



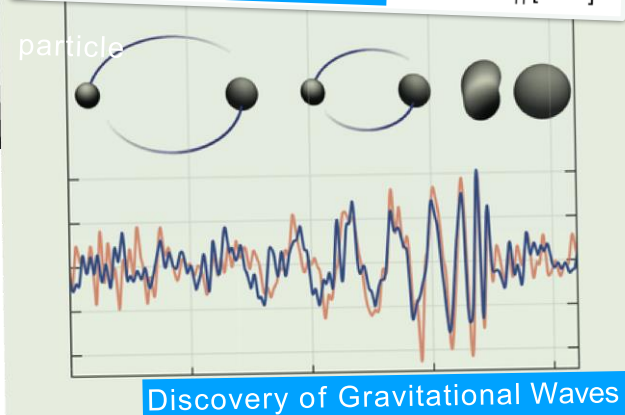
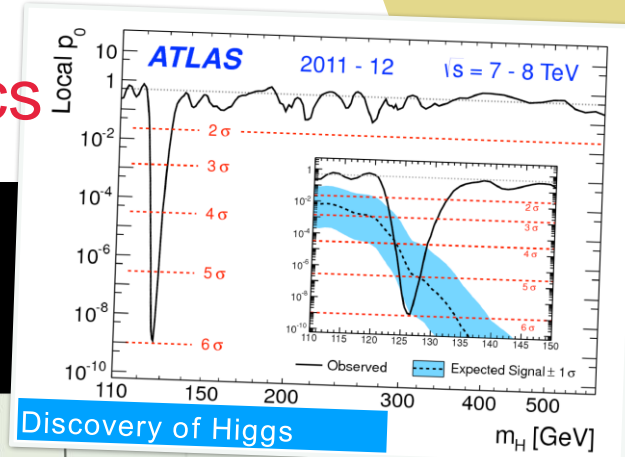
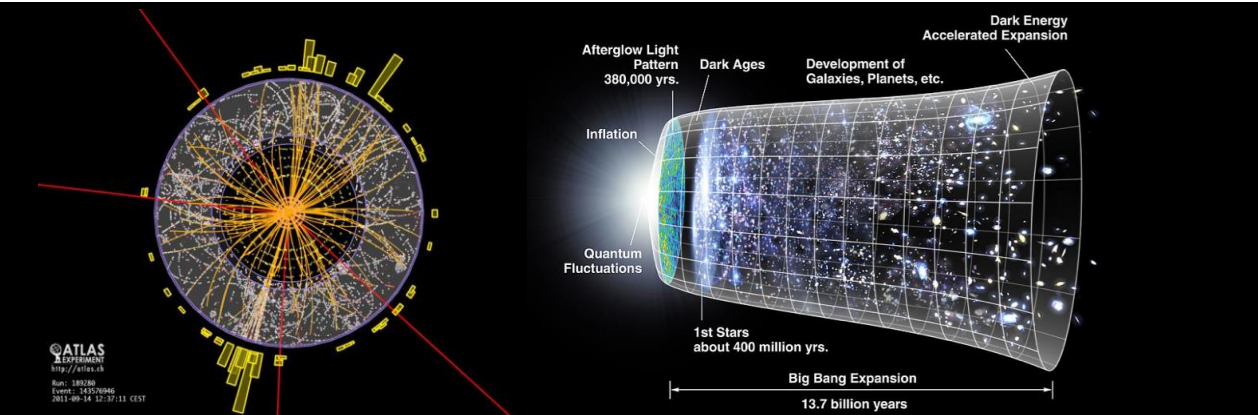
Maastricht University

*Federated computing ecosystems for science*

Nikhef, its Science Programme,  
and the Dutch National e-Infrastructure

David Groep  
for the OECD  
RI Ecosystem Workshop  
November 4, 2024

# Welcome to Nikhef the Dutch National Institute for Sub-atomic Physics



We probe our world, made of particles and fields,

- with collider physics, primarily at CERN
- astroparticle physics: particles, radiation, and ripples coming from the universe

# The Nikhef Partnership

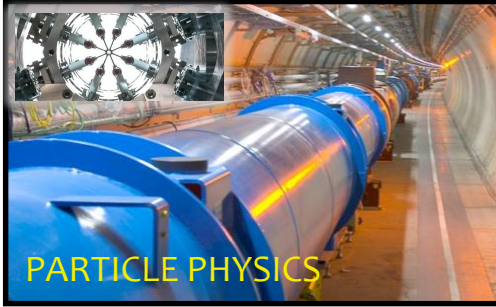
In itself a collaborative ecosystem

- university partners co-lead (most) research programmes
- aligned with a joint national strategy

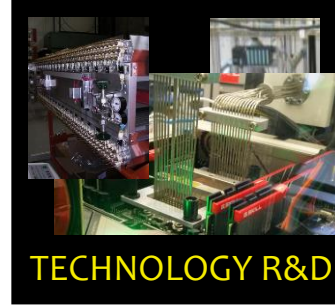
Permanent Staff	96
PhD candidates	125
Postdocs	43
Technical/engineer	88
Support	33



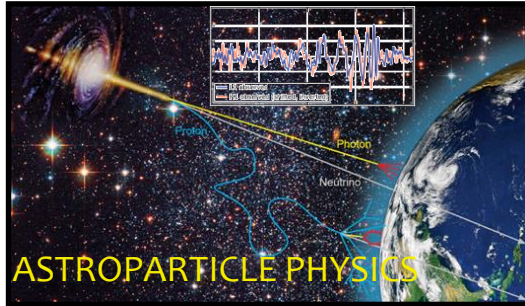
# Nikhef Scientific Programmes



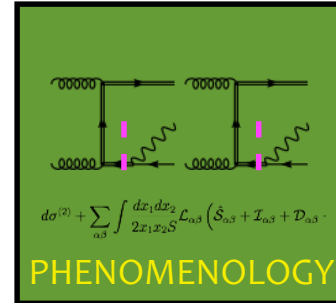
- Atlas
- LHCb
- Alice
- eEDM



- Detector R&D
- Physics Data Processing



- Neutrinos
- Gravitational waves
- Cosmic Rays
- Dark Matter



- Theoretical Physics



# Technical Engineering and technology transfer

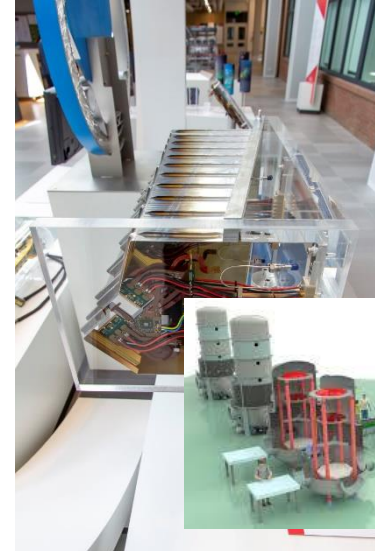
*'The research at Nikhef relies on the development of innovative technologies. The knowledge and technology transfer to third parties, i.e., industry, civil society and general public, is an integral part of Nikhef's mission.'*



pictures from Nikhef's 'Dimensions' magazine and Computing Office Hours; <https://www.nikhef.nl/en/nikhef-mission/>

# Infrastructure-intensive science

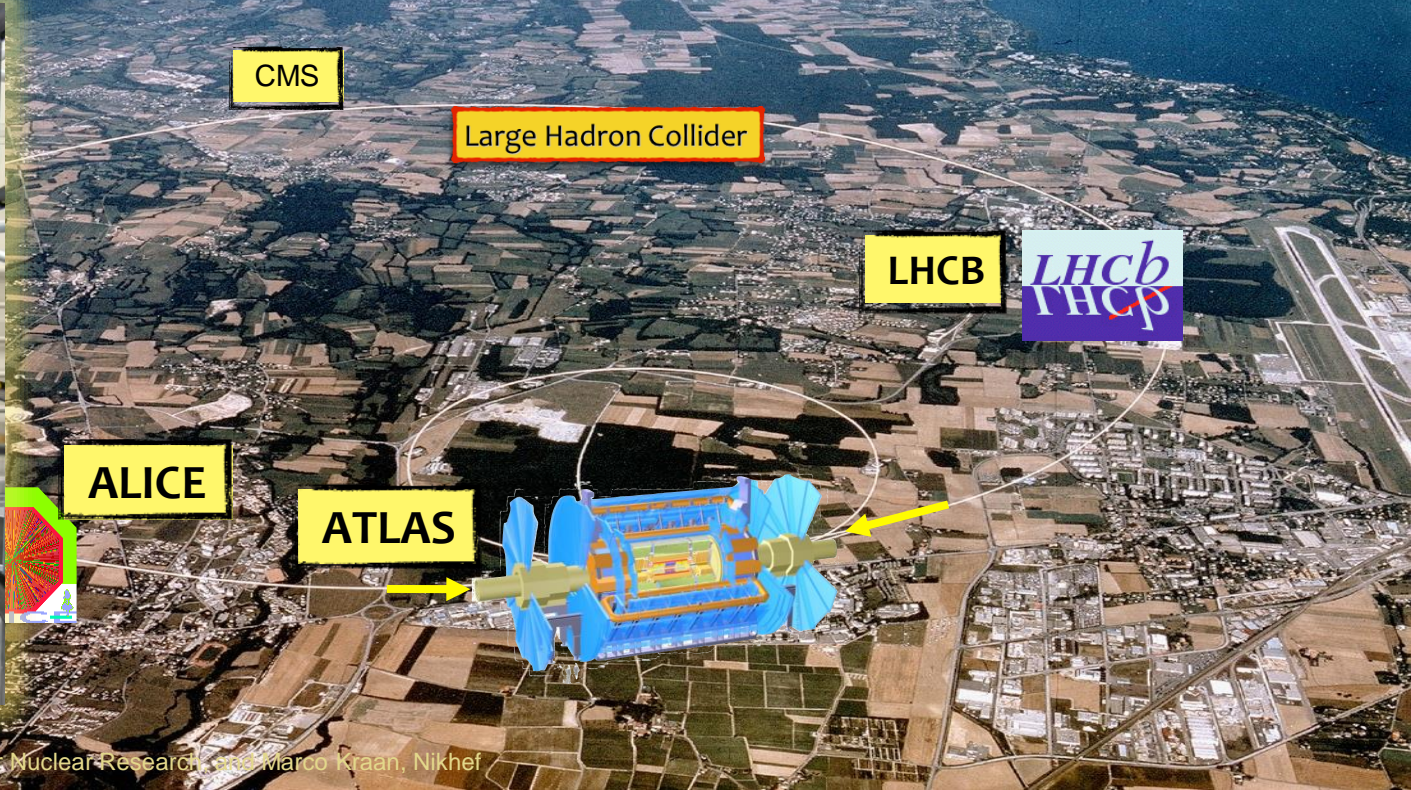
ATLAS AT CERN  
~ 150 INSTITUTES  
~1800 PHYSICISTS



Slide materials from: Stan Bentvelsen, 2016, ATLAS collaboration, CERN; LHCb VELO and RF box at Nikhef and ET Pathfinder visualisation: Marco Kraan, Nikhef



