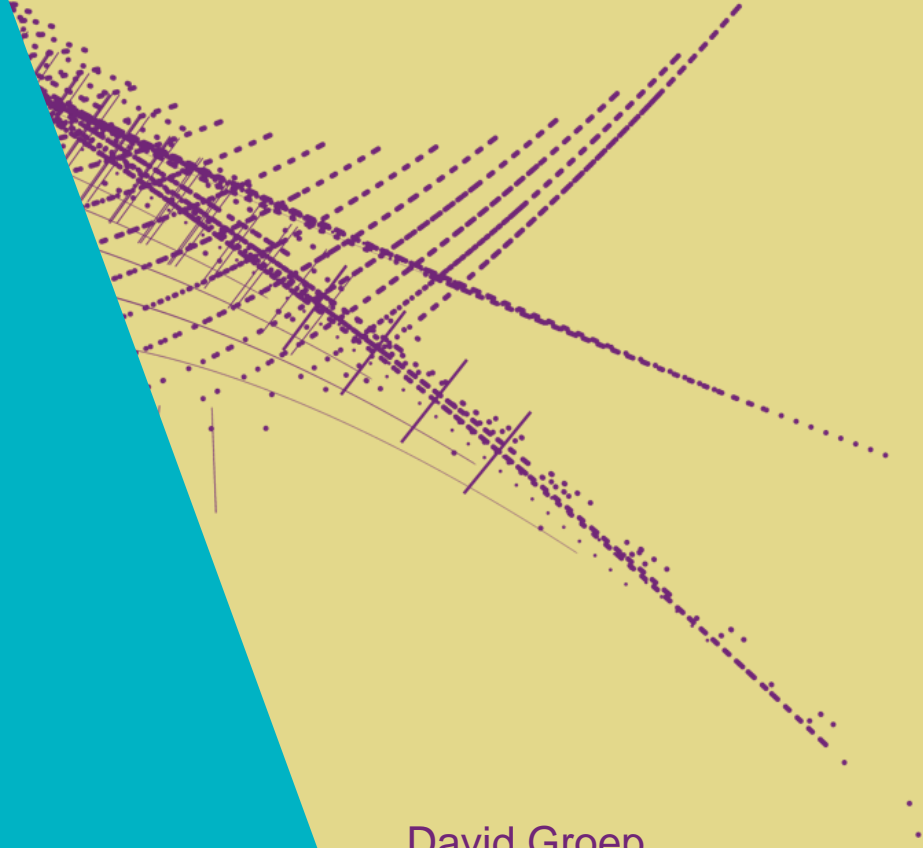




Introduction to Nikhef and  
the NikhefHousing Data Centre

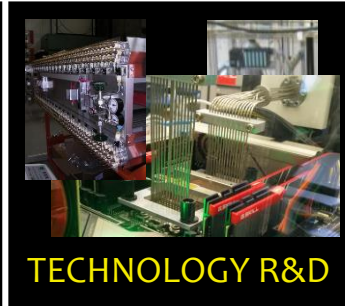
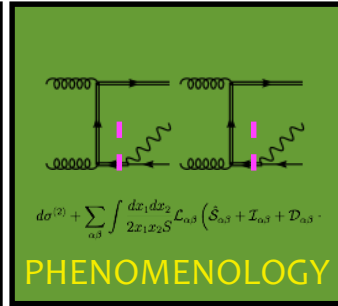
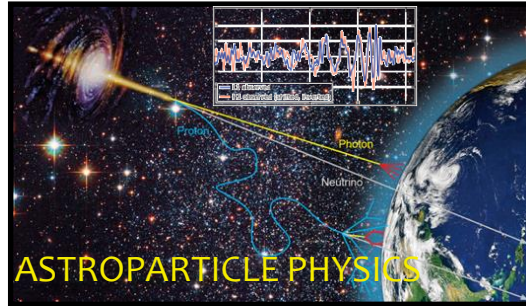
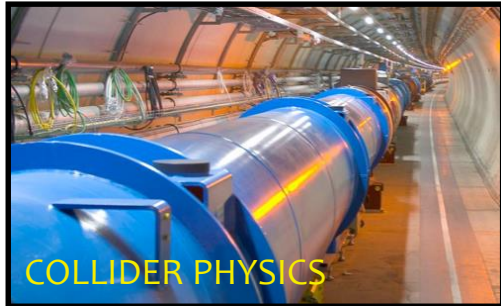
Welcome to Nikhef

David Groep  
May 2024



# Our world, made of particles and fields

- **Accelerator-based particle physics**  
*Experiments studying interactions in particle collision processes at particle accelerators, in particular at CERN;*
- **Astroparticle physics**  
*Experiments studying interactions of particles and radiation emanating from the Universe.*

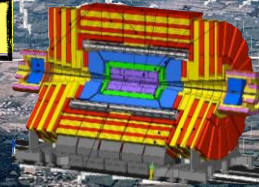




# CERN – Europe's laboratory for high-energy physics

Large Hadron Collider

CMS



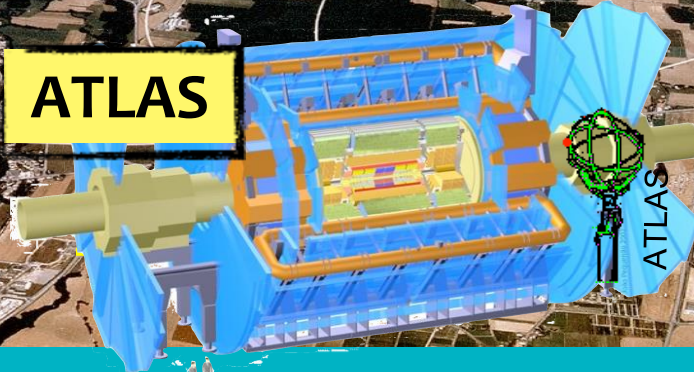
LHCb



ALICE



ATLAS

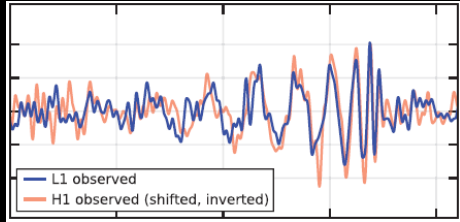
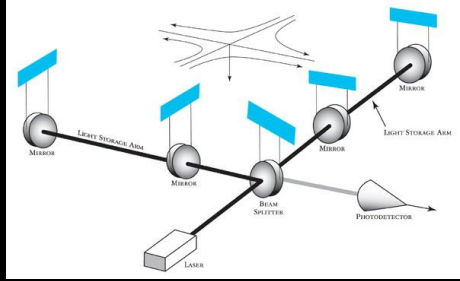


