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The LHC computing challenge

-The LHC and the experiments

-The computing challenges

- The LHC computing grid

- The LHC status (if time or questions)

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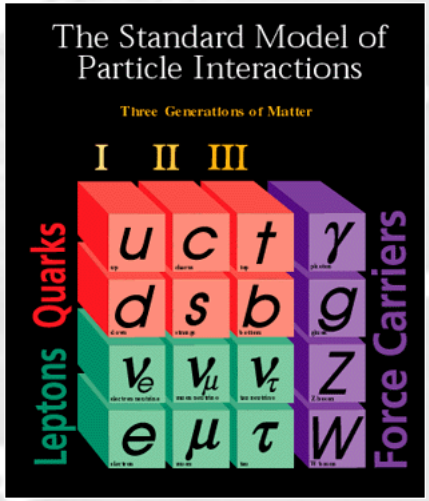
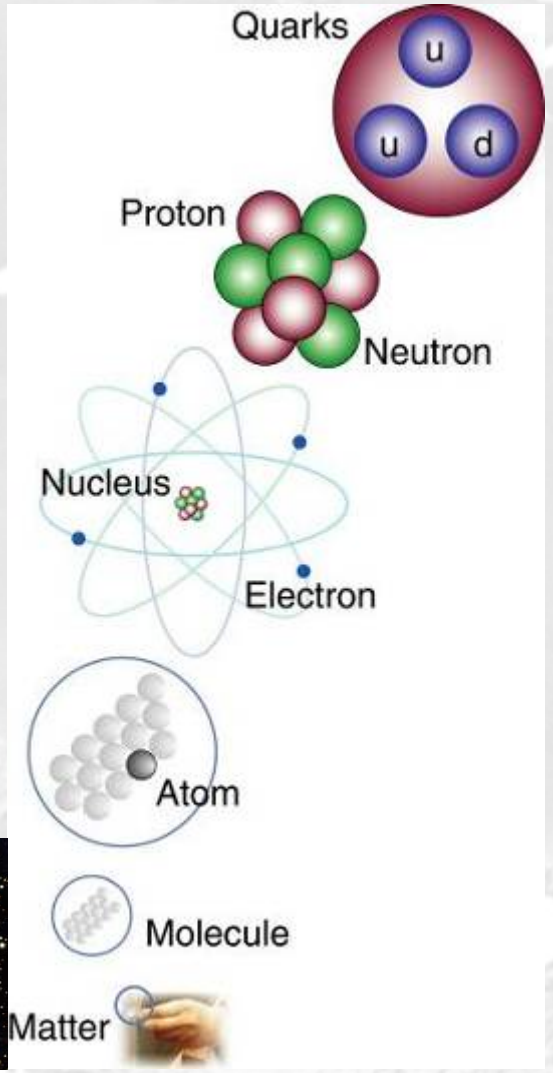
The LHC and the experiments

Motivations for the LHC experiments

Physics motivations:

We currently have a good and very accurate model that has been extensively validated by experiment!
But it is – **at best** – incomplete (or possibly wrong)





leaving some important open questions:

- What is the origin of the particle masses?
- Why three generation of quarks and leptons
- Why are neutrinos so light compared to charged leptons?
- What about quantum gravity?
- What is the origin of dark matter?
- What is the origin of dark energy?
- …

The Large Hadron Collider (LHC)

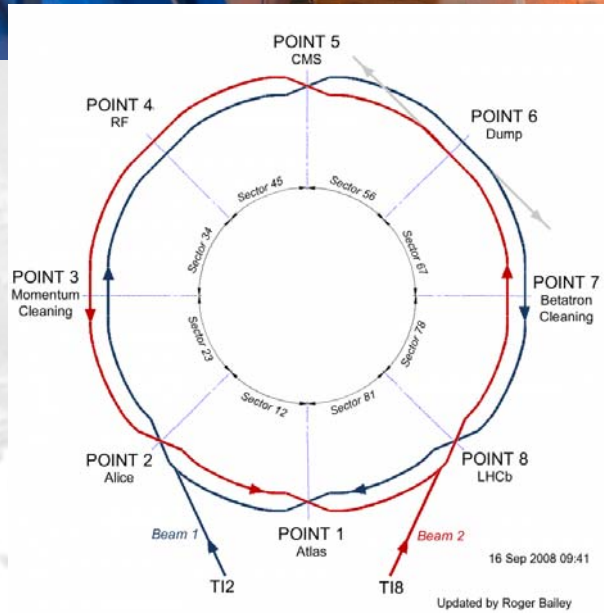
-A discovery machine able to open a new window in energy <-> mass

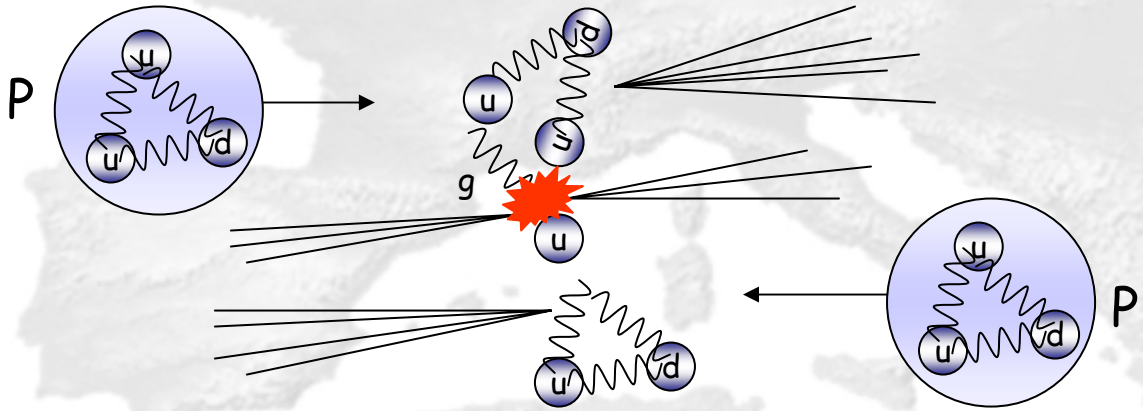
-A proton-proton collider (ion-ion) (two accelerators in one machine)

