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National Institute
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Nikhef
Nikhef
National Institute for Subatomic Physics

Visiting address
Science Park 105
1098 XG Amsterdam
The Netherlands

Post address
P.O. Box 41882
1009 DB Amsterdam
The Netherlands

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

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

Editors: Kees Huyser, Louk Lapikás, Frank Linde, Vanessa Mexner, Niels Tuning
Layout: Kees Huyser
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Photos: Ad van den Berg, Maximilien Brice, Eric Heine, Jaret Heise, Jacco Herzog, Kees Huyser, Jan Just Keijser, Wim de Knegt, Claudia Marcelloni, Hanne Nijhuis, Peter Tuffy, Marcel Vervoort, Jan Visser, CERN, Nikhef

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

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

Nikhef participates in experiments at the Large Hadron Collider at CERN, notably ATLAS, LHCb and ALICE. Astroparticle physics activities at Nikhef are threefold: the ANTARES and KM3NeT neutrino telescope projects in the Mediterranean Sea; the Pierre Auger Observatory for cosmic rays, located in Argentina; and gravitational-wave detection via the Virgo interferometer in Italy, and the projects LISA and Einstein telescope. Detector R&D, design and construction of detectors and data analysis take place at the laboratory located at Science Park Amsterdam as well as at the participating universities. Nikhef has a theory group with both its own research programme and close contacts with the experimental groups.
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Beyond any doubt, the 2009 highlight took place on 23 November when for the first time CERN’s LHC (Large Hadron Collider) delivered head-on proton-proton collisions to the experiments. Initially, the protons were collided at the injection energy of 450 GeV. Soon after, both proton beams were accelerated to 1.18 TeV and brought into collision, surpassing the world-record centre-of-mass energy held for almost a quarter century by the Tevatron collider at Fermilab near Chicago. With real data to analyse, ‘interactions’ in the ATLAS, LHCb and ALICE quarters at Nikhef increased by an order of magnitude overnight, as did the general spirit at Nikhef and at many other particle physics laboratories around the world. It was amusing to witness the fierce competition between PhD students, postdocs and staff physicists on who reconstructed the most convincing $p_0^0$, $\phi$, $\Lambda^0$ or $K_S^0$ invariant mass peak! The central values and widths of many of these peaks agree remarkably well with their Monte Carlo expectations. This shows that the experiments are very well positioned to run at the new energy scale, the TeV scale, which the LHC is designed for to explore in the coming years. Some experiments are even more ready than others as the ALICE collaboration proved by (probably much to the chagrin of the other three collaborations that experiment at the LHC) their submission of the first paper based on the analysis of LHC proton-proton collisions appropriately titled: “First proton-proton collisions at the LHC as observed with the ALICE detector: measurement of the charged particle pseudorapidity density at $\sqrt{s}=900$ GeV”. On this high note CERN did shutdown the LHC on 16 December for the Christmas holidays. The challenges after the restart in February 2010 are clear: a modest increase of the LHC beam energy to its nominal value of 7 TeV and a large boost in the LHC luminosity to eventually reach the scheduled $10^{34}$ cm$^{-2}$s$^{-1}$. Accelerator technology is outside my scope of expertise, but many machine physicists assure me that the LHC machine behaves like a charm and that these goals can be achieved.
can hardly wait for the days when the LHC will routinely deliver 10–100 fb$^{-1}$ per year at 14 TeV centre-of-mass energy.

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

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

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

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

Frank Linde
Nikhef director
1.1 Identifying Dark Matter

Patrick Decowski

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

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

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

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

Direct detection

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

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

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

Fig. 2 shows the upper limits (90% confidence level) on the spin-independent cross section for scattering of a WIMP off a nucleon, as a function of WIMP mass for different generations of experiments. Also shown in the figure is a blue region (called parameter space) that indicates the expected values for cross section versus WIMP mass in the constrained Minimal Supersymmetric Model (cMSSM). While the XENON10 experiment only started to probe the upper regions of the cmSSM parameter space, next-generation experiments like XENON100 and ultimately XENON1T will probe the bulk of it.
with potentially a large neutralino density and is nearby. The Sun
body to observe neutralino annihilation as it has a large mass
the solar material. The Sun is the most promising astronomical
(see Fig. 3). Any other decay products will be readily absorbed by
annihilation through heavy b-quarks and through W-bosons
high-energy neutrinos and that bracket the available models:
calculations predict two annihilation channels that produce
are identical to their own anti-particles, such as for instance
neutralinos), the probability that two WIMPs annihilate will grow.
over time, the local WIMP halo density will increase and,
as their energy is decreased through scattering with nuclei
get captured in the attractive gravitational field of these objects
production of neutrinos is strongly suppressed due to conservation
primary background for the analysis consists of atmospheric neutrinos and mis-reconstructed downgoing atmospheric muons. First
preliminary limits for the initial 5-line detector were presented
in the 2009 International Cosmic Ray Conference; analysis with
the full 12-line detector is ongoing.

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

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

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

**Indirect detection**

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

A number of experiments are presently searching for this type
of annihilation signal and one of the most promising searches
is to look for high-energy neutrinos from the Sun. Theoretical
calculations predict two annihilation channels that produce
high-energy neutrinos and that bracket the available models:
annihilation through heavy b-quarks and through W-bosons
(see Fig. 3). Any other decay products will be readily absorbed by
the solar material. The Sun is the most promising astronomical
body to observe neutralino annihilation as it has a large mass
with potentially a large neutralino density and is nearby. The Sun

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

![Figure 3. Neutrinos from neutralino ($\chi$) annihilation can be produced directly or indirectly through the decay of annihilation products. The direct production of neutrinos is strongly suppressed due to conservation of helicity. If the annihilation occurs in the Sun, the solar material will absorb particles other than neutrinos.](image)
WIMP mass and the momentum distribution an estimate of the interaction strength between WIMPS and quarks. However, collider experiments themselves cannot definitively prove the existence of dark matter particles, because they cannot verify that the produced particles are sufficiently stable to be dark matter. Nikhef is involved with dark matter searches at the LHC, in both the ATLAS and the LHCb experiments.

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

**Outlook**

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

**The neutralino as a WIMP candidate**

The neutralino —denoted by the symbol $\chi$— is introduced in an extension to the Standard Model of particle physics called supersymmetry (SUSY). This extension encompasses a natural grand unification of all interactions between elementary particles and solves the so-called hierarchy problem, a fine-tuning problem in the Standard Model. One of the consequences of SUSY is that there is an additional symmetry between bosons and fermions. SUSY pairs bosons with fermions and vice-versa so that each Standard Model particle has a supersymmetric partner with the same quantum numbers, but with spin differing by $\frac{1}{2}$. This mechanism modifies the running of the coupling constants (which describe the strength of the interaction as a function of energy) and leads to their unification at high energies as required by Grand Unification Theories. Since we do not observe the supersymmetric partners, the symmetry must be broken at low energies. A subset of SUSY is the Minimal Supersymmetric Standard Model (MSSM). It assumes that a symmetry called the R-parity is conserved and gives rise to a new quantum number. It also naturally leads to a supersymmetric particle called the Lightest Supersymmetric Particle (LSP) that must be stable. If there were supersymmetric particles in the early universe, they will have decayed to a large number of stable LSPs that would remain to the present day. Within the MSSM, the LSP is the neutralino, a neutral particle with a mass between 10 GeV and 1 TeV, that only very weakly interacts with other particles. In this framework the neutralino is a WIMP and a compelling candidate particle for being the dominant component of dark matter.
1.2 Cooling by carbon dioxide
the past at Nikhef and the future in HEP

Bart Verlaat and Auke-Pieter Colijn

2009 has been an interesting year for carbon dioxide (CO$_2$), not only because of climate issues, but also because of its usage as coolant in two high-energy physics experiments. During the last decade commercial refrigeration has made a move towards CO$_2$ cooling as well, because of the ‘green’ properties. In contrast to synthetic refrigerants CO$_2$ does not deplete the ozone layer and has a low green house effect.

CO$_2$ has been proven to be a very good cooling fluid for detectors as well. Not because we want to make our detectors ‘green’ (although it is always good to keep the environment in mind when building a detector), but because CO$_2$ has a very high volumetric cooling capacity, about a factor two better than conventional refrigerants. This means that CO$_2$ needs only small-volume tubing to remove large amounts of heat. These small volumes in the detector directly imply smaller cooling hardware masses and hence less radiation lengths inside the detector.

Nikhef has gained a lot of experience with CO$_2$ cooling over the last 10 years. We have successfully developed the only two CO$_2$ cooling systems presently in use in high-energy physics experiments. The first CO$_2$ cooling system was developed for the Silicon Tracker in the Alpha Magnetic Spectrometer (AMS), which is a cosmic-ray detector that is to be mounted in the International Space Station. The second system was built for the Vertex Locator in the LHCb-experiment at CERN and is presently operational. The goal for both these cooling systems is to remove heat produced by the readout electronics of the silicon detectors. In addition, for the LHCb experiment the silicon sensors themselves need to be at low temperature to keep radiation damage effects under control.