ATLAS

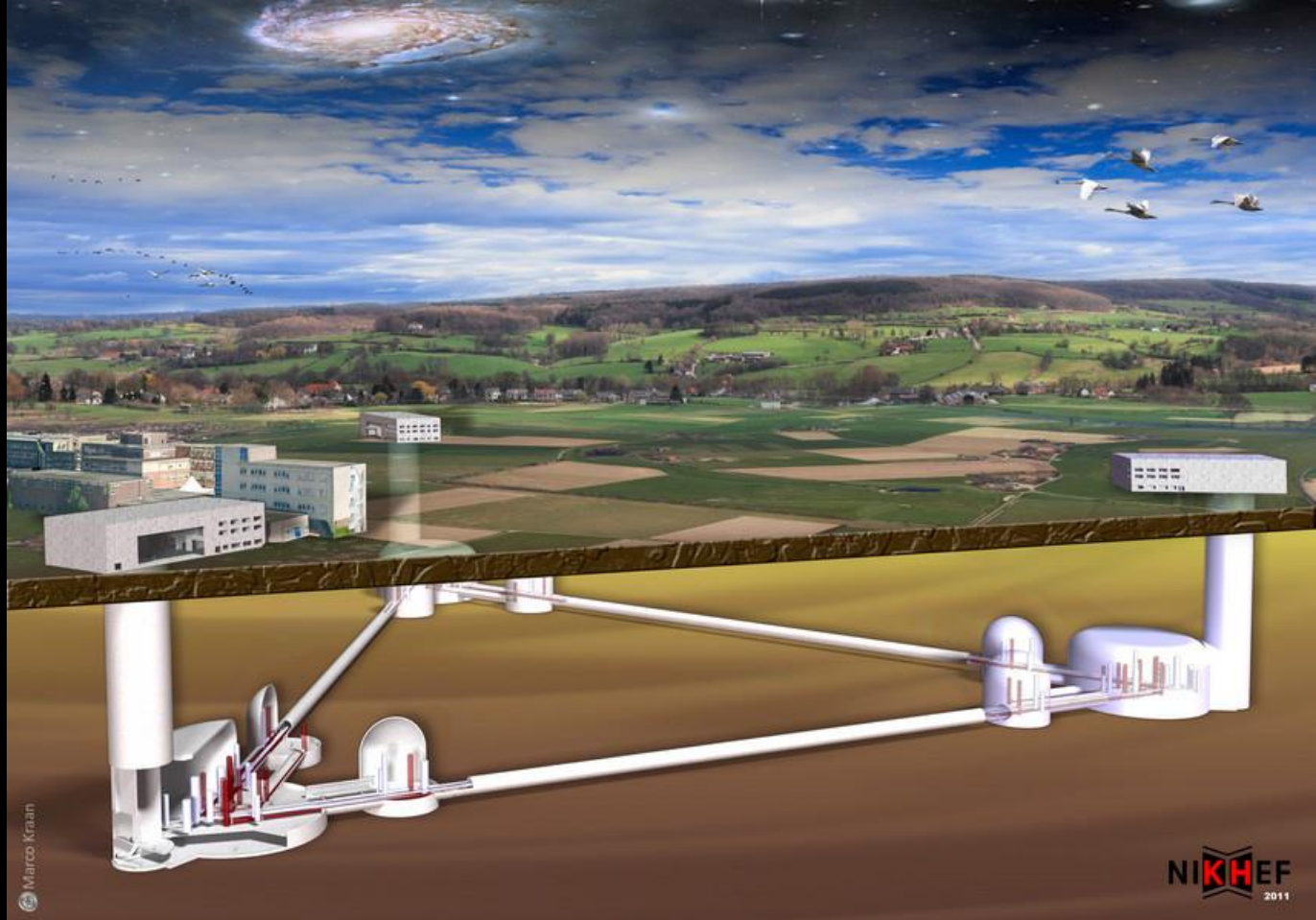
Imagery: CERN, European Organisation for Nuclear Research



[www.et-emr.eu!](http://www.et-emr.eu!)



Einstein Telescope projected in the EMR region, image: Marco Kraan  
GW150914 event:  
gw-astronomy collaborations, LIGO



Marco Kraan

**NIKHEF**  
2011



# Data at the Large Hadron Collider at CERN

## 1964

### BROKEN SYMMETRY AND THE MASSES OF GAUGE BOSONS

Peter W. Higgs

Tull Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland  
(Received 12 August 1964)

In a recent note<sup>1</sup> it was shown that the Goldstone theorem, that Lorentz-covariant fields describe in which spontaneous breakdown of symmetry under an internal Lie group occurs contains zero-mass particles, false if and only if the conserved currents associated with the internal group are coupled to gauge fields. The purpose of the present note is to report that, as a consequence of this coupling, the spin-zero quanta of some of the gauge fields acquire mass, the longitudinal degrees of freedom of these particles which would be absent if their mass were zero go over into the Goldstone bosons when the coupling tends to zero. This phenomenon is just the relativistic analog of the plasmon phenomenon in which Anderson<sup>2</sup> has drawn attention.

about the "vacuum" solution  $\phi_1(x) = \phi_0, \phi_2(x) = \phi_0$   

$$F^{\mu\nu}(\partial_\mu \phi_1 - \partial_\nu \phi_2) = 0, \quad (2a)$$

$$[\partial^\mu \phi_1 \partial_\mu \phi_2 - (\partial_\mu \phi_1)^2 - (\partial_\nu \phi_2)^2] = 0, \quad (2b)$$

$$m^2 \phi_1^2 + m^2 \phi_2^2 - (\partial_\mu \phi_1)^2 - (\partial_\nu \phi_2)^2 = 0, \quad (2c)$$

Equation (2a) describes waves whose quanta have invariant mass  $\hbar^{-1}(\partial_\mu \phi_1)^2 / (2\pi)^2$ . Eqs. (2b) and (2c) may be transformed, by the introduction of new variables

