

An introduction to CERN

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CERN and University of Birmingham



Accelerating Science and Innovation

1945 l'Europe après deux guerres dévastatrices en moins de 30 ans



Les chercheurs quittent l'Europe pour USA

CERN: founded in 1954: 12 European States

“Science for Peace”

Today: 22 Member States

~ 2'500 staff

~ 1'800 other paid personnel

~ 13'000 scientific users

Budget (2017) ~ 1'100 MCHF

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

Associate Member States: India, Pakistan, Turkey, Ukraine

Associate Members in the Pre-Stage to Membership: Cyprus, Serbia

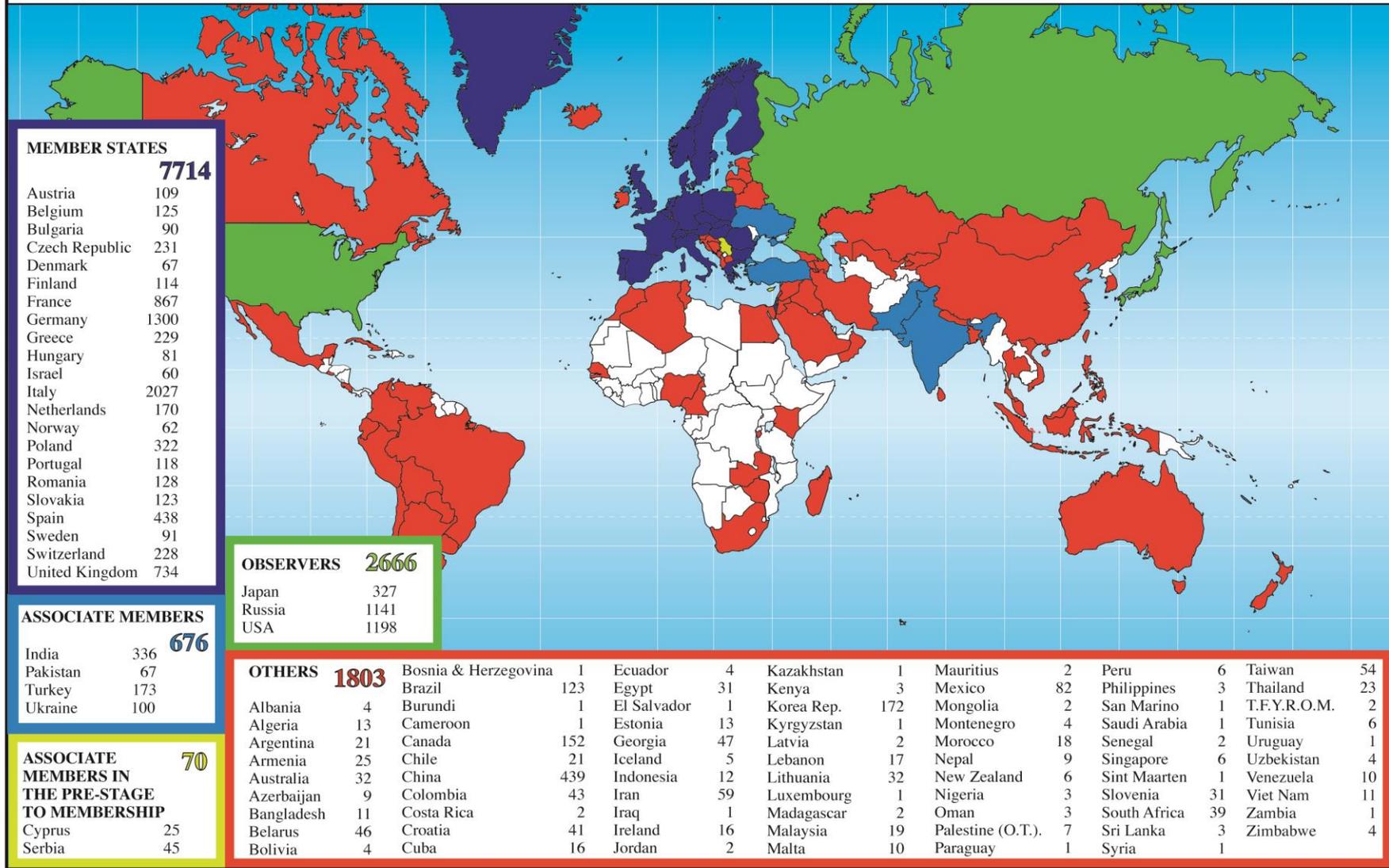
Applications for Membership or Associate Membership:

Brazil, Croatia, Lithuania, Russia, Slovenia

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

Science is getting more and more global

Distribution of All CERN Users by Nationality on 20 January 2017

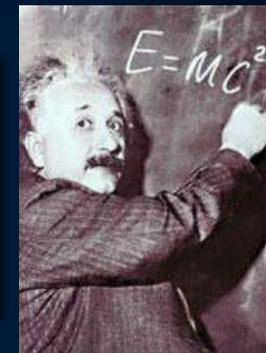




The Mission of CERN

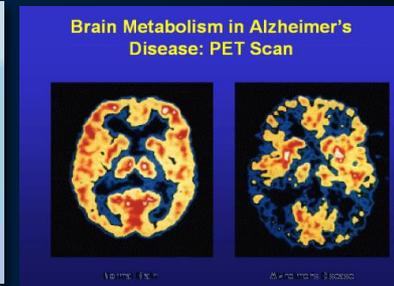
- **Push forward** the frontiers of knowledge

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, accelerators and detectors

