An aerial photograph of a valley with a river and mountains in the background. A red oval outline is drawn around the central text area.

SUMMER STUDENTS LECTURE PROGRAMME

WHAT IS CERN?

Dieter Schlatter. CERN. Geneva

July 6, 2005

The first proposal (De Broglie, 1949)

“...a laboratory or institution where it would be possible to do scientific work, but somehow beyond the framework of the different participating states.

...this body could be endowed with more resources than national laboratories and could, consequently, undertake tasks...beyond their scope...”

Collaboration could be easier due to the “true nature of science”

This kind of cooperation would serve also other disciplines

The twenty Member States of CERN (2005)



Left to Right: Pierre Auger, Edoardo Amaldi and Lew Kowarski, at the first session of the provisional CERN Council (1952)



States (Dates of Accession)

AUSTRIA (1959)	DENMARK (1953)	GREECE (1953)	NORWAY (1953)	SPAIN (1/1961-12/1968-1/1983)
BELGIUM (1953)	FINLAND (1991)	HUNGARY (1992)	POLAND (1991)	SWEDEN (1953)
BULGARIA (1999)	FRANCE (1953)	ITALY (1953)	PORTUGAL (1986)	SWITZERLAND (1953)
CZECH FR (1993)	GERMANY (1953)	NETHERLANDS (1953)	SLOVAK FR (1993)	UNITED KINGDOM (1953)

CERN AC/DI/MM - ES36C 1999 - 15/6/99



OBSERVERS:

UNESCO, EU, Israel, Japan, Turkey, USA, Japan, Russia

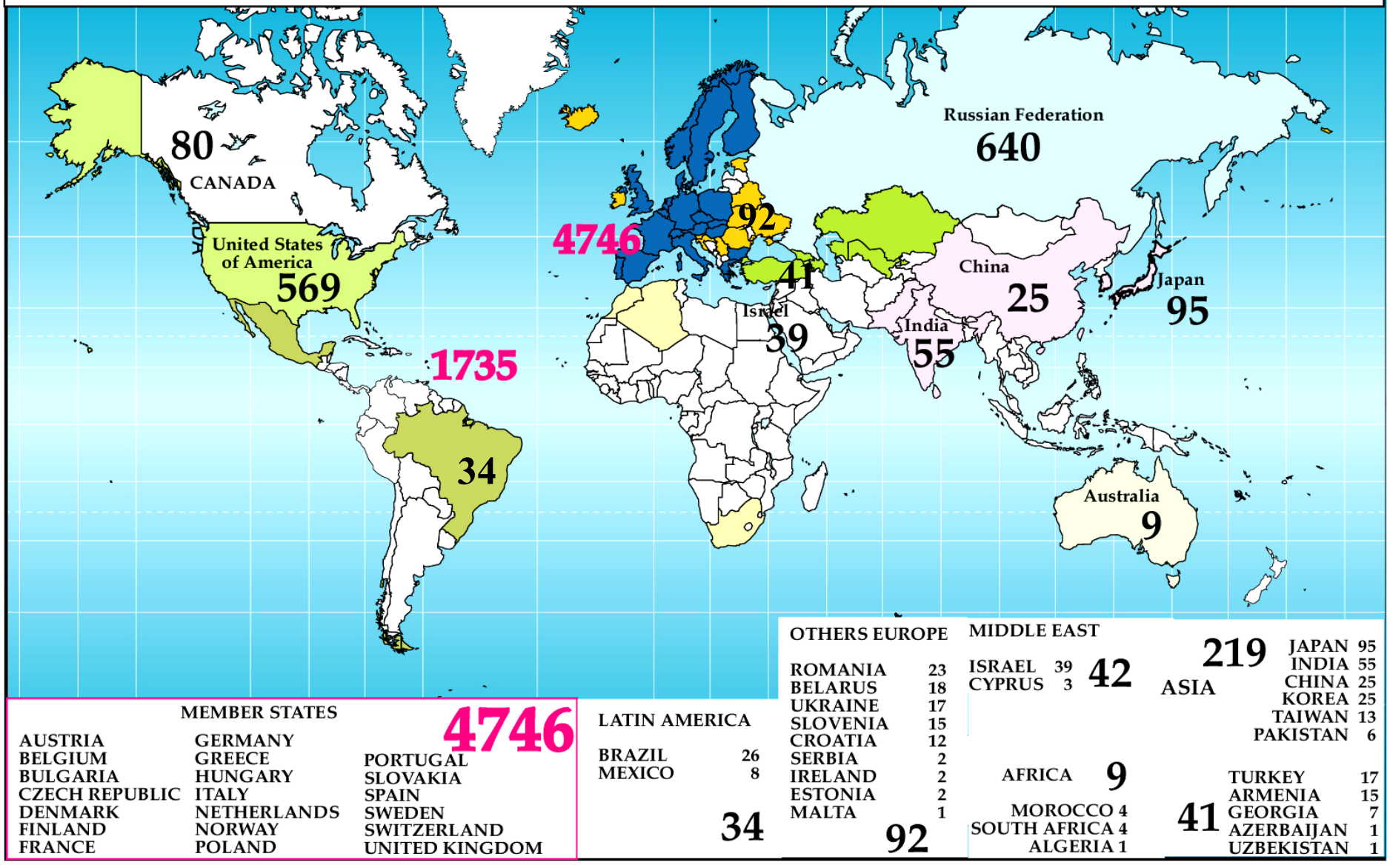
CERN in Numbers



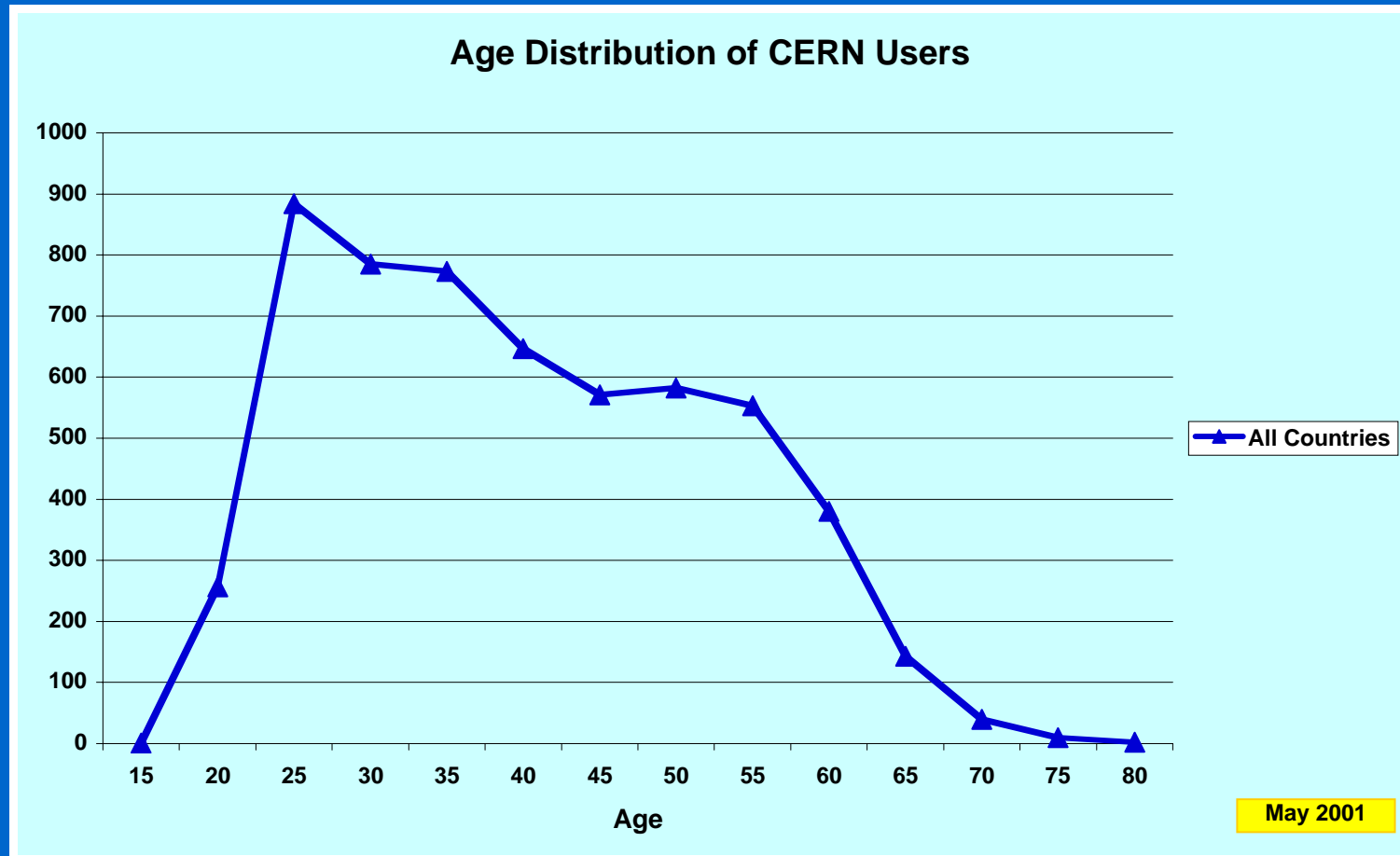
- 2500 staff
- 6500 users
- 500 Fellows and Associates
- Budget (2003) 1280MCHF (817M Euro)

- Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.
- Observers: India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and Unesco

Distribution of CERN users, May 1, 2001



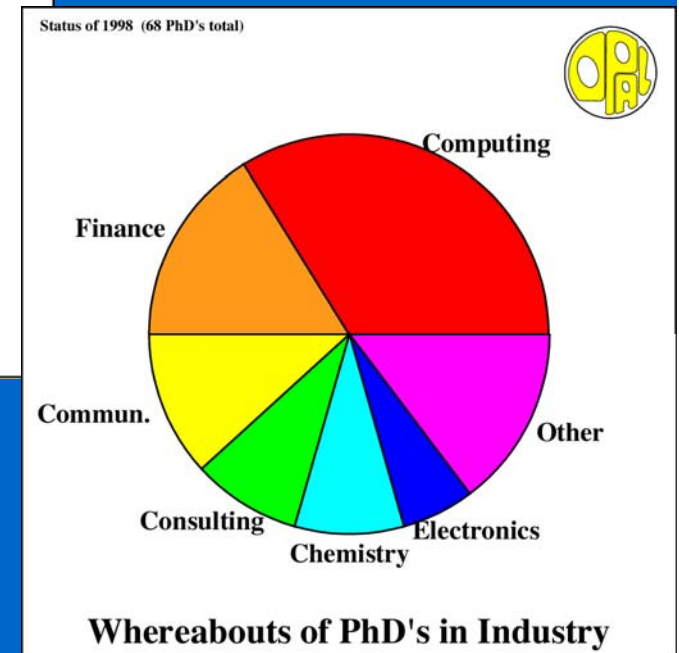
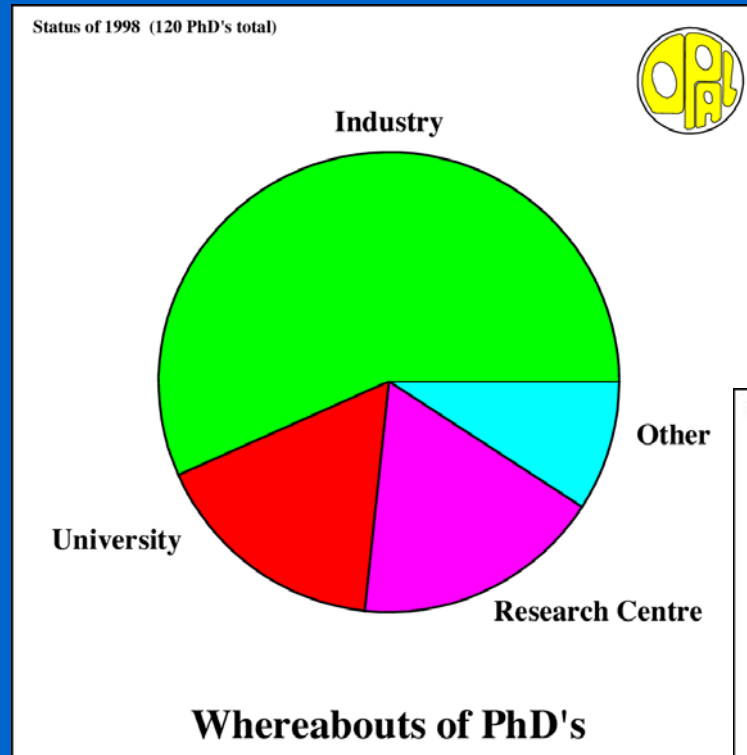
Age Distribution of CERN Users (May, 2001)



PhD thesis in LEP experiments

(over ten years):

ALEPH: 210
DELPHI: 227
L3: 250
OPAL: 198



What is CERN?

