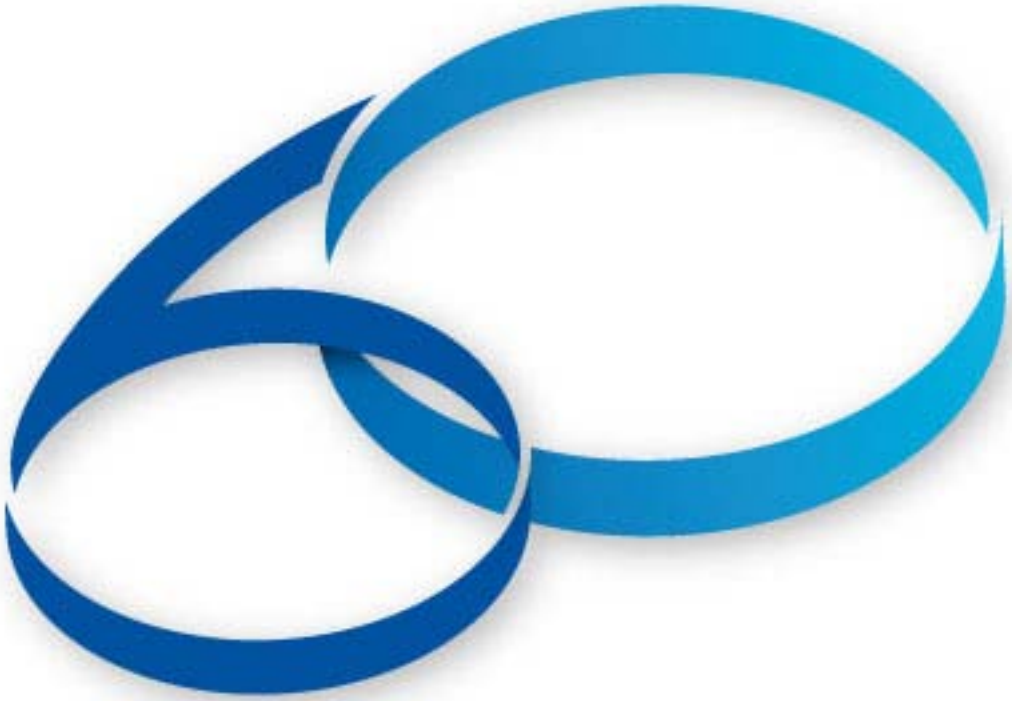


60 YEARS of SCIENCE FOR PEACE

YEARS/ANS CERN

CERN was founded 1954: 12 European States

"Science for Peace"

Today: 21 Member States

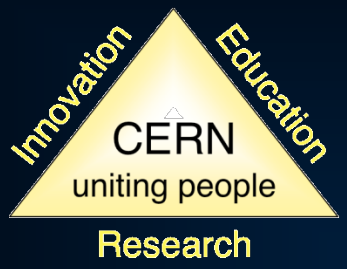
~ 2300 staff
~ 1600 other paid personnel
~ 10500 scientific users

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

States in accession to Membership: Romania, Serbia

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

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



The Mission of CERN

- **Push back** 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?

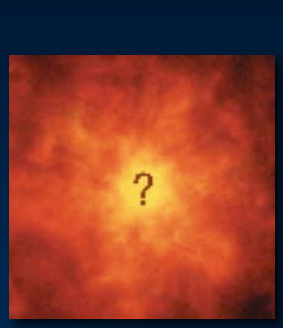
- **Develop** new technologies for accelerators and detectors

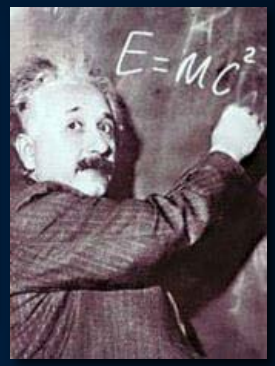
  Information technology - the Web and the GRID

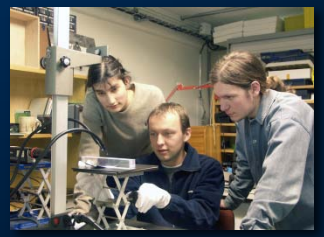
  Medicine - diagnosis and therapy

- **Train** scientists and engineers of tomorrow

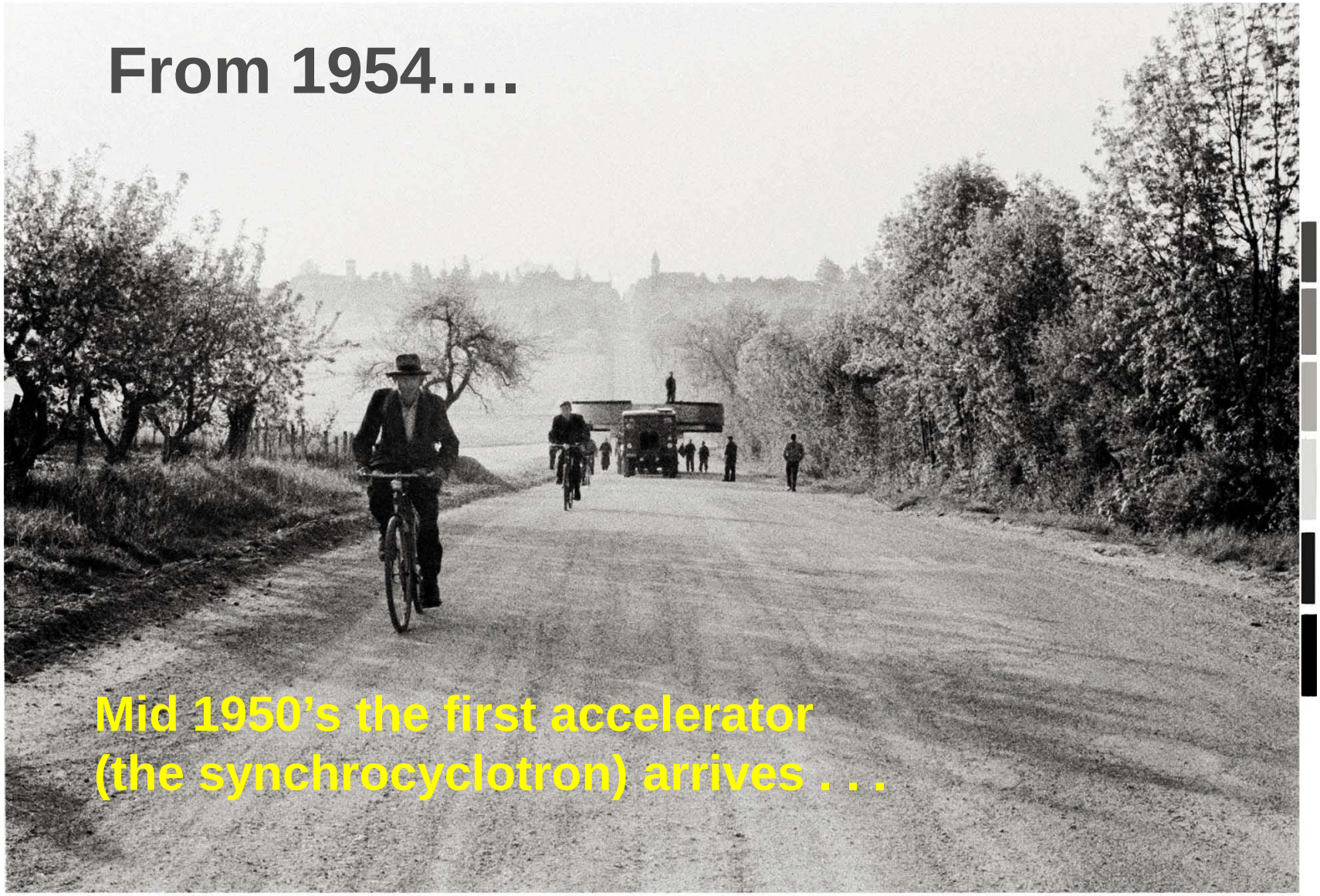
- **Unite** people from different countries and cultures







From 1954….



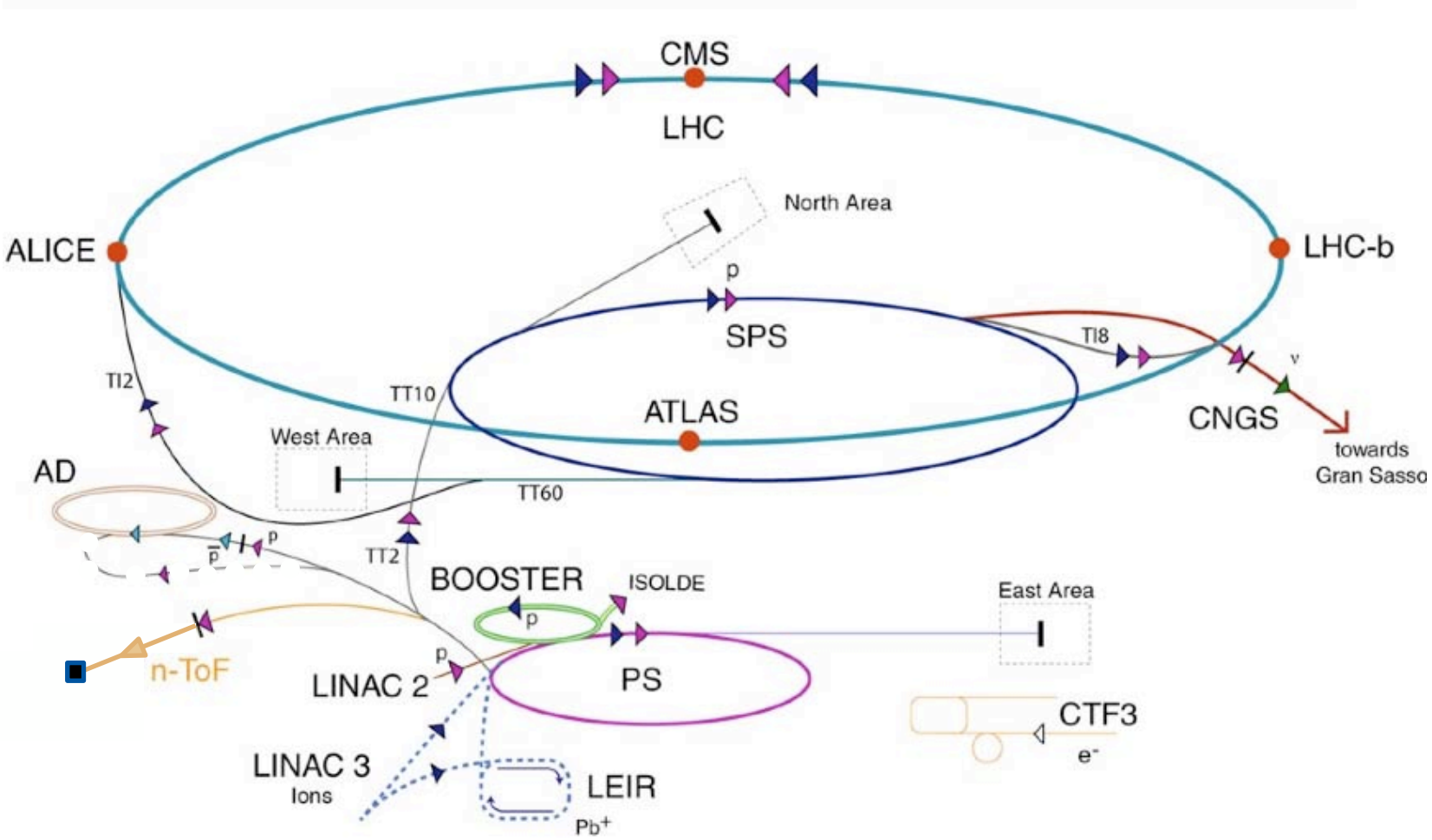
Mid 1950's the first accelerator (the synchrocyclotron) arrives . . .

CERN

60 YEARS / ANS CERN

….to today

CERN Accelerator Complex



CERN

YEARS / ANS CERN

The Particle Physics Landscape at CERN

High Energy Frontier

LHC

Hadronic Matter

deconfinement
non-perturbative QCD
hadron structure

Low Energy

heavy flavours / rare decays
neutrino oscillations
anti-matter

Non-accelerator

dark matter
astroparticles

Multidisciplinary

climate, medicine

Non-LHC Particle Physics = o(1000) physicist

Researchers from Prague participate in several activities within these different areas

unique facilities

maintain and upgrade these facilities

CERN

a European Intergovernmental Organization, globally used

→ an infrastructure belonging to all its member states

→ an example of what Europe and its partners can achieve when they are working together

Key Message

From the very beginning:
Peaceful cooperation at the forefront of science
independent of cultural and national differencies

