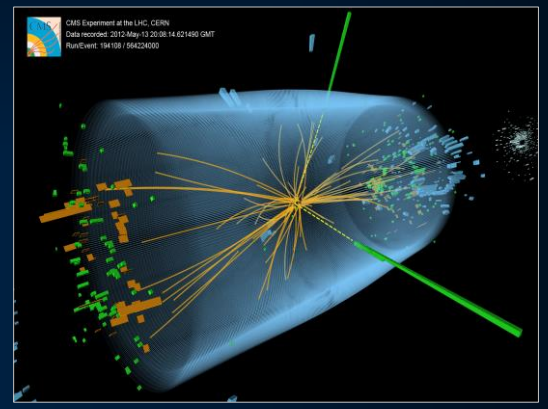
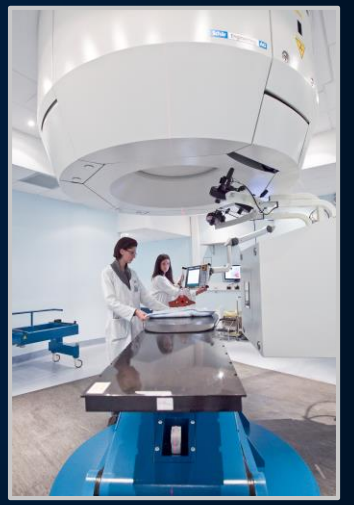
Fundamental research (and much more …) at CERN





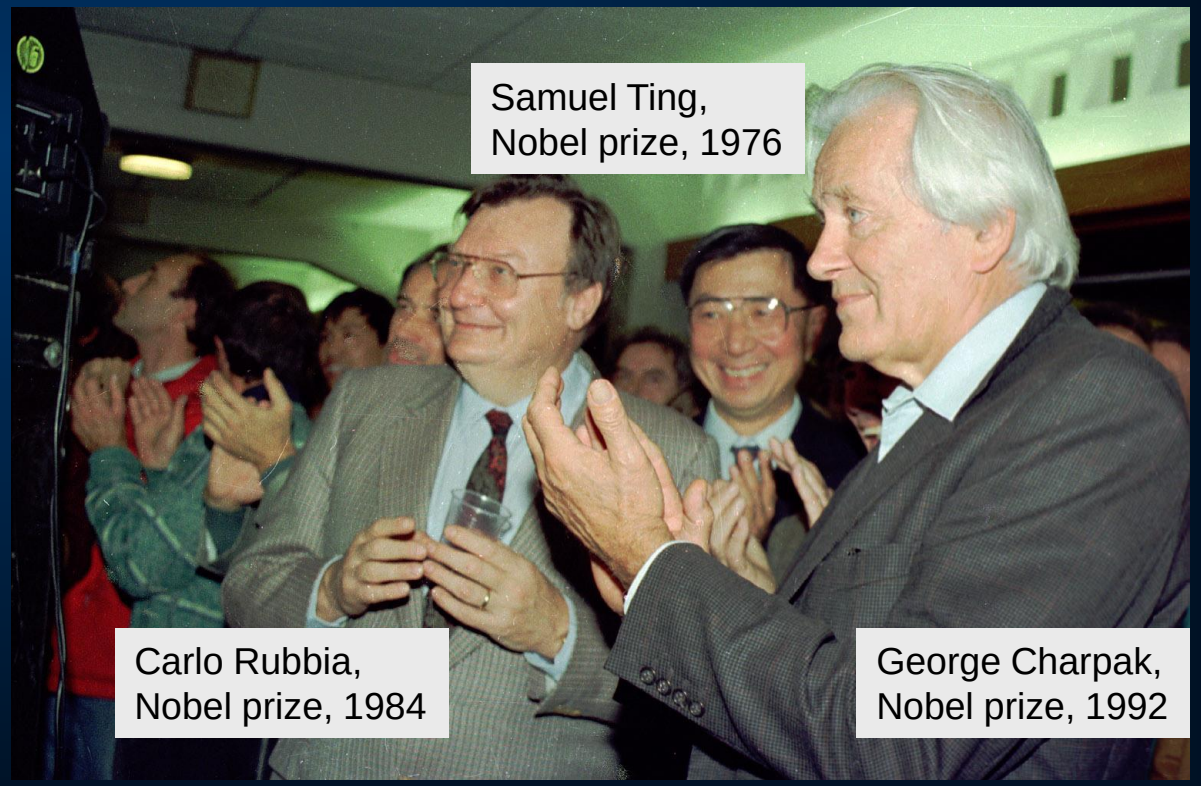
CERN : the largest particle physics laboratory in the world

Intergovernmental organisation based in Geneva

Mission:

- science: fundamental research in particle physics → discoveries (e.g. Higgs boson 2012)
- technology and innovation → transferred to society (e.g. the World Wide Web, medical applications)
- training and education
- bringing the world together: ~ 18000 scientists, > 110 nationalities

WEB@30 celebration, 12 March 2019 at CERN,
with T. Berners-Lee, former CERN staff member



