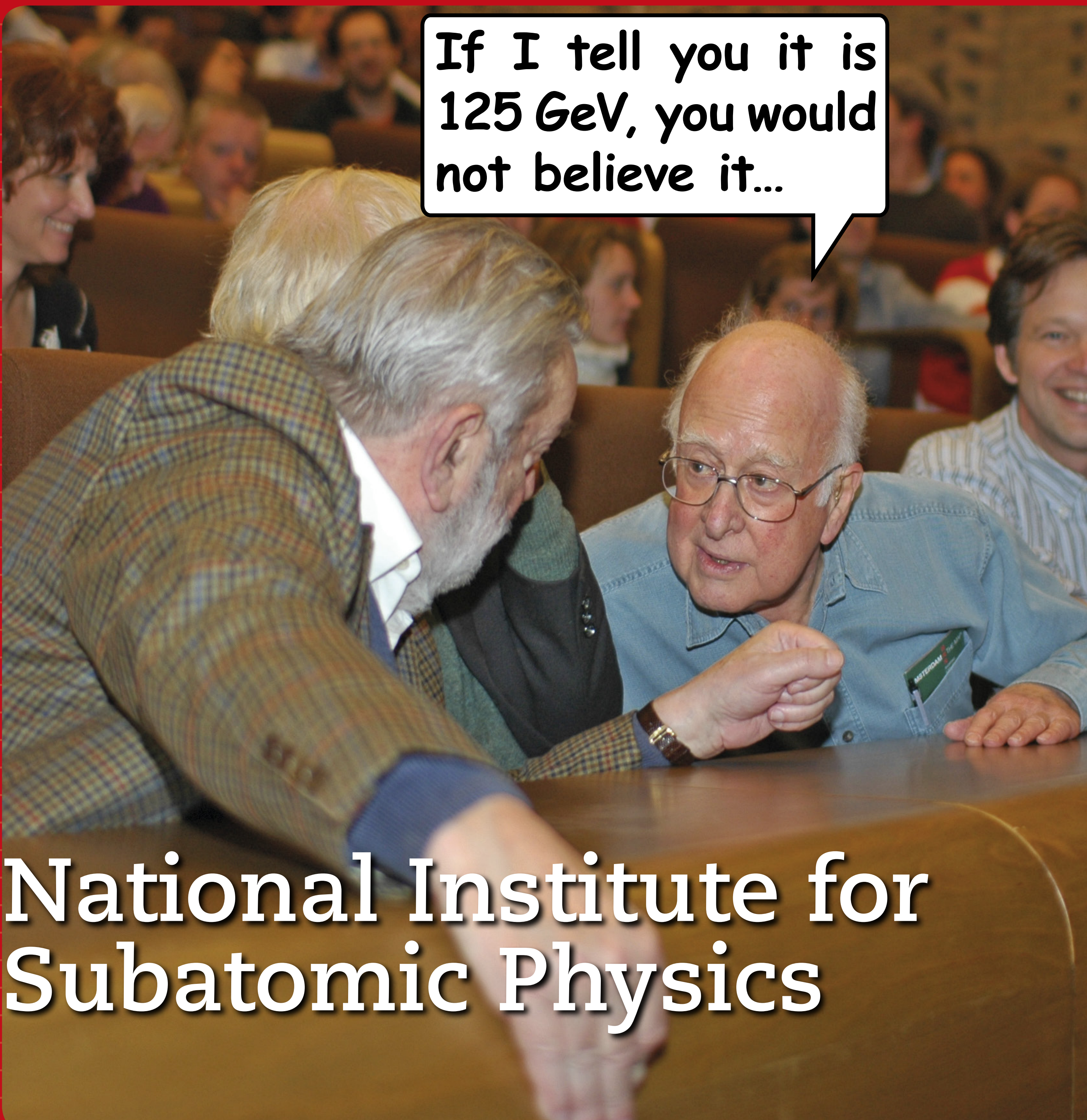
Annual Report 2011

Nikhef



National Institute for Subatomic Physics

NIKHEF

Annual Report 2011

National Institute for Subatomic Physics Nikhef

Colophon

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Cover: Peter Higgs (right) and Tini Veltman discussing physics at a colloquium at Nikhef in November 2009. Could this have been their text?

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

Contents

Introduction

For numerous reasons 2011 was an extremely exciting year for (astro)particle physics in general and Nikhef in particular!

Foremost, physics wise. On 23 September the OPERA collaboration announced in a packed CERN main auditorium that they had measured the speed of neutrinos between CERN and the deep-underground Laboratori Nazionali del Gran Sasso (732 km from CERN) to exceed the velocity of light by six standard deviations! If true, this would be a stunning discovery and a revolution in physics. Today, several months later, the OPERA claim, somewhat surprisingly, still stands. Nevertheless, like most physicists I remain skeptical. The experiment critically depends on two difficult to assess systematic accuracies: the absolute CERN-LNGS distance (claimed to be known to about 20 cm, whereas the measured effect corresponds to about 20 m) and the absolute CERN-LNGS time synchronisation (claimed to be known to about 6 ns, whereas the measured effect corresponds to about 60 ns *i.e.,* equivalent to a 12 meter long LEMO cable…). Probably the only way to settle the OPERA claim will be an independent confirmation by one or, ideally, both of the other long-baseline neutrino beams in the world: T2K for *Tokai to Kamioka* in Japan and NuMI, officially *Neutrinos at the Main Injector* but probably more appropriate named *Neutrinos to Minnesota* in the USA. Meanwhile we happily enjoy the enormous media attention.

Excitement also came from CERN's LHC project. Firstly, the accelerator again performed much better than expected resulting in a hundredfold increase in the integrated luminosity: from 50 pb^{-1} by the end of 2010 to 5000 pb^{-1} by the end of 2011! Beyond doubt the biggest LHC-related excitement occurred on 13 December: in front of a once again packed main CERN auditorium the ATLAS and CMS spokespersons presented the status of the Higgs searches. The Standard Model Higgs is now basically excluded with 95% confidence limit across its complete mass range except in the tiny region between 115 and 131 GeV. Moreover, both ATLAS and CMS observe excesses in the 124–126 GeV mass region. The significance of these excesses (few sigma) is insufficient to already claim the discovery (five sigma required) of the Higgs. However, provided the LHC continues to perform superbly also in 2012, the Standard Model Higgs will either be discovered or proven not to exist by the end of 2012. I am already looking forward to next year's Nikhef Jamboree: hopefully CERN will schedule their Higgs seminar again such that it fits in with Nikhef's Jamboree! This was really an unforgettable event, certainly for those Nikhef collaborators who made it to national television and/or newspapers. By now, many people in the Netherlands do know about CERN, LHC and the Higgs, as illustrated by the popular *Fokke & Sukke* cartoons in one of the leading Dutch newspapers.

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

Two complementary approaches are followed:

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

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

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

Compared to the CERN related excitement, progress in astroparticle physics was just business as usual. The experiments ANTARES (neutrino telescope), Auger (cosmic rays), Virgo (gravitational waves) and Nikhef's most recently started activity XENON100 (dark matter) continued regular data taking; the real focus is on the design and construction of 'next-generation' facilities in these fields: KM3NeT, Auger Radio, Advanced Virgo and XENON1T, respectively. Once completed, the discovery potential will be such that, I think, at least one Nobel-prize winning measurement will be made before the end of this decade!

Leaving physics aside, 2011 was also the year in which Nikhef was evaluated by an international team of renowned (astro) particle physicists. Hard to believe, but Nikhef surpassed the already first-class judgement of the previous evaluation in 2007! However, due to the harsh economic climate worldwide, it is unlikely that the excellent evaluation report will lead to the asked for budgetary increase of Nikhef's mission budget. The final verdict will come in mid-2012. As recommended by this evaluation committee, Nikhef vigorously continues to support 'valorisation' projects *i.e.,* the creation of economic value on the basis of (astro)particle physics technology. In 2011 Nikhef and a venture capitalist started *P2IP, Particle Physics Inside Products*, as an umbrella organisation for startup activities. Two startup companies were already launched in 2011. *Sensiflex* markets products based on Nikhef's RASNIK alignment technology (see Annual

Report 2005). *ASI, Amsterdam Scientific Instruments*, offers state-of-the-art instrumentation for notably synchrotron and Free Electron Laser (FEL) facilities worldwide. Both startups signed their first commercial contracts. Nikhef's CO_2-based cooling technology (originally developed for the AMS experiment presently running on the *International Space Station*, see Annual Report 2009) is likely to lead to another startup. Independent of these startup activities, Nikhef discusses the possibilities of joint projects with Shell, ASML and Philips and Nikhef continues its long-standing and fruitful collaboration with PANalytical as well as its AMS-IX housing activities.

Personnel wise, 2011 was unique in view of the fact that Nikhef needed to find a successor for the present Nikhef head of personnel, Teus van Egdom, who will retire in February 2012. In the person of Pieter van Braam van Vloten the selection committee is convinced to have found a worthy successor of Teus!

Regarding Nikhef's infrastructure, the mechanical technology department is undergoing a major upgrade. Two large 5-axes milling machines and one modern lathe have been ordered. Due to their physical dimensions, floor space needs to be enlarged and reinforced. The largest machine will be installed via a temporary hole in the roof. Once completed, our mechanical engineers can really show their ingenuity! Together with the nearby *AUC, Amsterdam University College*, and a student housing project, Nikhef also finally agreed to realise a so-called WKO ('*Warmte Koude Opslag' i.e.,* thermal storage). This WKO will reduce CO_2 emission by effectively balancing Nikhef's datacenter (AMS-IX & LHC Tier-1 node) cooling requirements with the heating requirements of the other partners. The WKO also provides Nikhef with an alternative cooling source in case of a major breakdown in its 47 standard cooling facilities. Despite some difficult moments in the process leading towards the final approval of this WKO projects, I must compliment the project leader, Joost van Echtelt, with his perseverance and patience until the very end.

Financially, Nikhef enjoyed a strengthening of (astro)particle physics activities at several of its partner universities thanks to the stimuli of the *"Sectorplan Scheikunde & Natuurkunde"* and the *GRAPPA, Gravitation and AstroParticle Physics Amsterdam*, initiative at the University of Amsterdam. A disappointment was the rejection of the FOM programme proposal titled *"What is the subatomic constituent of dark matter?"*.

Looking forward to 2012, I must repeat that for me 2012 will be the year of the Higgs. This will be very welcome input to the European Particle Physics Strategy process which after a first

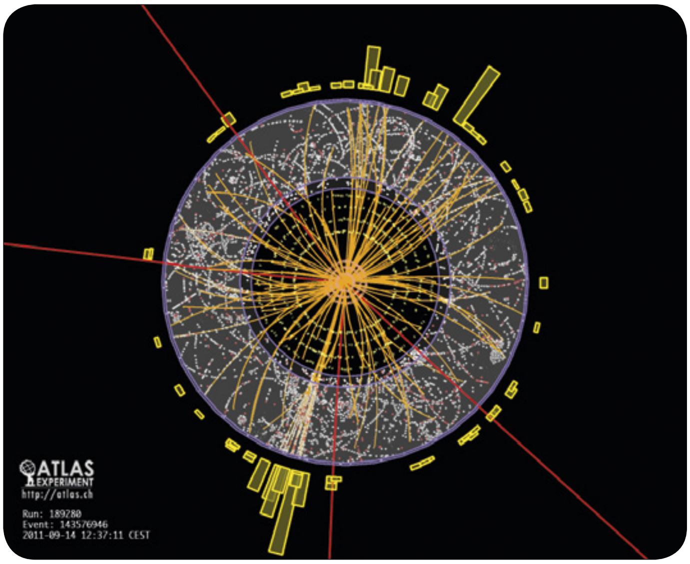


Figure 1. An event with four identified muons from a proton-proton collision in ATLAS. This event is consistent with coming from two Z particles with both Z particles decaying to two muons each. Such events are produced by Standard Model processes without Higgs particles. They are also a possible signature for Higgs particle production, but many events must be analysed together in order to tell if there is a Higgs signal. This view is a zoom into the central part of the detector. The four muons are picked out as red tracks. Other tracks and deposits of energy in the calorimeters are shown in yellow.

round in 2006, will be revisited starting with an open symposium 10–13 September in Cracow and ending in the European session of CERN Council in early Summer 2013 in Brussels. Conclusive evidence for the Higgs will also be invaluable for the new FOM programme proposal titled *LHC Physics*, which aims at continued exploitation of Nikhef's successful LHC activities ATLAS, LHCb and ALICE.

Frank Linde

Young visitors at the Nikhef Open Day watch as the workings of a mini version of a geometric anti-spring for Virgo are explained.

1

Reviews

1.1 The two standard models

Marieke Postma

"*Impossible to understand and madness to investigate*" is how Sophocles in 420 BC described the heavens. For a long time, this general attitude towards astroparticle physics and cosmology did not change. Even during the better half of the last century cosmology was not regarded "*as the sort of thing to which a respectable scientist would devote his time*", as Steven Weinberg put it. But times have changed. Cosmology has entered the league of respectable sciences, with already several Nobel prizes under its belt, including last year's for the discovery of the present accelerated expansion of our Universe.

The enormous progress in our understanding of the Universe has been propelled by experimental data. Lots of data. Thanks to technological breakthroughs it has become possible to observe our Universe in the whole electromagnetic spectrum, from radio waves to visible light to gamma rays. Ever fainter sources can be detected. Satellites are launched to watch the sky unhindered by the Earth's atmosphere and other mundane disturbances. Large (underground) detectors are looking for neutrinos, dark matter, and gravitational waves. To underline the astronomic scale of all these efforts, currently more than 20 direct dark matter experiments, more than 20 cosmic microwave background experiments, and more than 10 gravitational wave experiments are operating or are in development. We literally know more about our Universe every day.

Along with this influx of data came a better understanding of our Universe. Less than a hundred years ago people were still debating whether our Universe is expanding or in a steady state. Mere decades ago the parameters describing our Universe were only known to within an order of magnitude, and cosmologists were making lots of hand waving motions. In contrast, we now know the cosmological parameters with percent precision. Different types of experiments, with their own parameter dependencies and systematic errors, all point to the same basic picture of our Universe. And thus, inspired by their colleagues in particle physics, cosmologists now speak, albeit cautiously, about the 'standard model of cosmology'.

Standard model of cosmology

The standard model of cosmology posits that we live in an expanding Universe that started out some 14 billion years ago in a very hot and dense state. Initially the basic building blocks of matter –quarks, leptons and force carriers (see Fig. 1)– floated freely in an incredibly hot and dense 'soup'. As the Universe grew it cooled, and the matter went through a series of phase transitions. First, the quarks bound together into protons and neutrons. After about three minutes these nucleons combined into

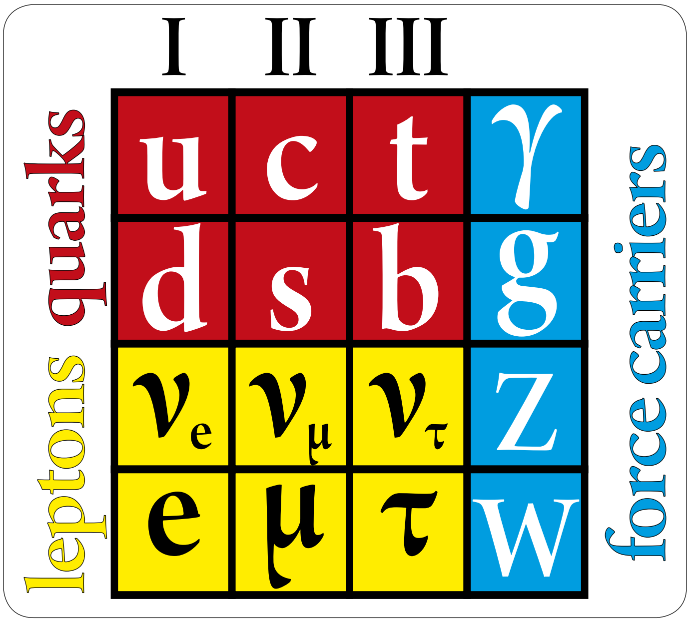


Figure 1. The Standard Model particles are divided in three families (I, II & III) of quarks and leptons, and force carriers.

the light elements, such as hydrogen, deuterium, and helium. About 400,000 years after the 'Big Bang' these elements captured electrons to form electrically neutral atoms.

Although for most of its lifetime the Universe grew moderately, it started out with a growth spurt called inflation. During this early period of rapid expansion the Universe increased its volume by more than a factor 10^{80} in less than a fraction of a fraction of a second. Inflation explains why the Universe we see today is so large, flat, and (on large scales) homogeneous. In addition, during inflation quantum fluctuations give rise to irregularities in the matter and energy distribution of the primordial soup of particles. Due to the enormous inflationary expansion of the Universe these perturbations are stretched to cosmic size. As time evolved, the initially small inhomogeneities grew through gravitational collapse to form all structure in our Universe. Without quantum fluctuations there would be no clusters of galaxies, no galaxies, no stars, and thus, no people (see box Cosmic Microwave Background).

Everything we see around us is made of atoms. The big surprise that emerged over the last decades is that atoms contribute less than five percent to the total energy density in our Universe. The rest is in the form of dark matter and dark energy (see Fig. 2). Dark, because it does not shine with electromagnetic radiation. We only know of their existence through their gravitational interactions. Dark matter provides the extra mass that speeds up the gravitational collapse of density perturbations; without

Cosmic Microwave Background

One of the pillars of modern day precision cosmology is the cosmic microwave background (CMB) radiation. This background of photons with a temperature of 3 K is quite literally the afterglow of the Big Bang. Some 400,000 years after the Big Bang protons and electrons combined to form electrically neutral atoms, at which time the Universe became transparent to light. No longer trapped in a fog of charged particles, the photons escaped, and they have been travelling ever since, without scattering, to fall on our detectors today. The CMB picture of the infant universe provides us with invaluable information about the parameters describing our Universe.

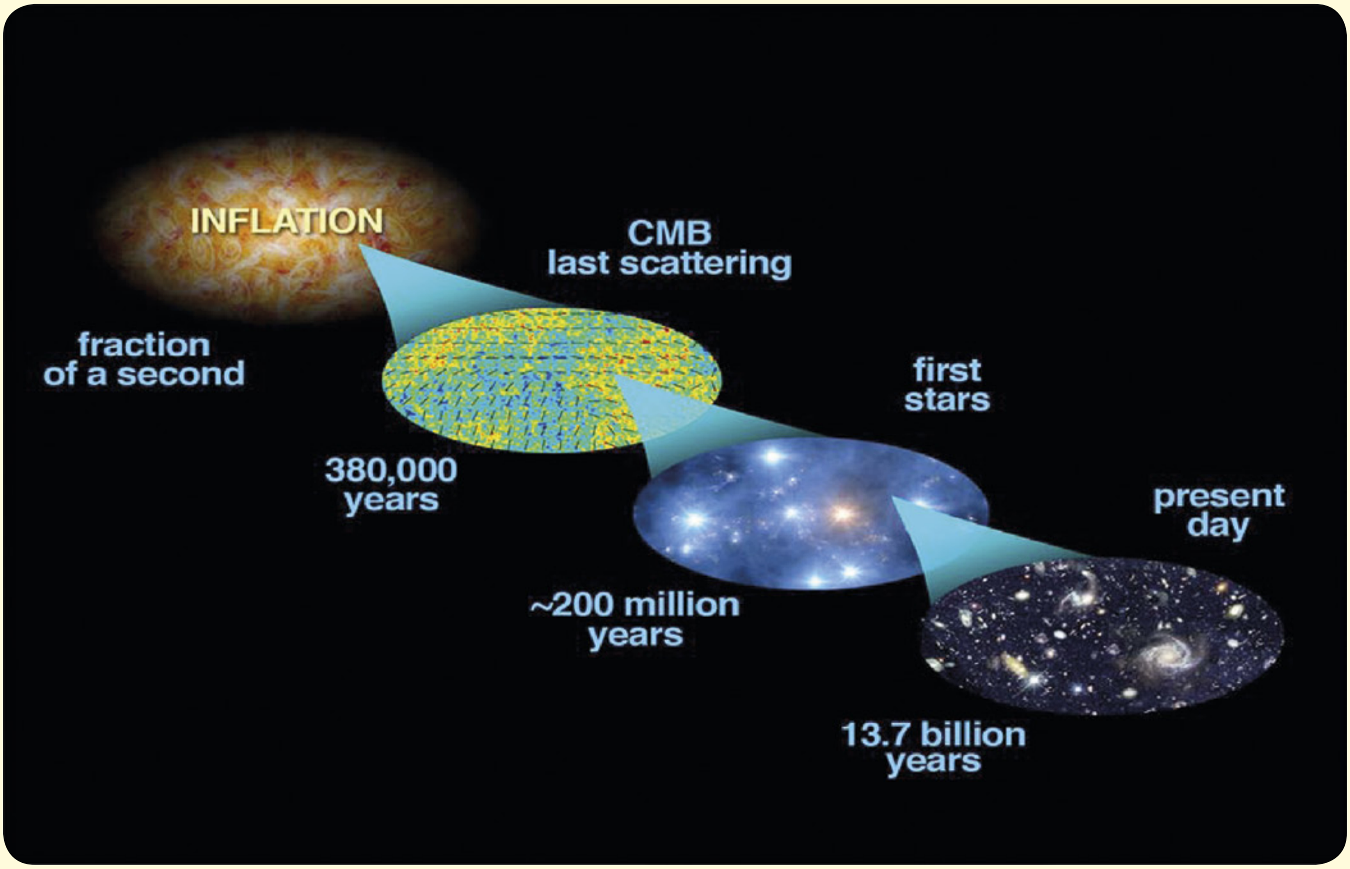


Figure 2. The Universe seen from inflation to present day. (Picture source: arXiv:astro-ph/0604101v1)

The rapid expansion of the Universe during inflation makes the early universe homogeneous and isotropic. On top, quantum fluctuations give rise to small perturbations in the energy density. This prediction of inflation is beautifully confirmed by the CMB data. In whatever direction you look, the CMB photons all have nearly the same 3 K temperature. The fluctuations in the temperature are small, only of the order 10^{-5}. The spectrum of fluctuations not only tells us about the physics responsible for inflation, it also gives detailed information about the matter content of our Universe. In particular, it points to a universe that is dominated by dark matter and dark energy; atoms contribute less than five percent to the total weight.

Using electromagnetic radiation it is impossible to penetrate the fog and look further back into the Universe. Not so for gravitational waves, they can originate from much earlier times, from before the first 400,000 years. Detection of the cosmic background of gravitational waves would thus provide a picture of the Universe at an even earlier age. This is still beyond the current generation of gravitational wave detectors, but becomes within reach with the proposed Einstein Telescope, a project in which Nikhef also participates.

it galaxies would not have formed yet. It also explains why the rotation curves of galaxies, that is the speed-distance relation of stars orbiting the centre of the galaxy, do not drop at large distances where there is no visible matter; the extra centripetal force is provided by dark matter. Dark energy is more mysterious (see box The cosmological constant). Instead of slowing down the expansion of the Universe, as normal matter does, dark energy speeds it up. As such it explains the current accelerated expansion of our Universe.

Although the formulation of the standard model of cosmology has been a huge achievement, it is not yet time for cosmologists to get smug. It can be viewed as slightly embarrassing that 96% of all the weight of our Universe is in some unknown form (see Fig. 3). Illuminating the nature of the dark Universe will be a big challenge. But with the multitude of experiments planned or already underway, probing different aspects of our Universe, this may well be possible in the (near) future. It will not only have a major impact on cosmology, but also far-reaching consequences for particle physics. The current standard model of particle physics does neither contain a dark matter candidate, nor can it explain the accelerated expansion of the Universe. A better understanding of all the dark stuff in the Universe also implies a better understanding of physics beyond the standard model.

Cosmology and particle physics

In the Large Hadron Collider (LHC) at CERN hadrons are being smashed together with enormous energies in an epic effort to better understand the elementary particles and their interactions. On the CERN website it is written *"Physicists use the LHC to recreate the conditions just after the Big Bang"*. One can reverse this statement. The Universe just after the Big Bang is one big particle accelerator. Temperatures were high, and particles in the primordial soup were constantly colliding violently. Of course, the Big Bang is an uncontrolled experiment, without the possibility to repeat it or change the conditions. Moreover, the results are revealed to us only billions of years later, when much of the original signal may have been lost.

There is, however, one big advantage of the Big Bang experiment over terrestrial laboratories, which is the energy scale it can potentially probe. The collision energy at the LHC is around 10 TeV. Future accelerators will be able to improve on this a bit, but to go much beyond the TeV scale requires accelerators as large as the circumference of the Earth. In contrast, the energies in the early Universe are arbitrarily high if one goes arbitrarily far back in time. If any of the energetic processes occurring in the early Universe leaves an observable trace, it allows a unique way to

The cosmological constant

Dismissing the cosmological constant as *"The biggest blunder of my life"*, Albert Einstein buried it in the graveyard of failed attempts to describe nature. A little too fast, as it turned out, for today the cosmological constant is resurrected as a source of dark energy. Despite its obscure name the cosmological constant has a clear physical interpretation: it is the energy density of the vacuum. Classically one tends to think of the vacuum as an empty state, pure nothingness, but quantum mechanically it is a very happening place. Pairs of particles and anti-particles constantly pop out of the vacuum to live for a brief instant before annihilating again. These quantum fluctuations are not just a theoretical concept, they are real; they are, for example, the cause of the force measured between two electrically conducting planes, which was predicted in 1948 by Hendrik Casimir and named after him.

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Einstein's equations of general relativity relate the geometry of space-time, encoded in the Einstein tensor $G_{\mu\nu}$, to the energy and momentum density of matter which is given in terms of the the energy-momentum tensor $T_{\mu\nu}$. The cosmological constant Λ, which multiplies the metric tensor $g_{\mu\nu}$, can be interpreted as the energy of the vacuum. In this formula c is the speed of light and G is Newton's constant.

There is a problem though when invoking the cosmological constant to explain the existence of dark energy. To calculate the energy density of the vacuum one has to sum over all the short-lived particle and anti-particle states which can have arbitrary momenta. Summing momenta up till the electroweak scale (about 10^2 GeV) –the energy scale up till which we know and have tested particle physics– gives a value that is a factor 10^{60} larger than the measured amount of dark energy. Needless to say, extending the cutoff to the Planck scale (about 10^{19} GeV), the scale where quantum effects of gravity become strong, leads to even greater disaster. Understanding the nature of the dark energy, and related to it, the smallness of the cosmological constant, will not only tell us about the Universe we inhabit but may also give invaluable insights in the quantum nature of gravity. No surprise then that this quest is often listed as one of the greatest scientific challenges of our time.

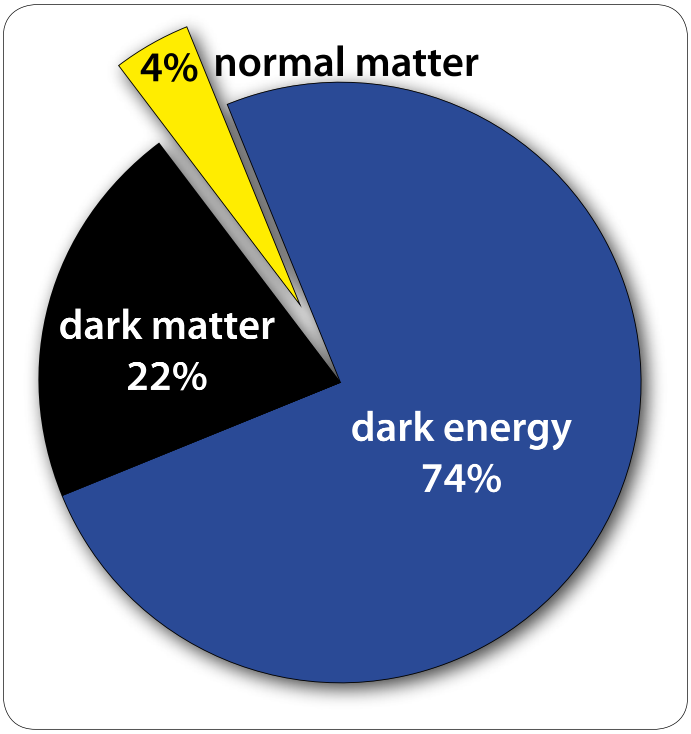


Figure 3. Of all the weight in the Universe 96% is in some unknown form.

test particle physics far beyond the TeV scale. Fortunately, there are such traces. Inflation, via the production of density perturbations, leaves its fingerprint on the cosmic microwave background (see box Cosmic Microwave Background) and on the large scale structure of our Universe. This allows to test particle physics models of inflation, and the nature of quantum fluctuations at high scales. The amount of the various kinds of matter around today is a direct consequence of processes and interactions in the early Universe. Dark energy is intimately linked with particle physics, as vacuum fluctuations of all particles contribute to it.

The hunt for dark matter provides a nice example of the scientific marriage between cosmology and particle physics, a union which can also be seen within the walls of the Nikhef building. The prime candidate for dark matter is the so-called WIMP, a stable weakly interacting massive particle. Examples of WIMPs are the lightest supersymmetric particle, and the lightest so-called Kaluza-Klein particle appearing in extra-dimensional models. In both cases, there are good theoretical motivations that the WIMP interacts with normal matter through typical electroweak scale cross sections. The 'WIMP miracle' is that such a particle automatically yields the right relic abundance, irrespective of its specific origin or other details. There are three ways to look for these WIMPs: they may be created in collisions of normal matter, they may interact with matter, and they may annihilate into matter. Nikhef takes part in all three of these efforts (see Annual Report 2009, section 1.1).

The ATLAS detector measures the outcome of proton collisions at the LHC. No one knows exactly what happens at such high energies, but if new particles are produced and one of them is a WIMP, the ATLAS experiment should see it. XENON hopes to detect dark matter particles via their scattering off the neutrons and protons making up the xenon gas that fills the detector. So far no positive signal has been found, but the planned upgrade XENON1T will push the limits of this type of direct detection experiments. ANTARES and its planned successor KM3NeT are large neutrino telescopes, which use the Mediterranean Sea as their detector. They may see indirect traces of dark matter in the form of an excess of energetic neutrinos. WIMPs will cluster in dense regions such as the Earth, the Sun or the centre of our galaxy. Packed together, they will regularly annihilate, and in the process produce normal matter including neutrinos that can be detected.

The future

Physics thrives on experimental data. In this respect the future for cosmology is bright. Many experiments are already taking place, and many more are being planned. Lensing surveys, which measure the deflection of light from distant sources by the gravitational force arising from massive objects along the line of sight, will precisely map the three-dimensional matter distribution of our Universe. The Planck satellite and other surveys of the cosmic microwave background now not only measure the temperature of the cosmic microwave background photons with tremendous precision, but also their polarisation. Gravitational wave detectors peer deeper in the Universe than ever before. Underground detectors register everything coming from outer space, from neutrinos to dark matter. The glasses through which we observe the heavens have advanced to become 3D, polarised, magnifying, and varied. The upcoming data will not only improve our understanding of the Universe, they will also shed new light on the workings of its significant other, the world of subatomic physics. And maybe one day the standard model of cosmology and the standard model of particle physics will merge into one big standard model of everything.

1.2 The quark gluon plasma

Raimond Snellings

A question that has fascinated physicists since the discovery of the strong interaction is how matter behaves when it reaches densities and temperatures that prevailed in the first microseconds after the Big Bang. To answer this question we currently collide, at the CERN Large Hadron Collider (LHC), lead nuclei at very large energies to create hundreds of mini Big Bangs per second. This provides us with a unique opportunity to study the surprising properties of the primordial matter created in these collisions.

Theory

To imagine what happens to matter when density is increased one can use the following simple picture. Nucleons (protons and neutrons), the building blocks of ordinary matter, are composite bound states of quarks held together by gluons. With increasing density the quarks from neighbouring nucleons start to overlap. Then the concept of a nucleon loses its meaning and a transition occurs from a state of matter consisting of nucleons to one where the quarks and gluons are not confined inside these nucleons anymore. This state of matter is called a quark-gluon plasma (QGP).

The theoretical understanding of a phase transition from nuclear matter to a QGP has to come from the underlying theory of the strong interaction, Quantum Chromodynamics (QCD). In QCD the fundamental degrees of freedom are quarks and gluons, which, however, do not exist in isolation. This confinement of quarks and gluons is poorly understood from first principles, since it occurs in a regime where the interaction between quarks is very strong and where theoretical calculations are notoriously difficult. Better understanding of this regime comes from numerical QCD calculations on a discrete space-time grid (lattice QCD).

Lattice QCD calculations show that at a temperature of about 10^{12} K (equivalent to an energy of 200 MeV, nearly a hundred thousand times hotter than the core of our Sun), a phase transition to a QGP indeed occurs. A clear signature of a crossover phase transition is that the pressure and energy density rapidly change with temperature. Fig. 1 shows that this happens in the region between 150 and 200 MeV. In addition, lattice QCD also provides the equation of state (EoS), which describes the relation between the various state variables of the QGP, like energy density, pressure and temperature.

We expect that the EoS of the QGP is similar to that of an ideal gas of massless quarks and gluons at extreme temperatures. This is because at these temperatures the interaction between the quarks and gluons becomes small (this is a characteristic property of QCD which occurs when quarks are very close to

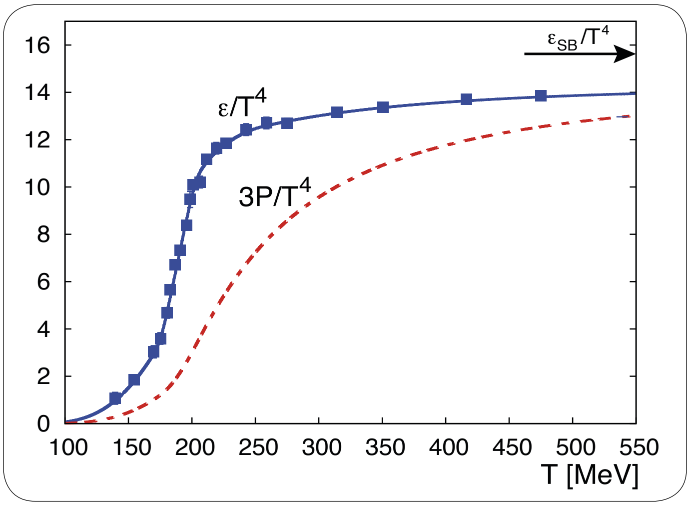


Figure 1: Energy density ε/T^4 (full curve) and pressure $3P/T^4$ (dashed curve) as function of temperature T from lattice calculations. The arrow indicates the Stefan Boltzmann limit of the energy density. For an ideal massless gas the equation of state would be given by: $P=\varepsilon/3$, $\varepsilon=\pi^2 gT^4/30$ where P is the pressure, ε the energy density, T the temperature and g is the effective number of degrees of freedom. Each bosonic degree of freedom contributes 1 unit to g, whereas each fermionic degree of freedom contributes $^7/_8$. The value of g is 47.5 for a three flavor QGP, which is an order of magnitude larger than that of a pion gas with approximately 3 effective degrees of freedom.

each other). Lattice QCD indeed shows that at temperatures just above the QCD phase transition the EoS is already very close to that of an ideal gas (horizontal arrow in Fig. 1).

Experiment

The next question is how to verify these lattice QCD predictions and how to study the properties of this QGP experimentally. Apart from in the early universe, a QGP may also exist in neutron stars with their very dense cores. Unfortunately, both the Big Bang and neutron stars are not readily available for a systematic study of the properties of the QGP.

However, in high-energy heavy-ion collisions we can produce droplets of matter with temperatures that are well above the strong phase transition temperature. These droplets should be large enough and long-lived enough to study the lattice QCD predictions. Heavy-ion collisions at the LHC are a unique tool to create the QGP and its phase transition to ordinary hadronic matter, and study this systematically in the laboratory.

The ALICE (A Large Ion Collider Experiment) detector is optimised for the measurement of heavy-ion collisions at the LHC. It is therefore very different both in design and purpose from the other LHC experiments. The ALICE collaboration was founded in

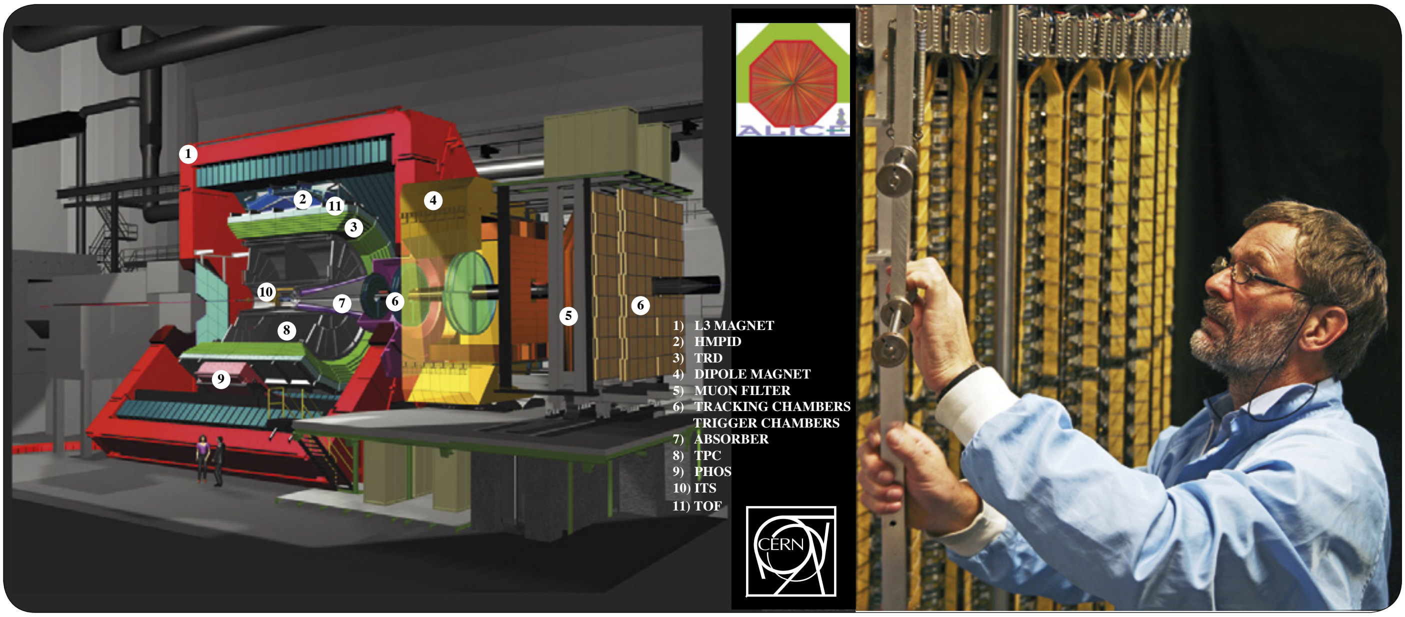


Figure 2. Left: Layout of the ALICE detector at the CERN LHC. Right: Final assembly of the silicon detector (labeled nr. 10) at Utrecht University.

1992 and consists of about 1000 physicists from 94 institutes in 28 countries. The subatomic physics groups at Nikhef and Utrecht University are members since 1994, and have been involved in the hardware construction of the ALICE inner silicon detector (in close collaboration with labs from Finland, France, Italy, Russia and the Ukraine). This detector plays an important role in measuring the thousands of charged tracks produced in a heavy-ion collision. A schematic view of the ALICE detector is shown in Fig. 2. ALICE consists of a central part, which measures hadrons, electrons and photons, and a forward part that measures muons.

With the central detectors, ALICE has robust and redundant tracking and can easily cope with the very large number of particles created in heavy-ion collisions. The small amount of material in the sensitive tracking volume (about 10% of a radiation length) keeps multiple scattering low and therefore enables the measurement of low momentum particles. Finally, ALICE is unique in its ability to identify particles (for instance pions, kaons and protons) over a large momentum range. The good performance of the ALICE detector was demonstrated in the first proton-proton and lead-lead collisions at the LHC.

Anisotropic flow

It was realised, in the last decade, that a phenomenon called anisotropic flow in heavy-ion collisions is one of the most powerful among the observables that measure the properties of the QGP. As in the early universe, the hot and dense system created in a heavy-ion collision will form a QGP when the quarks and gluons undergo multiple interactions such that the system thermalises early. Subsequently, due to collective expansion, this QGP will become so dilute that it undergoes a phase transition to hadronic matter. The collective expansion, which drives this evolution, is called flow.

The clearest experimental signature of flow in heavy-ion collisions is the azimuthal anisotropy in particle production (see Fig. 3). A convenient way of characterising the various patterns of anisotropic flow is to use a Fourier expansion where the Fourier coefficients v_n depend on the kinematic variables transverse momentum p_t and rapidity y. These coefficients are obtained from $v_n(p_t,y) = \langle \cos n(\Phi - \Psi_{PP}) \rangle$, where the angular brackets denote an average over the selected particles and events in the (p_t,y) bin under study. In this Fourier decomposition, the coefficients v_1 and v_2 are known as directed and elliptic flow, respectively. Elliptic flow is the largest contribution to the asymmetry because of the almond-like geometry of the interaction volume (see Fig. 3).

