Annual Report 2014

Nikhef

National Institute for Subatomic Physics

Nikhef

Annual Report
2014

National Institute
for Subatomic Physics
Nikhef

Nikhef

Colophon

Nikhef
Nationaal instituut voor subatomaire fysica
National Institute for Subatomic Physics

Visiting address	Post address
Science Park 105	P.O. Box 41882
1098 XG Amsterdam	1009 DB Amsterdam
The Netherlands	The Netherlands

Telephone: +31 (0)20 592 2000
Fax: +31 (0)20 592 5155
E-mail: info@nikhef.nl
URL: http://www.nikhef.nl

Science communication
Contact: Vanessa Mexner
Telephone: +31 (0)20 592 5075
E-mail: vanessa.mexner@nikhef.nl

Editors: Stan Bentvelsen, Wouter Hulsbergen, Kees Huyser, Louk Lapikás, Frank Linde, Melissa van der Sande
Layout: Kees Huyser
Printer: Gildeprint Drukkerijen, Enschede
Photos: Kees Huyser, Stan Bentvelsen, Jan Koopstra, Marco Kraan, Arne de Laat, Hanne Nijhuis, CERN
Front cover: First full KM3NeT string of 18 optical modules assembled at Nikhef.
Deployment in the Mediterranean Sea follows early 2015.
Back cover: The Standard Model of particles since the discovery of the Higgs boson.

Nikhef is the National Institute for Subatomic Physics in the Netherlands, in which the Foundation for Fundamental Research on Matter, the University of Amsterdam, VU University Amsterdam, Radboud University Nijmegen and Utrecht University collaborate. Nikhef coordinates and supports most activities in experimental particle and astroparticle physics in the Netherlands.

Nikhef participates in experiments at the Large Hadron Collider at CERN, notably ATLAS, LHCb and ALICE. Astroparticle physics activities at Nikhef are fourfold: the ANTARES and KM3NeT neutrino telescope projects in the Mediterranean Sea; the Pierre Auger Observatory for cosmic rays, located in Argentina; gravitational-wave detection via the Virgo interferometer in Italy, and the projects *e*LISA and Einstein Telescope; and the direct search for Dark Matter with the XENON detector in the Gran Sasso underground laboratory in Italy. Detector R&D, design and construction take place at the laboratory located at Science Park Amsterdam as well as at the participating universities. Data analysis makes extensive use of large-scale computing at the Tier-1 grid facility operated jointly by Nikhef and SURFsara. Nikhef has a theory group with both its own research programme and close contacts with the experimental groups.

Contents

Introduction

In 2014 CERN celebrated its 60th anniversary; a long period in which particle physics was shaped and where CERN became the research field's world leading institute with undisputed reputation. On 26 June 2014 Nikhef organised a symposium to celebrate this event in the Netherlands with a program containing the Dutch angle on the scientific endeavours, the connection to industry and the value of education. During the symposium the Nikhef-CERN Business Incubation Center was inaugurated, which will support companies to valorise the technologies developed at CERN in the Netherlands. The history of CERN is also summarized in a beautiful article written by Jos Engelen that you will find in this annual report. For me personally, CERN has kept the magic where projects beyond imagination are realised, where you can feel the driving force of scientific curiosity and at the same time experience the hard work by engineers and scientists who make this happen.

As an absolute highlight, two years ago experimental particle physics celebrated the discovery of the Higgs particle at CERN and Nikhef. And it was only one year later that the Nobel Prize was handed to François Englert and Peter Higgs, in September 2013, for their theoretical work. However, to me it was a pity that prize was not shared with experimentalists.

Now, two years later, people sometimes suggest that after the discovery of the Higgs particle, particle physics has come to an end. Obviously, this is very far from the truth. Particle physics has entered a completely new level in understanding the basic building blocks of the universe, with very fascinating but unanswered questions. Experiments are crucial to further understand how the Higgs particle can exist and what is the physics beyond the Standard Model. CERN with the LHC will provide an excellent opportunity to shape this progress, and astroparticle physics has become an integral part of this endeavour. The particle and astroparticle quests lie wide open to be explored, and this corresponds exactly to the mission and portfolio of scientific programs at Nikhef.

Nikhef is a key player in a number of opportunities for our field in the coming years. Perhaps it will be a new form of Quark-Gluon Plasma, a deviation from the predictions of the Standard Model in CP violation, new resonances, direct detection of supersymmetry, dark matter observation, violent gravitational wave emissions, point sources in neutrino emissions in the sky, abnormal cosmic ray composition *et cetera*! Viewed in this light, 2014 may have been an interbellum. In this report you find substantial progress in the construction of the astroparticle projects, while the existing LHC projects are being maintained. In addition, the analysis of the huge amount of data from the first LHC runs are being completed and double checked. Although intriguing hints appeared, no firm new phenomena beyond the Standard Model are yet found.

The mission of Nikhef is to study the interactions and structure of all elementary particles and fields at the smallest distance scale and the highest attainable energy.

Two complementary approaches are followed:

Accelerator-based particle physics
Studying interactions in particle collision processes at particle accelerators, in particular at CERN;

Astroparticle physics
Studying interactions of particles and radiation emanating from the Universe.

Nikhef coordinates and leads the Dutch experimental activities in these fields. The research at Nikhef relies on the development of innovative technologies. The knowledge and technology transfer to third parties, i.e., industry, civil society and general public, is an integral part of Nikhef's mission.

The Nikhef workshops were filled with activities mostly for Advanced Virgo and KM3NeT instrumentation. For example, the Seismic Attenuation Systems of Virgo have been finished and three of them are shipped to Pisa. Only a few days before the Christmas break the first full KM3NeT 800 meters long string with 18 Digital Optical Modules was finished. Jeff Templon wrote a nice article about the activities in Nikhef computing that you will find in this report.

The coming years will be very exciting. We will have high energy data from the LHC, a running XENON1T experiment for Dark Matter, Advanced Virgo coupled with the LIGO interferometer to detect gravitational waves and the composition of Ultra High Energy Cosmic Rays with Auger. And in two years we will also know to what extent KM3NeT is funded and can be realised.

Nikhef witnessed a number of highlights this year. Funding wise by far the most substantial grant was awarded on 1 July by the state secretary Sander Dekker and amounts to a total of 15.24 M€ for the upgrades of the ALICE, ATLAS & LHCb experiments and computing infrastructure. This secures Nikhef's signifi-

The scene in Nikhef's central hall at the end of the lipdub video shoot. The signs spell "Frank Linde, Thanks".

cant role in the LHC upgrades and a continuing challenge for the coming years. The funding of the theory programs is also a big success. With this funding the phenomenology of the Higgs physics will further be explored and a connection to cosmology is made.

It was also the year in which the Technology and Instrumentation in Particle Physics (TIPP) conference was organised with a very fresh Nikhef style, in the Beurs van Berlage in Amsterdam. The programme of the conference focused on the instrumentation in particle physics, and the attendees were able to participate in many activites, such as building a spaghetti bridge. The international CERN school on High Energy Physics was organised by the Netherlands and was held in Garderen.

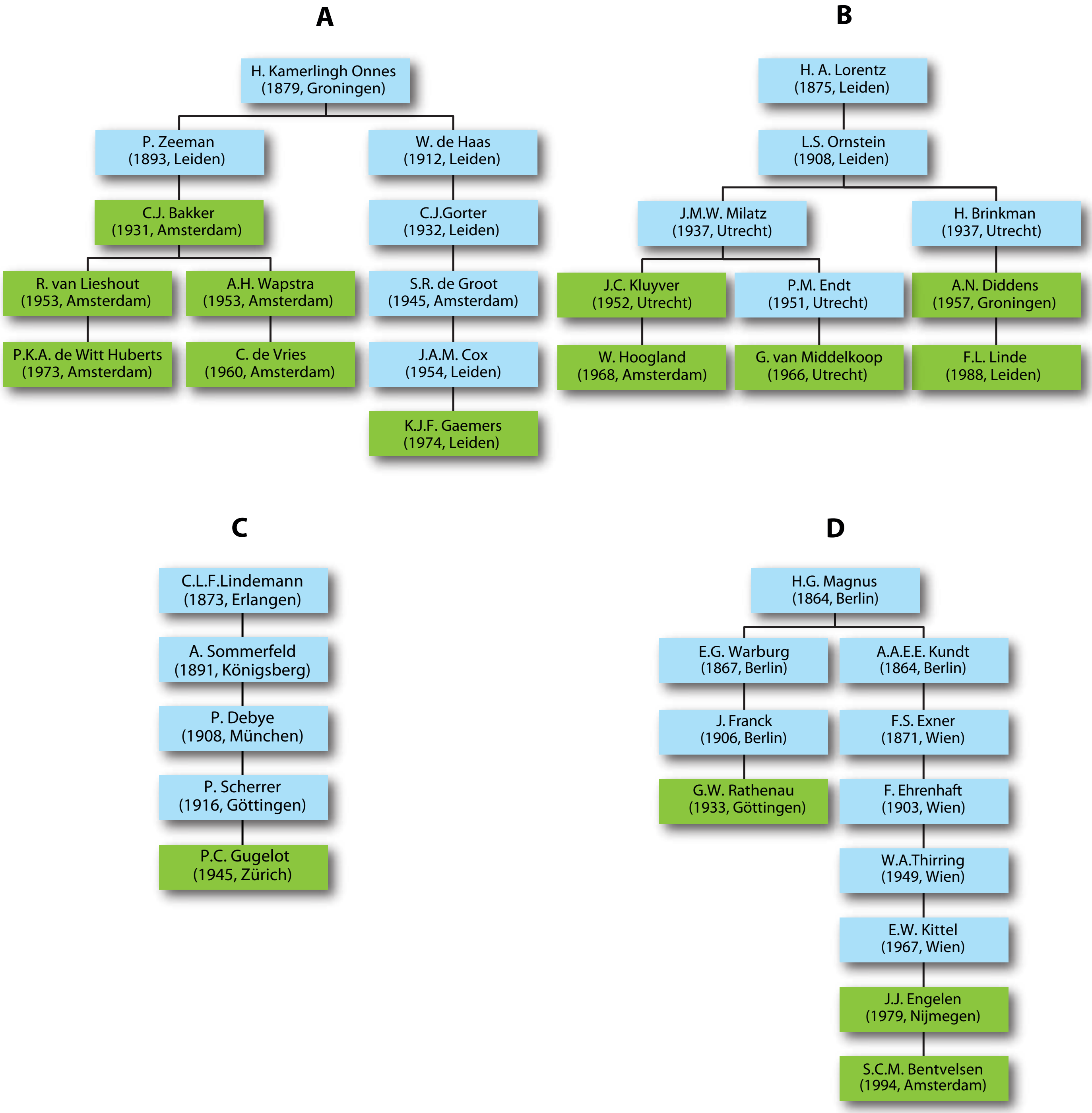
In 2014 we also sadly witnessed the sudden passing of our datahouse manager and head of facilities Koen Keijer. Somewhat later in the year, Dick Harting, one of the founding fathers of our institute, passed away. He was a key figure in the development of the infrastructure and facilities of what we now call Nikhef.

I succeeded Frank Linde as director on 1 December 2014. Frank has done a tremendous job with enormous energy, as witnessed in the past ten Annual Reports which breathes his presence. He developed particle physics and made astroparticle physics strong in the Netherlands. For his farewell party at NEMO in December Nikhef produced a 'lipdub' movie on Queen's music *"Don't stop me now!"* It was absolutely hilarious and typical of Nikhef staff and students to create this lipdub. It shows the spirit of our institute so well!

2015 will be crucial for almost all Nikhef experiments. The proton beams will re-start in the LHC with double the energy. The upgrade of XENON1T will be ready to take data starting in the Summer. After the Summer, Advanced Virgo will lock its beam and start its first science run. With this fantastic institute I'm looking forward to this intense period!

Stan Bentvelsen

Nikhef Directors



Scientific relationship between directors (green) since 1946 of Nikhef and its predecessors IKO and Zeeman Laboratory. Between brackets: year and place of dissertation, promotor: one line up. The four different branches A-D can not be traced back to a common scientific master. More information on Nikhef directors can be found at `https://www.nikhef.nl/over-nikhef/wat-is-nikhef/geschiedenis-nikhef/directeuren/`

1

Reviews

1.1 "It's a great privilege to work at Nikhef. No company will allow you to hunt the Higgs particle for decades."

An interview with Frank Linde

Bennie Mols

On 1 December 2014 Frank Linde stepped down as Nikhef's director. He led the institute for ten years. In this period he broadened Nikhef's research and witnessed the discovery of a particle that had remained elusive for almost fifty years: the Higgs particle.

What are your first feelings when you look back on your ten years as Nikhef's director?

First of all, I have always enjoyed it. It has never felt like a duty. I like to motivate people, especially the ones that develop the cutting-edge methods and technology for the experiments we participate in. And I have enjoyed opening new possibilities and directions in our research.

What was Nikhef's position back in 2004 and how do you see it now?

Nikhef has always been a great institute. But in my opinion the institute risked to become too dependent on the Large Hadron Collider (LHC) at CERN. Therefore, we have diversified Nikhef's activities over the last decade, notably into the field of astroparticle physics. In 2004, our only contribution was to the ANTARES neutrino telescope, now being upgraded to KM3NeT, in the Mediterranean Sea.

Today, we are contributing significantly to the detection of gravitational waves with the VIRGO laser-interferometer in Italy; to the detection of dark matter particles with the XENON experiment, also in Italy; and to the detection of high-energy cosmic rays using the Pierre Auger Observatory in Argentina.

Astroparticle physics touches upon fundamental questions such as: What is the nature of dark matter and dark energy? What is the true nature of neutrinos? Can we observe more signals from the very early Universe? Some of these questions have synergies with our LHC experiments, and the detection of particles and radiation from outer space relies on the same techniques as those used in our LHC experiments. It was therefore a logical development for Nikhef to expand its astroparticle physics activities.

What about the evolution of Nikhef's budget?

Back in 2004, just before I started as a director, our budget had just been structurally cut with 1.5 million euro. That's a lot. I'm proud of the fact that despite this severe budget cut Nikhef's turnover has grown with almost 50% over the last decade. This thanks to the monumental efforts of the numerous Nikhef employees, who have collectively managed to raise many new funds.

What are your personal highlights?

From a scientific point of view that is, beyond any doubt, the discovery of the Higgs particle, officially announced on 4 July 2012. This was the big discovery that we had been eagerly anticipating. It was one of the main reasons to build the LHC. With my colleagues I was witnessing the event live on screen here at Nikhef. There was a huge euphoria. But not just here. When I went back home in the evening, I went to a Chinese take-away restaurant. When I entered, another customer pointed at me and shouted: 'The Higgs!' He had seen me on TV and he turned out to be very interested in the discovery.

We will never develop a Higgs-telephone or Higgs-TV. The Higgs will probably not solve our energy problem. But the Higgs has captured the minds of many non-scientists and that is also of great value. I have been lecturing about the Higgs on the Lowlands Music Festival for a huge and mainly young audience! I have incredibly fond memories of such experiences.

Half of the scientists working at Nikhef are below thirty years old. Every year new, enthusiastic and clever young people arrive, with new ideas. Working with them has always been a great pleasure and inspiration for me.

In 2004 the Grid computing concept, a high-bandwidth interconnected world-wide network of CPUs and storage systems, was still in its infancy. I am very proud that I was part of the team that first scored the almost 30 million euro 'BiG Grid' grant and subsequently realised the so-called NL-Tier1 facility now operated jointly by SURFsara and Nikhef. At present, this infrastructure is not only being used by the LHC community, but also by numerous other Dutch research groups working in biology, astronomy, humanities, etc.

What has gone differently than you had hoped?

When I started as a director I hoped that Nikhef could play a role in the development of state-of-the-art medical instrumentation. For example monitoring equipment for proton therapy facilities. Proton therapy can be used to destroy cancerous tumors while minimising the damage to delicate surrounding tissues. In practice this all progressed much slower than I had anticipated.

What about other applications of particle accelerator technologies for society?

First of all, let me say that the core mission of Nikhef's particle physics research is entirely curiosity-driven. Of course we should keep an eye on practical applications and luckily history has already repeatedly proven that particle physics leads to completely new, and occasionally surprising, applications.

The whole world profits from the world wide web, which was originally invented at CERN. In our own country, the Amsterdam Internet Exchange, AMS-IX, is one of the busiest data-exchange hubs in the world. AMS-IX has become a key player in the Dutch economy, almost as important as the Rotterdam harbour or Schiphol airport. Nikhef stood at the cradle of AMS-IX in the nineties. Even today, a substantial fraction of the AMS-IX data exchange goes via hardware located just below my former office at Nikhef. And it even pays for some of our particle physics research activities!

Curriculum Vitae Franz Leo Linde (1958)

- **1976–1983** Master degree Experimental Physics at Utrecht University
- **1984–1988** PhD research at SLAC in Stanford, and Nikhef (PhD 1988 Leiden University)
- **1988–1991** Research physicist Carnegie Mellon University (USA) at the L3 experiment
- **1991–1993** CERN, Fellow at the L3 experiment
- **1993–present** Full Professor of Physics at the University of Amsterdam
- **1995–2000** CERN, Staff at the ATLAS experiment
- **1995–2004** Nikhef, programme leader of the Nikhef ATLAS group
- **2004–2014** Director of Nikhef
- **2015–present** Chair of Astroparticle Physics European Coordination (APPEC)

Member of various scientific advisory committees.
Physica Prize 2013 –together with Stan Bentvelsen– for their contributions to the discovery of the Higgs particle with the ATLAS experiment at CERN.
Numerous outreach lectures *e.g.*, NEMO, Universiteit van Nederland and Lowlands Festival.

I am also proud of the fact that Nikhef employees have created start-up companies such as Sensiflex B.V. , in the field of alignment, and ASI B.V., in the field of imaging sensors. Together with a venture capitalist we have founded 'Particle Physics Inside Products' as an umbrella organisation for such start-ups. Furthermore, we collaborate with Shell on seismic measurements building upon our expertise gained in the field of gravitational waves which requires the dampening of natural vibrations of the earth. With ASML, the world's biggest producer of lithography machinery to manufacture integrated circuits, we have collaborated on precision cooling technology.

Looking at the facts, we should not have to worry about proving our societal relevance. The only problem being that the time between our invention and market application might span a few decades, a period much longer than the mandate of most politicians and policy makers.

What type of director have you been?

I am decisive and fast and I like to take clear decisions. I am a very open and direct person and I always lay my cards on the table. That often works well. But I am not very diplomatic and that is not always appreciated by everyone. But that's the way I am…

I have always enjoyed dealing with people, especially the difficult ones, that is the creative, strong-willed and emotional ones. And of those Nikhef has quite a few characters. To me: they determine the institute's face and future.

I have little patience with people who don't do their best. You are not obliged to work at Nikhef. To me it is a privilege to work at Nikhef and to be allowed to do purely curiosity-driven research. Those who are structurally unhappy are welcome to explore alternatives elsewhere. But you have to realise: private industry will not allow you to hunt the Higgs particle for decades.

What are you going to miss?

Now that I am not the director anymore, it is sometimes difficult to watch things from a distance, instead of taking immediate action myself. And I will miss the close interactions with my decade-long buddy and Nikhef's institute manager Arjen van Rijn. A slight consolation: we now play Wordfeud and he wins all the time.

What are you not going to miss?

More than ninety percent of the time I have been doing things that I am passionate about. I have not always enjoyed meetings with higher echelons to defend Nikhef's ambitions or to negotiate funding. I fear that as a director I have been nicer for the people working below me in the hierarchy than for those working above me.

What are your future plans?

Well, after some initial hesitation, I put all my energy into becoming the next director general of CERN, but they opted for another person. So be it. In January 2015 I was appointed as the chairman of the Astroparticle Physics European Consortium (APPEC). I love astroparticle physics and I hope to help speed up the realisation of notably some of the beyond-the-imagination infrastructures in this field in the years to come.

Furthermore, I hope that I can assist some of our start-ups to expand their product range. I myself am also thinking about a new start-up called 'Particle Toys'. This start-up would market particle physics experiments at about cost price to notably schools.

Finally, I am convinced that The Netherlands should focus more on particle accelerator technology. Worldwide, very few accelerators are in use for particle physics experiments, but many accelerators are used in high-tech industry and for medical purposes. More generally I think a country like ours should focus more on high-tech research and industries, if we truly have the ambition to belong to the world top in that sector. Simply stating that, is not sufficient. Real investments, public and private, are essential. For me, Germany is a great example of a high-tech dominated nation. They have done relatively well despite the financial crisis, mainly because they have a huge research sector and they produce numerous high-tech products.

What do you wish for your successor?

I wish him, and myself as well, the discovery of supersymmetry, of dark matter particles or even better: the discovery of something entirely unexpected that will open up new particle physics opportunities. Most people outside our field have already forgotten the discovery of the Higgs particle. Especially for receiving funding it will be important that, apart from precision studies, new discoveries are made.

I also wish him more peace in fundraising. Over the past decade this has consumed more and more time and I think that many people can spend their time better doing real research than writing and refereeing zillions of proposals. An in-depth evaluation of Nikhef every six years is perfectly fine and desirable. But an institute like Nikhef should be funded structurally for many years and not have to annually compete for major chunks of its funding.

1.2 "Whatever we discover in the next decade, it will be something completely new."

An interview with Stan Bentvelsen

Bennie Mols

Nikhef's new director Stan Bentvelsen will be leading the institute into the fifth decade of its existence. Another exciting period with a lot of potential to learn more about the building blocks of the universe.

What is your vision on the future of the LHC research at Nikhef?

Our scientific programme is largely fixed and looks fantastic. The LHC is now planned to run even beyond 2020. The collision energy of the accelerator will be doubled in the coming years. Also, the number of particle collisions will be increased significantly. Taken together, this upgrade opens the way to a range of new discoveries.

In the next ten years we may discover completely new particles or new phenomena. For sure we will characterise the properties of the Higgs particle much more precisely. We will also investigate the dynamic state of the universe right after it was born: the story of the generation of nuclei from a soup of quarks and gluons. And we hope to further disclose the puzzle of why matter dominates over anti-matter in our universe. But although the scientific programme may be fixed, the potential for discovering new phenomena is wide open.

How is Nikhef going to contribute to the LHC upgrade?

We participate in three of the four detectors of the LHC: ATLAS, ALICE and LHCb. In each of them we have excellent expertise and reputation in building particle trackers. These particle trackers sit in the heart of a detector and measure the trajectories of all the particles that are made in the collision. Because the collisions will be so intense or, in other words, there are so many of them we need to replace and upgrade the particle trackers.

At Nikhef we design and build these cutting edge particle trackers, including the electronic readout. The rough designs may be ready, but many details are still unclear. The LHC upgrade will be a challenge for our technical departments for the coming five to eight years. Parts of the hardware will be installed in 2018, others not until 2022.

Apart from designing and building technological solutions for the LHC, we will also be involved in analysing part of the ever-growing collision data. In order to do this, we will have to upgrade our computing facilities with more processing power and more storage capacity.

Are you already thinking about life after the LHC for Nikhef?

In the coming years we will decide about our future steps. At the moment I see a number of interesting possible international collaborations for Nikhef. Japan is planning to build a linear electron-positron collider. In the USA there are plans for intense and long-based neutrino beams. Finally, at CERN and in China there are plans for a next generation proton-proton accelerator, with the circular accelerator reaching 80 or 100 kilometer circumference; much bigger than the LHC. In the coming years we plan to enter discussions on these developments. The upcoming scientific results of the LHC are crucial in shaping the future programme for Nikhef.

How is Nikhef going to contribute to big science experiments other than the LHC?

Over the last ten years we have become active in a number of large international astroparticle experiments, like the detection of gravitational waves, the search for dark matter particles and the detection of high-energy cosmic rays and neutrinos. All these experiments may give us new clues on particle physics at the most fundamental level. It's very characteristic for Nikhef to take a significant forefront role in these experiments, and not to take a back seat.

For example, the XENON experiment is built to search for dark matter particles and will start taking data sometime in 2015. When I just started in my role as Nikhef director, I visited this experiment at the Gran Sasso laboratory in Italy. The director told me out of the blue: 'You know, the best engineers we have here, are from Nikhef'.

The VIRGO interferometer is designed to discover gravitational waves. It forms a close collaboration with a similar experiment in the USA: LIGO. Discovery of gravitational waves at LIGO will be celebrated at VIRGO as well, and the other way around. I expect the VIRGO interferometer will be switched on in the second half of 2015. A lot of hardware and expertise for this experiment has been developed at Nikhef. Furthermore, we play a key role in the detection of these waves, that originate for example when two neutron stars or black holes merge. The management of the gravitational wave experiment VIRGO was very clear on this: 'We need Nikhef scientists to reach the best sensitivity for detecting gravitational waves.' It shows that the reputation of Nikhef excellent.

Before Christmas 2014, Nikhef completed a full string with eighteen complex optical modules, a first serious part of the huge KM3NeT detector. This detector will ultimately measure neutrinos from outer space that hit the waters of the Mediterranean Sea. A large number of these strings will be deployed near the coast of France and Italy. It's a tricky endeavour to unroll these eight hundred meter strings with optical modules under water. Again, Nikhef plays a key role in the whole design of the instrument.

To complete our activities in astroparticle physics, let me mention the Pierre Auger Observatory on the Argentinean pampas to detect ultra-high energetic cosmic rays. I'm looking forward to visiting this experiment soon. We take part in an upgrade to better understand the type of cosmic rays that hit our atmosphere. Are these simply protons or maybe heavy nuclei as well?

All in all, 2015 will give us a lot of chances for big discoveries. But the discoveries themselves are not in our hands. At the end nature decides. We can only detect gravitational waves if some big astronomical event takes place that creates strong enough waves, or dark matter only if it is really out there. Unraveling fundamental laws of nature is inherently uncertain. Getting no discovery also teaches us something.

Curriculum Vitae Stanislaus Cornelius Maria Bentvelsen (1965)

- **1989** Master degree Theoretical Physics at University of Amsterdam
- **1989–1994** PhD research at DESY (ZEUS) in Hamburg (PhD 1994 University of Amsterdam)
- **1994–2000** CERN, Fellow and Staff at the OPAL experiment at LEP.
- **2000–2005** Nikhef, Staff at the ATLAS experiment
- **2005–2013** Nikhef, programme leader of the Nikhef ATLAS group
- **2005–present** Full Professor of Physics at the University of Amsterdam
- **2014–present** Director of Nikhef

Member of various scientific advisory committees.
Protagonist –together with Peter Higgs– in the documentary film "Higgs – into the heart of the imagination" (2009).
Physica Prize 2013 –together with Frank Linde– for their contributions to the discovery of the Higgs particle with the ATLAS experiment at CERN.
Outreach lectures at Klokhuis, Museum Boerhave, Paradiso.

We all dream of these big discoveries. I hear people from outside the institute telling me: 'Now that you have found the Higgs particle, you can close down your activities and manage with less funding.' In a way we may have sold the discovery of the Higgs particle too well. And in reality this is so far from the truth. After the Higgs discovery the present challenges are much more diverse and open. We know that our present Standard Model cannot be the end of the story and there has to be a whole world beyond it. Wouldn't it be fantastic if we could see a hint of new physics in the coming years?

Apart from the scientific programme, what are your ideas for Nikhef as an institute in the Netherlands?

Soon I hope the Van Swinderen Institute from the University of Groningen will join the Nikhef collaboration. This will be the fifth university, besides the University of Amsterdam, the VU University Amsterdam, the University Utrecht and the Radboud University Nijmegen. My predecessor Frank Linde has already prepared for this extended collaboration and I only need to give the last kick to score this goal.

At the Amsterdam Science Park, we will also see a few important changes. The natural sciences departments of the Free University will join us here. Furthermore, SRON, the Netherlands Institute for Space Research, will move from Utrecht to the Science Park. They develop new technologies for space missions and experiments. Integrating the instrumentation at the Amsterdam Science Park is another one of my ambitions. Having institutes like Nikhef, AMOLF, SRON and also the recently formed Advanced Research Center for Nanolithography (ARCNL) in one location creates new possibilities to optimise our instrumentation. We all build cutting-edge technologies for physics experiments, and may benefit from our mutual expertise.

Last but not least, we are planning to renovate the Nikhef building. I hope we can realise this within the coming five years.

How do you look at the valorisation of Nikhef's research?

It's obviously important, but I will never let our scientific programme be guided by applications alone. Nikhef has a scientific mission. Nevertheless it is easy to show that developing the extreme technologies that we need for our particle experiments has already led to many innovations. Some readout chips that we developed are being used in medical or biological applications. So don't get me wrong, I find this type of valorisation important and Nikhef will continue to put a lot of effort into transfering the advanced detection techniques of particle physics outside its domain. Even beyond this utilisation of instrumentation, one can dream of new technologies and applications in the distant future based on the discovery of new laws of nature. Who knows, maybe one day we will be pulling energy out of the Higgs field. But this is very distant future music which I'm sure nobody can yet oversee.

What kind of director would you like to be?

I believe that laying responsibilities for our scientific future, and valorisation and outreach efforts, deeper in the organisation will make Nikhef stronger. There is an enormous drive of all scientific and technical staff, postdocs and PhD students at this institute, and that is great to feel.

I hope to be a director who can make a team out of all our programme leaders. They lead the scientific programme of our institute, and together with them I want to set the course of Nikhef, with a coherent scientific story. One of the first things I have introduced is a regular meeting with this team.

Being a director as such is not so important to me. I love to share my enthusiasm with both the people who work here and people outside our institute. That is my challenge. And to make sure that we remain an institute with such an excellent reputation and focus as we currently are and always have been.

Previous director Frank Linde wishes you new discoveries...

Well, yes that would be great! Connecting the physics at the very small scales, the scale of particle physics experiments, with the physics at the very large scales, the scale of the universe, is my ultimate dream. Discovering the Higgs was truly fantastic. Whatever we discover in the next decade, it will be something completely new.

1.3 CERN

A modern European centre of excellence is turning 60

Jos Engelen

CERN, the European Laboratory for Particle Physics, is celebrating its sixtieth anniversary. This article briefly reviews CERN's development into a prominent centre of expertise on the world stage. It also examines this organisation's ground-breaking contributions to fundamental physics, culminating in the discovery of the Higgs boson. Furthermore, it is widely anticipated that the Large Hadron Collider will soon be delivering even more exciting results.

The 60-year history of CERN features many outstanding scientific highlights, the most notable and most recent of which was the discovery of the Higgs boson. These scientific results were made possible by ground-breaking work in accelerator physics and technology, as well as by innovations in the field of particle detection. The stable environment that CERN offers leading scientists and technicians has contributed in no small way to these developments. This in turn was made possible by the support of Member States for the Medium and Long Term Plans which frame CERN's strategy. CERN started life in an era that was radically different from the one we know today. As a model for cooperation, it was far ahead of its time. It will also stand firm in the future, provided that CERN can embark on an ambitious new European accelerator project, building on the results of the Large Hadron Collider's scientific programme, which is still in full swing.

Initial ideas

In 1949, ideas began circulating about the desirability of a European research centre to rival centres in the United States or the Soviet Union. The establishment of CERN, in 1954, was fully in keeping with post-war momentum to achieve stability and a strong international position by means of European cooperation. The name of the provisional Council that paved the way for the creation of CERN is preserved in the organisation's current acronym, which stands for: *Conseil Européen pour la Récherche Nucléaire.* The idea was that CERN would contribute to that momentum through scientific collaboration in a new, world-class European laboratory in the field of fundamental nuclear physics. Twelve countries, including the Netherlands, founded this first European Intergovernmental Research Organisation. CERN's success is based on an organisational model that features the direct involvement of Member States and on robust funding for long-term, ambitious projects that are selected after a cautious and critical approval procedure. The organisation's success is also due to its excellent technical staff, who have been able to develop unique expertise and pass it on.

Figure 1. The provisional CERN Council meets at the Trippenhuis, seat of the Royal Netherlands Academy of Arts and Sciences, in October 1952. See the Dutch Polygoonjournaal at http://www.beeldengeluid.nl/media/1331/europese-atoomgeleerden-vergaderen-te-amsterdam .

One of the standard photos that illustrates the history of CERN was taken in the Trippenhuis[1], in 1952, when the provisional CERN Council met in Amsterdam. At the head of the central table is C.J. Bakker, professor at the University of Amsterdam (later Director General of CERN, who sadly died in a plane crash in 1960). Seated at the same table is Niels Bohr. The others present included Werner Heisenberg, and other prominent individuals from both politics and science, such as P.M.S. Blackett (1948 Nobel Prize winner), Paul Scherrer and Pierre Auger. The Dutch government was represented at these consultations by J.H. Bannier (Director of the Dutch Organisation for Pure Scientific Research (ZWO) and an influential member of the CERN Council from the very beginning). One of the decisions taken at the Trippenhuis meeting in October 1952 concerned the choice of the location of the new laboratory. Various locations were put forward, including one offered by the Dutch government. The following is an extract from the letter in which this offer was made:

"We consider that scientists would find in this country the rest and quietness necessary for strenuous intellectual endeavours in congenial academic surroundings as well as accommodation and opportunity for relaxation. Transportation by train, by ship and especially through the air makes this country easily accessible from all your member countries, amongst which it is one of the least expensive to live in.

1 My thanks to Hugo van Bergen and Joeri Meijer (KNAW - Royal Netherlands Academy of Arts and Sciences) for providing background information.

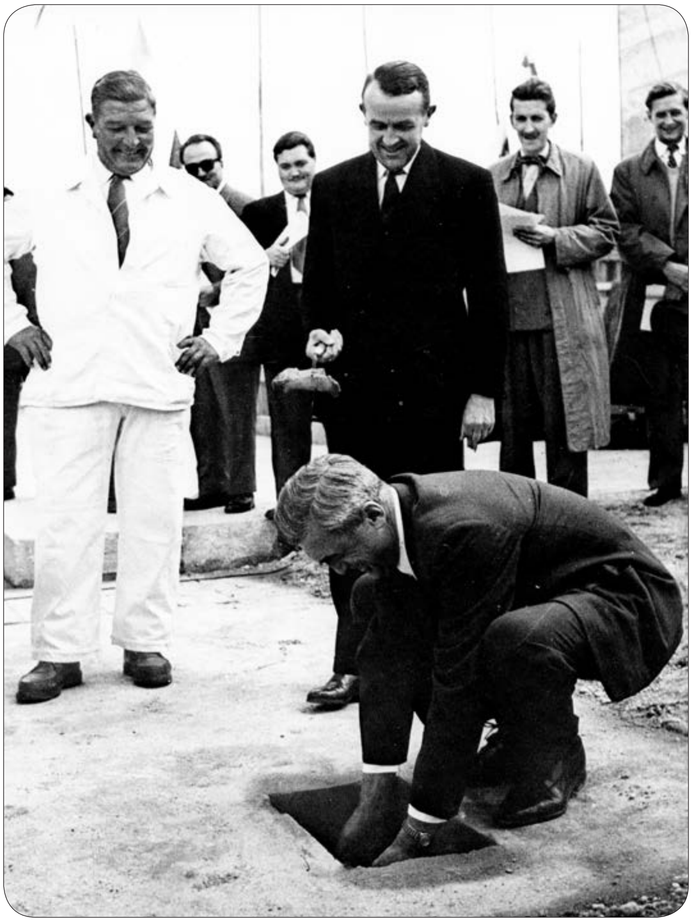


Figure 2. On 10 June 1955, Felix Bloch, CERN's first Director General, laid the first foundation stone at the laboratory site.

A site of sufficiently large size for your laboratory would be available at Arnhem within a comfortable distance from the universities which are, not wholly without reason, proud of the research carried out by their physicists. Very recent enlargements of power generating facilities and plans for still more increases guarantee the supply of electricity according to your needs and although the housing situation is still difficult we would be glad to support you in answering your needs in that direction."

This serious offer was set out, point by point, in the remainder of the letter. Nevertheless, at its meeting in Amsterdam, the provisional CERN Council opted for Geneva.

CERN's machines

The Synchro-Cyclotron (SC) (1957, 600 MeV beam) was CERN's first project, followed by the Proton Synchrotron (PS)

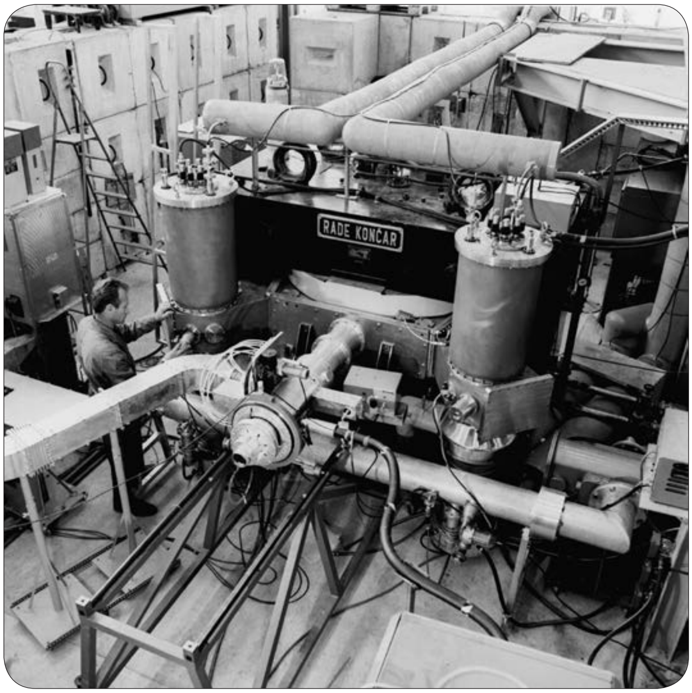


Figure 3. The Synchro-Cyclotron.

in 1959. The SC immediately put CERN on the map, through the discovery (in 1958) of the decay of the charged pion into an electron and a neutrino, with a branching ratio of 10^{-4}. At that time, this lent strong support to the emerging (V-A) theory of weak interactions. The PS was the first high-energy accelerator at CERN. Capable of accelerating protons to 28 GeV, it briefly held the world record. Since 2010, this record has been convincingly held by CERN's Large Hadron Collider (LHC). Having started at 3500 GeV per proton beam, it will shortly recommence operations at 6500 GeV per proton beam. The PS is still an indispensable part of CERN's infrastructure, being mainly used as an injector for other accelerators including the LHC. The discovery of Neutral Currents (1973)[2], one of CERN's great scientific achievements, was possible thanks to a neutrino beam derived from the PS (and thanks also to Simon van der Meer's invention of a magnetic horn to focus the pions that generate the neutrino beam). It was also the PS that prompted my first encounter with CERN. In 1971, while studying for my Master's Degree, I spent a few months working on an internship, as a summer student. I was involved in an experiment, set up by groups in Amsterdam and Nijmegen, to study the strong interaction between *K* mesons and protons. CERN has always provided a stimulating international environment, and that has had a great influence on me.

2 Neutrino scattering via *Z*-boson exchange; the discovery gave a strong boost to ideas about electroweak unification that had only recently been published by Sheldon Glashow, Abdus Salam, and Steven Weinberg; 1979 Nobel Prize.

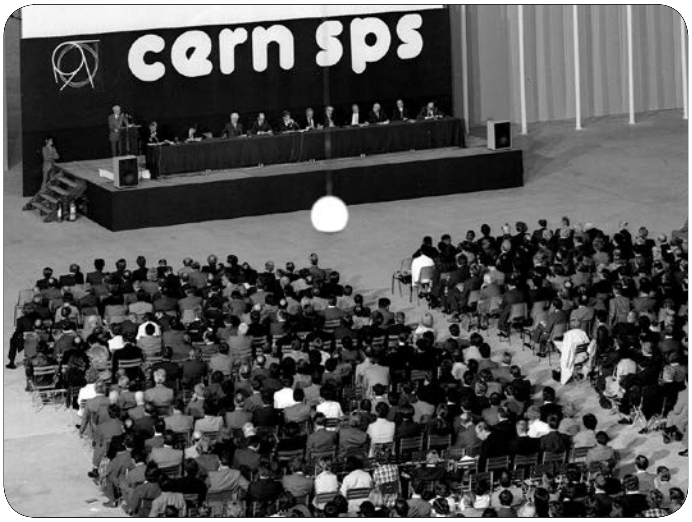


Figure 4. On 27 May 1977, about 2,000 people attended the inauguration ceremony for the Super Proton Synchrotron (SPS).

Figure 5. Physicists gathered around a computer monitor in the LEP control room at the start-up of the LEP on 14 July 1989. Carlo Rubbia (CERN's Director General at that time) is in the centre, with Herwig Schopper (a former Director-General of the organisation) to his left.

The next machine was the ISR (Intersecting Storage Rings; 1971): The world's first colliding-beam facility for protons. The ISR was far ahead (possibly too far ahead) of its time, with an incredibly high energy of 61 GeV in the centre-of-mass system, corresponding to a 2000 GeV beam (unthinkable at that time) on a fixed target. Although the ISR enjoyed a rich physics harvest, it did miss out on some major discoveries (especially the J/Ψ meson and the Υ meson: charm and beauty quarks, discovered in 1974 and 1977 respectively at SLAC, Brookhaven and Fermilab). Simon van der Meer, who went on to win a Nobel Prize, used the ISR to perform his first experiments on stochastic cooling of stored proton beams. He was one of a group of engineers from Delft who were among the pioneers of CERN, and who made vital contributions to that organisation.

In 1976, CERN commissioned the Super Proton Synchrotron (SPS), which was capable of accelerating protons to 450 GeV. Secondary beams from the SPS were employed for numerous innovative fixed-target experiments. However, the SPS's most important results, by far, were achieved when the machine was converted into a colliding-beam facility (1981), using 270 GeV proton and antiproton beams. Van der Meer's stochastic cooling of the antiproton beams, made it possible to achieve a collision frequency (proportional to luminosity, a performance indicator for colliding-beam machines) that was high enough for the discovery of *W* and *Z* bosons (which, together with the photon, are the carriers of the electroweak interaction). In 1984, Carlo Rubbia and Simon van der Meer were awarded the Nobel Prize for this work.

In 1989, CERN commissioned the Large Electron–Positron Collider (LEP), which used colliding beams of electrons and positrons. This was CERN's first and –to date– only lepton machine, and the largest accelerator ever built. Electrons are only 1/2000th the weight of protons, so they tend to lose more energy –in the form of synchrotron radiation– when following a circular trajectory. The LEP accelerator had a circumference of 27 km (as does the LHC accelerator, which was installed in the same tunnel). LEP needed this large circumference to limit the emission of synchrotron radiation, which causes energy loss from the electron and positron beams. The LHC, on the other hand, had to be built on this scale to achieve the highest energy possible at the available magnetic field strengths (which are subject to the limitations of state-of-the-art beam-bending magnet technology). If the LHC was to be feasible, various critical conditions had to be met. One of these was the successful development of superconducting magnets that were suitable for industrial (*i.e.* affordable) production. (Arranged at intervals around the ring are 1232 beam-bending magnets, each 15 metres long, operating at a temperature of 1.9 K, with an induction of 8.33 T.)

LEP was a precision machine because the colliding particles were structureless point particles, so the initial state was completely determined. This was not the case with the 'discovery machine' LHC. The colliding protons consist of quarks and gluons, which carry a fraction of the beam energy that is unknown a priori. LEP has yielded a wealth of results and has confirmed that the Standard Model (the theory of quarks and leptons and the corresponding fields, the W and Z bosons, photons and gluons) is a precision theory, to many decimal places. It would not have been possible to confirm the status of the Standard Model as a precision theory without a quantitative framework derived from the work of Gerardus 't Hooft and Martinus Veltman (renormalisability of interactions of massive gauge particles, especially the W and Z bosons, Nobel Prize 1999). Over time, LEP's energy was extended to just over 100 GeV per beam. However, it was unable to find any evidence of the Higgs boson (the vital missing ingredient of the Standard Model). This meant that it had to have a mass in excess of 114 GeV. The next step required the LHC.

Large Hadron Collider

Having spent a long time reviewing its options, the CERN Council finally gave the go-ahead for the LHC in 1994[3]. That go-ahead was accompanied by a plan to close LEP, to make way for the LHC[4] (in the same way as the ISR was closed to make way for LEP). The investment budget would have to come from the Member States' contributions (which, being more or less guaranteed, made it possible to take out loans as well). It was also necessary to acquire substantial additional resources through bilateral agreements with interested Non-Member States, particularly the United States and Japan.

In 2012, twelve years after the closure of LEP, the ATLAS and CMS (the two general-purpose detectors) teams announced the discovery of a Higgs-like boson, a particle with a mass of 125 GeV. Further measurements and analyses were (and still are) required to establish the properties of this Higgs-like particle. Evidence such as its spin and its couplings to the bosons, quarks and leptons into which it decays indicates that we can drop the term 'Higgs-like', and simply refer to this particle as the Higgs boson. In 2013, François Englert and Peter Higgs were finally able to collect their Nobel Prize. Full acknowledgement was, of course, given to the ATLAS and CMS teams.

Unlike CERN's accelerators, the particle physics experiments (detectors) are designed and built by consortia of universities and institutes (such as Nikhef), usually with the assistance of a CERN group. Among the scientists who work at CERN there are a number of top flight instrumentation physicists. This was amply demonstrated by the award of the 1992 Nobel Prize to Georges Charpak, for the invention of the Multi-wire Proportional Chamber. CERN also offered Tim Berners-Lee the ideal environment in which to develop his ideas about information management. In late 1990, he launched the world's first website.

Figure 6. A crowd looked on while the first proton beam was steered around the LHC ring on 10 September 2008.

The LHC's detectors are marvels of high-tech instrumentation. When the LHC project was given formal approval (1994), it still faced many technical hurdles. For instance, no one was entirely sure how to build detectors capable of recording the products of clumps of protons colliding forty million times per second (producing more than a billion particles each second) accurately enough to detect the decay products of the Higgs boson. (Walter Hoogland, who was CERN's Director of Research at the time, took the important initiative to combine the requisite R&D efforts and to introduce an element of competition.) The detectors proved to be a great success, thanks to imagination, perseverance and a little bit of luck. The LHC's detectors involve innovative semiconductor detectors, new deep submicron electronics, incredibly fast and smart online hardware and software (trigger and data acquisition) and a ground-breaking worldwide computing grid. They are universal precision instruments with a level of sophistication that, twenty years ago, no one would have thought possible.

Cooperation in the Netherlands

During the 1970s, the scientific community in the Netherlands became increasingly aware that cooperation at national level was a prerequisite for optimal participation in CERN. To this end, the National Institute for Nuclear Physics and High-Energy Physics (Nikhef) was established. The idea was to create partnerships between university groups that were active in the field of subatomic physics, in the form of a joint venture with a coherent scientific programme established by a single board, and implemented under the direction of a single executive. Nikhef was just such a partnership, consisting of four universities and the FOM

3 It was initially decided that the LHC would be constructed in two phases. The initial phase would involve fewer magnets, to spread the requisite investment over several years. This plan was reviewed in 1996, at which point the decision was taken to complete the project in a single step.
4 That took place in the year 2000. At that time, I was a member of CERN's Research Board. I supported the plan to close the LEP, even though it had provided hints of a putative Higgs boson at 110 GeV. That stance made me the target of some very angry comments at the time…

Foundation. A partnership that, set against the background of the contemporary Dutch research system, was far ahead of its time. While this approach does suffer from a few drawbacks (first-mover disadvantage), which I will not go into here, these are far outweighed by the benefits. These benefits relate to substance (a focused and ambitious research programme based on scientific choices) and infrastructure (infrastructure for innovative instrumentation development, state-of-the-art computing).

For instance, various LHC detectors (ATLAS, ALICE and LHCb) have benefitted from Nikhef's exceptionally creative, high-value contributions. (ALICE and LHCb are specialised detectors. ALICE makes unique measurements of 'drops' of quark-gluon plasma, a new aggregate state of matter generated in collisions of lead nuclei. LHCb specialises in measurements of *B* mesons and in the study of differences between matter and anti-matter.) This places Nikhef's physicists (including many talented PhD students) in an excellent position to wring every last drop of information out of the LHC's data, to track down the Higgs boson and –more… There are good reasons to believe that there is more beyond the Standard Model. If this were not the case, then higher order quantum corrections (radiative corrections) would tend to produce a very large mass for the Higgs boson. Without an extension of the Standard Model, an unnatural degree of fine-tuning is needed to keep these corrections under control. In fact, we can be certain that the Standard Model is incomplete, simply because neutrinos have mass. This does not fit the Standard Model, which states that these particles are all strictly 'left-handed' (*i.e.* the direction of spin is opposite to the direction of motion). It is not difficult to accommodate massive neutrinos in the Standard Model, but it is also entirely possible that the neutrino's vanishingly small mass indicates the existence of 'new physics'. Finally, we can cherish the hope that explanations for cosmological issues, such as dark matter and inflation, will be found in physics beyond the Standard Model. A first step beyond the Standard Model would be the discovery of supersymmetry, as this theory offers at least the beginning of a solution to some of the above problems. While its data have been subjected to some very profound and advanced analyses, the LHC has not yet afforded us so much as a glimpse of supersymmetry. All hopes are now pinned on the LHC upgrade, which will double the collider's energy when it resumes operation in 2015, and on an expanded investigation of the possible realisations of supersymmetry. The LHC's scientific programme will surely dictate trends at the forefront of high-energy physics for the next ten years, at least.

The future

The successful partnership at CERN, its haul of scientific results, and its level of technical excellence have drawn the interest of countries other than the original Member States. CERN currently has 21 Member States and two candidate Member States, plus five observers (including the United States, Japan and Russia). Possibly the growth in the number of Member States is somewhat out of step with CERN's plans for the future. The Trippenhuis would form an excellent backdrop to gatherings where people reflect on those plans for the future!

The big challenge facing CERN today is to be as successful in the future as the organisation has been over the past sixty years. Happily, the LHC's upcoming increase in beam energy and luminosity, together with the associated upgrade of the detectors, represent a solid bridge to that future. The new results, combined with recently acquired knowledge, should then serve as a springboard for a new, challenging and ambitious European accelerator project for the future. There are calls for CERN to participate in an interim project, such as a multi-billion dollar linear accelerator in Japan. In my view, that would be the end of CERN –an organisation whose *raison d'être* stems from pioneering projects in Europe.

My thanks to Karel Gaemers for his comments on an initial version of this article and for a discussion of neutrino physics, and to Bert Diddens for pointing out the discovery (made by a team working with the SC) of the electron decay of the pion.

1.4 Big Data: Wat en Hoe?

Jeff Templon

"Wat en Hoe" is Dutch for "What and How", and this title is borrowed from a series of very practical language guides I made frequent use of during my travels in the days before Google Translate existed. I hope that this piece can serve a similar function, to explain in a very practical fashion, *What* Big Data is, *What* it is good for, *How* it can be used, and *How* you can learn more.

What Is Big Data?
Big Data, in the most general sense, is the enormous amount of data stored in digital form on computers connected to networks. The network is important, because it enables the enormous amount of data to be collected (*e.g.*, computers at Vodafone collecting the location data from all mobile phones connected to their 3G network) as well as to be accessed by others (*e.g.*, TomTom traffic information being accessed by thousands of navigation devices spread across the country).

