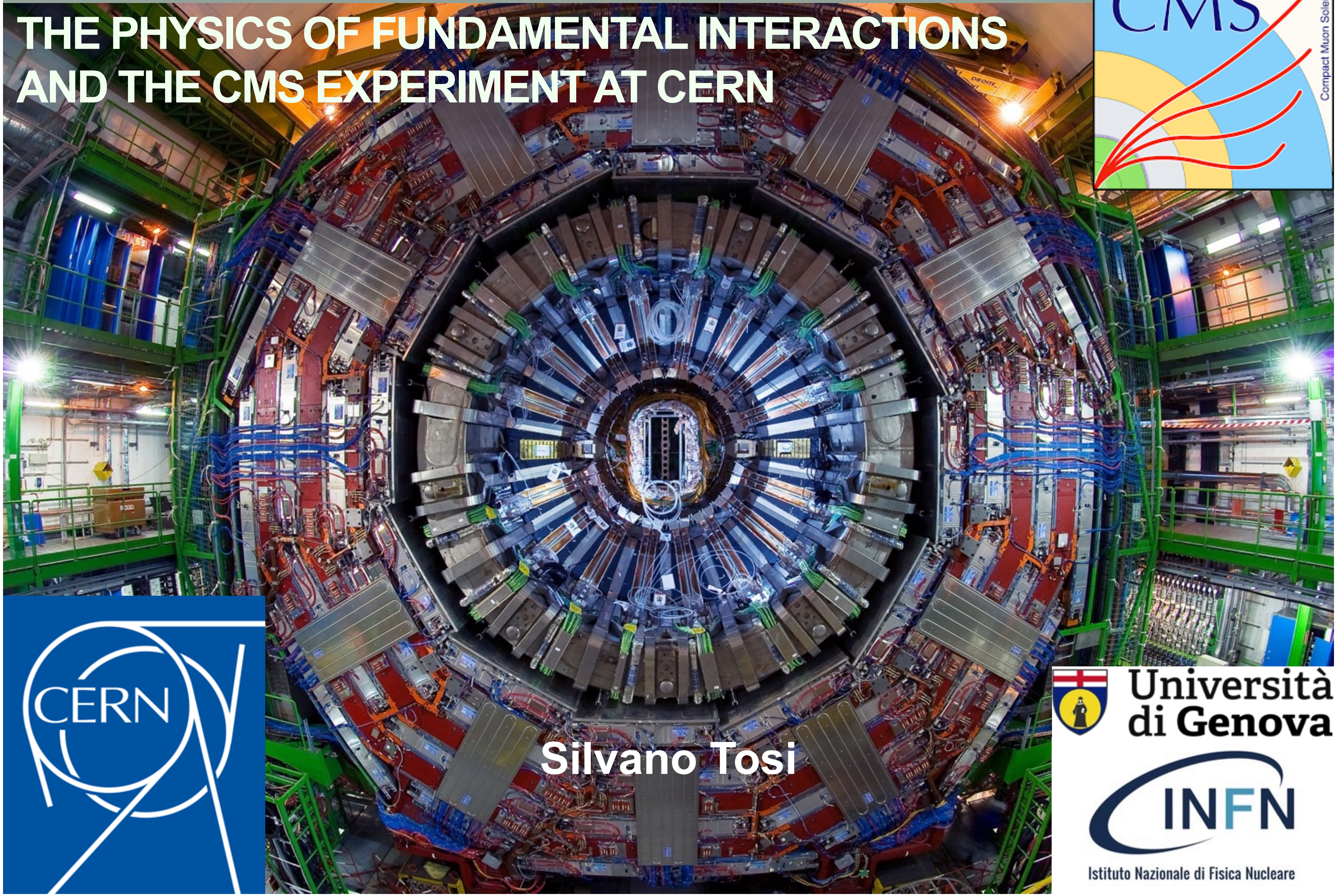
THE PHYSICS OF FUNDAMENTAL INTERACTIONS AND THE CMS EXPERIMENT AT CERN



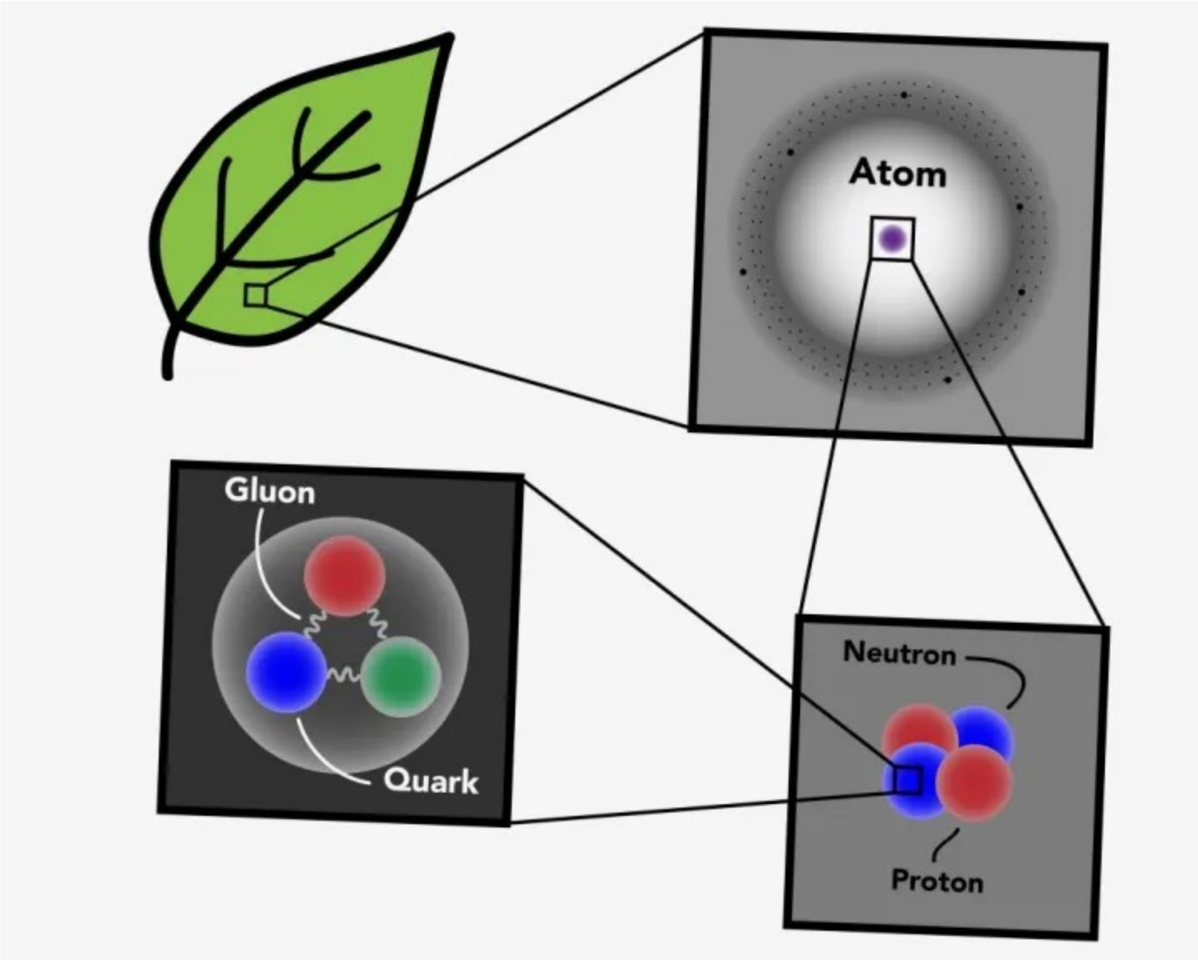
Silvano Tosi

Università di Genova

INFN Istituto Nazionale di Fisica Nucleare

23/11/2023 Science Week in Tirana

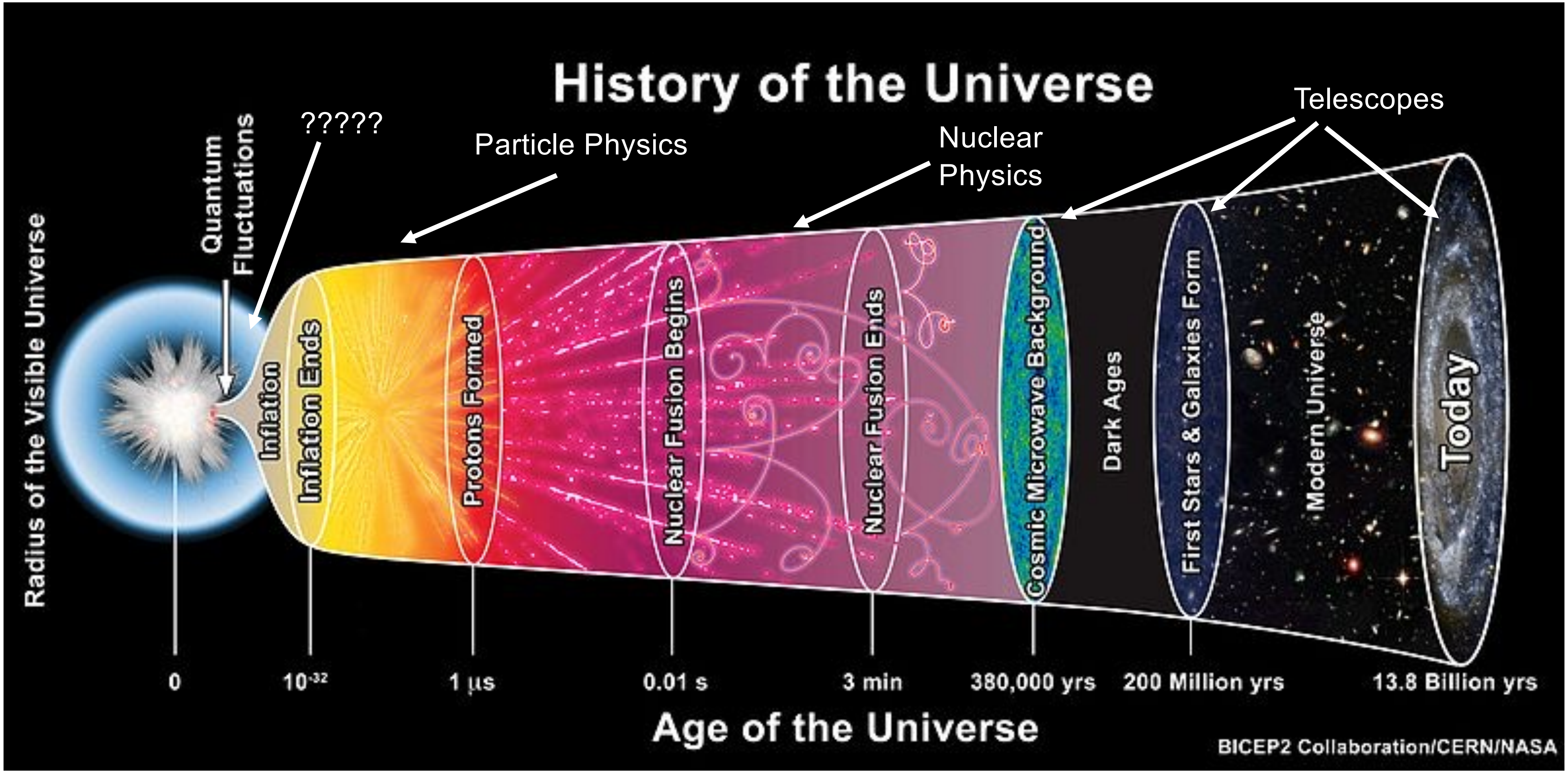
Fundamental questions



- 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?