A few days after the first heavy-ion collisions at the LHC, it was shown (see Fig. 4) that the elliptic flow v_2 is large and it agrees with hydrodynamic predictions. This indicates that the created system thermalises quickly and also that it behaves as an almost perfect (inviscid) liquid (see Fig. 5).

Geometry of heavy-ion collisions

Because heavy ions are not point-like, the size and shape of the collision region depend on the distance between the centers of the nuclei at impact (impact parameter b) as shown in Fig. 3. The plane defined by the impact parameter and the beam direction (here perpendicular to the plane of the drawing) is called the reaction plane Ψ_{RP}. The plane of symmetry Ψ_{PP} is defined by the colliding nucleon pairs (illustrated by the green circles) and Φ is the azimuthal angle of a produced particle. The figure shows the initial spatial distribution of a non-central (b≠0) heavy-ion collision (projected onto the plane of the drawing). The size of the created medium in these non-central collisions has an azimuthal asymmetry in coordinate space and therefore an outgoing produced parton or particle interacting with the medium will naturally reflect this azimuthal asymmetry in its momentum distribution.

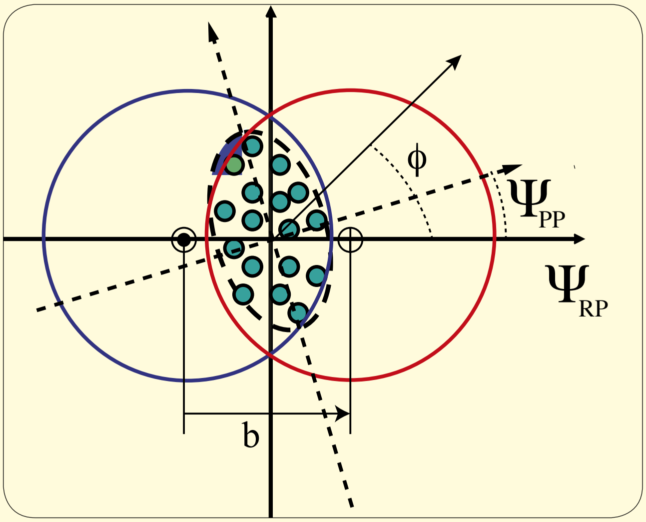


Figure 3. Definition of angles and planes in a heavy-ion collision.

Deviations from a perfect liquid behaviour depend on the shear viscosity to entropy ratio η/s of the system. QCD calculations for a weakly interacting system yield values of η/s much higher than what is obtained from our anisotropic flow measurements. This shows that the created system is not a weakly interacting ideal gas of quarks and gluons but is, instead, a strongly coupled system. Unfortunately, a very precise experimental determination of η/s from the elliptic flow measurements is difficult because v_2 is proportional to the initial spatial asymmetry of the created system and this spatial asymmetry cannot be measured directly. We therefore have to rely on phenomenological models, which leads to uncertainties of about a factor two in our experimental estimates of η/s.

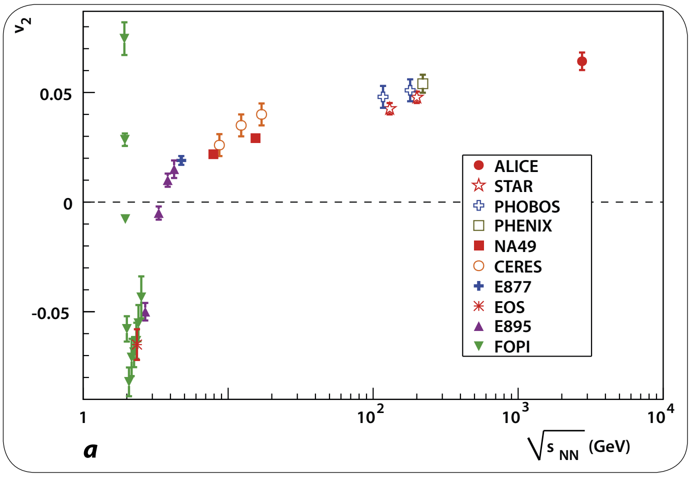


Figure 4. Elliptic flow as function of collision energy. The value of v_2 measured by ALICE at the LHC is about 30% larger than at the highest RHIC energy (STAR). Such an increase was predicted in hydrodynamic model calculations for an almost ideal fluid with a ratio η/s close to $\hbar/4\pi k_B$. In a strongly coupled N=4 super-symmetric Yang Mills theory with a large number of colors ('t Hooft limit), η/s can be calculated using a gauge gravity duality and is found to be: $\eta/s=\hbar/4\pi k_B$. Using the famous AdS/CFT correspondence, Kovtun, Son and Starinets conjectured that this value of η/s is a lower bound for all fluids (the KSS bound). We therefore call a fluid with η/s = ¼π (in natural units) a perfect fluid. The KSS bound raises the interesting question on how fundamental this value is in nature and whether the QGP behaves like an almost perfect fluid.

More asymmetries

Recently, a new way to strongly constrain the initial eccentricity and η/s was pointed out. Due to fluctuations in the spatial asymmetry of the initial matter distribution the plane of symmetry (Ψ_{PP} see Fig. 3) fluctuates event by event around the reaction plane. Event-by-event fluctuations of the spatial asymmetry generate additional odd harmonic symmetry planes Ψ_n, which are predicted to give rise to the odd harmonics like v_3. An example of such an initial matter distribution is shown in Fig. 6a. These fluctuating spatial asymmetries allow us to discriminate between the different phenomenological models used. In addition, the magnitude of the resulting odd and higher-order even v_n coefficients turns out to be very sensitive to the value of η/s.

Fig. 6b shows the measurements from ALICE of the odd and higher-order even v_n coefficients and we find that their magnitude is large. This is expected for a fluid with a value of η/s close to the so-called AdS/CFT bound. This bound follows from the conjectured equivalence between a string theory, including gravity, in one space and a quantum field theory without gravity defined on the conformal boundary of this space. In addition, the odd Fourier coefficients obtained from the flow analysis can describe

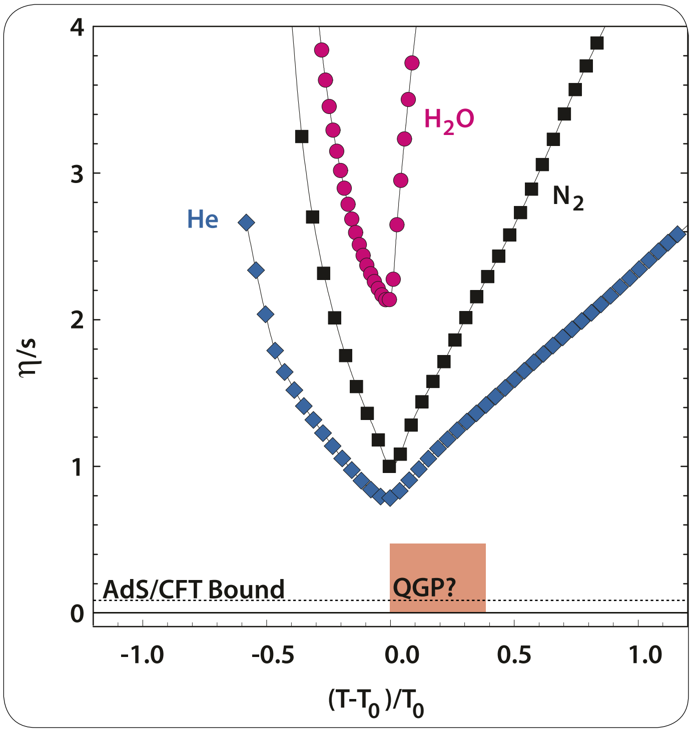


Figure 5. The ratio η/s versus temperature (with T_0 the critical temperature) is shown for various fluids compared to the KSS bound including an estimate for the QGP based on the elliptic flow measurements.

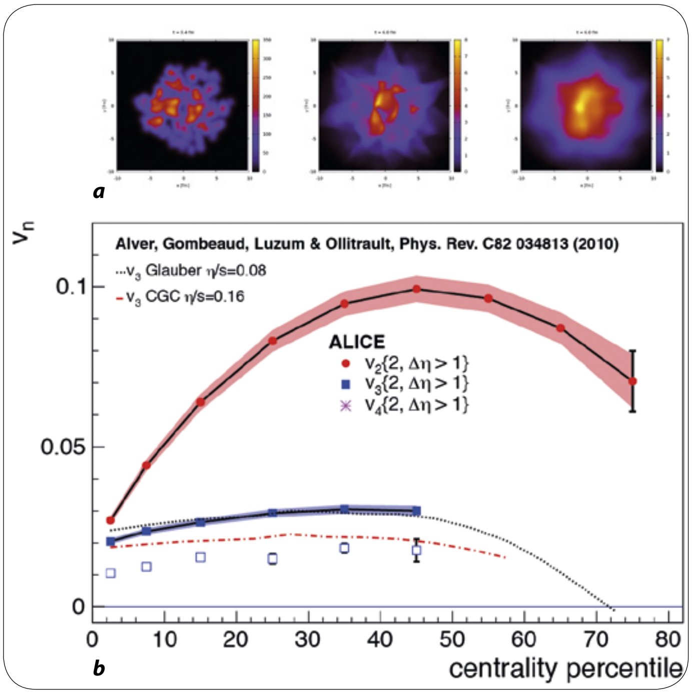


Figure 6. a) Simulated time evolution of a system with event-by-event initial conditions. Left: the initial energy density distribution in the transverse plane; centre: the energy density distribution after some time in an ideal hydrodynamic evolution (η/s=0); right: the energy density distribution after the same time in a viscous hydrodynamic evolution. b) Integrated v_2, v_3 and v_4 as function of collision centrality. The dashed curves are hydrodynamic model predictions described in the text.

previously observed correlations known as the 'ridge' and the 'Mach cone'. These observations now find a natural explanation in the event-by-event fluctuations of the initial energy densities.

Outlook

Studies of the hot and dense matter created in heavy-ion collisions at the LHC indicate that, at temperatures a hundred thousand times hotter than the core of our Sun, it behaves as an almost ideal fluid with a value of η/s close to the theoretical bound given by AdS/CFT. Better understanding of this novel state of matter will come from measurements with the ALICE detector at the LHC in the next couple of years. In particular, the production of heavy quarks and the modification, by the dense system, of emerging particle jets, holds the promise of providing us with much insight in the properties of the QGP.

1.3 Positioning up to femtometer resolution

Eric Hennes

Virgo is an interferometer with three kilometre long arms, located near Pisa in Italy, operated by a Dutch-French-Italian collaboration. Its goal is the detection of gravitational waves from distant stars and the early universe in a range between 10 Hz and 10 kHz. The coming upgrade, Advanced Virgo, will increase its sensitivity by an order of magnitude. At low frequencies this requires seismic isolation of most ancillary optical systems situated around the central interferometer. In 2010 Nikhef has designed, tested and installed a seismic attenuation system for the external injection bench. It will be followed by attenuation systems for a number of in-vacuum suspended optical benches. This review will focus on the mechanical anti-spring technology applied in the new seismic isolators. It builds on the experience developed at Caltech (USA) and the Albert Einstein Institute in Hannover (Germany.

Detection of gravitational waves

Einstein has shown that gravity corresponds to deformation of space and time. For instance, two heavy stars fast rotating around each other create large fluctuations in the local gravitational field. These propagate outward as a wave, with the speed of light. When the wave reaches the Earth after a long journey, its strength is reduced to very tiny length fluctuations.

The mutually perpendicular arms of Virgo function as three km long rulers (see Fig. 1 for a schematic layout). The passing wave makes one arm slightly longer (by ΔL_1), while the other gets shorter (ΔL_2) at the same time (and vice versa), both at most by an attometer (10^{-18} m), 0.1% of an atomic nucleus diameter! The difference $\Delta L = \Delta L_1 - \Delta L_2$ is measured by sending infrared

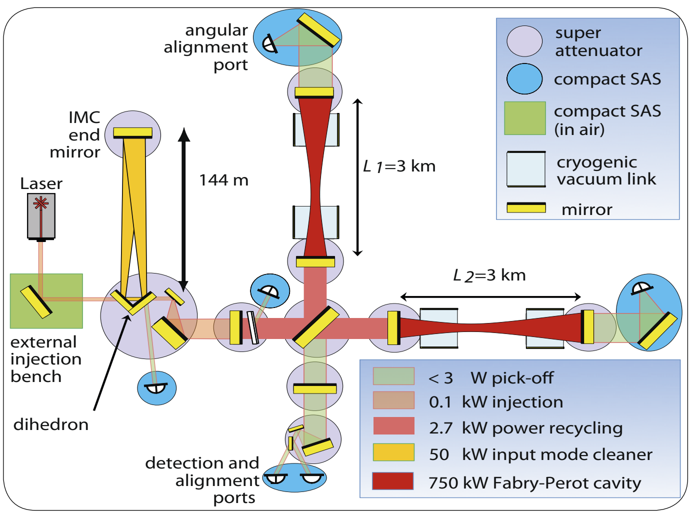


Figure 1. Schematic layout of Advanced Virgo, showing the new Seismic Attenuation Systems (SAS) in green and blue.

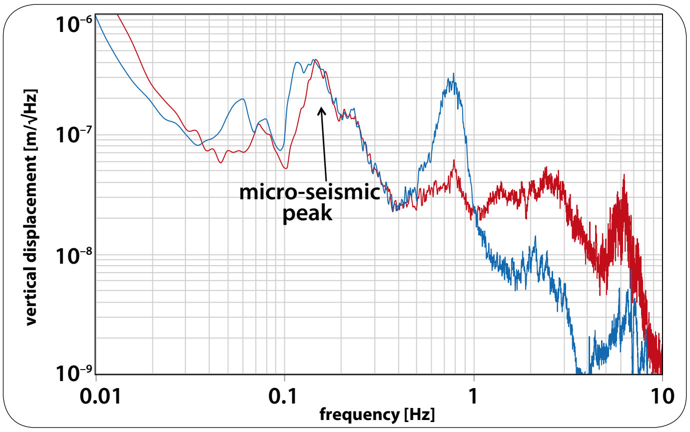


Figure 2. Typical seismic displacement noise spectra at the Virgo site, recorded during a weekday (red) and during a Saturday night (blue). The curves show the root of the distribution of mean square vertical displacements.

correlated laser beams along both arms. These are reflected by mirrors at the ends. The reflected beams are combined into an interferometric signal at the detector port. Analysis of this signal may reveal ΔL. Note that the arms are nothing more than long evacuated tubes in which a high power (750 kW) laser beam is running hence and forth between mirrors. The output signal can only be ascribed to a gravitational wave if all other mechanisms that move (or seem to move) the mirrors can be excluded. Typical disturbing sources are thermal noise, photon shot noise, radiation pressure noise, laser power fluctuation and a lot more. At low frequencies the main noise source is seismic noise[1].

Seismic noise isolation of Virgo's main mirrors

In Italy, the Earth's surface moves randomly in all directions with amplitudes up to several micrometer due to sea swell waves between 0.1 and 1 Hz that act on the Atlantic and Mediterranean sea floors and coasts. At higher frequencies the seismic displacement noise level decreases rapidly (see Fig. 2). Nevertheless, at 10 Hz it is still 10^{10} (10 billion!) times larger than the allowed displacement of the main mirrors (also called 'test masses') of Virgo. For that reason these mirrors and some critical optical benches are suspended from a long chain of mechanical filters in 10 meter high, 2 meter wide evacuated towers. Virgo's present 'super-attenuator' filter chains have proven to meet Advanced Virgo's requirements as well.

Isolating ancillary optical benches

The ancillary optics include the injection system that guides the laser beam nicely into the vacuum. Movements of the 900 kg external injection bench need to be damped by a factor 100 at frequencies above 10 Hz. Even more attention is paid to a number of sensors located at the arm ends and close to the input

1 For a general description on gravitational waves and the Virgo detector, see the Nikhef Annual Report 2006, p. 18.

Passive vibration attenuation

All mechanical oscillators share a characteristic response (x) to an excitation (x_0). An elementary example is the pendulum shown in Fig. 3. At frequencies well below resonance ($f \ll f_0$) the mass just follows the suspension point: $x/x_0=1$. At resonance the oscillator swings up to an amplitude level much larger than the excitation. Far above resonance ($f \gg f_0$) it is the other way around: this is the domain of passive attenuation, where the transfer function $|\hat{x}/\hat{x}_0|$ becomes rapidly smaller than unity. For example, a 1 Hz resonance pendulum (L=25 cm) attenuates vibrations of 100 Hz by a factor ten thousand (10^4). The transfer above resonance is close to f_0^2/f^2. In other words, decreasing the resonance frequency by a factor 10 will improve the attenuator by a factor 100. On the other hand, this requires a 25 meter long pendulum! The need for low frequency oscillators of reasonable size clarifies our search for anti-springs.

The attenuation can be further increased by putting a number of oscillators in cascade. Basically, for a cascade consisting of N oscillators, the attenuation decreases as $1/f^{2N}$.

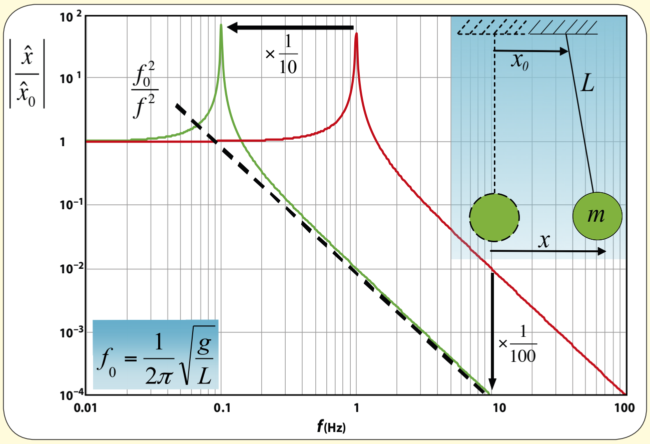


Figure 3. Typical transfer functions $|\hat{x}/\hat{x}_0|$ of a harmonic oscillator with resonance frequency f_0=0.1 Hz (green) and 1 Hz (red). The pendulum is an example. Well above resonance a 10 times lower resonance frequency is seen to result in a 100 times larger damping.

and output ports. Together these sensors precisely measure and control the beam orientation in both arms ('angular alignment'). Up to the present day these optical systems are operating in air and are not isolated at all. In order to achieve the enhanced sensitivity of Advanced Virgo the benches all need isolation from seismic vibrations, and Nikhef is responsible for this task. The alignment benches require attenuation of seismic noise up to a factor 10^5. Moreover, they have to operate in vacuum to prevent acoustic perturbations. The greatest challenge is how to meet the requirements in the limited space available (about 1 m^3).

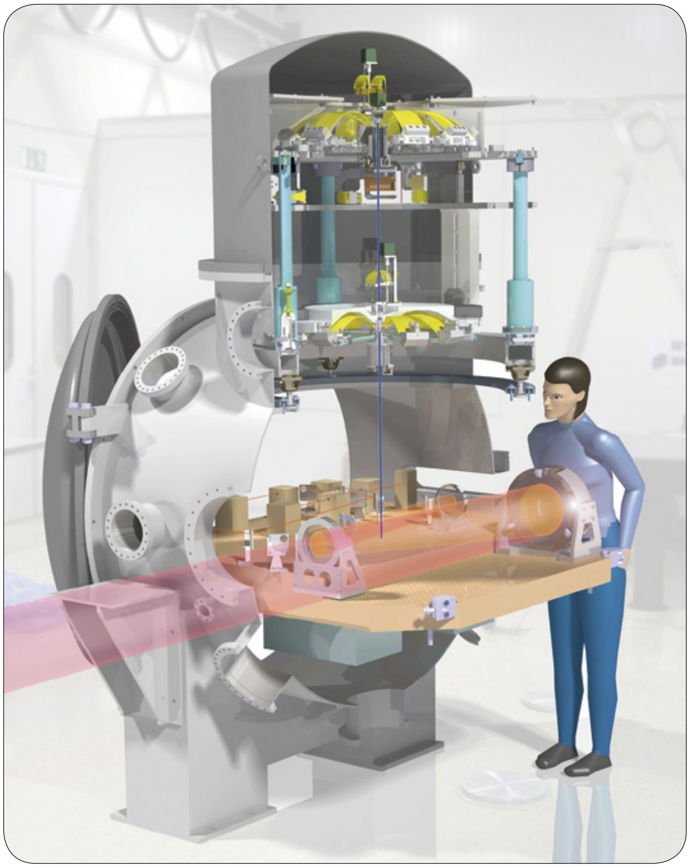


Figure 4. Design of a compact vacuum bench seismic attenuation system with three inverted pendulum legs (light blue) and two geometrical anti-spring filters (yellow) in cascade. The supension wires are shown in blue.

Oscillators and (anti-)springs

The gravitational wave detectors in Europe (Virgo) and Japan (LCGT, under construction) allow for excellent seismic attenuation by applying, both horizontally and vertically, low frequency mechanical oscillators. Mirrors and benches are almost 'floating', connected to the Earth by ultra-soft springs, which are provided by a combination of inverted or suspended pendulums (horizontal) and magnetic or geometric anti-springs (GAS, vertical). Technical details are elucidated in the boxes. At low frequencies this technique is superior to the actively controlled stiff systems of LIGO, our American partner running several detectors in the US.

Each attenuation system is equipped with position and motion sensors as well as electromagnetic force actuators in (at least)

Horizontal low-frequency oscillator: inverted pendulum

A widely applied low-frequency/small-sized horizontal oscillator consists of a mass on top of a stiff rod, which is attached to the ground with a thin flexural spring that just prevents it from turning over (Fig. 5). The horizontal restoring force for a small deflection *x* equals:

$$F_{tot} = F_{flex} + F_{anti} = -\left(k_{flex} - \frac{mg}{L}\right) \cdot x \ ,$$

where g is the gravitational acceleration, L is the length and k_{flex} is the spring constant. The second term shows that gravity acts as 'anti-spring': it contributes negatively to the stiffness. The resonance frequency can be tuned arbitrarily close to zero, for instance by adjusting the mass close to $k_{flex}L/g$. If it exceeds this value the pendulum will turn over. In practice 0.05 Hz is feasible. Note that a suspended pendulum would need a 100 m long wire to reach that frequency! The seismic attenuation systems for Virgo all contain three inverted pendulum legs, allowing isolation of the payload mass in three horizontal degrees of freedom (two horizontal displacements and the rotation around the vertical axis) without inducing unwanted tilt motion. The right panel of Fig. 5 shows a demonstration model of a single inverted pendulum built at Nikhef as a mechanical engineering student project.

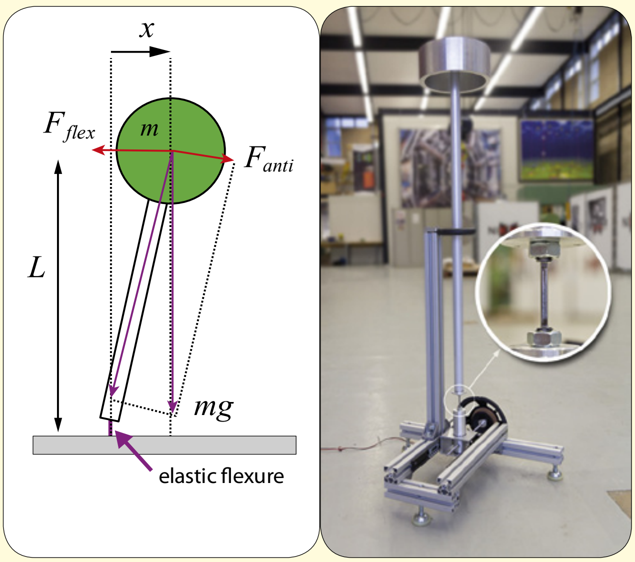


Figure 5. Left: inverted pendulum and its parameters. Right: demonstration model (height 1 m, mass 5 kg); the insert shows the flexure.

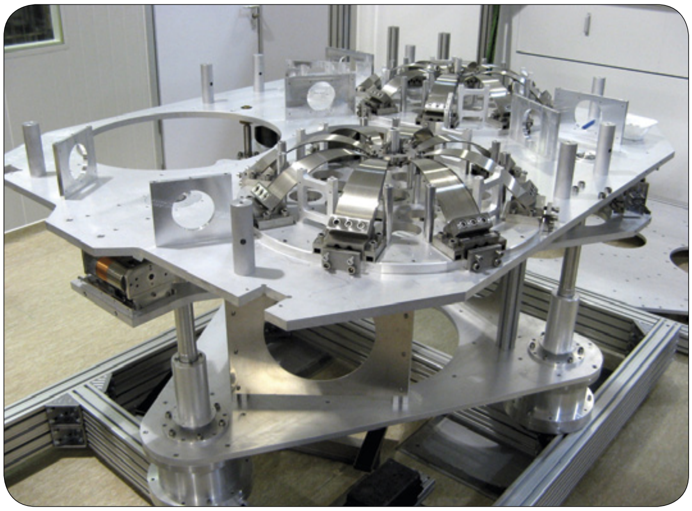


Figure 6. Seismic attenuation system of Advanced Virgo's external injection bench during assembly. Two of the three GAS filters (with eight blades each) are mounted on a plate which is supported by three inverted pendulum legs. The bench itself is not shown.

six degrees of freedom. Together with the connected electronic and digital control unit, they accommodate proper positioning and orientation of the benches and allow for active damping of frequency resonances below 10 Hz.

The new support of Virgo's external injection bench (Fig. 6) has been constructed and tested at Nikhef and was installed by December 2011. The bench floats on three GAS filters mounted on a plate which in its turn is suspended from three inverted pendulum legs. You can easily raise the 900 kg bench with your little finger!

The alignment benches will be isolated by a combination of three inverted pendulum legs, two GAS filters and two suspension wires, all housed in a vacuum tank (see design in Fig. 4). The legs carry the upper GAS, from which the lower GAS and the bench are suspended from thin wires. Both wires and GAS are made of maraging steel (low-carbon ultra-high-strength precipitation-hardened steel). The GAS filters only attenuate vertical seismic vibrations. In the horizontal directions the isolation is obtained by three oscillator stages consisting of the inverted pendulum and two normal pendulums (bench and lower GAS). As the bench is suspended from a single wire, its rotations around any horizontal axis (*i.e.*, tilt) will hardly be excited. And even if so, these tilt motions are largely attenuated, as the wire is attached close to the centre of mass of the bench, such that the tilt resonance frequencies are very low. The same holds for rotations around the vertical axis (yaw).

Vertical low-frequency oscillator: geometric anti-spring (GAS)
Fig. 7 shows the anti-spring principle for vertical oscillations. The oscillator mass is suspended from a vertical spring with spring constant k via a wire. The connecting 'keystone' is subjected to horizontal forces F_c from compressed springs at either side that cancel in the equilibrium state. At a small displacement y the vertical spring force changes by ΔF_1. This is partially cancelled by the vertical components of the two compressive forces:

$$F_{tot} = \Delta F_1 + \Delta F_2 = -\left(k - \frac{2F_c}{D}\right) \cdot y \, ,$$

where D is the length of the compressed springs. The second term acts as anti-spring: the compression contributes negatively to the total stiffness. The resonance frequency can be tuned arbitrarily close to zero by adjusting the compression such that F_c approaches $kD/2$. If it exceeds this critical value, the system becomes instable.

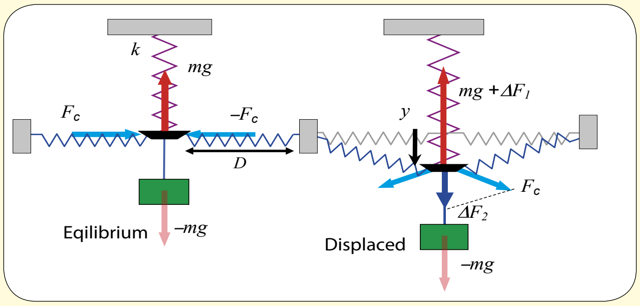


Figure 7. Principle of a geometric anti-spring with vertical tension spring and horizontal compression springs. Left: equilibrium state; right: vertically displaced.

In a GAS spring the horizontal and vertical spring functions are combined in a single elastic element, a triangular initially flat blade spring (Fig. 8). Two or more of these can be combined to establish a GAS-spring filter. The curvature of the blades in equilibrium depends on the imposed clamping angles, the suspended mass and the applied compressive force. This force can be adjusted by shifting the clamps in- or outward on the filter plate.

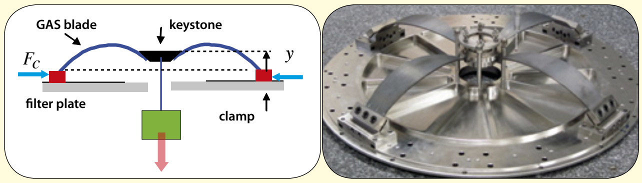


Figure 8. Left: sketch of GAS-filter with two blades. Right: 4-blade GAS filter, tested at Nikhef for the LCGT gravitational wave detector under construction in Japan.

Dedicated mathematical and numerical analysis delivers properties of the blade like its curvature, stress profile (Fig. 9) and force-displacement curves for different compression states. These studies enable designing blades with optimal characteristics, and help to predict the critical clamp and blade tip positions.

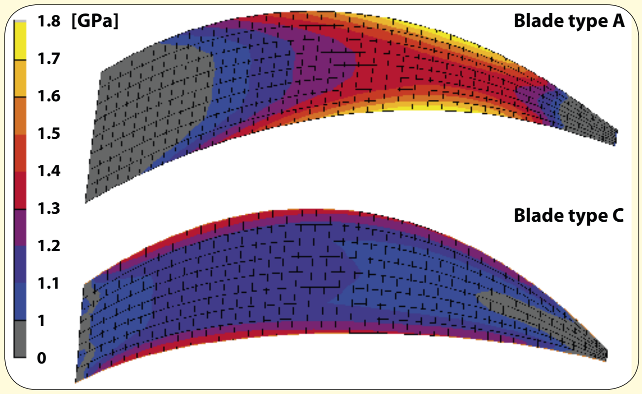


Figure 9. Top surface stress profiles of different GAS-blade types, calculated by Finite Element Analysis.

More Nikhef contributions to Advanced Virgo
Aside of seismic isolators, Nikhef has developed large cryogenic vacuum links, to be placed at each end of both interferometer arms, and ultra low-noise/low-power quadrant photodiode read-out electronics for the angular alignment. We are also involved in modifications of the input mode cleaner (IMC, see Fig. 1), in particular the design and support of the new 'dihedron' mirrors and the suspension of the IMC end mirror. Other contributions involve an improved wave-front camera and dedicated signal-analysis tools that enable parameter extraction of stellar systems, with a view on testing the Theory of General Relativity and on probing the late-time evolution of the Universe. With its improved capability, Advanced Virgo is expected to herald the era of gravitational wave astronomy after commissioning in 2015.

1.4 Starting up: how Nikhef creates its spinoffs

Niels van Bakel, Willem Dorresteijn, Hans Roeland Poolman, Arjen van Rijn

In the Netherlands, policy makers have frequently addressed the 'gap' between the excellent standing of Dutch fundamental research and the perceived inability to translate that into money making activities. For some time now a new approach has been proclaimed, called *"Van kennis en kunde naar kassa"* ("*From knowledge and expertise to the cash register*", perfectly fitting in the traditional Dutch 'merchant spirit'). Recently nine industrial 'top sectors' have been defined and the Dutch research community (primarily funded via NWO) is supposed to contribute heavily to these sectors. Although it is uncertain what the consequences of this top sector policy will be for the funding of fundamental research activities, we will not dwell further upon it, but instead describe Nikhef's first involvement in start-ups.

Nikhef's primary focus is and will always be curiosity driven research, pushing the boundaries of the fundamental knowledge. This (experimental) research is high risk, but Nikhef has always demonstrated to be a highly result driven community. Although curiosity is our main motivation, Nikhef acknowledges the increased importance of industrial applicability and societal gains from fundamental research. The past years the awareness has definitely grown within Nikhef to seize opportunities for making the connection between our research activities and industrial, societal or other scientific domains. The term used for this is *valorisation*: the translation of knowledge into technology in order to create commercially viable products or services.

There are several ways to view the economic value of research results, usually a technology in which Nikhef has vested intellectual property rights (IPR). The most straightforward way is to sell it at an agreed price, either a single payment, or via a royalty based structure, to some interested party. This only works if you have a sound and reasonable idea of what the technology is

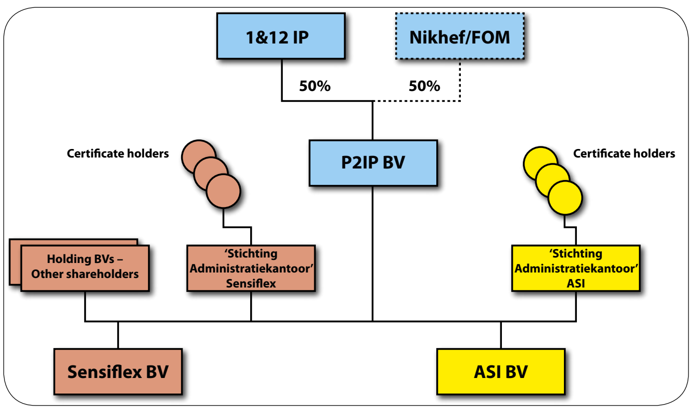


Figure 1: Current legal structure around Nikhef's start-ups.

worth. This is only rarely the case, since the valuation of the offered technology is extremely difficult, due to the many uncertain and unknown factors that will determine the potential success in the (commercial) market. Hence, another way is to license the technology to the interested party and charge a license fee, usually a percentage of the net sales value of the product containing the technology. In such a case there is a better warranty, that your IPR renders a turnover that is proportional to the value of the technology. However, the result of this approach depends on the combination of the market-readiness of the given technology and the ability of the third party to adopt and transform the technology into a (commercially) successful product or service. The involvement of Nikhef and its researchers is still less than optimal in this scenario. A third way is to become an 'entrepreneur': start up your own business around the technology. In this scenario the people that have (most likely) been involved in the design, development and realisation of the technology investigate its business opportunities (in a phased approach).

FOM's valorisation policy (May 2008) contains several incentives for researchers to become an 'entrepreneur'. One of them is to provide the start-up a loan (maximum of two annual salaries), on the condition that the researcher (or a FOM employee in general) leaves FOM employment. Furthermore, the researcher can be allowed to spend part of his time for the start-up enterprise. In that case a loan will not be provided. In this policy FOM does not pursue to obtain shares in a start-up and in fact is currently limited by its statutes to do so. The challenge of this scheme is always to assess and appease the possible conflict of interest and the conflict of commitment.

Early 2011 there were reasons for the Nikhef management to reconsider the elements of FOM's valorisation policy, also inspired by discussions with our valorisation partner, *1&12 Investment Partners* (1&12 IP), around the start-up of *Amsterdam Scientific Instruments* (ASI). It was felt, that for the involvement of Nikhef —as high tech provider— in making the start-up into a success, a position as share holder might be advantageous. Especially in the starting phase it is important for the research institution and the investor to collaborate and to help build the team that is needed to successfully market the technology. In the same spirit we decided to also allow Nikhef-employees to acquire shares in such an enterprise — under well defined conditions. This has resulted in the establishment of an investment company, called *Particle Physics Inside Products* (P2IP BV) on a 50–50 basis with our valorisation partner 1&12 IP. In parallel FOM is in the process of changing its statutes to enable taking shares in start-ups.

P2IP is a limited liability company, structured to allow Nikhef a way of sharing the control with 1&12 IP. It serves as the legal entity from which a share in a start-up can be acquired and has a supervisory board that monitors the participations of its two main stakeholders. P2IP is also instrumental in the administrative set up and management of the start-up. During 2011 P2IP has taken shares in two Nikhef start-ups, *Sensiflex BV* and *ASI BV*. The current legal structure is given in Fig. 1. Nikhef-employees are allowed to buy a limited amount of certificates of shares (to prevent a conflict of interest) in the start-up — four employees have taken this opportunity. Currently P2IP is also discussing the possibility of starting an enterprise around Nikhef's expertise in CO_2 cooling (see Annual Report 2009, p. 12). For this technology a shared patent with CERN has been filed in 2011. Furthermore, collaboration with the mass spectrometry group at AMOLF is under consideration. Further on, the activities of ASI and Sensiflex are described in more detail.

Amsterdam Scientific Instruments BV

The potential of hybrid silicon pixel detectors for tracking applications in High Energy Physics (HEP) has been successfully demonstrated over the last two decades. Extensive R&D at Nikhef contributed to the construction of new vertex detectors and trackers for LHC experiments. Essential in these developments have been the design of advanced CMOS readout ASICs and their integration with semi-conductor sensors. Nikhef has been involved from the start in the Medipix collaboration to transfer HEP pixel detector technology towards other applications such as Medical and Analytical X-ray imaging (see Annual Report 2006, p. 14).

Former Nikhef R&D department member Jan Visschers started the Medipix effort at Nikhef in 1999 and in 2009 he won a prize for the business proposal with the highest potential at the Valorisation workshop of the Dutch Technology Foundation STW. His wish was to start a high-tech start-up at Science Park Amsterdam to produce high quality semi-conductor radiation detectors. After Jan Visschers' retirement this idea was picked up by Niels van Bakel and Jan Visser from the Detector R&D group, together with Hans Roeland Poolman, from 1&12 IP (and also a former PhD from Nikhef). This team forms ASI's management and submission of a technology & business proposal resulted in an STW phase 1 Valorisation grant in December 2010 to explore the business opportunities for ASI. In July 2011 Amsterdam Scientific Instruments BV was officially founded as a high-tech spin-out from Nikhef. ASI has the ambition to become a global player on the market of radiation detectors for scientific and industrial applications, and builds upon strong ties with the scientific community, industrial partners and investors. An STW phase 2 Valorisation grant has been awarded in December 2011 to develop a product portfolio and to attract private funding. Further product development is needed to generate new intellectual property rights and will be based on open innovation: collaborations between research institutes and high-tech companies in an early stage to learn from future users and potential applications.

Novel X-ray sources with unprecedented beam properties have become operational around the world for exploring new scientific possibilities in photon science with X-rays. Experiments with these sources in material science, X-ray diffraction, and X-ray imaging pose great challenges on X-ray detectors and opened a niche market for the Timepix detector. The Timepix chip evolved from the Medipix development with additional functionality within each pixel. In Time-Over-Threshold mode the amount of energy deposited in each pixel is measured at a frame rate of at least 100 frames/s. Tiling multiple Timepix chips allows for

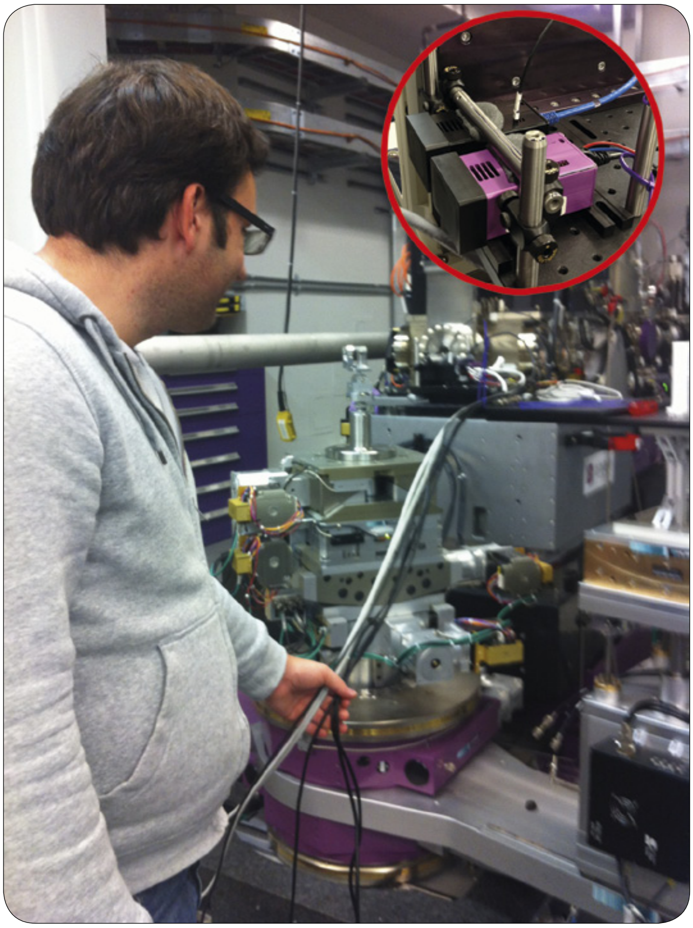


Figure 2. Nikhef engineer Bas van der Heijden integrating an ASI TPX Quad detector (see inset) in an X-ray beam line at one of ASI's first customers.

large area detectors. ASI has successfully tested the TPX detector technology for X-ray imaging in photon science both at Petra III (DESY) and at LCLS (SLAC), the first hard X-ray free electron laser in the world. Applications in neutron imaging and bio-medical imaging are pending and will extend the product portfolio of ASI. These early successes have already resulted in three purchase orders for ASI.

