Nikhef

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National
Institute for
Subatomic Physics

Nikhef is a partnership between the Institutes Organisation of NWO (NWO-I) and six Dutch universities: Maastricht University, Radboud University, University of Amsterdam, University of Groningen, Utrecht University, and VU Amsterdam.

NWO-I

Maastricht University

Radboud University in Nijmegen

University of Amsterdam

University of Groningen

Utrecht University

VU Amsterdam

INSPIRING SCIENCE AND SOCIETY

For half a century now the Dutch National Institute for Subatomic Physics, Nikhef, has been at the forefront of fundamental physics research.

In unlocking the secrets of the smallest building blocks of matter and their interactions, the impact of Nikhef's research punches above its weight thanks to enhanced collaboration.

Both nationally, with six partner universities, and internationally, Nikhef collaborates to enable new explorations of space and time through technological innovations that make the invisible visible at the smallest and largest scales in our universe.

Together, we cultivate a world-class expertise in experimental and theoretical particle and astroparticle physics, combined with profound technological know-how.

Nikhef has contributed to some of the most astonishing breakthroughs in physics of recent decades and is helping to shape the future of the field.

The core value and strength of Nikhef lies in nurturing talents, connecting all aspects of novel research, from its initial inception to the required technology, theory and dedicated experiments.

At Nikhef, we encourage curiosity-driven research and foster an inclusive research environment where innovations in science and technology are combined.

In this brochure we highlight the broad range of research at Nikhef, through which we contribute to ambitious international projects.

We hope to inspire you with our role in both science and society, and we invite you to join us on this great adventure to unravel the mysteries of our universe.

Jorgen D'Hondt
Nikhef director

CHASING THE LAWS OF NATURE

A CONTINUED SEARCH FOR FUNDAMENTAL ANSWERS

From observing the world around us, the ultimate question "why" has always fueled human fascination and imagination. The quest for answers has helped unravel the laws of nature and typically leads to even deeper, more fundamental questions.

By developing innovative technologies for improved observation, we have continually explored new territories, gaining sometimes revolutionary insights into the laws of nature that govern both the smallest and largest scales of our universe.

For centuries, this curiosity-driven research has gone hand in hand with society's urge to use these novel technologies for the benefit of our health, our security, our climate, and our survival itself.

Subatomic physics is one of the most fundamental sciences. Decades of theoretical study and ever bigger experiments worldwide have delivered detailed understanding about our existence, particles, space and time. The discoveries of the long-sought Higgs particle and gravitational waves have answered some outstanding questions.

Still many fundamental questions remain and new ones arise all the time. Where did all the antimatter go after the Big Bang? What are the properties of neutrinos and why are their masses so small? Why are there exactly three generations of elementary particles? How can we explain the seemingly missing Dark Matter in the universe?

The Standard Model of Particle Physics and the Standard Model of Cosmology comprise our current understanding of the field. But we know these models are still limited in scope. With ever more precise measurements and refined theories, we realise each time that nature is more complex and wonderful than we knew up till then. This inspires the quest for an even more fundamental understanding.

In the Netherlands, Nikhef is the partnership that seeks answers to such fundamental questions. Through our research programmes, labs and workshops we contribute to the construction and operation of world-class research infrastructures and experiments. This requires state-of-the-art technologies to be further developed and unprecedented volumes of data to be scrutinised. In turn, this also pushes theory to new limits.

At Nikhef the expertise of six university partners and NWO-I comes together in a national research agenda for subatomic physics. Two complementary approaches are followed. Accelerator-based particle physics studies interactions in particle-collision processes at particle accelerators, in particular at CERN. Astroparticle physics studies interactions of particles and the radiation and gravitational waves emanating from the universe which are captured by large international observatories on land and underground, at sea and in space. In addition, at the University of Groningen Nikhef is performing promising so-called eEDM experiments on the fundamental properties of the electron, decelerating molecules instead of accelerating particles.

SMALL PARTICLES, BIG MACHINES

PROBING THE BUILDING BLOCKS OF MATTER

Colliding particles at high energies provides a window into the fundamental building blocks of matter and the universe. Nikhef's scientific and technical groups are deeply involved in a range of such particle accelerator experiments.

At CERN in Geneva, Nikhef takes part in three of the four main experiments at the Large Hadron Collider (LHC), the most powerful particle collider in the world. Scientists, engineers and technicians from Nikhef contribute strongly to designing, building and upgrading the ATLAS, ALICE and LHCb detectors, and analysing the huge amounts of data from these experiments.