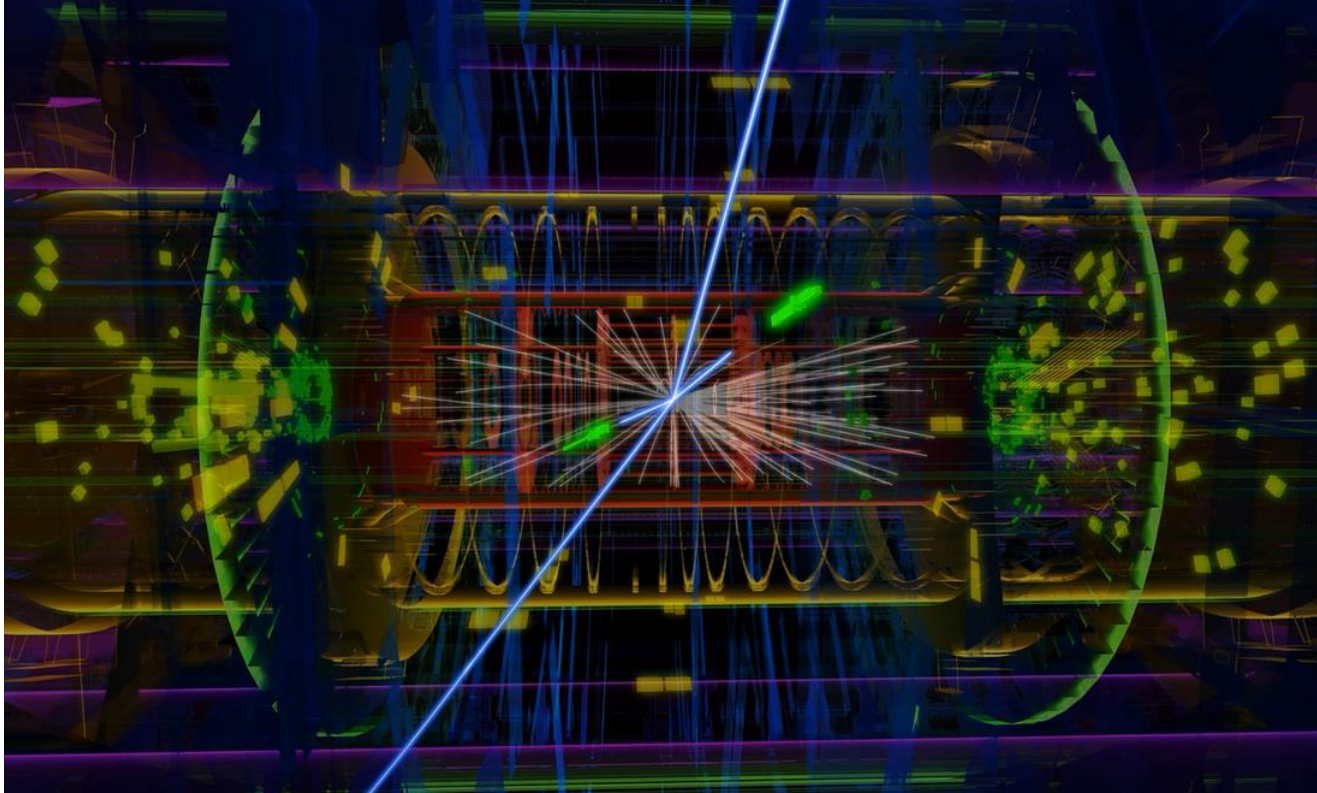
# Nikhef at CERN – LHCb, Atlas, Alice



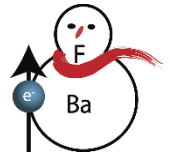
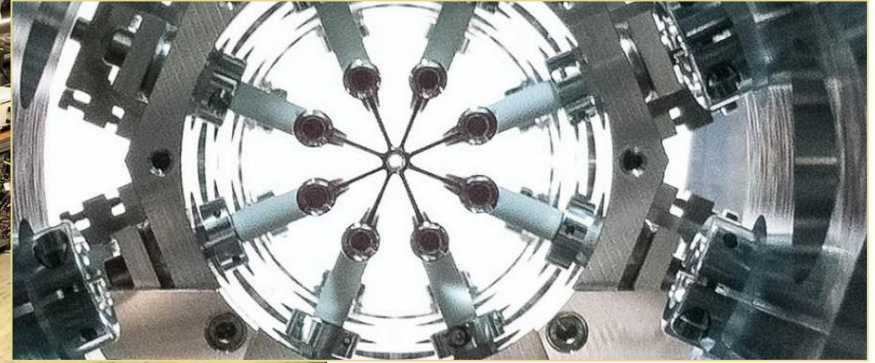
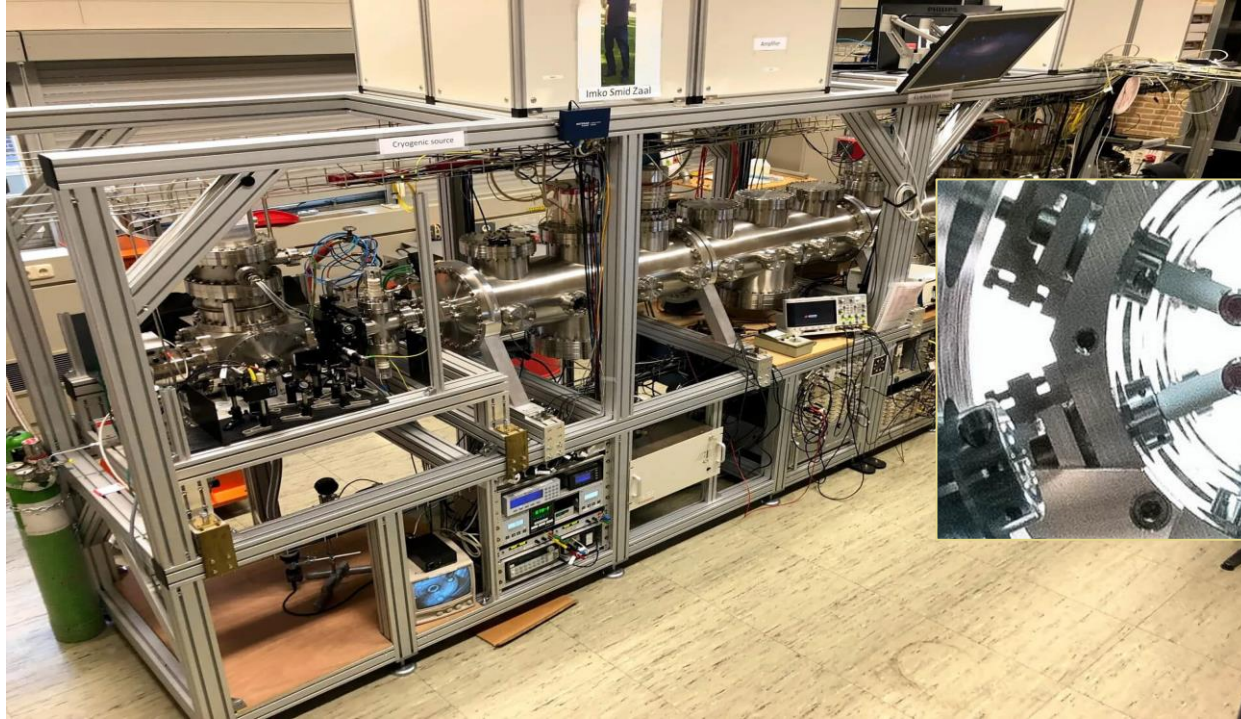
Imagery: CERN, European Organisation for Nuclear Research, and Marco Kraan, Nikhef



# Atlas: up to 40 Tbyte/day of fresh raw data



# And decelerate for ultra-high-precision measurements



<https://www.eedm.nl/> Nikhef and Rijksuniversiteit Groningen, images: Steven Hoekstra



# Particles at Extreme Energies

Multi-Messenger

*Propagation?*  
Mass composition!?

*Interactions?*  
Mass composition!?