CO$_2$ cooling in AMS

The cooling system for the Silicon Tracker in the Alpha Magnetic Spectrometer is named Tracker Thermal Control System (AMS-TTCS). Nikhef has designed the concept of the system using a new method for controlling the temperature of the cooling pipes. With a mix of technologies borrowed from satellite cooling and commercial refrigeration a concept called 2PACL was born, which has great advantages for a satellite like AMS. The heart of the system is a 2-phase accumulator used also in heat pipes (a passive heat transport technology in space). The acronym 2PACL stands for 2-Phase Accumulator Controlled Loop. The accumulator in the 2PACL is a pressure vessel that controls the carbon dioxide evaporation pressure throughout the whole system, such that boiling of the liquid CO$_2$ takes place at a constant temperature. In this way temperature changes inside the space station will not affect the working temperature of the detector.

Design and construction of the TTCS was done together with the Dutch National Aerospace Laboratory (NLR) in the Noordoostpolder. NLR has a research lab for satellite cooling and was interested in the 2PACL technology for the use in other satellites. In addition to the design, Nikhef has constructed the cooling pipes inside the Tracker (see Fig.1). The complete Alpha Magnetic Spectrometer was assembled in 2009 and will be transported by the Space Shuttle to its final destination in the International Space Station in the summer of 2010.

Figure 1. AMS CO$_2$ evaporator rings in the AMS-Tracker made by Nikhef.

Figure 2. (left) A Velo module with CO$_2$ cooling pipes and (right) the CO$_2$ cooling plant of the Velo Thermal Control System.
CO$_2$ cooling in LHCb

The 2PACL developed for AMS was applied to the CO$_2$ cooling system for the Vertex Locator (Velo) in the LHCb-experiment at CERN. The advantages of the 2PACL principle for earth based detectors are the temperature stability and the possibility of placing the control hardware away from the detector. The only mass remaining in the detector consists of tubes with a small diameter; all the active hardware is located in the radiation-free zone and always accessible for maintenance.

The CO$_2$ system for the Velo is more than a cooling system. It does not only cool away the heat generated in the detector, but it also keeps the detector permanently at a stable temperature. Whether the detector is powered or not makes no difference. The permanent low temperature is needed to slow down the effects of radiation damage in the silicon wafers. The system is therefore called Velo Thermal Control System (VTCS).

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

A ‘CO$_2$,L’ future

The success of CO$_2$ cooling in AMS and LHCb has inspired the high-energy physics community to further investigate the application of CO$_2$ cooling in the upgrade of the inner detectors of ATLAS and CMS. This upgrade is foreseen sometime during the next 10 years when the current vertex detector will be unusable due to radiation damage. Other projects that are considering CO$_2$ cooling as well are the Gridpix projects (readout of gaseous detectors with pixel chips) at Nikhef, DESY and ILC. At tens of other locations CO$_2$ test facilities are being built following the technologies developed at Nikhef, like the 2PACL. At CERN a dedicated research department for CO$_2$ cooling development is set-up. At Nikhef we are setting up a specialized laboratory for development of cooling systems. The laboratory will avail of all necessary equipment for detector thermal development. A 2PACL CO$_2$ test facility is under construction; it will be able to cool and test detector structures. The 2PACL test facility will also be used to perform fundamental research of CO$_2$ heat transfer in small diameter tubes.
1.3 For love of magnets
an interview with Arjan Verweij

Karina Meerman

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

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

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

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

Model magnet

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

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

Superconductivity

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

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

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

An unexpected flaw

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

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

Specialist

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

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

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

Curriculum Vitae

Arjan Peter Verweij (1968)

1986–1991 Physics studies at Twente University
1991–1995 Research appointment at Twente University and CERN
September 1995 PhD at Twente University
1995–1998 Research appointment at CERN
1998–present Staff physicist at CERN
Member of the CERN Scientific Information Policy Board
Department representative to the CERN Technical Students Committee
Department representative to the CERN Associates and Fellows Committee
The world may have changed a lot, but Teus van Egdom has been the same solid presence at Nikhef for nearly 25 years. He is the face of Human Resources, on the work floor and in the management team. He is well liked and respected, but when he starts a sentence with “If I were you...” he is a little feared. When Teus offers advice, people listen.

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

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

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

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

Being right
Although Teus speaks calmly and in a quiet voice, he is not as stoic as he looks. “I can kick up a storm too, you know. I can be quite a nuisance when I know I am right but no one sees that, yet. I can be very direct in speech and in writing. I don’t always realise when my words are too harsh. I just don’t always get the nuance. That’s rarely a problem at Nikhef, but I am sometimes considered too direct when I communicate with other organisations. At Nikhef, being right is never an issue. It’s getting people to acknowledge you’re right, that’s the difficulty. Because they are all scientists and scientists are always right.”

Before he became a personnel manager, Teus wrote policy on personnel matters at FOM. One day he decided to switch careers. “I am happier getting my hands dirty than I am pushing paper. What I mean by that is that I rather work at the same level as other people, than dictate rules for them from above.” And he loves HR. “I am a bit of a whiz-kid on terms and conditions of employment.” According to Teus, the ideal position for an HR Officer is at the heart of an organisation, where he is kept informed about every single proc-
ess. “That is how it works here. I have always been allowed to voice my opinion.” He is confident that the next HR manager will look after Nikhef well, but in his own way. “My advice for the next HR manager is: remain true to your self and don’t allow yourself to be led by the physicists’ issues of the day.”

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

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

Curriculum Vitae
Teus van Egdom (1946)
1964–1970 Various studies in Higher Business and Administrative Management
1964–1977 Managerial and administrative positions in metal industry
1977–1986 Staff member Personnel and Organisation at FOM
1986–present Staff member Human Resource management at Nikhef

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

NAMBU & JONA-LASINIO, WHO BROKE CHIRAL SU(2) X SU(2)
IN A MODEL WITH ELEMENTARY (P)
FOUND A MASSLESS TRIPLET
O- BOUND STATE (\(\pi^+, \pi^0, \pi^-\)).

GOLDSTONE MADE THE GENERATION
OF MASSLESS SCALARS INTUITIVELY
OBVIOUS IN MODELS WITH
ELEMENTARY SCALARS
GOLDSTONE BOSONS (m=0
EXCITATIONS AROUND T
OF THE WINE-BOTTLE

1962 THEOREM, FORMALLY
BY GOLDSTONE: SO
"BROKEN SU"

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

Research
2.1 ATLAS & DØ

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

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

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

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

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

The reconstruction of muons was scrutinised using the cosmic rays, and is based primarily on the recognition of so-called muon segments, i.e. local muon hit patterns inside the MDT chambers. In a second stage the segments are connected and fit to a muon track in the Muon Spectrometer, which is subsequently fitted to tracks of the Inner Detector. Using this 'home grown' software, the segments and tracks are shown to be reconstructed very efficiently. It is particularly worth mentioning that Nikhef also developed a muon tagging algorithm that starts from tracks reconstructed in the Inner Detector, where muon segments are used to ‘tag’ these tracks as originating from muon particles. This algorithm is proven to be very robust for detector effects and will play an important role during the start-up phase of ATLAS.
The performance of the Inner Detector (ID) was checked with the cosmic muons as well. In particular the misalignments of the ID were investigated by comparing the downward-going tracks with the upward-going tracks at the beamline. These studies show that the detector is understood in great detail and that also the ID is ready for physics collisions.

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

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

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

The performance of the direct search for the Higgs boson was improved significantly, especially in the low-$m_H$ regime with the publication of a search in the ZH associated production channel, followed by the decays $Z \rightarrow \nu \nu$ and $H \rightarrow b\bar{b}$. Despite an increased data sample, the $m_H$ range excluded at 95% CL by a combination of Tevatron measurements was reduced slightly, to the region 163–166 GeV.
The LHCb experiment is constructed to perform precision measurements on rare decays of B-hadrons. By selecting specific decay processes that are suppressed in the Standard Model these measurements allow to search for manifestations of physics beyond the Standard Model that affect these B-decays, such as supersymmetry or the presence of extra dimensions. In particular, by comparing the decays of B-particles to corresponding decays of anti-B particles, LHCb hopes to solve the riddle of the absence of antimatter in the universe.

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

### Tracking: Charged particle detection

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

### Momentum measurement with the Outer Tracker

The Outer Tracker detector measures the deflection of the charged particles by the LHCb dipole magnet and effectively determines their momentum. The detector consists of 53,760 drift straw tube detectors of 5 mm diameter arranged in 3 stations of 4 double-layers each. The straw volume is filled with Ar/CO₂ drift gas providing a precise drift time measurement of the traversing particle. In 2009 the detector has been calibrated and the momentum measurement procedure has been fully commissioned. The detector timing has been tuned to provide a precise t₀ reference time and the drift-time relationship has been established. A particular effort has been placed to understand the alignment of the individual detector layers. Firstly, the detectors have been positioned in the LHCb reference system with a precision of better than a millimeter. Secondy, a software alignment algorithm has been commissioned using cosmic ray data to determine the positions of the individual detector modules.

### Vertex Determination with the Velo

The Velo detector is installed around the interaction region. The detector consists of 23 stations of silicon strip detectors measuring the radial (R) and azimuthal coordinates (φ) of charged particles. The active measurement planes are brought as close as possible (8 mm) to the LHC beam. To achieve this, the Velo
First Collisions
On 20 November, the first beams were injected into the LHC ring with an energy of 450 GeV. Interactions of the beam with remnant gas atoms in the beam vacuum were observed in so-called beam-gas events the next day. After both beams had been captured in stable orbits the first collisions were observed on 23 November, by an excited crew in the LHCb control room, see Fig. 2.

