

# LHC and LCG

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- **CERN**
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# **CERN**

**European Organization for Nuclear research**

# CERN



- CERN is the world's largest particle physics centre
- Particle physics is about:
  - elementary particles which all matter in the Universe is made of
  - fundamental forces which hold matter together
- Particle physics requires:
  - Accelerators, huge machines able to speed up particles to very high energies before colliding them into other particles
  - Detectors, massive instruments which register the particles produced when the accelerated particles collide

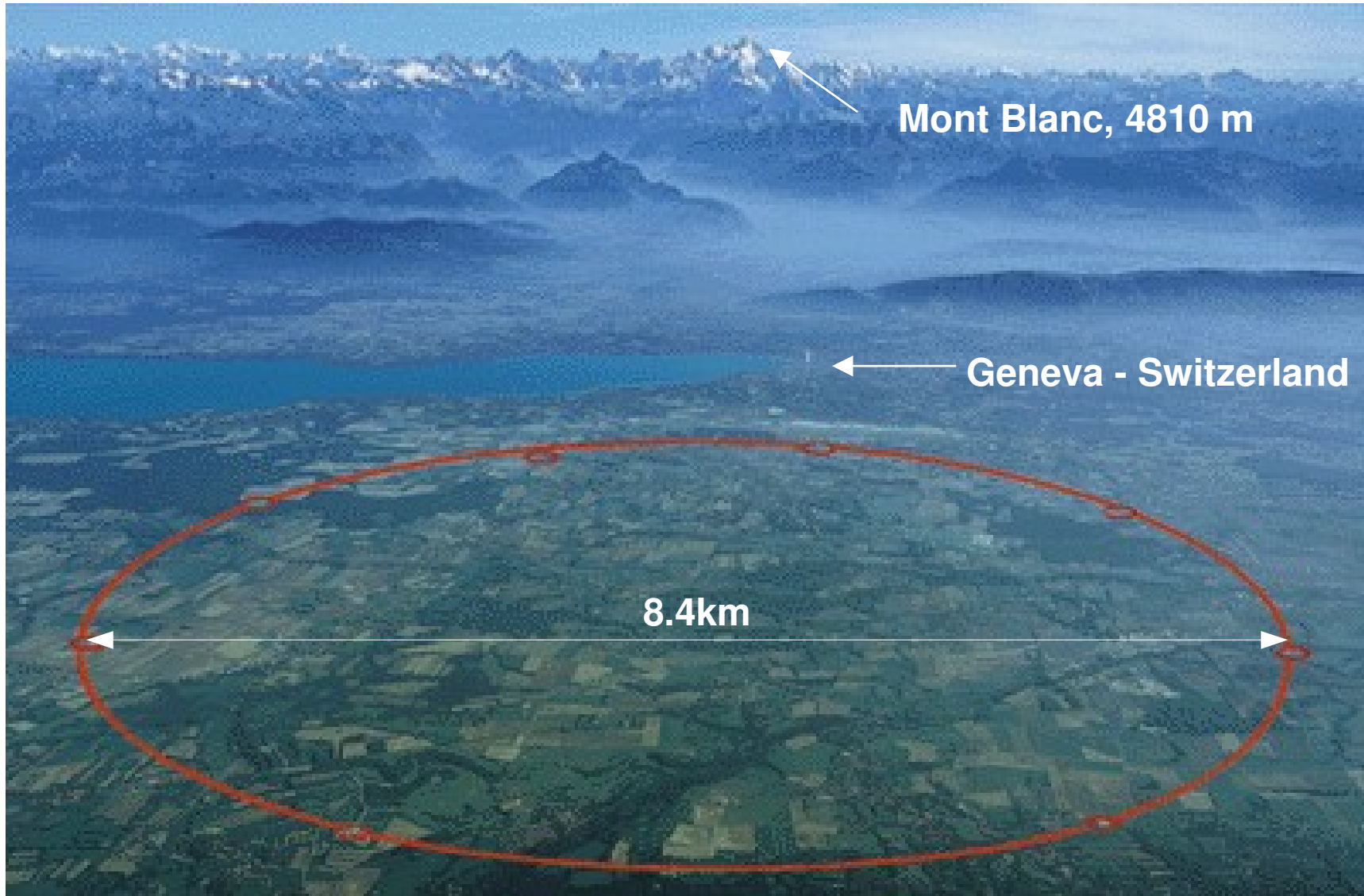
**CERN is:**

**- ~ 2500 staff scientists (physicists, engineers, ...)**

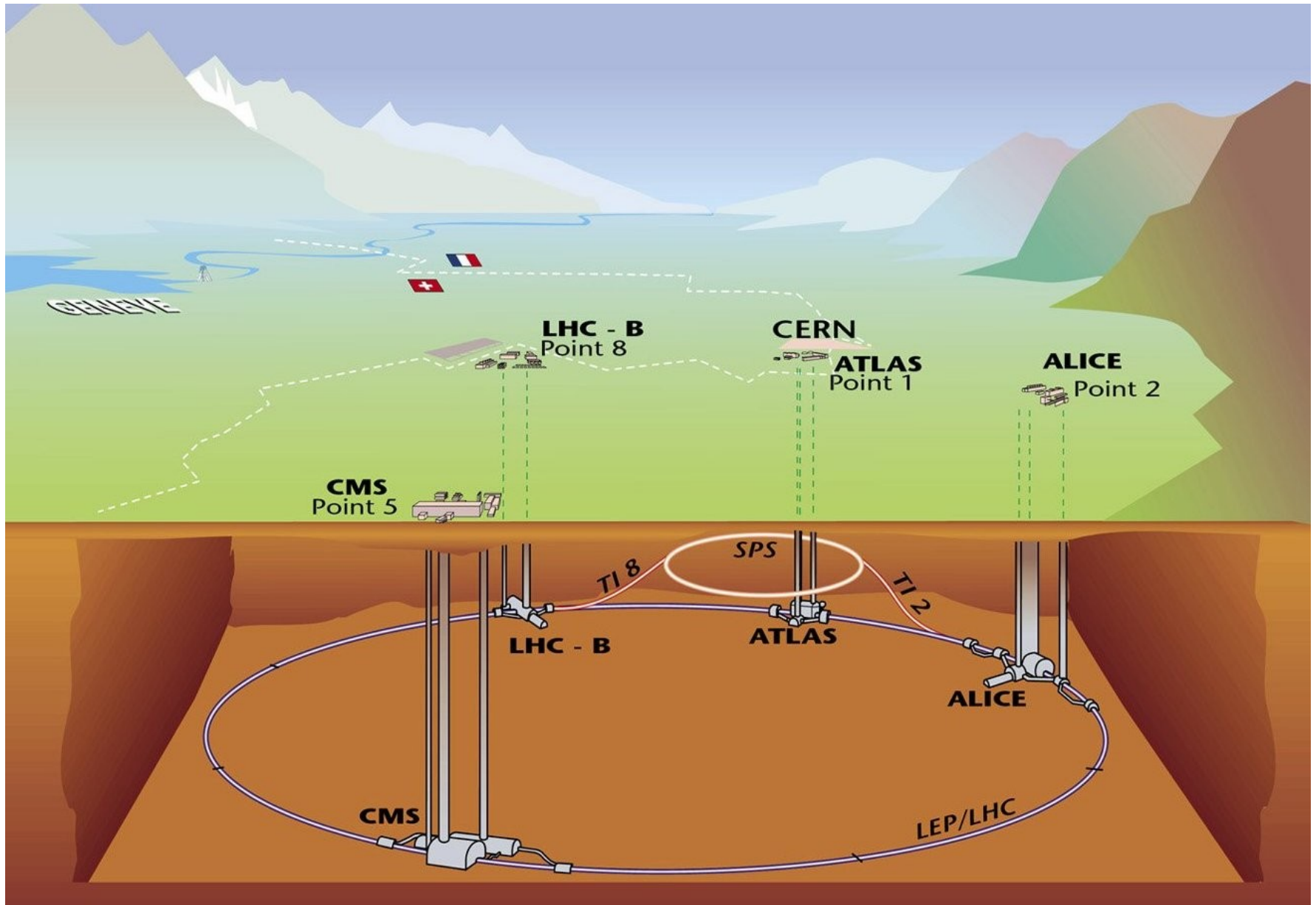
**- Some 6500 visiting scientists (half of the world's particle physicists)**

