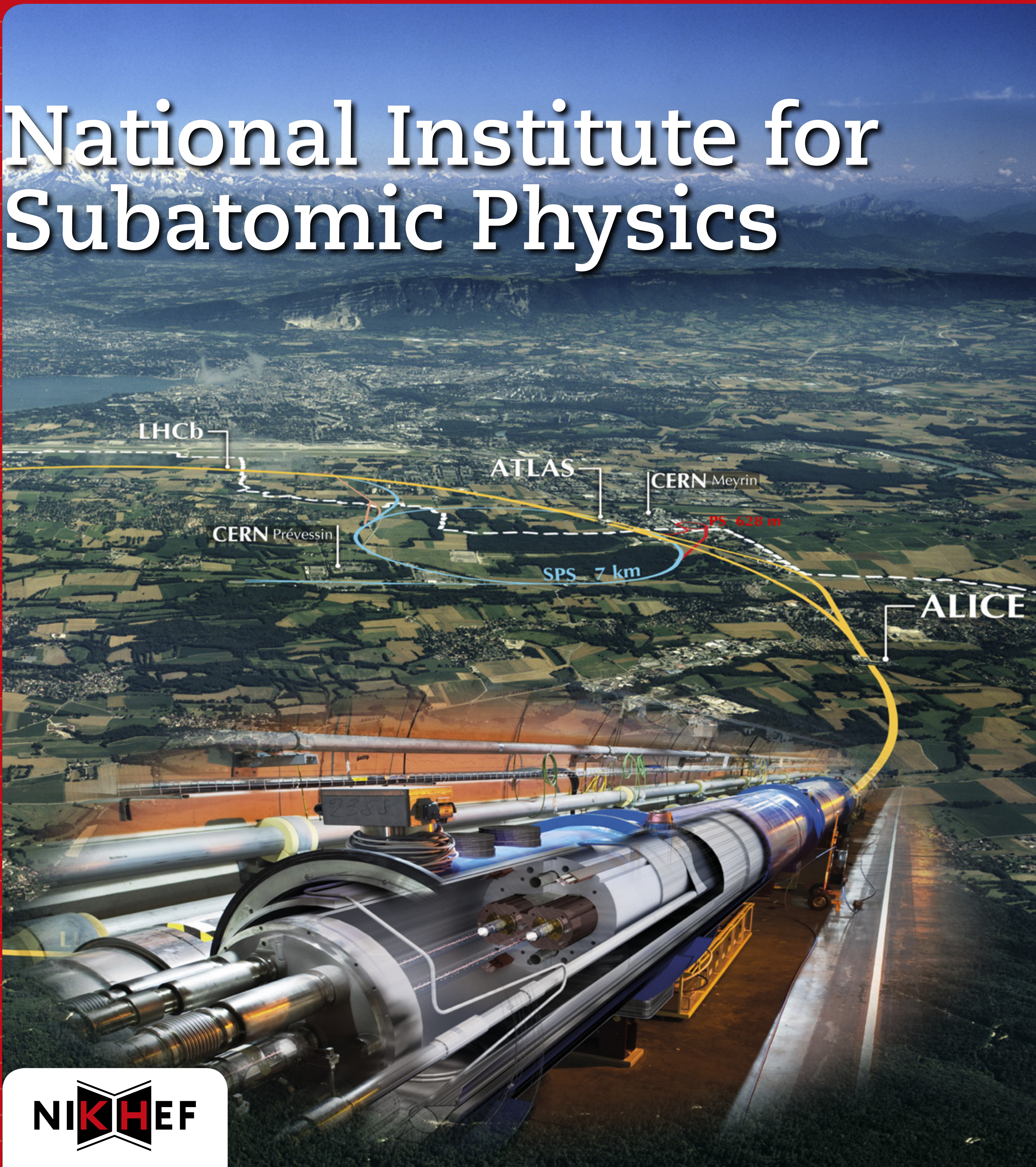
Annual Report 2010

Nikhef



Annual Report 2010

National Institute for Subatomic Physics Nikhef

Colophon

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Cover: Large Hadron Collider at CERN, Geneva, Switzerland

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 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 facility operated by the Grid group. Nikhef has a theory group with both its own research programme and close contacts with the experimental groups.

Contents

Introduction

My introduction in Nikhef's Annual Report 2009 concluded with: *"For 2010 I can be really brief: let the LHC deliver a significant fraction of 1 fb^{-1} integrated luminosity at multi-TeV centre-of-mass energy!"* With about 50 pb^{-1} delivered at a world-record centre-of-mass energy of 7 TeV the Large Hadron Collider (LHC) came close to fulfilling my desire. With a peak luminosity of 2×10^{32} cm^{-2}s^{-1} with only 15% of the available bunches filled, the design LHC luminosity (10^{33} cm^{-2}s^{-1} for the first three years and 10^{34} cm^{-2}s^{-1} thereafter) seems within reach. What really surpassed even my most optimistic expectations: already with this modest 2010 dataset the four LHC experiments basically rediscovered half a century of particle physics, culminating in the first observation of 'European' top-quarks. And to really top it off, the switch from proton-proton to heavy-ion (lead-lead) collisions in the last month of the 2010 LHC run went extremely smoothly and resulted already in several very interesting results e.g. the clear suppression of jets in lead-lead collisions in comparison to proton-proton collisions. All this sets high expectations for the LHC's future. I eagerly look forward to the first real discovery at the LHC, supersymmetry, the elusive Higgs-particle or the totally unexpected alike!

2010 was also a reality check for Nikhef's LHC Tier-1 (NL/Tier–1) grid compute facilities. Despite the occasional frustration of the local Nikhef user community, which could not always easily access the data directly, the overall NL/Tier–1 performance (throughput, uptime, …) met the worldwide LHC compute grid specifications. Meanwhile, within the BiG Grid project new grid-compute user communities are actively scouted for as was e.g. evident at the well-attended joint BiG Grid user and the first European Grid Initiative technical forum event in September. Regarding the prospect of structural funding of the Dutch grid-compute infrastructure, positive developments were the approval of the e-Science Research Center (to be located at Science Park Amsterdam) and the award of the first 2 M€ subsidy (out of hopefully four) by SURFnet.

For astroparticle physics research 2010 was an eventful year. The turn-down of the '*NWO-groot*' investment proposal to complement the Pierre Auger Observatory for cosmic-rays in Argentina with a prototype radio-antenna array was a major disappointment. Better news came from KM3NeT, the European consortium that envisages building a multi-km^3 neutrino telescope at the bottom of the Mediterranean Sea. The baseline technology for the optical module is now the multi (31) photomultiplier-tube concept pioneered by Nikhef, while the mechanical structure will be based on the bar-concept advocated by our Italian colleagues. KM3NeT funding remains a major challenge, in particular

Tristan du Pree receives the 2010 Jan Kluyver-Prize for the best thesis summary in English from the hands of Karel Gaemers, chair of the jury and former Nikhef director.

given the present economic crises. The Virgo gravitational-wave observatory in Italy concluded its science run mid-2010, which signaled the start of the advanced-Virgo project. Nikhef took major responsibilities in this upgrade project that should boost the sensitivity by an order of magnitude by 2015. In 2010 Nikhef also started a new astroparticle research line by joining the XENON100 and XENON1T experiments. These experiments aim at the direct detection of dark matter using a xenon-filled time projection chamber operated at the deep-underground and therefore low-background Gran Sasso laboratory in Italy. With these four state-of-the-art endeavors, astroparticle physics is, a decade after its start, a mature activity at Nikhef. I hope that before the end of the present decade astroparticle physics will yield at least one major breakthrough.

A novelty in 2010 was the award of the Jan Kluyver-Prize to LHCb PhD student Tristan du Pree for the best thesis summary in English. The jury in particular appreciated Tristan's clear presentation of the research challenge ("What is the matter with antimatter?") and his use of illustrations. I hope that this Jan Kluyver-Prize will stimulate many future PhD students at Nikhef to deliver a thesis summary that can be understood by a much wider audience than is presently the case.

At the Nikhef institute itself, 2010 also brought some changes. The mechanical engineering department and workshop became the integrated Mechanical Technology department. Nikhef's e-mail services were successfully upgraded and a modern telecom system based on Voice over IP (VoIP) was ordered. Construction work inside and directly outside the Nikhef buildings (new data centre, green cooling infrastructure, parking facilities, etc.) are near completion.

In the area of technology transfer, Nikhef's Rasnik alignment system was for the first time used in real life to monitor movements in the Weena tunnel in Rotterdam. Rasnik is now exploited commercially by Nikhef's first start-up company: Sensiflex B.V. Jos Vermaseren's world-renowned algebraic manipulation package FORM was converted to Open Source. In October, Nikhef helped to organise the highly-appreciated Holland@CERN event in Geneva where numerous Dutch companies displayed their products and engineering expertise to CERN's user community.

For outreach and publicity 2010 was once again a fantastic year. The first 7 TeV centre-of-mass energy collisions in the LHC made it to the eight o'clock (and ten o'clock) news and to a major talk show on Dutch television. This was really very special, even more so because Nikhef's management and mechanical department experienced this together at a mechanics brainstorm session in Bergen aan Zee. Cosmic-rays were also center-stage in 2010, with the opening of a Nikhef sponsored cosmic-ray exhibition in the NEMO science museum in Amsterdam and the Cosmic Sensation dance event in Nijmegen.

2011 will foremost be interesting because it promises more than an order of magnitude increase in the LHC data sample and if Nature is kind this might reveal the first glimpses of physics beyond the Standard Model, e.g. supersymmetry. In addition, 2011 will be very important for Nikhef from an entirely different perspective: in September FOM-Nikhef will, like all other NWO institutes, be evaluated. The outcome of this evaluation will impact Nikhef's (financial) future.

Frank Linde
Nikhef director

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Reviews

1.1 The gang of four

Martinus Veltman

The history of the NIKHEF has been published several times, in particular there is an overview due to Tiecke that may be found at the NIKHEF website[1]. Yet there is a strange gap, namely the period 1973-1976. What happened?

Let me first briefly review what happened until 1973. Concerning high energy physics people were often holding meetings that in general did not result in any practical progress. The reason for this lack of progress had to do with the integration of the various groups. Basically, there were the following groups:

- The Amsterdam group, located in the Zeeman laboratory directed by Kluyver;
- The Nijmegen group under the direction of Van de Walle;
- A group under the direction of Sens working at locations such as CERN;
- The Amsterdam nuclear physics group, located in the IKO.

In 1965 the NIKHEF was essentially born, to be built at the present location. Other than that nothing happened. In 1968 or so there was a lot of commotion, because the RAWB (a committee advising the government) brought out an advice against participation at CERN and encouraging nuclear physics, in particular the IKO, the Amsterdam institute for nuclear-physics research. Noteworthy members of the RAWB were Casimir (Philips) and Böttcher (Chemistry, Leiden). Philips had been involved with the IKO, giving them a cyclotron. Personally I was flabbergasted that Casimir was so anti-CERN. I tried to organize opposition but I was very ineffective. I had a friend who had been active in the underground during the war, and he was one of the founders of the daily journal *"Het Parool"*. He then used his influence there, resulting in an interview of me done by J.J. Peereboom (not the sports journalist). I think Peereboom never really understood what I was telling him. For some more details see an interview of me by Wigmans (NTvN **B49**, 3 (1983) 97), as well as the ensuing reactions.

At that time (1968) CERN was about to construct the Intersecting Storage Rings. Not long thereafter the planning for the 300 GeV machine (the SPS) was started. Meanwhile, another committee, the WRK (Scientific council for Nuclear energy) led by Van Bueren (Astronomy, Utrecht) came in 1970 with a radically different advice: support CERN and the construction of the SPS (see Fig. 1), coordinate all high energy and nuclear physics activities. This meant in particular coordination of the Amsterdam high energy group and the Nijmegen group. In 1972 the government gave in principle permission to start with the NIKHEF, provided the

This article deals with the time that the official name of the institute was spelled 'NIKHEF' in capitals. We preserved that spelling in the text, although since 2007 we write 'Nikhef'.

Figure 1. Last stage of preparation in the SPS tunnel at CERN (April 1976).

recommendations made by the Van Bueren committee were implemented. This turned out te be very difficult. In particular, Nijmegen had invested heavily in high energy physics, and was not really prepared to make concessions on that.

Funny things happened. Brinkman (Experimental physics, Groningen), bypassing and upsetting everybody, succeeded in getting a cylotron in Groningen that started operation in 1970. Furthermore, there was a plan for the construction of a 300 MeV linear electron accelerator (MEA) in Amsterdam. In those paternalistic days (prior to 1970) physics was run by Casimir and De Boer (theoretical physics Amsterdam and then chairman of the FOM council), and De Boer had bulldozered the MEA proposal through a hearing in Utrecht. I am still mad when I think about that meeting. I had brought in Telegdi (Experimental physics, University of Chicago) as foreign expert, and De Boer tried to effectively block that by insisting that the language at the meeting should be Dutch. Telegdi responded by asking if he could answer in English. Both De Boer and Casimir were clearly in favour of expanding nuclear physics rather than high energy physics. To this day I find that unbelievable. Neither of them ever did nuclear physics.

So what now? The government had approved the NIKHEF and in principle the money was available, but the participants did not seem to be able to reach an agreement. Effectively nothing happened.

1. http://www.nikhef.nl/fileadmin/Doc/Docs%20%26%20pdf/historynikhef.pdf

Dramatis Personae

Prof.dr. J. de Boer, *professor of theoretical physics Amsterdam 1946-1981, president of the FOM board 1959-1981*
Dr. A.A. Boumans, *director of FOM 1963-1984*
Prof.dr. H. Brinkman, *professor of experimental physics Groningen 1950-1980, director of KVI 1968-1972*
Prof.dr. C.J.F. Böttcher, *professor of physical chemistry Leiden 1947-1980, co-founder of the Club of Rome, first president of the RAWB 1966-1974*
Prof.dr. H.B.G. Casimir, *professor of theoretical physics Leiden 1938-1942, director and member of the board of Philips 1946-1972, member of the Curatorium of IKO 1946-1972, president of KNAW 1973-1978 and EPS 1972-1975*
Prof.dr. C. Daum, *professor of high-energy physics Twente 1991-1996*
Prof.dr. A.N. Diddens, *professor of physics Leiden 1979-1994, first director of NIKHEF section H 1976-1982*
Prof.dr. P. Duinker, *professor of experimental physics Nijmegen 1988-2001*
Prof.dr. D. Harting, *professor of experimental physics Amsterdam 1964-1988*
Prof.dr. W. Hoogland, *professor of experimental physics Amsterdam 1988-2005, director NIKHEF section H 1983-1988, scientific director CERN 1989-1993*
Prof.dr. E.W. Kittel, *professor of experimental physics Nijmegen 1973-2003*
Prof.dr. J.C. Kluyver, *professor of experimental physics Amsterdam 1960-1986, director Zeeman laboratory 1960-1980, secretary of the Curatorium of IKO 1960-1980*
Prof.dr. G. van Middelkoop, *professor of experimental physics VU Amsterdam 1979-2001, director NIKHEF section K 1983-1988 and NIKHEF 1996-2001*
Prof.dr. A. Pais, *professor of theoretical physics in Princeton 1950-1963 and at Rockefeller University in New York 1963-1988, science historian*
Prof.dr.ir. J.C. Sens, *professor of experimental physics Utrecht 1966-1993*
Prof.dr. H.G. van Bueren, *professor of solid state physics Delft (1962-1965) and scientific director IRI Delft (1962-1965), professor of astronomy (1965-1979) and astrophysics (1979-1981) Utrecht, president WRK 1967-1975, president RAWB 1979-1989*
Prof.dr. M.J.G. Veltman, *professor of theoretical physics Utrecht 1966-1981, Ann-Arbor 1981-1996, Nobel Prize physics 1999*
Prof.dr. R.T. Van de Walle, *professor of experimental physics Nijmegen 1963-1996*

Figure 2. Gang of four. From upper left clockwise: Dick Harting, Wolfram Kittel, Hans Sens, Tini Veltman.

Then, somewhere in 1973, Sens visited me in my office in Utrecht. He proposed to make a committee and asked me to be part of that. It was the strangest thing. The committee was not proposed by anybody else, there was thus no task description and finally, what did I have to do with it, being a theorist? In retrospect I think that I was needed to act as a buffer between the parties. Personally I was somewhat reluctant, because I had just gone through a bruising experience with two committees (I was the chairman of both), namely one to reform the physics teaching program in Utrecht, and one about getting a new computer and initiating a new institute (the Academic Computer Centre Utrecht) running that computer.

However, I accepted. Sens went ahead and asked the FOM to provide us with a meeting room. Furthermore, he invited representants from Amsterdam and Nijmegen, namely Harting and Kittel, respectively. Kittel joined in March 1974 the experimental high energy group of Van de Walle in Nijmegen. Harting became our chairman. And so the first meeting was held in Utrecht, in a room in the FOM building. I recall it as a weird thing. Here we were, without task, talking in the wind and who is going to listen to us? Somewhere in the beginning we (?) organized a big meeting for everyone interested. This meeting was held in the Frommer Hotel at Schiphol Airport. There, Hoogland and others presented their plans. I am unsure about the date of this meeting. Perhaps as early as 1973. But let us go back to the committee: Sens, Harting, Kittel and myself (see Fig. 2).

Well, there are no notes of the meetings and I do not remember how things went in detail. Both Sens and Harting are no longer available, which leaves Kittel and me, and Kittel's memory is rather vague as well. I do not think all participants mentioned were present in the first few meetings. Anyhow, let's continue. Basically, we were acting as if we were running NIKHEF-H, NIKHEF's high energy section. Gradually, over the course of several meetings the powers higher up became interested. So much so, that in 1974 an interim governing board of the NIKHEF was initiated, with Brinkman as chairman. I think that I was present at the meeting were this was done because Boumans, then FOM director, remembers some anecdote involving me: it seems that I supported Brinkman on the ground that his manipulations leading to the Groningen machine showed that he was able to achieve things. One of the actions of this board was to call us the WPC (Scientific Program Committee) and make us official, giving us the task to develop a scientific program. And so we did. In fact, we were more or less acting as if we were the directorate of NIKHEF-H. I believe that in the interim board very little physics was ever discussed.

The WPC committee was a good one. I can best quote Kittel here: *"I think that I learned a lot in the WPC. The discussions were always friendly and there was open and frank collaboration but nonetheless the committee was very businesslike. In fact, I have never encountered another committee that worked as well as the WPC"*.

What did the WPC do? We talked often about money. I vaguely remember that we talked about a NIKHEF-H budget of 10 million guilders. A scientific collaborator costed about 100,000 guilders for salary and equipment. First, we discussed a lot about the money going to BEBC (the Big European Bubble Chamber), ACCMOR (the collaboration involving a group in Amsterdam led by Hoogland) and CERN. But secondly, we initiated new activities. Without any attempt at completeness some will be mentioned here.

We felt that we should develop some activity at DESY (Hamburg) and we asked Duinker to become active there. See his biography titled *"Zwanenzang"*[2] (in Dutch). He joined the MARK-J experiment of Ting. That collaboration later formed the core of the L3 experiment at the LEP electron–positron collider at CERN.

Kittel proposed the NA22 experiment. This was a hybrid experiment in a 250 GeV beam, involving a fast bubble chamber with 40 meter downstream a lot of electronic apparatus. The NIKHEF-H invested much money in large drift chambers exploited at CERN. That experiment, for which Kittel was the spokesperson, led to a large number of publications, high up in the citation lists.

Later on, the WPC also discussed the NIKHEF-H building plans. Harting was chairman of the construction committee, with Daum as a member doing much of the actual work (see Fig.3).

2. http://www.nikhef.nl/~d82/zwanenzang.html

To my knowledge nuclear physics – the realm of NIKHEF section K – was never discussed in the WPC.

17 May 1975 the various parties signed the NIKHEF agreement. Hoogland told me about the difficulties to get everybody to sign. Personally I remember Van de Walle rather sourly congratulating the Amsterdam people with their extension of the Zeeman laboratory. I must add that I truly appreciated the fact that the Nijmegen people in the end decided to sign the agreement.

At the WPC we discussed about the director and proposed Sens, with the added restriction that he would still spend half the time at CERN. Somewhere in that period I discussed with Pais, trying to persuade him to come back to the Netherlands and be director, but he declined. He was busy writing his book about Einstein. In the end, 1 July 1976, without going into details, Diddens (originally from Groningen then employed by CERN, not from Amsterdam or Nijmegen) became director. The WPC was replaced by another committee created by the director. And that was it.

In retrospect, both Kittel and I believe that the WPC did put NIKHEF-H on the correct physics track. We did not bother to make official notes, and in fact, in an overview by Harting about the past and future of the NIKHEF (NTvN **A34** (1977) 39) the WPC was not even mentioned! Perhaps there is still some information hidden in the FOM archives deposited in the Noord-Hollands Archief in Haarlem, but I leave the task of looking it up to someone else. There is only one thing I like to say: in this kind of things if you first make the physics clear then eventually the rest will follow.

I would like to thank Kittel, Van de Walle, Duinker, Daum, Diddens, Hoogland, Van Middelkoop, Gaemers and Boumans for their help in trying to reconstruct this part of the actual history of the NIKHEF.

Figure 3. Nikhef-H building, as it was in the early 1990s.

1.2 Theoretical physics and the LHC

Jan-Willem van Holten

Since the fall of 2009 the Large Hadron Collider (LHC) at CERN in Geneva provides colliding beams of protons and nuclei to four large particle detectors situated at various points along its circumference. The results of these LHC experiments are expected to have great impact on theoretical particle physics. Will the Standard Model be confirmed in its minimal form, or will it turn out to be richer and more complex than expected? Will there be signs of completely new physics beyond the standard-model framework, and if so, in what direction do they point?

The Standard Model of particle physics is very successful in describing the properties and interactions of subatomic matter: quarks and leptons, from very light neutrinos to the very massive top quark (see Fig. 1). As such it unifies the description of constituents of matter ranging in mass from about 10^{-2} eV to 10^{11} eV, a range of thirteen orders of magnitude. Three different kind of interactions are known to take place between these particles. First, the strong interactions bind quarks into massive particles like the proton and the neutron, the constituents of nuclear matter. Second, the electromagnetic interactions bind electrons to atomic nuclei at larger distances, ten to a hundred thousand times the diameter of the nucleus itself. Finally, the weak interactions manifest themselves in the transmutation of particles, e.g. in β-decay or in the conversion of neutrino's to charged particles.

What these interactions have in common, is that they are transmitted by the exchange of spin-1 particles, collectively referred to as *vector bosons* (see box 1). More specifically, the set of eight vector bosons known as gluons mediate the strong interactions, whilst the photon is the vector boson responsible for the electromagnetic interactions. Both gluons and photons are massless, and always travel at the speed of light. In contrast, the W- and Z-bosons mediating the weak interactions are very massive: almost a hundred times more massive than a hydrogen atom. Their large mass limits the range of the weak interactions to distances of the order of 0.01 fm, small even compared to the size of atomic nuclei, which are in the range of 1–10 fm.

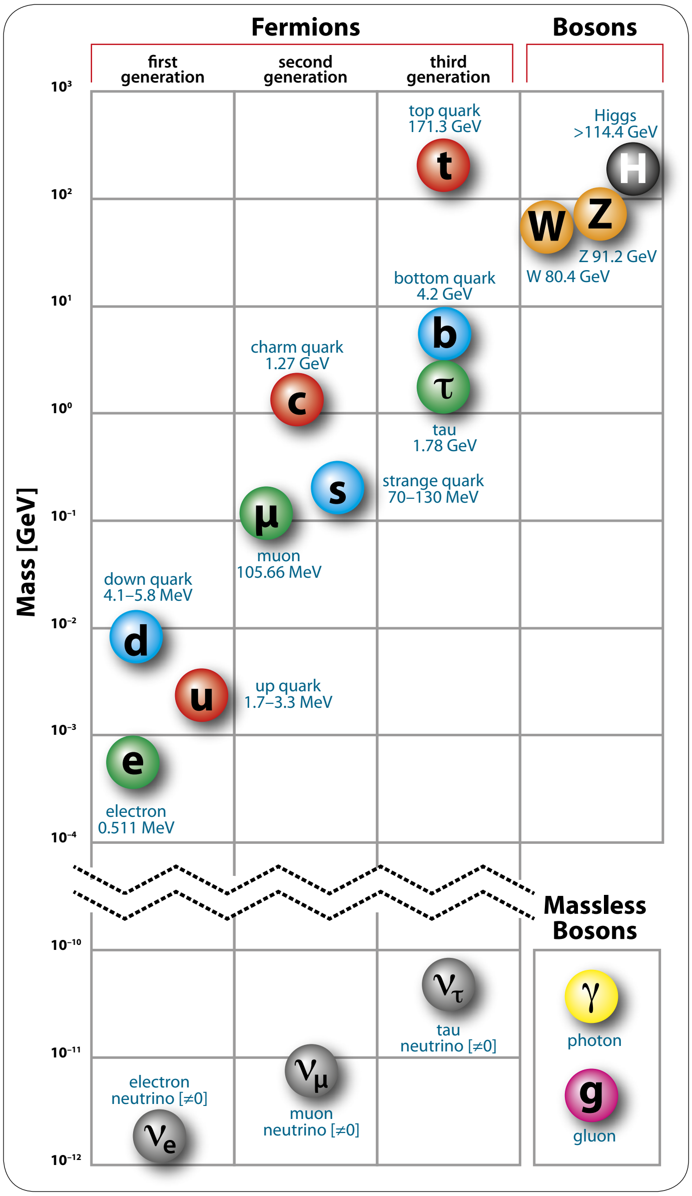

Figure 1. Particles in the Standard Model arranged according to mass (vertical scale) and species (horizontal).

A main theme of research at the LHC is the origin of the mass of the weak vector bosons. This is an issue for theoretical physics, because the dynamics of particles is governed by relativistic quantum theory, a very restricted set of rules for computing the effects of particle interactions. In this framework vector particles are the quanta of a special kind of fields: gauge fields, which generically describe only massless particles. However, the quanta of gauge fields can effectively behave as massive particles by interacting with a condensate of weakly charged particles in the vacuum (see box 2). The continuous scattering of weak vector bosons by the weak charges filling space affects their propagation and makes them behave non-relativistically at low energies. This mechanism was first proposed in the context of particle interactions by Robert Brout and François Englert. The question then is what creates the condensate of weak charges. The simplest model was proposed by Peter Higgs: a condensate of spin-0 particles, associated with a scalar field taking a constant,

What defines a particle?

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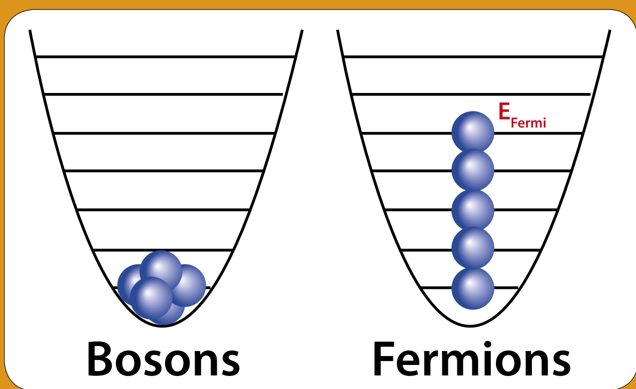
Subatomic particles can not be seen literally. We identify particles by their effects in interactions with other particles, and ultimately with an apparatus registering these effects. What we call a particle is an object recognized by its capacity to carry and transfer well-defined amounts of energy, mass, electric charge and other elementary physical quantities. Of these quantities the electric charge determines how strongly a particle interacts with an electromagnetic field, the color charge determines the strength of interaction with the strong-interaction field, whilst the mass and energy determine the state of motion through space-time, and as such are associated with the gravitational forces. There is one more important quantity characterizing particles: the spin. Spin is the amount of intrinsic rotation that a particle carries and that it can not get rid of. Just like electric charge, spin appears in integer amounts of a fundamental unit: $\hbar/2$. Similar to mass, spin also affects the way a particle moves through space-time and how it responds to gravity.

What makes subatomic particles special, is that they are *completely* characterized by this small, very restricted set of elementary quantities. Actually, subatomic particles of the same species are all *identical*, not just in the sense that they possess the same properties, but in the sense that they are absolutely indistinguishable: if you don't keep track of them for even a split second, you can no longer tell which one is which, not even as a matter of principle. Even so, two basic types of particles exist. There are particles which can be in the same state: same species, same energy, same spin, in arbitrary numbers. Such particles are called *bosons*; the photon is an example. There are also particles of which there can be at most one in any single state, called *fermions*; electrons are fermions. A fundamental implication of quantum theory is, that bosons always carry an even number of units of spin (an integer times $\hbar$), whereas fermions always carry an odd number of spin units (a half-integer times $\hbar$).



Bosons can all reside in the same quantum state (horizontal lines), whereas fermions can each occupy only one state.

non-zero value everywhere in space. If the Higgs-model is correct, an associated neutral spin-0 particle should exist and turn up in the high-energy proton-proton collisions at the LHC, the widely advertised Higgs-boson.

More complicated scenarios can be imagined. For example, there might be more than one kind of weakly charged scalar field contributing to the vacuum condensate; in this case, there will exist more than one kind of Higgs particle, among which some may carry electric charge. Or the condensate might find its origin in strong pairing interactions between a new type of matter particles, just like the pairing interactions between electrons give rise to the condensate of Cooper pairs in superconductors. This scenario necessarily requires also the existence of a new type of strong interactions, mediated by gluon-like massless vector bosons. As the three types of strong-interaction charges of quarks are usually labeled by the colors red, green and blue, by analogy these hypothetical new interactions are sometimes called technicolor interactions.

The interactions of particles in the Standard Model obey certain strict conservation laws, most importantly the conservation of electric charge and the conservation of color charges. From the theoretical point of view these conservation laws are firmly rooted in the theory of electromagnetic and strong interactions, and are an unavoidable consequence of the mathematical formalism. But there are also conservation laws which are supported by experimental observations without strict theoretical foundation. Among these are the conservation of baryon number (essentially, the number of quarks minus the number of anti-quarks) and the conservation of lepton number (the number of leptons minus the number of anti-leptons). In fact, although rare and so far not observed, the Standard Model predicts processes violating these conservation laws.

In contrast, the difference of baryon and lepton number (the excess of baryons over leptons or vice versa) could be truly conserved in full agreement with the minimal Standard Model: if violations of the conservation of baryon-minus-lepton number were observed, this would necessarily imply the existence of new interactions which are not part of the minimal Standard Model, for example interactions turning neutrinos into anti-neutrinos. How would such interactions be mediated? In principle a strictly conserved baryon-minus-lepton number could act as charge for a new massless vector boson, interacting with this charge just like photons interact with electric charge. Such interactions would then be abundant and readily observable, in contradiction to the established facts. However, if there were a vacuum condensate of baryon-minus-lepton charge, the new vector boson would become massive, whilst processes violating the conservation of baryon-minus-lepton charge would become possible, as it can be dumped into or extracted from the condensate. Hypothetical massive vector bosons such as the one associated with this charge are generically called Z′-bosons. This scenario also implies the existence of a new Higgs-type particle associated with the condensate of baryon-minus-lepton charge. The LHC-experiments can either set limits on the possibility for such new weak interactions to exist, or they will eventually find Z′-bosons.

The Brout-Englert-Higgs mechanism is not the only scenario for expecting scalar particles to turn up at the LHC. A large number of heavy spin-0 particles is expected if supersymmetry is realized in nature. Basically, supersymmetry supposes all particles to exist in pairs of a boson and a fermion with the same charges under any interaction (see Fig. 2). In this scheme any quark or lepton will have a spin-0 partner with the same electric or strong color charge, which is realistic only if these particles are all quite a bit more massive than most quarks and leptons themselves.

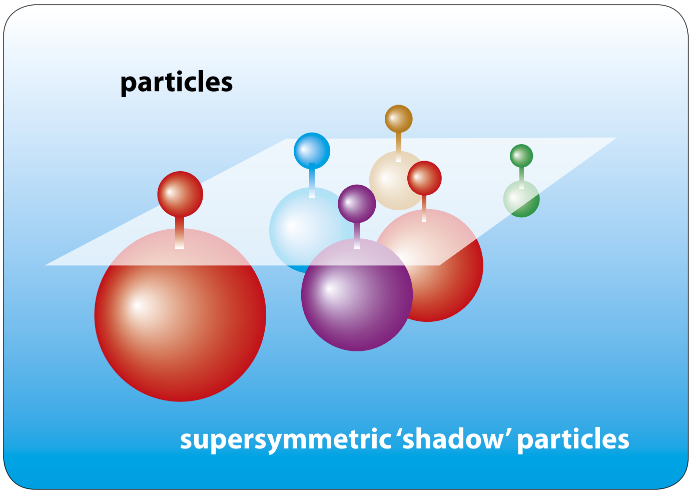


Figure 2. In supersymmetry all particles (bosons and fermions) have a -more massive- partner with the same quantum numbers except spin. Hence all bosons have a supersymmetric fermion partner and vice-versa.

At the same time, supersymmetry also predicts new matter particles as partners of the vector bosons, such as neutral spin-½ partners of the photon and the Z-boson. The existence of such particles could explain the mystery of dark matter in astronomy. This mystery arose from detailed studies of the motion of stars and galaxies, which point to the existence of large amounts of non-luminous matter in the Universe. It is possible that this dark matter consists predominantly of neutral supersymmetric partners of the photon and/or Z-boson and/or Higgs particle left over from the Big Bang[1].