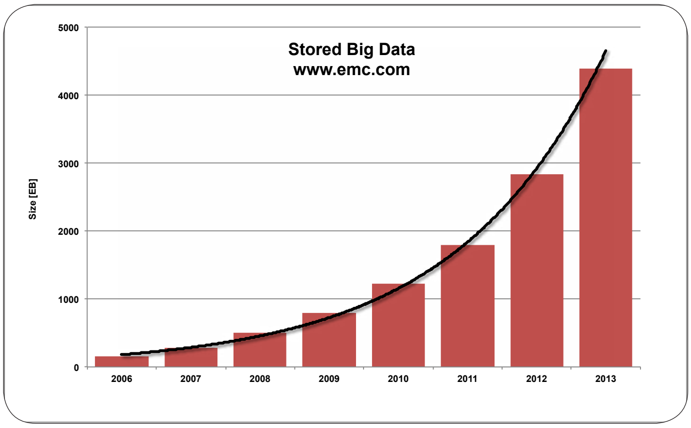


Figure 1: Estimated total amount of stored data in the past eight years. One Exabyte [EB] is equal to 1000 million Gigabyte. The curve represents exponential growth that doubles the size each 18 months.

There are a lot of definitions for 'Big Data' in circulation, partly because of industry hype — if you call it 'Big Data' then it sells better. Below I will describe two ways of understanding Big Data, and they are both linked to what is called 'exponential growth' as displayed in Fig. 1. For example, if you start with two cents and add two cents each day, this is called linear growth. Exponential growth is if you double your money each day. In both cases, on the second day you will have four cents instead of two; on the second day you will have either six cents (linear) or eight cents (exponential). At the end of the month, this is 62 cents (linear) or 21 million euros (exponential). Big data is, in many cases, growing exponentially.

One way to see Big Data is how big it is. Taking digital music as an example, music in mp3 format started to become popular in 1997, when the WinAmp program was introduced. In those days, an average computer disk drive could hold about 400 songs of high-quality mp3 music (2 GB). Nowadays a home computer can hold more like one hundred thousand songs — assuming you don't already have your disk filled up with digital photos, also a novelty in 1997. However, many people now use streaming music services like Spotify to listen to music; these services offer around 50 million songs. This is too much data to fit within a single computer, and this is another common definition of 'Big Data' — your data is big if it no longer fits on a single computer.

At Nikhef, about 50 large-capacity storage computers are networked together to hold our share of the data from the experiments we work on at CERN and elsewhere in the world. Taken together, these computers at Nikhef have enough storage capacity to hold three copies of the entire (all 50 million songs) iTunes store. Although Nikhef operates one of the largest data repositories, there are hundreds of others scattered across the globe, leading to yet another definition used for 'Big Data': your data is big if it no longer fits in the same building.

Why is there so much interest in Big Data?
Big Data is certainly interesting just because it is 'big', as the digital music example shows. In the early 1990s, when I went on vacation, I used to carry two small briefcase-sized cases full of cassette tapes with me. Now a mobile phone, a pair of speakers and an internet connection takes up much less space and provides access to much more music.

Big Data is, however, much more than this, as the large amounts of data allow us to do many new things that were previously difficult, if not impossible, to do. The very first examples mentioned in this article (mobile phones and traffic information) make a good example. The mobile phone location data, collected several times per minute, can be converted to a mobile phone 'speed', especially for those mobile phones located in cars moving along highways and streets. Taken together, these speeds show how fast traffic is moving. If the speed limit on a certain portion of the A9 is 100 km/hr but the phones are moving at 40 km/hr, this indicates a traffic jam, and that information is sent out to connected navigation devices.

In the past, traffic jams were deduced mainly by looking at traffic cameras on major highways. There was a significant delay before this information reached drivers, since the traffic report was broadcast only a few times per hour on the radio. The modern systems include all roads, and are updated every few minutes;

they also include other information like gasoline prices, lists of nearby restaurants, and weather reports, having collected this data from other sources on the internet.

Big Data and machine learning

Perhaps the most exciting (and sometimes frightening) aspect of Big Data has to do with how it has changed how we program computers. Until recently, in most cases scientists, or other programmers, 'wrote a program' and the computer used this program to produce some output. So you put a program 'in' to the computer and you get data back 'out'.

There is another way to do it: you put the data 'in' to the computer, and you get the program back 'out'. The program you get out is the one that would have generated the data you put in. This program can then be put back 'in' and used for tasks to generate similar data that you don't have yet. This is called Machine Learning and can best be illustrated by example.

Suppose you have a lot of text that was originally written in English, and had been translated into Dutch. You have computer files containing the text in both English and Dutch. You can give these files to a Machine Learning system, and it will give you back a program that would have been able to translate the Dutch text from the English. This in itself is not so useful, as you already had the Dutch text, but you could now give it a *different* English text and your program will translate it into Dutch.

The connection to Big Data comes because, in many interesting cases, Machine Learning needs *a lot* of examples in order to 'learn' a program like the translator. As an example, one can teach a speech-recognition program to make the proper choice between confusing words: did the speaker say "go to", "go too", or "go two"? In order to learn a program that gets the right answer 99% of the time, you need to give it *billions* of examples. This was unthinkable in the pre-internet age, so people were still trying to write the translation program in the old-fashioned way. Now with so much written text on the web, and much of it already translated, it is possible (even relatively easy) to get billions of examples. Big Data is making things possible which were not possible before.

Translation programs, recommendation systems at web stores like Amazon, the little boxes that appear by people's faces on your camera (how did the camera know that this part of the picture was a face?), web services like Evernote that can recognise words inside scanned images: all these systems are based on Machine Learning systems. Some of the most advanced Machine Learning systems are called 'Neural Networks' and are built to mimic the way neurons are connected in the human brain.

I mentioned that this aspect of Big Data could be frightening. More on this later on, but one of the problems is that the Machine Learning 'output' program is only as good as the data 'input'.

The financial crisis of 2008 was a surprise to most; with all the financial data available, and claims being made that economic theory was no longer needed, we could use Big Data to understand everything: why did nobody predict the crisis? One of the main reasons is: the machine learning programs that were used to predict how well the market would do, were produced from input data on the previous ten or so years. Those years were economically quite calm, so the learned programs had no example data on what a financial crisis looked like, and hence had no way of being able to spot all the warning signs.

Some example uses of Big Data

Most of what we call 'Big Data' is publicly available on the web, so anyone can use it. One use I personally like is, checking how well weather forecasters are doing. In the pre-web times, you could find the weather forecast for the coming days, but they never included data on how well they predicted yesterday, or for this day in history, how much did the forecast and the actual weather differ, on average? If you were a determined person, you could keep a notebook every day of the forecast and the actual weather, the more cities and more forecasts you try, the more of a chore this becomes.

Once the weather services started making web sites where current temperatures, and the forecasts, were published, anybody could write a small program that picks up the forecast once per day, and the temperatures a few times a day, for as many cities as they liked. It turns out that the weather predictions are generally better than a) guessing, b) saying *"tomorrow will be just like today"* and c) *"tomorrow's weather will be the historical average high and low for today"*. This is true for the day after tomorrow, but just barely true for today next week … and the weather services may like to publish weather forecasts for two weeks, but after 8 days, the forecasts are actually *worse* than just looking at the historical weather.

Also how well the forecast predicts the weather, depends on where you get your forecasts from. The national weather services are generally pretty good; local radio and tv stations are the worst. This was unexpected, as these stations get their weather predictions from the national services. So why are they worse? Because these local stations adjust the forecasts to be 'wetter'. They do this because people in general prefer a pleasant surprise to an unpleasant

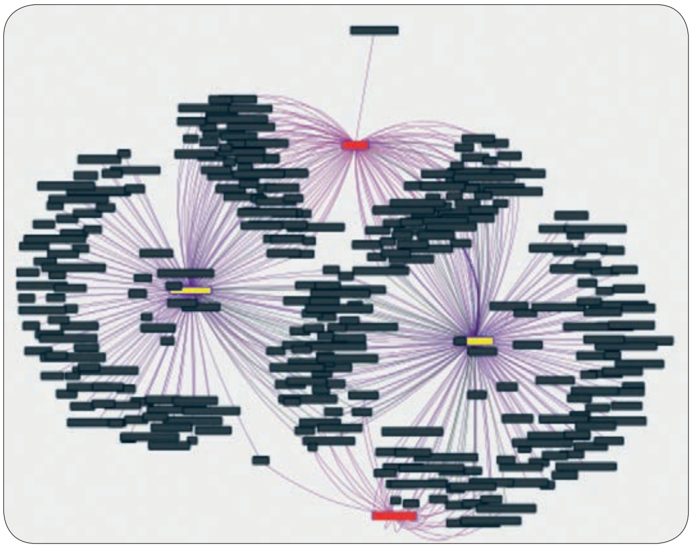


Figure 2. Graphical representation of a big-data search for genes related to both HIV and inflammation. Those genes (yellow boxes) are identified when published papers (black boxes) can be found mentioning either HIV or inflammation (red boxes). None of the papers mention both diseases; the link between them is only evident through the massive data set.

surprise, so you will make your audience happier if you are wrong about rain more often than wrong about sunshine.

The weather example is from 2002, and was discovered by a computer-science graduate student, who was doing Big Data before it was called Big Data. A more recent example comes from one of our colleagues, prof.dr. Barend Mons, who works at the Leiden University Medical Center. Prof. Mons' group has played a leading role in collecting all available biomedical data into a single unified framework. Fig. 2 shows a graphical representation of a research result extracted from that data collection. The research question was to find genes (yellow boxes) involved in both 'inflammation' and 'HIV disease progression' (red boxes). The black boxes represent published papers linking genes to either HIV or inflammation. The two genes displayed in the figure have many published papers that link to either of the diseases, but never to both diseases in the same paper. This link is only discovered when big-data analysis techniques are used on the entire collection.

How can Big Data keep expanding exponentially?

Big Data has continued to expand because the number of connected things continues to increase, and because the underlying technology — especially in networks — allows more and more stuff to be put online.

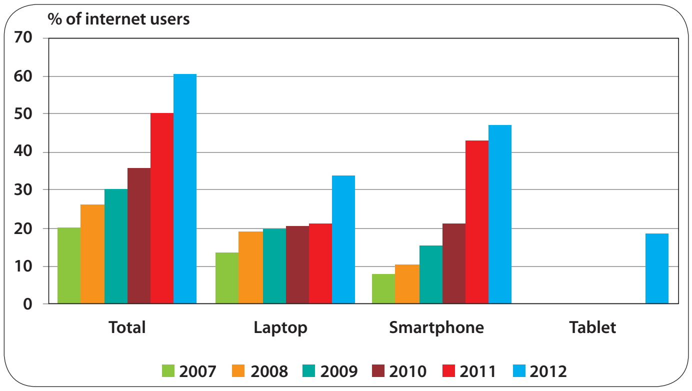


Figure 3. Growth of the usage of –location revealing!– items like laptops, smartphones and tablets in the years 2007–2012. Source: CBS

When the World Wide Web was started, first all high-energy physics labs were connected together; the Web was invented at CERN, and Nikhef was the third site to join worldwide. Very quickly many other academic departments and research institutes joined the web, and commerical sites started to join. In 1992 there were only about 15,000 .com sites, now there are several hundred million. The expansion continued as people (not companies) started to put more and more things online, think of Facebook, Instagram, Twitter, and the many Google services. In recent years, the number of smartphones (see Fig. 3) has been increasing rapidly, adding the location history of millions of people (and millions of 'selfies') to the available Big Data. One might think that with all companies online, all people online, and everyone using a smartphone, the expansion would be over; the next wave is to connect 'everything' to the internet. This wave has started with home thermostats; now there are internet-connected washing machines, cars, garage doors, home lighting, pet collars; you can even have your doorbell send you an email if someone rings it. In most cases, cloud services are involved which means that there is a company that receives this data on its servers and can process it to learn things about the owners. You might be able to learn a lot about a neighborhood, or a person, by studying how often, and at what times, the doorbell is being rung. Even more if you could connect that data to a Facebook profile, and use cellphone tracking data to find out exactly who it is that is visiting when the doorbell rings.

Risks of Big Data

The situation just described makes it pretty clear that the more we get connected, and the more connected our data is, the less privacy we have. Even if the company you give your data to (doorbell, thermostat, cell phone location) is not doing anything shady with this data, they do have the data and it is connected to the internet. Lots of people who would like to misuse your data

Getting the right answers
A short aside on using computers to process large amounts of data and make a decision: computers are very literal. They do exactly what you tell them to do. There is the old joke about a computer washing its hair: it runs out of shampoo, because the instructions say *"apply shampoo; lather; rinse; repeat"*— nowhere do the instructions say *"stop and dry your hair"* so the computer repeats until it runs out of shampoo. When you write a computer program, you have to get it exactly right — there are more than millions of ways to get the program wrong, and only a handful of ways to get it right. In the profit and loss case, it is pretty quickly clear whether the answer was right. In other cases, for example if you're trying to predict something that won't happen for several years, it might not be at all obvious whether your answer is correct. Unfortunately, some of the most important possible uses of big data are like this. Big data is a valuable tool, but we also need to have an understanding of what we're trying to predict, and to be able to check whether the analysis makes sense.

are also connected to the internet. If the people you give your data to are not very careful about security, your data winds up in the wrong hands and can be misused.

A somewhat more subtle form of Big Data risk is called 'targeting' and already happens on a large scale. Because of all the Big Data present, there is no such thing as 'the internet'. When you visit a website, a few pieces of information arrive with you, and in many cases this information is enough so that the website knows it is specifically you that is visiting. Via connected data from Facebook and Google, the website might have a good idea of your income and how much you could pay for a particular product, also of your interests and so how much you might want to buy that product. The website will present in some cases a higher price if it believes you can and will pay it.

These examples come from the cases of companies using your personal 'Big Data', or maybe coupling your data with that of similar people (like Amazon recommendations). There is a natural feedback at work to make sure that the companies are getting the right answer out of this Big Data: money. If the companies process the Big Data and use it to make decisions like what services to offer or products to produce, or to guess how much you might be willing to pay for a product, they had better get the right answer; if they don't they will lose money, and if they lose enough they will go out of business.

A final risk of Big Data has already been presented earlier: how can we be sure that the results being presented, have been honestly presented without 'fudging'? I refer here to the 'wetter weather' predictions. The average citizen can't repeat a big-data analysis to check whether the numbers have been correctly presented — the best we can do is to check whether the numbers resemble the real weather (or economy, or expected lifespan, or unemployment rates).

How sure are we of what we know?
Recall the example given earlier about Machine Learning: that is when you give the computer data, and what you get back is a program that can compute similar things for you. Recall also that in order for the learned program to be really accurate, you need to have lots of data as input. There are a lot of questions:

1. Did you give your learning program enough data?
2. Did you give it the right data?
3. Did you write your learning program correctly? The program that turns your data into a program, is in itself a program, that might have mistakes in it.

Unfortunately the answers to these questions are usually not simple. You can answer 3) mostly by testing your program very well (see the text box "Getting the right answers"), but the answers to 1) and 2) require a good understanding of statistics. Companies selling you Big Data solutions usually leave this part out — they want to sell you the product, and you might not buy it if they tell you you need to spend months learning statistics before you can really understand what your Big Data analysis is telling you.

These problems can be illustrated with the following small-data situation: flipping a coin. You want to analyse coin flips to understand, what is the probability that a flipped two-euro coin will land on 'heads'. Easy, right? You just take data on coin flips, calculate the percentage of flips that come up heads, and that gives you the probability. I just did this: I flipped a two-euro coin eight times; it came up heads 5 times, so the probability is 62%. Right?

This is certainly a case of question 1) above — not enough data. Basic statistics tells us that if I only flip the coin eight times, my estimate of the probability will very likely be off by as much as 18%, this is called the 'uncertainty' in the answer. It might also be a case of question 2) — I am trying to figure out the probability when flipping 'a' two-euro coin, that is *any* coin, but I am only trying the one I had in my pocket — maybe this coin is bent or damaged so that it is different than most other two-euro coins.

For Big Data, question 2) can be a real problem, because the Big Data that is out there is very skewed in some cases. For example, there is a lot of current interest in analysing Twitter data for all sorts of reasons; a recent study tried to determine what was the happiest day of the year. However this analysis could only tell you how happy Twitter users are — recent studies show only about 20% of online adults use Twitter, and Twitter users are mostly below age 30.

There are unfortunately a lot of Big Data analyses being made by people with no background in statistics, meaning that there are a lot of Big Data conclusions out there for which we have no good idea if these conclusions are correct. When you want to analyse Big Data in this way, you move from Big Data to data science; Fig. 4 illustrates the relationship of 'hacking skills' (in this case, is the researcher good at dealing with very large amounts of data), statistics knowledge, and expertise in a field: all three are needed to do data science well. The 'danger zone' in the diagram illustrates a problem often encountered in Big Data studies: someone applied an analysis using a lot of data (= hacking skills) to some particular problem (= substantive expertise in some field) but without a good understanding of principles of statistics and the math needed to use those principles; such studies can be very powerful generators of, well, nonsense.

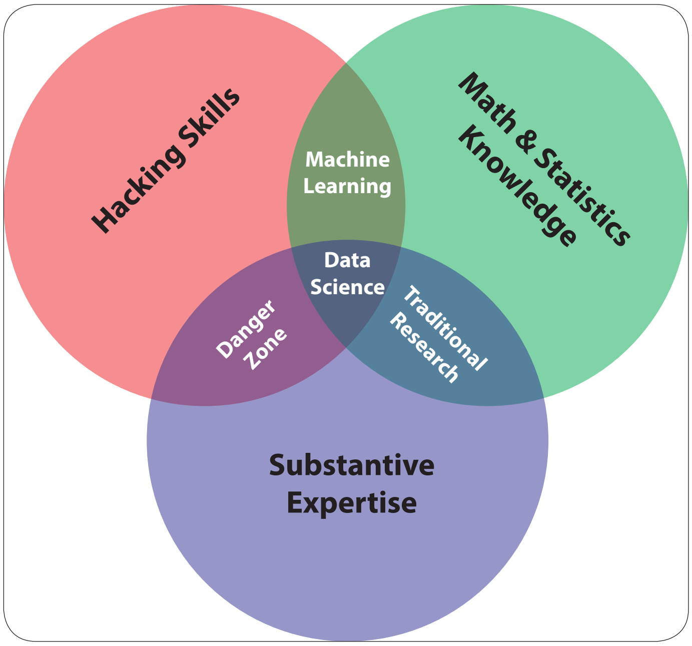


Figure 4. Data science (collection, analysis and interpretation of Big Data) requires simultaneous knowledge of various fields. A slightly modified version of this diagram is also in circulation among data scientists, with 'data science' replaced by 'unicorns', which refers to how few people have this particular skill set.

Nikhef and Big Data (Science)

In our research in high-energy physics at Nikhef, we deal with essentially all of the issues described above, and have been dealing with them long before 'Big Data' became a buzzword. High-energy physics was one of the first scientific fields to generate and analyse large amounts of data, and for a long time we had more data than pretty much anybody else. Only relatively recently, we've been overtaken in data size by a few companies like Google and Facebook.

From the beginning, our analyses have been aimed at getting scientific conclusions from Big Data. We learned — sometimes the hard way — how to avoid making 'bias' errors (wrong data) and how to understand the uncertainties in our answers related to how much data we have … the uncertainty only really goes to zero if you have a basically unlimited amount of data (which means an unlimited amount of money, which we don't have!).

My group at Nikhef has played a leading role in developing the Worldwide Computing Grid for the CERN physics experiments, and as mentioned before, we run a large data center ourselves here at Nikhef — we have the hacking skills in Fig. 4, and together with our physicists, we have the substantive expertise (in High-Energy Physics). All of our physicists know the basic rules and concepts of statistical analysis, and some of us are real experts; two Nikhef physicists contributed a chapter to a recently published book called *"Data Analysis in High Energy Physics: A Practical Guide to Statistical Methods"* [1].

I mentioned earlier how important it was to keep certain kinds of Big Data secure, and my group at Nikhef works on this problem too. The main problem is, how to make it possible to share certain types of data between a large group of researchers located all over the world, without making this data public to everybody. It turns out to not be so easy, especially since most things we could do to make the data more secure, makes the data also harder to use for research.

Machine Learning is used in many different applications in high-energy physics experiments and their analyses. A good example is how our analysis programs can figure out, for all the thousands of particles it detects in a collision, what *kind* of particles (*e.g.* proton, pion, muon, electron, …) they are. We teach these programs how to identify the particles using machine learning (and there is a whole chapter on machine learning in the book just mentioned).

Finally, Nikhef produces data scientists! There are many indications that data scientists — the people who know enough of all three areas in the diagram above to be able to get trustworthy conclusions out of Big Data — will be in short supply in the coming years.

In a variant of the data science diagram shown in Fig. 4 the word data science in the middle is replaced by 'unicorn'. The reason being is that the author of the diagram claims that people who are good in all three areas are as scarce as unicorns. All of our PhD students master the substantive expertise and statistical methods; many master the large-scale computer skills too. This is why many of our students go on to jobs in fields related to Big Data. For example, most of the big-data group at KPMG Netherlands have worked at Nikhef at some point in their career; one of these former Nikhef PhD students, dr. Sander Klous, was just named Professor of Big Data Ecosystems for Business and Society at the University of Amsterdam.

Further reading

I promised to tell you how you could learn more about Big Data. Nate Silver's book *"The Signal and The Noise"* [2]is a very readable description of the types of things you can (and cannot!) do with Big Data; a few of the examples presented here are described in much more detail in that book. A discussion of basic probability and statistics, presented mostly without equations and using only high-school math, with lots of examples, is John Allen Paulos' *"Innumeracy"* [3]. Finally, *"Thinking Fast and Slow"* [4] is a recent book by Nobel Prize laureate Daniel Kahneman, who talks about how the human brain works, why the brain is very bad at thinking statistically and probabilistically, and how easy it is to trick the brain with large numbers. This book reinforces, from a completely different viewpoint, the message made here: in the Big Data age it is increasingly important to have many people trained not only in working with the Big Data, but also interpreting, analysing, understanding, validating, and checking all that data — it is all too easy to draw wrong conclusions from data, intentionally or unintentionally.

By the way — I continued flipping that two-euro coin, just to see what would happen. After flipping another sixteen times, I was at 12 heads and 12 tails, giving the expected result of 50% heads. Although, statistics tells us, this could still be off by as much as 10% due to 'not enough data'!

Bibliography

1. "Data Analysis in High Energy Physics: A Practical Guide to Statistical Methods", Wiley-VCH, ISBN 978-3527410583
2. Nate Silver, "The Signal and the Noise", Penguin Group, ISBN 978-1-59-420411-1
3. John Allen Paulos, "Innumeracy", New York : Hill and Wang; ISBN 0-8090-7447-8
4. Daniel Kahneman, "Thinking Fast and Slow", Farrar, Straus and Giroux, ISBN 978-0374275631

2

Research

2.1 ATLAS
Harvesting LHC Run 1

Management: prof. dr. N. de Groot (PL)
dr. W. Verkerke (PL)

When Peter Higgs witnessed the discovery announcement of the Higgs boson on 4 July 2012, he proclaimed that he had never thought that this discovery would have happened in his lifetime. For particle physics this timely discovery of the Higgs boson opens a new window on fundamental physics that was never experimentally accessible before.

Nikhef students, postdocs and staff played an important role in various analyses in ATLAS that led to the discovery of the new particle, and have now embarked on a series of comprehensive studies that will allow to characterise the Higgs sector of nature in detail.

Harvesting 'Run 1'
'Run 1' of the LHC formally ended on 14 February 2013 when the beams were dumped and the LHC went into a two-year shutdown. The collected luminosity of 5 fb^{-1} at 7 TeV and 20 fb^{-1} at 8 TeV exceeded initial expectations, proved that the ATLAS detector is operating well, and led to a wealth of physics results. Nikhef contributes to the muon system, the silicon strip detector and to the trigger and readout system and takes part in their operation. Physics-wise we concentrate on top quark physics, Higgs physics, and searches for physics beyond the Standard Model. On these topics five Nikhef students have graduated in 2014, three of which earned the distinction cum laude, and one thesis was awarded the ATLAS thesis award.

Is the new boson the Standard Model Higgs boson?
The full 2011-2012 dataset is more than double the size of the discovery sample, which allowed us to study the properties of the new particle in more detail.

After an extensive recalibration of the ATLAS detector the measurements of the reconstructed mass of decays of Z boson pairs and photon pairs have been used to measure the mass of the Higgs boson with a precision of about 3 permille. This outstanding result, based on a detailed understanding of the detector performance after only two years of operation, is a crucial input to all theoretical calculations on Higgs physics.

Last year's determination of the observed Higgs boson being a 0^+ spin-parity state exploited the angular correlations between the decay products in the *WW* and *ZZ* decay channels. This analysis has been continued in a new form that also sets limits on the observed Higgs boson being an admixture of two CP eigenstates. Nikhef continues a leading role in this new analysis in the *WW* decay channel, as well as in the *WW/ZZ* combination effort.

The proverbial smoking gun in the assessment whether the observed particle is the Standard Model Higgs boson, or one of the Higgs bosons in a more elaborate theory, is the pattern of coupling strengths of the discovered particle to all other elementary particles. These coupling strengths can be inferred from Higgs decay rates to these particles, or production rates from these particles. Due to an unexpected gift of Nature —a Higgs boson with a mass of 125 GeV— the Higgs decay rate to many fermions and gauge bosons turn out to be large enough to be measurable at the LHC. These measurements will be the basis of a detailed 'fingerprinting' of the Higgs sector in the next decade.

Currently, seven of these Higgs coupling strengths are experimentally accessible. The most recently added measurement is the coupling of the Higgs to top quarks, through a search for Higgs bosons produced in association with a pair of top quarks, where the Higgs boson decays to a pair of *b*-quarks. The identification of these events is challenging due to large backgrounds from top-quark pair production, and has long been considered an analysis for the far future. Recent progress in measurements of top backgrounds and multivariate techniques, in which Nikhef has played a crucial role, has allowed a first constraint on $t\bar{t}H(b\bar{b})$ production this year. Furthermore we have contributed to the evidence for Higgs production through the vector boson fusion process in the *WW* decay channel.

We also studied the frequency of double parton interactions as a potential background to double Higgs production. These analyses will become particularly relevant for Run 2 of the LHC.

Searches for physics beyond the Standard Model
The discovery of the Higgs boson confirmed that its mass, 125.36 GeV, is of the order of the electroweak scale. However, in the Standard Model the mass of the Higgs boson is subject to quantum corrections that are many orders of magnitude larger, unless the parameters of the theory are highly fine-tuned. An important question is therefore: Why is the observed Higgs boson so light? One possible answer is that new physics regulates these quantum corrections so that the Higgs boson can be light without a delicate fine-tuning of theory parameters. One of these regulating theories is supersymmetry, which could explain the low mass of the Higgs boson, if the new particles predicted by supersymmetry are not too heavy.

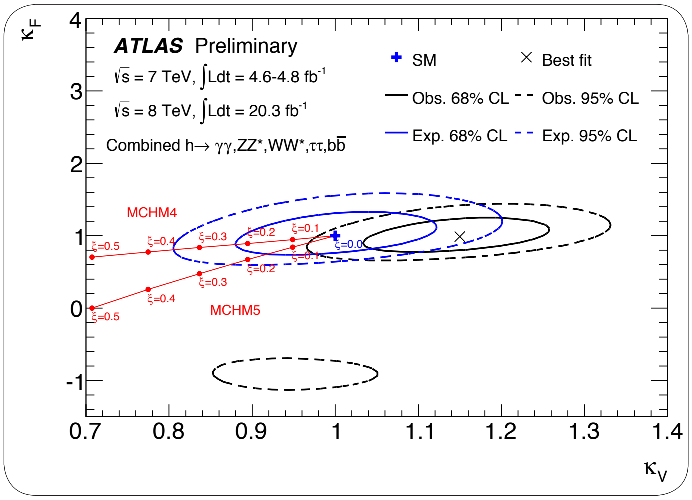


Figure 1. Measurement of Higgs coupling strengths to fermions (K_F) and gauge bosons (K_V) relative to the Standard Model expectation. The black contours indicate the allowed regions from a fit to all ATLAS Higgs decay rate measurements. In the context of a Minimal Composite Higgs Model, an extension of the Standard Model that predicts that the Higgs boson and fermions are composite particles, these couplings can deviate from the Standard Model values along the trajectories that are shown in red, depending on an assumed compositeness energy scale that is related to the parameter ξ. The data constrain ξ<0.15 (0.20) for MCHM type 4 (5) at 95% C.L., corresponding to a lower limit on the compositeness scale of 640 (550) GeV.

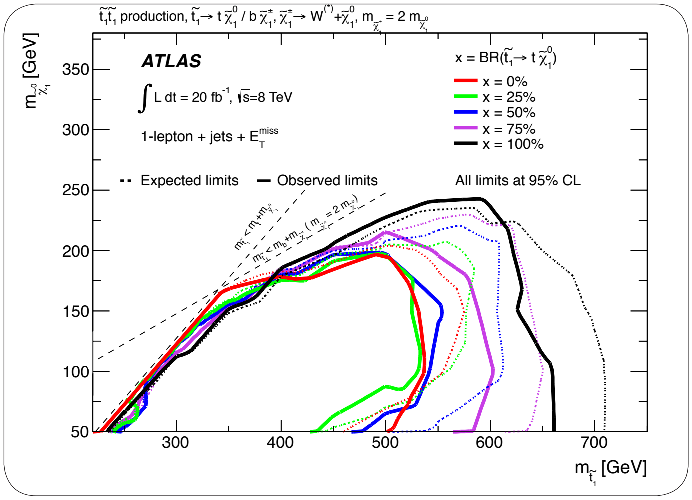


Figure 2. Result of the search in Run 1 data for pair production of supersymmetric top quark partners ($\tilde{t}_1$), where each $\tilde{t}_1$ can decay to either a top quark and a neutralino ($\tilde{\chi}_1^0$) or a b-quark and a chargino ($\tilde{\chi}_1^\pm$). Shown are the excluded masses of top quark partners ($m_{\tilde{t}_1}$) and neutralinos ($m_{\tilde{\chi}_1^0}$) obtained from the non-observation of such decays in Run 1 data. The excluded masses depend on the assumed branching fraction of top partners to neutralinos, and this dependence is illustrated by the contours in the various colours.

The Higgs discovery and the measured Higgs mass might be seen as new guiding principles to search for new physics. New physics that regulates the Higgs boson mass will on the one hand modify measurable properties of the observable Higgs boson, and on the other hand introduce additional heavy particles, *e.g.* superpartners, that might be produced and detected in the LHC.

Following the first strategy, a new Nikhef-led study tests the measured Higgs coupling strengths against predictions of a wide range new physics theories. Even with the present precision of coupling measurements this reinterpretation of ATLAS measurements constrains parameters of supersymmetric theories, portal dark matter models, composite Higgs models (see Fig. 1) and many more models.

Nikhef also actively participates in a number of dedicated direct searches for supersymmetric partner particles. These searches include final states with zero leptons, supersymmetric particles of the third generation, and general searches for supersymmetry. Figure 2 shows exclusion limits of an analysis with a strong Nikhef contribution on a model in which pairs of stops —the partners of top quarks— are pair-produced, and subsequently decay to a quark and either a neutralino or a chargino. Run 1 has set significant limits on supersymmetry; in constrained models squarks and gluinos below approximately 1.5 TeV are excluded. The 2015 LHC run at full energy will put supersymmetry to further stringent tests.

One of the fundamental questions of particle physics is whether elementary particles such as leptons and quarks are really elementary. To test this hypothesis we look for excited states of these particles that decay to three or more normal leptons. So far no evidence of such decays was found above background level. Nikhef also has a research line looking for lepton-flavour violating processes in tau decays. While experimentally very challenging, an observation would be indicative of new physics.

Top quark physics

The abundant production of top quarks at the LHC allows to perform precision tests of physics involving interactions with this heaviest quark found so far in nature. Top quarks almost always decay to a *b*-quark and a *W*-boson. No charge-parity (CP) violation is expected in this decay in the Standard Model. However, anomalous tensor couplings in this decay vertex may take complex values and introduce CP-violation that would manifest itself in modified decay distributions of polarised top quarks. We have analysed angular distributions of decay products of top quarks that originate in polarised form in electroweak production processes to set limits on CP violation in tensor couplings in the *Wtb* vertex.

Future physics in ATLAS

In the 2013-2014 LHC shutdown (LS1) the LHC machine was preparing for future operation at higher energies. Simultaneously ATLAS was upgrading the detector for running in 2015 and beyond at nominal LHC luminosity. Nikhef is involved in various projects in LS1. The ATLAS pixel detector is extended with an additional layer of silicon sensors, the insertable B-layer (IBL), closer to the interaction point. Nikhef has constructed a cooling plant for the IBL, based on evaporative CO_2 cooling. The plant has been delivered to CERN and has been commissioned in 2014. The cosmic events taken at the end of 2014 demonstrate a fully operational inner detector, now including the IBL, as shown in Fig. 3.

The level-1 trigger will have to cope with significantly larger collision rates in Run 2, which implies that it will have to become smarter. ATLAS tries to achieve this in the form of a topological trigger that will enable ATLAS to trigger at the first level on smart combinations of objects. Nikhef develops 'momentum imbalance' reconstruction algorithms to be run on the new topological trigger in order to improve searches for supersymmetry. Nikhef has also constructed an electronics board that will enable the feeding of muon detector information to the topological trigger. We have also adapted the MROD read-out modules of the muon system to deal with the higher data rate. In Run 2, which will last from 2015 to 2018, the LHC is expected to deliver some 150 fb^{-1} at a centre-of-mass energy of at least 13 TeV. The higher energy will be very beneficial for searches for new massive particles.

After Run 2, the LHC will shut down for an extended period again (LS2) in order to upgrade the LHC injectors and prepare for luminosities exceeding the design luminosity. ATLAS will replace a layer of endcap muon chambers with a layer of new chambers to improve triggering on muons in the forward region. Nikhef is involved in the readout of the new system, which will be based on a new design with high-speed optical links, configurable in a flexible way. This will also be used for the trigger system of the electromagnetic calorimeter and serve as a prototype for a readout of the full detector after future upgrades. The recently awarded NWO National Roadmap grant will fund the Nikhef contributions to ATLAS upgrades from 2014 until 2021.

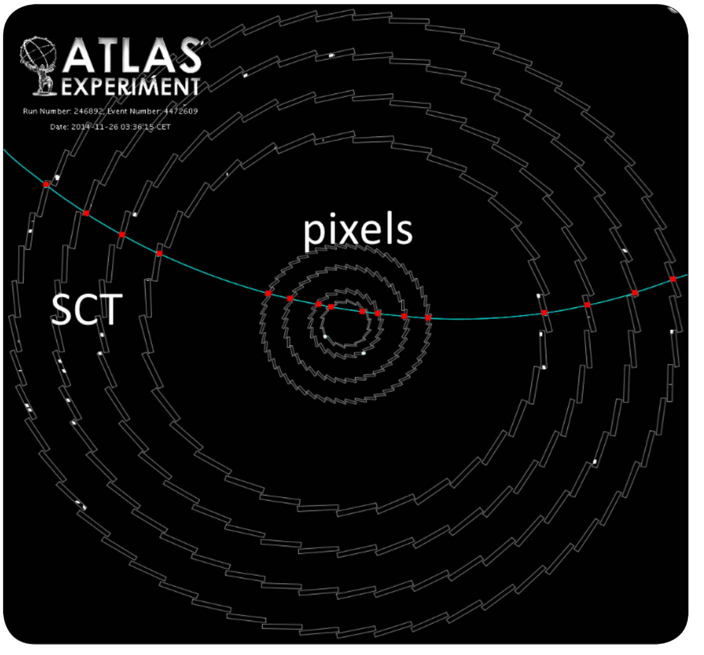


Figure 3. A cosmic muon passing through the ATLAS inner detector, including the newly installed Insertable B-layer (IBL), which is shown as the innermost ring.

The European Strategy for Particle Physics has prioritised the full exploitation of the LHC up to a delivered luminosity of 3000 fb^{-1}. This is achievable with a significant upgrade of the accelerator and the detectors after 2023, in a project known as the high-luminosity LHC (HL-LHC). The Nikhef ATLAS group has participated in physics studies for the HL-LHC upgrade, in particular in searches for supersymmetry, Higgs production and *WW* scattering. The HL-LHC will demand a new inner detector (ITk) for ATLAS, based on all-silicon sensors, able to stand the higher instantaneous and integrated luminosity and the corresponding radiation dose. Nikhef is involved in design studies and simulation, as well as in the design of an endcap strip detector, with the aim to construct one complete endcap detector at Nikhef. In November the ATLAS ITk upgrade project was formally kicked off, where Nikhef has expressed interest, among others, to design and assemble an ITk endcap.

2.2 LHCb
Probing physics beyond the Standard Model

Management: prof. dr. M.H.M.Merk (PL)
prof. dr. A. Pellegrino

During 2014 the LHCb detector was prepared for the upcoming Run 2 of the LHC at a higher beam energy of 13 TeV and a more frequent collision rate of 40 MHz. At the same time, the data collected in 2011 and 2012 were further analysed, in particular to search for signals from physics beyond the Standard Model. The results of three of these searches, with leading contributions of the Nikhef group, are summarised here.

Search for new matter vs antimatter asymmetries
The phenomenon of Charge-Parity (CP) violation is required to explain the absence of antimatter in the universe. Although the Standard Model with three generations of particles offers an elegant explanation for the existence of matter-antimatter asymmetries in particle physics via the so-called CKM mechanism, it falls short by many orders of magnitude to explain the cosmic absence of antimatter. The goal of the LHCb CP violation program is on the one hand to precisely measure the CKM model parameters, and on the other hand to search for signatures that cannot be explained with the Standard Model CKM picture. A beautiful measurement of the CKM parameter γ is performed through the detection of beauty-strange meson particles decaying to a charmed meson and a kaon in the decay $B_s^0 \rightarrow D_s K$.

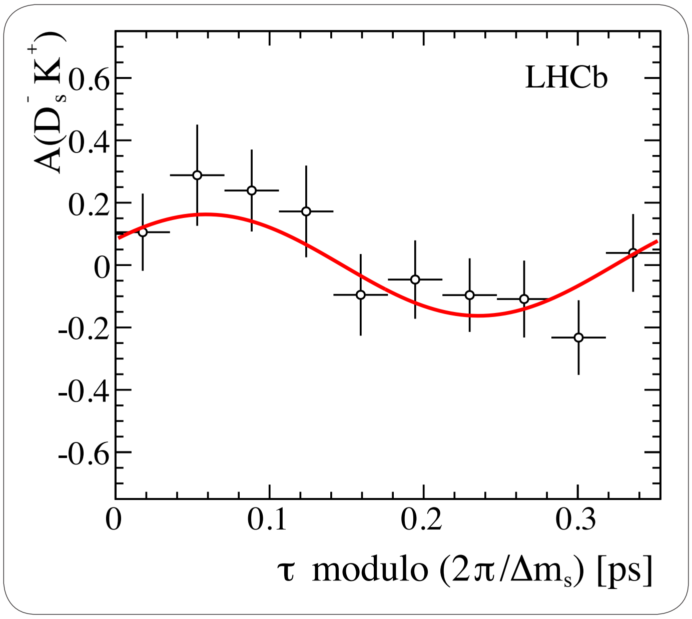


Figure 1. The asymmetry between B_s^0 and $\overline{B}_s^0$ decays into a final state of $D_s^- \pi^+$ in the 2011 LHCb dataset. The decay rate distribution is folded into a single period of a B_s^0-$\overline{B}_s^0$ oscillation. The black points are the data and the red line is the fitted curve. The amplitude of the oscillation curve is a measure for the amount of CP violation.

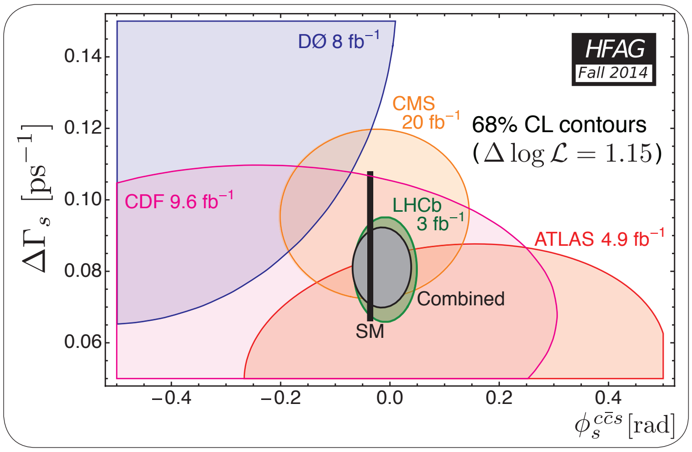


Figure 2. The result of the measurement of the B_s^0 oscillation parameter $\Delta\Gamma_s$ vs the CP violation parameter φ_s, comparing the measurement of LHCb (the green oval) with that of other experiments. The grey oval is the combined average and the black bar represents the Standard Model prediction.

Here, CP violation manifests itself through a time-dependent modulation of the decay rate, as shown for the 2011 dataset in Fig. 1. The combination of this measurement with similar other decays has resulted in the measurement of the CKM parameter, $\gamma=(73\pm10)^\circ$.

At the same time a precision study of alternative decays of beauty-strange mesons to hidden charm and strangeness mesons, $B_s \rightarrow J/\psi\varphi$, has been completed on the combined dataset of 2011 and 2012. For this particular decay the CKM mechanism of the Standard Model predicts the absence of any CP violation, making this decay a sensitive probe for contributions from alternative sources. This measurement involves the search for a time-dependent oscillation in the decay rate as well. The result is expressed with the CP violation parameter $\varphi_s=(-0.6\pm2.3)^\circ$. The LHCb measurement is compared with that of other experiments in Fig. 2.

Search for Forbidden decays
The occurrence of decays of neutral beauty mesons (both B^0 and B_s^0) into a final state of two muon particles is heavily suppressed in the Standard Model. As such, a more frequent occurrence of these so-called forbidden decays directly points to the existence of physics beyond the Standard Model. Following earlier reports of LHCb results, a common analysis of LHCb and CMS data was recently performed. The result of this analysis is shown in Fig. 3. This establishes the existence of the decay $B_s \rightarrow \mu^+\mu^-$ at 6σ standard deviations, while at the same time there is a 3σ hint for the decay $B^0 \rightarrow \mu^+\mu^-$. The latter result is somewhat surprising as it was not quite expected from the Standard Model prediction. The

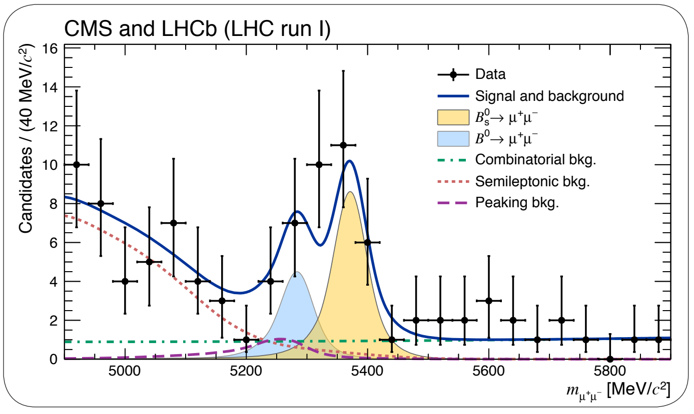


Figure 3. The combined LHCb and CMS invariant mass distribution of selected events with two oppositely charged muons in the final state. The black points are the data, the blue curve is the fitted lineshape of the mass spectrum including the B_s^0 resonance (yellow shaded area), the B^0 resonance (blue shaded area) and several backgrounds (coloured dotted lines).

relative occurrence of the corresponding ratio B^0 over B_s^0 decays is a stringent future test for the Standard Model, and at currently deviates slightly more than 2σ from its prediction.

Search for long-lived massive particles

Nature provides us with meta-stable massive particles that decay after travelling a macroscopic distance in our detectors. Similarly, various New Physics models predict in addition the existence of similar, but even heavier particles. LHCb is particularly suited to filter out decays of such metastable particles from the huge collision background, when they decay a distance between a fraction of a millimeter up to several tens of centimeters. A particularly interesting class of these particles are so-called Hidden Valley particles, also called v-pions. A search has been carried out to try and reconstruct decays of v-pions producing hadronic jets into the spectrometer. A candidate event is shown in Fig. 4. However, no signal was found in the data of 2011 and exclusion limits on the production rate of various different masses of hypothetical v-pion particles have been set.

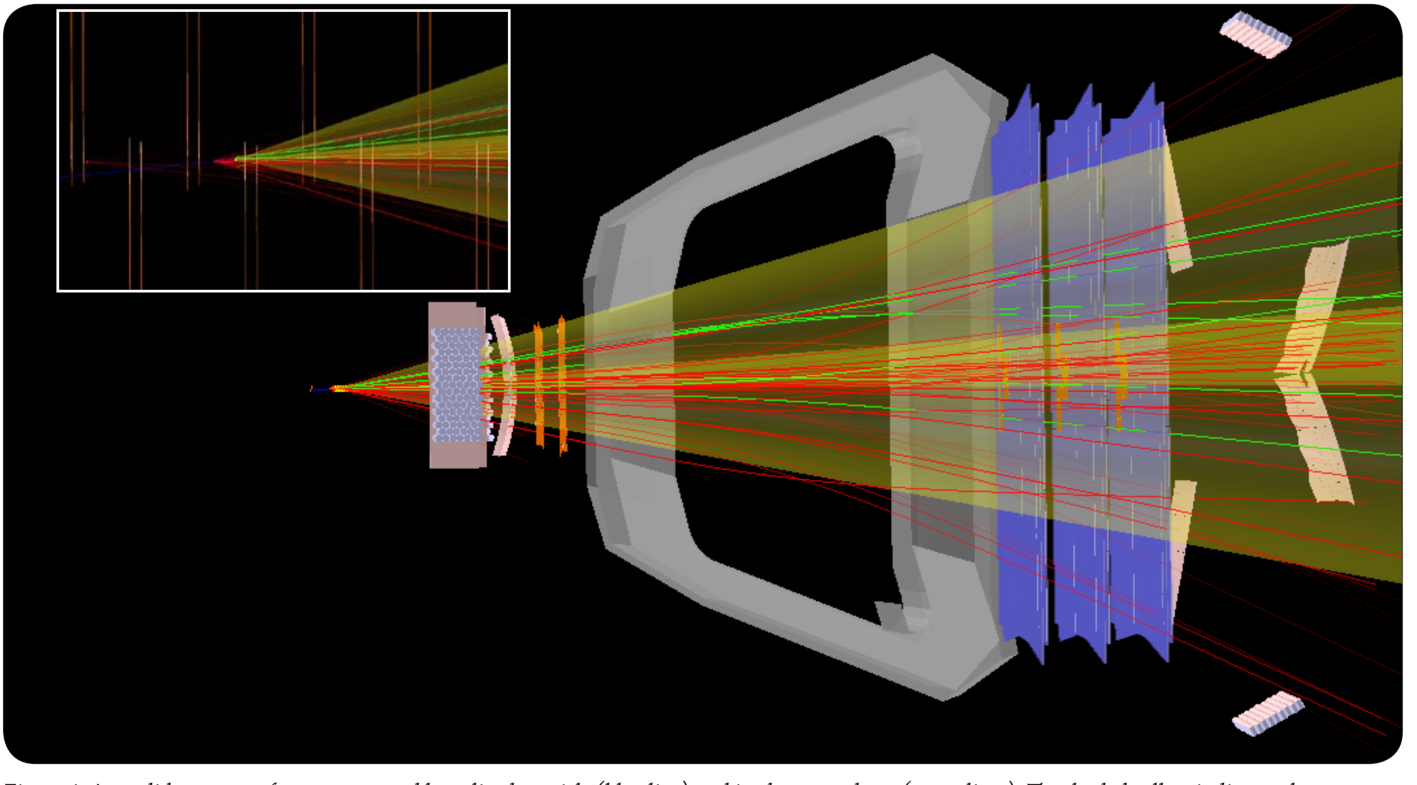


Figure 4. A candidate event of a reconstructed long-lived particle (blue line) and its decay products (green lines). The shaded yellow indicates the reconstructed jet and the red lines represent the additional particles produced in the collision. The insert shows a zoom-in on the production region.

2.3 ALICE
Relativistic Heavy-Ion Physics

Management: prof. dr. R. Snellings (PL)

One of the most remarkable predictions of the Standard Model of particle physics is that, at sufficiently high densities and temperatures, the protons and neutrons of ordinary matter should melt into a plasma where the quark and gluon degrees of freedom are not anymore confined. This hot and dense primordial state of matter, the Quark Gluon Plasma (QGP), is believed to have existed in the expanding universe up to a few microseconds after the Big Bang, when the phase transition to hadronic matter of confined quarks and gluons took place. At the LHC, by colliding Pb ions at high energies, conditions similar to those in the very early evolution of the universe are reproduced. The main goal of ALICE is to determine the properties of matter under such extreme conditions, and to improve our current understanding of the phenomenon of confinement and the generation of mass by the strong interaction.

Flow studies in Pb–Pb collisions

In ultra-relativistic heavy-ion collisions at the LHC more than 1000 particles can be produced per unit of rapidity. These particles move collectively under the influence of a common velocity field induced by the rapid expansion of the system. A very interesting feature of the collective motion is its anisotropy, originating from the almond-shaped region of the colliding nuclei and the initial inhomogeneities of the system density. These are transformed, through interactions between the produced particles, into an anisotropy in momentum space. This transformation depends on the ratio of shear viscosity over entropy (η/s), which quantifies the friction of the created matter. The resulting anisotropy in particle production can be quantified by a Fourier analysis of the azimuthal distribution relative to the system's symmetry plane, characterised by the Fourier coefficients v_n. The second harmonic, v_2 is known as the elliptic flow coefficient. Elliptic flow studies at the Relativistic Heavy Ion Collider (RHIC) and at the LHC contributed to the astonishing realisation that the hot and dense matter created in ultra-relativistic heavy-ion collisions acts as a system whose value of the shear viscosity to entropy density ratio η/s is very close to the lower bound of $\hbar/4\pi\, k_B$ conjectured based on the anti-de Sitter/conformal field theory duality (AdS/CFT). In other words, it behaves as a nearly perfect liquid.

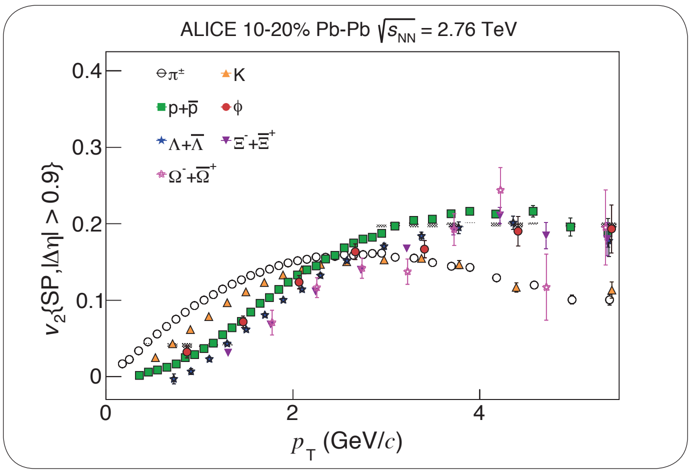


Figure 1. The p_T-differential v_2 for different particle species for the 10–20% centrality interval of Pb–Pb collisions at $\sqrt{s_{NN}}$= 2.76 TeV.

