Oltre il bosone di Higgs: le nuove tecnologie del CERN per esplorare nuovi orizzonti

Lucio Rossi
CERN
High Luminosity LHC Project Leader

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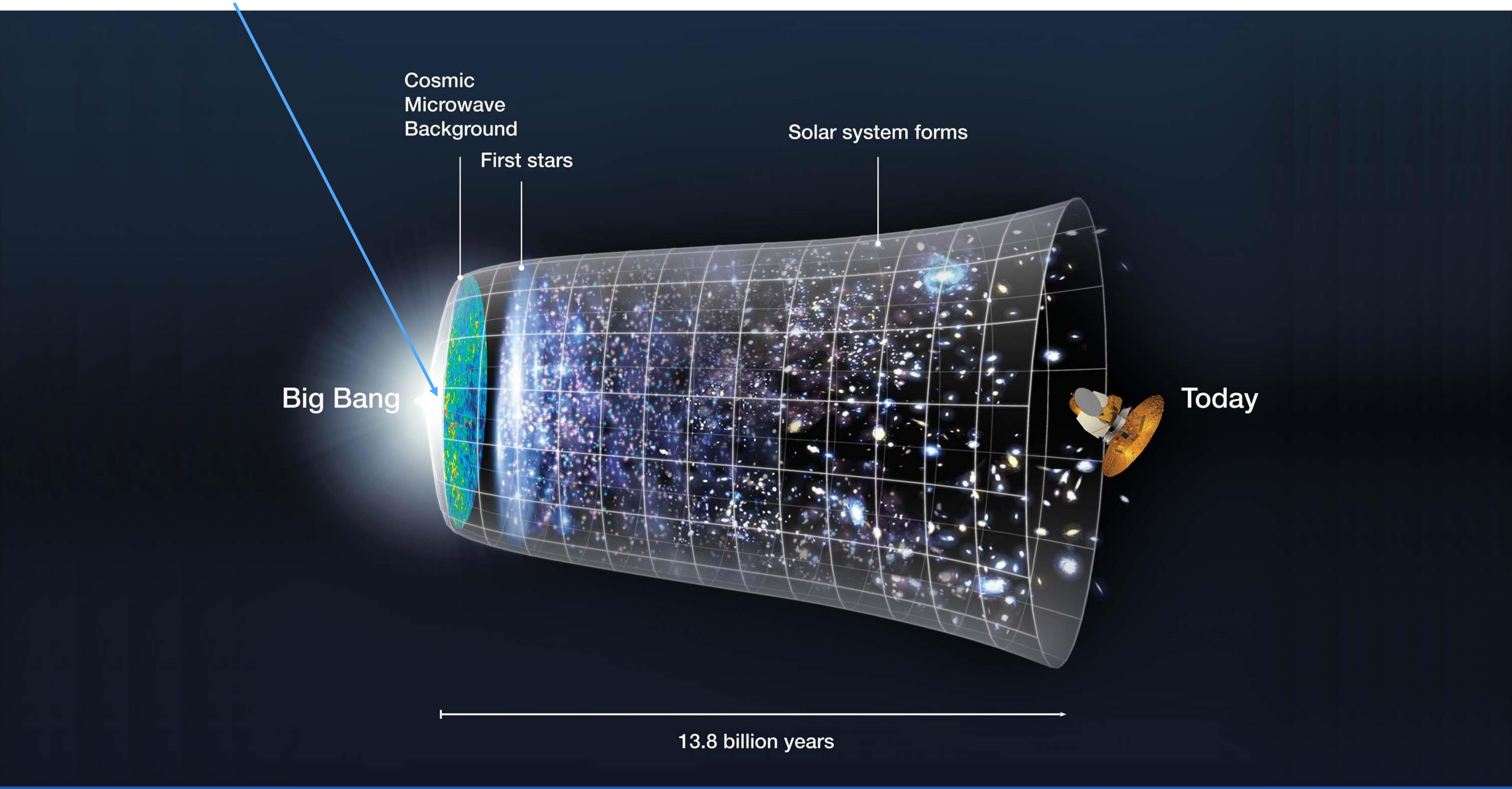
Associazione Edoardo Amaldi

FONDAZIONE DI PIACENZA E VIGEVANO

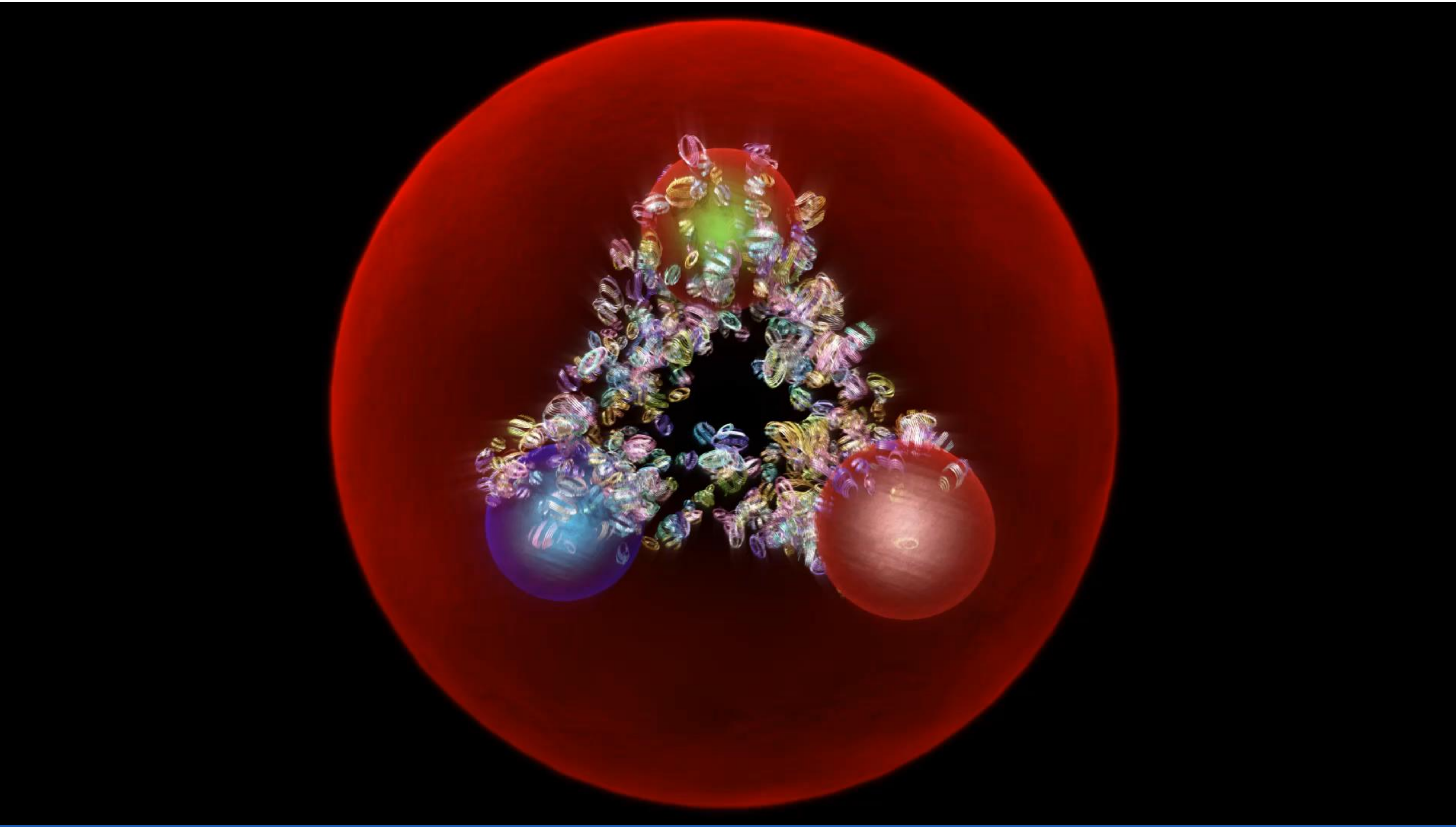
Unione Giornalisti Italiani Scientifici

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

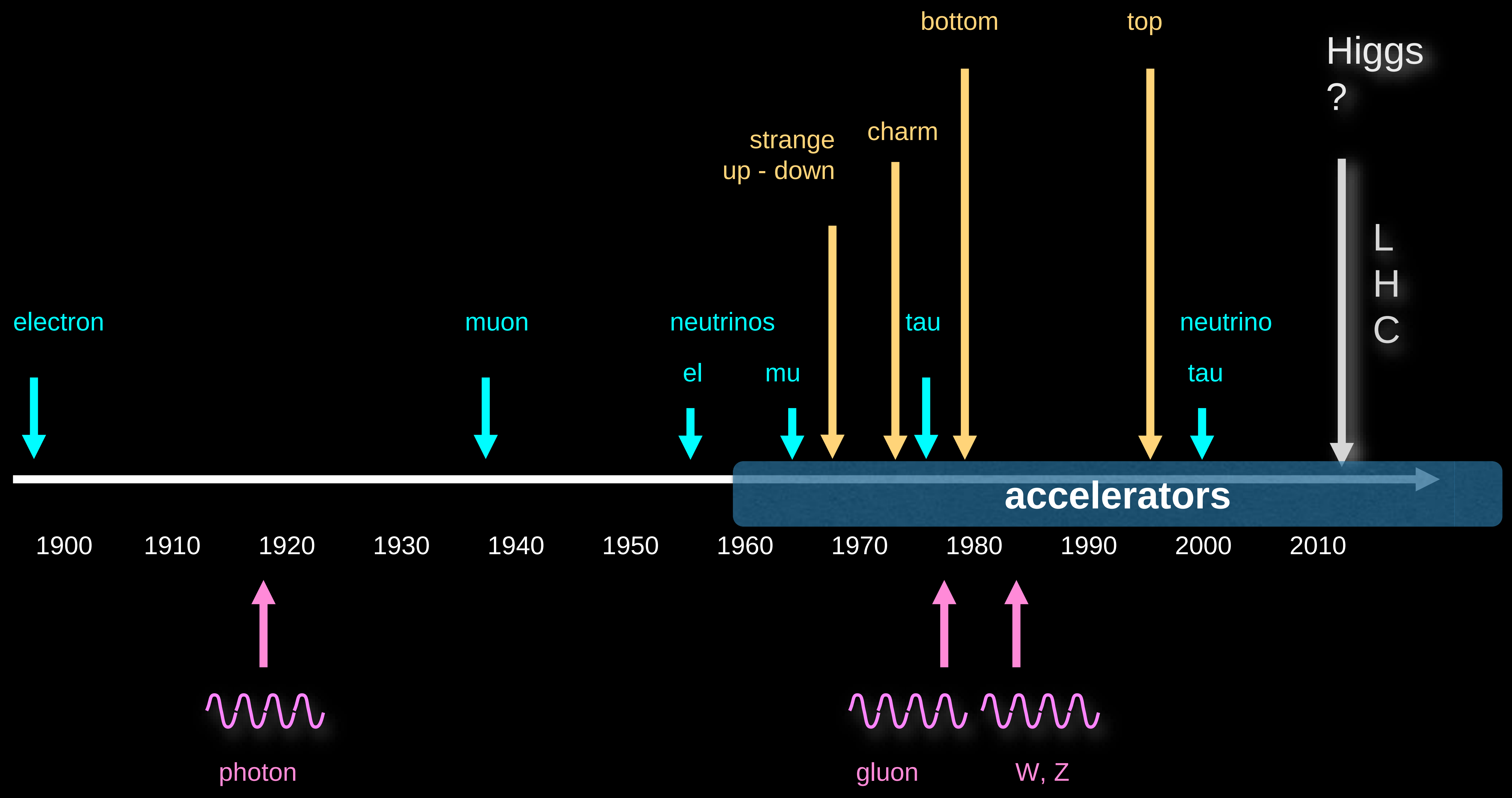
Particle physics reproduces the conditions of the Universe just after the Big Bang



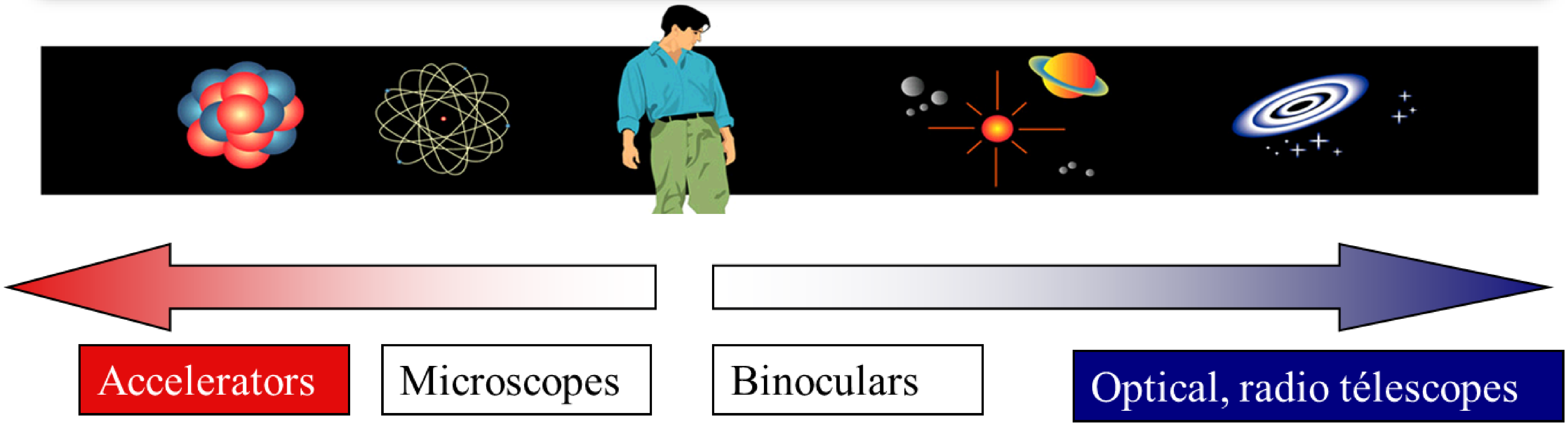
After one microsecond: protons and neutrons



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



What’s are particle acclerators?
Why they help us to see the basic constitutents of the universe?



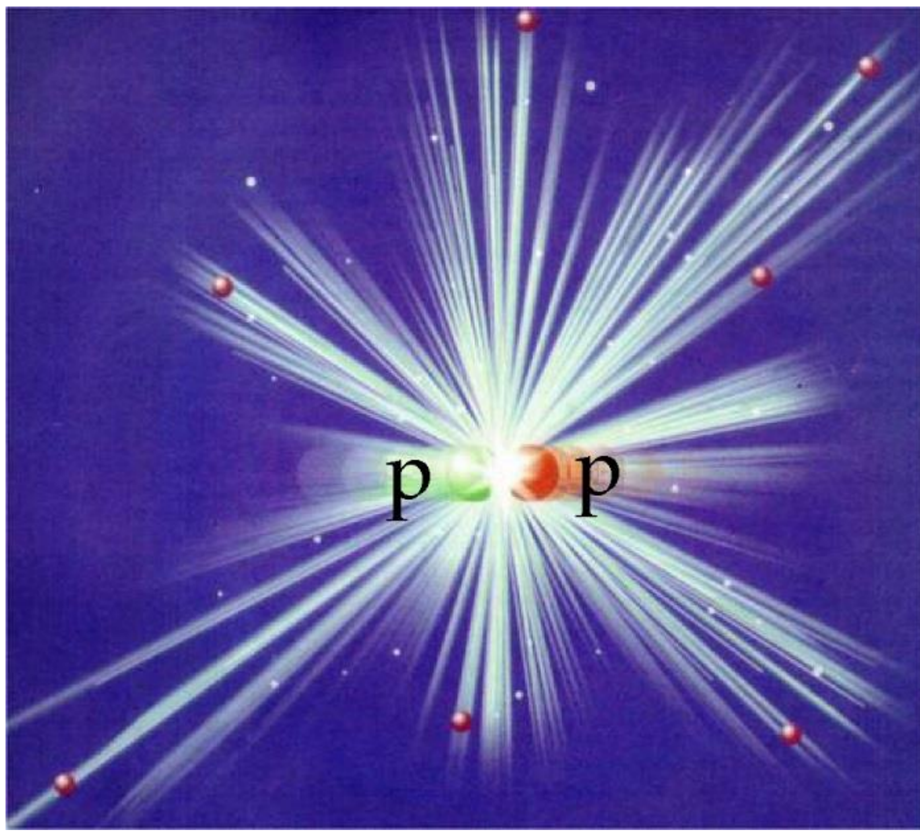
Particle physics looks at matter in its smallest dimensions and accelerators are very fine microscopes or, better, *atto-scopes!*

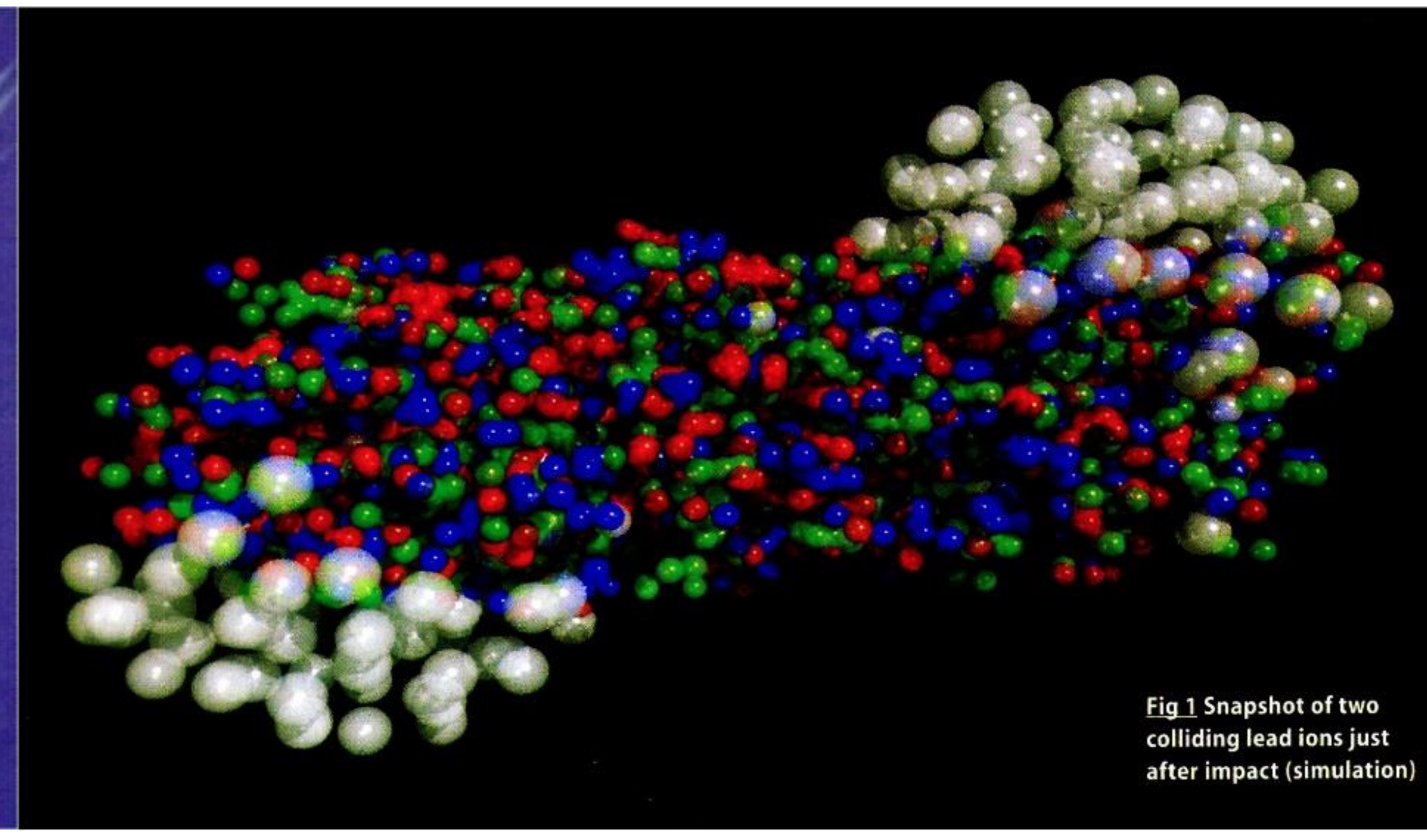
$\lambda = h/p$; @LHC: $T = 1$ TeV $\Rightarrow \lambda \cong 10^{-18}$ m

