

LHC Networking, Run 4, and the High Luminosity LHC

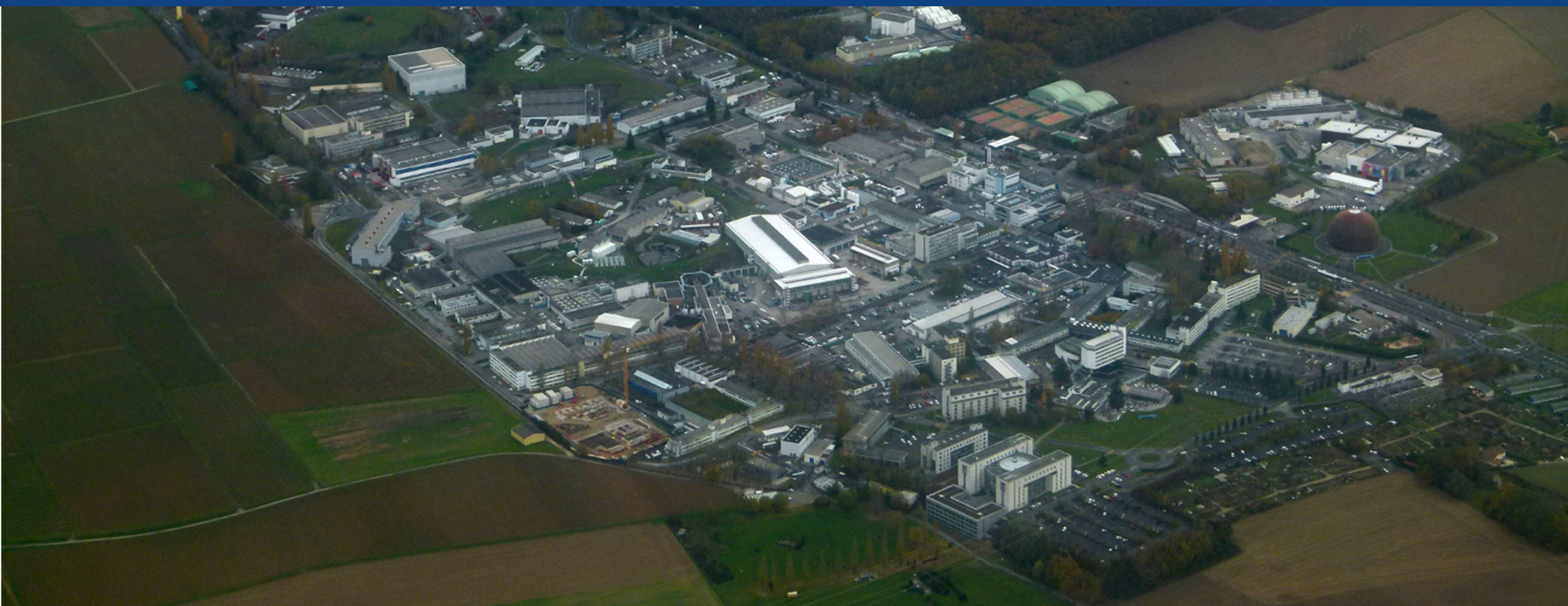
Bruno Hoefft



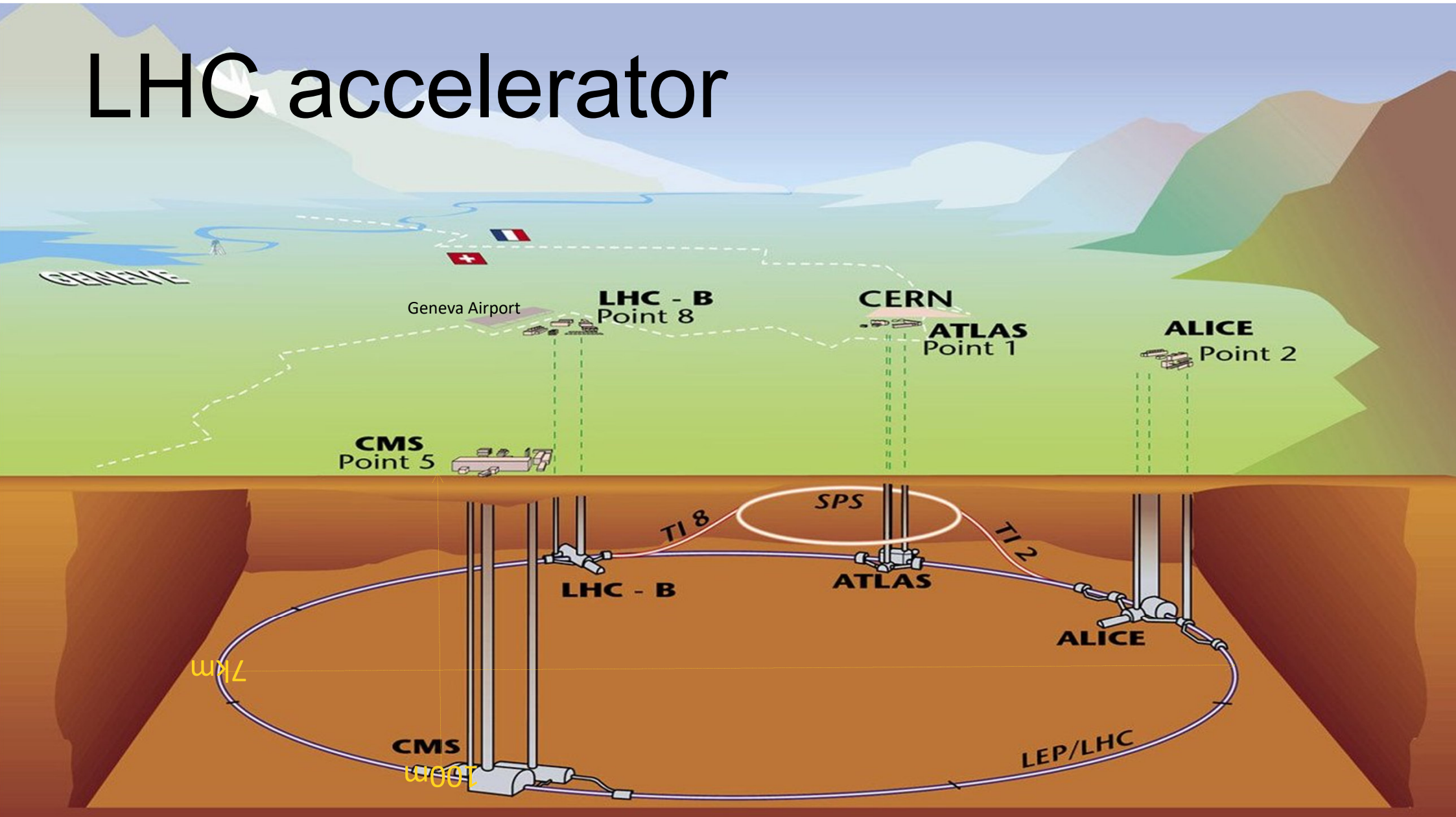
Agenda

- CERN and LHC
- WLCG and Networks
- NREN Community support
- Conclusion

CERN and LHC



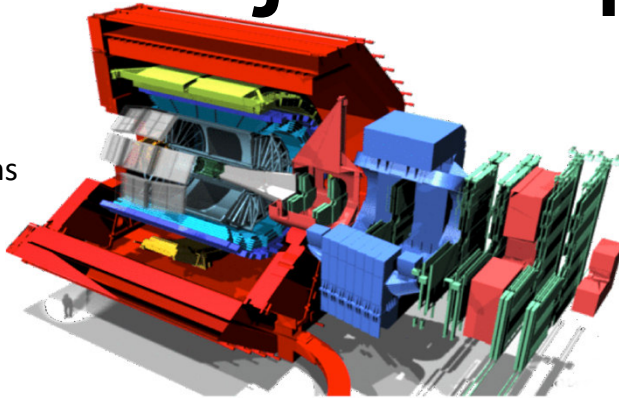
LHC accelerator



LHC major experiments

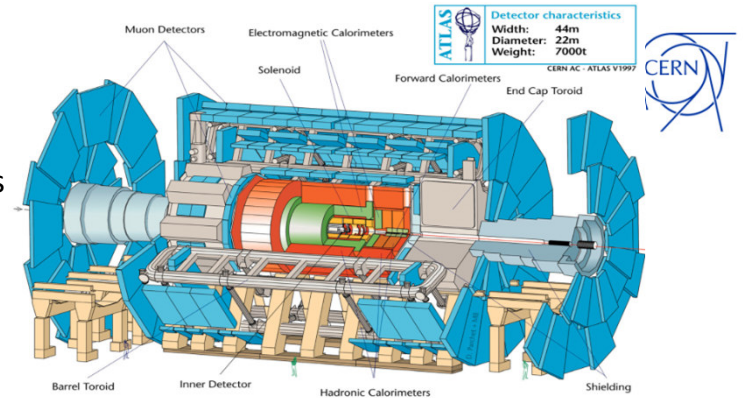
ALICE

Weight: 10,000 tons
Length: 26 m
Diameter 16 m



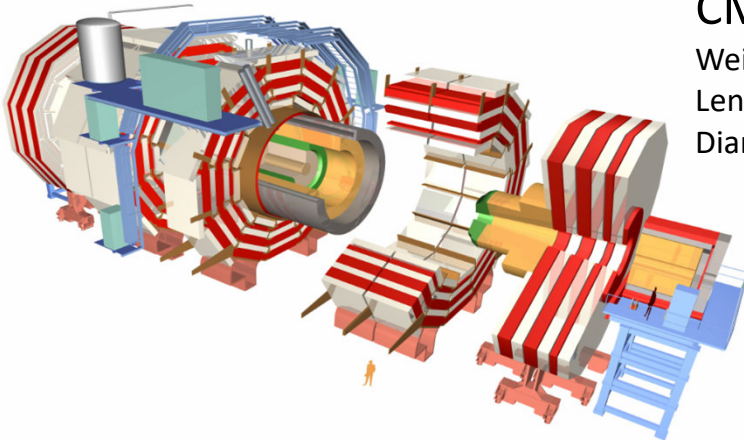
ATLAS

Weight: 7,000 tons
Length: 44 m