**They come from 500 universities representing 80 nationalities.**

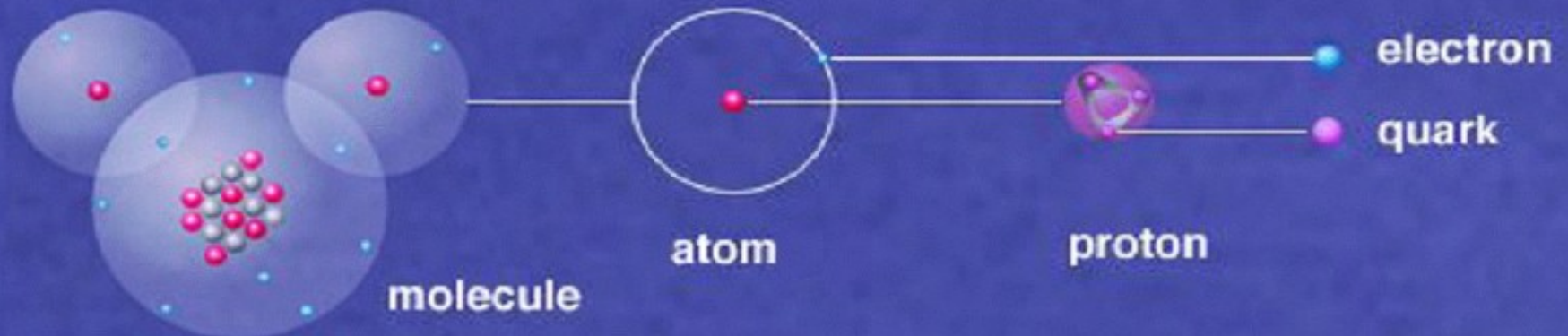




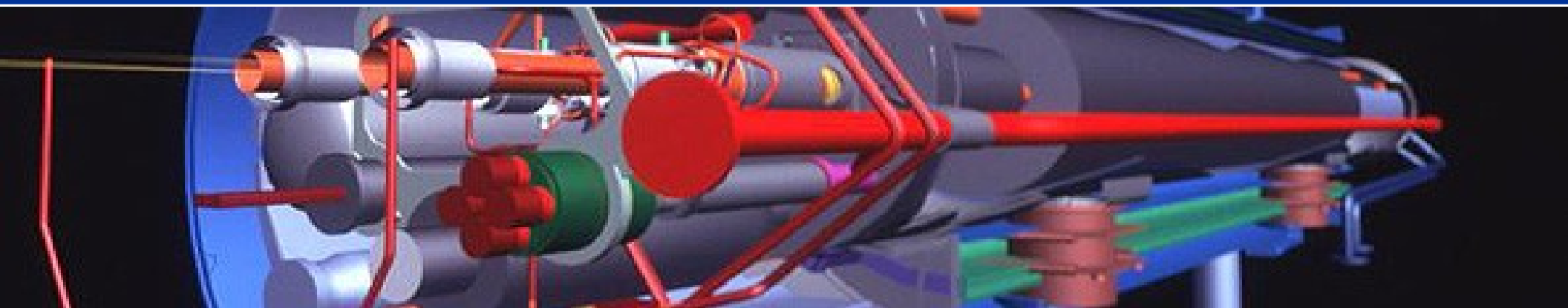
# CERN



- Physicists smash particles into each other to:
  - identify their **components**
  - **create** new particles
  - reveal the nature of the **interactions** between them
  - create an environment similar to the one present at the origin of our Universe
- **What for?** To answer fundamental questions like:  
*how did the Universe begin? What is the origin of mass?  
What is the nature of antimatter?*



- CERN has made many **important discoveries**, but our current understanding of the Universe is still incomplete!
- **Higher energy** collisions are the key to further discoveries of more massive particles ( $E=mc^2$ )
- One particle predicted by theorists remains elusive: the **Higgs boson**





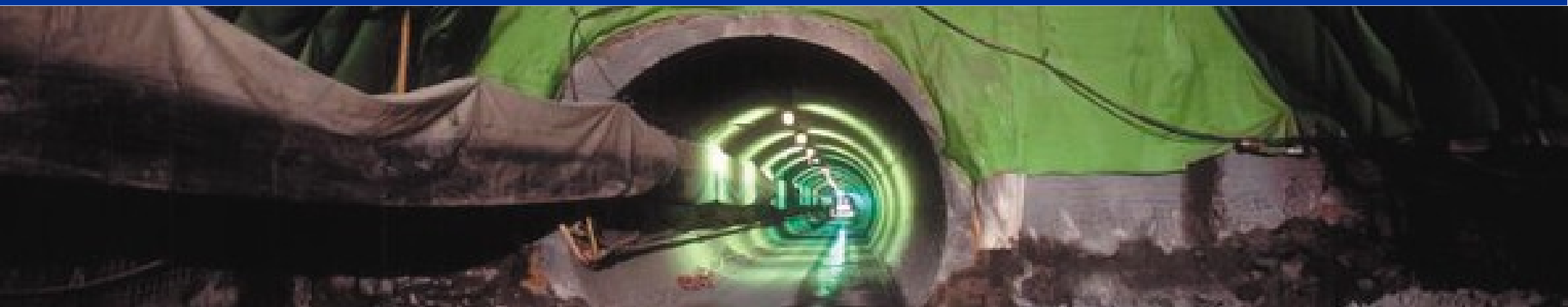
# LHC

## Large Hadron Collider

# LHC



- To answer questions still open, CERN is building the Large Hadron Collider ([LHC](#))
- The LHC will be the [most powerful instrument](#) ever built to investigate elementary particles
- If the Higgs boson exists, the LHC will almost certainly find it



# LHC



- LHC will collide beams of protons at an energy of 14 TeV
- Using the latest super-conducting technologies, it will operate at about  $-270^{\circ}\text{C}$ , just above absolute zero of temperature.
- With its 27 km circumference, the accelerator will be the largest superconducting installation in the world.