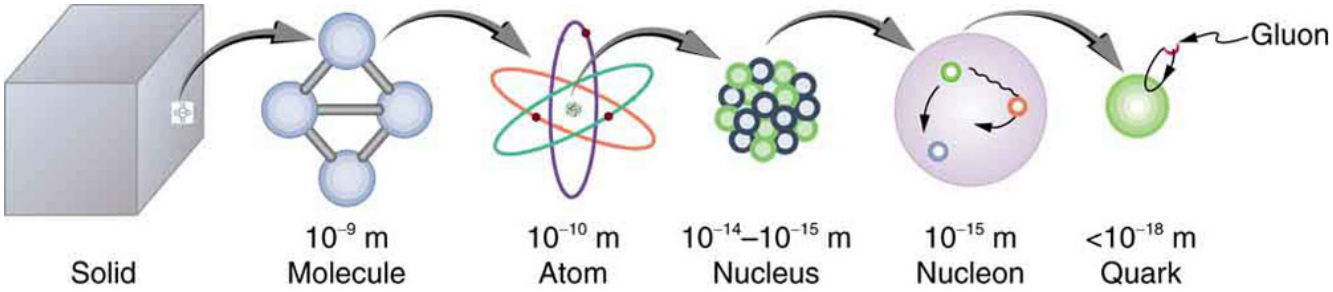
The quest for the **fundamental constituents** of matter is closely linked to the study of the **first moments and the evolution** of our Universe

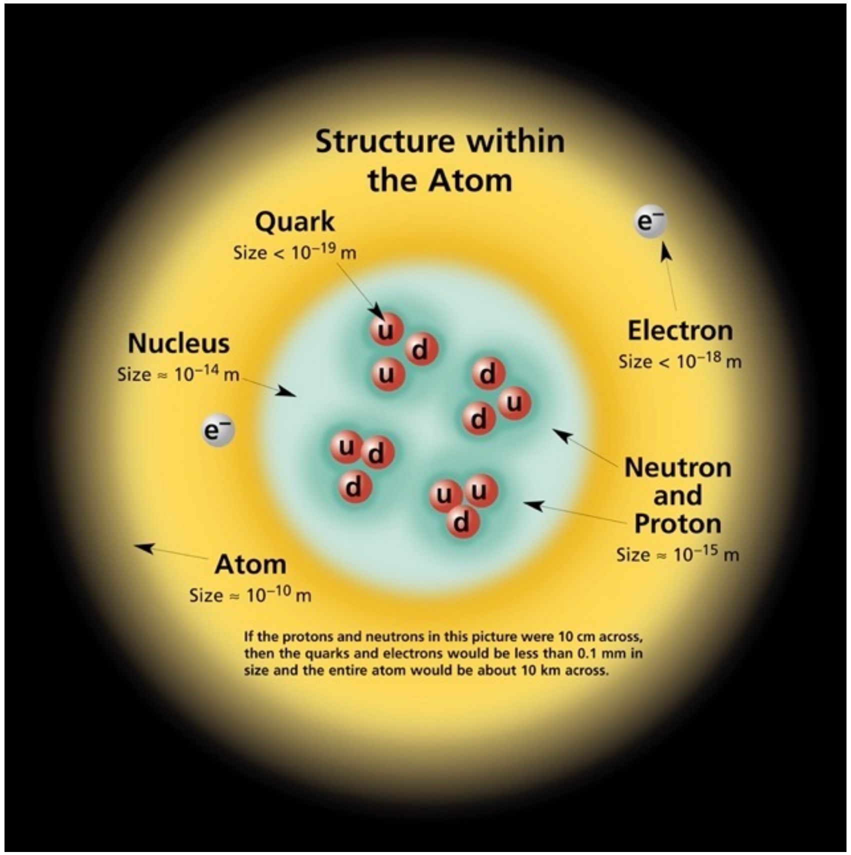
time



temperature

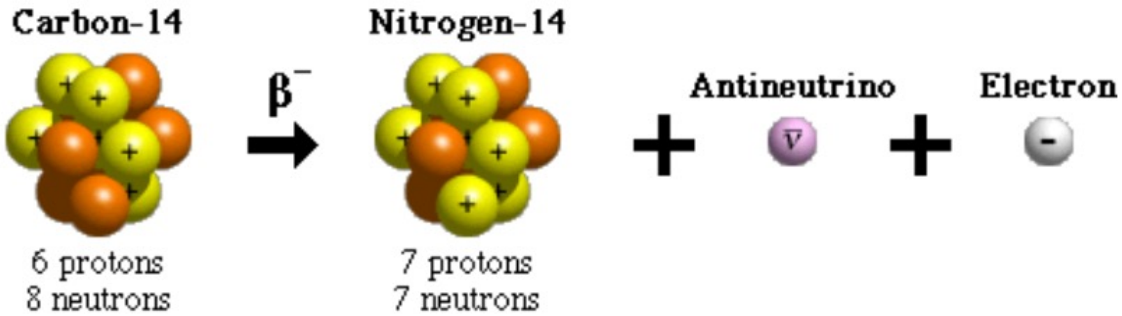
Electrons and quarks

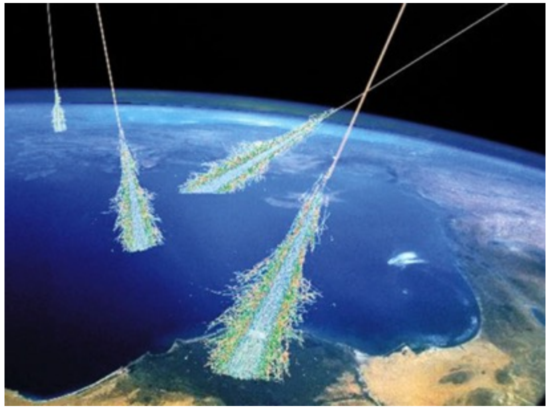


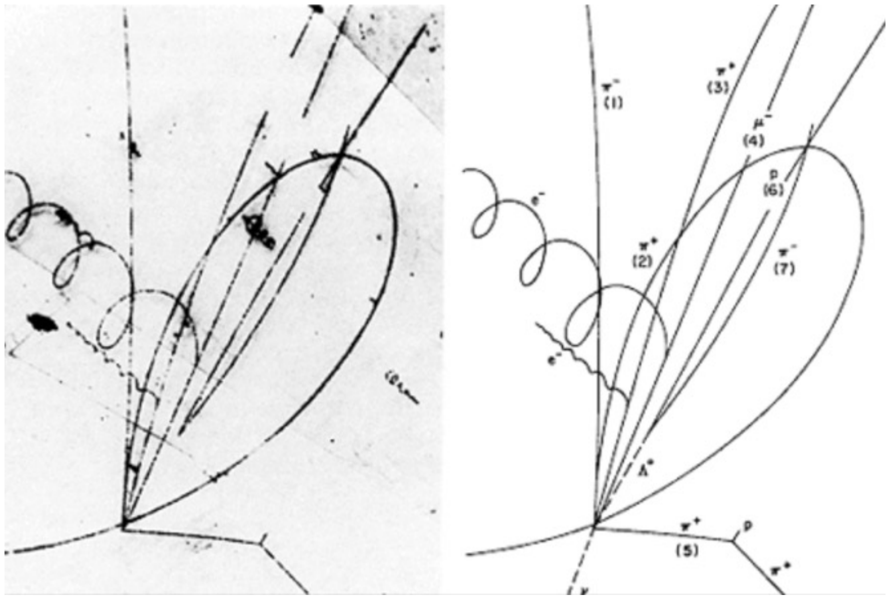


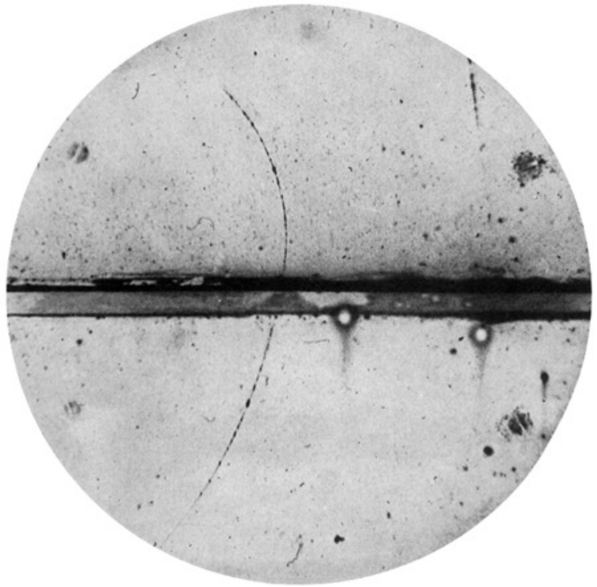
So, atoms (hence ordinary matter) are made up of **electrons** and two types of **quarks** (**up** and **down**).

