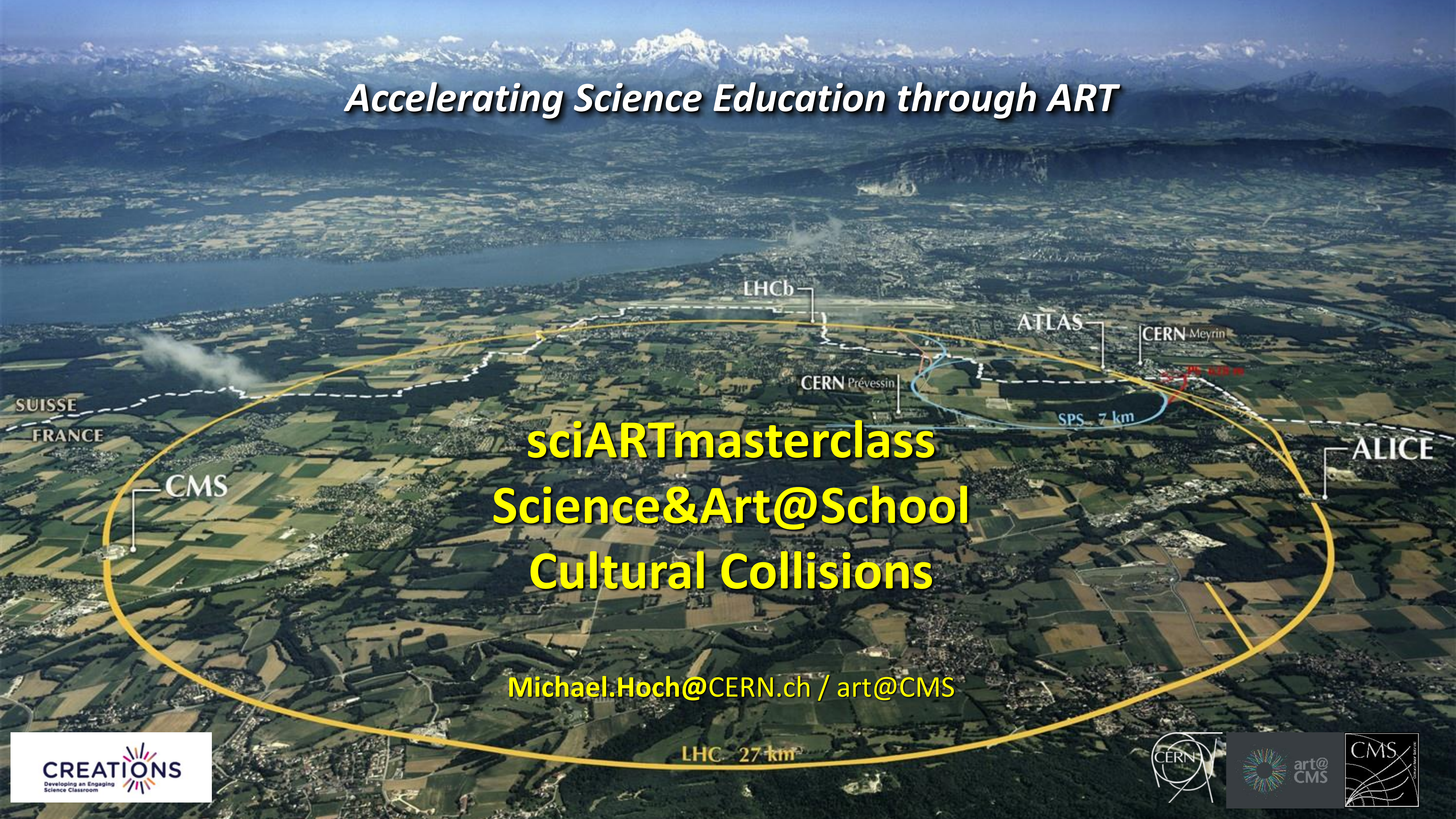
Accelerating Science Education through ART

sciARTmasterclass
Science&Art@School
Cultural Collisions

Michael.Hoch@CERN.ch / art@CMS



CREATIONS
Developing an Engaging Science Classroom

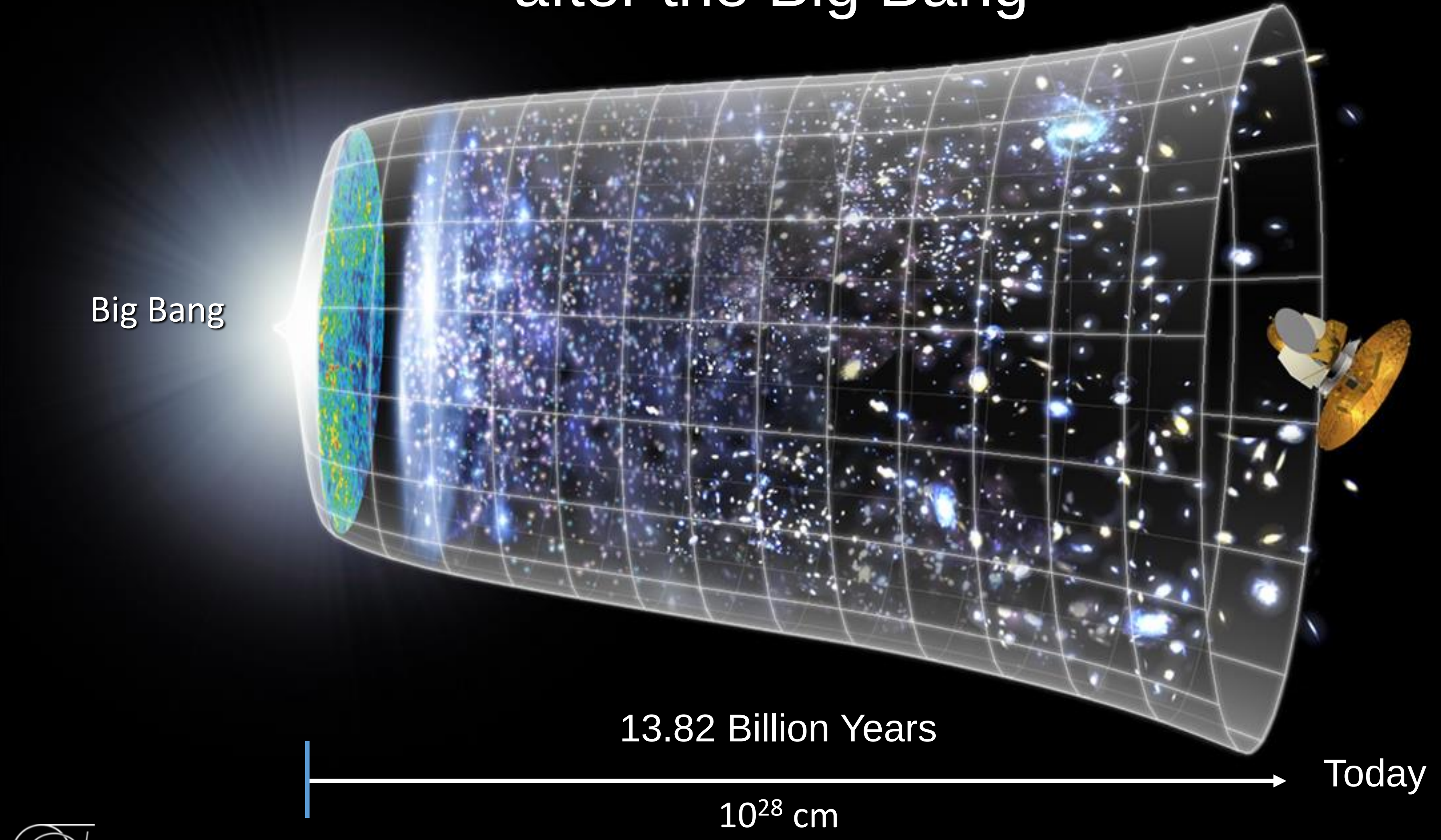
CERN

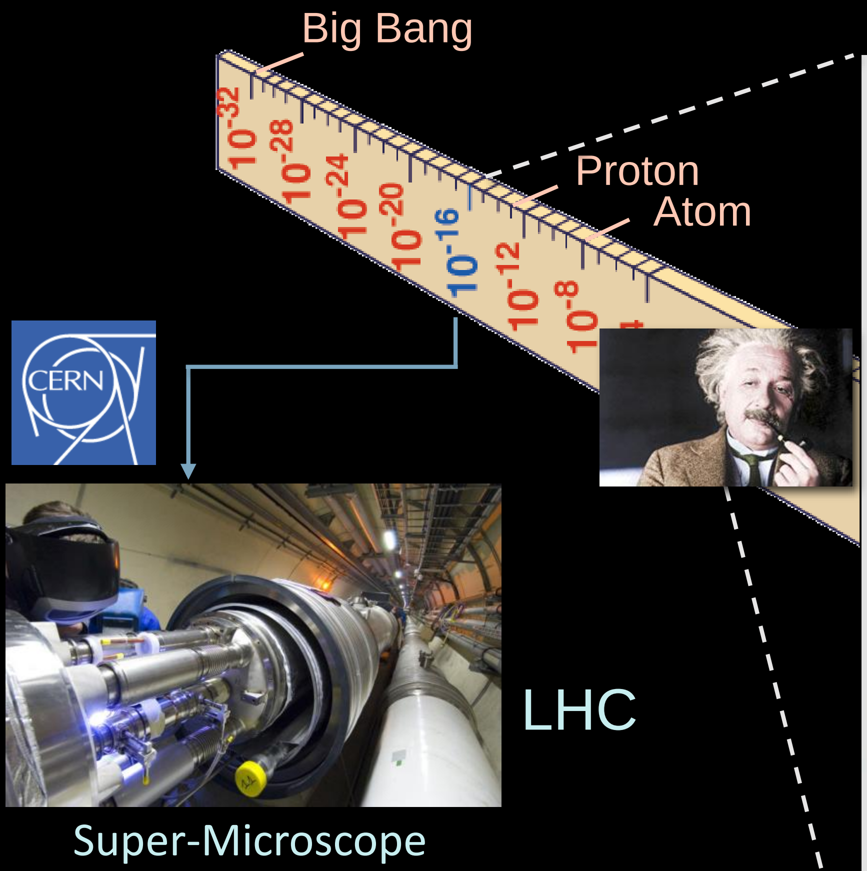
art@CMS

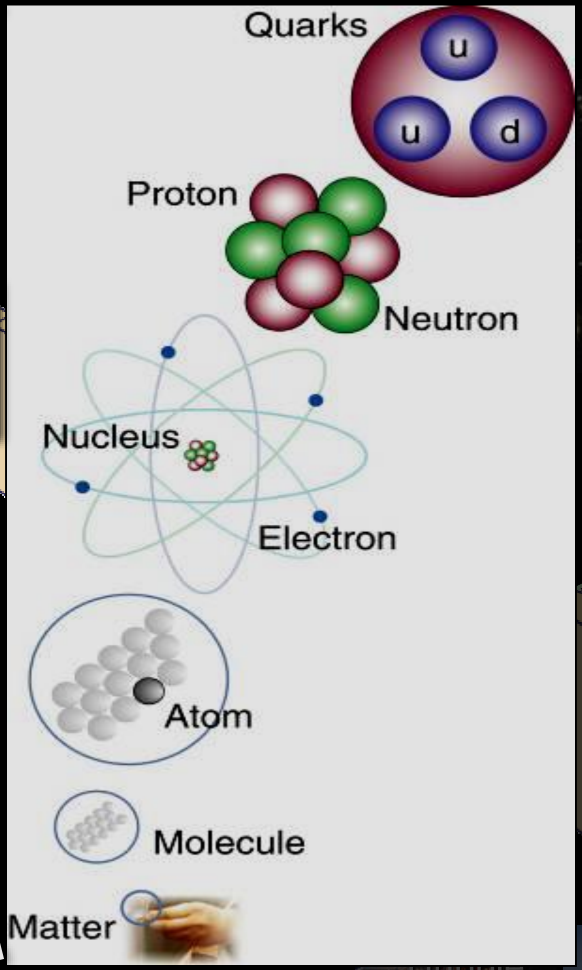
CMS

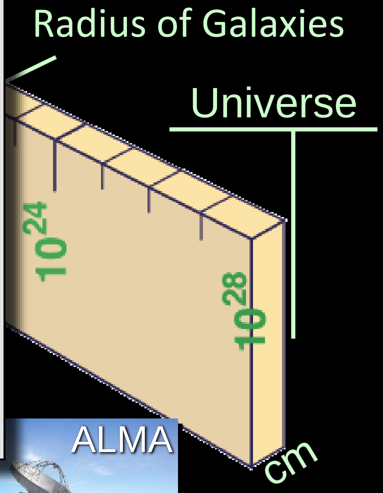
Next Scientific Challenge:

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



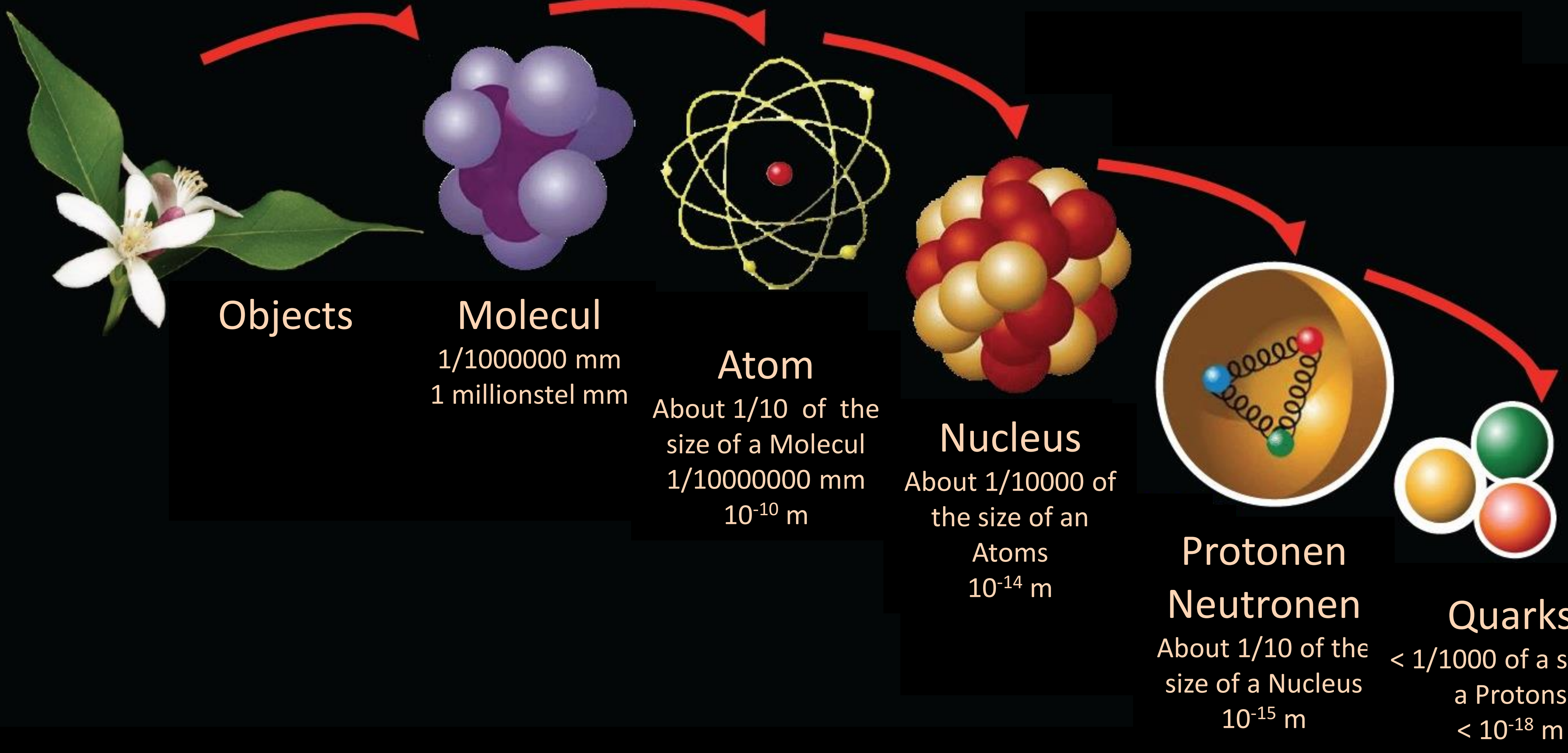




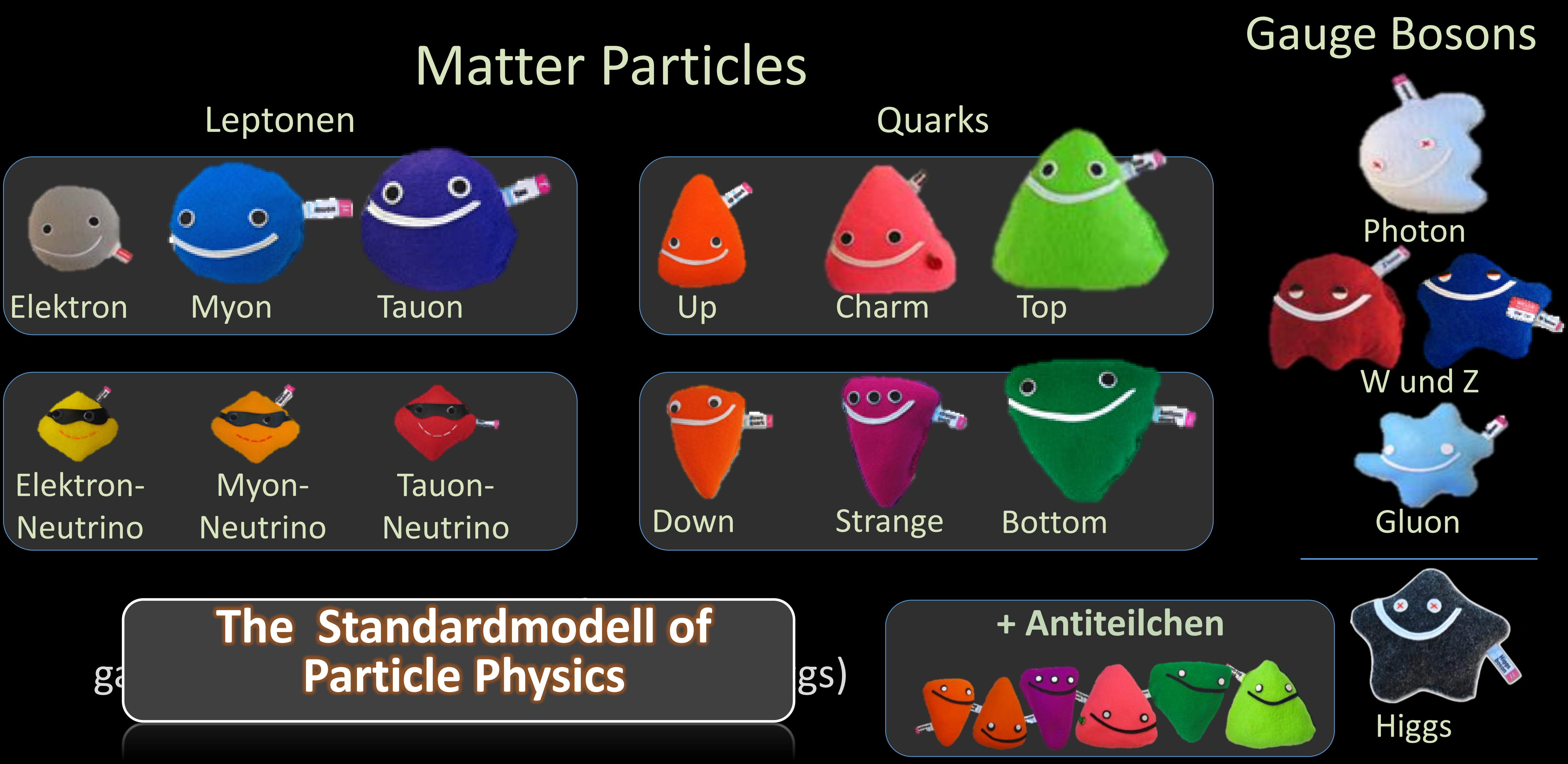


By studying physics laws of fundamental particles – the smallest construction elements of Nature - we can understand the rules of Astrophysics and Cosmology

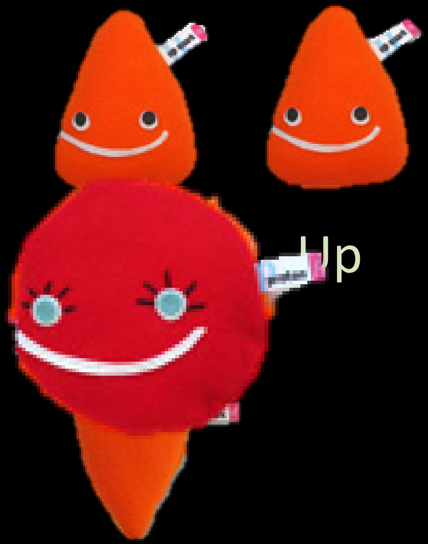
[redacted]


Objects
Molecul
1/1000000 mm
1 millionstel mm
Atom
About 1/10 of the
size of a Molecul
1/10000000 mm
10-10 m
Nucleus
About 1/10000 of
the size of an
Atoms
10-14 m
Protonen
Neutronen
About 1/10 of the
size of a Nucleus
10-15 m
Quarks
< 1/1000 of a size of
a Protons
< 10-18 m