*LHC is due to switch on in 2008*

*Four experiments, with detectors as 'big as cathedrals':*  
**ALICE**  
**ATLAS**  
**CMS**  
**LHCb**

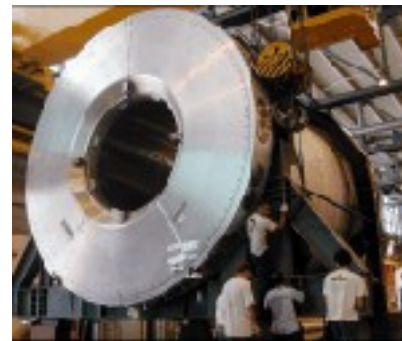
**CMS**



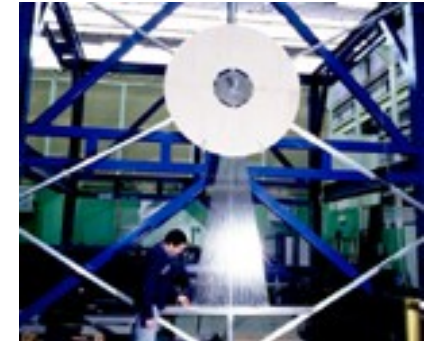
**LHCb**



**ATLAS**



**ALICE**



# LHC

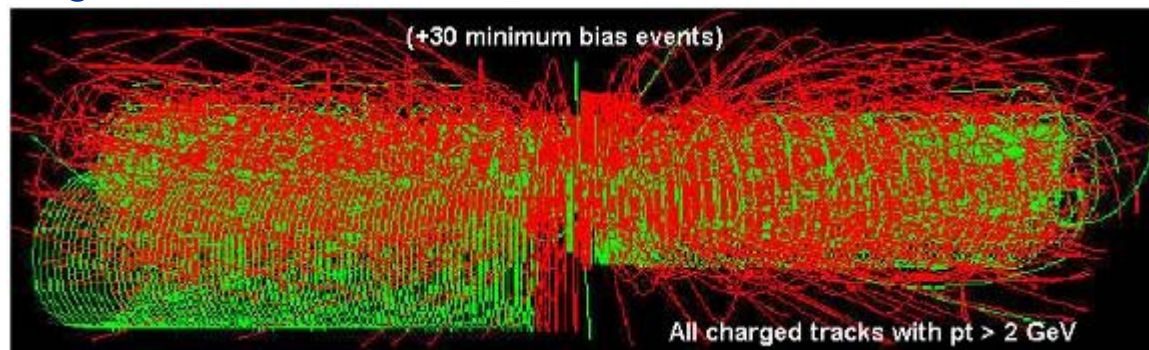


- A **particle collision** = an **event**
- Physicist's goal is to count, trace and characterize all the particles produced and **fully reconstruct the process**.
- Among all tracks, the presence of “**special shapes**” is the sign for the occurrence of interesting interactions.

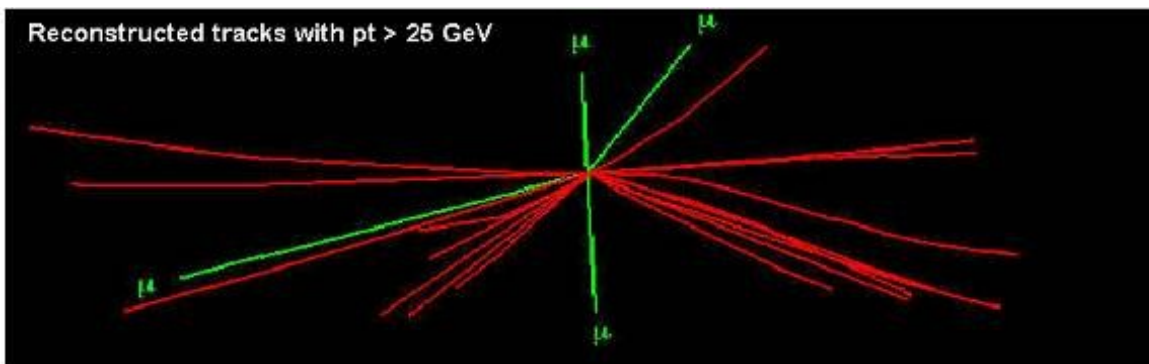


# LHC

One way to find the Higgs boson:  
 look for characteristic decay pattern producing 4 muons  
 Starting from this event...



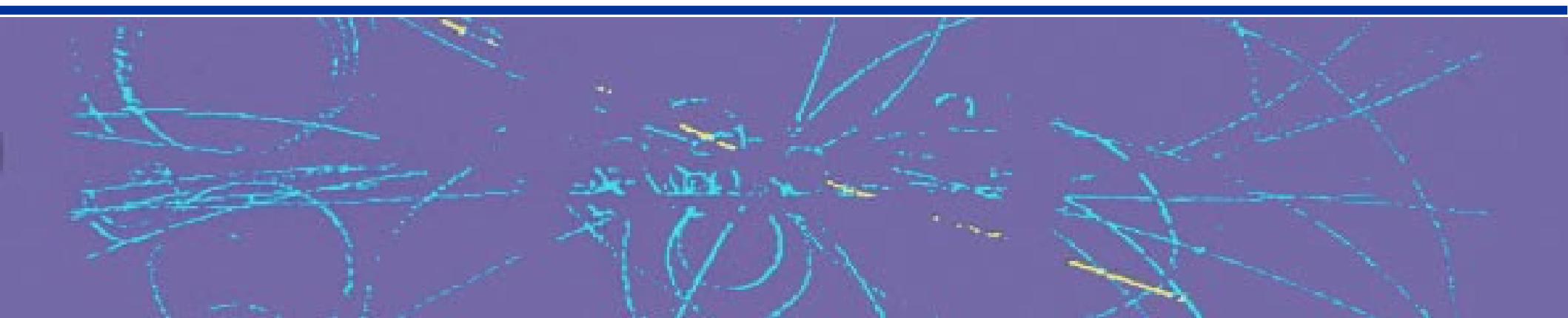
We are looking for this “signature”