More elementary particles… and antiparticles

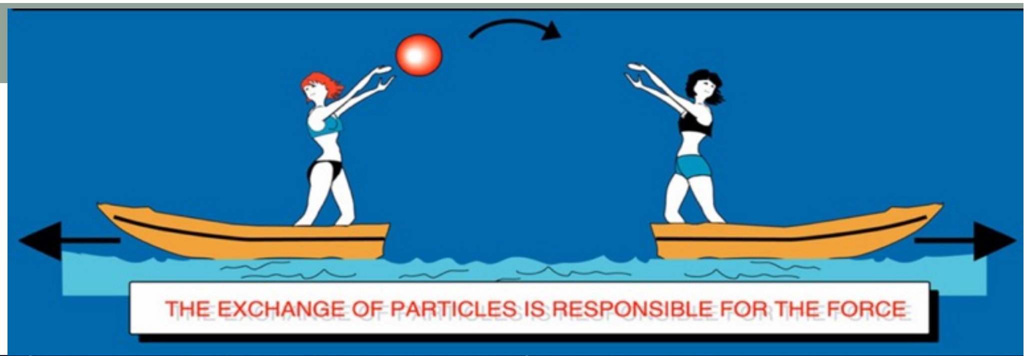


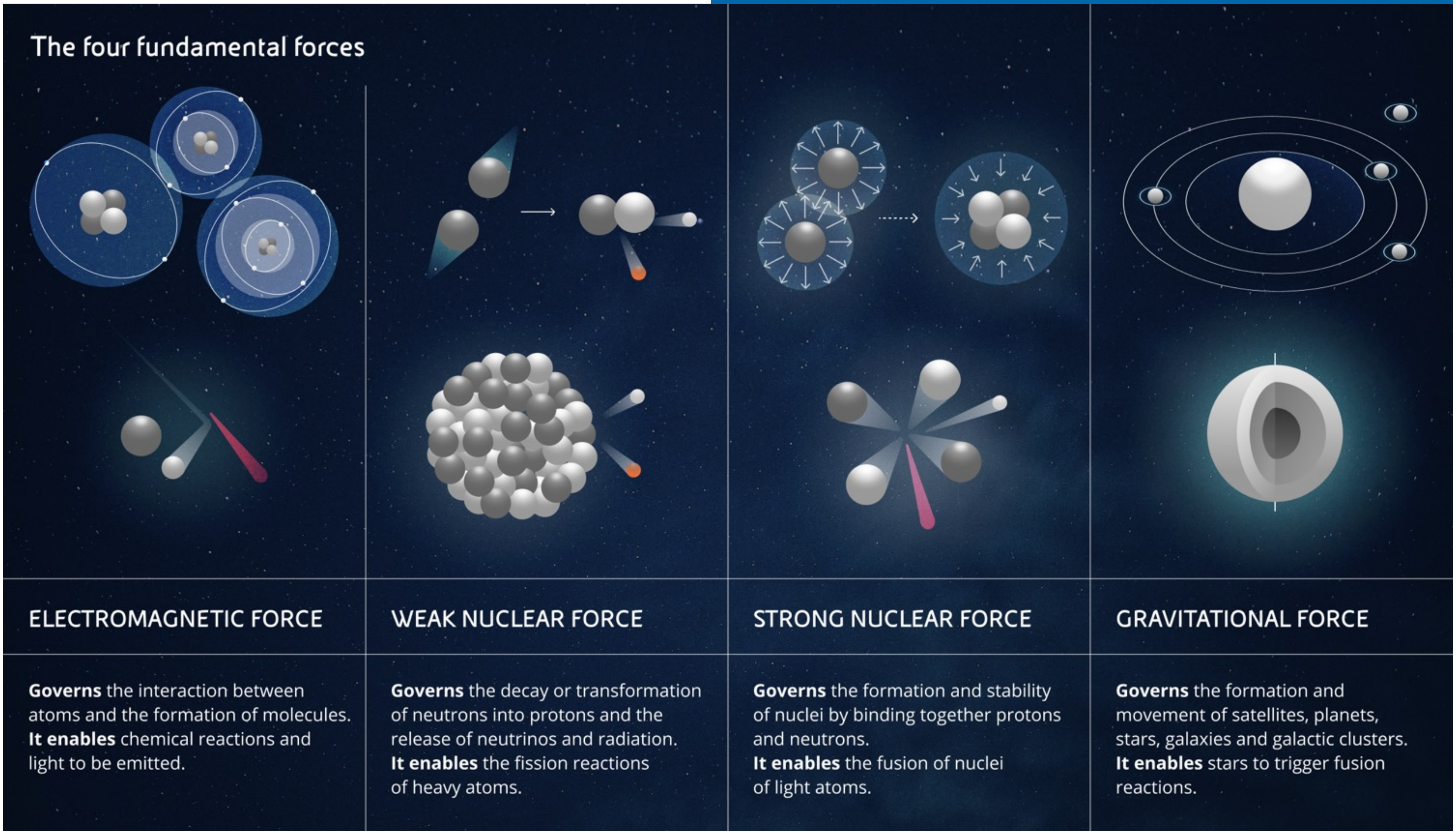




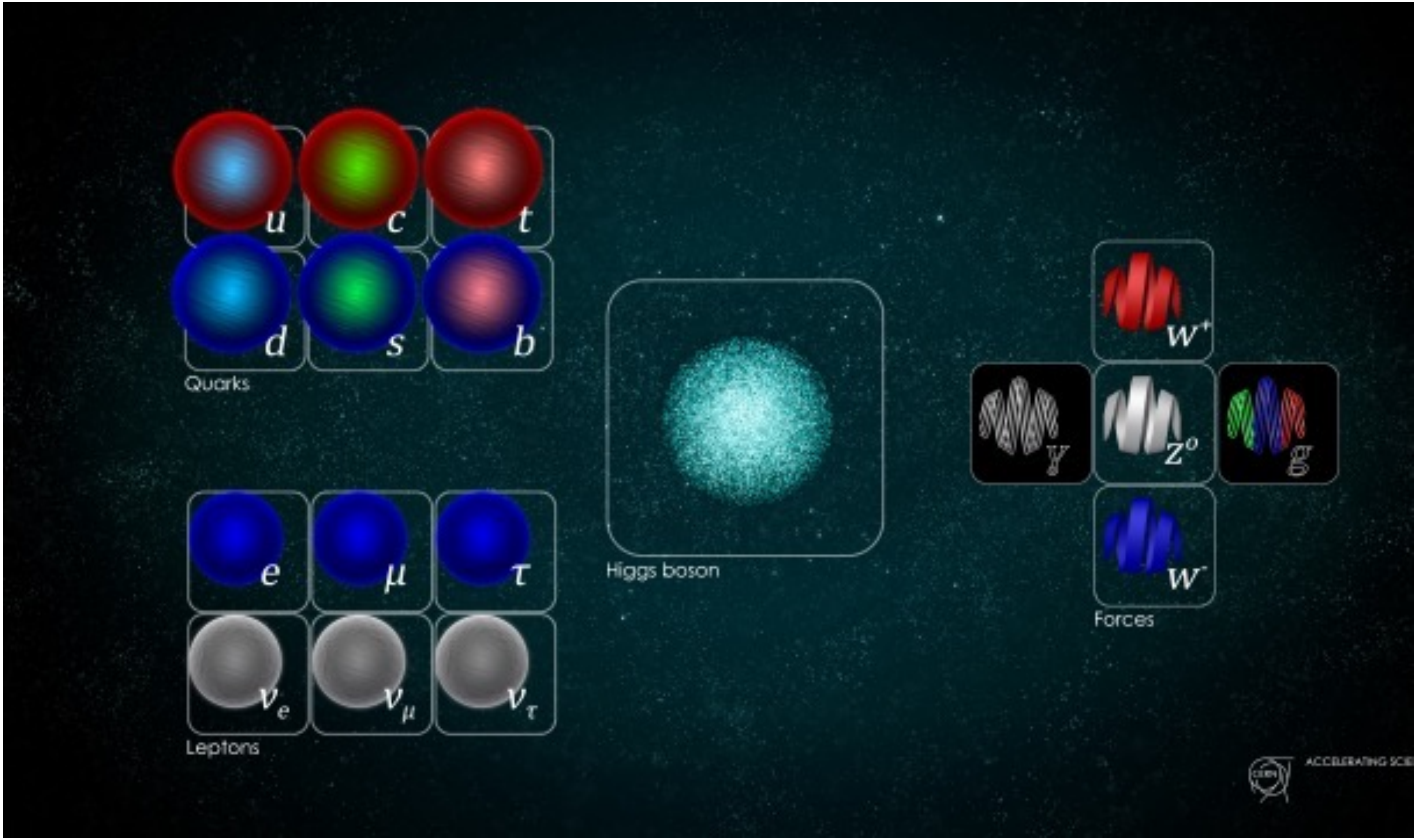


How particles interact: fundamental forces



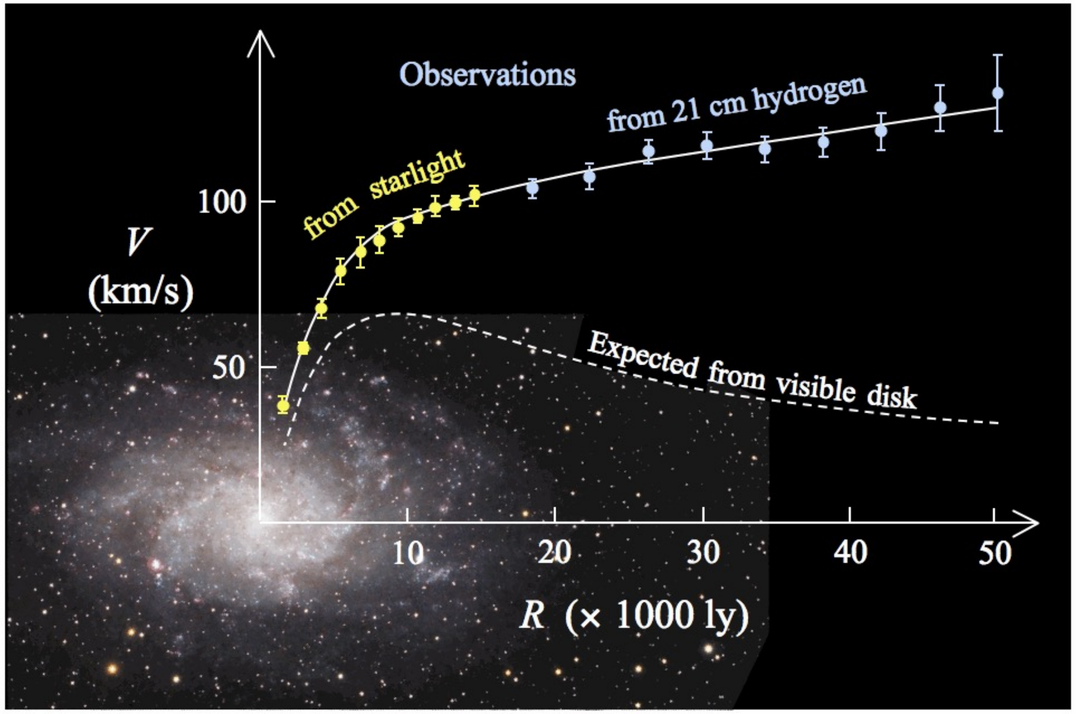


The Standard Model of Particle Physics

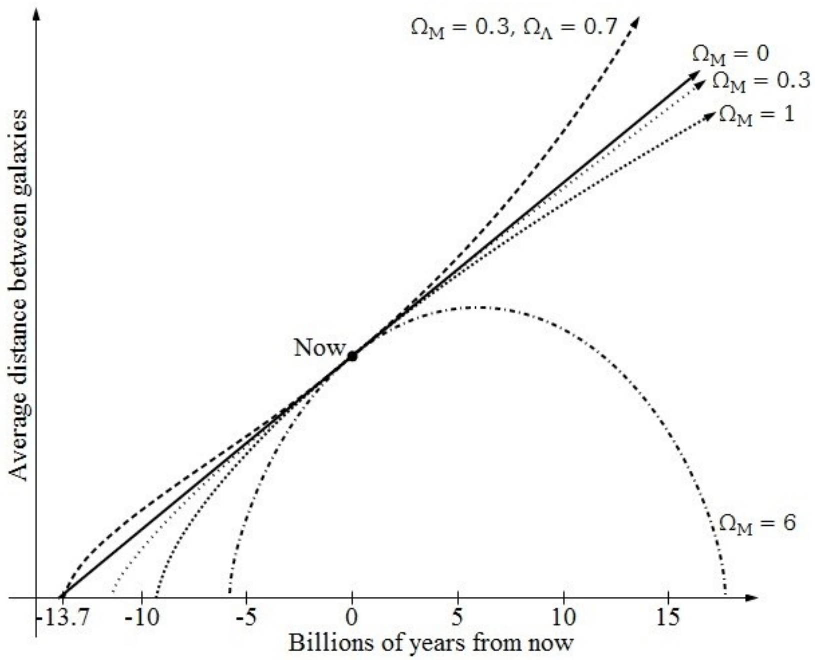


Open problems

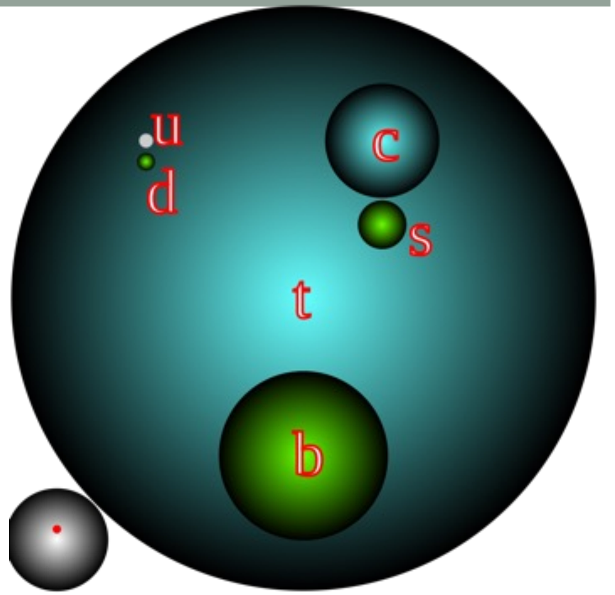
- The Standard Model is an excellent, well verified, theory
- **BUT**…..astrophysics and cosmology tell us that ordinary matter (planets, stars, gas, …) makes up <5% of the universe!! And the rest??



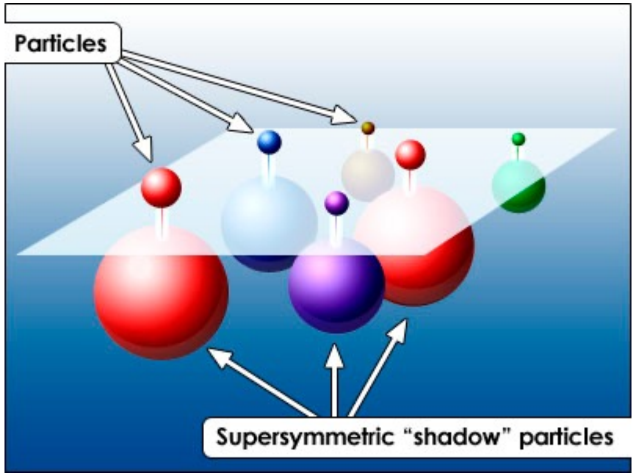
Dark matter explains galaxy rotation, clusters of galaxies and the formation of cosmic structures

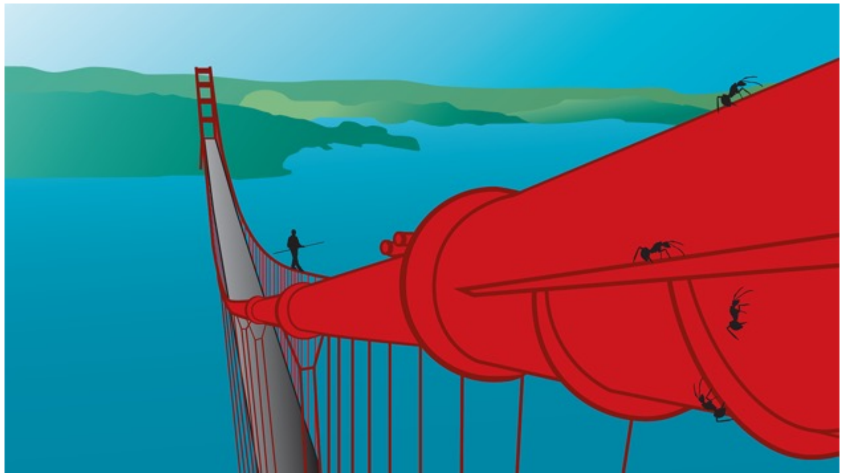


Dark energy is introduced to explain the accelerated expansion of the universe that we see today



- 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
  - ….