Sensiflex BV

On 1 September 2011 Sensiflex BV has been officially established. This happy event concluded a two year period of discussions between Nikhef management, Sensiflex management and the prospective share holders on the agreements to be drafted, including a share holder agreement and a license agreement between Nikhef and Sensiflex BV.

Already since early 2010 Sensiflex supplies the Rasnik monitoring system (see Annual Report 2005, p. 21) for the civil engineering industry. Engineering company Fugro, Sensiflex's launching customer, has played a major role in attracting the first few orders. In particular tunnels and bridges are monitored in three dimensions (plus time) with an accuracy up to 10 nanometer with relatively simple components. The first tunnel to be monitored was the Weenatunnel in Rotterdam, where Rasnik is continuously monitoring the alignment since 2010 (see Fig. 3).

Another example is the Vlaketunnel in Zeeland. It appeared that the entrance element of the Vlaketunnel was shifted upwards approximately 0.15 meters within just 45 minutes, causing a dangerous barrier for the traffic driving on the highway with a speed of 100 km/h. The tunnel was closed immediately and an

Figure 3. Installation of Rasnik alignment systems in the Weenatunnel in Rotterdam.

Figure 4. Rasnik monitoring set-up in the Vlaketunnel in Zeeland.

emergency monitoring program was started. A local contractor mobilised heavy loaded trucks to stabilise the deformations. He used sand, concrete blocks and anything he could find to fortify the entrance preventing it from shifting any further. Rasnik monitored this entire process (see Fig. 4).

Yet another application of the Rasnik-system was initiated by an event that attracted national attention in 2011: the near-collapse of shopping mall 't Loon in Heerlen (Limburg), probably caused by the cavernous ground below. This event necessitated the closure of the shopping mall, much to the distress of the shop owners, since it happened in December. Rasnik-systems were installed to monitor the progress of the near-collapse.

For 2012 Sensiflex aims to attract capital to upscale its activities, including the technical and production processes and the marketing and sales efforts.

Conclusions

In the past few years Nikhef has entered the 'valorisation arena'. Various cutting-edge techniques that were developed originally for application in particle-physics experiments turned out to have previously unforeseen commercial opportunities. Both Nikhef's employees and management realised the potential strength of these techniques and took rapid steps to turn pure science results into high-tech instrumentation for use in other domains. An investment company was founded to provide a solid legal basis for these activities. With two start-ups successfully initiated and a third underway Nikhef has made a flying start.

2

Research

2.1 ATLAS
A hint of the Higgs

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

For CERN and all of its collaborators the year 2011 was exciting in many respects. During its initial period in 2010 the Large Hadron Collider (LHC) produced a luminosity of approximately 40 pb^{-1} of 7 TeV proton-proton collisions. At the start of 2011 the plans for the LHC were to run with an instantaneous luminosity of 10^{33} $cm^{-2}s^{-1}$ in order to collect 1 to 2 fb^{-1} of data during the whole year. However, reality exceeded the expectations and the luminosity was increased up to 3.65×10^{33} $cm^{-2}s^{-1}$.

By the end of the year a total of 5.61 fb^{-1} data was delivered by LHC to the experiments. The large current and the small emittance and β^* pushed the mean number of proton interactions per bunch crossing above 11.

ATLAS
All parts of the ATLAS detector operated very well in this harsh environment. The up-times and efficiencies of all sub-detectors were close to 100%. For example, the MDT chambers, which are under Nikhef responsibility, were operational 99.8% of the time, with 99.7% of the channels alive. Of the 40,000 MDT tubes that Nikhef installed in the previous years only 40 were not functional, and no additional wires were broken. Also the SCT end cap, another part of ATLAS built with Nikhef involvement, reached a hit efficiency of more than 99.6%. During the year a problem occurred with the vertical cavity surface emitting lasers (VCSEL) that was solved by replacing the TX resistant to moisture. No data were lost.

Due to the high instantaneous luminosity the trigger menu evolved over the year. The trigger system scrutinised a total of more than 4×10^{14} events, and the average Event Filter acceptance rate was kept around a mean of 300 Hz. Nikhef activities, besides coordinating the trigger menu itself, involved the development and monitoring of the tau trigger and the reduction of noise in the LAr system. Nikhef also contributes to accommodate the ever growing trigger menu requests in the data acquisition, especially concerning the Read-Out-Sytem with the ROBINs. Offline, the GRID computing system is truly impressive, and the number of jobs that passed the Nikhef/SARA Tier-1 facility exceeded three million.

Traditionally, Nikhef plays a leading role in the development, maintenance and performance assessment of the tracking software for muons named *"Moore"*. This muon reconstruction is highly efficient and has a low fraction of 'fakes'. It is written in modular C++ and is well tested. The resolution of the muon tracks, as determined using the Z-mass constraint in di-muon samples, turned out to be very close to its design value, with a small residual detector misalignment causing the main systematic error. It was therefore no big surprise that toward the end of 2011 ATLAS decided to use this software suite as standard for muon tracking for all physics analyses.

The Nikhef upgrade activities concentrated around the development of the Front End chip (FE-I4) and cooling based on CO_2 for the insertable B-layer (IBL) that will be installed in 2013. For the more distant future Nikhef contributes to the track trigger and will ultimately assemble one end-cap of the new Inner Detector which is part of the high-luminosity upgrade, scheduled around 2022. The first carbon fibre support structures for this end cap have been prototyped.

Physics tour-de-force
Using the large data set collected by ATLAS in 2011 a wealth of physics results has been obtained. In total the collaboration published 156 papers and notes of which 84 dealt with physics and performance topics. To summarise these activities: the Standard Model reigns at 7 TeV as well as before. All calculable processes *e.g.,* involving the W and Z-bosons including the production of di-bosons, are well described by the predictions.

Nikhef focussed on the observation and properties of the top-quark. The determination of the top-anti-top inclusive production cross section turned out to be spot on its prediction from theory, with a precision of approximately 10%. Also the study of tau leptons in top-quark decay and the observation of the production of single top-quarks by the weak interaction, sensitive to anomalous couplings and charged Higgs production, were studied. However, the upcoming data set of 2012 is needed to make firm statistically significant statements.

Nikhef has been particularly active in the searches for supersymmetry in signatures with either one or zero leptons in the final state. The analyses are based on robust 'cut and count' methods, using the effective mass (sum of the missing transverse energy and the transverse momenta of the highest four jets). QCD multi-jets (zero lepton) and the top-quark production (zero and one lepton) are dominating backgrounds. These analyses have pushed the limits for new physics further out, as no signal was observed (see Fig. 1). We now focus on more complex signatures using effective supersymmetry models. Multivariant

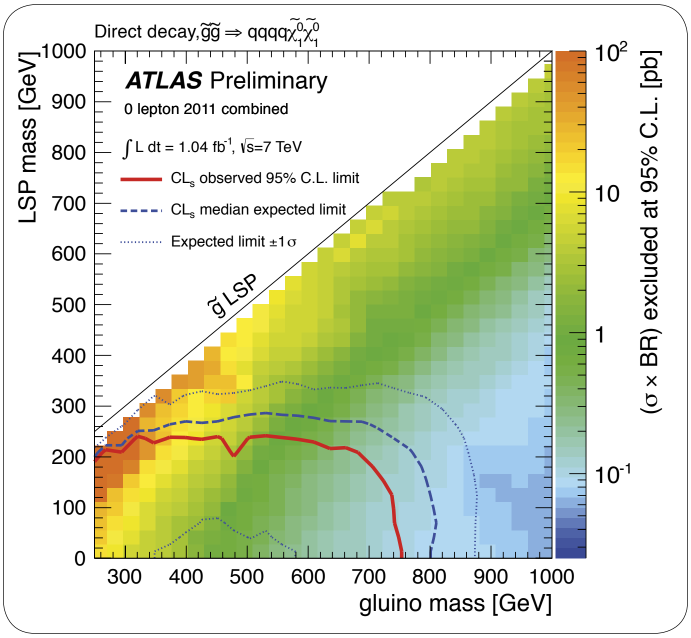


Figure 1. Exclusion limits in the gluino-LSP mass plane for direct gluino decays. LSP stand for Lightest Supersymmetric Particle. The colour scale shows the combined limit on the cross-section times branching ratio (sigma times BR) at the 95% C.L. The expected and observed limits are shown as blue and red contours respectively.

techniques are used to study the stop-quark, which needs to have a light mass for supersymmetry to be natural. It is worth noting that the two main ATLAS papers on supersymmetry have a large Nikhef involvement.

Search for Higgs

The search of the Higgs boson in ATLAS is based on its decay to two photons, to two Z-bosons subsequently decaying to four leptons, and likewise to two W-bosons decaying into leptons. Nikhef contributed for the decay to W-bosons in a 'cut-based' analysis and is implementing new methods to reconstruct the mass of the Higgs despite the presence of two neutrinos in the final state. The muon reconstruction plays an important role and is crucial for the two Z-boson channel.

Statistical tools implemented in RooFit and RooStat, developed at Nikhef, are used to assess the most likely (95% confidence level) mass range for the Higgs boson to be between 115.5 to 131 GeV. The compatibility of the data with the background, in and around the remaining mass window, is depicted in Fig. 2. A hint of a Higgs particle is observed around 126 GeV.

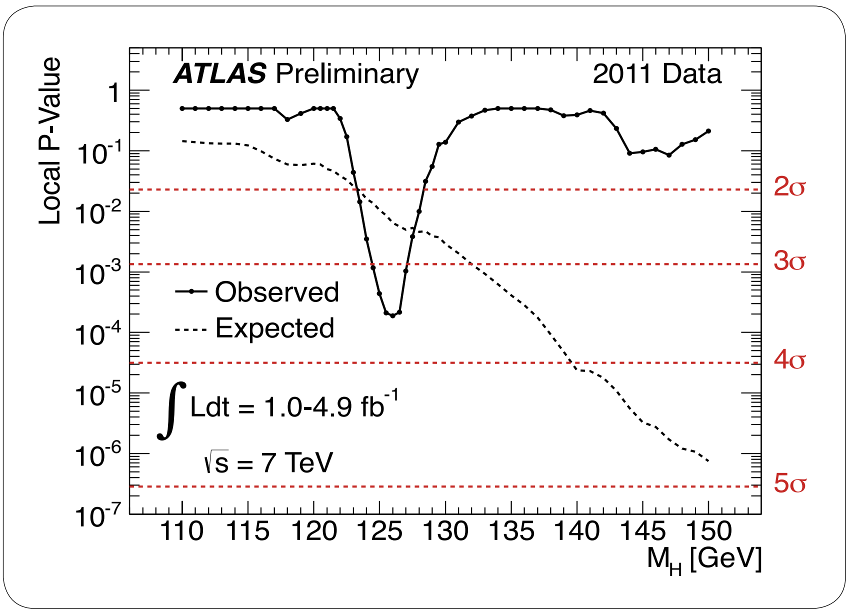


Figure 2. Consistency of the observed results on the Higgs search with the background-only hypothesis in terms of the probability (p-value). The dashed curve shows the median expected significance in the hypothesis of a Standard Model Higgs boson production signal. The four horizontal dashed lines indicate the p-values corresponding to significances of 2, 3, 4 and 5 sigma.

2.2 LHCb
Beauty physics and a charming surprise

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

LHCb has been designed to perform high-precision measurements in the field of heavy flavour physics. Its research focuses on the quest for new physics in CP violating processes and rare decays of B mesons. The first full year of data taking in LHCb has been very successful and the stream of exciting new results has started to flow.

Nikhef has contributed for a large part to the design and construction of the VErtex LOcator (VELO), with which the primary and secondary vertices are reconstructed, as well as of the Outer Tracker (OT), with which the momentum of the charged tracks is determined. In addition a major effort has gone into the design and implementation of the High Level Trigger and Pile-Up system.

Data taking in 2011
The LHCb detector was foreseen to operate at an instantaneous luminosity of 2×10^{32} cm^{-2}s^{-1}. Throughout the present running period the luminosity has gradually been increased to 4×10^{32} cm^{-2}s^{-1}, while the performance and ageing of the various sub-detectors were closely monitored. In 2011 the integrated luminosity surpassed expectations and amounted to 1.22 fb^{-1}. To optimise the data quality and the total integrated luminosity, the mechanism of luminosity leveling was introduced, which allowed LHCb to take data at a constant, predefined luminosity throughout the entire length of a fill of the LHC (see Fig. 1).

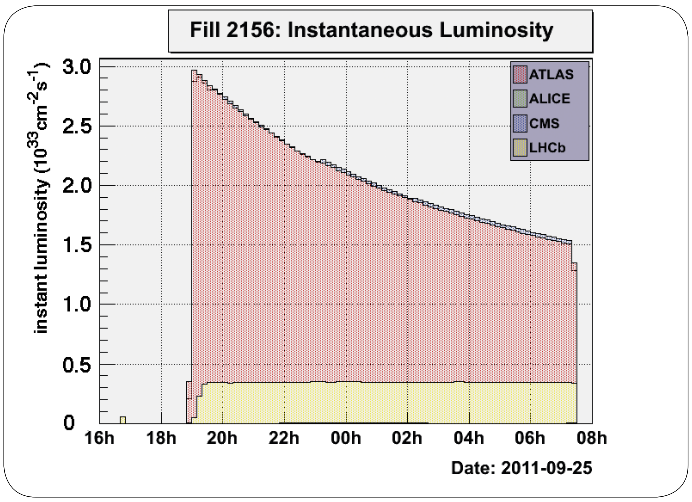


Figure 1: Luminosity of ATLAS, CMS and LHCb during a fill of the LHC.

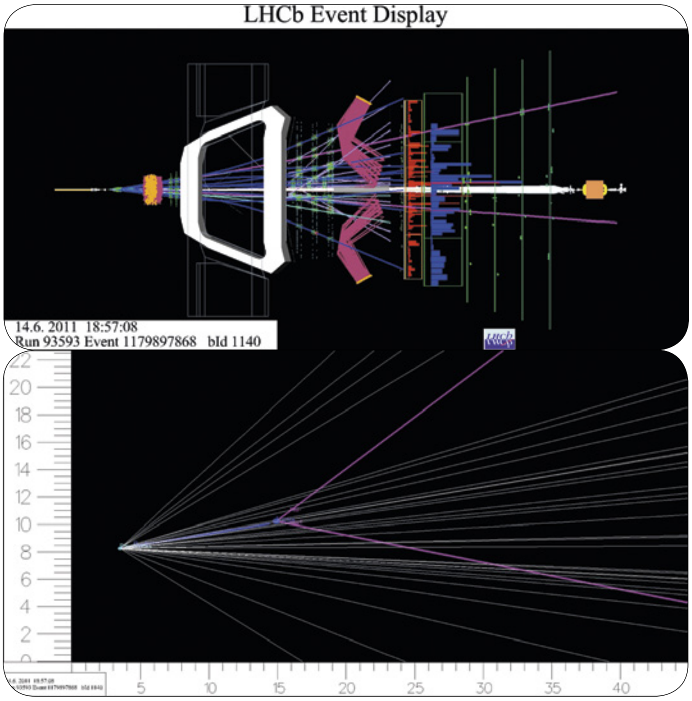


Figure 2. Top: Event display of a $B^0_s\to\mu^+\mu^-$ candidate event. The interaction point, surrounded by the VELO detector, is on the left. Both the hits in the various sub-detectors and the tracks that are associated with them are shown. The tracks of the two oppositely charged muons are drawn in purple. Bottom: Zoom of the vertex region of the $B^0_s\to\mu^+\mu^-$ candidate event. Primary vertex on the left, with the emerging B^0_s meson in blue, which decays after approximately 11 mm into two muons, indicated in purple.

Rare decay $B^0_s\to\mu^+\mu^-$
In the Standard Model (SM), Flavour Changing Neutral Current processes are highly suppressed and can only occur via higher-order diagrams. Therefore, they are good candidates for searches of signatures of new physics. A prime example is the decay $B^0_s\to\mu^+\mu^-$, for which the SM predicts a tiny branching fraction of $(3.2\pm0.2)\times10^{-9}$. Based on this value only 3.9 reconstructed $B^0_s\to\mu^+\mu^-$ events are predicted for the 0.37 fb^{-1} integrated luminosity that has been analysed thus far. However, this value can be significantly enhanced if new processes, by means of new heavy particles, contribute to this decay. Thanks to the excellent mass resolution of the LHCb detector the signal region could be limited to ±60 MeV/c^2 around the mass. A candidate signal event is shown in Fig. 2.

The branching fraction of the signal is obtained by normalising the observed yield to that of three well-known reaction channels. The resulting upper limit for the combined 2010 and 2011 data sets is 1.4×10^{-8} at 95% confidence level, which represents the world's most precise value. The upper limit exceeds the SM prediction by a factor 4.4. With the full dataset of 2011, together with the expected dataset to be collected in 2012, LHCb will be able to decrease this experimental limit by about a factor 3.

The B_s^0 mixing phase ϕ_s from $B_s^0 \to J/\psi\phi$

The interference between the amplitudes for direct decay and decay after oscillation leads to a time-dependent CP-violating asymmetry between the decay time distributions of B and $\overline{B}$ mesons. The decay $B_s^0 \to J/\psi\phi$ allows to measure this asymmetry, which can be expressed in terms of a single phase ϕ_s and the decay-width difference of the light (L) and heavy (H) B_s^0 mass eigenstates, $\Delta\Gamma_s \equiv \Gamma_L - \Gamma_H$. The SM prediction for ϕ_s is small, *i.e.*, –0.036 rad, but contributions from physics beyond the SM could lead to considerably larger values. With the data of the first half of 2011, corresponding to 0.37 fb^{-1}, J/ψ candidates are reconstructed from oppositely charged muons and the ϕ meson is identified by requiring two oppositely charged kaons within ±12 MeV of the nominal ϕ mass. A fit to the invariant mass distribution of $B_s^0 \to \mu^+\mu^- K^+K^-$ yields 8492±97 signal events. The flavour of the B_s^0 is determined by means of flavour tagging which has an efficiency of 1.91±0.23%. In order to extract ϕ_s, the CP-even and CP-odd components need to be disentangled, which is done via an angular analysis of the decay products. In Fig. 3 the 68%, 90% and 95% confidence level contours including systematic uncertainties are shown in the plane spanned by ϕ_s and $\Delta\Gamma_s$. This represents the most precise determination of ϕ_s and $\Delta\Gamma_s$ from $B_s^0 \to J/\psi\phi$ decays. The measurement is in agreement with the SM expectation and forms the first direct evidence for a non-zero value of $\Delta\Gamma$.

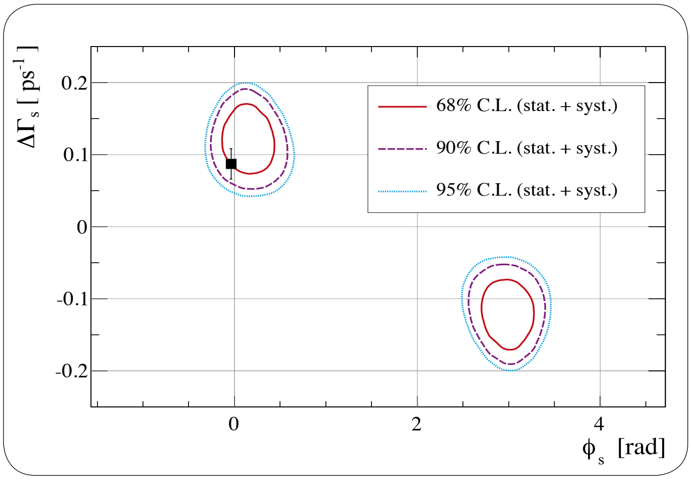


Figure 3: 2D likelihood confidence regions in the $\Delta\Gamma_s - \phi_s$ plane. The black square represents the Standard Model prediction.

World's first evidence for CP violation in the charm sector

In contrast to B decays the study of charm decays involves the couplings to up-type quarks and therefore provides an interesting complementary window to find signatures of new physics. No evidence for CP violation in charm decays has been observed thus far. The time-integrated CP asymmetry $A_{CP}(f)$ is defined as the ratio between the difference and sum of the decay rates for D^0 to f and $\overline{D}^0$ to $\bar{f}$, where the final state f is either a K^-K^+ or $\pi^-\pi^+$ pair. The difference between the asymmetry for D^0-decays in K^-K^+ and $\pi^-\pi^+$, ΔA_{CP}, is primarily sensitive to direct CP violation and is, according to the SM, expected to be small.

The flavour of the charm meson is determined by the charge of the slow pion in the $D^{*+} \to \overline{D}^0\pi^+$ and $D^{*-} \to \overline{D}^0\pi^-$ decay chains. From a data sample corresponding to 0.62 fb^{-1}, a value for ΔA_{CP} of –0.82±0.21(stat.) ±0.11(syst.)% is extracted. When adding the statistical and systematical error in quadrature, the significance of the measured deviation from zero is 3.5 σ and represents as such the first evidence for CP violation in the charm sector.

The splendid performance of LHC and LHCb in 2011 is considered as the prelude to more exciting high-precision measurements in the heavy flavour sector in 2012.

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 ALICE 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 studying both proton–proton and heavy–ion collisions at ultra–relativistic energies, we aim to determine the properties of matter under such extreme conditions, and to improve our current understanding of the phenomenon of confinement and the generation of mass by the strong interaction.

The Nikhef heavy–ion group participates in the ALICE experiment at the Large Hadron collider (LHC) at CERN. Nikhef contributed to the construction of the Silicon Strip Detector (SSD) of the Inner Tracking System (ITS) in ALICE. This detector has been operational since the start of the LHC run in 2009 and has been successfully aligned and calibrated. The Nikhef group is still involved in the ongoing operation of the detector and maintenance of the reconstruction software.

Flow studies in Pb–Pb collisions

Anisotropic flow is an important probe of the properties of the system created in heavy–ion collisions.The azimuthal distribution of particles is usually described in terms of a Fourier expansion, characterised by the coefficients $v_n = \langle \cos[n(\phi-\psi_n)]\rangle$, where ϕ is the azimuthal angle of a particle, ψ_n is the azimuthal angle of the symmetry plane and n is the order of the harmonic. For non–central collisions, the dominant coefficient is the second order v_2 due to the elliptic shape of the initial state. The first results published by the ALICE collaboration in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, revealed that the integrated elliptic flow (*i.e.*, v_2, the second Fourier coefficient), rises by about 30% compared to the highest RHIC energy of 0.2 TeV. The magnitude of the elliptic flow coefficient depends on the initial shape of the system which gives rise to pressure gradients, but also on the value of the shear viscosity to entropy ratio (η/s) which is connected to the friction of the created matter. The increased v_2 compared to lower energies indicates that the system created at the LHC behaves like an ideal fluid, with low η.

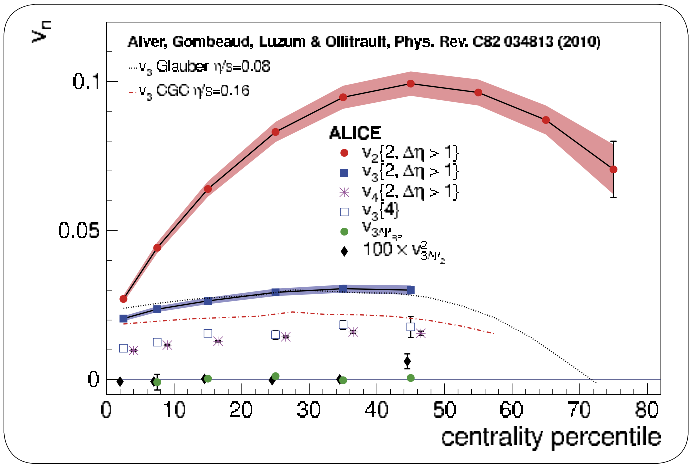


Figure 1. The centrality dependence of the integrated elliptic (v_2), triangular (v_3) and quadrangular (v_4) flow measured with two– and multi–particle techniques. Results on the v_3^2/Ψ_2 and v_3/Ψ_{RP} are also shown. The data are compared to hydro–dynamical calculations (dashed lines) incorporating different initial conditions and η/s values.

It was recently realised that the higher (odd) harmonics, like the triangular (v_3) or the pentagonal (v_5) flow, are more sensitive to both the value of η and the initial conditions. These odd harmonics develop due to fluctuations in the initial distribution of matter (*i.e.*, positions of the participating nucleons), which does not have an ideal almond shape but is described by a more complex spatial geometry.

Fig. 1 presents the integrated triangular (v_3) flow as a function of centrality. The value of v_3 is significant and does not depend strongly on centrality. These results can be used to discriminate between different hydro–dynamical models incorporating different initial conditions as suggested by the figure (dashed lines) and to further constrain the value of η/s. To further test the hypothesis that v_3 originates predominantly from event–by–event fluctuations of the initial spatial geometry, correlations between the symmetry plane Ψ_3 and the reaction plane Ψ_{RP} as well as Ψ_2 were studied. These correlations are represented by the v_3/Ψ_{RP} and v_3^2/Ψ_2 points in Fig. 1, respectively and are consistent with zero, as expected from a triangular flow originating from event–by–event fluctuations of the initial spatial geometry. A paper describing these measurements was accepted by *Physical Review Letters*.

Heavy flavour measurements in pp and Pb–Pb collisions

Another way to characterise the system that is created at the LHC energies, is by studying the interaction of hard probes with the medium, measuring the nuclear modification factor R_{AA} of hadrons, defined as $R_{AA} = 1/\langle N_{coll.}\rangle (dN_{AA}/dp_t)/(dN_{pp}/dp_t)$ (*i.e.*, the ratio of yields in AA and pp collisions normalised to the number of binary collisions). The published ALICE results for the R_{AA} of unidentified hadrons confirmed that the medium created at the LHC energies is more dense than the one created at the top RHIC energy of 0.2 TeV.

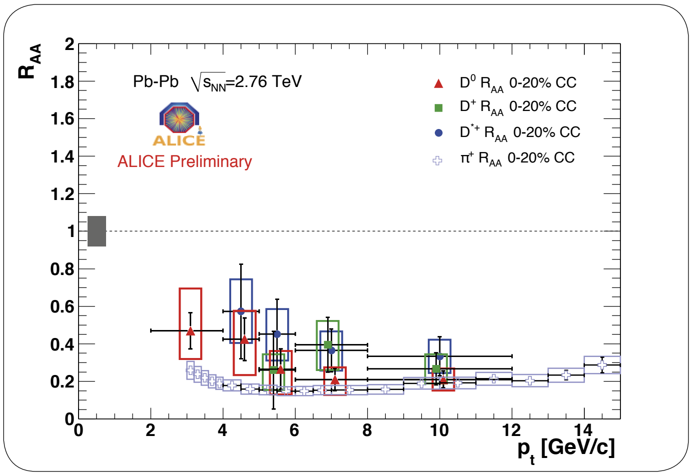


Figure 2. The nuclear modification factor R_{AA} for different charmed mesons (D^0, $D^{\pm}$ and $D^{*\pm}$) in 0–20% central Pb–Pb collisions. The p_t–differential inclusive cross section for prompt D^{*+} is extracted from the analysis of pp events at $\sqrt{s_{NN}}$ = 2.76 TeV. The R_{AA} for pions is shown for comparison.

The dominant energy loss mechanism for fast partons traversing the hot and dense medium is expected to be radiative energy loss. A specific prediction of the radiative energy loss calculation is that heavy quarks should lose less energy than light quarks, because of an interference effect that limits the gluon radiation to larger angles for quarks moving with a velocity below the speed of light (the 'dead cone effect'). The measurement of the R_{AA} of heavy–flavor hadrons allows to test this prediction.

The first result of these measurements can be seen in Fig. 2, which presents the R_{AA} of D^0, $D^{\pm}$ and $D^{*\pm}$ mesons as a function of p_t for central Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV. The nuclear modification factor for pions is also shown in the same figure. It can be seen that the R_{AA} for charmed mesons is slightly larger than for pions, which is qualitatively in agreement with the expectations. A more quantitative comparison with theoretical expectations is ongoing.

Outlook

The results presented here are highlights of early results from ALICE in which the Nikhef group played a significant role. The group is also involved in more advanced analyses using the same data sample. For the flow measurements, a next step is to use identified hadrons, such as π, K, p, Λ, Ξ and Ω, to study the mass-dependence of elliptic flow, which is directly connected to a common flow velocity. Of particular interest is also the study of the anisotropic flow of D–mesons, which will give more insight in the thermalisation process for heavy quarks.

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

In the area of penetrating probes and parton energy loss, the group will continue to be involved in various heavy flavour measurements and in addition is also involved in measurements of the jet spectrum and modifications of jet fragmentation due to interactions with the medium.

The successful heavy ion run in November/December 2011 will provide ten times more collisions to analyse in specific centrality bins and with jet triggers. This will improve the precision of some of the existing measurements and make it possible to explore parton energy loss and elliptic flow at higher transverse momentum.

2.4 ANTARES & KM3NeT
Neutrino telescopes

Management: prof.dr. M. de Jong (PL)
Running Period: ANTARES 2001–2013
KM3NeT 2009–2016

The ANTARES detector and its future successor KM3NeT are new-generation neutrino telescopes. Their aim is to detect neutrinos from astronomical sources in order to complement photon-based astronomy. They exploit large volumes of water in the Mediterranean Sea as a detection medium. Neutrino interactions with matter produce muons that lead to the emission of Cherenkov light when passaging through water. This can then be used to reconstruct the muon tracks. ANTARES has been operating since 2007 and is deployed 40 km from the French Coast at 2500 m depth. A total of 12 strings of 350 m length are instrumented with 900 optical modules. Each optical module contains a 10 inch photo-multiplier (PMT) to detect light signals. The data-acquisition system, which has in major parts been set up by the Nikhef group, has been operating smoothly over the past four years. It transfers the signals from the PMTs to the shore station, where they are filtered and stored. The system is linked in real-time to external triggers from the Swift and Fermi satellites which detect Gamma Ray Bursts (GRBs).

The Nikhef group is heavily involved in the main analysis efforts. Major progress has been achieved through extensive systematic studies of the behaviour of the signals from the PMTs and electronics and timing resolution which led to considerable improvement of the detector modelling and good agreement between data and simulations. Also, an analytical description of the light yield and scattering from muon tracks has been established and implemented in the standard software framework. Studies are ongoing to apply the formalism both for muon reconstruction and simulations. Work has also started to build a track reconstruction algorithm that examines the likelihood for all directions on a fine grid on the whole sky. This is expected to significantly improve the reconstruction efficiency for low energy muons that are selected by a dedicated directional trigger implemented by Nikhef.

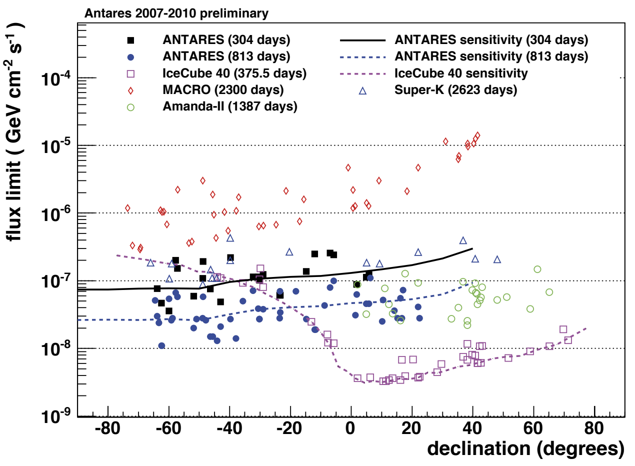


Figure 1. Upper limits set on the point source neutrino flux for a number of candidate sources as a function of their declination. Limits obtained by other experiments are also indicated.

The current track reconstruction software achieves an angular resolution of 0.5 degrees on the neutrino direction. It was used in a search for cosmic point sources of neutrinos, using data collected in 2007–2010. No significant sources were found, and world-best limits were obtained for the neutrino flux from a set of potential sources visible in the Southern Sky. The limits are shown in Fig. 1.

The correlation of detected neutrinos with signals measured by the Pierre Auger Observatory (PAO) has been studied using data from 2007 and 2008. Fig. 2. shows the neutrino candidates together with 69 ultra high ($E > 55$ EeV) energy cosmic ray events as detected by PAO. In the analysis, the number of neutrinos falling within 4.9 degrees of a PAO event is counted. No statistically significant correlation was found.

Neutrino signals from Gamma Ray Bursts were searched for by correlating the neutrino events with the external triggers. Preliminary limits were set on the GRB neutrino fluxes, using both muon tracks and particle showers originating from interactions of, for example, electron neutrinos. These analyses will be finalised in early 2012 and then expanded to the full data set. In addition, the detection capabilities for GRBs via muons induced by high energy gamma-rays have been studied. Unblinding of this analysis is expected in 2012.

Work has started on determining the potential of ANTARES for the detection of the neutrino flux from interactions of cosmic rays with the interstellar medium in our galaxy. The plan is to optimise this search by developing a specialised track reconstruction technique that has increased efficiency for events from the dense galactic centre region.

Simulations of down-going muon bundles were used to investigate the signatures of different cosmic ray primary particles initiating showers in the atmosphere. Being able to distinguish the cosmic ray primaries offers the opportunity to derive the cosmic ray composition which can help with clarifying possible production models for cosmic rays.

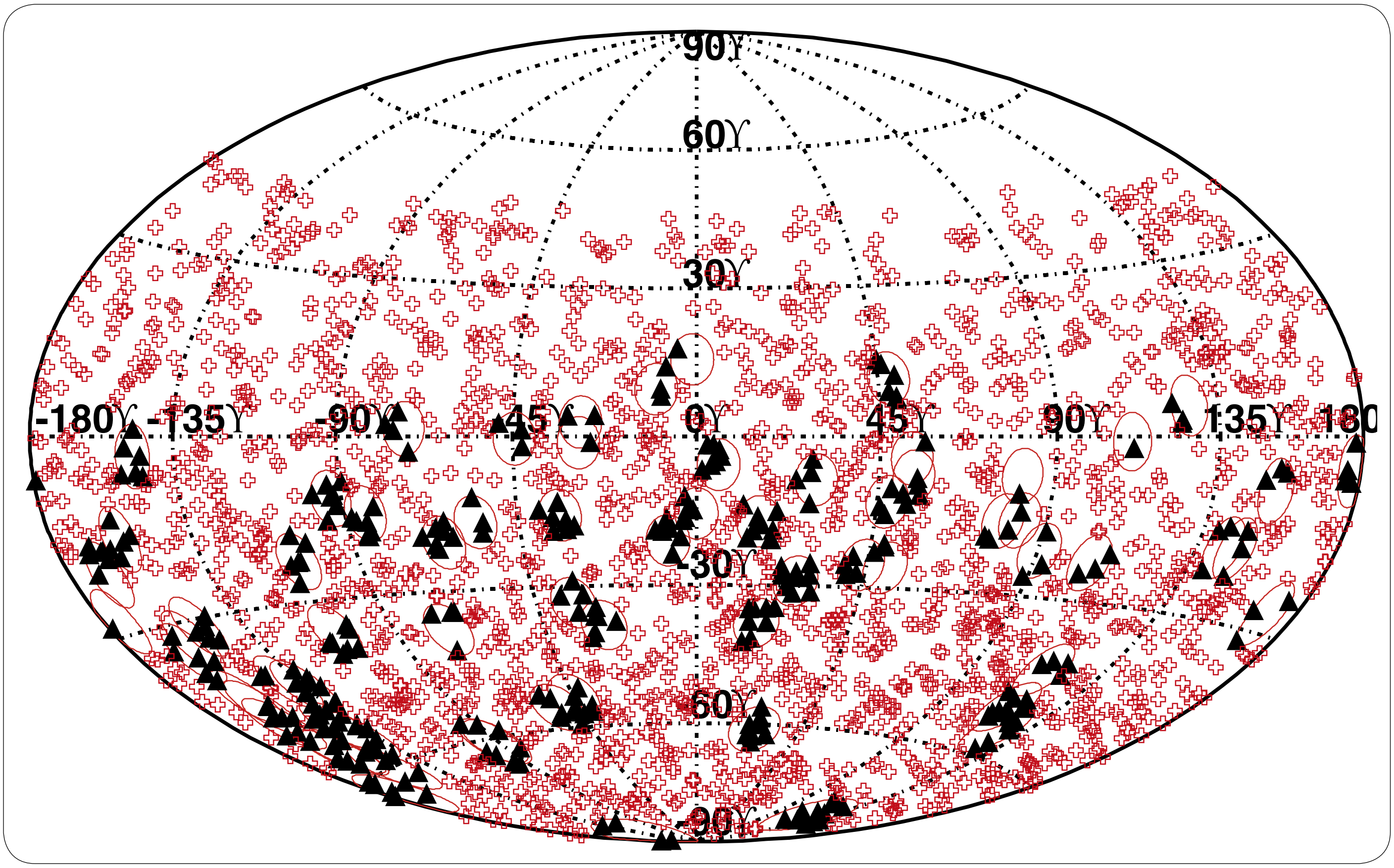


Figure 2. Sky-map showing ANTARES neutrino candidates and Ultra-High-Energy Cosmic Rays (UHECR) observed by the Pierre Auger Observatory. Crosses represent ANTARES neutrino events outside of 4.9 degree bins centered on UHECRs observed by the PAO, and triangles represent ANTARES neutrino events correlating with observed UHECRs.

A new likelihood-based energy estimator for the muon tracks has been developed. This algorithm is now used to measure the energy spectrum of atmospheric muon neutrinos. This will contribute to scrutinising models of the atmospheric neutrino fluxes.

KM3NeT is the planned successor of ANTARES for which a much larger volume of the Mediterranean Sea will be instrumented and with this significantly better sensitivities will be reached. The optical modules will change from spheres containing a single PMT to containing 31 small (3 inch) PMTs distributed around the sphere and with this refine the information for photon counting. A single PMT with the corresponding electronics bases for the different PMTs in an optical module is shown in Fig. 3. Work went into the simulation and reconstruction of muon tracks using several different detector configurations to optimise the physics reach. In this way it could already be demonstrated that the neutrino flux from galactic supernova remnants like RX J1713.7–3946 will be detectable within a five-year observing time in the case of a hadronic origin of its detected gamma-ray emission.

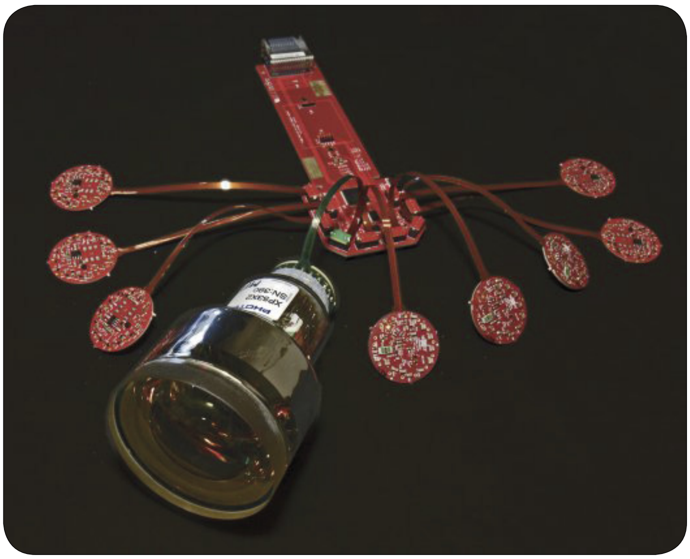


Figure 3. PMT to be used in the KM3NeT multi-PMT Optical modules. The electronics for providing high voltage and read-out for nine PMTs is also shown.

2.5 Gravitational Physics
The dynamics of spacetime

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

In general relativity, spacetime is not just a stage on which physical processes unfold; it is itself a dynamical entity. The dynamical character manifests itself through gravitational waves: ripples in the fabric of spacetime which propagate at the speed of light. The direct detection of gravitational waves would be an event of historical significance, as it would establish once and for all that gravitation is indeed a dynamical phenomenon. But its importance will be much more far-reaching than that. For the first time, we will have access to the strong-field dynamics, allowing the theory to be tested in the most extreme regimes. Should a deviation from general relativity show up, then it may well be due to a low-energy imprint of quantum gravity. The study of gravitational waves also has the potential to revolutionise astrophysics and cosmology, at first through the use of inspiralling and merging binary neutron stars and black holes as cosmic distance markers that are free from the usual systematics, and eventually by a direct measurement of primordial gravitational waves which were generated a fraction of a second after the Big Bang. The latter would allow us to directly probe the strong quantum gravity effects which will have manifested themselves at the very beginning of the Universe.

