Welcome

Students
"Science and physics of particle accelerators" Course
Joint Universities Accelerator School
15 January 2016

LHCb

ATLAS

CERN Meyrin

CERN Prévessin

SPS 7 km

ALICE

SUISSE

FRANCE

LHC 27 km

to *Accelerating Science and Innovation*

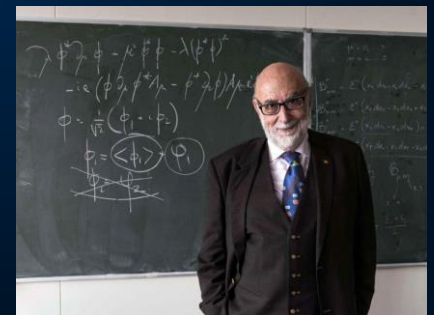# The origins of CERN

Conseil
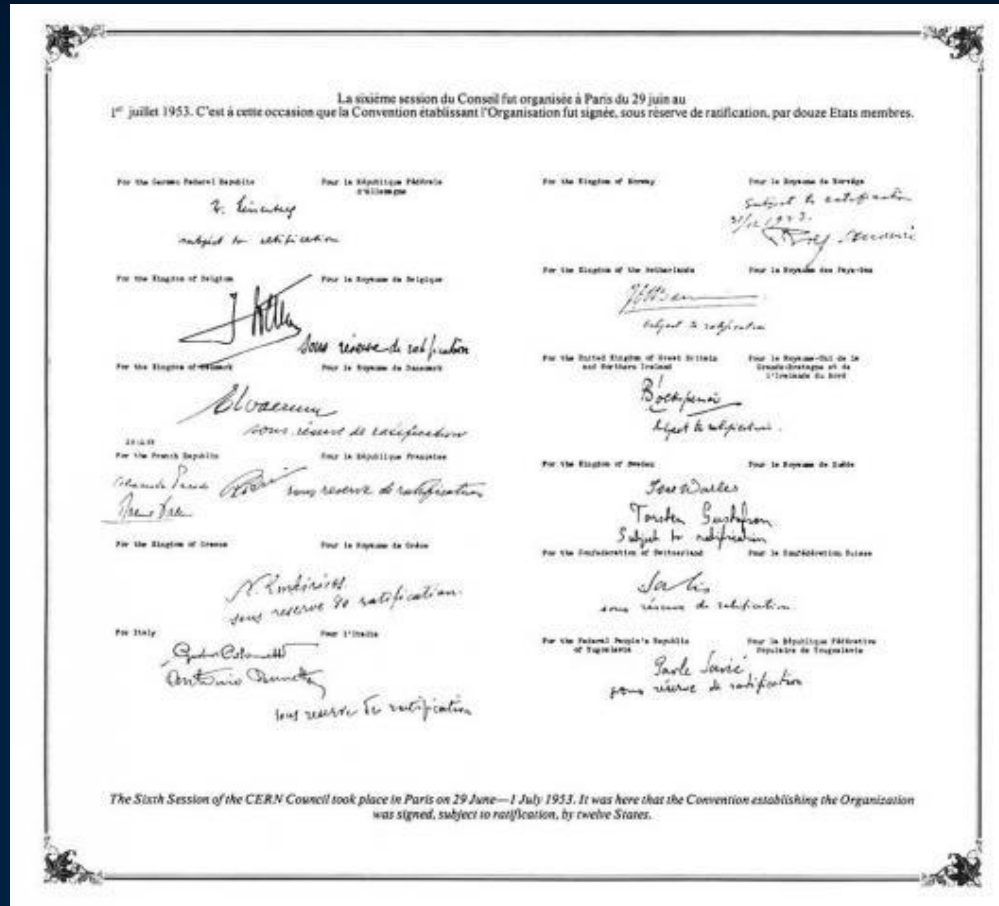**E**uropéen pour la
Recherche
Nucléaire

Nucléaire?

Only fundamental
research in physics

1954: the Convention, 12 founding Member States

«The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available»
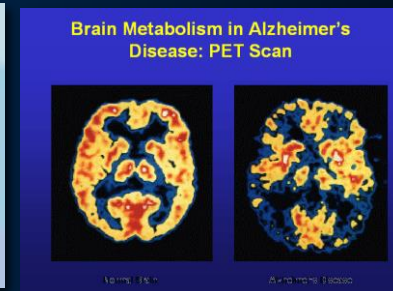
The mission of CERN

- ❑ **Push back** the frontiers of knowledge

  E.g. the secrets of the Big Bang …what was the matter like within the first moments of the Universe's existence?
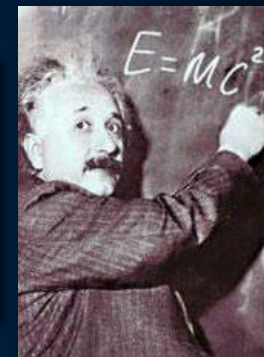
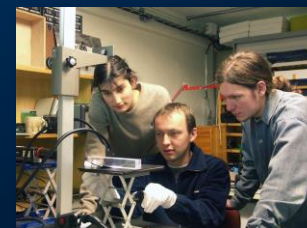- ❑ **Develop** new technologies for accelerators and detectors

  Information technology - the Web and the GRID

  Medicine - diagnosis and therapy

- ❑ **Train** scientists and engineers of tomorrow

- ❑ **Unite** people from different countries and cultures

CERN
uniting people
Innovation
Education
Research

CERN today: 21 Member States… and growing

~ 2300 staff
~ 1400 other paid personnel
~ 12500 scientific users
Budget (2015) ~1000 MCHF

Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom
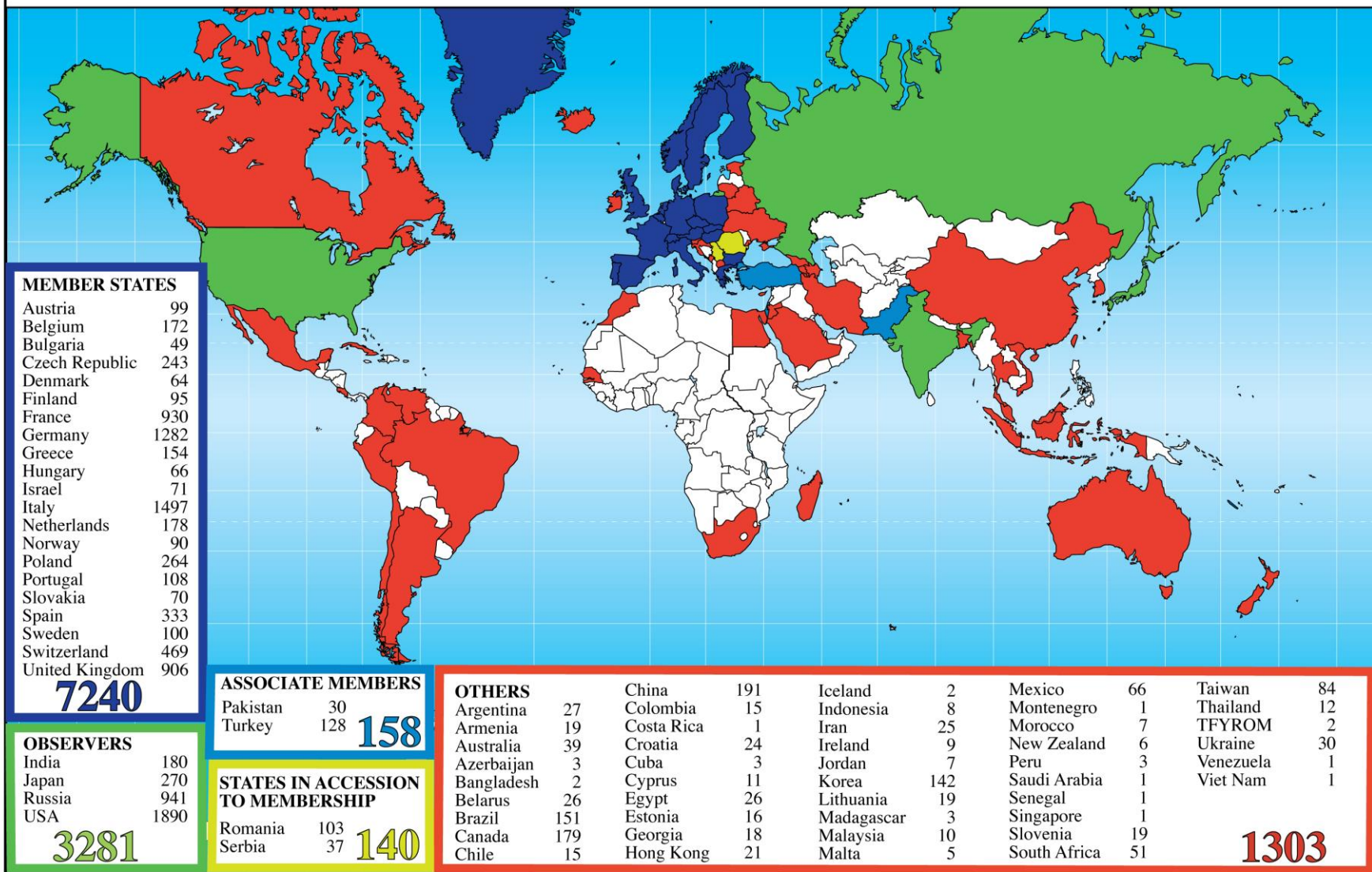
Associate Member States: Pakistan, Turkey

States in accession to Membership: Romania, Serbia

Applications for Membership or Associate Membership: Azerbaijan, Brazil, Croatia, Cyprus, India, Russia, Slovenia, Ukraine

Observers to Council: India, Japan, Russia, United States of America; European Union, JINR and UNESCO
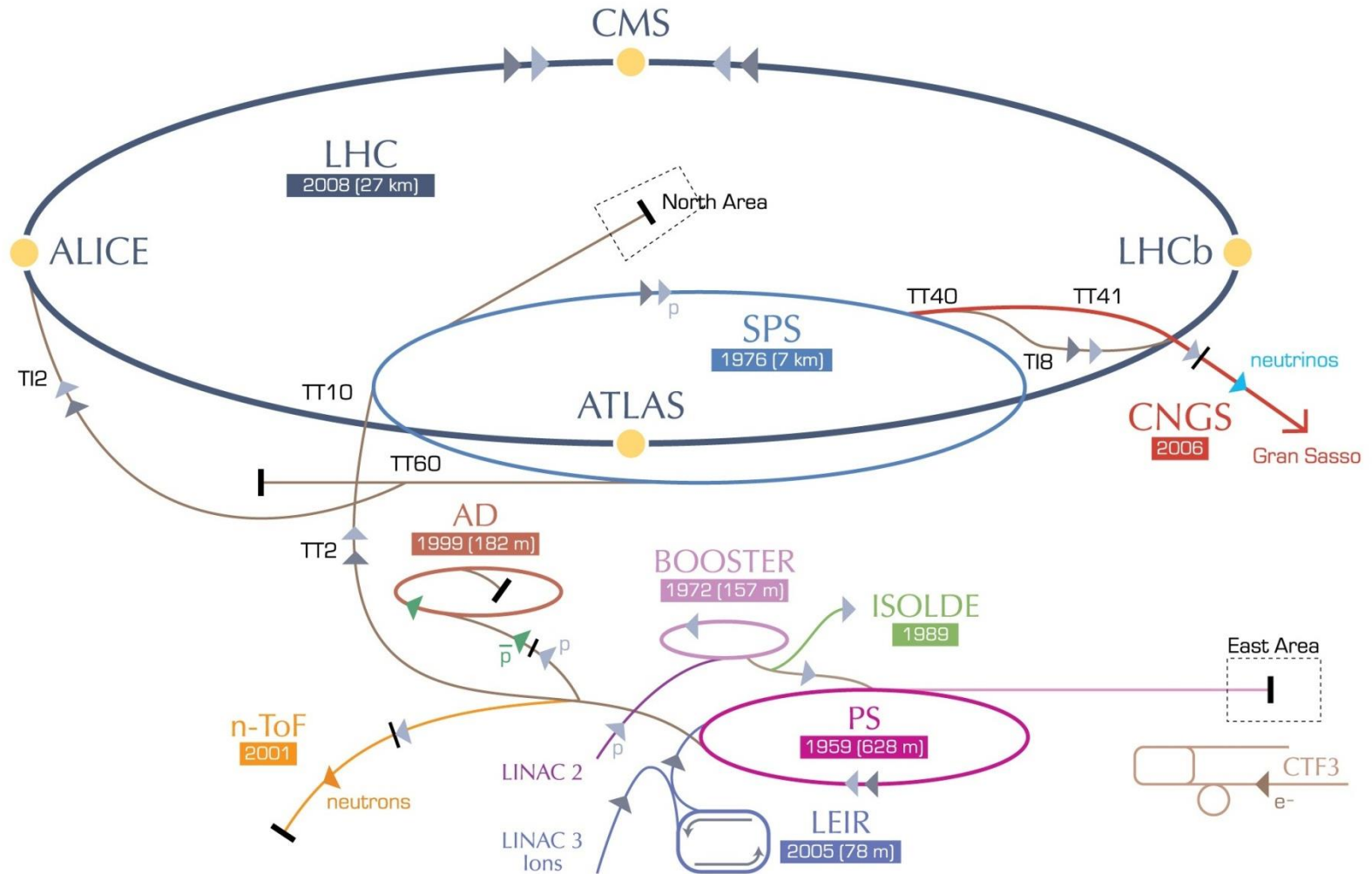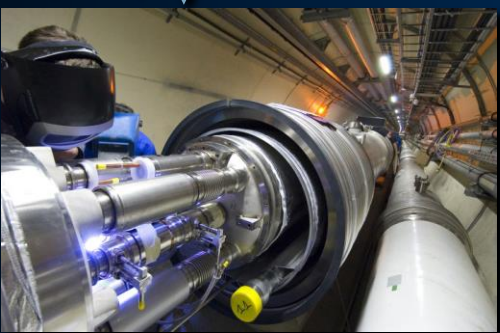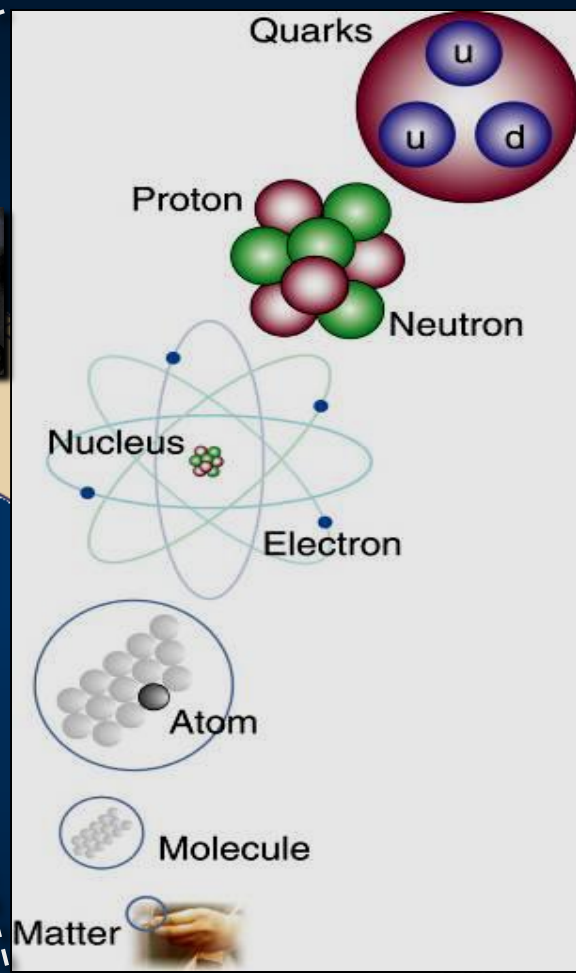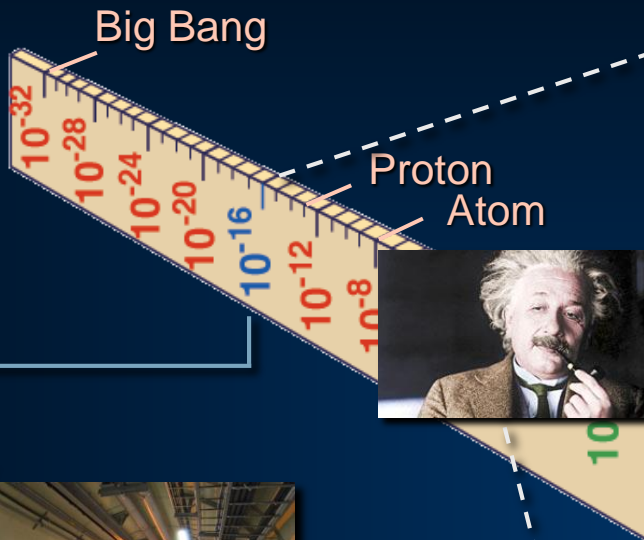
A global laboratory

