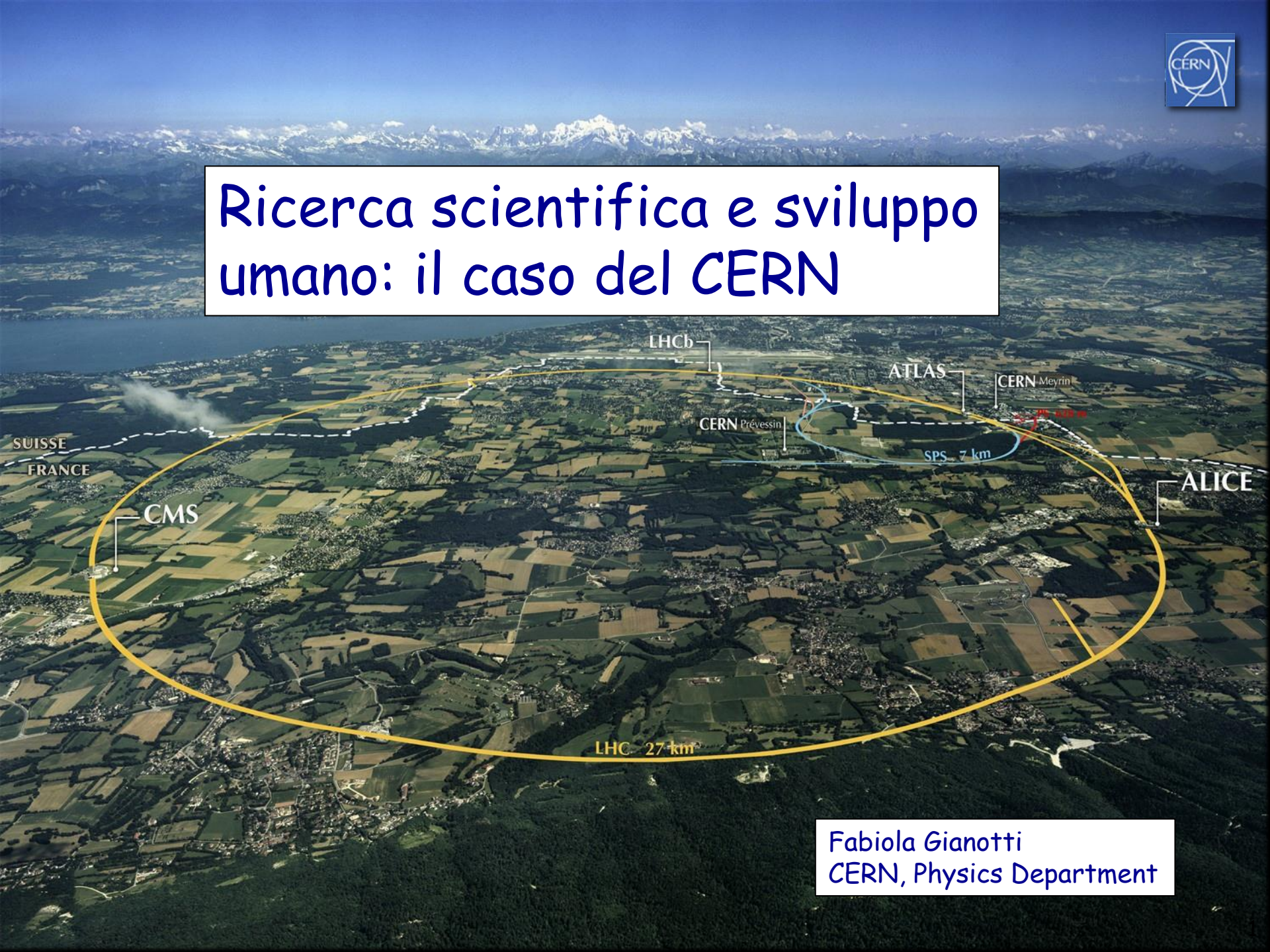
Ricerca scientifica e sviluppo umano: il caso del CERN



Fabiola Gianotti
CERN, Physics Department

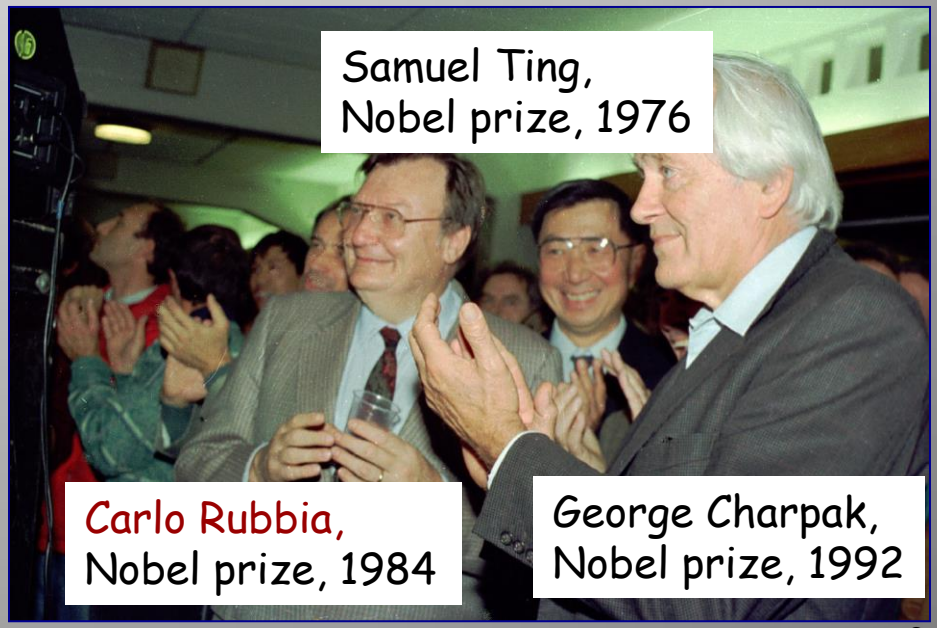
CERN : the largest particle physics laboratory in the world

International Organization based in Geneva

Mission:

- science: fundamental research in particle physics
- technology and innovation → transferred to society (e.g. the World Wide Web)
- training and education
- bringing the world together: > 11000 scientists, > 110 nationalities