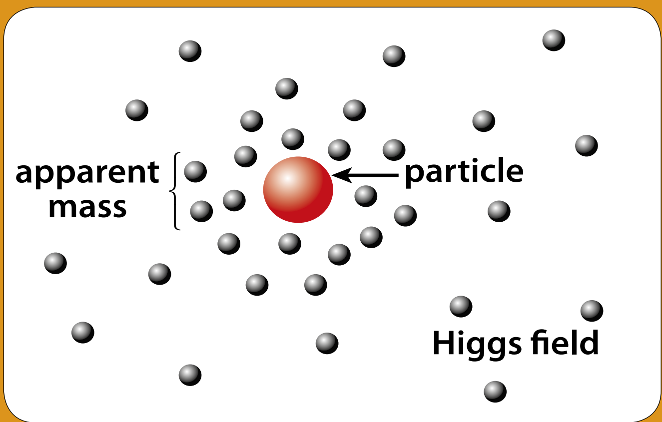
An important argument for supersymmetry comes from attempts to develop a consistent quantum theory of gravity. On subatomic scales gravity is too weak a force to have any observable effects. However, gravity has certainly played a dominant role in the very early Universe, long before stars and galaxies were formed. Therefore, a complete understanding of our Universe to the earliest times and the smallest distances does require fitting gravity and quantum theory together. Supersymmetry generally seems to be helpful in this quest. One straightforward prediction of supersymmetric gravity theories, or *supergravity*, is the existence of a gravitino, the spin-3/2 partner of the graviton; the gravitino is another potential dark matter particle. But supergravity could be a manifestation of a more radical scenario for the fundamental constituents of matter and their interactions: superstring theory (see Fig. 3). In this scenario all known particles including the graviton are represented by different states of a

1. This topic was reviewed in Nikhef Ann. Rep. 2009.

Condensates and the Brout-Englert-Higgs effect ②

As used here in the context of particle physics the word *condensate* has a particular meaning. In quantum theory the state of empty space is called the vacuum. But the word *empty* has to be taken with a grain of salt. First of all, quantum theory implies the existence of vacuum fluctuations: virtual particles of all kinds which can not be observed individually, but which do influence the propagation and interaction of real particles traveling through empty space, or making up atomic matter. Secondly, there can be static fields in the background which have similar effects. In experiments one usually tries to eliminate such fields, for example by using a Faraday cage to screen electric fields, or Helmholtz coils to compensate magnetic fields. But gravitational fields, for example, can not be eliminated by any such means.

In the Brout-Englert-Higgs scenario the Universe is filled with a constant background scalar field. Quantum theory describes these background fields as a coherent collection of virtual particles. If these particles carry some kind of charge, the vector bosons interacting with this charge are continuously scattered, like photons in a crystal of ions and electrons. Such a coherent state of virtual particles is what we here refer to as a condensate. According to the Standard Model the Universe is filled with a condensate of weak charges, affecting the propagation of the W- and Z-bosons, but not that of photons or gluons.



Left panel: An initially massless particle acquires apparent mass by interaction with the Higgs field. Right panel: Analogy: a movie star becomes hard to move because of interaction with the crowd of fans.

single elementary object, a tiny one-dimensional string vibrating and moving in ten space-time dimensions. The reason we don't normally observe nine space-dimensions is supposed to be, that quarks and leptons are confined to move in a three-dimensional hypersurface, or *brane*, representing our Universe. In contrast, gravity acts in all nine dimensions, which may explain why it is so much weaker than the other interactions.

From a theoretical point of view the superstring proposal has many attractive features: it can consistently combine gravity and quantum theory and it unifies all interactions and all forms of matter. Unfortunately the number of superstring configurations is so large, that it is virtually impossible to figure out top-down the ones relevant to the description of our Universe. Still, the study of superstrings has opened new avenues in the mathematical understanding of quantum systems, in particular by uncovering relations between the properties of a weakly interacting gravity theory acting in a specific type of space-time, and a strongly interacting field theory in a lower-dimensional space formed by the boundary of the original space. These relations, which go by the name of AdS/CFT duality, allow one to calculate properties in the weakly interacting gravity theory, and translate them into properties of a strongly interacting system which lives on the boundary of the space. The procedure has turned out to be quite useful for the understanding of certain condensed-matter systems. In particle physics it has found an application to the description of the quark-gluon plasma created in heavy-ion collisions, which seems to behave like a strongly interacting ideal

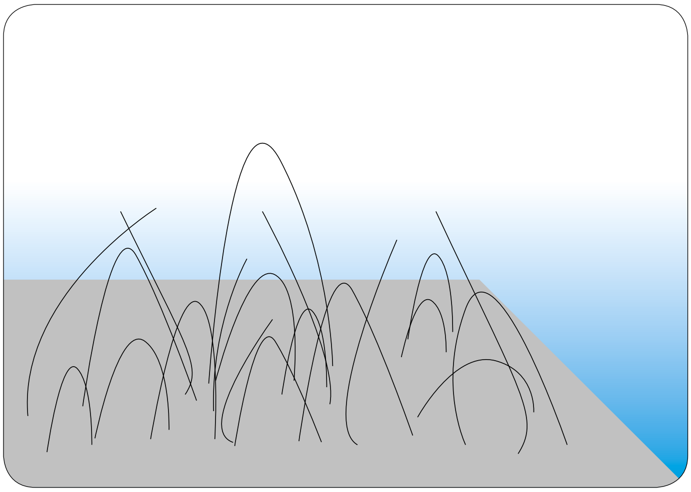


Figure 3. Superstrings (curved lines) live in nine space dimensions, but we observe them only as their intersections with everyday three-dimensional space (represented by the grey surface).

fluid. Such a fluid, which was an important component of the primordial matter in the early Universe, is studied under laboratory conditions in the collisions of heavy nuclei at the LHC.

A final theoretical issue on which the LHC may shed light is the origin of the matter-antimatter asymmetry in the Universe[2]. The present apparent abundance of matter over anti-matter can be explained if in the early Universe there were ten billion plus one protons for every ten billion antiprotons. This is a small difference which might result from very weak effects in the Standard Model, the violation of *CP*-symmetry, where *C* stands for particle-antiparticle interchange, and *P* for left-right interchange, as in a mirror. Indeed, not all Standard Model processes are invariant under such interchanges. However, presently we do not know whether the standard-model effects suffice for an explanation of the observed matter-antimatter asymmetry. A careful study may reveal whether other sources of *CP*-violation are required, and what their origin might be.

Many of the questions the LHC is addressing have arisen as a consequence of developments in theoretical physics. Now that experimental results are arriving, they will no doubt strongly influence the direction of theoretical model building in the years to come.

2. This topic was reviewed in Nikhef Ann. Rep. 2006.

2

Research

2.1 ATLAS
Re-discovery of 20th century particle physics

Management: prof.dr. S. Bentvelsen (PL)
prof.dr. N. de Groot
prof.dr.ir. P. de Jong
Running period: 1997–2015

2010 was by all means a remarkable year for ATLAS. Finally, high energetic collisions of protons were delivered and recorded by the ATLAS detector. The performance of the detector was found to be excellent and already the first publications are indicative for the huge potential of the ATLAS physics programme.

The very first events were recorded just seconds after 'stable beams' of 3.5 TeV each were declared on 30 March. By the end of 2010, the recorded luminosity for proton-proton collisions in ATLAS was a good 45 pb^{-1}, corresponding to a total of 3.2×10^{12} collisions. In addition, 9.2 μb^{-1} of heavy-ion collisions were recorded at the end of the year, corresponding to 6.5×10^5 events. A total of 21 publications, each with more than 3000 authors, were submitted by the collaboration to various journals. In at least eight of them Nikhef scientists have made a dominant contribution.

Throughout the year, the ATLAS trigger and data acquisition systems proved to be able to cope with the increasing instantaneous luminosity, which reached a maximum of 2.1×10^{32} $cm^{-2}s^{-1}$. The overall luminosity-weighted data taking efficiency of ATLAS in 2010 was 93.6%, which includes the read-out dead time and the warm start of the run. All sub-detectors were nearly completely functional during the running periods. For example, 99.5% of the muon drift tubes, constructed and installed by Nikhef scientists and others, were operational. The SCT end-cap detectors, of which the construction and installation was one of the other major Nikhef responsibilities, were also performing outstandingly and a total of 99.2% of the channels was operational.

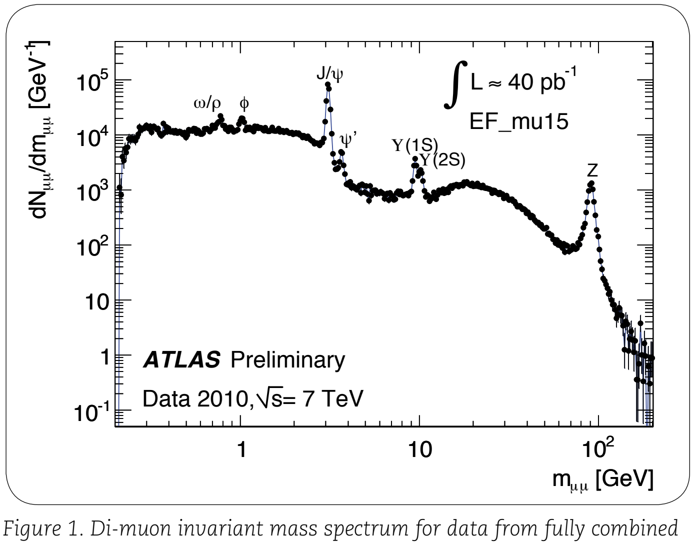


Figure 1. Di-muon invariant mass spectrum for data from fully combined oppositely charged muons. The muon Event Filter trigger applies a p_T threshold at about 15 GeV, which for consistency is reconfirmed offline for one of the two inner detector-muon spectrometer combined tracks (the other one is required to pass a p_T threshold of 2.5 GeV). The plot shown corresponds to an integrated luminosity of about 40 pb^{-1}.

Already during the first days of data taking the high quality of the data became clear. One of the first measurements was the determination of the track multiplicity of minimum bias events, which was determined at the LHC centre-of-mass energies in 2010: 0.9, 2.36 and 7 TeV. The data show a higher underlying event activity than that predicted by Monte Carlo models tuned to pre-LHC data. With the tracks of the Inner Detector Nikhef scientists further searched for resonance particles, like the Kaon and ϕ mesons and the Λ baryon. All these particles were reconstructed in perfect agreement with the expectations from Monte Carlo simulations. This shows that the detector response is well calibrated, the magnetic field is understood, the alignment is under control, and the reconstruction software is working properly.

In 2010 Nikhef remained very active in various aspects of the muon track reconstruction. The software suites Moore that reconstructs tracks in the Muon Spectrometer and MuId which combines these tracks with the Inner Detector, were stable and ran without problems on the data, after being tested extensively on cosmic ray data. For example, the calibration of the sagitta was performed using the straight tracks of cosmic muons obtained a year before without the presence of the toroid magnetic field. The momentum resolution was determined by comparing the cosmic tracks in the upper part of ATLAS with those of the lower part. And as expected, below a transverse momentum of approximately 40 GeV the resolution of the Inner Detector dominates the resolution of the reconstructed muon momentum and above 100 GeV the precision Muon Spectrometer resolution dominates the muon momentum resolution estimate.

In the collision data, events characterised by a high energetic isolated muon and missing transverse energy were found, which are unmistakeably the signature of the W-boson. This started the measurement of the production cross sections of the W- and Z-bosons and by October the paper based on 320 nb^{-1} of data was submitted. With 2250 $W\rightarrow l\nu$ and 179 $Z\rightarrow ll$ (electrons and muons), the observed cross section was shown to be in agreement with Standard Model predictions.

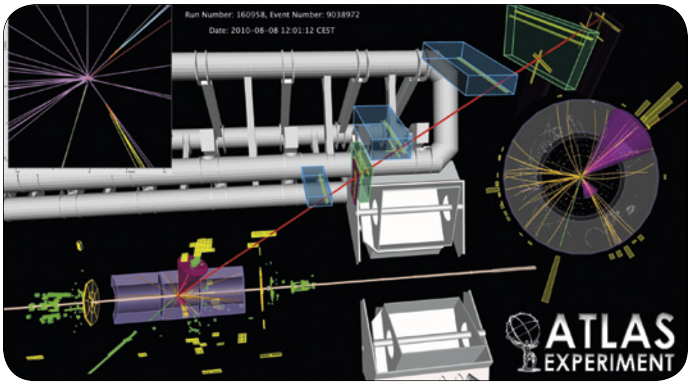


Figure 2. Event display of a top pair e-mu di-lepton candidate with two b-tagged jets. The electron is shown by the green track and calorimeter cluster in the 3D view, and the muon by the long red track intersecting the muon chambers. The two b-tagged jets are shown by the purple cones, whose sizes are proportional to the jet energies. The inset shows the XY-view of the vertex region, with the secondary vertices of the two b-tagged jets indicated by the orange ellipses.

Nikhef went on to optimise the efficiency and resolution of the muon tracks. For example, by comparing the tracks of the Inner Detector and the Muon Spectrometer the contribution from decaying pions and Kaons could be separated from prompt muons. With template fits the intrinsic resolution of prompt muons was determined. As shown in Fig. 1, all low-mass resonances were found in the di-muon mass spectrum where the J/Ψ and the Υ are clearly visible.

The activity in ATLAS was intense. Improved limits on new physics in di-jet events were published. Nikhef concentrated on finding top-quark production in the data. After the first top candidate events were found, see Fig. 2, the cross section for the leptonic top-anti-top production was determined. The yields of the corresponding expected reducible QCD background and the irreducible background coming from W-boson with associated jets were estimated from data itself. Based on 2.9 pb^{-1}, the kinematic properties of the events were found to be consistent with predictions and the production cross section of the ‘European’ top-quarks was measured to be $\sigma(t\bar{t}) = 145 \pm 31^{+42}_{-27}$ pb where the first uncertainty is statistical and the second systematic. The signal of top-quark events is visible in Fig. 3. This completed the re-discovery of particles of the Standard Model.

The last period of the run was devoted to heavy-ion collisions. In ATLAS observations have been made of a centrality-dependent di-jet asymmetry in these collisions. The transverse energies of di-jets in opposite hemispheres are observed to be more unbalanced with increasing event centrality, a phenomenon that is not observed in proton-proton collisions. In addition, the measured J/Ψ yield is found to significantly decrease from peripheral to central collisions and the first Z bosons that decay to muons where reconstructed in the heavy ion collisions.

Searches for the Higgs particle and Supersymmetry or other new physics are underway. No results were made public in 2010 yet and the data was still blinded partly to minimise the analysis bias. Nikhef concentrates on Higgs decay to W-and Z-bosons leading to muons in the final state. The study of new physics concentrates on events that are characterised by a large missing transverse energy, multiple jets and zero or one isolated leptons. We are looking forward to the large data samples expected in the coming years.

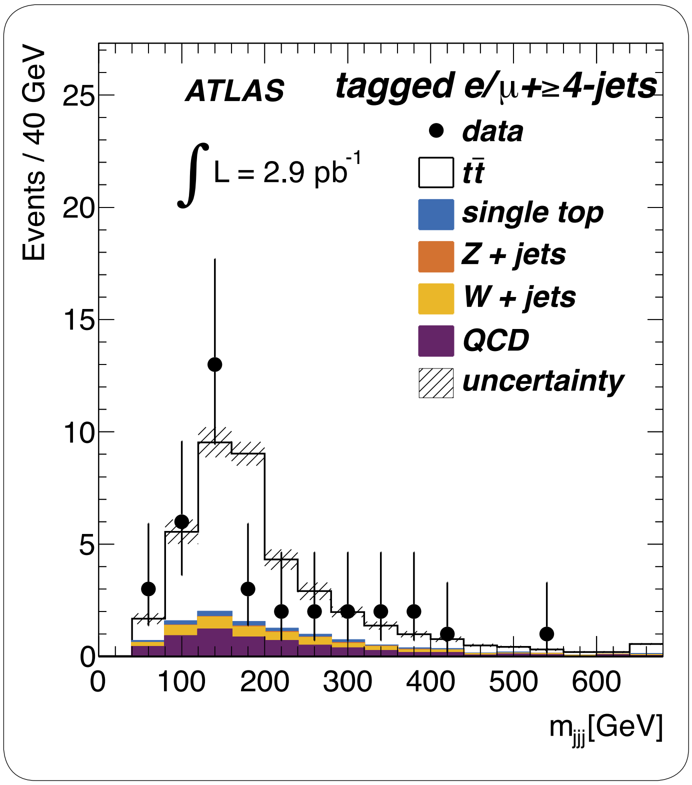


Figure 3. Distributions of the invariant mass of the 3-jet combination having the highest p_T for events with at least 4 jets present of which one is b-tagged. Also an isolated electron or muon is required. The data are compared to the sum of all expected contributions, and the contribution of top-quark events is clearly visible.The uncertainty on the total expectation due to backgrounds is represented by the hatched area.

2.2 LHCb
Hunting New Physics with *b* quarks

Management: prof.dr. M.H.M. Merk (PL)
dr. A. Pellegrino
Running period: 1999–2014

LHCb is a forward spectrometer to perform precision measurements on rare decays of B mesons and to find new physics beyond the Standard Model. After commissioning the detector with the first beams in the Large Hadron Collider in 2009, the year 2010 has been for LHCb a period of stable data taking and first physics results.

The crucial task of reconstructing the trajectories of the charged particles produced in the B-meson decays is entrusted to the tracking system, consisting of: a silicon strip VErtex LOcator (VELO); a 4 Tm dipole magnet; one silicon-strips tracking station (TT) upstream and three stations downstream of the magnet. The tracking stations behind the magnet have silicon-strips detectors in the high-occupancy inner region close to the beam pipe (IT) and straw-tubes modules in the rest of the acceptance (OT). Nikhef gave a major contribution to the realization of the LHCb detector, most notably to the construction of the VELO, the Pile-Up system, the OT, and to the design and implementation of the High Level Trigger (HLT).

In 2010, LHCb collected about 38 pb^{-1} of physics data, at different settings of the LHC machine, most notably increased instantaneous luminosities up to 1.6×10^{32} $cm^{-2}s^{-1}$, close to the LHCb design luminosity (2×10^{32} $cm^{-2}s^{-1}$). The detector has passed the test with flying marks, providing a performance close to the design one in all key sectors (trigger, tracking, particle ID, etc.). This rich harvest of data permitted the tuning of the reconstruction and analysis strategies, that have successfully been commissioned

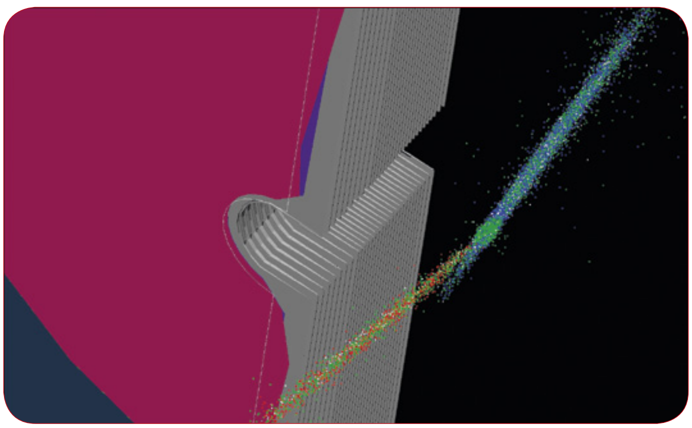


Figure 1. Three-dimensional view (compressed in the z-direction) of the LHC beams as seen by the VELO (partly shown).

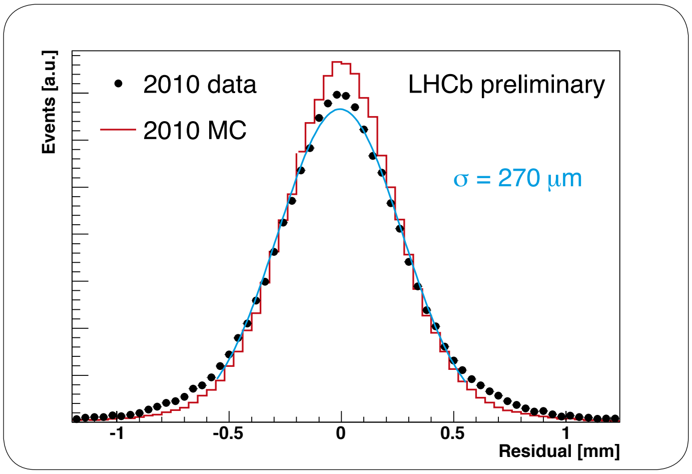


Figure 2. OT resolution estimated from the spatial residuals obtained from the tracking procedure.

and are now routinely producing a variety of physics results (particle production, total $b\bar{b}$ cross sections, D- and B-mesons decays, etc.), that have been presented at conferences and published in physics journals. Also in this field, the Nikhef group has been extremely active, most notably in the tracking and alignment software, and in the analysis of rare and CP violating decays.

Tracking and trigger
The VELO (23 stations equipped with silicon microstrip sensors arranged in an r-φ geometry around the interaction region) provides a three-dimensional measurement of virtually all interaction and decay vertices. Fig. 1 shows the LHC beams as seen by the VELO. During physics running, the sensors are operated at 7 mm from the beam, whereas during beam injection and machine studies they are retracted by 3 cm.

The detector has been time-aligned to the LHC beam within 2 ns. The signal-over-noise ratio is 20:1 and the measured cluster finding efficiency is 99.8%. For the detection of displaced vertices and for the measurement of time-dependent quantities it is essential to have excellent vertex and impact parameter resolutions; the VELO performance has achieved these objectives. The spatial alignment of the modules obtained with early data has an accuracy of 4.4 µm. A single hit precision of 4.4 µm has been achieved at the optimal track angle. The preliminary primary vertex resolution with 25 tracks/vertex is determined to be σ_x = 16 µm, σ_y = 15 µm, σ_x = 90 µm.

The OT detector has routinely taken data during the whole 2010 data taking period, with less than 1% of dead channels and very

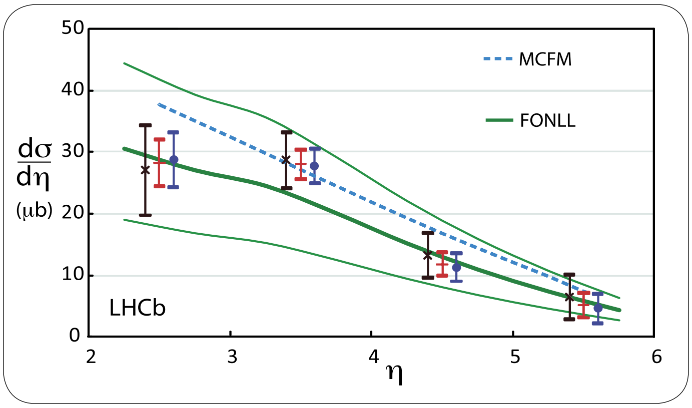


Figure 3. The total cross section σ ($b\bar{b} \rightarrow H_b X$) as a function of pseudo-rapidity η. Systematic uncertainties are not included. The solid and dashed line are theoretical predictions.

low noise (less than 1% of the average occupancy). The low discriminator thresholds have guaranteed high drift-cell efficiency (>98%). Time offsets and time-to-space calibrations have been performed and the results stored in the reconstruction database. The spatial alignment of the various detector layers with respect to each other and of the whole OT with respect to the other LHCb subdetectors has been determined with a precision of ± 100 µm in the x coordinate (dipole bending). The alignment of individual straw-tubes modules is still ongoing. A resolution of 250 µm has been obtained (see Fig. 2), close to the one expected from beam tests (200 µm), the discrepancy presumably being due to imperfections in the module-to-module alignment. Correspondingly, excellent invariant mass resolutions have been obtained in all decays under study: for example a resolution of 3.3 MeV for $K_s \rightarrow \pi\pi$ and 9 MeV for $D^0 \rightarrow K\pi$.

The LHCb trigger system employs the finite lifetime and relatively large mass of charm and beauty hadrons to distinguish heavy flavor from background. It is a two level system: the first level (hardware) reduces the visible interaction rate to a maximum of 1 MHz, at which the whole detector can be read out; the second trigger level is a C++ application running on an Event Filter Farm (several thousand CPU nodes) that uses the full event information to select the decays of interest, reducing the output rate to 2 kHz. The full trigger has been operational in 2010. Starting from low luminosity and gradually approaching nominal beam conditions, it has proven to operate flexibly and reliably. Trigger efficiencies, determined directly from the data both for the muon and the hadron selection lines, have been found to be as expected.

Physics with first data

In the first few months of LHC operation in 2010, the instantaneous luminosity has been well below the nominal value. This allowed trigger thresholds lower than what one would normally use to select hadronic B decays, thus providing a golden opportunity to rapidly collect very large samples of charm events. Besides proving invaluable to tune the detector and the reconstruction performance, the first data have been analysed to obtain and publish results on strangeness production and on the measurement of the $b\bar{b}$ production cross-section (see Fig. 3). In addition it provided a preliminary result on the measurement of the J/Ψ production cross section.

With the bulk of 2010 data, significant mass peaks have been reconstructed for a variety of B_d, B^+, and B_s decays (see e.g. $B^0 \rightarrow K\pi$ in Fig. 4), paving the road for the measurement of the mixing-induced CP violation in $B_s \rightarrow J/\Psi\varphi$ decays and the determination of the CKM angle γ. Moreover, the hunt for the very rare decay $B_s \rightarrow \mu^+\mu^-$ has been opened: background yields have been measured according to expectations and in 2011 LHCb will surpass the limits obtained in searches performed at the Tevatron.

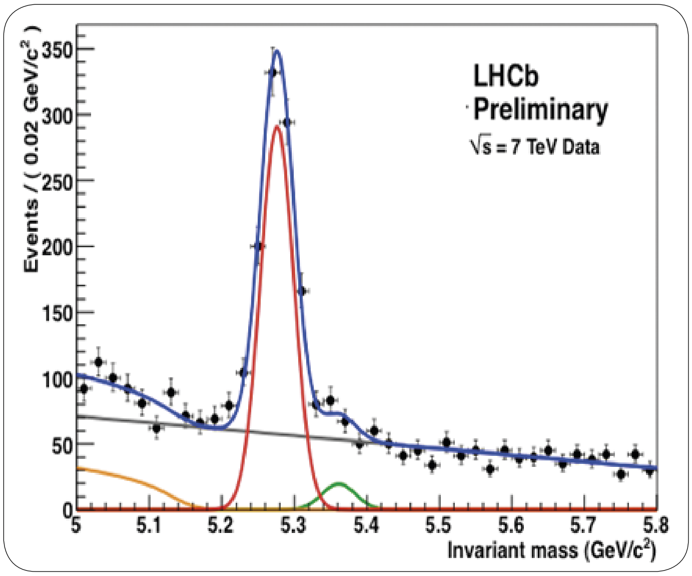


Figure 4. Invariant mass of the $B^0 \rightarrow K\pi$ decay reconstructed from the 2010 data sample (about 35 pb^{-1}), roughly yielding 840 decays.

2.3 ALICE
Relativistic Heavy-Ion Physics

Management: prof.dr. Th. Peitzmann (PL)
prof.dr. R. Snellings
Running period: 1998–2013

The main goal of the ALICE programme is to study the strong interactions of quarks and gluons at very high temperatures and densities, as prevailed a few microseconds after the Big Bang. In particular, by colliding heavy ions at high energy, the aim is to determine the properties of matter under such extreme conditions and to improve our understanding of the phenomenon of confinement and the generation of mass by the strong interaction.

The Nikhef heavy-ion group participates both in the STAR experiment at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory and, with the groups main focus, in the ALICE experiment at the Large Hadron collider (LHC) at CERN. In ALICE Nikhef contributed to the construction of the Silicon Strip Detector (SSD) of the Inner Tracking System (ITS). The main detectors of ALICE have all been successfully installed, a few elements of some detectors, including the first upgrades will be installed in the near future.

Excellent performance in proton-proton collisions

In 2010 the ALICE experiment has collected data of hundreds of millions of proton-proton collisions at a centre-of-mass energy of 7 TeV, which is still a factor of 2 lower than the final maximum energy achievable, but already about 4 times higher than available at any other accelerators. All of the detectors showed an excellent performance and a number of important measurements have been done of which several have already been published. From the first analyses it is evident that existing theoretical models have to be modified to be able to describe these collisions. Apparently, the increase of the number of produced particles with the higher beam energy and the average momenta of those are not yet described correctly. The Nikhef group has in particular contributed to the measurement of the relative amount of different sorts of particles, and it has turned out that the particle composition is significantly different from theoretical predictions. A good understanding of proton-proton collisions is very important for the further physics program of ALICE as they serve as reference measurements against which new phenomena in collisions of nuclei have to be discriminated.

First results from lead-lead collisions

In November 2010 the LHC accelerator delivered for the first time collisions of pairs of lead (Pb) nuclei at an energy of 2.76 TeV per nucleon pair, a factor of 13 higher than the energy of gold-ion collisions at RHIC, which previously held the world record of highly energetic nuclear collisions. Every such collision produces thousands of particles as can be seen from the event display of a central collision shown in Fig. 1. From the most central collisions about 2.2 times more particles are produced than at RHIC. Although one might expect an increase in the number of particles with higher energy, the measured number is higher than most theories predicted.

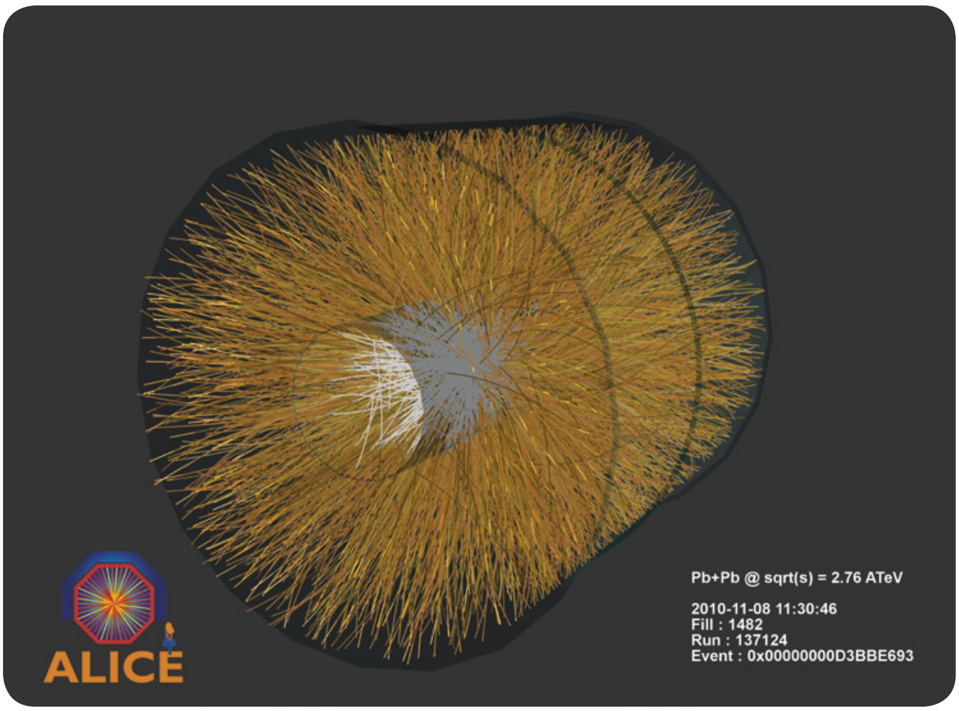


Figure 1. An event display of a single Pb+Pb collision at 2.76 TeV showing tracks from the Inner Tracking System and the Time Projection Chamber of ALICE.

One of the other early observations in heavy-ion collisions that concerns ALICE is the study of anisotropies in the emission of particles in more peripheral collisions, where the nuclei overlap only partially. It is known that the anisotropy of the particle distribution as a whole in such events reflects the collective behaviour of the matter produced. The hot and

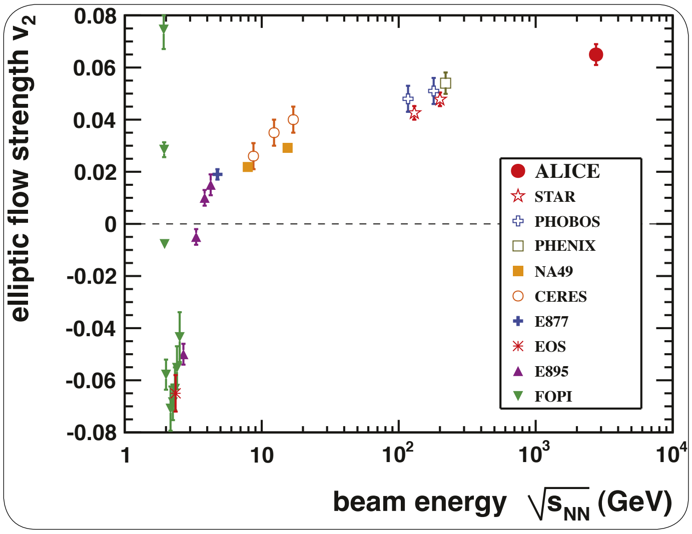


Figure 2. Strength of the elliptic anisotropy of the collective expansion in medium-central Pb+Pb collisions at 2.76 TeV compared to measurements at lower beam energy.

dense system produced from the collision will start to expand very rapidly immediately after. An asymmetry in the initial state from the partial overlap will be reflected in the anisotropy of the particles, with the major component having an elliptic shape (the effect is thus called *elliptic flow*). This phenomenon was seen at lower energies, most strongly again at RHIC. The strength of this flow is related to its internal friction, the *viscosity* of the produced matter, which in turn depends on the strength of the interaction between the constituents. The measurements at RHIC showed a stronger elliptic flow than in previous still lower energy measurements. They have led to the surprising finding that the quark gluon plasma formed when two nuclei collide appears to flow like a nearly perfect liquid with almost no viscosity.