CERN was founded in 1954: 12 European States
Today: 23 Member States

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

8 Associate Member States: Croatia, Cyprus, India, Lithuania, Pakistan, Slovenia, Turkey, Ukraine

6 Observers to Council: Japan, Russian Federation, USA, EU, JINR/Dubna, UNESCO

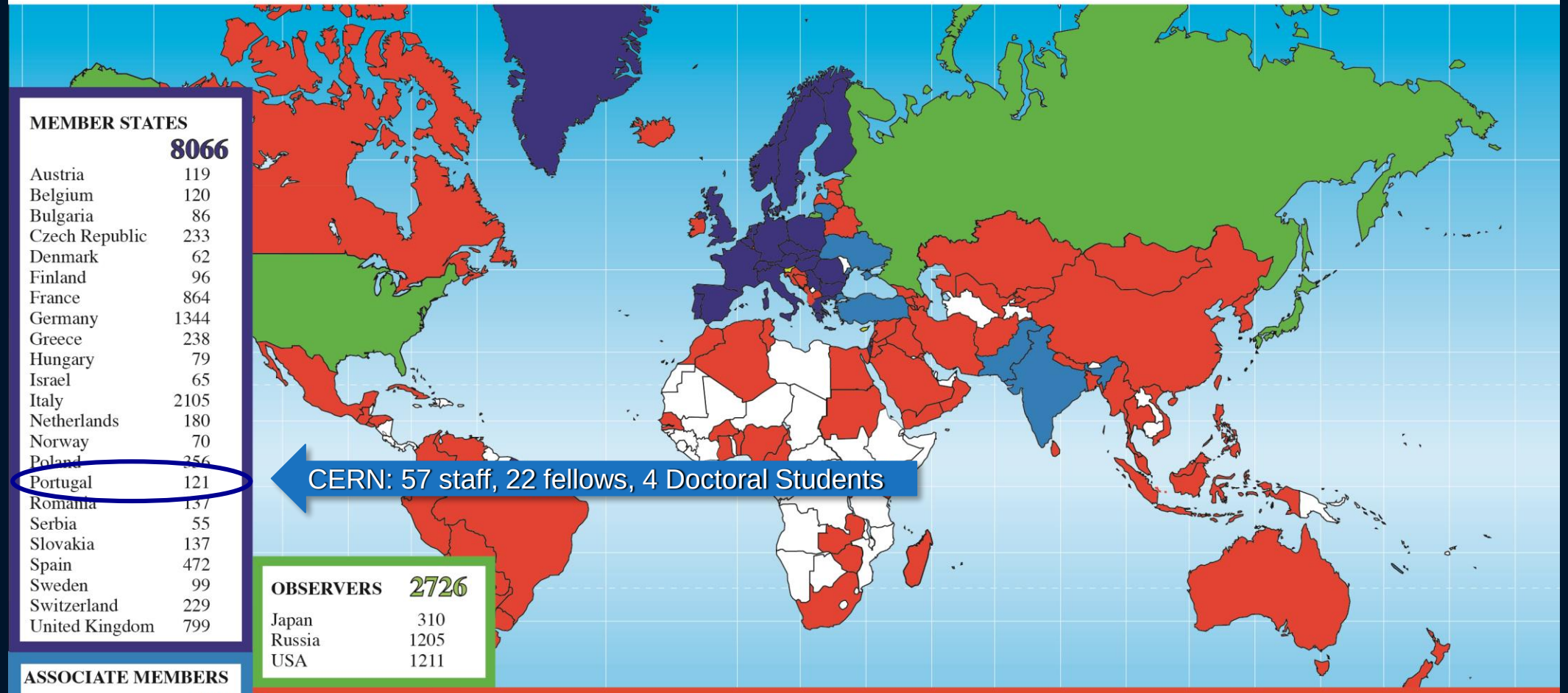
~ 2600 staff, ~4400 in total on payroll

~ 13600 users from all over the world

Budget (2019) ~1200 MCHF (on average: ~ 1 cappuccino/year per European citizen):

→ Member States contribute in proportion to their income: **Portugal: 1.1% (~ 12.5 MCHF/year)**

Distribution of All CERN Users by Nationality as of mid-April 2019



MEMBER STATES	8066
Austria	119
Belgium	120
Bulgaria	86
Czech Republic	233
Denmark	62
Finland	96
France	864
Germany	1344
Greece	238
Hungary	79
Israel	65
Italy	2105
Netherlands	180
Norway	70
Poland	356
Portugal	121
Romania	137
Serbia	55
Slovakia	137
Spain	472
Sweden	99
Switzerland	229
United Kingdom	799

CERN: 57 staff, 22 fellows, 4 Doctoral Students

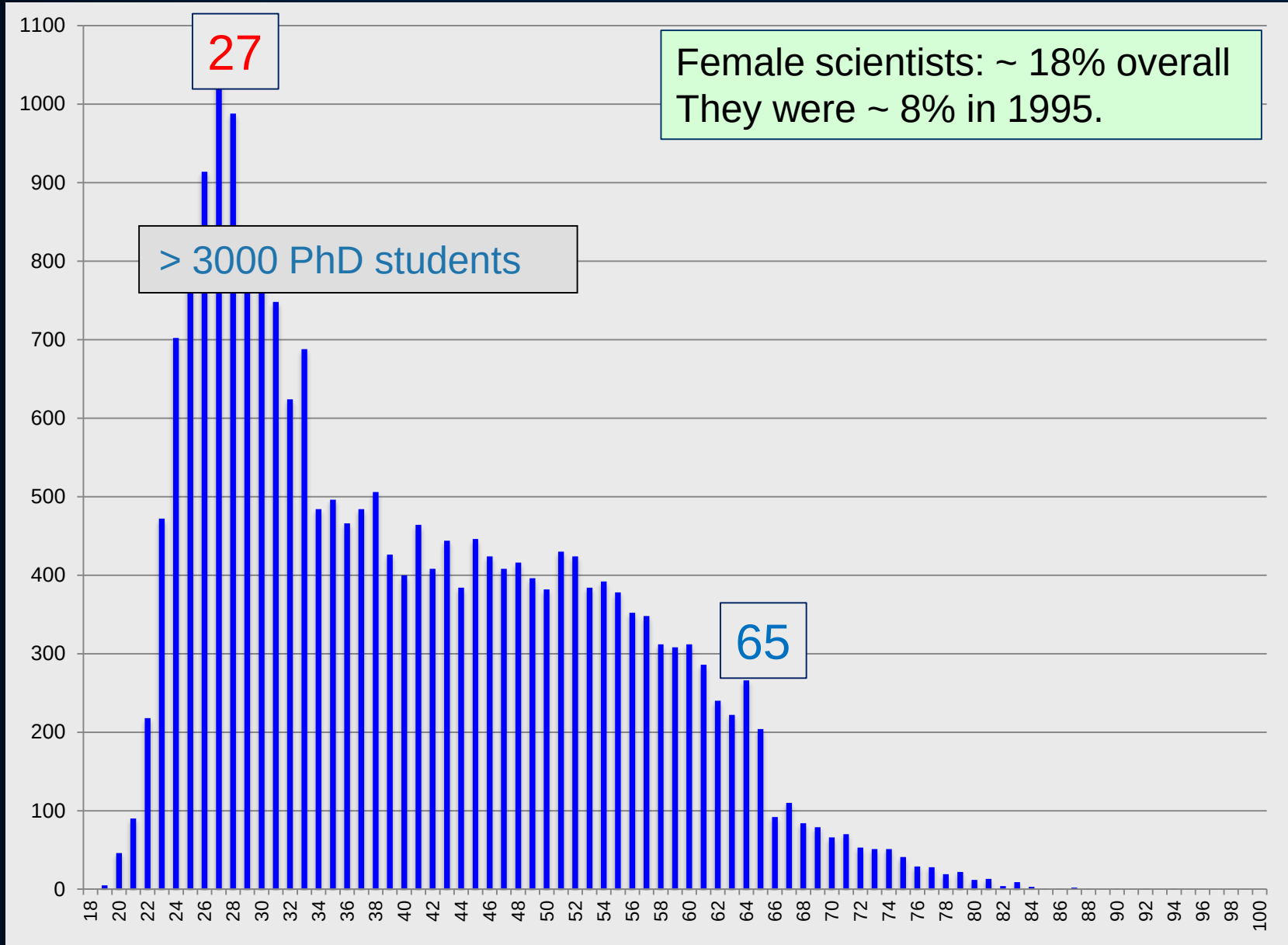
OBSERVERS	2726
Japan	310
Russia	1205
USA	1211

