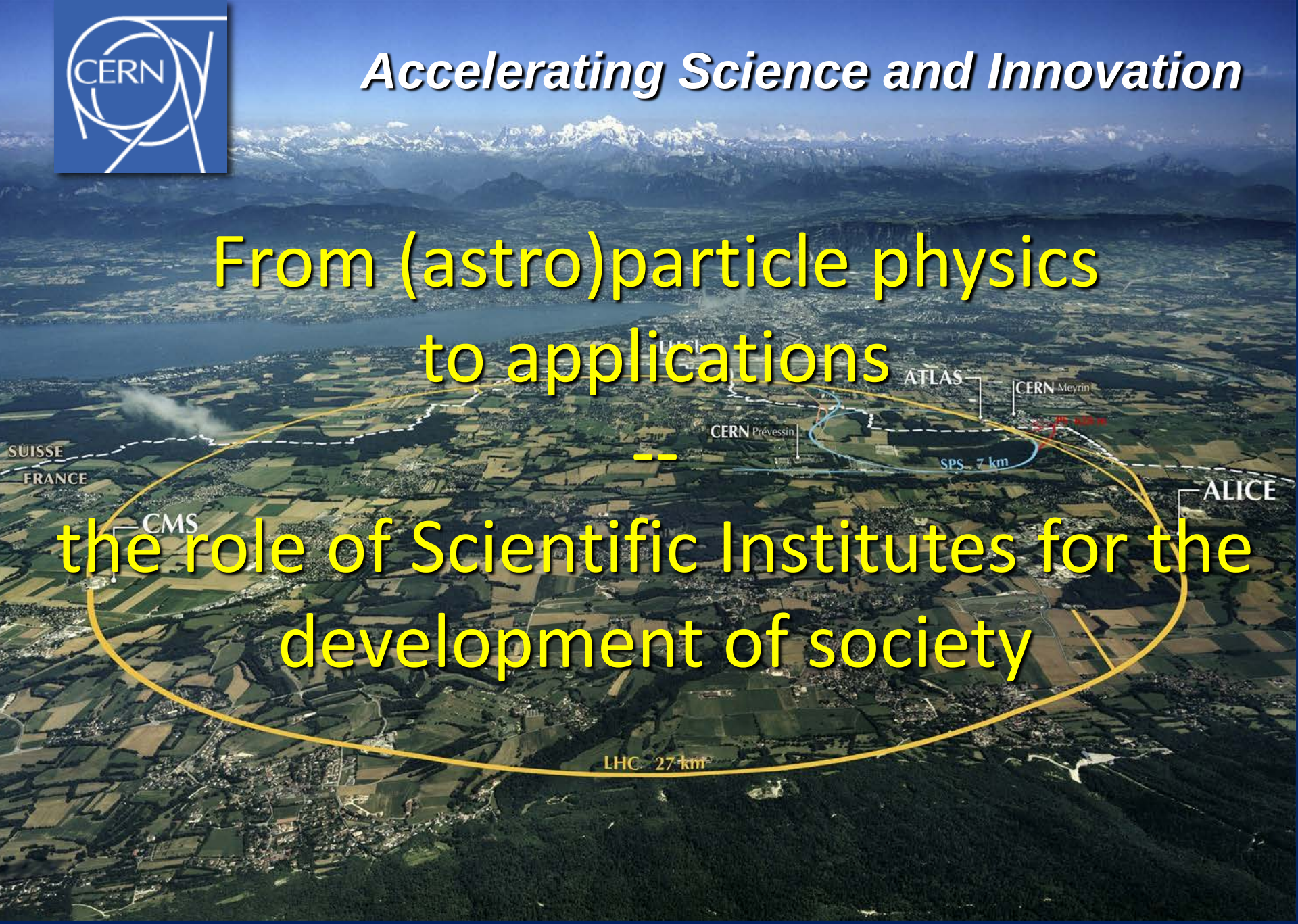
Accelerating Science and Innovation

From (astro)particle physics to applications

--

the role of Scientific Institutes for the development of society



Key Message (I)

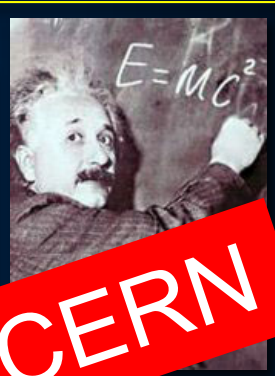
In today's challenging period, all regions need to step up support for research and innovation in order to ensure, in a global competitive environment, the sustainable development of science and technology necessary for the upturn and growth of everybody's economy.

Research Institutes

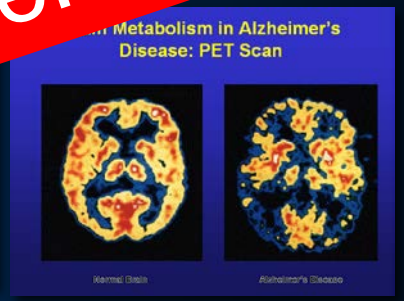
are important 'tools' for this

Mission of Research Institutes

- ***Research***
  Push forward the frontiers of knowledge



- ***Innovation***
  Develop new, cutting-edge technologies



Excellent global example: CERN

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

- ***Outreach***
  Promote Science in Society

CERN: founded in 1954 by 12 European States

“Science for Peace”

Today: 21 Member States

- ~ 2300 staff
- ~ 1400 other paid personnel
- ~ 12500 scientific users

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

Associate Member States: Cyprus, Pakistan, Turkey

States in accession to Membership: Romania, Serbia

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

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

Key Message (II)

CERN, as a unique international institute,
as a unique global research infrastructure
is vital for large scale projects

which in turn allows
technology
upturn and growth of
body's economy

Excellent example: LIP
LIP and CERN share the same missions

But CERN is only strong through its close collaboration with national institutes

LIP and CERN

Portugal joined CERN 1986

Portugal created LIP 1986 as a national institute focusing on the collaboration with CERN

30 years of fruitful collaboration LIP-CERN

many more exciting years of research and innovation ahead of us

Research

Large-scale Science Projects

- Address

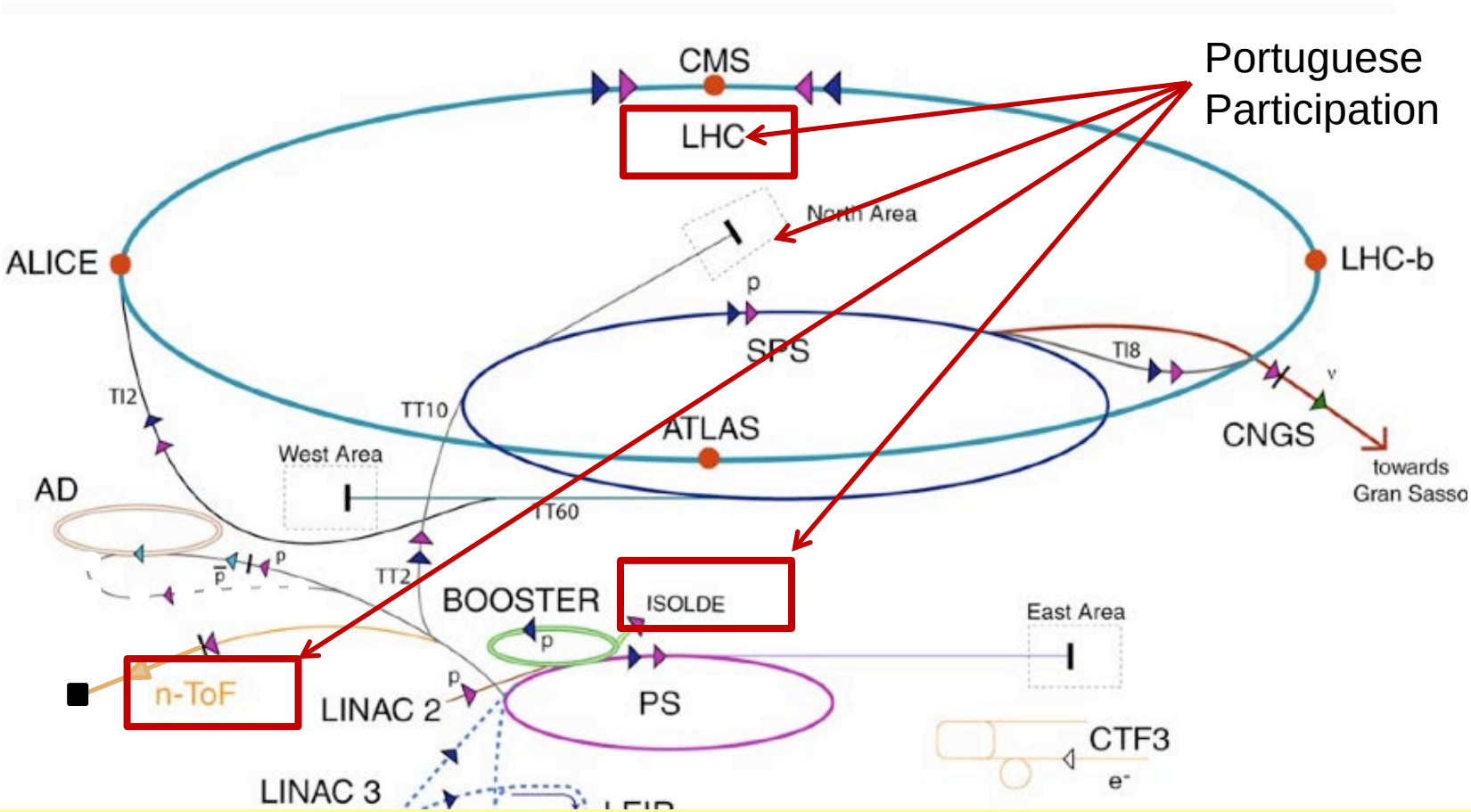
  - fundamental science questions

    at the forefront of research and technology

Provide fascination and insight into research and into the way how research is working.