Advanced Virgo is a new project at the frontier of laser interferometry that wants to achieve relative length sensitivities as good as $3\times10^{-24}/\sqrt{\text{Hz}}$. The design and prototyping is ongoing at present (in parallel with Advanced LIGO in the USA, and the construction of LCGT in Japan) and equipment will be installed in 2012–2014. Advanced Virgo will scan a 1000 times larger volume of the Universe than initial Virgo. It is expected that the Advanced detectors should record gravitational wave events within weeks after commissioning. This direct detection will be an epoch-defining result.

Testing general relativity

Coalescing binary neutron stars and black holes offer a unique opportunity to test the strong-field dynamics of gravity. To leading order in amplitude, the emitted gravitational waves have a phase that is simply $2\Phi(t)$, where $\Phi(t)$ is the orbital phase of the binary. Thus, the angular motion of the binary is directly encoded in the waveform's phase, and the radial motion follows from the instantaneous angular frequency $\omega(t) = d\Phi(t)/dt$ through the relativistic version of Kepler's Third Law. If there are deviations from general relativity, the different emission mechanisms and/or differences in orbital motion will be visible directly in the measured phase. The currently observed binary pulsars only probe general relativity at $(v/c)^2$ beyond leading order in the characteristic speed. Yet several of the more interesting dynamical effects occur starting from $(v/c)^3$ beyond leading order; this

Figure 1: The Virgo gravitational wave detector near Pisa, Italy, is operated by a Dutch-French-Italian collaboration. Each interferometer arm is 3 km long. Advanced Virgo will be realised in the same infrastructure.

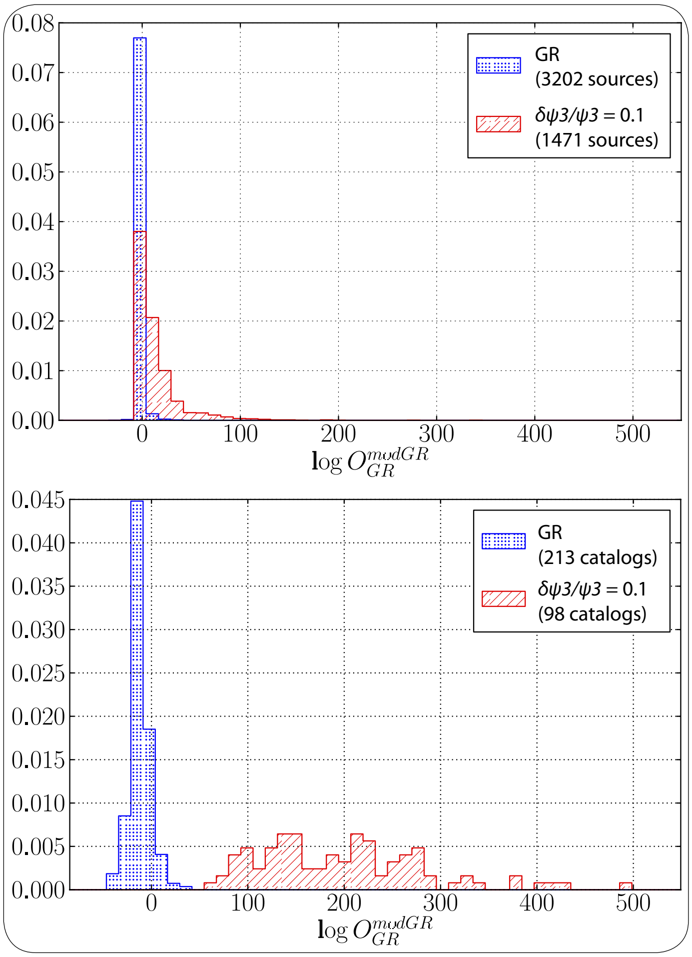


Figure 2. Illustration of a method developed at Nikhef to search for violations of general relativity by using binary mergers as seen with the Advanced LIGO/Virgo network. What is shown is a (log) odds ratio, essentially one's confidence in a violation of general relativity based on (in)consistency of the measured phase contributions with the general relativity predictions. The blue histograms are for simulations in which all sources have gravitational wave emission as predicted by general relativity, while the red ones have a 10% deviation in the (v/c)3 contribution to the phase of the waveform. Top panel: distributions of the odds ratio for individual sources. Bottom panel: distributions of the combined odds ratios for simulated 'catalogues' of 15 sources each. By combining information from multiple sources, even small deviations from general relativity will be detectable with high confidence.

includes 'tail effects' due to gravitational waves bouncing off the nominal spacetime background, and spin-orbit interactions if one of the binary components is a spinning black hole; spin-spin interactions first appear at order $(v/c)^4$. Gravitational wave observations can constrain these higher-order effects, or show them to be inconsistent with general relativity.

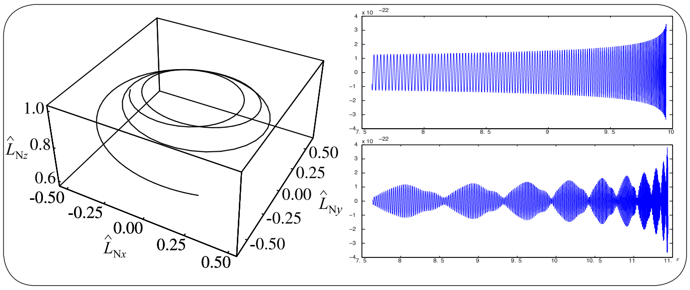


Figure 3. Left: Introducing black hole spins causes dramatic changes in the orbital evolution such as precession of the orbital plane, as shown by the changing direction of its unit normal. Right: GW amplitude versus time. Without spins the amplitude and frequency of the gravitational wave signal increase in a steady 'chirp' (top), while with spins, precession of the inspiral plane causes amplitude and frequency modulation (bottom).

Possible deviations from general relativity that have been considered in the past include scalar-tensor theories, a varying Newton constant, theories with a modified dispersion relation (usually referred to in literature as '*massive gravity*'), violations of the No Hair Theorem, violations of Cosmic Censorship, and parity violating theories. However, general relativity may be violated in some other manner, including a way that is yet to be envisaged. This makes it imperative to develop methods that can search for generic deviations from general relativity. As far as waveforms are concerned, a start was made with the 'parameterised post-Einsteinian' formalism. At the same time, a sufficiently general data analysis scheme will be necessary, and Nikhef scientists recently made the first steps in that direction (see Fig. 2).

The dynamics of binary coalescence are extremely rich, especially if two black holes are involved. Astrophysical black holes are predicted to be fast-spinning, causing extreme 'frame dragging' which influences the way they move around each other. If the two spins are not aligned, the orientation of the orbital plane will undergo precession, and in some cases even a tumbling motion, which modulates the phase and amplitude of the emitted waveform, as illustrated in Fig. 3. General relativity makes accurate predictions for these effects, which we will be able to study in considerable detail.

2.6 The Pierre Auger Observatory
Detecting ultrahigh-energy cosmic rays

Management: dr. C. Timmermans (PL)
Running Period: 2008–2013

The Pierre Auger Observatory measures cosmic radiation of the highest energy (above 10^{18} eV) through the showers created in the atmosphere of the Earth. These measurements are performed using particle detectors at the Earth's surface and telescopes overseeing the 3000 km² array, which detect the fluorescence light created by air showers during dark nights. The Pierre Auger Observatory, located in the province of Mendoza, Argentina, is an excellent place to pioneer and calibrate new air-shower-detection techniques such as the detection of air showers through their emission of radio signals. 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.

Measurement of self-triggered events in AERA
The Auger Engineering Radio Array started taking data in 2010. One of its main objectives was to prove the possibility of detecting air showers using the radio signal they produce. This objective has been reached in April 2011. In two periods over 50 events are recorded in time coincidence with the Auger surface detector. The quality of these events allows for much more detailed studies than we have seen in the past. Nikhef is taking the lead in these studies.

Charge excess in radio detection of cosmic rays
Because of the recent radio measurements at the Pierre Auger Observatory, the understanding of the mechanisms by which the radio signal is emitted has improved substantially. An observable to distinguish different mechanisms is the polarisation of the measured signal. The dominant mechanism is clearly geo-magnetic. The path of the electrons in the shower is bent due to the Earth magnetic field. However, Askaryan has predicted radiation induced by a negative charge excess in the front of the air shower. This causes a radial signature of the polarisation, directed inwards to the shower axis. Last year, the observation of this effect was reported, this year we were able to measure the strength of this effect relative to geo-magnetic, as shown in Fig. 1.

Our measurement provides the ratio of the radial component to geomagnetic component in the frequency band between 30 and 70 MHz. When averaging over all measurements, a value of 13.2±1.1%, is obtained. This measurement will soon be confronted with simulations.

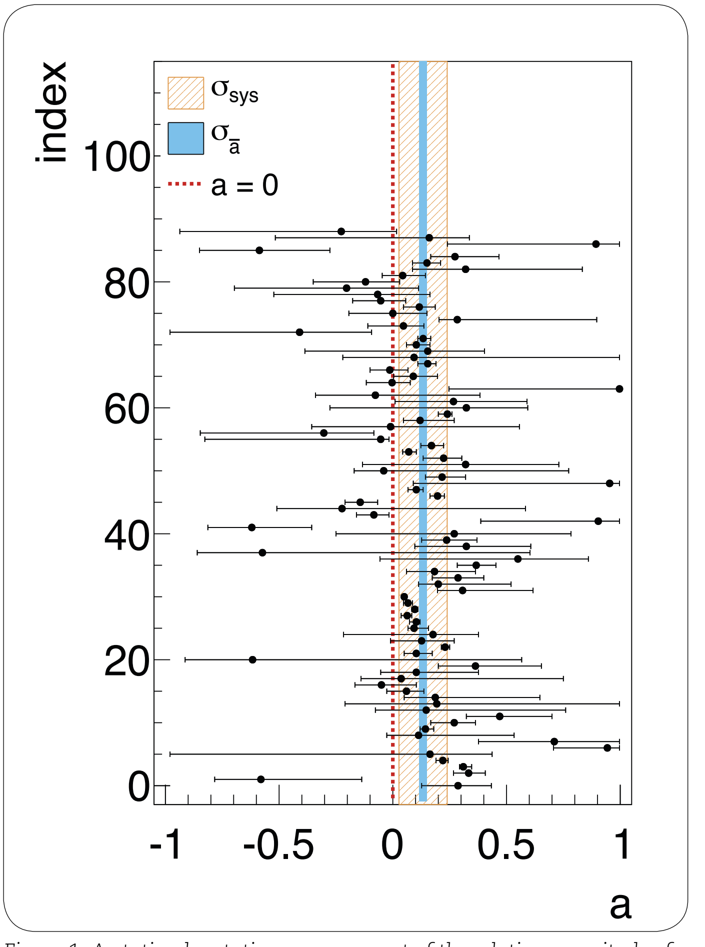


Figure 1. A station-by-station measurement of the relative magnitude of the radial polarisation of the radio signal. The horizontal axis displays the relative size of the radial component of the polarisation. A positive value means an inward polarisation. The vertical axis indicates different measurements. The (width of the) blue line indicates the (standard deviation of the) average of all data, while the hatched area represents the systematic uncertainty of the measurement.

Study on the sensitivity of shower development from the radio measurement
A study of the shower development is of great importance, and depends on the type of cosmic particle entering the atmosphere (the primary particle). If the primary particle is heavy (like an iron nucleus), the shower develops earlier than the shower created by a single proton of the same energy. The shower development also depends on the cross section of the primary particle with air. This cross section cannot be measured at particle accelerators as the centre of mass energy is far larger than can be reached at the LHC. It is clearly advantageous to have complementary measurements of the shower development. The radio measurement of air showers is complementary to fluores-

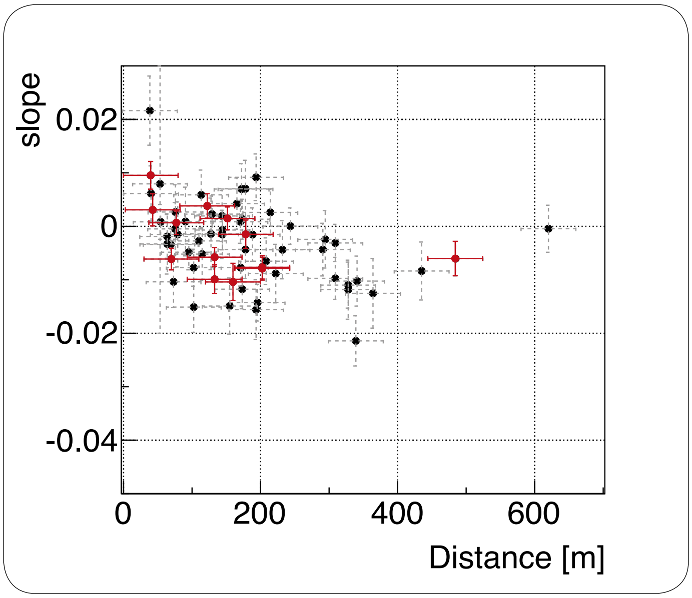


Figure 2. The spectral index (slope of the logarithm of the frequency spectrum) as a function of distance to the shower axis as measured from the 2011 AERA data. Events with a high signal to noise value (>4) are displayed in red. Events with a low signal to noise value (>2 but <4) are in shown in black.

cence as it probes changes in the number of charged particles, and not the total number of charged particles. Furthermore, it can be measured during daytime as well as nighttime. During the past year, we have shown that a spectral analysis of radio signals provides geometrical information on air showers. Furthermore, simulations show that such an analysis has sensitivity to the primary composition similar to the surface detector information. Finally, in Fig. 2 the measured spectral index, in the frequency range between 40 and 60 MHz, as a function of the distance to the shower axis is shown.

Fig. 2 indicates that at small distances, the spectral index in the measured frequency range is positive. This indicates that the maximal emission is at frequencies beyond 50 MHz. It is clear that the spectral index decreases for increasing distances. This is a purely geometric effect, and reflects that pulses at larger distances are wider than those close to the shower axis. At large distances the spectral slope is negative, thus the maximum emission lies at frequencies below 50 MHz. At around 200 m there is an indication for a local increase in the spectral index, which would mean that high frequencies become more important. In the time domain, this corresponds to a narrower pulse. This could indicate that the Cherenkov cone for the radio signal has a radius of about 200 m. This value is also obtained from recent simulations.

The analyses discussed here are performed by Nikhef graduate students, and they clearly show that the knowledge on the radio signal is rapidly increasing. Furthermore, first steps are taken to use the radio signal for the study of air shower development, which is a main purpose of the radio measurement.

2.7 XENON & DARWIN
Dark matter experiments

Management: dr. P. Decowski (PL)

Nikhef established a direct detection dark matter program in 2010. Direct detection experiments aim to measure the elastic scattering of Weakly Interacting Massive Particles (WIMPs) off a target material. WIMPs are compelling dark matter candidate particles and 2011 was an interesting year for dark matter searches. Two direct detection experiments, CoGeNT and CRESST-II, claimed (controversial) evidence for detection of dark matter in a WIMP parameter region that had already been excluded by other experiments. At the same time, LHC provided first data on supersymmetry related searches, further constraining WIMP parameters. Data in the coming years are bound to provide important insights, hopefully identifying the dark matter particle.

The XENON experiments

The XENON-series of direct detection experiments use xenon as the WIMP target material. Xenon is an excellent choice as a target material, since it is heavy, inert and has good scintillation properties. The XENON collaboration operates the running XENON100 experiment with 160 kg of very pure xenon of which the central 48 kg is the target. This experiment has provided the world's most stringent WIMP dark matter limits in 2011 (see Fig. 1), limits that exclude the new claims from CoGeNT and CRESST-II and the older detection claim from the DAMA experiment. The Nikhef group participates in analysis and shift taking and has prepared an upgrade to the high-voltage system to reduce electronic noise that will be installed after the present run. Three of six selected WIMP candidates in the 2011 analysis were identified as noise events; of the other, 1.8±0.6 are background events and the result is therefore consistent with no WIMP observation. XENON100 will continue operation in 2012, but the main focus of the collaboration is switching to the next-generation experiment, XENON1T.

XENON1T was approved for construction in Hall B of the Gran Sasso (Italy) underground laboratory in April 2011. This experiment will have a tenfold increase in mass relative to XENON100, roughly 2.5 t of xenon, and two orders of magnitude lower background contamination, with the aim of reaching a background of less than one event per ton per year. Apart from relying on the excellent self-shielding properties of xenon, the collaboration is performing an aggressive program for material selection through radioactive screening of materials. Placing the experiment underground reduces the cosmic muon flux and the associated production of neutrons and radioactive isotopes by five orders of magnitude. Nevertheless, the remaining neutrons can mimic WIMP-like nuclear recoils. The XENON1T detector will therefore be placed inside a 9.6 m diameter water tank. The water moderates and captures neutrons and is also an active muon Cherenkov veto for muons traversing the water. A number of important design choices were made in 2011. The collabora-

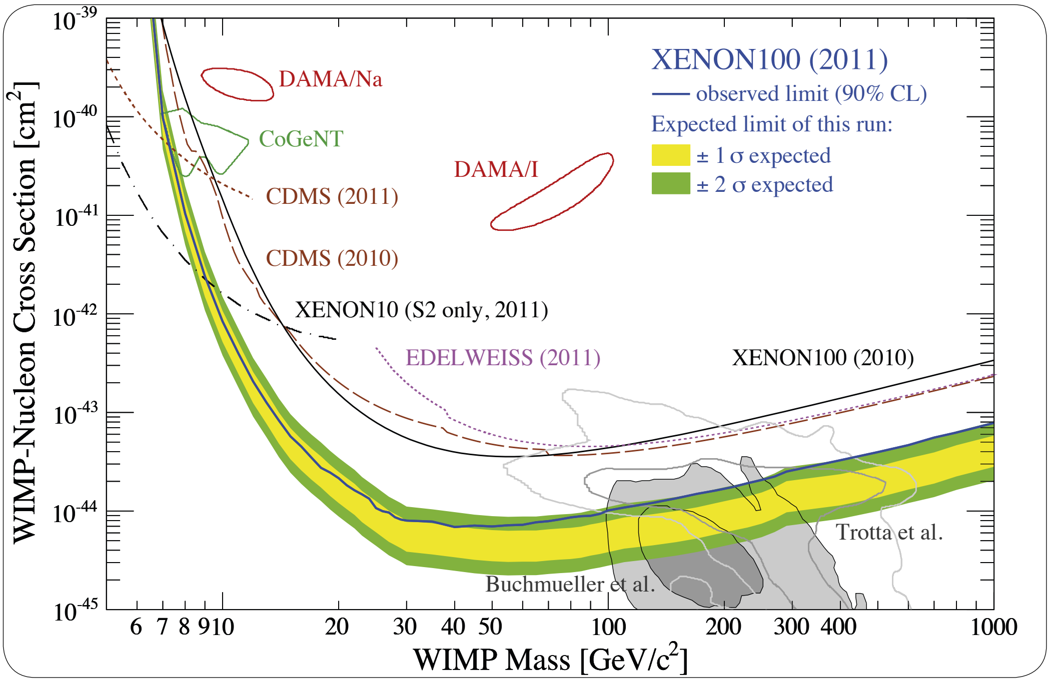


Figure 1. The blue line shows the 2011 WIMP-nucleon cross section versus WIMP mass observed exclusion limit from the XENON100 experiment. The analysis was done on 100.9 days of data, using only the central 48 kg of xenon target. The allowed regions from the DAMA and CoGeNT experiments are shown in the upper left corner (the CRESST-II result is not shown). Other exclusion limits from various experiments are also shown.

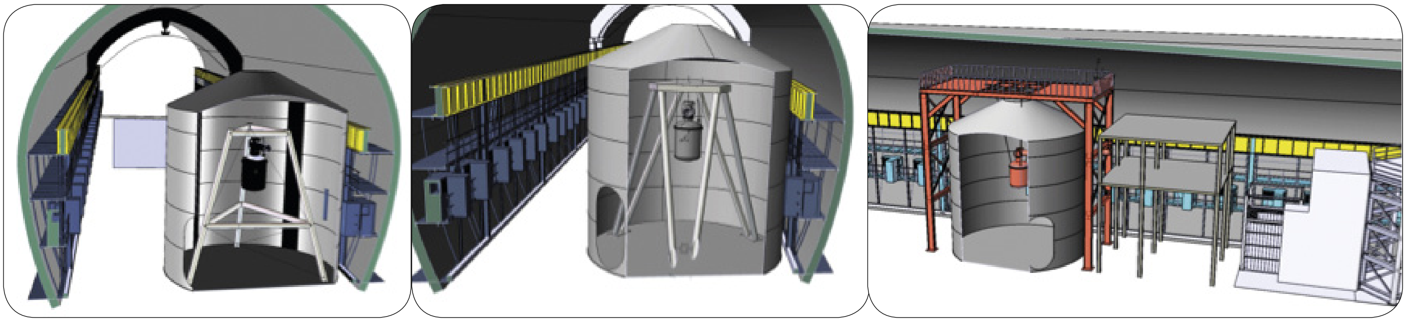


Figure 2. Nikhef is studying different cryostat support structures (both internal to the water tank and external are being considered). An important requirement is to have good vibrational damping while minimizing the amount of material in close proximity to the detector.

tion decided to use conventional PMTs for light readout instead of novel QUPIDs to reduce risk. We are finalising the detector dimensions (optimised through Monte Carlo simulations) and are in the process of completing the design for the water tank. On the management side, the collaboration finalised and signed a Memorandum of Understanding (MoU) that will facilitate the governance of the experiment.

Nikhef is involved in the design of the double vessel cryostat housing the liquid xenon and time projection chamber (TPC). Since the cryostat is in close proximity to the detector, it has to fulfill stringent background requirements. Titanium is a promising candidate for the construction of the two vessels. We are in the process of investigating different titanium grades for radioactive contamination. We are also investigating backgrounds through Monte Carlo simulations.

Another Nikhef responsibility is the design of the cryostat support structure holding the cryostat inside the water tank. The main design challenge here is to keep material away from the cryostat, while maintaining the detector stationary to better than a hundred microns. We are investigating various options of suspending the cryostat from structures either inside or outside the water tank (see Fig. 2). This effort also involves Monte Carlo simulations to optimise the design.

Finally, Nikhef hosted a XENON mini-collaboration meeting in July, when many aspects of the MoU and detector design were discussed.

DARWIN design study

The Nikhef dark matter group is also investigating experiments beyond XENON1T, to be operational around 2018–2020. DARWIN, funded through ASPERA, is a design study for R&D towards a dark matter facility that uses both argon and xenon as the target. 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. Nikhef is involved in various aspects of this experiment, the main being an investigation of the use of the Nikhef-developed GridPix detector in a cryogenic argon or xenon environment. We had lots of activity on this front in the first half of the year, when we tested a GridPix detector in a dual-phase argon detector in collaboration with ETH Zürich. While the operation was successful, the patient died. During the test we were able to confirm that the electronic circuits of the chip work at liquid argon temperatures (T=–185 °C) and that the gas amplification in the grid continued to operate. We are now investigating several possibilities to improve the design. Another highlight was Nikhef hosting the annual DARWIN collaboration meeting in September (see Fig. 3).

Figure 3. DARWIN collaboration meeting in Amsterdam in September 2011. DARWIN is a design study for a multi-target dark matter detector to be built after a few years of XENON1T running.

2.8 Theoretical Physics

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

Theoretical physics research at Nikhef, including that of the Free University and Radboud University partners, has again covered a wide range of topics, from collider physics to more theoretically oriented topics.

Research summary

In the field of B physics, various studies were performed, with the following key results: a detailed analysis was devoted to the ‘anatomy’ of the $B_s^0 \to J/\psi\ f_0(980)$ decay, which receives increasing attention to search for CP-violating New-Physics contributions to B_s^0–$\bar{B}_s^0$ mixing. It was also pointed out that the so far unobserved $B_d^0 \to J/\psi\ f_0(980)$ channel would allow us to constrain hadronic uncertainties in the corresponding measurements. It was furthermore shown that effective lifetimes of certain B_s-meson decays, such as such as $B_s^0 \to K^+K^-$ and $B_s^0 \to J/\psi f_0(980)$, offer promising, theoretically robust probes for the B_s^0–$\bar{B}_s^0$ mixing parameters, which are sensitive to possible New-Physics contributions. These could be confronted with 2012 B_s-decay lifetime measurements by LHCb. Also studied was the phenomenology of $B_{s,d}^0 \to J/\psi\eta'$ decays, being yet another system to search for New Physics in the quark-flavour sector, as well as determine the η–η' mixing parameters.

As yet undiscovered supersymmetric particles can be searched for effectively at the LHC. The lowest-order predictions for such processes are notoriously imprecise, so quantum corrections have to be calculated. These corrections are sizeable due to the nearby production threshold. To provide sufficiently stable and reliable predictions, threshold-resummation techniques can be used. In 2011 a grid with an interpolation code to calculate the resummed cross sections to next-to-leading accuracy was released. In addition, substantial progress was made in stabilising the predictions for squark-antisquark production by performing the resummation at next-to-next-to-leading order accuracy.

It is now clear that squarks, if they exist, must be heavier than a few hundred GeVs. The possibility that a supersymmetric partner of the top quark, stop, is the next-to-lightest supersymmetric particle in the constrained supersymmetric standard model was investigated and the allowed parameter space for this scenario has been determined. Observing stop for these cases might however be difficult.

The LHC is also a top factory. Most of the top quarks are produced by Standard Model processes, so it is difficult to find beyond the Standard Model (BSM) signals in them, but top polarisation, which can be distinctly different among BSM models, offers a possibility.

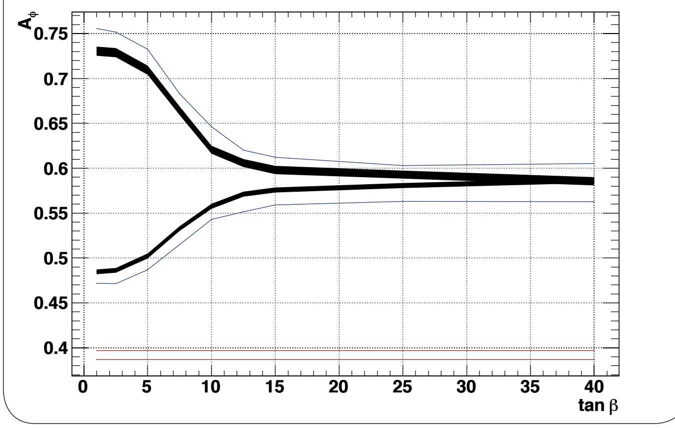


Figure 1. One of the polarisation-dependent observables plotted for top-charged Higgs production at LO (blue) and NLO+parton shower (black) level for different values of the model parameter tan ß. The upper curves are for a charged-Higgs mass of 1500 GeV and the lower curves for 200 GeV. The results for top-W-boson production are shown in red. There is a clear difference between the charged-Higgs and the W-boson case and between different model parameters. This remains the case at NLO+parton shower level.

It was found that for top plus charged Higgs production, as well as top plus W-boson production, polarisation-dependent observables are robust with respect to quantum corrections and therefore are promising probes of new physics, see Fig. 1.

In other work, the complete NLO corrections to the production of two $b\bar{b}$ pairs at the LHC were computed, and their size and uncertainty estimated. Moreover, a program for the numerical evaluation of one-loop integrals with complex masses, relevant for unstable particles, was completed.

The search for the Higgs boson will be the main activity at the LHC in the first few years. But once a Higgs-like particle has been found at the LHC, the next question will be whether it has exactly the properties predicted by the Standard Model. A method has been developed which uses the polarisations of gluons inside a hadron to determine the parity of the Higgs.

For decades, hadron structure in high-energy collisions was captured by collinear parton densities where all intrinsically transverse motion of confined partons is neglected. However, a description of the hadron as a three-dimensional dynamical object consisting of moving partons requires more general parton densities, such as transverse momentum dependent (TMD) parton distribution functions (PDFs). This year, major progress was made toward full QCD understanding (and testing) of TMD PDFs, which was lacking until recently.

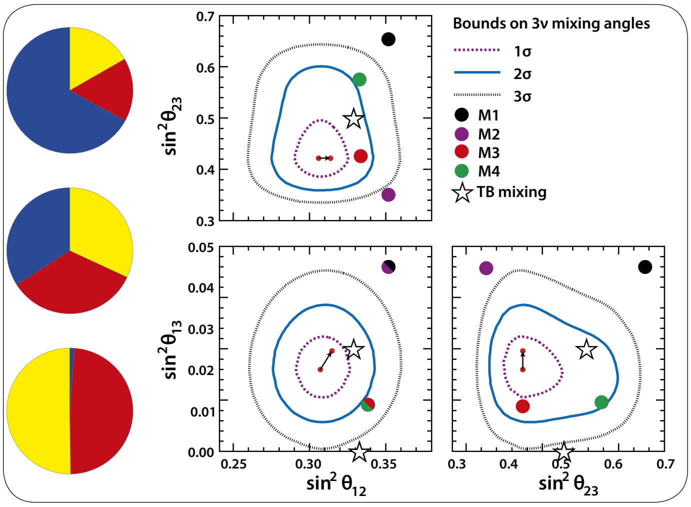


Figure 2. Left: the neutrino mass eigenstates as a function of the interaction eigenstates. Right: the mixing between these states can be described by three angles. Until recently, the tribimaximal mixing pattern was in agreement with the data, while more recent data might point at other patterns, such as M3 and M4, that are related to the discrete group Delta(384).

However, the proper gauge invariant definition of TMDs requires inclusion of gauge links with nontrivial paths originating from non-collinearity of the quark and gluon fields in transverse directions. Besides complications, new study possibilities in high-energy scattering processes, such as jet-jet production with characteristic deviations of the jets from being back-to-back were proposed.

The measured patterns of fermion families (quarks, leptons and neutrinos) were compatible with so-called tribimaximal mixing, where one of the mass eigenstates is a perfect combination of all three interaction eigenstates, while a second mixes two of them in equal amounts. This pattern can be reproduced with discrete flavour symmetries. This summer, early results of the T2K collaboration found small, but significant deviations from tribimaximal mixing. It was found that the existing discrete symmetry-based formalism could be extended to elegantly accommodate this situation, see Fig. 2.

Assuming warped extra dimensions, so-called truncated Randall-Sundrum models were studied, where the extra dimension is made smaller in size so that little hierarchies can be generated. A particular application of this is to obtain light neutrino masses using a mini-seesaw, and the phenomenology of this model was analysed. An interesting signal might be the enhanced decay of a muon to an electron plus a photon. From a more general point of view, symmetries and patterns in equations and physical models were searched for in a systematic and exhaustive way by the so-called Lie-point technique for simple models. This opens up the possibility of predicting the values of parameters in a model where symmetries are enhanced, also for the complicated Standard Model.

A new candidate for a single all-encompassing theory for general relativity and the Standard Model is called noncommutative geometry. It combines the two components by regarding spacetime and the internal degrees of freedom of particles as two sides of the same coin. Considerable progress was made in generalising this to the supersymmetric Standard Model, especially on the classification of possibly viable supersymmetric and noncommutative models.

In string theory four-dimensional models were constructed using ten-dimensional string theory. This was done by modifying an old construction in order to include additional symmetries (*e.g.*, permutation symmetries) of the building blocks of the models and suitably extending them according to a very well defined procedure. Thousands of new models were generated in this way. Some of them have features which are typical of the Standard Model, but some others are quite different. The differences consist of the presence of various gauge groups, fractionally charged particles and number of families. It was studied how often any specific property appears in the landscape of all possibilities.

In the context of BPS black hole entropy for N=2 supergravity with higher-derivative couplings, the nonholomorphic deformation of special geometry was studied, and the possible connection between the so-called Hesse potential and the topological string was discussed. General gaugings of N=2 supergravity theories were constructed. A general classification of the supersymmetric realisations in maximally symmetric spacetimes and in $AdS_2 \times S^2$ spacetimes was given, and the off-shell dimensional reduction of 5-dimensional N=1 supergravity to 4-dimensional N=2 supergravity was defined. Thereby the existence of a new higher-order derivative coupling that involves the square of the Ricci tensor was revealed.

In cosmology research it was found that constraints on a large class of extra-dimensional models seemingly forbid the observed accelerated expansion in our Universe. These existing no-go theorems were revisited, and their (hidden) assumptions exposed, thereby still giving these models viability.

In the framework of Higgs inflation, the role of the inflaton is played by the Standard Model Higgs boson. For this to work, however, one has to assume that the Higgs field is non-mininally coupled to gravity. The effective potential in this slowly rolling scenario was calculated for a time-dependent background.

Shortly after the big bang, the quantum fluctuations of spacetime were promoted by inflation to classical temperature fluctuations in the cosmic microwave background radiation (CMB), as famously observed by COBE and WMAP satellites, a process called decoherence. A method to quantitatively describe cosmological decoherence was developed.

Information from far-away sources in the Universe may be carried by gravitational waves, for which intense efforts to observe them are ongoing. Among the most promising sources of gravitational waves are black holes accompanied by compact masses orbiting in its strong gravitational field. The form of the expected waves was computed using a new, fully relativistic perturbation theory.

Other news
Version 4ß of the symbolic manipulation program FORM has been released. This version has many new features, including polynomial factorisation and gcd computation. These new features allow for attacking a much broader class of problems in physics and mathematics.

Together with Nikhef LHCb colleagues, Robert Fleischer co-organised the Beauty 2011 conference, which was held in Amsterdam.

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. The student-only seminar remains very popular. Additional lectures were given by Jan-Willem van Holten on BRST methods. In November, the program, together with Stan Bentvelsen of the ATLAS group, organised the Amsterdam Particle Physics Symposium, which was well attended by both theorists and experimenters.

Marieke Postma was appointed staff member. Jan-Willem van Holten was a speaker at a KNAW symposium on possibly faster-than-light neutrinos, and presented his inaugural lecture at Leiden University. Piet Mulders was elected APS fellow. Wim Beenakker received the RU Physics and Astronomy education prize. Postdoc Pierre Artoisenet was awarded an individual Marie Curie fellowship.

The Nikhef Academic Lectures were started up again, after an interruption of a few years. Marieke Postma gave four lectures on all the physics involved in the CMB background radiation spectrum.

The national Seminar on Theoretical High-Energy Physics continues to be held at Nikhef and attracts good speakers and excellent attendance. Outreach activities of the theory group include HiSPARC as well as giving lectures to secondary school students and other interested groups. At the Nikhef open day, the group hosts a 'Genius Bar' to answer sundry questions from visitors. PhD students de Adelhart Toorop and Hartgring were involved with the Weekend School initiative.

2.9 Detector Research & Development

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

The focus of the group in 2011 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. The group is also involved in valorisation: further development of scientific instrumentation towards commercial applications.

Gaseous detectors

Since a number of years the group is developing micro pattern gas detectors in combination with pixelated readout ASICs[1]. This so called GridPix has an aluminium mesh stretched 50 µm above a pixelated CMOS readout chip fabricated by means of wafer postprocessing technology. Operated in gas this provides a 50 µm gap with a high electric field where gas amplification occurs. The detector features a high spatial resolution and high single-electron efficiency.

The potential applications are manifold but the production of robust GridPix detectors has been difficult and needed to be transferred to 8 inch wafer technology. Two critical process steps have been developed in collaboration with the TU Twente and Bonn University. Firstly, to withstand sparks or energetic discharges the readout chip needs to be covered with a thin 8 µm protective

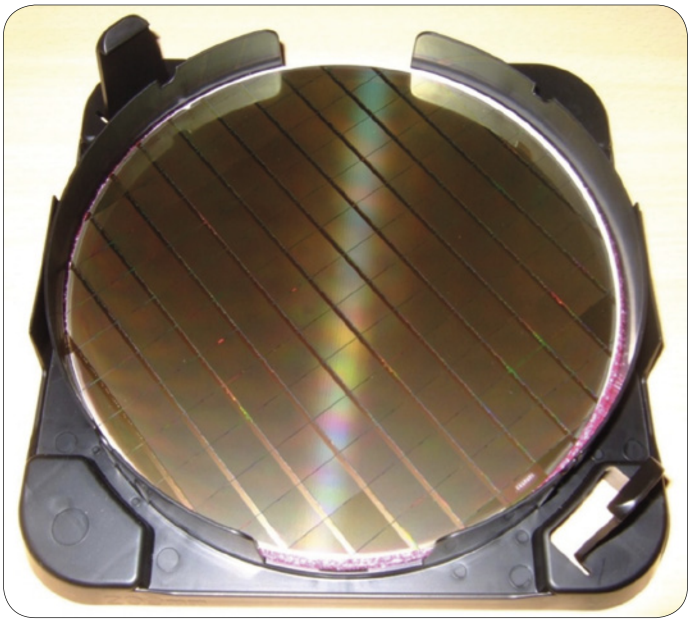


Figure 1. Full 8 inch wafer with GridPix detectors produced in collaboration with TU Twente and Bonn University.

1 Application Specific Integrated Circuit

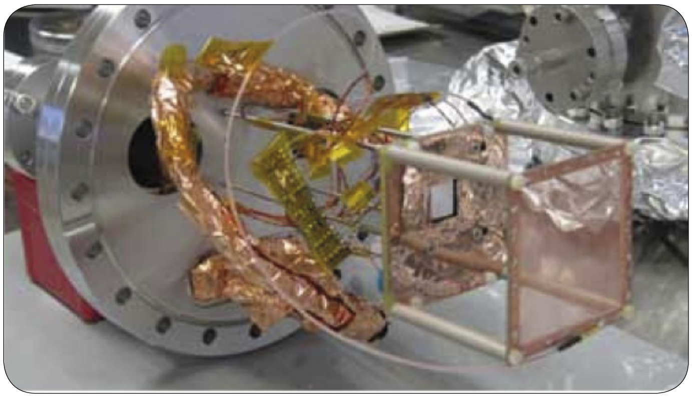


Figure 2. GridPix TPC customised for operation in an argon cryostat at CERN: flange holding a printed circuit board with the square GridPix detector in the centre, the copper mesh is the cathode.

Silicon-Nitride layer. Secondly, patterning of aluminium to form a grid on top of tiny 50 µm tall pillars. At last, in December of 2011 a first batch of wafer scale GridPix devices became available (see Fig. 1). This major milestone allows us to continue this detector research and assemble prototype detectors for *e.g.*, the 'hottest' parts of the tracking detectors at the future super-LHC and a large scale Time Projection Chamber (TPC) for the linear collider.

A new application, which came up as part of the DARWIN design study, is to use GridPix to detect Weakly Interacting Massive Particles (WIMP). The idea is to operate a GridPix in the cryogenic gas volume above a noble liquid. This alternative charge readout aims to detect the ionisation charge directly from the gas amplification rather than the proportional scintillation light. An additional advantage is the low natural radioactivity of the GridPix material, since it is mainly composed of silicon. The R&D ongoing at Nikhef needs to determine the robustness of the detector at liquid argon and liquid xenon temperatures, and demonstrate stable operation in a pure noble gas atmosphere with sufficient gas amplification.

In a first step a GridPix TPC has been tested (see Fig. 2) with a radioactive source in a dual phase argon cryostat at CERN[2] to detect electrons extracted from liquid argon into the gas volume. This required significant preparation at Nikhef to assemble a detector compliant with a cryogenic and pure environment. Measurements showed low outgassing of the GridPix detector and its customised cabling and PCBs. The readout chip has been operated at liquid nitrogen temperatures showing reduced noise figures. The gain measurements with GridPix in ultra pure argon (Ar6.0) at room temperature show that detection of primary electrons is possible.

2 Provided by André Rubbia's ArDM group

When going to CERN to operate at liquid argon temperatures, the higher density of the gas in the argon cryostat required an increase of the grid voltage and this led to a discharge. In combination with the mismatch of the thermal expansion coefficient of one of the GridPix components the detector was damaged. However, this test provided plenty of information and ideas how to improve the GridPix for operation in a noble liquid TPC.

Semiconductor detectors

Driven by the demand for large area detectors, we work on seamless tessellation of multiple modules. This requires sensors with a minimum amount of dead area at the edge. For this, edge effects must be understood and avoided or mitigated. Both slim-edge and active-edge sensors are being studied at Nikhef. Slim-edge structures are manufactured by dicing the sensor closer to the pixel matrix. The use of minimally deleterious dicing techniques, such as inductively coupled plasma etching or stealth dicing, and proper surface passivation is imperative as the electric field extends up to the edge. This is not the case for active-edge sensors. There, the electric field is terminated at the edge by extending the back electrode to the edge side-walls, for example by doping the edges after dicing. A doped edge, however, can result in a strong curvature of the junction's edge and could drastically lower the breakdown voltage of diode structures. From measurements on active-edge sensors an inactive area of only 2 μm was deduced. The price to pay for such small inactive areas is that the two outermost pixel columns of the matrix have a detection efficiency that depends on the depth of interaction, see Fig. 3.

