CRYOGENICS OPERATIONS 2008

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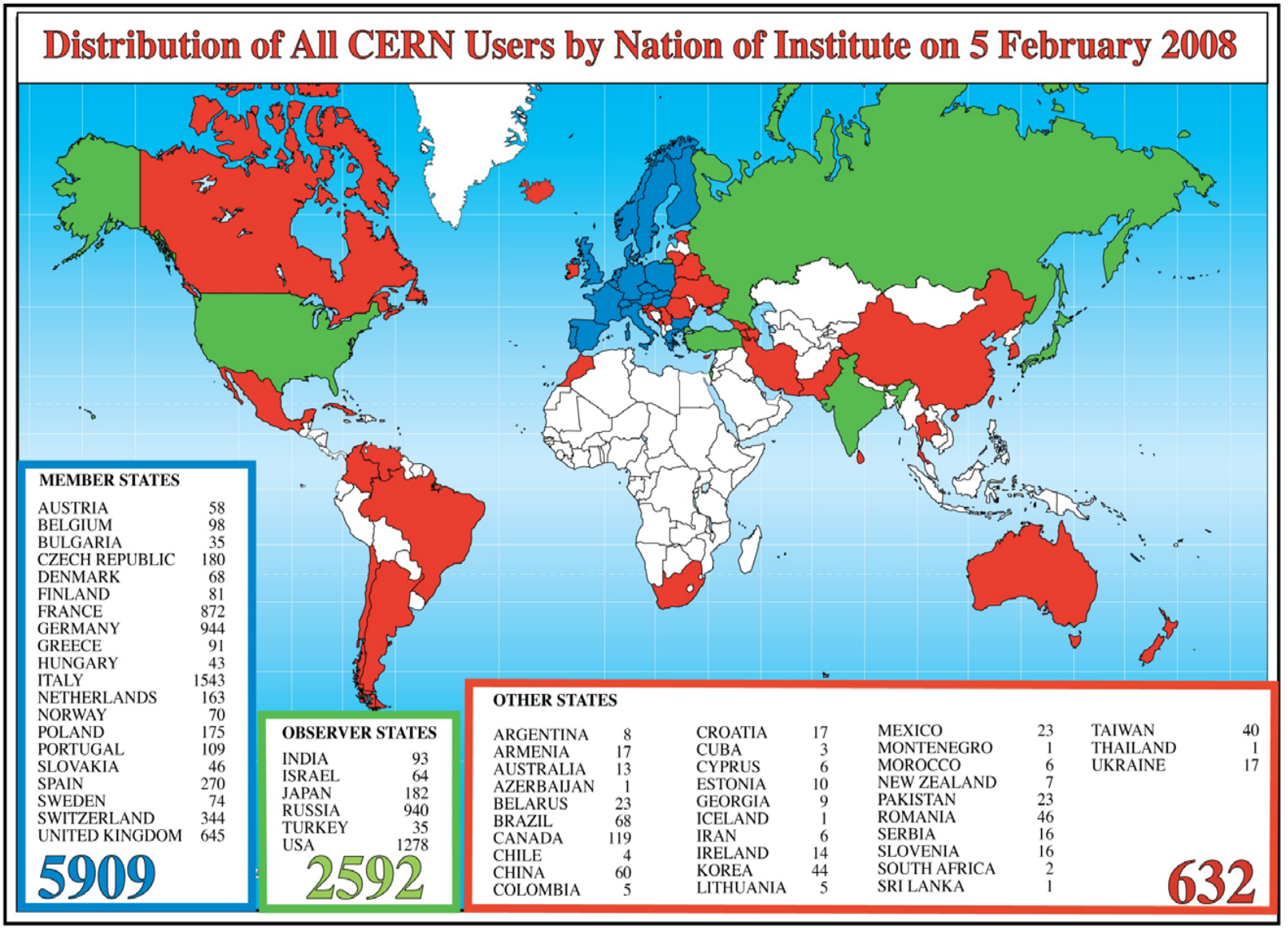
Organized by CERN

Welcome & Introduction to CERN

Philippe Lebrun

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

… serving the world community of particle physicists



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

Big Bang

Instruments | **Observables**

- 10^{-34}
- 10^{-30}
- 10^{-26}
- 10^{-22} — SUSY particle?
- 10^{-18} — Higgs? Z/W (range of weak force)
- 10^{-14} — Proton Nuclei (range of nuclear force)
- 10^{-10} — Atom
- 10^{-6} — Virus, Cell
- 1m
- 10^{6} — Earth radius
- 10^{10} — Earth to Sun
- 10^{14}
- 10^{18}
- 10^{22} — Galaxies
- 10^{26} — Radius of observable Universe

Accelerators
LHC
LEP

(Particle beams)
Electron Microscope
Microscope

Telescope

Radio Telescope

Universe

Quarks: u, u, d

Proton

Neutron

Nucleus

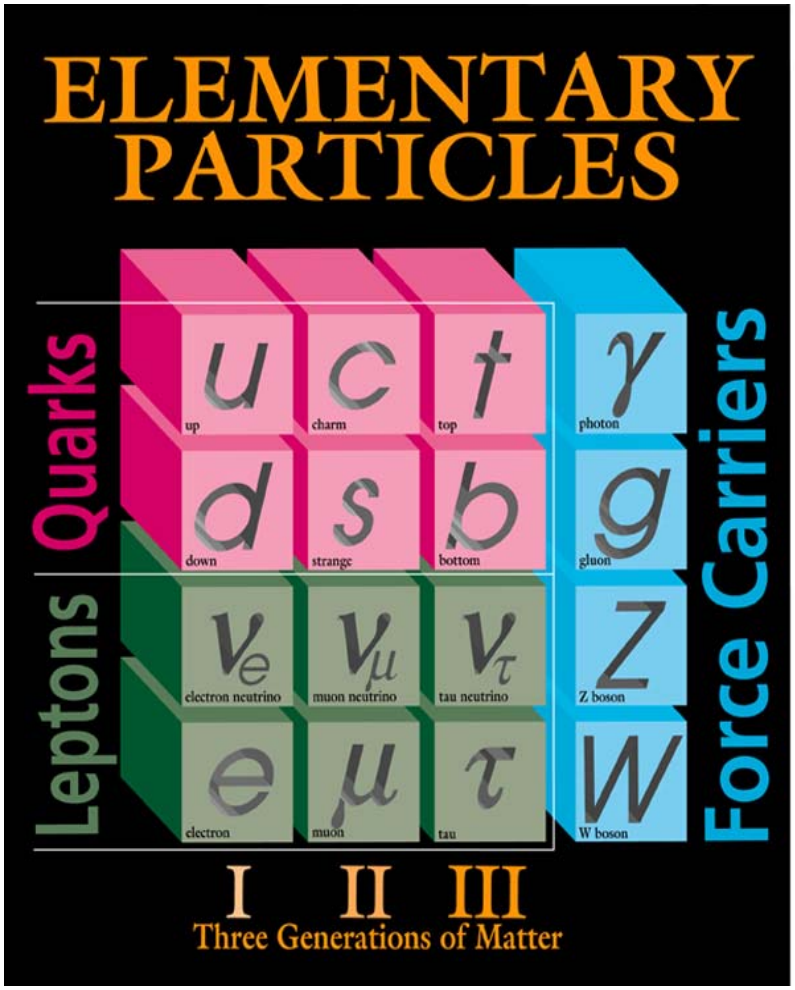
Electron

Atom

Molecule

Matter

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

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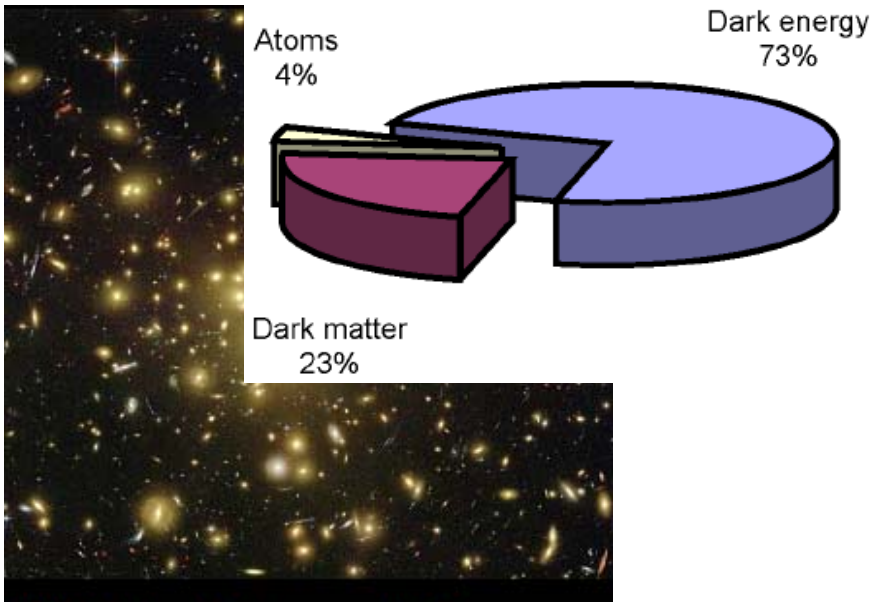
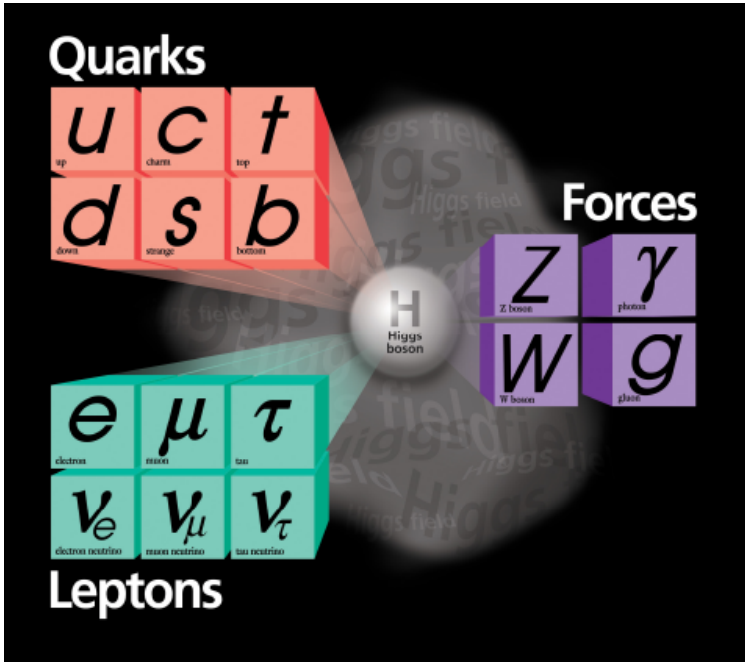
Limits of the Standard Model

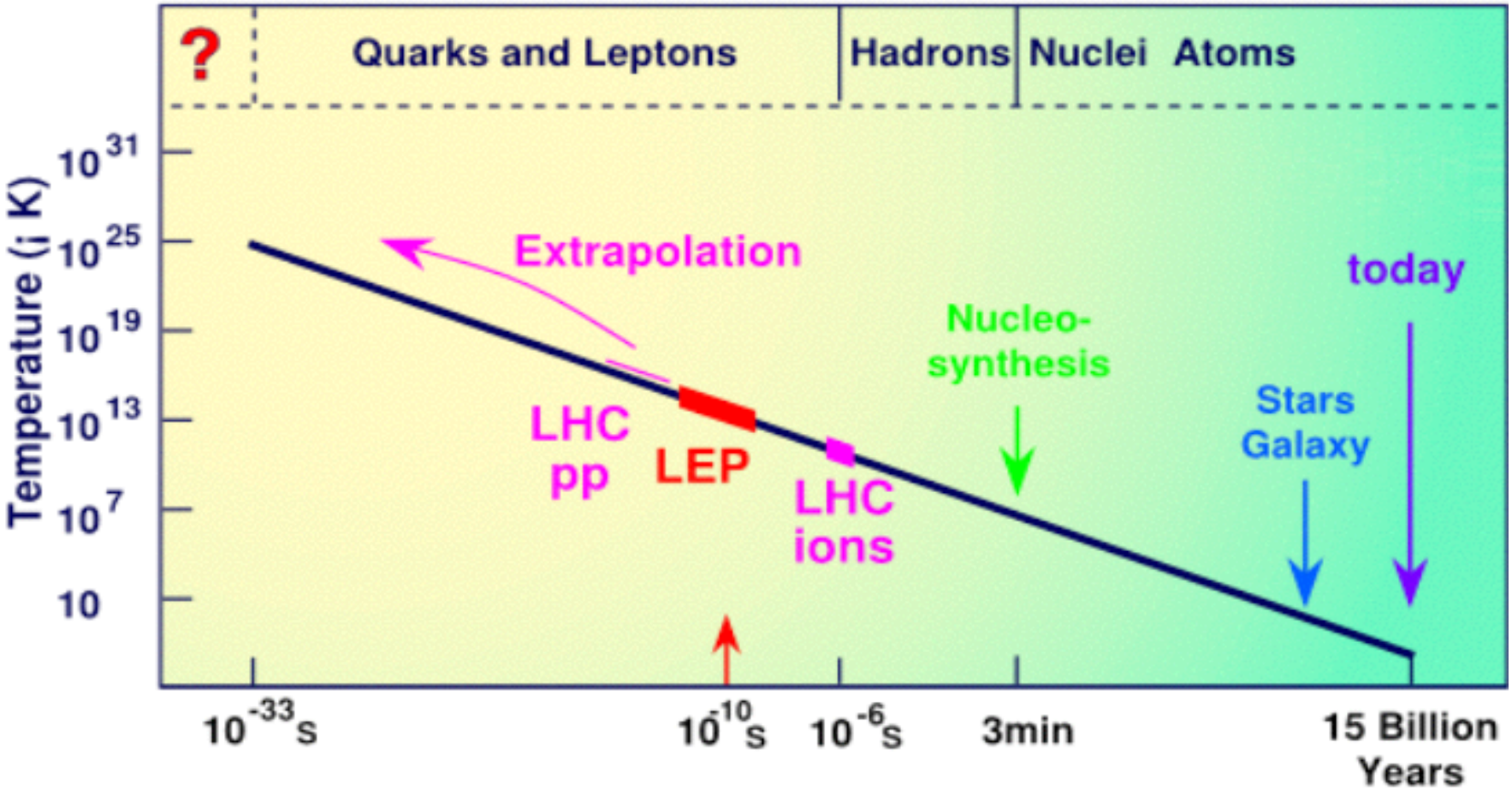
- Origin & hierarchy of particle masses: coupling with Higgs field (boson)?
- Fermion/boson supersymmetry?
- Gravity is not included!
- Unification of forces?