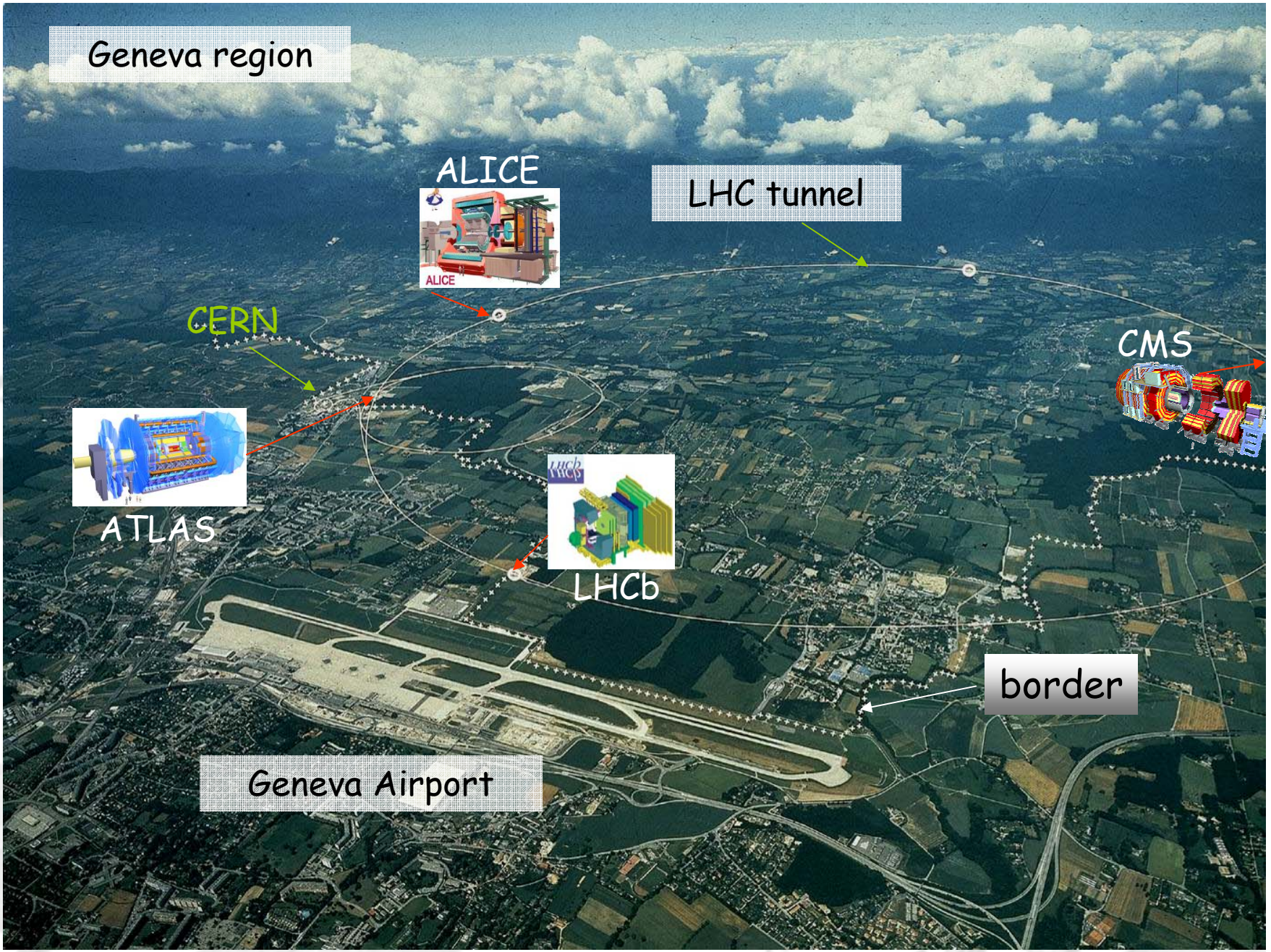
-27km, 100m deep,
40000 tons@1,8°K

-15 years of construction

-10^9 collisions/s at high luminosity






Geneva region
ALICE
ALICE
LHC tunnel
CERN
CMS
ATLAS
LHCb
border
Geneva Airport

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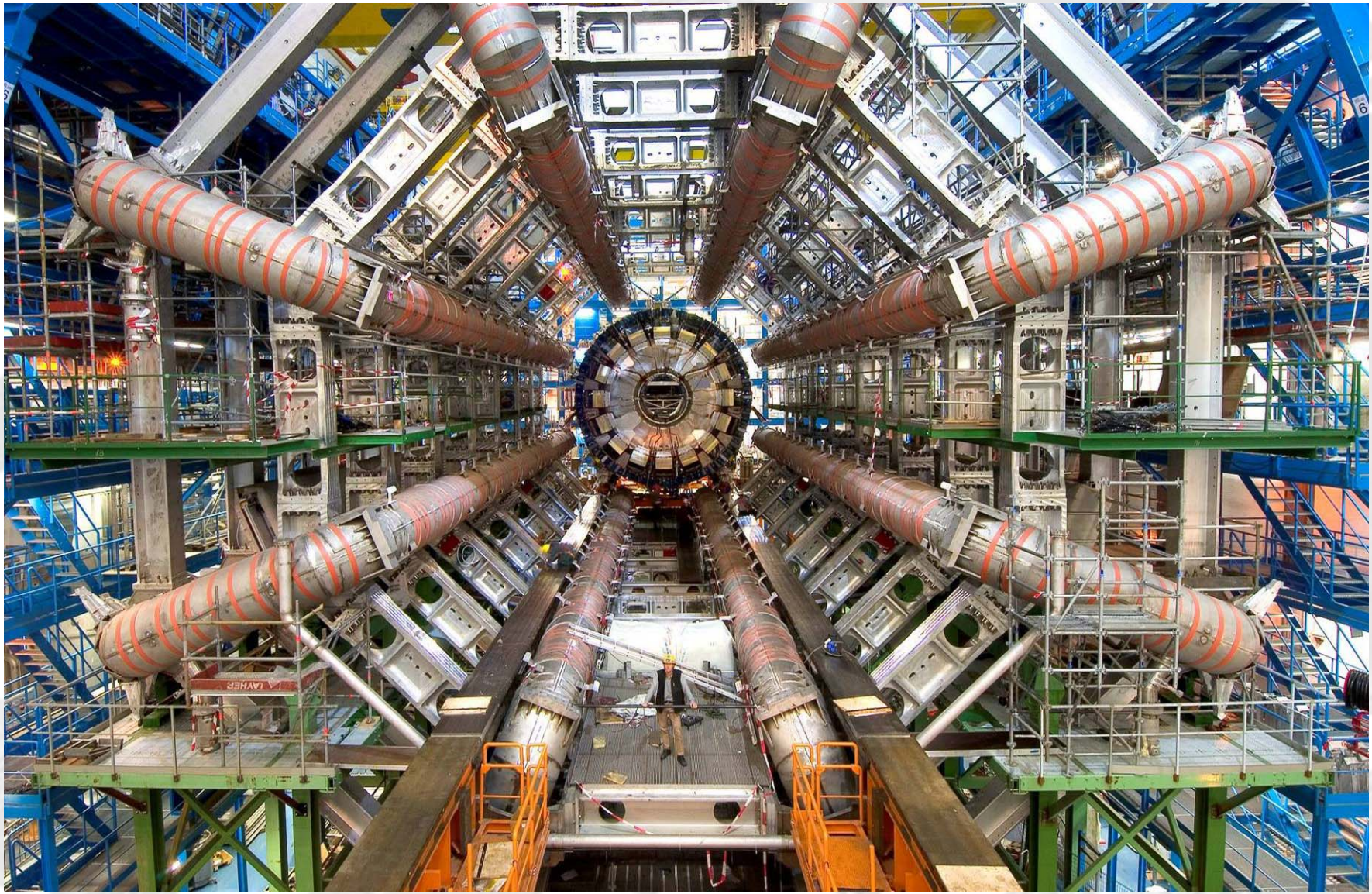
ATLAS November 2005



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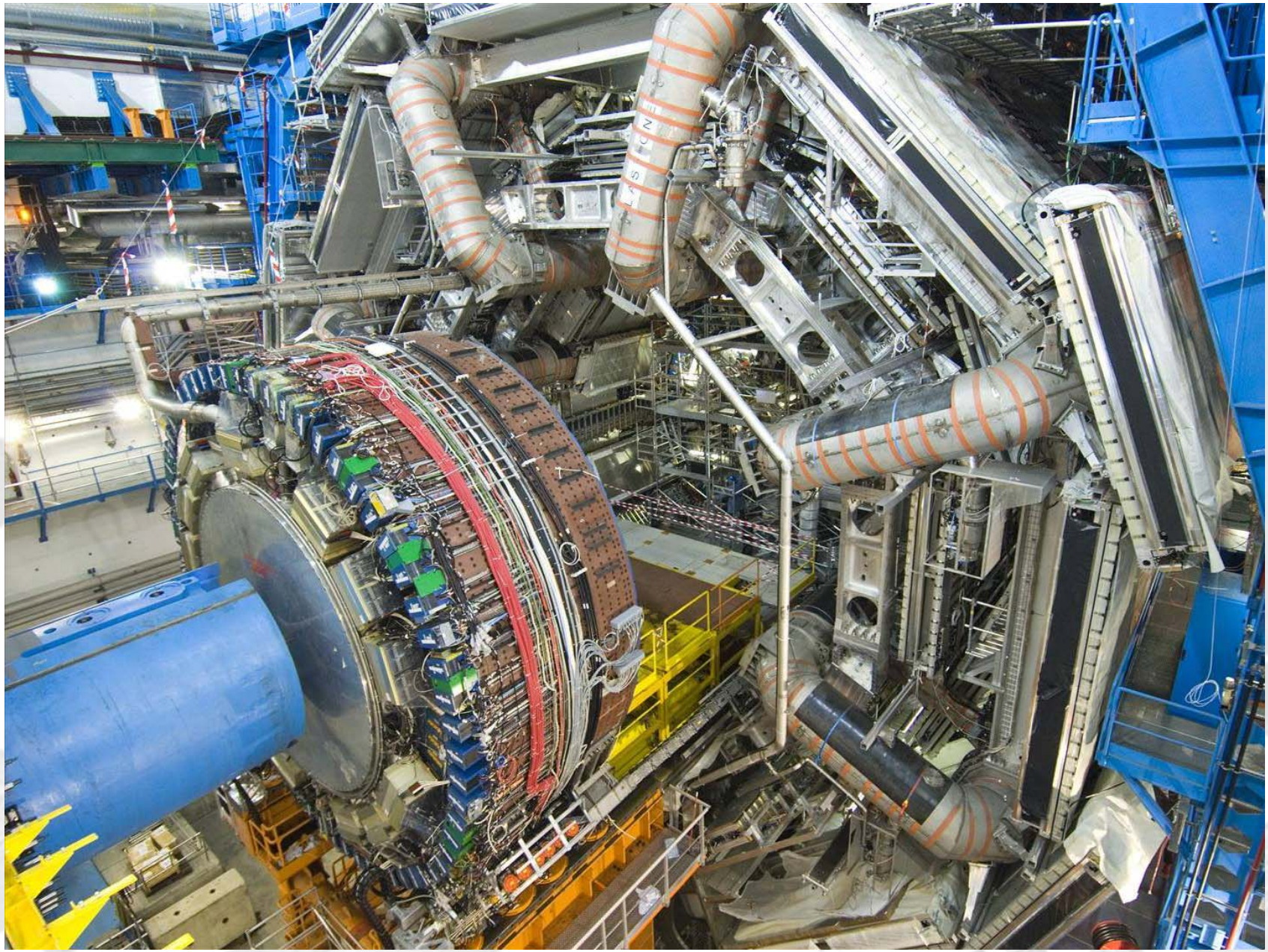

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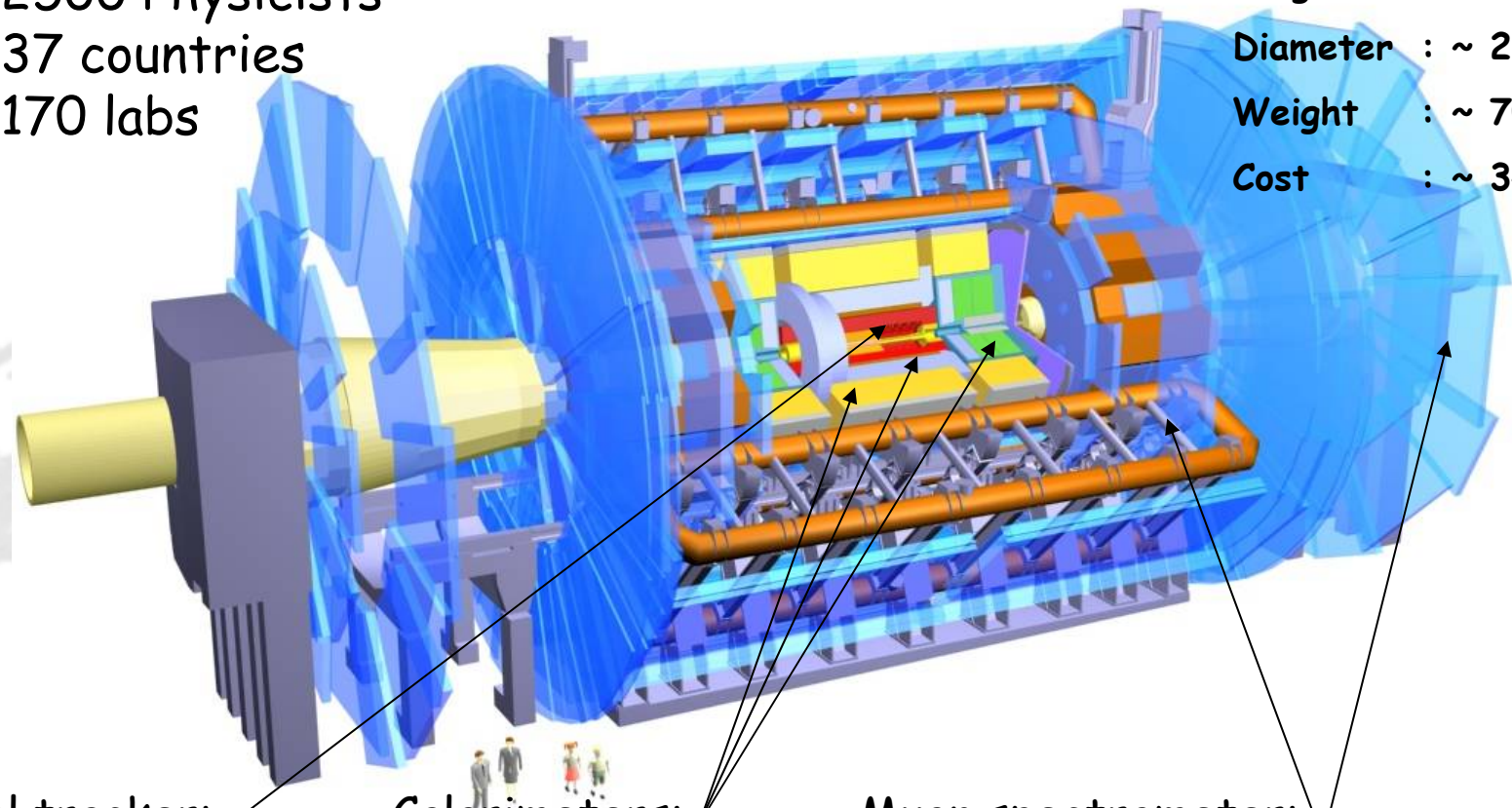
The LHC experiments