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

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

detectors have been installed in the LHC volume and are only separated from the beam vacuum by a 300 µm thin aluminum foil, the RF-foil. During injection of the LHC beams the detectors are retracted by 3 cm. Only during stable beam conditions can the detector be brought to the closed position, centered on the actual beam position, with an accuracy of 5 µm. An online monitoring process follows the beam location by reconstructing the event-by-event vertex positions.

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

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

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

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

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$\pi\pi m$ 0.4 0.42 0.44 0.46 0.48 0.5 0.52 0.54 0.56 0.58 0.6

Events

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Data 2009: $\sqrt{s}=900$ GeV
Fit: $m = 497.2 \pm 0.15$ MeV
The main goal of the ALICE programme is to study the strong interactions of quarks and gluons at very high temperatures and densities, as prevailed a few microseconds after the Big Bang. In particular the aim is to determine the properties of matter under such extreme conditions, and to improve our understanding of the phenomenon of confinement and the generation of mass by the strong interaction, by means of colliding heavy ions at high energy. The Nikhef heavy-ion group participates in the STAR experiment at the RHIC collider and in the ALICE experiment at the LHC, where Nikhef contributed to the construction of the Silicon Strip Detector (SSD) of the Inner Tracking System (ITS).

Detector Improvement

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

After re-installation and test of all connections, cosmics data taking was resumed in August, with and without magnetic field. The data without magnetic field were used for alignment and relative gain calibration. From the two hits of a straight cosmic track through one SSD layer, one can predict the position of the track in the other layer and compare it to the recorded hit position. Fig. 1 shows the distribution of the distances between measured and predicted hits, before and after survey data were used to position the detector modules in the software. These surveys, partly done at Nikhef, were made on the detector ladders before these were mounted. The spread in the distribution is found to be 25 µm, which compares well with the 20 µm measured on modules in beam tests. This result indicates that the mechanical precision was maintained during the subsequent steps of assembly, transport and installation of the SSD.

First Collisions

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

Alignment, calibration, and the physics analysis of these events is in progress. For the energy calibration, 2 million tracks with magnetic field were analysed. Using the combined energy signal from the Inner Tracking System, the energy lost by a traversing particle is determined as a function of the momentum derived from the tracking. The result is shown in Fig. 3, where one can clearly distinguish the various particle species that have traversed the detector.
The production of heavy quarks (charm and bottom) in heavy-ion collisions is interesting because they are produced early in the collision and therefore probe the expanding medium for a large part of its lifetime. Measurements of heavy quark production in proton-proton interactions or perturbative Quantum Chromodynamics calculations can serve as a benchmark. Nikhef participates in the measurement of open charm production in proton-proton and in heavy-ion collisions.

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

Preparing for Physics

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

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

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

Figure 3. Energy deposit measured in the Inner Tracking System, versus particle momentum obtained from the track reconstruction. The curves are parametrisations of the energy deposit for various particle species.
2.4 Neutrino Telescopes: ANTARES & KM3NeT

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

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

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

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

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

Figure 2. Neutrino sky map obtained with Antares in the years 2008–2009. The horizontal line in the centre corresponds to the Galactic disk. The grey coding corresponds to the relative observation time. Each blue point represents one neutrino candidate.
Neutrinos are the only particles that can cross the Earth. Events can thus be identified as a neutrino if the resulting muon travels in the upward direction. A sky map of neutrinos observed with the ANTARES detector is shown in Fig. 2. Approximately 1000 upward neutrinos have been detected last year. With these data, no evidence for a neutrino point source has been found.

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

**KM3NeT**

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

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

into the heart of imagination

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

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

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

A wireless setup for radio detection

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

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

![Figure 1. MAXIMA antenna deployed on the Pampa.](image)

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

Physics highlights of the Pierre Auger Observatory

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

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

![Figure 2. The Auger energy spectrum, only statistical errors are shown. The systematic uncertainty on the energy scale is 22%.](image)
2.6 Gravitational Physics
the dynamics of spacetime

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

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

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

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

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

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

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

Figure 1. Sensitivity of VIRGO in comparison to that of LIGO LHO and LLO 4 km long interferometers, LIGO LHO (2 km long) and GEO600.
The European Commission within the Seventh Framework Programme (FP7) awarded ET funding in 2008 to start a preliminary design study. Nikhef leads the work package WP-1 on site selection and infrastructure (See Fig. 2). These activities are carried out in close collaboration with geoscientists and industry. Projects at Nikhef are on (1) Newtonian noise modeling, (2) seismic measurements, and (3) underground infrastructure.

**Einstein Telescope**

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

Management: prof. dr. E. Laenen

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

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

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

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

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

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

Figure 1. A landscape of various string theory solutions.
The estimates for production rates of so-called supersymmetric particles (squarks and gluinos) were significantly improved. Methods were employed to compute classes of large terms to all orders in perturbation theory. This leads indirectly to stricter bounds on their possible masses. The FORM computer program was further developed, and used to compute a host of mathematical results for so-called multiple zeta values. Such a ‘data-mine’ is of great interest to theorists, and mathematicians. In another study, the three-loop corrections to deep-inelastic scattering via scalar bosons were determined. Though experimentally fictitious, the results of the calculations are very important to understand aspects of high-order QCD perturbation theory.

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

Figure 2. Invariant mass ($m_{bb}$) distribution of the two leading $b$-quarks in the reaction $qq\rightarrow bb\bar{b}\bar{b}$. The error bands are obtained by varying the renormalisation scale $\mu_{R}$ between $\mu_{R}/4$ and $2\mu_{R}$ with $\mu_{R} = \sqrt{\sum p_{T}(b)}$, involving the sum of transverse momenta of the 4 bottom quarks. The dashed line shows the prediction for $\mu_{R} = \mu_{R}/2$.

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

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

Other news

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

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

Marieke Postma gave lectures on “Inflationary cosmology” at the 2009 DRSTP postgraduate school for theoretical high energy physics in Utrecht.
2.8 Detector Research & Development

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

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

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

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

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

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

Read-out Electronics
The read-out system made for the Relaxd project has achieved its goal of 1 Gb/s read-out. This implies that for the Medipix2 and Timepix chip about 100 frames per second can be recorded. For the Medipix3 chip, which operates in a significantly different way, the work has started to realise many more frames per second, depending on the counter depth.
Poster for the 18th VERTEX Workshop which was organised by Nikhef in 2009. Photo © Jacco Herzog
2.9 Grid Computing

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

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

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

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

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

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

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

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

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

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

ATLAS/DØ
D. Arutinov (et al.), R. Kluit, J.D. Schipper
Digital architecture and interface of the new ATLAS pixel front-end IC for upgraded LHC luminosity

A. Dudarev (et al.), J. Buskop
Commissioning test of ATLAS End-Cap Toroidal Magnets

O. Igonkina, H. Garitaonandia Elejabarrieta, S. Klous (et al.)
Calorimetry triggering in ATLAS

Study of the ATLAS MDT spectrometer using high energy CERN combined test beam data

D. Bailey (et al.), N. de Groot, T. Wijnen
The LCFIVertex package: Vertexing, flavour tagging and vertex charge reconstruction with an ILC vertex detector

M. Barbero (et al.), R. Kluit
A new ATLAS pixel front-end IC for upgraded LHC luminosity

Z. Vykydal (et al.), J. Visschers
The Medipix2-based network for measurement of spectral characteristics and composition of radiation in ATLAS detector

M.P. Casado (et al.), O. Igonkina
The ATLAS τ trigger

DØ Collaboration:
A novel method for modeling the recoil in W boson events at hadron colliders

Measurement of the angular and lifetime parameters of the decays B^+_s \rightarrow J/\psi K^{*0} and B^+_s \rightarrow J/\psi \phi

Search for large extra spatial dimensions in the dielectron and diphoton channels in p\bar{p} collisions at \sqrt{s} = 1.96 TeV

Measurement of the semileptonic branching ratio of B^+_s to an orbitally excited D^{**} state: Br(B^+_s \rightarrow D^{**}(2536)\mu^-\nu_X)

Search for associated W and Higgs Boson production in p\bar{p} collisions at \sqrt{s} = 1.96 TeV

Search for neutral Higgs bosons at high tan β in the b(h/H/A) \rightarrow b\tau+\tau- channel

Evidence for the decay B^+_s \rightarrow D^{**}D^{(*)0} and a measurement of \Delta\Gamma_s^{CP}/\Gamma_s

Measurement of the lifetime of the B^+_s meson in the semileptonic decay channel

Search for anomalous top-quark couplings with the DØ detector

Evidence of WW and WZ production with lepton + jets final states in p\bar{p} collisions at \sqrt{s} = 1.96 TeV

Search for long-lived charged massive particles with the DØ detector

Search for charged Higgs bosons decaying into the top and bottom quarks in p\bar{p} collisions

Measurement of \gamma+b+X and \gamma+c+X production cross sections in p\bar{p} collisions at \sqrt{s} = 1.96 TeV

