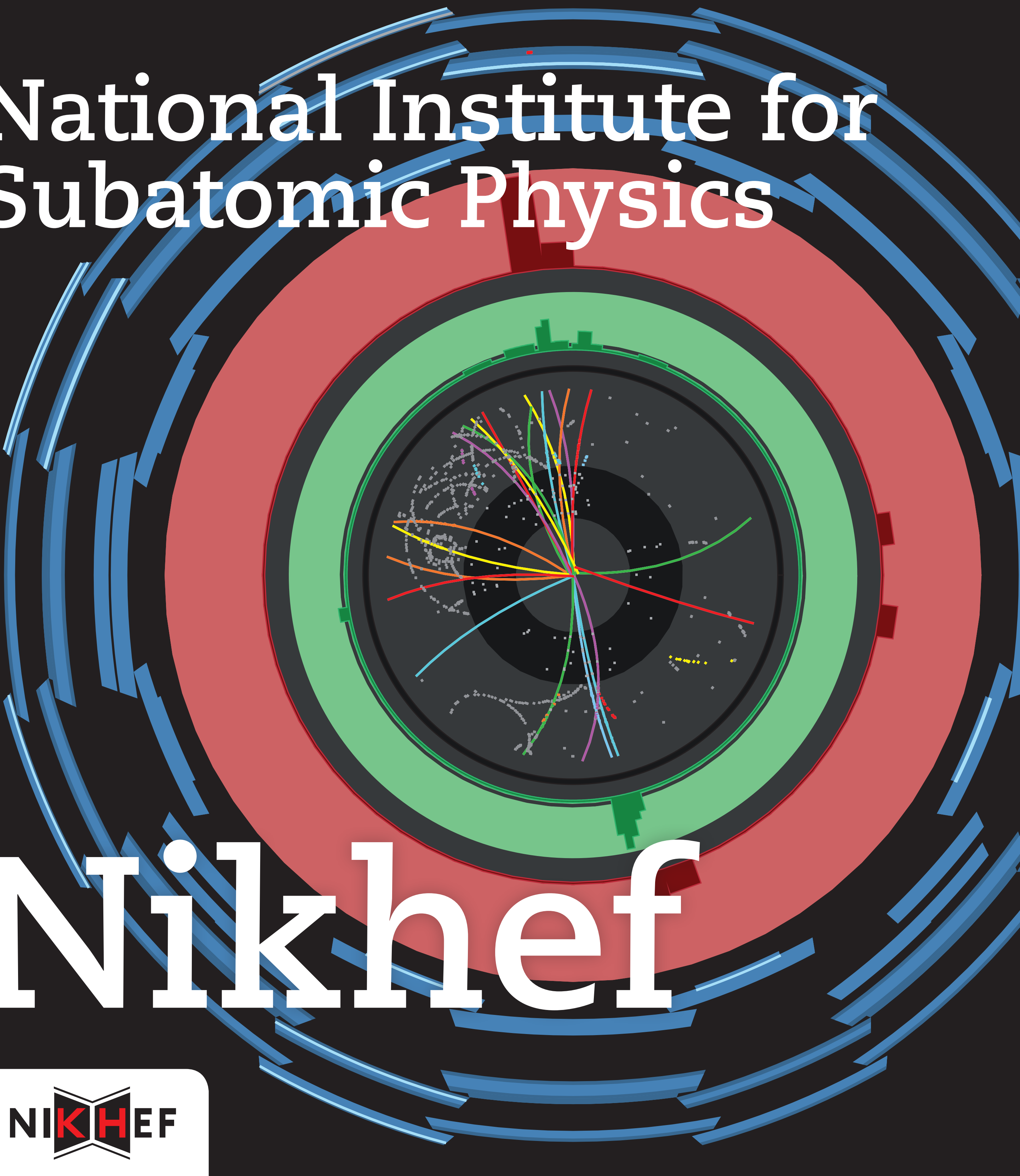
Annual Report 2009

National Institute for Subatomic Physics



Nikhef

NIKHEF

Annual Report
2009

National Institute
for Subatomic Physics
Nikhef

Colophon

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Cover: Two-jet event in the ATLAS detector, at the world-record centre-of-mass energy of 2.36 TeV, recorded in December 2009. Illustration by Eric Jansen (Radboud University Nijmegen)

Nikhef is the National Institute for Subatomic Physics in the Netherlands, in which the Foundation for Fundamental Research on Matter (FOM), 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 threefold: the ANTARES and KM3NeT neutrino telescope projects in the Mediterranean Sea; the Pierre Auger Observatory for cosmic rays, located in Argentina; and gravitational-wave detection via the Virgo interferometer in Italy, and the projects LISA and Einstein telescope. Detector R&D, design and construction of detectors and data analysis take place at the laboratory located at Science Park Amsterdam as well as at the participating universities. Nikhef has a theory group with both its own research programme and close contacts with the experimental groups.

Contents

Introduction

Beyond any doubt, the 2009 highlight took place on 23 November when for the first time CERN's LHC (Large Hadron Collider) delivered head-on proton-proton collisions to the experiments. Initially, the protons were collided at the injection energy of 450 GeV. Soon after, both proton beams were accelerated to 1.18 TeV and brought into collision, surpassing the world-record centre-of-mass energy held for almost a quarter century by the Tevatron collider at Fermilab near Chicago. With real data to analyse, 'interactions' in the ATLAS, LHCb and ALICE quarters at Nikhef increased by an order of magnitude overnight, as did the general spirit at Nikhef and at many other particle physics laboratories around the world. It was amusing to witness the fierce competition between PhD students, postdocs and staff physicists on who reconstructed the most convincing π^0, ϕ, Λ^0 or K_S invariant mass peak! The central values and widths of many of these peaks agree remarkably well with their Monte Carlo expectations. This shows that the experiments are very well positioned to run at the new energy scale, the TeV scale, which the LHC is designed for to explore in the coming years. Some experiments are even more ready than others as the ALICE collaboration proved by (probably much to the chagrin of the other three collaborations that experiment at the LHC) their submission of the first paper based on the analysis of LHC proton-proton collisions appropriately titled: *"First proton-proton collisions at the LHC as observed with the ALICE detector: measurement of the charged particle pseudorapidity density at* $\sqrt{s}$*=900 GeV"*. On this high note CERN did shutdown the LHC on 16 December for the Christmas holidays. The challenges after the restart in February 2010 are clear: a modest increase of the LHC beam energy to its nominal value of 7 TeV and a large boost in the LHC luminosity to eventually reach the scheduled 10^{34} $cm^{-2}s^{-1}$. Accelerator technology is outside my scope of expertise, but many machine physicists assure me that the LHC machine behaves like a charm and that these goals can be achieved. I

Many happy phycisists witnesssing the LHC start-up in November 2009. At bottom-left is Nikhef PhD student Ido Mussche.

can hardly wait for the days when the LHC will routinely deliver 10–100 fb^{-1} per year at 14 TeV centre-of-mass energy.

Just-in-time delivery was taken very literally by the Dutch LHC Tier-1 grid site. The floor space, the electrical infrastructure as well as the cooling plant at Nikhef and SARA all became available just in time to upgrade the grid services to about 10,108 KSI2K CPU cores and 2.7 PB disk storage in accordance with the LCG (LHC Computing Grid) pledges. Subsequently, these grid services did pass the challenges posed by the first batch of real LHC data.

Nikhef's astroparticle physics endeavours are in full swing. The Pierre Auger cosmic-ray observatory near Malargüe in Argentina is in routine data taking mode while the R&D programme on the detection of cosmic rays using radio antennas is making good progress. Together with KVI (Groningen) and the Radboud University Nijmegen, Nikhef submitted an investment proposal for a radio-antenna array to NWO. The ANTARES pilot neutrino telescope project at the bottom of the Mediterranean Sea off the coast of Toulon (France) was already completed in 2008 and continues to collect data. For the real kilometre cube, KM3NeT, neutrino telescope Nikhef put forward several original design ideas like a multi-PMT optical module and a self-buoyant detector line. The Royal Netherlands Institute for Sea Research (NIOZ) developed an elegant detector line storage-, transport- and deployment concept in which the full detector line is wound around a metal sphere. This complete assembly is deployed into the seawater and manoeuvred to its correct position on the sea floor whereafter an acoustic signal triggers the line to unwind automatically. This concept was successfully tested in the deep waters off the Greek shores during a 9-day cruise of NIOZ' *Pelagia* research vessel just before Christmas 2009. A complete Technical Design Report for KM3NeT is expected to become available early 2010. Dutch gravitational-wave research entered the list of elite activities supported by FOM with the approval of the national research programme entitled: "*Gravitational physics – the dynamics of spacetime*". The main focus of this programme is on the Dutch participation in the Virgo laser-interferometer for gravitational-wave detection just outside the city of Pisa in Italy. In 2009, the three Virgo partners (Italy, France and the Netherlands) approved the so-called advanced-Virgo project which will lead to a five-fold sensitivity increase corresponding to a factor 5^3=125 detection volume increase. With this upgrade the expected event rate will go up from a few to tens per year. This means that once advanced-Virgo comes online (about 2014), the much anticipated direct detection of a gravitational wave should follow soon, thereby opening up a whole new window onto our Universe including the possibility to eventually study primordial gravitational waves, i.e. signals originating from the very early Universe. On a much smaller scale Nikhef considers, backed by the EU-approved DARWIN project, to enter the race to directly detect dark matter particles using a noble liquid (xenon) as target material in a deep-underground and therefore low-background laboratory like LNGS (Laboratori Nazionali del Gran Sasso) in Italy or LSM (Laboratoire Souterrain de Modane) in France.

In 2009, Nikhef once again received plenty of media attention and not only because of the successful start-up of the LHC. On 13 May many Nikhef collaborators and guests were invited to a preview of Ron Howard's *"Angels & Demons"* (after the bestseller by Dan Brown) featuring CERN's LHC in Tuschinski cinema in Amsterdam. According to the Dutch newspaper NRC, scientists do so in style: they arrive half an hour early and before watching the movie they attend a presentation on the facts and fiction in this movie! On 20 November many from Nikhef were again in the cinema. This time for the premiere of the documentary titled *"Higgs – into the heart of imagination"* featuring Peter Higgs and our own colleague Stan Bentvelsen as main characters (and not to forget: the ATLAS experiment and the quest for the Higgs particle). Not only the creators of this documentary, Hannie van den Bergh en Jan van den Berg, but also Stan can be very proud of the result!

For 2010 I can be really brief: let the LHC deliver a significant fraction of 1 fb^{-1} integrated luminosity at multi-TeV centre-of-mass energy.

Frank Linde
Nikhef director

1

Reviews

1.1 Identifying Dark Matter

Patrick Decowski

One of the most interesting scientific questions of our time is why only about one-fifth of the matter in the universe is made up of known particles. The remaining four-fifths is not known, as yet 'invisible', and has been named dark matter. Several different dark matter search techniques are being used to establish the identity of dark matter.

Evidence for the existence of dark matter presently comes from cosmic observations. The first indication came from the Swiss astronomer Fritz Zwicky who in 1933 found that the amount of luminous matter was insufficient to explain the gravitational binding of clusters of galaxies. The masses of stars and other bright astronomical bodies together did not describe the observed gravity in clusters. Therefore, some unidentified, non-luminous, *dark matter* was required to explain the discrepancy. More astrophysical evidence has cumulated since then: the observation that stars in a spiral galaxy revolve around the center faster than expected from Newtonian dynamics, gravitational lensing, the anisotropy in cosmic microwave background, and the large-scale structure of the universe, all support the existence of dark matter. Current evidence disfavours astronomical bodies as the major contributor to dark matter and favours models in which the primary components are one or more new elementary particles, collectively called non-baryonic (cold) dark matter.

No currently known particle in the Standard Model of particle physics (see Glossary) has the right properties to be a dark matter candidate. Dark matter particles that are too light (less than about 1 keV in mass, i.e. five hundred times lighter than an electron) do not allow galaxies to form if they were produced in thermal equilibrium in the early universe. This means that neutrinos, that are now known to be massive but with a mass less than about 1 eV, cannot account for all of the dark matter. However, there are several well-motivated theories predicting new particles that have all the properties required to be dark matter and that simultaneously solve problems in the Standard Model. The two most compelling dark matter candidates are axions and weakly interacting massive particles (WIMPs). The existence of axions would solve the problem of the observed lack of CP violation in strong interactions (see Annual Report 2006). They are generated out of thermal equilibrium in the early universe and they are predicted to be light (10^{-6} eV to 10^{-3} eV), very feebly interacting and numerous. WIMPs on the other hand, interact through weak interactions and have masses of the order of 100 GeV. They are inherent to supersymmetric and other theories extending the Standard Model to describe a phenomenon called electroweak symmetry breaking. One particular WIMP of interest is the neutralino, the lightest supersymmetric particle (see Glossary). In these theories WIMPs are also naturally produced in the Big Bang with the cosmological density required for dark matter.

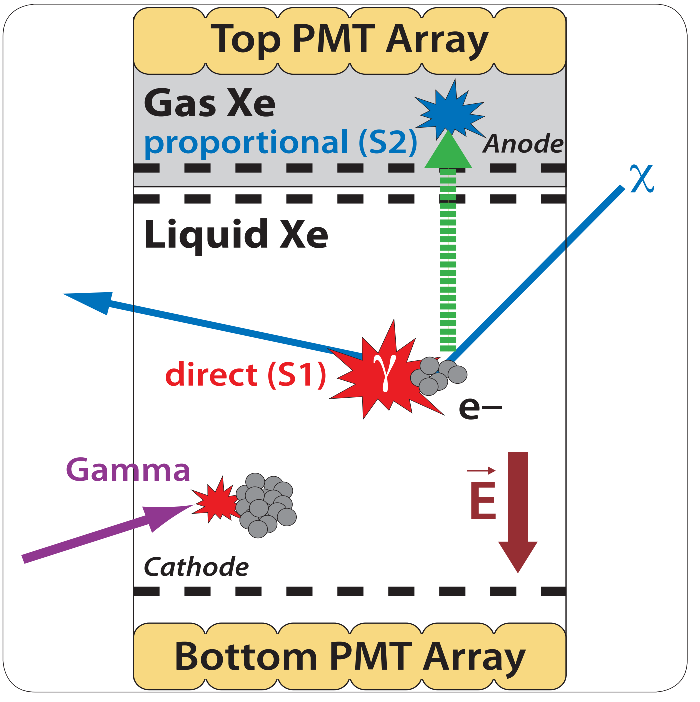


Figure 1. Schematic diagram of a dual-phase xenon Time Projection Chamber. The time correlation of the primary (S1) and secondary (S2) scintillation light allows the identification of recoil events in the detector. The relative amount of S1 and S2 light provides discrimination of background events from scattering of WIMPs (denoted by the symbol χ) off nuclei.

Besides cosmological measurements, there are three other types of dark matter searches being pursued: *direct detection* of dark matter in elastic scattering of WIMPs off atomic nuclei, *indirect detection* through observation of WIMP pair annihilation , and *production* of dark matter particles in collider experiments. Ideally, all three types of searches would independently confirm the existence of dark matter. Such an observation would be a major discovery and allow to unambiguously establish the identity of dark matter.

Direct detection

If WIMPs fill the galaxy, they will also pass through the Earth and occasionally scatter off nuclei. Direct detection experiments look for the nucleus that recoils when a WIMP interacts with the target material. The nuclear recoil energy is only a few tens of keV, requiring detectors with very low energy thresholds. Moreover, these interactions are exceedingly rare and necessitate sensitive detectors with excellent background rejection. To fulfill these requirements, the detectors have to be located deep underground and be built of materials free of radioactive contamination. Any remaining gamma and beta background, which produce electron recoils, must be discriminated from nuclear recoils.

One of the most promising techniques for direct dark matter detection is the so-called dual-phase xenon detector (see Fig. 1 for a schematic diagram). This instrument records direct scintillation and ionisation signals in a liquid-gas time projection chamber (TPC). An incoming WIMP scatters from a xenon atom in the liquid phase and the recoiling xenon atom generates a short track of ionisation and meta-stable atoms. The subsequent recombination produces scintillation light in the liquid xenon and leaves some ionisation electrons that are drifted upward in a uniform electric field of about 1 kV/cm that is applied across the detector. The electrons are extracted into the gas phase above the liquid by a stronger field (about 10 kV/cm) where they produce secondary photons through electroluminescence, in an amount proportional to the number of ionisation electrons. Arrays of photomultiplier tubes surrounding the TPC record the photons from both processes. The time correlation of the initial scintillation light (called S1) with the delayed luminescence light (called S2) in the gas identifies recoil events. Furthermore, the ratio of the amount of S1 and S2 light allows event-by-event suppression of background. Electron recoils due to beta or gamma background will produce less recombination and leave more drift electrons, which makes the S2 signal large. The highly ionizing WIMP nuclear recoils on the other hand, will leave a small number of drift electrons. The TPC provides complete three-dimensional position information of the event; this allows exploitation of the good self-shielding properties of xenon to further reduce external backgrounds by only analysing events originating in the central fiducial volume. While this type of detector allows good gamma and beta background rejection, background from external neutrons, primarily made through muon spallation, cannot be distinguished. Xenon recoils from neutrons will produce the same signal as their recoil from WIMPs and the neutron background has to be minimised through careful shielding.

The goal of dark matter experiments is to establish the existence of dark matter particles by directly observing the WIMP-xenon scattering signal in a detector. However, the probability for such reactions —expressed as their cross section— is extremely small. Therefore, the lowest measurable cross section of a detector (the limit) is considered its capacity to detect dark matter particles. Dark matter limits from small-scale dual-phase xenon TPCs have become very competitive in recent years. In 2007, the XENON10 collaboration published the best limit at the time with a 5.4 kg fiducial mass prototype detector [Phys. Rev. Lett. **100**, 021303 (2008)]. The collaboration is presently commissioning a 70 kg fiducial mass detector and will start the first science run in early 2010. This detector will be upgraded to incorporate a 150 kg fiducial mass and more refined background elimination in the coming years. The collaboration has also started the exploration of a ton-scale detector, which could produce first results in 2014. A ton-scale detector will need to be built of extremely low radioactive background materials. Nikhef, through the DARWIN consortium, is exploring the use of GridPix as an alternative charge readout device (see Box).

Fig. 2 shows the upper limits (90% confidence level) on the spin-independent cross section for scattering of a WIMP off a nucleon, as a function of WIMP mass for different generations of experiments. Also shown in the figure is a blue region (called parameter space) that indicates the expected values for cross section versus WIMP mass in the constrained Minimal Supersymmetric Model (cMSSM). While the XENON10 experiment only started to probe the upper regions of the cMSSM parameter space, next-generation experiments like XENON100 and ultimately XENON1T will probe the bulk of it.

The DARWIN Consortium:
towards a ton-scale direct detection dark matter detector

In April 2009, the European network of funding agencies coordinating Astroparticle physics, ASPERA, issued its first call for R&D and design study proposals for the realisation of future Astroparticle infrastructures identified in the ASPERA Roadmap. Nikhef, together with several other European groups, submitted a proposal for a ton-scale direct dark matter search design study. The study is called DARWIN and was approved in October 2009. The major goal of the DARWIN consortium is to produce a technical design report for a ton-scale dual-phase xenon and multi-ton scale dual-phase argon detection system, with the objective of reaching a WIMP-nucleon cross section sensitivity of 10^{-47}cm^2, which is three orders of magnitude below the current best results. To achieve this kind of sensitivity, the intrinsic backgrounds will have to be extremely small, while in addition, the detector should provide good discrimination of any remaining background. Nikhef is investigating the use of GridPix sensors (see Annual Report 2006) in liquid xenon as an augmentation or possibly alternative to readout by photomultiplier tubes as part of the design study.

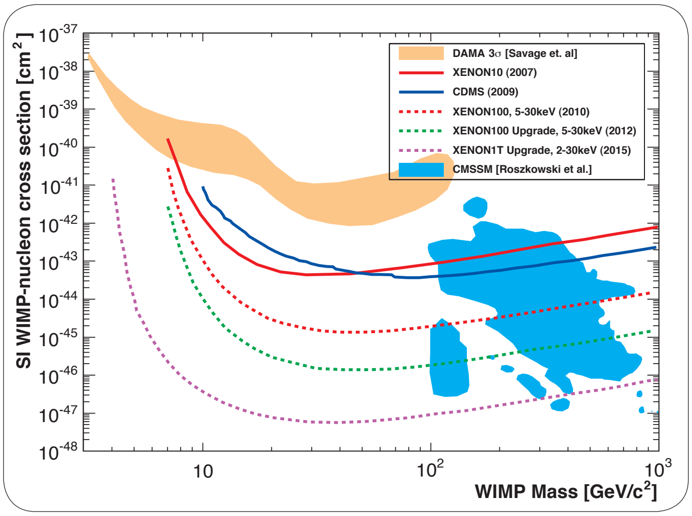


Figure 2. Spin-independent cross section for scattering of a WIMP off a nucleon, as a function of the WIMP mass. Shaded orange is the WIMP region allowed by the DAMA experiment. The solid red and blue lines show the exclusion limits obtained by the XENON10 and CDMS collaborations respectively. The dotted lines indicate the expected sensitivities for future stages in the XENON program. The shaded blue area represents the expected cross section in the cMSSM model.

Indirect detection

Indirect dark matter detection techniques try to find evidence for annihilation of WIMP pairs in astrophysical bodies. The motivation behind these searches is that dark matter particles may get captured in the attractive gravitational field of these objects as their energy is decreased through scattering with nuclei inside. Over time, the local WIMP halo density will increase and, provided that WIMPs are Majorana particles (i.e. particles that are identical to their own anti-particles, such as for instance neutralinos), the probability that two WIMPs annihilate will grow. The resulting flux of the annihilation products could be large enough to be detected on Earth, and signify the presence of large amounts of dark matter.

A number of experiments are presently searching for this type of annihilation signal and one of the most promising searches is to look for high-energy neutrinos from the Sun. Theoretical calculations predict two annihilation channels that produce high-energy neutrinos and that bracket the available models: annihilation through heavy b-quarks and through W-bosons (see Fig. 3). Any other decay products will be readily absorbed by the solar material. The Sun is the most promising astronomical body to observe neutralino annihilation as it has a large mass with potentially a large neutralino density and is nearby. The Sun also produces neutrinos due to nuclear fusion, however, these neutrinos have energies below 20 MeV, whereas the relevant decay neutrinos have energies of the order of 100 GeV. Neutrino telescopes such as ANTARES and KM3NeT (see elsewhere in this Annual Report) are well-suited for this type of study, as their low-energy threshold is tens of GeV.

Nikhef members are actively searching for the neutralino annihilation signal in ANTARES data by reconstructing upgoing muons from neutrino charged current interactions in the vicinity of the detector that point back to within a 3° cone around the Sun. The main background for the analysis consists of atmospheric neutrinos and mis-reconstructed downgoing atmospheric muons. First preliminary limits for the initial 5-line detector were presented in the 2009 International Cosmic Ray Conference; analysis with the full 12-line detector is ongoing.

WIMP production

The Large Hadron Collider (LHC) at CERN will explore the *weak scale* (i.e. the energy regime between 100 GeV and 1 TeV) in the coming years and it has a good chance of finding events characteristic of WIMP production. In theories such as supersymmetry (see Box), there are exotic heavy particles that can be produced at the LHC collider, and subsequently decay into a WIMP particle (e.g. neutralino) and a variety of Standard Model particles. Most of the collisions will have a balance of transverse energy (E_T) when summing over all visible particles in the collision. The signal for dark matter particle production will be the existence of collider events with visible particles, but also with an apparent imbalance of energy-momentum carried off by the WIMP (so-called missing energy). Fig. 4 shows a simulation of the most promising signal for identifying WIMP production, the multi-jet + $E_T^{missing}$ event signature. The amount of momentum imbalance of the visible particles will provide an approximation of the

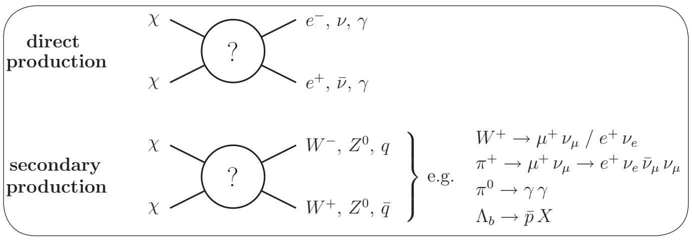


Figure 3. Neutrinos from neutralino (χ) annihilation can be produced directly or indirectly through the decay of annihilation products. The direct production of neutrinos is strongly suppressed due to conservation of helicity. If the annihilation occurs in the Sun, the solar material will absorb particles other than neutrinos.

WIMP mass and the momentum distribution an estimate of the interaction strength between WIMPS and quarks. However, collider experiments themselves cannot definitively prove the existence of dark matter particles, because they cannot verify that the produced particles are sufficiently stable to be dark matter. Nikhef is involved with dark matter searches at the LHC, in both the ATLAS and the LHCb experiments.

While the LHC is considered a machine with a large discovery potential, high-precision measurements are limited because the protons in the colliding beams are not fundamental particles. A future electron-positron collider will be able to further explore the parameter space. If pair production of supersymmetric partners is accessible to such a machine (e.g. via the annihilation reaction $e^+e^- \rightarrow \chi\chi$), a detailed parameter scan will be possible, allowing a precise measurement of the relic dark matter density. The relic density measurements in collider experiments could then be compared to astrophysical measurements to determine consistency. If the relic densities would agree, it would be the ultimate proof that microscopic theories that go beyond the Standard Model describe the cosmological dark matter particle.

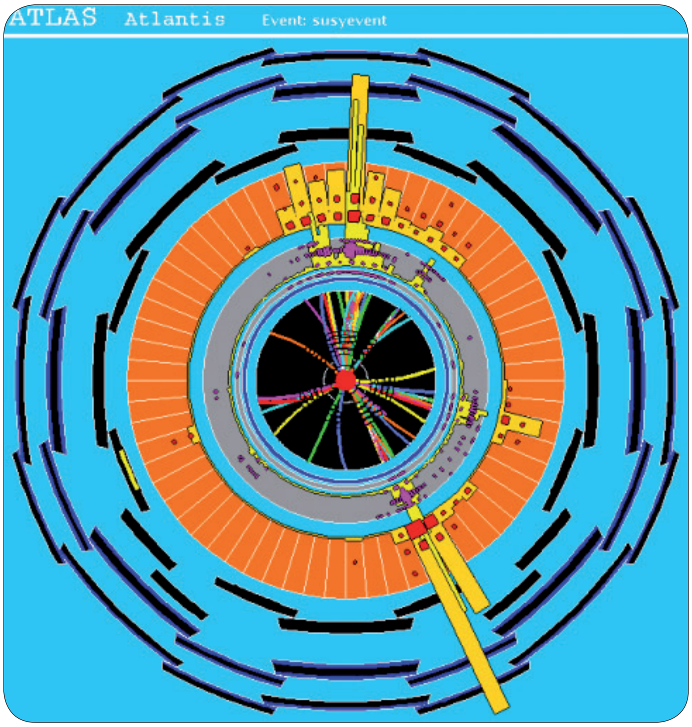


Figure 4. A simulation of an event in which supersymmetric particles are produced and their decay products subsequently observed in the ATLAS detector. There are six jets —indicated by (clusters of) yellow bars— in the event, whose summed transverse momentum (length of the bars) differs from zero. It corresponds to a missing transverse energy of 283 GeV, attributed to undetected neutralinos.

Outlook

Dark matter plays a central role in both particle physics and cosmology, making the revelation of the identity of dark matter one of the most important goals in science today. While the density of dark matter, required to explain a variety of cosmological observations, is becoming known to great precision, the dark matter particles have not yet been identified. The coming years will hopefully bring understanding of their identity. There is a good chance that dark matter will be observed by all three detection methods more or less simultaneously. Direct search experiments, in combination with indirect and collider searches, may not only establish the identity of dark matter, but also provide important additional cosmological information.

The neutralino as a WIMP candidate

The neutralino —denoted by the symbol χ— is introduced in an extension to the Standard Model of particle physics called supersymmetry (SUSY). This extension encompasses a natural grand unification of all interactions between elementary particles and solves the so-called hierarchy problem, a fine-tuning problem in the Standard Model. One of the consequences of SUSY is that there is an additional symmetry between bosons and fermions. SUSY pairs bosons with fermions and vice-versa so that each Standard Model particle has a supersymmetric partner with the same quantum numbers, but with spin differing by ½. This mechanism modifies the running of the coupling constants (which describe the strength of the interaction as a function of energy) and leads to their unification at high energies as required by Grand Unification Theories. Since we do not observe the supersymmetric partners, the symmetry must be broken at low energies. A subset of SUSY is the Minimal Supersymmetric Standard Model (MSSM). It assumes that a symmetry called the R-parity is conserved and gives rise to a new quantum number. It also naturally leads to a supersymmetric particle called the Lightest Supersymmetric Particle (LSP) that must be stable. If there were supersymmetric particles in the early universe, they will have decayed to a large number of stable LSPs that would remain to the present day. Within the MSSM, the LSP is the neutralino, a neutral particle with a mass between 10 GeV and 1 TeV, that only very weakly interacts with other particles. In this framework the neutralino is a WIMP and a compelling candidate particle for being the dominant component of dark matter.

1.2 Cooling by carbon dioxide
the past at Nikhef and the future in HEP

Bart Verlaat and Auke-Pieter Colijn

2009 has been an interesting year for carbon dioxide (CO_2), not only because of climate issues, but also because of its usage as coolant in two high-energy physics experiments. During the last decade commercial refrigeration has made a move towards CO_2 cooling as well, because of the 'green' properties. In contrast to synthetic refrigerants CO_2 does not deplete the ozone layer and has a low green house effect.