1954 European Reconstruction

1st Session of CERN Council

1980 The East Meets the West

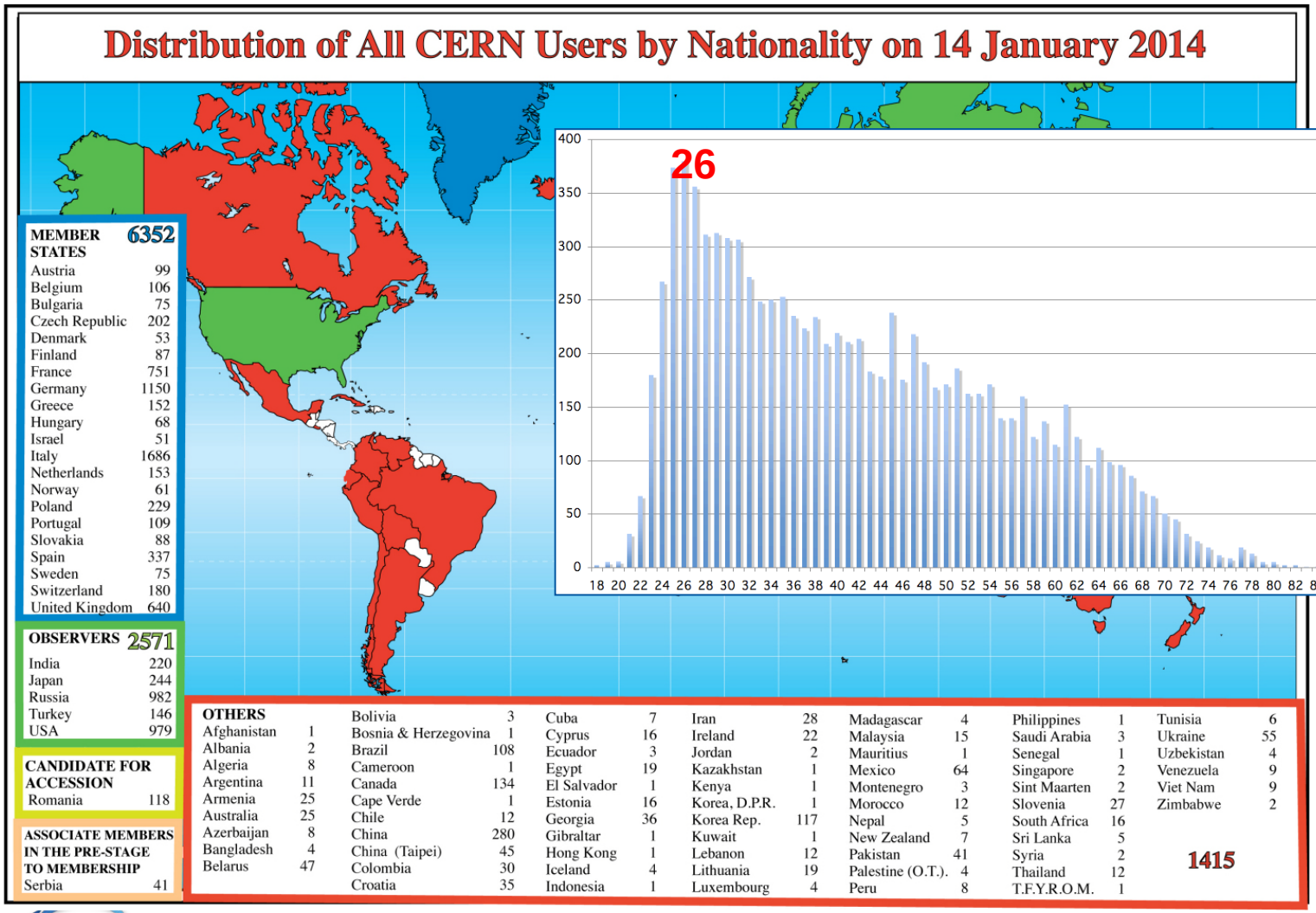
Visit of delegation from Beijing

Today Global Collaboration

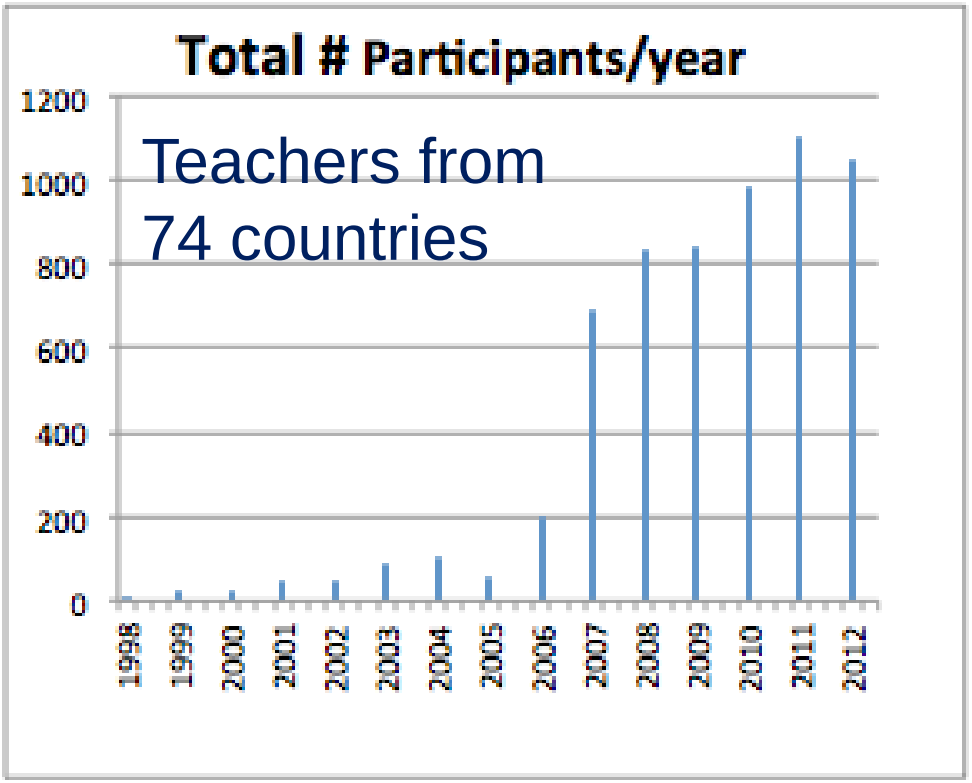
The LHC brings together > 8000 scientists and some 100 nationalities

Today: Global Collaboration

Breaking the Walls between Cultures and Nations since 1954



Education and Capacity Building

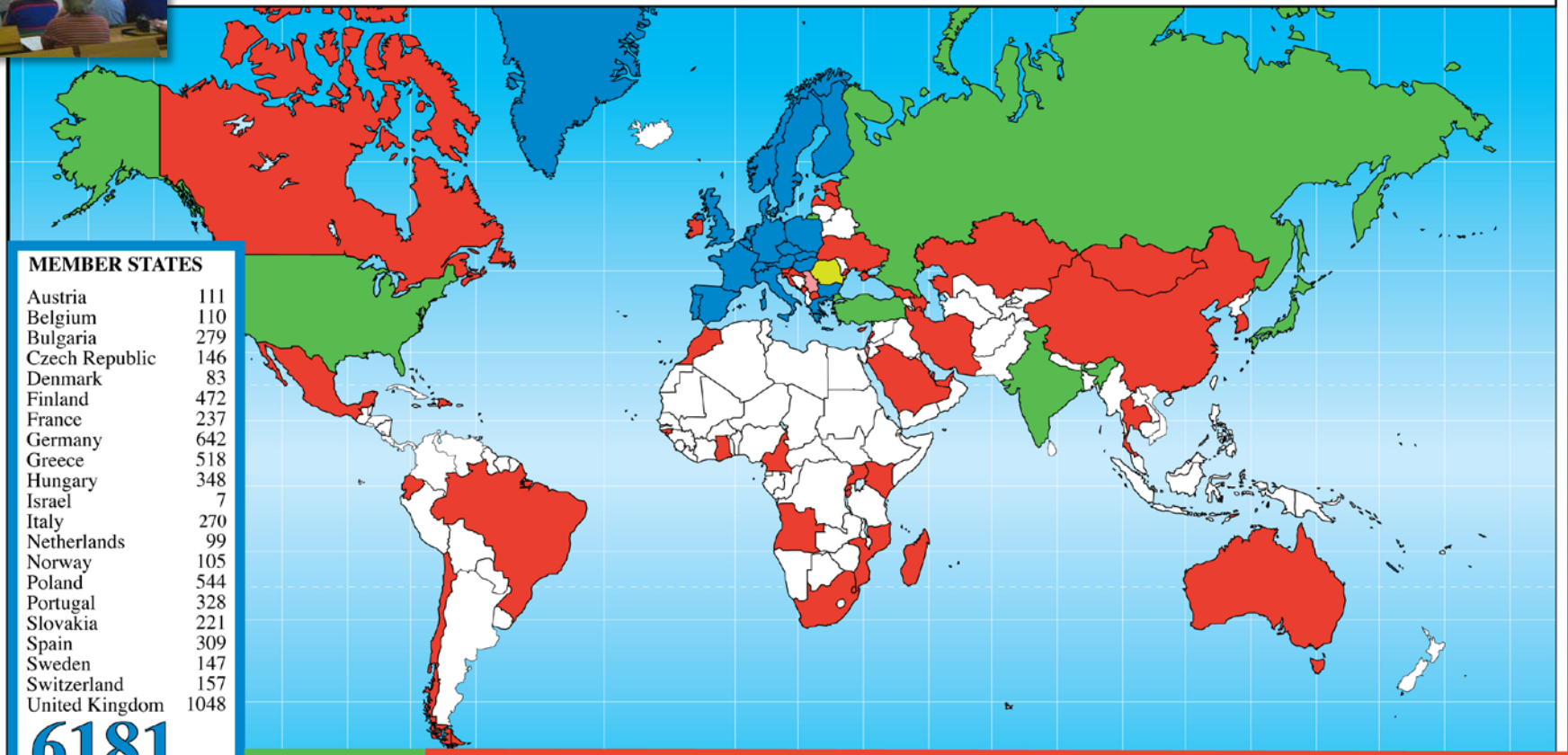


Teachers Programme: courses of one week duration in the mother language of the teachers

Today: ~1000 teachers per year

CERN Teacher Programme

Teacher Programme Participants 1998 - 2013 (Total: 7067)



MEMBER STATES

Austria	111
Belgium	110
Bulgaria	279
Czech Republic	146
Denmark	83
Finland	472
France	237
Germany	642
Greece	518
Hungary	348
Israel	7
Italy	270
Netherlands	99
Norway	105
Poland	544
Portugal	328
Slovakia	221
Spain	309
Sweden	147
Switzerland	157
United Kingdom	1048

6181

CANDIDATE FOR ACCESSION

Romania	12

ASSOCIATE MEMBER IN THE PRE-STAGE TO MEMBERSHIP

Serbia	14

OBSERVER STATES

India	2
Japan	5
Russia	193
Turkey	3
USA	65

268

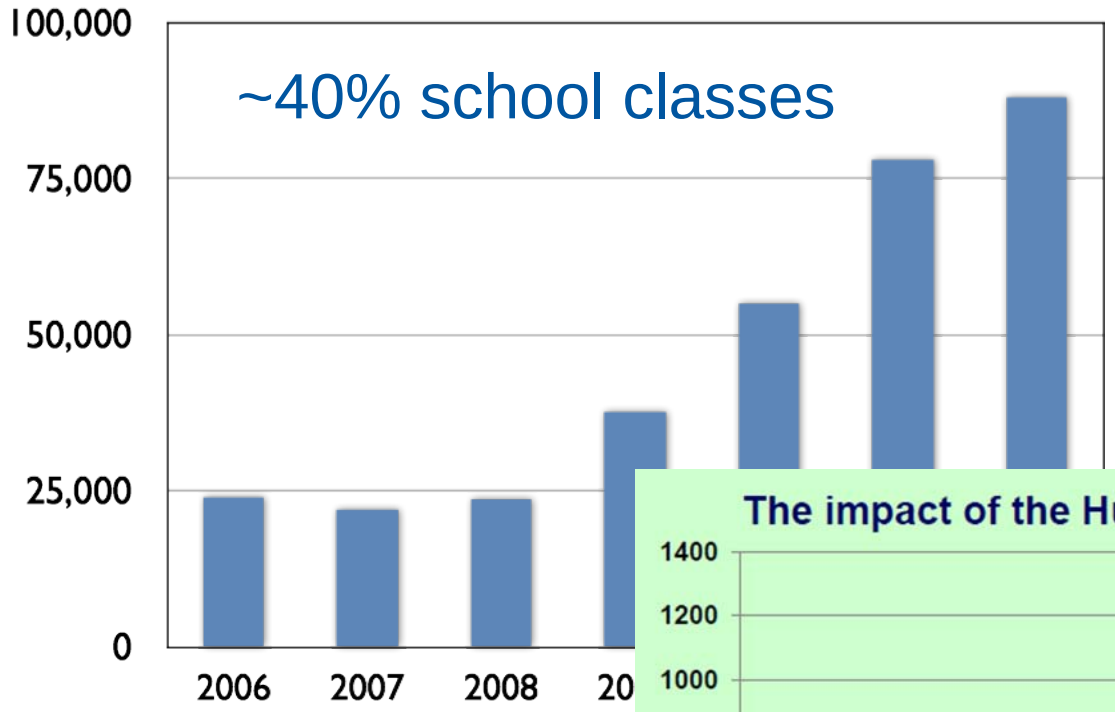
OTHERS

Angola	4	China	1	Ireland	5	Morocco	2	Swaziland	1
Australia	5	Croatia	1	Kazakhstan	3	Mozambique	17	Thailand	7
Azerbaijan	1	Cyprus	8	Kenya	4	Qatar	1	T.F.Y.R.O.M.	11
Brazil	114	Dominican Rep.	21	Latvia	1	Rwanda	17	Timor-Leste	7
Burundi	1	Ecuador	2	Lebanon	1	Sao Tome	4	Uganda	3
Cameroon	3	Estonia	46	Madagascar	2	Saudi Arabia	1	Ukraine	77
Canada	3	Georgia	74	Malta	36	Singapore	2	U.A.E.	1
Cape Verde	3	Ghana	6	Mexico	6	Slovenia	21		
Chile	3	Guinea Bissau	1	Mongolia	1	South Africa	6		
		Iran	1	Montenegro	13	South Korea	44		