Summary

- The CERN accelerator menu
- The LHC project: accelerators + experiments
- The LHC computing challenge
- Long base neutrino beam
- Cold antiprotons
- High energy muon and hadron beams
- R&D for future accelerators

CERN = Laboratory of Particle Physics

Quarks	u up	c charm	t top
	d down	s strange	b bottom
Leptons	ν_e e- Neutrino	ν_μ μ - Neutrino	ν_τ τ - Neutrino
	e electron	μ muon	τ tau
	I	II	III
The Generations of Matter			

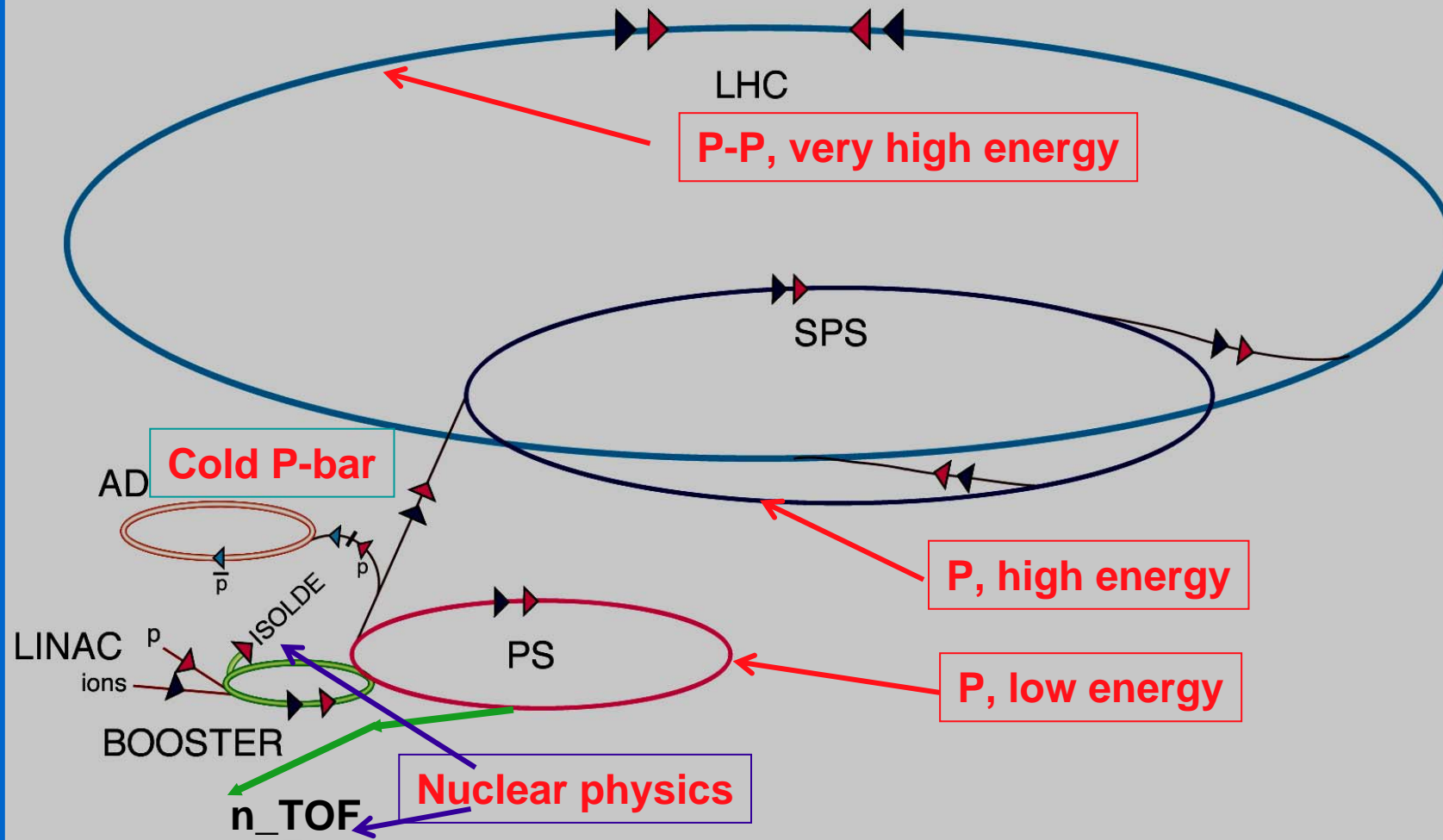
Fundamental Particles and Forces in nature



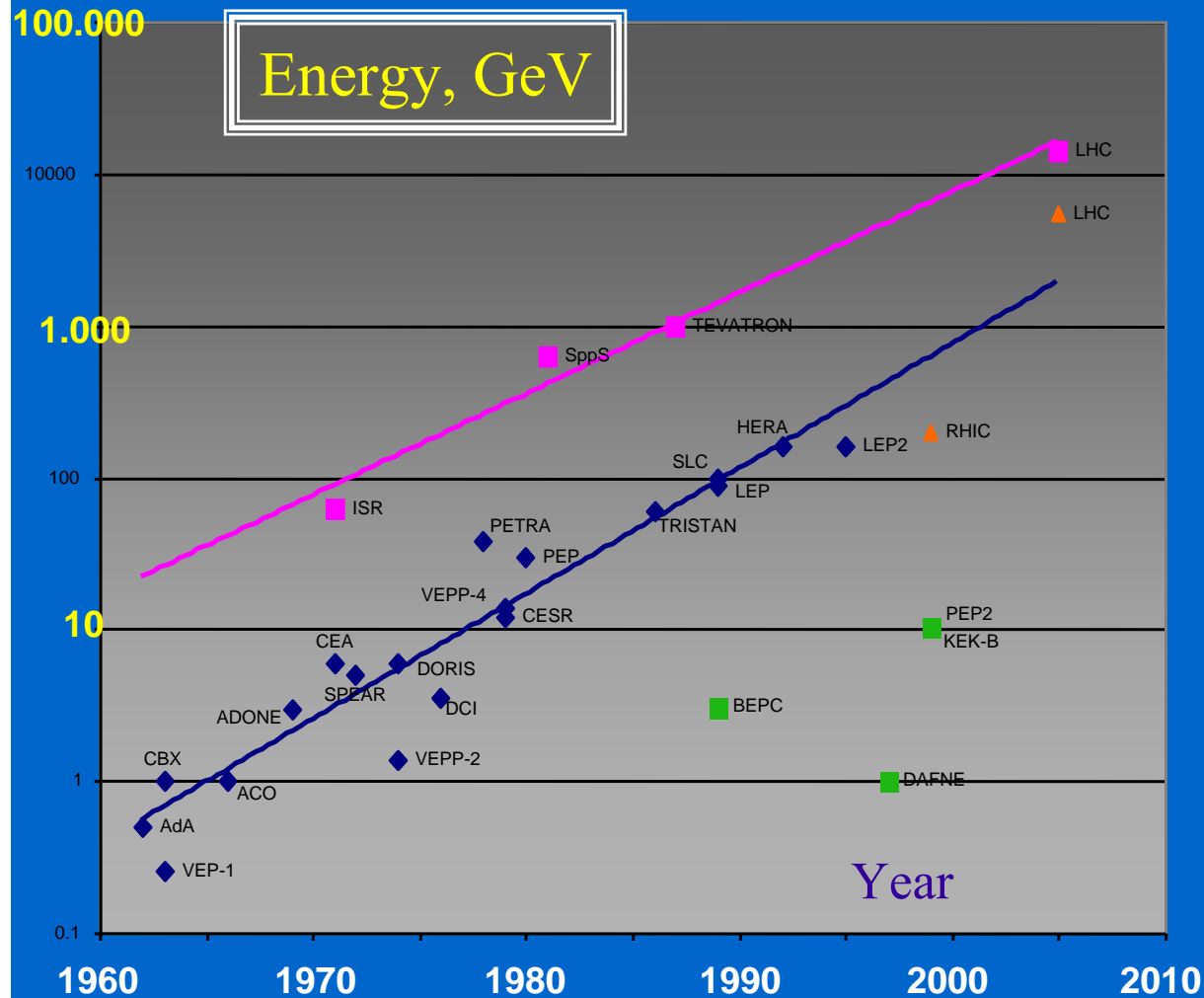
	Gravity	Weak (Electroweak)	Electromagnetic	Strong
Carried By	Graviton (not yet observed)	W^+ W^- Z^0	Photon	Gluon
Acts on	All	Quarks and Leptons	Quarks and Charged Leptons and W^+ W^-	Quarks and Gluons

Accelerator chain of CERN

Accelerator chain of CERN (operating or approved projects)



Energy available at Collider facilities vs. time



Equivalent energy in fixed target (P):

Tevatron: P-Pbar, 1987
 $E_{\text{equiv}} \approx 0.5 \cdot 10^3 \text{ TeV}$

LEP2: $e^+ e^-$, 1995
 \approx same range as Tevatron

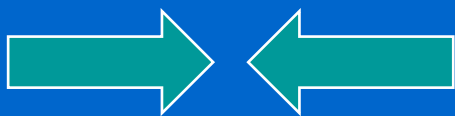
LHC: P-P, 2007
 $E_{\text{equiv}} \approx 1.1 \cdot 10^5 \text{ TeV}$

+ X-factories
 + Heavy Ions...

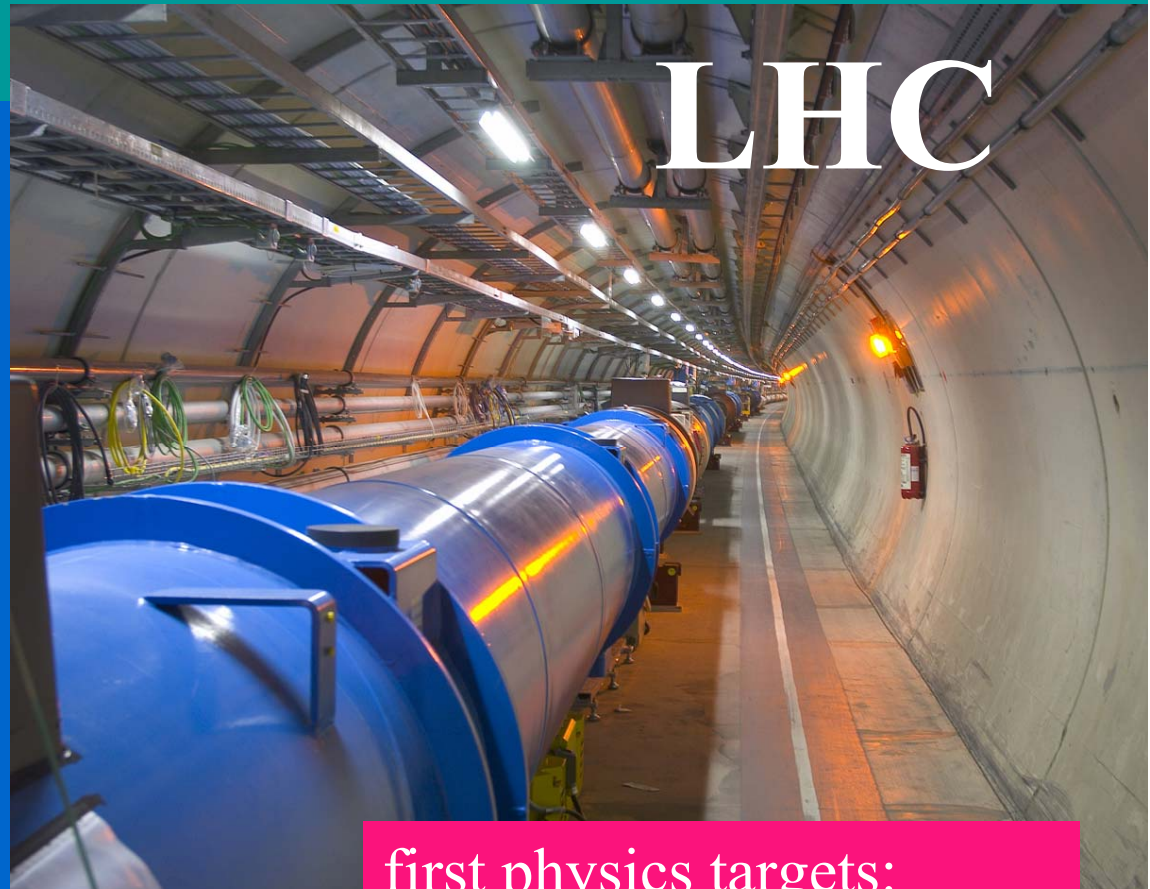
The Large Hadron Collider in the LEP Tunnel (27 km) ~100 m underground

Proton- Proton Collider

7 TeV + 7 TeV



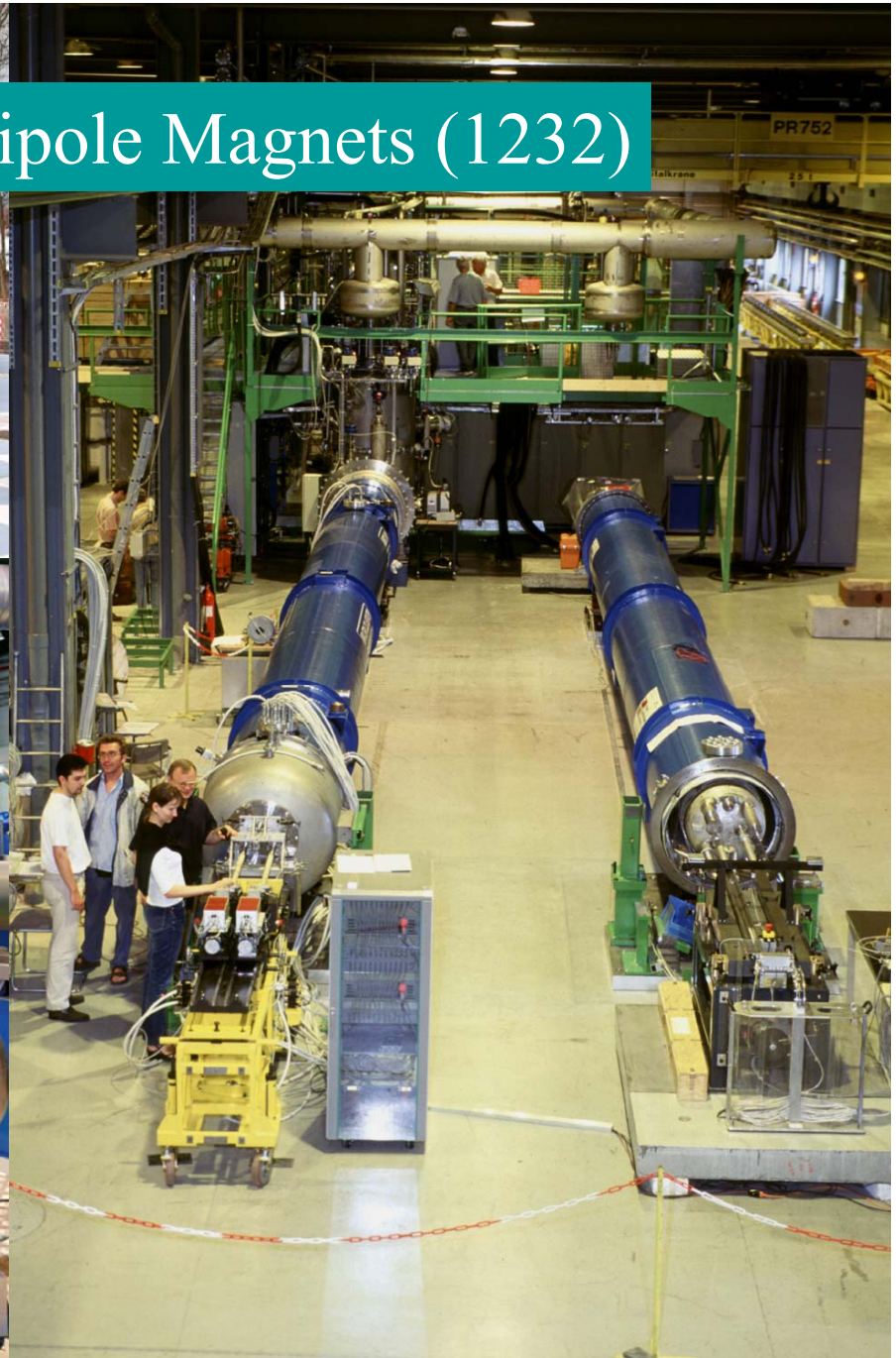
Luminosity = $10^{34} \text{cm}^{-2} \text{sec}^{-1}$



first physics targets:

- Higgs boson (s)
- Supersymmetric Particles
- Quark-Gluon Plasma
- CP violation in B

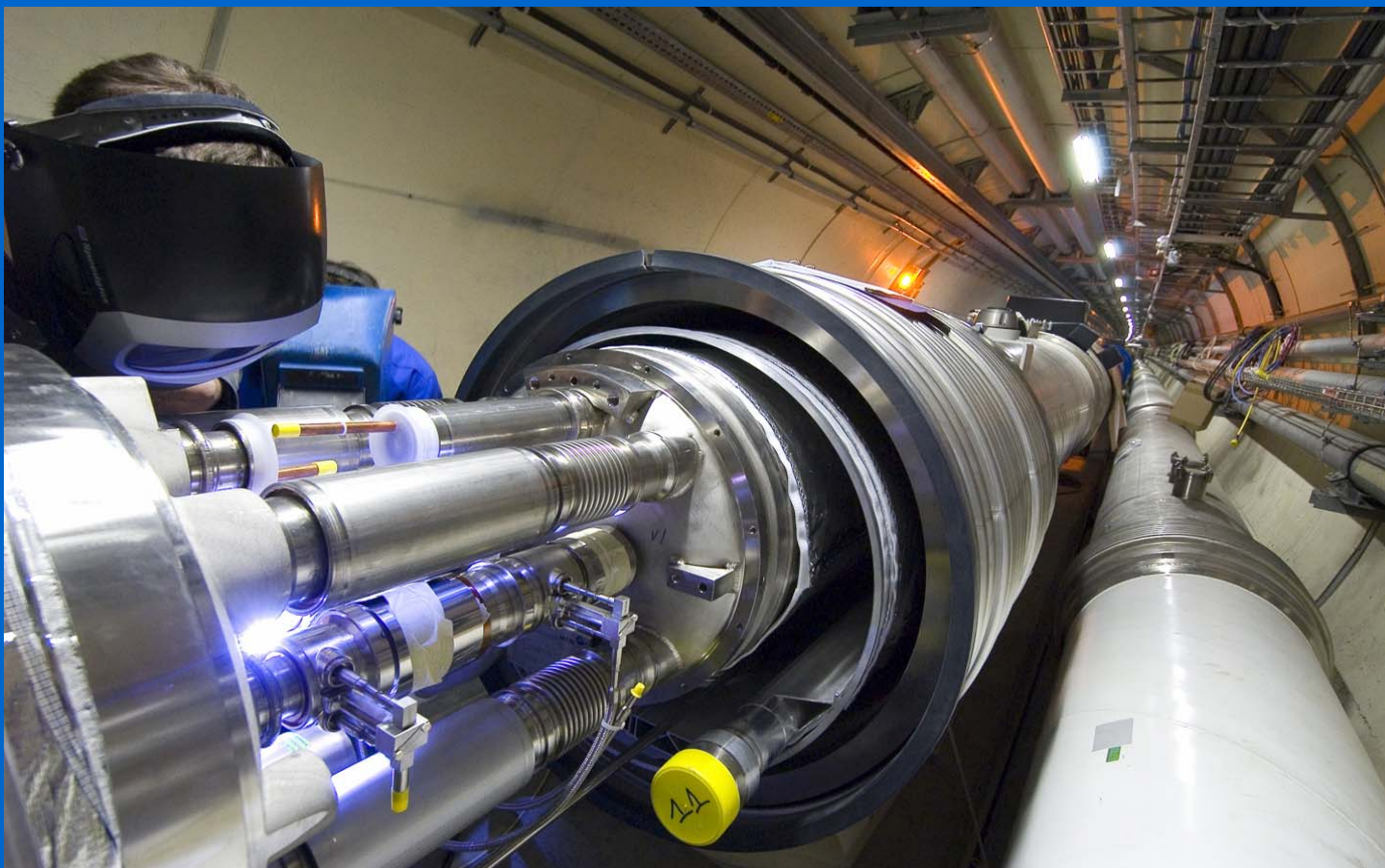
LHC main Dipole Magnets (1232)



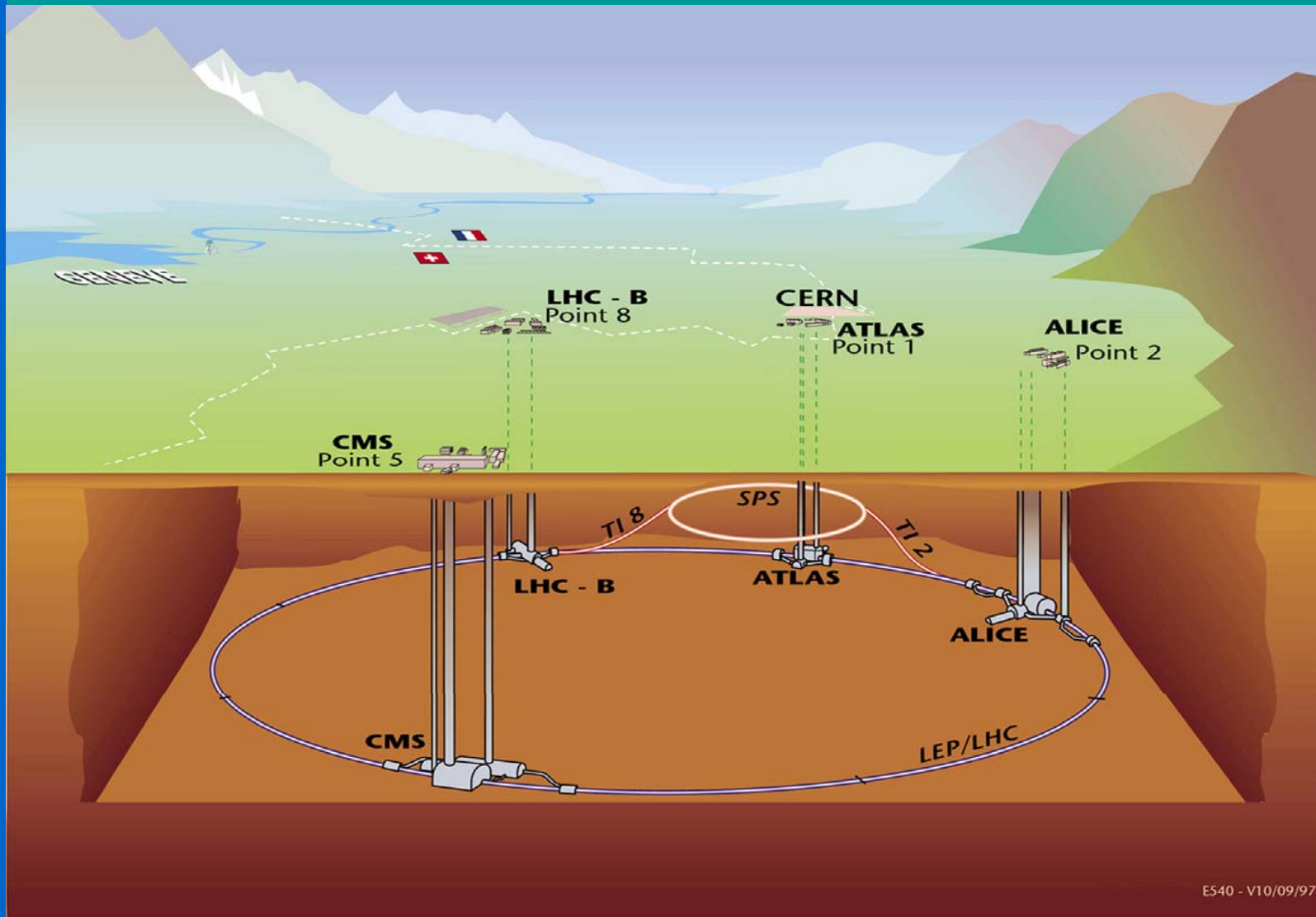
Transport in
the tunnel
by truck with
optical
guidance

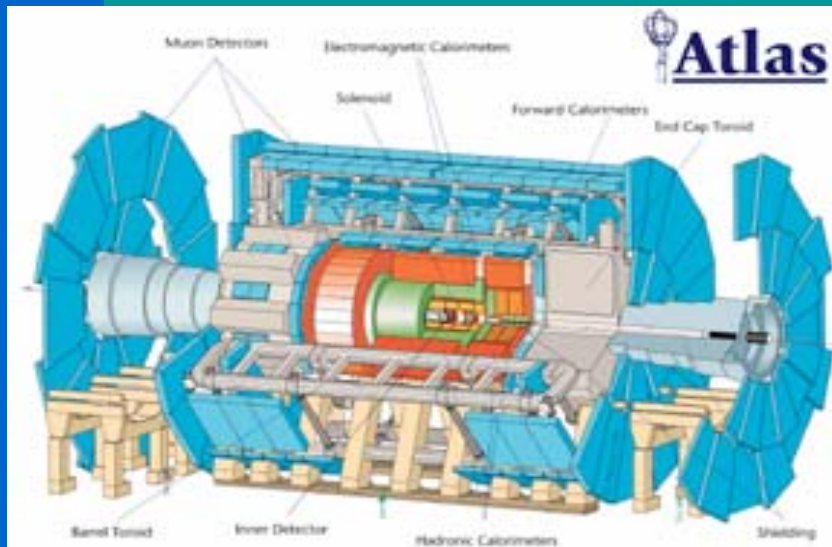


Interconnection of superconducting magnets

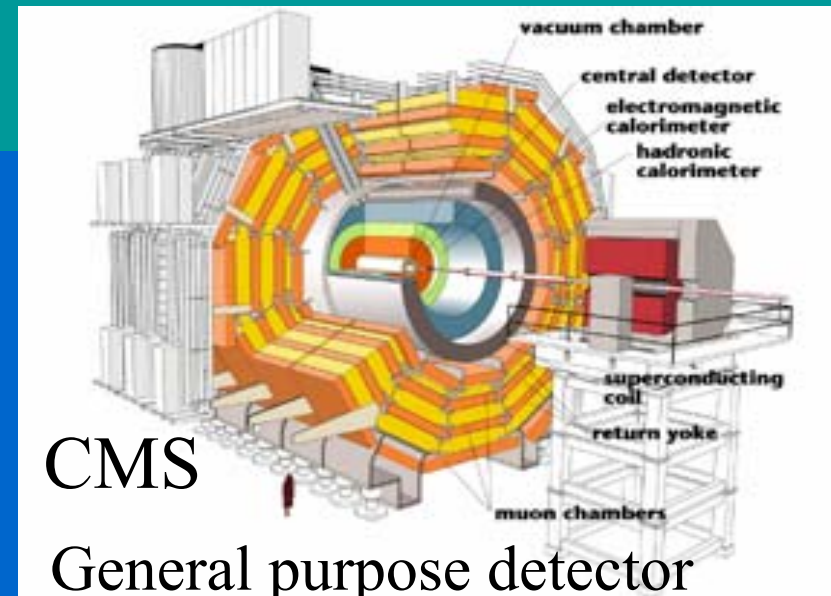


Overall View of the Large Hadron Collider (LHC)