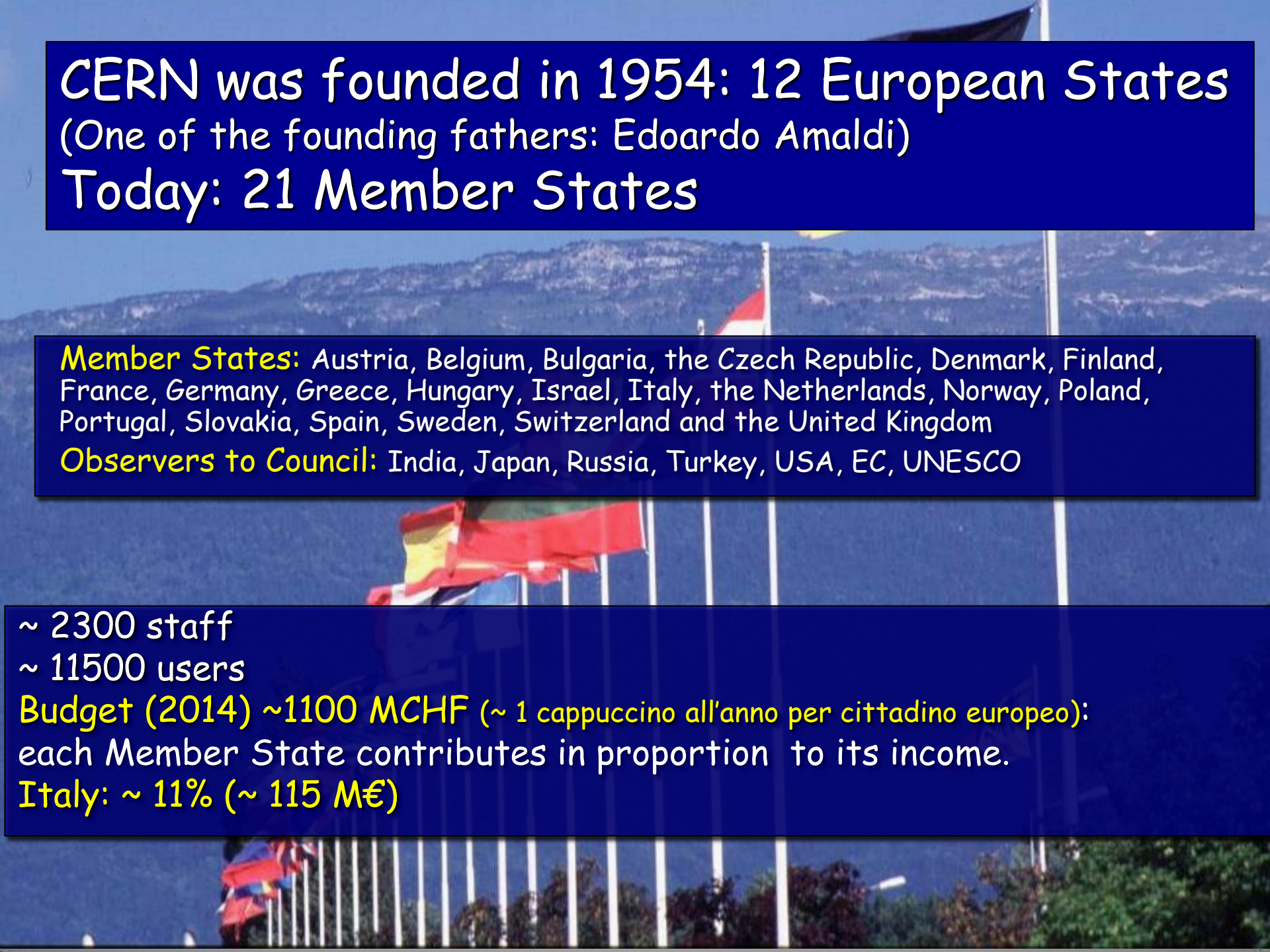
CERN staff member T. Berners-Lee, inventor of the WEB, with Kofi Annan and CERN DG Luciano Maiani



Samuel Ting, Nobel prize, 1976

Carlo Rubbia, Nobel prize, 1984

George Charpak, Nobel prize, 1992



CERN was founded in 1954: 12 European States
(One of the founding fathers: Edoardo Amaldi)
Today: 21 Member States

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

Observers to Council: India, Japan, Russia, Turkey, USA, EC, UNESCO

~ 2300 staff

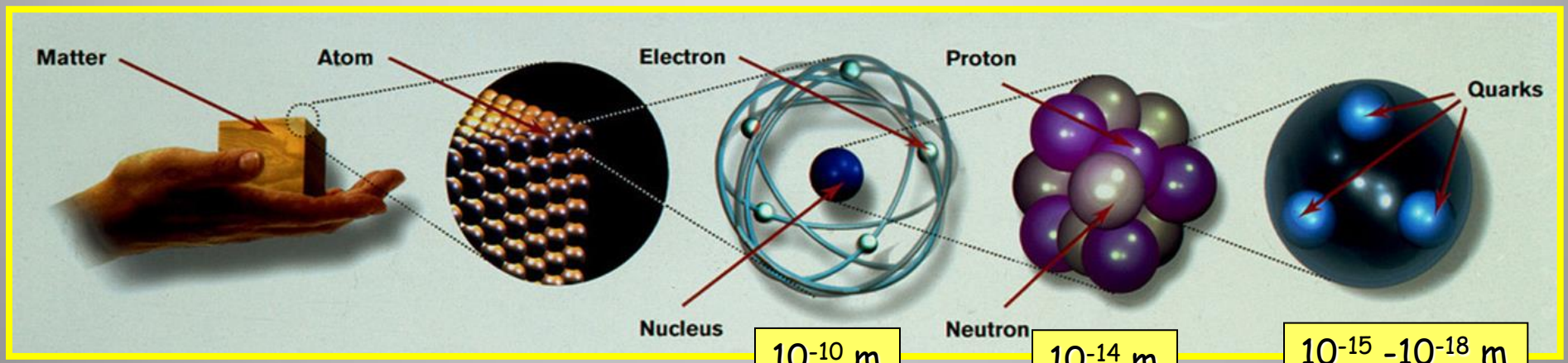
~ 11500 users

Budget (2014) ~1100 MCHF (~ 1 cappuccino all'anno per cittadino europeo):
each Member State contributes in proportion to its income.

Italy: ~ 11% (~ 115 M€)