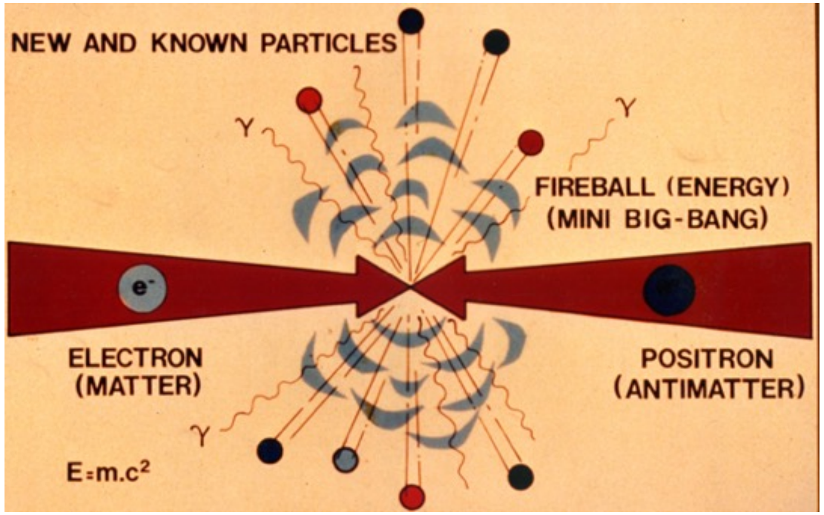


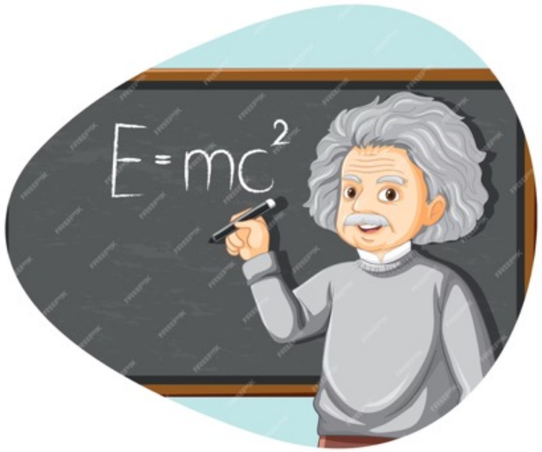


How to answer such questions?

We can observe the messengers originating by various astrophysical sources

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

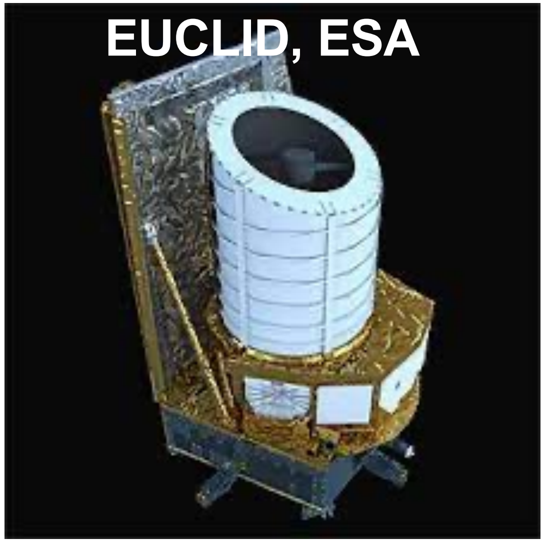




A synergy between various disciplines!

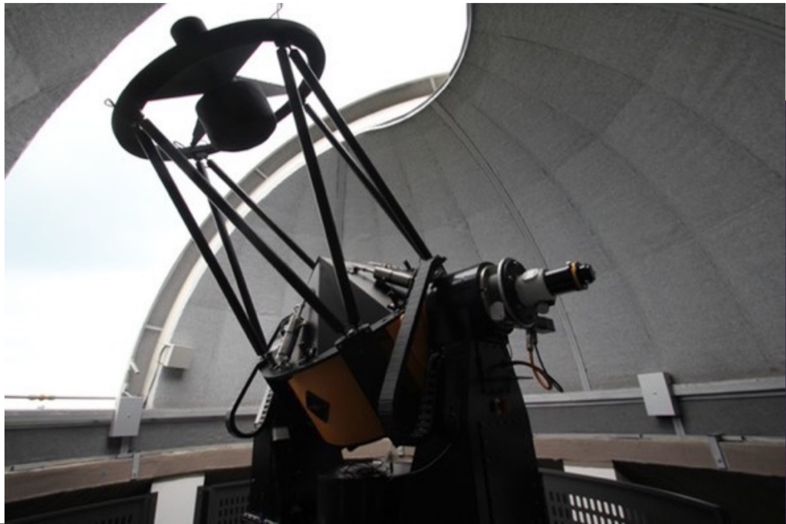
Nuclear and particle physics, astrophysics, cosmology come into play.

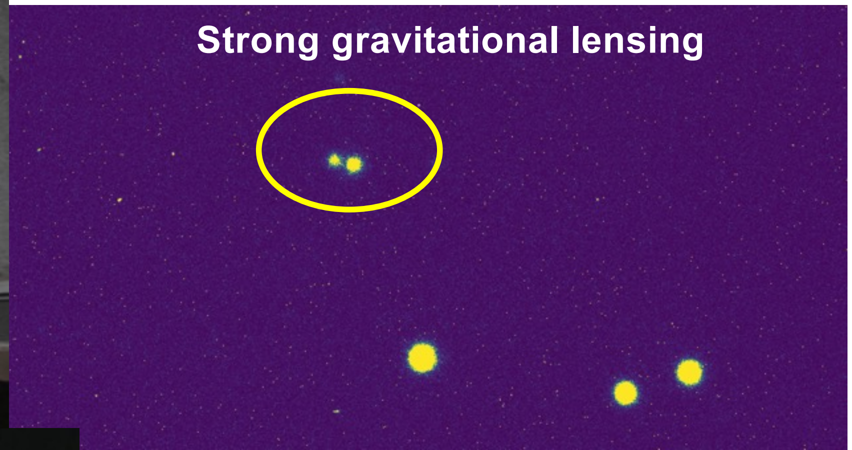
My personal path!