Information technology
Medicine - diagnosis and therapy



- **Train** scientists and engineers of tomorrow

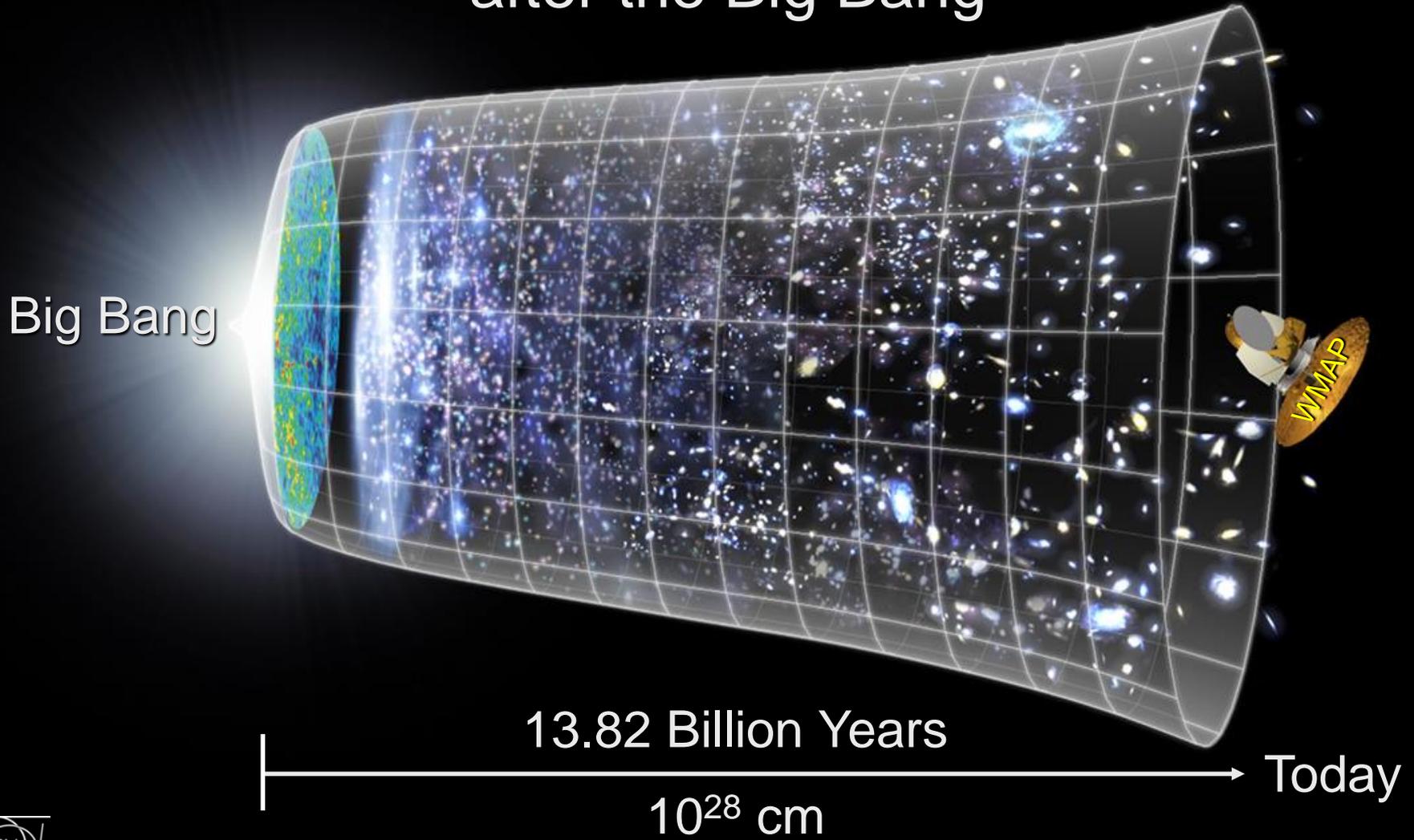


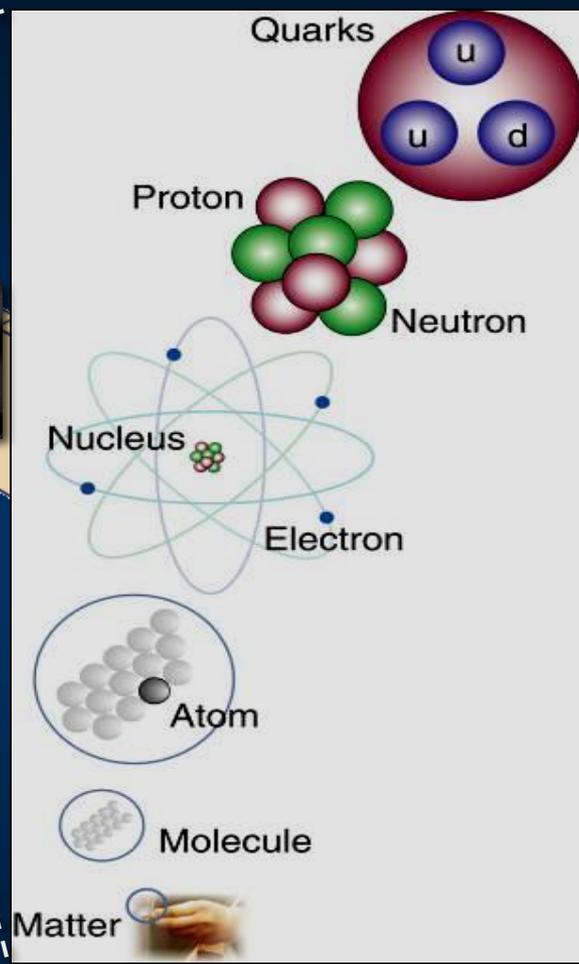
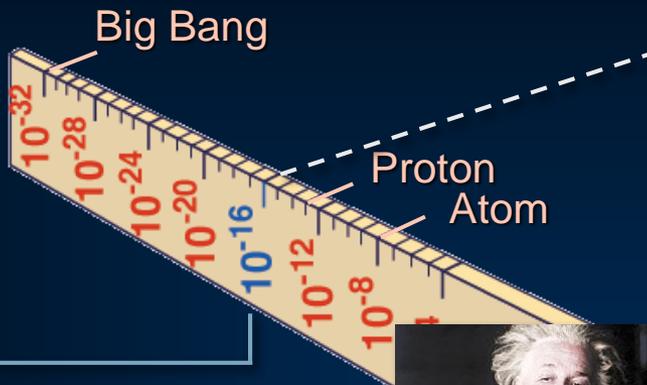
- **Unite** people from different countries and cultures



Next Scientific Challenge:

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





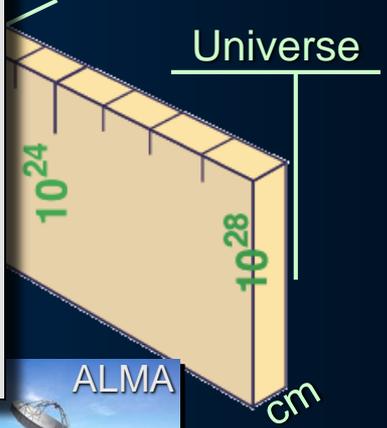
LHC

Super-Microscope

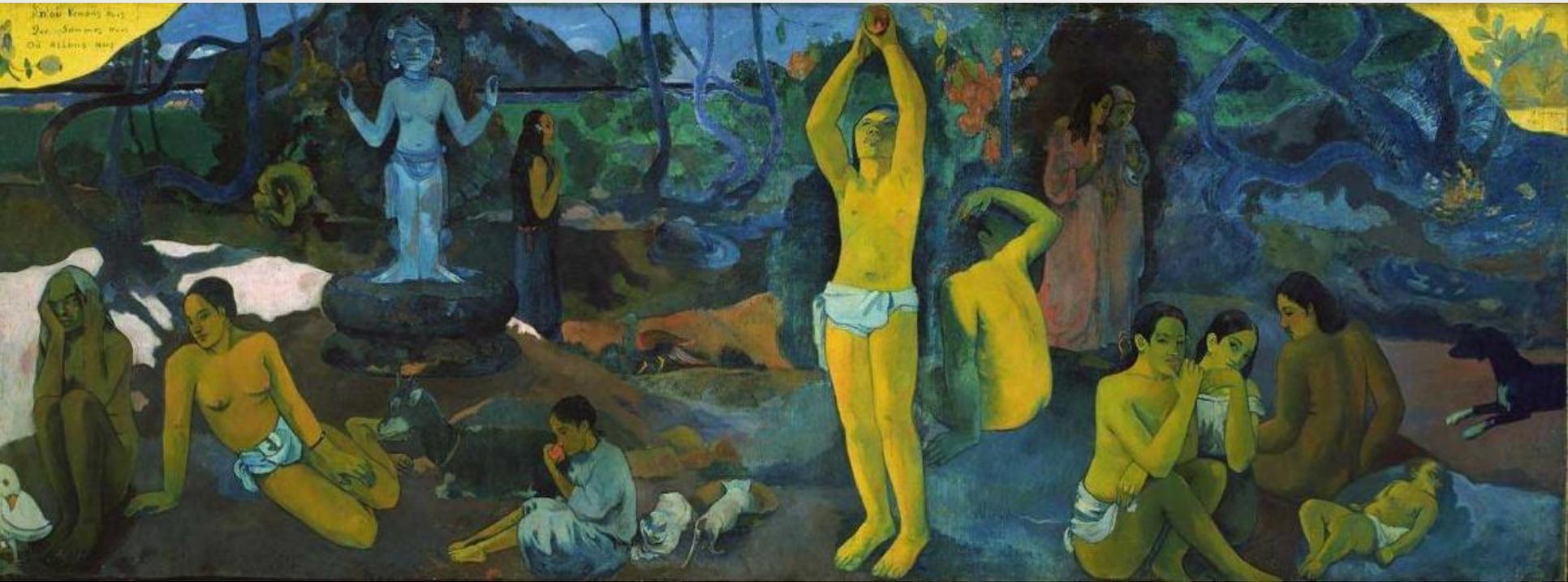


Study physics laws of first moments after Big Bang
 increasing Symbiosis between Particle Physics,
 Astrophysics and Cosmology

Radius of Galaxies



**“Where do we come from?
What are we?
Where are we going?”**

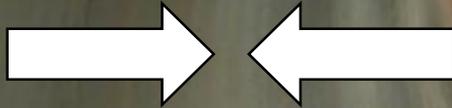


**The aim of particle physics, CERN & the LHC:
What is the Universe made of?**

The Large Hadron Collider (LHC)

Proton- Proton Collider

6.5 TeV · 6.5 TeV



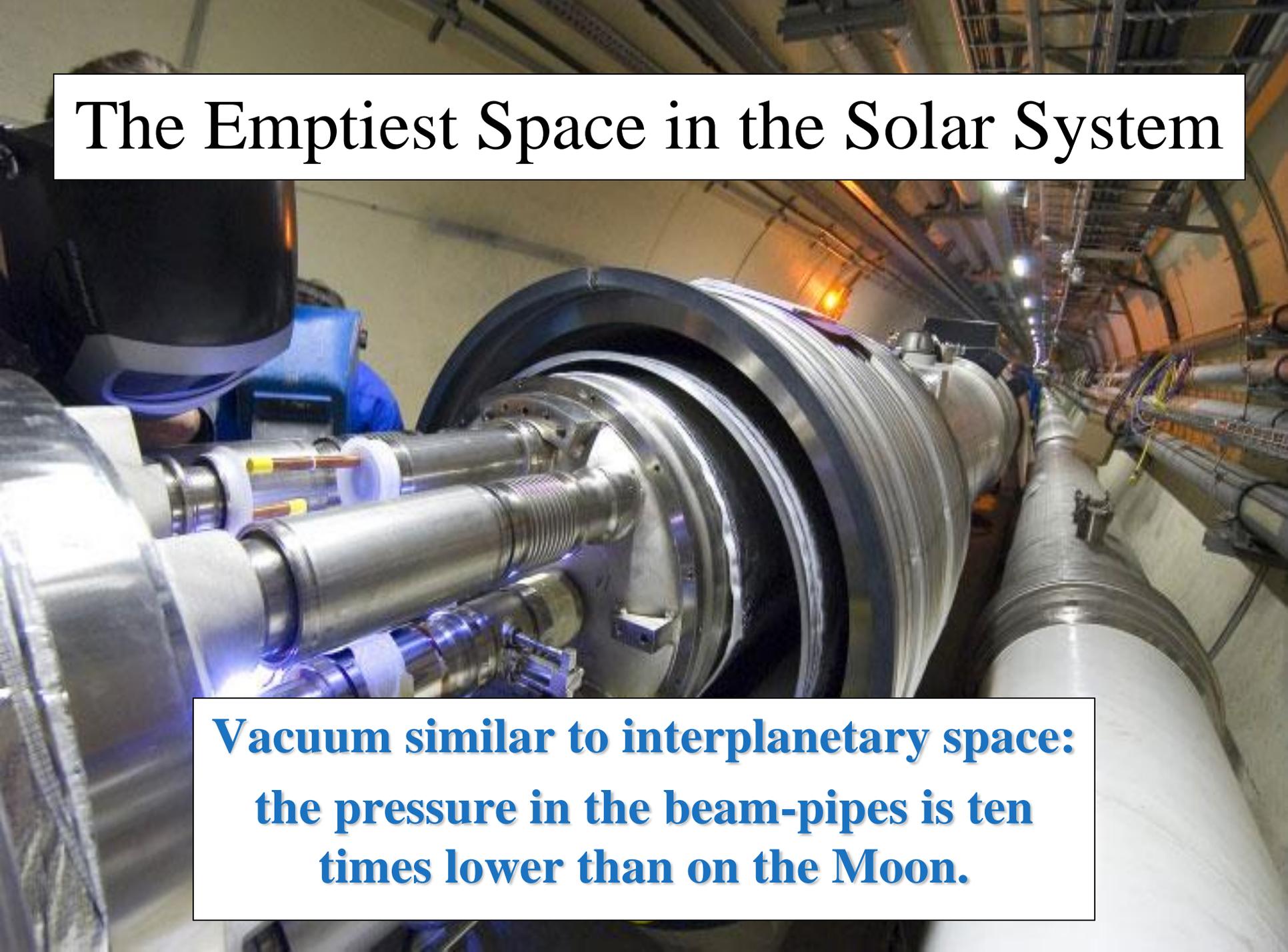
1,000,000,000 collisions/second

Total energy over 8,000 proton masses

Primary targets:

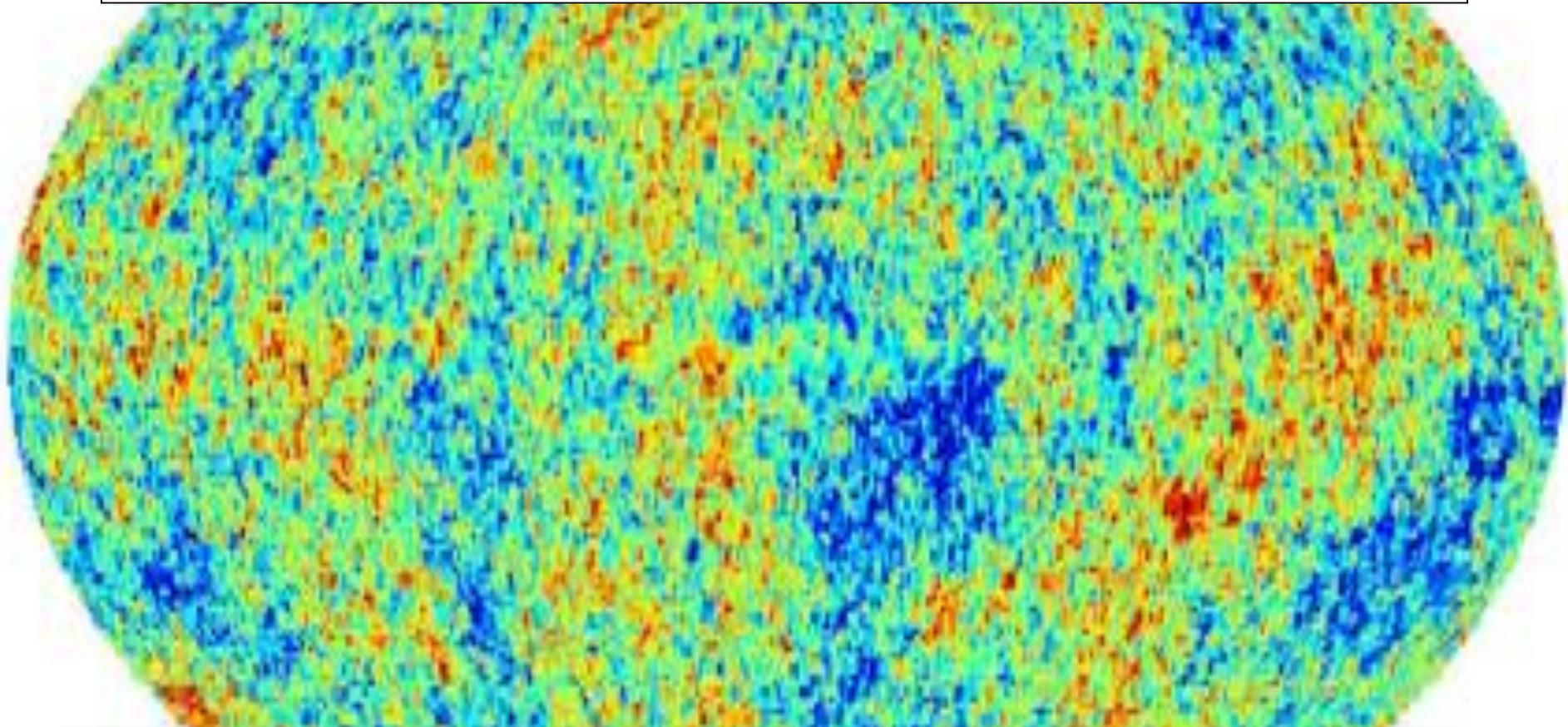
- Origin of mass
- Nature of Dark Matter
- Primordial Plasma
- Matter vs Antimatter

The Emptiest Space in the Solar System

A photograph of a particle accelerator tunnel. The tunnel is long and narrow, with a series of large, cylindrical components (beam pipes) extending into the distance. The walls are lined with various pipes, cables, and structural elements. The lighting is bright, creating a sense of depth and scale. The overall appearance is that of a highly technical and complex scientific facility.

**Vacuum similar to interplanetary space:
the pressure in the beam-pipes is ten
times lower than on the Moon.**

Colder than Outer Space

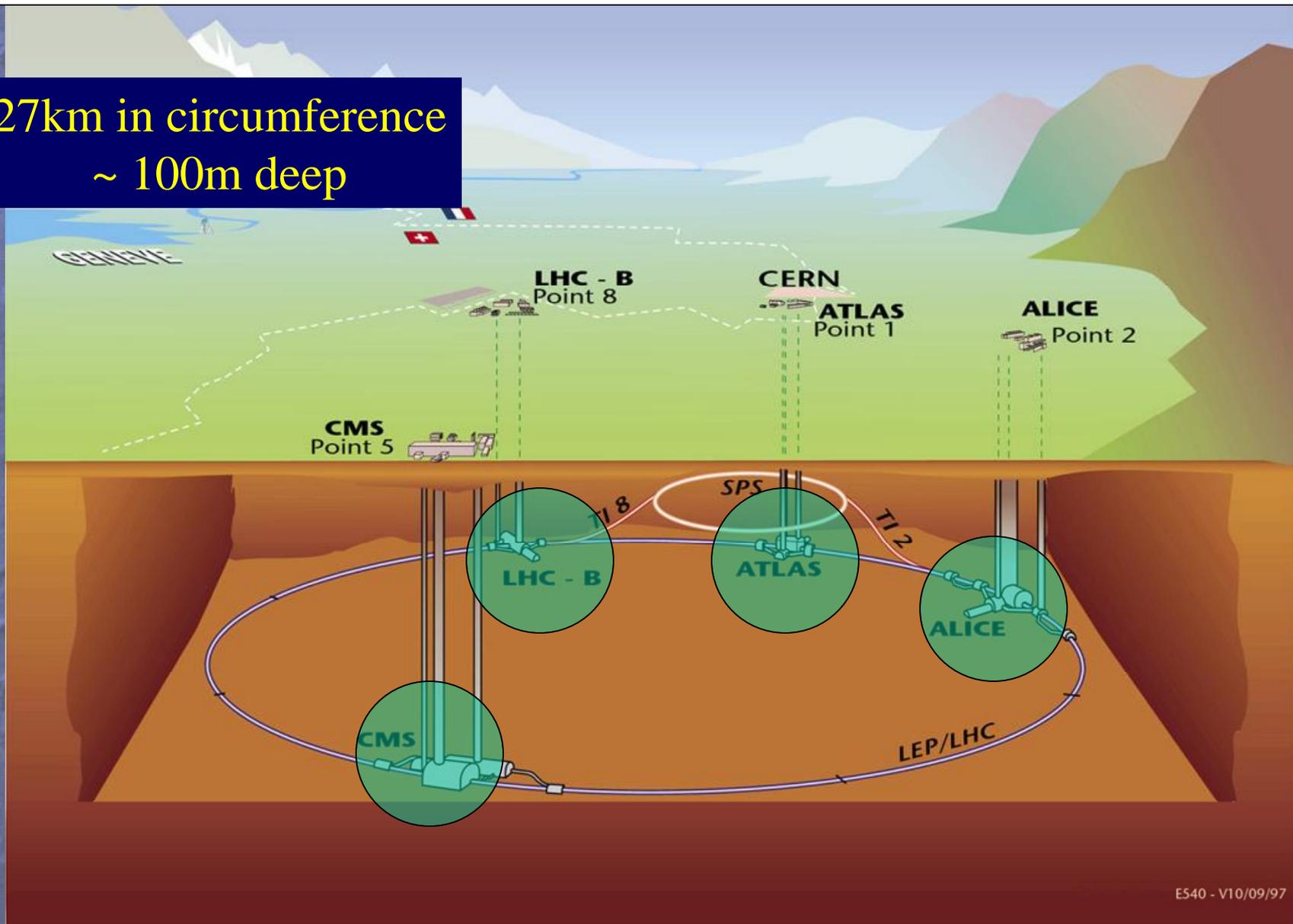


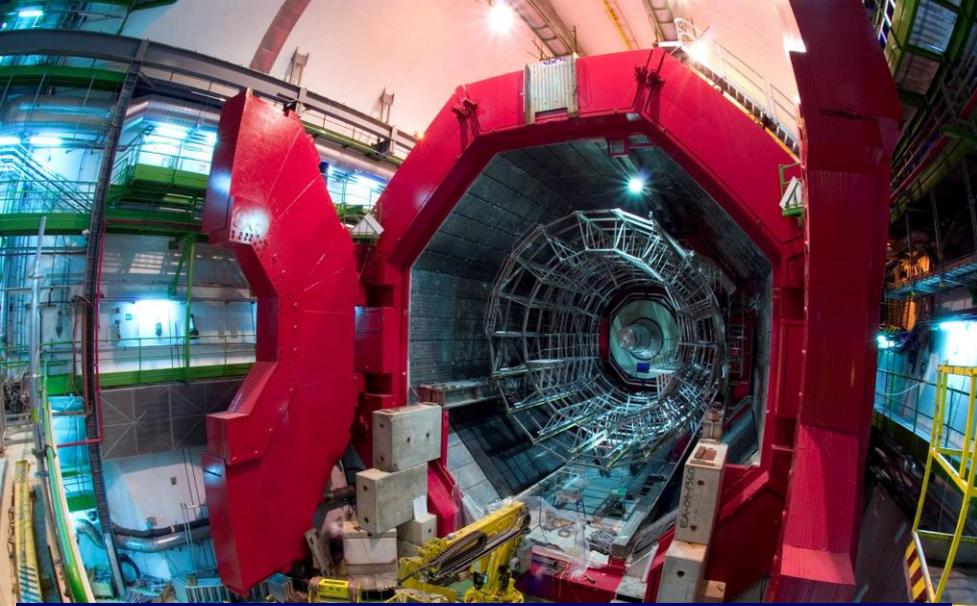
LHC 1.9 degrees above absolute zero = - 271 C