Need a large, exciting, curiosity generating flagship project (complemented by a broad spectrum of other scientific topics)

CERN Accelerator Complex



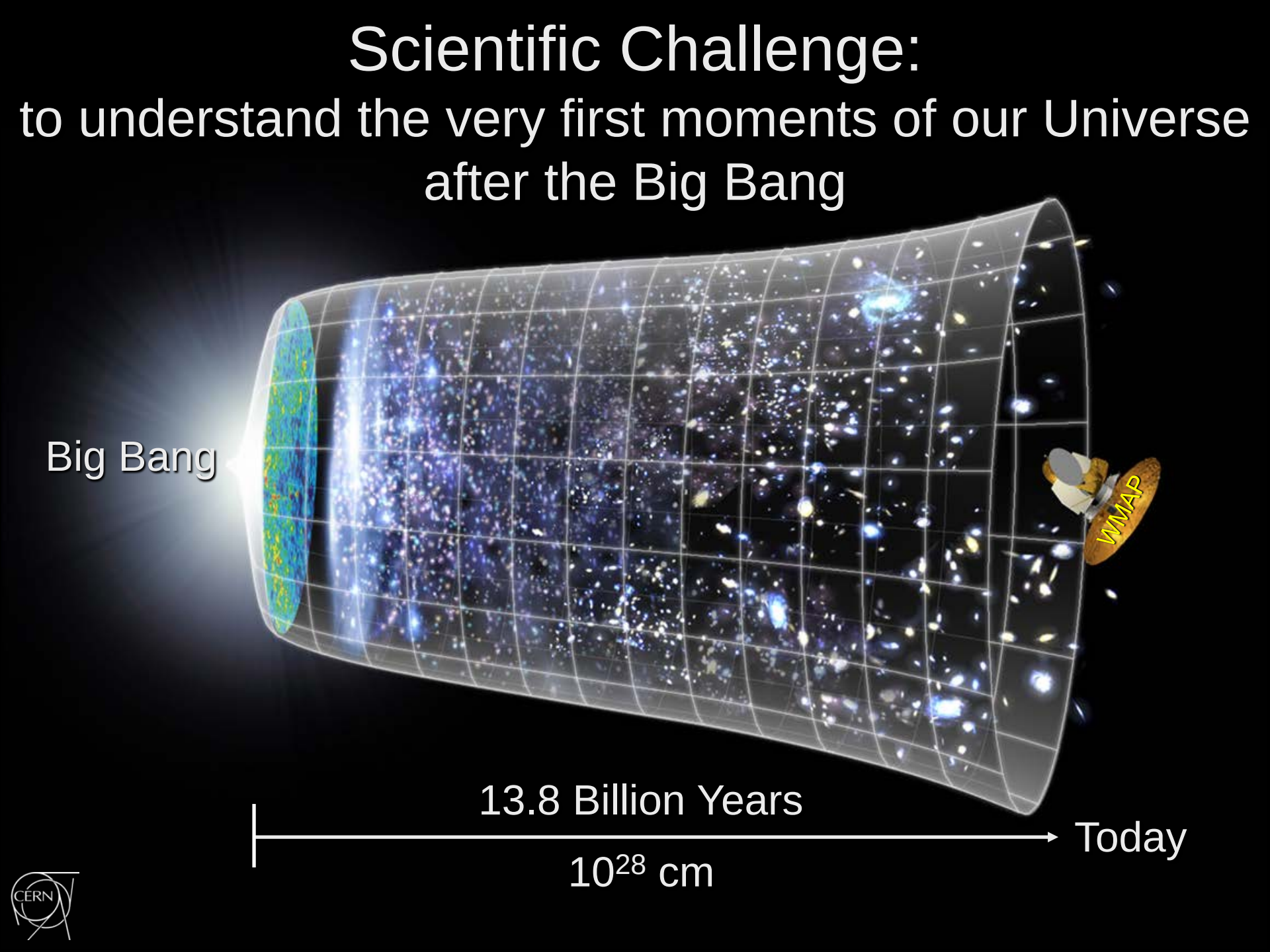
Scientific Diversity at **unique facilities**

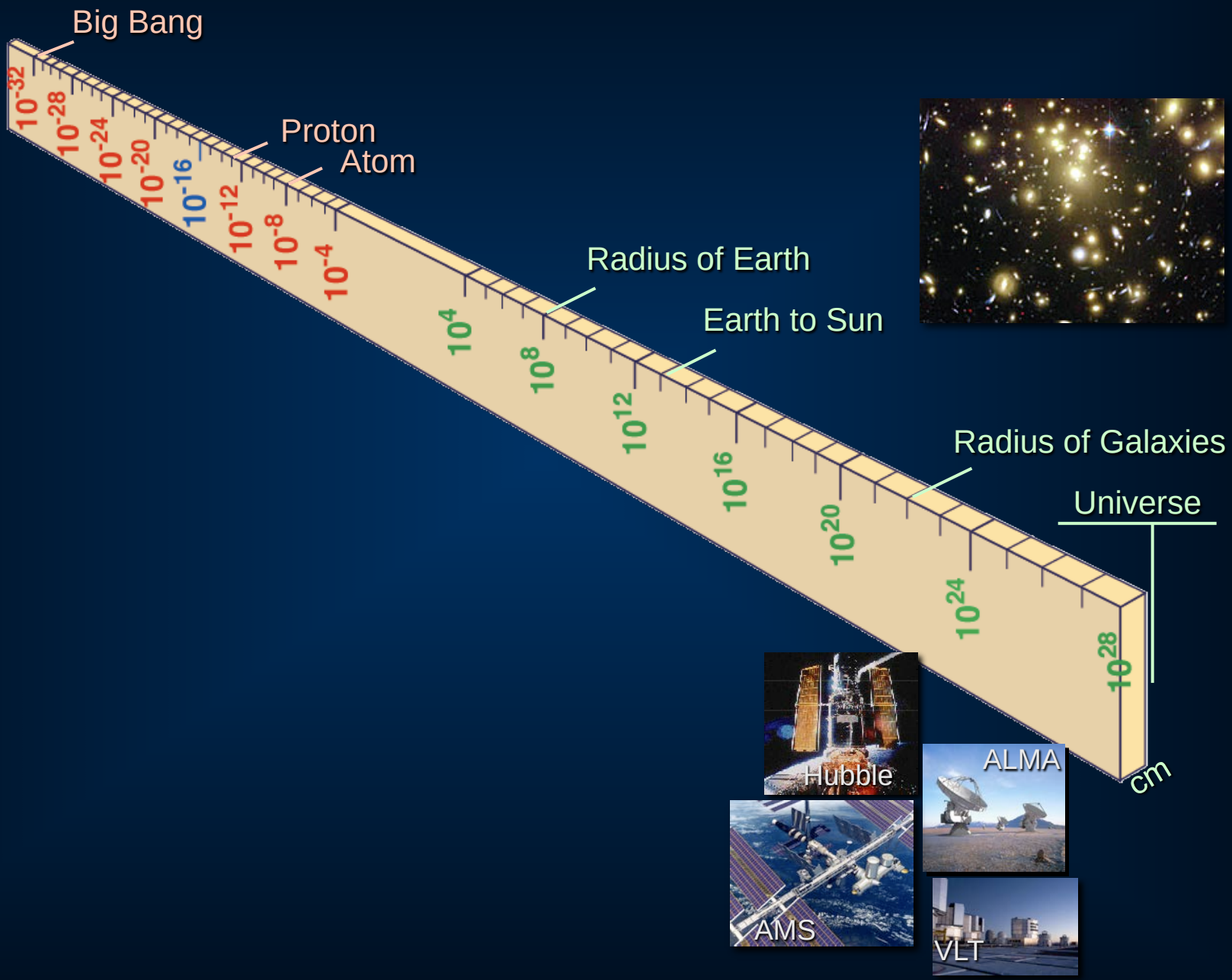
CERN maintains and upgrades all these facilities

Complemented and supported by Theory

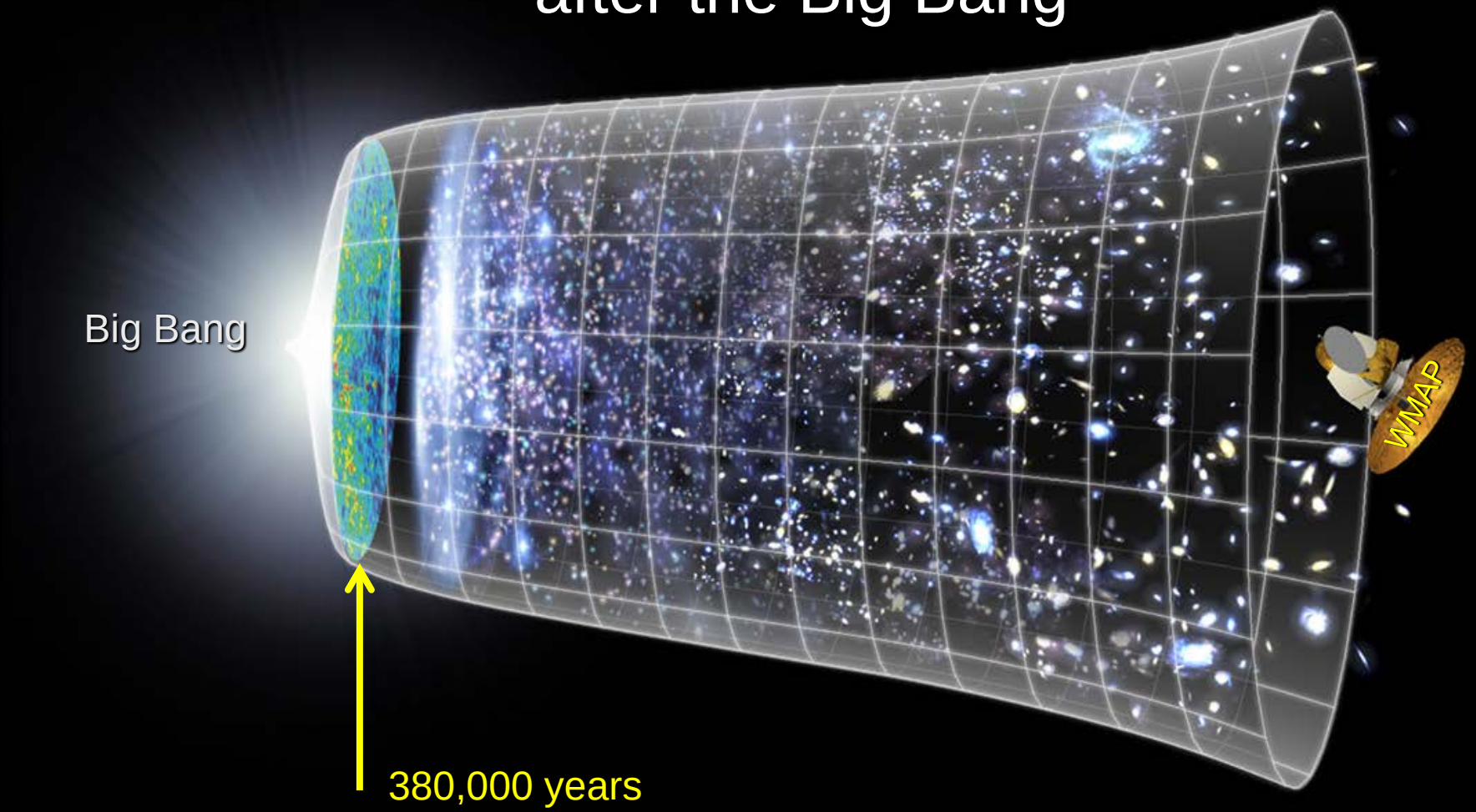
Scientific Challenge:

to understand the very first moments of our Universe after the Big Bang




Big Bang
Proton
Atom
Radius of Earth
Earth to Sun
Radius of Galaxies
Universe
10^{-32}
10^{-28}
10^{-24}
10^{-20}
10^{-16}
10^{-12}
10^{-8}
10^{-4}
10^{4}
10^{8}
10^{12}
10^{16}
10^{20}
10^{24}
10^{28}
cm
Hubble
ALMA
AMS
VLT