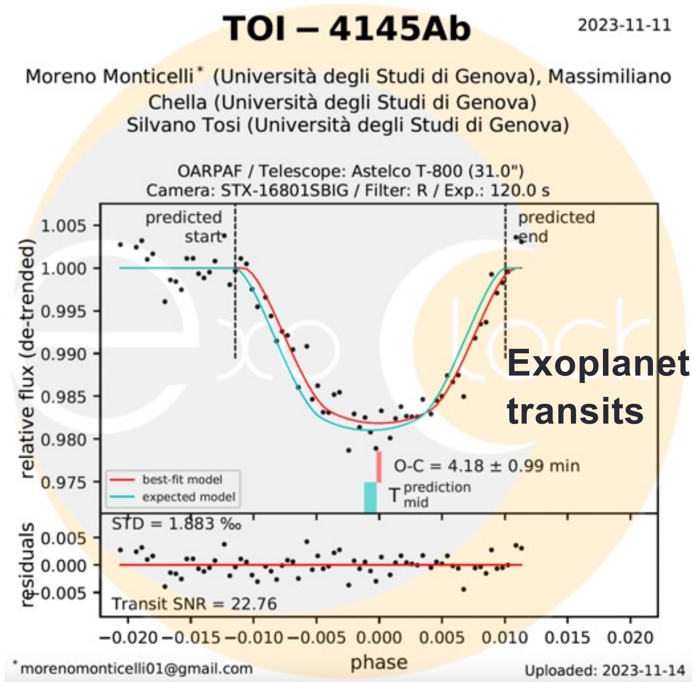


Osservatorio Astronomico Parco Antola

An 80 cm robotic telescope, usable from remote





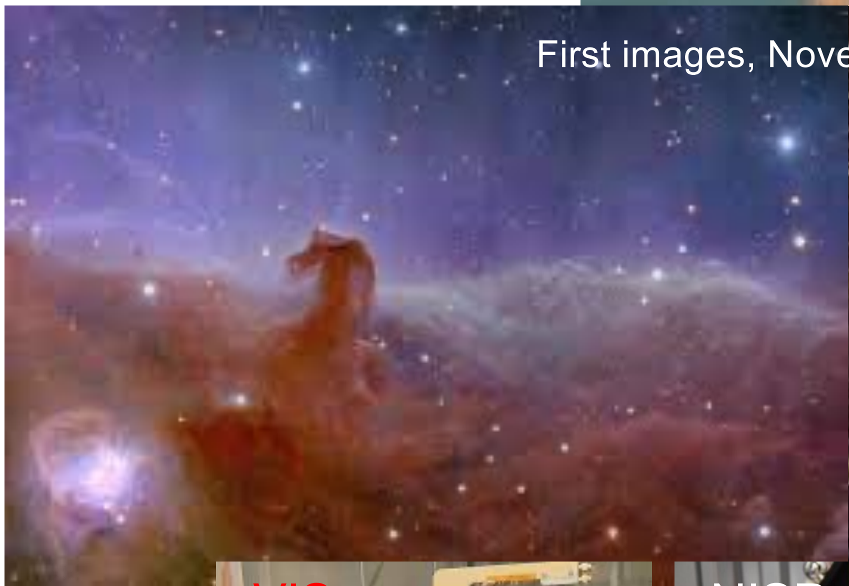


EUCLID

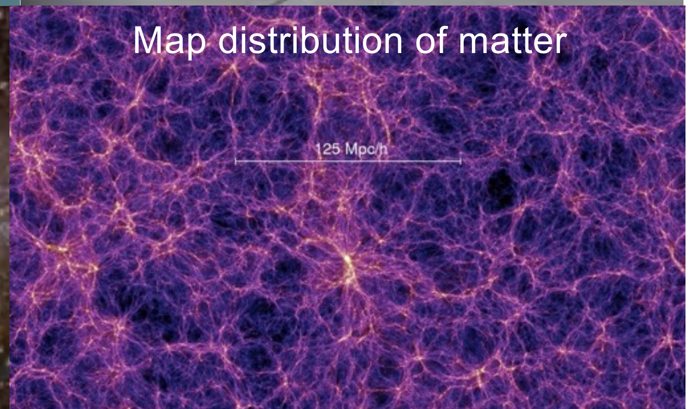
An ESA mission to map the dark universe



The launch, July 1st 2023

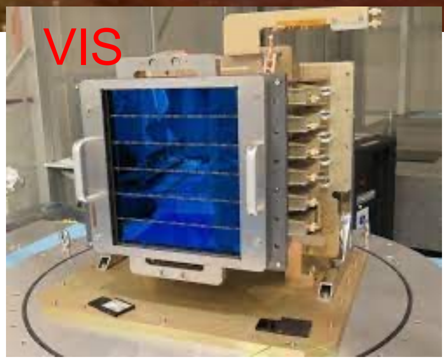


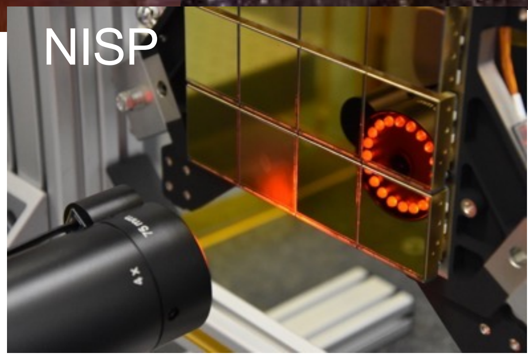
First images, November 7th 2023



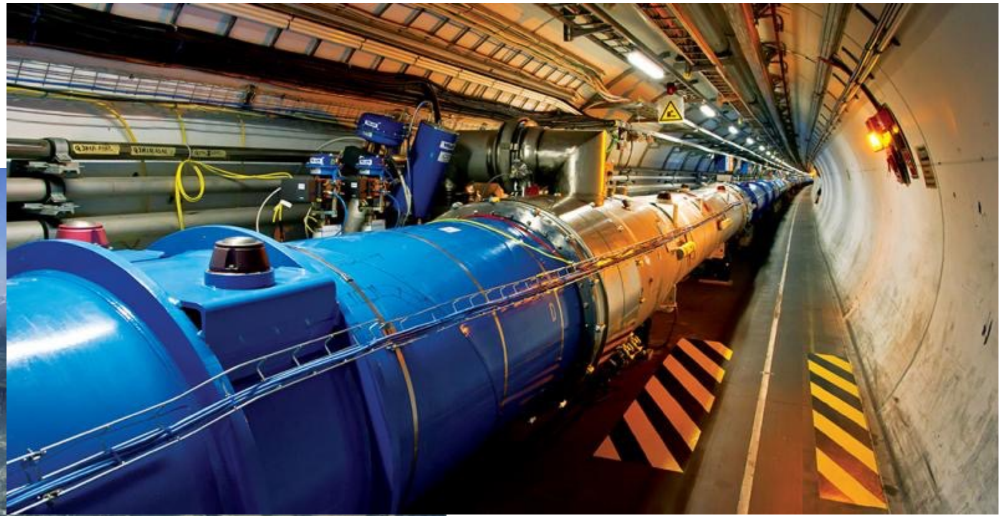
Map distribution of matter

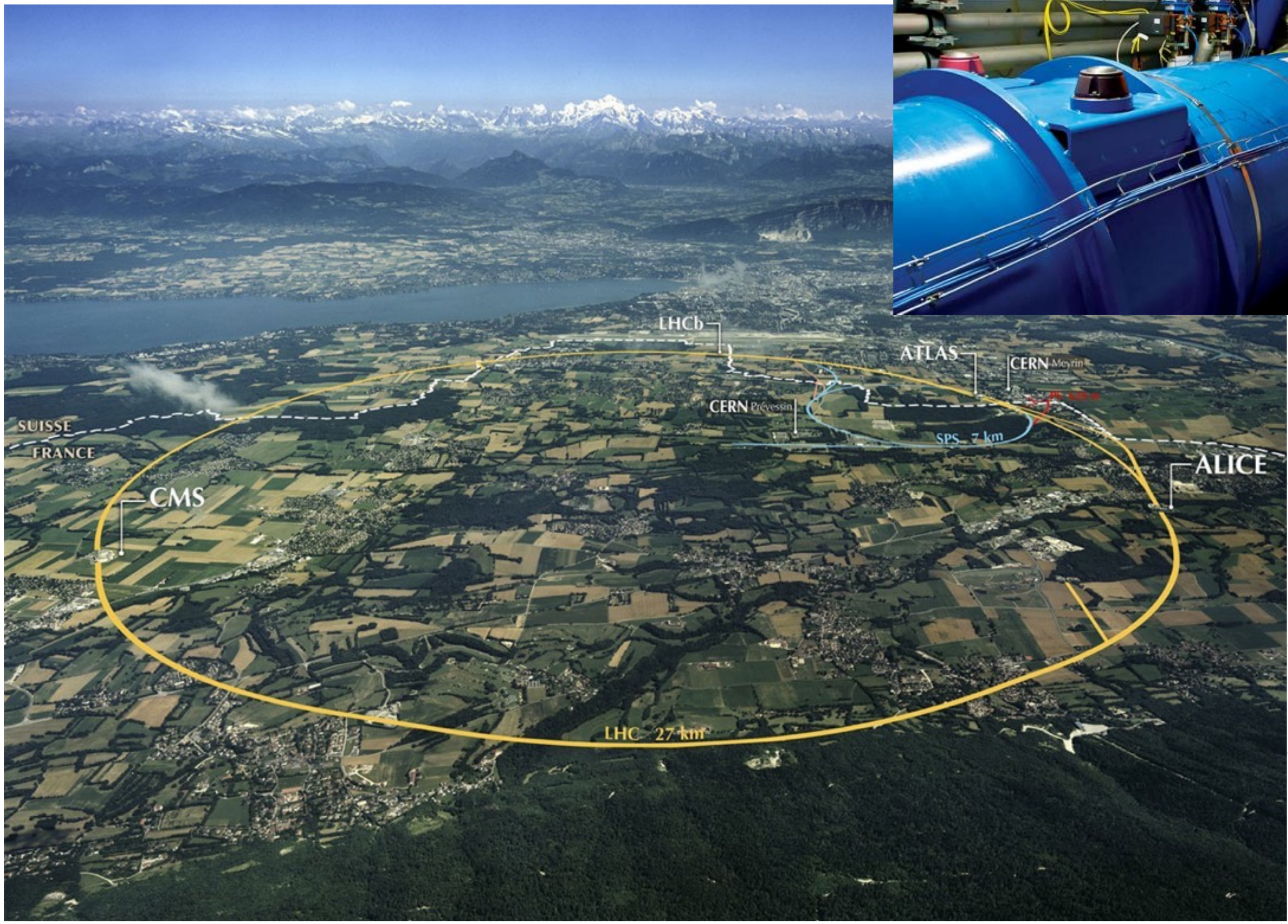

Distortions by dark matter


VIS


NISP

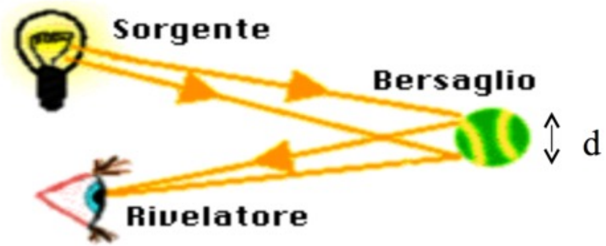
The LHC accelerator at CERN

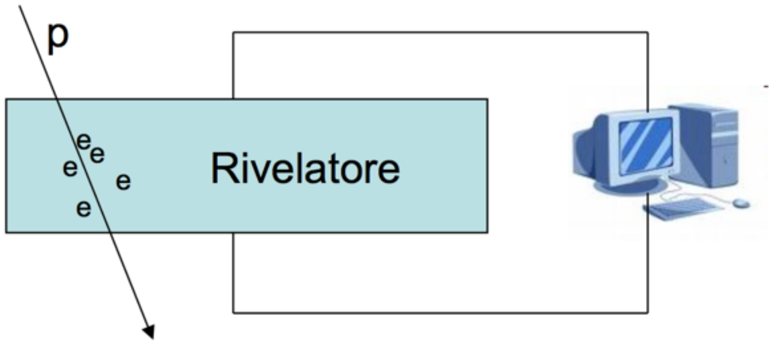


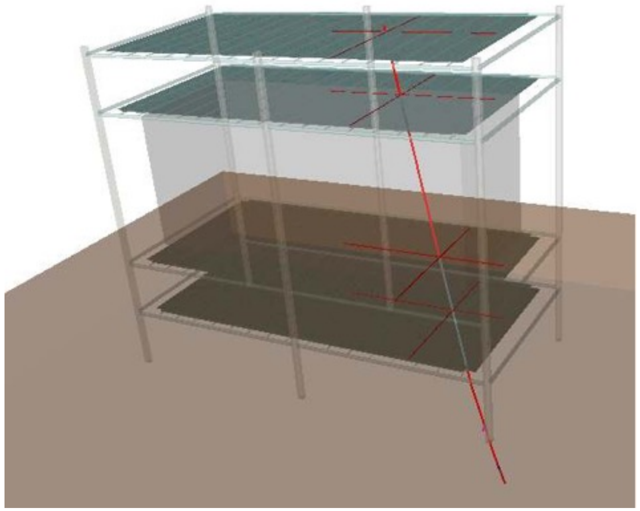


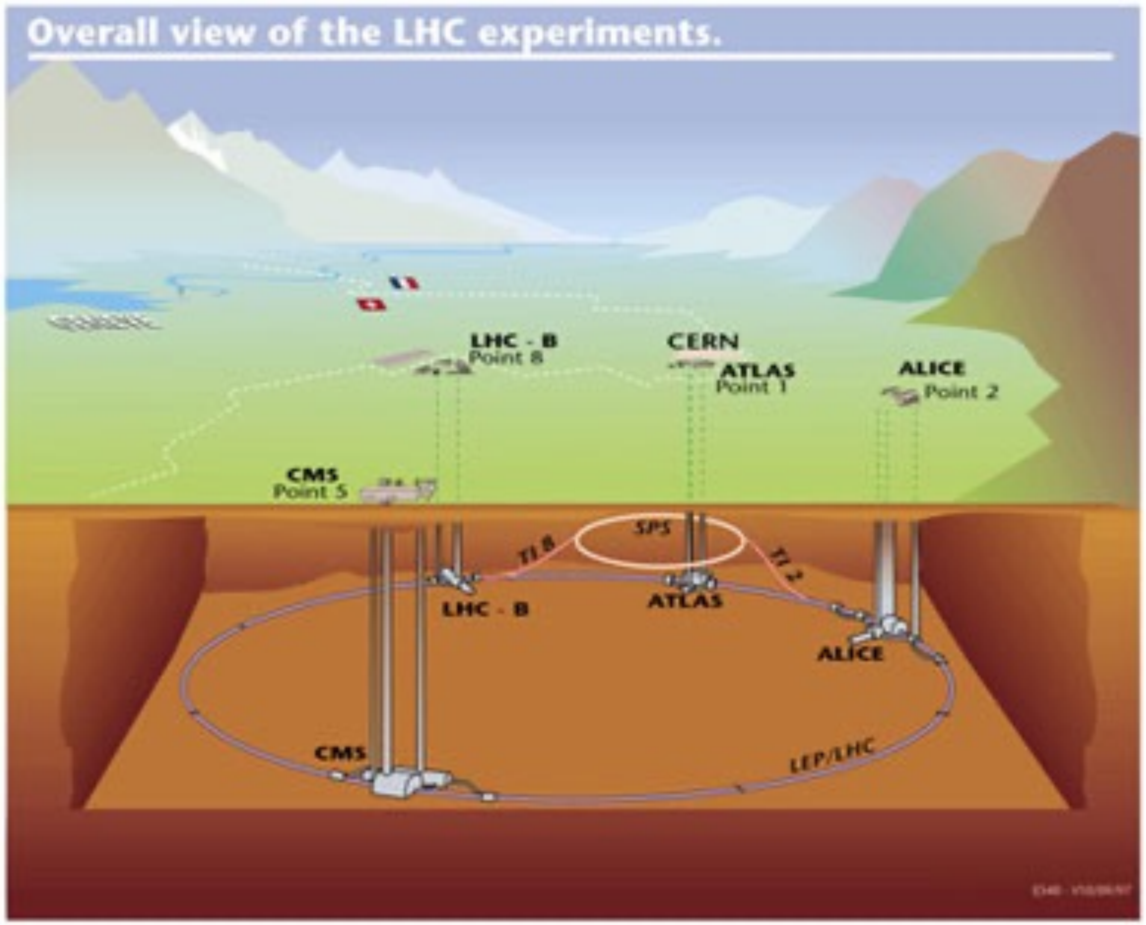
- Proton collisions at high energy (13.5 TeV)
- Can collide also heavy ions
- 4 collision points