Edgeless planar silicon sensors are interesting for applications that demand a detection area that is larger than the active area of a single readout chip. Examples in high-energy physics include detectors for close-to-beam and forward-physics experiments, such as the Roman Pots of the TOTEM experiment and the vertex detector of the LHCb experiment. Next to that, future full-field radiography detectors for medical imaging will benefit from edgeless sensors when based on intelligent, but small photon counting read-out chips like Medipix3.

Due to its advanced pixel circuitry Medipix3 can provide electronic-noise free and fine-grained colour X-ray images of high contrast, when bump-bonded to a good-quality mono-crystalline high-Z semiconductor sensor. Nevertheless, the limited active area of both the Medipix3 chip and single-crystal cadmium telluride sensor dies keep it from being a viable substitute for today's large-area X-ray imaging systems. Extensive studies

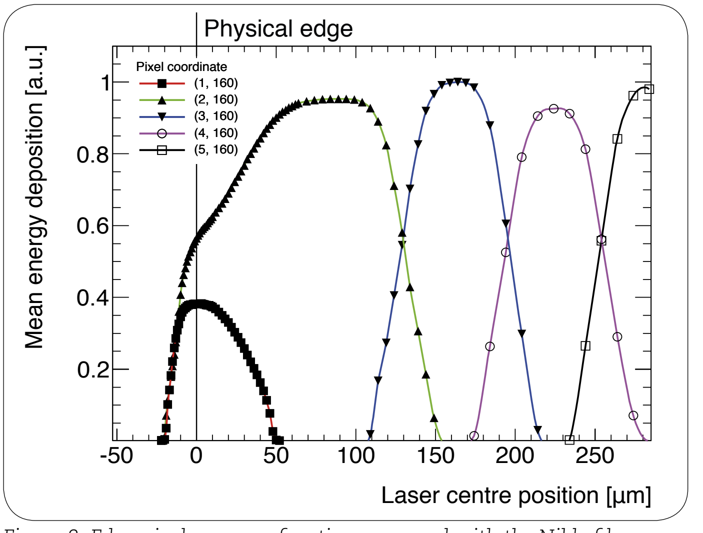


Figure 3. Edge-pixel response function measured with the Nikhef laser setup. The mean energy deposition recorded by single edge silicon pixels as a function of the laser spot centre position with respect to the physical edge, for 660 nm photons. Back side illumination; approximately 5 μm penetration depth.

have been performed on both active-edge silicon and slim-edge high-Z sensor materials such as gallium arsenide and cadmium telluride. The latter materials provide good absorption efficiency in the energy domain used in diagnostic radiography. Our work on CdTe and GaAs has shown that CdTe still exhibits serious polarisation effects that prevent continuous use. This effect shows up when irradiating the sensor under high flux and leads to a time-dependent decrease in counting rate and charge collection efficiency, mainly due to hole trapping which affects the electric field profile in the sensor. Power cycling is the only way to recuperate. GaAs does not show such effects and is still under study. The work on slim-edged CdTe devices has shown that the leakage current of a pixel in the first column does not deviate significantly from a pixel in the centre of the pixel matrix. It is encouraging to see that dicing only 65 μm from the pixel matrix does not compromise the performance of the edge pixels too much. This really makes it possible to look into tiling larger areas with CdTe without significant dead areas.

In addition to the extensive study on the viability of these sensors, the edge response and imaging performance have been characterised using a dedicated laser setup and X-ray setup.

2.10 Grid
Large-scale computing

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

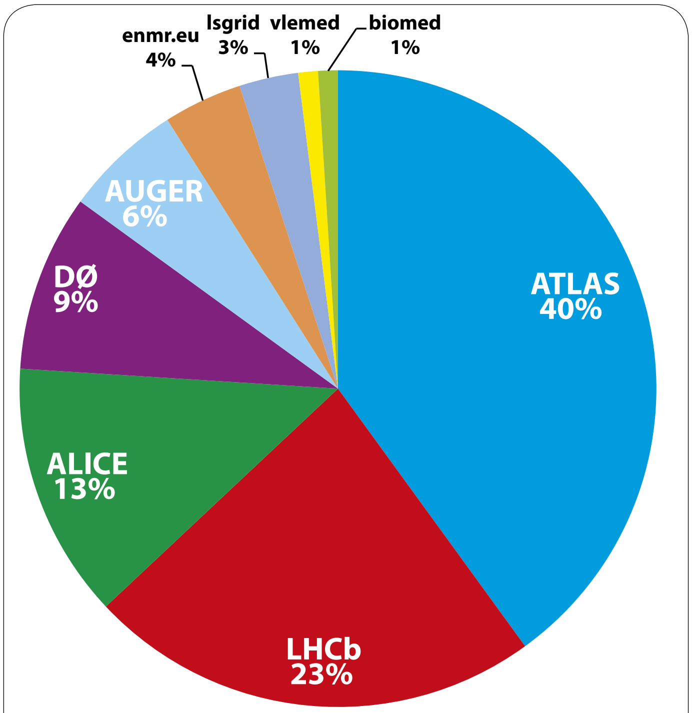
Ongoing Projects

Excellent progress has been made in the area of software development, in the context of two European Framework Projects in which we participate: European Middleware Initiative (EMI) and Initiative for Globus in Europe (IGE), despite a high overhead that accompanied the startup phase of those two projects. Our contributions to those projects are in the general area of 'grid security', one of our long-standing areas of specialisation and excellence. A related area is that of operational security in grids; Nikhef has the lead role in that area in the European Grid Initiative (EGI) project. We conducted a (very realistic) simulated cyber-attack on many grid sites across the globe as part of a large-scale test of grid security; these results were presented to an appreciative crowd at the 2011 EGI Technical Forum in Lyon, followed by a series of interviews, interest from companies, and YouTube films.

The BiG Grid project is now entering its final year, and as of this writing all the major communities identified in the original report are active on BiG Grid, with both LOFAR (radio astronomy) and DANS (humanities and social sciences) storing data on BiG Grid resources. So far there have been 44 new proposals to BiG Grid for use of the resources and/or assistance in developments needed to 'gridify' a scientific workflow. The proposals range from high-energy physics (XENON and Auger) to investigations of cloud-computing-based analyses by proteomics researchers. This and other cloud computing proposals will be run on the BiG Grid high-performance cloud instance at SARA, purchased in 2011.

For the Nikhef grid site, it has been business as usual in 2011. Business as usual entails constant improvements in monitoring and automation of responses to inevitable hardware or software failures, upgrades of infrastructure *e.g.*, an increase in internal network bandwidth from 160 to 200 Gb/s, deployment of new resources (compute and storage nodes) to follow our commitments to LHC experiments and to other scientific communities. Our infrastructure upgrades now take into account our plans to move in the direction of cloud computing in the medium term.

Fig. 1 shows how the computing power of the Nikhef grid cluster was used in 2011. The cluster now contains about 3600 cores of computing power and approximately 1.6 petabytes of storage, interconnected with 200 Gb/s of network bandwidth. A large part of this cluster and storage forms part of the Netherlands LHC Tier-1 computing centre; the rest is located at SARA, with slightly less computing power but significantly more storage as well as a large system for long-term data archiving based on magnetic tapes.



Nikhef grid cluster usage Dec. 2010 – Dec. 2011

Figure 1. Usage of computing resources on the Nikhef grid cluster in 2011. enmr.eu, lsgrid, vlemed, and biomed are all groups of life-sciences users; the other groups are from various high-energy physics experiments.

Data management and access

As reported last year, the group has a new activity in data management and access. We started this new activity for two reasons: firstly, as the volume of LHC data increases, data management and access become increasingly important to physicists in general and Nikhef physicists in particular. Secondly, most of our non-physics collaborators working on BiG Grid resources have a much bigger 'data' than 'compute' problem. These scientists are also more familiar with the windows-desktop analysis paradigm, hence our research focuses on ways of accessing grid data with standard tools, as well as new paradigms to improve the performance, efficiency, and ease of managing grid data.

Software distribution on the grid, and also on other computing infrastructures such as desktop machines and laptops, is a special case of data management; software is nothing more than executable data. This past year, we have deployed the CERN VM File System (CVMFS) on both our grid cluster as well as on the

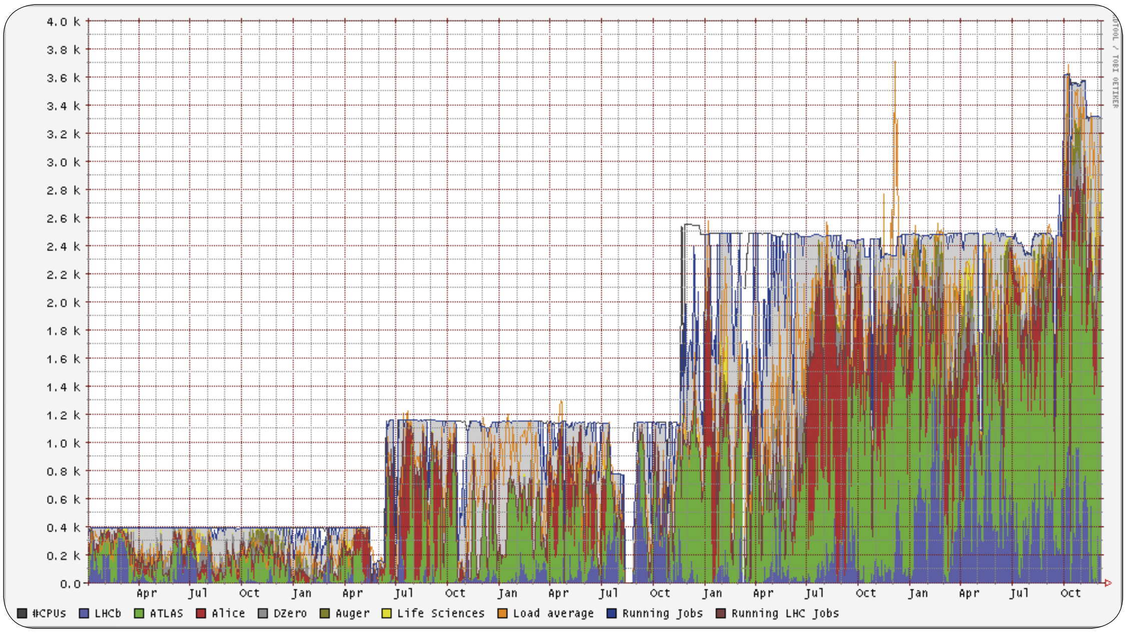


Figure 2. Jobs running on the Nikhef grid cluster, 2006-2011.The steps seen in the number of running jobs (vertical axis) are due to facility upgrades.

local analysis cluster. Files are added to CVMFS via an official experiment activity; these files are distributed worldwide via a tier of web caches, all the way down to the worker nodes. Files are only downloaded to the worker nodes when actually used. This is an important feature since the entire software suite of an experiment can measure in terabytes (including all versions still being used), whereas only a few gigabytes of this are actually in use on a worker node at any given moment.

We also carried out, in cooperation with the Software Technology Program at the Technical University of Eindhoven, a project to build a prototype grid data cache system. The goal of that project was to construct a prototype of the basic building block of a 'content delivery network' for grid data. A project mandate was to use existing components wherever possible, our attempt to buck the trend in high-energy physics computing of building our own products even though something already exists that will do the job. The project successfully delivered a prototype that worked well in two important cases: a) physics analysis, repeated processing of a fixed set of input files, and b) browsing of grid data via a windows or macintosh desktop computer. The system consists of 700 lines of code, which are all used to glue together existing components into a working system.

A final project in data access is that of replacing some of the important shared file systems in the Nikhef local computing infrastructure (a joint project with the computer technology group). Certain key file systems are mounted from user desktop machines, from the login servers, and from the local analysis cluster. Depending on how all those machines are being used, the file system can become unresponsive and in extreme cases makes it impossible to continue working on that file system until the 'offending user' can be found and convinced to moderate her usage. Moving to a distributed file system paradigm should improve the scalability of these shared systems, and the first user pilot tests are taking place on a cluster-based distributed system.

Formal methods in distributed systems

We started a new project in analysis of distributed computing systems, based on *Formal Methods*. The project is being carried out by a new PhD student in our group, who is also a member of the High Performance Distributed Computing group (Prof. dr. H. Bal) at the VU University Amsterdam. *Formal Methods* are mathematically-based techniques for the specification and verification of software and hardware systems. This project was inspired by our group's involvement in the *Stage Management System* (SMS) in the LHCb computing framework DIRAC. That system is responsible for accepting requests to *stage* files from tape onto disk, for example in preparation for a job that has requested to reprocess those data. DIRAC is largely based on small 'agent' programs which, based on the state of job or data requests, take simple actions (like "put this file on disk").We had seen that the state associated with jobs and files from time to time made 'impossible' transitions resulting in jobs or file requests being 'stuck'; an operator would have to manually change the states of those jobs or file requests in order to have them continue. A successful analysis demands identifying which features of the agents are important to mathematically model; also research focussed on inventing techniques to deal with the communication between agents, as formal methods are not normally applied to distributed systems. A paper on this research has been submitted to the CCGRrid conference.

3

Output

3.1 Publications

ATLAS/DØ

ATLAS Collaboration

G. Aad (*et al.*); S. Bentvelsen, G.J. Bobbink, K. Bos, H. Boterenbrood, E.J. Buis, M.A. Chelstowska, A.P. Colijn, M. Consonni, R. Dankers, C. Daum, A. Doxiadis, B. van Eijk, P. Ferrari, F. Filthaut, H. Garitaonandia, D.A.A. Geerts, M. Gosselink, H. van der Graaf, N. de Groot, F. Hartjes, P.J. Hendriks, N.P. Hessey, O. Igonkina, E. Jansen, P. de Jong, M.S. Kayl, Z. van Kesteren, P.F. Klok, S. Klous, P. Kluit, A.C. König, F. Koetsveld, E. Koffeman, A. Koutsman, E. van der Kraaij, H. Lee, R. van der Leeuw, T. Lenz, W. Liebig, 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, M. Rijpstra, N. Ruckstuhl, G. Salamanna, A. Salvucci, R. Sandstroem, R.C. Scholte, J. Snuverink, D. Ta, C.J.W.P. Timmermans, M. Tsiakiris, E. Turlay, W. Verkerke, J.C. Vermeulen, M. Vranjes Milosavljevic, M. Vreeswijk, I. van Vulpen

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AIP Conf. Proc. **1317** (2011) 9

ATLAS measurements of minimum bias and soft QCD
AIP Conf. Proc. **1317** (2011) 33

Diffraction and central exclusive production at ATLAS
AIP Conf. Proc. **1350** (2011) 164

Precision tests of the standard model using the ATLAS detector at the LHC
Acta Phys. Polon. **B 42** (2011) 1365

Heavy ion physics with the ATLAS detector
Acta Phys. Polon. **B 42** (2011) 1393

First results from the ATLAS experiment on production of W and Z bosons in proton-proton collisions at $\sqrt{s}$=7 TeV
Acta Phys. Polon. **B 42** (2011) 1505

The AFP Project
Acta Phys. Polon. **B 42** (2011) 1615

Electron performance with J/ψ with the ATLAS detector
Acta Phys. Polon. **B 42** (2011) 1645

Performance of tau trigger and tau reconstruction in ATLAS in pp collisions at $\sqrt{s}$=7 TeV
Acta Phys. Polon. **B 42** (2011) 1689

Performance of tau lepton identification in ATLAS 7 TeV data
Acta Phys. Polon. **B 42** (2011) 1717

Methods of multiplicity reconstruction in heavy ion collisions in the ATLAS experiment
Acta Phys. Polon. **B 42** (2011) 1729

QCD at ATLAS: The story so far
Acta Phys. Polon. Supp. **4** (2011) 615

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Eur. Phys. J. **C 71** (2011) 1512

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Eur. Phys. J. **C 71** (2011) 1577

Studies of the performance of the ATLAS detector using cosmic-ray muons
Eur. Phys. J. **C 71** (2011) 1593

Luminosity determination in pp collisions at $\sqrt{s}$=7 TeV using the ATLAS detector at the LHC
Eur. Phys. J. **C 71** (2011) 1630

Measurements of underlying-event properties using neutral and charged particles in pp collisions at $\sqrt{s}$=900 GeV and $\sqrt{s}$=7 TeV with the ATLAS detector at the LHC
Eur. Phys. J. **C 71** (2011) 1636

Search for an excess of events with an identical flavour lepton pair and significant missing transverse momentum in $\sqrt{s}$=7 TeV proton-proton collisions with the ATLAS detector
Eur. Phys. J. **C 71** (2011) 1647

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Eur. Phys. J. **C 71** (2011) 1682

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Eur. Phys. J. **C 71** (2011) 1728

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Eur. Phys. J. **C 71** (2011) 1744

Measurement of multi-jet cross sections in proton-proton collisions at a 7 TeV center-of-mass energy
Eur. Phys. J. **C 71** (2011) 1763

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Eur. Phys. J. **C 71** (2011) 1795

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Eur. Phys. J. **C 71** (2011) 1809

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Measurement of the inclusive and dijet cross-sections of b-jets in pp collisions at $\sqrt{s}$=7 TeV with the ATLAS detector
Eur. Phys. J. **C 71** (2011) 1846

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Indian J. Phys. **85** (2011) 1063

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J. High Energy Phys. **1109** (2011) 053

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J. High Energy Phys. **1109** (2011) 072

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J. High Energy Phys. **1110** (2011) 107

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J. High Energy Phys. **1111** (2011) 099

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J. Instr. **6** (2011) C 01019

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J. Instr. **6** (2011) C 01054

The ATLAS level-1 central trigger
J. Instr. 6 (2011) C 01075

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J. Instr. **6** (2011) C 01078

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J. Instr. **6** (2011) C 01082

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J. Phys. Conf. Ser. **270** (2011) 012013

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J. Phys. Conf. Ser. **293** (2011) 012015

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J. Phys. Conf. Ser. **293** (2011) 012027

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J. Phys. Conf. Ser. **293** (2011) 012031

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J. Phys. Conf. Ser. **293** (2011) 012053

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J. Phys. Conf. Ser. **293** (2011) 012055

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J. Phys. Conf. Ser. **293** (2011) 012061

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J. Phys. Conf. Ser. **293** (2011) 012063

First measurement of jets and missing transverse energy with the ATLAS calorimeter at $\sqrt{s}$=900 GeV and $\sqrt{s}$=7 TeV
J. Phys. Conf. Ser. **293** (2011) 012064

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J. Phys. Conf. Ser. **293** (2011) 012065

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J. Phys. Conf. Ser. **323** (2011) 012002

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J. Phys. Conf. Ser. **323** (2011) 012005

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J. Phys. Conf. Ser. **323** (2011) 012006

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J. Phys. Conf. Ser. **323** (2011) 012008

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J. Phys. Conf. Ser. **331** (2011) 032046

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Nucl. Instrum. Meth. **A 633** (2011) S216

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Nucl. Phys. Proc. Suppl. **210** (2011) 3

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Nucl. Phys. Proc. Suppl. **210** (2011) 29

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Nucl. Phys. Proc. Suppl. **210** (2011) 37

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Nucl. Phys. Proc. Suppl. **210** (2011) 49

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Nucl. Phys. Proc. Suppl. **215** (2011) 85

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Nucl. Phys. Proc. Suppl. **215** (2011) 176

The performance of the ATLAS inner detector trigger algorithms in pp collisions at the LHC
Nucl. Phys. Proc. Suppl. **215** (2011) 211

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Nucl. Phys. Proc. Suppl. **218** (2011) 267

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Nucl. Phys. Proc. Suppl. **218** (2011) 273

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Nucl. Phys. Proc. Suppl. **218** (2011) 285

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Phys. Lett. **B 697** (2011) 294

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Phys. Lett. **B 698** (2011) 325

Search for Massive Long-lived Highly Ionising Particles with the ATLAS Detector at the LHC
Phys. Lett. **B 698** (2011) 353

Search for high mass dilepton resonances in pp collisions at $\sqrt{s}=7$ TeV with the ATLAS experiment
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Search for stable hadronising squarks and gluinos with the ATLAS experiment at the LHC
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Search for Heavy Long-Lived Charged Particles with the ATLAS detector in pp collisions at $\sqrt{s}=7$ TeV
Phys. Lett. **B 703** (2011) 428

Measurement of the $\Upsilon(1S)$ production cross-section in pp collisions at $\sqrt{s}=7$ TeV in ATLAS
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Search for a heavy gauge boson decaying to a charged lepton and a neutrino in 1 fb^{-1} of pp collisions at $\sqrt{s}=7$ TeV using the ATLAS detector
Phys. Lett. **B 705** (2011) 28

Search for neutral MSSM Higgs bosons decaying to $\tau^+\tau^-$ pairs in proton-proton collisions at $\sqrt{s}=7$ TeV with the ATLAS detector
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Phys. Lett. **B 706** (2011) 150

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Phys. Part. Nucl. Lett. **8** (2011) 875

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Phys. Part. Nucl. Lett. **8** (2011) 891

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Phys. Rev. **D 83** (2011) 052003

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Phys. Rev. **D 83** (2011) 112001

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Phys. Rev. **D 84** (2011) 112006

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Phys. Rev. Lett. **106** (2011) 121803

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Phys. Rev. Lett. **106** (2011) 172002

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Phys. Rev. Lett. **106** (2011) 251801

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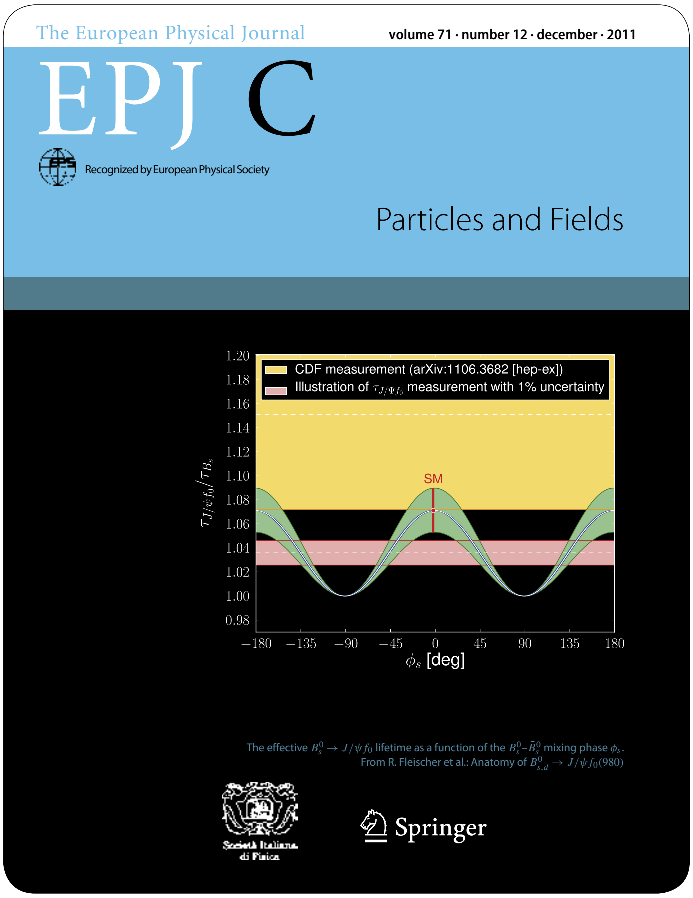

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A study of the b–quark fragmentation function with the DELPHI detector at LEP I and an averaged distribution obtained at the Z Pole
Eur. Phys. J. **C 71** (2011) 1557

L3 Collaboration
P. Achard *(et al.)*; M. van den Akker, S.V. Baldew, G.J. Bobbink, T. Csoergo, M. Dierckxsens, F. Filthaut, H. Groenstege, R. Hakobyan, P. de Jong, W. Kittel, A.C. König, E. Kok, J. Kuijpers, F.L. Linde, D. Mangeol, W.J. Metzger, A. van Mil, A.J.M. Muijs, T. Novak, B. Petersen, P. Rewiersma, A. Rojkov, D.J. Schotanus, C. Timmermans, H. Verkooijen, R.T. van de Walle, R.T. van der Walle, Q. Walle, R.T. van der Wang, Q. Wang, A.M. Wijnen, H. Wilkens

The solar flare of the 14^{th} of July 2000 (L3+C detector results)
Astron. Astrophys. **465** (2011) 351

Test of the τ–model of Bose–Einstein correlations and reconstruction of the source function in hadronic Z–boson decay at LEP
Eur. Phys. J. **C 71** (2011) 1648

Generalized event shape and energy flow studies in e^+e^- annihilation at $\sqrt{s}$=91.2–208.0 GeV
J. High Energy Phys. **10** (2011) 143

Miscellaneous

M. Botje
QCDNUM: Fast QCD evolution and convolution
Comput. Phys. Commun. **182** (2011) 490

G. Audi *(et al.)*; A.H. Wapstra
Atomic Mass Evaluation: the Mass Tables
J. Korean Phys. Soc. **59** (2011) 1318

P. Mulders, M. Vreeswijk
Fysica 2011, Energie en Klimaat
Ned. T. Nat. **77** (2011) 77

I.A. Rachek *(et al.)*; H. de Vries
Photoreactions with tensor–polarized deuterium target at VEPP–3
J. Phys. Conf. Series **295** (2011) 012106

Q.H.C. Snippe, T. Meinders
Mechanical experiments on the superplastic material ALNOVI–1, including leak information
Mater. Sci. Eng. **A 528** (2011) 950

KamLAND Collaboration
S. Abe *(et al.)*; M.P. Decowski
Partial radiogenic heat model for Earth revealed by geoneutrino measurements
Nature Geoscience **4** (2011) 647

Measurement of the ^8B solar neutrino flux with the KamLAND liquid scintillator detector
Phys. Rev. **C 84** (2011) 035804

Constraints on θ_{13} from a three–flavor oscillation analysis of reactor antineutrinos at KamLAND
Phys. Rev. **D 83** (2011) 052002

D. Pennink
Het HiSPARC–detector signaal verklaard
Ned. T. Nat. **77** (2011) 432

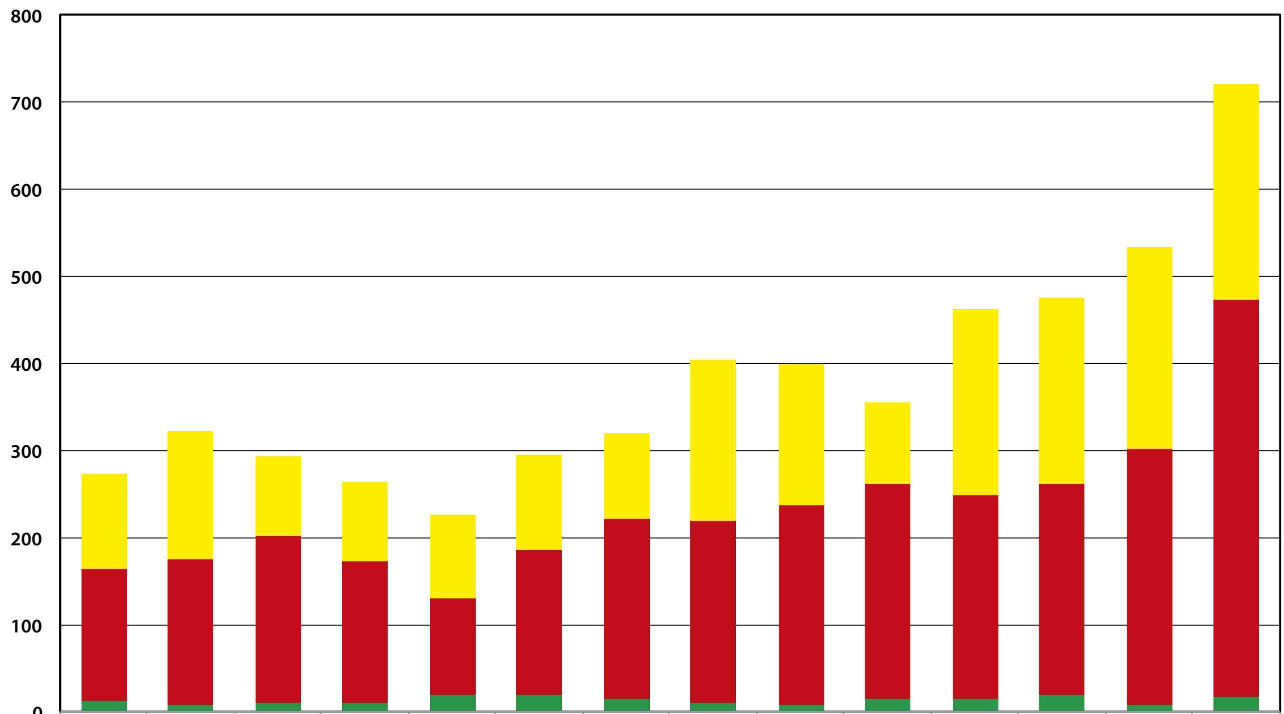
NA49 Collaboration (Heavy Ion Physics)
C. Alt *(et al.)*; M. Botje, P. Christakoglou, M.A. van Leeuwen

Proton–Λ correlations in central Pb+Pb collisions at $\sqrt{s_{NN}}$=17.3 GeV
Phys. Rev. **C 83** (2011) 054806

Energy dependence of kaon–to–proton ratio fluctuations in central Pb+Pb collisions from $\sqrt{s_{NN}}$=6.3 to 17.3 GeV
Phys. Rev. **C 83** (2011) 061902

$K^*(892)^0$ and $\bar{K}^*(892)^0$ production in central Pb+Pb, Si+Si, C+C, and inelastic p+p collisions at 158A GeV
Phys. Rev. **C 84** (2011) 064909

WA98 Collaboration
M.M. Aggarwal *(et al.)*; N.J.A.M. van Eijndhoven, F.J.M. Geurts, R. Kamermans, T. Peitzmann, E.C. van der Pijll
Event–by–event charged–neutral fluctuations in Pb+Pb collisions at 158A GeV
Phys. Lett. **B 701** (2011) 300



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Talks	109	147	92	91	95	108	97	186	162	93	212	215	231	248
Publications	150	165	190	163	113	168	207	209	228	246	234	243	293	455
Theses	13	9	11	10	18	18	15	10	9	15	15	18	8	17

Figure 2. Nikhef's scientific output in the past 14 years.

3.2 Theses

Ermes Braidot
Two-particle azimuthal correlations at forward rapidity in STAR
Universiteit Utrecht, 17 January 2011
Promotores: T. Peitzmann, E.L.N.P. Laenen
Copromotor: A. Mischke

Andreas Obermeier
A Direct Measurement of Cosmic Rays to Very High Energies: Implications for Galactic Propagation and Sources
Radboud Universiteit Nijmegen, 23 February 2011
Promotores: S.J.de Jong, D. Mueller
Copromotor: J.R. Hörandel

Quirin Hendrik Catherin Snippe
Design and optimization of vertex detector foils by superplastic forming
Universiteit Twente, 16 March 2011
Promotor: J. Huétink
Copromotores: V.T. Meinders, R. Akkerman, B. van Eijk, M.H.M. Merk

Manouk Rijpstra
The Top and Beyond: Missing Energy and Little Higgs in ATLAS
Universiteit van Amsterdam, 17 March 2011
Promotor: S.C.M. Bentvelsen
Copromotor: M. Vreeswijk

Jan Mennis Amoraal
Alignment with Kalman filter fitted tracks and reconstruction of $B_s^0 \rightarrow J/\Psi\Phi$ *decays*
Vrije Universiteit Amsterdam, 11 April 2011
Promotor: M.H.M Merk
Copromotor: W.D. Hulsbergen

Eric Jansen
Supersymmetry search using Z^0 *bosons produced in neutralino decays at the ATLAS detector*
Radboud Universiteit Nijmegen, 11 April 2011
Promotor: N. de Groot

Manuel Sebastian Kayl
Measurement of the charged particle density with the ATLAS detector: First data at $\sqrt{s}$ *= 0.9, 2.36 and 7 TeV*
Universiteit van Amsterdam, 13 May 2011
Promotor: E.N. Koffeman
Copromotor: A.P. Colijn

Gordon Max Alphonsius Lim
Searching for Dark Matter with the Antares Neutrino Telescope
Universiteit van Amsterdam, 26 May 2011
Promotores: P.M. Kooijman, M. de Jong

Eleonora Presani
Neutrino Induced Showers from Gamma-ray Bursts
Universiteit van Amsterdam, 27 May 2011
Promotor: P.M. Kooijman
Copromotores: C.J. Reed, E. de Wolf

Aleksei Jakovlevich Koutsman
On the road to Supersymmetry with ATLAS
Radboud Universiteit Nijmegen, 5 July 2011
Promotor: N. de Groot
Copromotor: W. Verkerke

Alexander Dimos Doxiadis
Searching for the Top: observation of the heaviest elementary particle at the LHC
Universiteit van Amsterdam, 7 July 2011
Promotor: S.C.M. Bentvelsen
Copromotor: I.B. van Vulpen

Sybren Harmsma
Radio signals of cosmic-ray-induced air showers at the Pierre Auger Observatory
Rijksuniversiteit Groningen, 8 July 2011
Promotores: A.M. van den Berg, F.L. Linde

Michele Maio
Permutation Orbifolds in Conformal Field Theories and String Theory
Radboud Universiteit Nijmegen, 5 October 2011
Promotor: A.N.J.J. Schellekens

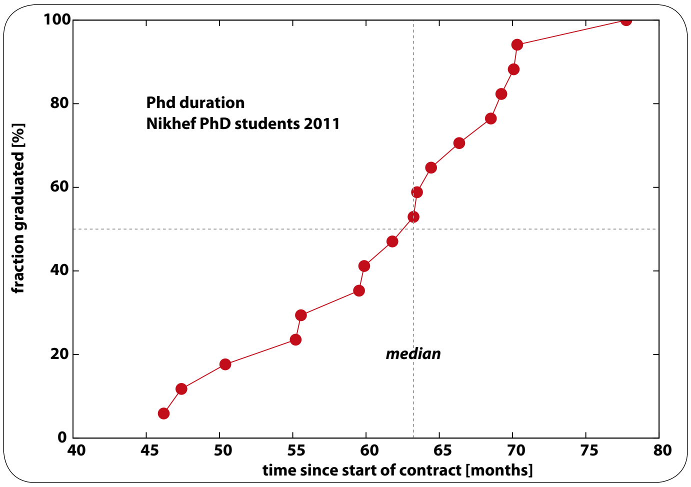


Figure 1. Fraction of PhD students working at Nikhef that graduated in the year 2011 as a function of time since the start of their thesis contract. The median PhD duration is 63 months (5.3 year).

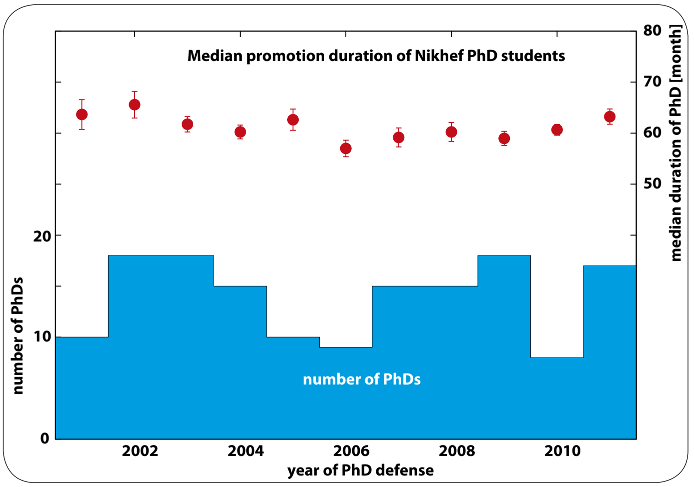


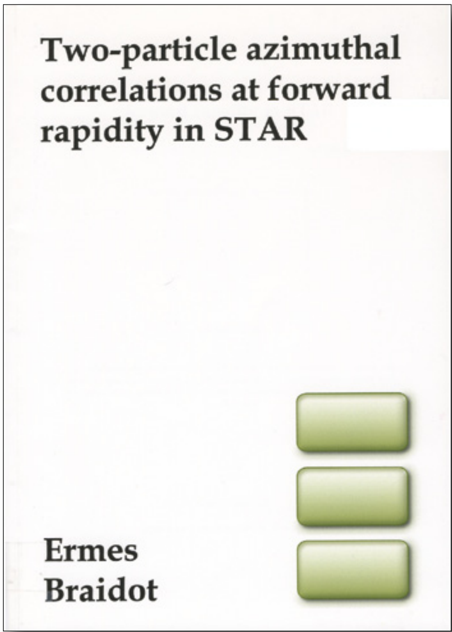
Figure 2. Median PhD duration of Nikhef PhD students since 2001 as a function of graduation year. The error bars represent the median absolute deviation (MAD)/√(n-1). The histogram gives the total number n of PhDs in each year.