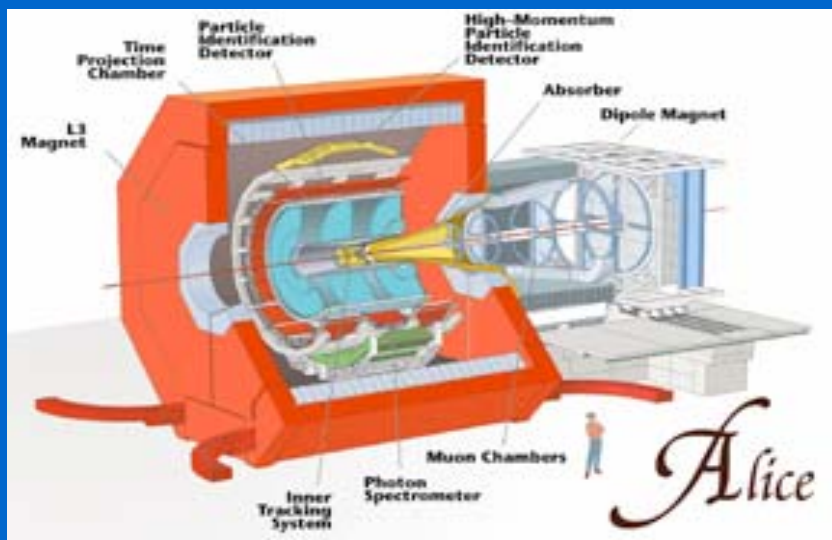


General purpose detector



CMS

General purpose detector

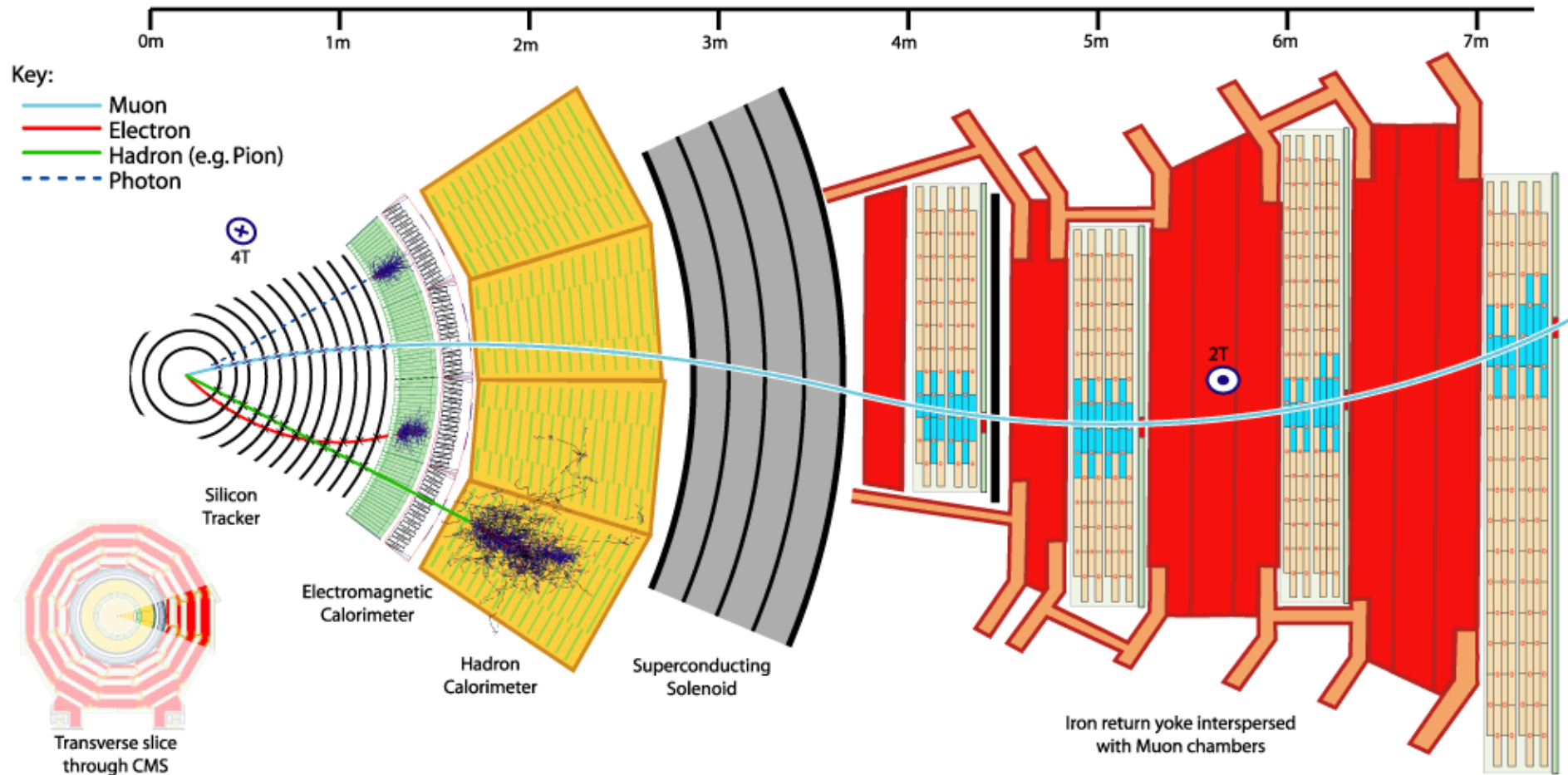


Heavy ion physics

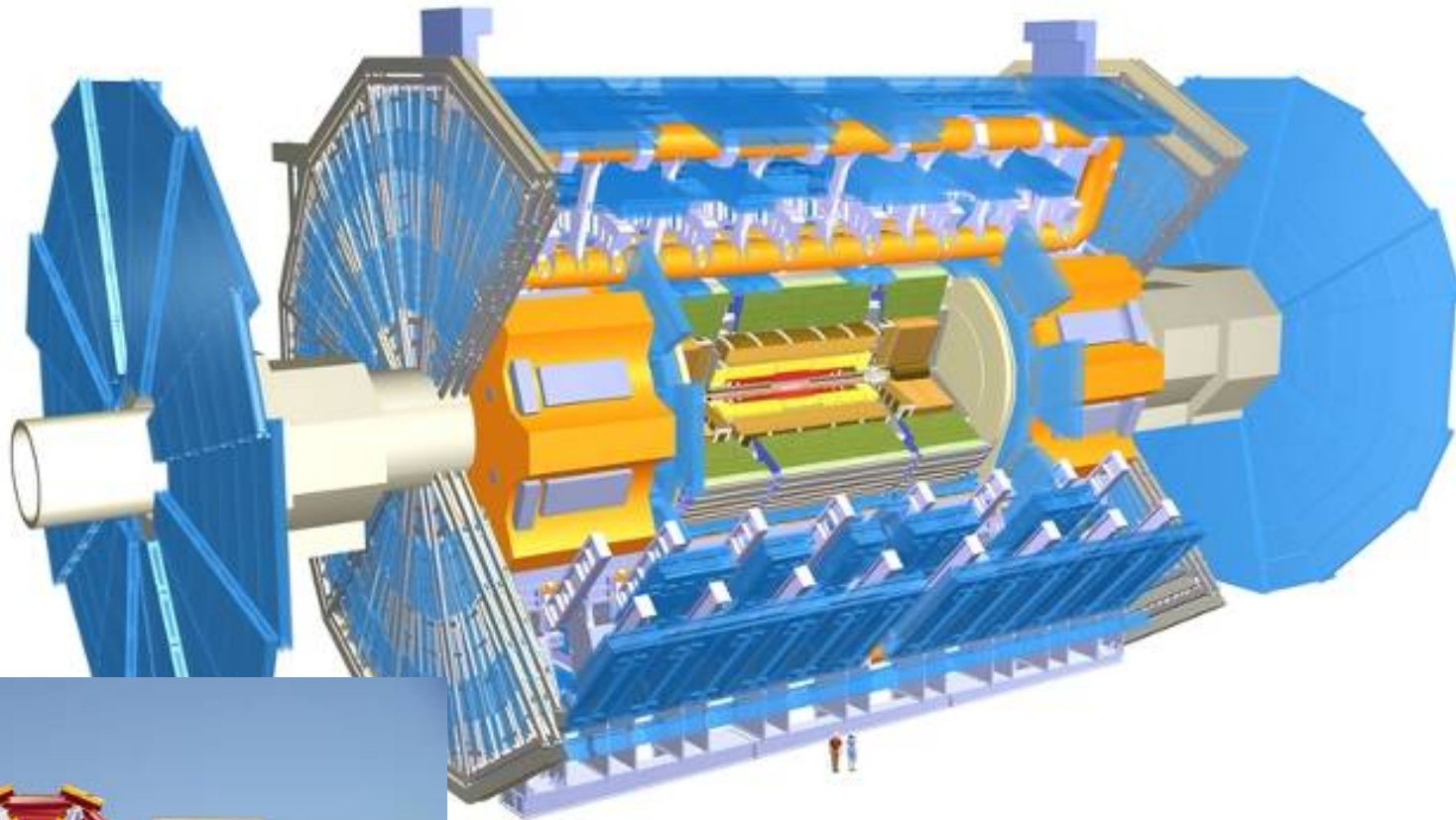


CP violation with b quarks

Anatomy of a Dectector

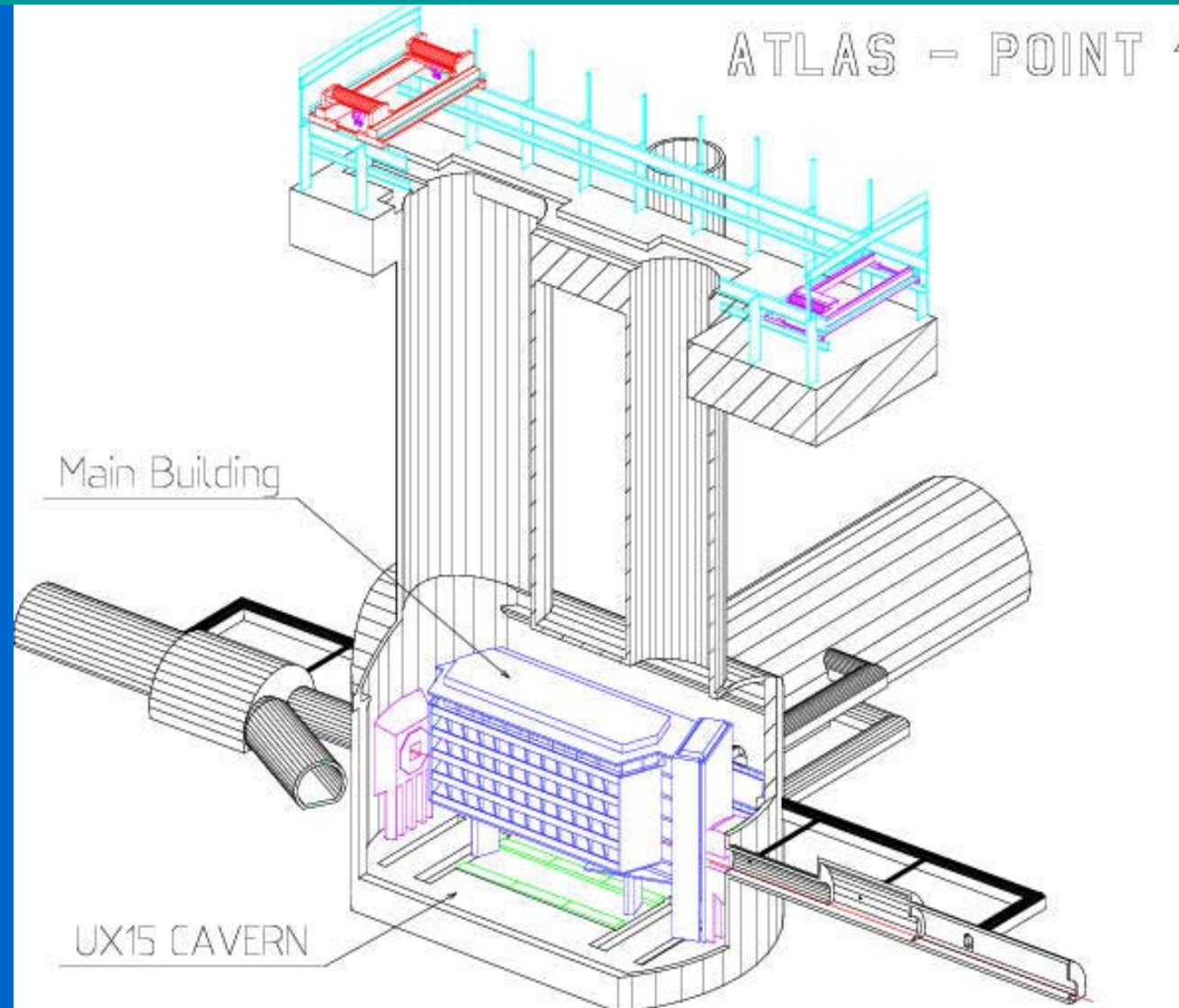


ATLAS



Diameter	25 m
Barrel toroid length	26 m
End-cap end-wall chamber span	46 m
Overall weight	7000 Tons