**Selectivity: 1 in  $10^{13}$**

**Like looking for 1 person in a thousand world populations!**

**Or for a needle in 20 million haystacks!**



# LHC data challenge

- 40 million collisions per second
- After filtering, 100 collisions of interest per second
- A Megabyte of data digitised for each collision  
= recording rate of 0.1 Gigabytes/sec
- $10^{10}$  collisions recorded each year  
= 10 Petabytes/year of data

**1 Megabyte (1MB)**  
*A digital photo*

**1 Gigabyte (1GB)**  
= 1000MB  
*A DVD movie*

**1 Terabyte (1TB)**  
= 1000GB  
*World annual book production*

**1 Petabyte (1PB)**  
= 1000TB  
*Annual production of one LHC experiment*

**1 Exabyte (1EB)**  
= 1000 PB  
*World annual information production*



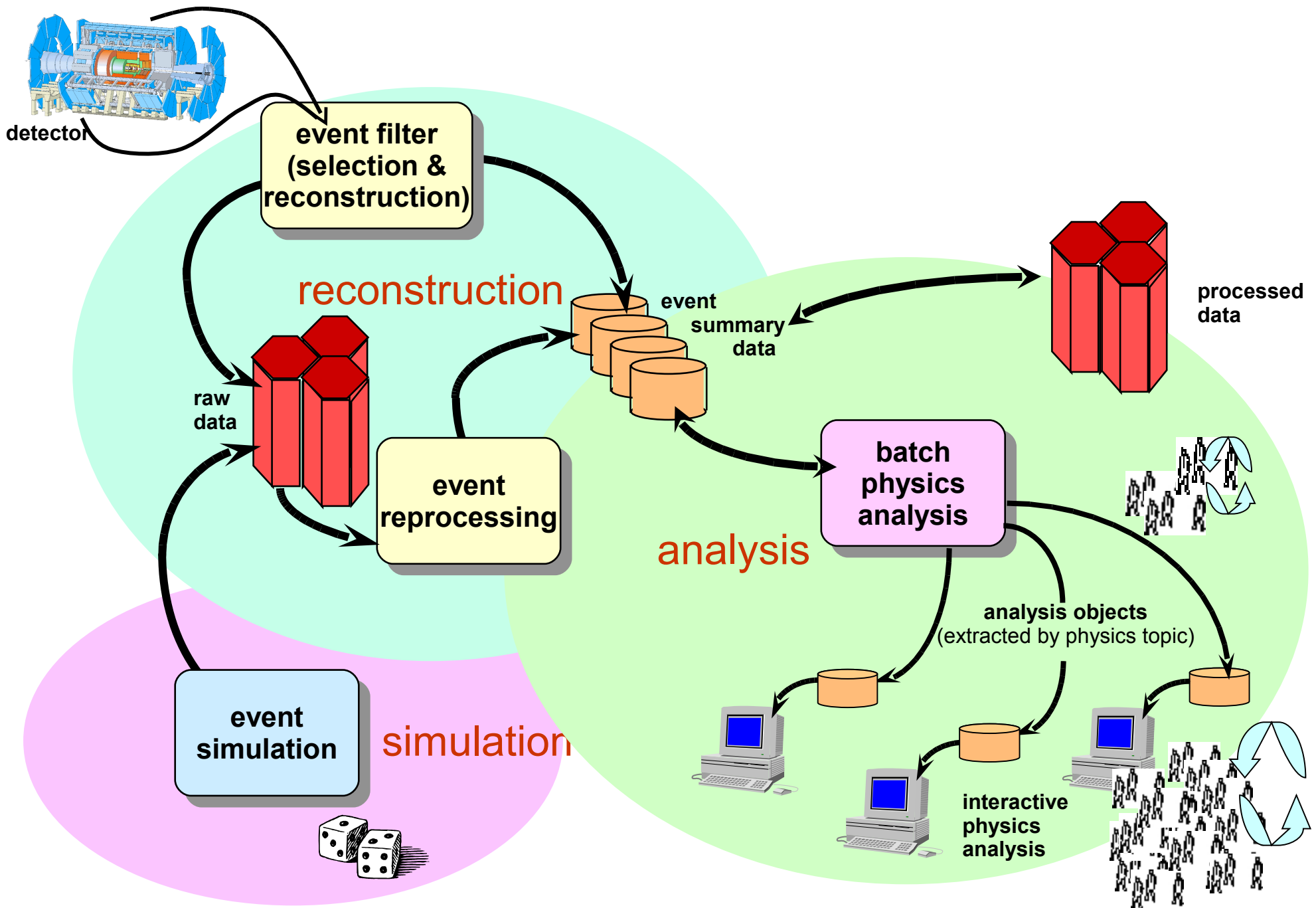


# LHC data processing

- **Simulation**: start from theory and detector characteristics and compute what detector should have seen
- **Reconstruction**: transform signals from the detector to physical properties (energies, charge of particles, ..)
- **Analysis**: Find collisions with similar features, use of complex algorithms to extract physics...



# LHC data processing



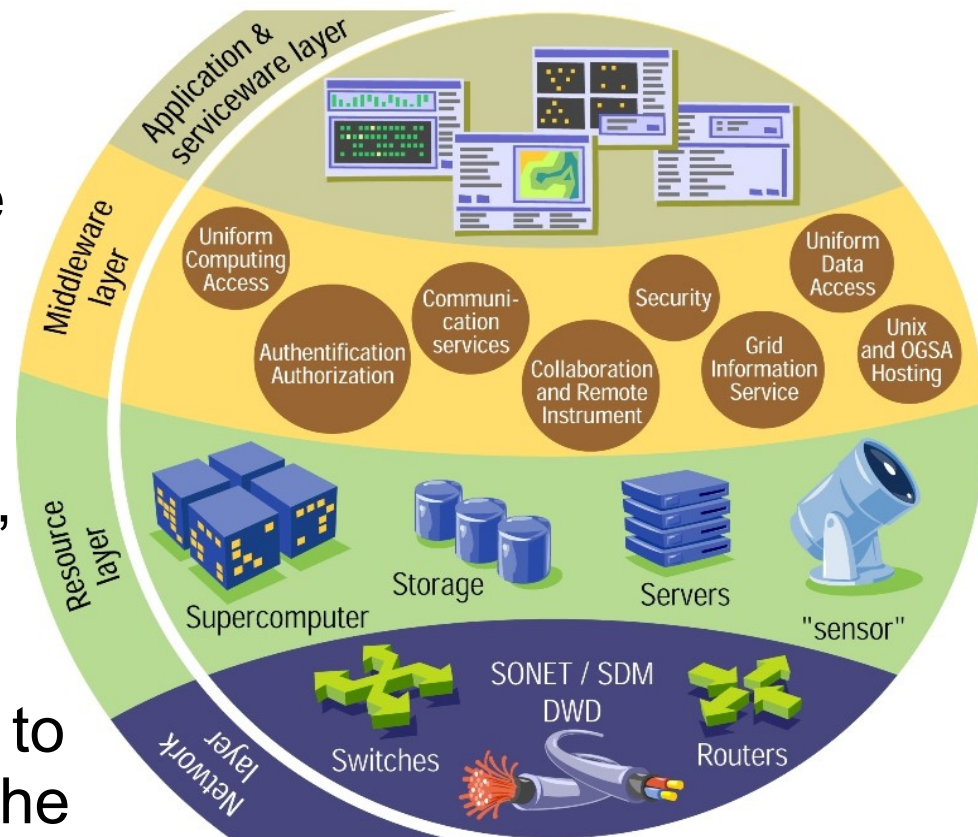


# **LCG**

## **LHC Computing Grid**

# LCG: the LHC Computing Grid

- The **Grid** is a virtual computing service uniting the world wide computing resources of particle physics
- The Grid provides the end users with seamless access to computing power, data storage, specialized services
- The Grid provides the computer service operation with the tools to manage the resources, move the data around