Distribution of All CERN Users by Location of Institute on 21 September 2015

MEMBER STATES

Austria	99
Belgium	172
Bulgaria	49
Czech Republic	243
Denmark	64
Finland	95
France	930
Germany	1282
Greece	154
Hungary	66
Israel	71
Italy	1497
Netherlands	178
Norway	90
Poland	264
Portugal	108
Slovakia	70
Spain	333
Sweden	100
Switzerland	469
United Kingdom	906

7240

ASSOCIATE MEMBERS

Pakistan	30
Turkey	128

158

OBSERVERS

India	180
Japan	270
Russia	941
USA	1890

3281

STATES IN ACCESSION TO MEMBERSHIP

Romania	103
Serbia	37

140

OTHERS

Argentina	27	China	191	Iceland	2	Mexico	66
Armenia	19	Colombia	15	Indonesia	8	Montenegro	1
Australia	39	Costa Rica	1	Iran	25	Morocco	7
Azerbaijan	3	Croatia	24	Ireland	9	New Zealand	6
Bangladesh	2	Cuba	3	Jordan	7	Peru	3
Belarus	26	Cyprus	11	Korea	142	Saudi Arabia	1
Brazil	151	Egypt	26	Lithuania	19	Senegal	1
Canada	179	Estonia	16	Madagascar	3	Singapore	1
Chile	15	Georgia	18	Malaysia	10	Slovenia	19
		Hong Kong	21	Malta	5	South Africa	51

Taiwan	84
Thailand	12
TFYROM	2
Ukraine	30
Venezuela	1
Viet Nam	1

1303

A unique network of interconnected accelerators

Big Bang

10^{-32} 10^{-28} 10^{-24} 10^{-20} 10^{-16} 10^{-12} 10^{-8}

Proton
Atom

CERN

LHC

Super-Microscope

Quarks

u
u   d

Proton

Neutron

Nucleus

Electron

Atom

Molecule

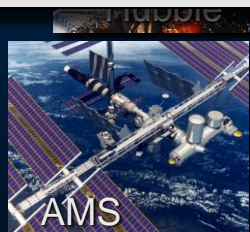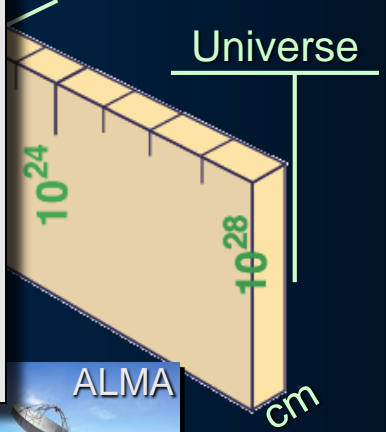Matter

