Science and Technology
Two Facets of CERN

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President of the CERN Council

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

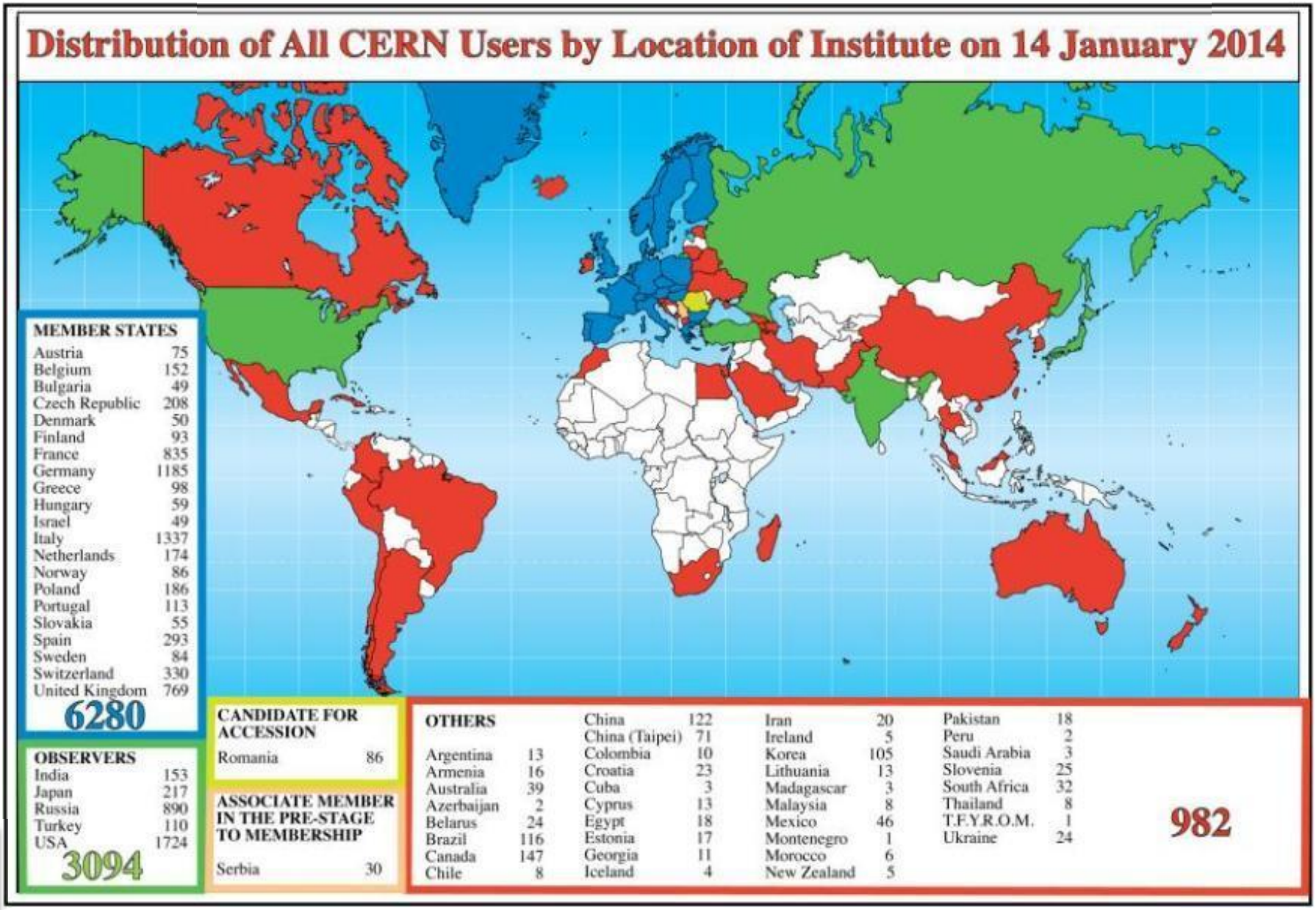
Associate Member States: Serbia, Turkey

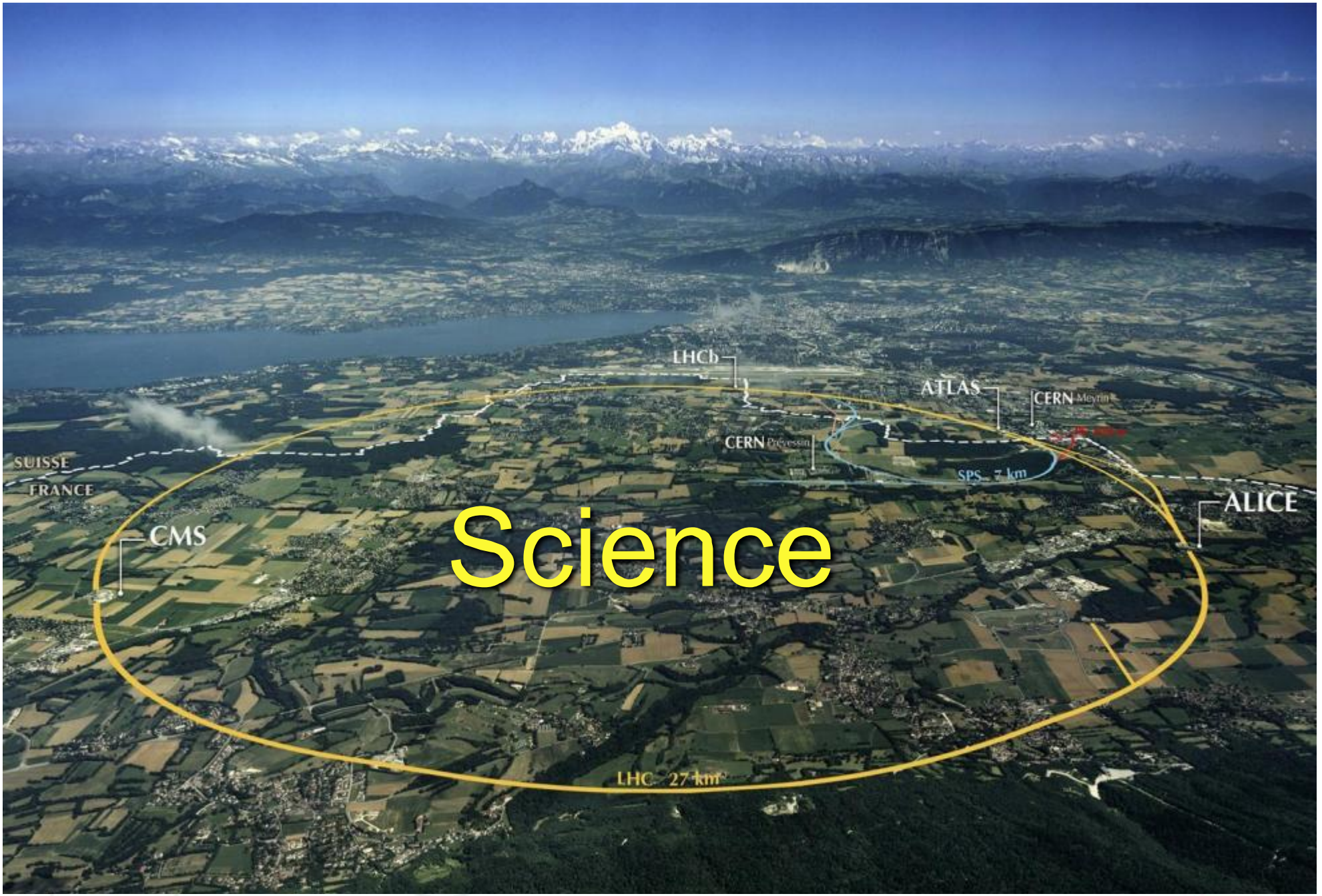
Applicant States for Membership or Associate Membership: Brazil, Cyprus, Pakistan, Russia, Slovenia, Ukraine

