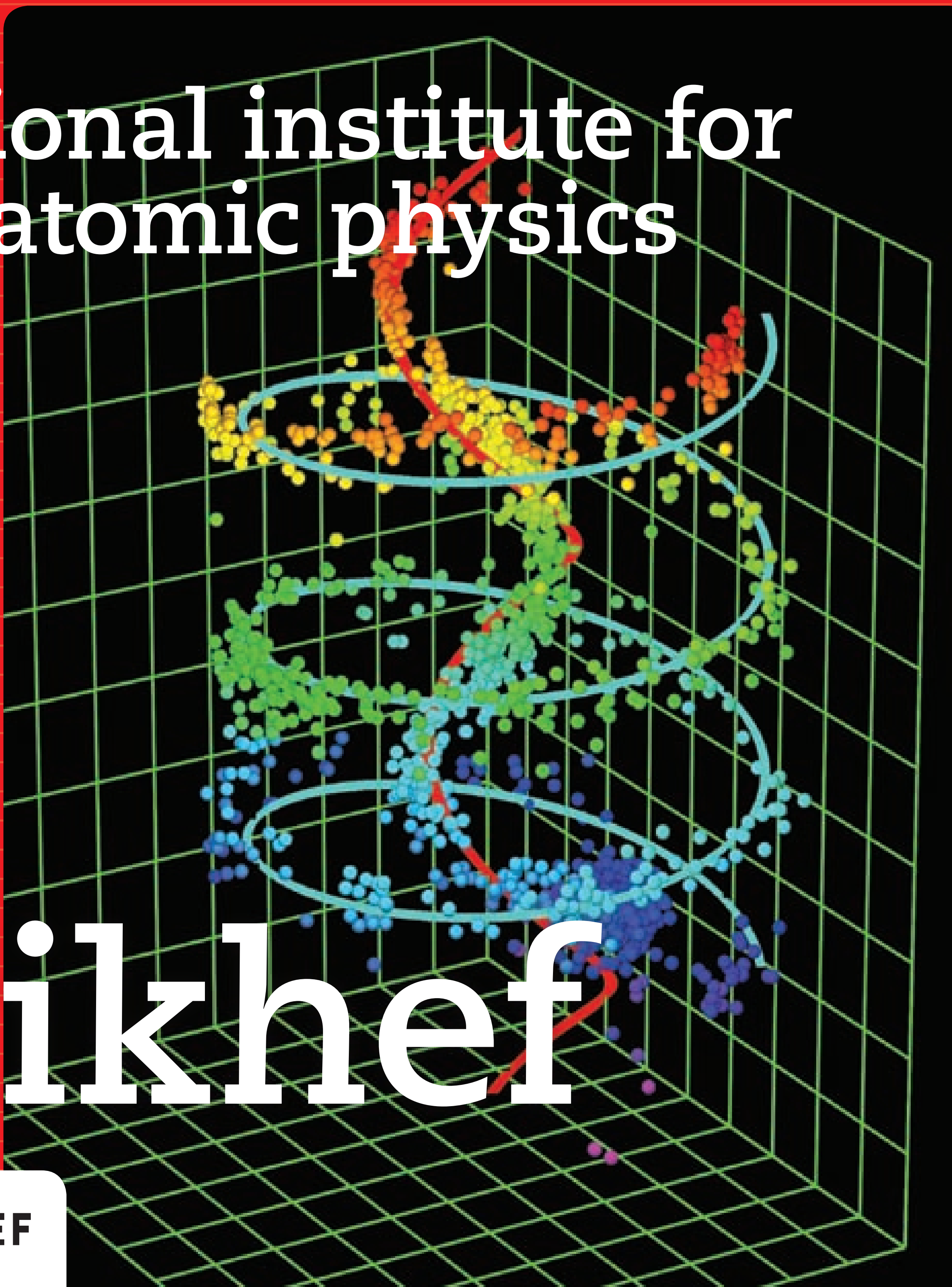
Annual Report 2007



National institute for subatomic physics

Nikhef

NIKHEF

Annual Report
2007

National institute
for subatomic physics
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NIKHEF

Colophon

Nikhef
Nationaal instituut voor subatomaire fysica
National institute for subatomic physics

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Cover: Two tracks recorded in a drift cell on top of a Timepix pixel chip. The colors indicate the drift time, transformed into drift distance (30 mm) on the vertical axis.

Nikhef is the National institute for subatomic physics in the Netherlands, in which the Foundation for Fundamental Research on Matter (FOM), the Universiteit van Amsterdam (UvA), the Vrije Universiteit Amsterdam (VU), the Radboud Universiteit Nijmegen (RU) and the Universiteit Utrecht (UU) collaborate. Nikhef co-ordinates and supports most activities in experimental particle and astro-particle physics in the Netherlands.

Nikhef participates in the preparation of experiments at the Large Hadron Collider at CERN, notably ATLAS, LHCb and ALICE. Astroparticle physics activities at Nikhef are threefold: the ANTARES neutrino telescope in the Mediterranean Sea; the AUGER cosmic ray observatory in Argentina; and the VIRGO gravitational wave interferometer in Italy. Detector R&D, design and construction of detectors and the 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.

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Introduction

The introduction to Nikhef's Annual Report 2006 concluded with: *"In 2007, NIKHEF will be evaluated by an international committee of renowned physicists. The outcome of this evaluation and of funding requests for a national theoretical physics programme and for a national astroparticle physics programme will have a profound impact on NIKHEF's future activities."* Both the theory and astroparticle physics programme proposals have been approved by FOM and the international evaluation committee submitted a very favourable review to NWO! One can hardly imagine a better start of a new year.

Conscientious readers certainly noticed the mixed use of NIKHEF and Nikhef in the previous paragraph. Last year we decided to abandon the NIKHEF acronym, '*Nationaal Instituut voor Kernfysica en Hoge-Energiefysica*', in favour of the Nikhef name, which from now on refers to the '*Nationaal instituut voor subatomaire fysica*'.

Figure 1. Cover of Science magazine showing the correlation between the origin of high-energy cosmic rays as measured by AUGER and the location of active galactic nuclei. Image by Kelly Krause/Science.

The Nikhef logo stays as it is (unless someone comes with a really good design). The Nikhef website will be restyled completely. These are only a few of the activities of Nikhef's very active communication department. As a consequence, Nikhef's media exposure has skyrocketed over the past few years to a level which will be hard to sustain in the future.

Nikhef's main scientific activity is aimed at the exploitation of CERN's Large Hadron Collider (LHC). Regretfully, the scheduled 2007 turn-on of the LHC had to be postponed due to several (unrelated) defects which only showed up while cooling down LHC magnets to temperatures near absolute zero. These defects have been repaired. Unless new setbacks are encountered, the LHC is expected to start colliding protons at the full 14 TeV centre-of-mass energy in the second half of 2008. A concern remains the occurrence of small leaks in the cryogenic helium distribution system requiring extra warming up and cooling down cycles which could delay LHC turn-on by several months. Meanwhile, the installation and subsequent commissioning of the three LHC experiments with Nikhef involvement, ALICE, ATLAS and LHCb, is progressing well. Throughout 2007, numerous Nikhef technicians and physicists have spent months in the underground LHC caverns. By the end of 2007, all three experiments started to collect cosmic ray muon tracks to debug both hardware and software. In April 2008, detector installation will come to an end; the LHC beam pipe will be closed, and shortly thereafter LHC operators will start to exercise the CERN accelerator complex sending protons from the proton synchrotron (PS) via the super proton synchrotron (SPS) into the LHC!

To analyze the plethora of proton-proton collisions to be recorded by the LHC experiments, Nikhef is, together with a dozen other sites in the world, setting up a powerful compute grid. This Dutch compute grid, coined BiG Grid, is funded by NWO and covers the 2007–2011 period and services, besides subatomic physics, many other research disciplines. The installation of the large number of PCs and data storage devices profits from the experience Nikhef gained over the past years in housing members of the Amsterdam internet exchange, AMS-IX. The combined power (and cooling) requirements of the BiG Grid and AMS-IX projects, call for a significant upgrade of Nikhef's infrastructure.

Astroparticle physics activities at Nikhef are threefold: the ANTARES neutrino telescope in the Mediterranean Sea (since 2000); the AUGER cosmic ray observatory in Argentina (since 2005); and the VIRGO gravitational wave interferometer in Italy (since 2007). The years in parentheses indicate when Nikhef formally joined these experiments. Not surprisingly, at

Figure 2. Nikhef PhD students Hylke Koers (left) and Jeroen Hegeman (centre) talking with evaluation committee member Christian Spiering (DESY, Zeuthen) (right). The evaluation committee was interested in hearing the students' views about the institute.

present ANTARES is Nikhef's largest astroparticle physics activity while VIRGO is Nikhef's smallest astroparticle physics activity. Regarding the long-term future of astroparticle physics, Nikhef hosted the second *'European strategy for astroparticle physics workshop'* in Amsterdam in September.

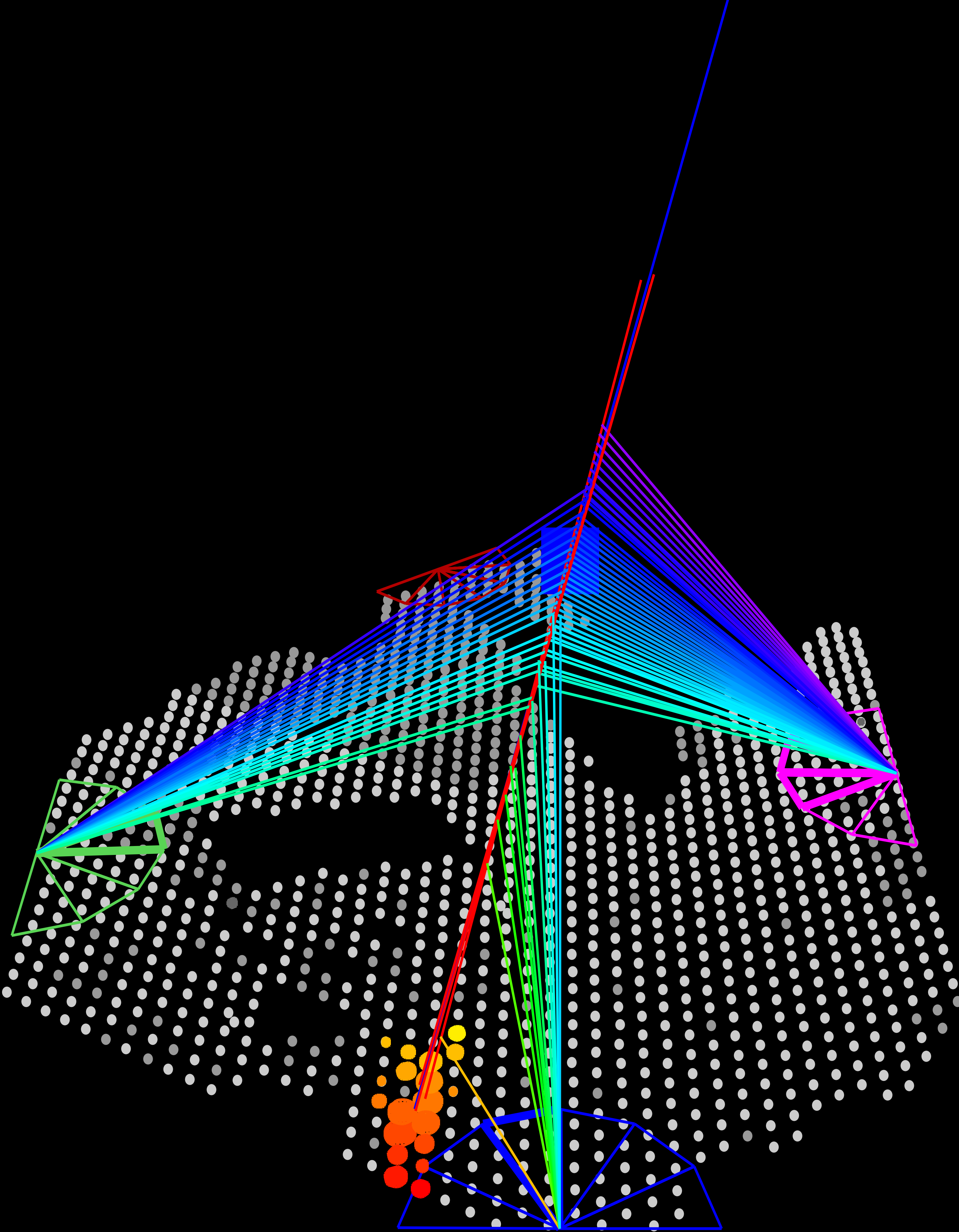
By the end of 2007, ten out of the 12 detector strings comprising ANTARES had been deployed; the last two detector strings completing ANTARES will be deployed and connected in 2008 thereby ending a long and sometimes difficult construction period. Meanwhile, datataking with already operational strings is proceeding, and preliminary measurements on e.g. multi-muon events, natural radioactivity and even up-going neutrino's have already been made. In many of these analyses, Nikhef physicists play a key role. Regarding the future, Nikhef has submitted an investment proposal ('*NWO-groot*') to secure the Dutch contribution to the full-size neutrino telescope called KM3NeT.

Beyond doubt, the scientific highlight of 2007 for Nikhef was the AUGER publication in the Science magazine (see Fig. 1) of the likely sources of high-energy cosmic rays: active galactic nuclei, i.e. galaxies of which the central core produces more radiation than the entire rest of the galaxy. Dutch detector R&D physicists played an important role in demonstrating the feasibility to complement AUGER's fluorescence and water-Cherenkov detectors with radio detectors thereby increasing the duty cycle for a two-fold detection of cosmic-ray signals from a mere 10% to almost 100%.

Finally, 2007 was the year in which Nikhef concluded two immensely successful experiments: the DESY (Hamburg) experiments ZEUS (studying the structure of the proton) and HERMES (studying the spin structure of the proton). A concise summary of the findings of and Nikhef's role in these experiments can be found in their final reports.

Looking forward, 2008 promises to become an incredibly exciting year for Nikhef: with LHC 14 TeV centre-of-mass energy proton-proton collisions imminent; with the BiG Grid compute and storage facility to face the first load of real physics events; with the completion of the ANTARES neutrino telescope; and with a substantial upgrade of the AMS-IX and BiG Grid related infrastructure.

Frank Linde



Visualisation of an event seen in the surface detector (coloured circles on the grid) and all four fluorescence telescopes (ray traces converging at the telescopes) of the Pierre Auger Observatory.

1

Reviews

1.1 The Pierre Auger Observatory
Signals from Outer Space

Charles Timmermans

Introduction
Already since 1962, it is known that ultra high energy particles originating from space collide onto our atmosphere. The energy of some of these particles is well beyond 1 EeV, or 10^{18} eV, and corresponds to more than a million times the energy of particles accelerated by the Tevatron at Fermilab. The problem in studying the particles from outer space is their extremely low flux. Hence, a large detector is required to reach an acceptable counting rate. The southern site of the Pierre Auger Observatory in Argentina meets these requirements: it was constructed with a total area of 3000 km^2. The mission of this experiment is to study the nature and origin of cosmic rays of the highest energies.

The Pierre Auger Observatory
Ultra high energy cosmic rays are detected indirectly. One makes use of the shower of particles that is created when an incoming particle hits the atmosphere. In these *'air showers'* billions of subatomic particles are formed, of which a small fraction reaches the surface of the Earth. The Pierre Auger Observatory, shown in Fig. 1, makes use of two different techniques for detecting air showers.

Figure 2. The two main detection techniques of the Pierre Auger Observatory. In the front a water-tank, and in the back a fluorescence detector with the doors in front of the telescopes shut. The antenna provides communication between water tanks and the fluorescence detector, as well as between the central campus and the fluorescence detector.

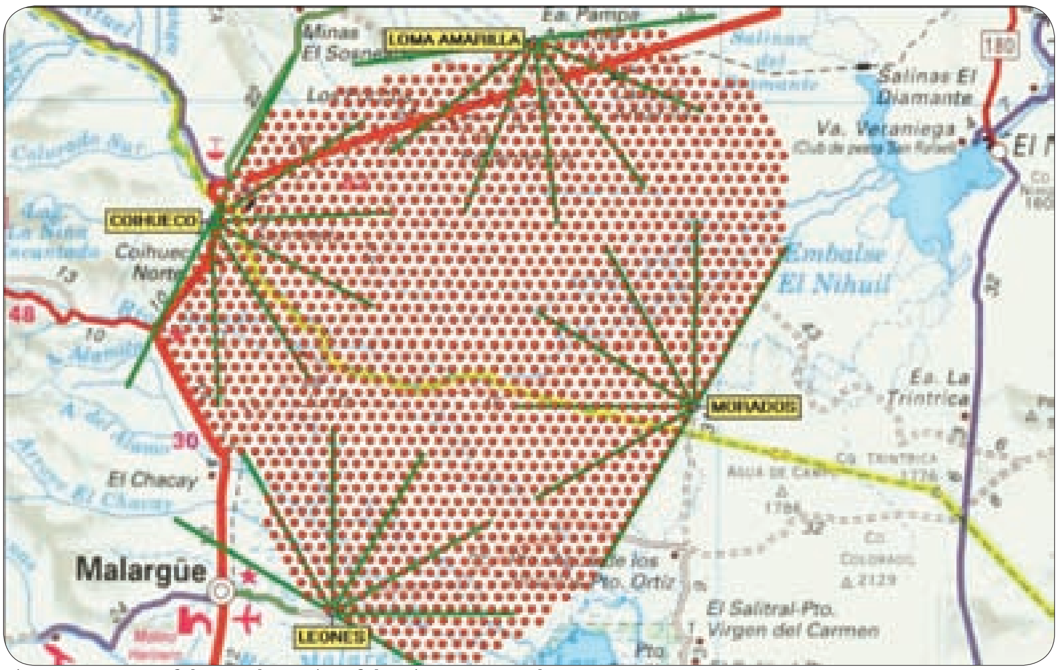


Figure 1. Layout of the southern site of the Pierre Auger Observatory near the Andes in Argentina. The location of the surface detectors is given by the red dots. The surface detector spacing is 1.5 km, and the total area 3000 km^2. Four fluorescence detectors, indicated by the yellow labels, are positioned at the edges of the observatory.

First, the number of particles at the Earth's surface is determined with water tanks. The Cherenkov light emitted by charged particles passing through water at a velocity larger than the speed of light in this medium is detected by three photo-tubes that monitor the tank continuously. The electrical signals from these tubes are proportional to the amount of light produced, thus to the number of particles passing through the detector. When combining the measurements of all surface detectors, a particle-density profile at the surface of the Earth is obtained.

In the second detection technique, the amount of fluorescence light created when charged particles excite the atmospheric nitrogen is measured by wide-view optical telescopes read out by photo-tubes. The number of excited nitrogen atoms is proportional to the total track length of all particles in the shower summed up, and thus to the number of particles. By measuring the amount of fluorescence light, one can follow the development of the air shower in the atmosphere. The detector elements are shown in Fig. 2.

An event reconstructed with the help of both techniques simultaneously is shown on page 6.

Both techniques have their own (dis)advantages. The surface detectors have a large uptime (more than 98%), and their data allow for a good angular reconstruction. However, the energy reconstruction has a relatively large uncertainty due to the modelling of the air shower as it progresses through the atmosphere. The fluorescence detector has a duty cycle of about 10%, as it can only operate in clear moonless nights. However, its data allow for a very good direction and energy determination, especially when combined with the data from the water tanks. The model uncertainties are small, because the whole shower development is measured. The combined data from fluorescence and surface detectors are used to calibrate the energy measurement of the surface detector, thus removing most of the model dependence in the energy determination. The correlation between the data of both detectors and their statistical accuracy determine the final uncertainty in the energy calibration. More details about the detection technique are described in the Box.

Air shower detection in the Pierre Auger Observatory.

The interesting parameters of the incoming particles are their energy, direction, and type (mass). The measurement of air shower parameters thus needs to be sensitive to these parameters. The number of particles produced in an air shower is directly related to the energy. The shower axis follows the direction of the original particle, and the depth of the shower-maximum into the atmosphere is sensitive to the type (e.g. heavy nucleus or single proton) of the incoming particle. All of these parameters can be measured using the fluorescence technique. The ground based detectors measure the number of particles at a single atmospheric depth, their distribution at the Earth' surface and the arrival times. From the timing information the direction and the curvature of the pancake of particles arriving on Earth can be determined. This curvature is related to the shower development. The number of particles as function of the distance to the shower axis provides a measure for the energy.

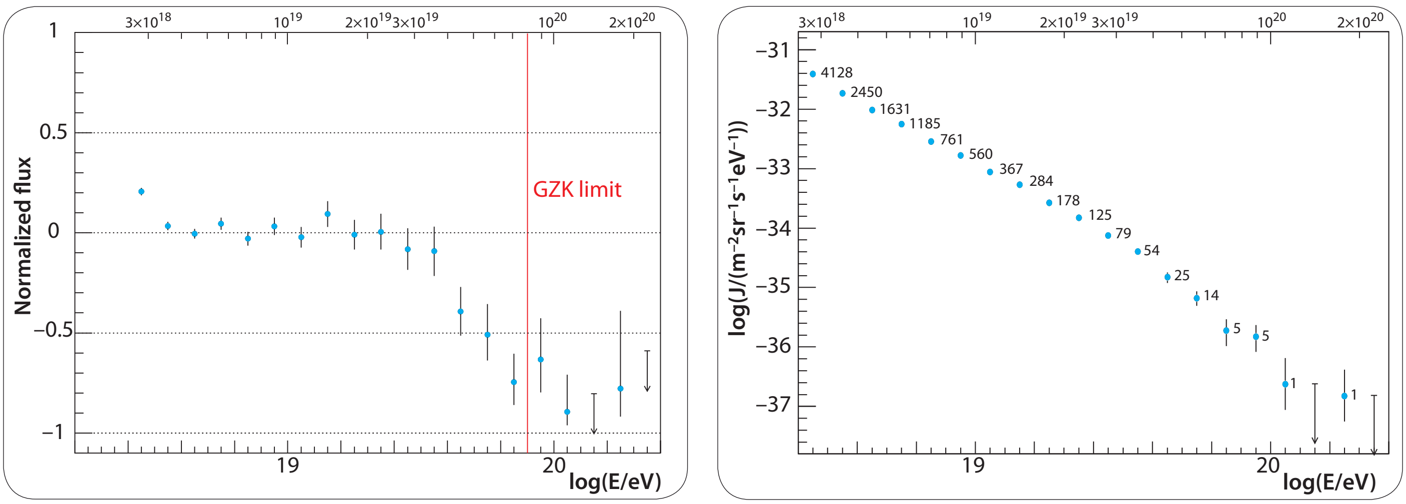


Figure 3. Left: The normalised AUGER energy spectrum as a function of the total shower energy. Vertical error bars represent statistical uncertainties only. The systematic uncertainty on the energy scale is about 22%. Right: The deviation of the measured spectrum with respect to an arbitrary $E^{-2.6}$ power-law spectrum. The upper horizontal scale directly displays the energy, the lower one its logarithm.

The Energy Spectrum: A depletion!
Fig. 3 shows the number of detected showers per square kilometre per second per steradian per eV as a function of the reconstructed energy. The measured energy ranges over two orders of magnitude. The maximum energy is more than 100 EeV. The numbers in the plot indicate the number of recorded showers after an exposure of 5165 $km^2 sr$ yr.

When comparing the measured energy spectrum to a power-law flux description (right part of Fig. 3), one clearly sees a steepening downward starting at an energy of about 40 EeV. This is the energy at which the so-called GZK-threshold can be expected (see **Box**). If the GZK-mechanism is really the explanation of this deviation from the power-law spectrum, then the consequence would be that the Universe is opaque for cosmic ray protons above this energy. This limits the range that cosmic rays of measured energies beyond 60 EeV travelled before reaching the Earth, to about 100 Mpc (1 Megaparsec (Mpc) = $3.26 \bullet 10^6$ lightyear). The consequence of this effect is that only a small fraction of potential sources of ultra high energy particles is visible at Earth. However, as the distance to the sources is small, the directionality of the cosmic rays is maintained even though

The GZK-mechanism

Immediately after the discovery of the existence of the cosmic microwave background in 1965, it was realised by Zatsepin and Kuzmin and independently by Greisen that cosmic rays can interact with the microwave background photons. When a proton of high enough energy hits a cosmic microwave background photon, a delta resonance can be produced, which decays into a nucleon and a pion. The pion removes on average some 20% of the proton's energy. This process continues until the energy of the decay proton is no longer enough to create both a proton and a pion. This occurs at a proton energy of about 40 EeV. These interactions thus lower the proton energy until it is below 40 EeV, which is therefore called the Greisen-Zatsepin-Kuzmin (GZK) threshold. It means that at energies slightly below this threshold, there is a pileup of cosmic rays that were originally accelerated to higher energies. When cosmic rays are observed on Earth *beyond* the GZK-threshold, the region where they were accelerated has to be nearby, that is to say within 100 Mpc.

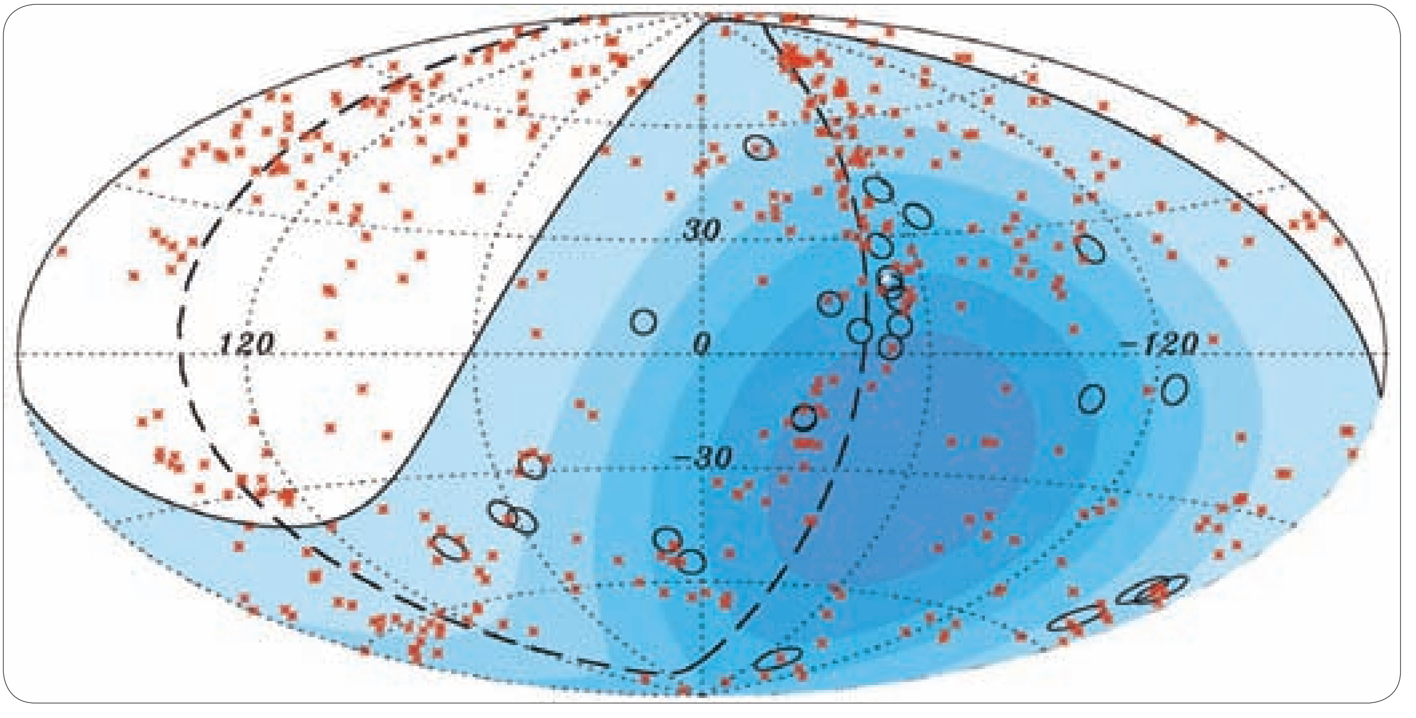


Figure 4. Aitoff projection of the celestial sphere in galactic coordinates. The circles indicate the direction of ultra high energy cosmic rays, and the red crosses the position of 472 active galactic nuclei in the field of view of the observatory. The white area cannot be seen by the observatory.

these electrically charged particles travel through magnetic fields in outer space. This directional information of the highest energy cosmic rays can thus be used to search for point-like sources of ultra high energy cosmic rays.

The Origin of the most energetic Cosmic Rays?

One of the most important questions about the existence of ultra high energy cosmic rays relates to their origin. There are many problems to be tackled before this question can be answered. First and foremost is the fight against statistics, which can only be overcome with a large detector or a lot of patience. Second, there is the problem that no mechanism is known that produces particles with these high energies. The AUGER Collaboration addresses the question whether particles above the GZK-threshold arrive uniformly. Also, answering the question whether the sources of ultra high energy particles can be identified with known celestial objects, is of considerable importance for an understanding of the generating mechanism.