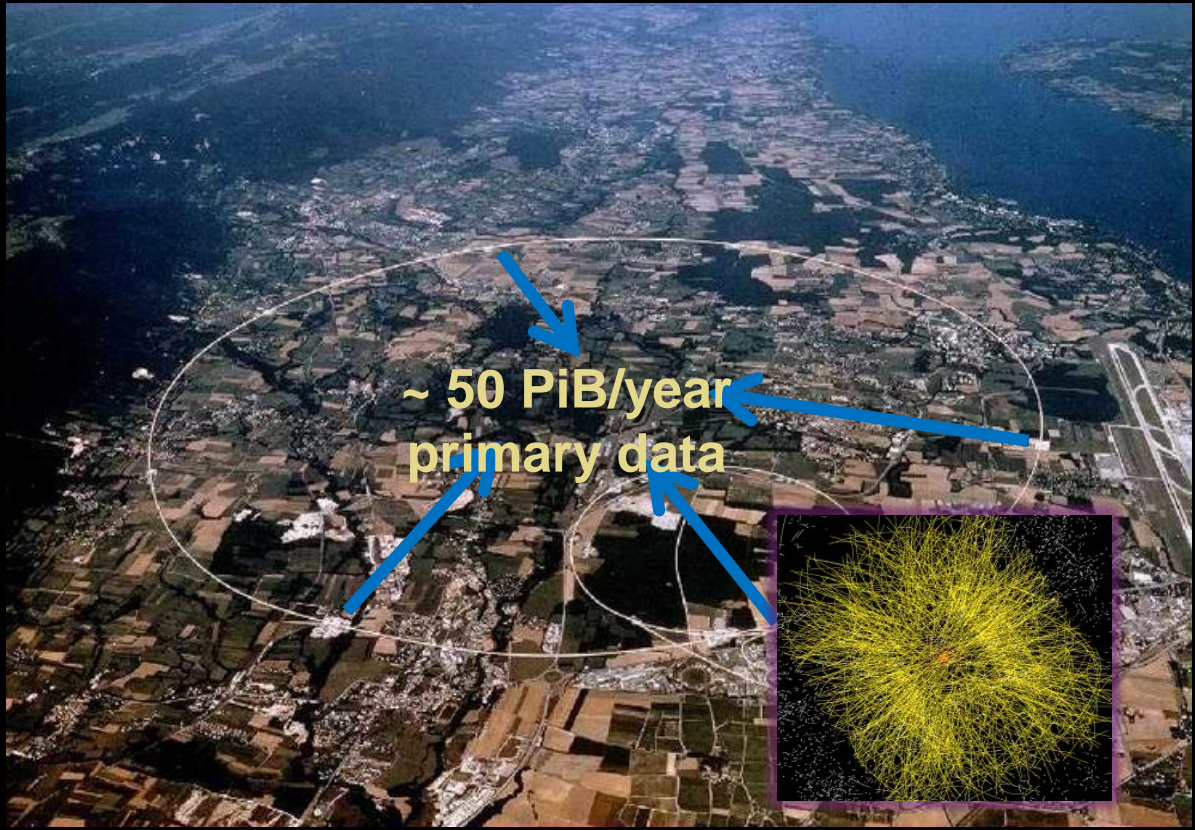
$$\phi_1 = \frac{1}{\sqrt{2}} (\phi_1' + \phi_2'), \quad \phi_2 = \frac{1}{\sqrt{2}} (\phi_1' - \phi_2'),$$

$$\phi_1 = \frac{1}{\sqrt{2}} (\phi_1' + \phi_2'), \quad \phi_2 = \frac{1}{\sqrt{2}} (\phi_1' - \phi_2'), \quad (2)$$

(2)

are quanta of the gauge bosons of zero mass. The zero-mass bosons are seen to be present in the vacuum state. The zero-mass bosons are seen to be present in the vacuum state. The zero-mass bosons are seen to be present in the vacuum state.

Let us suppose that  $\phi_1^2 = \phi_2^2 = \phi_0^2$ , then spontaneous breakdown of U(1) symmetry occurs. Consider the equations derived from (1) by breaking  $\phi_1, \phi_2$  and  $\phi_0$  as small quantities governing the propagation of small oscillations



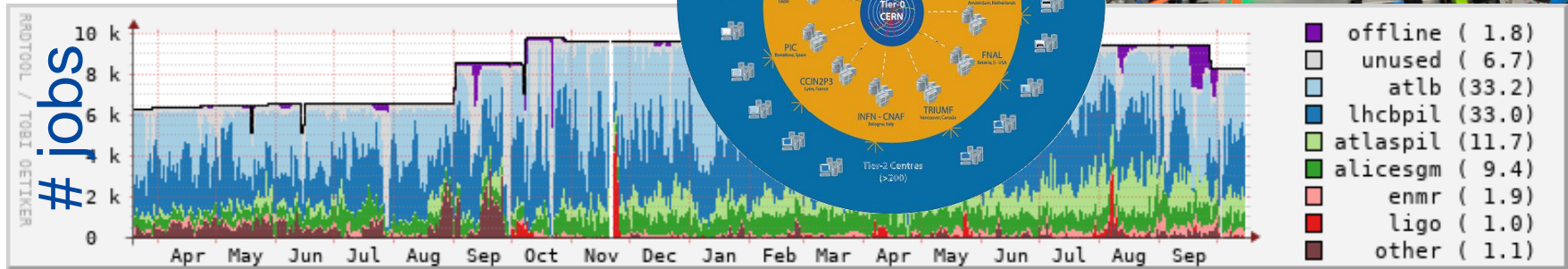
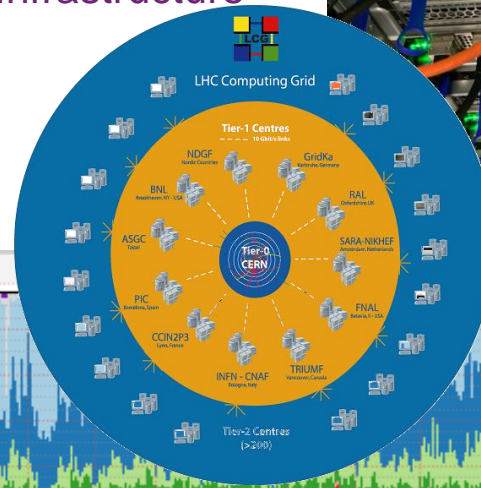
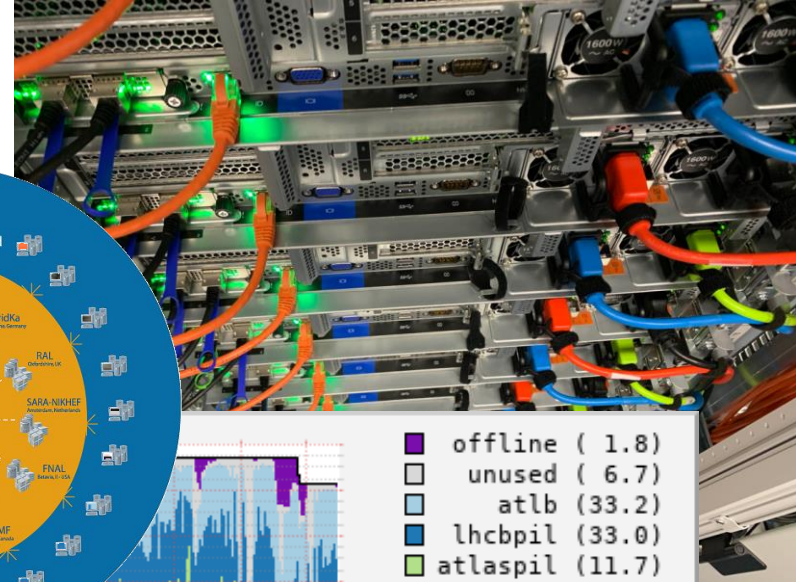
P. Higgs, Phys. Rev. Lett. 13, 508  
16823 characters, 165kByte PDF



