THE PHYSICS OF FUNDAMENTAL INTERACTIONS AND THE CMS EXPERIMENT AT CERN

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Silvano Tosi

Università di **Genova**

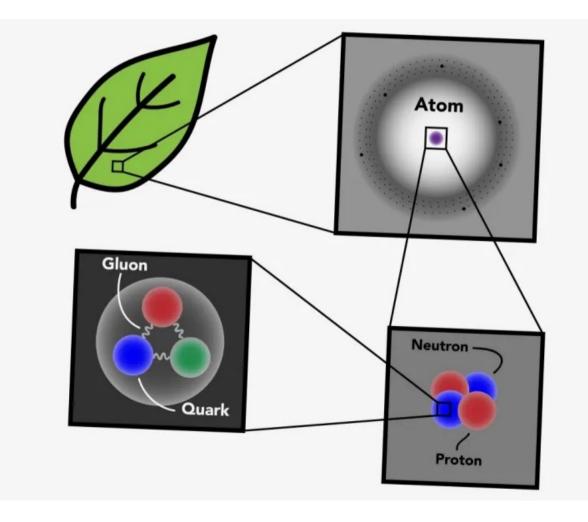
INFN

Istituto Nazionale di Fisica Nucleare

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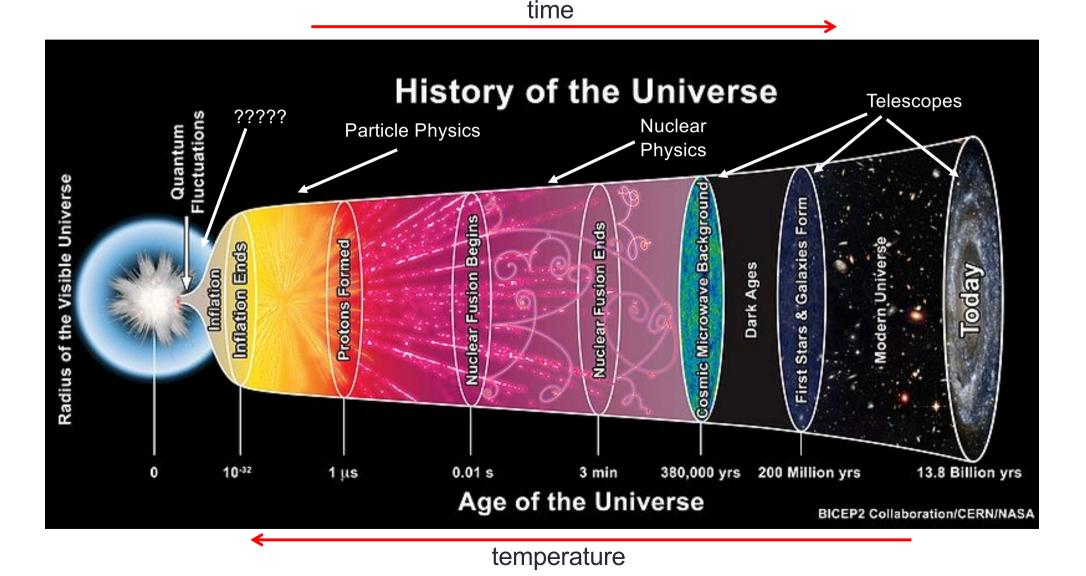
23/11/2023 Science Week in Tirana

Fundamental questions



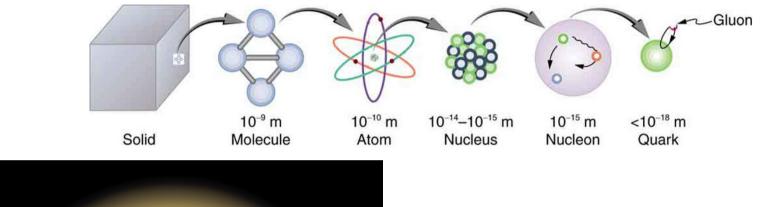
- What are the elementary constituents of matter?
- What are the forces with which they interact, and which bind them to form matter as we observe it?
- How did the universe originate, how did it evolve to what we see today?

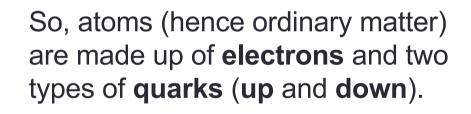
The quest for the **fundamental constituents** of matter is closely linked to the study of the **first moments and the evolution** of our Universe

