CERN – 60 Years of Science for Peace

Agnieszka Zalewska, IFJ PAN
President of CERN Council

Lviv, 21.07. 2014

CERN was founded in 1954: 12 European States "Science for Peace"

Today: 21 Member States

~ 2300 staff
~ 1600 other paid personnel
~ 10500 users
Budget (2014) ~1000 MCHF

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

Candidate for Accession: Romania

Associate Member in Pre-Stage to Membership: Serbia

Applicant States for Membership or Associate Membership: Brazil, Cyprus, Pakistan, Russia, Slovenia, Turkey, Ukraine

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

Mission of CERN

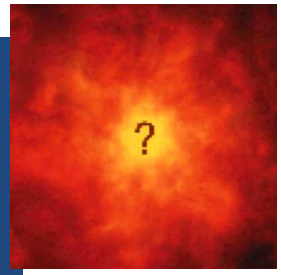
- **Research**
  Pushing the frontiers of knowledge

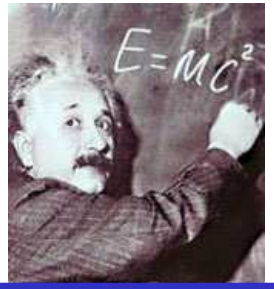
- **Innovation**
  Developing new technologies

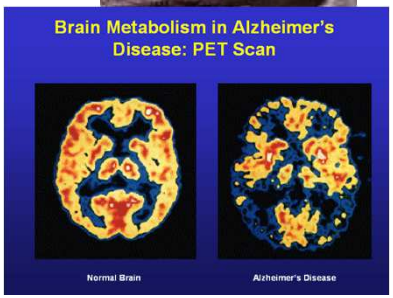
- **Education**
  Training scientists and engineers of tomorrow

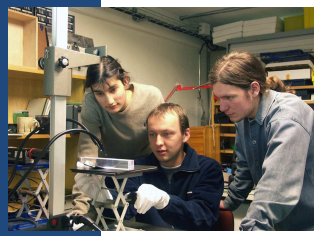
- **Outreach**
  Promoting science in society