# WLCG and Dutch National Infrastructure

## 11 global Tier-1 centres for CERN's LHC

- 'NL-T1' part of the Dutch National Infrastructure coordinated by SURF
- located at SURF and Nikhef
- **shared** across research domains: GWIs, WIs, and other instruments



Source: NDPF Statistics overview, <https://www.nikhef.nl/pdp/doc/stats/> GRISview images: Jeff Templon period: March 2021 .. October 2022; cluster nodes: 'Lotenfeest'

# Globally distributed computing: federated services

> 170 institutes in  
> 42 countries & economies  
no single administrative control



WLCG  
Worldwide LHC Computing Grid

XSEDE

Extreme Science and Engineering  
Discovery Environment

COMPUTING

~ 2,000,000 CORES

ON-LINE DISKS

> 400 PB

ARCHIVAL

> 600 PB



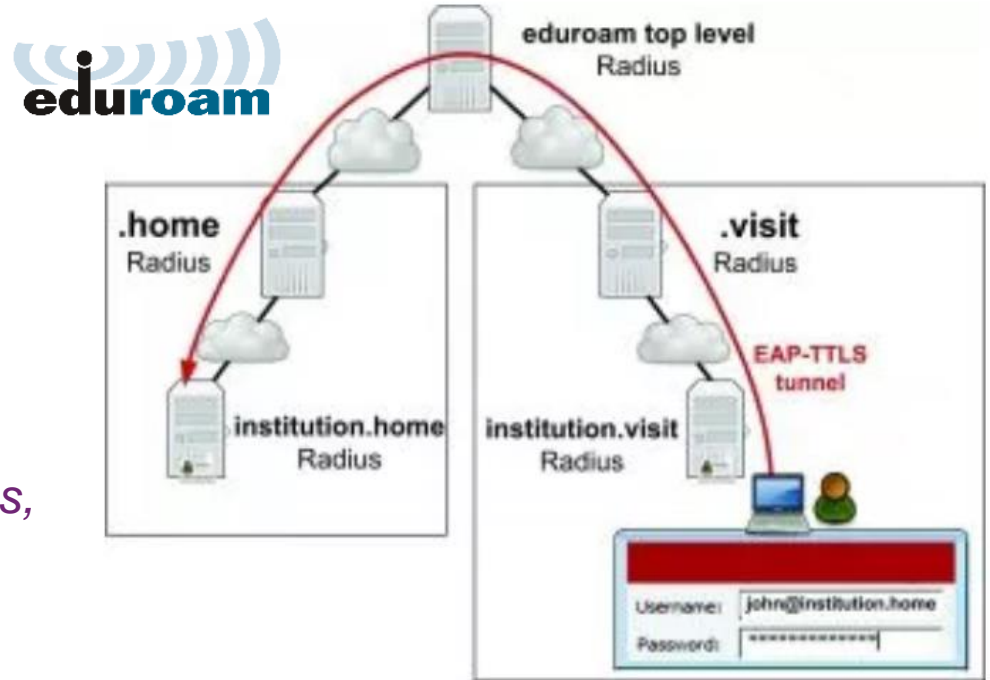
Nikhef

# From a simple federation: eduroam global WiFi ...

Service-specific “WiFi” federation  
trust between organisations, globally

local organization grants access  
based on your home credentials

*There are now multiple such federations,  
such as govroam*



eduroam: Klaas Wieringa et al., image from <https://eduroam.org/how/>, GEANT ; RADIUS: RC2865 <https://www.rfc-editor.org/rfc/rfc2865>; see also [freeradius.org](http://freeradius.org)



# ... to a global service federation for research and education

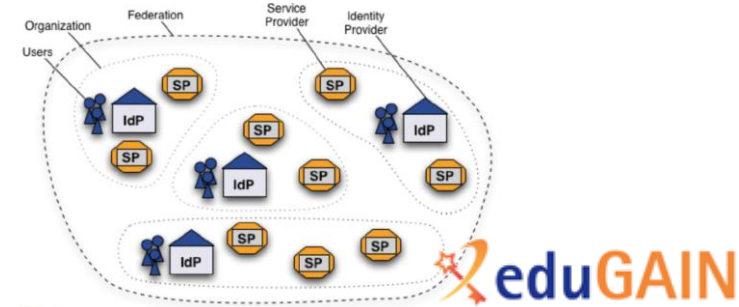
The screenshot shows the SURF CONEXT IdP Dashboard. The top navigation bar includes 'SURF CONEXT IdP Dashboard', 'Services', 'My institution', 'Statistics', 'Tickets', and a 'DG' dropdown. Below the navigation, there are tabs for 'Connected services' and 'All services'. A search bar and 'Export overview as csv' button are present. The main content area displays a table of services with filters on the left.

**Filters:** (Clear all)

**All services:** Search services... [Search] [Export overview as csv]

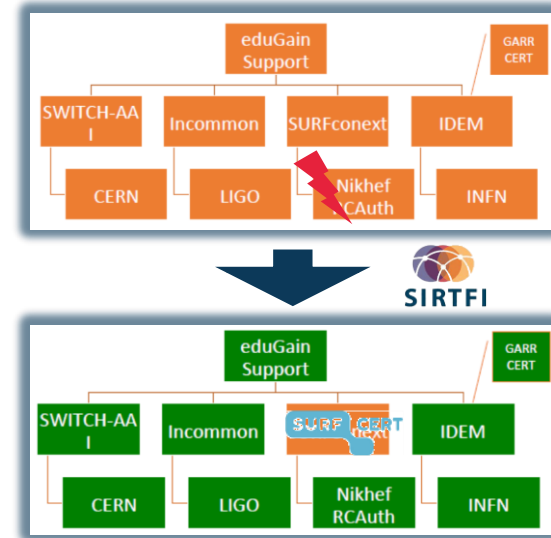
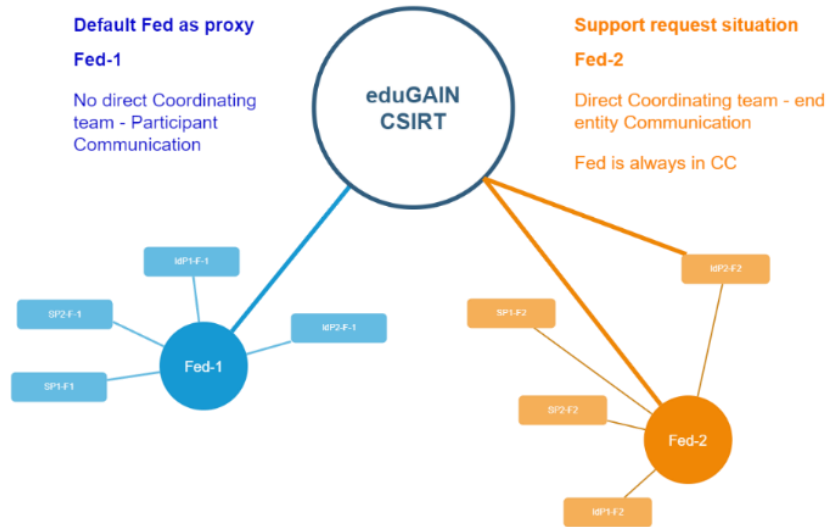
Showing 178 of 1218 services