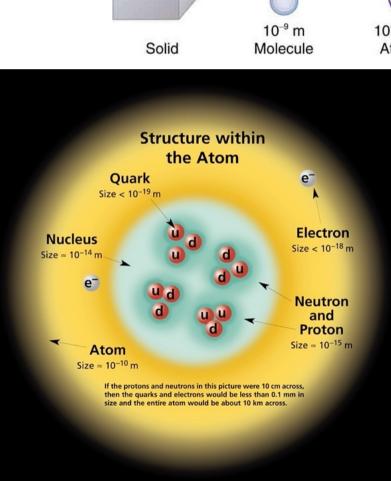


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Electrons and quarks

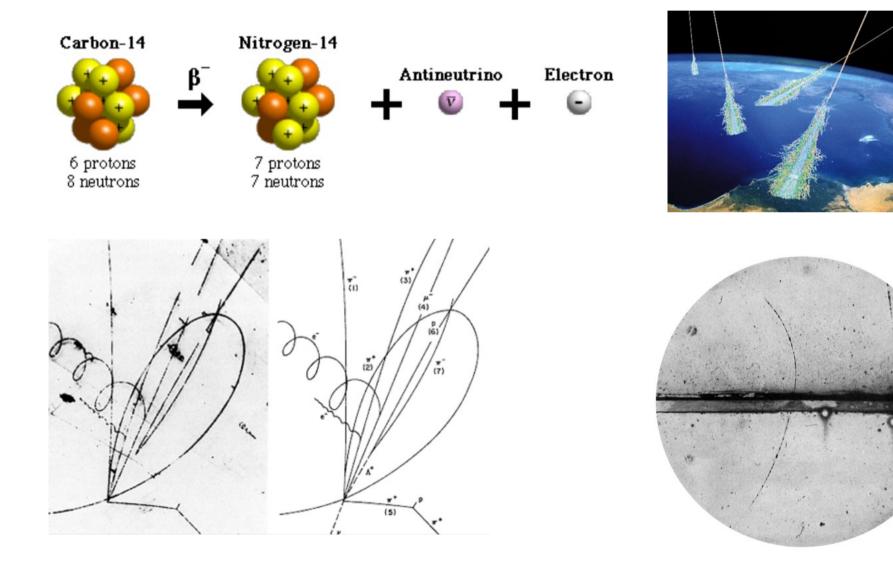






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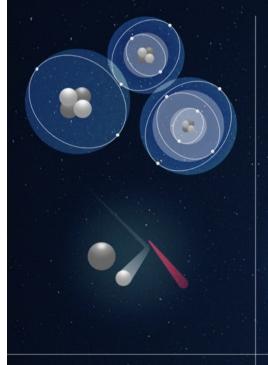
More elementary particles... and antiparticles



How particles interact: fundamental forces

THE EXCHANGE OF PARTICLES IS RESPONSIBLE FOR THE FORCE

The four fundamental forces



ELECTROMAGNETIC FORCE

Governs the interaction between atoms and the formation of molecules. **It enables** chemical reactions and light to be emitted.

WEAK NUCLEAR FORCE

Governs the decay or transformation of neutrons into protons and the release of neutrinos and radiation. **It enables** the fission reactions of heavy atoms.

STRONG NUCLEAR FORCE

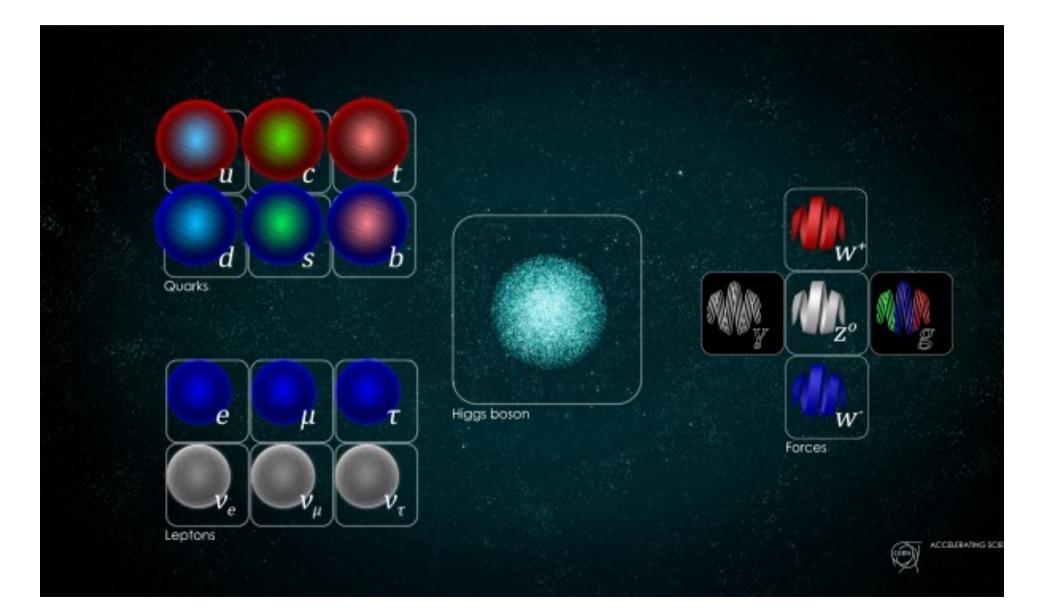
Governs the formation and stability of nuclei by binding together protons and neutrons. **It enables** the fusion of nuclei of light atoms.



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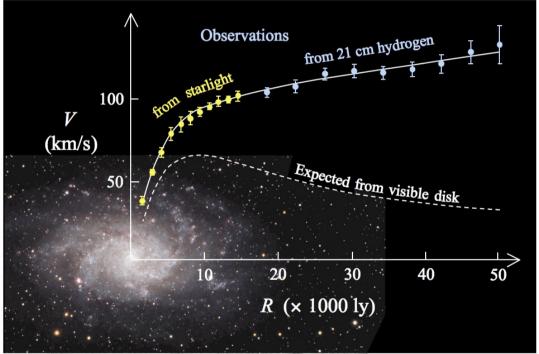
Governs the formation and movement of satellites, planets, stars, galaxies and galactic clusters. **It enables** stars to trigger fusion reactions.