2500 Physicists
37 countries
170 labs

Length : ~ 46m
Diameter : ~ 25m
Weight : ~ 7000 tons
Cost : ~ 340M€



Central tracker:
charged particles
140×10^6 channels

Calorimeters:
Particle energy
2×10^5 channels

Muon spectrometer:
Muon momentum
7×10^5 channels

Zero online suppression → ~1,6 MB/event
10^9 collisions/s → online selection → 200 Hz
→ 320 MB/s

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The computing challenges

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Estimation of the amount of data

Challenges:

-Running the four LHC experiments over 200 d/y. Taking into account several inefficiencies → 10-15 PB of data per year

-Need of large Monte-Carlo simulation → ~5PB/y at least

→ ~ 15-20 PB/y of data to treat

→ ~ 100000 cores needed to treat and simulate the LHC data

-About 6000 physicists from > 50 countries (>200 labs)

→ distributed access to the data is mandatory

Good news:

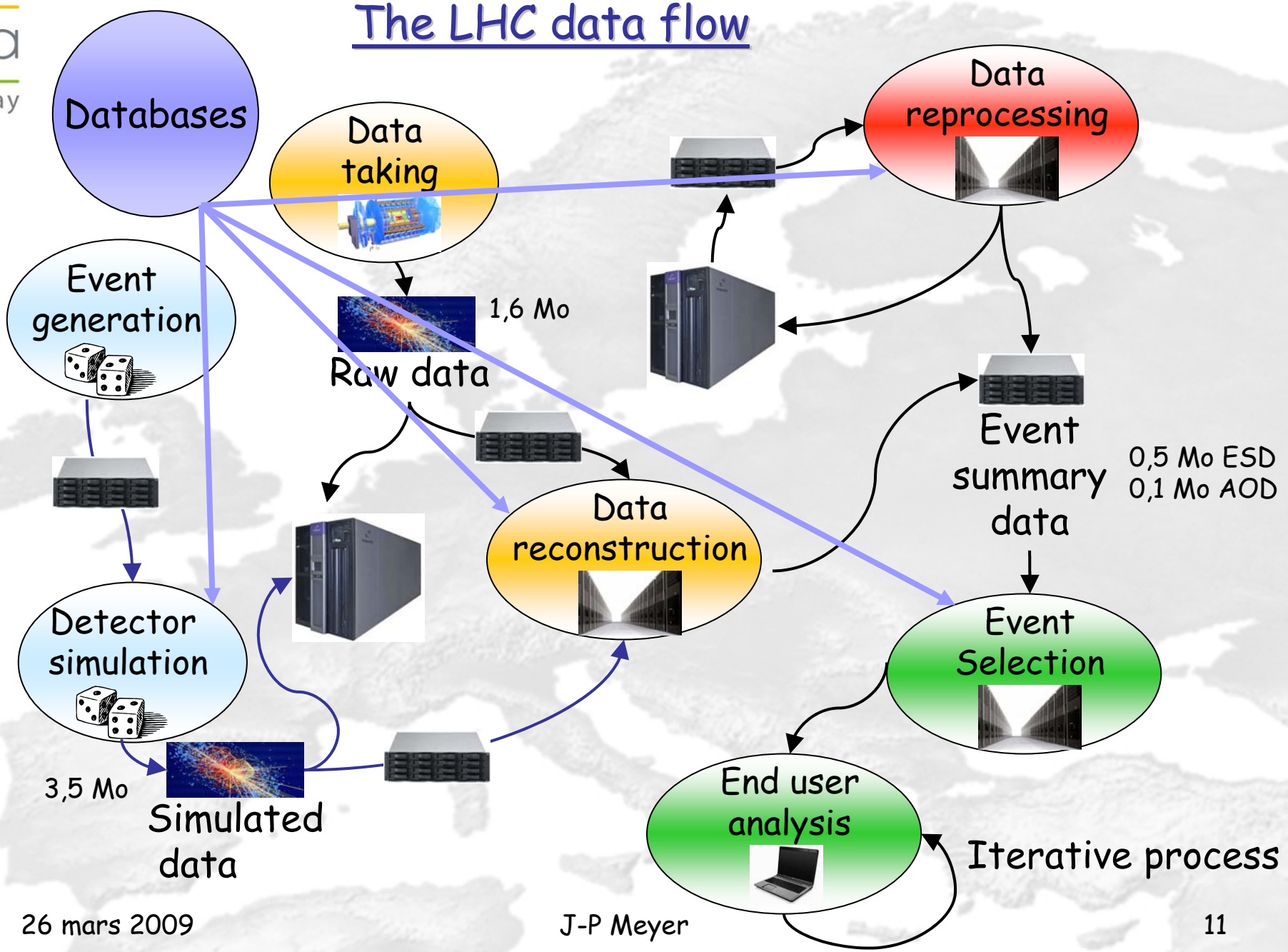
-The events are independent from each others.

-Each event can be treated in a single core having 2GB of memory

-Network bandwidth and computing power have strongly increased since 1995 (LHC approval)

→ early 2000: **could distributed computing by the solution?**

The LHC data flow



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needs for such a distributed resource

Inputs:

- CERN play's a central role as the data source
- national centres already exist in the HEP community
- end users running the analysis are spread around the world
- pan European network exists (GEANT) but what about fare countries?

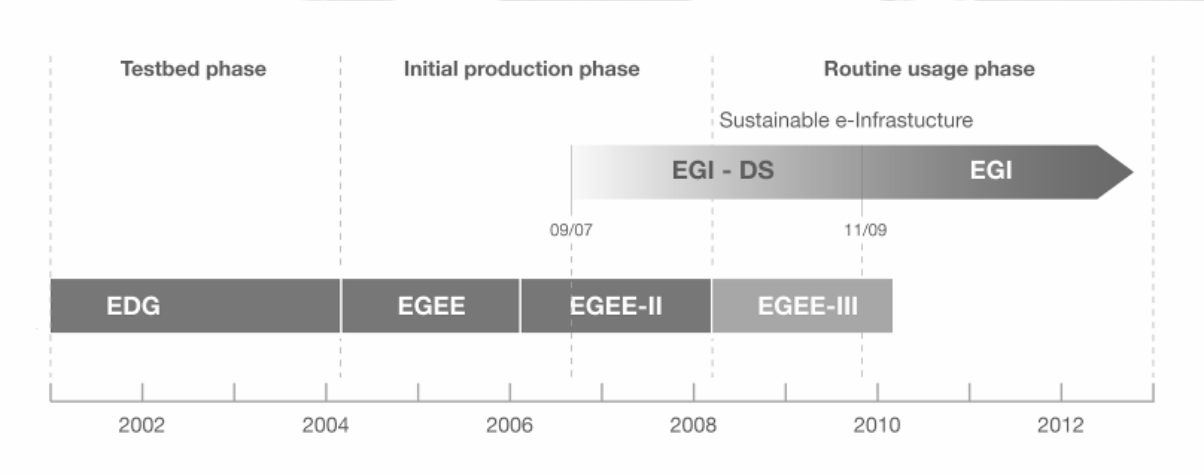
The major challenges are:

- distribution of large amount of data in almost real time over long periods of time
- disk to disk , disk to tape and tape to tape throughputs
- work around of possible single point of failure
- how can one bring all that together?
- …,…,…

→ **stability**, **scalability** and **robustness** of the **whole system**

Grid: the next generation large scale e-infrastructure ?

→ DataGrid and EGEE launched to build the European Grid having in mind to cover a much larger scientific domain a just the LHC physics.



Similar but independent efforts where undertaken in other countries like the US → several grids where burned up.