How this behaviour should continue at the higher energy of LHC was hotly debated among theorists. A number of theories predicted that the quark gluon plasma at the LHC should behave more like a gas than a liquid, which should result in a weaker elliptic flow. The measurements of ALICE, however, clearly demonstrate an even stronger elliptic flow than observed at RHIC, as can be seen from Fig. 2. The interpretation of these results will require much more discussion, however it is clear already now that matter behaves again, and even more strongly so, as a fluid. The two publications on the produced particle multiplicity and on elliptic flow are already accepted for publication in Physical Review Letters.

Other and more detailed analyses are under way. Elliptic flow measurements of different identified particles will provide important constraints for theoretical calculations. ALICE has demonstrated measurements of particles with high transverse momenta, which are mostly produced from single high energy quarks or gluons in so-called *jets*. Those measurements will be used to obtain information on the density of the produced matter via the energy loss of the quarks and gluons after their production. The measurements of rare heavy quarks will provide additional information, but are also more challenging experimentally, because particles containing such heavy quarks have a very short lifetime. The feasibility of such measurements has been shown in proton-proton collisions, and the analysis in lead-lead collisions is ongoing.

2.4 ANTARES & KM3NeT
Neutrino Telescopes

Management: prof.dr. M. de Jong
Running period: ANTARES 2001–2013
KM3NeT 2009–2016

The ANTARES detector and its future successor KM3NeT are a new generation of neutrino telescopes. To identify and study cosmic neutrino's, these experiments detect Cherenkov light from muons that have been produced by a neutrino interaction in sea-water, using a large number of photo-multiplier tubes.

ANTARES is operational since May 2008 and in total, twelve lines have been deployed at the bottom of the Mediterranean sea equipped with 900 optical modules, the 'eyes' of the detector. Each optical module houses one large (10″) photo-multiplier tube (PMT). Two detector lines, which had been recovered for repair, were reconnected in November 2010. Since then, all 12 detector lines are fully operational again. Over the past years, the data-acquisition system, to which the Nikhef group made major contributions, has been operating smoothly. Roughly 50 million muon tracks are recorded each year, about 500 of which are due to up-going atmospheric neutrinos. In addition, special minimum-bias data taking is externally triggered by the detection of gamma ray bursts by satellites.

ANTARES data analysis
On the analysis side, considerable effort has gone into understanding the detector and obtaining reliable simulations. Optical background and timing resolutions have been measured or

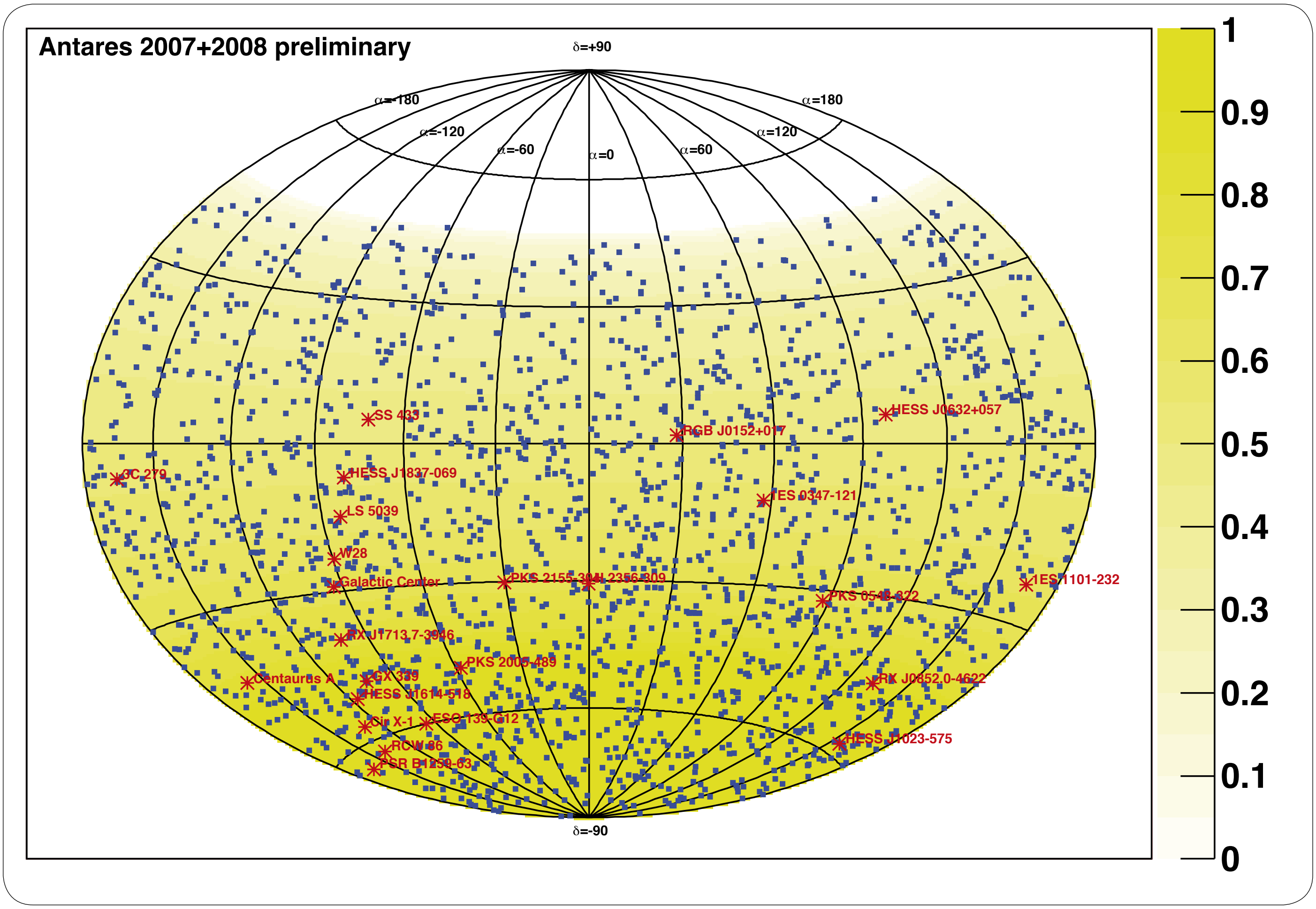


Figure 1. Celestial coordinates of 2040 selected neutrino candidates used for the point source search. Due to the optimised selection criteria, the events in the sky map mostly consist of mis-reconstructed muons (40%) and atmospheric neutrinos (60%). 24 source candidates are also shown in red. The yellow shading indicates the fraction of time available for observation (i.e. below the horizon).

constrained by data. The current analyses include a large fraction of 5-line data, but already achieve an angular resolution of 0.5°; which is better than what has been achieved by our colleagues from AMANDA/IceCube at the South Pole, despite ANTARES' smaller detector size.

The data of the first two years (see Fig. 1) have been used for a search for cosmic (point) sources of neutrinos. This is a major result of the experiment, and Nikhef has been the driving force behind this analysis. Unfortunately, no sources have been found (2% of the background-only experiments is expected to yield a significance higher than the most significant 'hot-spot' found in the data). Competitive limits on the neutrino flux have been set for a number of source candidates. We will continue this work with two more years of data to be analysed. The same data-set of selected up-going events is also being used to search for correlation of ANTARES neutrinos with the highest energy cosmic ray events detected at the Pierre Auger Observatory in Argentina.

Analyses looking for neutrinos from Gamma Ray Bursts (GRB) are particularly interesting because the time-correlation with external GRB detection can dramatically reduce the background. As a result, the detection of a few neutrinos can already imply a discovery. At Nikhef, such searches are progressing using both the 'regular' muon tracks, as well as shower events which are caused by electron or tau neutrinos (and neutral-current-interactions). The analyses are evolving rapidly and unblinding is foreseen for early 2011. A study into detecting GRBs via down-going muons induced by very high energy gamma rays themselves is also in progress.

Studies using simulated down-going atmospheric muon bundles have revealed several observables that may allow ANTARES to measure the composition of high energy cosmic rays. Cosmic ray composition is interesting as it is related to models of production and their propagation though the Galaxy. The measurement is expected to be completed in 2011.

KM3NeT

While ANTARES will keep operating for several years to come, the KM3NeT consortium aims at building its successor: a detector with an instrumented volume of at least 1 km^3. Over the past year, the K3MNeT Technical Design Report has been published and the community has converged on the detector design. This features the multi-photo-multiplier tube (PMT) optical module conceived at Nikhef (see Fig. 2). In this design, each glass sphere houses many 3″ PMTs, as opposed to one large one, which improves the directional sensitivity and the photon counting ability.

Figure 2. Prototype of a multi-PMT optical module for KM3NeT.

As a proof-of-principle, it is foreseen to deploy a few multi-PMT optical modules alongside the ANTARES detector in 2011.

Together with the Royal Netherlands Institute for Sea Research (NIOZ), a method was developed to deploy KM3NeT detector strings. This 'launcher' was successfully tested in a sea campaign in Greece in December 2009.

Work is also ongoing at Nikhef on developing reconstruction techniques dedicated for use with the KM3NeT detector design. These studies show that, due to the good optical properties of water, angular resolutions as small as 0.1° will be achievable.

2.5 The Pierre Auger Observatory
Detecting ultrahigh-energy cosmic rays

Management: dr. A. van den Berg (PL, KVI)
dr. Ch. Timmermans
Running period: 2008–2013

The Pierre Auger Observatory in Malargüe, Argentina aims at detecting the highest energy cosmic rays. Nikhef is involved in hardware development, data acquisition, data reconstruction and data analysis of radio detection of cosmic rays. The data set obtained by the Dutch operated setup is used by the whole collaboration for analysis.

Radio detection of cosmic rays

In 2010 the understanding of the radio signal generated by extensive air showers has been increased by the observation of a contribution to the radio signal due to the charge excess at the front of the air shower (Askaryan 1962). This charge excess leads to a position-dependent polarisation of the radio signal, which interferes with the main geomagnetic effect. The integrated signal of this effect with respect to the geomagnetic signal is about 10%, but for polarisation-dependent measurements in individual stations it can be the leading signal generating mechanism. This charge excess was first observed in the data of our engineering setup due to our measurement of not only the east-west polarisation component (perpendicular to the Earth's magnetic field) but also the north-south (NS) component. Fig. 1 shows a comparison of our measurement of the charge excess effect with theory (the MGMR model from Scholten, de Vries *et al.*).

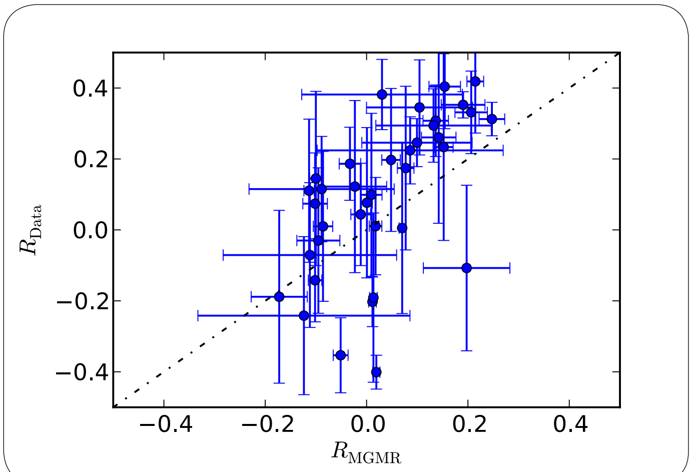


Figure 1. A comparison of the charge excess effect between measured data and simulation. Each point represents the relative magnitude of this effect in measured data (vertical axis) and the simulation of that specific event (horizontal axis).

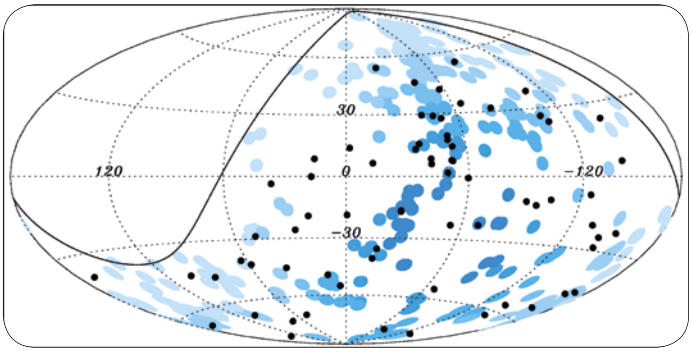


Figure 2. The 69 arrival directions of cosmic rays with energy E>55 EeV detected by the Pierre Auger Observatory up to 31 December 2009 are plotted as black dots in an Aitoff-Hammer projection of the sky in galactic coordinates. The solid line represents the border of the field of view of the Southern Observatory for zenith angles smaller than 60°. Blue circles of radius 3.1° are centred at the positions of the 318 AGNs in the VCV catalog that lie within 75 Mpc and that are within the field of view of the Observatory.

In 2010 the first phase of the Dutch-German-French AERA (Auger Engineering Radio Array) setup was constructed, commissioned and took first data. AERA will eventually be an 20 km^2 radio array, located in the north-west part of the Piere Auger Observatory. In this area additional enhancements to these experiments are located in order to measure cosmic rays in the Galactic-extra galactic transition energy region, as well as testing new techniques such as MHz and GHz radio detection of air showers. The first phase of AERA consists of 21 stations, which are very similar to the radio detection stations we have installed in our earlier setups. First measurements reconfirm that we are sensitive to the radio noise generated in the Milky Way, indicating that the noise generated by our own setup is well under control in the frequency range in which we are sensitive (between 30 and 80 MHz). Real physics measurements have started only just before Christmas, and first radio detections of cosmic rays of this setup are expected in 2011.

Physics highlights of the Pierre Auger Observatory

In 2010, we have released an update on the correlation of the direction of incoming cosmic rays with nearby Actice Galactic Nuclei (AGN). The released data set consists of all 69 cosmic rays recorded with energies above 55 EeV, detected until 31 December 2009. The distribution of these events is shown in Fig. 2.

It is known that since our original paper in 2007, the correlation-level has decreased. However, in recent years the amount of correlation has remained stable at about the 40% level, whereas a 21% level is expected from a purely isotropic distribution. This means that an isotropic hypothesis of our event distribution is still excluded at the 99.7% level.

Another important publication in 2010 deals with the chemical composition of the incoming cosmic rays. Using the fluorescence detector at the Pierre Auger Observatory, it is observed that the penetrating depth of showers of energies beyond 10 EeV does not seem to change much as function of energy, whereas a constant mass number would mean that the amount of penetration of a shower with higher energy in the atmosphere would be larger (see Fig. 3). This implies that either more heavy particles enter the atmosphere at high energies, which has implications for the particle sources, or that the cross-sections at high energies are different from the Standard Model extrapolations, which has particle physics implications. It should be noted that the variation of the position of the shower maximum decreases as a function of energy, which implies that the position of the first interactions contain less variation. Using the superposition model, this would imply that the average number of nucleons per incoming nucleus increases.

A more detailed study of the shower shape of all measured data would provide more insight into the air shower development, also at the highest measured energies. This is the goal we hope to achieve using radio measurement of extensive air showers.

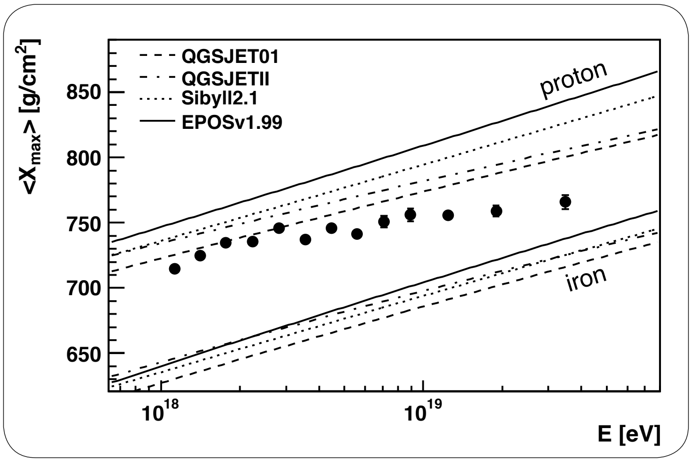


Figure 3. Measurement of the depth of the shower maximum in the atmosphere as function of the energy as performed by the fluorescence detector in the Pierre Auger Observatory. The measurement is compared to several recent model predictions for incoming hydrogen and iron nuclei.

2.6 Gravitational physics
The dynamics of spacetime

Management: prof.dr.ing. J.F.J. van den Brand
Running period: 2010–2015

The prime goal of the programme is to obtain the first direct experimental proof for the emission of gravitational waves (GW) by accelerated bodies. This would confirm once and for all that gravity is a fundamental dynamical phenomenon and lead to discoveries that impact on general relativity, quantum gravity, astrophysics of extreme objects and cosmology. The Virgo collaboration has developed a sensitive interferometer located within the site of the European Gravitational Observatory (EGO), near Pisa. On 2 July 2009, Nikhef became associate member of the EGO Council.

Interferometric GW detectors have demonstrated the validity of their working principle by coming close to, or even exceeding, the design sensitivity of the initial instruments: Virgo and GEO600 in Europe, LIGO in USA and TAMA in Japan. A second generation of interferometers (Advanced LIGO, Advanced Virgo, GEO-HF and LCGT) will be implemented over the next few years. These interferometers will at a later stage be joined by Einstein Telescope (ET) and LISA, and will be sensitive to GW produced over a wide frequency range, for example, by massive black holes, binary white-dwarf stars and phase transitions in the early Universe. GW detection opens up the possibility to test general relativity itself in the strong-field regime, to study questions about space-time, cosmology and structure in the Universe, and would be the first step on the experimental road to quantum gravity.

Figure 1. Assembly of the seismic attenuation system for the external injection bench of Advanced Virgo. This EIB-SAS provides more than 60 dB attenuation (> 10 Hz) in 6 degrees of freedom.

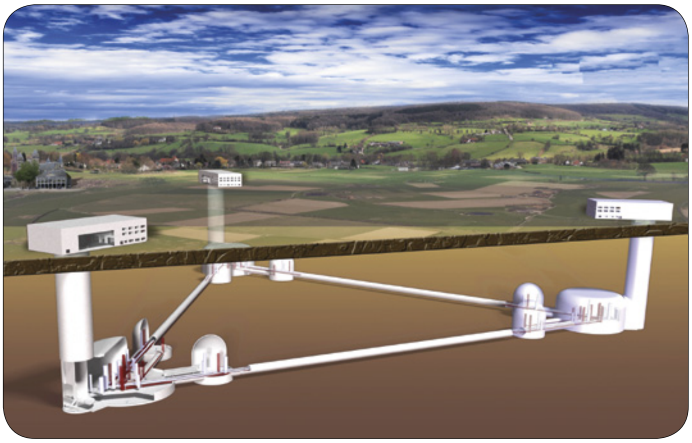


Figure 2. Pictorial view of the Einstein Telescope infrastructure. A triangular underground gravitational wave observatory, each arm 10 km long, with a series of halls, located at a depth of up to a few hundred meters.

The Advanced Virgo upgrade will allow Virgo to scan a 1000 times larger volume of the Universe than present Virgo. Numerous systems need to be improved. Nikhef has responsibility for:

- Vacuum-cryolinks: to obtain the required sensitivity of $3\times10^{-24}\sqrt{\text{Hz}}$ at 200–400 Hz, the interferometer arms will be separated from the towers that host the cavity mirrors, through four cryolinks. These links are realised in close collaboration with Dutch industry.
- Suspended benches and mirrors: with the use of non-degenerate power recycling cavities the injection- and detection benches as well as the recycling cavity mirrors will have to be suspended in vacuum. Moreover, seismic attenuation systems for various external benches (not located in vacuum) that host optical tables (see Fig. 1) will be realised.
- Optical systems: front-end optical systems will be redesigned in order to work with the new modulation frequencies and to provide all the needed demodulated signals for optical alignment. Phase cameras will image amplitude and phase of carrier wave and sidebands.

Longer term prospects

The search for gravitational waves belongs to the field of astroparticle physics, a rapidly growing research field at the interface of astronomy, cosmology and particle physics. The Astroparticle Physics European Coordination (ApPEC) announced a roadmap in which the scientific exploitation of Virgo figures prominently. Moreover, the Einstein Telescope is a multi-national project of eight European research institutes and is listed in the ASPERA Roadmap as one of the 'Magnificent Seven'. A conceptual design study for the Einstein Telescope formally started on 5 May 2008.

Nikhef scientists focus on the following questions to be addressed in the advanced detector era:

1. Studying the inspiral and merger of compact binary objects (neutron stars and black holes) will enable us to test General Relativity in an unprecedented way and constrain alternative theories of gravity, such as scalar-tensor and massive graviton theories, and models that arise as low-energy limits of string theory.
2. Inspiralling binary neutron stars (BNS) are ideal standard candles (or standard 'sirens'). A population of BNS merger events observed in coincidence with short hard-gamma ray bursts can be used to measure cosmological parameters, with GW observations providing accurate measurements of the luminosity distance and hosts of Gamma Ray Burstsgiving the source redshift.

To achieve the sensitivity required by these science targets, the Einstein Telescope observatory must implement new technologies and new solutions in many fields: optics (new high-power laser, crystalline material optics, low-dissipation coatings or coating-less optics), cryogenics (low-vibration cryocoolers, cryogenic test masses), mechanics (seismic filters), and opto-electronics. An intense R&D programme will be necessary in the next years to master all the technologies required by ET.

The main characteristic of the ET project is to consider it as a long-staying European research infrastructure, capable to host a family of evolving GW detectors. For this reason the design study focused on the site and infrastructure requirements of the ET observatory. ET will be a large underground installation, having a triangular shape, as pictorially represented in Fig. 2. The ET infrastructure allows the implementation of up to three different detectors, each of them realized by one or two interferometers, tuned in a so-called 'Xylophone' configuration (see Fig. 3). The release of the ET conceptual design study document and the corresponding cost evaluation is scheduled for July 2011.

LISA (Laser Interferometer Space Antenna) will be an interferometer in space. LISA is currently a candidate for the first large mission in ESA's Cosmic Vision 2015–2025 programme and was part of NASA's Beyond Einstein programme. The latter was recently reviewed by the BEPAC committee that strongly recommended LISA as 'the flagship mission of a long-term program addressing Beyond Einstein goals'. A large LISA community has formed over the years, organised in the LISA International Science Community (LISC). Bi-yearly symposia are attended by over 200 scientists and the number of LISA related papers exceeds 1000 (more than 500 refereed papers). Nikhef scientific staff contributed to the LISA science case through a study of cosmography with supermassive black holes.

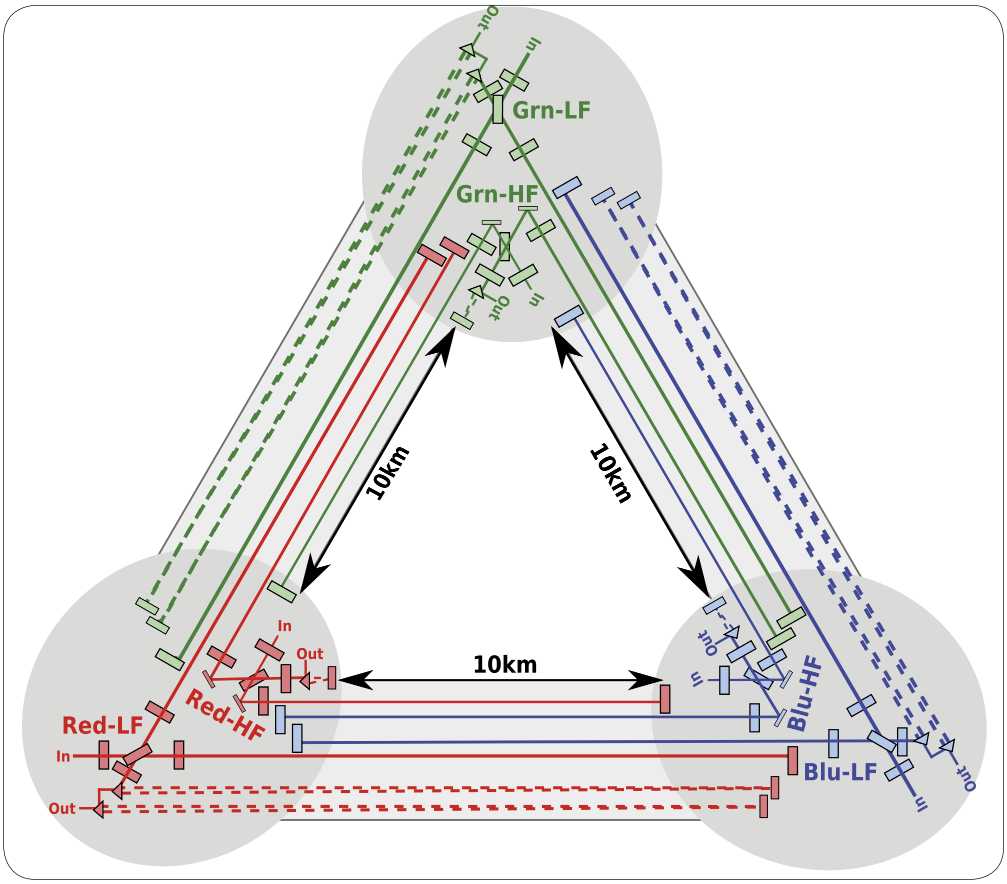


Figure 3. Possible optical scheme of the ET infrastructure. The observatory will be able to host up to three detectors, each composed of two interferometers in a Xylophone configuration.

2.7 XENON & DARWIN
Dark Matter Experiments

Management: dr. P. Decowski

One of the most exciting topics in physics today is the nature of dark matter in the Universe. Although indirect evidence for dark matter is well established, its composition is not yet known. Current evidence disfavours astronomical bodies as the major contributor to dark matter and favors models in which the primary components are one or more elementary particles, collectively called non-baryonic (cold) dark matter.

No currently known particle in the Standard Model has the right properties to be dark matter. One of the most compelling candidates is the Weakly Interacting Massive Particle (WIMP), since it naturally leads to the right dark matter abundance and is part of many of the required Standard Model extensions. WIMPs could be detected directly by their collisions with nuclei in underground experiments. The predicted interaction rates in these so-called direct detection experiments are very low (<1 event/kg-day) and detectors with significant mass with ultra-low backgrounds are necessary. A relatively new and promising technique is to use noble liquids such as xenon in a dual-phase time projection chamber (TPC) to investigate these WIMP-nucleus collisions.

The search for dark matter through direct detection is timely since these investigations are also being conducted at the LHC and through indirect methods (e.g. detection of high-energy

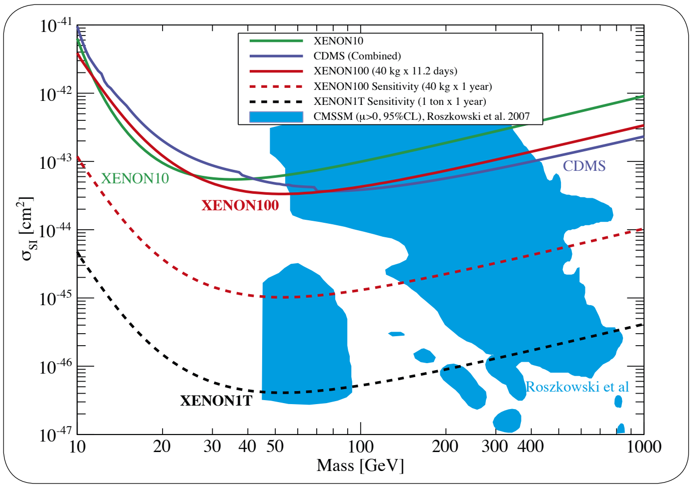


Figure 1. Spin-independent cross-section for scattering of a WIMP off a nucleon, as a function of the WIMP mass. The solid lines show the exclusion limits obtained by the XENON10 (green), CDMS (blue) and early XENON100 data (red). The dashed lines show the expected sensitivities for one year of running for XENON100 and XENON1T. The shaded blue area represents the expected cross-section in the cMSSM model.

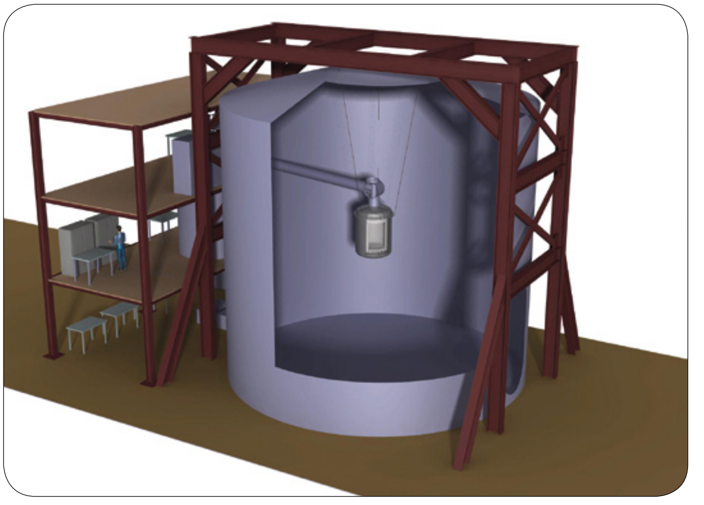


Figure 2. An artist's impression of the next-generation XENON1T experiment. Nikhef is designing the cryostat (middle of the figure) containing 2.4 t of liquid xenon and the detector. The cryostat is inside a 11 m diameter water tank for shielding from background. The experiment is planned to be sited at the Gran Sasso underground laboratory in Italy.

neutrinos from the Sun). There is significant complementarity between these and direct dark matter detection experiments and there is a reasonable probability that dark matter will be observed by all three detection methods more or less simultaneously in the coming decade (see Nikhef Annual Report 2009 for a review of dark matter). Nikhef joined two noble liquid dark matter efforts in 2010: the XENON collaboration and the DARWIN design study.

XENON

The XENON collaboration is currently operating the running 100 kg XENON100 experiment with the aim of exploring the spin-independent WIMP-nucleon cross-section down to about 10^{-45} cm^2 (for a benchmark WIMP of 100 GeV mass), see Fig. 1. The collaboration is also planning the next-generation XENON1T ton-scale experiment that will probe the majority of the theoretical favored WIMP parameter space ($\sigma_{SI} < 2\times10^{-47}$ cm^2). To achieve this sensitivity, the XENON1T experiment will have a xenon mass of about 2.4 t (with the central 1 t as the detection target), a significantly reduced background compared to XENON100 and better light collection. The goal is to start science running in 2014. The Nikhef group joined the XENON collaboration in Spring 2010. Apart from a material contribution of 100 kg xenon to the detection target (delivery in January 2011), the group is responsible for the design of the double-walled xenon cryostat, and the development of the front-end electronics and data acquisition

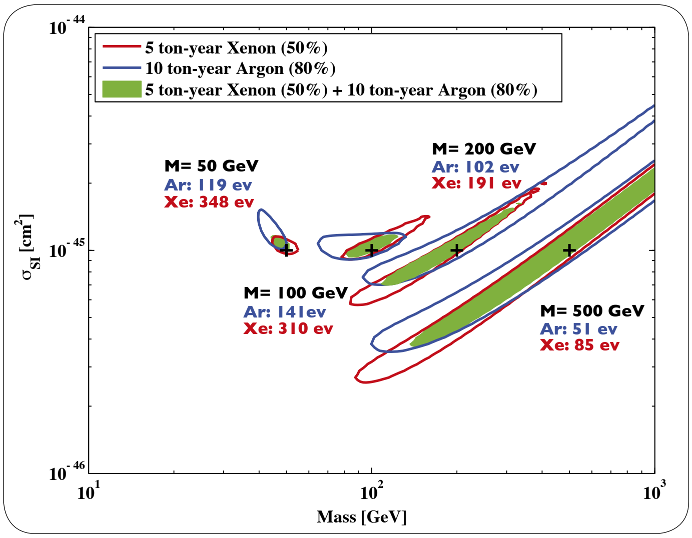


Figure 3. Spin-independent WIMP-nucleon cross-section as a function of WIMP mass for four WIMP benchmark scenarios ($\sigma = 10^{-45}$ cm^2 and M_{WIMP}=50 GeV, 100 GeV, 200 GeV and 500 GeV). The 1-sigma constraints and number of detected events are shown for a 5 ton-year xenon (red) and 10 ton-year argon exposure (blue). Due to differences in the xenon and argon WIMP recoil spectra, the constraints are improved by combining the results from both targets (filled green).

systems. Two highlights in the past year were the submission of the XENON1T proposal (April 2010) and the Technical Design Report (October 2010) to Gran Sasso National Laboratory (LNGS), an underground laboratory in Italy. The TDR specifically requested space in Hall-B of LNGS and featured a preliminary design by Nikhef of the cryostat and support structure (see Fig. 2). XENON1T received a strong recommendation for approval from the LNGS Scientific Committee. With most of the capital cost already secured by the participating institutions, the main remaining item is a siting commitment from LNGS. The Nikhef group also joined the running XENON100 experiment to gain valuable experience in analyzing dark matter data.

DARWIN design study

The Nikhef dark matter group is also investigating experiments beyond XENON1T. DARWIN, funded through ASPERA, is a design study for R&D towards a multi-target dark matter facility. The goal is to probe the cross-section region below 10^{-47} cm^2, or to provide a high statistics measurement of WIMP interactions in case of a positive detection by one of the earlier experiments, such as XENON100 or XENON1T. To convincingly demonstrate the dark matter nature of a signal, a measurement of the interaction rate with multiple targets is necessary. Operating a liquid argon (LAr) and a liquid xenon target (LXe) under similar experimental conditions would allow to measure the dependence of the rate with the target material and hence to better constrain the WIMP mass (for masses below about 500 GeV, as shown in Fig. 3), and to distinguish between spin-independent and spin-dependent couplings (^{40}Ar has no spin, while natural xenon contains two isotopes with spin, ^{129}Xe and ^{131}Xe). From a technical point of view, there are many common aspects to a LAr and a LXe detector which could be shared in a general design.