Nucleus

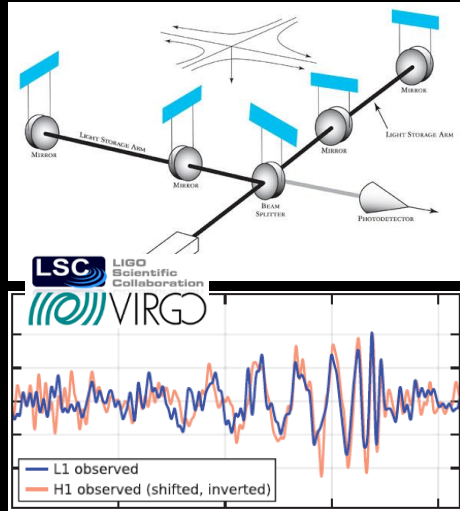
Proton

Photon

Neutrino

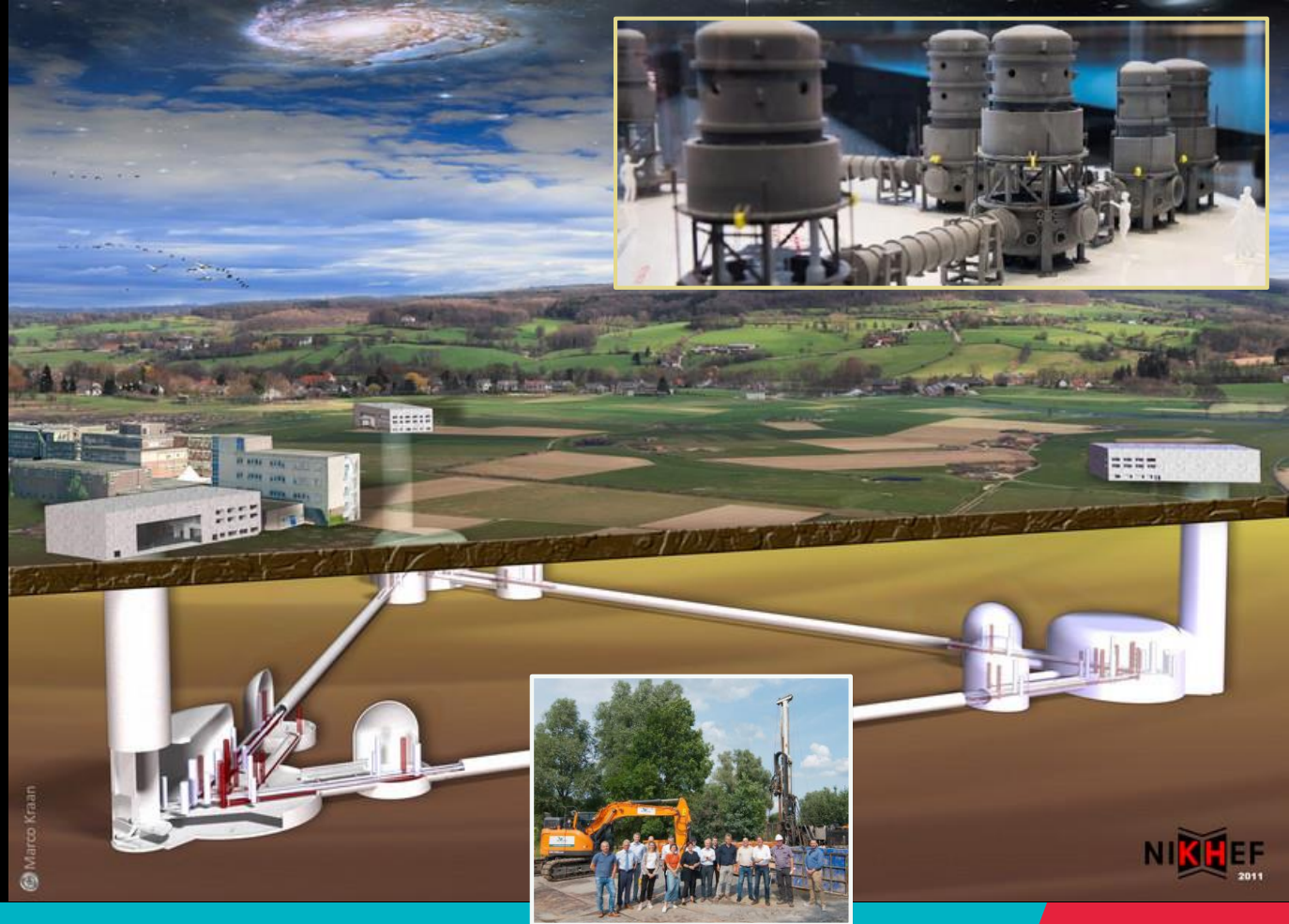
$\vec{B}$

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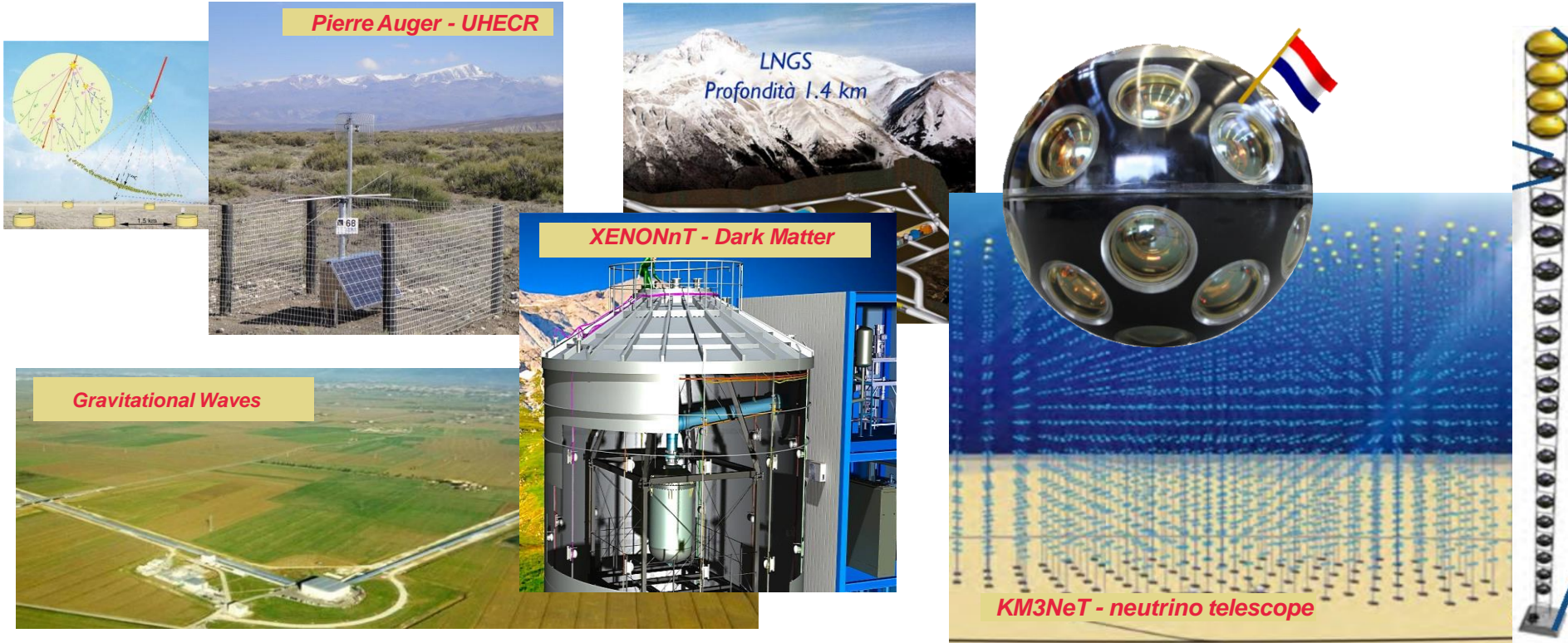
Einstein Telescope projected in the **Euregio Maas Rijn**,  
images: Marco Kraan;  
ET Pathfinder at UM, Maastricht, NL

GW150914 event:  
gw-astronomy collaborations, LIGO

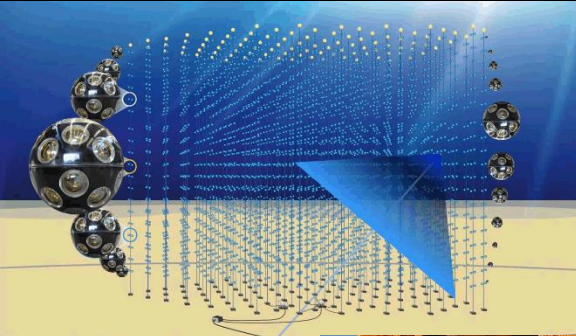




# The astro-particle physics programmes Nikhef



Slide: Stan Bentvelsen, Nikhef SEP 2023, KM3NeT collaboration, Virgo Collaboration, Xenon-nT collaboration, Pierre-Auger collaboration



Little white structures prevent the HV bases and cables to touch each other

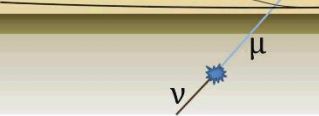


Image sources:  
Nikhef, NIOZ,  
KM3NET collaboration,  
NRC Handelsblad



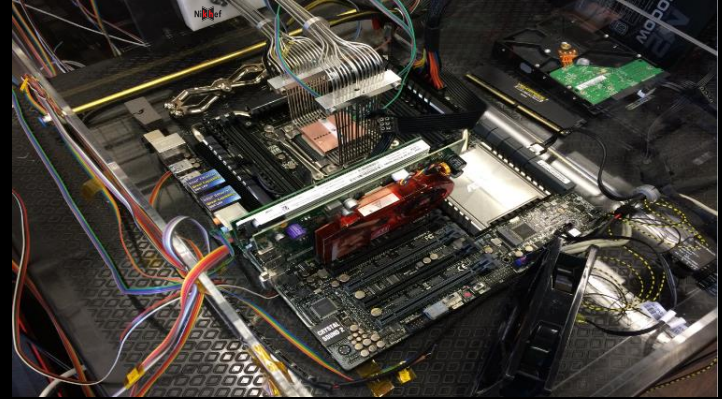


# Enabling Research Programmes – next gen infrastructure



Detector R&D

Theoretical  
Physics



Physics Data Processing



# LHC Computing – a global infrastructure



- > 2 million CPU cores
- > 2000 Petabyte  
disk + archival
- 170+ data centres
- 42+ countries
- 13 'Tier-1 sites'
- NL-T1 jointly by  
**SURF & Nikhef**

*built on many 'generic'*  
*e-Infrastructures*  
EGI, GEANT, EuroHPC  
OpenScienceGrid  
NSF ACCESS-CI, ESnet,  
KEK, CalculCanada, ...