CERN AC - Z11 - V11/5/98

Accelerators also bring us toward the Big Bang

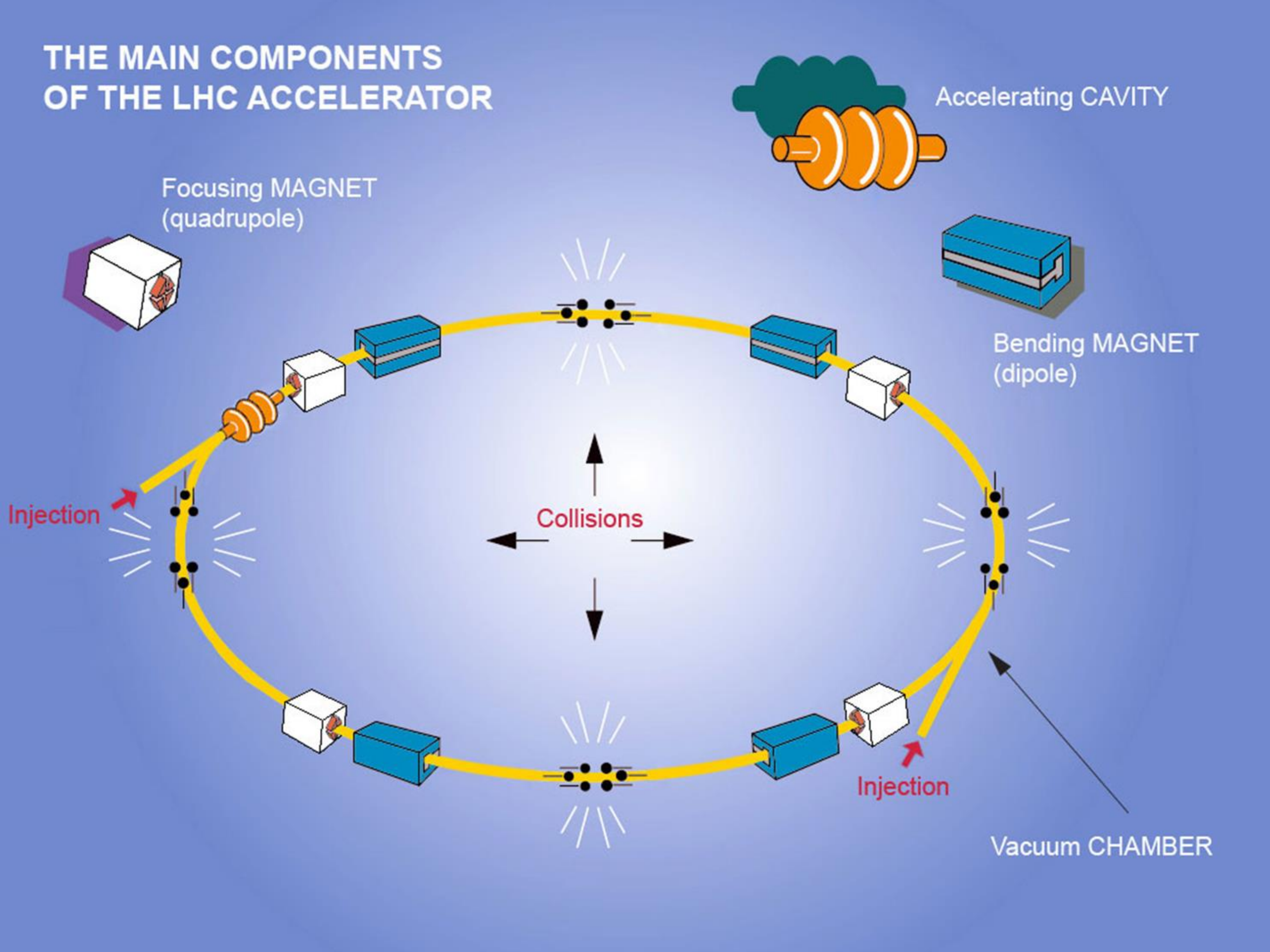
- Trip back toward the Big Bang: $t_{\mu s} \cong 1/E^2_{Gev}$
- $T \cong 1$ ps for single particle creation
- $T \cong 1$ μs for collective phenomena QGS (Quark-Gluon Soup)



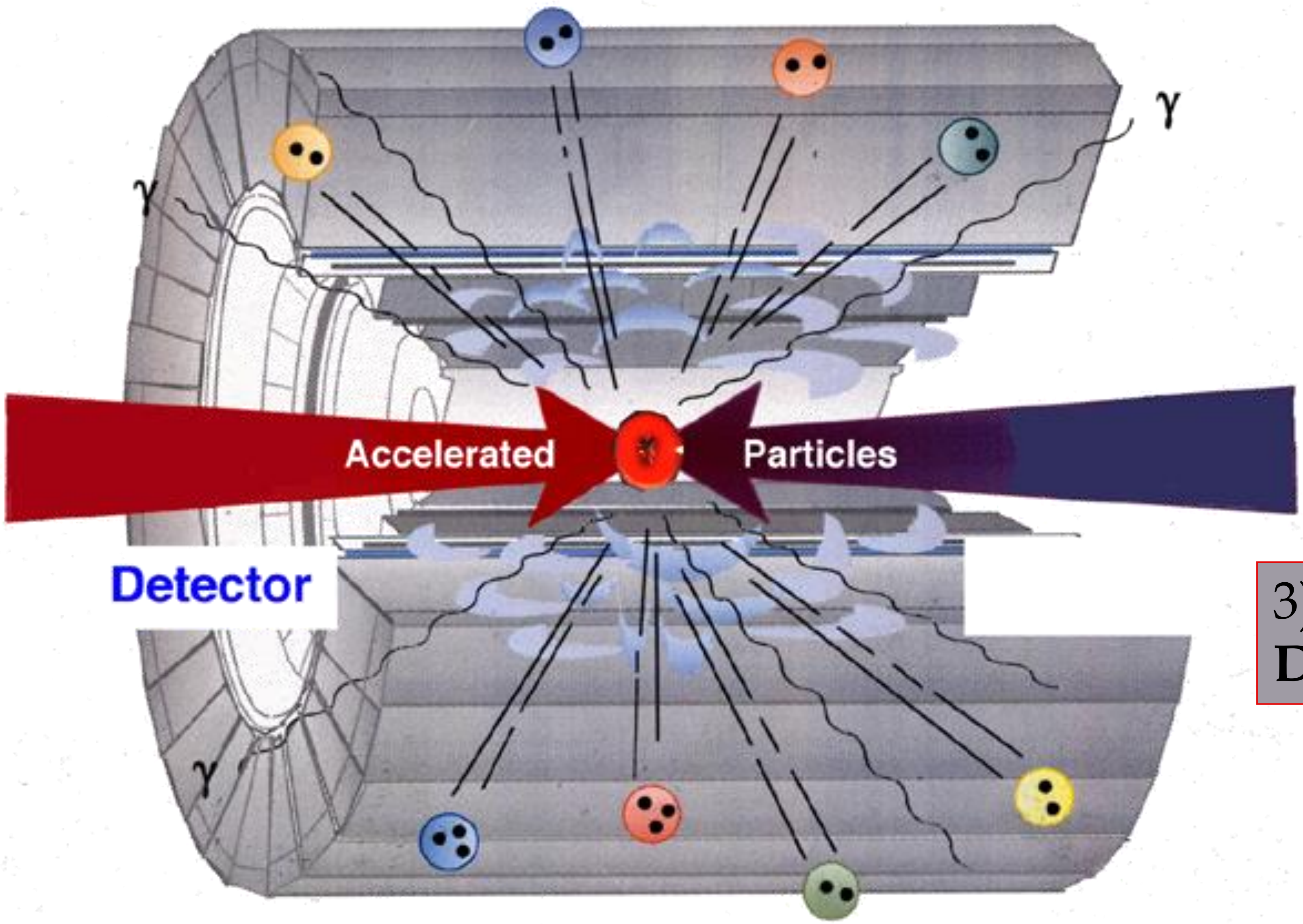


But we are left with the task of explaining how the rich complexity that developed in the ensuing 13.7 billion years came about…

Which is a much more complex task!


THE MAIN COMPONENTS
OF THE LHC ACCELERATOR
Accelerating CAVITY
Focusing MAGNET
(quadrupole)
Bending MAGNET
(dipole)
Injection
Collisions
Injection
Vacuum CHAMBER

Method of Particle Physics with Colliders

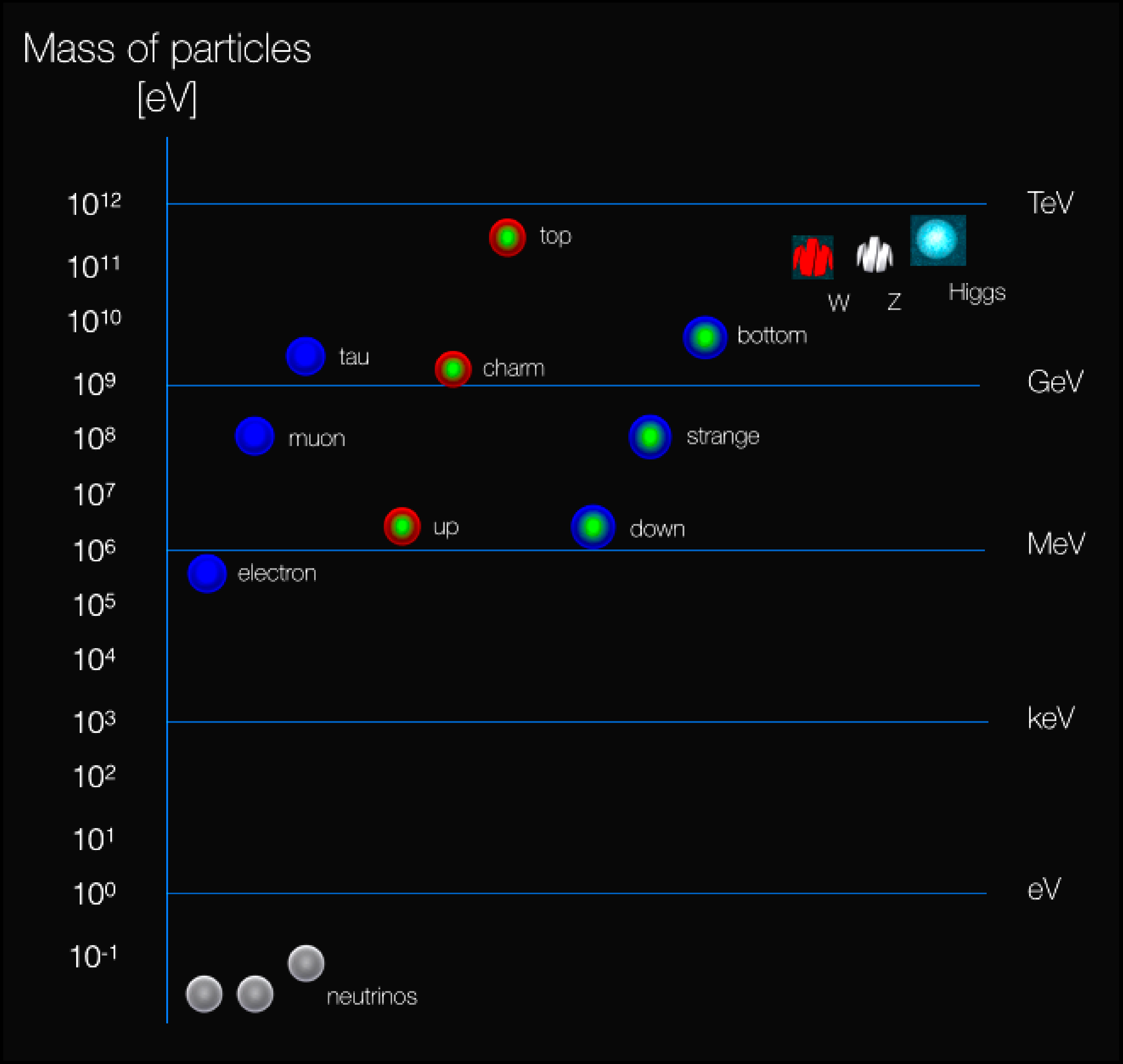


1) Concentrate energy on particles (**accelerator**)

2) **Collide** particles (recreate conditions after Big Bang)

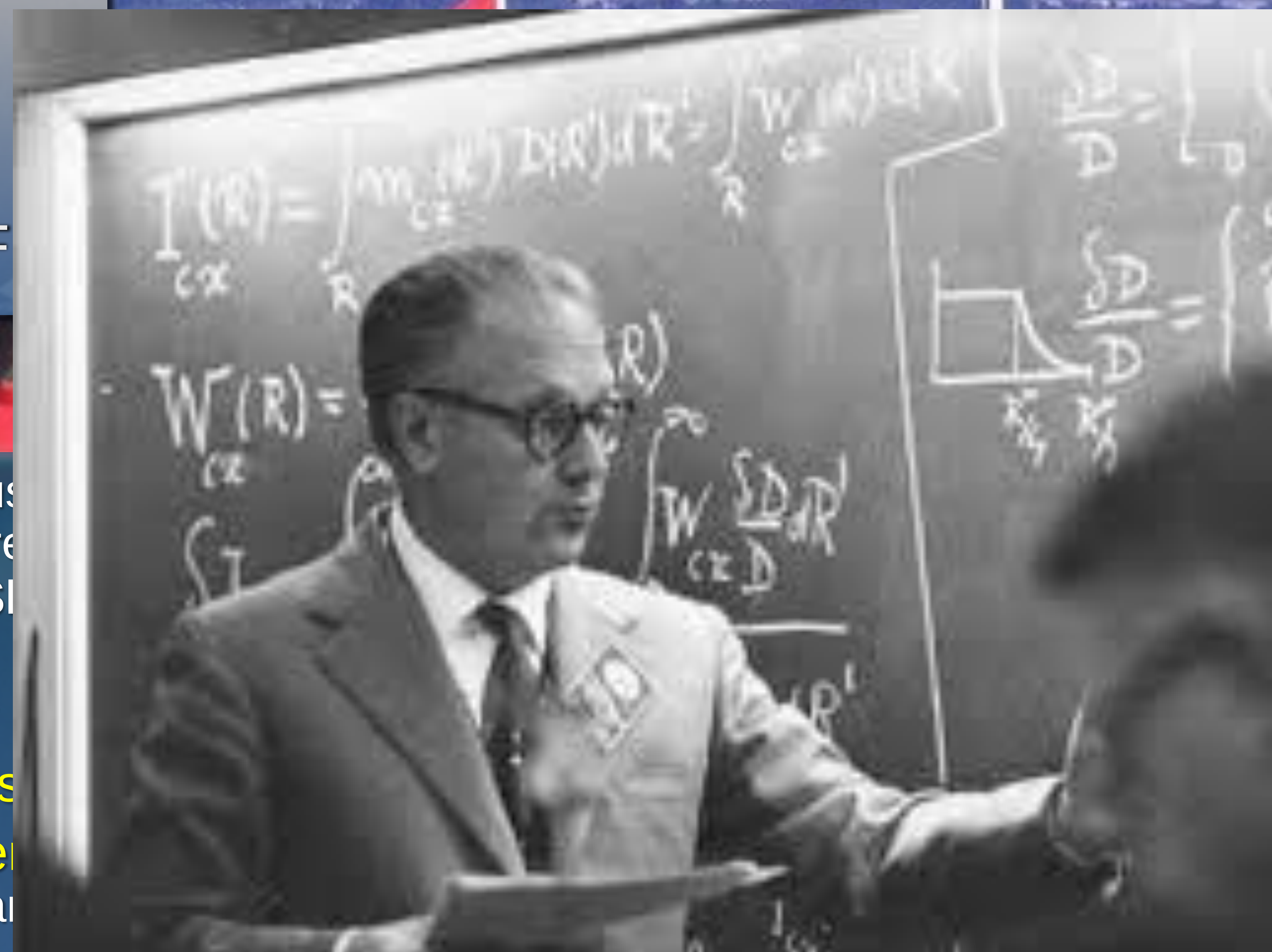
3) Identify created particles in **Detector** (search for new clues)

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



CERN: founded in 1954: 12 European States
"Science for Peace"
Today: 22 Member States

~ 2500 staff
~ 1800 other paid personnel
~ 13000 scientific users
Budget (2017) ~ 1100 MCHF



Member States: Aus
France, Germany, Gre
Portugal, Romania, Sl
United Kingdom

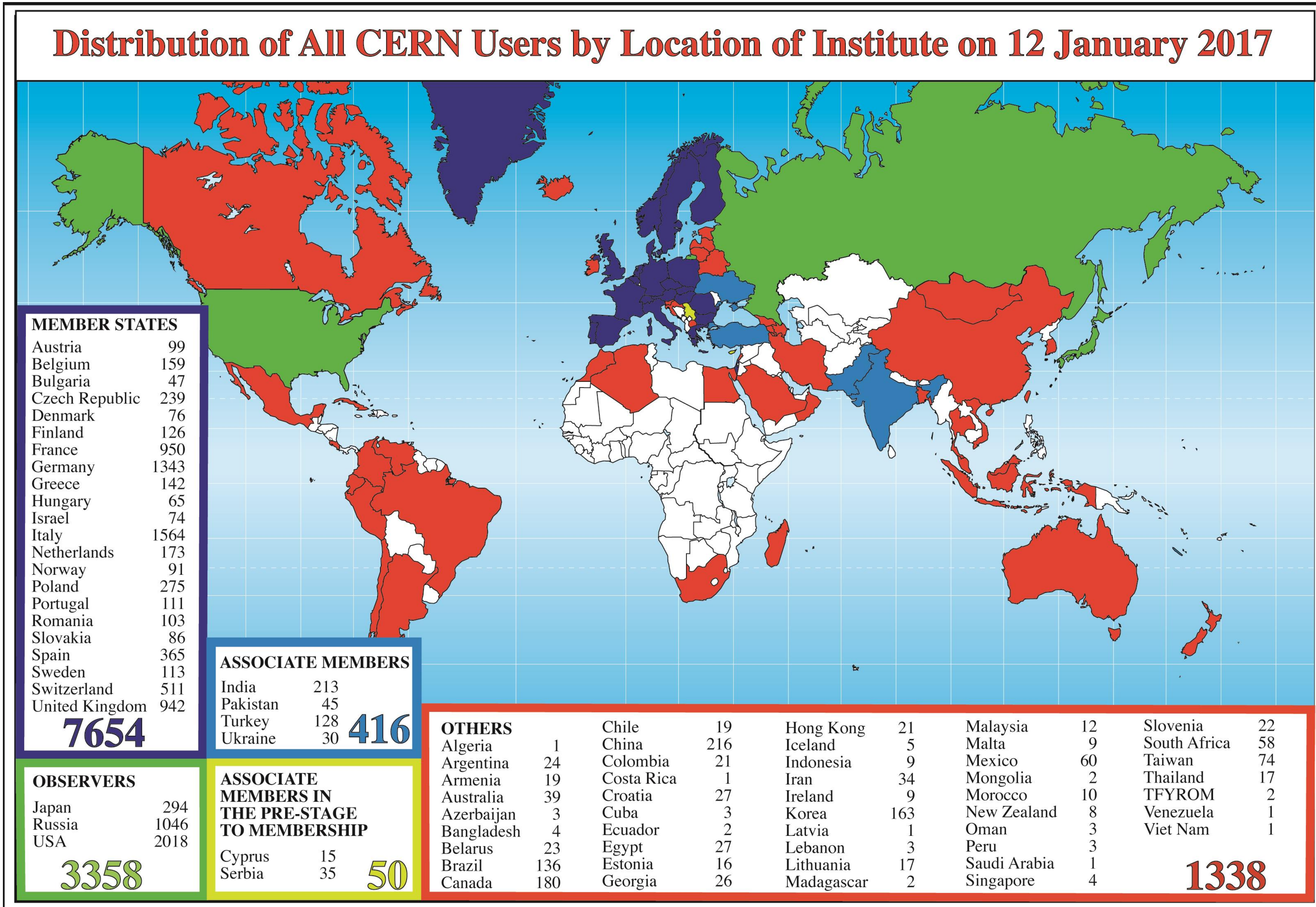
Associate Member

Associate Members

Applications for Me
Brazil, Croatia, Lithua

Observers to Council: Japan, Russia, United States of America;
European Union, JINR and UNESCO