Earlier experiments have claimed to see anisotropies in the arrival directions of ultra high energy cosmic rays. However, the statistical treatment of these claims has always been questioned. The debate has centered around the statistical penalty which is due to the optimisation of a signal. The AUGER Collaboration has eliminated this issue by first creating a GZK-inspired set of variables (energy, opening angle with respect to line of sight to an astrophysical object, and maximum distance of the astrophysical object to Earth), which are optimised using a test data set. The resulting criterion is used to determine if newly incoming data (statistically independent of the previous set) show an anisotropic behaviour. The data taken before May 28th 2006 are used to optimise these variables such that the agreement with an isotropic distribution is minimal. The optimal energy-threshold was found to be 56 EeV, which is slightly above the GZK-threshold. Using a catalogue of active galactic nuclei (AGNs), which is fairly complete up to a distance of 100 Mpc, it was found that in a cone of 3.1° between particle and source there was an excellent correlation, which disagrees with the correlation obtained from an isotropic distribution. When the range of the possible sources is limited to 75 Mpc, the correlation of the highest energy events is maximally different from the correlation obtained from an isotropic distribution. The values obtained in the optimisation support the hypothesis that the energy spectrum steepens downward at high energies due to the GZK-effect. Furthermore, it is hard to envision that without the GZK-effect this type of optimisation would be successful.

Pierre Victor Auger (1899–1993) was a French physicist, who in 1938 positioned particle detectors high in the French Alps. He noticed that particles arrive at the same time in two detectors located many meters apart, thus discovering *'extensive air showers'*. Auger concluded that he had observed showers with a total energy of 10^{15} eV, by far the highest energies measured at the time. The world's largest cosmic ray detector, the Pierre Auger Observatory, is named after him.

Next, optimised values are used to test if the incoming data can be used to either falsify the isotropic assumption at the 99% confidence level or verify it at the 95% confidence level. As soon as either of these conditions is met, the search is stopped and the corresponding conclusion is drawn. From the independent data taken between May 2006 and August 2007 an isotropic assumption was rejected at a 99% confidence level. Furthermore, this data set correlated with the active galactic nuclei in our selection. It was thus concluded that particles with ultra high energies do not arrive isotropically on Earth, but are correlated with the distribution of nearby active galactic nuclei. Fig. 4 displays this. Whether the real sources of ultra high energy particles are really active galactic nuclei, or other objects in the vicinity of AGNs remains to be seen. A search for the origin of this radiation has begun.

1.2 ZEUS
the end of an (H)ERA

Paul Kooijman

It was about twenty five years ago that the possibility of performing electron proton scattering in a colliding beam machine was investigated during a workshop organised at Nikhef. The machine being proposed was a colliding beam facility of very asymmetric energies: electrons of 30 GeV and protons of around 1000 GeV. It was to be placed in Hamburg at the Deutsches Elektronen-Synchrotron (DESY) laboratory. The inequality of the beam energies was of course due to the fact that both the electron ring and the proton ring were to be placed in a single tunnel of a circumference 6.3 km fitting mostly below the Volkspark in Hamburg. At the time the main interest was the investigation of the proton structure at the largest possible momentum transfer (or, equivalenty, at the smallest possible distance scale) and particularly at momentum transfers significantly above the mass of the W and Z bosons, which play an important role in the theoretical decription of elementary particles and their interactions. At such high momentum transfers the proton would be probed at a length scale of the order of 1/1000th of its radius. The hope was also that, when such energy scales would be utilised, new phenomena would become visible.

The machine, which was named HERA (*Hadron-Elektron-Ring-Anlage*), foresaw in several intersection regions, where the electrons and protons were steered out of their individual beam pipes and brought into head-on collision. Two general purpose detectors, H1 and ZEUS, were proposed to perform the measurements at two of these intersections.

The collaborations took shape and by 1985 the ZEUS Collaboration consisted of institutes from around the world. In order to make maximum use of the momentum transfer provided the collaboration decided to base the detector on a compensating calorimeter. This instrument was to have equal response to hadrons and electrons and so compensate for the fluctuations seen in the development of hadronic showers where a varying amount of energy can be dissipated in the production of undetected neutral pions. The compensating calorimeters were required to have resolutions a factor two better than hitherto achieved. Hence, the material used as absorber needed to be depleted uranium. The actual detecting material was still to be decided: people having previous experience with scintillators pushed for liquid argon, wheras others who had experience with cryogenics supported the scintillator option. Measurements done in the test beam proved that the optimal compensation could be obtained with a particular ratio of thickness of absorber and scintillator. A major contribution to this test beam work was given by a dedicated group from Nikhef.

Having proved that compensation really could be achieved, work started on the real design of the calorimeter. Institutes from the USA, Canada, Germany and Japan worked together with Nikhef to design a calorimeter to surround the intersection region at the collider. It was split in a forward and rear and a cylindrical barrel calorimeter. The genuine design, which started in 1986, was modular, 20 cm wide, 160 cm deep and in the largest modules

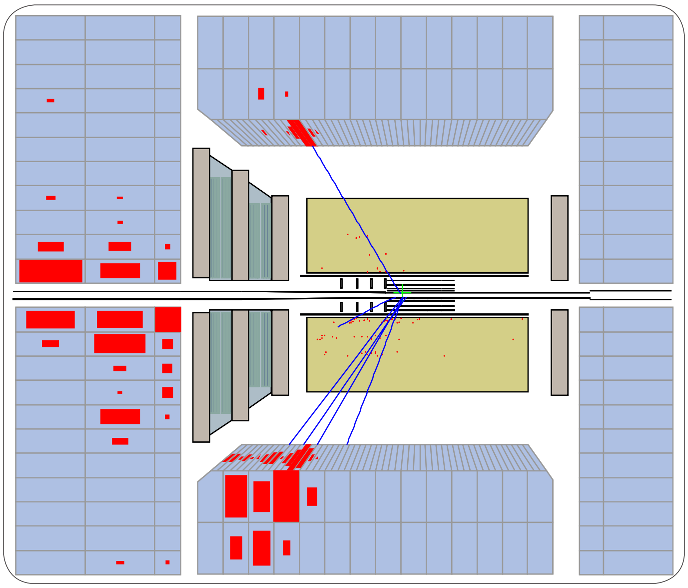


Figure 1. A deep-inelastic event caused by a neutral current interaction, observed in the ZEUS detector.

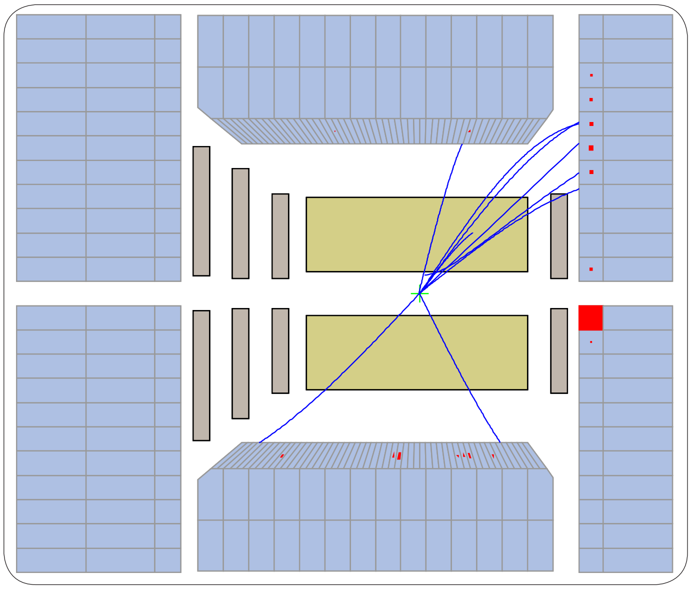


Figure 2. A diffractive event; note the absence of activity – no red colors at the lefthand side – around the beam pipe.

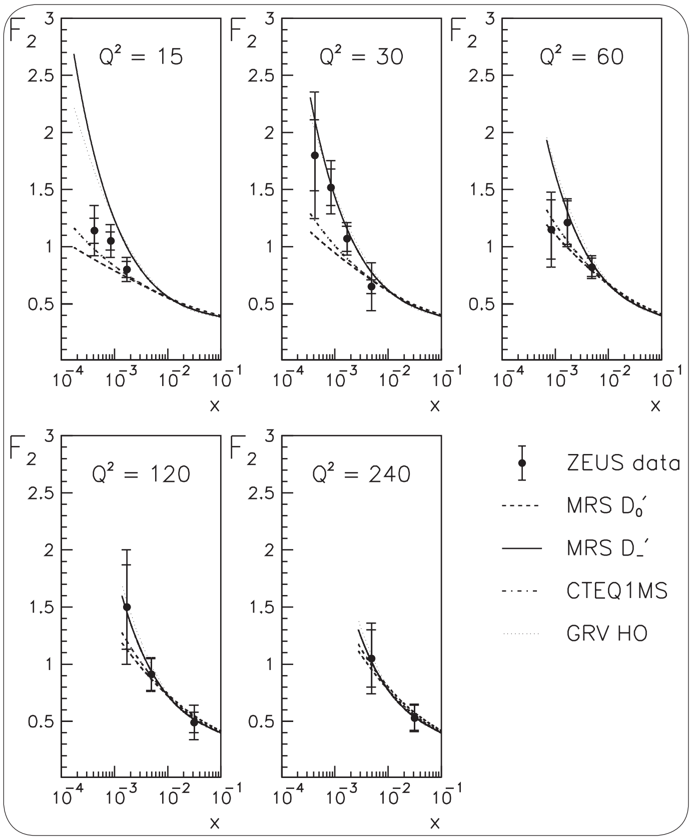


Figure 3. The first measurement by ZEUS in 1992 of the F_2 structure function

500 cm high, built of plates of stainless steel clad depleted uranium interspersed with scintillator tiles. The readout was done with wavelength shifters leading to photomultiplier tubes at the rear of the modules.

In the mean time a second major item had also been claimed by Nikhef: the global second-level trigger. This used a state of the art device for networking: the Transputer. This device, introduced by the Nikhef group, was accepted by the collaboration not only for the trigger but also for the readout and event building.

Together with these hardware activities tasks were undertaken in the simulation and analysis software of the experiment.

Following many trials and tribulations the detector was finished in time for the first beam at the collider in 1992. The first publications came at the end of 1992 providing a measurement of the photon-proton cross section at an unprecedented centre of mass energy of 210 GeV, a second indicating that the first deep-

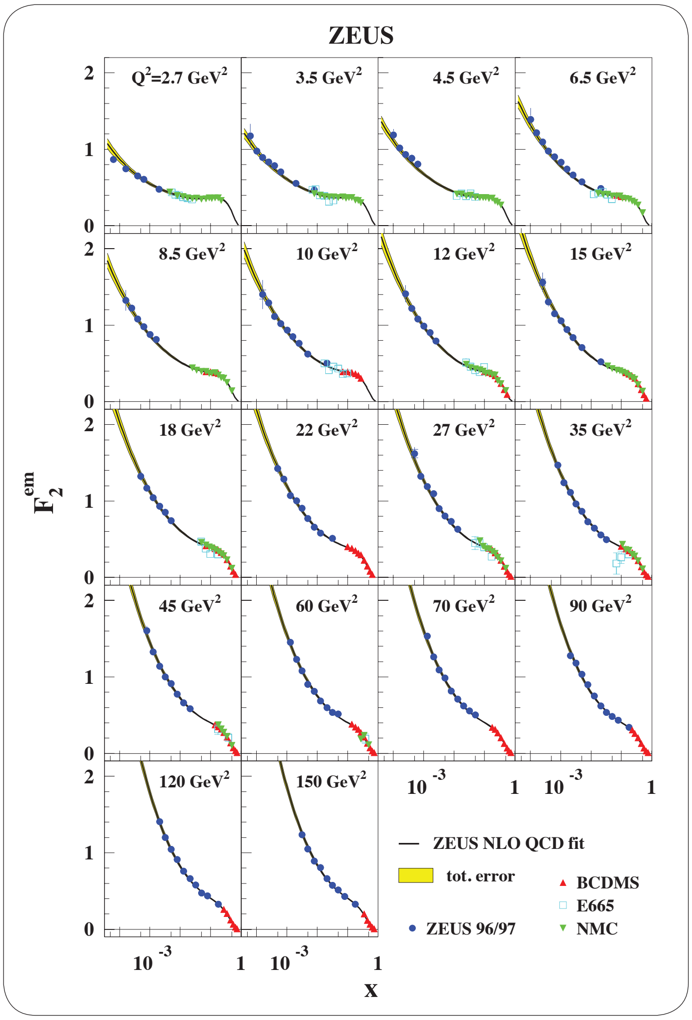


Figure 4. The final measurement by ZEUS of the F_2 structure function. The curves represent fits to the data based on the theory of Quantum Chromodynamics.

inelastic scattering events induced by neutral currents had been seen (see Fig. 1) and a third publishing the observation of jets in photo-production.

At the same time events started appearing in which hadrons were produced just like in standard deep-inelastic scattering but where the proton seemed to continue on unperturbed. (compare Fig. 1 and Fig. 2). These diffractive events had been seen before in proton-proton scattering and had been interpreted using the exchange of the hypothetical Pomeron particle. The occurrence of these events in deep-inelastic scattering allowed the investigation of this particle in terms of quarks and gluons.

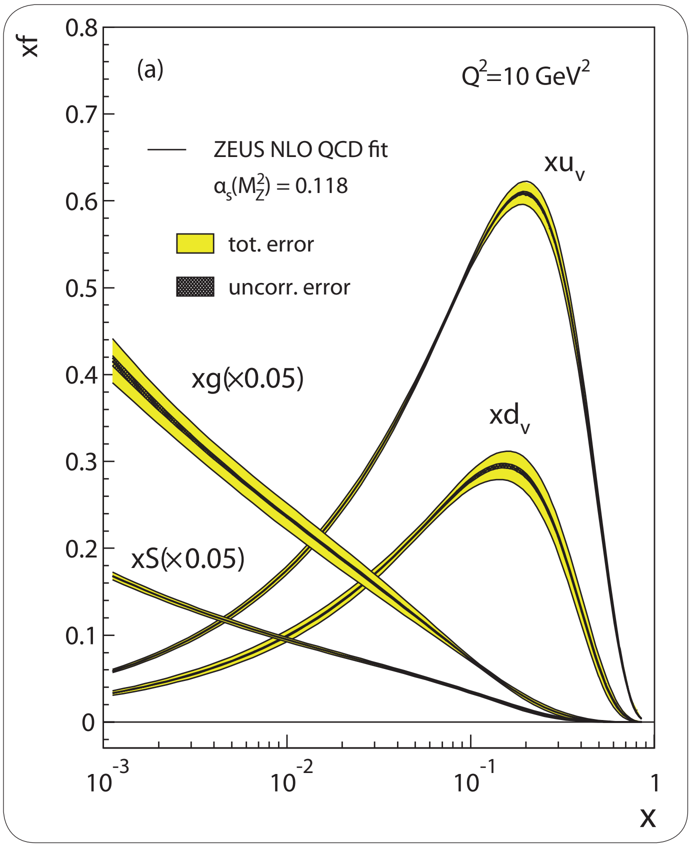


Fig. 5: Extracted distributions of quarks and gluons. Note the factor 20 suppression of the gluon (xg) and sea quark (xS) densities, compared to the valence quarks (xu_v, xd_v).

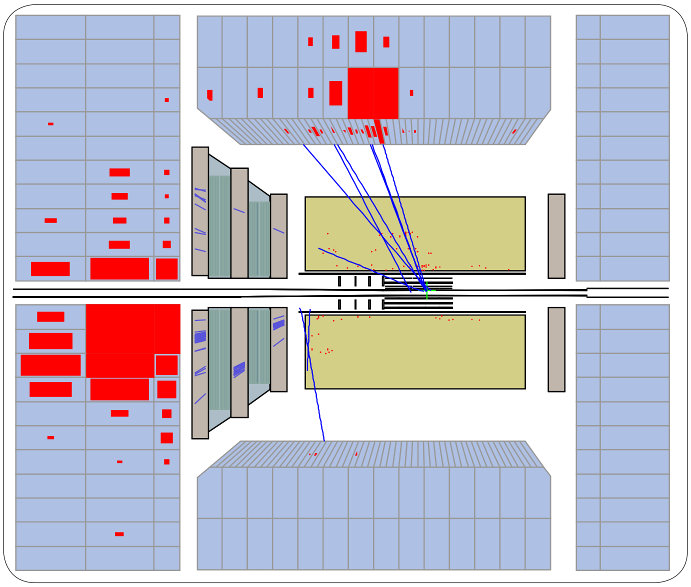


Fig. 6: An example of a charged current interaction.

In the following year the first surprises arrived. The cross section at very low values of the kinematic variable x, the fraction of the proton's momentum carried by the struck quark, turned out to be much larger than expected in deep-inelastic scattering. Fig. 3 shows the first measurement done by ZEUS of this effect. With an increasing amount of data not only did the statistical and systematic accuracy improve, but also the interpretation of the structure functions within the framework of Quantum Chromodynamics became more accurate. The simple leading-order models shown in Fig. 3 made way for more complicated next-to-leading-order models. Fig. 4 shows the state of the art data and model fitting. In a large fraction of the kinematic range the accuracy of the data reached 2%. The fits to these data have provided an accurate description of the densities of quarks and gluons inside the proton. Fig. 5 shows the quark and gluon densities extracted from these fits together with their errors. The latter are so small that for instance at present the production of Z^0 bosons through quark anti-quark annihilation can be calculated with an accuracy of 5–10% for the kinematic conditions of proton-proton collisions in LHC.

The structure function measurements and their interpretation have over the years been the particular expertise of the Nikhef group.

A second important part of the programme was the investigation of the charged current interaction, which is mediated by the exchange of a charged W boson. The incoming electron thereby changes into a neutrino that leaves the interaction region undetected. An example of such an interaction is shown in Fig. 6. The cross sections as a function of the squared momentum transfer Q^2 are given in Fig. 7 and compared to the cross sections mediated by the neutral current. Here, both scattering of positrons and electrons are shown. At large Q^2 all cross sections become of comparable size. It is again possible to deduce the cross sections from the fitted parton distributions which shows that these are the wanted universal distributions describing the inner structure of the proton.

After many years of experimentation the decision was made to upgrade the luminosity of the HERA collider (after nine years of running a total of 160 pb^{-1} of data had been collected, whereas the design had been 100 pb^{-1} per year). In 2001 a shutdown took place and new focussing magnets were installed in the interaction regions of H1 and ZEUS. At the same time spin rotating magnets were installed to allow the measurement of charged

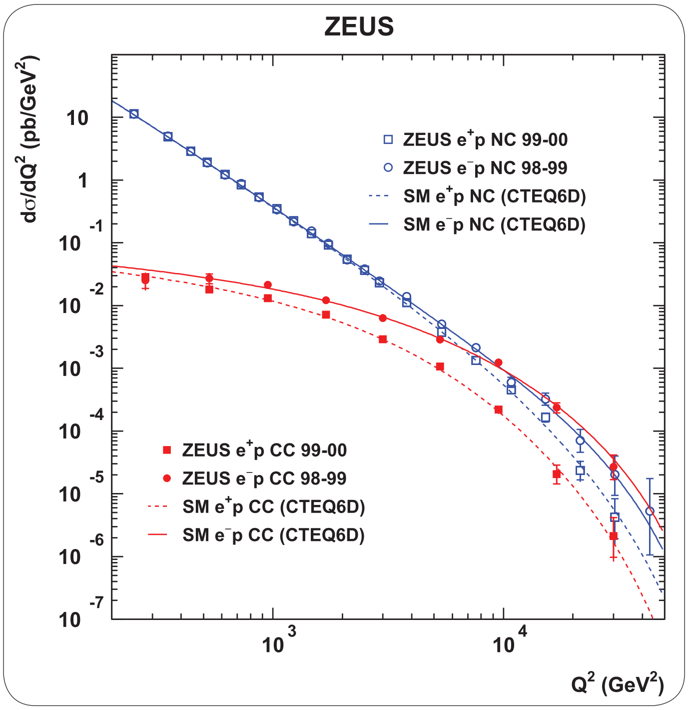


Fig. 7: The charged (red) and neutral (blue) current cross sections as a function of Q^2.

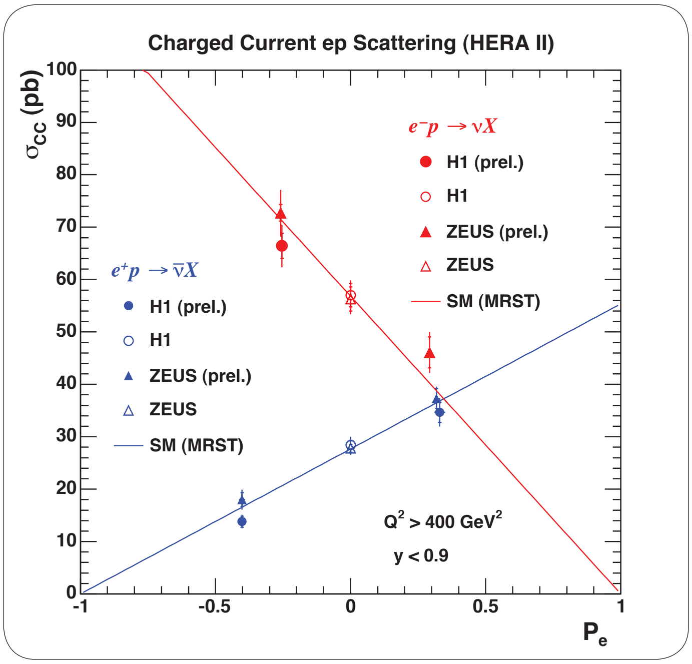


Fig. 8: Charged current total cross section as a function of the degree of polarisation. Cross sections for both positrons and electrons are given. The expected behaviour (straight lines) of the left-handed charged current is observed.

and neutral current interactions with longitudinally polarised beams. The charged current cross sections for electrons and protons as a function of the degree of polarisation showed the behaviour expected for the left handed current (see Fig. 8).

Simultaneously with the luminosity upgrade of the collider the ZEUS detector was upgraded with a silicon micro-vertex detector. It was assembled at Nikhef and allowed a more accurate investigation of heavy quark production by the reconstruction of the decay vertices of the particles containing these heavy quarks. Fig. 9 is taken from the latest thesis to come out of the ZEUS experiment (G. Grigorescu) and shows the reconstructed signal for D^0 particles. The new vertex detector helped to reduce the lowest measurable transverse momentum to 1.5 GeV.

In all ZEUS has been an active experiment for more than 15 years and in that time has published over 170 papers, the three F_2 structure function papers have together been cited over 1000 times. At Nikhef 21 theses have been produced from ZEUS data, where one more is still expected. All in all a successful enterprise, with its roots at Nikhef.

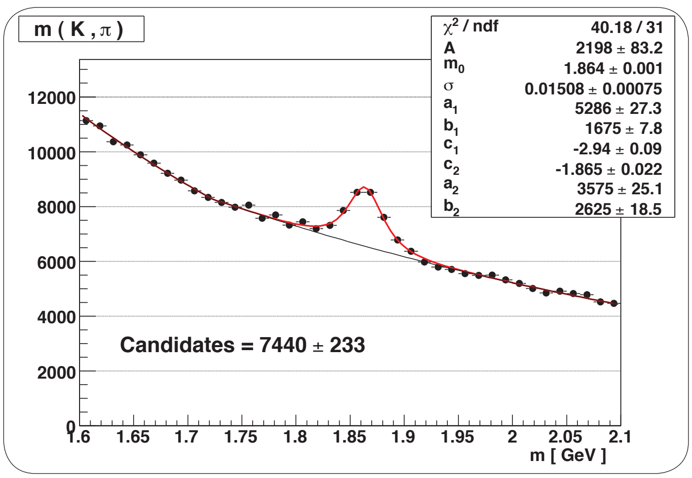


Fig. 9: The Kπ mass spectrum with the clear signal of the D^0 meson.

1.3 HERMES
Resolved a part of the Nucleon Spin Puzzle

Jos Steijger & Godelief Nieuwendijk

What is the contribution of the various quark flavours to the nucleon spin? And what exactly is the contribution of the gluon to this spin? That were the research questions with which the FOM research programme “Nucleon spin, flavour and glue” started in 1997. Now, at the end, the Nikhef research team has concluded that not one of the flavours specifically dominates the spin, but that it is a matter of a fine tuned collaboration of all these contributors. The scientists are also pretty sure that the influence of gluons on the nucleon spin is very small, and the same can be said of the orbital momentum of the up-quarks.

It is important to understand the spin of the nucleon as it plays a key role in the dynamics of quarks and gluons in the nucleon. Understanding that dynamics may result in understanding the origins of the mass of the nucleon and also in insight in the origins of the mass of the visible matter in the Universe. The Nikhef physicists were not only strongly involved in the analysis and interpretation of the data, they also developed several innovative technical systems as part of the research programme.

The FOM research programme was a part of the HERMES experiment at the accelerator lab DESY in Hamburg; in this collaboration participated about 31 research institutes from ten countries (see Fig. 1). The reason to start the HERMES experiment in 1990 was the so called spin crisis in 1988: the then emerging Quark Parton Model, which describes the structure of the nucleon, appeared to be inadequate. At the time, measurements of the EMC Collaboration at CERN showed that the spins of the individual quarks contributed only an unexpectedly low 13% of the total spin of the nucleon. Originally the research focus of HERMES was on the neutron structure functions as they were poorly known and considered necessary to resolve the spin crisis. When the Nikhef team joined the collaboration in 1995 the general HERMES objective was to study the spin structure of the nucleon with the polarized electron or positron beam of HERA and a polarized gas target, internal to the accelerator. The specific Nikhef goal was to determine the helicity (longitudinal spin) distribution more accurately, to determine the quark flavour decomposition and to provide early measurements of the transversity (transverse spin) and gluon spin distributions.

Figure 1. Aerial view of the DESY site showing the location of the HERA ring and the HERMES experiment.

Flavours

The spin dependent distribution functions can be measured with deep-inelastic scattering experiments. The sensivity of such reactions to the spins of the quarks is due to the use of a polarized beam and polarized target nucleons. When the quark spins contribute to the nucleon spin, the former are also polarized and their relative orientation can be determined by measuring the difference between the scattering with beam and target polarizations parallel and anti-parallel. When also the remaining parts of the target nucleon are detected, information on the flavour of the struck quark can be deduced.

The Nikhef researchers used the HERMES spectrometer and its detector to observe yields of some of the produced hadrons. From this they could deduce which quark flavours contributed to the nucleon spin and how much (see Fig. 2). They confirmed CERN and SLAC experiments as well as the earlier conclusion of the EMC experiment that the nucleon spin is not carried by the quarks alone. This contribution has now been determined more accurately to be 33% of the total spin of the nucleon. The flavour decomposition showed that the sea quarks do not contribute enough to make up the difference. So the researchers directed their attention to the gluon spin and the orbital momentum.

Gluon

The contribution of the gluon spin was deduced indirectly from analysis of QCD (Quantum chromodynamics)-fits with different beam energies, and also with a direct method. A direct measurement of the gluon contribution is possible if a process can be identified that has a gluon in the initial state. Photon-gluon-fusion is such a process, which is measurable in lepton scattering. The final state of this process contains a charmed quark, or consists of a quark-antiquark pair emitted back to back in the photon-gluon centre of momentum system. These quarks fragment to hadrons with a large transverse momentum which can be detected. Several background processes contribute to the same final state, but these are not sensitive to the gluon polarization.

Quark Orbital Angular Momentum

The HERMES researchers wanted to know more about the role of the orbital momentum, but experimental information on the orbital angular momentum of quarks and gluons in the nucleon was not available. They explored therefore a new method to obtain a first estimate of this component of nucleon spin. It is based on the framework of Generalized Parton Distributions (GPDs). GPDs take into account the dynamical correlations between partons with different momenta.

Experimentally, the yields of photons and mesons (hadrons consisting of a quark-antiquark pair) are measured which are produced when an electron or positron is scattered, considering only those events for which all products are seen. GPDs can be investigated by observing these processes. At HERMES various reaction channels have been explored, including Deeply-Virtual Compton Scattering and ρ^0 vector-meson production. One of the most interesting results has been obtained by measuring the asymmetry of the yield of ρ^0 vector-mesons produced on a transversely polarized target. The measured asymmetry is particularly sensitive to the total angular momentum of the quarks. By comparing these data to the results of GPD-based calculations, a model-dependent first estimate of the total angular momentum of the quarks in the nucleon can be obtained. As the spin angular momentum is known from previous experiments, information on the orbital motion of quarks can be deduced. The preliminary result for the contribution of the orbital momentum of the u-quarks to the spin of the nucleon is rather small.