# LCG - Middleware

The Grid relies on a special system software, the **middleware**, which:

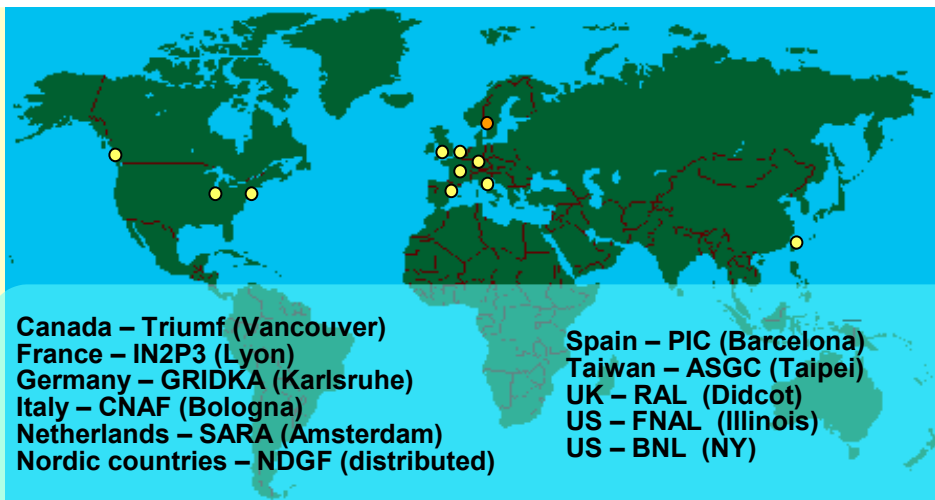
- keeps track of the location of the data and the computing power
- balances the load on various resources across the different sites
- provides common access methods to different data storage systems
- handles: authentication, security, monitoring, accounting



# LCG - Service Hierarchy

## Tier-0: The accelerator centre:

- data acquisition and initial processing
- long-term data storage
- distribution of data to the Tier-1 centres



## Tier-1s: data analysis and distribution

- managed mass storage
- grid enabled data services
- heavy data analysis

## Tier-2s: ~130 centres in 35 countries

- end users analysis (where the discovers are made)
- simulations

# LCG computing capabilities

	Tier0	Tier1s	Tier2s
CPU (MSPECint2000s):	25	56	61
DISKS (Petabytes):	7	31	19
TAPES (Petabytes):	18	35	





# CERN Computer Centre

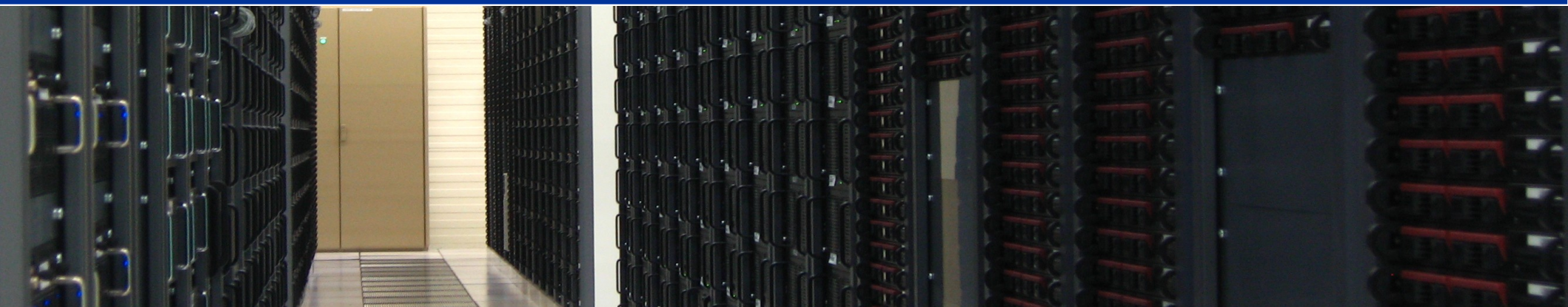
Network backbone capacity: **2.4TB** (will be 4.8TB in 2008)

Number of 10G interfaces: **500**

Number of active servers: **6000**

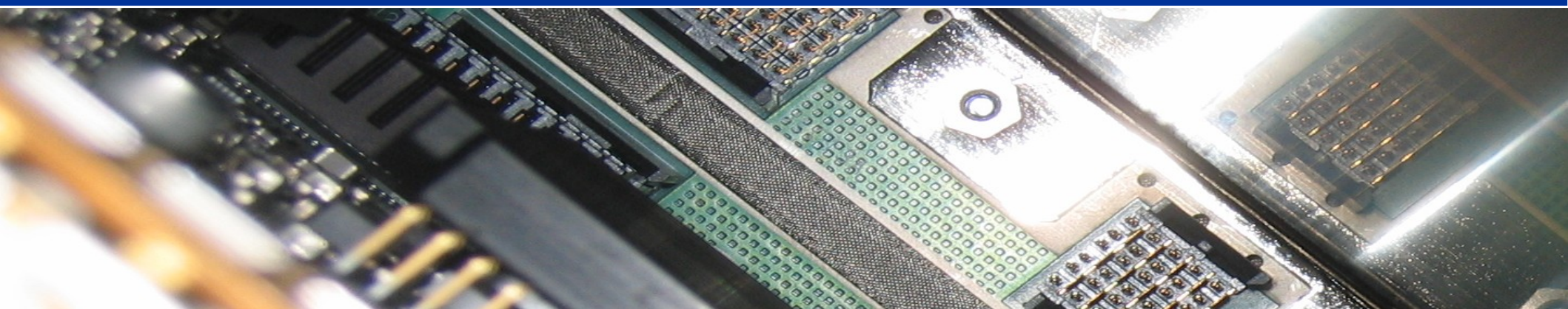
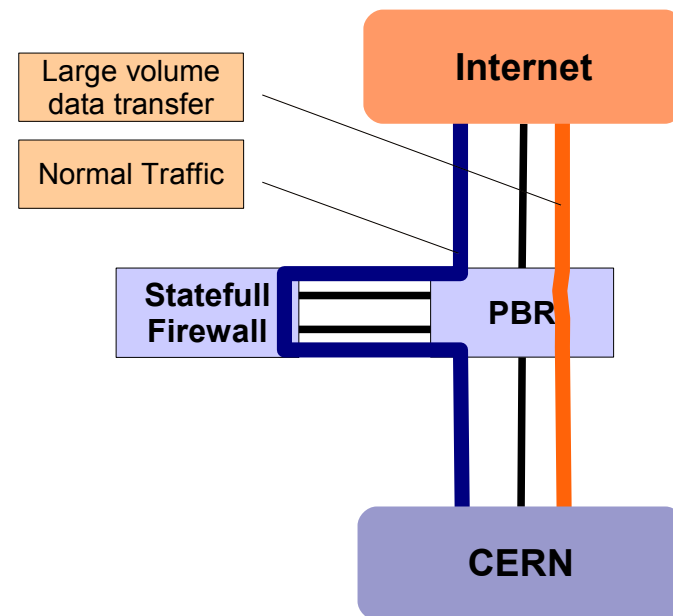
Electrical Power: **3MW**