592

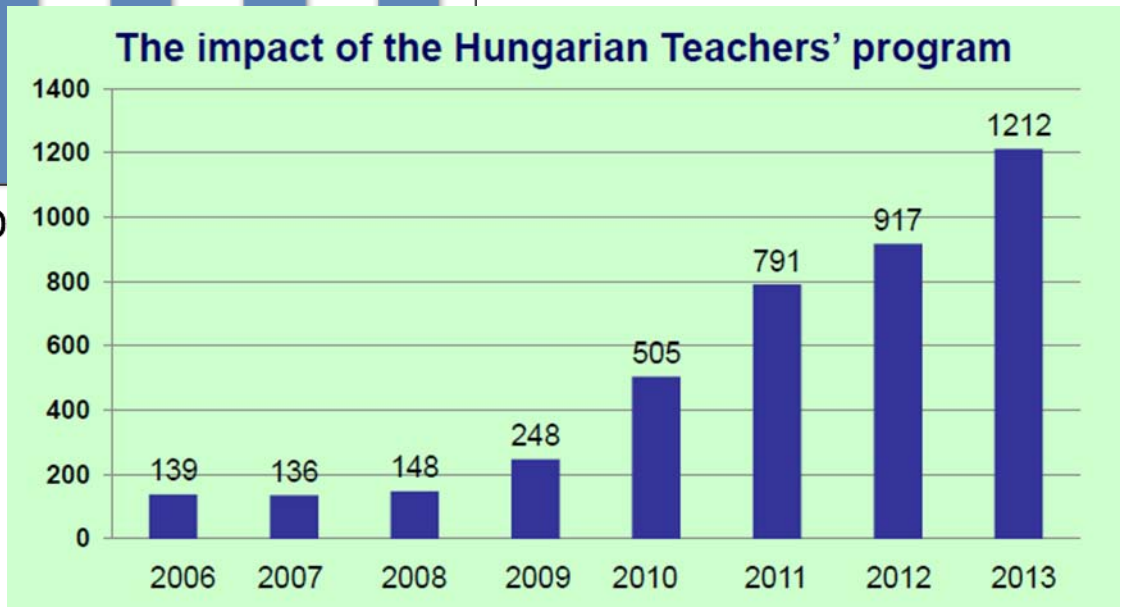
Education and Capacity Building

CERN guided tours: Participants



2013:
~95,000 participants

Over 200,000 requests

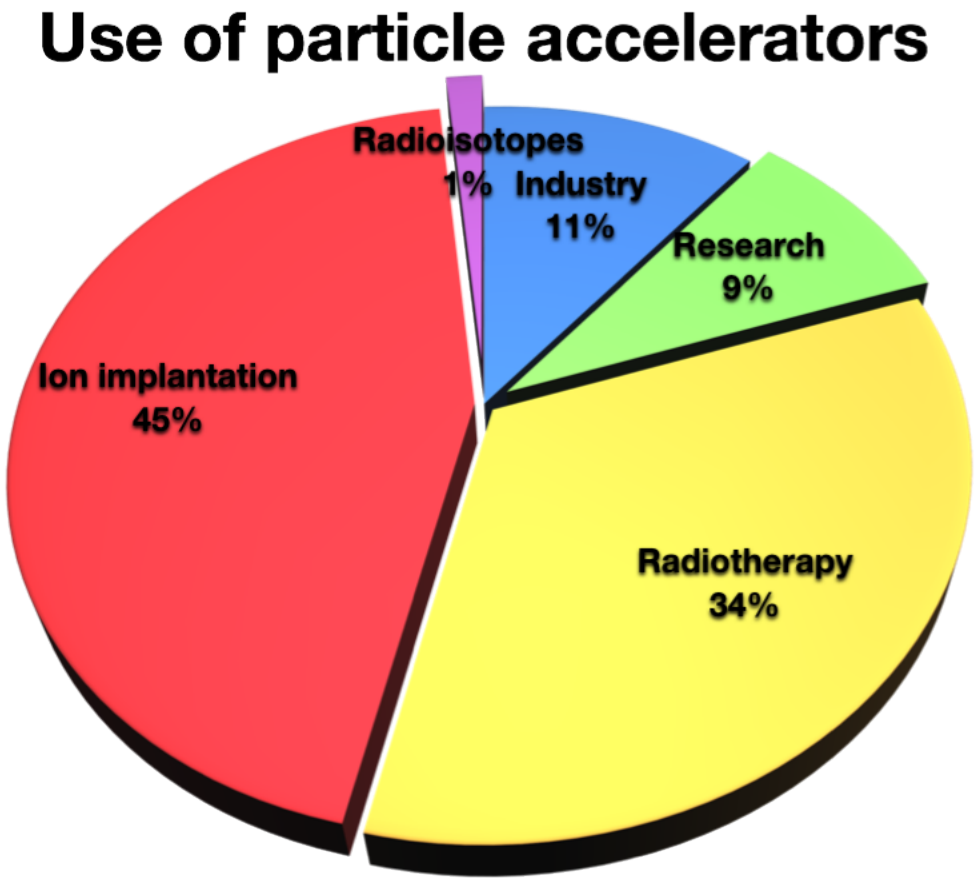


– S'cool Lab
– Summerstudents
– Beamline for Schools .

CERN | 60 YEARS / ANS CERN

CERN: research in and use of accelerator technology

Today: ~30,000 accelerators in use world wide



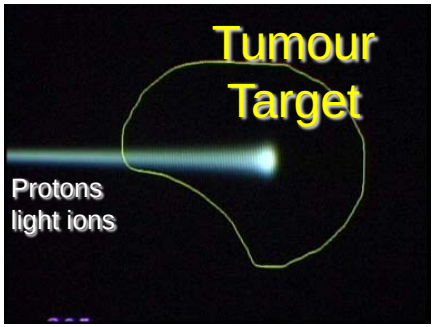
Medical application
Sterilisation of food
Ion-Implementation
Material research

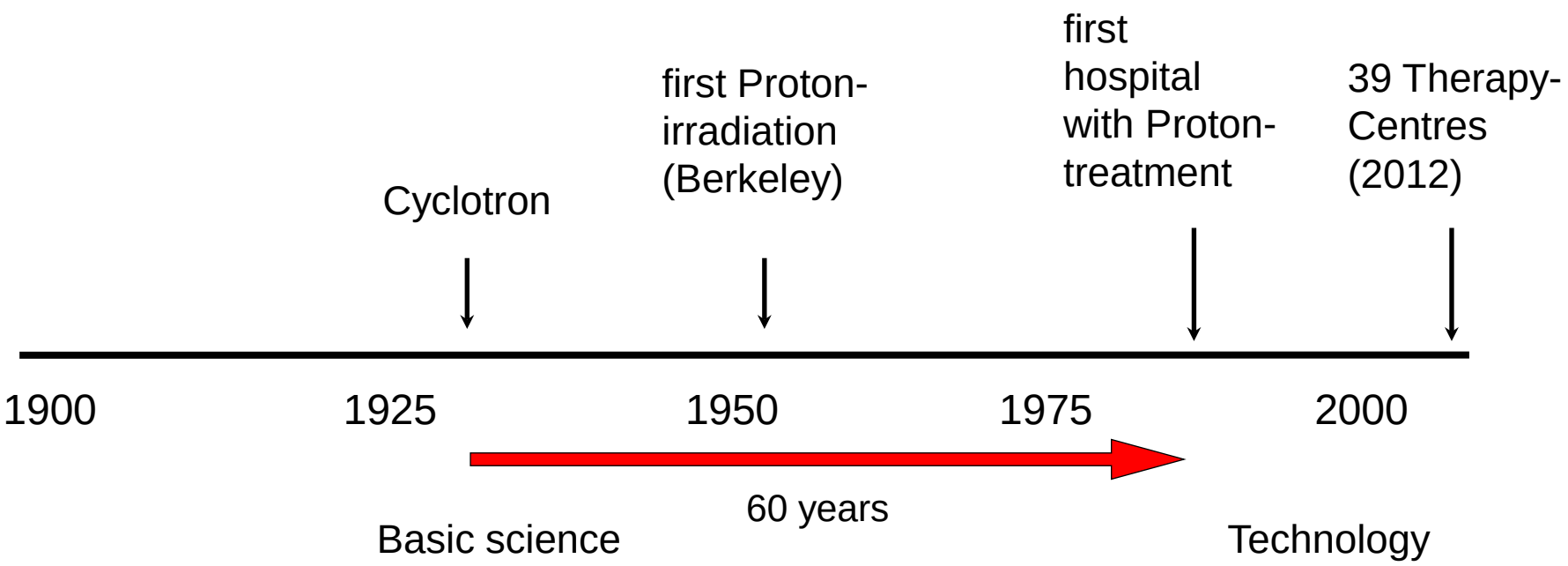
Source: US DoE

Accelerator-Technology: Proton-Therapy

Tumor treatment with less effects on healthy tissue

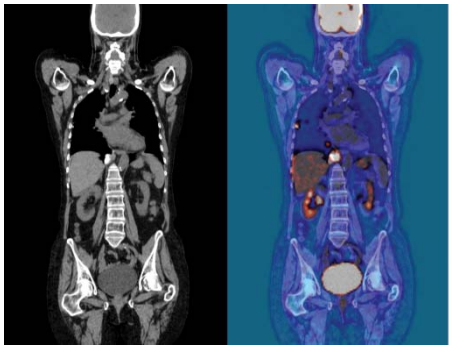
CERN: collaboration in design and development of new Proton-TherapyCcentres (e.g. Med-Austron in Wiener-Neustadt, CNAO in Pavia)





Medical Diagnostic with Antimatter

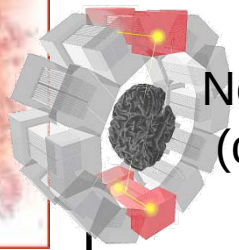
"Seeing" better and more with less radiaton dose



CT CT+PET

PET

Positron- Emission-Tomography



Prediction and Discovery of Antimatter

New generation of PET (crystals developed for LHCDetectors)