The Nikhef group is involved with several aspects of the design study. The main effort is R&D to operate GridPix in pure xenon and argon environments at liquid xenon (–110° C) and liquid argon (–185° C) temperatures. We have successfully tested GridPix at –75° C at NLR (Dutch National Aerospace Laboratory) and we are presently planning on testing the GridPix detectors in dedicated argon and xenon cryostats at participating DARWIN institutions. Separately, we are also involved in DARWIN background and science impact studies.

2.8 Theoretical physics

Management: prof.dr. E. Laenen

Research in the Nikhef theory group, including that of the VU University Amsterdam and Radboud University partners, has this year led to a large number of papers ranging from collider physics to cosmology and string theory. It is interesting to note that three of this years' papers involved work with Master students in the group.

Research highlights

In the exploration of weak decays of *B* mesons, strong interactions with Nikhef's experimental LHCb group were developed. A new strategy for reducing the uncertainty in the measurement of the rate for $B^0_s \longrightarrow \mu^+\mu^-$ at LHCb (one of the key processes to search for New Physics) was developed, doubling the new-physics reach in this channel. Another study put the $B^0_s \longrightarrow J/\psi K_S$ channel on the LHCb agenda, showing that this channel offers a tool to control Standard Model corrections to the exploration of CP violation in B^0_d–$\bar{B}^0_d$ mixing. It was also pointed out that $B^0_s \longrightarrow K^+K^-$ offers interesting observables to search for new phenomena in B^0_s–$\bar{B}^0_s$ mixing and points to a value of the CKM angle γ in agreement with the Standard Model. Finally, tests of factorisation and *SU(3)* flavour-symmetry relations in *B* decays into heavy-light final states were performed.

Aspects of a large muon electric dipole moment were studied, in particular how natural this would be within the general Minimal Supersymmetric Standard Model with CP violation from lepton flavour violation. In another study, implications of different Supersymmetry breaking scenarios were examined for the phenomenology of neutralinos and charginos, especially their decay modes and dark matter characteristics.

In scattering processes that are sensitive to the intrinsic transverse momentum of partons, a corresponding factorisation theorem and parton distribution functions are necessary. Collaborative work between Nikhef and the VU University Amsterdam has led to a set of transverse momentum dependent parton distribution and fragmentation functions with QCD evolution properly built-in. For unintegrated transverse momentum densities, factorisation is however broken due to the fact that these functions, being matrix elements of nonlocal operators, require the presence of gauge links that feel the colour flow in the process. It was found that for weighted asymmetries these problems can be solved, while the gluonic pole matrix elements for fragmentation functions vanish.

The efficient computation of one-loop Feynman diagrams with many external lines is very important for predicting LHC processes, where many produced particles are common. This year, new methods were developed in which necessary simplification steps are already performed at the integrand level. Related to this, two new software packages were produced: SAMURAI, for numerical evaluation of one-loop integrals, and SPINNEY, a FORM library for helicity spinors. In another effort, a C++ library called CAMORRA for recursive computation of scattering amplitudes was constructed.

One of the important issues in the describing LHC collisions is the treatment of heavy quark parton distribution functions. Though many schemes consistent with higher order calculations exist, a new one was developed based on heavy final state quark fragmentation, and shown to work well. In another study, it was shown, using the replica trick of statistical mechanics, how to write eikonal cross-sections involving any number of external quarks or gluons as an exponent of so-called 'Web' diagrams. Hitherto this was only known for cases with two external quarks. Moreover, it was shown in a complex diagrammatic analysis, how to organise next-to-eikonal corrections in an exponential fashion.

Regarding possible new physics, for certain supersymmetric models it was shown that single top quarks are predominantly produced in the forward region, and stand out well above simu-

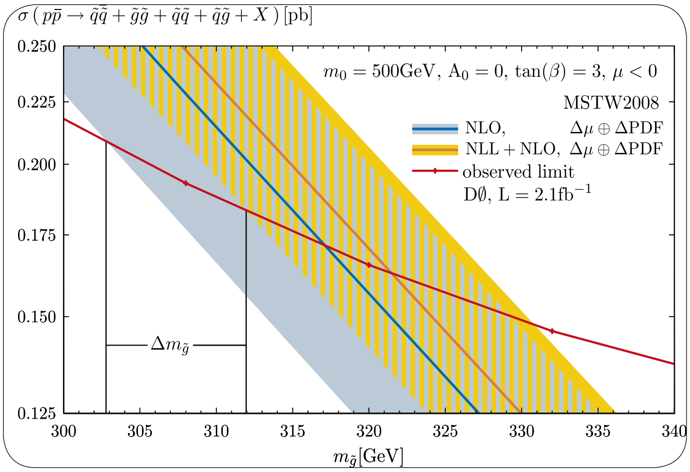


Figure 1. The search for supersymmetric particles at the Tevatron. In blue the uncertainty in the leading quantum corrections and in light orange the reduced uncertainty after including our improvements. As a result, the search capacity of the collider is extended by roughly 9 GeV in the sparticle masses, which effectively means that the same search capacity can be reached with roughly 30–40% less statistics.

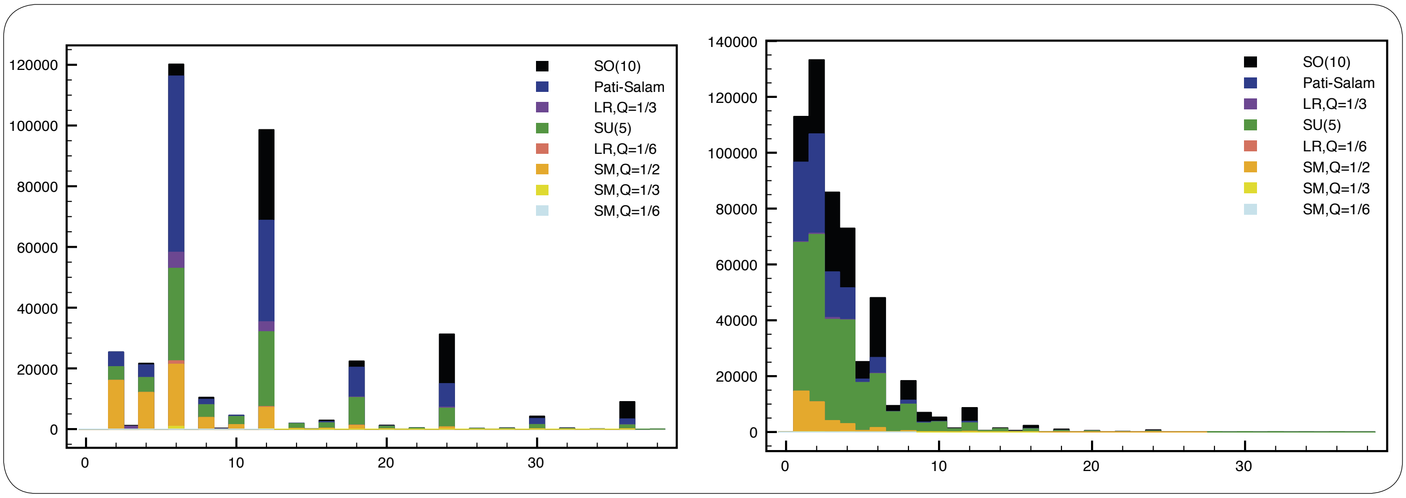


Figure 2. The distribution in the number of families of quarks and leptons for two different classes of models. The frequency of occurrence is shown versus the number of families. For the 'traditional' class on the left, 3 families is not very likely, whereas in the new, less constrained class the family problem is completely absent: the number of families now peaks at small numbers, and three is prominently present.

lated background there. For stop-quark production cross-sections at the Tevatron and LHC, the dominant effects from soft-gluon radiation were systematically isolated and summed to all orders, and their impact on sparticles (supersymmetric partners of the Standard Model particles) searches was assessed, see Fig. 1. Many new physics models have extra W' bosons, and certain spin-sensitive signatures were studied.

Examining the patterns of fermion masses and mixing angles in the Standard Model one notices a lot of structure. So-called family symmetries try to explain this structure. A promising choice involving the discrete symmetry group A4 was constructed and has been confronted in an extensive study with existing constraints. This symmetry was found to reproduce all known patterns and can give predictions for some near-future experiments, in particular those with neutrinos.

Cosmological inflation is an exponential explosion of spacetime that should have taken place just after the Big Bang, a concept that explains why the Universe looks the same everywhere and important in the determination of the first sources for structure formation. An existing, very interesting model of supergravitational inflation was extended to be compatible with string theory. In so-called 'M-flation' the early-Universe model has many non-commuting fields. This approach was proposed to keep the potentially large quantum corrections under control. Work in the group has shown however that starting with arbitrary initial conditions, the model will not end up in the M-flation regime.

Tiny quantum fluctuations of both the inflaton field of spacetime itself ultimately appear as tiny temperature fluctuations in the cosmic microwave background radiation, measurable by the Planck satellite. In collaborative work with Utrecht University, the Lagrangian was derived for cosmological perturbations of the inflaton field that is nonminimally coupled to gravity. An example is Higgs inflation, where the Higgs boson itself drives the accelerated expansion of the very early Universe.

Supersymmetry was studied in non-relativistic models of the interaction of spinning particles with magnetic monopoles. In other work, covariant perturbation theory for test masses in gravitational background fields was developed, allowing analytical computation of gravitational radiation from extreme mass-ratio binary star/black-hole systems.

The stability of extra-dimensional models, where our four-dimensional Universe is surrounded in the extra dimension by two sheets of singularity, or black branes, was analysed in detail, and it was shown that two scalar fields in a particular configuration can prevent the singularities from collapsing. A further understanding of the nature of the singularities has been developed to see if one can shield them by an event horizon.

In string theory, the 'heterotic string' has been popular from the beginning of the modern string era in 1984. It owed its quick rise in popularity to the fact the the rough outline of the Standard Model of particle physics came out right almost automatically. But some features were harder to get right. In nature, we observe three families of quarks and leptons. However, heterotic strings tend to produce numbers that are usually even, and far too large. Last year a new class of heterotic string theories was discovered in the group by a method we called 'heterotic weight lifting'. This year it was found that in this new and less constrained class the family number problem is solved, see Fig. 2.

In other work involving the derivation of possible field theories from string theory, the impact of certain generalised internal permutation symmetries in the string theory sector was studied, leading to the discovery of new structures among the string theory 'data'.

In the context of Bogomolny-Prasad-Sommerfeld (BPS) black hole entropy for N=2 supergravity with higher-derivative couplings, the non-holomorphic deformation of special geometry, and the possible connection between the so-called Hesse potential and the topological string was studied. A non-renormalisation theorem has been proven according to which certain new higher-derivative coupling terms cannot contribute to BPS black hole entropy and the electric charges. Also the 4D–5D connection has been investigated in the presence of these couplings.

Other news

This year saw the completion of a long term project: to make the computer program for symbolic manipulation 'FORM' open source. The source code can now be downloaded from a Nikhef website, and can be discussed through a locally hosted forum site. Also, new capabilities are being added, particularly prominent being the feature of polynomial factorisation, which will be a great help in tackling more difficult calculations in quantum field theory.

At the FOM *"Physics with Industry"* workshop at the Lorentz Center in Leiden, postdoc Damien George helped optimising the properties of an ultra-strong man-made fibre.

The monthly Theory Center Meetings, a key element of the FOM program *"Theoretical Particle Physics in the Era of the LHC"*, continue to be well-attended, strengthening interaction among theorists in the Netherlands. This year student-only seminars, and occasional lectures were added to the meeting days. The national Seminar on Theoretical High-Energy Physics continues to be held at Nikhef and attracts good speakers and excellent attendance.

2.9 Detector Research & Development

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

The focus of the group in 2010 remained on research towards new detector technologies for future particle physics experiments. Novel *micro pattern gas detectors* (MPGD) and semiconductor detectors under development for accelerator based research find new applications in particle-astrophysics experiments and industrial instrumentation.

Gaseous detectors

Since a number of years the group is developing micro pattern gas detectors in combination with pixelated Timepix readout ASICs (Application Specific Integrated Circuit) for example the 'hottest' parts of the ATLAS Inner Detector at the future super-LHC and a large scale Time Projection Chamber (TPC) for a future linear collider.

A GridPix detector consists of a drift-gas volume where incoming charged particles produce primary ionisation electrons, and a thin metallic grid mounted on a pixelated readout ASIC that acts as anode. This thin grid is integrated with the ASIC through (wafer) post-processing and placed on pillars about 50 μm above the ASIC surface. By applying a voltage difference of hundreds of volts between the grid and the anode, gas multiplication of the primary electrons by a factor of a few thousand occurs. The resulting charge avalanche for each of the primary single electrons can be detected with good efficiency on single pixels of size 55×55 μm^2. A high-resistive silicon rich nitride layer of 7 μm protects the readout chip from the unavoidable discharges. Further development of the production process to improve performance and yield has been a continuous effort.

A beam telescope has been assembled consisting of three Gridpix detectors, having a drift gap of 1 mm (named Gossip), and one Gridpix detector with a 20 mm drift gap. The telescope was placed in the H4 testbeam at CERN using 150 GeV/c muons. Testbeam experiments measured the basic operational parameters of the Gossip detectors like position resolution, angular resolution, efficiency and double track separation. The detectors were filled with a mixture of di-methyl-ether and CO_2, having a very small diffusion parameter. Runs were taken at different angles of incidence on one Gossip detector under test while the other detectors were used for a precise definition of the particle tracks. The measurements with the GridPix detector were used to study the superior 3D angular track resolution of this type of detector. In addition a number of measurements performed with parallel tracks in the GridPix detector determined fundamental

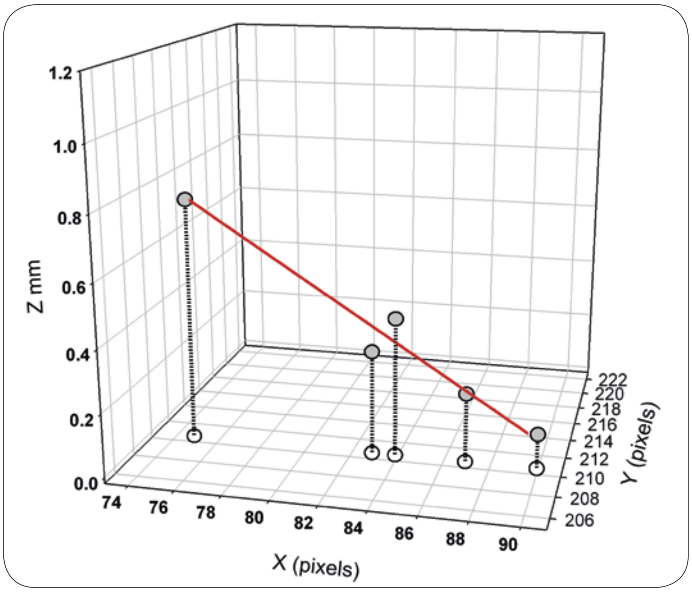


Figure 1. Typical event in a Gossip detector where the particle track is characterised by a straight line fit through the individual detected electrons. The pixels have a dimension of 55×55 μm^2.

gas parameters like drift velocity, diffusion, ionisation density and possible electron attachment. While the full analysis of the abundance of data is still in progress, preliminary analysis has resulted in a position resolution of 15 μm and a track detection efficiency of 99%. With an angular resolution of 0.6° a single gas layer GridPix detector could provide momentum information for the ATLAS Level-1 trigger.

This year the ATLAS experiment has reviewed the possible benefits of the GridPix detector and the ATLAS Executive Board supports the GridPix R&D effort for a duration of 3 years to demonstrate and quantify performance, cost and reliability, with the remark that silicon sensors remain the ATLAS baseline solution.

Nikhef is participating in the Linear Collider TPC collaboration, which pursues R&D for a large TPC as main tracker system at a future linear collider. We are investigating the possibility to have an integrated gas multiplication and readout system based on the Timepix ASIC for such a TPC. Early this year a scaled-up system of four Gridpix detectors was produced, assembled into a small gaseous detector and tested at a 5 GeV electron test beam at DESY. A few days of stable data taking were achieved with satisfactory operation of the detector. In collaboration with a CEA Saclay group an 8-fold Gridpix detector system has been prepared, and mounted on an endplate module for the EUDET (a project supported by the European Union for detector R&D

towards the International Linear Collider) Large Prototype TPC test facility, installed inside a 1 T solenoid at DESY. Successful data taking took place early December 2010. The anticipated high granularity of such a readout is well demonstrated in the image of a recorded testbeam particle track in Fig. 2.

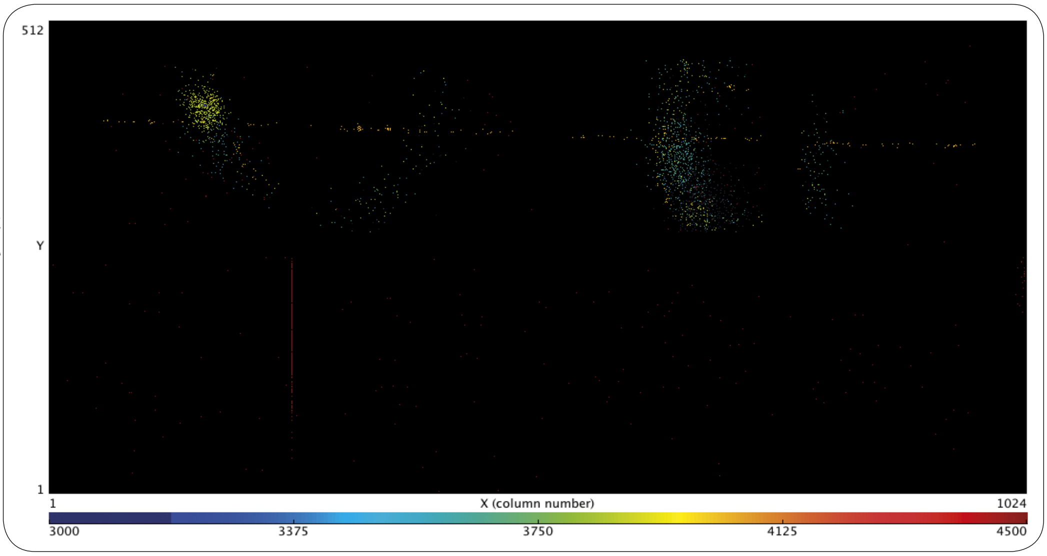


Figure 2. A 5 GeV electron test beam track from DESY II, recorded in the Large Prototype TPC of EUDET. Two secondary 'delta' electrons are strongly curling in the perpendicular 1 T solenoidal magnetic field.

Several projects have evolved last year as a spin-off from the gas detector and readout ASIC efforts within the group. Integrating a UV-photon sensitive CsI photocathode on top of a grid structure permits high resolution imaging of single UV-photons. This detector with a Timepix readout ASIC operated reliably with He/isobutane gas mixtures and attained sufficient charge gain. Another application uses a GridPix detector with a 2 cm drift gap, called PolaPix, to detect cosmic x-rays. By reconstructing the direction of the ejected electrons the associated polarisation angle of the x-rays can be determined. A new R&D activity is part of the DARWIN design study, and is planning to use GridPix in dual phase noble liquid detectors to detect rare processes like dark matter interactions. A first experimental setup has been assembled to operate a GridPix detector under cryogenic conditions.

Semiconductor detectors

In 2010 the Relaxd project came to a successful ending, achieving the goals outlined four years ago. The standard 1 Gb/s Ethernet connection between the detector read-out electronics and a data acquisition computer has been realized. This system is now the baseline readout system at Nikhef for all Medipix related experiments with gas and semiconductor detectors. The mechanical topology allows tiling of multiple modules in 2D. A proof of principle was established for significant reduction of the guard rings surrounding the active area of silicon pixel sensors. For a 300 μm thick silicon sensor the guard ring was reduced from 500 μm to about 50 μm from the sensor edge, decreasing the dead area from 7% to 1%. Two such sensors, each mounted on top of a TimePix readout ASIC were placed side by side. A testbeam experiment at CERN revealed a dead-area of only 90 μm between the two modules. Another part of the project was the development of Through-Silicon-Via (TSV) technology to enable vertical electrical connections and eliminate space consuming wire bonds. This was approached by making copper pillars in a silicon wafer. These pillars form a conductive interconnection between the bond pads at the back side of the readout ASIC and a printed circuit board with a ball-grid-array. Unfortunately, a first TSV assembly made at IMEC in Belgium was not fully functional but improved assemblies are being processed.

Silicon hybrid pixel detectors with Medipix readout have been used to measure local space vectors for particle trajectories instead of points. One setup consisted of two hybrid detectors closely assembled into a 2-layer vertical stack. This demonstrated a first volumetric pixel (voxel) system with full parallel readout, providing precision tracking, even at high densities of incident particles. Secondary 'delta' electrons have been observed, which have a high probability to create corrupted position measurements along the trail. If these can be recognised in a fitting procedure, an improved precision may be achieved.

RasCLIC

A new cooperation between Nikhef and CERN is the so-called RasCLIC optical alignment system, for pre-alignment of accelerator elements at a future e^+e^- linear collider (notably for CLIC), and to monitor the position of the final focus quadrupoles on each side of the detector. The commissioning of several test benches at Nikhef and CERN are under way to study the feasibility for short and long range alignment with micrometer precision.

2.10 Grid
Large-scale computing

Management: dr. J.A. Templon (PL)
ing. W. Heubers

This past year was an eventful one for our group. The biggest event was thankfully a non-event: our Tier-1 facility accepted and processed (and continues to process) the flood of data from the first long physics run of the LHC. For the facility, it was more or less business as usual.

Grid computing facilities
We reported last year our move to the new data centre on the second floor of the Nikhef building, and the large upgrades made to both the disk storage and computing resources. The new storage hardware gave us rather serious problems for the first few months, as it was the first time this particular hardware had been deployed at such a scale. Since these initial issues were solved, the disk storage has worked flawlessly.

Aside from this problem, the facility has run well this year, with a remarkably low incidence of issues affecting the users. Fig. 1 shows the usage of the computing at the Nikhef grid facility up through the end of November 2010. One can clearly see the peaks in facility use in January (analysis of data taken in December) and starting in July (when the high-luminosity physics started). The black line shows the amount of computing that was promised to the LHC experiments; the peak usage essentially agrees with this line, although the distribution amongst experiments is different from what we had expected. Here we see one of the original motivations for using grids, in action: sharing. LHCb (until October, ATLAS as well) did less computing than expected; these unused resources were effectively used by ALICE. This would not have been possible with dedicated clusters.

The Tier-1 is a service to high-energy physics provided by the Dutch national e-infrastructure project *"BiG Grid"*. BiG Grid supports many other user communities, some of whom have also made significant use of the Nikhef grid facility. The most notable example in 2010 was the European eNMR collaboration (NMR data analysis and structural modeling, life sciences research). Nikhef supplied nearly 40% of the computing cycles for this project, surpassed only by our colleagues operating the BiG Grid cluster at Philips High Tech Campus in Eindhoven.

European Grid Initiative
This past year marked the end of the successful EGEE series of European Framework Grid projects, in which Nikhef has played a key role. The European Grid Initiative has taken over as the flagship European e-Science project, with the project headquarters located in Amsterdam (the building next to Nikhef). Nikhef played an important role in bringing EGI to Amsterdam, and we participate also in the project itself, as well as in the new European Grid Middleware project, EMI. We also play a key role in IGE, the new project concerning Globus grid middleware in Europe. In September, the first EGI technical forum was held in Amsterdam. Nikhef played a major role in the organisation of the conference, as well as in making a major upgrade of the network infrastructure at the conference location in the *'Beurs van Berlage'*.

BiG Grid
Preceding the EGI technical forum, Nikhef also organised a well-attended and informative BiG Grid User Event. The programme reflected the wide range of research performed

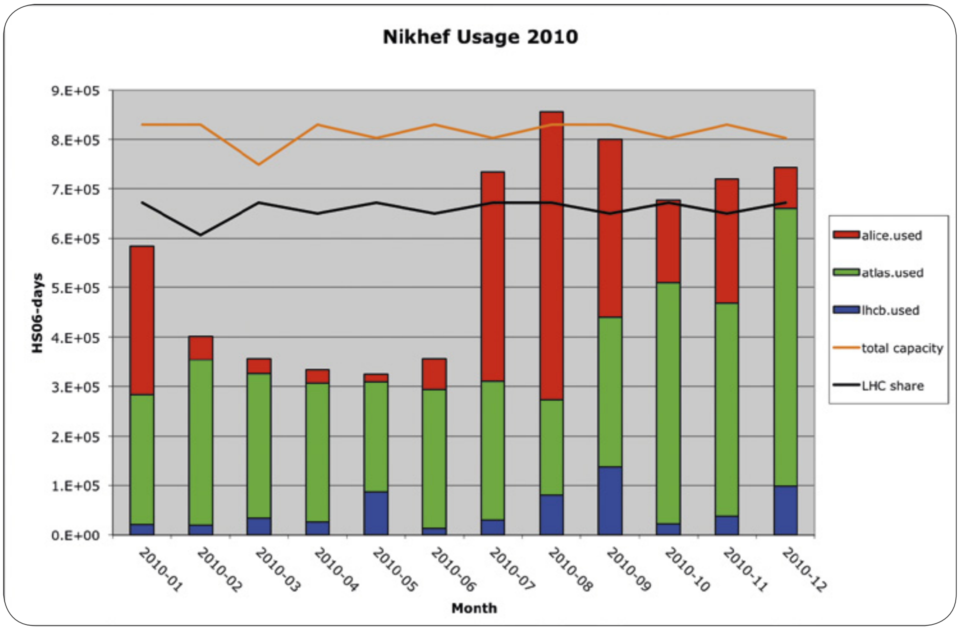


Figure 1. Usage of the Nikhef grid computing facility by the LHC experiments. The solid black line shows for each month the total amount of computer time dedicated to the LHC experiments expressed in hepspec06-days (the capacity of a single core on a modern high-end server is around 12 hepspec06). The usage can exceed this line since there are some computers dedicated to other experiments, and if these are not being used, the LHC experiments can make opportunistic use of them.

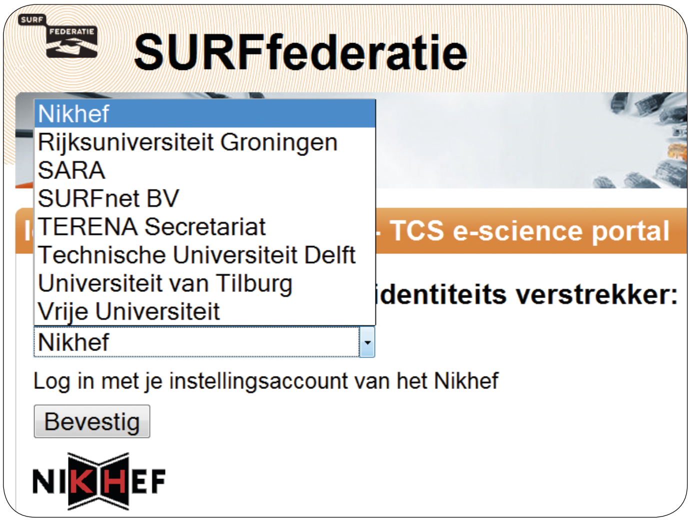


Figure 2. Requesting a grid certificate via the Terena e-Science Portal. When requesting a certificate, the user is first asked to select her country of residence from a clickable map; when clicking on the Netherlands, the user is sent to the page shown, and asked to select her home institute and then to log on using the same username and password that they would use at the home institute. The necessary information is securely retrieved from the home institute and the certificate is within seconds created and loaded into the user's browser. The previous procedure for obtaining a certificate usually took at least one business day.

with the help of BiG Grid resources and manpower. The work presented included life sciences, biodiversity, high-energy physics, DNA sequencing, radio astronomy, NMR structural modeling, and electron tomography.

Single sign on

This year saw the maturation of one of the research lines in our security area. This line concerns significant improvements in one of the core technologies of grid computing, 'single sign on'. This technology allows users, upon acquiring digital credentials, to access computing and storage resources at thousands of sites all over the world, without needing to create 'accounts' or request a 'username and password'. Until now acquiring and using these digital credentials was at best a cumbersome procedure, involving not only several steps on the computer, but also filling in forms and showing a valid passport to a person authorized to issue the certificates. The new research takes an important step by enabling users to create the and use these digital credentials, using only a web browser and the username and password assigned to them by their home research institution; this home institution has certainly seen their passport and has all the necessary information. Fig. 2 shows what a Dutch user requesting a new certificate sees, when going through the new certificate request sequence. HEP users will benefit from this, as will other scientists: a survey of European research-infrastructure (ESFRI) projects indicates that they perceive single sign-on technology to be the most useful aspect of grid computing.

Data management

Finally, this year marked our foray into the world of distributed data management. As the LHC is now producing data full steam, problems associated with analysis of these data at scale are surfacing. Our involvement began with a software project to alleviate data-access-related bottlenecks for local LHCb users. We developed a small component that handles data files in the background, after tests had revealed that when a network is involved, bulk data transfer performed much better than partial reads. This work has evolved into a wider interest in distributed data management, in particular approaches based on peer-to-peer technologies. Our group hosted the first workshop on the evolution of LHC data management in June at Felix Meritis in Amsterdam. Starting in January we will have two post-masters students working in this area; one PhD student as part of a joint project in data management with the computer science faculty of the VU University Amsterdam, the other as a thesis project with the Software Technology professional degree program of the Eindhoven University of Technology.