CO_2 has been proven to be a very good cooling fluid for detectors as well. Not because we want to make our detectors 'green' (although it is always good to keep the environment in mind when building a detector), but because CO_2 has a very high volumetric cooling capacity, about a factor two better than conventional refrigerants. This means that CO_2 needs only small-volume tubing to remove large amounts of heat. These small volumes in the detector directly imply smaller cooling hardware masses and hence less radiation lengths inside the detector.

Nikhef has gained a lot of experience with CO_2 cooling over the last 10 years. We have successfully developed the only two CO_2 cooling systems presently in use in high-energy physics experiments. The first CO_2 cooling system was developed for the Silicon Tracker in the Alpha Magnetic Spectrometer (AMS), which is a cosmic-ray detector that is to be mounted in the International Space Station. The second system was built for the Vertex Locator in the LHCb-experiment at CERN and is presently operational. The goal for both these cooling systems is to remove heat produced by the readout electronics of the silicon detectors. In addition, for the LHCb experiment the silicon sensors themselves need to be at low temperature to keep radiation damage effects under control.

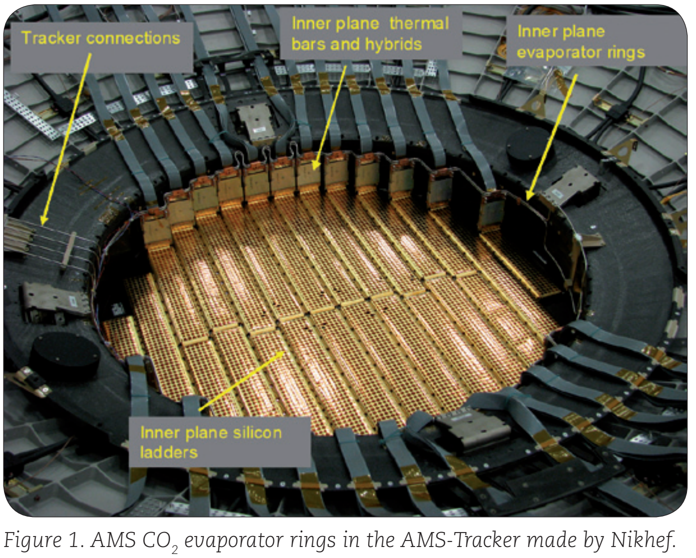


Figure 1. AMS CO_2 evaporator rings in the AMS-Tracker made by Nikhef.

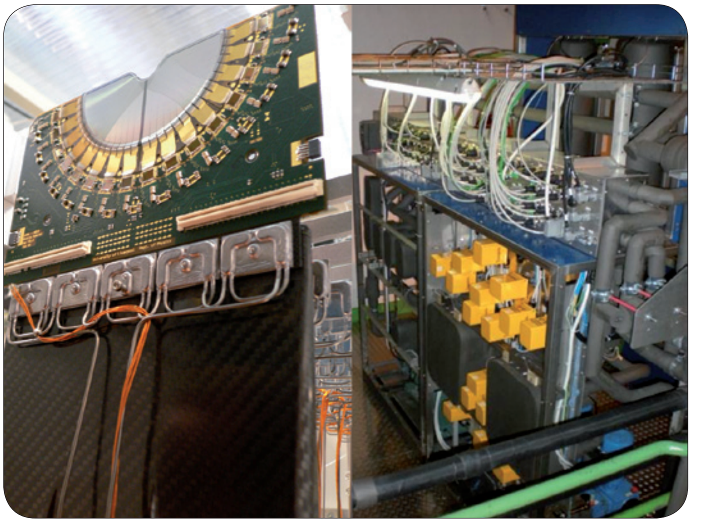


Figure 2. (left) A Velo module with CO2 cooling pipes and (right) the CO2 cooling plant of the Velo Thermal Control System.

CO_2 cooling in AMS

The cooling system for the Silicon Tracker in the Alpha Magnetic Spectrometer is named Tracker Thermal Control System (AMS-TTCS). Nikhef has designed the concept of the system using a new method for controlling the temperature of the cooling pipes. With a mix of technologies borrowed from satellite cooling and commercial refrigeration a concept called 2PACL was born, which has great advantages for a satellite like AMS. The heart of the system is a 2-phase accumulator used also in heat pipes (a passive heat transport technology in space). The acronym 2PACL stands for 2-Phase Accumulator Controlled Loop. The accumulator in the 2PACL is a pressure vessel that controls the carbon dioxide evaporation pressure throughout the whole system, such that boiling of the liquid CO_2 takes place at a constant temperature. In this way temperature changes inside the space station will not affect the working temperature of the detector.
Design and construction of the TTCS was done together with the Dutch National Aerospace Laboratory (NLR) in the Noordoostpolder. NLR has a research lab for satellite cooling and was interested in the 2PACL technology for the use in other satellites. In addition to the design, Nikhef has constructed the cooling pipes inside the Tracker (see Fig.1). The complete Alpha Magnetic Spectrometer was assembled in 2009 and will be transported by the Space Shuttle to its final destination in the International Space Station in the summer of 2010.

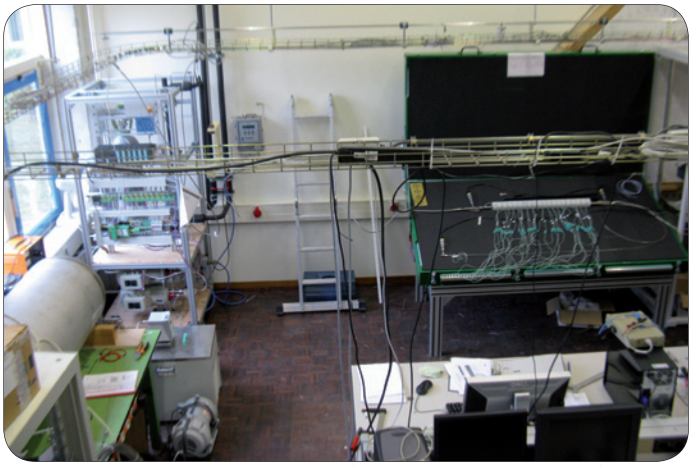


Figure 3. Cooling laboratory at Nikhef with the 2PACL research facility and insulated test-box.

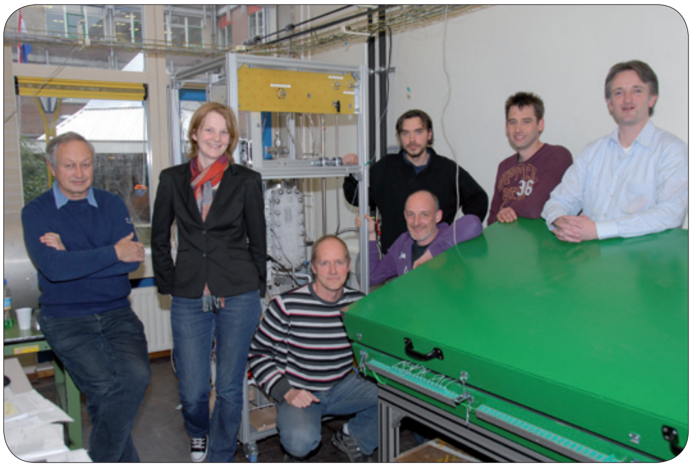


Figure 4. The CO_2 team, from left to right: Piet de Groen, Krista De Roo, Berend Munneke, Ad de Snaijer, Gertjan Mul, Bart Verlaat and Auke-Pieter Colijn. Not shown are team members Martijn van Overbeek, Erno Roeland and Luc Jansen.

CO_2 cooling in LHCb

The 2PACL developed for AMS was applied to the CO_2 cooling system for the Vertex Locator (Velo) in the LHCb-experiment at CERN. The advantages of the 2PACL principle for earth based detectors are the temperature stability and the possibility of placing the control hardware away from the detector. The only mass remaining in the detector consists of tubes with a small diameter; all the active hardware is located in the radiation-free zone and always accessible for maintenance.

The CO_2 system for the Velo is more than a cooling system. It does not only cool away the heat generated in the detector, but it also keeps the detector permanently at a stable temperature. Whether the detector is powered or not makes no difference. The permanent low temperature is needed to slow down the effects of radiation damage in the silicon wafers. The system is therefore called Velo Thermal Control System (VTCS).

The VTCS was designed, constructed and tested by Nikhef and VU University. Installation in LHCb took place in July 2007. Commissioning of the system started directly afterwards and has led to minor modifications to improve overall performance of the system. Early 2009 the system was finalized and it runs relatively smooth since then. System tests in October 2009 have shown excellent behaviour of the system. Cooling the full Velo down to –34° C was achieved with the detector Velo running at full power. The silicon wafer temperatures were below –10° C, which is adequate to avoid thermal runaway.

A 'CO_2L' future

The success of CO_2 cooling in AMS and LHCb has inspired the high-energy physics community to further investigate the application of CO_2 cooling in the upgrade of the inner detectors of ATLAS and CMS. This upgrade is foreseen sometime during the next 10 years when the current vertex detector will be unusable due to radiation damage. Other projects that are considering CO_2 cooling as well are the Gridpix projects (readout of gaseous detectors with pixel chips) at Nikhef, DESY and ILC. At tens of other locations CO_2 test facilities are being built following the technologies developed at Nikhef, like the 2PACL. At CERN a dedicated research department for CO_2 cooling development is set-up. At Nikhef we are setting up a specialized laboratory for development of cooling systems. The laboratory will avail of all necessary equipment for detector thermal development. A 2PACL CO_2 test facility is under construction; it will be able to cool and test detector structures. The 2PACL test facility will also be used to perform fundamental research of CO_2 heat transfer in small diameter tubes.

1.3 For love of magnets
an interview with Arjan Verweij

Karina Meerman

No Large Hadron Collider without magnets. Arjan Verweij is a specialist in superconductive electromagnets that form the heart of the LHC project. After twenty years at CERN he is still learning new things and he has signed on for twenty more.

Arjan Verweij carries Swiss francs in one trouser pocket and euros in the other. That is because when he wants to have lunch, he can choose from three canteens in two countries. It is just one of the curious things at CERN in Geneva.

CERN is a small village on the border of France and Switzerland. Its buildings are not very pretty; the whole compound has an old school Communist feeling to it. The building blocks are square, grey and slightly run-down. It's obvious the money is in the projects that draw bright minds from all over the world. Bright minds such as Arjan's.

This 42-year old, rather tall, Dutch man has worked at CERN for twenty years. He likes his life in Switzerland. He owns a house in the Jura foothills with a view on the Alps and his private life includes a lot of hiking, mountain biking and skiing. Professionally, over the last two decades, he has developed into an expert in the field of superconductivity: that which enables the dipole magnets to keep the particle beams of the LHC in their trajectory.

Model magnet

The first time Arjan visited CERN was in 1990, as a student from the Technical University in Enschede. He was involved in the development of small superconducting magnets and applied for an internship at CERN. At the time, he did not know that his speciality would become the key technology in one of the largest physics projects in the world. Arjan says: *"I have always been fascinated by superconductivity. To think that electricity can be transported without resistance, but only in artificially created circumstances. It is unnatural and illogical. It is a strange and interesting thought that electrons run on endlessly if they encounter no resistance."*

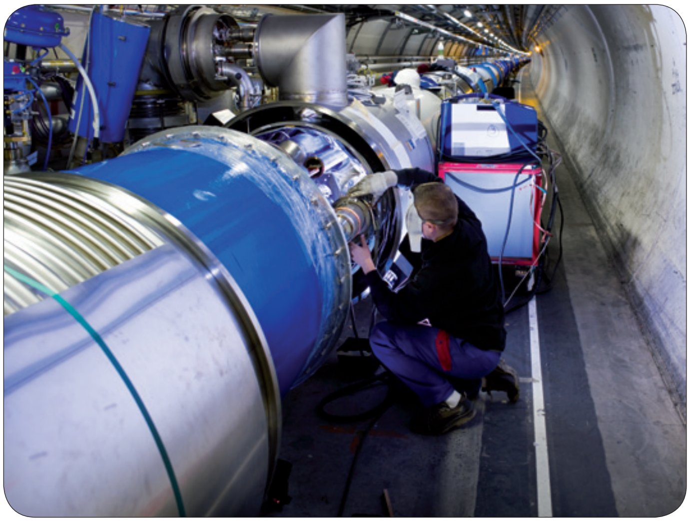
With eyes all over the world watching what goes on in that place of science, Arjan appears unaffected. He seems a rather modest person and prefers to sketch the big picture, relate the team effort and praise the science of it all rather than talk about his personal achievements. *"I was at the right place at the right time,"* he shrugs. *"And apparently I was good enough and motivated enough to stay. As a student I held an internship for nine months, a PhD position for four years, then a fellowship for three years. After that a temporary position for four years and only then did I permanently join the staff. There were a number of times they could have gotten rid of me, but they didn't."*

Magnet specialist Arjan Verweij: "It is unnatural and illogical."

Superconductivity

Dutchman Kamerlingh-Onnes discovered in 1911 that certain materials have no electrical resistance at very low temperatures. When these materials are used in electromagnets, they generate a very strong electromagnetic field. When the magnets are the size of those at CERN —15 meters long— and there are enough of them – 1,232 to be exact – they can generate a magnetic field powerful enough to make a charged particle follow a curved path. The tricky part is the very low temperature: material has to be cooled near absolute zero or –271° C. At CERN this is achieved with almost one million litres of liquid helium. The cable used in the magnets at CERN is made of niobium-titanium and it is a work of art. The cable consists of 28 or 36 wires, each constructed of 6,000 filaments, thinner than a human hair. If all the filaments were put end to end, they would travel from earth to sun six times and leave enough room for 150 trips to the moon. The total length of the cable used is 7,600 kilometres.

During his first ten years at CERN, Arjan mainly worked on testing the superconducting cable. He built a test station that reproduces the exact same circumstances as exist in the tunnel. He was the contract follower for the Italian and Finnish companies that manufactured the cable. *"There are only a handful of companies in the world that can manufacture this product. For five years, CERN provided them with half of the total global production. Cost? Over 340 million euro."* Arjan explains that one hundred production steps are required to realise the final product. *"Starting from an ingot of one meter by 20 centimetres, the material is extruded, drawn and stacked until it is thinner than a hair and anywhere between 10 and 100 kilometres long. There are a lot of interim step to perform —such as*



A welder works on the interconnection between two of the LHC's superconducting dipole magnets in the LHC tunnel.

Curriculum Vitae
Arjan Peter Verweij (1968)

1986–1991	Physics studies at Twente University
1991–1995	Research appointment at Twente University and CERN
September 1995	PhD at Twente University
1995–1998	Research appointment at CERN
1998–present	Staff physicist at CERN
	Member of the CERN Scientific Information Policy Board
	Department representative to the CERN Technical Students Committee
	Department representative to the CERN Associates and Fellows Committee

heating, shaving and cleaning— to prevent the material from breaking and to meet the high specifications."

The required accuracy is ridiculous: neighbouring cables in the same coil must be aligned with an accuracy of two to three hundredths of a millimetre over a length of 15 metres. Any misalignment results in field errors and can trigger small movements, which cause the cable to lose its superconducting qualities. The magnet would stop working and the entire machine that is LHC would come to a halt.

An unexpected flaw

In 2004 the cable production was finished and CERN started testing of the completed magnets. The testing station held twelve magnets at the time and a team of thirty people continued testing 24/7. Once approved above ground, the magnets were transported below into the tunnel, cooled to –271° C and retested. Everything seemed in order. The first test with the particle beam worked perfectly. And then the incident occurred in 2008.

Arjan was asked to calculate the cause and found a flaw in the connections between the dipole magnets. But during the process of investigation, he discovered something else. This hitherto unknown problem could have potentially caused overheating and rupture of the magnetic circuit and a release of powerful magnetic energy into the accelerator. Until this is fixed, which will probably take two years, the LHC will not run at full energy. *"We don't want to risk another incident. If the magnetic energy erupts uncontrolled, the damage would be enormous. We would have to shut down the project again in order to repair everything. Better to be safe than sorry."*

Specialist

Particles are sent around in packages, one clockwise, one counter-clockwise. Right now, a maximum of 16 packages —containing 10 billion particles each— go around the tunnel at 10,000 times a second. A million particle collisions have taken place, so far. At full intensity, each beam will contain 3,000 packages and there will be 600 million collisions per second. The amount of data this generates is staggering, but that is something for the particle physicists.

Arjan continues his work with superconductive magnets. *"After twenty years at CERN, I am still learning. The field continues to develop. And I think that age makes one a better specialist. It is the opposite of what happens in many businesses: when someone reaches the age of 50, he is often considered passed his prime. Not in science. Here we can still join in the conversation, even after retirement."*

Arjan Verweij definitely does not want to be anywhere else than here: *"Superconductivity, cryogenics, vacuum, electricity. At CERN they put it all together. It's great."*

1.4 "If I were you..." an interview with Teus van Egdom

Karina Meerman

The world may have changed a lot, but Teus van Egdom has been the same solid presence at Nikhef for nearly 25 years. He is the face of Human Resources, on the work floor and in the management team. He is well liked and respected, but when he starts a sentence with "If I were you..." he is a little feared. When Teus offers advice, people listen.

Teus van Egdom started at Nikhef in 1986 and he is due for retirement in 2011. He keeps his own life very private, but he knows the work history, current projects and personal issues of all of his three hundred colleagues. He has a phenomenal memory for faces. He solves problems, but not with standard solutions. It is said he produces a thousand letters a year. Rumour has it his only bad trait is his archaic filing system. But although it gives a lot of people a headache, it works. And at least it's digital.

Private man

The HR manager is not too thrilled by all this attention. He just does his job, which he rarely talks about outside the office. *"It took a long time before my children knew what I did for a living. Nowadays I tell people I work at a scientific institute, in personnel."* It's not about modesty. Teus just likes to keep work and private life as separate worlds and he has been married happily for 43 years. It is one reason why he doesn't fear retirement. The others are his children, grandchildren, dog and boat.

But until that day, Teus will enjoy working at Nikhef. *"It is a fantastic place, with some very colourful people. They are all scientific professionals, which means they are all curious, eager to learn and rather pigheaded. They know everything better and I have sometimes wondered how to get them all facing the same way. But the only way to steer scientists in any direction, is to remain true to your self and not to be led by the physicists' issues of the day. They are so passionate about their work, there is no way to stop that. I do not want to stop that. I just stand in the middle and accept it. It's a good thing I am a bit of an outsider. It wouldn't help to have yet another enthusiast in their midst."*

Teus also likes the fact there are so many young people at Nikhef. *"It makes for a great atmosphere. Post-graduates, twenty-somethings, they hang out together and become groups of friends. And me, an old man, will be sitting somewhere and suddenly be surrounded by these young folks. I just love that."*

Being right

Although Teus speaks calmly and in a quiet voice, he is not as stoic as he looks. *"I can kick up a storm too, you know. I can be quite a nuisance when I know I am right but no one sees that, yet. I can be very direct in speech and in writing. I don't always realise when my*

Teus van Egdom: "problem solver".

words are too harsh. I just don't always get the nuance. That's rarely a problem at Nikhef, but I am sometimes considered too direct when I communicate with other organisations. At Nikhef, being right is never an issue. It's getting people to acknowledge you're right, that's the difficulty. Because they are all scientists and scientists are always right."

Before he became a personnel manager, Teus wrote policy on personnel matters at FOM. One day he decided to switch careers. *"I am happier getting my hands dirty than I am pushing paper. What I mean by that is that I rather work at the same level as other people, than dictate rules for them from above."* And he loves HR. *"I am a bit of a whiz-kid on terms and conditions of employment."* According to Teus, the ideal position for an HR Officer is at the heart of an organisation, where he is kept informed about every single proc-

It seems impossible to find something bad about Teus. The worst anyone could come up with, is his weakness for the mechanical sciences. He nods when confronted. *"Yes, that's true. That is where my origins lie. There is a tension between the people who make things and those who designed it. Because who fixes that which is badly designed? I have always had a weakness for people who make things, they know everything –at least in our organisation– about materials and machines. Creating things in your head is one thing, constructing and building them with your hands is quite another. The makers provide the finishing touch."*

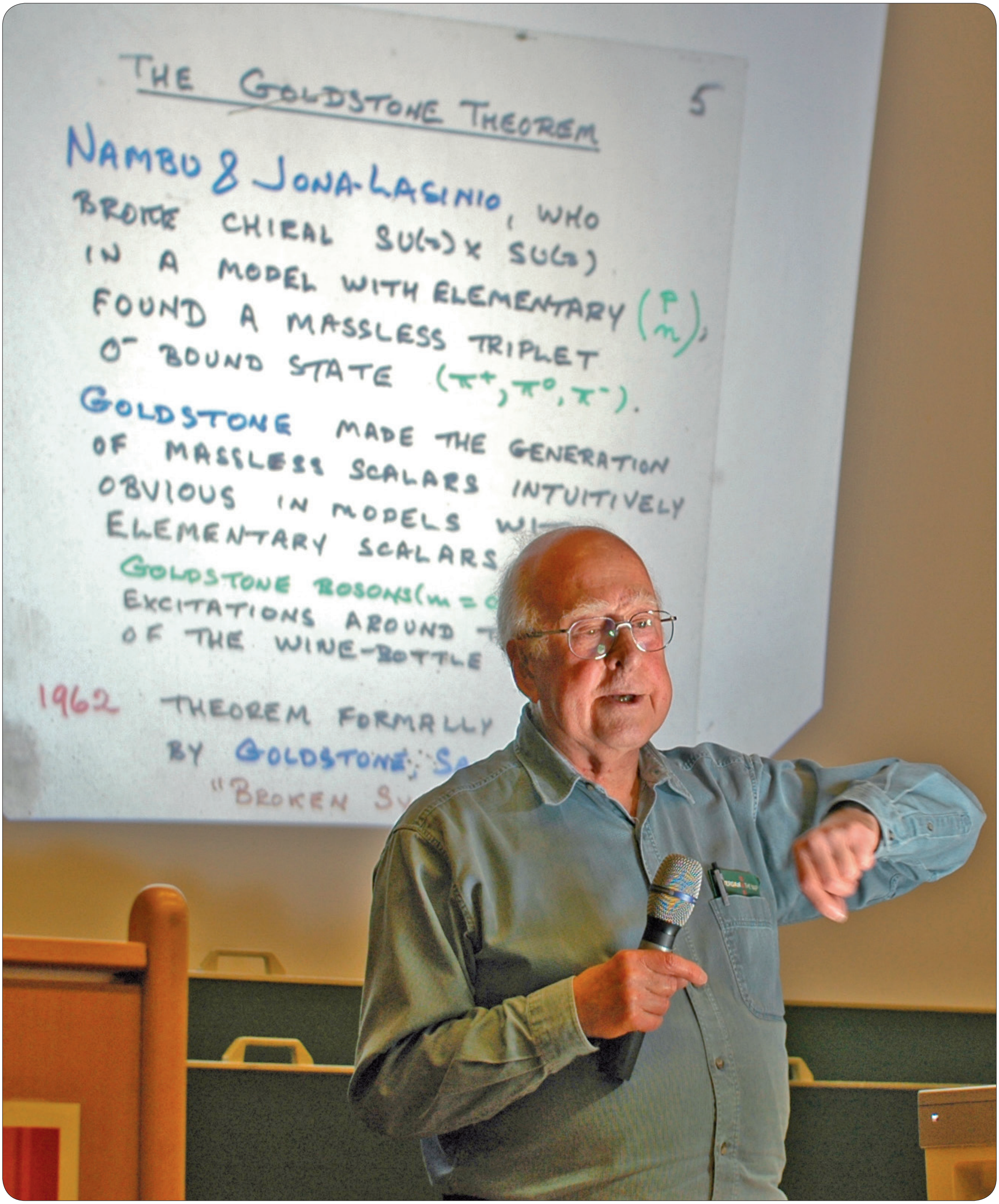
Curriculum Vitae
Teus van Egdom (1946)

1964–1970	Various studies in Higher Business and Administrative Management
1993–1994	Postgraduate training Personnel Management
1964–1977	Managerial and administrative positions in metal industry
1977–1986	Staff member Personnel and Organisation at FOM
1986–present	Staff member Human Resource management at Nikhef

ess. *"That is how it works here. I have always been allowed to voice my opinion."* He is confident that the next HR manager will look after Nikhef well, but in his own way. *"My advice for the next HR manager is: remain true to your self and don't allow yourself to be led by the physicists' issues of the day."*

Problem solver
One of Teus' duties at Nikhef is to be the bringer of bad news. In the past he has informed people of budget cuts, reorganisations and the like. He doesn't mind that, because he knows he does it well and it must be done. *"When the two organisations that are now Nikhef merged in 1998, we built a new organisation structure on paper, within the available financial room. I talked with everyone and I always found a solution for people, so no one left against their will. I am still in touch with a large number of ex-employees. Apparently I always find a solution, even if I have to go to unusual lengths. I never knew I was that kind of person: a problem solver of the worst kind."*

During that late nineties' reorganisation, Teus also realised how deeply involved people were with their work at Nikhef. *"The MEA/AmPS accelerator was going to be shutdown and no matter what person I spoke to, every single one of them had personally built that accelerator. They identified themselves with that machine."* He sounds very respectful when he says this. *"From the cleaning personnel to the technicians and the scientific secretary: It was their machine. It is that kind of passion that makes it so wonderful to work here. People want to learn from the things they do and from each other. They think about the how and why of things, that is their strength. We have health and safety officers who come round regularly and all the reports say the same: people work too many hours. But this work is their passion."*



Prof.dr. Peter Higgs lecturing at Nikhef on the occasion of the viewing of the eponymous documentary "Higgs – into the heart of imagination".

2

Research

2.1 ATLAS & DØ

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

The ATLAS 'general purpose' detector is designed to observe all aspects of the high energetic proton collisions of the LHC, in order to explore the physics at the TeV scale. This includes the mechanism of symmetry breaking in connection to the Higgs particle and the search for supersymmetry and other signs of new physics beyond the Standard Model.

Nikhef has been responsible for the large outer muon chambers in the barrel, including their alignment and read-out systems, and a large part of the inner vertex detector equipped with silicon sensors. The full detector is installed and operational. Research highlights at Nikhef during this year include finalising and maintaining the hardware, optimising the detector performance with cosmic muons, preparing the analyses of the high energy proton collisions, and analysing the very first collisions at the end of the year.

Cosmic muons
ATLAS is taking data since the beginning of 2009, and the data acquisition system and cosmic triggers are brought to a very mature state. All Level-1 hardware is available which allows to trigger on muons, calorimeter information, beam-pick-up monitors and on 'minimum bias' events. The high level trigger is oriented toward particle objects, like electrons, muons, taus, jets and missing transverse energy E_T.

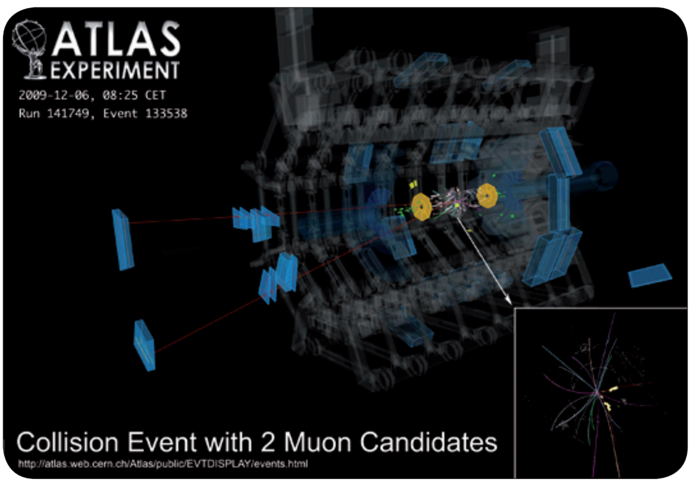


Figure 1. Collisions between protons as observed with the ATLAS detector.

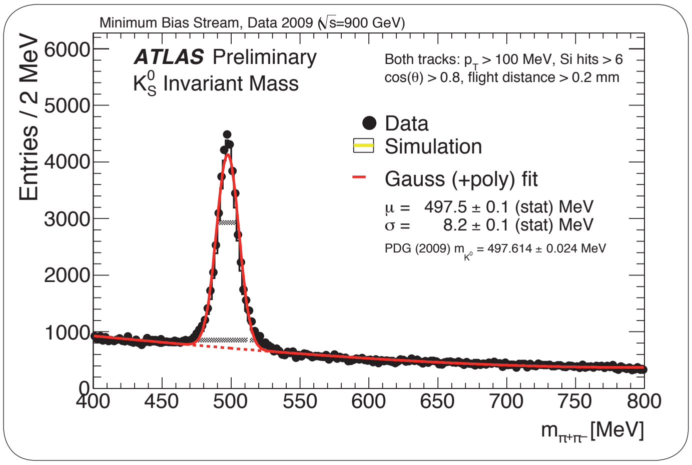


Figure 2. Reconstruction of the K^0_S invariant mass, in the decay $K^0_S \rightarrow \pi^+\pi^-$, using tracks of the ATLAS Inner Detector.

During the year, a total of approximately 200 million cosmic ray events were collected. These were utilised, among other things, to improve the performance of the Monitored Drift Tubes (MDT) that were installed by Nikhef, and to determine their deformations due to wire sag and thermal effects. Effects of the order of 100 μm in sagitta were detected, well above the ultimate precision requirement, and are effectively corrected for. We showed that the intrinsic tube efficiency was excellent, reaching above 99.8% close to the wire. The measured space-time relation in the tubes is compatible with the earlier test-beam results, and subtle effects of the order of 10 ns, like the variation in timing due to changes in humidity of the gas, were observed and corrected. The alignment of the barrel muon spectrometer, using the approximately 5800 optical sensor paths, was completely refurbished by the so-called 'Foam-2' software, and leads to a large improvement in stability and alignment uncertainty.