Measurement of the Z\gamma \rightarrow \nu\bar{\nu}\gamma production cross section and limits on anomalous ZZ\gamma and Z\gamma\gamma couplings in p\bar{p} collisions at \sqrt{s} = 1.96. TeV
Search for resonant diphoton production with the DØ detector  

Search for the Standard Model Higgs boson in $\tau$ final states  

Search for Next-to-Minimal supersymmetric Higgs bosons in the $h \rightarrow aa \rightarrow \mu\mu\mu\mu, \mu\mu\tau\tau$ channels using $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV  

Search for resonant pair production of neutral long-lived particles decaying to $b\bar{b}$ in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV  

Search for dark photons from supersymmetric hidden valleys  

Direct measurement of the mass difference between top and antitop quarks  

Measurement of the W boson mass  

Measurement of the $WW$ production cross section with dilepton final states in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV and limits on anomalous trilinear gauge couplings  

Measurement of dijet angular distributions at $\sqrt{s} = 1.96$ TeV and searches for quark compositeness and extra spatial dimensions  

Direct measurement of the W boson width  

Observation of single top-quark production  

Relative rates of $B$-meson decays into $\psi(2S)$ and $J/\psi$ mesons  

Search for charged Higgs bosons in decays of top quarks  

Measurement of trilinear gauge boson couplings from $WW+WZ \rightarrow l\nu jj$ events in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV  

Combination of $t\bar{t}$ cross section measurements and constraints on the mass of the top quark and its decays into charged Higgs bosons  

Measurement of the top quark mass in final states with two leptons  

Determination of the strong coupling constant from the inclusive jet cross section in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV  

Measurement of $\sigma(p\bar{p} \rightarrow Z+X) Br (Z \rightarrow \tau^{+}\tau^{-})$ at $\sqrt{s} = 1.96$ TeV  

Search for pair production of second generation scalar leptoquarks  

Search for a scalar or vector particle decaying into $Z\gamma$ in collisions at $\sqrt{s} = 1.96$ TeV  

Search for admixture of scalar top quarks in the $t\bar{t}$ lepton+jets final state at $\sqrt{s} = 1.96$ TeV  

Search for the lightest scalar top quark in events with two leptons in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV  

Measurements of differential cross sections of $Z/\gamma^{*}+jets+X$ events in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV  

Measurement of the $t\bar{t}$ production cross section and top quark mass extraction using dilepton events in $p\bar{p}$ collisions  

Search for squark production in events with jets, hadronically decaying $\tau$ leptons and missing transverse energy at $\sqrt{s} = 1.96$ TeV  

Search for associated production of charginos and neutralinos in the trilepton final state using 2.3 $fb^{-1}$ of data  

Search for pair production of first-generation leptoquarks in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV  
Search for charged Higgs bosons in top quark decays

J. Hegeman
Jet energy scale calibration in the DØ experiment

LHCb/BaBar
First LHC beam induced tracks reconstructed in the LHCb VELO

W.D. Hulsbergen
The global covariance matrix of tracks fitted with a Kalman filter and an application in detector alignment

BaBar Collaboration:
B. Aubert (et al.); M.A. Baak, G. Raven, H.L. Snoek
Measurement of the e⁺e⁻ → b ¯b cross section between √s = 10.54 and 11.20 GeV

Direct CP, lepton flavor, and isospin asymmetries in the decays B → K⁺τντ

Evidence for X(3872) → ψ(2S)γ in B⁺ → X(3872)K⁺ decays, and a study of B⁺ → e⁺e⁻K⁺K⁻

Improved measurement of B⁺ → ρ⁺ρ⁻ and determination of the quark-mixing phase angle α

Measurement of B → Xτ decays and determination of |V₁u|/|V₁d|

Improved limits on lepton flavor violating τ decays to lν, lπ, IK+ and IK⁻

Search for second-class currents in τ → ωπντ

Measurement of semileptonic B decays into orbitally excited charmed mesons

Search for dimuon decays of a light scalar boson in radiative transitions Y → γA⁰

Evidence for the ηb(1S) meson in radiative Y(2S) decay

Search for a low-mass Higgs boson in Y(3S) → γA⁰, A⁰ → τ⁺τ⁻ at BABAR

Measurement of D⁰–D⁰ mixing from a time-dependent amplitude analysis of D⁺ → K⁺π⁺π⁻ decays

Measurement of B → K⁺(892)γ branching fractions and CP and isospin asymmetries

Precise measurement of the e⁺e⁻ to π⁺π⁻(γ) cross section with the Initial State Radiation method at BABAR

A Search for invisible decays of the Y(1S)

Branching fractions and CP-violating asymmetries in radiative B decays to ηKγ

Measurements of the semileptonic decays B → Dlν and B → D*lν using a global fit to DXlν final states

Search for lepton flavor violating decays τ → l⁺K⁺γ with the BABAR Experiment

Angular distributions in the decay B → K⁺l⁻l⁺

Measurements of time-dependent CP asymmetries in B⁰ → D⁺l⁻l⁺

Dalitz plot analysis of D⁺ → π⁺π⁻π⁻

Search for the decay B⁺ → K⁺(IK+K-)π⁻
Evidence for $B^+ \rightarrow \overline{K}^{*0}K^+$

Measurement of time dependent CP asymmetry parameters in $B^0$ meson decays to $\omega K^0_S$, $\eta' K^0_S$, and $\pi^0 K^0_S$

Observation of $B$-meson decays to $\omega K^+$ and improved measurements for $\omega p$ and $\omega f_0$

Measurement of the $B^- \rightarrow \omega l^+\nu$ and $B^- \rightarrow \eta l^+\nu$ branching fractions

Constraints on the CKM angle $\gamma$ in $B^0 \rightarrow D^0(D^0)K^0$ from a Dalitz analysis of $D^0 \rightarrow K^+_S\pi^-\pi^+$

Dalitz plot analysis of $B^+ \rightarrow \pi^+\pi^0\pi^0$ decays

Measurement of time-dependent CP asymmetry in $B^0 \rightarrow c\overline{c}K^{*0}$ decays

Search for the rare leptonic decays $B^- \rightarrow l^-\nu_l (l=e,\mu)$

Exclusive initial-state-radiation production of the $D_s^0$, $D_s^+$, and $D^*$ systems

Measurement of the semileptonic decays $B \rightarrow D\tau\nu_\tau$ and $B \rightarrow D^*\tau\nu_\tau$

Search for the $Z(4430)^-$ at BABAR

Dalitz plot analysis of $B^- \rightarrow D^-\pi^-\pi^+$

Measurement of the branching fraction and $\overline{\Lambda}$ polarization in $B^0 \rightarrow \Lambda\pi^-$

Search for $B^0$ meson decays to $\pi^+K^0_S\overline{K}^0_S$, $\eta K^0_S\overline{K}^0_S$, and $\eta' K^0_S\overline{K}^0_S$

Search for $b \rightarrow u$ transitions in $B^0 \rightarrow D^0K^{*0}$ decays

Search for $B$-meson decays to $b\rho$ and $b\overline{K}^*$

Observation of the baryonic $B$-decay $B^0 \rightarrow \Lambda_+K\pi^-$

Measurement of the $\gamma^+ \rightarrow \pi^0$ transition form factor

Measurement of $D^0$-$\overline{D}^0$ mixing using the ratio of lifetimes for the decays $D^0 \rightarrow K\pi^-$ and $K'K^-$

Measurement of CP violation observables and parameters for the decays $B^+ \rightarrow DK^{*0}$

Study of $D_s^0$ decays to $D^*K$ in inclusive $e^+e^-$ interactions

Measurements of the $\tau$ mass and the mass difference of the $\tau^+$ and $\tau^-$ at BABAR

Observation and polarization measurement of $B^0 \rightarrow a_1(1260)^-a_1(1260)^+$ decay

$B$-meson decays to charmless meson pairs containing $\eta$ or $\eta'$ mesons

Model-independent search for the decay $B \rightarrow l\nu_l$

Time-dependent amplitude analysis of $B^0 \rightarrow K^0_S\pi^+\pi^-$

**ALICE/STAR**

**ALICE Collaboration:**

Commissioning and Prospects for Early Physics with ALICE
Nucl. Phys. A 830 (2009) 81c
P. Christakoglou
Event-by-event physics in ALICE

G. Giraudo (et al.), J. Buskop, A. van den Brink, G.J.L. Nooren
The SDD and SSD support structure for the ALICE Inner Tracking System
J. Instr. 4 (2009) P01003

R. Snellings
Parton collectivity from the RHIC to the LHC

R. Snellings
Heavy-Ion Collisions: Experimental Highlights
Nucl. Phys. A 820 (2009) 1c

H. Masui (et al.), R. Snellings
The Centrality dependence of \( v_2/\varepsilon \): The Ideal hydro limit and \( \eta/s \)

I. Kraus (et al.)
Statistical model predictions for p+p and Pb+Pb collisions at LHC
Prog. Part. Nucl. Phys. 26 (2009) 538

Particle production in p-p collisions and predictions for \( \sqrt{s} = 14 \) TeV at the CERN Large Hadron Collider (LHC)

