

CRYOGENICS OPERATIONS 2008

Organized by CERN

Welcome & Introduction to CERN

Philippe Lebrun

CERN, an international governmental organization with 20 Member States...



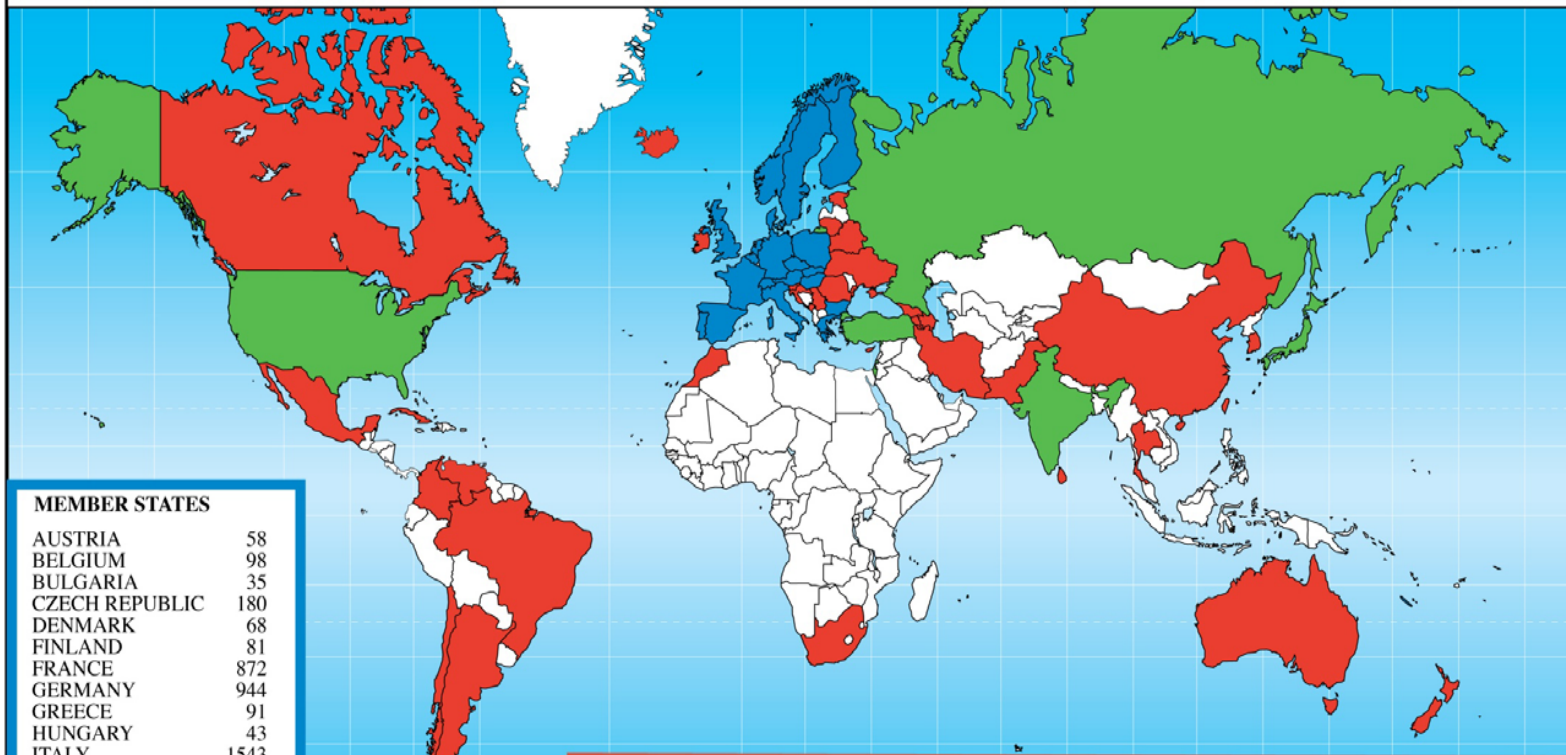
Member States (Dates of Accession)

 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)



... serving the world community of particle physicists

Distribution of All CERN Users by Nation of Institute on 5 February 2008



MEMBER STATES

AUSTRIA	58
BELGIUM	98
BULGARIA	35
CZECH REPUBLIC	180
DENMARK	68
FINLAND	81
FRANCE	872
GERMANY	944
GREECE	91
HUNGARY	43
ITALY	1543
NETHERLANDS	163
NORWAY	70
POLAND	175
PORTUGAL	109
SLOVAKIA	46
SPAIN	270
SWEDEN	74
SWITZERLAND	344
UNITED KINGDOM	645

5909

OBSERVER STATES

INDIA	93
ISRAEL	64
JAPAN	182
RUSSIA	940
TURKEY	35
USA	1278

2592

OTHER STATES

ARGENTINA	8	CROATIA	17	MEXICO	23	TAIWAN	40
ARMENIA	17	CUBA	3	MONTENEGRO	1	THAILAND	1
AUSTRALIA	13	CYPRUS	6	MOROCCO	6	UKRAINE	17
AZERBAIJAN	1	ESTONIA	10	NEW ZEALAND	7		
BELARUS	23	GEORGIA	9	PAKISTAN	23		
BRAZIL	68	ICELAND	1	ROMANIA	46		
CANADA	119	IRAN	6	SERBIA	16		
CHILE	4	IRELAND	14	SLOVENIA	16		
CHINA	60	KOREA	44	SOUTH AFRICA	2		
COLOMBIA	5	LITHUANIA	5	SRI LANKA	1		

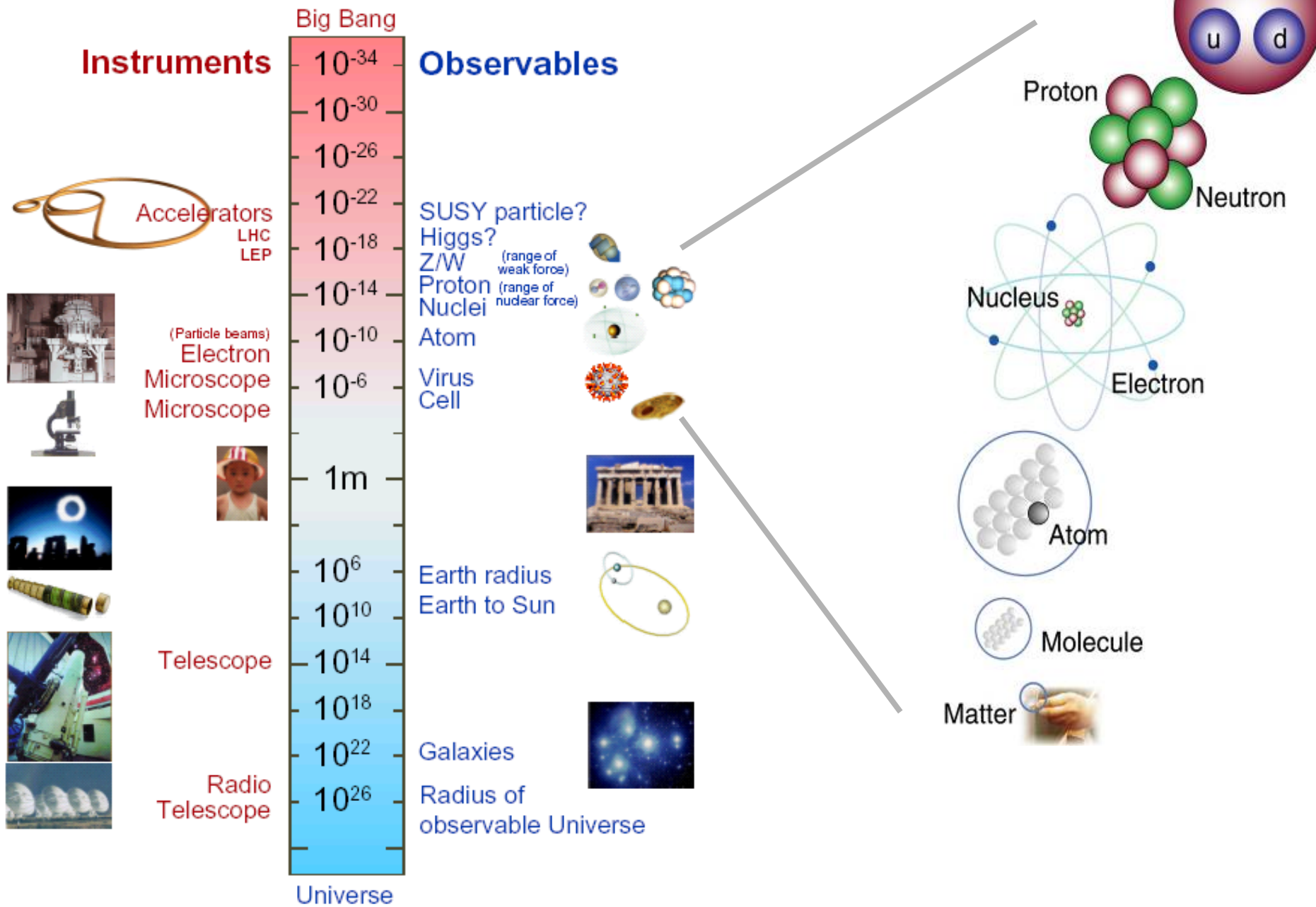
632

CERN in Numbers (2008)

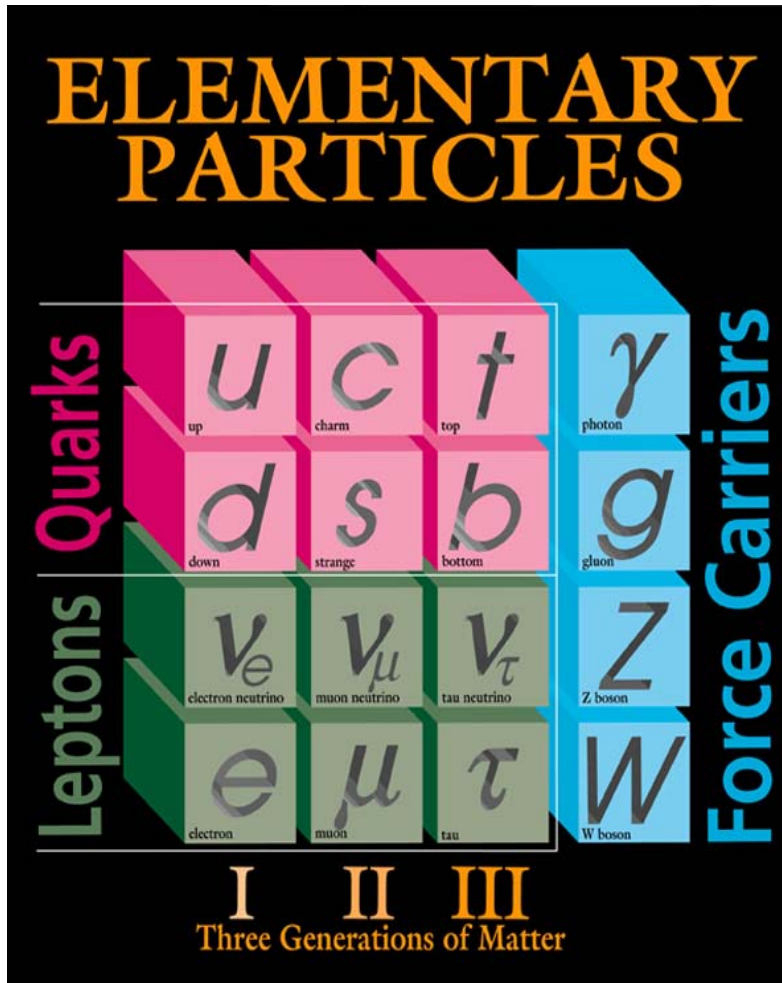
- 2415 staff
- 730 Fellows & Associates
- 9133 users
- Budget 1076 MCHF (668 MEuro)

- **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 to Council:** India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and Unesco

The size of things



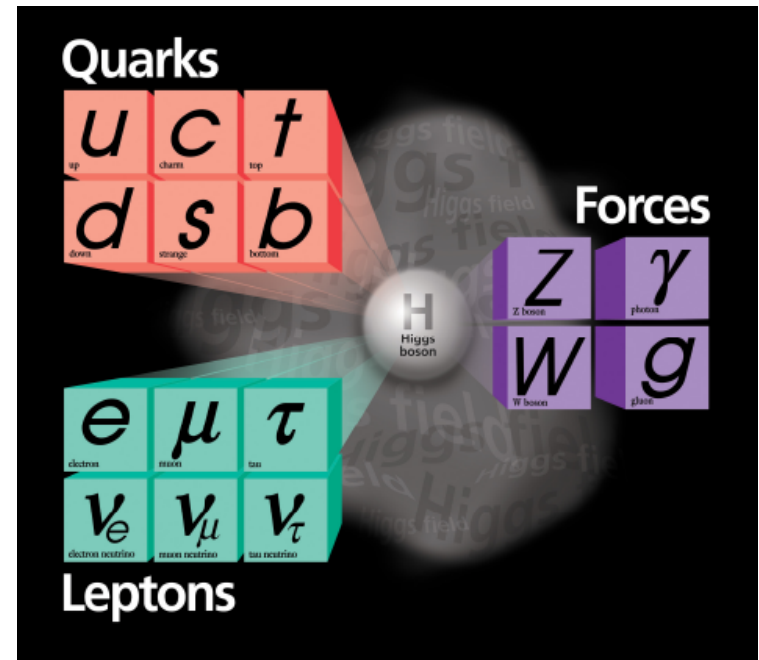
The Standard Model



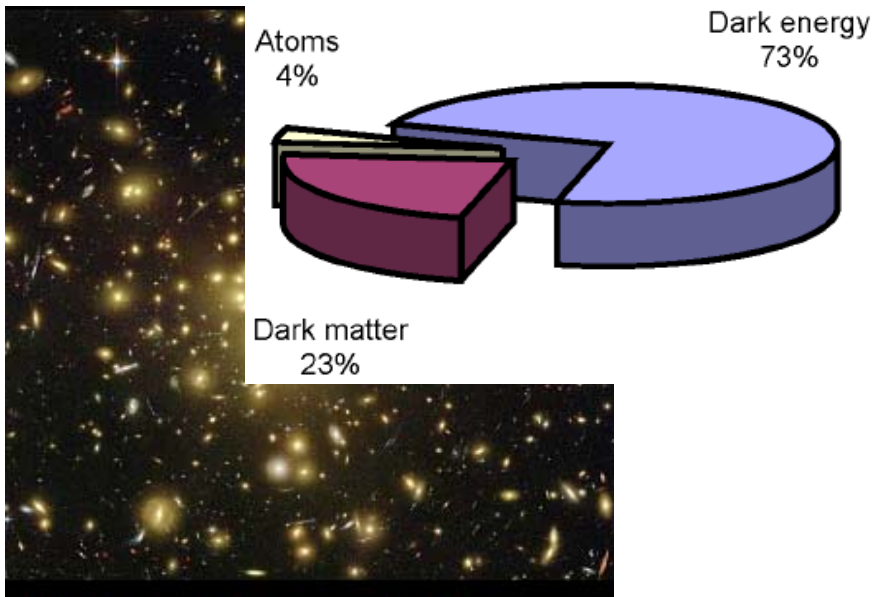
- Matter is composed of fermions (6 quarks and 6 leptons)
- All fermions have their antiparticles
- Three families of fermions of increasing masses, « normal » matter is made of the first family
- Interactions (strong nuclear, electromagnetic, weak) are carried by exchange of bosons (gluons, photons, weak bosons)
- Very successful description of nature, good precision

