
CERN

CERN and the LHC

The Higgs boson - and beyond

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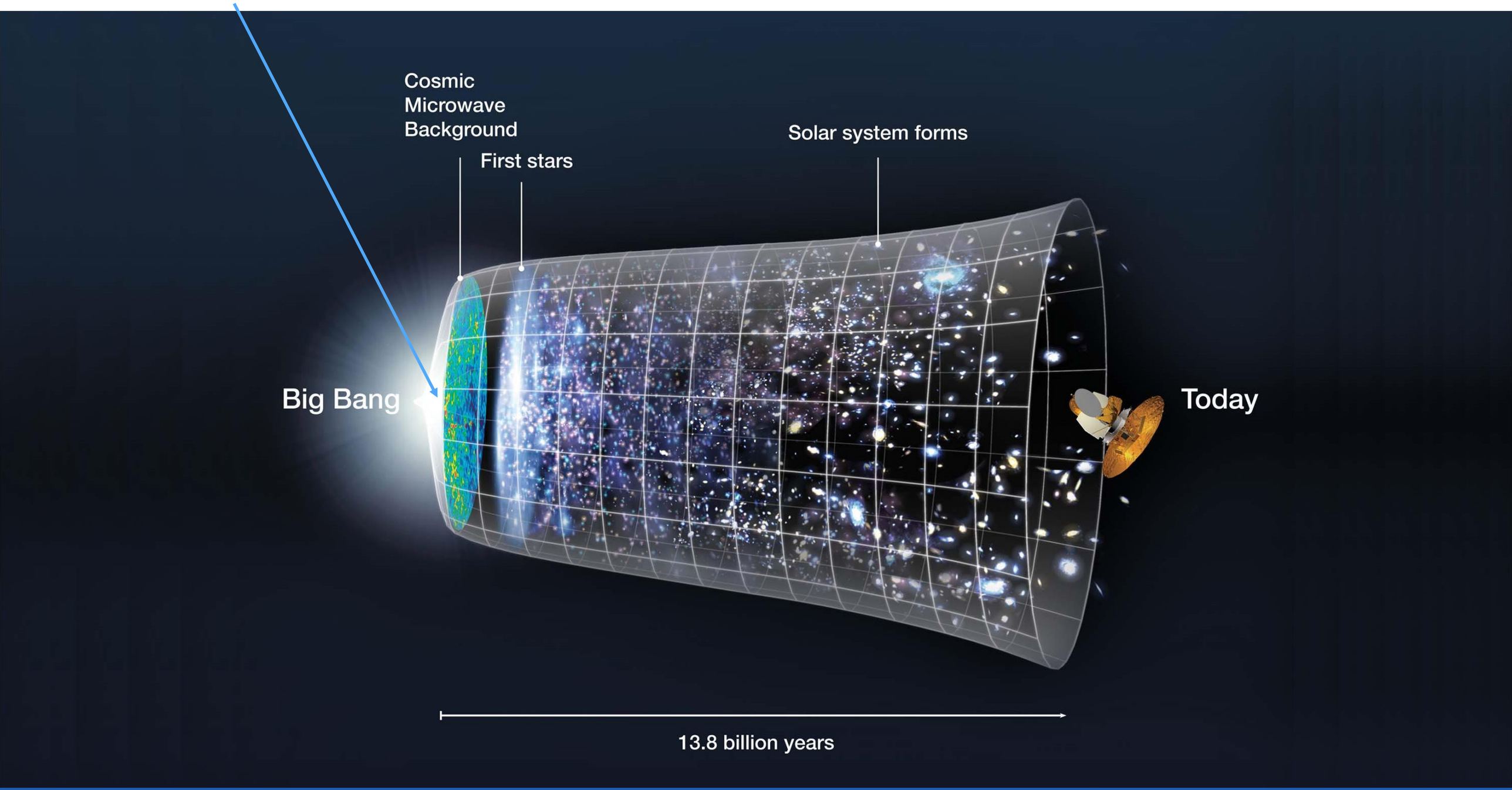
Old questions of philosophers

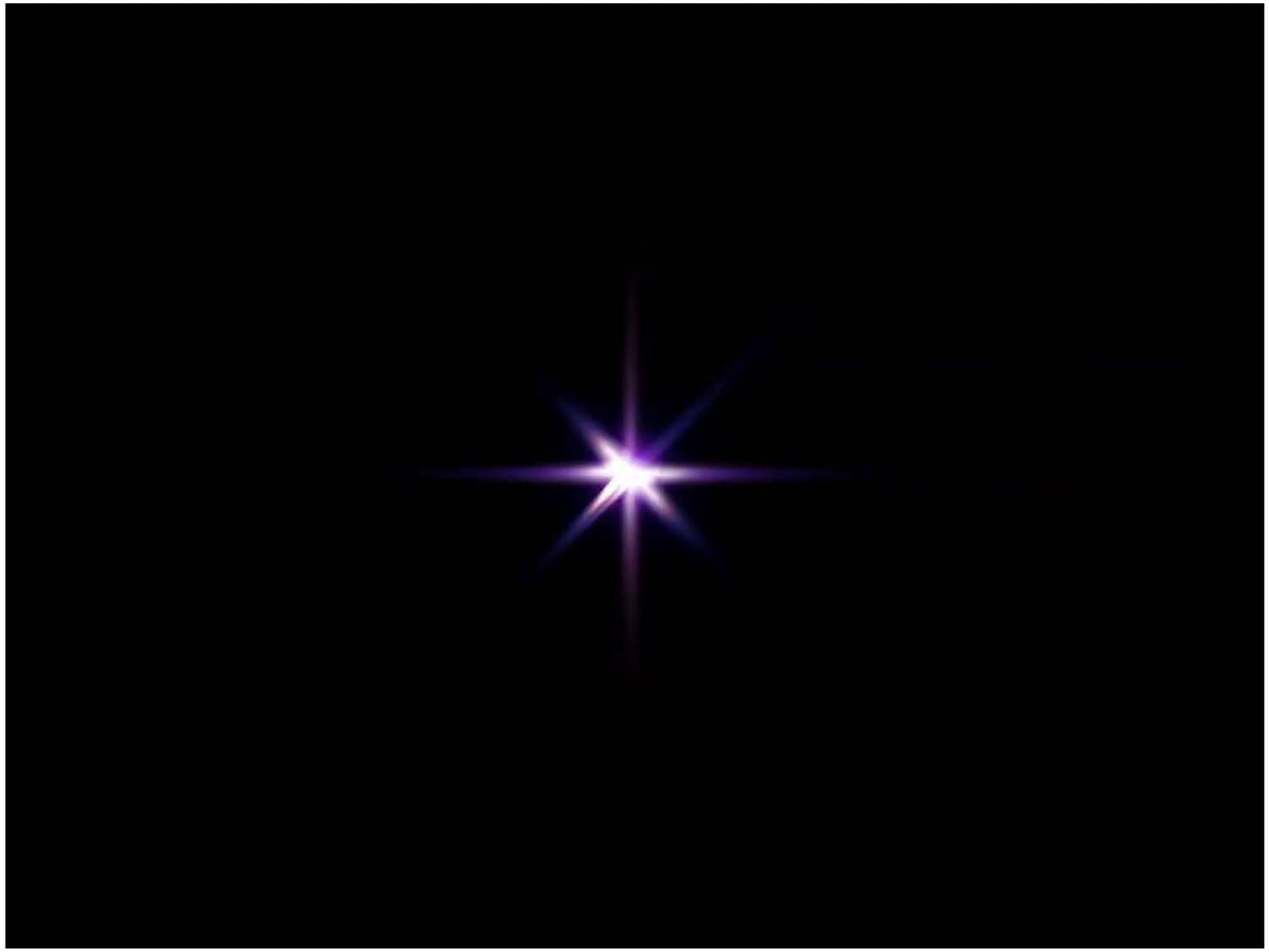
Physicists have taken over ….