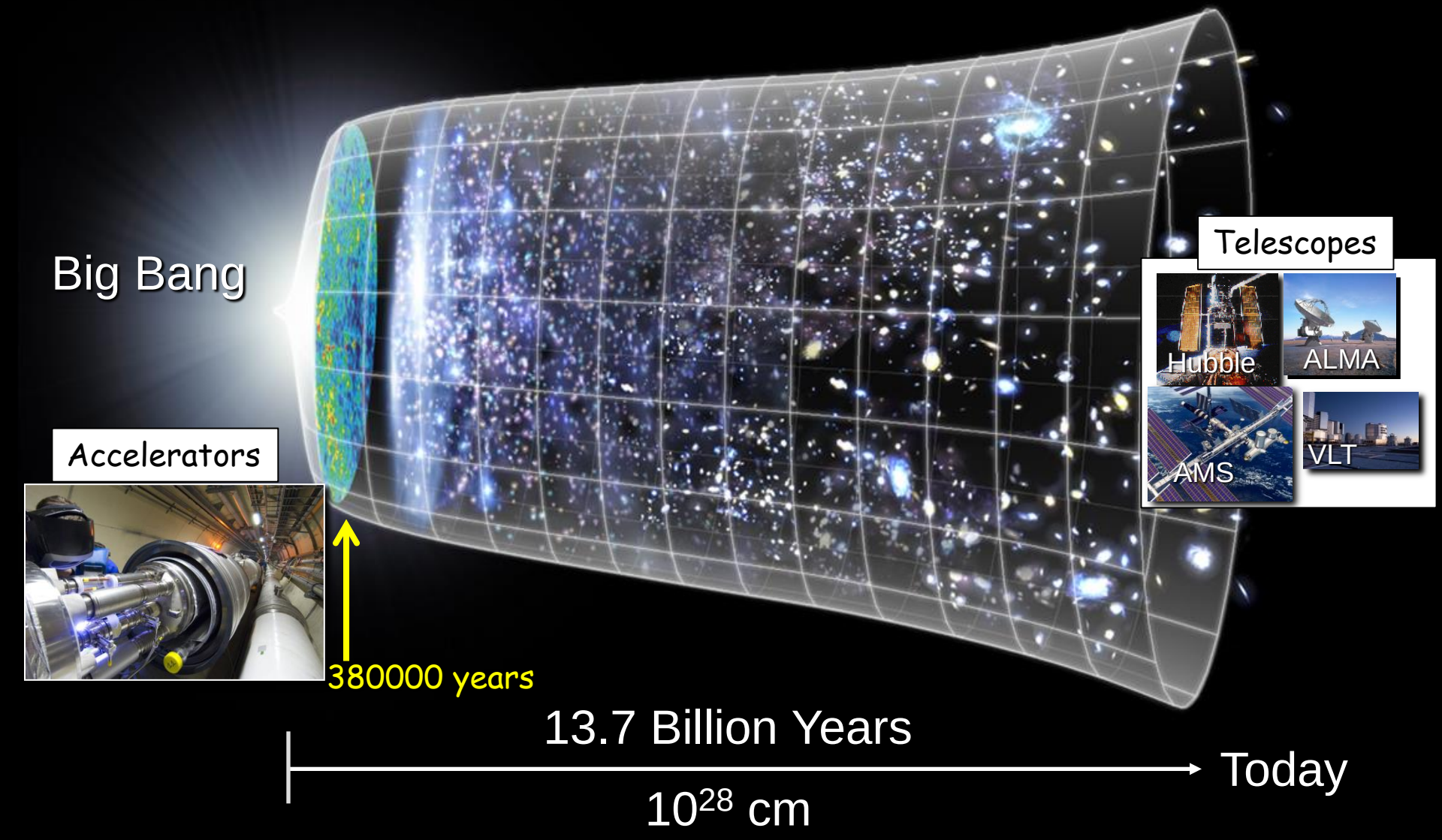
CERN's primary mission is SCIENCE

Study the elementary particles (e.g. the building blocks of matter: electrons and quarks) and the forces that control their behaviour at the most fundamental level

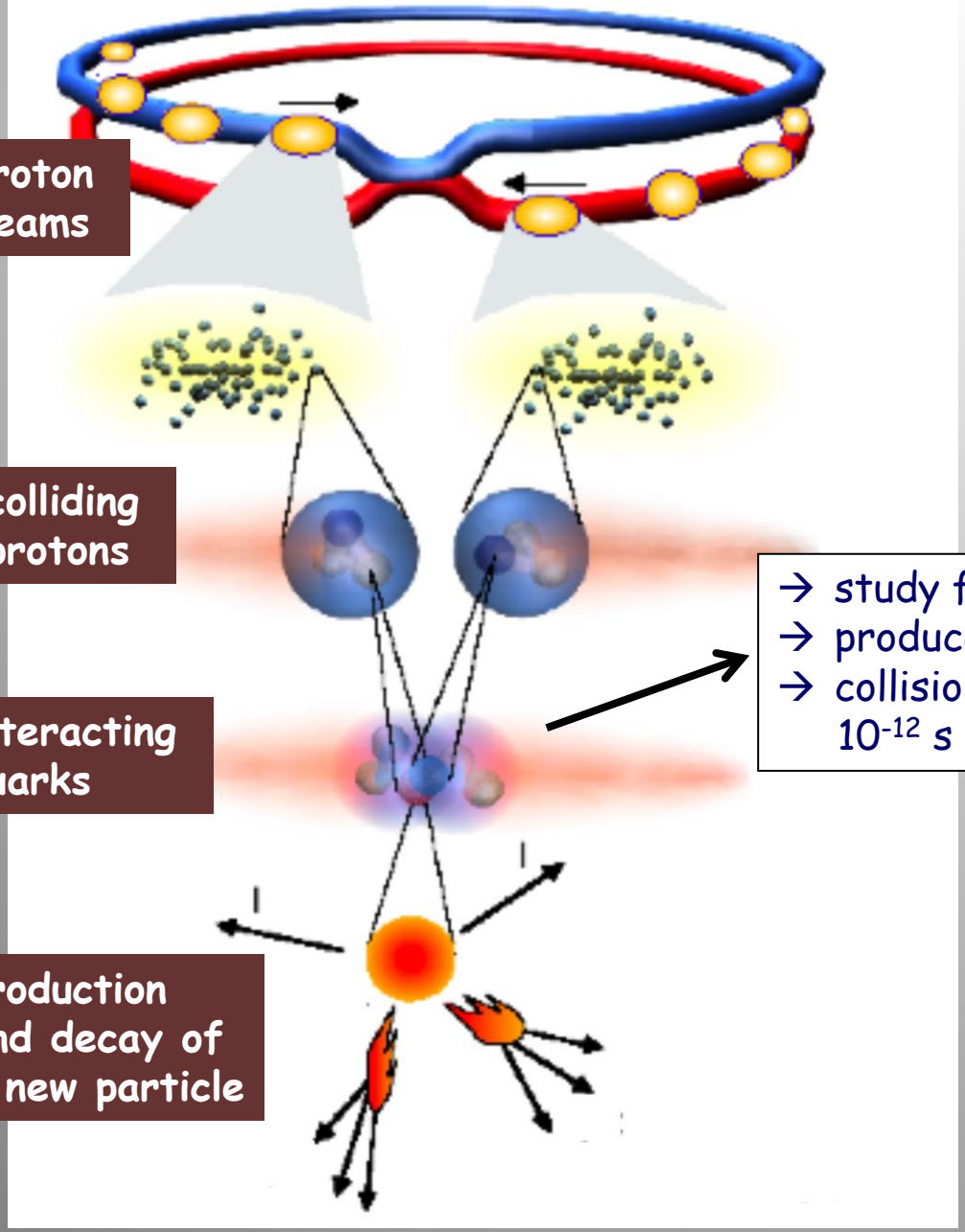


Particle physics at modern accelerators allows us to study the fundamental laws of nature on scales down to smaller than 10^{-18} m
→ insight also into the structure and evolution of the Universe
→ from the very small to the very big …

Evolution of the Universe



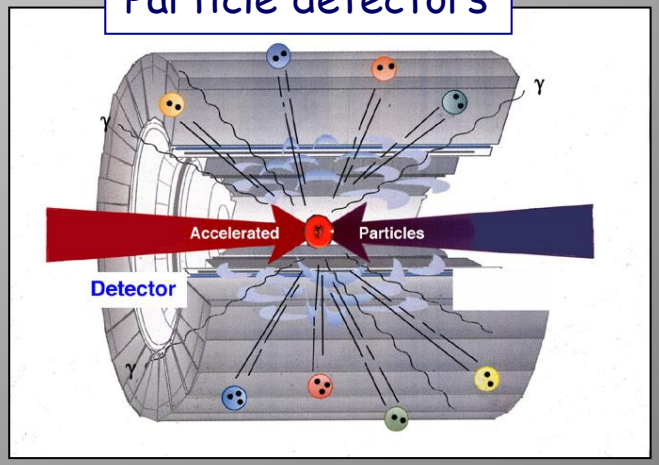
To study the elementary particles and their interactions:



→ study fundamental constituents of matter
→ produce (new) heavy particles
→ collision energy = temperature of universe 10^{-12} s after Big Bang

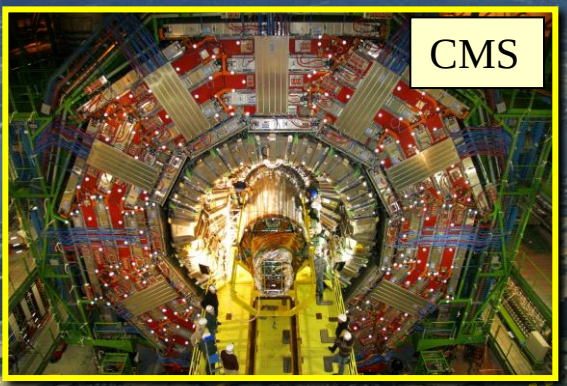
Accelerators

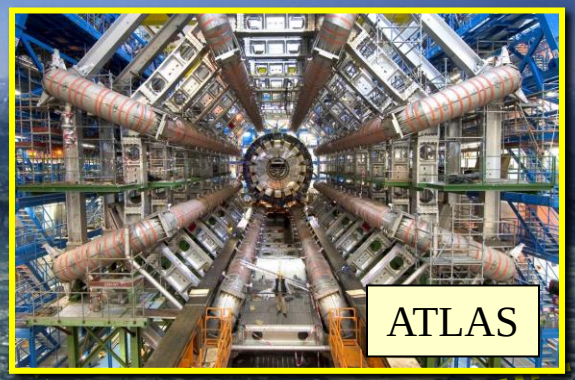
Particle detectors



The Large Hadron Collider (LHC): the most powerful accelerator ever

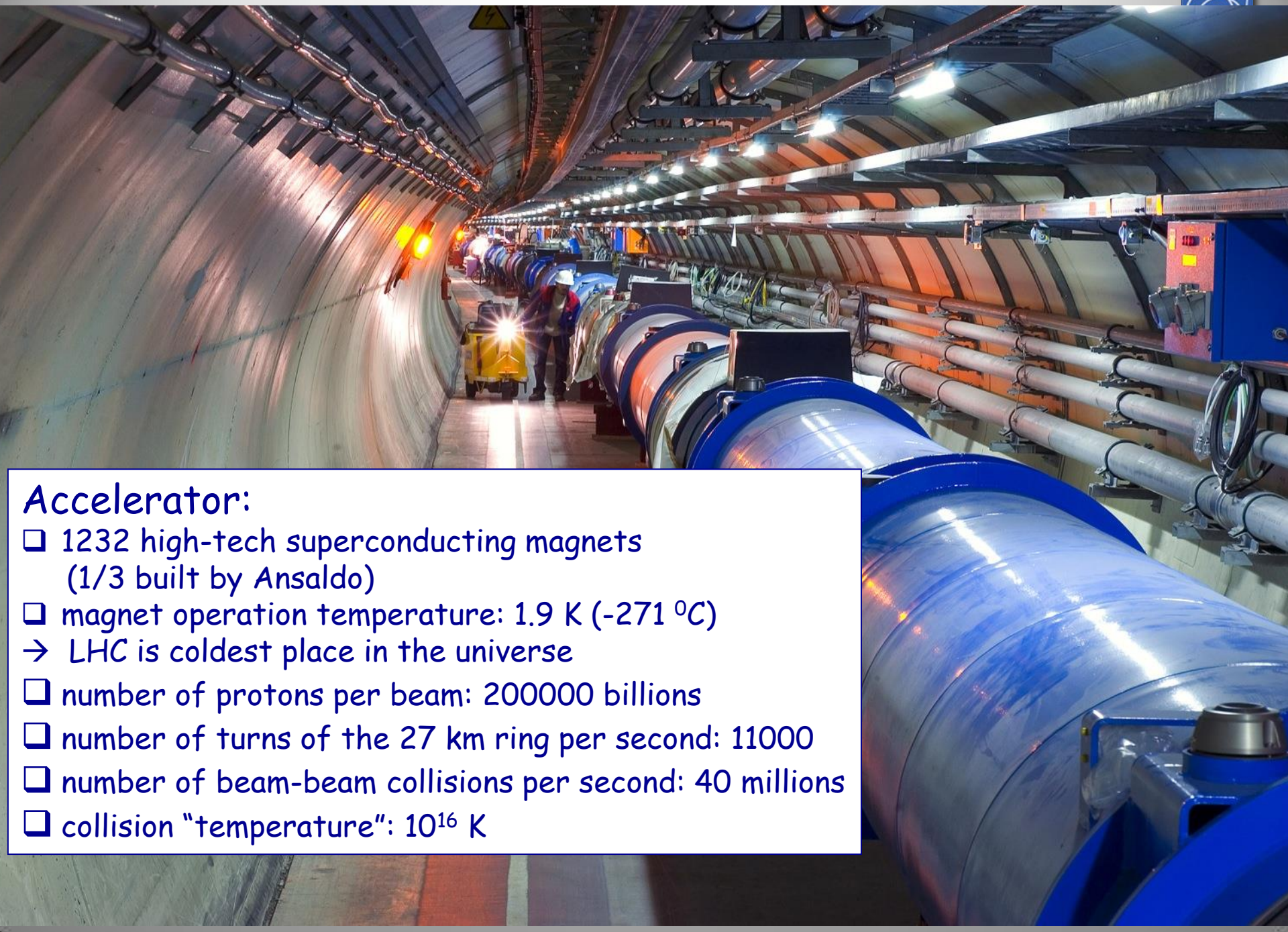
- 27 km ring, 100 m underground
- operation started in 2010 → exploration of new energy frontier





LHCb
ATLAS
CERN
CERN Prévessin
SPS 7 km
CMS
ALICE

On 4th July 2012, ATLAS and CMS announced the discovery of a new particle: the Higgs boson