Limits of the Standard Model

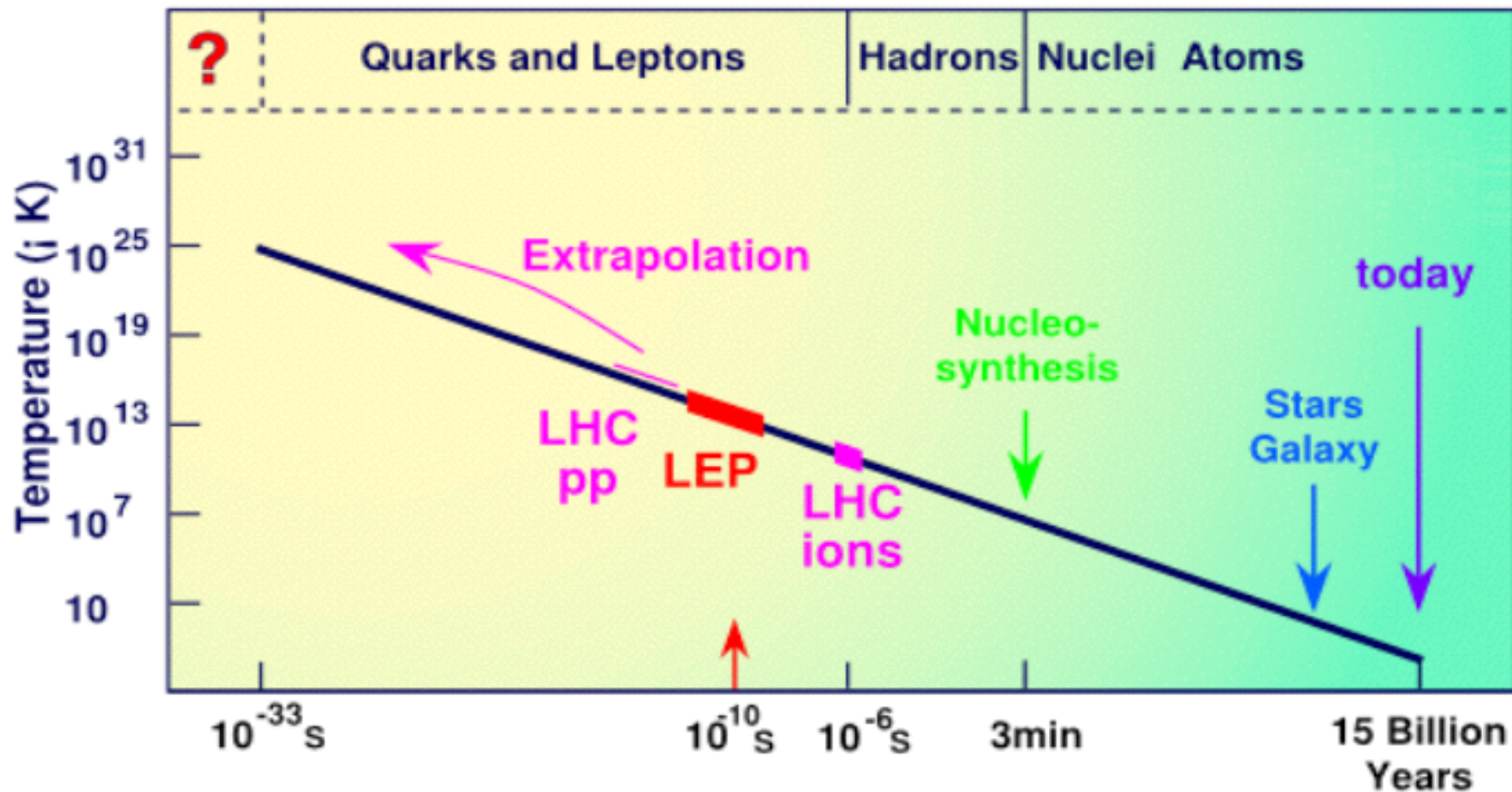
- Origin & hierarchy of particle masses: coupling with Higgs field (boson)?
- Fermion/boson supersymmetry?
- Gravity is not included!
- Unification of forces?



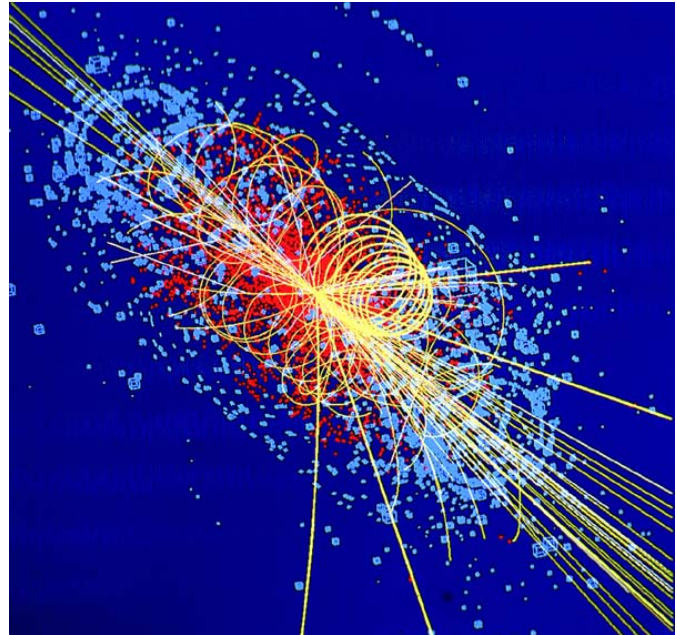
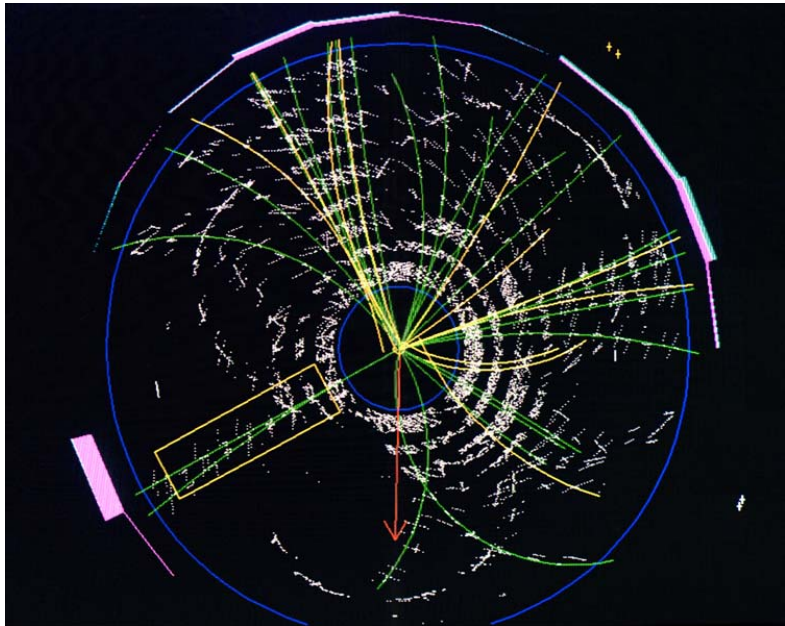
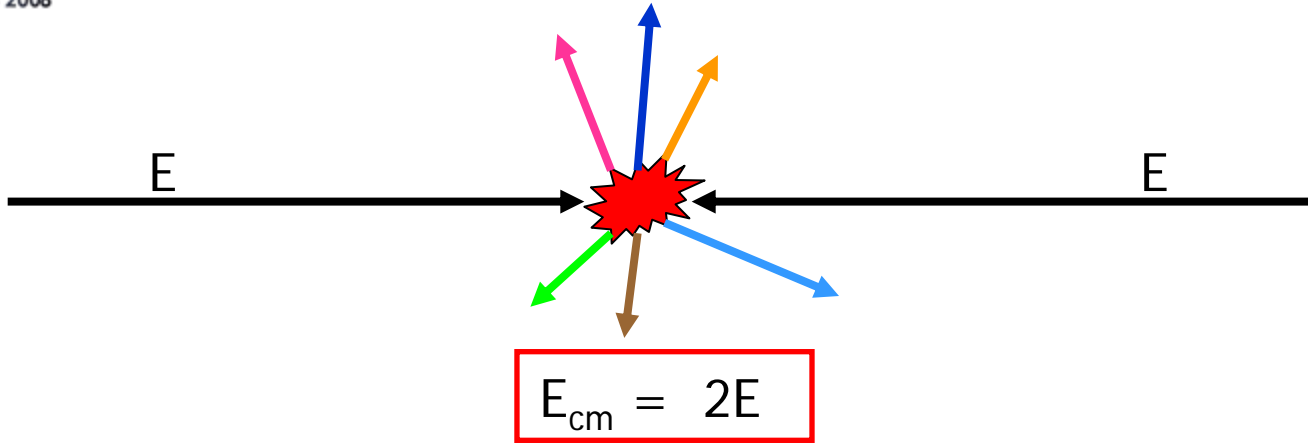
- Origin of matter-antimatter asymmetry in the universe?
- What constitutes dark matter?
- What is dark energy?



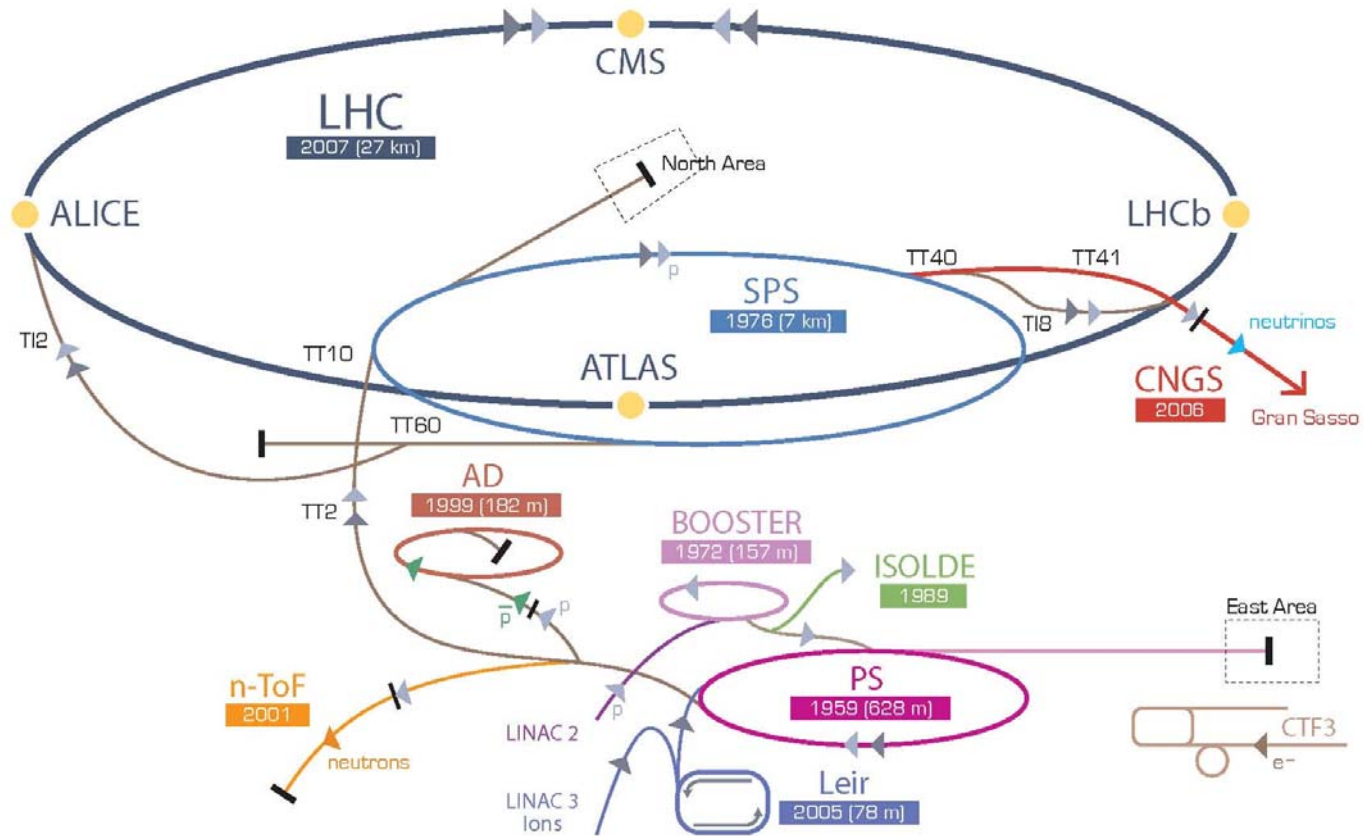
Time travel towards the big bang



High-energy collisions probe matter at small scale



The CERN accelerator complex



▶ p [proton] ▶ ion ▶ neutrons ▶ \bar{p} [antiproton] \leftrightarrow proton/antiproton conversion ▶ neutrinos ▶ electron

LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight



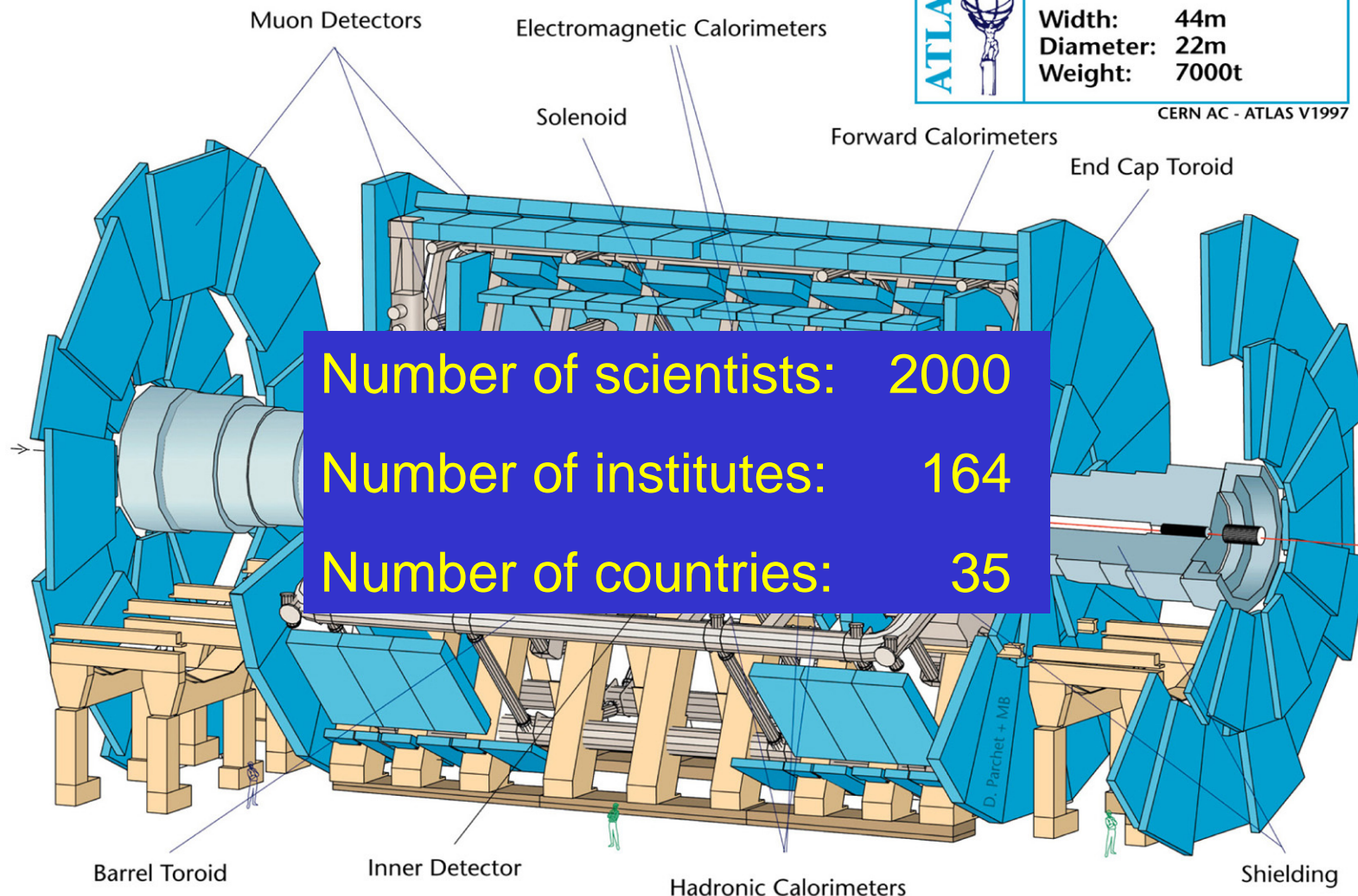
The ATLAS detector



Detector characteristics

Width: 44m
Diameter: 22m
Weight: 7000t

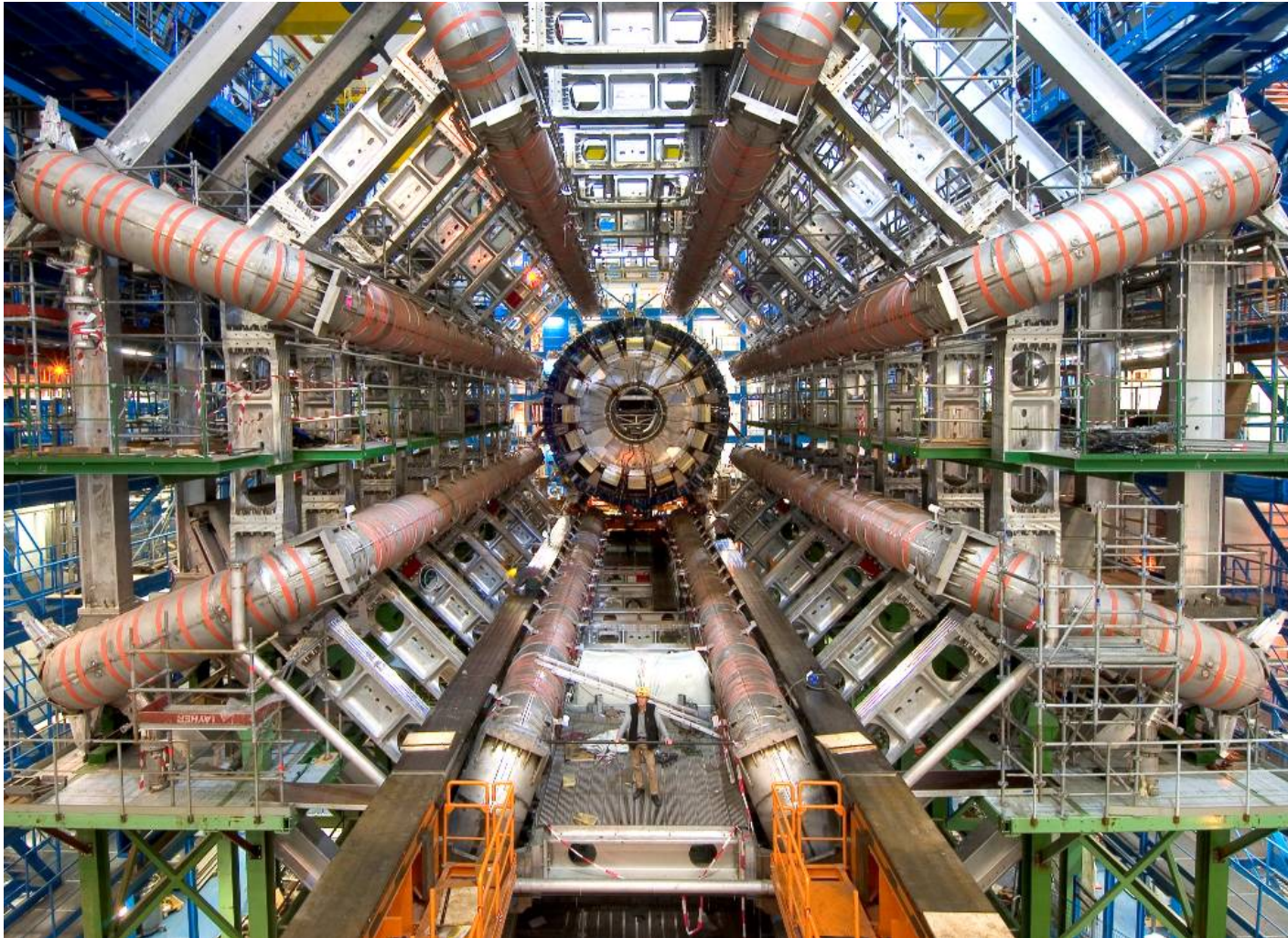
CERN AC - ATLAS V1997



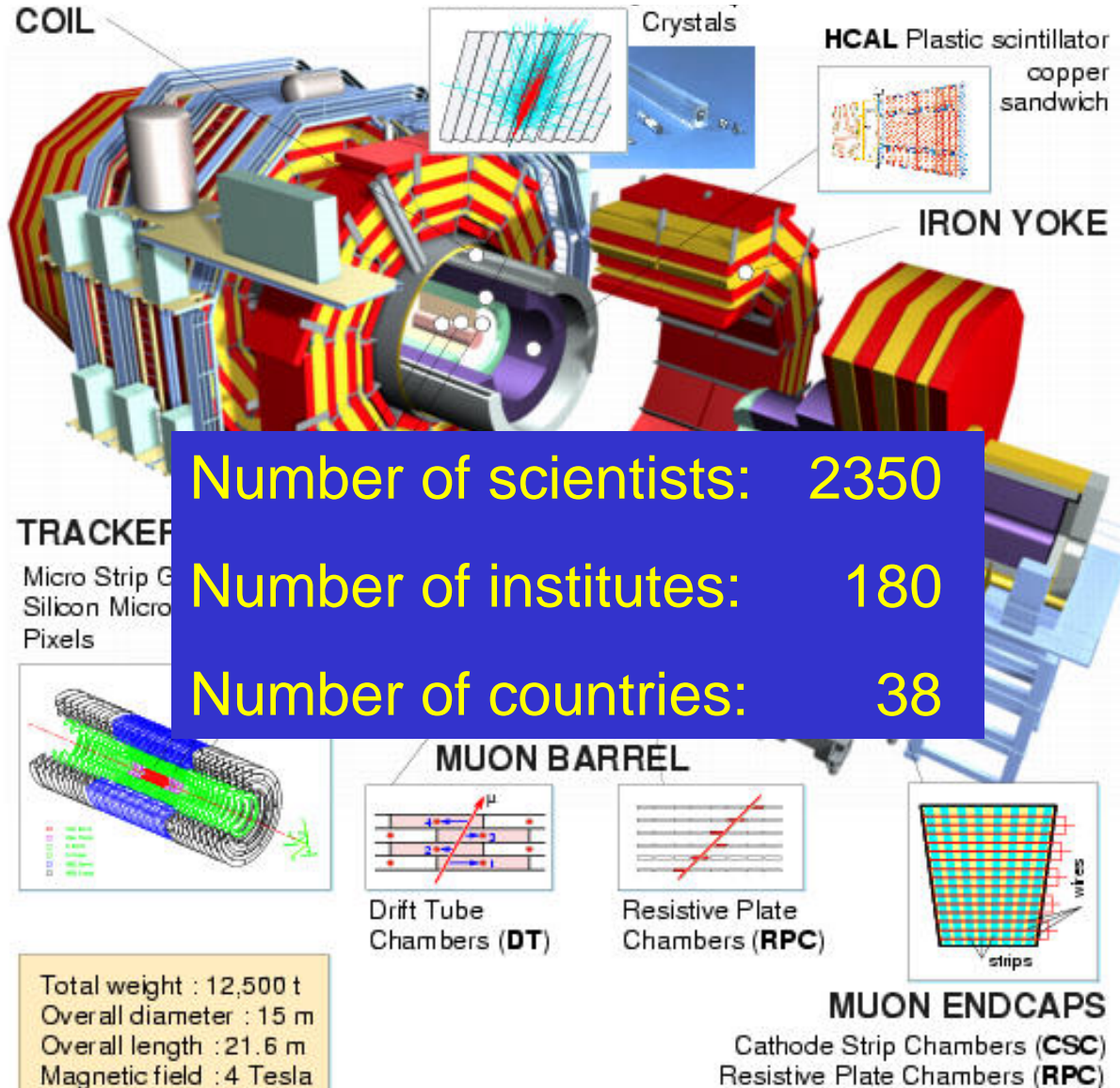
Number of scientists: 2000
Number of institutes: 164
Number of countries: 35