https://www.particlezoo.net/



Elektron

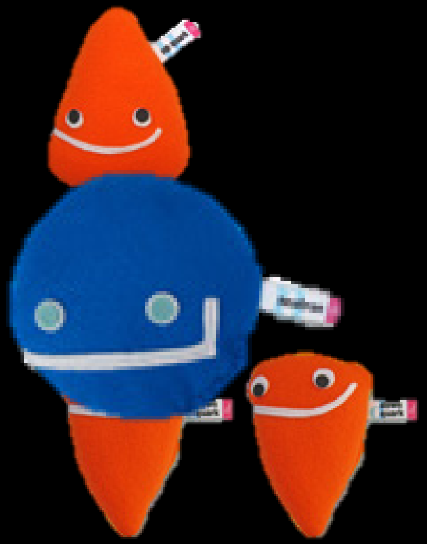


Up

Proton

Down

Elektron

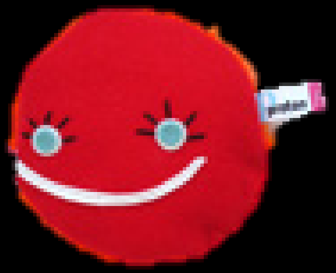


Down

Proton

Neutron

Elektron



Proton

Neutron

Wasserstoff Atom H

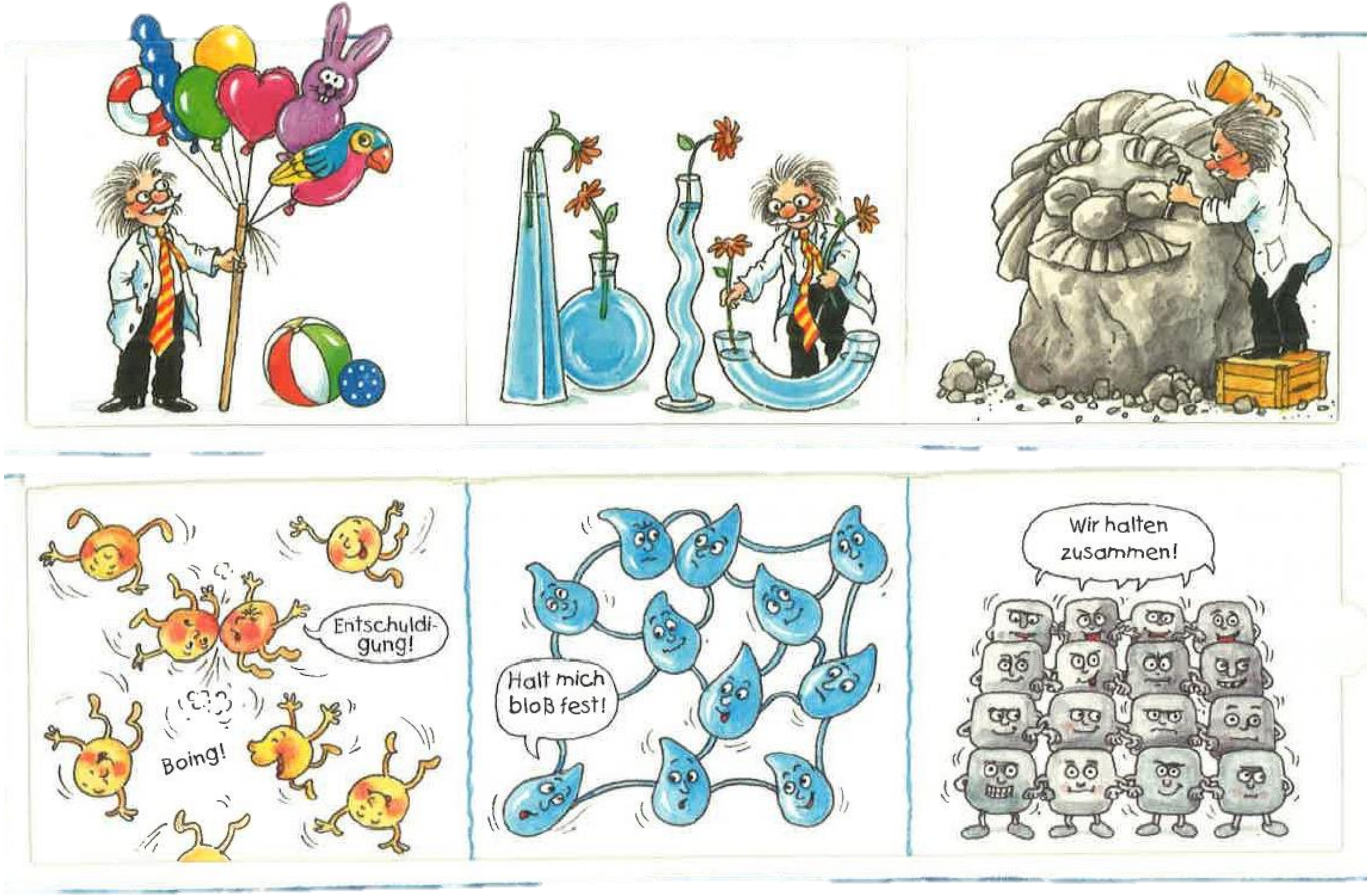
Elektron

Proton

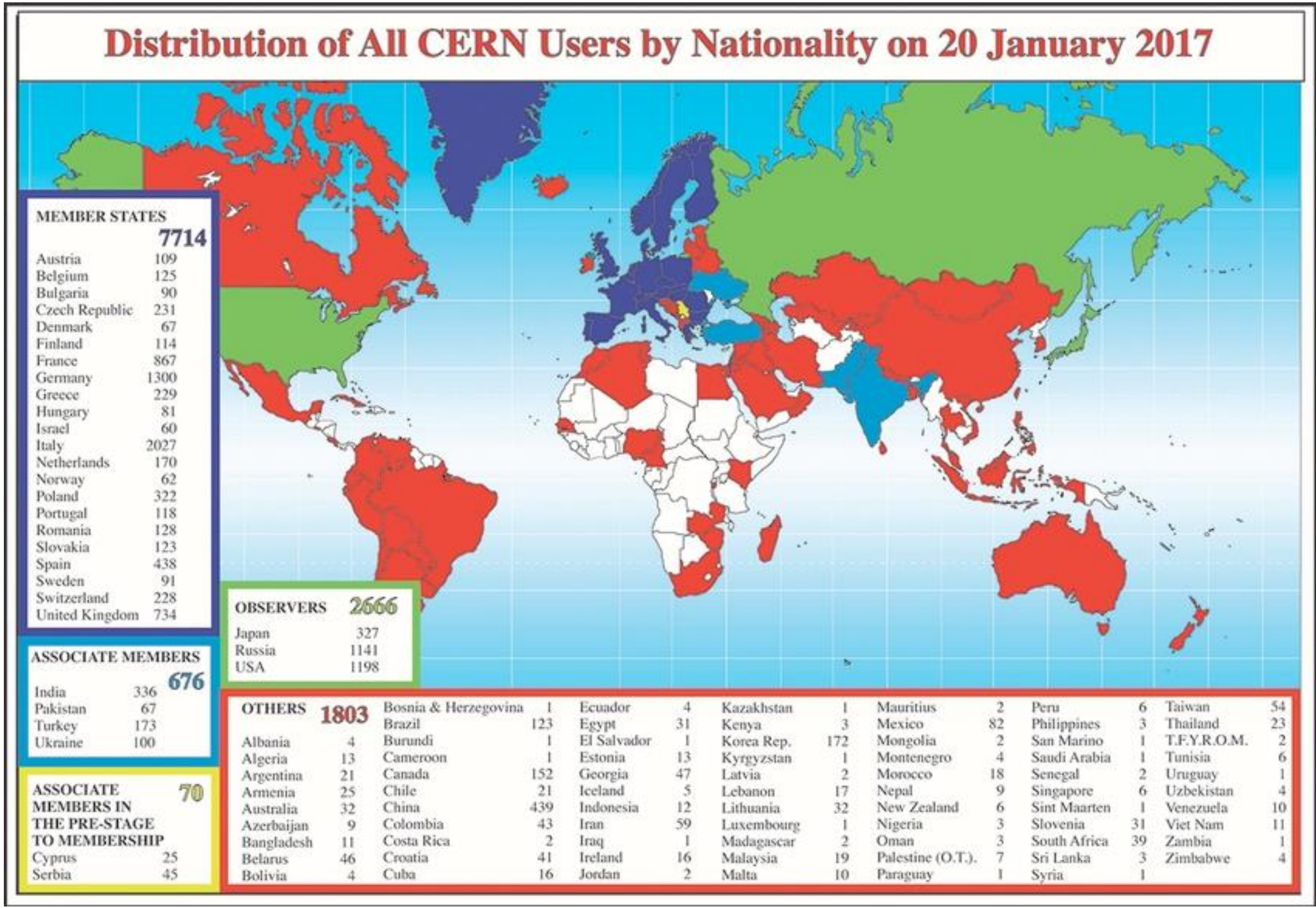
Neutron

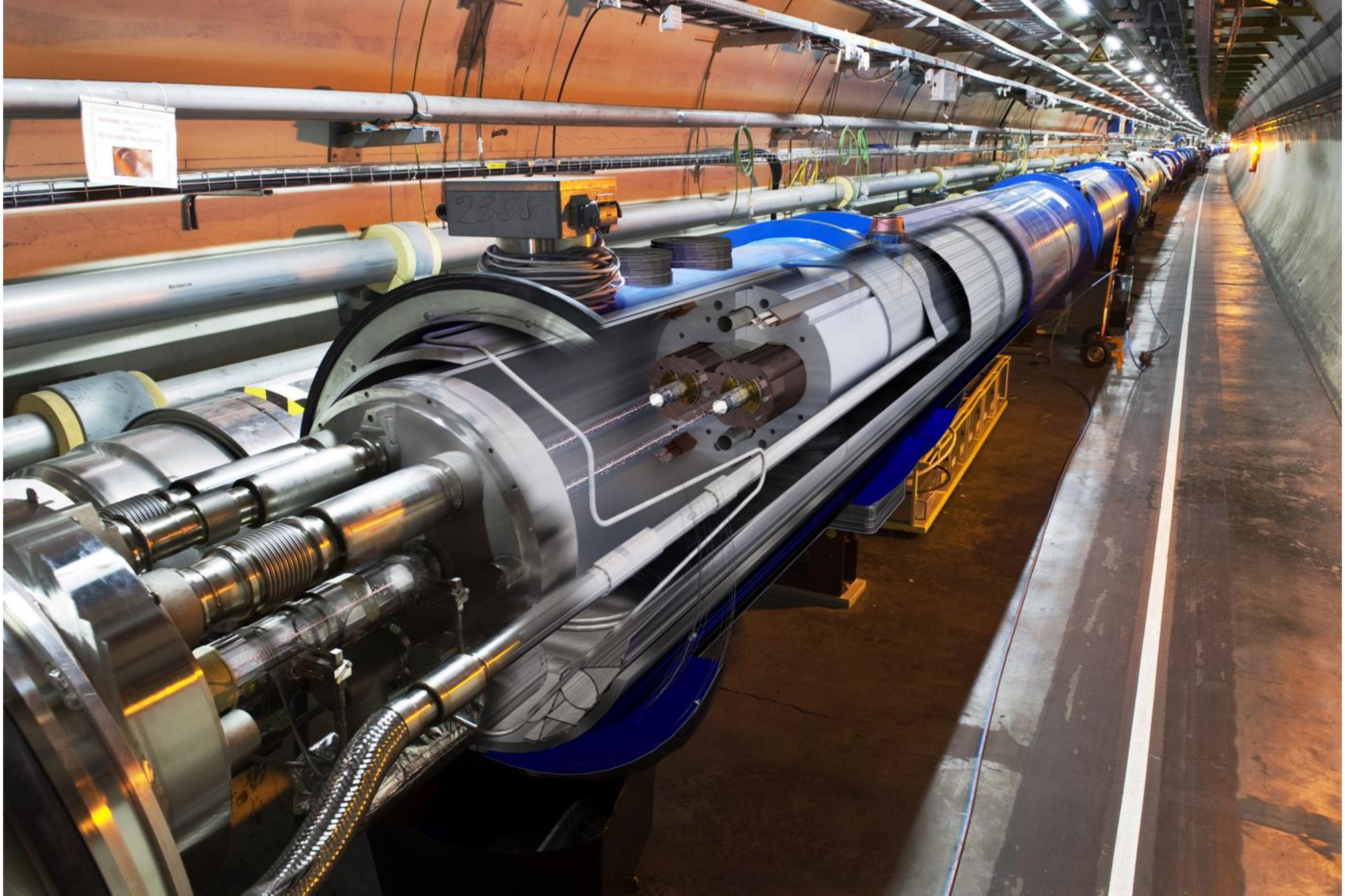
Helium Atom He

Everything is made out of elementary particles



13000 Scientists coming from more than 100 countries

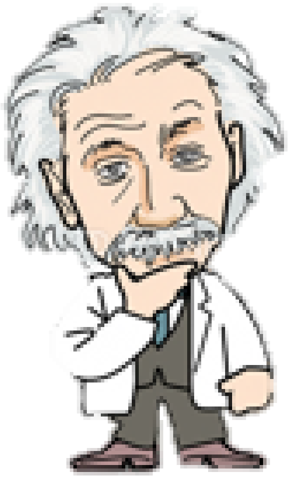





BANZAÏ!!!
J'VEUX PAS ÊTRE COLLISIONNÉ!
SSCRRRRRIIIIIIIITCHHHHHHH

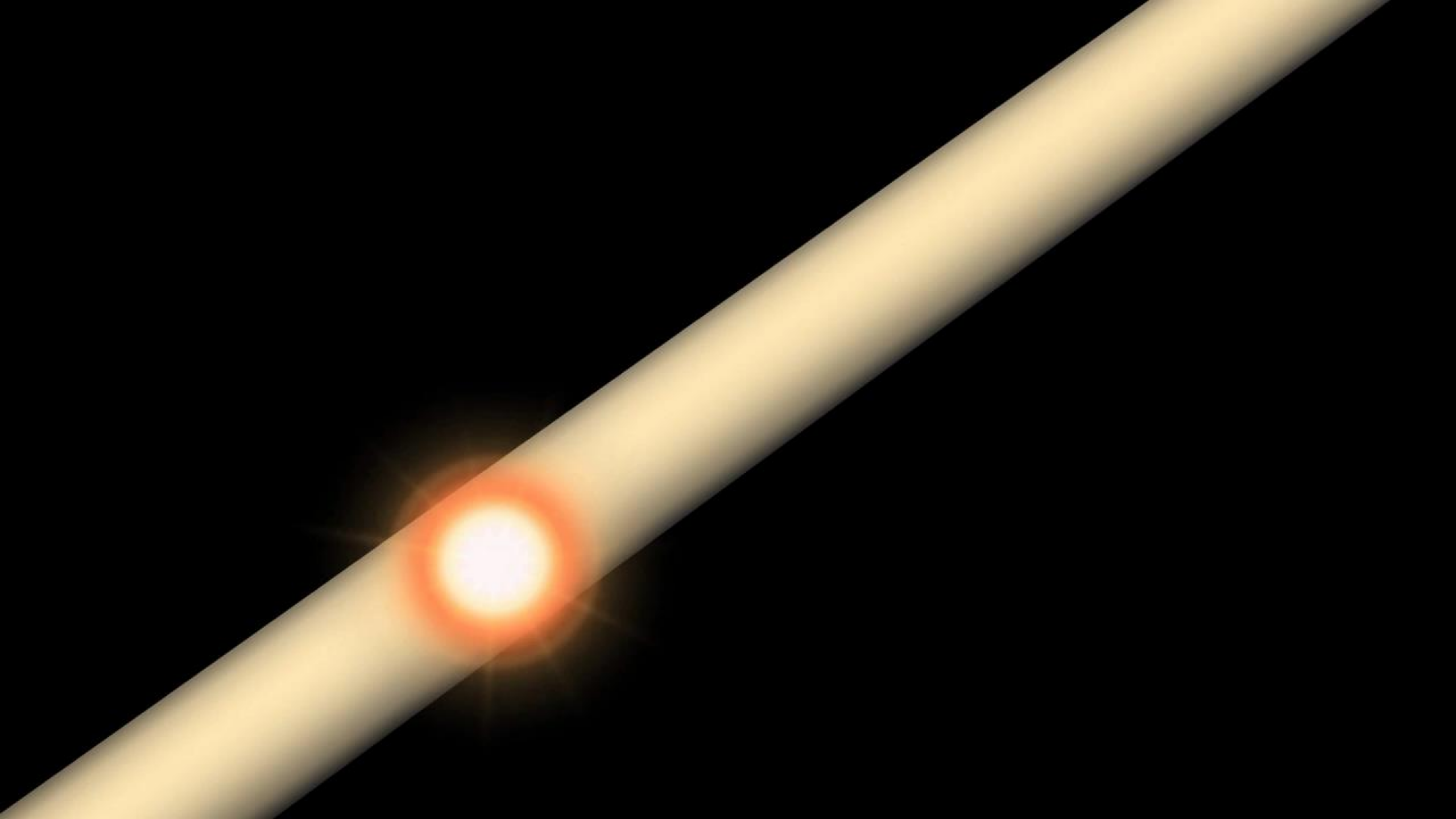
LHC: Collisions ? Why ?

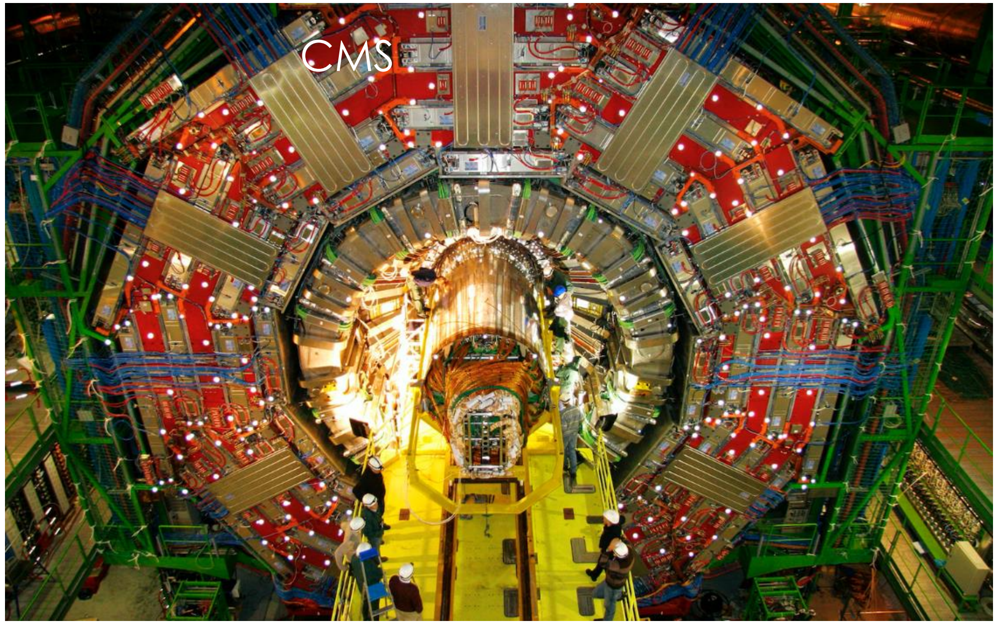
We can create MATTER !

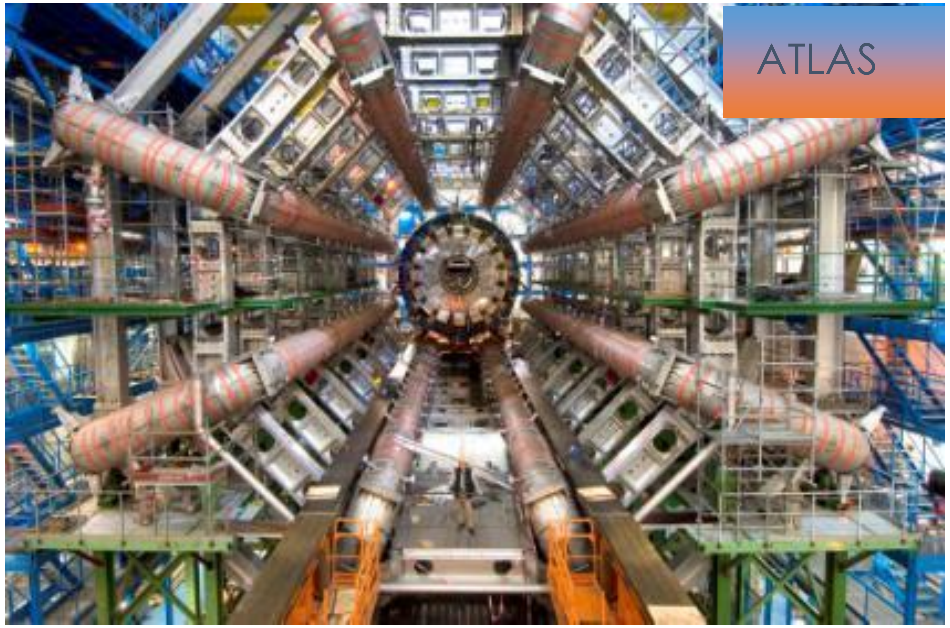


$$E = mc^2$$

What happens during a collision of Protons in the LHC accelerator ?