The reconstruction of muons was scrutinised using the cosmic rays, and is based primarily on the recognition of so-called muon segments, i.e. local muon hit patterns inside the MDT chambers. In a second stage the segments are connected and fit to a muon track in the Muon Spectrometer, which is subsequently fitted to tracks of the Inner Detector. Using this 'home grown' software, the segments and tracks are shown to be reconstructed very efficiently. It is particularly worth mentioning that Nikhef also developed a muon tagging algorithm that starts from tracks reconstructed in the Inner Detector, where muon segments are used to 'tag' these tracks as originating from muon particles. This algorithm is proven to be very robust for detector effects and will play an important role during the start-up phase of ATLAS.

The performance of the Inner Detector (ID) was checked with the cosmic muons as well. In particular the misalignments of the ID were investigated by comparing the downward-going tracks with the upward-going tracks at the beamline. These studies show that the detector is understood in great detail and that also the ID is ready for physics collisions.

First collisions

On 23 November ATLAS observed its first collision between protons, at a center-of-mass energy of 900 GeV. This happened a few days after the first 'splash' events were recorded, originating from the dump of a single beam on a closed collimater, placed 140 m upstream the ATLAS detector. In the following period, a total of approximately 800 million collisions were recorded at injection energy, and a small fraction at a center-of-mass energy of 2.36 TeV. Although the total amount of data only corresponds to approximately one second of running at nominal luminosity, the data were of great importance for the detector commissioning. An example collision event with two muon tracks going in the very forward direction is shown in Fig. 1.

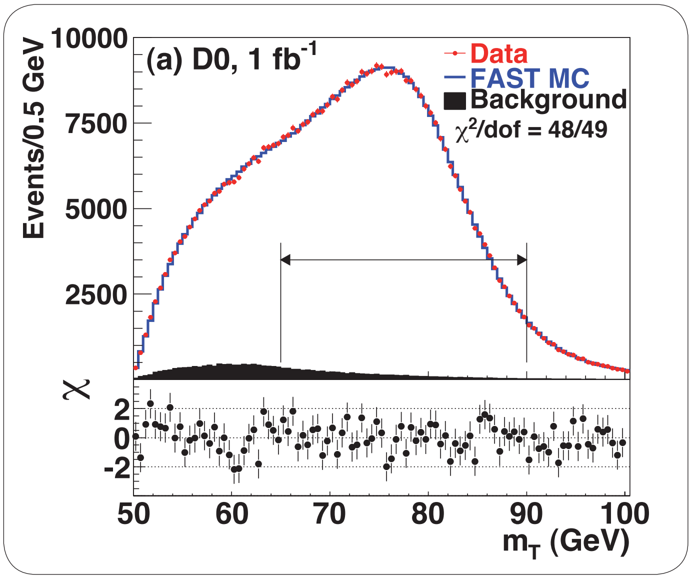


Figure 3. Distribution of the transverse mass m_T of the $e\bar{\nu}$ system in candidate $W \rightarrow e\bar{\nu}$ events.

Thanks to the years of preparation and cosmic muon events, the data were of extraordinary quality. The endcap of the Semi-Conducting-Tracker that was constructed under the responsibility of Nikhef performed very well. Within a short amount of time plots with the first physics results were available. As an example, a peak of the reaction $K^0_S \rightarrow \pi^+\pi^-$ is shown in Fig. 2, where the K^0_S-candidates peak above the background at a value of the invariant mass of 497 MeV, in excellent agreement with the PDG value. It shows that the detector is well understood and that we are ready (and eagerly waiting) for the high energy physics to come.

The DØ experiment

The Tevatron Collider at the Fermi National Accelerator Laboratory (FNAL) has been performing steadily, operating at peak luminosities exceeding $3 \cdot 10^{32}$ cm^{-2}s^{-1}. The integrated luminosity delivered to the DØ experiment in its present Run II was increased to 7.6 fb^{-1}. Not only the accelerator, but also the DØ experiment operated stably and efficiently, resulting in an increase of its collected integrated luminosity to 6.7 fb^{-1}. No deterioration in detector performance was observed. The experiment submitted in total 36 physics publications, of which highlights include the observation of single top quark production (following the evidence for this process published in 2007) and the measurement of the mass of the W-boson. This measurement, with a total uncertainty of only 43 MeV, is presently the world's most precise measurement of this quantity. An example demonstrating the excellent quality of the analysis is shown in Fig. 3.
The W-boson mass measurement provides an important constraint on the mass of the Standard Model's Higgs boson.

The performance of the direct search for the Higgs boson was improved significantly, especially in the low-m_H regime with the publication of a search in the ZH associated production channel, followed by the decays $Z \rightarrow \nu\bar{\nu}$ and $H \rightarrow b\bar{b}$. Despite an increased data sample, the m_H range excluded at 95% CL by a combination of Tevatron measurements was reduced slightly, to the region 163–166 GeV.

2.2 LHCb: Tracking beauty decays

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

The LHCb experiment is constructed to perform precision measurements on rare decays of B-hadrons. By selecting specific decay processes that are suppressed in the Standard Model these measurements allow to search for manifestations of physics beyond the Standard Model that affect these B-decays, such as supersymmetry or the presence of extra dimensions. In particular, by comparing the decays of B-particles to corresponding decays of anti-B particles, LHCb hopes to solve the riddle of the absence of antimatter in the universe.

To extract the B-decays a precise reconstruction of the trajectories of the produced charged particles is crucial. The Nikhef group focuses on the determination of the momentum and the point of origin of these particles. Nikhef has constructed major parts of two subdetector systems, the Outer Tracker (OT) and the Vertex detector (Velo), and developed the software to find the particle paths through the detector hits.

Tracking: Charged particle detection

The particle trajectories across the spectrometer are determined by a state-of-the-art Kalman filtering method. This method reconstructs the particle trajectories from the detector hit information over a distance of about 10 meters with a precision of approximately 8 μm at the vertex position and about 80 μm at the downstream end of the spectrometer. A 3-dimensional trajectory is reconstructed, using the positions of the individual detector elements as well as a precise map of the magnetic field. Also, the presence of inactive material layers is included to allow the fit to determine multiple scattering "kinks" along the full particle path. This fitting method has been developed by Nikhef and is used in the offline reconstruction as well as in the High Level Trigger of the experiment.

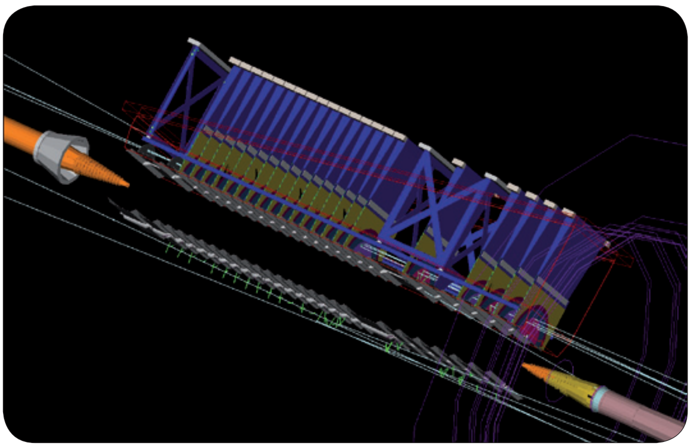


Figure 1. Muon tracks in the Vertex Detector. For illustration purposes only one half of the Velo detector is shown, together with the thin RF-foil that separates the detectors from the beam volume.

Figure 2. Members of the LHCb experiment following the screens in the control room showing the first collisions.

Momentum measurement with the Outer Tracker

The Outer Tracker detector measures the deflection of the charged particles by the LHCb dipole magnet and effectively determines their momentum. The detector consists of 53,760 drift straw tube detectors of 5 mm diameter arranged in 3 stations of 4 double-layers each. The straw volume is filled with Ar/CO_2 drift gas providing a precise drift time measurement of the traversing particle. In 2009 the detector has been calibrated and the momentum measurement procedure has been fully commissioned. The detector timing has been tuned to provide a precise t_0 reference time and the drift-time relationship has been established. A particular effort has been placed to understand the alignment of the individual detector layers. Firstly, the detectors have been positioned in the LHCb reference system with a precision of better than a millimeter. Secondly, a software alignment algorithm has been commissioned using cosmic ray data to determine the positions of the individual detector modules.

Vertex Determination with the Velo

The Velo detector is installed around the interaction region. The detector consists of 23 stations of silicon strip detectors measuring the radial (R) and azimuthal coordinates (ϕ) of charged particles. The active measurement planes are brought as close as possible (8 mm) to the LHC beam. To achieve this, the Velo detectors have been installed in the LHC volume and are only separated from the beam vacuum by a 300 μm thin aluminum foil, the RF-foil. During injection of the LHC beams the detectors are retracted by 3 cm. Only during stable beam conditions can the detector be brought to the closed position, centered on the actual beam position, with an accuracy of 5 μm. An online monitoring process follows the beam location by reconstructing the event-by-event vertex positions.

The detector was fully commissioned during 2009, where a major activity was to time-align the Velo detector readout with respect to the beam crossing time. Since too few cosmic rays traverse the Velo the detector was commissioned with the help of muons that are produced during injection tests of the LHC. The Nikhef group members have developed an automated procedure to find the optimal timing resulting in a signal-over-noise value of about 20. An example of the resulting tracks of muon particles traversing the Velo detector is shown in Fig. 1. These data were used to determine the alignment of the individual silicon measurement planes to about 5 μm.

Two dedicated silicon stations on the upstream side of the Velo detector are equipped with a binary detector readout system (Pile-Up), which allows to count the number of simultaneously occurring interaction vertices before the lowest LHCb trigger level. This detector, a full Nikhef project, was commissioned simultaneously with the other Velo detector planes.

First Collisions

On 20 November, the first beams were injected into the LHC ring with an energy of 450 GeV. Interactions of the beam with remnant gas atoms in the beam vacuum were observed in so-called beam-gas events the next day. After both beams had been captured in

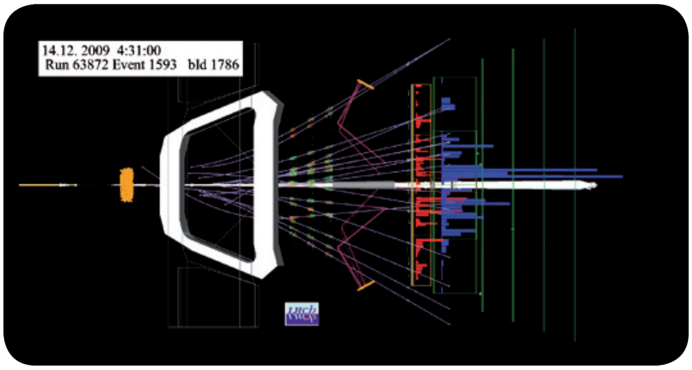


Figure 3. An event display of a collision at a center of mass energy of 2.36 TeV.

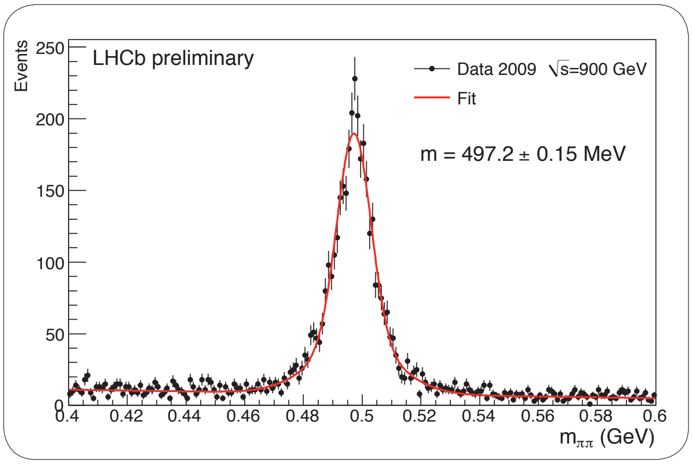


Figure 4. Preliminary result for the invariant mass of the $\pi^+\pi^-$ system as reconstructed from the 2009 LHCb data. The location of peak representing the K^0_s particle is close to the literature value.

stable orbits the first collisions were observed on 23 November, by an excited crew in the LHCb control room, see Fig. 2.

In total 500,000 events were collected. The resulting data were fully reconstructed on the computing grid infrastructure and available for the physics users in the home institutes only one hour after they were collected by the experiment. On 14 December, the proton beams were accelerated to a world record energy of 1.18 TeV, providing collisions at a center of mass energy of 2.36 TeV. An example of such an event is shown in Fig. 3.

These data are currently being used to further tune the reconstruction and physics algorithms. Well-known particles like the long-living K_s-meson and the Λ-baryon as well as the neutrally decaying π^0 were identified. As a proof that the track reconstruction mechanism is well on schedule a preliminary result of a reconstructed K_s signal is shown in Fig. 4. The reconstructed mass is 497.2±0.2 MeV, close to the known K_s mass of 497.7 MeV, indicating that the calibration and the alignment of the tracking system are close to the required precision. The LHCb group is eagerly looking forward to the 2010 physics run, during which the particles will collide at a center-of-mass energy of 7 TeV, an energy well suited to start exploring the rich B-physics programme.

2.3 Heavy-Ion Physics: ALICE & STAR

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

The main goal of the ALICE programme is to study the strong interactions of quarks and gluons at very high temperatures and densities, as prevailed a few microseconds after the Big Bang. In particular the aim is to determine the properties of matter under such extreme conditions, and to improve our understanding of the phenomenon of confinement and the generation of mass by the strong interaction, by means of colliding heavy ions at high energy. The Nikhef heavy-ion group participates in the STAR experiment at the RHIC collider and in the ALICE experiment at the LHC, where Nikhef contributed to the construction of the Silicon Strip Detector (SSD) of the Inner Tracking System (ITS).

Detector Improvement
Although ALICE was ready to take data in September 2008, and detected the first particles generated by the LHC beams, it was decided to use the long LHC shut-down in 2009 to carry out an extensive programme of detector improvement. For the silicon strip detector (SSD), this meant that half the detector was disconnected for major modifications in the cabling and piping. Ongoing research at the various SSD laboratories revealed a possible cause of the anomalous bias current seen in some ladders during 2008, and preventive measures were taken to reduce such currents. An almost ten-fold noise reduction in the raw data was achieved by implementing a correction for common mode signals in the firmware of the read-out electronics. This results in a significant reduction of the raw data volume by suppression of an increased number of empty data channels. Part of the bad ladders, modules and strips were recovered by tuning of the detector, while maintaining the low level of noise hits. This resulted in a 90% coverage of the SSD.

After re-installation and test of all connections, cosmics data taking was resumed in August, with and without magnetic field. The data without magnetic field were used for alignment and relative gain calibration. From the two hits of a straight cosmic track through one SSD layer, one can predict the position of the track in the other layer and compare it to the recorded hit position.

Fig. 1 shows the distribution of the distances between measured and predicted hits, before and after survey data were used to position the detector modules in the software. These surveys, partly done at Nikhef, were made on the detector ladders before these were mounted. The spread in the distribution is found to be 25 µm, which compares well with the 20 µm measured on modules in beam tests. This result indicates that the mechanical precision was maintained during the subsequent steps of assembly, transport and installation of the SSD.

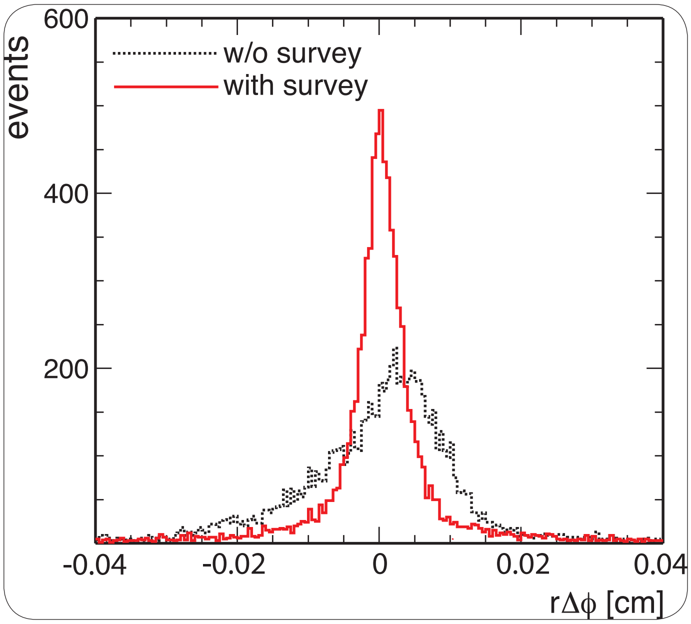


Figure 1. Distribution of differences between predicted and measured hits of straight cosmic tracks though the SSD. The distribution is shown before (dashed histogram) and after (full histogram) the detector modules were positioned using pre-assembly survey data, partly measured at Nikhef.

First Collisions
The highlight of 2009 was the start-up of the LHC, and the observation of the first proton-proton collisions at 900 GeV. Fig. 2 shows the event display of the first collision candidate, as it was seen in the ALICE counting room on the afternoon of November 23. Already on November 28, the first physics publication of charged particle production in proton-proton collisions at the LHC was submitted, based on a sample of 284 events. In total, about half a million proton-proton collisions were recorded in 2009 at 900 GeV, and about 30,000 at 2.4 TeV. The latter energy is, to date, the highest ever reached at a particle accelerator.

Alignment, calibration, and the physics analysis of these events is in progress. For the energy calibration, 2 million tracks with magnetic field were analysed. Using the combined energy signal from the Inner Tracking System, the energy lost by a traversing particle is determined as a function of the momentum derived from the tracking. The result is shown in Fig.3, where one can clearly distinguish the various particle species that have traversed the detector.

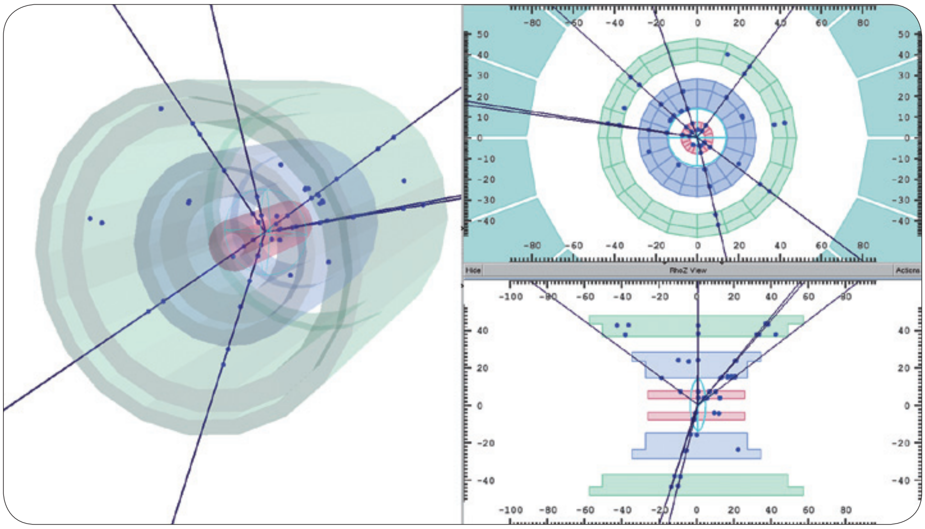


Figure 2. First proton-proton collision candidate from the event display in the ALICE counting room showing a 3D view (left), transverse view (top right) and longitudinal view (bottom right). The dots show hits in the Inner Tracking System and the lines correspond to reconstructed tracks.

The production of heavy quarks (charm and bottom) in heavy-ion collisions is interesting because they are produced early in the collision and therefore probe the expanding medium for a large part of its lifetime. Measurements of heavy quark production in proton-proton interactions or perturbative Quantum Chromodynamics calculations can serve as a benchmark. Nikhef participates in the measurement of open charm production in proton-proton and in heavy-ion collisions.

A different probe of the medium is provided by high-momentum partons which are produced in the initial state of the collision. As they propagate outwards, these partons lose energy by gluon radiation, stimulated by interactions with the medium. This effect has first been observed at RHIC with parton energies ranging from 10 to 20 GeV. The larger parton energies of a few hundred GeV at the LHC should provide a more accurate determination of the energy loss than is possible at RHIC. The group is involved in the preparations for energy loss measurements with ALICE and in the modelling of this process, to estimate the density of the medium produced in the collision.

Preparing for Physics

While ALICE expects to obtain important physics results from proton-proton interactions, the main goal of the experiment is the study of matter at extremely high densities and temperatures, created in lead on lead collisions at LHC energies. The first LHC run with colliding lead beams is foreseen at the end of 2010. Nikhef is involved in the preparations to measure anisotropic flow, heavy flavour production and energy loss in the hot and dense medium.

One of the most powerful tools to study the properties of the medium is the measurement of the anisotropy in the azimuthal angular distribution of the produced particles with respect to the reaction plane (anisotropic flow). The orientation of the reaction plane cannot be measured directly, but can be estimated from the event-by-event azimuthal correlations of the particles produced in the collision. Sophisticated multi-particle correlation techniques are being implemented to reduce contributions from non-flow correlations such as those from resonance production, jets and Bose-Einstein correlations. These non-flow effects are currently the main source of uncertainty in the flow analysis at RHIC energies. Recently we have developed an analytical treatment of up to eight-particle correlations, which cannot be accessed by a simple nested loop calculation because that would take about 10^{21} floating point operations for each lead-on-lead event.

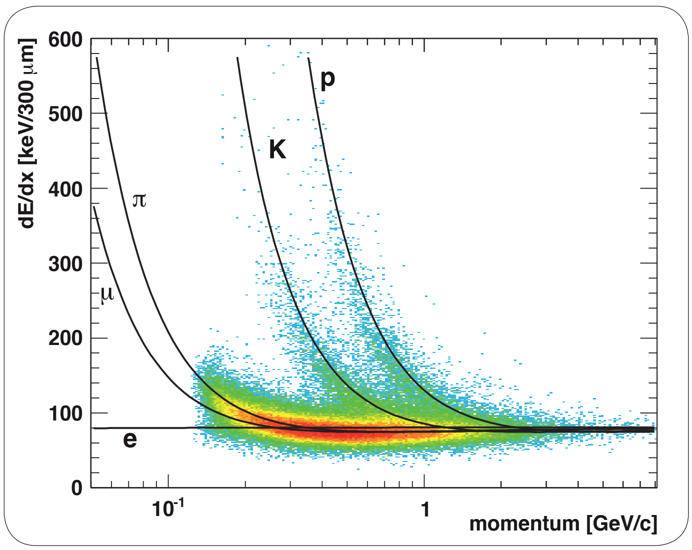


Figure 3. Energy deposit measured in the Inner Tracking System, versus particle momentum obtained from the track reconstruction. The curves are parametrisations of the energy deposit for various particle species.

2.4 Neutrino Telescopes: ANTARES & KM3NeT

Management: prof. dr. M. de Jong (PL),
dr. E. de Wolf
Running period: ANTARES 2001–2013
KM3NeT 2009–2016

The ANTARES detector and its future successor KM3NeT are a new generation of telescopes that study the Universe by means of neutrino detection instead of the conventional electromagnetic radiation. Cherenkov light from muons produced by a neutrino interaction are observed in photo-multiplier tubes (PMTs) and will shed light on the origin of cosmic rays and the mechanism of astrophysical particle acceleration.

ANTARES

The ANTARES detector is operational since May 2008. In total, twelve lines have been deployed at the bottom of the Mediterranean sea equipped with 900 optical modules, the 'eyes' of the detector. Each optical module houses one large (10") PMT.

A unique feature of the ANTARES detector, developed at Nikhef, is the so-called 'All-data-to-shore' readout system. This allows to search offline for a time-position correlation between a gamma-ray burst (GRB) and a possible neutrino signal. All analogue pulses from the PMTs are digitised and sent to shore where they are processed by a farm of commodity PCs. This PC farm has a real-time data communication link with the Swift and Fermi satellites that detect GRBs. The response time of the ANTARES detector to the satellite triggers is shown Fig. 1. Because data are buffered in the memory of the PCs, the search for a neutrino signal is also possible before the optical detection of the GRB.

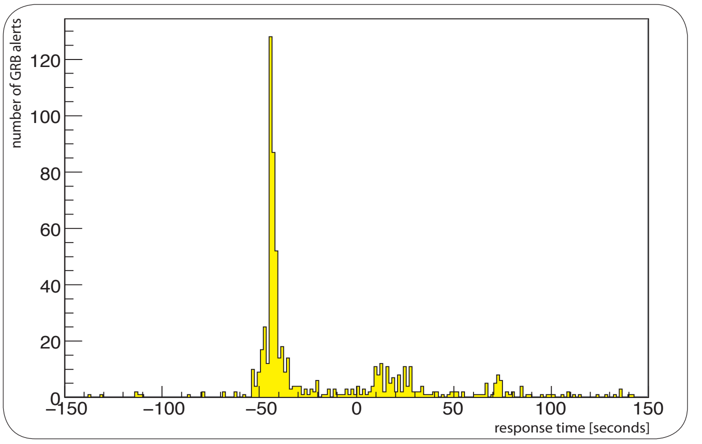


Figure 1. Response time (in seconds) of the Antares detector to satellite triggers.

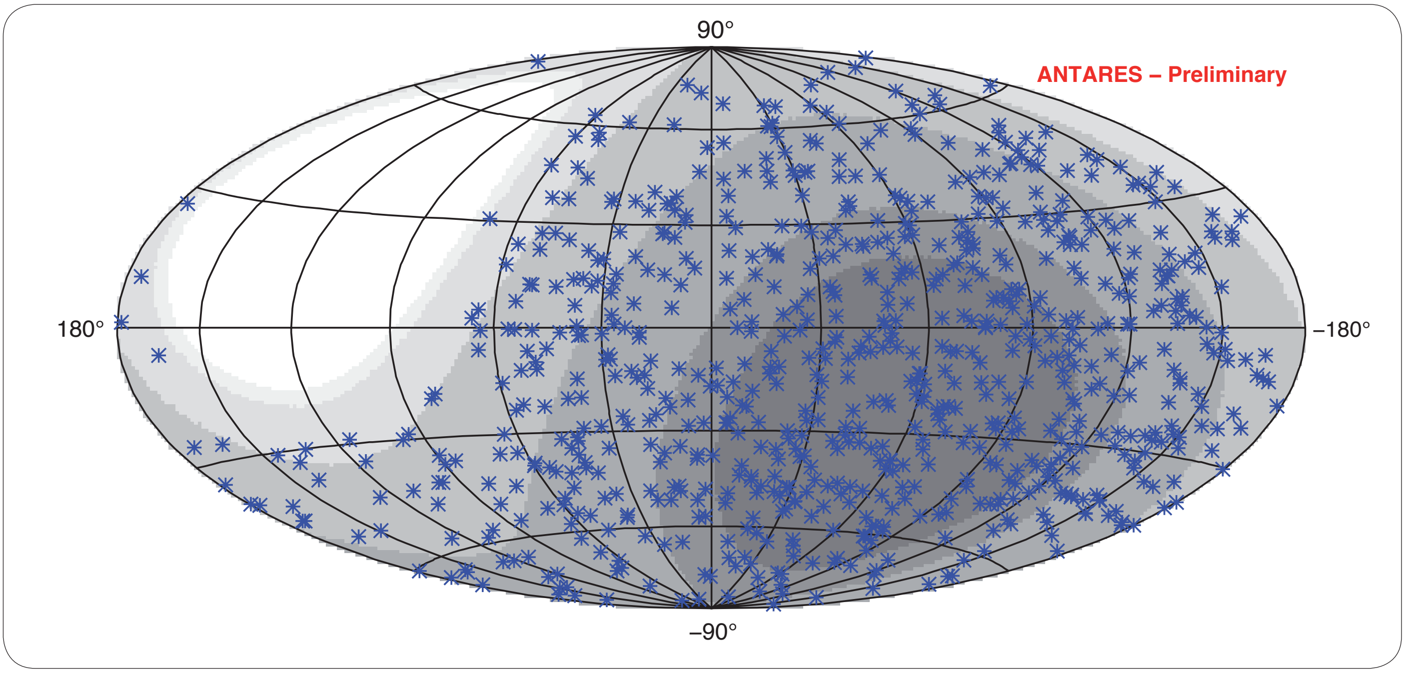


Figure 2. Neutrino sky map obtained with Antares in the years 2008–2009. The horizontal line in the centre corresponds to the Galactic disk. The grey coding corresponds to the relative observation time. Each blue point represents one neutrino candidate.

Figure 3. Design of an optical module for the KM3NeT neutrino telescope; it houses a large number of small photo-multiplier tubes inside one glass sphere.

Neutrinos are the only particles that can cross the Earth. Events can thus be identified as a neutrino if the resulting muon travels in the upward direction. A sky map of neutrinos observed with the ANTARES detector is shown in Fig. 2. Approximately 1000 upward neutrinos have been detected last year. With these data, no evidence for a neutrino point source has been found.

In addition, a combined analysis with ultra-high energy cosmic rays detected with the Auger observatory has been made, to investigate the conjecture that neutrinos are produced in the same sources as the cosmic rays. A preliminary analysis did not yield any evidence for such a possible correlation.

KM3NeT

It is foreseen that the operation of the ANTARES detector will continue until 2013. In the meantime, a design study for large deep-sea infrastructure hosting a cubic kilometre scale neutrino telescope is ongoing, named KM3NeT.

Previously, the approach to light detection was based on the use of the largest possible PMT that can be housed in a single glass sphere. The alternative design put forward by Nikhef consists of putting many small (3") PMTs inside one single glass sphere of the same size (see Fig. 3). This will not only maximise the total photocathode area (the sensitive area of the PMT) in a single sphere, but in addition it will improve the photon counting purity. The traditional approach relies on accurate integration and digitisation of a slow analogue pulse. The new approach makes use of discrete photon detection. After all, a photon is a single quantum and hence digital by nature.