Outer space 2.7 degrees above zero = - 270 C

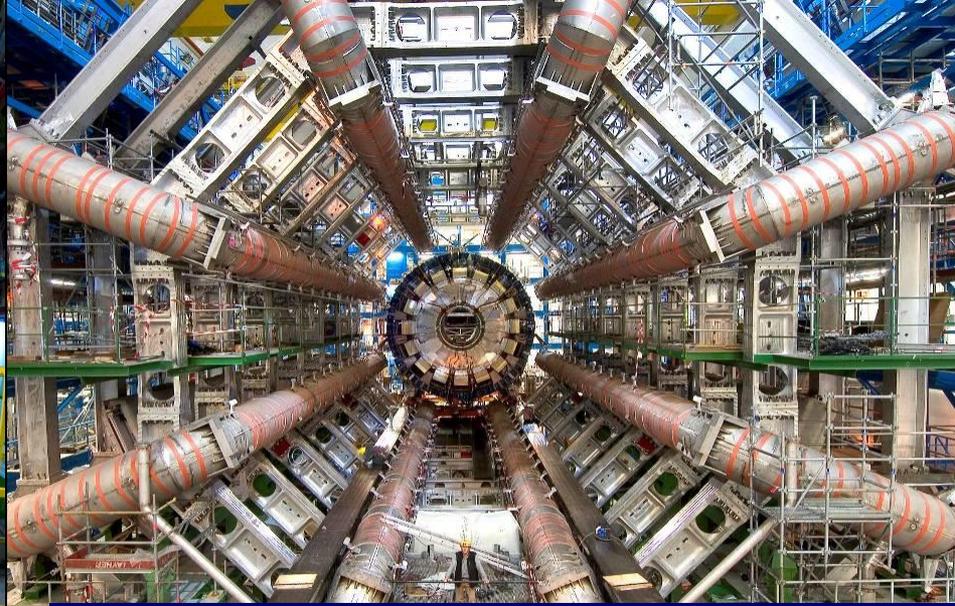
General View of LHC & its Experiments

27km in circumference
~ 100m deep

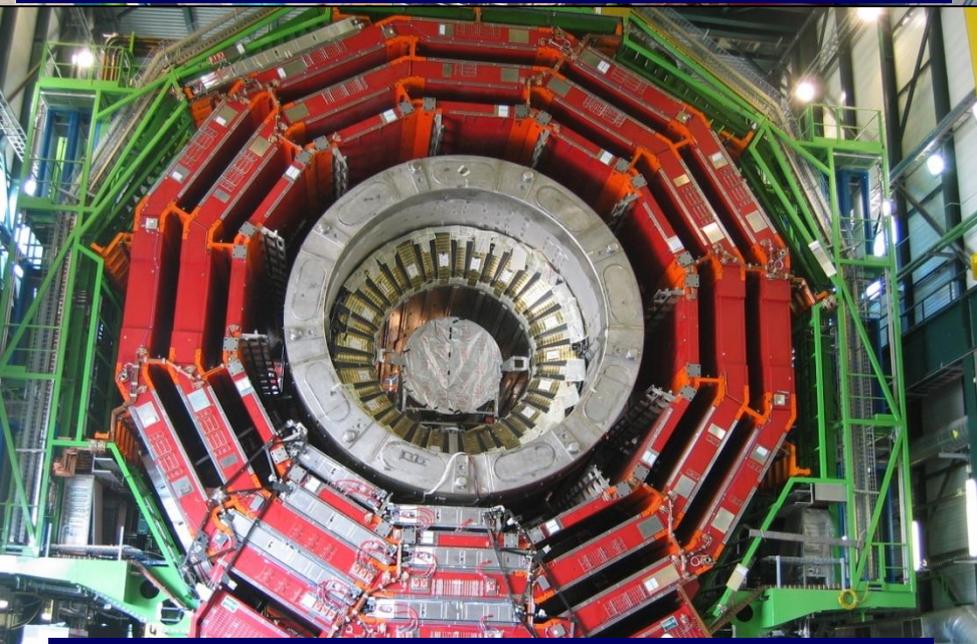




ALICE: Primordial cosmic plasma



ATLAS: Higgs and supersymmetry



CMS: Higgs and supersymmetry



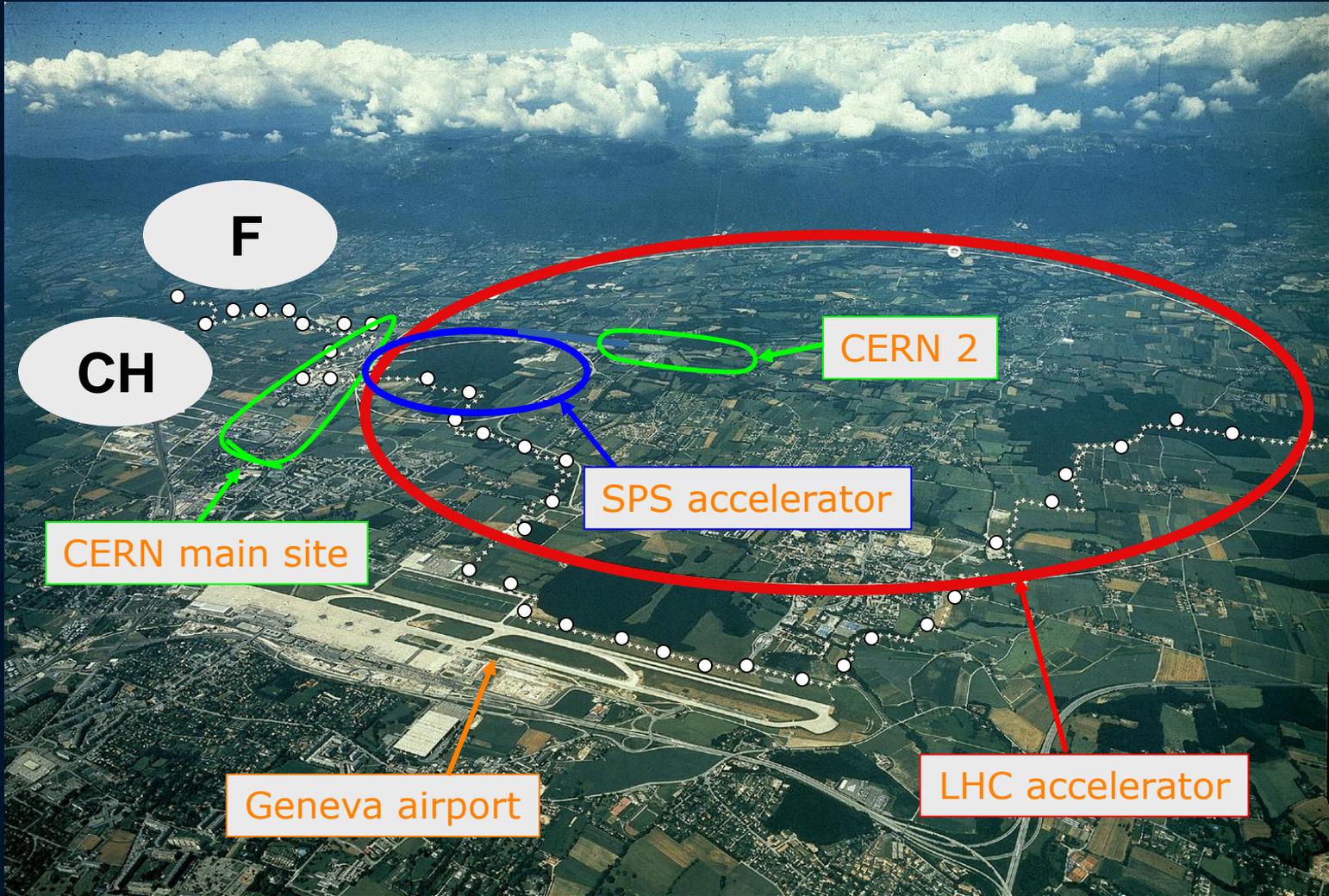
LHCb: Matter-antimatter difference



The Hottest Place in the Galaxy



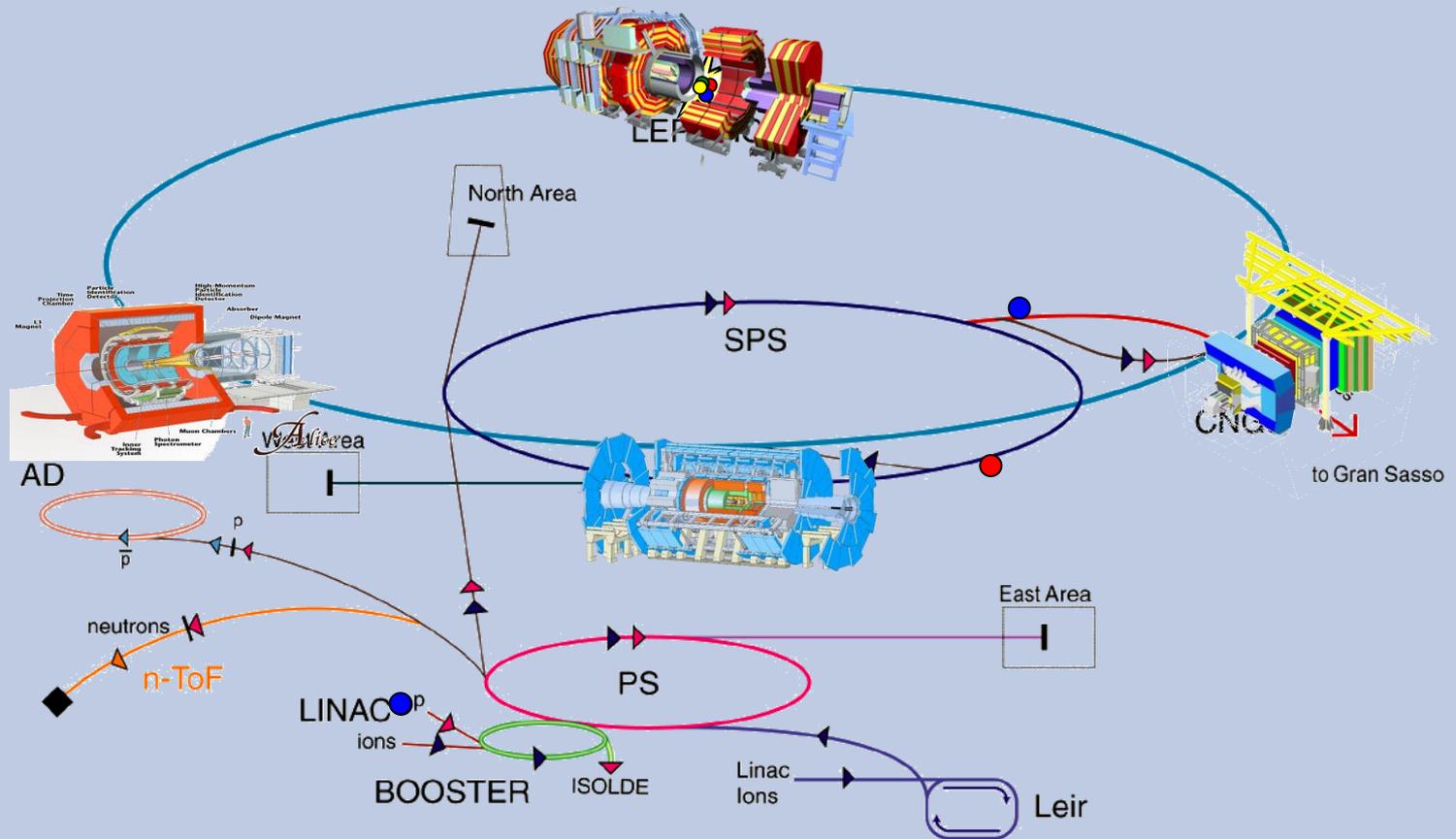
**Particle collisions create
(within a tiny volume)
temperatures a billion times higher than