Diameter 22 m



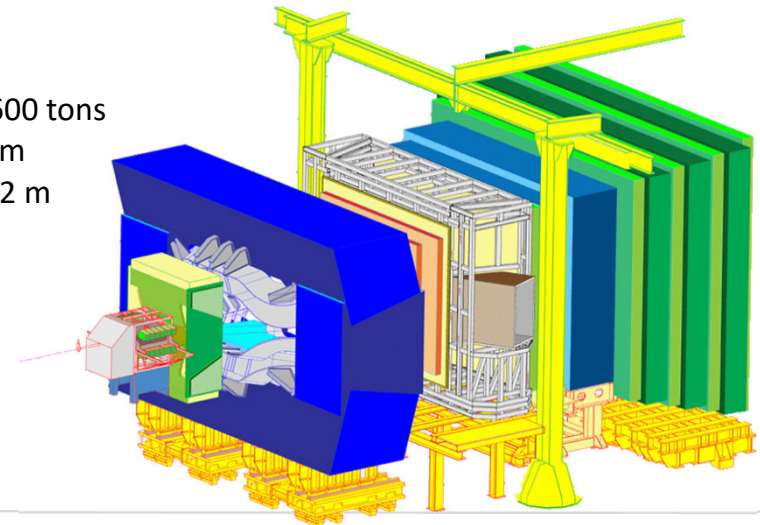
CMS

Weight: 14,000 tons
Length: 28 m
Diameter 15 m



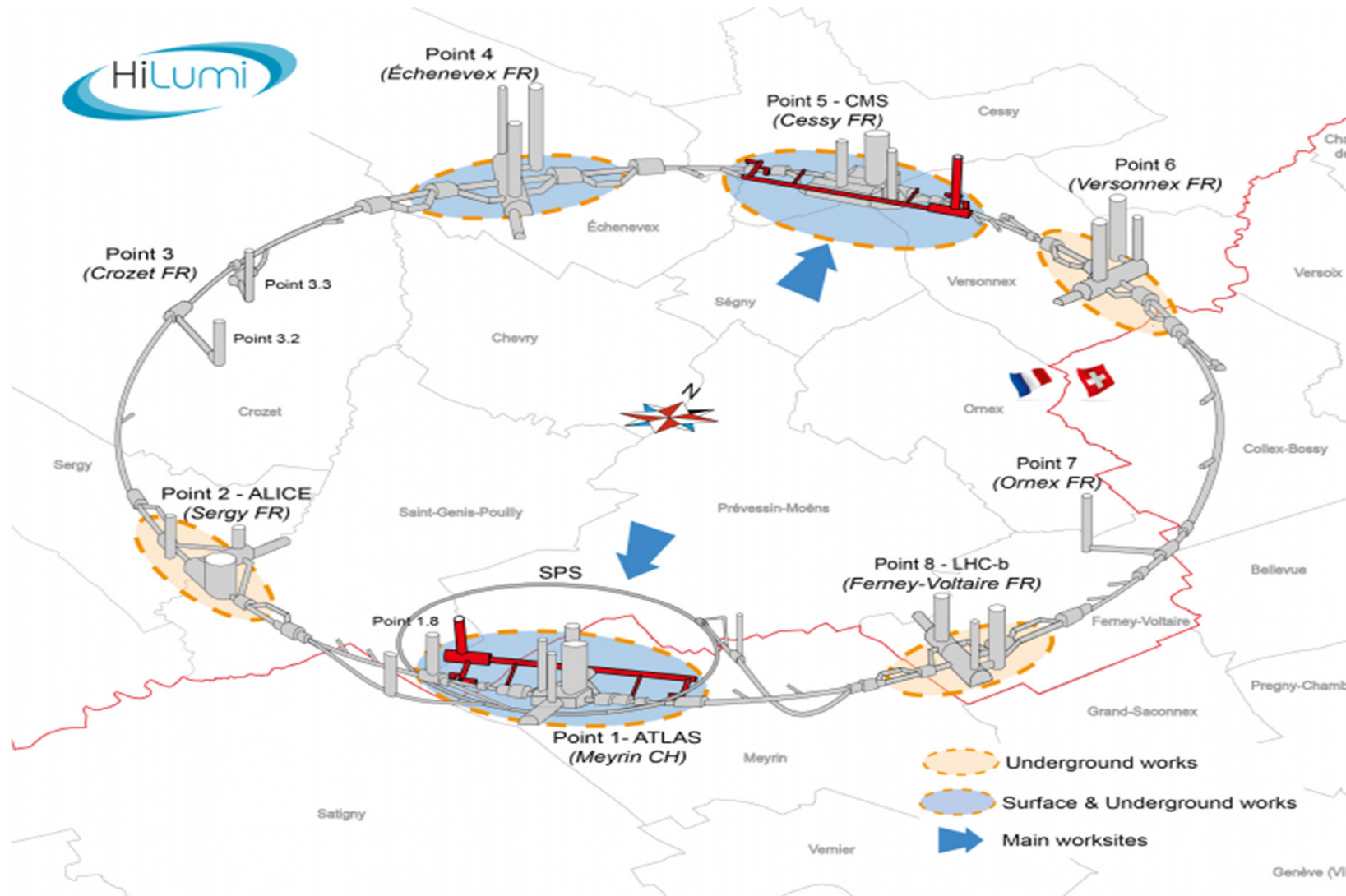
LHCb

Weight: 5,600 tons
Length: 21 m
Diameter 12 m





Next: the HL-LHC project

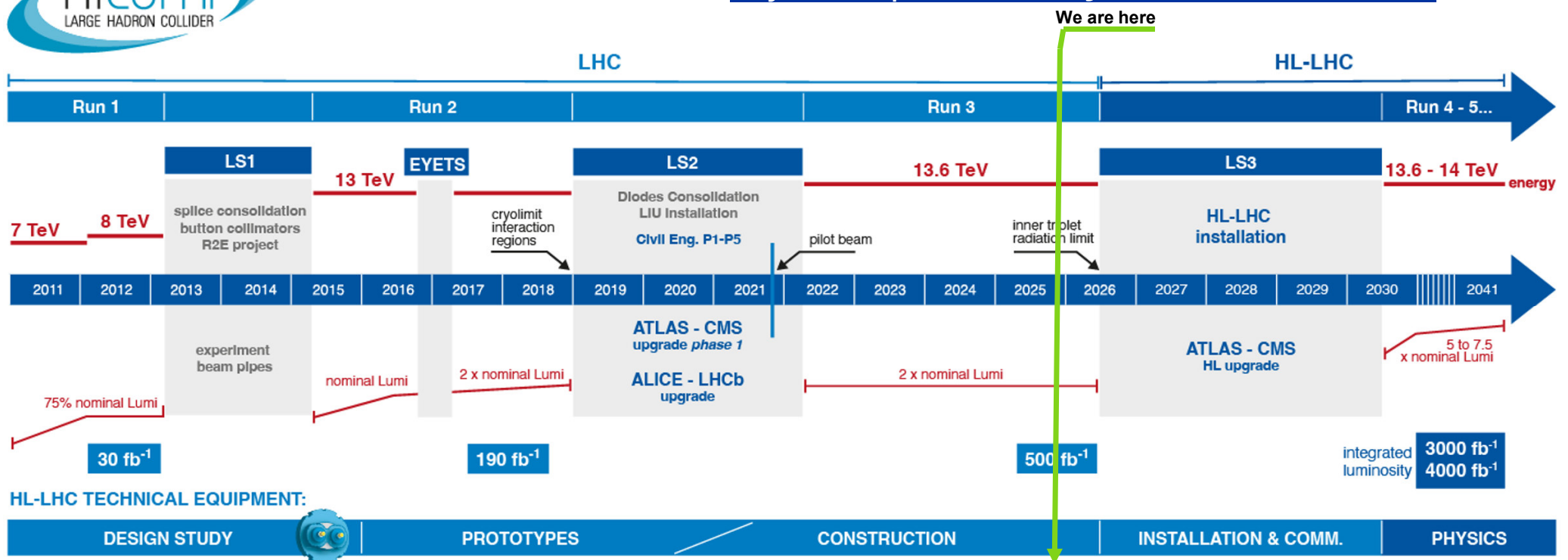


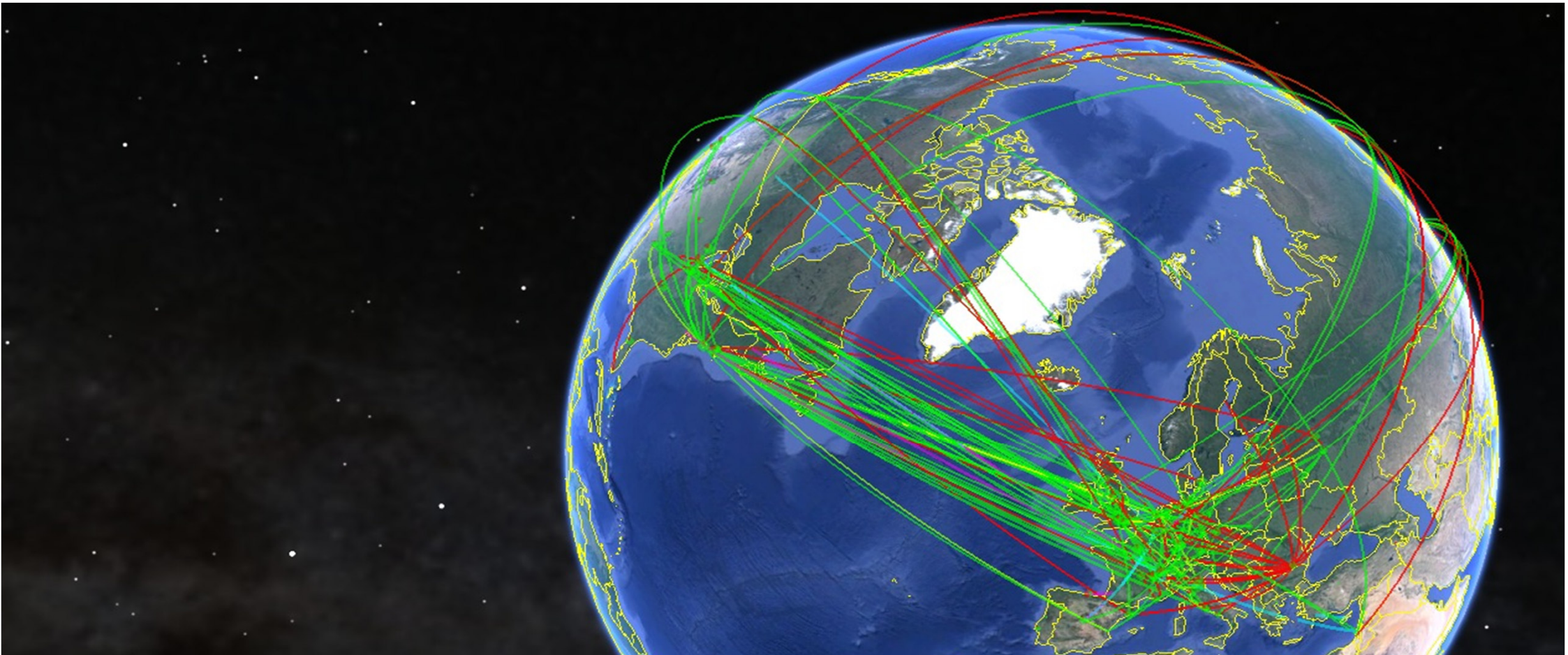
The **High-Luminosity Large Hadron Collider (HL-LHC)** is an **upgraded version of the LHC**

It will operate at a higher luminosity, i.e. it will produce more collisions and data