The ATLAS detector is the biggest multi-purpose particle camera in the world. In 2012 it discovered the elusive Higgs particle, together with the CMS experiment at the LHC. Predicted decades earlier, this keystone of the Standard Model tells us there is a background field that induces universal mass to elementary particles everywhere.

The ALICE detector is specially equipped to collect data from heavy ions like lead nuclei colliding in the LHC. The data are leading to insights into states of matter in the early universe, such as the quark-gluon plasma.

The LHCb experiment is another LHC flagship experiment. The detector is specifically designed to detect minute differences and tiny asymmetries between particles and their antiparticles created in particle collisions in the accelerator. The key physics goal is to explain why the universe seems to be full of just matter.

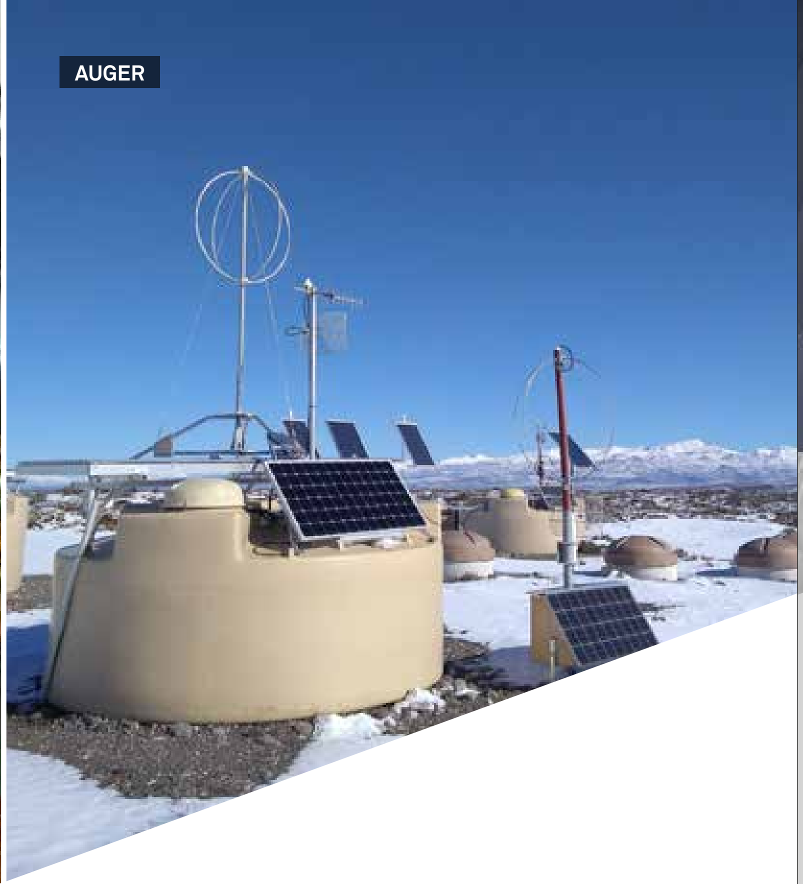
These efforts take place in large international collaborations, connecting up to thousands of researchers and hundreds of institutes worldwide. Nikhef regularly plays a prominent role in both management as well as operations and upgrades. Also, Nikhef has renowned mechanical and electronics workshops to design and produce parts and components. For example, Nikhef provides new silicon pixel and strip sensor technologies to trace trajectories of particles in the detectors.

The strong Nikhef involvement leads to research programmes for efficient data handling and new sensor concepts. An ever stronger input of machine learning and artificial intelligence technologies is expected.

Currently, the experiments are being upgraded for the higher intensity beams of the upcoming so-called HL-LHC. The upgraded detectors have to be able to handle up to tenfold larger signal volumes and data, keeping track of as many scientifically interesting events as possible.

As the Standard Model leaves many questions unanswered, new and even more powerful accelerators are being discussed. As world players in the field of particle physics, Nikhef researchers actively take part in the intense deliberations on all levels.


KM3NeT


AUGER


XENON


VIRGO

MESSENGERS FROM THE SKY

HARNESSING THE NATURAL PARTICLE ACCELERATORS OF THE UNIVERSE

Even the biggest human-built accelerators on earth are much less powerful than natural cosmic particle accelerators. Astrophysical objects and processes create particles with extreme energies that constantly arrive on earth. Nikhef is deeply involved in this research field of astroparticle physics.