The Standard Model of Particle Physics



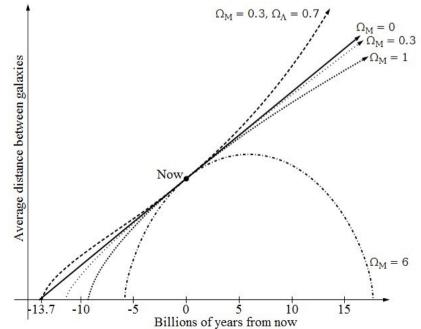
Open problems

- The Standard Model is an excellent, well verified, theory
- **BUT**....astrophysics and cosmology tell us that ordinary matter (planets, stars, gas, ...) makes up <5% of the universe!! And the rest??

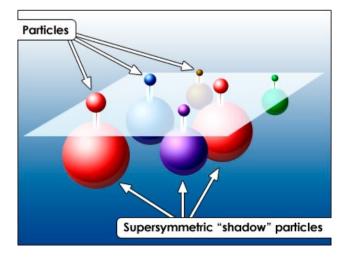


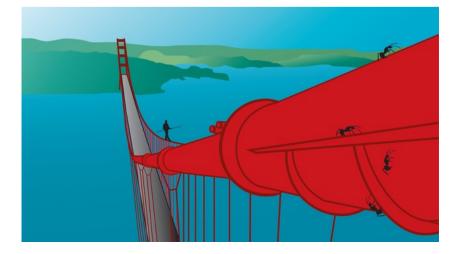
Dark energy is introduced to explain the accelerated expansion of the universe that we see today

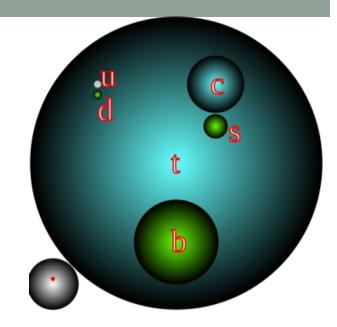
Dark matter explains galaxy rotation, clusters of galaxies and the formation of cosmic structures



- Other problems: too many free parameters!
 - Huge difference in mass between elementary particles
 - It does not explain why antimatter has disappeared....
 - It does not include gravity
 - It does not include dark matter
 - It does not include dark energy
- Many alternative theories proposed
 - SUSY: Supersymmetry (which adds more particles....)
 - Theories with additional dimensions of space-time
 - • •

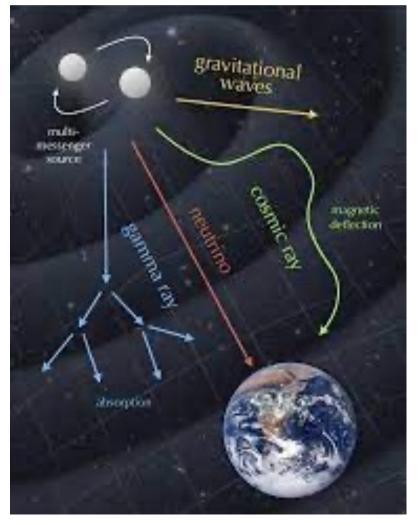




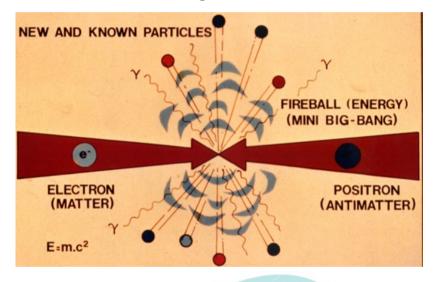


How to answer such questions?

We can observe the messengers originating by various astrophysical sources



We can exploit accelerator machines to reproduce in the laboratory high energy regimes.





A synergy between various disciplines!

Nuclear and particle physics, astrophysics, cosmology come into play.

My personal path!





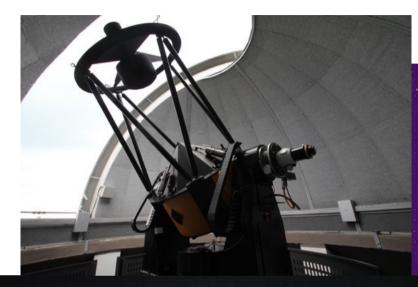


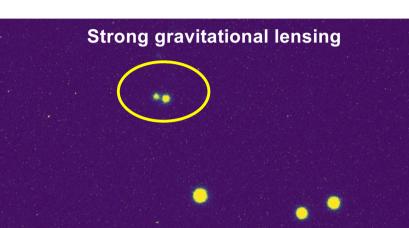


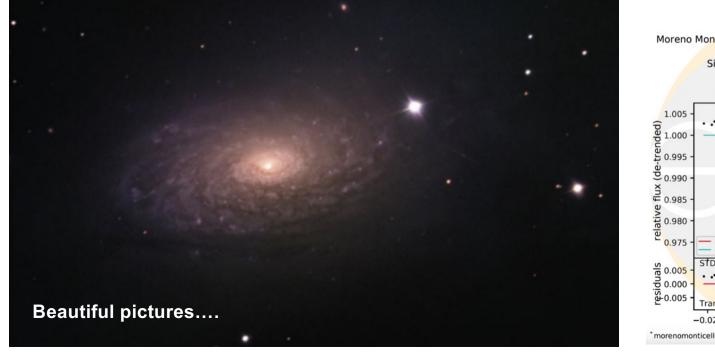
Osservatorio Astronomico Parco Antola

An 80 cm robotic telescope, usable from remote

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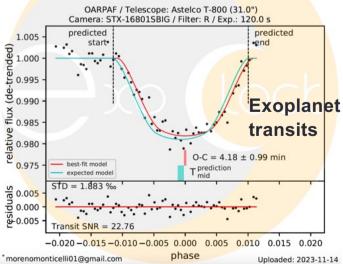