The Universe (and all particles within) is 13.800 billion years old

Particle physics reproduces the conditions of the Universe just after the Big Bang

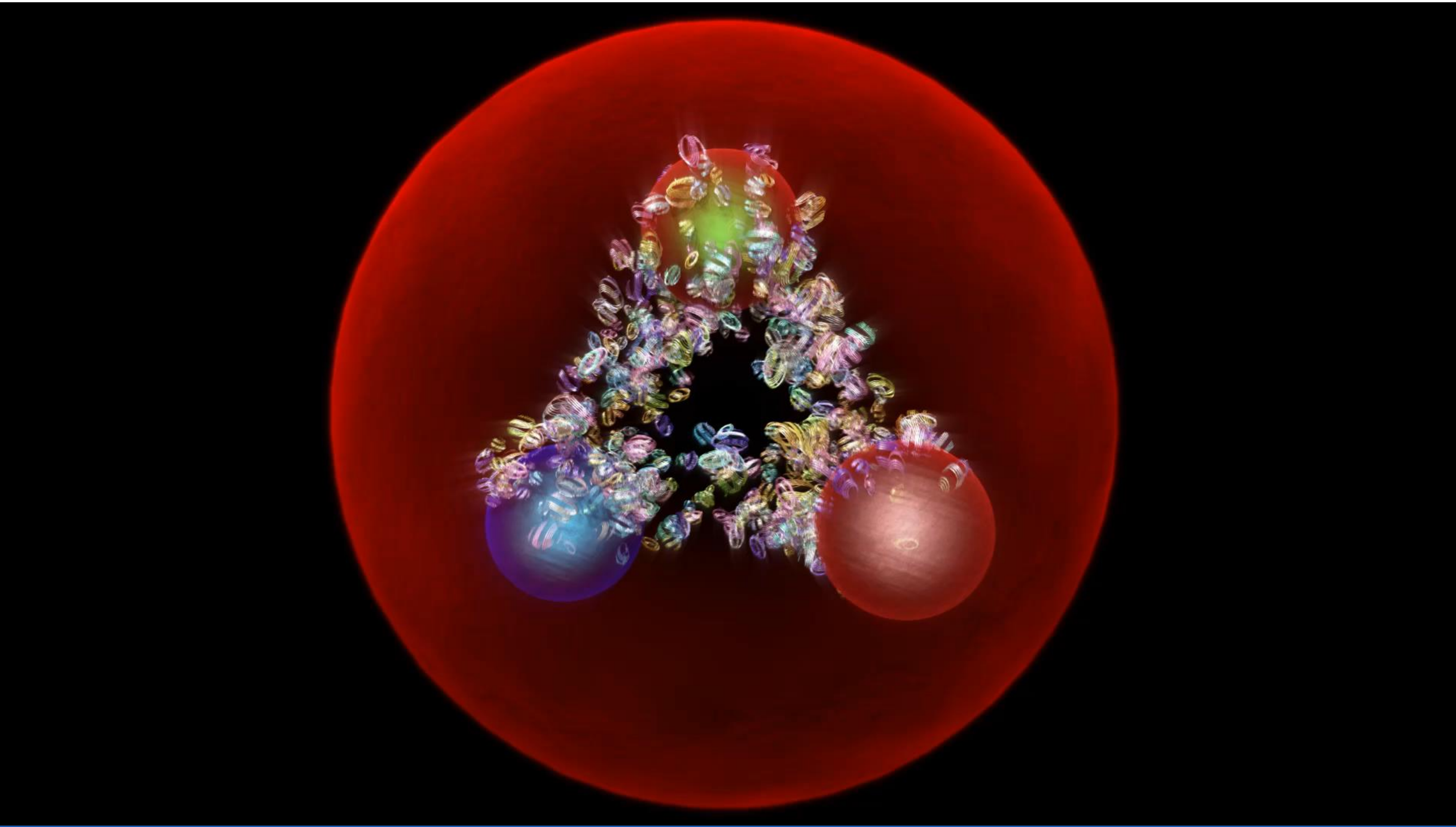


The first microsecond after the Big Bang

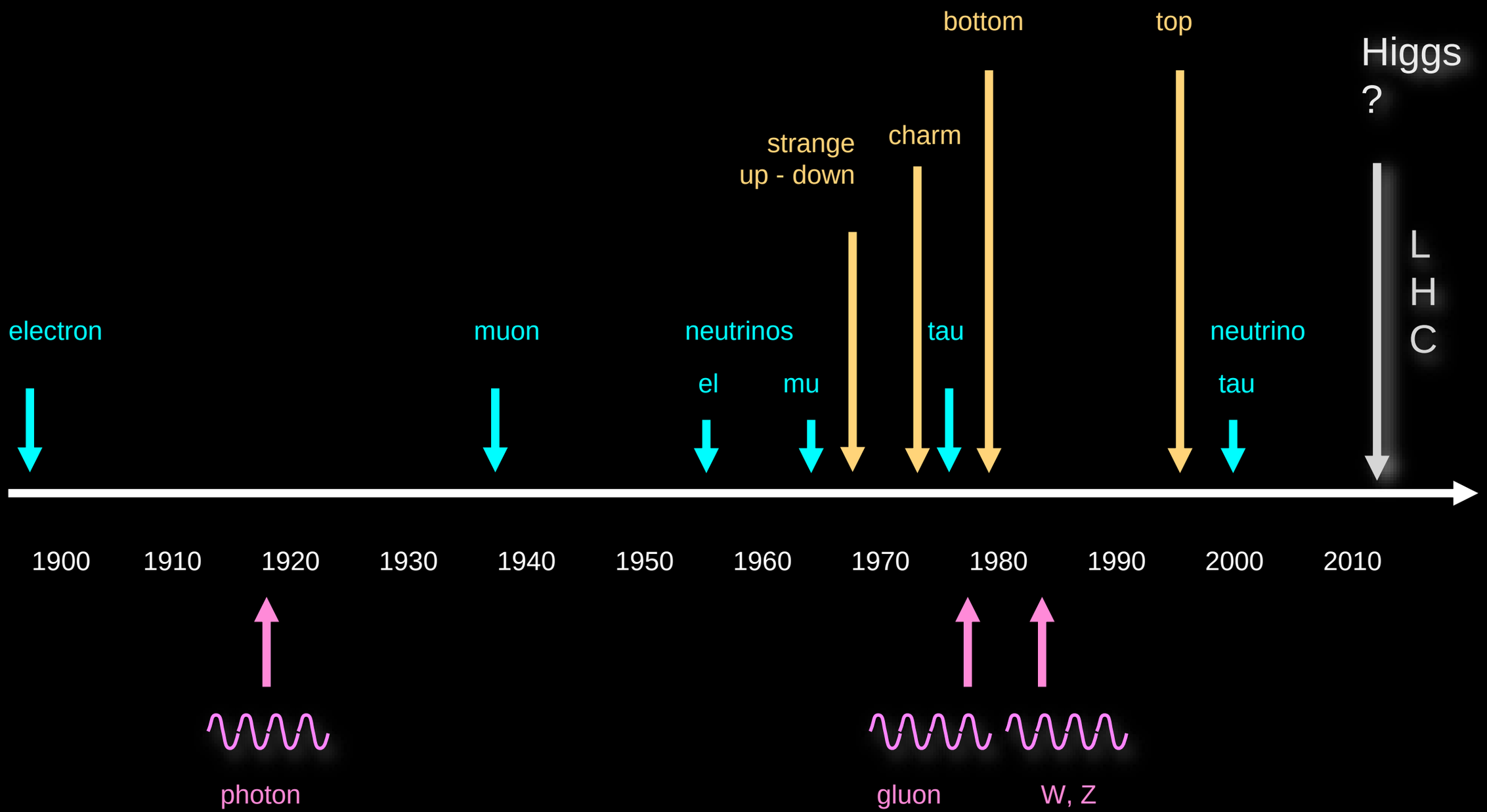


Energy transformed into particles

After one microsecond: protons and neutrons



60 years of experiments at accelerators have discovered the set of fundamental particles