1900 1925 1950 1975 2000

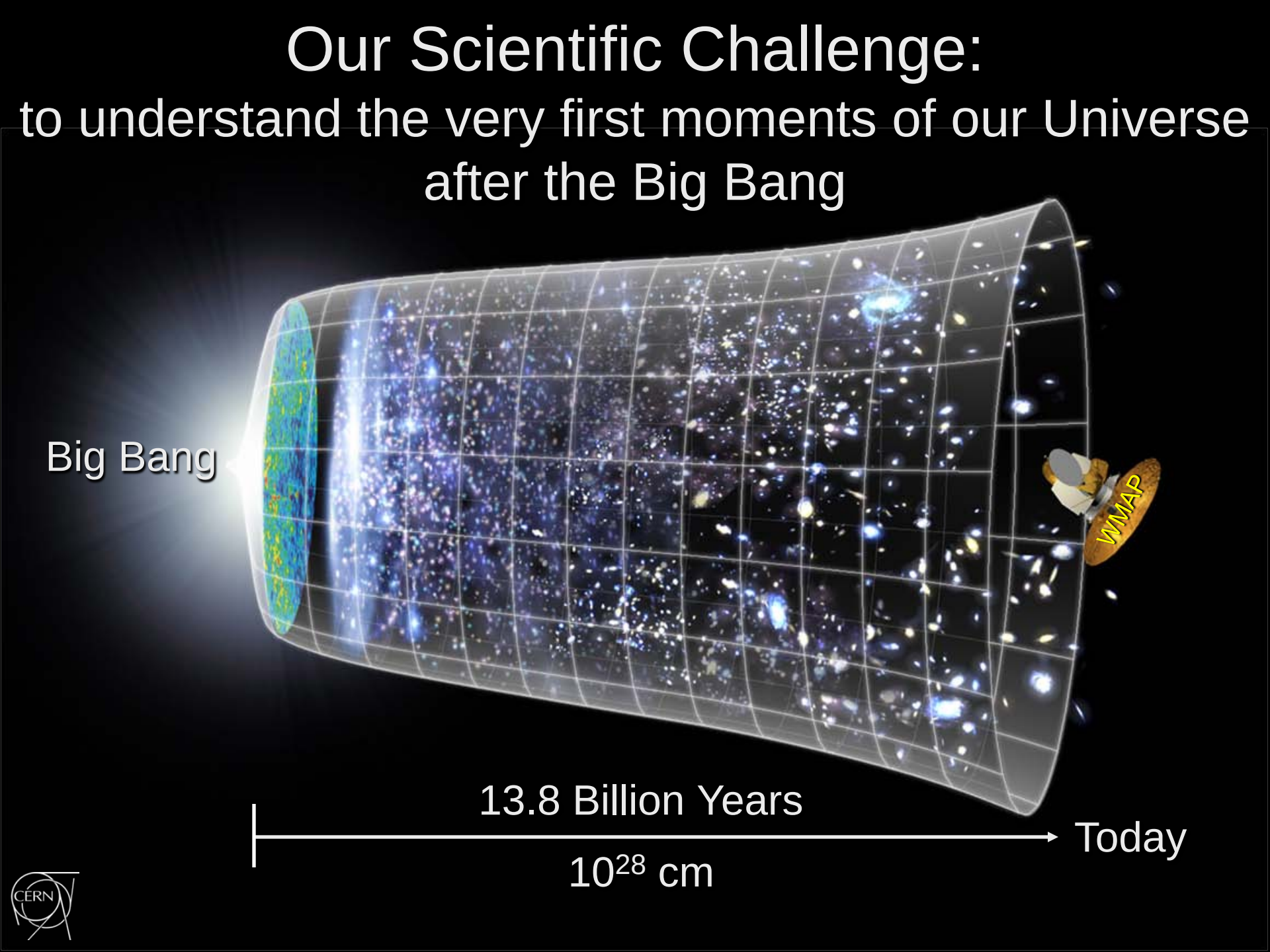
45 years

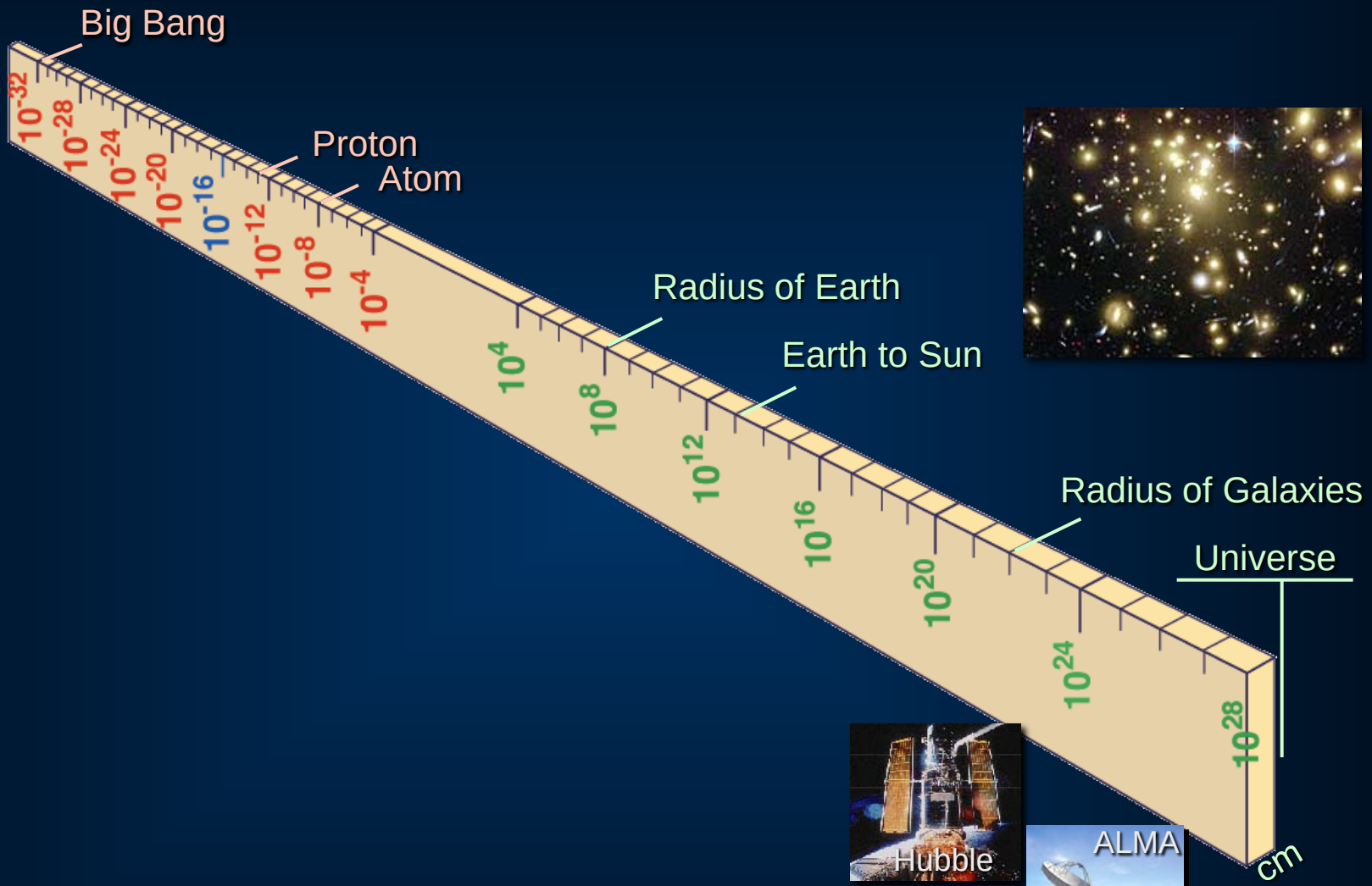
Basic Research

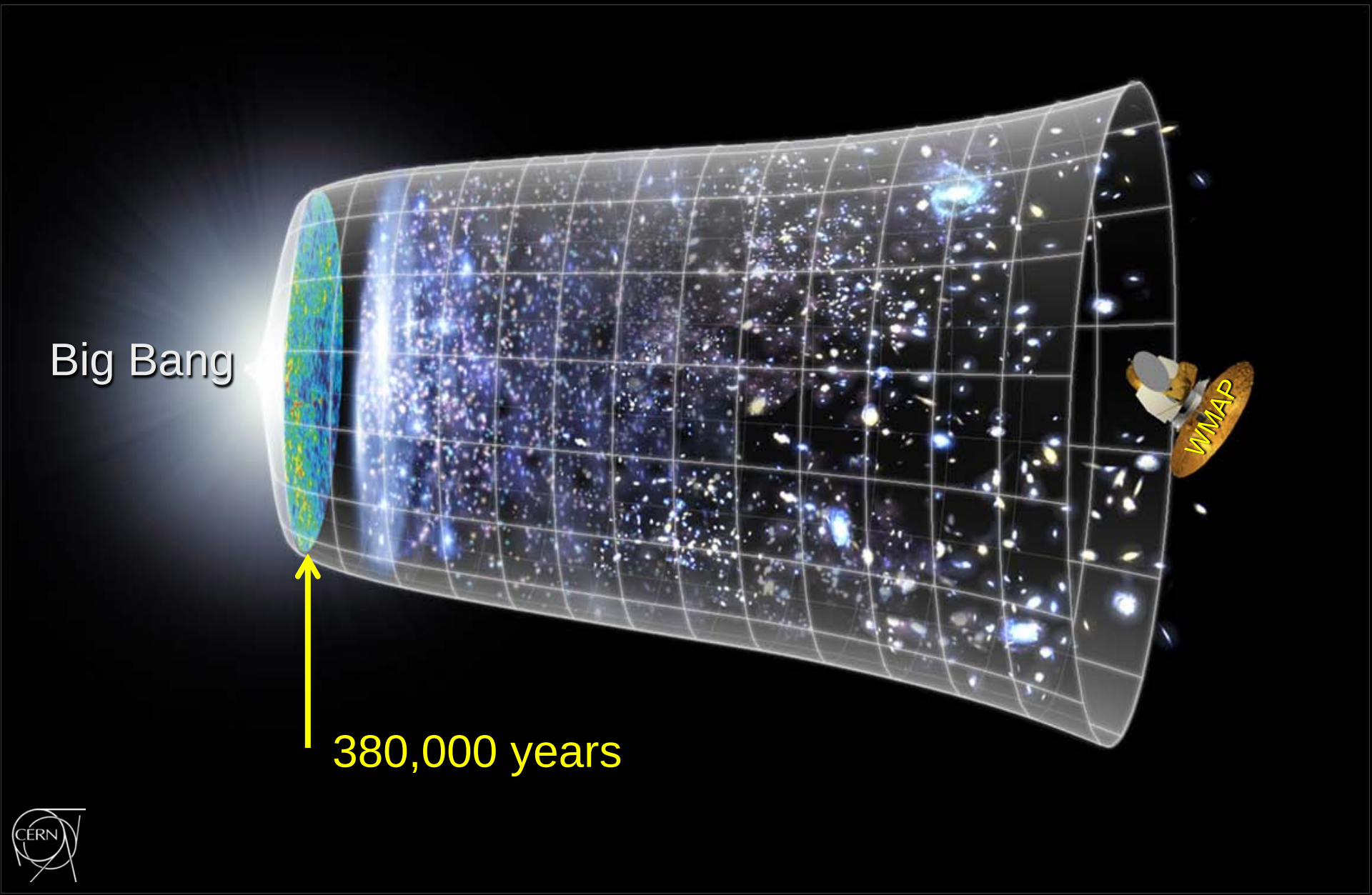
Technology

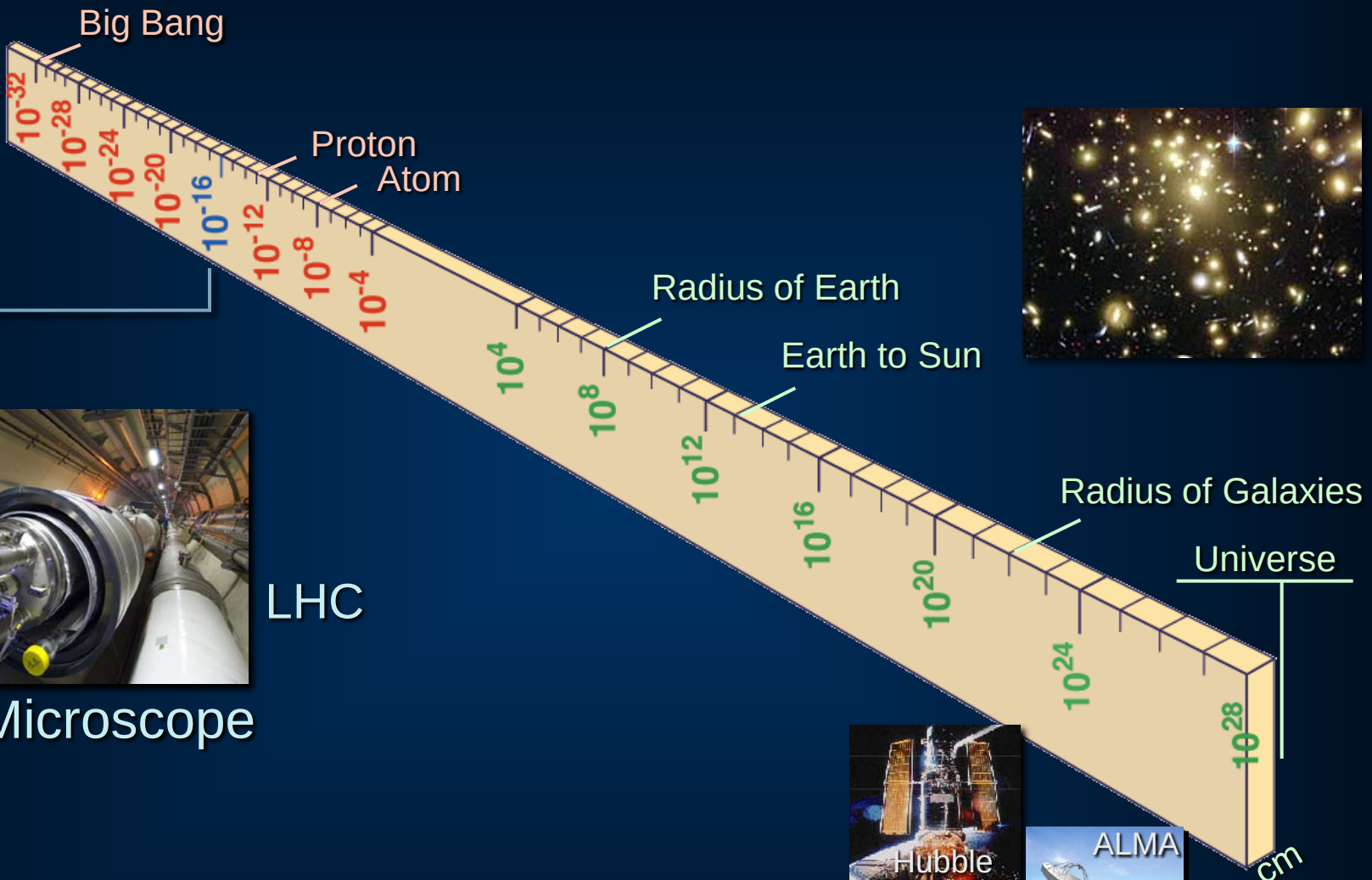
Our Scientific Challenge:

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




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
Hubble
ALMA
AMS
VLT


Big Bang
WMAP
380,000 years



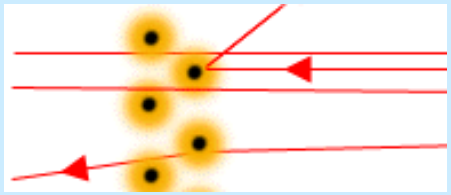
LHC

Super-Microscope

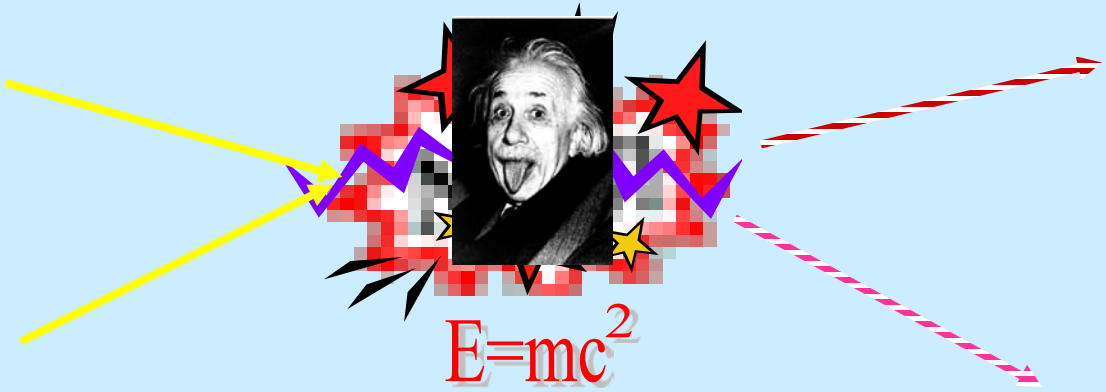
The role of accelerators

high energy:

Resolving the inner structure of matter: $E = hc/\lambda$

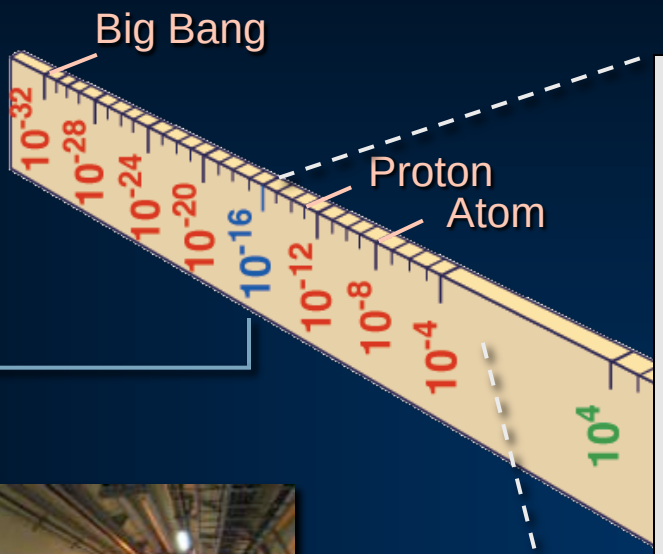


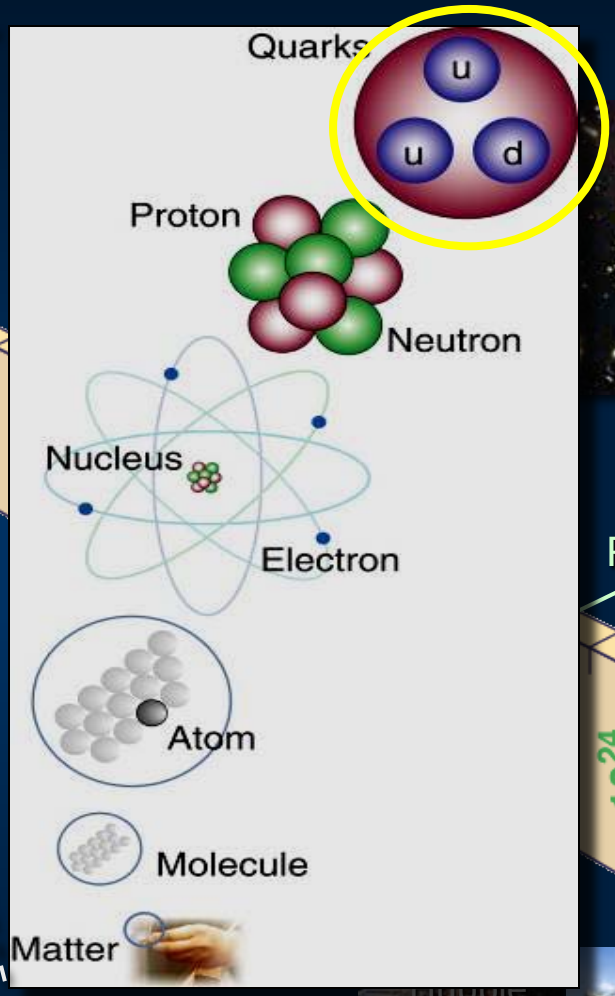
Production of new Particles : $E = m\,c^2$



high statistics:

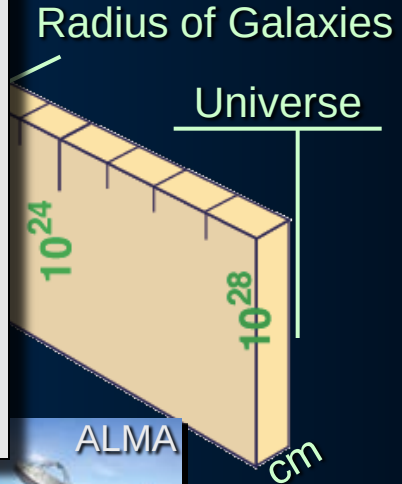
Precision measurements





LHC

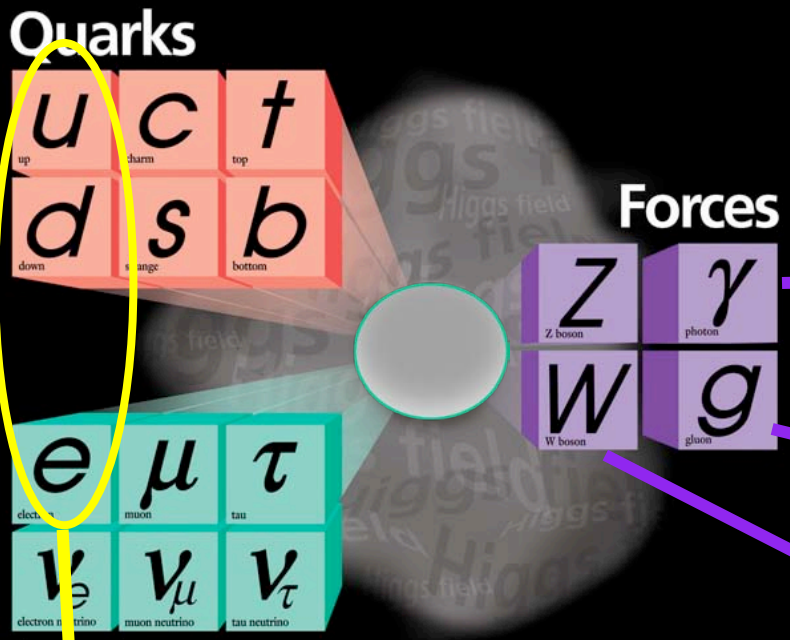
Super-Microscope

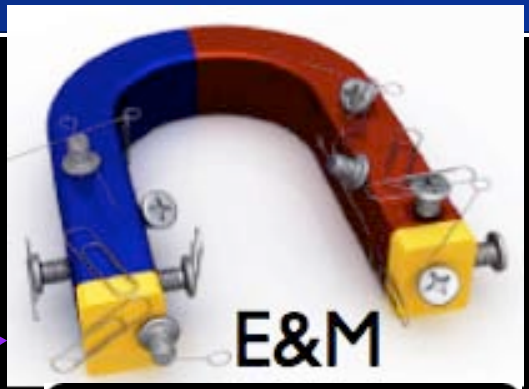


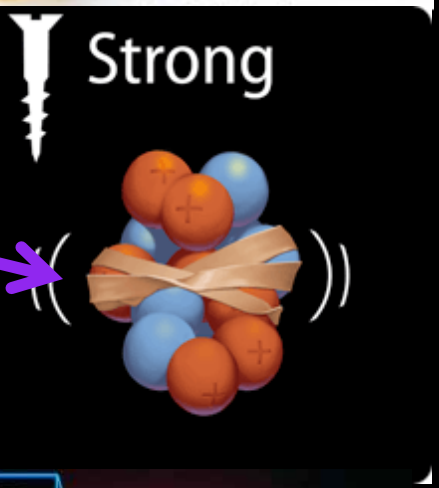
Getting closest to the Big Bang ($\leq 10^{-12}$ s)

→ breaking the wall of the Hidden Universe

The Standard Model

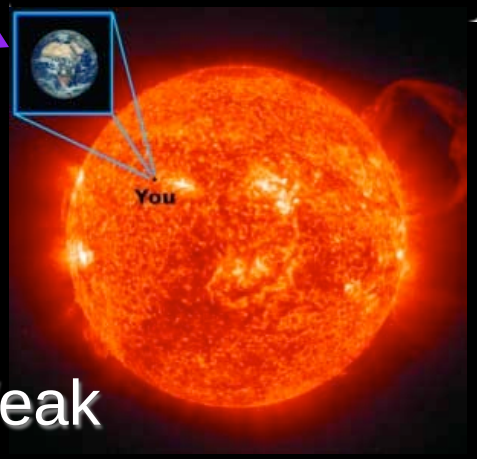






Standard Model tested over decades with high precision.

However before LHC one crucial question left open:
How do elementary particles acquire mass ?



THE last cornerstone of the Standard Model

What is the origin of mass of elementary particles?

Possible solution:

Mass = property of particles with energy E to move with velocity $v/c = (1-m^2/E^2)^{1/2}$ i.e. the higher the mass the lower the velocity (at the same energy)

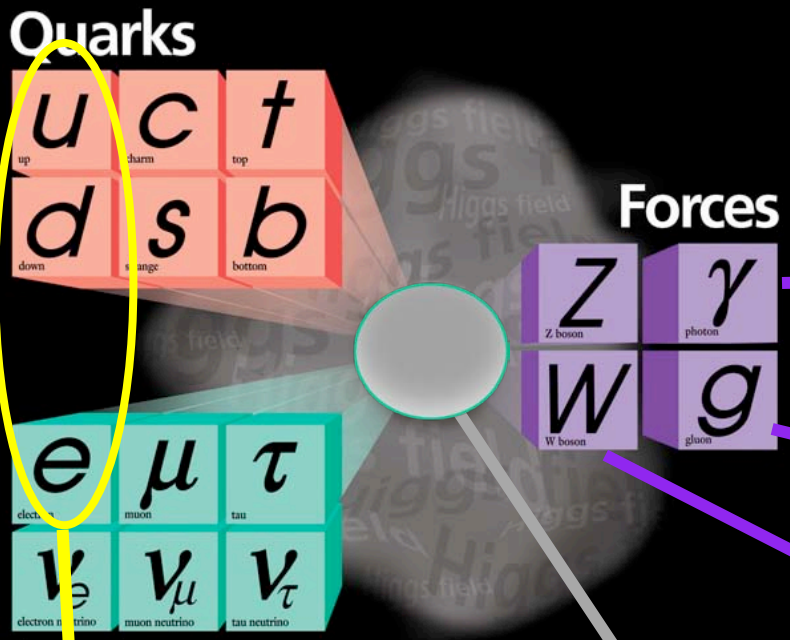
➔ introduction of a scalar field

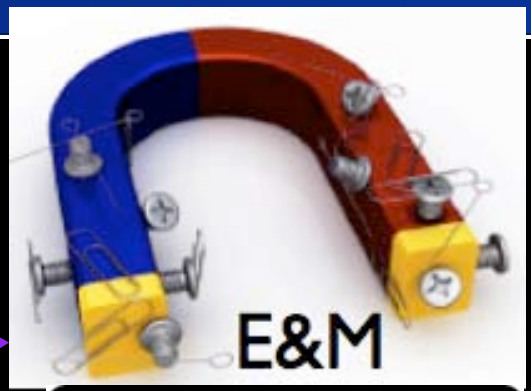
(Brout, Englert, Higgs, Kibble, Guralnik, Hagen)

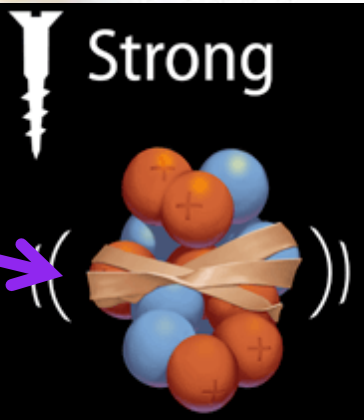
particles acquire mass through interaction with this field

Self interaction of the field → Higgs-Particle

The Standard Model

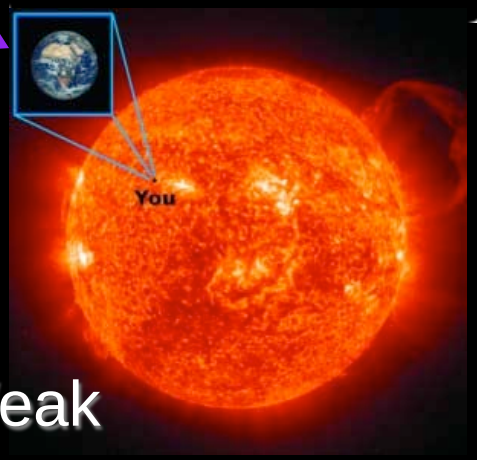






Standard Model tested over decades with high precision.

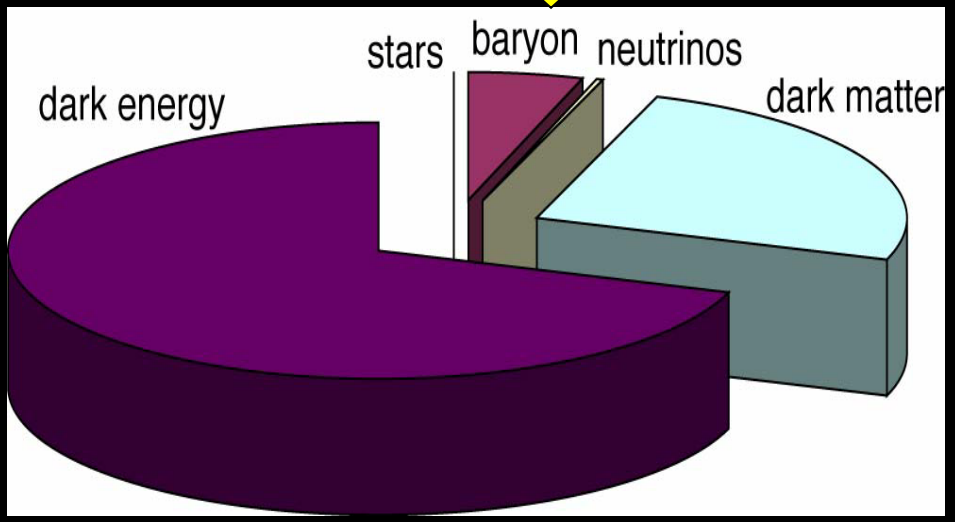
Has the LHC now answered the crucial question:
How do elementary particles acquire mass ?



. . . Standard Model leaves many key questions open,
e.g. where is antimatter ?

and in particular. . .:

Standard Modell



Ω_B BARYONS

Ω_{CDM} DARK MATTER

Ω_ν NEUTRINOS

Ω_{DE} DARK ENERGY

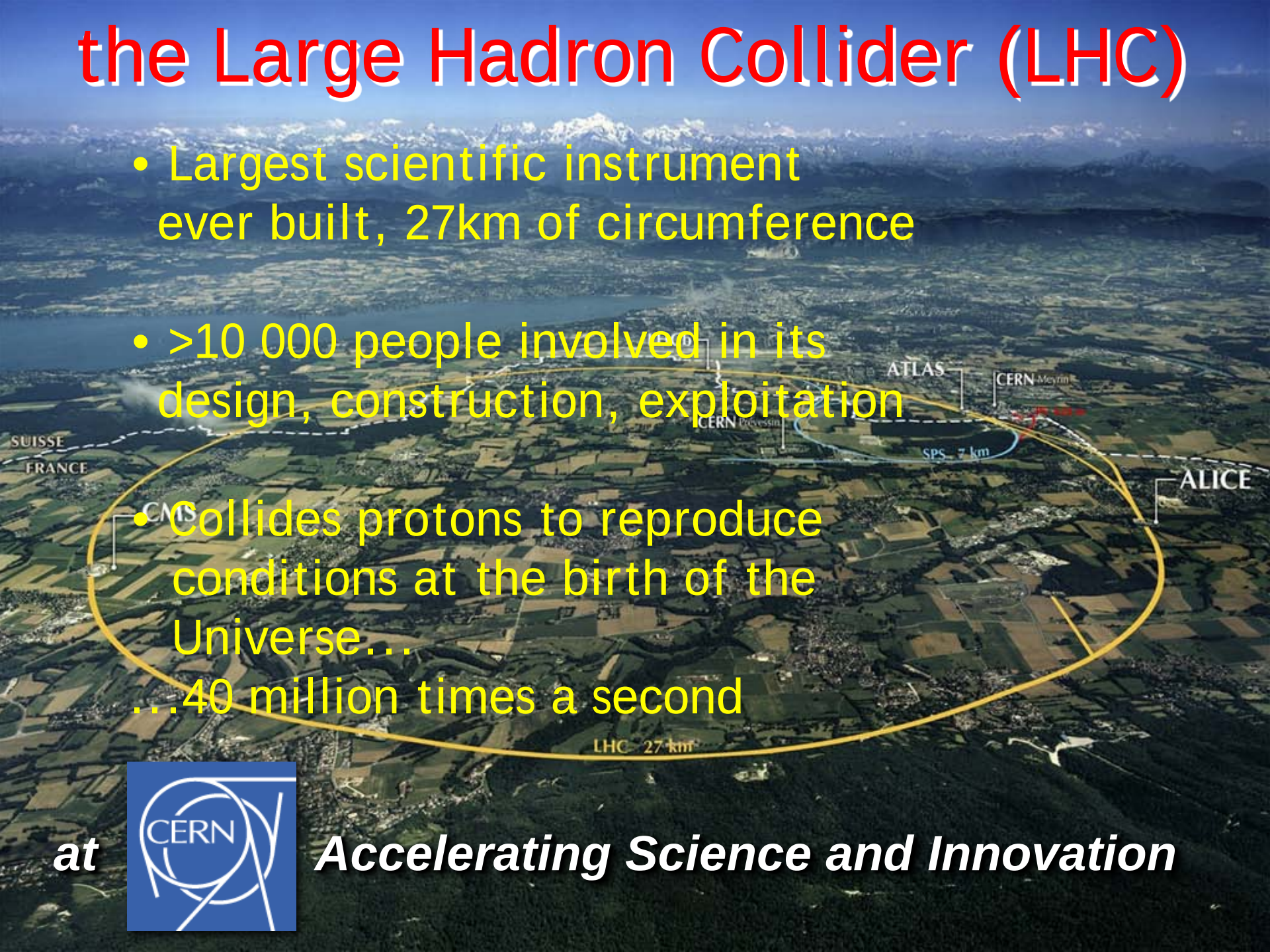
$$\Omega_{TOT} = \Omega_B + \Omega_{CDM} + \Omega_\nu + \Omega_{DE}$$

→ with the Large Hadron Collider
now entering the 'Dark Universe' !?