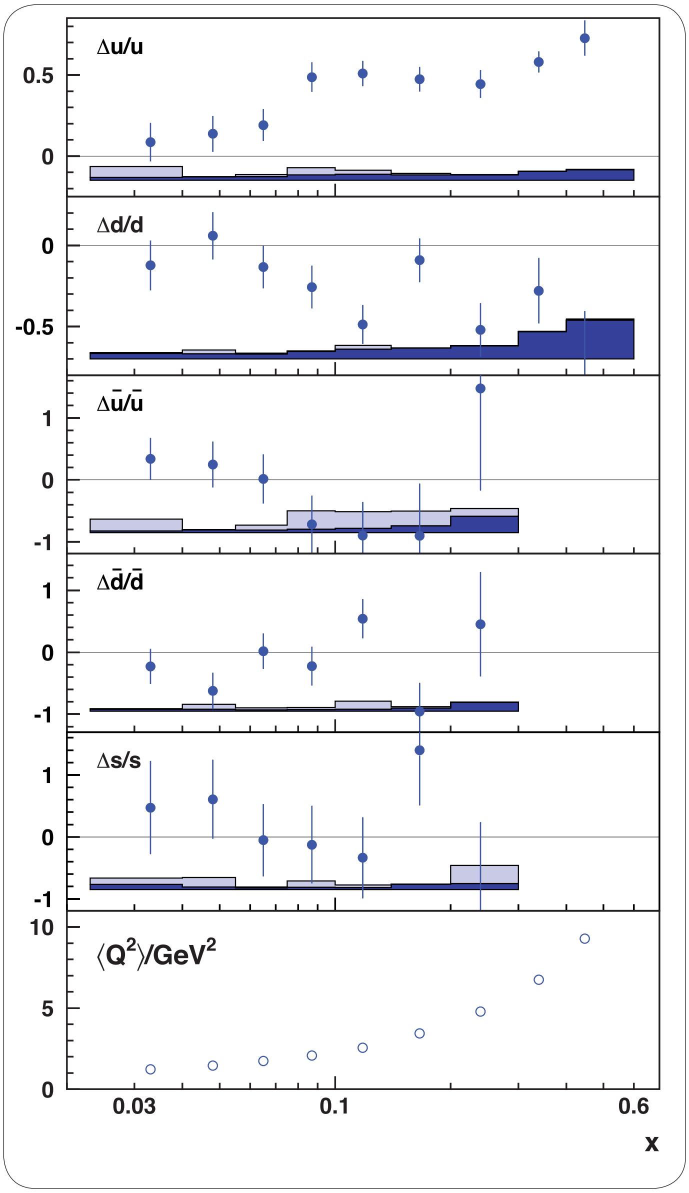


Figure 2. HERMES result for the decomposition of the quark spin contributions in the quark flavours u(p), d(own) and s(trange).

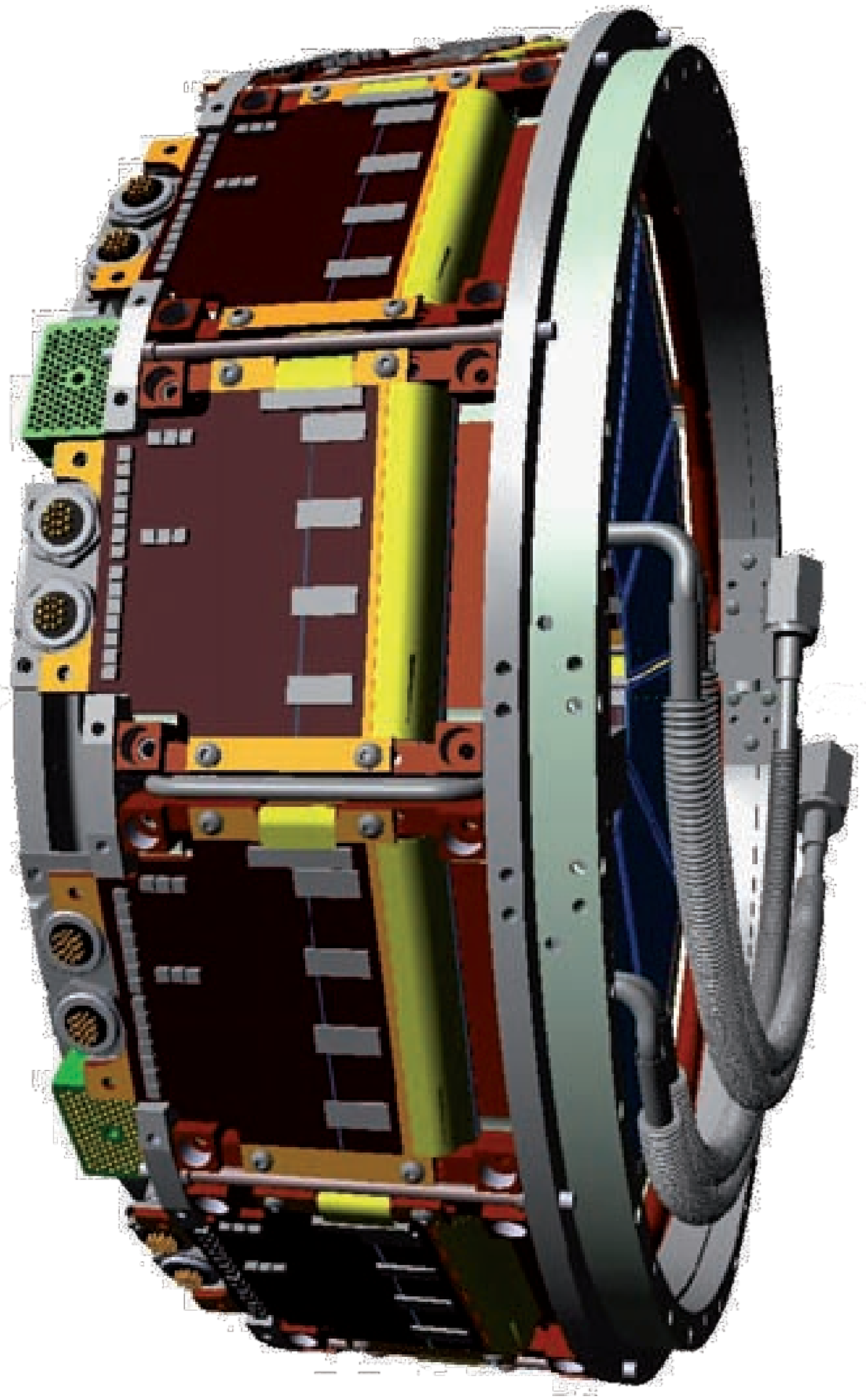


Figure 3. CAD-drawing of the Lambda Wheels detector.

Transversity and nuclear effects
New was the studying of the transversity distribution – the third of the five structure functions of the nucleon. This transversity distribution is not influenced by gluon contributions. The results were remarkable, because they contradicted former, intuitive expectations.

The study of nuclear effects on the structure of nucleons has resulted in an accurate determination of the A dependence of R: the relative hadron multiplicity measured on the nucleus with mass A with respect to that measure on the simplest compound nucleus: the deuteron. A comprehensive data set has been produced on a number of nuclei in the range from A=2 to A=131. Based on this data set evidence has been found for both partonic and hadronic energy-loss processes, by using the nucleus as a filter. Different nuclei have different sizes, and therefore a different mixture of partonic (before hadronization occurs) and hadronic (afterwards) energy loss. These data are also very valuable for experiments on the quark-gluon plasma in which the hadronization takes place completely within a nuclear medium.

Innovative instruments
Nikhef designed and built various detector systems for the HERMES programme: before 2000 a large part of the EM-calorimeter and a large MSGC-based detector. A Multi-Strip Gas Chamber (MSGC) is a gasdetector in which wires are replaced by thin strips layed on a glass substrate with a photographic process resembling the processes used in the IC production. Nikhef's MSGC detector was the first which was used in the hostile environment of a high-energy beam colliding on a dense gas target. Later, after 2000, a wheel shaped silicon detector array was built, called the Lambda Wheels (Fig. 3), which is installed inside the high vacuum of the accelerator. The experience gained in the construction of this detector was used for another, larger scale silicon array incorporated in the recoil detector assembly that was employed in the last three years of HERMES operation. The Nikhef group also pioneered the first very fast radiation monitor. It protects the expensive and sensitive detectors against the damage of an unintended loss of the beam in the storage ring.

Nikhef joined the HERMES Collaboration under the leadership of prof.dr.ing. J.F.J. van den Brand in 1993, succeeded by prof.dr. G. van der Steenhoven in 1996. As of 1997 the Nikhef contribution was embedded in the FOM programme "*Nucleon spin, flavour and glue*", the supervison of which was taken over by dr. J.J.M. Steijger in 2005. This programme resulted in a long list of publications and 14 doctoral theses (the 15th is due in the first half of 2008).

2

Research

2.1 Physics at the TeV Scale: ATLAS

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

"Simplicity does not precede complexity, but follows it"

The ATLAS Collaboration is building a large, multi-purpose detector for physics at the Large Hadron Collider (LHC), a 14 TeV proton-proton collider at CERN, Geneva. In the course of 2007 it became clear that the first collisions of LHC will not be produced before summer 2008. The ATLAS community needed this year to finish the installation of the immense and complex detector, and to be well prepared for data reconstruction and physics analysis. Nikhef plays a central role in various aspects of these. Spectacular was notably the installation of the large endcap toroidal magnets, which have been constructed by Dutch industry. The ATLAS detector is hereby nearly completed, and commissioning is well under way.

SCT detector

In January 2007, the semiconductor tracker (SCT) end-cap A, which was assembled at Nikhef and transported to CERN earlier, was integrated at the surface clean-room with the Transition Radiation Tracker (TRT). Each SCT end-cap, which consists of approximately 1000 detector modules mounted on nine carbon fiber wheels in one cylindrical construction, will measure the directions of charged particles with high precision, using 1.5 million channels. Technical difficulties, unrelated to the SCT, caused several delays to the subsequent installation in the ATLAS experiment, but towards the end of May the installation was completed. The technical difficulties involved the operation of the cooling system of all ATLAS silicon detectors, and parts

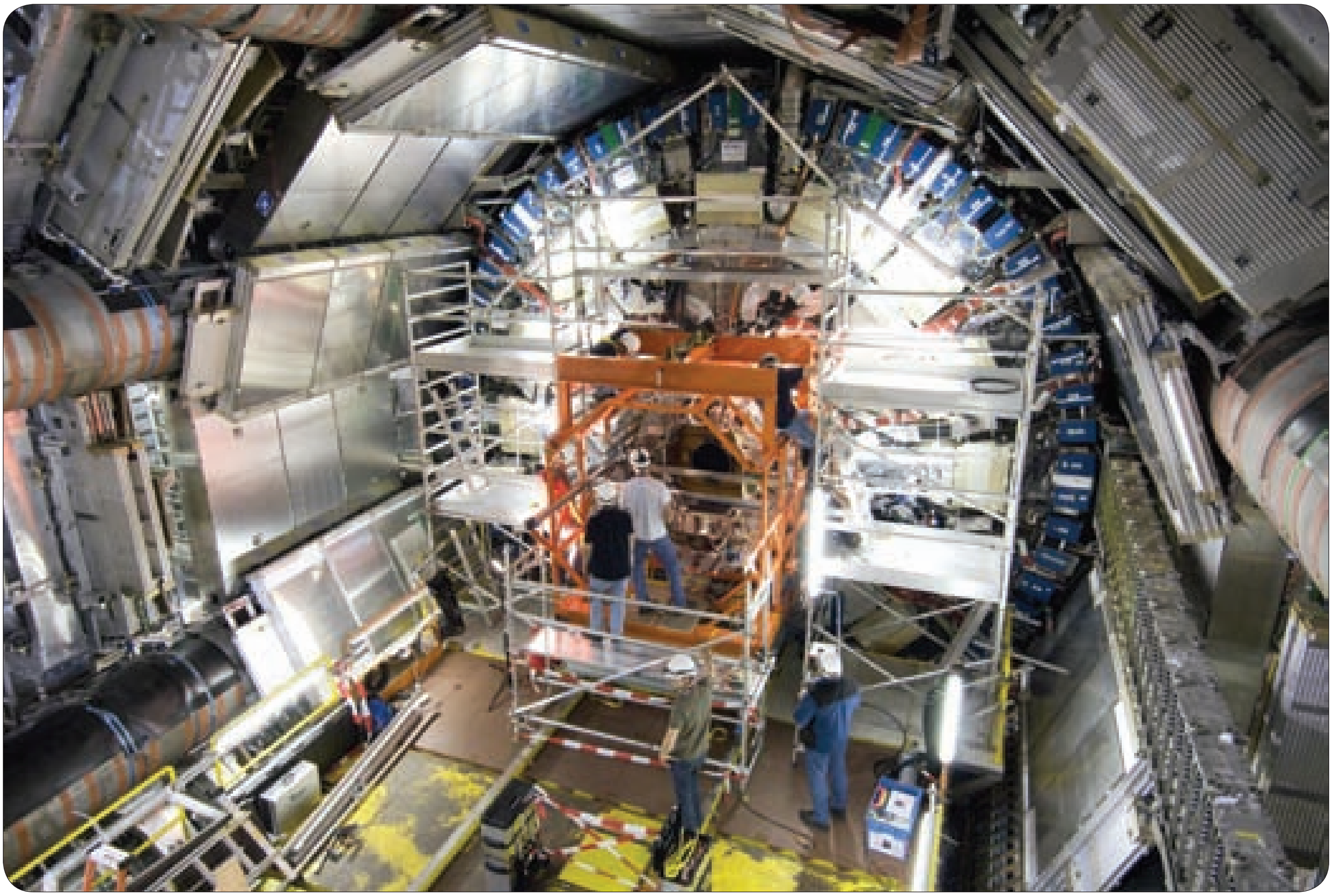


Figure 1. An inner detector endcap being installed in the heart of ATLAS.

of the system had to be reworked. Nikhef technicians stepped in to solve these complex technical problems. Final sign-off of the fully functional detector is expected during January 2008, simultaneously with endcap C, and the barrel, completing the total SCT system.

Muon system

The muon chamber installation activity reached its most intense period at the beginning of 2007, when the last of the 96 BOL chambers constructed at Nikhef was installed in the ATLAS cavern. After completion of the whole barrel system the Rasnik projective alignment systems were installed to allow precise placements of the chambers. The final version of the electronic read-out boards of the muon system (MROD) were assembled and tested and, with minor adjustments, installed in readout racks next to the ATLAS detector. Together with the Detector Control System (chamber initialization, temperature and magnetic field strength measurements) the Nikhef hardware installation is practically completed.

Parts of the muon spectrometer, calorimeter and a part of the inner detector, were active during several periods in the year and measured millions of cosmic muons passing through ATLAS. These tests were used to check the performance of the detectors, as well as the trigger and data acquisition systems and the muon track reconstruction software (which was largely developed at Nikhef). Following the ATLAS computing model, data were distributed via the CERN Tier-0 to the various Tier-1 centers all over the world, including Nikhef/SARA in Amsterdam. This test proved to be invaluable to guarantee efficient computing operation during ATLAS running in 2008.

Physics readiness

The analysis groups concentrated on the physics potential of ATLAS. Millions of collisions were simulated with a detailed ATLAS detector geometry, including the read-out and trigger simulations, to study the reconstruction of electrons, photons, muons, tau leptons, jets and missing energy. A large effort was made to assess the uncertainties of the 'known' Standard Model physics processes like Z-boson or top-quark production, to the benefit of reliably assessing new 'unknown' physics processes among the numerous and complex backgrounds. Nikhef scientists are actively searching for Higgs boson production using muons and, likewise, Nikhef participates in the reconstruction and analysis of top-quark production in order to search for the simple elegance of supersymmetry.

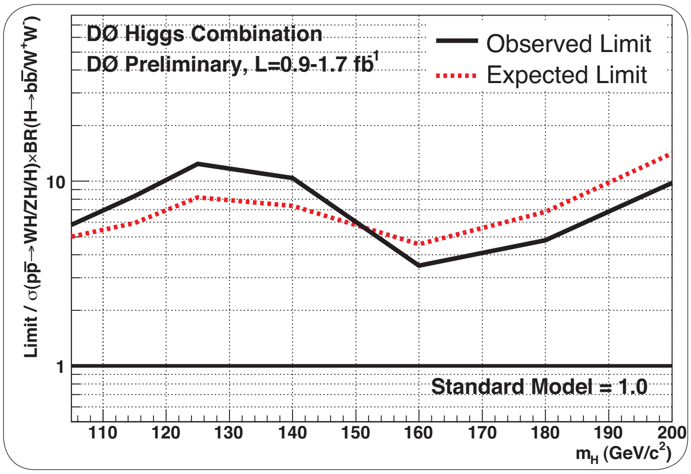


Figure 2. DØ upper limit, at 95% confidence level, of the Higgs boson production cross section, expressed in units of the Standard Model expectation, as a function of the Higgs boson mass.

DØ

In preparation for the LHC, and to do physics at the high-energy frontier before LHC starts, Nikhef physicists participate in the DØ experiment at the Tevatron (Fermilab, Chicago: proton-antiproton collisions at 2 TeV). The total delivered luminosity to DØ in run 2 now exceeds 3 fb^{-1}, and nearly 100 papers have been published or accepted for publication.

The fast increase in luminosity has been accompanied by an increase in sophistication in many physics analyses. Notably, the DØ evidence for electroweak production of single top quarks (October 2006) constitutes an important benchmark towards the search for the Standard Model Higgs boson. Fig. 2 shows the combined DØ limit on the Higgs boson search, demonstrating that part of the mass range is almost within reach of exclusion by DØ. Significant progress is also being made in the analysis of physics channels important to supersymmetry, notably an improved upper limit ($< 7.5\times10^{-8}$) on the branching fraction for the rare decay process $B_s \rightarrow \mu^+\mu^-$, and further constraints on the masses of squarks and gluinos.

The Nikhef DØ group works on muon and tau reconstruction, jet energy scale calibration, and bottom quark identification. It uses these results in the search for Higgs bosons, as well as in the measurement of the top-quark mass, and searches for large extra dimensions.

2.2 Physics with b-quarks: LHCb

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

The LHCb experiment at the LHC is in its final installation phase and almost ready for taking data. The experiment is dedicated to a study of asymmetries between the laws of physics for matter particles and those for anti-matter particles using the decays of beauty (B) mesons, which consist of a heavy b-quark and a light quark. The Nikhef group constructed and installed two tracking detector systems that measure the trajectories of charged particles produced in the decays of these B-mesons. The vertex locator (VELO) detector precisely determines the decay vertex of the B-particles and the Outer Tracker (OT) detector serves to measure the momentum of each particle.

VELO

The VELO detector consists of two detector halves of 21 measurement planes each. During the injection and acceleration of the proton beams in the collider these detector halves are retracted in a safe position, 30 mm away from the beam. As soon as the accelerator is in stable, low-background, collision mode the detectors are brought to a distance of 8 mm from the beam, allowing high precision vertexing. The two detector halves were assembled at CERN with parts produced at Nikhef during the first half of the year. A special support system was constructed in Liverpool to avoid mechanical contact between the silicon detectors and the RF-foil that separates the detectors from the beam vacuum. The installation included two dedicated detection layers that allow to count the number of vertices at the lowest trigger level. A major milestone was achieved in October when the detectors were installed around the interaction point in the experiment and the open/close moving system was commissioned. After installation the vacuum pumping system was tested and a vacuum pressure of 3×10^{-9} mbar was obtained. The special two-phase CO_2 cooling system developed at Nikhef, required to keep the detectors at a nominal temperature of –5 °C has been installed and is being commissioned.

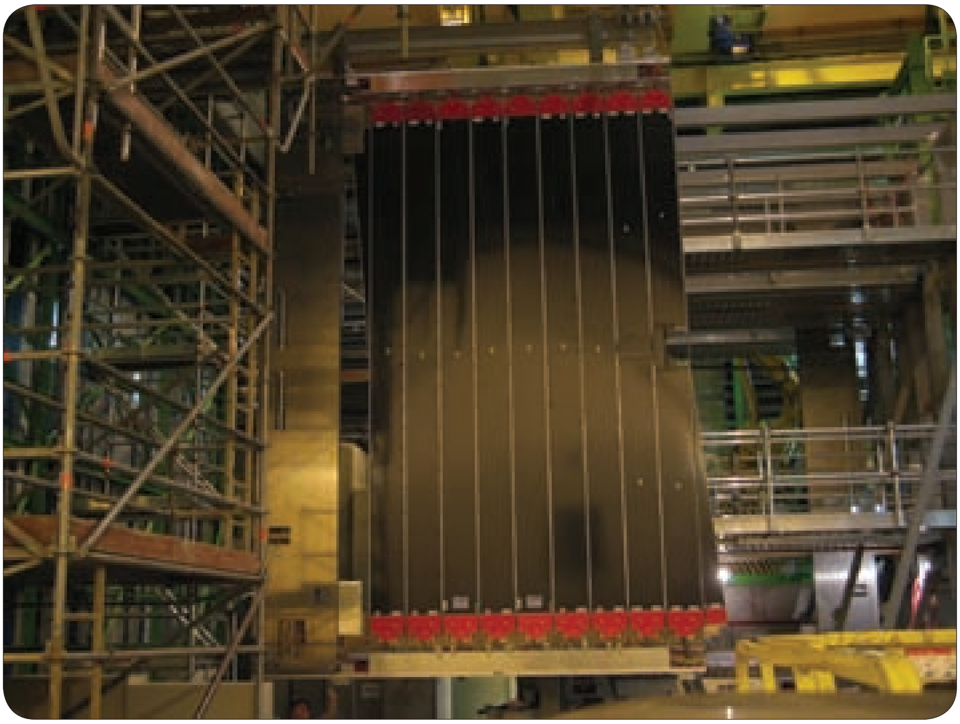
Outer Tracker

The Outer Tracker uses 54 000 precision straw drift detectors to determine the impact position of charged particles as they traverse the detectors. All detector modules have been installed in the experimental hall and have been tested to be functioning correctly. In the installation procedure special care was taken to align the 6×3 m^2 half-detector planes to within 1 mm of their design position. The mass production at Nikhef of the front-end electronics modules of the straw detectors is almost completed. To commission the detector, a cosmic ray muon trigger has been installed, and the first data have been taken exercising the full data acquisition system in the experiment as well as part of the reconstruction software.

Figure 1. A VELO detector half is being positioned into its final position around the collision point of LHCb. The silicon detector wafers are visible on the left side of the picture.

At the same time detector modules were observed to suffer from a gain loss after exposure to intense irradiation in a lab test setup. This effect was extensively studied during the year and the cause of the gain reduction has been determined to be a thin insulating carbon layer around the anode wire of the detector. This layer is formed in a complex process involving outgassing of the glue used to construct the modules and radiation incident on the detector. Treatments preventing formation of

Figure 2. The installation of a half-plane of Outer Tracker detectors. The aluminium C-frame carries two double-layers of straw tubes; the front side is mounted vertically, the backside layer is positioned under a 5 degree stereo angle.



the insulating layer as well as recovery procedures for possible gain loss are currently being established.

Track Reconstruction

In preparation for LHC data, software algorithms were further developed to convert the observed detector hits into reconstructed trajectories of the charged particles across the experiment. The 3-dimensional particle trajectories are fitted using a Kalman filter track-fitting procedure which has been fully integrated with the detector geometry database. Any known deviations of individual detector elements from their nominal geometry are thus automatically included into the tracking procedures. In addition, software procedures to measure possible misalignments of detector planes using the observed data were developed. The convergence of these algorithms is illustrated in Fig. 3. For the large Outer Tracker detector a software alignment precision of 50 μm is foreseen, while for the silicon planes in the VELO a precision better than 5 μm is expected.

Preparing for Physics

In anticipation of the high event rate for B-particle production at the LHC, software is prepared to (pre-)select candidate signals for dedicated B-decays in the High Level Trigger, as well as in offline analysis. For the first data, the Nikhef group is preparing the selection of B-decays that include a pair of muon particles in the final state, as these provide a clear trigger signature and allow further commissioning of the detector. On the longer term the Nikhef group is putting a focus on interactions that involve the coupling of a b-quark to an s-quark with the aim to find signs of physics beyond the Standard Model that could affect the matter-antimatter asymmetry in the laws of physics.

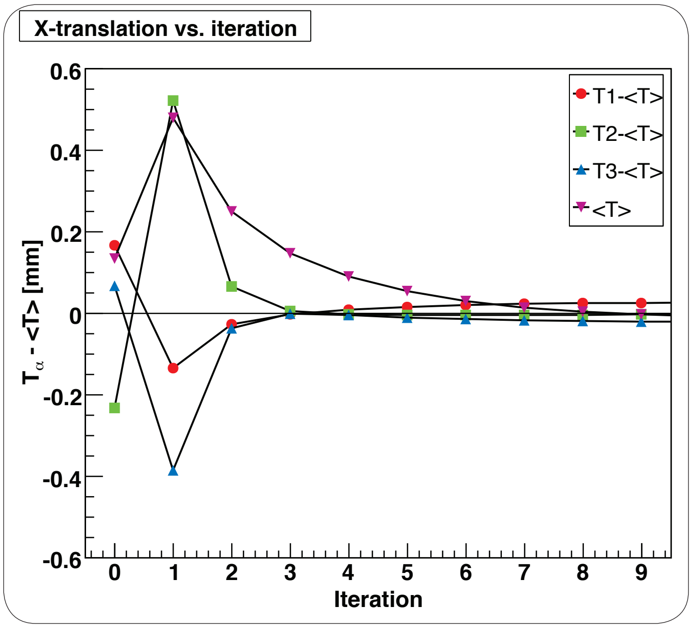


Figure 3. An illustration of the performance of the tracking software alignment algorithm using Monte Carlo data. The curves illustrate how the software corrects within several iterations for a simulated misalignment of all three Outer Tracker detection layers. The vertical axis is the deviation of the reconstructed layer position with the true position.

2.3 Relativistic Heavy-Ion Physics: ALICE

Management: Prof. dr. Th. Peitzmann
Running period: 1998 - 2013

Introduction
The prime goal of the heavy-ion research program is to study the phase diagram of subatomic matter at extreme temperatures and densities. The Standard Model of particle physics predicts a transition to a new state of matter dominated by quarks and gluons, the *quark-gluon plasma*. This state should have prevailed in the Universe the first few microseconds after the Big Bang, and is expected to be reached also in heavy-ion collisions in the laboratory. The Large Hadron Collider (LHC) at CERN will open up a new energy frontier in heavy-ion collisions. The energy available in heavy-ion collisions $\sqrt{s_{NN}}$ = 5.5 TeV, which is thirty times higher than at the Relativistic Heavy Ion Collider (RHIC, Brookhaven, USA), will allow us to probe quark-gluon matter at unprecedented values of energy density.

The Nikhef heavy-ion group participates in the STAR experiment at RHIC and in the ALICE experiment at the LHC. In 2007 the activities of the group were focussed on the installation and integration of the Silicon Strip Detectors (SSD) in ALICE. In addition to this hardware effort the Nikhef group continued with the analysis of the current STAR data and with the development of software to analyse the future LHC data from ALICE.

Results from STAR
The earlier results from STAR and other experiments at RHIC, show strong evidence for the creation of a highly interactive non-hadronic system in heavy-ion collisions. The system is perhaps best described as a non-viscous quark-gluon liquid and is in addition almost opaque to fast partons. The degree of thermalization of the system is still a strongly debated open issue. Recent detailed analysis of the azimuthal asymmetry in particle emission by our group, shown in Fig. 1, indicates that the hydrodynamical limit may not be reached even at the highest energies available at RHIC.

ALICE analysis preparations
The discoveries at RHIC have transformed our picture of nuclear matter at extreme energy densities and, in addition, also changed the emphasis in the observables best suited for extracting the properties of the created system. The ALICE detector is well suited for measuring the most successful probes which include: azimuthal asymmetry in particle emission, high-p_T jets and open and hidden heavy flavours. The group's main focus is on the measurements of the azimuthal asymmetry in particle emission, also known as anisotropic flow. Measurements of the anisotropic flow for inclusive charged particles are a high impact result, which can be obtained from a relatively small data set, obtained during the first weeks of running heavy-ion collisions at the LHC. From our experience at RHIC we know that the main systematic uncertainty

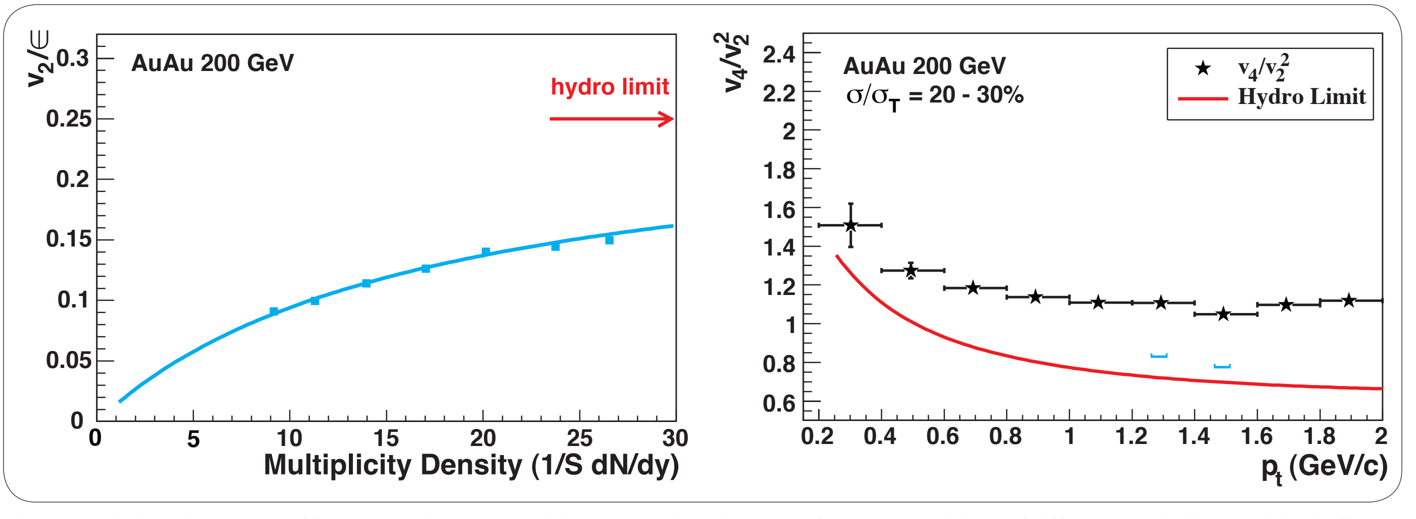


Figure 1. Elliptic anisotropy v_2 of flow normalized to the original geometric anisotropy ε for Au+Au collisions of different multiplicity densities (left), ratio of the fourth order anisotropy v_4 to the square of v_2 as a function of transverse momentum (right). In both cases the experimental results shown as data points do not agree with theoretical estimates using ideal hydrodynamics, as indicated with the red arrow (left) and red curve (right).

in the anisotropic flow measurement comes from so called 'nonflow' effects. Examples of nonflow contributions in traditional analysis methods are resonance decays and, a very important contribution at the LHC, jet fragmentation. To address this in a systematic way our group is developing and implementing analysis methods that eliminate nonflow contributions in a completely model-independent way. These methods also, for the first time, open the way for unbiased measurements of correlations of high-p_T jets and open-charm production with the reaction plane. Such measurements will allow us to better understand the parton energy loss mechanism and determine the color density of the created system.