Fig. 1 illustrates how v_2 develops for different particle species within the same centrality interval in central Pb–Pb collisions. A clear mass ordering is seen in the low p_T region (*i.e.* p_T < 2 GeV/c), which is also evident for all centrality intervals . Comparisons to hydrodynamic calculations in this transverse momentum range indicate that the produced matter at the LHC seems to favour a value of η/s smaller than two times the quantum mechanical limit.

Detector upgrade

Despite the success of ALICE, after only two and three years of Pb–Pb and pp running, respectively, and one p–Pb run, there are several frontiers, including high precision measurements of rare probes over a broad range of transverse momenta, for which the current experimental setup is not fully optimised. ALICE is therefore preparing a major upgrade of its apparatus, planned for installation in the second long LHC shutdown (LS2) in the years 2018–2019.

At this moment the main particle tracking device in the ALICE experiment is limited to a readout rate of approximately 500 Hz for Pb–Pb collisions. The ALICE upgrade will modify the detector such that it will be able to record all Pb–Pb interactions (50 kHz) that the LHC is expected to deliver. Besides a two orders of magnitude increase in data collection speed a new, high-resolution, low-material thickness Inner Tracking System (ITS) will improve the tracking precision significantly and allow the full reconstruction of beauty mesons and the Λ_c baryon, which cannot be separated from background with the current set-up. The improved tracking system will be positioned closer to the interaction point by reducing the diameter of the LHC beam pipe. This new detector, in combination with an upgraded Time Projection Chamber (TPC) and upgraded data acquisition, will allow us to collect about ten billion (10^{10}) lead-lead interactions in the period 2019–2021, two orders of magnitude more data than would be possible without the upgrade. Detailed simulation studies have shown that the improved resolution and significant increase in statistics will allow the ALICE experiment to address the main questions about heavy flavour thermalisation and in-medium energy loss.

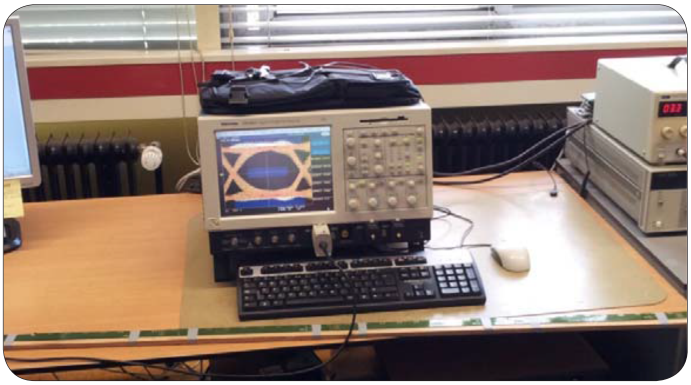


Figure 2. Test set-up for signal transmission tests

In 2013, Nikhef has joined the ALICE inner tracking system upgrade program. Nikhef will benefit from its experience gained with the design and production of the existing ITS to optimise the new system using modern technology. Only by integrating the power regulators into the sensor ASIC and by using a serial powering scheme the material used in the active volume can be reduced to the required amount. In addition, Nikhef is involved in the optimisation of the read-out chain. Due to the limited space available in the central part of the ALICE detector, the design of the data links in the pixel chip, the transmission of the signal through the signal lines on the front-end modules and in the long low mass cables to the data acquisition system are being studied in detail. During the production phase Nikhef will assemble a significant fraction of the detection staves for the two outer layers, using components produced in other laboratories, and assure the quality of the final product in accordance with the foreseen project leadership of Nikhef.

The group is also involved in R&D for a high granularity calorimeter, related to a potential further longterm (> 2023) upgrade of ALICE, to be used for the measurement of forward direct photons.

Outlook

The activities presented here are highlights of early results from ALICE in which the Nikhef group played a significant role. The group is also involved in more advanced topics and analyses using the same data sample. For the flow measurements, a next step is to study higher harmonics of identified hadrons, which are more sensitive to the vale of η/s and can help to constrain the initial conditions of a heavy ion collision.

In addition, the group is involved in several other correlation measurements that address different topics, such as the question whether parity symmetry is violated in strong interactions. Other correlation measurements, such as balance function measurements, may shed more light on the hadronisation dynamics.

In the area of penetrating probes and parton energy loss, the group will continue its strong role in heavy-flavour measurements, in measurements of the jet spectrum and modifications of jet fragmentation due to interactions with the medium, and in the measurement of real and virtual photons.

The upcoming pp and Pb–Pb runs in 2015 will provide the statistics to study in detail not only the intriguing phenomena that emerge in small systems related to the onset of collective effects, but also perform precision measurements while exploring parton energy loss and elliptic flow at higher transverse momentum.

2.4 Neutrino Telescopes
ANTARES & KM3NeT

Management: dr. A. Heijboer (PL)

Nikhef is heavily involved in the operational neutrino telescope ANTARES and the planned telescope KM3NeT, both in the Mediterranean Sea. Nikhef is one of the largest groups in the ANTARES collaboration, which is harvesting on already eight years of data. It is also a leading institute in the KM3NeT collaboration with Nikhef's Maarten de Jong as spokesperson. The construction of the KM3NeT detector has just started. For KM3NeT in Phase I (2015/2016) 31 strings will be deployed at the French and Italian sites and thus provide a more than three times larger detector than ANTARES. On the way to the final detector with 700 strings an intermediate step with 230 strings, called phase 1.5, is planned.

This intermediate step is motivated by the recent discovery of extraterrestial neutrinos of spectacularly high energy (PeV) by the IceCube experiment. The origin of these neutrinos so far remains a mystery. Although the spatial distribution seems to show an anisotropy towards the galactic center region, the low statistics and limited angular resolution of IceCube do not allow any rigorous conclusions. Therefore, further observations especially of that region are invaluable for a better understanding.

Although ANTARES' operational size is smaller than IceCube's it offers a better angular resolution and access to lower energies. The galactic 'hot spot' region of the IceCube excess has been scrutinised for possible point sources using ANTARES data. Nikhef was majorly involved in this effort and single point sources with a hard energy spectrum could thus already be excluded as the only origin of the neutrino excess discovered by IceCube.

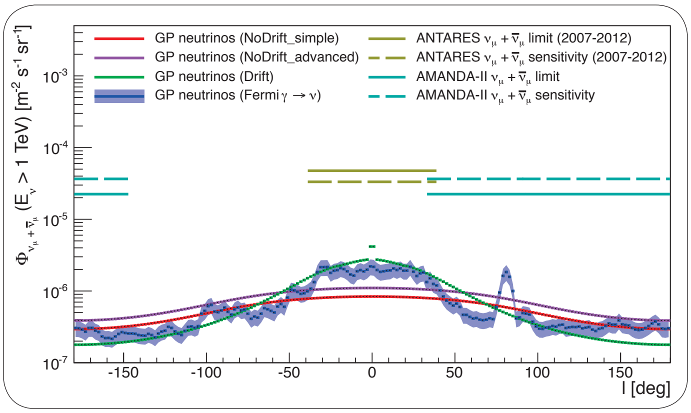


Figure 1. The diffuse neutrino flux integrated above 1 TeV shown as a function of longitude for various models together with the sensitivity and limit from Amanda and from the recent ANTARES analysis which constrains the flux in the central galactic region.

The galactic region has also been subject of another analysis at Nikhef in which the first limit on the diffuse neutrino emission expected from interactions of cosmic rays with the interstellar medium in this region has been set. For this emission a softer energy spectrum is expected than for point sources. In the meantime IceCube published energy spectra on a larger sample of their high energy extraterrestrial neutrinos which do favour soft energy spectra and still seem to show a spatial anisotropy. The new ANTARES limit can thus directly help to constrain models explaining the origin of those neutrinos with galactic emission.

With its excellent angular resolution and direct view of the galactic region KM3NeT will already within its first year of phase 1.5 be able to confirm or exclude the galactic center as the origin of the PeV neutrino signal.

For KM3NeT the construction phase has started and the building of prototypes is transitioning towards mass production. Nikhef is involved in many of the required developments of which a few are highlighted here. The Nikhef design of the optical modules with 31 photomultipliers mounted in a glass sphere has undergone its final revision and mass production has begun. The design of the electronic boards attached to the photomultipliers to produce the required high voltage was finalised and the 15,000 boards required for assembling of the first 26 strings were produced and tested. The Nikhef group was also responsible for the firmware on the central logic boards in the optical modules to establish the synchronisation in nanosecond precision using the 'White Rabbit' system and also contributed to the development of the DAQ software.

The complete production chain for a full KM3NeT string has been developed and set up at Nikhef culminating in the successful assembly of a first complete string with 18 optical modules which will be deployed in early 2015.

The mechanical structure for deploying strings for KM3NeT was developed at Nikhef in collaboration with NIOZ (Royal Netherlands Institute for Sea Research) and was this year successfully demonstrated in Motril (Spain).

In May 2014 the very first KM3NeT string with three prototype optical modules had been assembled at Nikhef and subsequently deployed in May at 3,200 m depth at the Italian KM3NeT site. The data were evaluated mostly by the Nikhef group and already with only three of the modules a full reconstruction of (down-going) muon tracks from combined signals in the three modules was demonstrated, proving also the powerful background suppression from the correlation between the small PMTs.

Figure 2. The first fully assembled KM3NeT string with 18 optical modules at Nikhef.

Nikhef is also substantially involved in exploring the potential for the full KM3NeT detector via simulations for which a new shower reconstruction has been developed with an unprecedented resolution of a few degrees.

A new opportunity for neutrino telescopes had arisen from the establishment of a non-zero mixing angle 'theta-1-3' in the neutrino sector in 2012, namely to identify the unknown mass hierarchy of the neutrinos by evaluating the flavour changing oscillations of atmospheric neutrinos. Depending on the mass hierarchy the oscillation pattern changes in the transition of the neutrinos through the Earth in different ways. The signature of the change is very subtle and unprecedented energy and angular resolutions at low energies (around ~6–10 GeV) are then crucial for a successful distinction. The same detector technology as for KM3NeT, but in a denser configuration, has since been studied for this purpose under the name ORCA. Nikhef has been instrumental in developing the analysis and reconstruction chain and evaluating the sensitivity. A three sigma distinction of the two mass hierarchies can be expected already within three years of operation of the proposed ORCA detector. The French site of KM3NeT will be devoted to further exploring the feasibility of this exciting option by implementing densely populated strings.

Overall the neutrino telescope technology has significantly matured and excellent prospects for the measurement of both high and low energy neutrinos could already be demonstrated ensuring a bright future for neutrino astronomy.

2.5 Gravitational Waves
The dynamics of spacetime

Management: prof. dr. J.F.J. van den Brand (PL)

General relativity is one of the pillars of modern physics, yet over the past century, empirical access has been limited to situations where gravitational fields are nearly stationary (as in the Solar System), or where they are dynamical but relatively weak (as with radio observations of binary neutron stars). Direct detection of gravitational waves (GW), ripples in the curvature of spacetime that propagate at the speed of light, appears in the foreseeable future the only way to observe the genuinely strong-field dynamics of space-time. The worldwide network of second generation laser interferometric GW detectors, with ten times enhanced sensitivity and a 1000 times larger accessible volume of universe and expected detection rate, is undergoing the commissioning phase towards the first joint data taking planned for 2017. Nikhef is involved in the historical quest of the first GW direct detection by participating in the Advanced Virgo project.

Instrumentation for Advanced Virgo

Nikhef is in charge of the design and production of crucial hardware components for the vacuum, injection, and detection subsystems of Advanced Virgo, an upgrade of the Virgo interferometer with three kilometre long arms located in Cascina near Pisa in Italy. The institute has important responsibilities in the angular alignment of core optics, seismic attenuation systems of Advanced Virgo's optical sensors, cryogenic ultra-high vacuum links, input-mode cleaner dihedron and end mirror suspension (see Fig. 1), and adaptive optics systems such as phase cameras.

Thanks to the deep expertise in vibration isolation technology and skills in high precision mechanics, Nikhef is the leading institution of the Suspended Benches project subsystem. The Nikhef group has conceived and produced six vibration isolation systems for Advanced Virgo: one single-stage six degrees of freedom in-air seismic attenuator, called EIB-SAS for the external injection bench, and five multiple-stage in-vacuum isolators, called MultiSAS (see Fig. 2) for the suspended optical benches.

Figure 2. Panorama of the BOL Clean Room at Nikhef during the assembly of the five MultiSAS units for Advanced Virgo.

Seismic isolation provided by EIB-SAS allows to take full advantage of the beam pointing feedback system located on the external injection bench, to inject the laser beam into the interferometer with the required picoradian level jitter in the detection frequency band. The large attenuation factors provided by the MultiSAS units will ensure that the seismic motion of the angular alignment sensors (and related pickoff telescopes) placed on the suspended benches will not couple to the output of the detector through scattered light. This year all five MultiSAS have been assembled and tested at Nikhef and three of them installed at the Virgo site and pre-commissioned; the installation of the remaining two units is foreseen before summer 2015.

The cryogenic ultrahigh vacuum links (*cryolinks*), allowing a 100-fold improvement in the residual gas pressure in the arm pipes, must be considered the major improvement in the vacuum infrastructure of the detector. The four units, designed at Nikhef, have been produced and transported to the Virgo site last spring. Their

Figure 1. Installation of the new end-mirror suspension in Virgo's Input Mode Cleaner.

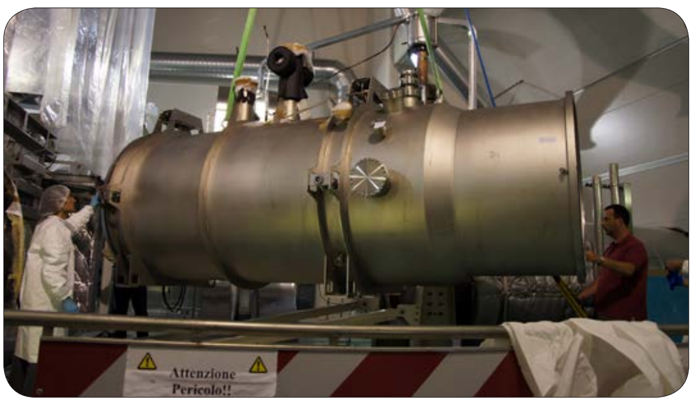


Figure 3. Installation of the first cryolink at Virgo's North End building, summer 2014.

installation (see Fig. 3) and commissioning is ongoing and will last till June 2015.

Prototyping of the phase cameras, developed by the Nikhef group after an intense R&D campaign, was completed in spring 2014. Phase cameras, providing accurate images of the spatial distribution of amplitude and phase of the laser fields (carrier and sidebands) circulating in the power recycling cavity, are instruments of paramount importance for the active compensation of the aberrations of the transmissive optics of the interferometer, which otherwise could compromise the detector stability and would limit the usable optical power. Installation of the three units is foreseen in early 2015.

During the last year Nikhef has also designed and produced all RF and DC quadrant photodiode modules (see Fig. 4) necessary to sense and control the alignment between the optics of the interferometer, and novel vacuum compatible low power galvoscanners needed for the automatic beam centering on the RF quadrant photodiodes used for differential wavefront sensing.

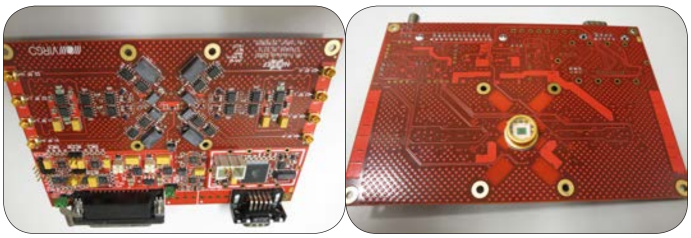


Figure 4. Front- and back-side of the PCB for the linear-alignment front-end systems. The right panel shows the quadrant photo-diode.

Data analysis

The gravitational wave group at Nikhef also carries an extensive research programme in data analysis, under the leadership of Chris Van Den Broeck who was recently appointed as Data Analysis Coordinator by the Virgo Collaboration. Focussing on the coalescence of compact binaries composed of neutron stars (NS) and black holes (BH), considered one of the most probable sources for the first direct detection of GW events, Nikhef has made leading contributions to the LIGO–Virgo effort towards developing software that will extract fundamental physical information from the signal. This comprises the determination of individual component masses and spins, the sky location and orientation of the binary, and the distance to the source, together with the identification and removal of instrumental calibration effects.

The Virgo group at Nikhef has studied a method to use future data from NS–NS coalescenses to characterise the equation of state of a neutron star, one of the most unknown observables in astrophysics, and it has developed a data analysis pipeline, called TIGER (Test Infrastructure for GEneral Relativity), to test the genuinely strong-field dynamics of general relativity in a model-independent way up to $(v/c)^6$ order (see Fig. 5). This latter effort has led to the creation of a new technical sub-group within the LIGO–Virgo collaboration to expedite the activity. This group has brought the TIGER pipeline for binary neutron stars coalescences to maturity by making it robust to unknown instrumental effects (*e.g.* calibration errors), to imperfect knowledge about the signal shape according to general relativity and to unknown astrophysical effects, *e.g.* the neutron star equation of state.

The TIGER framework has been proposed to also test the validity of the No-Hair Theorem when applied to ring downs of coalescing binary black-holes. A preliminary benchmarking has been made on simulated waveforms for ringdowns of massive (500–1000 solar masses) BH–BH binaries which will be seen by the Einstein Telescope. The Nikhef Virgo group is also involved in the search of continuous gravitational waves from fast-spinning neutron stars in binary systems for which it is developing a dedicated data analysis pipeline called Polynomial Search. Such a pipeline was benchmarked among others last summer in a mock-up data challenge.

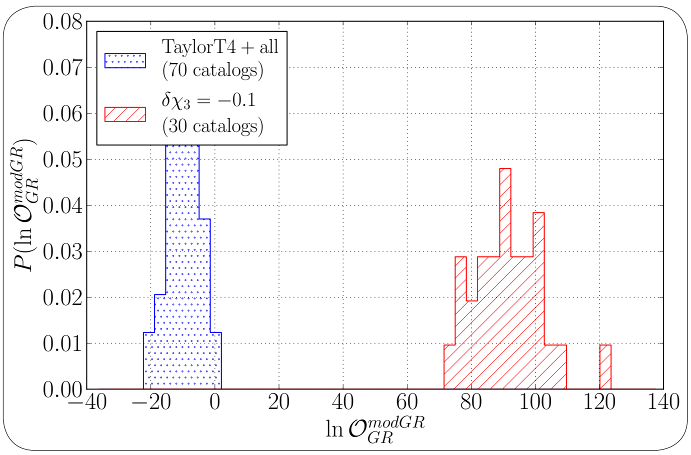


Figure 5. If the strong-field dynamics of spacetime is not as predicted by general relativity (GR), then the TIGER data analysis pipeline will be able to find out by studying gravitational wave signals from coalescing binary neutron stars. Shown are the distributions of TIGER's 'detection statistic' for GR violations, for the case where GR is correct (blue), and assuming a violation of the GR prediction for the self-interaction of spacetime (red).

2.6 Cosmic Rays
Pierre Auger Observatory

Management: prof. dr. S.J. de Jong (PL)

Ultra-high-energy cosmic rays are the most energetic particles we know, exceeding the LHC energy by many orders of magnitude. Yet we do not know the physics that is needed to generate them in the heavenly bodies, nor do we know the physics that governs their interactions with our own atmosphere. The Pierre Auger Observatory is world's largest cosmic ray observatory located on 3,000 km² near Malargüe in the province of Mendoza in Argentina and was built to resolve these mysteries.

A consortium of Dutch groups from Nikhef, the University of Groningen and the Radboud University Nijmegen has been participating in the Pierre Auger Collaboration since 2005. Besides analysing the Auger surface and fluorescence detector data, the Dutch group pioneers a complementary technique to measure ultra-high-energy cosmic rays by detecting the radio frequency radiation emitted by the air shower.

The origin of ultra-high-energy cosmic rays

The Pierre Auger Collaboration had shown definitively that the energy spectrum of cosmic rays exhibits a sharp drop around 10^{20} eV. This drop is compatible with the Greisen-Zatsepin-Kuz'min (GZK) cut-off caused by the universe becoming opaque due to resonant collisions between ultra-high-energy protons

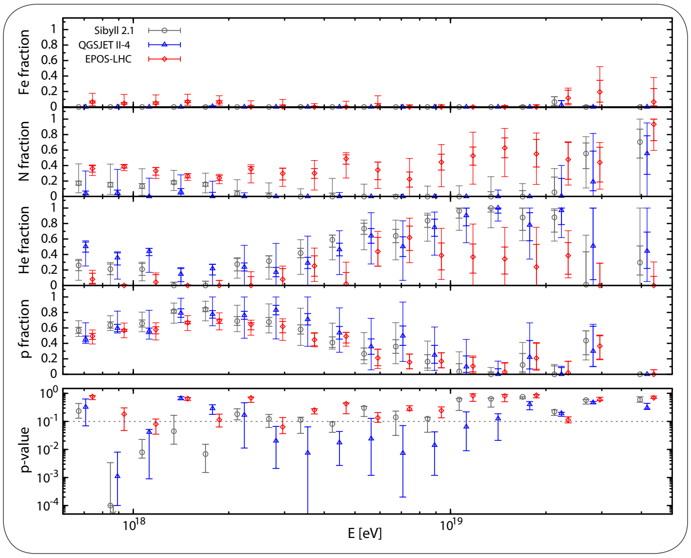


Figure 1. Fitted fraction of protons, helium, nitrogen and iron nuclei as a function of energy of the cosmic rays. The lower panel gives the fit probability for each fit. Different theoretical models, Sibyll2.1, QGSJET II-4 and EPOS-LHC, are used for the fit function.

and the photons of the cosmic microwave 2.7 K background radiation. Past measurements by the Pierre Auger Collaboration already have cast some doubt on this explanation, and this year's results further established that the GZK cut-off cannot be the entire story and even the extent of its contribution to the cut-off remains unclear.

Detailed composition spectra in the energy range $10^{18.5}$–$10^{19.5}$ eV show that most cosmic rays at these energies probably have a mass somewhere between the extremes of that of a proton or iron nucleus (see Fig. 1).

These spectra are measured with the fluorescence detector, one of the main hybrid detection methods of the Pierre Auger Observatory, which registers the fluorescence light that is caused by the particle shower in the atmosphere. This detector can only operate in darkness, which is about 13% of the time. The other main detection method is the surface detector that consists of 1.5 km spaced water Cherenkov tanks particle detectors that operate 24/7. This surface detector was not built with the intention to measure cosmic ray composition, but recently analyses have been developed that show that a composition measurement is possible with about half the resolution of the fluorescence detector, but on ten times as many events.

The weak anisotropy signal that remains in the Auger data is commensurate with cosmic ray masses, and therefore electric charges that are so large that accurate pointing to even relatively nearby sources is excluded. If the arriving cosmic rays are electrically neutral, they should be pointing to their sources quite accurately. However, both a dedicated analysis that required cosmic ray showers to be compatible with incoming photons, as well as an interpretation of incoming cosmic rays as neutrons have not revealed any point sources. Ultra-high-energy cosmic rays: we know they are there, but we have no idea yet where they are coming from.

Particle interactions at ultra-high energy

Collisions of ultra-high-energy cosmic rays on atmospheric molecules provide hadronic interactions at an energy that exceeds the LHC centre-of-mass energy by one to two orders of magnitude. Although progress was made in incorporating LHC results, some mysteries were not solved. The number of muons in Monte Carlo simulations is very significantly smaller than the number measured in experimental data. Also the depth at which most muons are produced that reach the Earth's surface cannot be described by Monte Carlo simulation for any reasonable composition mix of cosmic rays. Muons in ultra-high-energy hadron collisions: A sign of new physics?

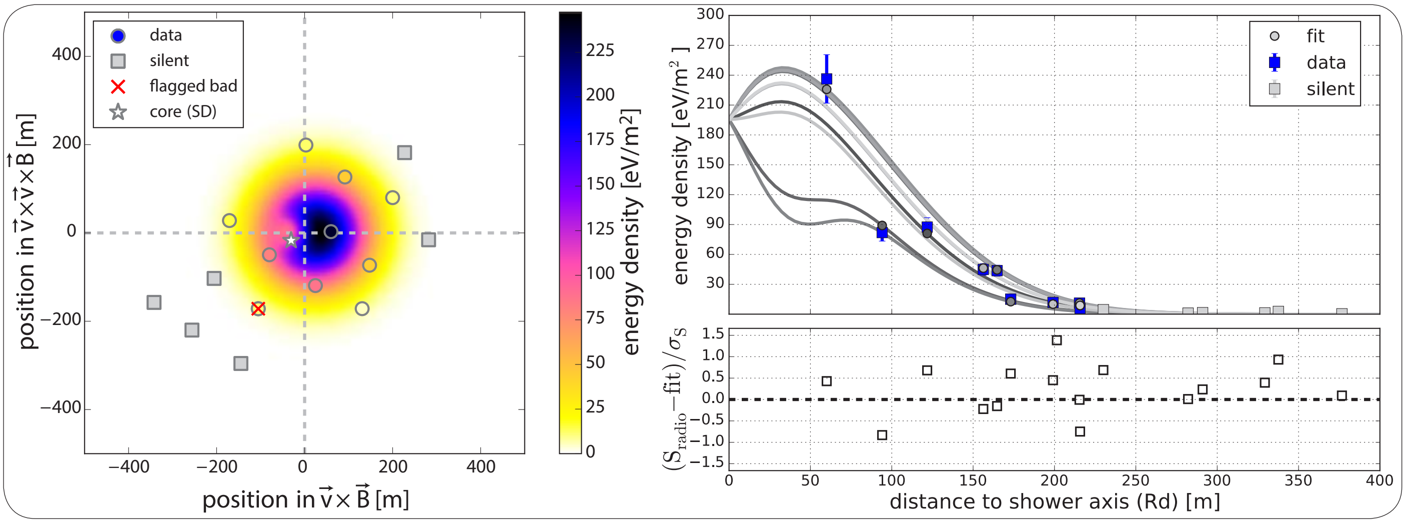


Figure 2. Lateral signal distribution of a single cosmic ray event in the plane perpendicular to the shower axis. Left: The energy density in the shower plane. The measurements are indicated as circles where the color shows the energy density. Grey squares are stations with signal below threshold and the red cross marks a rejected station. The background map shows the parametrisation of the lateral distribution function (LDF). Right: The radio energy density versus the distance to the shower axis. Blue squares are the measurements whereas the circular symbols indicate the value of the LDF parametrisation at the position of the measurement. Gray curves show the radial falloff along a line connecting the radio core position with every station position. Also shown are the residuals in units of the individual uncertainty of the measurement.

Upgrade of the Pierre Auger Observatory

To allow an event-by-event determination of the composition of ultra-high-energy cosmic rays an upgrade is being planned for the Pierre Auger Observatory. The main upgrade component, the dedicated detection of muons in the extensive air showers, has been agreed on as an additional detection layer on top of all water Cherenkov surface detector tanks. This addition is aimed at a separation of the muon and electromagnetic component of the shower for each measurement station and will allow to determine the cosmic ray composition event-by-event. Subsequently selecting the ultra-high-energy protons, guarantees that they have an energy at which they are hardly bent by the cosmic magnetic fields and thus point back to their sources. To enhance the capabilities of the surface detector, especially for composition measurements, it will be equipped with upgraded electronics with a larger sampling rate and a larger dynamic range. The fluorescence detector will be operated allowing for a larger background, thereby extending the time it can operate by about a factor of two.

The collaboration is currently investigating the realisation of a complementary array that provides an area in Auger of about 100–300 km^2 with a dense set-up of conventional detectors, as well as with dedicated muon detectors that are covered with a few meters of soil as a muon filter. This complementary array will both calibrate the main upgrade as well as measure in detail the composition of cosmic rays in the energy range of 10^{17}–10^{18} eV, where the transition from galactic to extra-galactic sources is thought to occur.

Radio detection of cosmic rays

The co-operation on radio detection of cosmic rays between the LOFAR radio telescope and the Auger Engineering Radio Array (AERA) has proven extremely fruitful. A detailed description of the spatial distribution of the radio signal can now be predicted and fitted to the experimental data. In Fig. 2 an example of an event is shown with a fitted lateral energy density profile. The non-rotational invariance around the shower axis can easily be noted and is due to the interference from geomagnetic radio wave emission and the negative charge excess that develops in the shower front. The maximum in the lateral density profile away from the shower core is due to the forming of the Cherenkov beam that results from the diffractive index of the atmosphere. These fits provide an accurate energy estimate for the cosmic rays and determine the composition on an event-by-event basis with an accuracy that is unprecedented. The use of polarisation information promises to further improve our understanding of the radio signal and to even better measure the cosmic ray properties. The AERA will undergo a modest extension in 2015. The next step is to prepare for a larger array that can match the Auger complementary array upgrade.

2.7 Dark Matter
Dark Matter Experiments

Management: dr. M.P. Decowski (PL)

With the ongoing construction of a new detector, it is an exciting time for the Nikhef direct-detection dark matter group. The Nikhef group was one of the first to install a large subsystem in the XENON1T experimental area in Hall B of the Gran Sasso laboratory (LNGS) in Italy. Meanwhile, XENON100 is still taking data with various calibration sources to further study the performance of this well-running detector and data analysis is ongoing. There was also a local success: the XAMS dual-phase xenon time projection chamber (TPC) that we built at Nikhef over the past two years, saw first signals in May 2014.

More globally, a number of experiments (*i.e.* CRESST, CoGeNT, CDMS-Si) that previously showed possible hints of having detected low-mass weakly interacting massive particles (WIMPs) either excluded or retracted their detection claims. The dark matter race is still very much ongoing.

XENON100 Data Analysis

While the focus of the XENON collaboration has clearly shifted to the construction of the XENON1T experiment, the XENON100 experiment continues to take data and results are being analysed. Early in 2014, we completed a 150 day lifetime dark matter science run. The analysis of these (still blinded) data is ongoing and will be combined with the earlier 225 day exposure

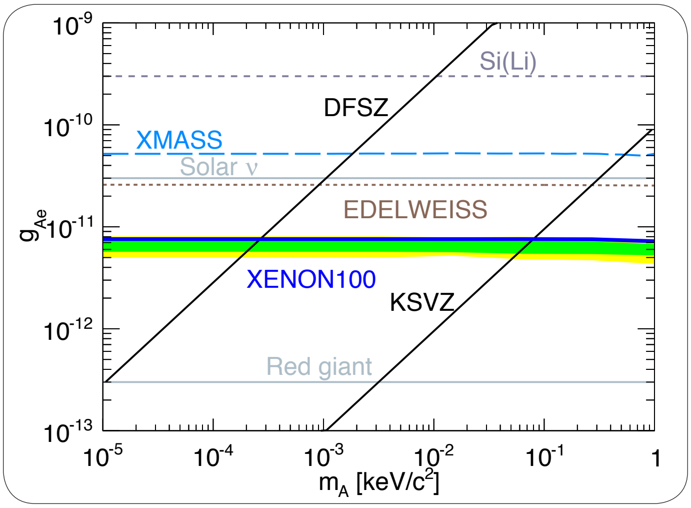


Figure 1. The XENON100 limit (90% CL) on the axion-electron coupling constant vs solar axion mass (blue line). The expected sensitivity is shown by the green/yellow bands (1σ/2σ). Two benchmark axion models, DFSZ and KSVZ, are represented by grey lines. Within these models, XENON100 excludes axion masses above 0.3 eV/c² and 80 eV/c², respectively.

data set. The ultra-low background of XENON100 has enabled us to study interactions different from the 'standard' WIMP-nucleus analysis, even without background rejection. We performed a sensitive search for solar axion and galactic axion-like-particle (ALP) interactions with electrons using the previous 225 day data-set, see Fig. 1. This result is the most stringent limit for the axion-electron coupling constant for solar axions with masses below 1 keV, and for galactic ALPs with masses below 10 keV.

Since longer dark matter running using XENON100 will not provide additional dark matter sensitivity, we have switched to running with various calibration sources. Of these, the ongoing multi-month run with a ^{88}Y-Be neutron source is most important. This source provides nuclear recoils similar to those of a few-GeV WIMP, and it is the first time that this kind of measurement is performed in a liquid xenon detector. It is an essential tool to give a deeper insight into the sensitivity for low-mass WIMPs. Meanwhile, the analysis at Nikhef has concentrated on the so-called S2-only analysis in XENON100, primarily aimed at setting competitive limits for low-mass WIMPs. This analysis sacrifices event-by-event particle identification for a much lower energy threshold. The analysis is advancing rapidly and results are expected soon.

XENON1T Construction

The construction of XENON1T has made rapid progress in 2014. The experiment has started to dominate the experimental hall in the LNGS laboratory, see Fig. 2. All major items, such as the water tank, cryostat and support structure, cryogenics and purification plant, xenon storage and recovery system etc. have been delivered underground and their integration is ongoing. Nikhef was responsible for the vibration-free cryostat support structure which was delivered and installed in a three-week-long campaign in May. We are presently finalizing the design of the calibration system (to be built by others). The automated system will deliver radioactive sources inside the water tank, externally to the cryostat. The signals from the radioactive source are essential to understanding the performance of the heart of XENON1T, the TPC.

The Nikhef team is also responsible for the trigger and event builder as part of the data acquisition group. This software will allow continuous readout of the XENON1T detector, implementing the trigger entirely in software. A lot of progress was made during 2014, moving from an early prototype to an almost final system. The full DAQ system will be tested and commissioned on the XENON100 experiment in Spring 2015 before moving it to XENON1T. Since the number of photomultiplier (PMT) channels in XENON100 and XENON1T is very similar,

Figure 2. View of XENON1T inside the water Cherenkov muon veto. The inner cryostat vessel, which will house the TPC, is hanging from the cryostat support structure. The large pipe will carry all the cryogen and signal lines from the cryostat to the support building outside of the water tank.

the XENON100 test will allow exercising the DAQ already before the XENON1T TPC is ready.

Finally, the Nikhef team has also started to develop the data processor and analyser. With this set of tools all the necessary actions to convert the PMT signals into physical quantities that are stored for further analysis are performed, including peak-finding, gain and signal corrections, event position reconstruction etc. It was written with flexibility and software sustainability in mind.

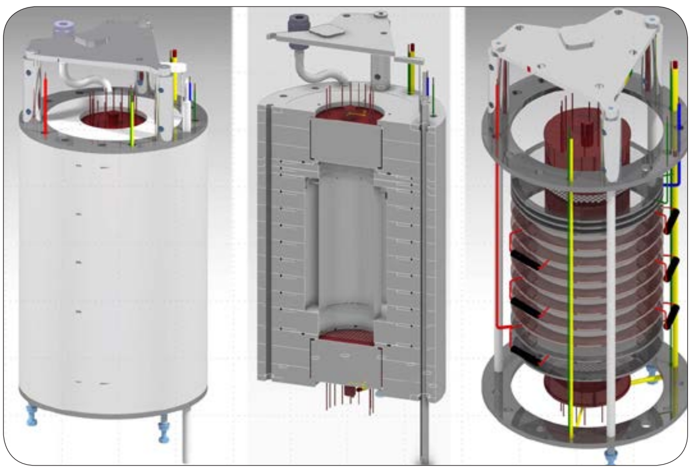


Figure 3. Illustration of the XAMS dual-phase xenon TPC. The setup consists of two PMTs and a variety of meshes and electrodes to maintain an electric field. The xenon in the TPC is cooled and purified using external equipment.

While the data processor was written for XENON1T, it is fully configurable and is able to also analyse XENON100 data and data from smaller setups, such as XAMS. The data processor has been benchmarked against the present XENON100 processor and found to have very similar performance and efficiency.

The Dark Matter group activities position us to have a leading role in the first XENON1T dark matter analysis. The XENON1T detector is expected to start data-taking in Fall 2015.

XAMS R&D at Nikhef

More locally at the Nikhef institute, the Dark Matter group finished and successfully operated a small dual-phase xenon TPC called XAMS. We designed and built the TPC during the first half of the year, see Figs. 3 and 4. The XAMS detector has an active mass of about 0.5 kg and it was operated during a few weeks in the summer using radioactive sources. We saw the tell-tale sign of 'electron drift' indicating high purity of the xenon. We are presently replacing the readout system and expect to start full commissioning soon.

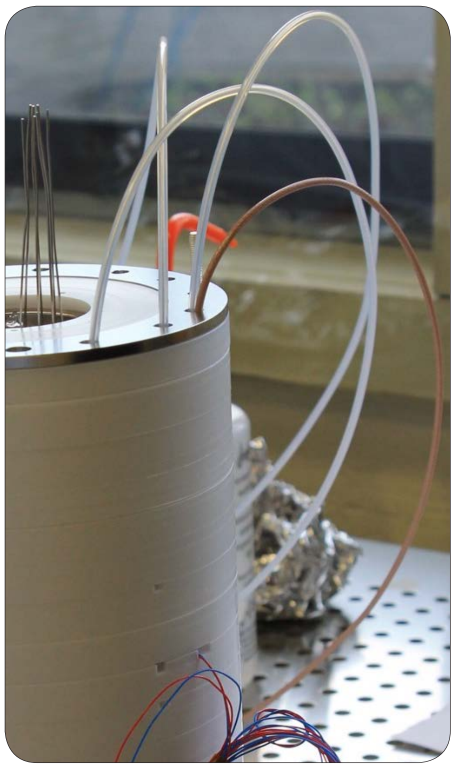


Figure 4. The fully assembled XAMS TPC.

2.8 Theoretical Physics

Management: prof. dr. E. Laenen (PL)

Many research results were obtained in the theory group this year, in a wide variety of areas. Below is a selection of some of these results.

Supersymmetry and supergravity

A major branch of this year's research has continued to be supersymmetry (SUSY) and supergravity in four dimensions, and the link to ten-dimensional string theory, which offers a consistent theory of quantum gravity coupled to matter. One particular focal point is N=2 extended supersymmetry: the additional SUSY, twice as much as in the Minimal Supersymmetric Standard Model (MSSM), is the maximal amount where one has separate matter multiplets involving spin-0 and spin-½ fields and gauge multiplets, which also include spin-1 fields. We characterised the conditions required for fully supersymmetric vacuum configurations of these multiplets. This is important for so-called BPS black holes in supergravity. There, the matter fields near the event horizon prefer to be fully supersymmetric configurations related to the black hole charge and similar quantities. We also developed new techniques in superspace, where supersymmetry is nothing but a translation in a fictitious dimension, to describe the couplings of these matter multiplets.

While interesting on its own merits, extended four-dimensional supersymmetry is also related to compactifications from higher dimensions. For example, when ten dimensional string theories are compactified on a six-dimensional Calabi-Yau manifold, the resulting four dimensional theory exhibits N=2 supersymmetry, and the couplings of the vector multiplets reflect the geometry of the Calabi-Yau. To understand this better, we have proposed a relation between the free energy of simpler topological string theories compactified on a Calabi-Yau and the effective supergravity action, using the language of special geometry and a mathematical object called the Hesse potential.

A unique possibility occurs when taking supersymmetry to its maximal N=8 version: there is only a single multiplet involving the graviton, 28 spin-1 fields, and 70 spin-0 fields. We identified the conditions under which this supergravity admits deformations that leave the gauge group unaffected, but modify the gauge field sector, leading to families of models that appear similar but whose physical properties can drastically differ depending on the deformation.

String theory may also lead to a 4D world with only N=1 supersymmetry. We analysed N=1 *STU* supergravity models arising from string theory, both from a 4D (bottom-up) perspective and a 10D (top-down) perspective. Working directly in four dimensions has the advantage of circumventing the 10D Einstein's equations. We identified the effects of Kaluza-Klein monopoles, magnetic charges in lower dimensions from gravitational configurations in higher dimensions.

We also explored the connection to theories in two dimensions. After deforming a 4D theory with a certain surface operator in the field theory, we showed how an interpretation is possible as a 4D gauge theory coupled to a 2D N=(2,2) theory. The exact partition functions of both these 4D and 2D theories were computed and compared.

Feynman diagrams and gravitational lensing

The photons from the Cosmic Microwave Background (CMB) are deflected on their way to us by the gravitational effect of large scale structure in the universe. This gravitational lensing results in correlations in the CMB radiation that break statistical isotropy. The Hu-Okamoto estimator exploits this to obtain an estimate for the gravitational potential φ from CMB data. Gravitational lensing has now been observed with a significance of more than 25 σ, and the power spectrum of φ is starting to be constrained.

We developed a new approach, based on Feynman diagrams, that allowed us to calculate the bias/noise of the Hu-Okamoto estimator up to $O(\varphi^4)$. Previous calculations had found an unusually large $O(\varphi^4)$ correction, that raised concerns about the convergence of the φ expansion. Our Feynman diagram approach made it easy to diagnose this as being due to a class of diagrams that only starts to contribute at this order. We also showed that a reorganisation of the φ expansion improves the convergence, and thus solves this problem.

Jets

There are many sources of soft hadronic activity in collisions at the LHC: soft radiation from the hard quarks/gluons that enter the primary hard collision, secondary collisions (multiple parton interactions), etc. These effects are modeled by Monte Carlo programs that simulate LHC collisions. We scrutinised this modeling, by working out the features that are rigorously predicted by quantum field theory and comparing to the Pythia and Herwig Monte Carlo programs.

As an example, we looked at the invariant mass of jets in Z + jet and Higgs + jet events. The main effect of soft hadronic activity is captured by a single parameter Ω, describing the shift of the jet mass spectrum. Focussing on the effect of hadronisation, field theory predicts that Ω^{had} does not depend on transverse momen-

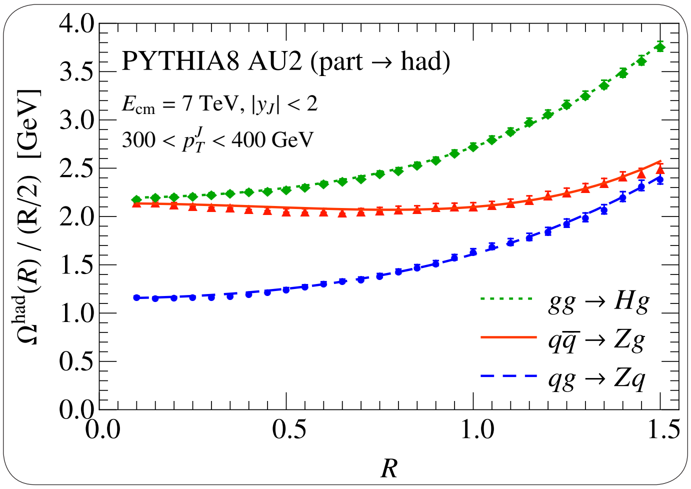


Figure 1. The jet radius R dependence of the hadronisation correction Ω^{had} to jet mass in Pythia. Ω^{had} behaves linearly at small R and only depends on whether the jet is initiated by a quark (blue dashed) or gluon (red solid and green dotted), in agreement with our field theoretic predictions.

tum or direction of the jet. However, Ω^{had} does depend on the jet radius R. For small R it scales linearly with R and only depends on whether the jet is initiated by a quark or gluon. Pythia and Herwig agree well with these features, see Fig. 1. On the other hand, there seems to be a degeneracy in Pythia and Herwig between multiple parton interactions and perturbative soft radiation associated with the primary collision. We showed that this degeneracy can be lifted by using the predicted dependence on the jet transverse momentum.

Self-interacting dark matter

The structure of our universe at galactic and subgalactic scales may be the key in unravelling the nature of dark matter. The canonical paradigm of collisionless cold dark matter has been extremely successful in explaining the structure of our universe in galaxy-cluster and larger scales. However, at galactic and subgalactic scales, the observed patterns of gravitational clustering deviate from the predictions of collisionless cold dark matter simulations; the latter predict very rich clumping of matter and too dense galactic centers. The discrepancies between simulations and observations suggest that a shift in the dark-matter paradigm may be needed. Self-interacting dark matter has emerged as a compelling alternative to collisionless cold dark matter. If the dark-matter particles scatter off each other inside haloes, then the redistribution of energy and momentum can heat up the low-energy material, smooth overdensities and suppress the star-formation rate, thus bringing theory in better agreement with observations.

This paradigm shift points to particle-physics models that are quite different from the scenario involving Weakly Interacting Massive Particles (WIMPs). Various aspects of dark-matter physics along this new direction were explored. The dark-matter self-scattering cross-section per unit mass required to affect the dynamics of haloes is around $\sigma_{scatt}/m_{DM} \sim 1$ barn/GeV, which far exceeds the weak-scale cross sections. This value suggests that dark matter couples directly to a new light force mediator. Sizeable couplings to light force carriers typically also imply large annihilation cross sections. This is well accommodated within the asymmetric dark matter scenario, in which the dark-matter relic abundance is due to an excess of dark particles over dark antiparticles that cannot be destroyed, independently of how large the annihilation cross section may be. A novel mechanism for the generation of particle-antiparticle asymmetries via CP-violating scatterings was investigated. Exploring the low-energy phenomenology of self-interacting asymmetric dark matter, including the effect on the dynamics of haloes, presupposes understanding the cosmology of these models, which can be quite complex. It may involve the formation of dark-matter bound states, and the late kinetic decoupling of dark matter from dark radiation. The role of such bound states in dark-matter physics was explored.

2.9 Detector Research & Development

Management: dr. N.A. van Bakel (PL)

The Nikhef Detector R&D group focuses on particle tracking and radiation imaging, developing novel gaseous and semiconductor based pixel detectors. We have presented at the IEEE-NSS conference the most precise gaseous pixel detector to date for measuring the position of individual ionisation electrons. This leads to improved angular (2.5 degrees) and position (in-plane 10 μm) resolutions on fitted tracks. This finds applications in self-triggering and on-chip pattern recognition for use in for example the ATLAS L1 trigger or Proton Radiography. To further enhance the capabilities of our pixel detectors and to be ready for novel detector concepts we started evaluating the requirements for the next generation readout chips, *e.g.* the successor of the Timepix3 ASIC (application-specific integrated circuit).

Together with the Nikhef Dark Matter group we have constructed XAMS –a Xenon facility in Amsterdam– now operational to investigate different detector technologies in a dual-phase Xenon time projection chamber (TPC). Work together with the Nikhef Gravitational Physics group led to alignment and monitoring systems for Virgo's optical test masses, a program to develop ultra-sensitive accelerometers for future Gravitational Wave detectors, and experimental studies to utilise mono-crystalline sapphire cantilevers for low-frequency suspension. Various projects have applications outside our field and encourage valorisation activities: the development of scientific instrumentation towards commercial applications outside the fields of (astro)particle physics.

A Silicon telescope for detector characterisation

Within the scope of the LHCb VELO upgrade project a particle tracking telescope has been constructed based on the Timepix3 ASIC. This ASIC has been jointly developed by CERN, Nikhef and Bonn University. The telescope consists of eight sensor planes, equally divided in two arms, and with the detector under test mounted on translation and rotation stages in the centre of the telescope. Each sensor plane consists of a 300 μm thick silicon sensor bump bonded to the Timepix3, which features $55 \times 55\ \mu m^2$ pixels, and has a total active area of $2\ cm^2$. The telescope is read out with the SPIDR readout system, which has been developed at Nikhef, and is (partially) funded by the AIDA FP7 project. Extensive commissioning of the telescope was performed during the summer with beams from both the PS and SPS beam lines at CERN. In the second half of 2014 the telescope has been successfully used at the 180 GeV mixed hadron beam at SPS to characterise the first prototype silicon sensors of the VELO upgrade. Thanks to the excellent pointing resolution of less than

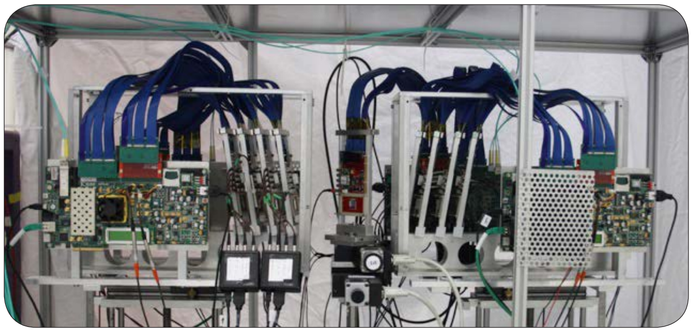


Figure 1. LHCb telescope with eight sensor planes bonded to Timepix3 front-end chips and read out by the SPIDR data acquisition system

2 μm, high resolution time tagging, and the enormous track rate capabilities (10 Mtrack/s), detailed studies of the sensors, and behaviour of the corresponding readout ASICs are now possible. Besides the VELO, also other LHCb upgrade groups and the Nikhef *GridPix* development benefitted from the availability of the telescope.

The Velopix design, which is the pixel readout chip tailored to the upgrade of the LHCb VELO, is progressing. One of the key building blocks, a 5 Gbit/s serialiser, has been submitted as a small test chip and subsequently characterised in the lab. The VeloPix project suffered from a serious delay because of a change of foundry for the 130 nm technology, which was triggered by the fact that the previous vendor could no longer guarantee the availability of the process to us for the timespan of the project.

Medical Instrumentation

In the Nikhef detector R&D group, a number of medical imaging projects are ongoing. The main focus is X-ray imaging and in particular spectral X-ray computed tomography (CT). With hybrid pixel detectors based on the Medipix3 chip it is possible to both count the number of photons, as well as separate these detected photons in a number of energy bins. This is achieved with a single detector while industry uses multiple detectors or multiple irradiations. As opposed to the mainstream use of energy information after CT reconstruction, a statistical approach is used to include energy information directly in the reconstruction algorithm. In this way, beam hardening artefacts can be removed and particular elements like contrast agents identified.

Within an ERC Proof-of-Concept grant with Utrecht University on mammography developments, the aim is to apply Medipix3 based detectors to enhance the contrast between calcifications and tumors. At the Utrecht Medical Centre a standard X-ray system is used for diagnosis of patients. The research goal is to improve this diagnostic tool, together with local radiologists, by adapting our Medipix3 system such that realistic phantoms can be measured yielding additional information for physicians.

Silicon is widely used as radiation detection medium and became a mature technology but has limited absorption capacity, especially for higher energetic X-rays used in medical applications. Research with Philips in the INFIERI training network tries to overcome limitation by edge-on illumination of Silicon sensors, which increases the effective absorption depth for X-rays. This project also develops new methods of signal processing per pixel in the read-out chip, to ensure maximum use of the dose applied to a patient.

Several proton therapy centers for advanced cancer treatment are envisioned in The Netherlands in the near future. The R&D group works with KVI-CART in Groningen on a system for proton radiography (PR): imaging with protons to develop advanced treatment plans. This allows to irradiate a patient with higher precision than currently possible with treatment plans solely based on X-ray CT data. Our proton radiography system uses Time Projection Chambers (TPC) based on our gaseous pixel detectors *Gridpix* to minimise scattering of the protons, thus providing accurate 3D proton tracks without the combinatorial background unavoidable with silicon based detectors. Over the last few years the system has evolved, such that the small density differences one finds in the human body can be distinguished. Next steps are to increase the active area of the detector and to work towards combining X-ray CT data with proton imaging data to increase the precision of the proton beam stopping power distribution. Overall this will lead to a substantial reduction of irradiation of healthy tissue and as such a reduction of negative side effects like the occurrence of secondary tumors.