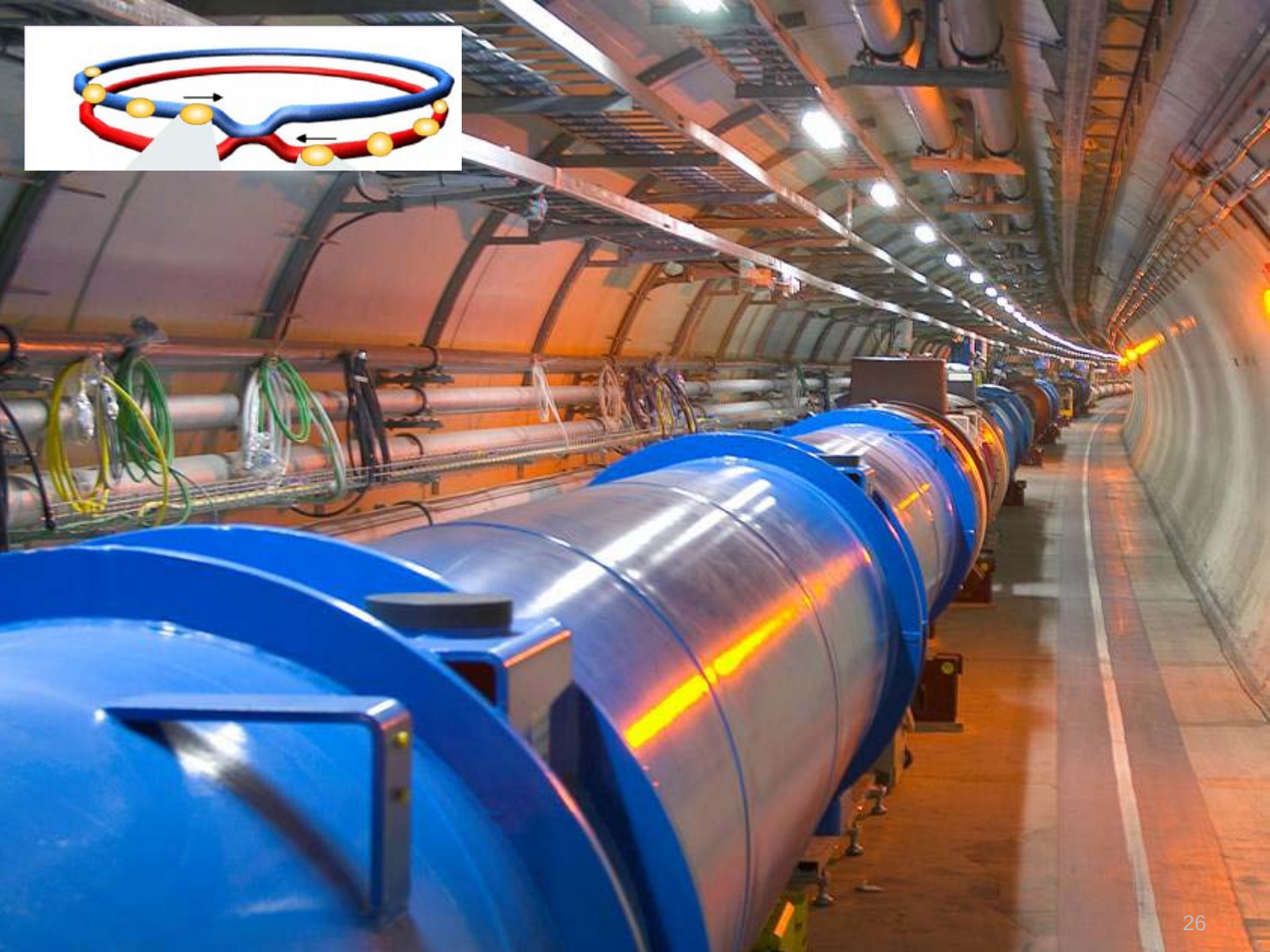
the Large Hadron Collider (LHC)

- Largest scientific instrument ever built, 27km of circumference
- >10 000 people involved in its design, construction, exploitation
- Collides protons to reproduce conditions at the birth of the Universe…

…40 million times a second



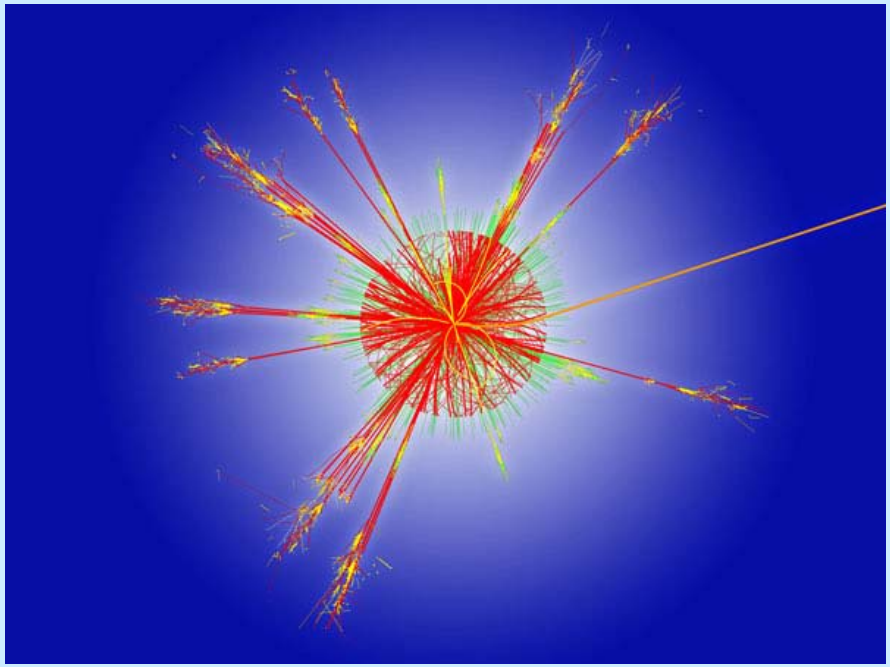
at CERN *Accelerating Science and Innovation*

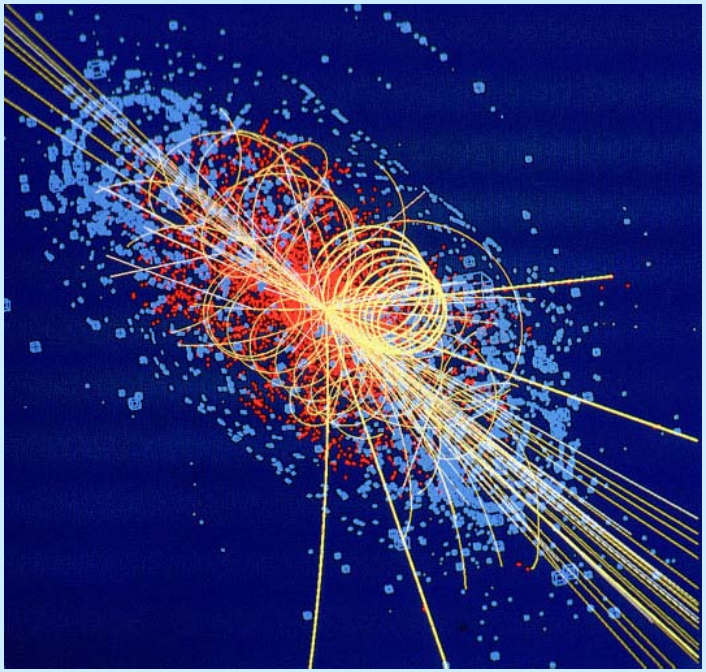


One of the coldest places in the Universe…

With a temperature of -271 C, or 1.9 K above absolute zero, the LHC is colder than outer space.

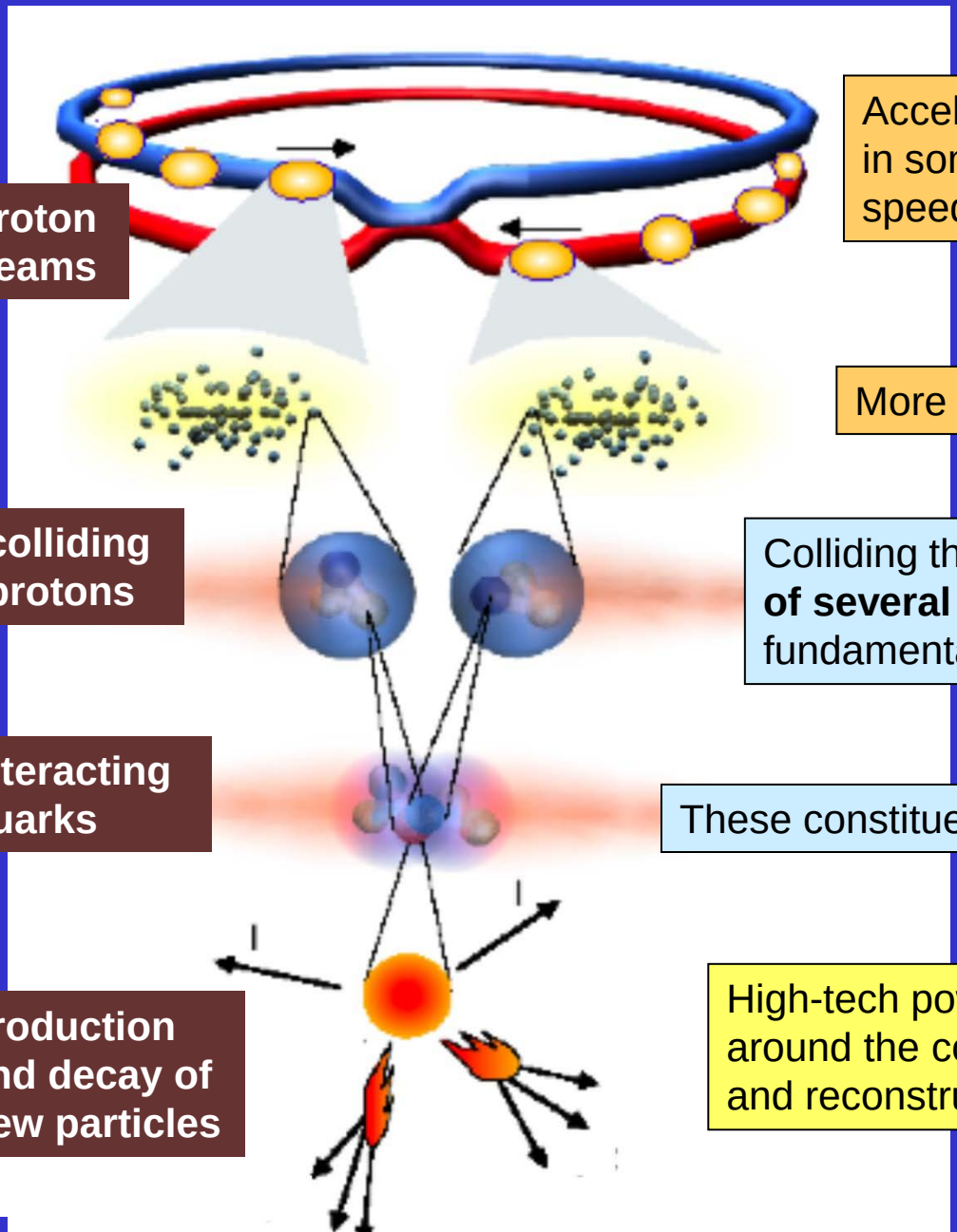
One of the hottest places in the galaxy...





The collision of two proton beams generates temperatures 1000 million times larger than those at the centre of the Sun, but in a much more confined space.

LHC: study the elementary particles and their interactions



proton beams

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

More than **100 billion protons** per bunch

colliding protons

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

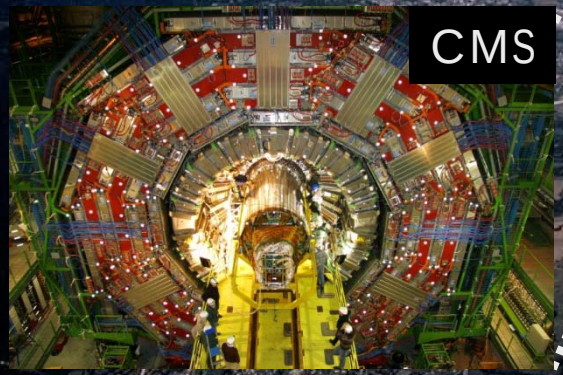
interacting quarks

These constituents interact at very high **energy density**

production and decay of new particles

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

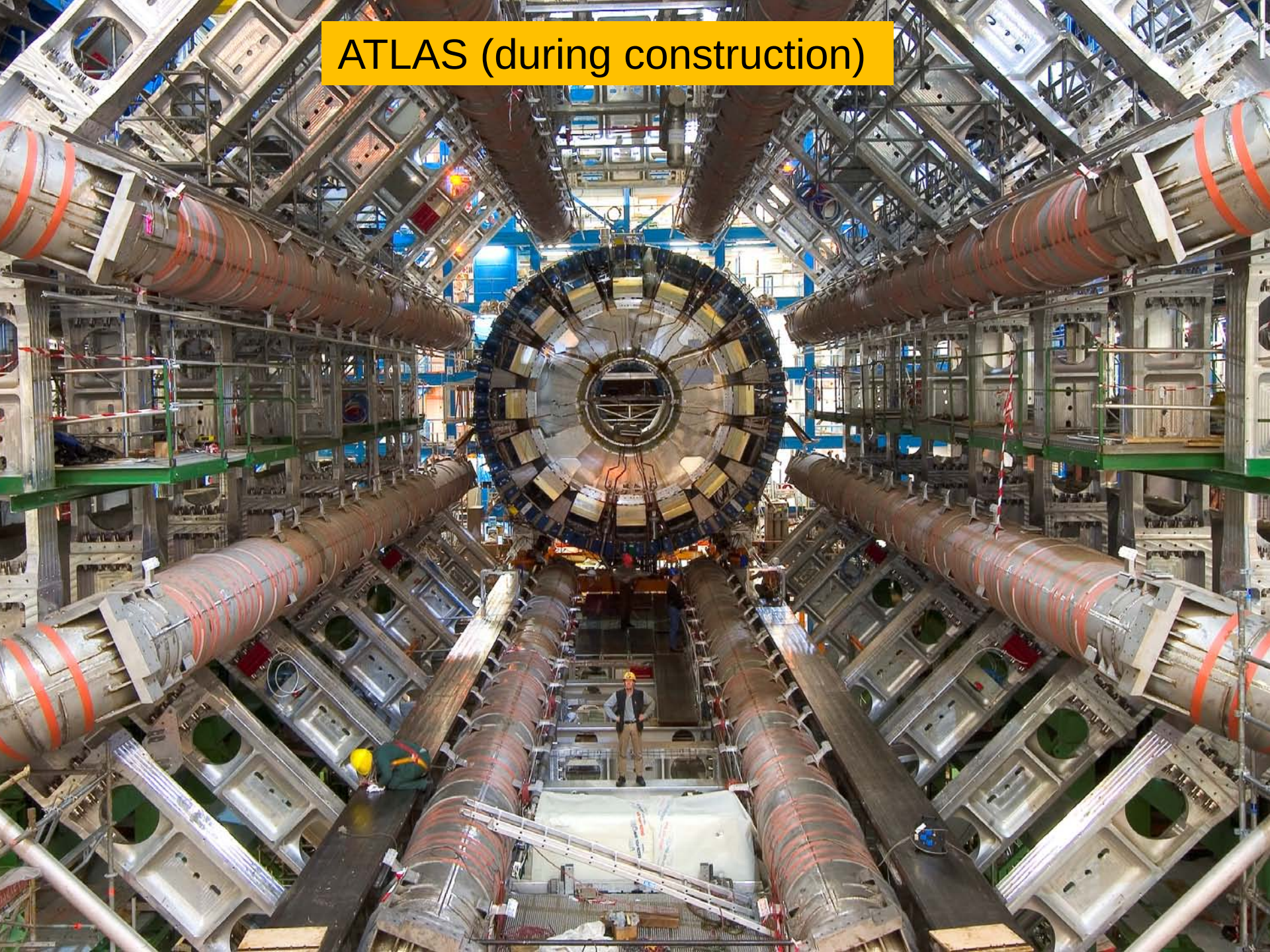
2010: Start of a New Era in Fundamental Science