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



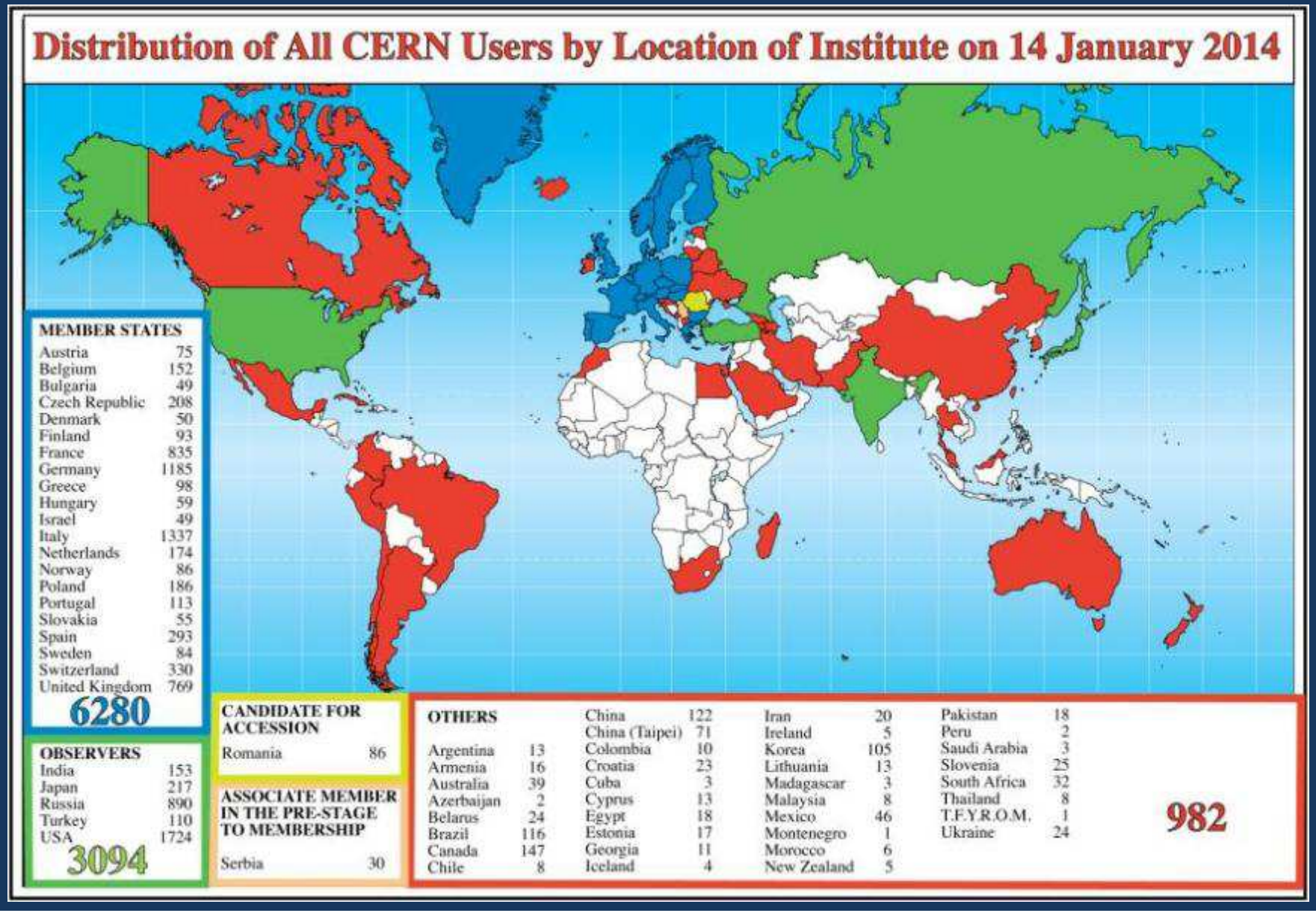




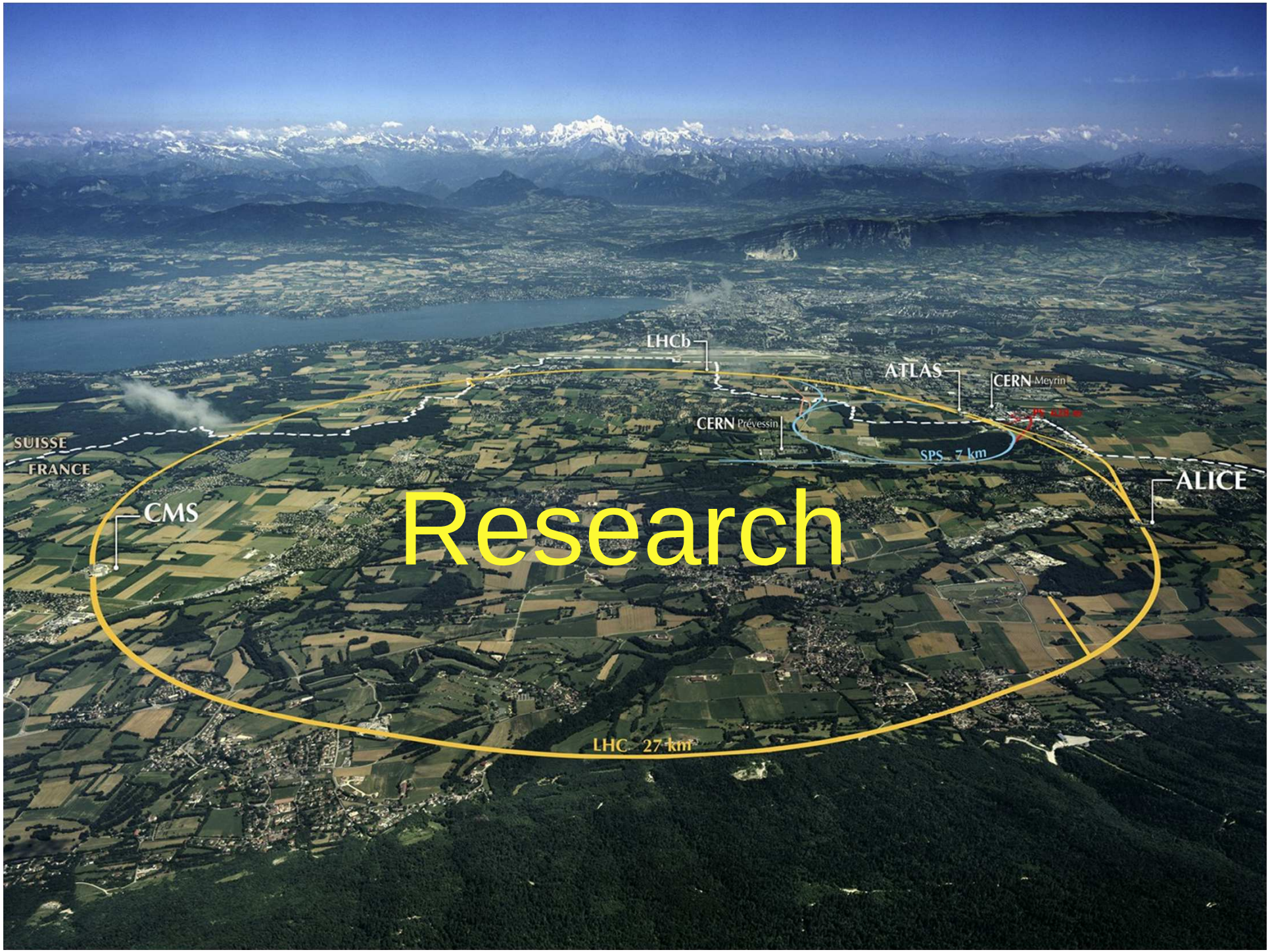


Uniting people

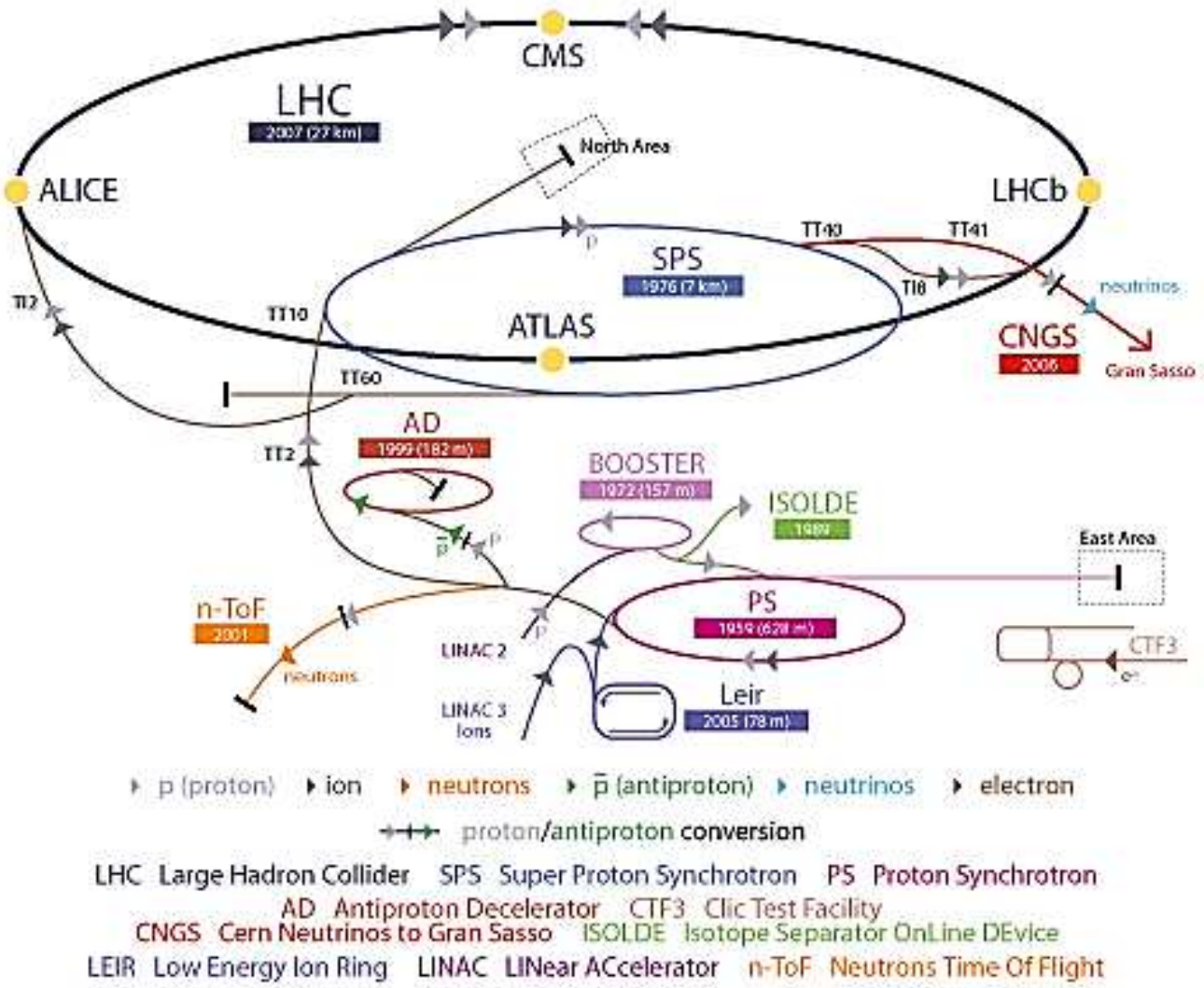
from different countries and cultures

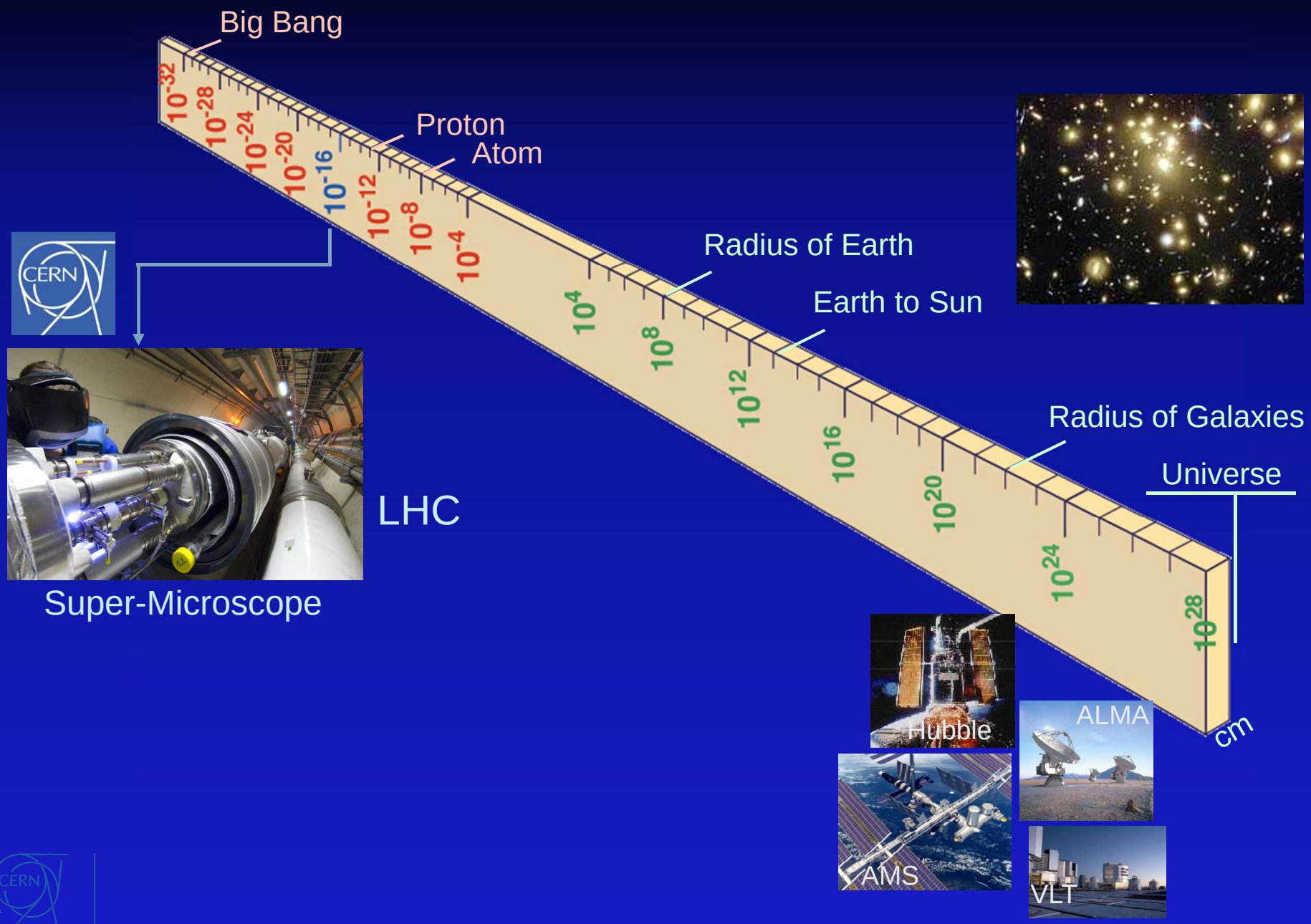


Research


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km

CERN – the leading accelerator centre in the world




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}
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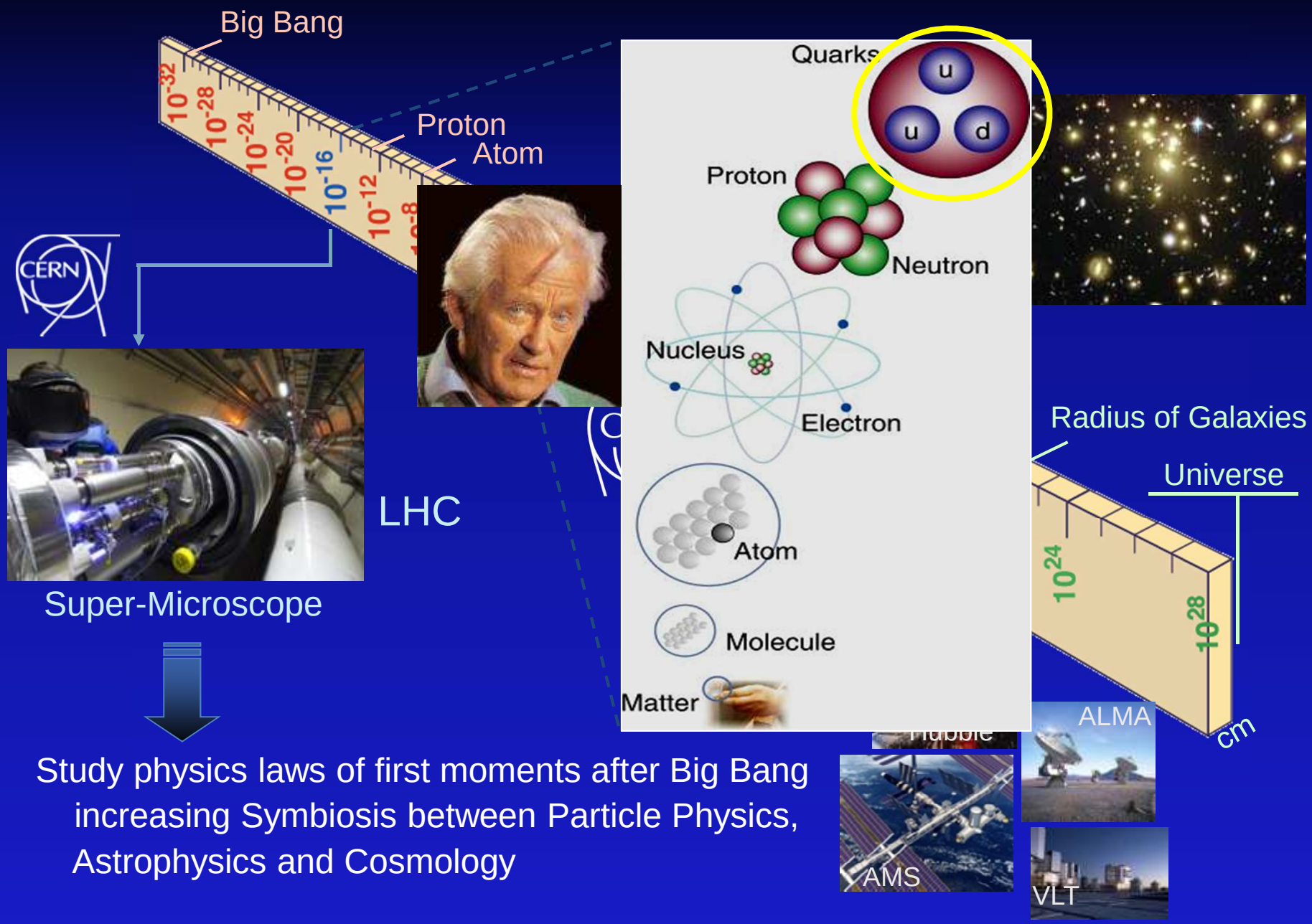
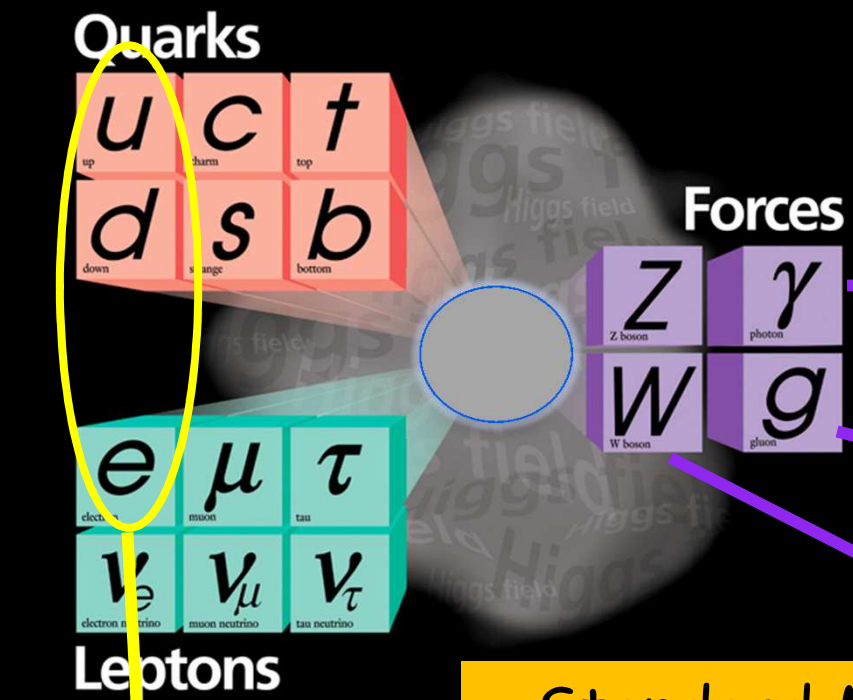
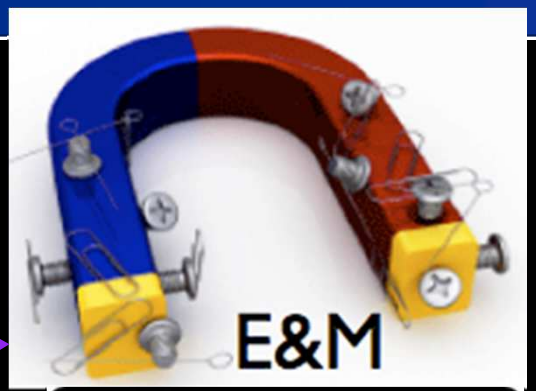
cm
LHC
Super-Microscope
Hubble
ALMA
AMS
VLT