Nikhef collaborates in some of the leading experiments and observatories, looking at a wide variety of signals using a wide range of technologies. The locations of these experiments are often as exotic, challenging and extreme as the phenomena they study. Nikhef is involved in KM3NeT, studying neutrinos, XENONnT, looking for dark matter particles, the Pierre Auger Observatory, analysing cosmic radiation, and Virgo, detecting gravitational waves.

KM3NeT, once completed, will be the biggest observatory for cosmic and atmospheric neutrinos in the northern hemisphere, located at the bottom of the Mediterranean Sea. The finished detector will consist of hundreds of long vertical lines in the pitch dark French and Italian deep sea. These are equipped with glass spheres full of light sensors, that can record flashes created by passing neutrinos colliding with an atom in the sea water.

Nikhef, together with international partners, designs and constructs much of the technology for these sensor spheres and detector lines. The steadily expanding detector already registered the most energetic neutrino ever observed.

Particles impacting the Earth's atmosphere and producing cascades of secondary particles are measured by the Pierre Auger Observatory on the Argentinian pampas. It maps and analyses these particle cascades and accompanying radio signals. Main research questions are the identity of the cosmic impacts and their sources. Nikhef is closely involved in detector upgrades and analyses.

Dark matter searches are looking for unknown particles that could form the invisible matter that evidently holds together galaxies. The XENONnT detector contains a large vessel of pure liquid xenon deep under the Gran Sasso mountains in Italy. It aims to detect signals of dark matter particles hitting a xenon nucleus. With intense scientific and technological inputs by Nikhef, the equipment has been upgraded several times.

SPACE, LIGHT & MIRRORS

STUDYING THE RIPPLES IN THE FABRIC OF THE UNIVERSE

Gravitational waves are tiny ripples in spacetime, created by distant colliding black holes or neutron stars. To measure these distortions that are smaller than the size of a proton, kilometres-long facilities are needed. Bouncing laser light between mirrors, detecting minute changes in distance.

In 2015, LIGO in the US first detected such a ripple passing through their detectors. Together with Virgo in Italy, hundreds of events have since been recorded and analysed. Nikhef is one of the partners in the international LIGO-Virgo-KAGRA (LVK) collaboration. Nikhef designs and builds equipment and analyses data, providing more and more glances at black holes, neutron stars and their collisions.

Following the first detection, gravitational wave science has swiftly grown, creating a new field of multimessenger astronomy. New plans have been put forward for more powerful detectors. Nikhef is a partner in the LISA project with ESA that will consist of special sensors in space for gravitational wave detection.

Nikhef is also closely involved in the preparations for a new underground detector with 10 kilometres-long arms, called Einstein Telescope (ET). Its huge size will allow for better localization of event sources and more detailed detection of weaker signals. ET is expected to look back in time close to the Big Bang.

A special test facility called ETpathfinder is being built in Maastricht for R&D of new and essential laser and mirror technologies needed in the Einstein Telescope. Nikhef and Maastricht University are driving forces in the ETpathfinder project, paving new ways to advanced gravitational wave detection.

NIKHEF 1975-2025

FIVE DECADES OF RESEARCH AND TECHNOLOGY

1975
NIKHEF established
On 17 June, Dutch physics council FOM, together with the institute for nuclear research IKO and the universities of Amsterdam and Nijmegen, establishes a national institute for nuclear and high energy physics, called NIKHEF after its Dutch acronym. Through the years, four more Dutch universities join this partnership, later called Nikhef. In Amsterdam a new laboratory is built, with a large mechanical workshop and assembly hall, computer facilities and offices. In 1980 the building is officially opened.

1984
Computer algebra
Theorists at Nikhef develop a new computer language called FORM to perform massive algebraic calculations in particle physics. FORM becomes a standard tool for theorists worldwide.

1989
Start LEP collider
Nikhef is involved in the Large Electron Positron Collider (LEP) at CERN and its experiments. LEP produces crucial insights into the Standard Model of Particle Physics.

1992
First website
On 3 February, www.nikhef.nl is the first ever Dutch website, and the third website in the world on the World Wide Web, an internet protocol developed in 1989 at CERN for data handling and distribution in physics. Later, Nikhef becomes heavily involved in the international internet infrastructure, with its data center in Amsterdam.