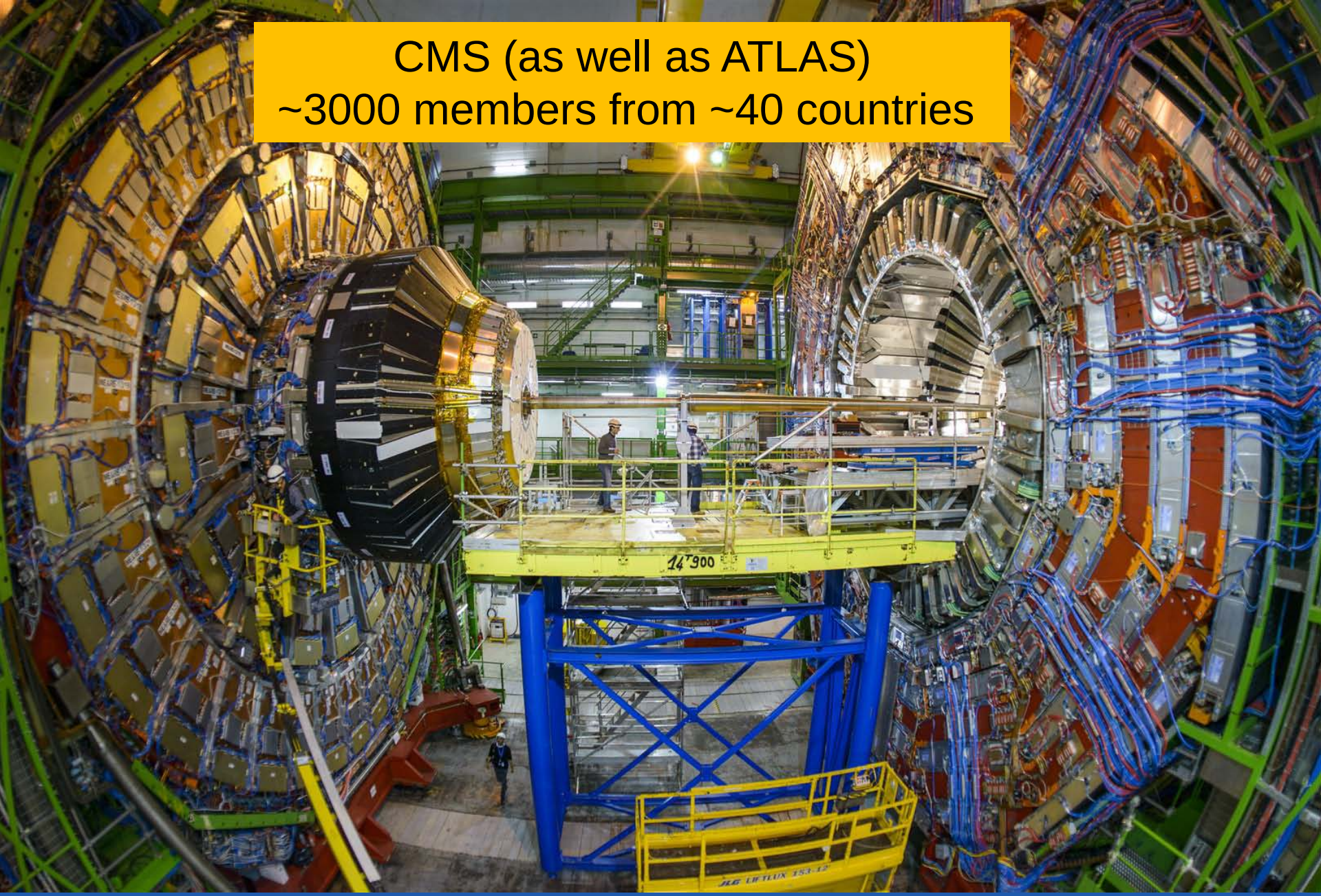


Exploration of a new energy frontier
Proton-proton and Heavy Ion collisions

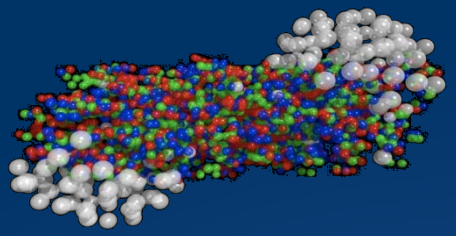
Prague

Prague

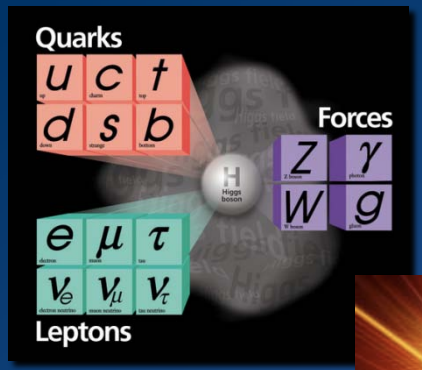

ATLAS (during construction)


CMS (as well as ATLAS)
~3000 members from ~40 countries

The study of LHC data will allow us to answer some of the key questions …



Will we understand the primordial state of matter after the Big Bang before protons and neutrons formed?



Have we found the Higgs particle that is 'responsible for giving mass' to all particles?

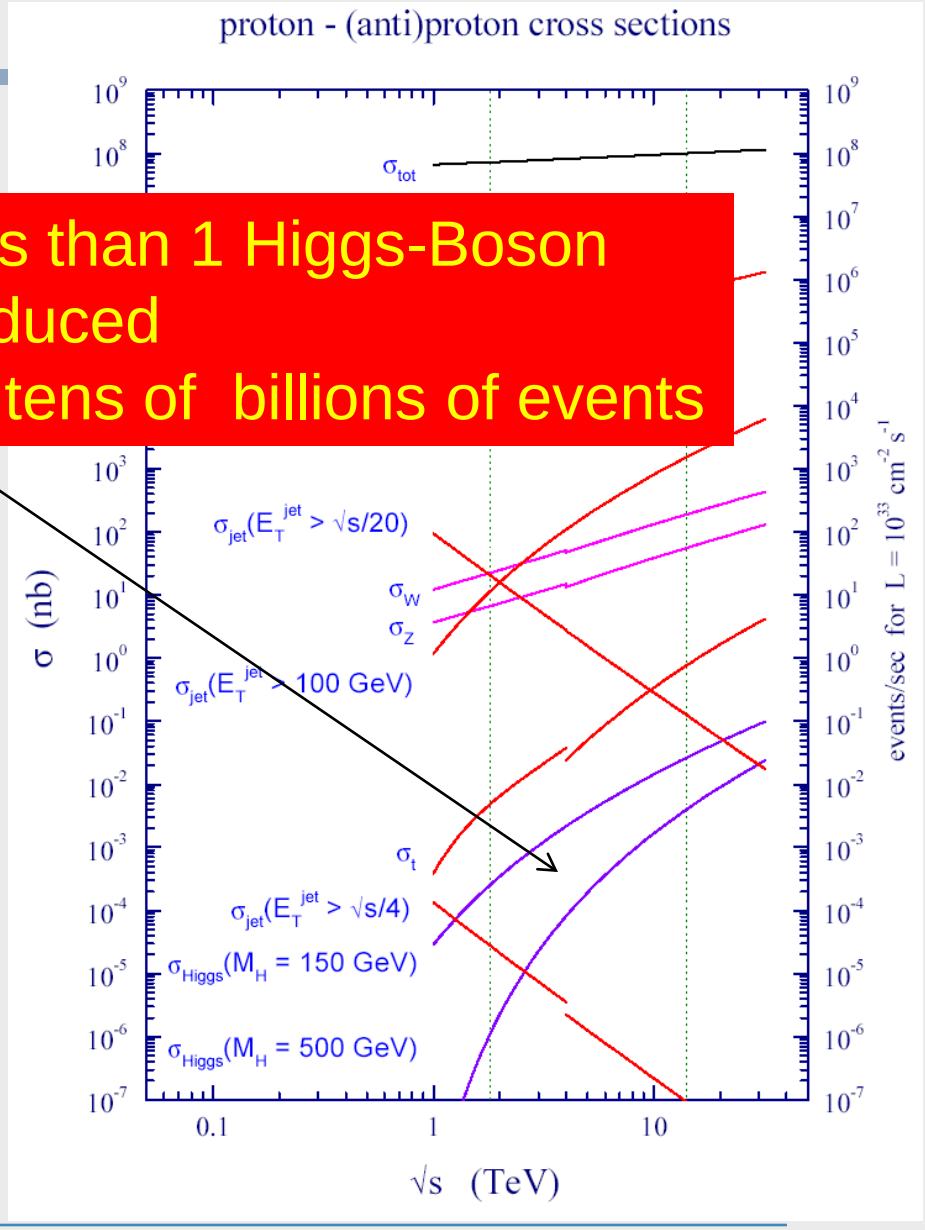
Will we find the reason why antimatter and matter did not completely destroy each other?

Will we find 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 Higgs-Bosons rather low

Less than 1 Higgs-Boson produced
per tens of billions of events



Computing Technologies: the Grid

After filtering, CERN detectors select ~200 interesting collisions per second (out of some 600 Million).
Several MBs of data to be stored for each collision...

→ more than 25 Petabytes/year of data!

8 Megabyte (8MB)
A digital photo

1 Gigabyte (1GB)
= 1000MB
A DVD movie

1 Terabyte (1TB)
= 1000GB
World annual
book production

> 25 Petabytes (25PB)
= 25000TB
Annual LHC data output

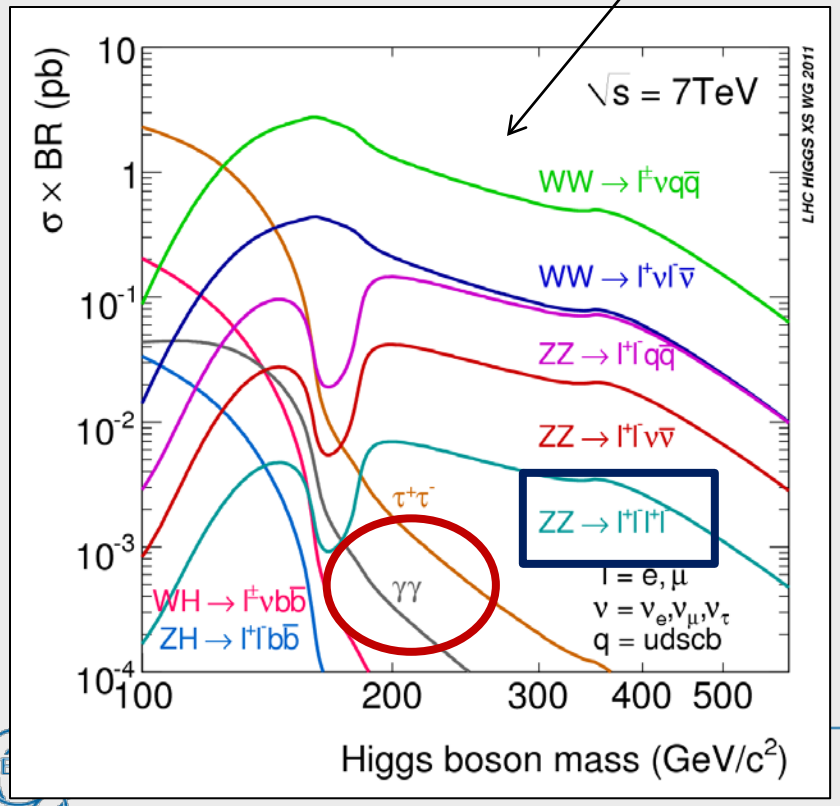
CERN, home of the World Wide Web, is a driving force in Grid Computing