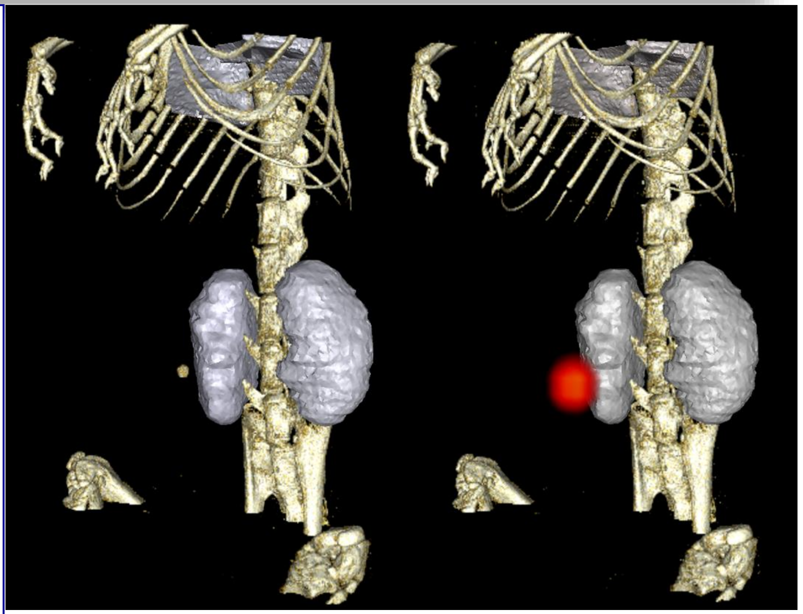
Science is getting more and more global

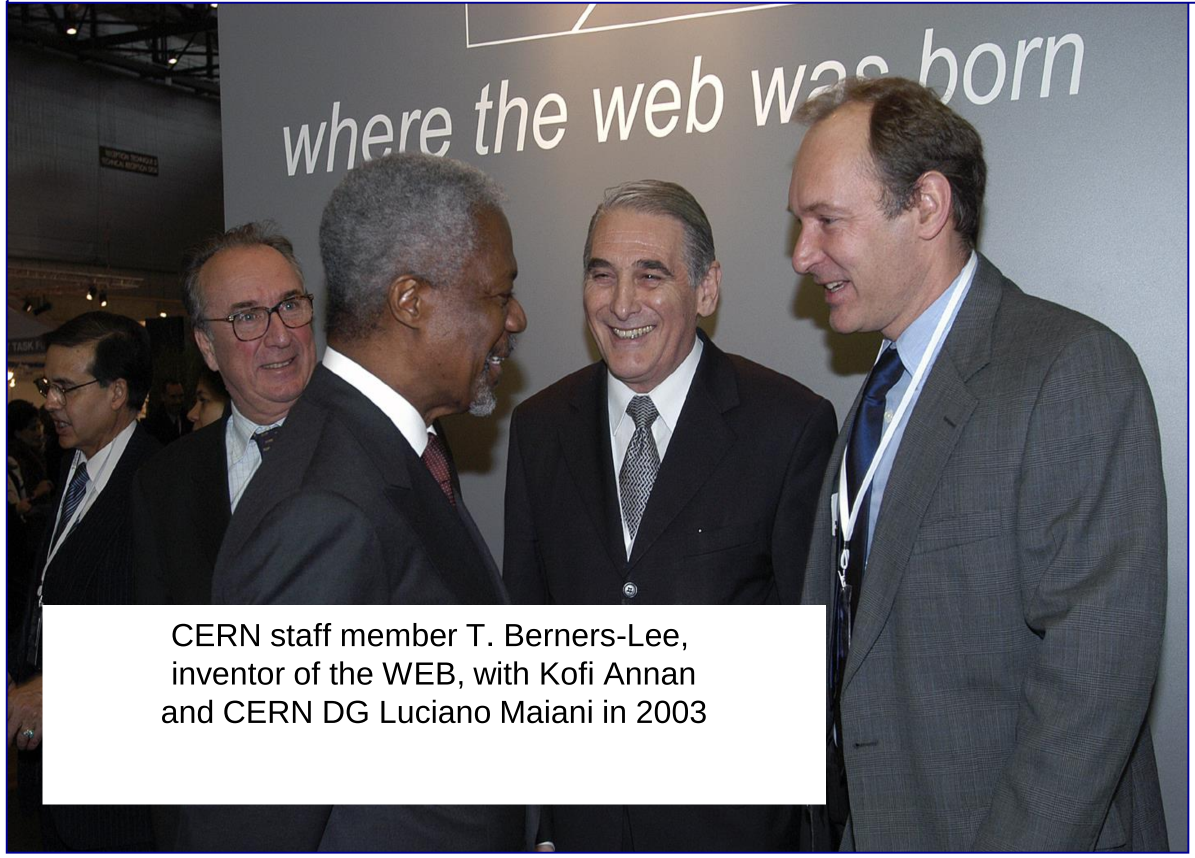


Intergovernmental Organization based in Geneva

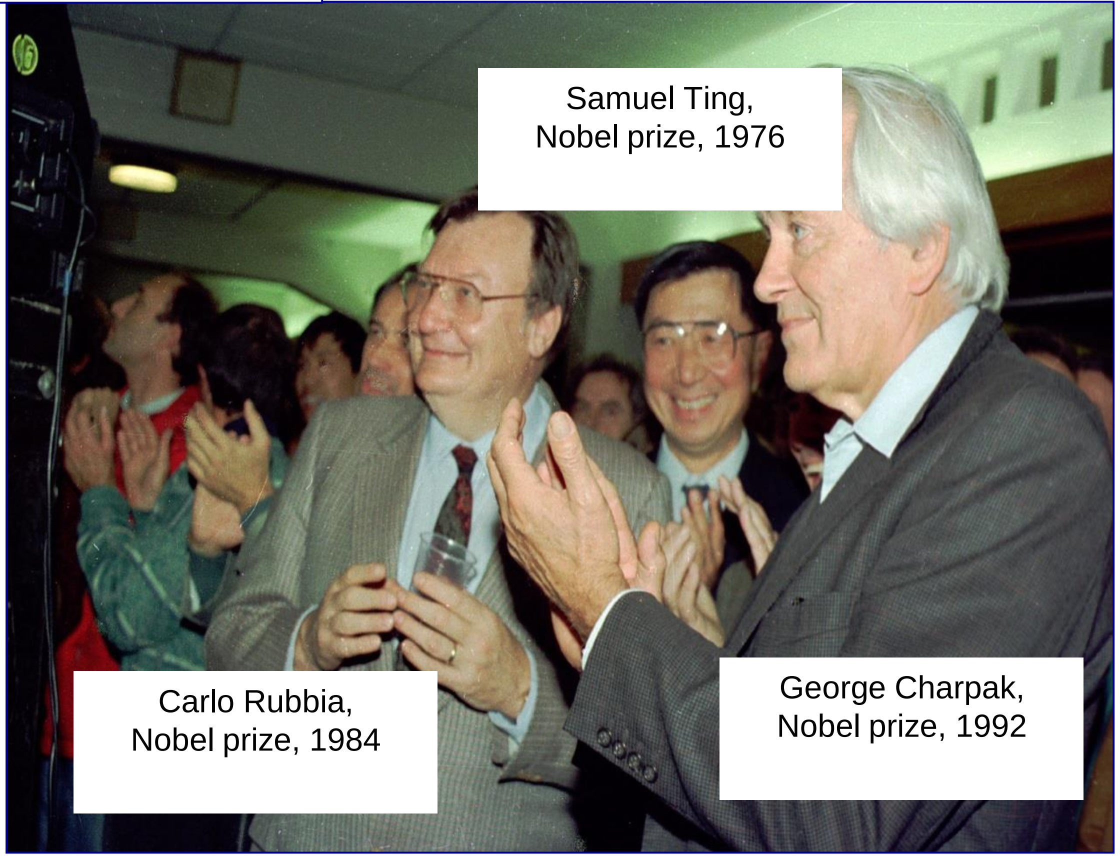
Mission:

- science: fundamental research in particle physics (many discoveries, e.g. Higgs boson)
- technology and innovation → transferred to society (e.g. the World Wide Web, medical applications)
- training and education
- bringing the world together: ~ 17000 scientists, > 110 nationalities





CERN staff member T. Berners-Lee, inventor of the WEB, with Kofi Annan and CERN DG Luciano Maiani in 2003



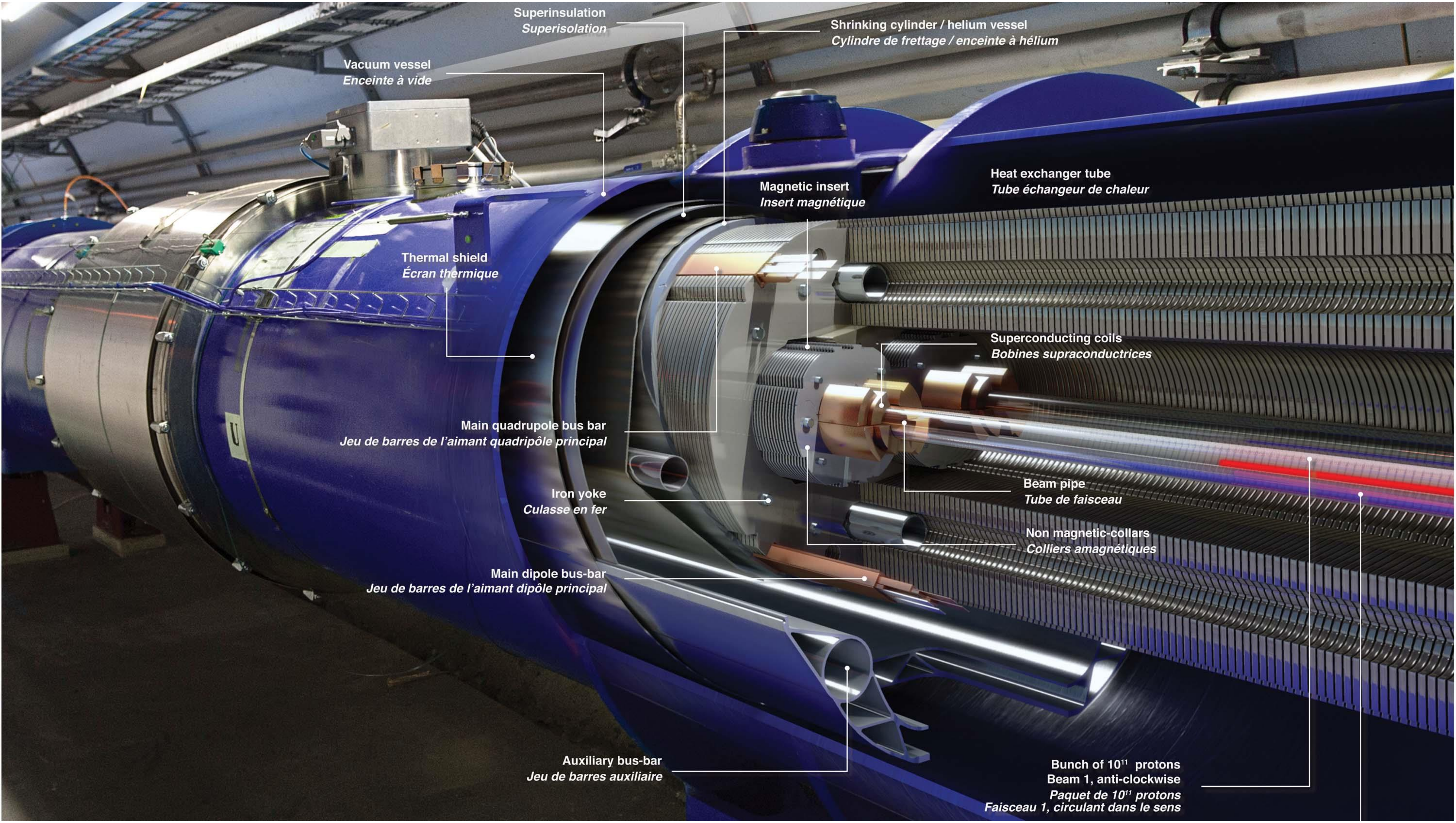
Samuel Ting, Nobel prize, 1976

Carlo Rubbia, Nobel prize, 1984

George Charpak, Nobel prize, 1992

CERN and LHC

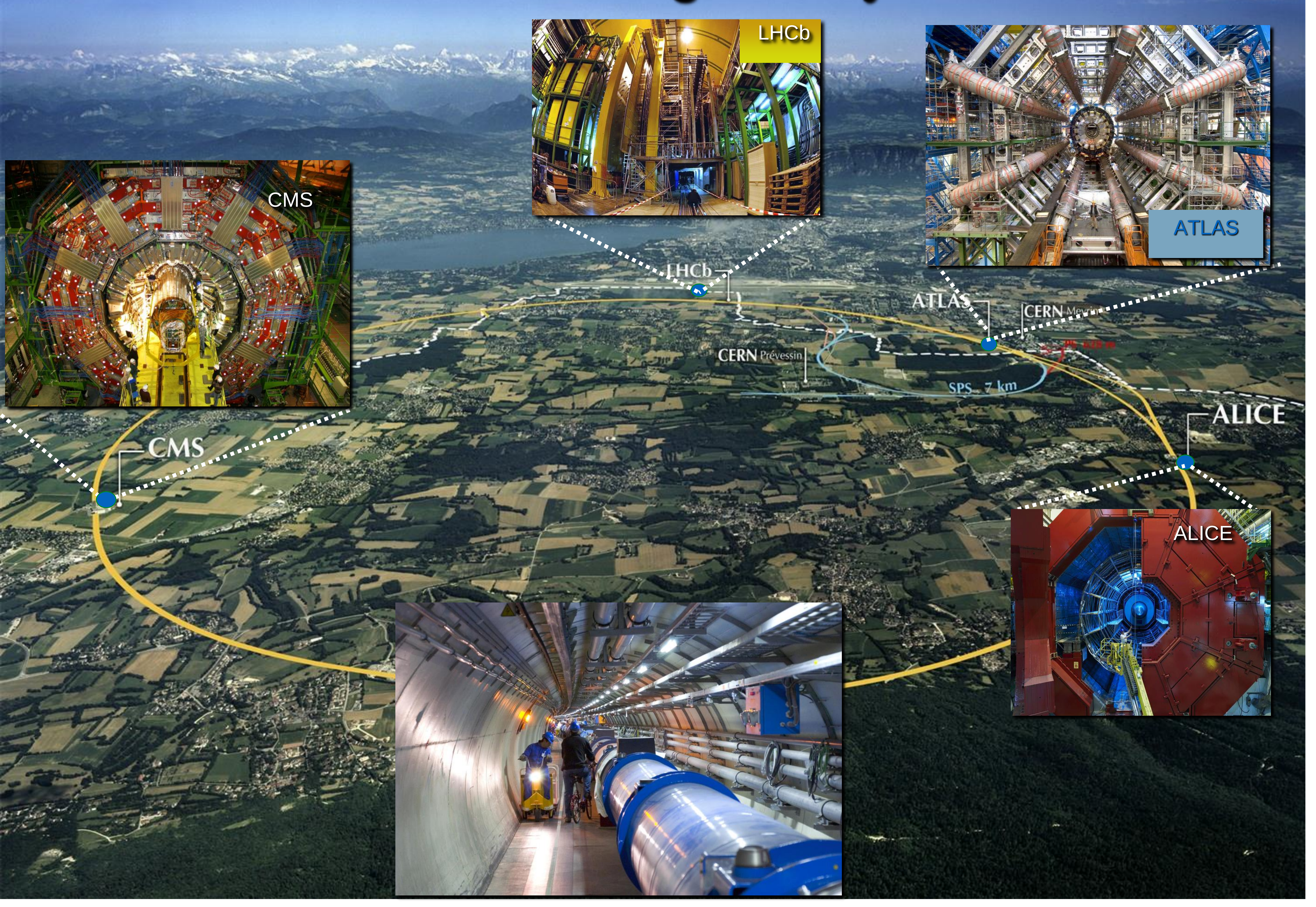
Large Hadron Collider (LHC) - a very complex machinery



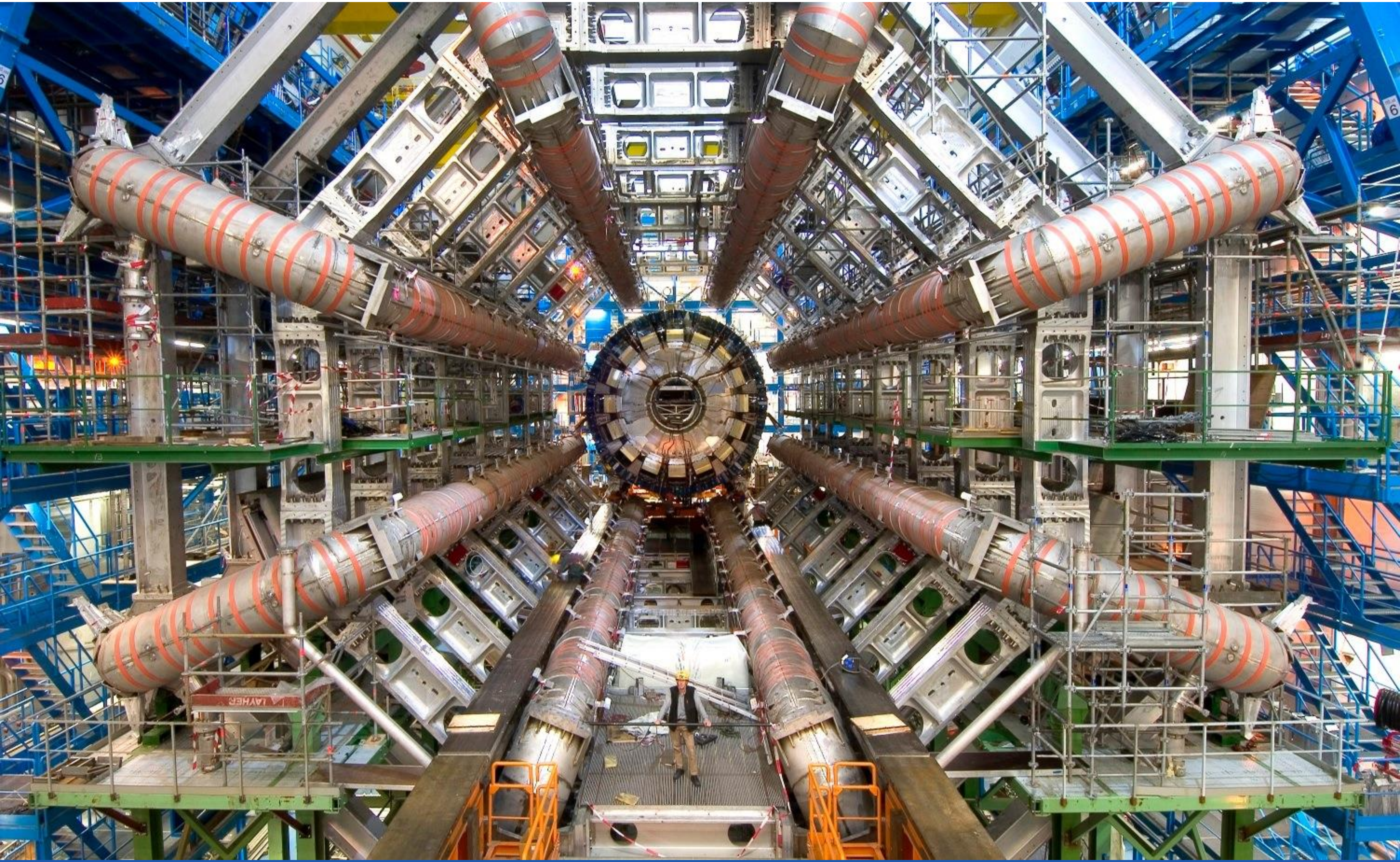
More than 20 years to develop and build the LHC dipole magnets

Beyond Pluto - 10 billion km ride through CERN

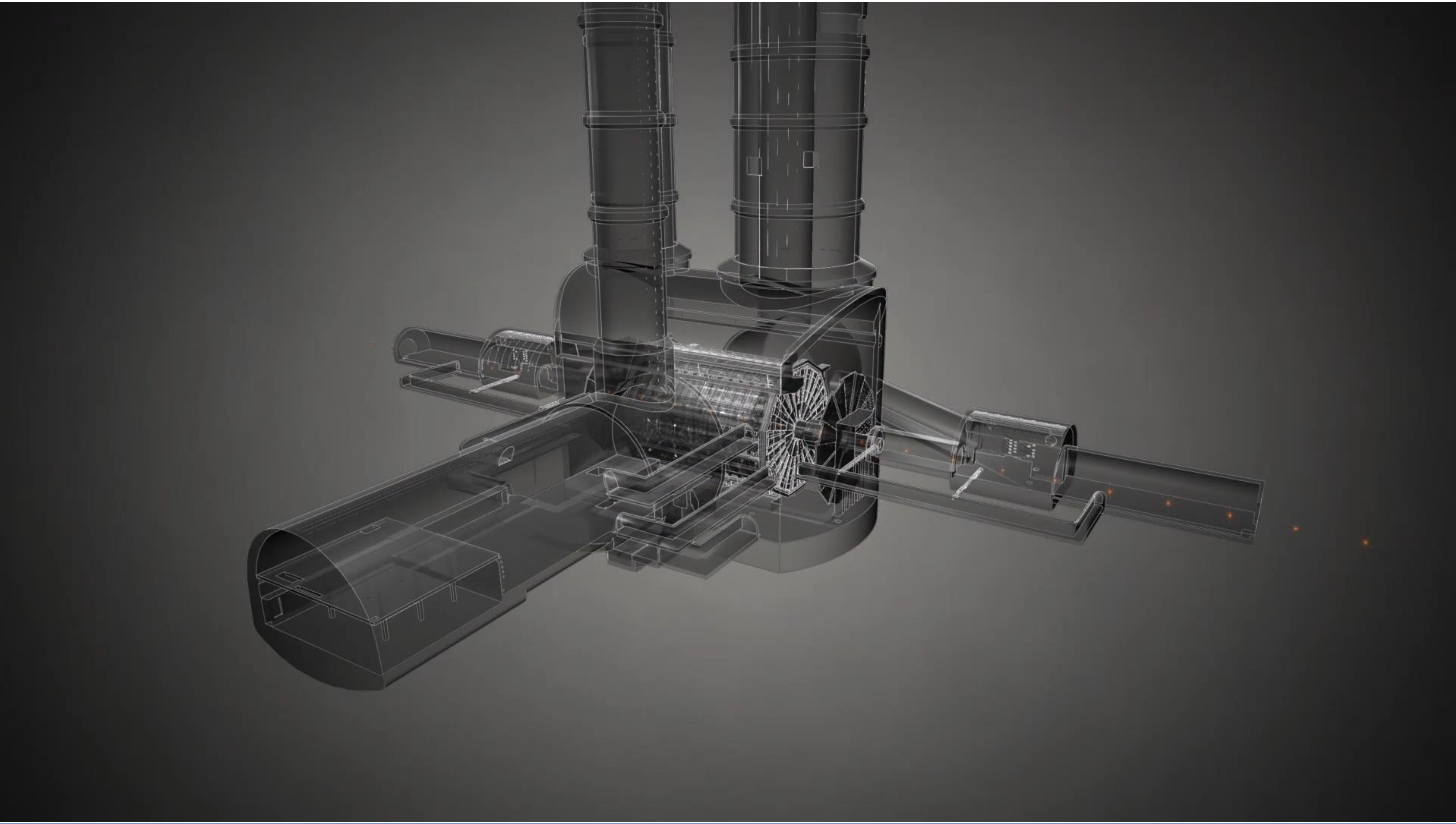
LHC and its big four eyes

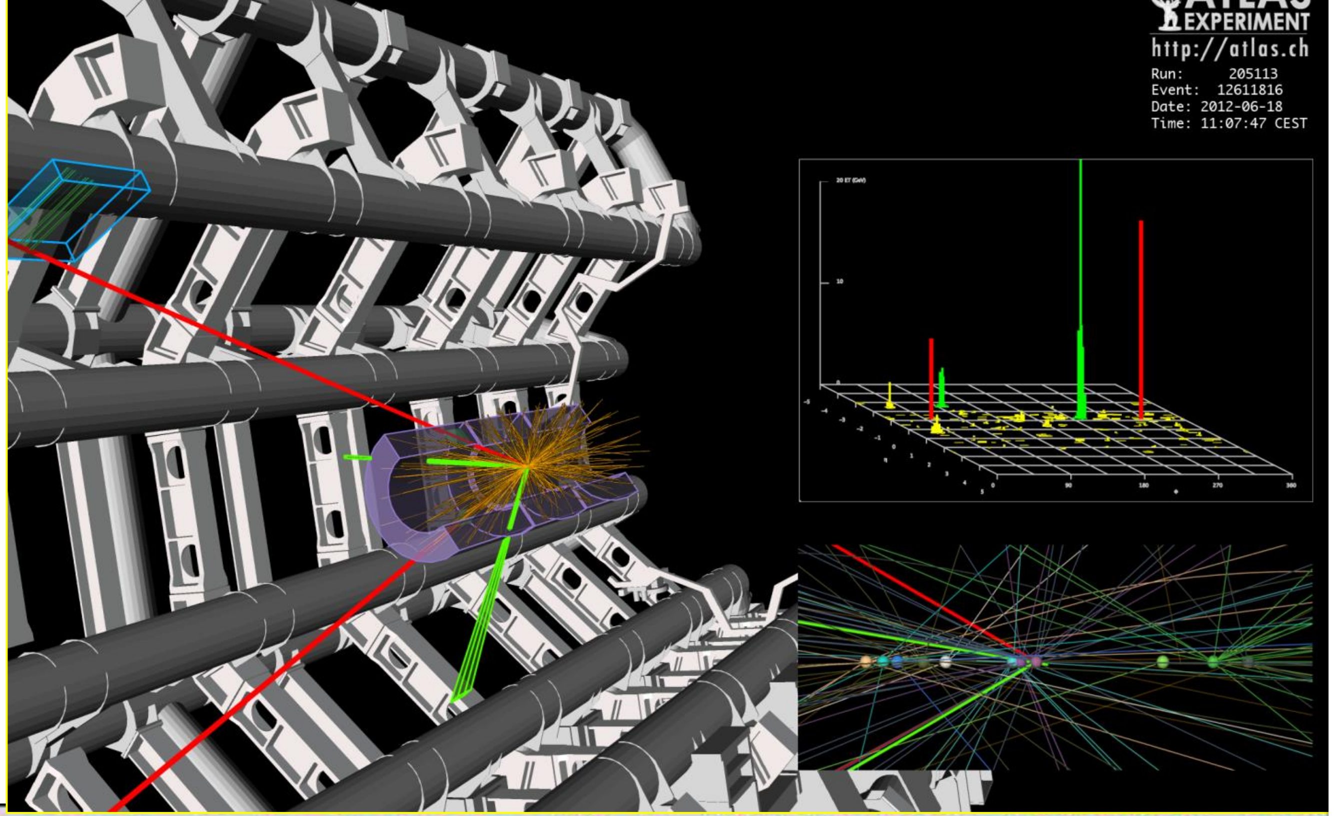


LHC experiments - huge detectors (e.g. ATLAS)