Poster for the documentary "Higgs – into the heart of imagination". Image © Peter Tuffy | graphic design Studio HB

2.5 The Pierre Auger Observatory

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

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

A wireless setup for radio detection
In 2009, the Multi Antenna eXperiment In Malargüe Argentina (MAXIMA) was improved in several aspects. The main improvement was the reduction of self-induced radio interference, being a challenging task since the antenna signals are amplified by 50 dB.

Using our current setup, shown in Fig. 1, the variations in the noise level due to the Galactic plane moving overhead are clearly seen. Furthermore, improved Nikhef-built digitizers have been put in place, which allow for an increased data rate. This in turn allows for handling relatively low threshold levels, which increases the physics reach of the detector towards lower energetic events or larger distances. First cosmic-ray data have been measured with this setup using a small particle detector to provide the trigger signal.

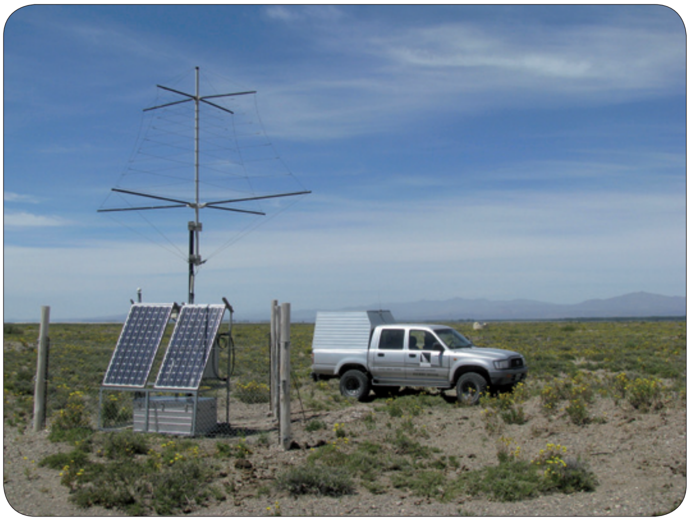


Figure 1. MAXIMA antenna deployed on the Pampa.

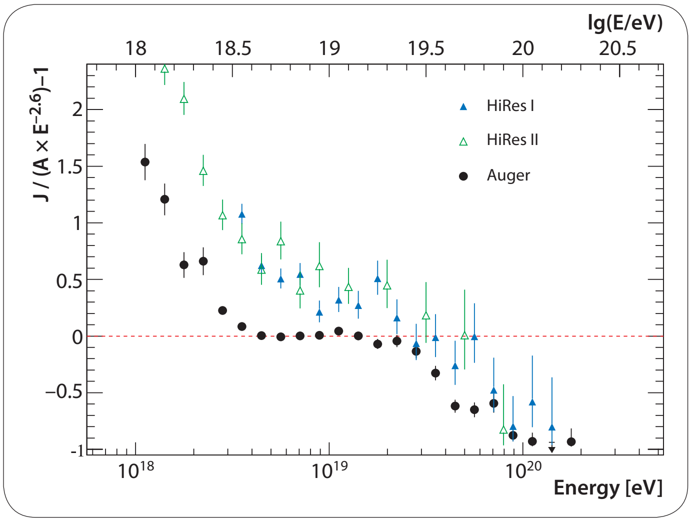


Figure 2. The Auger energy spectrum, only statistical errors are shown. The systematic uncertainty on the energy scale is 22%.

This MAXIMA setup, which is developed and operated by groups from the Netherlands, is a precursor for a 20 km^2 array of self triggered antenna stations called the Auger Engineering Radio Array. This AERA setup will contain about 150 antennas. Many of the ideas of the new radio detector stations originate from MAXIMA.

Physics highlights of the Pierre Auger Observatory
Last year an improved energy spectrum has been published, as shown in Fig. 2. The data are compared to the results from the HiRES experiment. Note that the Auger collaboration estimates a systematic uncertainty of 22% on the energy scale, which affects both the horizontal and vertical positions of the data points in this plot.

The Auger results clearly show two features in the cosmic ray energy spectrum, namely the ankle at ~3 EeV (1 EeV=10^{18} eV), and an additional depletion of the flux above ~30 EeV. Both regions are of extreme interest in the cosmic ray community. At the highest energies, it is not clear whether the depletion is due to the so-called GZK-cutoff (see Annual Report 2007) or whether the astronomic sources are stretched to their limit. Near the ankle, a transition from a galactic to an extra-galactic origin is suggested. It may be possible to confirm this theory by studying the incoming radiation in detail. When completed, AERA will perform measurements in this energy range.

2.6 Gravitational Physics
the dynamics of spacetime

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

The gravitational wave programme at Nikhef, with the recently approved FOM programme, aims first at the discovery of gravitational waves and second at increasing our understanding of both the past and future of the Universe.

Virgo

The Virgo experiment for detecting gravitational waves originating from any part of the Universe, consists of a Michelson laser interferometer made of two orthogonal arms each being 3 kilometers long. Multiple reflections between mirrors located at the ends of each arm extend the effective optical length of each arm up to about 400 kilometers. Virgo is located within the site of EGO, the European Gravitational Observatory, near Pisa in Italy. In the recent upgrade, Virgo+, the laser power was increased and thermal compensation systems were installed.

Nikhef took responsibility for the upgrade of front-end electronics for angular alignment of the various mirrors and for the input-mode cleaner (IMC) upgrade. In 2009 Virgo+ was commissioned and Virgo started her second science run, again in close collaboration with the Laser Interferometer Gravitational-Wave Observatory (LIGO) in the USA and GEO600 in Germany.

The increased sensitivity for gravitational waves is shown in Fig. 1. A further increase in sensitivity is expected from the monolithic suspensions that will be installed in the first half of 2010 and the double mirror (dihedron) replacement, made by Nikhef, in the input-mode cleaner. The common science run will last until the end of 2010. Data analysis is well advanced with searches for inspirals of neutron star (NS) and black hole (BH) binaries and with all-sky searches for periodic sources. A sensitivity for standard NS-NS inspirals at average horizon distances of 8 Mpc was reached.

Advanced Virgo

A new interferometer called Advanced Virgo will start in 2014 at the same location, again in collaboration with Advanced LIGO. Nikhef and VU take up responsibilities for a number of projects: (1) vacuum cryolinks, (2) suspension of six external and two internal benches, (3) alignment system, and (4) phase camera.

The cryogenic traps close to the end towers will improve the vacuum in the long arms to better than 10^{-9} mbar. The suspensions will reduce the seismic coupling of the benches to the optical system either by passive or by active damping. The alignment quad diodes have to operate partly in vacuum, at higher beam intensities, and with three different modulation frequencies.The phase camera will scan the wave front of the light in the interferometer.

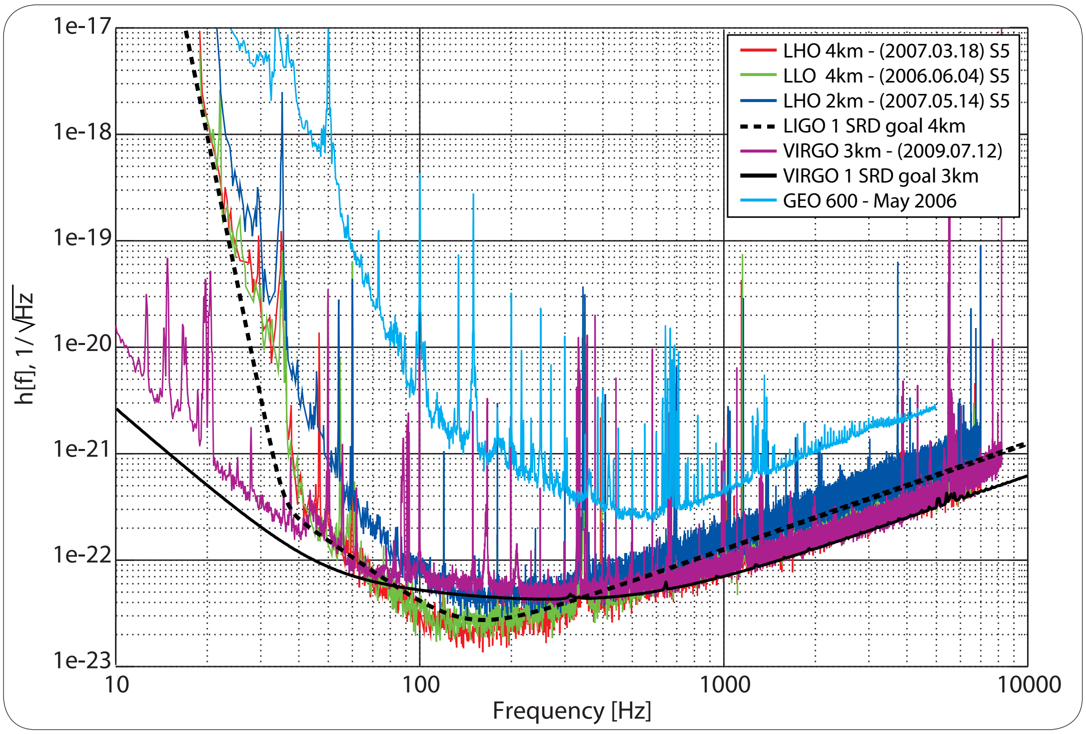


Figure 1. Sensitivity of VIRGO in comparison to that of LIGO LHO and LLO 4 km long interferometers, LIGO LHO (2 km long) and GEO600.

Figure 2. Nikhef researcher Jo van den Brand (in the centre, wearing a white tag around his neck) doing underground infrastructure research for the Einstein Telescope at a dept of 4850 feet (1478 metres) in the Homestake Mine (South Dakota). The Homestake Mine is famous in scientific circles for being the site at which the solar neutrino problem was first discovered. The deep underground laboratory was set up by Nobel Prize laureate Raymond Davis Jr. in the mid 1960s to become the first experiment to observe solar neutrinos.

Einstein Telescope

The Einstein Telescope (ET) is a new infrastructure project that will bring Europe to the forefront in the field of gravitational wave astronomy. The realisation of ET will be an important step in our quest to understand the history and future of the Universe. Challenges include the discovery and exploitation of gravitational waves as a probe of the Universe, putting experimental constraints on the corresponding quantum (the graviton) and the development of a quantum field theory of gravity.

The European Commission within the Seventh Framework Programme (FP7) awarded ET funding in 2008 to start a preliminary design study. Nikhef leads the work package WP-1 on site selection and infrastructure (See Fig. 2). These activities are carried out in close collaboration with geoscientists and industry. Projects at Nikhef are on (1) Newtonian noise modeling, (2) seismic measurements, and (3) underground infrastructure.

2.7 Theoretical Physics

Management: prof. dr. E. Laenen
Running period: 2008–2014

In 2009 research in the Nikhef theory group, including that of the VU University and Radboud University partners, ranged from research at and about the interface with experimental data all the way to explorations of possible universes.

Research Highlights
More than two decades after its discovery, the string theory landscape still remains largely unexplored, each valley describing a different universe (Fig. 1) with different particles and interactions. The challenge is to find the one corresponding to our universe, or at least prove that it must exist. Large numbers of standard model spectra were found using certain two-dimensional field theories as building blocks. This year, a new idea (involving the resolution of so-called conformal field theory fixed points) allowed to look further away from the lamppost, and gave a first glimpse of a novel part of the 'heterotic' landscape, where the standard model seems to fit fairly comfortably. In this context also effects from string theory on high-energy particle behaviour at the LHC were examined.

The grand scheme which appears to be the generalisation of string theory has been termed M-theory, which has however not yet been formulated fully mathematically. Nikhef contributed to this by obtaining certain special candidate theories. In addition, all 'vortex' solutions of the so-called Jackiw-Pi model were classified, which might be relevant for certain condensed matter physics, or, in a different way, for non-perturbative QCD studies.

Gaugino condensation is a generic ingredient of supersymmetric theories beyond the standard model, as it can trigger susy breaking and help stabilise extra dimensions. It has been shown that its presence puts a model-independent bound on the expansion rate of the early universe. In a related work the dynamics of the system was studied, and the initial conditions leading to successful stabilisation of extra dimensions identified.

The possibility has been studied that the matter and forces in our universe are in fact trapped to a brane, or a thin sheet, which then resides in a five-dimensional spacetime. Technical details of the brane itself have been analysed in the context of a particular model.

In 2009 developments were completed of the interface between two links (`Feynrules` and `Madgraph`) in a full tool chain that can automatically simulate realistic experimental signatures for theories expressed in terms of Lagrangians. This chain was employed to assess the possibility for signatures of a so-called 2-Higgs Doublet Model at the LHC. Also, precision corrections to charged higgs plus top quark production in the MC@NLO framework were calculated. Moreover, it was shown that the production of a single top quark together with a W boson can be isolated for the very similar process of top quark pair production, and it was indicated how to do so.

Figure 1. A landscape of various string theory solutions.

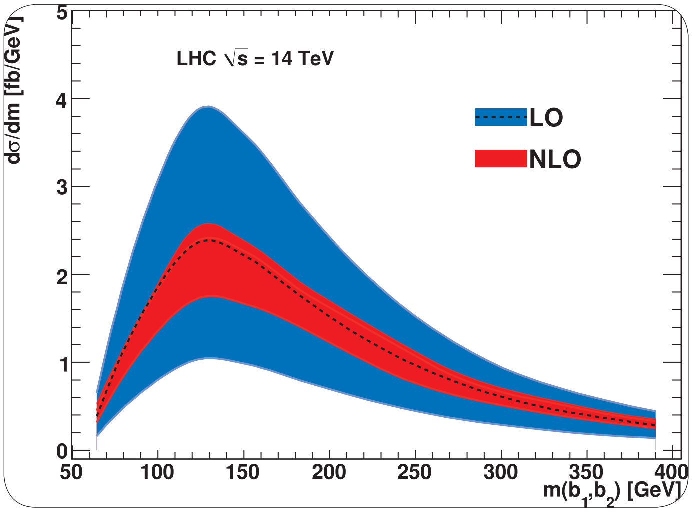


Figure 2. Invariant mass ($m_{b\bar{b}}$) distribution of the two leading b-quarks in the reaction $\$q\bar{q}\rightarrow b\bar{b}b\bar{b}$. The error bands are obtained by varying the renormalisation scale μ_R between $\mu_0/4$ and $2\mu_0$ with $\mu_0=\sqrt{\sum j}\, p_T(b_j)$, involving the sum of transverse momenta of the 4 bottom quarks. The dashed line shows the prediction for $\mu_R=\mu_0/2$.

The estimates for production rates of so-called supersymmetric particles (squarks and gluinos) were signficantly improved. Methods were employed to compute classes of large terms to all orders in perturbation theory. This leads indirectly to stricter bounds on their possible masses.

The FORM computer program was further developed, and used to compute a host of mathematical results for so-called multiple zeta values. Such a 'data-mine' is of great interest to theorists, and mathematicians. In another study, the three-loop corrections to deep-inelastic scattering via scalar bosons were determined. Though experimentally fictitious, the results of the calculations are very important to understand aspects of high-order QCD perturbation theory.

This year it has been pointed out that the extraction of the average transverse momentum of partons inside protons from the imbalance in transverse momentum between two jets produced in proton collisions is problematic due to polarisation effects of the partons. Also the phase transition issues involving CP symmetry restoration were examined, both in the low-energy phenomenology of QCD, and in the influence of strong magnetic fields in phase transitions in a model for heavy ion collisions, and magnetar stars.

Research into the shape of the effective potential for Higgs-like self-interacting fields has been continued and extended from Euclidean to the more realistic Minkowskian space in which our actual physics occurs. As a side-product the long-standing question was answered of why minima of the potential give the important contributions to the path integral and maxima are heavily suppressed. Furthermore, the complete set of so-called R2 terms has been computed both for the whole electroweak standard model as well as for supersymmetric QCD (for non-supersymmetric QCD these terms were known before). Such terms, which take the form of additional interaction vertices, are essential for the correct computation of one-loop effects using numerical methods.

Finally, highly automated computer programs were built and developed, especially for scattering processes with many final state particles. The process $pp\rightarrow b\bar{b}b\bar{b}$ was calculated, see Fig. 2, as one of the first results obtained with the program `golem-2.0`, a matrix element generator for one-loop amplitudes, developed by the GOLEM collaboration. As a spin-off, an optimising code generator (`haggies`) was built for efficient numerical evaluation of the constructed scattering amplitudes.

Other news

In 2009 two new staff members were recruited. Robert Fleischer, coming from CERN, joined the group per 1 September. Darren Forde coming from SLAC and CERN will join Nikhef in 2011. Daniel Boer moved from the VU University to the KVI institute in Groningen. Jan-Willem van Holten was appointed professor at Leiden University.

The monthly Theory Center Meetings, a key element of the FOM program "Theoretical Particle Physics in the Era of the LHC", continues to be well-attended. They have become a fixture in the Dutch theoretical high-energy physics landscape, and strengthen interaction among theorists from Dutch institutions, and with experimental colleagues. The National Seminar on Theoretical High-Energy Physics continues to be held at Nikhef and attracts good attendance.

Marieke Postma gave lectures on "Inflationary cosmology" at the 2009 DRSTP postgraduate school for theoretical high energy physics in Utrecht.

2.8 Detector Research & Development

Management: prof. dr. F. Linde (PL),
dr. J. Visser

In 2009 the group maintained its activities in the running projects, and continued its growth in staff members as well as PhD and master students. The focus of the group remains both on semiconductor detectors for the Relaxd and Hidralon projects and on gaseous detectors for future tracking detectors at LHC or ILC. Both efforts are Medipix chip based and will rely on the read-out system as being developed within the Relaxd project.

In addition, new projects were started, most notably the Hidralon project in close collaboration with Philips Healthcare and a chip design project with Bruco in the framework of the *'Kenniswerkersregeling'*. Both projects are described in more detail in the section on Knowledge Transfer.

Semiconductor detectors

The work within the semiconductor group is aimed at characterising edgeless sensors. In Fig. 1 two dicing techniques are compared in the quest for smoother edges that cause less leakage current in the active pixel matrix. It started with silicon sensors in the Relaxd project and has extended this year towards heavier materials like Gallium-Arsenide and Cadmium-Zinc-Telluride in cooperation with Philips Healthcare in the Hidralon project.

Gaseous detectors

Beam test experiments were performed with three gas chambers with a gas layer of only 1 mm above the combined grid and readout chip, called InGrid. The resolution has been determined and first results are close to the predictions from simulations. Further optimisation of the gas mixture is ongoing. The work on the InGrid pixel detectors has made a big step forward towards the ability to post-process 2×2 arrays of Timepix chips.

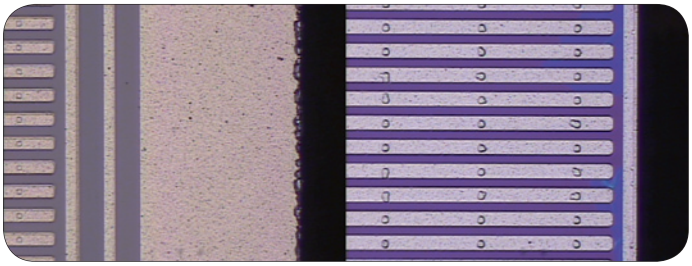


Figure 1: Comparison between edges and guard ring structures of silicon sensors: a sensor with conventional guard ring diced with a blade (left) and one cut out by deep reactive ion etching and a narrow guarding structure (right).

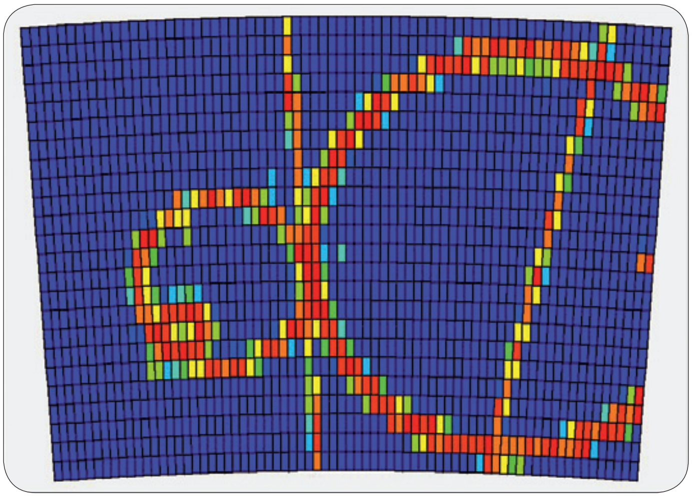


Figure 2. Image of a 5 GeV electron track accompanied by two delta curlers, recorded by the Large Prototype TPC equipped with a Micromegas end-plate module with conventional pad readout. The pad size is ~ 3×7 mm^2. The colours indicate the pulse height of the recorded signals.

Linear Collider

Nikhef is participating in the Linear Collider TPC (LCTPC) collaboration, which pursues R&D for a large Time-Projection Chamber (TPC) as main tracker system at a future linear collider. The performance goals for such a TPC are an order of magnitude better momentum resolution than obtained at LEP. A large prototype has been operated in a 1 T superconducting solenoid at a 6 GeV electron test beam at DESY. Different technologies, like Micromegas, GEMs with conventional pad readout or CMOS pixel readout ASICs (TimePix) as active anode have been tested for the detection of particle tracks. In Fig. 2 an example of detected tracks is shown.

Read-out Electronics

The read-out system made for the Relaxd project has achieved its goal of 1 Gb/s read-out. This implies that for the Medipix2 and Timepix chip about 100 frames per second can be recorded. For the Medipix3 chip, which operates in a significantly different way, the work has started to realise many more frames per second, depending on the counter depth.

Poster for the 18th VERTEX Workshop which was organised by Nikhef in 2009. Photo © Jacco Herzog

2.9 Grid Computing

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

Expanded Data Facility
In 2009 Nikhef has moved grid computing to a higher level - literally. The Nikhef Grid Centre as well as the local computing infrastructure for Nikhef users were moved from the first to the second floor to a new and expanded data facility. The reason for this operation was two-fold: to expand the local grid computing facility and to provide more space for the AMS-IX.

The new computer room has space for a total of 47 cabinets, each containing a so-called 19-inch rack. Each rack contains up to 33 servers (1 inch high). Each cabinet can draw up to 12 kW of power, with a maximum of 400 kW for the whole room. Currently 24 of these cabinets are in use by the Nikhef Grid Centre, with a total power usage of 134 kW (including the CT servers).

In 2009 the computing resources were expanded by another 1408 cores for a grand total of 2522 cores. Similarly the data resources were expanded by 1029 TB for a total of 1.26 PB (1 PB = 1,000,000 GB). The network between the computing and storage resources was vastly improved from 10 Gb/s to 160+40 Gb/s. In addition there is a dedicated 10 Gb/s link to the SARA data facility. All worker nodes have received a network upgrade to make use of this new bandwidth.

One of the core activities of the group remains the deployment and operation of the Dutch Tier-1 facility, of which the ATLAS NL cloud is a key customer. Apart from the ATLAS data production activity which is being stabilized after years of evolution and improvement, it is foreseen that the user analysis will become another major activity on the grid during the data taking period of LHC in 2009/2010.

Hammercloud
To perform a systematic test on the grid facility, a test framework called `HammerCloud` has been developed to simulate large-scale user analysis activities on the grid. The `HammerCloud` framework was built based on `Ganga`, the official ATLAS and LHCb user analysis tool for grid job management. In July, millions of user analysis jobs were generated by `HammerCloud`. The result helped to identify the bottlenecks of the Nikhef grid infrastructure for supporting user analysis and provided a guidance for the network re-configuration in the new grid data center. The re-test after data center movement shows that the new configuration can handle up-to 800 concurrent analysis jobs with 100% job efficiency.

Figure 1. The new computer room.

There are 5 new Tier-2s joining the ATLAS NL cloud in 2009: 2 from Russia and 3 from Israel. Those new sites are now in production and relying on the Tier-1 services running at the Netherlands (provided by Nikhef and SARA) for all ATLAS grid computing activities. In total, the Dutch Tier-1 grid facility is now serving 13 Tier-2 sites worldwide.

EGI
Nikhef is also still involved in the European EGEE-III project, which will end in May 2010. A proposal for continued maintenance and development of the grid middleware has been submitted, the European Middleware Initiative (EMI).

One of the prime customers of this EMI middleware will be the European Grid Initiative (EGI). In March it was announced that the headquarters of this new EGI organisation will be located at the Science Park Amsterdam.

The challenge for the grid group next year will remain to keep growing in a sustainable and controllable fashion. With an operational LHC and the start of the first data-taking of the LOFAR radio astronomy telescope a huge increase in the amount of data at SARA and Nikhef is expected. With the new data facility at hand, Nikhef is ready to take on these challenges.

3

Output

3.1 Publications

ATLAS/DØ

D. Arutinov (*et al.*), R. Kluit, J.D. Schipper
Digital architecture and interface of the new ATLAS pixel front-end IC for upgraded LHC luminosity
IEEE Trans. Nucl. Sci. **56** (2009) 388

A. Dudarev (*et al.*), J. Buskop
Commissioning test of ATLAS End-Cap Toroidal Magnets
IEEE Trans. Appl. Superconductivity **19** (2009) 1307

O. Igonkina, H. Garitaonandia Elejabarrieta, S. Klous (*et al.*)
Calorimetry triggering in ATLAS
J. Phys. : Conf. Series **160** (2009) 012601

C. Adorisio (*et al.*), M. Barisonzi, G. Bobbink, H. Boterenbrood, H. van der Graaf, H. Groenstege, R. Hart, A. Konig, F. Linde, J. Vermeulen, P. Werneke, T. Wijnen
Study of the ATLAS MDT spectrometer using high energy CERN combined test beam data
Nucl. Instr. Meth. **A 598** (2009) 400

D. Bailey (*et al.*), N. de Groot, T. Wijnen
The LCFIVertex package: Vertexing, flavour tagging and vertex charge reconstruction with an ILC vertex detector
Nucl. Instr. Meth. **A 610** (2009) 573

M. Barbero (*et al.*), R. Kluit
A new ATLAS pixel front-end IC for upgraded LHC luminosity
Nucl. Instr. Meth. **A 604** (2009) 397

Z. Vykydal (*et al.*), J. Visschers
The Medipix2-based network for measurement of spectral characteristics and composition of radiation in ATLAS detector
Nucl. Instr. Meth. **A 607** (2009) 35

M.P. Casado (*et al.*), O. Igonkina
The ATLAS τ trigger
Nucl. Phys. **B** (Proc. Suppl.) **189** (2009) 291

DØ Collaboration:
V.M. Abazov (*et al.*); M. Anastasoaie, L.S. Ancu, P.J. van den Berg, F. Filthaut, C.F. Galea, J.G. Hegeman, P. Houben, S.J. de Jong, W.M. van Leeuwen, M. Meijer, N.A. Naumann, P. Svoisky

A novel method for modeling the recoil in W boson events at hadron colliders
Nucl. Instr. Meth. **A 609** (2009) 250

Measurement of the angular and lifetime parameters of the decays $B_d^0 \to J/\psi K^{*0}$ and $B_s^0 \to J/\psi\phi$
Phys. Rev. Lett. **102** (2009) 032001

Search for large extra spatial dimensions in the dielectron and diphoton channels in $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV
Phys. Rev. Lett. **102** (2009) 051601

Measurement of the semileptonic branching ratio of B_s^0 to an orbitally excited D_s^{**} state: $Br(B_s^0 \to D_{s1}^-(2536)\mu^+\nu X)$
Phys. Rev. Lett. **102** (2009) 051801

Search for associated W and Higgs Boson production in $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV
Phys. Rev. Lett. **102** (2009) 051803

Search for neutral Higgs bosons at high tan β in the $b(h/H/A) \to b\tau^+\tau^-$ channel
Phys. Rev. Lett. **102** (2009) 051804

Evidence for the decay $B_s^0 \to D_s^{(*)}D_s^{(*)}$ and a measurement of $\Delta\Gamma_s^{CP}/\Gamma_s$
Phys. Rev. Lett. **102** (2009) 091801

Measurement of the lifetime of the $B_c^{\pm}$ meson in the semileptonic decay channel
Phys. Rev. Lett. **102** (2009) 092001

Search for anomalous top-quark couplings with the DØ detector
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T. Anticic (*et al.*); M. Botje, P. Christakoglou, M.A. van Leeuwen, A. Mischke

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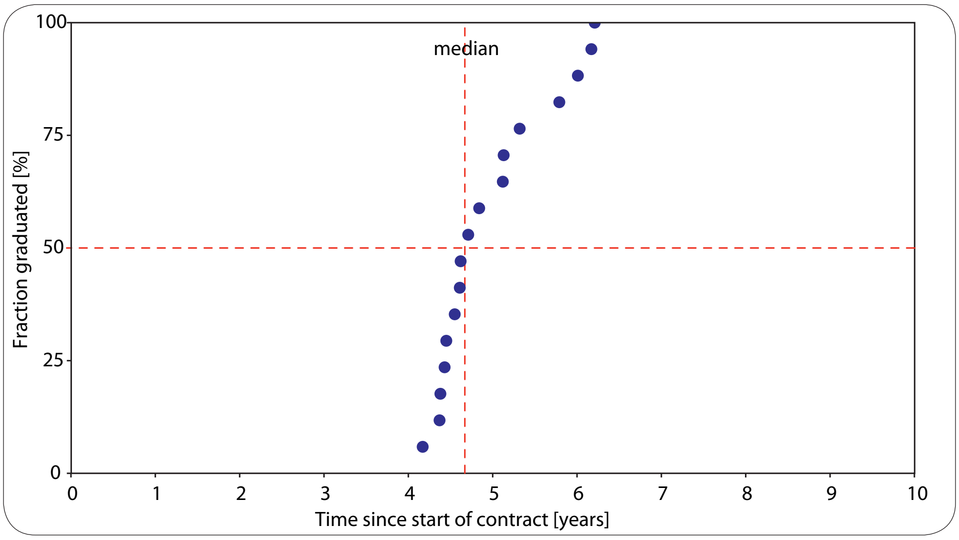


Fraction of PhD students working at Nikhef that graduated in the year 2009 as a function of time since the start of their thesis contract. The median promotion duration is 4.7 year.