3

Output

3.1 Publications

ATLAS/DØ

ATLAS Collaboration

G. Aad (*et al.*); Z. Aad (*et al.*), S. Bentvelsen, G.J. Bobbink, R. de Boer, K. Bos, H. Boterenbrood, G. Brouwer, E.J. Buis, J.J.F. Buskop, A.P. Colijn, M. Consonni, R. Dankers, C. Daum, A. Doxiadis, B. van Eijk, J. Ennes, P. Ferrari, F. Filthaut, H. Garitaonandia, M. Gosselink, H. van der Graaf, H. Groenstege, N. de Groot, F. Hartjes, R.G.G. Hart, P.J. Hendriks, N.P. Hessey, O. Igonkina, E. Jansen, P.P.M. Jansweijer, P. de Jong, M.S. Kayl, Z. van Kesteren, G. Kieft, P.F. Klok, S. Klous, P. Kluit, A.C. König, F. Koetsveld, E. Koffeman, A. Koutsman, E. van der Kraaij, H. Lee, W. Liebig, M. Limper, F. Linde, G. Luijckx, C.A. Magrath, G. Massaro, J. Mechnich, A. Muijs, I. Mussche, L. de Nooij, G. Ordonez, J.P. Ottersbach, S.J.M. Peeters, O. Peters, E. van der Poel, M. Raas, A. Reichold, P. Rewiersma, M. Rijpstra, N. Ruckstuhl, G. Salamanna, R. Sandstroem, R.C. Scholte, H.W. Schuijlenburg, J. Snuverink, D. Ta, C.J.W.P. Timmermans, M. Tsiakiris, E. Turlay, W. Verkerke, J.C. Vermeulen, M. Vreeswijk, I. van Vulpen, P. Werneke, T. Wijnen

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Acta Phys.Polon.Supp **3** (2010) 809

Looking for technicolor in ATLAS
Acta Phys.Polon.Supp **3** (2010) 867

Searches for Supersymmetry in ATLAS
Acta Phys. Pol. **B 41** (2010) 1629

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Acta Phys. Pol. **B 41** (2010) 1675

Readiness of the ATLAS liquid argon calorimeter for LHC collisions
Eur. Phys. J. **C 70** (2010) 723

Drift Time Measurement in the ATLAS Liquid Argon Electromagnetic Calorimeter using Cosmic Muons
Eur. Phys. J. **C 70** (2010) 755

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Eur. Phys. J. **C 70** (2010) 787

The ATLAS Simulation Infrastructure
Eur. Phys. J. **C 70** (2010) 823

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Eur. Phys. J. **C 70** (2010) 875

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Eur. Phys. J. **C 70** (2010) 1193

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IEEE Trans. Nucl. Sci. **57** (2010) 566

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IEEE Trans. Nucl. Sci. **57** (2010) 650

Performance of the ATLAS detector using first collision data
J. High Energy Phys. **09** (2010) 056

Measurement of the $W \longrightarrow l\nu$ and $Z/\gamma^* \longrightarrow ll$ production cross sections in proton-proton collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector
J. High Energy Phys. **12** (2010) 060

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J. Instr. **5** (2010) C11006

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J. Instr. **5** (2010) C11010

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J. Instr. **5** (2010) C12011

The ATLAS silicon microstrip tracker. Operation and performance
J. Instr. **5** (2010) C12050

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J. Instr. **5** (2010) C12051

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J. Phys.: Conf. Series **219** (2010) 022006

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J. Phys.: Conf. Series **219** (2010) 022017

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J. Phys.: Conf. Series **219** (2010) 022021

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Nucl. Instr. Meth. **A 617** (2010) 1

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Nucl. Instr. Meth. **A 617** (2010) 411

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Nucl. Instr. Meth. **A 623** (2010) 394

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Nucl. Instr. Meth. **A 623** (2010) 552

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Phys. Rev. Lett. **105** (2010) 161801

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Phys. Lett. **B 688** (2010) 21

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J. Instr. **5** (2010) C12047

First-year experience with the ATLAS online monitoring framework
J.Phys.: Conf.Series **219** (2010) 022005

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J.Phys.: Conf.Series **219** (2010) 022047

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J.Phys.: Conf.Series **219** (2010) 032006

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Nucl. Instr. Meth. **A 617** (2010) 306

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Nucl. Instr. Meth. **A 623** (2010) 519

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Phys. Rev. Lett. **104** (2010) 061801

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Phys. Rev. Lett. **105** (2010) 081801

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Phys. Rev. Lett. **105** (2010) 211802

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Phys. Rev. **D 82** (2010) 012003

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Phys. Rev. **D 82** (2010) 071102

Measurement of the t-channel single top quark production cross section
Phys. Lett. **B 682** (2010) 363

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Phys. Lett. **B 682** (2010) 370

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Phys. Lett. **B 690** (2010) 5

Measurement of direct photon pair production cross sections in $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV
Phys. Lett. **B 690** (2010) 108

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Phys. Lett. **B 693** (2010) 81

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Phys. Lett. **B 693** (2010) 95

Dependence of the $t\bar{t}$ production cross section on the transverse momentum of the top quark
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Phys. Lett. **B 693** (2010) 522

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Phys. Lett. **B 693** (2010) 531

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LHCb/BABAR

LHCb Collaboration

R. Aaij (*et al.*); J.M. Amoraal, Th.S. Bauer, I. Belyaev, M. van Beuzekom, E. Bos, J. van den Brand, K. Carvalho Akiba, D. van Eijk, C. Farinelli, W. Hulsbergen, E. Jans, F. Jansen, T. Ketel, P. Koppenburg, A. Kozlinskiy, A. van Lysebetten, B. M'charek, M. Merk, I. Mous, S. Oggero, J. Palacios, A. Papadelis, A. Pellegrino, T. du Pree, G. Raven, N. Serra, E. Simioni, B. Storaci, H. Terrier, N. Tuning, L. Wiggers, G. Ybeles Smit

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Phys. Lett. **B 693** (2010) 69

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Nucl. Instr. Meth. **A 617** (2010) 23

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Nucl. Instr. Meth. **A 617** (2010) 329

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Nucl. Instr. Meth. **A 618** (2010) 108

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Nucl. Instr. Meth. **A 623** (2010) 82

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Phys. Rev. **D 81** (2010) 011102

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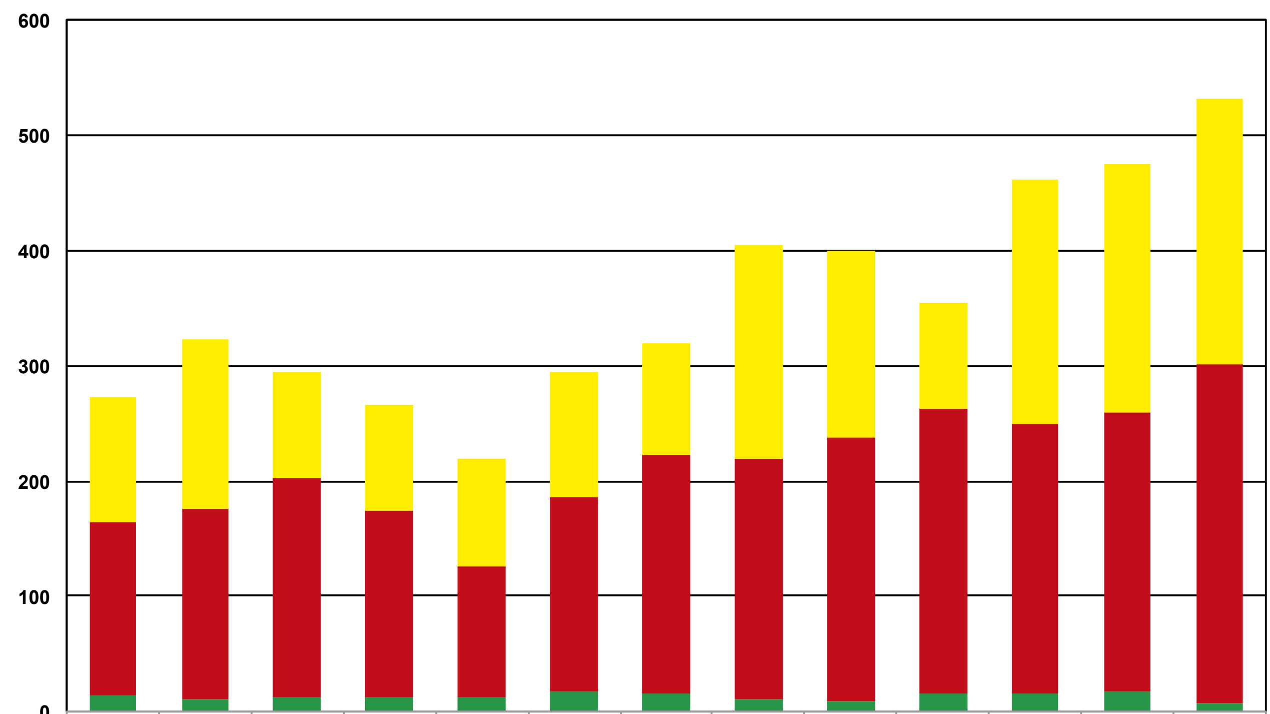

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Talks	109	147	92	91	95	108	97	186	162	93	212	215	231
Publications	150	165	190	163	113	168	207	209	228	246	234	243	293
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D.M. Nikolenko *(et al.)*, H. de Vries
Two-photon exchange and elastic scattering of electrons/positrons on the proton
Proc. of Science ICHEP (2010) 164

KamLAND Collaboration
S. Abe (*et al.*), M.P. Decowksi

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Phys. Rev. **C 81** (2010) 025807

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C. Alt (*et al.*); T. Anticic (*et al.*), M. Botje, P. Christakoglou, M.A. van Leeuwen

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Phys. Rev. **C 81** (2010) 064907

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Phys. Rev. **C 83** (2010) 014901

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F. Antinori *(et al.)*, R. Kamermans, P.G. Kuijer, E. Schillings, P. van de Ven

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3.2 Theses

Edwin Bos
Reconstruction of charged particles in the LHCb experiment
Vrije Universiteit Amsterdam, 10 February 2010
Promotor: M.H.M. Merk
Copromotor: H.G. Raven

Gabriel Ybeles Smit
Asymmetries in the decay of beauty
Vrije Universiteit Amsterdam, 23 February 2010
Promotores: M.H.M. Merk, J.F.J. van den Brand
Copromotor: H.J. Bulten

Eduard Ebron Simioni
New physics from rare beauty
Vrije Universiteit Amsterdam, 1 March 2010
Promotor: M.H.M. Merk
Copromotores: A. Pellegrino, W.D. Hulsbergen

Zdenko van Kesteren
Identification of muons in ATLAS
Universiteit van Amsterdam, 12 March 2010
Promotor: S. Bentvelsen
Copromotor: P.M. Kluit

Lucian-Stefan Ancu
A search for ZH $\longrightarrow \mu\mu\, b\bar{b}$ production at the Tevatron
Radboud Universiteit Nijmegen, 20 April 2010
Promotor: S.J.de Jong
Copromotor: F. Filthaut

Jorn Kerst Boomsma
Effects of instanton interactions on the phases of quark matter
Vrije Universiteit Amsterdam, 17 June 2010
Promotor: P.J.G. Mulders
Copromotor: D. Boer

Martijn Gosselink
Radiating top quarks
Universiteit van Amsterdam, 14 October 2010
Promotor: E.N. Koffeman
Copromotor: A.P. Colijn

Tristan Arnoldus du Pree
Search for a strange phase in beautiful oscillations
Vrije Universiteit Amsterdam, 22 October 2010
Promotor: M.H.M. Merk
Copromotor: H.G. Raven

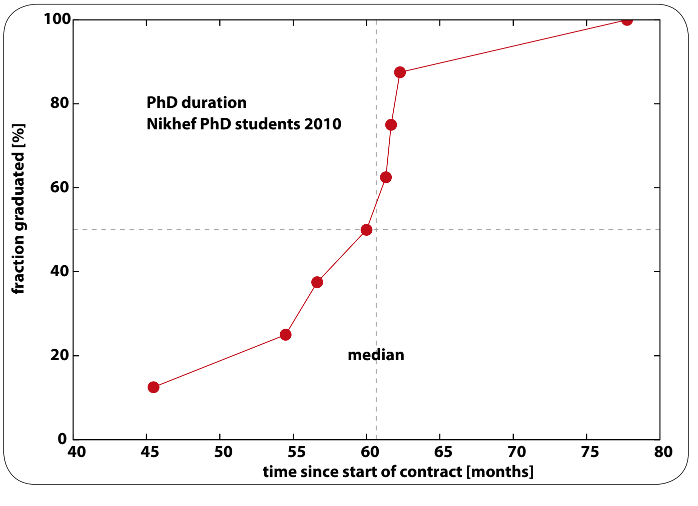


Figure 1. Fraction of PhD students working at Nikhef that graduated in the year 2010 as a function of time since the start of their thesis contract. The median PhD duration is 61 months (5.1 year).

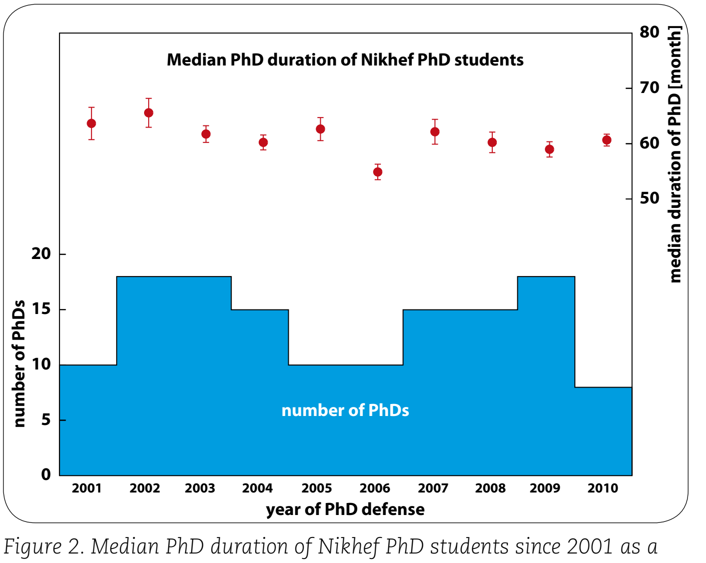
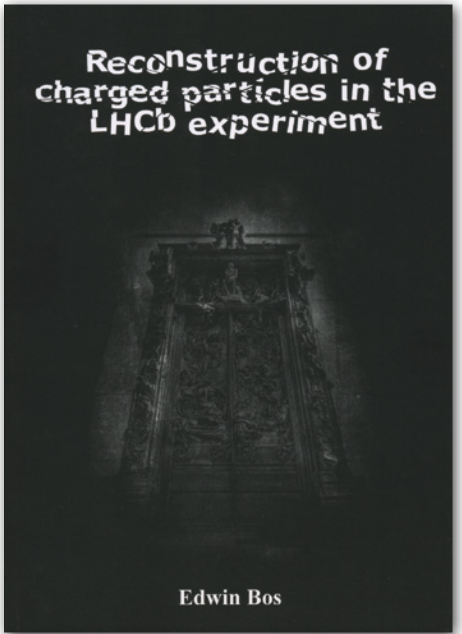
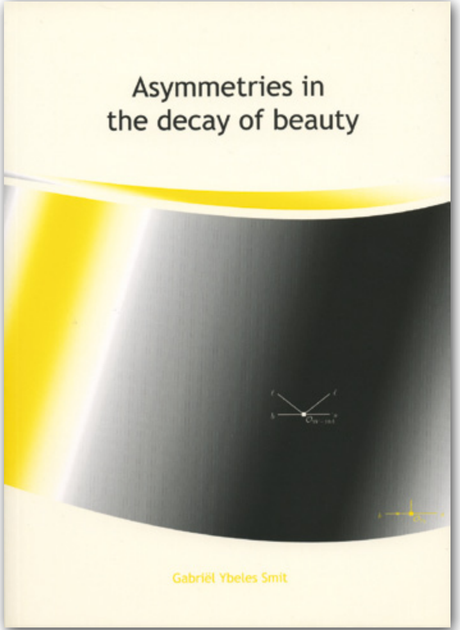
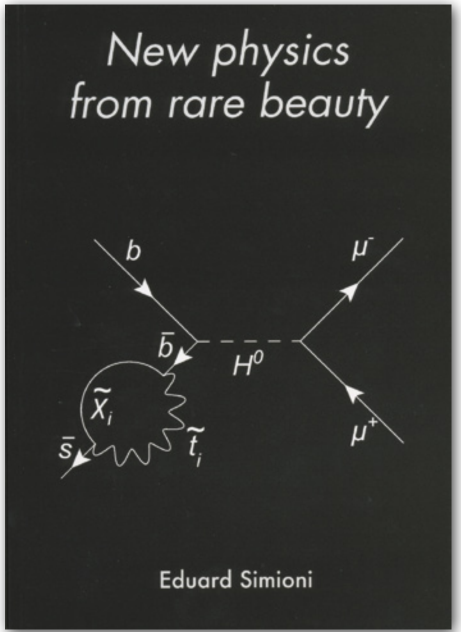
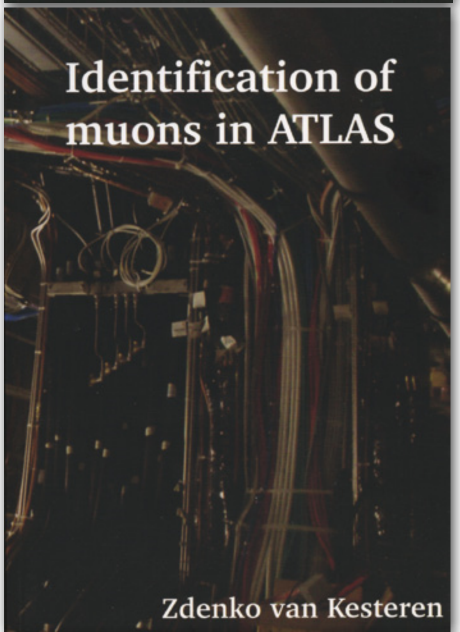


Figure 2. Median PhD duration of Nikhef PhD students since 2001 as a function of graduation year. The error bars represent the median absolute deviation (MAD)/√(n-1). The histogram gives the total number n of PhDs in each year.

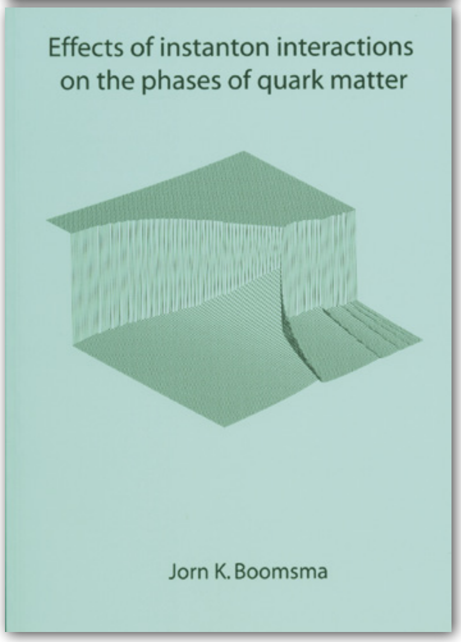

Reconstruction of charged particles in the LHCb experiment
Edwin Bos

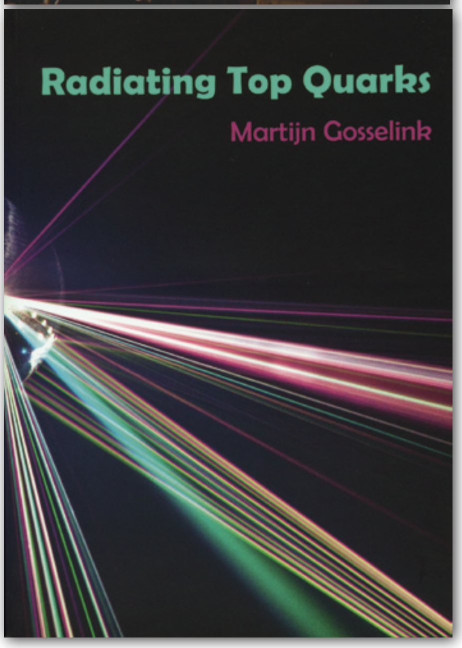

Asymmetries in the decay of beauty
Gabriël Ybeles Smit

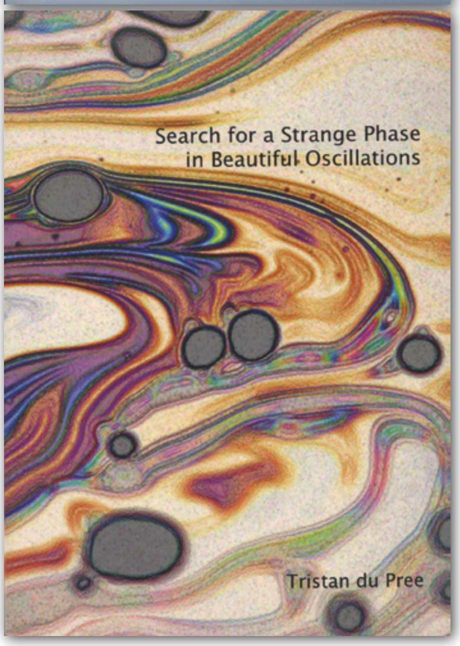

New physics from rare beauty
Eduard Simioni


Identification of muons in ATLAS
Zdenko van Kesteren


A search for ZH → μμbb̄ production at the Tevatron
Lucian Ancu


Effects of instanton interactions on the phases of quark matter
Jorn K. Boomsma


Radiating Top Quarks
Martijn Gosselink


Search for a Strange Phase in Beautiful Oscillations
Tristan du Pree

3.3 Talks

ATLAS/DØ

Bentvelsen, S., First results with the LHC, Symp. "Thursday's Universe", Groningen, The Netherlands, 18 November 2010

LHC on the road to new Physics, GRAPPA colloquium, Universiteit van Amsterdam, Amsterdam, The Netherlands, 24 November 2010

Colijn, A.P., CO_2 Cooling for Particle Physics Experiments, 9th IIR Gustav Lorentzen Conf. 2010, Sydney, Australia, 12 April 2010

Filthaut, F., The Quest for the Higgs Boson: Results from the Tevatron Collider, Physics@FOM Meeting, Veldhoven, The Netherlands, 18 January 2010

The Quest for the Higgs Boson: Results from the Tevatron Collider, RUG, Groningen, The Netherlands, 11 March 2010

BSM Higgs Boson Searches at the Tevatron Collider, MCTP Higgs Symp., Ann Arbor, USA, 14 May 2010

Challenging the Standard Model at the Tevatron Collider, Kruger2010 Workshop on Discovery Physics at the LHC, Kruger park, South Africa, 8 December 2010

Gosselink, M., Top physics with ATLAS, Conf. on LHC First Data, University of Michigan, Ann Arbor, USA, 12 December 2010

Groot, de, N., The LHC at CERN, Huygens colloquium Radboud Universiteit, Nijmegen, The Netherlands, 7 June 2010

Hessey, N.P., ATLAS Upgrade for the sLHC, Colloquium at Edinburgh University, Edinburgh, United Kingdom, 27 January 2010

ATLAS Upgrade for the sLHC, Colloquium at Glasgow University, Glasgow, United Kingdom, 28 January 2010

Coordination for the S-ATLAS experiment implementation, SLHC-PP Annual Meeting, Madrid, Spain, 5 February 2010

Challenges arising from the Super-LHC project, EIRO Workshop on Radiation Hardness Measurement Testing and Materials, Lisbon, Portugal, 17 March 2010

Jong, P.J. de, Characterization of new physics: the ATLAS perspective, LHC Physics Day, CERN, Geneva, Switzerland, 4 June 2010

Topological searches for new physics in ATLAS, SLAC, Stanford, USA, 24 September 2010

Status of ATLAS and prospects for 1 fb^{-1}, Prometeo Workshop, Valencia, Spain, 18 November 2010

Salamanna, G., Measurement of the Top quark pair production at ATLAS with the first data from LHC, Centre de Physique de Particules de Marseille, Marseille, France, 17 February 2010

Atlas Electroweak results, XIX Int. Workshop "High Energy Physics and Quantum Field Theory", Golitsyno, Moscow, Russia, 8 September 2010

Tsiakiris, M., Data-driven estimation of muon trigger efficiency using semi-leptonic top pair decays in the ATLAS detector, 2010 Workshop on Recent Advances in Particle Physics and Cosmology, Thessaloniki, Greece, 28 March 2010

Vulpen, I.B. van, *b*-tagging, leptons and missing energy in ATLAS after first data, Top2010 Conf., Bruges, Belgium, 2 June 2010

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Beuzekom, M.G. van, Experience from vertex triggering at the LHC, Vertex 2010 - 19th Int. Workshop on Vertex Detectors, Luss (Loch Lomond), United Kingdom, 11 June 2010

Hulsbergen, W.D., Running status and first results from LHCb, Moriond EW 2010, La Thuile, Italy, 7 March 2010

Koppenburg, P.S., LHCb Status and Plans, Indirect Searches for New Physics at the time of LHC Conf., Galileo Galilei Institute, Florence, Italy, 22 March 2010

LHCb Status Report, LHCC Open Session, Geneva, Switzerland, 5 May 2010

Rare Decays at LHCb, University of Zürich Seminar, Zürich, Switzerland, 11 May 2010

Rare Decays, Ecole de Gif, Besse et Saint Anastaise, France, 7 September 2010

Rare Decays, Ecole de Gif, Besse et Saint Anastaise, France, 10 September 2010

Pellegrino, A., The Commisioning and Performance of the Outer Tracker Detector for LHCb, VCI2010 - Vienna Conf. on Instrumentation 2010, University of Technology, Vienna, Vienna, Austria, 16 February 2010

First results from the LHCb experiment, Symp. on High Energy Strong Interactions, Yukawa Institute for Theoretical Physics, University of Kyoto, Kyoto, Japan, 12 August 2010

Searches for new physics in Heavy Flavour Rare *b* decays at LHCb, Workshop on Discovery Physics at the LHC, Kruger Park, South Africa, 7 December 2010

Raven, G., Prospects for CP violation in $B^0_s \longrightarrow J/\psi\varphi$ from first LHCb data, 35th Int. Conf. on High Energy Physics (ICHEP) 2010, Paris, France, 14 July 2010

CP Violation, CERN summer student lecture program, Geneva, Switzerland, 3 August 2010

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ALICE/STAR

Christakoglou, P., First identified particle studies at the CERN-LHC with the ALICE experiment, 2010 Workshop on Recent Advances in Particle Physics and Cosmology, Thessaloniki, Greece, 26 March 2010

Alice Silicon Tracker (drift detector and strips) operations and performance, 19th Int. Workshop on Vertex Detector, Loch Lomond, United Kingdom, 7 June 2010

Baryon number transport at LHC energies with the ALICE experiment, 4th Hot Quarks Workshop, La Londe Les Maures, France, 21 June 2010

Identified particle studies at the LHC with the ALICE experiment, 9th Quark Confinement and the Hadron Spectrum, Madrid, Spain, 31 August 2010

First result of the ALICE experiment and prospects for the first heavy-ion measurements, Colloquium at National Technical University of Athens, Athens, Greece, 1 December 2010

The ALICE experiment: Detector commissioning and performance, Colloquium at National Technical University of Athens, Athens, Greece, 2 December 2010

Kuijer, P.G., ALICE status and first results, 12th Topical Seminar on Innovative Particle and Radiation Detectors, Siena, Italy, 7 June 2010

Physics at Alice, Quasiparticles or Quasinormal Modes, Vienna, Austria, 26 August 2010

Overview of the Alice results, Workshop on Discovery Physics at LHC, Kruger park, South Africa, 6 December 2010

Leeuwen, M. van, ALICE at the LHC, Brazilian Nuclear Physics School, Sao Paulo (via EVO), Brazil, 2 February 2010

Status of the TECHQM brick report, JET Symp., Berkeley, USA, 18 June 2010

Parton energy loss in a realistic geometry, INT Program: Quantifying the properties of Hot QCD Matter, Seattle, USA, 21 June 2010

Mischke, A., Heavy-quark production in high-energy nucleus-nucleus collisions, Physics@FOM Meeting, Veldhoven, The Netherlands, 19 January 2010

Heavy-flavour production in nucleus-nucleus collisions: From RHIC to LHC Int. Workshop XXXVIII on Gross Properties of Nuclei and Nuclear Excitations, Hirschegg, Kleinwalsertal, Austria, 22 January 2010

Heavy quarks as probe of matter produced in collisions of heavy atomic nuclei, Laboratoire de Physique Subatomique et des technologies associes, Nantes, France, 13 April 2010

Heavy-flavour meson production at RHIC, 11th Int. Workshop on Meson Production, Properties and Interaction, Krakow, Poland, 10 June 2010

Heavy-quark production in hot and dense QCD matter, 9th Int. Conf. on Quark Confinement and the Hadron Spectrum, Universidad Complutense de Madrid, Spain, 31 August 2010

Identified charged hadrons and strange particle production in 900 GeV proton-proton collisions with the ALICE experiment, 40th Int. Symp. on Multiparticle Dynamics, Antwerp, Belgium, 22 September 2010

Heavy-flavour production in high energy nucleus-nucleus collisions, Kernphysikalisches Kolloquium, Helmholtz Int. Center for FAIR, Frankfurt am Main, Germany, 18 November 2010

Nooren, G.J.L., The making of ALICE's SiliconStripDetector, 4th Work Meeting of the CBM-MPD STS Consortium, Hirschhorn am Neckar, Germany, 26 October 2010

Peitzmann, T., ALICE at LHC – first data from p+p and perspectives for A+A, Origins of Mass 2010 Conf., Odense, Denmark, 4 May 2010

Snellings, R.J.M., Elliptic Flow: lessons from RHIC, Strongly Interacting Matter under Extreme Conditions, Hirschegg, Austria, 19 January 2010

Elliptic Flow: A Survey, Workshop on Critical Examination of RHIC Paradigms, Austin, USA, 15 April 2010

The ALICE experiment at the LHC, IV Int. Workshop on the interconnection between particle physics and cosmology, Torino, Italy, 12 July 2010

Heavy-Ion Collisions and Flow, CERN Summer Student Program (ALICE students), Geneva, Switzerland, 17 July 2010

Elliptic Flow: Current Status, Quark Confinement and the Hadron Spectrum IX, Madrid, Spain, 1 September 2010

Elliptic Flow: An Overview, Int. Workshop on the interplay between soft and hard interactions in particle production at ultra-relativistic energies, Catania, Italy, 9 September 2010

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Verweij, M., Comparing energy loss models, Hard Probes 2010, Eilat, Israel, 12 October 2010

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Gajana, D., A Front-end ASIC for the readout of the PMT in the KM3NeT detector, Topical Workshop on Electronics for Particle Physics (TWEPP 2010), Aachen, Germany, 21 September 2010

Kooijman, P., Status of KM3NeT, ICHEP, Paris, France, 24 July 2010

Fibreoptic network for deep-sea infrastructures, Workshop on technology for deep-sea infrastructures, Aberdeen, United Kingdom, 1 November 2010

Timmer, P., Low power High Voltage supply circuit for Photomultiplier tubes in the KM3NeT detector, Topical Workshop on Electronics for Particle Physics (TWEPP 2010), Aachen, Germany, 21 September 2010

Wolf, E. de, Antares, a stepping stone to KM3NeT, Van der Waals-Zeeman Institute, University of Amsterdam, Amsterdam, The Netherlands, 16 February 2010

Searching for DM with Antares and KM3NeT, GRAPPA Symp., Amsterdam, The Netherlands, 3 March 2010

KM3NeT, a multi-km^3 neutrino detector, 22nd European Cosmic Ray Symp., Turku, Finland, 5 August 2010

Pierre Auger Observatory

Coppens, J., Radio detection of ultra high energy cosmic rays at the world's largest cosmic-ray observatory, Physics@FOM Meeting, Veldhoven, The Netherlands, 20 January 2010

Radio detection at the Pierre Auger Observatory: arrival direction reconstruction and lateral distribution studies, NNV Fall meeting, Lunteren, The Netherlands, 5 November 2010

Jong, S.J. de, Charged particle astronomy: a new window on the universe, Technische Universiteit, Eindhoven, The Netherlands, 28 January 2010

Kelley, J., The Pierre Auger Observatory: Recent Results and Future Plans, 5th Int. Conf. "Beyond 2010", Cape Town, South Africa, 4 February 2010

Searching for Quantum Gravity with High-energy Neutrinos, Symp. Experimental Search for Quantum Gravity, NORDITA, Stockholm, Sweden, 12 July 2010

Schoorlemmer, H., Radio detection of cosmic rays @ Pierre Auger Observatory, Fysica 2010, Utrecht, The Netherlands, 23 April 2010

Results from polarization studies of radio signals induced by cosmic rays, ARENA 2010, Nantes, France, 30 June 2010

Virgo/LISA

Bauer, Th.S., Gravitational Wave Interferometers Virgo an LIGO, University of Zurich, Zürich, Switzerland, 21 April 2010

Progress Towards Gravitational Wave Astrophysics, Rencontres de Blois 2010, Blois, France, 20 July 2010

Beker, M.G., Einstein Telescope: seismic and GGN studies, Gravitational Wave Advanced Detector Workshop, Kyoto, Japan, 18 May 2010

Gravity gradient noise and site characterization for the Einstein Telescope, NNV Fall meeting, Lunteren, The Netherlands, 5 November 2010

Gravity gradient noise and site characterization for the Einstein Telescope, 3rd Annual Einstein Telescope Workshop, Budapest, Hungary, 22 November 2010

Seismic noise studies of underground locations for ET site selection, KNMI, De Bilt, The Netherlands, 7 December 2010

Broeck, C.F.F. Van Den, Cosmography with gravitational waves, Physics@FOM Meeting, Veldhoven, The Netherlands, 20 January 2010

Cosmography with gravitational waves, ESTEC Seminar, Noordwijk, The Netherlands, 7 May 2010

Physics and astrophysics with gravitational waves, 3rd GRAPPA Meeting, Amsterdam, The Netherlands, 19 May 2010

Multi-messenger cosmology with Einstein Telescope: Some recent results, Einstein Telescope WG4 Meeting, Nice, France, 1 September 2010

Multi-messenger cosmology with Einstein Telescope, 3rd Annual Einstein Telescope Workshop, Budapest, Hungary, 23 November 2010

Del Pozzo, W.D.P., Cosmology with Advanced Detectors, University of Birmingham, Birmingham, United Kingdom, 8 December 2010

Li, T.G.F., Fisher Matrix for General Time Domain Waveforms and its Applications, Gravitational Physics Seminars, Cardiff, United Kingdom, 20 August 2010

Comparison of Parameter Estimation between ET-B and ET-C Sensitivities, Einstein Telescope WG4 Meeting, Nice, France, 1 September 2010

Testing General Relativity with Gravitational Waves, NNV Fall meeting, Lunteren, The Netherlands, 5 November 2010

Fundamental Physics with Einstein Telescope: Relevance of the low frequency sensitivity, 3rd Annual Einstein Telescope Workshop, Budapest, Hungary, 22 November 2010

Rabeling, D.S., A Preliminary Site Evaluation for Einstein Telescope, Gravitational Wave Advanced Detector Workshop, Kyoto, Japan, 20 May 2010

Terrestrial Laser Interferometric Gravitational Wave Detection, KNMI, De Bilt, The Netherlands, 7 December 2010

Impedance Sensing and Control, AEI sensing and control Workshop, Hannover, Germany, The Netherlands, 14 December 2010

XENON

Decowski, M.P., The Search for Neutrinoless Double Beta Decay, KVI, Groningen, The Netherlands, 6 July 2010

The Search for Dark Matter Particles, Radboud University, Nijmegen, The Netherlands, 28 October 2010

Measuring Neutrino Properties and Geoneutrinos with KamLAND, University of Bonn, Bonn, Germany, 11 November 2010

Theory

Adelhart Toorop, R. de, Discrete flavour symmetries in GUTs: the Beauty and the Beast, Università degli Studi di Padova, Padua, Italy, 24 March 2010

The interplay between GUT and flavour symmetries in a Pati-Salam x S4 model, PASCOS 2010, the 16th Int. Symp. on Particles, Strings and Cosmology, Valenica, Spain, 23 July 2010

Familiensymmetrien und GUTs in einem Pati-Salam x S4 Modell, 42 Herbstschule für Hochenergiephysik Maria Laach, Maria Laach, Germany, 9 September 2010

Constraining non-Abelian flavour symmetries, Discrete 2010, Rome, Italy, 7 December 2010

Beenakker, W., Introduction to SUSY phenomenology, AIO/OIO school Theoretical High Energy Physics, Driebergen, The Netherlands, 8 February 2010

Boomsma, J.K.
Influence of instantons and strong magnetic fields on quark matter, Norwegian Winter Workshop on QCD in Extreme Conditions, Trondheim, Norway, 24 February 2010

The Combined Influence of Instantons and Strong Magnetic Fields on Quark Matter, P- and CP-odd Effects in Hot and Dense Matter, Brookhaven National Laboratory, Brookhaven, USA, 29 April 2010

Broek, T.C.H. van den, Noncommutative geometry & supersymmetry, Westfälische Wilhelms-Universität Münster, Münster, Germany, 19 June 2010

Noncommutative geometry & supersymmetry, Centre de Physique Théorique de l'Université de Marseille, Marseille, France, 25 June 2010

To commute or not to commute, NNV Fall meeting, Lunteren, The Netherlands, 5 November 2010