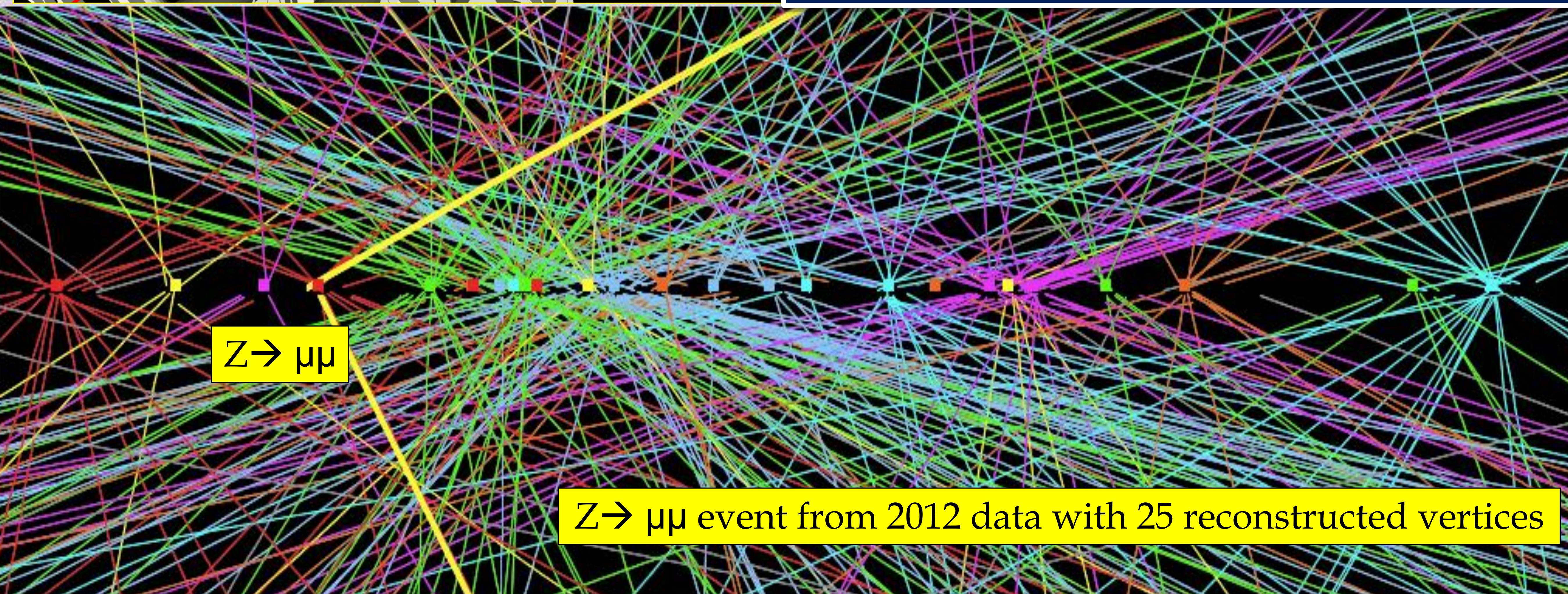
1 billion collisions per second

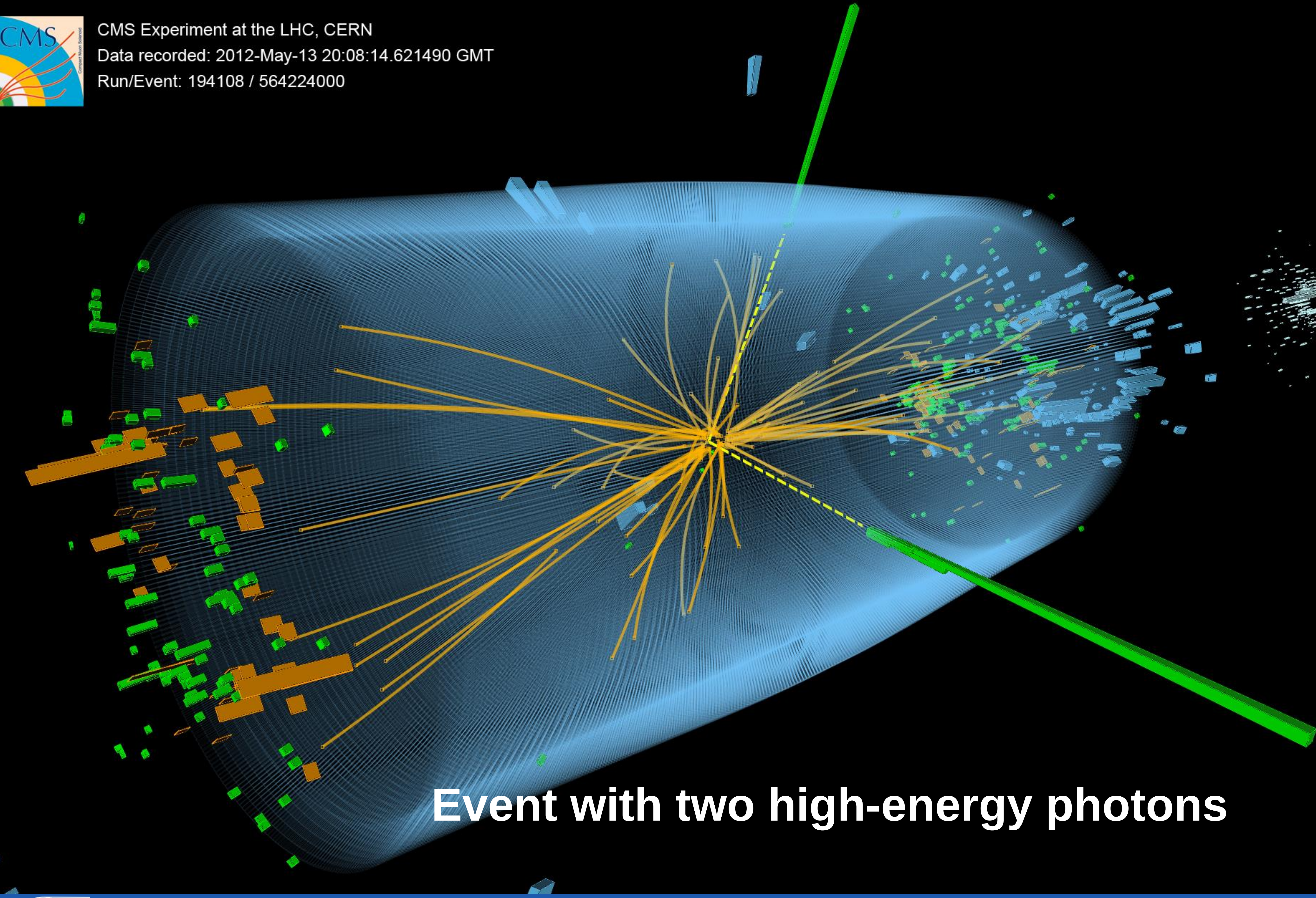




Beams collides 40 MHz
25-40 Pile up
⇒1-2 Billions collisions/s!
Only 1/10 Bil we “can see” a Higgs boson!

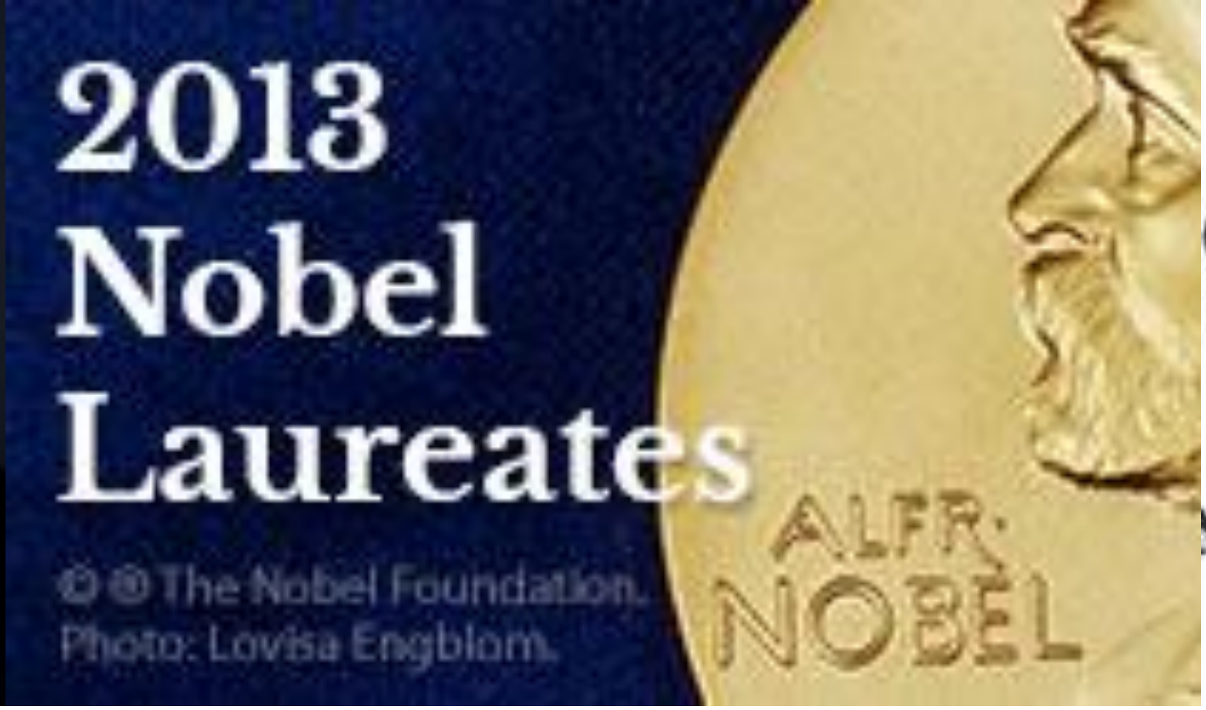
It si really searching for the needle in a haystack!





Event with two high-energy photons





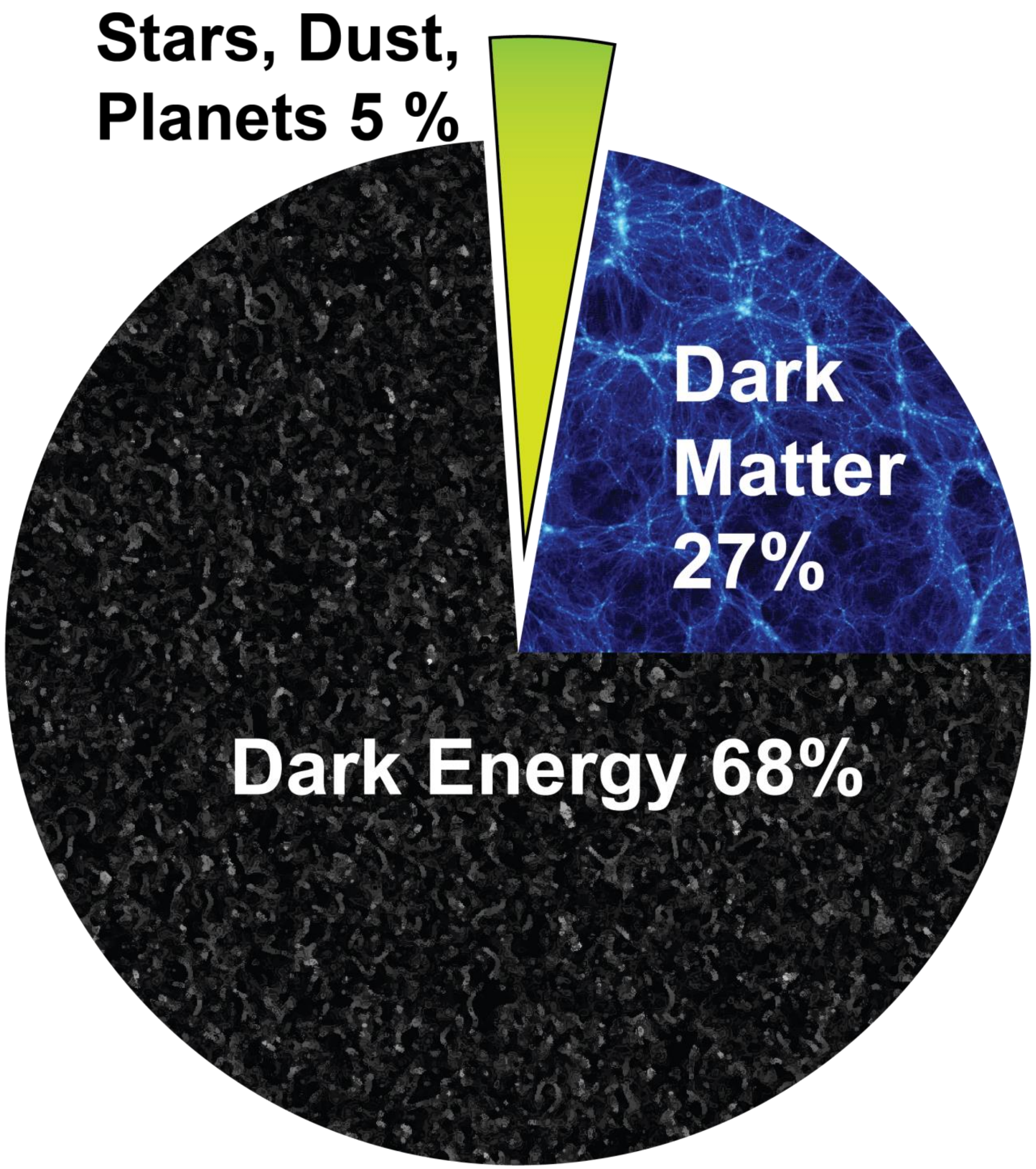
…for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider

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

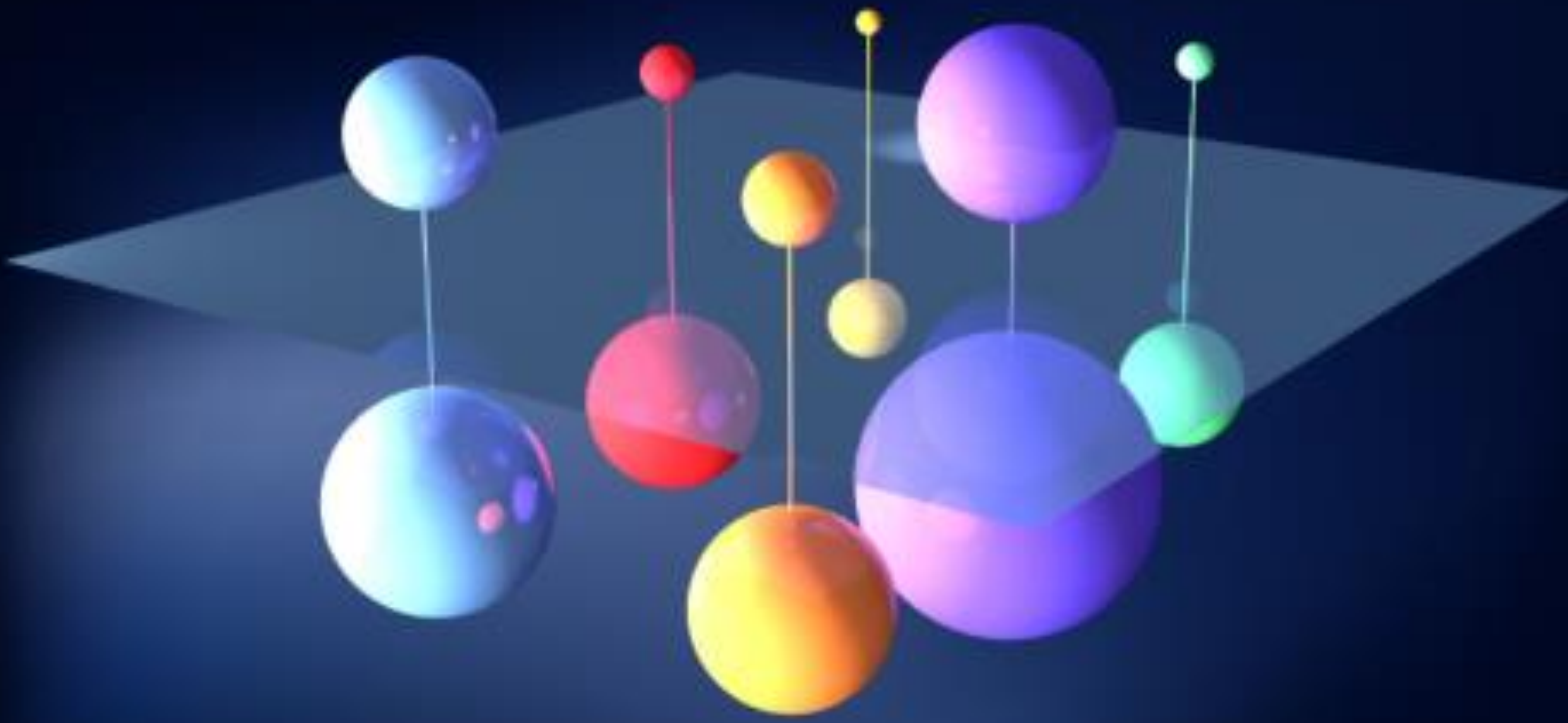
Cosmic Microwave Background

Dark energy ...?

The expansion of the Universe accelerates ...