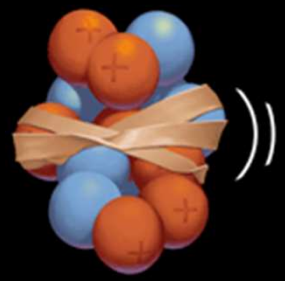
Study physics laws of first moments after Big Bang
increasing Symbiosis between Particle Physics,
Astrophysics and Cosmology

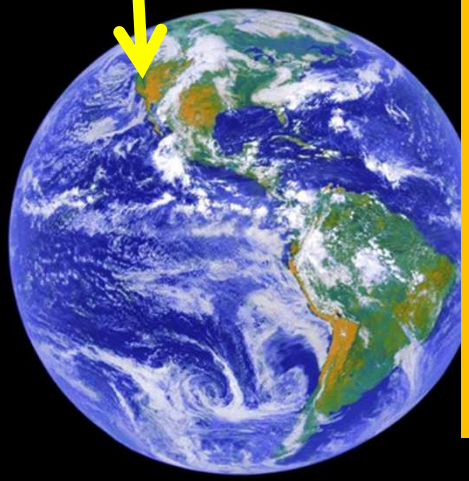
The Standard Model





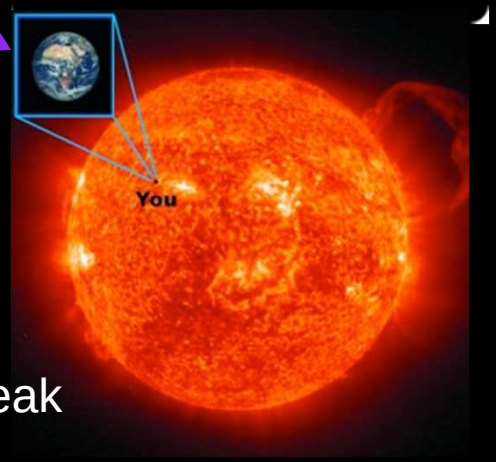
Strong





Standard Model tested over decades with high precision.

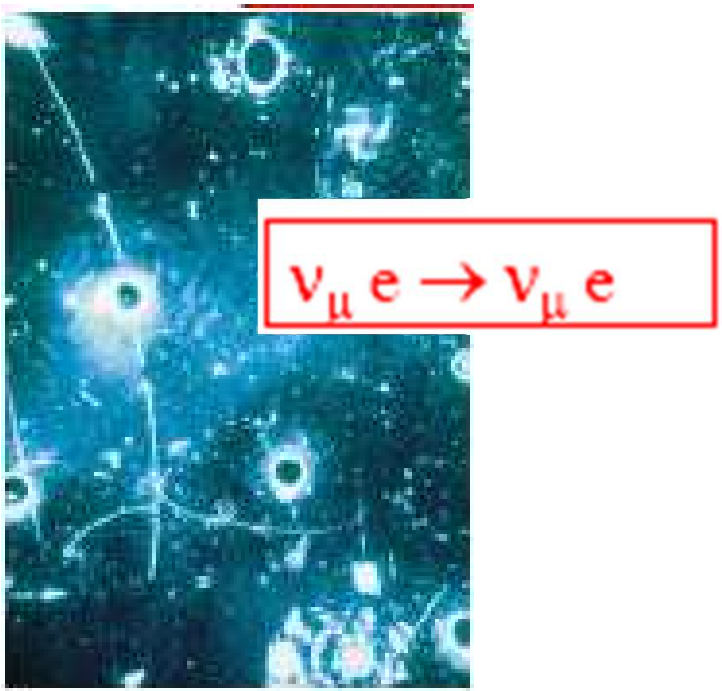
Major input from CERN to the understanding of weak interactions

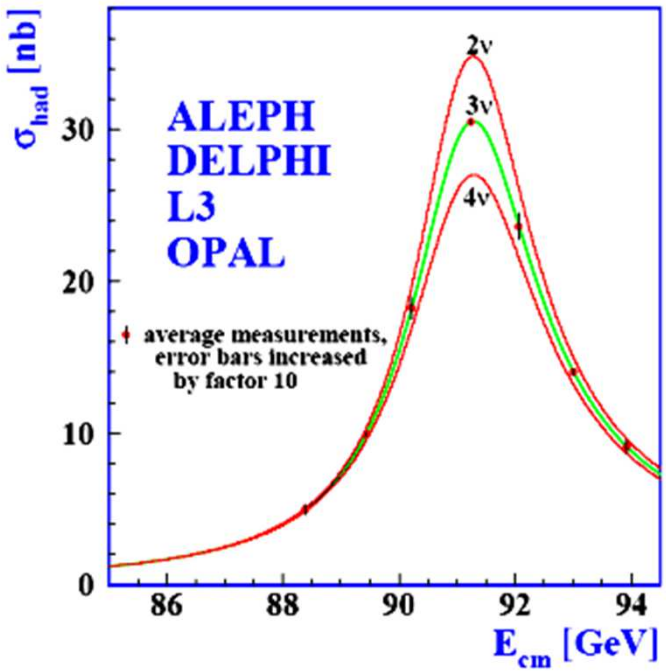


Weak

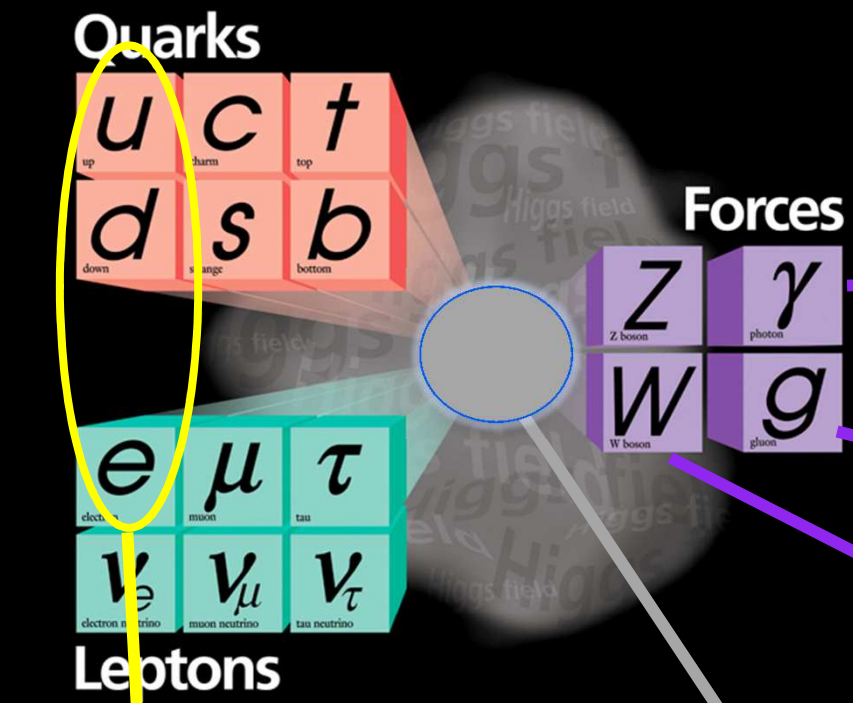
CERN – milestones from the past

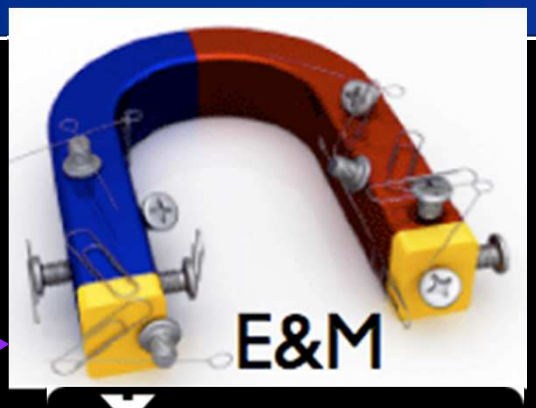
- 1973 – discovery on neutral current in the Gargamelle experiment
- 1982 – discovery of intermediate bosons W and Z
- 1990 – experimental evidence for the existance of three families of quarks and leptons