Moreno Monticelli^{*} (Università degli Studi di Genova), Massimiliano Chella (Università degli Studi di Genova)

2023-11-11

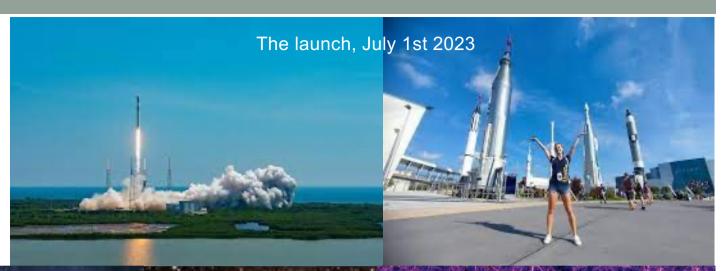
Silvano Tosi (Università degli Studi di Genova)

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EUCLID

An ESA mission to map the dark universe

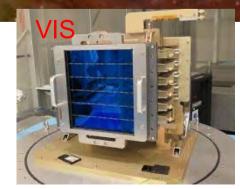


First images, November 7th 2023

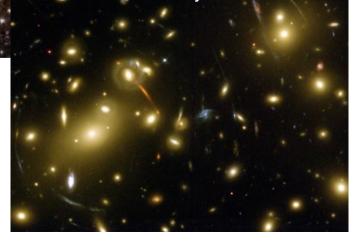