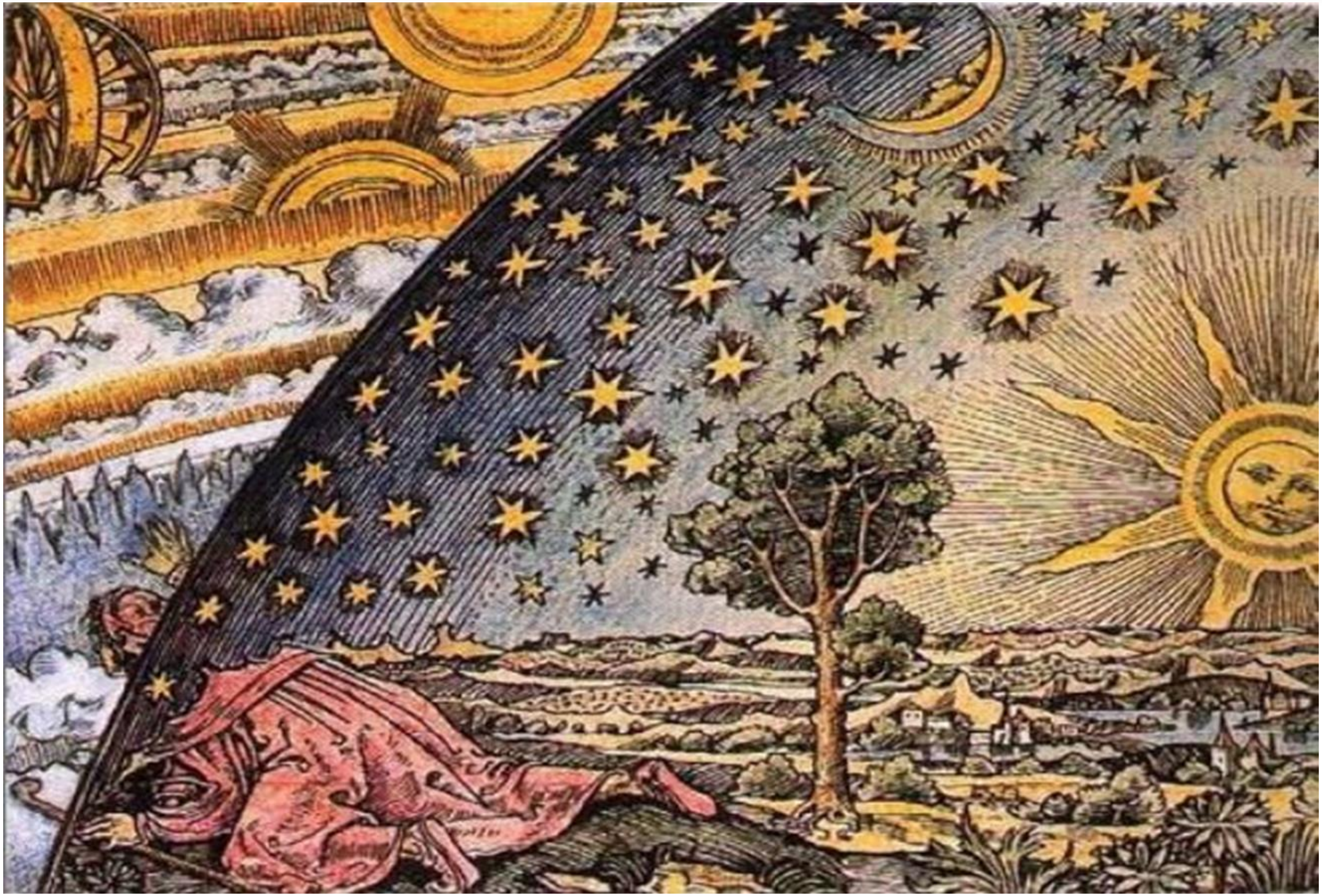
SUPERSYMMERTRY:

A Superworld ahead of us?

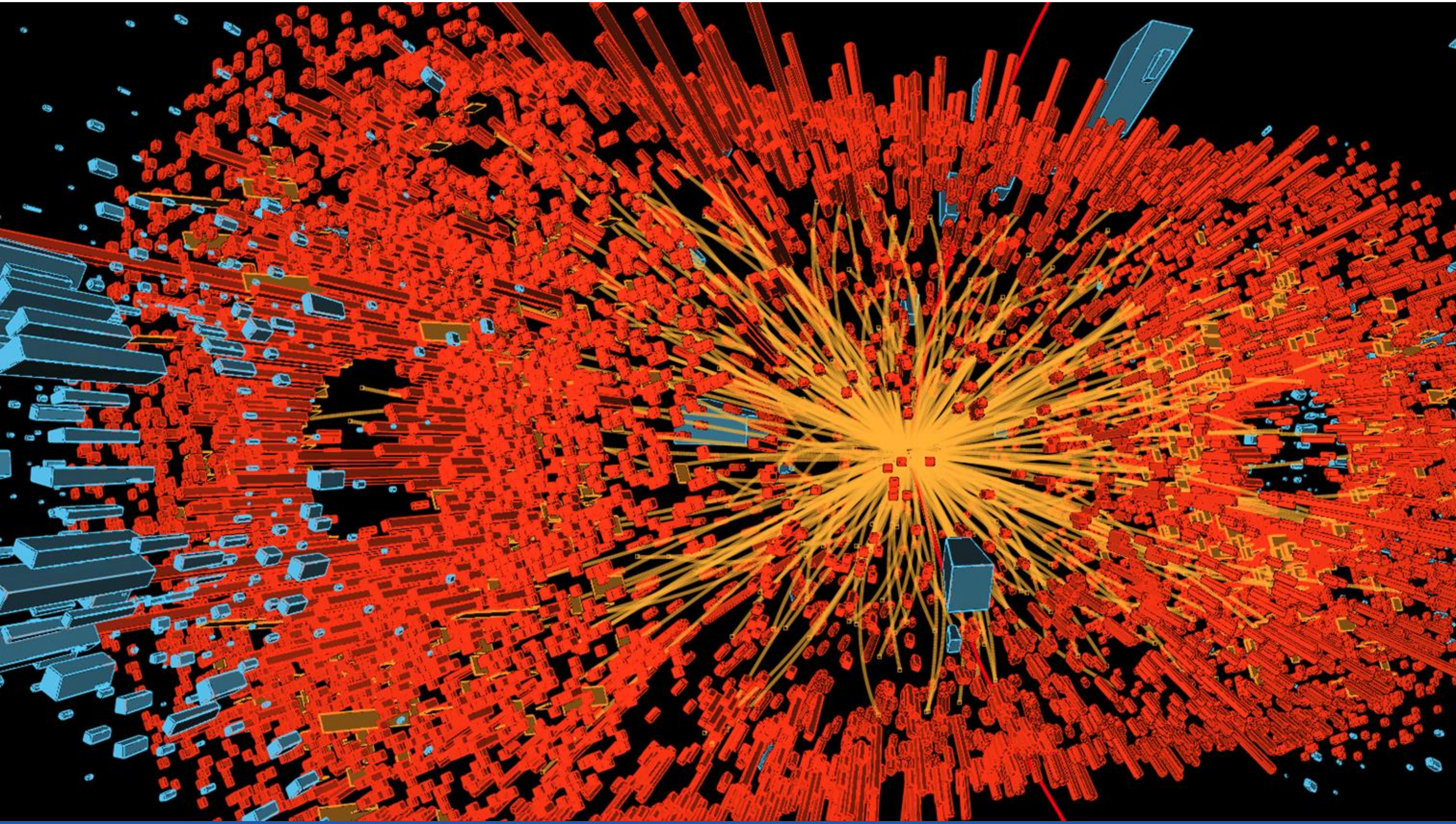


Sheding light on Dark Matter?

Standard Model is our cage: need to go beyond!

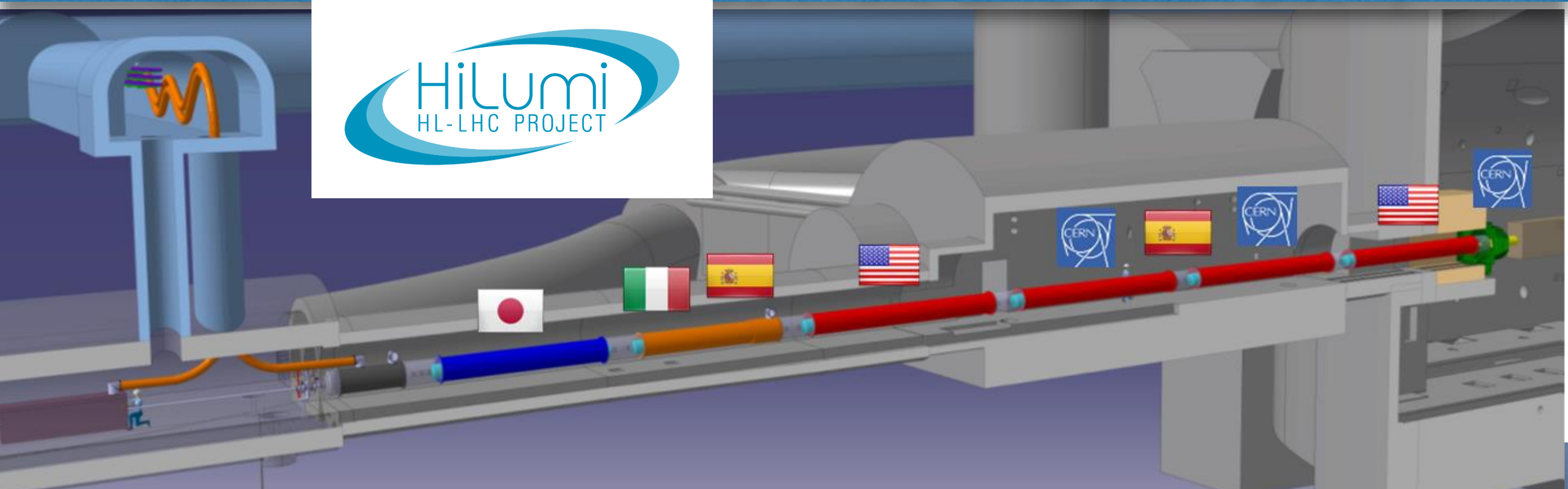


More light (luminosity) to see better!

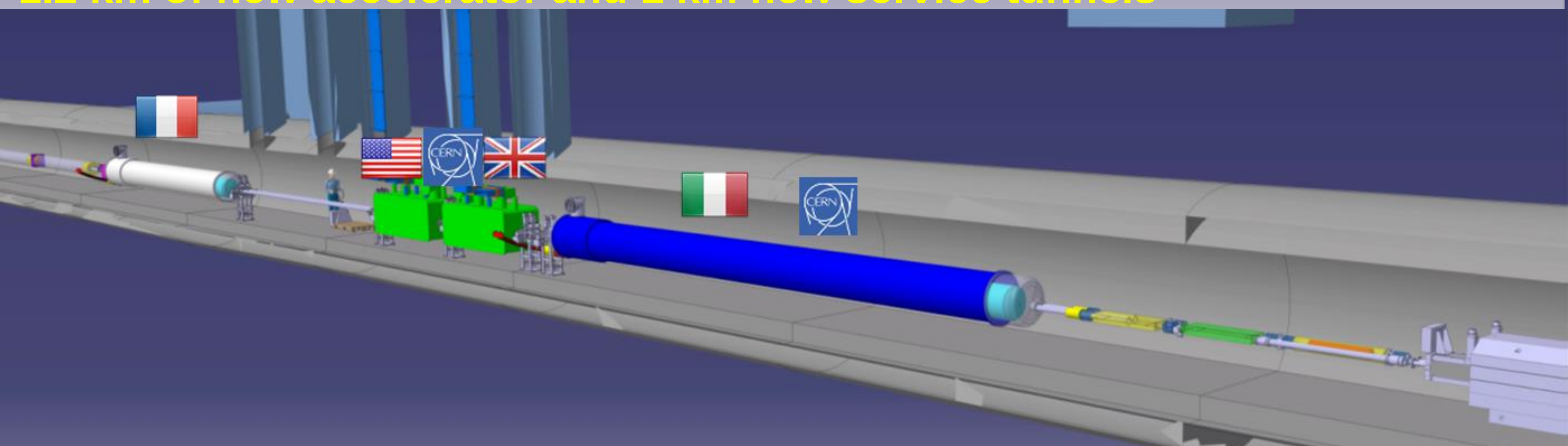


High Luminosity LHC Project: ten time more collisions than originally planned in the LHC (start 2026)

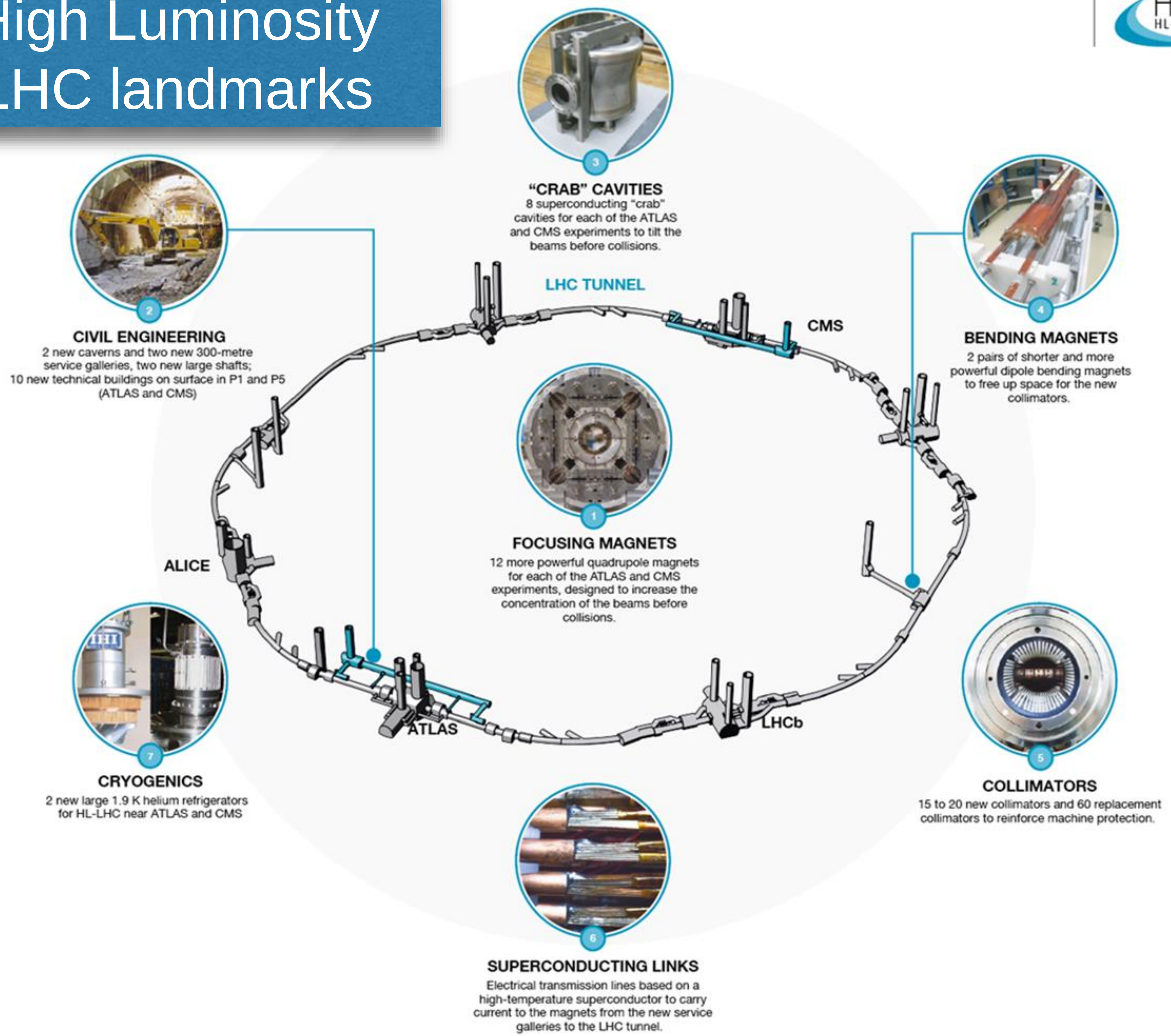
HiLumi
HL-LHC PROJECT



HL-LHC new equipment + service in the new galleries
1.2 km of new accelerator and 1 km new service tunnels



High Luminosity LHC landmarks



HiLumi HL-LHC PROJECT

CERN May 2016

2016 Full approval of HL-LHC by Council
2016 HL-LHC new ESFRI landmark (right)

The High-Luminosity LHC Project

Abstract

The scientific case for a luminosity upgrade of the Large Hadron Collider (High-Luminosity LHC, HL-LHC) is presented. It includes measurements of the Higgs boson properties with unprecedented precision and increased potential in the search for new physics. Construction is expected to be completed by the mid-twenties, and by the mid-thirties the HL-LHC should have provided a tenfold increase in the integrated luminosities recorded by the experiments. Main upgrade components include new-technology supercoducting magnets and current leads. The cost of the collider upgrade, which will be realised within a constant CERN Budget, is estimated to be 950 MCHF. The main technical challenges, as well as the ongoing R&D work and the main milestones of the implementation plan, are described.

ESFRI ROADMAP 2016

PART 1 PART 2 PART 3 ANNEXES

ESFRI LANDMARKS

PHYSICAL SCIENCES & ENGINEERING

An upgrade of the highest-energy particle collider in the world for exploring new physics

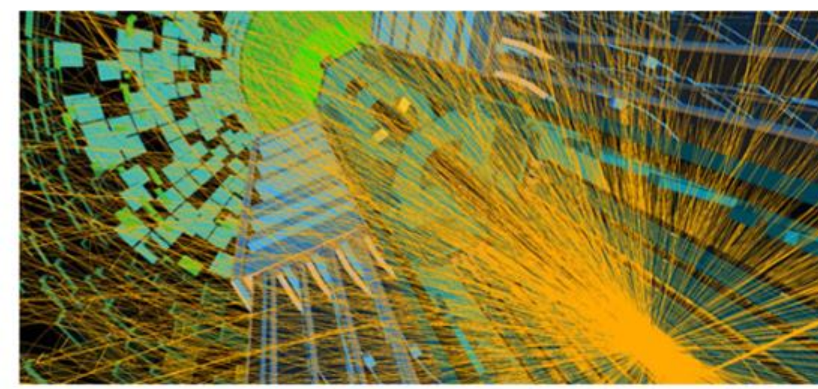
HL-LHC

High-Luminosity Large Hadron Collider

TYPE: single-sited
COORDINATING ENTITY: CERN
MEMBER COUNTRIES: AT, BE, BG, CH, CZ, DE, DK, EL, ES, FI, FR, HU, IL, IT, NL, NO, PK, PL, PT, RO, RS, SE, SK, TR, UK

PARTICIPANTS: See
ACCELERATOR COLLABORATION
ATLAS COLLABORATION
CMS COLLABORATION

TIMELINE
- ESFRI Roadmap entry: 2016
- Preparation phase: 2014-2017
- Construction phase: 2017-2025

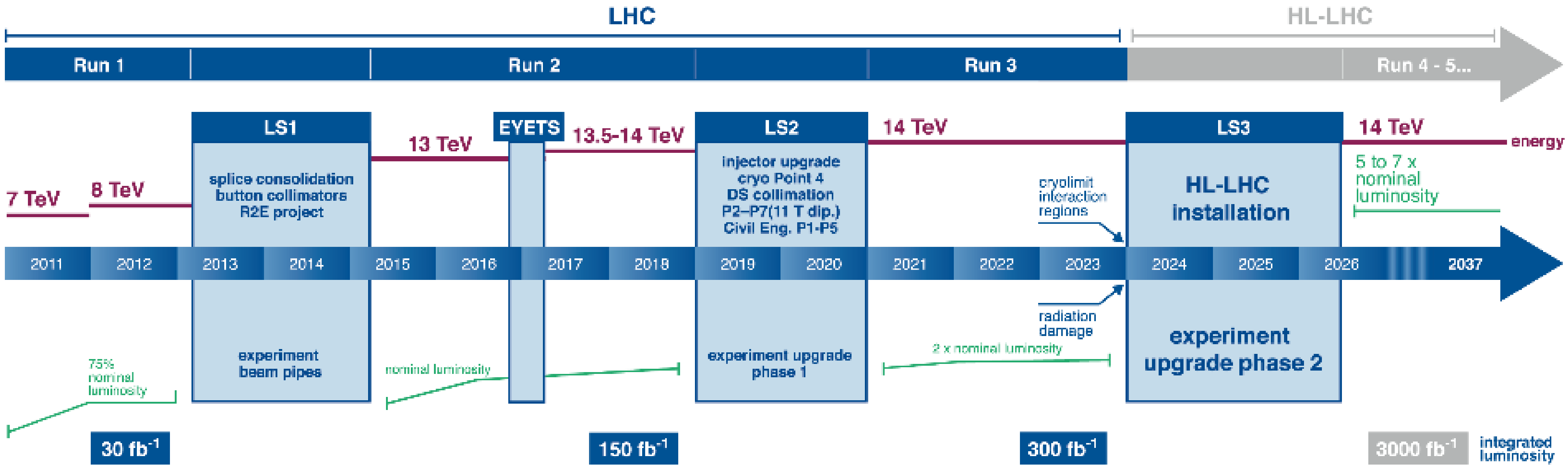


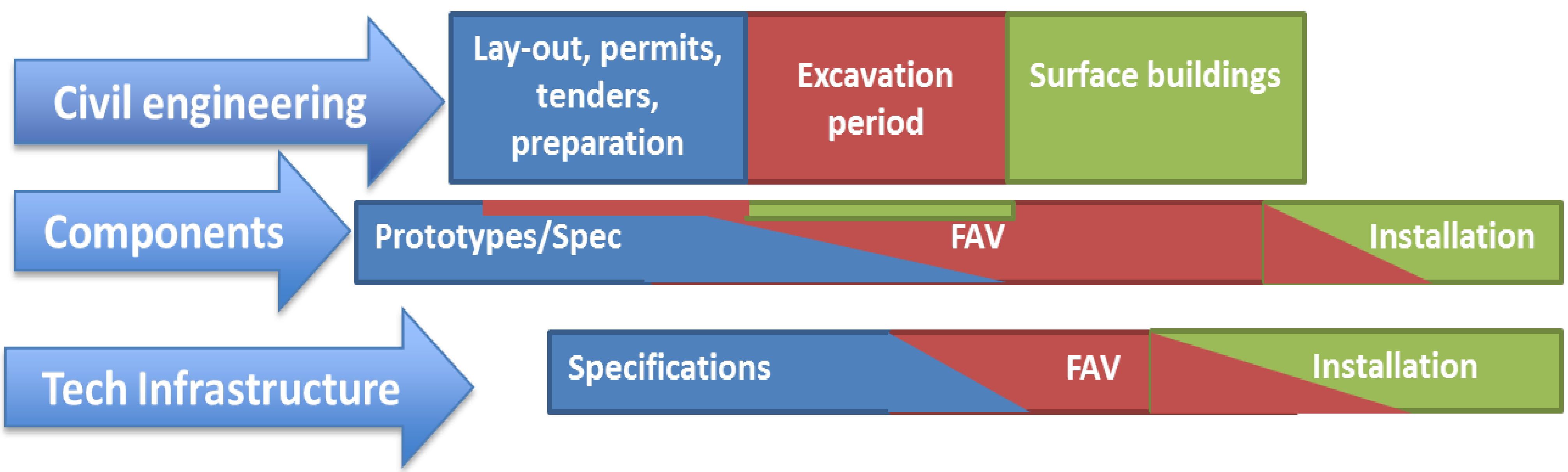
Description

The Large Hadron Collider (LHC) at CERN is the highest-energy particle collider in the world. The ATLAS and CMS experiments at the LHC have provided the breakthrough discovery of the so-called Higgs boson. This discovery is the start of a

The 29 ESFRI Landmarks which have now reached the implementation phase are pan-European hubs of scientific excellence, generating new ideas and pushing the boundaries of science and technology. They are important pillars of European research and innovation for the next decades and they will require continuous support to fulfil their mission and ensure their long-term sustainability.