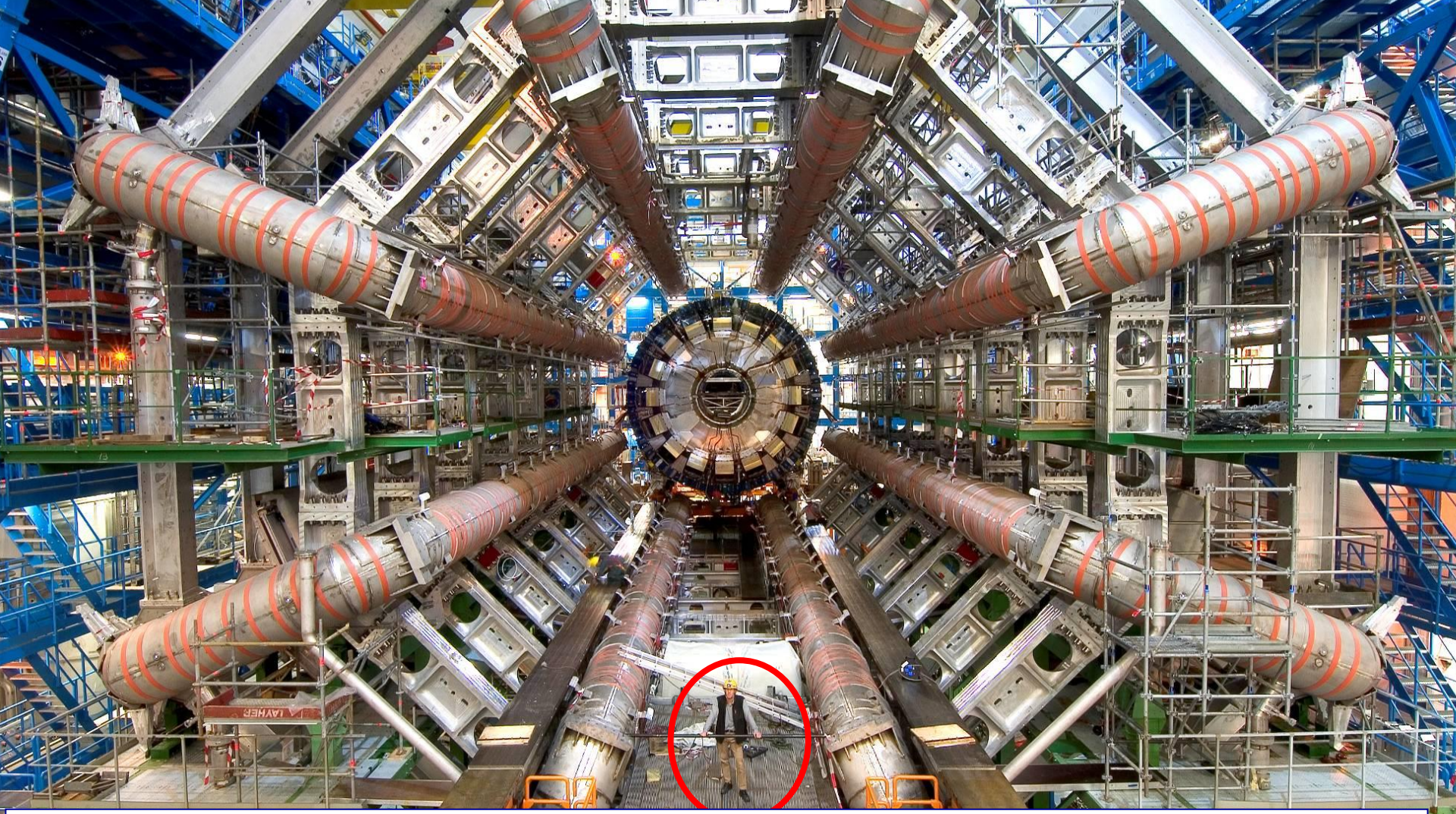


Accelerator:

- 1232 high-tech superconducting magnets (1/3 built by Ansaldo)
- magnet operation temperature: 1.9 K (-271 ^{0}C)

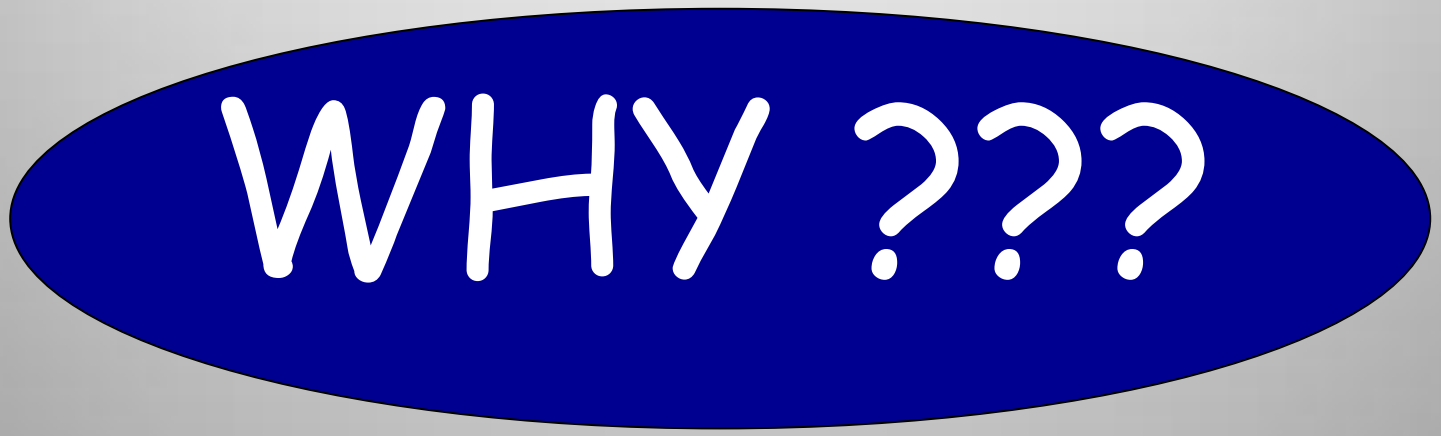
→ LHC is coldest place in the universe

- number of protons per beam: 200000 billions
- number of turns of the 27 km ring per second: 11000
- number of beam-beam collisions per second: 40 millions
- collision "temperature": 10^{16} K



Detectors:

- size of ATLAS: ~ half Notre Dame cathedral
- weight of CMS experiment: 13000 tons (more than Eiffel Tour)
- number of detector sensitive elements: 100 millions
- cables needed to bring signals from detector to control room: 3000 km
- data in 1 year per experiment: ~10 PB (20 million DVD; more than YouTube, Twitter)


WHY ???

LHC built to address outstanding questions in fundamental physics

What is the origin of the masses of the elementary particles (quarks, electrons, …) ? → related to the Higgs boson ✔

95% of the universe is unknown (dark): e.g. 20% of dark matter

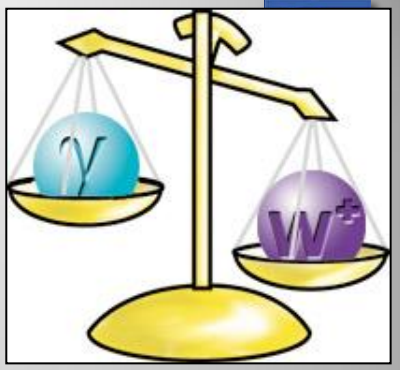
Why is there so little antimatter in the universe ?

What are the features of the primordial plasma permeating the universe ~10 μs after the Big Bang ?

Are there other forces in addition to the known four ?

Etc. etc.