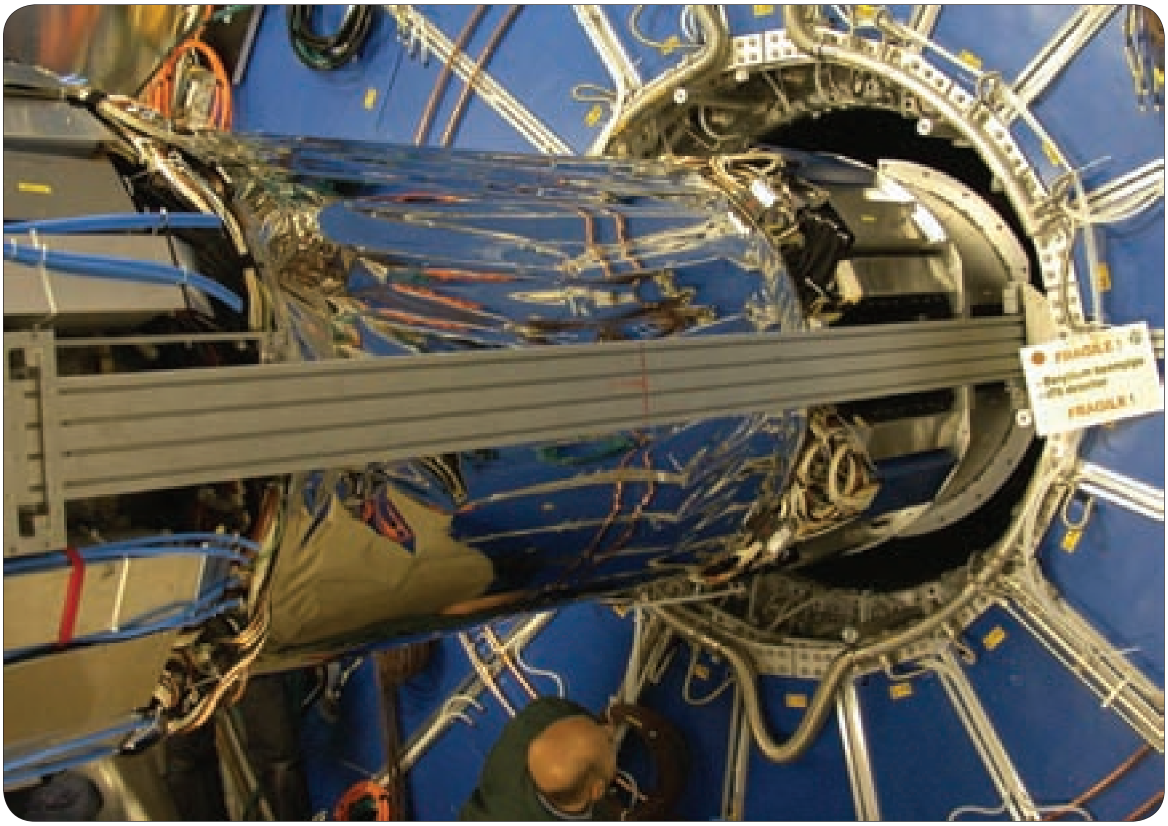


Figure 2. The Inner Tracking System (ITS) and Time Projection Chamber (TPC) during the installation of the TPC. The ITS in the center is covered by a metallized foil serving both as a thermal and electromagnetic shield. Behind and slightly to the right is the TPC, to the left is the front absorber of the muon spectrometer.

ALICE detector construction

After the transport of the Silicon Strip Detector (SSD) to CERN it was put together with its partner detector in the Inner Tracking System, the Silicon Drift Detector (SDD), and this detector assembly was lowered into the underground experimental area of the ALICE experiment in March 2007. After this all connections to the outside world, cables and cooling pipes, were made, and one half of the detector, which was accessible, was tested before the main detector of ALICE (the TPC) was moved into its final position surrounding the SSD in September 2007. Then also the other side of the detector became accessible and was tested. A large effort went into connecting the detector to the infrastructure. The cooling system, where parts of its circuits are shared with the SDD, proved difficult to handle, filling and draining require utmost care. The requirement to operate it below atmospheric pressure could finally be achieved. Because the digitisation of the signals is done in the electronics racks outside the solenoid magnet, the analogue signals are transported over up to 40 m. This required special production of non-standard cables which had to be extremely thin (weighing approximately 1.4 g per meter of wire for the innermost cables) in line with the overall lightweight design of the SSD. Tests of the system after installation has shown that the number of bad channels is within the 3% specification. In November part of the installed detector was successfully operated together with the ALICE common trigger, control and data acquisition systems. In December the detector has been used for measurements of cosmic muons.

2.4 The Proton Structure: ZEUS

Management: Prof. dr. P. Kooijman

After 15 years of running, the ZEUS experiment at the HERA collider in Hamburg stopped data taking on June 30th 2007. Nikhef was involved from the beginning right up to the end, as documented in a review article in this annual report.

The total integrated luminosity that has been collected with the ZEUS experiment since the HERA accelerator was upgraded in the year 2000 is summarized in Table 1.

Period	HERA delivered	ZEUS recorded
Nominal energy	561.6 pb^{-1}	406.7 pb^{-1}
Medium energy	15.7 pb^{-1}	13.2 pb^{-1}
Low energy	9.4 pb^{-1}	7.8 pb^{-1}

Table 1. Overview of ZEUS integrated luminosity since 2000.

For the 2007 run, which was to last only 6 months, a special program has been carried out at lower proton beam energy: 575 GeV (medium energy) and 460 GeV (low energy) instead of the nominal 920 GeV. The purpose of these low energy runs was the extension of the determination of the longitudinal structure function at low values of the Bjorken scale 'x' (this represents the fractional momentum of a quark or gluon inside the proton). The combined set of measurements of the proton structure will not be improved in any future accelerator currently being planned, and will be invaluable for the interpretation of data from the proton-proton collider LHC.

At Nikhef two PhD students, both in their final year, were completing the analysis on the charm quark contribution to the proton structure. The measurements resulted in the determination of the charm structure function, which is a measure of the probability that the electron scatters off a charm quark instead of one of the three valence quarks. This measurement is confronted with QCD calculations and leads to better predictions of the proton behaviour in collisions with very high momentum transfers. Although the ZEUS Collaboration will continue to analyse other interesting data which were recorded during the last years, the completion of the charm structure function determination marks the end of the ZEUS program at Nikhef.

The ZEUS experiment and the HERA accelerator complex will have to make space for DESY's future ambitions as a synchrotron radiation facility. The ZEUS experiment is currently being taken apart with great care: scintillators and photomultipliers that have been used for the calorimeter are still in good shape and may be used for building cosmic ray detectors for high school projects. The heart of the ZEUS experiment, formed by the silicon strip detector, will also return to Nikhef where it was built, and will be put on display.

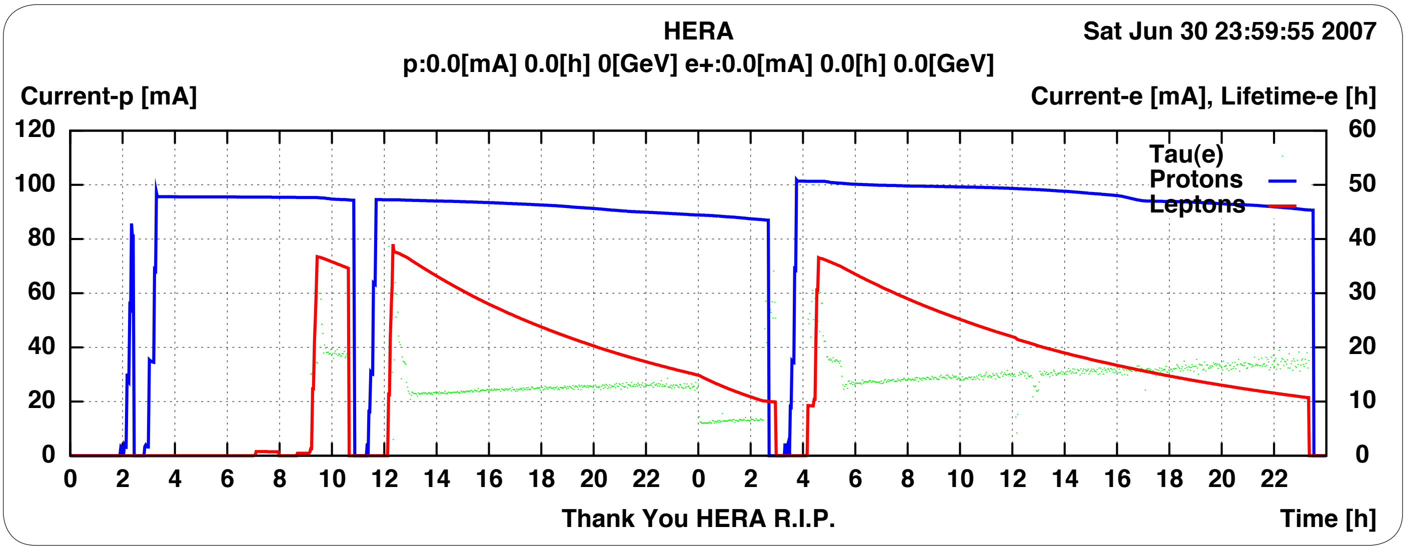


Figure 1. The online display with the last run of the HERA collider.

2.5 The Nucleon Spin Structure: HERMES

Management: dr. J.J.M. Steijger

The FOM programme *'Nucleon Spin, Flavour and Glue'* formally ended when the year 2007 began. In July 2007 the HERMES experiment stopped datataking when the HERA accelerator at DESY in Hamburg was shut down. Finally, three PhD theses were successfully defended this year and a number of analyses were concluded, including for example the study on hadronization. This is the process in which partons produced in the deep-inelastic scattering of leptons, form the hadrons which are observed experimentally.

Hadronization

In deep-inelastic scattering of electrons from a nucleon or nucleus one of the quarks in a nucleon is hit by an incoming virtual photon. This quark might subsequently escape. Since a free quark cannot exist stably, a process called hadronization sets in. In this process quark-antiquark pairs are created, which may combine with the hit, escaping quark, or with the remnant quarks, to form stable particles called hadrons. This process has been studied in colliding beam experiments. Using electrons as projectiles has the advantage that energy and momentum of the hit quark that hadronizes is precisely known. However, the time development of this process is not accessible in this case.

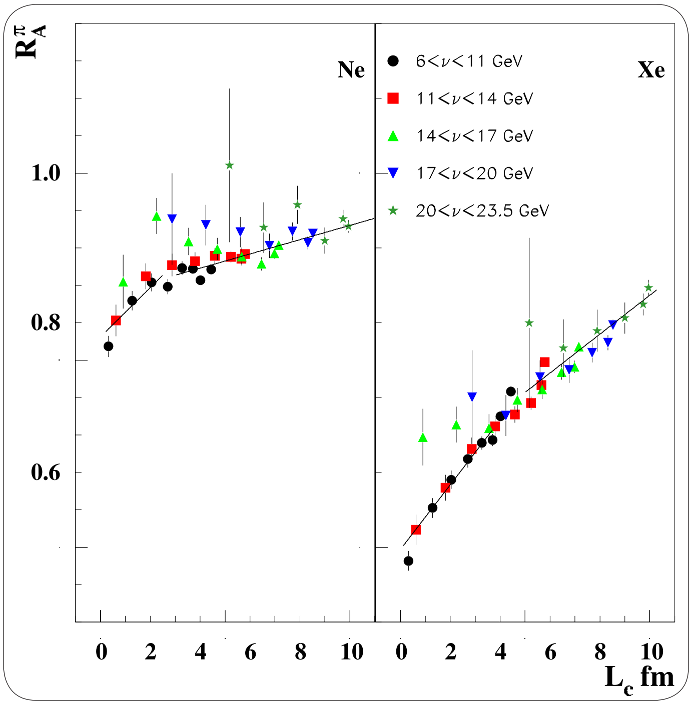


Figure 1. Pion production multiplicities on Ne and Xe nuclei, normalized to those on the deuteron, as a function of the formation length, showing the kink in the multiplicity curve at the nuclear surface.

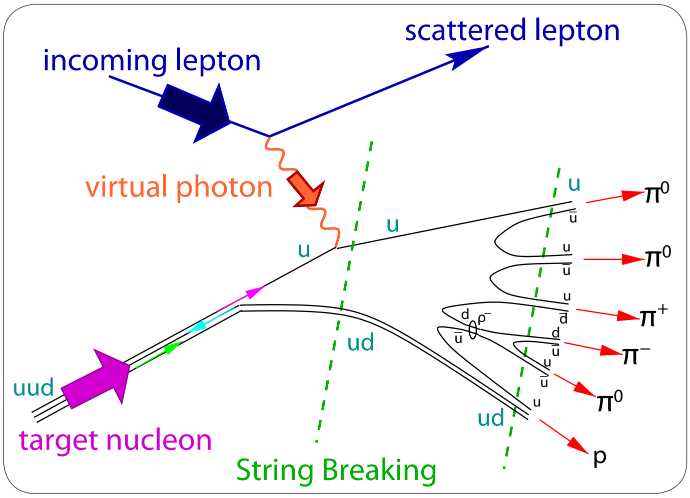


Figure 2. Schematic diagram of a semi-inclusive event showing the struck quark and the subsequent hadronization.

Inside a nucleus a quark interacts differently from a hadron. This fact is used at HERMES to study the time development of hadronization. Nuclei of different atomic species are used in the scattering experiment. The produced quarks experience different –average– path lengths inside the nucleus, depending on the particular nuclear size, and therefore a different combination of interactions. Since all relevant particles travel at approximately the speed of light, these distances translate into a timescale.

The number of hadrons produced per scattering event is used as the observable in these experiments. This number was measured as a function of four kinematical variables for four nuclei. To ease the comparison of the results, the ratio with results for deuterium is used. The interactions of the hit quark and the final hadron travelling in the nucleus, both lead to a decrease in the number of hadrons produced, although at a different rate and with a different kinematical signature.

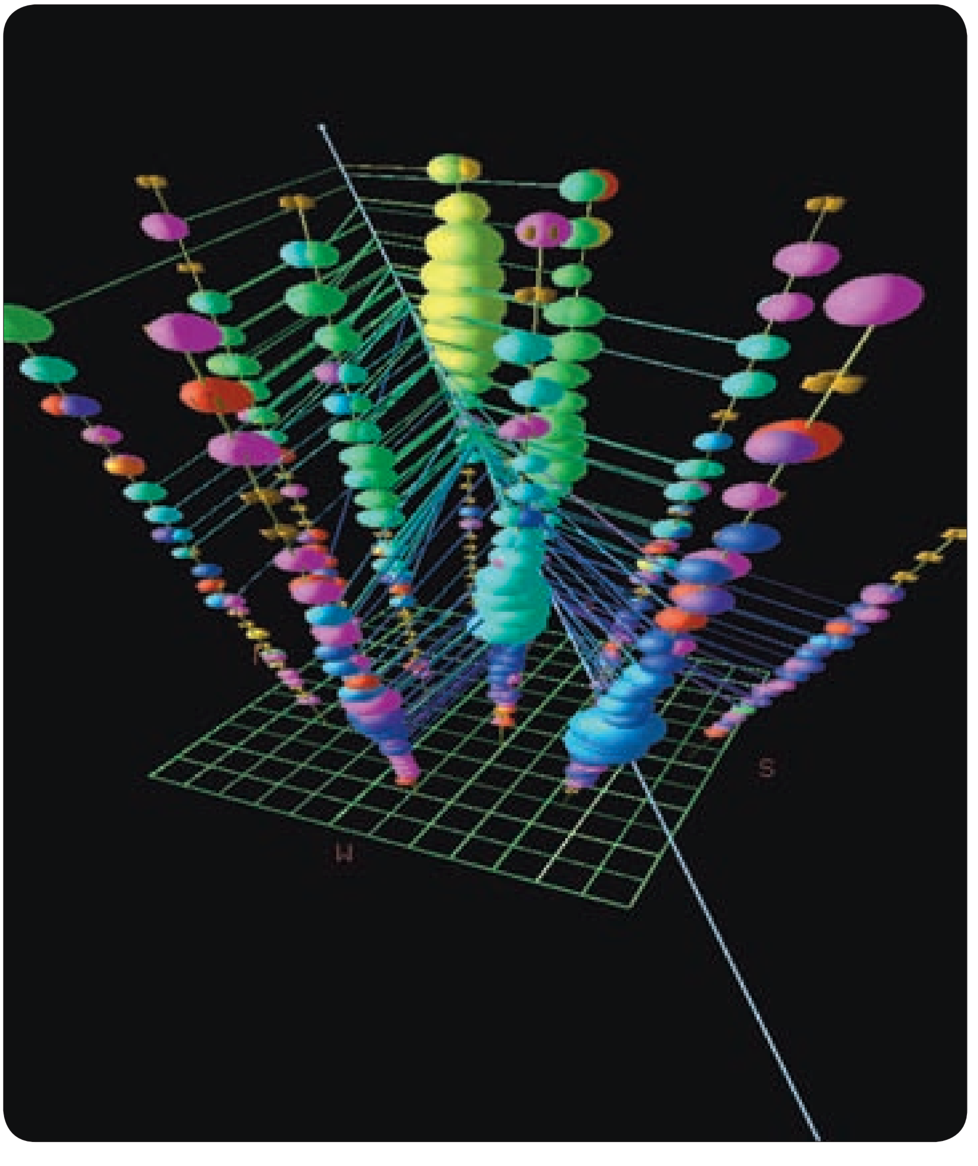
A combination of the kinematical variables z and ν gives in the Lund model the average formation length L_c. The measured multiplicity ratio plotted against this variable shows two straight sections connected approximately where L_c is equal to the radius of the target nucleus. This is interpreted that for the larger values of L_c the hadron is formed predominantly outside of the nucleus and the interactions of the quark in the nucleus dominate, while for lower values also the hadron interacts with the nucleus, resulting in a different multiplicity ratio.

2.6 Neutrino Telescope: ANTARES

Management: Prof. dr. G. van der Steenhoven
Running period: 2001–2007

The year 2007 marks the beginning of the observational period of the ANTARES neutrino telescope in the Mediterranean Sea. For more than 10 months data have been collected with 5 detector lines, which comprise more than 40% of the full telescope. In the mean time 5 more detector lines have been constructed and deployed. These additional lines were successfully connected to the shore station by means of a dedicated submarine operation in December. Within 24 hours the first tracks were reconstructed (see Fig. 1). Hence, by the end of 2007 ANTARES was completed and operational at more than 80% of its design specifications.

Scientifically, the purpose of high-energy neutrino telescopes such as ANTARES is twofold: (i) the search for the (unknown) origin of very high-energy cosmic rays; and (ii) the search for particles that compose the mysterious dark matter in the Universe. A positively identified neutrino point source in the sky, or any (indirect) evidence for the existence of dark-matter particles would represent a break-through in astroparticle physics research.

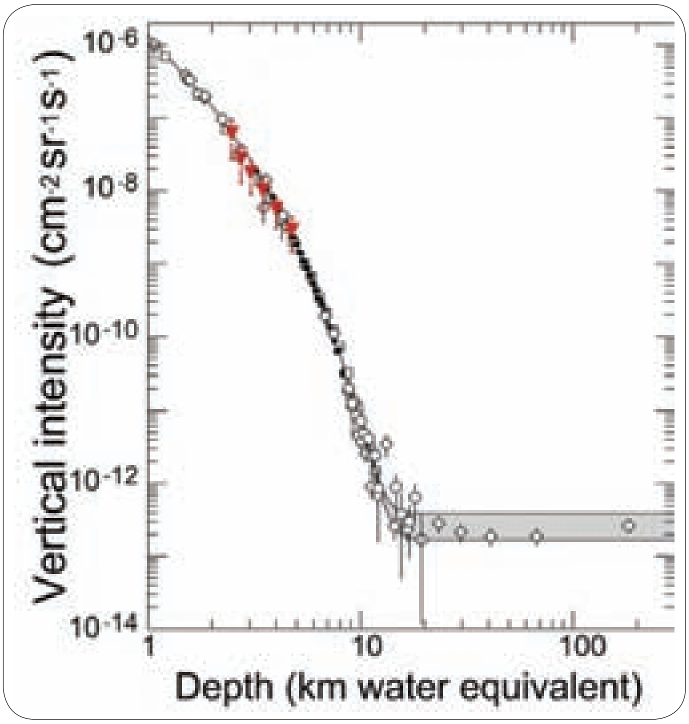


In 2007 the data collected in the previous year with a single detector line were carefully analyzed. This resulted, for instance, in a measurement of the intensity of downward going atmospheric muon events. The resulting data compared well to existing data of this kind, thus validating the analysis and acceptance simulations (see Fig. 2).

Moreover, the Nikhef team was the first to succeed in cleanly identifying upward-going muon tracks in ANTARES that could be unambiguously associated with neutrino events. This observation provides the proof-of-principle for high-energy neutrino detection in the deep sea (see Fig. 3).

At the same time the team developed and operated a dedicated trigger enabling the (static) telescope to follow a given source in the sky. This represents one of the first examples of a software telescope, i.e. a telescope in

Figure 1: Event display of a muon track in the ANTARES detector. The display shows the status of ANTARES in December 2007, when it consisted of 10 detector lines. The grid drawn on the sea bed measures 300×300 m². The coloured spheres represent detected light. Their sizes correspond to the number of photons detected, while the colours correspond to the relative arrival times (from red at 0 μs to purple at 2.5 μs.)



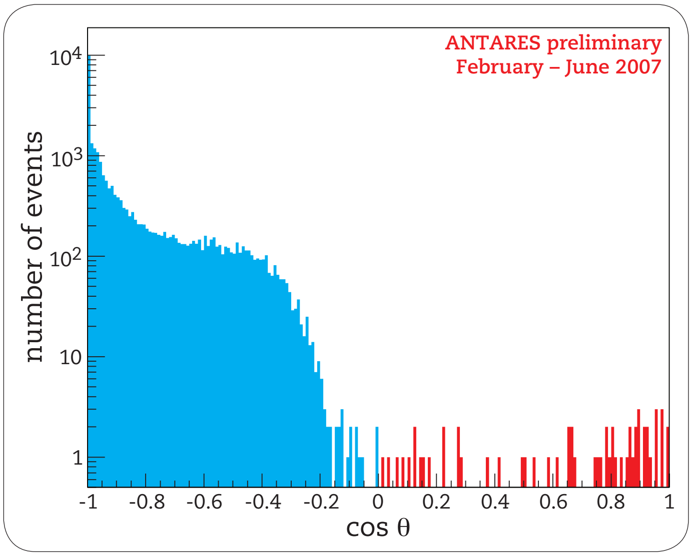


Figure 3: Zenith angle distribution of the reconstructed muons detected with the ANTARES neutrino telescope. The blue area (cos θ < 0) corresponds to downward going atmospheric muons. The red area (cos θ > 0) corresponds to upward going atmospheric neutrinos.

Figure 2: Intensity of atmospheric muons observed at given depth of water (or equivalent). The preliminary ANTARES data (red triangles) are based on measurements obtained with the first detector line. The data are compared to other existing measurements (open symbols).

which a source can be traced without hardware adjustments. The ANTARES neutrino telescope, which will be completed through the deployment and connection of two more lines in early 2008, represents the largest high-energy neutrino telescope on the Northern Hemisphere. Its location is such that the Galactic Centre and its environment are visible for 70% of the time. For the scientific exploitation of this unique instrument in the period 2008–2013, funding has been secured through the approval of a new FOM research programme. This new research programme will also enable a Dutch research team to study the origin of high-energy cosmic rays at the Pierre Auger Observatory (PAO) in Argentina, which represents the largest air-shower detector array worldwide. Data collected at PAO are complementary to those obtained with ANTARES, as they cover the same skyview but use a different probe (charged particles rather than neutrinos).

The development of high-energy neutrino astronomy requires the construction of deep-sea neutrino telescopes that enable the observation and characterization of many point sources. As this goes well beyond the ground-breaking purpose of ANTARES, a large km-scale neutrino telescope is under design in Europe. For this so-called KM3NeT project additional EU-funds could be secured in 2007, because the project appeared on the list of recommended facilities prepared by the European Forum for Research Infrastructures (ESFRI). Moreover, a large investment proposal has been submitted to NWO to cover the Dutch contribution to this largest neutrino telescope in Europe.

2.7 Air-shower Array: Pierre Auger Observatory

Management: dr. A.M. van den Berg (KVI)

General results in 2007

In 2007, the southern site of the hybrid Pierre Auger Observatory, near Malargüe in Argentina, was almost completed. The goal of the observatory is to be a telescope for the highest energy cosmic rays, originating from outer space. All four fluorescence detectors are now completed (the first 4-fold event was seen on May 20th), and the surface detector is more than 80% operational. A rich physics program is already unfolding. Clear highlights for 2007 are the confirmation of a cut-off in the measured energy spectrum of cosmic rays at the energy expected from the so-called GZK limit and the discovery of an anisotropy in the arrival direction of high energy cosmic rays, which correlates with the location of active galactic nuclei. Both of these exciting results are discussed in the reviews section of this Annual Report.

Nikhef activities in 2007

The main Nikhef activity is dedicated to implementing radio detection of cosmic ray induced showers as a viable detection technique. In Fig. 1 Nikhef physicists are busy installing a radio antenna. In the past year we have introduced a fast trigger system into the setup. This trigger is essentially a slightly modified HiSPARC (see section 4.1) system. The antenna readout system has been improved by adding additional amplification

Figure 1. Nikhef physicists participate in the installation of an antenna for the radio detection of cosmic ray showers at the Pierre Auger Observatory in Argentina.

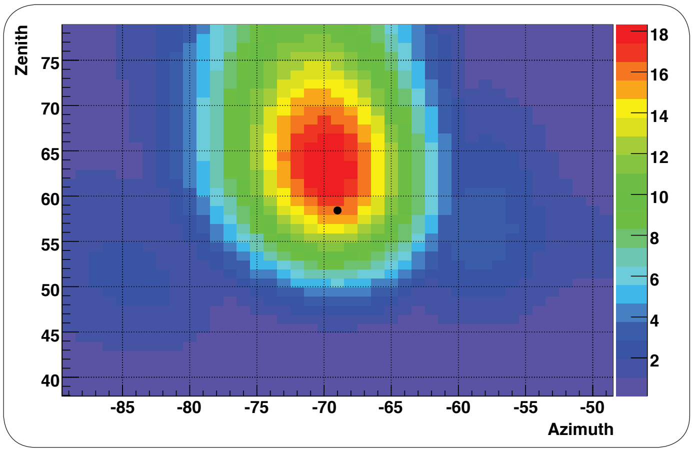


Figure 2. Directional reconstruction of a single event, compared to the reconstructed direction from the Auger surface detectors, shown as the dot in the center. The color code (shown to the right in arbitrary units) reflects the combined signal strength for all antennas in the specified direction.

(30 dB) and various filter systems. The heart of the data acquisition, a Nikhef-made 400 MHz 2-channel digital oscilloscope, has been modified to better match the readout requirements, and its internal noise has been reduced. The results of all improvements can be summarized as follows:

- There are coincidences between our trigger and the Auger surface detector trigger;
- Cosmic ray induced showers are clearly seen in the signals from the radio antennas;
- We clearly see the galactic background;
- The direction of the incoming cosmic ray can be reconstructed from the antenna data.

Fig. 2 clearly demonstrates that the direction obtained from radio antenna signals corresponds to the standard Auger reconstruction within 5 degrees, which matches the expected uncertainty in our reconstruction. The measurements in Argentina have allowed us to perform a thorough study of the background conditions as well. This was absolutely necessary in order to understand why a simple threshold level trigger will not work. A more elaborate trigger algorithm has been designed, which has been tested on our measurements. It reduces the noise rate by about a factor 500 to an acceptable level. This algorithm is programmed into a newly designed 4-channel oscilloscope. This new scope will be at the heart of a standalone antenna system, which was designed together with our partners from KVI and RWTH-Aachen and which is fully assembled and tested in Groningen and Nijmegen before shipment to Argentina. Deployment in Malargüe is expected in January of 2008.

2.8 Gravitational-wave detector: VIRGO

Management: Prof. dr. ing. J.F.J. van den Brand

Gravitational waves are produced by unique astronomical events, such as mergers of pairs of black holes or neutron stars, and supernovae explosions. The VIRGO experiment, located close to Pisa in Italy, is a Michelson-type interferometer with two perpendicular arms of 3 km each, sensitive to passing gravitational waves.