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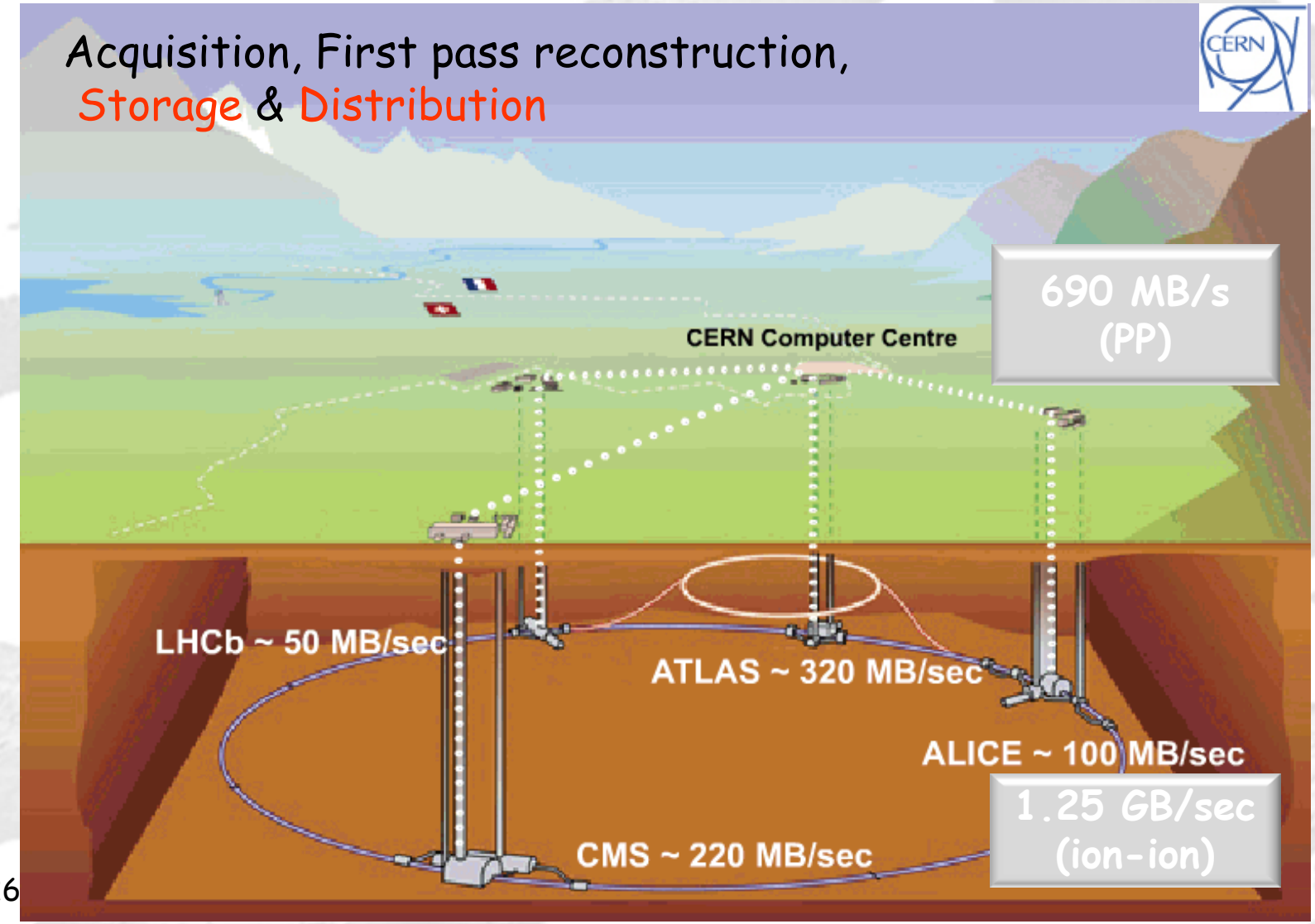
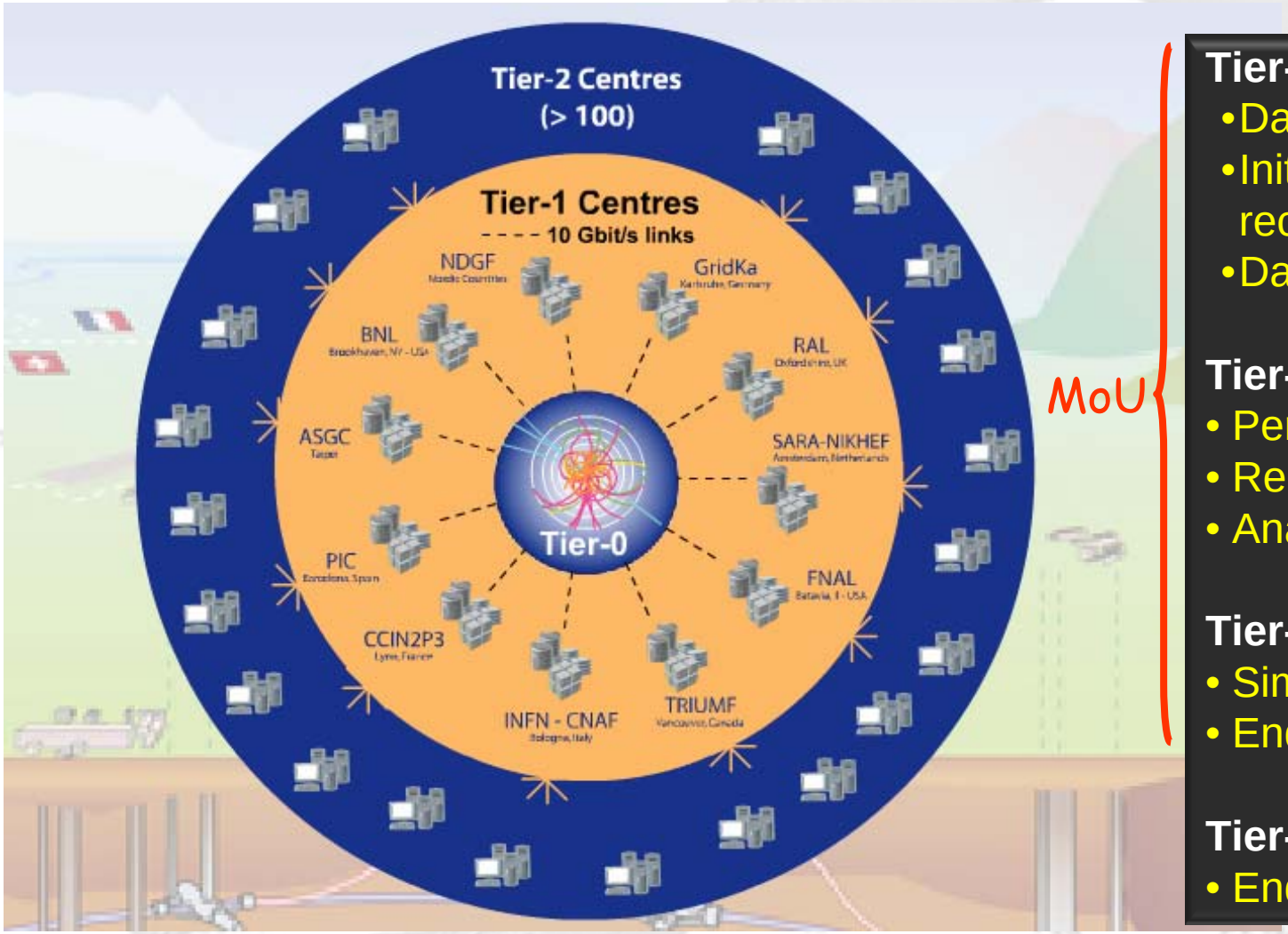
The LHC Computing Grids

Tier 0 at CERN



The LCG hierarchical computing model



MoU

Tier-0 (CERN):
- Data recording
- Initial data reconstruction
- Data distribution