in the heart of the Sun**



Large Hadron Collider

Collision of proton beams...

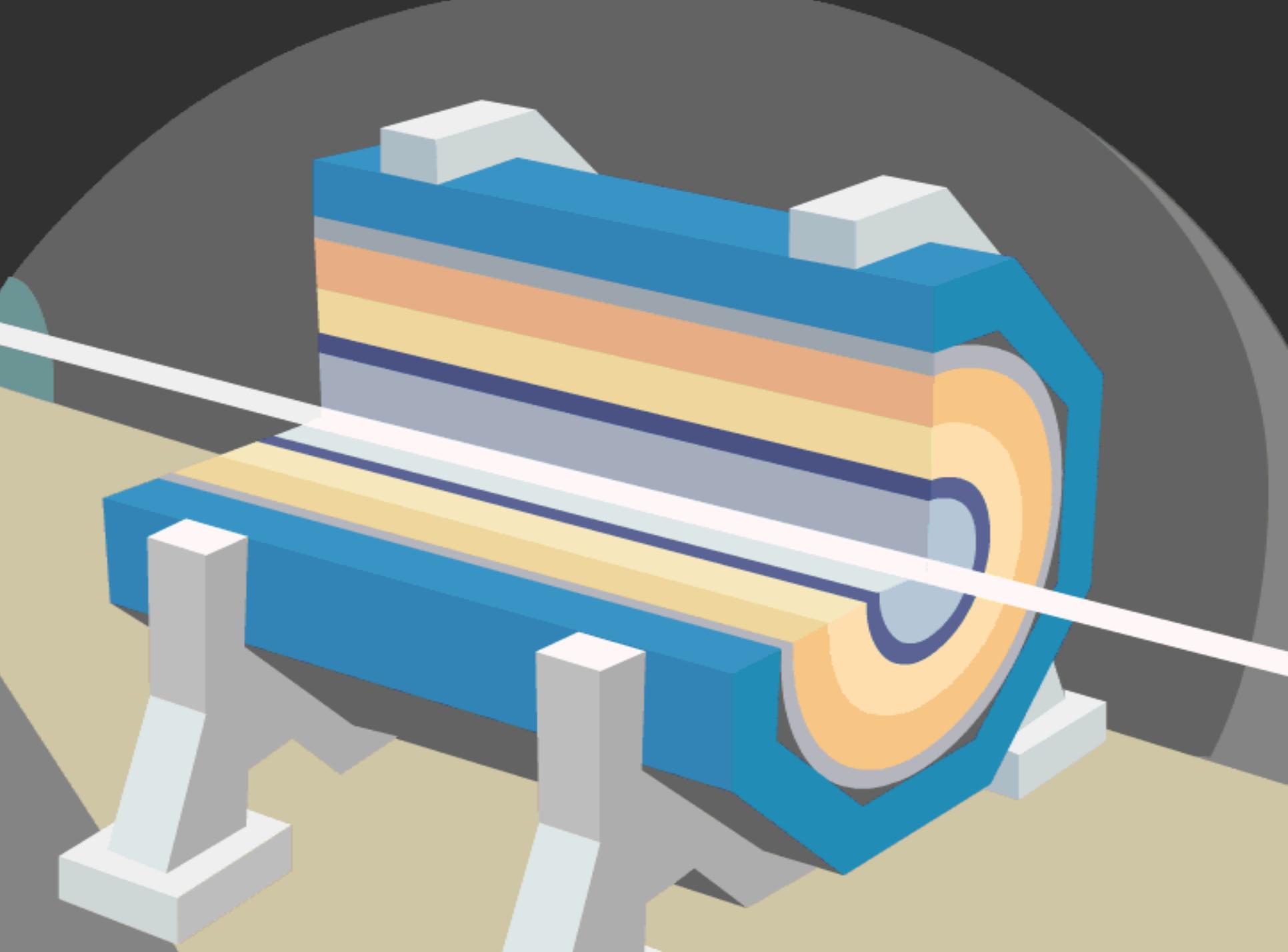
...observed in giant detectors



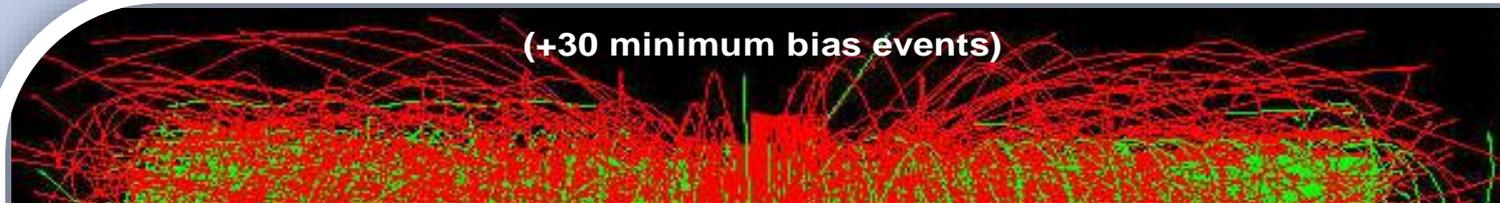
- ▶ p (proton)
- ▶ \bar{p} (antiproton)
- ▶ ion
- ▶ neutron
- ▶ \rightarrow proton/antiproton conversion
- ▶ neutrino

- AD Antiproton Decelerator
- PS Proton Synchrotron
- SPS Super Proton Synchrotron

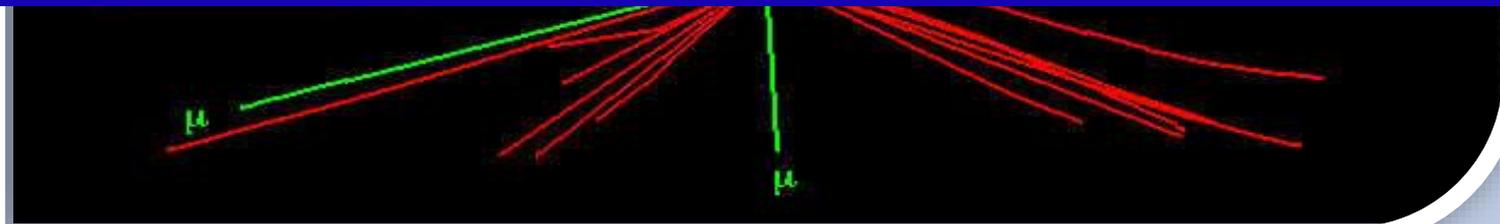
- LHC Large Hadron Collider
- n-ToF Neutron Time of Flight
- CNGS CERN Neutrinos to Gran Sasso