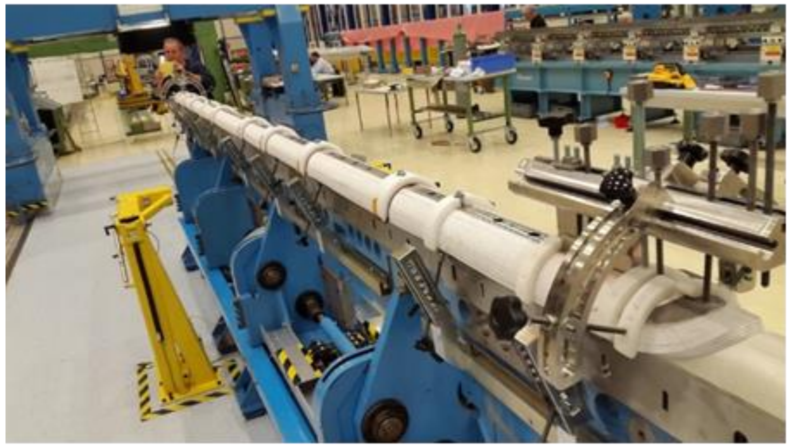
LHC / HL-LHC Plan

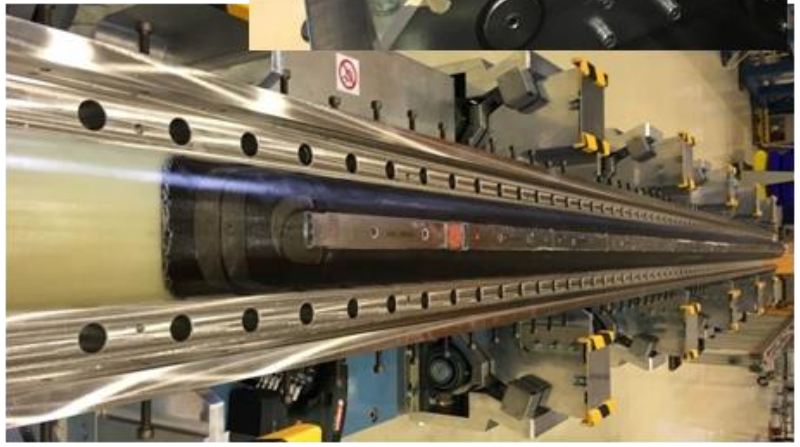




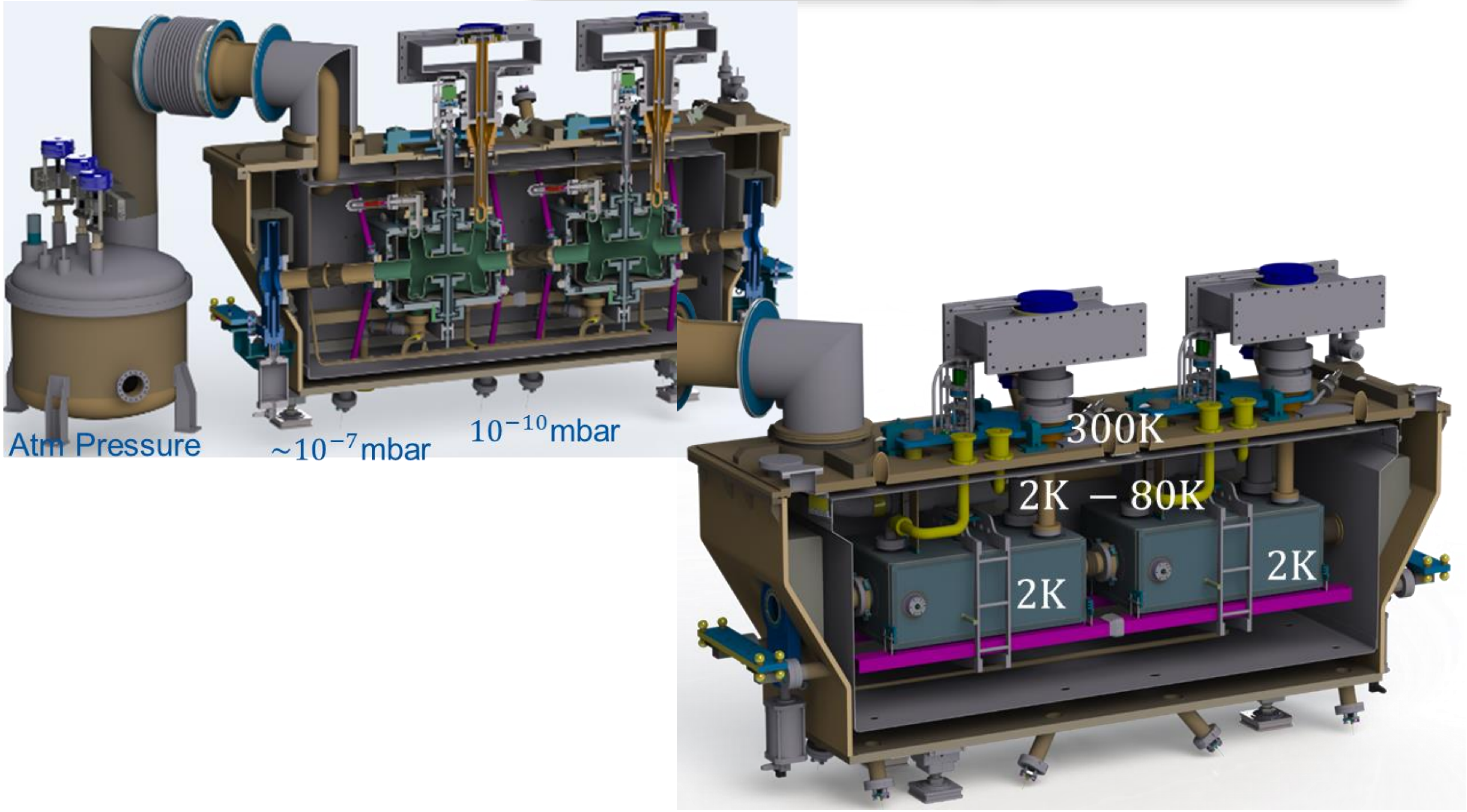
Advanced Technology: Nb_3Sn Supercondcuting Magnets



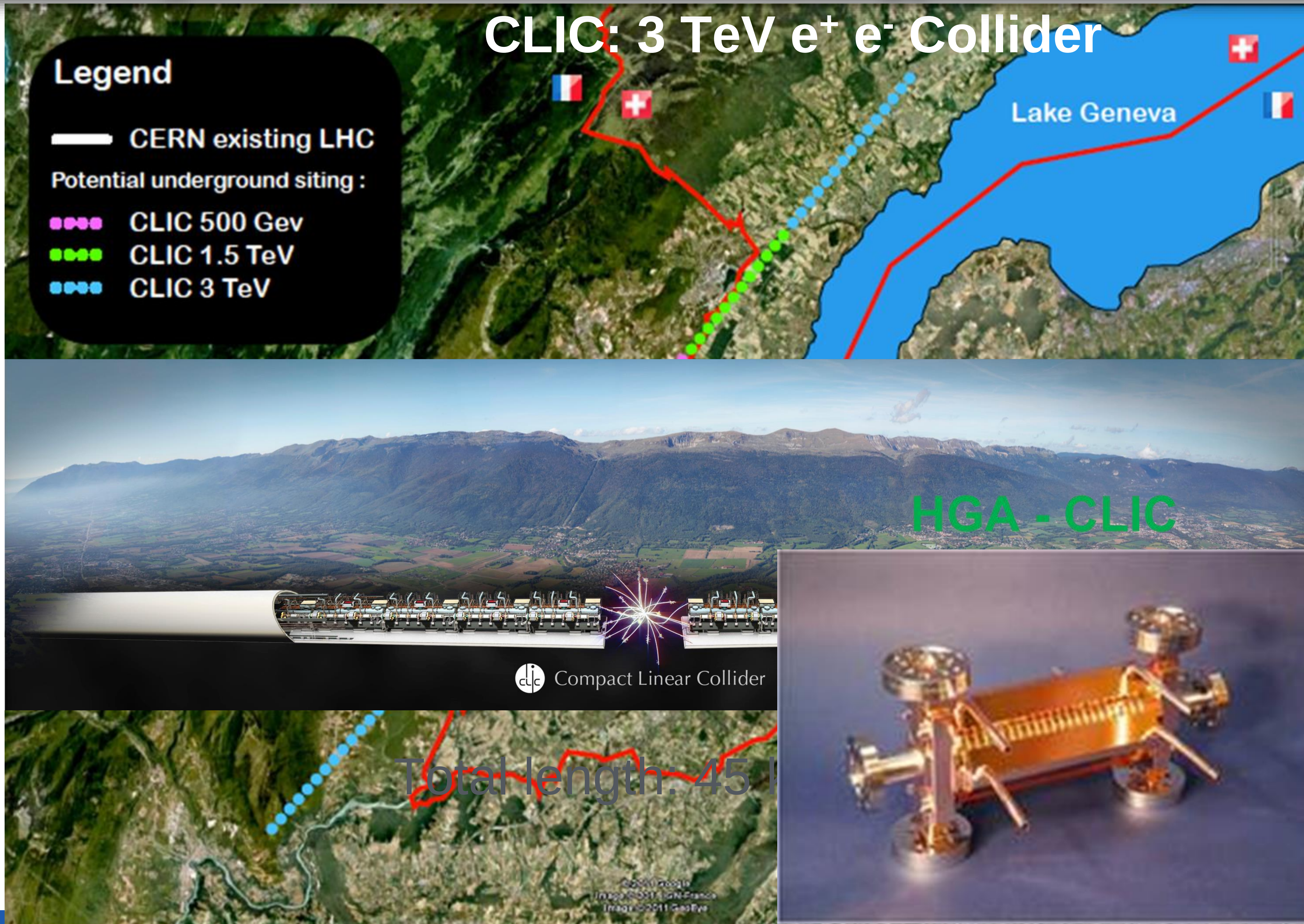



Advanced Technology: Supercondcuting Crab Cavities



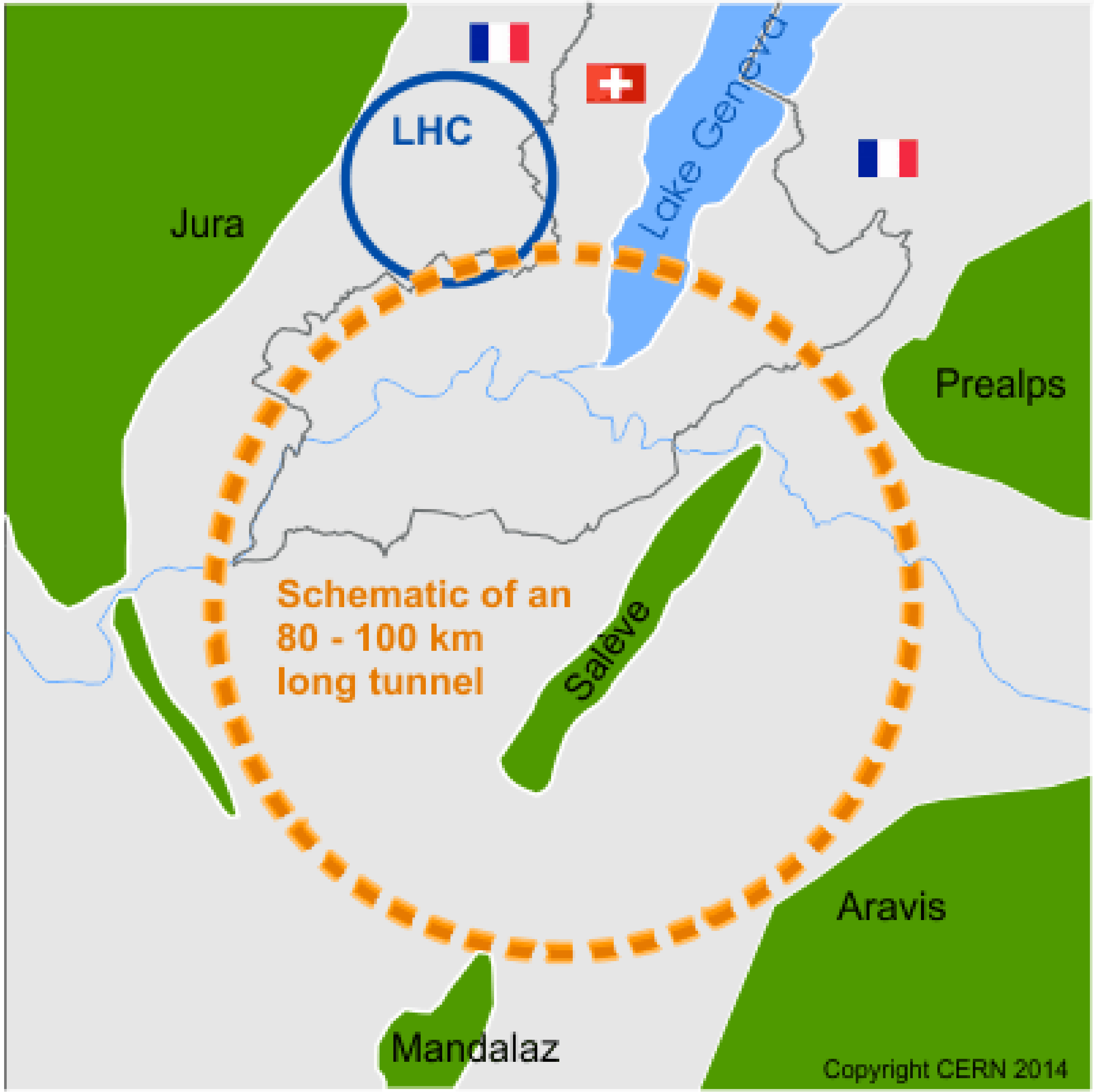
How to go to increase collision energy of constituents

CLIC: 3 TeV $e^+ e^-$ Collider



HGA - CLIC

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)

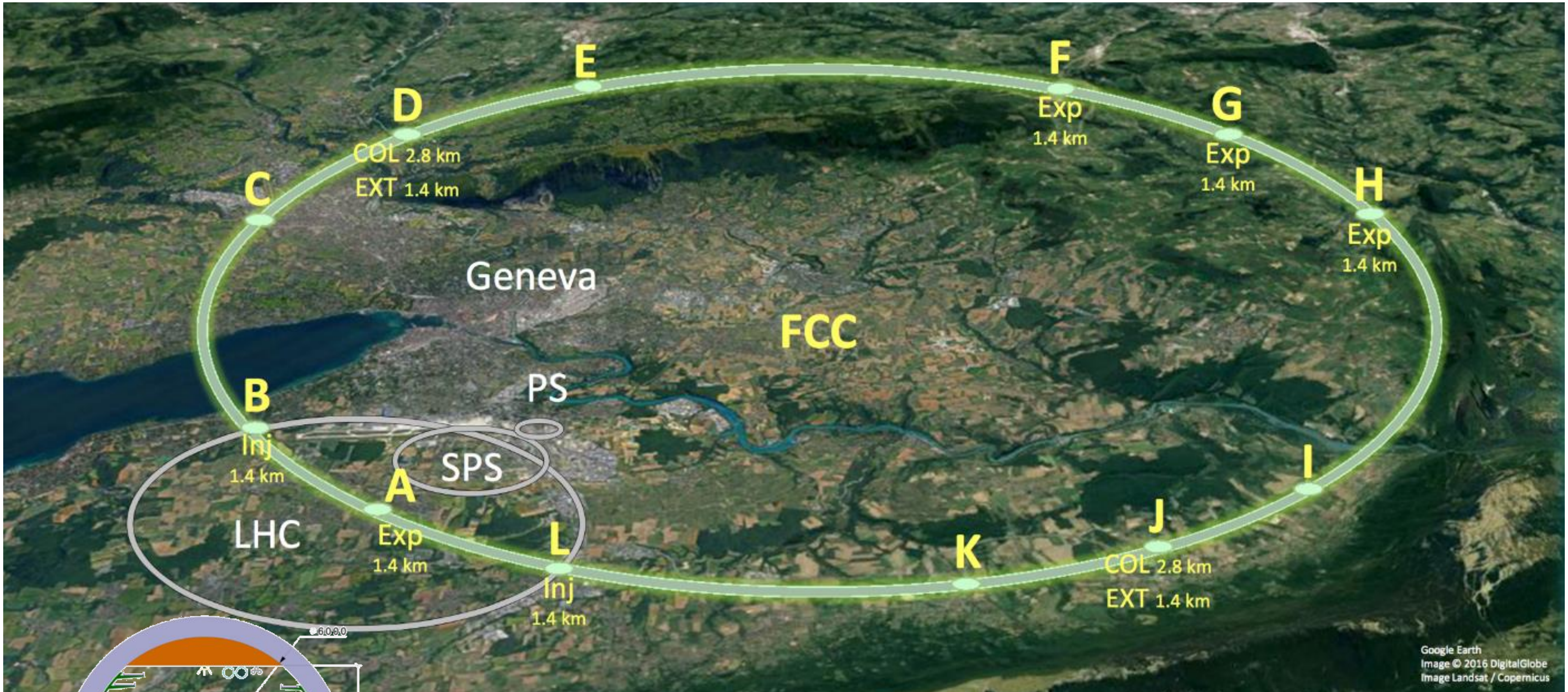
Lepton-Hadron collider (like HERA)
(***50 TeV p + 100 GeV e***)

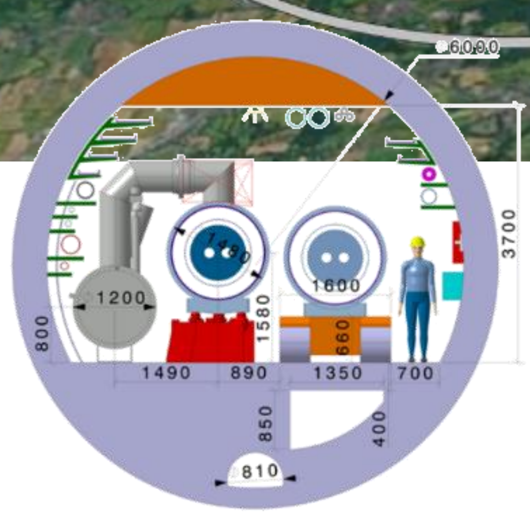
Alternatively:

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

FCC hh ee he

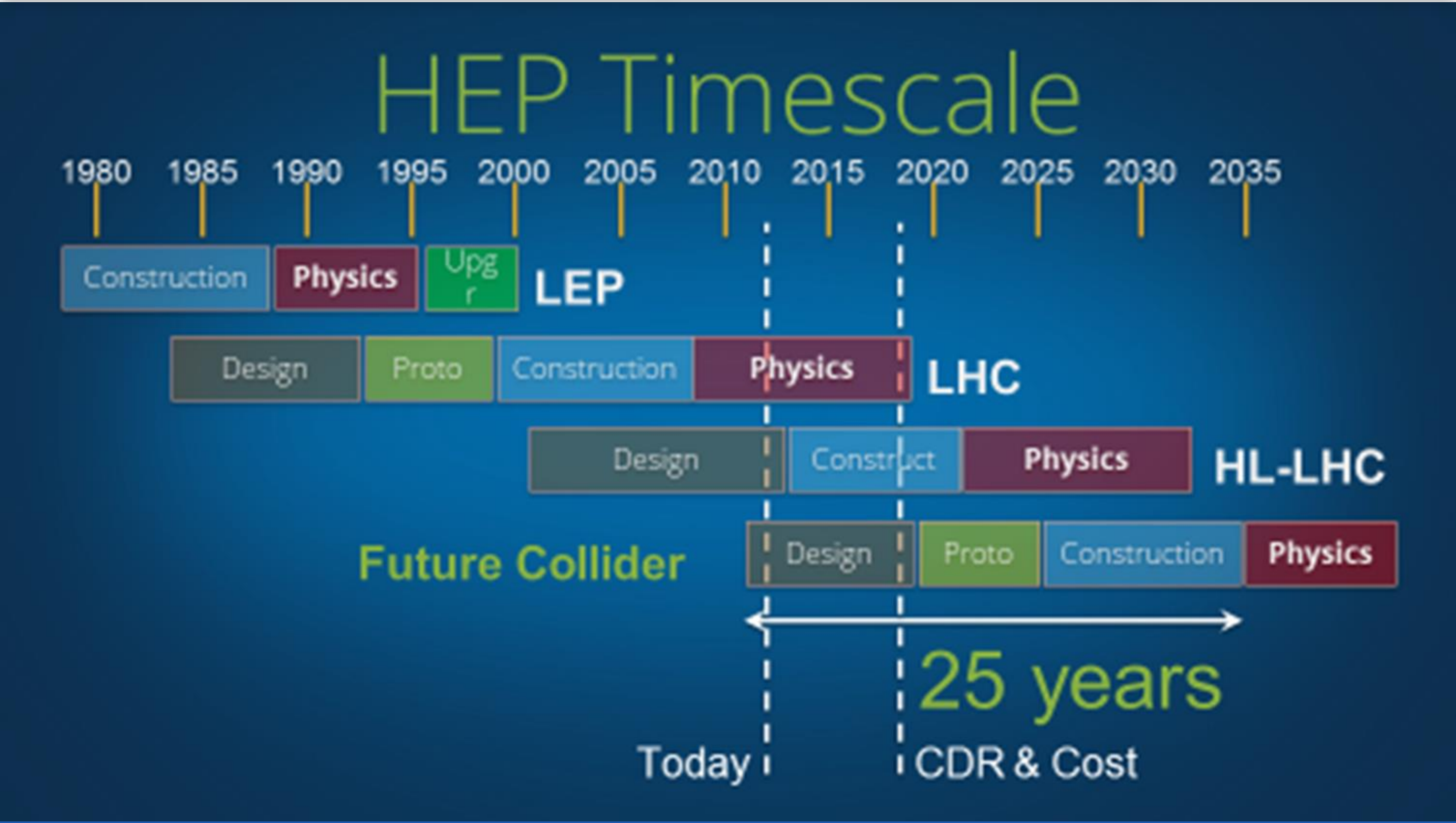
Future circular collider - project study (FCC)