ASSOCIATE MEMBERS		778
India	387	
Lithuania	39	
Pakistan	71	
Turkey	165	
Ukraine	116	

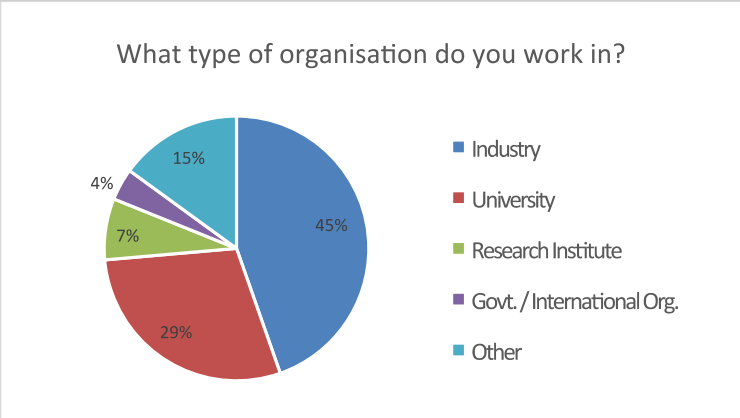
ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP	59
Cyprus	26
Slovenia	33

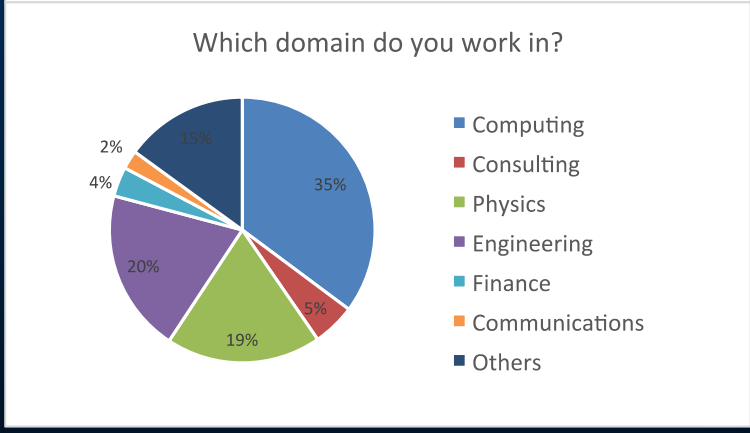
OTHERS	1999
Albania	4
Algeria	14
Argentina	26
Armenia	22
Australia	36
Azerbaijan	10
Bahrain	1
Bangladesh	8
Belarus	45
Benin	1
Bolivia	3
Bosnia & Herzegovina	3
Brazil	127
Burkina Faso	1
Burundi	1
Cameroon	1
Canada	170
Chile	21
China	576
Colombia	44
Croatia	50
Cuba	16
Ecuador	10
Egypt	27
El Salvador	1
Estonia	15
Georgia	51
Ghana	1
Guatemala	1
Hong Kong	1
Honduras	1
Iceland	4
Indonesia	11
Iran	58
Iraq	1
Ireland	13
Jordan	2
Kazakhstan	10
Kenya	1
Korea	183
Kyrgyzstan	1
Latvia	4
Lebanon	27
Luxembourg	4
Madagascar	1
Malaysia	22
Malta	9
Mexico	85
Mongolia	2
Montenegro	11
Morocco	24
Myanmar	2
Nepal	7
New Zealand	5
Nigeria	4
North Korea	4
North Macedonia	3
Oman	3
Palestine	7
Paraguay	1
Peru	6
Philippines	3
Saint Kitts and Nevis	1
San Marino	1
Saudi Arabia	4
Senegal	1
Singapore	5
South Africa	56
Sri Lanka	10
Sudan	1
Syria	1
Taiwan	56
Thailand	26
Tunisia	4
Uruguay	1
Uzbekistan	3
Venezuela	9
Viet Nam	11
Zambia	1
Zimbabwe	2

Age distribution of scientists working at CERN



~ 10% of the young people stay in particle physics: where do the others go?





CERN education activities

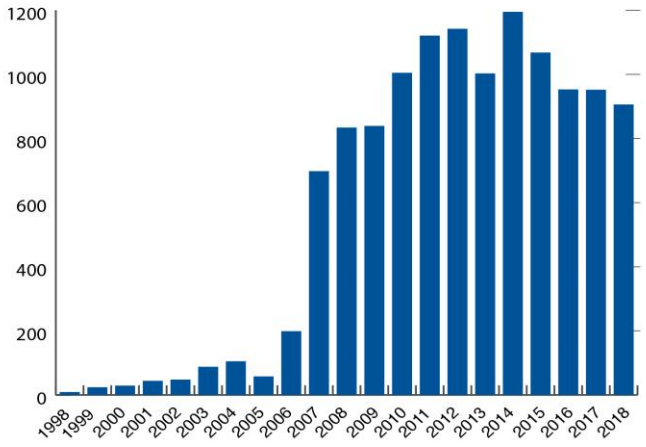
Europe/Russia School

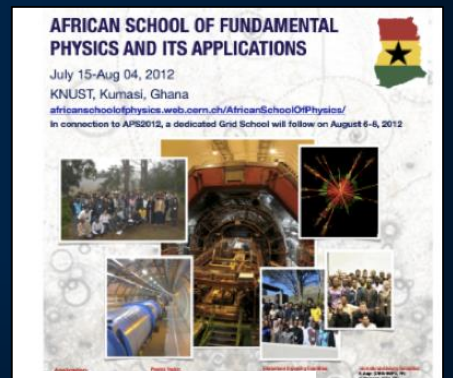
For young researchers
For physics/engineering students
For high school students
For school teachers

Asia-Europe-Pacific School:
India 2014,
China 2016,
Vietnam 2018

Latin American School:
Ecuador 2015,
Mexico 2017,
Argentina 2019

Teachers' Programme 1998-2018:
total 12320 participants (Portugal: 453)