Tier-1 (11 centers):
- Permanent storage
- Re-processing
- Analysis

Tier-2 (>100 centers):
- Simulation
- End-user analysis

Tier-3 (>100 centers)
- End-user analysis

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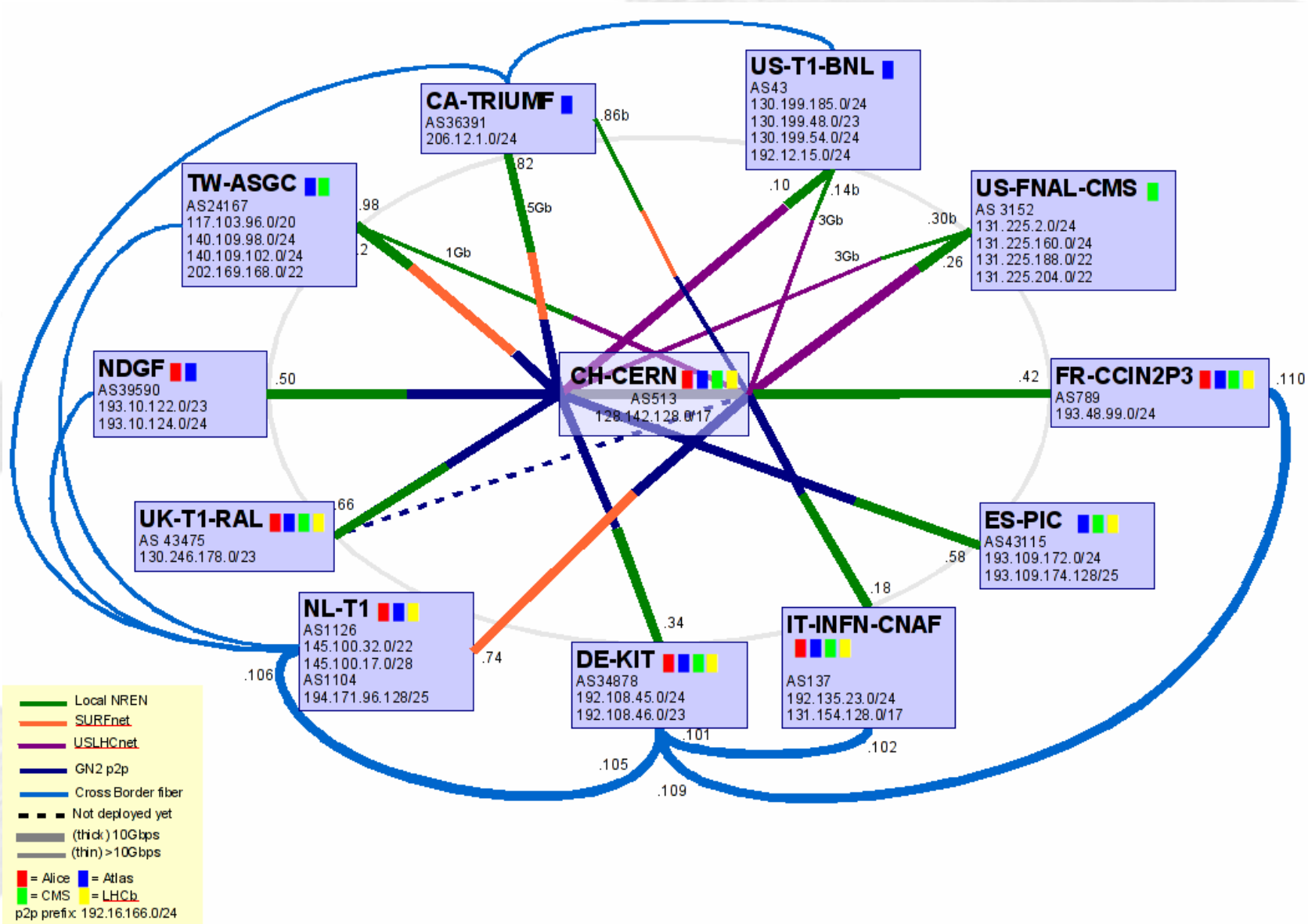
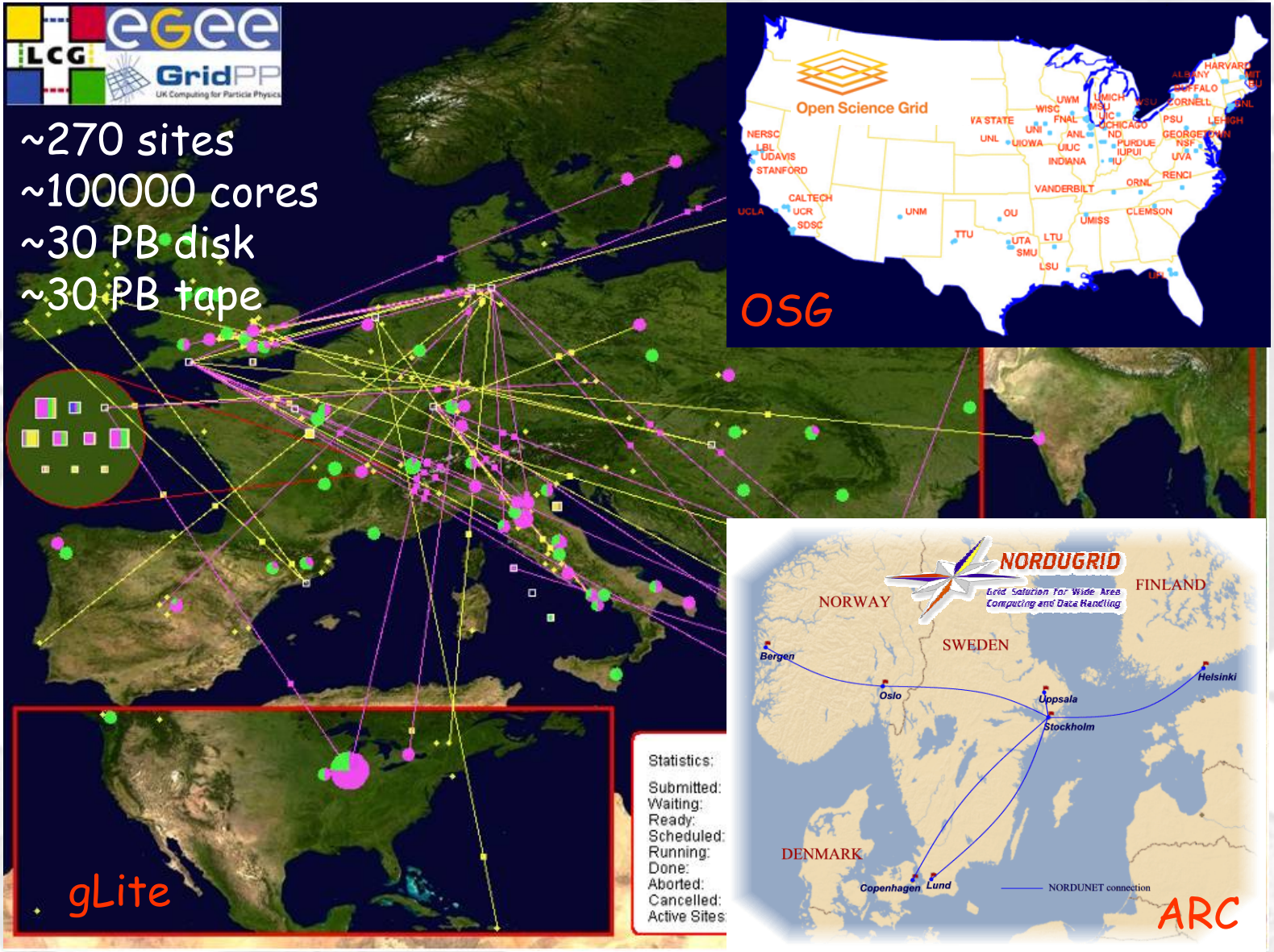
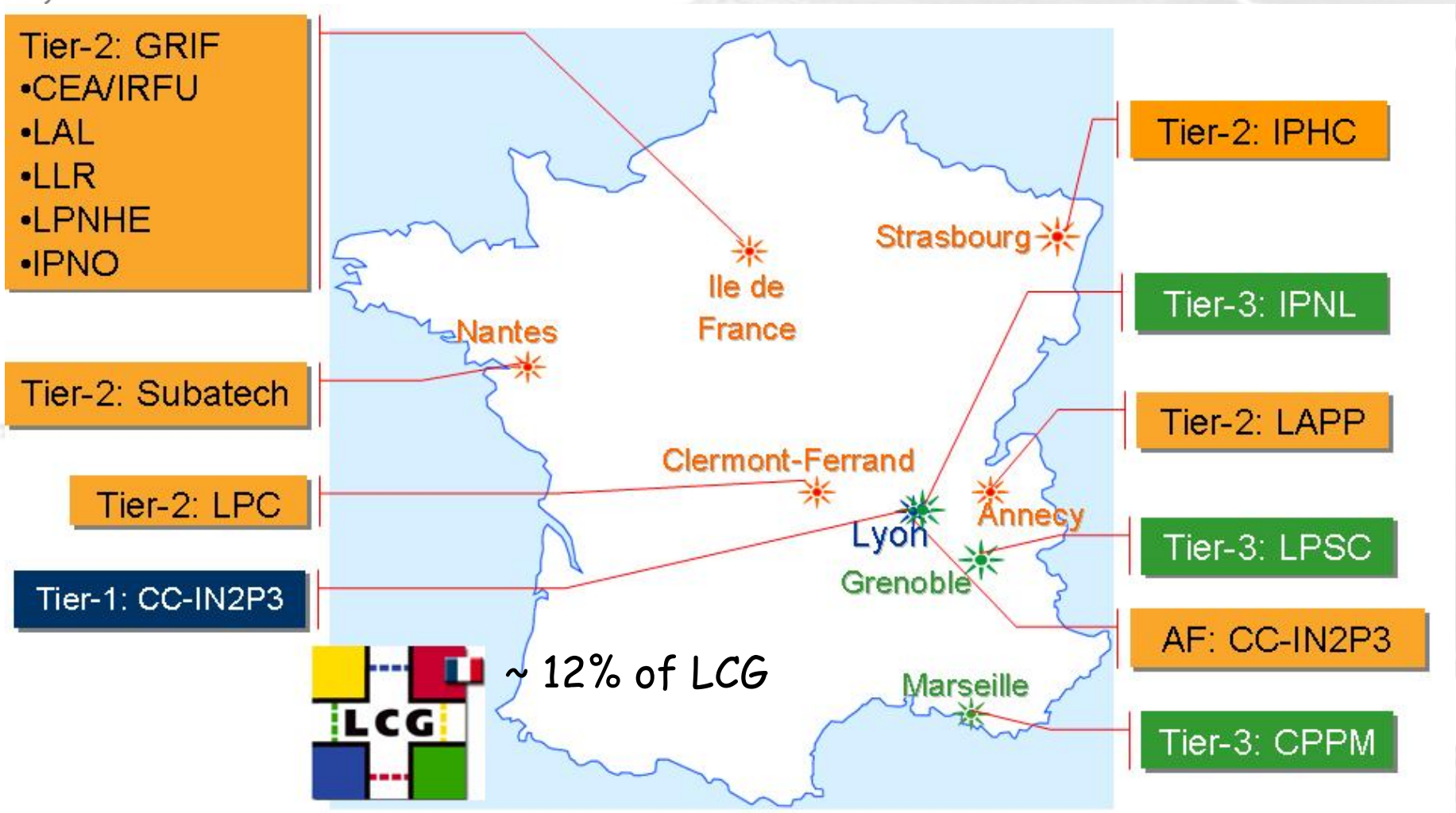
Network infrastructure status → LHCOPN