# Data in the Dutch National e-Infrastructure



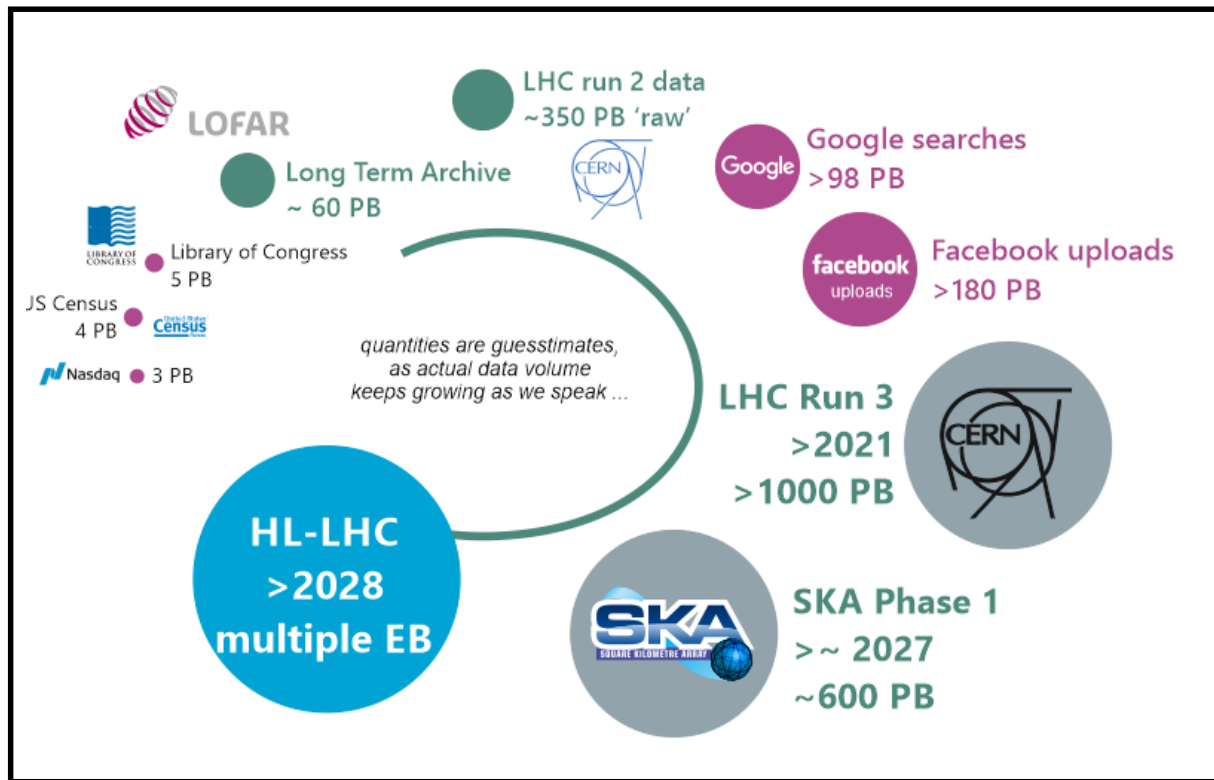
Nikhef

Fundamental  
Sciences  
E-infrastructure

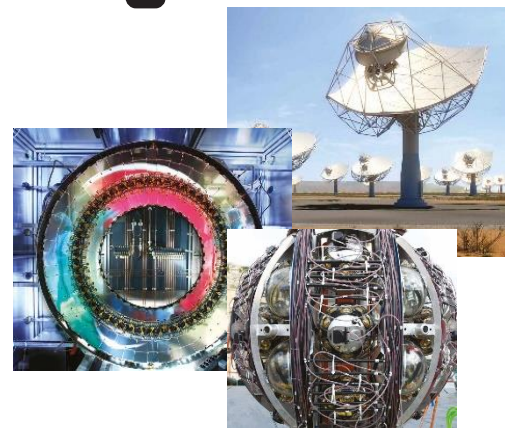
ASTRON

Netherlands Institute for Radio Astronomy

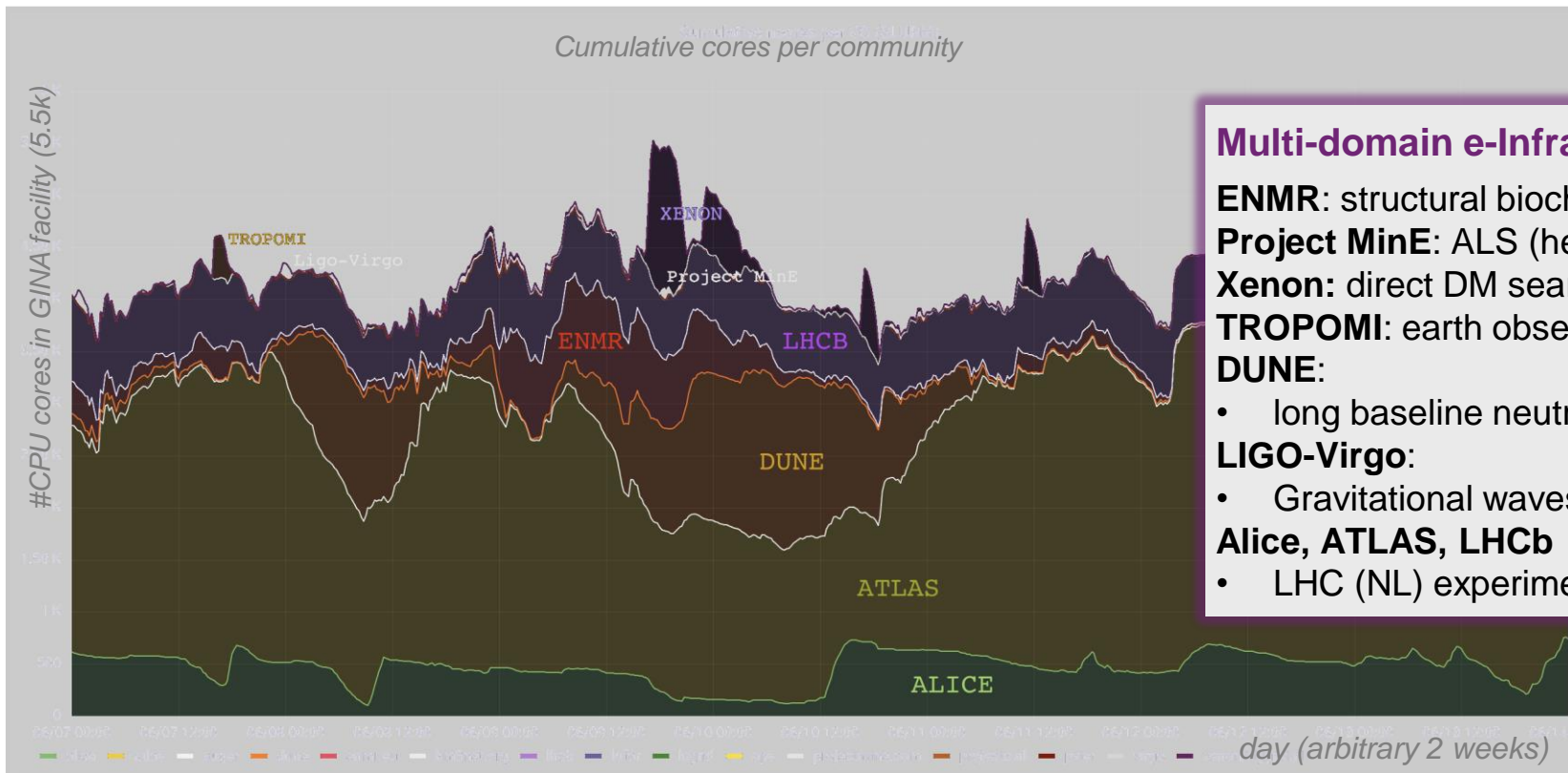
SURF



approximate volumes for LoC, Google searches and FB uploads from ~ 2018. Source: WLCG publicity presentations  
Imagery: SKA mid (South Africa) courtesy SKAO. Silicon tracker composite photo Nikhef. KM3Net DOM deployment module: Nikhef and NIOZ



# Data Processing infrastructure – the Dutch SURF example



## Multi-domain e-Infrastructure

**ENMR:** structural biochemistry

**Project MinE:** ALS (health)

**Xenon:** direct DM searches

**TROPOMI:** earth observation

**DUNE:**

- long baseline neutrinos

**LIGO-Virgo:**

- Gravitational waves

**Alice, ATLAS, LHCb**

- LHC (NL) experiments

# Coordinated e-Infrastructure: the SURF cooperative

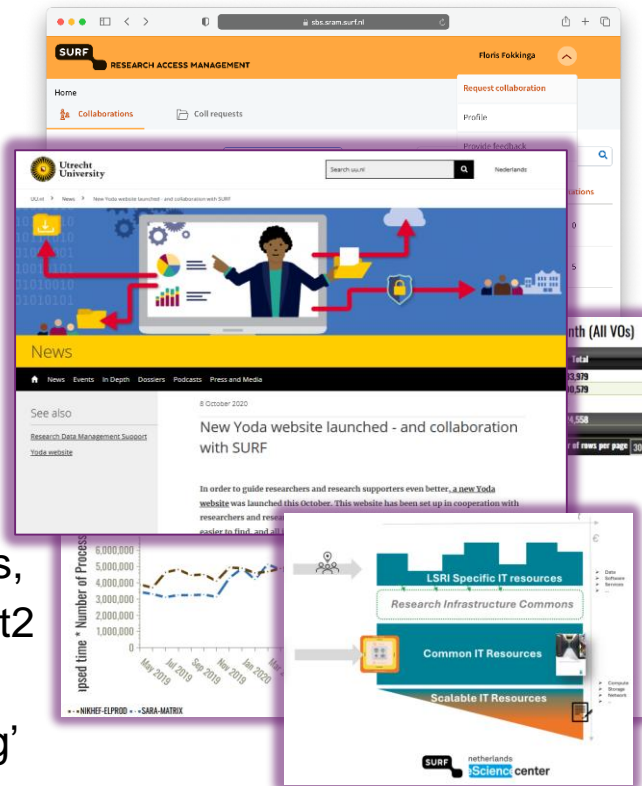
SURF

SURF nationally aligns and supports computing for members (RPOs and education) and research council

- **networking** (the physical ones) with global links
- **HPC and HTC** facilities, data storage
- **federation services**: trust, identity, and security

Coordinates joint infrastructure, initiatives, and projects

- nationally with members and the LSRIIs
- in Europe with GEANT, EGI, EUDAT, EuroHPC and ESFRIs,
- globally with collaborations like WLCG, SKA, IGWN, Internet2
- ‘digital competences’: FAIR data ... and beyond
- technology innovation, digital autonomy, policy, and ‘futuring’



# Scalable HPC: from local “Tier-2” to European “Tier-0”



Nikhef “Stoomboot”  
Analysis Facility



...



SURF National Infrastructure  
foundation as *well* as stepping stone

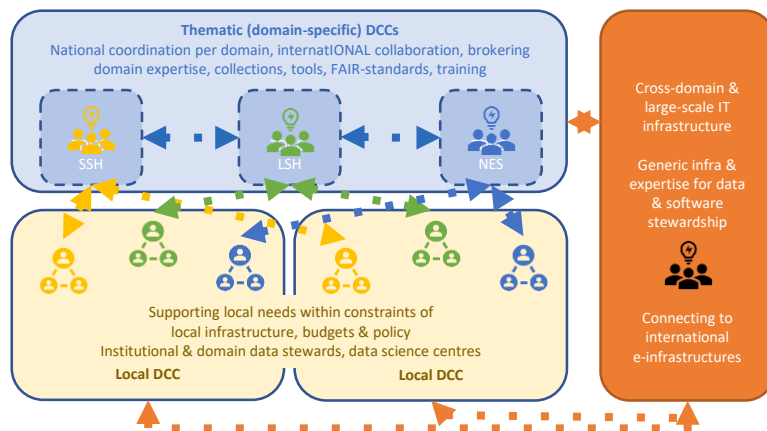


You need **local expertise**  
to enable exploitation  
**of European and**  
**global resources**



# Sharing more than resources: data, software, research pipelines, expertise

*Thematic Digital Competence Centres -  
beyond data stewards and 'dead' data for open science*



*Image by: Ruben Kok, LSH TDCC and DTL*

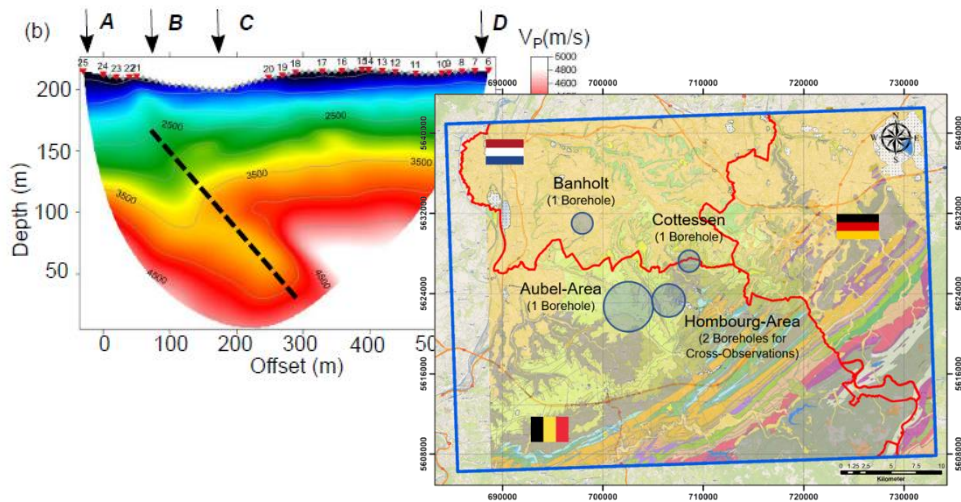
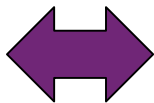
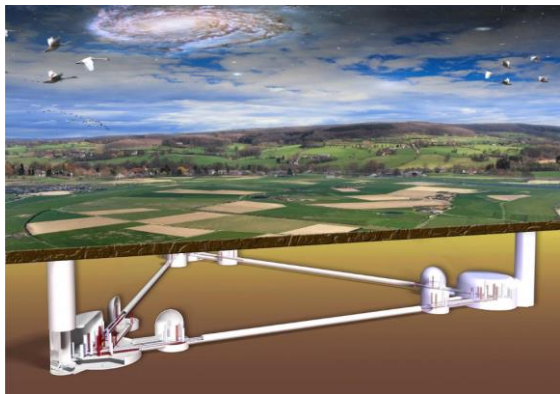
Software and infrastructure essential to bring 'dead' data to life!



# Sharing expertise: thematic digital competence centres

## *an example from the Natural and Engineering Sciences domain*

Case study: Einstein Telescope seismic studies in EUregio Meuse-Rhine in the *E-TEST* project



Data collected here is also useful for many other domains outside of the ET planning ...

ET impression: Marco Kraan (Nikhef) from "Terziet drilling campaign" <https://www.nikhef.nl/wp-content/uploads/2019/10/Terziet-Drilling-Campaign-Final-NoC.pdf>  
Seismic data: S Koley (VU and Nikhef) *Sensor networks to measure environmental noise at gravitational wave detector sites*, ISBN 978-94028-2054-6; map image: etest-emr.eu project site

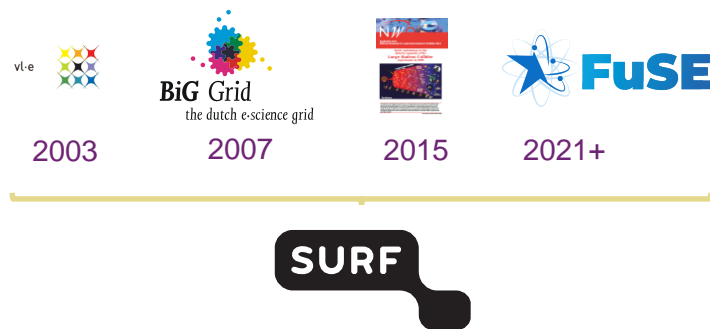
# Looking at ICT as a research instrument, like our detectors

‘ICT infrastructure for research – distinct from the office and enterprise service’

- research data today is ‘born digital’ and has joint challenges, hence: shared e-Infrastructure!