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

Uniting people

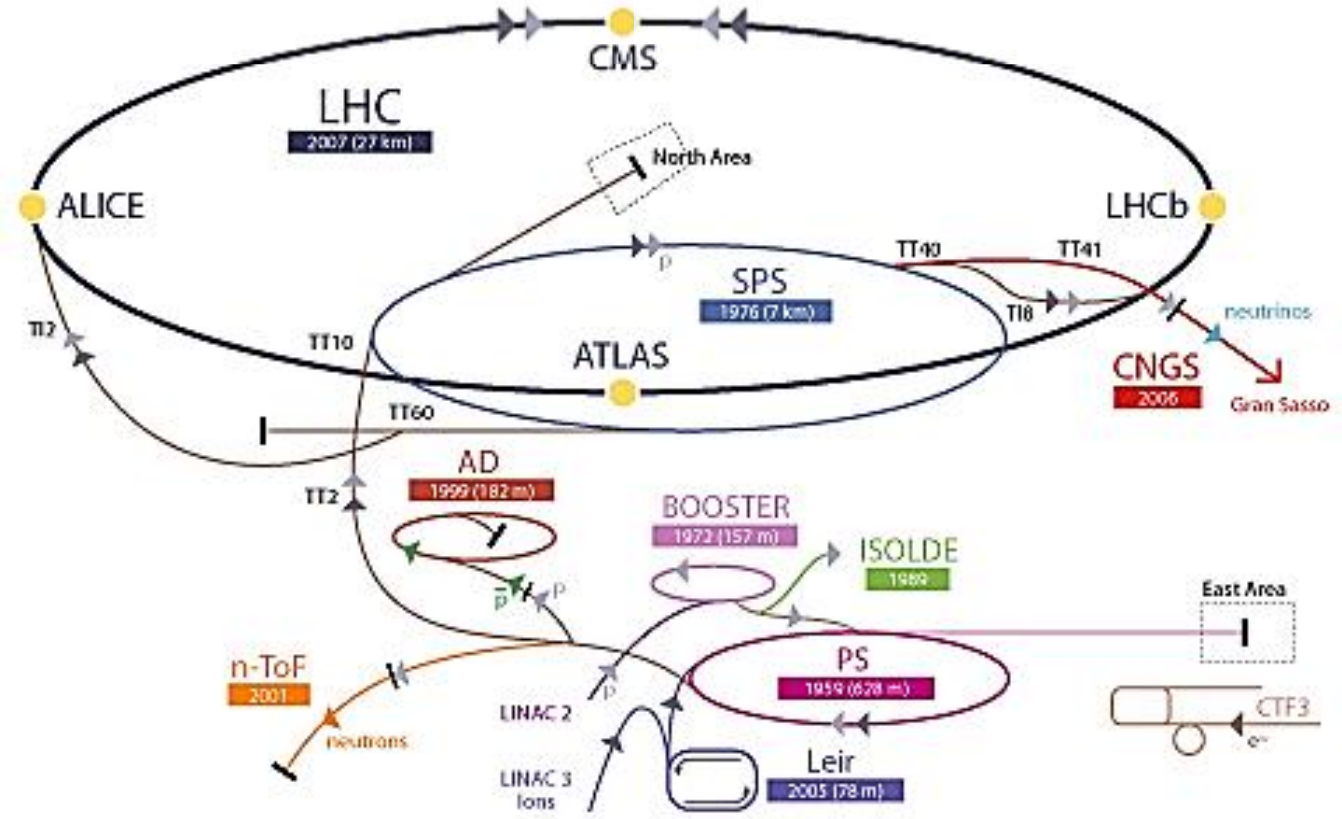
from different countries and cultures



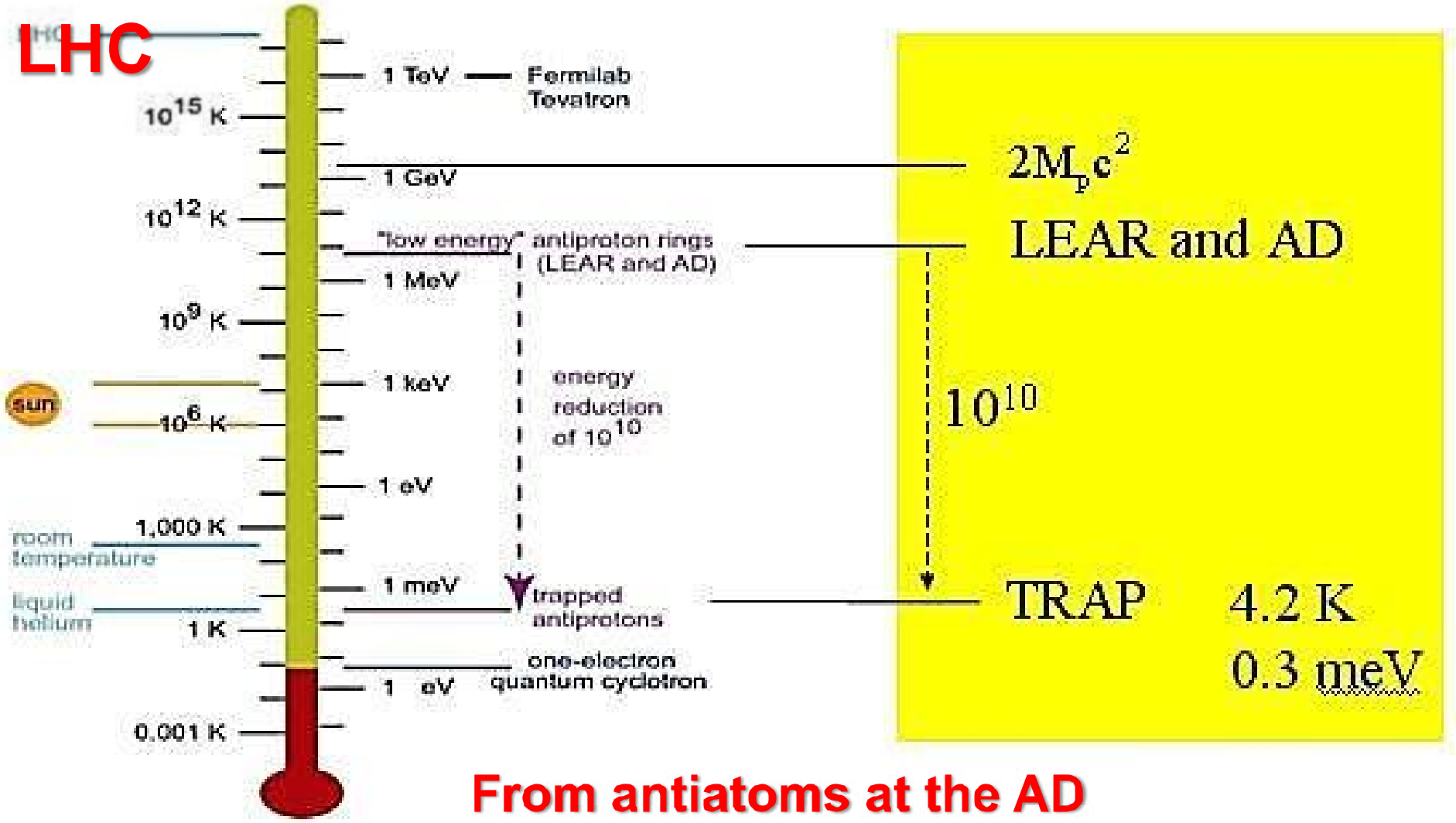

LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km

Science

CERN – the leading accelerator centre in the world

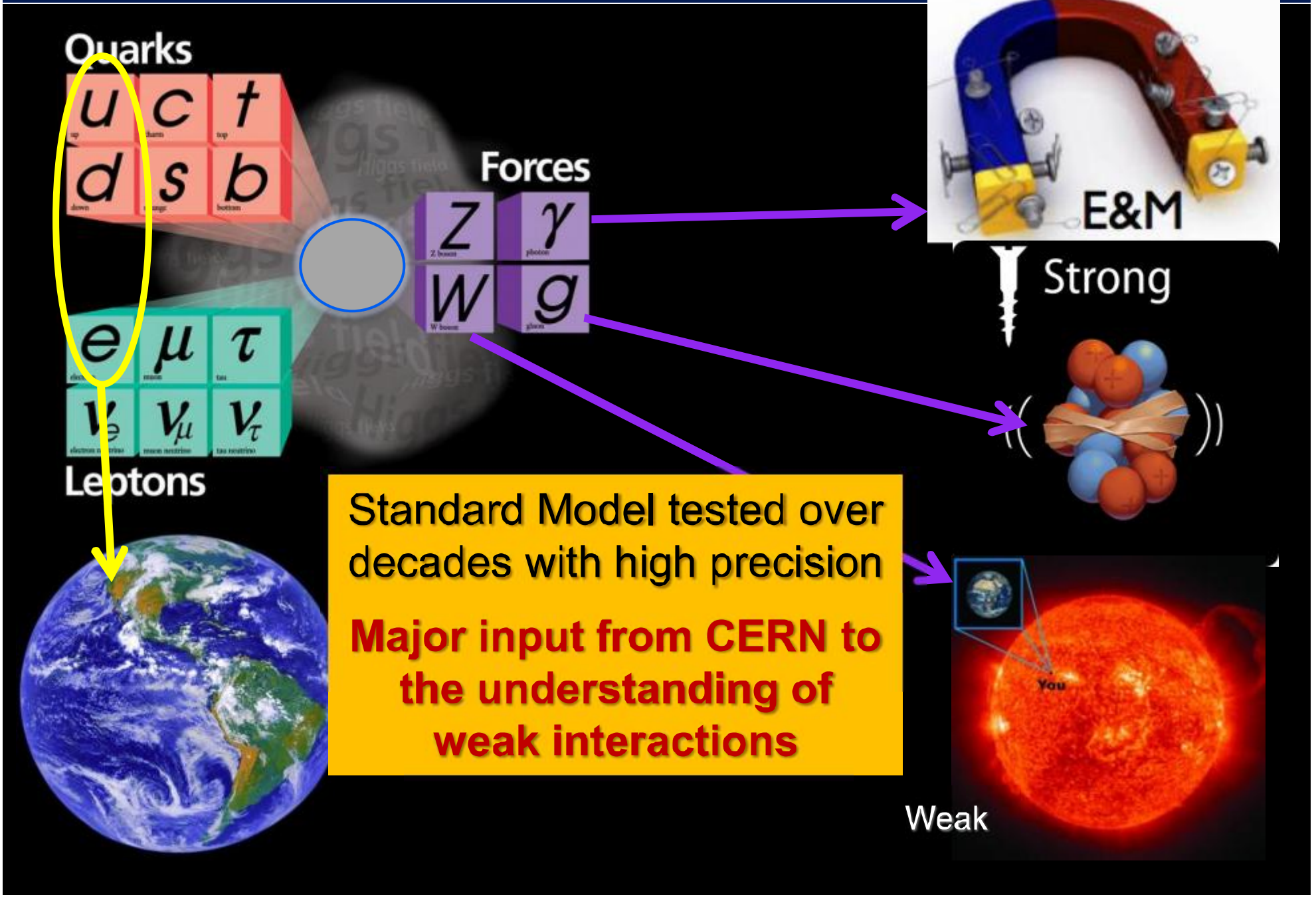


Energy range of the research conducted at CERN



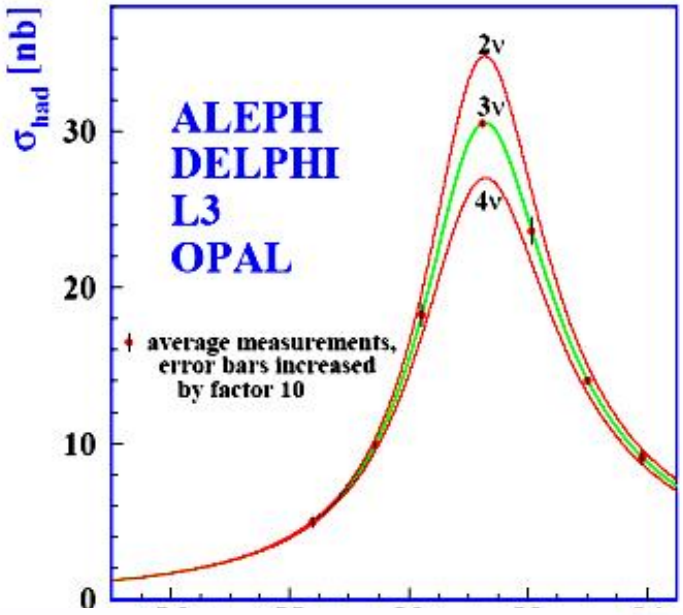
From antiatoms at the AD till Higgs boson at the LHC