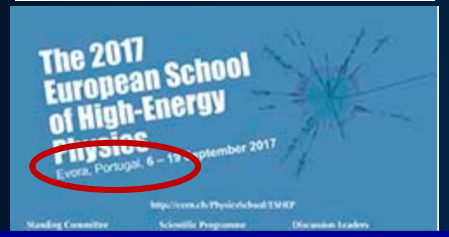




African School:
Ghana 2012,
Senegal 2014,
Rwanda 2016,
Namibia 2018

CERN education activities

Europe/Russia School



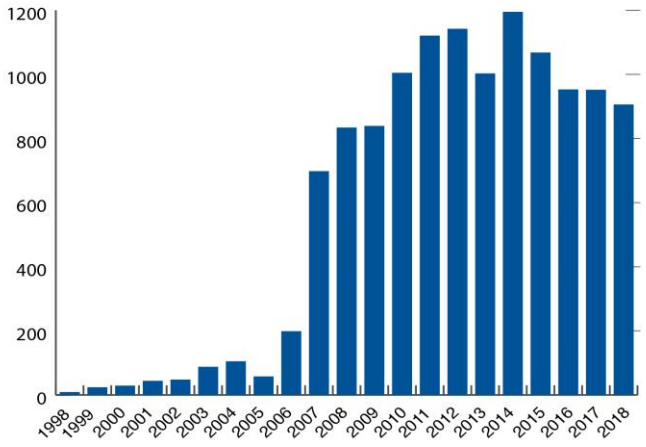
Asia-Europe-Pacific School:
India 2014,
China 2016,
Vietnam 2018

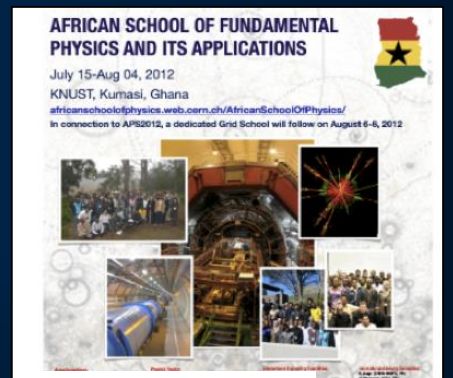
And ~130000 visitors every year (300000 requests)

> 60% are high-school students; ~ 80% come from > 700 km away

Latin American School:
Ecuador 2015,
Mexico 2017,
Argentina 2019

Teachers' Programme 1998-2018:
total 12320 participants (Portugal: 453)

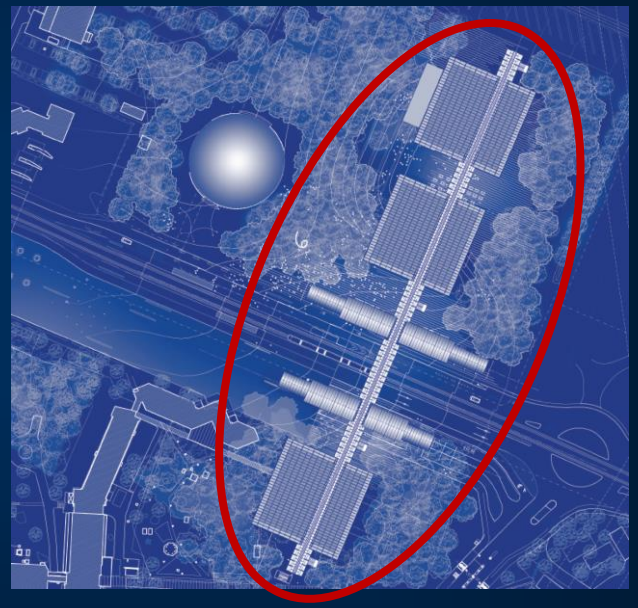




African School:
Ghana 2012,
Senegal 2014,
Rwanda 2016,
Namibia 2018

CERN Science Gateway

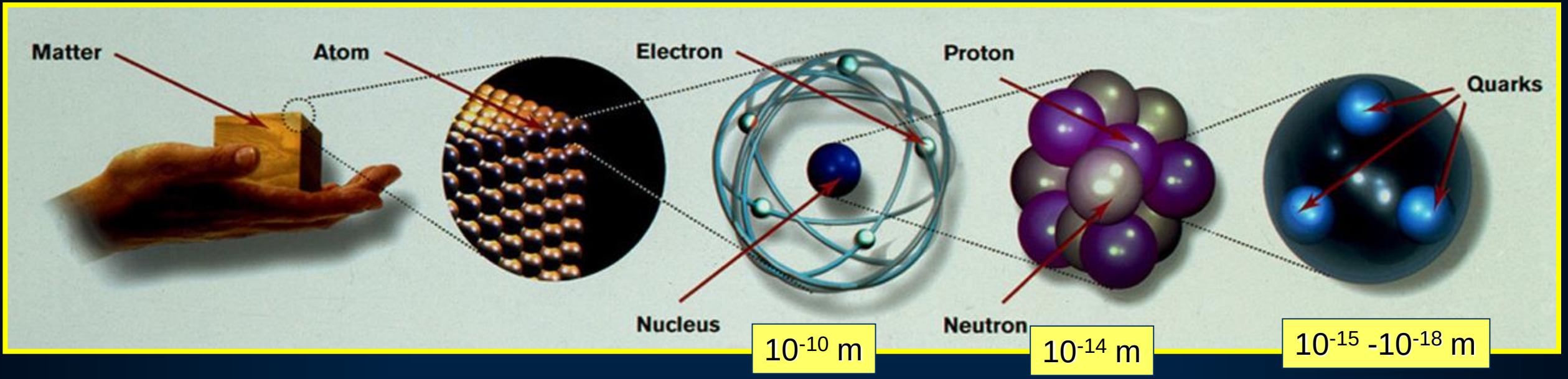
A new facility for education and outreach targeting the general public of all ages. It will include exhibitions, immersive spaces and laboratories for hands-on physics experiments for school children and students from 5 years up. Expect at least 300,000 visitors annually.