1994
Inside nucleons
Physicists from Nikhef, together with international colleagues, map the distribution of quarks and gluons in the proton at the German institute DESY in Hamburg.. In 1999, Nikhef researchers measure the distribution of up and down quarks in the neutron using the AmPS accelerator in Amsterdam.

1999
Astroparticle physics
Nikhef broadens the research particle physics agenda to astroparticle sources with the ANTARES project, an underwater neutrino detector in the Mediterranean Sea. This detector is succeeded by the current large KM3NeT neutrino detector in the deep sea near France and Italy. In 2005 Nikhef also becomes a partner in the Pierre Auger observatory for cosmic rays in Argentina, and the underground XENON experiment in Italy that searches for dark matter.

2007
Gravitational waves programme
Nikhef scientists and engineers get involved in building and upgrading the Virgo detector near Pisa, aimed at searching for gravitational waves, ripples in spacetime caused by cataclysmic events like black hole collisions.

2008
Start Large Hadron Collider
Nikhef participates in three of the four large international experiments at the new LHC accelerator starting up at CERN in Geneva: ATLAS, ALICE and LHCb. The Nikhef groups contribute to designing and building parts and equipment, and are involved in data handling and data analysis.

2012
Higgs boson discovery
On 4 July, the ATLAS and CMS experiments at CERN announce the discovery of the long-sought Higgs particle, evidence for a universal field that gives mass to elementary particles. Nikhef researchers are heavily involved through the ATLAS collaboration.

2015
Gravitational waves discovery
The two LIGO detectors in the US measure, for the first time, a gravitational wave passing the Earth. Nikhef is deeply involved in the signal analysis. In the following years, LIGO and Virgo detect hundreds of new events, opening a new window on the cosmos, working closely with astronomers.

2019
ETpathfinder facility
At the youngest Nikhef partner Maastricht University, the ETpathfinder facility is being built for testing and developing new laser, vacuum and optical technologies for gravitational wave detection. Nikhef is aiming at a new large gravitational wave detector, the Einstein Telescope, in a European context and possibly based in the South Limburg border region.

2025
Record neutrino detection
KM3NeT announces the detection of the most energetic neutrino ever observed. Nikhef researchers are heavily involved in the data analysis. This remarkable detection was achieved with only one tenth of the final configuration, demonstrating the great potential of the full detector.

CONNECTING DISCIPLINES

WORKING CLOSELY TOGETHER
TO ACHIEVE MORE

A key ingredient of the Nikhef partnership is the national connection of people, institutions and disciplines, both scientific and technical. Shared interests and facilities, from workshops to test labs, are the main reason a small country like the Netherlands does so well on the world stage in particle physics research. Evaluations of Nikhef have made this point repeatedly.

One of the most apparent connections within Nikhef is the link between the experimental groups and the theoretical physics department. A phenomenological approach, connecting theory to experimental data and observations, is crucial in the research programmes. This helps to design cutting-edge experiments on one hand, and enables efficient testing of new theories on the other hand. The Theory group has a broad and flexible research agenda, from quark physics to Big Bang cosmology.

Technology is another essential part in experimental particle and astroparticle physics. From its start, Nikhef has maintained a large and well-equipped Mechanical Technology department for designing and building parts and components for the many experiments it participates in. The Nikhef Electronics Technology department is involved in many experiments with specialized chips and control systems.

Over the years Nikhef experts have contributed to essential elements of the immense detectors at CERN and elsewhere. Also, a significant share of the KM3NeT detector spheres and lines is assembled by Nikhef for deployment at sea.

More fundamental innovations come from the Detector R&D group, providing new sensor concepts for particle physics and gravitational wave detection. Resolving particle tracks in time and space is a leading idea for experiments with extremely intense signal streams.

Efficiently handling and storing the huge volumes of data from these experiments is the main aim of the Nikhef Physics Data Processing group and the Computing Technology department. Here, major innovations have been helped by the arrival of new Artificial Intelligence technology and the use of graphics processing units.

Most equipment needed for advanced particle physics experiments is custom made and far from ‘off-the-shelf’. Nikhef has an extensive network of industrial contacts, and works closely together with industry when innovative parts have to be produced.