	Name	Vendor
<b>Service connected</b>		
<input type="checkbox"/> Yes (158)		
<input type="checkbox"/> No (20)		
<b>Offered by my institution</b>		
<input type="checkbox"/> Yes (2)		
<input type="checkbox"/> No (176)		
<b>Federation source</b>		
<input type="checkbox"/> SURFconext (44)		
<input type="checkbox"/> eduGAIN (134)		
<input type="checkbox"/> Entree (0)		
<b>eduGAIN Entity Category</b>		



Images: SURFconext IdP dashboard by SURF, showing some services tagged with REFEDS R&S; eduGAIN map: GEANT, <https://technical.edugain.org/status>

# When something happens to it: federated incident response



- *Joint **operational trust baseline** for the global R&E federations*
- *Supplemented by **sectoral policy guidance***
- *focus on **infrastructure and data integrity, confidentiality, availability***

images: AARC Sirtfi v1 exercise (Hannah Short), eduGAIN security TTX (Sven Gabriel, eduGAIN CSIRT); joint with GN5-1 EnCo





# Security Service Challenges: exercise finding & removing malware and spyware in global collaboration

The image displays three screenshots from the SSC5 monitoring interface. The leftmost screenshot shows a list of site statuses: Site 20 (+1 bot), Site 21 (+1 bot), Site 22 (+1 bot), Site 33 (+1 bot), Site 1 (-2 bots), Site 3 (-2 bots), Site 4 (-2 bots), Site 5 (-1 bot), and Site 7 (-1 bot). A world map shows bot locations with yellow and red markers. The middle screenshot is a browser window titled 'SSCS CCC - REPLAY...' showing a similar map and statistics for 'SSCS CCC - REPLAY'. The rightmost screenshot is a chat window with a 'Command' prompt area. The chat log contains the following text:

```
2011-05-25 10:43:21 ewang: comment does not go to the customers (sites) reply will also go the other way  
2011-05-25 10:43:21 christos: I'm trying to follow the incident on RTIR, I don't like very much the small  
2011-05-25 10:43:21 christos: Triantafyllidis: in RT (I guess the same applies for RTIR) Comment goes to us  
2011-05-25 10:43:21 ewang: thanks christos  
2011-05-25 10:43:21 ewang: ssc5 pakiti: thanks a lot to Michal and Daniel  
2011-05-25 10:43:21 christos: li: Requeston = Correspondents ??  
2011-05-25 10:43:21 christos: Triantafyllidis: hm.. yes  
2011-05-25 10:43:21 christos: ti: ok, thanks
```

The command prompt area shows the following text:

```
no idea why the tickets were created by your account.  
(2011-05-25 17:19:43) mhochad: no problem!  
(2011-05-25 17:20:39) epting: think ours are already merged,  
can't find #332.. leif has probably done it...  
(2011-05-25 17:20:52) lrixon: Ok, I need to go home now.
```

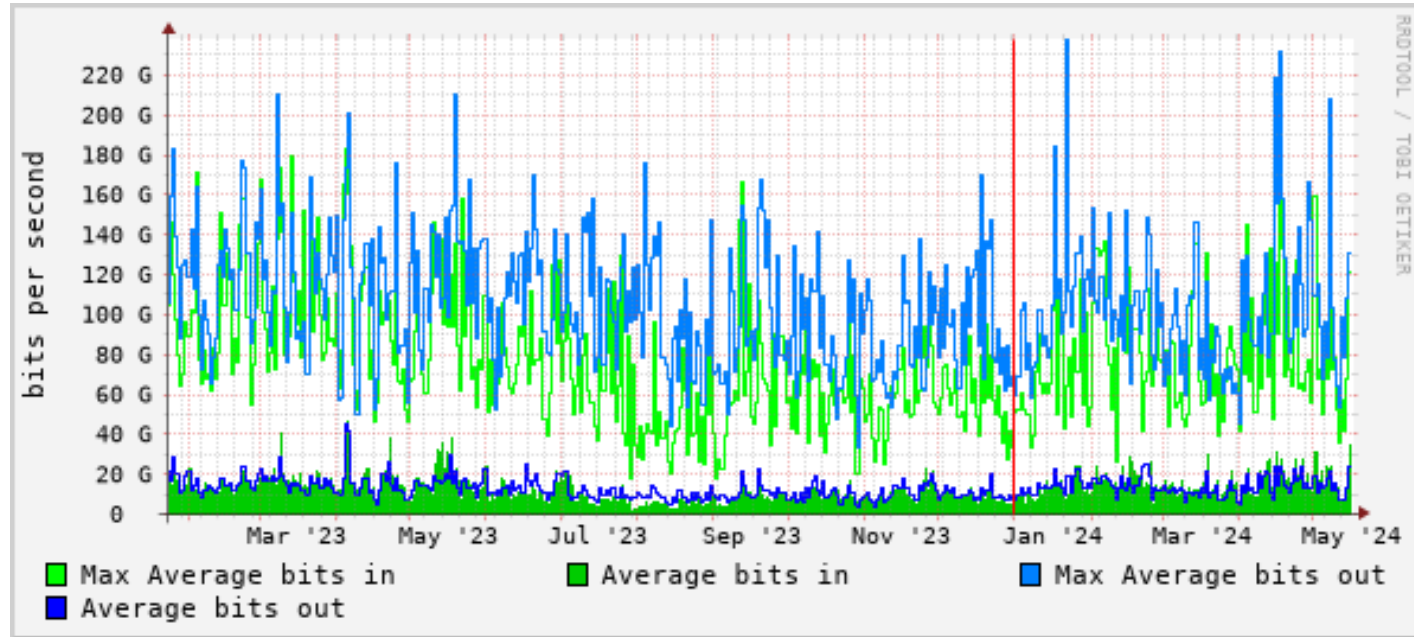
Screenshots: Oscar Koeroo *et al.*, Nikhef, for EGI SSC5