Radius of Galaxies

Universe

10^{24}

10^{28}

cm

ALMA

AMS

VLT

Study physics laws of first moments after Big Bang
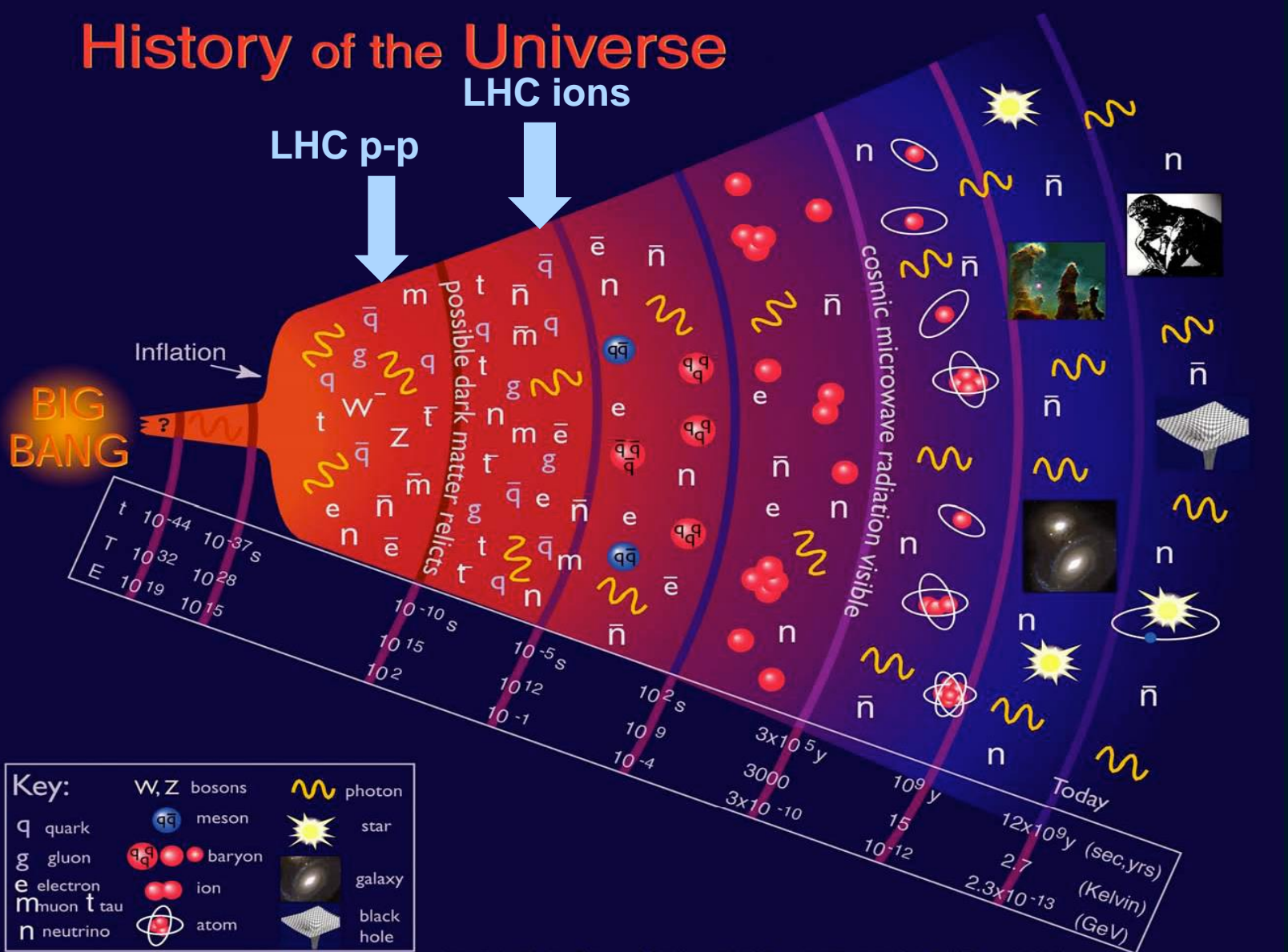increasing Symbiosis between Particle Physics,
Astrophysics and Cosmology

CERN

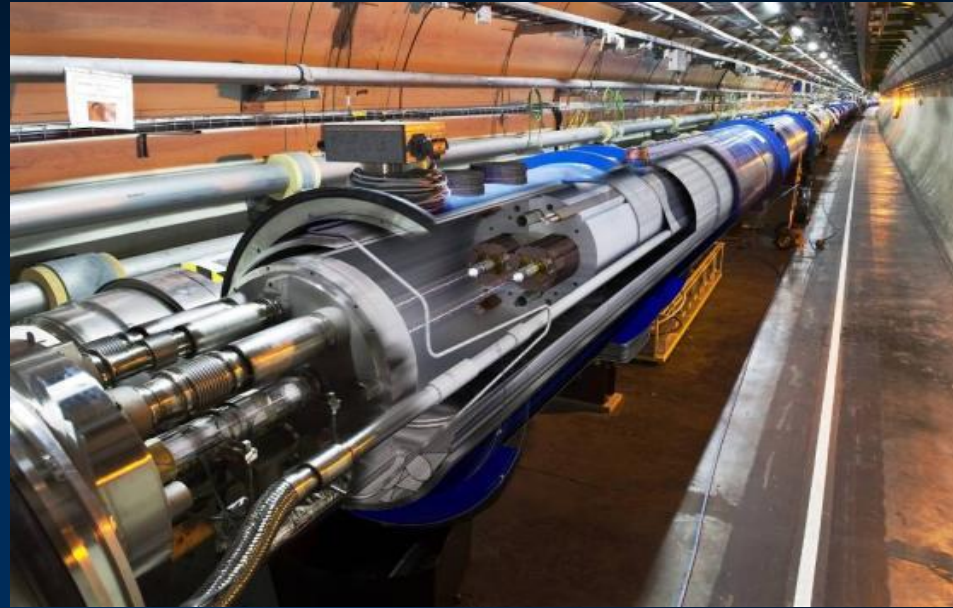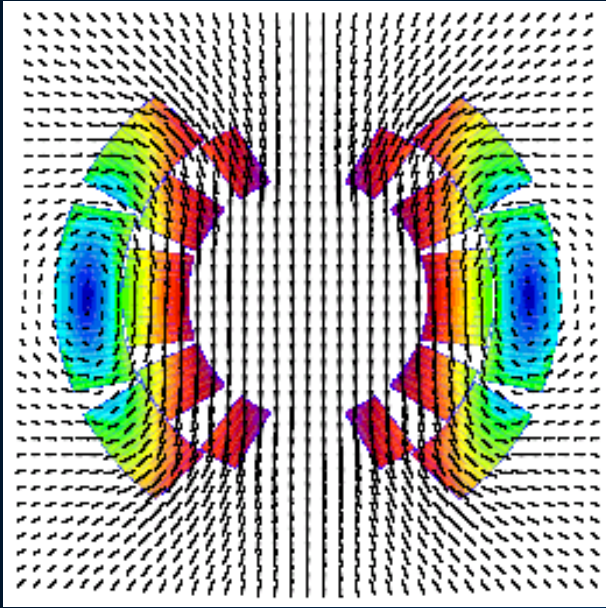# Time back-travel towards the Big Bang

History of the Universe

LHC ions

LHC p-p

Inflation

BIG BANG

possible dark matter relics

cosmic microwave radiation visible

t	10^{-44}	10^{-37} s
T	10^{32}	10^{28}
E	10^{19}	10^{15}

10^{-10} s
10^{15}
10^{2}

10^{-5} s
10^{12}
10^{-1}

10^{2} s
10^{9}
10^{-4}

3×10^{5} y
3000
3×10^{-10}

10^{9} y
15
10^{-12}

Today
12×10^{9} y (sec,yrs)
2.7 (Kelvin)
2.3×10^{-13} (GeV)

Key:
q quark
g gluon
e electron
m muon t tau
n neutrino

W, Z bosons
qq̄ meson
qqq baryon
ion
atom

photon
star
galaxy
black hole

Particle Data Group, LBNL, © 2000.   Supported by DOE and NSF

CERN

LHC, the largest scientific instrument in the world

LHCb

CMS

ATLAS

ALICE

LHCb

ATLAS

CERN Meyrin

CERN Prévessin

SPS 7 km

ALICE

CMS

LHC ring:
27 km circumference

CERN

Technological challenges of the LHC

- **High-field superconducting magnets: 8.3 T** (1232 dipoles each 15 m long)
- **The largest system of superconducting magnets** (~10'000 magnets)
- **The largest cryogenic system at 1.9 K** (superfluid helium, 150 t He to cool 37'500 t magnets)
- **Cryogenic ultra-high vacuum for the beams** (10^{-13} bar, 10 times better than on the moon)
- **High electrical currents controlled with high precision** (up to 13 kA at the ppm level)
- **Efficient beam collimation to limit beam losses around the machine**
  (losing a few ppm of the circulating beams can « quench » the magnets)
- **Ultra-reliable magnet and accelerator protection system**
  (stored energy in magnets > 10 GJ, stored energy in beams >700 MJ)