3.2 Theses

Maximilien Alexandre Chefdeville
Development of Micromegas-like gaseous detectors using a pixel readout chip as collecting anode
Universiteit van Amsterdam, 15 January 2009
Promotor: J. Schmitz, Copromotor: P. Colas

Jeroen Guido Hegeman
Measurement of the top quark pair production cross section in $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV : Hadronic top decay with the DØ detector
Universiteit Twente, 16 January 2009
Promotor: B. van Eijk

Marcel van Kessel
The Path-Integral Approach to Spontaneous Symmetry Breaking
Radboud Universiteit Nijmegen, 3 February 2009
Promotores: R. Kleiss, E.N. Argyres

Pieter Johannes van den Berg
Search for heavy resonances in the dimuon channel with the DØ detector
Universiteit van Amsterdam, 24 February 2009
Promotor: S.C.M. Bentvelsen, Copromotor: P.J. de Jong

Claudine Marie Marguerite Colnard
Ultra-high energy neutrino simulations
Universiteit van Amsterdam, 16 April 2009
Promotor: G. van der Steenhoven, Copromotor: E. de Wolf

Hella Leonie Snoek
Suppressed charmed B decays
Vrije Universiteit Amsterdam, 2 June 2009
Promotor: J.F.J. van den Brand, Copromotor: H.G. Raven

Pieter Willem Huib Houben
A measurement of the mass of the top quark using the ideogram technique
Universiteit van Amsterdam, 3 June 2009
Promotores: M.W.J.M. Demarteau, F.L. Linde,
Copromotor: M. Vreeswijk

Caroline Alexandra Magrath
The heart of ATLAS: Commissioning and performance of the ATLAS silicon tracker
Radboud Universiteit Nijmegen, 12 June 2009
Promotores: E.N. Koffeman, N. de Groot

Gustavo Ordóñez Sanz
Muon Identification in the ATLAS Calorimeters
Radboud Universiteit Nijmegen, 12 June 2009
Promotor: N. de Groot, Copromotor: P. Kluit

Erik Aras Papadelis
Characterisation and commissioning of the LHCb VELO detector
Vrije Universiteit Amsterdam, 17 June 2009
Promotor: M.H.M. Merk, Copromotor: E. Jans

Erik Wessels
Signatures of gluon saturation in high energy scattering
Vrije Universiteit Amsterdam, 17 June 2009
Promotor: P.J.G. Mulders, Copromotor: D. Boer

Jan-Willem Wagenaar
Pion-Nucleon Scattering in Kadyshevsky Formalism and Higher Spin Field Quantization
Radboud Universiteit Nijmegen, 10 July 2009
Promotor: R. Kleiss, Copromotor: T.A. Rijken

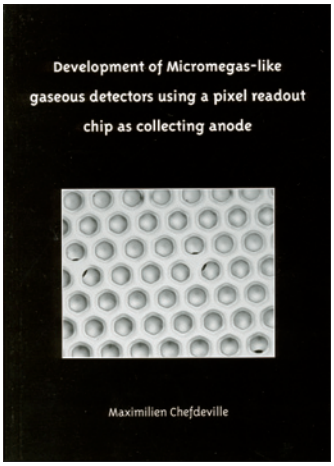
Maaike Limper
Track and vertex reconstruction in the ATLAS inner detector
Universiteit van Amsterdam, 12 October 2009
Promotor: S.C.M. Bentvelsen, Copromotor: A.P. Colijn

Jochem Snuverink
The ATLAS muon spectrometer: commissioning and tracking
Universiteit Twente, 16 October 2009
Promotores: B. van Eijk, F.L. Linde, Copromotor: P.M. Kluit

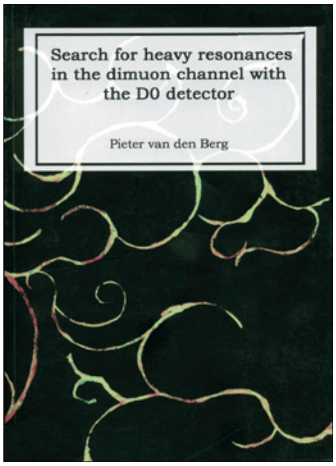
Gerben Cornelis Stavenga
Soft radiation in quantum chromodynamics
Universiteit Utrecht, 14 September 2009
Promotor: E.M.L.P. Laenen

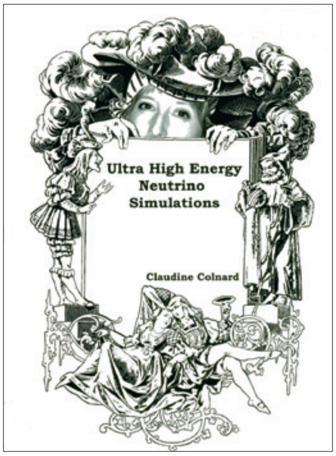
Cristian George Ivan
Open charm analysis with the ALICE detector in pp collisions at LHC
Universiteit Utrecht, 30 November 2009
Promotor: R. Kamermans

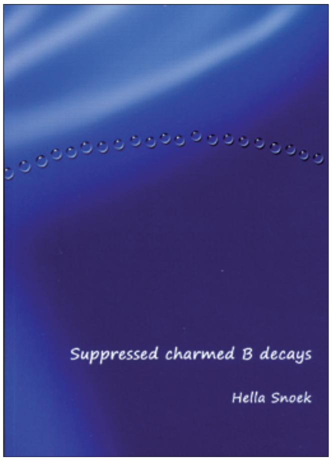
Erik Eise van der Kraaij
First top quark physics with ATLAS – a prospect
Universiteit van Amsterdam, 4 December 2009
Promotor: S.C.M. Bentvelsen, Copromotor: P.J. de Jong

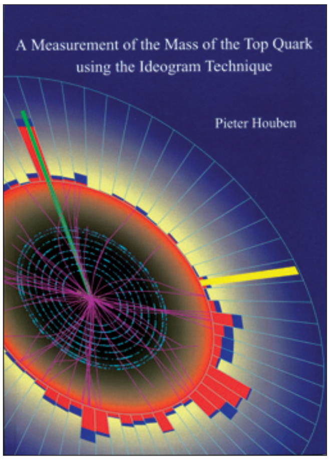

Development of Micromegas-like
gaseous detectors using a pixel readout
chip as collecting anode
Maximilien Chefdeville

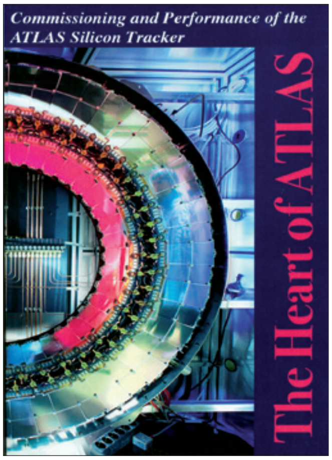

Measurement of the top quark
pair production cross section
in proton-antiproton collisions
at √s = 1.96 TeV
Hadronic top decays with the D0 detector
DØ
ØD
Jeroen Hegeman

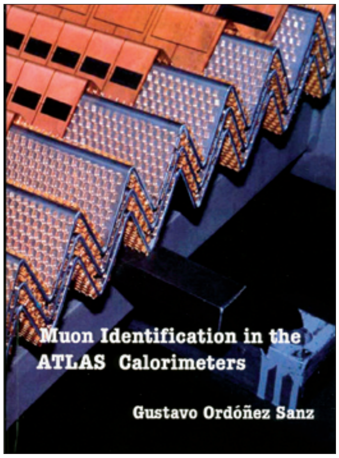

Search for heavy resonances
in the dimuon channel with
the D0 detector
Pieter van den Berg

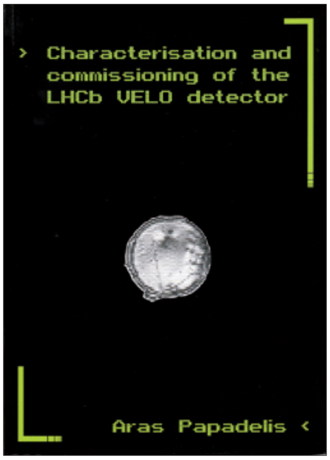

Ultra High Energy
Neutrino
Simulations
Claudine Colnard

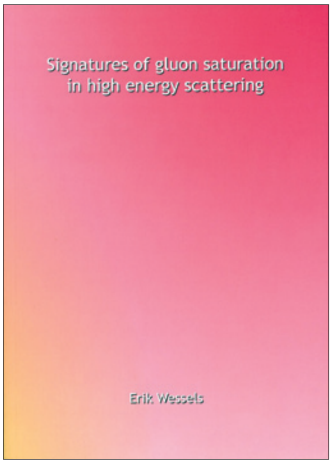

Suppressed charmed B decays
Hella Snoek

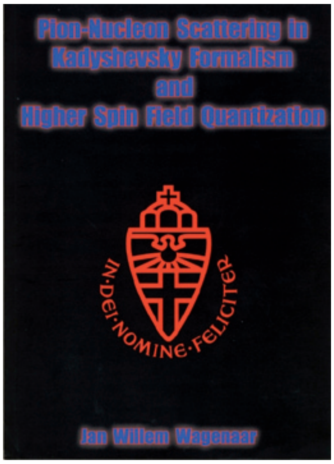

A Measurement of the Mass of the Top Quark
using the Ideogram Technique
Pieter Houben

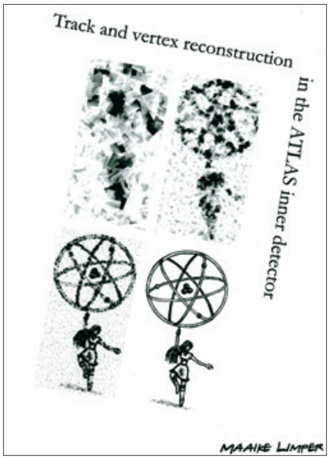

Commissioning and Performance of the
ATLAS Silicon Tracker
The Heart of ATLAS

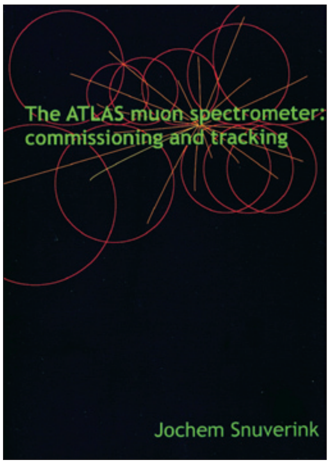

Muon Identification in the
ATLAS Calorimeters
Gustavo Ordóñez Sanz

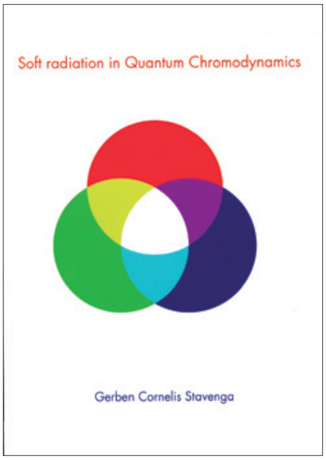

› Characterisation and
commissioning of the
LHCb VELO detector
Aras Papadelis ‹

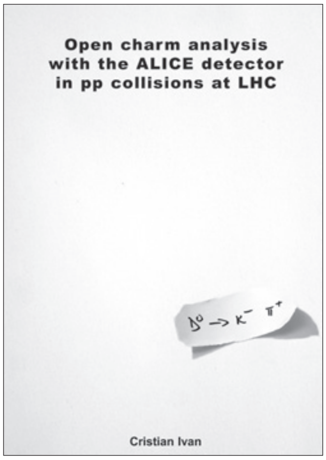

Signatures of gluon saturation
in high energy scattering
Erik Wessels

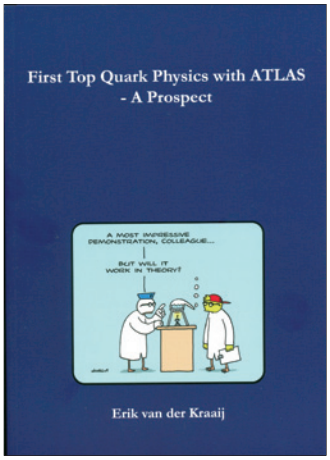

Pion-Nucleon Scattering in
Kadyshevsky Formalism
and
Higher Spin Field Quantization
IN·DEI·NOMINE·FELICITER
Jan Willem Wagenaar


Track and vertex reconstruction
in the ATLAS inner detector
MAAIKE LIMPER


The ATLAS muon spectrometer:
commissioning and tracking
Jochem Snuverink


Soft radiation in Quantum Chromodynamics
Gerben Cornelis Stavenga


Open charm analysis
with the ALICE detector
in pp collisions at LHC
Cristian Ivan


First Top Quark Physics with ATLAS
- A Prospect
Erik van der Kraaij

3.3 Talks

ATLAS/DØ

Ancu, L.S., Search for Associated Production of Z and Higgs Bosons in the μμbb Final State in $p\bar{p}$ Collisions at $\sqrt{s}$=1.96 TeV, 2009 APS April Meeting, Denver, CO, USA, 3 May, 2009

Bentvelsen, S., ATLAS en de speciale relativiteitstheorie, Goois Lyceum, Bussum, The Netherlands, 24 March, 2009

De oerknal in het laboratorium, Koninklijke Nederlandse Vereniging voor Weer- en Sterrenkunde, Zwolle, The Netherlands, 24 September, 2009

De oerknal in het laboratorium, Volkssterrenwacht Amsterdam, Amsterdam, The Netherlands, 17 February, 2009

De Speciale Relativiteitstheorie, Universiteit van Amsterdam Open Dag, Amsterdam, The Netherlands, 7 March, 2009

Getting ATLAS and the LHC ready for Physics, 21^{st} symposium Plasma Physics and Radiation Technology, Lunteren, The Netherlands, 3 March, 2009

Kun je meten wat je niet ziet?, NEMO kinderlezing, Amsterdam, The Netherlands, 15 June, 2009

Workshop Top Quark Physics, Deutscher Akademischer Austausch Dienst – Studienstiftung Stipendiaten, Rot and der Rot, Germany, 11 August, 2009

Bos, K., Status and Prospects of The LHC Experiments Computing, 17^{th} Int. Conf. on Computing in High Energy and Nuclear Physics, Prague, Czech Republic, 23 March, 2009

Eijk, B. van, Elementaire Deeltjes in het Standaard Model en…?, Nikhef, Amsterdam, The Netherlands, 20 March, 2009

The LHC: 'Beyond the Horizon of the Standard Model', SRON Science Days, Dalfsen, The Netherlands, 25 May, 2009

Beyond the Horizon of the Standard Model, Nikhef, Amsterdam, The Netherlands, 2 June, 2009

The Era of the LHC, Hanoi Technical University, Hanoi, Vietnam, 19 June, 2009

Higgs: 'The Lightness of Being', EPS-2009, Krakow, Poland, 21 July, 2009

Filthaut, F., Computers bij experimenten in de deeltjesfysica, Gastcollege, Technische Universiteit Eindhoven, Eindhoven, The Netherlands, 14 December, 2009

Hart, R.G.K., The ATLAS Barrel Alignment Readout System, Int. Conf. on Accelerator and Large Experimental Physics Control Systems, Kobe, Japan, 12 October, 2009

The ATLAS MDT Control System, Int. Conf. on Accelerator and Large Experimental Physics Control Systems, Kobe, Japan, 12 October, 2009

Jong, P.J. de, (Some of) the physics of the LHC, Universiteit van Amsterdam IT students tour of CERN, CERN, Geneva, Switzerland, 11 February, 2009

The night before the LHC, Universiteit van Amsterdam FNWI faculty colloquium, Amsterdam, The Netherlands, 5 October, 2009

'Twas the night before the LHC, NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009

Jong, S.J. de – Kleiss, R., Higgs; massa verklaard?, Science Café, Nijmegen, The Netherlands, 21 April, 2009

Jong, S.J. de, Harvest time at the Tevatron: CP violation, W, top and Higgs, Colloquium, Utrecht University, 8 April, 2009.

Kosmische Straling, Guest lecture Raayland College, Venray, The Netherlands, 23 June, 2009

Reis naar het binnenste van het atoom, Science cafe/Studium Generale, Tilburg, The Netherlands, 22 October, 2009

Kayl, M.S., The ATLAS silicon strip detector running experience, VERTEX 2009, Putten, The Netherlands, 14 September, 2009

Koetsveld, F., New developments in data-driven background determinations for SUSY searches in ATLAS 2009 NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009

Koutsman, A.J., Data driven background determination for SUSY searches with ATLAS, Lake Louise Winter Institute 2009, Lake Louise, Canada, 20 February, 2009

Lee, H.C., Ganga development, ATLAS Software and Computing Workshop, Geneva, Switzerland, 30 November, 2009

Liebig, W., Tracking and Vertexing, Lecture at Terascale School on Detector Understanding with First LHC Data, Hamburg (DESY), Germany, 1 July, 2009

Meijer, M., Search for a Standard Model Higgs boson with 4.0 fb^{-1} at the Tevatron, specifically in the $WH \rightarrow \tau\nu b\bar{b}$ channel at DØ, 2009 NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009

Salamanna, G., Top-quark physics with first LHC data: reconstruction and production cross-section, Physics@FOM Veldhoven 2009, Veldhoven, The Netherlands, 21 January, 2009

Results from the ATLAS Barrel Level-1 Muon Trigger Timing Studies Using Combined Trigger and Offline Tracking, 2009 IEEE Nuclear Science Symposium and Medical Imaging Conf., Orlando USA, 27 October, 2009

Verkerke, W., Statistical Data Analysis Techniques, Niels Bohr Institute, Copenhagen, Denmark, 19 October, 2009

Statistical Data Analysis Techniques, Niels Bohr Institute, Copenhagen, Denmark, 20 October, 2009

Statistical Data Analysis Techniques, Niels Bohr Institute, Copenhagen, Denmark, 21 October, 2009

Maximum Likelihood Fitting, BaBar Analysis School, Stanford Linear Accelerator Center, Menlo Park, CA, USA, 27-28-29 October, 2009

The RooFit toolkit for Data Modeling, INFN Ferrara, Ferrara, Italy, 19 November, 2009

Vreeswijk, M., Energy and Extreme Machines (Eureka!Cup 2009), Science Park Amsterdam, Amsterdam, The Netherlands, 12 February, 2009

Vulpen, I.B. van, Nieuwe natuurwetten ontrafeld, Science Café Leiden, Leiden, The Netherlands, 3 March, 2009

De Large Hadron Collider, Kroniglezing, Studium Generale Universiteit Delft, Delft, The Netherlands, 11 March, 2009

Preparing for first physics at the LHC. The role of the top quark., Universität Göttingen, Goettingen, Germany, 26 June, 2009

Zoektocht naar de elementaire bouwstenen van de natuur, Volksuniversiteit Haarlem, Haarlem, The Netherlands, 11 November, 2009

LHCb/BaBar

Akiba, K., LHCb Velo: commissioning, performance and High rate tests, 9th Int. Conf. on Large Scale Applications, Florence, Italy, 30 September, 2009

Hulsbergen, W.D., Alignment with Tracks, Vertex 2009, Putten, The Netherlands, 15 September, 2009

Jans, E., The LHCb detector, 2009 Meeting for the Division of Particles and Fields of the American Physical Society, Detroit, USA, 26 July, 2009

Jansen, F.M., Construction, installation and commissioning of a high-efficiency and high-resolution straw tube tracker for the LHCbnext term experiment, 11th Pisa meeting on advanced detectors, La Biodola, Italy, 24 May, 2009

Merk, M.H.M., Physics with bottom quarks: The LHCb experiment, Physics@FOM 2009, Veldhoven, The Netherlands, 20 January, 2009

Physics with beauty quarks: The LHCb experiment, VU journal club, Vrije Universiteit, Amsterdam, The Netherlands, 18 March, 2009

Waar is de Antimaterie heen?, European Masterclass, Nikhef, Amsterdam, The Netherlands, 19 March, 2009

Feiten en Fictie in Angels & Demons, Tuschinski Theater, Amsterdam, The Netherlands, 13 May, 2009

Feiten en Fictie in Angels & Demons, Nikhef Open Dag, Amsterdam, The Netherlands, 11 October, 2009

De LHC: zoektocht naar elementaire bouwstenen van de materie, Publieke lezing op het Nikhef, Amsterdam, The Netherlands, 26 October, 2009

Raven, G., CP Violation, Lectures given as part at the CERN Summer Student Lecture Program, Geneva, Switzerland, 27 July, 2009

CP Violation, Lectures given as part at the CERN Summer Student Lecture Program, Geneva, Switzerland, 28 July, 2009

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CP Violation, Lectures given at the 2009 BND school, Rathen, Germany, 17 September, 2009

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Pree, T.A. du, Prospects for CP violation measurements at LHCb, 14th Lomonosov Conference, Moscow, Russia, 24 August, 2009

Storaci, B.S., BR extraction techniques for searching New Physics in the $B_s \rightarrow \mu^+\mu^-$ decay., NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009

Tuning, N., De LHC: Zoektocht naar de elementaire bouwstenen van de Natuur, Eerste Christelijk Lyceum, Haarlem, The Netherlands, 17 March, 2009

Zoektocht naar de elementaire bouwstenen van de Natuur, Lions Ophelia, Aalsmeer, The Netherlands, 23 March, 2009

De LHC: Zoektocht naar de elementaire bouwstenen van de Natuur, Vereniging Industriële Belangengemeenschap, Mijdrecht, The Netherlands, 28 September, 2009

De LHC: Reis naar het Allerkleinste…, Scientific Festival NEMO, Amsterdam, The Netherlands, 3 October, 2009

ALICE/STAR

Botje, M., QCDNUM17: Fast QCD evolution and convolution, PDF4LHC workshop, CERN, Geneva, Switzerland, 6 August, 2009

Introduction to Bayesian Inference, Lectures given at the 2009 BND school, Rathen, Germany, 18 September, 2009

Introduction to Bayesian Inference, Lectures given at the 2009 BND school, Rathen, Germany, 19 September, 2009

Braidot, E., Looking forward for Color Glass Condensate signatures, Quark Matter 2009, Knoxville, USA, 2 April, 2009

Christakoglou, P., Studies of the baryon number transport at LHC energies with the ALICE experiment, Lecture given at the Heavy Ion Forum at CERN, Geneva, Switzerland, 25 May, 2009

Commissioning of the Silicon Strip Detector (SSD) of ALICE, Europhysics Conf. on High Energy Physics 2009, Krakow, Poland, 16 July, 2009

Kolk, N. van der, Elliptic flow measurements at ALICE, Workshop on Particle Correlations and Femtoscopy, CERN, Geneva, Switzerland, 17 October, 2009

Leeuwen, M. van, Comparing energy loss phenomenology, 4th Int. Workshop High-p_T physics at LHC 09, Prague, Czech Republic, 4 February, 2009

Nooren, G.J.L., HiSPARC in Utrecht, University College Utrecht, Utrecht, The Netherlands, 13 May, 2009

Experience with the Silicon Strip Detector of ALICE, RD09 – 9th Int. Conf. on Large Scale Applications and Radiation Hardness of Semiconductor Detectors, Florence, Italy, 30 September, 2009

Peitzmann, T., The ridge laboratory, 4th Int. Workshop High-p_T physics at LHC 09, Prague, Czech Republic, 5 February, 2009

Recent Results from RHIC, XXIV Int. Symposium On Lepton Photon Interactions At High Energies, Hamburg, Germany, 18 August, 2009

Gluon Saturation – Towards Classical Strong Fields, NUPECC Long-Range Plan Scoping Workshop, Frankfurt, Germany, 12 October, 2009

Heavy-Ion Physics at the LHC, ITF Colloquium, Utrecht University, Utrecht, The Netherlands, 11 November, 2009

Snellings, R., Viscosity, Hydrodynamics and Flow, Helmholtz Research School, Kemer, Turkey, 22 November, 2009

Viscosity, Hydrodynamics and Flow, Helmholtz Research School, Kemer, Turkey, 23 November, 2009

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Transport Properties of Nuclear Matter at High Temperature and Density, NuPECC, Frankfurt, Germany, 12 October, 2009

The Knoxville Number, Quark Matter 2009, Knoxville, USA, 2 April, 2009

The Knoxville Number, Nearly Perfect Fluids, Research Triangle, North Carolina, USA, 6 April, 2009

The Knoxville Number, Nearly Perfect Fluids, Research Triangle, North Carolina, USA, 7 April, 2009

The Knoxville Number, Nearly Perfect Fluids, Research Triangle, North Carolina, USA, 8 April, 2009

Heavy-Ion Physics, 65th Scottish Universities Summer School in Physics, St Andrews, Scotland UK, 27 August, 2009

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ANTARES/KM3Net

Assis Jesus, A.C., KM3NeT: Design & Developments, 11th National APP Symposium, Leiden, The Netherlands, 20 March, 2009

KM3NeT: a new window on our Universe, BUE, CTP Int. Conf. on Neutrino Physics in the LHC Era, Luxor, Egypt, 19 November, 2009

Lim, G.M.A., Searching for dark matter with the Antares neutrino telescope, Physics@FOM Veldhoven, Veldhoven, The Netherlands, 20 January, 2009

First results on the search for dark matter in the Sun with the Antares neutrino telescope, 31st Int. Cosmic Ray Conf., Łódź, Poland, 9 July, 2009

Wolf, E. de, KM3NeT, a Research facility in the Mediterranean Sea, NIOZ, Texel, The Netherlands, 8 January, 2009

Antares and KM3NeT: fishing for neutrinos in the Mediterranean Sea, GIREP/EPEC Int. Conference, Leicester, United Kingdom, 18 August, 2009

A sensor architecture for neutrino telescopes, Int. Workshop on Very Large Volume Neutrino Telescopes 2009 (VLVνT09), Athens, Greece, 15 October, 2009

Virgo/LISA

Broeck, C.F.F. Van Den, Testing star formation rates with Einstein Telescope, 2nd Annual Einstein Telescope Workshop, Erice, Italy, 4 October, 2009

Putten, S. van der, Searching for gravitational waves from pulsars in binary systems: An all sky search, Amaldi8, Colombia University, New York, USA, 25 June, 2009

The Quadratic Search: A method for detecting gravitational waves from pulsars in binary systems, 12th Marcel Grossmann meeting, Paris, France, 17 July, 2009

Rabeling, D.S., FE implementation of seismically driven GGN in subterranean GW detectors, Einstein Telescope WP1 meeting, Gran Sasso, Italy, 9 February, 2009

Progress on FE modeling for Newtonian noise estimates, Gravitational-Wave Advanced Detector Workshop, Ft Lauderdale, Florida, USA, 13 May, 2009

Sensing and subtraction of gravity gradient noise in ET, 2nd Annual General Einstein Telescope meeting, Erice, Italy, 1 October, 2009

Newtonian noise in 3rd generation GW detectors, Deep Underground Science and Engineering Laboratory meeting, Rapid City, USA, 10 October, 2009

Sensing and subtraction of gravity gradient noise in 3rd gen. GW detectors, Gravitation and Fundamental Physics in Space Kick-Off Colloquium, Les Houches, France, 20 October, 2009

AUGER

Coppens, J., HiSparc and cosmic rays, Van Nellefabriek (JetNet career event), Rotterdam, The Netherlands, 11 November, 2009

Grebe, S., Towards a self-trigger for the radio detector of cosmic rays at the Pierre Auger Observatory, 2009 NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009

S.J. de Jong, C. Timmermans, J. Coppens, H. Schoorlemmer, A. Fitzner, Cosmic Sensation, Academische Jaarprijs 2009, Museum Boerhaave Leiden, The Netherlands, 7 October, 2009

Kelly, J., A Radio-Frequency Extension to the Pierre Auger Cosmic Ray Observatory, 2009 NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009

Theory

Bazzocchi, F., Phenomenology of A4 and S4 based models, Rencontres de Moriond, LaThuile, Italy, 10 March, 2009

SO(10) versus flavor symmetries: possible strategies to describe fermion masses and mixings, Università di Padova, Padova, Italy, 2 April, 2009

Sneutrino as DM candidate in an inverse see-saw scenario, Topics in Astroparticle and Underground Physics 2009, Roma, Italy, 4 July, 2009

SO(10) versus flavor symmetries: possible strategies to describe fermion masses and mixings, Universidad de Valencia, Valencia, Spain, 6 July, 2009

Neutrino masses and DM candidate in an inverse see-saw scenario, Workshop on DM at IFT-UAM, Madrid, Spain, 18 September, 2009

SQuark-Lepton complementarity in a S4 x Pati Salam scenario, Universidad de Valencia, Valencia, Spain, 18 November, 2009

Fleischer, R., Precision B Physics at the LHC and the Quest for New Physics, Primosten 09: Progress and Challenges in Flavour Physics, Primosten, Croatia, 3 October, 2009

Flavour Physics and CP Violation: Expecting the LHC, II Prometeo Workshop: CP Violation and the Baryon/Lepton Asymmetry, Valencia, Spain, 10 December, 2009

Gmeiner, F., Threshold corrections in intersecting brane models, Rijksuniversiteit Groningen, Groningen, The Netherlands, 3 March, 2009