The Main Building « fits in » the ATLAS Cavern

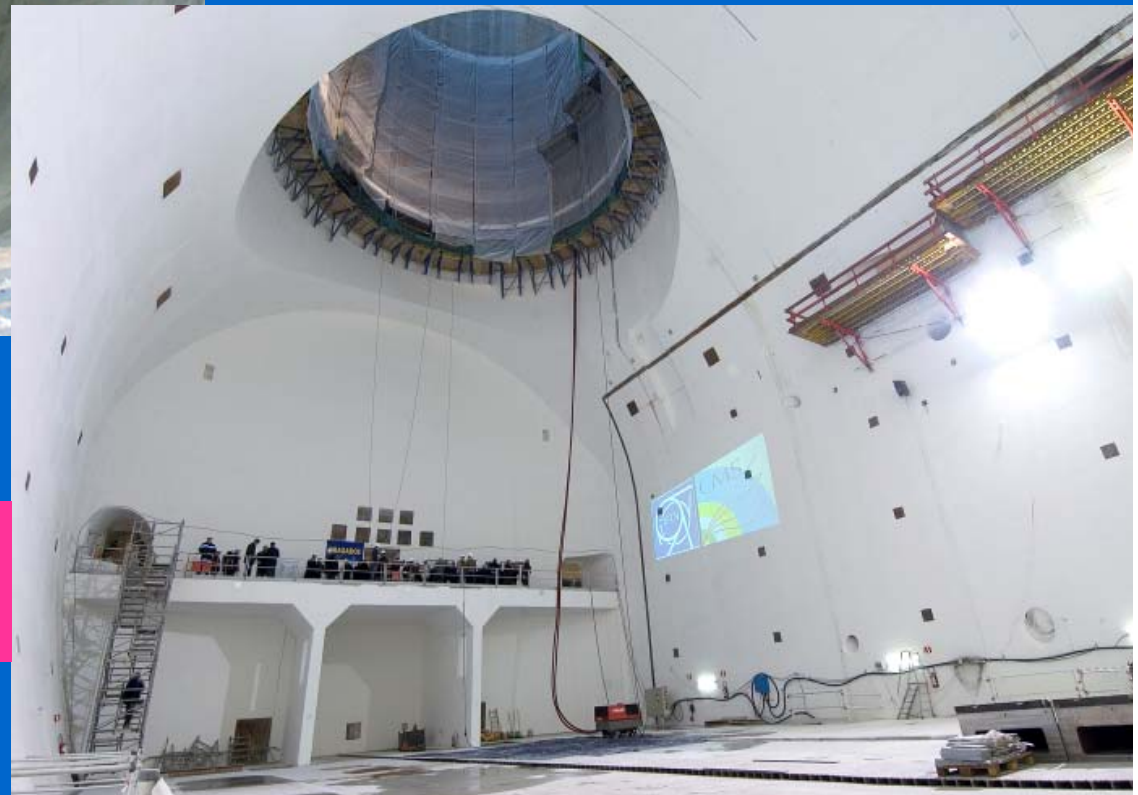


ATLAS shaft



Point 1 - PX14 shaft - July 18, 2000 - CERN ST-CE

CMS cavern Feb. 2005

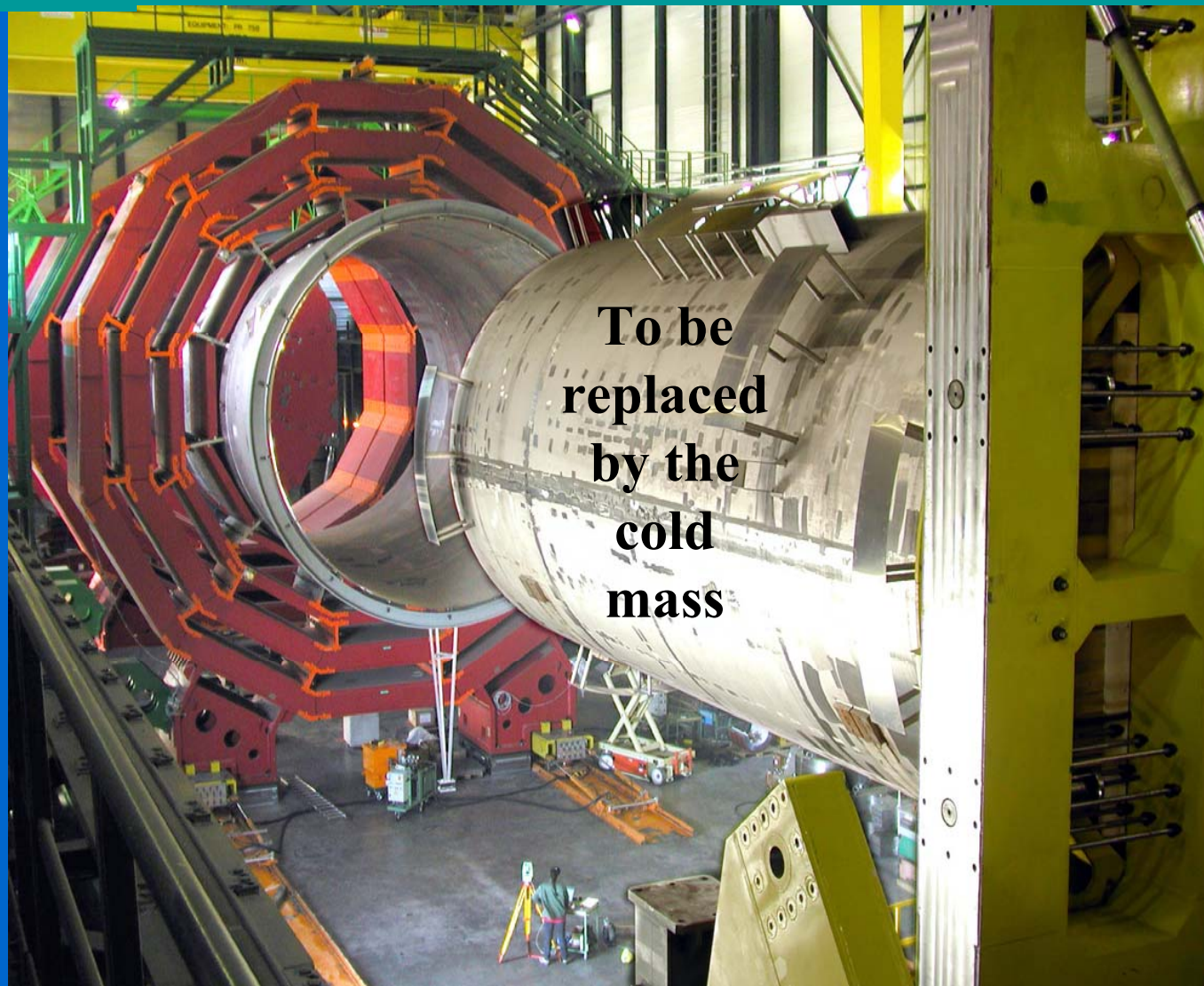


ATLAS cavern

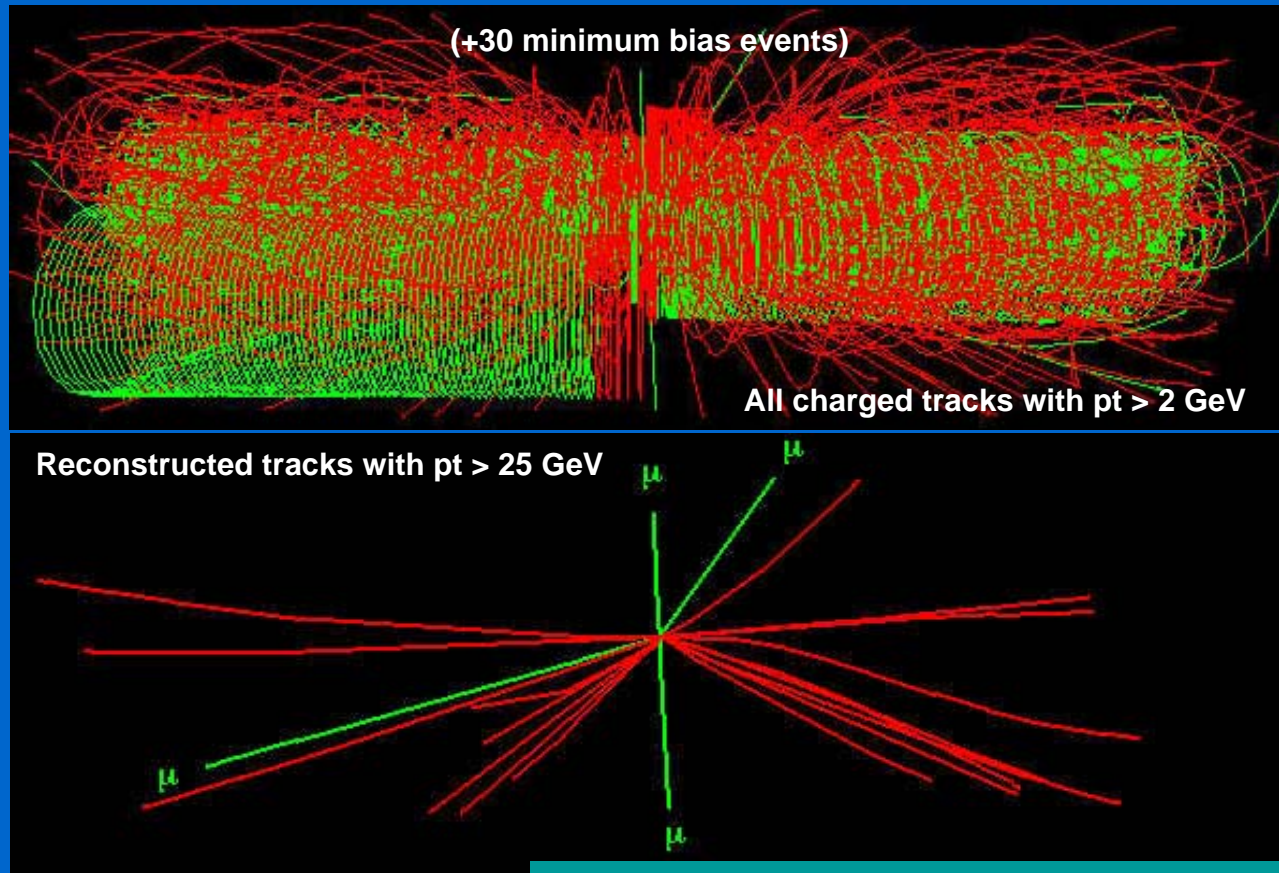


CMS

Insertion of coil in vacuum tank foreseen
Sept. 2005



Computing in LHC experiments



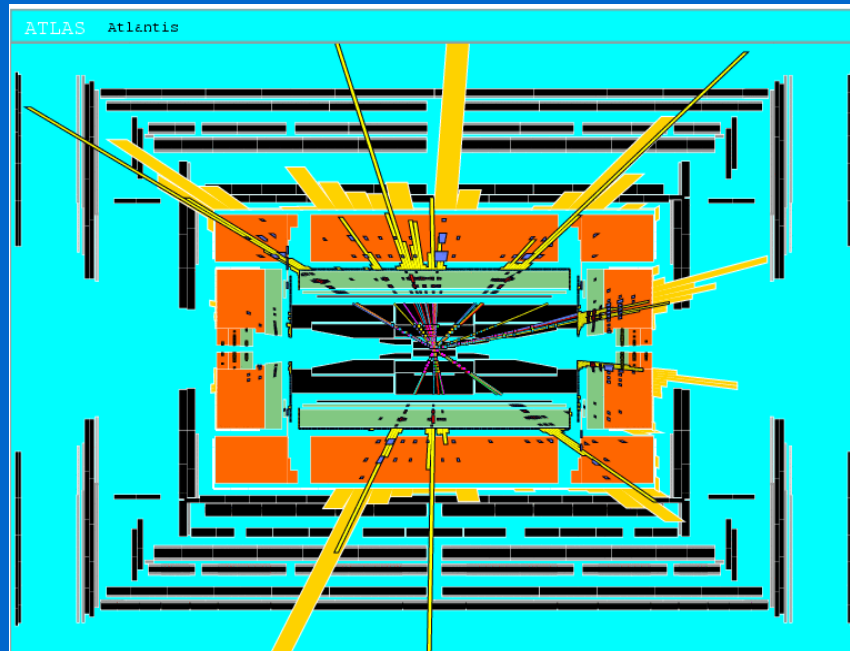
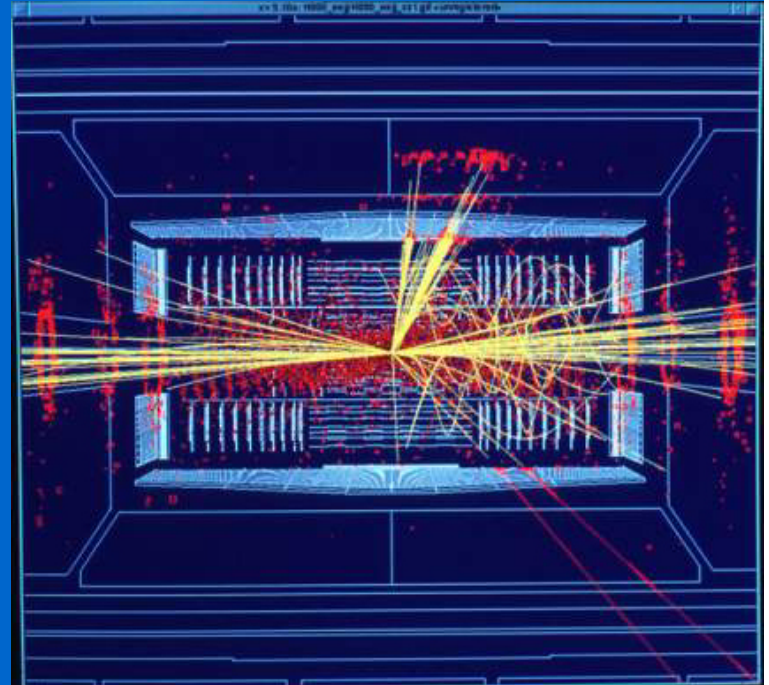
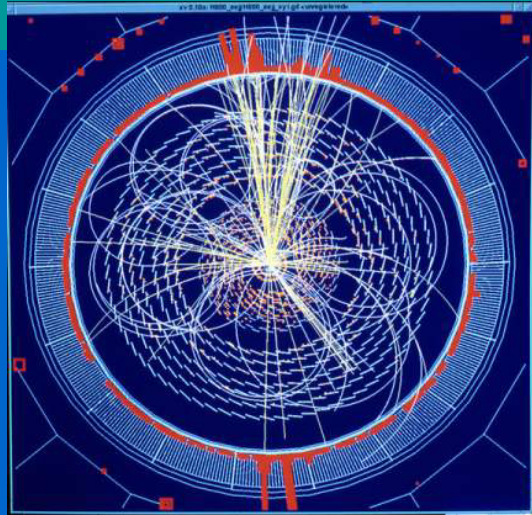
**Higgs boson decay in 4 muons
1 in 10^{13} events**

The data transmitted in ONE SECOND of LHC running

is equivalent to:

the information exchanged by WORLD TELECOM (≈ 100 million phone calls)

What we hope to see in the LHC detectors!



LHC data volume (simplified)

Per experiment:

- 40 million collisions per second
- After filtering, 100 collisions of interest per second
- A Megabyte of digitised information for each collision = recording rate of 100 Megabytes/sec
- 1 billion collisions recorded = 1 Petabyte/year

With four experiments, processed data we will accumulate 15 PetaBytes of new data each year

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
10% of the annual production by LHC experiments

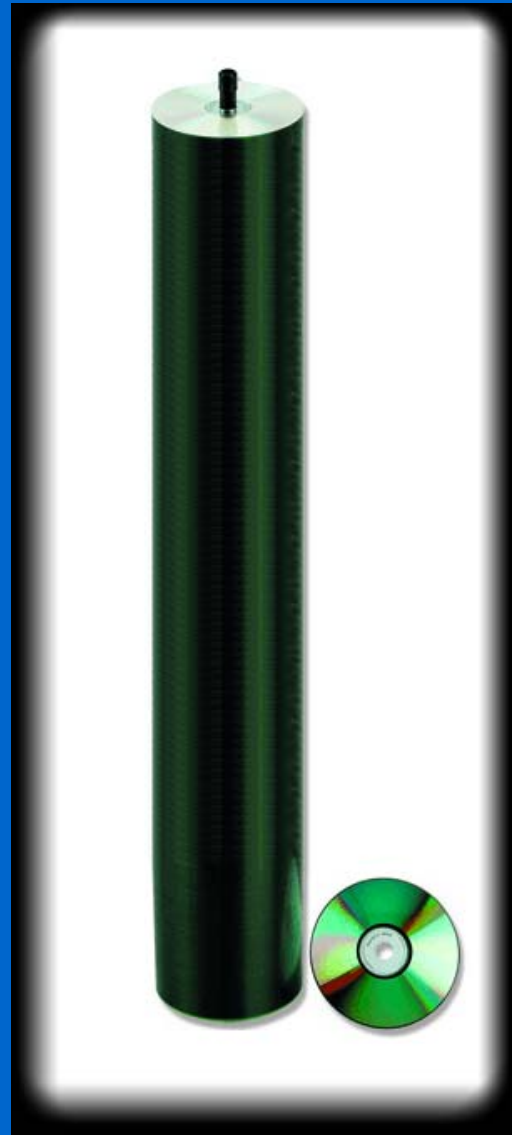
1 Exabyte (1EB)
= 1000 PB
World annual information production



Data storage of one experiment

	per year	Weight of DVDs
Raw data	3,2 PB	14'000 kg
Reconstructed data	1,0 PB	4'400 kg
Physics data	0,2 PB	784 kg
Publications	10 MB	