The Standard Model

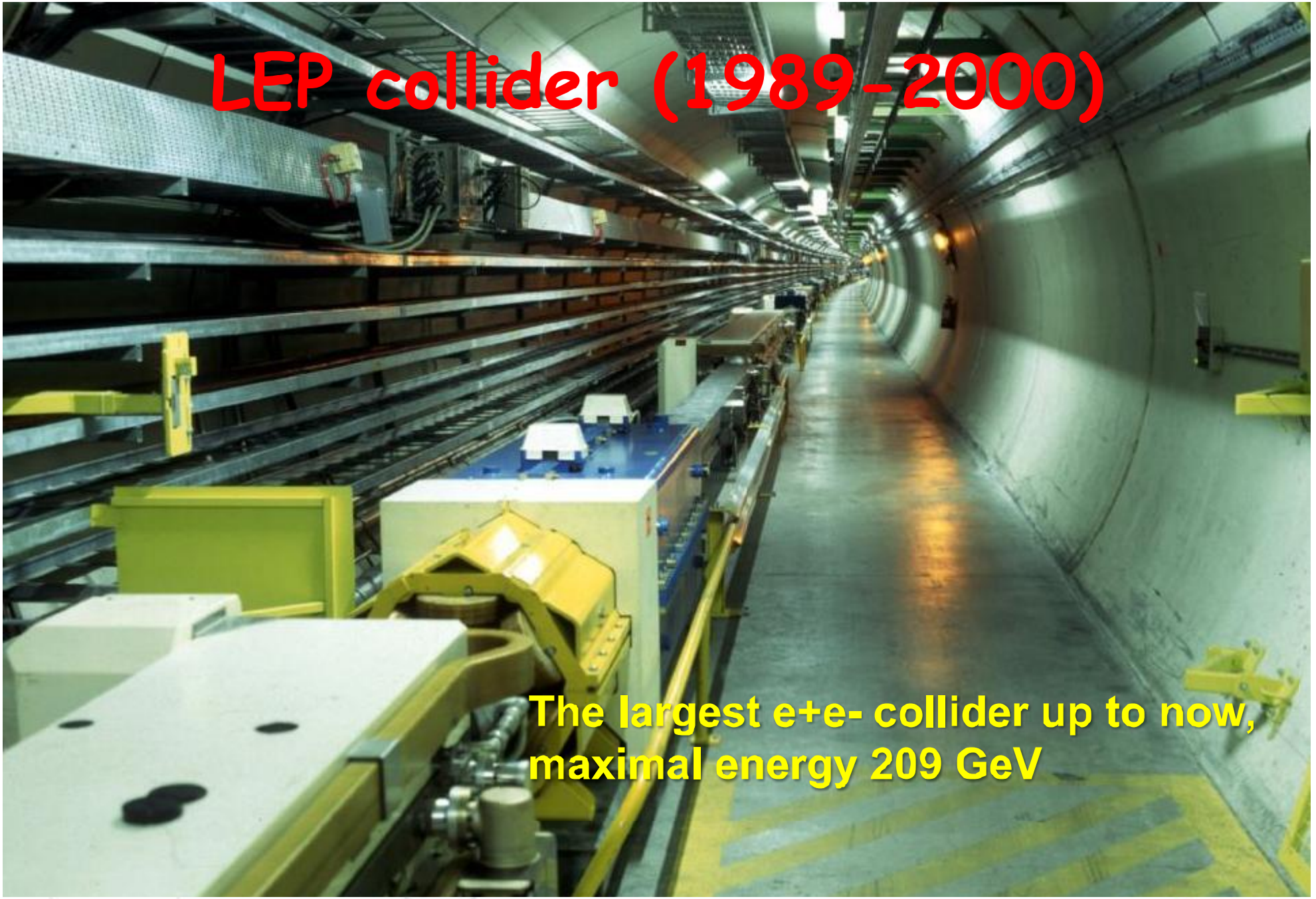


Research - highlights from the past

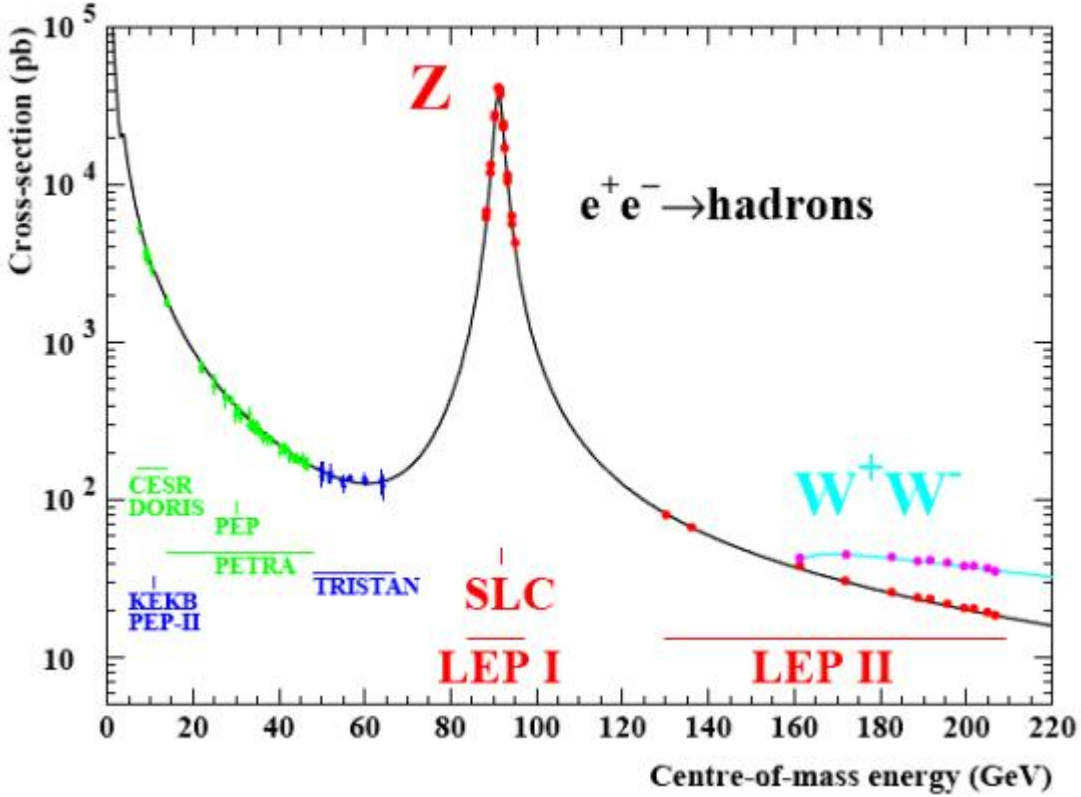
- 1973 – discovery on neutral current in the Gargamelle experiment
- 1982 – discovery of intermediate bosons W and Z
- 1990 – experimental evidence for the existance of three families of quarks and leptons



LEP collider (1989-2000)



Research programme at LEP: Precise tests of Standard Model



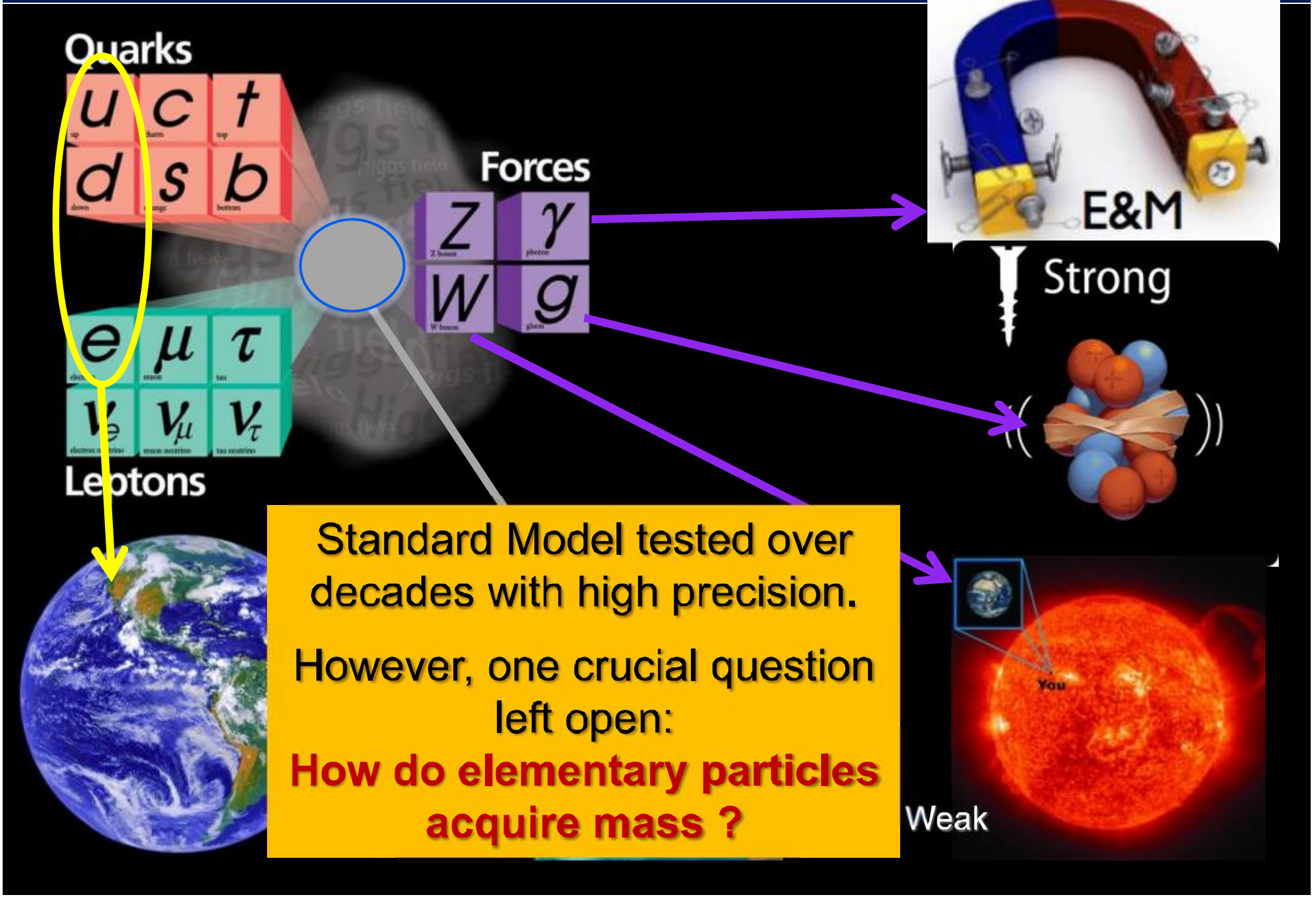
Electroweak theory for EM and weak interactions

Quantum chronodynamics for strong interactions

Correcting for such systematic effects like influence of tidal forces, ground water level or magnetic effects due to the TGV trains

The LEP legacy includes about 1300 publications, eg. predictions of the t quark and Higgs masses,
but also silicon vertex detectors and WWW protocol

The Standard Model



The LHC: A New Era in Fundamental Science

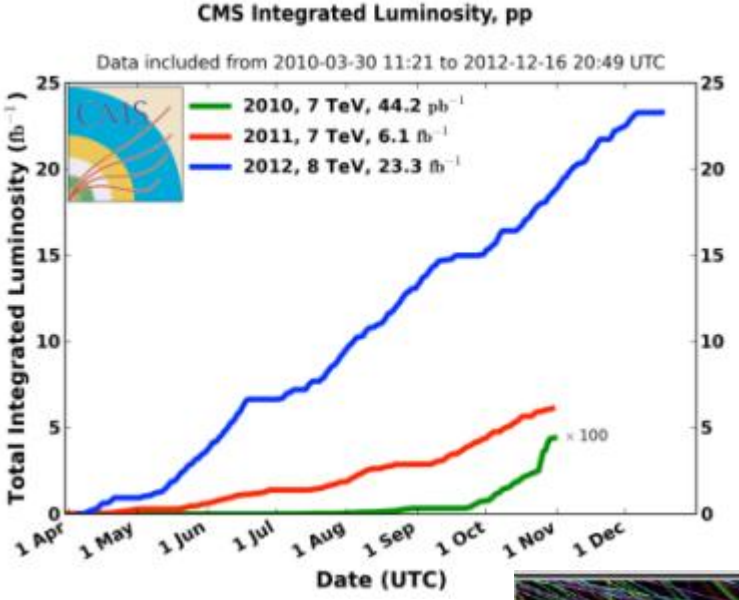
Exploration of a new energy frontier
proton-proton and heavy Ion collisions