Cooling capacity: **3MW**



# CERN Firewall

- Recently upgraded
- Statefull inspection capacity: **2.2 Gbps**
- High speed data transfer (stateless inspection): **40Gbps**
- Fully redundant



# LCG - Current status

## Status at August 2007

- Established the 10 Gigabit/sec optical network that interlinks CERN and the Tier-1 centres
- Demonstrated data distribution from CERN to the Tier-1 centres at 1.3 GByte/sec – the rate that will be needed in 2008
- ATLAS and CMS can each transfer 1 PetaByte of data per month between their computing centres
- Running ~2 million jobs each month across the grid
- The distributed grid operation, set up during 2005, has reached maturity, with responsibility shared across 7 sites in Europe, the US and Asia
- End-user analysis tools enabling “real physicists” to profit from this worldwide data-intensive computing environment



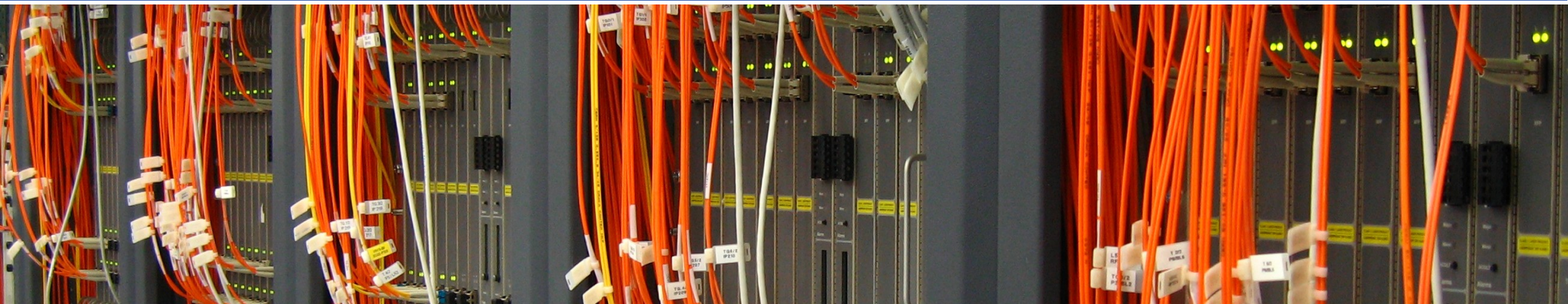
# **LHCOPN**

## **LHC Optical Private Network**

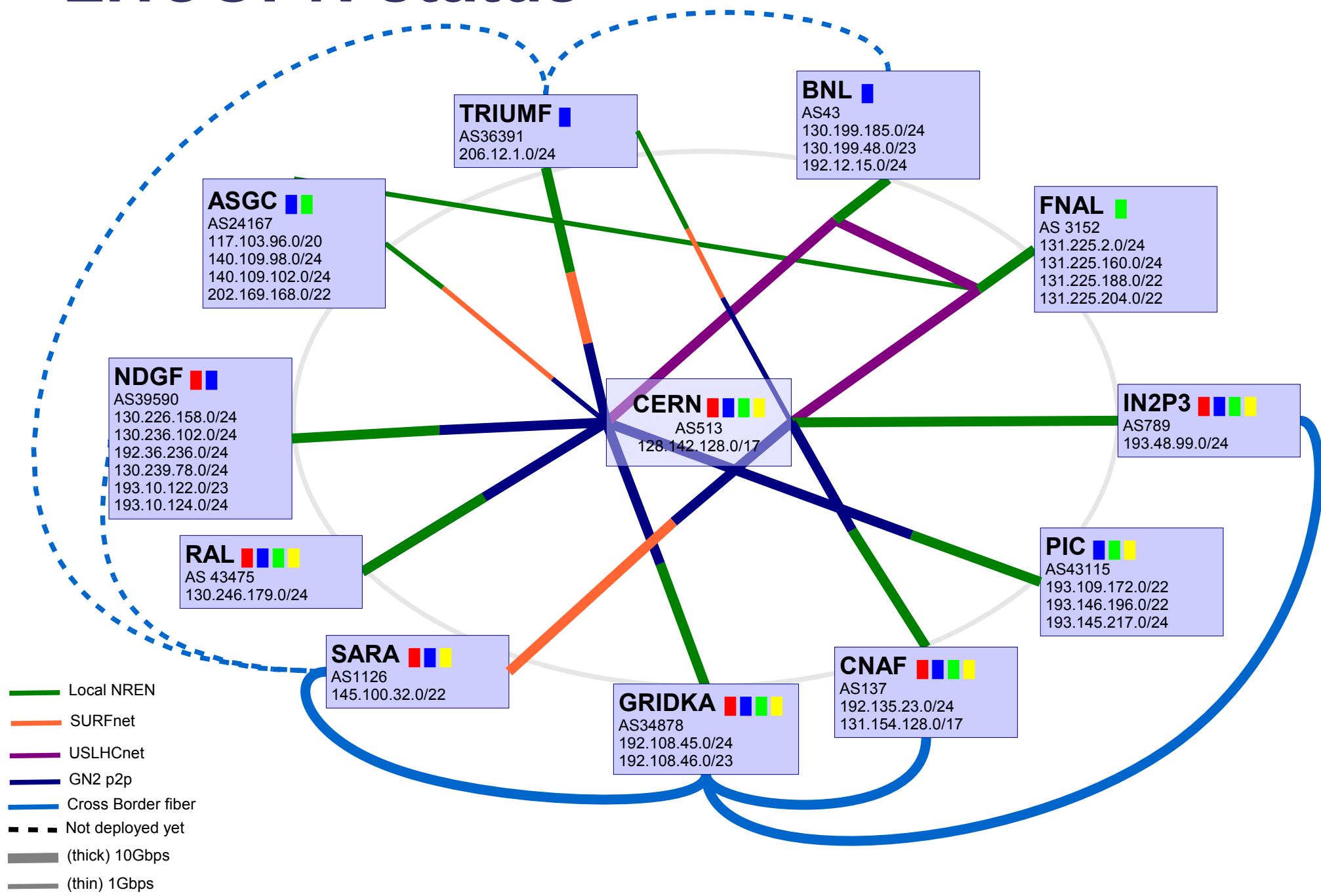
# LHCOPN



- It's a network dedicated to the LCG traffic.
- Connects the Tier0 centre with the 11 Tier1s.
- Provides the Tier1s with Tier1-Tier1 connectivity and redundant paths to the Tier0