But our ‘open data’ increasingly stresses *capacity*

- data volume and bandwidth keeps growing:  
there is no sustainable funding model yet
- same for research software:  
continued maintenance eats into innovation



But project-based mechanisms are not solution for the sustainability issues like data & compute:  
a better programmatic approach needed, including long-term financial stability in the ecosystem

# Riding the infrastructure innovation chain together

Computing  
Sciences  
Research

Operational Research  
(near-term, NextGen storage,  
800G+ network, QC & simulators)

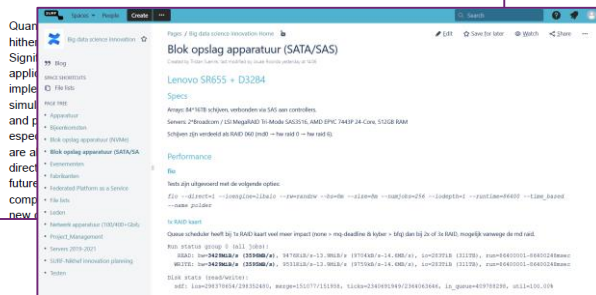
Operational innovation  
(procurement, systems  
vendor co-engineering)



## From Quark to Quantum ... with LHCb

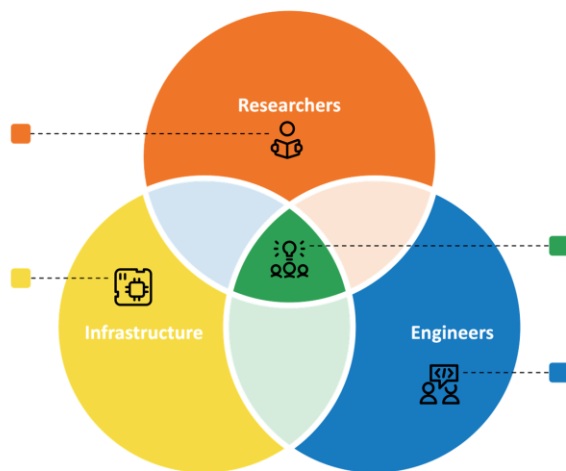
Jacco de Vries: Maastricht University/Nikhef [jdevries@nikhef.nl](mailto:jdevries@nikhef.nl)  
Daniel Campora: Maastricht University/CERN [dcampora@cern.ch](mailto:dcampora@cern.ch)  
Kareljan Schoutens: UvA/QuSoft [c.j.m.schoutens@uva.nl](mailto:c.j.m.schoutens@uva.nl)  
David Groep: Nikhef [davidg@nikhef.nl](mailto:davidg@nikhef.nl)  
Ariana Torres: SURF [ariana.torres@surf.nl](mailto:ariana.torres@surf.nl)

## Introduction



involving non-CS research domains

# SURF Experimental Technologies Platform



**SURF-ETP**  
Open and collaborative environment to foster the assessment of cutting-edge technologies and methodologies.

**Engineers**  
Leverage their technical skills and motivation to surf the state-of-the-art.

The screenshot shows the SURF Experimental Technologies Platform website. The header includes the SURF logo, a 'Spaces' dropdown, a search bar, and a 'Log in' link. The left sidebar contains a navigation menu with links to iRODS, JupyterHub for education, Object Store, ODISSEI Secure Supercomputer, Persistent Identifiers (PIDs), Research Drive, Service Desk, Snellius, LUMI, NLSRC, and Experimental Technologies Platform. The main content area is titled 'Overview' and is divided into three sections: 'Compute', 'Network', and 'Storage'. Each section displays a grid of featured hardware products with their logos and brief descriptions.

**Overview**

**Compute**

- AMD Instinct MI210**: AMD Instinct MI210 accelerators power enterprise, research, and academic HPC and AI workloads for single server systems and more.
- NVIDIA Grace Hopper Superchip**: NVIDIA Grace Hopper combines the Grace and Hopper architectures via NVLink-2C to deliver a 2P/2000F coherent memory model.
- Intel GPU Max 1100**: Designed to accelerate AI workloads and enable vector and matrix capabilities with Intel oneAPI Extensions (oneAPI).
- Xilinx ALVEO U250**: The Alveo U250 card uses Xilinx VU19P technology to deliver breakthrough HPC capacity, bandwidth, and power efficiency.
- NextSilicon Maverick**: Intelligently adapts its architecture to meet algorithmic requirements, all without the need for code modifications.
- Asus CRL-G116U-P30F**: An accelerator card based on Google Coral Edge TPU processor, enabling AI-based real-time decision process at edge.
- Xilinx VCK5000 Versal**: The VCK5000 Versal is built on the AMD Versal adaptive SoC architecture and is designed for AI engine development with AI and CoE and HPC and AI software development.
- Cerebras WSE-2**: 800,000 cores, 40 GB of on-chip SRAM, 20 PB/s of memory bandwidth, and 220 PB/s of interconnect bandwidth.

**Network**

- Cornelis Omni-Path Express**: Cornelis Omni-Path Express is a new generation of high performance fabrics, a proven hardware foundation combined with the OpenFabric interface (OFI) software framework.
- Nokia 7750 SR-1x-48D**: The Nokia 7750 SR-1x-48D provides dedicated virtualized performance, scale and versatility for the full array of AI edge and core applications.

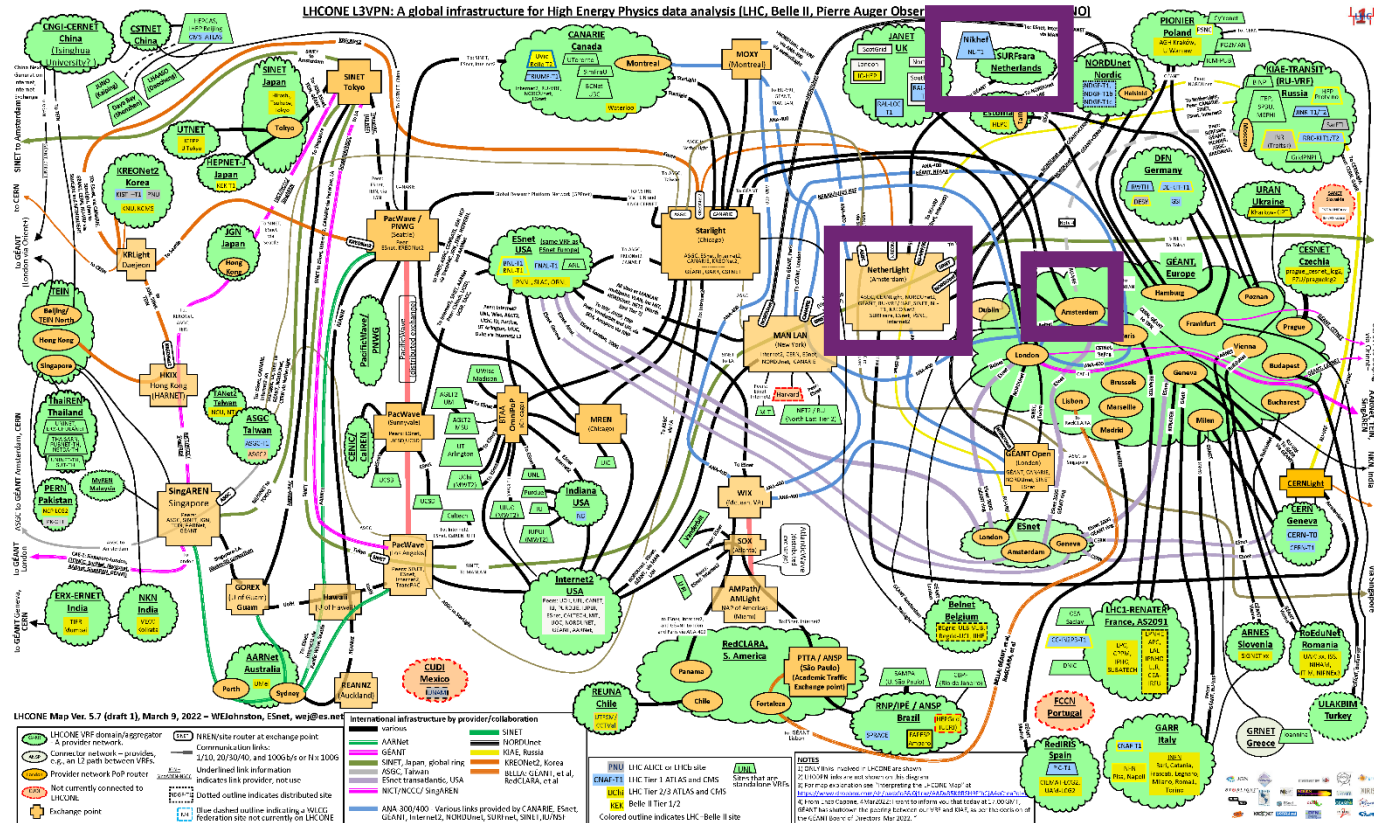
**Storage**

- Fungible FS1600**: The FS1600 is powered by new Fungible GPUs, a new class of processors designed to deliver virtualized performance and efficiency in existing infrastructure services.

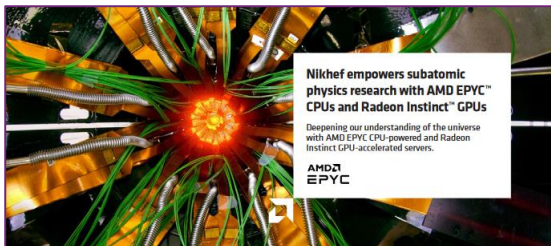
<https://servicedesk.surf.nl/wiki/display/WIKI/Experimental+Technologies+Platform> and <https://www.surf.nl/en/etp> - contact Raymond Oonk at SURF for more info



# It's all about networking – of all kinds, and globally



# And since speed does matter ..



**Nikhef empowers subatomic physics research with AMD EPYC™ CPUs and Radeon Instinct™ GPUs**

Deepening our understanding of the universe with AMD EPYC CPU powered and Radeon Instinct GPU-accelerated servers.

**AMD EPYC**

**CUSTOMER**  
Nikhef

**INDUSTRY**  
Subatomic Physics

**CHALLENGES**  
Increasing data throughput with higher I/O and memory bandwidth

**SOLUTION**  
Dedicated AMD EPYC™ X86 and T800 CPUs, and AMD Radeon Instinct™ M50 GPUs

**RESULTS**  
Faster processing and the ability to harness GPU-accelerated machine learning to cope with rapidly expanding experiment data volume

**AMD TECHNOLOGY AT A GLANCE**  
AMD EPYC T800 processors with 32 cores  
AMD EPYC T800 processors with 64 cores  
AMD Radeon Instinct M50 GPUs

**TECHNOLOGY PARTNER**  
Lenovo

**AMD + NIKHEF CASE STUDY**

Many of the latest scientific discoveries are as much about the computing power used to analyze experimental data as they are about the theories behind them. At the forefront of advancing the processing capabilities for subatomic physics research is Nikhef, the Dutch National Institute for Subatomic Physics. Nikhef has provided computing that has helped with the discovery of gravitational waves in 2015, the Higgs boson, and the fundamental physics in between, including confirmation that many of the heavy elements in the universe are produced in neutron star mergers.

"The institute performs blue-sky research to learn more about the nature of the universe and the building blocks of matter," explains Rolf Aaij, Scientific Staff Member at Nikhef. "The fundamental goal of this institute is to find the big universal box of building blocks everything is made from," adds Tristan Smeets, IT Architect at Nikhef. The more computing power that the institute can draw at this specific, the more that can be discovered. This led the team to AMD EPYC processors and Radeon Instinct™ GPUs, which delivered the performance Nikhef's workloads required and the solution price that aligned with their budget.