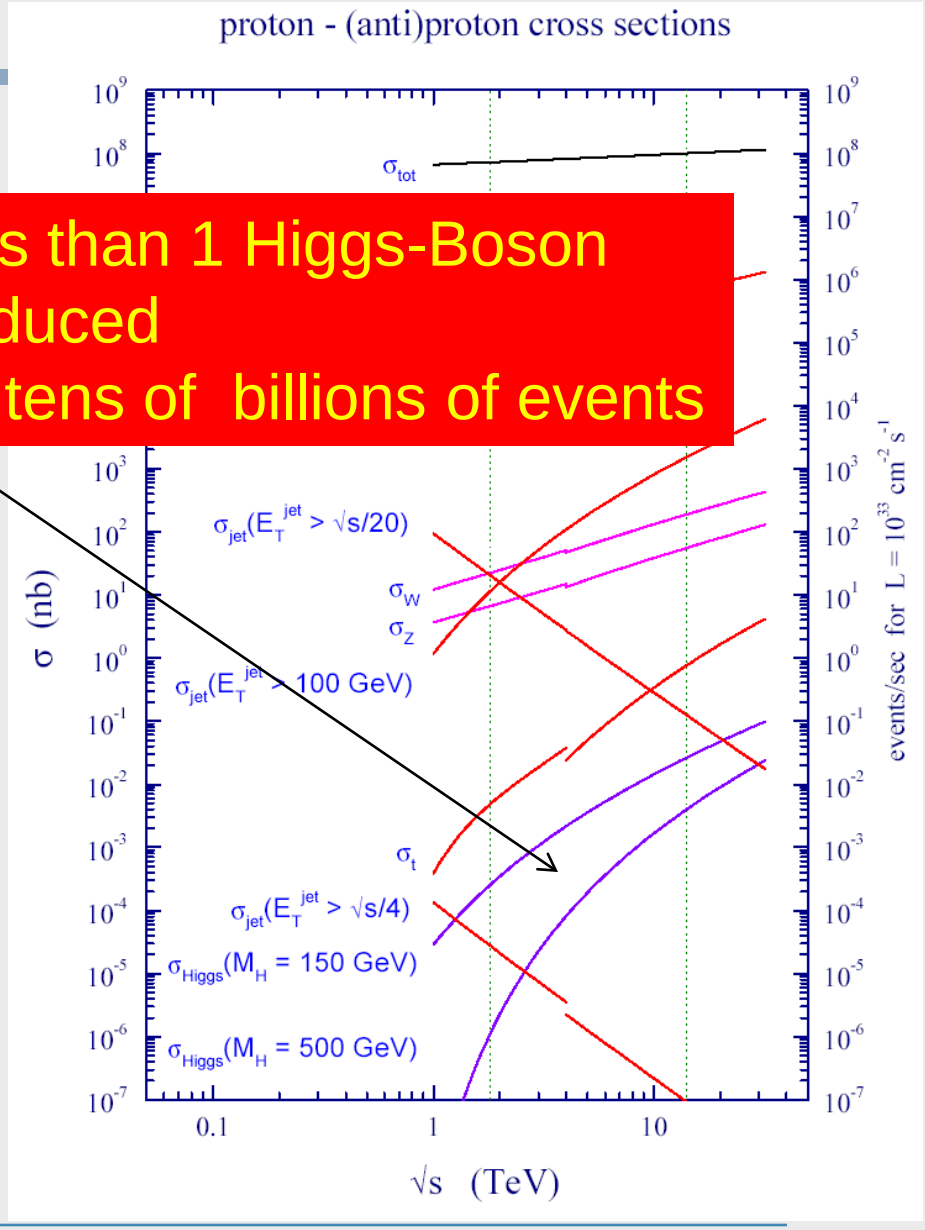
Search for the Higgs-Boson at the LHC

Production rate of Higgs-Bosons rather low

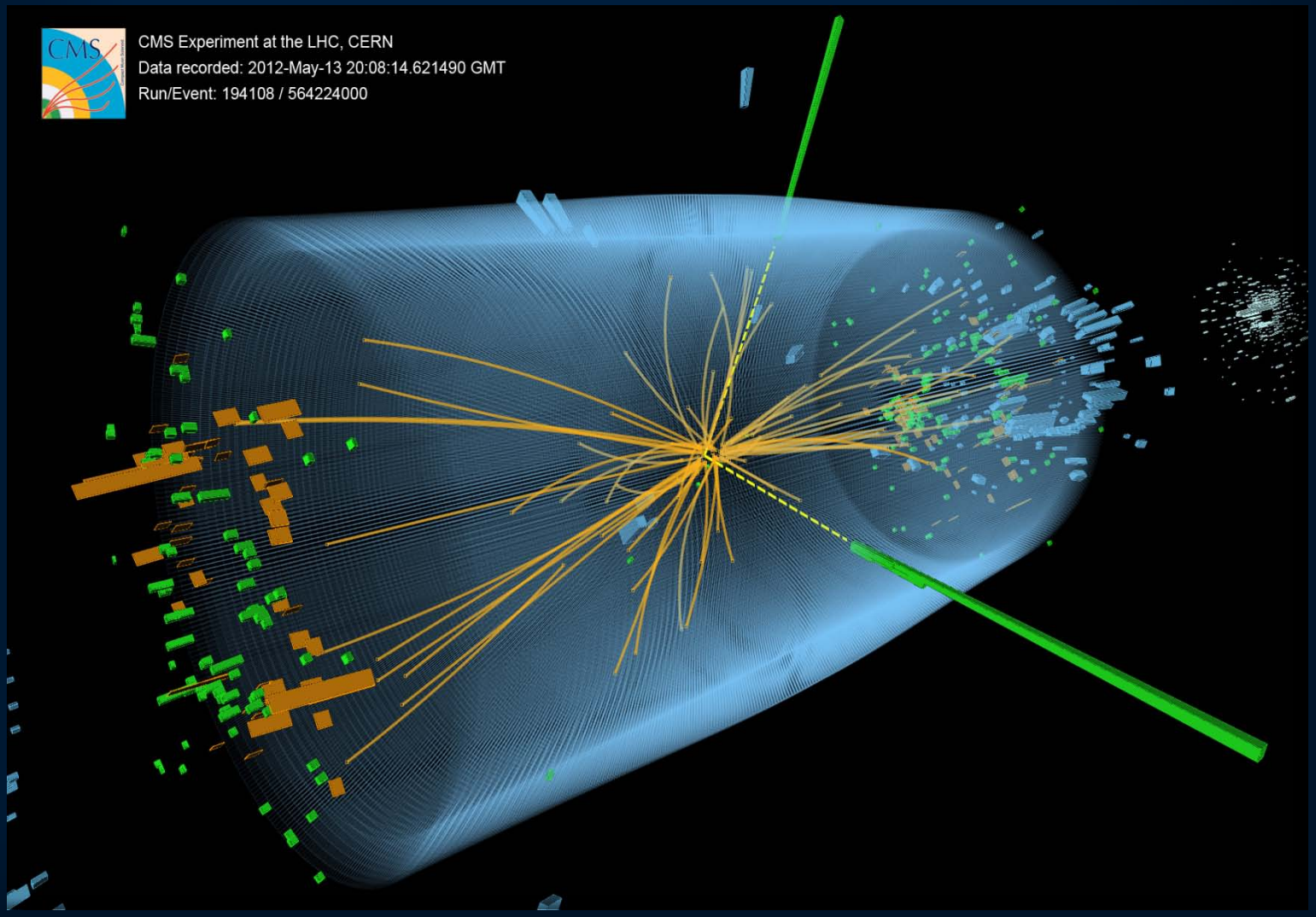
Many different decay possibilities
→different signatures in detector

Less than 1 Higgs-Boson produced per tens of billions of events



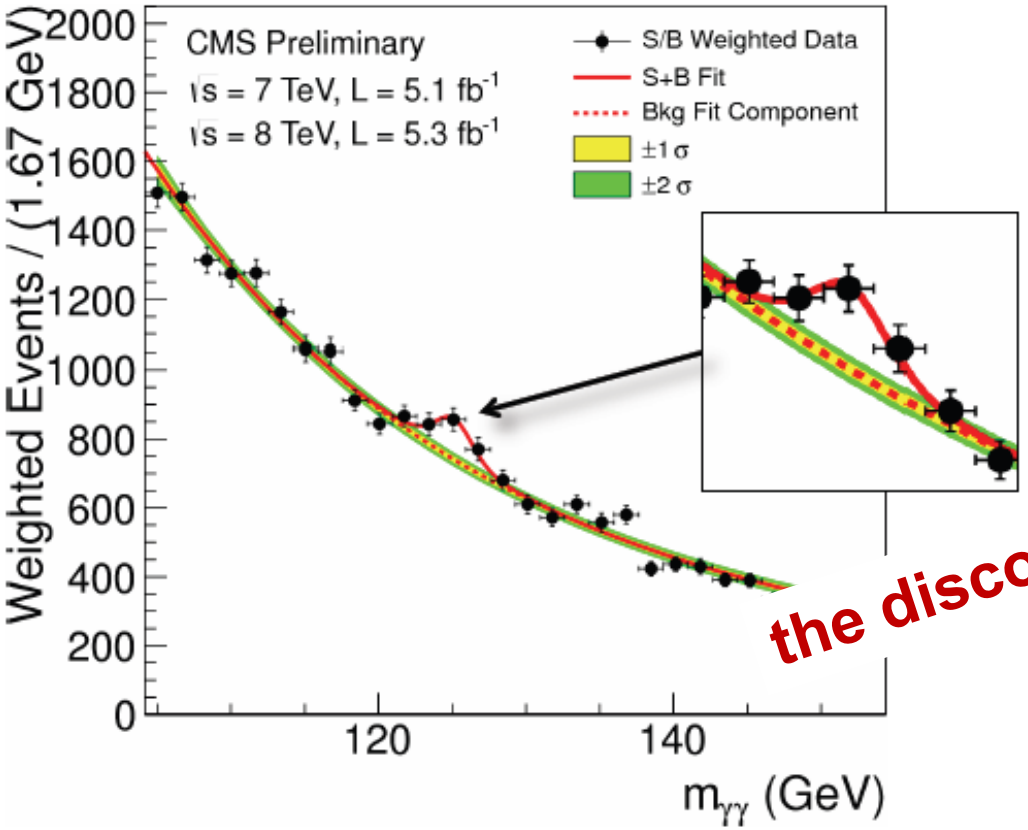


A striking signature of a possible Higgs boson decay
H -> γ γ



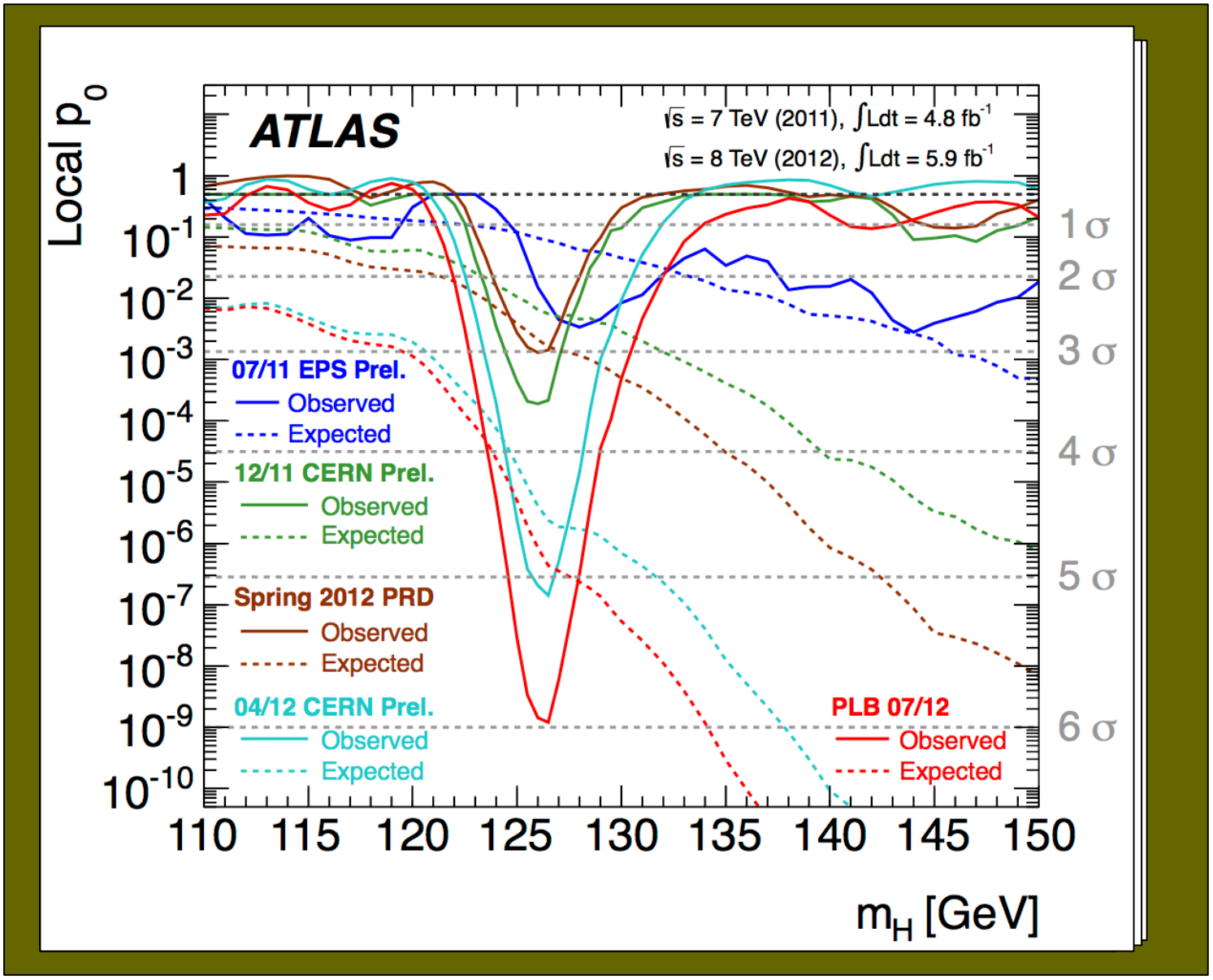
S/B Weighted Mass Distribution

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



the discovery…..

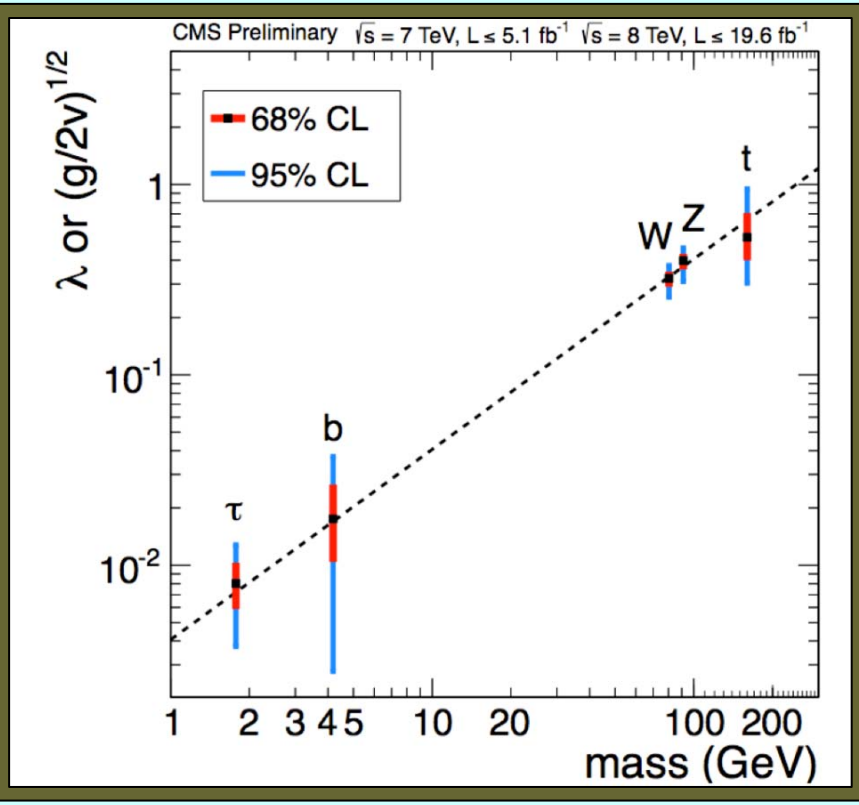
Development of signal strength over 12 months



Is the new particle a Higgs boson ?

ATLAS and CMS have verified the two “fingerprints”

1) To accomplish its job (providing mass) it interacts with other particles (in particular W, Z) with strength proportional to their masses



2) It has spin 0, it is representing a scalar field

YES !

It completes the Standard Model

thus describing ~5% of the Universe

The Higgs-Particle is special!

All Matter Particales are Spin-1/2 Fermionen
All Force Particles are Spin-1 Bosonen

Higgs-Particles are Spin-0 Bosons: Scalars
Higgs is neither Matter nor Force
Higgs is different
It is the first fundamental Scalar ever discovered

the BEH-Field is a scalar field everywhere in the Universe
-> maybe hints on properties of Dark Energy (Scalar, too)?

And: why should the Higgs-Boson be the
only one of its kind ?

LHC can search for such scalars and (if found) investigate them

Siscovery 2012, Nobelprize 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".*

Today

- Data taking 2010-2013 at an energies of 7 and 8 TeV terminated
- Data analysis still in full swing

- LHC and all other accelerators at CERN 2013/2014: maintenance and improvement
  In particular all High Current Connections at the LHC consolidated
- Experiments maintained and improved

Tomorrow

… this is only the beginning !
what's next ?

… Data taking will be restarted 2015
at an energy of 13 TeV;
later on at design energy of 14 TeV

… it is *a* Higgs-Boson !
… is it *THE* Higgs-Boson (of the Standard Model) ?
or is in one of several (one of a family) ?

… but that's only the beginning !
What's next ?

… it is a Higgs Boson !
… is it *the* Higgs Boson (of th… …del) ?
or one of several ?

… its properti… …give information
on Dark Matter
… its properties could give first hints
on Dark Energy

Physics program at the LHC
beyond 2030

our understanding of the Universe
is about to change

Past decades saw precision studies of 5 % of our Universe → Discovery of the Standard Model

The LHC delivers data and **we have a discovery**

We are just at the beginning of exploring 95 % of the Universe

Past decades saw precision studies of 5 % of our Universe → Discovery of the Standard Model

The LHC delivers data and **we have a discovery**

We are just at the beginning of exploring 95 % of the Universe

the future is bright in the Dark Universe

CERN

– innovate, discover, publish, share

… and bring the world together