The
4
Large
Scale

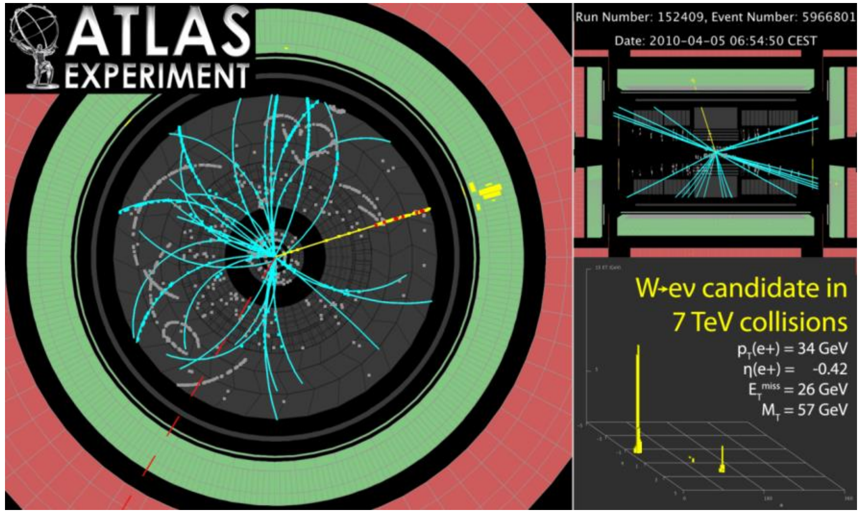
LHC

Experiments

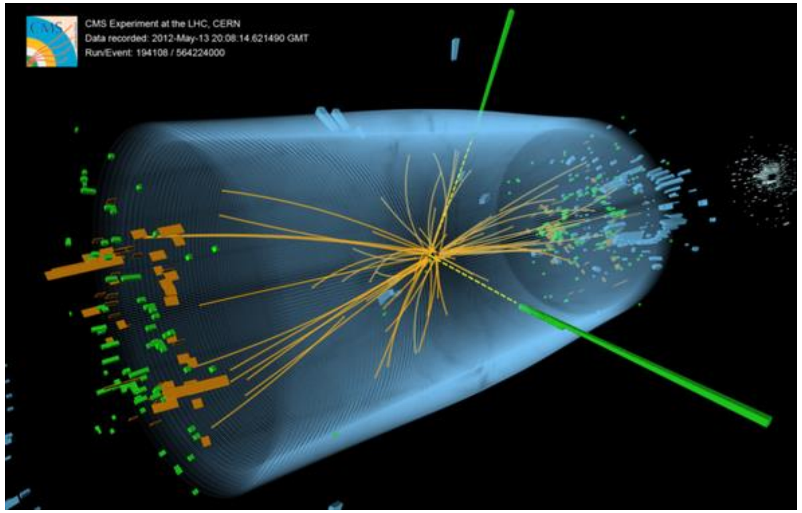
@

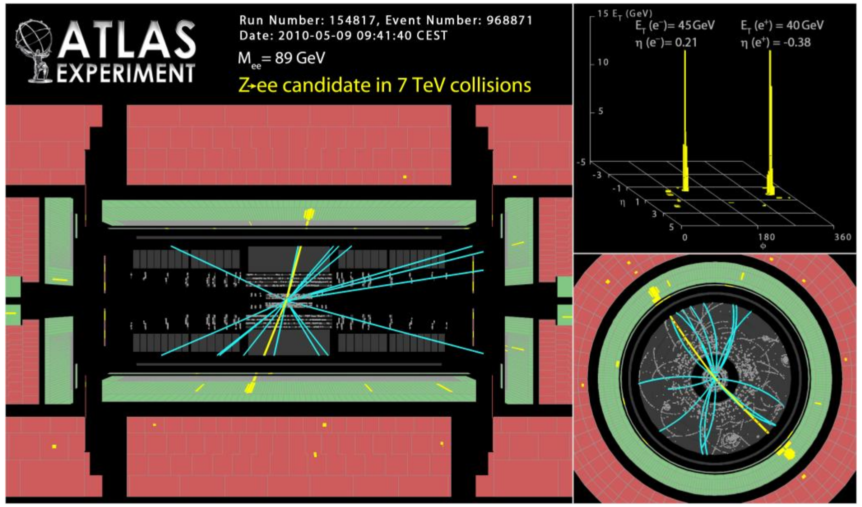
CERN

W, Z, H, ttH candidates

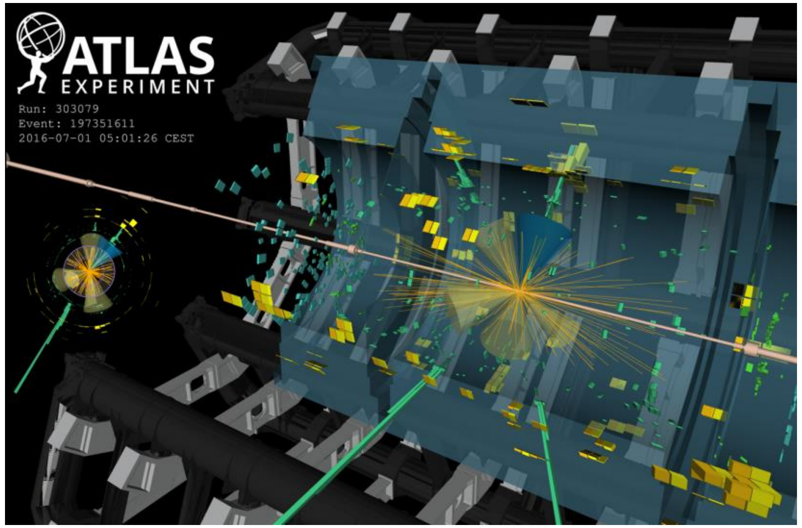


H → $\gamma\gamma$





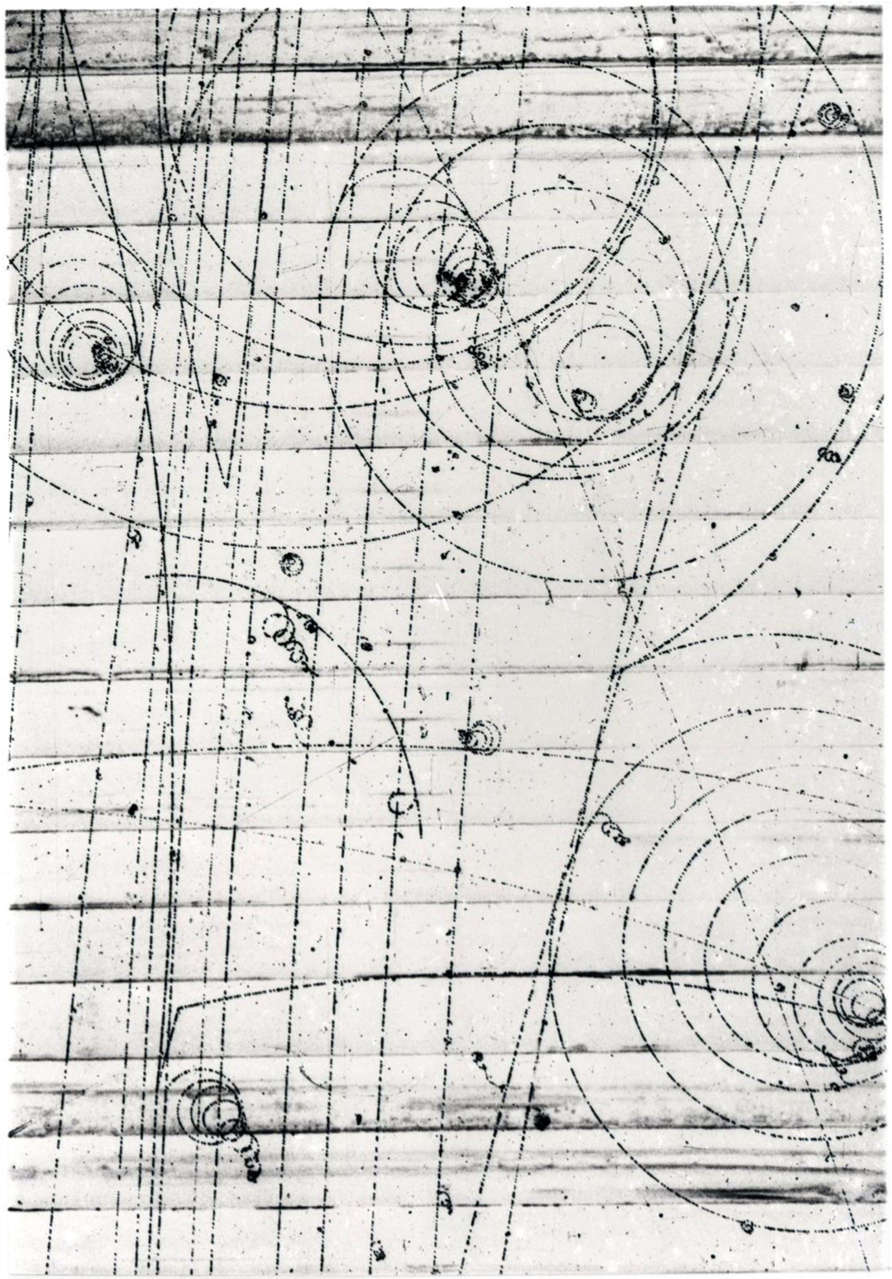
ttH

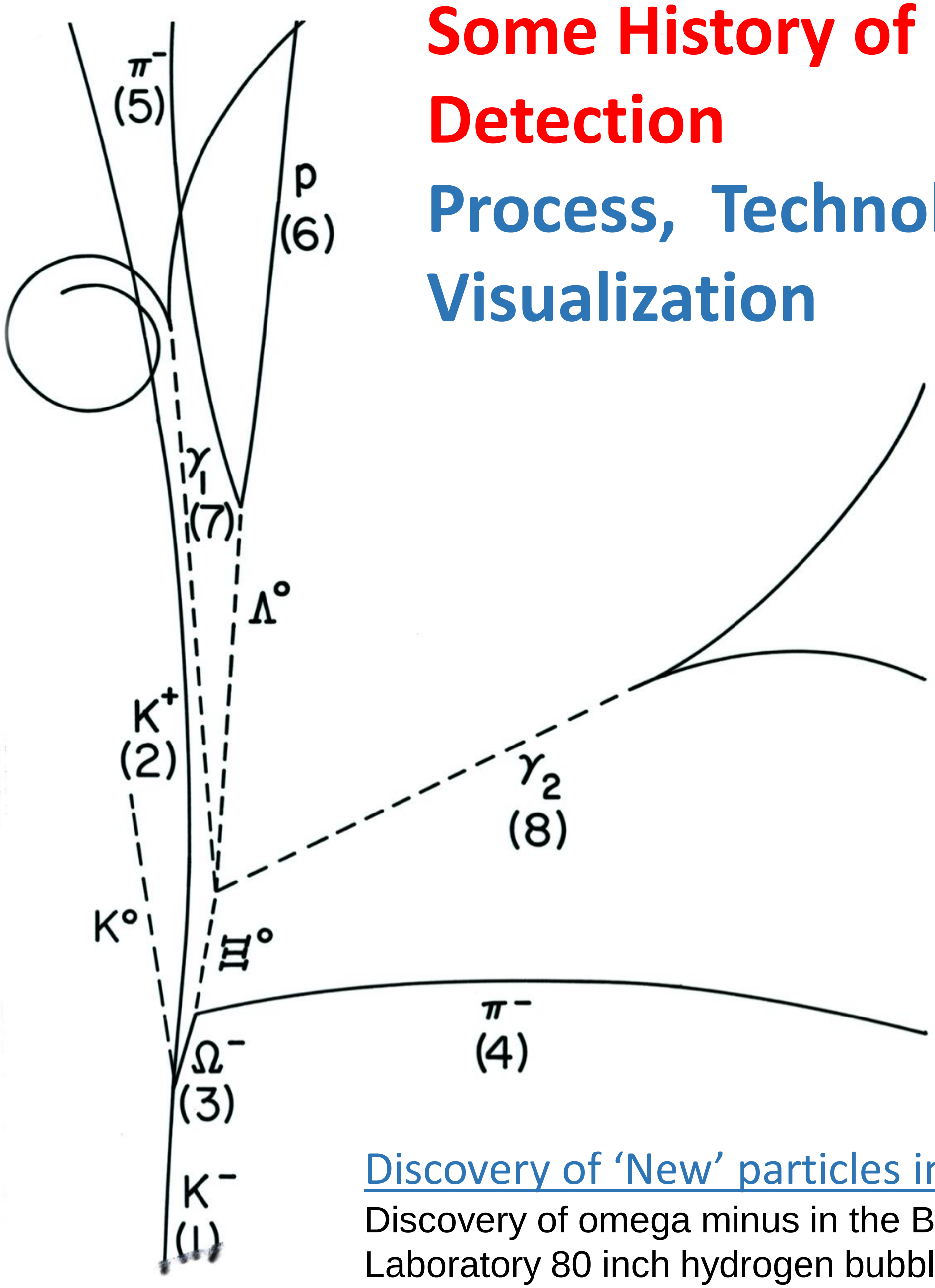


W. Riegler/CERN

Some History of Particle Detection

Process, Technology and Visualization

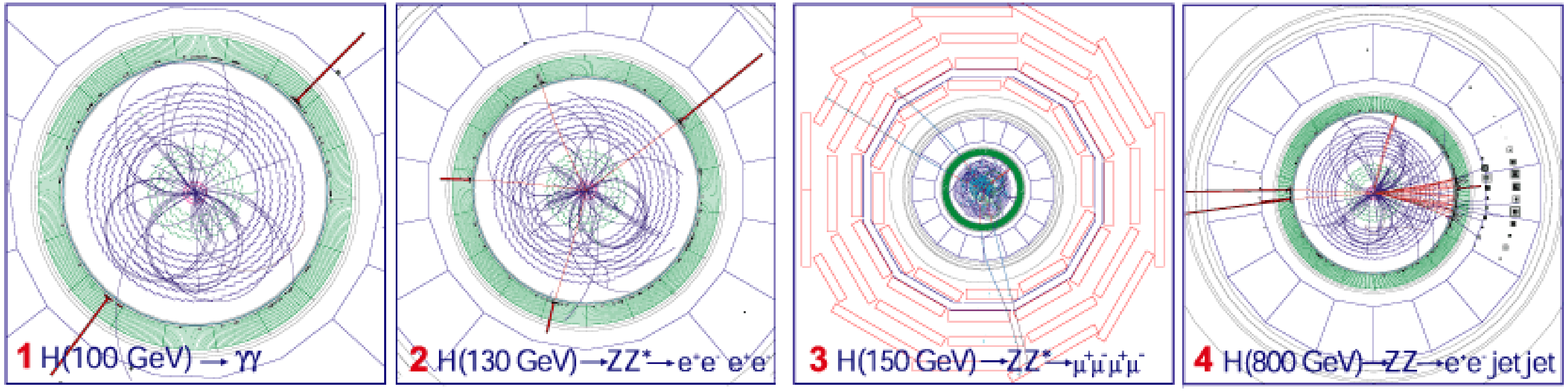




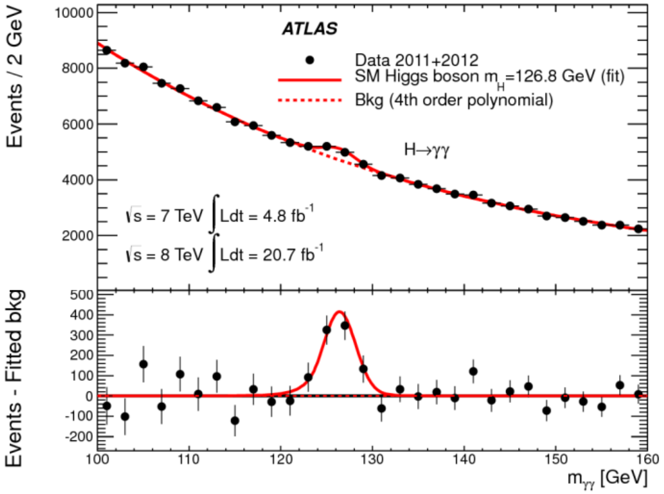
Discovery of 'New' particles in 1964

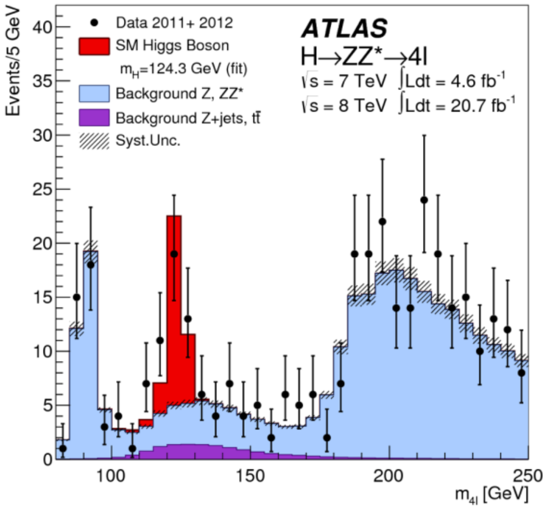
Discovery of omega minus in the Brookhaven National Laboratory 80 inch hydrogen bubble chamber in 1964. Discovery claimed by a single event – 'background free'

Simulated Higgs Boson at CMS



Particles are typically seen as an excess of events above an irreducible (i.e. indistinguishable) background.





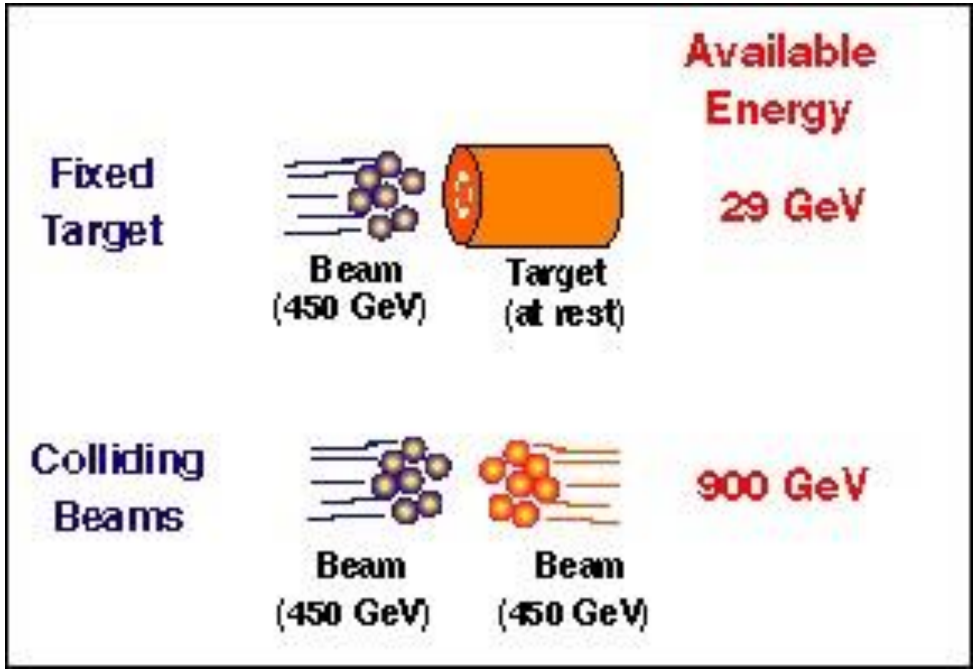
Fixed Target versus Collider

The collider is the most efficient way to get the max usable energy:

$$(E_{cm})^2 = s = 2E_1E_2\{1 + \sqrt{[1-(m_1/E_1)^2][1-(m_2/E_2)^2]}\} + m_1^2 + m_2^2$$

collider with $m_1 = m_2 = m$ et $E_1 = E_2 = E$ $\qquad \sqrt{s} = 2E$

fixed target of mass m_2 $\qquad \sqrt{s} \cong \sqrt{2m_2E_1}$



W. Riegler/CERN

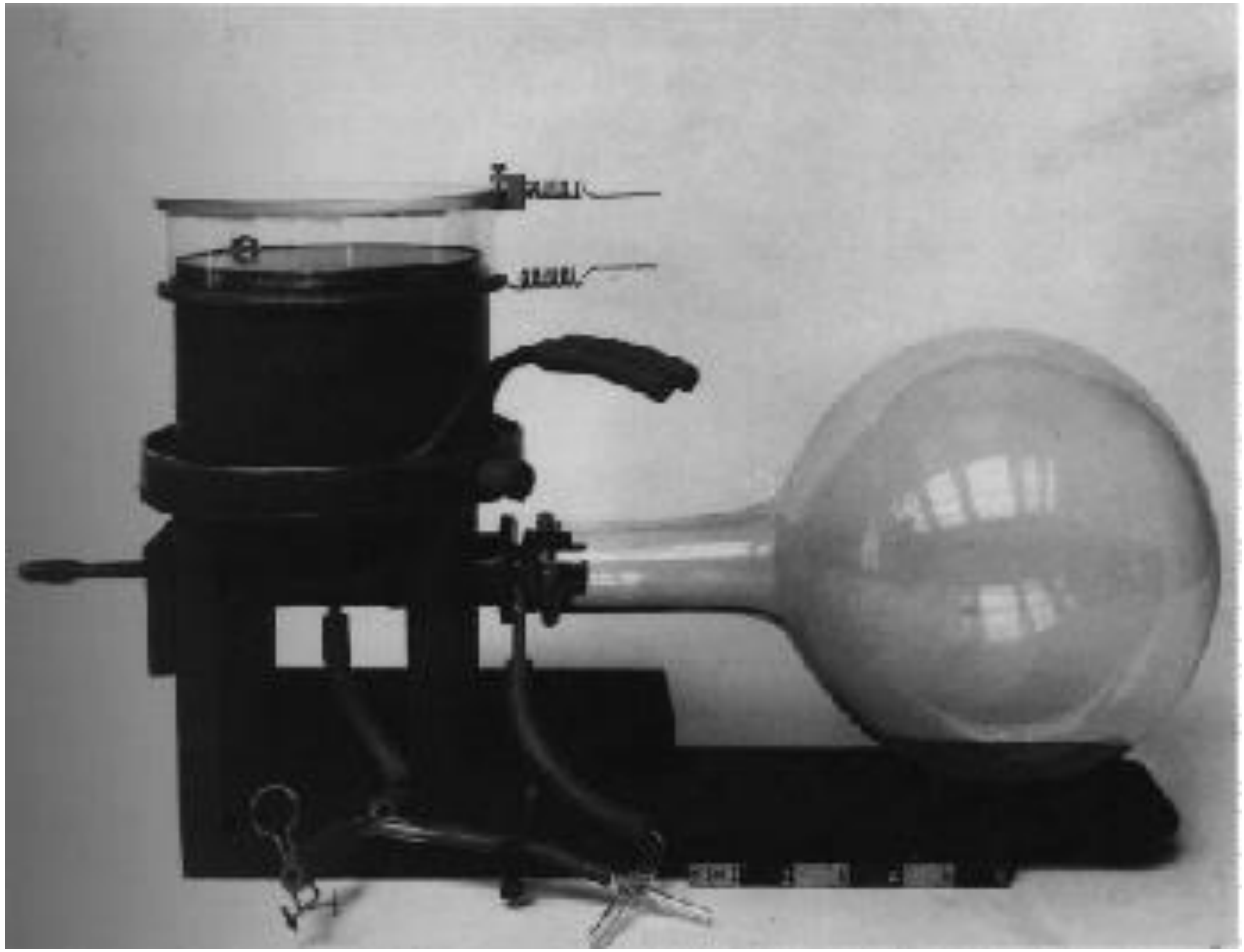
There are many experiments where it is not the maximum energy, but the maximum particle rate that counts:

Very rare decays e.g. NA61

Intense neutrino beams e.g. CNGS

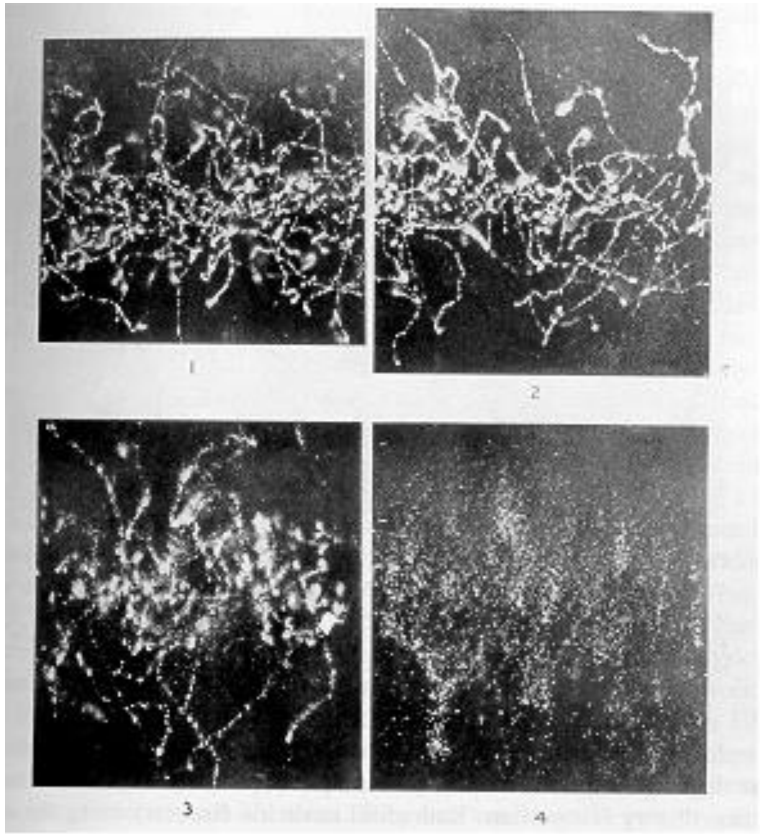
…

Cloud Chamber



Wilson Cloud Chamber 1911

Cloud Chamber



X-rays, Wilson 1912

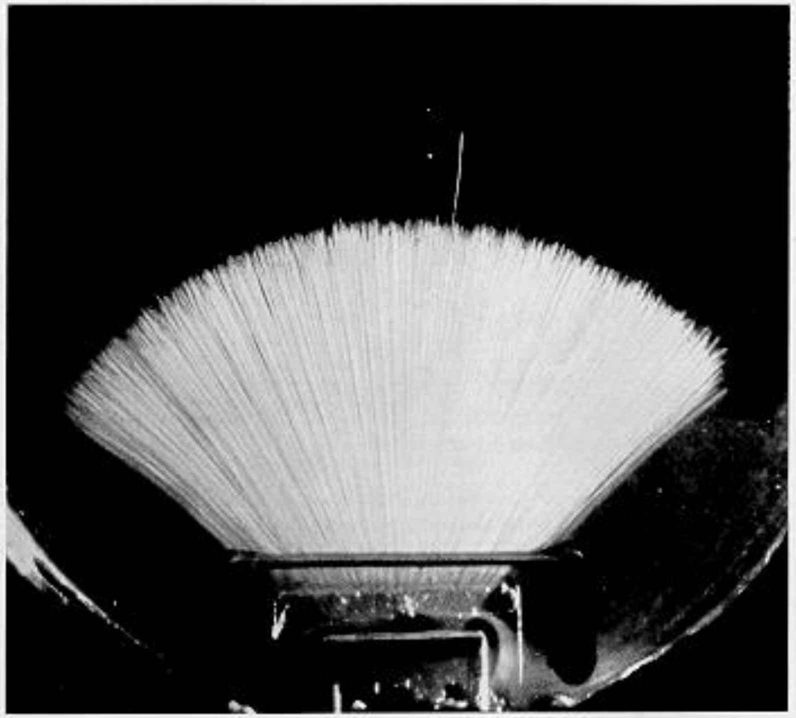
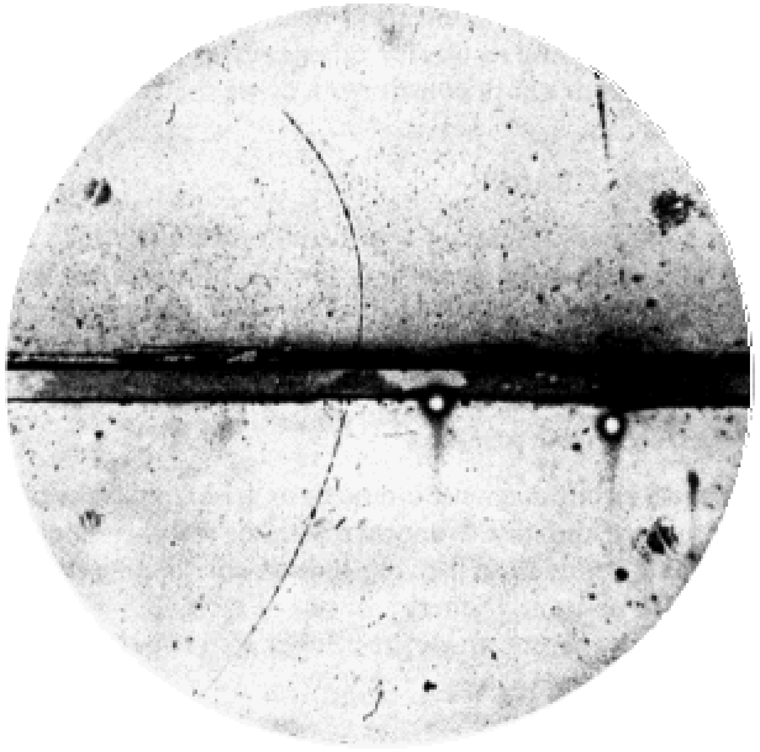


Fig. 13. K. Philipp, Naturwiss. 14, 1203 (1926).

Alphas, Philipp 1926

Cloud Chamber

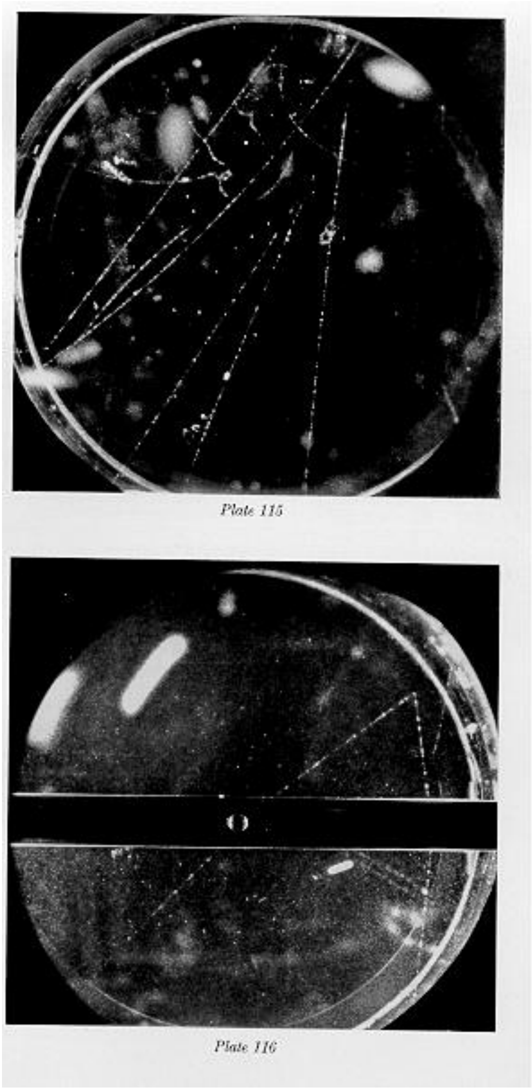


Positron discovery,
Carl Andersen 1933

Magnetic field 15000 Gauss, chamber diameter 15cm. A 63 MeV positron passes through a 6mm lead plate, leaving the plate with energy 23MeV.

The ionization of the particle, and its behaviour in passing through the foil are the same as those of an electron.

Cloud Chamber



Rochester and Wilson

Particle momenta are measured by the bending in the magnetic field.

‘ … The V0 particle originates in a nuclear Interaction outside the chamber and decays after traversing about one third of the chamber.
The momenta of the secondary particles are 1.6+-0.3 BeV/c and the angle between them is 12 degrees … ‘

By looking at the specific ionization one can try to identify the particles and by assuming a two body decay on can find the mass of the V0.

‘… if the negative particle is a negative proton, the mass of the V0 particle is 2200 m, if it is a Pi or Mu Meson the V0 particle mass becomes about 1000m …’

Bubble Chamber

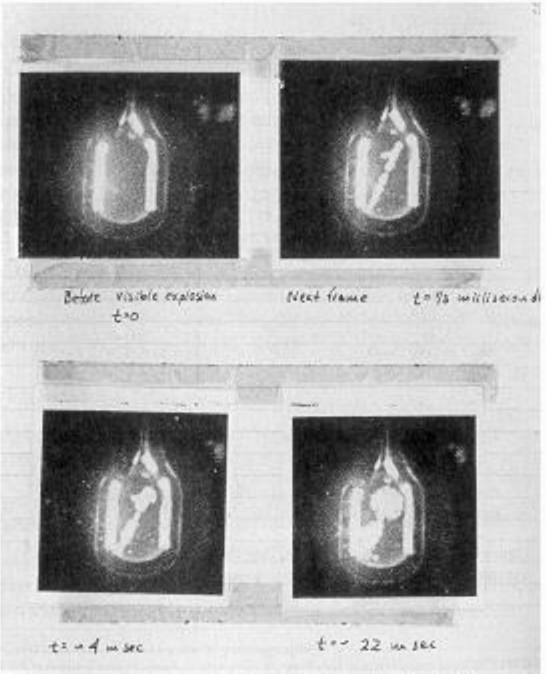


Figure 5.5 Bubble chamber movies (1952). Glaser first filmed distinct track

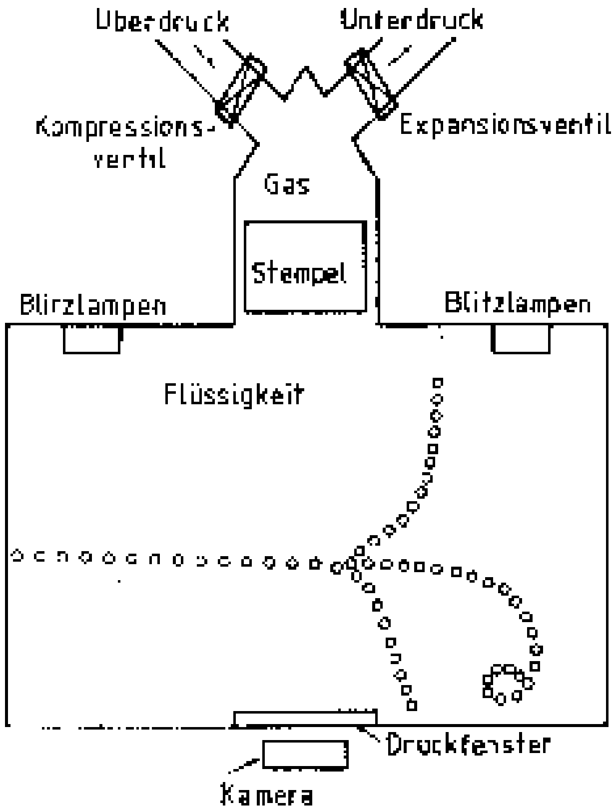
In the early 1950ies Donald Glaser tried to build on the cloud chamber analogy:

Instead of supersaturating a gas with a vapor one would superheat a liquid. A particle depositing energy along it's path would then make the liquid boil and form bubbles along the track.

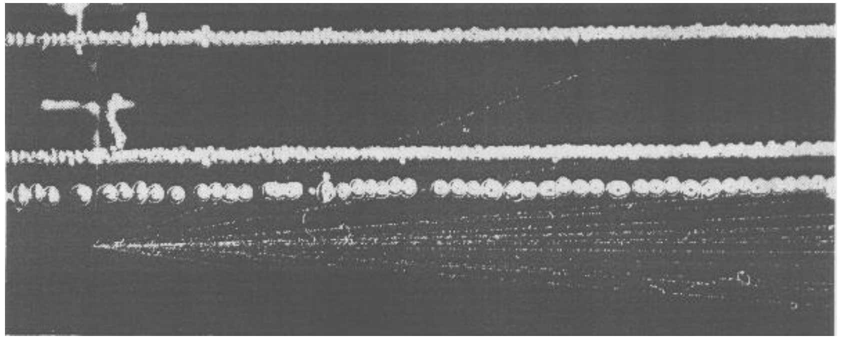
In 1952 Glaser photographed first Bubble chamber tracks. Luis Alvarez was one of the main proponents of the bubble chamber.

The size of the chambers grew quickly
1954: 2.5''(6.4cm)
1954: 4'' (10cm)
1956: 10'' (25cm)
1959: 72'' (183cm)
1963: 80'' (203cm)
1973: 370cm

Bubble Chamber



'old bubbles'

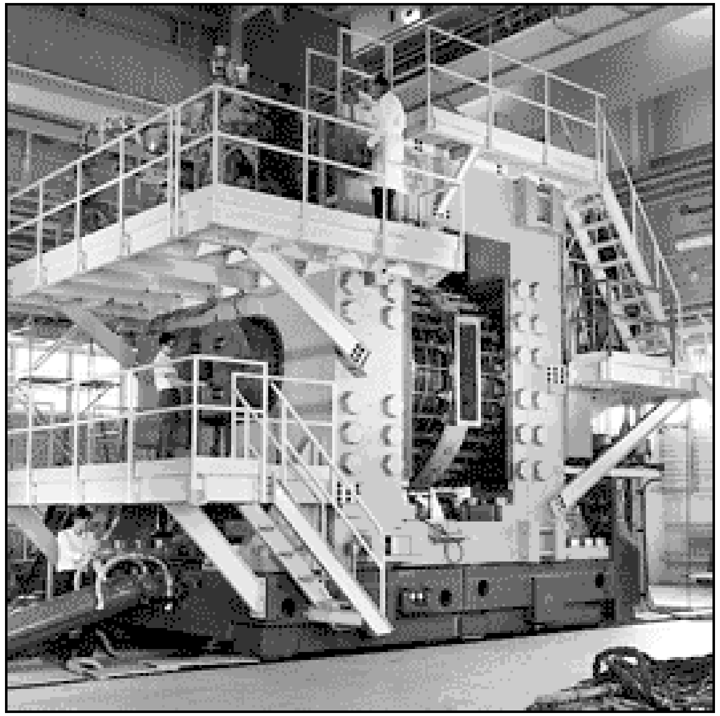


'new bubbles'

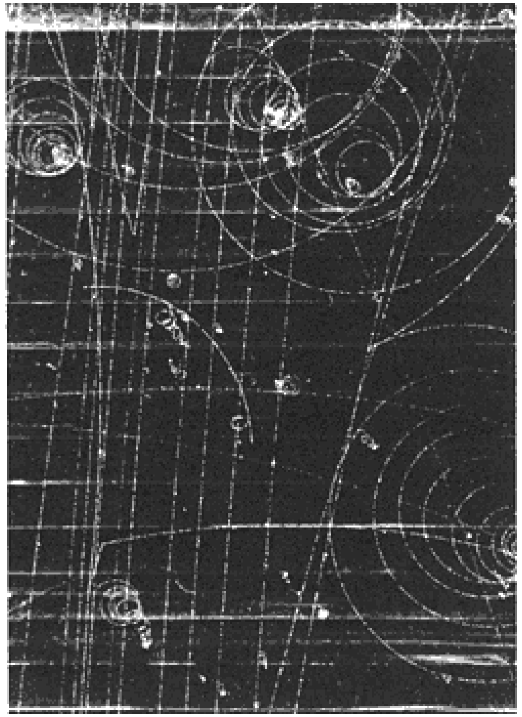
Unlike the Cloud Chamber, the Bubble Chamber could not be triggered, i.e. the bubble chamber had to be already in the superheated state when the particle was entering. It was therefore not useful for Cosmic Ray Physics, but as in the 50ies particle physics moved to accelerators it was possible to synchronize the chamber compression with the arrival of the beam.