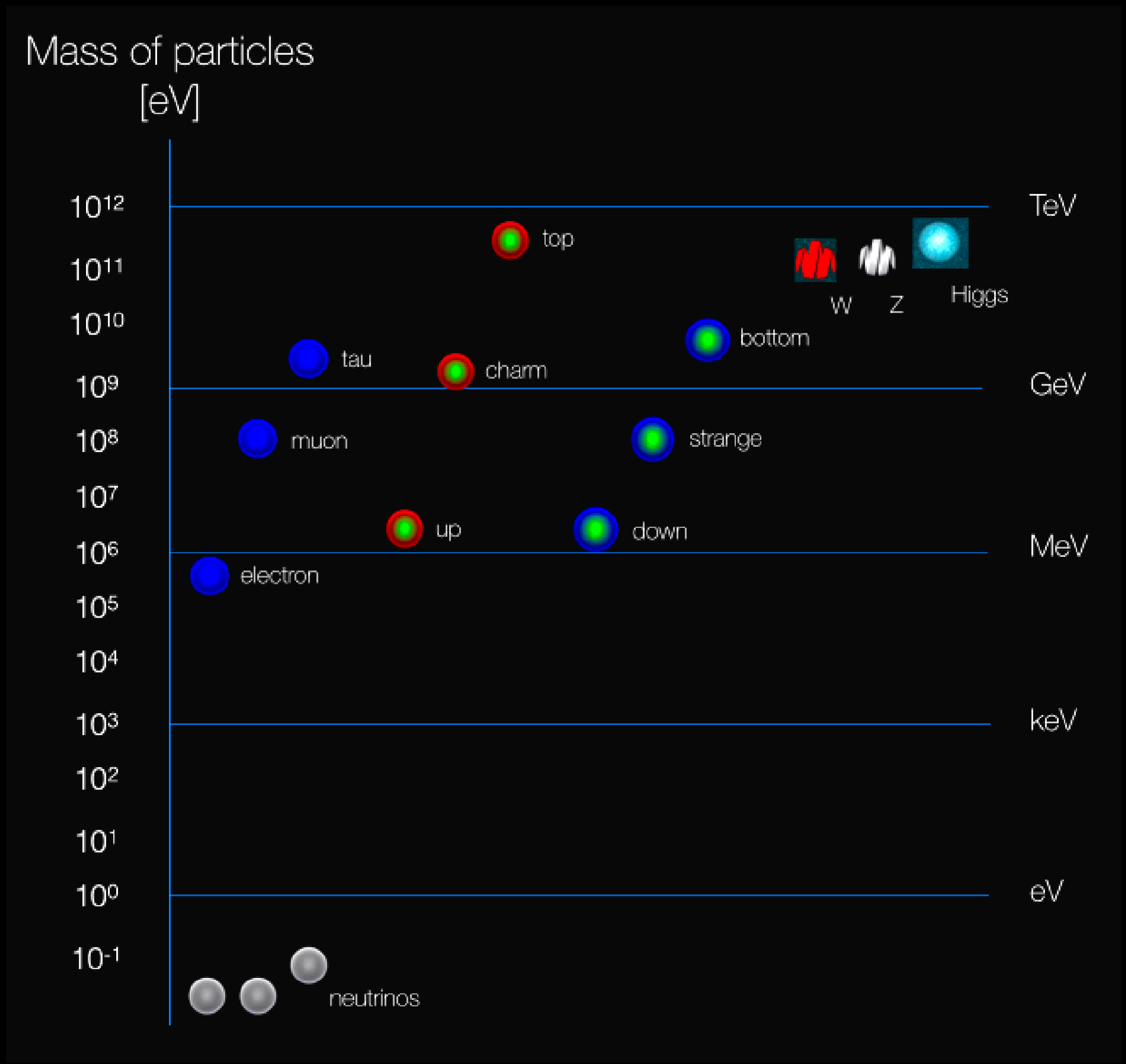


Standard model =

‘periodic system’ of elementary particles and their interactions

ACCELERATING SCIENCE

How do particles obtain their rest mass? Why so different ?



Animation: the Higgs mechanism

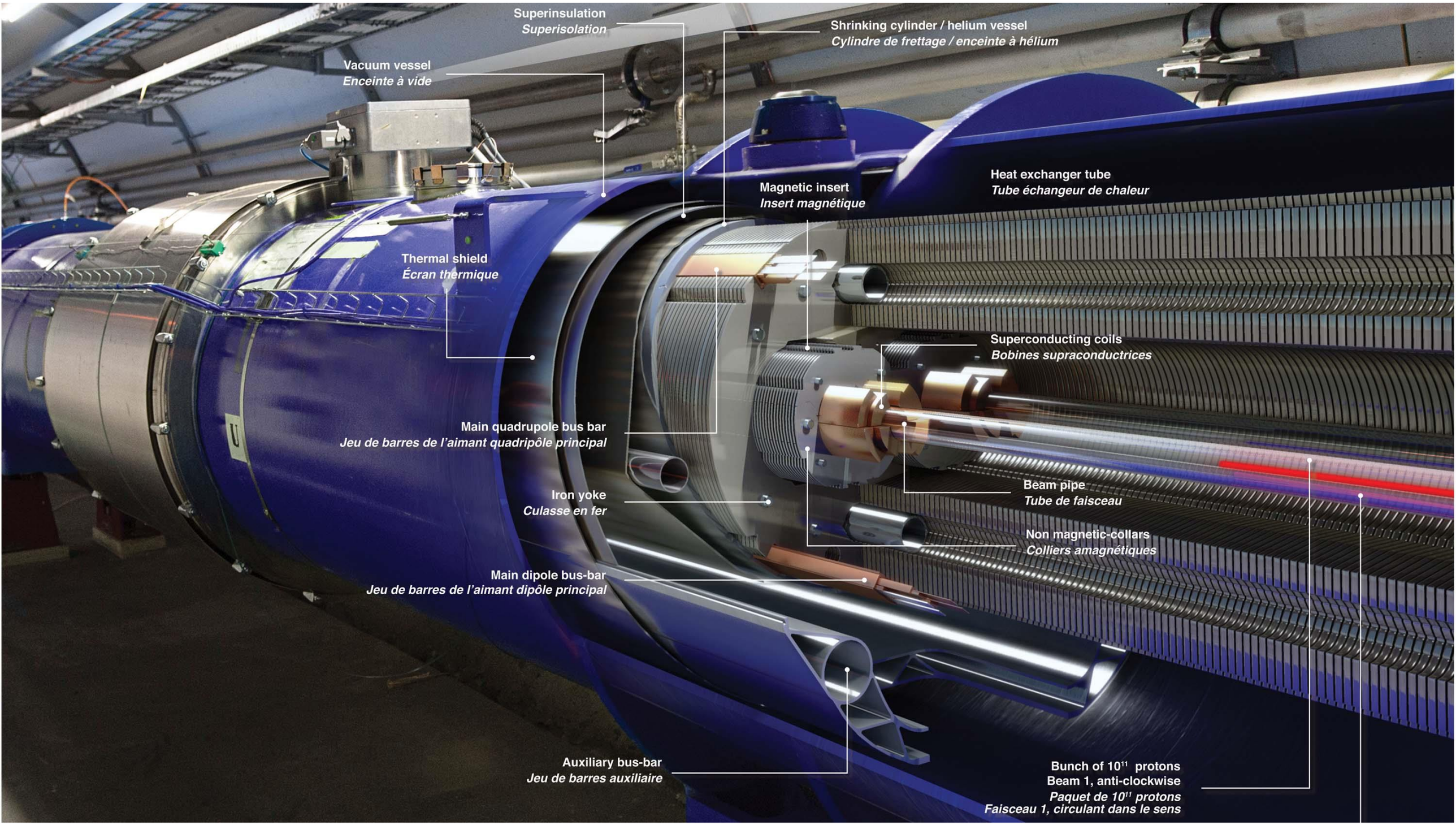
Exciting the Brout-Englert-Higgs field: the “Higgs boson”

... but this happens on average once per 10,000,000,000 (10^{10}) collisions !

How to find a Higgs boson?

CERN and LHC

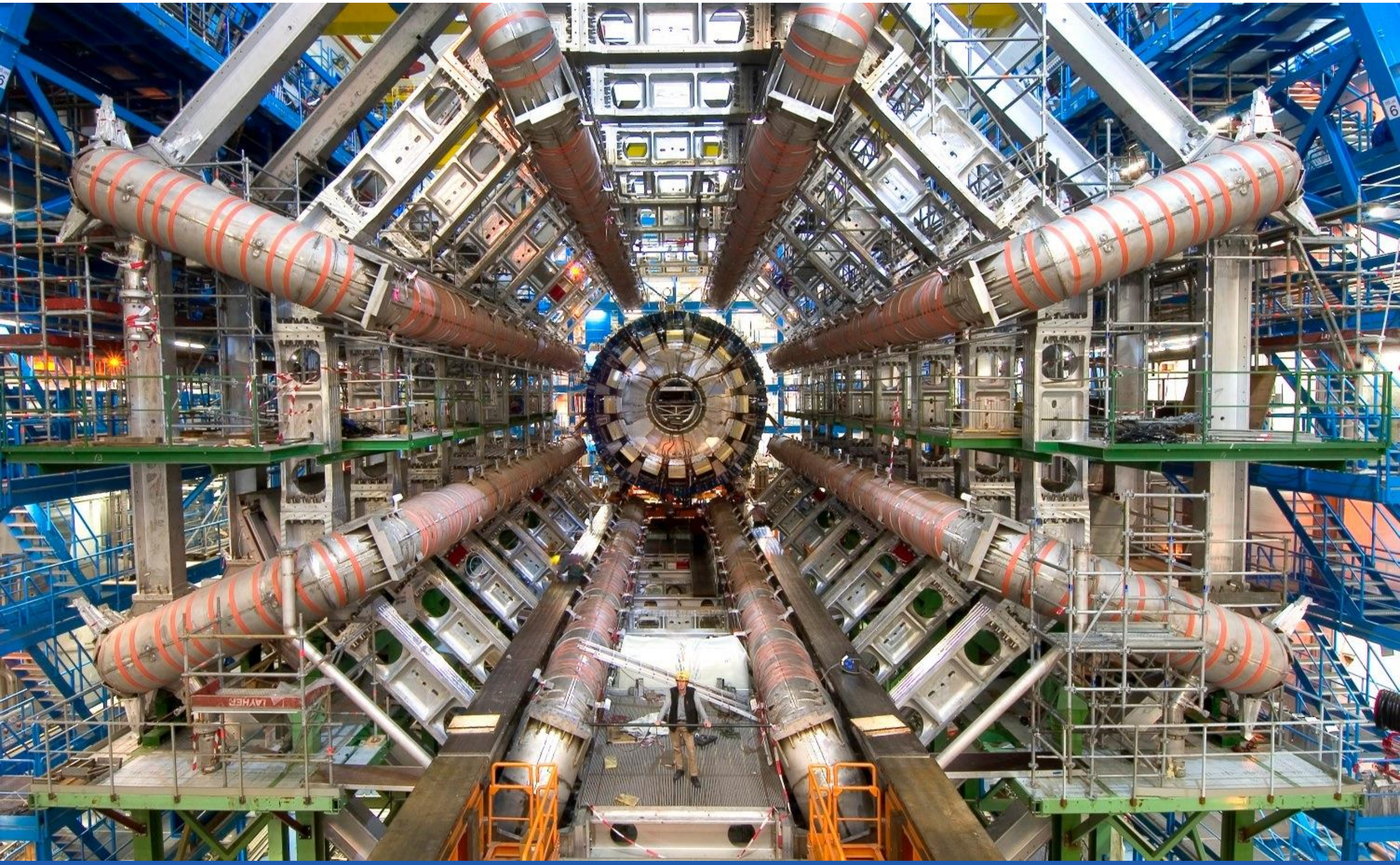
Large Hadron Collider (LHC) - a very complex machinery