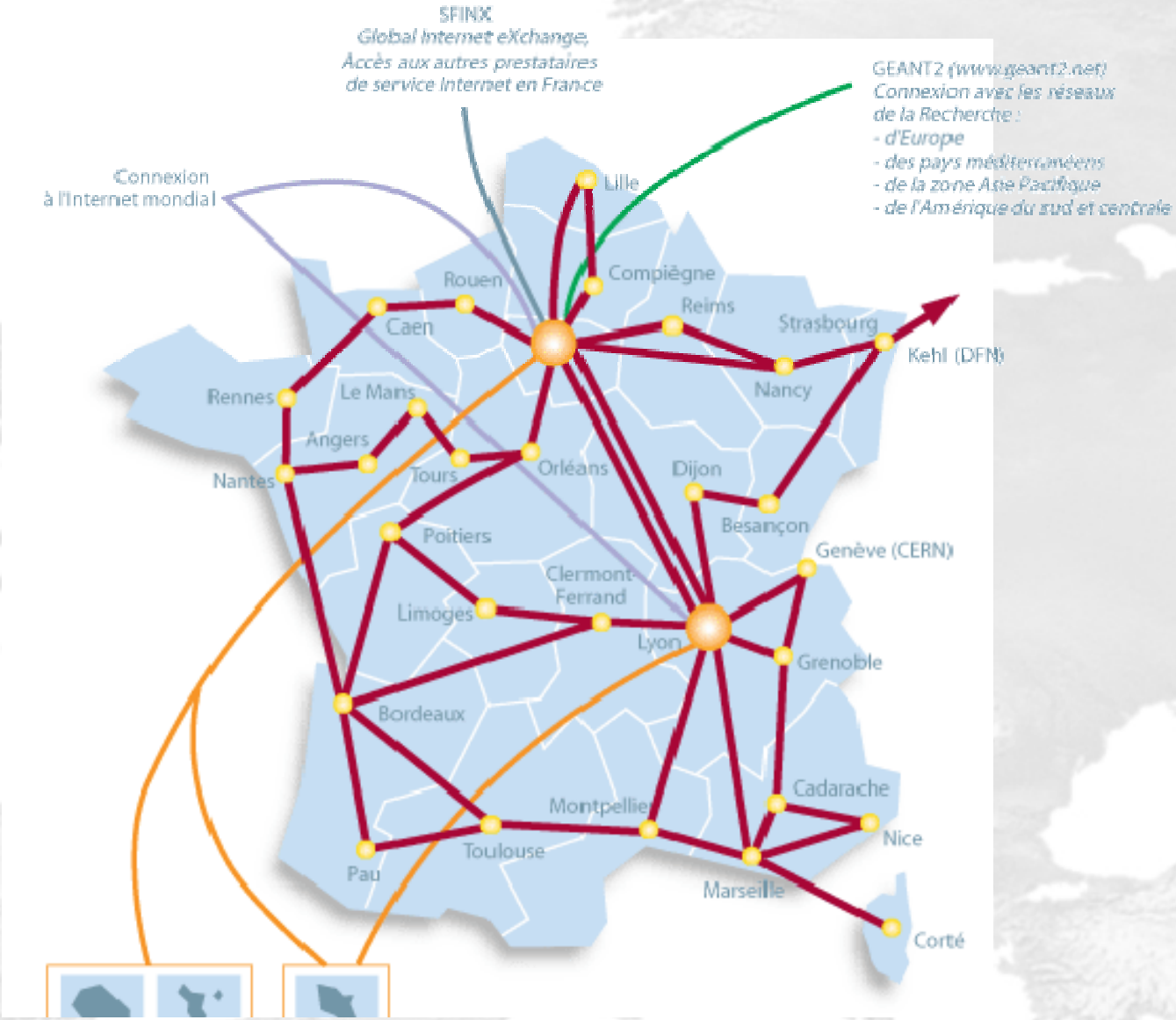
Grids supporting LCG



The French part of LCG



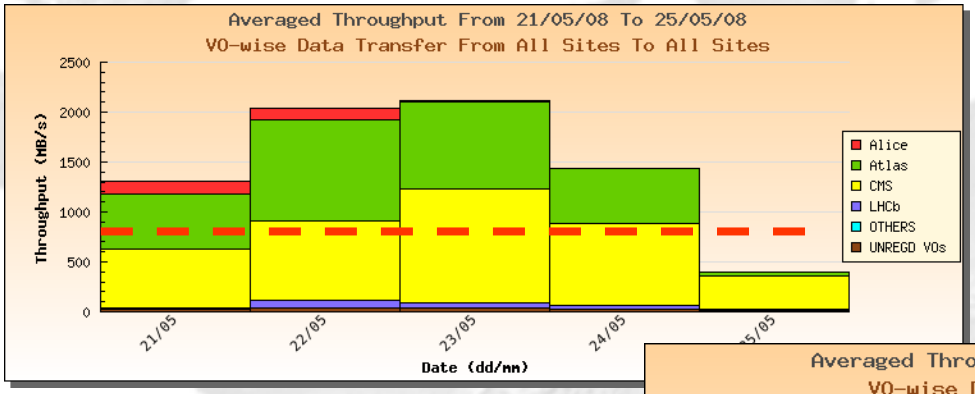
LCG-Fr fully supported by RENATER(5)

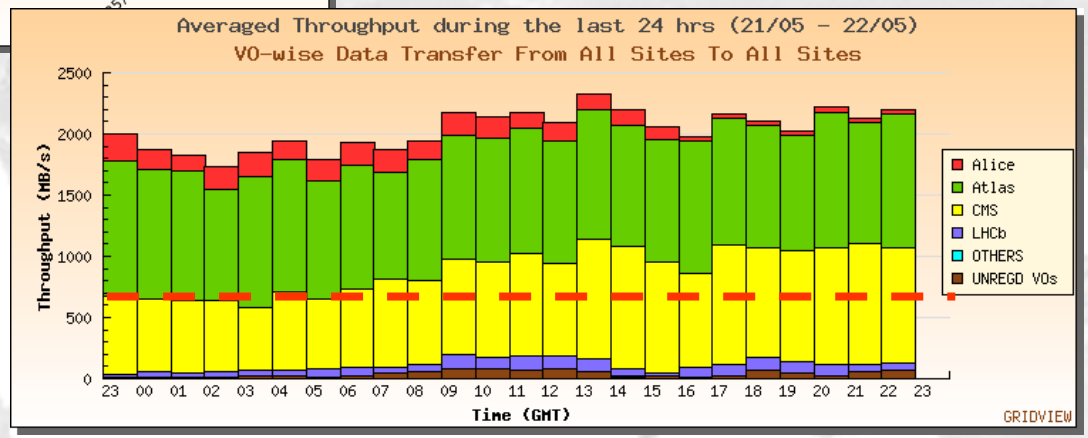


LCG Readiness

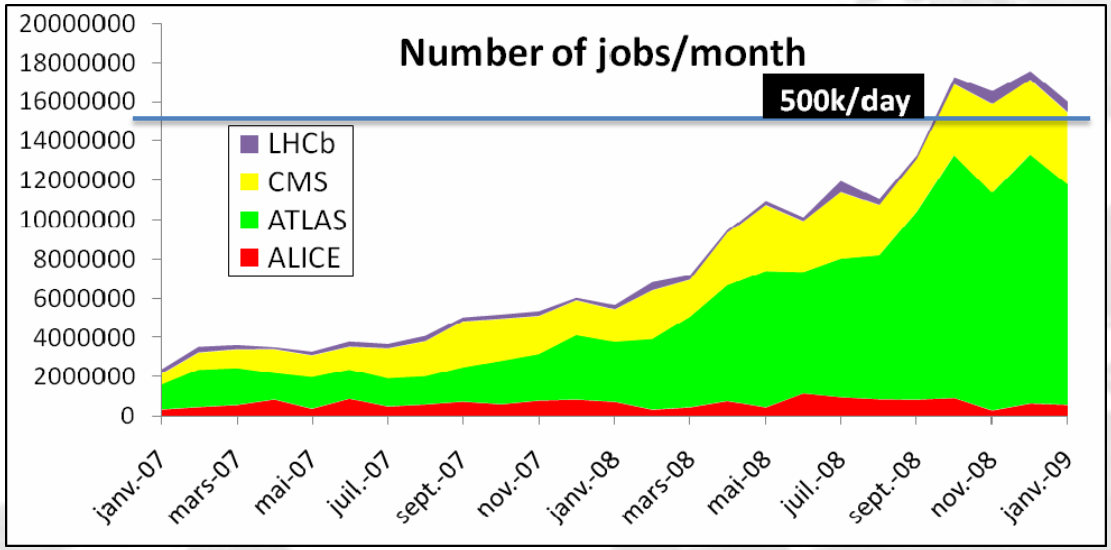
- Many tests of data transfer and distributed computing have been organized these last years under the forms of challenges in order to show our capability to achieve the need performances.

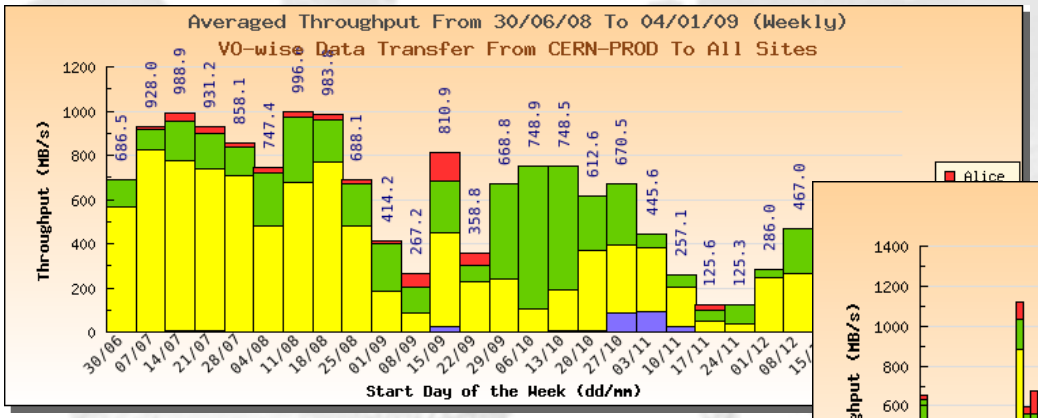
- 2008 we the first **Combined Computing Readiness Challenge (CCRC08)**