P. Girigori, T. Peitzmann
Transverse flow of charmed hadrons in relativistic heavy-ion collisions

STAR Collaboration:
B.I. Abelev (et al.), Y. Bai, F. Benedosso, M. Botje, E. Braidot, M. van Leeuwen, A. Mischke, T. Peitzmann, M.J. Russcher, R. Snellings
Indications of conical emission of charged hadrons at the BNL relativistic heavy ion collider

Observation of two-source interference in the photoproduction reaction AuAu \( \rightarrow Au + Au^0 \)

Growth of long range forward-backward multiplicity correlations with centrality in Au+Au collisions at \( \sqrt{s_{NN}} = 200 \) GeV

Azimuthal charged-particle correlations and possible local strong parity violation

K/\pi fluctuations at relativistic energies

Beam-energy and system-size dependence of dynamical net charge fluctuations

Systematic measurements of identified particle spectra in pp, d+Au, and Au+Au collisions at the STAR detector

Measurements of \( \phi \) meson production in relativistic heavy-ion collisions at the BNL Relativistic Heavy Ion Collider (RHIC)

Pion interferometry in Au+Au and Cu+Cu collisions at \( \sqrt{s_{NN}} = 62.4 \) and 200 GeV

J/\psi production at high transverse momentum in p+p and Cu+Cu collisions at \( \sqrt{s_{NN}} = 200 \) GeV

Neutral pion production in Au+Au collisions at \( \sqrt{s_{NN}} = 200 \) GeV

Long range rapidity correlations and jet production in high energy nuclear collisions

Measurement of D* mesons in jets from p+p collisions at \( \sqrt{s} = 200 \) GeV

Longitudinal spin transfer to \( \Lambda \) and \( \Lambda^- \) hyperons in polarized proton-proton collisions at \( \sqrt{s} = 200 \) GeV

Longitudinal double-spin asymmetry and cross section for inclusive neutral pion production at midrapidity in polarized proton collisions at \( \sqrt{s} = 200 \) GeV
Energy and system size dependence of $\phi$ meson production in Cu+Cu and Au+Au collisions

**ANTARES/KM3NeT**

**ANTARES Collaboration:**

**Performance of the first ANTARES detector line**
Astropart. Phys. 31 (2009) 277

**ANTARES completed: First selected results**

E. Heine, M. van der Hoek, J. Hogenbirk, P. Jansweijer, S. Mos, H. Peek

**Developments for a passive optical node network for deployment in deep sea enabling time synchronous data readout**

M. van der Hoek

**Photonic sensors for Very Large Volume neutrino Telescopes**

E. Heine, J. Hogenbirk, P.P.M. Jansweijer, H. Peek

**Using VDSL2 over copper in the vertical string**

**Virgo/LISA**

**VIRGO Collaboration:**
F. Acernese (et al.); Th.S. Bauer, J.F.J. van den Brand, H.J. Bulten, S. van der Putten

**Gravitational wave burst search in the Virgo C7 data**
Class. Quantum Grav. 26 (2009) 085009

**Cleaning the Virgo sampled data for the search of periodic sources of gravitational waves**
Class. Quantum Grav. 26 (2009) 204002

**Laser with an in-loop relative frequency stability of $1.0 \times 10^{-21}$ on a 100-ms time scale for gravitational-wave detection**

**The LIGO Scientific Collaboration & The Virgo Collaboration:**
An upper limit on the stochastic gravitational-wave background of cosmological origin
Nature 460 (2009) 990

**AUGER**

**Pierre Auger Collaboration:**

**Upper limit on the cosmic-ray photon fraction at EeV energies from the Pierre Auger Observatory**
Astropart. Phys. 31 (2009) 399

**Atmospheric effects on extensive air showers observed with the surface detector of the Pierre Auger observatory**
Astropart. Phys. 32 (2009) 89

**Observation of radio signals from air showers at the Pierre Auger Observatory**

**Limit on the diffuse flux of ultrahigh energy $\tau$ neutrinos with the surface detector of the Pierre Auger Observatory**

**Theory**

E.N. Argyres, M.T.M. van Kessel, R.H.P. Kleiss

**The Path-Integral Approach to the $N = 2$ Linear Sigma Model**

E.N. Argyres, C.G. Papadopoulos, M.T.M. van Kessel, R.H.P. Kleiss

**Path Integrals in Polar Field Variables in QFT**

R. Kleiss, I. Malamos, G. van den Oord

**Majoranized Feynman rules**

A.M. Badalian (et al.), B.I.G. Bakker

**On the possibility to observe higher $n^3D_1$ bottomonium states in the \(e^+e^-\) processes**

**The S-D mixing and di-electron widths of higher charmonium $1^-$ states**
F. Bazzocchi (et al.)
Tri-bi-maximal mixing in viable family symmetry unified model with extended seesaw

Phenomenological consequences of see-saw in $S_4$ based models

F. Bazzocchi (et al.)
Tri-bi-maximal mixing in viable family symmetry unified model with extended seesaw

Phenomenological consequences of see-saw in $S_4$ based models

Fermion masses and mixings in a $S_4$-based model

S. Moch (et al.), J.A.M. Vermaseren, C.D. White
Theoretical issues
HERA and the LHC: 2nd workshop on the Implications of HERA for LHC Physics, 26-30 May, 2006-2008, DESY, Hamburg, Germany and CERN, Geneva, Switzerland

B.L.G. Bakker (et al.)
Nambu monopoles in lattice Electroweak theory

D. Boer
Angular dependences in inclusive two-hadron production at BELLE

D. Boer, P.J. Mulders, C. Pisano
Dijet imbalance in hadronic collisions

D. Boer, A. Utermann, E. Wessels
The Saturation scale and its $x$-dependence from $\Lambda$ polarization studies

J.K. Boomsma, D. Boer
The High temperature CP-restoring phase transition at $\theta = \pi$

Spontaneous CP violation in the NJL model at $\theta = \pi$

L. Gamberg (et al.), P.J. Mulders
Universality and gluonic pole matrix elements

E. Laenen, D. Wackeroth
Radiative Corrections for the LHC and Linear Collider Era

T. Binoth (et al.), T. Reiter
golem95: A numerical program to calculate one-loop tensor integrals with up to six external legs

S. Moch (et al.), J.A.M. Vermaseren, C.D. White
Theoretical issues
HERA and the LHC: 2nd workshop on the Implications of HERA for LHC Physics, 26-30 May, 2006-2008, DESY, Hamburg, Germany and CERN, Geneva, Switzerland

A. Mukherjee (et al.), P.J. Mulders
Working group report: Quantum chromodynamics sub-group
Pramana 72 (2009) 277

P.J. Mulders
Non-collinearity in high energy processes
Pramana 72 (2009) 83

C. D. White
Single Top Production in the Wt mode with MCNLO
HERA and the LHC: 2nd workshop on the Implications of HERA for LHC Physics, 26-30 May, 2006-2008, DESY, Hamburg, Germany and CERN, Geneva, Switzerland

J. Redondo, M. Postma
Massive hidden photons as lukewarm dark matter
J. Cosmol. Astropart. Phys. 02 (2009) 005

E. Kiritsis (et al.), B. Schellekens
Free fermion orientifolds

J.A. Andersen, V. del Duca, C.D. White
Higgs boson production in association with multiple hard jets
J. High Energy Phys. 02 (2009) 015

E. Laenen, G. Stavenga, C. D. White
Path integral approach to eikonal and next-to-eikonal exponentiation

M. Postma, C.P. Burgess, J.M. Cline
Axionic D3–D7 inflation
S. Das, S. Ghosh, J.W. van Holten, S. Pal
Generalized particle dynamics: modifying the motion of particles and branes

S. de Visscher (et al.), M. Herquet
Unconventional phenomenology of a minimal two-Higgs-doublet model

C. D. White, E. Laenen (et al.)
Isolating Wt production at the LHC

W. Beenakker, S. Brensing, M. Kramer, A. Kulesza, E. Laenen, I. Niessen
Soft-gluon resummation for squark and gluino hadroproduction

J.W. van Holten
Kosmologie: een geschiedenis van licht en donker
Nikhef publication, 2009

J. Vollinga
Higgs production via gluon-induced weak boson fusion

M. Postma
Hoe het heelal in een eeuw 13 miljard jaar ouder werd
Ned. T. Nat. 75 (2009) 260

T. Motoba (et al.), Th. A. Rijken
Structure and production of p-shell Ξ-hypernuclei predicted with realistic interactions

S. Moch, J. Vermaseren, A. Vogt
Third-order QCD corrections to the charged-current structure function F)

M. Maio, A.N. Schellekens
Fixed point resolution in extensions of permutation orbifolds

Complete analysis of extensions of D(n)/l) permutation orbifolds

B. Gato-Rivera, A.N. Schellekens
Non-supersymmetric orientifolds of Gepner models

J.J. Lopez-Villarejo, J.A.M. Vermaseren
The reaction e+e− → hh recomputed

J.W. Wagenaar, T.A. Rijken
Pion-nucleon scattering in Kadyshevsky formalism. I. Meson exchange sector

Pion-nucleon scattering in Kadyshevsky formalism. II. Baryon exchange sector

On the Quantization of higher spin fields

Detector R&D
M. Attie (et al.), D. Chefdeville, H. van der Graaf, J. Timmermans, J. Visschers
Gas pixel detector for x-ray observation