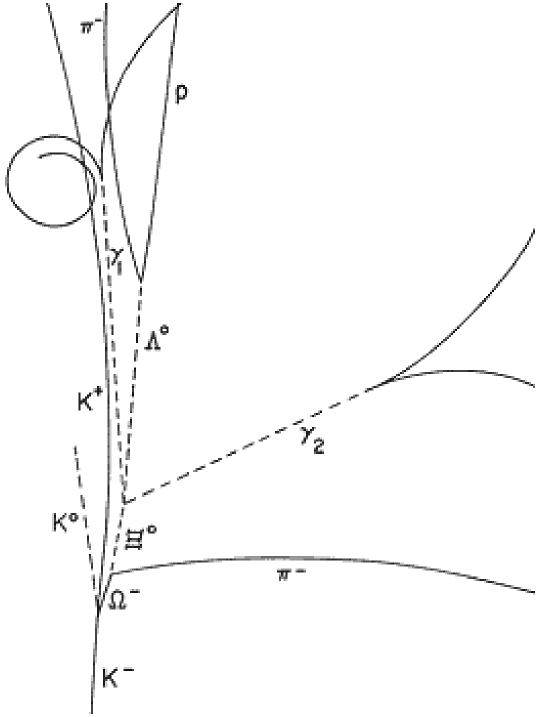
For data analysis one had to look through millions of pictures.

Bubble Chamber



The 80-inch Bubble Chamber





BNL, First Pictures 1963, 0.03s cycle

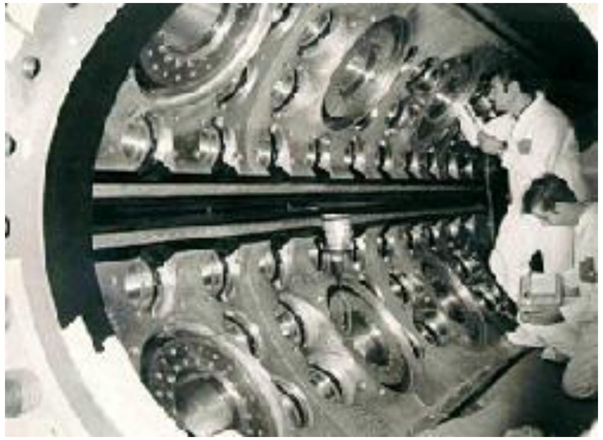
Discovery of the Ω^- in 1964

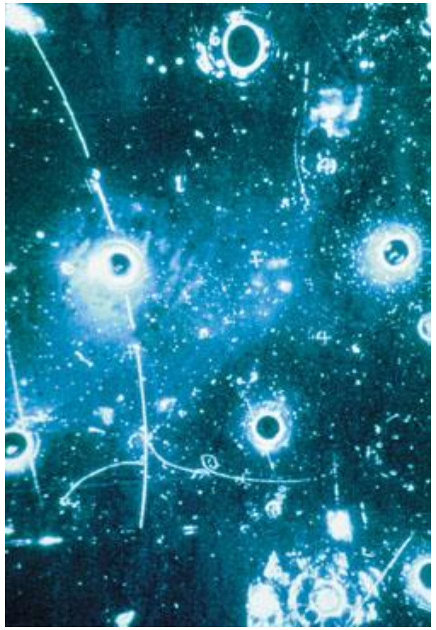
Bubble Chamber

Gargamelle, a very large heavy-liquid (freon) chamber constructed at Ecole Polytechnique in Paris, came to CERN in 1970.
It was 2 m in diameter, 4 m long and filled with Freon at 20 atm.

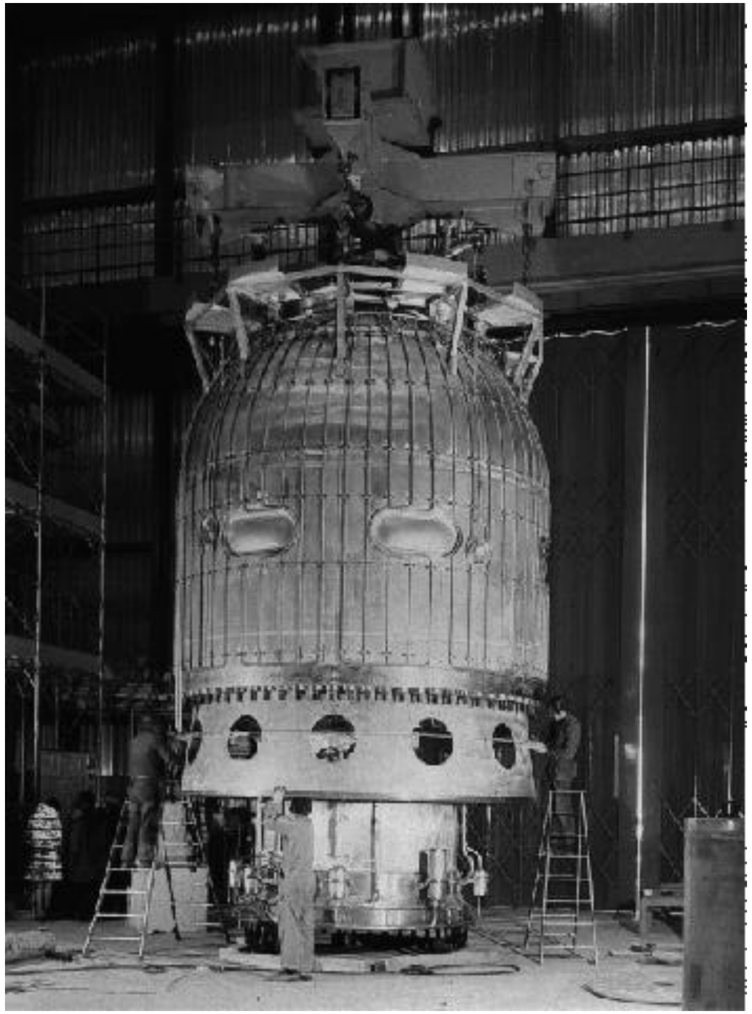
With a conventional magnet producing a field of almost 2 T, Gargamelle in 1973 was the tool that permitted the discovery of neutral currents.

Can be seen outside the Microcosm Exhibition



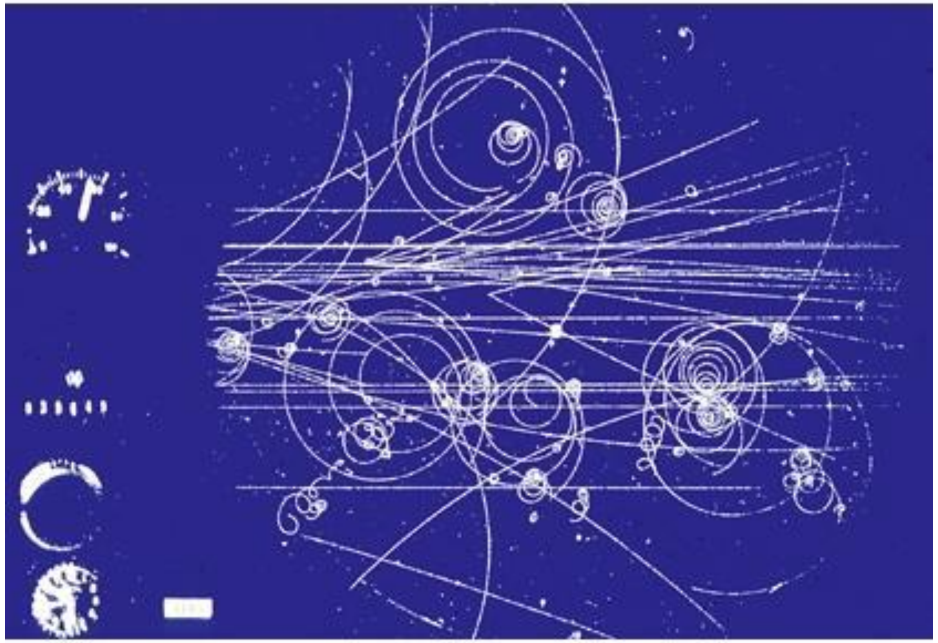


Bubble Chamber



3.7 meter hydrogen bubble chamber at CERN, equipped with the largest superconducting magnet in the world.

During its working life from 1973 to 1984, the "Big European Bubble Chamber" (BEBC) took over 6 million photographs.



Can be seen outside the Microcosm Exhibition

Bubble Chambers

The excellent position (5μm) resolution and the fact that target and detecting volume are the same (H chambers) makes the Bubble chamber almost unbeatable for reconstruction of complex decay modes.

The drawback of the bubble chamber is the low rate capability (a few tens/ second). E.g. LHC 10^9 collisions/s.

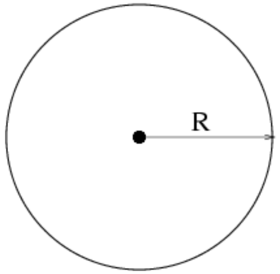
The fact that it cannot be triggered selectively means that every interaction must be photographed.

Analyzing the millions of images by ‘operators’ was a quite laborious task.

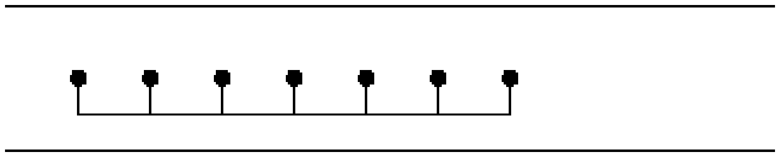
That’s why electronics detectors took over in the 70ties.

Multi Wire Proportional Chamber

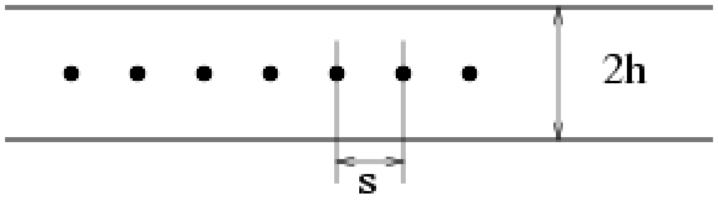
Tube, Geiger- Müller, 1928

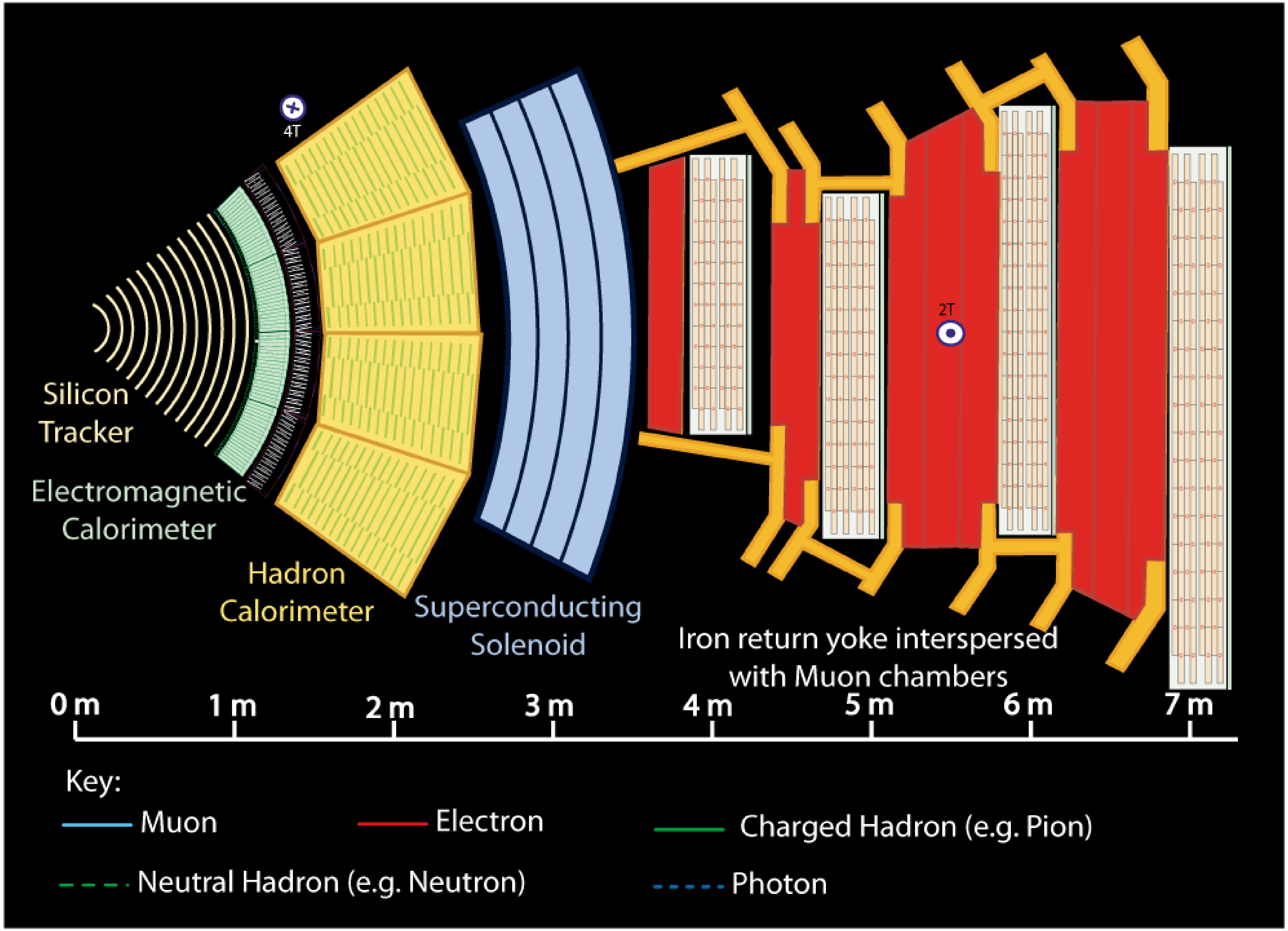


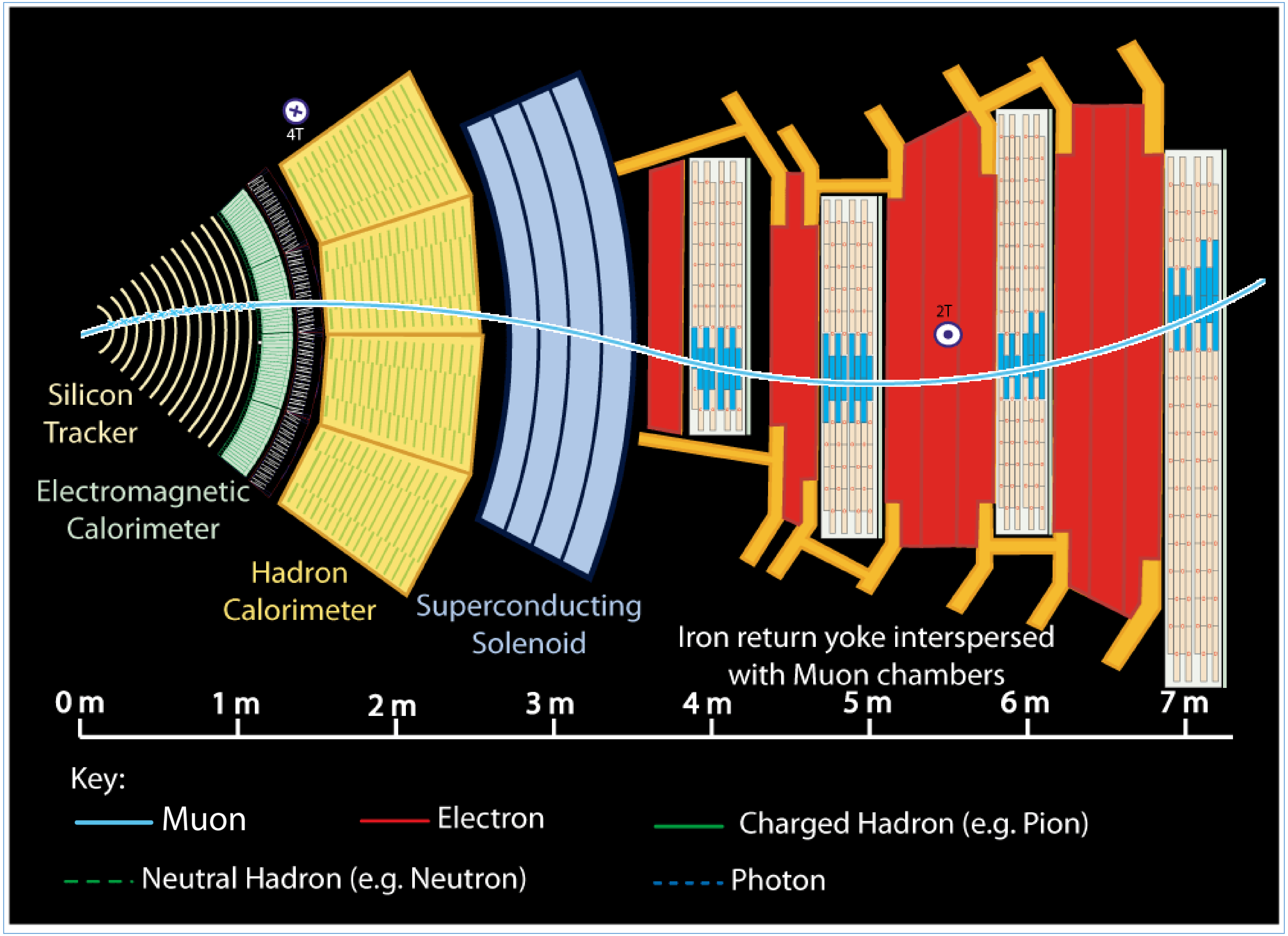
Multi Wire Geometry, in H. Friedmann 1949