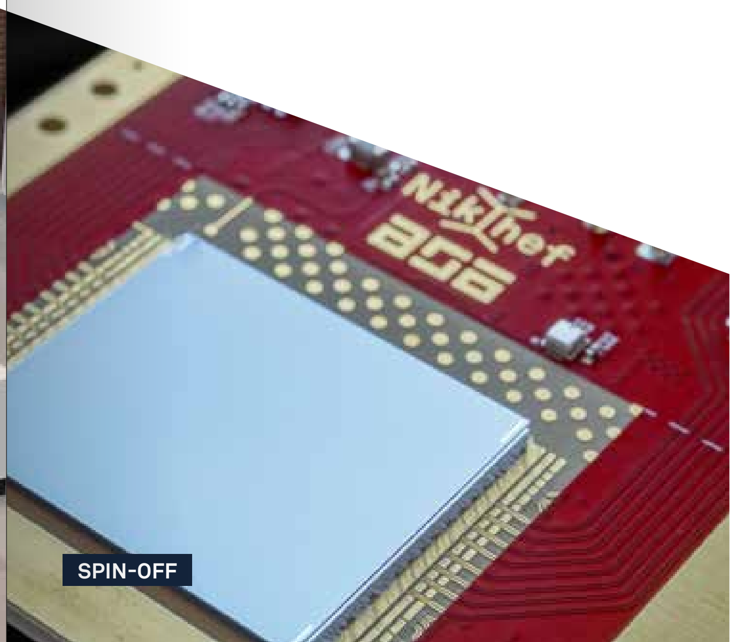
Nikhef engineers and data specialists are full partners in many scientific research teams and communities. Nikhef is a well-known brand name found at many experiments worldwide.

OPEN DOORS TO SOCIETY

FUNDAMENTAL PHYSICS
WITH EVERYDAY RELEVANCE

TEACHING

OUTREACH



SPIN-OFF

The world of elementary particles can seem very far removed from daily life. Still, a publicly funded partnership like Nikhef has both the ambition and the responsibility to be connected to society. Partly because fundamental physics is a common human endeavour that answers big questions. But also because particle physics is a catalyst for innovative technology, international cooperation and talented scientific minds.

Nikhef strives to be accountable as an institution, making a difference scientifically but also being firmly grounded in society and acting responsibly. In practice, this happens in many different ways. It involves connecting to industries with relevant expertise or related interests, ranging from microelectronics and materials, to construction technology and modelling. In some cases, technology developed at Nikhef is transferred to spin-off companies that specialise in commercial applications. Also, Nikhef is dedicated to open access publishing, making knowledge publicly available as much as possible.

Nikhef is very closely connected to academia. Many scientific staff members teach physics courses at one of the six partner universities. PhD students from these universities are directly involved in the Nikhef research agenda, from theory to experiments. Many of these PhD students continue their career outside academia, using the skills acquired in their scientific training.

To foster physics talent early on, Nikhef has a broad outreach programme, reaching out to schools and welcoming interested groups and individuals. Both scientific breakthroughs and important developments are publicised widely through the media and our own publications. In the renovated building at Amsterdam Science Park a special science exhibition, the Expostrip, invites visitors to come face to face with particle physics and real research equipment.

Finally, the environmental impact of the institute and its research requires responsible behaviour. The Nikhef building in Amsterdam has been redesigned for sustainability, with minimum energy use and emissions. For instance, heat recovery from the data center is used for heating nearby student housing, effectively reducing the carbon footprint. In many designs of new experiments or equipment, minimising environmental impact is a serious boundary condition to consider, both for Nikhef and its partners.

NIKHEF IN NUMBERS

434
TEAM IN TOTAL

104
PERMANENT SCIENTIFIC STAFF

133
PHD CANDIDATES

54
POSTDOCS

90
TECHNICAL STAFF

53
SUPPORT STAFF

53
DIFFERENT NATIONALITIES

11
MAIN RESEARCH PROGRAMMES

102
MASTER AND BACHELOR STUDENTS

6
UNIVERSITY PARTNERS

3
TECHNICAL GROUPS

+400
REFEREED SCIENTIFIC PUBLICATIONS ON AVERAGE PER YEAR

On 30.06.2025

Colophon

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Nikhef

Photo credits: Auger, CERN, KM3NeT, Nikhef, Virgo, XENON
Graphic Design: Enchilada

Nikhef works together with thousands of colleagues worldwide and collaborates in large international experiments in particle and astroparticle physics.