ACTIVITIES AT NIKHEF

NOVEMBER 19, 2021

Stan Bentvelsen
Covid:
- Workshops always remained open
- Prioritize access to younger colleagues

Renovation:
- Activities continue, in march 2023 we have beautiful building
  - In mean time we struggle here & there
THE MISSION OF NIKHEF

Elementary constituents and forces of our Universe

- Accelerator based Particle Physics - at CERN
- Astroparticle physics - particles and fields from the cosmos

LHC involvement
ATLAS, LHCb, ALICE
Various upgrade activities

Astroparticle physics
GW, DM, Neutrino, UHECR, eEDM
Activities in h/w, DAQ & analysis

- Enabling programs
  - Detector R&D
  - Theory - phenomenology
  - Data Processing

- Technical workshops
  - Mechanical
  - Electronics
  - Computing
NATIONAL SCIENCE PROGRAM

Symbiosis NWO institute and six University partners

- University partners in key positions
  - Leaders of the scientific programs
  - 63% of our scientific staff hired by universities

Institute provides the infrastructure

- Engineers and technicians
  - Mechanical and electronics workshops
- Computing infrastructure

Total annual budget ~50ME

- Institute, universities and (open) competition

<table>
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<tr>
<th>Permanent Staff</th>
<th>88</th>
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<tr>
<td>PhD candidates</td>
<td>97</td>
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<tr>
<td>Postdocs</td>
<td>31</td>
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<td>Technical/engineer</td>
<td>77</td>
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<td>Support</td>
<td>33</td>
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Scientific staff

- Growth over past years
  - Notably GW group@Universities

Gender diversity

- Scientific staff ~22% female!

Junior scientist (PhD/PD)

- Large fluctuations in funding
TECHNICAL WORKSHOPS

Rather busy at the moment

- LHC expt, KM3NeT, GW
- COVID challenges
- Renovation of the building
- Closed during this summer

COVID-19 challenge: safety before quality before schedule!

Mechanical Technology ~27 fte
Electronics Technology ~25 fte
Computing Technology ~25 fte
LONG TERM LHC ACTIVITIES FROM NIKHEF

<table>
<thead>
<tr>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
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**Long Shutdown 2 (LS2)**

- **LHCb:** RF box, VELO modules, SciFi tracker, HLT/GPU
- **ALICE:** ITS-2 Alpine modules
- **ATLAS:** NSW - services

**Run 3**

- **ATLAS:** ITk endcaps, FELIX TDAQ
- **LHCb:** 4d fast timing R&D
- **ALICE:** ITS-3 design

In line with ESPPU: ambitions on 4d fast timing tracking, R&D started

Joint efforts for ITS-3 (ALICE), HGTD (ATLAS), VELO-3 (LHCb)

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<th>2028</th>
<th>2029</th>
<th>2030</th>
<th>2031</th>
<th>2032</th>
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**Run 4**

**LS4**

**Run 5**

**Long Shutdown 3 (LS3)**

**LS5**
Tracking upgrades

- VELO RF box
  - machining and test/tightness
- VELO modules
  - design & production
  - various set-backs
- SciFi - large project!
  - Module design & production
  - Electronics and control
  - Cold boxes
- High Level Trigger
  - HLT1 GPU, HLT2 CPU
  - Real Time alignment, calibration
LHCB SCIFI TRACKER

Design and construction of SciFi

- 11km fibre, 128 modules, 256 cold boxes in 12 units (C-frames)
- 6 units behind BP installed
  - closure for beam-pipe
  - fully loaded and being tested
- Remaining 6 units half-way
  - finish next few months
ITk endcaps - ATLAS

- Two structures produced @ Nikhef
  - Carbon fibre with services
- Instrument with petals
  - Final assembly one endcap
  - Other endcap @ DESY

Production delayed (covid/renovation)

- Test structure to DESY @ jan2022
Nikhef/SURF provides a Tier-1 computing centre

- Recently successful continuation of funding - period 2021-2025
- National Roadmap - joint together with astronomy
  - CERN Tier-1, SKA, KM3NeT, ET

supported by SURF, coordinating the Dutch National e-Infrastructure
ELECTRON EDM

Facility in Groningen to determine e-EDM

- Enhancement internal E-field in BaF molecule
- In 2022: measurement at $10^{-27}$ e.cm
- Deceleration of molecules to increase precision
ASTROPARTICLE PORTFOLIO @ NIKHEF

Pierre Auger - cosmic rays

XENONnT - Dark Matter

Adv VIRGO - Gravitational Waves

KM3NeT - neutrino detection
KM3NET: ORCA & ARCA

Neutrino properties and astronomy

- ORCA: 1 dense block in France, oscillations.
- ARCA: 2 sparse blocks in Italy, astronomy.
- Nikhef: Design, instrumentation, production

Digital Optical Module (DOM)

Production site at Nikhef

One block = 115 DU lines
FIRST RESULTS

ORCA with 6 lines deployed

- First determination of neutrino oscillation
- Target: neutrino mass hierarchy

Mass production DOMS

- 218 DOMs for phase-1 done now ~160 DOMs for phase-2
- Integration in DUs to be deployed
Challenges with UHECR with Auger

- Particle interactions at the highest energy
- Multi-messenger to find point sources
- Particle ID is the key!