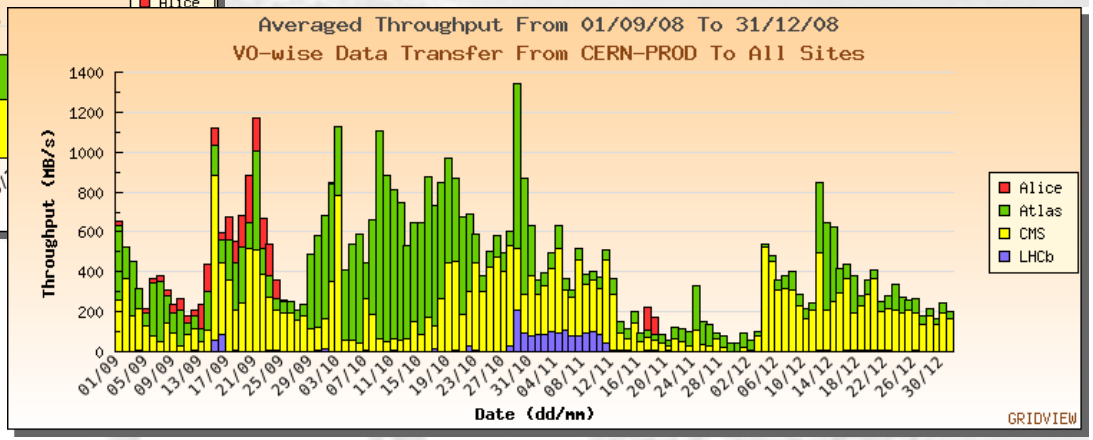




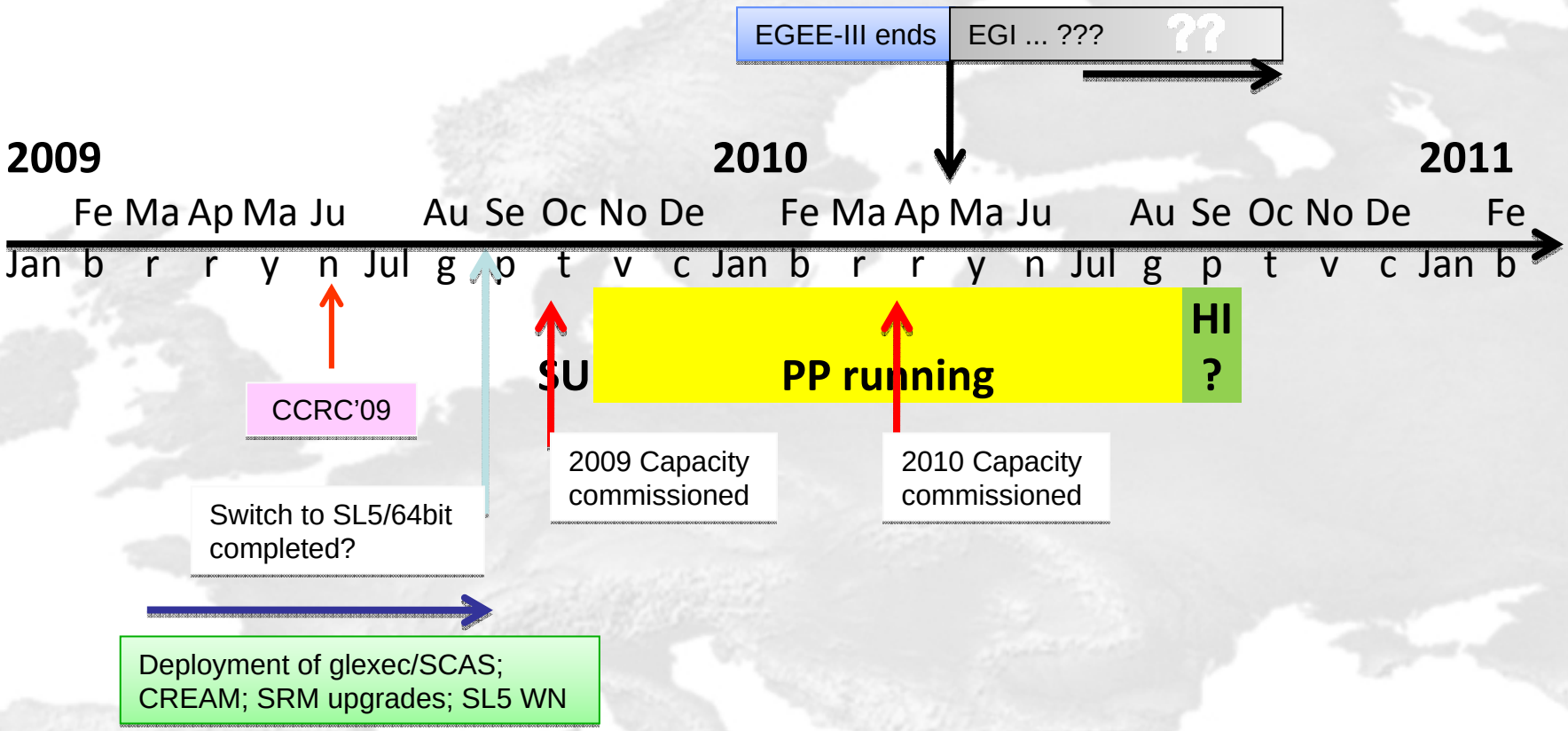
Post CCRC08


Number of jobs/month
500k/day
LHCb
CMS
ATLAS
ALICE
20000000
18000000
16000000
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
janv.-07
mars-07
mai-07
juil.-07
sept.-07
nov.-07
janv.-08
mars-08
mai-08
juil.-08
sept.-08
nov.-08
janv.-09


Averaged Throughput From 30/06/08 To 04/01/09 (Weekly)
VO-wise Data Transfer From CERN-PROD To All Sites
Throughput (MB/s)
Start Day of the Week (dd/mm)
Alice


Averaged Throughput From 01/09/08 To 31/12/08
VO-wise Data Transfer From CERN-PROD To All Sites
Throughput (MB/s)
Date (dd/mm)
Alice
Atlas
CMS
LHCb
GRIDVIEW

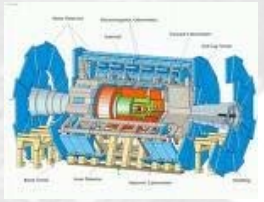
WLCG timeline 2009-2010



We will have a hard but exciting time during this period…
… and probably beyond …

The LHC status

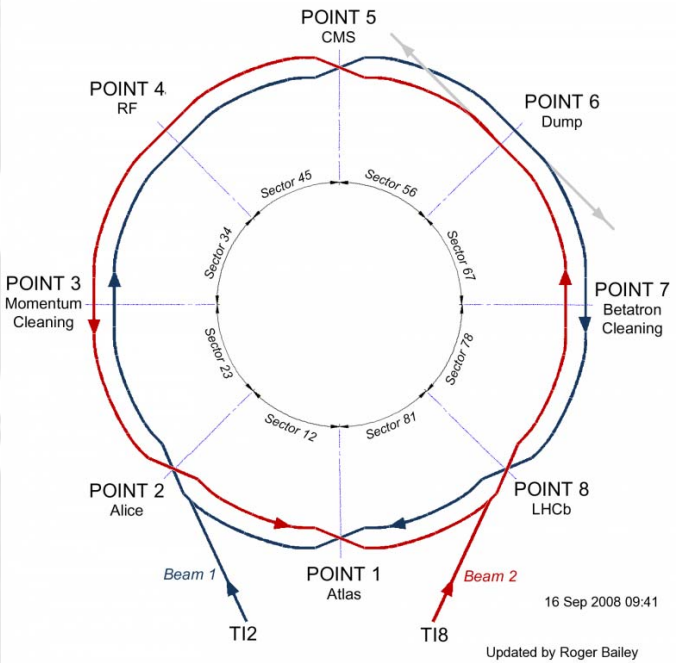
Physics results

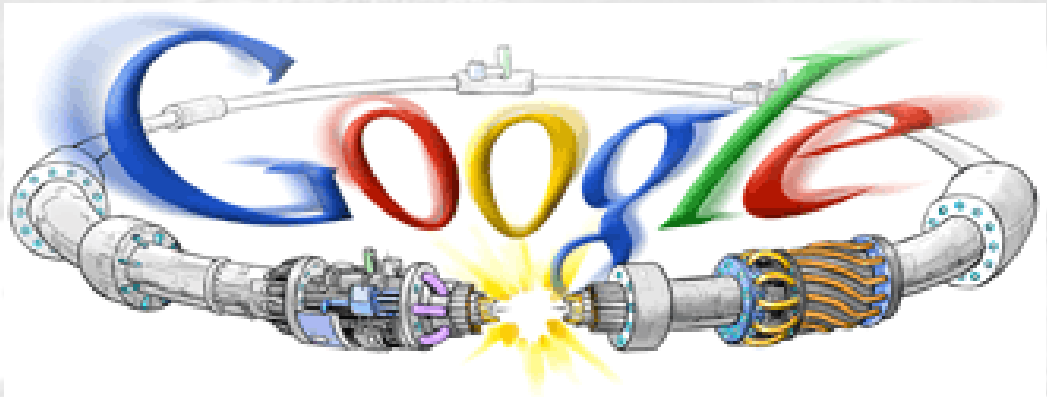


September 10th

- Achieved
  - Beam 1 injected IP2 (450 GeV)
  - Threaded around the machine in 1h
  - Trajectory steering gave 2 or 3 turns

  - Beam 2 injected IP8 (450 GeV)
  - Threaded around the machine in 1h30
  - Trajectory steering gave 2 or 3 turns
  - Q and Q' trims gave a few hundred turns





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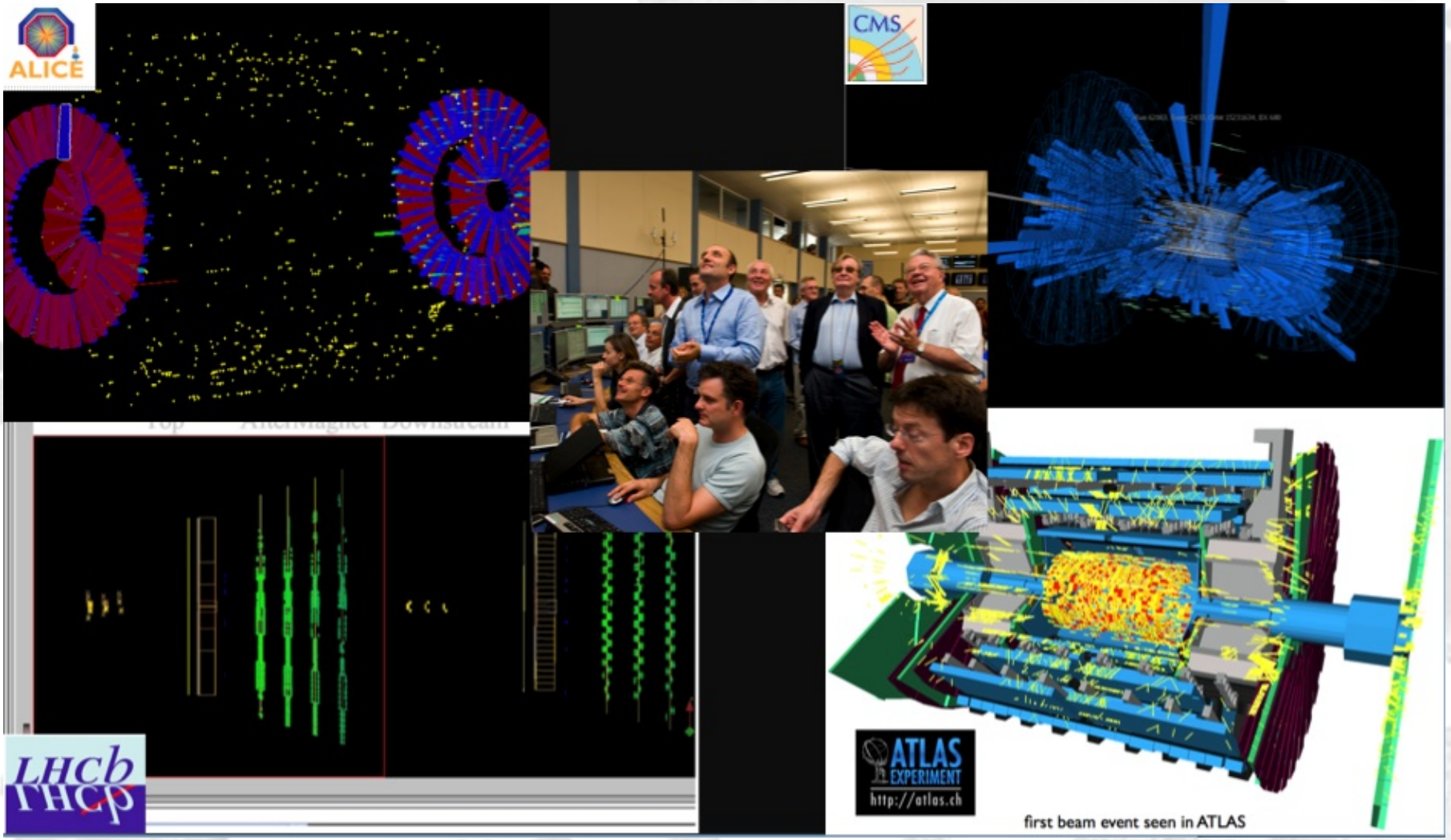
First Beam Events