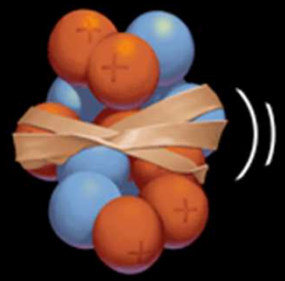


The Standard Model





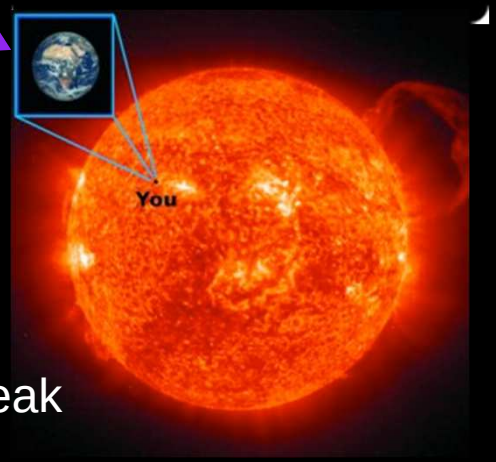
Strong



Standard Model tested over decades with high precision.

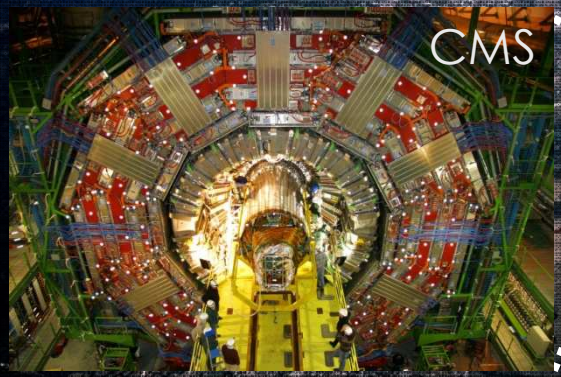
However, one crucial question left open:

How do elementary particles acquire mass ?

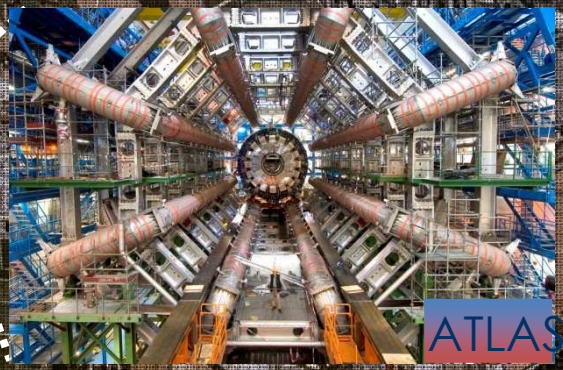


Weak

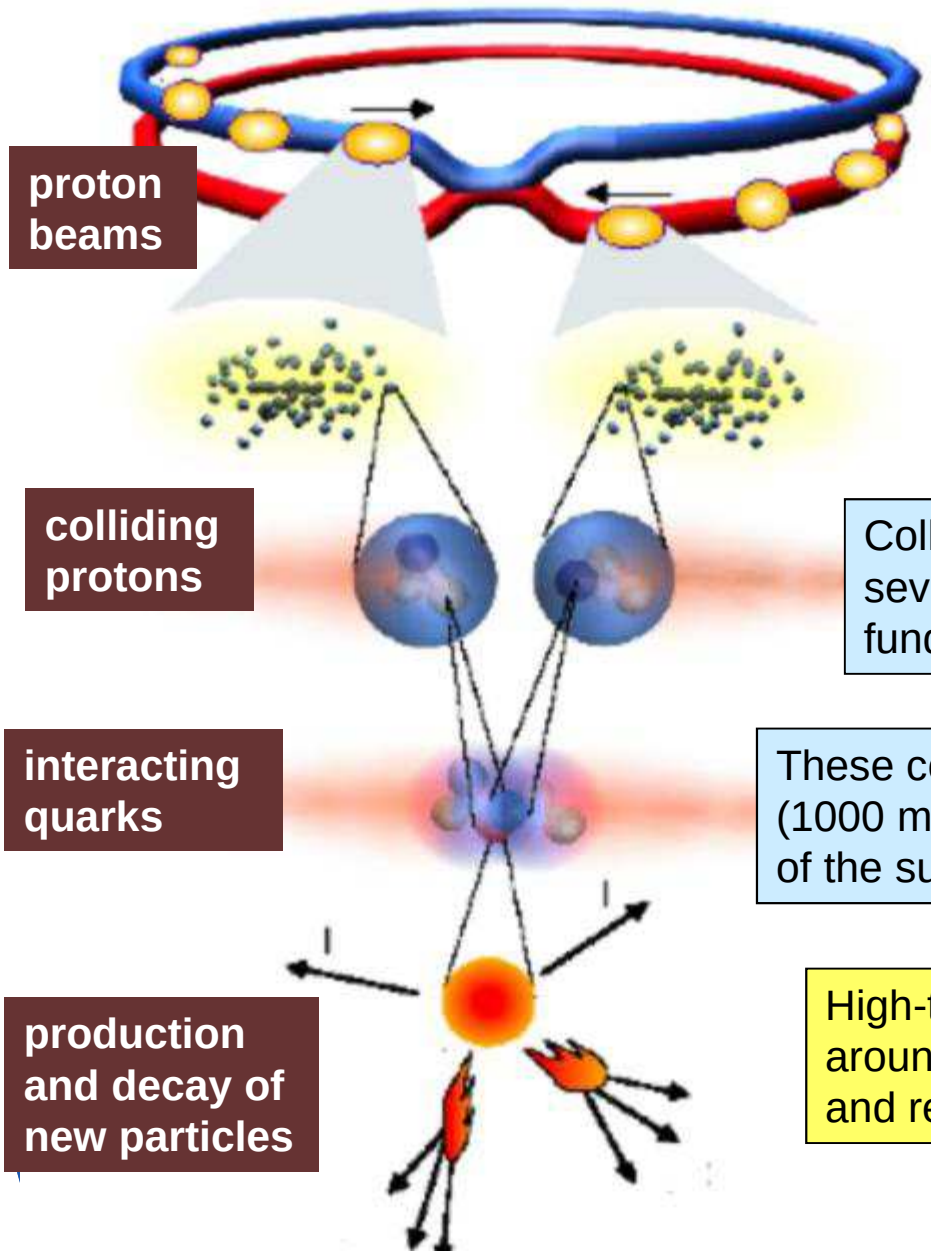
The LHC: A New Era in Fundamental Science



Exploration of a new energy frontier
Proton-proton and Heavy Ion collisions



LHC: study the elementary particles and their interactions



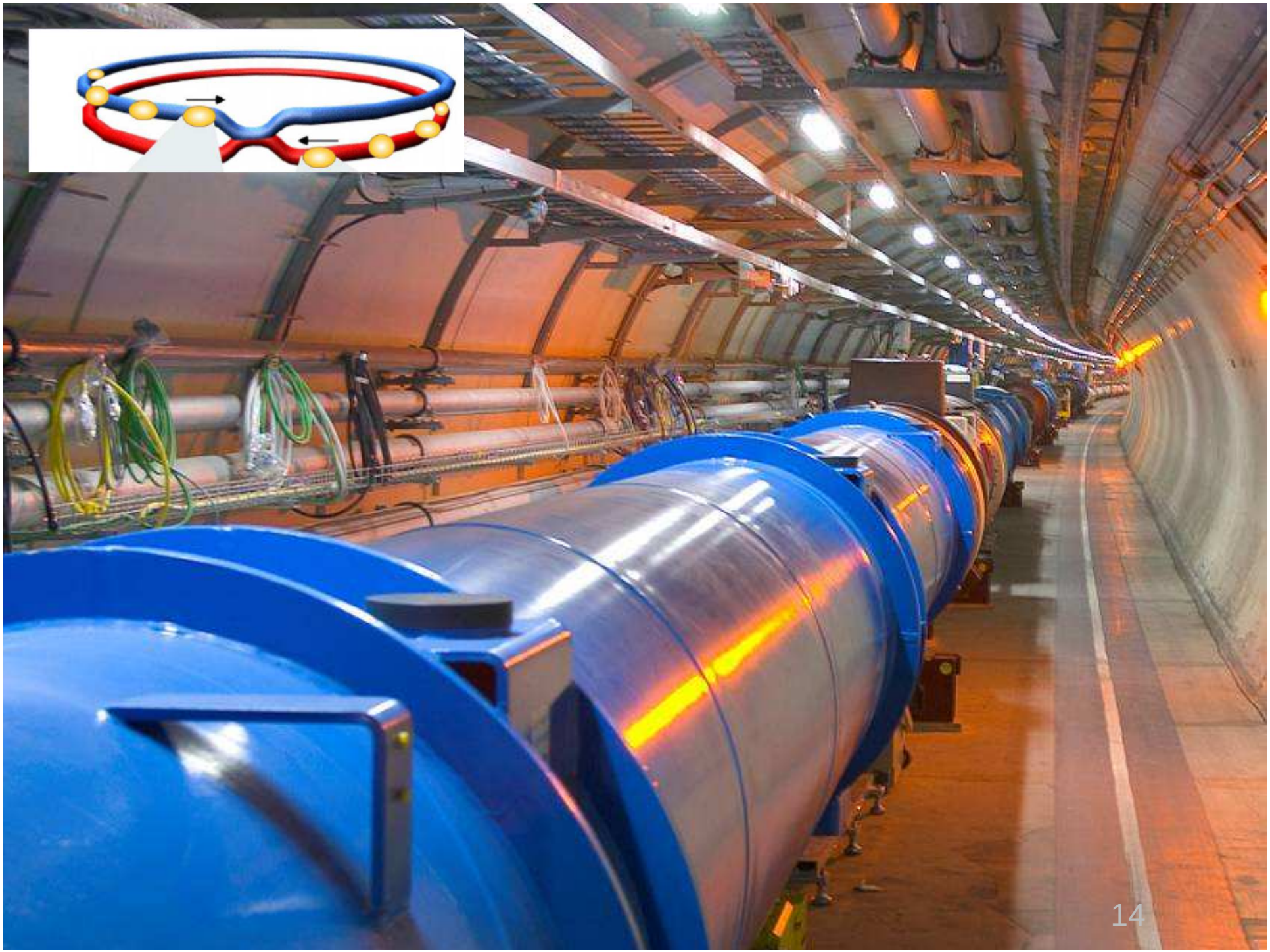
Acceleration of two beams of protons in some **2800 'bunches'** close to the speed of light