Nikhef provides large part of upgrades

- New SSD modules
  - Separation electrons / muon
  - Installation almost finished this year
- Radio Array
  - Extension to wide inclination
  - Pilot in the field since November 2019
- Nikhef responsible for all 1550 radio detectors

**UHECR - AUGER**

**e + µ in shower tail**

total # e

combination gives e and µ separately
GROUND BASED GW PROJECTS

Virgo:
- Currently being upgraded
  - Nikhef recently installed FDS system
  - Nikhef joined EGO (founded by CNRS & INFN)

Einstein Telescope:
- Plan for future observatory in Europe
  - Currently design, site selection, research and technology development

ETpathfinder:
- 10m scale prototype interferometer
  - a testbed for future GW technologies, currently under construction
EINSTEIN TELESCOPE IN EUROPE

ESFRI launch in December (Lubljiana)
• Scientists from 40 institutes & 10 countries - growing
Coordination by Italy and the Netherlands
• Political support IT, NL, Belgium, Poland, Spain +…
• Scientific reps from IT, NL, B, G, Fr, Sp, Hu, Po, Au, CH, UK
• Site selection around 2025

Timeline for ET
• Design phase (2008 - 2017, 5ME)
• Preparatory phase (2018 - 2027, 171ME)
• Implementation phase (2026 - 2035, 1736ME)
• Exploitation phase (2035 - 2080, 37ME / yr)
ESFRI acknowledgement of scientific excellence of Einstein Telescope, the intrinsic value, the urgency, and of the significance for scientific leadership for Europe is of paramount importance

**Underground infrastructure**
- M€ 932 excavation, civil and services for 2026 to 2033 National and/or regional funding
  - Substantial contribution provided by host(s)

**Vacuum system**
- M€ 566 for 2026 to 2032
  - Provided as national and/or regional funding, and/or common fund contributions from agencies/institutes

**Detector**
- M€ 238 for 2026 to 2035 Agency/institutes/national funding schemes

At this time in the process it is premature to give full clarity on the financial backing of all stakeholders
- Participating Ministries will decide on site selection (2024) and on sharing of the cost
ET-PATHFINDER R&D FACILITY

Activity in Maastricht/Nikhef

- First phase fully funded, opening last week
  - Clean rooms ready, parts delivered
  - First laser beams in 2023

ET operational from 2035 to 2085.

- Expect ET detector upgrades over the 50 years.
  - While ET operates and observes in “generation X technology” ETpathfinder can do R&D for “generation X+1 technology”

ET requires technological advances on all fronts:
- New mirror material => Silicon
- New temperature => 10-20K
- New laser wavelength => 1.5-2.1 microns
- Advanced quantum-noise-reduction schemes
STRATEGY 2017-2022

1. Proven approaches
   - Construct the upgrades and exploit the physics of the LHC experiments ATLAS, LHCb and ALICE
   - Build KM3NeT phase 2.0 and exploit neutrino (astro)physics
   - Exploit the astroparticle experiments Advanced Virgo, XENON1T/NT and the Auger Observatory
   - Full utilisation of the theory, detector R&D and computing activities

2. New opportunities:
   - Determine the electron EDM with world-class precision
   - Prepare for a post-LHC high-energy accelerator period
   - Strengthen and exploit the thematic connections between individual scientific programmes
   - Prepare a bid to locate the Einstein Telescope in the Netherlands

3. Beyond scientific’ goals:
   - Establish further links with industry in terms of transfer of knowledge generated at Nikhef
   - Attract and train a new generation of scientists and engineers
   - Modernise the Nikhef branding and building
   - Inspire and nurture scientifically aware general audiences
WE LIVE IN A MOST FASCINATING TIME!

\[ R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \kappa T_{\mu\nu} \]

**Dynamics of strong field?**
- Gravitational Waves

**Large energy in vacuum?**
- Cosmological constant?

**Black holes**
- Neutron stars

**Large quantum effects?**
- Origin dark matter?

**Higgs mass for particles?**
- Differences matter-anti-matter?
- Mass of neutrino’s?
- Family structure?

**Higgs self coupling?**
- Is our universe stable?

\[ \mathcal{L}_{QCD} = \bar{\Psi} \left( i \gamma^\mu D_\mu - m \right) \Psi - \frac{1}{4} G^a_{\mu\nu} G^{a\mu\nu} \]

**Survey: personal scientific motivation**
- One day being part of a discovery that will give us a new insight on how Nature works.

**Survey: personal scientific motivation**
"That I may understand whatever binds the world's innermost core together" (J.W von Goethe, Faust)