**Data-hungry science**  
Nikhef is involved in many different experiments, but all of them require a considerable level of computing power. "About 100 scientific staff work at Nikhef," explains Aaij. "These staff usually work on one (or sometimes more than one) of the experiments Nikhef is involved in.

Three of these experiments are at CERN, the ATLAS, LHCb, and ALICE experiments. There are several astroparticle physics experiments. One is the Pierre Auger experiment, covering several thousand square kilometers of Pampa in Argentina. The area is equipped with detectors to search for air showers caused by extremely high energy particles that arrive from the universe. Then there is the neutrino physics experiment KM3NeT, and dark-matter research with the XENON experiment. Finally, there is a large gravitational waves physics group that is a member of the LIGO-Virgo experiment collaboration."

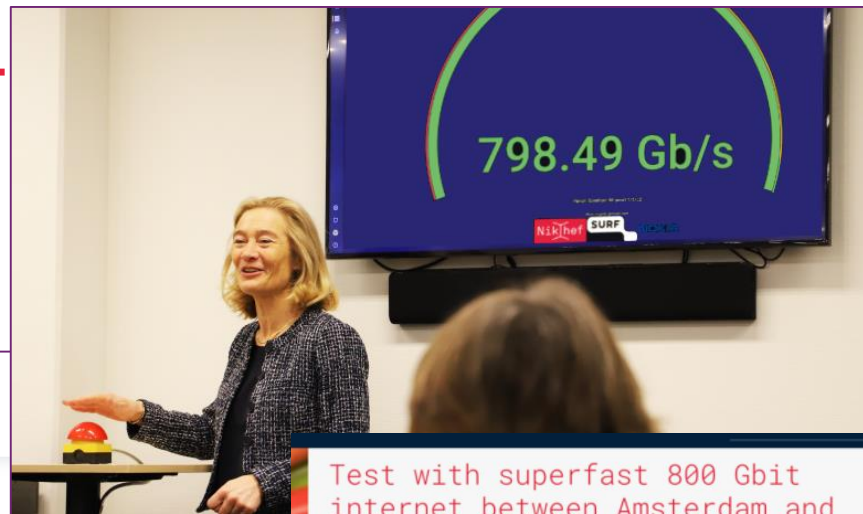
If there's one thing all these experiments have in common, it's the increasing amounts of data that the experiments produce. "The scientists always want more data," says Smeets. "Think there are few experimental physics papers that do not end with 'we need more data.' And in the field of physics, to get more data you build a more sensitive experiment." In the case of the Large Hadron Collider (LHC) at CERN, the big in data produced will be particularly huge.

"In about five years the LHC will increase the number of collisions detected by about a factor of 10," says Aaij. "This means that the experiments will start producing a similarly increasing amount of data. If we look at the growth of storage space and compute capacity over time, then we do not expect to even get close to a factor 10 in increase of performance for a long time. We need to deal with that, because we need to process the data. Otherwise, we can't do science with it." This is where AMD EPYC processors and GPU acceleration have offered the best solutions to satiate the hunger for growing data processing ability.



## NIKHEF, SURF AND FUNGIBLE SET NEW BENCHMARK FOR THE WORLD'S FASTEST STORAGE PERFORMANCE

Companies Double Current Performance Record, Set the New Bar at 6.55 Million Read IOPS



Test with superfast 800 Gbit internet between Amsterdam and CERN successful

15 April 2024

Nokia and SURF have successfully tested an 800 Gbit/s data connection between Nikhef in Amsterdam and CERN in Geneva. Such a connection is needed to transmit data from the upcoming high-luminosity LHC accelerator.

The test used existing fiber-optic connections through Belgium and France toward Geneva in Switzerland over a total distance of 1,648 kilometers. An 800 Gbit/s connection is about a thousand times faster than the Internet connection in an average household.

Nokia's latest photonic technology, the sixth-generation super-coherent Photonic Service Engine (SPE-6s), was deployed in the tests, along with 16QAM-shaped modulation. The results of the tests will be announced in more detail next week at a Nokia expert conference in Athens.

Data hub

Image: Minister of Economic Affairs M. Adriaansens launched the Innovation Hub with Nikhef, SURF, Nokia and NL-ix, January 2023. Composite image from <https://www.surf.nl/nieuws/minister-adriaansens-lanceert-testomgeving-voor-supersnelle-netwerktechnologie>

# Our science data flows are somebody else's DDoS attack



Belastingdienst

Home Menu Zoeken

Home > Actueel > ICT en informatievoorziening > De systemen testen dankzij een unieke samenwerking

[Lees voor](#)

## De systemen testen dankzij een unieke samenwerking

Dinsdag 14 maart 2023 | Het laatste nieuws het eerst op NU.nl



**Forse ddos-aanvallen en nerdgrapjes tijdens nachtelijke oefening overheid**

Door Rutger Otto

12 feb 2023 om 05:02  
Update: een maand geleden

202 reacties



Betastingsdienst

Home

Home > Aanslagen > Ik heb een DDoS aanslag ontvangen - wat nu?

## Ik heb een DDoS aanslag op mijn netwerk ontvangen - wat nu?

U ontvangt een DDoS aanslag op uw netwerk, bijvoorbeeld omdat u vergeten bent werkende tegenmaatregelen te nemen. Er staat dan een geschat aantal pakketten per seconde op uw monitoring.



Bandbreedte

Pakketjes

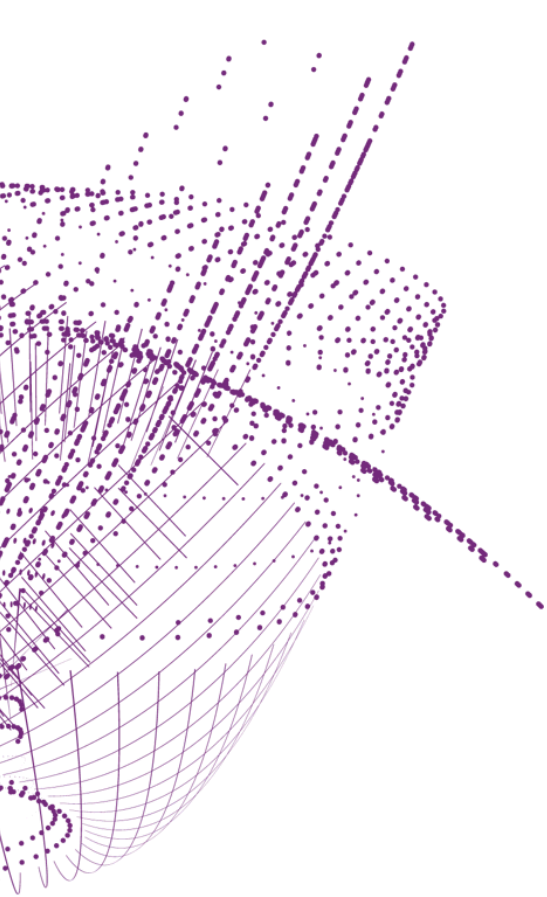
Tb/s

Gp/s

Het begon in 2018. Een bijzondere samenwerking tussen overheden, internetproviders- en exchanges, academische instanties, non-profitorganisaties en banken. Nadat duidelijk was dat de aanval was uitgevoerd door een 'red team' is verantwoordelijk voor de aanvallen, het 'blue team' voor de verdediging. Een van de partijen die aan de avond meedoet is [Nikhef](#). Tristan, IT architect bij Nikhef, geeft aan "dat zij dit

Image sources: belastingdienst.nl, rws.nl, nu.nl, werkentegnederland.nl





A collaborating 'ecosystem'  
for science and innovation

# How did we get here?

# Once upon a time ... a green fields approach?



Watergraafsmeer and volkstuinencomplex Frankendael, 1974, starting the construction of the WCW. Image: Beeldbank Amsterdam, gemeente Amsterdam

# The Nikhef data centre – at the end of the 1980s



Gould, Sun, and DEC systems, taking several racks each

- 500 m<sup>2</sup> floor area
- Raised floor: +60cm
- walls are 'movable' to accommodate expansion

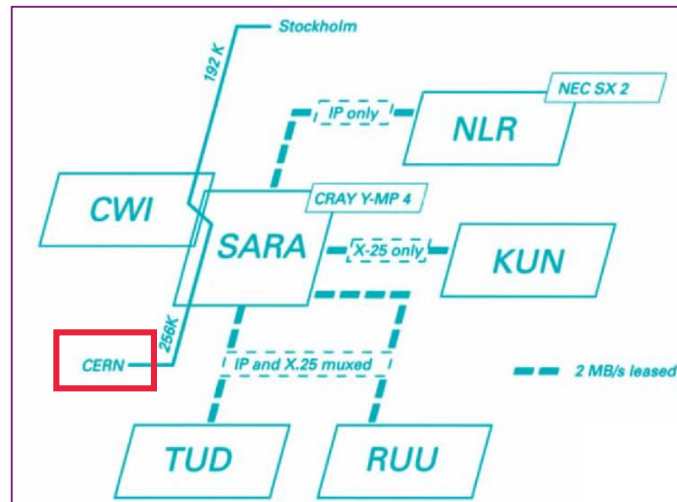
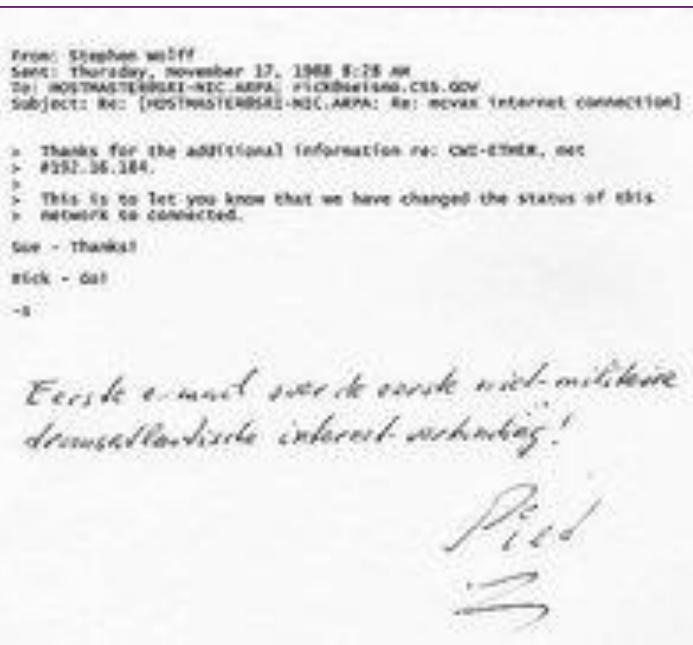
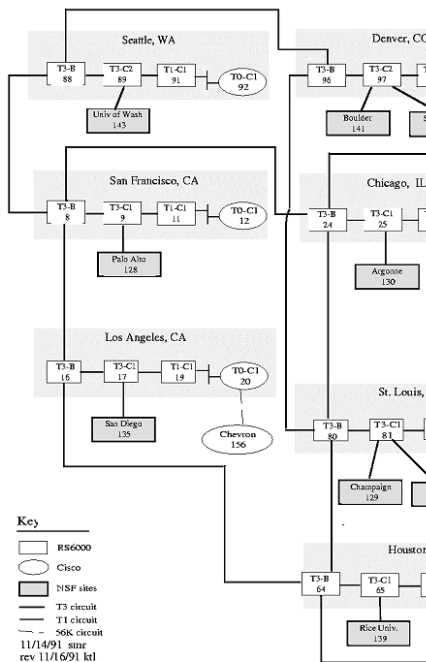
Nikhef room H1.37 – terminal stations on the raised data floor of the computer room (H1.40, behind the glass-panel walls)