Dunnen, W.J. den, Double Transverse Spin Asymmetries as a Probe for New Physics, Workshop on Progress in High-pT Physics at RHIC, Brookhaven, USA, 18 March 2010

Double transverse spin asymmetries at RHIC as a probe for new physiscs, INT Program "Gluons and the quark sea at high energies", Seattle, USA, 28 October 2010

Measuring W-W' mixing with spin asymmetries at RHIC, NNV Fall meeting, Lunteren, The Netherlands, 5 November 2010

Fleischer, R., Precision *B* Physics in the LHC Era, Colloquium, Institute for Theoretical Physics, Utrecht University, Utrecht, The Netherlands, 24 February 2010

B Physics in the LHC Era: Selected Topics, 3rd Workshop on Heavy Flavour Physics, Capri, Italy, 5 July 2010

A Fresh Look at $B_{s,d} \longrightarrow \pi\pi, \pi K$, KK Decays, 6th Int. Workshop on the CKM Unitarity Triangle - CKM2010, Warwick, United Kingdom, 9 September 2010

Extracting gamma and Penguin Parameters from $B_s \longrightarrow J/\psi K_S$, 6th Int. Workshop on the CKM Unitarity Triangle - CKM2010, Warwick, United Kingdom, 9 September 2010

Towards New Frontiers in *B* Physics in the LHC Era, Symporium on Flavour Physics: Strong Dynamics, Rare Decays and New Phenomena, Berg, Starnberger See, Germany, 9 October 2010

B Physics Perspectives in the LHC Era, Int. Conf. on Flavor Physics in the LHC Era, Singapore, Singapore, 9 November 2010

Towards New Frontiers in Precision *B* Physics in the LHC Era, Colloquium, Institute for Theoretical Physics, University of Amsterdam, Amsterdam, The Netherlands, 25 November 2010

B Physics Perspectives in the LHC Era, VIII Latin American Symp. on High-Energy Physics, SILAFAE 2010, Valparaiso, Chile, 7 December 2010

George, D.P., Stability of gravity-scalar systems for domain-wall models with a soft wall, PASCOS 2010: The 16th Int. Symp. on Particles, Strings and Cosmology, Valencia, Spain, 19 July 2010

Holten, J.W. van, Deeltjesfysica en de LHC, University Leiden, Leiden, The Netherlands, 22 March 2010
The realization of conformal symmetry in non-relativistic QFT, Non-commutative Structures and Non-relativistic Supersymmetries, Univ. Tours, Tours, France, 23 March 2010

HiSPARC, EPPOG meeting, CERN, Geneve, Switzerland, 15 October 2010

Gravitational Waves, University Groningen, Groningen, The Netherlands, 22 November 2010

Knegjens, R.K., In Pursuit of New Physics with $B_s \longrightarrow K^+K^-$, NNV Fall meeting, Lunteren, The Netherlands, 5 November 2010

Laamanen, J., A large Muon Electric Dipole Moment from Flavor?, KVI, Groningen, The Netherlands, 26 October 2010

Laenen, E., Top quark physics at the LHC, University of Iceland, Reykjavik, Iceland, 26 February 2010

The ubiquitous top, Université Libre de Bruxelles, Brussels, Belgium, 8 April 2010

Next-to-eikonal exponentiation, Loops and Legs 2010, Woerlitz, Germany, 29 April 2010

Concluding remarks, Loopfest 2010, Stony Brook, New York, USA, 23 June 2010

Next-to-eikonal exponentiation, HO10 CERN Theory Institute, Geneva, Switzerland, 1 July 2010

Recent developments in QCD resummation, Freiburg University, Freiburg, Germany, 6 July 2010

Heavy Flavor: From Top to Bottom (and Charm), MIT-Berkeley Workshop on “Implications of first LHC data”, Boston, USA, 12 August 2010

QCD Resummation, INT Workshop on “Perturbative and Non-Perturbative Aspects of QCD at Collider Energies”, Seattle, USA, 15 September 2010

Some recent developments in resummation, ECT* Workshop “QCD at the LHC”, Trento, Italy, 27 September 2010

Developments in (next-to)-eikonal exponentiation, Levinfest, Tel Aviv University, Tel Aviv, Israel, 7 October 2010

Soft gluon resummation for squark and gluino hadroproduction, Mini-Workshop “Soft Gluons and New Physics at the LHC”, Manchester, United Kingdom, 1 November 2010

Maio, M., Simple current extensions and permutation orbifolds, Workshop “Beyond the standard model”, Bad Honnef, Germany, 8 March 2010

Extensions in permutation orbifolds, Cargese Summer School, Cargese (Corsica), France, 24 June 2010

Extensions and the permutation orbifold, Institute for Advanced Studies, Princeton, USA, 27 July 2010

Schellekens, A.N., The Emperor’s Last Clothes?, AIO school THEP (Evening Lecture), Driebergen, The Netherlands, 8 February 2010

Heterotic Weight Lifting, Workshop GUTs and Strings, Munich, Germany, 10 February 2010

Heterotic Weight Lifting, KITP program Strings at the LHC and in the Early Universe, Santa Barbara, USA, 8 April 2010

Exploring The String Theory Landscape, Freiburg University, Freiburg, Germany, 19 May 2010
Heterotic Weight Lifting, String Phenomenology, Paris, France, 6 July 2010

Mulders, P.J., Transverse momentum dependent distribution functions at high energies, Int. Workshop on High Energy Physics in the LHC Era, Valparaiso, Chile, 3 January 2010

Tranverse momentum dependent PDFs in high energy processes - Theory Overview and Applications, AGS-RHIC User’s meeting, Brookhaven National Laboratory, Upton, USA, 8 June 2010

Transverse momentum dependence in high-energy scattering processes, Workshop on Transverse momentum Distributions, ECT*, Trento, Italy, 21 June 2010

Overview of TMD factorization in high energy scattering processes, Brookhaven Summer Program on Nucleon Spin Physics, Upton, USA, 15 July 2010

Universality of Transverse Momentum Dependent Distribution Functions, Workshop on Perturbative and Nonperturbative Aspects of QCD at Collider Energies, University of Washington, Seattle, USA, 14 September 2010

Niessen, A.I., Improving predictions for SUSY cross sections, DRSTP Postgraduate School, Driebergen, The Netherlands, 11 February 2010

Rogers, T.C., Complications in QCD Factorization with Transverse Momentum Dependent PDFs, DESY, Hamburg, Germany, 3 May 2010

TMD factorization breaking, ECT* Workshop, TMD 2010, Trento, Italy, 22 June 2010

Factorization and factorization breaking with TMD PDFs, Int. Workshop Gluons and the Quark Sea at high energies, Seattle, USA, 20 September 2010

Detector R&D
Bosma, M.J., Edgeless sensors for low-dose X-ray imaging applications, 12th Int. Workshop on Radiation Imaging Detectors, Cambridge, United Kingdom, 14 July 2010

Fransen, M., The performance of GridPix detectors, NSS-MIC IEEE, Knoxville convention center, Knoxville, USA, 3 November 2010

Hartjes, F.G., Concept and operation of the high resolution gaseous micro-pixel detector Gossip, 12th Topical Seminar on Innovative Particle and Radiation Detectors, Siena, Italy, 7 June 2010

Snippe, Q.H.C., Prediction of gas leak tightness of superplastically formed products, NUMIFORM 2010, POSCO Int. Center, Pohang, South Korea, 14 June 2010

Timmermans, J., Pixel readout for a TPC, LCWS 2010, Beijing, China, 27 March 2010

Electron-positron Linear Collider, Summer student lecture, DESY, Hamburg, Germany, 26 July 2010

Some results with NIKHEF Ingrids at DESY test beams, EUDET Annual Meeting, DESY, Hamburg, Germany, 29 September 2010

The Silicon TPC System, EUDET Annual Meeting, DESY, Hamburg, Germany, 30 September 2010

R&D by LCTPC Collaboration (IDAG review), IWLC 2010, Geneva, Switzerland, 21 October 2010

Visser, J., Detector R&D at Nikhef, KVI, Groningen, The Netherlands, 13 April 2010

Detector R&D at Nikhef, Radboud University Nijmegen, Nijmegen, The Netherlands, 16 April 2010

Advances in photon-counting detection systems, CMOS emerging technologies Workshop, Whistler, Canada, 21 May 2010

Grid Computing

Keijser, J.J., (BiG) Grid: from research to e-Science, Universiteit Groningen, Groningen, The Netherlands, 8 June 2010

Koeroo, O.A., Demonstrator - Using existing tools and emerging technologies, Felix Meritis, Amsterdam, The Netherlands, 18 June 2010

Linde, F., LCG, EGI & BiG Grid user event, Beurs van Berlage, Amsterdam, The Netherlands, 13 September 2010

Templon, J.A., Peer to Peer technologies and Data Access and Management, Workshop on the Evolution of WLCG Data Management, Amsterdam, The Netherlands, 17 June 2010

Miscellaneous

Decowski, M.P., Measuring Terrestrial and Solar Neutrinos with KamLAND, Moriond - Electroweak Interactions and Unifiied Theories 2010, La Thuile, Italy, 11 March 2010

Measuring Terrestrial and Solar Neutrinos with KamLAND, University of Heidelberg, Heidelberg, Germany, 25 May 2010

Eijk, van, B., Elementaire Deeltjes in het Standaard Model, Symp. Universiteit Twente, Enschede, The Netherlands, 27 April 2010

New Horizons at the LHC at CERN, Colloquium Universiteit Twente, Enschede, The Netherlands, 29 September 2010

Metzger, W.J., L3 Measurement of Bose-Einstein correlations in hadronic Z decays and the Tau model, VI Workshop on Particle Correlations and Femtoscopy, Kiev, Ukraine, 16 September 2010

L3 Measurement of Bose-Einstein correlations in hadronic Z decays and the Tau model, XL Int. Symp. on Multiparticle Dynamics, Antwerpen, Belgium, 22 September 2010

Rijn, van, A.J., EGI governance experience, EGITF2010 (session for coordinators of ESFRI preparatory projects), Amsterdam, The Netherlands, 17 September 2010

Samtleben, D.F.E., The Challenges and Rewards of Seeing the Oldest Light, Colloquium, Anton Pannekoek Institute, Amsterdam, The Netherlands, 4 June 2010

News from the oldest light, Physikalisches Kolloquium Universität Bielefeld, Bielefeld, Germany, 15 November 2010

3.4 Posters

ATLAS/DØ

Kayl, M.S.
ATLAS inner detector track resolution measured for cosmic ray data
Physics@FOM Meeting, Veldhoven, The Netherlands, 20 January 2010

Kayl, M.S. *(on behalf of the ATLAS collaboration)*
Tracking performance of the ATLAS inner detector and observation of known hadron resonances
Hadron Collider Physics 2010, Toronto, Canada, 24 August 2010

Mechnich, J. *(for the ATLAS Collaboration)*
FATRAS – the ATLAS Fast Track Simulation project
Conference on Computing in High Energy and Nuclear Physics 2010, Taipei, Taiwan, 18 October 2010

Meijer, M.M. *(et al.)*
First hint of Higgs?
Physics@FOM Meeting, Veldhoven, The Netherlands, 19 January 2010

LHCb/BABAR

Oggero, S. *(for the PileUp group)*
The LHCb Pile-Up detector
Flavor Physics and CP Violation 2010, Torino, Italy, 27 May 2010

ALICE

Thomas, D. and **Mischke, A.**
Azimuthal angular correlations between single electrons and open charmed mesons at LHC
4th Int. Conf. on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions (HP2010), Eilat, Israel, 10–15 October 2010

ANTARES/KM3Net

Presani, E. *(for the ANTARES collaboration)*
Search for neutrinos from Gamma-Ray Bursts with Antares
GRB2010, Annapolis, USA, 2 November 2010

Pierre Auger Observatory

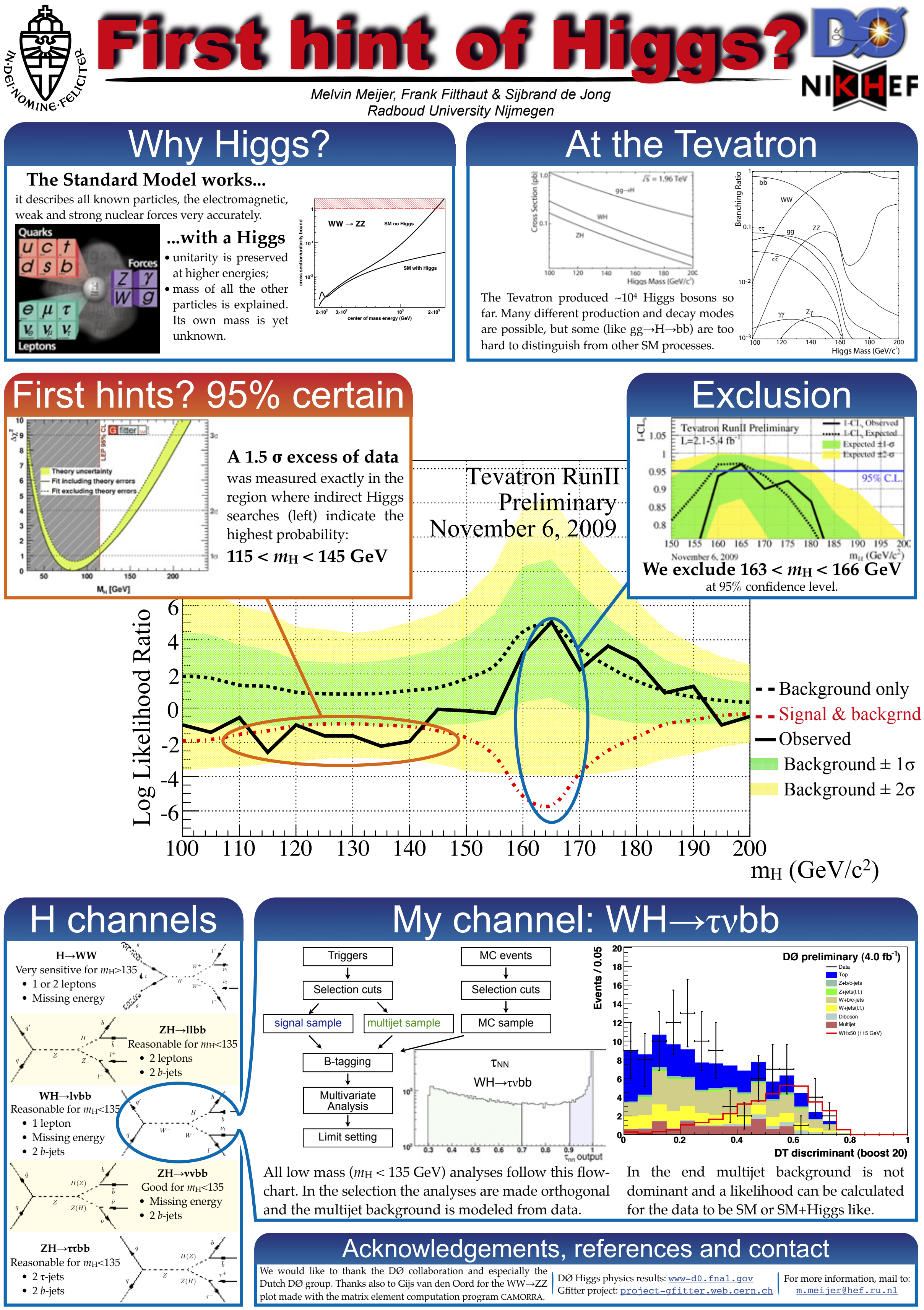
Timmermans, C., *(et al.)*
Results from the Pierre Auger Observatory
Physics@FOM Meeting, Veldhoven, The Netherlands, 19 January 2010

Detector R&D

Bosma, M.J.
Edge Effects in CdTe-Based Sensors
17th Room Temperature Semiconductor Detector Workshop, Knoxville, USA, 2 November 2010

Grid Computing

Remenska, D. *(on behalf of the LHCb collaboration)*
Optimization of Large Scale HEP Data Analysis
Conference on Computing in High Energy and Nuclear Physics 2010, Taipei, Taiwan, 18 October 2010



Prize-winning poster by Melvin Meijer (et al.) presented at Physics@FOM Meeting, Veldhoven, The Netherlands, 19 January 2010.

3.5 Jamboree

By the end of each year Nikhef physicists and technicians gather in an Annual Meeting traditionally called Jamboree. In the meeting reports are given about the status of Nikhef's various programmes and projects, while young students and postdocs get the opportunity to present their work for a broader audience. The 2010 Jamboree was held at Radboud University in Nijmegen and organised by Nicolo de Groot.

Naturally, this year's focus of attention was on the many results that were obtained from the first months of stable LHC operation. The three LHC experiments in which Nikhef participates showed convincingly that their detectors are fully operational and understood, allowing (complex) physics output to be extracted and published. Further talks illustrated the broad scope of Nikhef's research topics: from non-commutative geometry, via detection of muons both in the deep sea and in Argentina, to detection of dark matter particles in liquid Xenon and the progress in the programme for the search of gravitational waves.

Unfortunately, due to heavy snow on the Friday afternoon the session with talks on research and development had to be skipped.

Thursday 16 December

Opening
10:15 Welcome by the dean of the faculty Prof.dr. Stan Gielen
10:20 Nicolo de Groot: *opening & practicalities*
10:30 Els Koffeman: *LHC in 2010*

ATLAS
10:50 Stan Bentvelsen: *Introduction*
10:55 Ivo van Vulpen: *Status of ATLAS*
11:15 Egge van der Poel: *Muons in ATLAS*
11:30 Hegoi Garitaonanda: *Top physics*
11:45 Folkert Koetsveld: *SUSY*
12:00 Frank Filthaut: *DØ Highlights and Higgs*

LOFAR
13:15 Heino Falcke: *Lofar*

Pierre Auger Observatory
13:35 Charles Timmermans: *Introduction*
13:45 John Kelley: *Recent Results from AUGER and Commissioning of the AUGER Engineering Radio Array*
14:05 Jos Coppens: *Radio detection of cosmic rays at the Pierre Auger Observatory*

ANTARES
14:25 Maarten de Jong: *Status of ANTARES*
14:45 Claudio Bogazzi: *Point source searches with ANTARES*
15:05 Paul Kooijman: *Status KM3NeT*

ALICE
15:45 Thomas Peitzmann: *ALICE in 2010*
16:10 Ante Bilandzic: *Elliptic Flow at LHC*
16:35 Andre Mischke: *Open Heavy Flavour in ALICE*

XENON
17:00 Patrick Decowski: *Searching for Dark Matter – XENON & DARWIN*

Friday 17 December

Virgo
09:00 David Rabeling: *Status of the Virgo group*
09:20 Walter Del Pozzo: *Testing general relativity with gravitational waves*
09:40 Mathieu Blom: *Seismic attenuation systems for Advanced Virgo*

Grid Computing
10:00 Jeff Templon: *Overview*
10:20 David Groep: *Ensuring Availability – Security, Protection, Trust. Walking the line between paranoia and laisser-faire in a highly connected world*

Theory
11:20 Walter van Suijlenkom: *Non communative geometry and the Standard Model*
11:40 Eric Laenen: *Nikhef theory in 2010*
11:55 Irene Niessen: *Improving predictions for SUSY cross sections*
12:10 Bert Schellekens: *Back to the Heterotic String*
12:35 Thomas Reiter: *Predictions for the LHC – Pushing for NLO Standards*

LHCb
13:30 Marcel Merk: *Introduction and overview*
13:50 Patrick Koppenburg: *What we learnt from LHCb first year*
14:20 Daan van Eijk: *Towards the B_s mixing phase with $B_s \to J/\psi\Phi$*
14:40 Barbara Storaci: *Looking for the rare decay $B_s \to \mu\mu$*

Detector R&D
15:15 Niels van Bakel: *Detector R&D overview*
15:25 Martin Fransen: *Gaseous Detectors*
15:45 Francesco Zappon: *ASIC design – New Developments in Timing Circuits*
15:55 Jan Visser: *Semiconductor Detectors*
16:15 Peter Jansweijer: *Subnanosecond Synchronization*

Closing
16:30 Leo Wiggers: *SWOT analysis*
Frank Linde: *Summary and Outlook*

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 2010 are listed. Please refer to Section 5.4 for a full overview of all current grants regarding Nikhef, namely newly awarded grants in 2010, still running grants and recently terminated grants awarded in earlier years.

NWO grants
The Research School Subatomic Physics received a grant of 800 k€ from the new NWO-Graduate Programme. This grant is meant to fund four PhD-positions for the duration of four years each. The new NWO-Graduate Programme facilitates excellent education and research environments for talented young researchers.

A Vidi grant was awarded to Olga Igonkina (ATLAS) for her proposal *"Lepton flavor violation: the key towards a matter dominated Universe"*. She receives, distributed over a period of five years, a maximum of 800 k€ from NWO to start her own research group. The Vidi grants of NWO are aimed at young excellent researchers with several years of successful postdoctoral research experience.

FOM grants
André Mischke (ALICE) won a FOM-*'projectruimte'* grant for his proposal *"Charm content in jets"*. This grant will fund a PhD-position for the duration of four years and a postdoc position for two years.

Other Dutch awards & grants
The Dutch Ministry of Education, Culture and Science provided 35 k€ via the *Platform Bèta Techniek* for the HiSPARC project (High School Project on Astrophysics Research with Cosmics). The grant is awarded for outreach activities.

The exhibition Holland@CERN was sponsored with 75 k€ from the budget of the Collective Promotional Activities (CPA) programme of the Dutch Ministry of Economic Affairs. This exhibition of Dutch high-tech companies at the CERN site near Geneva, co-organised by Nikhef, was aimed at facilitating contact between research and industry.

A valorisation grant of the Technology Foundation STW was given to Niels van Bakel and Jan Visser (R&D) for their proposal *"Hybrid Pixel Detector Arrays for Industrial and Photon Science Instrumentation"*. They receive 25 k€ to develop pixel detectors, similar to the Relaxd project, for other applications in the framework of a Nikhef spin-off company.

Figure 1. Acting Mayor of Amsterdam Lodewijk Asscher (left) and Rob Blokzijl (right) at the ceremony where Blokzijl received the royal honour of Officer in the Order of Orange-Nassau.

Rob Blokzijl, retired Nikhef-employee, received the royal honour of Officer in the Order of Orange-Nassau. He is honoured for his leadership and contribution concerning the development of the Internet over the past 20 years.

Melvin Meijer (ATLAS) won the first prize for the best poster at the conference Physics@FOM Veldhoven 2010.

European grants
An ERC Advanced Grant of almost 2 M€ was awarded to Bernard de Wit, professor emeritus at Utrecht University and guest researcher at Nikhef, for his proposal *"Supersymmetry: a window to non-perturbative physics"*. The ERC Advanced Grant is a prestigious European grant for experienced, exceptional and trend-setting researchers who conduct innovative and excellent research.

A new Marie Curie Initial Training Network was installed under the name of *"LHCPhenoNet"* with Nikhef being one of the partners. Nikhef's theory group receives about 400 k€ to fund three years of PhD, one year of postdoc, and four months of guest contract. These transnational networks focus on a joint research training programme to make research careers more attractive to young people.

4

Nikhef & Society

4.1 Outreach & Communication

One of the highlights of 2010 has undoubtedly been the First Physics Event at the Large Hadron Collider (LHC) on 30 March. On that day, for the first time beams collided at 7 TeV, marking the start of the LHC research programme. The excitement of the particle physics community when these first high-energy collisions were recorded by all LHC experiments was witnessed by the media with an impressive worldwide coverage. In the Netherlands, the major national TV news programme *'NOS Journaal'* filmed at Nikhef. Interviews with Nikhef physicists appeared furthermore in another TV news programme, on nearly all radio stations, and in countless newspapers and magazines. The next day, the very popular TV talk show *'De Wereld Draait Door'* invited two Nikhef PhD students to share their enthusiasm with a TV audience of more than one million people (see Fig. 1).

Beyond this special milestone, the year 2010 has of course also seen many other exciting and interesting moments of communicating science research to various target audiences. As every year, a variety of activities were organised by Nikhef in 2010 to explain what kind of research Nikhef does and why. Most of these activities are coordinated by the Nikhef communication department and are carried out with the much appreciated support of many Nikhef staff and students. Additional activities are based on enthusiastic initiatives of individual Nikhef members. Below, an extensive overview of the communication activities during 2010 can be found. For education activities please refer to the following subsection.

Figure 1. Nikhef PhD students Egge van der Poel and Lucie de Nooij were interviewed in the TV talk show 'De Wereld Draait Door'. In the middle is talk show host Matthijs van Nieuwkerk, on the right is Robbert Dijkgraaf, president of the Royal Netherlands Academy of Arts and Sciences KNAW).

Figure 2. Intense concentration whilst soldering at Nikhef's Open Day.

Nikhef & the general public

Every year Nikhef holds an open day for the general public. This event is organized together with the other institutes at the Science Park Amsterdam, and is timed to fall into the annual Dutch Science Month. This year's open day took place on 9 October, under the 2010 theme of the Dutch Science Month *'Leve(n) de variatie'*. Both children and adults interested in particle and astroparticle physics followed the invitation to explore Nikhef and to learn more about the research conducted at this institute. The exhibits and demonstrations in the main hall and the workshop covered the LHC experiments, the astroparticle physics projects, the technical departments, computer infrastructure, and theoretical physics. Visitors could ask questions to Nikhef scientists and technicians, attend short lectures, watch demonstrations, or even carry out little experiments themselves.

The special programme for children included a science quiz, a treasure hunt, and kids' labs for building their own mechanical constructions or soldering their own electronic gadgets (see Fig. 2).

Throughout the year, Nikhef scientists gave again numerous outreach talks for the general public, at science cafes, museums, science associations, cultural organisations, universities and schools (see section 4.5 for a complete list). To name one

Figure 3. Nikhef staff member Ivo van Vulpen gives a presentation during the European Researchers' Night.

prime example, Nikhef physicists participated in the European Researchers' Night in September 2010 (see Fig. 3), which was hosted in the Netherlands by the *'Erasmus Medisch Centrum'* in a cinema in Rotterdam. During this event several European institutes, such as CERN, presented their research via live video connections to the general public in different European cities. In Rotterdam, Nikhef scientists commented on the topics related to particle physics and answered questions from the local audience.

Furthermore, Nikhef continuously develops new exhibits to demonstrate particle and astroparticle physics principles to the general public. In 2010, several spark chambers were built that visualize cosmic rays reaching the earth. One such spark chamber installation is on display in the Nikhef main hall, another one has been donated to the science centre NEMO where it is part of the new permanent *'Ruimtedouche'* (Cosmic shower) exhibition opened in 2010 (see Fig. 4).

Special events
In autumn 2010, the unique dance event *"Cosmic Sensation"* took place, at which cosmic rays triggered live dance music. In an enormous dome temporarily set up in Nijmegen for three days, the visitors listened to this 'cosmic music' via headsets in a silent disco where they were surrounded by spectacular visualizations of the cosmic rays (see Fig. 5). The event was organized by a team of students and scientists of the Radboud University Nijmegen (RU) led by a Nikhef physicist who is professor at RU. His team had won the *'Academische Jaarprijs 2009'* for their project proposal.

For the documentary *"Higgs – into the heart of imagination"* released in 2009, Nikhef sponsored the production of a DVD in 2010. This film features Nikhef researchers and other scientists on their quest for the Higgs particle. It was produced by Theater Adhoc, Viewpoint Productions and the broadcast-foundation HUMAN and co-financed by Nikhef.

Nikhef & the media
2010 has been a very successful year in terms of media relations. Especially the ongoing interest of the media in the LHC has led to an impressive number of contacts between Nikhef scientists and journalists from print media as well as radio and TV stations. A peak of media interest was of course seen around the LHC

Figure 4. Nikhef staff member Fred Hartjes installing a spark chamber at the NEMO science centre.

First Physics Event on 30 March 2010 as mentioned above. But also throughout the year, media attention on LHC-related topics remained high, with other highlights being the publications of the first physics results obtained with data from the LHC, and the smooth switching from proton to heavy ion running in the LHC.

Also many other topics from various Nikhef activities were covered by the media in 2010. All in all, Nikhef issued six press releases in 2010, often in collaboration with science communication officers from other institutes like CERN or the Dutch universities, on such diverse topics as research results, knowledge transfer and education. Nikhef scientists contributed to many articles in various newspapers and magazines (*NRC Handelsblad, Volkskrant, Natuurwetenschap en Techniek, Kijk*, and many more), and regularly gave interviews on many different radio programmes (e.g. *Radio 1 Journaal*, *BNR Nieuwsradio*). Nikhef employees had several appearances on national TV (*NOS journaal, RTL4 Nieuws, De Wereld Draait Door*) . And also the local Amsterdam TV station AT5 produced three items on Nikhef research for the programme *'Amsterdam Inc'*.

Guided tours at Nikhef and at CERN

Nikhef organises guided tours for everybody interested in the research done at the institute. Visitors are welcome to join the Friday afternoon visits programme which is routinely offered twice per month and comprises a lecture, the viewing of a film, and a tour of the institute. Special guided tours are set up on request. In the summer of 2010, for example, a delegation of the National Natural Science Foundation of China (NSFC) visited Nikhef on invitation of the Netherlands Organisation for

Figure 5. 'Silent disco' dancers at Cosmic Sensation in Nijmegen.

Figure 6. Representatives of the Netherlands School of Public Administration are guided in the ATLAS visitor centre at CERN by ATLAS Collaboration member and Nikhef staff member Ger Jan Bobbink.

Scientific Research (NWO). Moreover, there is a lot of interest in CERN visits by various Dutch groups. Nikhef supports these visits by providing Dutch speaking guides and lecturers from a pool of Nikhef employees stationed at CERN (see Fig. 6). In some cases, these CERN visits are in addition sponsored financially by Nikhef.

Nikhef & science communication networks

Nikhef collaborates with both national and international communication networks to develop, coordinate and organize certain communication activities. To this end, the Nikhef communication department worked also in 2010 together with:

- the communication staff of the other institutes at the Science Park Amsterdam for all Science Park wide activities (e.g open day, communication on the development of the Science Park);
- the communication staff of the FOM organisation and the FOM-institutes Amolf and Rijnhuizen for all FOM-related topics (e.g. annual Physics@FOM Veldhoven conference);
- the Platform Wetenschapscommunicatie (PWC), an association for science communication staff in the Netherlands, for professional exchange of ideas and information (e.g. december 2010 network meeting hosted at Nikhef);
- the European Particle Physics Communication Network (EPPCN) for coordinating activities between CERN and its member states (e.g. synchronization of press releases, media events);
- the outreach committee of the ASPERA European network for astroparticle physics for developing a sustainable network of communicators for this field in Europe;
- the InterAction collaboration of communicators for particle physics laboratories worldwide for increasing support for fundamental particle physics research in general around the world.

4.2 Education

To stimulate young people's interest in science and technology Nikhef participates in science education at all levels. By offering various activities for elementary and secondary school pupils and their teachers, as well as for bachelor, master and PhD students, Nikhef wants to share the fascination of scientific research.

Nikhef & elementary schools

Young children between the age of four and twelve can participate in the *'Techniek Toernooi'*, a science tournament organised by the Dutch Physical Society (*'Nederlandse Natuurkundige Vereniging'*, NNV) with contributions by many Nikhef staff members (see Fig. 1). In 2010, three regional tournaments took place followed by the national tournament in the Dutch *'Openluchtmuseum'* in Arnhem. The technical assignments are prepared at school by the entire class. At the tournament the class is represented by a team of four children. This tournament provides teachers with a platform to show their talents in educating young children in science and technology and at the same time gets young children fascinated.

This year, the younger children competed for the highest tower built from wooden sticks and marsh mellows. The older children designed and built a boat with jet propulsion. Other challenges were to build a pneumatic arm to transfer a heavy weight or to design a structure to transfer water to a higher level. The jury, composed of Dutch professors including many Nikhef members, selected the winners and Bart Meijer, one of the presenters of the popular TV programme *'Klokhuis'*, awarded the winning teams.

Nikhef & secondary schools

Nikhef engages very actively in introducing secondary school students to particle and astroparticle physics. In 2010, almost 250

Figure 1. Young scientists experimenting at the 'Techniek Toernooi'.

Figure 2. Nikhef staff member Bob van Eijk lecturing to secondary school students at the European Masterclass on Particle Physics.

secondary school students attended the Friday afternoon visits programme at Nikhef which consists of a lecture and a film, followed by a guided tour. Over twenty secondary school students carried out their *'profielwerkstuk'* (research project) at Nikhef under the supervision of Nikhef staff. Moreover, Nikhef scientists visited several schools to give lectures.

On 5 March more than 30 high school students participated in the European Masterclass on Particle Physics held at Nikhef. This yearly event is organized simultaneously at several European particle physics institutes, and includes introductory lectures, hands-on exercises and a live video conference to finally share their findings with students at other European institutes (see Fig. 2). Nikhef also supported numerous CERN visits of secondary school students by providing Dutch guides for these tours.

Nikhef & HiSPARC

One of Nikhef's best known programmes for secondary school students is HiSPARC (High School Project on Astrophysics Research with Cosmics). Within this programme students are given the opportunity to build their own cosmic ray detector and subsequently to analyse data obtained with it. This experience gives students more insight into the world of scientific research and helps them prepare for their career choice.

Nikhef is in charge of the central coordination of the HiSPARC project which is a collaboration of universities and scientific institutes, founded in 2002 and divided over seven regional clusters in the Netherlands. In 2010, the network of detectors consisted of 87 active detectors in the Netherlands, located at more than 70 schools and a number of other locations. Furthermore, several detectors abroad were connected to the HiSPARC database through the international collaboration EuroCosmics.