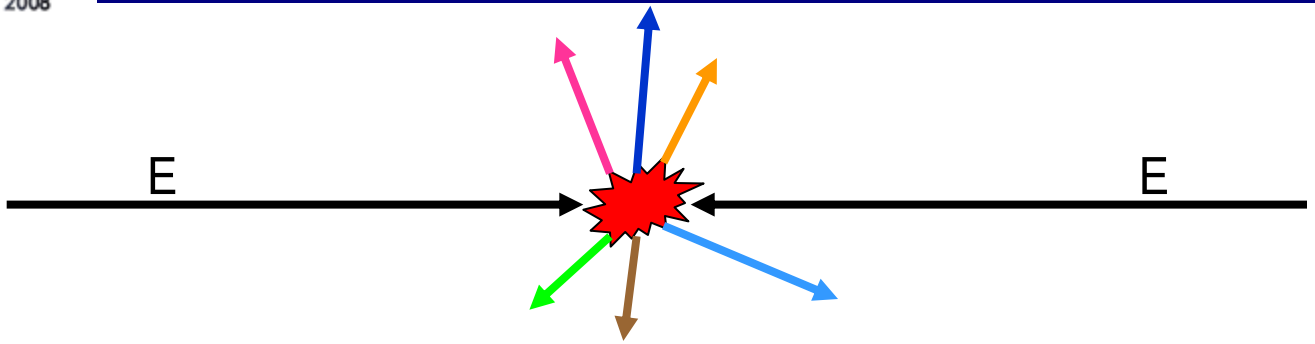


- Origin of matter-antimatter asymmetry in the universe?
- What constitutes dark matter?
- What is dark energy?