Evolution of high-energy hadron colliders

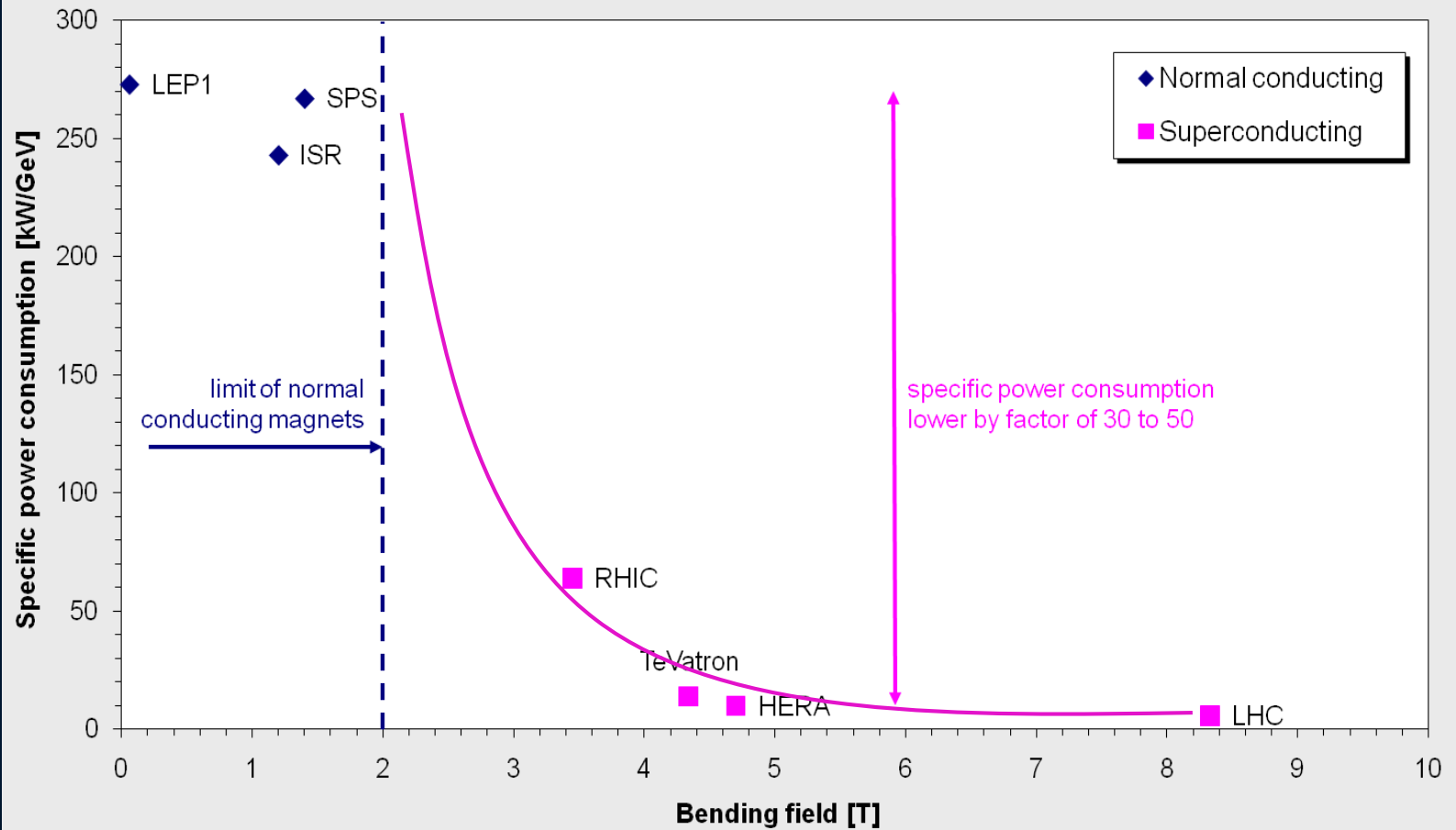## Technological progress helps containing increase in size and cost
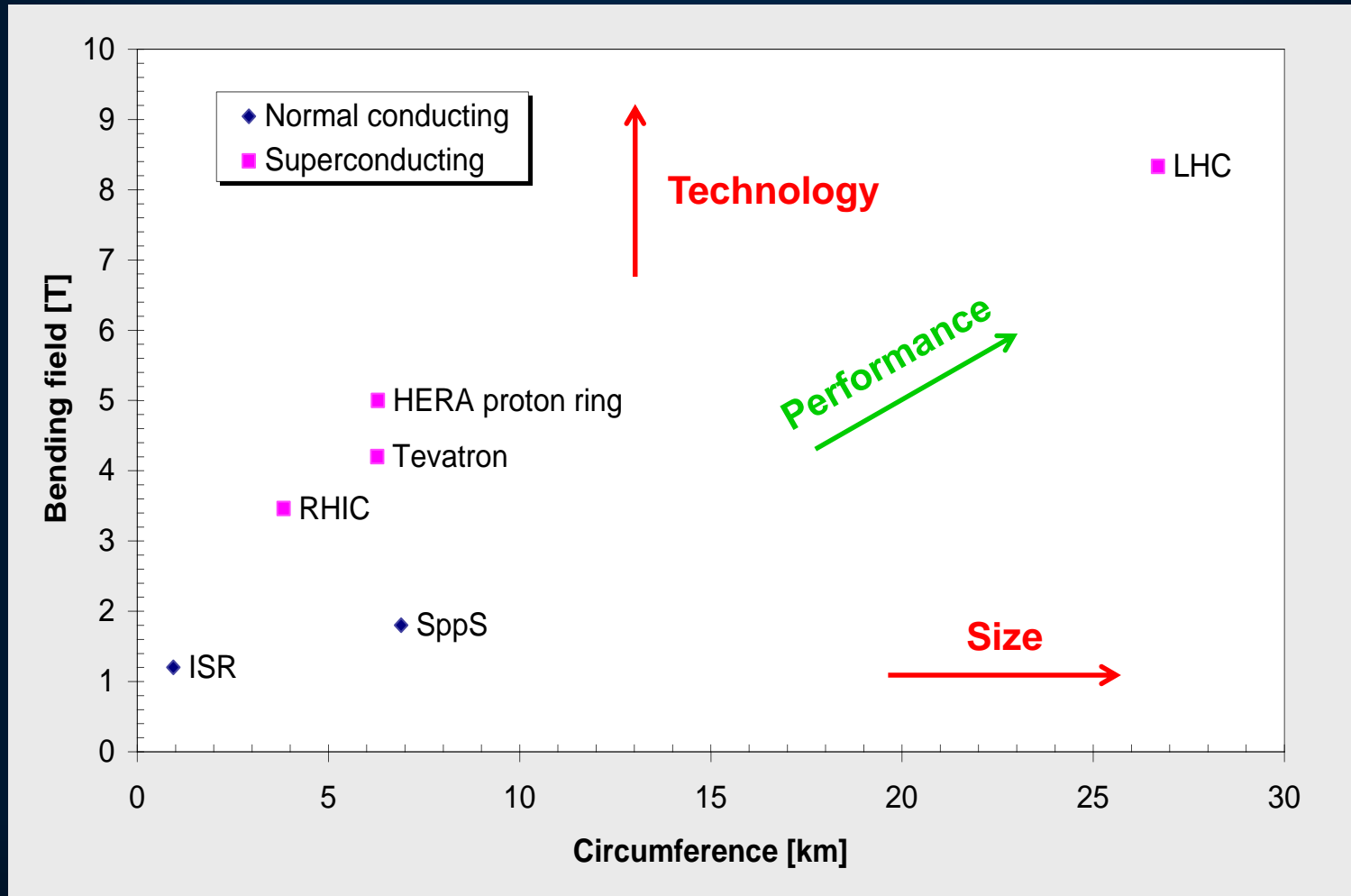