LHC / HL-LHC Plan

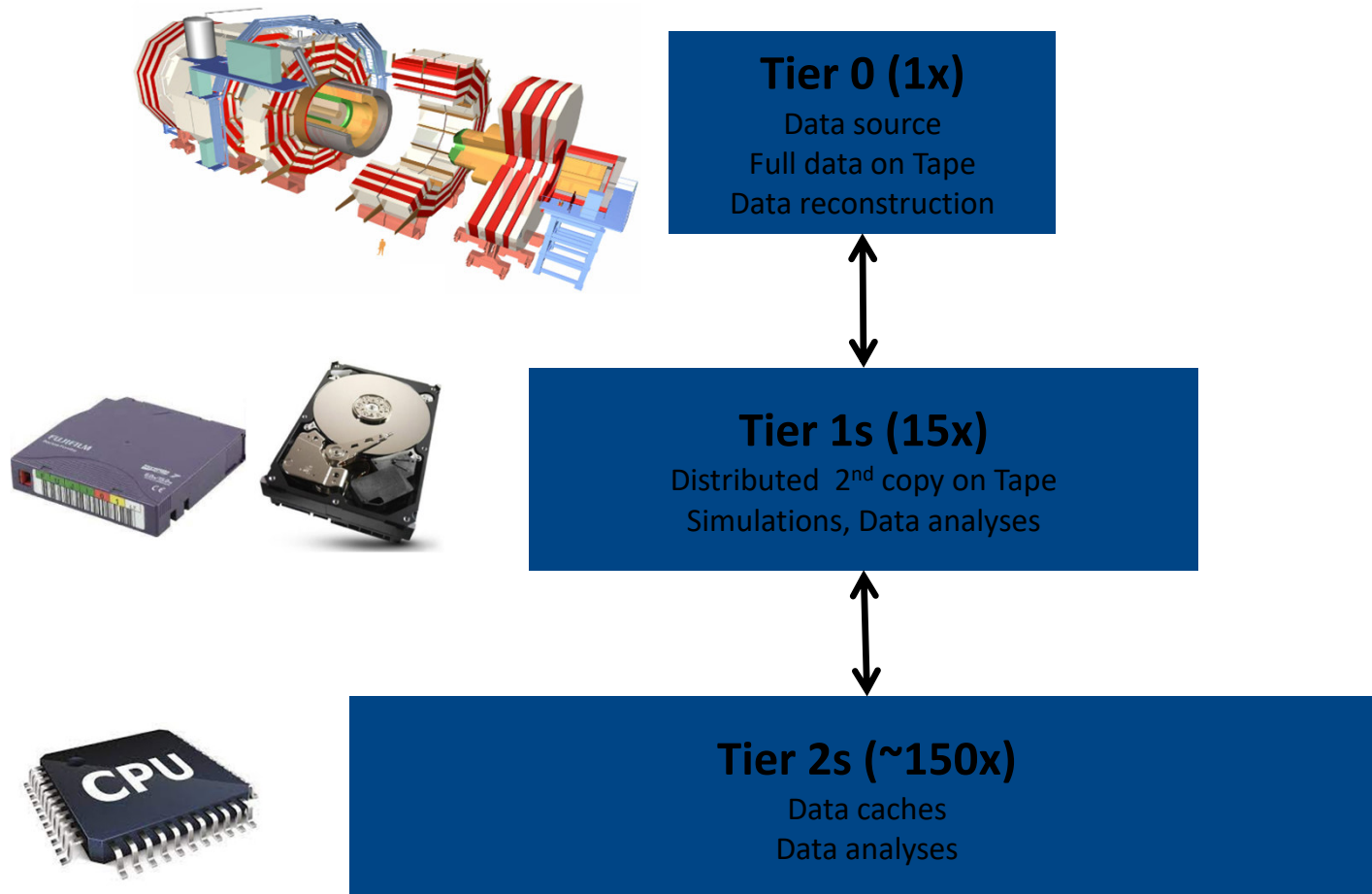
The HL-LHC will enter service in 2030,
increasing the volume of data produced
by the experiments **by a factor of 10**





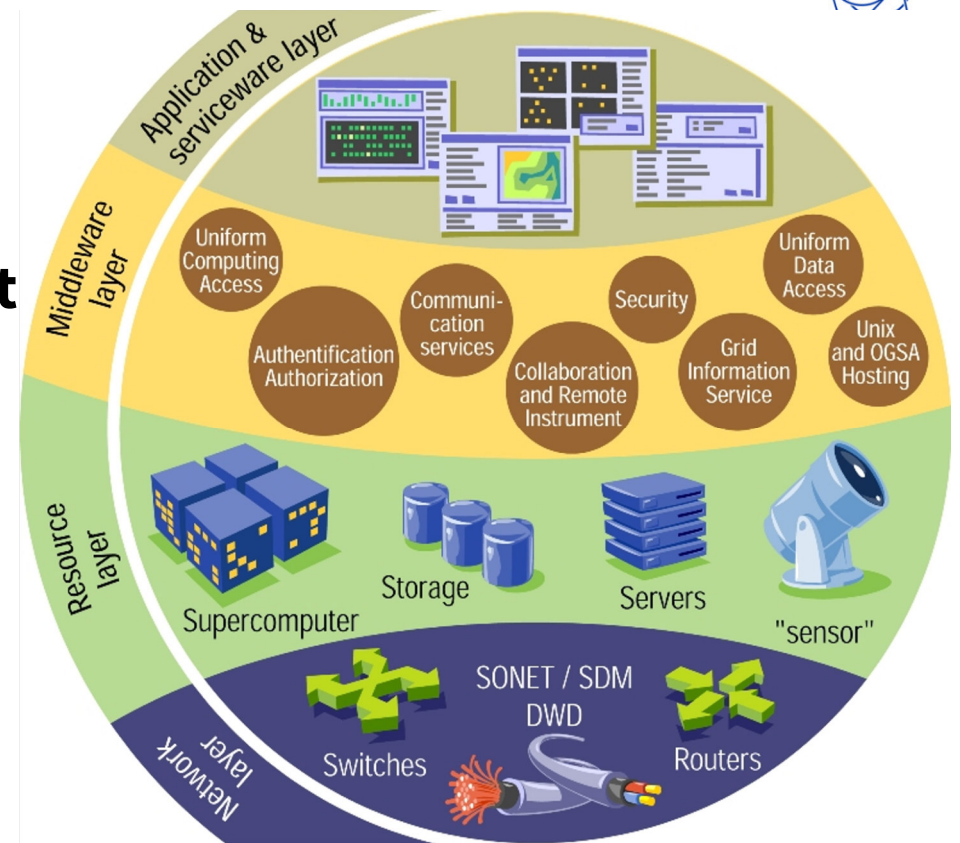
WLCG and Networks

LHC Computing Model

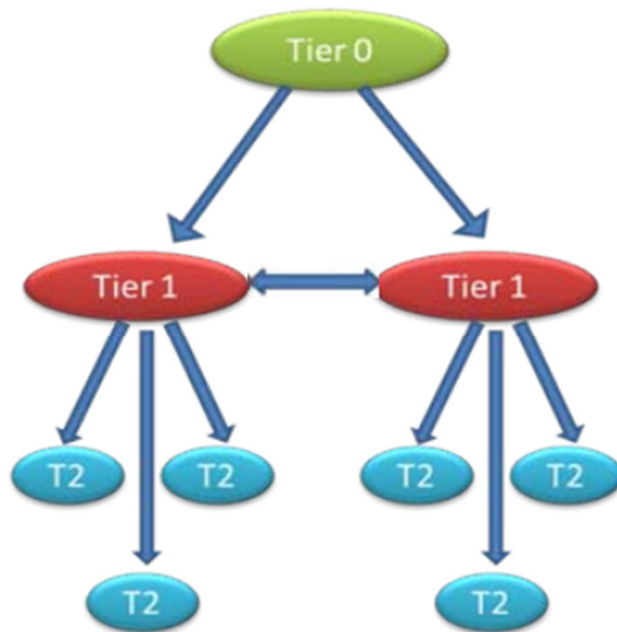


WLCG

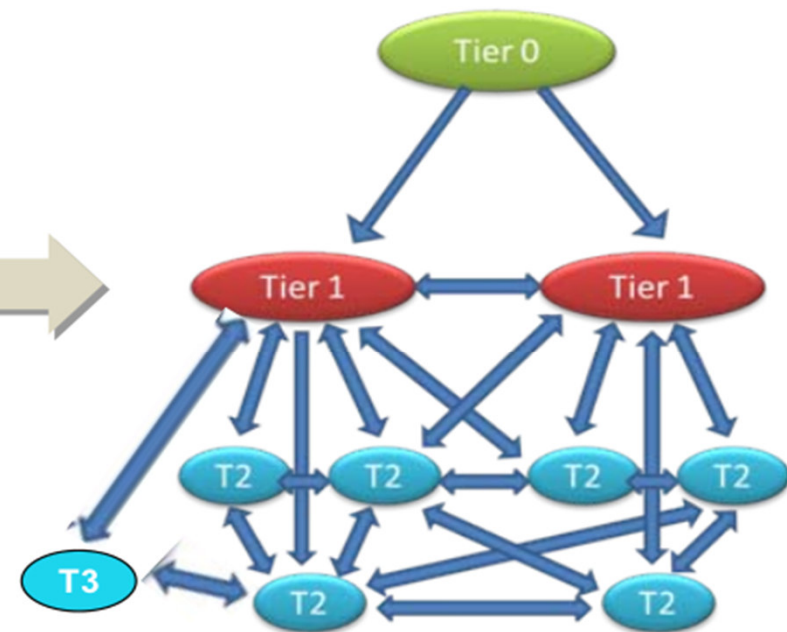
The Worldwide LHC Computing Grid (WLCG) is **a large, distributed computing and storage infrastructure and the software framework to exploit it**