How to «see» particles



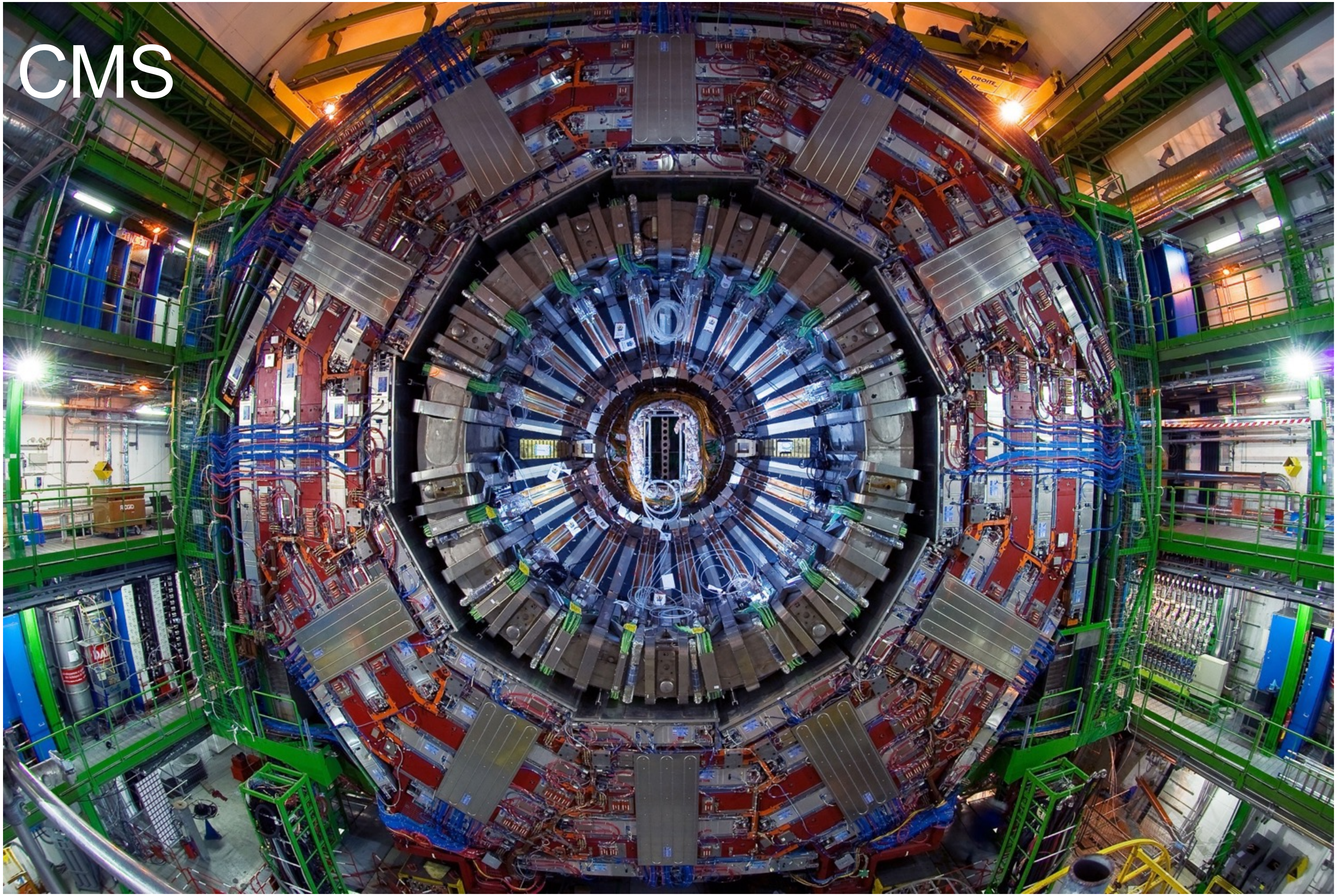






Particles are made to interact with materials and the effects of their interactions are observed

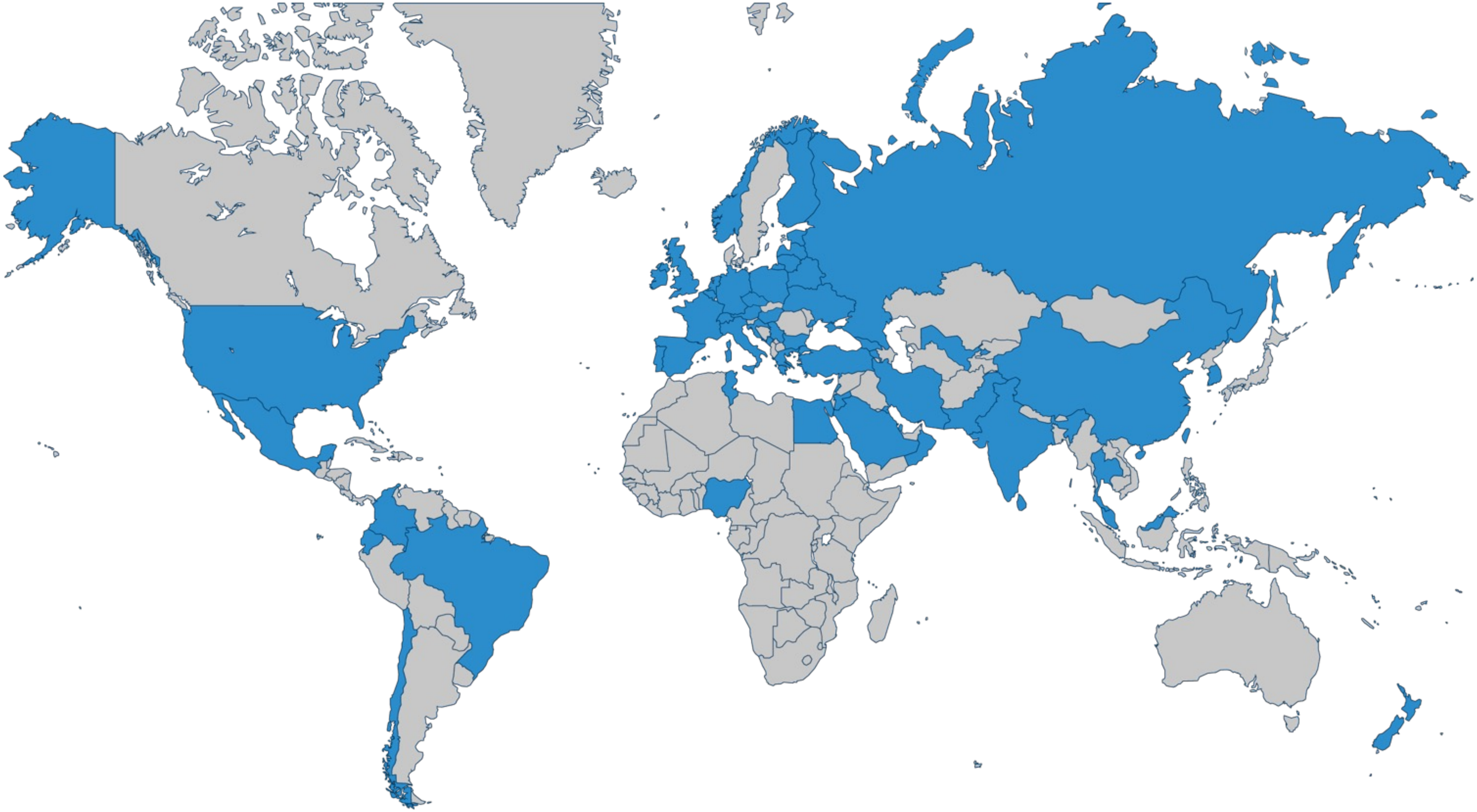
CMS



A big collaboration

3394	1102	282	247	57
PHYSICISTS (1228 STUDENTS)	ENGINEERS	TECHNICIANS	INSTITUTES	COUNTRIES & REGIONS

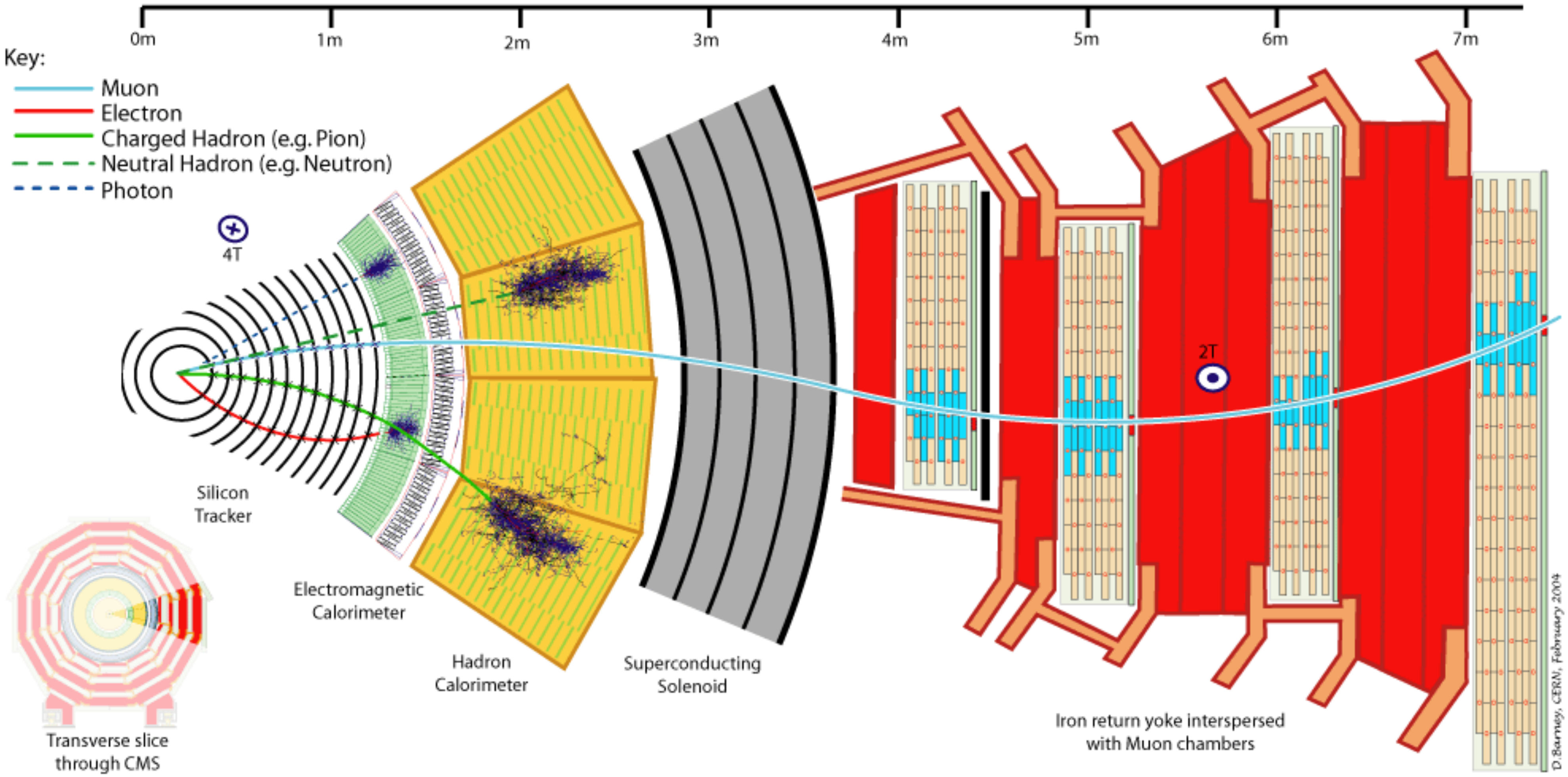
A worldwide collaboration



And now also Albania!