❑ Searching for new particles requires selection and analysis of enormous quantity of data from LHC detectors



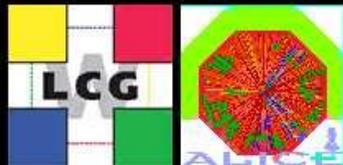
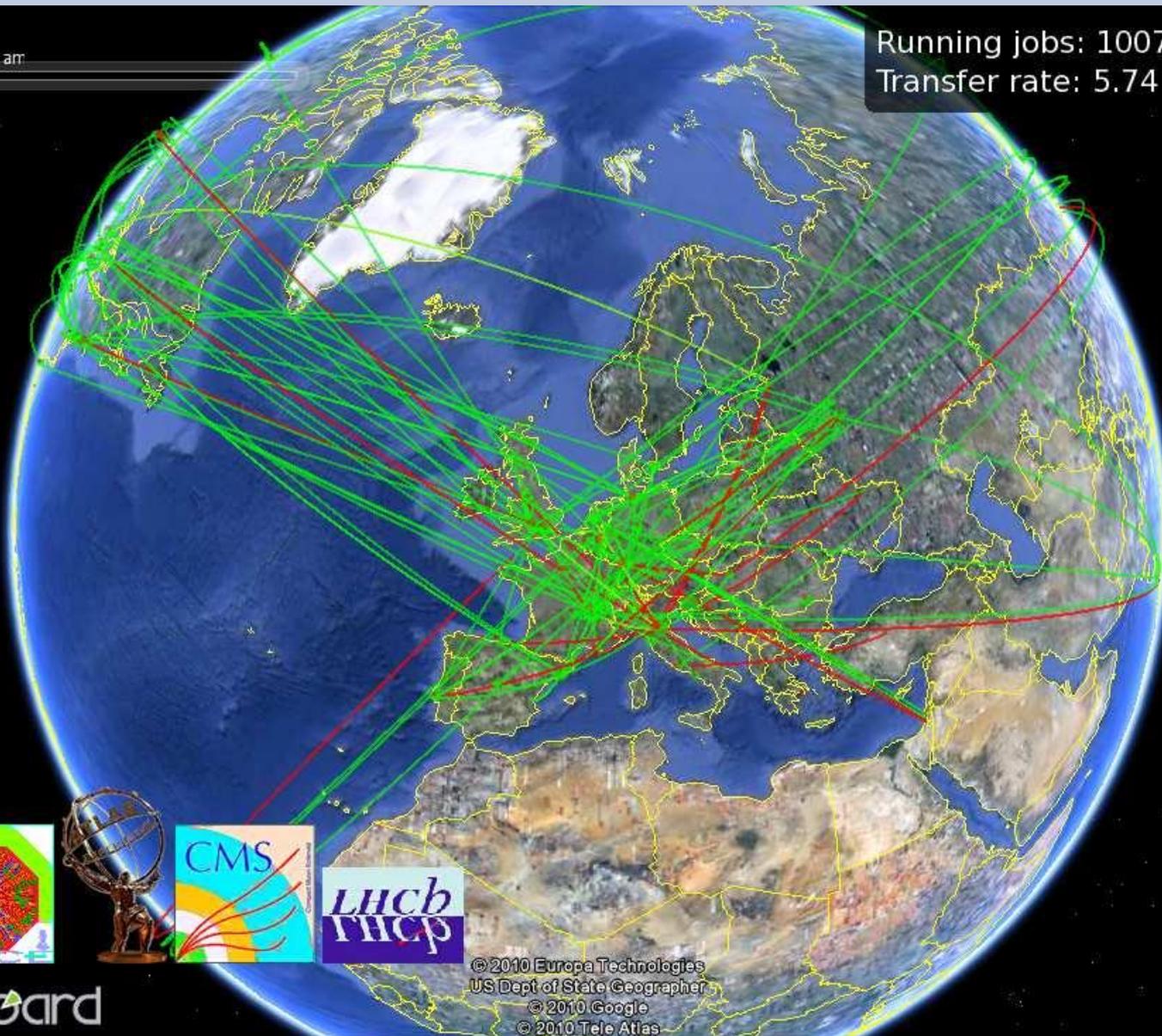
- LHC experiments produce **15-20 million Gigabytes** of data each year (about 20 million CDs!)
- LHC data analysis requires a computing power equivalent to **~500,000 of today's fastest PC processors.**



LCG-LHC Computing GRID

Oct 6, 2010 7:20:00 am

Running jobs: 100767.0
Transfer rate: 5.74 GiB/sec



© 2010 Europa Technologies
US Dept of State Geographer

© 2010 Google
© 2010 Tele Atlas

22°34'45.42" N 15°53'35.50" E elev=2326 ft

©2010 Google

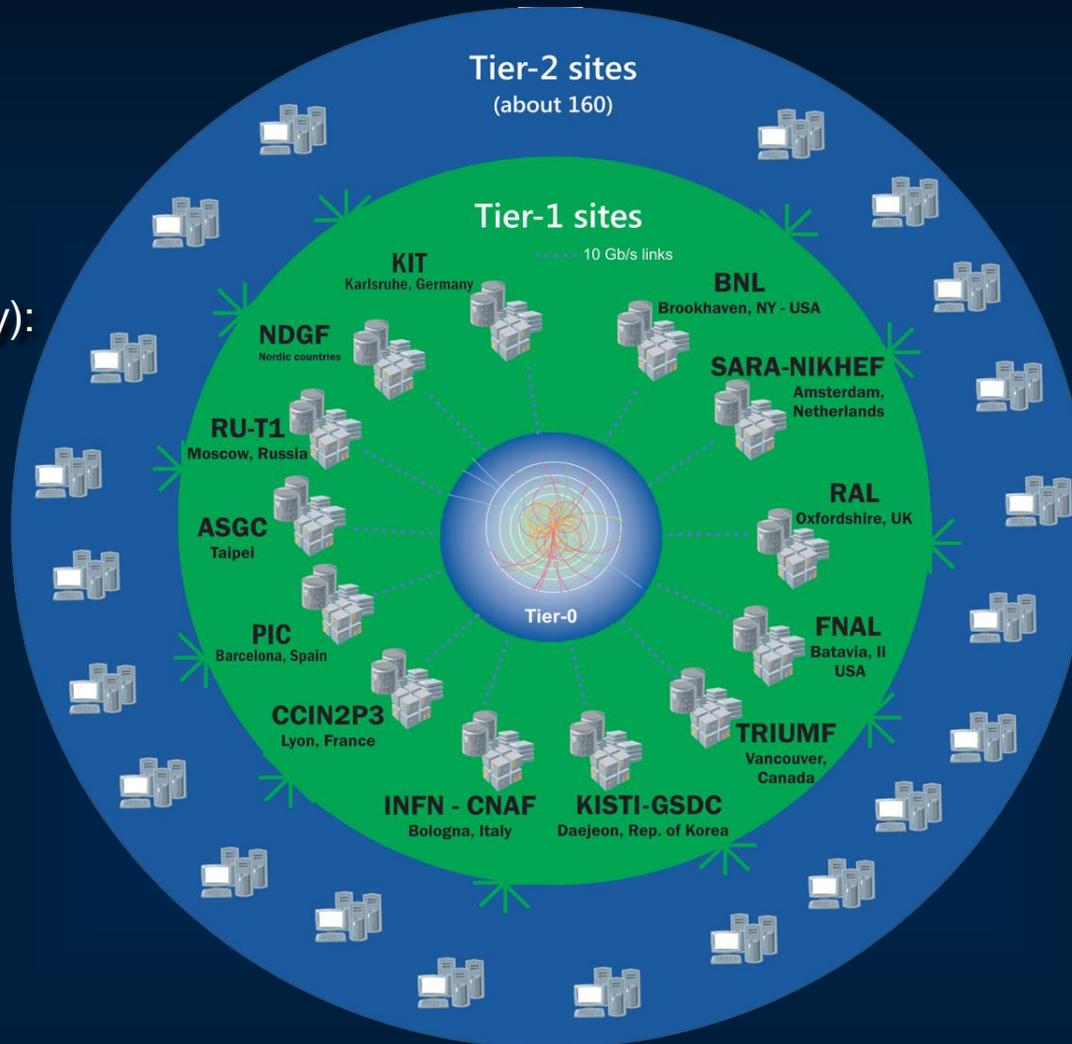
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The Worldwide LHC Computing Grid

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

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

Tier-2: Simulation,
end-user analysis



~170 sites,
40 countries

~500k CPU cores

500 PB of storage

> 2 million jobs/day

10-100 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: Particle Physics and Innovation

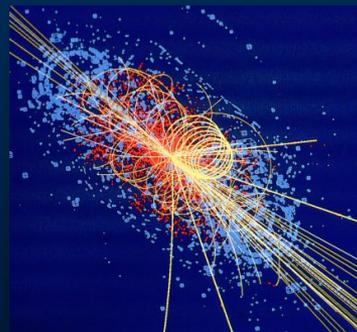
- **Interfacing** between fundamental science and key technological developments



- **CERN Technologies and Innovation**



Accelerating particle beams



Detecting particles



Large-scale computing (Grid)