Computing model evolution



Original MONARCH model



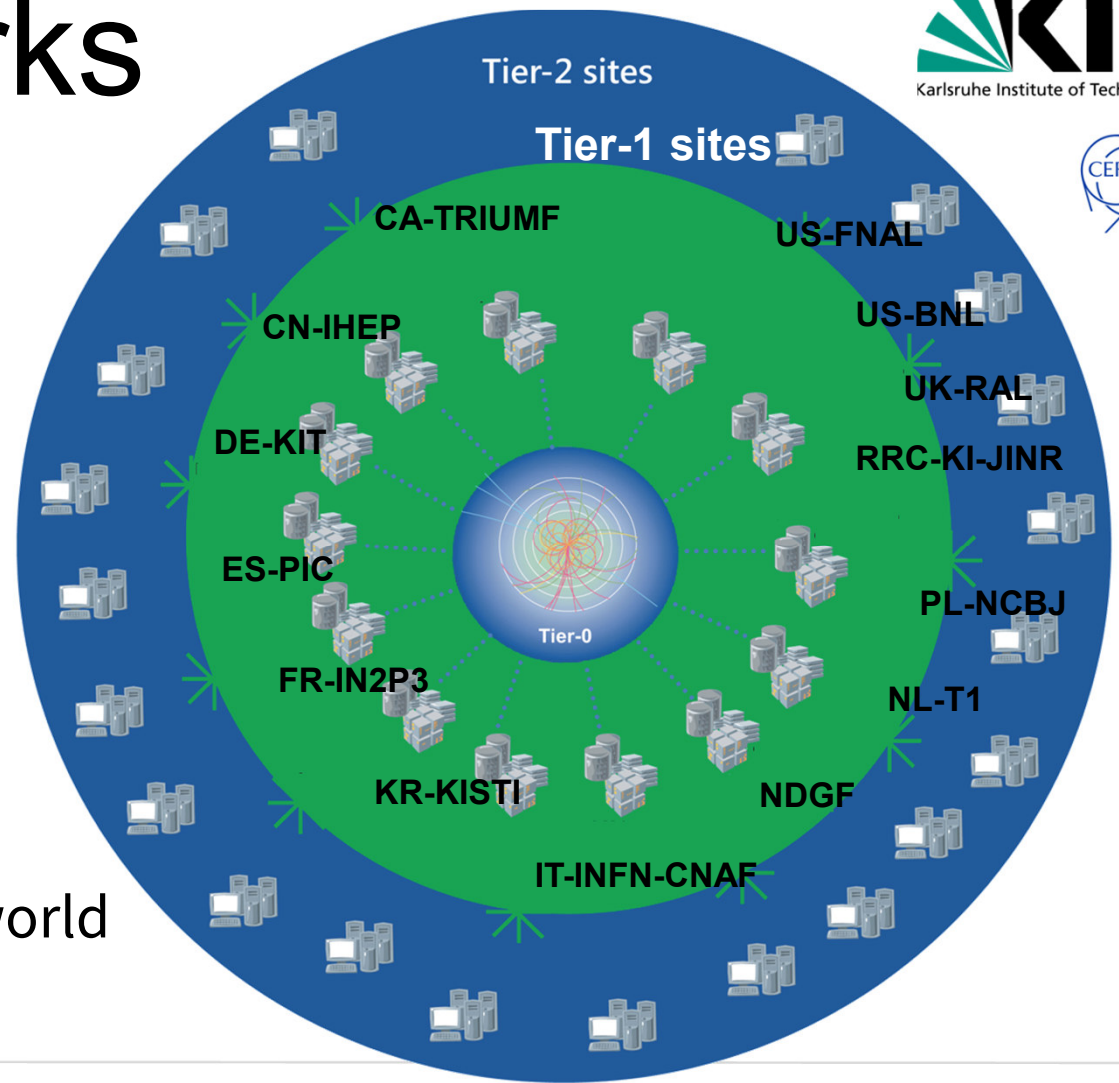
Model evolution in the 2010s'

WLCG networks

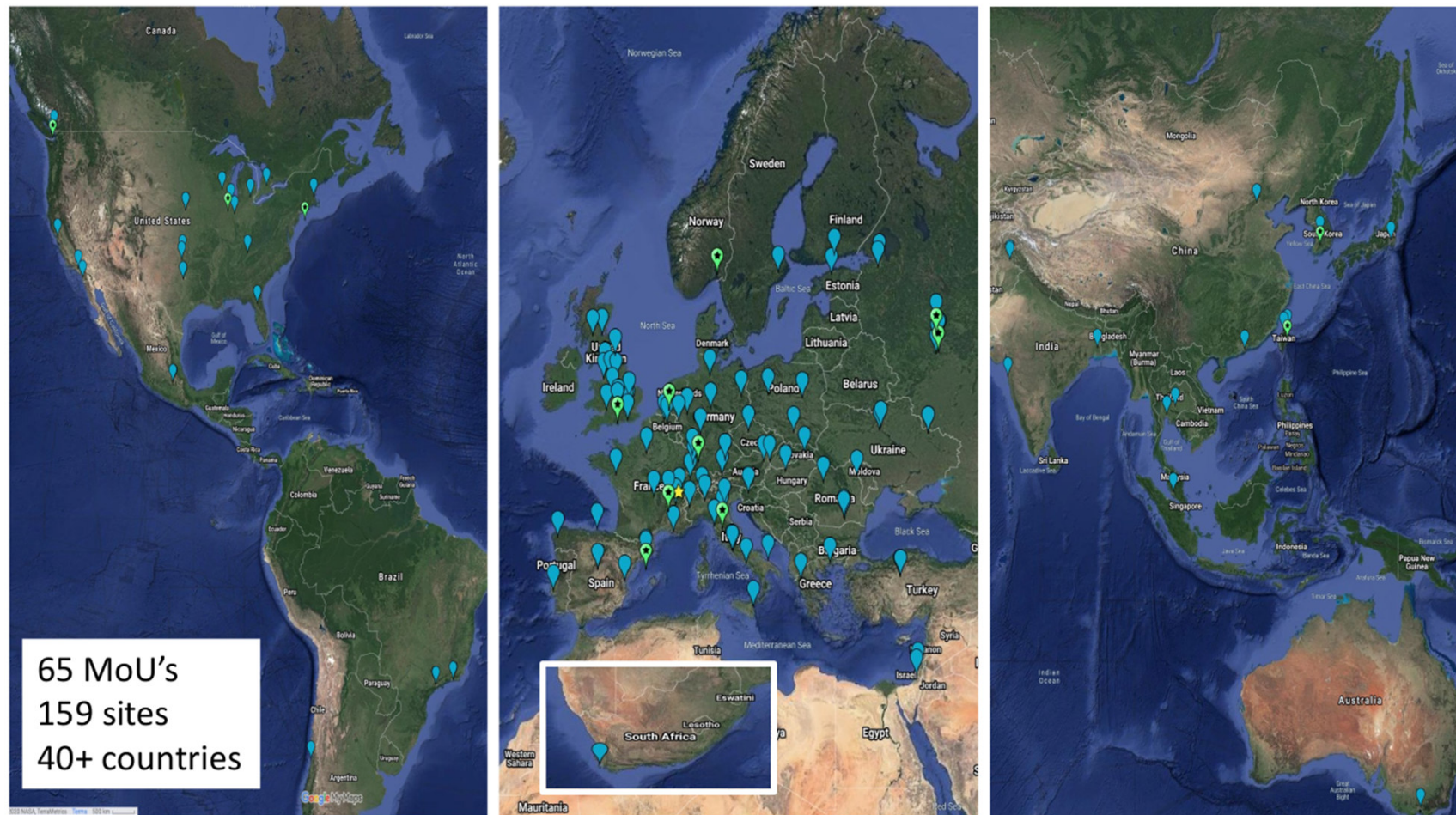
Computer

Networks are an essential component of WLCG;

they connect all the computing resources distributed in more than 150 institutes around the world



WLCG sites



LHCOPN

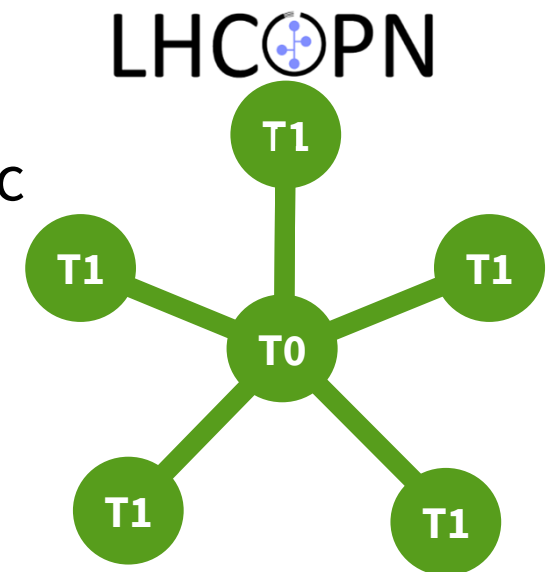
Private network connecting Tier1s to the Tier0

Secure:

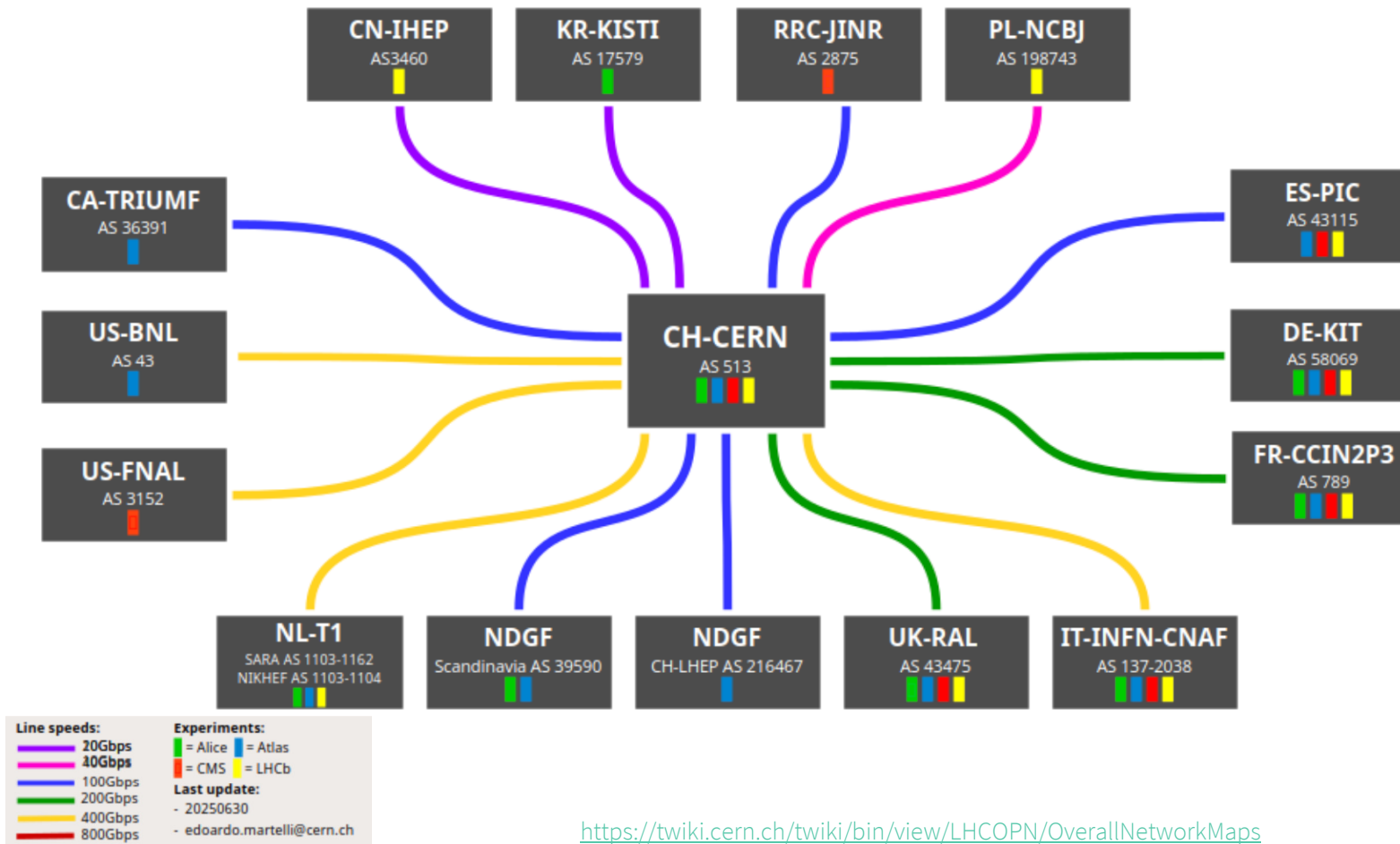
- Dedicated to LHC data transfers
- Only declared IP prefixes can exchange traffic
- Can connect directly to Science-DMZ, bypass perimeter firewalls