D. Panchet + MB

ATLAS superconducting toroid



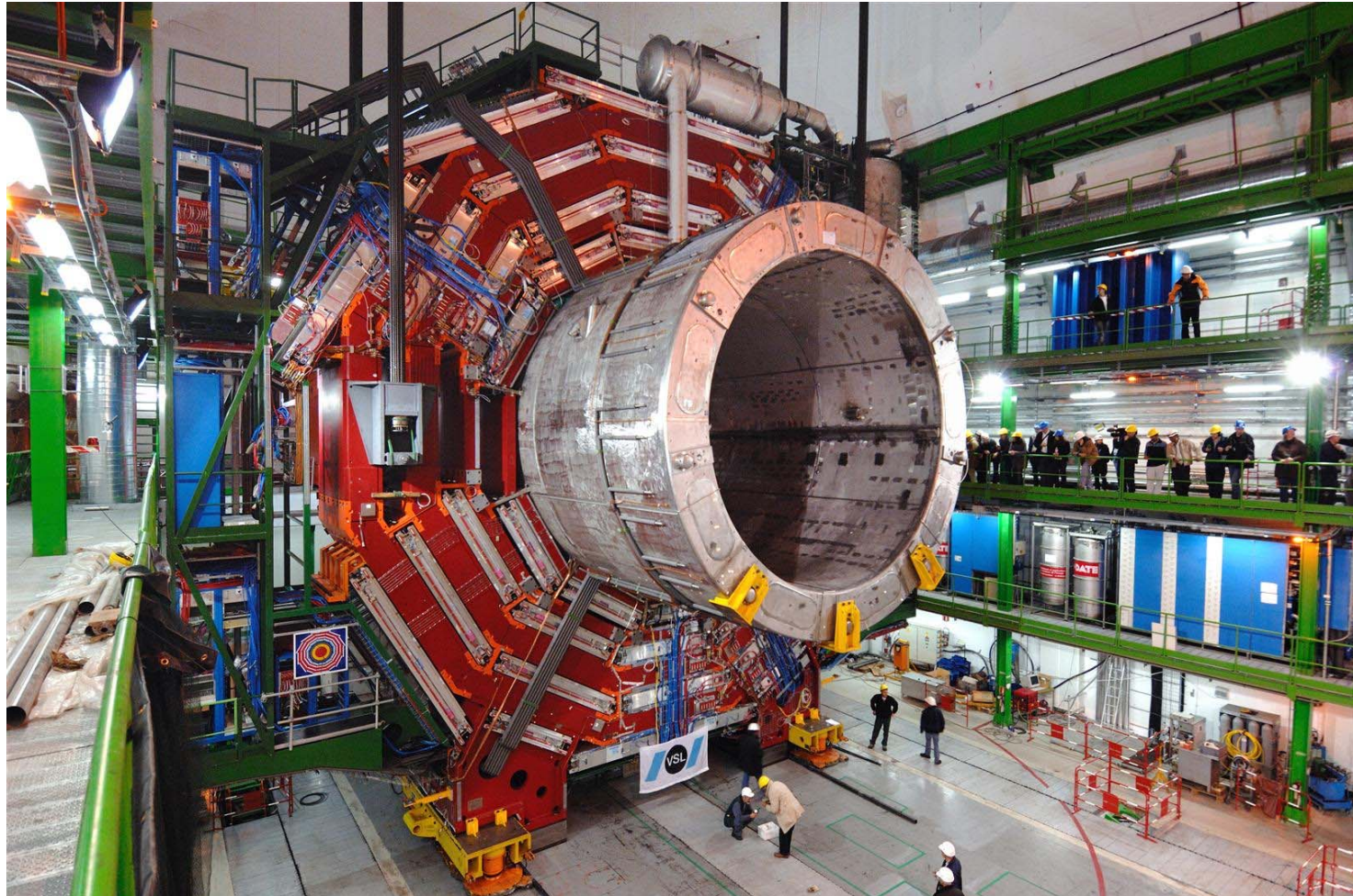
The CMS detector



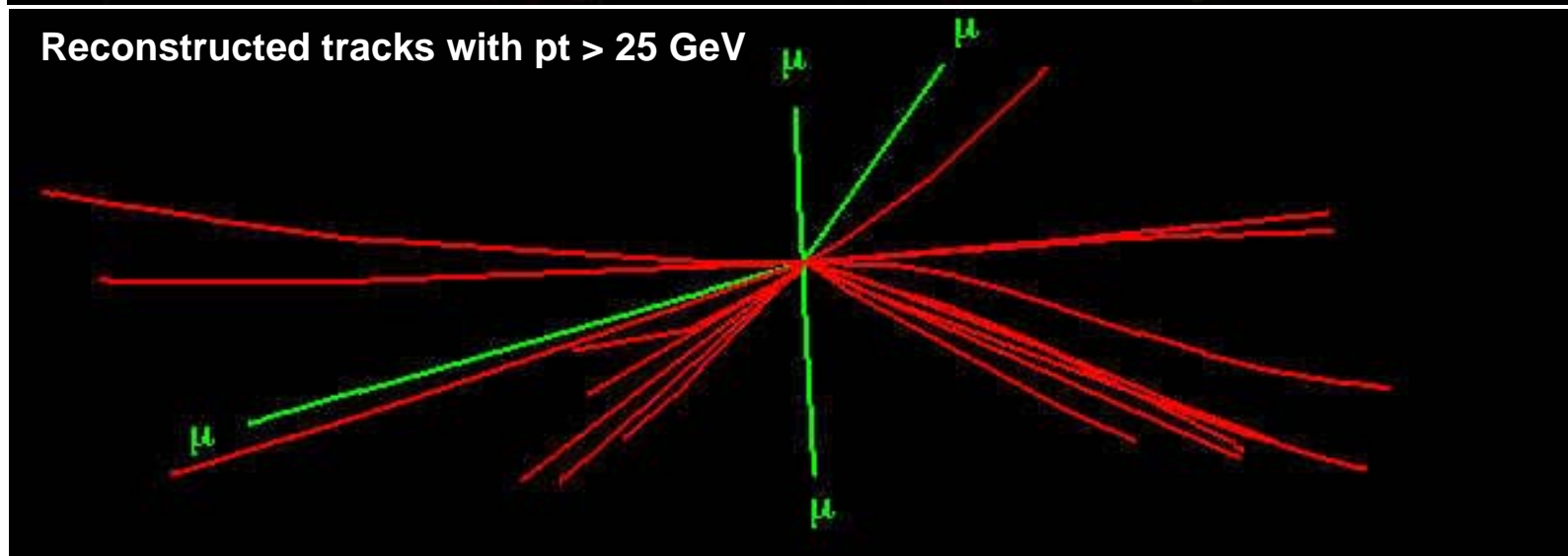
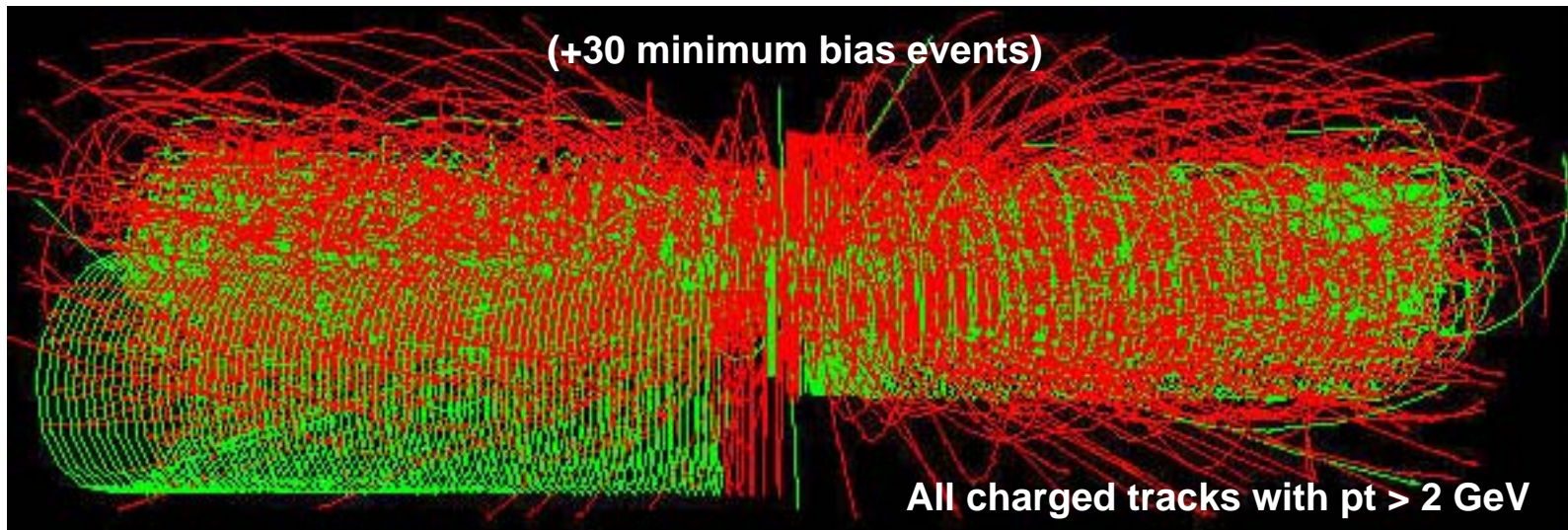
Number of scientists: 2350
Number of institutes: 180
Number of countries: 38

Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

CMS superconducting solenoid

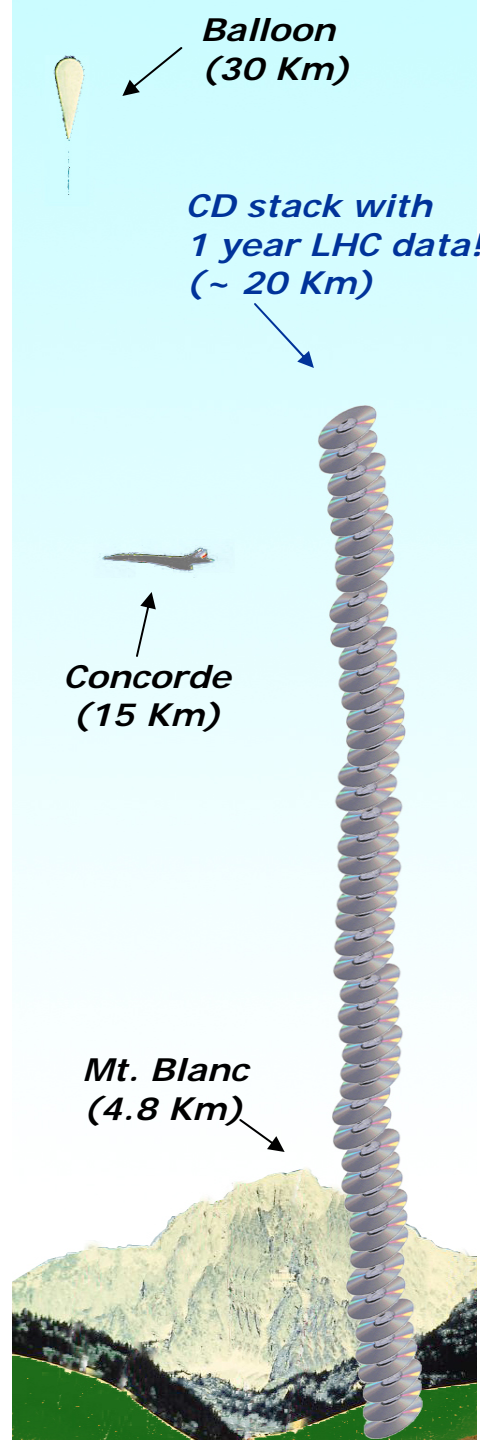


Finding the Higgs boson: a needle in 20'000'000 haystacks

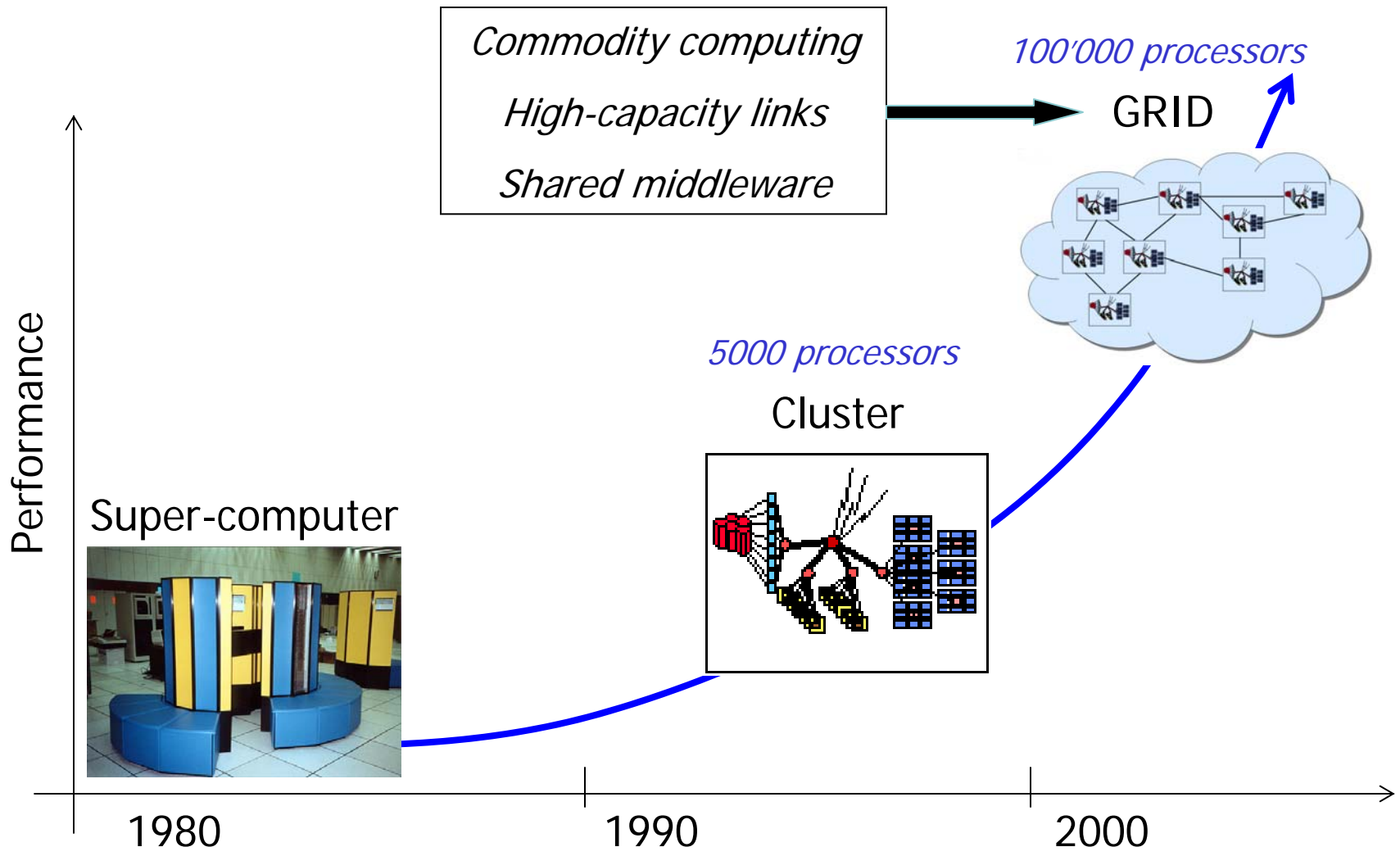


A volume of data to process without precedent

12-14 petabytes/year
(1 petabyte = 1 million gigabytes)



Towards a world computing « grid »

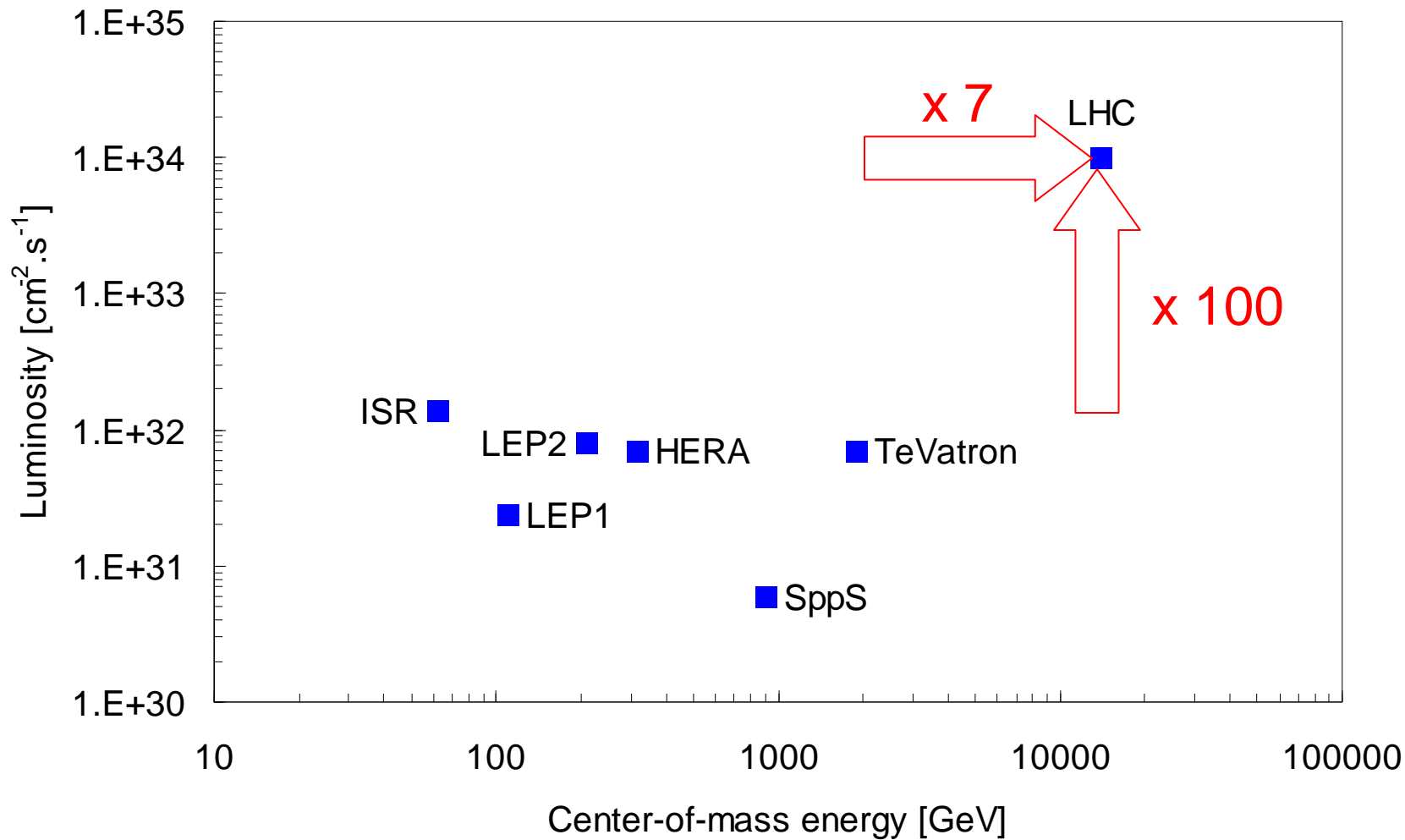


The LHC Computing Grid



A map of the worldwide LCG infrastructure operated by EGEE and OSG.