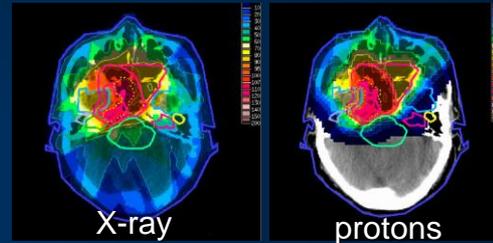
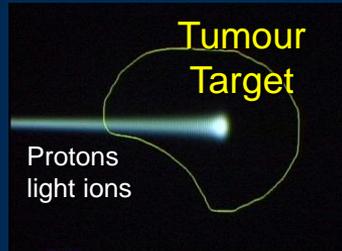
Medical Application as an Example of Particle Physics Spin-off

Combining Physics, ICT, Biology and Medicine to fight cancer



Hadron Therapy

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



Leadership in Ion Beam Therapy now in Europe and Japan

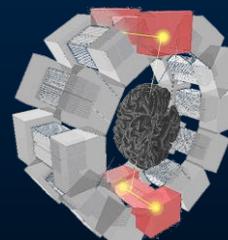
>70'000 patients treated worldwide (30 facilities)
>21'000 patients treated in Europe (9 facilities)



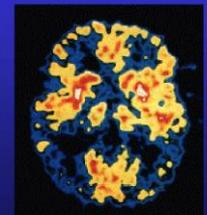
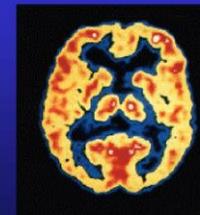
Imaging

PET Scanner

Clinical trial in Portugal for new breast imaging system (ClearPEM)



Brain Metabolism in Alzheimer's Disease: PET Scan



Normal Brain

Alzheimer's Disease



Detecting particles

CERN Education Activities

Scientists at CERN
Academic Training Programme



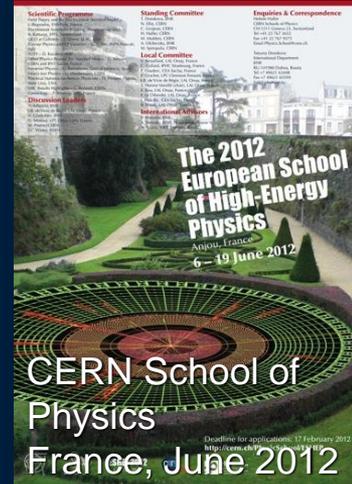
NEW:
Asia-Europe-Pacific School
of High-Energy Physics
Fukuoka, Oct 2012



Latin American School
Natal, Brazil, 2011

Young Researchers

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



The 2012
European School
of High-Energy
Physics
Anjou, France
6 - 19 June 2012

CERN School of
Physics
France, June 2012

Deadline for applications: 17 February 2012
<http://cern.edu>



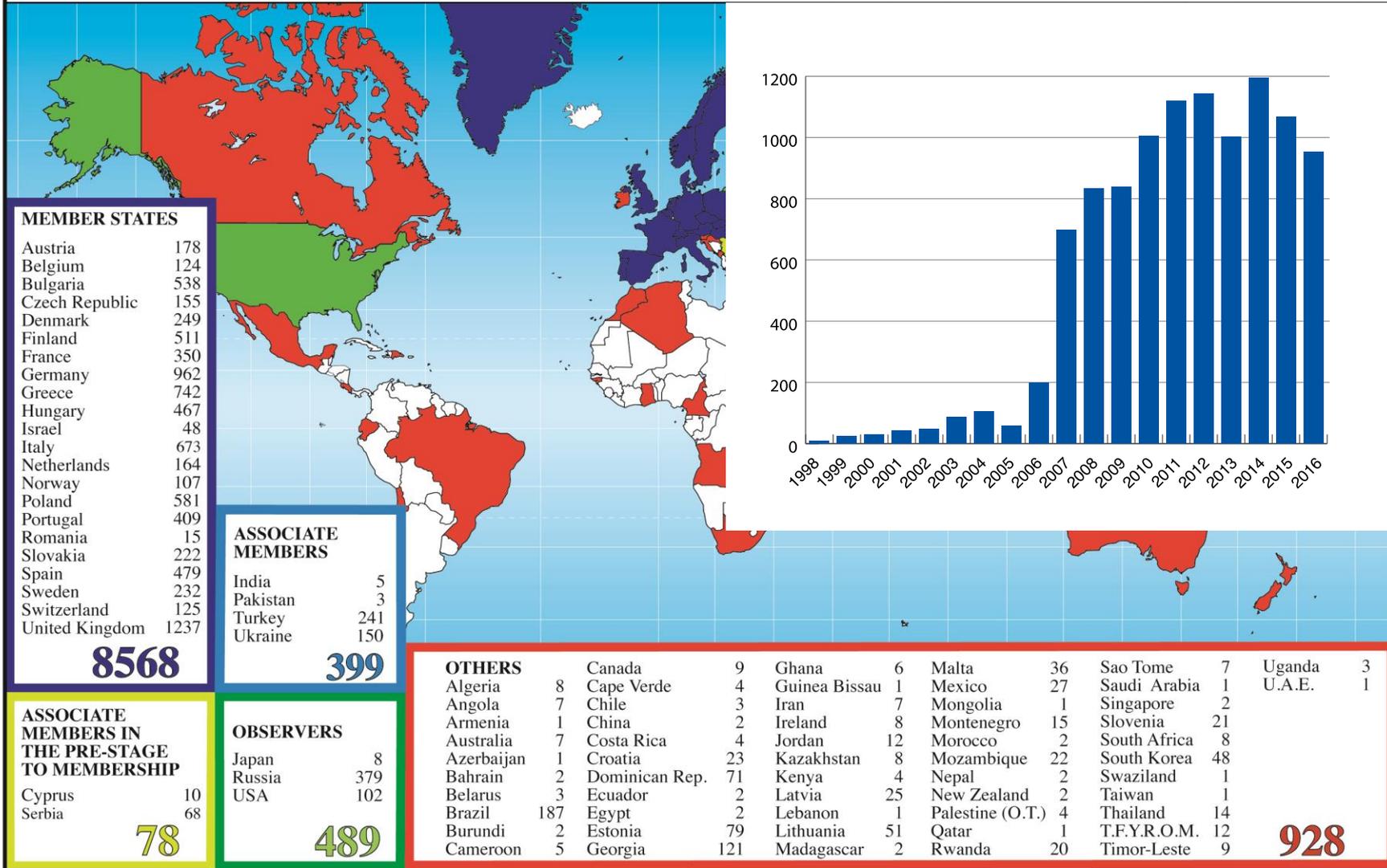
Physics Students
Summer Students
Programme



CERN Teacher Schools
International and National
Programmes

CERN Teacher Programme

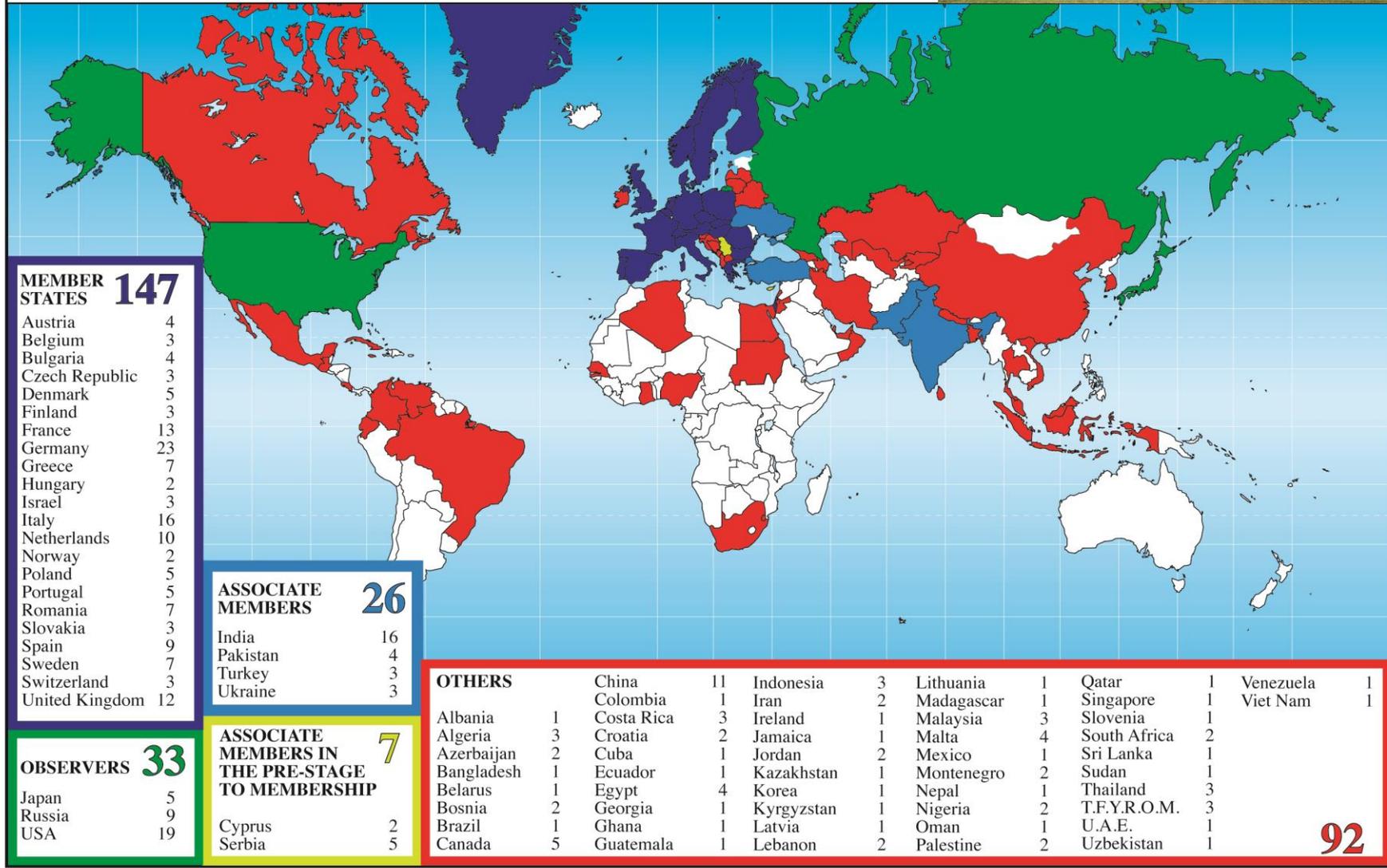
Teacher Programme Participants 1998 - 2016 (Total: 10462)