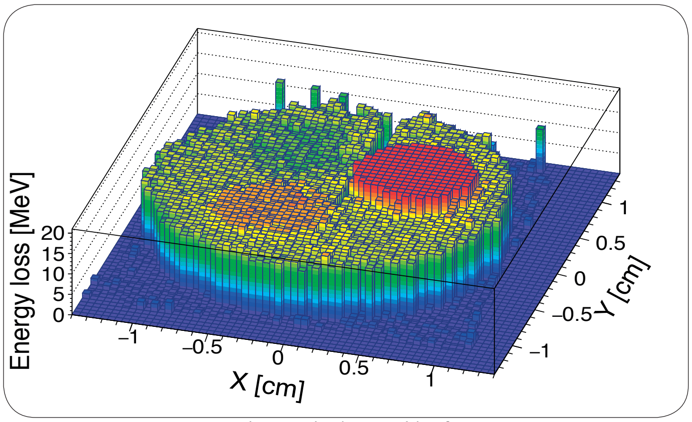


Figure 2. Proton energy radiograph obtained by firing 150 MeV protons through a sample of solid water with human body density-like inserts such as plastic (PMMA), bone and fat.

Ultra-fast photon detectors

Harry van der Graaf proposed in his ERC-ARG 'MEMBrane' a photon detector based on Micro Electro Mechanical Systems (MEMS) technology aiming at sub-ps temporal resolution. The difference between a traditional photo multiplier tube (PMT) and this novel detector is in the nature of their dynodes. A PMT has reflective dynodes, whereas this research is developing transmission dynodes that will be stacked on top of each other. This simplifies the configuration and reduces the size to the scale of a pixel chip (55 μm). As a consequence, the time response is improved and the sensitivity to magnetic fields is decreased. The main challenge is to fabricate ultra-thin transmission dynodes with sufficient Secondary Electron Yield (SEY) at low primary electron energy, *i.e.* a yield of four electrons at 500 eV. The need of realizing sufficient SEY of the dynodes resulted in three main research themes: theoretical simulations, fabrication of the dynodes and measurements of SEY with prototype membranes. Monte Carlo simulations are used to study the physics of electron-matter interactions and predict the SEY of the dynodes, using a low energy extension of GEANT4 package in collaboration with an industrial partner FEI. Data obtained with SEY measurements are used for model validation and to further develop the simulation code. The effects of surface termination on the electron affinity, an important parameter for the SEY, have been studied by Density Functional Theory (DFT) simulations. DFT results showed very promising termination candidates, such as hydrogen or alkali-oxide terminations.

In 2014 various crucial research collaborations have been established. Fabrication of the dynodes with MEMS technology takes place at the Delft Institute for Microsystems and Nano-electronics (DIMES). A first generation of transmission dynodes with a thickness of 15 nm has been successfully fabricated. Additional generations with improved recipes and different surface terminations are under study. Besides ultra-thin dynodes, thin films with different Silicon doping ratios have been produced for SEY measurements on top of a TimePix3 chip. As a side project, alternative all-ceramic grid structures have been processed in collaboration with IZM-Berlin to enhance the spark protection of our *Gridpix* gaseous detectors. Measurements with a scanning and transmission electron microscope have been done to study SEY of the dynodes at the Particle Optics Group at the Technical University of Delft. In addition, a dedicated setup for synchronous measurements of both the transmission and reflective SEY has been built and calibrated at Nikhef, and used to study the fabricated films and dynodes in more detail. Soft X-ray photoemission spectroscopy (XPS) at a synchrotron beam line at Brookhaven National

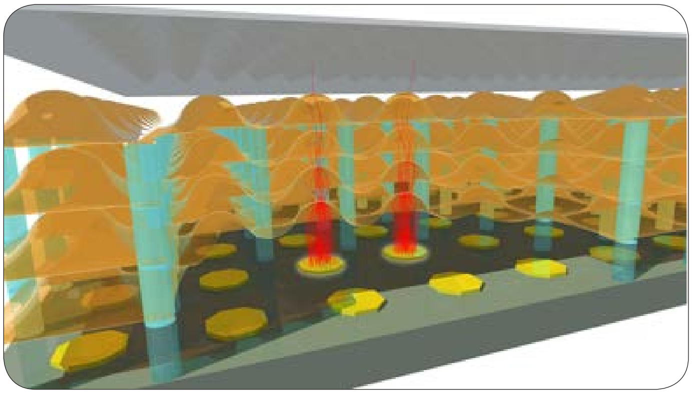


Figure 3. A stack of ultra-thin transmission dynodes forms a 'miniaturised' PMT on top of each 55 μm squared pixel of the readout chip at the bottom. A photoelectron escapes from the photo-cathode at the top, further electron multiplication results in a detectable signal that will be processed by the front-end circuitry in each pixel.

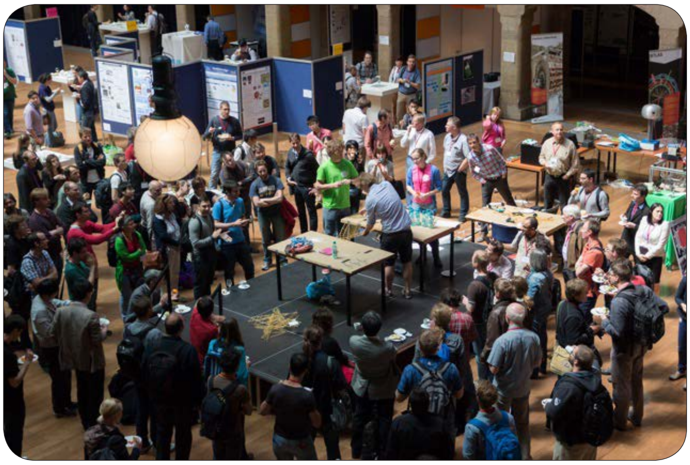


Figure 4. Impression of TIPP2014: building 'spaghetti' bridges between attendees.

Laboratory is essential to characterise the materials used in the dynodes and to understand the SEY performance of different terminations. Hence, low Silicon doped material was eliminated due to the severe charging effect while an important improvement in SEY has been established with hydrogen terminated dynode samples. The XPS results support our DFT predictions and provide validation of the Monte Carlo simulations.

Hosting the TIPP 2014 conference

The Technology and Instrumentation in Particle Physics 2014 (`www.tipp2014.nl`) conference has been hosted by Nikhef in *De Beurs van Berlage*, downtown Amsterdam from June 2–6. This new series of cross-disciplinary conferences on detector and instrumentation falls under the auspices of the International Union of Pure and Applied Physics (IUPAP). The program focused on all areas of detector development and instrumentation in particle physics, astroparticle physics and closely related fields like photon science, biology, medicine, and engineering. This medium-sized conference with 450 attendees brought together world experts from the scientific and industrial communities to discuss current work and to initiate partnerships that may lead to transformational new technologies.

Next to an exciting scientific program a number of social events were organised to stimulate interaction between participants, especially for newcomers to the field, and to challenge colleagues via problems encountered in their research. The program was solidly booked and highly appreciated by the participants. Various interactive events took place during the day: discussion sessions, a 'spaghetti' bridge contest, networking with industry, interactive theatre with installations, several physics demonstrations, and a chance to build an instrument from a scrapheap. In the evening, leisure activities in the historic center of Amsterdam included a pub-quiz, a conference dinner in the historic Heineken brewery, and a pub crawl, hearing about the history of Amsterdam and the forgotten Einstein-Rupp experiment, and the opportunity to play Arcade and board games with Nikhef director Frank Linde. Prof. Robbert Dijkgraaf gave an excellent outreach lecture for the general public about the frontiers of physics and 'What is it good for?'

2.10 Grid Computing
Physics Data Processing and ICT infrastructure

Management: dr. J. Templon (PL)

The Physics Data Processing (PDP) group, in close collaboration with the Computer Technology (CT) department, in 2014 implemented the new strategic plan focussing on scalable computing R&D and scalable multi-domain security. Important advances were made related to our data processing facilities, both in capacity ramp-up for LHC Run 2 and in broadening the user base. These facilities provide essential computing and storage resources for producing scientific results, and are also a key ingredient in validating our research and engineering work on scalable computing and multi-domain security.

Scalable infrastructure
The expected data rates and the reprocessing volume foreseen for 2015 and beyond will stress our network as well as our compute and data infrastructure. With increased CPU core counts, getting the data delivered to the systems sufficiently quickly has become the major challenge. Already the interconnect between storage and compute systems within the Nikhef site exceeds 200 Gbps. In 2014 we deployed storage arrays featuring a 40 Gbps network interface per 100 Terabyte of storage and replaced the core network equipment, co-sponsored by SURFnet and in close collaboration with the neighbouring institutes AMOLF and CWI. The new network core permitted an upgrade of the cross-connect within the NL-Tier1 (between Nikhef and SURFsara) to 100 Gbps. It also allowed Nikhef to act as a destination and transit provider for the new ATLAS Tier-1 center at the Kurchatov Institute in Moscow. Limited analysis runs by ATLAS in December 2014 demonstrated that this increased capacity can be effectively used, and that it will be needed given the expected network rates once the LHC data taking restarts in 2015. The fraction of the NL-Tier1 facility housed at Nikhef now comprises 3100 CPU cores, and 2 of the 5 Petabyte of NL-T1 disk dedicated to wLCG. Fig.1 shows the division of Nikhef CPU resources over the different projects.

Such advances in computing, data, and network performance are enabled through the national e-Infrastructure, coordinated by SURFsara and funded largely through SURF. However, that funding is insufficient to provide the capacity needed to deal with energy, luminosity, and detector upgrades of the LHC in 2015 and beyond. For the next 5 years, funding to increase capacity of the NL-Tier1 has been obtained in the NWO BIG LHC Upgrade project that was awarded in 2014 —giving us a solid basis to exploit the results of Run 2.

Despite the continuous replacement of hardware and replacement of the core routing equipment, availability and reliability the Nikhef and the wLCG NL-Tier1 remain above target at 98.5% over 2014.

Scaling the computing for Nikhef physics analyses
Also the 'stoomboot' analysis facility, used by Nikhef physicists for daily analysis tasks, has been significantly increased in size. Whereas compute capacity is now in ample supply, the way data is accessed during the analysis phase puts severe strain on storage systems —traditional data access patterns no longer suffice, leading the PDP group in collaboration with the users to experiment with various alternative file systems and the underlying disk configuration. More than ever we observed a complex interplay between low-level systems configuration at the per-disk level, the file systems used, and the way data is distributed across storage clusters. Performance analysis and subsequent tuning of the 'glusterfs' filesystem alleviated some of the pressure, but in order to fully exploit the enlarged 'stoomboot' analysis facility we foresee a need to shift more of data access logic away from traditional file systems.

But there is much more to computing than just capacity —we also work with other Nikhef groups and with CPU and network vendors including Intel, Juniper, and Aruba to stress new hardware in an environment that is markedly different from the commodity market— often identifying potential issues before they make it into products, and thus enhancing the usefulness of future products for our user communities.

Significant challenges remain in applying acceleration techniques like massive multi-core computing to actual physics codes —partly due to the data sizes and throughput requirements involved. While we work on adapting such cores to use massive multi-processing, such as on the Intel Xeon Phi, and while also CPU vendors are addressing the issue of data throughput from general-purpose cores to co-processing systems, we foresee this as a major area of activity for the PDP and CT groups in the years to come.

Beyond a single institute
Whilst having computing capacity at a single location is nice, all our research is based on collaboration. Being able to transgress (electronically) institutional, organisational, and political boundaries is therefore essential, and the Scalable Multi-Domain Security (SMDS) activity of the PDP group addresses the complex authentication and authorisation issues of global collaboration. This area is strongly driven by research beyond traditional high-energy physics, has gained much European and global interest, and now appears to have gathered enough

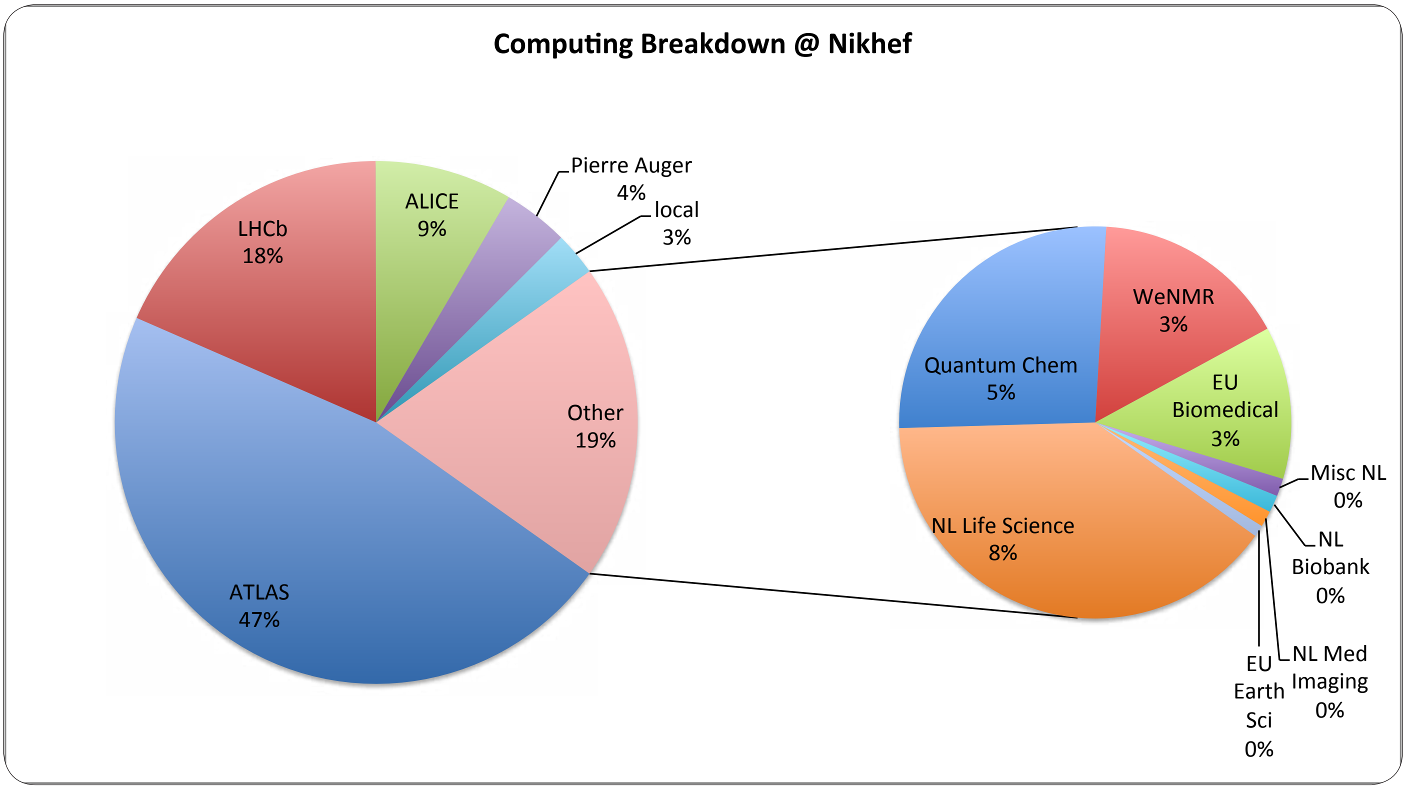


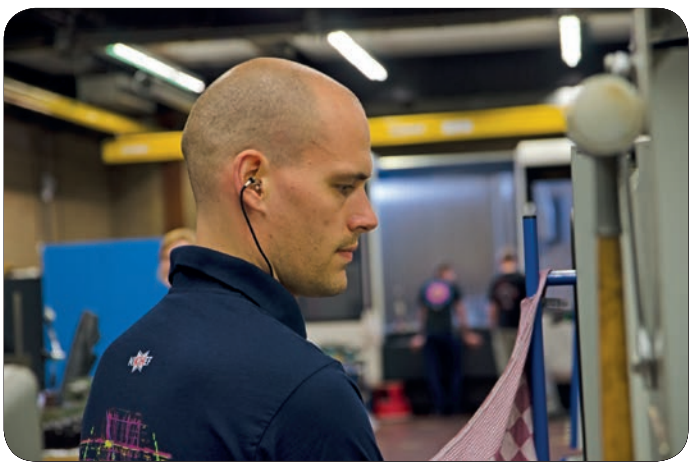
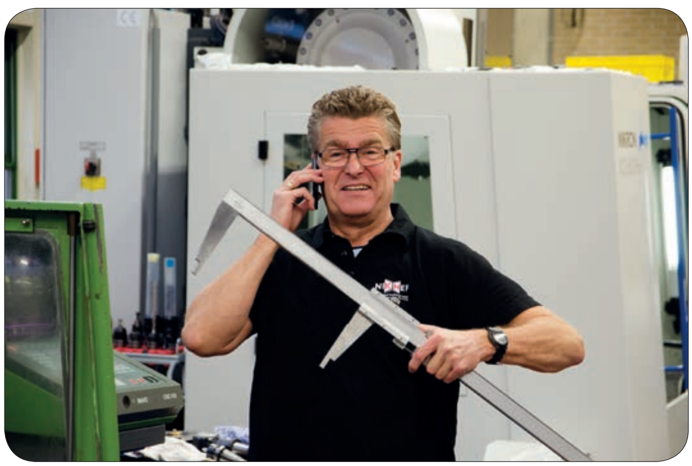
Figure 1. Division of Nikhef CPU resources over different projects in- and outside Nikhef.

momentum to make a major breakthrough in the next couple of years. For the last decade the LHC community has managed to deal with relatively complex technology such as user-controlled public key infrastructure because of the then-still-niche need to use command-line applications and non-web technology. Most other research domains have been able to work largely in a web-only environment and did not have to deal with large data volumes. This is now changing rapidly, an all major ESFRI infrastructures have aligned their requirement for global federation and the use of non-web single sign-on in the 'Federated Identity Management for Research' (FIM4R) activity, that formed also the basis for the FIM activities in the Research Data Alliance RDA. In 2014 the Nikhef SMDS team, with its background in policy coordination and software engineering for community-based site access control, joined four European project initiatives to further the role of federated identity management specifically for cross-national collaborations like those in sub-atomic physics, and for the non-web technologies that are critical for data-intensive research. Of these, the European Grid Infrastructure (EGI) ENGAGE initiative and the Authentication and Authorization for Research Collaborations (AARC) initiative, coordinated by the Geant Association (TERENA), have been targeted at dedicated calls in the EU Horizon 2020 programme. Nikhef is a leading partner for (authentication) policy development and involved in software engineering.

Meanwhile, our site access control middleware continues to see world-wide adoption, with increasing deployment in the US as part of Open Science Grid supporting the US LHC community. Our role in authentication coordination and the Interoperable Global Trust Federation warrants a seat for Nikhef on the Geant Association's TERENA Technical Committee, overseeing its Technical Programme, and engaged in the Phase-I testing of the pan-European TCS Certificate Service.





A few of the many highly-skilled technicians and engineers who build the prototypes and parts used in the experiments in which Nikhef participates. Shown from left-to-right and top-to-bottom are Arnold Rietmeijer, Willem Kuilman, Krista de Roo, Michiel Jaspers, Erno Roeland and Joop Rövekamp.

Output

3

3.1 Publications

ATLAS/D0
ATLAS Collaboration: G. Aad (*et al.*)**; R. Aben, I. Angelozzi, L.J. Beemster, S. Bentvelsen, E. Berglund, G.J. Besjes, G.J. Bobbink, K. Bos, H. Boterenbrood, P.-F. Butti, S. Caron, A. Castelli, M.A. Chelstowska, A.P. Colijn, V. Croft, V. Dao, I. Deigaard, P.C. Van Der Deijl, C. Deluca, P.O. Deviveiros, D. Dhaliwal, A. Doxiadis, B. van Eijk, P. Ferrari, F. Filthaut, S. Gadatsch, C. Galea, H. Garitaonandia, R. van der Geer, D.A.A. Geerts, M. Gosselink, H. van der Graaf, N. de Groot, F. Hartjes, N.P. Hessey, N. Hod, O. Igonkina, P. de Jong, N. Karastathis, M.S. Kayl, P.F. Klok, S. Klous, P. Kluit, A.C. König, F. Koetsveld, E. Koffeman, H. Lee, R. van der Leeuw, T. Lenz, F. Linde, G. Luijckx, J. Mahlstedt, G. Massaro, J. Mechnich, I. Mussche, L. de Nooij, J.P. Ottersbach, K.P. Oussoren, P. Pani, E. van der Poel, M. Raas, M. Rijpstra, N. Ruckstuhl, G. Sabato, D. Salek, A. Salvucci, A.H. Strübig, D. Ta, M. Tsiakiris, E. Turlay, N. Valencic, W. Verkerke, J.C. Vermeulen, M. Vranjes Milosavljevic, M. Vreeswijk, I. van Vulpen, H. Weits, W. van den Wollenberg**

Search for direct top squark pair production in events with a Z boson, b-jets and missing transverse momentum in $\sqrt{s}$ = 8 TeV pp collisions with the ATLAS detector
Eur. Phys. J. **C 74** (2014) 2883

The differential production cross section of the φ(1020) meson in $\sqrt{s}$ = 7 TeV pp collisions measured with the ATLAS detector
Eur. Phys. J. **C 74** (2014) 2895

Electron reconstruction and identification efficiency measurements with the ATLAS detector using the 2011 LHC proton-proton collision data
Eur. Phys. J. **C 74** (2014) 2941

Measurement of the underlying event in jet events from 7 TeV proton-proton collisions with the ATLAS detector
Eur. Phys. J. **C 74** (2014) 2965

Measurement of the centrality and pseudorapidity dependence of the integrated elliptic flow in lead-lead collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with the ATLAS detector
Eur. Phys. J. **C 74** (2014) 2982

Light-quark and gluon jet discrimination in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector
Eur. Phys. J. **C 74** (2014) 3023

Muon reconstruction efficiency and momentum resolution of the ATLAS experiment in proton-proton collisions at $\sqrt{s}$ = 7 TeV in 2010
Eur. Phys. J. **C 74** (2014) 3034

Electron and photon energy calibration with the ATLAS detector using LHC Run 1 data
Eur. Phys. J. **C 74** (2014) 3071

Measurement of the $t\bar{t}$ production cross-section using eμ events with b-tagged jets in pp collisions at $\sqrt{s}$ = 7 and 8 TeV with the ATLAS detector
Eur. Phys. J. **C 74** (2014) 3109

Measurements of jet vetoes and azimuthal decorrelations in dijet events produced in pp collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector
Eur. Phys. J. **C 74** (2014) 3117

Search for contact interactions and large extra dimensions in the dilepton channel using proton-proton collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Eur. Phys. J. **C 74** (2014) 3134

A measurement of the ratio of the production cross sections for W and Z bosons in association with jets with the ATLAS detector
Eur. Phys. J. **C 74** (2014) 3168

Measurement of distributions sensitive to the underlying event in inclusive Z-boson production in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector
Eur. Phys. J. **C 74** (2014) 3195

Measurement of the top quark pair production charge asymmetry in proton-proton collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector
J. High Energy Phys. **02** (2014) 107

Measurement of the electroweak production of dijets in association with a Z-boson and distributions sensitive to vector boson fusion in proton-proton collisions at $\sqrt{s}$ = 8 TeV using the ATLAS detector
J. High Energy Phys. **04** (2014) 031

Search for direct production of charginos and neutralinos in events with three leptons and missing transverse momentum in $\sqrt{s}$ = 8 TeV pp collisions with the ATLAS detector
J. High Energy Phys. **04** (2014) 169

Measurement of the production cross section of prompt J/ψ mesons in association with a $W^{\pm}$ boson in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector
J. High Energy Phys. **04** (2014) 172

Measurement of dijet cross-sections in pp collisions at 7 TeV centre-of-mass energy using the ATLAS detector
J. High Energy Phys. **05** (2014) 059

Measurement of the production of a W boson in association with a charm quark in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector
J. High Energy Phys. **05** (2014) 068

Search for direct production of charginos, neutralinos and sleptons in final states with two leptons and missing transverse momentum in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
J. High Energy Phys. **05** (2014) 071

Search for top quark decays $t \to qH$ with $H \to \gamma\gamma$ using the ATLAS detector
J. High Energy Phys. **06** (2014) 008

Search for supersymmetry at $\sqrt{s}$ = 8 TeV in final states with jets and two same-sign leptons or three leptons with the ATLAS detector
J. High Energy Phys. **06** (2014) 035

Measurement of the low-mass Drell-Yan differential cross section at $\sqrt{s}$ = 7 TeV using the ATLAS detector
J. High Energy Phys. **06** (2014) 112

Search for direct top-squark pair production in final states with two leptons in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
J. High Energy Phys. **06** (2014) 124

Measurement of χ_{c1} and χ_{c2} production with $\sqrt{s}$ = 7 TeV pp collisions at ATLAS
J. High Energy Phys. **07** (2014) 154

Search for microscopic black holes and string balls in final states with leptons and jets with the ATLAS detector at $\sqrt{s}$ = 8 TeV
J. High Energy Phys. **08** (2014) 103

Search for direct pair production of the top squark in all-hadronic final states in proton-proton collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
J. High Energy Phys. **09** (2014) 015

Search for new particles in events with one lepton and missing transverse momentum in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
J. High Energy Phys. **09** (2014) 037

Search for supersymmetry in events with large missing transverse momentum, jets, and at least one tau lepton in 20 fb^{-1} of $\sqrt{s}$ = 8 TeV proton-proton collision data with the ATLAS detector
J. High Energy Phys. **09** (2014) 103

Measurements of fiducial and differential cross sections for Higgs boson production in the diphoton decay channel at $\sqrt{s}$ = 8 TeV with ATLAS
J. High Energy Phys. **09** (2014) 122

Measurement of the Z/γ^* boson transverse momentum distribution in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector
J. High Energy Phys. **09** (2014) 145

Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum using $\sqrt{s}$ = 8 TeV proton-proton collision data
J. High Energy Phys. **09** (2014) 176

Search for new phenomena in final states with large jet multiplicities and missing transverse momentum at $\sqrt{s}$ = 8 TeV proton-proton collisions using the ATLAS experiment
J. High Energy Phys. **10** (2013) 130 , erratum J. High Energy Phys. **01** (2014) 109

Search for strong production of supersymmetric particles in final states with missing transverse momentum and at least three b-jets at $\sqrt{s}$ = 8 TeV proton-proton collisions with the ATLAS detector
J. High Energy Phys. **10** (2014) 024

Search for the direct production of charginos, neutralinos and staus in final states with at least two hadronically decaying taus and missing transverse momentum in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
J. High Energy Phys. **10** (2014) 096

Measurement of differential production cross-sections for a Z boson in association with b-jets in 7 TeV proton-proton collisions with the ATLAS detector
J. High Energy Phys. **10** (2014) 141

Search for neutral Higgs bosons of the minimal supersymmetric standard model in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
J. High Energy Phys. **11** (2014) 056

Standalone vertex finding in the ATLAS muon spectrometer
J. Instr. **9** (2014) P02001

Monitoring and data quality assessment of the ATLAS liquid argon calorimeter
J. Instr. **9** (2014) P07024

Operation and performance of the ATLAS semiconductor tracker
J. Instr. **9** (2014) P08009

A neural network clustering algorithm for the ATLAS silicon pixel detector
J. Instr. **9** (2014) P09009

Measurement of the total cross section from elastic scattering in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector
Nucl. Phys. **B 889** (2014) 486

Search for dark matter in events with a hadronically decaying W or Z boson and missing transverse momentum in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Rev. Lett. **112** (2014) 041802

Study of heavy-flavor quarks produced in association with top-quark pairs at $\sqrt{s}$ = 7 TeV using the ATLAS detector
Phys. Rev. Lett. **112** (2014) 072012

Search for quantum black-hole production in high-invariant-mass lepton+jet final states using proton-proton collisions at $\sqrt{s}$ = 8 TeV and the ATLAS detector
Phys. Rev. Lett. **112** (2014) 091804

Search for invisible decays of a Higgs boson produced in association with a Z boson in ATLAS
Phys. Rev. Lett. **112** (2014) 201802

Measurements of four-lepton production at the Z resonance in pp collisions at $\sqrt{s}$ = 7 and 8 TeV
Phys. Rev. Lett. **112** (2014) 231806

Evidence for electroweak production of $W^{\pm}W^{\pm}$ jj in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Rev. Lett. **113** (2014) 141803

Search for scalar diphoton resonances in the mass range 65-600 GeV with the ATLAS detector in pp collision data at $\sqrt{s}$ = 8 TeV
Phys. Rev. Lett. **113** (2014) 171801

Observation of an excited $B_c^{\pm}$ meson state with the ATLAS detector
Phys. Rev. Lett. **113** (2014) 212004

Measurement of event-plane correlations in $\sqrt{s_{NN}}$ = 2.76 TeV lead-lead collisions with the ATLAS detector
Phys. Rev. **C 90** (2014) 024905

Measurement of long-range pseudorapidity correlations and azimuthal harmonics in $\sqrt{s_{NN}}$ = 5.02 TeV proton-lead collisions with the ATLAS detector
Phys. Rev. **C 90** (2014) 044906

Search for a multi-Higgs-boson cascade in $W^{+}W^{-}b\bar{b}$ events with the ATLAS detector in pp collisions at $\sqrt{s}$ = 8 TeV
Phys. Rev. **D 89** (2014) 032003

Measurement of the inclusive isolated prompt photons cross section in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector using 4.6 fb^{-1}
Phys. Rev. **D 89** (2014) 052004

Measurement of the parity-violating asymmetry parameter α_b and the helicity amplitudes for the decay $\Lambda_b^0 \to J/\psi + \Lambda^0$ with the ATLAS detector
Phys. Rev. **D 89** (2014) 092009

Search for dark matter in events with a Z boson and missing transverse momentum in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Rev. **D 90** (2014) 012004

Search for supersymmetry in events with four or more leptons in $\sqrt{s}$ =8 TeV pp collisions with the ATLAS detector
Phys. Rev. **D 90** (2014) 052001

Measurement of the Higgs boson mass from the $H\to\gamma\gamma$ and $H\to ZZ^*\to 4\ell$ channels in pp collisions at center-of-mass energies of 7 and 8 TeV with the ATLAS detector
Phys. Rev. **D 90** (2014) 052004

Search for high-mass dilepton resonances in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Rev. **D 90** (2014) 052005

Flavor tagged time-dependent angular analysis of the $B_s^0\to J/\psi\varphi$ decay and extraction of $\Delta\Gamma_s$ and the weak phase φ_s in ATLAS
Phys. Rev. **D 90** (2014) 052007

Search for pair-produced third-generation squarks decaying via charm quarks or in compressed supersymmetric scenarios in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Rev. **D 90** (2014) 052008

Measurements of normalized differential cross sections for $t\bar{t}$ production in pp collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector
Phys. Rev. **D 90** (2014) 072004

Search for the lepton flavor violating decay $Z\to e\mu$ in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Rev. **D 90** (2014) 072010

Search for nonpointing and delayed photons in the diphoton and missing transverse momentum final state in 8 TeV pp collisions at the LHC using the ATLAS detector
Phys. Rev. **D 90** (2014) 112005

Comprehensive measurements of t-channel single top-quark production cross sections at $\sqrt{s}$ = 7 TeV with the ATLAS detector
Phys. Rev. **D 90** (2014) 112006

Measurement of Higgs boson production in the diphoton decay channel in pp collisions at center-of-mass energies of 7 and 8 TeV with the ATLAS detector
Phys. Rev. **D 90** (2014) 112015

Measurements of spin correlation in top-antitop quark events from proton-proton collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector
Phys. Rev. **D 90** (2014) 112016

Measurement of the mass difference between top and anti-top quarks in pp collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector
Phys. Lett. **B 728** (2013) 363

Search for new phenomena in γ + jet events collected in proton-proton collisions at $\sqrt{}$= 8 TeV with the ATLAS detector
Phys. Lett. **B 728** (2014) 562

Search for Higgs boson decays to a photon and a Z boson in pp collisions at $\sqrt{s}$ = 7 and 8 TeV with the ATLAS detector
Phys. Lett. **B 732** (2014) 8

Search for WZ resonances in the fully leptonic channel using pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Lett. **B 737** (2014) 223

Fiducial and differential cross sections of Higgs boson production measured in the four-lepton decay channel in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Lett. **B 738** (2014) 234

Measurement of the cross section of high transverse momentum $Z\to b\bar{b}$ production in proton-proton collisions at $\sqrt{}$= 8 TeV with the ATLAS detector
Phys. Lett. **B 738** (2014) 25

Search for the Standard Model Higgs boson decay to $\mu^{+}\mu^{-}$ with the ATLAS detector
Phys. Lett. **B 738** (2014) 68

Search for new resonances in $W\gamma$ and $Z\gamma$ final states in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Lett. **B 738** (2014) 428

Measurement of inclusive jet charged-particle fragmentation functions in Pb+Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with the ATLAS detector
Phys. Lett. **B 739** (2014) 320

Search for s-channel single top-quark production in proton-proton collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector
Phys. Lett. **B 740** (2014) 118

S. Gonzalez-Sevilla (*et al.*), N. Hessey
A double-sided silicon micro-strip Super-Module for the ATLAS Inner Detector upgrade in the High-Luminosity LHC
J. Instr. **9** (2014) P02003

S. Diez (*et al.*), E. Hennes, N. Hessey
A double-sided, shield-less stave prototype for the ATLAS Upgrade strip tracker for the High Luminosity LHC
J. Instr. **9** (2014) P03012

E. Vilucchi (*et. al*), A. Salvucci
PROOF-based analysis on the ATLAS Grid facilities: first experience with the PoD/PanDa plugin
J. Phys. Conf. Ser. **513** (2014) 032102

N. de Groot, P. de Jong
De LHC, vooruitzichten voor run 2
Ned. T. Nat. **80** (2014) 390

L. Zwalinski (*et al.*), B. Verlaat
CO_2 Cooling System for Insertable B Layer Detector into the Atlas Experiment
PoS (**TIPP 2014**) 224

Particle Data Group Collaboration: K.A. Olive (*et al.*), **P. de Jong**
Review of particle physics
Chin. Phys.**C 38** (2014) 090001

C. Strege, G. Bertone, G.J. Besjes, S. Caron, R. Ruiz de Austri, A. Strubig, R. Trotta
Profile likelihood maps of a 15-dimensional MSSM
J. High Energy Phys. **09** (2014) 081

DØ Collaboration: V.M. Abazov (*et al.*); **F. Filthaut, S.J. de Jong, W.M. van Leeuwen, M.M. Meijer**

Muon reconstruction and identification with the Run II DØ detector
Nucl. Instr. Meth. **A 737** (2014) 281

Electron and photon identification in the DØ experiment
Nucl. Instr. Meth. **A 750** (2014) 78

Improved b quark jet identification at the DØ experiment
Nucl. Instr. Meth. **A 763** (2014) 290

Jet energy scale determination in the DØ experiment
Nucl. Instr. Meth. **A 763** (2014) 442

Measurement of associated production of Z bosons with charm quark jets in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
Phys. Rev. Lett. **112** (2014) 042001

Measurement of the W boson production charge asymmetry in $p\bar{p} \to W + X \to e\nu + X$ events at $\sqrt{s} = 1.96$ TeV
Phys. Rev. Lett. **112** (2014) 111803

Measurement of the direct CP-violating charge asymmetry in $D_s^\pm \to \varphi\pi^\pm$ decays
Phys. Rev. Lett. **112** (2014) 111804

Observation of s-channel production of single top quarks at the Tevatron
Phys. Rev. Lett. **112** (2014) 231803

Precision measurement of the top quark mass in lepton+jets final states
Phys. Rev. Lett. **113** (2014) 032002

Constraints on models for the Higgs boson with exotic spin and parity in $VH \to Vb\bar{b}$ final states
Phys. Rev. Lett. **113** (2014) 161802

Study of CP-violating charge asymmetries of single muons and like-sign dimuons in $p\bar{p}$ collisions
Phys. Rev. **D 89** (2014) 012002

Search for the X(4140) state in $B^+ \to J/\psi\varphi K^+$ decays with the DØ detector
Phys. Rev. **D 89** (2014) 012004

Measurement of the W boson mass with the DØ detector
Phys. Rev. **D 89** (2014) 012005

Combination of measurements of the top-quark pair production cross section from the Tevatron Collider
Phys. Rev. **D 89** (2014) 072001

Double parton interactions in γ + 3 jet and γ + b/cjet + 2 jet events in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
Phys. Rev. **D 89** (2014) 072006

Measurement of the electric charge of the top quark in $t\bar{t}$ events
Phys. Rev. **D 90** (2014) 051101

Measurement of the forward-backward asymmetry in the distribution of leptons in $t\bar{t}$ events in the lepton + jets channel
Phys. Rev. **D 90** (2014) 072001

Measurement of the forward-backward asymmetry in top quark-antiquark production in pp collisions using the lepton+jets channel
Phys. Rev. **D 90** (2014) 072011

Measurement of differential $t\bar{t}$ production cross sections in $p\bar{p}$ collisions
Phys. Rev. **D 90** (2014) 092006

Observation and studies of double J/ψ production at the Tevatron
Phys. Rev. **D 90** (2014) 111101

Measurement of the direct CP-violating parameter A_{CP} in the decay $D^+ \to K^-\pi^+\pi^+$
Phys. Rev. **D 90** (2014) 111102

Measurement of the differential γ + 2b-jet cross section and the ratio $\sigma(\gamma + 2b\text{-jets})/\sigma(\gamma + b\text{-jet})$ in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
Phys. Lett. **B 737** (2014) 357

LHCb/BaBar
LHCb Collaboration: R. Aaij (*et al.*); **S. Ali, Th.S. Bauer, M. van Beuzekom, J. van den Brand, K. Carvalho Akiba, V. Coco, P.N.Y. David, K. De Bruyn, F. Dettori, D. van Eijk, C. Farinelli, V. Heijne, W. Hulsbergen, E. Jans, F. Jansen, T. Ketel, R.F. Koopman, P. Koppenburg, A. Kozlinskiy, R.W. Lambert, J. van Leerdam, M. Martinelli, D. Martinez Santos, M. Merk, I. Mous, S. Oggero, A. Pellegrino, T. du Pree, G. Raven, M. Schiller, B. Storaci, V. Syropoulos, H. Terrier, S. Tolk, P. Tsopelas, N. Tuning, J.A. de Vries, L. Wiggers**

Measurement of Υ production in pp collisions at $\sqrt{s} = 2.76$ TeV
Eur. Phys. J. **C 74** (2014) 2835

Measurement of the B_c^+ meson lifetime using $B_c^+ \to J/\psi\mu^+\nu_\mu X$ decays
Eur. Phys. J. **C 74** (2014) 2839

Measurement of $\psi(2S)$ polarisation in pp collisions at $\sqrt{s} = 7$ TeV
Eur. Phys. J. **C 74** (2014) 2872

Measurement of charged particle multiplicities and densities in pp collisions at $\sqrt{s} = 7$ TeV in the forward region
Eur. Phys. J. **C 74** (2014) 2888

Study of χ_b meson production in pp collisions at $\sqrt{s} = 7$ and 8 TeV and observation of the decay $\chi_b(3P) \to \Upsilon(3S)\gamma$
Eur. Phys. J. **C 74** (2014) 3092

Study of forward Z + jet production in pp collisions at $\sqrt{s} = 7$ TeV
J. High Energy Phys. **01** (2014) 033

Study of J/ψ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}} = 5$ TeV
J. High Energy Phys. **02** (2014) 072

Searches for Λ_b^0 and Ξ_b^0 decays to and $K_S^0 p K^-$ final states with first observation of the $\Lambda_b^0 \to K_S^0 p \pi^-$ decay
J. High Energy Phys. **04** (2014) 087

Observation of associated production of a Z boson with a D meson in the forward region
J. High Energy Phys. **04** (2014) 091

Measurements of the B^+, B^0, B_s^0 meson and Λ_b^0 baryon lifetimes
J. High Energy Phys. **04** (2014) 114

Measurement of polarization amplitudes and CP asymmetries in $B^0 \to \varphi K^*(892)^0$
J. High Energy Phys. **05** (2014) 069

Angular analysis of charged and neutral $B \to K \mu^+\mu^-$ decays
J. High Energy Phys. **05** (2014) 082

Evidence for the decay $B_c^+ \to J/\psi\, 3\pi^+ 2\pi^-$
J. High Energy Phys. **05** (2014) 148

Observation of double charm production involving open charm in pp collisions at $\sqrt{s} = 7$ TeV
J. High Energy Phys. **06** (2012) 141, addendum **03** (2014) 108

Differential branching fractions and isospin asymmetries of $B \to K^{(*)}\mu^+\mu^-$ decays
J. High Energy Phys. **06** (2014) 133

Measurement of CP asymmetry in $D^0 \to K^- K^+$ and $D^0 \to \pi^-\pi^+$ decays
J. High Energy Phys. **07** (2014) 041

Study of the Υ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$ = 5 TeV
J. High Energy Phys. **07** (2014) 094

Observation of the $\Lambda_b^0 \to J/\psi \pi^-$ decay
J. High Energy Phys. **07** (2014) 103

Observation of the $B_s^0 \to J/\psi K_S^0 K^\pm \pi^\pm$ decay
J. High Energy Phys. **07** (2014) 140

Study of the kinematic dependences of Λ_b^0 production in pp collisions and a measurement of the $\Lambda_b^0 \to \Lambda_c^+ \pi^-$ branching fraction
J. High Energy Phys. **08** (2014) 143

Observation of Z production in proton-lead collisions at LHCb
J. High Energy Phys. **09** (2014) 030

Measurement of CP asymmetries in the decays $B^0 \to K^{*0}\mu^+\mu^-$ and $B^+ \to K^+\mu^+\mu^-$
J. High Energy Phys. **09** (2014) 177

Search for CP violation using T-odd correlations in $D^0 \to K^+ K^- \pi^+ \pi^-$ decays
J. High Energy Phys. **10** (2014) 005

Search for CP violation in $D^\pm \to K_S^0 K^\pm$ and $D_s^\pm \to K_S^0 \pi^\pm$ decays
J. High Energy Phys. **10** (2014) 025

First observations of the rare decays $B^+ \to K^+\pi^+\pi^-\mu^+\mu^-$ and $B^+ \to \varphi K^+\mu^+\mu^-$
J. High Energy Phys. **10** (2014) 064

Measurement of the $\chi_b(3P)$ mass and of the relative rate of $\chi_{b1}(1P)$ and $\chi_{b2}(1P)$ production
J. High Energy Phys. **10** (2014) 088

Measurement of the CKM angle γ using $B^\pm \to DK^\pm$ with $D \to K_S^0\pi^+\pi^-$ $K_S^0 K^+ K^-$ decays
J. High Energy Phys. **10** (2014) 097

Measurement of CP asymmetry in $B_s^0 \to D_s^\mp K^\pm$ decays
J. High Energy Phys. **11** (2014) 060

Measurement of the forward W boson cross-section in pp collisions at $\sqrt{s}$ = 7 TeV
J. High Energy Phys. **12** (2014) 079

Precision luminosity measurements at LHCb
J. Instr. **9** (2014) P12005

Updated measurements of exclusive J/ψ and $\psi(2S)$ production cross-sections in pp collisions at $\sqrt{s}$ = 7 TeV
J. Phys. **G 41** (2014) 055002

Evidence for the decay $X(3872) \to \psi(2S)\gamma$
Nucl. Phys. **B 886** (2014) 665

Measurement of CP violation and constraints on the CKM angle γ in $B^\pm \to DK^\pm$ with $D \to K_S^0\pi^+\pi^-$ decays
Nucl. Phys. **B 888** (2014) 169

Measurement of CP violation in the phase space of $B^\pm \to K^+ K^- p\, \pi^\pm$ and $B^\pm \to \pi^+\pi^-\pi^\pm$ decays
Phys. Rev. Lett. **112** (2014) 011801

Measurements of indirect CP asymmetries in $D^0 \to K^- K^+$ and $D^0 \to \pi^-\pi^+$ decays
Phys. Rev. Lett. **112** (2014) 041801

Measurement of the $B_s^0 \to D_s D_s^\pm$ and $B_s^0 \to D^- D^+{}_s$ effective lifetimes
Phys. Rev. Lett. **112** (2014) 111802

Search for Majorana neutrinos in $B^- \to \pi^+\mu^-\mu^-$ decays
Phys. Rev. Lett. **112** (2014) 131802

Observation of photon polarization in the $b \to s\,\gamma$ transition
Phys. Rev. Lett. **112** (2014) 161801

Study of beauty hadron decays into pairs of charm hadrons
Phys. Rev. Lett. **112** (2014) 202001

Observation of the resonant character of the $Z(4430)^-$ state
Phys. Rev. Lett. **112** (2014) 222002

Precision measurement of the mass and lifetime of the Ξ_b^0 baryon
Phys. Rev. Lett. **113** (2014) 032001

First measurement of the charge asymmetry in beauty-quark pair production
Phys. Rev. Lett. **113** (2014) 082003

Evidence for CP violation in $B^+ \to ppK^+$ decays
Phys. Rev. Lett. **113** (2014) 141801

Test of lepton universality using $B^+ \to K^+\ell^+\ell^-$ decays
Phys. Rev. Lett. **113** (2014) 151601

First observation of a baryonic B_c^+ decay
Phys. Rev. Lett. **113** (2014) 152003

Observation of overlapping spin-1 and spin-3 $D^0 K^-$ resonances at mass 2.86 GeV/c^2
Phys. Rev. Lett. **113** (2014) 162001

Measurement of the B_s^0 meson lifetime in $D_s^+\pi^-$ decays
Phys. Rev. Lett. **113** (2014) 172001

Measurement of the CP-violating phase φ_s in $B_s^0 \to D_s^+ D_s^-$ decays
Phys. Rev. Lett. **113** (2014) 211801

Precision measurement of the mass and lifetime of the Ξ_b^- baryon
Phys. Rev. Lett. **113** (2014) 242002

Observation of $B_{(s)}^0 \to J/\psi\, f_1(1285)$ decays and measurement of the $f_1(1285)$ mixing angle
Phys. Rev. **D 112** (2014) 091802

Studies of beauty baryon decays to $D^0 ph^-$ and $\Lambda_c{}^+ h^-$ final states
Phys. Rev. **D 89** (2014) 023001

Measurement of resonant and CP components in $B_s^0 \to J/\psi\pi^+\pi^-$ decays
Phys. Rev. **D 89** (2014) 092006

Measurement of the resonant and CP components in $B^0 \to J/\psi\pi^+\pi^-$ decays
Phys. Rev. **D 90** (2014) 012003

Measurement of the ratio of B_c^+ branching fractions to $J/\psi\pi^+$ and $J/\psi\mu^+\nu_\mu$ final states
Phys. Rev. **D 90** (2014) 032009

Measurement of CP violation in $B_s^0 \to \varphi\varphi$ decays
Phys. Rev. **D 90** (2014) 052011

Dalitz plot analysis of $B_s^0 \to D^0 K^-\pi^+$ decays
Phys. Rev. **D 90** (2014) 072003

Measurement of CP violation parameters in $B^0 \to DK^{*0}$ decays
Phys. Rev. **D 90** (2014) 112002

Measurements of CP violation in the three-body phase space of charmless $B^\pm$ decays
Phys. Rev. **D 90** (2014) 112004

Measurement of the charge asymmetry in $B^\pm \to \varphi K^\pm$ and search for $B^\pm \to \varphi\pi^\pm$ decays
Phys. Lett. **B 728** (2014) 85

Search for the decay $D^0 \to \pi^+\pi^-\mu^+\mu^-$
Phys. Lett. **B 728** (2014) 234

Search for CP violation in the decay $D^+ \to \pi^-\pi^+\pi^+$
Phys. Lett. **B 728** (2014) 585

A study of CP violation in $B^\pm \to DK^\pm$ and $B^\pm \to D\,\pi^\pm$ decays with $D \to K_S^0 K^\pm \pi^\pm$ final states
Phys. Lett. **B 733** (2014) 36

Precision measurement of the ratio of the Λ_b^0 to B^0 lifetimes
Phys. Lett. **B 734** (2014) 122

Measurement of the Ξ_b^- and Ω_b^- baryon lifetimes
Phys. Lett. **B 736** (2014) 154

Measurement of the CP-violating phase φ_s in $B_s^0 \to J/\psi\pi^+\pi^-$ decays
Phys. Lett. **B 736** (2014) 186

Effective lifetime measurements in the $B_s^0 \to K^+ K^-$, $B^0 \to K^+\pi^-$ and $B_s^0 \to \pi^+ K^-$ decays
Phys. Lett. **B 736** (2014) 446

Measurement of the $B^0\, B^0$ and $B_s{}^0\, B_s{}^0$ production asymmetries in pp collisions at $\sqrt{s}$ = 7 TeV
Phys. Lett. **B 739** (2014) 218

R. Koopman
Overview of recent measurements of CP violation with B-mesons at LHCb
Acta Phys. Pol. **B 45** (2014) 1269

A.J. Bevan (*et al.*), M.A. Baak, N. van Bakel, H. Bulten, G. Raven, H.L. Snoek
The physics of the B factories
Eur. Phys. J. **C 74** (2014) 3026

BaBar Collaboration: J.P. Lees (*et al.*)**; M. Martinelli, G. Raven**

Measurement of the $B \rightarrow X_s \ell^+ \ell^-$ branching fraction and search for direct CP violation from a sum of exclusive final states
Phys. Rev. Lett. **112** (2014) 211802

Search for a dark photon in e^+e^- collisions at BaBar
Phys. Rev. Lett. **113** (2014) 201801

Search for lepton-number violating $B^+ \rightarrow X^- \ell^+ \ell'^+$ decays
Phys. Rev. **D 89** (2014) 011102

Evidence for the decay $B^0 \rightarrow \omega\omega$ and search for $B^0 \rightarrow \omega\varphi$
Phys. Rev. **D 89** (2014) 051101

Search for the decay $B^0 \rightarrow \Lambda_c^+ \bar{p} p p$
Phys. Rev. **D 89** (2014) 071102

Cross sections for the reactions $e^+ e^- \rightarrow K_S^0 K_L^0$, $K_S^0 K_L^0 \pi^+\pi^-$, $K_S^0 K_S^0 \pi^+\pi^-$, and $K_S^0 K_S^0 K^+K^-$ from events with initial-state radiation
Phys. Rev. **D 89** (2014) 092002

Antideuteron production in $\Upsilon(nS)$ decays and in $e^+e^- \rightarrow q\bar{q}$ at $\sqrt{s} \approx 10.58$ GeV
Phys. Rev. **D 89** (2014) 111102

Study of the reaction $e^+e^- \rightarrow \psi(2S)\, \pi^+\pi^-$ via initial-state radiation at BaBar
Phys. Rev. **D 89** (2014) 111103

Evidence for the baryonic decay $B^0 \rightarrow D^0 \Lambda \bar{\Lambda}$
Phys. Rev. **D 89** (2014) 112002

Dalitz plot analysis of $\eta_c \rightarrow K^+ K^- \eta$ and $\eta_c \rightarrow K^+ K^- \pi^0$ in two-photon interactions
Phys. Rev. **D 89** (2014) 112004