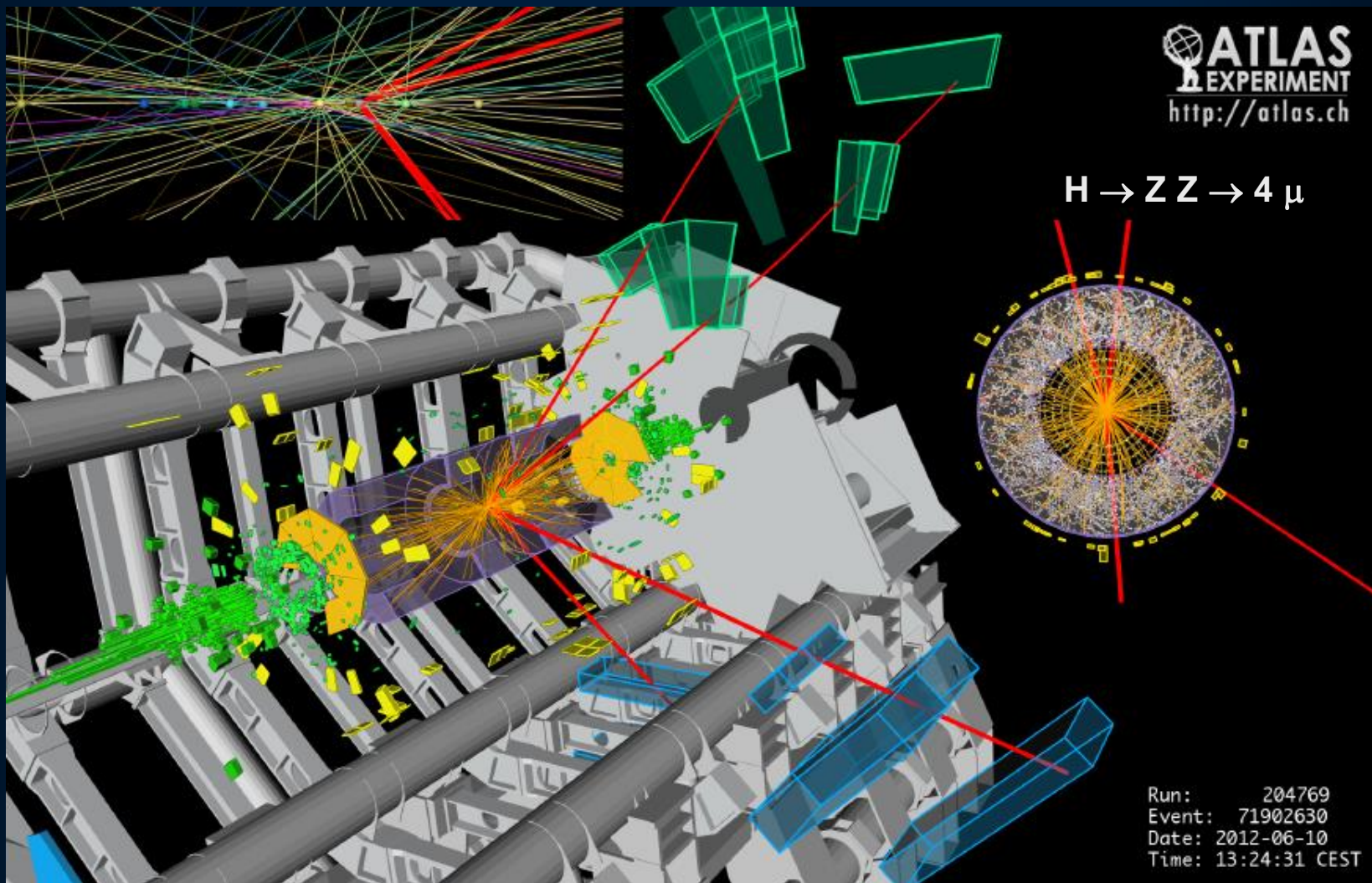# Superconductivity to produce high magnetic fields
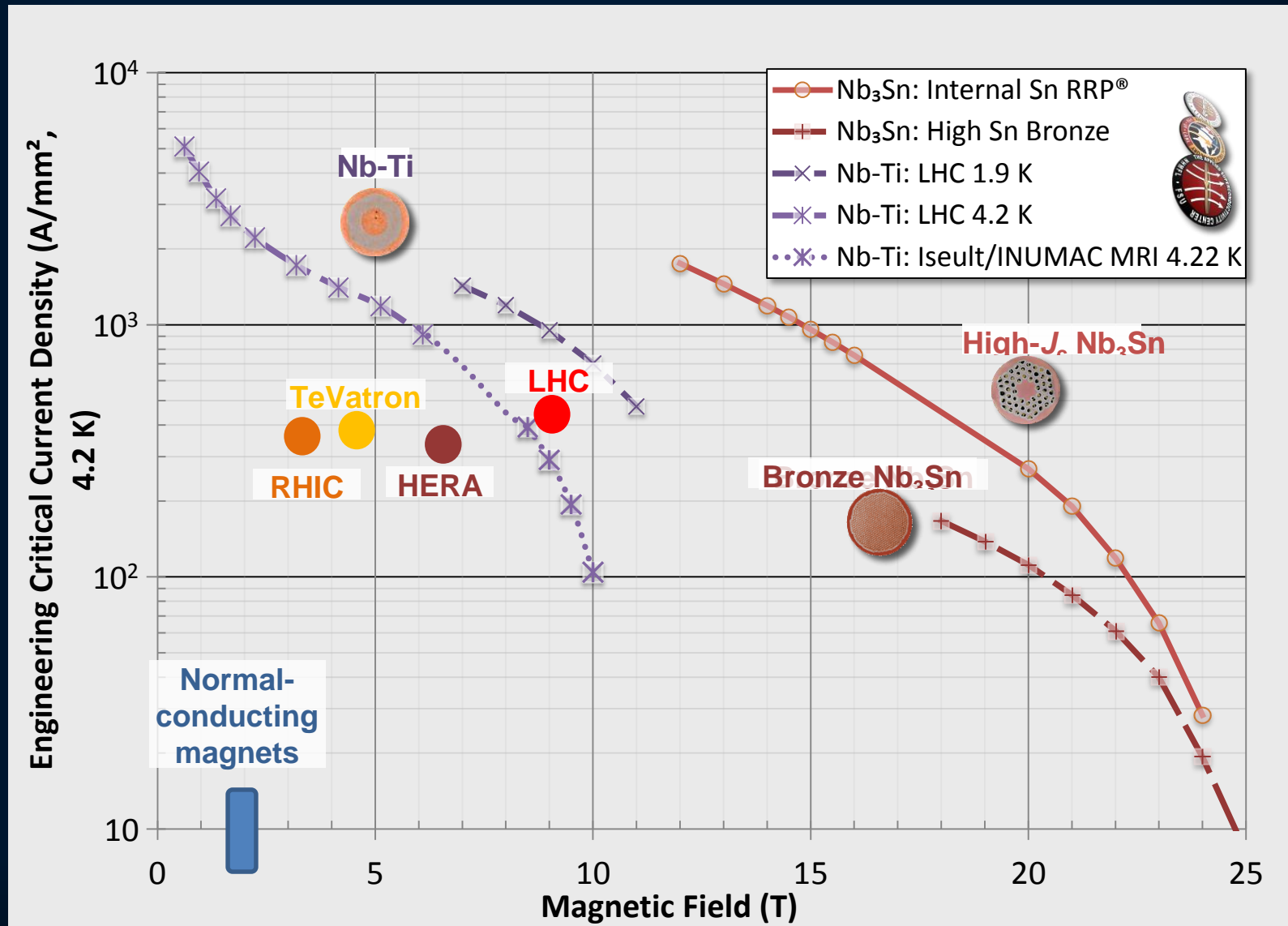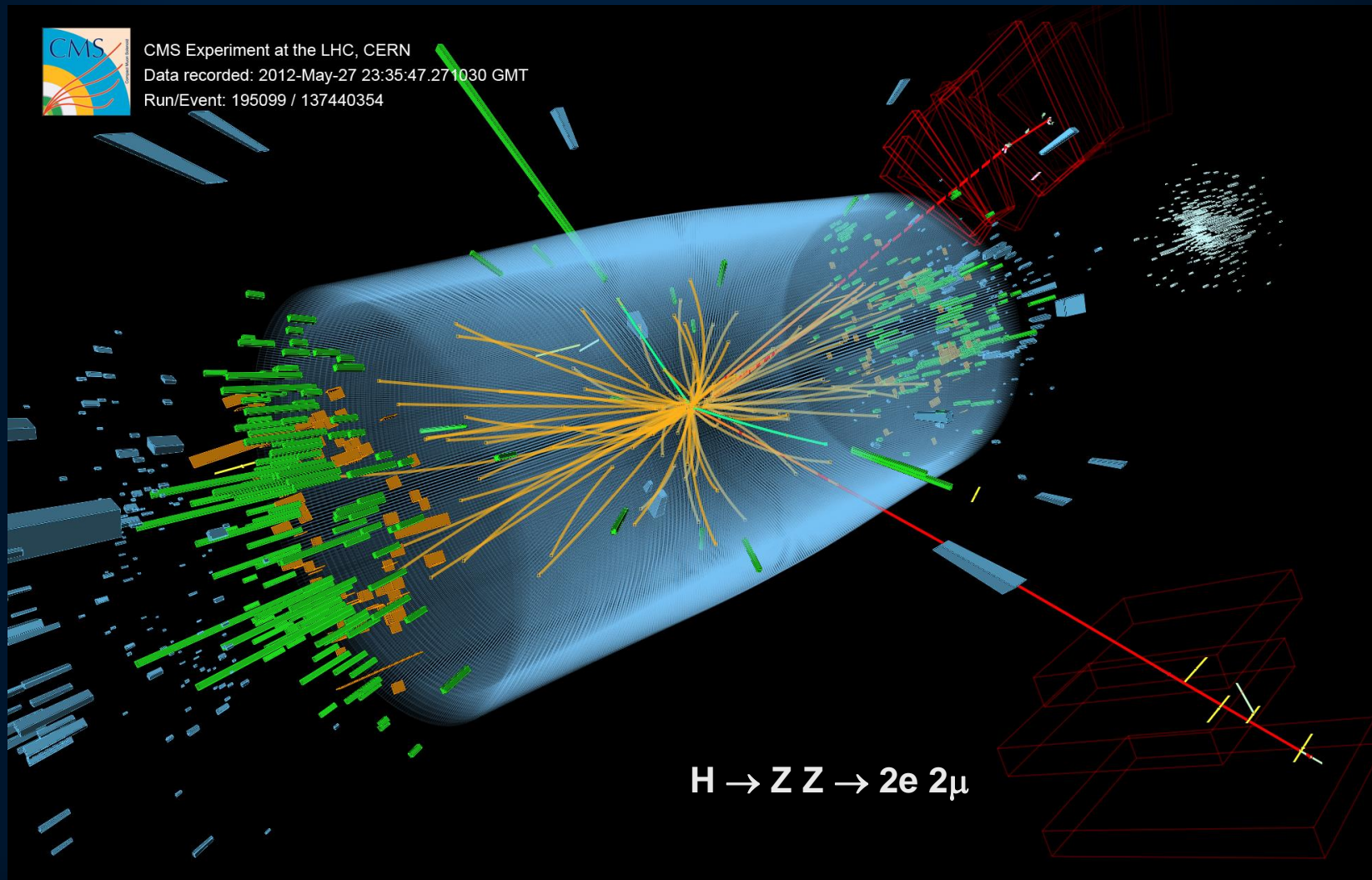
Superconductivity for energy efficiency