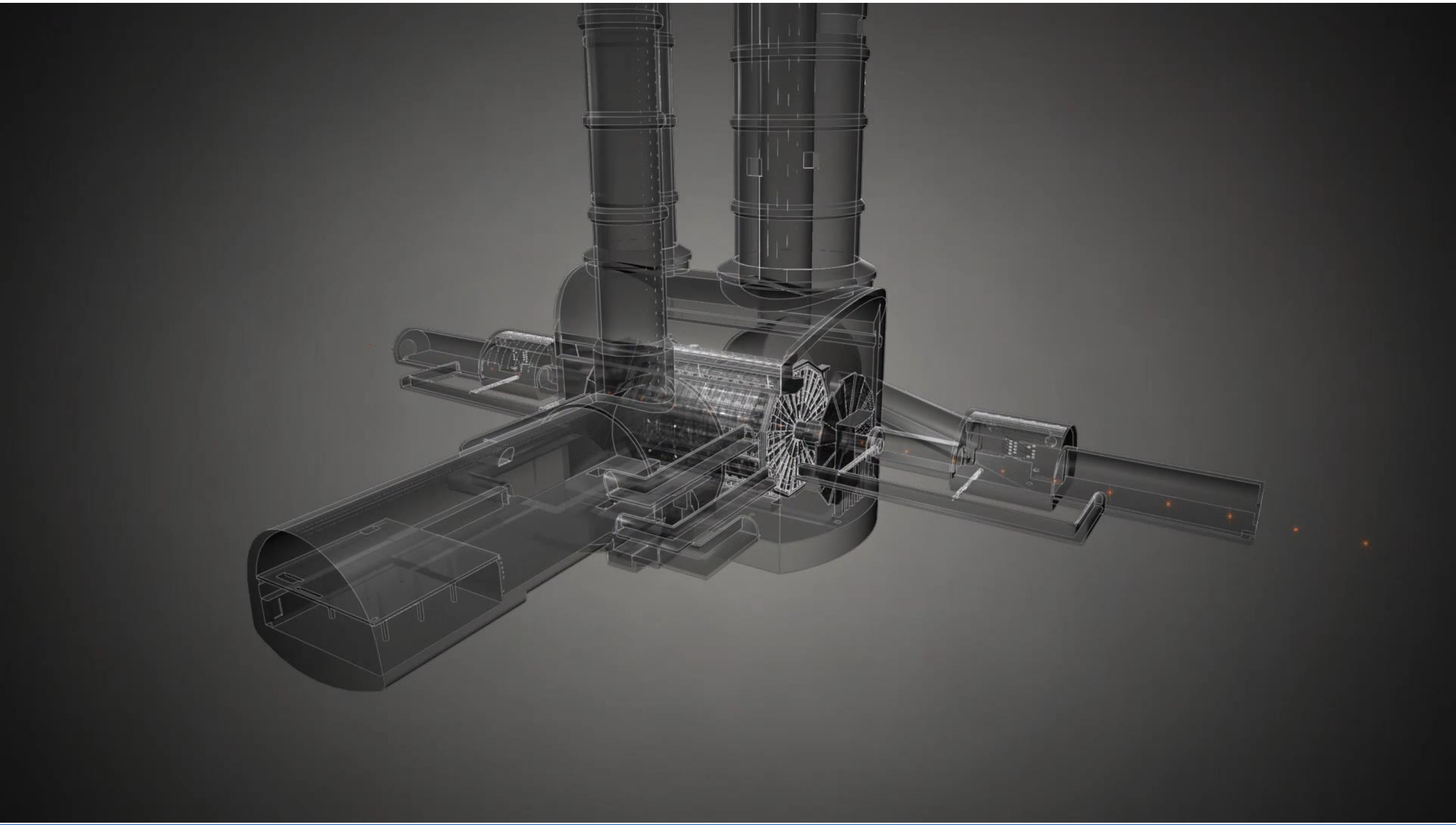
It took more than 10 years to develop the LHC dipole magnets

Beyond Pluto - 10 billion km ride through CERN

LHC experiments - huge detectors (e.g. ATLAS)



1 billion collisions per second

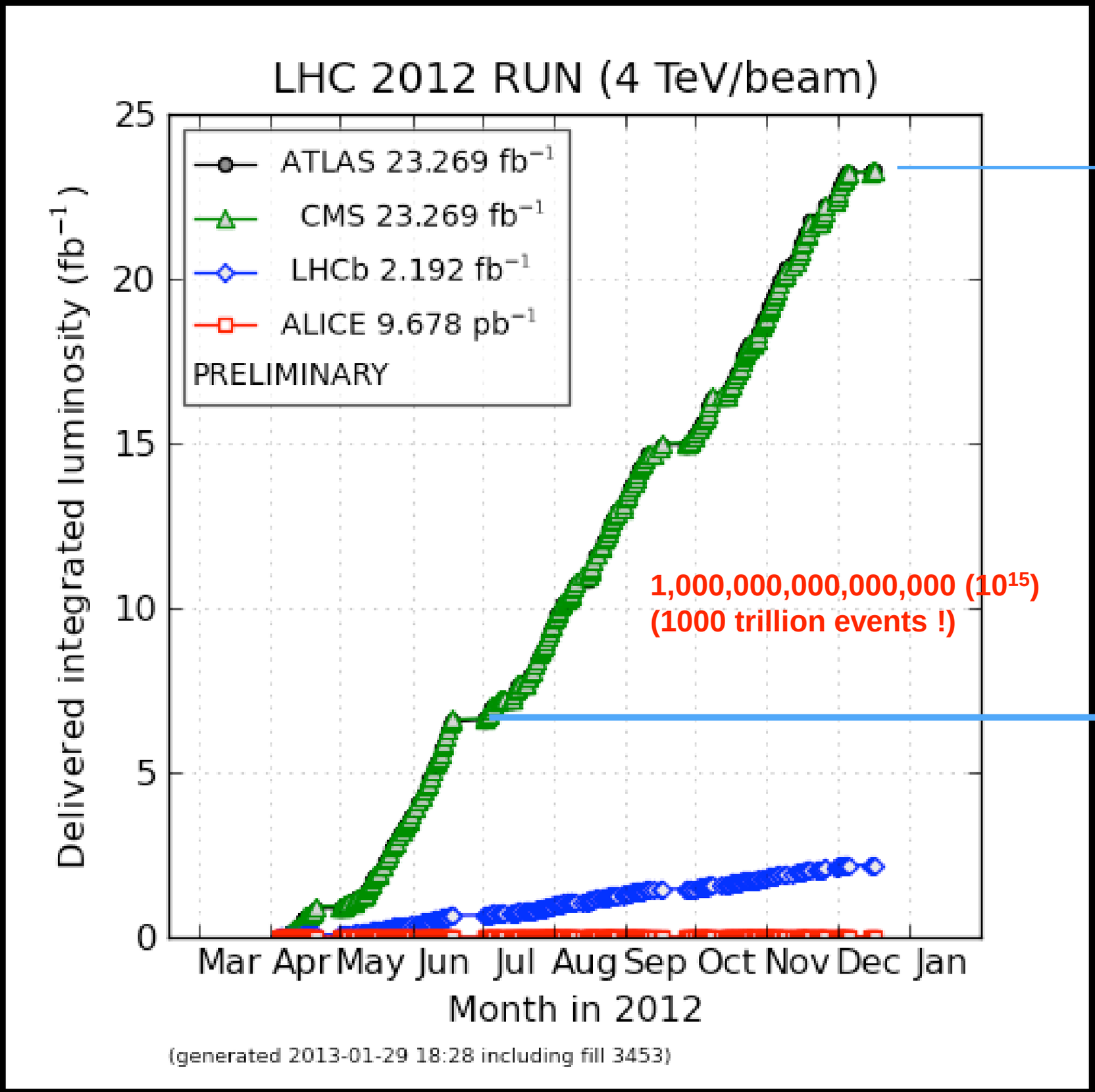


2012: The discovery of the Higgs boson

The Higgs boson can decay in two photons ...