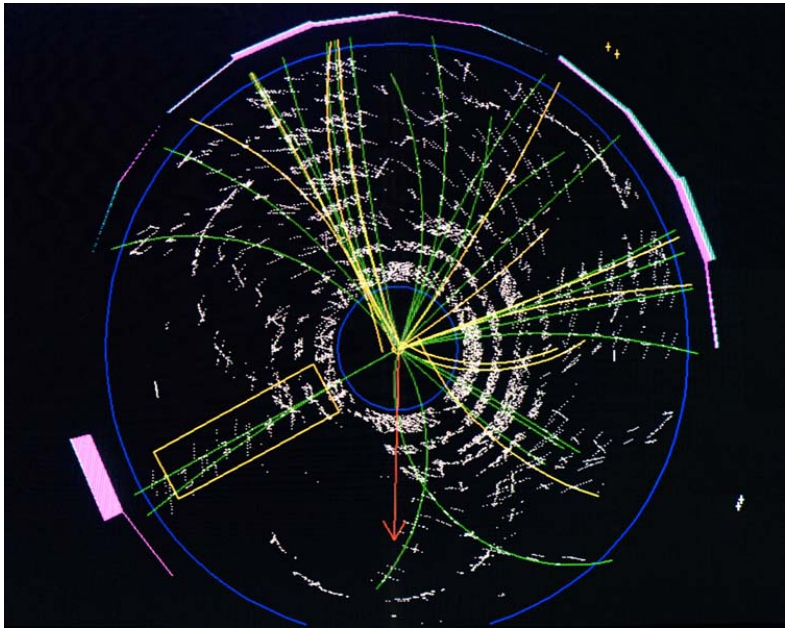
Time travel towards the big bang

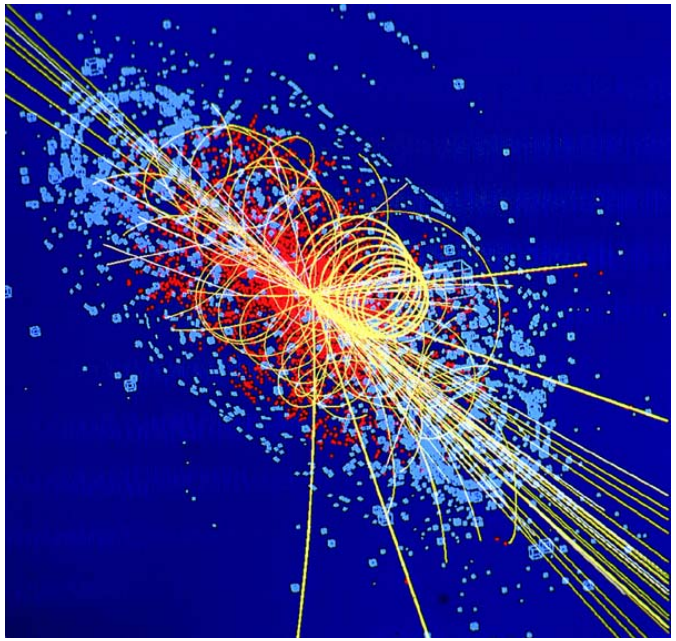


High-energy collisions probe matter at small scale

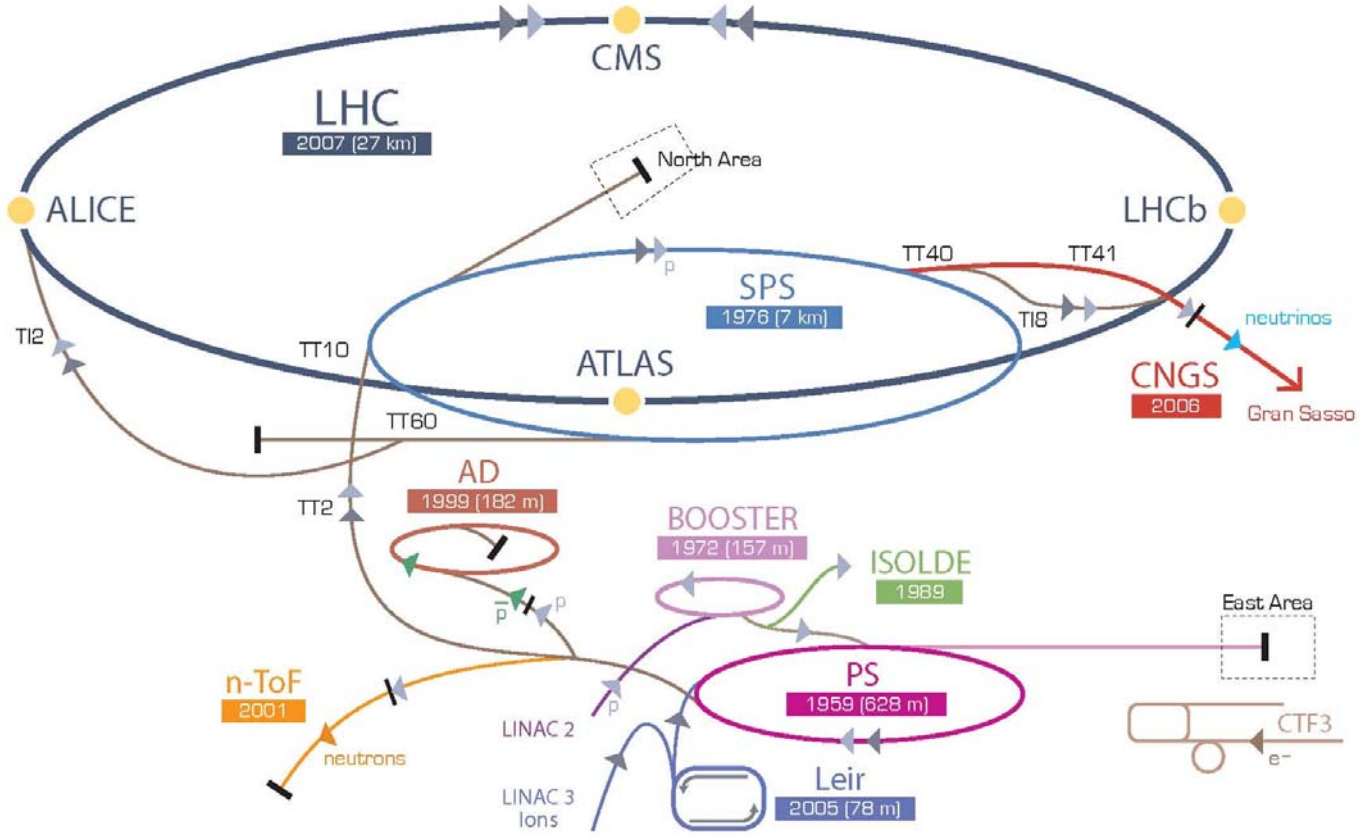


$E_{cm} = 2E$

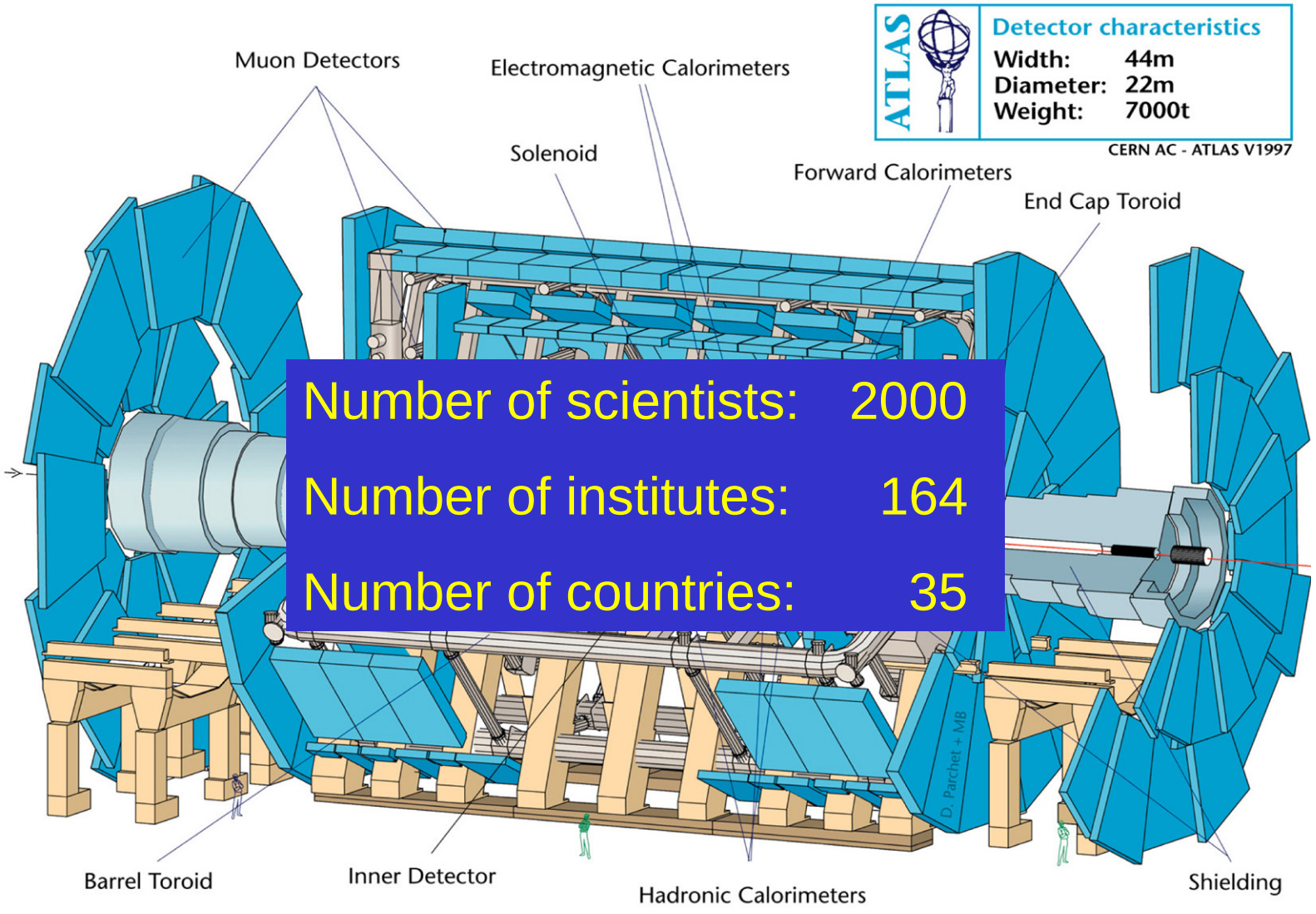




The CERN accelerator complex



The ATLAS detector

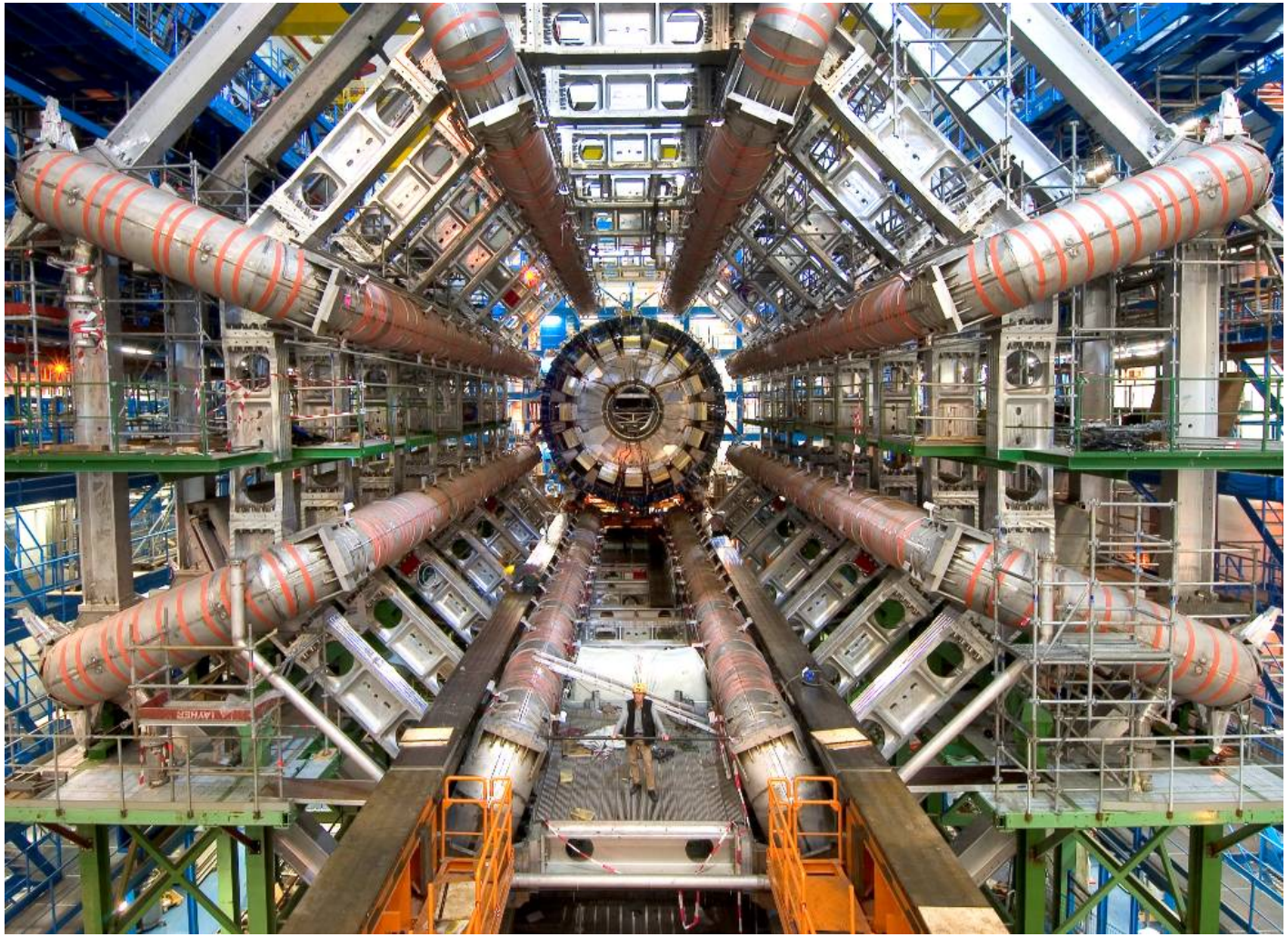


Number of scientists: 2000

Number of institutes: 164

Number of countries: 35

ATLAS superconducting toroid



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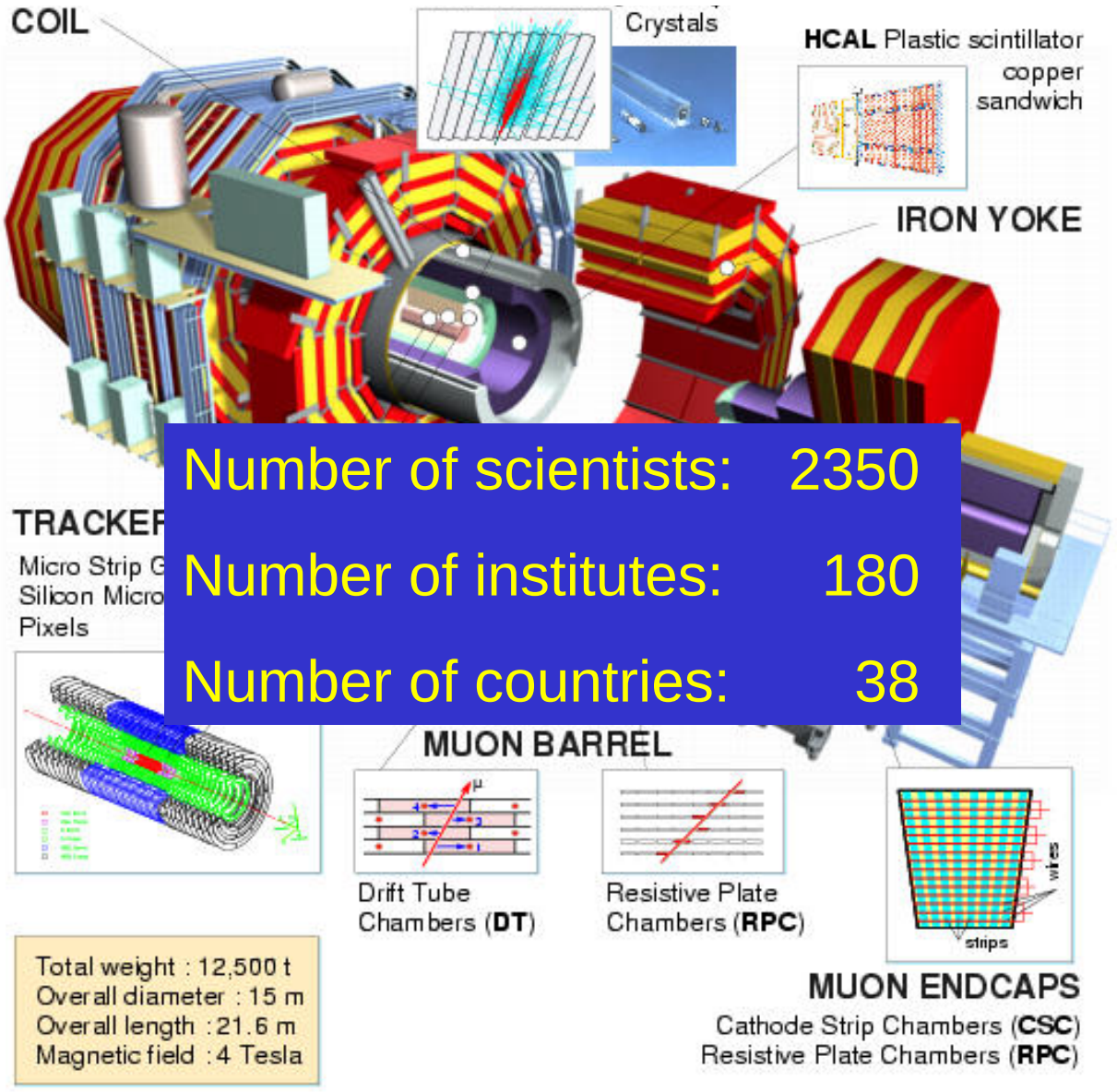
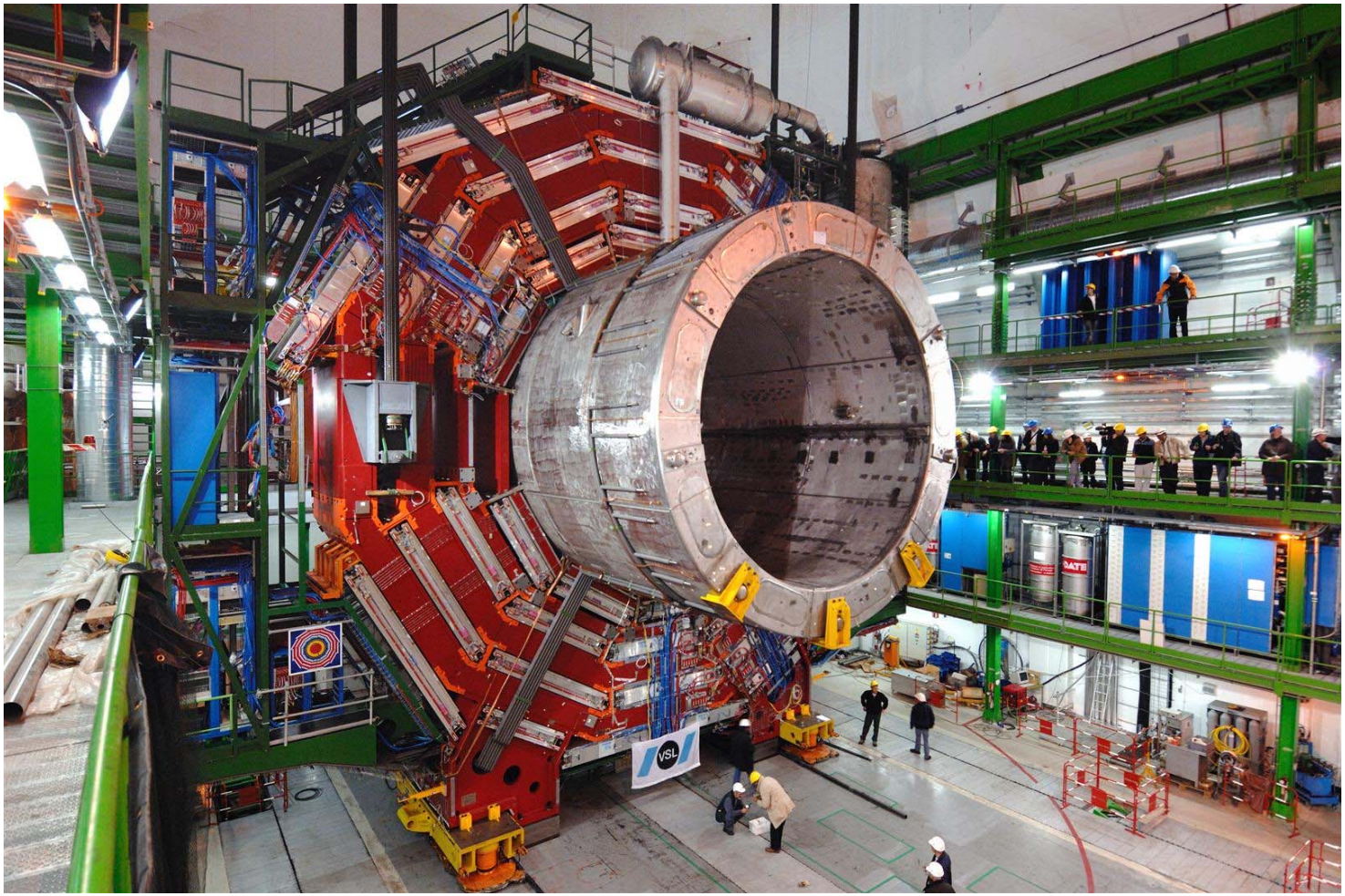
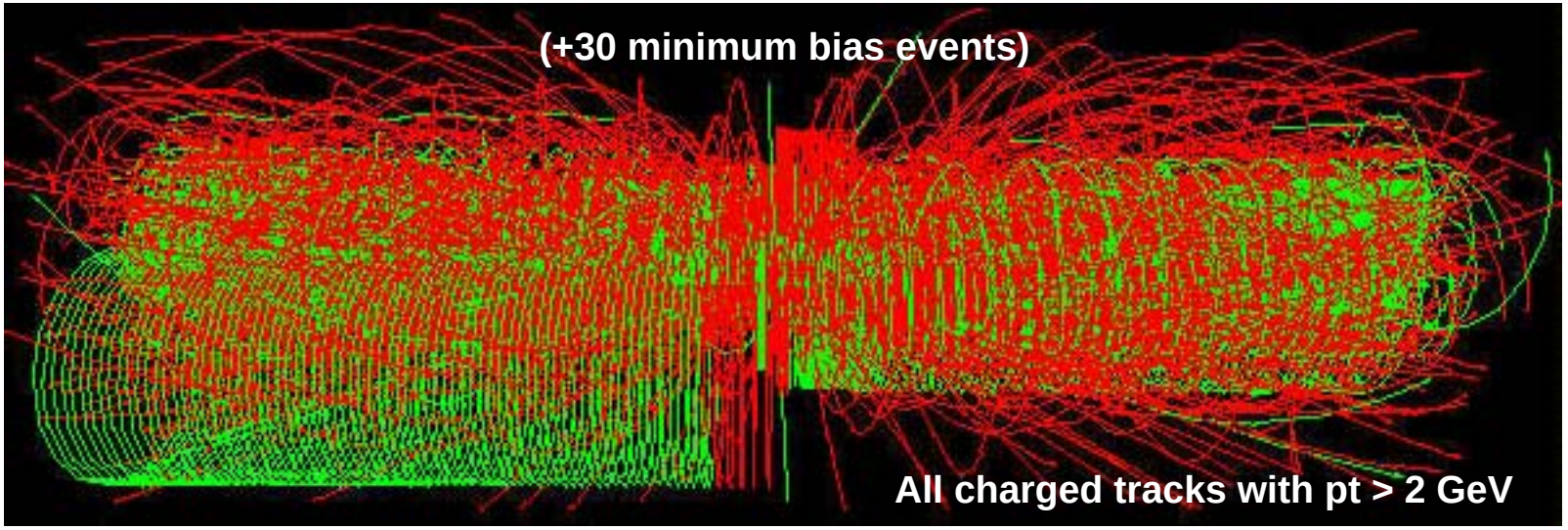
The CMS detector