Map distribution of matter

125 Mpc

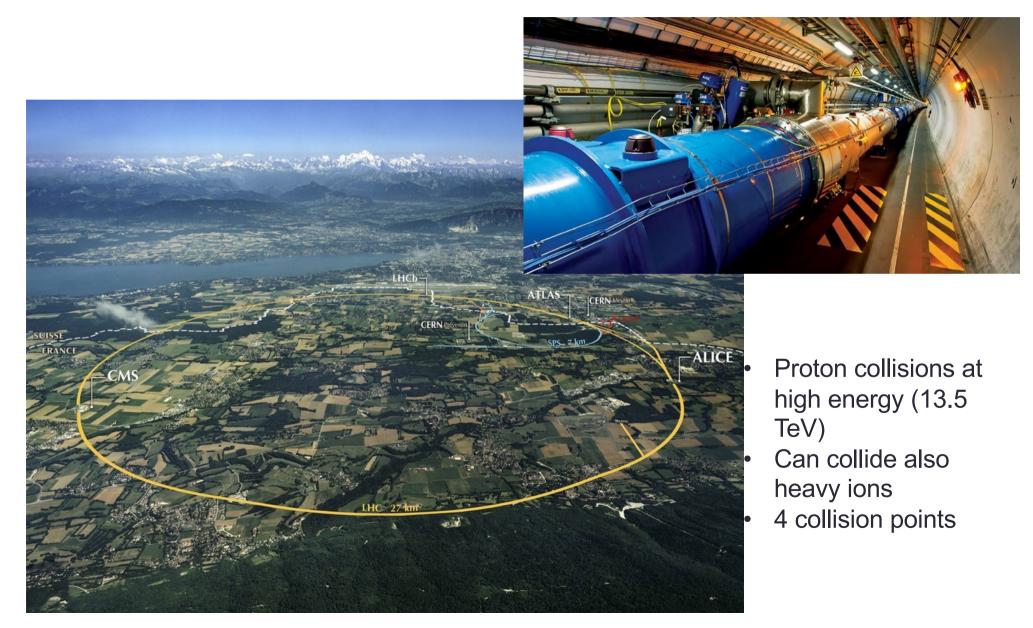
Distortions by dark matter



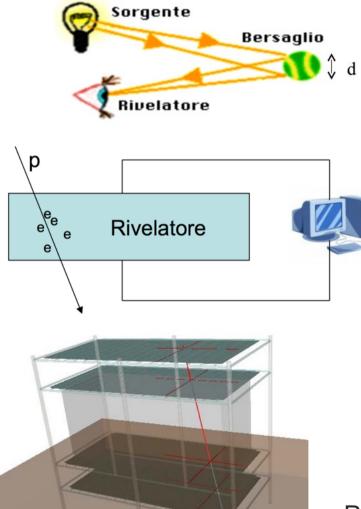


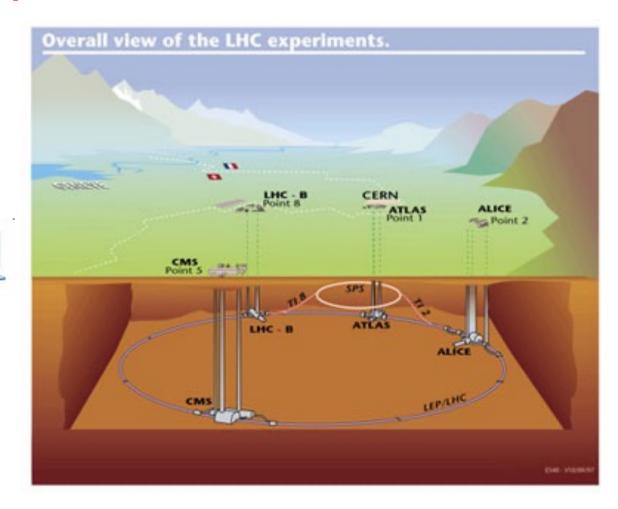


The LHC accelerator at CERN

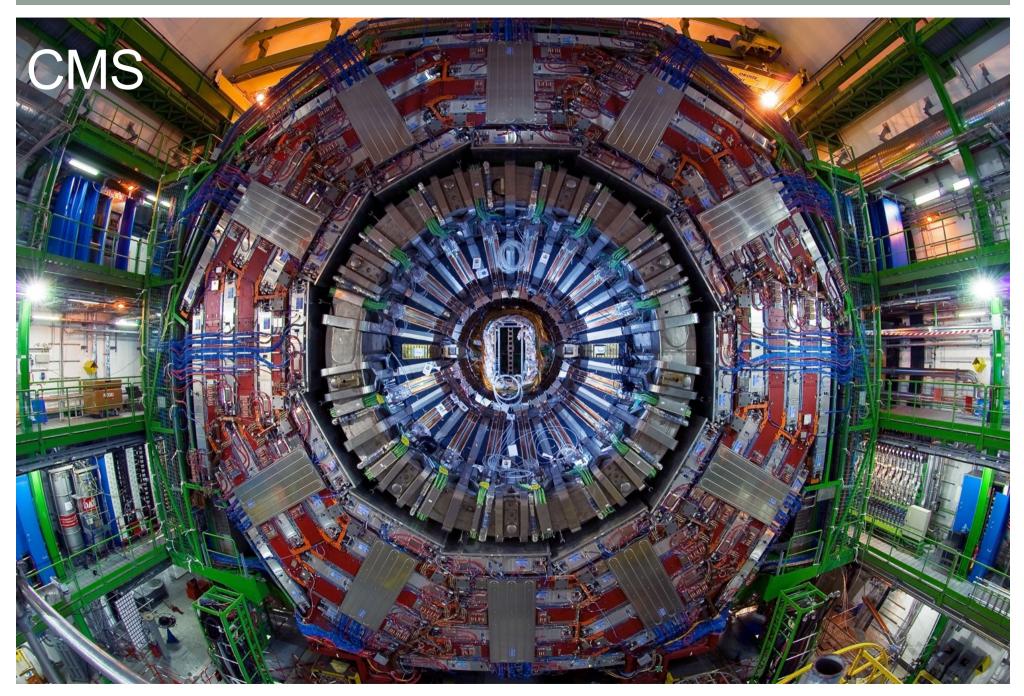


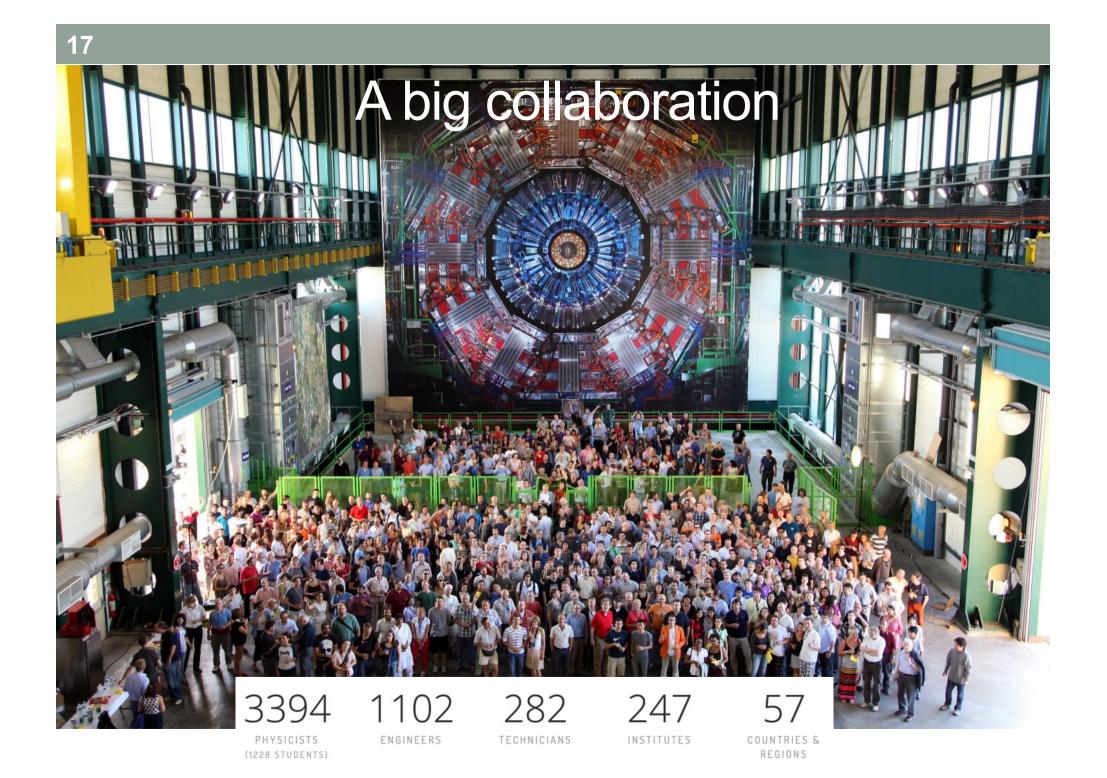
How to «see» particles



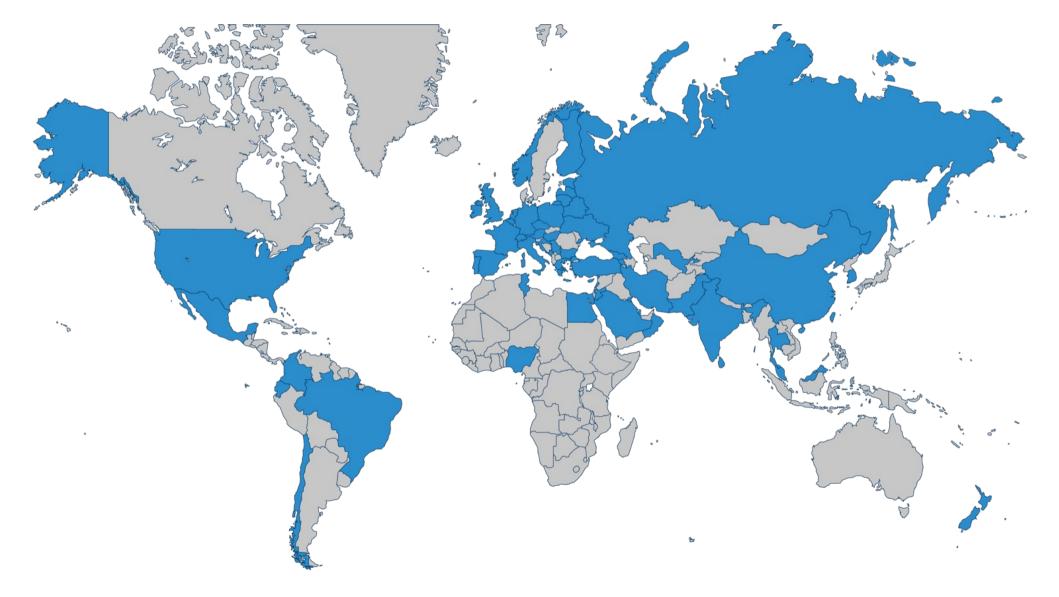