but only with a probability of 0.2 %

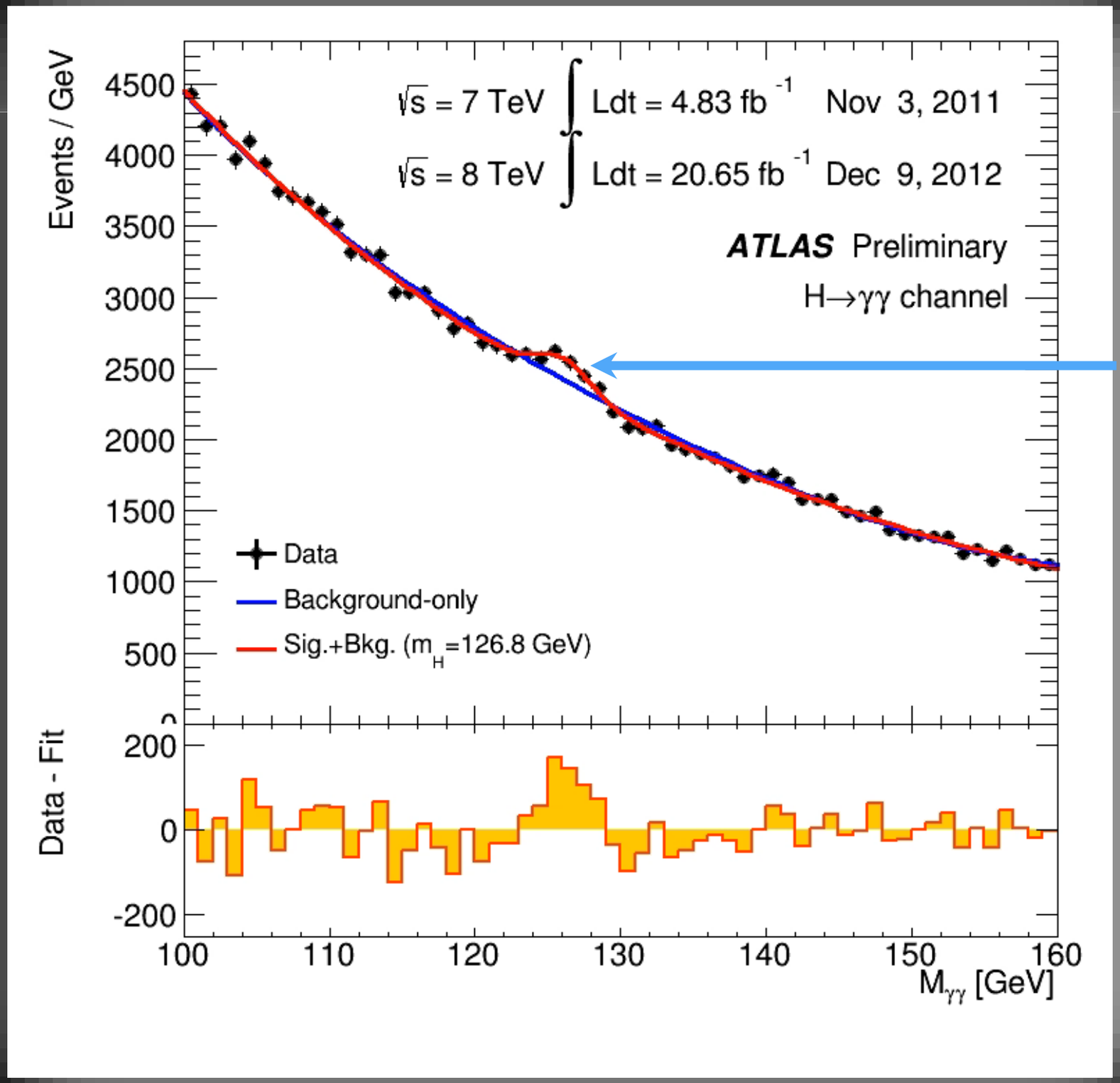
The CERN hunt for the Higgs boson



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

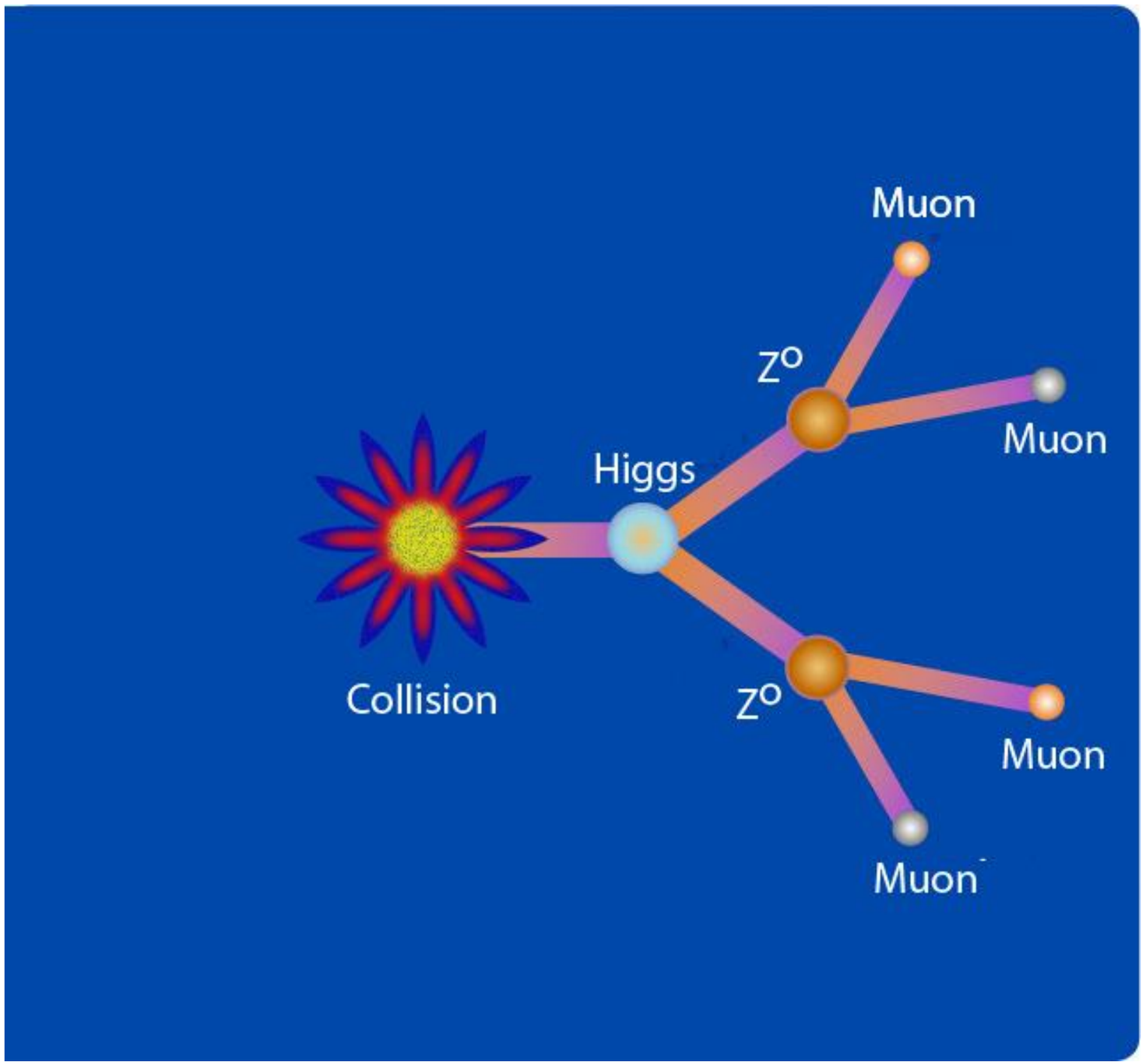
Event with two high-energy photons

The evolution of the histogram with two-photon events