Scientific Challenge:
to understand the very first moments of our Universe after the Big Bang



Particle and Astro(particle) Physics address similar questions with complementary methods

Big Bang

Proton

Atom

Earth to Sun

Radius of Galaxies

Universe

cm

LHC

Super-Microscope

Reproducing conditions

Looking back

Super-Microscope

LHC

Big Bang

Proton

Atom

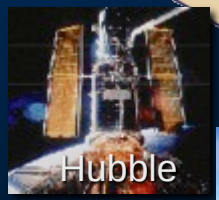
Radius of Earth

Earth to Sun

Radius of Galaxies

Universe

10^{-32} 10^{-28} 10^{-24} 10^{-20} 10^{-16} 10^{-12} 10^{-8} 10^{-4} 10^{4} 10^{8} 10^{12} 10^{16} 10^{20} 10^{24} 10^{28} cm



Hubble

ALMA

AMS

VLT

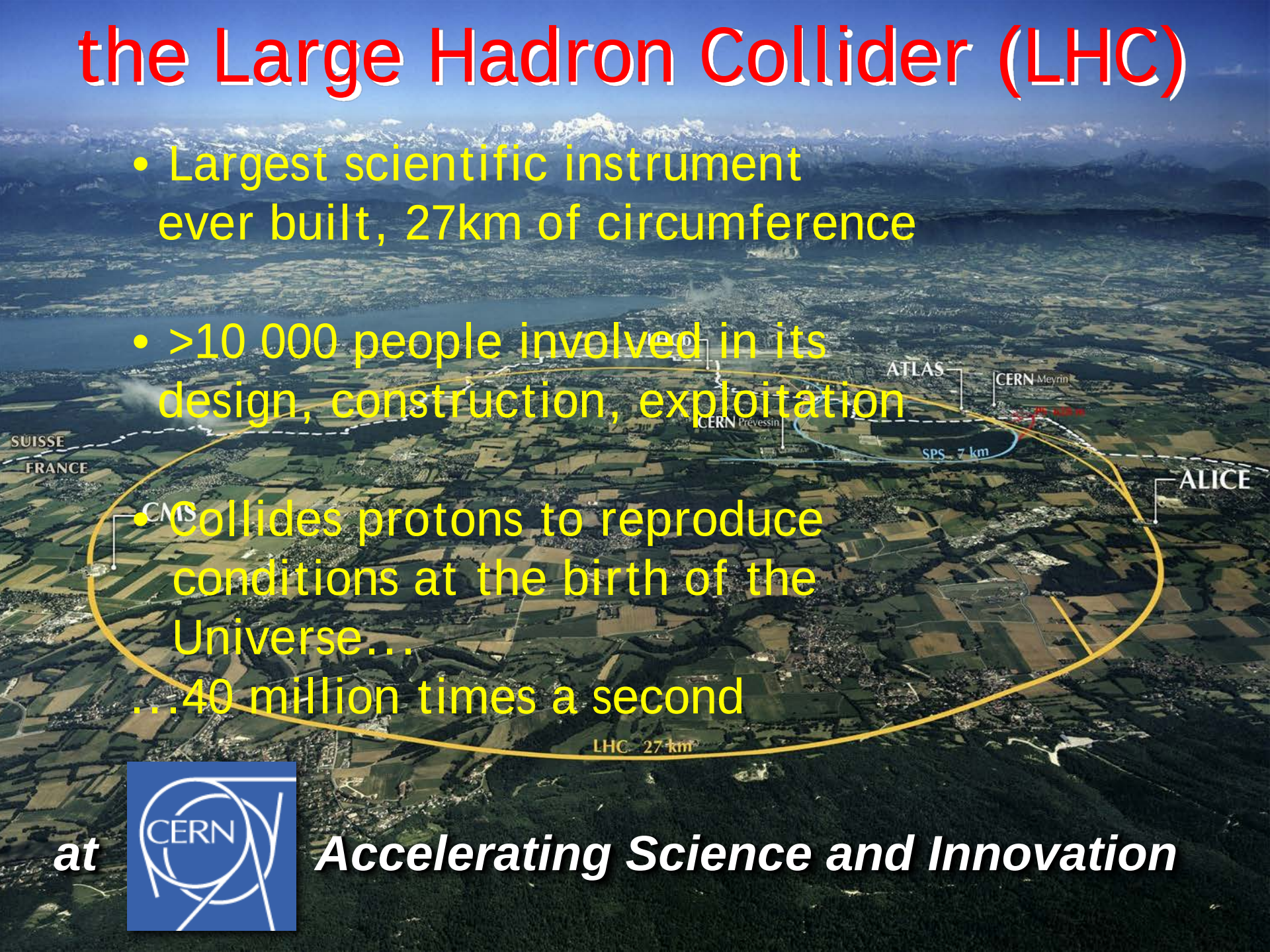
Getting closest to the Big Bang (≤10^{-12} s)

→ breaking the wall of the Hidden Universe

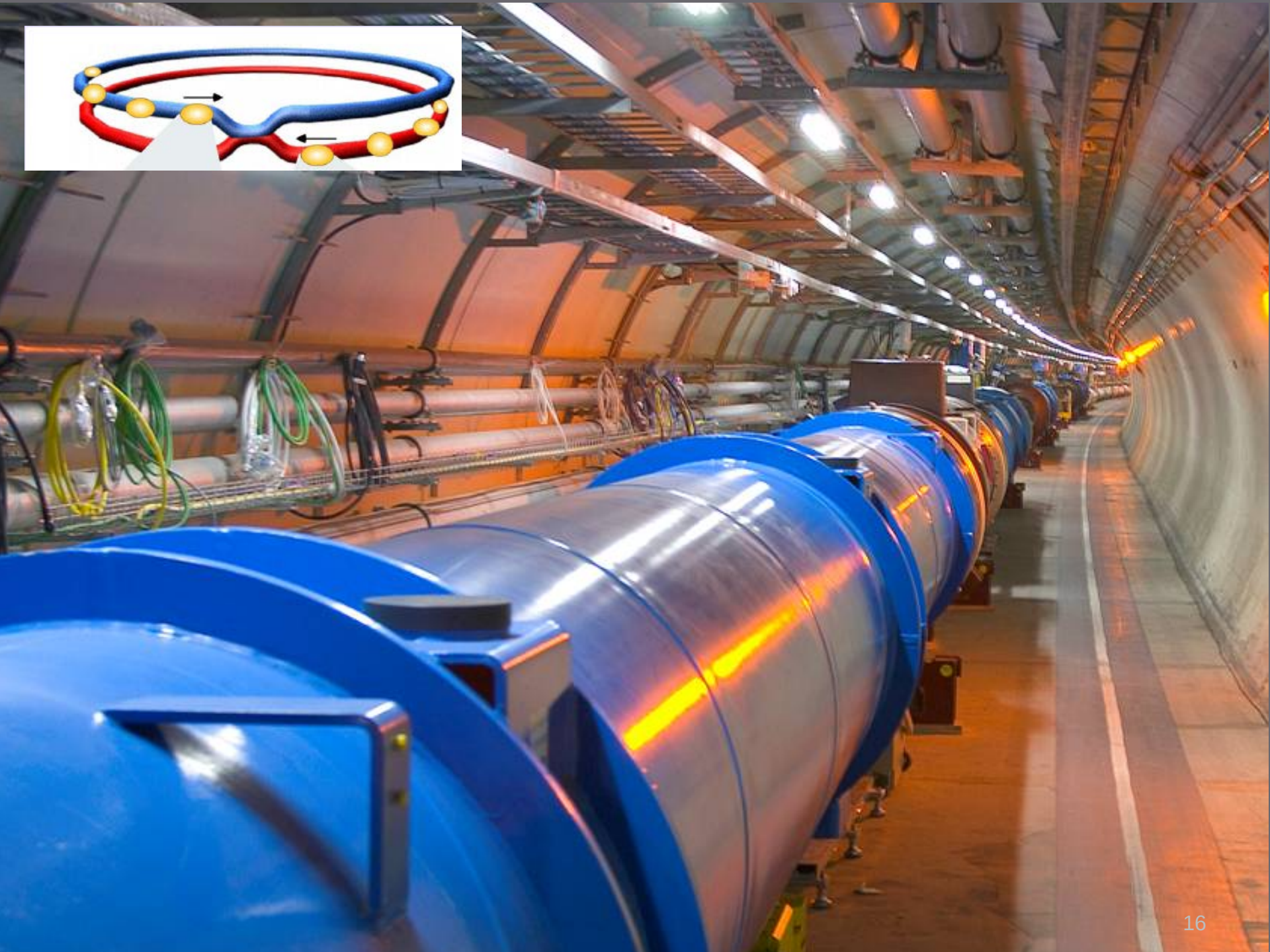
the Large Hadron Collider (LHC)

- Largest scientific instrument ever built, 27km of circumference
- >10 000 people involved in its design, construction, exploitation
- Collides protons to reproduce conditions at the birth of the Universe…