- It will be housed in an iconic building complex designed by architect Renzo Piano
- Construction will start mid-2020 and will be completed end 2022
- Total cost: ~ 79 MCHF to be entirely covered from external donations. 67 MCHF secured so far.
- It will allow stronger collaboration with education and outreach initiatives in CERN's Member States

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

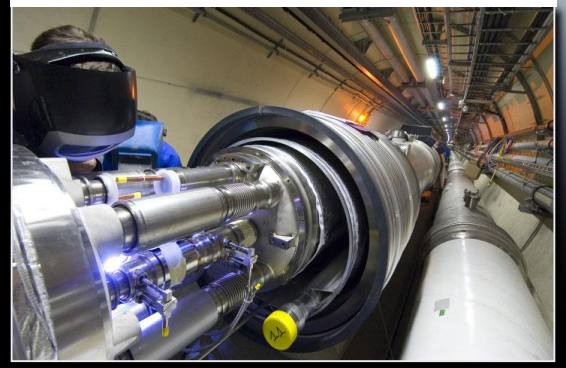
→ insight also into the structure and evolution of the Universe

→ from the very small to the very big …

Evolution of the Universe

Big Bang

Accelerators



380,000 years

13.7 Billion Years

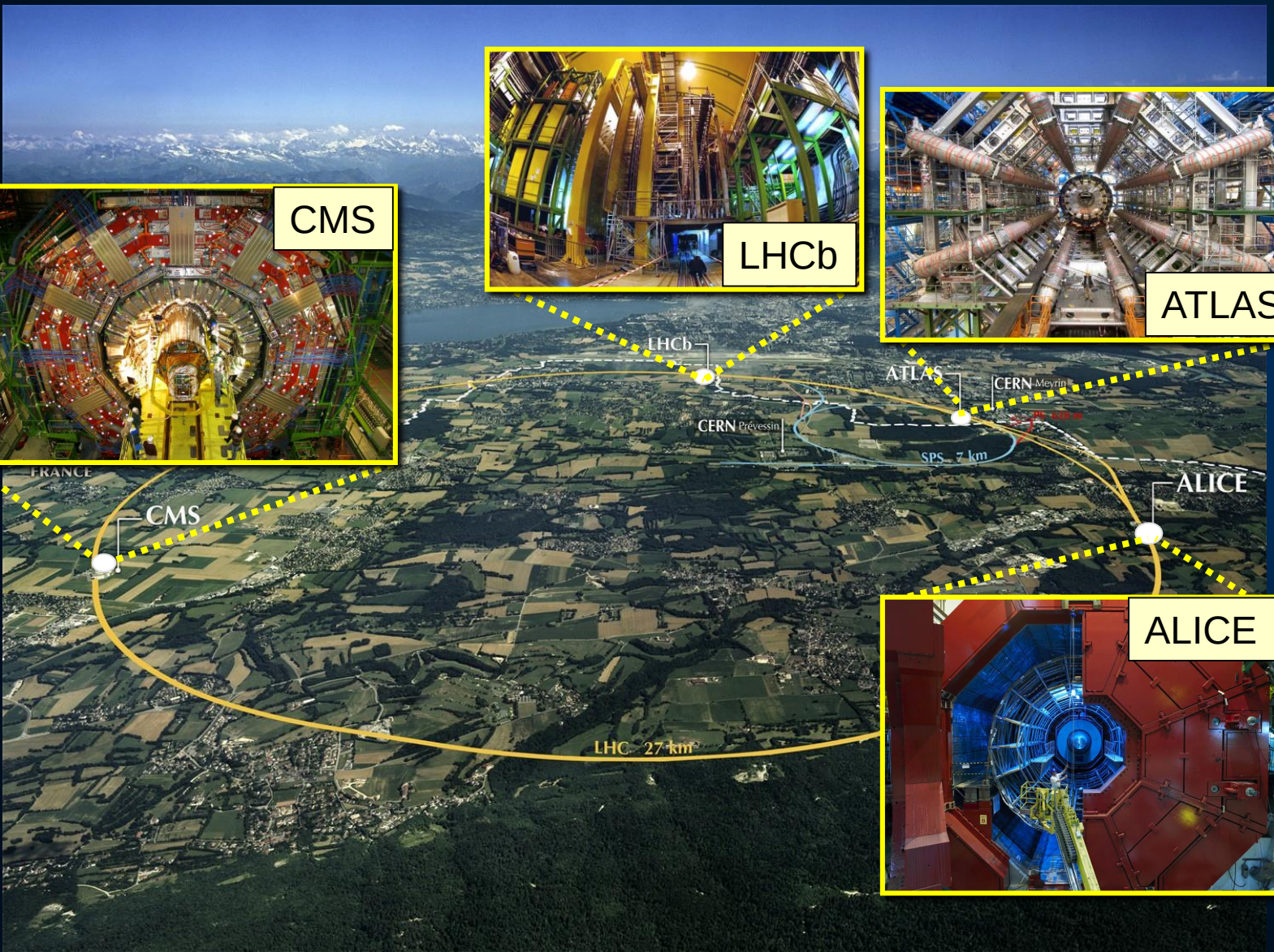
Today

10^{28} cm

Telescopes