J. Melai (et al.), J. Visschers
The electrical conduction and dielectric strength of SU-8

H. van der Graaf
New results of GridPix TPCs

H. van der Graaf
Novel gas-based detection techniques

GridPix/Gossip Group: H. van der Graaf
New developments in gaseous tracking and imaging detectors

V.M. Blanco Carballo (et al.), Y. Bilevych, M. Chefdeville, M. Fransen, H. van der Graaf, J. Timmermans
GEMGrid: a wafer post-processed GEM-like radiation detector
Y. Bilevych, M. Chefdeville, M. Fransen, H. van der Graaf, J. Timmermans
TwinGrid: A wafer post-processed multistage Micro Patterned Gaseous Detector

F.W.N. de Boer (et al.), M. Fransen, H. van der Graaf, T.J. Ketel, W.J.C. Koppert
DICE (Delft Internal Conversion Experiment)

G. Gademann (et al.), J. Visschers
Velocity map imaging using an in-vacuum pixel detector

ISS Accelerator Working Group: A. Bandyopadhyay, F. Filthaut
Physics at a future Neutrino Factory and super-beam facility
Rept. Prog. Phys. 72 (2009) 106201

Grid Computing
J.T. Moscicki (et al.), H.C. Lee
Ganga: A tool for computational-task management and easy access to Grid resources

G. Garzoglio (et al.), D. Groep, O. Koeroo
Definition and implementation of a SAML-XACML profile for authorization interoperability across grid middleware in OSG and EGEE

HERA
HERMES Collaboration:
Spin density matrix elements in exclusive $p^0$ electroproduction on $^1$H and $^2$H targets at 27.5 GeV beam energy

Separation of contributions from deeply virtual Compton scattering and its interference with the Bethe-Heitler process in measurements on a hydrogen target

Observation of the naive-T-odd Sivers effect in deep-inelastic scattering

Exclusive $p^0$ electroproduction on transversely polarized protons

ZEUS Collaboration:
Production of excited charm and charm-strange mesons at HERA

Measurement of charged current deep inelastic scattering cross sections with a longitudinally polarised electron beam at HERA

Measurement of high-$Q^2$ neutral current deep inelastic e-p scattering cross sections with a longitudinally polarised electron beam at HERA

Measurement of $D^+$ and $D^0$ production in deep inelastic scattering using a lifetime tag at HERA

Subjet distributions in deep inelastic scattering at HERA

Measurement of beauty production from dimuon events at HERA
J. High Energy Phys. 02 (2009) 032

Measurement of the charm fragmentation function in $D^*$ photoproduction at HERA

A measurement of the $Q^2$, $W$ and $t$ dependences of deeply virtual Compton scattering at HERA

Deep inelastic scattering with leading protons or large rapidity gaps at HERA
Nucl. Phys. B 816 (2009) 1

Search for events with an isolated lepton and missing transverse momentum and a measurement of $W$ production at HERA

Multi-lepton production at high transverse momentum at HERA
Exclusive photoproduction of Υ mesons at HERA

Measurement of the longitudinal proton structure function at HERA

HERA-B Collaboration:
I. Abt (et al.); Th.S. Bauer, M. Bruinsma, W. Hulsbergen, M. Ouchrif, A. Sbrizzi, H. Wahlberg

Angular distributions of leptons from J/ψ’s produced in 920 GeV fixed-target proton-nucleus collisions

Kinematic distributions and nuclear effects of J/ψ production in 920 GeV fixed-target proton-nucleus collisions

V^0 production in p+A collisions at \(\sqrt{s} = 41.6\) GeV

Production of the charmonium states \(\chi_{c1}\) and \(\chi_{c2}\) in proton nucleus interactions at \(\sqrt{s} = 41.6\) GeV

LEP

DELPHI Collaboration:

A Study of b\overline{b} production in e^+e^- collisions at \(\sqrt{s} = 130\) GeV–207 GeV

Search for one large extra dimension with the DELPHI detector at LEP

Correlations between polarisation states of W particles in the reaction e^+e^- → W^-W^+ at LEP2 energies 189–209 GeV

Inclusive single-particle production in two-photon collisions at LEP II with the DELPHI detector

T. Novak, T. Csorgo, W. Kittel, W.J. Metzger
Initial conditions, time evolution and BE correlations in e^+e^- annihilation

W.J. Metzger
Recent L3 Results (and Questions) on BEC at LEP
Proc. 38th Int. Symposium on Multiparticle Dynamics

Miscellaneous
Jefferson Lab E00-116 Collaboration: S.P. Malace (et al.), H.P. Blok
Applications of quark-hadron duality in the \(F_2\) structure function

Muon (g-2) Collaboration: G.W. Bennett (et al.), C. Timmermans
Improved limit on the muon electric dipole moment

J. van Es (et al.), B. Verlaat
AMS02 tracker thermal control system overview and spin-off for the future spacecraft cooling system developments
60th Int. Astronautical Congress, 12-16 Oct. 2009 Daejeon, Republic of Korea

ISS Accelerator Working Group: M. Apollonio (et al.), F. Filthaut
Accelerator design concept for future neutrino facilities

D. Hasell (et al.), J.F.J. van den Brand
The BLAST experiment

Investigation of the exclusive \(^3\text{He}(e,e'p)n)^1\text{H}\) reaction

NA49 Collaboration:
T. Anticic (et al.); M. Botje, P. Christakoglou, M.A. van Leeuwen, A. Mischke

Energy dependence of transverse momentum fluctuations in Pb+Pb collisions at the CERN Super Proton Synchrotron (SPS) at 20A to 158A GeV

System-size dependence of Ξ and Λ production in nucleus-nucleus collisions at 40A and 158A GeV measured at the CERN Super Proton Synchrotron

Energy dependence of particle ratio fluctuations in central Pb+Pb collisions from \(\sqrt{s_{NN}} = 6.3\) to 17.3 GeV
Astrophysics
C. Maceroni (et al.), C. Aerts
HD 174884: a strongly eccentric, short-period early-type binary system discovered by CoRoT

C. Aerts (et al.)
Collective pulsational velocity broadening due to gravity modes as a physical explanation for macroturbulence in hot massive stars

S. Lafebre (et al.), H. Falcke, J. Horandel, J. Kuijpers
Universality of electron-positron distributions in extensive air showers
Astropart. Phys. 31 (2009) 243

Z. Wang (et al.), C. Bassa
An accurate determination of the optical periodic modulation in the X-ray binary SAX J1808.4-3658

T.N. Li (et al.), C. Bassa
X-ray sources and their optical counterparts in the galactic globular cluster M12 (NGC 6218)
Astropart. Phys. 705 (2009) 175

G. Nelemans
The Galactic gravitational wave foreground
Class. Quantum Grav. 26 (2009) 072006

P.J. Groot (et al.)
High spatial resolution Galactic 3D extinction mapping with IPHAS

P.F.L. Maxted (et al.), G. Nelemans
A survey for post-common-envelope binary stars using GALEX and SDSS photometry

O. Scholten (et al.), S. Buitink, H. Falcke
Improved flux limits for neutrinos with energies above $10^{22}$ eV from observations with the Westerbork Synthesis Radio Telescope

First results of the NuMoon experiment

Analysis of inclined showers measured with LOPES

Air shower measurements with LOFAR

Radio emission of energetic cosmic ray air showers: Polarization measurements with LOPES

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

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

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

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

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

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

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

Pieter Willem Huib Houben
A measurement of the mass of the top quark using the ideogram technique
Universiteit van Amsterdam, 3 June 2009

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

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

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

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

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

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

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

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

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

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

**ATLAS/DØ**

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


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

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

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


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

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

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

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


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

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

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


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

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

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

The night before the LHC, Universiteit van Amsterdam FNWI faculty colloquium, Amsterdam, The Netherlands, 11 February, 2009

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

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

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

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

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

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


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

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

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

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

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

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

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

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

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

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

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

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


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

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

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

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

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

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


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

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

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

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

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

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

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

CP Violation, Lectures given as part at the CERN Summer Student Lecture Program, Geneva, Switzerland, 29 July, 2009
CP Violation, Lectures given at the 2009 BND school, Rathen, Germany, 17 September, 2009

CP Violation, Lectures given at the 2009 BND school, Rathen, Germany, 18 September, 2009

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

Storaci, B.S., BR extraction techniques for searching New Physics in the B_s→µ⁺µ⁻ decay, NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009


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

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

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

ALICE/STAR

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Viscosity, Hydrodynamics and Flow, Helmholtz Research School, Kemer, Turkey, 24 November, 2009


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

The Knoxville Number, Quark Matter 2009, Knoxville, USA, 2 April, 2009
The Knoxville Number, Nearly Perfect Fluids, Research Triangle, North Carolina, USA, 6 April, 2009

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

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

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

Heavy-Ion Physics, 65th Scottish Universities Summer School in Physics, St Andrews, Scotland UK, 28 August, 2009

**ANTARES/KM3Net**


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

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

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

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

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

A sensor architecture for neutrino telescopes, Int. Workshop on Very Large Volume Neutrino Telescopes 2009 (VLVvT09), Athens, Greece, 15 October, 2009