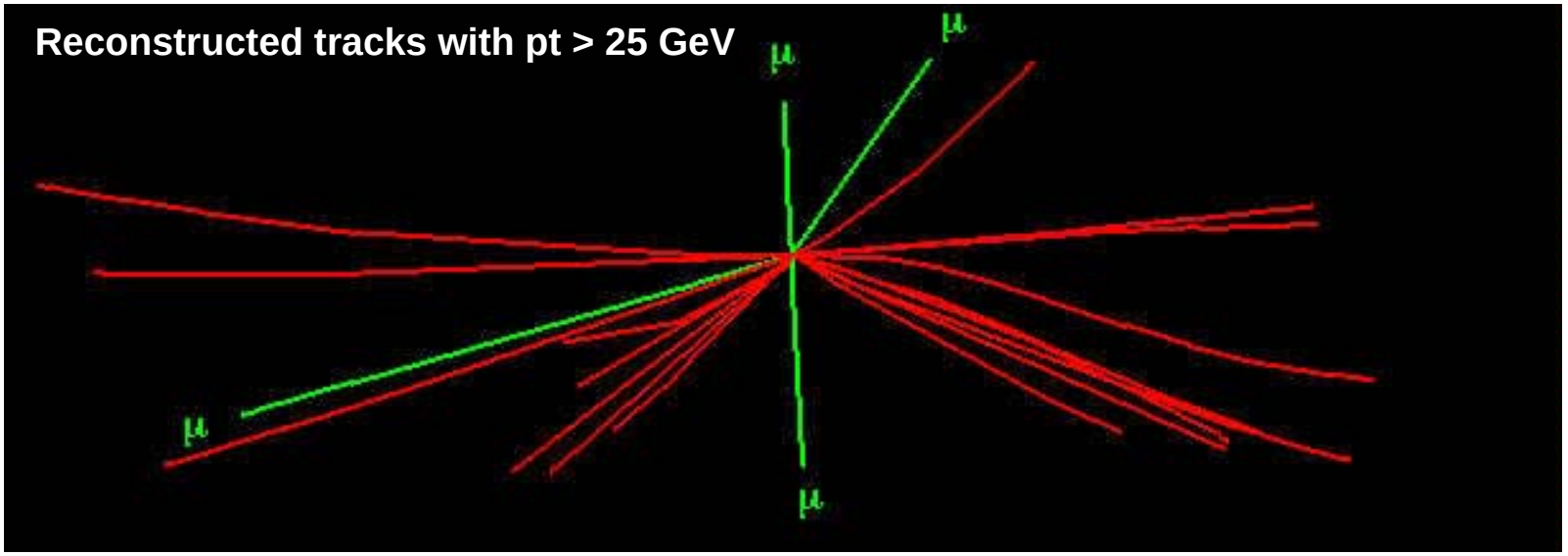


CMS superconducting solenoid



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





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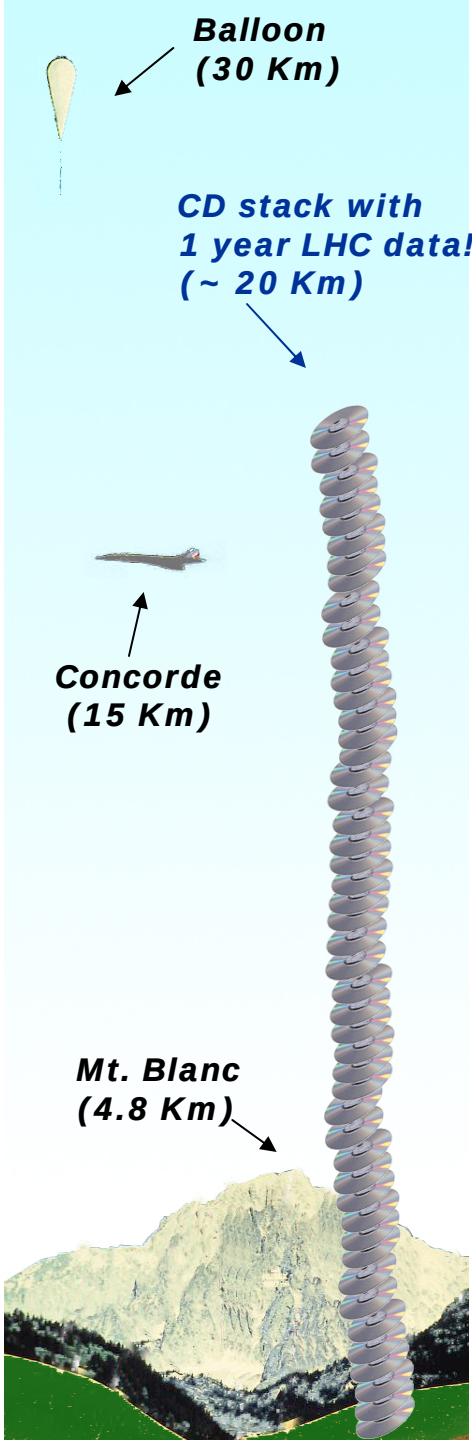
A volume of data to process without precedent

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



Towards a world computing « grid »

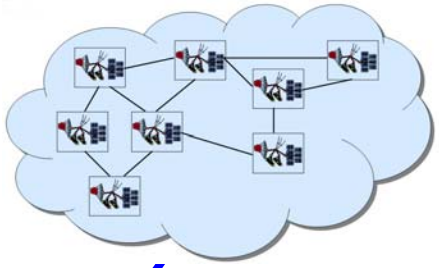
Commodity computing

High-capacity links

Shared middleware

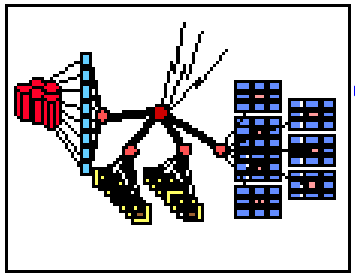
100'000 processors

GRID



5000 processors

Cluster



Performance

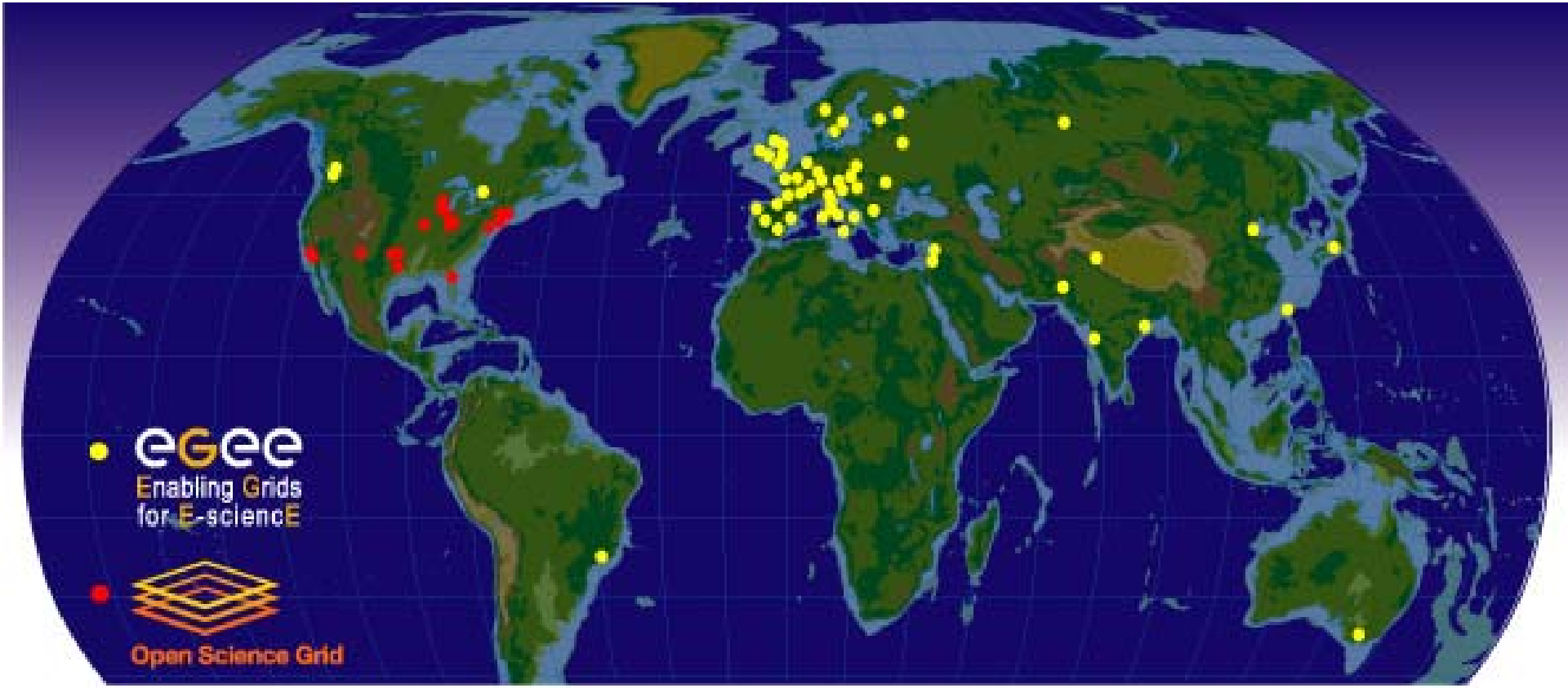
Super-computer

1980

1990

2000

The LHC Computing Grid



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

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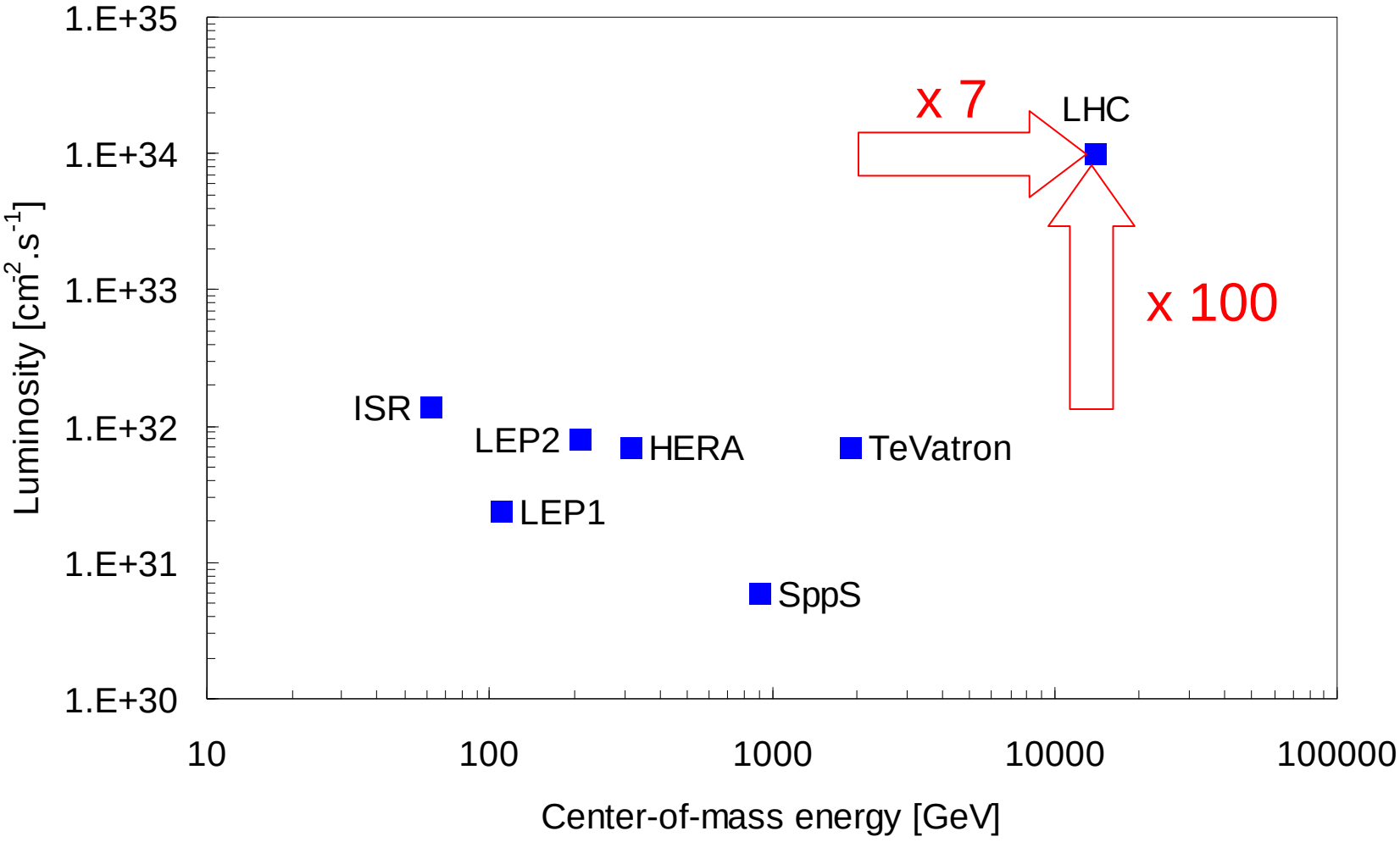
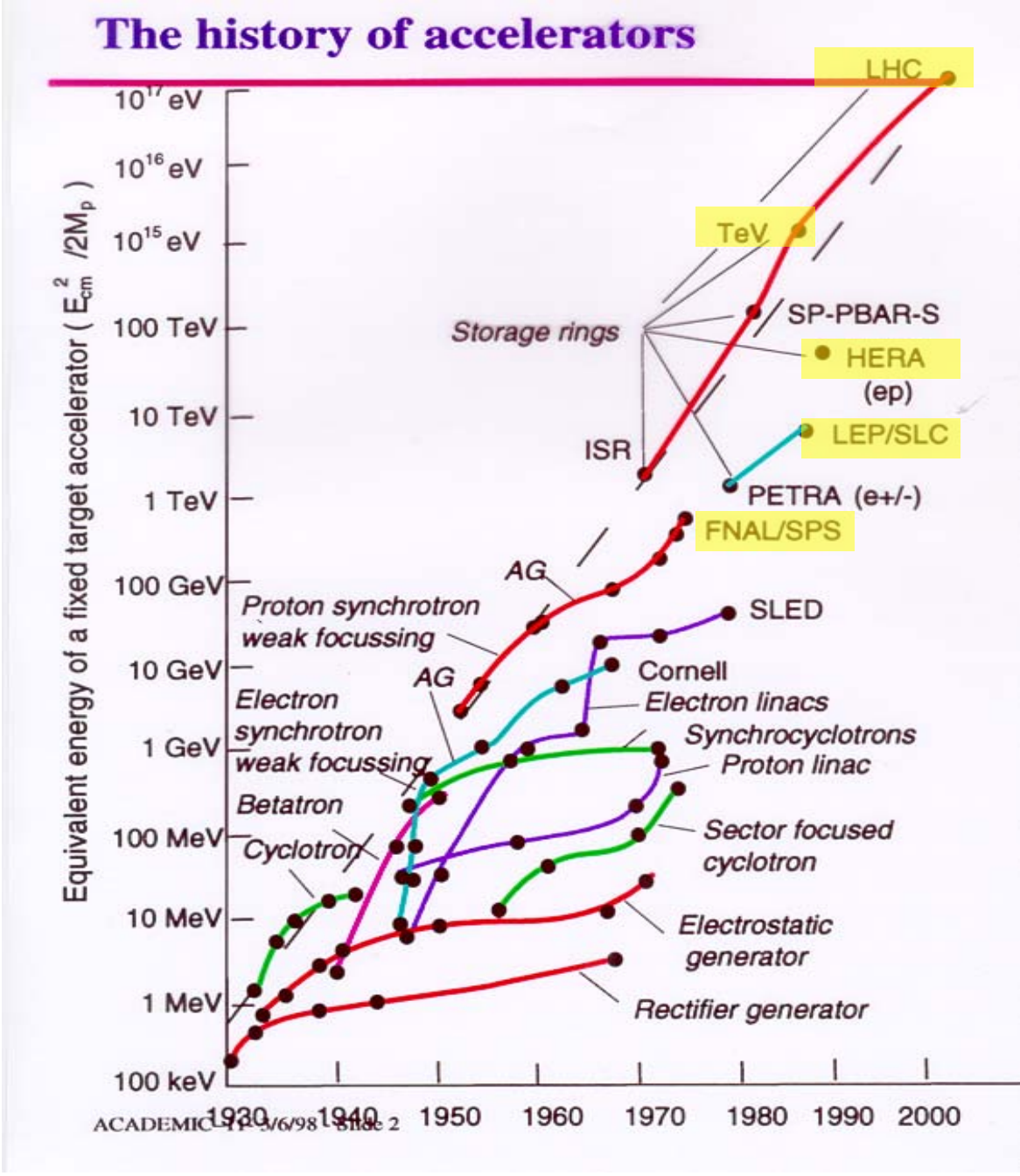
A particle collider well beyond the pre-existing state-of-the-art