More than **100 billion protons** per bunch

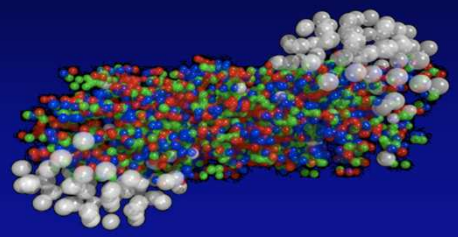
Colliding these bunches results in the collision of several tens of protons which break into their fundamental constituents (e.g. quarks)

These constituents interact at very high **energy density** (1000 million times higher temperature than at the centre of the sun but in a much more confined space)

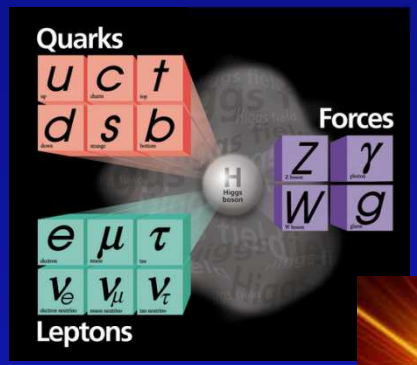
High-tech powerful detectors ("**digital cameras**") around the collision point detect the collision products and reconstruct what happened in the collision



The study of LHC data helps to answer some of the key questions ...

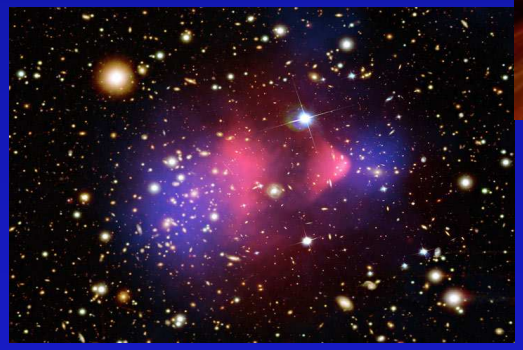


What was the primordial state of matter after the Big Bang before protons and neutrons formed?



Is there a Higgs particle that is 'responsible for giving mass' to all particles?

What is the reason why antimatter and matter did not completely destroy each other?

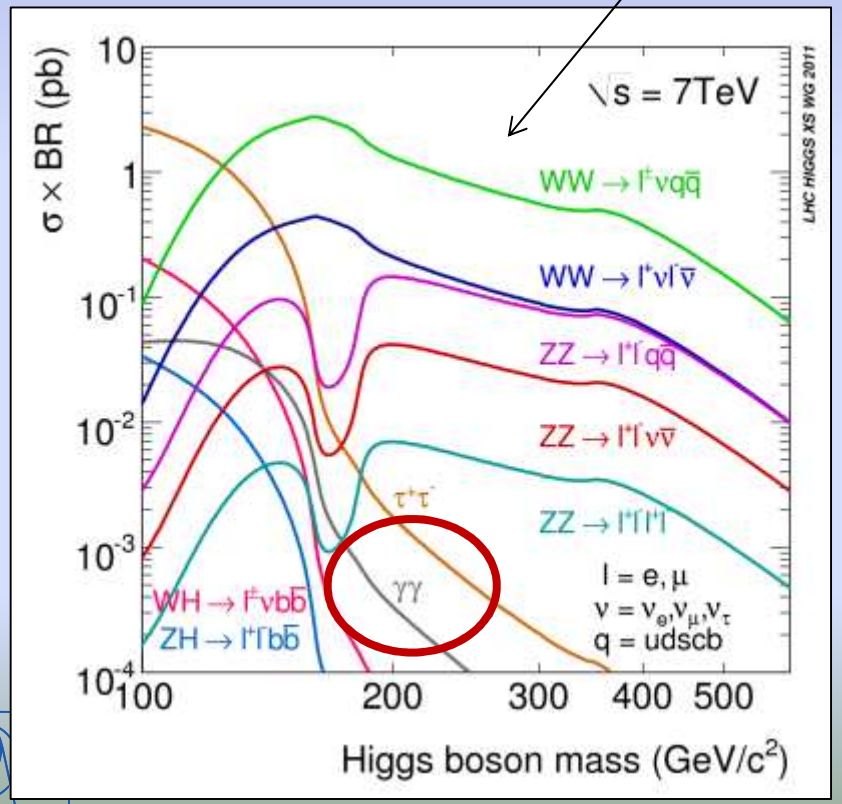


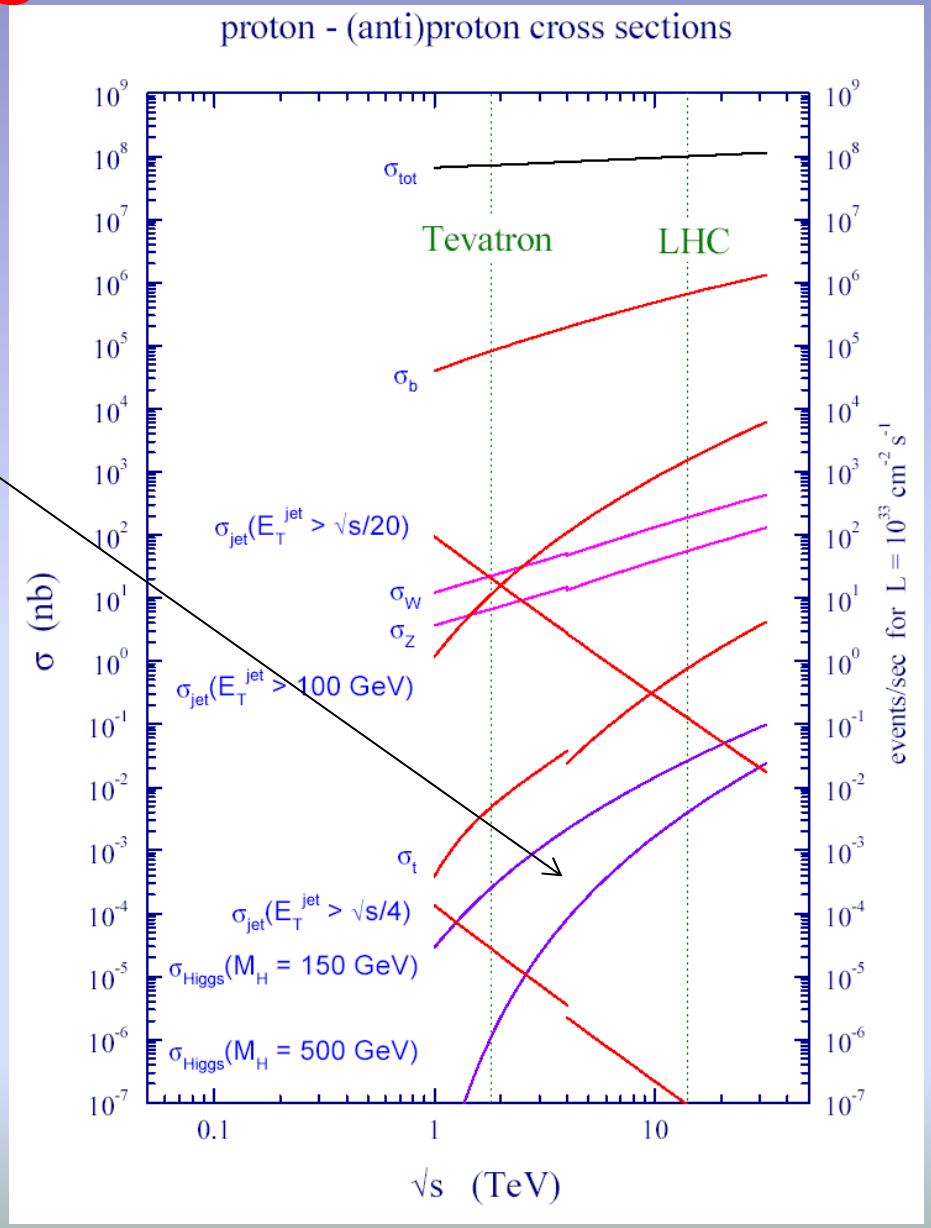
What is (are) the particle(s) that make up the mysterious 'dark matter' in our Universe? And what's 'dark energy'?