# Data Centres – housing and connectivity





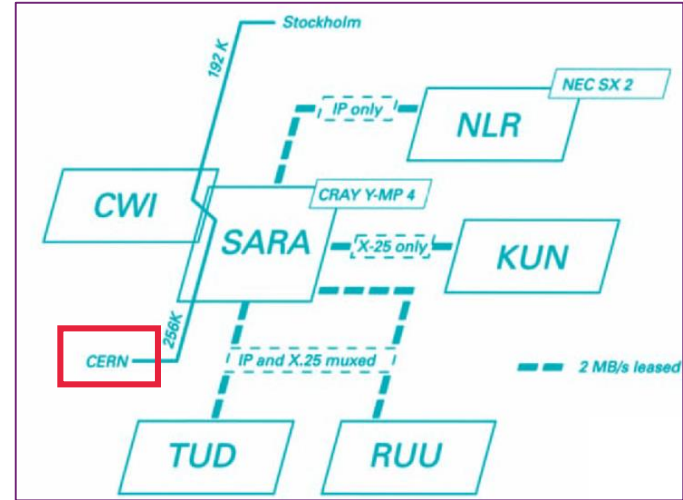
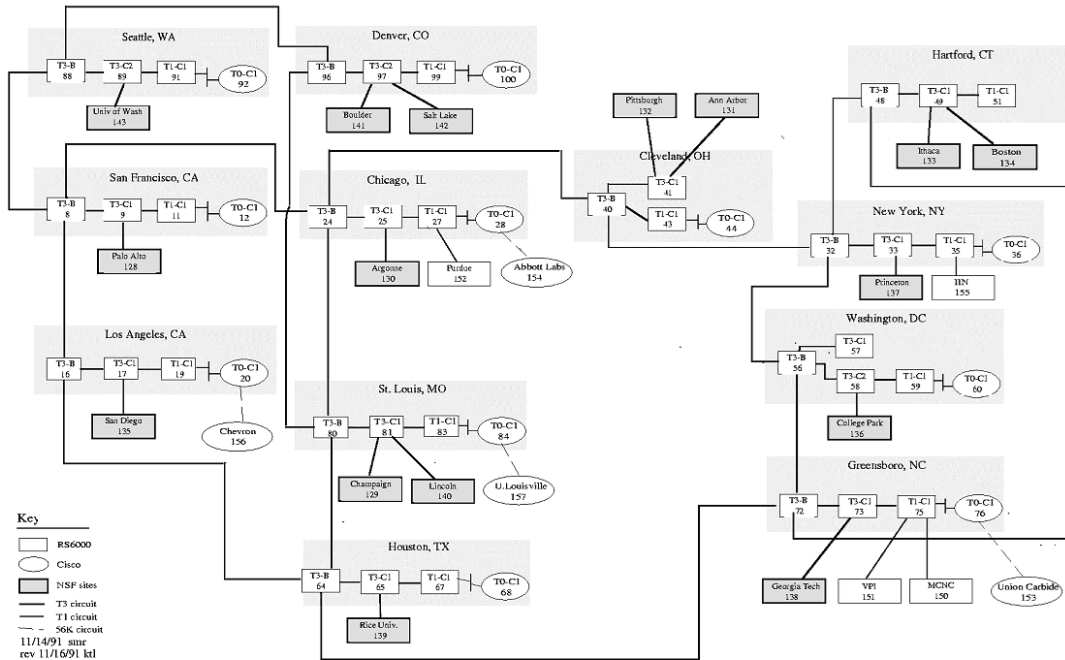
# Typical data traffic to and from our processing cluster



Source: Nikhef cricket graphs period January 2023 – May 2024 – aggregated (research) traffic to external peers from deelfx – <https://cricket.nikhef.nl/>

# Getting to CERN from the Netherlands

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



See <https://personalpages.manchester.ac.uk/staff/m.dodge/cybergeography/atlas/historical.html> for more historic maps ; right-hand image: SURFnet2, 1990



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



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

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

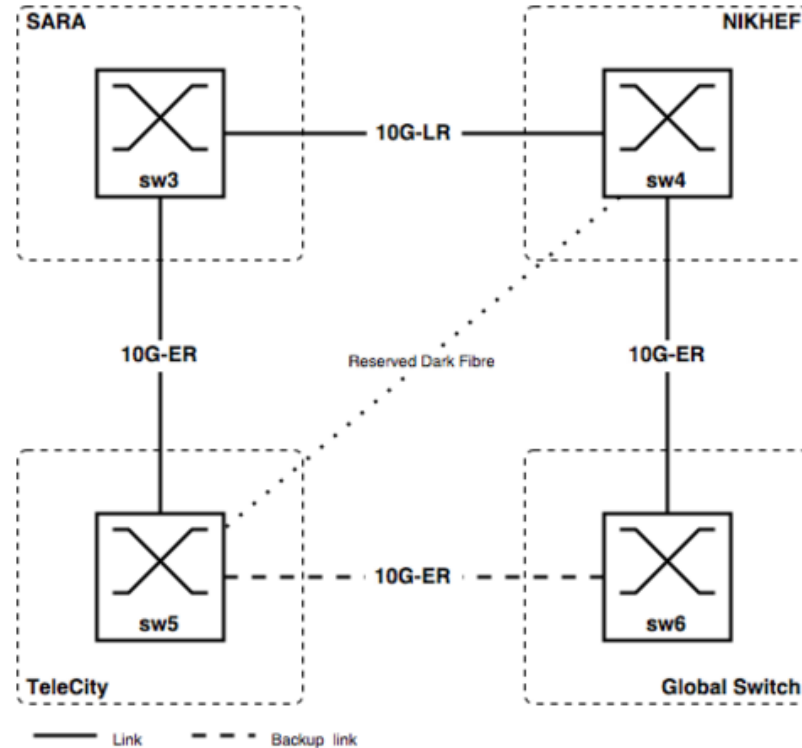
- 500 m<sup>2</sup> floor area
- Raised floor: +60cm
- walls are 'movable'  
to accommodate expansion