Technologies:

- L2 VPN
- BGP communities for traffic engineering



LHCOPN



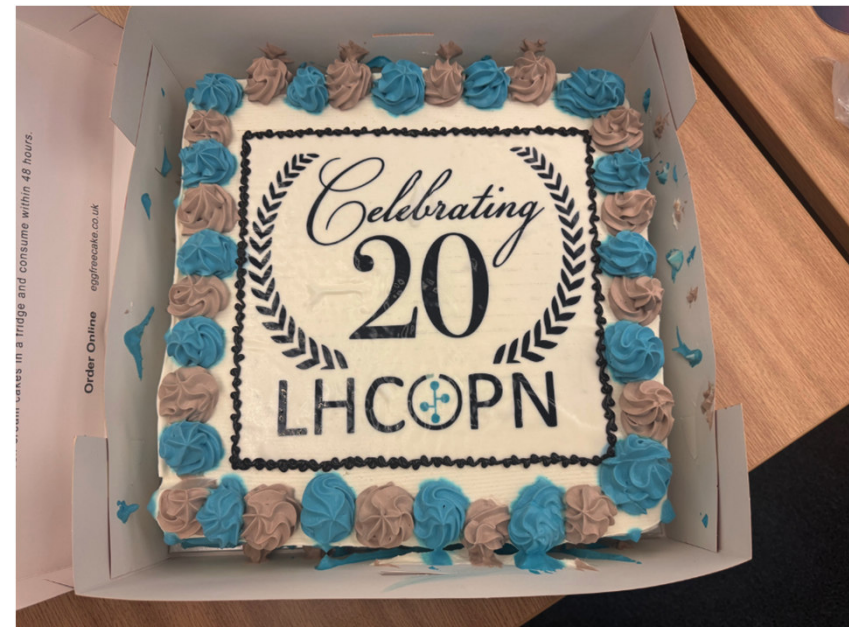
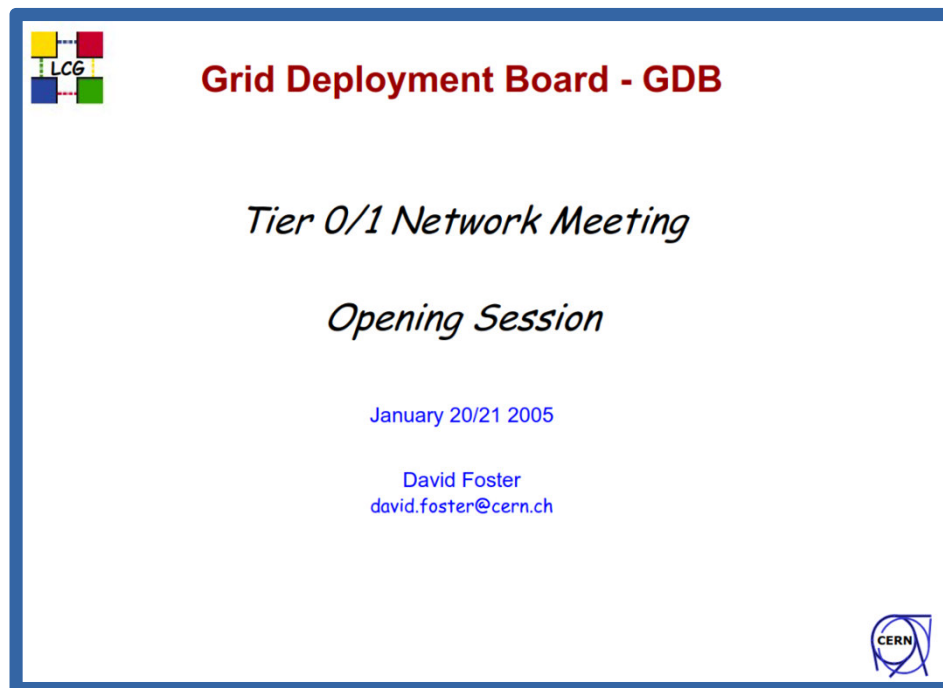
Numbers

- 16 sites for 15 Tier1s + 1 Tier0
- 14 countries in 3 continents
- 2.88 Tbps to the Tier0

<https://twiki.cern.ch/twiki/bin/view/LHCOPN/OverallNetworkMaps>

20 years of LHCOPN

First LHCOPN meeting: <https://indico.cern.ch/event/420981/>
20-21 of January 2005 in Amsterdam



LHCONE L3VPN service



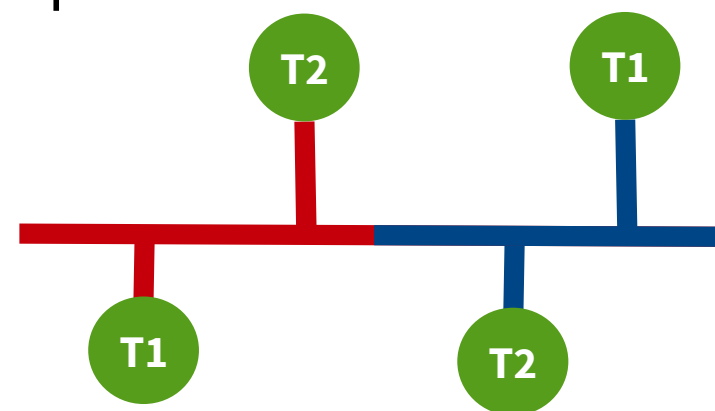
Private network connecting Tier1s and Tier2s

Secure:

- Dedicated to LHC data transfers
- Only declared IP prefixes can exchange traffic
- Can connect directly to Science-DMZ, bypass perimeter firewalls

Technologies:

- Multi domain L3 VPN
- BGP communities for traffic engineering

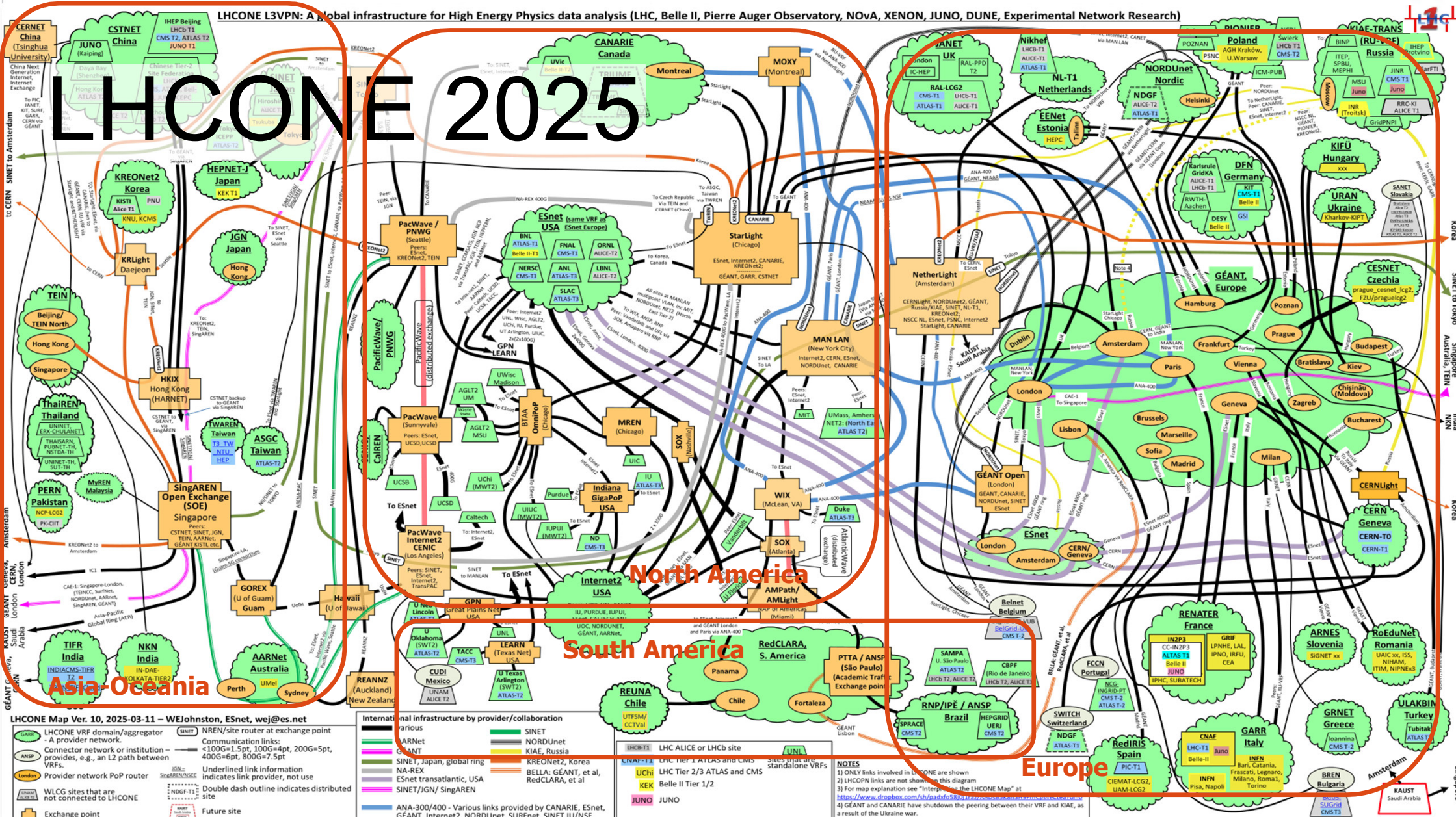


Open to other HEP collaborations





LHCONE 2025



LHCONE status



- **VRFs: 32 national and international Research Networks**
- **Connected sites: ~110 in Europe, North and South America, Asia, Australia**
- Trans-Atlantic connectivity provided by ESnet, GEANT, Internet2, RedCLARA, NORDUnet, CANARIE and SURF
- Trans-Pacific connectivity provided by KREOnet, SINET, TransPAC
- Interconnections at Open Exchange Points including NetherLight, StarLight, MANLAN, WIX, CERNlight, Hong Kong, Singapore and others

WLCG network requirements for HL-LHC



Each Major Tier1s:

1 Tbps to the Tier0 (LHCOPN)

1 Tbps to the Tier2s (aggregated, LHCONE)

Each Major Tier2s:

>400 Gbps (LHCONE)

WLCG and the NREN community are already working on the implementation of these requirements



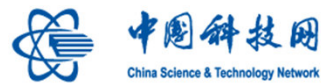
NREN community support

LHCOPN+LHCONE community meetings

- A forum for site managers, NRENs, experiments to discuss requirements and policies, plan upgrades, design new features
- Meeting two times per year
- Just held meeting #54, hosted by SKAO in UK



NRENs supporting HEP



The NREN community brings



- network know-how and savoir-fair
- collaborating attitude that has allowed to connect HEP centres in any region of the world
- new tools and innovative services, allowing the development of advanced data distribution and computing orchestration frameworks
- advanced technologies, robustness and always increasing capacity, which have driven the evolution of the HEP computing models from mostly-local to mostly-distributed

Fasterdata

Long lasting and authoritative repository for:

- tuning networks and servers for fast, long distance (RTT) data transfers

- Science DMZ architecture

- performance tests



Fasterdata
ENERGY SCIENCES NETWORK

myESnet

ESnet

SEARCH...