The highlight of the activities of the VIRGO Collaboration in 2007 is the first VIRGO science run (VSR1). VSR1 which was started on May 18th has been completed on October 1st at the same time as the S5 run of LIGO, a set of similar interferometers in the United States. VSR1 has been followed by a two-week activity for extensive calibration and various noise measurements in the VSR1 configuration of the detector.

The VSR1 duty cycle was 81% in 'science mode' (data that could be used for data analysis). The down time has been due to the maintenance, commissioning, and various problems. The triple coincidence duty cycle between LIGO (two interferometers) and VIRGO was 58%, while the quintuple coincidence efficiency between LIGO (three interferometers), Geo600 (Germany) and VIRGO was 40%.

Fig. 1 shows that VIRGO and LIGO have similar efficiencies for frequencies above 500 Hz. During the run, some time has been dedicated to commissioning activities which led to an improvement of the VIRGO sensitivity, resulting in an increase in the horizon for visible binary neutron star mergers (averaged over all angles) from 3.6 to 4.9 Mpc.

The commissioning activity to improve the low and mid frequency reqion has restarted after the run. This activity is expected to continue until the beginning of 2008. At the same time the detector upgrade programme, termed VIRGO+, is proceeding. Nikhef has responsibility for two VIRGO+ upgrade activities: front-end electronics for angular alignment of the various mirrors, and an upgrade of the input-mode cleaner (IMC). The IMC is a 144 m long high finesse ring cavity, used to filter out unwanted modes of the light beam that is injected into the interferometer. Furthermore, the IMC is used as a first stage in the frequency stabilisation of the optical frequency. The end mirror of the IMC is suffering from low optical quality of both substrate and coating which leads to significant scattering losses. In addition, the weight of the mirror and its reference mass is too small, making the system sensitive to radiation pressure effects. We have decided to replace the test mass with a new mirror (heavier, better quality) and the payload with a heavier reaction mass. The mirror has been ordered, polished and coated, while the marionette, reaction mass and the required installation tooling is being fabricated in mechanical workshops at Nikhef, UvA, VU and Rome.

VIRGO+ installation will be finalized in mid-2008, a date to be fulfilled to keep our goal to be back online at the same time as enhanced LIGO and start our second science run.

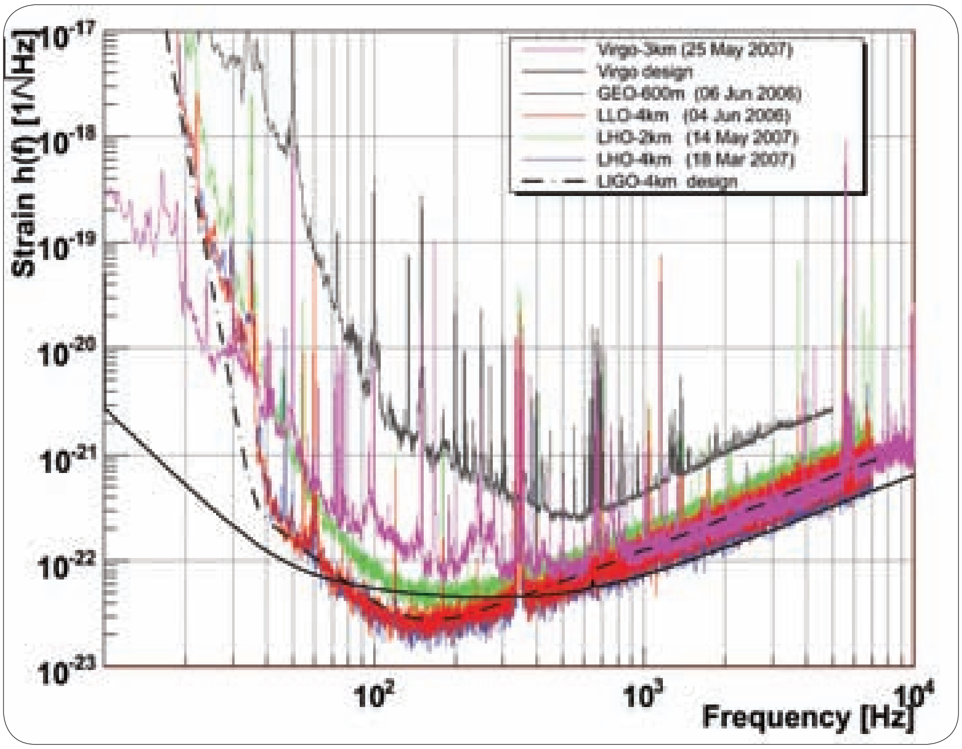


Figure 1. Sensitivity of VIRGO in comparison to that of LIGO L1 and H1 4 km long interferometers, LIGO H2 (2 km long) and GEO600.

2.9 Theoretical Subatomic Physics

Management: Prof. dr. E. Laenen
Running period: 2000–2008

Because the Nikhef theory group has diverse research interests, a report of its activities will necessary be fairly wide in scope. But also in the era of 'focus and mass' there lies strength in diversity, and unplanned progress.

Considerable progress was made in the construction of string theories whose symmetries and particles reflect those of the Standard Model. In particular, incorporating small neutrino masses, and having supersymmetry be *absent* was shown to be a possible feature in the database of string theory models assembled in earlier work. In a more quantitative investigation of the landscape of string theory vacua, novel, statistical, computer-aided analysis techniques gave deeper understanding.

As an example of the abovementioned unplanned progress – a collaboration between string theory and phenomenology – the relation between string theory and cosmological inflation, in which the Universe expanded exponentially fast just after the Big Bang, was investigated, and a family of string-inspired inflation scenarios was put forward.

Additional investigations of the link between string theory and cosmology revealed that fields arising in string theory from compactifying extra dimensions (strings need to live in more than four space-time dimensions) tend to ruin otherwise well-working inflation models (see Fig. 1), except for specific couplings of these fields and the inflaton (the particle associated with the field responsible for inflation). More detailed studies and comparisons with experimental data narrowed the class of viable inflation models.

In astrophysics, the role of neutrinos in a gamma-ray burst, was shown to be a possible tell-tale of its early stage dynamics. The formalism to describe gravitational wave production was also investigated.

In collider physics, it was shown how to include spin correlations into Monte Carlo programs efficiently. In other work, the description of an important production process for single top quark production was significantly improved, as was that of the pattern of jets accompanying Higgs bosons at the LHC. Important further improvements to the computer algebra program FORM were made. Theorists' tool sets were also extended in projects involving Hamiltonian dynamics, and the structure of symmetry algebra's.

Other news
Members of the group were remarkably succesful in their applications for external funding in 2007. A 5-year VIDI grant was awarded on the topic of *"The early Universe as a particle laboratory"*, and a FOM projectruimte grant was approved for a project involving the combination of the FORM computer algebra program with the program GRACE, which performs automatic calculation of Feynman amplitudes. In November, the FOM program proposal *"Theoretical particle physics in the era of the LHC"* was awarded. Three Nikhef staff participate, one as program leader. The succesful monthly *Theory Meetings*, which started last year, are a key part of the running of this program.

In 2007 staff members of the group have been active in schools, lectures and courses at Nikhef, in Nijmegen and Delft, at the Free University and the University of Amsterdam, in Sao Paolo, Brazil, and Allahahad, India. Academic Lectures were held on the Higgs System by Nobel prize winner M. Veltman, and on Monte Carlo topics by R. Kleiss. The National Seminar on Theoretical High-Energy Physics also continues to be held at Nikhef and attracts excellent attendence. Outreach activities included, among others, HiSPARC, and presentations to high school students and amateur astronomers.

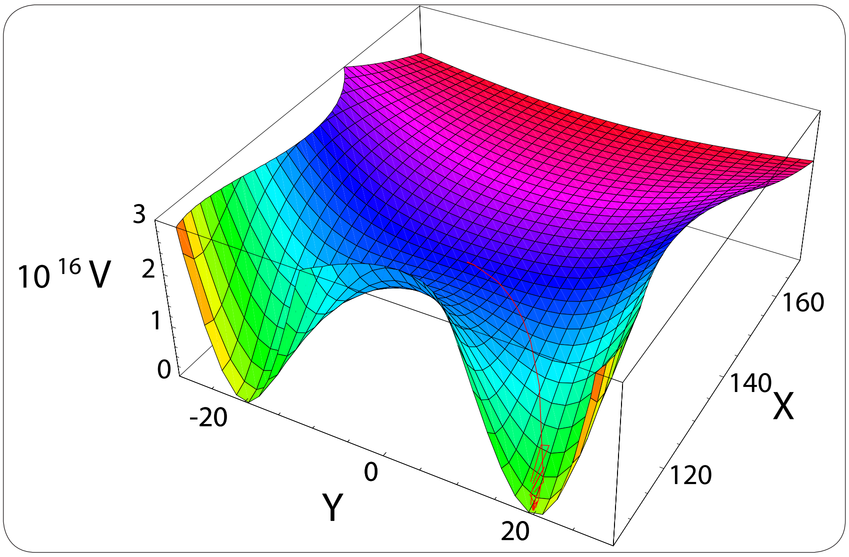


Figure 1. Pictorial representation of the potential for the inflaton field.

2.10 Detector R&D: Gridpix Detectors

Management: dr. J.J.M. Timmermans

A gas-filled Gridpix detector for charged particles consists of a drift volume where these particles produce primary ionization clusters (electrons) that drift towards a thin metallic grid mounted at a short distance (typically 50 µm) on a pixelised CMOS readout chip that acts as anode. The '*Timepix*' chip is based on the Medipix2 chip (see below), with extended functionality to measure also arrival time and/or pulseheight. By applying a voltage difference of order 400 V between the grid and the anode, gas multiplication of the primary electrons by a factor of a few thousand occurs, and the resulting charge avalanche for each of the primary single electrons can be detected with good efficiency on single pixels of size 55×55 µm^2.

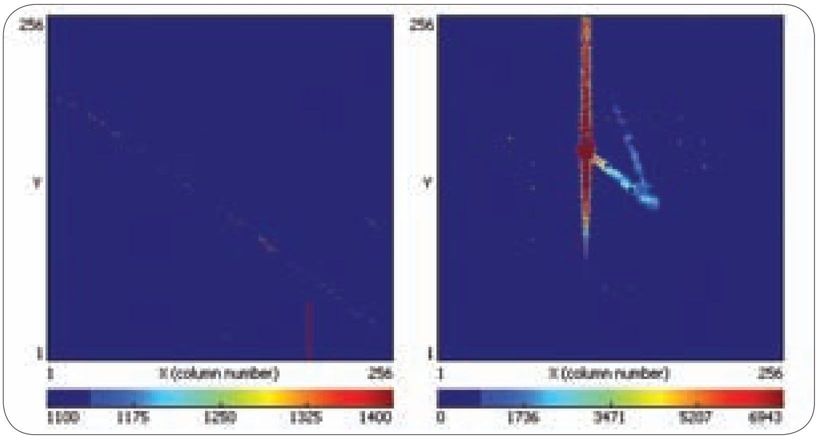


Figure 1. Examples of tracks recorded with the newly developed Timepix chip. Left: a cosmic ray track recorded in a He/Isobutane gas mixture. Right: two heavily ionizing alpha particles from radon decay; one alpha particle provokes a discharge that saturates the inputs of about 100 pixels (the red circular blob) and 'upsets' a whole group of readout columns.

In the first half of 2007, detectors 'protected' by a 3 µm thick amorphous silicon layer were kept in operation for more than 3 months in a 80/20 He/Isobutane gas mixture, but were still damaged by a discharge in a 80/20 Ar/Isobutane mixture after only 24 hours. From July onwards two detectors with 20 µm thick protection layers were in operation. In the first, the gas multiplication grid was integrated onto the Timepix chip using wafer post-processing technology at the MESA+ institute of the University of Twente. Beautiful cosmic ray tracks were observed (see Fig. 1, left panel) in He/Isobutane.

A real breakthrough came with the second detector, which operated successfully also in Ar/Isobutane mixtures, even with a small admixture of radon, leading to heavily ionizing alpha particles being detected. In about 1% of the cases these alpha particles are accompanied by a large discharge in the detector (see Fig. 1, right panel). Sofar, the 20 µm thick protection layer prevents the Timepix chip from being damaged. This detector, equipped with a 30 mm long drift volume and operated with a 80/20 Xe/CO_2 mixture, was also tested for the first time in a CERN PS tagged electron beam as possible transition radiation detector. Another first was the detection of charged particle tracks in a 1.4 mm thick gas filled detector, with a protected PSI-46 pixel chip as readout device. This type of detector (GOSSIP) could possibly be used as tracking detector in the harsh radiation environment of the (super-)LHC. No significant ageing of such detectors was observed up to an irradiation of 3×10^{15} particles/cm^2.

Medipix en RELAXD

Nikhef participates in the Medipix2/3 Collaborations at CERN for the development of deep-submicron readout circuits for single-photon counting hybrid pixel detectors. The Medipix3 chip forms a new generation of spectral imaging chips, especially for medical applications. Nikhef is involved in the chip architecture, special aspects of 4-side tileability and readout hardware.
The RELAXD project is an Eureka collaborative effort with the Dutch company PANalytical and the IMEC research centre and Canberra company in Belgium, to develop large sensitive detector areas, without dead spaces and with multi-gigabit per second readout. Nikhef is responsible for the 2×2 chip high-bandwidth readout module. A pre-series of 10 carrier boards is in production. In its final form the aim is to replace the wire bond connections by ball-grid-array bonding with electrical connections through the CMOS readout chip to the backside.

RasClic

RasClic is a laser based three-point alignment system, derived from the short-range system RASNIK but using diffraction rather than imaging, dedicated to the alignment of ILC/CLIC elements and monitoring slow oscillations resulting from earth quakes ('earth hum'). A patent for both applications is submitted; earth hum wave packets were first observed on 12 September. Observed precision of the 91 m prototype at CERN is below 200 nm per measurement, with improved light insertion by optical fiber. Recent and current upgrades are extension to 140 m (projected 500 m), increased measurement repetition rate from average 12.5 Hz to stabilized 62.5 Hz, temperature monitoring of the environment for drift correction, and improved pattern analysis; target precision is from 10 down to 1 nm.

2.11 Physics Data Processing: Grid Computing

Management: dr. J.A. Templon

With the official launch of the national BiG Grid facility, the approach of LHC operations, and Nikhef participation in the Dutch Virtual Laboratory for e-Science, the year 2007 saw a steep increase in the number of users of the grid computing facilities.

The community of grid facility users is widespread and diverse, and not limited to high-energy physicists. The medical imaging group from the Universiteit van Amsterdam and the Academisch Medisch Centrum uses the grid to archive and analyse functional MRI (fMRI) experiments. This translates into a large amount of data, and its analysis resembles in many ways the data problem associated with the analysis of high-energy physics event data. Grid computing presents a natural paradigm for handling both.

This grid work resulted in a collaboration between the medical imagers, Nikhef, and the ARDA (Advanced Research in Distributed Analysis) team at CERN, which will continue in 2008.

Usage of the Dutch grid resources by researchers in the humanities is also increasing, thanks in part to a collaboration between Nikhef and DANS (Data Archiving and Networked Services), an initiative of the Dutch Royal Academy of Sciences (KNAW). A current project involves analysing the origin of medieval texts. The project requires a substantial amount of computer power, for which grid computing techniques are being developed.

Collaboration with other scientific partners proceeded previously via informal channels; this changed in 2007 with the official start of the BiG Grid project. BiG Grid reserves a substantial sum for funding practical research into the use of the grid. Any interested user group can write a proposal. The first such proposal — a collaboration between researchers from Nikhef, SARA, and the Max Planck Institute for Psycholinguistics in Nijmegen, is nearing completion.

The software arm of the group had a very busy year, making numerous contributions to European, US, and worldwide grid middleware projects. Nikhef staff continue to play a leading role in international grid-security and policy bodies such as the Open Grid Forum, International Grid Trust Federation, and the Joint Security Policy Group.

With the turn-on of the LHC less than a year away, the Tier-1 LHC data analysis part of our efforts becomes ever more focussed on operations, and on scaling up to the large amount of storage and computer power that will be needed with the LHC up and running. The Tier-1 resources at Nikhef experienced a modest increase, about 50% in total computing capacity and a factor of five in allocated disk space. Fig. 1 shows the load by various users during the year. Further hardware expansion is in progress. The facility monitoring has been vastly improved, necessitated by requirements in operational uptime once the LHC starts running.

Next year will be full of challenges for the grid group. In February, the Combined Computing Readiness Challenge will begin, aiming to reproduce and test the full-scale 'LHC beam-on' situation for the first time. The Challenge will be repeated a second time in May, and we hope this will be our final chance for a major test of the system before real data start to arrive. The other major challenge will be the tenfold scaling in storage capacity which is planned for spring 2008.

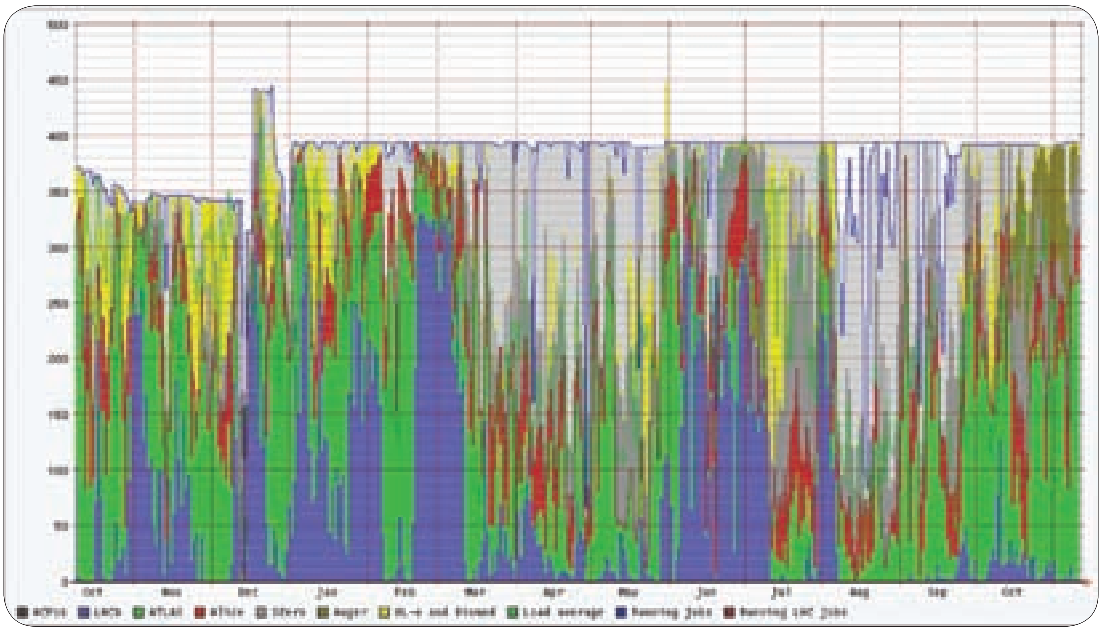


Figure 1. Computing capacity during 2007; the various colours represent the use by various experiments.

3

Output

3.1 Publications

ANTARES Collaboration:
J.A. Aguilar (*et al.*), M.C. Bouwhuis, R. Bruijn, C. Colnard, R. van Dantzig, A. Heijboer, E. Heine, J. Hogenbirk, M. Jaspers, M. de Jong, E. Kok, H. Kok, P. Kooijman, A. Kruijer, G. Lim, S. Mangano, H. Peek, J. van Randwijk, B. van Rens, P. Rewiersma, G. van der Steenhoven, G. Venekamp, B. Verlaat, G. de Vries-Uiterweerd, R. van Wijk, G. Wijnker, P. de Witt Huberts, E. de Wolf

The data acquisition system for the ANTARES neutrino telescope
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Acta Phys. Pol. **B 38** (2007) 515

K. Kordas (*et al.*); G. Kieft, S. Klous, J. Vermeulen
The ATLAS Data Acquisition and Trigger: concept, design and status
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V.M. Abazov (*et al.*); M. Anastasoaie, L.S. Ancu, P.J. van den Berg, K. Bos, S. Caron, B. van Eijk, F. Filthaut, C.F. Galea, J.G. Hegeman, P. Houben, P. de Jong, S. de Jong, M.H. Kirby, W.M. van Leeuwen, N.A. Naumann, M. Vreeswijk

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Measurement of the charge asymmetry in semileptonic B_s^0 decays
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Phys. Rev. Lett. **98** (2007) 181802

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Phys. Rev. Lett. **98** (2007) 221801

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Phys. Rev. Lett. **99** (2007) 052001

Search for third-generation scalar leptoquarks in $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV
Phys. Rev. Lett. **99** (2007) 061801

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Phys. Rev. Lett. **99** (2007) 142001

Properties of L=1 B_1 and B_2^* mesons
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Phys. Rev. **D 75** (2007) 092001

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Phys. Rev. **D 75** (2007) 092007

Measurement of the shape of the boson rapidity distribution for $p\bar{p} \rightarrow Z/\gamma^* \rightarrow e^+e^- + X$ events produced at $\sqrt{s}$ of 1.96 TeV
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Phys. Rev. **D 76** (2007) 057101

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Phys. Rev. **D 76** (2007) 072007

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Phys. Rev. **D 76** (2007) 092001

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Phys. Rev. **D 76** (2007) 092007

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3.2 Theses

Max Arjen Baak
Measurement of CKM-angle γ with charmed B^0 meson decays
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Promotor: J.F.J. van den Brand, Copromotor: H.G. Raven

Niels van Eldik
The ATLAS muon spectrometer: calibration and pattern recognition
Universiteit van Amsterdam, 22 February 2007
Promotor: F.L. Linde, Copromotor: S.C.M. Bentvelsen

Michiel Demey
The polarization of Λ^0 hyperons in quasi-real photoproduction
Universiteit van Amsterdam, 16 March 2007
Promotor: G. van der Steenhoven, Copromotor: J.J.M. Steijger

Achilleas Lazopoulos
Developments in quantum chromodynamics and quasi Monte Carlo
Radboud Universiteit Nijmegen, 26 March 2007
Promotor: R.H.P. Kleiss, Copromotor: C.G. Papadopoulos

Andreas Johannes Reischl
Quasi-real photo-production of hyperons and their impact on Λ^0 polarization measurements
Universiteit van Amsterdam, 3 April 2007
Promotor: G. van der Steenhoven, Copromotor: J.J.M. Steijger

Garmt de Vries-Uiterweerd
Signal and background in the underwater neutrino telescope ANTARES
Universiteit Utrecht, 8 May 2007
Promotor: P.M. Kooijman

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Supersymmetric Standard Model spectra from RCFT orientifolds
Radboud Universiteit Nijmegen, 11 June 2007
Promotor: A.N.J.J. Schellekens

Johannes Wilhelmus Edmond Uiterwijk
Detection and reconstruction of short-lived particles produced by neutrino interactions in emulsion
Universiteit Leiden, 12 June 2007
Promotor: M. de Jong, Copromotor: J. Panman

Paul Bastiaan van der Nat
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Vrije Universiteit Amsterdam, 5 September 2007
Promotor: G. van der Steenhoven, Copromotor: L. Lapikás

Hylke Bernd Jan Koers
The Astrophysical Herald: Neutrinos as probes for particle physics and astronomy
Universiteit van Amsterdam, 21 September 2007
Promotores: K.J.F. Gaemers, R.A.M. Wijers

Cedran Jonathan Bomhof
Azimuthal spin asymmetries in hadronic processes
Vrije Universiteit Amsterdam, 1 October 2007
Promotor: P.J.G. Mulders

Jacopo Nardulli
Reconstruction of two-body B decays in LHCb
Vrije Universiteit Amsterdam, 4 October 2007
Promotores: J.F.J. van den Brand, M. Merk

Johan Hendrik Rutger Schrader
Wireline equalization using pulse-width modulation
Universiteit Twente, 11 October 2007
Promotor: B. Nauta

Yuting Bai
Anisotropic flow measurements in STAR at the relativistic heavy ion collider
Universiteit Utrecht, 29 October 2007
Promotor: Th. Peitzmann, Copromotor: R.J.M. Snellings

Oleksandr Grebenyuk
Neutral meson production in d+Au and p+p collisions at $\sqrt{s_{NN}} = 200$ GeV in STAR
Universiteit Utrecht, 29 November 2007
Promotor: Th. Peitzmann, Copromotor: M.A.J. Botje

Andrea Fuster
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Vrije Universiteit Amsterdam, 6 December 2007
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3.3 Talks

ALICE

Botje, M., NNLO upgrade of QCDNUM, HERA-LHC workshop, DESY, Hamburg, Germany, 13 March 2007

Kraus, I.C., Statistical model predictions in pp and PbPb collisions at LHC, Heavy Ion Collisions at the LHC, Workshop, CERN, Geneva, Switzerland, 31 May 2007

Peitzmann, T., Working under pressure - QCD thermodynamics at RHIC, QCD at Work Conference, Martina Franca, Italy, 19 June 2007

De slavernij van de quarks, Natuurkundig Gezelschap Utrecht, Utrecht, The Netherlands, 11 December 2007

ANTARES

Bouwhuis, M., First observations with the ANTARES neutrino telescope, 8th National Astroparticle Physics Symposium, ASTRON, Dwingeloo, The Netherlands, 7 June 2007

GRB satellite triggers for neutrino telescopes, Workshop on the hot-wiring of the Transient Universe, Tucson, Arizona, USA, 7 June 2007

The ANTARES neutrino telescope, Colloquium at ITP, University of Innsbruck, Innsbruck, Austria, 20 October 2007

Kooijman, P.M., Results from the ANTARES neutrino telescope, The 2007 Europhysics Conference on High Energy Physics, Manchester, United Kingdom, 25 July 2007

Lim, G.M.A., Indirect search for Dark Matter with the ANTARES neutrino telescope, Workshop on SuperSymmetry (SUSY07), Karlsruhe, Germany, 26 July 2007

Mangano, S., Algorithm for muon electromagnetic shower reconstruction, Roma International Conference on Astro-Particle physics, Roma, Italy, 22 June 2007

Presani, E., Astronomy with Neutrino Telescopes, Seminar Physics Department of the University of Trieste, Trieste, Italy, 11 October 2007

Steenhoven, G. van der, Update on astroparticle physics research in The Netherlands, 8th National Astroparticle Physics Symposium, ASTRON, Dwingeloo, The Netherlands, 8 February 2007

The deep-sea neutrino telescope projects ANTARES and Nederlands Instituut voor het Onderzoek der Zee (NIOZ), Den Burg, Texel, The Netherlands, 12 March 2007

Astroparticle Physics Research in the Netherlands, 2nd Aspera National Day, Nikhef, Amsterdam, The Netherlands, 13 April 2007

Introduction - purpose of the meeting and EU funding status, Aspera meeting on the European strategy for Astroparticle Physics: defining priorities, Felix Meritis, Amsterdam, The Netherlands, 20 September 2007

Kosmische Neutrino's, KNVWS symposium 'Het extreme heelal', Universiteit van Amsterdam, Amsterdam, The Netherlands, 6 October 2007

Report on Astroparticle Physics research in the Netherlands, 9th National Astroparticle Physics Symposium, Kapteyn Institute, Groningen, The Netherlands, 12 October 2007

Wolf, E. de, ANTARES opens its eyes, 21nd Rencontres de Physique de la Valle d'Aoste on Results and Perspectives in Particle Physics, La Thuile, Italy, 6 March 2007

KM3NeT: a next generation neutrino telescope, Roma International Conference on Astro-Particle physics (RICAP 2007), Roma, Italy, 20 June 2007

ATLAS

Bentvelsen, S.C.M., Top quark physics in University of Wuppertal, Wuppertal, Germany, 10 May 2007

The ATLAS experiment, GlobalQ Diamond at Cern, Geneva, Switzerland, 14 November 2007

Filthaut, F., Measurement of masses and lifetimes of B hadrons, 42nd Rencontres de Moriond, on QCD and Hadronic Interactions, La Thuile, Italy, 18 March 2007

Houben, P.W.H., Measurement of the top quark mass at DØ using the ideogram method in the lepton+jets channel, APS April Meeting, Jacksonville, FL, USA, 15 April 2007

Jong, P.J. de, Challenges for early discovery in ATLAS and CMS, 42nd Rencontres de Moriond 2007, Electroweak interactions and Unified Theories, La Thuile, Italy, 11 March 2007

ATLAS: first data and the interplay between collider and flavour physics, Kickoff meeting of the Workshop on the Interplay between Collider and Flavour Physics, CERN, Switzerland, 3 December 2007

Klous, S., ATLAS Remote Online Farms, ACAT'07, Amsterdam, The Netherlands, 24 April 2007

Koetsveld, F., Standaard Model: Hoekverdelingen bij Beauty productie bij proton/anti-proton botsingen, Vrije Universiteit, VIP 07 symposium, Amsterdam, The Netherlands, 14 February 2007

Liebig, W., Track and Vertex Reconstruction in 16th International Workshop on Vertex detectors (Vertex'07), Lake Placid, NY, USA, 26 September 2007

Limper, M., ATLAS SCT commissioning, TWEPP 2007, Topical Workshop on Electronics for Particle Physics, Prague, Czech Republic, 9 September 2007

Linde, F.L., Large Hadron Collider, Diligentia, Den Haag, The Netherlands, 26 November 2007

Grid

Koeroo, O.A., VOMS from A to Z, University of California, San Diego (UCSD), San Diego, USA, 1 March 2007