Measurement of Collins asymmetries in inclusive production of charged pion pairs in e^+e^- annihilation at BABAR
Phys. Rev. **D 90** (2014) 052003

Measurements of direct CP asymmetries in $B \rightarrow X_s \gamma$ decays using sum of exclusive decays
Phys. Rev. **D 90** (2014) 092001

Bottomonium spectroscopy and radiative transitions involving the $\chi_{bJ}(1P,2P)$ states at BaBar
Phys. Rev. **D 90** (2014) 112010

Search for new π^0-like particles produced in association with a τ-lepton pair
Phys. Rev. **D 90** (2014) 112011

ALICE/STAR
ALICE Collaboration: B. Abelev (*et al.*)**; R.A. Bertens, C. Bianchin, S. Bjelogrlic, M. Botje, A. Caliva, M. Chojnacki, P. Christakoglou, A. Dobrin, A. Dubla, A. Grelli, R. Kamermans, N. van der Kolk, M. Krzewicki, P.G. Kuijer, S.L. La Pointe, M. van Leeuwen, E. Leogrande, D.F. Lodato, G. Luparello, A. Mischke, G. Nooren, T. Peitzmann, C.E. Perez Lara, M. Reicher, E. Rocco, A. Rodriguez Manso, R. de Rooij, R. Snellings, D. Thomas, M. Veldhoen, M. Verweij, H. Yang, Y. Zhou**

Measurement of quarkonium production at forward rapidity in pp collisions at $\sqrt{s} = 7$ TeV
Eur. Phys. J. **C 74** (2014) 2974

Transverse momentum dependence of inclusive primary charged-particle production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
Eur. Phys. J. **C 74** (2014) 3054

Event-by-event mean p_T fluctuations in pp and Pb-Pb collisions at the LHC
Eur. Phys. J. **C 74** (2014) 3077

Neutral pion production at midrapidity in pp and Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
Eur. Phys. J. **C 74** (2014) 3108

J/ψ production and nuclear effects in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
J. High Energy Phys. **02** (2014) 073

Measurement of charged jet suppression in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
J. High Energy Phys. **03** (2014) 013

Suppression of $\psi(2S)$ production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
J. High Energy Phys. **12** (2014) 073

Measurement of prompt D-meson production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
Phys. Rev. Lett. **113** (2014) 232301

Exclusive J/ψ photoproduction off protons in ultraperipheral p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
Phys. Rev. Lett. **113** (2014) 232504

Two- and three-pion quantum statistics correlations in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV at the CERN Large Hadron Collider
Phys. Rev. **C 89** (2014) 024911

Azimuthal anisotropy of D-meson production in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
Phys. Rev. **C 90** (2014) 034904

Multiparticle azimuthal correlations in p-Pb and Pb-Pb collisions at the CERN Large Hadron Collider
Phys. Rev. **C 90** (2014) 054902

Multiplicity dependence of pion, kaon, proton and lambda production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
Phys. Lett. **B 728** (2014) 25

Multi-strange baryon production at mid-rapidity in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
Phys. Lett. **B 728** (2014) 216

Centrality, rapidity and transverse momentum dependence of J/ψ suppression in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
Phys. Lett. **B 734** (2014) 314

Production of charged pions, kaons and protons at large transverse momenta in pp and Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
Phys. Lett. **B 736** (2014) 196

Beauty production in pp collisions at $\sqrt{s} = 2.76$ TeV measured via semi-electronic decays
Phys. Lett. **B 738** (2014) 97

Freeze-out radii extracted from three-pion cumulants in pp, p-Pb and Pb-Pb collisions at the LHC
Phys. Lett. **B 739** (2014) 139

Suppression of $\Upsilon(1S)$ at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
Phys. Lett. **B 739** (2014) 361

Production of inclusive $\Upsilon(1S)$ and $\Upsilon(2S)$ in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
Phys. Lett. **B 740** (2014) 105

N. Brambilla (*et al.*), P. Christakoglou, A. Mischke
QCD and strongly coupled gauge theories: challenges and perspectives
Eur. Phys. J. **C 74** (2014) 2981

A. Bilandzic, C.H. Christensen, K. Gulbrandsen, A. Hansen, Y. Zhou
Generic framework for anisotropic flow analyses with multiparticle azimuthal correlations
Phys. Rev. **C 89** (2014) 064904

STAR Collaboration: G. Agakishiev (*et al.*)**; E. Braidot, T. Peitzmann**

Event-plane-dependent dihadron correlations with harmonic v_n subtraction in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV
Phys. Rev. **D 89** (2014) 041901

Neutrino Telescopes
ANTARES Collaboration: S. Adrian-Martinez (*et al.*)**; C. Bogazzi, R. Bormuth, M.C. Bouwhuis, R. Bruijn, A.J. Heijboer, M. de Jong, P. Kooijman, T. Michael, D. Palioselitis, D.F.E. Samtleben, S. Schulte, J.J.M. Steijger, E. Visser, E. de Wolf**

Searches for Point-like and extended neutrino sources close to the Galactic Centre using the ANTARES neutrino Telescope
Astrophys. J. **786** (2014) L5

Searches for clustering in the time integrated skymap of the ANTARES neutrino telescope
J. Cosmol. Astropart. Phys. **05** (2014) 001

KM3NeT Collaboration: S. Adrian-Martinez (*et al.*)**; H. Band, E. Berbee, A. Berkien, V. van Beveren, H. Boer Rookhuizen, R. Bormuth, M.C. Bouwhuis, R. Bruijn, D. Gajana, M. Gebyehu, H. van Haren, A. Heijboer, E. Heine, M. van der Hoek, J. Hogenbirk, P. Jansweijer, M. de Jong, G. Kieft, E. Koffeman, H. Kok, P. Kooijman, J. Koopstra, A. Korporaal, T. Michael, S. Mos, H. Peek, D.F.E. Samtleben, J. Schmelling, J. Steijger, P. Timmmer, J. Vermeulen, P. Werneke, L. Wiggers, E. de Wolf, A. Zwart**

Deep sea tests of a prototype of the KM3NeT digital optical module
Eur. Phys. J. **C 74** (2014) 3056

Gravitational Waves
T. Accadia (*et al.*), Th.S. Bauer, M.G. Beker, M. Blom, J.F.J. van den Brand, C. Van Den Broeck, H.J. Bulten, T.G.F. Li, W. Del Pozzo, S. van der Putten, D.S. Rabeling, S. Vitale
Characterization of the Virgo seismic environment
Class. Quantum Grav. **29** (2012) 025005

M. Punturo, H. Lueck, M. Beker
A third generation gravitational wave observatory: The Einstein telescope
Advanced Interferometers and the Search for Gravitational Waves; Astrophysics and Space Science Library, Vol. **404**, 2014, 333-362. ISBN 9783319037912

F. Acernese (*et al.*), K. Agatsuma
Concepts and research for future detectors
Gen. Rel. Grav. **46** (2014) 1700

M. Adier (*et al.*), M.G. Beker, A. Bertolini, M.R. Blom, J.F.J. van den Brand, H.J. Bulten, M. Doets, E. Hennes, F. Mul, A. Schimmel
Progress and challenges in advanced ground-based gravitational-wave detectors
Gen. Rel. Grav. **46** (2014) 1749

C. Van Den Broeck
Astrophysics, cosmology, and fundamental physics with compact binary coalescence and the Einstein Telescope
J. Phys. Conf. Ser. **484** (2014) 012008

S. Vitale, W. Del Pozzo, T.G.F. Li, C. Van Den Broeck, B. Aylott, J. Veitch
Effect of calibration errors on Bayesian parameter estimation for gravitational wave signals from inspiral binary systems in the advanced detectors era: Further investigations
J. Phys. Conf. Ser. **484** (2014) 012026

W. Del Pozzo
Measuring the Hubble constant using gravitational waves
J. Phys. Conf. Ser. **484** (2014) 012030

S. Vitale, R. Lynch, J. Veitch, V. Raymond, R. Sturani
Measuring the spin of black holes in binary systems using gravitational waves
Phys. Rev. Lett. **112** (2014) 251101

S. Vitale, W. Del Pozzo
How serious can the stealth bias be in gravitational wave parameter estimation?
Phys. Rev. **D 89** (2014) 022002

T. Dent, J. Veitch
Optimizing gravitational-wave searches for a population of coalescing binaries: Intrinsic parameters
Phys. Rev. **D 89** (2014) 062002

M. Agathos, W. Del Pozzo, T.G.F. Li, C. Van Den Broeck, J. Veitch, S. Vitale
TIGER: A data analysis pipeline for testing the strong-field dynamics of general relativity with gravitational wave signals from coalescing compact binaries
Phys. Rev. **D 89** (2014) 082001

T. Sidery (*et al.*), J. Veitch
Reconstructing the sky location of gravitational-wave detected compact binary systems: Methodology for testing and comparison
Phys. Rev. **D 89** (2014) 084060

J. Meidam, M. Agathos, C. Van Den Broeck, J. Veitch, B.S. Sathyaprakash
Testing the no-hair theorem with black hole ringdowns using TIGER
Phys. Rev. **D 90** (2014) 064009

C. Van Den Broeck, Probing dynamical spacetimes with gravitational waves, in Springer Handbook of Spacetime, Springer Verlag, Berlin, 2014

M. Beker, A. Bertolini, J.F.J. van den Brand, H.J. Bulten, E. Hennes, D. Rabeling
State observers and Kalman filtering for high performance vibration isolation systems
Rev. Sci. Instrum. **85** (2014) 034501

LIGO Scientific Collaboration and Virgo Collaboration: J. Aasi (*et al.*); M. Agathos, Th.S. Bauer, M.G. Beker, A. Bertolini, M. van Beuzekom, S. Bloemen, M. Blom, A.P.M. ter Braack, J.F.J. van den Brand, C. Van Den Broeck, H.J. Bulten, S. Ghosh, J. van Heijningen, R.J.G. Jonker, T.G.F. Li, V. Loriette, I. Maksimovic, J. Meidam, G. Nelemans, W. Del Pozzo, S. van der Putten, D.S. Rabeling, S. Shah, M.V. van der Sluys, J. Veitch, S. Vitale

First searches for optical counterparts to gravitational-wave candidate events
Astrophys. J. **211** (2014) 00702

Constraints on cosmic strings from the LIGO-Virgo gravitational-Wave detectors
Phys. Rev. Lett. **112** (2014) 131101

Search for gravitational waves associated with γ-ray bursts detected by the interplanetary network
Phys. Rev. Lett. **113** (2014) 011102

Improved upper limits on the stochastic gravitational-wave background from 2009-2010 LIGO and Virgo data
Phys. Rev. Lett. **113** (2014) 231101

Search for gravitational wave ringdowns from perturbed intermediate mass black holes in LIGO-Virgo data from 2005-2010
Phys. Rev. **D 89** (2014) 102006

Search for gravitational radiation from intermediate mass black hole binaries in data from the second LIGO-Virgo joint science run
Phys. Rev. **D 89** (2014) 122003

Methods and results of a search for gravitational waves associated with γ-ray bursts using the GEO 600, LIGO, and Virgo detectors
Phys. Rev. **D 89** (2014) 122004

First all-sky search for continuous gravitational waves from unknown sources in binary systems
Phys. Rev. **D 90** (2014) 062010

ANTARES Collaboration and LIGO Scientific Collaboration and Virgo Collaboration: J. Abadie (*et al.*); T. Accadia (*et al.*), S. Adrian-Martinez (*et al.*), M. Agathos, A.C. Assis Jesus, T. Astraatmadja, Th.S. Bauer, M.G. Beker, M. Blom, C. Bogazzi, M.C. Bouwhuis, J.F.J. van den Brand, C. Van Den Broeck, H.J. Bulten, M.P. Decowski, M. Doets, H. Groenstege, J. Hartman, A.J. Heijboer, E. Hennes, M. de Jong, T. Ketel, P. Kooijman, C. Kopper, G. Lim, T.G.F. Li, F.A.. Mul, D. Palioselitis, J. Petrovic, W. del Pozzo, E. Presani, S. van der Putten, D.S. Rabeling, C. Reed, D.F.E. Samtleben, J.J.M. Steijger, S. Vitale, D. Wijnker, E. de Wolf

A search for neutrino emission from the Fermi bubbles with the ANTARES telescope
Eur. Phys. J. **C 74** (2014) 2701

Cosmic Rays
Pierre Auger Collaboration: P. Abreu (*et al.*); G. van Aar, A. Aminaei, J. Coppens, H. Falcke, S. Grebe, S. Harmsma, J.R. Horandel, A. Horneffer, S. Jansen, S. Jiraskova, S.J. de Jong, J. Kelley, A. Nelles, J. Petrovic, H. Schoorlemmer, C. Timmermans

A targeted search for point sources of EeV neutrons
Astrophys. J. Lett. **789** (2014) L34

A search for point sources of EeV photons
Astrophys. J. **789** (2014) 160

Searches for Large-Scale Anisotropy in the arrival directions of Cosmic Rays detected above energy of 10^{19} eV at the Pierre Auger Observatory and the Telescope Array
Astrophys. J. **794** (2014) 172

Origin of atmospheric aerosols at the Pierre Auger Observatory using studies of air mass trajectories in South America
Atmos. Res. **149** (2014) 120

Highlights from the Pierre Auger Observatory
Braz. J. Phys. **44** (2014) 560

Reconstruction of inclined air showers detected with the Pierre Auger Observatory
J. Cosmol. Astropart. Phys. **08** (2014) 019

Probing the radio emission from air showers with polarization measurements
Phys. Rev. **D 89** (2014) 052002

Muons in air showers at the Pierre Auger Observatory: Measurement of atmospheric production depth
Phys. Rev. **D 90** (2014) 012012

Depth of maximum of air-shower profiles at the Pierre Auger Observatory. I. Measurements at energies above $10^{17.8}$ eV
Phys. Rev. **D 90** (2014) 122005

Depth of maximum of air-shower profiles at the Pierre Auger Observatory. II. Composition implications
Phys. Rev. **D 90** (2014) 122006

J.-F. Hochedez, C. Timmermans, A. Hauchecorne, M. Meftah
Dark signal correction for a lukecold frame transfer CCD. Application to the SODISM solar telescope on board the PICARD space mission
Astron. Astrophys. **561** (2014) A17

Dark Matter
XENON100 Collaboration: E. Aprile (*et al.*)**; M. Alfonsi, A.P. Colijn, M.P. Decowski, A. Tiseni**

Analysis of the XENON100 dark matter search data
Astropart. Phys. **54** (2014) 11

Observation and applications of single-electron charge signals in the XENON100 experiment
J. Phys. **G 41** (2014) 035201

First axion results from the XENON100 experiment
Phys. Rev. **D 90** (2014) 062009

Theoretical Physics
B. Koch, F. Saueressig
Structural aspects of asymptotically safe black holes
Class. Quantum Grav. **31** (2014) 015006

J. H. Cooperman, J. Miller
A first look at transition amplitudes in (2 + 1)-dimensional causal dynamical triangulations
Class. Quant. Grav. **31** (2014) 035012

M. Cariglia (*et al.*), J.W. van Holten
Killing tensors and canonical geometry
Class. Quantum Grav. **31** (2014) 125001

J. Ambjorn, A. Goerlich, J. Jurkiewicz, A. Kreienbuehl, R. Loll
Renormalization group flow in CDT
Class. Quantum Grav. **31** (2014) 165003

O. Buchmueller (*et al.*), D. Martinez Santos
The CMSSM and NUHM1 after LHC Run 1
Eur. Phys. J. **C 74** (2014) 2922

O. Buchmueller (*et al.*), D. Martinez Santos
The NUHM2 after LHC Run 1
Eur. Phys. J. **C 74** (2014) 3212

F. Hautmann, H. Jung, M. Kramer, P.J. Mulders, E.T. Nocera, T.C. Rogers, A. Signori
TMDlib and TMDplotter: library and plotting tools for transverse-momentum-dependent parton distributions
Eur. Phys. J. **C 74** (2014) 3220

P.J. Mulders, M.G.A. Buffing
Wilson Lines off the Light-Cone in TMD PDFs
Few-Body Systems **55** (2014) 275

J.W. van Holten, R. Kerner
Time-reparametrization invariance and Hamilton-Jacobi approach to the cosmological σ-model
Fortschr. Phys. **62** (2014) 543

S. Gryb, K. Thebaault
Symmetry and evolution in quantum gravity
Found. Phys. **44** (2014) 305

B. Koch, F. Saueressig
Black holes within asymptotic safety
Int. J. Mod. Phys. **A 29** (2014) 1430011

R. Fleischer
Probing New Physics with $B_s^0 \to \mu^+\mu^-$: Status and Perspectives
Int. J. Mod. Phys. **A 29** (2014) 1444004

A. Signori, A. Bacchetta, M. Radici
Flavor dependence of unpolarized TMDs from semi-inclusive pion production
Int. J. Mod. Phys. Conf. Ser. **25** (2014) 1460020

A. Pavan, A. Contillo, G. Mather
Modelling fast forms of visual neural plasticity using a modified second-order motion energy model
J. Comp. Neuroscience 37 (2014) 493

D.P. George, S. Mooij, M. Postma
Quantum corrections in Higgs inflation: the real scalar case
J. Cosmol. Astropart. Phys. **02** (2014) 024

K. Petraki, L. Pearce, A. Kusenko
Self-interacting asymmetric dark matter coupled to a light massive dark photon
J. Cosmol. Astropart. Phys. **07** (2014) 039

E.E. Jenkins (*et al.*), W.J. Waalewijn
Higher-order gravitational lensing reconstruction using Feynman diagrams
J. Cosmol. Astropart. Phys. **09** (2014) 024

I. Baldes (*et al.*), K. Petraki
The role of CP violating scatterings in baryogenesis - case study of the neutron portal
J. Cosmol. Astropart. Phys. **11** (2014) 041

B. von Harling, K. Petraki
Bound-state formation for thermal relic dark matter and unitarity
J. Cosmol. Astropart. Phys. **12** (2014) 033

S. Nawata, P. Ramadevi, Zodinmawia
Colored Kauffman homology and super-A-polynomials
J. High Energy Phys. **01** (2014) 126

J.A. Harvey, S. Murthy
Moonshine in fivebrane spacetimes
J. High Energy Phys. **01** (2014) 146

D. Butter, B. de Wit, I. Lodato
Non-renormalization theorems and N=2 supersymmetric backgrounds
J. High Energy Phys. **03** (2014) 131

M. Diehl, T. Kasemets, S. Keane
Correlations in double parton distributions: effects of evolution
J. High Energy Phys. **05** (2014) 118

M. Demmel, F. Saueressig, O. Zanusso
RG flows of quantum Einstein gravity on maximally symmetric spaces
J. High Energy Phys. **06** (2014) 026

J. Ambjorn, J. Gizbert-Studnicki, A. Gorlich, J. Jurkiewicz
The effective action in 4-dim CDT. The transfer matrix approach
J. High Energy Phys. **06** (2014) 034

A. Codello, G. D'Odorico, C. Pagano
A functional RG equation for the c-function
J. High Energy Phys. **07** (2014) 040

G. Dall'Agata, G. Inverso, A. Marrani
Symplectic deformations of gauged maximal supergravity
J. High Energy Phys. **07** (2014) 133

G.L. Cardoso, B. de Wit, S. Mahapatra
Deformations of special geometry: in search of the topological string
J. High Energy Phys. **09** (2014) 096

A.J. Larkoski, J. Thaler, W.J. Waalewijn
Gaining (mutual) information about quark/gluon discrimination
J. High Energy Phys. **11** (2014) 129

E. Laenen (*et al.*)
NNLL resummation for squark and gluino production at the LHC
J. High Energy Phys. **12** (2014) 023

W. Beenakker, C. Borschensky, M. Kr√§mer, A. Kulesza, E. Laenen, V. Theeuwes, S. Thewes
NNLL resummation for squark and gluino production at the LHC
J. High Energy Phys. **14** (2014) 023

M. Demmel, F.Saueressig, O. Zanusso.
RG flows of Quantum Einstein Gravity on maximally symmetric spaces
J. High Energy Phys. **14** (2014) 026

M. Cariglia (*et al.*), J.W. van Holten
Conformal Killing Tensors and covariant Hamiltonian Dynamics
J. Math. Phys. **55** (2014) 122702

J. Ambjorn, B. Durhuus, J.F. Wheater
A restricted dimer model on a two-dimensional random causal triangulation
J. Phys. **A 47** (2014) 3650014

R. Fleischer
Towards New Frontiers in CP Violation in B Decays
J. Phys. Conf. Ser. **556** (2014) 012035

P. Artoisenet, L.-A. Minsart
Statistical genetics in traditionally cultivated crops
J. Theoretical Biology **360** (2014) 208

B. Gato-Rivera, A.N. Schellekens
GUTs without guts
Nucl. Phys. **B 883** (2014) 529

S. Moch, J.A.M. Vermaseren, A. Vogt
The three-loop splitting functions in QCD: The helicity-dependent case
Nucl. Phys. **B 889** (2014) 351

J. Ambjorn, T. Budd
Geodesic distances in Liouville quantum gravity
Nucl. Phys. **B 889** (2014) 676

D. Butter
The N = 2 Gauss-Bonnet from conformal supergravity
Phys. Part. Nuclei Lett. **11** (2014) 941

E. Hiyama, S. Ohnishi, B.F. Gibson, T.A. Rijken
Three-body structure of the nn Lambda system with Lambda N - Sigma N coupling.
Phys. Rev. **C 89** (2014) 061302

A. Dumitru, Y. Guo, C.P. Korthals Altes
Two-loop perturbative corrections to the thermal effective potential in gluodynamics
Phys. Rev. **D 89** (2014) 016009

M.G. Echevarria, A. Idilbi, Z.B. Kang, I. Vitev
QCD evolution of the Sivers asymmetry
Phys. Rev. **D 89** (2014) 074013

A. Codello, G. D'Odorico, C. Pagani
Consistent closure of renormalization group flow equations in quantum gravity
Phys. Rev. **D 89** (2014) 081701

A. Achucarro, V. Atal, P. Ortiz, J. Torrado
Localized correlated features in the CMB power spectrum and primordial bispectrum from a transient reduction in the speed of sound
Phys. Rev. **D 89** (2014) 103006

J. Ambjorn, Y. Makeenko, A. Sedrakyan
Effective QCD string beyond Nambu-Goto
Phys. Rev. **D 89** (2014) 106010

H. Johansson, D.A. Kosower, K.J. Larsen
Maximal unitarity for the four-mass double box
Phys. Rev. **D 89** (2014) 125010

N. Brouzakis, A. Codello, N. Tetradis, O. Zanusso
Quantum corrections in Galilean theories
Phys. Rev. **D 89** (2014) 125017

M.G. Echevarria, A. Idilbi, I. Scimemi
Unified treatment of the QCD evolution of all (un-)polarized transverse momentum dependent functions: Collins function as a study case
Phys. Rev. **D 90** (2014) 014003

A. Achucarro, V. Atal, B. Hu, P. Ortiz, J. Torrado
Generic framework for anisotropic flow analyses with multiparticle azimuthal correlations
Phys. Rev. **D 90** (2014) 023511

A. Codello, M. Demmel, O. Zanusso
Scheme dependence and universality in the functional renormalization group
Phys. Rev. **D 90** (2014) 027701

Y. Yamamoto, T. Furumoto, N. Yasutake, Th.A. Rijken
Hyperon mixing and universal many-body repulsion in neutron stars
Phys. Rev. **D 90** (2014) 045805

M. Ritzmann, W.J. Waalewijn
Fragmentation in jets at NNLO
Phys. Rev. **D 90** (2014) 054029

V. Keraenen, H. Nishimura, S. Stricker, O. Taanila, A. Vuorinen
Dynamics of gravitational collapse and holographic entropy production
Phys. Rev. **D 90** (2014) 064033

M. Postma, M. Volponi
Equivalence of the Einstein and Jordan frames
Phys. Rev. **D 90** (2014) 103516

T. Elghozi, W. Nelson, M. Sakellariadou
Cusps and pseudocusps in strings with Y-junctions
Phys. Rev. **D 90** (2014) 123517

R. Loll, L. Pires
Role of the extra coupling in the kinetic term in Horava-Lifshitz gravity
Phys. Rev. **D 90** (2014) 124050

J.H. Cooperman
Scale-dependent homogeneity measures for causal dynamical triangulations
Phys. Rev. **D 90** (2014) 124053

C.P. Korthals Altes, A. Sastre
Thermal instanton determinant in compact form
Phys. Rev. **D 90** (2014) 125002

A. Barrau, C. Rovelli, F. Vidotto
Fast Radio Bursts and White Hole Signals
Phys. Rev. **D 90** (2014) 127503

O. Zanusso
Effective models of membranes from symmetry breaking
Phys. Rev. **E 90** (2014) 052110

M.G.A. Buffing, P.J. Mulders
Color entanglement for Azimuthal asymmetries in the Drell-Yan process
Phys. Rev. Lett. **112** (2014) 092002

W. den Dunnen, J.P. Lansberg, C. Pisano, M. Schlegel
Accessing the transverse dynamics and the polarization of the gluons inside the proton at the LHC
Phys. Rev. Lett. **112** (2014) 212001

G. D'Odorico, F. Saueressig, M. Schutten
Asymptotic freedom in Horava-Lifshitz gravity
Phys. Rev. Lett. **113** (2014) 171101

I. Baldes, N.F. Bell, K. Petraki, R.R. Volkas
Particle-antiparticle asymmetries from annihilations
Phys. Rev. Lett. **113** (2014) 181601

J. Ambjorn, A. Goerlich, A.C. Ipsen, H.G. Zhang
A note on the Lee-Yang singularity coupled to 2d quantum gravity
Phys. Lett. **B 735** (2014) 191

E.E. Jenkins, A.V. Manohar, W.J. Waalewijn, A.P.S. Yadav
Gravitational lensing of the CMB: A Feynman diagram approach
Phys. Lett. **B 736** (2014) 006

J. Ambjorn, T. Budd, Y. Watabiki
Scale-dependent Hausdorff dimensions in 2d gravity
Phys. Lett. **B 736** (2014) 339

C. Rovelli and F. Vidotto
Covariant Loop Quantum Gravity: An Elementary Introduction to Quantum Gravity and Spinfoam Theory, Cambridge University Press, 2014, ISBN-13: 9781107069626

Detector R & D
C. Brezina (*et al.*), M. van Beuzekom, H. van der Graaf, V. Gromov, P. Kluit, F. Zappon, V. Zivkovic
GOSSIPO-4: evaluation of a novel PLL-based TDC-technique for the readout of GridPix-detectors
IEEE Trans. Nucl. Sci. **60** (2014) 1007

T. Poikela (*et al.*), V. Gromov, R. Kluit, M. van Beuzekom, F. Zappon, V. Zivkovic
Digital column readout architectures for hybrid pixel detector readout chips
J. Instr. **9** (2014) C01007

E. Schioppa, A. Ellis, A.L. Bruinen, J. Visser, R.M.A. Heeren, J. Uher, E. Koffeman
Combined X-ray CT and mass spectrometry for biomedical imaging applications
J. Instr. **9** (2014) C04029

P. Tropea (*et al.*), B. Verlaat
Design, construction and commissioning of a 15 kW CO2 evaporative cooling system for particle physics detectors: lessons learnt and perspectives for further development
PoS (**TIPP 2014**) 223

E. Schioppa Jr., W. Verkerke, J. Visser, E. Koffeman
Solving CT reconstruction with a particle physics tool (RooFit)
Proc. 6^{th} Int. Conf. on Numerical Analysis, pp 234-239, ISBN: 978-960-8475-22-9

Grid Computing
D. Remenska, A.C. Tim, T.A.C. Willemse, K. Verstoep, J. Templon, H. Bal
Property specification made easy: harnessing the power of model checking in UML designs
Formal Techniques for Distributed Objects, Components, and Systems, Lecture Notes in Computer Science Volume 8461, 2014, pp 17-32

HERA
HERMES Collaboration: A. Airapetian (*et al.*)**; H.P. Blok, L. Lapikás, J.J.M. Steijger**

Spin density matrix elements in exclusive ω electroproduction on ^{1}H and ^{2}H targets at 27.5 GeV beam energy
Eur. Phys. J. **C 74** (2014) 3110

Beam-helicity asymmetry in associated electroproduction of real photons ep→γπ N in the delta-resonance region
J. High Energy Phys. **01** (2014) 077

Reevaluation of the parton distribution of strange quarks in the nucleon
Phys. Rev. **D 89** (2014) 097101

Transverse polarization of Λ hyperons from quasireal photoproduction on nuclei
Phys. Rev. **D 90** (2014) 072007

Transverse target single-spin asymmetry in inclusive electroproduction of charged pions and kaons
Phys. Lett. **B 728** (2014) 183

G.M. Huber (*et al.*), H.P. Blok, V. Tvaskis
Separated response function ratios in exclusive, forward $\pi^{\pm}$ electroproduction
Phys. Rev. Lett. **112** (2014) 182501

ZEUS Collaboration: A. Abramowicz (*et al.*)**; G. Grigorescu, A. Keramidas, E. Koffeman, P. Kooijman, A. Pellegrino, H. Tiecke, M. Vazquez, L. Wiggers**

Measurement of $D^{*\pm}$ production in deep inelastic scattering at HERA
J. High Energy Phys. **05** (2013) 097 , erratum J. High Energy Phys. **02** (2014) 106

LEP
DELPHI Collaboration: J. Abdallah (*et al.*)**; M. Blom, P. van Dam, P. Kluit, J. Montenegro, M. Mulders, D. Reid, J. Timmermans, I. van Vulpen**

Measurement of the electron structure function F_2^e at LEP energies
Phys. Lett. **B 737** (2014) 39

Miscellaneous
J.M.C. Montanus
An extended Heitler-Matthews model for the full hadronic cascade in cosmic air showers
Astropart. Phys. **59** (2014) 4

H. Buisman, D.W. de Souza, J. Steijger
Showering from high-energy cosmic rays
Europhys. News **45** (2014) 25

P. Monaghan (*et al.*), E. Jans
Measurement of the $^{12}C(e,e'p)^{11}B$ two-body breakup reaction at high missing momentum
J. Phys. **G 41** (2014) 105109

R. Crane (*et al.*), C. Timmermans
Middelbare scholieren veroveren CERN
Ned. T. Nat. **80** (2014) 434

T.I. Banks (*et al.*), M.P. Decowski
A compact ultra-clean system for deploying radioactive sources inside the KamLAND detector
Nucl. Instr. Meth. **A 769** (2014) 88

NA49 Collaboration (Heavy Ion Physics): C. Alt (*et al.*)**; M. Botje, P. Christakoglou, M.A. van Leeuwen, M. Rybczynski**

Phase-space dependence of particle-ratio fluctuations in Pb+Pb collisions from 20A to 158A GeV beam energy
Phys. Rev. **C 89** (2014) 054902

Astrophysics
P. Petrucci (*et al.*), E. Koerding
The return to the hard state of GX 339-4 as seen by Suzaku
Astron. Astrophys. **564** (2014) A371

V. Schaffenroth (*et al.*), T. Kupfer
Binaries discovered by the MUCHFUSS project: SDSS J162256.66+473051.1: An eclipsing subdwarf B binary with a brown dwarf companion
Astron. Astrophys. **564** (2014) A98

A. Corstanje (*et al.*), J.R. Horandel
The shape of the radio wavefront of extensive air showers as measured with LOFAR
Astropart. Phys. **61** (2014) 22

G.C. Bower (*et al.*), H. Falcke
The angular broadening of the Galactic Center Pulsar SGR J1745-29: A new constraint on the scattering medium
Astrophys. J. **780** (2014) L2

S. Shah, G. Nelemans
Constraining parameters of white-dwarf binaries using gravitational-wave and electromagnetic observations
Astrophys. J. **790** (2014) 161

S. Shah, G. Nelemans
Measuring tides and binary parameters from gravitational wave data and eclipsing timings of detached white dwarf binaries
Astrophys. J. **791** (2014) 76

P. Andre (*et al.*), M. Haverkorn
PRISM (Polarized Radiation Imaging and Spectroscopy Mission): An Extended White Paper
J. Cosmol. Astropart. Phys. **02** (2014) 006

LOPES Collaboration: W.D. Apel (*et al.*)**, H. Falcke, J.R. Horandel, J. Kuijpers**
The wavefront of the radio signal emitted by cosmic ray air showers
J. Cosmol. Astropart. Phys. **09** (2014) 025

M. Marcolli, W.D. van Suijlekom
Gauge networks in noncommutative geometry
Jrnl. Geom. and Phys. **75** (2014) 71

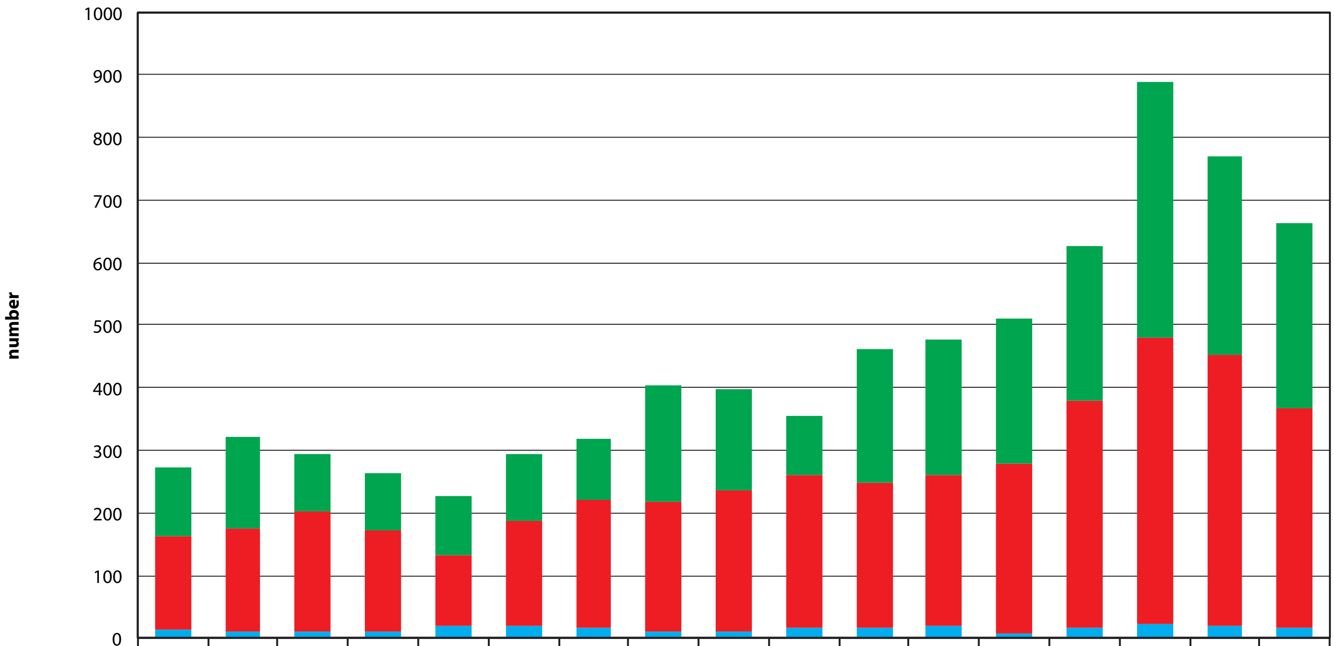
A.N. Semena (*et al.*), R. Coppejans
On the area of accretion curtains from fast aperiodic time variability of the intermediate polar EX Hya
Mon. Not. R. Astron. Soc. **442** (2014) 1123

LOFAR Collaboration: H. Falcke, J.R. Horandel, A. Nelles
Recent results from cosmic-ray measurements with LOFAR
Nucl. Instr. Meth. **A 742** (2014) 115

S. Thoudam, S. Buitink, A. Corstanje, J.E. Enriquez, H. Falcke, W. Frieswijk, J.R. Horandel, A. Horneffer, M. Krause, A. Nelles, P. Schellart, O. Scholten, S. ter Veen, M. van den Akker
LORA: A scintillator array for LOFAR to measure extensive air showers
Nucl. Instr. Meth. **A 767** (2014) 339

S. Buitink, A. Corstanje, J.E. Enriquez, H. Falcke, J.R. Horandel, T. Huege, A. Nelles, J.P. Rachen, P. Schellart, O. Scholten, S. ter Veen, S. Thoudam, T.N.G. Trinh
Method for high precision reconstruction of air shower X_{max} using two-dimensional radio intensity profiles
Phys. Rev. **D 90** (2014) 082003

Nikhef Scientific Output



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Talks	109	147	92	91	95	108	97	186	162	93	212	215	231	248	410	316	304
Publications	150	165	190	163	113	168	207	209	228	246	234	243	270	361	458	435	352
Theses	13	9	11	10	18	18	15	10	9	15	15	18	8	17	22	18	15

Figure 1. Nikhef's scientific output in the last 17 years.

3.2 Theses

Robert Jan Knegjens
Strategies to hunt for new physics with strange beauty mesons
Vrije Universiteit Amsterdam, 11 March 2014
Promotor: R. Fleischer

Robin Hans Ludar van der Leeuw
Strong supersymmetry : A search for squarks and gluinos in hadronic channels using the ATLAS detector
Universiteit van Amsterdam, 15 April 2014
Promotor: P.J. de Jong
Copromotor: O.B. Igonkina

Lucie de Nooij
The φ(1020)-meson production cross section measured with the ATLAS detector at $\sqrt{s}$ *= 7 TeV*
Universiteit van Amsterdam, 15 May 2014
Promotor: E.N. Koffeman
Copromotor: A.P. Colijn

Claudio Bogazzi
Search for cosmic neutrinos with ANTARES
Universiteit Leiden, 15 May 2014
Promotor: M. de Jong
Copromotor: A.J. Heijboer

Deepa Thomas
Jet-like heavy-flavour particle correlations in proton-proton and lead-lead collisions at ALICE
Universiteit Utrecht, 16 June 2014
Promotor: T. Peitzmann
Copromotor: A. Mischke

Wilke van der Schee
Gravitational collisions and the quark-gluon plasma
Universiteit Utrecht, 2 July 2014
Promotor: T. Peitzmann
Copromotor: G. Arutyonov

Thijs Cornelis Henricus van den Broek
Supersymmetry and the spectral action: on a geometrical interpretation of the MSSM
Radboud Universiteit Nijmegen, 5 September 2014
Promotores: R.H.P. Kleiss, W.J.P. Beenakker
Copromotor: W.D. van Suijlekom

Priscilla Pani
To the bottom of the stop: Calibration of bottom-quark jets identification algorithms and search for scalar top-quarks and dark matter with the Run 1 ATLAS data
Universiteit van Amsterdam, 10 September 2014
Promotor: P.J. de Jong
Copromotor: A.P. Colijn

Antonio Salvucci
The Higgs boson in the $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ *decay channel with the ATLAS detector at the LHC*
Radboud Universiteit Nijmegen, 23 September 2014
Promotor: N. de Groot
Copromotor: F. Filthaut

Chiara Farinelli
Performance of the LHCb Vertex Locator and flavour tagging studies for the measurement of the CKM angle γ
Vrije Universiteit Amsterdam, 25 September 2014
Promotor: M.H.M. Merk
Copromotor: E. Jans

Ivano Lodato
Supersymmetric higher derivative couplings and their applications
Universiteit Utrecht, 29 September 2014
Promotor: B.Q.P.J. de Wit

Pablo Ortiz
Effects of heavy fields on inflationary cosmology
Universiteit Leiden, 30 September 2014
Promotor: A. Achucarro
Copromotor: J.W. van Holten

Anna Friederike Nelles
Radio emission of air showers: the perspective of LOFAR and AERA
Radboud Universiteit Nijmegen, 1 October 2014
Promotor: S.J. de Jong
Copromotor: J.R. Horandel

Valerio Dao
Over the Top: from $t\bar{t}$ *measurements to the search for the associated production of the Higgs boson and a top quark pair with the ATLAS detector*
Radboud Universiteit Nijmegen, 25 November 2014
Promotor: N. de Groot
Copromotor: F. Filthaut

Enrico Junior Schioppa
The color of X-rays. Spectral computed tomography using energy sensitive pixel detectors
Universiteit van Amsterdam, 14 December 2014
Promotor: E.N. Koffeman
Copromotor: J. Visser

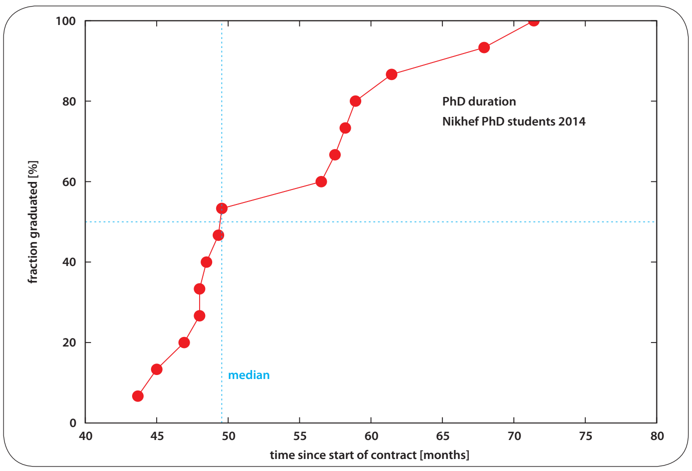


Figure 1. Fraction of PhD students working at Nikhef that graduated in the year 2014 as a function of time since the start of their thesis contract. The median PhD duration is 49.6 months (4.1 year).

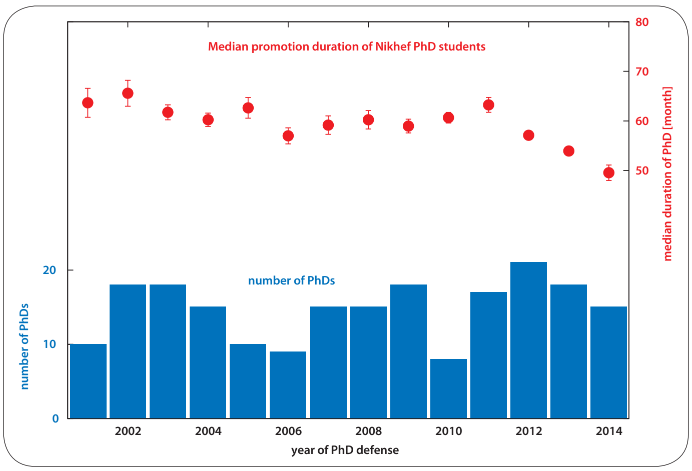
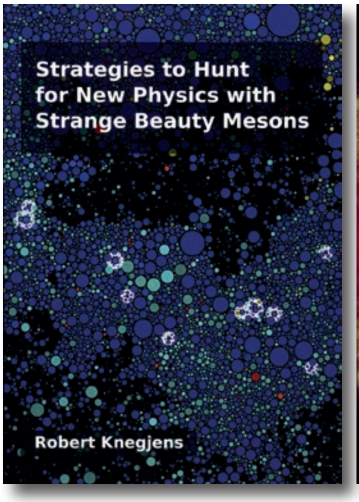
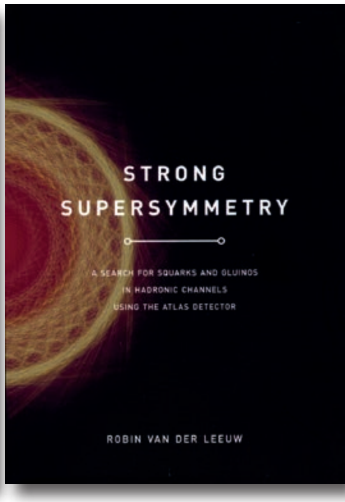
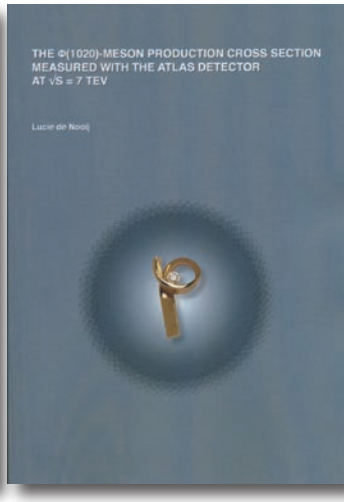
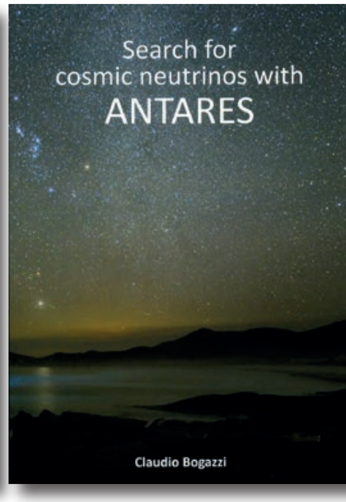


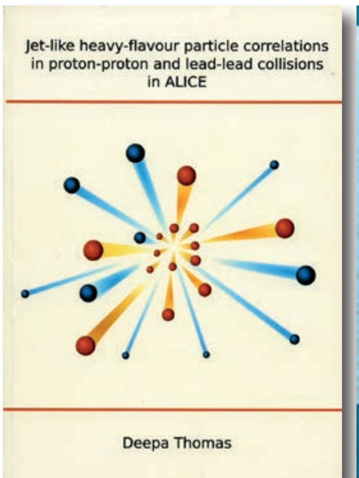
Figure 2. Median PhD duration of Nikhef PhD students since 2001 as a function of graduation year. The error bars represent the median absolute deviation (MAD)/√(n-1). The histogram gives the total number n of PhDs in each year.