Search for the Higgs-Boson at the LHC

Production rate of the Higgs-Bosons rather low

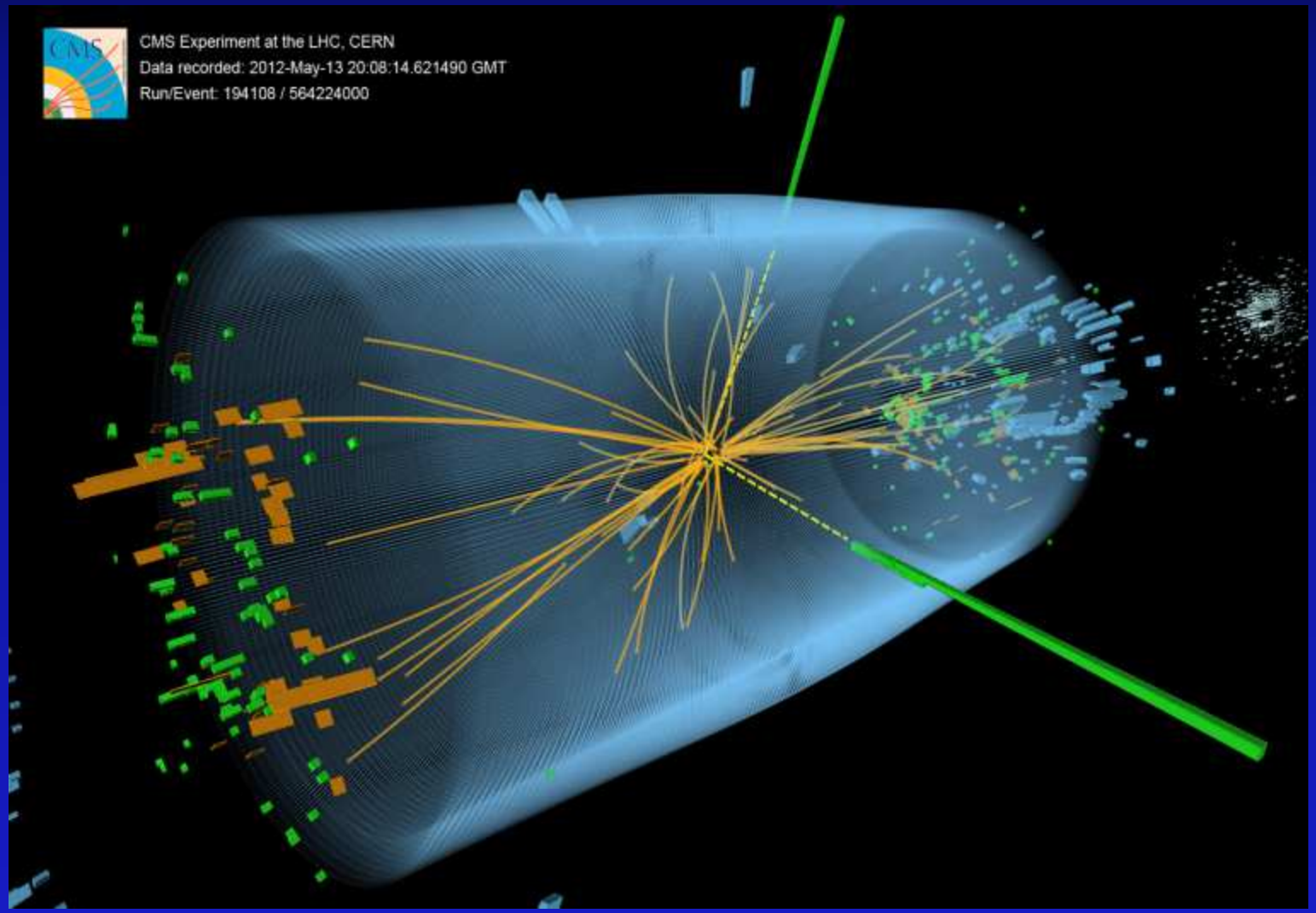
Many different decay possibilities





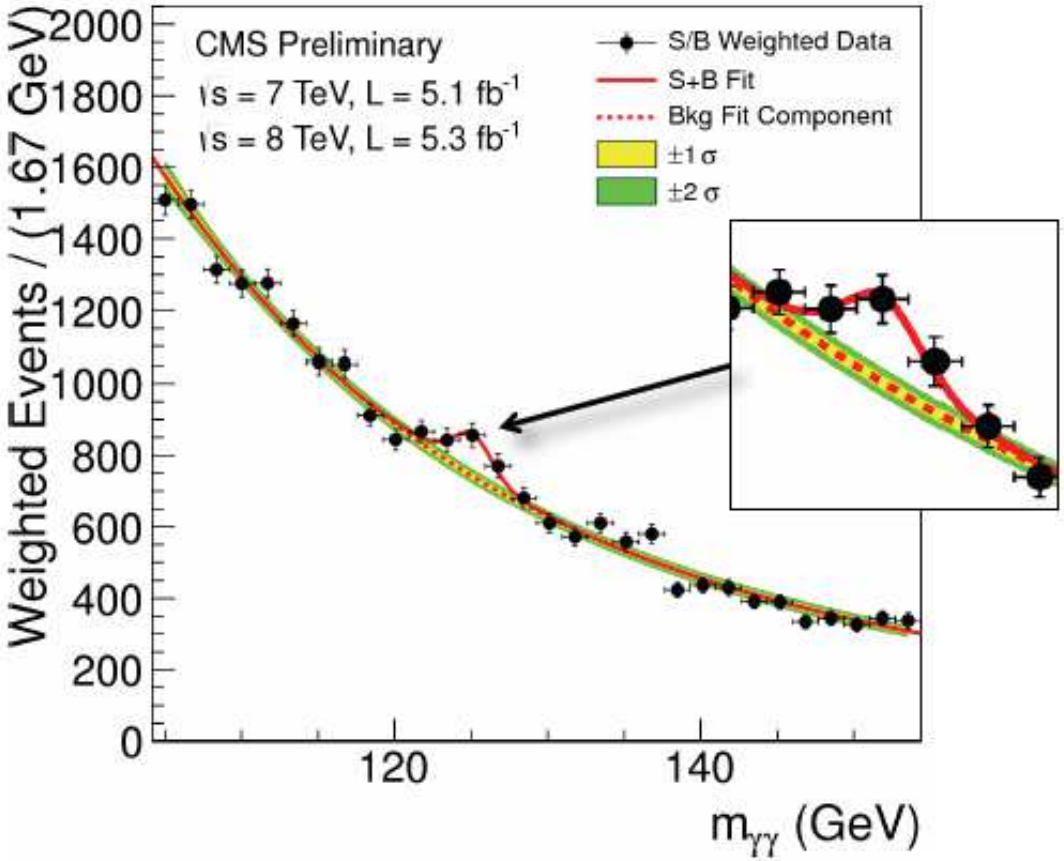
4 July 2012: CERN scientific seminar

“CERN experiments observe particle consistent with long-sought Higgs boson”



S/B Weighted Mass Distribution

- Sum of mass distributions for each event class, weighted by S/B
  - B is integral of background model over a constant signal fraction interval



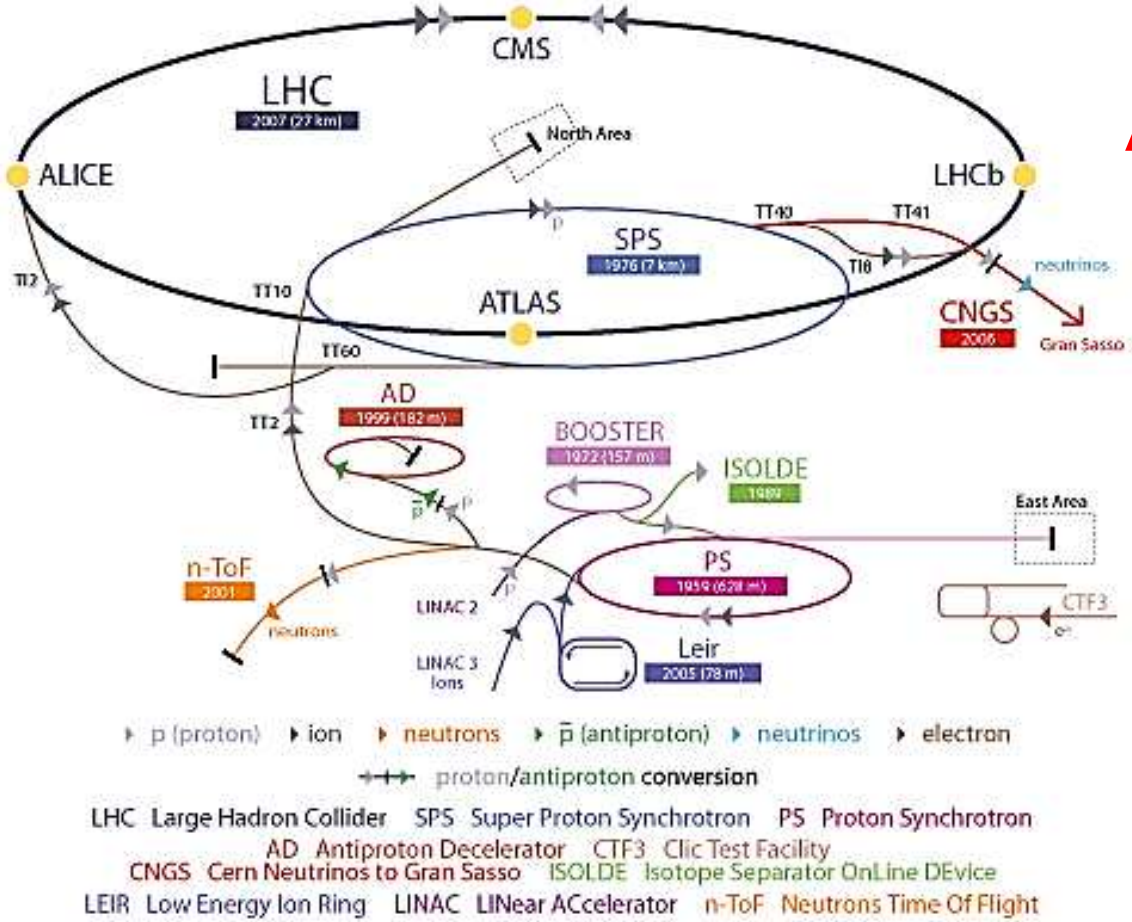
Nobel Prize in Physics 2013

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".*


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km

Innovation

Technologies – development and transfer to other fields of research, industry and society



Accelerators

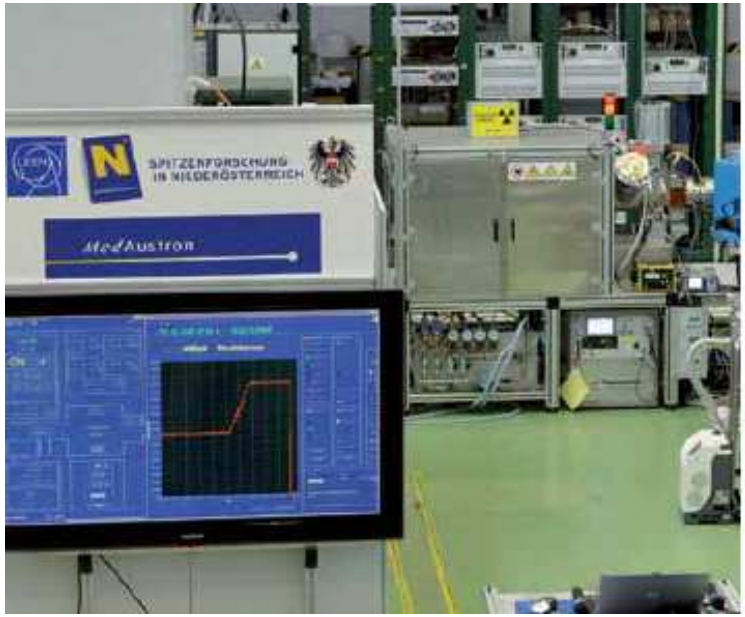
Detectors

Computing

Accelerators from the past

Low energy synchrotrons and cyclotrons are now commonly used in industry, e.g. food industry (around 20000) and in hospitals (around 10000). Their annual commercial output is valued at up to €500 billion.