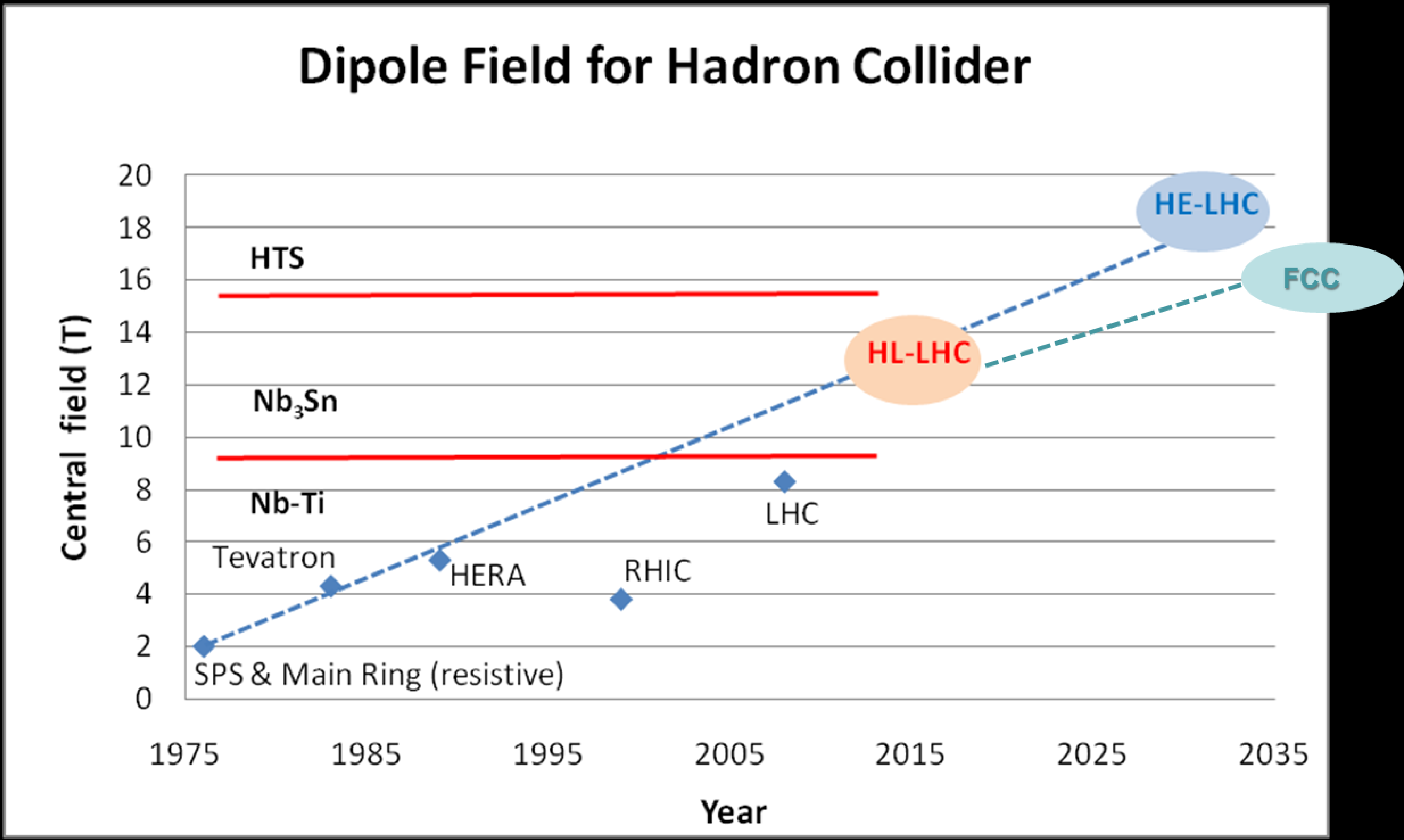


	LHC	FCC
Circumference (km)	26.7	97.5
Dipole field (T)	8.33	16
C.o.M. energy (TeV)	14	100

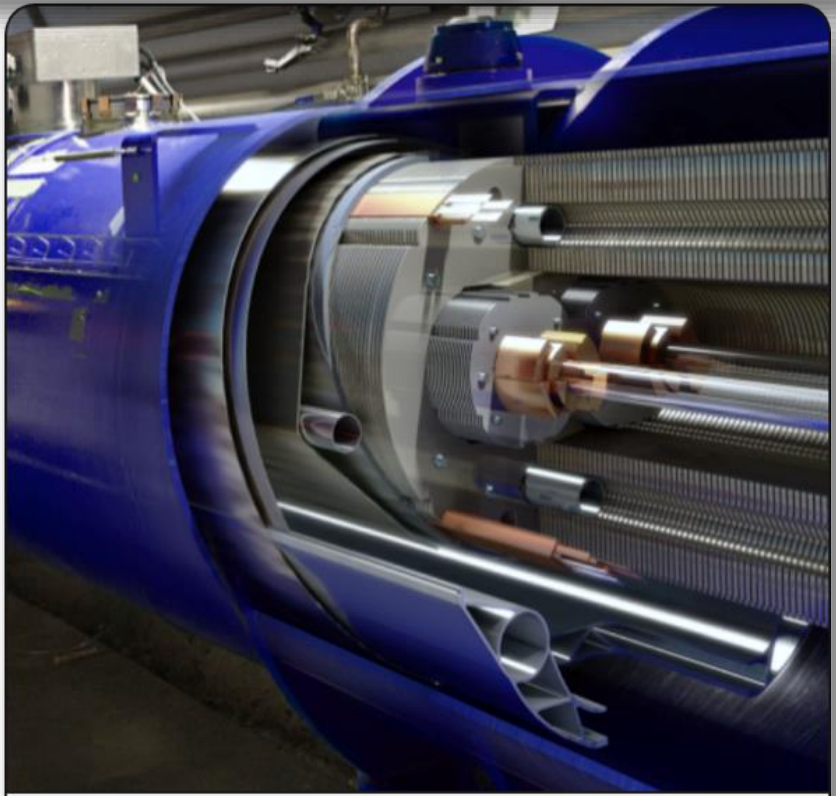
The long route of CERN: building on existing infrastructure (Tradition at best…)



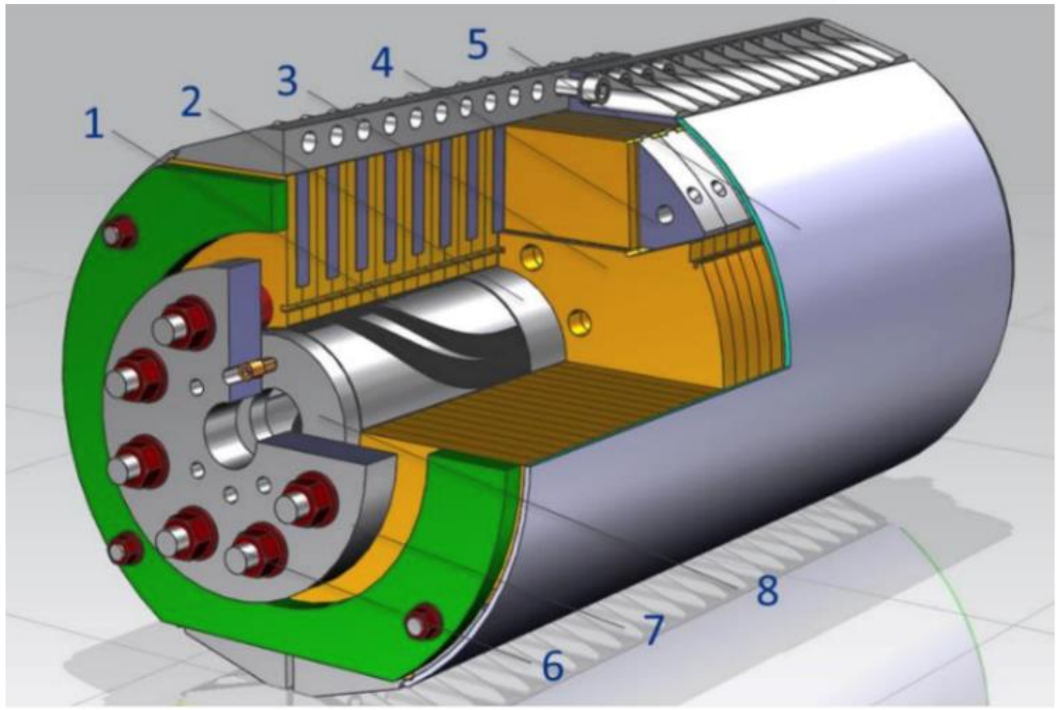
HL-LHC prepares the technology for FCC/HE-LHC

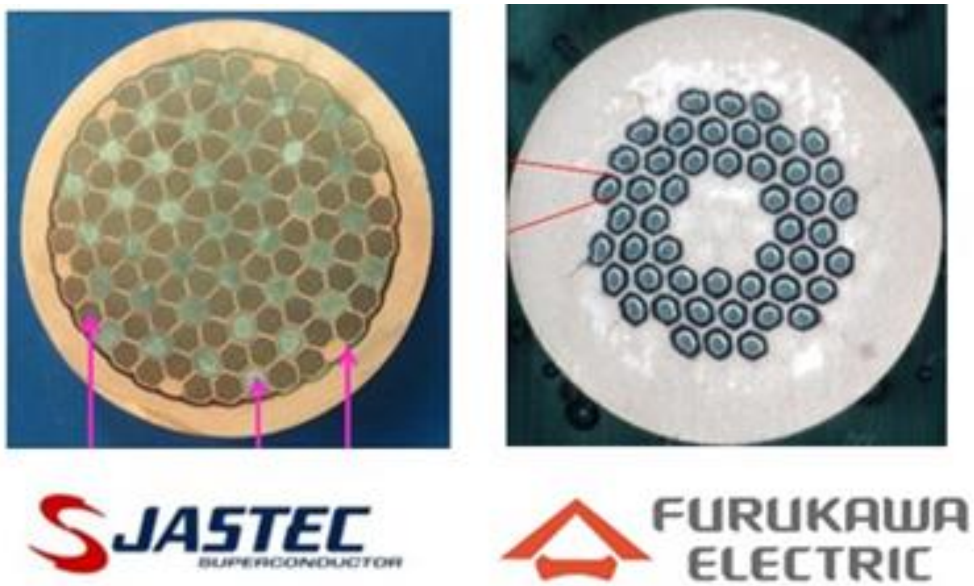


Magnet technolgy for 16 T (twice LHC!)



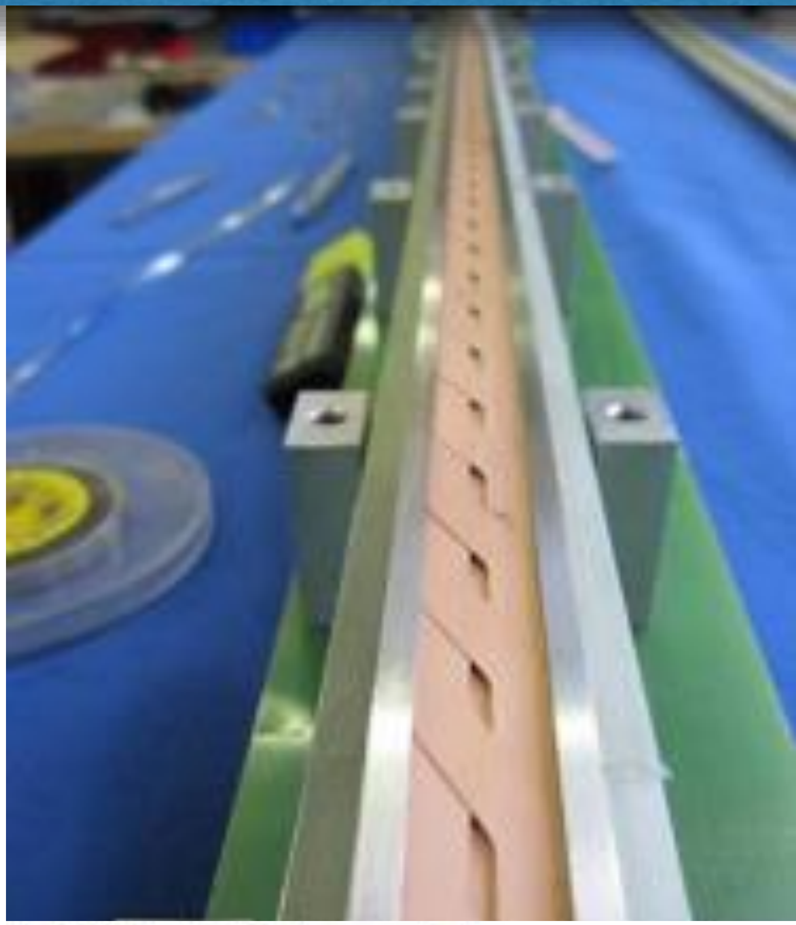
Cut through accelerator magnet

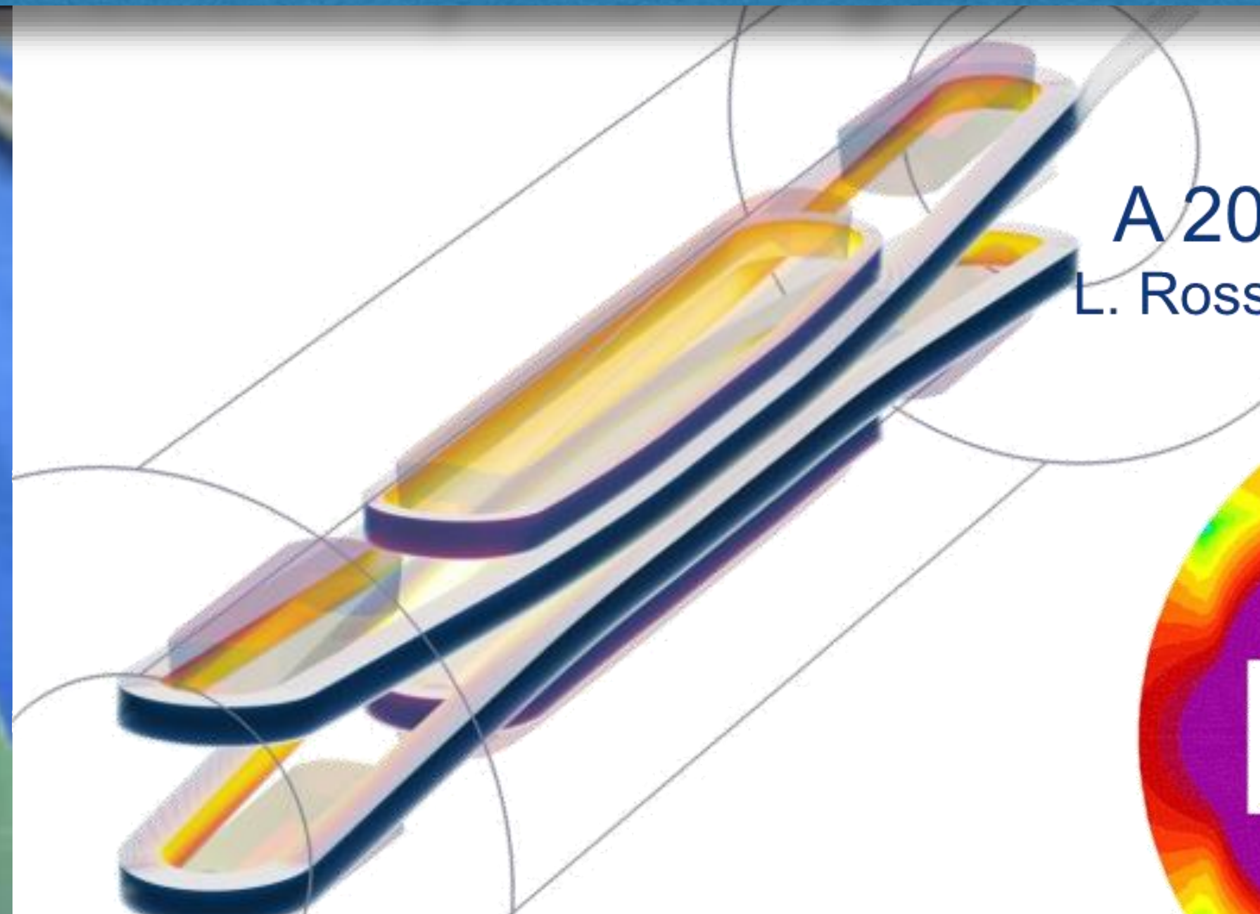




≈ 950 A/mm² @ 16T, 4.2K

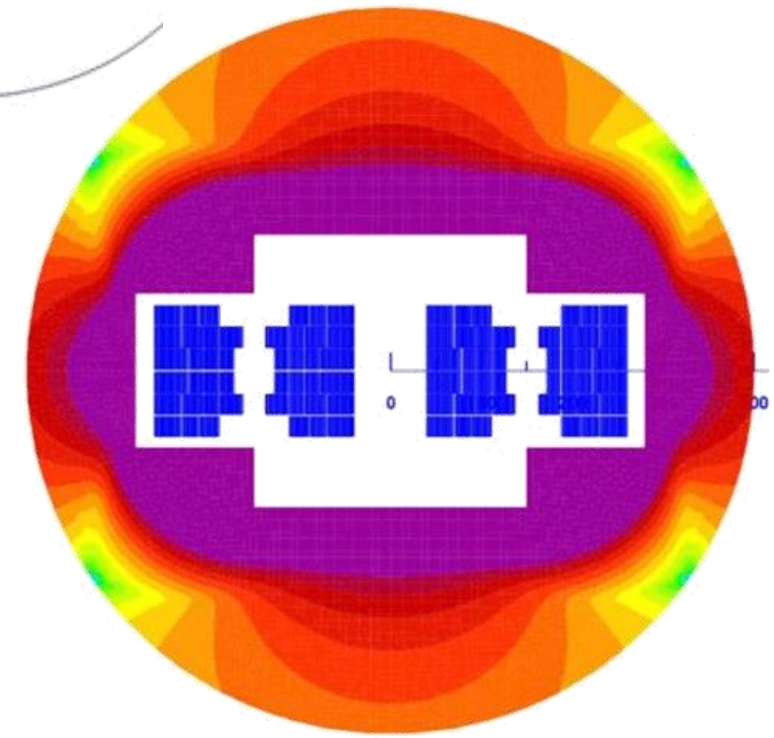
Take the best of each: hybrid magnets (Nb3Sn +HTS)