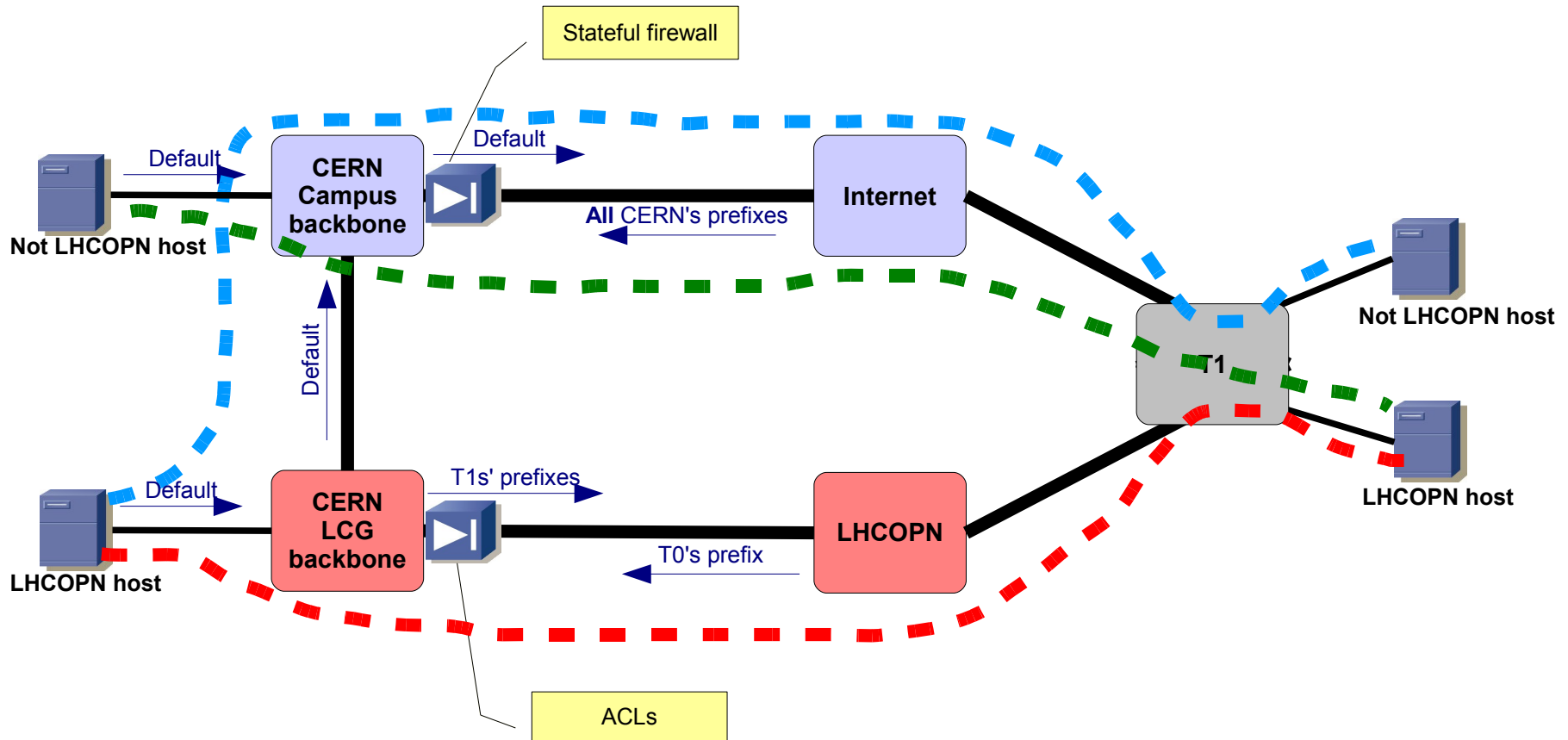


# LHCOPN status



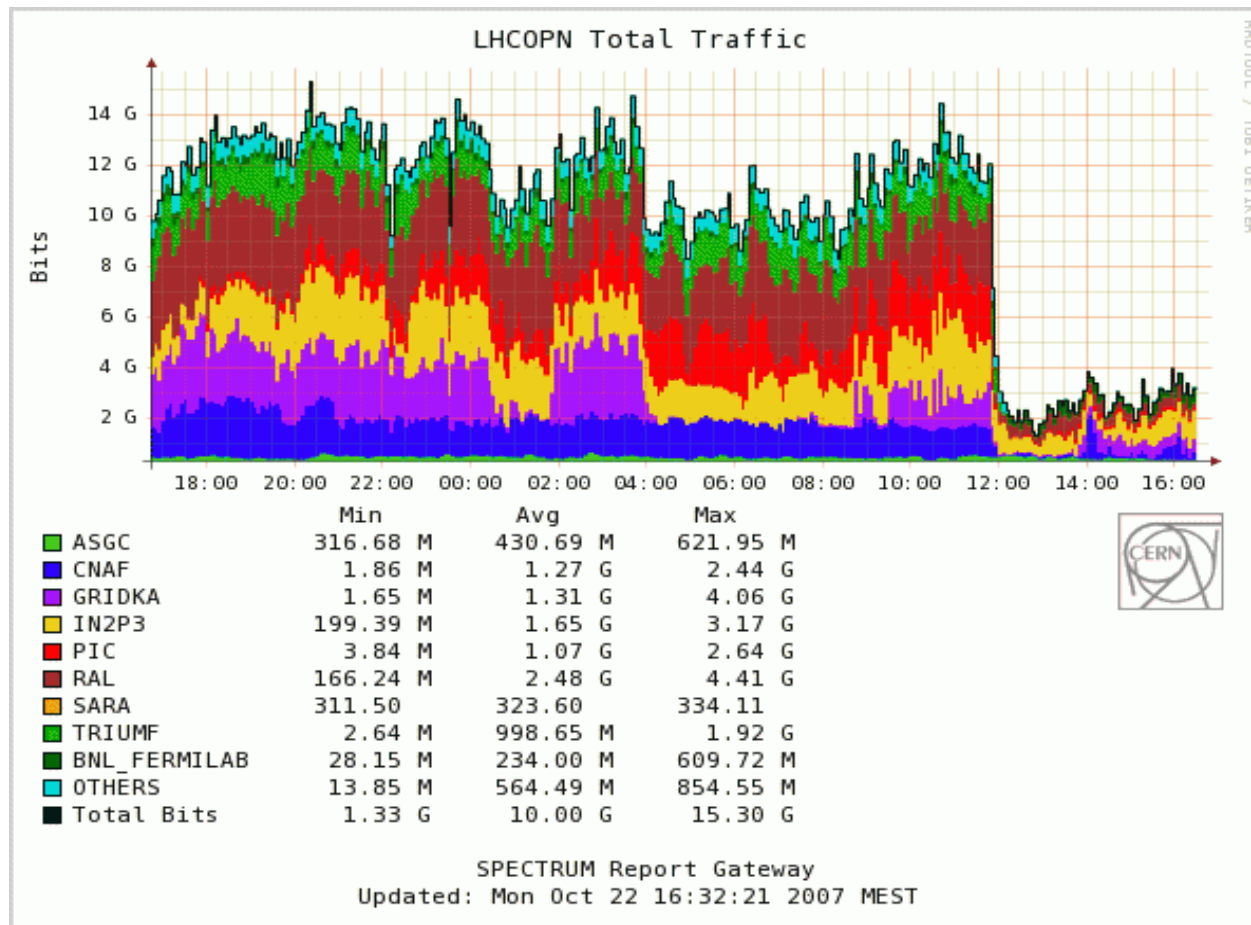
# LHCOPN - Routing

Routing must be symmetric



- LHCOPN host to LHCOPN host
- T0's LHCOPN host to T1's not LHCOPN host
- T0's not LHCOPN host to T1's LHCOPN host

# LHCOPN traffic





# LHCOPN - Multivendor

- Routing: Cisco, Force10, Juniper, Nortel
- Transmission: Alcatel-Lucent, Ciena, Huawei, Nortel, Sorrento



# Geant2

- Geant2 provides the LHCOPN with nine 10Gbps circuits
- It is an active member of the LHCOPN engineering group
- CERN hosts the Swiss Geant2 PoP



## Monitored Links for Domain CERN (Prod.)

Mon. Link Local Name	E2E Link ID	Topology Point A	Role	Topology Point B	Role	Link Type	Oper. Status	Admin. Status	Time Stamp
S513-C-BE12	<a href="#">CERN-PIC-LHCOPN-001</a>	CERN-T0	EP	GEANT2-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:40:15+02:00
S513-C-BE2	<a href="#">CERN-CNAF-LHCOPN-001</a>	CERN-T0	EP	GEANT2-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:40:46+02:00
S513-C-BE3	<a href="#">CERN-SARA-LHCOPN-001</a>	CERN-T0	EP	NETHERLIGHT-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:40:14+02:00
S513-C-BE7	<a href="#">CERN-IN2P3-LHCOPN-001</a>	CERN-T0	EP	RENATER-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:39:52+02:00
S513-C-BE9	<a href="#">CERN-GRIDKA-LHCOPN-001</a>	CERN-T0	EP	GEANT2-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:40:19+02:00
S513-C-RE1-VLAN	<a href="#">CERN-FERMI-LHCOPN-002</a>	CERN-T0	EP	USLHCNET-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:40:16+02:00
S513-C-RE10-VLAN	<a href="#">CERN-BNL-LHCOPN-002</a>	CERN-T0	EP	USLHCNET-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:40:19+02:00
S513-C-VE1-VLAN	<a href="#">CERN-FERMI-LHCOPN-001</a>	CERN-T0	EP	USLHCNET-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:40:17+02:00
S513-C-VE2-VLAN	<a href="#">CERN-BNL-LHCOPN-001</a>	CERN-T0	EP	USLHCNET-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:40:47+02:00