Particles are made to interact with materials and the effects of their interactions are observed





A worldwide collaboration

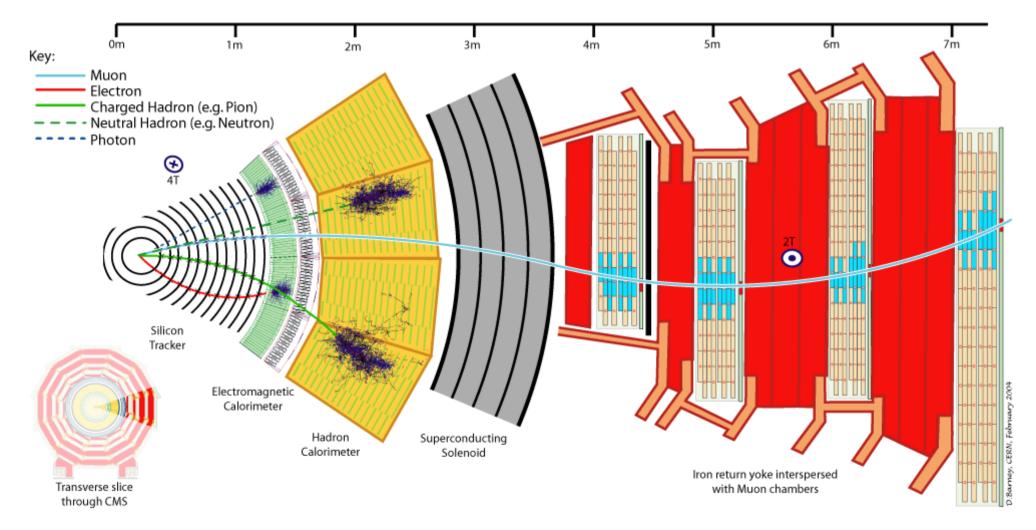


And now also Albania!



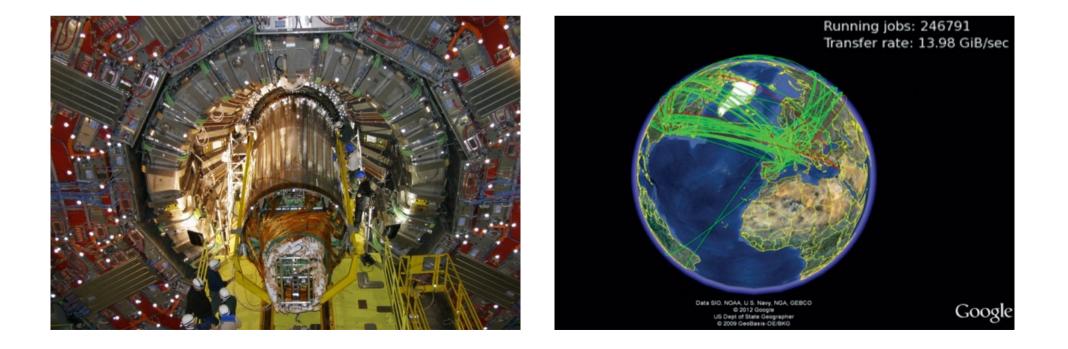
CMS: many detectors

Many particles are very short-lived. They decay into other (known) particles before leaving any trace. The decay products are observed, and the properties of the parent particle are reconstructed