The fundamental role of the Higgs boson

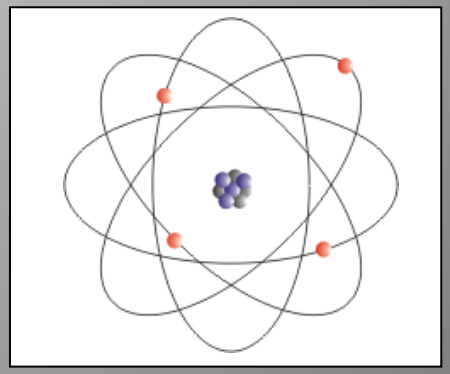


Before the discovery of the Higgs boson at the LHC in 2012 we didn't know how the elementary particles get their masses

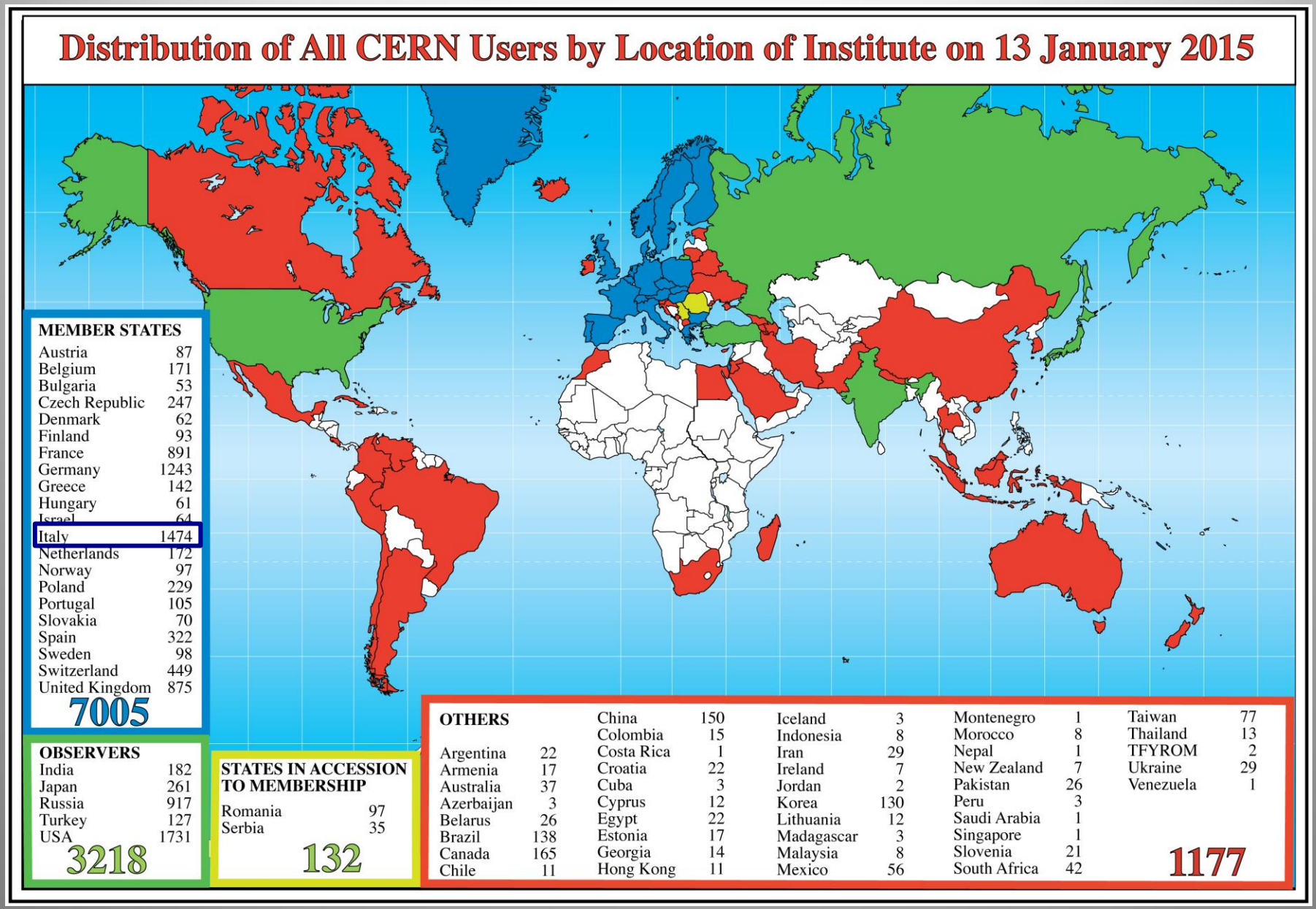
Proposed mechanism (Brout, Englert, Higgs et al., 1964): origin of masses ~ 10^{-11} s after the Big Bang, when the "Higgs field" permeated the universe → particles acquired masses proportional to their interactions with the Higgs field

Consequence of the BEH theory: existence of the Higgs boson
This particle has been searched for > 30 years at accelerators all over the world → finally found at the LHC in 2012
→ 2013 Physics Nobel Prize to F. Englert and P. Higgs

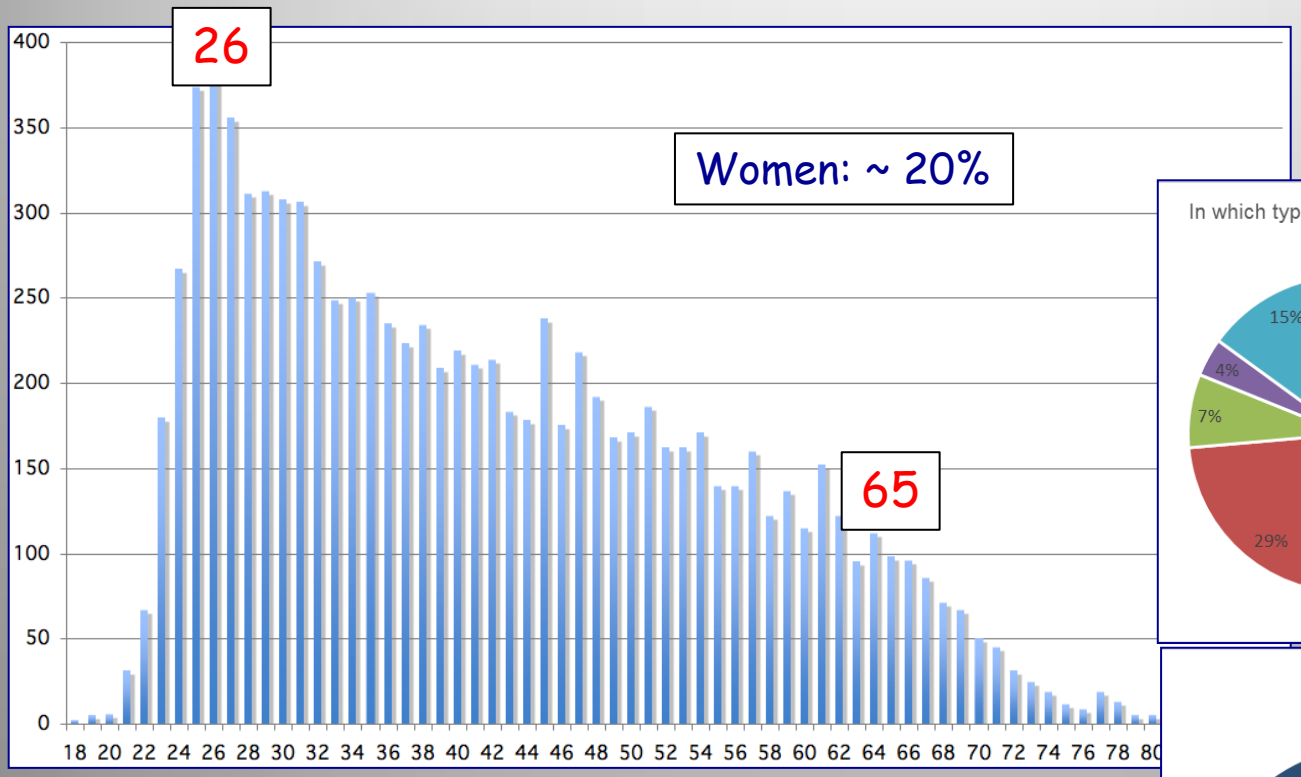
Note: a world without Higgs boson would be very strange.
If electrons and quarks had no mass, atoms would not exist
→ universe would be very different