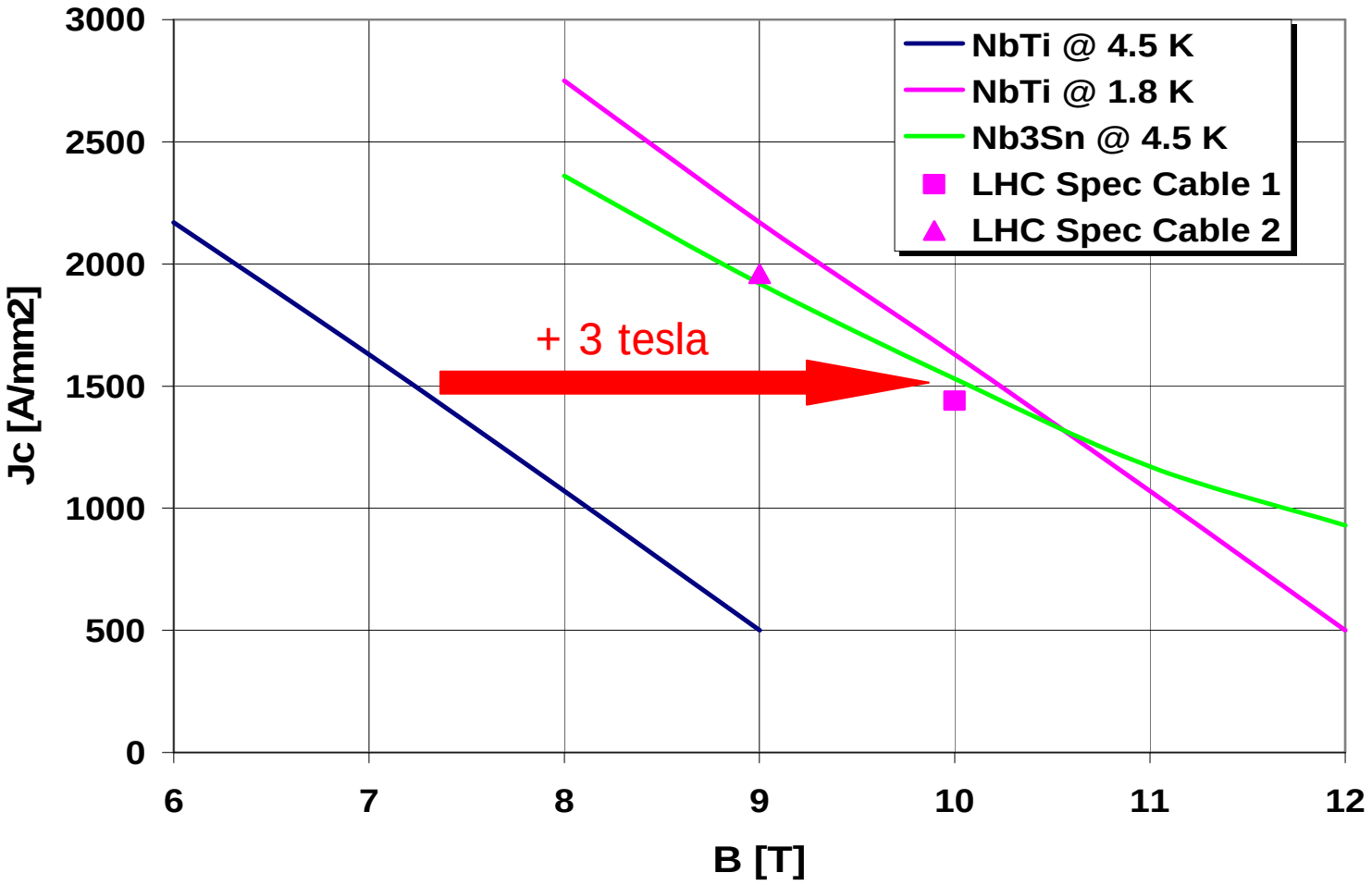


Superconductivity, a key technology

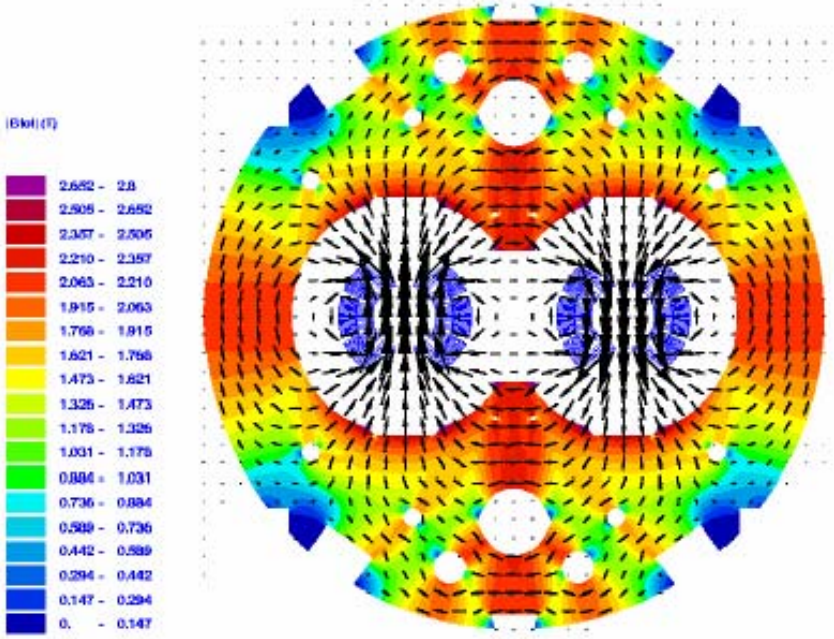
- to produce high electromagnetic fields,
- to limit electrical power consumption,
- to sustain the development of high-energy particle accelerators

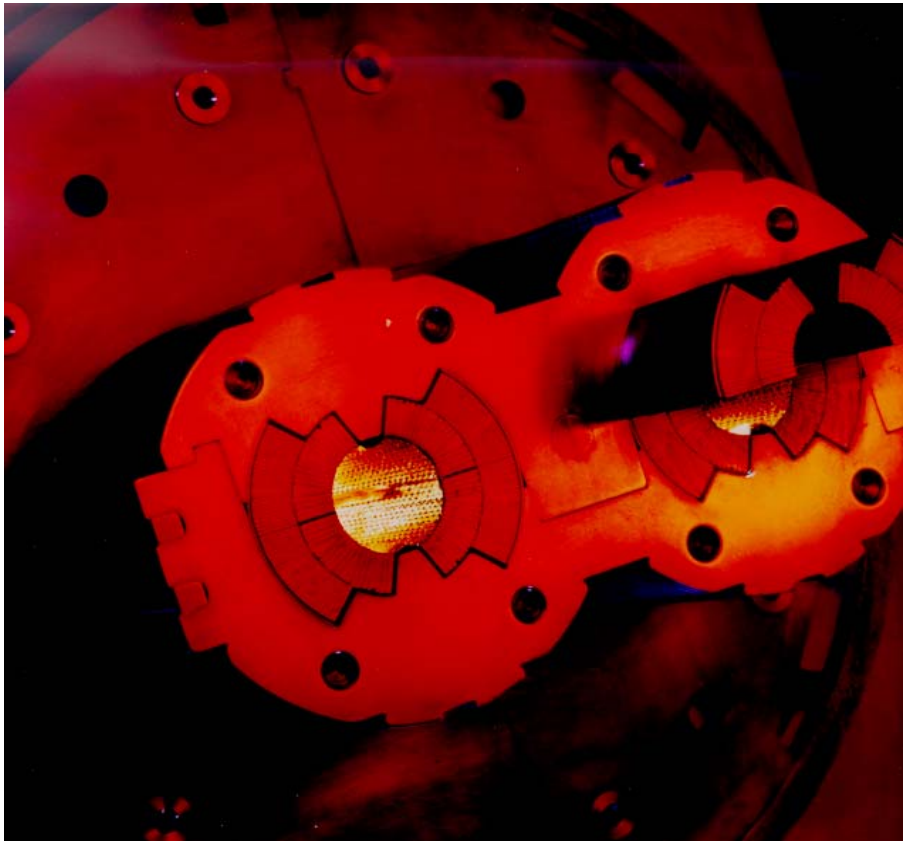


Critical current density of technical superconductors



Twin-aperture dipole magnet





Field reproducibility/precision ~ 10^{-3}

Field homogeneity ~ 10^{-4}

$\Rightarrow$ Winding precision < 0.05 mm

Final assembly of cryomagnets at CERN

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Cryogenic test station

Interconnections in tunnel

65’000 electrical joints

Induction-heated soldering

Ultrasonic welding

Very low residual resistance

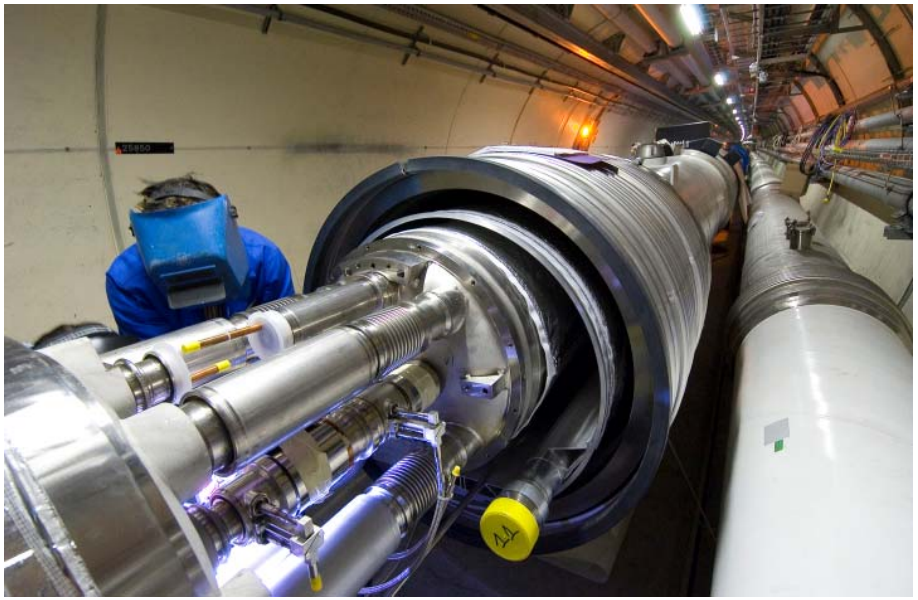
HV electrical insulation

40’000 cryogenic junctions

Orbital TIG welding

Weld quality

Helium leaktightness



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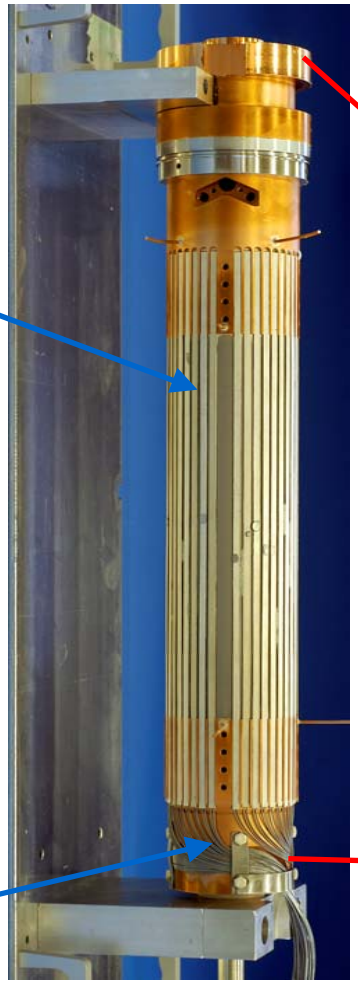
13 kA current leads using HTS superconductor