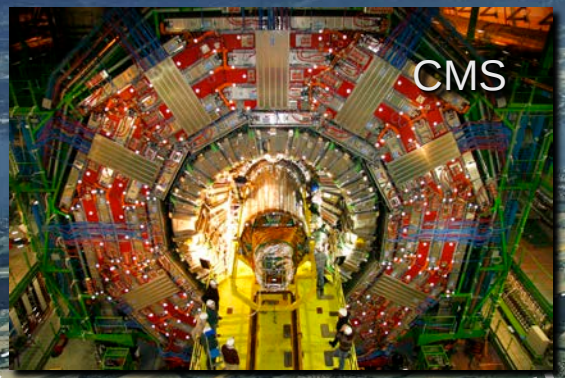
…40 million times a second



at CERN *Accelerating Science and Innovation*



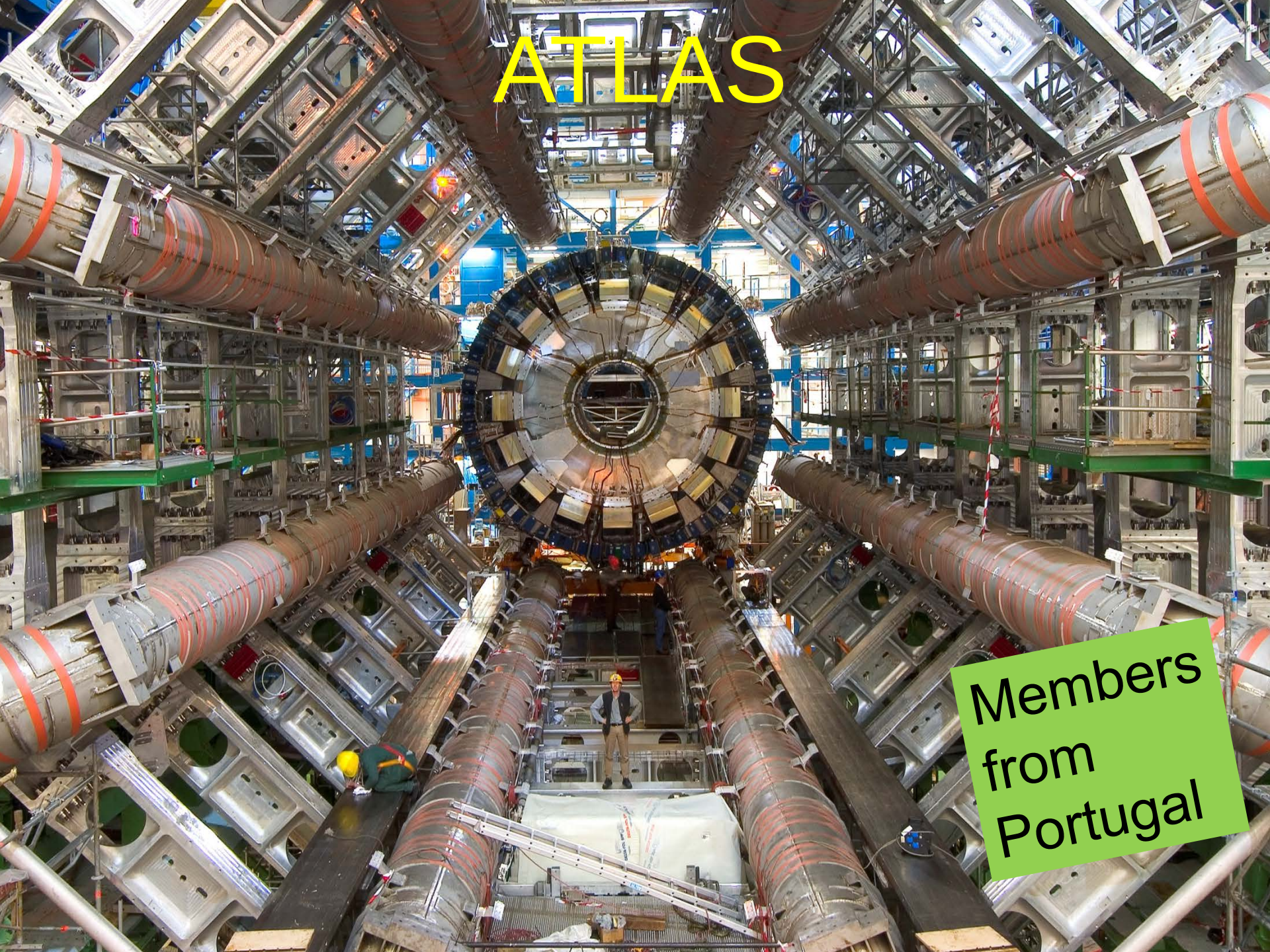
LHC : a New Era in Fundamental Science

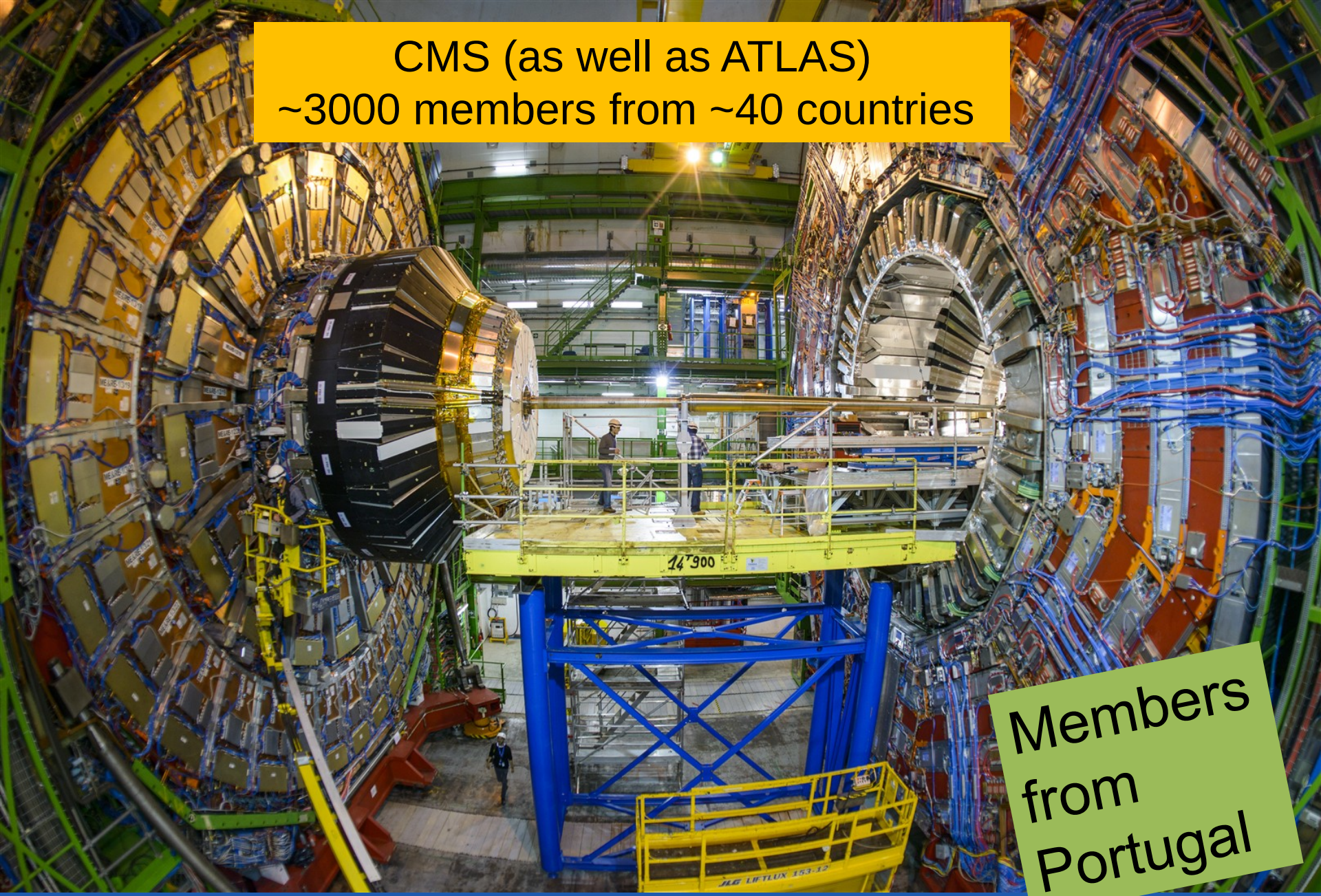


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
CMS
ALICE

Exploration of a new energy frontier
in p-p and Pb-Pb collisions

CERN


ATLAS
Members from Portugal


CMS (as well as ATLAS)
~3000 members from ~40 countries
Members from Portugal

Sociology

Large International Collaborations

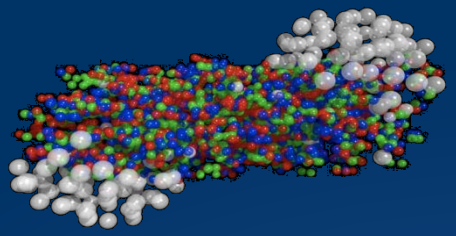
- a place where people learn to work together
- collaboration and competition
- diversity: good a… …erences, acce… …em
- … …y of thinking, planning at general level
- information sharing: role of computing in internationalization and communication
- experience can be used by individuals and in other fields

Training ground for academia and private sector for today's challenging global markets

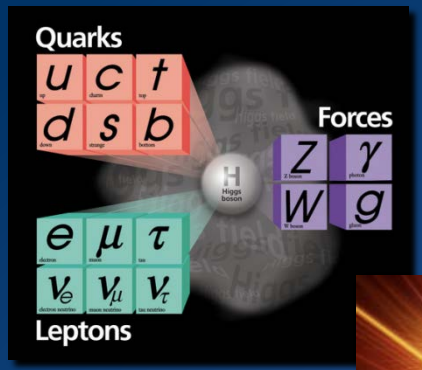
→ management through 'common goals'

→ management by 'convincing partners'

The study of LHC data will allow us to address some of the key 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 destroy each other?

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

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".*

The Higgs-Particle is special!

All Matter Particles are Spin-1/2 Fermionen
All Force Particles are Spin-1 Bosonen

Higgs-Particles are Spin-0 Bosons: Scalars
Higgs is neither Matter nor Force
Higgs is different
It is the first fundamental Scalar ever discovered

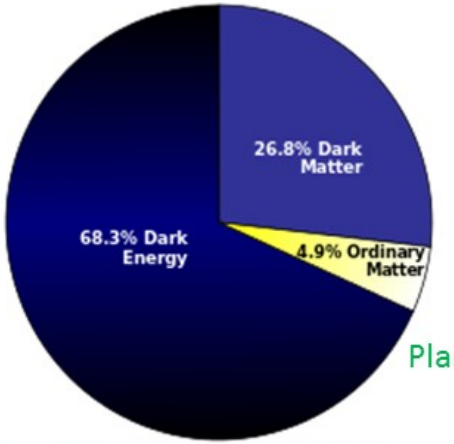
the BEH-Field is a scalar field everywhere in the Universe
-> maybe hints on properties of Dark Energy (Scalar, too)?