PB = Peta Byte = 1000 Tera Byte

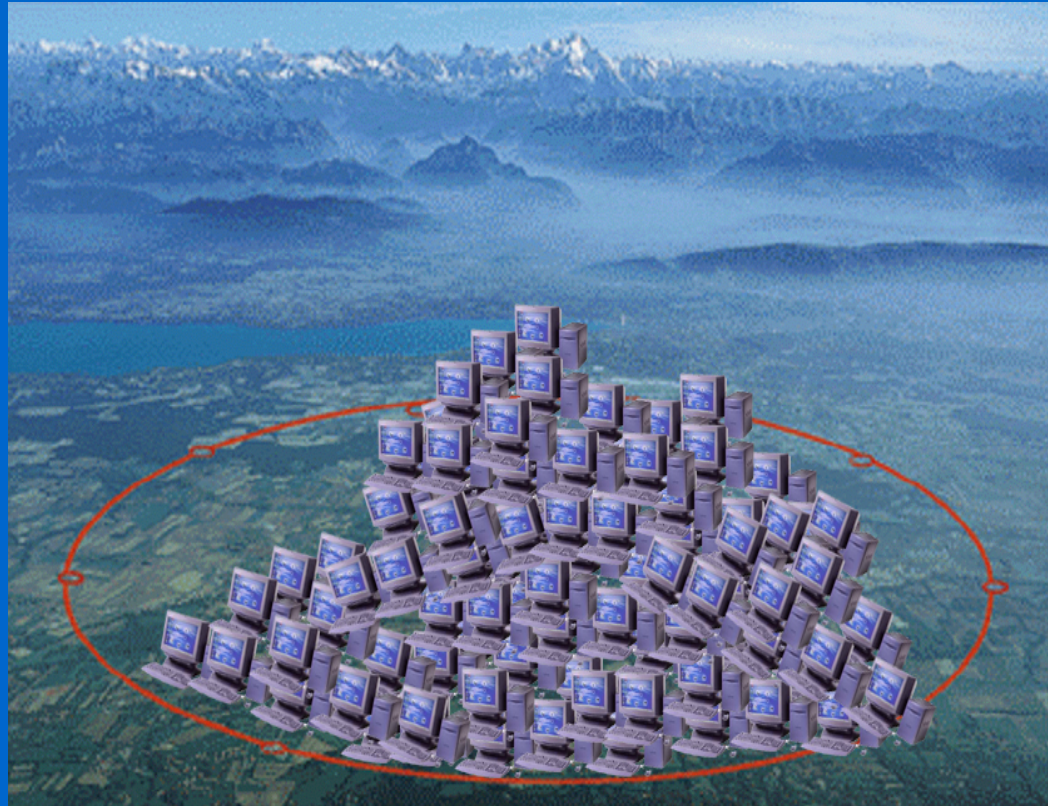


Therefore: Provide mountains of CPU

*Calibration
Reconstruction
Simulation
Analysis*

*For final LHC computing,
some 100 000
of today's PC processors
are needed!*

*Produced by industry
today in ~6 hours*



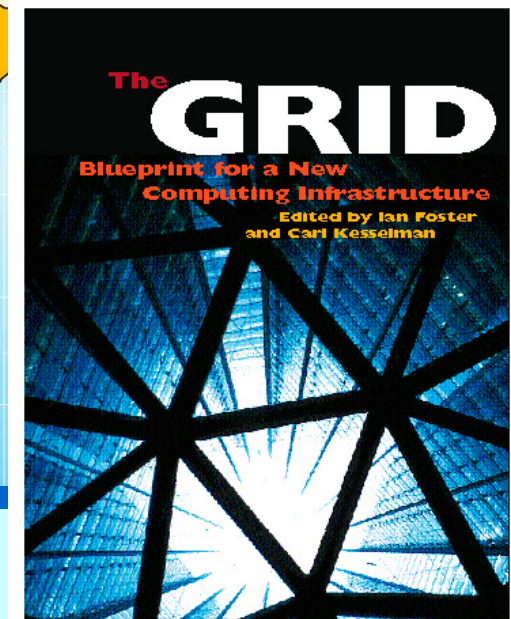
Even with technology-driven improvements in performance and costs – CERN cannot provide enough capacity for LHC!

World Wide Collaboration

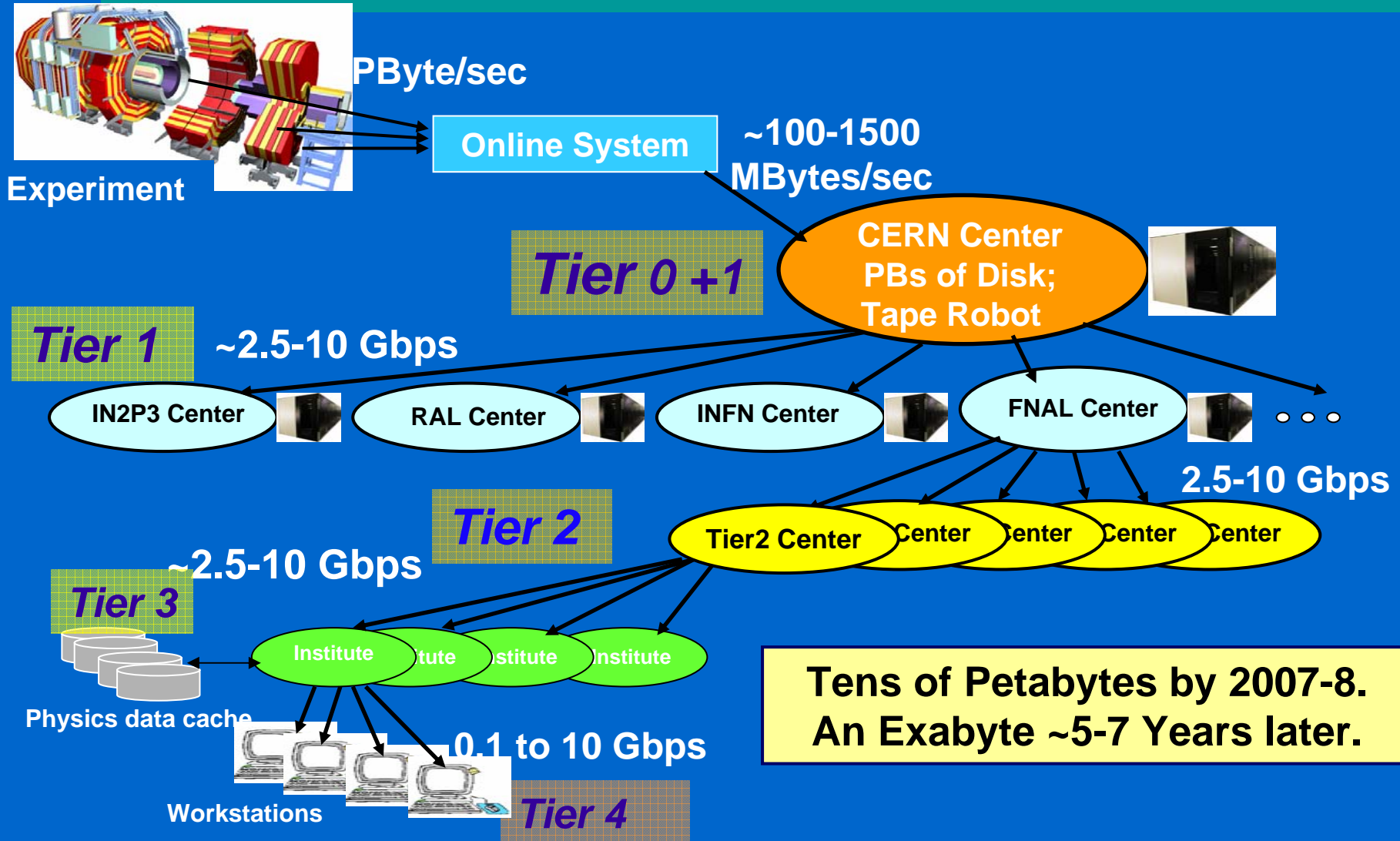
⇒ distributed computing & storage capacity



Europe: 267 institutes, 4603 users
Other: 208 institutes, 1632 users

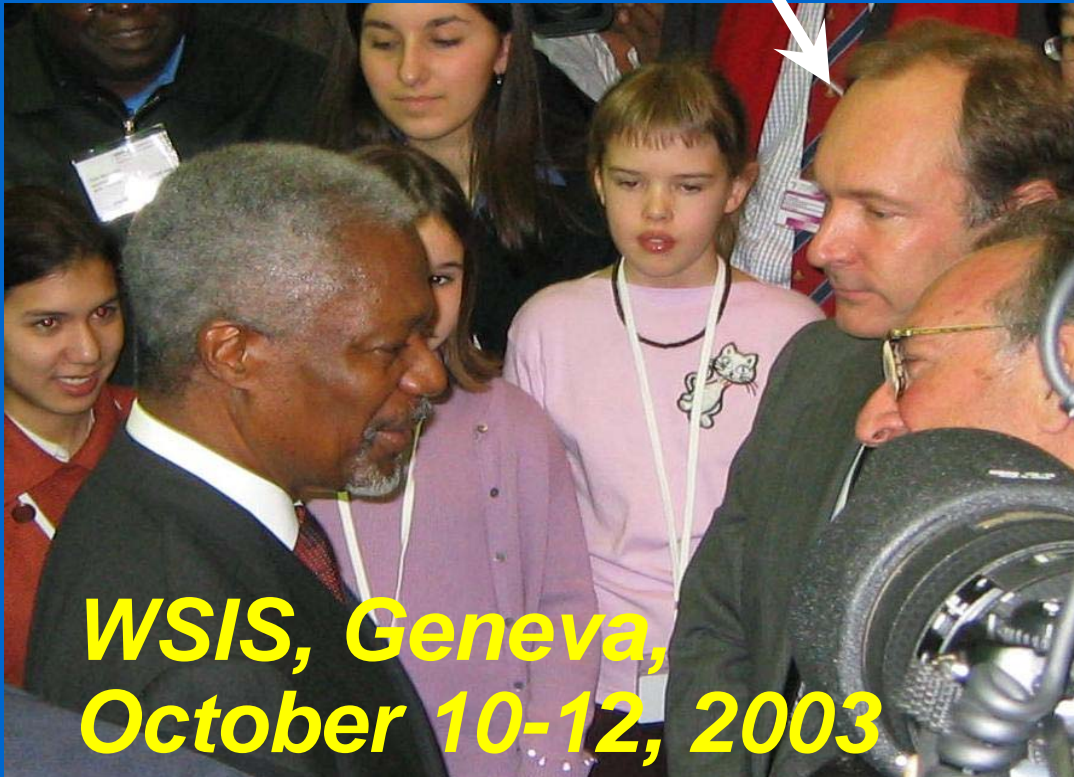


LHC GRID computing hierarchy



The WWW invented at CERN

Tim Berners-Lee



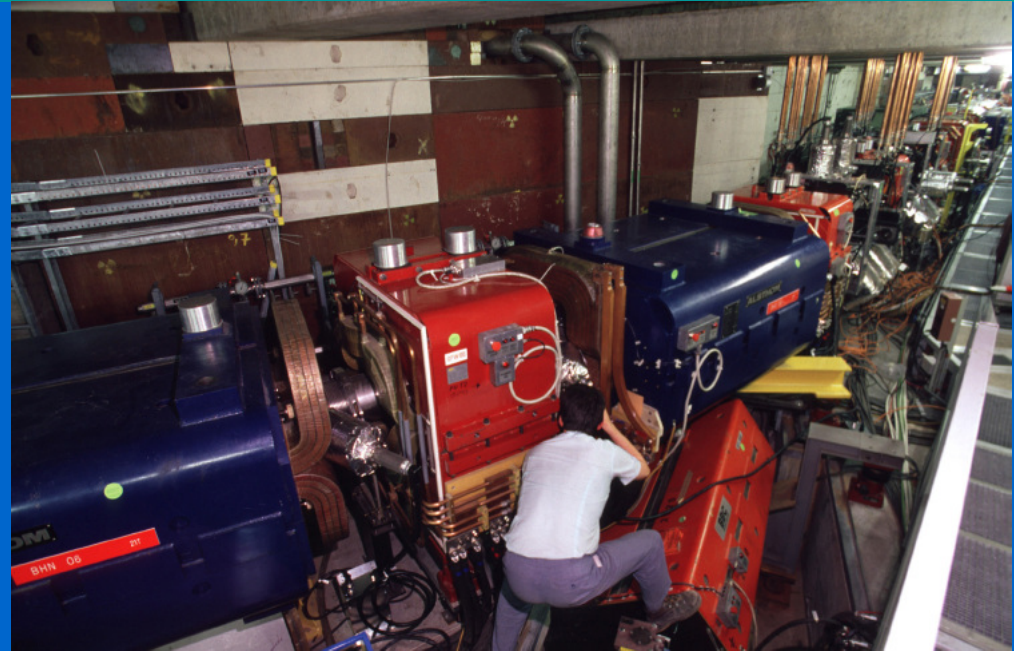
The **World Wide Web** provides seamless access to information that is stored in many millions of different geographical locations

In contrast, the **Grid** is an emerging infrastructure that provides seamless access to computing power and data storage capacity distributed over the globe.

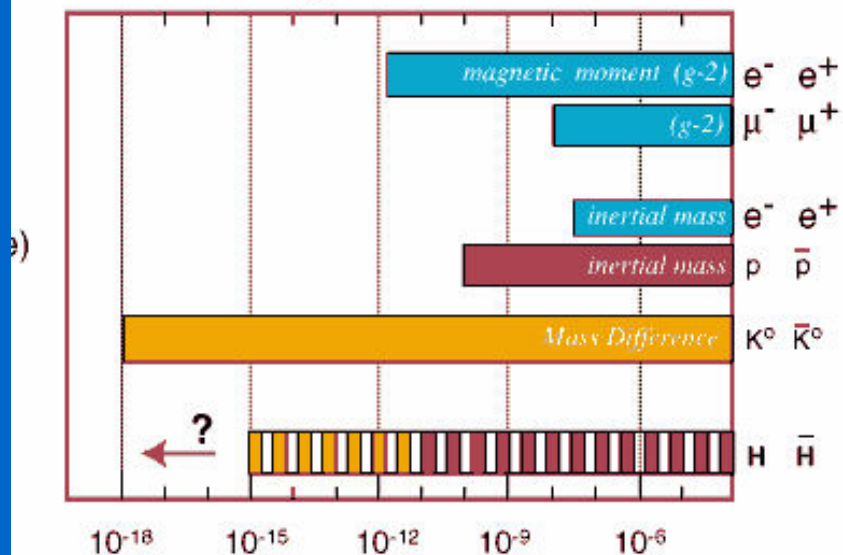
Besides the LHC project,
what else is going on at CERN?