**Virgo/LISA**

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

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


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

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

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

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


**AUGER**

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

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


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

**Theory**

**Bazzocchi, F.,** Phenomenology of A4 and S4 based models, Rencontres de Moriond, LaThuile, Italy, 10 March, 2009
SO(10) versus flavor symmetries: possible strategies to describe fermion masses and mixings, Università di Padova, Padova, Italy, 2 April, 2009

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

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

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

SQuark-Lepton complementarity in a $S_4 \times$ Pati Salam scenario, Universidad de Valencia, Valencia, Spain, 18 November, 2009

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

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

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

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

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

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

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

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

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

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

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

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


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

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

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

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

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

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

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

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

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

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

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

CFT: Review and Applications. Fixed point resolution in permutation orbifolds, NNV Annual Meeting of the section Subatomic Physics, Lunteren, The Netherlands, 6 November, 2009
Malamos, I., Feynman rules for the rational part of the electroweak 1-loop amplitudes, 3rd HEPTOOLS Annual meeting, Vienna, Austria, 1 December 2009

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

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

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

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

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

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

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

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

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

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

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


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

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

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

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

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

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

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

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

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

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

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


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

RCFT String Model Building, University of Crete, Heraklion, Greece, 13 October, 2009
The Emperor’s last Clothes?, RWTH Aachen, Aachen, Germany, 17 November, 2009

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

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

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

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

**Detector R&D**

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


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

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

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

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


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


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

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

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

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

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

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

Verlaat, B.A., CO2 Cooling developments for HEP detectors, The 18th Int. Workshop on Vertex detectors, Putten, The Netherlands, 17 September, 2009

**Grid Computing**

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

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

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

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

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


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


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

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


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

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

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

HiSPARC


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

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

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


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

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

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

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

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

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

Timmermans, J., Precision electroweak measurements at the LEP e’e’ collider, Radboud Universiteit, Nijmegen, The Netherlands, 9 April, 2009
3.4 Posters

**ATLAS/DØ**

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

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

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

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

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

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


**LHCb/BaBar**

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

**ALICE/STAR**

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

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

**ANTARES/KM3NeT**

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

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

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

**Theory**


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


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

Supersymmetric phenomenology in the mSUGRA parameter space, School on Particle Physics and Cosmology, Oran, Algeria, 5 and 9 May, 2009
Supersymmetric phenomenology in the mSUGRA parameter space, Trends in Theory, Dalfsen, The Netherlands, 14-15 May, 2009


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

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

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

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

Grid Computing
Gabriel, S., Security Service Challenges in WLCG: SSC3 2009 Results, EGEE’09 Conference, Barcelona, Spain, 21–25 September, 2009
By the end of each year Nikhef physicists and technicians gather in an Annual Meeting traditionally called Jamboree. In the meeting reports are given about the status of Nikhef's various programmes and projects, while young students and postdocs get the opportunity to present their work for a broader audience. The 2009 Jamboree was organised by Jo van den Brand and Chris Van Den Broeck.

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

**Tuesday 15 December 2009**

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

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

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

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

**Wednesday 16 December 2009**

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

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

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

**Session VIII: Future**
- 16:00 ILC and CLIC (Jan Timmermans)
- 16:25 Direct Dark Matter Searches (Patrick Decowski)
- 16:50 Nikhef future (Frank Linde)
3.6 Awards & Grants

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

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

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

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

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

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

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

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

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

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

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

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

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

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Nikhef & Society
4.1 Communication

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

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

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

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

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

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

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

On the other hand Nikhef is often approached by journalists requesting interviews or background information on certain topics. This has led to numerous articles and items in national newspapers.
Especially the restart of the LHC in autumn 2009 has generated a lot of media attention. The milestones of first beams at injection energy in the LHC, first collisions at this energy, and setting a new world record by reaching 1.18 TeV per beam, were all covered extensively in nearly all national and regional newspapers as well as in radio and TV news journals.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The HiSPARC detectors are built by the students of the schools, under the supervision of a HiSPARC team member, and consist of scintillators and advanced electronic equipment. They are placed on the roof of the schools and register the impact of cosmic rays. Such impacts frequently come in showers distributed over a large area and hit different detectors. Therefore, the data are stored in a central database at Nikhef. Students and teachers have access to the data of their own detector as well as to data stored in the central database. The latter can be used to analyse coincidences between two or more stations.
Each year in March, the students of the participating schools join in a symposium for a hands-on part that focuses on analyzing HiSPARC data and a part where the students present the work they have done for their ‘profielwerkstuk’. This year the contestants with the best ‘profielwerkstuk’ won a visit to CERN.

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

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

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

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

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

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

Since its start in 2002, Nikhef has facilitated the programme with a classroom and a ‘master-room’ for the first year master students. As a result, already in their first year, students spend most of their time at the Nikhef institute where they socialise not only...
with each other but also with the PhD students of the institute. This is why the nickname of the Masters’ programme has become the 'Nikhef-master'. In 2009, a total of more than forty students were enrolled in the two-year programme. The Dutch students enrolled, graduated of in total seven different universities in the Netherlands. Other students came from universities in Europe, South America and India.

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

**Research School Subatomic Physics**

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

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

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

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

75 PhD students were enrolled and 15 PhD students graduated in the school in 2009. Nicolo de Groot from the Radboud University Nijmegen is chair and the Radboud University Nijmegen is ‘penvoerder’ of the school.
4.3 Knowledge transfer

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

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

Philips Healthcare
The Hidralon project is a large European project conducted under the flag of Catrene (Cluster for Application and Technology Research in Europe on NanoElectronics) with many institutes and companies throughout Europe. The cooperation between Philips Healthcare and Nikhef is on studying the possibilities of making edgeless Cadmium-Zinc-Telluride sensors to allow tiling them into a large enough area required in medical imaging applications. The switch from silicon to Cadmium-Zinc-Telluride is necessary to achieve higher detection efficiency for X-rays in the energy range from 60 keV to 120 keV. Other activities within the Hidralon project are aimed at developing a new generation of CMOS imagers, for example for the automotive and entertainment industries.

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

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

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

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

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

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

Computer Algebra Nederland – Board
J. Vermaseren

CERN SPS Committee
P. Kooijman

DESY, Hamburg – Program Review Committee
J. Timmermans

EGI Organizational Task Force
A. van Rijn (chair)

EUROCOSMICS
B. van Eijk (chair)

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

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

European Particle Physics Outreach Group
V. Mexner

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

European Physics Journal – Scientific Advisory Committee
P. Mulders

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

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

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

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

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

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

GridKa Overview Board, Karlsruhe
K. Bos

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

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

International Grid Trust Federation
D. Groep (chair)

InterAction
V. Mexner

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

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

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

* as of 31 December 2009.
Laboratoire de l’Accélérateur Linéaire, Orsay – Scientific Committee
F. Linde

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

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

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

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

Nuclear Physics European Collaboration Committee (NuPECC)
Th. Peitzmann

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

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

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

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

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

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

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

Stichting Industriële Toepassing van Supergeleiding
B. van Eijk

Stichting Techniek Toernooi
E. de Wolf (chair)

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

Vereniging Gridforum Nederland
A. van Rijn (treasurer)

Virtual Laboratory for e-Science, VI-e
A. van Rijn (Directorate)
5.1 Organigram*

* as of 31 December 2009.
5.2 Organisation*

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

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

**Scientific Advisory Committee (SAC)**
S. Bethke (Max-Planck-Institut für Physik, Munich)
R. Cashmore (Brasenose College, Oxford)
C. De Clercq (Vrije Universiteit Brussel, Brussels)
T. Hebbeker (chair, RWTH Aachen, Aachen)
Y. Karyotakis (LAPP, Annecy le Vieux)
B. Webber (University of Cambridge, Cambridge)

**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
L. Wiggers

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

**Dutch Research School Theoretical Physics – Governing Board**
E. Laenen

**Dutch Research School Theoretical Physics – Educational Board**
W. Beenakker

| R. Kleiss |
| P. Mulders (chair) |
| J. van Holten |

**Scientific Council (WAR)**
S. Bentvelsen
A. van den Berg (KVI, Groningen)
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)
J. Templon
R. Timmermans (KVI, Groningen)

**Onderzoekschool Subatomaire Fysica – Onderwijscommissie**
Th. Bauer
S. Bentvelsen
J. van den Brand
T. van Egdom (personnel)
B. van Eijk
N. de Groot (chair)
S. de Jong
R. Kleiss
J. Koch
E. Koffeman
E. Laenen
F. Linde
M. Merk
P. Mulders,
Th. Peitzmann
E. Schram-Post (secretary)

**Committee for Astroparticle Physics in the Netherlands (CAN)**
J. van den Brand
M. de Jong
S. de Jong
F. Linde
R. van der Meer (secretary)
P. Mulders
E. de Wolf

* as of 31 December 2009.
From a funding perspective the year 2009 has again been very fruitful. Via a dedicated call (‘Dynamisering instituutsfinanciering’) aimed at the NWO-institutes, Nikhef has been awarded a one-time amount of 3.4 million euro, added to the mission budget, spread over the years 2009, 2010 and 2011. Another milestone was the recent (November 2009) awarding of the FOM-programme “Gravitational Physics – the dynamics of spacetime”, which will appear in the Nikhef budgets from 2010 onward. Two new Vidi grants were also awarded, starting next year. The funding in 2009 shows the result of earlier successes, both in the NWO ‘Vernieuwingsimpulsen’ as in SenterNovem sponsored projects (such as Relaxd and Hidralon) and EC sponsored projects (such EGEE, EUDET, ASPERA-2, KM3NeT and MC-PAD). Finally, the turnover in contracts with customers of the Internet Exchange datacenter facility has also increased (to about 2.3 M€), so that the funding of the Nikhef collaboration is now at the level of 26.6 M€ (as compared to 23.5 M€ in 2008).