The Landscape of Intersecting Brane Models, Institute for the Physics and Mathematics of the Universe, Tokyo, Japan, 21 April, 2009

Towards the Standard Model in the type IIA Landscape, Universität Heidelberg, Heidelberg, Germany, 29 June, 2009

Holten, J.W. van, The fate of conformal symmetry in non-relativistic QFT, NORDITA, Stockholm, Sweden, 22 April, 2009

The fate of conformal symmetry in non-relativistic QFT, Friedrich-Schiller-Universität, Jena, Germany, 14 October, 2009

What drives cosmic inflation?, Friedrich-Schiller-Universität, Jena, Germany, 15 October, 2009

Conformal symmetry in non-relativistic QFT, National Seminar Theoretical High-Energy Physics, Amsterdam, The Netherlands, 20 November, 2009

Kleiss, R.H.P., Higgs, Genesis and the weight of wet light, Physics@FOM Veldhoven 2009, Veldhoven, The Netherlands, 20 January, 2009

Anti-materie, Leer- en Sterrenkundige Kring, Appingedam, The Netherlands, 1 Aril, 2009

Laenen, E., Theory@LHC, DRSTP school on Condensed Matter and Statistical Physics, Utrecht, The Netherlands, 25 March, 2009

The Standard Model: what else?, Fysica 09, Groningen, The Netherlands, 24 April, 2009

Recent developments in QCD resummation, Niels Bohr Institute, Copenhagen, Denmark, 7 May, 2009

The Ubiquitous Top, CERN Top Theory Institute, Geneva, Switzerland, 18 May, 2009

Heavy Flavour Production, MCNet school, Lund, Sweden, 2 July, 2009

Top quark physics at the ILC and hadron colliders, LC09 Linear Collider workshop, Perugia, Italy, 22 September, 2009

Theorie van bijna alles, Leerkrachten Basisschool Octopus, Amsterdam, The Netherlands, 26 October, 2009

Eikons, University of Manchester, Manchester, United Kingdom, 4 November, 2009

Top physics at the LHC, Institute for Mathematical Sciences, Chennai, India, 24 November, 2009

Top physics at the LHC, Indian Insitute of Science, Bangalore, India, 27 November, 2009

Theoretical particle physics for CERN and the Universe, Quantum Universe Symposium, Groningen, The Netherlands, 9 December, 2009

All-order perturbation theory and collider physics, Theory seminar, Groningen, The Netherlands, 14 December, 2009

Maio, M., Towards resolving fixed points in CFT extensions, Dutch Research School of theoretical Physics, Driebergen, The Netherlands, 23 February, 2009

CFT: Review and Applications. Fixed point resolution in permutation orbifolds, NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009

Malamos, I., Feynman rules for the rational part of the electroweak 1-loop amplitudes, 3rd HEPTOOLS Annual meeting, Vienna, Austria, 1 December 2009

Mulders, P.J., Transverse momentum in hard processes, Workshop on Transverse Partonic Structure of Hadrons, Yerevan, Armenia, 23 June, 2009

Universality of transverse momentum dependent distribution functions, Workshop on three-dimensional parton structure of the nucleon encoded in GPDs and TMDs, Seattle, USA, 16 September, 2009

The standard model of particle physics and beyond, Symposium 'At the right place at the right time', Universiteit Twente, Enschede, The Netherlands, 25 November, 2009

Postma, M., Inflation on a torus, Landelijk seminarium, Nikhef, Amsterdam, The Netherlands, 27 March, 2009

Inflation on a torus, Max Planck Institute, Munich, Germany, 4 June, 2009

Inflation on a torus, 15th Int. Symposium on Particles, Strings and Cosmology, Hamburg, Germany, 6 July, 2009

Gaugino condensation in the early universe, Cosmo Int. Conference on Particle Physics and Cosmology 2009, CERN, Geneva, Switzerland, 8 September, 2009

Oord, G. van den, A Radio-Frequency Extension to the Pierre Auger Cosmic Ray Observatory, 2009 NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009

Niessen, I., Improving predictions for SUSY cross sections, 2009 NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009

Rogers, T.C., Fully Unintegrated Parton Distribution Functions, Institute on Parton Shower and Resummation, DESY, Hamburg, Germany, 11 May, 2009

Fully Unintegrated Parton Distributions and Extensions of Perturbative QCD, Jefferson Lab, Newport News, USA, 20 May, 2009

Unintegrated Parton Distibutions and Issues in Parton Correlations, Int. Workshop: Quantum Chromodynamics from Colliders to Super-High Energy Cosmic Rays, Int. Center for Theoretical Physics, Trieste, Italy, 26 May, 2009

Factorization and Fully Unintegrated Factorization, The Jefferson Lab 12 GeV Upgrade workshop, Institute for Nuclear Theory, Seattle, USA, 18 September, 2009

Factorization with Unintegrated and Fully Unintegrated PDFs, Seminar, École Polytechnique, Paris, France, 3 December, 2009

Rijken, Th.A., ESC08 NN/YN/YY-interactions for S=-1,-2,-3,-4 systems; Meson-exchange viewpoint,Workshop Tokyo-Institute of Technology, Tokyo, Japan, 11 September, 2009,

Status of understanding the YN/Yy-interactions; Meson-exchange viewpoint, The 10th Int. Conf. on Hypernuclear and Strange Particle Physics, Tokai, Ibaraki, Japan, 16 September, 2009

ESC08 NN/YN/YY-interactions for S=-1,-2,-3,-4 systems; Meson-exchange viewpoint, RIKEN, Strangeness Laboratory, Tokyo, Japan, 23 October 2009,

ESC08 NN/YN/YY-interactions for S=-1,-2,-3,-4 systems; Meson-exchange viewpoint, Hosei University, Tokyo, Japan, 29 October, 2009

Recent Nijmegen Extended-Soft-Core ESC08-models, Workshop Hadrons and Nuclear Physics, RCNP, Osaka University, Osaka, Japan, 19 November, 2009

ESC08 NN/YN/YY-interactions for S=-1,-2,-3,-4 systems; Meson-exchange viewpoint, RCNP, Osaka University, Osaka, Japan, 20 November, 2009

Strange and Charmed Baryon-baryon Interactions Λ- and Λ_c-Nucleon ESC-potentials, Workshop on Flavor Nuclear Physics, Hida Takayama, Gifu, Japan, 28 November, 2009

Schellekens, A.N, Orientifold GUTs, Workshop GUTs in Strings, Hamburg, Germany, 5 February, 2009

RCFT Orientifolds: SU(5) GUTs, GGI String Theory Workshop, Florence, Italy, 6 April, 2009

The Standard Model, String Theory, and the Anthropic Principle, DRSTP Workshop, Dalfsen, The Netherlands, 14 May, 2009

Asymmetric Gepner Models, String Phenomenology 2009 conference, Warsaw, Poland, 16 June, 2009

RCFT String Model Building, University of Crete, Heraklion, Greece, 13 October, 2009

The Emperor's last Clothes?, RWTH Aachen, Aachen, Germany, 17 November, 2009

Vermaseren, J., Introduction to FORM, Lecture at the 2009 CAPP (Computer Algebra in Particle Physics) school, DESY, Zeuthen, Germany, 30 March, 2009

Lecture at the 2009 CAPP (Computer Algebra in Particle Physics) school, DESY, Zeuthen, Germany, 31 March, 2009

Some obstacles in the calculation of structure functions, XVII Int. Workshop on Deep-Inelastic Scattering and Related Subjects, Madrid, Spain, 27 April, 2009

The Multiple Zeta Value Data Maine, Workshop on Quantum Fields, Periods and Polylogarithms, IHES, Paris, France, 9 June, 2009

Detector R&D

Bosma, M.J., Possible applications of the Medipix chip in health care, Physics@FOM, Veldhoven, The Netherlands, 20 January, 2009

Fransen, M., The performance of GridPix detectors, 2009 IEEE Nuclear Science Symposium and Medical Imaging Conf., Orlando USA, 27 October, 2009

The performance of GridPix detectors, NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 7 November, 2009

Graaf, H. van der, Gossip (GridPix) in the Upgraded ATLAS Inner Detector, 4th Trento Workshop on Advanced Silicon Detectors, Trento, Italy, 17 February, 2009

New Developments in Tracking Detectors, Université catholique de Louvain, Louvain-La-Neuve Belgium, 26 March, 2009

Results of and plans for new tracking detectors, LHeC Workshop, Divonne-les-Bains, France, 2 September, 2009

Gromov, V., Gossipo-3: a prototype of a Front-end Pixel Chip for Read-out of Micro-Pattern Gas Detectors, Topical Workshop on Electronics for Particle Physics, Paris, France, 22 September, 2009

Hartjes, F.G., The LHC Luminosity Upgrade and Related ATLAS Detector Plans, Micro Pattern Gas Detectors 2009, Kolympari, Crete, Greece, 12 June, 2009

Snippe, Q.H.C., Superplastic Forming Simulations of RF Detector Foils, ESAFORM Conference, Universiteit Twente, Enschede, The Netherlands, 28 April, 2009

Extracting Material Data for Superplastic Forming Simulations, Int. Deep Drawing Research Group 2009 Conf., Colorado School of Mines, Golden, CO, USA, 2 June, 2009

Timmermans, J., Update on Silicon Pixel Readout for a TPC at NIKHEF, TILC'09, Tsukuba, Japan, 18 April, 2009

TPC R&D by LCTPC, TILC'09, Tsukuba, Japan, 20 April, 2009

Pixel readout for a LC TPC, LCWA 2009, Albuquerque, NM, USA, 30 September, 2009

TPC R&D, status and plans, LCWA 2009, Albuquerque, NM, USA, 1 October, 2009

Highly pixellated TPC readout (the 'digital' TPC), CLIC09 Workshop, CERN, Geneva, Switzerland, 15 October, 2009

The Silicon TPC System, EUDET Annual Meeting, Geneva University, Geneva, Switzerland, 20 October, 2009

Verlaat, B.A., CO_2 Cooling developments for HEP detectors, The 18th Int. Workshop on Vertex detectors, Putten, The Netherlands, 17 September, 2009

Grid Computing

Balint, T., Command line security tools: client connect, EGEE'09 Conf., Barcelona, Spain, 22 September, 2009

Gabriel, S., Security Service Challenge – Toolset Current Status, OSCT F2F Meeting, Madrid, Spain, 12 March, 2009

Security Service Challenge – Run 02/03 2009 Preliminary Results, CERN GDB Meeting, Geneva, Switzerland, 8 April, 2009

Security Workshop – Site Security, GridKa-School, Karlsruhe, Germany, 4 September, 2009

Security Service Challenges – testing our incident response capabilities, EGEE'09 Conf., Barcelona, Spain, 25 September, 2009

SURFcert Kennismiddag Security Drills – Results in the Benelux Region, SURFcert Kennismiddag, Utrecht, The Netherlands, 25 November, 2009

Groep, D.L., Web Cachability of Certificate Revocation Lists, 15th EUGridPMA, Nicosia, Cyprus, 26 January, 2009

Grid Computing and Site Infrastructures, University of Amsterdam SNE Master, Amsterdam, The Netherlands, 13 March, 2009

Integrating Federations in the Int. Grid Trust Fabric, Int. Seminar on Grid Computing 2009, Taipei, Taiwan, 9 April, 2009

Middleware Security, Int. Seminar on Grid Computing 2009 Security Workshop, Taipei, Taiwan, 14 April, 2009

From Zero To IGTF, Open Grid Forum 27, Banff, Canada, 16 October, 2009

De BiG Grid e-Infrastructuur: digitaal onderzoek verbonden, KennisKring Amsterdam, Amsterdam, The Netherlands, 28 October, 2009

Grid Security, an Introduction, SURFcert Kennismiddag, Utrecht, The Netherlands, 25 November, 2009

Klous, S., Virtual Machines at a Tier-1 site, EGEE'09 Conf., Barcelona, Spain, 21 September, 2009

Koeroo, O.A., SCAS – interoperability, EGEE'09 Conf., Barcelona, Spain, 22 September, 2009

Sallé, M., Introduction of the Execution Environment Service (EES), EGEE'09 Conf., Barcelona, Spain, 23 September, 2009

HiSPARC

Eijk, B. van, Elementaire Deeltjes en het Heelal, Coornhert Lyceum, Haarlem, The Netherlands, 21 January, 2009

HiSPARC: 'Business as usual' of Uitdaging?, Technische Universiteit Eindhoven, Eindhoven, The Netherlands, 23 April, 2009

HiSPARC, Hanoi Technical University, Hanoi, Vietnam, 19 June, 2009

Holten, J.W. van, HiSPARC, University College, Utrecht, The Netherlands, 13 May, 2009

Miscellaneous

Decowski, M.P., Measuring Terrestrial and Solar Neutrinos with KamLAND, Universität Erlangen, Erlangen, Germany, 8 January, 2009

Linde, F.L., Particle physics and its dependence of ICT infrastructure, GigaPort Next Generation Network Slotevent, Rotterdam, The Netherlands, 24 March, 2009

Large Hadron Collider – micro deeltjes & giga experimenten, Koninklijk Genootschap PHYSICA, Alkmaar, The Netherlands, 6 April, 2009

Chasing the world's smallest particles with the world's largest experiment(s), The Sense of Contact 2009, Woudschoten, The Netherlands, 8 April, 2009

De schoonheid en de troost van het niet-weten, Theater Frascati (Theater Adhoc), Amsterdam, The Netherlands, 25 April, 2009

Large Hadron Collider – Doet hij het of doet hij het niet?, Kennis op Zondag, NEMO, Amsterdam, The Netherlands, 11 October, 2009

Rijn, A.J. van, Governance models for the long-term sustainability model of EGI, EGEE'09 Conf., Barcelona, Spain, 22 September, 2009

EGI Headquarters in Amsterdam, EGI Design Study Workshop, Stockholm, Sweden, 3 December, 2009

Timmermans, J., Precision electroweak measurements at the LEP e^+e^- collider, Radboud Universiteit, Nijmegen, The Netherlands, 9 April, 2009

3.4 Posters

ATLAS/DØ

Ancu, L, & Meijer, M., Standard Model Higgs Searches at the Tevatron, Physics@FOM, Veldhoven, The Netherlands, 20 January, 2009

Doxiadis, A.D., *(for the ATLAS Collaboration)*, Top Quark Pair Production Cross-section at LHC with ATLAS, Lepton Photon 2009, Hamburg, Germany, 17 August, 2009

Hart, R.G.K., *(for the ATLAS Collaboration)*, The ATLAS MDT Control System, Int. Conf. on Accelerator and Large Experimental Physics Control Systems, Kobe, Japan, 13 October, 2009

The ATLAS Barrel Alignment Readout System, Int. Conf. on Accelerator and Large Experimental Physics Control Systems, Kobe, Japan, 13 October, 2009

Koetsveld, F., Finding Supersymmetry with the ATLAS detector using a data-driven background fit, 5th Latin American School of High-Energy Physics, Medellin, Colombia, 15-28 March, 2009

Finding Supersymmetry with the ATLAS detector using a data-driven background fit, The 2009 Europhysics Conf. on High Energy Physics, Krakow, Poland, 16-22 July, 2009

Resende, B., *(for the ATLAS Collaboration)*, ATLAS Muon Identification Algorithms, The 2009 Europhysics Conf. on High Energy Physics, Krakow, Poland, 16-22 July, 2009

LHCb/BaBar

Jansen, F.M., The FE Electronics of the LHCb Straw Tube Tracker , 11th Pisa meeting on advanced detectors, La Biodola, Isola d'Elba, Italy, 24 May, 2009

ALICE/STAR

Braidot, E., Searching for the colour glass condensate with the STAR forward meson spectrometer, Physics@FOM , Veldhoven, The Netherlands, 20 January, 2009

Chojnacki, M., *(for the ALICE Collaboration)*, Preparations for the measurement of identified charged hadron spectra with ALICE, Int. Conf. on Strangeness in Quark Matter, Buzios, Brazil, 27 September, 2009

ANTARES/KM3NeT

Assis Jesus, A.C., *(for the ANTARES collaboration)*, Detection of gamma-ray induced muons with ANTARES, High-Energy Gamma-rays and Neutrinos from Extra-Galactic Sources, Heidelberg, Germany, 13 January, 2009

Bouwhuis, M.C., *(for the ANTARES collaboration)*, Concepts and performance of the ANTARES data acquisition system, Int. Cosmic Ray Conf., Łódź, Poland, 8 July, 2009

Search for gamma-ray bursts with the ANTARES neutrino telescope, ANTARES/KM3Net, Int. Cosmic Ray Conf., Łódź, Poland, 8 July, 2009

Theory

Adelhart Toorop, R. de, Family Physics: a quest for structure in the fermion mass sector, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Family Physics: a quest for structure in the fermion mass sector, Fysica 2009, Groningen, The Netherlands, 24 April, 2009

Boomsma, J., Phases of quark matter with induced CP violation, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Dunnen, W. den, Vacuum structure of the strong interaction with a Peccei-Quinn symmetry, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Hartgring, L., Single top quark production, Fysica 2009, Groningen, The Netherlands, 24 April, 2009

Single top quark production, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Malamos, I., Feynman rules for the rational part of the full standard model 1-loop amplitudes, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Mantz, C., Color flow in hard hadronic processes, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Maio, M., Fixed Point Resolution in Permutation Orbifolds, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Mooij, S., Inflation, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Niessen, I., Supersymmetric phenomenology in the mSUGRA parameter space, Physics@FOM, Veldhoven, The Netherlands, 20 January, 2009

Supersymmetric phenomenology in the mSUGRA parameter space, School on Particle Physics and Cosmology, Oran, Algeria, 5 and 9 May, 2009

Supersymmetric phenomenology in the mSUGRA parameter space, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Oord, G. van den, Introducing Camorra: A Tool for Recursive Computation of Matrix Elements, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009

Detector R&D

Bosma, M.J., Development of edgeless high-Z sensors for endless medical detectors, EIROforum school on Instrumentation, CERN, Geneva, Switzerland, 14 May, 2009

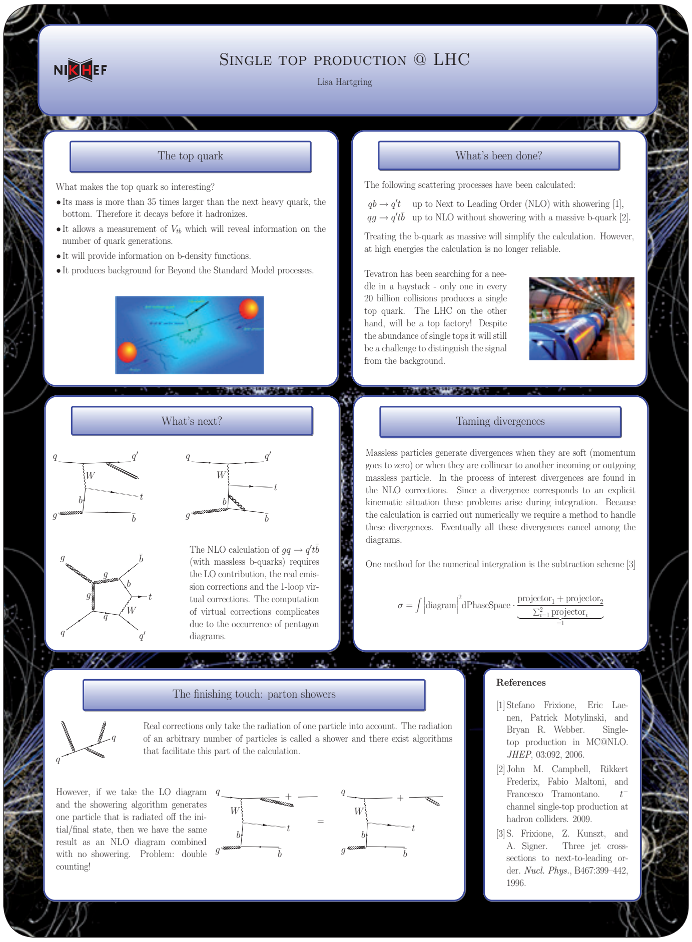
Development of edgeless high-Z sensors for endless medical detectors, 11th Int. Workshop on Radiation Imaging Detectors, Prague, Czech Republic, 30 June, 2009

Koppert, W.J.C., *(et al.)*, DICE (Delft internal Conversion Experiment), Micro Pattern Gas Detector Conf., Crete, Greece, 13 June, 2009

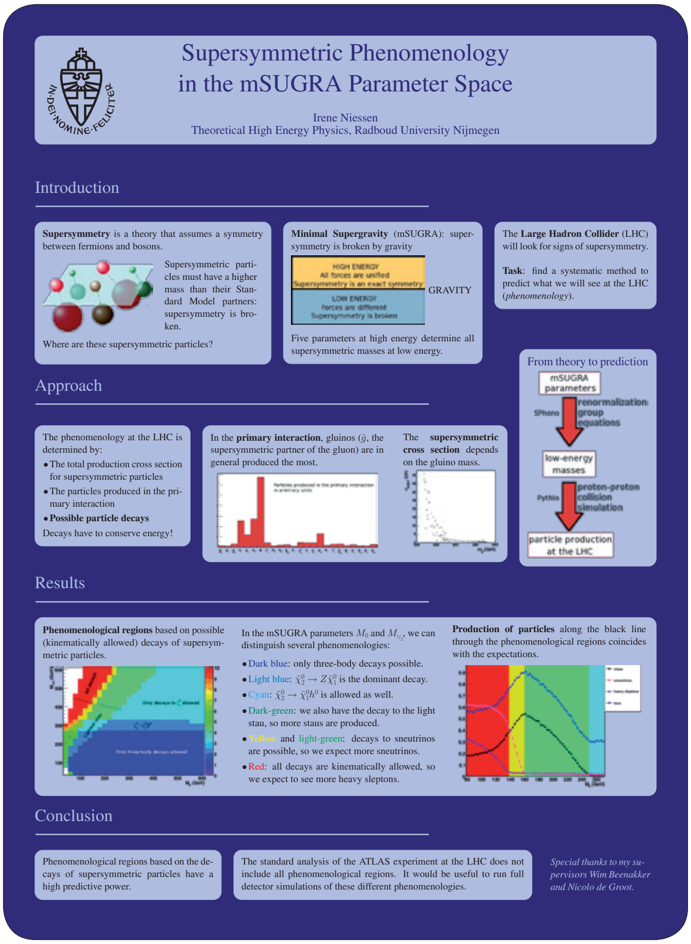
Applications for Gridpix detectors, Micro Pattern Gas Detector Conf., Crete, Greece, 13 June, 2009

Grid Computing

Gabriel, S., Security Service Challenges in WLCG: SSC3 2009 Results, EGEE'09 Conference, Barcelona, Spain, 21–25 September, 2009



Lisa Hartgring's prize-winning poster.



Irene Niessen's prize-winning poster.

3.5 Jamboree

By the end of each year Nikhef physicists and technicians gather in an Annual Meeting traditionally called Jamboree. In the meeting reports are given about the status of Nikhef's various programmes and projects, while young students and postdocs get the opportunity to present their work for a broader audience. The2009 Jamboree was organised by Jo van den Brand and Chris Van Den Broeck.

Naturally, this year's focus of attention was on the first data from the three LHC experiments in which Nikhef participates. After the successful start of the LHC in November all three showed convincingly that their detectors are fully operational and could produce reconstructed events virtually on-line. Further talks illustrated the broad scope of Nikhef's research topics: from Ptolemaean orbits around black holes, via particle detection in deep sea to the application of in-house developed pixel detectors in commercial instruments.

Tuesday 15 December 2009

Session I: LHCb

09:25 Welcome
09:30 B-physics: Introduction (Marcel Merk)
09:40 The Outer Tracker (Niels Tuning)
10:00 The VELO (Kazu Akiba)
10:20 Rare Decays (Vanya Belyaev)
10:40 The Bs mixing phase (Juan Palacios)

Session II: Antares and KM3Net

11:20 Status Antares – KM3Net (Maarten de Jong)
11:35 Search for dark matter with the Antares neutrino telescope (Gordon Lim)
11:50 KM3Net Technical Design Study (Eric Heine)

Session III: Auger and GW

13:30 Overview and Status of the Pierre Auger Experiment (Charles Timmermans)
13:50 The third level trigger of the MAXIMA setup (Sybren Harmsma)
14:10 Auger Radio: Events and background (Harm Schoorlemmer)
14:30 Status of GW program (Jo van den Brand)
14:40 Gravity gradient noise studies for Einstein Telescope (Mark Beker)
14:55 Fundamental physics with binary black holes (Chris Van Den Broeck)
15:15 Cosmography with gravitaional waves (Tjonnie Li)

Session IV: ALICE and STAR

15:50 First Measurements with the ALICE detector (Thomas Peitzmann)
16:20 Heavy Flavor in ALICE (Alessandro Grelli)
16:40 Searching for the Color Glass Condensate in STAR (Ermes Braidot)

Wednesday 16 December 2009

Session V: ATLAS and DØ

09:15 ATLAS09 (Stan Bentvelsen)
09:30 Status of ATLAS in the control room (Olga Igonkina)
09:50 Performance tracking and validation with cosmics (Manuel Kayl)
10:10 Muon performance and validation with cosmics (Giuseppe Salamanna)
10:30 Status of DØ and Higgs searches (Melvin Meijer)

Session VI: R&D and technology

11:15 Detector R&D overview (Jan Visser)
11:25 Vertex detection for the future (Martin van Beuzekom)
11:45 Status gaseous detectors (Martin Fransen)
12:05 Common sense applying FEM's: Highlights in calculational services (Eric Hennes)
12:25 High throughput data readout (Tom Sluijk)

Session VII: Theory and Computing

14:00 Nikhef theory in 2009 (Eric Laenen)
14:15 Trapped in an infinite extra dimension (Damien George)
14:30 Entering new territory of the B-Physics landscape (Robert Fleischer)
14:45 Disturbance of the force: modeling gravity waves from binary star system (Gideon Koekoek)
15:00 Overview Grid 2009 (Jeff Templon)
15:10 Nikhef Grid facilities (Ronald Starink)
15:25 Simplifying grid certificates: jGridstart and future developments (Willem van Engen)

Session VIII: Future

16:00 ILC and CLIC (Jan Timmermans)
16:25 Direct Dark Matter Searches (Patrick Decowski)
16:50 Nikhef future (Frank Linde)

3.6 Awards & Grants

NWO Grants
In 2009 Nikhef received 3.4 M€ via the special programme *'Dynamisering Instituutsfinanciering'* of the Netherlands Organisation for Scientific Research (NWO). These funds supply extra support to Nikhef's regular research activities as defined in the strategic plan. Nikhef is planning to spend this money on additional activities within the three LHC-programmes, the gravitational physics programme, mechanical technology and detector R&D.

Two Vidi grants were awarded to Nikhef-related research: to Wouter Hulsbergen (B-Physics) for his proposal *"Quest for dark matter"*, and to Martijn Wijnholt (Theory) for his proposal *"Geometric Engineering and Particle Physics"*. The Vidi grants of NWO can amount to 800 k€ and enable young promising researchers –who have already performed top research at postdoc level for several years– to start their own research group.

NWO also honoured the proposal *"Virgo on GPUs"* by Sander Klous (ATLAS) with 26.4 k€. This proposal was submitted within the framework of the Grants Programme Parallelisation of the Netherlands National Computing Facilities Foundation (NCF) within NWO. The programme supports the parallelisation of existing scientific application software and the development of expertise in this field.

FOM Grants
A new FOM research programme *"Gravitational physics – the dynamics of spacetime"* has been established under the leadership of Jo van den Brand (Virgo/LISA). FOM awarded a budget of 2.9 M€ for gravitational physics research for the period of 2010–2015. These so-called free programmes are available for promising research initiatives of excellent quality.

Robert Fleischer (Theory) and Gerhard Raven (LHCb) won a FOM-*'projectruimte'* grant. 400 k€ were granted to their proposal *"Exploring a New Territory of the B-Physics Landscape at LHCb"*, which will fund two PhD-positions (one in the theory group, and one in the LHCb group) for the duration of four years each.

Other Dutch Awards & Grants
The team of Sijbrand de Jong won the *'Academische Jaarprijs 2009'* with their *"Cosmic Sensation"* project. The award –an initiative of the Dutch newspaper *NRC Handelsblad* in cooperation with NWO and other organisations– honours the best proposal to make scientific research accessible to a broad audience, and rewards the winner with 100 k€. Team de Jong will use this award to organise during the Nijmegen summer festival in July 2010 a dance event, at which cosmic rays will trigger live dance music. Sijbrand de Jong was also proclaimed *'Nijmegenaar van het Jaar 2009'* (Nijmegen Citizen of the Year 2009) which is an initiative of the mayor of Nijmegen. The selection committee stated that by winning the *'Academische Jaarprijs'* he promoted Nijmegen as a city in which top-level research is done.

The HiSPARC project received a grant for outreach activities. The Dutch Ministry of Education, Culture and Science provides 35 k€ via the *'Platform Bèta Techniek'* for this programme.

Senter*Novem*, an agency of the Dutch Ministry of Economic Affairs, accepted a Nikhef proposal for its *'Kenniswerkers Regeling'*. This enables two technicians of the company Bruco to work for a period of 18 months on two pixel-detector-projects at Nikhef. (see section 4.3 for details).

Ivo van Vulpen (ATLAS) received a Van Gogh grant of € 3750 from the *'Frans-Nederlandse Academie'*, a bilateral organisation that aims to strengthen the relations between France and the Netherlands in education and research. This grant is meant to facilitate the exchange between Dutch and French postdocs or PhD students within collaborative projects.

Jan Visschers (R&D) won the first prize in the entrepreneurship workshop of the Technology Foundation STW. His business idea –the development, production and sale of digital camera modules based on Medipix ASICs– was acknowleged by the selection committee as the most promising one.