HOST TUNING

NETWORK TUNING

SCIENCE DMZ

DATA TRANSFER NODES

DATA TRANSFER TOOLS

PERFORMANCE TESTING

NSF DOCS

Home » Science DMZ

Science DMZ

Motivation

Architecture

Network Components

Performance Monitoring

Security

Practices and Policy

FAQ

Learn More

Science DMZ Community Presentation

Science DMZ

A Scalable Network Design Pattern for Optimizing Science Data Transfers

The Science DMZ is a portion of the network, built at or near the campus or laboratory's local network perimeter that is designed such that the equipment, configuration, and security policies are optimized for high-performance scientific applications rather than for general-purpose business systems or "enterprise" computing.

Developed by ESnet engineers, the Science DMZ model addresses common network performance problems encountered at research institutions by creating an environment that is tailored to the needs of high performance science applications, including high-volume bulk data transfer, remote experiment control, and data visualization.

The Science DMZ is scalable, incrementally deployable, and easily adaptable to incorporate high performance and advanced technologies such as 100 Gigabit Ethernet services, virtual circuits, and software-defined networking capabilities.

Short Cuts

- [Science DMZ Overview video](#)
- [Data Transfer Node Info](#)
- [Science DMZ FAQ](#)
- [Set of short Science DMZ videos \(at learn.nslc.org\)](#)
- [Longer Video by the EPOC project](#)
- [A Comprehensive Tutorial on a Science DMZ](#)

Cite the Science DMZ

Citation information for the [SC13 Science DMZ](#)

perfSONAR

perf20NAR
years



perfSONAR network monitoring platform

- Developed by the collaboration of Internet2, GEANT, ESnet, RNP, Indiana University, University of Michigan
- Toolkits installed at NRENs PoPs and WLCG sites
- Essential to monitor WLCG network performances and investigate issues



LHCONE traffic engineering

LHCONE BGP communities for traffic engineering

Community	Type	Meaning	Notes
65001:XXXX	Operational	prepend 1x to ASxxxx	Mandatory
65002:XXXX	Operational	prepend 2x to ASxxxx	Mandatory
65003:XXXX	Operational	prepend 3x to ASxxxx	Mandatory
65010:XXXX	Operational	do not announce to ASxxxx	Mandatory

- Implemented by all the NRENs providing LHCONE
- Used by end-sites to improve their trans-continental routing

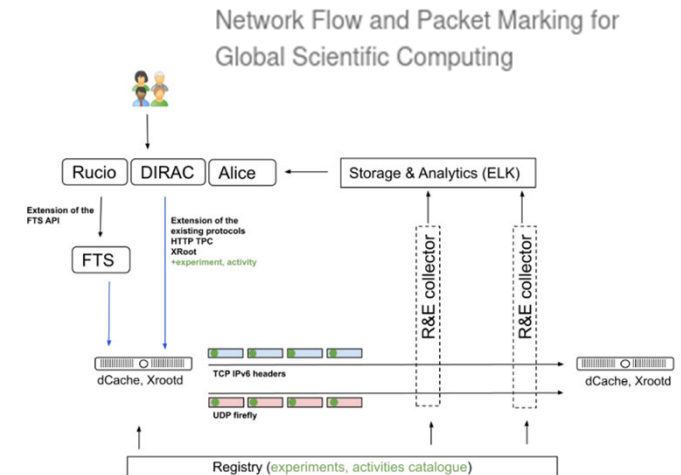
SciTags

Science Tags: marking of data packets and flows with Experiment and Application IDs for better network accounting

scitags.org

Two options being implemented:

- Tag in the IPv6 flowlabel field (proposed IETF draft: draft-cc-v6ops-wlwg-flow-label-marking)
- Tags (and more info) in UDP fireflies (UDP packets sent in parallel to each flow)



NRENs run fireflies collectors, supports deployment and testing

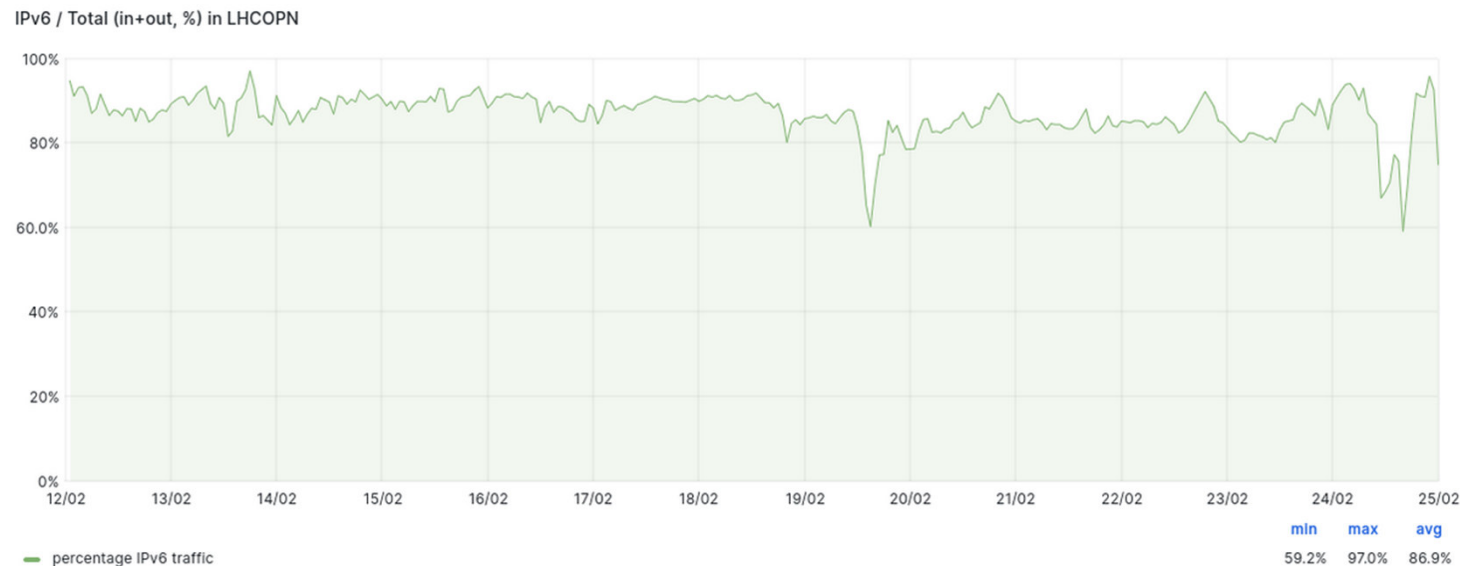
IPv6 deployment

IPv6 needed to overcome IPv4 address space shortage

- IPv6 Traffic in LHCOPN: ~90% of the total.