Disintegration of Higgs boson
produced in proton collisions at the LHC

Disintegration of Higgs boson produced in proton collisions at the LHC

CMS Experiment at the LHC, CERN
Data recorded: 2012-May-27 23:35:47.271030 GMT
Run/Event: 195099 / 137440354

$H \rightarrow Z\,Z \rightarrow 2e\,2\mu$

Discovery 2012, Nobel Prize in Physics 2013

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".*

Experimental research at the LHC will allow us to answer some of the big questions ...

Will we understand the primordial state of matter after the Big Bang before protons and neutrons formed?
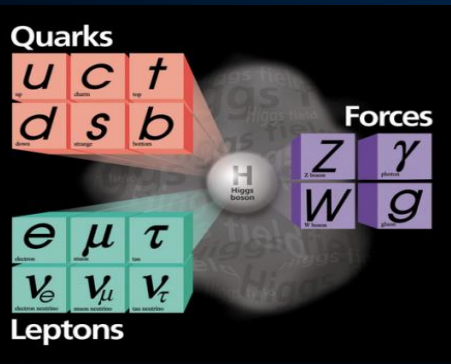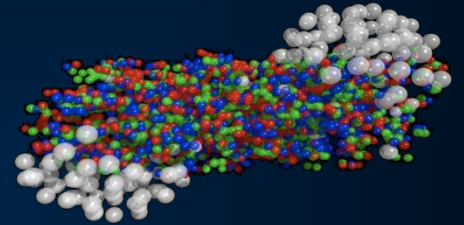
Have we found "THE" Higgs particle that is responsible for giving mass to all elementary particles?

Will we find the reason why antimatter and matter did not completely annihilate each other?

Will we find the particle(s) that make up the mysterious 'dark matter' in our Universe?