# Collaborative Research Infrastructures: all about networking!

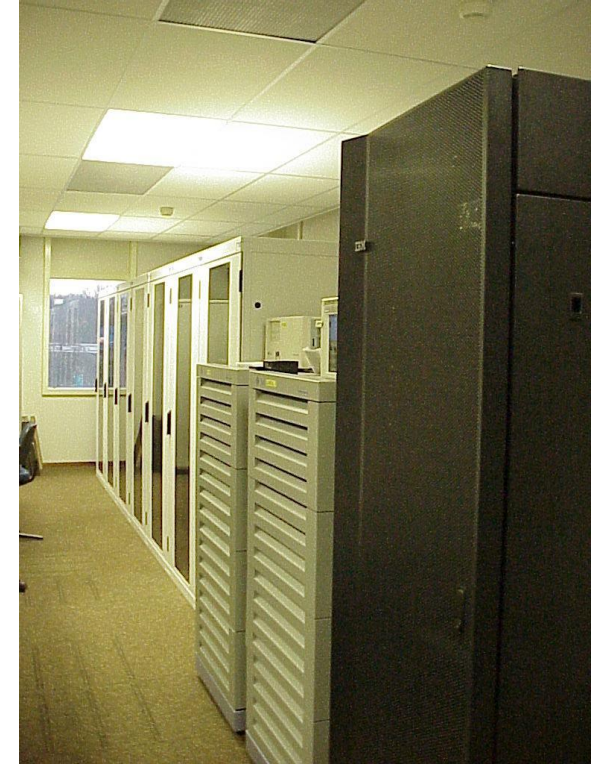
ANSNET/NSFNET T3 Topology as of 11/18/91

*be it human or computer networks ...*



See <https://personalpages.manchester.ac.uk/staff/m.dodge/cybergeography/atlas/historical.html> for more historic maps ; right-hand image: SURFnet2, 1990  
first email to MCVAX at CWI from <https://www.cwi.nl/en/news/cwi-celebrates-25-years-of-open-internet-in-europe-in-november/> (Piet Beertema, CWI, 1988)

# 'IBR-LAN' at Nikhef – connecting local and global networks



International Backbone Router Local Area Network "IBR-LAN" at Nikhef, room H1.40 as seen in 1996. Right: H1.39 with nikhef.nikhef.nl racks and early DAS-2 system

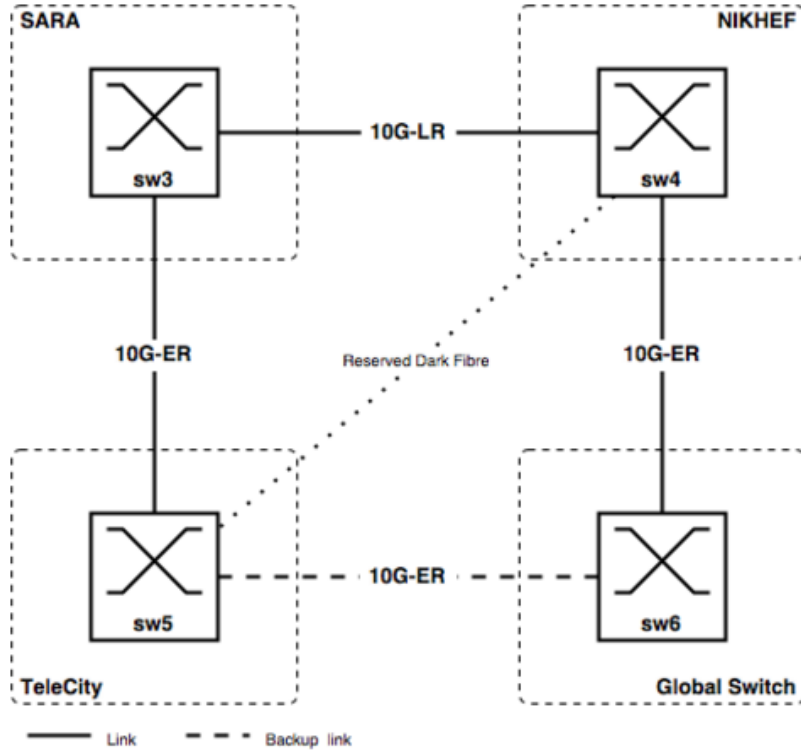
# What happens if you welcome two networks onto your floor



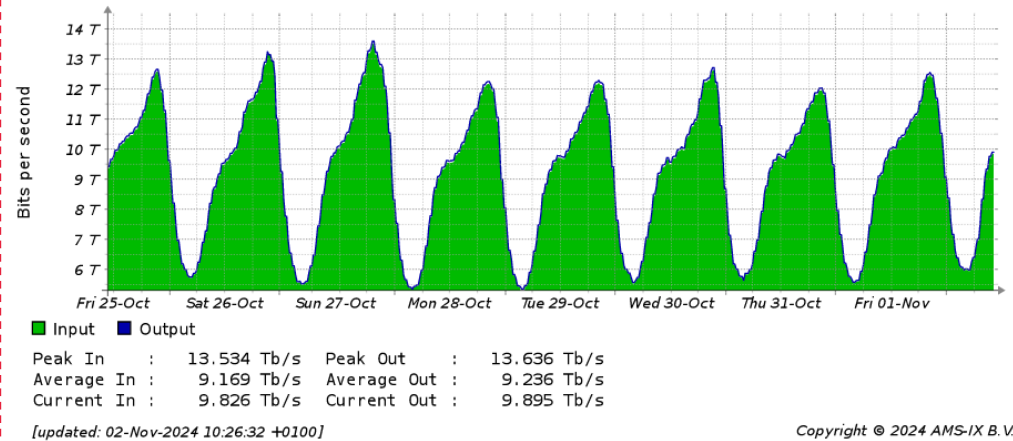
Image: AmsIX at Nikhef H140 in 2007 – foto Beeldbank Amsterdam <https://archief.amsterdam/beeldbank/detail/a95bc475-8fcc-d0d1-37f9-b077ba3729db/media/>



# A growing internet!



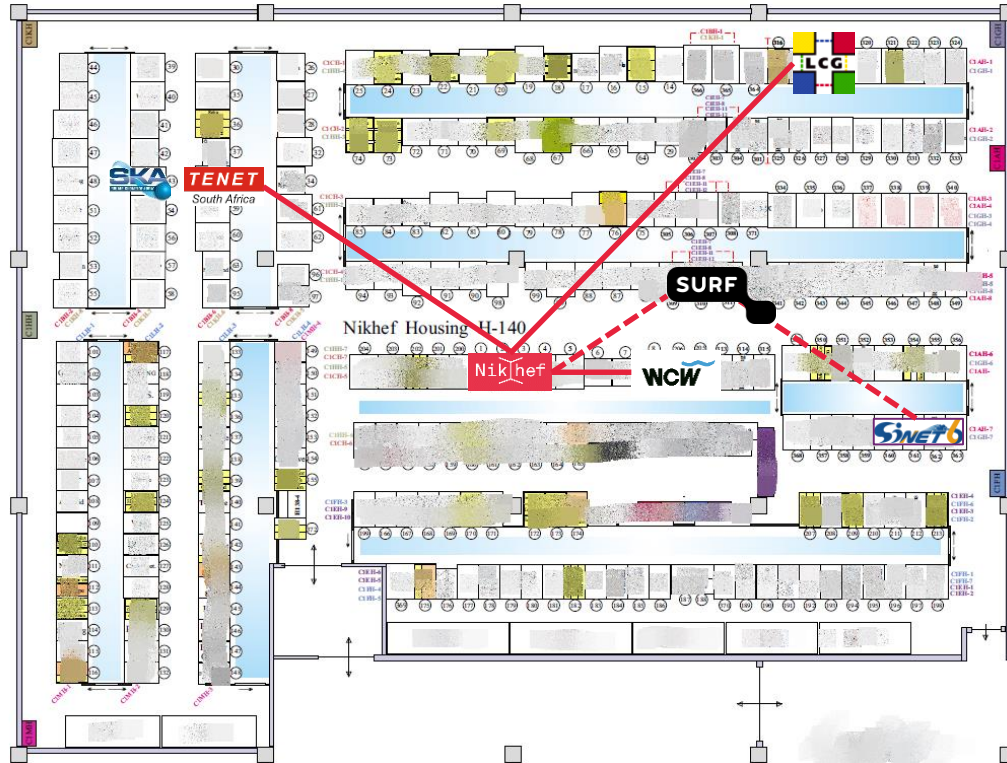
AMS-IX topology, 2002



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AMS-IX traffic Nov 2, 2024; <https://stats.ams-ix.net/> <https://www.ams-ix.net/ams/colocations>

# Connect each other ... and scientific data and instruments



dashed lines: traffic is routed via ancillary facilities of SURF and GEANT first (currently: AMS9 at WCU) SKA Meerkat traffic via TENET

# What happens inside a data centre ...



‘Connectivity’ housing and ‘hosting’ are different things:

- NikhefHousing (H140) has connectivity parties only, and does not host any content
- what you see on the 1<sup>st</sup> floor tour is *network* equipment: shipping data, but not keeping anything

**2<sup>nd</sup> floor** has our science data centre

And no single connectivity data centre is a single point of failure:  
Internet protocols are engineered to re-route traffic



# Today's data centre at Nikhef

## 'NikhefHousing' data centre

- from the first 2 racks in a corner
- to now > ~400 racks
- many different connectivity parties
- **376** networks present in PeeringDB
- connectivity-focus, not hosting



## Nikhef 'science' data centre H234b

- 47 racks and ~350 kW
- hosts Nikhef, CERN, gravitational waves, and SURF *research* data
- strengthens connectivity at, and uses NikhefHousing

# Data centre installation management, ever growing

- active/free cooling chillers installed on the roof in 2009
- data floor: ~400 racks
- evolving hot-isle/cold-isle configuration
- electricity generator sets 2003, 2009, 2021
- aquifer thermal energy storage (ATES) system installed 2010

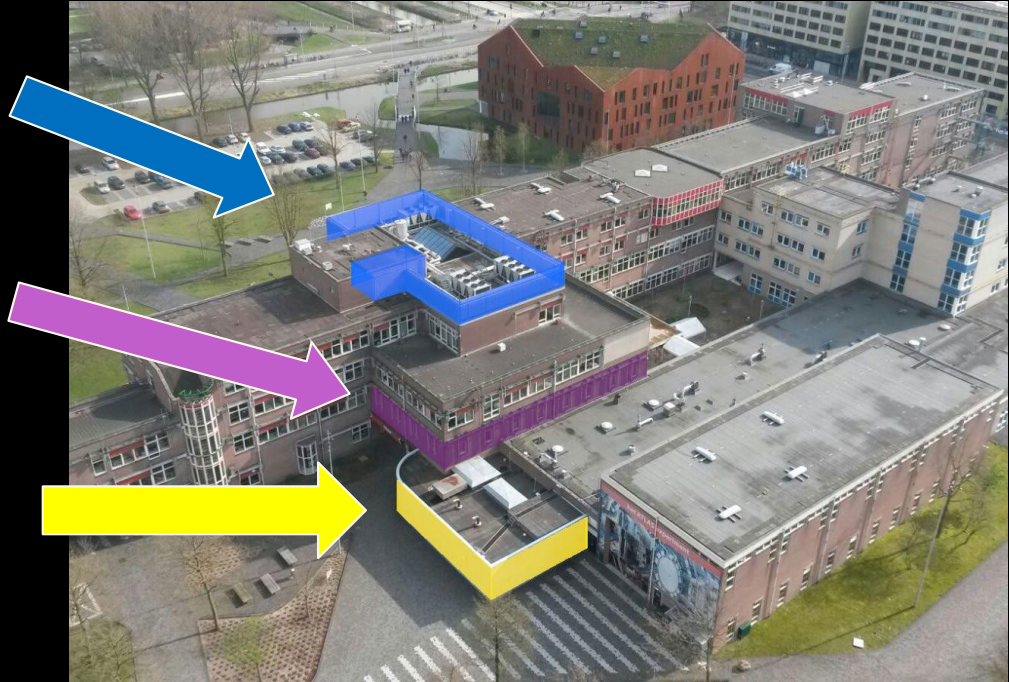
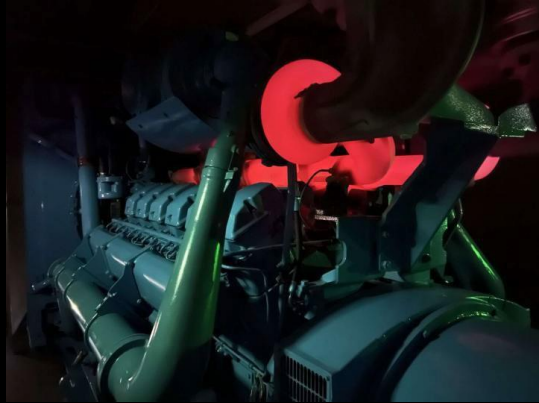