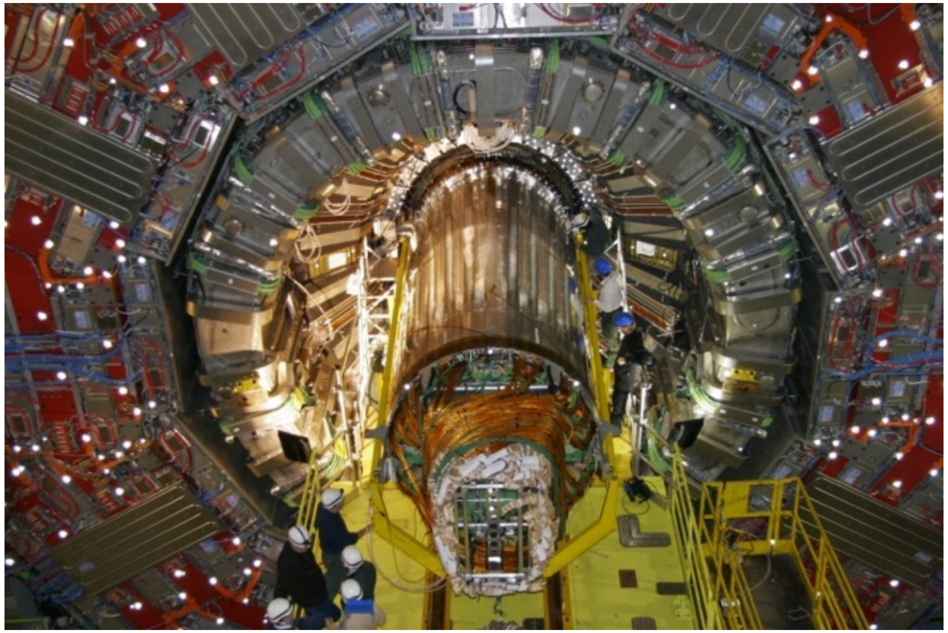
CMS: many detectors

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

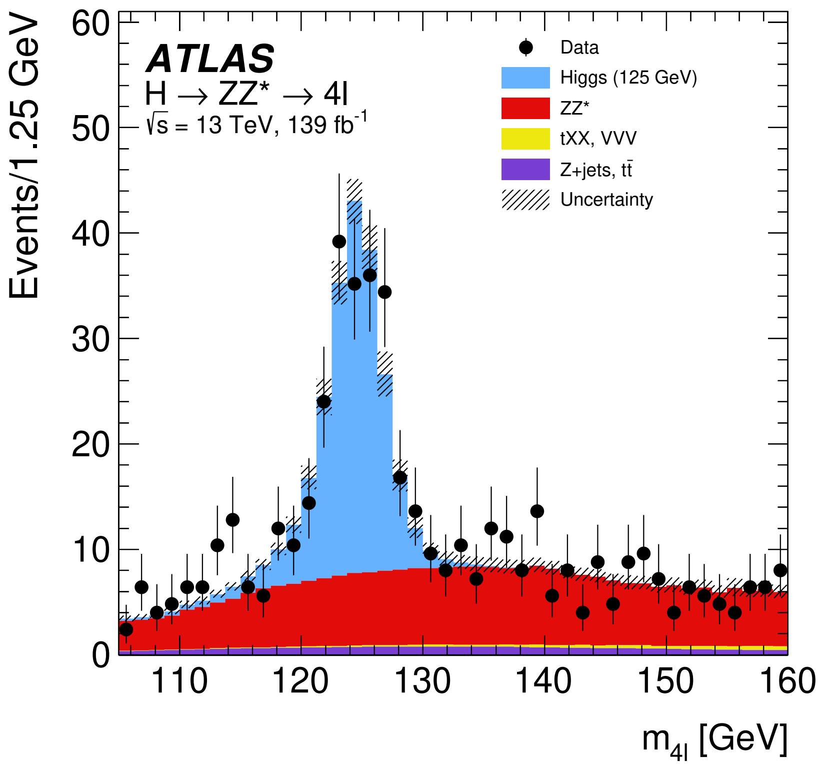


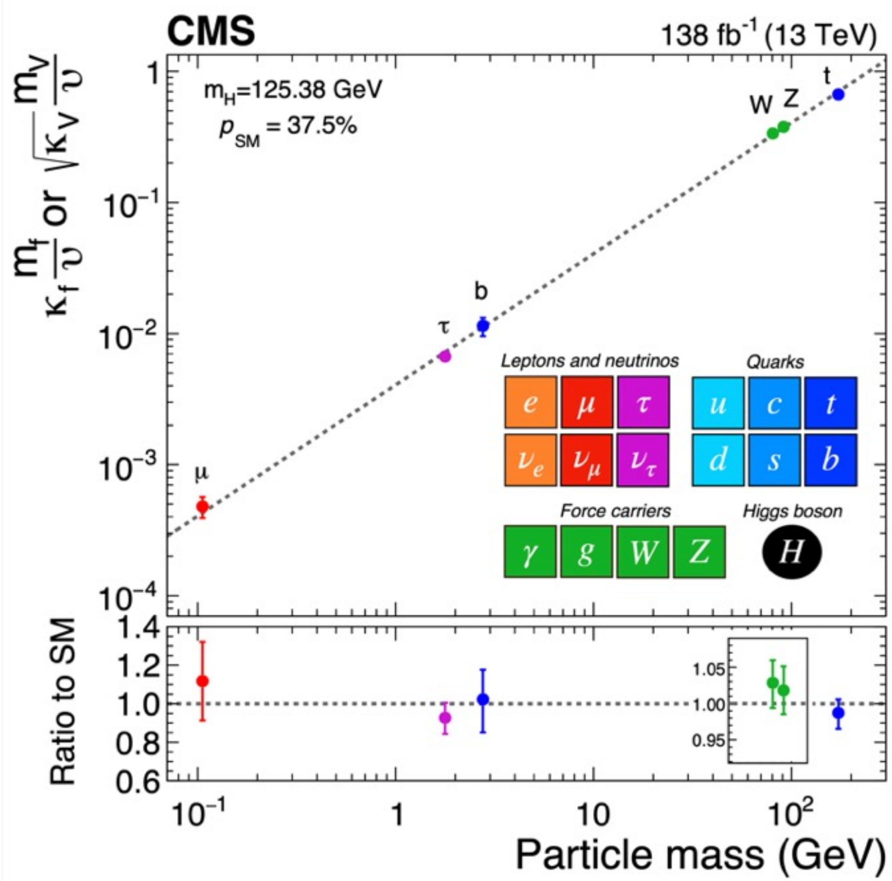
Frontier technologies

- 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

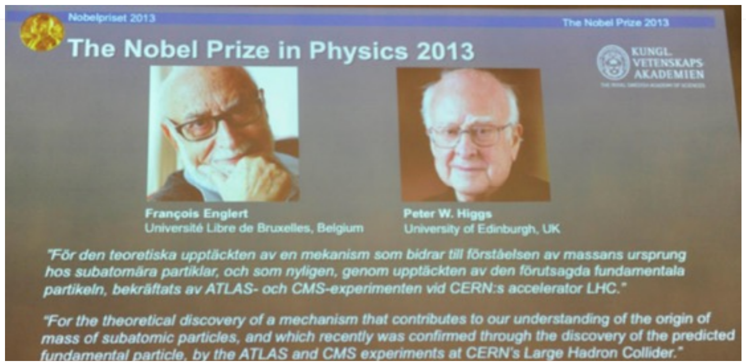


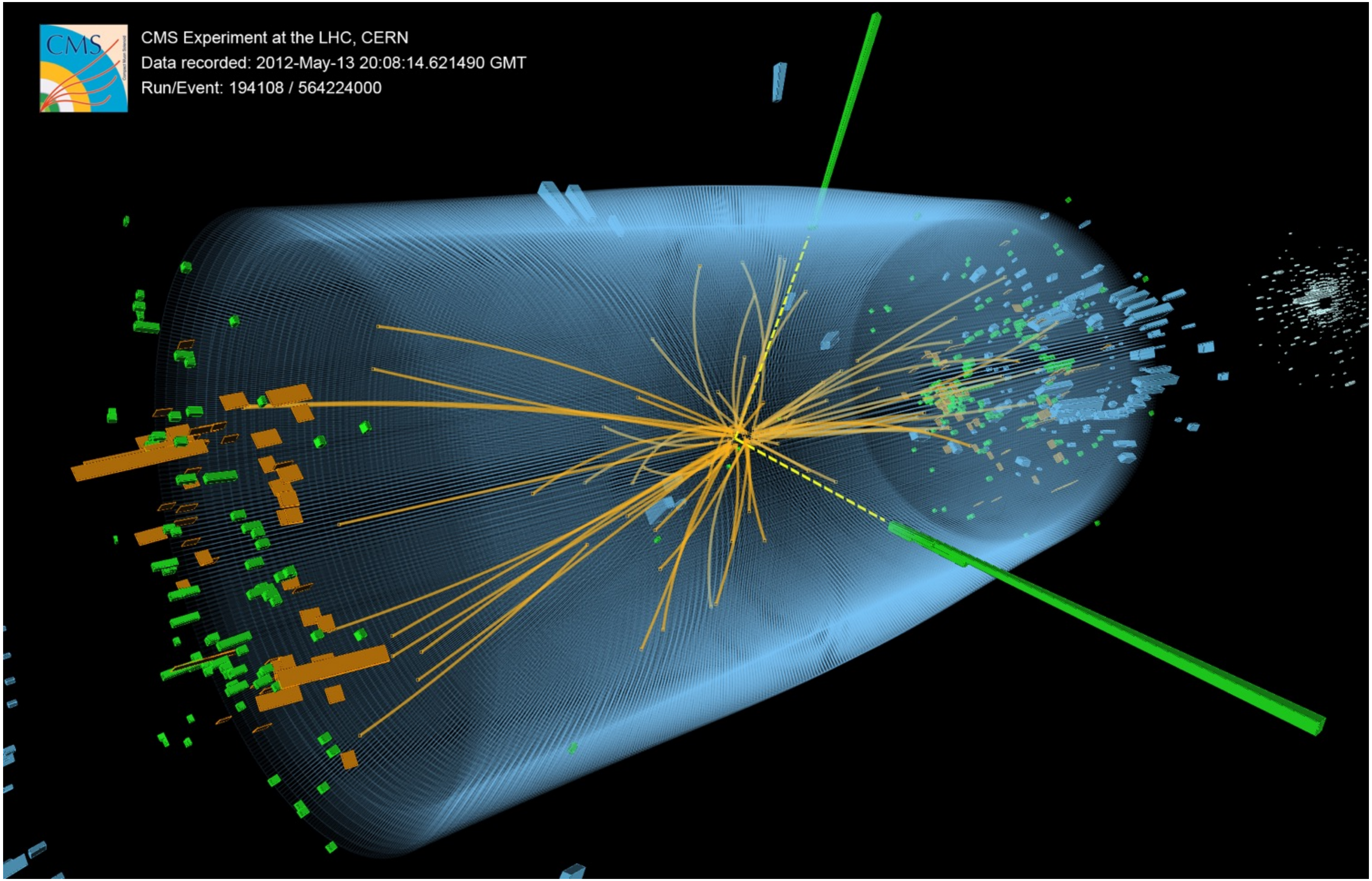
11 years of Higgs boson!