BSCCO 2223 tapes

Nb-Ti wires

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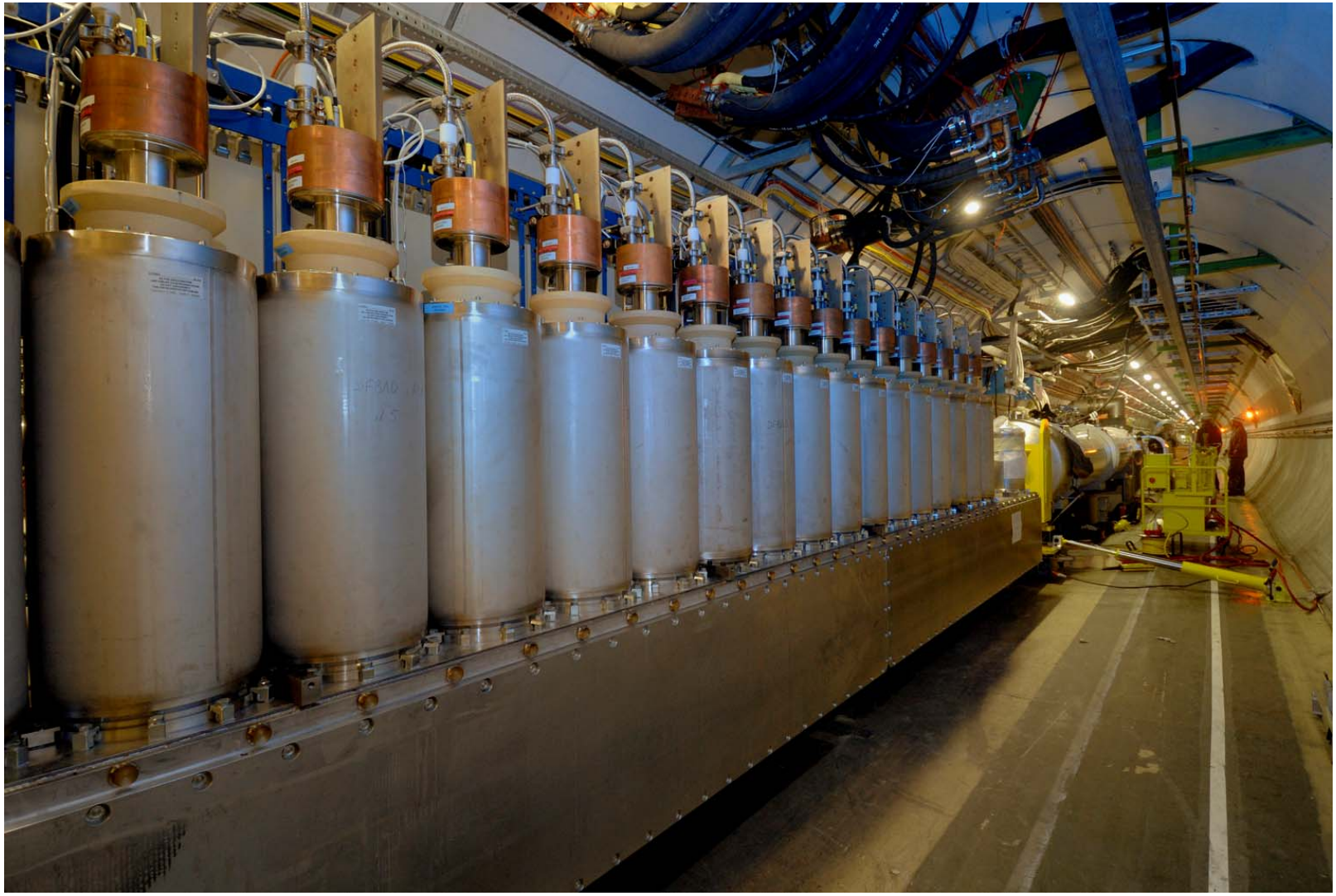
HTS current leads in the LHC tunnel

The largest high-current application to date of HTc superconductors



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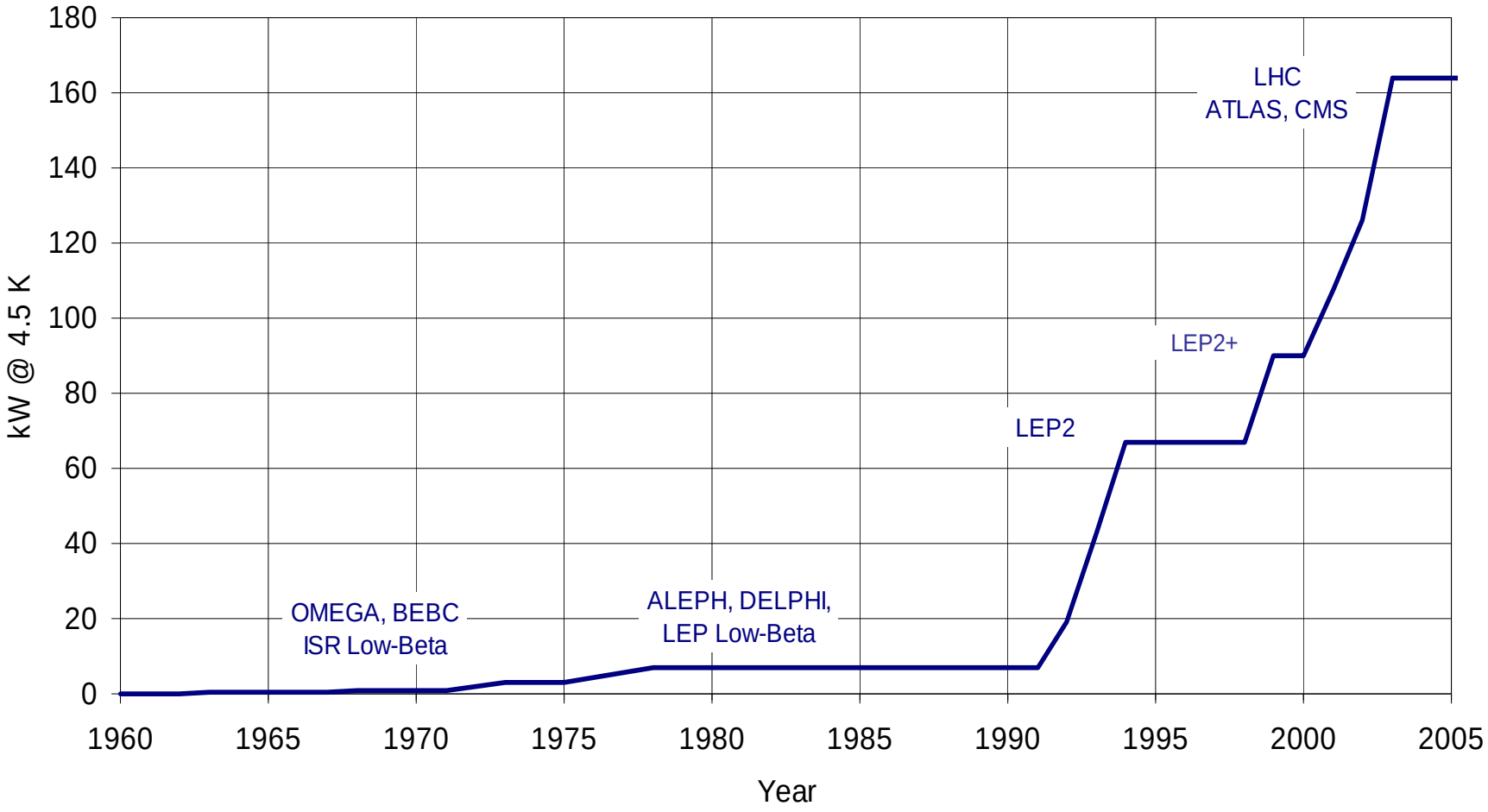
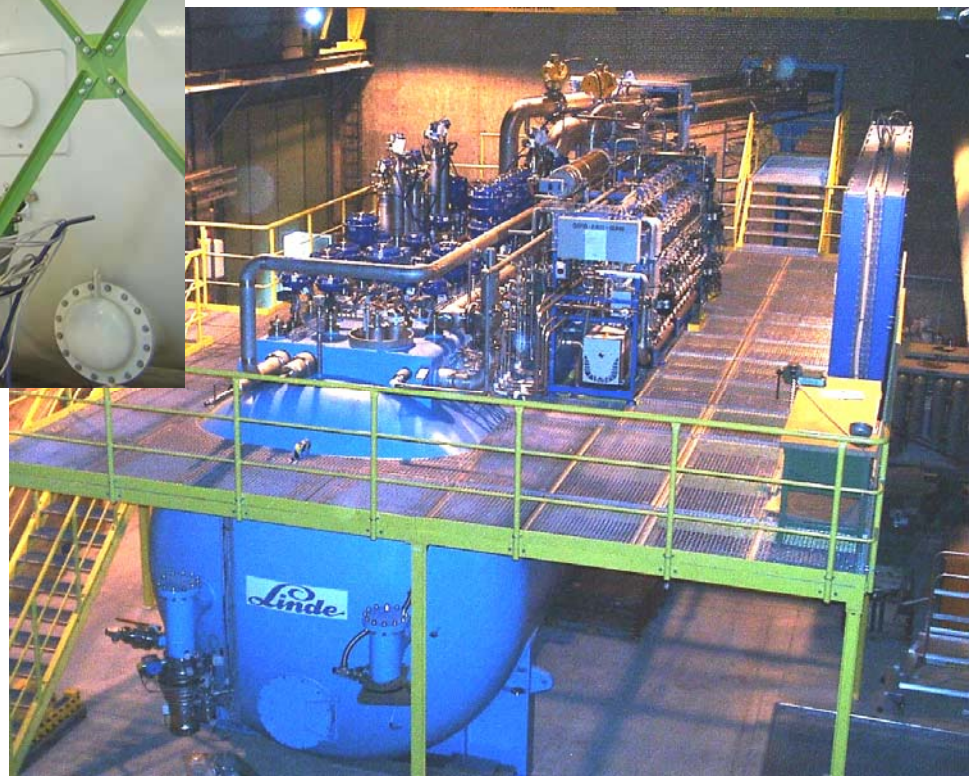
Cryogenic refrigeration capacity at CERN



18 kW @ 4.5 K helium cryoplants

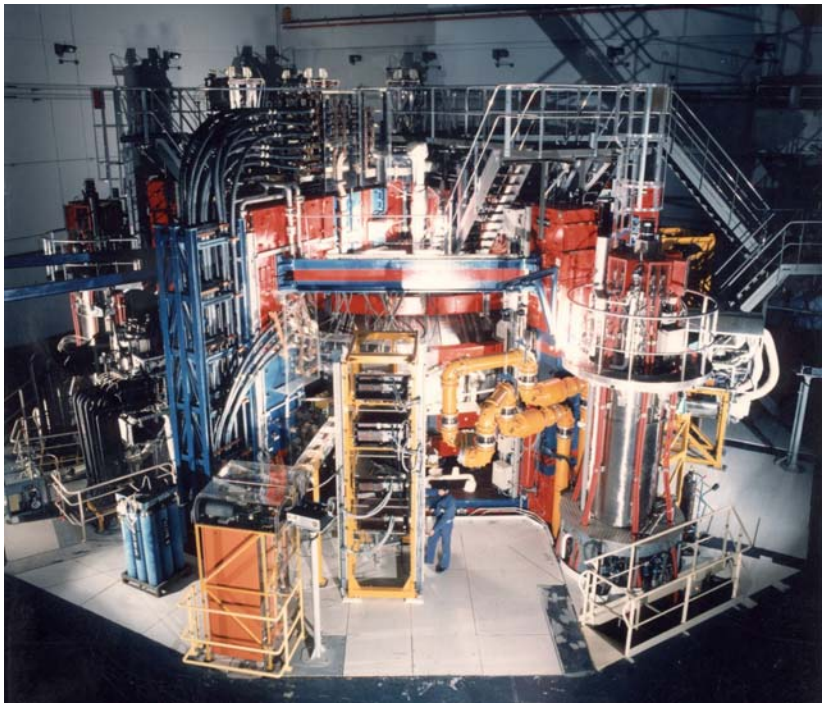
33 kW @ 50 K to 75 K
23 kW @ 4.6 K to 20 K
41 g/s liquefaction

Air Liquide



Linde

Large projects cooled by superfluid helium



Tore Supra tokamak,
Cadarache (France)

CEBAF accelerator,
Newport News (USA)