Particle Physics and Innovation

Il n'y pas d'un côté la recherche fondamentale et de l'autre la recherche appliquée. Il y a la recherche et les applications de celle-ci, unies l'une à l'autre comme le fruit de l'arbre est uni à la branche qui l'a porté

Louis Pasteur

❑ CERN Technologies and Innovation

Accelerating particle beams
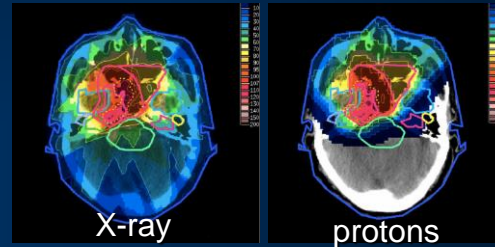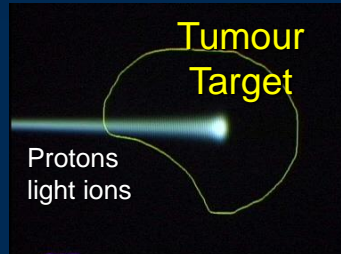
Detecting particles

Large-scale computing (Grid)

Medical Application as an Example of Particle Physics Spin-off

## Combining Physics, ICT, Biology and Medicine to fight cancer

Accelerating particle beams
~30'000 accelerators worldwide
~17'000 used for medicine

Hadron Therapy

Tumour Target

Protons
light ions

X-ray

protons

Leadership in Ion Beam Therapy now in Europe and Japan

>100'000 patients treated worldwide (45 facilities)
>50'000 patients treated in Europe (14 facilities)
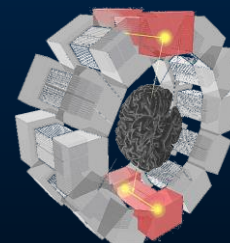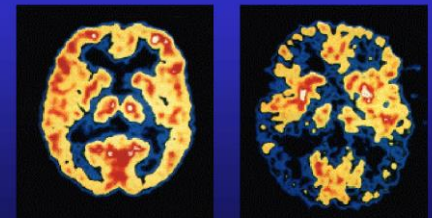
Detecting particles
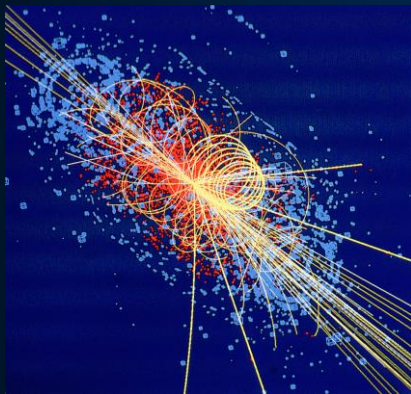
Imaging

Clinical trial in Portugal, France and Italy for new breast imaging system (ClearPEM)

PET Scanner

Brain Metabolism in Alzheimer's Disease: PET Scan
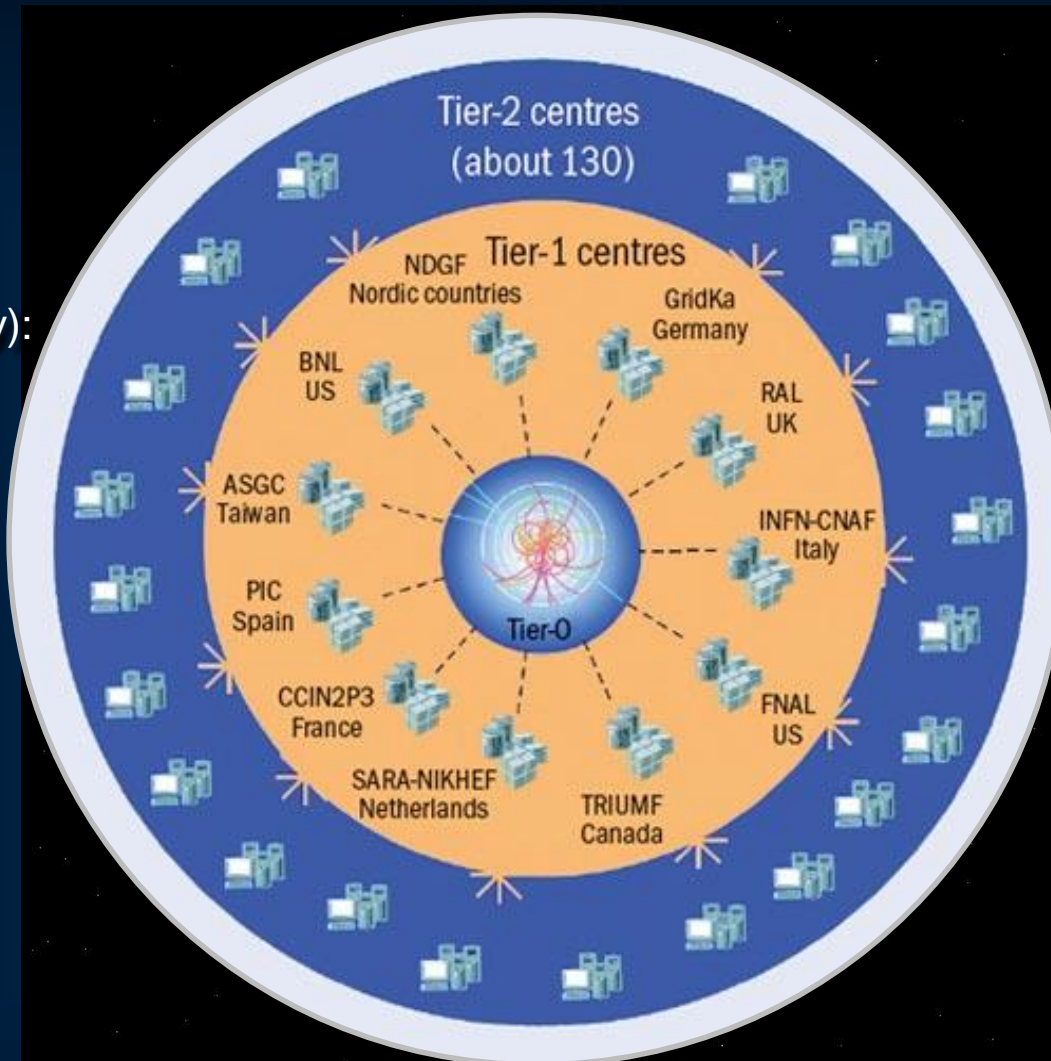
The Worldwide LHC Computing Grid

Tier-0
(CERN and Hungary):
data recording,
reconstruction and
distribution

Tier-1: permanent
storage, re-
processing,
analysis

Tier-2: simulation,
end-user analysis

nearly 160 sites,
35 countries

~250'000 cores

173 PB of storage

> 2 million jobs/day

10 Gb links

WLCG:
An International collaboration to distribute and analyse LHC data

Integrates computer centres worldwide that provide computing and storage
resource into a single infrastructure accessible by all LHC physicists

CERN Education Activities

Scientists at CERN
Academic Training Programme

Asia-Europe-Pacific School of High-Energy Physics

Fukuoka, Japan, 2012
Puri, India, 2014
China, 2016

Latin American School of High-Energy Physics

Natal, Brazil, 2011
Arequipa, Peru, 2013
Ibarra, Ecuador, 2015

Young Researchers
CERN School of High Energy Physics
CERN School of Computing
CERN Accelerator School

The 2014 European School of High-Energy Physics

CERN School of Physics
Bulgaria, June 2015

Physics Students
Summer Students Programme

CERN Teacher Schools
International and National Programmes

Questions?

Accelerating Science and Innovation