Proposal to disable IPv4 in LHCOPN at least by 2029

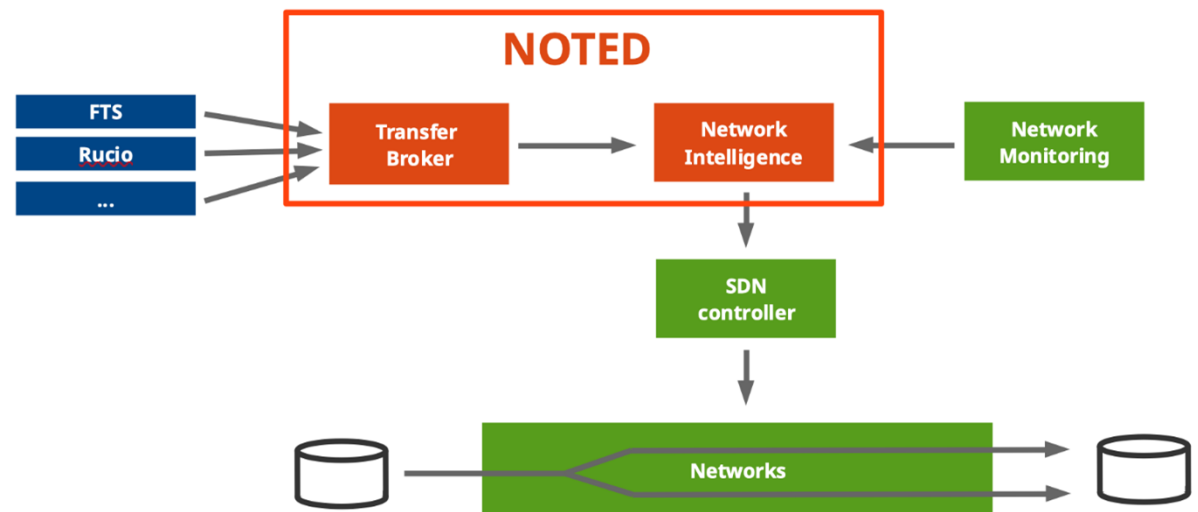
- Supported by all NRENs



R&D: NOTED SDN

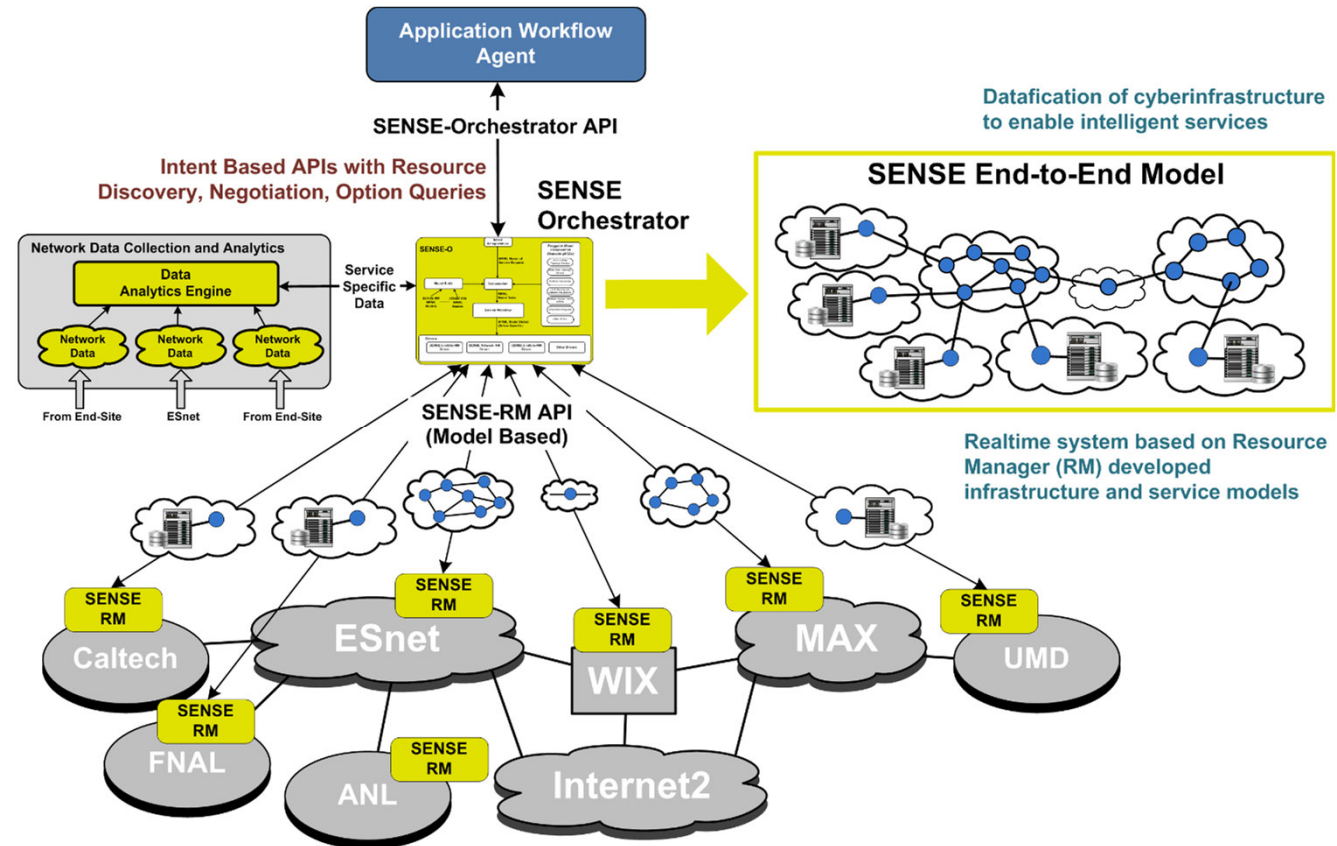
NOTED is a framework that detects large data transfers in real-time and trigger network optimization actions to speed up the execution of those transfers

- Already used with production data transfers during SC22 and SC23
- Demonstrated integration with ESnet SENSE dynamic circuit provisioning system



ESnet SENSE

Software Defined Networking (SDN) for End-to-End Networked Science at the Exascale



Data Challenges for HL-LHC



WLCG has planned for a series of data challenges to prepare for HL-LHC data taking



- Demonstrate readiness for the expected HL-LHC data rates with:
 - Increasing volume/rates
 - Increase complexity (e.g. additional technology)

2021: 10% of HL-LHC requirements (*480Gbps minimal – 960Gbps flexible*)

2024: 25% of HL-LHC requirements (*1.2Tbps minimal – 2.4Tbps flexible*)

2027: 50% of HL-LHC requirements (*date and % to be confirmed*)

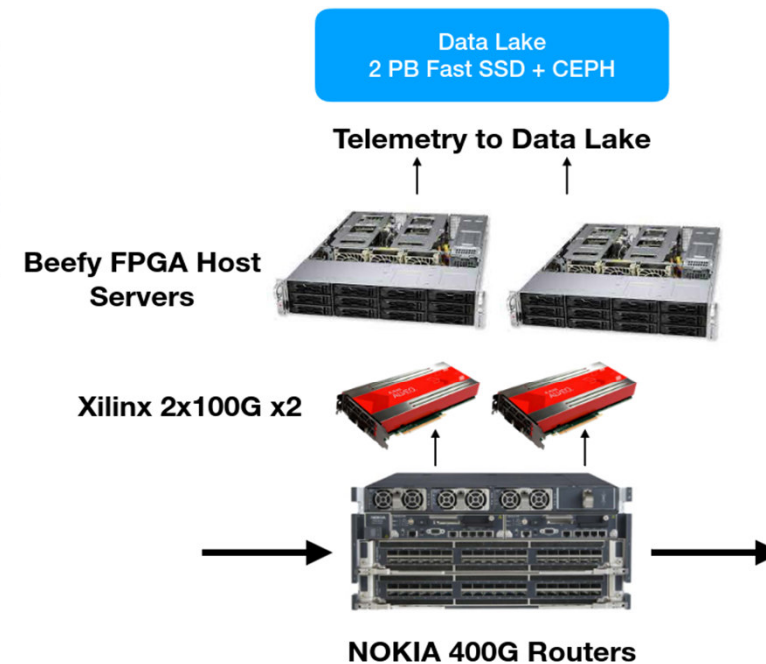
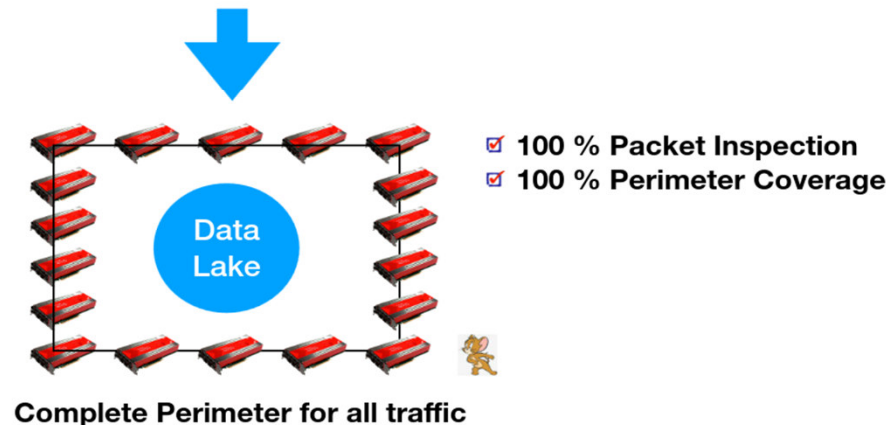
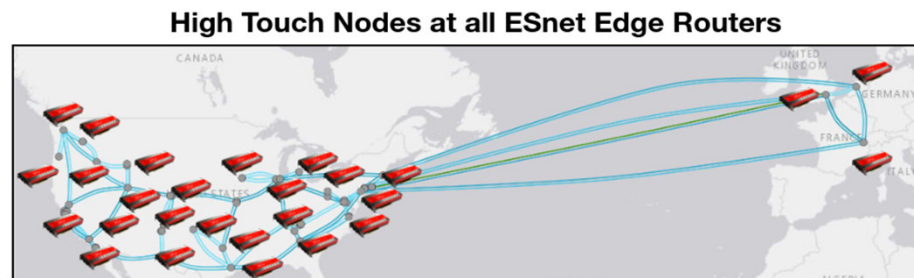
2029: 100% of HL-LHC requirements (*date and % to be confirmed*)

2030: start of HL-LHC (Run4) (*4.8Tbps minimal – 9.6Tbps flexible*)

ESnet High Touch

High Touch collected LHCONe transfers during DC24.

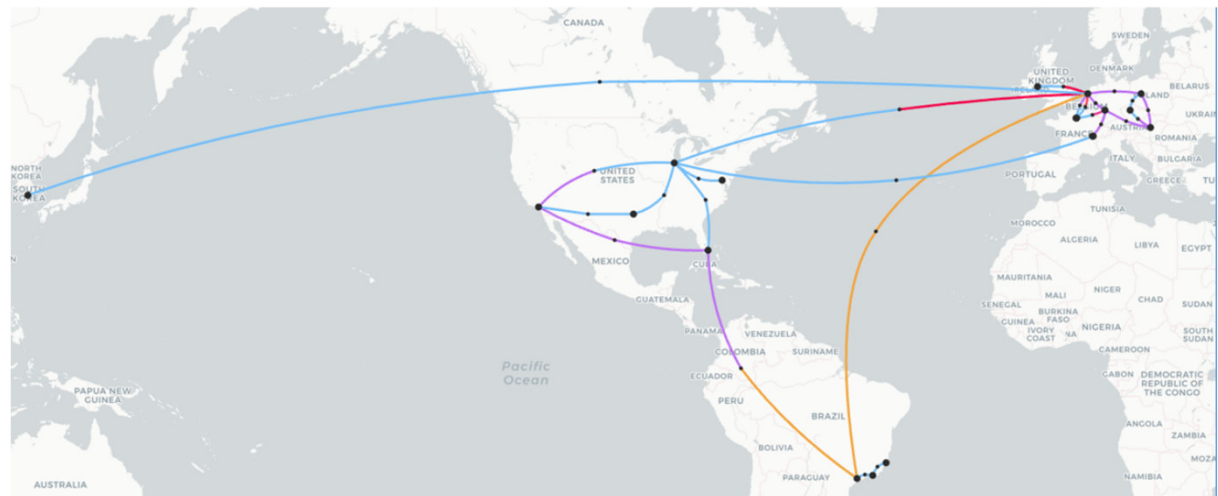
It allowed deep understanding of network flows: short duration, no retransmissions



Global P4 Lab

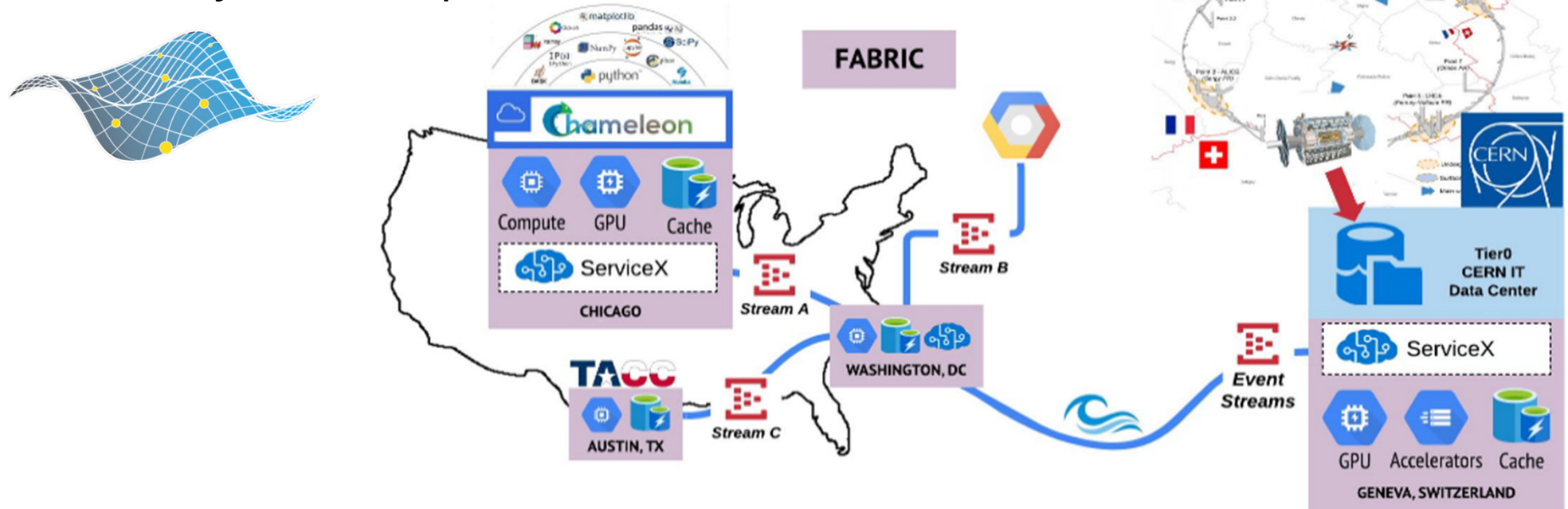
Network of P4 switches provided by the GNA-G AutoGOLE / SENSE
Persistent Multi-Resource Testbed and the GÉANT P4 Lab