Summer Students 2016



Summer Students 2016



Personnel



Workforce

- **Physicists**
 - **Experimental**
 - **Theoretical**
- **Applied Physicists and Engineers**
- **Technicians**
- **Craftsmen**
- **Administrative personnel**
- **Fellows**
- **Doctoral Students**
- **Technical Students**
- **Associates**
- **Summer Students**
- **Employees of CERN**
- **Users**

30th November 2009 LHC sets new world record

Early this morning CERN's Large Hadron Collider become the world's highest energy particle accelerator, having accelerated its twin beams of protons to an energy of **1.18 TeV**. This exceeds the previous world record of 0.98 TeV, which had been held by the US Fermi National Accelerator



What next ?

ATLAS and CMS experiments present Higgs search status

13 December 2011. In a seminar held at CERN¹ today, the ATLAS² and CMS³ experiments presented the status of their searches for the Standard Model Higgs boson.

Their results are based on the analysis of considerably more data than those presented at the summer conferences, sufficient to make significant progress in the search for the Higgs boson, but not enough to make any conclusive statement on the existence or non-existence of the elusive Higgs.

The main conclusion is that the Standard Model Higgs boson, if it exists, is most likely to have a mass constrained to the range 116-130 GeV by the ATLAS experiment, and 115-127 GeV by CMS.

Tantalising hints have been seen by both experiments in this mass region, but these are not yet strong enough to claim a discovery.

CERN experiments observe particle consistent with long-sought Higgs boson Geneva, 4 July 2012.

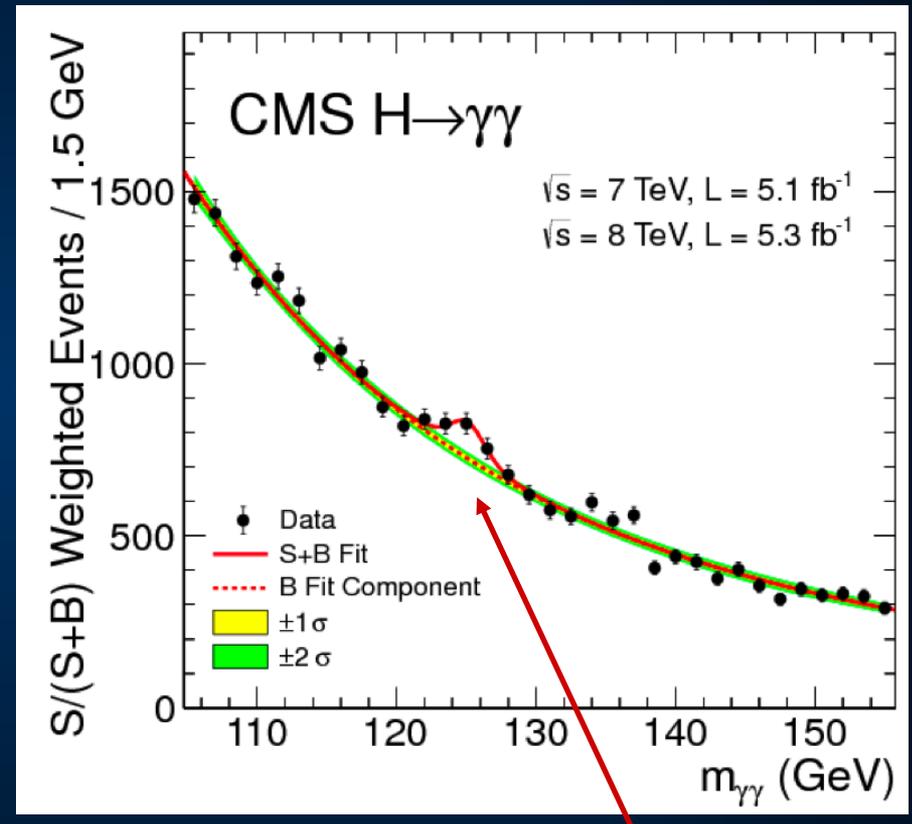
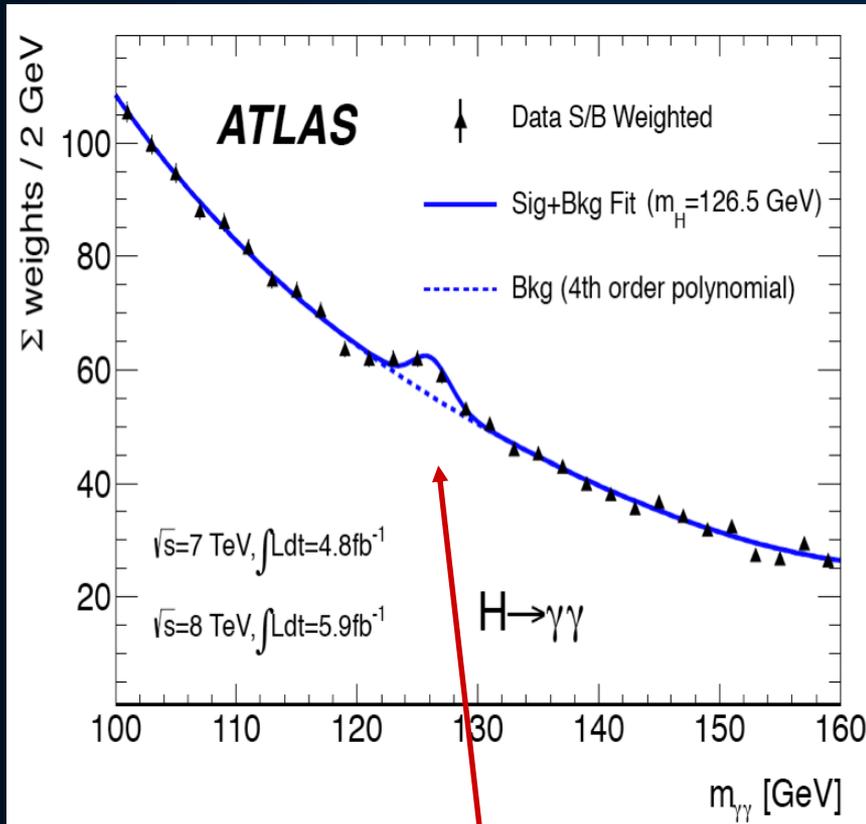
At a seminar held at CERN¹ today as a curtain raiser to the year's major particle physics conference, ICHEP2012 in Melbourne, the ATLAS and CMS experiments presented their latest preliminary results in the search for the long sought Higgs particle. **Both experiments observe a new particle in the mass region around 125-126 GeV.**

“We observe in our data clear signs of a new particle, at the level of 5 sigma, in the mass region around 126 GeV. The outstanding performance of the LHC and ATLAS and the huge efforts of many people have brought us to this exciting stage,” said ATLAS experiment spokesperson Fabiola Gianotti, *“but a little more time is needed to prepare these results for publication.”*

“The results are preliminary but the 5 sigma signal at around 125 GeV we’re seeing is dramatic. This is indeed a new particle. We know it must be a boson and it’s the heaviest boson ever found,” said CMS experiment spokesperson Joe Incandela. *“The implications are very significant and it is precisely for this reason that we must be extremely diligent in all of our studies and cross-checks.”*



Higgs decay to $\gamma\gamma$, ATLAS and CMS, summer 2012 data



July 4th at CERN, after the Higgs seminar



4 JULY 2012 CERN Press conference

Discovery opens world of physics

CERN reports finding particle that could solve mysteries large and small

The Economist A giant leap for science Finding the Higgs boson



ヒッグス粒子発見か 新素粒子検出 年内に結論

Milhares de moradores de bairros sociais em risco de perderem RSI

Le Monde Science : la matière dévoilée

Physicists Find Elusive Particle Seen as Key to Universe



The Gazette EL PAIS

MK 5 июля 2012 ПОСЛЕДНИЙ КИРПИЧ В СТЕНУ МИРОЗДАНИЯ

AD ALGEMEEN DAGBLAD Eindelijk gelijk na 48 jaar

Frankfurter Allgemeine Zeitung für Deutschland

CHINA DAILY Thursday, July 5, 2012

THE TIMES OF INDIA Big bang moment: Scientists may have found 'God particle'

THE HINDU Elusive particle found, looks like Higgs boson

CORRIERE DELLA SERA La particella che può svelare i segreti dell'universo

gazeta WYBORCZA.PL Cząstke Higgsa fizycy najpierw wymyślił, potem szukali 40 lat

বিশ্বজ্ঞানের 'সিঁধুর' দর্শন

Peter Higgs and Francois Englert