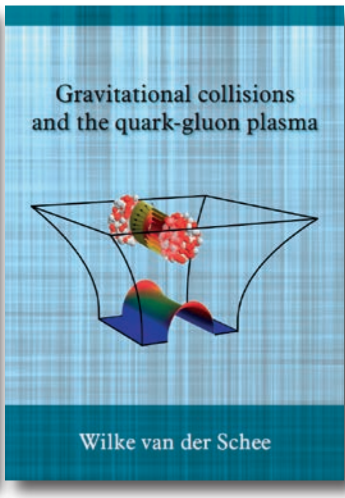

Strategies to Hunt
for New Physics with
Strange Beauty Mesons
Robert Knegjens

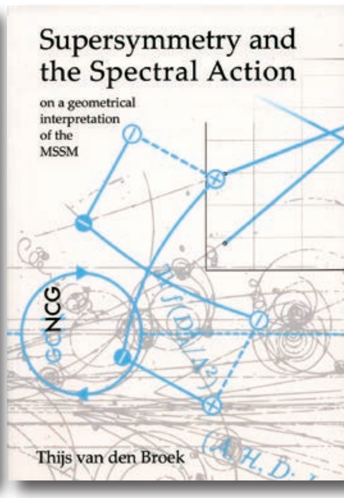

STRONG
SUPERSYMMETRY
A SEARCH FOR SQUARKS AND GLUINOS
IN HADRONIC CHANNELS
USING THE ATLAS DETECTOR
ROBIN VAN DER LEEUW


THE Φ(1020)-MESON PRODUCTION CROSS SECTION
MEASURED WITH THE ATLAS DETECTOR
AT √S = 7 TEV
Lucie de Nooij

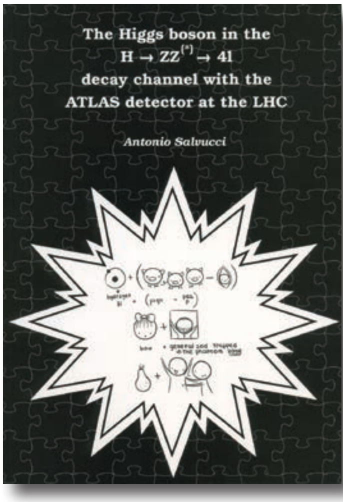

Search for
cosmic neutrinos with
ANTARES
Claudio Bogazzi

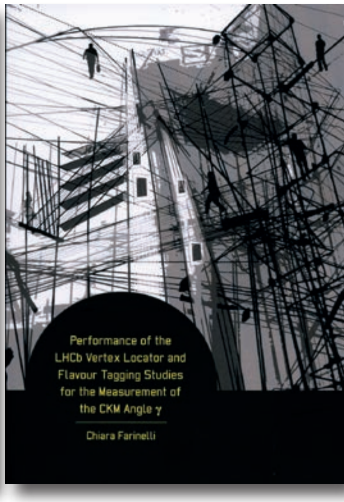

Jet-like heavy-flavour particle correlations
in proton-proton and lead-lead collisions
in ALICE
Deepa Thomas

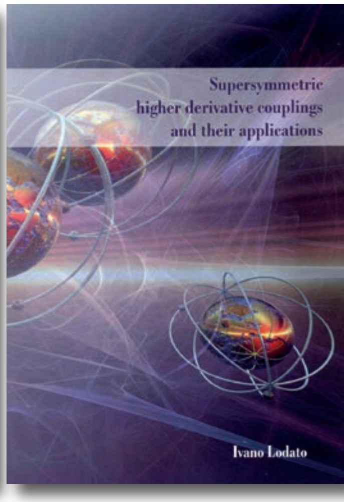

Gravitational collisions
and the quark-gluon plasma
Wilke van der Schee

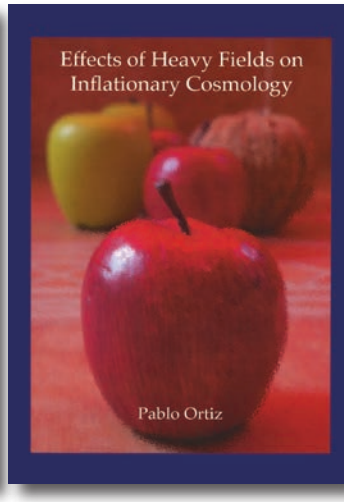

Supersymmetry and
the Spectral Action
on a geometrical
interpretation
of the
MSSM
NCG
Thijs van den Broek


TO THE BOTTOM OF THE STOP
Calibration of bottom-quark jets identification
algorithms and search for scalar top-quarks
and dark matter with the Run I ATLAS data
Priscilla Pani

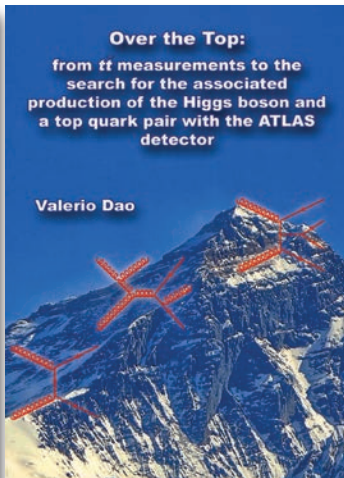

The Higgs boson in the
$H \rightarrow ZZ^{(*)} \rightarrow 4l$
decay channel with the
ATLAS detector at the LHC
Antonio Salvucci

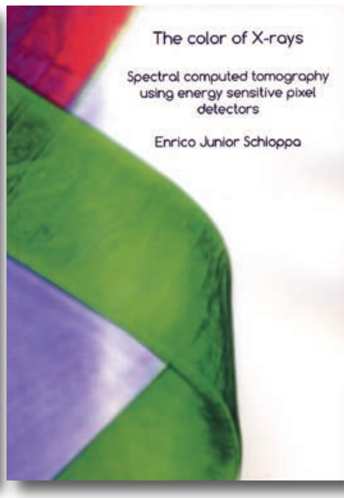

Performance of the
LHCb Vertex Locator and
Flavour Tagging Studies
for the Measurement of
the CKM Angle γ
Chiara Farinelli


Supersymmetric
higher derivative couplings
and their applications
Ivano Lodato


Effects of Heavy Fields on
Inflationary Cosmology
Pablo Ortiz


Radio emission of air showers
The perspective of LOFAR and AERA
Anna Nelles


Over the Top:
from $t\bar{t}$ measurements to the
search for the associated
production of the Higgs boson and
a top quark pair with the ATLAS
detector
Valerio Dao


The color of X-rays
Spectral computed tomography
using energy sensitive pixel
detectors
Enrico Junior Schioppa

3.3 Talks

ATLAS

Besjes, G.J., Searching for supersymmetry without leptons with ATLAS, Physics@FOM, Veldhoven, The Netherlands, 21-01-2014

Colijn, A.P., Summary talk, TIPP2014, Amsterdam, The Netherlands, 06-06-2014

Croft, V.A., ATLAS Tau and Higgs to Tau Tau Annual Workshop, Paris, France, 24-06-2014

Hessey, N.P., High Precision Tracking with Gossip: a Gaseous Pixel Detector Made with MEMS Post-Processing of CMOS Pixel Chips, IEEE Nuclear Science Symp., Seattle, USA, 13-11-2014

Holten, van, J.W., Listening to the universe, Physics colloquium, Salt Lake City, USA, 09-01-2014

Igonkina, O., LHC energy frontier, Physics@FOM, Veldhoven, The Netherlands, 21-01-2014

LHC searches for BSM physics in events with multiple leptons, DIS2014, Warsaw, Poland, 01-05-2014

ATLAS status report, Large Hadron Collider experiments Committee, CERN, Switzerland, 19-11-2014

Jong, de, P.J., Experimental challenges for SUSY searches at the LHC13-14, Physics challenges in the face of LHC14, Madrid, Spain, 16-09-2014

Particle detection with micrometer precision at the LHC, Nanocity 2014, Utrecht, The Netherlands, 28-10-2014

Kluit, P.M., Combined measurements of the properties of the Higgs boson using the ATLAS detector, Particles and Nuclei Int. Conf. 2014, Hamburg, Germany, 25-08-2014

Koffeman, E.N., Summary talk, TIPP2014, Amsterdam, The Netherlands, 06-06-2014

Oussoren, K.P., Higgs Properties Seen from the Collins-Soper Frame, NNV Fall Meeting, Lunteren, The Netherlands, 07-11-2014

Valenčič, N., Search for H→WW in Atlas, Higgs Hunting 2014, Orsay, France, 21-01-2014

Verkerke, W., Systematic uncertainties and profiling, IN2P3 School of Statistics 2014, Autrans, France, 27-05-2014

Systematic uncertainties and profiling, IN2P3 School of Statistics 2014, Autrans, France, 28-05-2014

Profile Likelihood – What is it and how does it work?, Physics Seminar, Bonn, Germany, 05-06-2014

Practical statistics, 2014 European School of High-Energy Physics, Garderen, The Netherlands, 21-06-2014

Practical statistics, 2014 European School of High-Energy Physics, Garderen, The Netherlands, 22-06-2014

Practical statistics, 2014 European School of High-Energy Physics, Garderen, The Netherlands, 23-06-2014

Discovering the Higgs – finding the needle in the haystack, CERN Openlab lecture, Geneva, Switzerland, 31-07-2014

Statistical analysis tools for the Higgs discovery and beyond, 16th Int. workshop on Advanced Computing and Analysis Techniques in physics research (ACAT), Prague, Czech Republic, 01-09-2014

Advanced methods in statistical data analysis, Third Nordic School of Statistics, København, Denmark, 08-10-2014

Advanced methods in statistical data analysis, Third Nordic School of Statistics, København, Denmark, 09-10-2014

Advanced methods in statistical data analysis, Third Nordic School of Statistics, København, Denmark, 10-10-2014

Practical statistics, Second Asia-Europe-Pacific School of High-Energy Physics, Puri, India, 05-11-2014

Practical statistics, Second Asia-Europe-Pacific School of High-Energy Physics, Puri, India, 06-11-2014

Practical statistics, Second Asia-Europe-Pacific School of High-Energy Physics, Puri, India, 07-11-2014

Vulpen, van, I.B., Introduction to ROOT and statistics, HASCO hadron collider summerschool, Göttingen, Germany, 25-07-2014

Higgs physics, BND graduate summerschool, Kerkrade, The Netherlands, 02-09-2014

LHCb

De Bruyn, K.A.M., Measurement of CP Violation in the B_s System, 11th Int. Conf. on Hyperons, Charm and Beauty Hadrons (BEACH 2014), Birmingham, United Kingdom, 23-07-2014

Heijne, V.A.M., Exotic searches at LHCb, Beauty 2014, Edinburgh, United Kingdom, 17-07-2014

Jans, E., The VELO Upgrade, Int. workshop on semiconductor pixel detectors for particles and imaging, Niagara Falls, Canada, 04-09-2014

Koopman, R.F., CP violation with B mesons at LHCb, Epiphany Conf., Krakow, Poland, 08-01-2014

Koppenburg, P., Present and future CKM studies from b-hadron physics at hadron machines, 8th Int. Workshop on the CKM Unitarity Triangle, Vienna, Austria, 08-09-2014

Rare Decays and Search for New Physics
26th Rencontres de Blois on Particle Physics and Cosmology, Blois, France, 22-05-2014

Merk, M., The LHCb Experiment, Workshop at Esaote company, Maastricht, The Netherlands, 27-04-2014

CP Violation in LHCb, Nikhef Colloquium, Amsterdam, The Netherlands, 31-10-2014

Tilburg, van, J., Beauty and charm at the LHC: searches for TeV scale phenomena in flavour transitions, Physics@FOM, Veldhoven, The Netherlands, 21-01-2014

Probing the TeV scale with flavour transitions at the LHC, Quantum Universe, Groningen, The Netherlands, 16-04-2014

ALICE

Bertens, R.A., Event plane dependence of charged jet yields in $\sqrt{s_{NN}}$ = 2.76 TeV Pb–Pb collisions with ALICE, NNV Fall Meeting, Lunteren, The Netherlands, 07-11-2014

Christakoglou, P., What have we learned from angular correlation analyses in p–Pb collisions?, Int. Conf. on matter under extreme conditions: there and now, Kolkata, India, 15-01-2014

Elliptic flow of identified particles measured with ALICE, 10th Workshop on particle correlations and femtoscopy – WPCF, Gyöngyös, Hungary, 27-08-2014

Experimental overview of collective flow with identified particles at RHIC and the LHC, 44th Int. Symp. on Multiparticle Dynamics – ISMD, Bologna, Italy, 11-09-2014

Anisotropic flow measurements of identified particles from RHIC to LHC, Zimanyi winter school on heavy-ion physics, Budapest, Hungary, 02-12-2014

Leeuwen, van, M., Lectures on high-p_T probes of the Quark Gluon Plasma, Helmholtz graduate school, Manigod, France, 17-02-2014

Summary of the Color Glass Condensate sessions, Arbeitstreffen Kernphysik, Schleching, Germany, 27-02-2014

Experimental techniques, ECT* Doctoral training program, Trento, Italy, 21-04-2014

Lectures: Hard Probes and Jets (experiment), JET summer school, Davis, USA, 19-06-2014

Jets and high-p_T probes: Recent results, 24th Int. Conf. on ultrarelativistic nucleus-nucleus collisions, Darmstadt, Germany, 19-06-2014

Centrality dependent measurements, centrality determination and biases in p+Pb collisions, Third Heavy Ion Jet Workshop, Lisbon, Portugal, 09-07-2014

Hard Probes of the QGP: what do we know and what can we learn?, Heavy Ion Cafe, Tokyo, Japan, 27-09-2014

Hard Probes of the Quark Gluon Plasma, Tsukuba Global Science Week, Tsukuba, Japan, 29-09-2014

Mischke, A., Prospects for heavy-flavour measurements in Pb–Pb collisions at the LHC with the new ALICE inner tracker, Physics@FOM, Veldhoven, The Netherlands, 21-01-2014

Heavy flavours, 22nd Int. Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2014), Warsaw, Poland, 28-04-2014

Heavy-flavour results from the CERN-LHC, Int. Workshop on Collectivity in Relativistic Heavy Ion Collisions, Kolymbari, Crete, Greece, 15-09-2014

Overview of ALICE results, 9th LHC Days, Split, Croatia (Hrvatska), 30-09-2014

Nooren, G., A particle counting EM calorimeter using MAPS, CALOR2014, Giessen, Germany, 06-04-2014

Peitzmann, T., Forward Physics at the LHC with ALICE, Low-x Meeting, Kyoto, Japan, 19-06-2014

Direct Photon Production in High-Energy Nuclear Collisions, Conf. on Quark Confinement and the Hadron Spectrum, St. Petersburg, Russia, 11-09-2014

Rocco, E., Highly granular digital electromagnetic Calorimeter with MAPS, 37th Int. Conf. on High Energy Physics (ICHEP2014), Valencia, Spain, 05-07-2014

Snellings, R.J.M., Recent Results From ALICE, 52nd Int. Winter Meeting on Nuclear Physics, Bormio, Italy, 28-01-2014

Multi-particle angular correlations as a tool to study the properties of the strongly interacting QGP, seminar, Munich, Germany, 18-06-2014

Heavy Ion Physics, BND School, Kerkrade, The Netherlands, 03-09-2014

Heavy Ion Physics, BND School, Kerkrade, The Netherlands, 04-09-2014

The Standard Model for QGP Evolution: experimental status and future, Confinement Conf., St. Petersburg, Russia, 10-09-2014

The Standard Model for QGP Evolution: experimental status and future, APS long range plan meeting, Philadelphia, USA, 14-09-2014

What is the effect of the hadronic phase on the anisotropic flow of identified particles, Resonance Workshop, Catania, Italy, 04-11-2014

What is the effect of the hadronic phase on the anisotropic flow of identified particles, LBNL, Berkeley, USA, 02-12-2014

Yang, H., Dilepton and future measurements at ALICE, Int. Workshop on Thermal Photons and Dileptons in Heavy-Ion Collisions, Upton, New York, USA, 21-08-2014

Low-mass dileptons Measurements with ALICE at the LHC, Discovery Physics at the LHC, Kruger, South Africa, 02-12-2014

Zhou, Y., Searches for p_T dependent flow angle and flow magnitude fluctuations with the ALICE detector, Quark Matter 2014, Darmstadt, Germany, 20-05-2014

Neutrino Telescopes

Jansweijer, P.P.M., Implementing White Rabbit in your design, Third Int. VLBI Technology Workshop, Groningen, The Netherlands, 12-11-2014

Michael, T.M., Latest Results from the ANTARES and KM3NeT Neutrino Telescopes, Lake Louise Winter Institute 2014, Lake Louise, Canada, 21-02-2014

Visser, E.L., ANTARES constraints on the neutrino flux from the Milky Way, TeVPA-IDM 2014, Amsterdam, The Netherlands, 24-06-2014

Diffuse flux results from the ANTARES neutrino telescope, ECRS 2014, Kiel, Germany, 03-09-2014

Wolf, de, E., KM3NeT and Baikal GVD: new northern neutrino telescopes, 10th Rencontres de Vietnam: Very High Energy Phenomena in the Universe, Qui Nhon, Vietnam, 08-08-2014

Gravitational Waves

Agathos, M., TIGER: A Bayesian pipeline for testing the strong-field dynamics of GR, Third Dutch Gravitational Waves meeting 2014, Dwingeloo, The Netherlands, 07-02-2014

Probing the neutron star equation of state with second-generation gravitational wave detectors, The Structure and Signals of Neutron Stars, from Birth to Death, Florence, Italy, 28-03-2014

A model-independent way of testing the strong-field dynamics of GR with gravitational waves, NEB 16 Recent Developments in Gravity, Mykonos, Greece, 17-09-2014

Brand, van den, J.F.J., Gravitational Waves - The dynamics of spacetime, Physics@FOM, Veldhoven, The Netherlands, 21-01-2014

Status of Advanced Virgo, Third Dutch Gravitational Waves meeting 2014, ASTRON, Dwingeloo, The Netherlands, 07-02-2014

Probing Dynamical Spacetimes, University College London, London, United Kingdom, 27-02-2014

Gravitational Physics - Status of Advanced Virgo, 19th Symposium on Astroparticle Physics in the Netherlands, Beekbergen, 27-03-2014

Probing dynamical Spacetimes with Gravitational Waves – Status of Advanced Virgo, Vrije Universiteit Brussel, Brussls, Belgium, 04-04-2014

Introduction to gravitational wave physics, Topical Lectures, Nikhef, Amsterdam, The Netherlands, 23-06-2014

Einstein Telescope – A new big science facility, Big Science meets Industry, VDL, Eindhoven, The Netherlands, October 15-10-2014

Einstein Telescope –Probing the dynamics of spacetime, Precision Fair 2014, Veldhoven, The Netherlands, 12-11-2014

Heijningen, van, J.V., Interferometric Readout of a Monolithic Accelerometer, towards the fm/√Hz resolution, TIPP2014, Amsterdam, The Netherlands, 03-06-2014

Interferometric Readout of a Monolithic Accelerometer, towards the fm/√Hz resolution, National Astronomical Observatory of Japan, Mitaka, Japan, 22-05-2014

Van Den Broeck, C., Towards the direct discovery of gravitational waves, evening lecture, Joint Belgian-Dutch-German Graduate School, Kerkrade, The Netherlands, 04-09-2014

Testing the strong-field dynamics of general relativity with gravitational waves, Gravitational Wave Advanced Detector Workshop 2014, Takayama, Japan, 25-05-2014

Testing the strong-field dynamics of general relativity with gravitational wave signals from coalescing compact binaries, Workshop Testing General Relativity with Astrophysical Observations, Oxford, Mississippi, USA, 06-01-2014

Dark Matter

Alfonsi, M., XENON Dark Matter Project: from XENON100 to XENON1T, 37th Int. Conf. on High Energy Physics (ICHEP), Valencia, Spain, 04-07-2014

Breur, P.A., Modulations in the rate of radioactive decays, 19th APP Symp. in the Netherlands, Beekbergen, The Netherlands, 27-03-2014

Irreducible neutrino background in Xenon direct detection dark matter experiments, NNV Fall Meeting, Lunteren, The Netherlands, 07-11-2014

Colijn, A.P., The Missing Universe, Fysica 2014, Leiden, The Netherlands, 01-04-2014

XENON & the hunt for dark matter, Oxford seminar, Oxford, United Kingdom, 25-11-2014

Decowski, M.P., Dark Matter Searches, DRSTP PhD School, Doorn, The Netherlands, 05-02-2014

Future Noble Liquid Dark Matter Detectors, Latest Results in Dark Matter Searches, Stockholm, Sweden, 12-05-2014

Ghostly Particles in the Universe, Piotr Decowski Memorial Symp., Northampton, USA, 01-11-2014

Tiseni, A., Experimental Review on Low Mass WIMP Searches, Symposia on Astroparticle Physics, Beekbergen, The Netherlands, 28-03-2014

Dark Matter Search with the Xenon Experiment, PASCOS Conf., Warsaw, Poland, 25-06-2014

Tunnell, C.D., Sterile neutrinos, 19th APP Symp. in the Netherlands, Beekbergen, The Netherlands, 20-03-2014

Dark-matter direct detection, Dark matter at the LHC, Oxford, United Kingdom, 26-09-2014

Theoretical Physics

Alkofer, N., Spectral dimensions from the spectral action, Oberwölz Symp., Oberwölz, Austria, 11-09-2014

Dimensional Reduction in Asymptotically Safe Gravity, Int. Conf. on the Exact Renormalisation Group 2014, Lefkada Island, Greece, 22-09-2014

Spectral dimensions from the spectral action, PhD Day of the Dutch Research School of Theoretical Physics, Utrecht, The Netherlands, 03-10-2014

Spectral dimensions from the spectral action, Workshop on Non-Perturbative Methods in Quantum Field Theory, Balatonfüred, Hungary, 10-10-2014

Ambrosi, d', G., EMRI modeling: exploring beyond the ISCO, Third Dutch Gravitational Waves meeting, Dwingeloo, The Netherlands, 07-02-2014

Buffing, M.G.A., How to observe color in hadronic interactions if you are color blind, Physics@FOM, Veldhoven, The Netherlands, 22-01-2014

Color entanglement in hadronic processes for TMD PDFs, QCD Evolution Workshop, Santa Fe, USA, 12-05-2014

How to observe color in a color-blind world, C.N. Yang Institute for Theoretical Physics, Stony Brook, USA, 20-05-2014

Color effect for transverse momentum dependent parton distribution functions in hadronic processes?, Light Cone 2014 Meeting, Raleigh, North Carolina, USA, 27-05-2014

Universality of TMD correlators, Transversity 2014, Chia, Sardinia, Italy, 10-06-2014

Transverse momentum dependent processes in particle physics, PLaneT talk, Utrecht, The Netherlands, 28-10-2014

Gauge links and color structures in transverse momentum dependent correlators, Int. workshop on Frontiers of QCD, Mumbai, India, 02-12-2014

Butter, D.P., Covariant techniques in projective and harmonic superspace, SUSY 2014 Conf., Manchester, United Kingdom, 25-07-2014

Complex geometry and conformal supergravity in projective-harmonic superspace, ITF Utrecht, Utrecht, The Netherlands, 12-09-2014

Hypermultiplets and conformal supergravity in projective-harmonic superspace, Groningen String Seminar, Groningen, The Netherlands, 06-11-2014

Cooperman, J., Renormalization of entanglement entropy and the gravitational effective action, Workshop on Renormalization Group Approaches to Quantum Gravity, Waterloo, Canada, 24-04-2014

Homogeneity measures for causal dynamical triangulations , Conceptual and Technical Challenges for Quantum Gravity 2014 , Rome, Italy, 10-09-2014

A perspective on causal dynamical triangulations in 3+1 vignettes , Perimeter Institute, Waterloo, Canada, 04-12-2014

Daal, van, T.A.A., Renormalization group invariants in the Minimal Supersymmetric Standard Model, NNV Fall Meeting, Lunteren, The Netherlands, 07-11-2014

De Bruyn, K.A.M., Hunting Penguins: Precision Measurements in the B Meson System, Physics@FOM, Veldhoven, The Netherlands, 22-01-2014

Echevarría, M.G., QCD Evolution of the Sivers Asymmetry, QCD Evolution 2014, Santa Fe, USA, 12-05-2014

Scale Evolution of Gluon TMDs, Transversity 2014, Chia, Sardinia, Italy, 10-06-2014

Higgs q_T-distribution: Effective Field Theory Approach, TMD-uPDF Workshop, Antwerp, Belgium, 24-06-2014

Higgs boson q_T distribution: TMD approach, REF workshop 2014, Antwerp, The Netherlands, 09-12-2014

Fleischer, R., Probing New Physics with $B_s^0 \to \mu^+\mu^-$: Status and Perspectives, Int. Conf. on Flavour Physics and Mass Generation, Singapore, Singapore, 11-02-2014

New Perspectives to Probe New Physics with $B_s^0 \to \mu^+\mu^-$, FLASY 2014 – 4th Workshop on Flavour Symmetries and Consequences in Accelerators and Cosmology, Brighton, United Kingdom, 19-06-2014

Towards New Frontiers in CP Violation in B Decays, BEACH 2014 – 11th Int. Conf. on Hyperons, Charm and Beauty Hadrons, Birmingham, United Kingdom, 23-07-2014

Gryb, S., Symmetry and Evolution in Quantum Gravity, University of Oxford, Oxford, United Kingdom, 06-03-2014

Symmetry and Evolution in Quantum Gravity, Int. Conf. on Quantum Time, Pittsburgh, USA, 29-03-2014

Cosmological Perturbation Theory of Shapes, Int. Workshop on Shape Dynamics, Fredericton, Canada, 08-05-2014

Cosmological Perturbation Theory of Shapes, Ludwig Maximilians University, Munich, Germany, 23-06-2014

On the Role of Scale in Quantum Gravity, Int. Conf. on Conceptual and Technical Challenges for Quantum Gravity, Rome, Italy, 09-09-2014

Holten, van, J.W., HiSPARC, Physics seminar, Salt Lake City, USA, 10-01-2014

Gauge-covariant extensions of killing tensors and conservation laws, Group 30 Conf., Gent, Belgium, 14-07-2014

Laenen, E., The Ubiquitous Top Quark, Conf. on New directions in Theoretical Physics, Edinburgh, United Kingdom, 08-01-2014

The Nobelprize 2013, Physics Dept. Colloquium, Groningen, The Netherlands, 13-02-2014

Eikonal QCD, Theoretical Physics Colloquium, Utrecht, The Netherlands, 05-03-2014

Resummation for Squark and Gluino Production, DAMPT-Cavendish HEP phenomenology seminar, Cambridge, United Kingdom, 23-05-2014

Overview of Recent Developments in Resummation, Workshop on Resummation and Parton Showers, Muenster, Germany, 10-06-2014

Four Lectures on QCD, European School of High-Energy Physics, Garderen, The Netherlands, 22-06-2014

Eikonal methods, Seminar at Lawrence Berkeley National Lab., Berkeley, USA, 02-07-2014

Threshold Resummation for Spartons and New Aspects of the Eikonal Approximation, SFB Workshop on Advances in Computational Particle Physics, Durbach, Germany, 17-09-2014

Factorization Proofs, Mini-workshop on Webs and Unitarity, Edinburgh, United Kingdom, 24-09-2014

Lectures on Perturbative QCD and Resummation, GGI Workshop, Florence, Italy, 29-09-2014

Loll, R., Causal Dynamical Triangulations: Creating Quantum Spacetime Dynamically, Heidelberg University, Heidelberg, Germany, 31-01-2014

Causal Dynamical Triangulations: Cosmology from first principles, Workshop on Quantum Gravity and Fundamental Cosmology, Potsdam-Golm, Germany, 03-03-2014

Searching for the quantum structure of spacetime: Why 3+1 sometimes equals 2, Koninklijk Natuurkundig Genootschap, Groningen, The Netherlands, 18-03-2014

Causal Dynamical Triangulations: Creating Quantum Spacetime Dynamically, Tel Aviv University, Tel Aviv, Israel, 23-03-2014

Nonperturbative Quantum Gravity for the Uninitiated, The COST action Fundamental Problems in Quantum Physics , Rehovot, Israel, 24-03-2014

What you always wanted to know about CDT, but did not have time to read about in our papers, Workshop on Renormalization Group Approaches to Quantum Gravity, Waterloo, Canada, 22-04-2014

Causal structure and time in (generalized) CDT Quantum gravity, Workshop on Combinatorics, Geometry and Physics, Vienna, Austria, 16-07-2014

Plenary Talk, Untitled, Conf. on Conceptual and Technical Challenges for Quantum Gravity 2014, Rome, Italy, 11-09-2014

Quantum gravity as quantum field theory of pure geometry, Conf. Isham at 70: Modern Issues in Foundations of Physics, London, United Kingdom, 28-09-2014

Martin-Benito, M., The Quantum echo of the Early Universe , 2014 COST meeting on Fundamental problems in Quantum Physics, Rehovot, Israel, 24-03-2014

Echoes of the Early Universe, Experimental Search for Quantum Gravity, Trieste, Italy, 02-04-2014

The Quantum echo of the Early Universe, 6th Jerte Advanced Relativity meeting , Navaconcejo, Extremadura, Spain, 09-04-2014

Refinement limit of quantum group spinnets, Workshop on Renormalization Group Approaches to Quantum Gravity, Waterloo, Canada, 23-04-2014

Modelling effective FRW cosmologies with perfect fluids from states of the hybrid quantum Gowdy model, Second i-Link workshop Macro-from-Micro: Quantum Gravity and Cosmology, Madrid, Spain, 17-09-2014

Mulders, P.J., Transverse momentum dependent parton distribution functions in hadrons, 42nd Int. Workshop on Gross Properties of Nuclei and Nuclear Excitations: Hadrons from Quarks and Gluons, Hirschegg, Kleinwalsertal, Austria, 14-01-2014

Transverse momentum dependent distribution functions of definite rank, the QCD Evolution 2014 Workshop, Santa Fe, USA, 13-05-2014

Transverse momentum dependent distribution and fragmentation functions in high energy scattering processes, 17th Taiwan Nuclear Physics Summer School, Institute of Physics, Academia Sinica, Taipei, Taiwan, 26-08-2014

Color entanglement and Universality of TMDs, Int. Workshop on Physics Opportunities at an ElecTron-Ion Collider (POETIC 2014), Yale University, New Haven, USA, 25-09-2014

Spin dependent TMDs of definite rank, 21st Int. Symp. on Spin Physics (SPIN2014), Peking University, Beijing, China, 22-10-2014

TMDs, offering opportunities at small k_T and small x!, Annual meeting of the Groupement de Recherche on QCD and Hadron Physics, Ecole Polytechnique, Palaiseau, France, 16-12-2014

Odorico, D', G., Asymptotic freedom in projectable Horava-Lifshitz gravity, 7th Int. Conf. on the Exact Renormalization Group (ERG2014), Lefkada Island, Greece, 23-09-2014

Petraki, K., Self-interacting and asymmetric dark matter, Seminar, Trieste, Italy, 20-03-2014

Atomic dark matter, Workshop, Odense, Denmark, 01-04-2014

Atomic dark matter, Seminar, Barcelona, Spain, 25-11-2014

Pisano, C., TMD gluon distributions and quarkonium production in unpolarized pp collisions, Workshop on AFTER@LHC: Probing the strong interactions at A Fixed Target ExpeRiment with the LHC beams, Les Houches, France, 12-01-2014

Probing the transverse dynamics and the polarization of gluons inside the proton at the LHC, 49th Rencontres de Moriond on QCD and High-Energy Hadronic Interactions, La Thuile, Italy, 27-03-2014

Transverse momentum dependent gluon distributions at the LHC, QCD Evolution Workshop, Santa Fe, USA, 12-05-2014

Azimuthal asymmetries in $pp \rightarrow jet\ \pi X$, 4th Int. Workshop on Transverse Polarization Phenomena in Hard Scattering (Transversity 2014), Chia, Sardinia, Italy, 09-06-2014

Impact of gluon polarization on Higgs production at the LHC, Workshop on Resummation, Evolution, Factorization (REF 2014), Antwerp, Belgium, 08-12-2014

Saueressig, F., Asymptotic Safety – relating the FRG and CDT, Regards sur la gravité quantique, Clermont-Ferrand, France, 08-01-2014

Gravitational RG flows on foliated spacetime, Third UK-QFT Meeting: Non-Perturbative Quantum Field Theory and Quantum Gravity, Southampton, United Kingdom, 24-01-2014

Black holes within asymptotic safety, 26th Workshop Beyond the Standard Model, Bad Honnef, Germany, 13-03-2014

Probing Quantum Spacetime with the FRG, IMAPP day: RU Nijmegen, Nijmegen, The Netherlands, 02-04-2014

Gravitational RG flows for foliated spacetimes, Renormalization Group Approaches to Quantum Gravity Conf., Waterloo, Canada, 24-04-2014

Universality classes of Quantum Gravity, FLAG Meeting The Quantum and Gravity, Bologna, Italy, 28-05-2014

Asymptotic Safety and Quantum Gravity, Institut für Theoretische Teilchenphysik und Kosmologie, Aachen, Germany, 26-06-2014

Black holes within asymptotic safety, 14th Annual Int. Symp. Frontiers of Fundamental Physics (FFP14), Marseille, France, 16-07-2014

Universality classes of quantum gravity, 7th Int. Conf. on the Exact Renormalization Group (ERG2014), Lefkada Island, Greece, 20-09-2014

Universality classes of quantum gravity, Workshop on Non-Perturbative Methods in Quantum Field Theory, Balatonfüred, Hungary, 09-10-2014

Reys, V., Black hole degeneracies in string theory and supergravity, DRSTP PhD School, Doorn, The Netherlands, 30-01-2014

Rijken, T.A., Extended-soft-core- Baryon-baryon Model ESC08, Flavor SU(3) Meson-exchange viewpoint, Int. Hypernuclear Workshop, TJNAF, Newport News, USA, May 28-5-2014

Nucleon-Nucleon Interactions. Generalized Yukawa Meson-exchange Potentials, INFN, Catania, Italy, 14-6-2014

Nucleon-Nucleon Interactions. Generalized Yukawa Meson-exchange Potentials, Int. KITPC workshop on strong interactions, Beijing, China, (23-31)-8-2014

Schellekens, A.N., Now What?, Physics@FOM, Veldhoven, The Netherlands, 22-01-2014

The String Theory Landscape, RTG Colloquium, Hannover, Germany, 05-02-2014

Particle Physics in the Multiverse, VU LaserLab Colloquium, Amsterdam, The Netherlands, 26-02-2014

Asymmetric Heterotic RCFTs, Bethe Forum Workshop, Bonn, Germany, 12-06-2014

Particle Physics in the Multiverse, Bethe Colloquium, Bonn, Germany, 03-07-2014

GUTs without guts, Workshop Frontiers in String Phenomenology, Ringberg Castle, Germany, 28-07-2014

Particle Physics in the Multiverse, Niels Bohr Colloquium, København, Denmark, 10-09-2014

GUTs without guts, Theory Seminar, København, Denmark, 11-09-2014

GUTs without guts, Seminar University of Crete, Heraklion, Greece, 22-10-2014

Particle Physics in the Multiverse, Physics Colloquium, Heraklion, Greece, 23-10-2014

Particle Physics in the Multiverse, Mathematics Department Colloquium, Liverpool, United Kingdom, 31-10-2014

Signori, A., TMDs in a nutshell, Theoretical High Energy Physics school 2014, Doorn, The Netherlands, 30-01-2014

Phenomenology of unpolarized TMDs from SIDIS data, 22nd Int. Workshop on Deep-Inelastic Scattering and Related Subjects, Warsaw, Poland, 30-04-2014

Multiplicities and phenomenology, 4th Int. workshop on transverse polarisation phenomena in hard processes, Chia, Sardinia, Italy, 10-06-2014

TMDs vs uPDFs?, Mini-workshop on TMDs and quarkonia, Orsay, France, 04-11-2014

TMDlib, a library for TMDs, REF workshop 2014, Antwerp, Belgium, 08-12-2014

Vidotto, F., Spinfoam Cosmology , XI SIGRAV graduate school Gravity and the Quantum, Como, Italy, 05-06-2014

Atomism and Relationalism as guiding principles for Quantum Gravity, 14th annual Int. Symp. Frontiers of Fundamental Physics (FFP14) , Marseille, France, 16-07-2014

What can we learn from Loop Quantum Cosmology? The case of Planck Stars, WE-Heraeus-Seminar Quantum Cosmology, Bad Honnef, Germany, 01-08-2014

Experimental Search for Planck Stars , Experimental Search for Quantum Gravity, Trieste, Italy, 04-09-2014

Spinfoam Cosmology and Maximal Acceleration, Conceptual and Technical Challenges for Quantum Gravity, Rome, Italy, 11-09-2014

What can we learn from Loop Quantum Cosmology? The case of Planck Stars, 21st SIGRAV Conf. on General Relativity and Gravitational Physics, Alessandria, Italy, 16-09-2014

A relational ontology from General Relativity and Quantum Mechanics, 11th Int. Ontology Congress, Barcelona, Spain, 02-10-2014
Planck Stars Physics, University of Trento, Trento, Italy, 04-12-2014

Waalewijn, W.J., A Field Theory Look at the Underlying Event, Boston Jets Workshop 2014, Boston, USA, 21-01-2014

Dissecting Soft ISR, Underlying Event, and Hadronization with Factorization, SCET 2014, Munich, Germany, 26-03-2014

Jet Substructure at the LHC, DESY Hamburg Theory Seminar, Hamburg, Germany, 19-05-2014

Dissecting Soft Radiation with Factorization, MPI@LHC 2014, Krakow, Poland, 04-11-2014

QCD at the LHC, National Seminar, Amsterdam, The Netherlands, 21-11-2014

Jet Substructure at the LHC, Utrecht University Theory Colloquium, Utrecht, The Netherlands, 26-11-2014

Wit, de, B., Off-shell dimensional reduction, Workshop Aspects of Supergravity, Simons Center, Stony Brook, USA, 07-01-2014

Deformations of special geometry: searching for the topological string, Harvard University, Boston, USA, 27-03-2014

Deformations of special geometry: searching for the topological string, University Milano-Bicocca, Milano, Italy, 15-04-2014

Locally USp(8) invariant IIB Supergravity and $E_{6(6)}$ covariance, Université de Mons, Mons, Belgium, 21-05-2014

Locally USp(8) invariant IIB Supergravity and USp(8), UPMC-ENS, Paris, France, 27-05-2014

Deformations of special geometry: searching for the topological string, LPTENS Institut d'été, Paris, France, 25-08-2014

IIB Supergravity and the $E_{6(6)}$ covariant vector-tensor hierarchy, workshop Exceptional Symmetries and Emerging Spacetime, Nanyang Technological University, Singapore, 10-11-2014

Detector R&D

Beuzekom, M. van, Pixel Detectors in Particle Physics, Physics@FOM, Veldhoven, The Netherlands, 23-01-2014

Graaf, H. van der, Fast pixels change our view on physics, FOM-Veldhoven, 22-01-2014

The Gaseous GridPix detector, Bethe Forum on Detector Physics- Trends and Challenges, Bonn University, Germany, 04-04-2014

Tipsy and Trixy ultrafast photon, electron and MIP detectors, Bethe Forum on Detector Physics- Trends and Challenges, Bonn University, Germany, 11-04-2014

The Tipsy single soft photon detector, NDIP Conference, Tours, France, 03-07-2014

Alternatives to MicroChannelPlates. MCP/LAPSD Conference, Argonne NL, Argonne, Ill, USA, 04-12-2014

Heijne, E.H.M., How Chips Pave the Road to the Higgs Particle and the Attoworld Beyond, 2014 IEEE Int. Solid-State Circuits Conf., San Francisco, USA, 10-02-2014

Hessey, N.P., High Precision Tracking with Gossip: a Gaseous Pixel Detector Made with MEMs Post-Processing of CMOS Pixel Chips, IEEE NSS MIC, Seattle, USA, 13-11-2014

Schioppa, E.J., Prospects for spectral CT with Medipix detectors, TIPP 2014, Amsterdam, The Netherlands, 05-06-2014

Solving CT reconstruction with a particle physics tool (RooFit), NumAn 2014, Chania, Greece, 02-09-2014

Tsopelas, P.C., The Timepix3 telescope, Telescopes and Testbeams Workshop at DESY, Hamburg, Germany, 30-06-2014

The LHCb Velo Upgrade, IEEE NSS-MIC, Seattle, USA, 13-11-2014

Visser, J., Medical Applications of Pixel Detectors, Physics@FOM, Veldhoven, The Netherlands, 23-01-2014

Miscellaneous

Decowski, M.P., Neutrinoless Double Beta Decay Results from KamLAND-Zen, PATRAS Workshop on Axions, WIMPs and WISPs, CERN, Switzerland, 03-07-2014

What other Quirks do Neutrinos have?, NNV Fall Meeting, Lunteren, The Netherlands, 07-11-2014

Kasemets, T., Correlations in double parton scattering: effects of evolution, QCD Evolution Workshop, Santa Fe, USA, 15-05-2014

Interference DPDs and polarization in double ccbar, MPI@LHC 2014, Krakow, Poland, 05-11-2014

Transverse momentum dependent (un)polarized gluon distributions in Higgs production, Theory Seminar, RWTH Aachen, Germany, 27-11-2014

Exploring the hadron structure: TMDs and DPDs, Int. Workshop on Frontiers of QCD, Mumbai, India, 02-12-2014

Metzger, W.J., BEC in e^+e^- Annihilation, 10th Workshop on Particle Correlations and Femtoscopy, Gyöngyös, Hungary, 25-08-2014

BEC in e^+e^- Annihilation, 44th Int. Symp. on Multiparticle Dynamics, Bologna, Italy, 08-09-2014

Bose-Einstein Correlations in e^+e^- annihilation, LHCb Workshop on quantum interference effects, QCD measurements and generator tuning, Geneva, Switzerland, 20-10-2014

Schultheiss, N.G., HiSPARC als kosmische straling telescoop, Woudschoten–conferentie Natuurkunde-Didactiek, Noordwijkerhout, The Netherlands, 12-12-2015

3.4 Posters

ATLAS

Mahlstedt, J.
Search for excited leptons
Physics@FOM, Veldhoven, The Netherlands, 21-01-2014

Deigaard, I.
Prospects of Searching for Supersymmetry with the ATLAS Detector with an Upgrade of the Large Hadron Collider
Physics@FOM, Veldhoven, The Netherlands, 22-01 -2014

Oussoren, K.P.
Spin and CP of properties of the SM Higgs and BSM Higgses
Physics@FOM, Veldhoven, The Netherlands, 22-01-2014

Higgs Spin/CP Studies in the Collins-Soper Frame
2014 European School of High-Energy Physics, Garderen, The Netherlands, 27-06-2014

LHCb

Bel, L.J., for the LHCb collaboration
Branching ratio of $B_s^0 \rightarrow D_s^{\mp} K^{\pm}$
LHCC Poster Session, CERN, Geneva, Switzerland, 05-03-2014

ALICE

Zhou, Y. *et al.*
Generic framework for anisotropic flow analyses with multi-particle azimuthal correlations
Quark Matter 2014, Darmstadt, Germany, 20-05-2014

Bertens, R.A.
Event plane dependence of charged jet yields in $\sqrt{s_{NN}} = 2.76$ *TeV Pb–Pb collisions with ALICE*
Quark Matter 2014, Darmstadt, Germany, 20-05-2014

Yang, H.
Dielectron elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ *TeV with the ALICE Experiment*
Quark Matter 2014, Darmstadt, Germany, 20-05-2014

Gravitational Waves

Hennes, E., A. Bertolini, M. Jaspers, S. van Leeuwen
Annealing and strength testing of mono-crystalline sapphire cantilevers
Gravitational Wave Advanced Detector Workshop , Takayama, Japan, 28-05-2014

Hennes, E., A. Bertolini, M. Doets, M. Jaspers
Low-frequency suspension with compressed sapphire beams
Gravitational Wave Advanced Detector Workshop , Takayama, Japan, 28-05-2014

Heijningen, van, J.V., A. Bertolini, D. Rabeling, J. van den Brand
Interferometric Readout of a Monolithic Accelerometer, towards the $fm/\sqrt{Hz}$ *resolution!*
Gravitational Wave Advanced Detector Workshop, Takayama, Japan, 28-05-2014

d'Ambrosi, G., J.W. van Holten
Ballistic orbits and EMRs
DPF school GR@99, Bad Honnef, Germany, 16-09-2014

Dark Matter

Breur, P.A., for the XENON collaboration
DAQ of the XENON1T Dark-Matter Experiment
TIPP2014, Amsterdam, The Netherlands, 02-06-2014

Theoretical Physics

d'Ambrosi, G.
Beyond ISCO orbits for EMRIs
Physics@FOM, Veldhoven, The Netherlands, 21-01-2014

Reys, V.,
Black hole entropy and full-superspace integrals
Int. Conf. on string theory, Strings 2014, Princeton University, USA, 23-6-2014

Signori, A.
Does the transverse motion of quarks depend on their flavor?
Physics@FOM, Veldhoven, The Netherlands, 21-01-2014

Detector R&D

Doni, M.
Edge-on illumination photon-counting for medical imaging
Université Paris Diderot, Paris, France, 15-07-2014

Theulings, A.M.M.G., for the MEMBrane collaboration
Simulations of Low-Energy Electron Interactions with Matter
IEEE NSS, Seattle, USA, 11-11-2014

Visser, J. *et al.*
Proton Radiography with Timepix-based Time Projection Chambers
NSS-MIC IEEE, Seattle, USA, 13-11-2014

HiSPARC

Laat, de, A.P.L.S., for the HiSPARC collaboration
EAS direction reconstruction with HiSPARC
18th International Symposium on Very High Energy Cosmic Ray Interactions (ISVHECRI), CERN, Geneva, Switzerland, 18-08-2014

3.5 Jamboree

At the end of each year Nikhef physicists and technicians gather in a two-day Annual Meeting traditionally called the Jamboree. The 2014 edition of this event was held in the Huygens building of the Radboud University Nijmegen. The organisers were Nicolo de Groot and Frank Filthout. Reports were given about the status of Nikhef's various programmes and projects by staff members, post-docs and young students. At the end of the afternoon of the first day Frank Linde formally handed over the directorship of Nikhef to Stan Bentvelsen with the exchange of massive adjustable spanner (see Fig. 1). Memorable speaches were given by prof. dr. Stan Gielen (dean of the Faculty of Science in Nijmegen and chair of the Nikhef Board), prof. dr. Niek Lopes Cardozo (chair of the FOM Board) and Arjen van Rijn (Nikhef institute manager). The day was concluded with a festive dinner in the monumental *Huize Heyendael*.

Monday 15 December 2014

10:30 *Welcome*, Nicolo de Groot, Stan Gielen

Detector R&D

10:45 *The Knights who say…*, Niels van Bakel
11:00 *The Timepix3 beam telescope*, Panagiotis Tsopelas
11:15 *Status, Progress and Plans for MEMBrane*, Annemarie Theulings
11:30 *Applications of the Medipix family of detectors*, John Idarraga
11:45 *Stiff and Cool*, Afroditi Koutoulaki

Xenon

12:00 *Dark Matter Activities*, Patrick Decowski
12:10 *Low-mass WIMP analysis in XENON100*, Andrea Tiseni
12:25 *Getting XENON1T ready for data*, Auke-Pieter Colijn

Auger

13:30 *Highlights from the Auger Experiment*, Charles Timmermans
13:55 *Recent Progress in Radio Detection of Cosmic Rays with AERA*, Stefan Jansen

KM3NeT

14:15 *Status of KM3NeT and ANTARES*, Aart Heijboer
14:30 *Results from protoype KM3NeT Line*, Robert Bormuth
14:45 *Neutrino mass hierarchy studies*, Martijn Jongen

ATLAS

15:30 *Introduction & Overview*, Nicolo de Groot
15:45 *Detector and upgrade activities*, Paul de Jong
16:05 *Search for Lepton Flavor Violation*, Noam Tal Hod
16:23 *Polarization and CP violation in single top production*, Rogier van der Geer
16:41 *Study of spin and parity of the Higgs boson*, Rosemarie Aben

17:00 *Change of Nikhef director*

Tuesday 16 December 2014

LHCb

09:00 *Introduction*, Marcel Merk
09:05 *Semileptonic Decays*, Jeroen van Tilburg
09:20 *The B_s mixing phase*, Jeroen van Leerdam
09:35 *Long-lived massive particles*, Pieter David
09:50 *Search for Lorentz Invariance Violation*, Gerco Onderwater
10:05 *The LHCb Upgrade*, Hella Snoek

Computing

10:20 *Physics Data Processing and ICT*, David Groep

ALICE

11:25 *ALICE*, Raimond Snellings
11:30 *Bulk Properties*, Panos Christakoglou
11:53 *Jets and Heavy Quarks*, Alessandro Grelli
12:16 *ALICE upgrades*, Paul Kuijer

Theory

13:30 *What you always wanted to know about quantum gravity…*, Renate Loll
14:15 *Theory in 2014*, Robert Fleischer
14:28 *Holographic models of thermalization*, Olli Taanila
14:47 *Double parton scattering*, Tomas Kasemets
15:06 *Ballistic orbits for Gravitational Waves*, Giuseppe d'Ambrosi

Gravitational Waves

15:25 *Status: Gravitational Physics*, Chris Van Den Broeck
15:35 *Gravitational Wave Data Analysis*, Chris Van Den Broeck
15:55 *Advanced Virgo Installation*, Alessandro Bertolini

16:15 *Conclusions and send-off*

Figure 1. Parting Nikhef director Frank Linde (left) hands over the director's tools to his successor Stan Bentvelsen at the Jamboree in Nijmegen.

3.6 Awards & Grants

Every year numerous Nikhef members make a great effort to apply for grants or compete for awards. Below, the proposals honoured and the awards received in 2014 are listed. Please refer to Section 5.4 for a full overview (including precise amounts) of all current grants regarding Nikhef, namely newly awarded grants in 2014, still running grants, and recently completed grants awarded in earlier years.

NWO grants

An '*NWO-Groot'* grant was awarded to the Nikhef contributions to the upgrades of the experiments at the LHC. The *NWO-Groot* grant amounts to 15.24 M€ and was awarded within the framework of the National Roadmap for Large-Scale Research Facilities.

FOM grants

Eric Laenen was awarded a *'Vrij FOM-programma'* for his research project *"Higgs as a probe and portal"*. This amounts to 2.1 M€. The research will focus on answering fundamental questions about the Higgs boson from a theoretical perspective.

The FOM Valorisation Chapter prize went to Mark Beker for a chapter in his thesis in which he describes the influence of seismic ground motions on gravitational wave detectors.

Jo van den Brand received a grant for *"Field studies with seismic and gravity-gradient sensor networks for gravitational waves physics and oil-and-gas exploration"*. This was financed by a contribution from the Dutch governmental funding programme Top consortia for Knowledge and Innovation (TKI) together with a cash contribution by Shell.

Awards

Bernard de Wit was awarded the title Knight in the Order of the Lion of the Netherlands for his outstanding achievements as a scientist and administrator. De Wit is recognised worldwide as one of the leading researchers in the field of supergravity and black holes. He also held important administrative positions both nationally and internationally, among which chair of the Nikhef Board.

Tjonnie Li was awarded the prestigious international GWIC/Stefano Braccini Thesis Prize for his dissertation titled *"Extracting Physics from Gravitational Waves: Testing the Strong-field Dynamics of General Relativity and Inferring the Large-scale Structure of the Universe"*. The prize is awarded annually to pioneering research in the field of gravitational waves.

Figure 1. Still from their video "Crystal calorimeter" sent in for the CERN beamline competition by the Dominicus College from Nijmegen, that went on to win the competition.

Priscilla Pani received one of the six ATLAS 2014 thesis awards for her dissertation titled *"To the bottom of the stop: Calibration of bottom-quark jets identification algorithms and search for scalar top-quarks and dark matter with the Run 1 ATLAS data"*.

Deepa Thomas received the ALICE thesis award 2014 for her dissertation titled *"Jet-like heavy-flavour particle correlations in proton-proton and lead-lead collisions in ALICE"*.

At the spring meeting FYSICA 2014 of the Netherlands' Physical Society Melissa van Beekveld was honoured as winner of the SPIN bachelor project competition with her Bachelor Thesis *"De zoektocht naar supersymmetrie"*.

The Dominicus College from Nijmegen –supported by Nikhef staff– was one of the two winners of the competition for schools with a proposal for an experiment at CERN's fixed-target beamline. In the competition, organised by CERN on the occasion of its sixtieth anniversary, almost 300 teams from all over the world took part.

Nikhef & Society

4

4.1 Outreach & Communication

2014 was the year in which CERN turned 60. Nikhef celebrated this with a festive symposium on 26 June. Guest of honour was CERN's Director General Rolf Heuer, who spoke about the power of CERN: bringing people together from different countries and cultures. Nikhef director Frank Linde, FOM director Wim van Saarloos and many others contributed to the afternoon with a talk about their view on CERN. During the symposium Rolf Heuer and Frank Linde signed the agreement for the Nikhef-CERN Business Incubation Center (BIC). Theatre and film maker Jan van den Berg presented the symposium.

During 2014 the Large Hadron Collider (LHC) at CERN was still in shutdown for consolidation and maintenance, and this enabled Nikhef to organise more visits to the detector systems, which are inaccessible during runtime. The general public as well as school children and teachers had ample opportunities for visits, too.

On 1 December, Nikhef's new director Stan Bentvelsen took office and this was announced by a press release which was picked up by the media, resulting in a number of interesting articles in national and regional newspapers.

Every year, Nikhef organises a variety of activities aimed at different audiences (general public, decision makers and opinion leaders, media, students and teachers) to explain what Nikhef's particle and astroparticle research entails and how the technical departments support this research by designing, constructing and operating cutting-edge instrumentation. The communications department initiates many of these activities, but also relies on Nikhef staff and PhD students' much appreciated dedication to reach out about research projects to the different target audiences. Additional activities occur on the basis of enthusiastic initiatives by individual Nikhef members. Below, a comprehensive overview of all communication activities during 2014 is given. For education activities please refer to section 4.2.

Figure 1. CERN director Rolf Heuer speaking at the CERN60 symposium.

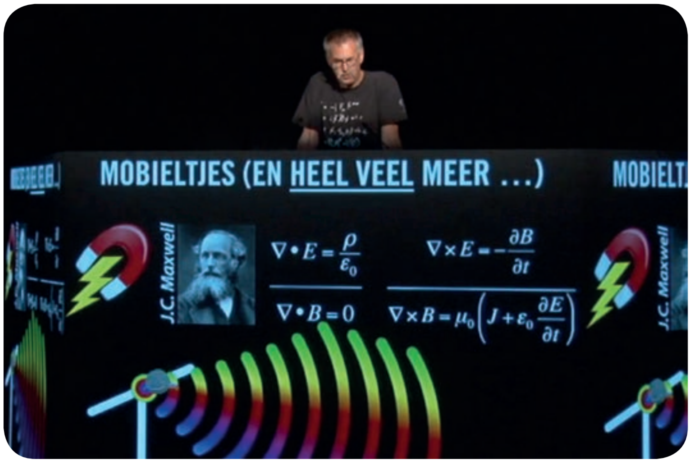


Figure 2. Frank Linde gave a popular lecture at Lowlands University.

Nikhef & the general public
Nikhef engages with the general public on various occasions. Numerous outreach talks were again given by Nikhef scientists all across the Netherlands and throughout the year. Frank Linde gave two wildly popular lectures at the University of the Netherlands and at Lowlands University (see Fig. 2). Piet Mulders lectured at Theatercollege VU (Quarks, Higgs and neutrinos, from idea to reality) and Raimond Snellings appeared in the *KIJK Live!* event. Niels Tuning gave a lecture about Higgs and anti-matter at *Bessensap*, a special purpose event to bring science communicators, science journalists and researchers together. For a full list of outreach talks please refer to section 4.4.

A prime occasion for the general public to become familiar with Nikhef is, of course, the annual Open Day which is organised together with the other institutes at Amsterdam Science Park. This year's Open Day (see Figs. 3 & 4) was held on Saturday 4 October during the *"Weekend van de wetenschap"* (Weekend of Science) and was very much appreciated by the hundreds of people who visited.

Special events
In addition to the CERN 60 symposium already described above, three other events deserve mentioning here.

In June and July, visitors at Science Centre NEMO in Amsterdam were able to find out more about the LHC at CERN by visiting the CERN exhibition 'LHC time tunnel'. This takes people into the world of subatomic particles by using state-of-the-art

Figure 3. Visitors at the Open Day gather around the cloud chamber.