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

### Overview of Nikhef personnel in fte (2009)

<table>
<thead>
<tr>
<th>I – Scientific groups</th>
<th>fte – 2009, institute &amp; university groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent scientific staff</td>
<td>54.0</td>
</tr>
<tr>
<td>PhD students</td>
<td>66.4</td>
</tr>
<tr>
<td>Post-docs</td>
<td>36.8</td>
</tr>
<tr>
<td><strong>Total I</strong></td>
<td><strong>157.2</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II – Management, technical/engineering and general support (fte – 2009, institute)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Management team</strong></td>
</tr>
<tr>
<td>Director</td>
</tr>
<tr>
<td>Institute manager</td>
</tr>
<tr>
<td>Personnel/HRM officer</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical/engineering support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic workshop</td>
</tr>
<tr>
<td>Computer technology</td>
</tr>
<tr>
<td>Mechanical engineering</td>
</tr>
<tr>
<td>Mechanical workshop</td>
</tr>
<tr>
<td>Project management support</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial administration</td>
</tr>
<tr>
<td>Personnel/HRM administration</td>
</tr>
<tr>
<td>Library</td>
</tr>
<tr>
<td>Technical and domestic services</td>
</tr>
<tr>
<td>Secretariat and reception desk</td>
</tr>
<tr>
<td>PR &amp; communication</td>
</tr>
<tr>
<td>Occupational health &amp; safety</td>
</tr>
<tr>
<td>Staff</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
</tr>
</tbody>
</table>

**Total I & II**                              258.9

<table>
<thead>
<tr>
<th>III – Other groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>(persons 2009)</td>
</tr>
<tr>
<td>Guests (researchers, retired staff)</td>
</tr>
<tr>
<td>Master students</td>
</tr>
</tbody>
</table>

**Total III**                                 71.0

**Total**                                     329.9

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* as of 31 December 2009.

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### ATLAS/DØ

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

**B-Physics**

Amoraal, Drs. J.M. (Jan) GST
Bauer, Dr. T.S. (Thomas) FOM
Belyaev, Dr. I. (Vanya) FOM
Bos, Dr. E. (Edwin) GST
Carvalho Akiba, Dr. K. (Kazuyoshi) FOM/VU
Eijk, Msc. D. (Daan) van FOM
Farinelli, Msc. C. (Chiara) FOM/VU
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Jansen, Ir. F.M. (Fabian) FOM
Ketel, Dr. T.J. (Teerd) FOM/VU
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Pree, Drs. T.A. (Tristan) du FOM
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Tuning, Dr. N. (Niels) GST
Vries, Dr. H. (Hans) de FOM
Wiggers, Dr. L.W. (Leo) FOM
Ybeles Smit, Drs. G.V. (Gabriel) GST

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Botje, Dr. M.A.J. (Michiel) FOM
Braidot, Drs. E. (Ermes) FOM/UU
Chojnacki, Msc. R. (Marc) FOM/UU
Christakoglou, Dr. P. (Panagiotis) FOM
Greli, Dr. A. (Alessandro) FOM/UU
Kamermans, Prof.dr. R. (René) FOM/UU
Kolk, Drs.ing. N. (Naomi) van der FOM
Kruit, Dr. P.G. (Paul) FOM
Leeuwen, Dr. M.A. (Marco) van der FOM
Mischke, Dr. A. (André) FOM
Nooren, Dr.ir. G.J.L. (Gert-Jan) FOM/UU
Peitzmann, Prof.dr. T. (Thomas) UU
Rooij, Msc. R. (Raoul) de UU
Snellings, Dr. R.J.M. (Raimond) FOM
Thomas, Msc. D. (Deeps) UU
Verweij, Msc. M. (Martha) UU

**ANTARES/KM3NeT**

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Botje, Dr. M.A.J. (Michiel) FOM
Kolster, Drs.ing. N. (Naomi) van der FOM
Rooij, Msc. R. (Raoul) de UU
Snellings, Dr. R.J.M. (Raimond) FOM
Vries, Dr. H. (Hans) de GST

**AUGER**

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Grebe, Msc. S. (Stefan) FOM/RU
Harmsma, Ir. S. (Sybren) FOM
Jong, Prof.dr. S.J. (Sijbrand) de RU
Kelley, Dr. J.L. (John) FOM/RU
Schoorlemmer, Msc. H. (Harm) FOM/RU
Timmermans, Dr. C.W.J.P. (Charles) FOM

**Theory**

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Åkerblom, Dr. N. (Nikolas) FOM
Aybat, Dr. S.M. (Mert) FOM
Beenakker, Dr. W.J.P. (Wim) RU

**Virgo/LISA**

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Brand, Prof.dr.ing. J.F.J. (Jo) van den FOM
Broeck, Dr. C.F.F. (Chris) Van Den FOM
Bulten, Dr. H.J. (Henk-Jan) FOM
Koekoeck, Drs. G. (Gideon) FOM
Li, Msc. T.G.F (Tjonnie) FOM
Putten, Drs. S. (Sipho) van der FOM
Rabeling, Dr. D.S. (David) VU

**No text in this section**
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Broek, Msc. T.C.H. (Thijs) van den FOM
Dunnen, Msc. W. (Wilco) den FOM
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Laenen, Prof.dr. E.L.M.P. (Eric) FOM/UvA
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Weenink, Msc. J.G. (Jan Gerard) UU

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Visser, Dr. J. (Jan) FOM
Zappon, Msc. F. (Francesco) FOM

Grid Computing
Balint, T. (Tünde) FOM
Bernabé Pellicer, Msc. F.J. (Paco) FOM

HiSPARC
Bonam, S. (Surya) FOM

Miscellaneous
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Engelen, Prof.dr. J.J. (Jos) UvA
Keramidas, Drs. A.A. (Avraam) GST
Laan, Dr. J.B. (Jan) van der FOM

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Meeuwsen, Drs. W.M. (Willem) GST

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

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

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

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

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

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

**Antiproton**
The antiparticle of the proton.

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

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

**Baryon**
See Particles.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Electron
See Particles.

End cap
Detector placed at each end of a barrel–shaped detector to provide the most complete coverage in detecting particles.
EUDET (European Detector R&D towards the International Linear Collider)
EU–funded R&D project for research on future ILC detectors.

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

Fermion
General name for a particle that is a matter constituent, characterized by spin in odd half integer quantum units (\(\frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \ldots\)). 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 unifying the electromagnetic and weak forces was proposed. This was later confirmed in a Nobel prize–winning experiment at CERN.

fte (Full Time Equivalent)
Unit of manpower.

Gluon
See Particles.

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

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

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

High–Energy Physics
A branch of science studying the interactions of fundamental particles; called ‘high–energy’ because very powerful accelerators produce very fast, energetic particles probing deeply into other particles.

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

HiSPARC (High School Project on Astroparticle Cosmic Rays)
Cosmic–ray experiment with schools in the Netherlands.

ILC
International Linear Collider, now under study. A possible future electron–positron accelerator, proposed to be built as an international project.

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

Kaon
A meson containing a strange quark (or antiquark). Neutral kaons come in two kinds, long–lived and short–lived. The long–lived ones occasionally decay into two pions, a CP–violating process (see also Particles).

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

LCG (LHC Computing Grid)
The mission of the LCG is to build and maintain a data–storage and analysis infrastructure for the entire high–energy physics community that will use the LHC.

LEP
The Large Electron–Positron collider at CERN which ran until 2000. Its tunnel has been reused for the LHC.
Supersymmetry (SUSY) for every type of boson there exists a corresponding type of fermion with the same mass and internal quantum numbers, and vice-versa.
Lepton
A class of elementary particles that includes the electron. Leptons are particles of matter that do not feel the strong force (see also Particles).

LHC (Large Hadron Collider)
CERN’s accelerator which started in 2008.

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

Linac
An abbreviation for linear accelerator.

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

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

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

Meson
See Particles.

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

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

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

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

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

Nucleon
The collective name for protons and neutrons.

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

Photon
See Particles.

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

Pion
See Particles.

Positron
The antiparticle of the electron.

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

Quantum chromodynamics (QCD)
The theory for the strong interaction analogous to QED.
Quark
The basic building blocks of matter (see also Particles).

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

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

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

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

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

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

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

Spin
Intrinsic angular momentum of a particle.

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

STAR
Experiment at RHIC.

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

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

SURFnet
Networking organisation in the Netherlands.

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

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

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

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

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

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

Z boson
A carrier particle of weak interactions; involved in all weak processes that do not change flavour and charge.
Team de Jong after winning the €100,000 Academic Year Prize. Centre-front is Sijbrand de Jong, holding the Cup is Charles Timmermans.