Poster prizes were awarded to Lisa Hartgring (Theory) at the symposium in Dalfsen of the Dutch Research School of Theoretical Physics (DRSTP) and at Physica 09, and to Irene Niessen (Theory), whose poster won the first prize at the DRSTP symposium.

European Grants
Nikhef is funded to work on the DARWIN (DARk matter WImp search with Noble liquids) project together with groups in Italy, France and Switzerland. This design study of a next-generation noble liquid dark matter facility in Europe receives funds from the first ASPERA (AStroParticle ERAnet) common call amounting to a total of 633 k€, of which the Dutch group led by Patrick Decowski (ANTARES/KM3NeT) has been allocated 150 k€.

A Marie Curie Intra-European Fellowship for Career Development was awarded to Michel Herquet (Theory). For the duration of 24 months he will work as a Marie Curie fellow on *"New tools for new Physics at the LHC"*.

4

Nikhef & Society

4.1 Communication

Among the different topics covered in 2009, especially the Large Hadron Collider (LHC) has again attracted much attention. Its successful restart in autumn was followed closely and with excitement by both Nikhef employees and the media. When the LHC produced for the first time collisions at low energy, scientists at Nikhef celebrated together with colleagues at CERN and around the world this important milestone towards high-energy collisions in the future.

Another highlight of the year 2009 was the release of the film *"Higgs – into the heart of imagination"* by Theater Adhoc at the International Documentary Filmfestival Amsterdam in November. This documentary about the quest for the Higgs particle prominently features some Nikhef researchers, and was sponsored partly by Nikhef.

Altogether, a variety of communication activities were organised by Nikhef in 2009. Important target groups of these activities have been the general public, the media, and schools. In addition, Nikhef is busy to increase its activities aimed at alumni, industrial partners and decision makers. The main intention is to explain what kind of research Nikhef does and why. Nikhef strives to be known by the general public, to be appreciated by the media as a reliable information source, and to be renowned at schools for interesting science education. Moreover, the aim is to keep in touch with alumni, to make contact with potential industrial partners, and to inform decision makers about Nikhef's mission and international reputation.

In all activities the Nikhef communication department is extremely well supported by the Nikhef staff. In the following, a more complete and detailed report of the communication activities 2009 will be given.

Nikhef & the general public

It is considered one of the main communication tasks to inform the public about the research Nikhef is engaged in. A wide range of activities is centred around this aim. Throughout the year, Nikhef scientists regularly give lectures for the public. Upon request, they visit schools and science associations as well as participate in science events organised by museums and other cultural organisations. Some examples of such activities in 2009 are the lectures given at *'Kennis op Zondag'* (Science on Sunday), *'Klokhuis vragendag'* (Klokhuis day for questions), the Scientific '09 opening of the Dutch Science Month, and *'Nemo kinderlezing'* (Nemo lecture for children). People interested in Nikhef are also welcome to visit the institute for a guided tour.

Concentration is high during the 2009 Open Day 'Kennisquiz', the science quiz for kids.

On 10 October, in the context of the annual Dutch Science Month, Nikhef held its open day. Young and old, laymen and professionals, everybody interested in particle and astroparticle physics was welcome. The event was organised in collaboration with the other research institutes located at Science Park Amsterdam. About 1300 visitors made use of this excellent opportunity to get to know more about the research of the different institutes.
This year's open day motto was *'Reis naar het onbekende'* (Travel to the unknown). The Nikhef main hall was transformed into an exhibition about astroparticle physics while the workshop displayed information on the LHC experiments. Visitors could attend short lectures, carry out little experiments themselves, ask all their questions, or take part in a science quiz. For children special activities took place such as a treasure hunt, a special edition of the science quiz, and a kids' lab where they could solder their own electronic gadget.

Nikhef & the media

To establish and maintain good relationships with the media is another important communication task. Nikhef regularly interacts with journalists from print media and from radio and TV stations.

On the one hand Nikhef proactively issues press releases on important scientific research results as well as on technical milestones achieved by the experiments in which Nikhef participates. In 2009 six press releases were published.

On the other hand Nikhef is often approached by journalists requesting interviews or background information on certain topics. This has led to numerous articles and items in national newspapers

Nikhef staff gathering in the foyer of the Tuschinski cinema for the sneak preview of "Angels & Demons".

Peter Higgs (left) and Stan Bentvelsen (right) at the viewing of the documentary "Higgs – into the heart of the imagination" at Nikhef.

(e.g. NRC Handelsblad, Volkskrant), popular science magazines (e.g. Kijk), and radio and TV programmes (e.g. Radio 1, Klokhuis).

Especially the restart of the LHC in autumn 2009 has generated a lot of media attention. The milestones of first beams at injection energy in the LHC, first collisions at this energy, and setting a new world record by reaching 1.18 TeV per beam, were all covered extensively in nearly all national and regional newspapers as well as in radio and TV news journals.

CERN visits organised by Nikhef

Nikhef continuously receives requests to help organise and/or sponsor CERN visits of various Dutch groups including high school pupils, teachers, student associations, and science journalists. For this purpose Nikhef employees stationed at CERN regularly give introductory lectures and guided tours at the LHC in Dutch. In 2009 several Dutch groups were welcomed at CERN, e.g. a delegation of the *'Vereniging Wetenschapsjournalisten in Nederland'* (Association of science journalists in the Netherlands). Again, the perspective of the LHC restart evoked an increased interest in excursions to CERN.

Special events

A couple of special events provided a most welcome change in the daily affairs at Nikhef.

In May 2009, Nikhef invited all its employees and some special guests to attend a closed preview of the film *"Angels and Demons"* in the Tuschinski cinema. An excited audience of a few hundred people enjoyed the viewing with popcorn and drinks. Especially the thrilling shots taken at CERN (where in the film antimatter is produced and stolen) were followed enthusiastically.

On 20 November, some Nikhef employees had the opportunity to attend the premiere of the film *"Higgs – into the heart of imagination"* at the International Documentary Filmfestival Amsterdam (IDFA), and afterwards the premiere celebration. This documentary is a co-production of Viewpoint Productions, Theater Adhoc and HUMAN. For the last four years, the filmmakers Hannie van den Bergh en Jan van den Berg from Theater Adhoc have filmed the preparations for the start of the LHC and its experiments at CERN. They followed Stan Bentvelsen, the programme leader of the Nikhef ATLAS group, and his team, and asked several international scientists to explain what the Higgs particle is. Furthermore Peter Higgs, the 80-year-old British physicist whom the Higgs particle is named after, recalled how he developed his ideas about the Higgs mechanism.

On 27 November professor Higgs, who was visiting Amsterdam as the main guest of Theater Adhoc and Viewpoint productions to view their Higgs film at the IDFA, held a special colloquium at Nikhef. The lecture was much appreciated by a fascinated audience which fully exhausted the capacity of the lecture room. In his talk filled with British humour he gave an interesting account of his own research work and his collaboration with colleagues, leading to the postulation of the Higgs boson in the 1960s.

Nikhef & science communication networks

The Nikhef communication department is an active member of several national and international communication networks. Together with the communication staff of the other institutes at the Science Park Amsterdam all Science Park wide activities are coordinated such as the open day in October, visits of the *Kenniskring Amsterdam*, and the communication around the development of the Science Park Amsterdam.

Communication tasks specifically related to the FOM organisation are carried out in close collaboration with colleagues from FOM and the FOM-institutes Amolf and Rijnhuizen. For the first time in 2009, this included a representation of Nikhef at the annual Physics@FOM Veldhoven conference in January.

Within the European Particle Physics Communication Network (EPPCN), established in 2007 by the CERN Council, activities are coordinated between CERN and its member states. In 2009 these were especially clustered around the restart of the LHC. The EPPCN spring meeting 2009 was hosted by Nikhef and took place in Amsterdam on 9 & 10 March.

The outreach committee of the ASPERA European network for astroparticle physics was founded in 2009 to set up a sustainable network of communicators for astroparticle physics in Europe. In October 2009 Nikhef participated in a first collaborative effort during the European Week of Astroparticle Physics.

The goal of the InterAction collaboration of communicators from particle physics laboratories worldwide is to increase support around the world for fundamental particle physics research. In this framework Nikhef collaborates with other laboratory communication departments in order to share resources and to convey a common science message. Since 2009 Nikhef contributes in particular in a sub-committee to update the InterAction image bank.

Young 'scientists' enjoying the result of an experiment involving vacuum and candy at the 2009 Open Day.

4.2 Education

Nikhef engages in science education at all levels, that is for elementary and secondary school pupils and their teachers, as well as for bachelor, master and PhD students. The institute therefore offers a wide range of projects meant to encourage young people to interact with scientists and take part in research.

Nikhef & elementary schools

One of the projects Nikhef participates in is the *'Techniek Toernooi'*, a science tournament for young children in the age group of four to twelve years. In 2009, the fifth edition of the national tournament took place in the Dutch *'Openluchtmuseum'* in Arnhem. Since the start in the International World Year of Physics in 2005, the number of children attending has been growing steadily. That is why in 2009, for the first time, three additional regional satellite tournaments were organised, thus doubling the number of children who could participate.

The youngest children were competing for the highest tower of pencils or the fastest 'balloon cars', while the older children made fast hovercrafts or launched squash balls over large distances. Traditionally, a jury of professors from the Dutch universities –among them many members of Nikhef– selected the winners. Sharon Dijksma, Dutch state secretary for Education, Culture and Science, and Jan Terlouw, Dutch physicist, writer and poltician, awarded the prizes and were assisted by Bart Meijer, one of the presenters of the popular TV production Klokhuis.

Nikhef & secondary schools

Nikhef considers itself a conveyer of fundamental science research to secondary school students. In 2009, more than 300 high school students attended guided tours at Nikhef. Besides, Nikhef scientists visited several schools to give lectures. Nearly two dozen high school students carried out their *'profielwerkstuk'* (research project) on a topic within the Nikhef research programme and under the supervision of Nikhef staff.

On 20 March Nikhef invited more than 30 high school students to participate in the European Masterclass on Particle Physics, an event held simultaneously at many European particle physics institutes. During this event the students attended introductory lectures, did some hands-on exercises and finally shared their findings with students at other European institutes in a live video conference.

Nikhef & HiSPARC

Another way of motivating young students and introducing them to the world of (astro)particle physics is through the *'High School Project on Astrophysics Research with Cosmics'* (HiSPARC).

A proud participant in the squash ball throwing competition at the 'Techniek Toernooi' follows his shot. On the left Nikhef staff member professor Els Koffeman is amazed by the distance.

The objectives of this project are:

- Getting high school students acquainted with a scientific research environment and with astroparticle physics;
- Giving high school students and their teachers the opportunity to participate in frontier scientific research;
- Doing actual research of high-energy cosmic rays that penetrate the earth's atmosphere.

The HiSPARC project is a collaboration between a number of universities and scientific institutes divided over seven regional clusters in the Netherlands. Nikhef is in charge of the central coordination of the project. Since 2002, a network of detectors has been built within the HiSPARC project. In 2009 the network in the Netherlands consisted of almost 90 detectors, spread over 70 schools and a number of other locations. Through the international collaboration EuroCosmics several detectors abroad are connected to the HiSPARC database. Furthermore, several countries have contacted HiSPARC for its expertise and electronic equipment.

The HiSPARC detectors are built by the students of the schools, under the supervision of a HiSPARC team member, and consist of scintillators and advanced electronic equipment. They are placed on the roof of the schools and register the impact of cosmic rays. Such impacts frequently come in showers distributed over a large area and hit different detectors. Therefore, the data are stored in a central database at Nikhef. Students and teachers have access to the data of their own detector as well as to data stored in the central database. The latter can be used to analyse coincidences between two or more stations.

High school students participating in the 2009 European Masterclass study how a cloud chamber works.

Nikhef & LiOs

Since 2008 FOM is financing a program which enables high school teachers to take part in scientific research (LiO: *'Leraar in Onderzoek'*, teacher in research). The teachers spend one day per week working on research at one of the FOM institutes. The main goal of the program is to give teachers a new drive and a fresh look on physics, which they can pass on to their students.

In the 2008/2009 academic year, a group of six FOM supported teachers were assigned to do research in the field of astroparticle physics. Three were stationed at Nikhef (Amsterdam), one at KVI (Groningen), and two at Radboud University (Nijmegen).

Each year in March, the students of the participating schools join in a symposium for a hands-on part that focuses on analyzing HiSPARC data and a part where the students present the work they have done for their *'profielwerkstuk'*. This year the contestants with the best *'profielwerkstuk'* won a visit to CERN.

During summer 2009, a team of the *'Ontwerpersopleiding Technische Informatica'* (OOTI, a post-graduate program on Software Engineering at the Technical University Eindhoven) has investigated and optimised the extensive HiSPARC software package.

For the second part of 2009 and 2010 the focus is on developing educational materials. For NLT (Nature, Life and Technology) a new module on Cosmic Rays has been developed and field tested. Also, material is being developed that students can work on individually.

In November 2009 HiSPARC participated in the Jet-Net Career Days. Jet-Net (Youth and Technology Network Netherlands) is a joint venture between Dutch companies and high schools in the Netherlands. The career day allows students to gain a better understanding of their future career prospects in industry and technology. Through hands-on activities at the HiSPARC stand, a large number of students were able to get acquainted with (astro) particle physics.

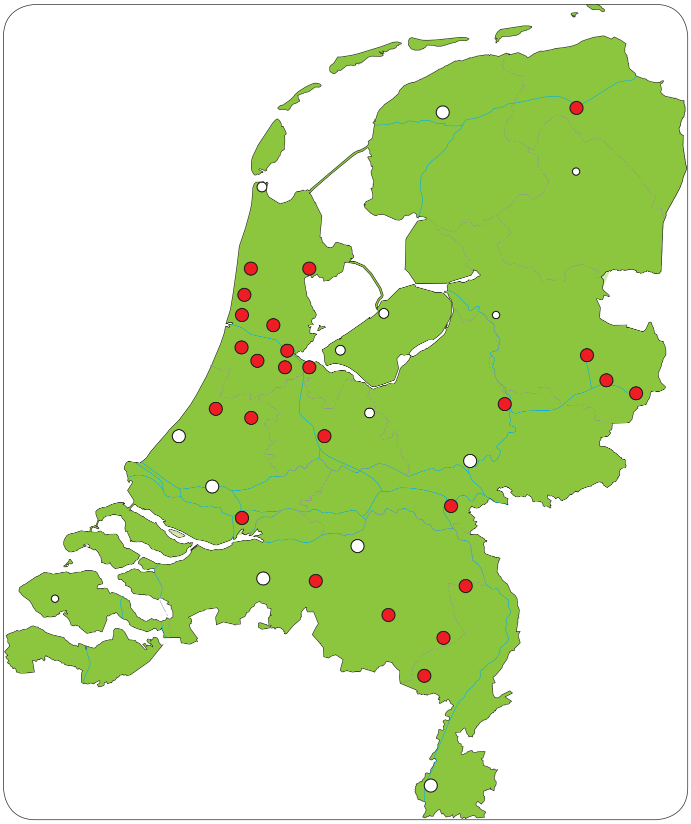
During the year, guidance was provided by the scientific staff of the institutes and regular meetings were scheduled, enabling the teachers to present their work and discuss any obstacles in their research. All teachers worked on their individual research within the HiSPARC project, which is described above. Since this project is a small-scale experiment with a small team of scientists and students, it forms an ideal and easily accessible scientific environment for the LiO participants.

All teachers completed the program and the results of their research were presented in a detailed, combined report *'Leraar in Onderzoek – Hoogenergetische Kosmische Straling'*. Based on the positive experiences of the first group of LiOs the program has been continued. At the start of the new school year, five new LiOs have been accepted at Nikhef.

Master of Science in Particle and Astroparticle Physics

The Masters' programme in Particle and Astroparticle Physics is jointly offered by all partners of Nikhef, and firmly embedded in the research at Nikhef.

Since its start in 2002, Nikhef has facilitated the programme with a classroom and a 'master-room' for the first year master students. As a result, already in their first year, students spend most of their time at the Nikhef institute where they socialise not only



Distribution of HiSPARC detector (sub)clusters in the Netherlands. A red dot signifies a detector (sub)cluster. White dots are major cities.

with each other but also with the PhD students of the institute. This is why the nickname of the Masters' programme has become the 'Nikhef-master'. In 2009, a total of more than forty students were enrolled in the two-year programme. The Dutch students enrolled, graduated of in total seven different universities in the Netherlands. Other students came from universities in Europe, South America and India.

During the summer, fifteen students spent several weeks at CERN for a project in one of the research groups. Following this experience, most of these students started their one-year research project in one of the research groups of Nikhef. One of them acquired the prestigious Huygens Grant and is spending a year in Australia for her research project in the ATLAS group at the University of Melbourne. Another student enrolled in the ERASMUS exchange programme and has spent six months at the University of Stockholm for a project in the IceCube group. She will continue her work in the ANTARES/KM3NeT group at Nikhef. Of the students who graduated this year, five have accepted a position as PhD student at Nikhef.

Research School Subatomic Physics

Nikhef bundles its educational programme for graduate students working in subatomic physics in the '*Onderzoekschool Subatomaire Fysica*' (OSAF, Research School Subatomic Physics).

Throughout the year, the members of the research school's board arrange one to two interviews ('C3 *gesprekken*') with each PhD student and his/her promotor and thesis advisor to monitor and evaluate the progress of his/her research project and his/her participation in the educational programme of the research school. Furthermore, each year the research school holds academic training courses (Topical Lectures) and, in collaboration with Belgian and German research groups, a summer school (BND summer school) for PhD students.

In 2009, three Topical Lectures were organized. In April the topic was neutrino physics, the subject of the June lectures was heavy ions, and in December supersymmetry was scheduled. The typical attendance of the Topical Lectures was 20–30 PhD students during the morning sessions (lectures) and 15–25 PhD students during the afternoon sessions (exercises).

The 2009 BND summer school was organised by Michael Kobel from the Technical University Dresden. It was held from 13 to 24 September in Rathen, Saxony and hosted 53 participants (16 Belgian, 23 Dutch and 14 German). This year's edition was devoted to electroweak physics with lecture series on quantum field theory (8 h), electroweak physics (8 h), supersymmetry (3 h), flavour physics (3 h), neutrino physics (3 h) and cosmology (3 h). In addition, there were lectures on dark matter searches (3 h), statistical methods (4 h), electroweak measurements (3 h) and proton–proton physics at hadron colliders (3 h). Seven hours were devoted to short presentations by 28 students on their thesis work. The summer school was very well appreciated by the participants, also due to its social programme including a sports tournament.

75 PhD students were enrolled and 15 PhD students graduated in the school in 2009. Nicolo de Groot from the Radboud University Nijmegen is chair and the Radboud University Nijmegen is '*penvoerder*' of the school.

4.3 Knowledge transfer

In 2009 two new projects with industrial partners have started while the close collaboration with PANalytical continued. The first new project, Hidralon, is being conducted with Philips Healthcare in Best and many other European partners and the second one has been initiated with Bruco, a chip design house in Borne, in the framework of the 'Kenniswerkers Regeling' of the Dutch Ministry of Economic Affairs.

PANalytical

The work with PANalytical is twofold. First, we employ a fully operational production line for the PIXcel detector, and second, we cooperate in the Relaxd project (see Fig. 1), which is aimed at the development of large-area detectors (see Annual Report 2007). This is focused on high-speed read-out and production of an integrated system consisting of edgeless sensors produced by Canberra, through-silicon-vias made by the nano-technology research center IMEC and a mechanical system and cooling produced by Nikhef. PANalytical is responsible for the application side and is especially working closely together with Nikhef on the development of the software implementation of the read-out electronics.

Philips Healthcare

The Hidralon project is a large European project conducted under the flag of Catrene (Cluster for Application and Technology Research in Europe on NanoElectronics) with many institutes and companies throughout Europe. The cooperation between Philips Healthcare and Nikhef is on studying the possibilities of making edgeless Cadmium-Zinc-Telluride sensors to allow

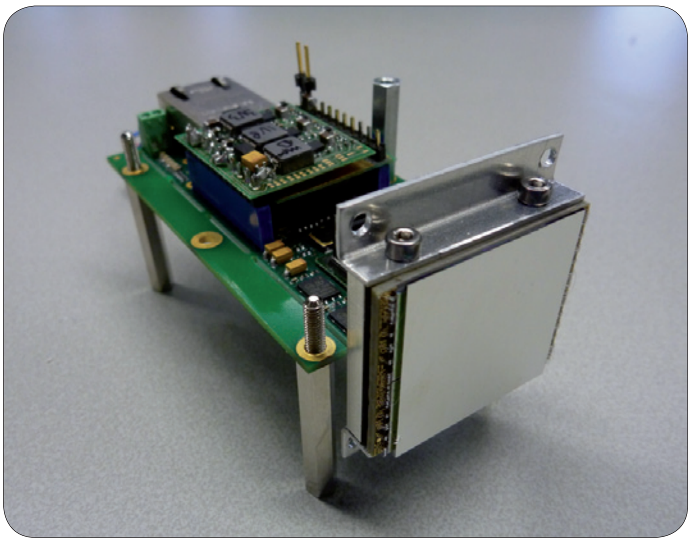


Figure 1. Relaxd read-out module: 1 Gb/s standard ethernet with a silicon sensor of 3×3 cm^2 read out by four Medipix chips.

Figure 2. Harry van der Graaf (right) receives from Nikhef director Frank Linde the patent document for the RasClic alignment technology. Amsterdam, 25 June 2009.

tiling them into a large enough area required in medical imaging applications. The switch from silicon to Cadmium-Zinc-Telluride is necessary to achieve higher detection efficiency for X-rays in the energy range from 60 keV to 120 keV. Other activities within the Hidralon project are aimed at developing a new generation of CMOS imagers, for example for the automotive and entertainment industries.

Bruco

To help companies keep their personnel during the current economic crisis, the government instigated the 'Kenniswerkers Regeling'. It funds projects that are submitted by a collaboration between a commercial company and a research institute such as Nikhef. These projects are run at the institute using manpower from the company, while the government pays the salary of the company's personnel involved. The approved project has two lines of research. The first is aimed at designing a chip that will allow the data to be transported from the chip to e.g. a field programmable gate array with 10 Gb/s. The second part comprehends the study of different chip architectures to efficiently select only those pixels that harbour information and thereby increasing the frame rate by reading out those selected pixels.

Rasnik patent

The Rasnik alignment technology (see Annual Report 2005) has gathered its firm place in scientific instruments like in the ATLAS detector and in the LHCb detector. Rasnik has formed the basis for Nikhef's first patent application (RasClic), which has been granted officially on 4 March 2009 (see also Fig. 2).

4.4 Memberships*

ASPERA
F. Linde (Governing Board)
R. van der Meer (joint secretariat)

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

BEAUTY, Intern. 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 SPS Committee
P. Kooijman

DESY, Hamburg – Program Review Committee
J. Timmermans

EGI Organizational Task Force
A. van Rijn (chair)

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 Particle Physics Outreach Group
V. Mexner

European Physical Society
E. de Wolf (*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

European Science Foundation – Physical and Engineering Sciences Unit
R. Kamermans

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

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

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

GridKa Overview Board, Karlsruhe
K. Bos

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

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

International Grid Trust Federation
D. Groep (chair)

InterAction
V. Mexner

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

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

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

* *as of 31 December 2009.*

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

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

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

Nederlands Tijdschrift voor Natuurkunde – Editorial Board
M.Decowski, S. de Jong

Nederlandse Natuurkundige Vereniging
J. van Holten, S. de Jong, P. Mulders (secretary), E. de Wolf (*Board)*
P. Kluit, E. Koffeman (*Sectie H*)
S. de Jong (vice chair, *Sectie Onderwijs en Communicatie)*

Nuclear Physics European Collaboration Committee (NuPECC)
Th. Peitzmann

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

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

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

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

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

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

Stichting Hoge-Energie Fysica
J. van den Brand, R. Kleiss, F. Linde (chair), Th. Peitzmann,
A. van Rijn (treasurer)

Stichting Industriële Toepassing van Supergeleiding
B. van Eijk

Stichting Techniek Toernooi
E. de Wolf (chair)

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

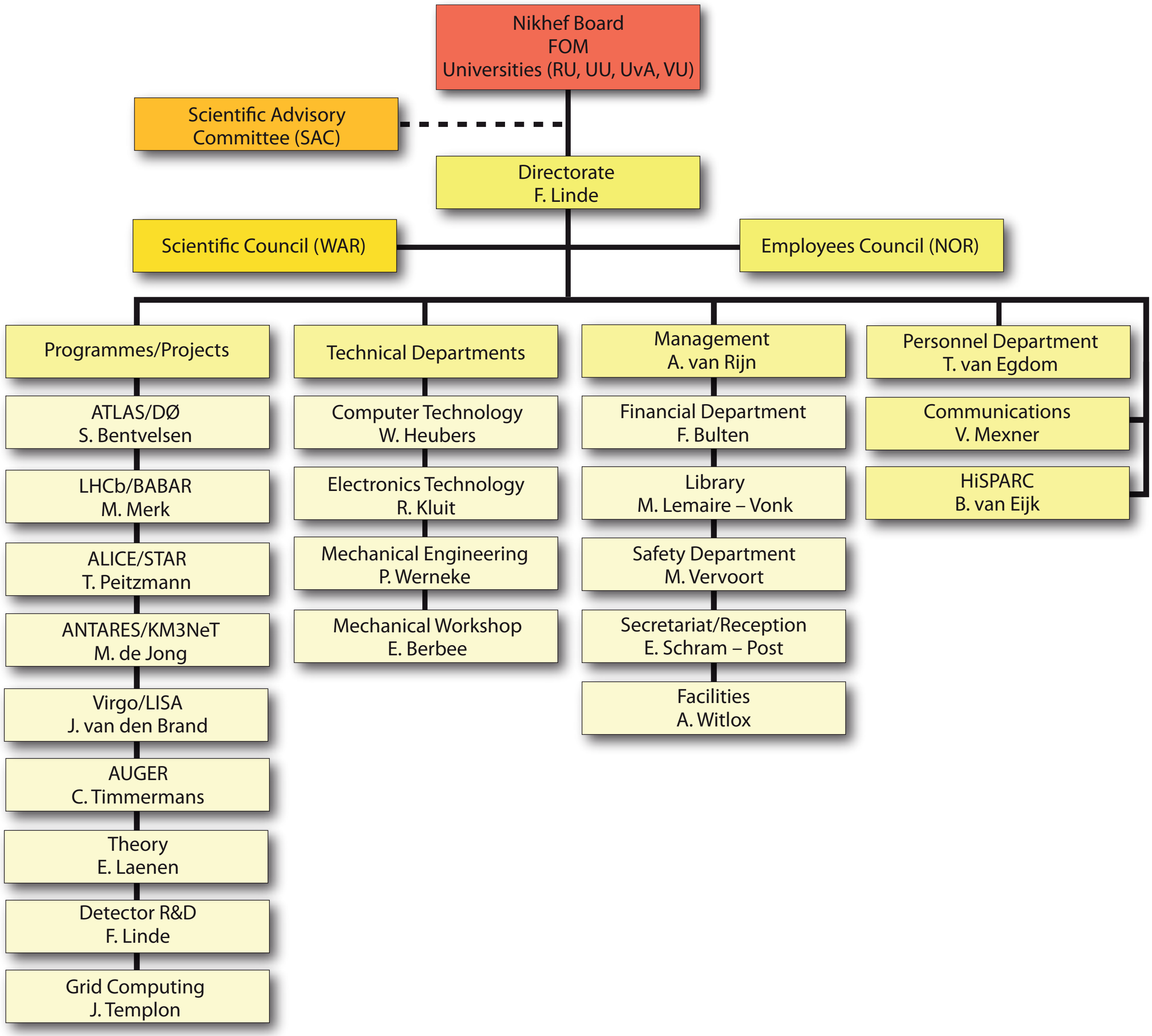
Vereniging Gridforum Nederland
A. van Rijn (treasurer)

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

5

Resources

5.1 Organigram*



* *as of 31 December 2009.*

5.2 Organisation*

Nikhef Board
A. Bliek (Utrecht University)
K. Chang (FOM)
R. Griessen (FOM, VU University Amsterdam)
J. de Kleuver (secretary, FOM)
J. Kuijpers (Radboud University Nijmegen)
J. van Mill (chair, VU University Amsterdam)
K. van der Toorn (chair, University of Amsterdam)

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

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S. de Jong
F. Linde
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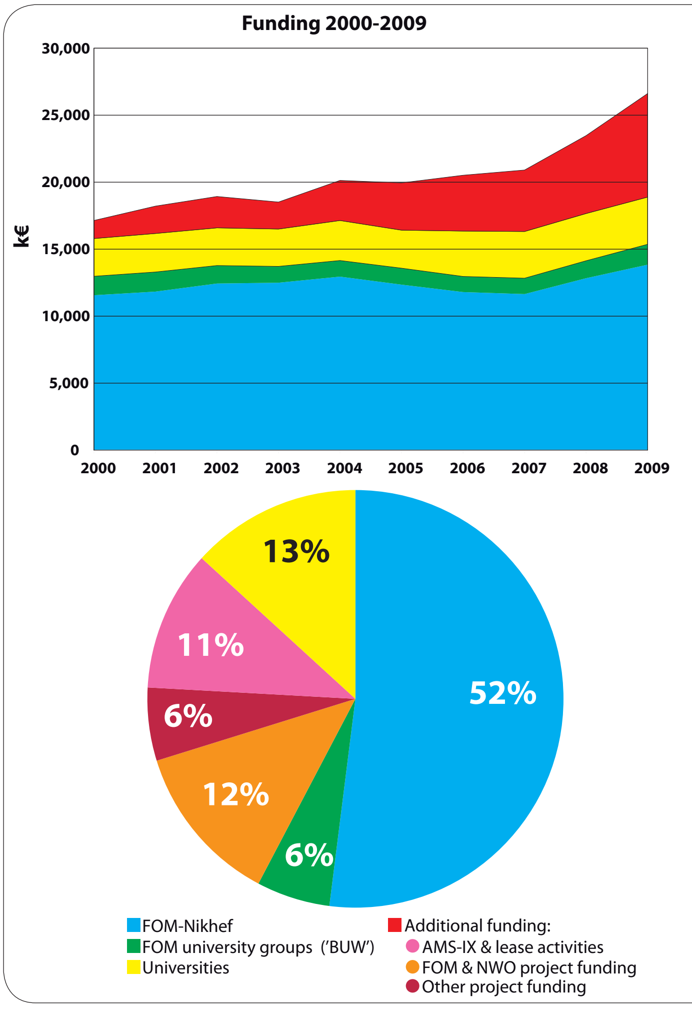
E. de Wolf

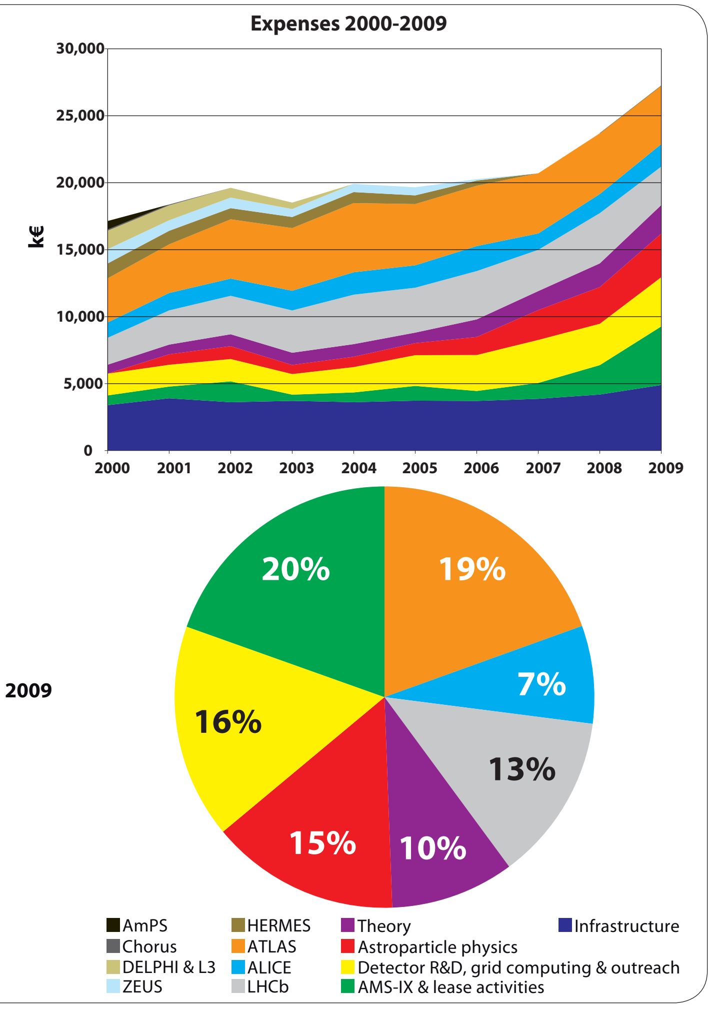
* *as of 31 December 2009.*

5.3 Funding & Expenses

From a funding perspective the year 2009 has again been very fruitful. Via a dedicated call (‘*Dynamisering instituutsfinanciering*’) aimed at the NWO-institutes, Nikhef has been awarded a one-time amount of 3.4 million euro, added to the mission budget, spread over the years 2009, 2010 and 2011. Another milestone was the recent (November 2009) awarding of the FOM-programme “*Gravitational Physics – the dynamics of spacetime*”, which will appear in the Nikhef budgets from 2010 onward. Two new Vidi grants were also awarded, starting next year. The funding in 2009 shows the result of earlier successes, both in the NWO ‘*Vernieuwingsimpulsen*’ as in SenterNovem sponsored projects (such as Relaxd and Hidralon) and EC sponsored projects (such EGEE, EUDET, ASPERA-2, KM3NeT and MC-PAD). Finally, the turnover in contracts with customers of the Internet Exchange datacenter facility has also increased (to about 2.3 M€), so that the funding of the Nikhef collaboration is now at the level of 26.6 M€ (as compared to 23.5 M€ in 2008).