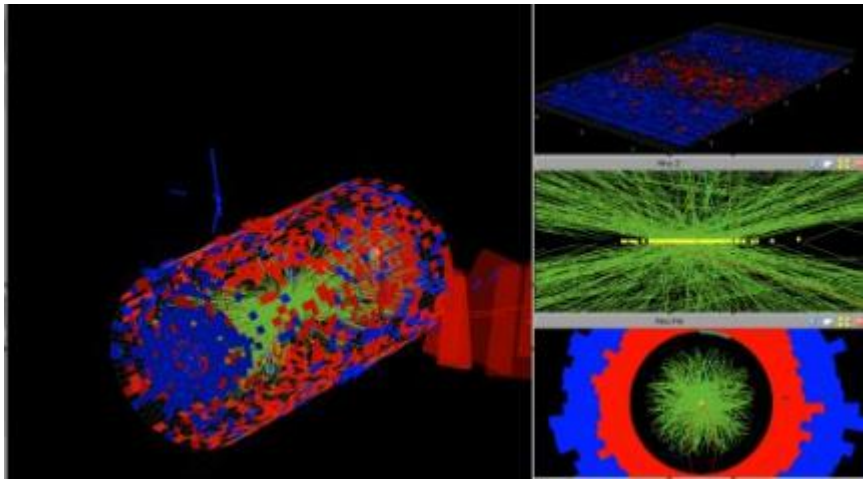
LHC collider (2008…, 2009 -)

LHC – fantastic performance in 2010-2012

p-p, Pb-Pb and p-Pb collisions

p-p: up to 1380 bunches per beam and 1.5×10^{11} protons/bunch

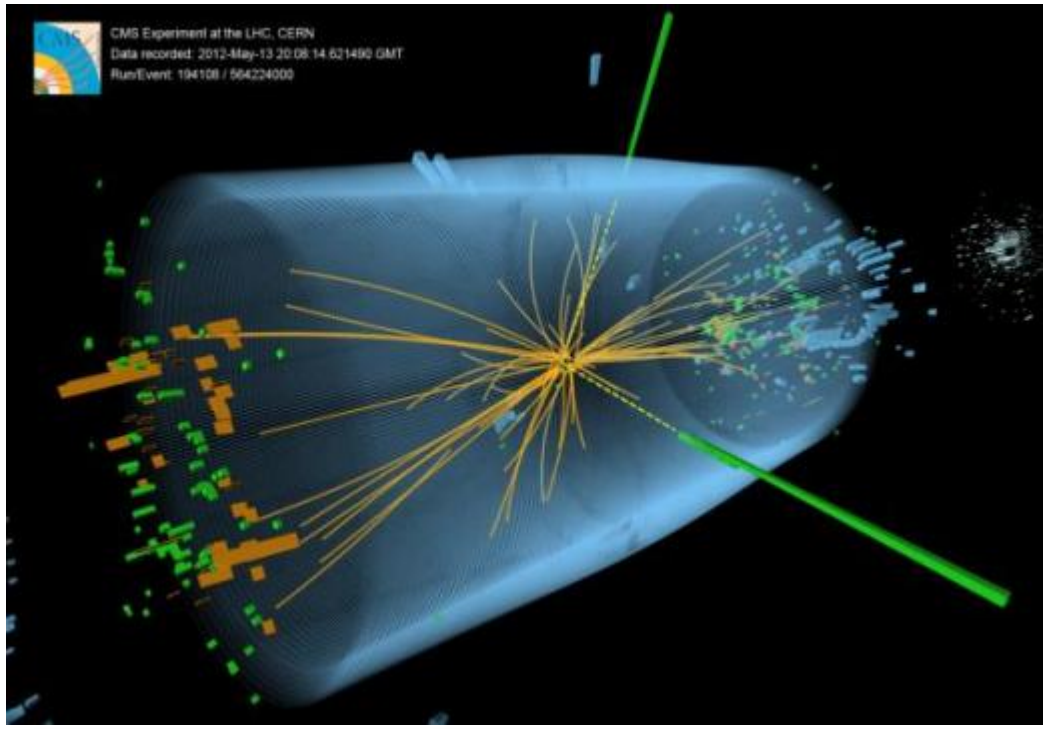




…And look for a Higgs boson in such a mess Is it necessary?

Yes, because one Higgs boson has to be selected out of 10 billions of ordinary (less interesting) pp interactions

Higgs boson decays on many different ways
A relatively „clean" decay channel is H→γγ



4 July 2012: CERN scientific seminar
"CERN experiments observe particle consistent with long-sought Higgs boson"

Further studies confirmed that:

1. It is a scalar particle with spin 0
2. Decay probability increases with masses of decay products

m_H = 125.09 ± 0.24 GeV
(0.21 stat. ± 0.11 syst.)

-- common result of the ATLAS and CMS experiments, announced on 17 March 2015

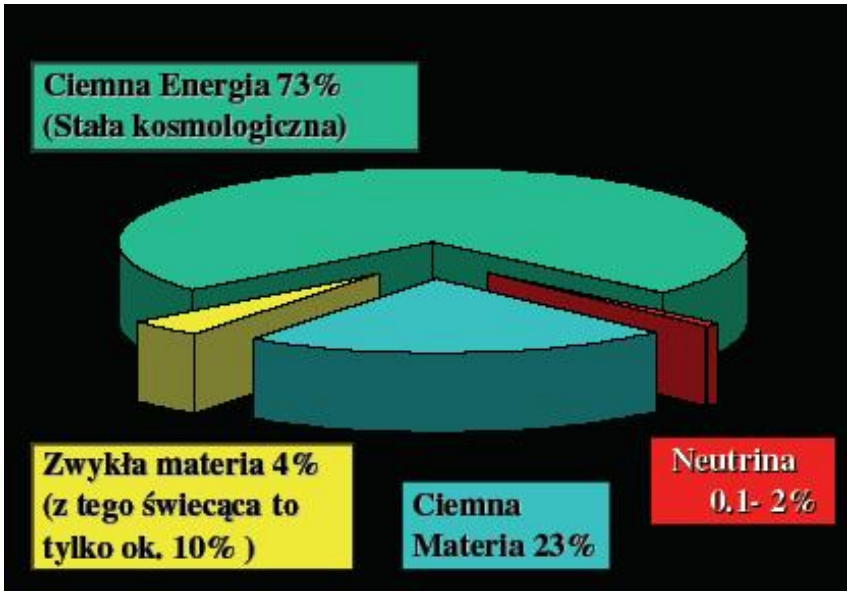
confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".

What else is/will be studied at the LHC ?

- The fundamental structure of matter and the origin of its mass.
  - Search for symmetry unifying all interactions of fundamental particles
  - Sources of the observed asymmetry between matter and antimatter
  - Studies of quark-gluon plasma

- What is Dark Matter ?
- What is Dark Energy ?

The completion of Standard Model means that we understand 5% of mass-energy of Universe!!!



Higgs boson is a unique fundamental particle

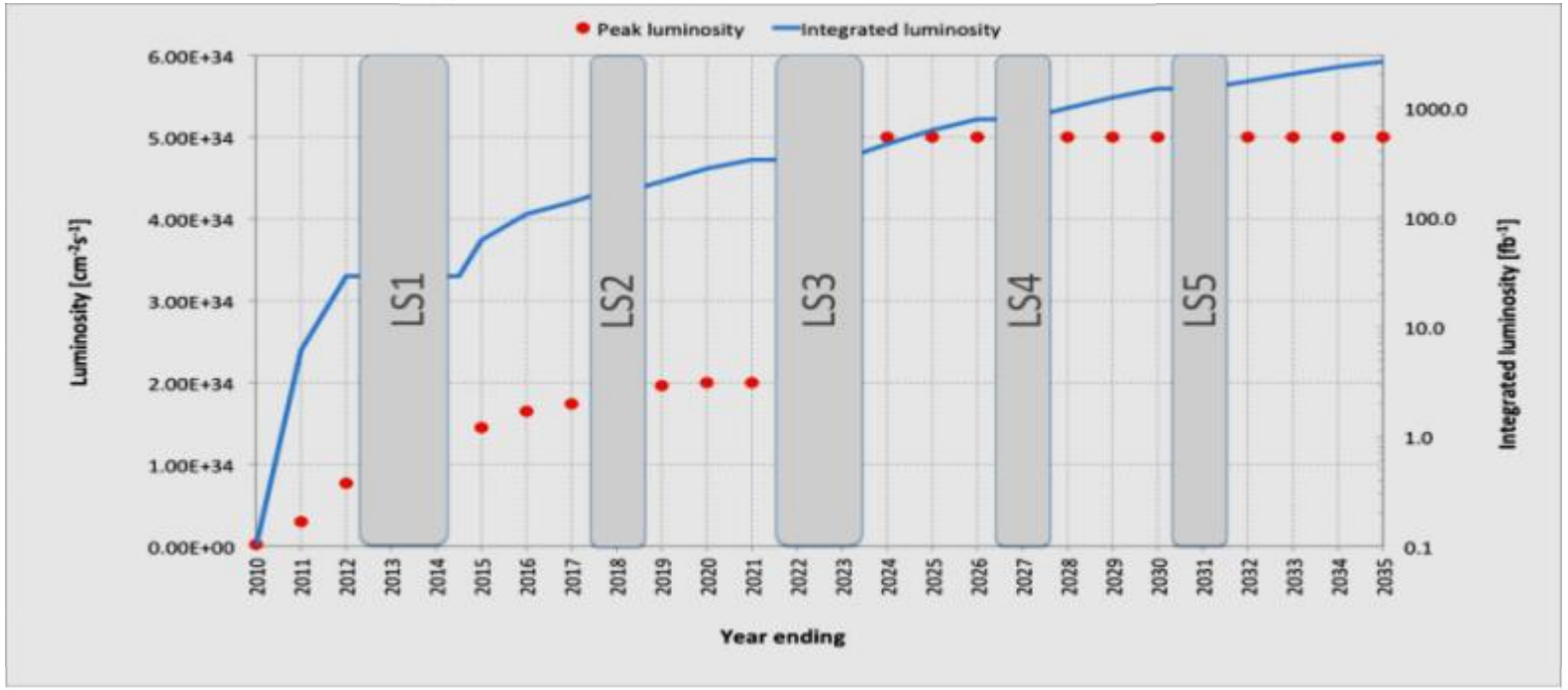
Fundamental particles of matter are fermions with a spin 1/2
Fundamental particles mediating in the interactions are bosons with a spin 1

Higgs boson is a scalar particle with spin 0
This is the first fundamental particle of this type

The Higgs field is everywhere in the Universe – does this have deaper consequences ?