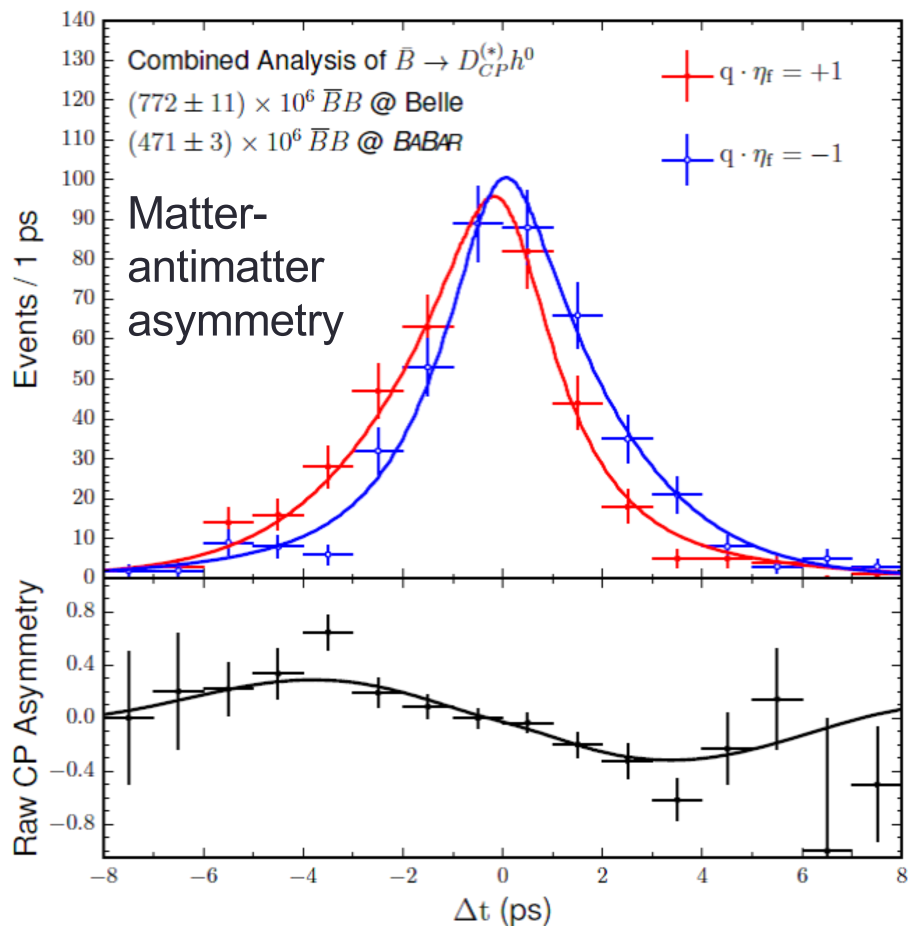


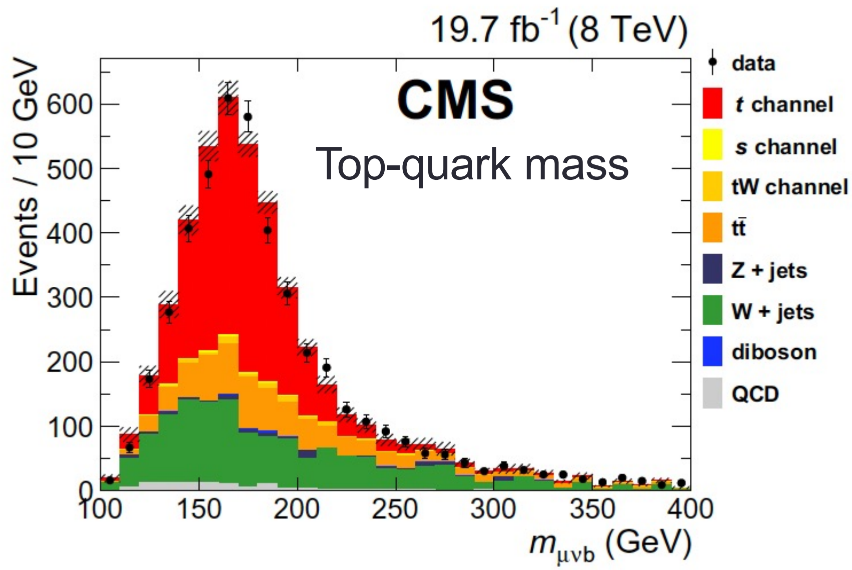
2013 Nobel Prize in Physics
to Prof.s Higgs and Englert

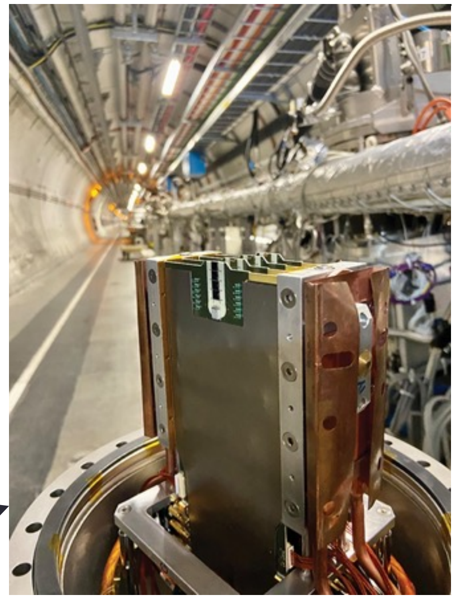



CMS
CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000

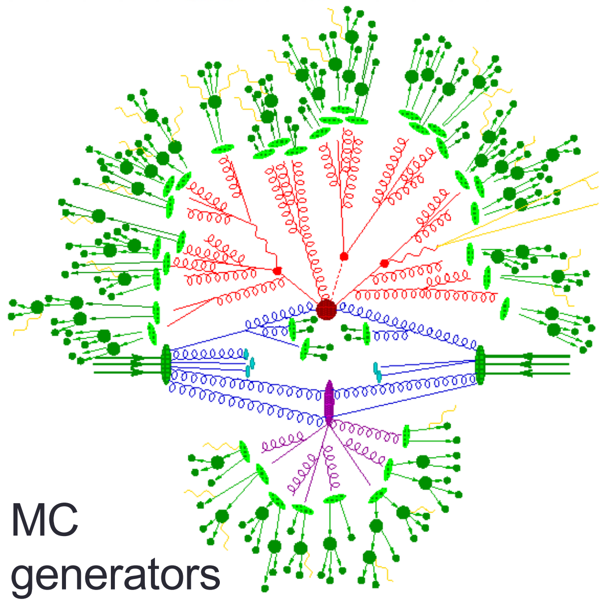
Examples of activities to which I contributed





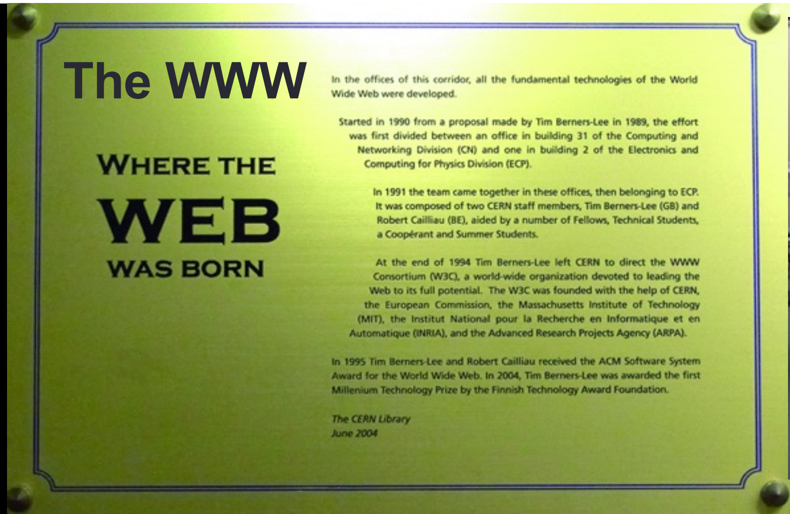


CMS proton precision spectrometer



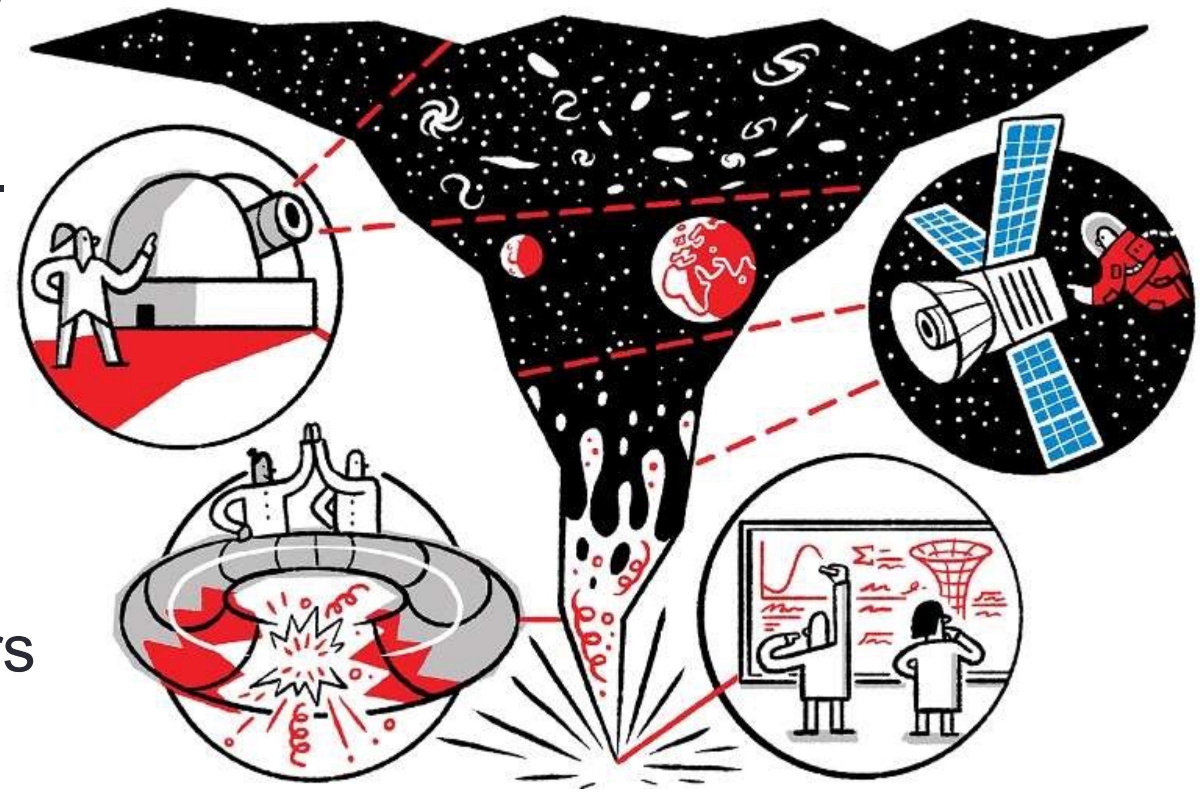
MC generators

A few immediate applications



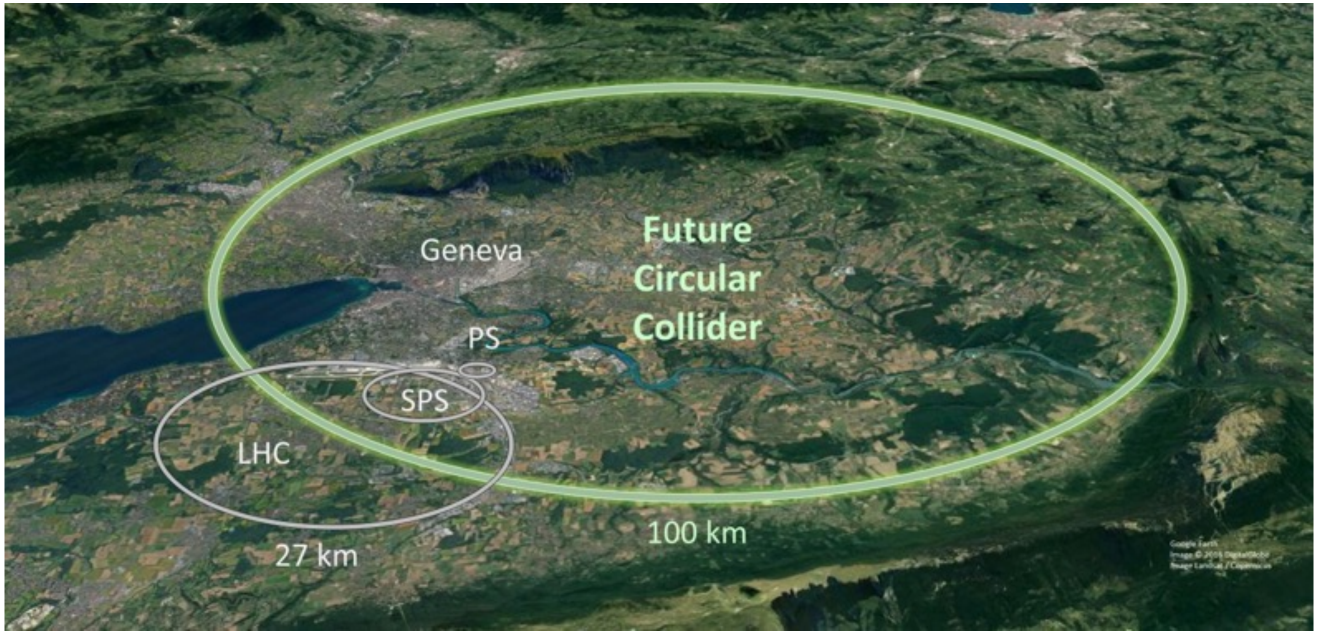
So, where are we?

- 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 !