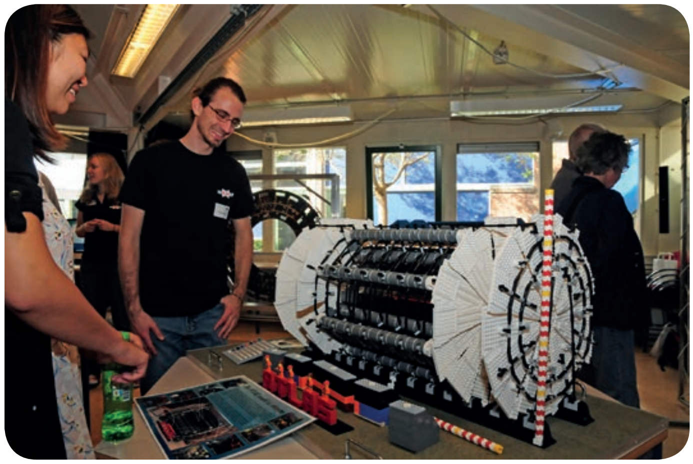


Figure 4. A LEGO model of the ATLAS detector was built by Nikhef staff (and their children!) and was displayed at the Open Day.

motion sensors and projectors to simulate the effect of the Higgs field. Visitors can visualise protons moving inside the LHC and can kick virtual particles as hard as they can to see how they collide (see Fig. 5). People enjoyed the exhibition very much, especially the many children among them. This brand new CERN exhibition was brought to the Netherlands by Nikhef and is currently touring through Europe.

The CERN European School of High-Energy Physics was held in Garderen, the Netherlands this year. One special part of the programme was an outreach training for the students on 20 June. The training was provided by a media training company and focused on communicating clearly and concisely with non-specialist audiences. Part of the training were practice interviews with journalist Hugh Schofield, a correspondent for BBC Paris. On 29 June the students presented their outreach projects to a jury of people who work in science communications and journalism.

In 2014, the third Technology and Instrumentation in Particle Physics (TIPP) conference was hosted by Nikhef and held in the Beurs van Berlage in Amsterdam from 2-6 June. The conference provided a stimulating atmosphere for scientists and engineers from around the world. The program focused on all areas of detector development and instrumentation in particle physics, astroparticle physics and closely related fields.

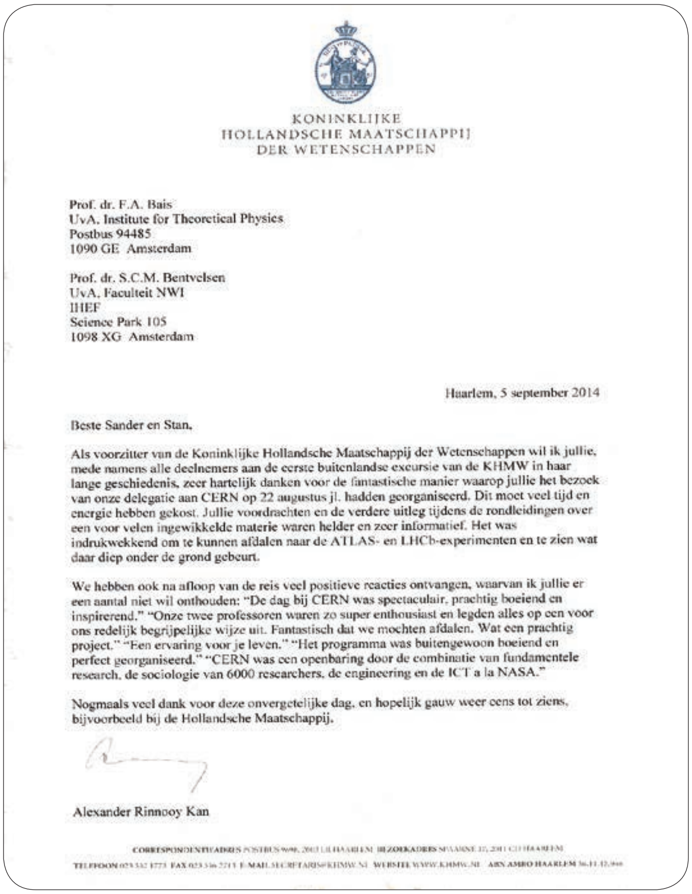
Internet & social media

On the Nikhef website, a focus was put this year on providing up-to-date information for the general public about the various research groups at Nikhef and their specific interests. A new web series was launched called 'Updates from the experiments' that puts the focus on one research group at a time, and describes highlights of their current work and where the next years will take them. This web series will stretch into the new year. In 2014, Nikhef's social media channels got the attention of an ever increasing public. The Nikhef Facebook page now has more than 330 likes, and posts on it garnered a lot of likes and comments. Twitter saw an enormous increase from about 500 to over 700 followers.

Nikhef & decision makers and opinion leaders

In January, State Secretary (Education, Culture and Science) Sander Dekker visited CERN. He was welcomed by CERN's Director General Rolf Heuer and given the unique chance to see the impressive LHC experiments and the LHC tunnel. The delegation was given a tour by Nikhef director Frank Linde and Nikhef researcher Sijbrand de Jong (scientific delegate for the Netherlands in the CERN council). Sander Dekker was impressed by the search for the smallest particles and shared his

Figure 5. Children kicking virtual particles in the LHC time tunnel.


KONINKLIJKE
HOLLANDSCHE MAATSCHAPPIJ
DER WETENSCHAPPEN

Prof. dr. F.A. Bais
UvA, Institute for Theoretical Physics
Postbus 94485
1090 GE Amsterdam

Prof. dr. S.C.M. Bentvelsen
UvA, Faculteit NWI
IHEF
Science Park 105
1098 XG Amsterdam

Haarlem, 5 september 2014

Beste Sander en Stan,

Als voorzitter van de Koninklijke Hollandsche Maatschappij der Wetenschappen wil ik jullie, mede namens alle deelnemers aan de eerste buitenlandse excursie van de KHMW in haar lange geschiedenis, zeer hartelijk danken voor de fantastische manier waarop jullie het bezoek van onze delegatie aan CERN op 22 augustus jl. hadden georganiseerd. Dit moet veel tijd en energie hebben gekost. Jullie voordrachten en de verdere uitleg tijdens de rondleidingen over een voor velen ingewikkelde materie waren helder en zeer informatief. Het was indrukwekkend om te kunnen afdalen naar de ATLAS- en LHCb-experimenten en te zien wat daar diep onder de grond gebeurt.

We hebben ook na afloop van de reis veel positieve reacties ontvangen, waarvan ik jullie er een aantal niet wil onthouden: "De dag bij CERN was spectaculair, prachtig boeiend en inspirerend." "Onze twee professoren waren zo super enthousiast en legden alles op een voor ons redelijk begrijpelijke wijze uit. Fantastisch dat we mochten afdalen. Wat een prachtig project." "Een ervaring voor je leven." "Het programma was buitengewoon boeiend en perfect georganiseerd." "CERN was een openbaring door de combinatie van fundamentele research, de sociologie van 6000 researchers, de engineering en de ICT a la NASA."

Nogmaals veel dank voor deze onvergetelijke dag, en hopelijk gauw weer eens tot ziens, bijvoorbeeld bij de Hollandsche Maatschappij.

Alexander Rinnooy Kan

Figure 6. Letter of appreciation from the KHMW about their CERN visit.

thoughts on Twitter. During his visit he said to be proud of what CERN has achieved and the role of the Netherlands in this.

CERN visits

On 22 August a delegation from the *Koninklijke Hollandsche Maatschappij der Wetenschappen* (KHMW) paid a visit to CERN and the ATLAS and LHCb experiments. This visit gained high praise from Alexander Rinnooy Kan, president of the KHMW, which he voiced in a letter (see Fig. 6).

On 30 September, Nikhef organised a visit to CERN for Business Leaders NL, a network of business owners and directors from diverse companies such as Samsung, Wolter & Dros and Boon Edam. The group was welcomed at CERN by Nikhef director Frank Linde and had a discussion about knowledge transfer with Giovanni Anelli, who leads the Knowledge Transfer Group at CERN. He told the group how CERN intends to optimise the impact of science, technology and knowledge on society. The day ended with visits to the ALICE and ATLAS experiments.

On 14 November the Executive Board of the VU University and the Board of Directors of the Faculty of Exact Sciences (including Karen Maex, dean of the joint beta faculties of the VU University and University of Amsterdam) visited CERN. They were welcomed by Nikhef researchers from both universities and visited the ATLAS and LHCb experiments.

Nikhef & the media

In 2014, two press releases were sent out, one regarding the signing of the agreement of the Nikhef-CERN Business Incubation Center and one to announce the appointment of Stan Bentvelsen as the new Nikhef director. These garnered both online and print articles. Throughout the whole year, Nikhef-related research appeared in many articles in various newspapers and magazines (*e.g.* Trouw, Algemeen Dagblad, Volkskrant, NRC, Telegraaf, Technisch Weekblad, NWT and regional newspapers). There were also interviews with Nikhef researchers on several radio programmes (*e.g.* De Kennis van Nu, Met het Oog op Morgen, NTR).

Much of the media coverage either follows one of the press or news releases Nikhef issues, or results from requests by journalists who directly approach Nikhef researchers for interviews and background information.

Nikhef & science communication networks

Nikhef's communication department works together with national and international communication networks to develop, coordinate, and organise communication activities concerning science in general and particle and astroparticle physics in particular.

International networks

- EPPCN – The European Particle Physics Communication Network;
- InterActions – A collaboration of communicators for particle physics worldwide.

In 2014 a joint EPPCN/Interactions/IPPOG (International Particle Physics Outreach Group) meeting was held at CERN, which the Nikhef communications department attended.

National Networks

- Communication departments of institutes and organisations at Science Park Amsterdam;
- Communication departments of the FOM institutes and the central FOM office;
- *Platform Wetenschapscommunicatie* (PWC) – An association for science communication staff.

4.2 Education

Education and awareness of science and technology in general and (astro-)particle physics specifically, are deemed very important by Nikhef. Throughout each year the aim is to inspire youngsters, students and teachers with one of the many programmes that are set up for this purpose.

Nikhef & Primary schools
The *'Techniek Toernooi'* is a tournament for primary schools in which young students are introduced to scientific problems in a playful fashion. Traditionally, members of the Nikhef staff participate in the academic jury that judges the results of the competition.

Nikhef & Secondary schools
Each year many secondary school students pay a visit to Nikhef to get acquainted with various aspects of work and study at a particle physics research laboratory. Through the Nikhef website, schools can apply for a Friday or Wednesday afternoon visit, which contains a lecture by a Nikhef scientist, a film and a guided tour. In some cases a custom programme is offered. In 2014 the afternoon visits were attended by more than 200 students.

In March, over 60 students participated in the International Masterclass on Particle Physics held at Nikhef, both in Amsterdam and Nijmegen. This yearly event is organised simultaneously in particle physics institutes across the world and includes lectures, exercises and a live video conference with CERN to share the results of the day with students at the other participating institutes. This year, for the first time the LHCb group organised a Masterclass in addition to the regular ATLAS ones.

All Thursdays in November were dedicated to students working on a small experiment for their *profielwerkstuk* (research project). Almost 30 students were able to attend one of these sessions.

On the occasion of its sixtieth anniversary CERN organised a competition for schools. Teams were invited to send in a proposal for an experiment at a fixed-target beamline. The team with the best proposal was allowed to actually carry out their experiment at CERN. From the overwhelming number of almost 300 teams from all over the world who sent in their proposals, six teams were Dutch. Four of these teams were supported by Nikhef (both in Amsterdam and Nijmegen). The teams were invited for an introduction afternoon and brainstorm. The Dominicus College from Nijmegen (one of the teams supported by Nikhef, see Fig. 1), won the beamline competition together with the Varvakios Pilot School in Athens, Greece.

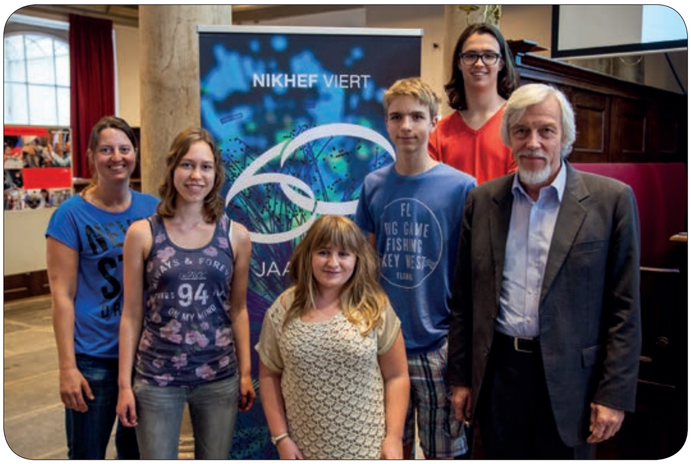


Figure 1. Pupils of the Dominicus College from Nijmegen pose with CERN's Director General Rolf Heuer at the CERN60 event in Amsterdam.

Nikhef & HiSPARC
The High School Project on Astrophysics Research with Cosmics (HiSPARC) offers students a chance to participate in real scientific research. Schools can take part in the project and their students work together in building a detector that is designed to detect high-energy cosmic rays. In 2014, the Dutch branch of the HiSPARC detector network consisted of approximately 120 stations throughout the country. Abroad, the HiSPARC network included clusters in Aarhus, Denmark and the cities of Birmingham, Durham, Bristol (and nearby villages) in England.

Nikhef and teachers
Teachers are very welcome to learn more about (astro)particle physics at Nikhef and they are offered to take part in several different programmes.

In the academic year 2013/2014 three teachers participated in the teacher-in-research programme (*Leraar in Onderzoek*), which was made possible by FOM and Nikhef. These teachers were supervised by staff members and they all carried out a separate piece of research within the HiSPARC project.

In cooperation with the UvA and *Bètasteunpunt* Amsterdam (the Its Academy), Nikhef organised a teachers course about particle physics. The course (six weekly evenings) was attended by 23 teachers, all of whom valued it highly.

In September, Nikhef and CERN organised the annual Dutch CERN Teachers Programme. A group of 26 teachers visited CERN and attended this special four-day programme. The LHC shutdown made it possible for the teachers to go underground and inspect the ATLAS and CMS detectors at close range.

Master's programmes at Nikhef

All four partner universities (UU, UvA, RU and VU) offer a two year Master's programme focused on the research done at Nikhef. In the first year, the programme typically consists of lectures on Particle and Astroparticle Physics. These lectures include a solid introduction to the Standard Model, including Higgs physics, physics beyond the Standard Model, cosmology, field theory, general relativity, CP violation, gravitational waves etc., as well as advanced experimental methods like statistical data analysis, particle detection, detector R&D and a C++ course. The various aspects of experimental particle physics are combined in a semester-long project, and this year a BGO detector was built.

During their second year the students work on their own research project in one of the groups at Nikhef. In 2014 more than 20 new students enrolled in the first year of the Master's programme, among them students from various European countries.

A total number of 22 students graduated in 2014 (see section 5.6).

Research School Subatomic Physics

All PhD students at Nikhef receive academic training through the Research School Subatomic Physics (*'Onderzoeksschool Subatomaire Fysica'*, OSAF). After 10 years the management of OSAF has changed: Raimond Snellings has taken over from Nicolo de Groot as chairperson. The University of Utrecht is now the responsible body (*'penvoerder'*).

In 2014, a total of 89 students were registered with the school. In this year, the number of new PhD registrations was 22 and 15 PhDs were awarded, four of these with special distinction (*'cum laude'*).

The Jan Kluyver Prize for the best English PhD thesis summary of 2014 was awarded to Enrico Junior Schioppa. Mark Beker was awarded the FOM Prize for the best valorisation chapter in a PhD thesis. In his thesis he describes a low-power wireless network of seismic sensors that can be applied in the oil and gas industry.

This year, the BND summer school (Belgium, the Netherlands, Germany) was organised by Jo van den Brand. It was held in the buildings of the Seminary Rolduc in Kerkrade. There were 48 participants.

OSAF organised three topical lectures in 2014. The subjects were Nuclear Physics, Gravitational Waves and Cosmology, and CP Violation.

4.3 Knowledge Transfer
Valorisation & Spin-off Activities

In June 2014, on the occasion of the CERN60 event in Amsterdam, an agreement was signed between CERN director Rolf Heuer and Nikhef director Frank Linde, on the establishment of a CERN Business Incubation Center at Nikhef. This Nikhef-CERN BIC, aimed at helping entrepreneurs to develop and bring to the market technologies emerging from subatomic physics, is located adjacent to Nikhef. In the Nikhef-CERN BIC, these entrepreneurs can make use of CERN and Nikhef facilities and of the services of the Nikhef-CERN BIC partners: P2IP B.V., Amsterdam Venture Lab and the Innovation Exchange Amsterdam (the collaboration of Technology Transfer Offices of the two universities in Amsterdam and their two academic medical centers).

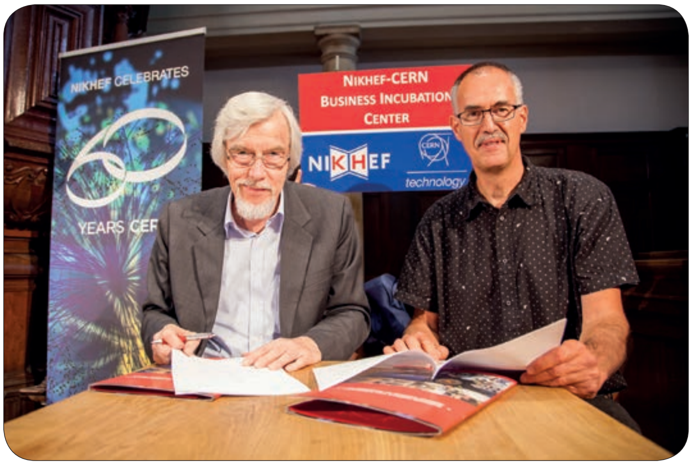


Figure 1. CERN Director General Rolf Heuer and Nikhef director Frank Linde sign the contract for the CERN Business Incubation Center at Nikhef.

Nikhef's detector R&D activities around the Medipix and Timepix family of chips (with our emphasis on ASIC development and readout expertise) continue to be a fruitful basis for valorisation and cooperation with industry; we point to the longtime collaboration with Panalytical and the establishment of spin-off company Amsterdam Scientific Instruments (ASI, further described below). Another example is the EC sponsored Initial Training Network 'INFIERI', in which Nikhef, together with Philips, investigates new architectures for front-end circuitry used in edge-on illumination. A second goal is to develop high-speed optical data links for fast electronics in radiation environments. The focus is on data serialisation and transmission, aimed not only at high-energy physics detectors but also with an application perspective towards medical imaging, such as this edge-on illumination.

The Medipix activities are also central in the ERC Proof of Concept project, acquired by André Mischke, but then focused on its application in mammography in which edge-on illumination is also applied. Within this project we are also collaborating with Philips and ASI.

Finally, in 2014 a PhD thesis was finished by Enrico Schioppa focusing on spectral X-ray computed tomography. The focus of the thesis was the incorporation of the energy information in the iterative reconstruction algorithm. This work will continue in both the edge-on illumination project and the mammography project.

Also the gravitational waves (GW) detection programme has an impressive valorisation potential. The 'Tremornet'-project, a collaboration between Shell and Nikhef/VU on the development of (wireless) seismic sensor nodes, with Nikhef's spin-off company Innoseis as subcontracted party, was completed successfully in early 2014, with all deliverables accepted by Shell. This project generated a modest 'TKI-allowance' (TKI = Top consortia for Knowledge and Innovation, an instrument in the industrial topsector policy of the Dutch government), which will be used in a follow-up project with Shell and Innoseis, entailing the pilot deployment of seismic nodes at a large industrial scale.

In the context of the GW activity a (European) patent application titled *"MEMS sensor structure comprising mechanically loaded suspension springs"* was filed in 2014, jointly with VU University.

With regard to Nikhef's cooling expertise, in 2014, Nikhef carried out a small engineering project for ASML. Other work for ASML, acquired in 2012, was completed in early 2014.

Finally, Nikhef's datacenter activities (in particular for customers of the Amsterdam Internet Exchange, AMS-IX) have further increased. Likewise, our position as provider in the national e-infrastructure, coordinated by SURF, has been consolidated.

Start-ups
As with most start-ups every year brings its challenges and opportunities, 2014 has been a turbulent, yet exciting, year for ASI and Omics2image. There have been many changes and new insights that drive a clearer focus on the company's vision, path and value to customers. The company is convinced that its technology platform for the next generation radiation cameras will yield the biggest impact in the field of Life Sciences. The implementation in the area of Mass Spectrometry and Electron Microscopy has shown some great results that have triggered interest from around the globe. The holding company ASIH has secured funding with a group of informal investors. Other local and international opportunities for funding with institutional investors are

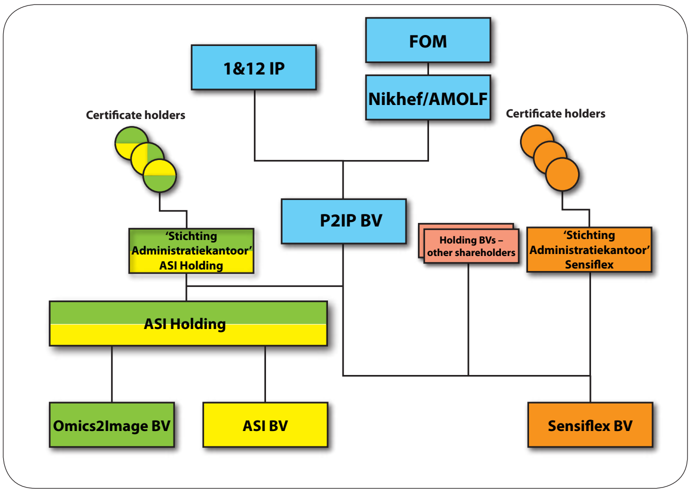


Figure 2. The current legal structure around Nikhef's start-ups.

being explored. The goal is to complete this funding early 2015. In the last six months, the focus has been on expanding sales channels and opportunities beyond the scientific market. ASI has agreements in place with a number of resellers in China, Japan, Russia and India. The company is also looking at establishing OEM (Original Equipment Manufacturer) relationships with multinational scientific equipment companies. Also in 2014, the company has entered into several collaborative projects: a Eureka/Eurostars project has been granted to a consortium with a Spanish partner and in the NWO funding scheme 'New Chemical Innovations /Technology Area' a project was awarded to a consortium together with Leiden University and the new research institute M4I at Maastricht University.

Finally, the team is growing again! The company was joined by four new team members, who will seek to employ its cutting-edge detection technology in further innovative applications.

Sensiflex, Nikhef's startup aimed at selling the Rasnik alignment system in non-scientific domains had another quiet year with a moderate turnover. Attempts to attract a new CEO have not yet succeeded.

Innoseis, established mid 2013, aims to commercialise technologies arising from Nikhef's gravitational waves program. In the previous year Innoseis has focussed on further developing its ultra-low power wireless seismic sensing system for applications in the Oil & Gas industry. This technology allows companies to make more efficient use of their existing hydrocarbon resources. Innoseis was present at two major conferences during 2014 and received a lot of interest from potential users around the globe.

A large-scale industrial pilot conducted together with Shell is planned for the second half of 2015. Innoseis has also received orders for its vibration isolation systems, including a project to reduce vibrations in a high-precision cryogenic experiment in the Netherlands. Like the previous year, 2015 will be a very exciting and challenging year for Innoseis and will see its team and client base grow.

At the end of 2014, *NoZAP*, the startup aimed at developing live streaming television on demand, has decided to stop its activities, after one and a half years of operations, due to the unclear business perspective.

4.4 Memberships*

Academia Europaea
R. Loll

Advances in High Energy Physics – Editorial Board
F. Filthaut

Annual Conference on Large Hadron Collider Physics (LHCP)
P. Koppenburg (Program Committee)

ApPEC – Particle Astrophysics and Cosmology Theory (PACT)
J. van Holten (board member)

Astroparticle Physics European Coordination (ApPEC)
J. van den Brand, P. Kooijman (Scientific Advisory Committee), F. Linde (Steering Committee)

BEAUTY, Int. Conf. on B-Physics at Hadron Machines – International Advisory Committee
R. Fleischer (co-chair)

Committee for Astroparticle Physics in the Netherlands
G. Bertone, J. van den Brand, P. Decowski, J. Hörandel, D. Samtleben, C. Timmermans, C. Van Den Broeck

Computer Algebra Nederland – Board
J. Vermaseren

CERN Council
S. de Jong

Combinatorics, Physics and Their Interactions, Annales de Henri Poincaré l'Institut D (AIHPD)
R. Loll (editor)

e-Infrastructure Reflection Group (e-IRG)
A. van Rijn (Dutch delegate)

EUROCOSMICS
B. van Eijk (chair)

European Center for Theoretical Studies in Nuclear Physics and Related Areas (ECT) – Scientific Board*
P. Mulders

European Committee for Future Accelerators (ECFA)
S. Bentvelsen (restricted ECFA), N. de Groot, M. Merk, Th. Peitzmann

ECFA PG1 – steering group
S. Caron (ATLAS representative for SUSY and Exotics)

European Particle Physics Communication Network (EPPCN)
G. Bobbink , V. Mexner

European Physical Society
E. de Wolf (Executive Committee, Physics Education Board)
B. van Eijk (HEP Board)

European Physical Journal – Scientific Advisory Committee
P. Mulders (past-chair)

European Policy Management Authority for Grid Authentication in e-Science (EUGridPMA)
D. Groep (chair)

FOM
Th. Peitzmann, R. Loll, J. van den Brand, W. Beenakker, R. Kleiss, E. Laenen (chair) (network Theoretical High Energy Physics)

FOM network Theoretical High Energy Physics
R. Loll

FOM-Shell CSER (Computing Science Energy Research)
J. van den Brand (Board)

Fonds Wetenschappelijk Onderzoek, Vlaanderen – Expertpanel Physics
E. de Wolf

FP7 Marie Curie Actions "Initial Training Networks" – Mathematics-Physics Panel, EU Research Executive Agency
A. Mischke

General Relativity and Gravitation (Springer)
R. Loll (associate editor)

Helmholtz Alliance for Astroparticle Physics, Germany (HAP)
E. de Wolf (Advisory Board)

Instituto Nazionale di Fisica Nucleare (INFN)
F. Linde (member Technical Scientific Committee)

Institute of Research in Mathematics and Physics (IR MP) – Université Catholique de Louvain
E. Laenen (Scientific Advisory Committee)

* *as of 31 December 2014.*

21st Int. Conf. on General Relativity and Gravitation (GR21) – Advisory Committee
R. Loll

International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions
M. van Leeuwen (International Advisory Committee)

International Particle Physics Outreach Group (IPPOG)
S. Caron

International Conference on Computing in High Energy and Nuclear Physics (CHEP)
D. Groep (International advisory committee)

Interoperable Global Trust Federation (IGTF)
D. Groep (chair)

International Symposium on Grids and Clouds
D. Groep (programme committee)

International Union for Pure and Applied Physics – Commission on Astroparticle Physics
J. Hörandel

Int. Workshop on Heavy Quark Production in Heavy-Ion Collisions
P. Kuijer, A. Mischke (co-chairs)

InterActions
V. Mexner

International Society for General Relativity and Gravitation
J. Veitch

Kamioka Gravitational Wave Detector (KAGRA)
J. van den Brand (Program Advisory Board)

Landelijk coördinatorenoverleg HiSPARC
B. van Eijk (chair), J. van Holten

LHCPhenoNet ITN network
E. Laenen (Supervisory Board)

Living Reviews in Relativity – Editorial Board
R. Loll (member and subject editor for Quantum Gravity)

Natuur Leven Technologie – Regionaal Steunpunt Arnhem-Nijmegen
S. de Jong

Nijmegen Centre for Advanced Spectroscopy – Supervisory Board
F. Linde (chair)

Nederlands Tijdschrift voor Natuurkunde – Editorial Board
P. Decowski, M van Leeuwen

Nederlandse Natuurkundige Vereniging (NNV)
S. de Jong, E. de Wolf (deputy chair)

Nederlandse Natuurkundige Vereniging (NNV) – Advisory Board
M. Vreeswijk

Nederlandse Natuurkundige Vereniging (NNV) – Sectie Onderwijs en Communicatie
S. de Jong (vice chair)

Nederlandse Natuurkundige Vereniging (NNV) – Sectie Subatomaire Fysica
F. Filthaut, A. Mischke (board) J. van Holten, I. van Vulpen (secretary), E. Koffeman (deputy chair)

Netherlands eScience Center
J. Templon (eScience Integrator)

Nuclear Physics European Collaboration Committee (NuPECC)
R. Snellings

Open Grid Forum CA – OPS working group
D. Groep (co-chair)

Particle Physics Inside Products (P2IP BV)
A. van Rijn (board member)

Platform Universitaire Natuurkunde (PUN)
N. de Groot, P. de Jong

PDF4LHC (Parton Density Functions for the LHC) workshop series – Organising committee
M. Botje

Perimeter Institute for Theoretical Physics, Waterloo, Canada – Scientific Advisory Committee
R. Loll (chair)

Platform Bèta Techniek – Ambassador
F. Linde, E. de Wolf

Science Cafe Nijmegen
S. Caron (organiser)

Sectorplan committee for Physics and Chemistry (Commissie Breimer)
B. de Wit
Stichting Conferenties en Zomerscholen over de Kernfysica (StCZK)
S. de Jong, P. Mulders

Stichting EGI.eu
A. van Rijn (Dutch delegate in EGI Council)

Stichting Hoge-Energie Fysica
J. van den Brand, R. Kleiss, F. Linde (chair), Th. Peitzmann, A. van Rijn (treasurer)

Stichting Industriële Toepassing van Supergeleiding
B. van Eijk

Stichting Natuurkunde.nl
F. Linde (chair), A. van R ijn (treasurer), M.Vreeswijk (editorial board), S. de Jong (editorial board)

Stichting Natuurkunde Olympiade Nederland
E. de Wolf (board member)

Stichting Physica
P. Mulders (treasurer)

TERENA Technical Committee (TTC) of the Geant Association
D. Groep (member)

Topsector High Tech Systems & Materials (HTSM) – Scientific Committee and Roadmap Circuits & Components Committee
N. van Bakel

Topsector HTSM – Advanced Instrumentation / Precision Mechanics Board
J. van den Brand

University of Edinburgh – Higgs Centre
E. Laenen (associate member)

Vereniging Gridforum Nederland
A. van Rijn (treasurer)

VUB Brussel
N. de Groot (Curriculum advisory board)

Worldwide LHC Computing Grid
J. Templon (overview board)

Young Academy of Europe
A. Mischke (chair)

4.5 Outreach Talks

Bentvelsen, S.C.M., Jacht naar het Higgs deeltje, Scholengemeenschap de Breul, Zeist, The Netherlands, 10-04-2014

Ontdekking van het Higgs deeltje, Vereniging Probus, Bilthoven, The Netherlands, 10-06-2014

Ontdekking van de Higgs, Science Café Zeist, Zeist, The Netherlands, 12-06-2014

CERN en het Higgs deeltje, Studievereniging Ångström, Delft, The Netherlands, 26-11-2014

Besjes, G.J, Discovering new particles at CERN, Third United Netherlands Alumni Conf., Amsterdam, The Netherlands, 15-11-2014

Brand, van den, J.F.J., Studies van materie-antimaterie gedrag en het Higgs mechanisme met LHC, Gemeentelijk Gymnasium, Hilversum, The Netherlands, 05-02-2014

Nikhef: wetenschappelijke missie en maatschappelijke impact, Visit State Secretary Sander Dekker, Holland High Tech House, Hannover Messe, Hannover, Germany, 10-04-2014

Gravitatiegolven - de dynamica van ruimtetijd, Centaurus A, KNVWS afdeling Nijmegen, Nijmegen, The Netherlands, 09-10-2014

Colijn, A.P, Donkere Materie, Academisch-Cultureel Centrum SPUI25, Amsterdam, The Netherlands, 12-02-2014

Het heelal gevuld met onzichtbare deeltjes, Academisch-Cultureel Centrum SPUI25, Amsterdam, The Netherlands, 12-02-2014

The Missing Universe, Vereniging voor Weer- en Sterrenkunde Triangulum, Apeldoorn, The Netherlands, 09-10-2014

Decowski, M.P, Op zoek naar donkere materie in het heelal, Viva Fysica!, Amsterdam, The Netherlands, 31-01-2014

Het heelal gevuld met Neutrino's, Academisch-Cultureel Centrum SPUI25, Amsterdam, The Netherlands, 12-02-2014

Filthaut, F, Het Higgsdeeltje, twee jaar later, Stichting J.C. van der Meulen, Hoorn, The Netherlands, 10-10-2014

Holten, van, J.W, Special Relativity, Senior High-School Students Lecture, Leiden, The Netherlands, 13-02-2014

Elmentaire deeltjes, HOVO Lecture, Leiden, The Netherlands, 18-03-2014

Voorbij het Standaard Model, HOVO Lecture, Leiden, The Netherlands, 29-05-2014

Keijser, J.J, Grid Computing & Distributed e-Infrastructures, Network of Talents Grid lezing, Eindhoven, The Netherlands, 19-02-2014

Koffeman, E.N, Elementaire deeltjes en de ontdekking van het Higgsboson, Academisch-Cultureel Centrum SPUI25, Amsterdam, The Netherlands, 12-11-2014

Laenen, E, Beyond the Higgs, Physica 2014, Leiden, The Netherlands, 01-04-2014

Linde, F.L., Wat maakt donkere materie zo spannend?, Universiteit van Nederland, Amsterdam, The Netherlands, 07-01-2014

Hoe kunnen natuurkundigen zien wanneer de zon is opgebrand?, Universiteit van Nederland, Amsterdam, The Netherlands, 07-01-2014

Hoe kun je van een biljartbal een banaan maken?, Universiteit van Nederland, Amsterdam, The Netherlands, 07-01-2014

Waarom is kosmische straling levensgevaarlijk voor astronauten?, Universiteit van Nederland, Amsterdam, The Netherlands, 07-01-2014

Hoe heeft het Higgs deeltje de wereld veranderd?, Universiteit van Nederland, Amsterdam, The Netherlands, 07-01-2014

CERN Masterclass, Nikhef, The Netherlands, Amsterdam, 20-03-2014

Muon levensduur meting, Het Baken, Almere, The Netherlands, 02-04-2014

Muon levensduur meting, Het Baken, Almere, The Netherlands, 11-06-2014

Nikhef, 68 Years in Love with Physics, 26 June 2014, CERN60 celebration, The Netherlands, Amsterdam.

De microkosmos: Higgs, Oerknal en meer!, Lowlands University college, Biddinghuizen, The Netherlands, 15-08-2014

Merk, M, Het Quantum Universum – Het Macro Universum, Cygnus Gymnasium College, Amsterdam, The Netherlands, 23-01-2014

Het Quantum Universum – Het Micro Universum, Cygnus Gymnasium College, Amsterdam, The Netherlands, 06-02-2014

Het Quantum Universum – Antimaterie, Cygnus Gymnasium College, Amsterdam, The Netherlands, 13-02-2014

Het Antimaterie mysterie, Dept. Arnhem of Koninklijke Nederlandse Vereniging voor Weer- en Sterrenkunde, Arnhem, The Netherlands, 20-03-2014

Het Quantum Universum - Eindsymposium, Cygnus Gymnasium College, Amsterdam, The Netherlands, 27-03-2014

Het Antimaterie mysterie, Nikhef Master Class, Amsterdam, The Netherlands, 01-04-2014

Het Antimaterie mysterie, Dept. Venlo of Koninklijke Nederlandse Vereniging voor Weer- en Sterrenkunde, Venlo, The Netherlands, 29-09-2014

Het Quantum Universum - Het Macro Universum 1, Cygnus Gymnasium College, Amsterdam, The Netherlands, 06-11-2014

Het Quantum Universum - Het Macro Universum 2, Cygnus Gymnasium College, Amsterdam, The Netherlands, 13-11-2014

Mischke, A, Breast cancer detection with technology from CERN, De kennis van nu, Radio 5 (interview), Hilversum, The Netherlands, 07-03-2014

The hottest man-made matter, Department's Day, Utrecht, The Netherlands, 08-05-2014

From detecting quarks to detecting breast cancer, video documentary: http://we.tl/9gyyKscvcs, Utrecht, The Netherlands, 12-06-2014

Detectives of the Microcosm, Session 'A Revolution of the Mind', EuroScience Open Forum – Science building bridges (ESOF2014), Copenhagen, Denmark, 24-06-2014

Mulders, P.J, Ontdekkingsreis naar het allerkleinste en het allergrootste in het heelal, VU Publiekslezing, de Balie, Amsterdam, The Netherlands, 10-03-2014

Oussoren, K.P, Using the largest to look at the tiniest, PANCART, Amsterdam, The Netherlands, 18-07-2014

Samtleben, D.F.E, Nieuws van het oudste licht, KNAW minisymposium 'De Oerknal binnen handbereik', Amsterdam, The Netherlands, 07-04-2014

Saueressig , F, Forschung am Institut für Hochenergiephysik, Schuppertag, RU Nijmegen, Nijmegen, The Netherlands, 31-01-2014

Snellings, R.J.M, Oerknalsoep, KIJK Live!, Amsterdam, The Netherlands, 15-05-2014

Suerink, T.C.H, Sneller en virtueel netwerken, Juniper & IDC breakfast session, Loosdrecht, The Netherlands, 27-11-2014

Tuning, N, Higgs en anti-materie (Hoe de Higgs het verschil maakt), Bessensap, Utrecht, The Netherlands, 06-06-2014

Alles en Niks: van de Oerknal tot Higgs, Lezing WV Nieuwe Meer, Aalsmeer, The Netherlands, 26-10-2014

Verkerke, W, De zoektocht naar het Higgs deeltje – de oorsprong van massa, fundament van de moderne deeltjesfysica, Lezing Probus Zaanstreek, Wormerveer, The Netherlands, 11-03-2014

Zoeken naar het Higgs deeltje, Vakantiecursus – Platform Wiskunde Nederland, Eindhoven, The Netherlands, 23-08-2014

Zoeken naar het Higgs deeltje, Vakantiecursus – Platform Wiskunde Nederland, Amsterdam, The Netherlands, 30-08-2014

Vulpen, van, I.B, De elementaire bouwstenen van de natuur, Serious Request, Geneva, Switzerland, 09-04-2014

De ontdekking van het Higgs boson, New Scientist lezersreis, Geneva, Switzerland, 28-08-2014

Het ontdekken van een nieuwe wereld, TOpAS bijeenkomst, Gemeentelijk Gymnasium, Hilversum, The Netherlands, 29-10-2014

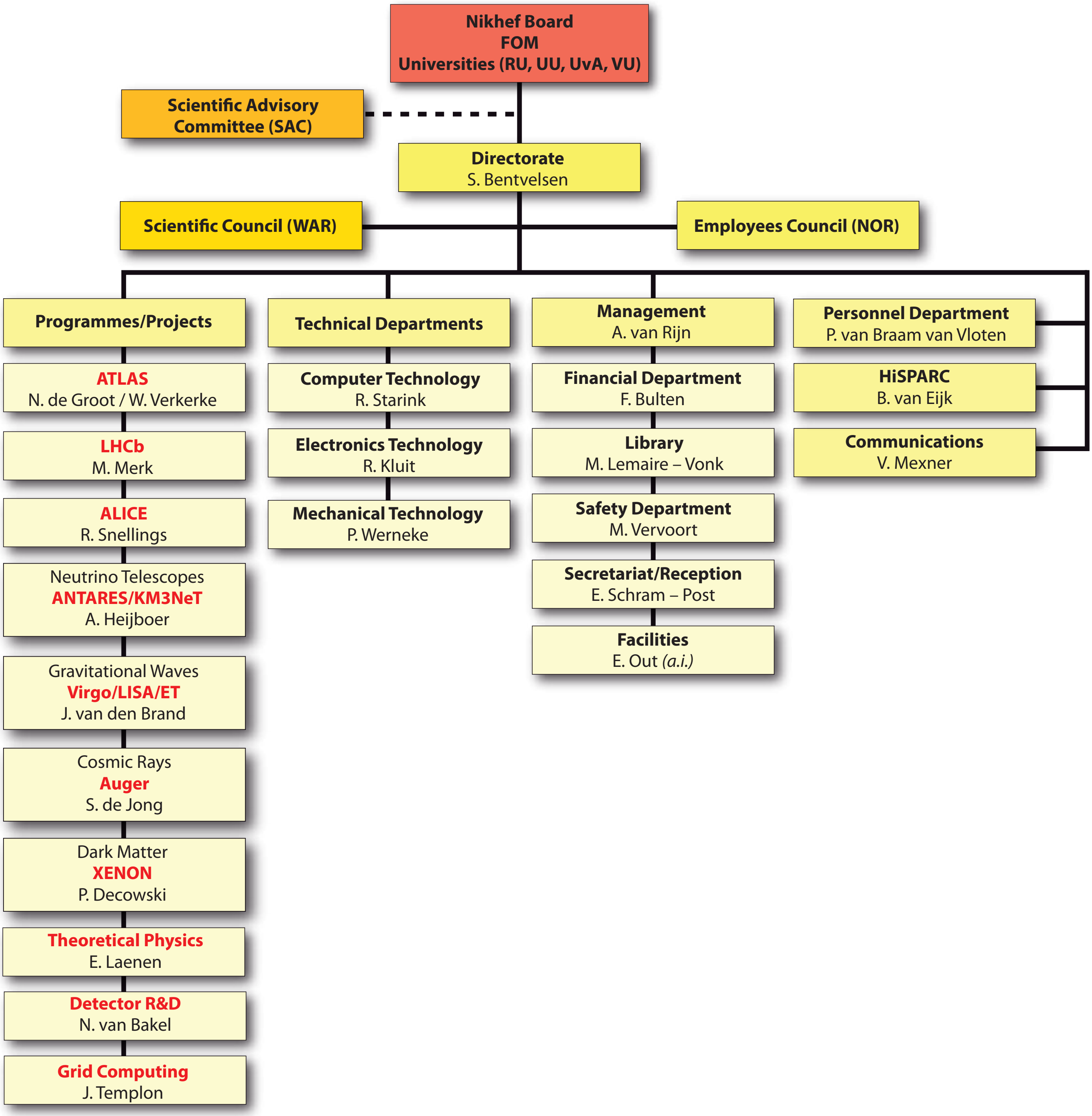
Elementaire deeltjes en de ontdekking van het Higgs boson, Academisch-Cultureel Centrum SPUI25, Amsterdam, The Netherlands, 12-11-2014

Wolf, de, E, Hoe gaat het met de neutrinos?, Rotary Club, Amsterdam, The Netherlands, 26-03-2014

5

Resources

5.1 Organigram*



* *as of 31 December 2014.*

5.2 Organisation*

Nikhef Board
C.C.A.M. Gielen (chair, Radboud University Nijmegen)
J.J. de Kleuver (secretary, FOM)
H. Irth (VU University Amsterdam)
N.J. Lopes Cardozo (FOM)
G.F.B.P. van Meer (Utrecht University)
K. Maex (University of Amsterdam)
W. van Saarloos (FOM)

Management Team
S. Bentvelsen
P. van Braam van Vloten
A. van Rijn

Scientific Advisory Committee (SAC)
F. Gianotti (CERN, Geneva)
N. Glover (IPPP, Durham)
J. Mnich (DESY, Hamburg)
T. Nakada (EPFL, Lausanne)
A. Rubbia (chair, ETH, Zürich)
J. Schukraft (CERN, Geneva)
C. Spiering (DESY Zeuthen, Berlin)

Employees Council (NOR)
L. Brenner
R. Hart (secretary)
J.J. Keijser (vice chair)
N. Rem
B. Schellekens
F. Schreuder (vice secretary)
H. Snoek
G. Visser
J. Visser (chair)

CERN Contact Commissie
S. Bentvelsen
S. de Jong (chair)
R. Kleiss
F. Linde
M. Merk (secretary)
Th. Peitzmann

Dutch Research School Theoretical Physics
W. Beenakker (Educational Board)
J. van Holten (Educational Board)
R. Kleiss (Governing Board)
E. Laenen (Governing Board)
P. Mulders (Educational Board)
F. Saueressig (Educational Board)

Scientific Council (WAR)
N. van Bakel
S. Bentvelsen
J. van den Brand
S. Caron
P. Decowski
H. Falcke
P. de Jong
S. de Jong
E. Koffeman
E. Laenen
M. Merk
J. Messchendorp (KVI, Groningen)
G. Onderwater (KVI, Groningen)
Th. Peitzmann (chair)
G. Raven
A. van Rijn (secretary)
R. Snellings
N. Tuning (staff meeting)
L. Wiggers

Onderzoekschool Subatomaire Fysica – Onderwijscommissie
S. Bentvelsen
J. Berger (secretary)
J. van den Brand
P. van Braam van Vloten (personnel)
B. van Eijk
N. de Groot
P. de Jong
S. de Jong
E. Koffeman
E. Laenen
F. Linde
M. Merk
P. Mulders
Th. Peitzmann
A. Pellegrino
G. Raven
A. Schellekens
R. Snellings (chair)

Committee for Astroparticle Physics in the Netherlands (CAN)
J. van den Brand
P. Decowski
J. Hörandel (chair)
D. Samtleben
C. Timmermans
C. Van Den Broeck (vice chair)

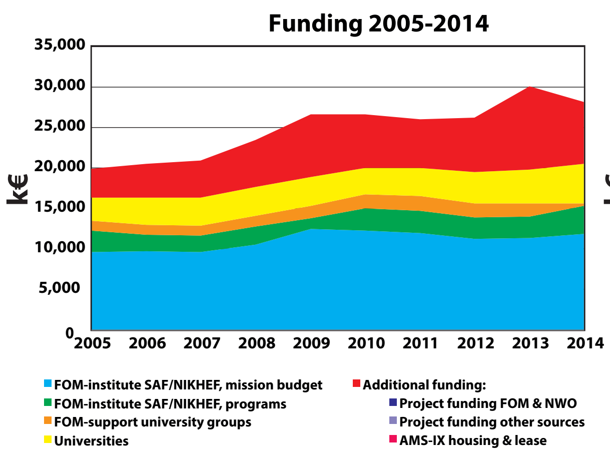
* *as of 31 December 2014.*

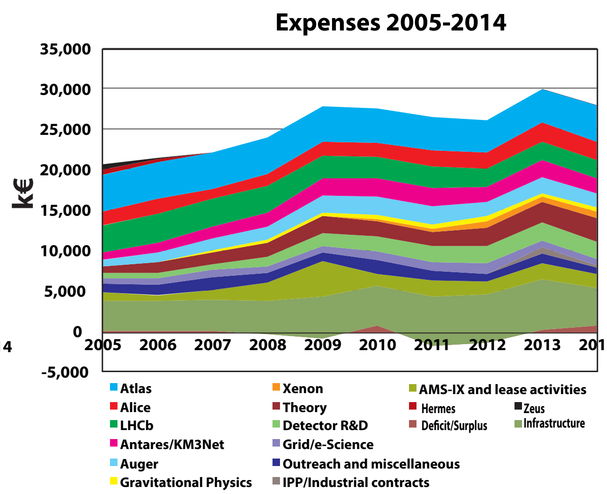
5.3 Funding & Expenses

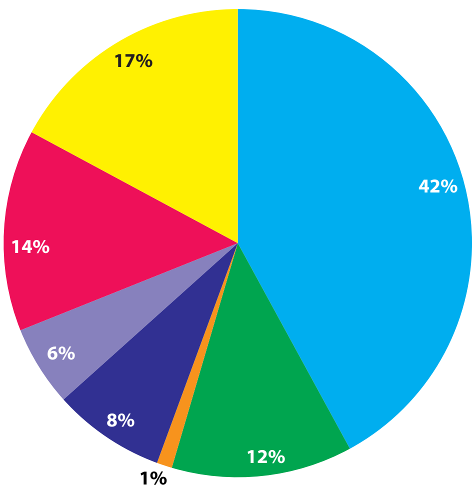
The 2014 funding level of the Nikhef collaboration is lower than last year: 28.2 M€ versus 30.1 M€, due to fewer grants obtained. The single most important grant acquired in 2014 is the 15.24 M€ funding for the LHC upgrade projects and computing, from the National Roadmap for Large-Scale Research Facilities. This funding, which will be consumed in the period 2015–2021, enables Nikhef to position itself perfectly in the upgrade ambitions of the LHC detectors ATLAS, LHCb and ALICE.

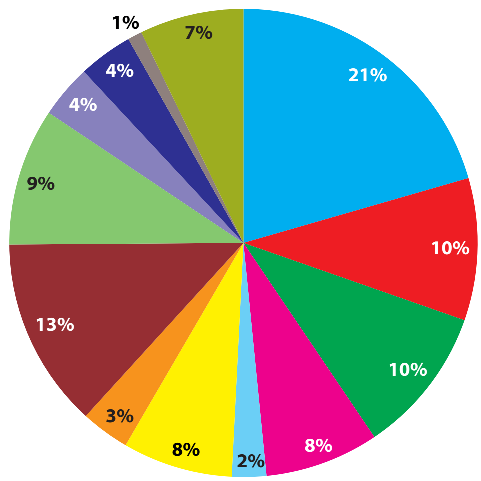
Two FOM-programmes on Theory with Nikhef involvement have been acquired in 2014, which will appear in the books as of 2015. The first is a 2.1 M€ programme (2015–2019) titled *"Higgs as a probe and portal"*, acquired by Eric Laenen; the Nikhef share is 0.46 M€. The second is a 2.3 M€ programme (2015–2019) titled *"Observing the Big Bang: the quantum universe and its imprint on the sky"*, acquired by Ana Achucarro; the Nikhef share is 0.34 M€. The expenses for accelerator-based particle physics (ATLAS, LHCb and ALICE) have stabilised at 39%, with an emphasis on scientific staff (notably PhD students). The astroparticle physics activities, for which construction activities are large, have consumed about 20% of expenses. The enabling activities (computing, detector R&D and particularly theory) comprise 26% of expenses, whilst industrial activities, outreach and lease activities make out the remainder (15%) of the direct costs.

Budget and grants labelled as investments are not included in the graph, in particular SURF funded equipment for the national e-infrastructure, the KM3NeT detector, Advanced Virgo and the above mentioned LHC upgrade, together budgeted at about 2.6 M€ in 2014.









5.4 Grants

The table below shows from top to bottom grants awarded in 2014, running grants and completed grants, awarded in earlier years, including their financial envelope, running period and –if not the FOM institute– the name of the Nikhef partner university via which the grants have been obtained. FOM programmes and the LHC upgrade investment grant are not included in the table. More information on some of the grants of 2014 can be found in section 3.6 'Awards and grants'.

After two extremely successful years, the harvest of 2014 has been very modest: only 0.7 M€. Part can be explained by the lack of opportunities in European funding (Horizon2020). Nikhef has participated in some of the first Horizon2020 calls, but has not yet been successful.