The HiSPARC detectors are built by the students of the schools, under the supervision of a HiSPARC team member, and consist of scintillators and advanced electronic equipment. They are placed on the roof of the schools and register the impact of cosmic rays which frequently come in showers distributed over a large area covered by several detectors. The data are stored in a central database at Nikhef. Students and teachers have access to the data of their own detector and of all other stations in the network. In this way coincidences between stations in a single cluster and also correlations between different clusters can be studied.

Each year, students can participate in a symposium including hands-on exercises on analysing HiSPARC data and sessions where students present their *'profielwerkstuk'*. Furthermore, there is a plenary session. This year's keynote speaker was Vincent Icke, professor at the University of Leiden and an active ambassador for science outreach, e.g. known for his appearances on Dutch TV. As in previous years, the students presenting the best '*profielwerkstuk*' won a visit to CERN. For the first time the symposium also offered a workshop for teachers.

HiSPARC is also involved in the development of educational material. In 2010 the NLT (Nature, Life and Technology) module 'Cosmic Rays' was certified and can now be officially used in Dutch physics classes. In addition, an extensive collection of study material related to (astro)particle and general physics has been developed. The focus has now turned to creating tools for students to help them understand and process the HiSPARC data.

Nikhef & teachers

The main goal of the programmes existing for school teachers is to update them on modern developments in physics, which they then can pass on to their students.

On 17 March, Nikhef scientists organised the yearly one-day Mastercourse on particle physics for secondary school teachers. As a follow-up, several school teachers got the possibility to participate in a CERN excursion from 25 to 27 June, co-organised and -financed by Nikhef and for the first time embedded in the official CERN teachers programme.

Furthermore, since 2008 a few secondary school teachers every year are enabled to take part in scientific research via the FOM teacher-in-research programme ('*Leraar in Onderzoek*', LiO). The

Figure 3. Secondary-school students Jacek Smit (left) and Matthijs Kuik (right) won a visit to CERN with their presentation at the HiSPARC 2010 Symposium.

teachers spend one day per week working on research at one of the FOM institutes or university working groups.

In the academic year of 2009/2010, seven teachers were supported by FOM to do research in astroparticle physics. Five were stationed at Nikhef (Amsterdam), one at KVI (Groningen), and one at Radboud University (Nijmegen). During the year, guidance was provided by the scientific staff of the institutes and regular meetings were scheduled, enabling the teachers to present their work and discuss any obstacles in their research. Each teacher had his/her own research topic within HiSPARC. Since this project is a small-scale experiment led by a small team of scientists and university students, it forms an ideal and easily accessible scientific environment for the LiO participants. The results of the research are presented in a detailed report.

For the year 2010/2011, four new LiO's have been selected and two LiO's have prolonged their contract with a second year.

Master of Science in Particle and Astroparticle Physics

The two-year Master's programme Particle and Astroparticle Physics, known as the 'Nikhef-master', offers students the opportunity to specialise in this field. Students are admitted to the programme after an in-take interview by the programme coordinator. Lectures on particle and astroparticle physics are given by active researchers of Nikhef. First year students participate in the 'Nikhef-project', in which all aspects of experimental particle physics are addressed: designing and building a particle detector, simulation of the expected response and data taking and analysis. Furthermore, project management is practiced by the definition and assignment of project tasks, making a planning, organising progress meetings etc. A senior physicist supervises the process 'from a distance' to give the students the opportunity to overcome difficulties as much as possible by themselves. In 2010, they built an iron scintillation calorimeter. After a summer at CERN, during their second year, students work on their research project in one of the experimental groups of Nikhef. A 'double' master programme allows the most ambitious students to combine the Nikhef-master with e.g. a Master's programme in Theoretical Physics. These students combine theoretical work at the theoretical department of Nikhef with data analysis in one of the experimental groups.

In 2010, fifteen new students enrolled in the first year of the programme, while thirteen students graduated from the programme, five of them with *Cum Laude*. Eight of the students who graduated continued as PhD student in (astro)particle research. The Master's programme therefore proves to be an excellent entrance possibility to the Research School Subatomic Physics (see below).

Also for ERASMUS students, the Master's programme appears to be attractive. In particular, a total of four students from the University of Göttingen in Germany enrolled in the programme for one or two semesters.

For a detailed list of master students and their work 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).

Every year, OSAF offers several three-day academic training courses (Topical Lectures) and, in collaboration with Belgian and German research groups, a two-week summer school (BND school) for PhD students.

Topical Lectures were organized twice in 2010, in June on 'Gravitational waves' and in December on 'CP violation'. To boost the programming skills of the PhD students an intensive C++ course took place in September.

The annual BND school was held this year from 6 to 17 September in Ravelingen, near Ostend, Belgium. 51 participants attended the school, with an equal distribution over the participating countries: 17 from the Netherlands, 17 from Belgium and 17 from Germany. This year's topic was the strong interaction. The program included the following lectures: 'QCD' by Darren Forde, 'Hadron Collisions' by Gregory Soyez, 'Experimental Results of Colliders' by Stan Bentvelsen, 'Accelerators' by Bernard Holzer, 'Trigger and Data Acquisition' by Gilles de Lentdecker, 'Calorimetry' by Christian Zeitnitz, 'Astroparticle Physics' by Charles Timmermans, 'Beyond the Standard Model' by Paul de Jong, 'Analysis Methods' by Christophe Delaere and 'Lattice QCD' by Zoltan Fodor. There were also a number of students sessions where the students presented their thesis research work.

Furthermore, the members of the research school's board organise every year one to two interviews (*'C3 gesprekken'*) with each PhD student and his/her promotor and thesis advisor to discuss the progress of the thesis work and the training of the student.

In 2010 80 PhD students were enrolled and 8 PhD students graduated in the school. *'Penvoerder'* (responsible body) of the school is the Radboud University Nijmegen, with Nicolo de Groot from the Radboud University Nijmegen being chairperson.

The past year was a very successful one for OSAF. An NWO committee honoured the "impressive proposal" from OSAF, and awarded a grant of 800 kEuro from the new NWO graduate programme (see also section 3.6). OSAF is currently working on a better integration of the Master into the PhD phase.

4.3 Knowledge transfer

In 2010, several projects involving industrial partners have successfully come to a close, while new initiatives have been developed to increase the valorisation of technical advances, which are continuously generated in Nikhef's cutting edge research.

Sensiflex

The most important achievement concerning knowledge transfer in 2010 is the establishment of the first spin-off company originating from Nikhef, called Sensiflex and based in Science Park Amsterdam. The patent of Harry van der Graaf on RASNIK, an alignment technology with the aid of laser beams developed originally for fundamental research at experiments at CERN, now has led to a commercial product that is being used in the metro tunnels under construction in both Amsterdam and Rotterdam.

Figure 1. A Sensiflex RASNIK system is installed in the Weena Tunnel in Rotterdam by Nikhef staff members Harry van der Graaf and Gerrit Brouwer.

Relaxd

The Relaxd project has yielded the intended pixel detector that can be read out with standard 1Gb/s Ethernet. A proof of principle was achieved for edgeless sensors, which will be implemented to reduce the inactive area. Another step in this direction is the application of Through-Silicon-Vias produced by the nanotechnology research centre IMEC. However, it will still take some further studies to bring this technology to maturity. The final system produced within the Relaxd project will be marketed by PANalytical in their X-ray diffraction systems in the near future. The idea to produce similar detectors for other fields led to a proposal for an STW valorisation grant by Niels van Bakel and Jan Visser. Their proposal was honoured and they receive a grant meant to start a Nikhef spin-off company (see also section 3.6).

Bruco

The programme, which started in autumn 2009 under the '*Kenniswerkers regeling*', was successfully finalized at the end of 2010. This programme funded by SenterNovem, an agency of the Dutch Ministry of Economic Affairs, was a collaboration between Bruco, an ASIC design house specialised in mixed signal design, and Nikhef on two projects. In the first project, a prototype chip was designed and tested, which proved that it is possible to transfer data over micro twisted-pair cables of two meter length with speeds in excess of 8 Gbit/s. The typical application for such links is in the inner detectors of particle physics experiments where optical transmission is not feasible due to the harsh radiation environment.

The second project consisted of extensive studies to optimise the readout architecture of pixel detector readout chips. A strong reduction in the data volume was obtained by implementing sparse readout, i.e. only those pixels are readout which have been hit. A further reduction in the amount of data was achieved by clustering hits from adjacent pixels, which allows removal of redundant address and timing information. The studies have shown that it is possible to readout more than 500 million pixel hits per second with a loss of less than 1%.

Collaboration with Amolf

Amolf and Nikhef, both members of the Medipix collaboration, have teamed up to use the knowledge of Nikhef on read-out electronics for the application in mass spectrometry. This has led to the use of Medipix and Timepix chips in the field of mass spectrometry and to several leading publications on the significant improvement the Medipix device brings to this field.

Hidralon

Within the Hidralon project Nikhef collaborates with Philips Healthcare to study edgeless sensors made of Cadmium-Telluride (CdTe) to more efficiently detect X-rays of around 100 keV. First studies are done on silicon sensors, while the material on CdTe is being designed and produced. For the production of CdTe sensors Nikhef works together with various suppliers.

KNAW

The Royal Academy of Science ('*Koninklijke Nederlandse Academie van Wetenschappen*', KNAW) interviewed a number of experts in their study of "*Quality Assessment in the design and engineering disciplines*". Jan Visschers was invited to give his view based on his experience in the field of detector system design[1].

1. http://www.knaw.nl/publicaties/pdf/20101065.pdf (ISBN 978-90-6984-620-0.)

4.4 Memberships*

ASPERA
F. Linde (Governing Board)
H. Demonfaucon (joint secretariat)

Astroparticle Physics European Coordination (ApPEC)
P. Kooijman (peer review committee),
F. Linde (steering committee)

BEAUTY, Int. Conference on B-Physics at Hadron Machines – International Advisory Committee
R. Fleischer

Big Grid – Directorate
F. Linde, A. van Rijn

Computer Algebra Nederland – Board
J. Vermaseren

CERN Council
S. de Jong

CERN SPS Committee
P. Kooijman

DESY, Hamburg – Program Review Committee
J. Timmermans

EUROCOSMICS
B. van Eijk (chair)

European Committee for Future Accelerators (ECFA)
S. de Jong, M. Merk, F. Linde (restricted ECFA), Th. Peitzmann

European Particle Physics Communication Network (EPPCN)
G. Bobbink , V. Mexner

European Physical Society
E. de Wolf (Executive Committee, Physics Education Board)
B. van Eijk (High Energy Physics Board)

European Physics Journal – Scientific Advisory Committee
P. Mulders

European Policy Management Authority for Grid Authentication in e-Science (EUGridPMA)
D. Groep (chair)

European Research Council – Advanced Grants panel PE2
S. de Jong

FOM
S. de Jong, S. Bentvelsen (Board)
E. de Wolf (Adviescommissie FOM/v programma)
W. Beenakker, R. Kleiss, E. Laenen (chair) (network Theoretical High Energy Physics)

Fonds Wetenschappelijk Onderzoek, Vlaanderen – Expertpanel Physics
E. de Wolf

Gesellschaft für Schwerionenforschung, Darmstadt – Program Advisory Committee
Th. Peitzmann

GridKa Overview Board, Karlsruhe
K. Bos

Helmholtz-Alliance for Physics at the Terascale – International Advisory Board
K. Bos

International Particle Physics Outreach Group (IPPOG)
V. Mexner

Landelijk co-ordinatorenoverleg HiSPARC
B. van Eijk (chair), J. van Holten

The International Detector Advisory Committee for the European XFEL (XDAC)
N. van Bakel

International Grid Trust Federation
D. Groep (chair)

InterAction
V. Mexner

Kernfysisch Versneller Instituut, Groningen – Scientific Advisory Committee (WAC)
P. Mulders

Laboratori Nazionali del Gran Sasso, L'Aquila – Scientific Committee
F. Linde

* *as of 31 December 2010.*

Laboratori Nazionali di Frascati, Frascati – Scientific Committee
F. Linde

Laboratoire de l'Accélérateur Linéaire, Orsay – Scientific Committee
F. Linde

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
M.Decowski, S. de Jong

Nederlandse Natuurkundige Vereniging (NNV)
S. de Jong, P. Mulders (secretary), E. de Wolf (deputy chair)
NNV Sectie Onderwijs en Communicatie
S. de Jong (vice chair)
NNV Sectie Subatomaire Fysica
J. van Holten, P. Kluit (secretary), E. Koffeman (deputy chair)

Nuclear Physics European Collaboration Committee (NuPECC)
Th. Peitzmann

Open Grid Forum – Standards Function Security Area
D. Groep (director)

PDF4LHC (Parton Density Functions for the LHC) workshop series – Organising committee
M. Botje

Platform Bèta Techniek – Ambassador
F. Linde, E. de Wolf

International Workshop on Radiation Imaging Detectors – Scientific Advisory Committee
J. Visschers

Stichting Conferenties en Zomerscholen over de Kernfysica (StCZK)
S. de Jong, P. Mulders

Stichting Cosmic Sensation
S. de Jong (chair, secretary and treasurer)

Stichting EGI.eu – Executive Board
A. van Rijn (vice chair)

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 Techniek Toernooi
E. de Wolf (chair)

Thomas Jefferson National Accelerator Facility, Newport News – Program Advisory Committee
P. Mulders

Vereniging Gridforum Nederland
A. van Rijn (treasurer)

Virtual Laboratory for e-Science, Vl-e
A. van Rijn (directorate)

4.5 Outreach Talks

Bentvelsen, S., De oerknal in het laboratorium, Haarlemse Chemische Kring, Haarlem, The Netherlands, 17 February 2010

Op jacht naar het Higgs deeltje, UvA Alumni Dag, Universiteit van Amsterdam, Amsterdam, The Netherlands, 12 July 2010

Op jacht naar het Higgs deeltje, Scholengemeenschap de Breul, Zeist, The Netherlands, 1 September 2010

Botsende bundels in de deeltjesversneller: LHC in actie, Open Dag Nikhef, Amsterdam, The Netherlands, 9 October 2010

Beker, M.G., Gravitational wave astronomy, a new window on the universe, BECA, Tauranga, New Zealand, 6 January 2010

Coppens, J., Kosmische straling, Lux Researchers night, Nijmegen, The Netherlands, 12 March 2010

Dok, D.H. van, Grid: van wetenschap naar e-Science, Unix Professionals group meeting, Spakenburg, The Netherlands, 4 October 2010

De speld, de hooiberg en de zoekmachine, Open Dag Nikhef, Amsterdam, The Netherlands, 9 October 2010

BiG Grid: the Dutch production grid, Masterclass Grid computing, Universiteit van Amsterdam, Amsterdam, The Netherlands, 14 October 2010

Eijk, B. van, Elementaire Deeltjes en het Heelal, Assink College, Haaksbergen, The Netherlands, 4 February 2010

Elementaire Deeltjes in het Standaard Model, European Master Class, Nikhef, Amsterdam, The Netherlands, 5 March 2010

Elementaire Deeltjes en het Heelal, RSG, Middelharnis, The Netherlands, 22 June 2010

Nieuwe Grenzen: De Large Hadron Collider, HOVO cursus Universiteit Leiden, Leiden, The Netherlands, 26 October 2010

De Schoonheid van Symmetrie, Interferentie (kunst en wetenschap), Breda, The Netherlands, 16 November 2010

De Large Hadron Collider, Sterrewacht Twentse Welle, Enschede, The Netherlands, 23 November 2010

Filthaut, F., ATLAS: 's-werelds grootste microscoop, Technical University, Eindhoven, The Netherlands, 3 May 2010

Deeltjesfysica in vogelvlucht, Technical University, Eindhoven, The Netherlands, 9 July 2010

Computers bij experimenten in de deeltjesfysica, Technical University, Eindhoven, The Netherlands, 13 December 2010

Groot, N. de, Antimaterie in de film en in de wetenschap, Lux researchers night, Nijmegen, The Netherlands, 12 March 2010

De Large Hadron Collider in Genève, Propus Nijmegen Ulpia, Nijmegen, The Netherlands, 28 October 2010

Heubers, W.P.J., Wat doen we met de data van de deeltjesversneller in Genève?, Hogeschool van Amsterdam, Amsterdam, The Netherlands, 8 June 2010

Case-studie Nikhef, Datacenter Dynamics, Hotel Krasnapolsky, Amsterdam, The Netherlands, 23 November 2010

Holten, J.W. van, Versnellers en de kosmos, University Leiden, Leiden, The Netherlands, 21 January 2010

Materie en krachten, University Leiden, Leiden, The Netherlands, 5 February 2010

Elementaire deeltjes, HOVO lectures, University Leiden, Leiden, The Netherlands, 5 October 2010

Voorbij het Standaard Model, HOVO lectures, University Leiden, Leiden, The Netherlands, 9 November 2010

Jong, P.J., de, (Some of) the physics of the LHC, Visit of UT students to CERN, Geneva, Switzerland, 28 May 2010

Jong, S.J. de, Recente ontwikkelingen op CERN (belang wetenschap en onderwijs), Pax Christi College, Druten, The Netherlands, 15 January 2010
Remweg, Eureka cup, Nijmegen, The Netherlands, 26 February 2010

Donkere energie, Lux Researchers night, Nijmegen, The Netherlands, 12 March 2010

Het nut van de deeltjesversneller, Radboud University Nijmegen, Nijmegen, The Netherlands, 15 April 2010

Cosmic Sensation, Summer School Movement Disorders, Nijmegen, The Netherlands, 10 July 2010

Genesis 2.0, 20x20 NOP Arthouse LUX, Nijmegen, The Netherlands, 9 December 2010

Koeroo, O.A., Grid Security on a Global scale, eth0, Wieringerwerf, The Netherlands, 16 January 2010

Laenen, E., Fysica bij de Large Hadron Collider, University Maastricht, Maastricht, The Netherlands, 18 March 2010

Zwakke wisselwerkingen, Radboud University Nijmegen, Nijmegen, The Netherlands, 21 May 2010

Linde, F., Elementaire deeltjes fysica - klein, groot & snel!, De Forum, Hilversum, The Netherlands, 17 February 2010

Elementaire deeltjes fysica - klein, groot & snel!, Rotaryclub Minerva, Amsterdam, The Netherlands, 22 February 2010

Geleerd gelovig, Salvation Army, Amsterdam, The Netherlands, 16 March 2010

Large Hadron Collider – Bouwstenen van ons Universum, AWSV Metius, Alkmaar, The Netherlands, 23 April 2010

Large Hadron Collider – subatomaire fysica, Het Baken, Almere, The Netherlands, 26 April 2010

Particle physics introduction - Dutch experimental activities, Diderik van der Waals symposium, Eindhoven, The Netherlands, 5 October 2010

Merk, M.H.M., Onderzoek aan het aller-grootste en het allerkleinste, Basisschool St Franciscus, Reijmerstok, The Netherlands, 19 March 2010

Materie en Antimaterie (Het mysterie van verdwenen antimaterie), Studium Generale, Universiteit Maastricht, Maastricht, The Netherlands, 18 March 2010

Feiten en Fictie in Angels & Demons, Cafe de Polder, Amsterdam, The Netherlands, 22 March 2010

Materie en Antimaterie, Hampshire Inn hotel Vue des Montagnes, Berg en Terblijt, The Netherlands, 24 September 2010

Mischke, A., Hoe zag het heelal uit aan het begin van de tijd?, Natuurkundig Gezelschap, Utrecht, The Netherlands, 11 May 2010

Renaissance for Discovery at CERN
European Science Forum - Passion for Science, Torino, Italy, 6 July 2010

Nooren, G.J.L., Van 3 MV naar LHC: een halve eeuw kernfysica in Utrecht, Utrechts Universiteitsmuseum, Utrecht, The Netherlands, 14 December 2010

Peitzmann, Th., Physik des Klaviers, Workshop for Physics Teachers, Bad Honnef, Germany, 22 October 2010

Suerink, T.C.H., 10Gbit en sneller, Hogeschool van Amsterdam, Amsterdam, The Netherlands, 8 June 2010

Timmermans, C., HiSPARC and other Cosmic Ray outreach activities in the Netherlands, University of Cambridge, Cambridge, United Kingdom, 2 March 2010

Universe's highest energy particles, Technical University, Eindhoven, The Netherlands, 5 October 2010

HiSPARC and other Cosmic Ray outreach activities in the Netherlands , ICATPP conference, Como, Italy, 7 October 2010

Vulpen, I.B. van, Zoektocht naar de elementaire bouwstenen van de natuur, Volksuniversiteit Amsterdam, Amsterdam, The Netherlands, 29 April 2010

Het atoom: hoe beter men keek / hoe kleiner het leek, Nacht van de onderzoeker, Rotterdam, The Netherlands, 24 September 2010

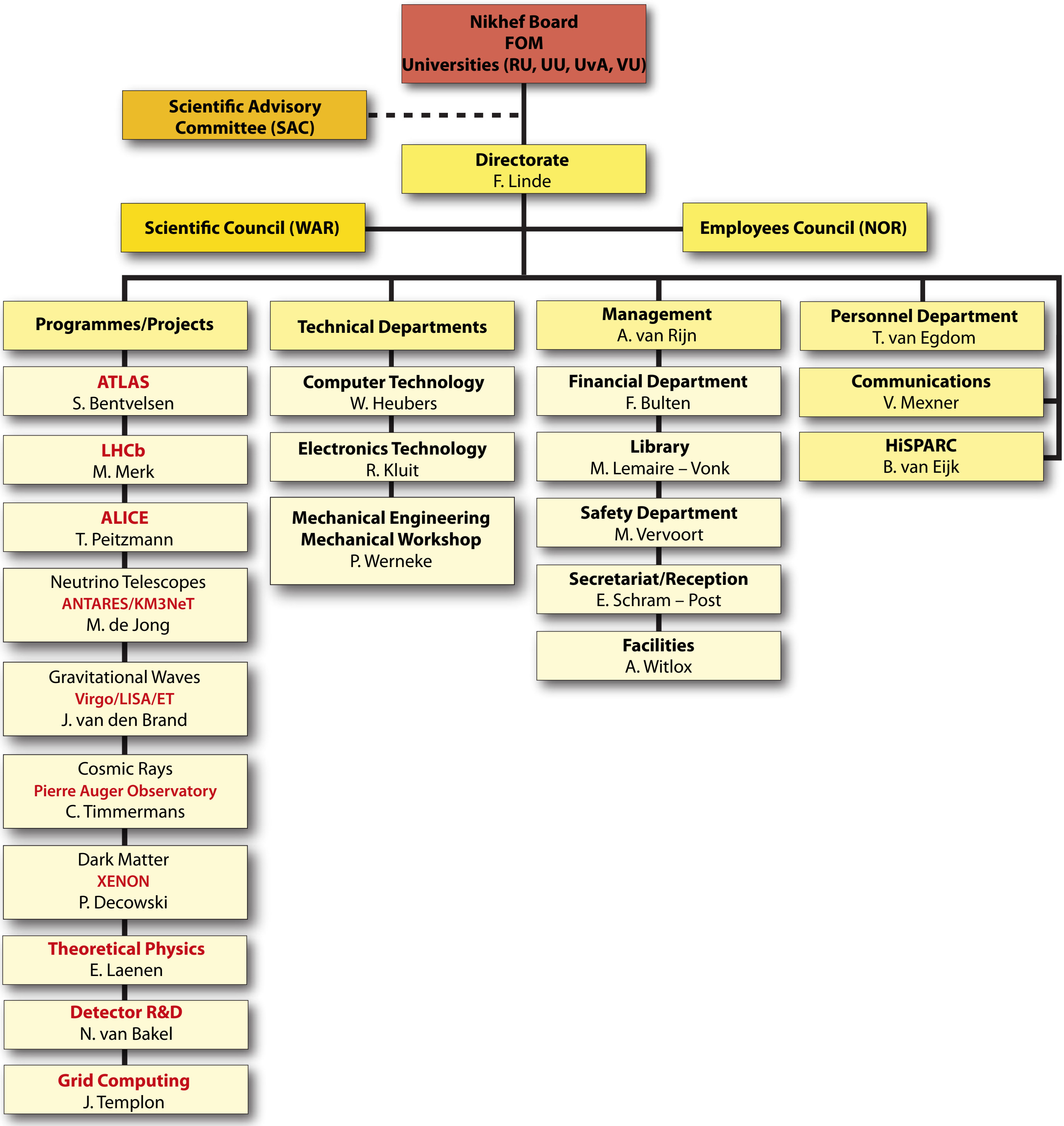
Zoektocht naar de elementaire bouwstenen van de natuur, De societeit, Schagen, The Netherlands, 9 November 2010

Wolf, E. de, Vissen naar neutrino's, Rotary Amsterdam, Amsterdam, The Netherlands, 8 December 2010

5

Resources

5.1 Organigram*



* *as of 31 December 2010.*

5.2 Organisation*

Nikhef Board
C.C.A.M. Gielen (Radboud University)
H. Irth (VU University Amsterdam)
J.J. de Kleuver (secretary, FOM)
N.J. Lopes Cardozo (chair, FOM)
G.F.B.P. van Meer (Utrecht University)
L.D. Noordam (University of Amsterdam)
W. van Saarloos (FOM)

Management Team
T. van Egdom
F. Linde
A. van Rijn

Scientific Advisory Committee (SAC)
R. Cashmore (University of Oxford, Oxford)
C. De Clercq (Vrije Universiteit Brussel, Brussels)
T. Hebbeker (chair, RWTH Aachen, Aachen)
Y. Karyotakis (LAPP, Annecy le Vieux)
A. Rubbia (ETH, Zürich)
J. Schukraft (CERN, Geneva)

Employees Council (NOR)
Th. Bauer (chair)
J. Dokter
M. Fransen
G. Kieft (secretary)
J. Kok
E. van der Poel (vice secretary)
N. Rem
H. Schuilenburg (vice chair)

CERN Contact Commissie
S. Bentvelsen
S. de Jong (secretary)
R. Kleiss
F. Linde
M. Merk
Th. Peitzmann

Dutch Research School Theoretical Physics – Governing Board
R. Kleiss
E. Laenen

Dutch Research School Theoretical Physics – Educational Board
W. Beenakker
J. van Holten
P. Mulders (chair)

Scientific Council (WAR)
S. Bentvelsen
A. van den Berg (KVI, Groningen)
J. van den Brand
B. van Eijk
H. van der Graaf
N. de Groot
M. de Jong
P. de Jong (chair)
S. de Jong
E. Koffeman
E. Laenen
F. Linde
M. Merk
Th. Peitzmann
A. van Rijn (secretary)
J. Templon
R. Timmermans (KVI, Groningen)
L. Wiggers

Onderzoekschool Subatomaire Fysica – Onderwijscommissie
S. Bentvelsen
J. Berger (secretary)
J. van den Brand
T. van Egdom (personnel)
B. van Eijk
N. de Groot (chair)
P. de Jong
S. de Jong
E. Koffeman
E. Laenen
F. Linde
M. Merk
P. Mulders
Th. Peitzmann
A. Schellekens

Committee for Astroparticle Physics in the Netherlands (CAN)
J. van den Brand
C. Van Den Broeck (vice chair)
P. Decowski
C. Timmermans

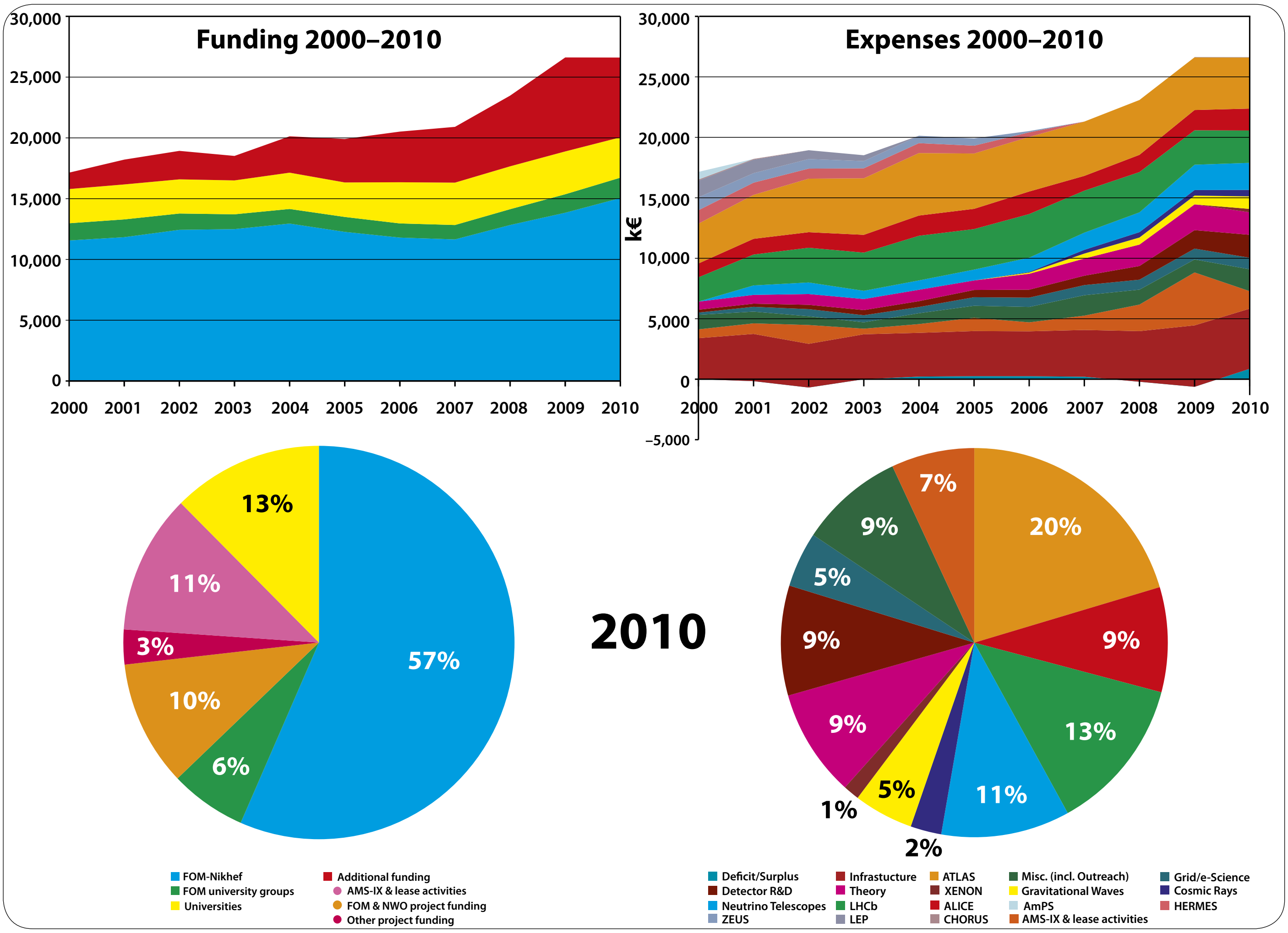
* *as of 1 January 2011.*

5.3 Funding and Expenses

From a funding perspective the year 2010 has been stable. The mission budget has increased in the years 2009–2011, thanks to the *'Dynamisering instituutsfinanciering'* granted in 2009. Furthermore the FOM-programme *"Gravitational Physics – the dynamics of spacetime"*, also granted in 2009, appears in the Nikhef budgets from 2010 onward.

A new Vidi grant has been awarded, starting next year. The funding in 2010 shows the result of earlier successes, both in the NWO *'Vernieuwingsimpulsen'* as in SenterNovem (now AgentschapNL) sponsored projects (such as Relaxd and Hidralon) and EU sponsored projects (such as EGEE, EUDET, ASPERA-2, KM3NeT and MC-PAD). New EU-projects have been granted. EGI InSPIRE, EMI and IGE in the realm of grid computing, all started in 2010. LHCPhenoNet, an MC training network in theory, and AIDA, a project on detector R&D, will start in 2011. Finally, the turnover in contracts with customers of the Internet Exchange datacenter facility has also increased (to about 2.5 M€). All in all the funding of the Nikhef collaboration is in 2010 at the same level as in 2009: 26.6 M€.

The expenses for accelerator-based particle physics (ATLAS, LHCb and ALICE) are more or less stable at 42%, with a shift to more scientific staff (notably PhD students), now that the analysis phase of the LHC experiments has started. The astroparticle physics activities have grown to represent 19% of expenses, including a small involvement in XENON (direct dark matter search). The enabling activities (theory, grid and detector R&D) form 23% of expenses, whilst outreach and the lease activities make out the remainder of the direct costs. Not included in the graph are the investments in the KM3NeT prototype detector and Advanced Virgo, totaling about 1 M€ in 2010.



5.4 Grants

New in this Annual Report is the table below, showing from top to bottom all grants awarded in 2010, 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 large investment subsidies (such as BiG Grid and KM3NeT) are not included in the table. More information on some of the grants of 2010 can be found in the section 'Awards and grants' (see section 3.6).

The table shows that the Nikhef collaboration is quite succesful in obtaining additional project funding from various funding sources. The financial envelope of projects awarded in 2010 amounts to 4.7 M€. However, this success cannot be taken for 'granted' – it requires continuous effort in preparing project proposals.