Future of the LHC

„Europe's top priority should be the exploitation of the full potential of the LHC"



Milestones: design energy of 13-14 TeV in 2015-2016 and the luminosity upgrade up to 5 10^{34} cm^{-2} s^{-1} (HL-LHC)

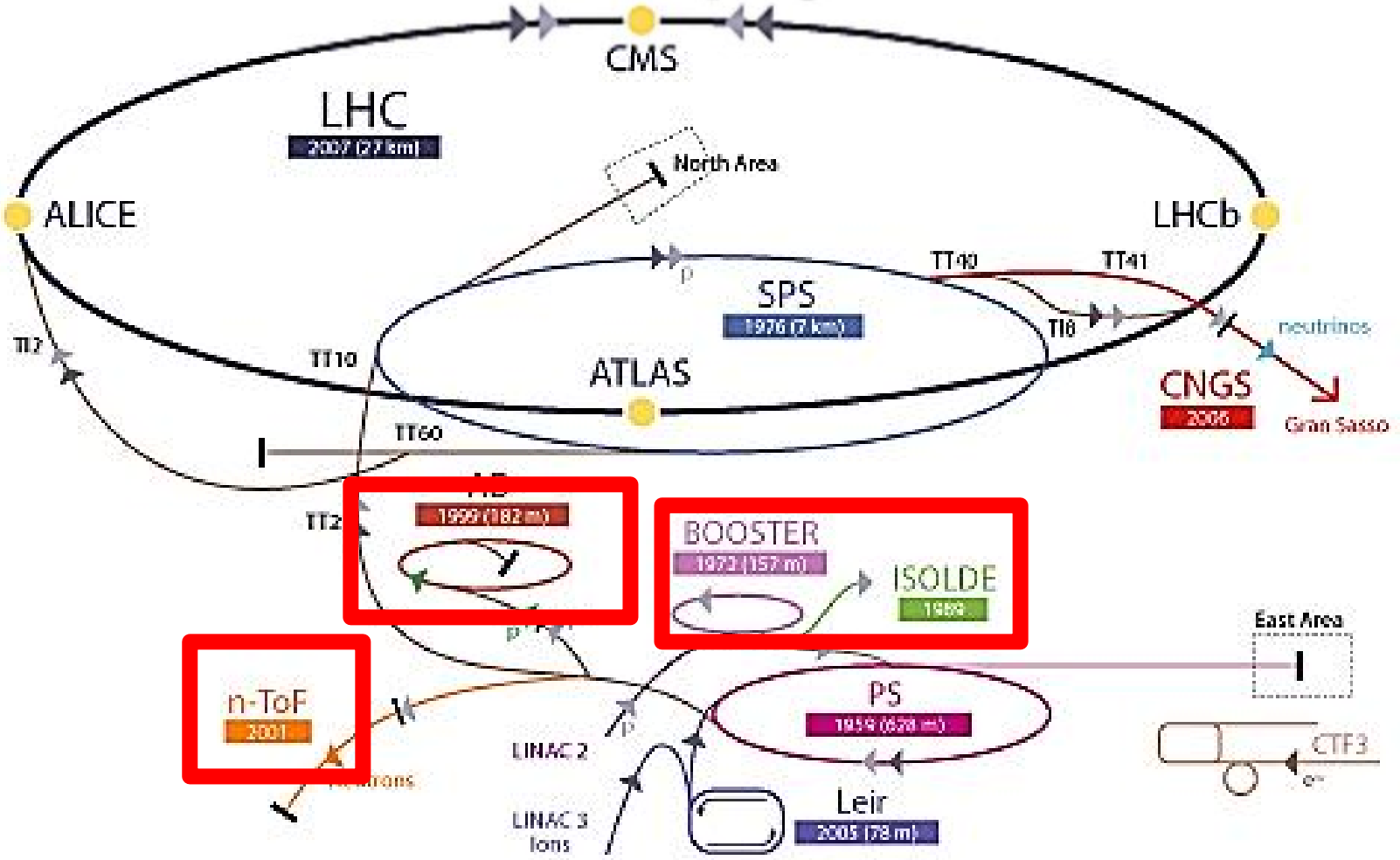
HL-LHC (for pp collisions): on average 140 interactions every 25 ns.

First physics runs planned in June !

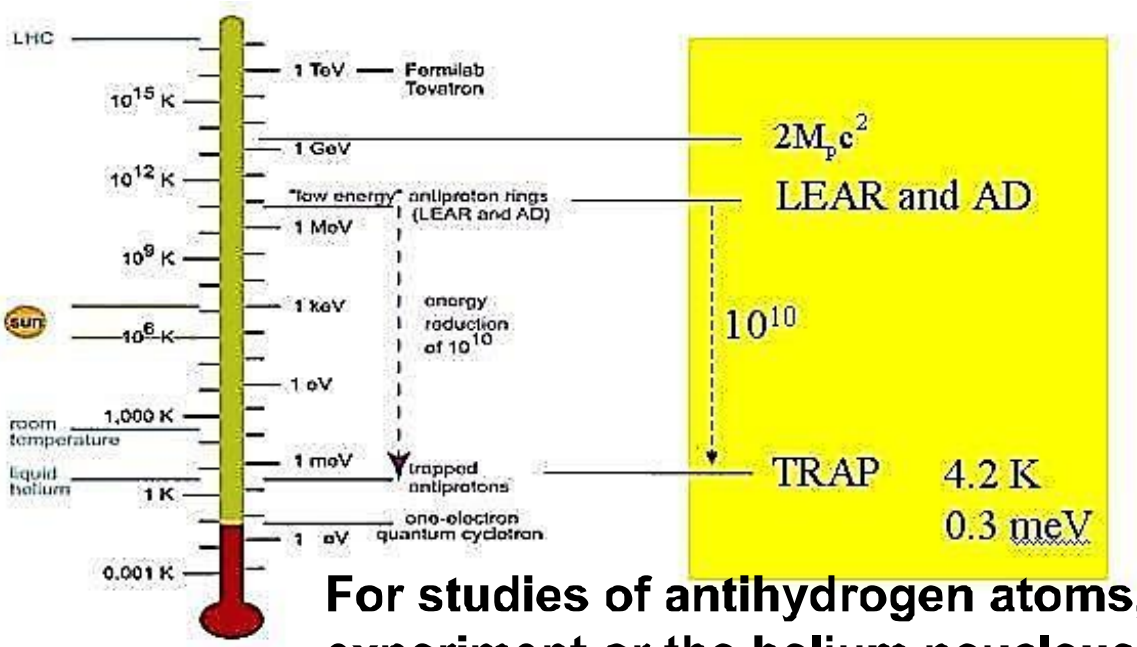
Unique non-LHC research programme at CERN:

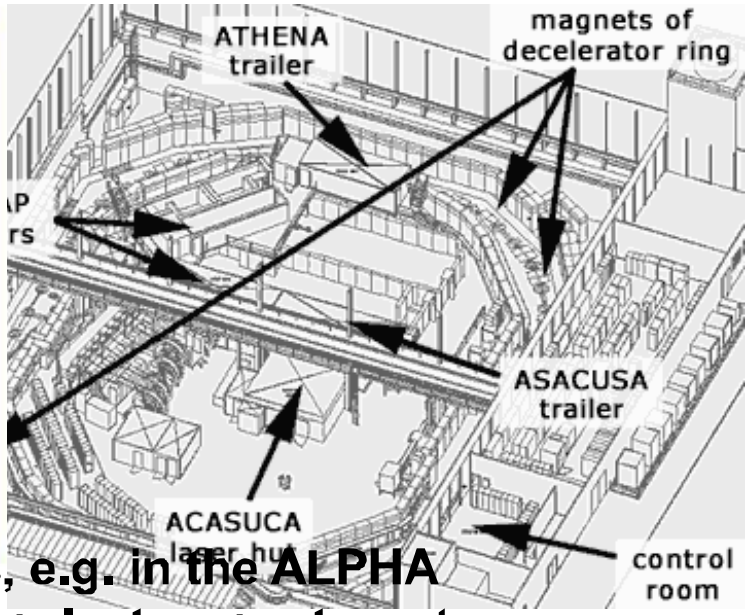
- Atomic physics at AD (→ +ELENA)
- Nuclear physics at ISOLDE (→ HIE-ISOLDE) and nTOF (→ +nTOF EAR2)
- Experimental programme at the SPS – searches for new phenomena in Kaon decays, studies of quark-gluon plasma, neutrino physics: CNGS beam till the end of 2012, „neutrino platform" at present
- CAST and OSQAR – searches for axions
- Cloud – laboratory studies of clouds formation

Atomic and nuclear physics at CERN

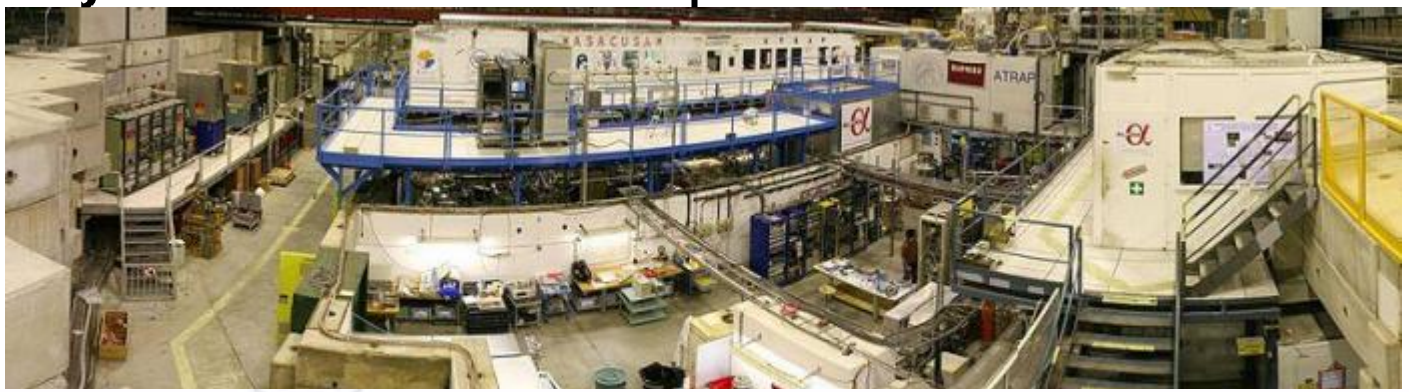


Antiproton Decelerator (-> ELENA) – unique facility for studies of antiatoms at CERN





For studies of antihydrogen atoms, e.g. in the ALPHA experiment or the helium neucleus+electron+antyproton system in the ASACUSA experiment`



What is the research programme behind the production of antihydrogen atoms ?