The expenses show a slight shift from accelerator-based particle physics to astroparticle physics and to enabling activities (theory, grid and detector R&D). The expenses for the LHC experiments form about 40% of (direct) expenses, for astroparticle physics about 15% and for enabling activities about 25%. A remarkable increase in expenses is visible for the lease activities: these are the costs for the extension and upgrade of the datacenter infrastructure for the grid and Internet Exchange activities, which had their peak in 2009. Not included in the graph are the investments in the grid resources (storage and computing), funded by the BiG Grid project, for a total of 1.3 million euro in 2009.





5.4 Personnel*

Overview of Nikhef personnel in fte (2009)

I – Scientific groups
(fte – 2009, institute & university groups)

Permanent scientific staff	54.0
PhD students	66.4
Post–docs	36.8
Total I	157.2

II – Management, technical/engineering and general support (fte – 2009, institute)

Management team	
Director	1.0
Institute manager	1.0
Personnel/HRM officer	0.8
Subtotal	2.8
Technical/engineering support	
Electronic workshop	24.9
Computer technology	21.2
Mechanical engineering	13.3
Mechanical workshop	16.5
Project management support	1.3
Subtotal	77.2
General support	
Financial administration	3.8
Personnel/HRM administration	1.0
Library	0.5
Technical and domestic services	7.4
Secretariat and reception desk	4.3
PR & communication	1.7
Occupational health & safety	1.0
Staff	2.0
Subtotal	21.7
Total II	101.7
Total I & II	258.9

III – Other groups
(persons 2009)

Guests (researchers, retired staff)	24.0
Master students	47.0

ATLAS/DØ

Ancu, Drs. L.S. (Lucian)	GST
Bentvelsen, Prof.dr. S.C.M. (Stan)	UvA
Bobbink, Dr. G.J. (GerJan)	FOM
Bos, Dr. K. (Kors)	FOM
Chelstowska, Msc. M.A. (Magda)	FOM/RU
Colijn, Dr. A.P. (Auke Pieter)	UvA
Consonni, Dr. M. (Michele)	FOM/RU
Doxiadis, Msc. A.D. (Alexander)	FOM
Ferrari, Dr. P. (Pamela)	FOM
Filthaut, Dr. F. (Frank)	RU
Geerts, Msc. D.A.A. (Daniel)	FOM
Gosselink, Ir. M. (Martijn)	FOM
Groot, Prof.dr. N. (Nicolo) de	RU
Hessey, Dr. N.P. (Nigel)	FOM
Igonkina, Dr. O.B. (Olga)	FOM
Jansen, Drs. E. (Eric)	FOM
Jong, Prof.dr.ir. P.J. (Paul) de	FOM
Kayl, Msc. M.S. (Manuel)	FOM
Kesteren, Drs. Z. (Zdenko) van	GST
Klok, Drs. P.F. (Peter)	FOM/RU
Klous, Dr.ing. S. (Sander)	FOM
Kluit, Dr.drs. P.M. (Peter)	FOM
Koetsveld, Drs. F. (Folkert)	FOM/RU
Koffeman, Prof.dr.ir. E.N. (Els)	FOM
König, Dr. A.C. (Adriaan)	RU
Koutsman, Drs. A.J. (Alex)	FOM
Lee, Msc. H.C. (Hurng-Chun)	FOM
Leeuw, Msc. R.H.L. (Robin) van der	FOM
Liebig, Dr. W. (Wolfgang)	FOM
Mechnich, Dipl.Phys. J. (Jörg)	FOM
Meijer, Msc. M.M. (Melvin)	FOM/RU
Mussche, Msc. I. (Ido)	FOM
Naumann, Drs. N.A. (Axel)	GST
Nooij, Msc. L. (Lucie) de	FOM
Oord, Drs. G.J.W.M. (Gijs) van den	FOM
Ottersbach, Dipl.Phys. J.P. (John)	FOM
Poel, Msc. E.F. (Egge) van der	FOM
Raas, Msc. M.J.P. (Marcel)	FOM/RU
Resende Vaz de Melo Xavier, Dr. B. (Bernardo)	FOM
Rijpstra, Drs. M. (Manouk)	FOM
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Salamanna, Dr. G. (Giuseppe)	FOM
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Tsiakiris, Msc. M. (Menelaos)	FOM
Turlay, Dr. E.J.Y. (Emmanuel)	FOM

* *as of 31 December 2009.*

Vanbavinckhove, Ir. G. (Glenn)	GST
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Vreeswijk, Dr. M. (Marcel)	UvA
Vulpen, Dr. I.B. (Ivo) van	UvA
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Amoraal, Drs. J.M. (Jan)	GST
Bauer, Dr. T.S. (Thomas)	FOM
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Bos, Dr. E. (Edwin)	GST
Carvalho Akiba, Dr. K. (Kazuyoshi)	FOM/VU
Eijk, Msc. D. (Daan) van	FOM
Farinelli, Msc. C. (Chiara)	FOM/VU
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Oggero, Msc. S. (Serena)	FOM
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Tuning, Dr. N. (Niels)	FOM
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Wiggers, Dr. L.W. (Leo)	FOM
Ybeles Smit, Drs. G.V. (Gabriel)	GST
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Braidot, Drs. E. (Ermes)	FOM/UU
Chojnacki, Drs. M. (Marek)	FOM/UU
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Fransen, J.P.A.M. (Jean-Paul)	FOM

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Gotink, G.W. (Gerrit Willem)	FOM
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Hogenbirk, Ing. J.J. (Jelle)	FOM
Jansen, L.W.A. (Luc)	FOM
Jansweijer, Ing. P.P.M. (Peter)	FOM
Kieft, Ing. G.N.M. (Gerard)	FOM
Kluit, Ing. R. (Ruud)	FOM
Koopstra, J. (Jan)	UvA
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Peek, Ing. H.Z. (Henk)	FOM
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Sluijk, Ing. T.G.B.W. (Tom)	FOM
Timmer, P.F. (Paul)	FOM
Verkooijen, Ing. J.C. (Hans)	FOM
Vink, Ing. W.E.W. (Wilco)	FOM
Zivkovic, Msc. V. (Vladimir)	FOM
Zwart, Ing. A.N.M. (Albert)	FOM

Mechanical Engineering Group (ME)

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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
Oskamp, C.J. (Cornelis)	FOM/UU
Roo, B.Eng. K. (Krista) de	FOM
Schuijlenburg, Ing. (H.W.A. (Henk)	FOM
Thobe, P.H. (Peter)	FOM
Verlaat, Ing. B.A. (Bart)	FOM
Werneke, Ing. P.J.M. (Patrick)	FOM

Mechanical Workshop (MW)

Berbee, Ing. E.M. (Edward)	FOM
Boer, R.P. (René) de	FOM
Brouwer, G.R. (Gerrit)	FOM
Buis, R. (Rob)	FOM
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Homma, J. (Jan)	FOM
Jaspers, M.J.F. (Michiel)	UvA
John, D. (Dimitri)	FOM
Kok, J.W. (Hans)	FOM
Kuilman, W.C. (Willem)	FOM
Leguyt, R. (Rob)	FOM
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Rietmeijer, A.A. (Arnold)	FOM
Roeland, E. (Ernö)	FOM
Rövekamp, J.C.D.F. (Joop)	UvA

Management and Administration

Azarfane, M. (Mohamed)	PANTAR
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Berg, A. (Arie) van den	FOM
Berger, J.M. (Joan)	Uitzend
Bulten, F. (Fred)	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, W. (Wijnanda) de	Uitzend
Huyser, K. (Kees)	FOM
Kleinsmiede-Van Dongen, T.W.J. (Trees) zur	FOM
Klöpping, Ir. R. (Rob)	FOM
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Mexner, Dr. I.V. (Vanessa)	FOM
Mors, A.G.S. (Anton)	FOM
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Pancar, M. (Muzaffer)	FOM
Rem, Drs.ing. N. (Nico)	FOM
Rijksen, C. (Kees)	FOM
Rijn, Drs. A.J. (Arjen) van	FOM
Schram-Post, E.C. (Eveline)	FOM
Vervoort, Ing. M.B.H.J. (Marcel)	FOM
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Woortmann, E.P. (Eric)	FOM

Glossary

Accelerator
A machine in which beams of charged particles are accelerated to high energies. Electric fields are used to accelerate the particles whilst magnets steer and focus them. A collider is a special type of accelerator where counter–rotating beams are accelerated and interact at designated collision points. A synchrotron is an accelerator in which the magnetic field bending the orbits of the particles increases with the energy of the particles. This keeps the particles moving in a closed orbit.

ALICE (A Large Ion Collider Experiment)
One of the four major experiments that uses the *LHC*.

AMS–IX (Amsterdam Internet Exchange)
The main place in the Netherlands for Internet Service Providers to interconnect and exchange IP traffic with each other at a national or international level.

Annihilation
A process in which a particle meets its corresponding antiparticle and both disappear. The resulting energy appears in some other form: as a different particle and its antiparticle (and their energy), as many mesons, or as a single neutral boson such as a Z boson. The produced particles may be any combination allowed by conservation of energy and momentum.

ANTARES (Astronomy with a Neutrino Telescope and Abyss Environmental Research)
Large area water *Cherenkov* detector in the deep Mediterranean Sea near Toulon, optimised for the detection of muons resulting from interactions of high–energy cosmic neutrinos.

Antimatter
Every kind of matter particle has a corresponding antiparticle. Charged antiparticles have the opposite electric charge as their matter counterparts. Although antiparticles are extremely rare in the Universe today, matter and antimatter are believed to have been created in equal amounts in the *Big Bang*.

Antiproton
The antiparticle of the proton.

ASPERA
Sixth Framework Programme for co–ordination across European funding agencies for financing astroparticle physics. The seventh Framework Programme started in 2009 and is called ASPERA-2.

ATLAS (A Toroidal LHC ApparatuS)
One of the four major experiments that uses the *LHC*.

BaBar
Detector at SLAC's B Factory. Named for the elephant in Laurent DeBrunhoff's children's books.

Baryon
See *Particles*.

Beam
The particles in an accelerator are grouped together in a beam. Beams can contain billions of particles and are divided into discrete portions called bunches. Each bunch is typically several centimeters long and can be just a few μm in diameter.

Big Bang
The name given to the explosive origin of the Universe.

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

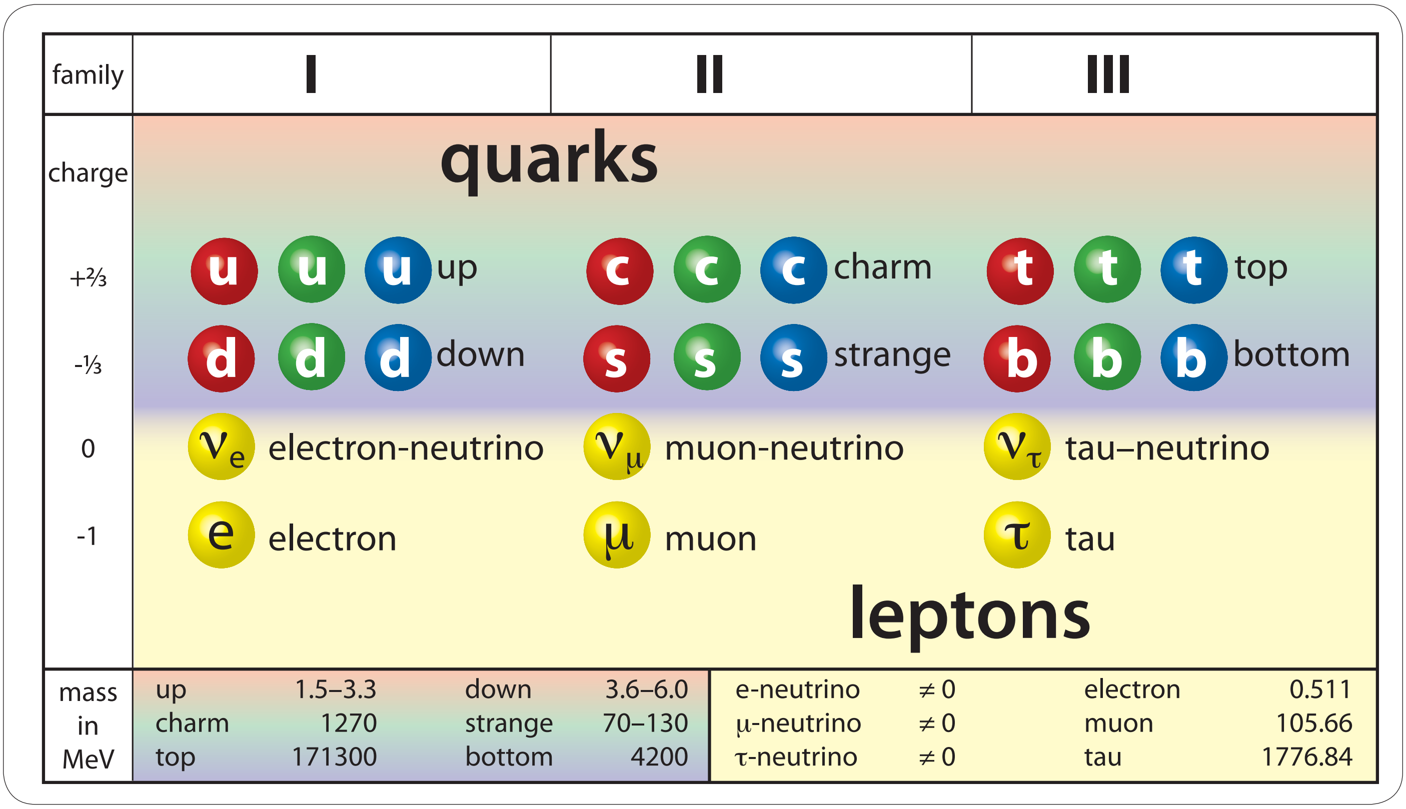
Boson
The general name for any particle with a spin of an integer number (0, 1 or 2...) of quantum units of angular momentum (named for Indian physicist S.N. Bose). The carrier particles of all interactions are bosons. Mesons are also bosons.

Calorimeter
An instrument for measuring the amount of energy carried by a particle.

Cherenkov radiation
Light emitted by fast–moving charged particles traversing a dense transparent medium faster than the speed of light in that medium.

CLIC (Compact LInear Collider)
A feasibility study aiming at the development of a realistic technology at an affordable cost for an electron–positron linear collider for physics at multi–TeV energies.

Collider
See *Accelerator*.



The three families of particles according to the Standard Model.

Cosmic ray
A high–energy particle that strikes the Earth's atmosphere from space, producing many secondary particles, also called cosmic rays.

CP violation
A subtle effect observed in the decays of certain particles that betrays nature's preference for matter over antimatter.

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

Dark matter
Only 4% of the matter in the Universe is visible. The rest is known as dark matter and dark energy. Finding out what it consists of is a major question for modern science.

Detector
A device used to measure properties of particles. Some detectors measure the tracks left behind by particles, others measure energy. The term '*detector*' is also used to describe the huge composite devices made up of many smaller detector elements. Examples are the ATLAS, the ALICE and the LHCb detectors.

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

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

Electron
See *Particles*.

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

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

eV (Electronvolt)
A unit of energy or mass used in particle physics. One eV is extremely small, and units of million electronvolts, MeV, thousand MeV = 1 GeV, or million MeV = 1 TeV, are more common in particle physics. The latest generation of particle accelerators reaches up to several TeV. One TeV is about the kinetic energy of a flying mosquito.

Fermion
General name for a particle that is a matter constituent, characterized by spin in odd half integer quantum units ($\frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$...). Named for Italian physicist Enrico Fermi. Quarks, leptons and baryons are all fermions.

Forces
There are four fundamental forces in nature. Gravity is the most familiar to us, but it is the weakest. Electromagnetism is the force responsible for thunderstorms and carrying electricity into our homes. The two other forces, weak and strong, are connected to the atomic nucleus. The strong force binds the nucleus together, whereas the weak force causes some nuclei to break up. The weak force is important in the energy–generating processes of stars, including the Sun. Physicists would like to find a theory that can explain all these forces in one common framework.
A big step forward was made in the late 1970s when the electroweak theory uniting the electromagnetic and weak forces was proposed. This was later confirmed in a Nobel prize–winning experiment at CERN.

fte (Full Time Equivalent)
Unit of manpower.

Gluon
See *Particles*.

Gravitational wave
The gravitational analog of an electromagnetic wave whereby gravitational radiation is emitted at the speed of light from any mass that undergoes rapid acceleration.

Grid
A service for sharing computer power and data storage capacity over the Internet.

Hadron
A subatomic particle that contains quarks, antiquarks, and gluons, and so experiences the strong force (see also *Particles*).

High–Energy Physics
A branch of science studying the interactions of fundamental particles; called 'high–energy' because very powerful 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 Astroparticle Cosmic Rays)
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.

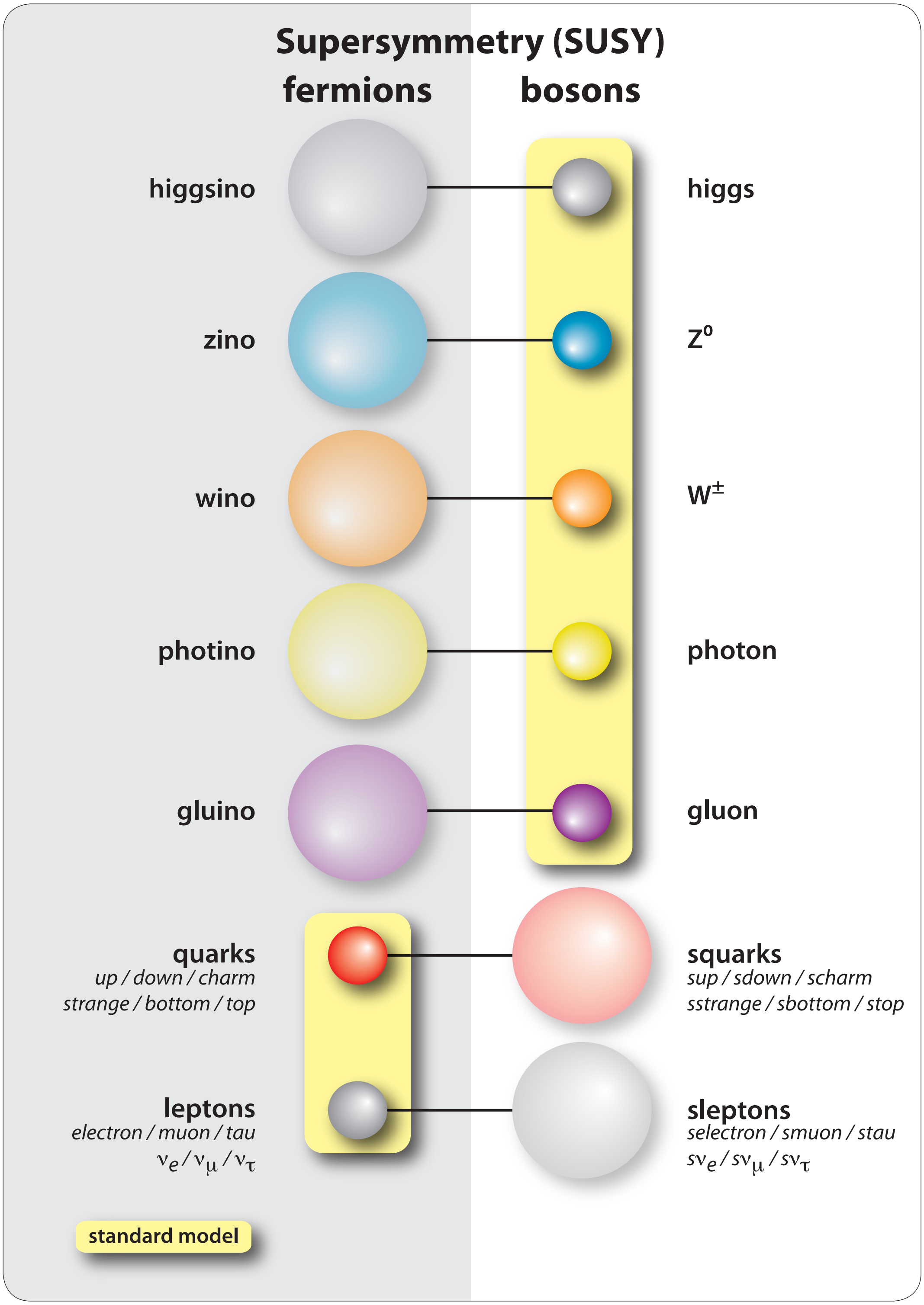
KSI2K
The Kilo SpecInt 2000 (KSI2K) is a unit in which integer computing power is expressed. It is only partially correlated with computing speed.

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.



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

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*.

Linac
An abbreviation for linear accelerator.

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

LOFAR (Low Frequency Array)
First radio telescope of a new generation of astronomical facilities, mainly in the Netherlands.

Medipix
A family of photon counting pixel detectors based on the Medipix CMOS read-out chips that can be provided with a signal from either a semi-conductor sensor or ionisation products in a gas volume. The detectors are developed by an international collaboration, hosted by CERN, and including Nikhef. Medipix-3 is the prototype that is currently in the development phase.

Meson
See *Particles*.

Muon
A particle similar to the electron, but some 200 times more massive (see also *Particles*).

Muon chamber
A device that identifies muons, and together with a magnetic system creates a muon spectrometer to measure momenta.

Neutrino
Uncharged, weakly interacting lepton, most commonly produced in nuclear reactions such as those in the Sun. There are three known flavours of neutrino, corresponding to the three flavours of leptons. Recent experimental results indicate that all neutrinos have tiny masses (see also *Particles*).

NLO (Next–to–Leading Order)
Second order calculations in perturbative *QED* and *QCD*.

NWO
The Netherlands Organisation for Scientific Research funds thousands of top researchers at universities and institutes and steers the course of Dutch science by means of subsidies and research programmes

Nucleon
The collective name for protons and neutrons.

Particles
There are two groups of elementary particles, quarks and leptons, with three families each. The quarks are named up and down, charm and strange, top and bottom (or beauty). The leptons are electron and electron neutrino, muon and muon neutrino, tau and tau neutrino. There are four fundamental forces, or interactions, between particles, which are carried by special particles called bosons. Electromagnetism is carried by the photon, the weak force by the charged W and neutral Z bosons, the strong force by the gluons and gravity is probably carried by the graviton, which has not yet been discovered. Hadrons are particles that feel the strong force. They include mesons, which are composite particles made up of a quark–antiquark pair, and baryons, which are particles containing three quarks. Pions and kaons are types of meson. Neutrons and protons (the constituents of ordinary matter) are baryons; neutrons contain one up and two down quarks; protons two up and one down quark.

Photon
See *Particles*.

Pierre Auger Observatory
International experiment in Argentina to track down the origin of ultra–high–energy cosmic rays.

Pion
See *Particles*.

Positron
The antiparticle of the electron.

Quantum electrodynamics (QED)
The theory of the electromagnetic interaction.

Quantum chromodynamics (QCD)
The theory for the strong interaction analogous to QED.

Quark
The basic building blocks of matter (see also *Particles*).

Quark–gluon plasma (QGP)
A new kind of plasma, in which protons and neutrons are believed to break up into their constituent parts. QGP is believed to have existed just after the Big Bang.

RASNIK (Red Alignment System Nikhef)
Optical alignment system where a pattern is projected by a lens on a CCD and deviations measured.

Relaxd
EU–funded development of the large area fast detector system using Medipix technology.

RHIC
Brookhaven's Relativistic Heavy Ion Collider; began operation in 2000. RHIC collides beams of gold ions to study what the Universe looked like in the first few moments after the Big Bang.

Scintillation
The flash of light emitted by an electron in an excited atom falling back to its ground state.

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

Spectrometer
In particle physics, a detector system containing a magnetic field to measure momenta of particles.

Spin
Intrinsic angular momentum of a particle.

Standard Model
A collection of theories that embodies all of our current understanding about the behaviour of fundamental particles.

STAR
Experiment at *RHIC*.

String Theory
A theory of elementary particles incorporating relativity and quantum mechanics in which the particles are viewed not as points but as extended objects. String theory is a possible framework for constructing unified theories that include both the microscopic forces and gravity (see also *Forces*).

Supersymmetry
Supersymmetry (often abbreviated SUSY) is a symmetry that relates elementary particles of one spin to other particles that differ by half a unit of spin and are known as superpartners.

SURFnet
Networking organisation in the Netherlands.

Tevatron
Fermilab's 2–TeV proton–antiproton accelerator near Chicago.

Tier–1
First tier (category) in the *LHC* regional computing centers. Tier–0 is the facility at CERN collecting, reconstructing and storing the data.

Trigger
An electronic system for spotting potentially interesting collisions in a particle detector and triggering the detector's read–out system.

Vertex detector
A detector placed close to the collision point in a colliding beam experiment so that tracks coming from the decay of a short–lived particle produced in the collision can be accurately reconstructed and seen to emerge from a 'vertex' point that is different from the collision point.

Virgo
Detector near Pisa for gravitational waves: a Michelson laser interferometer made of two orthogonal arms, each 3 km long.

W boson
A carrier particle of weak interactions; involved in all electric–charge–changing weak processes.

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

Team de Jong after winning the € 100,000 Academic Year Prize. Centre-front is Sijbrand de Jong, holding the Cup is Charles Timmermans.