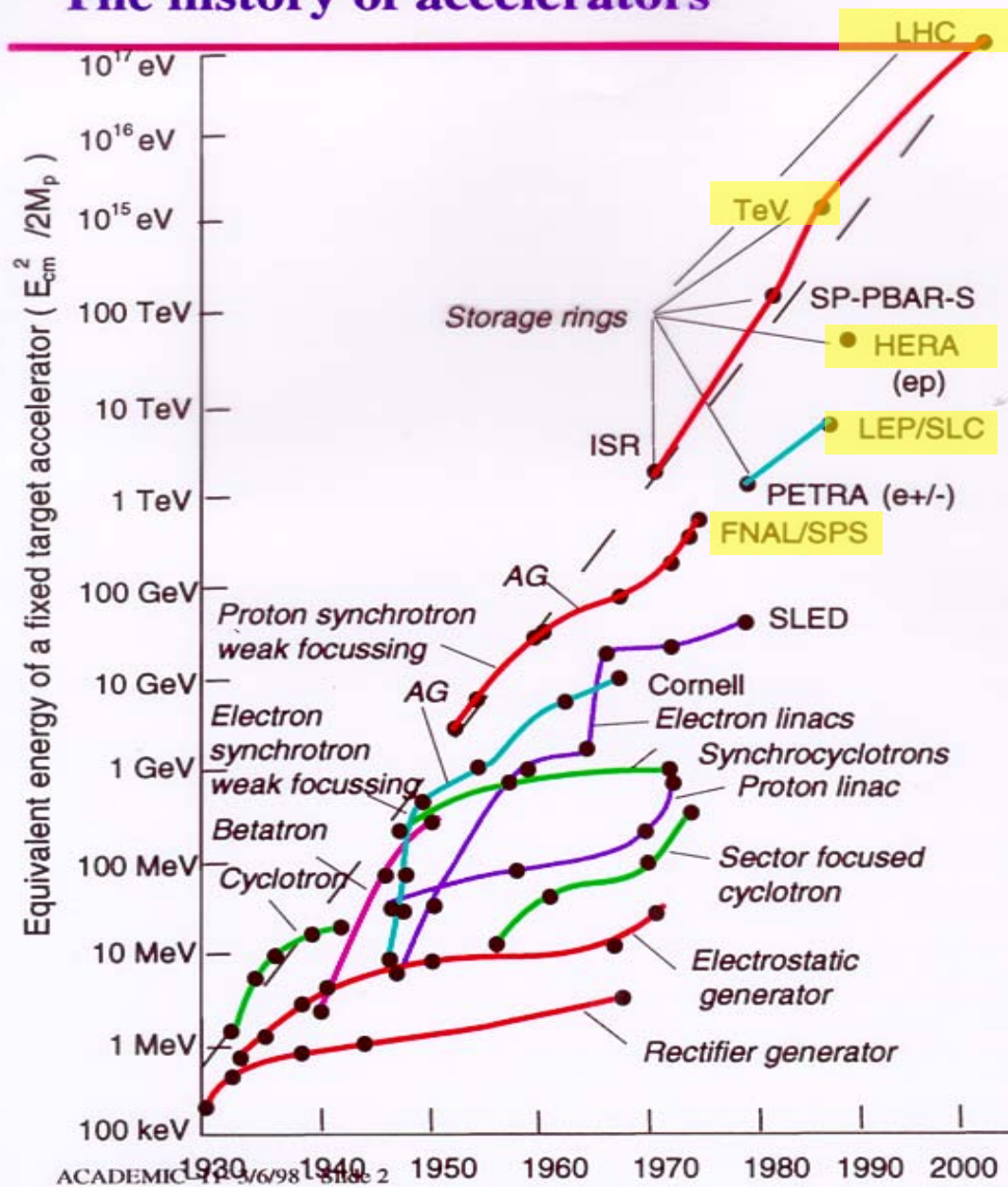
A particle collider well beyond the pre-existing state-of-the-art



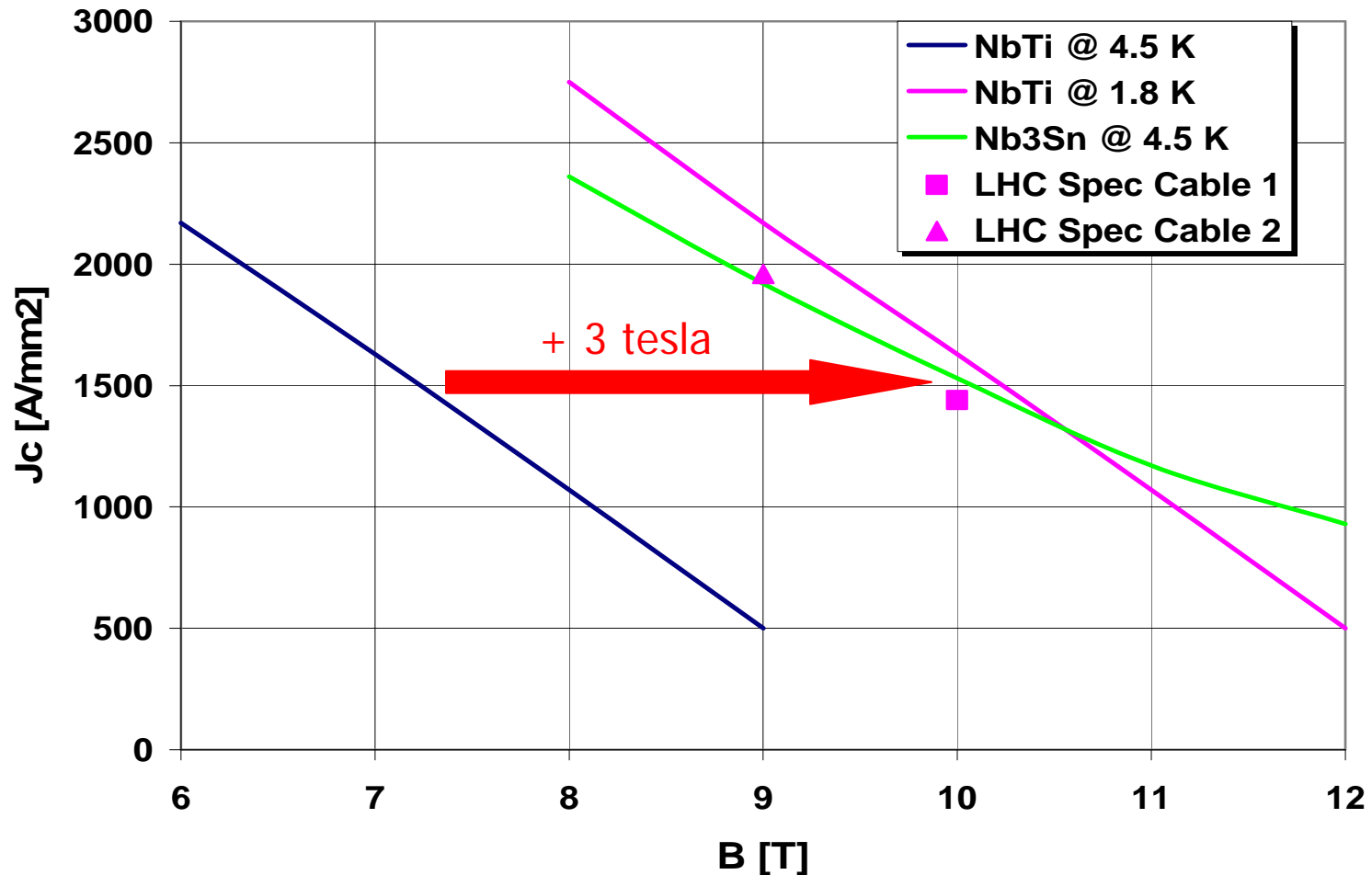
Superconductivity, a key technology

- to produce high electromagnetic fields,
- to limit electrical power consumption,
- to sustain the development of high-energy particle accelerators

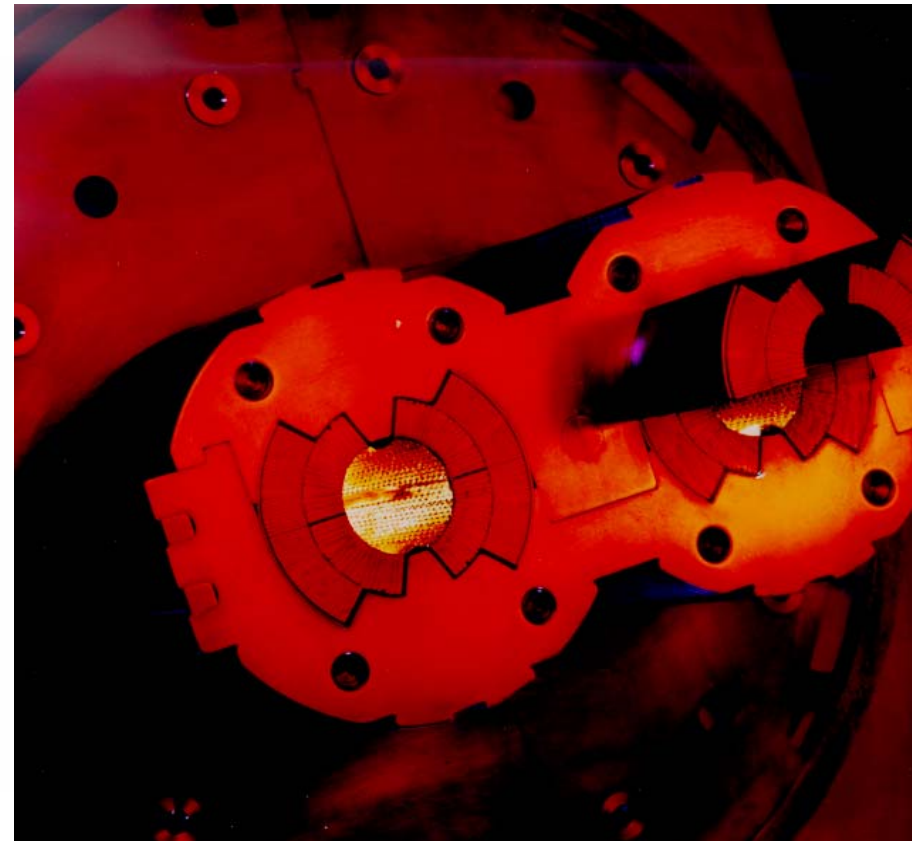
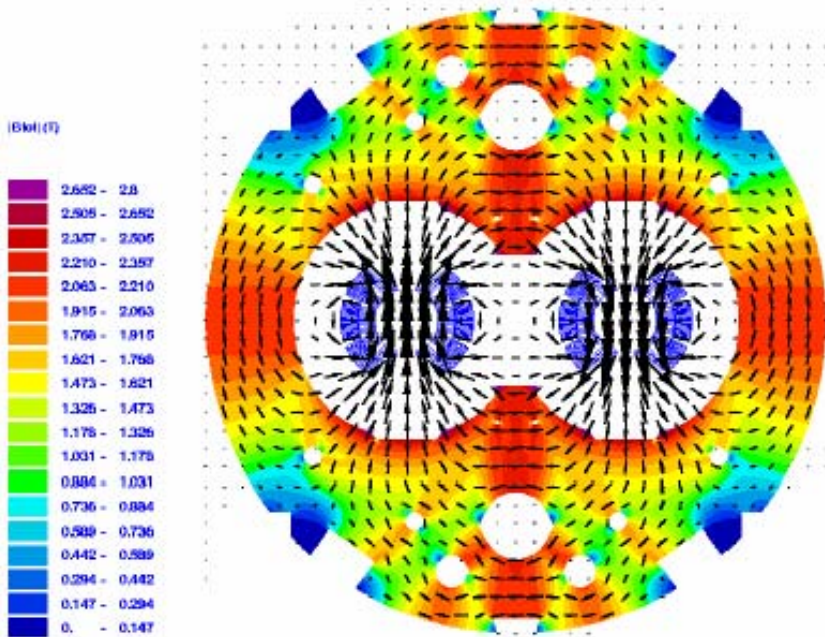
The history of accelerators