Are the spectroscopic properties of hydrogen and antihydrogen atoms identical?

Is the gravitational interaction for hydrogen exactly the same as for antihydrogen?

The answer „no” to these questions would mean discovering new phenomena

ISOLDE/REX-ISOLDE/HIE-ISOLDE

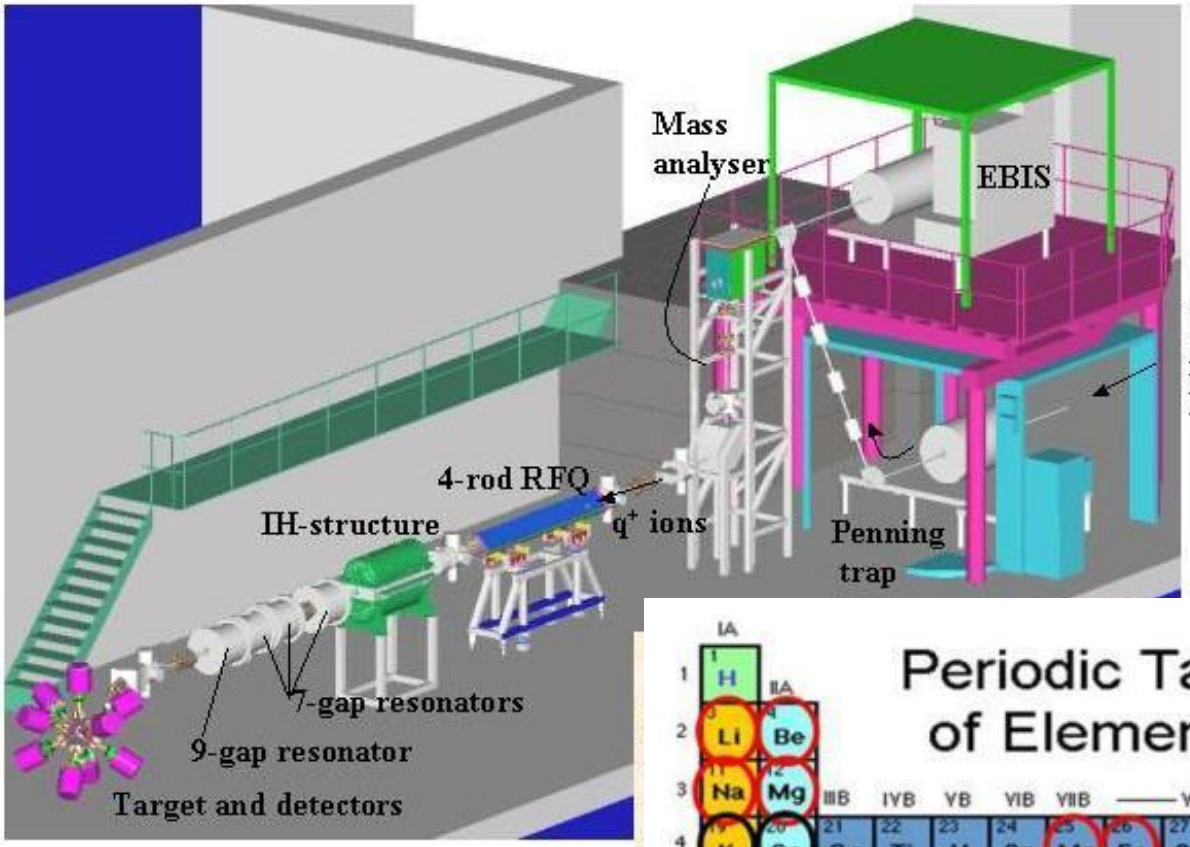
- High intensity proton beam, accelerated in PSB up to the energy of 1.4 GeV, is extracted from the accelerator and collided with a thick target.

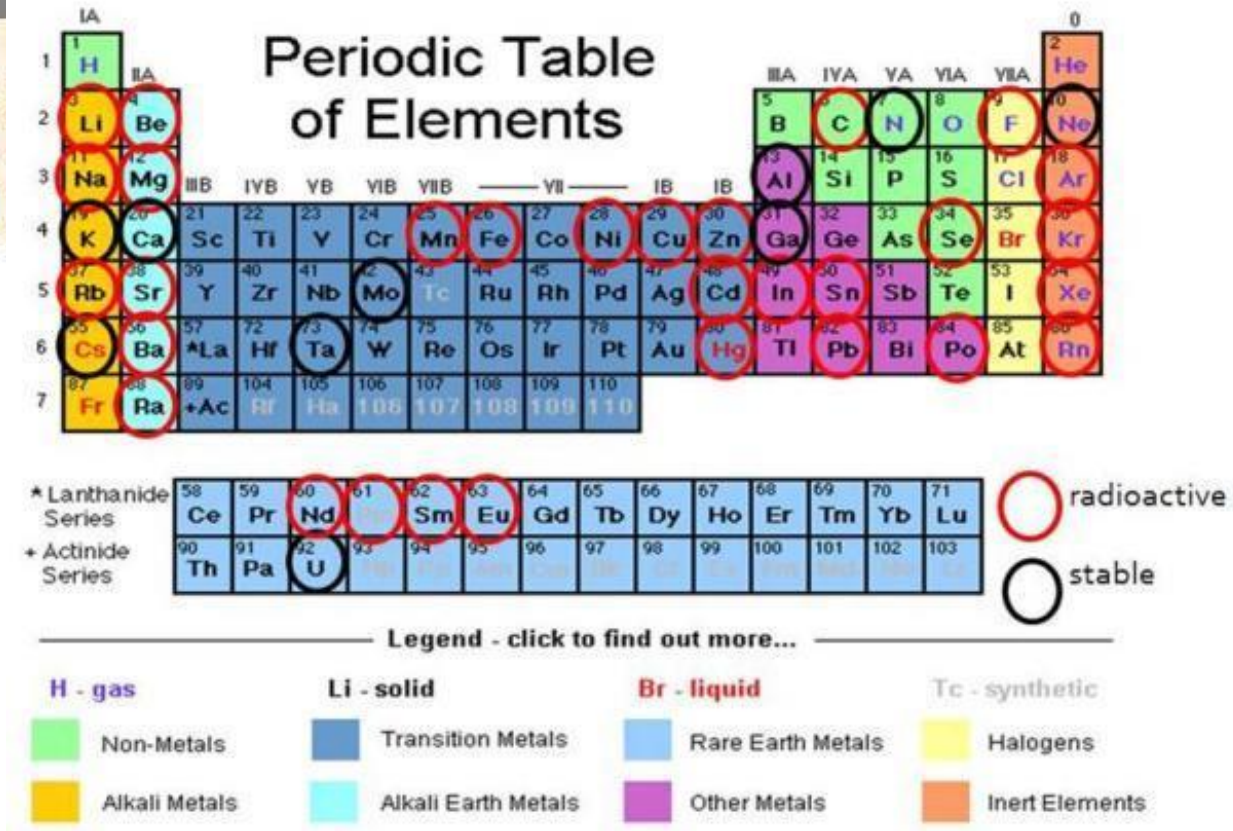
- Products of nuclear reactions, extracted from the target, are separated according to their masses and collected. This way **beams of more than 600 isotopes of almost 70 elements have been produced**, with lifetimes as short as single miliseconds and with intensities as high as 10^{11} atoms per 1 microA of the proton beam.

- Such beams can be then accelerated in REX-ISOLDE till the energy between 0.8 and 3 MeV/u and collided with different nuclei.

- The currently performed upgrade of REX-ISOLDE to HIE-ISOLDE will give an increased energy of accelerated radionuclei, first till 5.5 and then till 10 MeV/u. This will largely extend possibilities to study structure of nuclei as well as performing measurements important for astrophysics, solid state physics and material science.

REX-ISOLDE

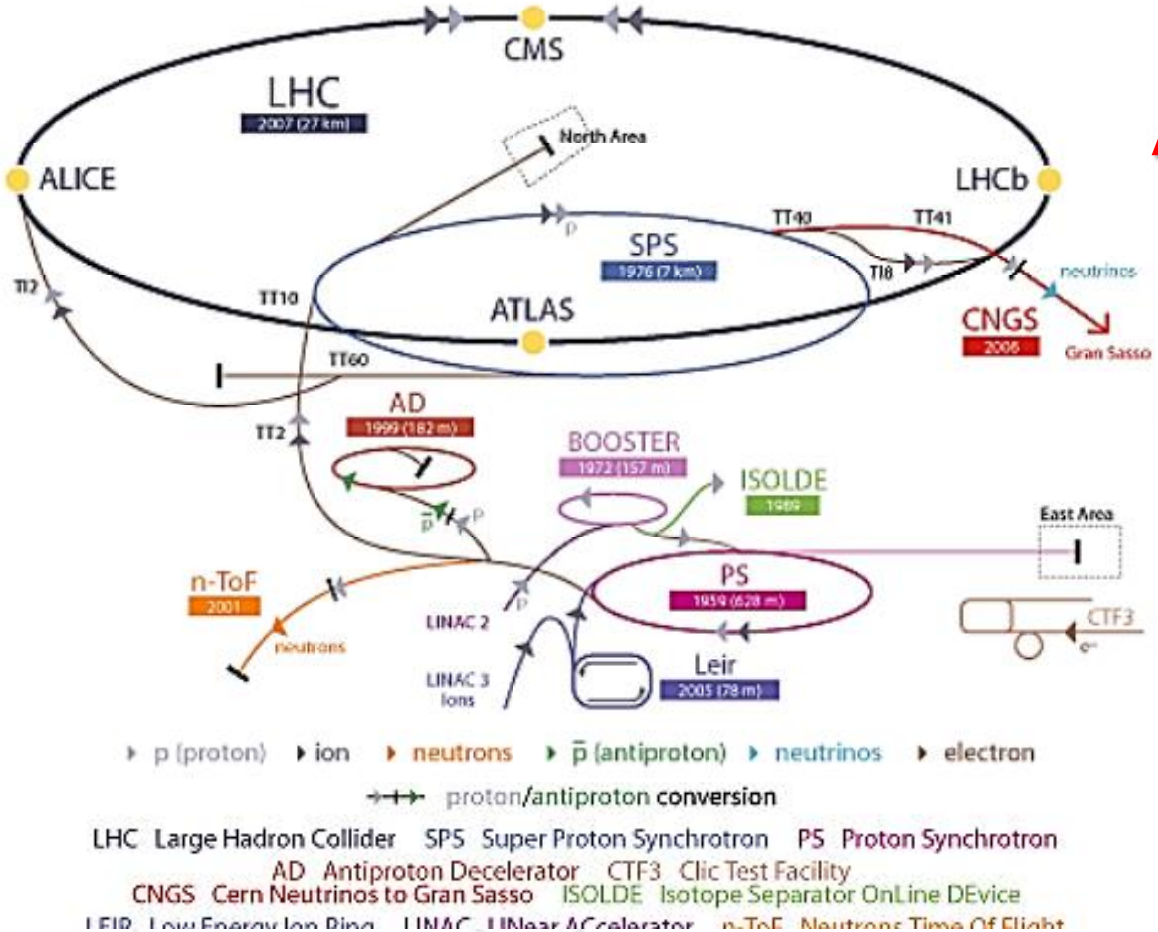

Mass analyser
EBIS
1+ ions from ISOLDE
4-rod RFQ
q+ ions
IH-structure
Penning trap
7-gap resonators
9-gap resonator
Target and detectors


Periodic Table of Elements
* Lanthanide Series
+ Actinide Series
radioactive
stable
Legend - click to find out more...
H - gas
Li - solid
Br - liquid
Tc - synthetic
Non-Metals
Transition Metals
Rare Earth Metals
Halogens
Alkali Metals
Alkali Earth Metals
Other Metals
Inert Elements


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

Technology

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.