And: why should the Higgs-Boson be the
only one of its kind ?

LHC can search for such scalars and (if found) investigate them

The Higgs boson discovery is only the beginning!
What's next?

- Is it ***the*** Higgs boson…or one of many?
- Measure with precision the properties of the discovered Higgs boson
  - …its properties could give information on Dark Matter
  - …its properties could give first indications on Dark Energy



Planck Space Observatory, ESA (2013)

Our understanding of the Universe is changing!

Supersymmetry: an additional possible symmetry of the space-time

... in fact, the largest possible symmetry of the space-time as we know it ....

foremost consequence: each SM particle has a "supersymmetric partner"

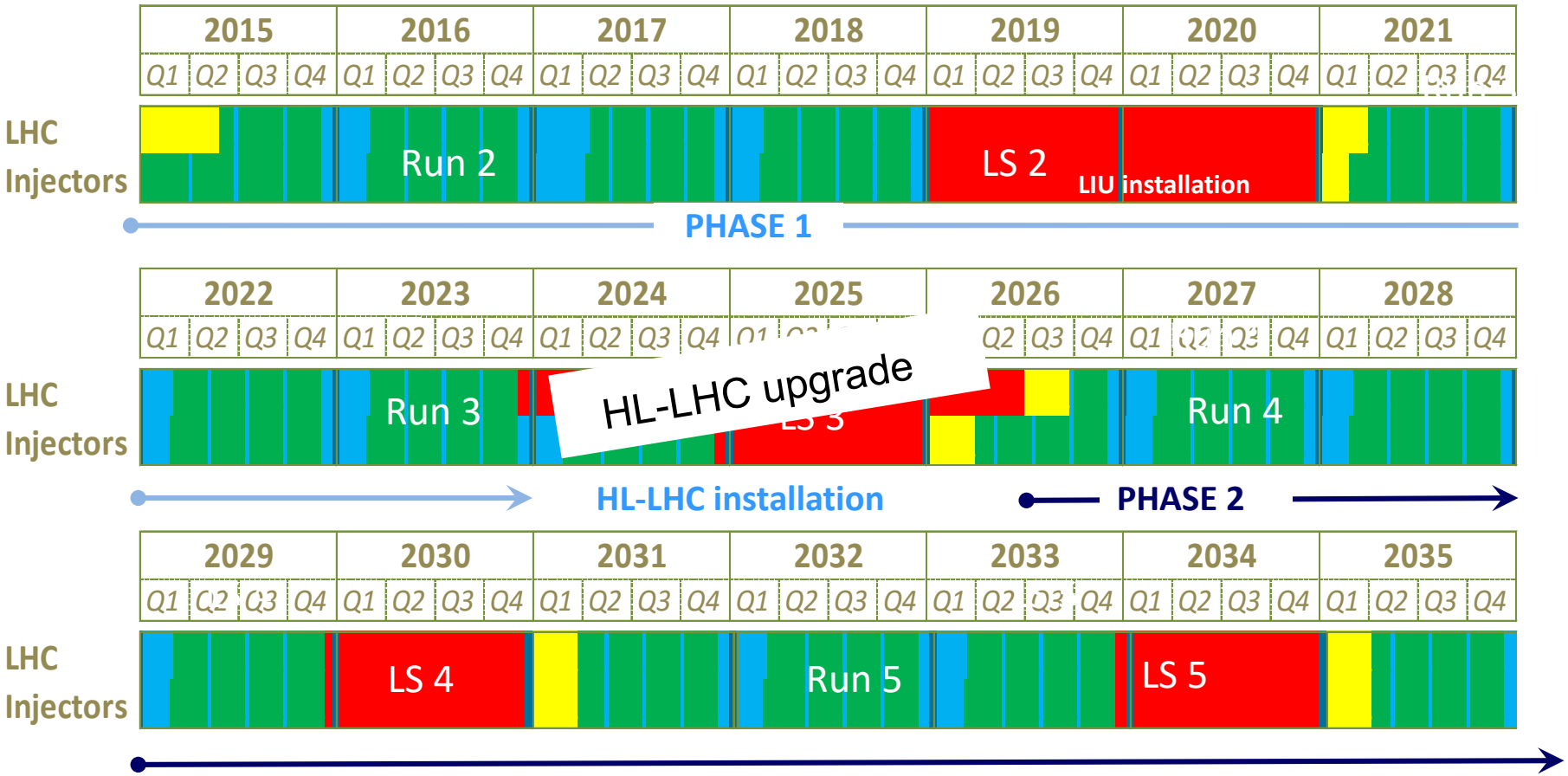
Th[illegible] could interact also with SUSY particles

This would change its properties (even tiny)

Measure all properties of the Higgs-Boson precisely

LHC roadmap

LS2 starting in 2019 => 24 months + 3 months BC
LS3 LHC: starting in 2024 => 30 months + 3 months BC
Injectors: in 2025 => 13 months + 3 months BC



LHC

Key

Upgrades to accelerator complex, detectors, and computing Grid are vital to fully exploit the physics potential of LHC

Lots of exciting opportunities for (young) researchers and engineers in all areas

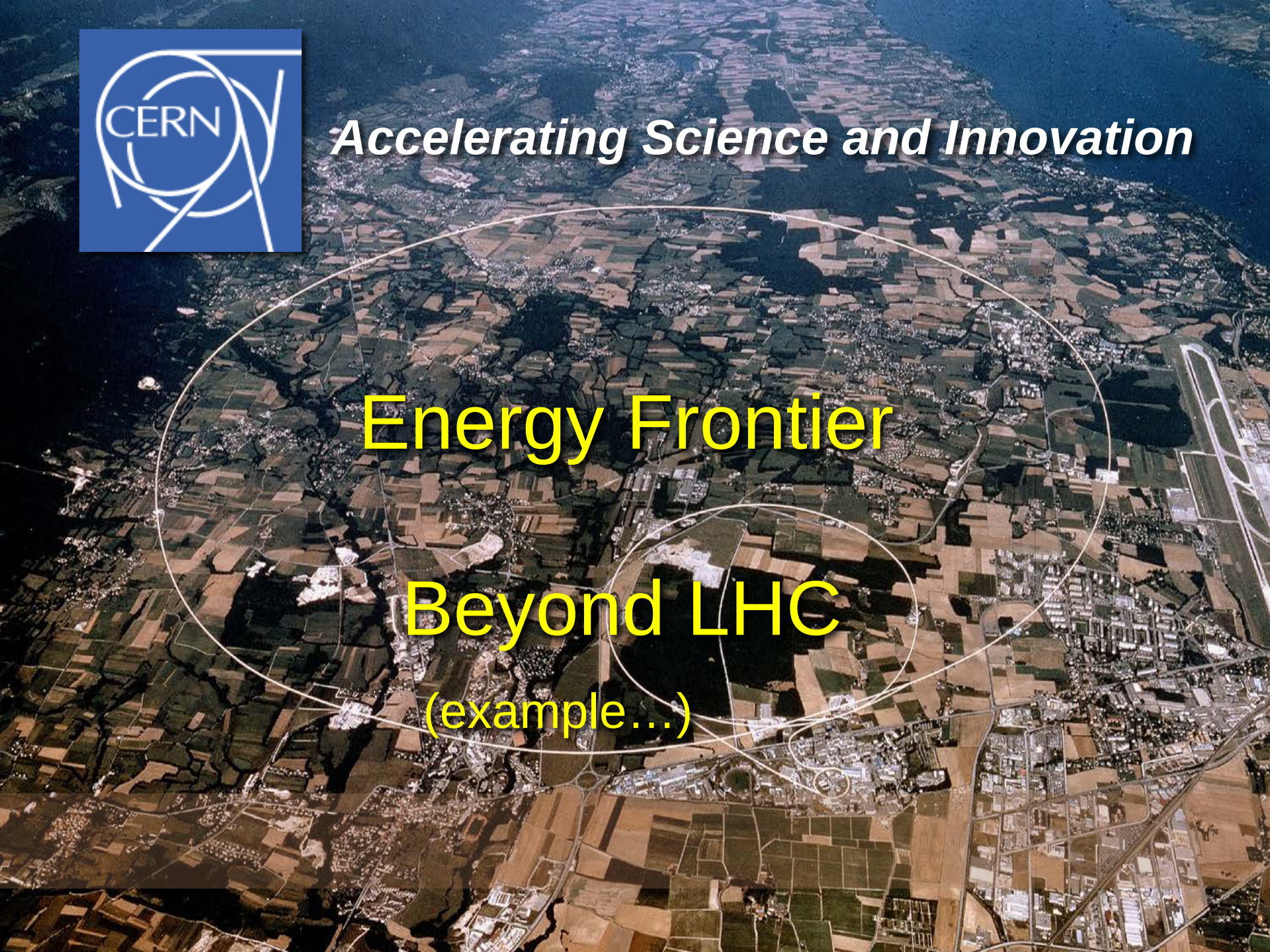
gy frontier

ond 2030:

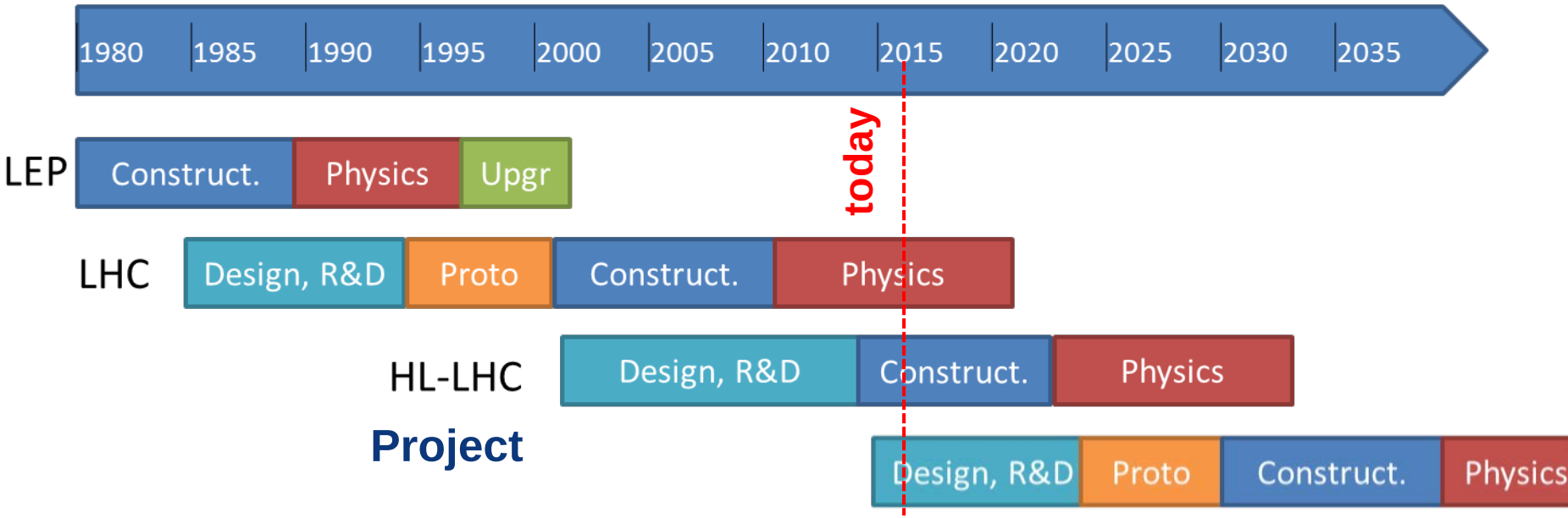
and 8 TeV accomplished

14 TeV design luminosity

14 TeV high luminosity (HL-LHC)


CERN
Accelerating Science and Innovation
Energy Frontier
Beyond LHC
(example…)

European Strategy: "CERN should undertake design studies for accelerator projects in a global context, with emphasis on ***proton-proton*** *and electron- positron* ***high-energy frontier machines.****"*



FCC Study: p-p towards 100 TeV

Kick-off meeting: February 2014 Geneva

First Coll. Meeting: March 2015 Washington

FCC: Future Circular Colliders

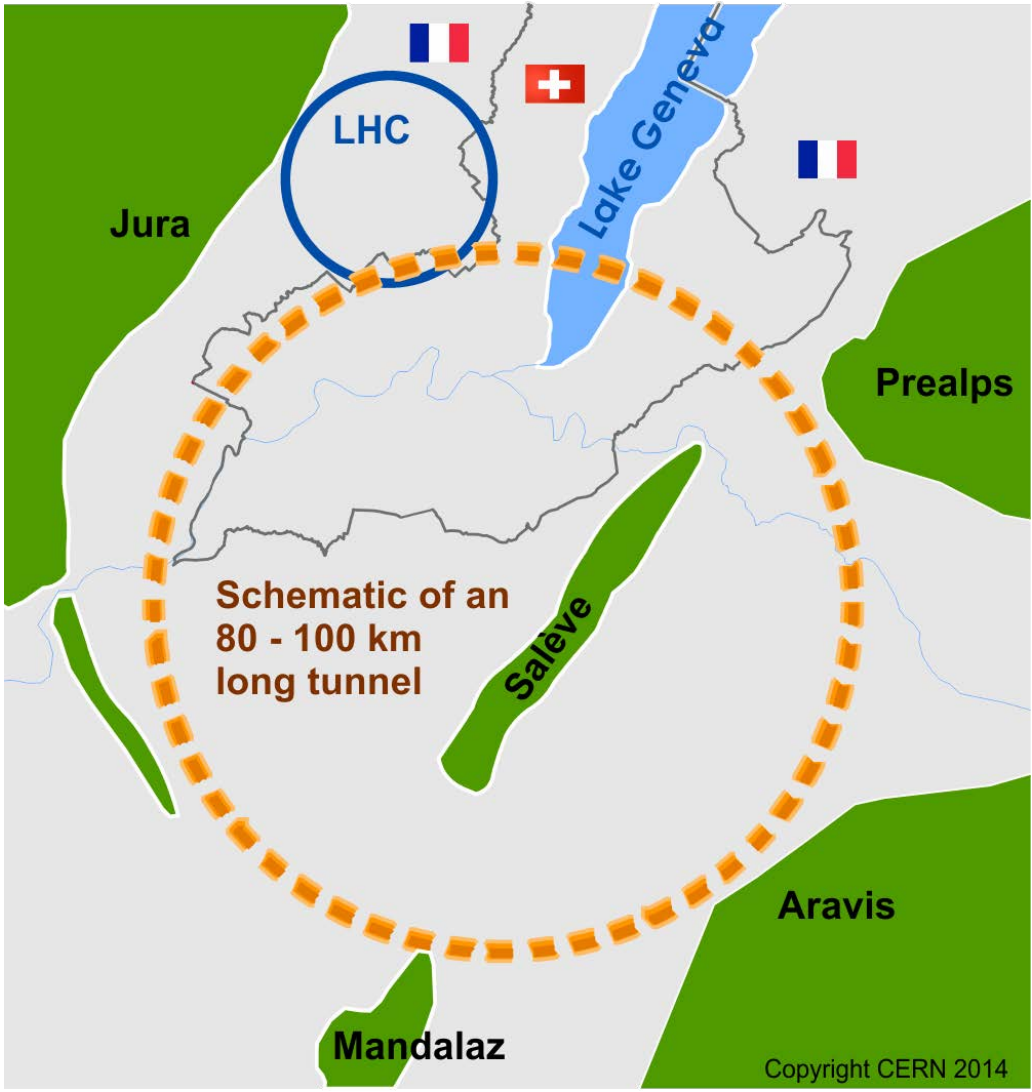
Future Circular Collider Study
CDR and cost review for the next ESU (2018)

<u>international collaboration</u> to study:

- ***pp*-collider (*FCC-hh*)**
  → defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km
~20 T ⇒ 100 TeV *pp* in 80 km

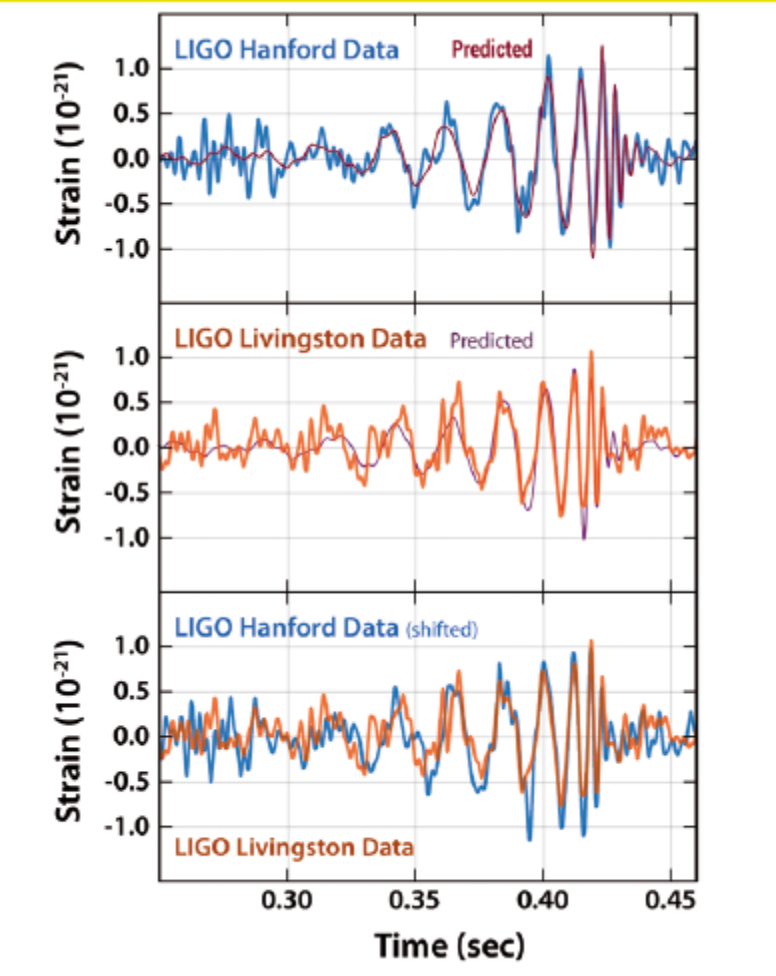
- **e^+e^- collider (*FCC-ee*)** as potential intermediate step
- ***p-e* (*FCC-he*) option**
- **80-100 km infrastructure** in Geneva area



Astro(particle) Physics

Gravitational Waves

Prediction
1916



Discovery
2016

Detection of Gravitational Waves opens a new research window into the Universe

Discovery of a ‘Higgs-Boson’ :
48 years after theoretical prediction

First detection of Gravitational Waves :
100 years after theoretical prediction

Why ?

such experimental observations need
development of new forefront technologies

Technology and Innovation

Large-scale Science Projects

- Address
  - fundamental science questions
    at the forefront of research and technology
- Provide
  - unique equipment
  - stimulating ideas which in turn attract good people
  - occasion to bring people together
  - challenging requests for high technology and innovation

Innovation in Fundamental Research

Large scientific projects stimulate innovation

- Space : Apollo missions, Space Station, Pioneer/Voyager Missions
- Particle Physics : accelerators in general
  - at CERN : LEP, LHC

Pushing the frontiers of technology. CERN Examples:

- Superconductivity, magnets, cryogenics, vacuum, survey/metrology.
- Transport and installation of heavy equipment.
- Solid-state detectors resistant to high-intensity radiation.
- Large-scale industrial control systems.
- Electronic and information systems.
- Project management and co-ordination.