Critical current density of technical superconductors



Twin-aperture dipole magnet



Field reproducibility/precision $\sim 10^{-3}$

Field homogeneity $\sim 10^{-4}$

\Rightarrow Winding precision < 0.05 mm

Final assembly of cryomagnets at CERN



Cryogenic test station



Interconnections in tunnel

65'000 electrical joints

Induction-heated soldering

Ultrasonic welding

Very low residual resistance

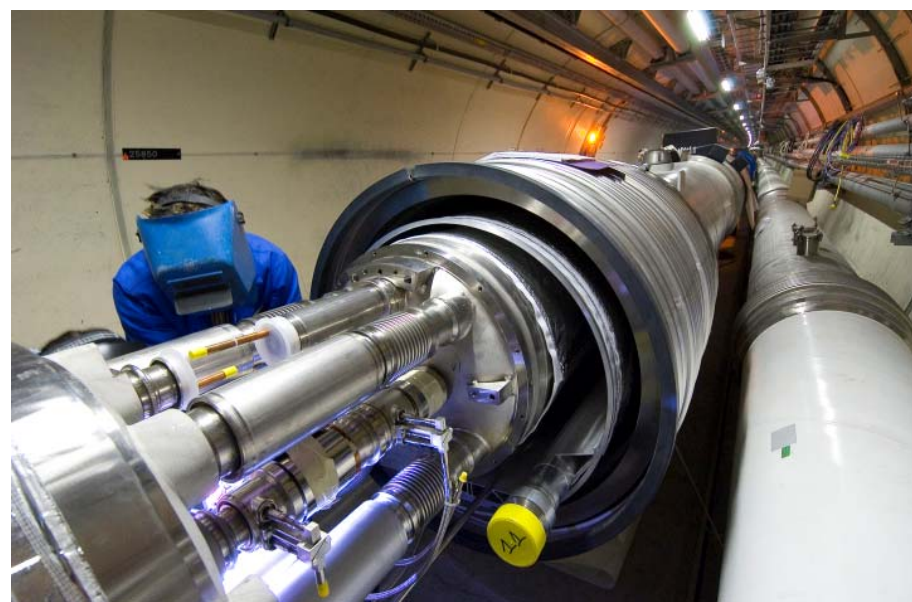
HV electrical insulation

40'000 cryogenic junctions

Orbital TIG welding

Weld quality

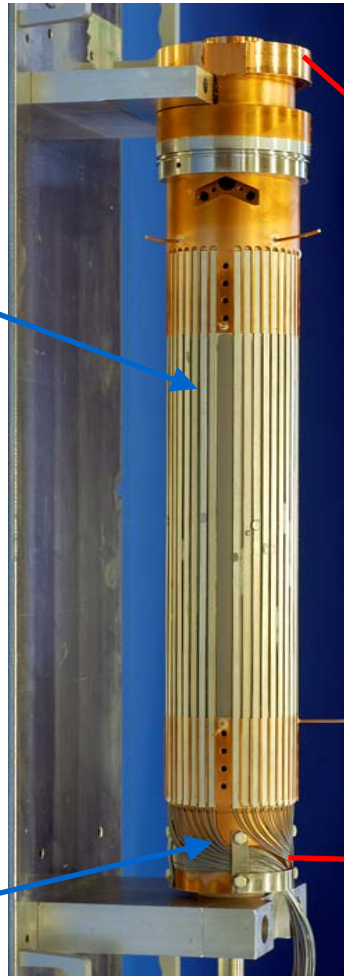
Helium leaktightness



13 kA current leads using HTS superconductor

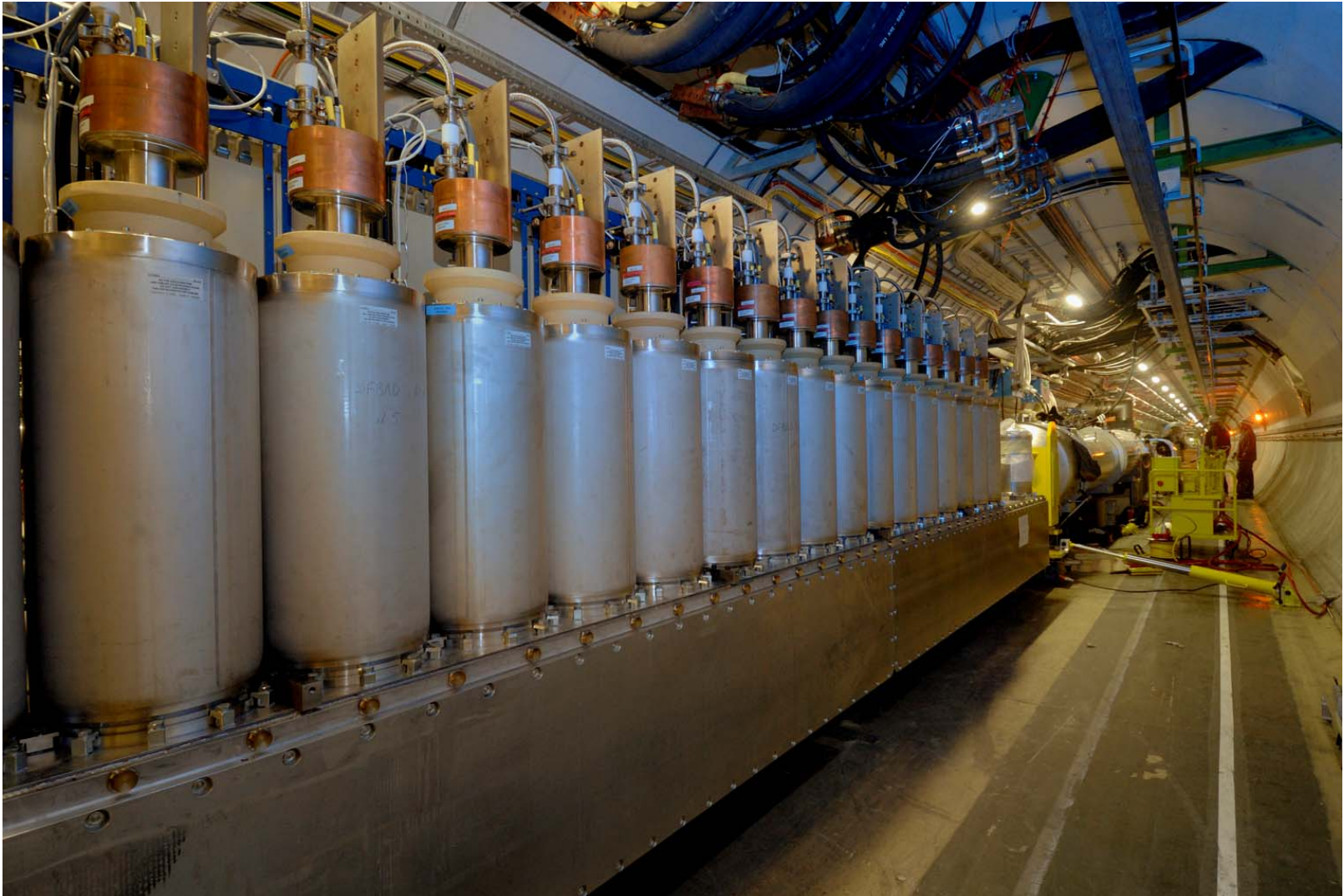
BSCCO 2223 tapes

Nb-Ti wires

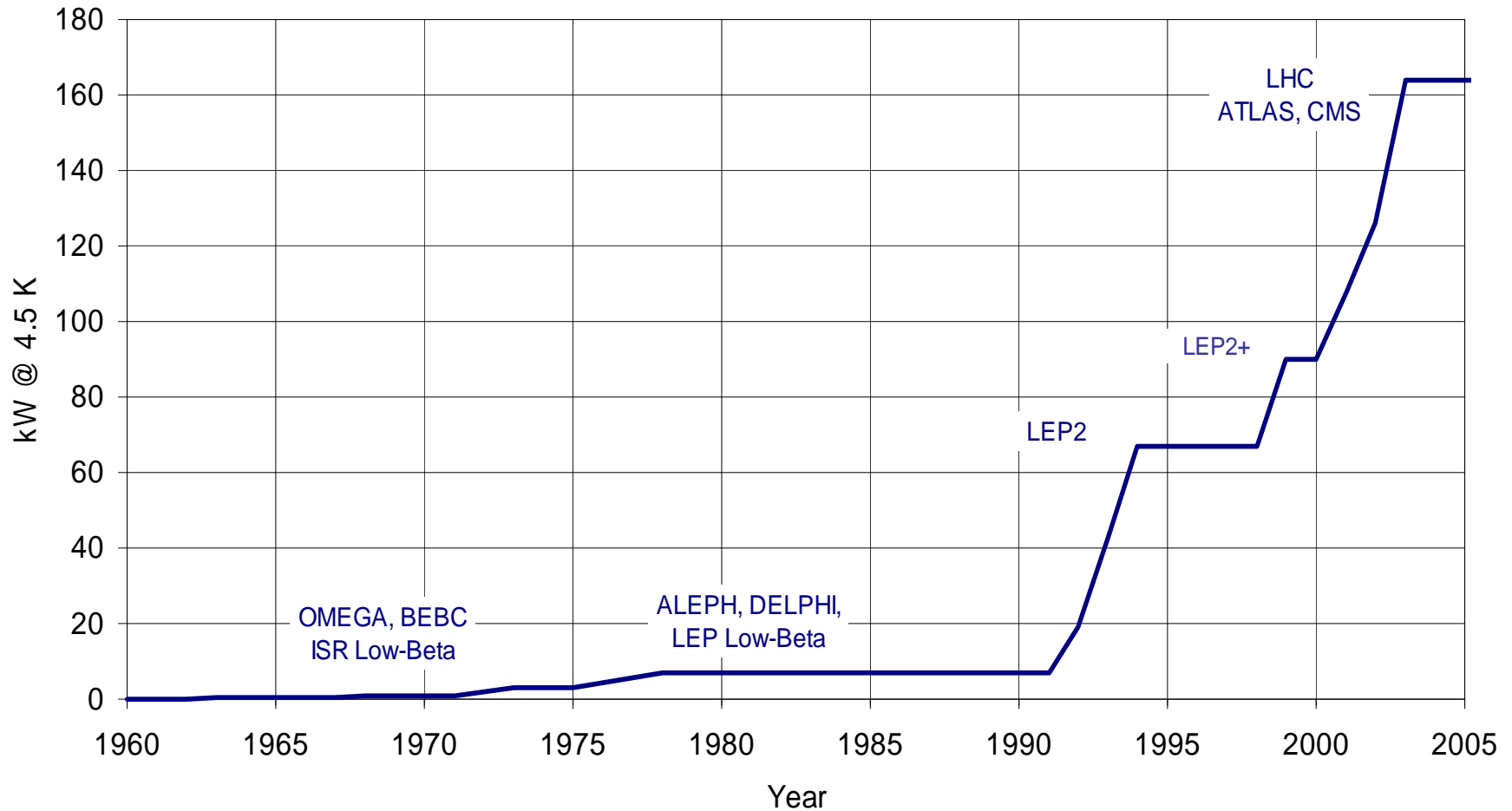


HTS current leads in the LHC tunnel

The largest high-current application to date of HTc superconductors



Cryogenic refrigeration capacity at CERN



18 kW @ 4.5 K helium cryoplants



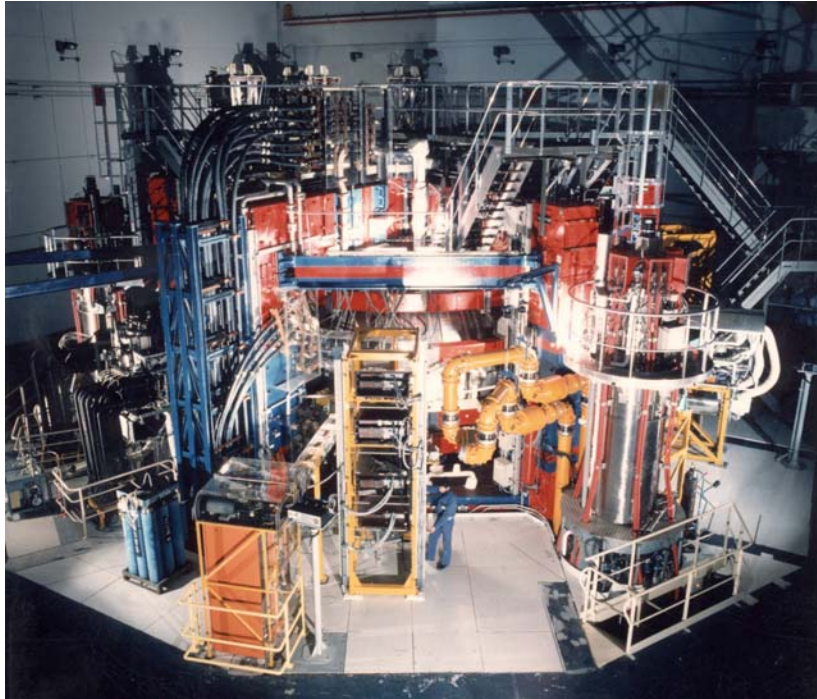
Air Liquide



Linde

33 kW @ 50 K to 75 K
23 kW @ 4.6 K to 20 K
41 g/s liquefaction

Large projects cooled by superfluid helium



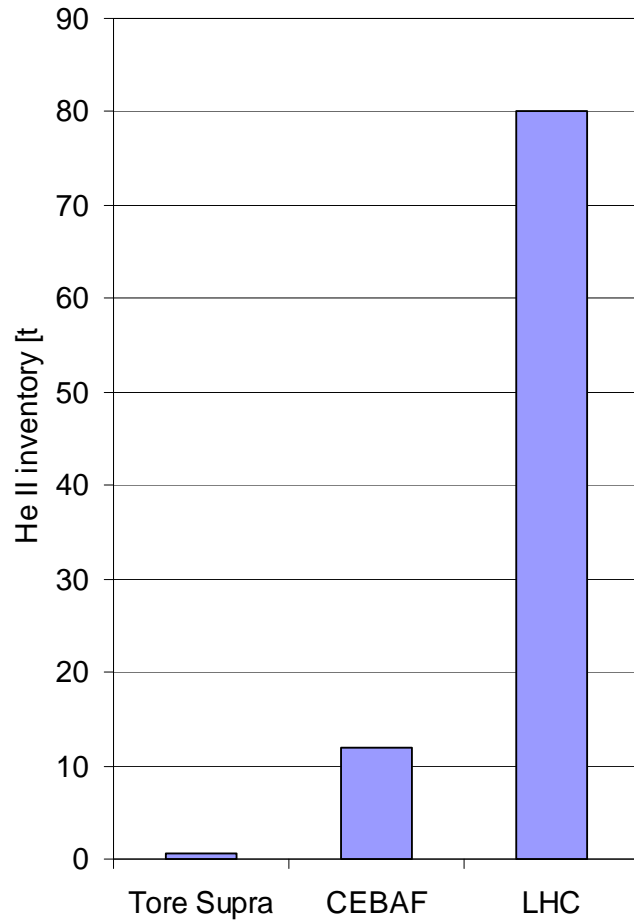
Tore Supra tokamak,
Cadarache (France)