The Proton Ion Medical Machine Study (PIMMS) at CERN produced an accelerator design optimized for hadron therapy, deployed in MedAustron and CNAO.



A test facility at CERN
for the MedAustron project

The synchrotron at Italy's CNAO facility

From accelerators to solar panels

A kind of molecular flypaper was developed to keep perfect vacuum inside the LEP accelerator pipe. This technology, applied to solar collectors, provides ultra-efficient thermal insulation and increases by a factor of 10 the efficiency of standard rooftop solar panels.

Inside the LEP beam pipe.
The metal ribbon acts as molecular flypaper.

The same technology is at work inside solar panels on the roof of Geneva airport.

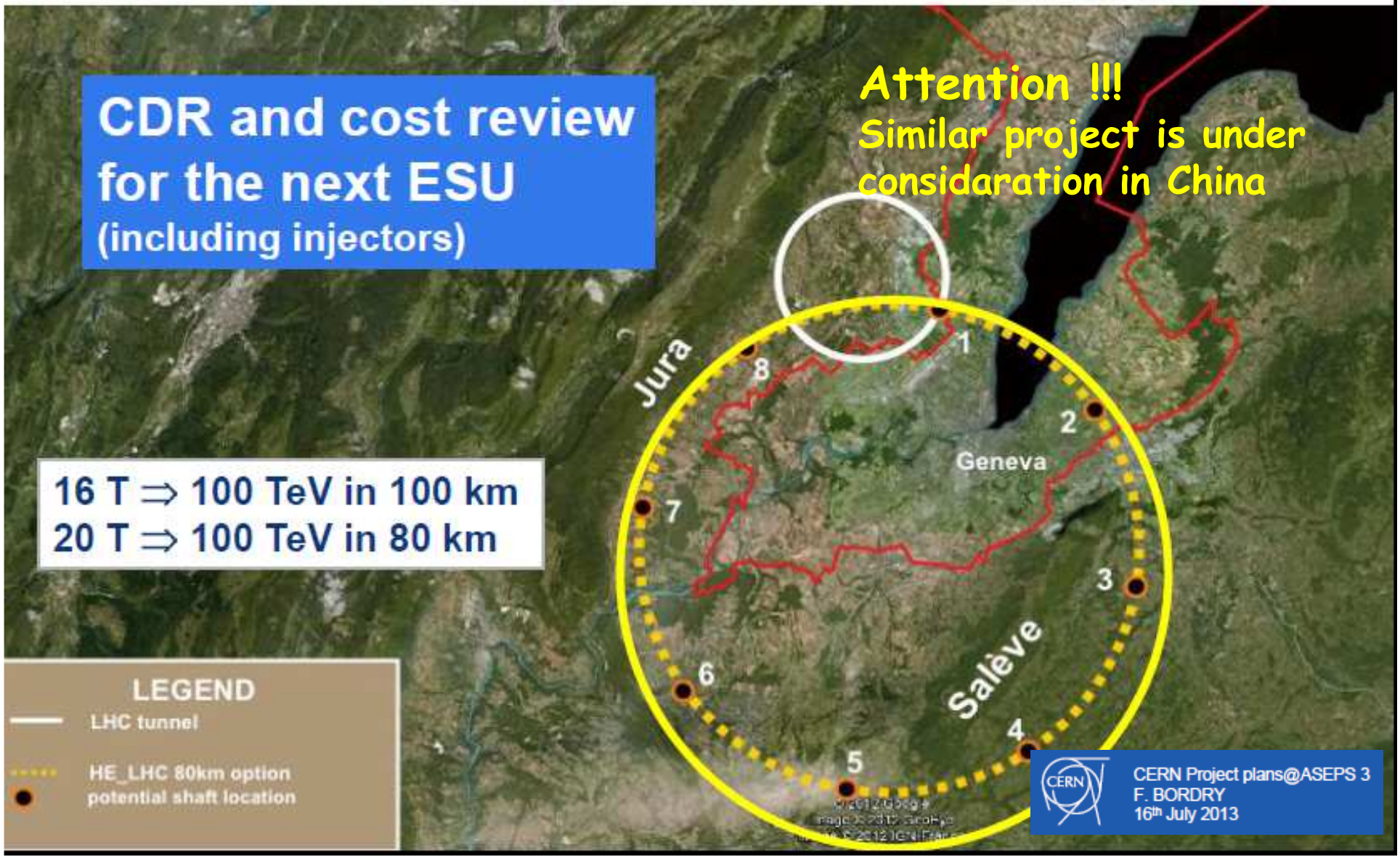
Accelerators for the future

CERN and other major European laboratories in 2011 at the workshop in Lund committed themselves to making the best and most efficient use of power that drives accelerators: to concentrate on the best ways to deliver and recover energy, to store it, to recycle heat and save water etc.

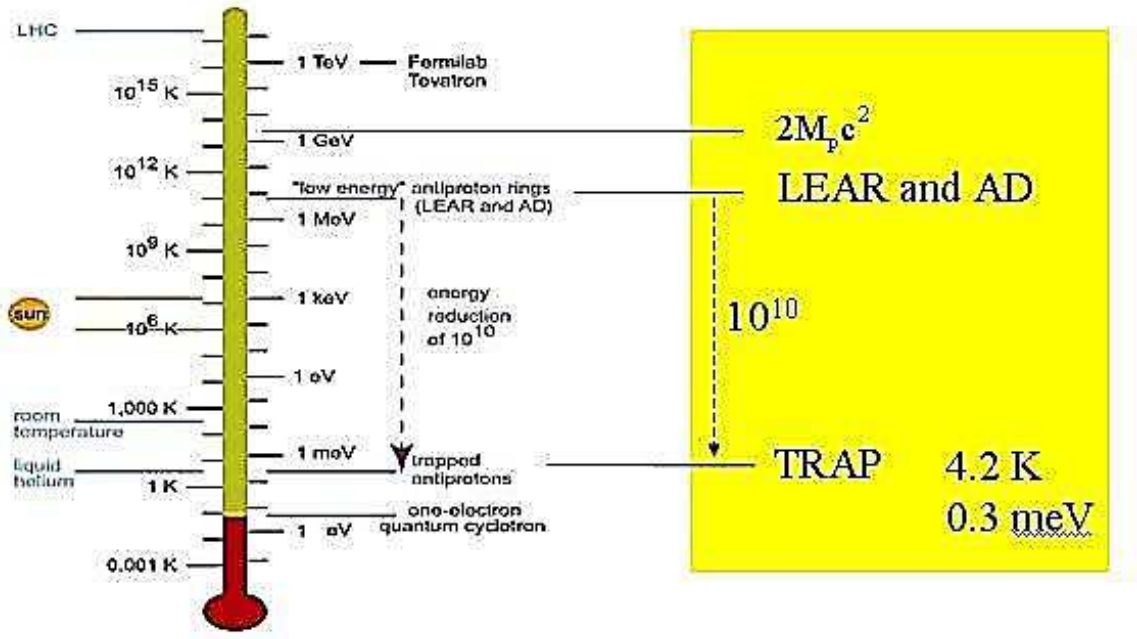
Important studies in this direction: R&D for superconducting cables of magnesium diboride that can have similar parameters at 25 K as the LHC cables at around 3 K. This will result in a considerable reduction of accelerators' power consumption.

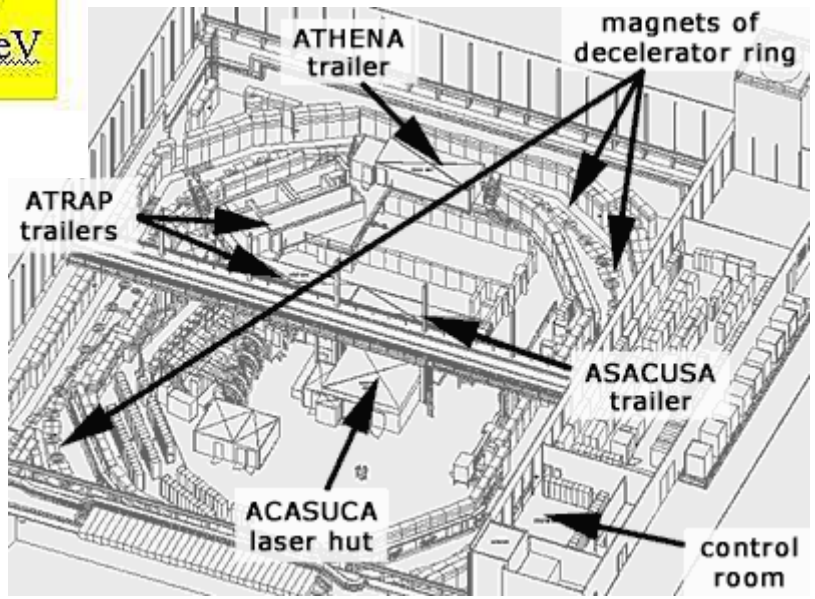
80-100 km tunnel in Geneva area – VHE-LHC

with possibility of e+-e- (TLEP) and p-e (VLHeC)



Antiproton Decelerator – a unique facility for studies of antiatoms at CERN





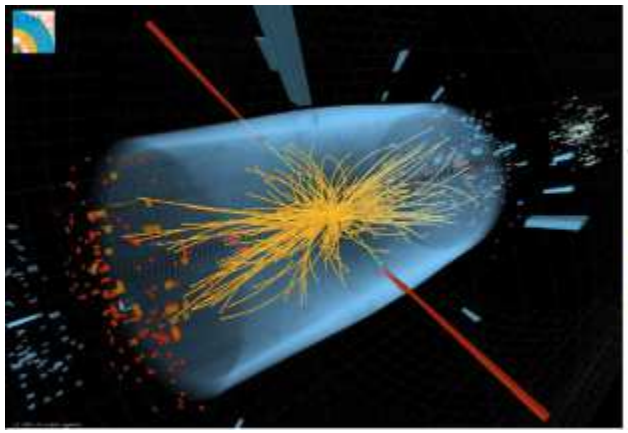
But also for the ACE experiment studying the potential use of antiprotons in cancer therapy

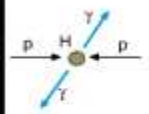
Detectors from the past

The most impressive example are the multiwire proportional drift chambers, developed by George Charpac during the 1960' at CERN for particle physics experiments, which have found also multiple other applications, notably in medical diagnosis.