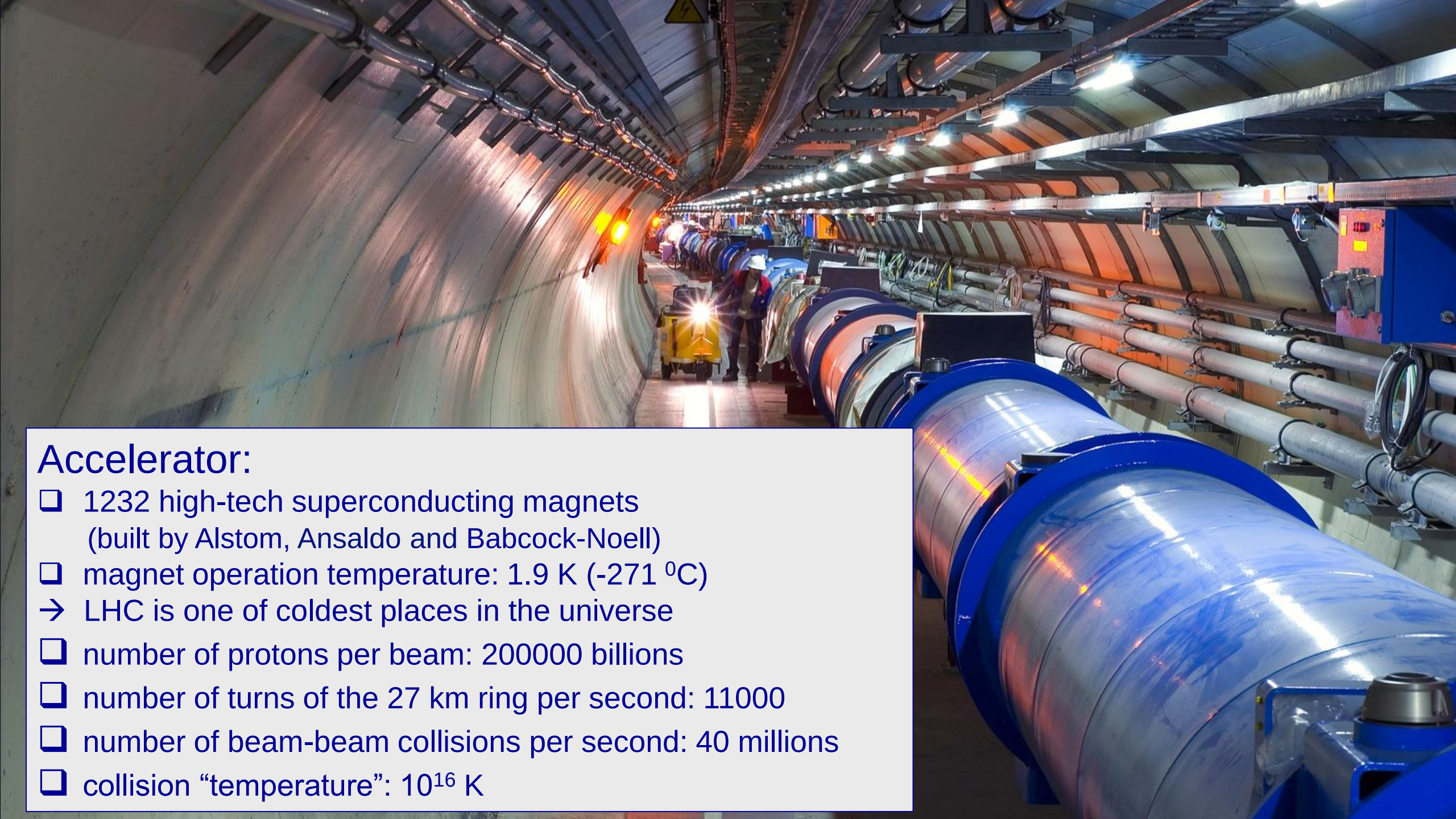
CERN

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

On 4th July 2012, ATLAS and CMS announced the discovery of a new (very special!) particle:
the Higgs boson

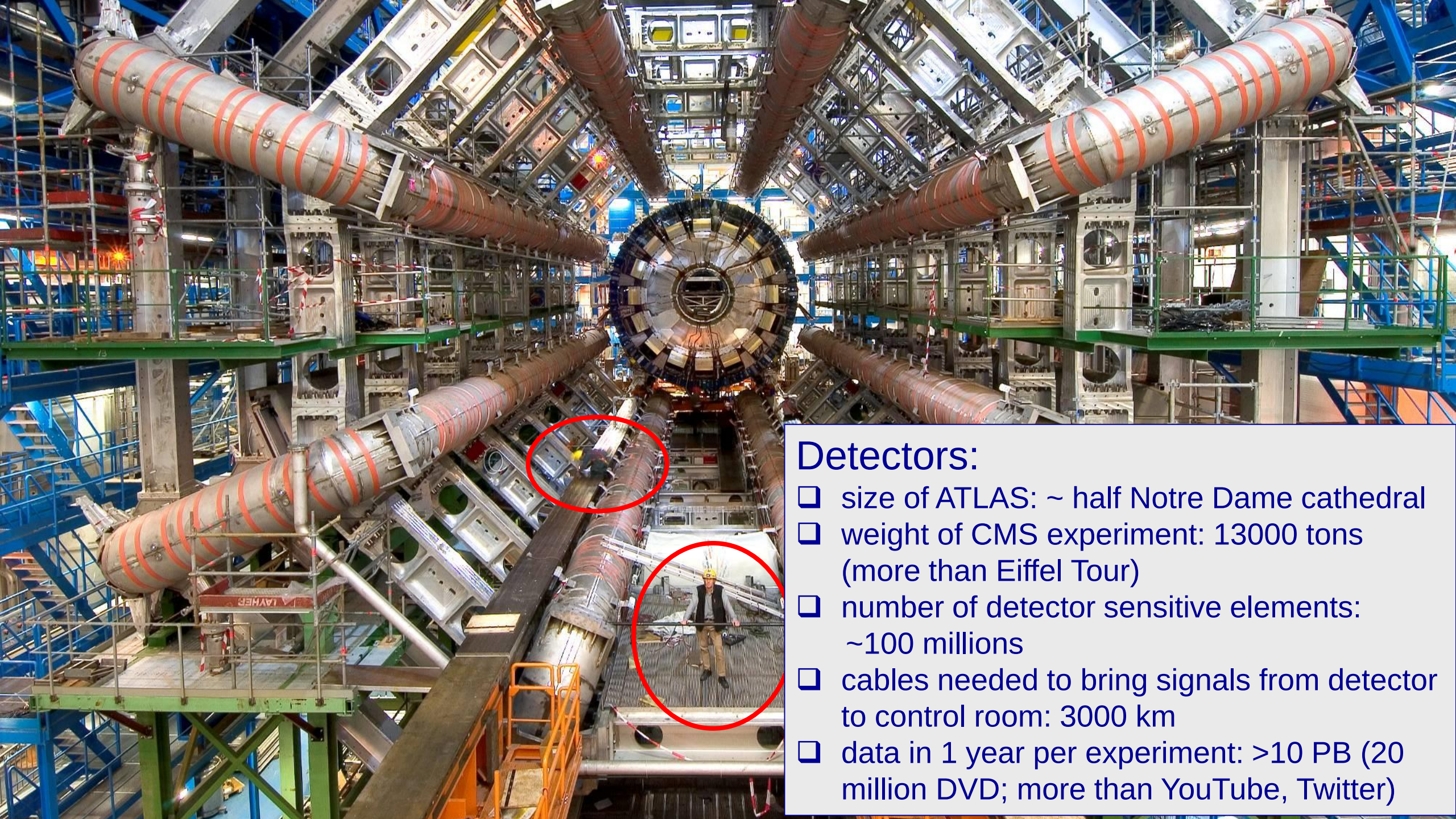


Accelerator:

- 1232 high-tech superconducting magnets
  (built by Alstom, Ansaldo and Babcock-Noell)
- magnet operation temperature: 1.9 K (-271 ^{0}C)

→ LHC is one of coldest places in the universe

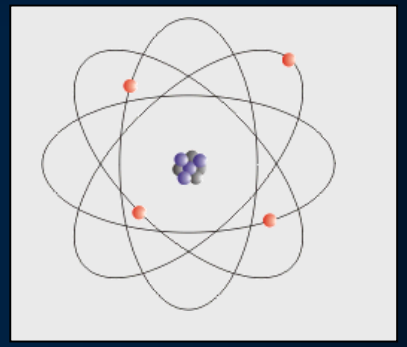
- number of protons per beam: 200000 billions
- number of turns of the 27 km ring per second: 11000
- number of beam-beam collisions per second: 40 millions
- collision “temperature”: 10^{16} K



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)