CERN

Accelerator Technologies

example LHC

Superconductivity
(12kA)

Cryogenics
(1.9 K)

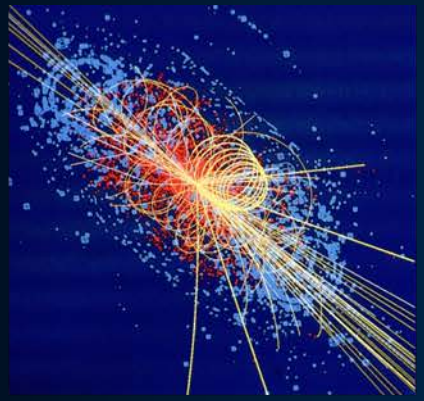
New developments needed e.g. for LHC upgrade (HL-LHC) and new facilities

Vacuum
(10^{-13} atm)

Magnets
(8 T)

Medical Application as an Example of Particle Physics Spin-off

Combining Physics, ICT, Biology and Medicine to fight cancer

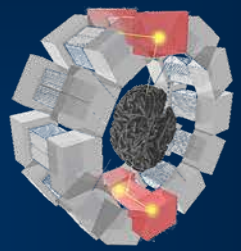


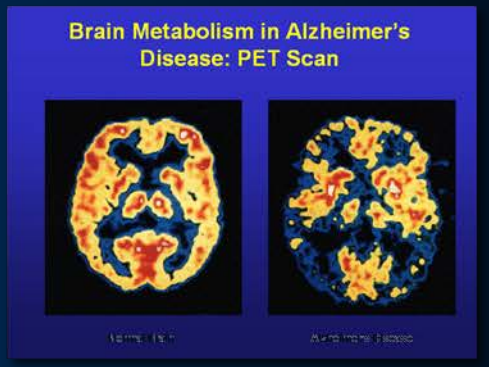
Detecting particles

Imaging

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

PET Scanner

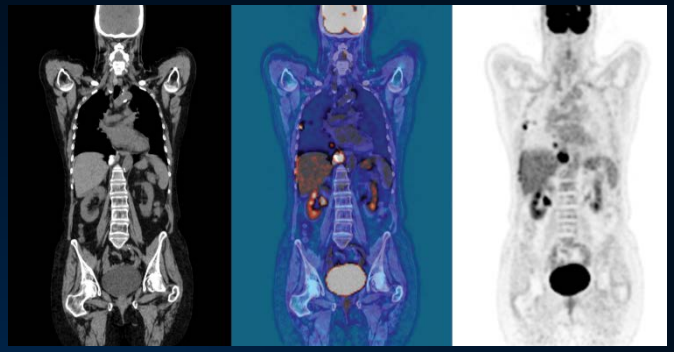




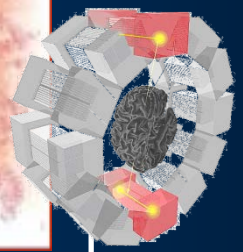
Medical diagnosis using Antimatter

"See more and better" with less radiation dose

Positron- **E**mission-**T**omography



CT CT+PET PET



prediction and discovery of Antimatter

new PET Generation (cristals from LHC detectors)

1900 1925 1950 1975 2000

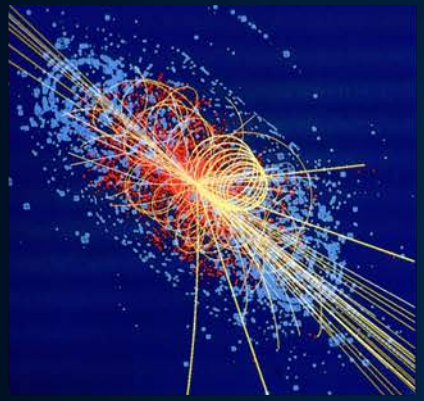
45 years

Basic Research

Technology

Medical Application as an Example of Particle Physics Spin-off

Combining Physics, ICT, Biology and Medicine to fight cancer



Detecting particles

⟺ Imaging

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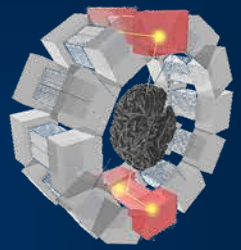
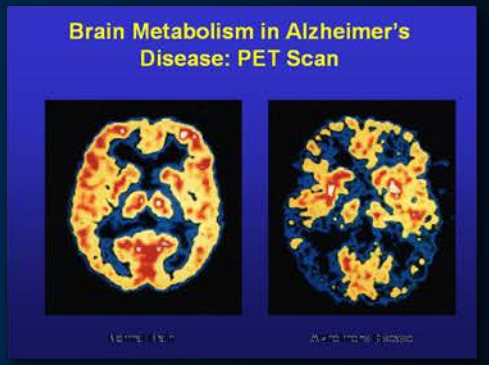
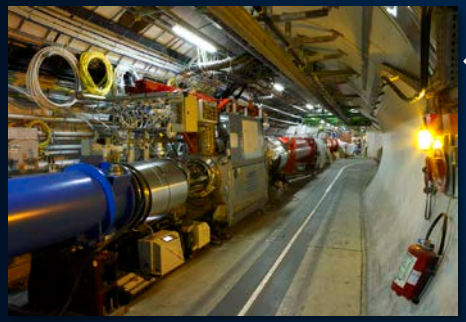
PET Scanner





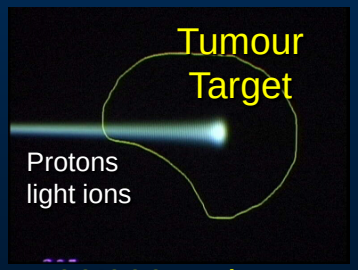


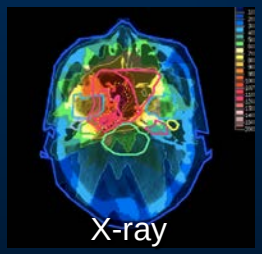
Accelerating particle beams

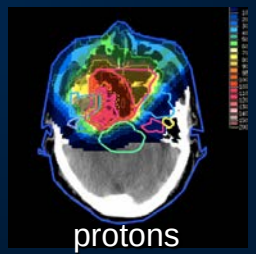
~30’000 accelerators worldwide

~17’000 used for medicine

⟺ Hadron Therapy







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)

Research

generates Knowledge

generates Innovation

can generate Disruptive Innovation

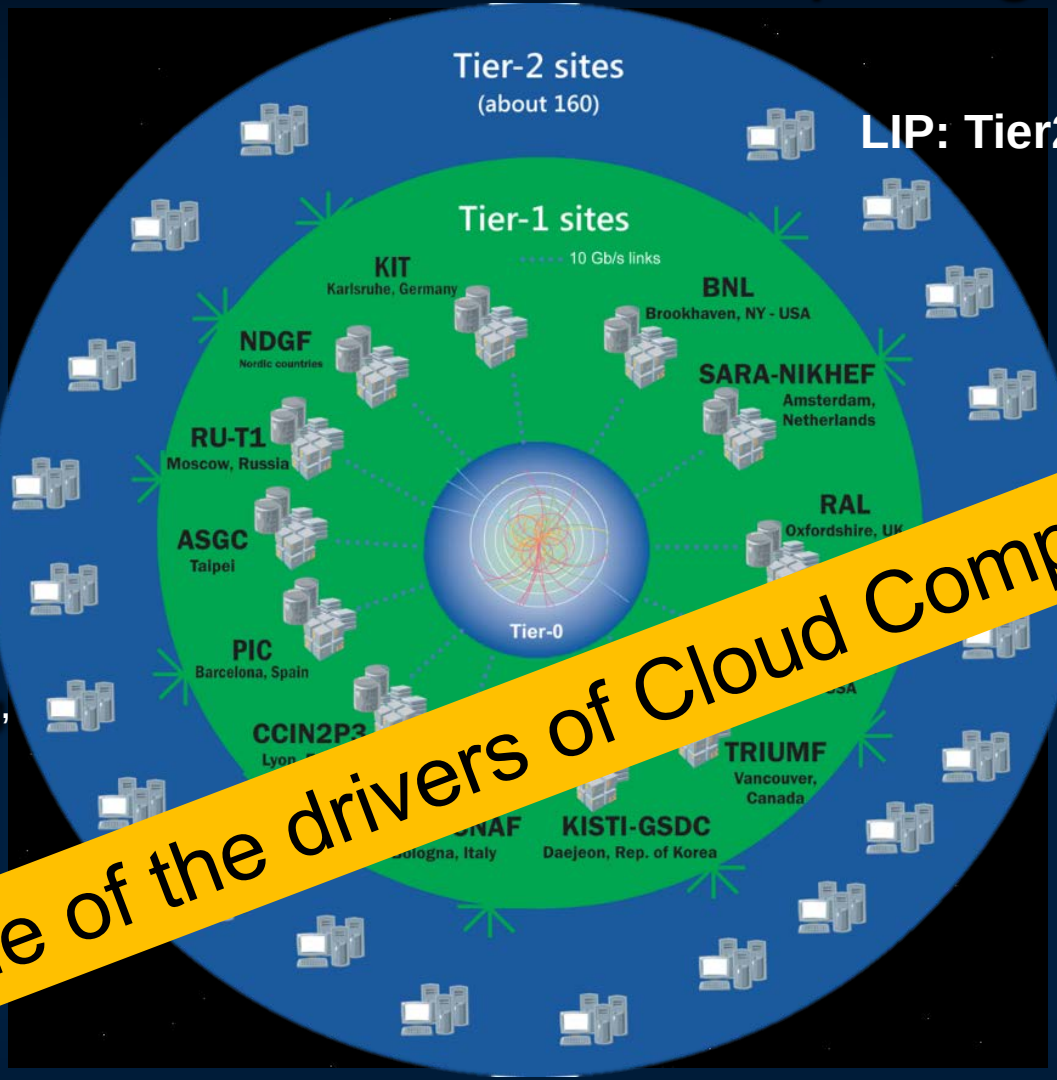
thereby changing society

Example from CERN:

World Wide Web

The Worldwide LHC Computing Grid

today



LIP: Tier2

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

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

Tier-2: Simulation,
end-user analy

nearly 160 sites,
35 countries

0 cores

173 PB of storage

> 2 million jobs/day

10 Gb links

One of the drivers of Cloud Computing

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

The Virtuous Circle

basic research ↔ innovation ↔ applied research

- Synergy between research and innovation results not only in societal and economic impact but also, and very importantly, in the creation of enhanced opport[illegible]urther developments.