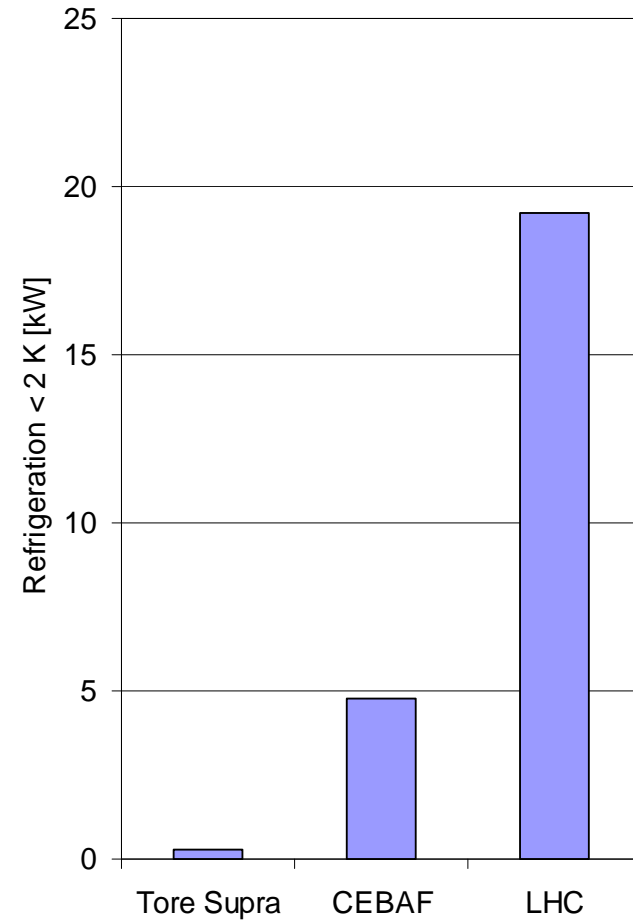
CEBAF accelerator,
Newport News (USA)

Large-scale superfluid helium systems

He II inventory

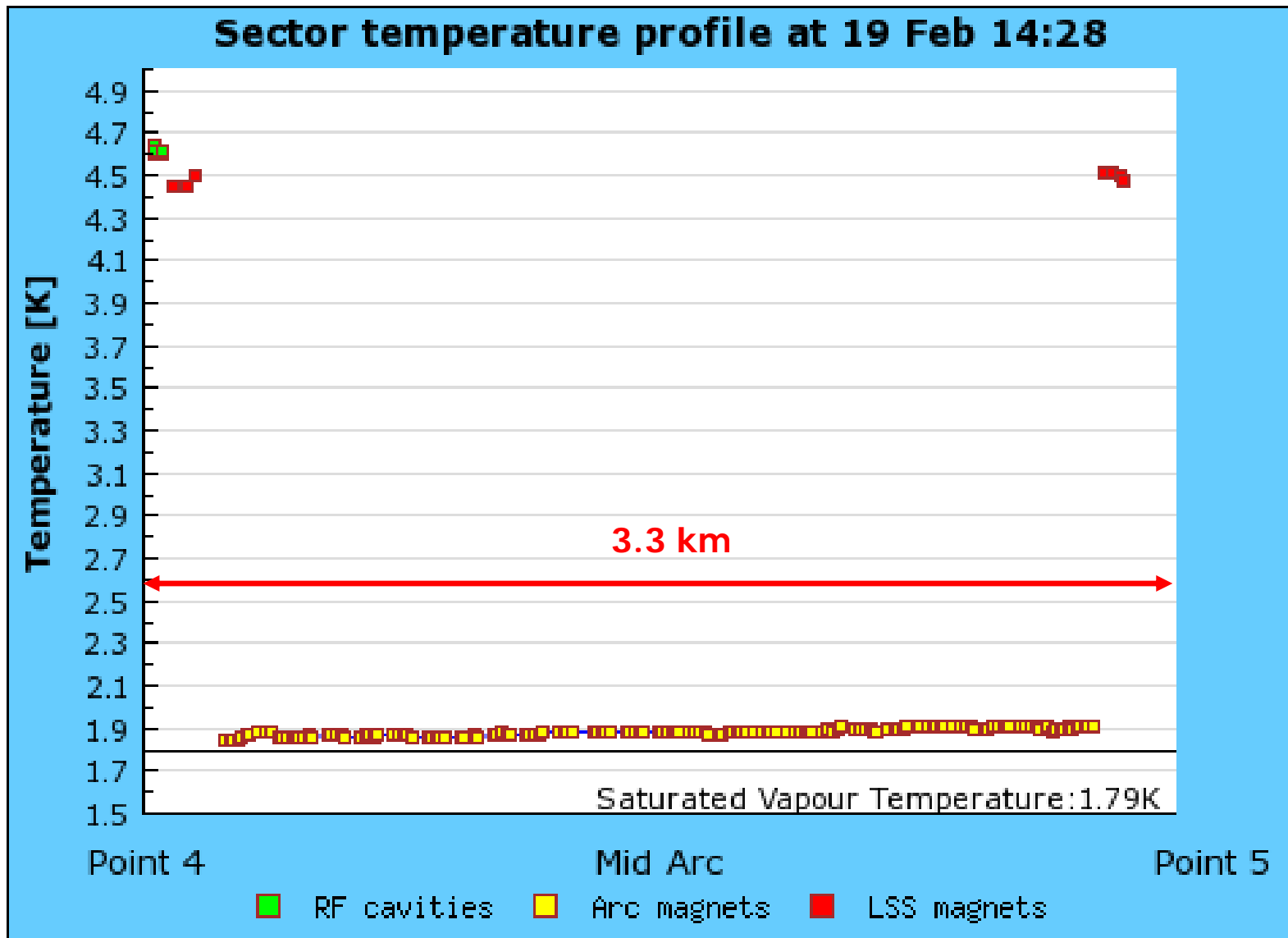


Refrigeration power < 2 K

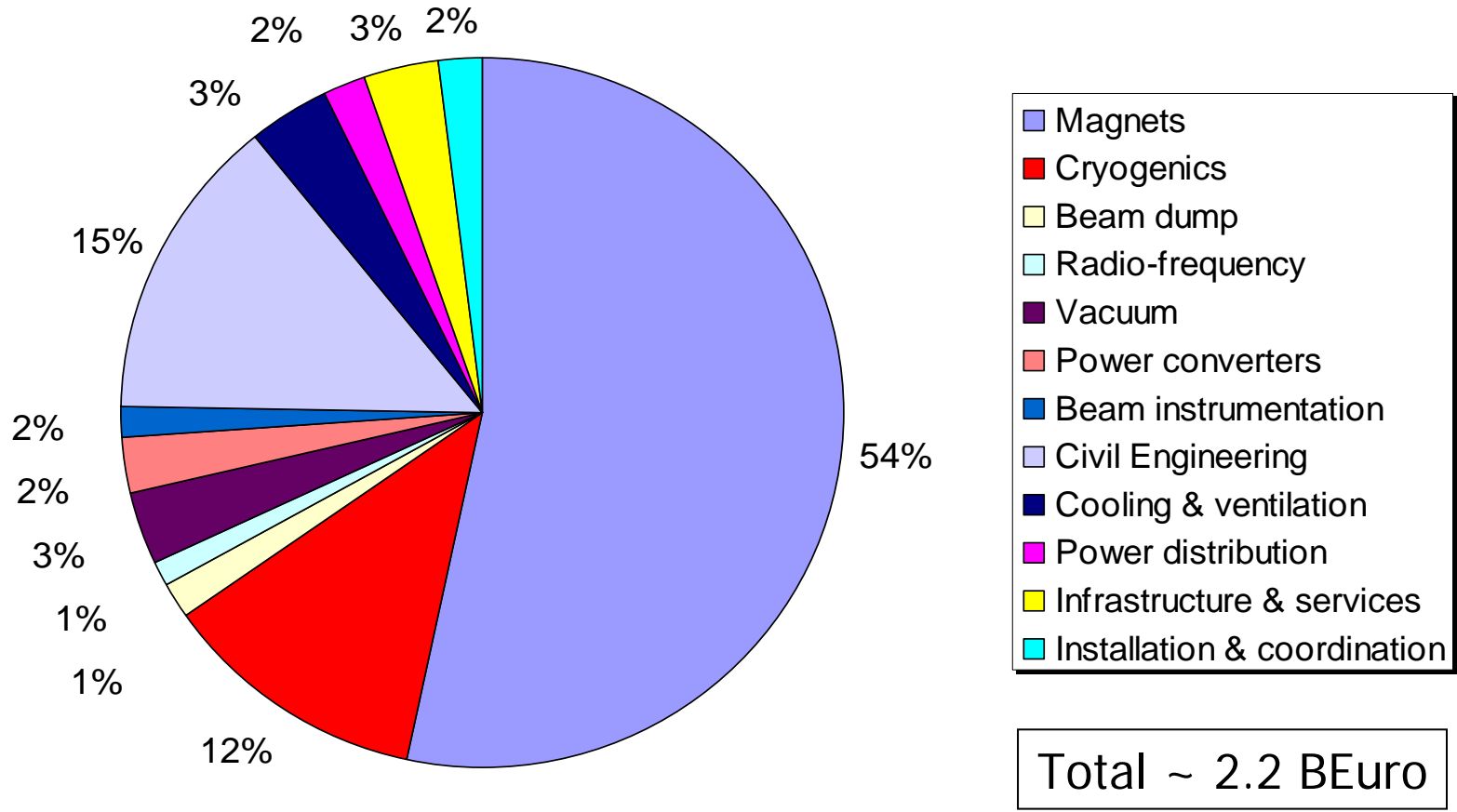




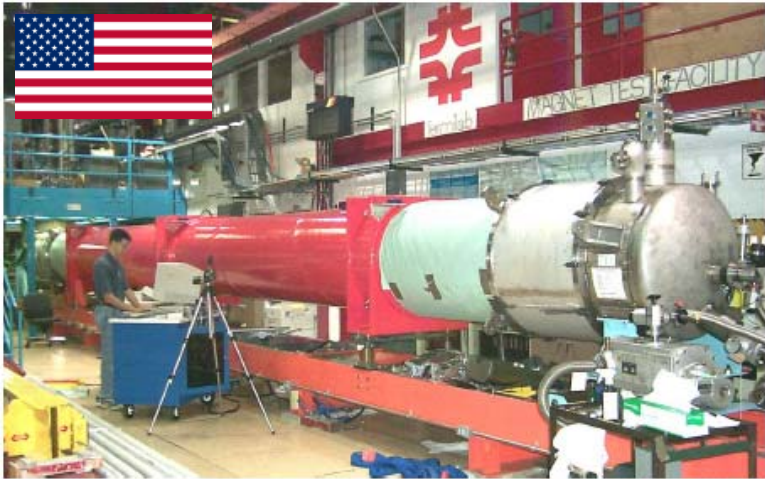
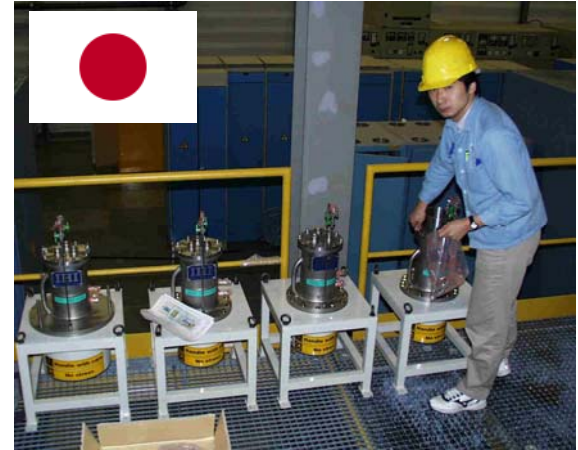
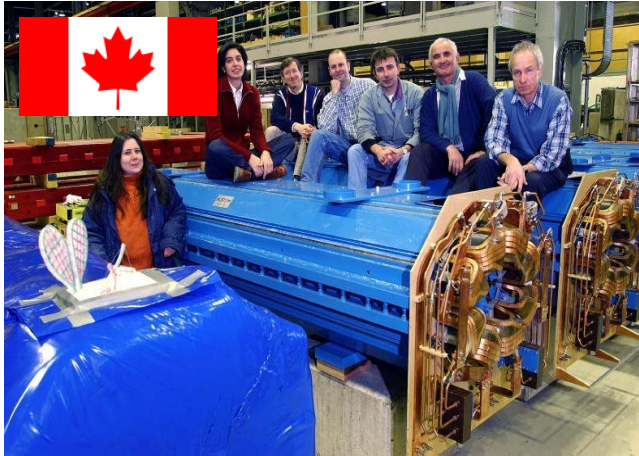
Cryogenic operation of LHC sector