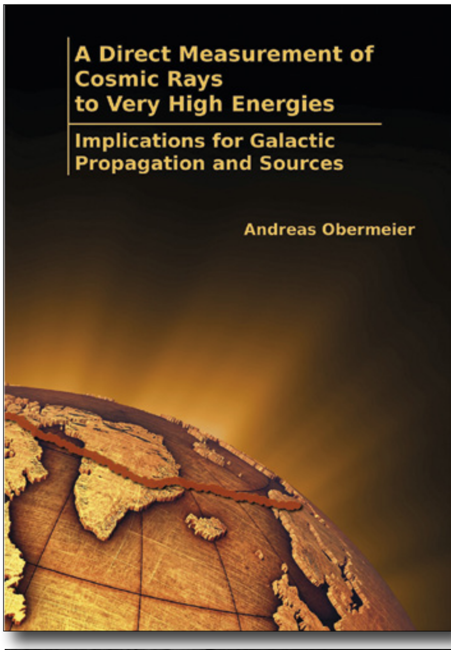
Josephina Maria Sophia Coppens
Cosmic rays are on the air: Studying the properties of radio signals from cosmic-ray induced air showers
Radboud Universiteit Nijmegen, 26 October 2011
Promotores: S. de Jong, F. Linde
Copromotor: C. Timmermans

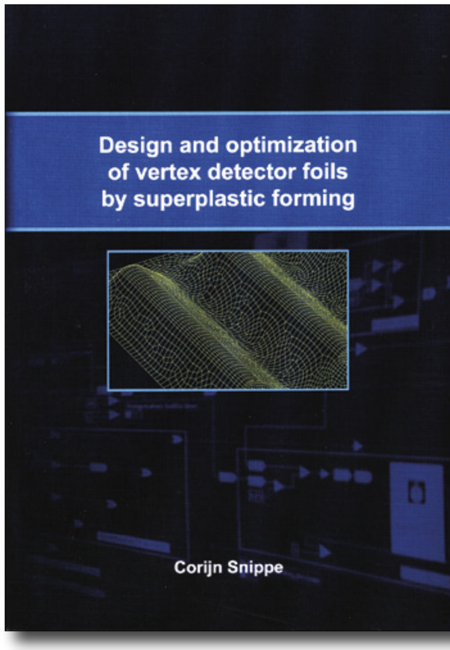
Sipho van der Putten
Thermal lensing in Virgo and Polynomial search: an all-sky search for gravitational waves from spinning neutron stars in binary systems
Vrije Universiteit Amsterdam, 6 December 2011
Promotores: J.F.J. van den Brand, F.L. Linde

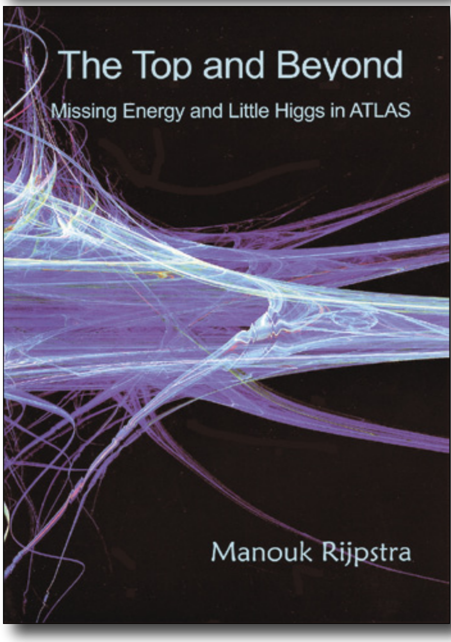
Gideon Koekoek
The Geodesic Deviation Method and Extreme Mass-ratio Systems: Theoretical methods and application to the calculation of gravitational waves
Vrije Universiteit Amsterdam, 15 December 2011
Promotores: J.F.J. van den Brand, J.W. van Holten

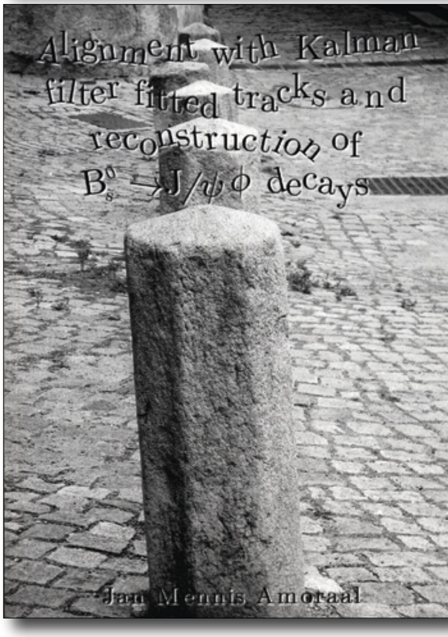
Fabian Jansen
Unfolding single-particle efficiencies and the Outer Tracker of the LHCb
Vrije Universiteit Amsterdam, 16 December 2011
Promotor: M.H.M. Merk
Copromotores: N. Tuning, A. Pellegrino

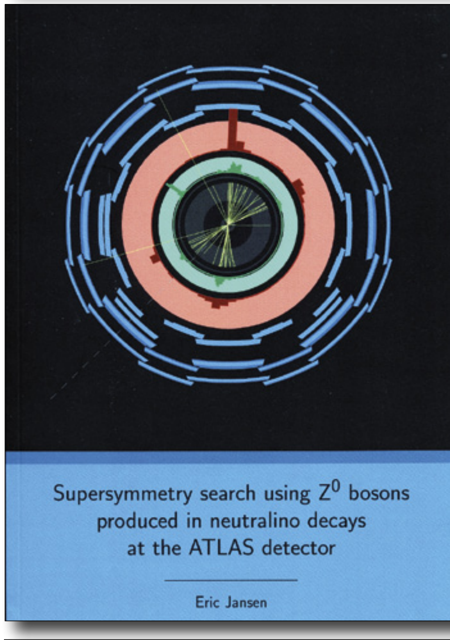

Two-particle azimuthal correlations at forward rapidity in STAR
Ermes Braidot

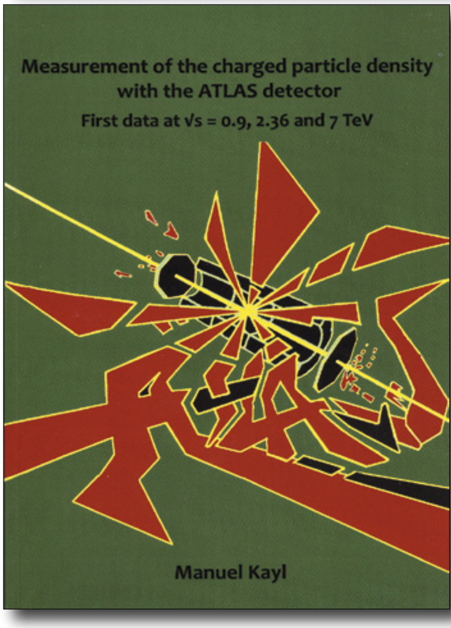

A Direct Measurement of Cosmic Rays to Very High Energies
Implications for Galactic Propagation and Sources
Andreas Obermeier

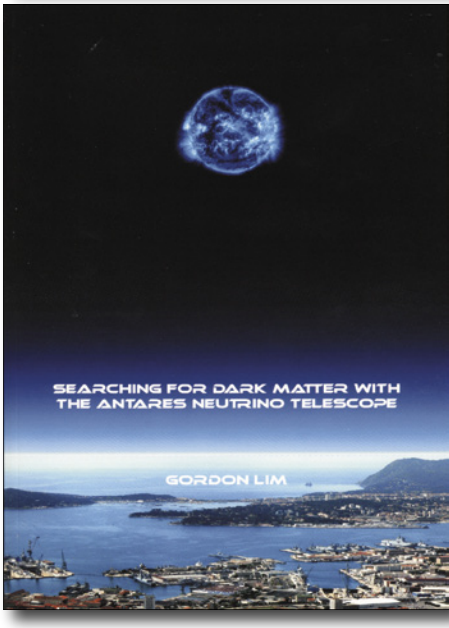

Design and optimization of vertex detector foils by superplastic forming
Corijn Snippe

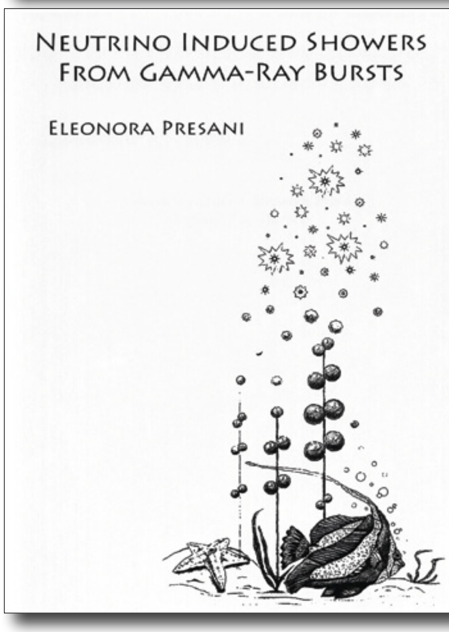

The Top and Beyond
Missing Energy and Little Higgs in ATLAS
Manouk Rijpstra


Alignment with Kalman filter fitted tracks and reconstruction of $B^0_s \to J/\psi\phi$ decays
Jan Mennis Amoraal

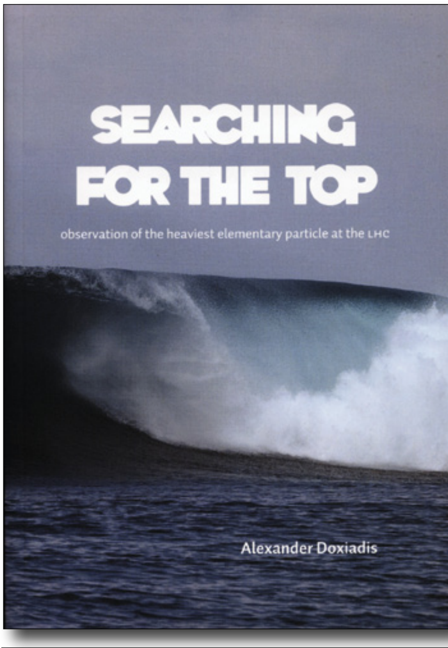

Supersymmetry search using Z^0 bosons produced in neutralino decays at the ATLAS detector
Eric Jansen

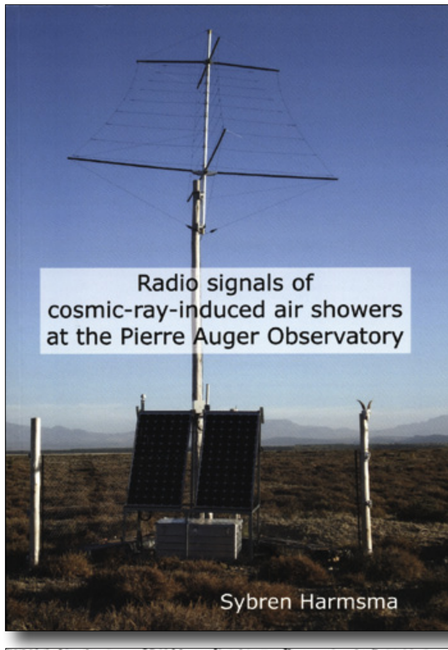

Measurement of the charged particle density with the ATLAS detector
First data at √s = 0.9, 2.36 and 7 TeV
Manuel Kayl

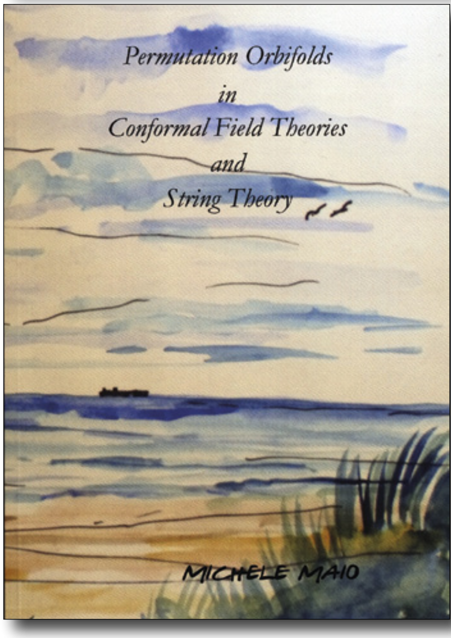

SEARCHING FOR DARK MATTER WITH THE ANTARES NEUTRINO TELESCOPE
GORDON LIM

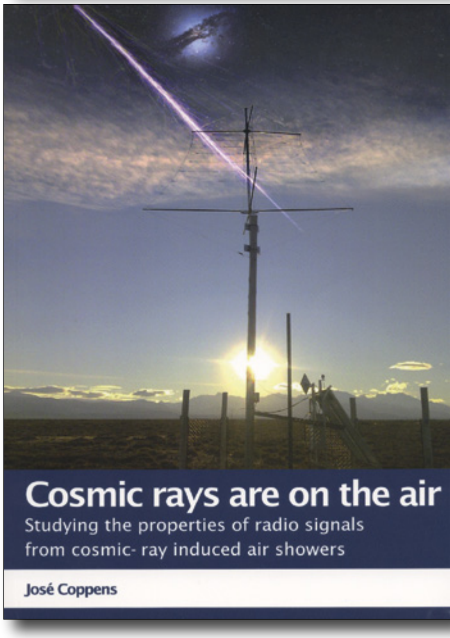

NEUTRINO INDUCED SHOWERS FROM GAMMA-RAY BURSTS
ELEONORA PRESANI

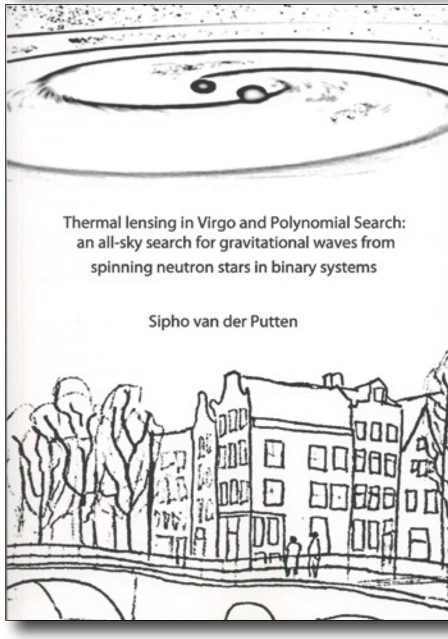

ON THE ROAD TO SUPERSYMMETRY WITH ATLAS
ALEX KOUTSMAN

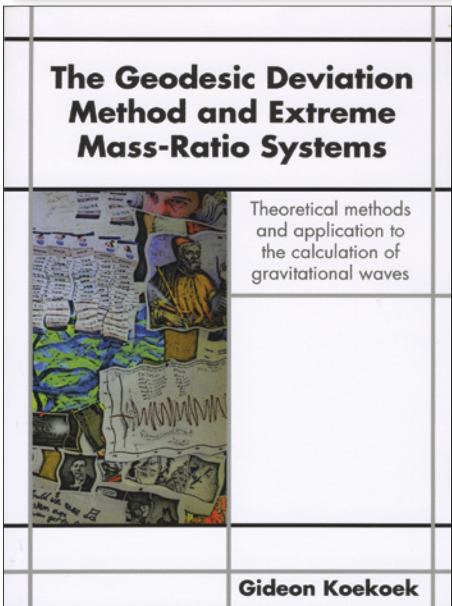

SEARCHING FOR THE TOP
observation of the heaviest elementary particle at the LHC
Alexander Doxiadis

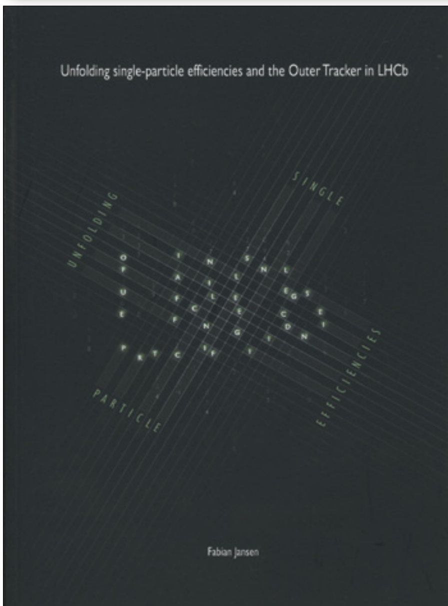

Radio signals of cosmic-ray-induced air showers at the Pierre Auger Observatory
Sybren Harmsma


Permutation Orbifolds in Conformal Field Theories and String Theory
MICHELE MAIO


Cosmic rays are on the air
Studying the properties of radio signals from cosmic- ray induced air showers
José Coppens


Thermal lensing in Virgo and Polynomial Search: an all-sky search for gravitational waves from spinning neutron stars in binary systems
Sipho van der Putten


The Geodesic Deviation Method and Extreme Mass-Ratio Systems
Theoretical methods and application to the calculation of gravitational waves
Gideon Koekoek


Unfolding single-particle efficiencies and the Outer Tracker in LHCb
Fabian Jansen

3.3 Talks

ATLAS/DØ

Bentvelsen, S., New results on LHC physics, Int. Conf. on baryogenesis, Leiden, The Netherlands,31 August 2011

Physics at the LHC, University of Amsterdam, Amsterdam, The Netherlands, 7 December 2011

Hessey, N.P., ATLAS Upgrade Plans, SLHC, the High-Luminosity Upgrade (public event), Geneva, Switzerland, 8 March 2011

Final status of WP3: Coordination of S-ATLAS experiment implementation, SLHC-PP Annual Meeting, Paris, France, 7 February 2011

Igonkina, O.B., Supersymmetry and Beyond Standard Model Higgs at ATLAS, Hadron Collider Physics Symposium, Paris, France, 17 November 2011

Jong, P.J. de, First searches for new physics beyond the Standard Model with the ATLAS experiment at the LHC, Physics@FOM 2011, Veldhoven, The Netherlands, 18 January 2011

Supersymmetry searches in ATLAS, Hadron Collider Physics Symposium, Paris, France, 17 November 2011

BSM/Supersymmetry searches in ATLAS, Amsterdam Particle Physics Symposium, Amsterdam, The Netherlands, 30 November 2011

Jong, S.J. de, The Higgs: elusive, illusive, delusive, Quantum Universe 1, University of Groningen, Groningen, The Netherlands, 20 April 2011

Mechnich, J., Tau Leptons from Top Quark Pair Decays in ATLAS, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

Mussche, I., Top quark physics results from ATLAS, HEP-MAD, Antananarivo, Madagascar, 26 August 2011

Salvucci, A., Measurement of the muon momentum resolution using the ATLAS detector, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

Ta, D.B., Top Quark Mass and Properties at ATLAS, Particles and Nuclei Int. Conf. (PANIC11), Cambridge, USA, 28 July 2011

Single top at ATLAS, Amsterdam Particle Physics Symposium, Amsterdam, The Netherlands, 1 December 2011

Verkerke, W., Measurement of W+jet production and of the top-pair production cross-section with ATLAS, CERN LPCC Seminar, Geneva, Switzerland, 1 February 2011

Advanced methods in statistical data analysis (I), Nordic PhD School, Niels Bohr Institute, Copenhagen, Denmark, 14 November 2011

Advanced methods in statistical data analysis (II), Nordic PhD School, Niels Bohr Institute, Copenhagen, Denmark, 15 November 2011

Advanced methods in statistical data analysis (III), Nordic PhD School, Niels Bohr Institute, Copenhagen, Denmark, 16 November 2011

Higgs statistics explained, Amsterdam Particle Physics Symposium, Amsterdam, The Netherlands, 1 December 2011

LHCb/BABAR

Beuzekom, M.G. van, Performance of the LHCb Detector during 2010-2011 data taking, Europhysics Conf. on High-Energy Physics 2011, Grenoble, France, 22 July 2011

Performance of the LHCb Vertex Locator, 2011 IEEE Nuclear Science Symposium andMedical Imaging Conference, Valencia, Spain, 25 October 2011

Eijk, van, D., Search for CP violation in the B_s–$\bar{B}_s$ system with LHCb, DPF 2011, Providence, USA, 10 August 2011

Hulsbergen, W.D., Results from the LHCb Experiment, SLAC Summer Institute 2011, Menlo Park, USA, 15 April 2011

Neutral meson mixing, IPPP Workshop on Flavour and the 4th Family, Durham, United Kingdom, 15 September 2011

Constraining New Physics in B_s oscillations at LHCb, CERN LHC seminar, Meyrin, Switzerland, 25 October 2011

Searches for New Physics with the LHCb experiment, Amsterdam Particle Physics Symposium, Amsterdam, The Netherlands, 1 December 2011

Koppenburg, P.S., LHCb Status and First Results, Physics@FOM 2011, Veldhoven, The Netherlands, 18 January 2011

Heavy Flavour Results at the LHC, Physics in Collision, Vancouver, Canada, 30 August 2011

Pellegrino, A., The LHCb experiment upgrade, CBPF, LISHEP conference, Rio de Janeiro, Brazil, 9 July 2011

A High-Performance Tracking System for the LHCb Spectrometer, CERN Seminar, Geneva, Switzerland, 16 September 2011

Raven, G., CP Violation (I), CERN Summer Student Lecture Program, Geneva, Switzerland, 2 August 2011

CP Violation (II), CERN Summer Student Lecture Program, Geneva, Switzerland, 4 August 2011

CP Violation (III), CERN Summer Student Lecture Program, Geneva, Switzerland, 5 August 2011

CP Violation (IV), CERN Summer Student Lecture Program, Geneva, Switzerland, 8 August 2011

B Physics Results from the LHC, XXV Int. Symposium on Lepton and Photon Interactions at High Energies, Mumbai, India, 27 August 2011

Storaci, B., Rare decays results and prospects with LHCb, Lake Louise Winter Conf., Lake Louise, Canada, 22 February 2011

The Performance of the Outer Tracker Detector at LHCb, 13th ICATPP Conf., Como, Italy, 3 October 2011

Tuning, N., b production cross section and fragmentation fractions at LHCb, 13th Int.Conf. on B-Physics at Hadron Machines, Amsterdam, The Netherlands, 4 April 2011

Lectures CP Violation, Capita Selecta Vrije Universiteit Brussel, Brussels, Belgium, 19 April 2011

View on recent results of LHCb, Amsterdam Particle Physics Symposium, Amsterdam, The Netherlands, 30 November 2011

ALICE/STAR

Bilandzic, A., Anisotropic flow of charged particles at $\sqrt{s_{NN}}$=2.76 TeV measured with the ALICE detector, Quark Matter 2011, Annecy, France, 23 May 2011

Botje, M., Introduction to Bayesian Inference (I), FANTOM Research School, Groningen, The Netherlands, 7 November 2011

Introduction to Bayesian Inference (II), FANTOM Research School, Groningen, The Netherlands, 8 November 2011

Introduction to Bayesian Inference (III), FANTOM Research School, Groningen, The Netherlands, 9 November 2011

Introduction to Bayesian Inference (IV), FANTOM Research School, Groningen, The Netherlands, 10 November 2011

Christakoglou, P., QCD phase transition, hydrodynamics, hadronization from the experimental point of view, Quark Matter 2011, Annecy, France, 22 May 2011

Charge dependent azimuthal correlations in Pb–Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV, Quark Matter 2011, Annecy, France, 27 May 2011

First results on the event-by-event fluctuations and correlations inPb–Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV, EPS-HEP 2011, Grenoble, France, 21 July 2011

Charge separation measurements in Pb–Pb collisions at LHC energies, Rutherford Centennial Conf. on Nuclear Physics, Manchester, United Kingdom, 11 August 2011

Kuijer, P.G., Results from the ALICE experiment, Barcelona University, Barcelona, Spain, 31 January 2011

Soft physics in PbPb at the LHC, Hadron Collider Physics, Paris, France, 15 November 2011

Leeuwen, M. van, Jets, high-p_T hadrons and prompt photons (student lecture), Quark Matter 2011, Annecy, France, 22 May 2011

The Quark Gluon Plasma as seen by ALICE, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

High-p_T results from ALICE, Hadron Collider Physics Symposium 2011, Paris, France, 14 November 2011

Mischke, A., Heavy-flavour particle correlations – From RHIC to LHC, Int. Workshop on Heavy Quark Production in Heavy-ion Collisions, Purdue University, USA, 5 January 2011

Jet-like correlations of heavy-flavour particles, 27th Winter Workshop on Nuclear Dynamics, Winter Park, Colorado, USA, 9 February 2011

Heavy-flavour production in p–p and Pb–Pb collisions at ALICE, XLVI Rencontres de Moriond on “QCD and High Energy Hadronic Interactions”, La Thuile, Italy, 23 March 2011

A first taste of hot dense matter at the LHC by ALICE, Physics Colloquium, Kernfysisch Versneller Instituut, Groningen, The Netherlands, 23 August 2011

Heavy Ion Results from the ALICE Experiment at LHC, High Energy Physics Colloquium, Radboud University, Nijmegen, The Netherlands, 8 September 2011

Nooren, G.J., Extremely fine grained electro-magnetic calorimeter, 10th Int. Conf. Large Scale Applications and Radiation Hardness of Semiconductor Detectors, Florence, Italy, 7 July 2011

Snellings, R., A “little Bang” arrives at the LHC (and is seen by ALICE), Johann Wolfgang Goethe University, Frankfurt, Germany, 3 February 2011

Hydrodynamics (Experiment), Int. School on Quark-Gluon Plasma and Heavy Ion Collisions: past, present, future, Torino, Italy 2011, 10 March 2011

Hydrodynamics (Experiment), Int. School on Quark-Gluon Plasma and Heavy Ion Collisions: past, present, future, Torino, Italy 2011, 11 March 2011

Hydrodynamics (Experiment), Int. School on Quark-Gluon Plasma and Heavy Ion Collisions: past, present, future, Torino, Italy 2011, 12 March 2011

A “little Bang” arrives at the LHC (and is seen by ALICE), 6th International Workshop High-p_T physics at LHC 2011, Utrecht, The Netherlands, 6 April 2011

Anisotropic Flow Measurements from ALICE, Quark Matter 2011, Annecy, France, 24 May 2011

Anisotropic Flow Measurements from ALICE, EPIC 2011, Bari, Italy, 7 July 2011

Anisotropic Flow Measurements from ALICE, Symposium on jet physics at RHIC and LHC, Hangzhou, China, 18 July 2011

Collective Motion, Rutherford Centennial Conf. on Nuclear Physics, Manchester, United Kingdom, 12 August 2011

Angular Correlations, Niels Bohr Institute, Copenhagen, Denmark, 7 November 2011

Azimuthal Anisotropy (a few selected topics), XII GDRE Workshop on Relativistic Heavy Ion Physics, Warsaw, Poland, 7 December 2011

Angular Correlations of Hadrons Measured at the LHC, Recontres du Vietnam, Qui Nhon, Vietnam, 18 December 2011

Verweij, M., Modeling energy loss in a realistic geometry, 6th Int. Workshop High-p_T physics at LHC 2011, Utrecht, The Netherlands, 6 April 2011

Jets in ALICE, High-p_T Probes of High-Density QCD at the LHC – Ecole Polytechnique, Palaiseau, Paris, France, 30 May 2011

Zhou, Y., Higher harmonic anisotropic flow measurements of charged particles at 2.76 TeV with the ALICE detector, Strangeness in Quark Matter, Krakow, Poland, 23 September 2011

Azimuthal correlations in Pb–Pb and pp collisions measured with the ALICE detector, CPOD2011, Central China Normal University, Wuhan, China, 10 November 2011

ANTARES/KM3NeT

Astraatmadja, T.L., Detecting TeV Gamma-rays from GRB with km^3 neutrino telescopes, 7th TeV Particle Astrophysics Conference, Oskar Klein Centre, Stockholm, Sweden, 4 August 2011

Bogazzi, C., Searching for point sources of high energy cosmic neutrinos with the ANTARES telescope, 32nd Int. Cosmic Ray Conf., Beijing, China, 11 August 2011

Time integrated search for point sources of cosmic neutrinos with the ANTARES telescope, Very Large Volume Neutrino Telescope Workshop 2011, Erlangen, Germany, 12 October 2011

Heijboer, A., Recent results from the ANTARES deep sea neutrino telescope, 32nd Int. Cosmic Ray Conf., Beijing, China, 11 August 2011

Hsu, C.C., Cosmic ray composition study using ANTARES telescope, 13th ICATPP 2011, Como, Italy, 8 October 2011

Mul, G., A vertical electro-optical backbone cable for KM3NeT, Very Large Volume Neutrino Telescope Workshop, Erlangen, Germany, 12 October 2011

Palioselitis, D., Muon energy reconstruction and atmospheric neutrino spectrum unfolding with the ANTARES detector, 32nd Int. Cosmic Ray Conf., Beijing, China, 11 August 2011

Status and recent results from the ANTARES experiment, Rencontres de Blois 2011 “Particle physics and cosmology”, Blois, France, 1 June 2011

Samtleben, D.F.E., Observing the High Energy Neutrino Sky, Quantum Universe Symposium University of Groningen, Groningen, The Netherlands, 21 April 2011

Pierre Auger Observatory

Jong, S.J. de, Lectures on the Future of CERN, Belgium-Dutch-German Research School, Hoenderloo, The Netherlands, 27-30 September 2011

Kelley, J., Recent Results from the Pierre Auger Cosmic Ray Observatory, Nederlands Astronomen Conferentie, Texel, The Netherlands, 19 May 2011

LOFAR: Detecting Cosmic Rays with a Radio Telescope, 32nd Int. Cosmic Ray Conference, Beijing, China, 17 August 2011

Data Acquisition, Triggering, and Filtering at the Auger Engineering

Radio Array, Very Large Volume Neutrino Telescope workshop (VLVνT11), Erlangen, Germany, 13 October 2011

Nelles, A.F., The Auger Engineering Radio Array, 14th Symposium on Astroparticle Physics in the Netherlands, Groningen, The Netherlands, 19 April 2011

Schoorlemmer, H., Cosmic rays detected with the Auger Engineering Array, 13th ICATPP, Como, Italy, 3 October 2011

Timmermans, C., Front end electronics and triggering at the Auger Engineering Radio Array, TIPP, Chicago, USA, 6 October 2011

Virgo

Agathos, M., Binary black holes as laboratories for studying the dynamics of spacetime, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

Beker, M.G., Seismic attenuation technology for the advanced Virgo gravitational waves detector, Technology and Instrumentation in Particle Physics 2011, Chicago, USA, 9 June 2011

A compact seismic attenuation system for the Advanced Virgo external injection bench, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

Brand, J.F.J. van den, Gravitation – The dynamics of spacetime, Kronig Lecture TU Delft, Delft, The Netherlands, 8 March 2011

Gravitation – The dynamics of spacetime, Trends in Theory 2011 Symposium, Dutch Research School on Theoretical Physics, Dalfsen, The Netherlands,19 May 2011

Einstein Telescope: Site and Infrastructure, Gravitational Wave Advanced Detector Workshop (GWADW 2011), Elba, Italy, 24 May 2011

Gravity Gradient Noise: Limitations for Advanced GW Detectors, The 9th Edoardo Amaldi Conf. on Gravitational Waves, Cardiff, United Kingdom, 14 July 2011

Lectures on the Science Case for Gravitational Wave Experiments, Belgium-Dutch-German Research School, Hoenderloo, The Netherlands, 16 September 2011

Laser interferometry for the study of gravitation and cosmology, Annual LaserLab Symposium 2011, Amsterdam, The Netherlands, 15 December 2011

Del Pozzo, W., Precision measurement of the Hubble constant using Gravitational Waves, 9th Edoardo Amaldi Conference, Cardiff, United Kingdom, 14 July 2011

Measurement of the Hubble constant using Gravitational Waves, 15th Astroparticle symposium, Leiden, The Netherlands, 3 November 2011

Hennes, E., Modeling and measuring puzzling effects of GAS blades, Gravitational Wave Advanced Detector Workshop, ELba, Italy, 24 May 2011

Li, T.G.F., Coalescing binary neutron stars and black holes as laboratories for testing General Relativity, 14th Symposium on Astroparticle Physics, Groningen, The Netherlands, 19 April 2011

Coalescing Binary Neutron Stars and Black Holes as Laboratories for Testing General Relativity, 9th Edoardo Amaldi Conf. on Gravitational Waves, Cardiff, United Kingdom, 14 July 2011

Towards a generic test of the strong field dynamics of general relativity using compact binary coalescence, 15th Symposium on Astroparticle Physics, Leiden, The Netherlands, 3 November 2011

Measuring cosmological parameters through the mergers of tidally deformed binary neutron stars, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

Coalescing binary neutron stars and black holes as laboratories for testing general relativity, 7th Int. Conf. on Gravitation and Cosmology, Goa, India, 15 December 2011

Rabeling, D.S., Seismic Measurements and Newtonian Noise Predictions for Underground Environments in Europe, GWADW, Elba, Italy, 24 May 2011

Van Den Broeck, C.F.F., Binary black holes as laboratories for testing general relativity, Institute for Theoretical Physics, University of Utrecht, Utrecht, The Netherlands, 24 October 2011

Fundamental physics, astrophysics, and cosmology with gravitational waves, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

Astronomy, cosmology, and fundamental physics with Einstein Telescope, 7th Int. Conf. on Gravitation and Cosmology, Goa, India, 18 December 2011

Vitale, S., Sky localization with a network of gravitational wave detectors, 15th Symposium on astroparticle physics, Leiden, The Netherlands, 3 November 2011

Sky localization with a network of gravitational wave detectors, APC – Paris VII University, Paris, France, 25 November 2011

XENON

Decowski, M.P., The XENON100 and XENON1T Experiments, Amsterdam Particle Physics Symposium, Amsterdam, The Netherlands, 1 December 2011

Direct Detection Dark Matter Experiments, GRAPPA Kickoff, University of Amsterdam, Amsterdam, The Netherlands, 21 October 2011

Schön, R., Operating the GridPix detector in Dark Matter search experiments, DPG annual meeting, Karlsruhe, Germany, 30 March 2011

Operating GridPix in a dual-phase noble element time projection chamber, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

Alfonsi, M., Development of the GridPix Detector for Dual Phase Noble Gas Time Projection Chambers, IEEE Nuclear Science Symposium, Valencia, Spain, 24 October 2011

Theory

Adelhart Toorop, R. de, Family physics and structure in the fermion mass sector, Physics@FOM 2011, Veldhoven, The Netherlands, 19 January 2011

Family Symmetries and the quest to explain quark and lepton masses, Radboud Universiteit, Nijmegen, The Netherlands, 3 March 2011

Particle Physics at the time of the first results of the LHC, University of Indonesia, Jakarta, Indonesia, 30 June 2011

Particle Physics at the time of the first results of the LHC, Bandung Institute of Technology, Bandung, Indonesia, 5 July 2011

Particle Physics at the time of the first results of the LHC, Indonesian Seminar Nasional Fisiki 2011, LIPI, Indonesian institute of sciences, Jakarta, Indonesia, 12 July 2011

Artoisenet, P.A., Matrix Element Methods for Discovery at the LHC, MadGraph Meeting 2011 at Academia Belgica Roma, Roma, Italy, 20 September 2011

Broek, T.C.H. van den, To commute … or not to commute?, DRSTP Winter School, Sao Paulo, Brazil, 15 February 2011

Supersymmetry & noncommutative geometry, Workshop Noncommutativity and Physics, Bayrischzell, Germany, 20 May 2011

The Standard Model & Beyond with noncommutative geometry, Radboud University, Nijmegen, The Netherlands, 15 December 2011

Dunnen, W.J. den, Impact of Sivers effect on transversity measurements, XIX Int. Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2011), Newport News, VA, USA, 14 April 2011

Can the LHC tell us the parity of the Higgs?, DRSTP PhD-Day, Utrecht, The Netherlands, 14 October 2011

Can the LHC tell us the parity of the Higgs?, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

Can the LHC tell us the parity of the Higgs?, Universität Tübingen, Tübingen, Germany, 8 December 2011

Fleischer, R., Precision Physics with B Mesons: New Probes for New Physics in the LHC Era, Physics@FOM 2011, Focus Session "CP violation and the genesis of matter", Veldhoven, The Netherlands, 18 January 2011

Precision B Physics in the LHC Era, University of Cambridge, Cavendish Laboratory, Cambridge, United Kingdom, 8 March 2011

In Pursuit of New Physics with B Decays, Moriond 2011 – QCD and High Energy Interactions, La Thuile, Italy, 22 March 2011

B-Physics Probes for New Physics in the LHC Era, Portorož 2011: The Role of Heavy Fermions in Fundamental Physics, Portorož, Slovenia, 12 April 2011

Precision Physics with B Mesons: New Probes for New Physics in the LHC Era, Trends in Theory 2011, Dalfsen, The Netherlands, 20 May 2011

Searching for New Physics through B-Meson Decays at the LHC, Baryogenesis and First Order Phase Transitions in the Early Universe, Lorentz Center, Leiden, The Netherlands, 1 September 2011

B Physics in the LHC Era: Status and Perspectives, UK HEP Forum 2011 "Physics at the LHC", Abingdon, United Kingdom, 8 September 2011

Penguin Uncertainties in ϕ_s and Effective B_s Lifetime Measurements, Workshop on Implications of LHCb Measurements and Future Prospects, CERN, Geneva, Switzerland, 10 November 2011

George, D.P., Model building and Lie point symmetries, MPIK Heidelberg, Heidelberg, Germany, 25 May 2011

A systematic approach to model building, PASCOS 2011, Cambridge, United Kingdom, 5 July 2011

Model building using Lie-point symmetries, CERN LPCC Summer Institute, Geneva, Switzerland, 18 August 2011

Model building using Lie-point symmetries, University of Zurich, Zurich, Switzerland, 11 October 2011

Holten, J.W. van, The gravitational field of a light wave, ITF, Univ. Utrecht, Utrecht, The Netherlands, 7 March 2011

Gravitatiegolven, Leiden University, Leiden, The Netherlands, 21 September 2011

Superluminal neutrino's, Leiden University, Leiden, The Netherlands, 27 September 2011

Knegjens, R.J., In Pursuit of New Physics with B_s Mesons, DRSTP Winter School, Sao Paulo, Brazil, 14 February 2011

Recent Theoretical Studies of B_s Physics, Amsterdam Particle Physics Symposium, Amsterdam, The Netherlands, 1 December 2011

Kuipers, J., Polynomial Algebra in Form 4, ACAT 2011, London, United Kingdom, 6 September 2011

Laamanen, J.A., Stop NLSP in CMSSM, University of Helsinki and Helsinki Inst. of Physics, Helsinki, Finland, 3 November 2011

Laenen, E., Next-to-eikonal exponentiation, ETH & University of Zurich joint seminar, Zurich, Switzerland, 22 March 2011

Heavy flavour production, some issues, some results, Beauty 2011, Amsterdam, The Netherlands, 4 April 2011

Next-to-eikonal exponentiation, Academica Sinica, Taipei, Taiwan, 1 June 2011

Some recent developments in QCD resummation for the LLC, 9th Particle Physics Phenomenology Workshop (PPP9), Chungli, Taiwan, 4 June 2011

Top physics: theoretical aspects, Physics at the LHC 2011, Perugia, Italy, 9 June 2011

Top physics: theoretical aspects, Aspects of top physics, Torino, Italy, 12 July 2011

Top Quark Theory, Lepton-Photon 2011, Tata Institute for Fundamental Research, Mumbai, India, 23 August 2011

Next-to-eikonal exponentiation, Workshop on Quarks, hadrons and LHC, IIT Bombay, Mumbai, India, 29 August 2011

Top Quark News, Lorentz Center workshop on Baryogenesis, Leiden, The Netherlands, 2 September 2011

Top Quark News, IISc Bangalore, Bangalore, India, 18 October 2011

Next-to-eikonal exponentiation in QCD and QED, IMSc, Chennai, India, 24 October 2011

Standard Model theory for the LHC, IIT Madras, Chennai, India, 25 October 2011

Basics of resummation, IISc Bangalore, Bangalore, India, 31 October 2011

Threshold resummation for squark/gluino hadroproduction, Bethe Forum on LHC, Dark Matter and Unification, Bonn, Germany, 19 November 2011

Mooij, S.J.N., Goldstone bosons in Higgs inflation, DRSTP winter school, Sao Paulo, Brazil, 15 February 2011

Goldstone bosons in Higgs inflation, 6. Kosmologietag, Bielefeld University, Bielefeld, Germany, 6 May 2011

Goldstone bosons in Higgs inflation, PASCOS conference, Cambridge, United Kingdom, 7 July 2011

Goldstone bosons in Higgs inflation, Workshop "Cosmology meets particle physics", DESY-Hamburg, Hamburg, Germany, 28 September 2011

Goldstone bosons in Higgs inflation, Seminar at University of Groningen, Groningen, The Netherlands, 25 October 2011

Higgs in the sky, NNV Fall Meeting, Lunteren, The Netherlands, 4 November 2011

Higgs in the sky, Seminar at Anton Pannekoek Instituut, Amsterdam, The Netherlands, 8 December 2011

Mulders, P.J., Universality of TMDs, Brookhaven National Laboratory, Brookhaven, USA, 11 May 2011

Transverse momenta of partons in high-energy scattering processes, Enrico Fermi School, Varenna, Italy, 28 June 2011

The Three-dimensional Partonic Structure of the Nucleon, Thomas Jefferson National Accelerator Facility, Newport News, USA, 22 August 2011

Theoretical aspects of TMDs, Conf. on Partons in Nucleons and Nuclei (PINAN), Marrakech, Morocco, 28 September 2011

Niessen, I., How much SUSY are we looking for?, Physics@FOM 2011, Veldhoven, The Netherlands, 19 January 2011

Finding SUSY, Workshop 'The First Quantum Universe', Groningen, The Netherlands, 21 April 2011

NNLL Resummation for Supersymmetry, THEP Colloquium, Radboud University, Nijmegen, The Netherlands, 16 June 2011

NNLL resummation for squark-antisquark production, RADCOR 2011, Mammalapuram, India, 30 September 2011

Rogers, T.C., TMD factorization, factorization breaking, and evolution, 19th Int. Workshop on Deep Inelastic Scattering, Newport News, Virginia, USA, 13 April 2011

Gauge-Links and TMD factorization, Workshop on Opportunities for Drell-Yan Physics at RHIC, Brookhaven National Laboratory, Brookhaven, USA, 11 May 2011

Schellekens, A.N., Heterotic Strings Revisited, Universidad Autonoma, Madrid, Madrid, Spain, 4 March 2011

The Standard Model, The Anthropic Principle and the String Theory Landscape, Quantum Universe Workshop, Groningen, The Netherlands, 20 April 2011

Conformal Field Theory with Applications to String Phenomenology, Nordita Workshop on String Phenomenology, Stockholm, Sweden, 30 May 2011

Anomalies, Characters and Strings, Nordita Theory Colloquium, Stockholm, Sweden, 8 June 2011

Electric Charge Quantization in String Theory, CSIC, Madrid, Spain, 21 June 2011

The Kreuzer bi-homomorphism, Memorial Conf. for Max Kreuzer, Vienna, Austria, 27 June 2011

RCFT constructions of Heterotic Strings, StringVac11, Busan, South Korea, 5 September 2011

Wit, B. de, Lessons learned from BPS black holes, Indian Strings Meeting 2011, Puri, India, 6 January 2011

Elementary Particles, Strings and Black Holes, Indian Strings Meeting 2011, Institute of Physics & National Institute of Science Education and Research, Bhubaneswar, India, 7 January 2011

BPS near-horizon geometry of 5D black holes and rings, Indian Institute of Science,Bangalore, India, 18 January 2011

Elementary Particles, Strings and Black Holes, Indian Institute of Science,Bangalore, India, 20 January 2011

Lessons learned from BPS black holes, Swieca/DRSTP School, Campos do Jordão/Sao Paulo, Brazil, 7 February 2011

Elementary Particles, Strings and Black Holes, School of Physical Sciences, Jawaharlal Nehru University, New Delhi, India, 21 February 2011

BPS near-horizon geometry of 5D black holes and rings, QFT 2011 Conference, Indian Institute of Science Education and Research, Pune, Pune, India, 23 February 2011

Lessons learned from BPS black holes, University of Rome Tor Vergata, Rome, Italy, 11 March 2011

BPS near-horizon geometry of 5D black holes and rings, Institut des Hautes Études Scientifiques, Bures-sur-Yvette, France, 13 April 2011

Deformations of special geometry: in search of the topological string, Institut des Hautes Études Scientifiques, Bures-sur-Yvette, France, 17 May 2011

Elementary particles, strings and black holes, Raman Research Institute, Bangalore, India, 28 October 2011

BPS near-horizon geometry of 5D spinning black holes and the 4D/5D connection,Harish Chandra Research Institute, Allahabad, India,2 November 2011

BPS near-horizon geometry of 5D spinning black holes and the 4D/5D connection, Workshop 'Geometry of Strings and Fields', Nordita, Stockholm, Sweden, 15 November 2011

Detector R&D

Bosma, M.J., Edge effects in detector-grade cadmium telluride, Physics@FOM 2011, Veldhoven, The Netherlands, 18 January 2011