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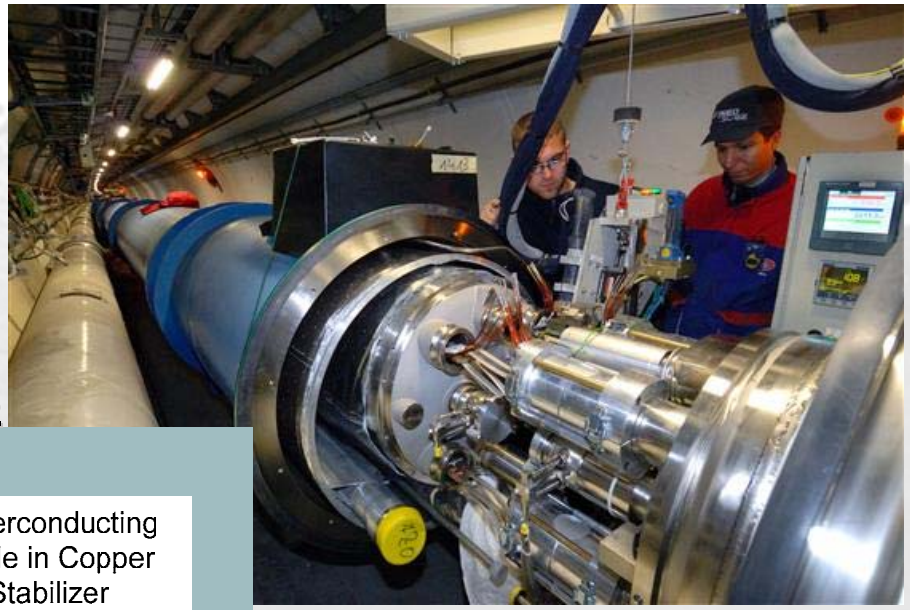
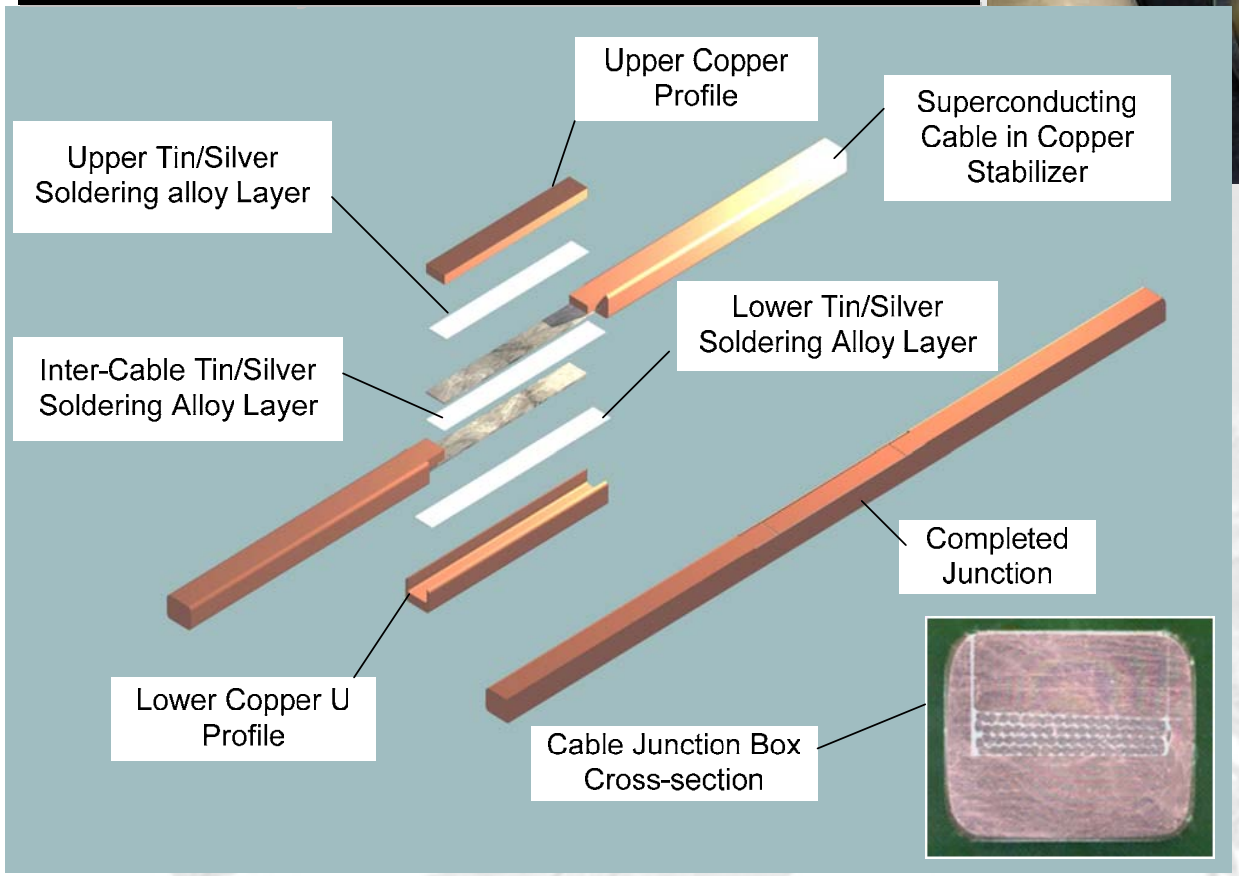
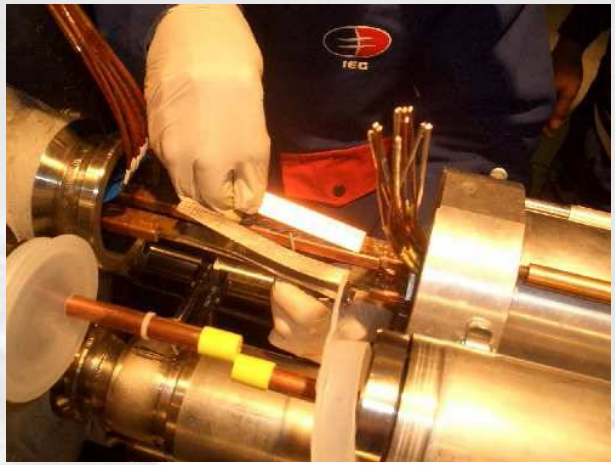
One junction became resistive → local heating up → over pressure and failure of a security vent → **accident**



Electrical joints on 12 kA bus bars





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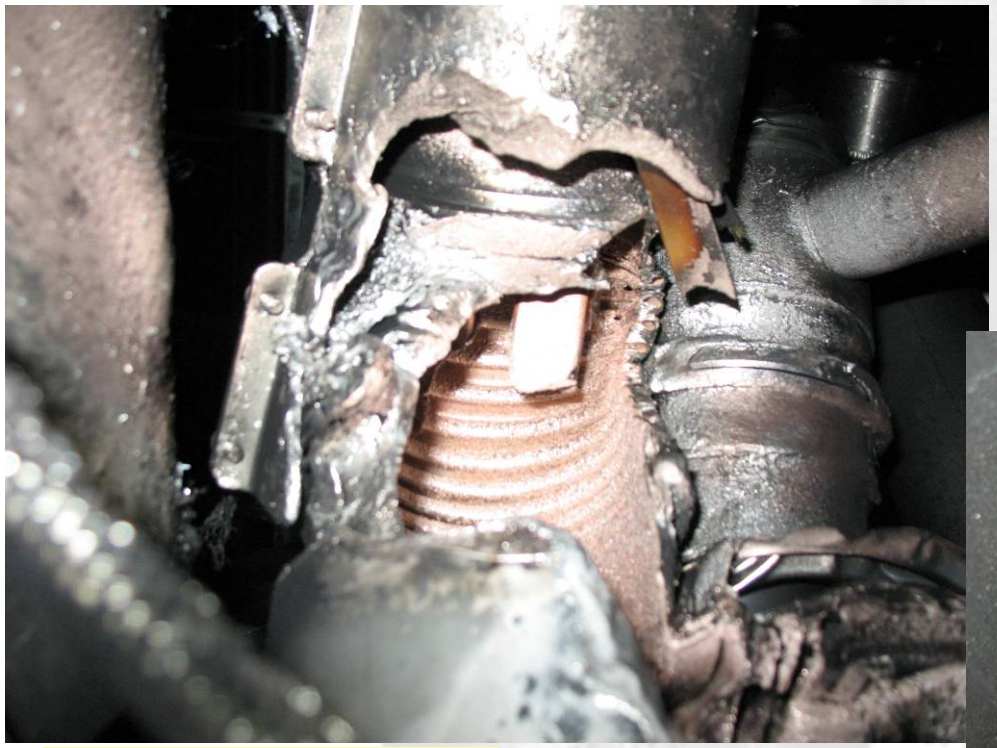
magnet displacements

QQBI.27R3

secondary arcs



QQBI.27R3 M3 line

QBBI.B31R3 M3 line

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Broken ground supports

LHC Schedule

Schedule with running in winter months

- Gains 20 weeks of LHC physics (independent of "slip")