S513-E-EE1	<a href="#">CERN-NDGF-LHCOPN-001</a>	CERN-T0	EP	GEANT2-GEN	DP	ID Part.Info	Up	Normal Oper.	2007-10-22T16:40:44+02:00



# Operations: E2ECU and ENOC



E2E Link Monitoring System - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://stats.geant2.net/e2emon/mon/G2\_E2E\_index\_PROD.html

W testbed

E2E Link Monitoring System

[E2E Links](#)  
[Mon. Links](#)  
[Problem E2E Links](#)  
[Problem Mon. Links](#)

**Domain view**

[CANARIE](#)  
[CERN](#)  
[CESNET](#)  
[DFN](#)  
[ESNET](#)  
[FERMI](#)  
[GARR](#)  
[GEANT2](#)  
[HOPI](#)  
[IN2P3](#)  
[INTERNET2](#)  
[NETHERLIGHT](#)  
[PSNC \(?\)](#)  
[REDIRIS](#)  
[RENATER](#)  
[SWITCH](#)  
[USLHCNET](#)

**Project view**

[IGTMD](#)  
[LHCOPN](#)

**Alarms**

[Alarms by ID](#)

**Status of E2E Link CERN-IN2P3-LHCOPN-001**

Time of State Aggregation: 2007-10-23, 08:24:19 GMT (Cycle time: 60 s.)  
Operational State: **Up**  
Administrative State: **Normal Oper.**

Domain	IN2P3		RENATER				CERN		
Link Structure	EP	←.....	.....→	DP	↔	DP	←.....	.....→	EP
Type	EndPoint	ID Part.Info	ID Part.Info	Demarc	Domain Link	Demarc	ID Part.Info	ID Part.Info	EndPoint
Local Name	IN2P3-LHCOPN1	IN2P3-CERN_LYON	RENATER-LYO-CERN-IN2P3	RENATER-LYO	RENATER-GEN-LYO	RENATER-GEN	RENATER-GEN-CERN	S513-C-BE7	CERN-T0
State Oper.	-	Up	Up	-	Up	-	Up	Up	-
State Admin.	-	Normal Oper.	Normal Oper.	-	Normal Oper.	-	Normal Oper.	Normal Oper.	-
Timestamp	-	2007-10-23 T07:25:01.0-6:00	2007-10-23 T9:28:00.0+0000	-	2007-10-23 T9:28:00.0+0000	-	2007-10-23 T9:28:00.0+0000	2007-10-22 T17:56:56+02:00	-

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Done

# Tier2s

Traffic among Tier1s and Tier2s goes outside the LHCOPN, via NREN backbones (GN2, Esnet, Abilene...) or direct links.

The CERN Tier1 is directly connected with Moscow (1Geth provided by Surfnet and RIPN), Mumbai (1Geth provided by Surfnet and Flag).



# Conclusions

- Network and computing are parts of the big LHC instrument.
- June 2008: starts of LHC
- LCG ready for physics



**Thank you**