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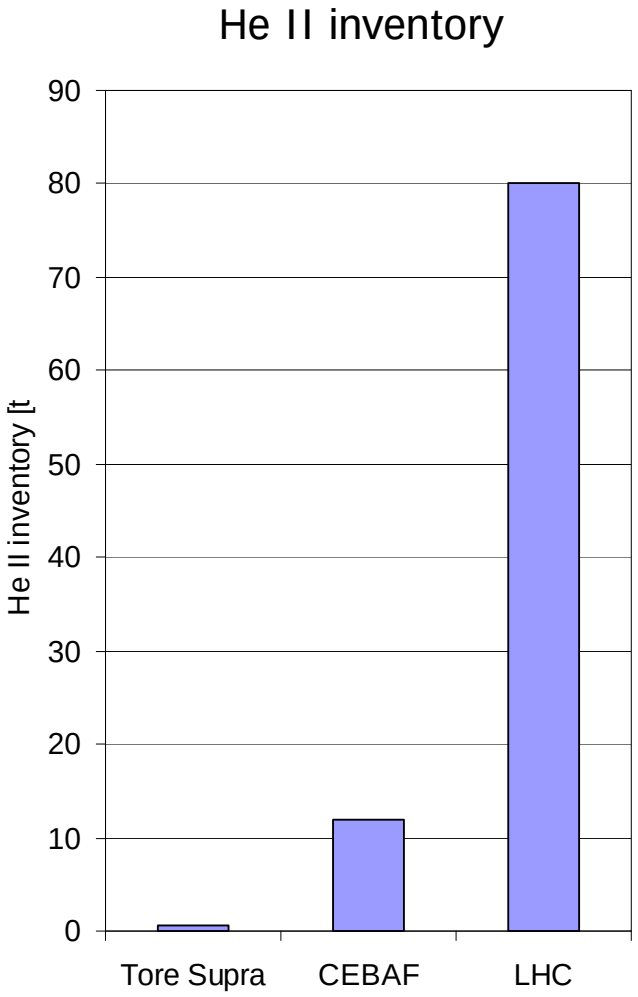
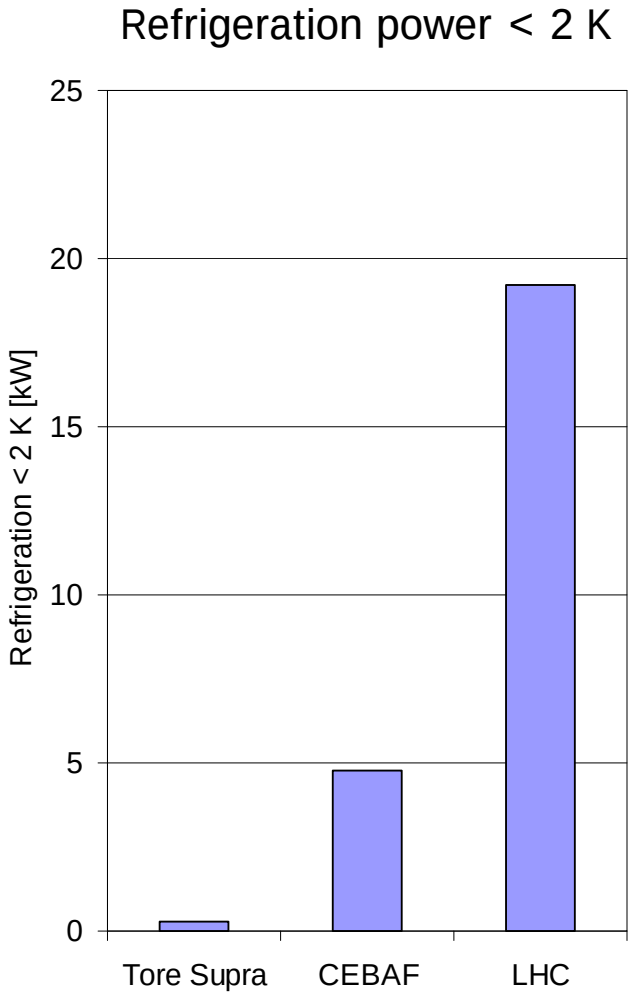
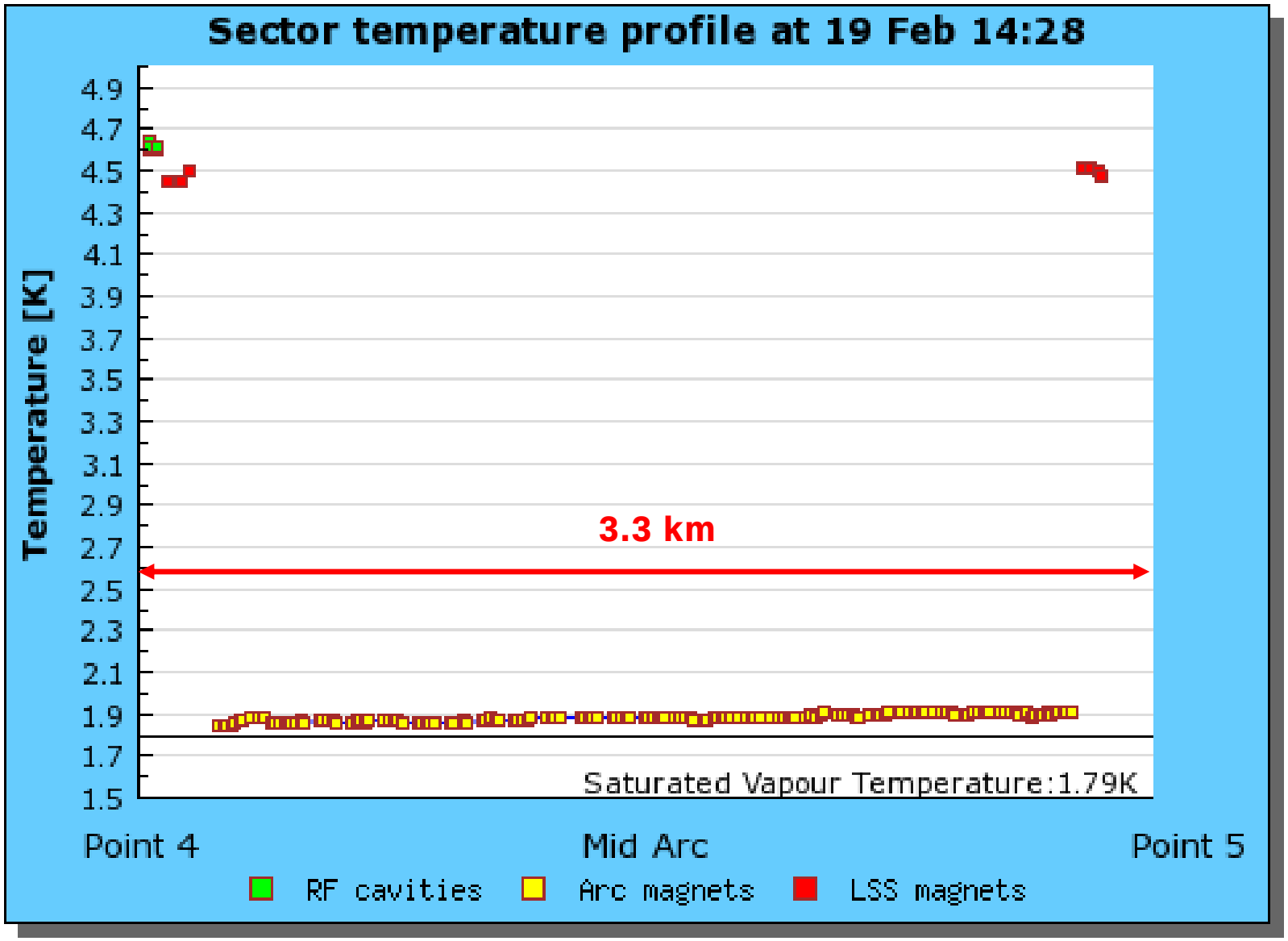
Large-scale superfluid helium systems





Cryogenic operation of LHC sector



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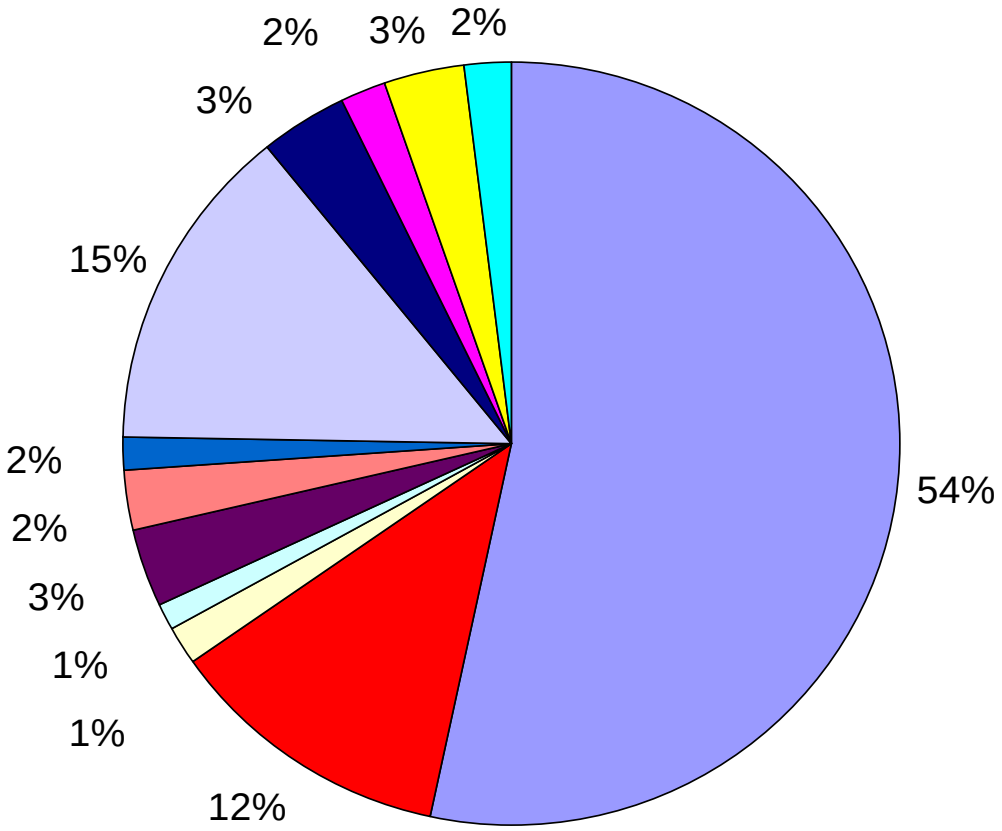
Cost structure of the LHC accelerator



Total ~ 2.2 BEuro

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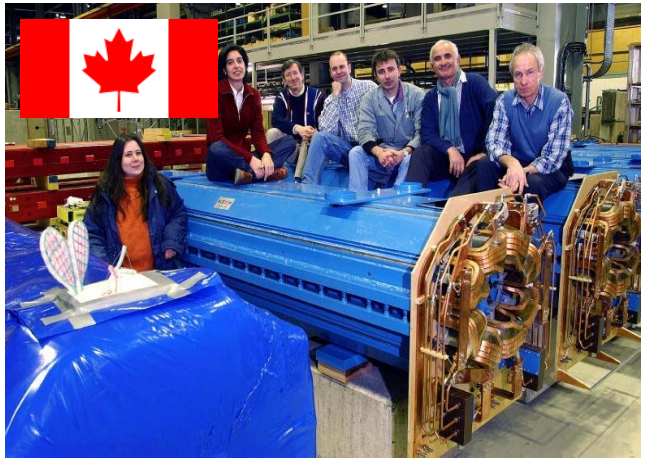
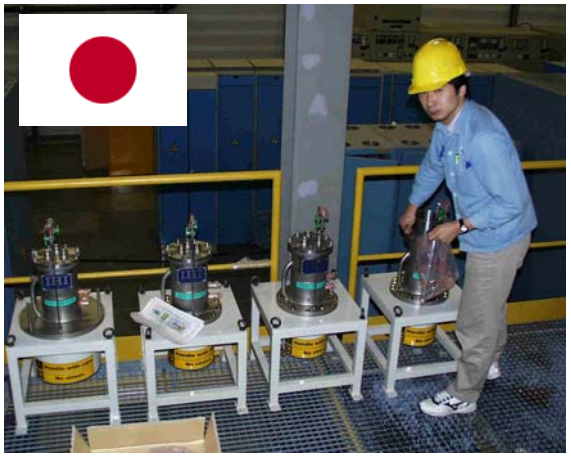
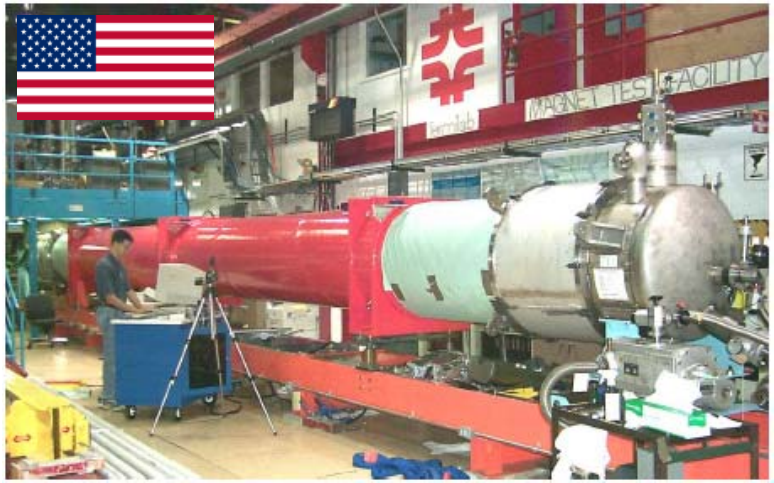
A global project