Edgeless planar semiconductor sensors for a Medipix3-based digital radiography detector, Int. Workshop on Radiation Imaging Detectors, Zurich, Switzerland, 4 July 2011

Active-Edge Planar Silicon Sensors for Large-Area Pixel Detectors, IEEE Nuclear Science Symposium, Valencia, Spain, 25 October 2011

The Influence of Edge Effects on the Detection Properties of Detector-Grade Cadmium Telluride, 18th Int. Workshop on Room-Temperature Semiconductor X- and Gamma-ray Detectors, Valencia, Spain, 28 October 2011

Graaf, H. van der, The alignment of CLIC with Rasnik systems, CLIC CERN/Nikhef Alignment Workshop, Geneva, Switzerland, 12 January 2011

The GridPix gaseous detector, CERN EDIT School Excellence in Detector Technology, Geneva, Switzerland, 31 January 2011

The GridPix Gaseous Pixel detector: status, plans & applications, Tipp2011: Tech. & Instr. in Particle Physics, Chicago, USA, 9 June 2011

A new solid state tracking detector: Electron Emission Membranes and a MEMS made vacuum electron multiplier, Tipp2011: Tech. & Instr. in Particle Physics, Chicago, USA, 11 June 2011

GridPix TPC and their application in Dark Matter and Double Beta Decay experiments + The Single Soft Photon counter 'Tipsy', 7th Patras Workshop on Axions, WIMPs and WISPs, Mykonos, Greece, 30 June 2011

Characterizing Discharge protection and improving drift time resolution for Grid Pix, MPGD2011: 2nd Int. Conf. on MicroPatternGasDetectors, Kobe, Japan, 29 August 2011

Pixel detectors: status, plans & applications of the gaseous GridPix/Gossip detector and a new vacuum electron multiplying detector, Seminar at KEK-Tsukuba, Kobe, Japan, 5 September 2011

Pixel detectors: status, plans & applications of the gaseous GridPix/Gossip detector and a new vacuum electron multiplying detector, Seminar at Kamioka, Kobe, Japan, 8 September 2011

A New Tracking Detector with ps Time Resolution, LCWS2011, Granada, Spain, 26 September 2011

Status and Plans of the GridPix/Gossip Gaseous Tracking Detectors, LCWS2011, Granada, Spain, 27 September 2011

MDI alignment progress: The pre-alignment of the QD0's, LCWS11, Granada, Spain, 29 September 2011

Timmermans, J., Progress with pixelised readout of gaseous detectors, American Linear Collider Physics Group (ALCPG) 2011, Eugene, Oregon, USA, 20 March 2011

TPC Large Prototype (LP) Beam Tests, American Linear Collider Physics Group (ALCPG) 2011, Eugene, Oregon, USA, 21 March 2011

Electron-Positron Linear Collider, Summer student lecture, DESY, Hamburg, Germany, 25 July 2011

Verlaat, B.A., CO_2 Cooling, DESY Joint Instrumentation Seminar, Hamburg, Germany, 18 February 2011

CO_2 Cooling, CERN detector seminar, Geneve, Switzerland, 8 April 2011

The Future of CO_2 Cooling in Particle Physics Detectors, Int. Conf. of Refrigeration, Prague, Czech Republic, 24 August 2011

Quality related experience in CO_2 cooling systems, Workshop on Quality Issues in Current and Future Silicon Detectors, CERN, Geneve, Switzerland, 4 November 2011

Grid Computing

Gabriel, S., Operationelle IT-Sicherheit in einem internationalen Grid-Umfeld, DFN Workshop "Sicherheit in vernetzten Systemen", Hamburg, Germany, 16 February 2011

348 sites, 57 countries, 1 security team: Operational Security in EGI, 23rd Annual FIRST Conference, Vienna, Austria, 16 June 2011

Groep, D., Getting Real about Virtual Organisations on the Grid TERENA Networking Conference 2011, Prague, Czech Republic, 18 May 2011

The International Grid Trust Federation – building an interoperable global trust fabric, European E-Infrastructure Forum workshop on Identity Management, Geneva, Switzerland, 10 June 2011

In Grid We Trust, Int. Symposium on Grids and Clouds 2011, Taipei, Taiwan, 22 March 2011

Keijser, J.J., Grid Data Access: Proxy Caches and User Views, EGI Technical Forum 2011, Lyon, France, 19 September 2011

The LGI Pilot job portal, EGI Technical Forum 2011, Lyon, France, 20 September 2011

Koeroo, O.A., Argus Overview, EGI Technical Forum 2011, Lyon, France, 20 September 2011

How to install and configure gLExec, EGI Technical Forum 2011, Lyon, France, 22 September 2011

Argus and Globus, EGI Technical Forum 2011, Lyon, France, 10 October 2011

SSC5: a simultaneous multi site security drill. Code Name: World Domination, EGI Technical Forum 2011, Lyon, France, 10 October 2011

Templon, J.A., Summary: Monitoring, EGI Virtualization Workshop, Amsterdam, The Netherlands, 13 May 2011

Grids and Clouds: A step back from the fray, GridKa School, Karlsruhe Institute of Technology, Karlsruhe, Germany, 5 September 2011

Miscellaneous

Beenakker, W., Physics and Astronomy in Nijmegen, Kavli Institute for Theoretical Physics China (KITPC), Beijing, China, 26 October 2011

Physics and Astronomy in Nijmegen, Department of Physics, Shanghai University, Shanghai, China, 1 November 2011

Physics and Astronomy in Nijmegen, School of Material Science and Engineering, Shanghai University, Shanghai, China, 1 November 2011

Physics and Astronomy in Nijmegen, Shanghai Institute of Applied Physics (SINAP), Shanghai, China, 4 November 2011

Decowski, M.P., Investigating Neutrino Properties with KamLAND, University of Warsaw, Warsaw, Poland, 18 February 2011

Investigating Neutrino Properties with KamLAND, University of Münster, Münster, Germany, 7 July 2011

Metzger, W.J., BEC, the tau-model, and jets in e^+e^- annihilation, VII Workshop on Particle Correlations and Femtoscopy, Tokyo, Japan, 20 September 2011

BEC in e^+e^- collisions, XLI Int. Symposium on Multiparticle Dynamics, Miyajima, Japan, 28 September 2011

Samtleben, D.F.E., News from the oldest light – Measuring the Polarization of the Cosmic Microwave Background Radiation, Forschungsseminar Physik, Humboldt Universität Berlin, Berlin, Germany, 18 February 2011

Measuring the Cosmic Microwave Background Radiation, Int. Conf. on Results and Perspectives in Particle Physics, La Thuile 2011, La Thuile, Italy, 28 February 2011

News from the Oldest Light, Joan van der Waals colloquium, Leiden University, Leiden, The Netherlands, 11 March 2011

3.4 Posters

ATLAS/DØ
Mechnich, J. *(on behalf of the ATLAS Collaboration)*
Performance of the ATLAS Tau Trigger in High Luminosity Scenarios
Physics at the LHC 2011, Perugia, Italy, 6 June 2011

Salvucci, A.
Measurement of the muon momentum resolution of the ATLAS detector
HCP 2011, Paris, France, 17 November 2011

LHCb/BABAR
Oggero, S.
Alignment of the LHCb Pile-Up detector
Beauty2011, Amsterdam, The Netherlands, 4 April 2011

ALICE
Reicher, M. (et al.) *(for the FoCal collaboration)*
A Forward Calorimeter (FoCal) as upgrade for the ALICE experiment at CERN
Quark Matter 2011, Annecy, France, 24 May 2011

ANTARES/KM3NeT
Astraatmadja, T.L.
Can we detect TeV photons from GRB with a neutrino telescope?
Nederlandse Astronomen Conferentie 2011, Texel, The Netherlands, 18 May 2011

Hsu, C.C.
Cosmic ray composition study using ANTARES telescope
ICRC2011, Beijing, China, 11 August 2011

Virgo
Blom, M.R. *(et al.)*
Compact seismic attenuation systems for the Advanced Virgo gravitational wave detector
9th Edoardo Amaldi Conference on Gravitational Waves, Cardiff, United Kingdom, 14 July 2011

Del Pozzo, W.
Cosmology with Gravitational Waves: statistical inference of the Hubble constant
7th International Conference on Gravitation and Cosmology, Goa, India, 15 December 2011

Vitale, S.
Effects of calibration errors on parameter estimation for gravitational wave signals from inspiral binary systems in the advanced detector era
International Conference on Gravitation and Cosmology, Goa, India, 14 December 2011

Pierre Auger Observatory
Grebe, S.
Determination of air shower parameters from the radio frequency spectrum by fitting the slope
WE Heraeus Seminar, Bad Honnef, Germany, 4 October 2011

Nelles, A.F. *(for the Pierre Auger Collaboration)*
The Auger Engineering Radio Array
Nederlandse Astronomen Conferentie 2011, Texel, The Netherlands, 18 May 2011

AERA - Data Acquisition, Background and First Data
W.E. Heraeus Seminar Radio Detection in Astroparticle Physics, Bad Honnef, Germany, 4 October 2011

Theory
Adelhart Toorop, R. de,
Family symmetries // helping to understand the fermion masses
Trends in Theory, Dalfsen, The Netherlands, 20 May 2011

Broek, T.C.H. van den,
Noncommutative geometry: a new approach to supersymmetry?
Trends in Theory, Dalfsen, The Netherlands, 19 May 2011

Buffing, M.G.A.
Transverse momentum of partons and color gauge invariance
Trends in Theory, Dalfsen, The Netherlands, 19 May 2011

Dunnen, W.J. den,
Bounding W-W' mixing with spin asymmetries at RHIC
Physics@FOM 2011, Veldhoven, The Netherlands, 18 January 2011

Detector R&D
Koppert, W.J.C.
High precision 3D Measurements of Single Electrons with GridPix Detectors
Physics@FOM 2011, Veldhoven, The Netherlands, 17 January 2011

Discharge protection characterisation and drift time resolution improvement for Gridpix
IEEE Nuclear Science Symposium, Medical Imaging Conference, Valencia, Spain, 26 October 2011

Bounding W-W' mixing with spin asymmetries at RHIC
Trends in Theory, Dalfsen, The Netherlands, 19 May 2011

Knegjens, R.J.
In Pursuit of New Physics with B_s Mesons
Physics@FOM 2011, Veldhoven, The Netherlands, 18 January 2011

In Pursuit of New Physics with $B_s \rightarrow K^+K^-$
Beauty 2011, Amsterdam, The Netherlands, 4 April 2011

In Pursuit of New Physics with B_s Mesons
Trends in Theory, Dalfsen, The Netherlands, 19 May 2011

Mooij, S.J.N.
Higgs inflation: a cosmological role for the Higgs boson?
Physics@FOM 2011, Veldhoven, The Netherlands, 18 January 2011

Goldstone bosons in Higgs inflation
Trends in Theory, Dalfsen, The Netherlands, 19 May 2011

Niessen, I.
Supersymmetry vs Extra Dimensions
Trends in Theory, Dalfsen, The Netherlands, 21 April 2011

XENON
Schön, R.
Operating a GridPix detector in dark matter search experiments
Physics@FOM 2011, Veldhoven, The Netherlands, 19 January 2011

Operating a GridPix detector in dark matter search experiments
ISAPP 2011 Graduate School, Heidelberg, Germany, 10 July 2011

3.5 Jamboree

The 2011 Jamboree was held at Nikhef in Amsterdam and organised by Leo Wiggers and Paul Kuijer. They had composed a two-day schedule in which representatives of all particle physics and astroparticle physics programmes in which Nikhef participates would present their results, together with talks from the enabling programmes. However, a few days before the Jamboree it was announced that on 13 December an important seminar and subsequent press conference would be held at CERN about the latest results of Higgs boson searches by ATLAS and CMS. The organisers adapted the Jamboree program by joining all ATLAS talks into one enthusiastic overview presentation by Nikhef's ATLAS programme leader Stan Bentvelsen, which was then followed by the webcast of the seminar at CERN. At this memorable Tuesday afternoon it was viewed by a large audience distributed over two rooms, while Dutch television crews and newspaper reporters were present to register first-hand comments from the highest density of Standard Model experts in the Netherlands.

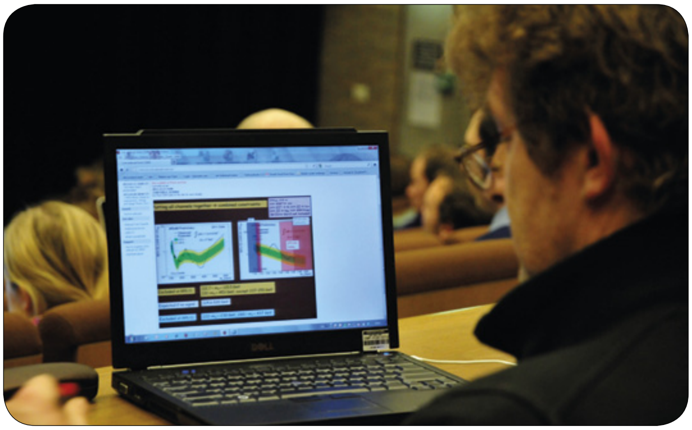


Figure 1. A journalist making notes during the CERN Higgs seminar. There was extensive media coverage of the seminar in which the LHC experiments ATLAS and CMS jointly announced a glimpse of the Higgs particle.

Monday 12 December 2011

Introduction

ANTARES/KM3NeT

09:40 Aart Heijboer: *Results from ANTARES*
10:00 Tri Astraatmadja: *Detection of high energy gamma-rays from GRBs*
10:20 Els de Wolf: *Status of KM3NeT*

R&D

10:40 Niels van Bakel: *Overview*
10:50 Harry van der Graaf: *Tipsy Photon Detector*
11:10 Francesco Zappon: *Asic Design*
11:20 Marten Bosma: *Semiconductor Detectors*

HiSPARC

11:40 David Fokkema: *Scientific results from HiSPARC*

AUGER

13:05 Charles Timmermans: *Overview of Dutch Auger topics*
13:30 Stefan Grebe: *Obtaining shower dependent variables from radio*

ALICE

13:55 Thomas Peitzmann: *Introduction*
14:10 Martijn Reicher: *Focal*
14:30 André Mischke: *Open Charm results*
14:50 Ante Bilandzic: *Elliptic Flow*

Theory

15:30 Eric Laenen: *Theory in 2011*
15:45 Rob Knegjens: *Lessons from lifetimes*
16:00 Reinier de Adelhart Toorop: *A flavour of family symmetries*
16:15 Pierre Artoisenet: *Quarkonium production: unbinding the secrets*

Computing

16:30 Jeff Templon: *Introduction*
16:45 Wim Heubers: *Status update Nikhef datacenter facilities*
17:05 Ronald Starink: *PDA*

Tuesday 13 December 2011

LHCb

09:00 Marcel Merk: *Introduction and Status*
09:15 Gerhard Raven: *Physics overview*
09:40 Alexandr Kozlinskiy: *Charm Physics*
10:05 Victor Coco: *Search for long-lived unstable particles*

Virgo

10:50 Jo van den Brand: *Status Virgo*
11:00 David Rabeling: *Wavefront sensing and angular alignment of Virgo's optics*
11:15 Mark Beker: *Femtometer positioning for Advanced Virgo*
11:30 Michail Agathos: *Testing GR using Compact Binary Coalescence*

XENON

11:50 Matteo Alfons: *XENON & DARWIN*

ATLAS

13:20 Stan Bentvelsen: *ATLAS activities at Nikhef*

Higgs Seminar at CERN & Discussion

14:00 Fabiola Gianotti: *Update on the Standard Model Higgs searches in ATLAS*
14:30 Guido Tonelli: *Update on the Standard Model Higgs searches in CMS*
15:00 *Joint question session*

Concluding Session

16:00 Frank Linde: *Nikhef – status and future*

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 2011 are listed. Please refer to Section 5.4 for a full overview of all current grants regarding Nikhef, namely newly awarded grants in 2011, still running grants and recently completed grants awarded in earlier years.

NWO grants

NWO granted Raimond Snellings (ALICE) a Vici grant for *"A new state of matter: The Quark Gluon Plasma"*, which entails 1.5 M€ over a period of five years. This form of grant is directed at senior researchers who have shown that they have the ability to successfully develop their own innovative lines of research and to act as coaches for young researchers.

FOM grants

Two FOM-'projectruimte' grants were awarded in 2011. Chris Van Den Broeck (Gravitational Physics) received one for his proposal *"Binary black holes as laboratories for fundamental physics"* and Paul de Jong (ATLAS) received one for his proposal *"Mind the gap! Generalizing dark matter searches at the LHC"*. For Marieke Postma (Theory) a FOm/v grant was acquired.

Other Dutch awards & grants

Niels van Bakel and Jan Visser (Detector R&D) received a valorisation grant from the technology foundation STW for their proposal *"Amsterdam Scientific Instruments: radiation detectors for industrial and photon science applications"*. The STW grant of 200 k€ is meant for further developing scientific findings into applications. Another proposal, titled *"New Detector Systems for Biomedical Imaging: X-ray, Ion and Electron Imaging Using the Medipix Chip Family"* was submitted by AMOLF (Open Technology) with Jan Visser (Detector R&D) as co-applicant, and received an STW grant worth € 749,732.

European grants

Jo van den Brand participates in a EU funded exchange project between Europe and Japan on gravitational wave (GW) detection, called EliTES (*ET–LCGT Interferometric Telescopes: Exchange of Scientists*). It will furnish the initial kick-off to this exchange programme, which aims at a fully collaborative exchange of know-how on new technologies and R&D for the third generation GW detectors.

Nigel Hessey received a TALENT (*Training for cAreer deveLopment in high–radiation ENvironment Technologies*) grant. Under the TALENT programme Nikhef receives funding for two Marie Curie PhD Fellowships. These will be for engineering PhDs to study high performance carbon compounds to construct lightweight, radiation hard supports for the new Inner Tracker for ATLAS in 2021.

Pierre Artoisenet (Theory) received IEF (*Marie Curie Intra-European Fellowship*) funding for his proposal *"Resolving short–distance physics mechanisms in hadron collisions at TeV scale energies"*. The IEF funding is provided for advanced training and career development. The project is based on a personal career development programme agreed between the researcher and the supervisor (Eric Laenen) at the host organisation (Nikhef). Financial support is provided for a period of 24 months.

Other awards

Niels van Eldik (formerly ATLAS) was awarded the Marc Virchaux Prize 2010 by the ATLAS Muon Spectrometer collaboration. He received this award for his thesis *"The ATLAS Muon Spectrometer: Calibration and Pattern Recognition"* (2007).

Piet Mulders (see Fig. 1) was appointed Fellow of the American Physical Society. He is appointed for his influential contributions to the field of spin physics and in particular to the development of the theoretical formalism of transverse momentum dependent parton distribution functions.

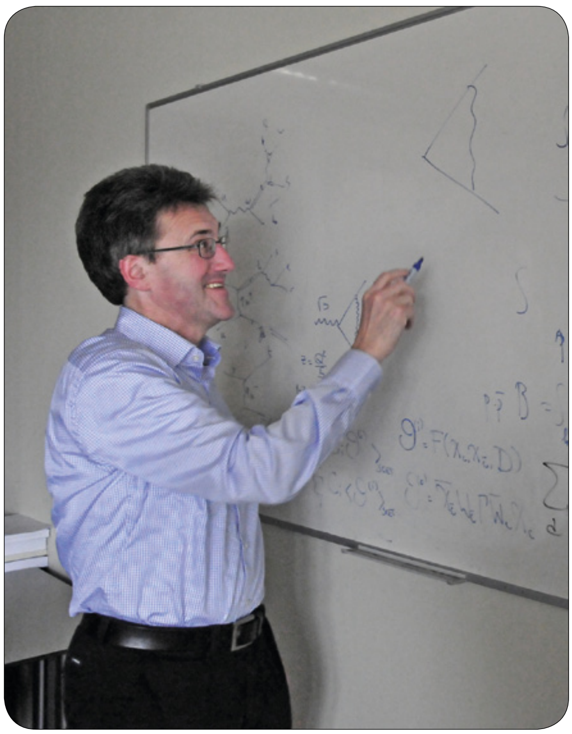


Figure 1. Piet Mulders was honoured by an appointment as Fellow of the American Physical Society.

4

Nikhef & Society

4.1 Outreach & Communication

The biggest news for Nikhef came late in the year 2011. On 13 December CERN broadcast a joint colloquium for the two experiments ATLAS and CMS, where the spokespersons presented the latest results of their searches for the Standard Model Higgs boson. The main Dutch televison news channels NOS and RTL4 were there to follow the presentation and subsequent press conference and ask questions and interview Nikhef scientists on camera and radio. As a consequence of this press conference, more than 40 articles were published in newspapers and magazines highlighting that the search for Higgs might be nearing its culmination point.

Preceding this event, the OPERA experiment's faster-than-light neutrinos were also a hit with the Dutch media in September. Almost 100 articles came out in the days following the research results being made public. The phones at Nikhef were ringing nonstop during those days, with journalists requesting background information and interviews from Nikhef researchers. Although Nikhef is not a member of the OPERA collaboration, our scientists were able to communicate excellently the importance of these results and were often quoted in articles and interviewed on radio and TV news programs. The national news channel NOS visited the institute to film Nikhef employees watching the press statement and conference by Gran Sasso National Laboratory at CERN.

Every year, Nikhef organises a variety of activities for different target audiences (general public, students and teachers) to explain what Nikhef's particle and astroparticle research entails and how the technical departments support all these research endeavours. The communications department initiates many of these activities, but also relies on Nikhef staff and PhD-students' much appreciated dedication towards reaching out to the different target audiences about our research projects. Additional activities are based on enthusiastic initiatives of individual Nikhef members. Below, a comprehensive overview of all communication activities during 2011 is given. For education activities please refer to section 4.2.

Nikhef & the general public

This year, Nikhef again participated in the organisation of the annual Science Park Amsterdam Open Day for the general public, which took place in October during the *Dutch Science Month*. Nikhef was involved in the public relations side of the Science Park-wide organisation of the open day, working on the promotional flyer, the poster and the schedule brochure. On the Open Day, all institutes on the Science Park opened their doors to people of all ages who are interested in science and want to find out more about it. This year, the theme was "*Action – Reaction in Science*" and one of the sub themes was the 25 year anniversary of the top-level domain '.nl'.

Figure 1. Frank Linde's Open Day mini lecture on faster-than-light neutrinos was so well attended that there wasn't enough seating!

At Nikhef people visited the exhibits and demonstrations in the main hall and the workshop set up by the LHC detector research groups, the astroparticle physics project groups, and the technical, computer infrastructure and theoretical physics departments. Children were able to participate in a search for particles, including the elusive Higgs boson! They were also able to construct their own electronic gadgets.

Specially focused on the topic *'Faster-than-light neutrinos'*, the communications department organised two extra mini lectures during the open day on this subject. One was by Nikhef director Frank Linde (see Fig. 1) and one by film and theatre producer Jan van den Berg, who was also responsible for the 2009 movie *"Higgs: into the heart of the imagination"*. Linde's lecture was so popular it had to be repeated later in the day for a second group of highly interested listeners. Willem van Leeuwen's lecture *"How Nikhef got caught in the World Wide Web"*, in which he sketched Nikhef's involvement in the creation of the WWW at CERN, was a very popular lecture as well (see Fig. 2).

In November the Nikhef blog – "*Blogging at Lightspeed*", was opened for Nikhef employees and everybody outside Nikhef interested in Nikhef and its research and researchers (see Fig. 2). The aim is to have a blog post added every two weeks. The hope is that this blog, and also the other social media efforts, will offer an interesting insight into the lives and work of our scientists, our scientific endeavours all over the world and the challenges and issues that we face in the scientific world of today.

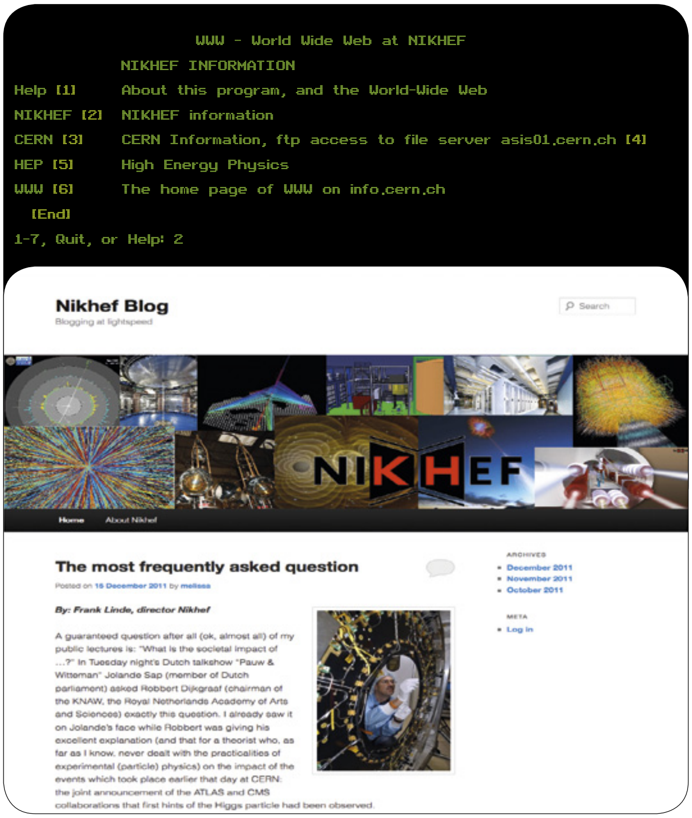


Figure 2. Top: How Nikhef got caught in the World Wide Web: a screen dump of Nikhef's first website (1991). Bottom: Twenty years later: "Blogging at Lightspeed".

Nikhef took its first serious steps onto the social media field in the latter part of 2011. A Twitter account was set up, through which the latest news, jobs and events are posted. In a few months, *@nikheftweets* garnered more than 100 followers. The new Facebook page gained more than 50 likes. Facebook lends itself perfectly for posting longer news articles, links to interesting videos, and job postings. Twitter has shown to be especially good for keeping in touch with science journalists and general media.

The Nikhef website underwent a first round of revision of the scientific content and the look and feel. A start was made with creating an online media archive of lecture registrations (such as the ones during the open day), especially for outreach purposes.

In 2011, Nikhef scientists travelled all across the Netherlands to give numerous outreach talks at different venues and for many different audiences (see section 4.4 for a complete list). For instance, Frank Linde gave a general astroparticle and particle physics lecture at Mensa, the largest and oldest high-IQ society in the world, and was then asked to also tell something about the faster-than-light neutrinos. He later blogged about it enthusiastically on the Nikhef blog and received many responses from happy Mensa members.

Figure 3. A model of a KM3NeT detector string was placed in the hall.

Permanent exhibits

In the main hall of the Nikhef building, two additional exhibits were placed, to immediately attract the attention of visitors. An *Arche Cosmique* was built to roughly demonstrate the spatial distribution of cosmic rays, and a water-filled perspex pipe that reaches all the way to the third floor is a scale model of part of the neutrino telescope KM3NeT that is currently being designed by Nikhef scientists and engineers and their international colleagues (see Fig. 3). The existing cloud chamber now features a comprehensive explanation of its workings and use in particle detection.

Figure 4. PhD-student Rosemarie Aben was interviewed by NOS TV about the Higgs results presented by CERN.

Nikhef & the media

Nikhef issues five to seven press releases each year, often in collaboration with other institutes and universities. This year, those press releases dealt with CERN results, the faster-than-light neutrinos, the new Einstein Telescope Collaboration, and a congress organised by Nikhef. The communication department is deliberately selective in choosing items that are sent out as press releases, in order to build a credible relationship with the (science) press. Nikhef scientists contributed to many articles in various newspapers and magazines (*NRC Handelsblad, Trouw, Volkskrant, Natuurwetenschap & Techniek, Kijk,* and many more), and regularly gave interviews on many different radio programmes (*e.g., Radio 1 Journaal, BNR Nieuwsradio*) and on TV (*NOS journaal, RTL4 nieuws, Een Vandaag.* See Fig. 4).

Guided tours at Nikhef and at CERN

Nikhef organises guided tours for everybody interested in the research performed 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 (see Fig. 5). Special guided tours are set up upon request. 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. In some cases, these CERN visits are in addition sponsored financially by Nikhef.

Nikhef & science communication networks

Nikhef's communication department works together with national and international communication networks to develop, coordinate and organise communication activities surrounding science in general and particle and astroparticle physics in particular.

International networks

- **EPPCN** – The European Particle Physics Communication Network for coordinating activities between CERN and its member states (*e.g.,* synchronisation of press releases, media events). In 2011, two meetings in Oslo and Geneva were attended and the most important discussion topic was the 2013 Council Meeting for the European strategy for particle physics in Brussels;
- The **outreach committee** of the **ASPERA European network for astroparticle physics** for developing a sustainable network of communicators for this field in Europe;
- **InterAction** – The collaboration of communicators for particle physics laboratories worldwide for increasing support for fundamental particle physics research in general around the world.

National networks

- Every two months, the communication staff of the various institutes, universities and organisations meet with the Science Park Amsterdam organisation to discuss all Science Park-wide activities (such as the Open Day) and communication about the (development of) Science Park Amsterdam;
- Every three months, FOM organises a meeting with all the communications officers of all the FOM institutes, which also includes AMOLF and Rijnhuizen, for all FOM-related topics (*e.g.,* annual Physics@FOM Veldhoven conference);
- Several times a year, the Platform Wetenschapscommunicatie (PWC), an association for science communication staff in the Netherlands, organises a meeting for a professional exchange of ideas and information.

Figure 5. During a guided tour Nikhef scientists explain the various experiments. In the foreground is an open model of the ATLAS detector.

4.2 Education

Nikhef is heavily committed to educating young people and to stimulating their interest in science and technology. From the very young, budding physicists to the PhD students, there are appropriate programmes for each age group. The teachers are not forgotten either, they can participate in various activities as well.

Nikhef & Primary schools

The *Techniek Toernooi* is a science tournament for primary schools, where the academic world of science meets that of the primary schools. In 2011, the children in the age group between 4 and 12 years were challenged to make the best glue, to build as many separate layers of different fluids, to design a transport system for water or to design the best Coca Cola-fountain. Traditionally, many members of the Nikhef staff participate in the jury of academic staff that assesses the designs. Bart Meijers and Professor Amito of popular Dutch science TV productions awarded the winning teams. More information can be found at the website http://www.techniektoernooi.nl/ (in Dutch).

Nikhef & Secondary schools

Every year Nikhef makes great effort to introduce secondary school students to particle and astroparticle physics.

Through the Nikhef website schools can apply for a Friday afternoon visit, which consists of a lecture by a Nikhef scientist, a film and a guided tour. In 2011 the Friday afternoon visits were attended by more than 250 students. Over 20 secondary school students were assisted by Nikhef scientists to carry out their *'profielwerkstuk'* (research project). Apart from this, several schools were visited by Nikhef staff members for private lectures. Nikhef also supported numerous CERN visits of secondary school students by providing Dutch guides for tours.

On 18 March almost 45 students participated in the International Masterclass on Particle Physics held at Nikhef. This yearly event is organised simultaneously in several particle physics institutes across the world and includes lectures, exercises and a live video conference with CERN to share the results of the day with students at the other institutes. This year the event was held globally instead of only in Europe. Also, this was the first time that data from the LHC were used for the exercises.

Nikhef & HiSPARC

The *High School Project on Astrophysics Research with Cosmics* (HiSPARC) gives students a chance to participate in real scientific research. Schools can take part in the project and their students work together in building a detector that is designed to detect high-energy cosmic rays. In 2011, the HiSPARC detector network consisted of over 90 stations throughout the country.

Not only scientific aspects of HiSPARC were regarded, but also a major effort has been made to develop educational material that can be used by teachers and students. All the material is easily accessible through the HiSPARC website.

Towards the end of each school year HiSPARC organises the annual HiSPARC Symposium. This event is an opportunity for all students of the HiSPARC community to meet, and attend lectures and presentations of *'profielwerkstukken'*. Each year, the students with the best presentations can win a VIP trip to CERN. This year HiSPARC introduced a full day programme with workshops for teachers, which was highly appreciated.

Nikhef & Teachers

One way to enthuse students is through their teachers. Therefore, Nikhef reaches out to teachers, keeping them informed on the latest developments in physics, which they can pass on to their students. In the academic year 2010/2011 the FOM teacher-in-research programme (*'Leraar in Onderzoek'*, LiO) continued. Four new teachers were selected and two extended their contract to continue their research (from the previous year). Of the six teachers one was stationed at Radboud University (Nijmegen) and one at KVI (Groningen), the others were based at Nikhef (Amsterdam). All teachers were supported by staff members and all had their own research activities within the HiSPARC project.

One of the teachers has been rewarded with a PhD scholarship for teachers (*'promotiebeurs voor leraren'*) by NWO.

For the year 2011–2012 four new LiOs have been selected and two LiOs have prolonged their contract with a second year.

On Thursday 3 March the yearly Mastercourse on particle physics for teachers was held at Nikhef. All teachers that attended, as well as all (former) LiOs, were invited to participate in a 3-day CERN teachers programme at the end of September. Of this group 19 teachers joined the CERN programme, which was partly funded by Nikhef.

MSc in Particle and Astroparticle Physics

In 2011, 18 new students enrolled in the first year of the Master's programme Particle and Astroparticle Physics, among them six students from other European countries. Three students from the University of Göttingen, Germany, enrolled in the programme

Figure 1. Nikhef students networking during lunch at the CERN terrace.

Figure 2. The Jan Kluyverprijs for the best summary of a PhD thesis was shared by Gideon Koekoek (right) and Alexander Doxiadis.Stan Bentvelsen (left) accepted the prize on behalf of Alexander Doxiadis.

as ERASMUS students. For the first time, the number of students registered at the University of Utrecht matched that of students registered at the universities in the Amsterdam region. It underlines the importance of Nikhef for synergy in education of students in this field of research in the Netherlands. A total number of 11 students graduated in 2011, of which two concluded a double Master's programme Particle and Astroparticle Physics and Theoretical Physics, taking advantage of the presence of the theory department of Nikhef. Four students received the laudation *cum laude*. Six continued their career in industry, while seven chose a position as a PhD student at Nikhef or abroad. One of the students, Siim Tolk was the winner of the *"Amsterdam Master of Physics Award 2011"*. He is now a PhD student in the LHCb group of Nikhef.

An important ingredient of the Master's programme is the Nikhef project. This 'mini-experiment' introduces the first year students to all aspects of experimental particle physics. In 2011, the students designed and constructed a wire drift chamber for the measurement and reconstruction of cosmic muon tracks[1]. Together with the theoretical courses, the project is a good preparation for a research project at CERN, where the students can also extend their personal network to enhance career perspectives (see Fig. 1).

Research School Subatomic Physics

All PhD students at Nikhef receive academic training through the Research School Subatomic Physics (*'Onderzoeksschool Subatomaire Fysica'*, OSAF). In 2011, PhD degrees were obtained by 17 students from OSAF. The number of new PhD registrations in 2011 was 21. The Jan Kluyverprijs for the best summary of a PhD thesis was shared by Gideon Koekoek and Alexander Doxiadis (see Fig. 2). A PhD council was established in 2011 with student representation in the education committee (OWC) of the graduate school as well.

The BND summer school (Belgium, the Netherlands, Germany) was held in September in Hoenderloo, the Netherlands, at the same venue where the Dutch national football team prepares for their matches and tournaments. The summer school was organised this year by Radboud University Nijmegen/Nikhef. There were 53 participants. New in 2011 was the participation of students from France. The school was supported with a grant from the EU Erasmus Life Long Learning programme.

There were three topical lectures in 2011. The subjects were signal processing, heavy-ion physics and statistics.

1 A. Apostolou *et al.*, Cosmic muon track reconstruction with single anode wire drift chambers. See http://master.particles.nl/NikhefProjectArchive/

4.3 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

DRSTP (Dutch Research School for Theoretical Physics)
J.W. Van Holten (Education Committee)
E. Laenen (Governance Board)

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
Th. Peitzmann, 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

Institute of Research in Mathematics and Physics (IRMP) – Université Catholique de Louvain
E. Laenen (Scientific Advisory Committee)

International Particle Physics Outreach Group (IPPOG)
V. Mexner

International Union for Pure and Applied Physics (IUPAP)
P. Mulders (Liaison for the Netherlands)

International Grid Trust Federation
D. Groep (chair)

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

InterAction
V. Mexner

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

KNAW – Commissie Evaluatie Wetenschappelijk Ruimteonderzoek in Nederland
S. de Jong

* *as of 31 December 2011.*

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

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

LHCPhenoNet ITN network
E. Laenen (Supervisory Board)

Natuur Leven Technologie – Regionaal Steunpunt Arnhem-Nijmegen
S. de Jong

Nijmegen Centre for Advanced Spectroscopy – Supervisory Board
F. Linde (chair)

Nederlands Tijdschrift voor Natuurkunde – Editorial Board
P. Decowski

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)

Particle Physics Inside Products (P2IP BV)
F. Linde, A. van Rijn

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

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

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 Natuurkunde.nl
F. Linde (chair), M. Vreeswijk (editor)

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)

Worldwide LHC Computing Grid
J. Templon (Management Board)

4.4 Outreach Talks

Adelhart Toorop, R. de, Nieuwe natuurkunde op het VWO: quantum mechanica op de middelbare school?, Onderwijsdag Natuurwetenschappen Wolters Noordhoff, Ede, The Netherlands, 15 February 2011

Bakel, N.A. van, Detector R&D and CLIC alignment; Nederlandse sleutelexpertise voor ZFEL, FOM bureau, Utrecht, The Netherlands, 11 February 2011

Beker, M.G., Nuclear energy, SP Utrecht evening debate, Utrecht, The Netherlands, 24 June 2011

Star clusters, transformation by age and gravity, Art exposition Harm Hollestelle, The Hague, The Netherlands, 27 October 2011

Bentvelsen, S., Op jacht naar het Higgs deeltje, Nederlandse Vereniging voor Weer- en Sterrenkunde, afd. Arnhem, Arnhem, The Netherlands, 26 January 2011

Wat doet de deeltjesversneller in Genève?, St Vitus college Bussum, Bussum, The Netherlands, 11 March 2011

Big Bang in het laboratorium, HiSPARC Eindhoven, Amsterdam, The Netherlands, 7 April 2011

Wat doet de deeltjesversneller in Genève?, De Breul scholengemeenschap, Zeist, The Netherlands, 28 April 2011

Big Bang in het laboratorium, NSA University of Amsterdam, Amsterdam, The Netherlands, 11 June 2011

Higgs: hebben we hem nou of niet?, Nikhef Open Dag, Amsterdam, The Netherlands, 8 October 2011

Masterclass deeltjesfysica – Topas, Gemeentelijk Gymnasium Hilversum, Amsterdam, The Netherlands, 16 November 2011

Neutrino's sneller dan licht, Studium Generale University of Amsterdam, Amsterdam, The Netherlands, 16 November 2011

Klokhuis vragendag, NEMO Amsterdam, Amsterdam, The Netherlands, 27 November 2011

De jacht naar het Higgs deeltje, Academische Club University of Amsterdam, Amsterdam, The Netherlands, 15 December 2011

Brand, J.F.J. van den, About gravitational waves, Studium Generale, University Maastricht, Maastricht, The Netherlands, 27 January 2011

Gravitation and the dynamics of spacetime, Astronomical Society 'Volkssterrenwacht Amsterdam', Amsterdam, The Netherlands, 22 February 2011

Gravitation and the dynamics of spacetime, Astronomical Society 'Hoorn', Hoorn, The Netherlands, 8 April 2011

Gravitational Wave Experiments: Interest to Industry, Big Science for Business: industry meeting at Nikhef, Amsterdam, The Netherlands, 21 September 2011

Science with Gravitational Waves, Nederlandse Vereniging voor Weer- en Sterrenkunde, afdeling Delft, Delft, The Netherlands, 18 October 2011

Gravity: decoding vibrations of spacetime, Eindhovensche Weer- en Sterrenkundige Kring, Eindhoven, The Netherlands, 20 October 2011

Laser interferometry for the study of gravitation and cosmology, Annual LaserLab Symposium 2011, Amsterdam, The Netherlands, 15 December 2011

Groot, de, N., De Large Hadron Collider op CERN, Natuurkundig Gezelschap Middelburg, Middelburg, The Netherlands, 11 March 2011

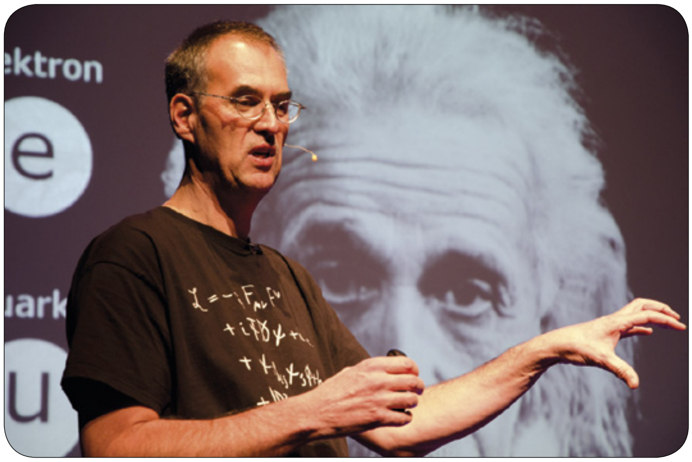


Figure 1. Frank Linde talking about faster-than-light neutrinos at NWO's "Spinoza te Paard" public lectures.