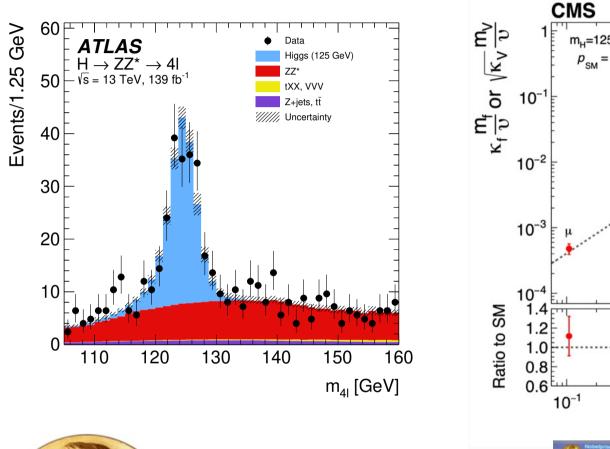


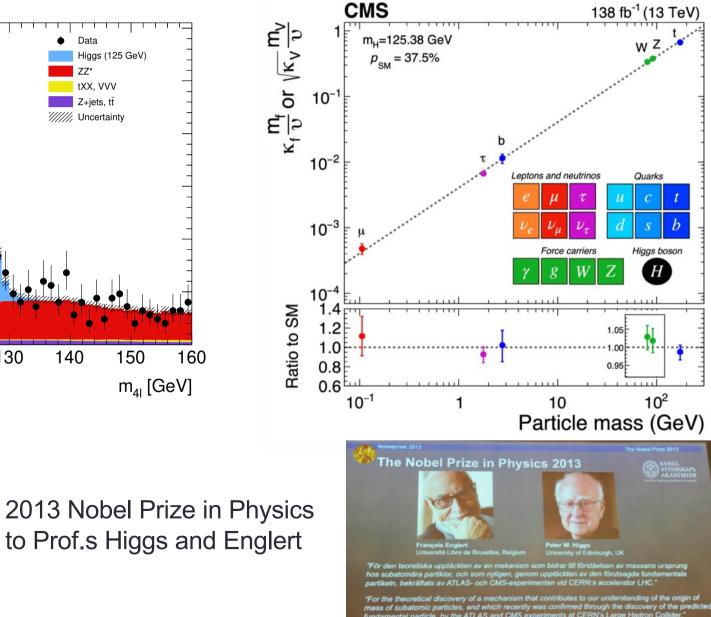
Frontier technologies

- The accelerator, the detector, the data collection and analysis exploit state-of-the-art technologies.
 - At the frontier of electronics, material science, computing and IT.
 - Several R&D works for current and future applications



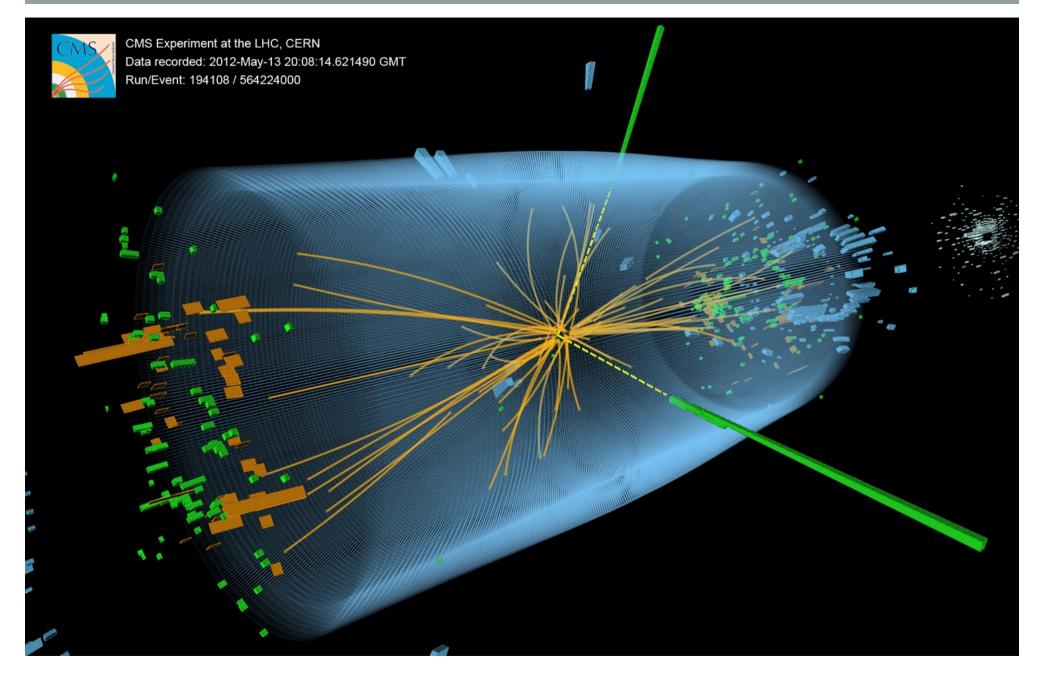
11 years of Higgs boson!