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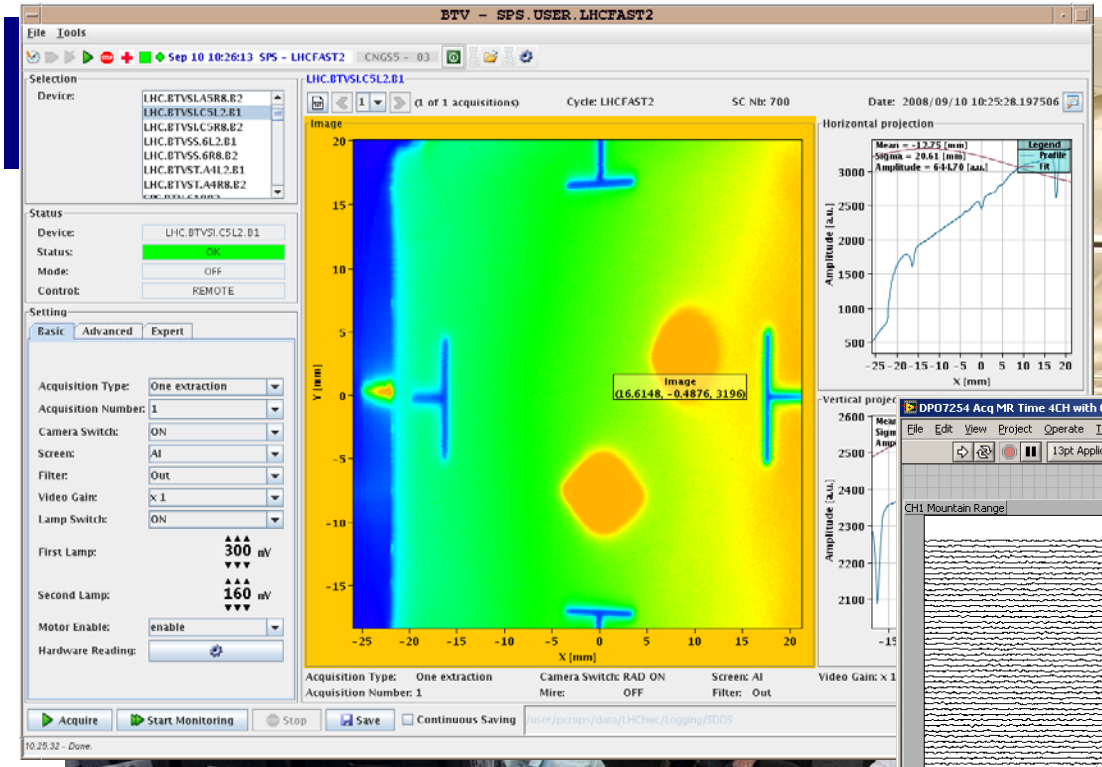
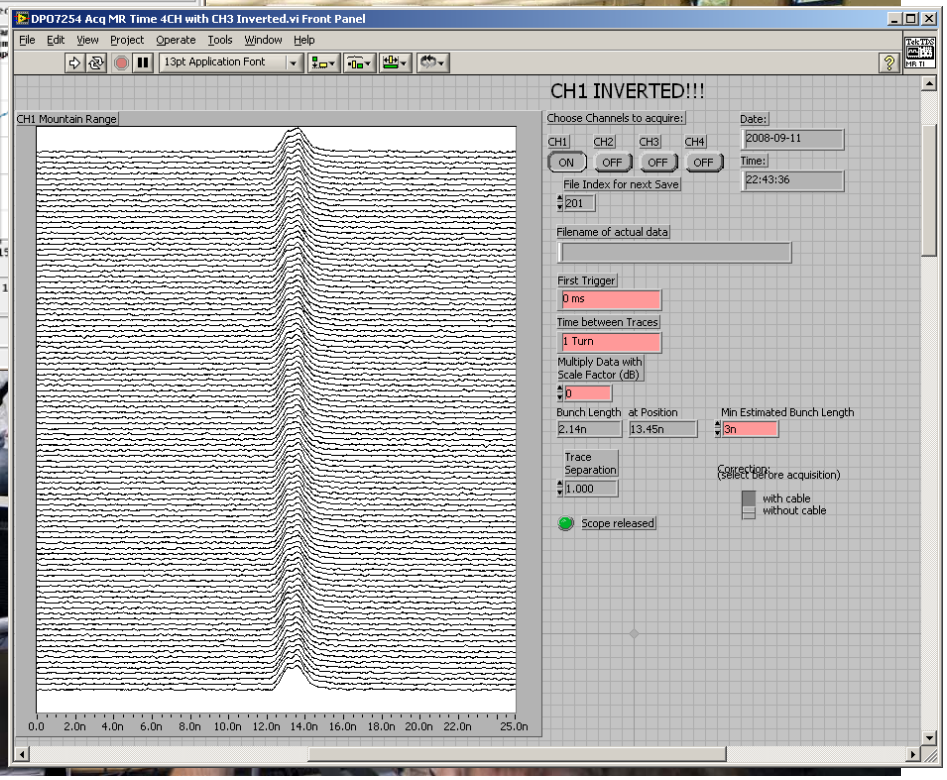
LHC startup





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

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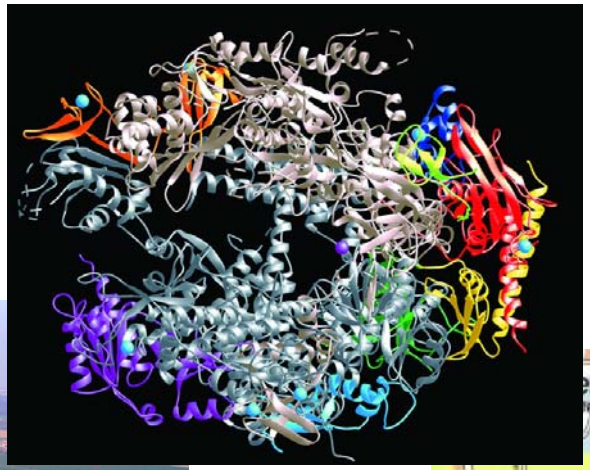
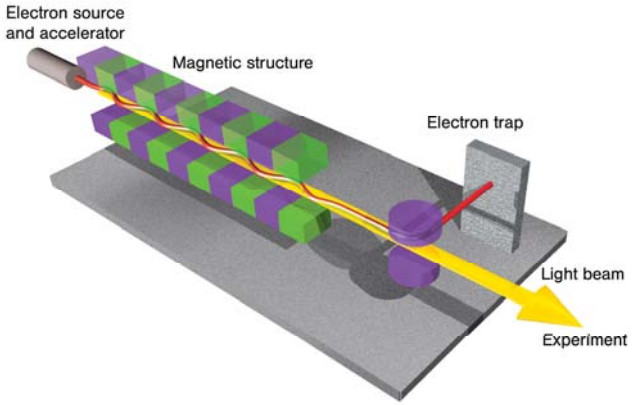
Impact on society
X-rays for science and industry

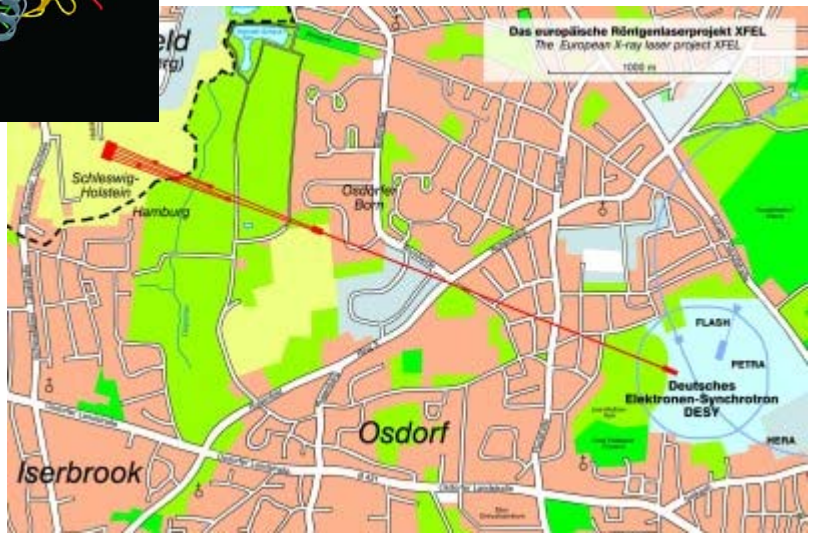
SOLEIL synchrotron,
Saclay (France)

Protein structure analysed
by X-ray diffraction



European X-FEL,
Hamburg (Germany)





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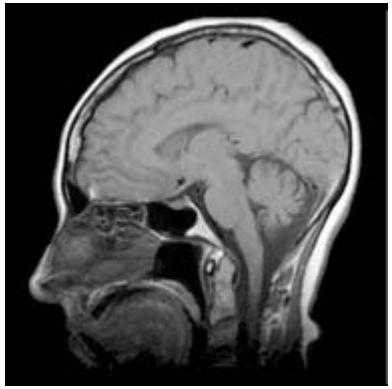
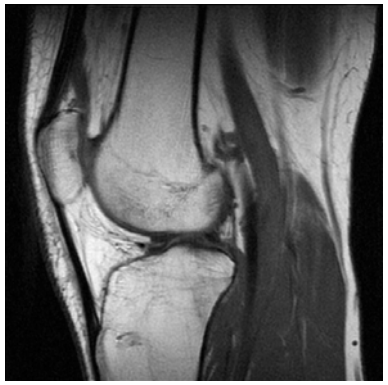
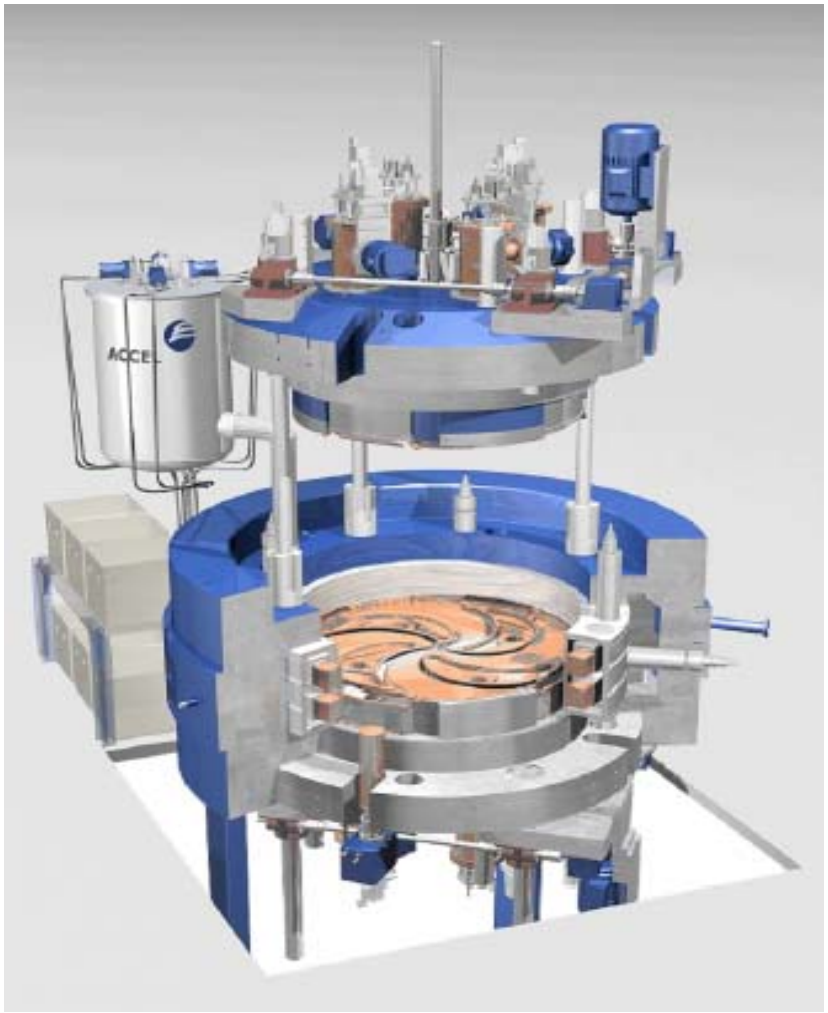
Impact on society
superconductivity & accelerators for health

Over 25'000 MRI systems
in operation in the world



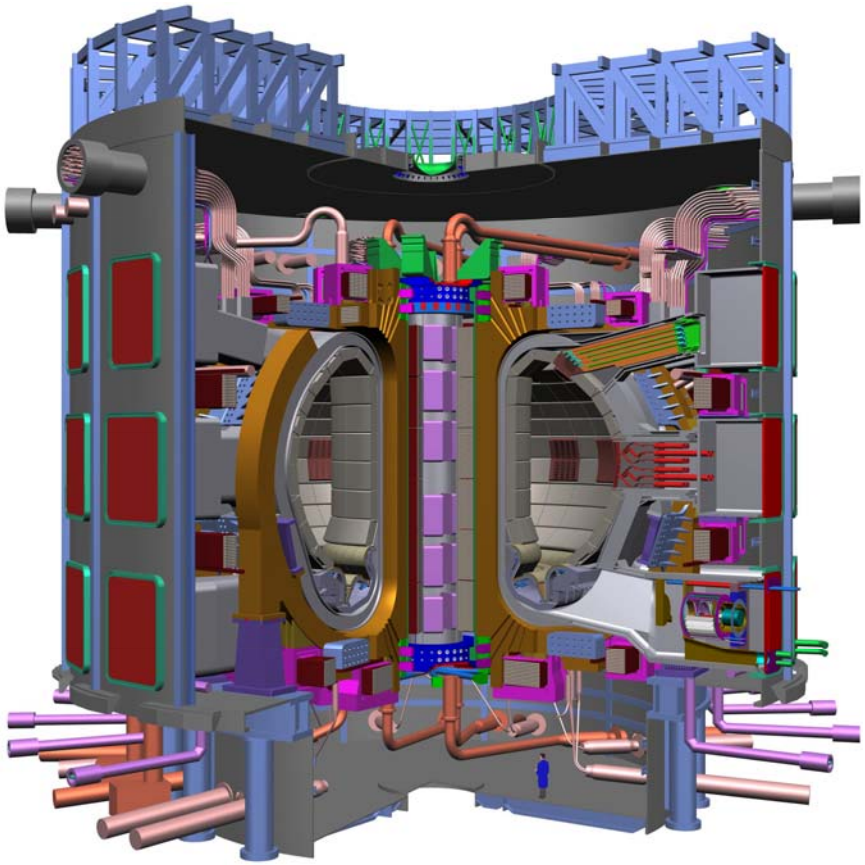


250 MeV superconducting
cyclotron for hadrontherapy



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