Hennes, E., Nikhef, gravitational waves detection and seismic isolation using anti-springs, Insumma Innovation Day 2011, Evoluon, Eindhoven, The Netherlands, 12 October 2011

Holten, J.W. van, Elementaire deeltjes, Leiden University, Leiden, The Netherlands, 4 February 2011

Supersnelle neutrino's, tijdreizen en causaliteit, KNAW, Amsterdam, The Netherlands, 24 October 2011

Hulsbergen, W.D., The LHCb Experiment at CERN, The Quantum Universe, Fysica 2011, VU University Amsterdam, Amsterdam, The Netherlands, 15 April 2011

Jong, de, P.J., Super?!symmetrie, NSA Symposium University of Amsterdam, Amsterdam, The Netherlands, 26 January 2011

Eerste resultaten van de Large Hadron Collider op CERN, Viva Fysica 2011, University of Amsterdam, Amsterdam, The Netherlands, 28 January 2011

Jong, S.J. de, & Kleiss, R., Boulevard of broken symmetries, Honours programme, Radboud Universiteit Nijmegen, Nijmegen, The Netherlands, September–December 2011

Jong, S.J. de, Carla Rieterprijs award ceremony, Stedelijk Gymnasium Nijmegen, Nijmegen, The Netherlands, 28 February 2011

Kosmische straling, Vrienden van de Sonnenborgh, Utrecht, The Netherlands, 15 May 2011

Radboud Pre-University College of Science: Beter voorbereid, Huygens Colloquium, Nijmegen, The Netherlands, 5 September 2011

CERN, Pax Christi & Stedelijke Scholengemeenschap Nijmegen, Nijmegen, The Netherlands, 10 November 2011

Complexe getallen, Natuur Leven Techniek cluster Nijmegen, Radboud Universiteit Nijmegen, 11, 18 & 25 November 2011

Welkom op CERN, CERN, Geneva, Switzerland, 14 November 2011

Ontdekking Higgs deeltje: Higgs of niks, Raayland College, Venray, The Netherlands, 9 December 2011

Quantumwereld, Woudschoten conferentie, Zeist, The Netherlands, 17 December 2011

Hoe klein kan het zijn?, WND Conferentie voor natuurkundedocenten, Noordwijkerhout, The Netherlands, 17 December 2011

Keijser, J.J., Grid Computing: van wetenschap naar e-Science, Leidsche Flesch lunchlezing, Leiden, The Netherlands, 16 March 2011

OpenVPN Guest Lecture, OS3 System & Network Engineering, Amsterdam, The Netherlands, 11 May 2011

Kleiss, R., Zwaartekracht Ontkracht, Science Café Nijmegen, Nijmegen, The Netherlands, 14 March 2011

Knegjens, R.J., Waar is al de antimaterie gebleven?, Probus club (Rotary), Roermond, The Netherlands, 24 November 2011

Koeroo, O.A., Grid Security on a Global Scale, Guest Lecture: Security, Amsterdam University of Applied Sciences (HvA), Amsterdam, The Netherlands, 18 february 2011

Nikhef and Grid Computing with Arista Networks, Arista Networks and Palo Alto Networks technology partnership solution brief, Antwerpen, Belgium, 10 November 2011

König, A.C., Straling, Lunchcollege, Radboud University Nijmegen, Nijmegen, The Netherlands, 20 April 2011

Laenen, E., Particle physics, the Standard Model, and more?, Mumbai University, Mumbai, India, 26 August 2011

Linde, F.L., Common interests: Particle Physics – SHELL, CERN, SHELL visit, Geneva, Switzerland, 21 March 2011

Tini 80 Fest, Nikhef, Amsterdam, The Netherlands, 24 June 2011

Neutrino's faster than light?, Nikhef Open Dag, Amsterdam, The Netherlands, 8 October 2011

Neutrino's faster than light?, KNAW, Amsterdam, The Netherlands, 24 October 2011

Large Hadron Collider - Bouwstenen van ons Universum, MENSA weekend 2011, Elspeet, The Netherlands, 28 October 2011

Neutrino's faster than light?, MENSA weekend 2011, Elspeet, The Netherlands, 28 October 2011

De LHC: op jacht naar de kleinste bouwstenen van ons Universum, Studium Generale Maastricht University, Maastricht, The Netherlands, 8 December 2011

Neutrino's faster than light?, Science Park, Nextstage event, Amsterdam, The Netherlands, 15 December 2011

Sneller dan het licht, Spinoza te Paard, Paard van Troje, Den Haag, The Netherlands, 20 December 2011

Mischke, A., What does a piece of lead tell us about the early universe?, Emmy Noether Meeting, German Research Foundation (DFG), Potsdam, Germany, 21 July 2011

Mooij, S.J.N., Einstein valt, Cultureel genootschap 'Vandiebank!', Amsterdam, The Netherlands, 6 January 2011

Nooren, G.J., Werken bij 's werelds grootste versneller, Vlaams-Nederlandse Vereniging OvdP 't Sticht, Amersfoort, The Netherlands, 25 January 2011

Werken bij 's werelds grootste versneller, Probus Bilthoven 84, Bilthoven, The Netherlands, 14 December 2011

Raven, G., Materie, Antimaterie en de Large Hadron Collider, VU University Amsterdam Alumni dag, Amsterdam, The Netherlands, 28 May 2011

Suerink, T.C.H., Experimenteel Netwerken, Nikhef, Amsterdam, The Netherlands, 23 March 2011

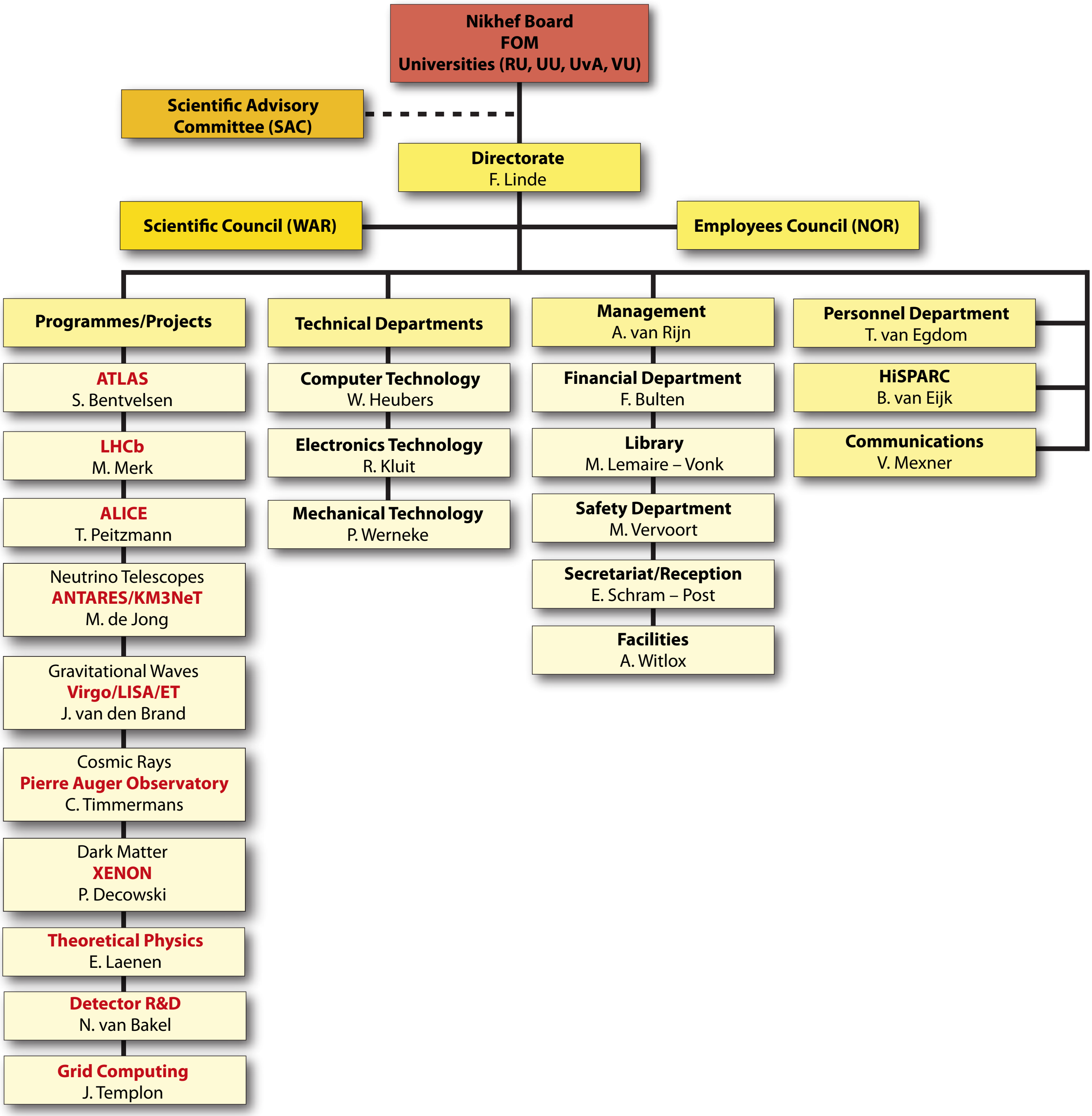
Vulpen, van, I., Elementaire deeltjes en de Large Hadron Collider, Whiqend, Barendonk, The Netherlands, 16 April 2011

Wolf, E. de, Vissen naar neutrino's, Rotary Club, Amsterdam, The Netherlands, 2 May 2011

Wat zijn de allerkleinste bouwstenen?, NEMO, Wakker Worden lezing, Amsterdam, The Netherlands, 25 September 2011

5 Resources

5.1 Organigram*



* *as of 31 December 2011.*

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)
B. Webber (University of Cambridge, Cambridge)
C. De Clercq (Vrije Universiteit Brussel, Brussels)
Y. Karyotakis (chair, LAPP, Annecy le Vieux)
A. Rubbia (ETH, Zürich)
J. Schukraft (CERN, Geneva)

Employees Council (NOR)
L. Wiggers (chair)
R. Schön
H. Boer Rookhuizen (vice-chair)
R. Hart (secretary)
J.J. Keijzer
G. Kieft (vice secretary)
P. Thobe
W. Vink
N. Rem
E. van Willigen

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

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

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
R. Snellings

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

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

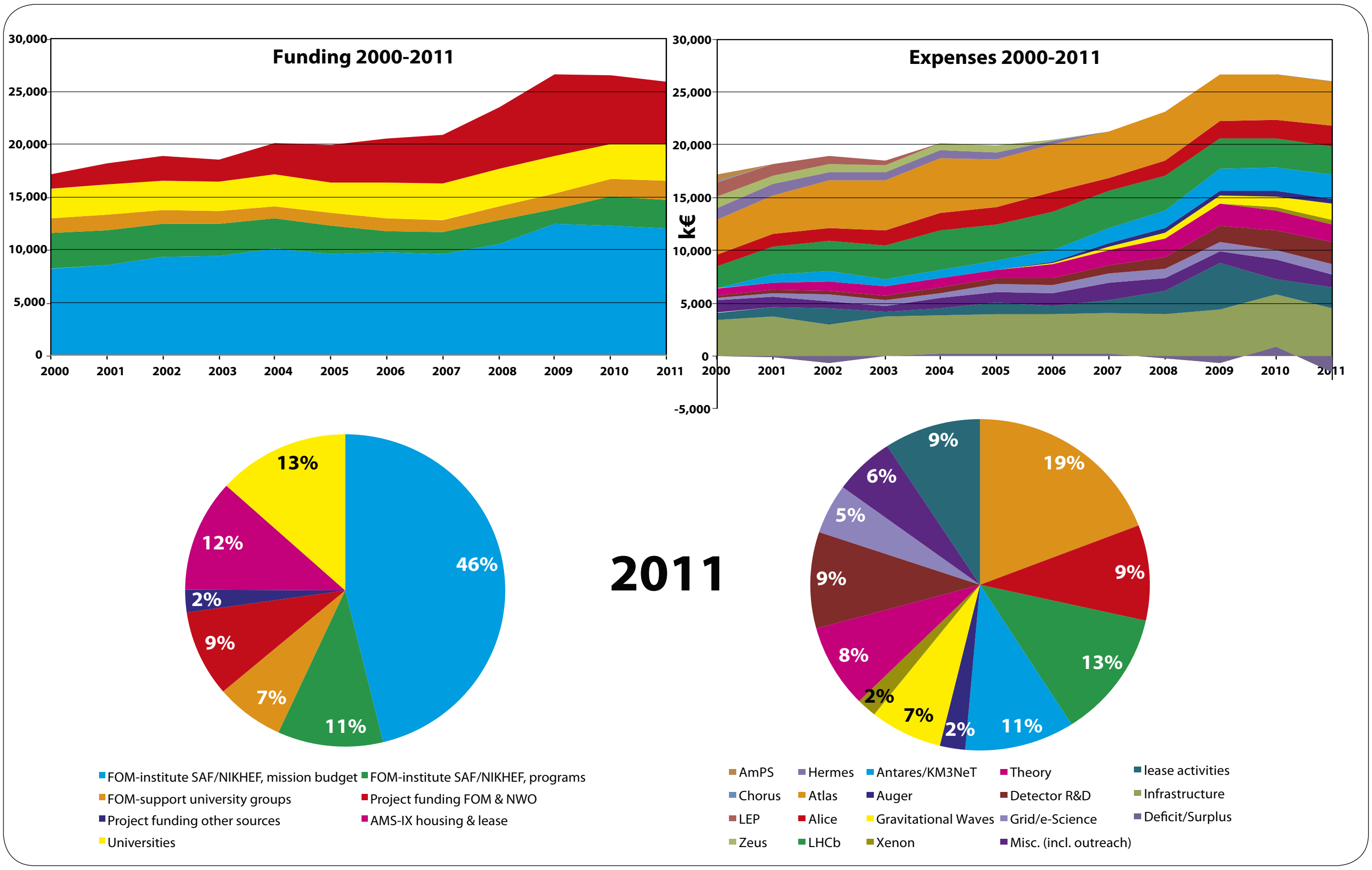
* *as of 31 December 2011.*

5.3 Funding & Expenses

From the income perspective 2011 has been the last year profiting from the temporary increase enabled by the *'Dynamisering instituutsfinanciering'* granted in 2009. No new programme funding has been acquired in 2011. However, new grants have been awarded (see section 5.4 for the complete list), which will appear in the funding scheme in 2012, in particular a prestigious Vici grant (Raimond Snellings), a Marie Curie (MC) training network (TALENT), a MC fellowship, a valorisation grant and an STW project. Further details can be found in section 3.6 'Awards and grants' of this Annual Report.

Finally, the turnover in contracts with customers of the Internet Exchange datacenter facility has also increased (to about 2.6 M€). All in all the 2011 funding level of the Nikhef collaboration is slightly below the level of 2010: 26.0 M€ versus 26.6 M€.

The expenses for accelerator-based particle physics (ATLAS, LHCb and ALICE) are more or less stable at 41%, 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 22% of expenses, including a small involvement in XENON (direct dark matter search). The enabling activities (Theory, Grid Computing and Detector R&D) form 22% 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 BiG Grid funded equipment, KM3NeT prototype detector and Advanced Virgo, totaling about 2.6 M€ in 2011.



5.4 Grants

In the table below we show from top to bottom all grants awarded in 2011, 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 2011 can be found in section 3.6 'Awards and Grants'.

The table shows that in 2011 the Nikhef collaboration has been quite successful in obtaining additional project funding from various funding sources. However, the financial envelope of projects awarded in 2011 amounts to 3.7 M€, about a million less than the 2010 level, which demonstrates that success cannot be taken for 'granted'.

Leader	Title	Source	Period	Budget k€	Partner
	Awarded				
Van den Broecke	Binary black holes as laboratories for fundamental physics	FOM/Pr	2011–2015	354	
P. de Jong	Mind the gap! Generalizing dark matter searches at the LHC.	FOM/Pr	2011–2015	264	
Linde	Tiling appointment M. Postma	FOm/v	2013–2017	326	
Snellings	A new state of matter: The Quark Gluon Plasma	NWO	2012–2016	1,500	UU
Van den Brand	ELiTES: ET–LCGT Interferometric Telescopes: Exchange of Scientists	EU	2012–2016	32	
Hessey	TALENT: Training for cAreer deveLopment in high–radiation ENvironment Technologies	EU	2012–2016	545	
Laenen/Artoisenet	PROBE4TeVSCALE: Resolving short–distance physics mechanisms in hadron collisions at TeV scale energies	EU	2012–2014	192	
Visser	New Detector Systems for Biomedical Imaging (together with AMOLF)	STW	2012–2016	300	
Van Bakel/Visser	Valorisation grant 2nd phase (Amsterdam Scientific Instruments)	STW	2012–2013	200	
				3,713	
	Running				
Vermaseren	Precision phenomenology at the LHC	FOM/Pr	2008–2012	335	
S. de Jong	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
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 O. Igonkina	FOm/v	2007–2012	310	
Linde	Tiling appointment P. Ferrari	FOm/v	2010–2014	470	
Linde	High school teachers	FOM/EK	2010–2012	92	
Linde	Valorization	FOM	2010–2012	200	
Linde	HiSPARC nationale coördinatie fase–III	FOM/Out	2010–2013	215	
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	2008–2012	141	
Mischke	Vidi: Characterisation of a novel state of matter: The Quark–Gluon Plasma	NWO	2008–2013	365	UU
Heijboer	Vidi: Exploring the Cosmos with Neutrinos	NWO	2009–2014	600	

Leader	Title	Source	Period	Budget k€	Partner
P. de Jong	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	2009–2012	26	
Igonkina	Vidi: Lepton flavor violation: the key towards a matter dominated universe	NWO	2011–2016	800	
De Groot	OSAF Research school for subatomic physics – NWO graduate programme	NWO	2010–2015	800	RU
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	2008–2012	447	
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
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	EU	2011–2015	397	
Visser	Hidralon: High Dynamic Range Low Noise CMOS sensors	Senter	2009–2012	794	
Van Eijk	HiSPARC – 'betadecanen'	Univ.	2011– …	30	
				14,190	
			Completed		
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
Van Vulpen	Vidi: Top quarks and fundamental physics at 100 zeptometer	NWO	2006–2011	406	
Van Beuzekom	Kenniswerkersregeling (Bruco)	Senter	2009–2010	45	
Klöpping	Holland at CERN	Senter	2010–2011	75	
Van Bakel	Pixel innovations	STW	2010–2011	25	
				1,172	

5.5 Personnel*

ATLAS

Aben	MSc	R.Z. (Rosemarie)	FOM
Beemster	MSc	L.J. (Lars)	FOM
Bentvelsen	Prof.dr.	S.C.M. (Stan)	UvA
Berglund	Dr.	F.E. (Elina)	FOM
Besjes	MSc	G.J. (Geert-Jan)	RU
Bobbink	Dr.	G.J. (Gerjan)	FOM
Bos	Dr.	K. (Kors)	FOM
Caron	Dr.	S. (Sascha)	RU
Castelli	MSc	A. (Angelantonio)	FOM
Chelstowska	MSc	M.A. (Magda)	FOM
Deijl	MSc	P.C. (Pieter), van der	UT
DeViveiros	Dr.	P-O. (Pier-Olivier)	FOM
Ferrari	Dr.	P. (Pamela)	FOM
Filthaut	Dr.	F. (Frank)	RU
Gadatsch	MSc	S. (Stefan)	FOM
Garitaonandia	Drs	H. (Hegoi)	FOM
Geer	MSc	R. (Rogier), van der	RU
Geerts	MSc	D.A.A. (Daniel)	FOM
Groot	Prof.dr.	N. (Nicolo), de	RU
Hessey	Dr.	N.P. (Nigel)	FOM
Igonkina	Dr.	O.B. (Olga)	FOM
Jong	Prof.dr.ir.	P.J. (Paul), de	FOM
Klok	Drs.	P.F. (Peter)	FOM
Klous	Dr.ing.	S. (Sander)	GST
Kluit	Dr.drs.ir.	P.M. (Peter)	FOM
Koffeman	Prof.dr.ir.	E.N. (Els)	FOM
König	Dr.	A.C. (Adriaan)	RU
Lee	MSc.	H.C. (Hurng-Chun)	FOM
Leeuw	MSc	R.H.L. (Robin), van der	FOM
Lenz	Dr.	T. (Tatjana)	FOM
Mahlstedt	Dipl.Phys	J. (Joern)	FOM
Mechnich	Dipl.Phys.	J. (Jörg)	FOM
Meijer	MSc	M.M. (Melvin)	GST
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	GST
Ottersbach	Dipl.Phys.	J.P. (John Philip)	FOM
Oussoren	MSc	K.P. (Koen)	FOM
Pani	MSc	P. (Priscilla)	FOM
Poel	Dr.	E.F. (Egge), van der	GST
Raas	MSc	M.J.P. (Marcel)	GST
Ruckstuhl	MSc	N.M. (Nicole)	FOM
Salvucci	MSc	A. (Antonio)	RU
Ta	Dr.	D.B. (Duc Bao)	FOM
Tsiakiris	MSc	M. (Menelaos)	FOM
Valencic	MSc	N. (Nika)	FOM
Verkerke	Dr.	W. (Wouter)	FOM
Vermeulen	Dr.ir.	J.C. (Jos)	UvA
Vranjes Milosavljevic	Dr.	M. (Marija)	FOM
Vreeswijk	Dr.	M. (Marcel)	UvA
Vulpen	Dr.	I.B. (Ivo), van	UvA

LHCb

Aaij	MSc	R.J.M. (Roel)	FOM
Ali	MSc	S. (Suvayu)	FOM
Bauer	Dr.	T.S. (Thomas)	FOM
Bruyn	MSc	K.A.M. (Kristof), de	FOM
Coco	Dr.	V.A.G. (Victor)	FOM
David	MSc	P.N.Y. (Pieter)	FOM
Dettori	Dr.	F. (Francesco)	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

* *as of 31 December 2011.*

Overview of Nikhef personnel in fte (2011)

I – Scientific groups
(fte – 2011, institute & university groups)

Permanent scientific staff	60.6
PhD students	81.1
Post–docs	26.8
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	0.7
Subtotal	***2.7***
Technical/engineering support	
Electronics technology	25.7
Computer technology	23.1
Mechanical engineering	18.5
Mechanical workshop	14.6
Project management support	1.8
Subtotal	**83.8**
General support	
Financial administration	3.8
Personnel/HRM administration	1.0
Library	0.6
Technical and domestic services	9.3
Secretariat and reception desk	5.7
PR & communication	2.1
Occupational health & safety	0.8
Education (HiSPARC)	2.3
Staff	1.0
Subtotal	***26.6***
Total II	**113.1**
Total I & II	**281.6**

III – Other groups (persons 2011)

Guests (researchers, retired staff)	45.0
Master students	11.0
Apprentices	12.0

Ketel	Dr.	T.J. (Tjeerd)	FOM
Koopman	MSc	R.F. (Rose)	FOM
Koppenburg	Dr.	P.S. (Patrick)	FOM
Kozlinskiy	MSc	A. (Alexandr)	FOM
Lambert	Dr.	R.W. (Rob)	FOM
Leerdam	MSc	J. (Jeroen), van	FOM
Martinelli	Dr.	M. (Maurizio)	FOM
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	Prof.dr.	H.G. (Gerhard)	VU
Schiller	Dr.	M.T. (Manuel)	FOM
Storaci	MSc	B. (Barbara)	FOM
Tolk	MSc	S. (Siim)	FOM
Tuning	Dr.	N. (Niels)	FOM
Vries	Dr.	H. (Hans), de	GST
Wiggers	Dr.	L.W. (Leo)	FOM

ALICE

Bilandžic	Drs.	A. (Ante)	FOM
Bjelogrlic	MSc	S. (Sandro)	FOM
Botje	Dr.	M.A.J. (Michiel)	FOM
Chojnacki	Drs.	M. (Marek)	GST
Christakoglou	Dr.	P. (Panos)	FOM
Kolk	Drs.ing.	N. (Naomi), van der	GST
Krzewicki	MSc	M. (Mikolaj)	GST
Kuijer	Dr.	P.G. (Paul)	FOM
LaPointe	Dr.	S. (Sarah)	FOM
Leeuwen	Dr.	M.A. (Marco), van	UU
Luparello	Dr.	G. (Grazia)	FOM
Mischke	Dr.	A. (Andre)	UU
Nooren	Dr.ir.	G.J.L. (Gert-Jan)	FOM
Peitzmann	Prof.dr.	T. (Thomas)	UU
Pérez Lara	MSc	C.E. (Carlos)	FOM
Reicher	MSc	M. (Martijn)	UU
Rodriguez Manso	MSc	A. (Alis)	FOM
Rooij	MSc	R. (Raoul), de	UU
Schee	MSc	W. (Wilke), van der	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
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
Palioselitis	MSc	D. (Dimitrios)	FOM
Petrovic	Dr.	J. (Jelena)	FOM
Samtleben	Dr.	D.F.E. (Dorothea)	FOM
Schulte	Dr.	S. (Stephan)	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

Grebe	MSc	S. (Stefan)	FOM
Hörandel	Prof.dr.	J.R. (Jörg)	RU
Jansen	MSc	S. (Stefan)	FOM
Jong	Prof.dr.	S.J. (Sijbrand), de	RU
Nelles	MSc	A.F. (Anna)	FOM
Schoorlemmer	MSc	H. (Harm)	FOM
Timmermans	Dr.	C.W.J.P. (Charles)	FOM
Zarza	MSc	G.A. (Gabriel)	GST

Virgo

Agathos	MSc	M. (Michalis)	FOM
Ambrosi	MSc	G. (Giuseppe)	FOM
Beker	Ir.	M.G. (Mark)	FOM
Bertolini	Dr.	A. (Alessandro)	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
Jonker	MSc	R.J.G. (Reinier)	FOM
Li	MSc	T.G.F. (Tjonnie)	FOM
Rabeling	Dr.	D.S. (David)	FOM
Vitale	Dr.	S. (Salvatore)	FOM

XENON

Alfonsi	Dr.	M. (Matteo)	FOM
Colijn	Dr.	A.P. (Auke Pieter)	UvA
Decowski	Dr.	M.P. (Patrick)	UvA

Theory

Adelhart Toorop	MSc	R. (Reinier), de	FOM
Artoisenet	Dr.	P.D. (Pierre)	FOM
Aybat	Dr.	S.M. (Mert)	FOM
Beenakker	Dr.	W. (Wim)	RU
Bonocore	MSc	D. (Domenico)	FOM
Broek	MSc	T.C.H. (Thijs), van den	FOM
Buffing	MSc	M.G.A. (Maarten)	VU
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	MSc	R.J. (Rob)	FOM
Kuipers	Dr.	J. (Jan)	FOM
Laenen	Prof.dr.	E.L.M.P. (Eric)	UvA
Maio	Dr.	M. (Michele)	GST
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
Schellekens	Prof.dr.	A.N.J.J. (Adrianus)	FOM
Veltman	Prof.dr.	M.J.G. (Martinus)	GST
Vermaseren	Dr.	J.A.M. (Jos)	FOM
Weenink	MSc	J.G. (Jan Gerard)	FOM
Wit	Prof.dr.	B.Q.P.J. (Bernard)	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)	FOM
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
Koppert	MSc	W.J.C. (Wilco)	FOM
Schioppa	MSc	E.J. (Enrico)	RU
Schön	Dipl.Phys.	R. (Rolf)	FOM
Timmer	Dr.	B.H. (Björn)	GST
Timmermans	Dr.	J.J.M. (Jan)	GST
Vanbavinckhove	Ir.	G. (Glenn)	FOM
Visschers	Dr.	J.L. (Jan)	GST
Visser	Dr.	J. (Jan)	FOM
Zappon	MSc	F. (Francesco)	FOM

HiSPARC

Bakker	Drs.	W. (Wytse)	GST
Bonam		S. (Surya)	FOM
Bosboom	MSc	C.H. (Niels)	GST
Eijk	Prof.dr.ing.	B. (Bob), van	FOM
Fokkema	Drs.	D.B.R.A. (David)	FOM
Hidden	Ing.	F.J. (Frits)	GST
Laat	MSc	A.P.L.S. (Arne)	FOM
Montanus	Drs.	J.M.C. (Hans)	GST
Neuraij	Ir.	P.J. (Paul)	GST
Offerhaus	Drs.	S.H. (Sjoerd)	GST
Rozendom		G.J. (Hans)	GST
Schultheiss		N.G. (Nicolaas)	GST

Grid Computing

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

Computer Technology

Akker		T.G.M. (Theo), van den	FOM
Beveren	Ing.	V. (Vincent), van	FOM
Boterenbrood	Ir.	H. (Henk)	FOM
Bouwhuis	Dr.	M.C. (Mieke)	FOM
Damen		A.C.M. (Ton)	FOM
Harapan	Drs.	D. (Djuhaeri)	FOM
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
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
Borga	Ing.	A.O. (Andrea)	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
Ietswaard		G.C.M. (Charles)	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)	FOM
Kuijt	Ing.	J.J. (Jaap)	FOM
Mos	Ing.	S. (Sander)	FOM
Oskamp		C.J. (Kees)	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
Visser	Ing.	G.C. (Guido)	FOM
Wijnen	Ing.	T.A.M. (Thei)	RU
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. (Loek)	FOM
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)	GST
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)	FOM

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. (Hélène)	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), zur	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

Engelen	Prof.dr.	J.J. (Jos)	UvA

5.6 Master students

In 2011, 11 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*
30-5-2011	Kristof De Bruyn	UvA Double Master *(Cum Laude)*	Analysis of the Penguin Topologies in $B_s \rightarrow J/\psi\ K_s$	R. Fleischer P. Koppenburg	Theory/LHCb
27-6-2011	Nicolas Gutierrez Ortiz	UvA *(Cum Laude)*	Heavy Flavour Electron Elliptic Flow	R. Snellings	ALICE
27-6-2011	Siim Tolk	UvA *(Cum Laude)*	A CP violation study in the B_d meson system with the first LHCb data	A. Pellegrino	LHCb
26-8-2011	Piotr Kukla	UU	D^{*+} analysis in proton-proton collisions at $\sqrt{s}$=2.76 TeV using the ALICE detector at CERN	A. Mischke A. Grelli	ALICE
26-8-2011	Menno de Bell	UvA	KM3NeT Detector design studies	C. Kopper	KM3NeT
26-8-2011	Bardo Bakker	UvA	Trigger studies for the Antares and KM3NeT neutrino telescopes	M. de Jong	ANTARES/KM3NeT
29-8-2011	Stamatios Gkaitatzis	UvA	Point Source Searches Using High-Energy Down-going Neutrinos With the ANTARES Telescope	A. Heijboer	ANTARES
29-8-2011	Meike de With	UvA Double Master *(Cum Laude)*	Signals of minimal Gauge-Mediated Supersymmetry Breaking in ATLAS	E. Laenen P. de Jong	Theory/ATLAS
29-8-2011	Koen Oussoren	UvA	Flavor Changing Neutral Currents in Top Quark decay at the ATLAS Detector	M. Vreeswijk	ATLAS
29-8-2011	Akshay Katre	UvA	Pions Misidentified as Muons in the LHCb Detector	T. Bauer	LHCb
23-9-2011	Gijs Hemink	UT *(Cum Laude)*	GRIDPIX A pixel sensor for noble liquid dark matter searches	B. van Eijk	R&D

Table 1. Master students who graduated in 2011. The term Double Master in the column University refers to students who graduated both in Particle and Astroparticle Physics and Theoretical Physics.

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 2011 in the departments Computer Technology (CT), Electronics Technology (ET) and Mechanical Technology (MT).

Date	*Name*	*School*	*Subject / Title*	*Supervisor(s)*	*Group*
March 2011	J.J. van Bergen	MBO Nova College Haarlem	Web-based PDU read-out	T. Suerink	CT
July 2011	S. Broekema	MBO Nova College Hoofddorp	Proeve van bekwaamheid	H. Verkooien	ET
Dec. 2011	M. Daverveldt	HBO Hogeschool Utrecht	Implementatie LEON3 processor in FPGA	P. Jansweijer	ET
Dec. 2011	F. van Son	HBO Hogeschool van Amsterdam	Meeloopstage	H. Verkooien	ET
July 2011	B.W.H.J. van der Kroon	HBO Hogeschool van Amsterdam	Spanning op de mechanische kabels van KM3NeT	G. Mul	MT
Jan. 2011	N. Mahmud	HBO Hogeschool van Amsterdam	XENON1T Cryostat support	K. de Roo	MT
Jan. 2011	M.D. van den Muijsenberg	HBO Hogeschool van Amsterdam	Inverted Pendulum als seismische isolator	E. Hennes	MT
July 2011	K. van den Norel	HBO De Haagse Hogeschool	Designing, Modelling, Simulating and Testing of GAS filters	E. Hennes	MT
June 2011	R. Tier	MBO ROC van Amsterdam	Breakout Box KM3NeT	A. Korporaal	MT
July 2011	M.H. Dokter	MBO ROC van Amsterdam	Een behuizing voor Medipix 3	O. van Petten	MT
June 2011	B.P. Huiskamp	MBO ROC van Amsterdam	Manometer interface	O. van Petten	MT
Jan. 2011	T. Nieuwenhuijse	MBO ROC van Amsterdam	In hoogte verstelbare kruistafel	O. van Petten	MT

Table 1. Apprentices who finished their training period at Nikhef in 2011.

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.

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 and dark energy
Only 4% of the matter in the Universe is visible. The rest is known as dark matter and dark energy. Finding out what it consists of is a major question for modern science.

Detector
A device used to measure properties of particles. Some detectors measure the tracks left behind by particles, others measure energy. The term '*detector*' is also used to describe the huge composite devices made up of many smaller detector elements. Examples are the ATLAS, the ALICE and the LHCb detectors.

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*.

ET
Einstein Telescope. Design project for a third generation *gravitational wave* observatory consisting of three –underground and typically 10 km long– cryogenic xylophone interferometers in a triangular shape.

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, characterised by spin in odd half integer quantum units ($\frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$...). Named for Italian physicist Enrico Fermi. Quarks, leptons and baryons are all fermions.

Forces
There are four fundamental forces in nature. Gravity is the most familiar to us, but it is the weakest. Electromagnetism is the force responsible for thunderstorms and carrying electricity into our homes. The two other forces, weak and strong, are connected to the atomic nucleus. The strong force binds the nucleus together, whereas the weak force causes some nuclei to break up. The weak force is important in the energy–generating processes of stars, including the Sun. Physicists would like to find a theory that can explain all these forces in one common framework.
A big step forward was made in the late 1970s when the electroweak theory uniting the electromagnetic and weak forces was proposed. This was later confirmed in a Nobel prize–winning experiment at CERN.

fte (Full Time Equivalent)
Unit of manpower.

Gluon
See *Particles*.

Gravitational wave
The gravitational analog of an electromagnetic wave whereby gravitational radiation is emitted at the speed of light from any mass that undergoes rapid acceleration.

Grid
A service for sharing computer power and data storage capacity over the Internet.

Hadron
A subatomic particle that contains quarks, antiquarks, and gluons, and so experiences the strong force (see also *Particles*).

High–Energy Physics
A branch of science studying the interactions of fundamental particles; called 'high–energy' because very powerful accelerators produce very fast, energetic particles probing deeply into other particles.

Higgs boson
A particle predicted 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.

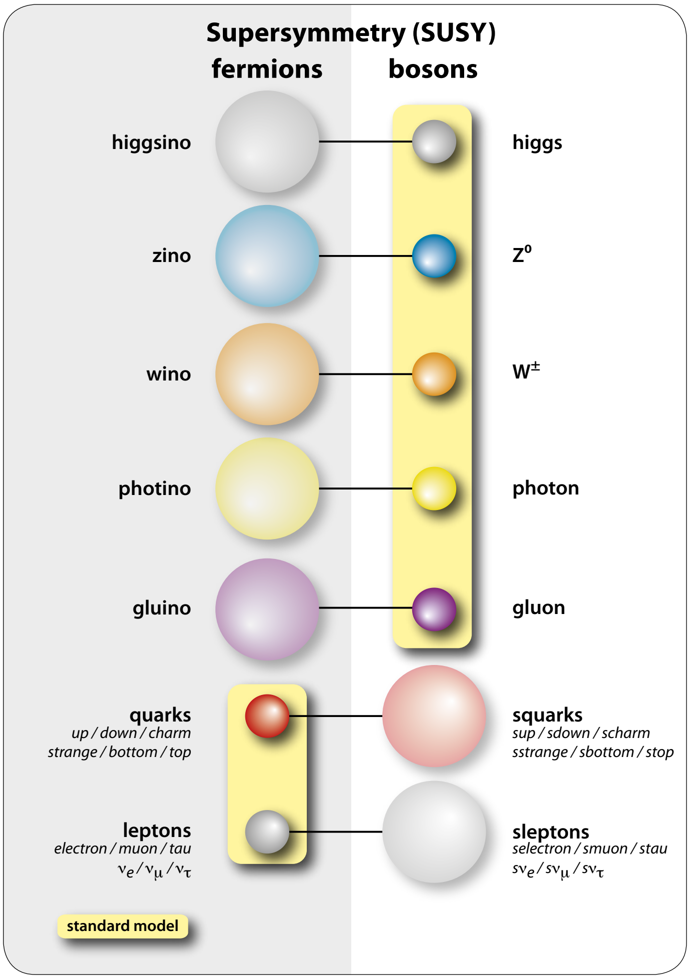
LCG (LHC Computing Grid)
The mission of the LCG is to build and maintain a data–storage and analysis infrastructure for the entire high–energy physics community that will use the LHC.

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.

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



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

Linac
An abbreviation for linear accelerator.

LISA (Laser Interferometric Space Array)
ESA/NASA mission, 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 block of matter (see also *Particles*).

Quark–gluon plasma (QGP)
A new kind of plasma, in which protons and neutrons are believed to break up into their constituent parts. QGP is believed to have existed just after the Big Bang.

RASNIK (Red Alignment System Nikhef)
Optical alignment system where a pattern is projected by a lens on a CCD and deviations measured.

Relaxd (high-REsolution Large-Area X-ray Detection)
EU–funded development of the large area fast detector system using Medipix technology.

RHIC
Brookhaven's Relativistic Heavy Ion Collider; began operation in 2000. RHIC collides beams of gold ions to study what the Universe looked like in the first few moments after the Big Bang.

Scintillation
The flash of light emitted by an electron in an excited atom falling back to its ground state.

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

Spectrometer
In particle physics, a detector system containing a magnetic field to measure momenta of particles.

Spin
Intrinsic angular momentum of a particle.

Standard Model
A collection of theories that embodies all of our current understanding about the behaviour of fundamental particles.

STAR
Experiment at *RHIC*.

String Theory
A theory of elementary particles incorporating relativity and quantum mechanics in which the particles are viewed not as points but as extended objects. String theory is a possible framework for constructing unified theories that include both the microscopic forces and gravity (see also *Forces*).

Supersymmetry
Supersymmetry (often abbreviated SUSY) is a symmetry that relates elementary particles of one spin to other particles that differ by half a unit of spin and are known as superpartners.

SURFnet
Networking organisation in the Netherlands.

Tevatron
Fermilab's 2–TeV proton–antiproton accelerator near Chicago.

Tier–1
First tier (category) in the *LHC* regional computing centers. Tier–0 is the facility at CERN collecting, reconstructing and storing the data.

Trigger
An electronic system for spotting potentially interesting collisions in a particle detector and triggering the detector's read–out system.

Vertex detector
A detector placed close to the collision point in a colliding beam experiment so that tracks coming from the decay of a short–lived particle produced in the collision can be accurately reconstructed and seen to emerge from a 'vertex' point that is different from the collision point.

Virgo
Detector near Pisa for gravitational waves: a Michelson laser interferometer made of two orthogonal arms, each 3 km long.

W boson
A carrier particle of weak interactions; involved in all electric–charge–changing weak processes.

WIMP
Weakly Interacting Massive Particles are the most compelling candidates for *dark matter* particles. They can interact with normal matter through the weak nuclear force and through gravity and are often inherent to models extending the *Standard Model*.

XENON
A series of experiments aiming at direct detection of Weakly Interacting Massive Particles (*WIMPs*). The detectors are located in the Gran Sasso laboratory in Italy and use xenon as the target material.

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

NIKHEF