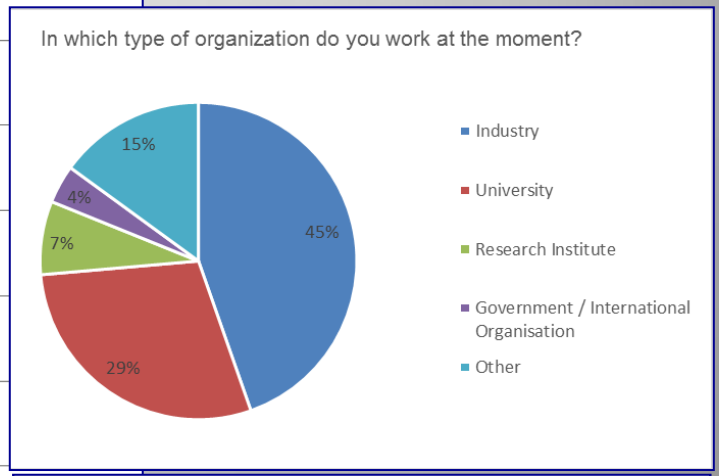
About 11500 scientists of 113 nationalities

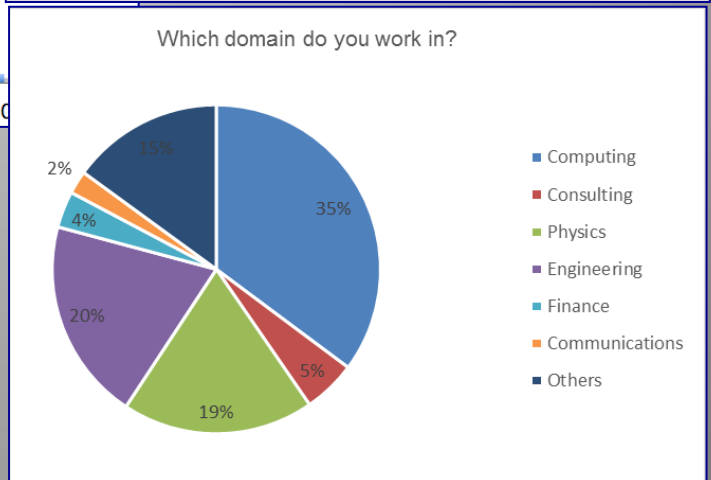


Age distribution of scientists working at CERN



Age (years)





> 2500 PhD students at any time
Where do young people go afterwards ?

CERN education activities

Europe/Russia School

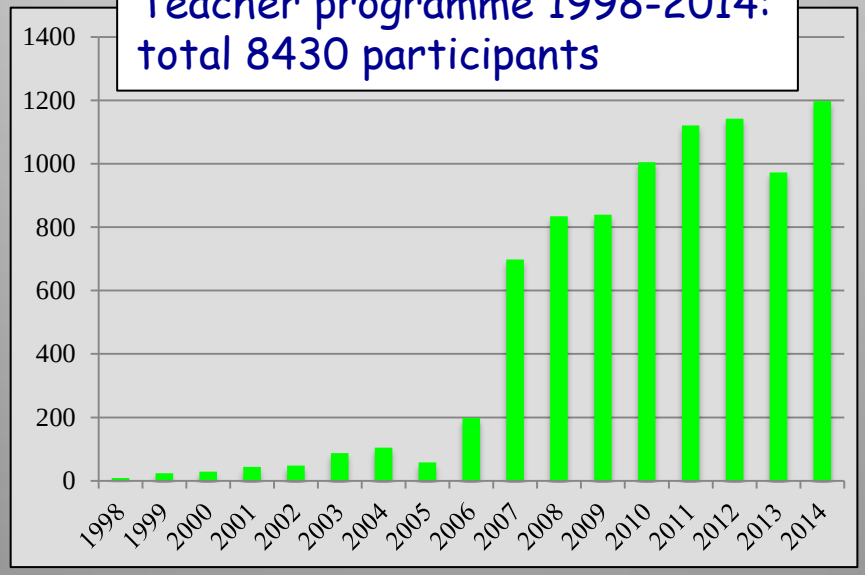
For young researchers
For physics students
For high school students
For school teachers

Asia-Europe-Pacific School: Japan 2012, India 2014

African School: South Africa 2010, Ghana 2012, Senegal 2014

Latin American School: Brazil 2011, Peru 2013, Ecuador 2015

Teacher programme 1998-2014: total 8430 participants



CERN education activities

Europe/Russia School

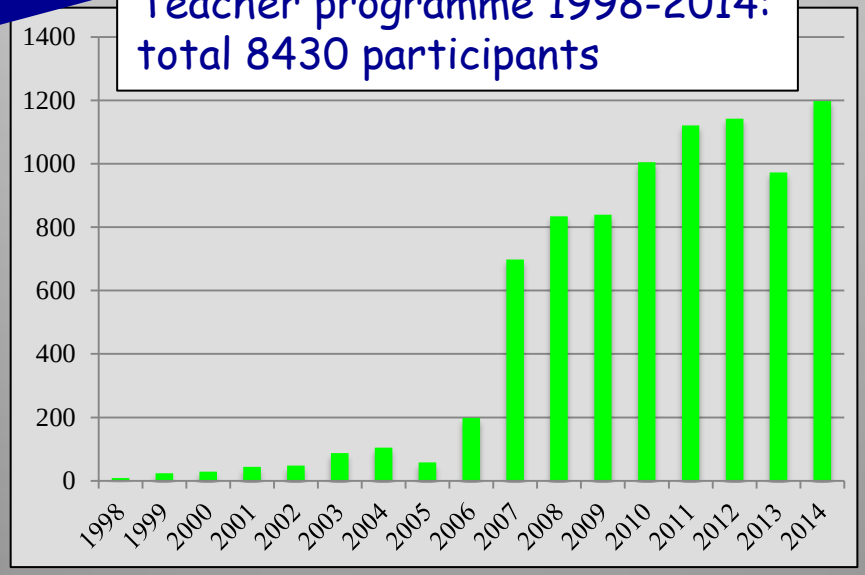
Asia-Europe-Pacific School: Japan 2012, India 2014