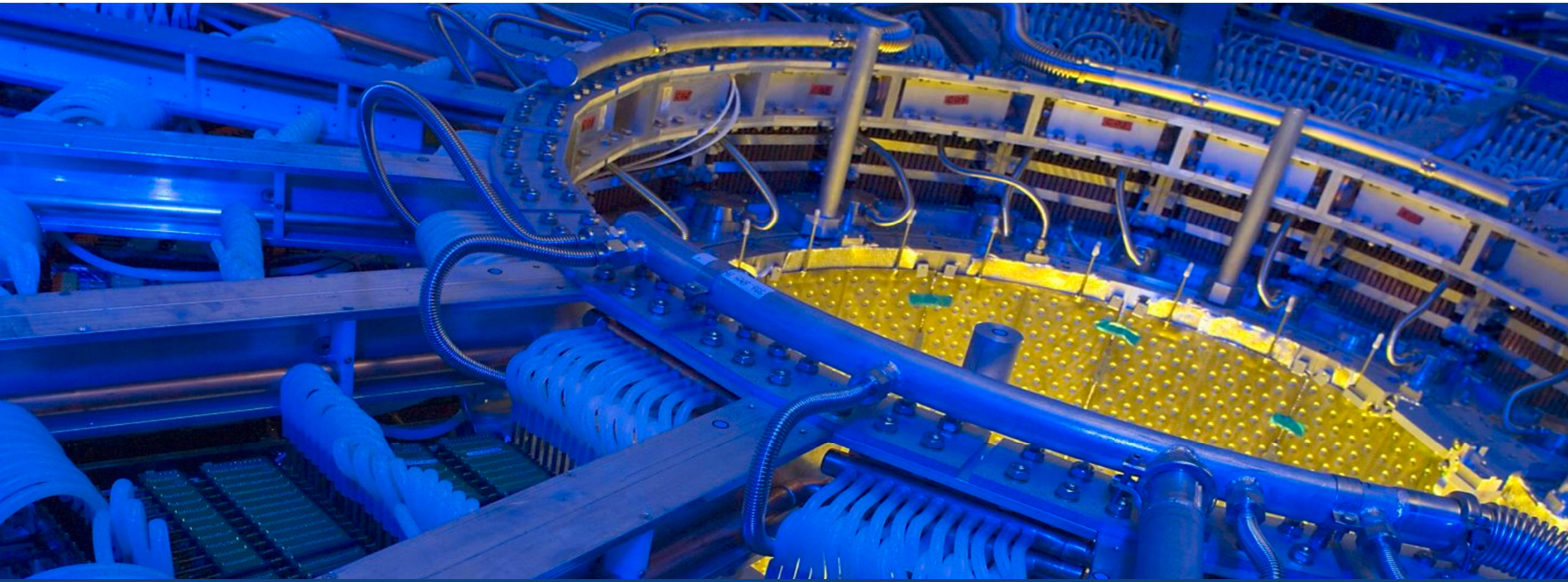
Used to demonstrate a LHCONE MultiONE implementation using
Flowlabel policy routing



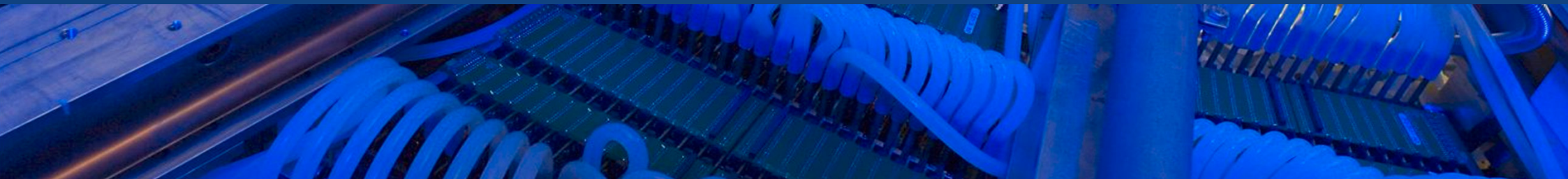
FABRIC and FAB

International research infrastructure funded by NSF and built by ESnet that enables the computer science and networking community to develop and test new architectures



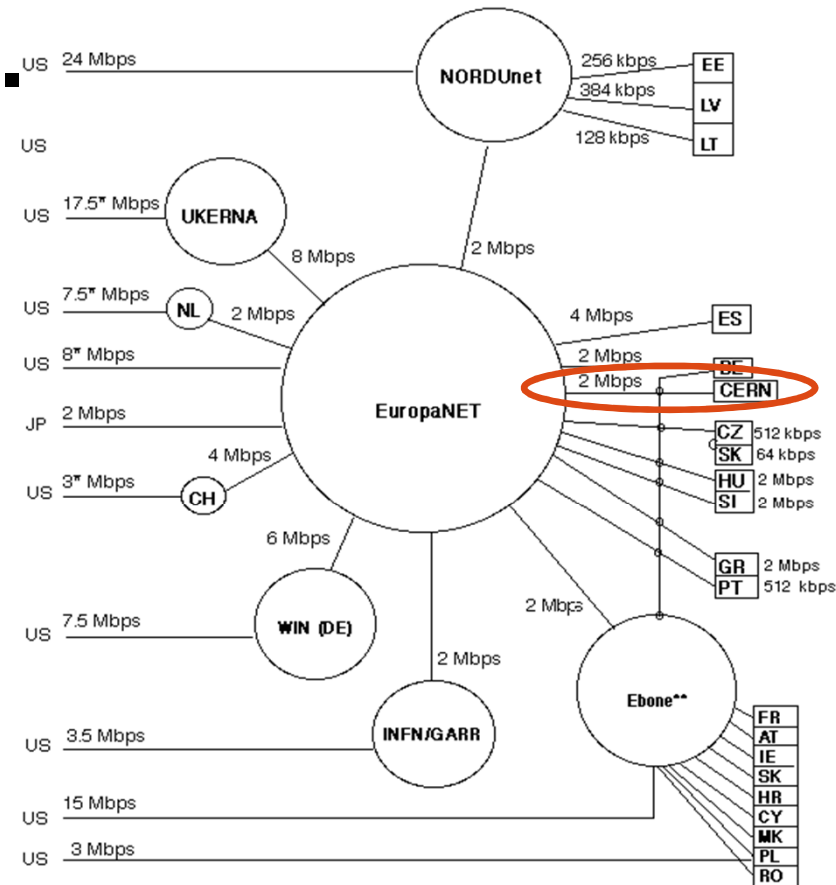


Conclusions



From the 90s...

(Intercontinental) connectivity of European research networks, August 1996



Notes:

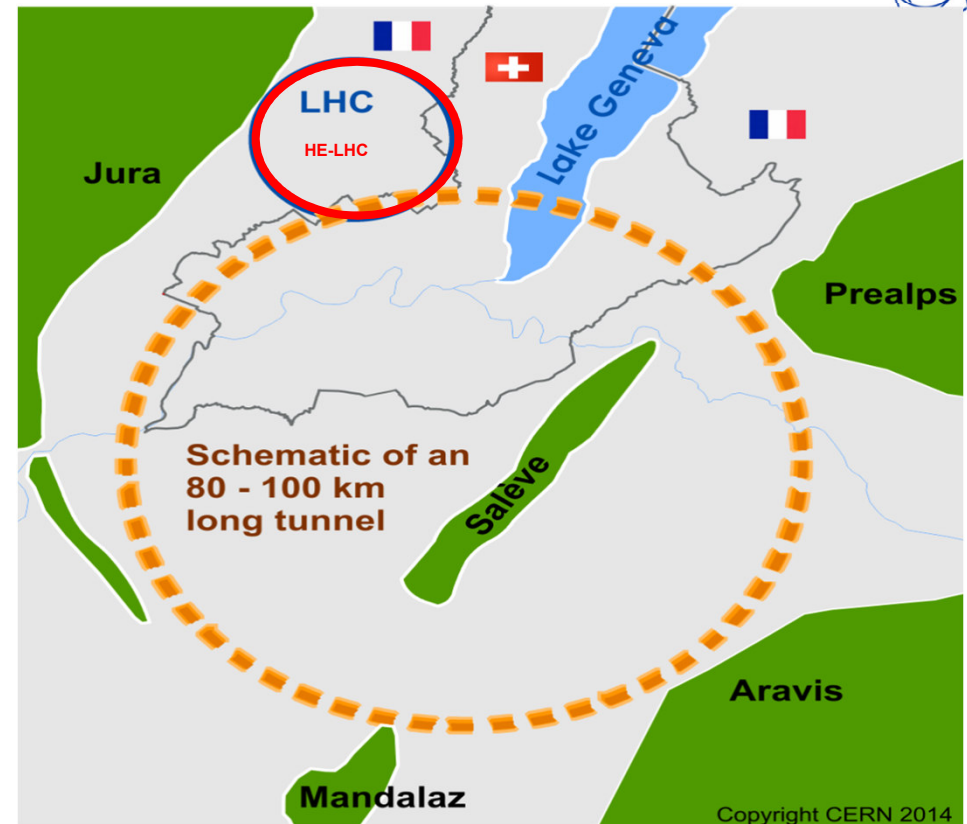
1. Connections shown are symbolic; actual line configuration may be different.
 2. Other links with Europe and transatlantic connections used exclusively by commercial service providers are not shown.
 3. Link capacities are those in place in December 1995; figures in parentheses indicate committed upgrade.
 4. Several of the networks shown also provide transit services for countries in North Africa, the Middle East and for Russia.
- *DANTE organises 9 Mbps of the UKERNA (UK) connectivity, 6 Mbps of the SURFnet (NL) connectivity and the 3 Mbps SWITCH (CH) capacity
- ** Ebone connects research as well as commercial networks

...to the Future Circular Collider...

Purely technical schedule, assuming
green light to preparation work

A 70 years scientific program

8 years preparation	10 years tunnel and FCC-ee construction	15 years FCC-ee operation	11 years FCC-hh preparation and installation	25 years FCC-hh operation pp/PbPb/eh
2020-2028		2038-2053		2064-2090



An effective collaboration

Computing and networking are essential components of the LHC instrument

The NREN community has been supporting WLCG and HEP science over many years: an outstanding collaboration

Nobel prize in Advanced Collaborative Science!!



Photo credits: Nobel Media AB 2013. Photo: Alexander Mahmoud

Questions