VOMS Usage in various Middleware, The Royal Institute of Technology (KTH), Stockholm, Sweden, 13 June 2007

The SAML-XACML protocol in EGEE & OSG Authorization and resource enforcement tools, EGEE'07, Budapest, Hungary, 2 October 2007

Authorization Interoperability: A common XACML Profile and its current implementation, Lawrence Berkeley National Laboratory, Berkeley, USA, 6 December 2007
Security Incidents and Countermeasures, Lawrence Berkeley National Laboratory, Berkeley, USA, 6 December 2007

KM3NeT

Kooijman, P.M., Multi-PMT optical module for undersea neutrino telescopes, 30th International Cosmic Ray Conference, ICRC07, Merida, Yucatan, Mexico, 11 July 2007

Photonic readout of optical modules in neutrino telescopes, 30th International Cosmic Ray Conference, ICRC07, Merida, Yucatan, Mexico, 11 July 2007

LHCb

Beuzekom, M.G. van, Status and prospects of the LHCb Vertex Locator , 8th International Conference on Large Scale Applications and Radiation Hardness of Semiconductor Detectors (RD07), Florence, Italy, 27 June 2007

Tuning, N., Ageing Phenomena in the LHCb Outer Tracker, IEEE 2007, Honolulu, USA, 1 November 2007

Vankov, P., Sensitivity to the B_s^0 mixing phase at LHCb, Lake Louise Winter Institute 2007: Fundamental Interactions, Lake Louise, Alberta, Canada, 23 February 2007

Miscellaneous

Kluit, R., Development of a small-scale prototype of the GOSSIPO-2 chip in, Topical Workshop on Electronics for Particle Physics (TWEPP 2007), Prague, Czech Republic, 3 September 2007

Linde, F.L., Elementaire Deeltjes Fysica, Utrecht University College, Utrecht, The Netherlands, 8 February 2007

Deeltjes, overal deeltjes!, Lost & Found, de Waag, Amsterdam, The Netherlands, 6 April 2007

Astroparticle physics: when ∞-small meets ∞-large, UvA/FNWI speerpunten, Amsterdam, The Netherlands, 14 December 2007

Hoge-Energie Fysica, Christelijk Lyceum Utrecht, Utrecht, The Netherlands, 30 January 2007

Elementary particles, Publiekssterrenwacht VESTA, Oostzaan, The Netherlands, 22 March 2007

Hoge-Energie Fysica, Michael College Zaandam, Zaandam, The Netherlands, 24 May 2007

Snippe, Q.H.C., FE-Based Radiation Length Analysis of Superplastically Formed Products, COMPLAS 2007 (Conference on Computational Plasticity, Technical university of Barcelona), Barcelona, Spain, 5 September 2007

Constitutive Modeling of Superplastic Materials, Simulia / ABAQUS Users' Meeting, Hoeven, The Netherlands, 19 November 2007

AUGER
Timmermans, C., Radio Detection of Cosmic Rays at the Pierre Auger Observatory, Colloquium Annecy, Annecy, France, 12 January 2007

Radio Detection of Cosmic Rays at the Pierre Auger Observatory, 10th ICATPP, Como, Italy, 11 October 2007

Theory
Bomhof, C.J., The role of gauge invariance in single-spin asymmetries, 15th International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2007), Munich, Germany, 19 April 2007

Gmeiner, F., A magical mystery tour around some spots in the Landscape, DAMTP, Cambridge, United Kingdom, 8 March 2007

Wandering the Landscape - Statistics of Intersecting Brane Models, GGI, Florence, Italy, 30 March 2007

Statistics in the Landscape of Intersecting D-Brane Models, CERN, Geneva, Switzerland, 16 April 2007

Exploring the Landscape - Statistics of String Theory Vacua, SUSY '07 Conference, Karlsruhe, Germany, 26 July 2007

Holten, J.W. van, Kosmologie, HOVO College, VU Amsterdam, Amsterdam, The Netherlands, 21 March 2007

Kosmische straling, U Twente, Enschede, The Netherlands, 3 April 2007

Koers, H.B.J., Neutron-rich GRB outflows, Dutch Astrophysics Days 2007, Leiden, The Netherlands, 3 February 2007

Neutron-rich GRB outflows, Max-Planck-Institut fur Astrophysik, Garching, Germany, 1 July 2007

Laenen, E., The phenomenology of particle physics, Shell-FOM theory workshop, Rijswijk, The Netherlands, 10 January 2007

The Standard Model, the Cosmos and the LHC, Bogazici University, Istanbul, Turkey, 28 February 2007

Resummation, Feza Gursey Institute, Istanbul, Turkey, 9 March 2007

Physics of the LHC, University of Iceland, Reykjavik, Iceland, 28 March 2007

Top quarks from Stony Brook to the LHC, Stony Brook University, Stony Brook, USA, 4 May 2007

Theory for the LHC, DRSTP biennial meeting, Dalfsen, The Netherlands, 31 May 2007

QCD at the LHC, Lectures at RECAPP school, Harish-Chandra Research Institute, Allahabad, India, 26 November 2007

Top quark physics, Inaugural meeting of Physics at the Terascale Helmholtz Alliance, DESY, Hamburg, Germany, 5 December 2007

Mulders, P.J., Het ongrijpbare neutrino, Natuurkundig Genootschap, Rotterdam, The Netherlands, 19 March 2007

Appearance of single spin asymmetries in hard scattering processes, Workshop on Transverse Momentum, Spin and Position Distributions of Partons in Hadrons, Trento, Italy, 12 June 2007

Postma, M., The trouble with inflation, Universiteit Leiden, Leiden, The Netherlands, 12 April 2007

The trouble with inflation, King's College, London, United Kingdom, 2 July 2007

Schellekens, A.N., Model Building With RCFT Orientifolds, Ecole Polytechnique, Paris, France, 29 March 2007

Instanton induced neutrino masses in RCFT Orientifolds, String Phenomenology 2007, Frascati, Italy, 7 June 2007

The RCFT orientifold Landscape, Strings 2007, Madrid, Spain, 25 June 2007

The Emperor's last clothes, DESY, Hamburg, Germany, 10 July 2007

The Emperor's last clothes, University, Utrecht, The Netherlands, 10 October 2007

The RCFT orientifold Landscape, University, Bonn, Germany, 15 October 2007

Neutrino masses from Instantons in RCFT orientifolds, Workshop on instantons and effective actions, Munich, Germany, 14 November 2007

The RCFT orientifold Landscape, University, Turin, Italy, 11 December 2007

White, C.D., A Global Fit to Scattering Data with NLL BFKL Resummations, HERA-LHC meeting, Hamburg, Germany, 14 March 2007

A Global Fit to Scattering Data with NLL BFKL Resummations, DIS07 Conference, Munich, Germany, 18 April 2007

Constraining Geometries in the AdS / QCD Correspondence, Nikhef theory meeting, Amsterdam, The Netherlands, 22 June 2007

Constraining Geometries in the AdS / QCD Correspondence, GGI Workshop, Florence, Italy, 17 October 2007

Single top production in the Wt mode with MC@NLO, HEPTools network meeting, Athens, Greece, 26 November 2007

Detector R&D

Chefdeville, M.A., Recent Gridpix results, LCWS2007, DESY, Hamburg, Germany, 29 May 2007

Recent Gridpix results, IWORID 07, Erlangen, Germany, 22 July 2007

Measurements and modelling of the ion backflow fraction of integrated Micromegas detectors, 2007 IEEE Nuclear Science Symposium and Medical Imaging Conference, Honolulu, Hawaii, USA, 28 October 2007

Graaf, H. van der, The Glorious Future of Gaseous Detectors, Micro Pattern Gas Detectors Workshop, CERN, Geneva, Switzerland, 11 September 2007

Results from MPGDs with a Protected TimePix or Medipix-2 Pixel Sensor as Active Anode, 2007 IEEE Nuclear Science Symposium and Medical Imaging Conference, Honolulu, Hawaii, USA, 28 October 2007

Timmermans, J., Towards 3D reconstruction of single-electron clusters with the TimePix pixel circuit, Vienna Conference on Instrumentation, Vienna, Austria, 20 February 2007

Pixel readout of MPGD - Some recent results at NIKHEF, Micro Pattern Gas Detectors Workshop, CERN, Geneva, Switzerland, 11 September 2007

Silicon Pixel Readout for a TPC, ALCPG07, Fermilab, Batavia, USA, 23 October 2007

Visschers, J.L., Medipix and RelaxD: een geslaagde samenwerking, Nationale MicroNano Conferentie '07, WICC, Wageningen, The Netherlands, 15 November 2007

Figure 1. Both Stan Bentvelsen and Els Koffeman delivered their inaugural lecture on the 15th of February 2007 at the University of Amsterdam.

3.4 Prizes & Grants

NWO awards Vernieuwingsimpuls grants
Each year the Netherlands Organisation for Scientific Research (NWO) awards *Veni* and *Vidi* grants to promising researchers. The Veni grants are for young researchers to develop their ideas (about € 200,000), while the Vidi-grants enable young excellent postdocs – who have developed innovative ideas – to start a research group (up to € 600,000).

In 2007 a Veni grant was awarded to Jelena Petrovic for her proposal *'Search for sources of high energy cosmic rays with the ANTARES neutrino telescope and the Auger observatory'*.

Vidi grants were awarded to Marieke Postma for *'The early Universe as a particle laboratory'*, to Niels Tuning for *'No GUTs, no Glory: a Search for Grand Unified Theories with B-decays'* and to Marco van Leeuwen for *'Hard probes of the quark gluon plasma'*.

Rubicon
The aim of the Rubicon programme is to encourage talented researchers at Dutch universities and research institutes run by the Royal Netherlands Academy of Arts and Sciences (KNAW) and NWO to dedicate themselves to a career in postdoctoral research. Rubicon offers researchers who have completed their doctorates in the past year the chance to gain experience at a top research institution outside the Netherlands.

In 2007 Max Baak was awarded a Rubicon grant by NWO for two years research at CERN.

European Physical Journal – Poster competition
Guus Wijnker was awarded the second prize in the European Physical Journal Poster Competition for his poster *"ANTARES' first neutrinos?"* He received the prize in April 2007 at the annual congress of the Nederlandse Natuurkundige Vereniging (NNV) 'Fysica 2007'.

European Physical Society Outreach Prize
Charles Timmermans (RU and Nikhef) received on 23 July 2007 in Manchester the European Physical Society (EPS) High Energy Physics Outreach Prize, together with dr. Richard Jacobsson (CERN). They were honoured because of their enthousiastic involvement in physics activities for high school students. Timmermans is initiator of the HiSPARC project – a network of high school students and research institutes for particle research. The EPS considers the participation of scientists in outreach activities very important. The prize is awarded bi-annually and amounts to 25,000 Swiss francs.

Science Park Good Ideas Contest
The Nikhef teams of Harry van der Graaf and Jan Just Keijser won the second and third prize in the *'Science Park Goed Idee Competition'*. Harry van der Graaf was also awarded the *'Publieksprijs'*.

Figure 1. Charles Timmermans, one of the winners of the 2007 EPS High Energy Physics Outreach Prize.

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. This year highlights were first data and results coming in from the astroparticle physics experiments. Obviously, the status of LHC and Nikhef's contributions to its detectors received ample attention. The Jamboree was concluded with reflections on the future of CERN and Nikhef by their respective directors.

Monday 17 December 2007

09:30	Welcome (C. Erkelens)
09:35	LHC status (J. Engelen)
09:50	B-physics introduction (A. Pellegrino)
10:00	LHCb VELO and Pile-Up Detectors (M. van Beuzekom)
10:20	LHCb Outer Tracker (H. Terrier)
11:17	BaBar search for rare decay $B \to Da^0$ (H. Snoek)
11:40	APP introduction (G. van der Steenhoven)
11:50	First ANTARES Neutrino Data (G. Lim)
12:05	Counting EM showers in the sea (S. Mangano)
13:50	The GZK limit and the search for particle point sources at Auger (C. Timmermans)
14:05	Radio Detection at Auger (S. Harmsma)
14:20	ALICE/STAR introduction (R. Snellings)
14:25	High p_T and heavy flavour (A. Mischke)
14:45	Elliptic Flow Analysis (N. v.d. Kolk)
15:35	The AdS/CFT correspondence (K. Schalm)
16:30	Status of the ALICE SSD (P. Christakoglou)

Figure 2. Ivo van Vulpen talking about ATLAS physics readiness.

Figure 1. CERN's Science Director Jos Engelen giving an overview of the LHC status at the 2007 Jamboree.

Tuesday 18 December 2007

09:30	Status of ATLAS (S. Bentvelsen)
09:40	The SCT detector (M. Limper)
09:55	Cosmics in the muon detector (J. Snuverink)
10:10	Status of DØ (F. Filthaut)
10:25	Hunt for Higgs at DØ (L. Ancu)
11:10	Trigger in ATLAS (S. Klous)
11:25	Physics readiness (I. van Vulpen)
11:40	Theory '07 overview (E. Laenen)
11:50	Graceful exit from inflation and dark energy (T. Prokopec)
12:10	Estimating Mutiple Hard Jet Final States in Higgs Production (C. White)
14:00	Gravitatiegolven (T. Ketel)
14:15	Periodieke bronnen (S. van der Putten)
14:30	GRID (J. Templon)
14:50	Detector R&D (J. Schmitz)
15:50	ILC (J. Timmermans)
16:10	CERN future (J. Engelen)
16:25	Nikhef future (F. Linde)
16:40	Open discussion

Nikhef's director Frank Linde (left) and presenter Bart Meijer, at the shooting of a scene for the children's TV programme 'Klokhuis' at CERN.

4

Nikhef & Society

4.1 Communication

Nikhef is in the process of reinforcing its image as a modern, high quality research institute and increasing its visibility in a national and international context. Target groups range from scientists to funding agencies and the general public. Informing a general audience about the what and why of Nikhef activities will in return influence Nikhef's visibility, funding and human capital influx.

The Nikhef communication strategy follows several routes to guarantee a good internal and external communication. The website plays of course an important role in both. It is one of the key priorities to release a redesigned, efficient and user-oriented website which will meet the needs of both internal and external users. The preparation for this reconstruction and redesigning has been completed, for the technical part in collaboration with the Computer Department. The next step will be taken with the assistance of external experts. By frequently contributing items for the newsletter *"FOM express"*, the Communications Department to keep the Nikhef staff, including those working in other institutes, and our other FOM colleagues informed. Another instrument to realise this are the 'Nikhef-wide' emails, which, amongst other things, are used for invitations to lectures, colloquia and Science Park Lectures.

To offer a glance at how the outside world is experiencing Nikhef, the FOM press cuttings bulletin is a good instrument. Lying around in the Nikhef coffee corner it has become a much referred to source of discussions and often a resource of pride as well. Other instruments for internal communication are being discussed with the Nikhef Management Team and will be part of the new communication plan, which is under development.

In 2007 the general focus of the Communications Department was on increasing the media exposure and on carrying on with the implementation of the new Nikhef house style, by restyling some of the communication instruments such as leaflets, stationary, business cards and research exhibits in the entrance hall of the Nikhef building.

As the evaluation of Nikhef by an international panel required a careful presentation of the Nikhef research activities and its output, much time was spent on the production and editing of a self-evaluation report and a strategic plan.

Outreach activities: Science communication
During the annual Dutch Science Week ('*Weten Week*') in October Nikhef opened its doors to the general public. It is a perfect opportunity to be in direct contact with a very diverse audience. In 2007 the Open Day's theme was *"Top of the iceberg"* and as usual it was organised in collaboration with all the other research institutes at the Science Park Amsterdam, where Nikhef is based. This year approximately 1200 visitors found their way to the research presentations, the mini-lectures, the technical facilities and the special children's activities.

The theatre company *Theater Adhoc* is preparing a documentary on the search for the Higgs boson, partly sponsored by Nikhef. They visited CERN several times and received all the necessary assistance from Nikhef. They even interviewed Peter Higgs, the Scottish physicist who predicted in 1964 the existence of the so far elusive particle named after him. The progress of their work can be viewed at www.theateradhoc.nl. Theater Adhoc also performed a play on the mysteriously disappeared physicist Ettore Majorana in several university cities.

Contacts with the media
The Nikhef Communications Department is always trying to improve its – already quite good – relations with the press. By frequently issuing press releases and by personal contacts the Nikhef science communicator keeps in touch. Many science journalists of printing and broadcasting media now know where to find Nikhef's specialists, and quite a lot of them visited CERN or Nikhef in 2007. They were shown around by Nikhef staff, which resulted in a huge amount of articles, often full page and often illustrated, in national newspapers, opinion magazines and popular scientific magazines, and in several radio interviews.

Figure 1. "You've got to be joking!" Not everybody believes everything said at Nikhef during the Open Day.

Figure 2. Minister Ronald Plasterk (middle) is shown around CERN by CERN's Chief Scientific Officer Jos Engelen (left) and Herman ten Kate, project leader of the ATLAS magnet system (right).

The famous children's TV programme *Klokhuis* did some shooting in April at CERN, with Nikhef's director Frank Linde playing a key role, rolling around on his favourite skeelers. The TV broadcasting of the programme has been postponed until 2008, but visitors of the Open Day in October had a preview.

As there probably will be even more media attention in 2008, because of the LHC start up, the Communications Department and the Personnel Department started to develop a Media Training Programme for Nikhef staff in collaboration with the science theatre group *Pandemonia*.

The CERN visiting programme

Nikhef supports visits to CERN. Apart from (science) journalists, a lot of student groups, varying from high school and university students to Honours and HOVO (elderly) students and other interested parties got a guided CERN tour. Also the Minister of Education, Culture and Science, Ronald Plasterk, a scientist himself, visited CERN, on October 25, 2007. He was shown around by prof. Jos Engelen, CERN's Chief Scientific Officer, prof. Herman ten Kate, project leader of the ATLAS magnet system, the Dutch permanent representative in Geneva Boudewijn van Eenennaam, ATLAS spokesman Peter Jenni, and Nikhef director prof. Frank Linde.

Collaboration on communication

Nikhef collaborates in several national and international outreach committees to share ideas and to coordinate science communication. Frequent contacts with the CERN science communication office exist, and with the start of new large international projects, a worldwide particle and astroparticle physics communication strategy is necessary. Nikhef is a (pro) active partner in many European outreach activities. In 2007 the international meetings dealt mainly with the LHC start-up activities. Possibilities for exhibits and collaborations with local science centres were discussed.

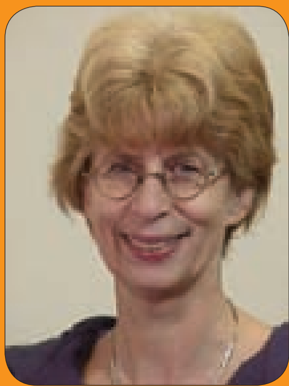
Education

Nikhef considers it one of its tasks to encourage the interaction between scientists and (high school) students.The institute invests in special educational projects on all levels, as well as in visits of students to Nikhef and CERN, and it offers special facilities. Nikhef provides, for example, scientific speakers for schools or other organisations ('*Professor on demand*'), school technicians can borrow research equipment and it is possible for high school students to do some research at Nikhef. In their final high school year Dutch students carry out a dedicated science project. For this purpose several projects have been developed, including one aimed at measuring the muon life.

Around ten school groups from all over the country visited Nikhef in 2007. They were offered a guided tour, a lecture by a (young) scientist and a film. They obviously liked it, considering their and their teacher's reactions. Some of them returned on the Open Day for a second look around, bringing their father or friends. Nikhef staff members were also involved in other educational activities throughout the Netherlands, initiated by the universities or on special occasions

One of the projects in which Nikhef participates is the national '*Techniek Toernooi*', a competition for primary school children (4-12 years) in which they have to succeed in several technical challenges. The third edition of this Techniek Toernooi in 2007 was extremely successful. The organisers tried to cope with three hundred subscriptions for two hundred places, and in the end they managed to find a compromise. The result was that more than one thousand participants (divided in two hundred fifty teams of four children and a supervisor) from about hundred fifty Dutch schools, and another thousand supporters had the day of their life in '*Het Land van Ooit*' – an attraction park in the southern part of the Netherlands. One of the two main objectives of the Techniek Toernooi is to offer an opportunity to school kids and their teachers to experience science and technology as something interesting and pleasant, and as very important for society.

Nikhef's Els de Wolf, one of the coordinators of the Techniek Toernooi, emphasised that there were about as many girls as boys, and that the organisers had succeeded in attracting participants from all over the country.



The other objective is to support the technical curriculum at primary schools. Schools can win interesting prizes – sponsored by Dutch industries, funding agencies and universities – by developing good educational material. University professors in flying colours (even at temperatures of 30° Celsius or more) acted as jurors, amongst them a lot of Nikhef scientists.

Eureka Cup

A further initiative in which Nikhef participates is the *'Eureka Cup'* competition, in which high school teams (first, second and third year) do some research and development. In 2007 the tasks were focused on the theme *'Space exploration'*. After several months of studying and constructing there was a Eureka Day on May 30 in the Evoluon in Eindhoven with the end presentations of the winners. The organisers of this project hope that the school kids like this first sniff of science and technology, and that they will continue to like it.

HiSPARC

National attention went to HiSPARC (*High School Project on Astrophysics Research with Cosmics Glos!*). This programme started in 2002 as a joint project of high schools and scientific institutions to measure cosmic radiation and participate in front-line scientific research on the origin of high-energy particles from outer space. The HiSPARC coordinator is based at Nikhef. The participating schools build a set of scintillators for measuring cosmic rays, which is placed on the school's roof. As many schools throughout the Netherlands are participating in the project – in 2007 again a few schools joined in so the total is nearing fifty – a true network has been established, enabling the observation of very high-energy cosmic rays. There also have been a few clusters of schools/research institutes started up, one in the region around Enschede, coordinated by Twente University, and one in Eindhoven, coordinated by the Technical University Eindhoven. In Groningen a detector has been placed in the university's *'Discovery bus'*.

In Nijmegen radio antennas have been placed as well as new data-acquisition stations. They are expected to be able of sampling the output of both the antennas and the HiSPARC detectors.
In 2007 a PhD student started his research with HiSPARC, focusing on airshowers. To collect the necessary data twenty detectors have been constructed by students of several schools. These detectors are placed, in sets of four, on the roofs of buildings at the Science Park Amsterdam.

A new data-acquisition system is being constructed, increasing the performance and the reliability of the detection systems.

The success of the project has led to the formation of a European network (*EuroCosmics*) of physics teachers and scientists who are using similar systems. In 2007 EuroCosmics has submitted a proposal for support to the European FP7 programme.

International Masterclass on Particle Physics

The *European Masterclass on Particle Physics* is since the *World Year of Physics* in 2005 annually organised in March by the European Particle Physics Outreach Group (EPPOG). On March 22 and 23, 2007, Nikhef had the honour to be host of about 40 high school students (mostly fifth grade). They were offered a varied, interesting programme with theoretical and practical items and informal meetings with scientists. This also happened at the same time in research institutes in Athens, Prague, Göttingen, Zaragoza and Stockholm. As ad hoc 'scientists' the school students analyzed particle collisions, observed with the Delphi detector at LEP. They had the choice between an electron, muon, tau or hadron event. At the end of the day they all participated in a videoconference, organised by CERN, to exchange the results of their data analysis and to compete in a quiz. This year's winner was …… Greece.

New physics curriculum

Since 2006 Nikhef participates in the development of the novel physics curriculum for secondary schools in the Netherlands: NiNa (*'Nieuwe Natuurkunde'/New Physics*) and NLT (*'Natuur, Leven en Technologie'/Nature, Life and Technology*), which is a new optional high school subject.

In 2007 six modules on cosmic radiation, relativity theory and astroparticle physics were designed and written by high school teachers with the help of Nikhef staff. Some of the modules are being tested in high school classes.

Mega media attention for HiSPARC
A few years ago nobody would have thought that the audience at a pop festival would be seen listening fascinated and breathlessly to a physics professor. At the Lowland Festival in August 2007 it happened: in fact, last year Prof. Robbert Dijkgraaf – excellent scientist in the field of string theory, and also a gifted speaker – did it. His lecture on quantum mechanics, relativity theory, string theory, and astroparticles attracted hundreds of young pop music lovers and very much media attention. Prof. Dijkgraaf explained the existence of astroparticles with the so called HiSPARC ski-boxes. These red 'ski-boxes' are in fact detectors. Robbert Dijkgraaf was also keynote speaker at the annual HiSPARC High School Meeting in Amstelveen.

Master programme
Nikhef enjoyed the graduation of 7 masters in the Master of Science Programme *"Particle and Astroparticle Physics"* in 2007. Several of the graduates surprised their supervisors by definitely choosing for a career as a teacher instead of researcher – a unique choice that never happened before in the master programme.

As usual about 30 students were enrolled in 2007 in the two year master programme in which Nikhef collaborates with several Dutch universities, especially the Universiteit van Amsterdam and the Vrije Universiteit. Many Nikhef researchers perform as lecturers and workshop leaders in this programme.

Part of the curriculum is the development of a detector, including its construction, data collection and analysis as well as project management. The students also spend several months at CERN doing research and in the second and last year of the programme they participate in a research project at Nikhef.

Research School Subatomic Physics
The research school for subatomic physics organises each year academic training courses (*Topical Lectures*) and, in collaboration with Belgian and German research groups, a summer school (BND Summerschool) for PhD students.
The 2007 BND summer school was held in Spa (Belgium). The main focus was on strong interactions. The school was widely appreciated by the more than 40 registered participants. It was organised by prof. Krzysztof Piotrzkowski of the Catholic University Louvain.

As usual, also in 2007 three Topical Lectures were organised: one dealing with tracking in detectors, one on computational methods in particle physics and one on CP violation. The typical attendance of the Topical Lectures was 20–25 PhD students during the morning sessions (lectures) and 15–20 PhD students during the afternoon sessions (exercises).

In December 2007 61 PhD students were enrolled in the Research School and 16 PhD students graduated in 2007. Since December 2004 prof. Nicolo de Groot (Radboud Universiteit Nijmegen) is secretary, and the coordination of the school is handled by the Radboud Universiteit.

Throughout the year, the members of the research school's board organise one or two interviews ('C3 *gesprekken*') with each PhD student and their promotor (supervisor) and thesis advisor to monitor the progress of their research project and their participation in the Topical Lectures and the BND Summer school.

4.2 Knowledge transfer

Nikhef's strong technological skills lead to a number of opportunities, where technology is transferred to industry or other science domains. These are typically spin-offs of Nikhef's detector R&D and computing expertise.

Rasnik

The Rasnik alignment technology has gathered its firm place in scientific instruments like the ATLAS detector and the LHCb detector. It is now also being investigated as the alignment tool for CERN's next linear collider ('Rasclic'). A proposal to use Rasnik for seismic registrations, which was an award-winner at FOM's 60th anniversary in November 2006, has formed the basis for Nikhef's first patent application (4 September 2007). Contacts have been established with a company in the realm of oil and gas exploration to follow up on this patent.

Medipix

One of the most successful examples of technology transfer, to a company called PANalytical, has resulted from Nikhef's involvement in the Medipix Collaboration. PANalytical, a medium sized company, formerly part of Philips, is a leading manufacturer of analytical X-ray instrumentation in two lines of business, X-Ray Diffraction and X-Ray Fluorescence. Several years of intense collaboration, starting in 2001, between Nikhef and Panalytical, have resulted in the successful market introduction (in 2006) of the PIXcel detector, the first commercially available X-ray detector based on Medipix technology. In 2007 PANalytical has started a small unit for detector production based on the Medipix technology, using Nikhef's refurbished *'Silicon Alley'* cleanroom facilities (see sect. 5.5) for wafer probing, wire bonding, scanning electron microscopy etc. This demonstrates nicely how commercial and research interests may run in parallel.

Grid activities

In 2007 the flagship national e-Science project, the *'Virtual Laboratory for e-Science'* (VL-e) has been favorably evaluated by an international panel during a midterm review. A key observation of the panel was, that in VL-e "*...the GRID, often seen as 'a universal solution to everything' in itself, is here fulfilling its correct role, namely that of one of the important enabling components of e-Science. The important aim of this project is to enable better Science through the use of informatics and networking and hence new ways of working together.*" Nikhef contributes heavily to VL-e and is particularly involved in the packaging of middleware tools, which enables end users to easily access the underlying grid infrastructure. Grid as an essential infrastructure is further disseminated to industry and society by way of *'Gridforum Nederland'*. In 2007 Gridforum has organized various meetings: a spring school, a business day, a grid tutorial and several masterclasses and evening lectures (see http://gridforum.nl).

Success for Dutch industry

In the summer of 2007 the second ATLAS Endcap Toroid Magnet (ECT) was put in its place deep into the earth (80 meters) at CERN near Geneva , which means a big success for the Dutch industry. Together with the earlier placed first ECT the 280 tons weighing second magnet is an important part of the ATLAS detector at the Large Hadron Collider.

Quite a range of Dutch industrial organizations contributed to the ATLAS detectors and the innovative character of the ECT justified a rather big subsidy from SenterNovem (Ministry of Economic Affairs). The two ECT magnets were designed by the Rutherford Appleton Laboratory and built by Nikhef in close collaboration with Dutch industry: Corus produced aluminium plates, of which Schelde Exotech and Machinefabriek Amersfoort manufactured huge and heavy (70 tons) aluminium barrels. This required high quality welding. Brush-HMA and RDM realised the vacuum impregnation and winding of the coils and Schelde Ecotech assembled the vacuum barrels.