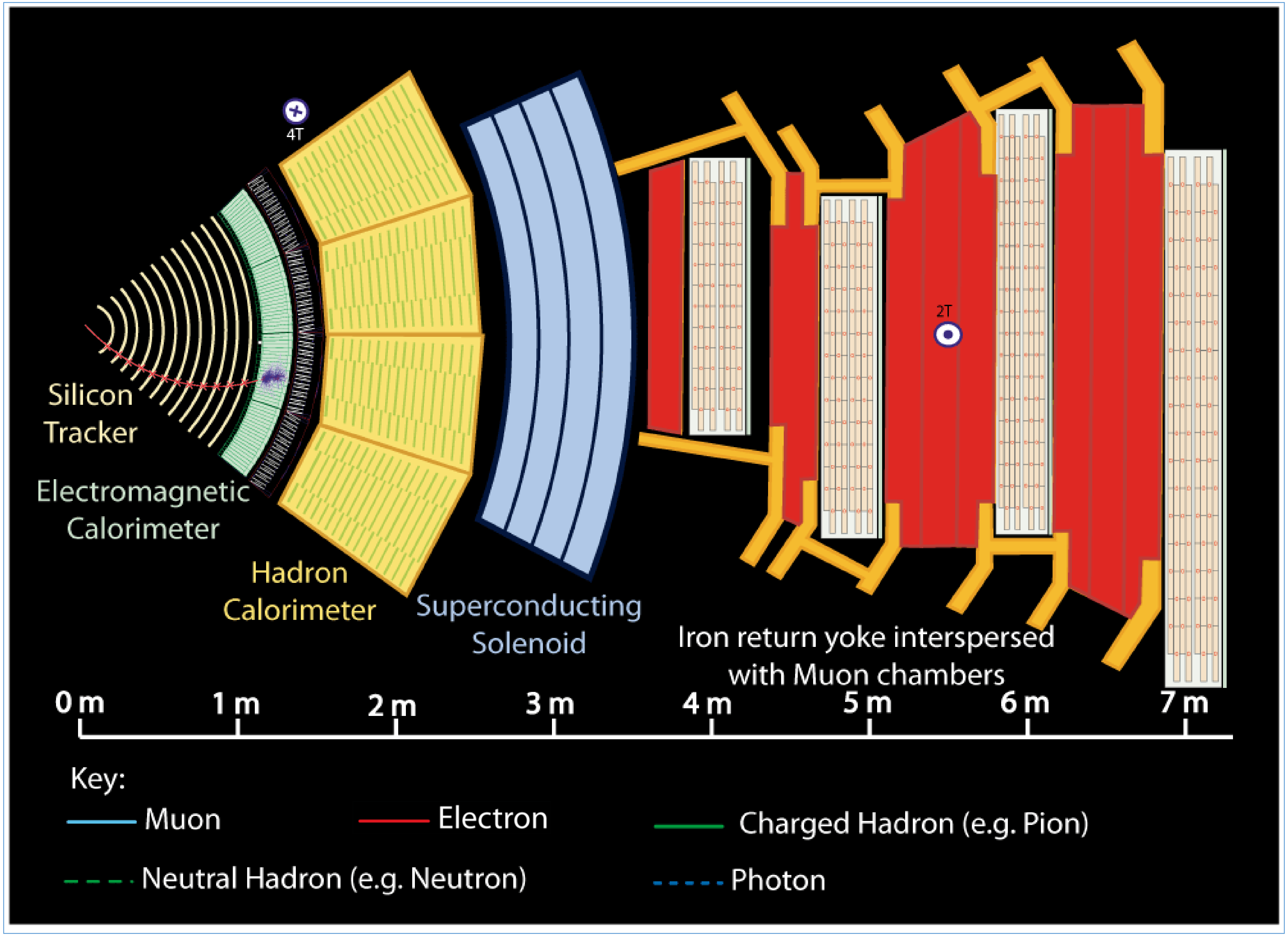


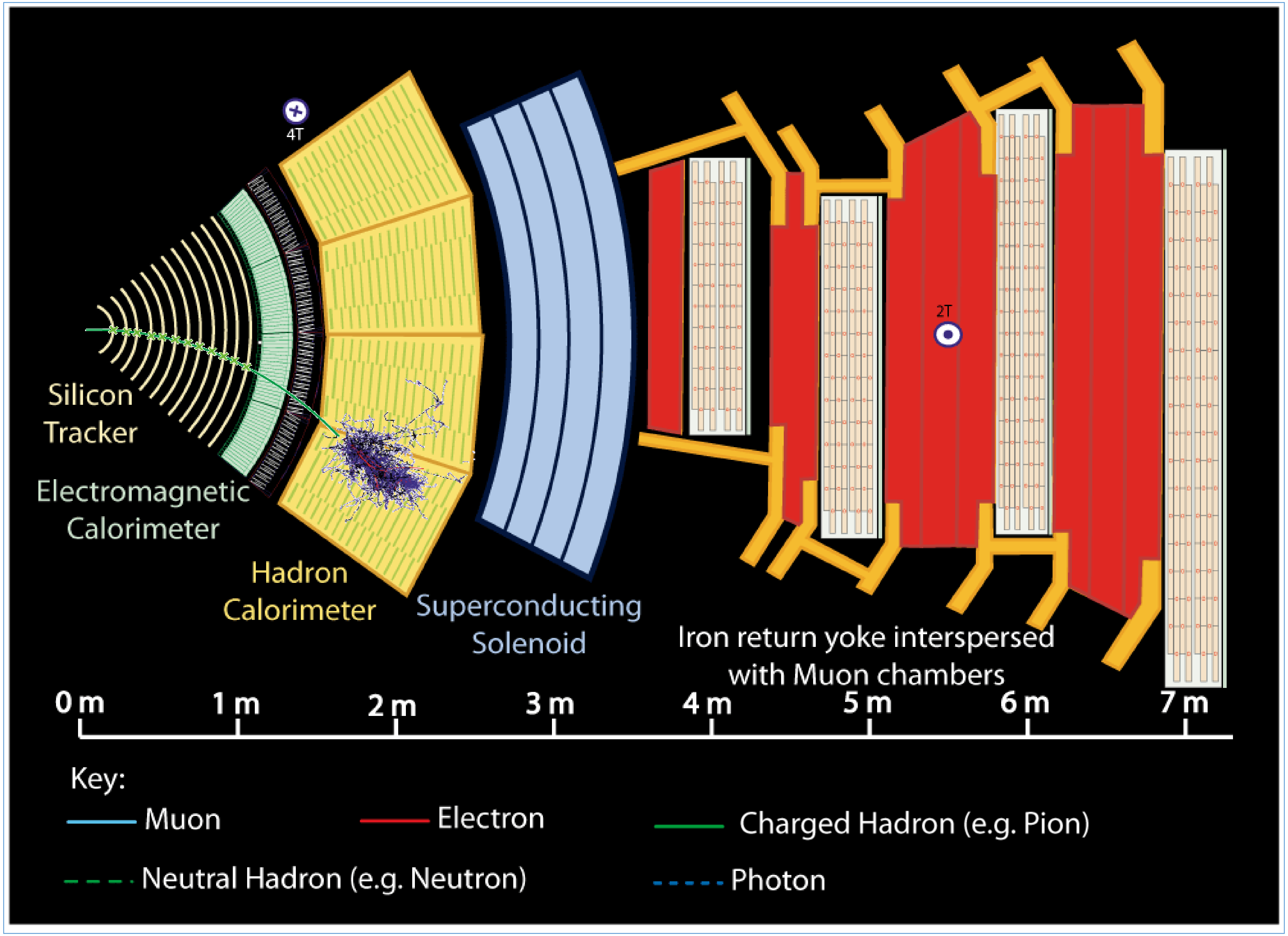
G. Charpak 1968, Multi Wire Proportional Chamber,
readout of individual wires and proportional mode working point.