Leader	Title	Source		Budget (k€)	Partner
	Awarded				
Fleischer	Exploring a new territory of the B-physics landscape at LHCb	FOM/Pr	2010-2013	408	
Mischke	Charm content in jets	FOM/Pr	2011-2014	398	UU
Linde	Tiling appointment P. Ferrari	FOM/v	2010-2014	470	
Linde	High school teachers	FOM/EK	2010-2011	92	
Linde	Valorization	FOM	2010-2011	200	
Linde	HiSPARC nationale coördinatie fase-III	FOM/Out	2010-2013	215	
Igonkina	Vidi: Lepton flavor violation: the key towards a matter dominated universe	NWO	2011-2016	800	
De Groot	OSAF Research School Subatomic Physics - NWO graduate programme	NWO	2010-2015	800	RU
Klöpping	Holland@CERN	SenterNovem	2010	75	
Van Bakel	Pixel innovations	STW	2010	25	
Groep	EMI: European Middleware Initiative	EU	2010-2013	189	
Groep	IGE: Initiative for Globus in Europe	EU	2010-2013	202	
Van Rijn	EGI InSPIRE: European Grid Infrastructure	EU	2010-2014	251	
Koffeman	AIDA (detector R&D)	EU	2011-2014	152	
Laenen	LHCPhenoNet (theory)	EU	2011-2015	397	
				4,674	
	Running				
Bentvelsen	Higgs or no Higgs at the LHC	FOM/Pr	2007-2011	323	
De Groot	Muons as a probe of supergravity	FOM/Pr	2006-2011	298	RU
Vermaseren	Precision phenomenology at the LHC	FOM/Pr	2008-2012	335	
De Jong (S.)	Radio detection of ultra high energy cosmic rays at Auger	FOM/Pr	2008-2012	124	RU
De Groot	A search in proton- anti-proton collisions for Higgs (ASAP Higgs)	FOM/Pr	2008-2012	335	RU
Mulders	Color flow in hard hadronic scattering processes	FOM/Pr	2008-2013	331	VU
Linde	Tiling appointment O. Igonkina	FOM/v	2007-2012	310	
Van Vulpen	Vidi: Top quarks and fundamental physics at 100 zeptometer	NWO	2006-2011	406	
Van Leeuwen	Vidi: Hard probes of the Quark Gluon Plasma at the LHC	NWO	2007-2012	406	UU
Bentvelsen	Vici: Beyond the top - a new era in particle physics	NWO	2007-2013	844	
Postma	Vidi: The early universe as a particle laboratory	NWO	2008-2013	406	
Tuning	Vidi: No GUTs, no Glory: a search for Grand Unified Theories with B-decays	NWO	2008-2013	406	
Petrovic	Veni: Search for sources of high energy cosmic rays with the ANTARES neutrino telescope and the Auger observatory	NWO	2008-2011	141	
Mischke	Vidi: Characterisation of a novel state of matter: The Quark-Gluon Plasma	NWO	2008-2013	365	UU

Leader	Title	Source		Budget (k€)	Partner
Heijboer	Vidi: Exploring the Cosmos with Neutrinos	NWO	2009-2014	600	
De Jong (P.)	Vici: Between bottom and top: supersymmetry searches with flavour	NWO	2009-2014	1,250	
Hulsbergen	Vidi: A search for long-lived heavy particles	NWO	2010-2015	800	
Klous	Virgo on GPU	NCF	2009-2010	26	
Mischke	StG: Characterisation of a novel state of matter: The Quark-Gluon Plasma	EU/ERC	2008-2012	850	UU
De Wolf	KM3NeT-Preparatory Phase	EU	2008-2011	425	
Koffeman	MC-PAD: R&D training network	EU	2009-2012	424	
Linde	ASPERA-2: astroparticle physics coordination	EU	2009-2012	192	
Van den Brand	Einstein Telescope - design study	EU	2009-2012	200	VU
Visser	Hidralon: High Dynamic Range Low Noise CMOS sensors	SenterNovem	2009-2012	794	
Van Beuzekom	Kenniswerkersregeling (Bruco)	SenterNovem	2009-2010	45	
Van Eijk	HiSPARC - 'betadecanen'	Universities	2010	35	
				10,671	
		Completed			
Schellekens	Theme conformal field theory	FOM	2006-2010	423	
Schellekens	Standard model interactions from open string theory	FOM/Pr	2006-2010	186	
Raven	The asymmetry between matter and antimatter	FOM/Pr	2006-2010	296	
Peitzmann	A STARry eyed look at color glass	FOM/Pr	2006-2010	260	UU
Linde	HiSPARC nationale coördinatie fase-II	FOM/Out	2006-2010	242	
Linde	High school teachers	FOM/EK	2008-2010	122	
Snellings	Vidi: A new state of matter: the quark-gluon plasma	NWO	2005-2010	406	
Colijn	Vidi: Radiating top quarks	NWO	2005-2010	406	
Mischke	Veni: Probing the temperature in ultrarelativistic heavy ion collisions using thermal photons	NWO	2006-2009	200	UU
Bouwhuijs	Veni: Search for neutrinos from cosmic accelerators	NWO	2005-2010	135	
Klous	Veni: Chasing the Higgs boson with a world wide distributed trigger system	NWO	2006-2010	141	
Visser	Relaxd	SenterNovem	2005-2010	533	
Templon/Groep	Virtual Laboratory for e-Science	SenterNovem	2004-2009	1,359	
Timmermans	EUDET (detector R&D)	EU	2006-2010	278	
De Wolf	KM3NeT - design study	EU	2006-2009	658	
Linde	ASPERA: astroparticle physics coordination	EU	2006-2009	218	
Hessey	sLHC: preparatory phase	EU	2007-2010	64	
Templon	Enabling Grid for e-Science (EGEE-III)	EU	2008-2010	732	
				6,659	

5.5 Personnel*

Overview of Nikhef personnel in fte (2010)

I – Scientific groups (fte – 2010, institute & university groups)	
Permanent scientific staff	58.6
PhD students	75.1
Post–docs	32.1
Total I	165.8
II – Management, technical/engineering and general support (fte – 2010, institute)	
Management team	
Director	1.0
Institute manager	1.0
Personnel/HRM officer	0.8
Subtotal	2.8
Technical/engineering support	
Electronics technology	25.5
Computer technology	22.8
Mechanical engineering	16.8
Mechanical workshop	15.6
Project management support	1.8
Subtotal	82.4
General support	
Financial administration	3.8
Personnel/HRM administration	1.0
Library	0.6
Technical and domestic services	9.1
Secretariat and reception desk	4.8
PR & communication	1.8
Occupational health & safety	1.0
Education (HiSPARC)	2.3
Staff	1.3
Subtotal	25.7
Total II	110.9
Total I & II	276.7
III – Other groups (persons 2010)	
Guests (researchers, retired staff)	30.0
Master students	59.0

ATLAS

Aben	MSc	R.Z. (Rosemarie)	FOM
Beemster	MSc	L.J. (Lars)	FOM
Bentvelsen	Prof.dr.	S.C.M. (Stan)	UvA
Bobbink	Dr.	G.J. (Ger Jan)	FOM
Bos	Dr.	K. (Kors)	FOM
Chelstowska	MSc	M.A. (Magda)	FOM
Colijn	Dr.	A.P. (Auke Pieter)	UvA
Consonni	Dr.	M. (Michele)	FOM
Deijl	MSc	P.C. (Pieter), van der	UT
Doxiadis	MSc	A.D. (Alexander)	FOM
Ferrari	Dr.	P. (Pamela)	FOM
Filthaut	Dr.	F. (Frank)	RU
Geerts	MSc	D.A.A. (Daniel)	FOM
Gosselink	Dr.ir.	M. (Martijn)	FOM
Groot	Prof.dr.	N. (Nicolo), de	RU
Hessey	Dr.	N.P. (Nigel)	FOM
Igonkina	Dr.	O.B. (Olga)	FOM
Jansen	Drs.	E. (Eric)	GST
Jong	Prof.dr.ir.	P.J. (Paul), de	FOM
Kayl	Dipl.Phys.	M.S. (Manuel)	FOM
Klok	Drs.	P.F. (Peter)	FOM
Klous	Dr.ing.	S. (Sander)	GST
Kluit	Dr.drs.ir.	P.M. (Peter)	FOM
Koetsveld	Drs.	F. (Folkert)	FOM
Koffeman	Prof.dr.ir.	E.N. (Els)	FOM
König	Dr.	A.C. (Adriaan)	RU
Koutsman	Drs.	A.J. (Alex)	GST
Lee	MSc.	H.C. (Hurng-Chun)	FOM
Leeuw	MSc	R.H.L. (Robin), van der	FOM
Mechnich	Dipl.Phys.	J. (Jörg)	FOM
Meijer	MSc	M.M. (Melvin)	FOM
Mussche	MSc	I. (Ido)	FOM
Naumann	Drs.	N.A. (Axel)	GST
Nooij	MSc	L. (Lucie), de	FOM
Oord	Drs.	G.J.W.M. (Gijs), van den	FOM
Ottersbach	Dipl.Phys.	J.P. (John Philip)	FOM
Pani	MSc	P. (Priscilla)	FOM
Poel	MSc	E.F. (Egge), van der	FOM
Raas	MSc	M.J.P. (Marcel)	FOM
Rijpstra	Drs.	M. (Manouk)	GST
Ruckstuhl	MSc	N.M. (Nicole)	FOM
Salamanna	Dr.	G. (Giuseppe)	FOM
Sandström	Dr.	A.R. (Rikard)	FOM
Ta	Dr.	D.B. (Duc Bao)	FOM
Tsiakiris	MSc	M. (Menelaos)	FOM
Verkerke	Dr.	W. (Wouter)	FOM
Vermeulen	Dr.ir.	J.C. (Jos)	UvA
Vreeswijk	Dr.	M. (Marcel)	UvA
Vulpen	Dr.	I.B. (Ivo), van	UvA

LHCb

Aaij	MSc	R.J.M. (Roel)	FOM
Amoraal	Drs.	J.M (Jan)	FOM
Bauer	Dr.	Th.S. (Thomas)	FOM
Carvalho Akiba	Dr.	K. (Kazuyoshi)	FOM
Coco	Dr.	V.A.G. (Victor)	FOM
Eijk	MSc	D. (Daan), van	FOM
Farinelli	MSc	C. (Chiara)	FOM
Heijne	MSc	V.A.M. (Veerle)	FOM
Hulsbergen	Dr.	W. (Wouter)	FOM
Jans	Dr.	E. (Eddy)	FOM
Jansen	Ir.	F.M. (Fabian)	FOM
Ketel	Dr.	T.J. (Tjeerd)	FOM
Koppenburg	Dr.	P.S. (Patrick)	FOM
Kozlinskiy	MSc	A. (Alexandr)	FOM
Leerdam	MSc	J. (Jeroen), van	FOM

* as of 31 December 2010.

Merk	Prof.dr.	M.H.M. (Marcel)	FOM
Mous	MSc	I.V.N. (Ivan)	FOM
Oggero	MSc	S. (Serena)	FOM
Pellegrino	Dr.	A. (Antonio)	FOM
Raven	Dr.	H.G. (Gerhard)	VU
Serra	Dr.	N. (Nicola)	FOM
Storaci	MSc	B. (Barbara)	FOM
Tuning	Dr.	N. (Niels)	FOM
Vries	Dr.	H. (Hans), de	GST
Wiggers	Dr.	L.W. (Leo)	FOM

ALICE

Bilandžic	Drs.	A. (Ante)	FOM
Botje	Dr.	M.A.J. (Michiel)	FOM
Braidot	Drs.	E. (Ermes)	GST
Chojnacki	Drs.	M. (Marek)	FOM
Christakoglou	Dr.	P. (Panos)	FOM
Grelli	Dr.	A. (Alessandro)	UU
Kolk	Drs.ing.	N. (Naomi), van der	FOM
Krzewicki	MSc	M. (Mikolaj)	FOM
Kuijer	Dr.	P.G. (Paul)	FOM
Leeuwen	Dr.	M.A. (Marco), van	UU
Mischke	Dr.	A. (André)	UU
Nooren	Dr.ir.	G.J.L. (Gert-Jan)	FOM
Peitzmann	Prof.dr.	Th. (Thomas)	UU
Pérez Lara	MSc	C.E. (Carlos)	FOM
Reicher	MSc	M. (Martijn)	UU
Rooij	MSc	R. (Raoul), de	UU
Snellings	Prof.dr.	R.J.M. (Raimond)	UU
Thomas	MSc	D. (Deepa)	UU
Veldhoen	MSc	M. (Misha)	FOM
Verweij	MSc	M. (Marta)	UU
Zhou	MSc	Y. (You)	FOM

ANTARES/KM3NeT

Astraatmadja	MSc	T.L. (Tri)	UL
Bogazzi	MSc	C. (Claudio)	FOM
Grebe	MSc	S. (Stefan)	FOM
Hartman	MSc	J. (Joris)	FOM
Heijboer	Dr.	A.J. (Aart)	FOM
Hsu	Dr.	C.C. (Ching-Cheng)	FOM
Jong	Prof.dr.	M. (Maarten), de	FOM
Kooijman	Prof.dr.	P.M. (Paul)	UvA
Kopper	Dr.	C. (Claudio)	FOM
Lim	Ir.	G.M.A. (Gordon)	GST
Petrovic	Dr.	J. (Jelena)	FOM
Samtleben	Dr.	D.F.E. (Dorothea)	FOM
Steijger	Dr.	J.J.M. (Jos)	FOM
Visser	MSc	E.L. (Erwin)	FOM
Wijnker	Drs.	G.P.J.C. (Guus)	GST
Wolf	Dr.	E. (Els), de	UvA

Pierre Auger Observatory

Coppens	Drs.	J.M.S. (Jose)	FOM
Harmsma	Ir.	S. (Sybren)	GST
Jong	Prof.dr.	S.J. (Sijbrand), de	RU
Kelley	Dr.	J.L. (John)	FOM
Nelles	MSc	A.F. (Anna)	FOM
Obermeier	Dipl.Phys	A. (Andreas)	FOM
Palioselitis	MSc	D. (Dimitrios)	FOM
Presani	Drs.	E. (Eleonora)	GST
Reed	Dr.	C.J. (Corey)	FOM
Schoorlemmer	MSc	H. (Harm)	FOM
Timmermans	Dr.	C.W.J.P. (Charles)	FOM
Zarza	MSc	G.A. (Gabriel)	GST

Virgo/LISA

Beker	Ir.	M.G. (Mark)	FOM
Blom	MSc	M.R. (Mathieu)	FOM
Brand	Prof.dr.ing.	J.F.J. (Jo), van den	VU
Broeck	Dr.	C.F.F. (Chris), Van Den	FOM
Bulten	Dr.	H.J. (Henk Jan)	VU
Del Pozzo	Dr.	W. (Walter)	FOM
Koekoek	Drs.	G. (Gideon)	FOM
Li	MSc	T.G.F. (Tjonnie)	FOM
Putten	Drs.	S. (Sipho), van der	FOM
Rabeling	Dr.	D.S. (David)	VU
Vitale	Dr.	S. (Salvatore)	FOM

XENON

Alfonsi	Dr.	M. (Matteo)	FOM
Decowski	Dr.	M.P. (Patrick)	FOM

Theory

Adelhart Toorop	MSc	R. (Reinier), de	FOM
Aybat	Dr.	S.M. (Mert)	VU
Beenakker	Dr.	W. (Wim)	RU
Broek	MSc	T.C.H. (Thijs), van den	FOM
Dunnen	MSc	W. (Wilco), den	VU
Fleischer	Dr.	R. (Robert)	FOM
Gaemers	Prof.dr.	K.J.F. (Karel)	GST
Gato-Rivera	Dr.	B. (Beatriz)	GST
George	Dr.	D.P. (Damien)	FOM
Hartgring	MSc	L.C. (Lisa)	FOM
Holten	Prof.dr.	J.W. (Jan-Willem), van	FOM
Kleiss	Prof.dr.	R.H.P. (Ronald)	RU
Knegjens		R.J. (Rob)	FOM
Korthals Altes	Dr.	C.P. (Chris)	GST
Kuipers	Dr.	J. (Jan)	FOM
Laenen	Prof.dr.	E.L.M.P. (Eric)	UvA
Maio	MSc	M. (Michele)	FOM
Mantz	MSc	C.L.M. (Christiaan)	FOM
Mooij	MSc	S.J.N. (Sander)	FOM
Mulders	Prof.dr.	P.J.G. (Piet)	VU
Ortiz Cabello	MSc	P. (Pablo)	FOM
Postma	Dr.	M.E.J. (Marieke)	FOM
Reiter	Dr.	T. (Thomas)	FOM
Schellekens	Prof.dr.	A.N.J.J. (Bert)	FOM
Veltman	Prof.dr.	M.J.G. (Martinus)	GST
Vermaseren	Dr.	J.A.M. (Jos)	FOM
Vollinga	Dr.	J. (Jens)	GST
Weenink	MSc	J.G. (Jan Gerard)	FOM
Wit	Prof.dr.	B.Q.P.J. (Bernard), de	GST

Detector R&D

Bakel	Dr.ing.	N.A. (Niels), van	FOM
Beuzekom	Dr.Ing.	M.G. (Martin), van	FOM
Boer Rookhuizen	Ing.	H. (Herman)	FOM
Bosma	MSc	M.J. (Marten)	FOM
Bouwens	Dr.	B.T. (Bram)	GST
Fransen	MSc	M. (Martin)	FOM
Graaf	Dr.ir.	H. (Harry), van der	FOM
Hartjes	Dr.	F.G. (Fred)	GST
Heijne	Dr. ir.	E.H.M. (Erik)	GST
Hejtmánek	MSc	M. (Martin)	GST
Koppert	MSc	W.J.C. (Wilco)	FOM
Schioppa	MSc	E.J. (Enrico)	RU
Schön	Dipl.Phys.	R. (Rolf)	FOM
Snippe	Ir.	Q.H.C. (Corijn)	FOM
Timmer	Dr.	B.H. (Björn)	GST
Timmermans	Dr.	J.J.M. (Jan)	GST
Tsagri	Ir.	M. (Maria)	GST

Tsopelas	MSc	P. (Panos)	GST
Vanbavinckhove	Ir.	G. (Glenn)	GST
Visschers	Dr.	J.L. (Jan)	FOM
Visser	Dr.	J. (Jan)	FOM
Zappon	MSc	F. (Francesco)	FOM

Grid Computing

Bernabé Pellicer	MSc	F.J. (Paco)	FOM
Dok	Drs.	D.H. (Dennis), van	FOM
Engen	Ir.	W.S. (Willem), van	FOM
Gabriel	Dr.	S. (Sven)	FOM
Garitaonandia	Drs	H. (Hegoi)	FOM
Groep	Dr.	D.L. (David)	FOM
Keijser	Drs.	J.J. (Jan Just)	FOM
Koeroo	Ing.	O.A. (Oscar)	FOM
Remenska	MSc	D. (Daniela)	FOM
Sallé	Dr.	M. (Mischa)	FOM
Starink	Dr.	R. (Ronald)	FOM
Suerink	Ing.	T.C.H. (Tristan)	FOM
Templon	Dr.	J.A. (Jeff)	FOM
Verstegen	Ing.	A.C.Z. (Aram)	FOM

HiSPARC

Bonam		S. (Surya)	FOM
Bosboom	MSc	C.H. (Niels)	GST
Buisman	Dr.	H.P. (Henk)	FOM
Eijk	Prof.dr.ing.	B. (Bob) van	FOM
Fokkema	Drs.	D.B.R.A. (David)	FOM
Kniest	Drs.	R.A.M.N. (Remon)	FOM
Marcelis	Ir.	F.G. (Frans)	GST
Montanus	Drs.	J.M.C. (Hans)	GST
Schultheiss		N.G. (Nicolaas)	GST
Wilke de Souza		D.D. (Daniel)	GST

Computer Technology

Akker		T.G.M. (Theo), van den	FOM
Boterenbrood	Ir.	H. (Henk)	FOM
Bouwhuis	Dr.	M.C. (Mieke)	FOM
Damen		A.C.M. (Ton)	FOM
Deurzen	Dr.	P.A.J. (Paul), van	GST
Grootes		E.P. (Erwin)	Uitzend
Hart	Ing.	R.G.K. (Robert)	FOM
Heubers	Ing.	W.P.J. (Wim)	FOM
Kan		A.C. (André), van	FOM
Kerkhoff		E.H.M. (Elly), van	FOM
Kuipers	Drs.	P. (Paul)	FOM
Leeuwen	Drs.	W.M. (Willem), van	GST
Oudolf		J.D. (Jan)	PANTAR
Pushkina	Dr.	I. (Irina)	FOM
Schimmel	Ing.	A. (Fred)	FOM
Tierie		J.J.E. (Joke)	FOM
Wal		B. (Bart), van der	FOM
Wijk		R.F. (Ruud), van	GST

Electronics Technology

Berkien		A.W.M. (Ad)	FOM
Fransen		J.P.A.M. (Jean-Paul)	FOM
Gajanana	MSc	D. (Deepak)	FOM
Gotink		G.W. (Wim)	FOM
Groen		P.J.M. (Piet), de	FOM
Groenstege	Ing.	H.L. (Henk)	FOM
Gromov	Drs.	V. (Vladimir)	FOM
Haas	Ing.	A.P.J. (Arie), de	FOM
Heijden	Ing.	B.W. (Bas), van der	FOM
Hogenbirk	Ing.	J.J. (Jelle)	FOM
Jansen		L.W.A. (Luc)	FOM
Jansweijer	Ing.	P.P.M. (Peter)	FOM
Kieft	Ing.	G.N.M. (Gerard)	FOM
Kluit	Ing.	R. (Ruud)	FOM
Koopstra		J. (Jan)	UvA
Kuijt	Ing.	J.J. (Jaap)	FOM
Mos	Ing.	S. (Sander)	FOM
Peek	Ing.	H.Z. (Henk)	FOM
Schipper	Ing.	J.D. (Jan David)	FOM
Schmelling	Ing.	J.W. (Jan-Willem)	FOM
Sluijk	Ing.	T.G.B.W. (Tom)	FOM
Timmer		P.F. (Paul)	FOM
Verkooijen	Ing.	J.C. (Hans)	FOM
Vink	Ing.	W.E.W. (Wilco)	FOM
Zivkovic	MSc	V. (Vladimir)	FOM
Zwart	Ing.	A.N.M. (Albert)	FOM

Mechanical Engineering

Alaei		A. (Aran)	FOM
Band	Ing.	H.A. (Hans)	FOM
Berbee	Ing.	E.M. (Edward)	FOM
Brink		A. (Ton), van den	UU
Doets		M. (Martin)	FOM
Hennes	Drs.	E. (Eric)	FOM
Korporaal		A. (Auke)	FOM
Kraan	Ing.	M.J. (Marco)	FOM
Mul	Ing.	G. (Gertjan)	FOM
Munneke	Ing.	B. (Berend)	FOM
Roo	B.Eng.	K. (Krista), de	FOM
Rosing	Dr.ir.	R. (Richard)	FOM
Schuijlenburg	Ing.	H.W.A. (Henk)	FOM
Snaijer	B.Eng	A.D. (Ad), de	FOM
Thobe		P.H. (Peter)	FOM
Verlaat	Ing.	B.A. (Bart)	FOM
Werneke	Ing.	P.J.M. (Patrick)	FOM

Mechanical Workshop

Boer		R.P. (René), de	FOM
Brouwer		G.R. (Gerrit)	FOM
Buis		R. (Rob)	FOM
Ceelie		L. (Lukas)	UvA
Jaspers		M.J.F. (Michiel)	UvA
John		D.M. (Dimitri)	FOM
Kok		J.W. (Hans)	FOM
Kuilman		W.C. (Willem)	FOM
Leguyt		R. (Rob)	FOM
Mul		F.A. (Frans)	FOM
Overbeek		M.G. (Martijn), van	FOM
Petten		O.R. (Oscar), van	FOM
Rietmeijer		A.A. (Arnold)	FOM
Roeland		E. (Erno)	FOM
Rövekamp		J.C.D.F. (Joop)	UvA

Management and Administration

Azarfane		M. (Mohamed)	PANTAR
Azhir		A. (Ahmed)	FOM
Barneveld		K.M. (Katja), van	FOM
Berg		A. (Arie), van den	FOM
Berger		J.M. (Joan)	FOM
Bulten		F. (Fred)	FOM
Demonfaucon		H. (Helene)	FOM
Dokter		J.H.G. (Johan)	FOM
Echtelt	Ing.	H.J.B. (Joost), van	FOM
Egdom		T. (Teus), van	FOM
Greven-Van Beusekom		E.C.L. (Els)	FOM
Haan-Hekkelman		W.R. (Wijnanda)	FOM

Heine	Ing.	E. (Eric)	FOM
Huyser		K. (Kees)	FOM
Kleinsmiede-Van Dongen		T.W.J. (Trees)	FOM
Klöpping	Ir.	R. (Rob)	FOM
Langenhorst		A. (Ton)	FOM
Lapikás	Dr.	L. (Louk)	GST
Lemaire-Vonk		M.C. (Maria)	FOM
Linde	Prof.dr.	F.L. (Frank)	FOM
Mexner	Dr.	I.V. (Vanessa)	FOM
Mors		A.G.S. (Anton)	FOM
Oosterhof-Meij		J.E.G. (Annelies)	FOM
Pancar		M. (Muzaffer)	FOM
Rem	Drs. ing.	N. (Nico)	FOM
Rijksen		C. (Kees)	FOM
Rijn	Drs.	A.J. (Arjen), van	FOM
Sande		M. (Melissa), van der	FOM
Schram-Post		E.C. (Eveline)	FOM
Vervoort	Ing.	M.B.H.J. (Marcel)	FOM
Vreeken		D. (Daniel)	PANTAR
Willigen		E. (Ed), van	FOM
Witlox	Ing.	A.M (Arie)	FOM
Woortmann		E.P. (Eric Paul)	FOM

Miscellaneous

Blok	Dr.	H.P. (Henk)	GST
Engelen	Prof.dr.	J.J. (Jos)	UvA
Laan	Dr.	J.B. (Jan), van der	FOM

5.6 Master students

In 2010, thirteen 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*
22/02/2010	Roel Aaij	UvA	Cosmics in the LHCb Outer Tracker	Th. Bauer	LHCb
14/04/2010	Jeroen van Leerdam	UT	Higher Order QCD Corrections in Top-Antitop production at the LHC	B. van Eijk	ATLAS
26/04/2010	Robbert Bosman	UvA	Reconstruction of electromagnetic showers with the Antares neutrino telescope	P. Kooijman E. de Wolf	ANTARES
26/04/2010	Sjoert van Velzen	UvA, Double Master programme *(Cum Laude)*	Optical Flares and Cosmic Particles	G. Farrar (NY University) E. de Wolf R. Wijers	ANTARES NYU
7/5/2010	Merlin Kole	UT	Phenomenology of Extra-Dimensional Higgsless Models	B. van Eijk	ATLAS
28/07/2010	Rosemarie Aben	UvA *(Cum Laude)*	Precision studies of the ATLAS MDT Chambers	P. Kluit S. Bentvelsen	ATLAS
31/08/2010	Veerle Heijne	UvA *(Cum Laude)*	Characterisation of the Timepix Chip for the LHCb VELO Upgrade	M. van Beuzekom	Detector R&D LHCb
31/08/2010	Erwin Visser	VU *(Cum Laude)*	Preventing, monitoring and curing the ageing in the LHCb Outer Tracker	N. Tuning	LHCb
18/10/2010	Philip de Vries	VU, Onderwijsvariant *(Cum Laude)*	Kosmische straling en detectoren: practica voor middelbare scholen	M. Vreeswijk	HiSPARC
20/10/2010	Lars Beemster	UT *(Cum Laude)*	Multi-messenger correlation studies: the ANTARES neutrino telescope and the Pierre Auger Ultra High Energy Cosmic Ray Observatory	B. van Eijk J. Petrovic	ANTARES AUGER
22/11/2010	Nikos Tsirintanis	UvA	Cooling processes in radio galaxies: application to jets and giant lobes of Centaurus B	S. Jiraskova J. Petrovics	ANTARES AUGER
26/11/2010	Pieter van der Deijl	UT	The ATLAS discovery potential of hadronic Z'-Strahlung decays	B. van Eijk	ATLAS
20/12/2010	Rose Koopman	UvA *(Cum Laude)*	Background estimates in searches for the supersymmetric light top quark at the LHC	I. van Vulpen P. de Jong E. Barberio (Univ. of Melbourne)	ATLAS

Table 1. Master students who graduated in 2010.

5.7 Apprentices

The presence of high quality technical departments at Nikhef allows us to offer interesting internship positions for students in secondary (MBO) and higher (HBO) vocational education. The table below lists the apprentices who finished their training period in 2010 in the departments Computer Technology (CT), Electronics Technology (ET) and Mechanical Workshop (MW) and Engineering (ME).

Date	Name	School	Subject / Title	Supervisor(s)	Group
June 2010	N.O. Dijk	HBO Hogeschool van Amsterdam	Virtualization in a grid environment	M. Sallé	CT
July 2010	J.E.Vermeer	HBO Hogeschool Windesheim Zwolle	Webinterface voor het uitlezen van PDU's in het datacentrum	T. Suerink	CT
Feb. 2010	J. Lacunes	MBO ROC van Amsterdam	Rasnik	M. Jaspers	MW
May 2010	A. Alaei	HBO Hogeschool van Amsterdam	Ontwerpen van een gereedschap	H. Schuijlenburg	ME
2010	S. Broekema	MBO NOVA college Hoofddorp	Algemeen	H. Verkooien	ET
Feb. 2010	J. Hogers	HBO Hogeschool van Amsterdam	CPU in FPGA met I2C besturing	P. Jansweijer B. van der Heiden	ET
Feb. 2010	N. Baars	HBO Hogeschool van Amsterdam	FPGA programmeren via USB	H. Verkooien	ET

Table 2. Apprentices who finished their training period at Nikhef in 2010.

Glossary

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 co–ordination 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.

BNL (Brookhaven National Laboratories)
Laboratory at Long Island, New York, where the RHIC accelerator is located.

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.

DØ (named for location on the Tevatron Ring)
Collider detector, studies proton–antiproton collisions at Fermilab's Tevatron.

Dark matter
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.

Dipole
A magnet with two poles, like the north and south poles of a horseshoe magnet. Dipoles are used in particle accelerators to keep the particles on a closed orbit.

EGEE (Enabling Grids for E–SciencE)
An EU–funded project led by CERN, now involving more than 90 institutions over 30 countries worldwide, to provide a seamless Grid infrastructure that is available to scientists 24 hours a day.

Electron
See *Particles*.

End cap
Detector placed at each end of a barrel–shaped detector to provide the most complete coverage in detecting particles.

EUDET (European Detector R&D towards the International Linear Collider)
EU–funded R&D project for research on future *ILC* detectors.

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, characterized 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 accelera-

tors produce very fast, energetic particles probing deeply into other particles.

Higgs boson
A particle predicted by theory, linked to the mechanism by which physicists think particles acquire mass.

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*).

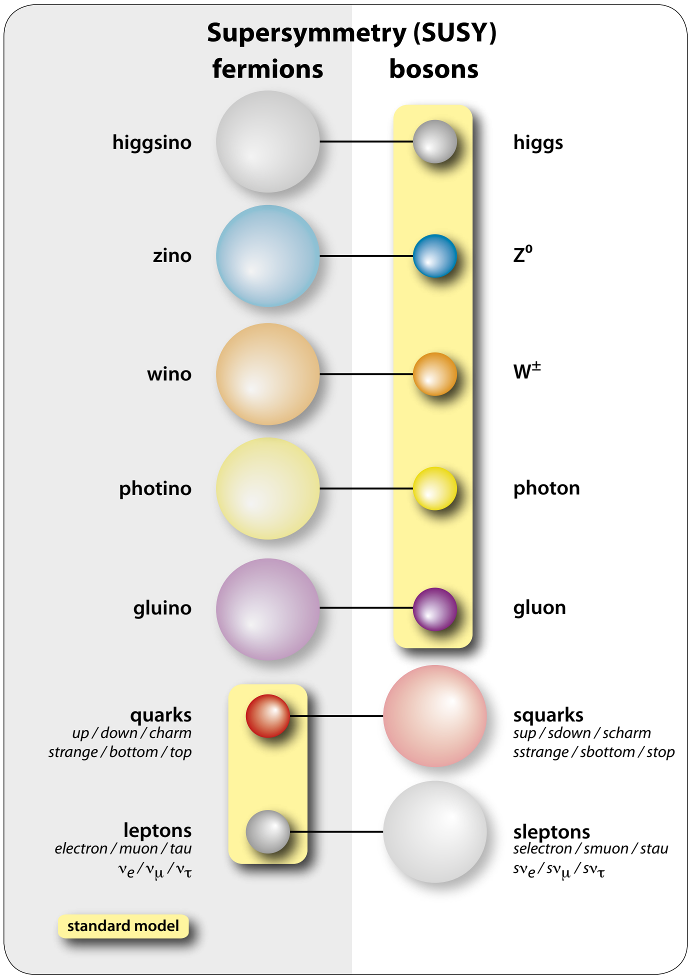
KM3NeT (Cubic Kilometre Neutrino Telescope)
Planned European deep–sea neutrino telescope with a volume of at least one cubic kilometre at the bottom of the Mediterranean Sea.

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.



Supersymmetry; for every type of boson there exists a corresponding type of fermion with the same mass and internal quantum numbers, and vice-versa.

LHCb (Large Hadron Collider beauty)
One of the four major experiments that uses the *LHC*.

Linac
An abbreviation for linear accelerator.

LISA (Laser Interferometric Space Array)
ESA/NASA mission, the first space–based gravitational wave observatory; to be launched in 2015; three spacecraft, orbiting around the Sun as a giant equilateral triangle 5 million km on a side.

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 blocks 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.

Solenoid
An electromagnet produced by current flowing through a single coil of wire. Many particle detectors are surrounded by a solenoidal magnet, since this produces a fairly uniform magnetic field within.

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.

Z boson
A carrier particle of weak interactions; involved in all weak processes that do not change flavour and charge.