Cold anti-protons for anti-hydrogen @AD facility

Physicists are setting traps to catch **anti-hydrogen**, the simplest element in the mirror world of antimatter.



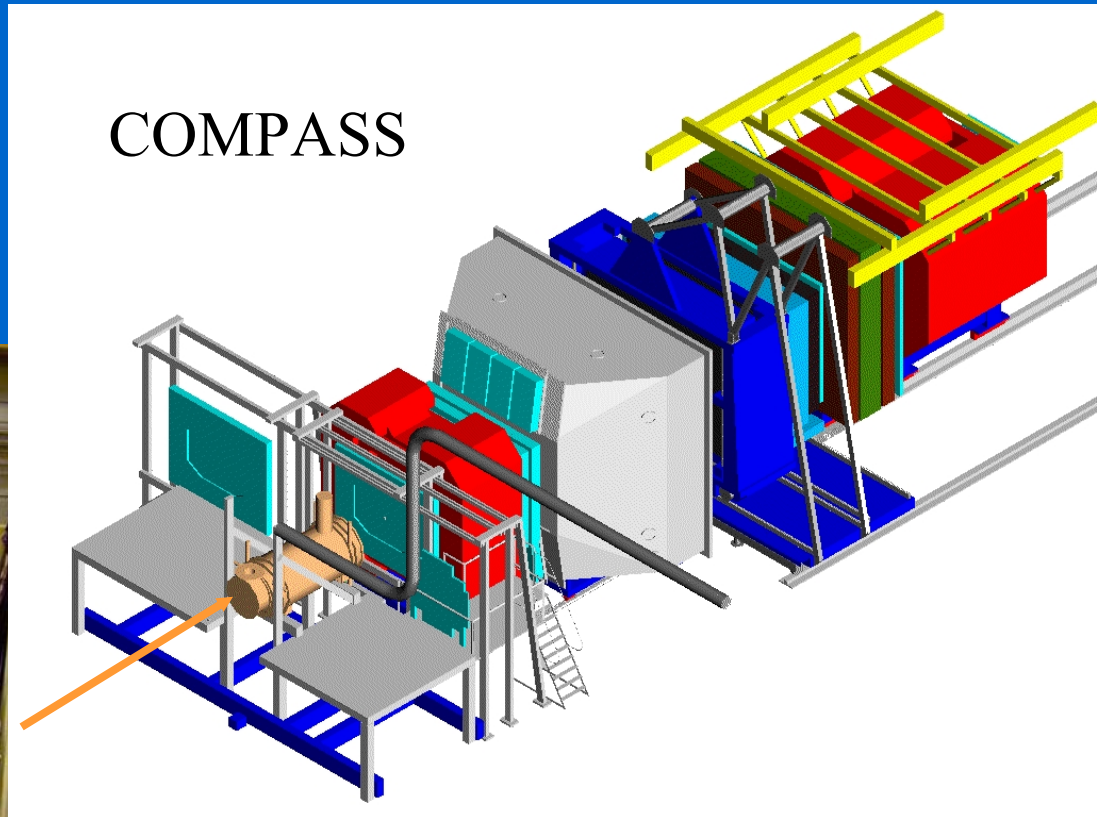
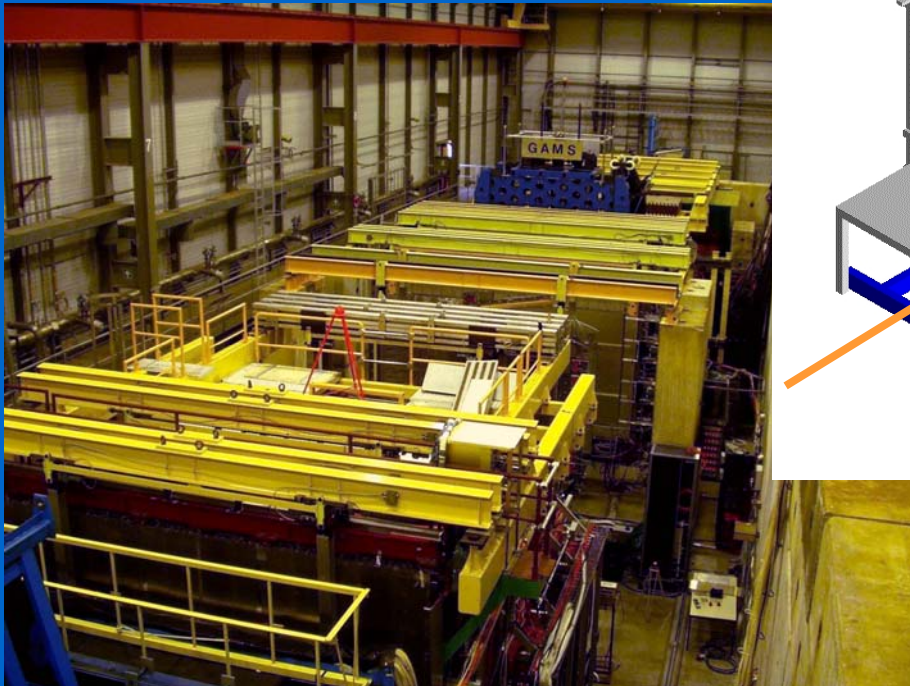
The most precise CPT Tests



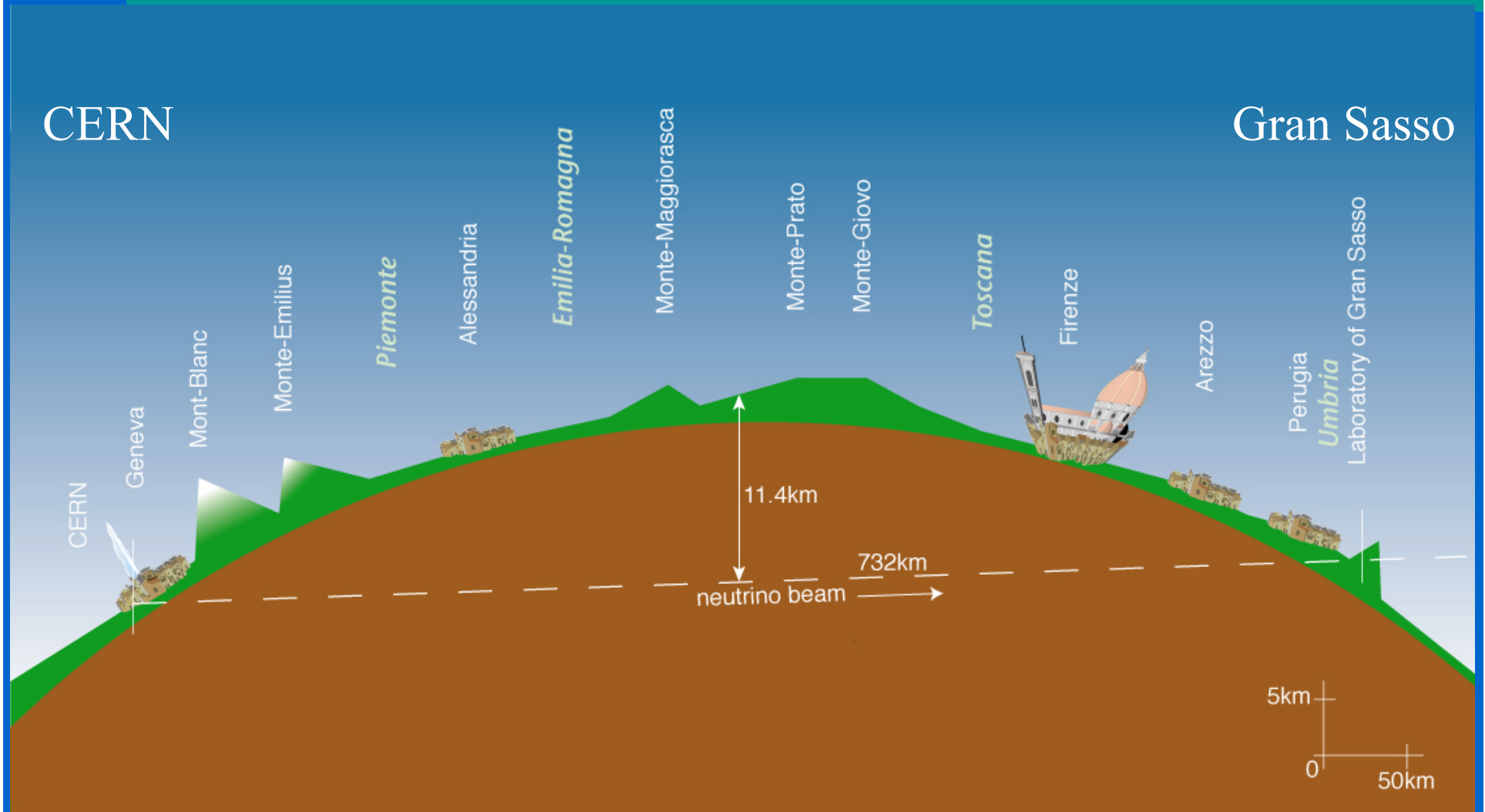
Longterm physics goal:
Spectroscopy with anti-H

COMPASS fixed target experiment at the SPS

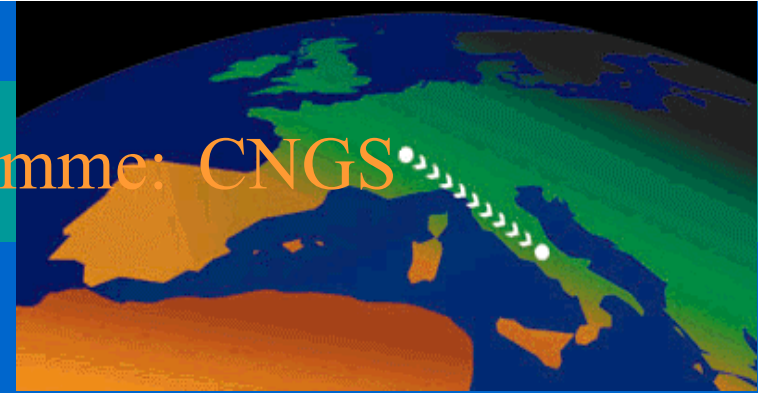
to study hadron structure
and hadron spectroscopy
with high intensity
muon beam (160 GeV)
and **hadron beams**.



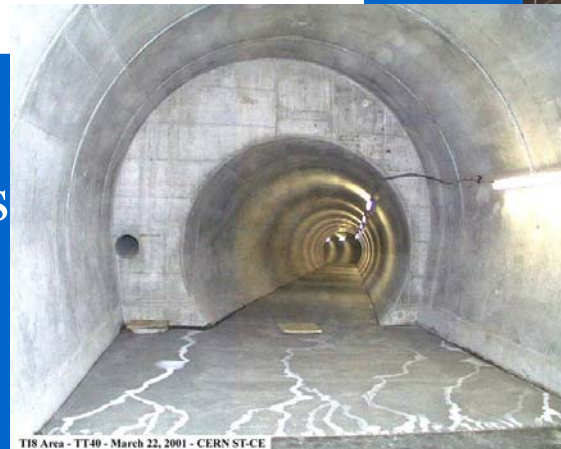
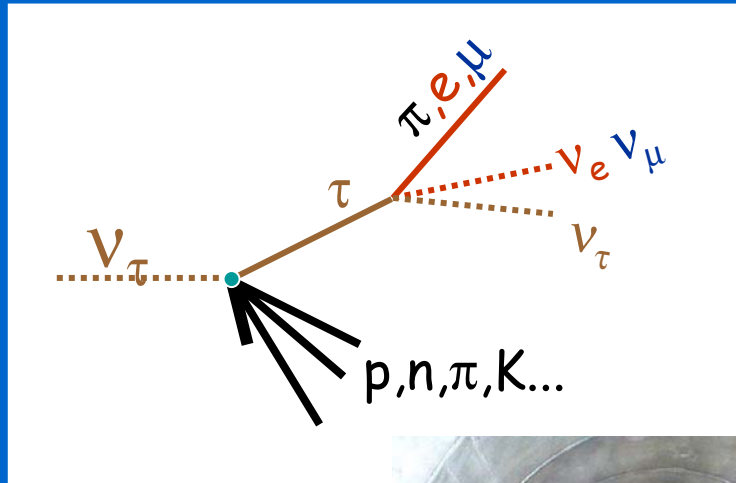
CNGS neutrino Beam