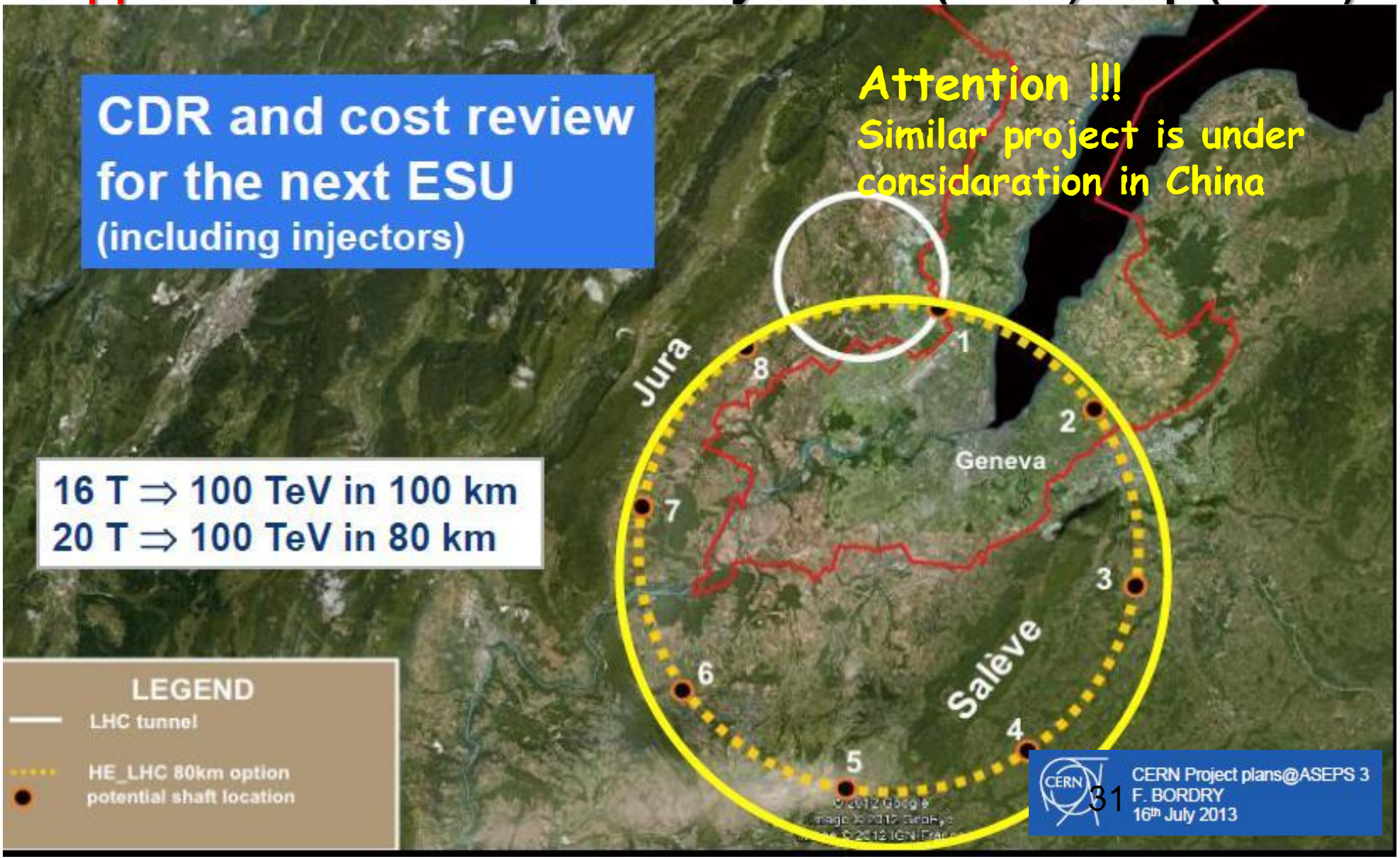
The same technology is at work inside solar panels on the roof of Geneva airport.

Accelerators for the future

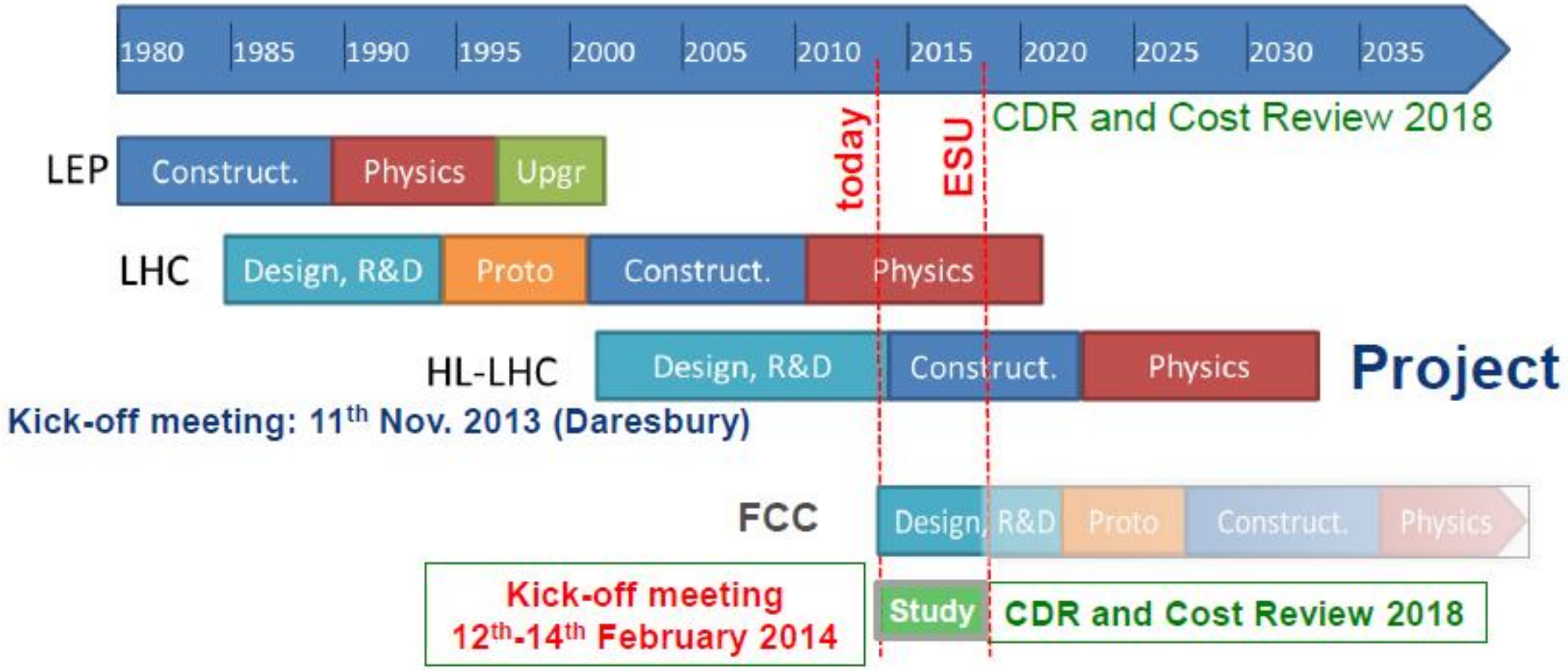
In 2011 at the workshop in Lund CERN and other major European laboratories committed themselves to making the best and most efficient use of power that drives accelerators: to concentrate on the best ways to deliver and recover energy, to store it, to recycle heat and save water etc.

What after the LHC at CERN ?

FCC (Future Circular Colliders) at the energy of about 100 TeV in pp collisions with a possibility of e+e- (TLEP) i e±p (LHeC)



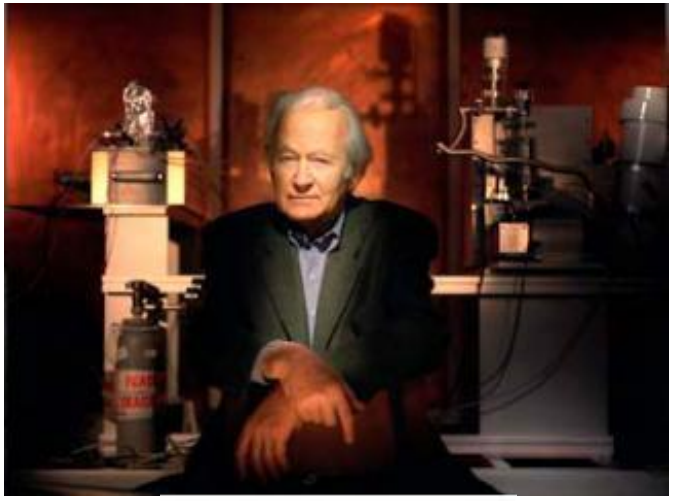
Timescale for colliders at CERN



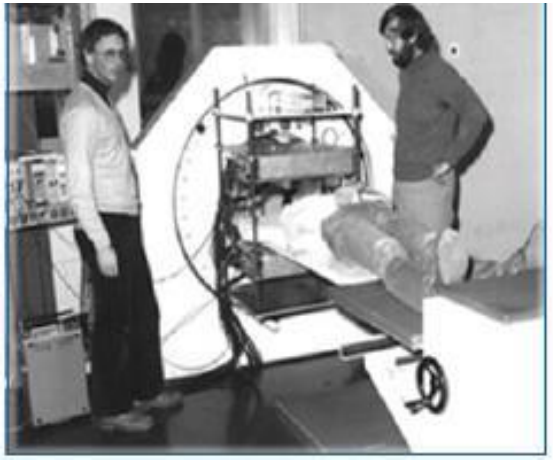
M.Benedikt

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. They have found multiple other applications, notably in medical diagnosis and radioactive control.