Discovery in 2012 → Nobel Prize in Physics in 2013



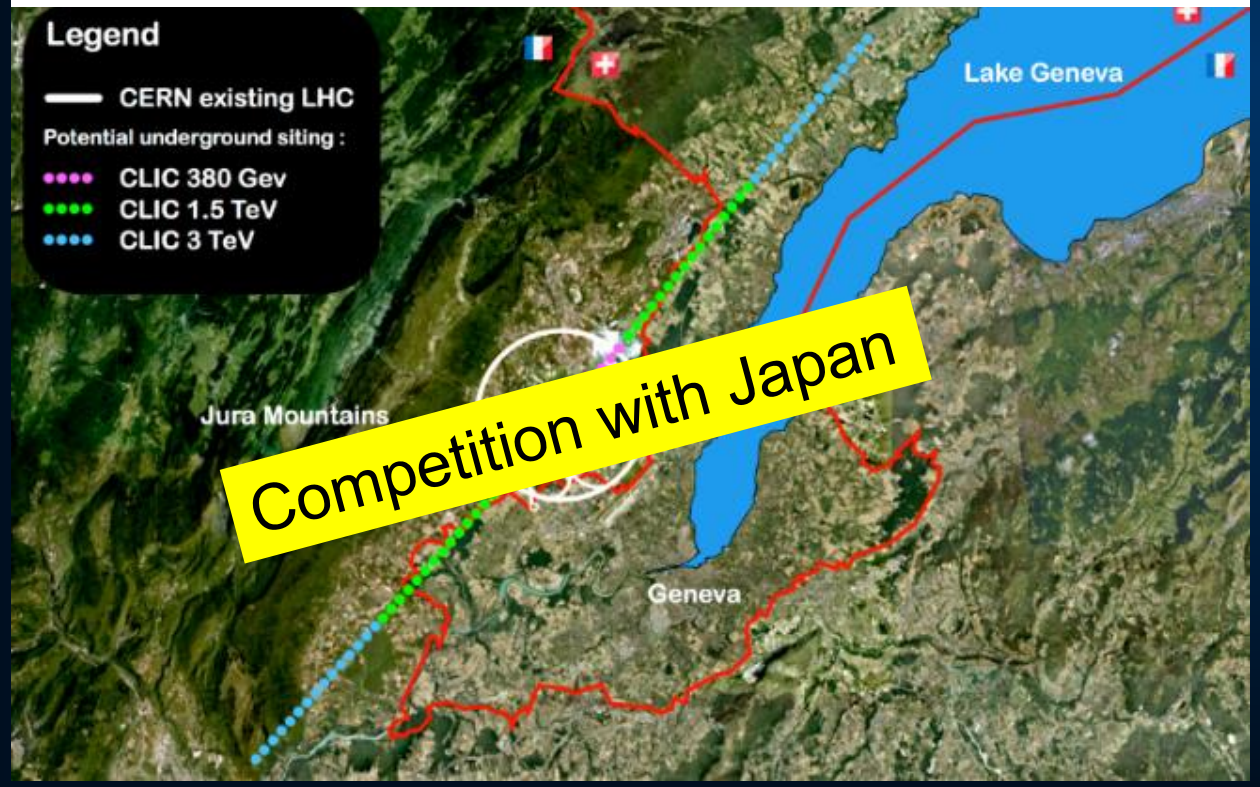
Note: a world without the Higgs boson would be very strange. Atoms would not exist → universe would be very different

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".*

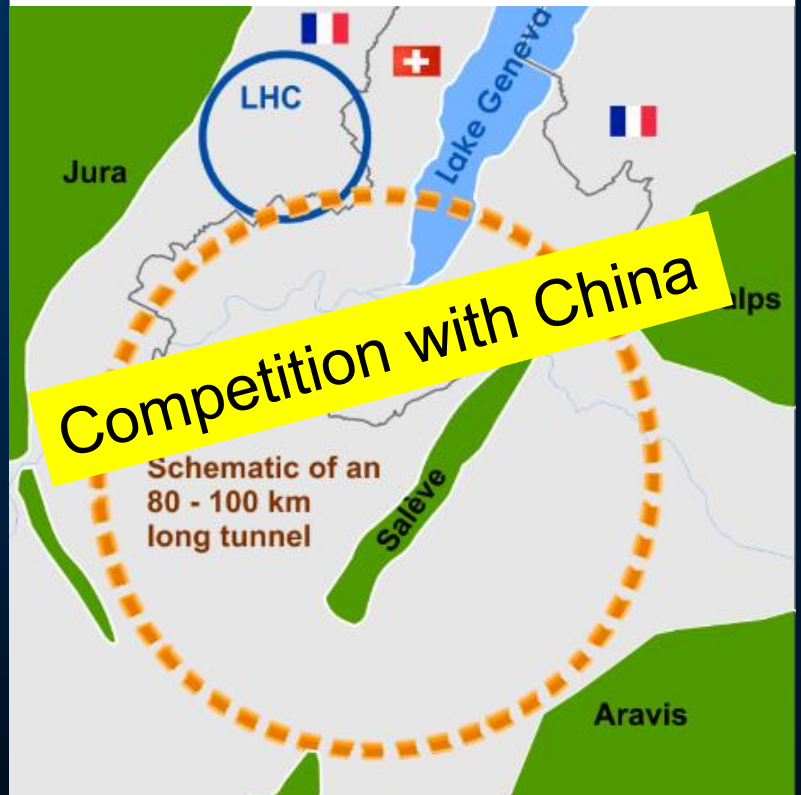
Which accelerator after the LHC ?

Various options for future, more powerful colliders being studied and the needed, advanced technologies being developed

CLIC: e^+e^- linear collider 11 km → 50 km tunnel

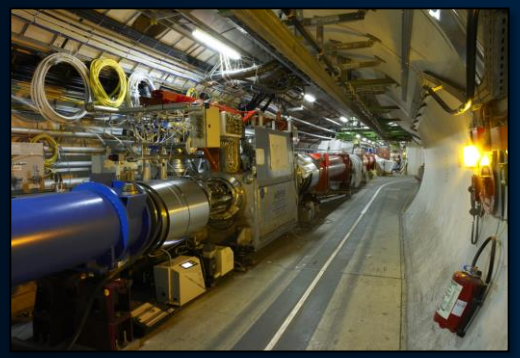


FCC: Future Circular Collider: 100 km ring for e^+e^- and proton-proton collisions