• Long-Baseline Neutrino Programme: CNGS



- To observe the appearance of tau neutrino in a muon neutrino beam from CERN



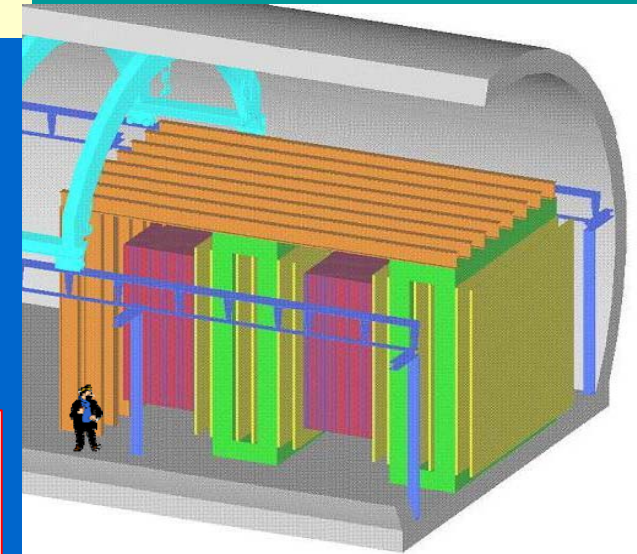
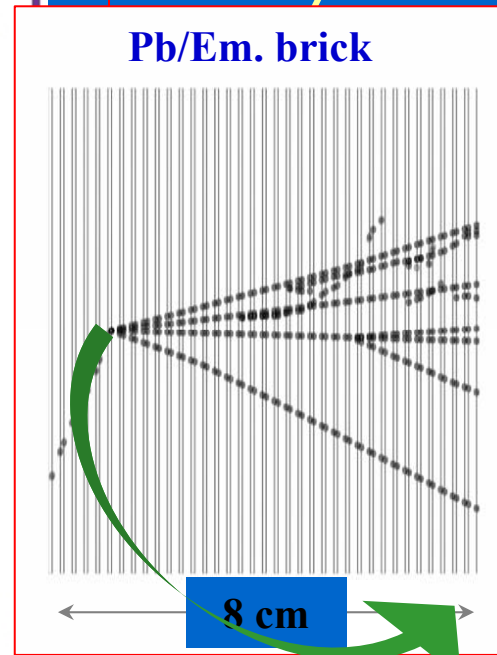
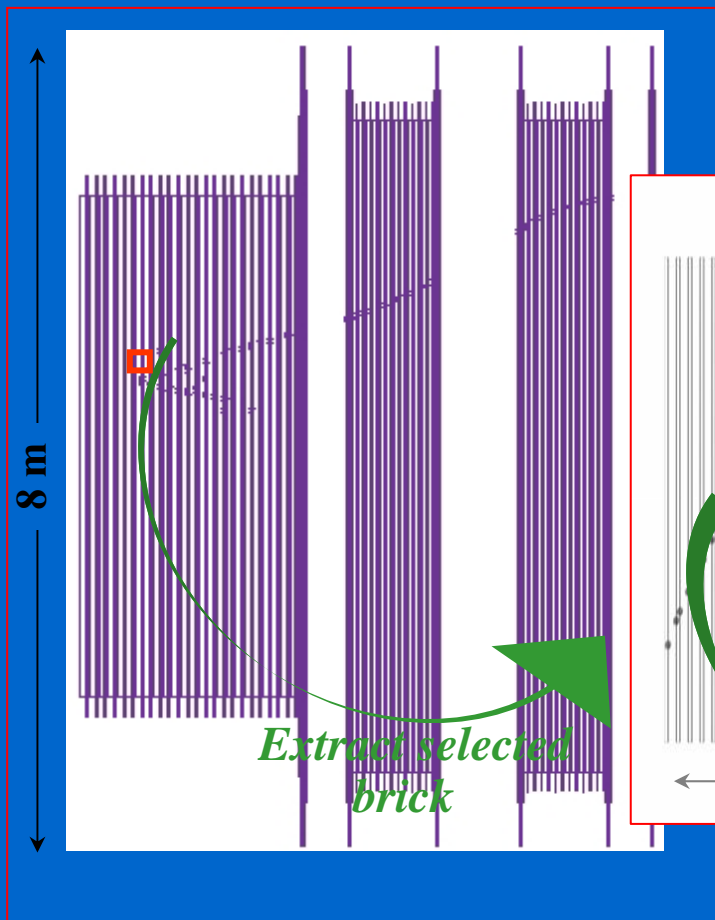
T18 Area - TT40 - March 22, 2001 - CERN ST-CE

Expect ~10 evts
after 5 yrs
running

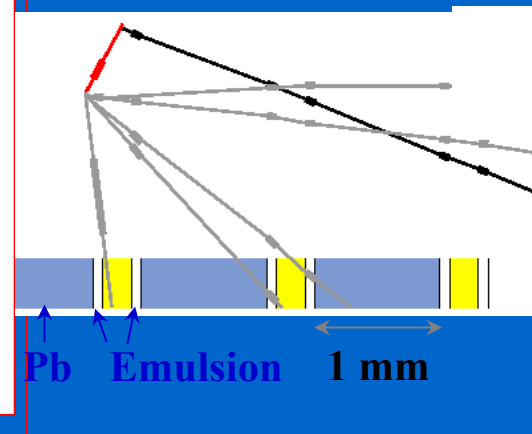


OPERA an hybrid neutrino detector at Gran Sasso Laboratory

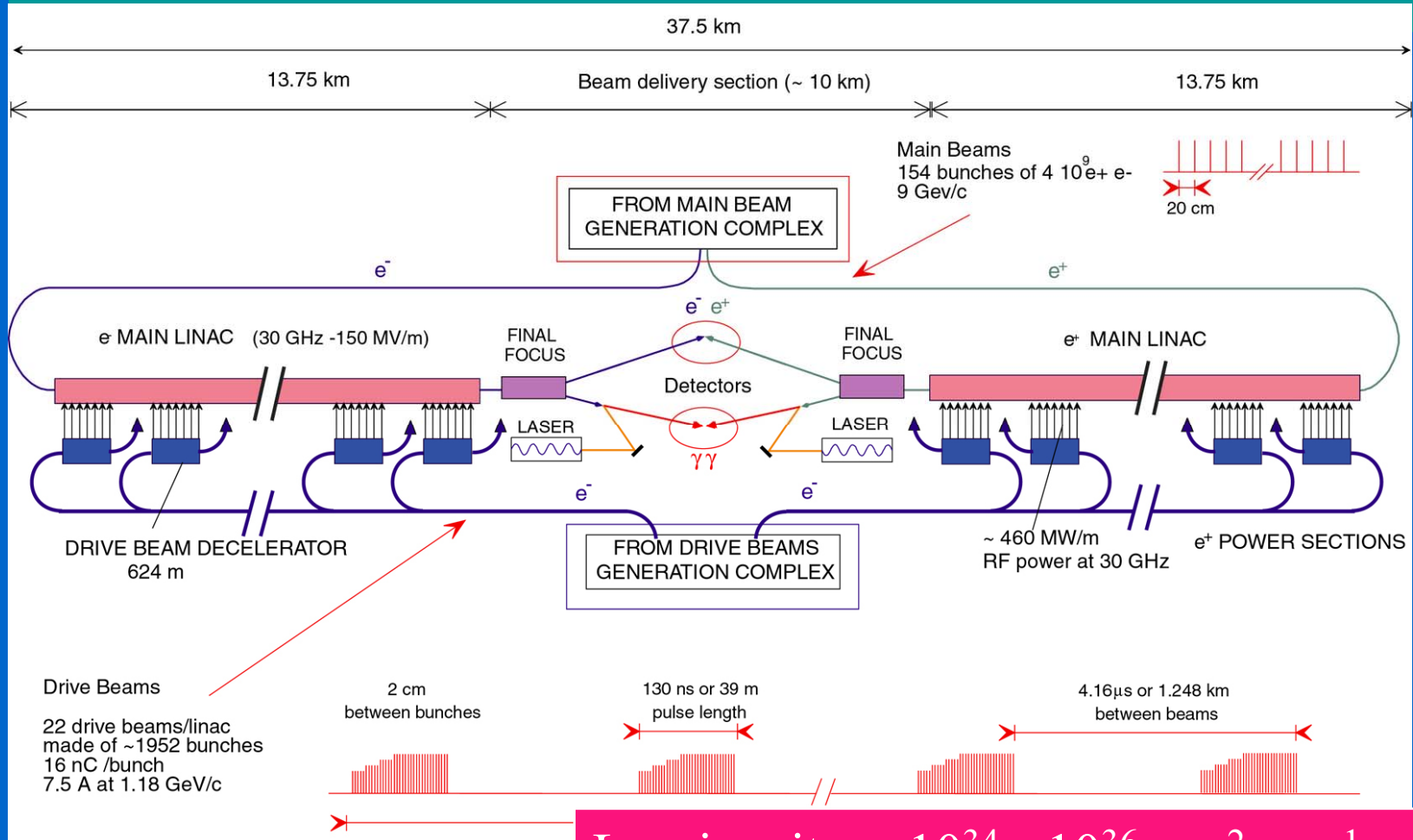
Lead – nuclear emulsion sandwich



Basic "cell"



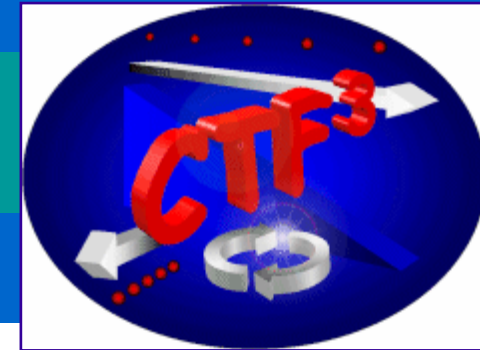
CLIC e^+e^- Linear Collider at $E_{\text{tot}} = 3 \text{ TeV}$



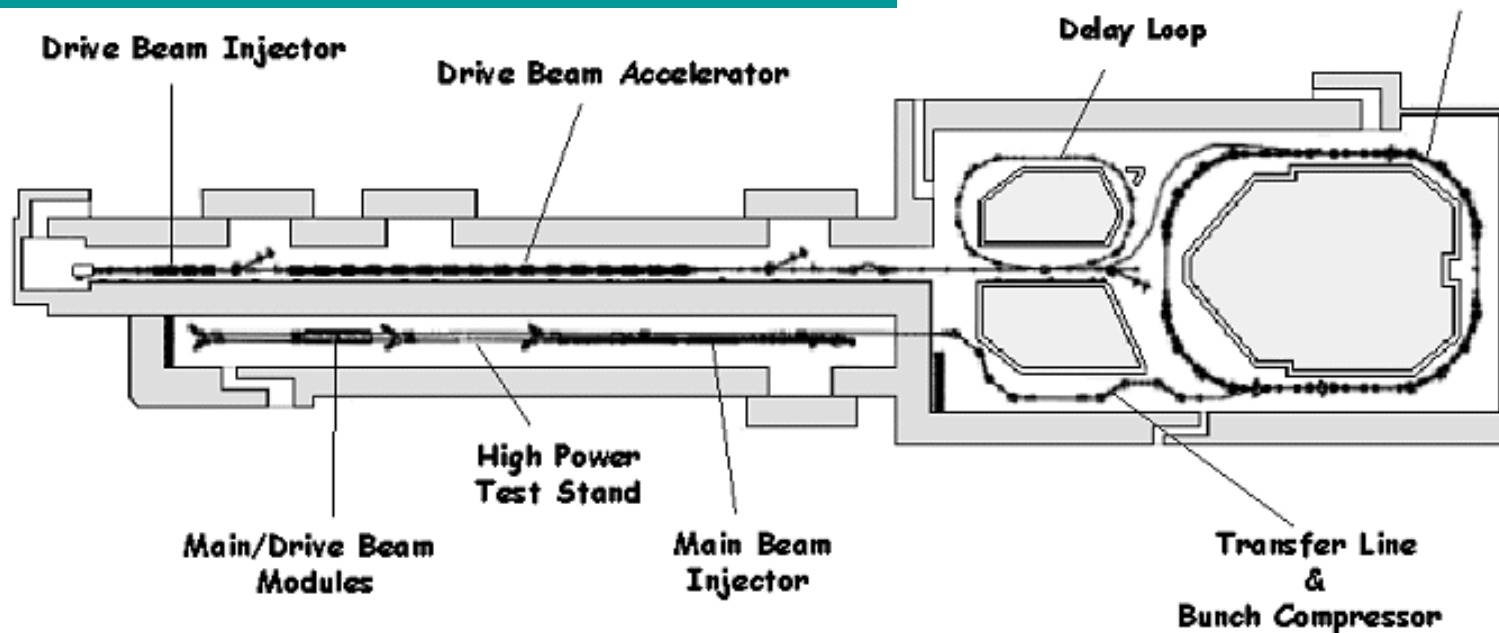
Luminosity = $10^{34} - 10^{36} \text{ cm}^{-2} \text{ sec}^{-1}$
 Total Length = 39 km

Accelerator R&D

CLIC Test Facility 3



Combiner Ring



CLIC = Compact Linear Collider

Two beam linear acceleration

$150 \text{ MeV/m} = 1.5 \text{ TeV/10km}$

Housed in LEP
pre-Injector building

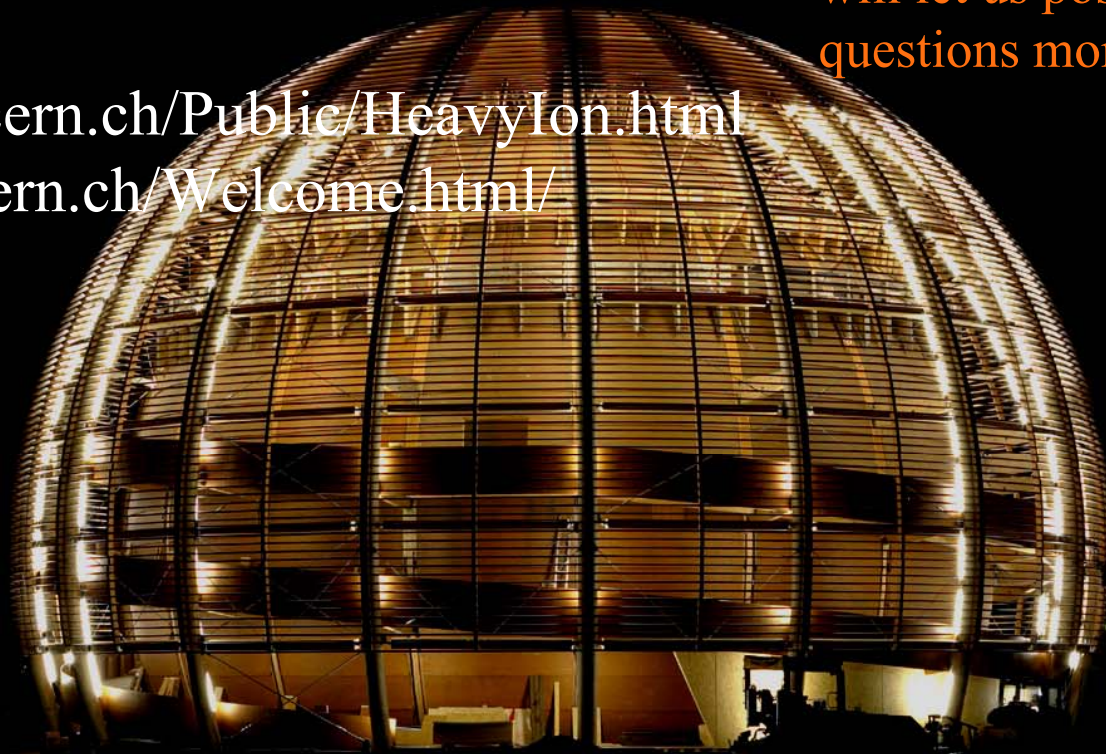
Links for further reading

<http://aliceinfo.cern.ch/Public/HeavyIon.html>

<http://cmsinfo.cern.ch/Welcome.html/>

<http://atlas.ch/>

“Knowing more about the Higgs and Supersymmetry will let us pose the next questions more sensibly”



<http://public.web.cern.ch/Public/Welcome.html>

<http://en.wikipedia.org/wiki/CERN>

http://hands-on-cern.physto.se/hoc_v21en/index.html