Figure 1. An ATLAS end cap toroid magnet in its cryostat is transported at CERN.

4.3 ASPERA
towards a European Research area for Astroparticle Physics

In 2007 Nikhef organised two major events for ASPERA – the Astroparticle ERA-network: a National Day in April and the workshop *"Defining priorities for astroparticle physics"* in September.

ASPERA is a network of national governmental agencies responsible for coordinating and funding national research efforts in Astroparticle Physics. It started as an ERA-NET in July 2006 within the 6th Framework Programme of the European Commission, involving agencies from 12 European countries. The main objective of ASPERA is to facilitate and improve collaboration in astroparticle physics research in Europe, especially in view of the various new large-scale infrastructures that are needed in this field.

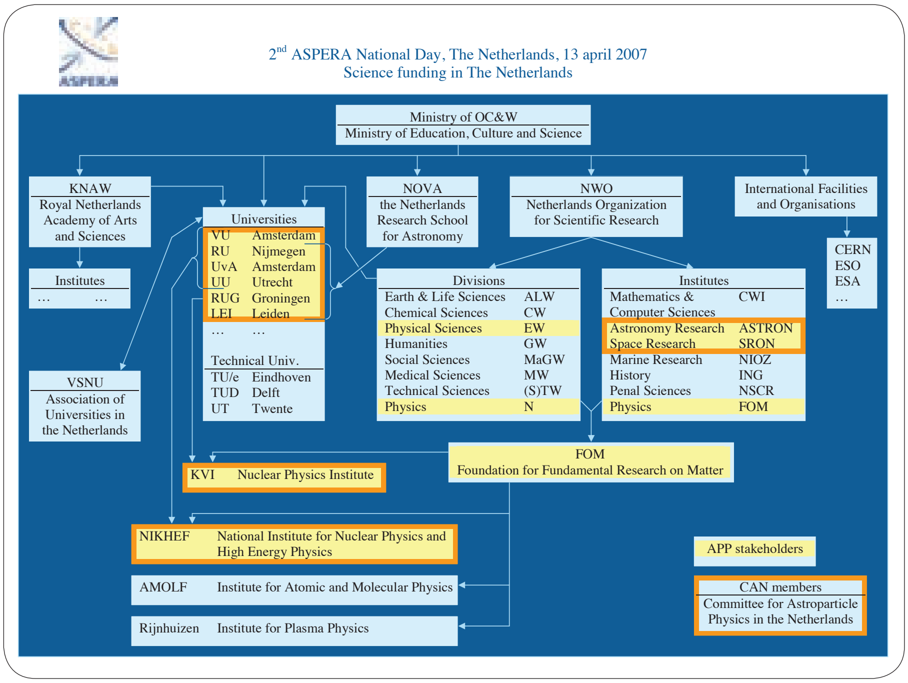


Figure 1. Schematic overview of the various agencies and institutes contributing to science funding in the Netherlands. Yellow boxes mark those institutions that contribute to astroparticle physics funding. The orange squares mark institutions that are represented in the Committee for Astroparticle Physics in the Netherlands (CAN).

The ASPERA-activities are organised in five work packages. The Netherlands (FOM/Nikhef) is coordinating work package 1 and strongly involved in work package 2.

Work package 1 aims at determining the present status of European research funding in Astroparticle Physics, and work package 2's objective is to prepare a roadmap and other activities towards the development of Astroparticle Physics as a European Research Area.

Figure 2. Panel discussion concluding the ASPERA Roadmap meeting in Felix Meritis in Amsterdam, 21 September 2007.

Realising the objectives of work package 1 included for each participating country organising a 'National Day' and filling out a Questionnaire concerning scientific content, available resources and evaluation and decision making procedures in all participating countries. The Dutch National Day was organised at Nikhef on 13 April 2007. The meeting was well attended by representatives from all relevant organisations in the Netherlands, and was well appreciated by the international ASPERA colleagues. During the meeting a schedule was shown (Fig. 1) representing the Dutch system of funding agencies. The writing of a report on the funding methodology of astroparticle physics research in all countries involved started in 2007.

In the framework of work package 2, a dedicated workshop was organised in Amsterdam on 20 and 21 September 2007 entitled *"Defining priorities for astroparticle physics"*. At this meeting seven working groups, each covering a well-defined research area within astroparticle physics, presented their priorities, budgets and timelines until 2018. These plans were compared to strategic plans for astroparticle physics in other parts of the world (USA and China). The meeting included a panel discussion (Fig. 2).

4.4 Memberships

ASPERA - Joint secretariat
R. van der Meer
G. van der Steenhoven

Astroparticle Physics European Coordination (ApPEC)
P. Kooijman (peer review committee)
F. Linde (steering committee)
G. van der Steenhoven (steering committee)

Board of Computer Algebra Nederland
J. Vermaseren

CERN Contact Commissie
S. Bentvelsen
J. van den Brand
S. de Jong (secretary)
R. Kamermans
R. Kleiss
F. Linde
Th. Peitzmann

CERN Council Strategy Group
S. de Jong
F. Linde

CERN Large Hadron Collider Committee
S. de Jong

CERN SPS Committee
P. Kooijman

Committee for Astroparticle Physics in the Netherlands (CAN)
S. de Jong
F. Linde
R. van der Meer (secretary)
P. Mulders
G. van der Steenhoven (chair)

DESY, Hamburg - Program Review Committee
J. Timmermans

Deutsche Physikalische Gesellschaft Hadronen Physik - Scientific Advisory Committee
J. Koch

Development and Commissioning of LOFAR for Astronomy Review Committee (DCLA review)
G. van der Steenhoven

Dutch Research School Theoretical Physics - Educational Board
P. Mulders (chair)

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

European Particle Physics Outreach Group
G. Zegers

European Physical Society High Energy Physics Board
B. van Eijk

European Physics Journal - Scientific Advisory Committee
P. Mulders

European Policy Management Authority for Grid Authentication
D. Groep (chair)

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

FOM Board
J. Engelen
S. de Jong

FOM - Adviescommissie FOM/v programma
E. de Wolf (chair)

Gesellschaft fur Schwerionenforschung, Darmstadt - Program Advisory Committee
Th. Peitzmann

GridKa Overview Board, Karlsruhe
K. Bos

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

International Grid Trust Federation
D. Groep

Institute for Particle Physics Phenomenology, Durham - Steering Committee
N. de Groot

InterActions
A. van den Bergen

Kamer Natuurkunde (VSNU)
G. van der Steenhoven

KNAW Raad voor Natuur- en Sterrenkunde
F. Linde
Th. Peitzmann

KVI, Groningen - Wetenschappelijke Adviescommissie (WAC)
P. Mulders
G. van der Steenhoven

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

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

Nederlands Tijdschrift voor Natuurkunde - Redactie
S. de Jong

Nederlandse Natuurkundige Vereniging (NNV) - Board
P. Mulders (secretary)
G. van der Steenhoven (chair)
E. de Wolf

NNV - Sectie H
P. Kluit
E. Koffeman

NNV - Sectie Onderwijs en Communicatie
S. de Jong (vice chair)

Nuclear Physics European Collaboration Committee (NuPECC)
Th. Peitzmann

Onderzoekschool Subatomaire Fysica - Onderwijscommissie
Th. Bauer
S. Bentvelsen
J. van den Brand
T. van Egdom (personnel)
B. van Eijk
N. de Groot (chair)
J. van Holten
S. de Jong
M. Kesgin (secretary)
J. Koch
E. Laenen
F. Linde
M. Merk
P. Mulders
Th. Peitzmann
G. van der Steenhoven

Open Grid Forum
D. Groep (area director security)

Platform Beta en Techniek - ambassadeur
F. Linde
G. van der Steenhoven
E. de Wolf

Stichting Conferenties en Zomerscholen over de Kernfysica (StCZK)
S. de Jong
P. Mulders
G. van der Steenhoven (chair)

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

Stichting Natuurkunde.nl
G. van der Steenhoven

Stichting Physica
G. van der Steenhoven

Stichting Quality Assurance Netherlands Universities Evaluation Committee Liberal Arts and Sciences
N. de Groot

Techniek Toernooi 2008
E. de Wolf

Vereniging Gridforum Nederland
A. van Rijn (treasurer)

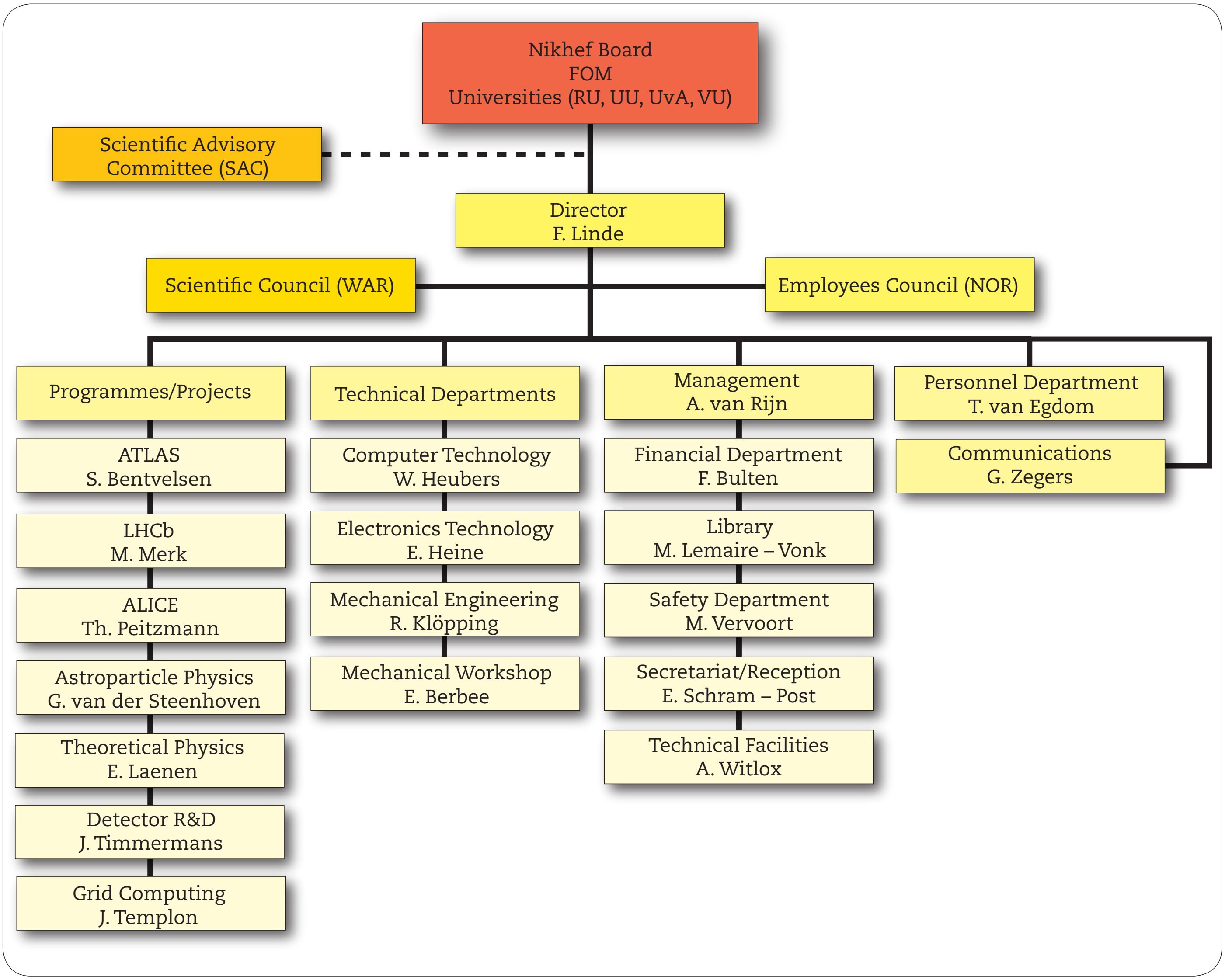
Worldwide LHC Computing Grid Management Board
J. Templon

In 2007 an international committee of experts visited Nikhef for an evaluation of the institute. Here they are seen inspecting a clean room. Foreground: committee members Felicitas Pauss (ETH, Zürich), Jos Benschop (ASML, Veldhoven), Christian Spiering (DESY, Zeuthen), background: Jan Visser (Nikhef/PANalytical).

5

Resources

5.1 Organigram



5.2 Organisation*

Nikhef Board

K. Chang (FOM)
R. Griessen (chair, FOM, VU)
J. de Kleuver (secretary, FOM)
R. van Kooten (UU)
J. Kuijpers (RU)
J. van Mil (VU)
K. van der Toorn (UvA)

Management Team

T. van Egdom
F. Linde
A. van Rijn

Scientific Advisory Committee (SAC)

S. Bethke (Max-Planck-Institut für Physik, Munich)
R. Cashmore (Brasenose College, Oxford)
J. Dainton (chair, Liverpool University, Liverpool)
C. De Clercq (Vrije Universiteit Brussel, Brussel)
T. Hebbeker (RWTH Aachen, Aachen)
Y. Karyotakis (LAPP, Annecy le Vieux)

Employees Council (NOR)

J. Amoraal (secretary)
Th. Bauer (vice chair)
H. Boer Rookhuizen (chair)
J. Dokter
M. Gosselink (vice secretary)
J. Kok
A. Korporaal
N. Rem
Y. Tona
L. Wiggers

Scientific Council (WAR)

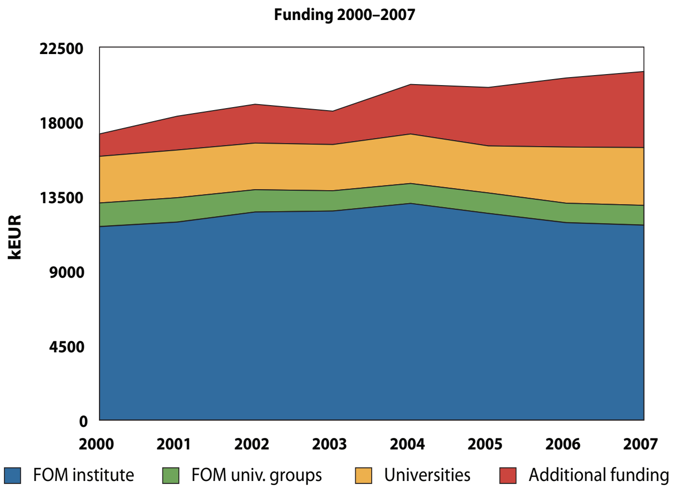
S. Bentvelsen
J. van den Brand
H. van der Graaf
N. de Groot
M. de Jong
P. de Jong
S. de Jong
E. Koffeman
E. Laenen
F. Linde
M. Merk (chair)
Th. Peitzmann
A. van Rijn (secretary)
G. van der Steenhoven
J. Templon
R. Timmermans (KVI, Groningen)

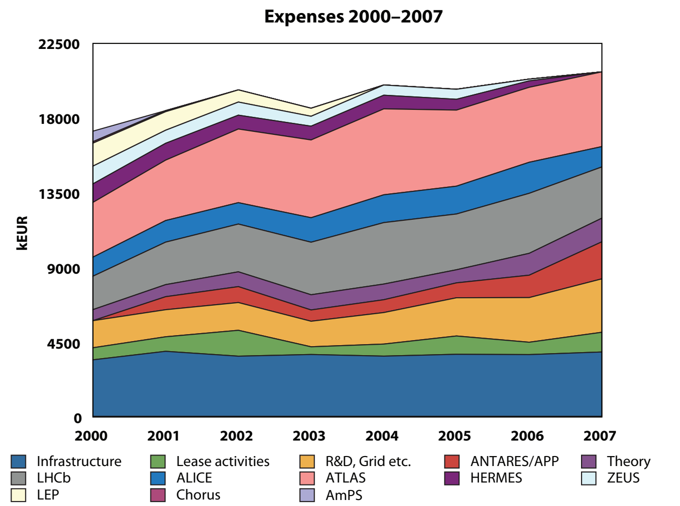
* *as of 31 December 2007.*

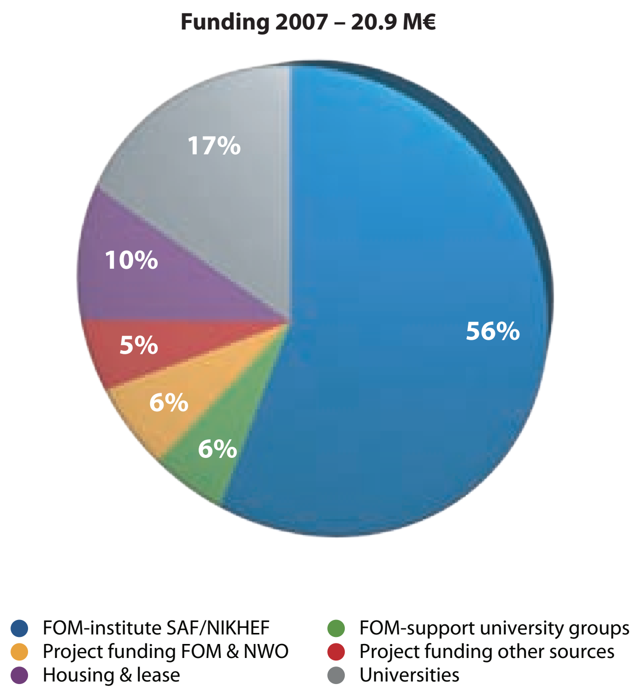
5.3 Funding & Expenses

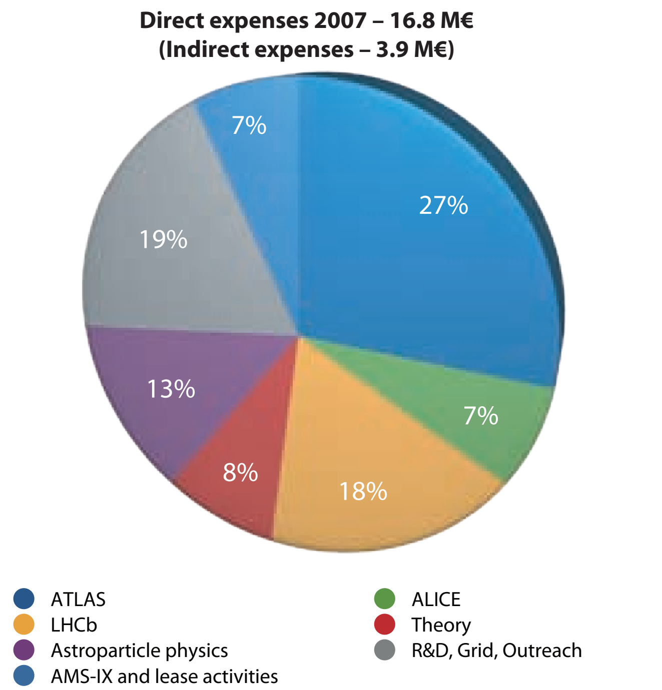
In 2007 the total funding of Nikhef has increased with almost half a million euro, despite the further downward base funding from FOM. The total funding is at the level of 20.9 M€ of which 62% is FOM mission and program budget, 17% is university funding, whilst the remainder is project funding and income from housing and lease activities. This external funding has increased to 4,6 M€ (4,2 M€ in 2006), distributed as follows: FOM and NWO projects: 1,35 M€, other sources (EU, Economic Affairs, etc.): 1,15 M€, housing and lease: 2,1 M€. In 2007 several new projects (funded by FOM, NWO and EU) have been acquired, of which the financial effects will become visible from 2008 onwards.

The expenses graphs show the disappearance of ZEUS and HERMES (administratively closed per ultimo 2006). The expenses for the LHC experiments stabilize, with personnel cost moving from technical to physics efforts. R&D, including grid and outreach, and astroparticle physics activities are increasing, together now at the level of 32% of direct expenses (2006: 24%).









5.4 Nikhef invests in training programmes

Quite in line with the changing focus at Nikhef and CERN – from production to research activities – the number of personnel at Nikhef, expressed in full time equivalent (fte) has been going down in the period 2006–2007 from 240 to 235 fte. The number of personnel of the scientific groups has slightly increased from 132 fte to 134 fte. The decrease of technical staff started in 2004 from 109 fte to the level in 2007 of 78 fte. It is related to the construction activities for the present and future experiments. For the next period a constant level is expected of about 80 fte of technical staff and 20 fte for the support staff.

Nikhef continued in 2007 its courses and training programme to enhance the expertise and employability of its employees. Especially the courses of Nikhef partner FOM, the Foundation for Research on Matter, for PhD students were very successful. Some of them – *Goal oriented working and planning* and the *Dutch language course* are compulsory, others – such as *The art of presenting science, Being successful in Dutch organisations, Business Orientation Programme, Personal Skills Offer,* and *Personal Career Planning* are optional.

The complete management team and department's and group leaders of Nikhef, including director Frank Linde, participated in management trainings in 2006 and 2007. They all considered it very useful.

Eric Heine, group leader of the Electronics Technology Group, was one of the staff who participated in 2007 in the training *'Leiding geven tussen professionals'*, organized by the CPD, the Central Personnel Office of FOM.

"It seems easy to manage professionals, because you are dealing with intelligent, independent people who can manage on their own," Eric Heine observes, *"but exactly that is the problem, because they all are individual persons with whom you would like to work towards one and the same goal."*

All employees had job evaluation meetings with their group leader to evaluate past performances and to discuss plans for their future.

Nikhef closely monitors sick leave. The absence due to illness showed a decrease from 2.2 % in 2006 to 2% in 2007, which is about half the average absence due to illness in the Netherlands.

Figure 2. Safety first! Fire–extinguisher training at Nikhef.

5.5 Infrastructure: Cleanroom Facilities

Top scientific research at Nikhef can only be performed with state-of-the-art instrumentation, or even better. Since e.g. high-quality detectors are often not commercially available, Nikhef engineers and physicists design and construct such devices themselves. For this purpose Nikhef avails of cleanrooms with several grades of cleanliness. The Nikhef cleanroom facilities were intensively used and extended over the past 10 years, mainly for development, assembly, and testing of detector systems for the Large Hadron Collider experiments. During this period, and culminating in 2007, several almost industrial-scale projects were simultaneously realized to accomplish the challenging goals set by international scientific collaborations such as ATLAS, LHCb, and ALICE. With these highly visible activities, Nikhef has confirmed its excellent name in the field of circuit-design, detector- and micro-systems design, lightweight mechanical supports, challenging cooling designs, and excellent quality control of dimensional as well as functional aspects.

Delivery of the detector subsystems to their subterranean caverns at CERN in Geneva was needed almost simultaneously for all three LHC experiments in which Nikhef participates. The subsequent decrease in large-scale projects at Nikhef has caused a temporary overcapacity in our cleanroom area. But, within the next several years, we expect new large-scale cleanroom activities to appear, in the wake of projects like LHC upgrades and detectors for the International Linear Collider (ILC). On top of that, Nikhef contributes increasingly to non-accelerator projects such as ANTARES/KM3NeT, the Pierre Auger Observatory, VIRGO, LISA, etc. A similar trend can be observed there, to use advanced technologies requiring a modern cleanroom infrastructure.

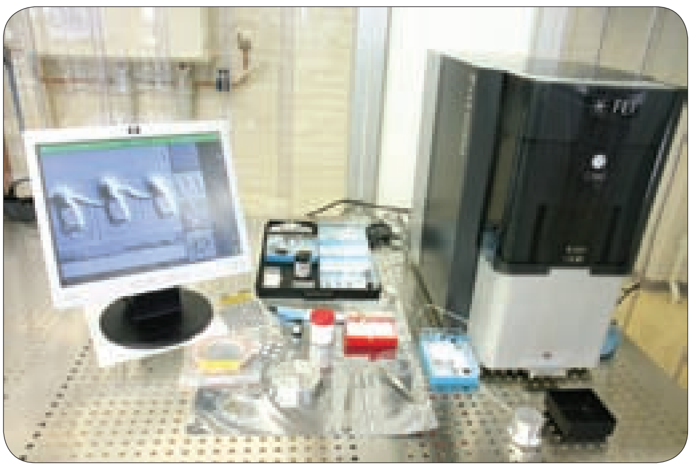


Figure 1: Scanning Electron Microscope (FEI-Phenom), for quality analysis of high-density interconnects.

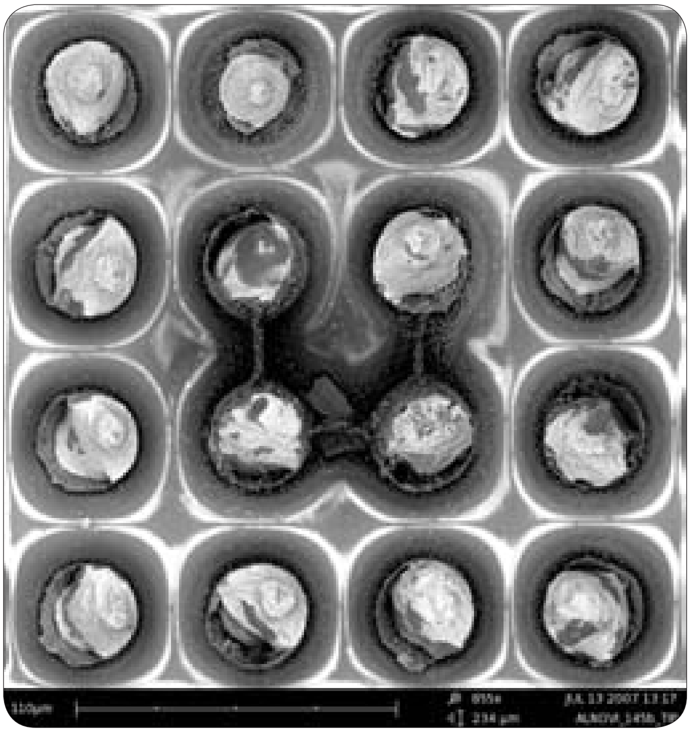


Figure 2: SEM image of faulty flip-chip bonds. Three 25 μm bumps are shorted by solderbridges.

Finally, a growing effort is invested by Nikhef in research and development of completely new radiation detectors, based on modern semiconductor processing technologies (see sect. 2.10). This has led to the formation of a detector R&D group at Nikhef, closely collaborating not only with our traditional partners in high-energy physics (HEP), but also with technical universities and industrial R&D laboratories in the Netherlands and Europe. Funding for such activities comes partly from non-HEP sources, like FOM-IPP, STW, SenterNovem, EU-FP7, and also from direct support by Dutch industry, who are now using part of our infrastructure.

To maintain our momentum in detector R&D, and to be ready in time to play a leading role in the design and construction of new large-scale detector systems, the Nikhef cleanroom facilities needed streamlining and improvement. A project group of scientists and engineers has formulated and executed a plan, satisfying our needs in the medium term. The result is an updated facility for chip- and wafer-processing, including precision dicing, die-bonding, wire-bonding, plasma-cleaning and sputtering, pull- and shear-testing, and a scanning electron microscope (SEM). Purchase of a precision laser-cutting and dicing equipment is still foreseen for 2008.

5.6 Personnel

Overview of Nikhef personnel in fte (2007)

I – Scientific groups
(fte – 2007, institute & university groups)

Permanent scientific staff	54
PhD students	60.8
Post–docs	19.4
Total I	***134.2***

II – Management, technical/engineering and general support (fte – 2007, institute)

Management team	
Director	1
Institute manager	1
Personnel/HRM officer	0.8
Subtotal	***2.8***
Technical/engineering support	
Electronics workshop	27.6
Computer technology	18.2
Mechanical engineering	11.8
Mechanical workshop	18.6
Project management support	1.6
Subtotal	***77.8***
General support	
Financial administration	3.8
Personnel/HRM administration	1
Library	0.9
Technical and domestic services	8.3
Secretariat and reception desk	4.3
PR & communication	0.9
Occupational health & safety	1
Subtotal	***20.2***
Total II	***100.8***
Total I & II	***235***

III – Other groups
(persons 2007)

Guests (researchers, retired staff)	22
Master students	25

Table 1. Overview of Nikhef personnel in full time equivalents (fte).

Experimental physicists

Amoraal, drs. J.M	FOM	B-Physics
Anastasoaie, mevr. drs. C.M.	GST	ATLAS/DØ
Ancu, drs. L.S.	RU	ATLAS/DØ
Baak, dr. M.A.	GST	ATLAS/DØ
Bauer, dr. Th.S.	FOM	B-Physics
Benedosso, mevr. drs. F.	UU	ALICE
Bentvelsen, prof. dr. S.C.M.	UvA	ATLAS/DØ
Berg, drs. P.J. van den	FOM	ATLAS/DØ
Bilandžic, drs. A.	FOM	ALICE
Bilevych, dr. Y.	FOM	Other Projects
Blanco Carballo, MSc. V.M.	UT	Other Projects
Blok, dr. H.P.	GST	Other Projects
Bobbink, dr. G.J.	FOM	ATLAS/DØ
Boer, dr. F.W.N.	GST	Other Projects
Bos, drs. E.	FOM	B-Physics
Bos, dr. K.	FOM	Other Projects
Botje, dr. M.	FOM	ALICE
Bouwhuis, mevr. dr. M.C.	FOM	Astroparticle Physics
Braidot, drs. E.	FOM-UU	ALICE
Brand, prof. dr. ing. J.F.J. van den	VU	B-Physics
Bruijn, drs. R.	GST	Astroparticle Physics
Bruinsma, ir. P.J.T.	GST	Other Projects
Bulten, dr. H.J.	VU	B-Physics
Chefdeville, drs. M.A.	FOM	Other Projects
Chojnacki, drs. M.	FOM-UU	ALICE
Christakoglou, dr. P.	FOM-UU	ALICE
Colijn, dr. A.P.	UvA	ATLAS/DØ
Colle, dr. J.	GST	HISPARC
Colnard, mevr. drs. C.	FOM	Astroparticle Physics
Coppens, mevr. drs. J.M.S.	FOM	Astroparticle Physics
Dantzig, dr. R. van	GST	Other Projects
Decowski, dr. M.P.	FOM	Astroparticle Physics
Djordjevic, drs. M.	GST	ATLAS/DØ
Doxiadis, MSc. A.D.	FOM	ATLAS/DØ
Dreschler, drs. J.	FOM	Other Projects
Duinker, prof. dr. P.	GST	Other Projects
Eijk, prof. dr. ing. B. van	FOM	Other Projects
Eijndhoven, dr. N. van	UU	ALICE
Engelen, prof. dr. J.J.	UvA	Other Projects
Filimonov, dr. V.	GST	ATLAS/DØ
Filthaut, dr. F.	RU	ATLAS/DØ
Fransen, MSc. M.	FOM	Other Projects
Galea, mevr. drs. C.F.	GST	ATLAS/DØ
Garitaonandia, drs. H.	FOM	ATLAS/DØ

Figure 1: Some of Nikhef's staff gathered at the entrance to the main building.