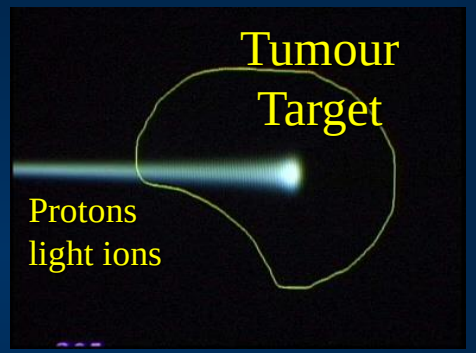


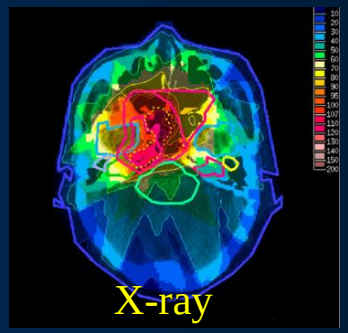
Complex, high-tech instruments needed in particle physics → cutting-edge technologies developed at CERN and collaborating Institutes → transferred to society

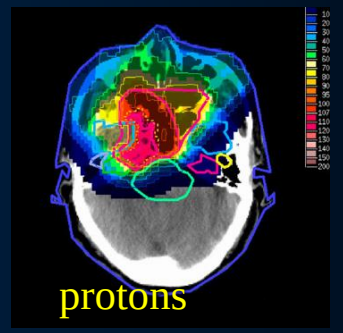
Examples of applications: medical imaging, cancer therapy, solar panels, material science, airport scanners, cargo screening, food sterilization, nuclear waste transmutation, analysis of historical relics, etc. etc. … not to mention the WEB …



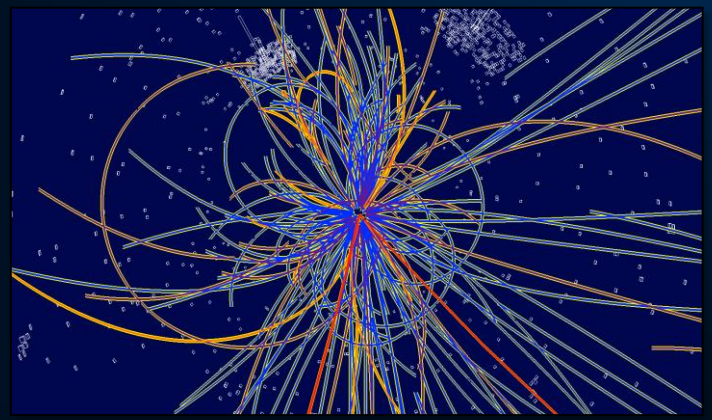
Hadron Therapy





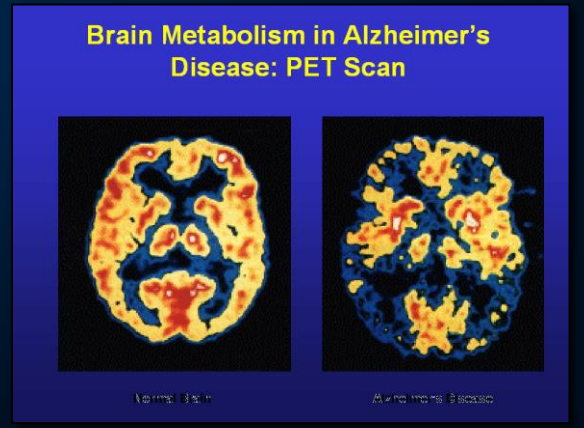


Particle accelerators: ~30’000 worldwide, of which ~17’000 used for medical applications
E.g. Hadron Therapy: > 50000 patients treated in Europe (14 facilities for protons, two for Carbon ions)



Imaging

e.g. PET scanner (based on CERN technology) is main cancer diagnostic technique since 2000
(great contributions from Portugal!)



Plans for proton therapy in Portugal

Typical multi-room configurations units for proton therapy from IBA (Belgium, left) and Varian (US, right): 2-3 rooms for patients and 1 room for research.

Goal would be to treat ~ 700 patients/year initially.
First unit would be located at the Campus Tecnológico e Nuclear of Instituto Superior Técnico.
FCT is committed to fund a training program for physicians and researchers over the next five years.

Portugal and CERN

- Portugal joined CERN as a Member State in 1986
- The Laboratório de Instrumentação e Física Experimental de Partículas (LIP) was created at the same time to carry out all activities related to experimental particle physics, involving researchers coming from universities as well as LIP's own scientific staff
- Strong participation in LHC (ATLAS, CMS) and other experiments (CLOUD, COMPASS, ISOLDE, nTOF) and strong partner in the GRID
- Strong participation in R&D programmes for medical application (Clear PEM, PET consortium)
- Training/Education:
  - Excellent example of engineer training programme
  - Very successful teacher training and outreach programmes
- Very balanced approach between contributions at CERN and investments at home and very good industrial relations

Contributions to the ATLAS and CMS experiments at LHC

LIP is a member of ATLAS since 1992

Major role in the construction of the TileCal Hadron Calorimeter and Trigger/Data Acquisition system, in collaboration with industry and technology institutes

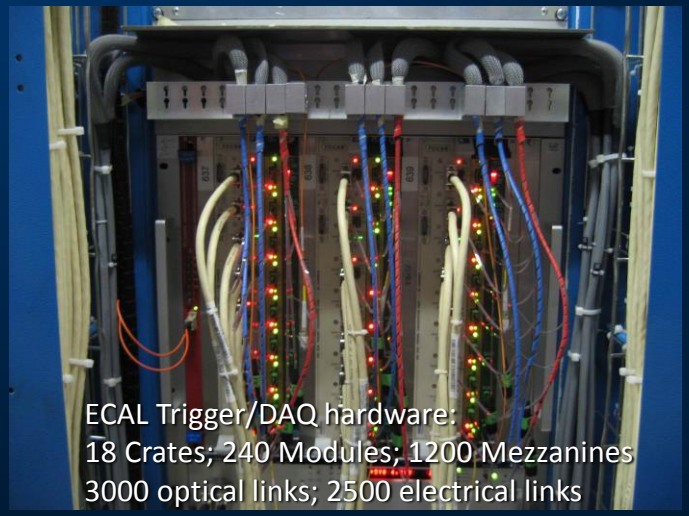
Robot for fiber insertion.
600 000 fibers inserted in Lisbon and later in Coimbra

WLS optical fibers routing.
Fiber aluminization done in Lisbon

Detector Commissioning and Operation
Data analysis

LIP is a member of CMS since 1992

Major role in the construction of the Trigger and Data Acquisition of the Electromagnetic Calorimeter, in collaboration with industry and technology institutes



ECAL Trigger/DAQ hardware:
18 Crates; 240 Modules; 1200 Mezzanines
3000 optical links; 2500 electrical links

Detector Commissioning and Operation
Data analysis


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km
Thank You!
CERN
Accelerating Science and Innovation

EXTRAS

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. 25% 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.