needs investment in people

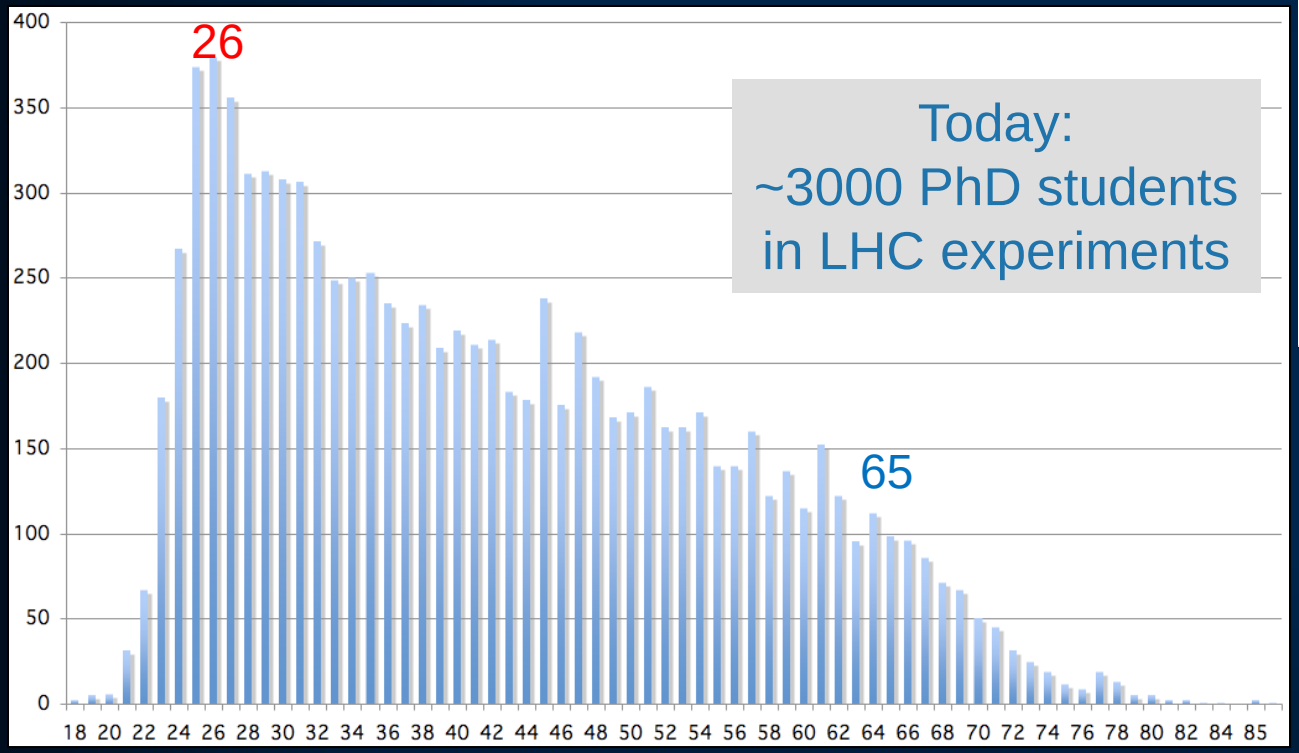
- This circle needs to remain strong, to be unbroken and to be supported over long term.

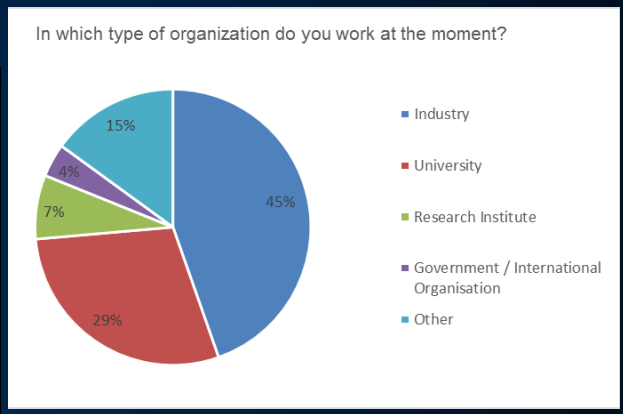
Training:

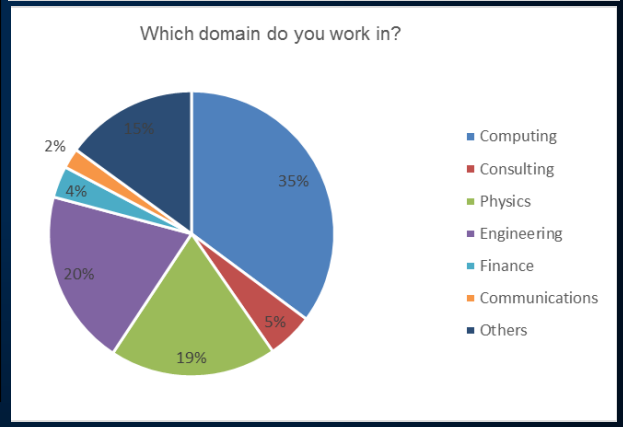
Knowledge Gain
Knowledge Transfer

Age distribution of visiting Scientists at CERN

- and where they go afterwards







They do not all stay: where do they go?

Graduate Engineering Training at CERN

The Graduate Engineering Training (**GET**) scheme, integrated within the Fellowship Programme, is aimed for engineering graduates who are looking for professional experience in a wide range of engineering and technical fields.

Technician Training Experience at CERN

The **TTE** programme is aimed at technicians who are looking to get a first professional experience to further their career, or before they embark on advanced study programmes.
Opportunity to work in a diversity of fields at the cutting edge of technology, examples include: electronics, electricity, mechanics, IT (including sysadmin/data centre technician), vacuum, cooling and ventilation, safety, radioprotection, survey engineering,

Portuguese Trainee Programme

This Trainee Programme has been established through a bilateral agreement between CERN the Foundation for Science and Technology in Portugal (FCT).

The Trainee Program is aimed at recently graduated scientists, engineers and technicians seeking further training in a wide area of technological projects. Selected trainees will join a team working at CERN and have the opportunity to enlarge their knowledge through participation in the hi-tech activities of the laboratory, in fields such as computer science, electrical, electronic and mechanical engineering, cryogenics, ultra-high vacuum, radiation protection, instrumentation for accelerators and particle physics experiments, development of conventional, super-conducting magnets, surveying, large scale metrology and positioning systems.

> 140 young Portuguese Engineers trained until today

Education and Outreach

Key Issue: Outreach and Education

- All countries need more scientists, engineers, staff, . . .

- targeted outreach activities
- encourage interest in careers in science

- Society needs to realize and appreciate science

- bring innovative science and exciting results (achieved at Research Infrastructures, Universities, etc), and their application to societal challenges, to the notice of society, and, in particular, to the schools

Outreach is vital to all levels of society:

Politicians

Students

Teachers

Pupils

Youngsters

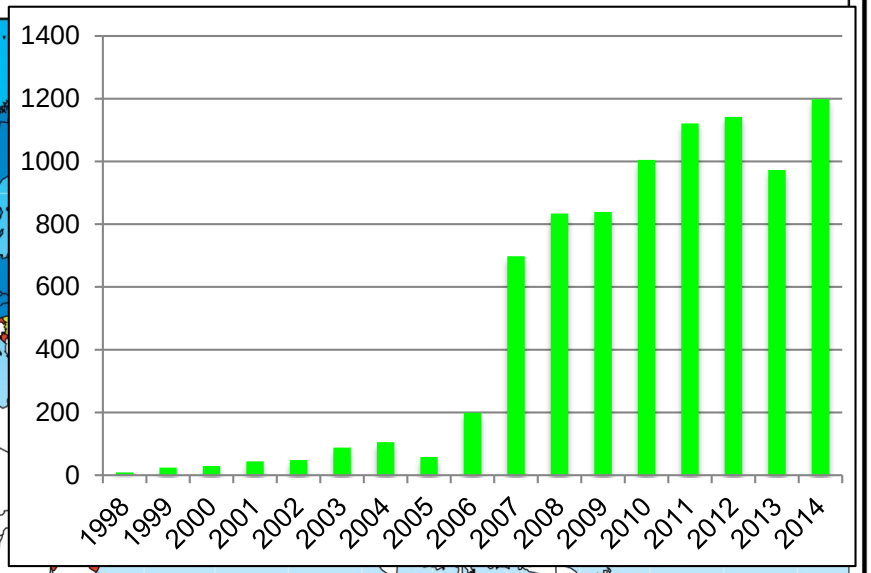
General Public

CERN exhibition

CERN open days

CERN Teacher Programme

Teacher Programme Participants 1998 - 2014 (Total: 8430)



Exemplary role of Portugal

MEMBER STATES

Austria	154
Belgium	122
Bulgaria	375
Czech Republic	153
Denmark	132
Finland	472
France	282
Germany	842
Greece	574
Hungary	407
Israel	44
Italy	403
Netherlands	126
Norway	105
Poland	579
Portugal	361
Slovakia	221
Spain	402
Sweden	206
Switzerland	127
United Kingdom	1077

7164

CANDIDATE FOR ACCESSION

Romania	13
Serbia	47

60

OBSERVER STATES

India	3
Japan	6
Russia	279
Turkey	74
USA	92

454

OTHERS

Angola	7	Chile	3	Ireland	7	Montenegro	13	Slovenia	21
Armenia	1	China	2	Jordan	11	Morocco	2	South Africa	6
Australia	6	Croatia	2	Kazakhstan	5	Mozambique	19	South Korea	48
Azerbaijan	1	Cyprus	8	Kenya	4	Nepal	1	Swaziland	1
Belarus	2	Dominican Rep.	24	Latvia	1	New Zealand	1	Thailand	10
Brazil	144	Ecuador	2	Lebanon	1	Palestine (O.T.)	1	T.F.Y.R.O.M.	11
Burundi	2	Estonia	54	Lithuania	16	Qatar	1	Timor-Leste	7
Cameroon	4	Georgia	88	Madagascar	2	Rwanda	20	Uganda	3
Canada	7	Ghana	6	Malta	36	Sao Tome	5	Ukraine	113
Cape Verde	4	Guinea Bissau	1	Mexico	10	Saudi Arabia	1	U.A.E.	1
		Iran	3	Mongolia	1	Singapore	2		

752

LIP and CERN: intertwined since 1986

due to their mission . . .

- ***Research***
  Push forward the frontiers of knowledge
- ***Innovation***
  Develop new, cutting-edge technologies
- ***Education***
  Train scientists and engineers of tomorrow
- ***Outreach***
  Promote Science in Society

. . . alive through their common projects

Last paragraph of the Editorial in The Guardian, 4 March 2015, on CERN/LHC

The search will invoke mini black holes, antimatter, quark-gluon plasma, and extra dimensions of space. The partnership so far has spun off colossal technological and computing rewards, but that is not the point. The point is that Europe is working together in a thrilling intellectual exploration that can have no conceivable commercial or political payoff but could, in some still intangible way, enlighten all humankind. In these otherwise murderous and mean-spirited times, that is something to salute.

The role of Science:

– innovate, discover, publish, share

… and bring the world together