Gosselink, ir. M.	FOM	ATLAS/DØ
Graaf, dr. ir. H. van der	FOM	ATLAS/DØ
Grigorescu, drs. G.T.	FOM	Other Projects
Groep, dr. D.L.	FOM	Other Projects
Groot, prof. dr. N. de	RU	ATLAS/DØ
Harmsma, ir. S.	FOM	Astroparticle Physics
Hartjes, dr. F.G.	FOM	Other Projects
Hegeman, ir. J.G.	GST	ATLAS/DØ
Heijne, dr. ir. E.H.M.	GST	Other Projects
Herzberger, prof. dr. L.O.	GST	Other Projects
Hesselink, dr. W.H.A.	GST	Other Projects
Hessey, dr. N.P.	FOM	ATLAS/DØ
Hoek, ir. M.J. van der	GST	Astroparticle Physics
Hoogland, prof. dr. W.	GST	Other Projects
Houben, drs. P.	GST	ATLAS/DØ
Hug, MSc. J.J.	FOM	Other Projects
Hulsbergen, dr. W.	GST	B-Physics
Igonkina, mevr. dr. O.B.	GST	ATLAS/DØ
Ivan, ir. C.G.	FOM-UU	ALICE
Jans, dr. E.	FOM	B-Physics
Jansen, drs. E.	FOM	ATLAS/DØ
Jansen, ir. F.M.	FOM	B-Physics
Jong, prof. dr. M. de	FOM	Astroparticle Physics
Jong, dr. ir. P. de	FOM	ATLAS/DØ
Jong, prof. dr. S. de	RU	ATLAS/DØ
Kamermans, prof. dr. R.	FOM-UU	ALICE
Kayl, drs. M.S.	FOM	ATLAS/DØ
Keramidas, drs. A.	GST	Other Projects
Kesteren, drs. Z. van	UvA	ATLAS/DØ
Ketel, dr. T.J.	FOM-VU	B-Physics
Klok, drs. P.F.	FOM-RU	Other Projects
Klous, dr. ing. S.	FOM	ATLAS/DØ
Kluit, dr. drs. ir. P.	FOM	ATLAS/DØ
Koekoek, drs. G.	VU	Astroparticle Physics
Koetsveld, drs. F.	FOM-RU	ATLAS/DØ
Koffeman, mevr. prof. dr. ir. E.	FOM	ATLAS/DØ
Kolk, mevr. drs. ing. N. van der	FOM	ALICE
König, dr. A.C.	RU	ATLAS/DØ
Konijn, dr. J.	GST	Other Projects
Kooijman, prof. dr. P.	UvA	Astroparticle Physics

Koutsman, drs. A.J.	FOM	ATLAS/DØ
Kraaij, drs. E. van der	FOM	ATLAS/DØ
Kraus, mevr. dr. I.C.	FOM	ALICE
Krzewicki, MSc. M.	FOM	ALICE
Kuijer, dr. P.G.	FOM	ALICE
Laan, dr. J.B. van der	FOM	Other Projects
Lapikás, dr. L.	FOM	Other Projects
Liebig, dr. W.	FOM	ATLAS/DØ
Lim, ir. G.	UvA	Astroparticle Physics
Limper, mevr. drs. M.	UvA	ATLAS/DØ
Linde, prof. dr. F.L.	FOM	Directorate
Lingeman, dr. E.W.A.	GST	Other Projects
Lysebetten, mevr. dr. A. Van	FOM	B-Physics
Magrath, mevr. MSc. C.A.	FOM	ATLAS/DØ
Mangano, dr. S.	FOM	Astroparticle Physics
Massaro, dr. G.G.G.	GST	ATLAS/DØ
M'charek, mevr. drs. B.	VU	B-Physics
Meer, dr. R.L.J. van der	FOM	Astroparticle Physics
Meijer, MSc. M.M.	FOM	ATLAS/DØ
Merk, prof. dr. M.H.M.	FOM	B-Physics
Nooren, dr. ir. G.J.L.	FOM-UU	ALICE
Novak, drs. T.	GST	Other Projects
Oord, drs. G.J.W.M. van den	FOM	ATLAS/DØ
Ordonez Sanz, drs. G.	RU	ATLAS/DØ
Palacios, dr. J.P.	FOM	B-Physics
Palioselitis, MSc. D.	FOM	Astroparticle Physics
Papadelis, drs. E.A.	FOM	B-Physics
Peitzmann, prof. dr. Th.	UU	ALICE
Pellegrino, dr. A.	FOM	B-Physics
Petrovic, mevr. dr. J.	GST	Astroparticle Physics
Poel, MSc. E.F. van der	FOM	ATLAS/DØ
Pree, drs. T.A. du	FOM	B-Physics
Presani, mevr. drs. E.	FOM	Astroparticle Physics
Putten, drs. S. van der	FOM	Astroparticle Physics
Raas, MSc. M.J.P.	RU	ATLAS/DØ
Raven, dr. G.	VU	B-Physics
Reinhold, dr. E.	FOM	Other Projects
Resende Vaz de Melo Xavier, dr. B.	FOM	ATLAS/DØ
Rijpstra, mevr. drs. M.	FOM	ATLAS/DØ
Ruckstuhl, mevr. MSc. N.M.	FOM	ATLAS/DØ
Russcher, drs. M.J.	FOM-UU	ALICE
Simili, drs. E.L.	GST	ALICE
Simioni, drs. E.	FOM-VU	B-Physics
Snellings, dr. R.J.M.	FOM	ALICE
Snippe, ir. Q.H.C.	FOM	Other Projects
Snoek, mevr. drs. H.L.	FOM	B-Physics
Snuverink, ir. J.	FOM	ATLAS/DØ
Steenhoven, prof. dr. G. van der	FOM	Astroparticle Physics
Steijger, dr. J.J.M.	FOM	Other Projects
Tánczos, mevr. dr. I.	FOM	HISPARC
Templon, dr. J.A.	FOM	Other Projects
Terrier, dr. H.J.C.	FOM	B-Physics
Timmermans, dr. C.	FOM	ATLAS/DØ
Timmermans, dr. J.J.M.	FOM	Other Projects
Toet, dr. D.Z.	GST	Other Projects
Tsiakiris, MSc. M.	FOM	ATLAS/DØ
Tuning, dr. N.	FOM	B-Physics
Vankov, drs. P.	FOM	B-Physics
Verkerke, dr. W.	FOM	ATLAS/DØ
Vermeulen, dr. ir. J.C.	UvA	ATLAS/DØ
Visschers, dr. J.L.	FOM	Other Projects
Visser, dr. J.	FOM	Other Projects
Vreeswijk, dr. M.	UvA	ATLAS/DØ
Vries, dr. H. de	FOM	B-Physics
Vulpen, dr. I. van	UvA	ATLAS/DØ
Wiggers, dr. L.	FOM	B-Physics
Wijnker, drs. G.	FOM	Astroparticle Physics
Witt Huberts, prof. dr. P.K.A. de	GST	Astroparticle Physics
Wolf, mevr. dr. E. de	UvA	Astroparticle Physics
Ybeles Smit, drs. G.V.	FOM	B-Physics
Zupan, drs. M.	GST	B-Physics

Theoretical physicists

Beenakker, dr. W.J.P.	RU
Boer, dr. D.	VU
Boomsma, MSc. J.K.	VU
Gaemers, prof. dr. K.J.F.	UvA
Gato - Rivera, mevr. dr. B.	GST
Gmeiner, dr. F.	FOM
Holten, prof. dr. J.W. van	FOM
Kleiss, prof. dr. R.H.P.	RU
Koch, prof. dr. J.H.	FOM-UvA
Koekoek, drs. G.	VU
Laenen, prof. dr. E.	UvA-FOM
Maio, MSc. M.	FOM
Motylinski, MSc. P.	GST
Mulders, prof. dr. P.J.	VU
Schellekens, prof. dr. A.N.J.J.	FOM
Veltman, prof. dr. M.J.G.	GST
Vermaseren, dr. J.A.M.	FOM
Vollinga, dr. J.	FOM
Wessels, drs. E.	VU
White, dr. C.D.	FOM

Computer Technology Group

Akker, T.G.M. van den	FOM
Blokzijl, dr. R.	GST
Boterenbrood, ir. H.	FOM
Damen, A.C.M.	FOM
Deurzen, dr. P.A.J. van	GST
Dok, drs. D.H. van	FOM
Gabriel, dr. S.	FOM
Harapan, drs. D.	FOM
Hart, ing. R.G.K.	FOM
Heubers, ing. W.P.J.	FOM
Huyser, K.	FOM
Kan, A.C. van	FOM-Rijnhuizen
Keijser, drs. J.J.	FOM
Kerkhoff, mevr. E.H.M. van	FOM
Koeroo, ing. O.A.	FOM
Kuipers, drs. P.	FOM
Leeuwen, drs. W.M. van	GST
Oudolf, J.D.	PANTAR
Schimmel, ing. A.	FOM
Starink, dr. R.	FOM
Tierie, mevr. J.J.E.	FOM
Venekamp, drs. G.M.	FOM
Wijk, R.F. van	FOM

Electronics Technology Group

Berkien, A.W.M.	FOM
Beuzekom, dr. ing. M.G. van	FOM
Fransen, J.P.A.M.	FOM
Gotink, G.W.	FOM
Groen, P.J.M. de	FOM
Groenstege, ing. H.L.	FOM
Gromov, drs. V.	FOM
Haas, ing. A.P.J. de	FOM
Heijden, ing. B.W. van der	FOM
Heine, ing. E.	FOM
Hogenbirk, ing. J.	FOM
Jansen, L.W.A.	FOM
Jansweijer, ing. P.P.M.	FOM
Kieft, ing. G.N.M.	FOM
Kluit, ing. R.	FOM
Koopstra, J.	UvA
Kruijer, A.	FOM
Kuijt, ing. J.J.	FOM
Mos, ing. S.	FOM
Peek, ing. H.Z.	FOM
Reen, A.T.H. van	FOM
Schipper, ing. J.D.	FOM
Sluijk, ing. T.G.B.W.	FOM
Stolte, J.	FOM
Timmer, P.F.	FOM
Tona, Y.	FOM
Verkooijen, ing. J.C.	FOM
Vink, ing. W.E.W.	FOM
Vliet, J.G.M. van der	RU
Zevering, J.	FOM-VU
Zwart, ing. A.N.M.	FOM
Zwart, F. de	FOM

Mechanical Engineering Group

Band, ing. H.A.	FOM
Boer Rookhuizen, ing. H.	FOM
Buskop, ir. J.J.F.	FOM
Doets, M.	FOM
Klöpping, ir. R.	FOM
Korporaal, A.	FOM
Kraan, ing. M.J.	FOM
Munneke, ing. B.	FOM
Oskamp, C.J.	FOM-UU
Schuijlenburg, ing. H.W.A.	FOM
Thobe, P.H.	FOM
Verlaat, ing. B.A.	FOM

Mechanical Workshop

Berbee, ing. E.M.	FOM
Boer, R.P. de	FOM
Brink, A. van den	UU
Brouwer, G.R.	FOM
Buis, R.	FOM
Ceelie, L.	UvA
Homma, J.	FOM
Jaspers, M.J.F.	UvA
John, D.	FOM
Kok, J.W.	FOM
Kuilman, W.C.	FOM
Leguyt, R.	FOM
Mul, F.A.	FOM-VU
Overbeek, M.G. van	FOM
Petten, O.R. van	FOM
Rietmeijer, A.A.	FOM
Roeland, E.	FOM
Rövekamp, J.C.D.F.	UvA

Management and Administration

Barneveld, mevr. K.M. van	FOM
Berg, A. van den	FOM
Bulten, F.	FOM
Dekker, mevr. C.E.	FOM
Dokter, J.H.G.	FOM
Echtelt, ing. H.J.B. van	FOM
Egdom, T. van	FOM
Faassen, mevr. N.F.	FOM
Greven - van Beusekom, mevr. E.C.L.	FOM
Heuvel, mevr. G.A. van den	FOM
Kesgin - Boonstra, mevr. drs. M.J.	FOM
Kleinsmiede - van Dongen, mevr. T.W.J. zur	FOM
Langenhorst, A.	FOM
Lemaire - Vonk, mevr. M.C.	FOM
Mors, A.G.S.	FOM
Pancar, M.	FOM
Rem, drs. ing. N.	FOM
Rijksen, C.	FOM
Rijn, drs. A.J. van	FOM
Schram - Post, mevr. E.C.	FOM
Spelt, ing. J.B.	FOM
Vervoort, ing. M.B.H.J.	FOM
Vreeken, D.	PANTAR
Werneke, ing. P.J.M.	FOM
Willigen, E. van	FOM
Witlox, ing. A.M	FOM
Woortmann, E.P.	FOM
Yilmaz, E.	PANTAR
Zegers, mevr. drs. G.E.	FOM

Apprentices in 2007

Aaij, R.J.M.	ATLAS/DØ
Adelhart Toorop, R. de	Other Projects
Aerts, M.J.	Computer Technology
Airoude, A.Y.	Technical Facilities
Bazzotti, M.	Astroparticle Physics
Beemster, L.J.	HISPARC
Biesheuvel, J.	Other Projects
Blom, M.R.	Other Projects
Boer Rookhuizen, E.H.L.	Mechanical Engineering
Boltje, D.B.	Other Projects
Bos, mevr. E.M.	Other Projects
Bosma, M.J.	Other Projects
Bruyn, K.A.M. de	B-Physics
Canio, G.R.	Technical Facilities
Caputa, P.P.	B-Physics
Caspers, P.J.M.	Electronics Technology
Çelik, S.	Electronics Technology
Chim, W.M.	Electronics Technology
Cohen, mevr. S.	B-Physics
Dorp, W.A.M. van	HISPARC
Ebeling, R.P.	HISPARC
Eijk, D. van	Theory
Evangelakou, mevr. D.	ALICE
Fransen, M.	ATLAS/DØ
Geer, R. van der	ATLAS/DØ
Grange, Y.G.	Astroparticle Physics
Hanraads, G.J.S.	ATLAS/DØ
Hartman, J.	Other Projects
Hilgersom, D.	Electronics Technology
Hooft van Huysduynen, L.	B-Physics
Hooijberg, N.	Electronics Technology
Kappel, M.F.J. van	Theory
Kea, M.J.	ATLAS/DØ
Keune, A.	Other Projects
Kok, M.O. de	Theory
Kole, M.R.	HISPARC
Koppert, W.J.C.	Other Projects
Koster, R.S.	Theory
Kramer, R.S.	Other Projects
Kuijken, mevr. I.	Other Projects
Leerdam, J. van	ATLAS/DØ
Leeuw, R.H.L. van der	Theory
Leeuwen, M. van	Electronics Technology
Meester, S.	Astroparticle Physics
Meijer, M.M.	Other Projects
Millan Mejias, B.	Other Projects
Mous, I.V.N.	B-Physics
Mussche, I.	ATLAS/DØ
Nooij, mevr. L. de	ATLAS/DØ
Osei, B.	Electronics Technology
Otto, J.	Electronics Technology
Poel, E.F. van der	ATLAS/DØ
Qureshie, M.Y.	Electronics Technology
Reppel, C.	Theory
Ruckstuhl, mevr. N.M.	ATLAS/DØ
Schoorlemmer, H.	Other Projects
Schotten, S.	Other Projects
Spaargaren, B.	Computer Technology
Stoffers, A.	Theory
Strunks, G.D.	Electronics Technology
Suerink, T.C.H.	Other Projects
Terra, F.	HISPARC

Theunissen, A.J.	B-Physics
Til, S. van	ATLAS/DØ
Tsiakiris, M.	ATLAS/DØ
Velzen, S. van	Astroparticle Physics
Versloot, T.W.	B-Physics
Vries, A.S.M. de	HISPARC
Weber, A.C.	B-Physics
Wegloop, mevr. A.J.	Theory
Witteveen, mevr. M.L.M.	Other Projects
Zevenbergen, P.H.A.	Theory

They left us

Anastasoaie, mevr. drs. C.M.	ATLAS/DØ
Arrizabalaga, dr. A.	Theory
Baak, dr. M.A.	ATLAS/DØ
Bai , mevr. dr. Y.	ALICE
Barthel, R.G.E.	Mechanical Workshop SAF-UU
Bergen, mevr. A.M. van den	Secretariat - Reception
Bomhof, dr. C.	Theory
Bruijn, drs. R.	Astroparticle Physics
Caputa, P.P.	B-Physics
Demey, dr. M.	Other Projects
Ebeling, R.P.	HISPARC
Eldik, dr. dipl. phys. N. van	ATLAS/DØ
Ennes, drs. P.	ATLAS/DØ
Fanizzi, G.	Electronics Technology
Ferreira Montenegro, mevr. drs. J.	Other Projects
Fuster, mevr. dr. A.	Theory
Galea, mevr. drs. C.F.	ATLAS/DØ
Geerts, M.L.	Computer Technology
Grebenyuk, drs. O.	ALICE
Heijns, K.P.	Algemeen
Hidden, F.J.	HISPARC
Hoek, ir. M.J. van der	Astroparticle Physics
Houben, drs. P.W.H.	ATLAS/DØ
Jongsma, S.	Other Projects
Keramidas, drs. A.A.	Other Projects
Kirby, dr. M.H.	ATLAS/DØ
Koers, drs. H.B.J.	Theory
Korthals Altes, T.E.	HISPARC
Lefevere, Y.	Other Projects
Li, drs. Z.	Other Projects
Liempt, drs. F.J.P. van	HISPARC
Lopez - Villarejo, drs. J.J.	Theory
Massaro, dr. G.G.G.	ATLAS/DØ
Millan Mejias, B.	B-Physics
Motylinski, MSc. P.	Theory
Nardulli, drs. J.	B-Physics
Nat, dr. P.B. van der	Other Projects
Nguyen Mau, dr. C.	HISPARC
Otto, J.	Electronics Technology
Petrovic, mevr. dr. J.	Astroparticle Physics
Plumeri, dr. S.	ALICE
Postma, mevr. dr. M.E.J.	Theory
Reischl, dr. dipl. phys. A.	Other Projects
Rodrigues, dr. E.	B-Physics
Schrader, dr. ir. J.H.R.	Other Projects
Simili, drs. E.L.	ALICE
Tomasek, ing. L.	Other Projects
Uiterwijk, dr. ir. J.W.E.	Other Projects
Vankov, drs. P.	B-Physics
Vykydal, Z.	Other Projects
Wang, mevr. drs. Q.	Other Projects
Zupan, drs. M.	B-Physics

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.

Aitoff projection
Aitoff projection is a modified azimuthal map projection. Proposed by David A. Aitoff in 1889, it is the equatorial form of the azimuthal equidistant projection, but stretched into a 2:1 ellipse while halving the longitude from the central meridian.

ALICE (A Large Ion Collider Experiment)
One of the four major experiments that will use 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.

ApPEC (Astroparticle Physics European Coordination)
Consortium of national funding agencies aiming to develop long–term strategies in the field of astroparticle physics research.

ASPERA
Sixth Framework Programme for co–ordination across European funding agencies for financing astroparticle physics.

ATLAS (A Toroidal LHC Apparatus)
One of the four major experiments that will use the *LHC*.

BaBar
$B\bar{B}$ detector at SLAC's B Factory. Named for the elephant in Laurent DeBrunhoff's children's books.

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.

B Factory
SLAC's electron–positron collider, built to produce B–mesons, started in 1999.

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

BNL (Brookhaven National Laboratories)
Laboratory 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.

CHORUS (CERN Hybrid Oscillation Research Apparatus)
Experiment at CERN.

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

Collider
See *Accelerator*.

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

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

CWI
Dutch Centre for Mathematics and Computer Science, Amsterdam

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.

DELPHI
Experiment at LEP, CERN.

D–brane
In string theory, a higher dimensional membrane that provides an anchoring surface for strings.

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.

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.

Elliptic flow
When two heavy nuclei collide in the centre of the *STAR* detector, the initial shape of the collision zone is usually an ellipse. Pressure in the liquid seeks to make the matter round, and so makes the liquid flow faster in the shorter direction. This elliptic flow can be measured in the speed and direction of the particles when they reach the detector, and the flow is largest when many particles are emitted from a given collision. The number of particles emitted depends on the intensity of that collision: how *'head–on'* the collision between the two nuclei was.

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.

EUnet
European UNIX network, Europe's largest Internet Service Provider.

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

Fermion
General name for a particle that is a matter constituent, characterized by spin in odd half integer quantum units (½, 3/2, 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

GeV
See *Electronvolt*.

Globus
Grid middleware toolkit development in the USA.

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*).

HERA
Hadron–Electron Ring Accelerator at DESY.

HERA–B
Fixed–target experiment at DESY, to investigate *CP violation* in the B–meson.

HERMES
DESY fixed–target experiment to explore spin.

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.

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.

L3
Experiment at LEP, CERN.

LCAS (Local Centre Authorization System)
System to verify the *GRID* authorization.

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.

LCMAPS (Local Credential MAPping Service)
Provides all credentials necessary to access *GRID* services within a centre.

LEP
The Large Electron–Positron collider, which ran until 2000.

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 next big accelerator.

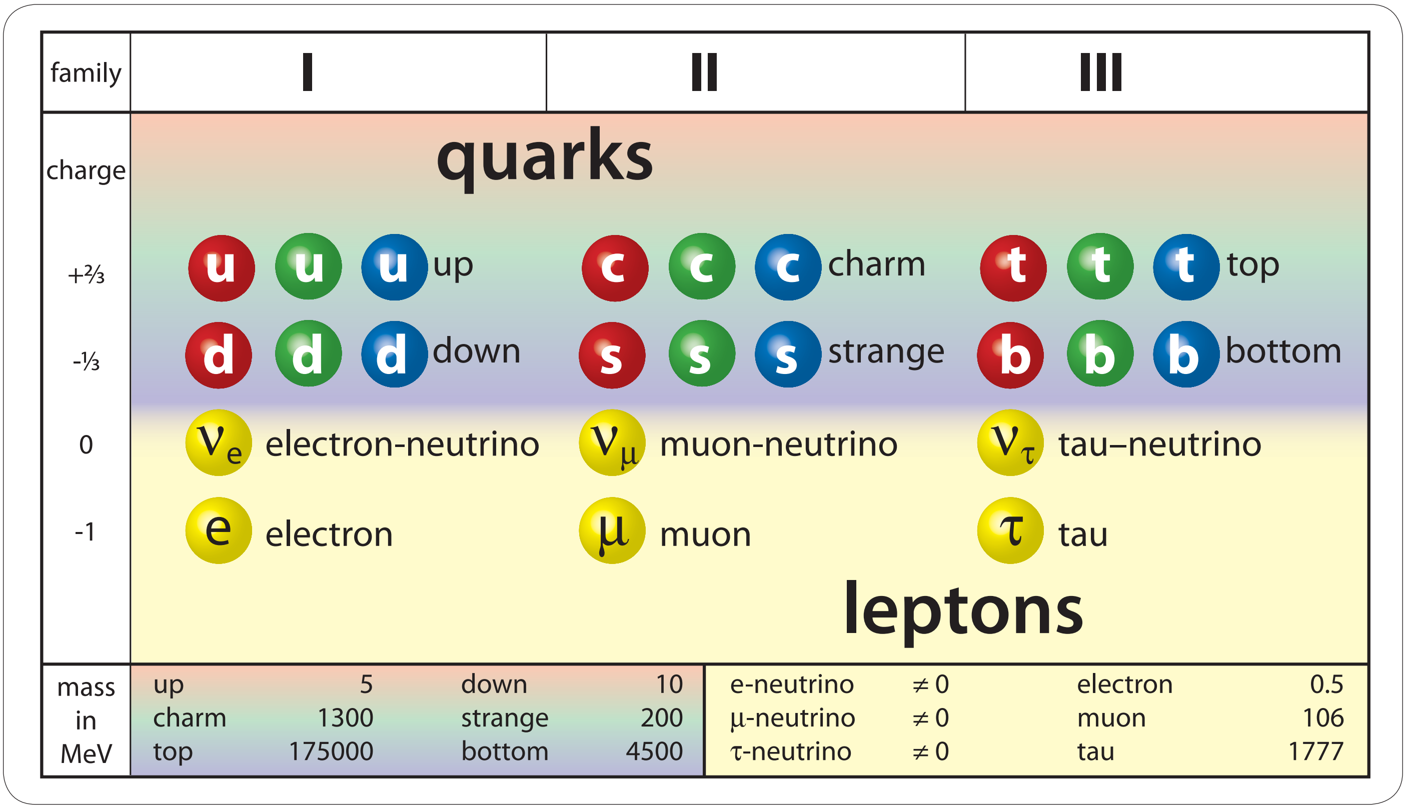


Figure 1: The three families of particles according to the Standard Model.

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

Linac
An abbreviation for linear accelerator.

LISA (Laser Interferometric Space Array)
ESA/NASA mission, the first space–based gravitational wave observatory; 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.

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*.

Nucleon
The collective name for protons and neutrons.

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

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; 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*.

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.
RICH (Ring Imaging CHerenkov)
A kind of particle detector that uses the light emitted by fast–moving charged particles as a means of identifying them.

RIPE (Réseaux IP Européens)
A collaboration between European networks which use the *TCP/IP* protocol suite. RIPE NCC is an IP registry, allocating Internet Protocol numbers to the European region.

SARA
Academic Computing Services of Amsterdam.

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
A theory linking matter and forces.

SURFnet
Networking organisation in the Netherlands.
Synchrotron
See *Accelerator*.

TCP/IP *(Transmission Control Protocol / Internet Protocol)*
Suite of communications protocols to connect hosts on the Internet, invented in 1981.

TDR (Technical Design Report)
The blueprint for a (LHC) detector system.

Technology transfer
The promotion and dissemination of technologies, developed originally for scientific research, to third partied for socio–economic and cultural benefits.

TeV.
See *Electronvolt*.

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

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 to record the data resulting from the collision.

Valorisation
French term for dissemination and exploitation of results.

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.

ZEUS
Collider experiment at DESY's *HERA*.

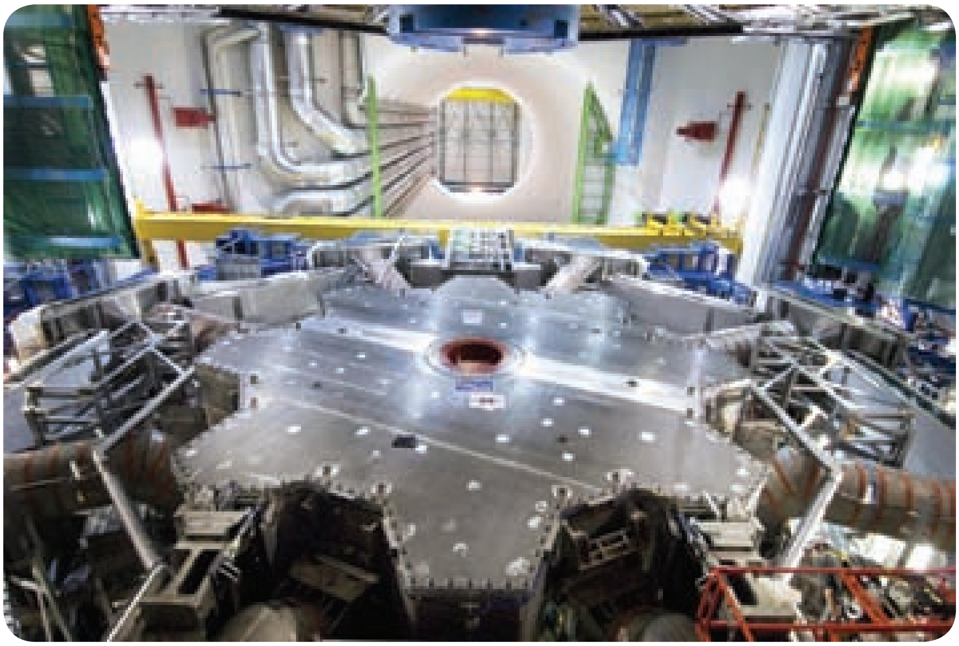


Figure 2: The result of years of hard work, an End Cap Toroid –built by Dutch industry– has arrived in its final position in the ATLAS cavern.