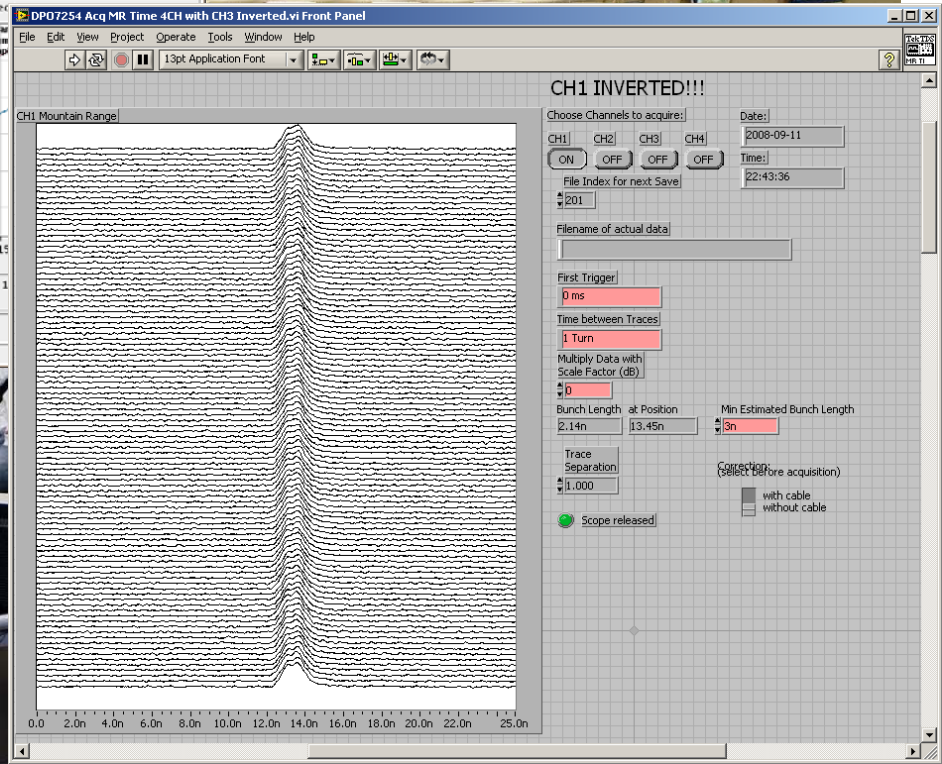
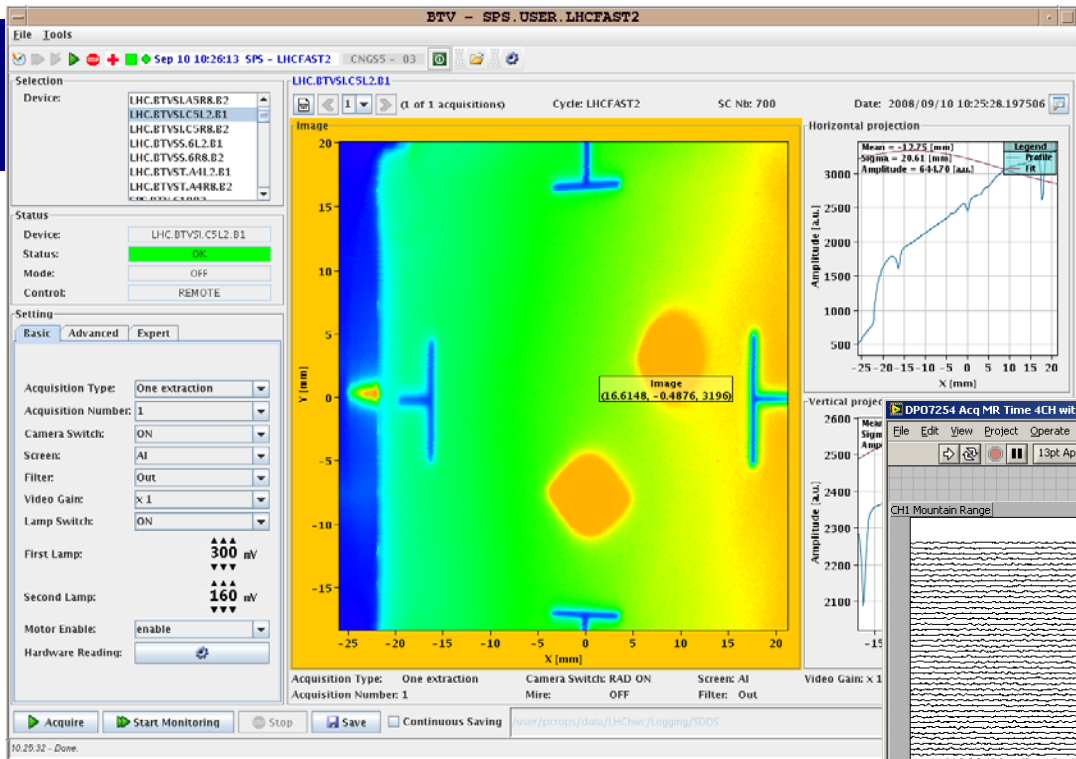
Cost structure of the LHC accelerator



A global project



LHC startup



Impact on society knowledge & training

> 50 doctoral theses
> 120 diploma theses
in magnetism, cryogenics and
applied superconductivity

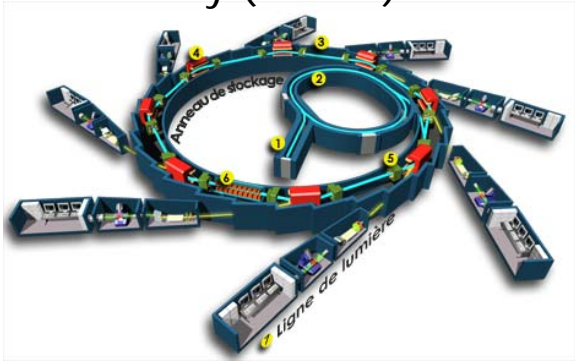
A first, highly qualified job for
hundreds of young scientists,
engineers and technicians



Impact on society

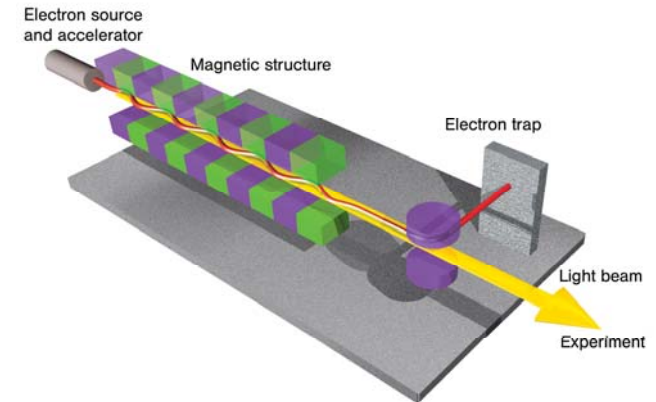
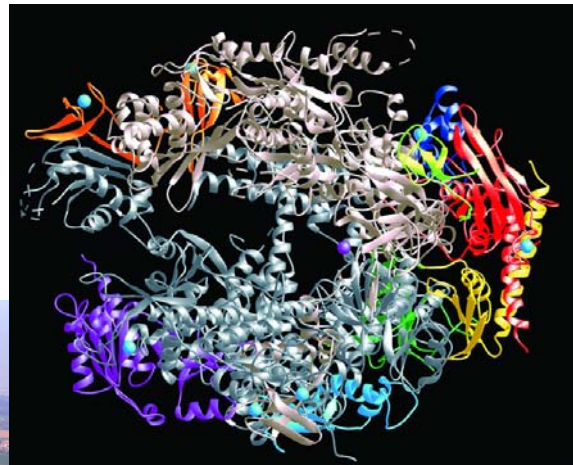
X-rays for science and industry

SOLEIL synchrotron,
Saclay (France)



European X-FEL,
Hamburg (Germany)

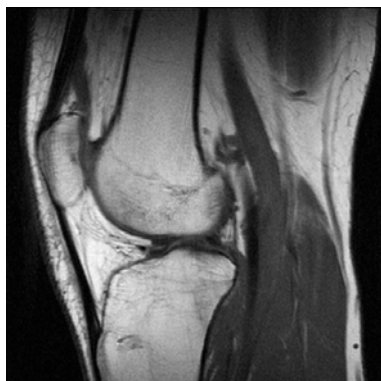
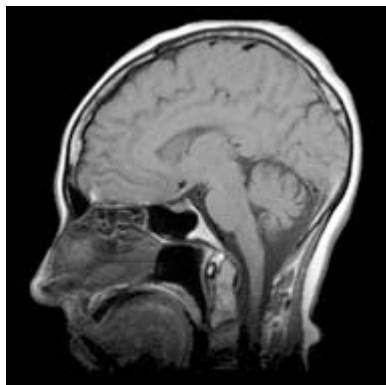
Protein structure analysed
by X-ray diffraction



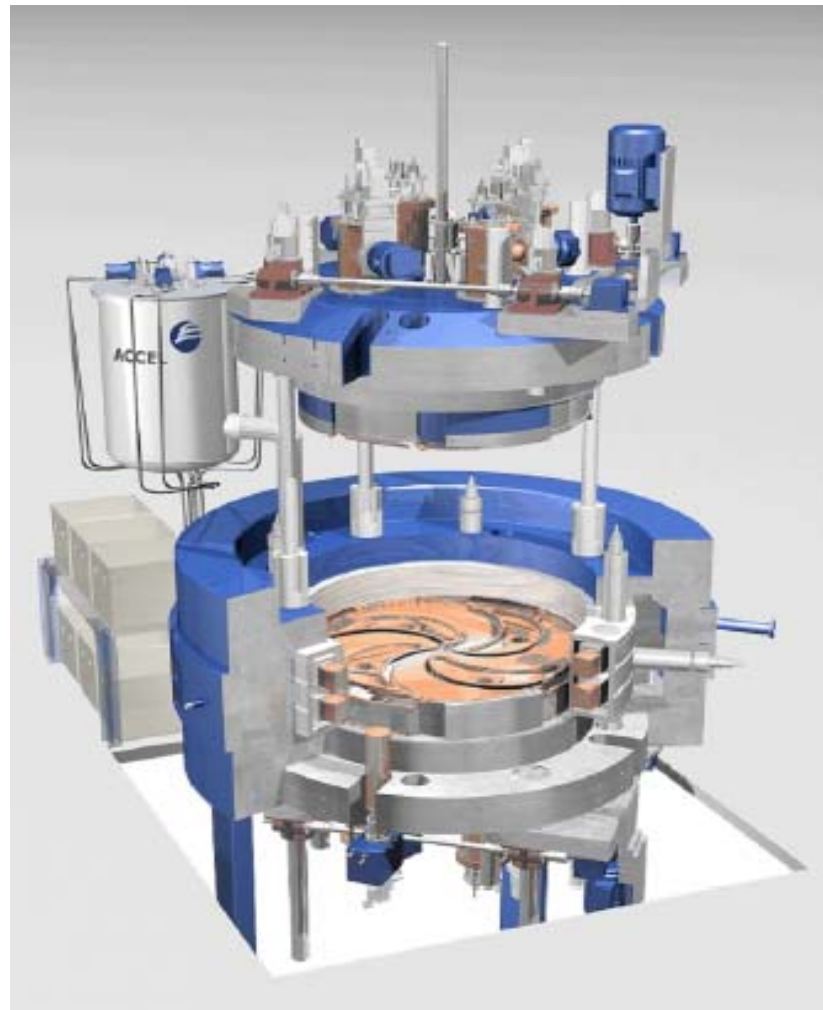
Impact on society superconductivity & accelerators for health



Over 25'000 MRI systems
in operation in the world

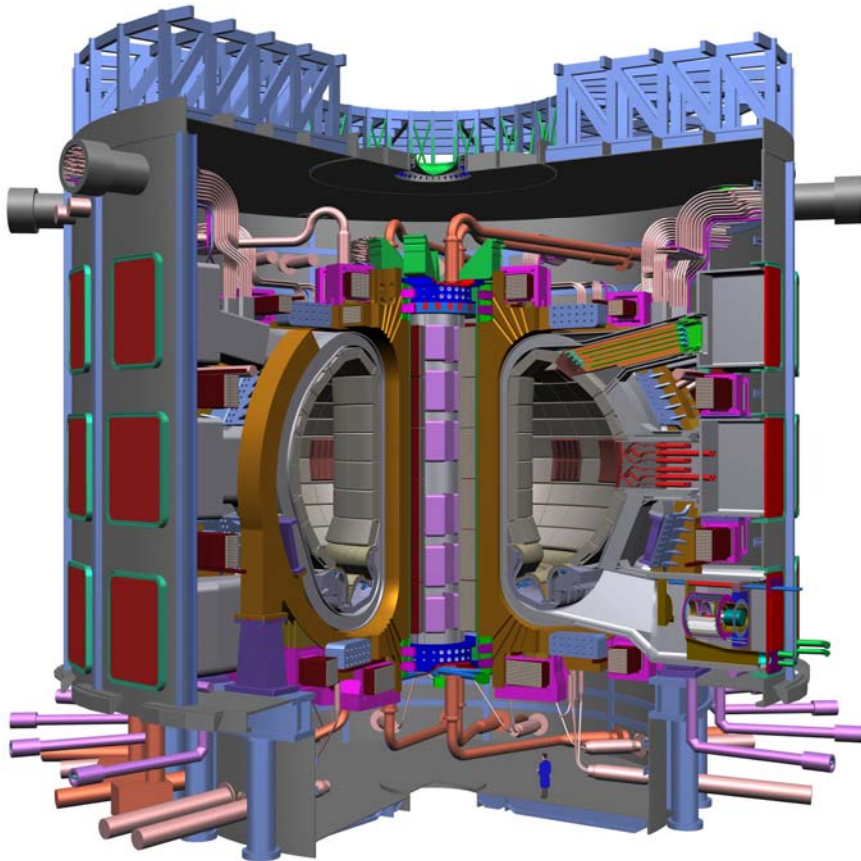


250 MeV superconducting
cyclotron for hadrontherapy



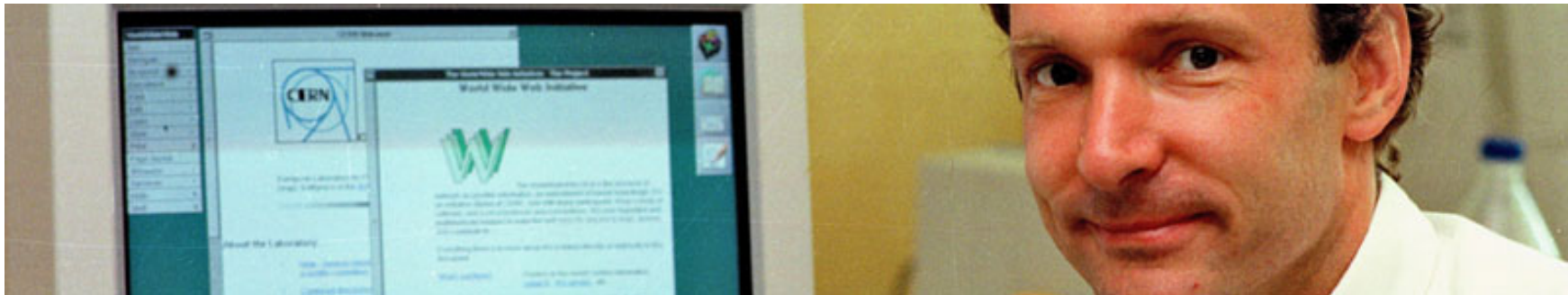
Impact on society energy production and distribution

Magnetically confined
nuclear fusion: ITER



138 kV, 574 MVA power line (LIPA)
using high-temperature superconductors

Impact on society easy Internet for everyone: the WWW



<http://www.cern.ch/>
<http://www.w3.org/>
<http://www.esa.int/>
<http://bulletin.cern.ch/>

<http://www.sciencemag.org/>
<http://cdsweb.cern.ch/>
<http://www.scoap3.org/>
<http://www.w3c.org/>
<http://www.nikhef.nl/>
<http://www.cerncourier.com/>
<http://www.interactions.org/>
<http://info.cern.ch/>
<http://www.desy.de/>