Detectors – from LHC to medicine

Silicon pixel detectors, used for tracking at LHC, and crystals of lead tangstate, used for energy measurements in CMS, have already found various applications, especially in medicine. For example, Silicon pixels are deployed as Medipix, for medical imaging and diagnosis. The CMS electronics to read out these crystals in a magnetic field opened the way to combined PET/MRI scanners.





A Higgs or a 'background' process without a Higgs?

In yellow – particle tracks measured by Silicon detectors
In red – energy deposits in crystals of CMS's calorimeter

Silicon pixels in ATLAS and crystals In CMS under test

Computing – WWW in the past

World Wide Web was developed at CERN to help share information among scientists working at the Large Electron Positron collider, at institutes all around the globe. Twenty one years ago it was made publicly available.

This was a generous gift from CERN to the mankind.

Web-inventor Tim Berners-Lee with student Nicola Pellow and the world's first Web browser.

The Web's international annual economic value is now estimated at €1.5 trillion

Computing – LHC Grid now

Worldwide LHC Computing Grid was launched by CERN in 2002 in view to processing more than 20 petabytes of data generated each year by LHC experiments. The system integrates thousands of computers and storage systems all over the world.

In 2010, Cloud and Grid computing was valued €35 billion. By 2015 it could be €120 billion.

A 2010 snapshot of European traffic on Worldwide LHC Computing Grid.


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km

Education

CERN – education activities

This mission of CERN is treated very seriously and new initiatives are born all the time.

- CERN has state-endorsed programmes for primary schools in France and Switzerland
- The particle physics community runs particle physics masterclasses for high-school students, which effectively complement school visits to CERN
- CERN runs high-school teachers programmes
- Summer courses at CERN are addressed to university students
- Technical Student programmes and Schools of Particle Physics, Computing and Accelerators are organised for young researchers and engineers
- An Academic Training Programme is dedicated to scientists at CERN
- Special initiatives are developed to help train engineers from Member States

CERN Education Activities

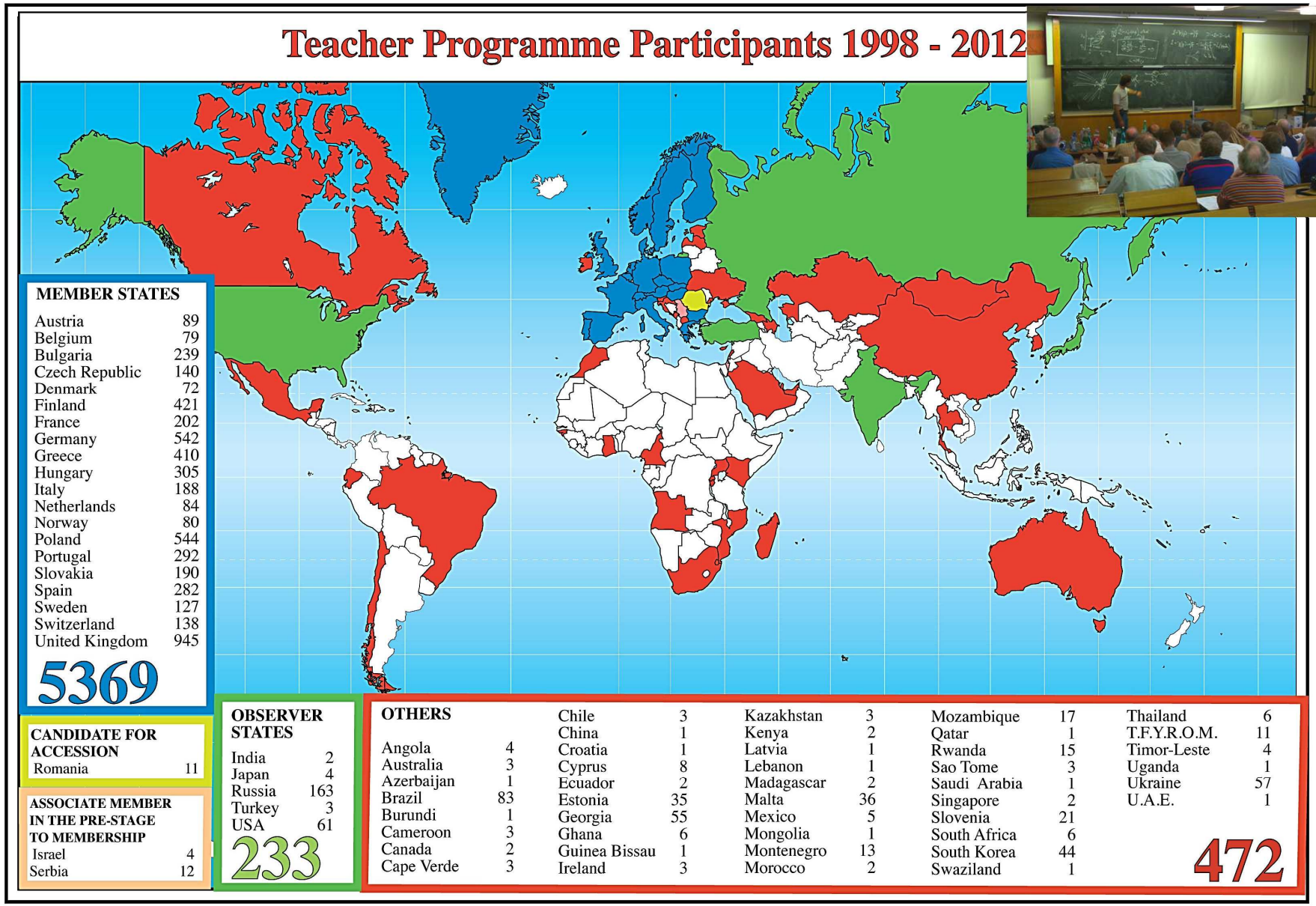
Scientists at CERN
Academic Training Programme

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

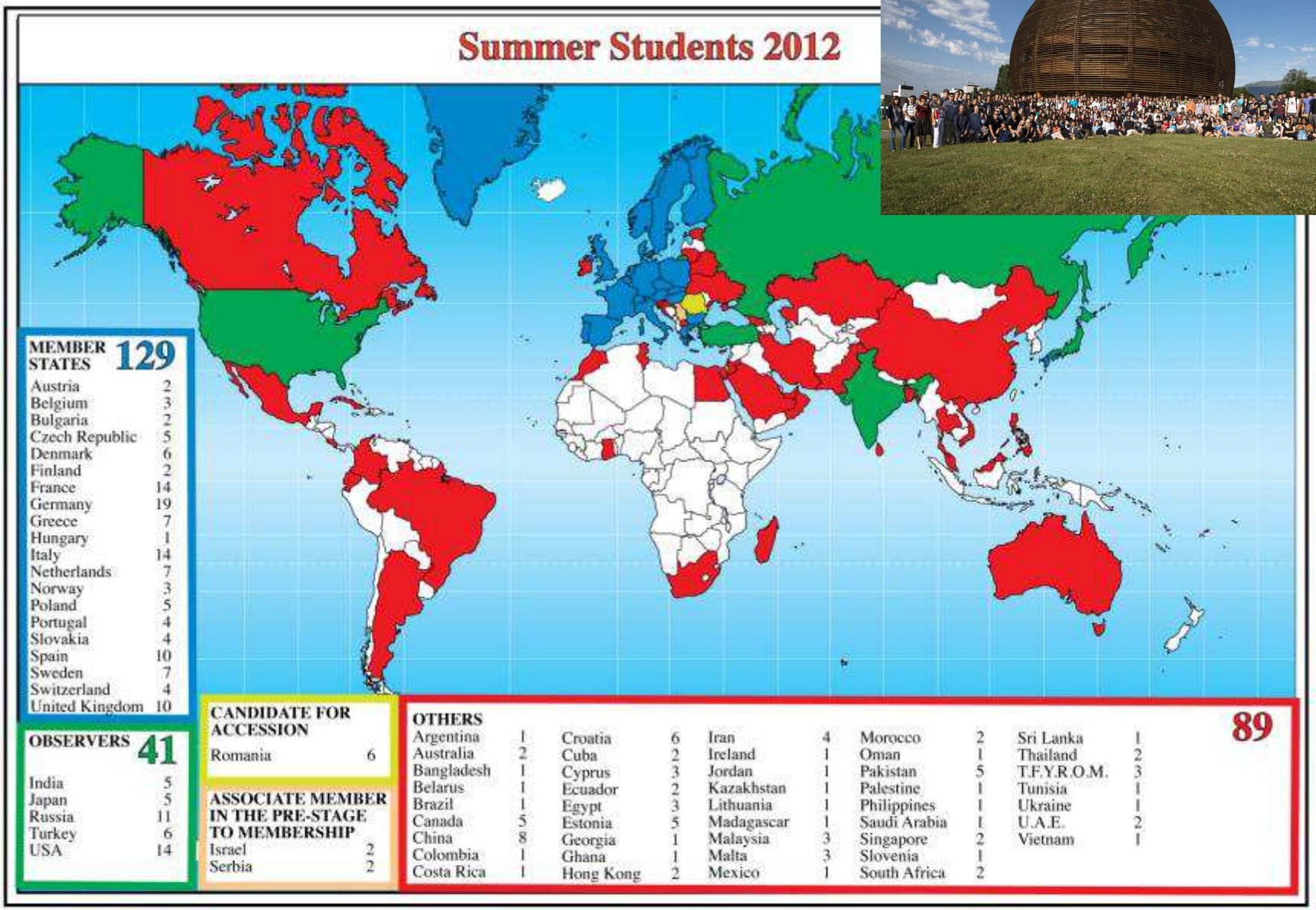
Physics Students
Summer Students
Programme

CERN Teacher Schools
International and National
Programmes

CERN Teacher Programme



Summer Students 2012



Key elements in CERN's success

- Ambitious scientific projects with defined deadlines
- Excellent scientists and engineers forming very creative environment
- Sustainable support of Member States
- Close collaboration with the MS research institutes and universities on one side and with leading industrial firms on the other side
- Promoting knowledge and technology transfer
- Opening to the world

CERN Organization