# IBR-LAN at Nikhef



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

# A growing internet!

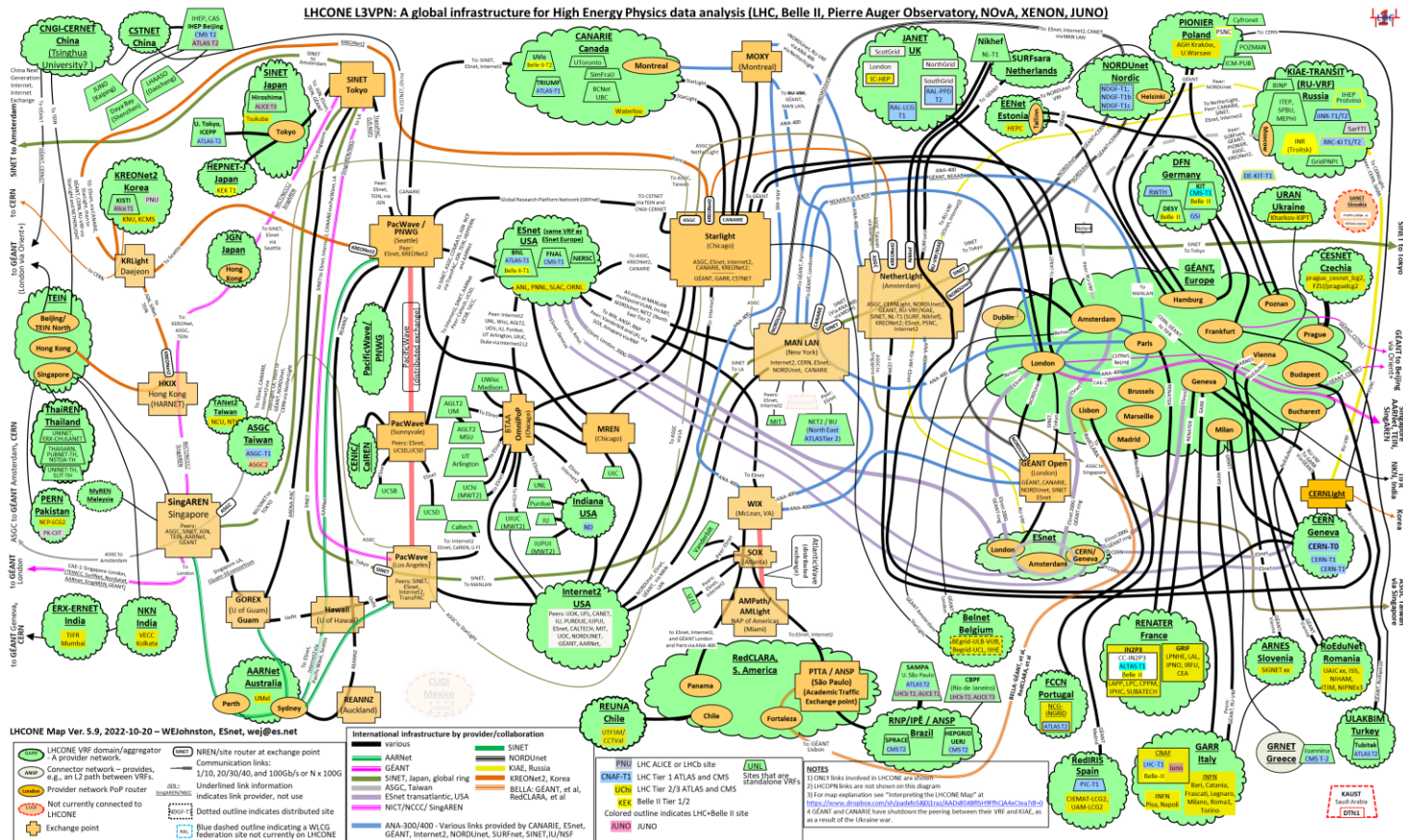


AMS-IX topology, 2002



# LHCone

LHCONE L3VPN: A global infrastructure for High Energy Physics data analysis (LHC, Belle II, Pierre Auger Observatory, NOvA, XENON, JUNO)



LHCone (“LHC Open Network Environment”) – visualization by Bill Johnston, ESNet version: October 2022 – updated with new AS1104 links

# Today's data centre at Nikhef

Nikhef 'science' data centre H234b

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



'NikhefHousing' data centre

- from once just 2 racks in a spare space
- to now > ~400 racks
- many different connectivity parties
- connectivity only, but not hosting

# Data centre installation management

- three 400kW active/free cooling chillers installed in 2009
- data floor: grown to ~400 racks
- additional electricity generator set added in 2009
- Aquifer Thermal Energy Storage (ATES) system in 2010

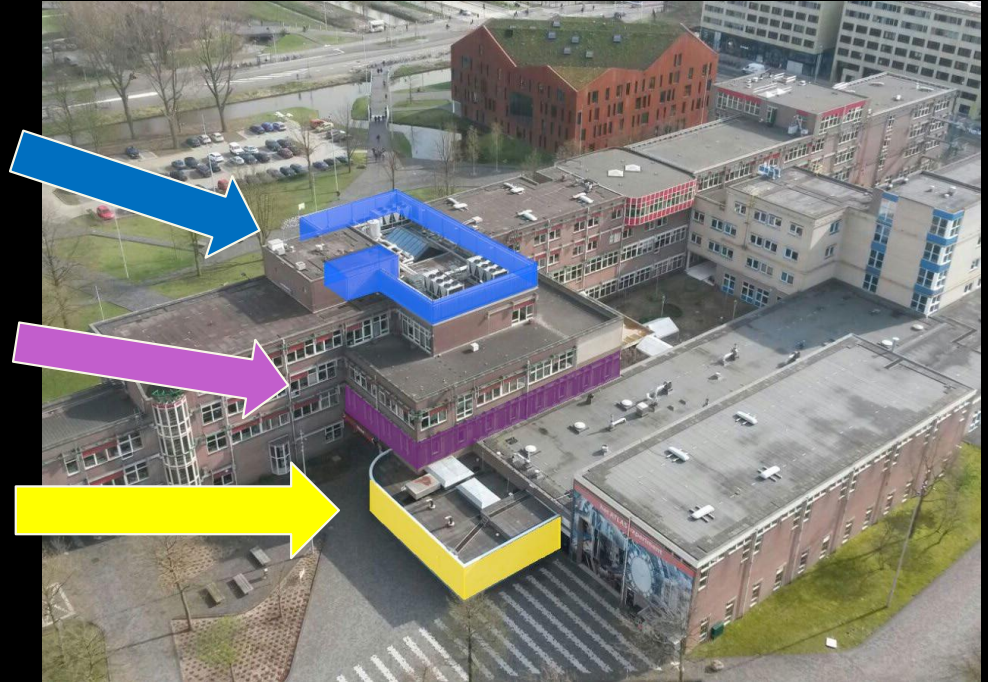


Image: Floris Bieshaar, Nikhef



# Power in ... and energy 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. MacGillevrylaan sketch: Science Park Amsterdam

# What happens inside a data centre ...



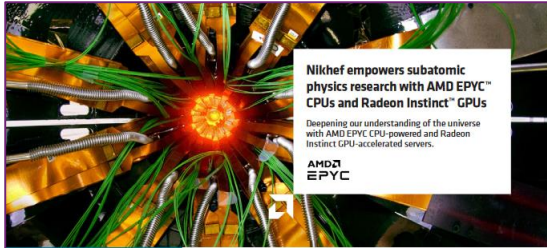
Yet ‘connectivity’ housing and ‘hosting’ are also quite different

- NikhefHousing (H140) has connectivity parties only, and does not host any content
- what you will be seeing on tour is *network* equipment, shipping data, but not keeping anything

(H234b has our science data, only)

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

# But some are faster than ...



**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.



**CUSTOMER**  
Nikhef

**MICROSECTOR**  
Subatomic Physics

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

**SOLUTION**  
Diverse AMD EPYC™ processors and T7000 CPUs, and AMD Radeon Instinct™ M50 GPUs

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

**AMD TECHNOLOGY AT A GLANCE**  
AMD EPYC™ 7002 processors with 32 cores  
AMD EPYC™ 7002P 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 concentrating on this area. Nikhef has provided computing that has helped with the discovery of gravitational waves in 2016, 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 many-sky research to learn more about the nature of the universe and the building blocks of matter," explains Toed 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 Saelens, 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, LHC, 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 OPERA, 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."