Awarded					
Leader	**Title**	**Source**	**Period**	**Budget(k€)**	**Partner**
Bentvelsen	Director's budget	FOM	2015–2019	500	
Van den Brand	Field studies with seismic and gravity–gradient sensor networks for gravitational waves physics and oil–and–gas exploration	FOM/ HTSM	2015	182	VU
				682	
Running					
Leader	**Title**	**Source**	**Period**	**Budget(k€)**	**Partner**
Van Eijk/ Bentvelsen	Splitting the Higgs: the connection to dark matter	FOM/Pr	2013–2017	400	
Filthaut/ N. de Groot	Higgs as a portal to new physics	FOM/Pr	2013–2017	396	RU
Mischke	A charming way to disentangle initial– and final–state effects at the LHC	FOM/Pr	2013–2017	270	UU
Ferrari	CP violation in the Higgs sector	FOM/Pr	2014–2018	396	
Saueressig	Black hole dynamics in asymptotically safe quantum gravity	FOM/Pr	2014–2018	398	RU
Mischke	Charm content in jets	FOM/Pr	2011–2015	398	UU
Van Den Broeck	Binary black holes as laboratories for fundamental physics	FOM/Pr	2011–2015	354	
P. de Jong	Mind the gap! Generalizing dark matter searches at the LHC	FOM/Pr	2011–2015	264	
Linde	Tiling appointment	FOM/v	2013–2017	326	
(Various)	FOM/v projects	FOM/v	2013–2016	425	RU
Igonkina	Search for tau decays to a muon and a photon to understand the lack of anti–matter in the universe	FOM/Pr	2012–2016	400	
Peitzmann	Thermal photon measurements in ALICE: probing the initial temperature of the quark–gluon plasma	FOM/Pr	2012–2016	394	UU
Mulders	Quantum chromodynamics at work in the Higgs sector	FOM/Pr	2012–2016	379	VU
Postma	Keeping track of time during inflation	FOM/Pr	2012–2016	385	
Van den Brand	Wireless seismic sensors	FOM/IPP	2013–2017	256	
Van Tilburg	VIDI: The high–precision frontier in beauty and charm decays	NWO	2013–2018	800	
Heijboer	VIDI: Exploring the Cosmos with Neutrinos	NWO	2009–2015	600	
P. de Jong	VICI: Between bottom and top: supersymmetry searches with flavour	NWO	2009–2015	1,250	
Hulsbergen	VIDI: A search for long–lived heavy particles	NWO	2010–2015	800	
Van den Brand	Advanced Virgo – Probing the dynamics of spacetime	NWO	2012–2015	2,000	
Grelli	VENI: Research into a new state of matter	NWO	2012–2016	250	UU
Igonkina	VIDI: Lepton flavor violation: the key towards a matter dominated universe	NWO	2011–2016	800	
De Groot	OSAF Research school for subatomic physics – NWO graduate programme	NWO	2010–2015	800	RU
Snellings	VICI: A new state of matter: The Quark Gluon Plasma	NWO	2012–2016	1,500	UU
Van Bakel	SENSEIS: Silent sensors for stellar echo's and seismic surveys	STW	2014–2019	495	UT
Visser	New Detector Systems for Biomedical Imaging (together with Amolf)	STW	2012–2016	300	
PDP group	Contribution to the national e–infrastructure	SURFsara	2013–2015	2,310	

Leader	Title	Source	Period	Budget(k€)	Partner
Butter	HYPERGRAV: The last piece of the puzzle: Off-shell hypermultiplets in string theory and complex geometry	EU	2014–2016	183	
Laenen	HIGGSTOOLS: The Higgs quest – exploring electroweak symmetry breaking at the LHC	EU	2014–2017	251	
Van den Brand	ELiTES: ET-LCGT Interferometric Telescopes: Exchange of Scientists	EU	2012–2016	32	VU
Hessey	TALENT: Training for cAreer deveLopment in high-radiation ENvironment Technologies	EU	2012–2016	545	
Waalewijn	PRECISIONJETS4LHC: Precise Predictions for Higgs and New Physics Signals with jets at the Large Hadron Collider	EU	2013–2015	183	
Hessey/Visser	INFIERI: INtelligent Fast Interconnected and Efficient Devices for Frontier Exploitation in Research and Industry	EU	2013–2017	404	
De Wit	AdG: Supersymmetry: a window to non-perturbative physics	EU/ERC	2010–2016	1,910	UU
Mulders	AdG: Quantum Chromodynamics at Work	EU/ERC	2013–2018	2,069	VU
Van der Graaf	AdG: MEMS-made Electron Emission Membranes	EU/ERC	2013–2018	2,396	
Vermaseren	AdG: Solving High Energy Physics Equations using Monte Carlo Gaming Techniques – HEPGAME	EU/ERC	2013–2018	1,739	
Mischke	ERC PoC: MammoMedipix: High Sensitivity Mammography with a new generation of silicon pixel sensors	EU/ERC	2014–2015	149	UU
Van Eijk	HiSparc – 'betadecanen'	Univ.	2014–2015	90	
				27,297	
		Completed			
Leader	**Title**	**Source**	**Period**	**Budget(k€)**	**Partner**
Fleischer	Exploring a new territory of the B-physics landscape at LHCb	FOM/Pr	2010–2014	408	
Linde	Tiling appointment	FOM/v	2010–2014	470	
Mischke	VIDI: Characterisation of a novel state of matter: The Quark-Gluon Plasma	NWO	2008–2014	365	UU
Heubers	The 'Research Campus' (with Amolf and CWI)	SURFnet	2013–2014	100	
Van Rijn	EGI InSPIRE: European Grid Infrastructure	EU	2010–2014	251	
Koffeman/ Hessey	AIDA (detector R&D)	EU	2011–2014	152	
Laenen	LHCPhenoNet	EU	2011–2014	397	
Laenen/ Artoisenet	PROBE4TeVSCALE: Resolving short-distance physics mechanisms in hadron collisions at TeV scale energies	EU	2012–2014	192	
Van den Brand	TremorNet	Shell	2013–2014	783	VU
				3,118	

5.5 Personnel*

ATLAS

Aben	MSc.	R.Z. (Rosemarie)	FOM
Angelozzi	MSc.	I. (Ivan)	FOM
Bedognetti	MSc.	M. (Matteo)	FOM
Beemster	MSc.	L.J. (Lars)	FOM
Berge	Dr.	D. (David)	UvA
Bobbink	Dr.	G.J. (Gerjan)	FOM
Brenner	MSc.	L. (Lydia)	FOM
Butti	MSc.	P. (Pierfrancesco)	FOM
Caron	Dr.	S. (Sascha)	RU
Castelijn	MSc.	R.J.A.M. (Remco)	FOM
Castelli	MSc.	A. (Antonio)	FOM
Colasurdo	MSc.	L. (Luca)	FOM
Croft	MSc.	V.A. (Vince)	FOM
Deigaard	MSc.	I. (Ingrid)	FOM
Deluca Silberberg	Dr.	C. (Carolina)	FOM
Ferrari	Dr.	P. (Pamela)	FOM
Filthaut	Dr.	F. (Frank)	RU
Gadatsch	MSc.	S. (Stefan)	FOM
Galea	Dr.	C.F. (Cristina)	FOM
Garitaonandia	MSc.	H. (Hegoi)	other
Geer	MSc.	R. van der (Rogier)	RU
Geerts	MSc.	D.A.A. (Daniel)	other
Groot	Prof.dr.	N. de (Nicolo)	RU
Hessey	Dr.	N.P. (Nigel)	FOM
Igonkina	Dr.	O.B. (Olga)	FOM
Jong	Prof.dr.ir.	P.J. de (Paul)	UvA
Karastathis	MSc.	N. (Nikos)	FOM
Kluit	Dr.drs.ir.	P.M. (Peter)	FOM
König	Dr.	A.C. (Adriaan)	RU
Koutoulaki	MSc.	A. (Afroditi)	FOM
Mahlstedt	Dipl. Phys.	J. (Joern)	FOM
Meyer	MSc.	J. (Jochen)	FOM
Nektarijevic	Dr.	S. (Snezana)	FOM
Oussoren	MSc.	K.P. (Koen)	FOM
Sabato	MSc.	G. (Gabriele)	FOM
Salvucci	Dr.	A. (Antonio)	FOM
Slawinska	Dr.	M.K. (Magdalena)	FOM
Strübig	Dipl. Phys.	A.H. (Antonia)	FOM
Tal Hod	Dr.	N. (Noam)	FOM
Toptop	MSc.	K. (Koral)	FOM
Valenčič	MSc.	N. (Nika)	FOM
Vankov	Dr.	P.H. (Peter)	FOM
Verkerke	Dr.	W. (Wouter)	FOM
Vermeulen	Dr.ir.	J.C. (Jos)	UvA
Vreeswijk	Dr.	M. (Marcel)	UvA
Vulpen	Dr.	I.B. van (Ivo)	UvA
Weits	MSc.	H. (Hartger)	FOM
Woerden	MSc.	M.C. van (Marco)	CERN
Wolf	MSc.	T.M.H. (Tim)	FOM
Wollenberg	MSc.	W. van den (Wouter)	UT

LHCb

Ali	MSc.	S. (Suvayu)	FOM
Bel	MSc.	L.J. (Lennaert)	FOM
Bruyn	MSc.	K.A.M. de (Kristof)	FOM
Ciezarek	Dr.	G.M. (Greg)	FOM
David	MSc.	P.N.Y. (Pieter)	FOM
Dufour	MSc.	L.J.I.J. (Laurent)	FOM
Heijne	MSc.	V.A.M. (Veerle)	other

* as of 31 December 2014.

Overview of Nikhef personnel in FTE (2014)

I – Scientific groups (fte – 2014, institute & university groups)	
Permanent scientific staff	68.7
PhD students	104.0
Post–docs	28.3
Other scientific staff	1.4
Total I	**204.4**
II – Management, technical/engineering and general support (fte – 2014, institute)	
Management team	
Director	1.0
Institute manager	1.0
Personnel manager	1.0
Subtotal	**3.0**
Technical/engineering support	
Electronics technology	24.0
Computer technology	23.5
Mechanical technology	26.8
Subtotal	**74.3**
General support	
Financial administration	3.8
Personnel/HRM administration	1.0
Library	0.6
Facilities & Datacenter	9.6
Secretariat and reception desk	3.9
PR & communication	3.1
Occupational health & safety	2.0
Staff	2.4
Subtotal	**26.4**
Total II	**103.7**
Total I & II	**306.1**
III – Other groups (persons 2014)	
Guests (researchers, retired staff)	114
Master students	38
Apprentices	9

Hulsbergen	Dr.	W.D. (Wouter)	FOM
Jans	Dr.	E. (Eddy)	FOM
Koopman	MSc.	R.F. (Rose)	FOM
Koppenburg	Dr.	P.S. (Patrick)	FOM
Leerdam	MSc.	J. van (Jeroen)	other
Martinez Santos	Dr.	D. (Diego)	FOM
Merk	Prof.dr.	M.H.M. (Marcel)	FOM
Onderwater	Dr.	C.J.G. (Gerco)	RUG
Pellegrino	Prof.dr.	A. (Antonio)	FOM
Raven	Prof.dr.	H.G. (Gerhard)	VU
Snoek	Dr.	H.L. (Hella)	FOM
Syropoulos	MSc.	V. (Vasiliis)	FOM
Tilburg	Dr.	J.A.N. van (Jeroen)	FOM
Tolk	MSc.	S. (Siim)	FOM
Tsopelas	MSc.	P.C. (Panos)	FOM
Tuning	Dr.	N. (Niels)	FOM
Vries	MSc.	J.A. de (Jacco)	FOM
Wiggers	Dr.	L.W. (Leo)	FOM

ALICE

Bertens	MSc.	R.A. (Redmer)	UU
Bianchin	Dr.	C. (Chiara)	UU
Bjelogrlić	MSc.	S. (Sandro)	FOM
Caliva	MSc.	A. (Alberto)	FOM
Christakoglou	Dr.	P. (Panos)	FOM
Deplano	Dr.	C. (Caterina)	FOM
Dobrin	Dr.	A.F. (Alexandru)	UU
Dubla	MSc.	A. (Andrea)	UU
Grelli	Dr.	A. (Alessandro)	UU
Keijdener	MSc.	D.L.D. (Darius)	UU
Kofarago	MSc.	M. (Monika)	other
Kuijer	Dr.	P.G. (Paul)	FOM
Leeuwen	Dr.ir.	M. van (Marco)	FOM
Lehas	MSc.	F. (Fatiha)	FOM
Leogrande	MSc.	E. (Emilia)	UU
Lodato	MSc.	D.F. (Davide)	UU
Maarel	MSc.	J. van der (Jasper)	FOM
Margutti	MSc.	J. (Jacopo)	FOM
Mischke	Dr.	A. (Andre)	UU
Mohammadi	MSc.	N. (Naghmeh)	UU
Peitzmann	Prof.dr.	T. (Thomas)	UU
Perez Lara	MSc.	C.E. (Carlos)	other
Reicher	MSc.	M. (Martijn)	UU
Rocco	Dr.	E. (Elena)	FOM
Rodriguez Manso	MSc.	A. (Alis)	FOM
Snellings	Prof.dr.	R.J.M. (Raimond)	UU
Veen	MSc.	A.M. (Annelies)	FOM
Veldhoen	MSc.	M. (Misha)	FOM
Yang	Dr.	H. (Hongyan)	FOM
Zhang	MSc.	C. (Chunhui)	FOM
Zhou	MSc.	Y. (You)	other

Neutrino Telescopes

Bormuth	MSc.	R. (Robert)	UL
Bruijn	Dr.	R. (Ronald)	UvA
Eijk	Dr.	D. van (Daan)	FOM
Heijboer	Dr.	A.J. (Aart)	FOM
Jong	Prof.dr.	M. de (Maarten)	FOM
Jongen	MSc.	M.H.G. (Martijn)	FOM
Kooijman	Prof.dr.	P.M. (Paul)	UvA
Michael	Dipl. Phys.	T. (Tino)	FOM
Samtleben	Dr.	D.F.E. (Dorothea)	UL
Steijger	Dr.	J.J.M. (Jos)	FOM
Visser	MSc.	E.L. (Erwin)	FOM
Wolf	Dr.	E. de (Els)	UvA

Gravitational Waves

Agathos	MSc.	M. (Michail)	FOM
Agatsuma	Dr.	K. (Kazuhiro)	FOM
Ambrosi	MSc.	G. d' (Giuseppe)	FOM
Bertolini	Dr.	A. (Alessandro)	FOM
Blom	MSc.	M.R. (Mathieu)	other
Brand	Prof.dr.ing.	J.F.J. van den (Jo)	VU
Bulten	Dr.	H.J. (Henk Jan)	VU
Heijningen	Ir.	J.V. van (Joris)	FOM
Janssens	MSc.	S.M.J. (Stef)	CERN
Jonker	Drs.	R.J.G. (Reinier)	FOM
Koley	MSc.	S. (Soumen)	FOM
Meidam	MSc.	J. (Jeroen)	FOM
Nelemans	Prof.dr.	G.A. (Gijs)	RU
Schaaf	MSc.	L. van der (Laura)	FOM
Van Den Broeck	Dr.	C.F. (Chris)	FOM

Cosmic Rays

Aar	MSc.	G.A. van (Guus)	RU
Falcke	Prof.dr.	H. (Heino)	RU
Hörandel	Dr.	J.R. (Jörg)	RU
Jansen	MSc.	S. (Stefan)	FOM
Jong	Prof.dr.	S. de (Sijbrand)	RU
Mauro	MSc.	G. de (Giuseppe)	FOM
Timmermans	Dr.	C.W.J.P. (Charles)	FOM

Dark Matter

Aalbers	MSc.	J. (Jelle)	UvA
Breur	MSc.	P.A. (Sander)	FOM
Colijn	Dr.	A.P. (Auke Pieter)	UvA
Decowski	Dr.	M.P. (Patrick)	UvA
Tiseni	MSc.	A. (Andrea)	FOM
Tunnell	Dr.	C.D. (Chris)	FOM

Theoretical Physics

Beenakker	Prof.dr.	W. (Wim)	RU
Bonocore	MSc.	D. (Domenico)	FOM
Buffing	MSc.	M.G.A. (Maarten)	VU
Butter	Dr.	D.P. (Dan)	FOM
Ciceri	MSc.	F.P.M.Y. (Franz)	FOM
Cotogno	MSc.	S. (Sabrina)	VU
Daal	MSc.	T.A.A. van (Tom)	VU
Fleischer	Prof.dr.	R. (Robert)	FOM
Fumagalli	MSc.	J. (Jacopo)	FOM
García Echevarría	Dr.	M. (Miguel)	VU
Guarino Almeida	Dr.	J.A. (Adolfo)	FOM
Herzog	Dr.	F. (Franz)	FOM
Holten	Prof.dr.	J.W. van (Jan-Willem)	FOM
Inverso	Dr.	G. (Gianluca)	FOM
Kasemets	Dr.	T. (Tomas)	VU
Kleiss	Prof.dr.	R.H.P. (Ronald)	RU
Laenen	Prof.dr.	E.L.M.P. (Eric)	FOM
Loll	Prof.dr.	R. (Renate)	RU
Mariani	MSc.	E. (Elisa)	FOM

Mirsoleimani	MSc.	S.A. (Ali)	FOM
Mulders	Prof.dr.	P.J.G. (Piet)	VU
Petraki	Dr.	K. (Kallia)	FOM
Postma	Dr.	M.E.J. (Marieke)	FOM
Reys	MSc.	V. (Valentin)	FOM
Rietkerk	MSc.	R.J. (Robbert)	UvA
Ritzmann	Dr.	M.M. (Mathias)	FOM
Ruijl	MSc.	B.J.G. (Ben)	FOM
Saravanan	MSc.	S. (Satish)	UL
Schellekens	Prof.dr.	A.N.J.J. (Bert)	FOM
Signori	MSc.	A. (Andrea)	VU
Taanila	MSc.	O.K.T. (Olli)	FOM
Ueda	Dr.	T. (Takahiro)	FOM
Vermaseren	Dr.	J.A.M. (Jos)	FOM
Waalewijn	Dr.	W.J. (Wouter)	FOM
Wiechers	MSc.	M. (Michael)	UvA
Wit	Prof.dr.	B.Q.P.J. de (Bernard)	FOM
Zhou	Dr.	J. (Jian)	other

Detector R&D

Bakel	Dr.	N.A. van (Niels)	FOM
Beuzekom	Dr.ing.	M.G. van (Martin)	FOM
Chan	BSc.	H.W. (Hong Wah)	FOM
Doni	MSc.	M. (Michele)	FOM
Graaf	Dr.ir.	H. van der (Harry)	FOM
Hartjes	Dr.	F.G. (Fred)	other
Koffeman	Prof.dr.ir.	E.N. (Els)	FOM
Koppert	MSc.	W.J.C. (Wilco)	other
Linde	Prof.dr.	F.L. (Frank)	FOM
Prodanović	MSc.	V. (Violeta)	FOM
Schioppa	MSc.	E.J. (Enrico)	other
Schön	Dipl. Phys.	R. (Rolf)	other
Tao	Dr.	S. (Shuxia)	FOM
Theulings	Ir.	A.M.M.G. (Annemarie)	FOM
Timmermans	Dr.	J.J.M. (Jan)	other
Tsagri	Ir.	M. (Mary)	other
Tsigaridas	MSc.	S. (Stergios)	FOM
Visser	Dr.	J. (Jan)	FOM
Zappon	MSc.	F. (Francesco)	other

Grid Computing

Groep	Dr.	D.L. (David)	FOM
Remenska	MSc.	D. (Daniela)	FOM
Templon	Dr.	J.A. (Jeff)	FOM

HiSPARC

Beijen	MSc.	S.I. (Sabine)	other
Carmelia		G.P. (Gilbert)	other
Eijden		J.V.R. van (Vincent)	FOM
Eijk	Prof.dr.ing.	B. van (Bob)	FOM
Fokkema	Dr.	D.B.R.A. (David)	other
Kooij	Ir.	T. (Tom)	other
Laat	MSc.	A.P.L.S. de (Arne)	FOM
Montanus	Drs.	J.M.C. (Hans)	other
Schultheiss	Ing.	N.G. (Niek)	other
Veen	MSc.	C.G. van (Norbert)	FOM

Computer Technologie

Akker		T.G.M. van den (Theo)	FOM
Baan Hofman		W.M. (Wilco)	FOM
Balogh		T. (Tamas)	FOM
Beveren	Ing.	V. van (Vincent)	FOM
Boterenbrood	Ir.	H. (Henk)	FOM
Bouwhuis	Dr.	M.C. (Mieke)	FOM
Damen		A.C.M. (Ton)	FOM
Dok	Drs.	D.H. van (Dennis)	FOM
Gabriel	Dr.	S. (Sven)	FOM
Harapan	Drs.	D. (Djuhaeri)	FOM
Hart	Ing.	R.G.K. (Robert)	FOM
Heubers	Ing.	W.P.J. (Wim)	FOM
Kan		A.C. van (André)	FOM
Keijser	Drs.	J.J. (Jan Just)	FOM
Kerkhoff		E.H.M. van (Elly)	FOM
Kuipers	Drs.	P. (Paul)	FOM
Oudolf		H. (Jan)	other
Sallé	Dr.	M. (Mischa)	FOM
Schimmel	Ing.	A. (Alfred)	FOM
Starink	Dr.	R. (Ronald)	FOM
Suerink	Ing.	T.C.H. (Tristan)	FOM
Thijssen		A.E. (Arne)	FOM
Tierie		J.J.E. (Joke)	FOM
Wal	B.ICT	B. van der (Bart)	FOM

Electronische Technologie

Amico		A. d' (Antonio)	FOM
Berkien		A.W.M. (Ad)	FOM
Borga	B.ICT	A.O. (Andrea)	FOM
Buurmans	Ing.	J. (Jeroen)	FOM
Fransen		J.P.A.M. (Jean-Paul)	FOM
Gajanana	MSc.	D. (Deepak)	FOM
Gebyehu	Ir.	M. (Mesfin)	FOM
Gotink		G.W. (Wim)	FOM
Gromov	Ir.	V. (Vladimir)	FOM
Heijden	Ing.	B.W. van der (Bas)	FOM
Ietswaard		G.C.M. (Charles)	FOM
Jansweijer	Ing.	P.P.M. (Peter)	FOM
Kieft	Ing.	G.N.M. (Gerardus)	FOM
Kluit	Ing.	R. (Ruud)	FOM
Koopstra		J. (Jan)	FOM
Miryala		S. (Sandeep)	FOM
Schipper	Ing.	J.D. (Jan David)	FOM
Schmelling	Ing.	J.W. (Jan-Willem)	FOM
Schreuder		F.P. (Frans)	FOM
Timmer		P.F. (Paul)	FOM
Verkooijen	Ing.	J.C. (Hans)	FOM
Vink	Ing.	W.E.W. (Wilco)	FOM
Visser	Ing.	G.C. (Guido)	FOM
Wijnen	Ing.	T.A.M. (Thei)	RU

Mechanische Technologie

Band	Ing.	H.A. (Hans)	FOM
Berbee	Ing.	E.M. (Edward)	FOM
Boer		R.P. de (René)	FOM
Brouwer		G.R. (Gerrit)	FOM
Buis		R. (Robert)	FOM
Ceelie		L. (Loek)	FOM
Doets		M. (Martin)	FOM
Dongen	MSc.	J. van (Jesse)	FOM
Hennes	Drs.	E. (Eric)	FOM
Jaspers		M.J.F. (Michiel)	UvA

John		D.M. (Dimitri)	FOM
Kok		J.W. (Hans)	FOM
Korporaal		A. (Auke)	FOM
Kraan	Ing.	M.J. (Marco)	FOM
Kroon	Ing.	B.W.H.J. van der (Boudewijn)	FOM
Kuilman		W.C. (Willem)	FOM
Leguyt		R. (Robert)	FOM
Munneke	Ing.	B. (Berend)	FOM
Overbeek		M.G. van (Martijn)	FOM
Petten		O.R. van (Oscar)	FOM
Rietmeijer		A.A. (Arnoldus)	FOM
Roeland		E. (Erno)	FOM
Roo	B.Eng	K. de (Krista)	FOM
Rövekamp		J.C.D.F. (Joop)	FOM
Verlaat	Ing.	B.A. (Bart)	FOM
Walet	Ing.	R.C. (Rob)	FOM
Werneke	MSc.	P.J.M. (Patrick)	FOM

Management & administration

Azarfane		M. (Mohamed)	other
Azhir		A. (Ahmed)	FOM
Bentvelsen	Prof.dr.	S.C.M. (Stan)	FOM
Berg		A. van den (Arie)	FOM
Berger		J.M. (Joan)	FOM
Bieshaar		F.H.G. (Floris)	FOM
Bonam	B.Com	S. (Surya)	FOM
Braam van Vloten	MSc.	P. van (Pieter)	FOM
Bulten	bc	F. (Fred)	FOM
Dokter		J.H.G. (Johan)	FOM
Echtelt	Ing.	H.J.B. van (Joost)	FOM
Hekkelman		W.R. (Wijnanda)	FOM
Huyser		K. (Kees)	FOM
Ising		E.A. (Erwin)	FOM
Kleinsmiede – van Dongen		T.W.J. zur (Trees)	FOM
Klöpping	Ir.	R. (Rob)	FOM
Langenhorst		A. (Ton)	FOM
Lemaire – Vonk		M.C. (Maria)	FOM
Matthesius		K.H. (Karin)	FOM
Mexner	Dr.	I.V. (Vanessa)	FOM
Mors		A.G.S. (Anton)	FOM
Oosterhof – Meij		J.E.G. (Annelies)	FOM
Out		E.P.N. (Erwin)	other
Pancar		M. (Muzaffer)	FOM
Rem	Drs.ing.	N. (Nico)	FOM
Rijksen		C. (Kees)	FOM
Rijn	Drs.	A.J. van (Arjen)	FOM
Sande	B.Art	M. van der (Melissa)	other
Schram – Post		E.C. (Eveline)	FOM
Vervoort	Ing.	M.B.H.J. (Marcel)	FOM
Vreeken		D. (Daniel)	other
Willigen		E. van (Ed)	FOM
Witlox	Ing.	A.M. (Arie)	FOM
Woortmann		E.P. (Eric)	FOM

Miscellaneous

Engelen	Prof.dr.	J.J. (Jos)	UvA

5.6 Master Students

In 2014, 22 students graduated from the Master's programme Particle and Astroparticle Physics, see Table 1. For more information about the Master's programme, please refer to Section 4.2.

Date	Name	University (honours)	Master thesis title	Supervisor(s)	Group
18-03-2014	Ariën de Graaf	UvA	Analysis of untriggered data from the ANTARES neutrino telescope in search of signal events from gamma-ray bursts	D. Samtleben	ANTARES
12-06-2014	Dave Otte	RU	Determining the Gerasimova-Zatsepin effect	C. Timmermans	HiSPARC
04-06-2014	Job Jonkergouw	UvA	The implementation of systematic and MC uncertainties by nuisance parameters on $H \to WW^{(*)} \to \ell\nu\ell\nu$	W. Verkerke	ATLAS
06-06-2014	Tim Janssen	RU	Scale-independent scale dependence and renormalization in zero dimensions	R. Kleiss	Theory
30-06-2014	Dana van der Wende	UvA	A multivariate analysis of Higgs to hadronic taus for Vector Boson Fusion production	S. Bentvelsen	ATLAS
04-07-2014	Lennaert Bel	UU	Determination of the Branching ratio of $B_s^0 \to D_s^{\mp} K^{\pm}$	N. Tuning, R. Snellings	LHCb
09-07-2014	Annelies Veen	UU	D^{*+} reconstruction in proton-proton reactions at $\sqrt{s} = 8$ TeV with the ALICE detector at the Large Hadron Collider	A. Mischke	ALICE
01-08-2014	Mischa Reitsma	UvA	A search of the top squark in the decay $\tilde{t} \to b\,\tilde{\chi}_1^{\pm}$ with the ATLAS detector	P. de Jong	ATLAS
25-08-2014	Susanne Lepoeter	RU	Properties of the vacuum: A new way of interpreting the cosmological constant and the influence of a universal Casimir effect	W.P.J. Beenakker	Theory
26-08-2014	Bas de Gier	UvA	Prospect of measuring Gerasimova-Zatsepin events using the HiSPARC network	B. van Eijk	HiSPARC
26-08-2014	Jeffrey Wouda	UvA	Simulation of the Gerasimova-Zatsepin effect for HiSPARC	B. van Eijk	HiSPARC
29-08-2014	Erik Hogenbirk	VU *(cum laude)*	Development, commissioning and first results of XAMS	M.P. Decowski	Dark Matter
31-08-2014	Ricardo van den Akker	RU	HiSPARC: Detecting Cosmic Rays in our backyard	C. Timmermans	HiSPARC
09-09-2014	Cyriana Roelofs	VU	Reheating the universe after inflation	M. Postma, P.J.G. Mulders	Theory
11-09-2014	Remco Castelijn	RU	Supersymmetry and the Higgs boson: a better marriage after all	S. Caron, W.P.J. Beenakker	Theory
15-09-2014	Matteo Bedognetti	UvA	$Z \to \mu\mu\gamma$ as a control sample for the LFV $\tau \to \mu\gamma$ analysis at ATLAS	O.Igonkina	ATLAS
17-09-2014	Otto Rottier	UU	One-loop corrections at future linear colliders	J. Vermaseren, E. Laenen	Theory
30-09-2014	Tom van Daal	RU	Renormalization Group Invariants in the Minimal Supersymmetric Standard Model	W.P.J. Beenakker	Theory
30-10-2014	Edo van Veen	RU	Quantum interpretations and world war two: An analysis of the interpretive debate from the twenties to the sixties in historical context	W.P.J. Beenakker, M. Seevinck	Theory
04-12-2014	Marie Lanfermann	RU	From the Standard Model Higgs boson towards Supersymmetry: Improving Supersymmetry Searches at the Large Hadron Collider	S. Caron	ATLAS
17-12-2014	Mark Bogers	UL	Supersymmetric quantum cosmology	J.W. van Holten	Theory
18-12-2014	Claudio Pollice	VU	Maxwell's equations in General Relativity	J.W. van Holten	Theory

Table 1. Master students who graduated in 2014.

5.7 Apprentices

The presence of high quality technical departments at Nikhef allows us to offer interesting traineeship positions for students in secondary (MBO) and higher (HBO) vocational education. The table below lists the apprentices who finished their training period in 2014 in the Computer Technology (CT), Electronics Technology (ET) and Mechanical Technology (MT) departments.

Date		School	Subject / Title	Supervisor	Group
1 January 2014	Pascal Bos	HBO Hogeschool van Amsterdam	LHCb OT digital electronics (traineeship)	W. Vink	ET
15 January 2014	Sander van Velzen	MBO Leidse instrumentmakers School	third year traineeship	O. van Petten	MT
24 January 2014	Fabian Stens	MBO ROC van Amsterdam	third year traineeship	O. van Petten	MT
30 January 2014	Alex Korporaal	MBO ID College Gouda	Systeembeheer (traineeship)	B. van der Wal	CT
31 January 2014	Jack Kwakman	MBO ROC Horizon College Hoorn	Arche Cosmique (*"proeve van bekwaamheid"*)	H. Verkooijen	ET
3 February 2014	Daan Giessen	HBO Hogeschool van Amsterdam	Pressure Compensator KM3NeT	R. Walet	MT
19 March 2014	Niels Linde	MBO ROC van Amsterdam	Machining	M. Jaspers	MT
21 March 2014	Alexander van Leeuwen	HBO Haagse Hogeschool	Annealing and strength testing of polycrystalline tungsten in relation to the average grain size	E. Hennes	MT
19 June 2014	Ronald Huijzer	MBO ROC van Amsterdam	Pressure compensator	O. van Petten	MT
23 June 2014	Mark Kaper	HBO Hogeschool van Amsterdam	Slow Speedy Detector Readout (*"afstudeerverslag"*)	F. Schreuder	ET
25 June 2014	Willem-Jaap Koomen	HBO Hogeschool van Amsterdam	Industrial design of a mobile CO_2 cooling system	B. Verlaat	MT
13 July2014	Lara Veldt	MBO Leidse instrumentmakers School	second year traineeship	O. van Petten	MT

Table 1. Apprentices who finished their training period at Nikhef in 2014.

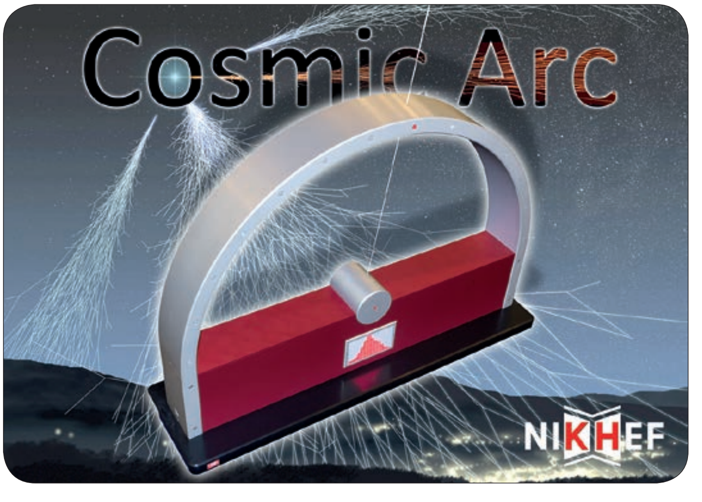


Figure 1. Artist's impression of the 'Arche Cosmique' (described in Jack Kwakman's report). The instrument detects cosmic muons via scintillators and photo-multipier tubes in the arch, displays their angular distribution in a histogram, and produces light and sound effects. In December 2014 Frank Linde received a copy at his farewell party as Nikhef director.

GLOSSARY

G

Accelerator
A machine in which beams of charged particles are accelerated to high energies. Electric fields are used to accelerate the particles whilst magnets steer and focus them. A collider is a special type of accelerator where counter–rotating beams are accelerated and interact at designated collision points. A synchrotron is an accelerator in which the magnetic field bending the orbits of the particles increases with the energy of the particles. This keeps the particles moving in a closed orbit.

ALICE (A Large Ion Collider Experiment)
One of the four major experiments that uses the *LHC*.

AMS–IX (Amsterdam Internet Exchange)
The main place in the Netherlands for Internet Service Providers to interconnect and exchange IP traffic with each other at a national or international level.

Annihilation
A process in which a particle meets its corresponding antiparticle and both disappear. The resulting energy appears in some other form: as a different particle and its antiparticle (and their energy), as many mesons, or as a single neutral boson such as a Z boson. The produced particles may be any combination allowed by conservation of energy and momentum.

ANTARES (Astronomy with a Neutrino Telescope and Abyss Environmental Research)
Large area water *Cherenkov* detector in the deep Mediterranean Sea near Toulon, optimised for the detection of muons resulting from interactions of high–energy cosmic neutrinos.

Antimatter
Every kind of matter particle has a corresponding antiparticle. Charged antiparticles have the opposite electric charge as their matter counterparts. Although antiparticles are extremely rare in the Universe today, matter and antimatter are believed to have been created in equal amounts in the *Big Bang*.

Antiproton
The antiparticle of the proton.

ASPERA
Sixth Framework Programme for coordination across European funding agencies for financing astroparticle physics. The seventh Framework Programme started in 2009 and is called ASPERA-2.

ATLAS (A Toroidal LHC ApparatuS)
One of the four major experiments that uses the *LHC*.

BaBar
Detector at SLAC's B Factory. Named for the elephant in Laurent DeBrunhoff's children's books.

Baryon
See Particles.

Beam
The particles in an accelerator are grouped together in a beam. Beams can contain billions of particles and are divided into discrete portions called bunches. Each bunch is typically several centimeters long and can be just a few μm in diameter.

Big Bang
The name given to the explosive origin of the Universe.

Boson
The general name for any particle with a spin of an integer number (0, 1 or 2...) of quantum units of angular momentum (named for Indian physicist S.N. Bose). The carrier particles of all interactions are bosons. Mesons are also bosons.

Calorimeter
An instrument for measuring the amount of energy carried by a particle.

Cherenkov radiation
Light emitted by fast–moving charged particles traversing a dense transparent medium faster than the speed of light in that medium.

CLIC (Compact LInear Collider)
A feasibility study aiming at the development of a realistic technology at an affordable cost for an electron–positron linear collider for physics at multi–TeV energies.

Collider
See Accelerator.

Cosmic ray
A high–energy particle that strikes the Earth's atmosphere from space, producing many secondary particles, also called cosmic rays.

CP violation
A subtle effect observed in the decays of certain particles that betrays nature's preference for matter over antimatter.

D0 (named for location on the Tevatron Ring)
Collider detector, studies proton–antiproton collisions at Fermilab's Tevatron.

Dark matter and dark energy
Only 4% of the matter in the Universe is visible. The rest is known as dark matter and dark energy. Finding out what it consists of is a major question for modern science.

Detector
A device used to measure properties of particles. Some detectors measure the tracks left behind by particles, others measure energy. The term 'detector' is also used to describe the huge composite devices made up of many smaller detector elements. Examples are the ATLAS, the ALICE and the LHCb detectors.

Electron
See Particles.

ET
Einstein Telescope. Design project for a third generation gravitational wave observatory consisting of three –underground and typically 10 km long– cryogenic xylophone interferometers in a triangular shape.

eV (Electronvolt)
A unit of energy or mass used in particle physics. One eV is extremely small, and units of million electronvolts, MeV, thousand MeV = 1 GeV, or million MeV = 1 TeV, are more common in particle physics. The latest generation of particle accelerators reaches up to several TeV. One TeV is about the kinetic energy of a flying mosquito.

Fermion
General name for a particle that is a matter constituent, characterised by spin in odd half integer quantum units ($\frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$...). Named for Italian physicist Enrico Fermi. Quarks, leptons and baryons are all fermions.

Forces
There are four fundamental forces in nature. Gravity is the most familiar to us, but it is the weakest. Electromagnetism is the force responsible for thunderstorms and carrying electricity into our homes. The two other forces, weak and strong, are connected to the atomic nucleus. The strong force binds the nucleus together, whereas the weak force causes some nuclei to break up. The weak force is important in the energy–generating processes of stars, including the Sun. Physicists would like to find a theory that can explain all these forces in one common framework. A big step forward was made in the late 1970s when the electroweak theory uniting the electromagnetic and weak forces was proposed. This was later confirmed in a Nobel prize–winning experiment at CERN.

FTE (Full Time Equivalent)
Unit of manpower.

Gluon
See Particles.

Gravitational wave
The gravitational analog of an electromagnetic wave whereby gravitational radiation is emitted at the speed of light from any mass that undergoes rapid acceleration.

Grid
A service for sharing computer power and data storage capacity over the Internet.

Hadron
A subatomic particle that contains quarks, antiquarks, and gluons, and so experiences the strong force (see also Particles).

High–Energy Physics
A branch of science studying the interactions of fundamental particles; called 'high–energy' because very powerful accelerators produce very fast, energetic particles probing deeply into other particles.

Higgs boson
A particle predicted in 1964 independently by theoreticians Brout, Englert and Higgs in order to explain the mechanism by which particles acquire mass. In 2012 the ATLAS and CMS experiments at the LHC announced the discovery of a particle with mass 125 GeV that fits the properties of this Higgs boson. The particle plays a central role in the Standard Model of elementary particle physics. In 2013 Englert and Higgs received the Nobel Prize *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"*.

HiSPARC (High School Project on Astrophysics Research with Cosmics)
Cosmic–ray experiment with schools in the Netherlands.

ILC
International Linear Collider, now under study. A possible future electron–positron accelerator, proposed to be built as an international project.

KSI2K
The Kilo SpecInt 2000 (KSI2K) is a unit in which integer computing power is expressed. It is only partially correlated with computing speed.

Kaon
A meson containing a strange quark (or antiquark). Neutral kaons come in two kinds, long–lived and short–lived.
The long–lived ones occasionally decay into two pions, a CP–violating process (see also Particles).

KM3NeT (Cubic Kilometre Neutrino Telescope)
Planned European deep–sea neutrino telescope with a volume of at least one cubic kilometre at the bottom of the Mediterranean Sea.

LCG (LHC Computing Grid)
The mission of the LCG is to build and maintain a data–storage and analysis infrastructure for the entire high–energy physics community that will use the LHC.

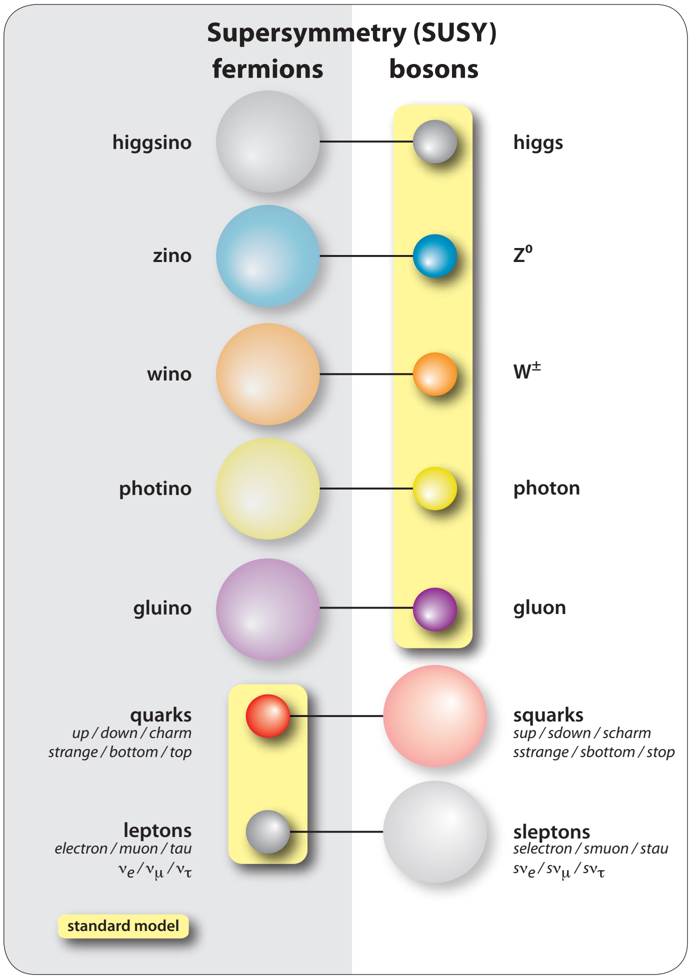
LEP
The Large Electron–Positron collider at CERN which ran until 2000. Its tunnel has been reused for the LHC.

Lepton
A class of elementary particles that includes the electron. Leptons are particles of matter that do not feel the strong force *(see also Particles).*

LHC (Large Hadron Collider)
CERN's accelerator which started in 2008.

HL-LHC (High Luminosity Large Hadron Collider)
Proposed upgrade of CERN's LHC to increase its luminosity (rate of collisions) by a factor of 10 beyond its design value.

LHCb (Large Hadron Collider beauty)
One of the four major experiments that uses the LHC.



Supersymmetry; for every type of boson there exists a corresponding type of fermion with the same mass and internal quantum numbers, and vice-versa.

Linac
An abbreviation for linear accelerator.

LISA (Laser Interferometric Space Array)
ESA/NASA mission concept; three spacecraft, orbiting around the Sun as a giant equilateral triangle 5 million km on a side. Superseded by ESA-only *e*LISA mission

eLISA (evolved LISA)
ESA only gravitational wave space mission, orbiting around the Sun as a giant equilateral triangle 1 million km on a side. Formerly known as NGO (New Gravitational Wave Observatory). Candidate for launch in 2028.

LOFAR (Low Frequency Array)
First radio telescope of a new generation of astronomical facilities, mainly in the Netherlands.

Medipix
A family of photon counting pixel detectors based on the Medipix CMOS read-out chips that can be provided with a signal from either a semi-conductor sensor or ionisation products in a gas volume. The detectors are developed by an international collaboration, hosted by CERN, and including Nikhef. Medipix-3 is the prototype that is currently in the development phase.

Meson
See Particles.

Muon
A particle similar to the electron, but some 200 times more massive (see also Particles).

Muon chamber
A device that identifies muons, and together with a magnetic system creates a muon spectrometer to measure momenta.

Neutrino
Uncharged, weakly interacting lepton, most commonly produced in nuclear reactions such as those in the Sun. There are three known flavours of neutrino, corresponding to the three flavours of leptons. Recent experimental results indicate that all neutrinos have tiny masses (see also Particles).

NLO (Next–to–Leading Order)
Second-order calculations in perturbative QED and QCD.

NWO
The Netherlands Organisation for Scientific Research funds thousands of top researchers at universities and institutes and steers the course of Dutch science by means of subsidies and research programmes.

Nucleon
The collective name for protons and neutrons.

Particles
There are two groups of elementary particles, quarks and leptons, with three families each. The quarks are named up and down, charm and strange, top and bottom (or beauty). The leptons are electron and electron neutrino, muon and muon neutrino, tau and tau neutrino. There are four fundamental forces, or interactions, between particles, which are carried by special particles called bosons. Electromagnetism is carried by the photon, the weak force by the charged W and neutral Z bosons, the strong force by the gluons and gravity is probably carried by the graviton, which has not yet been discovered. Hadrons are particles that feel the strong force. They include mesons, which are composite particles made up of a quark–antiquark pair, and baryons, which are particles containing three quarks. Pions and kaons are types of meson. Neutrons and protons (the constituents of ordinary matter) are baryons; neutrons contain one up and two down quarks; protons two up and one down quark.

Photon
See Particles.

Pierre Auger Observatory
International experiment in Argentina to track down the origin of ultra–high–energy cosmic rays.

Pion
See Particles.

Positron
The antiparticle of the electron.

Quantum electrodynamics (QED)
The theory of the electromagnetic interaction.

Quantum chromodynamics (QCD)
The theory for the strong interaction analogous to QED.

Quark
The basic building block of matter (see also Particles).

Quark–gluon plasma (QGP)
A new kind of plasma, in which protons and neutrons are believed to break up into their constituent parts. QGP is believed to have existed just after the Big Bang.

RASNIK (Red Alignment System Nikhef)
Optical alignment system where a pattern is projected by a lens on a CCD and deviations measured.

Relaxd (high-REsolution Large-Area X-ray Detection)
EU–funded development of the large area fast detector system using Medipix technology.

RHIC
Brookhaven's Relativistic Heavy Ion Collider; began operation in 2000. RHIC collides beams of gold ions to study what the Universe looked like in the first few moments after the Big Bang.

Scintillation
The flash of light emitted by an electron in an excited atom falling back to its ground state.

Spectrometer
In particle physics, a detector system containing a magnetic field to measure momenta of particles.

Spin
Intrinsic angular momentum of a particle.

Standard Model
A collection of theories that embodies all of our current understanding about the behaviour of fundamental particles.

STAR
Experiment at RHIC.

String Theory
A theory of elementary particles incorporating relativity and quantum mechanics in which the particles are viewed not as points but as extended objects. String theory is a possible framework for constructing unified theories that include both the microscopic forces and gravity (see also Forces).

Supersymmetry
Supersymmetry (often abbreviated SUSY) is a symmetry that relates elementary particles of one spin to other particles that differ by half a unit of spin and are known as superpartners.

SURFnet
Networking organisation in the Netherlands.

Tevatron
Fermilab's 2–TeV proton–antiproton accelerator near Chicago.

Tier–1
First tier (category) in the LHC regional computing centers. Tier–0 is the facility at CERN collecting, reconstructing and storing the data.

Trigger
An electronic system for spotting potentially interesting collisions in a particle detector and triggering the detector's read–out system.

Vertex detector
A detector placed close to the collision point in a colliding beam experiment so that tracks coming from the decay of a short–lived particle produced in the collision can be accurately reconstructed and seen to emerge from a 'vertex' point that is different from the collision point.

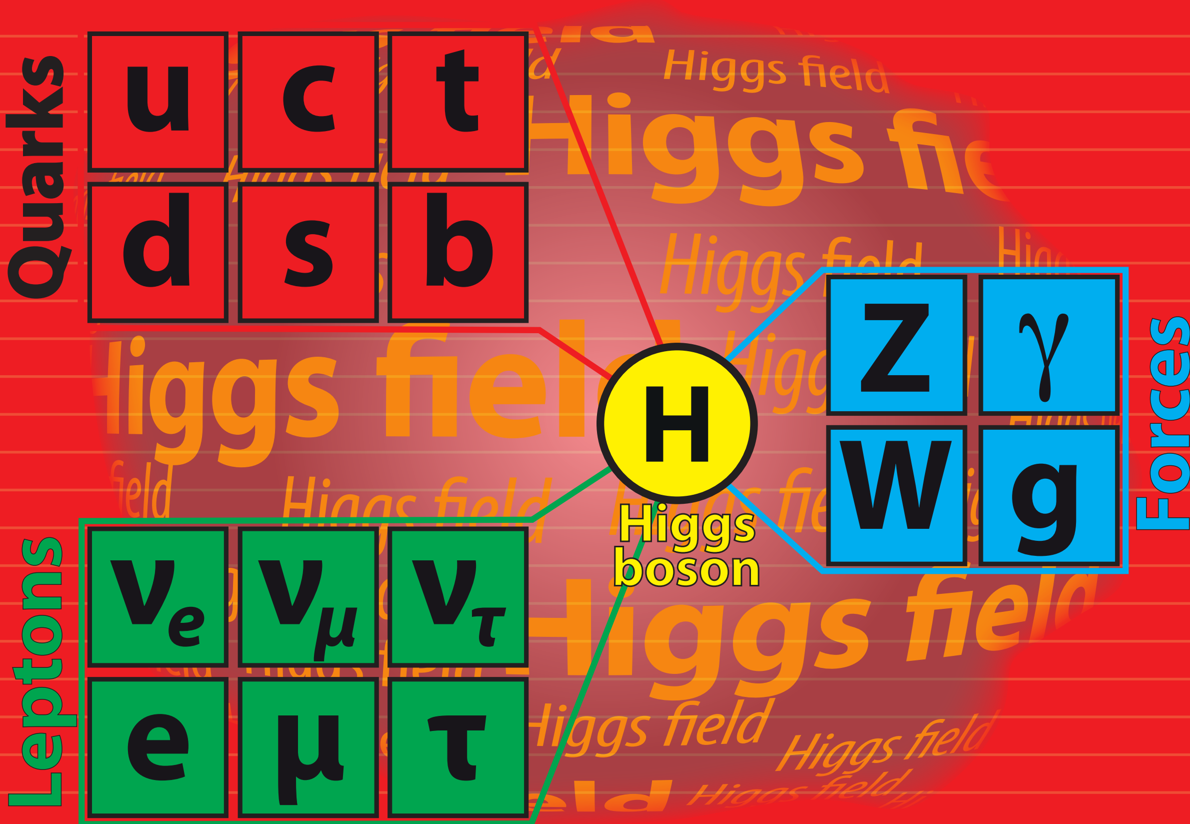
Virgo
Detector near Pisa for gravitational waves: a Michelson laser interferometer made of two orthogonal arms, each 3 km long.

W boson
A carrier particle of weak interactions; involved in all electric–charge–changing weak processes.

WIMP
Weakly Interacting Massive Particles are the most compelling candidates for *dark matter* particles. They can interact with normal matter through the weak nuclear force and through gravity and are often inherent to models extending the *Standard Model.*

XENON
A series of experiments aiming at direct detection of Weakly Interacting Massive Particles (*WIMPs*). The detectors are located in the Gran Sasso laboratory in Italy and use xenon as the target material.

Z boson
A carrier particle of weak interactions; involved in all weak processes that do not change flavour and charge.


Quarks
u c t
d s b
Leptons
νe νμ ντ
e μ τ
Forces
Z γ
W g
H
Higgs boson
Higgs field

Nikhef