And 100000 visitors every year

n School:
n Africa 2010,
Ghana 2012,
Senegal 2014

Latin America School:
Brazil 2011, Peru 2013,
Ecuador 2015

Teacher programme 1998-2014: total 8430 participants



Italy and CERN

Italy has a strong tradition in particle physics and is a founding member of CERN

- Director Generals: Edoardo Amaldi, Carlo Rubbia, Luciano Maiani (F. Gianotti 2016-2020)
- Nobel prize: Carlo Rubbia
- Many Italian scientists in other important leading roles

INFN (Istituto Nazionale di Fisica Nucleare), Universities, and industry: crucial intellectual and technological contributions to the LHC
E.g. Ansaldo built 1/3 of the high-tech dipole magnets

- ~ 1500 Italian scientists involved today in projects at CERN (out of 11500)
- ~ 1100 Italian firms in the CERN supplier database

Contribution to CERN annual budget: ~115 M€ (~ 11% of total)
Returns (industrial purchases): up to 110% of contribution in LHC construction period, ~ 30% now

How can so many people from all over the world work successfully together ?

E.g.: ATLAS and CMS detector components designed by hundreds of physicists and engineers from hundreds of institutions, and built by hundreds of firms on four continents. Each experiment involves 3000 scientists from ~ 40 countries.
Resources contributions from involved countries based on Memoranda of Understanding with no legal constraints (just "moral" commitment by Funding Agencies to honour them)

Common passion for knowledge → sharing of universal, "noble" values transcending passport, culture, language, ethnicity, …
"Il piacere più nobile è la gioia di comprendere", Leonardo da Vinci

Very ambitious, inspiring scientific goals can only be accomplished by working together

Light organisation and management structure, minimal bureaucracy
→ effective operation and exploitation of very complex instruments without suffocating ideas and initiatives (the fuel of research)

Authority comes from ideas and demonstrated merits, not from management hierarchy
→ youngest student can drive a strategic decision

Decisions taken "by consensus" after discussions open to everybody

→ CERN "model" is the object of study by sociologists, business schools, …

The Economist | World politics | Business & finance | Economics | Science & technology | Culture | Bl

Schumpeter

Titans of innovation

What can business learn from Big Science?

Apr 27th 2013 | From the print edition | Timekeeper | Like 949 | Tweet 230 | Ad

could be that Big Science has more to teach big business than vice versa. A recent Strategic Management Society

Schumpeter heard on a visit to the CERN canteen concerned physics. The television screens were all tuned to live feeds from experiments—on a Saturday morning. Few firms inspire such commitment; and no mission statement or desk massage will change that.

Nevertheless, many innovative firms appear, consciously or not, to have recreated aspects of the Big Science model. Google and 3M encourage workers to spend some office hours tinkering with pet projects. Infosys, an Indian IT company, gets people from different parts of the company to vet each other's ideas. Valve, a big American maker of computer games, eschews hierarchy in favour of majority decision-making, including to select new staff. AT&T even had a pure-maths department. The snag is that only the best companies can enjoy the luxury of picking the best brains and letting them roam.

The importance of fundamental research …

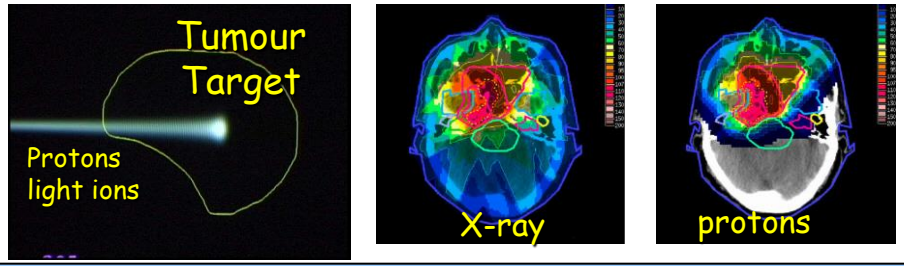
Will the Higgs boson change our life ?

It did already !

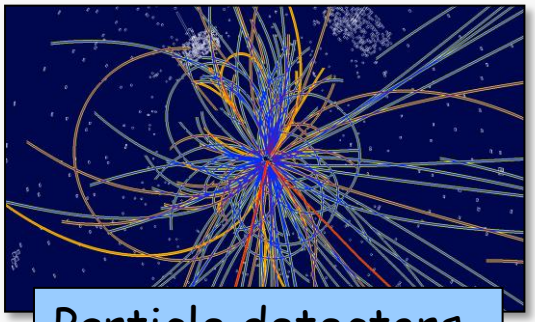
Complex, high-tech instruments needed in particle physics → cutting-edge technologies developed at CERN and collaborating Institutes → transferred to society

Examples of applications: medical imaging, cancer therapy, solar panels, materials science, airport scanners, cargo screening, food sterilization, nuclear waste transmutation, analysis of historical relics, etc. etc. …not to mention the WEB …

Hadron Therapy



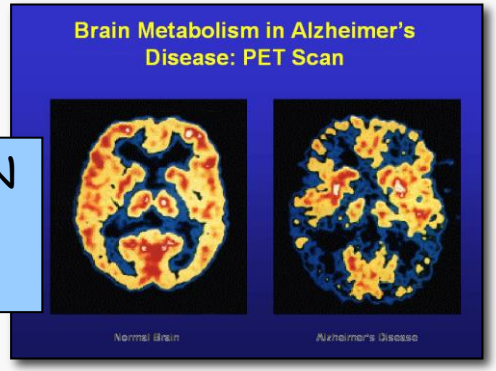
Particle accelerators: ~30'000 worldwide, of wich ~17'000 used for medical applications
E.g. Hadron Therapy: > 50000 patients treated in Europe (14 facilities)
Italy: CNAO (Centro Nazionale Adroterapia Oncologica), Pavia



Particle detectors

Imaging

e.g. PET scanner (based on CERN technology) is main cancer diagnostic technique since 2000



Fundamental research is the one that mostly stimulates ideas and creativity, because it is curiosity-driven, with no constraints from profit or delivery of specific products

Ideas and creativity are the fuel of progress: without new, revolutionary ideas, progress sooner or later stagnates.

History shows that often major breakthroughs come from fundamental research, e.g.

- quantum mechanics → transistors
- relativity → GPS

Perhaps most importantly, knowledge (as the arts) is among the highest expressions of human beings as clever beings → it is justified by its intrinsic value.

"Nati non foste a viver come bruti, ma per seguir virtute et conoscenza", D. Alighieri, Inferno, XXVI

In the 1970s, Bob Wilson, founder of Fermi National Accelerator Laboratory, Illinois (the second biggest accelerator laboratory in the world, after CERN) asked by US Congress "What will your lab contribute to the defense of the US ?", replied: "Nothing, but it will make it worth defending"

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

GRAZIE !