"We were able to be the worldwide number one in the public projects like Rosetta@home and Worldwide Computers Grid with the AMD EPYC™ design,"

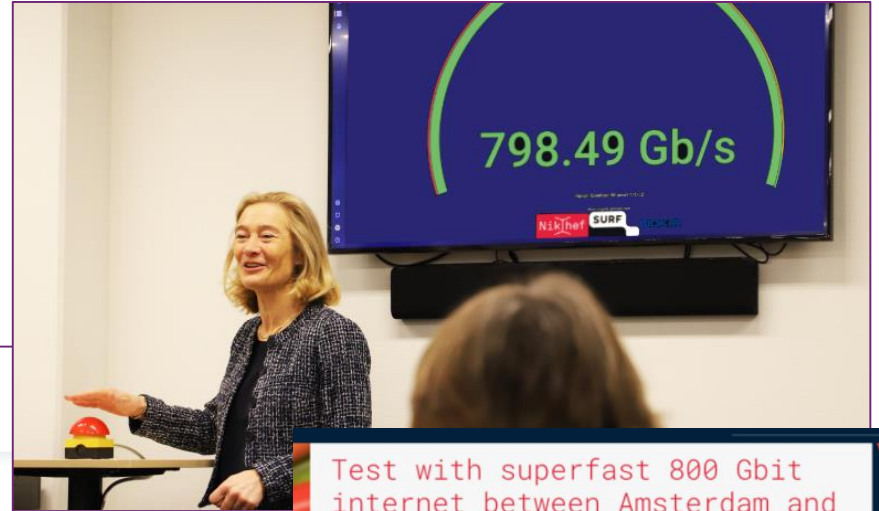
Toed Aaij, Scientific Staff Member at Nikhef

"In about four 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 open get close to a factor 10 in increase of performance for a flat budget. 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.

## FUNGIBLE

### 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>

Introduction to Nikhef and the NikhefHousing Data Centre





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



Het begon in 2018. Een bijzondere samenwerking tussen overheden. Het '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

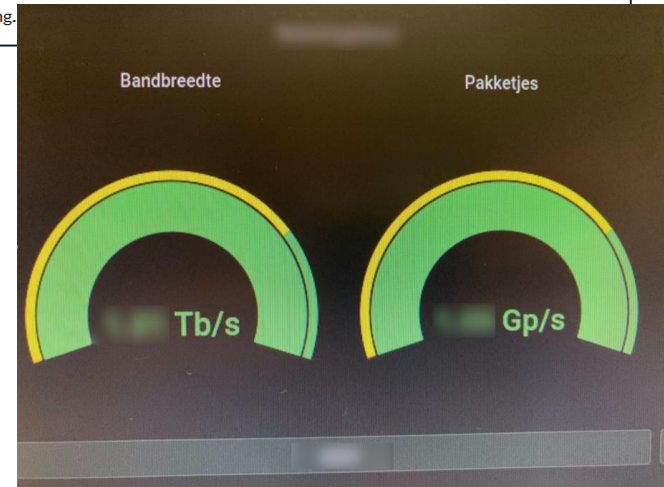



Image sources: belastingdienst.nl, rws.nl, nu.nl, werkentegennederland.nl

Thanks, and enjoy Nikhef



David Groep  
davidg@nikhef.nl

<https://www.nikhef.nl/~davidg/presentations/>  
 <https://orcid.org/0000-0003-1026-6606>



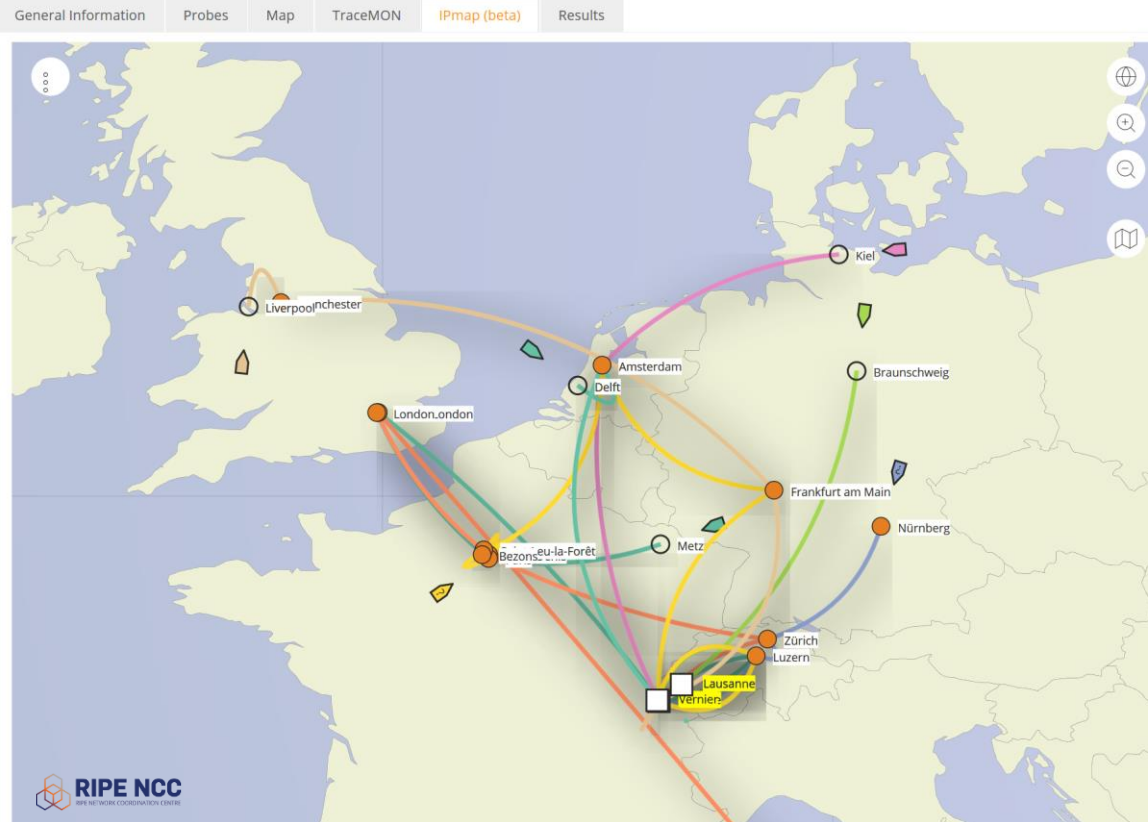
Maastricht University

Nikhef



# Getting to CERN

## ⚡ Traceroute measurement to linuxsoft.cern.ch (multihomed)



Data: TraceMON IPmap from RIPE NCC Atlas atlas.ripe.net measurement 9249079