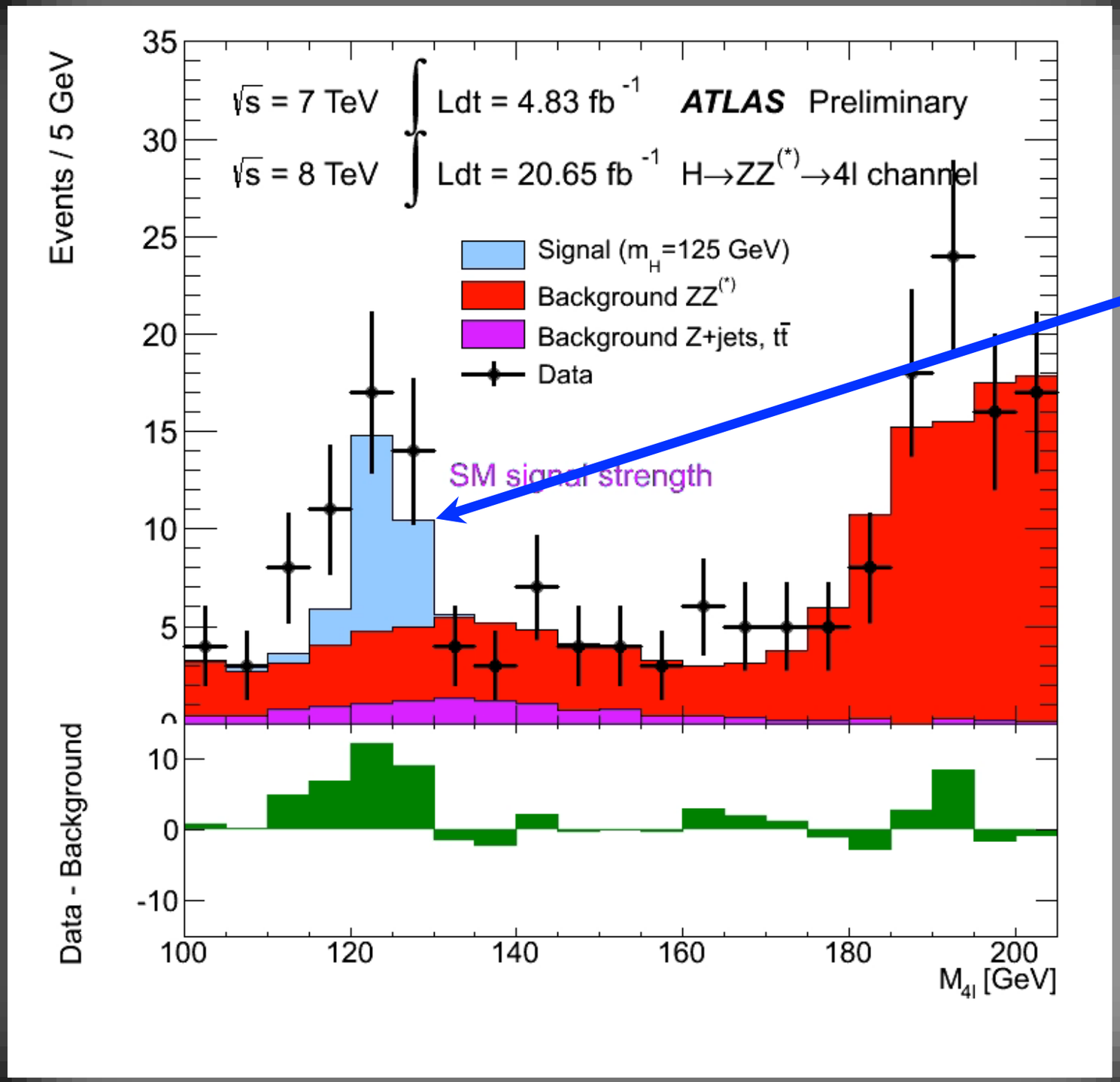


Higgs boson

Higgs decay into four muons



The evolution of the histogram with four leptons

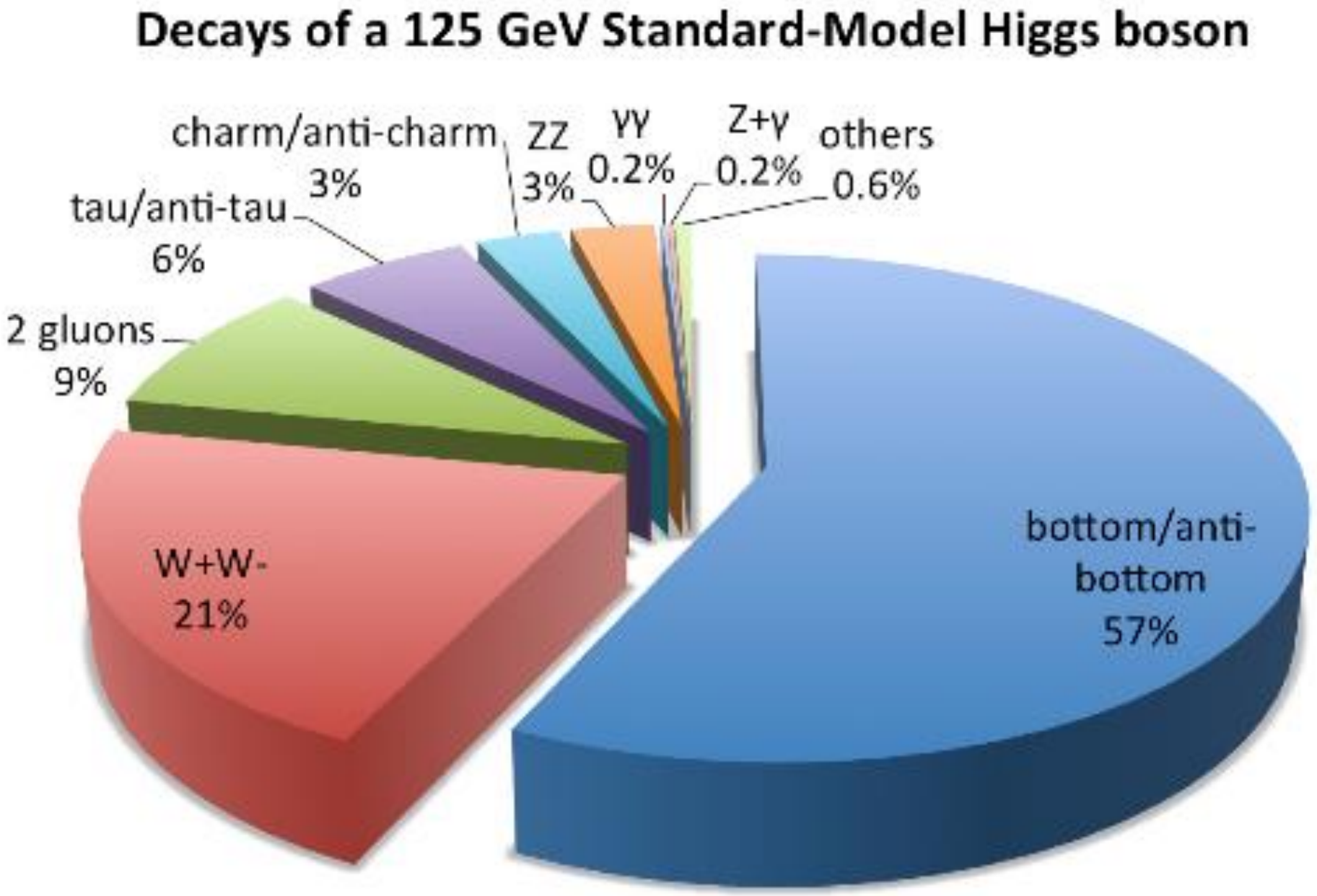


Higgs boson

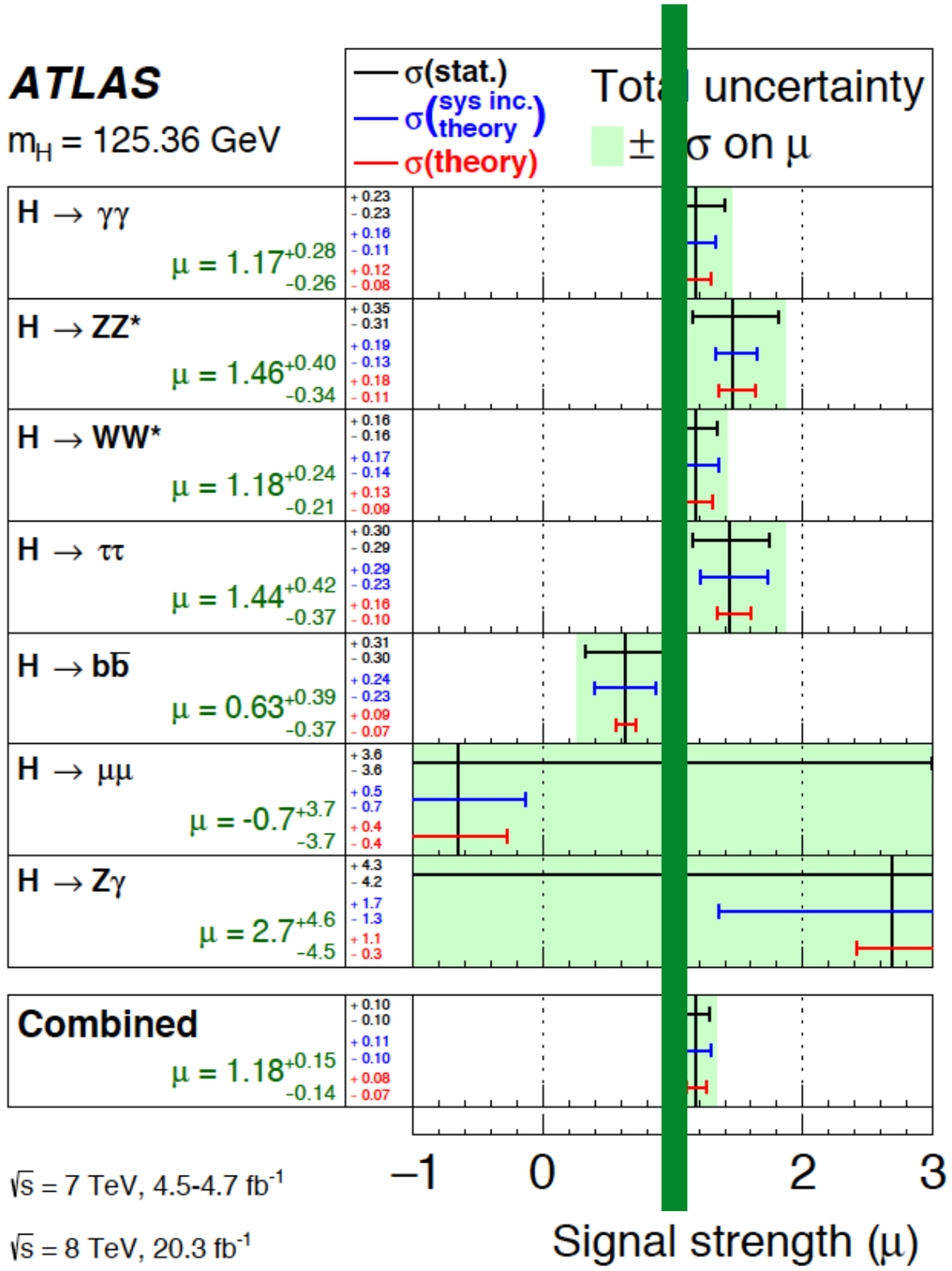
But: is this **the** Higgs boson ?