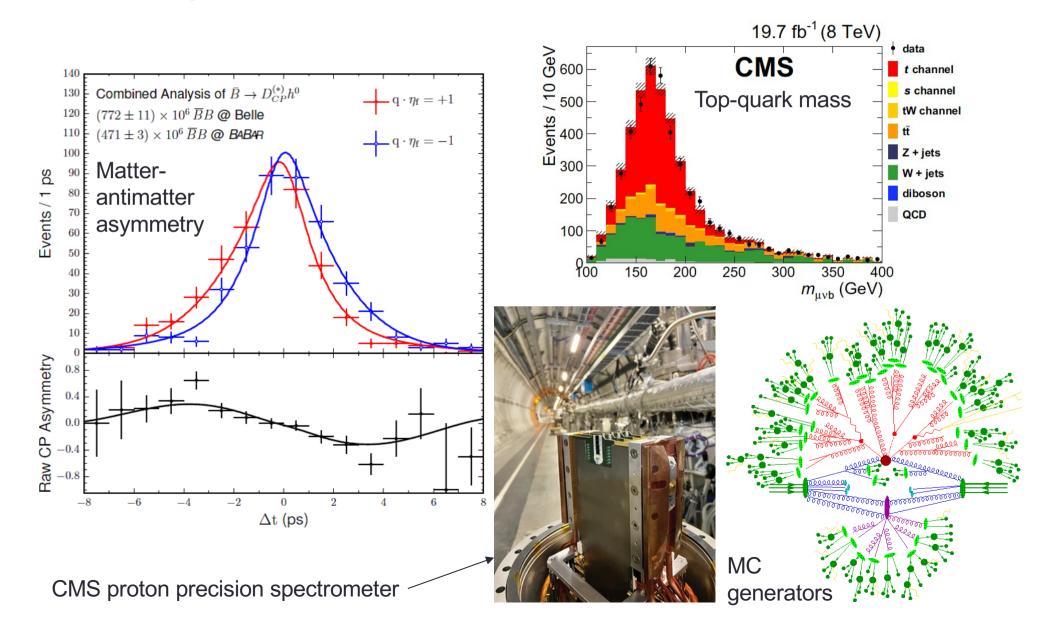








Examples of activities to which I contributed



A few immediate applications





In the offices of this corridor, all the fundamental technologies of the World Wide Web were developed.

Started in 1990 from a proposal made by Tim Berners-Lee in 1989, the effort was first divided between an office in building 31 of the Computing and Networking Division (CN) and one in building 2 of the Electronics and Computing for Physics Division (ECP).

In 1991 the team came together in these offices, then belonging to ECP. It was composed of two CENN staff members, Tim Berners-Lee (GB) and Robert Cailliau (BE), aided by a number of Fellows, Technical Students, a Cooperant and Summer Students.

At the end of 1994 Tim Berners-Lee left CERN to direct the WWW Consortium (W3C), a world-wide organization devoted to leading the Web to its full potential. The W3C was founded with the help of CERN, the European Commission, the Massachusetts Institute of Technology (MIT), the Institut National pour la Recherche en Informatique et en Automatigue (MIRA), and the Advanced Research Projects Agency (ARPA).

In 1995 Tim Berners-Lee and Robert Cailliau received the ACM Software System Award for the World Wide Web. In 2004, Tim Berners-Lee was awarded the first Millenium Technology Prize by the Finnish Technology Award Foundation.

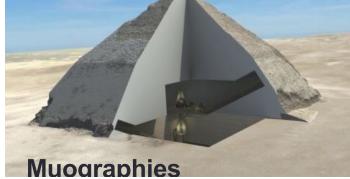
The CERN Library
June 2004





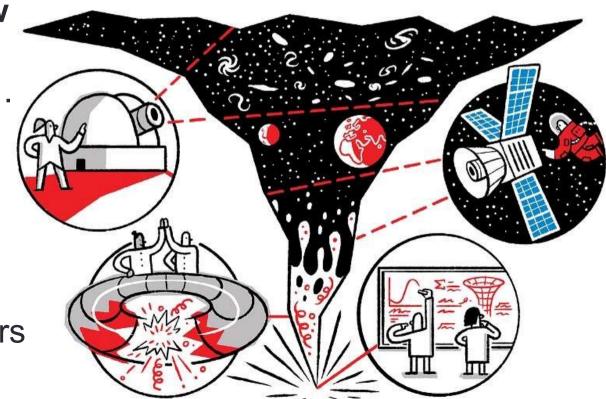


Touch screen



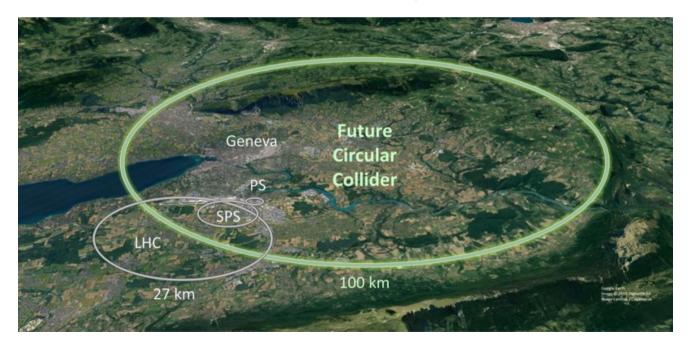
So, where are we?

- The discovery of the Higgs boson represents an important step in particle physics. The Standard Model continues to be tested with great precision.
- No clear sign of New Physics beyond the Standard Model yet....
- Efforts continue in various directions
 - Accelerator
 experiments
 - Experiments with cosmic messengers



And in the future ?

- The LHC has recently started taking data again at an energy never reached before... who knows if there will be news soon!!
- Many plans for the near- and long-term future



• And we welcome your new ideas !