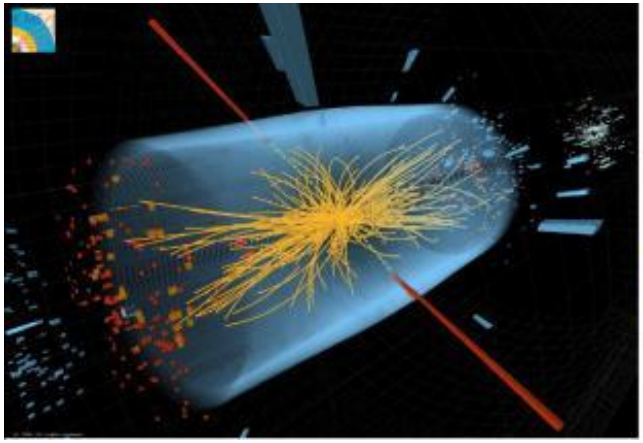
1924 – 2010

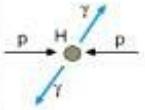


1980 – first PET HIDAC (High-Density Avalanche Chamber) scanner,
Installed in the Nuclear Medicine Department at Geneva Cantonal Hospital and used for medical imaging by applying the ^{124}I isotope

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 two years ago it was made publicly available.

This was a generous gift from CERN to the humanity.

Web-inventor Tim Berners-Lee

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.

Key elements in CERN's success

- Ambitious scientific projects with defined deadlines
- Excellent scientists and engineers forming very creative environment → mariage of science and technology
- 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

Collaboration between Cracow University of Technology and CERN

- **Started in 1990 (25 years ago!)** – prof. Michał Życzkowski i B. Nizioł from CUT and C. Arnaud, P. Faugeras, D. Gùseweld, T. Kurtyka, A.Poncet, P. Rohmig from CERN

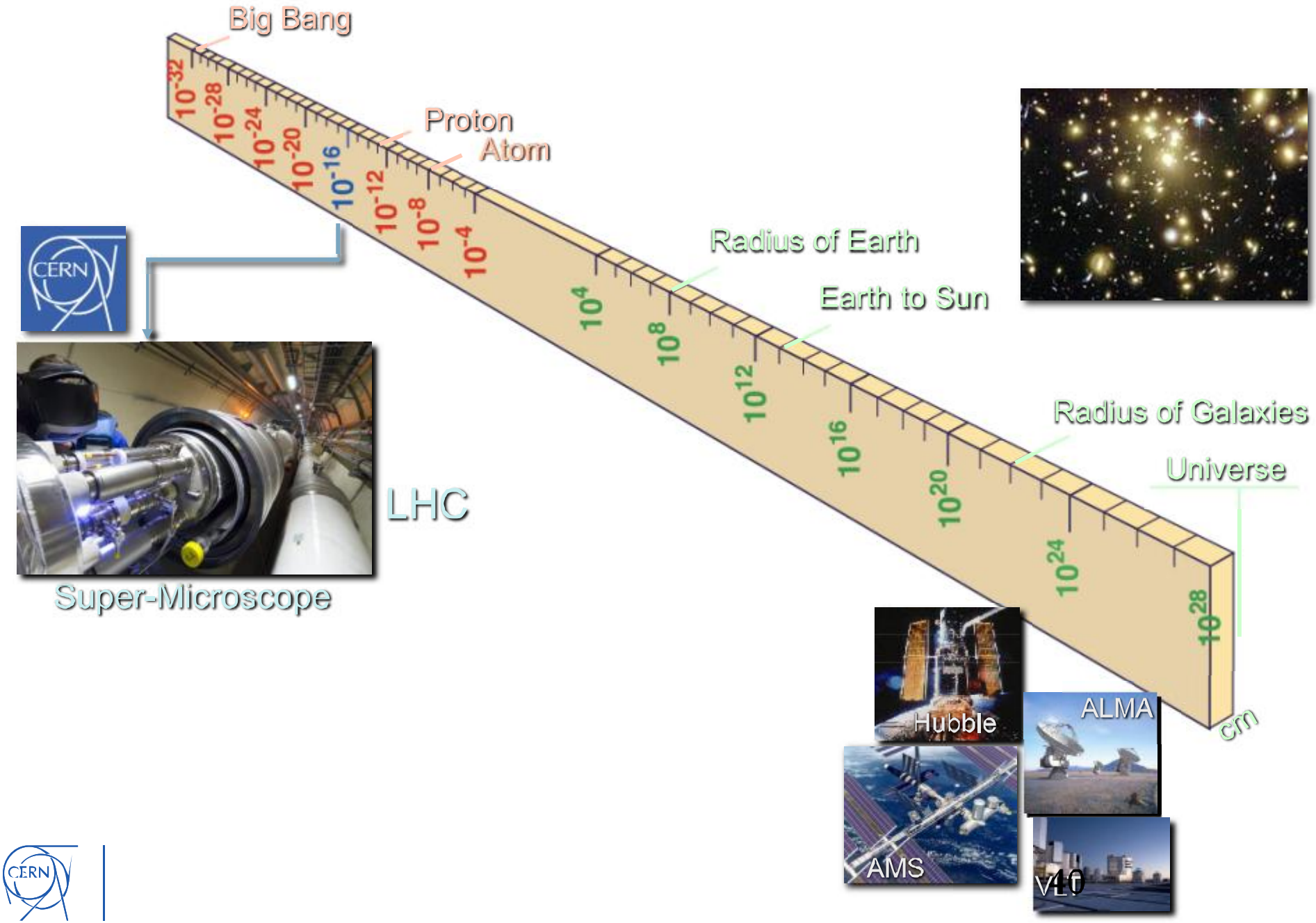
  About 20 staff members and 30 students from CUT have participated in various CERN projects, eg. Concerning the LHC collider and detectors
- **Main research subjects:**contributions to accelerator designs, beam transport systems, superconducting magnets and supply lines, magnet control systems, termo-mechanical compensation systems, cryogenic systems, cryostats, cooling systems and mechanical support systems for detectors
- **Results:** 3 monographs, 1 habilitation, 6 PhD theses, 11 diploma theses, about 100 technical notes and CERN reports, about 50 publications
- **Centre for Particle Accelerators Design** – since 2007, led by Professor Błażej Skoczeń.

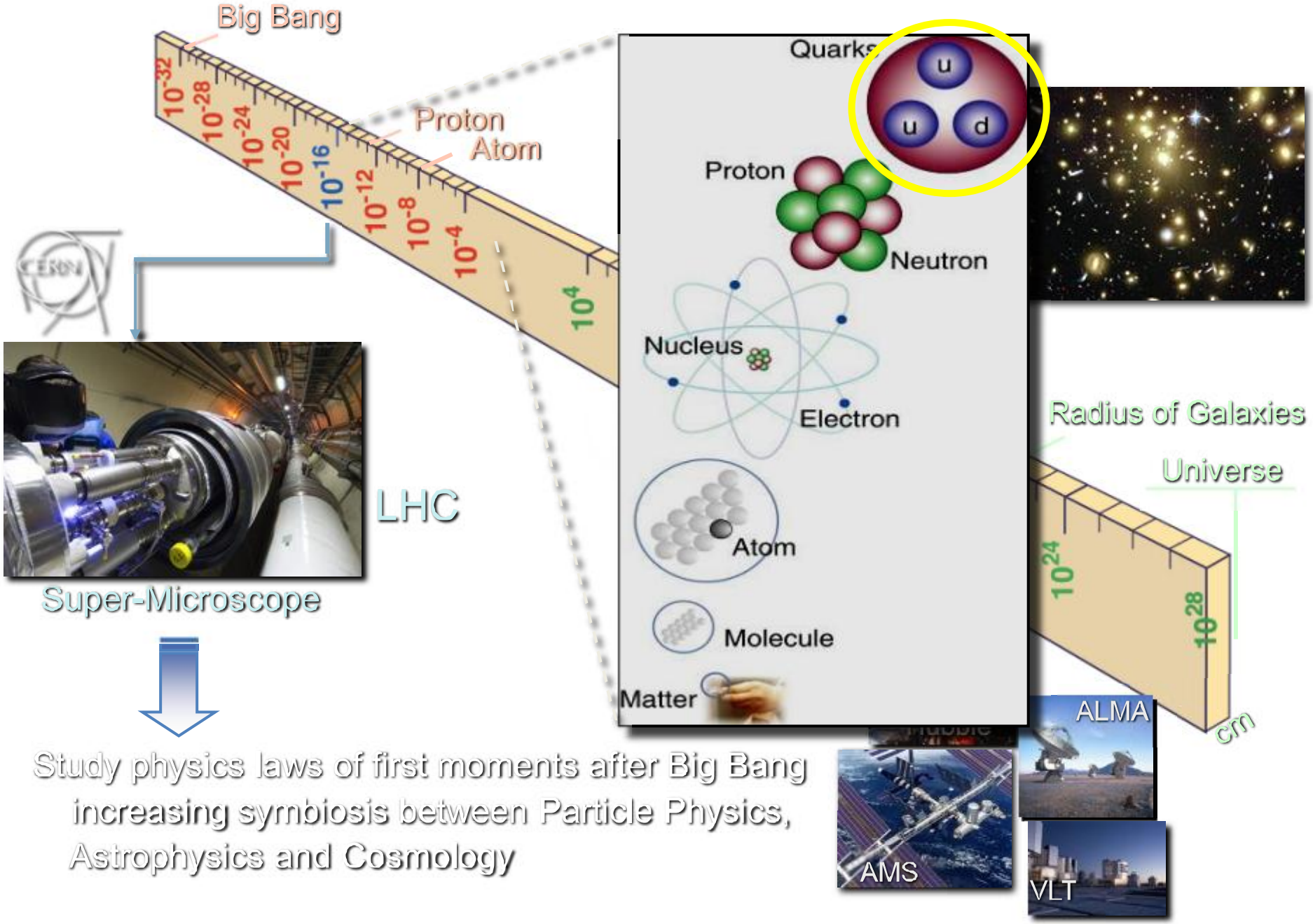
We should never forget that

"There is no applied science without science to be applied"

(Bernardo Houssay, a Nobel Prize winner in medicine)

Thank you


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
CERN
LHC
Super-Microscope
Hubble
ALMA
AMS
VLT


Big Bang
Proton
Atom
10^{-32}
10^{-28}
10^{-24}
10^{-20}
10^{-16}
10^{-12}
10^{-8}
10^{-4}
10^{4}
Quarks
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d
Proton
Neutron
Nucleus
Electron
Atom
Molecule
Matter
Radius of Galaxies
Universe
10^{24}
10^{28}
cm
LHC
Super-Microscope
ALMA
AMS
VLT
Study physics laws of first moments after Big Bang
increasing symbiosis between Particle Physics,
Astrophysics and Cosmology