Interaction with particles proportional to their mass?

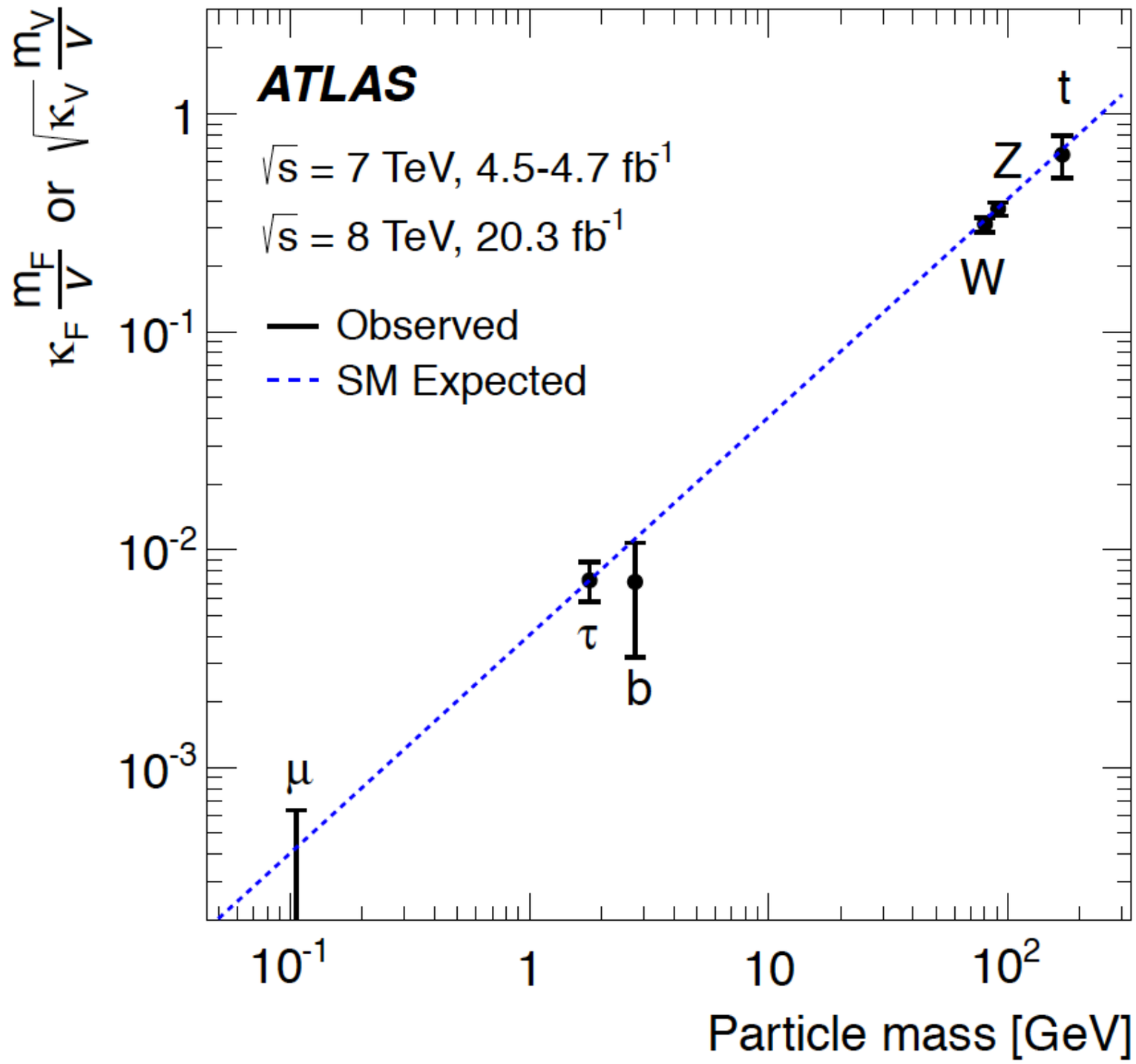
Decay probabilities agree with the Standard Model predictions?



The Higgs Boson decays **very** much as predicted:



Decay: **proportional** to the mass of daughter particles

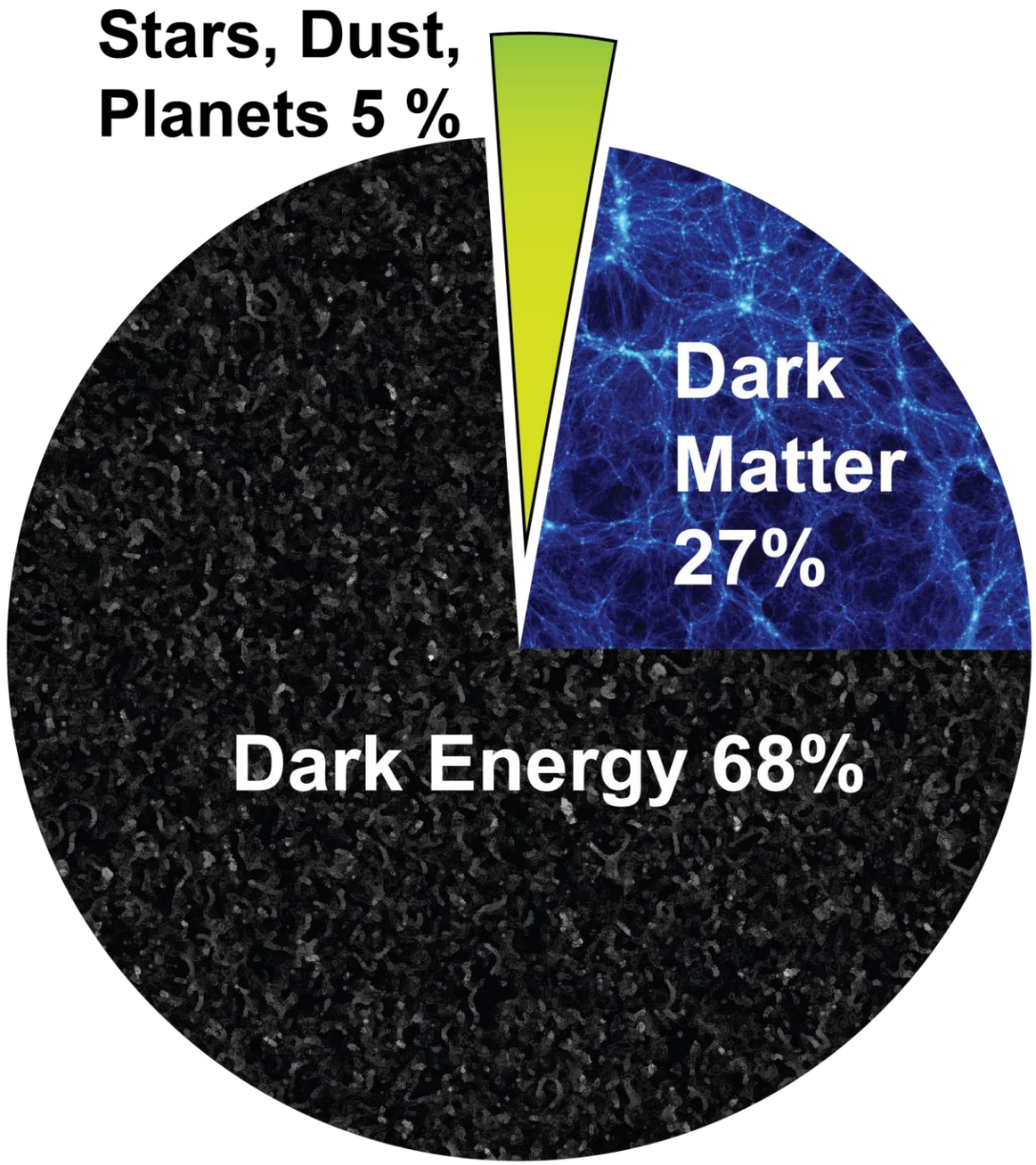


Ok - we found the Higgs.
Is that the end of particle physics?

No - **cosmology** tells us differently

No - **Standard Model** cannot explain everything

95 % of the mass-energy content of the Universe are unknown ‘dark energy’ and ‘dark matter’



Dark matter ...?

Galaxies rotate too fast

Movement of galaxy clusters

Gravitational lensing

Cosmic Microwave Background

Dark energy ...?