Image: Floris Bieshaar, Nikhef

# Power in ... and power out ...



## Three generators

- A-Feed 1250 kVA (pictured under load while testing)
- B-Feed 1700 kVA
- C-Feed 1250 KVA added with the current expansion

Separate redundant UPS for each



## Heat re-use: aquifer thermal energy storage

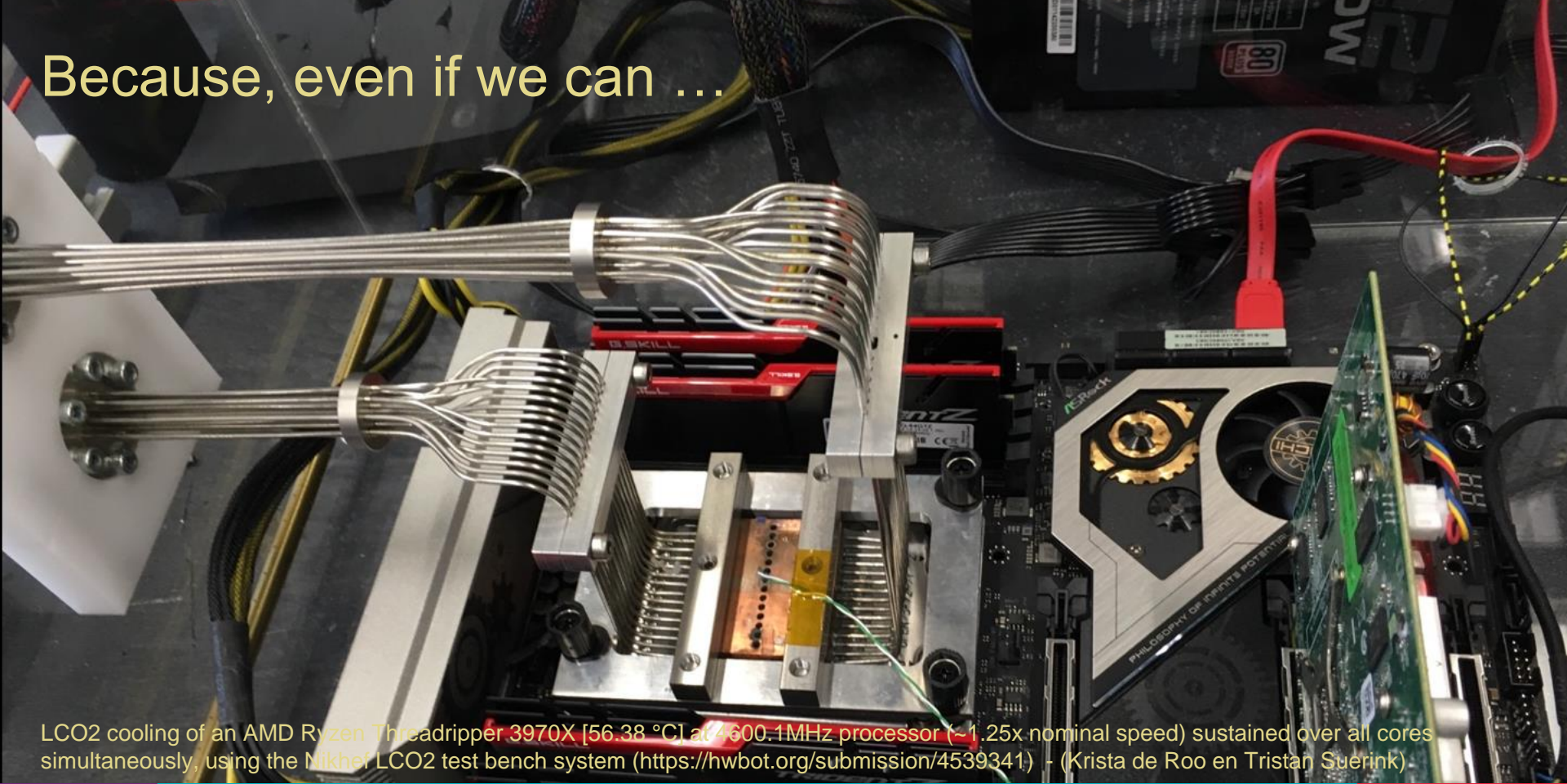
*re-use heat to warm our building (pretty warm)  
AND feed more heat to student housing opposite  
nominal 'PUE' ~ 1.21*



Generator image source: Floris Bieshaar. MacGilleevrylaan sketch: Science Park Amsterdam

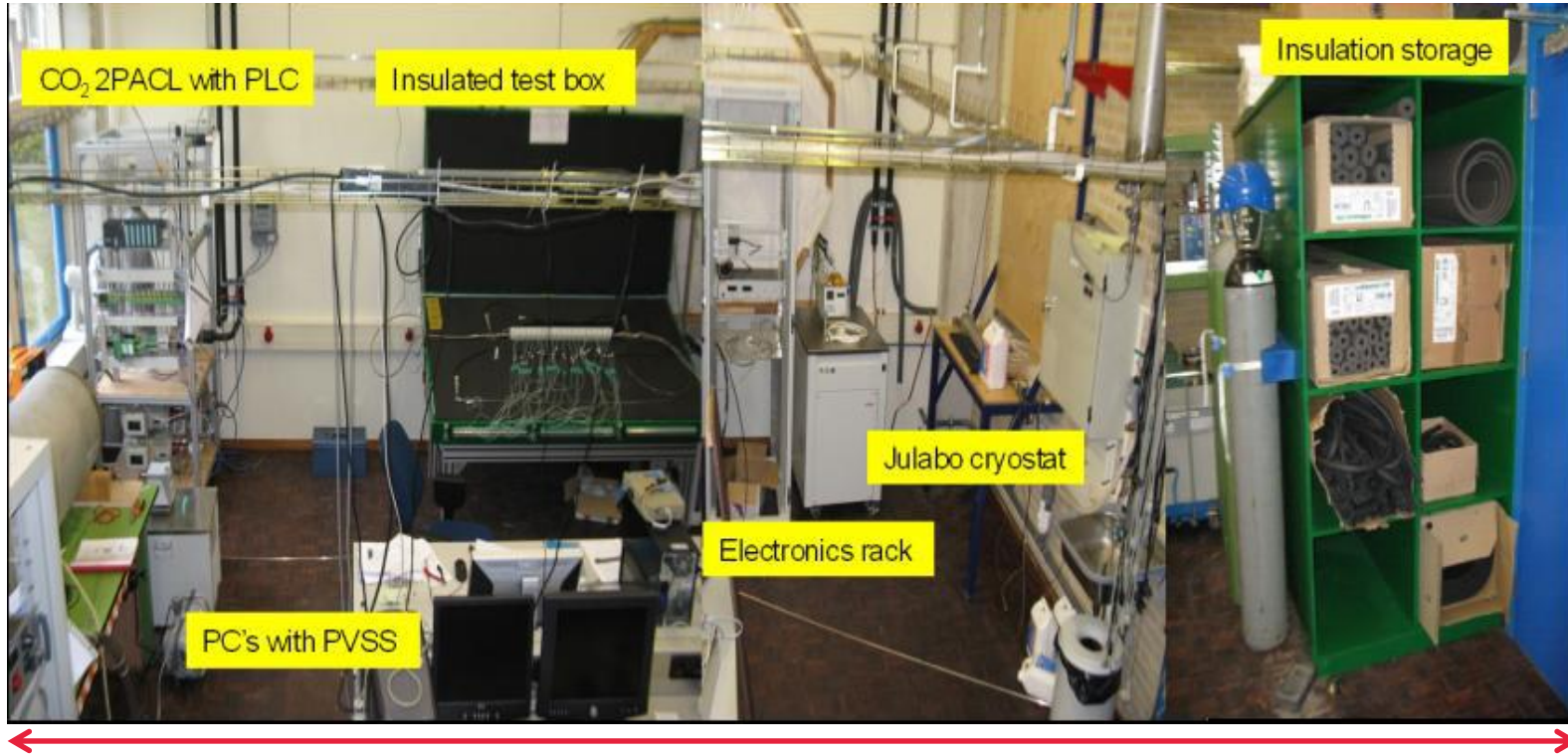


# Because, even if we can ...



LCO2 cooling of an AMD Ryzen Threadripper 3970X [56.38 °C] at 4600.1MHz processor (~1.25x nominal speed) sustained over all cores simultaneously, using the Nikhef LCO2 test bench system (<https://hwbot.org/submission/4539341>) - (Krista de Roo en Tristan Suerink)

... it is not always the most scalable solution!



Nikhef 2PA LCO2 cooling setup. Image from Bart Verlaat, Auke-Pieter Colijn *CO2 Cooling Developments for HEP Detectors* <https://doi.org/10.22323/1.095.0031>

# Thanks, and enjoy Nikhef and the Amsterdam Science Park



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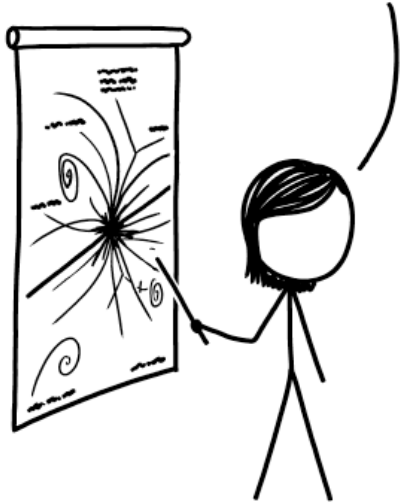
# Tours

1. Data Centre: assemble here on Nikhef ground-floor
2. KM3NeT BOL Assembly: Ronald Bruijn, from the NikhefHousing entrance

Return here for the

*Introduction to the local ecosystem of the Amsterdam Science Park*

OUR LAB WAS TRYING TO RECREATE THE CONDITIONS THAT OCCURRED SECONDS AFTER THE BIG BANG.



BUT IT TURNS OUT THEY WERE *EXTREMELY* HOT AND UNPLEASANT.



SO NOW WE'RE TRYING TO RECREATE THE CONDITIONS THAT OCCURRED ON THIS TROPICAL BEACH IN EARLY 2014.



HONESTLY DON'T KNOW WHY WE WERE DOING THAT OTHER THING.