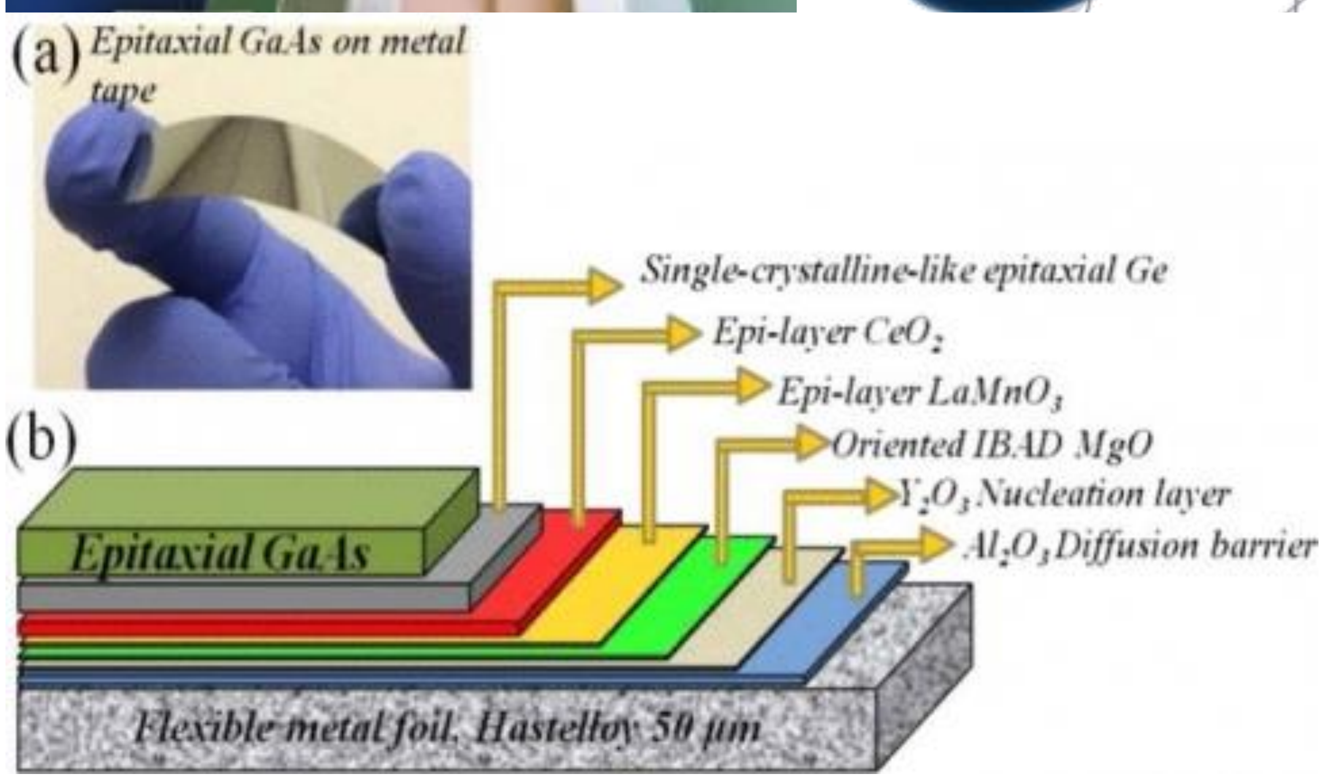


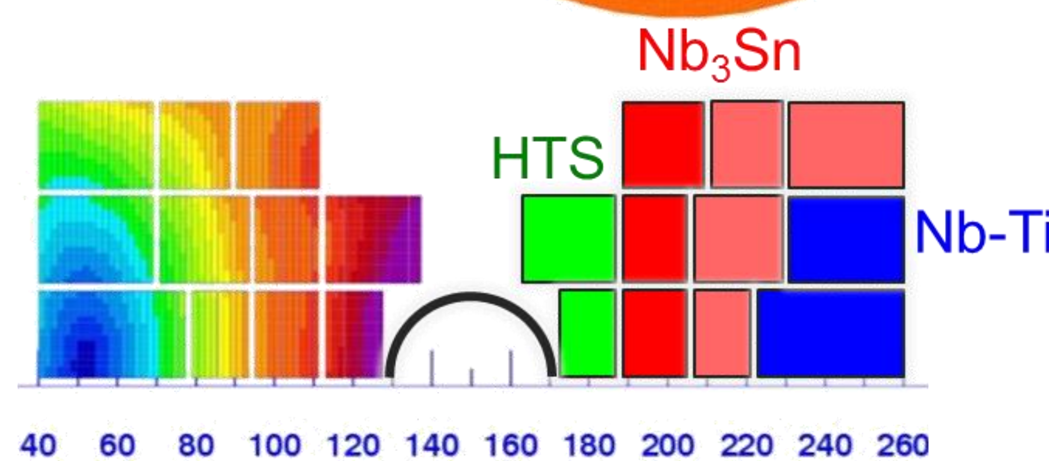


A 20 T HE-LHC dipole

L. Rossi & E. Todesco, (CERN)

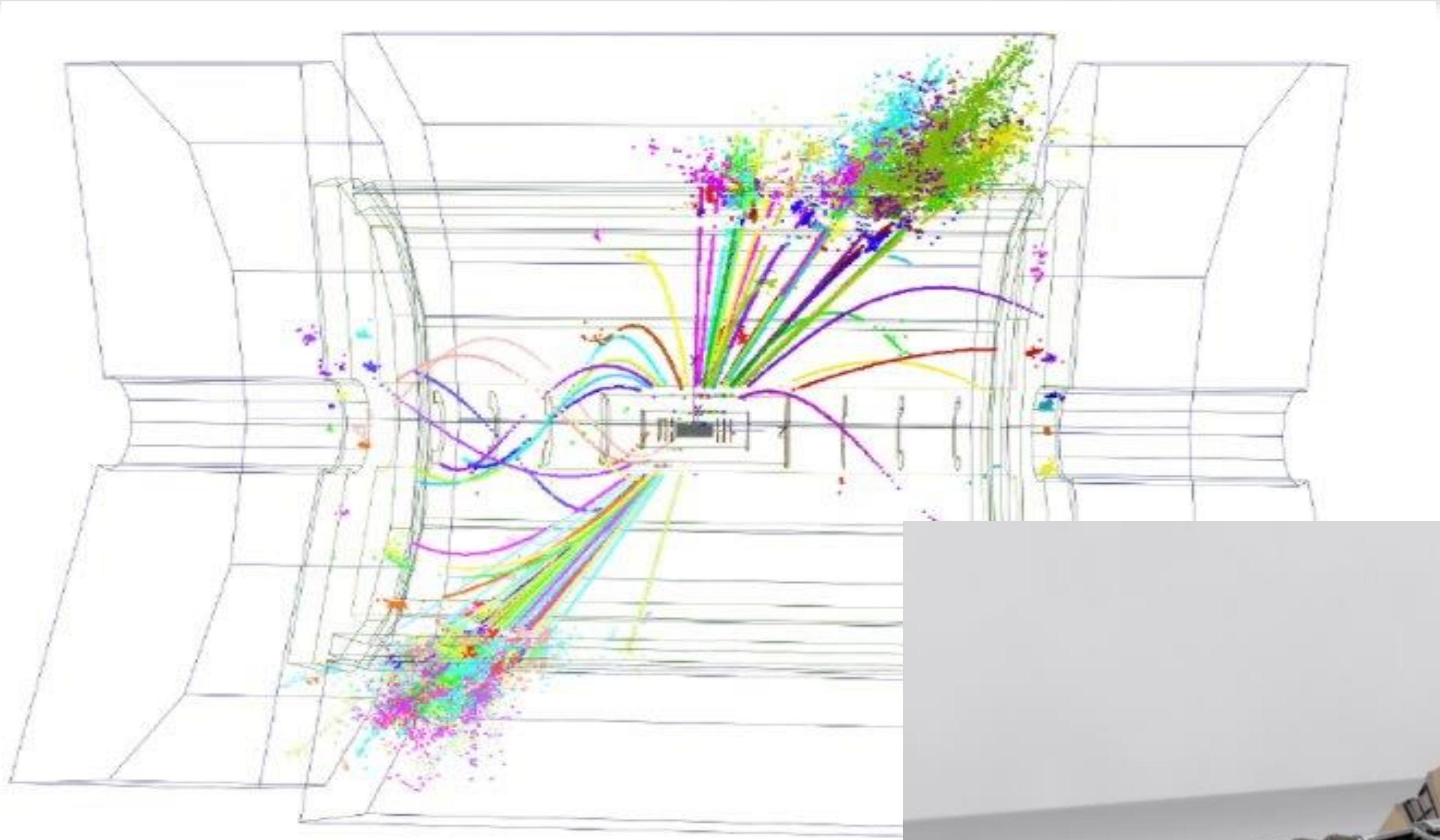


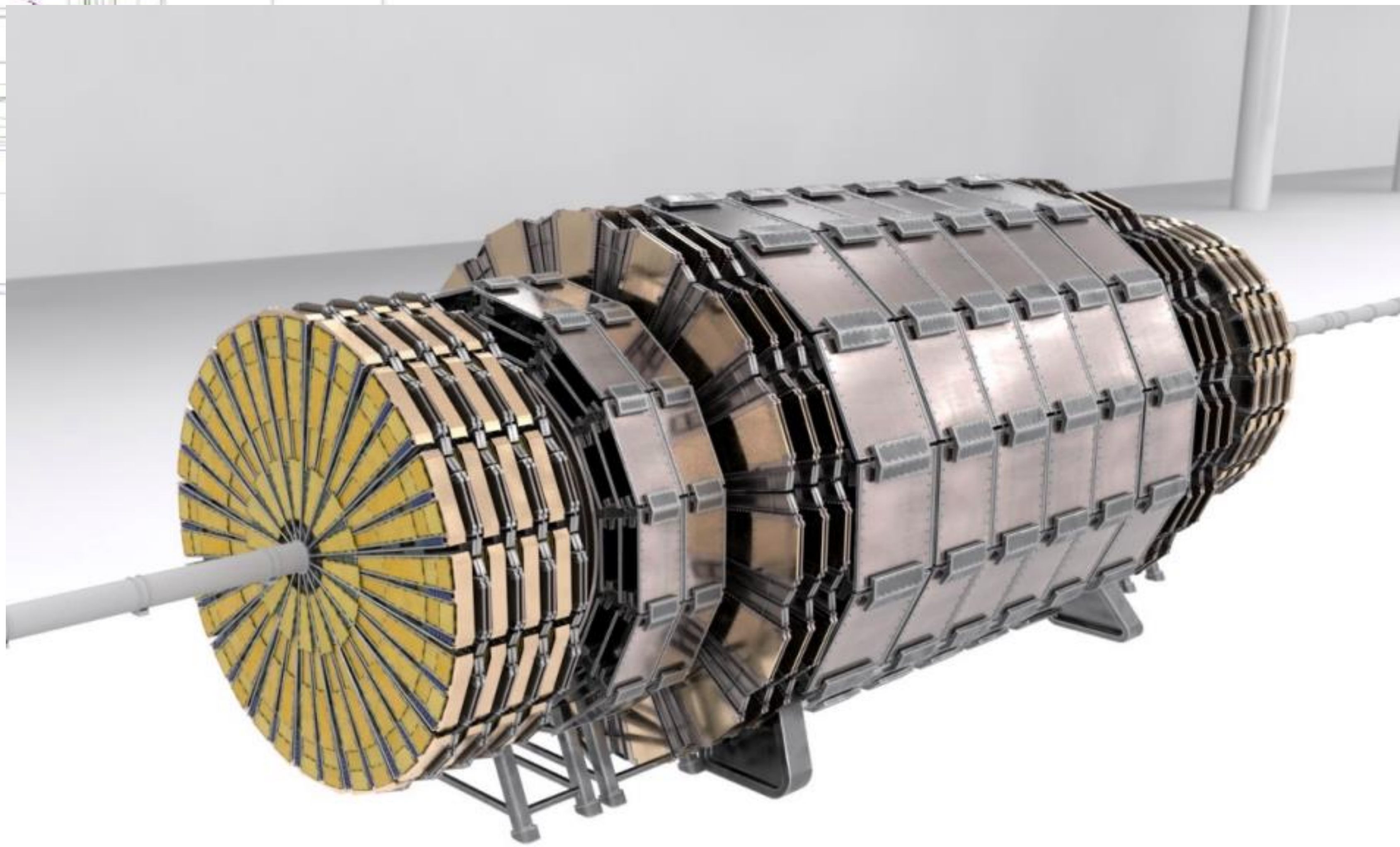




Cost optimized, graded winding

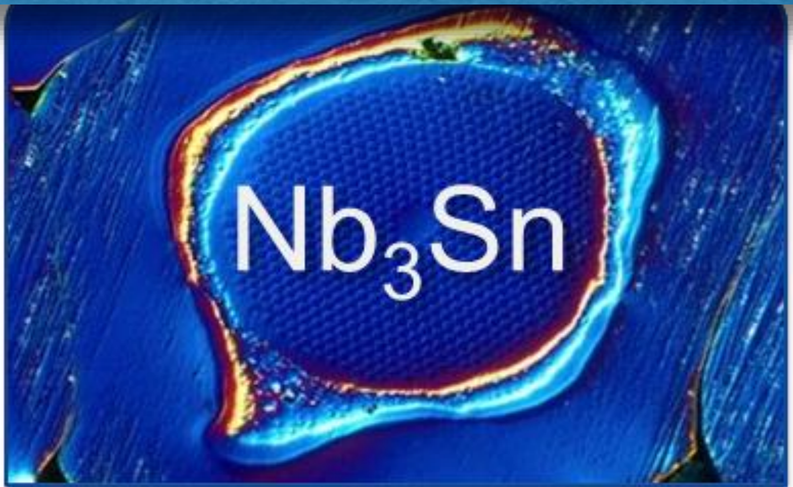
Anlso ne «eyes»: giganttic detectors 30-50 m





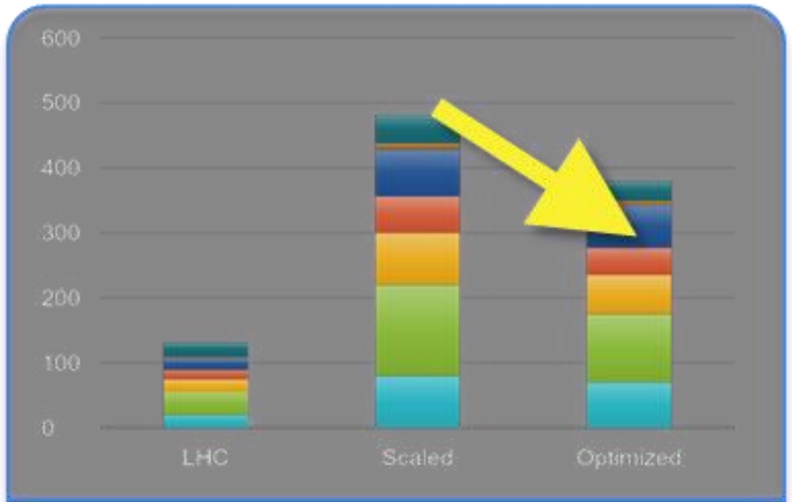
FCC is the natural evolution of HL-LHC but need further piushed technology advancement

High-field Magnets



Novel Materials and Processes

Large-scale Cryogenics



Power Efficiency

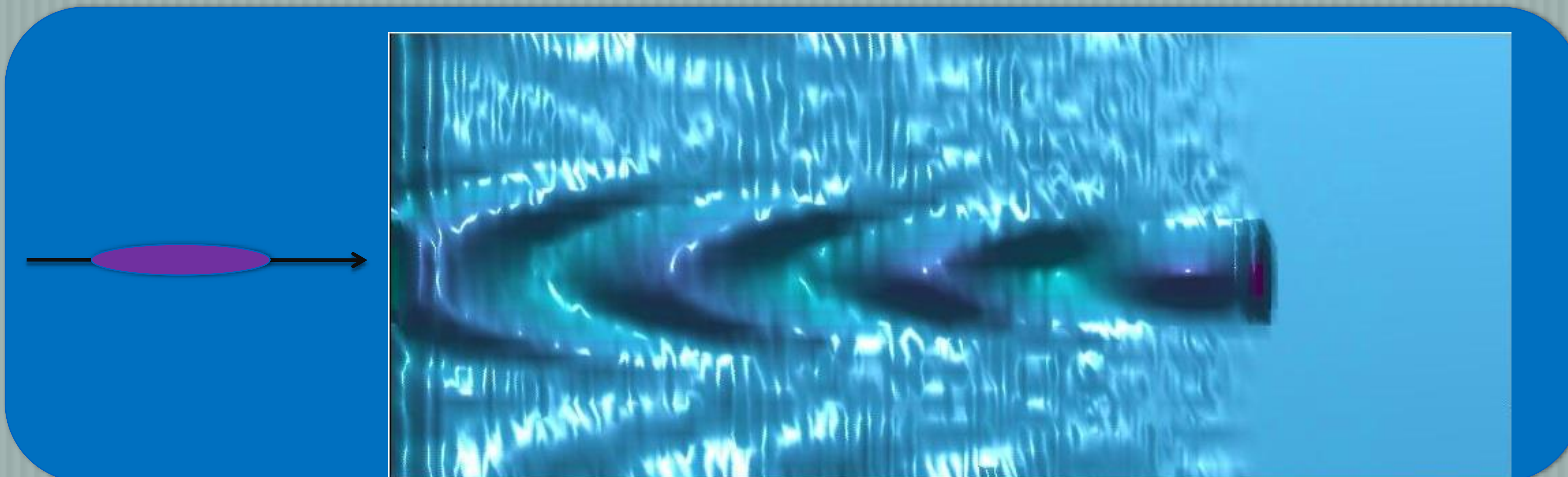
Reliability & Availability

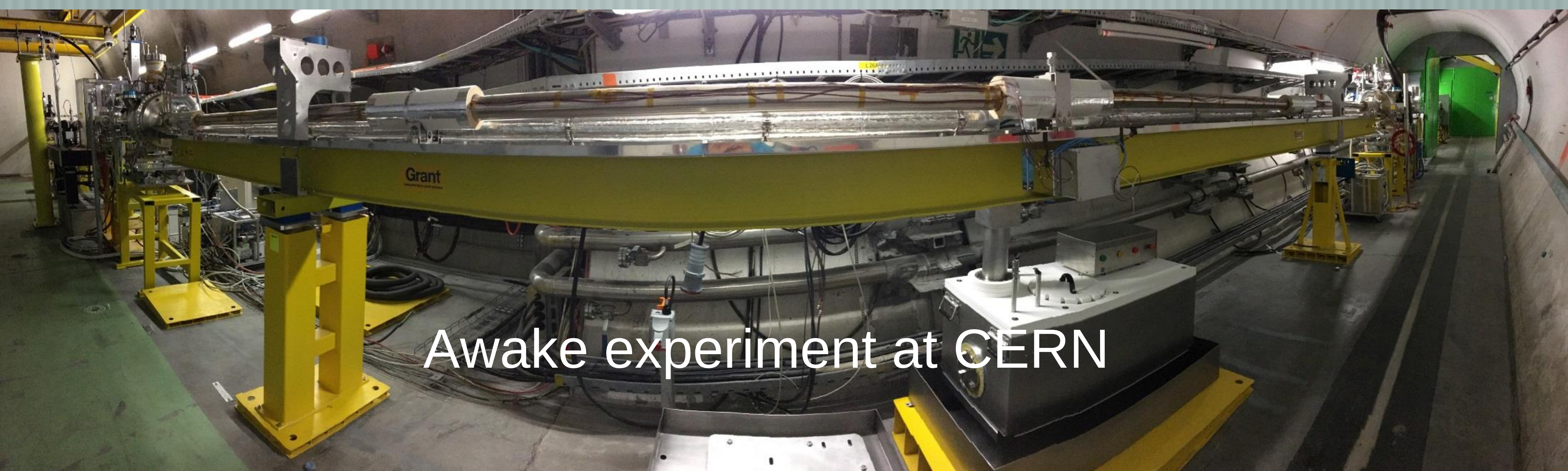
Global Scale Computing

COMPETITION? YES….

Proposed CEPC+SppC in China

Plasma acceleration: 1000 times smaller… Or 1000 times more powerful?



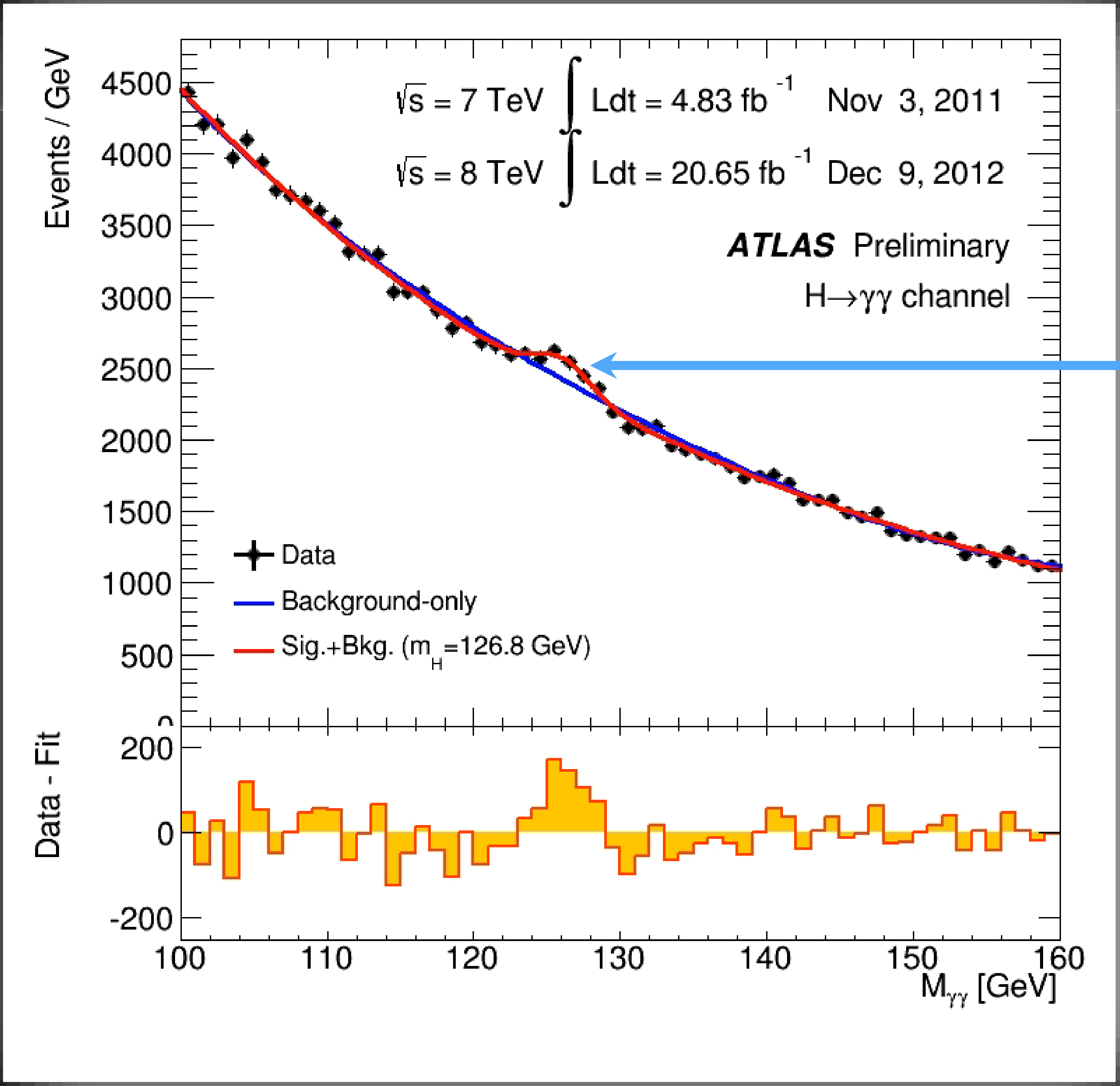


Awake experiment at CERN

Stimulating innovation…

Thanks to Rolf Landua
Head of Global Engagement
CERN

The evolution of the histogram with two-photon events



Higgs boson