The expansion of the Universe accelerates ...

Known problems of the Standard Model

The pattern:

- Origin of particles (‘periodic table’)
- Origin of forces (their number, strengths)
- Origin of 26 parameters (particle masses, mixing angles)

Higgs mass (126 GeV) is very light - why?

Neutrino masses

- Experiment: non-zero, but very small (~0.01-0.1 eV)
- Relevant physics may be at much higher energies

Cosmological antimatter mystery

So many theories! The LHC is needed:

a) Supersymmetric particles - link to dark matter ?

b) Gravity and extra dimensions ?

c) New fundamental interactions ?

d) More Higgs bosons?

e) New generations of quarks/leptons ?

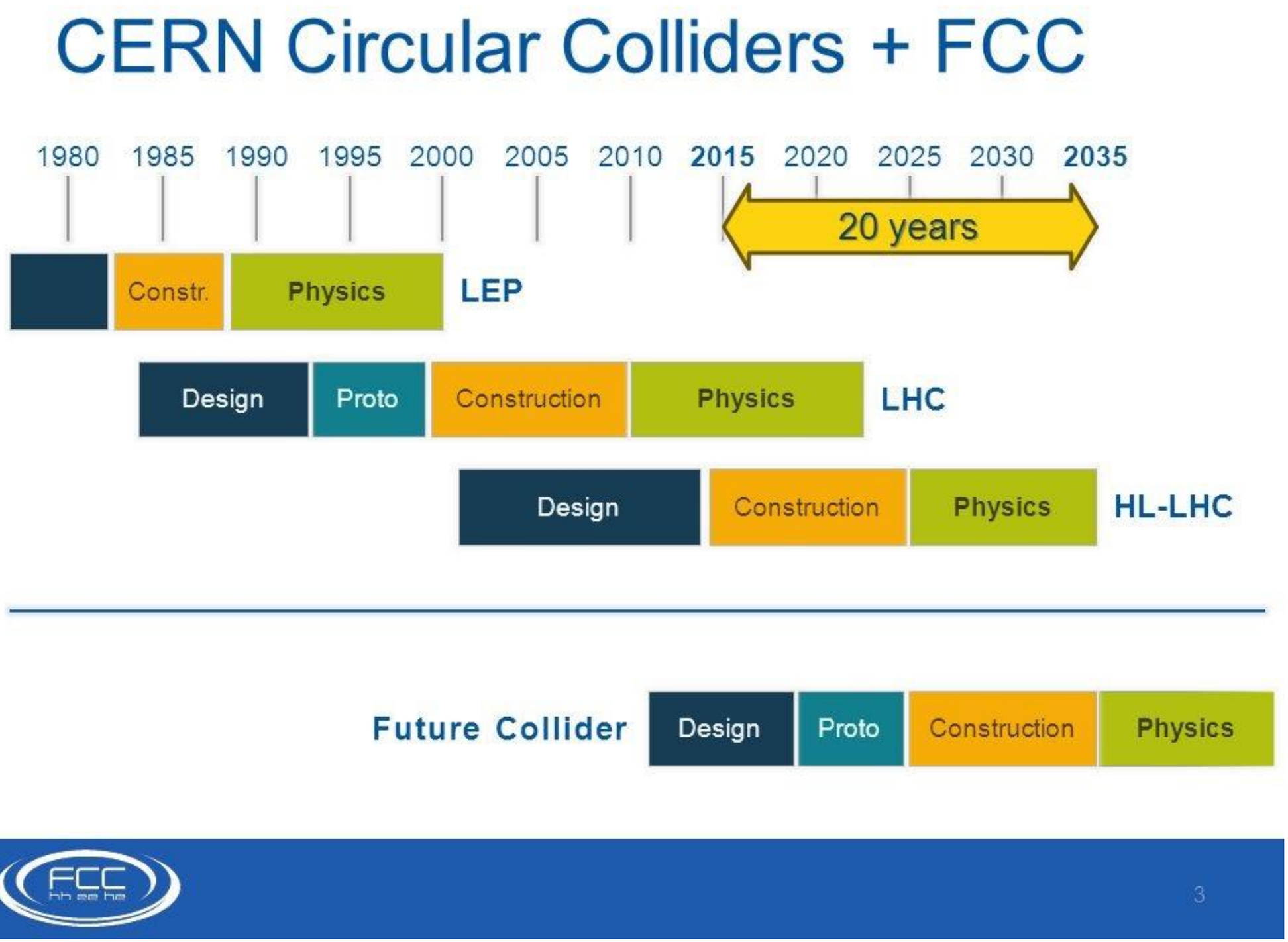
f) Leptoquarks ?

g) Something **completely new** ?

Prospects of particle physics

- The next 20 years
- After 2035

How to get there ?

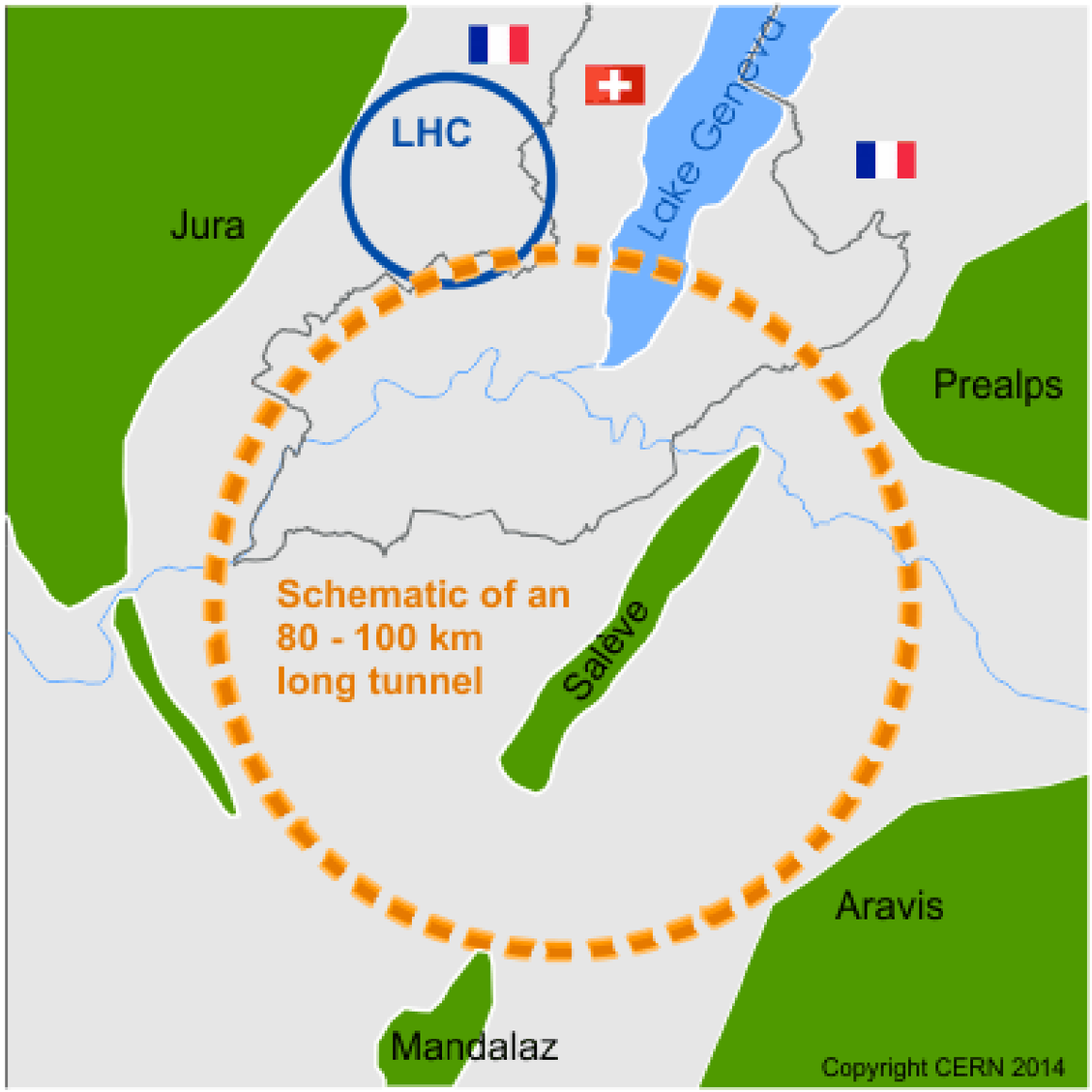


How to go to increase collision energy of constituents ?

CLIC: 3 TeV e^+ e^- Collider

Total length: 45 km

Future circular collider - project study (FCC)



Conceptual design report ~ late 2018

Circular collider in new tunnel

80- 100 km circumference

Circular proton-proton collider
100 TeV collision energy (p+p)

Circular electron-positron collider (VLEP)
(***350 GeV c.m.*** energy, t-tbar threshold)

Lepton-Hadron collider (like HERA)
(***50 TeV p + 100 GeV e***)

Alternatively:

30 TeV p-p collider in LHC tunnel ?
(***16 T magnets***)


Thank you!