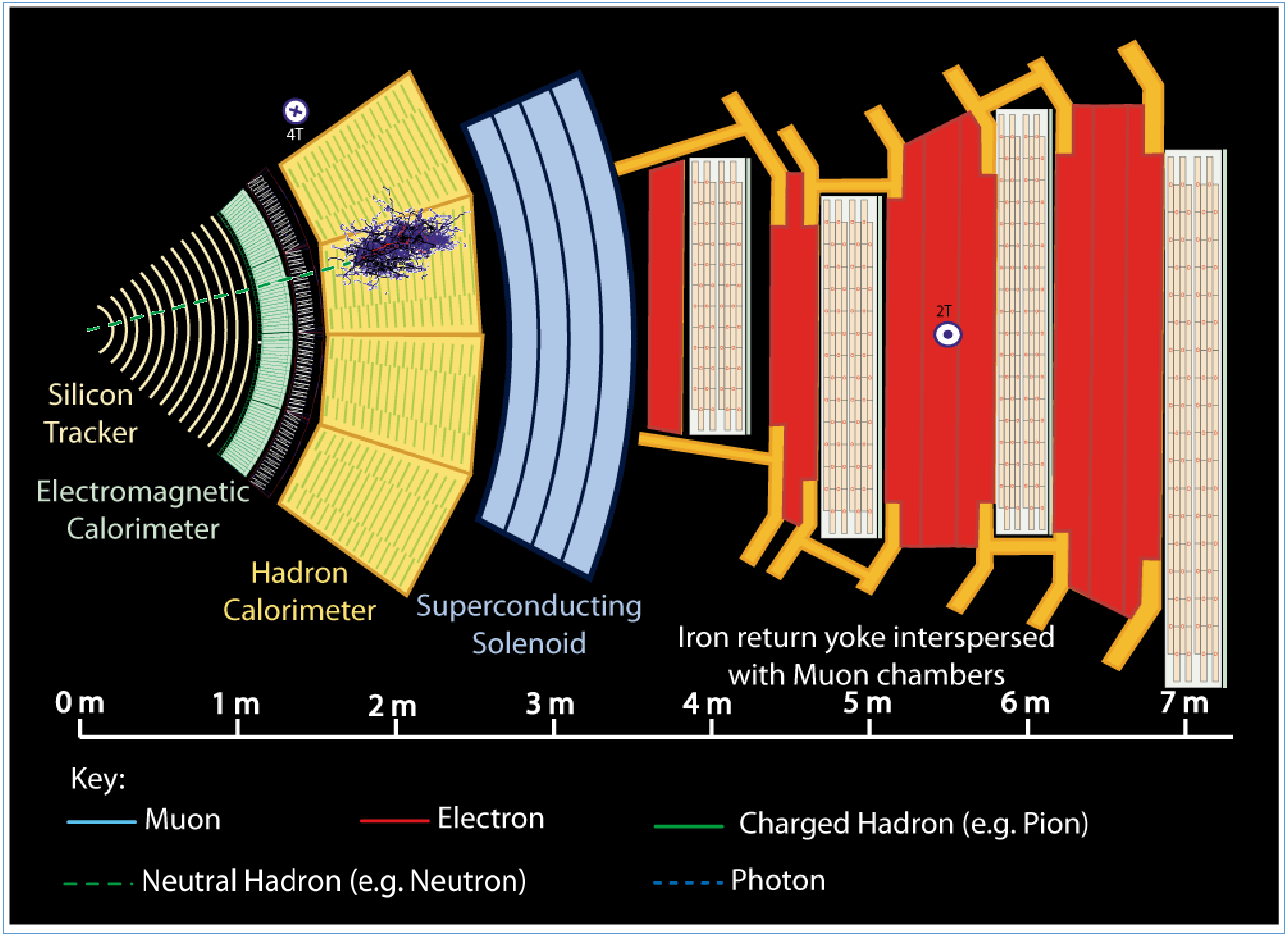

4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon

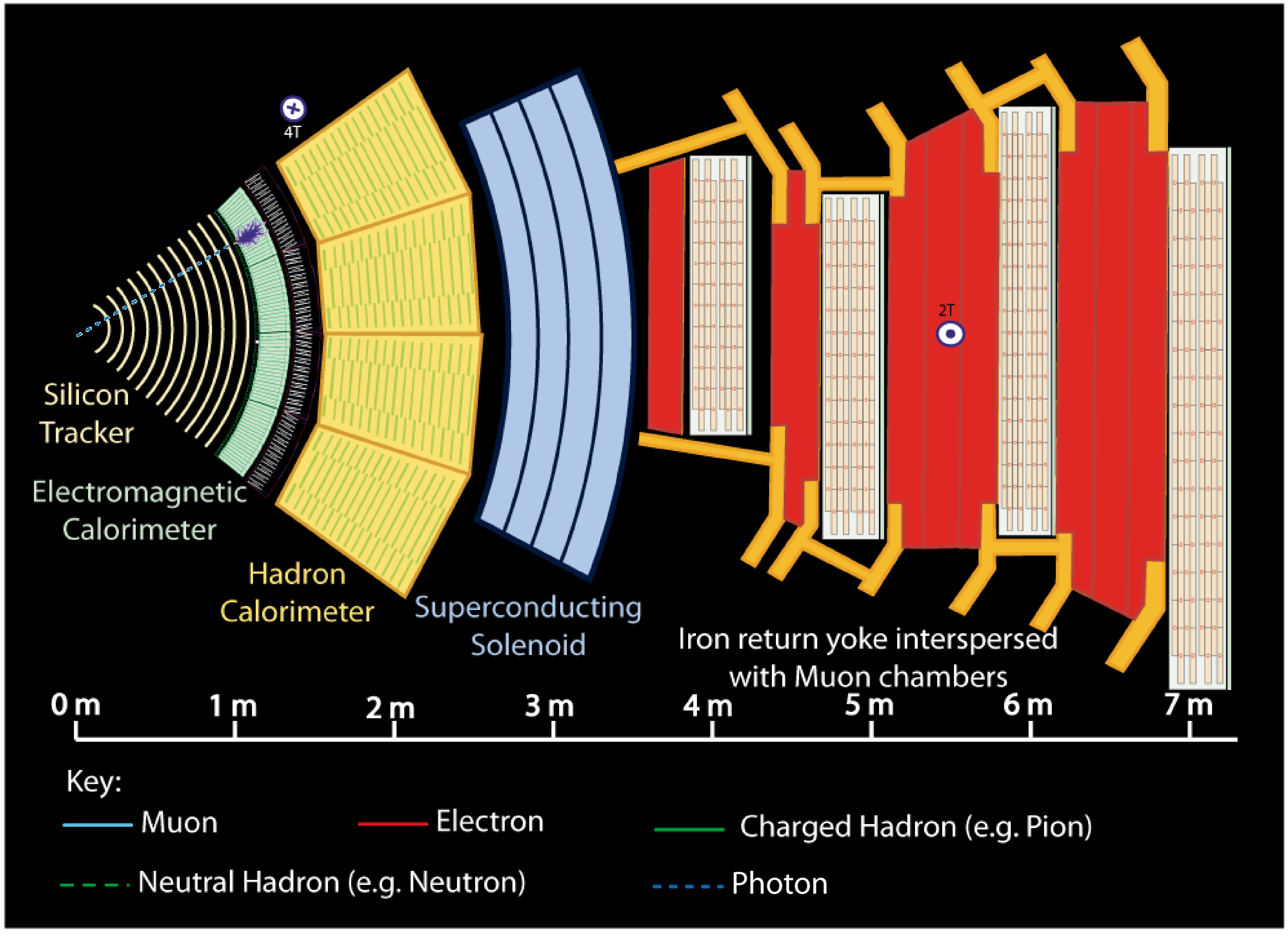

4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon

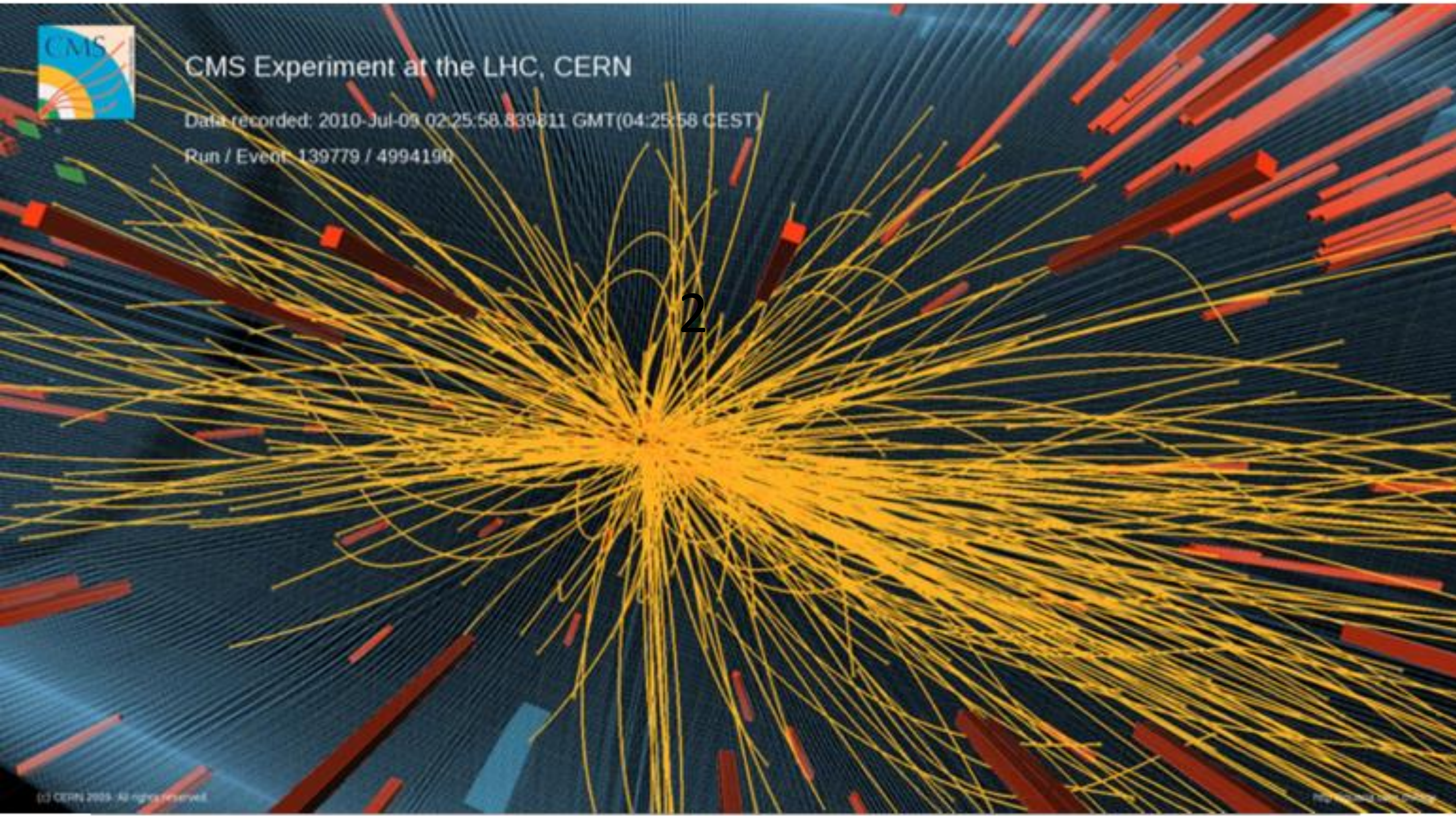

4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon



4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon


4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon


4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon

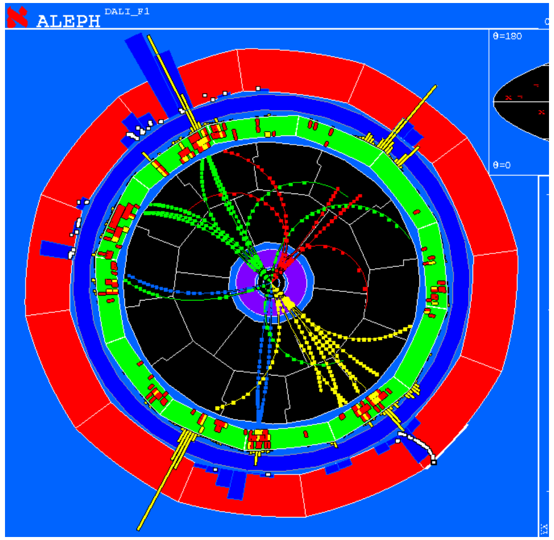

CMS
CMS Experiment at the LHC, CERN
Data recorded: 2010-Jul-09 02:25:58.839811 GMT(04:25:58 CEST)
Run / Event: 139779 / 4994190
2

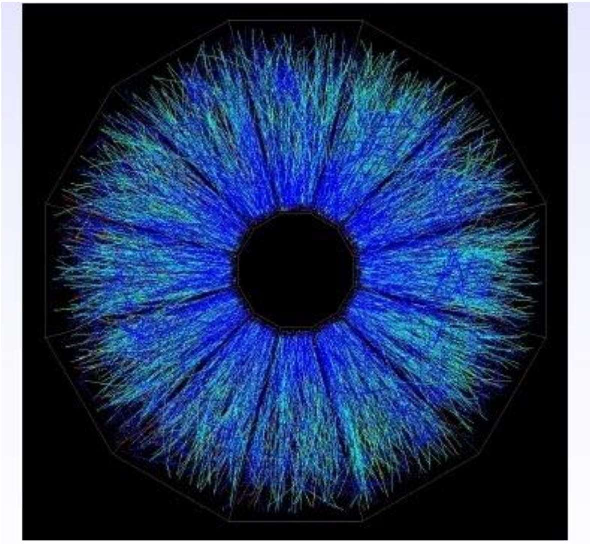
Increasing Multiplicities in Heavy Ion Collisions

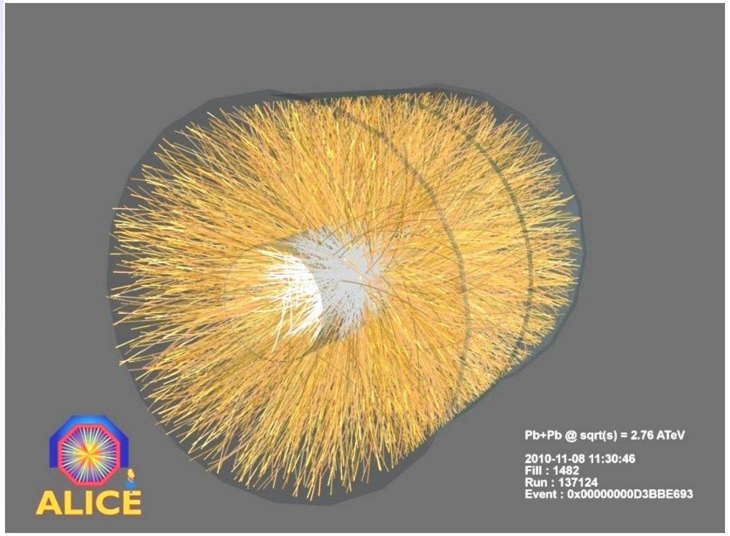
e+ e- collision in the ALEPH Experiment/LEP.

Au+ Au+ collision in the STAR Experiment/RHIC
Up to 2000 tracks

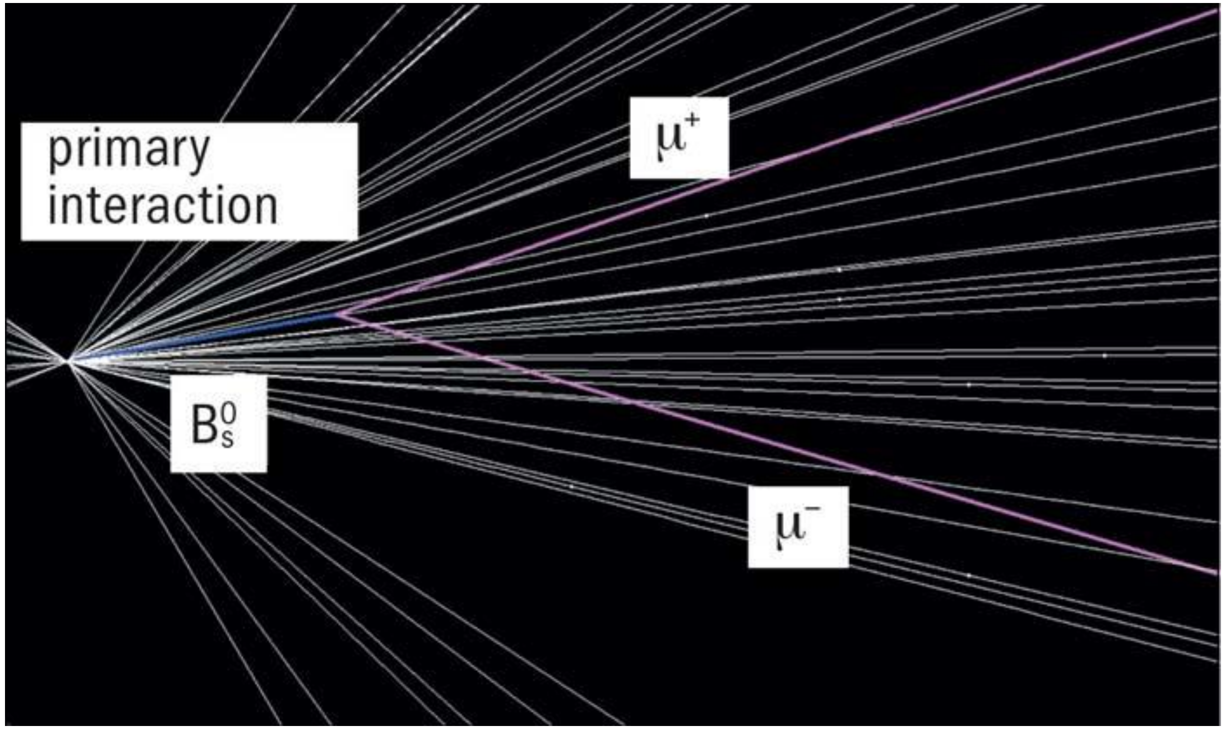
Pb+ Pb+ collision in the ALICE Experiment/LHC
Up to 10 000 tracks/collision

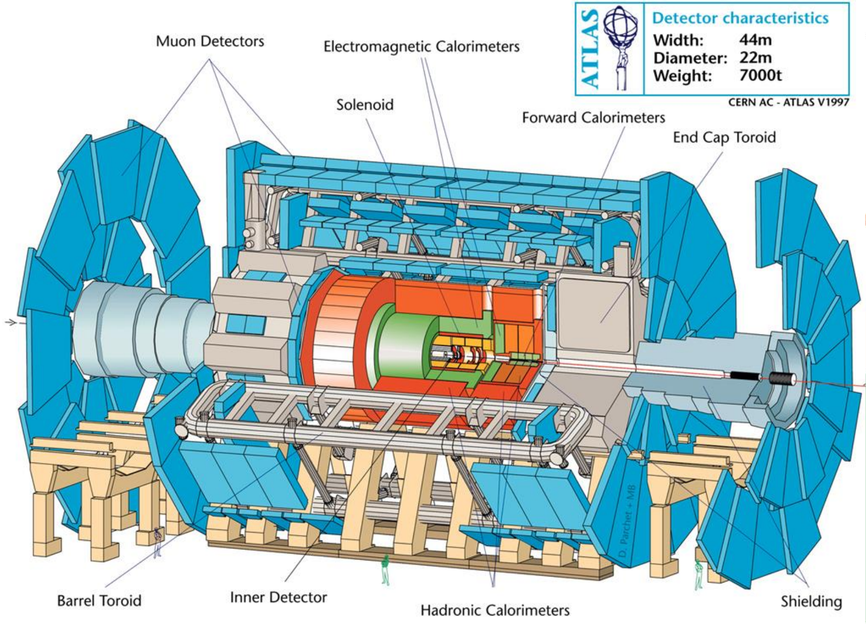


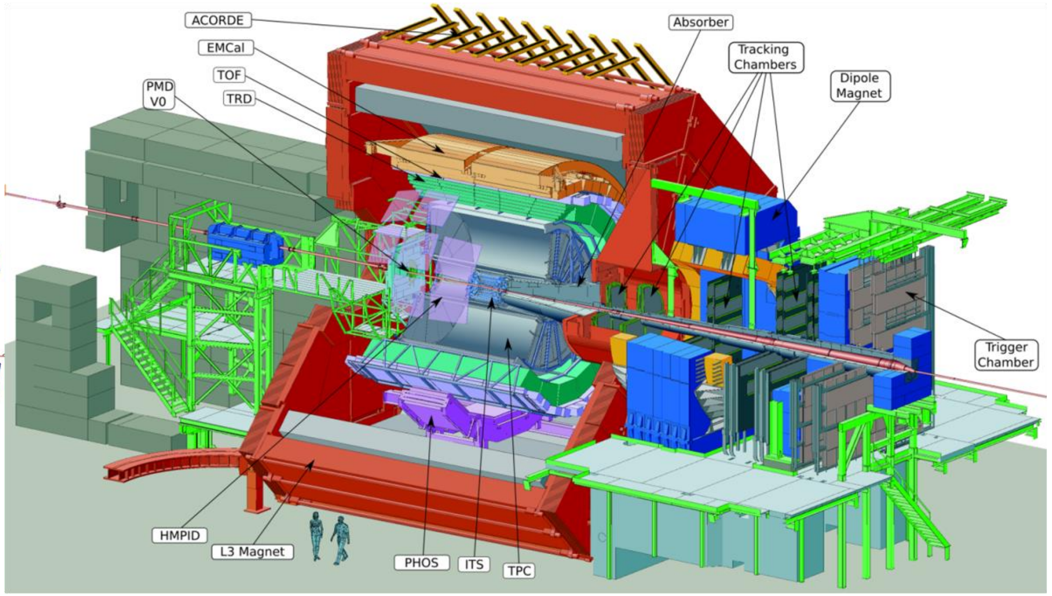


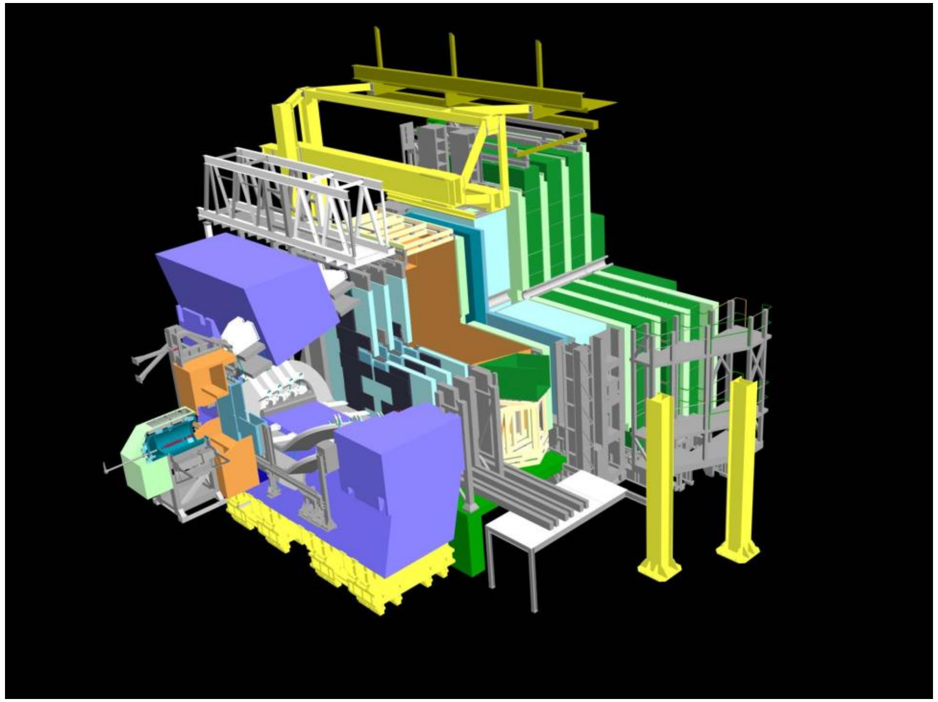


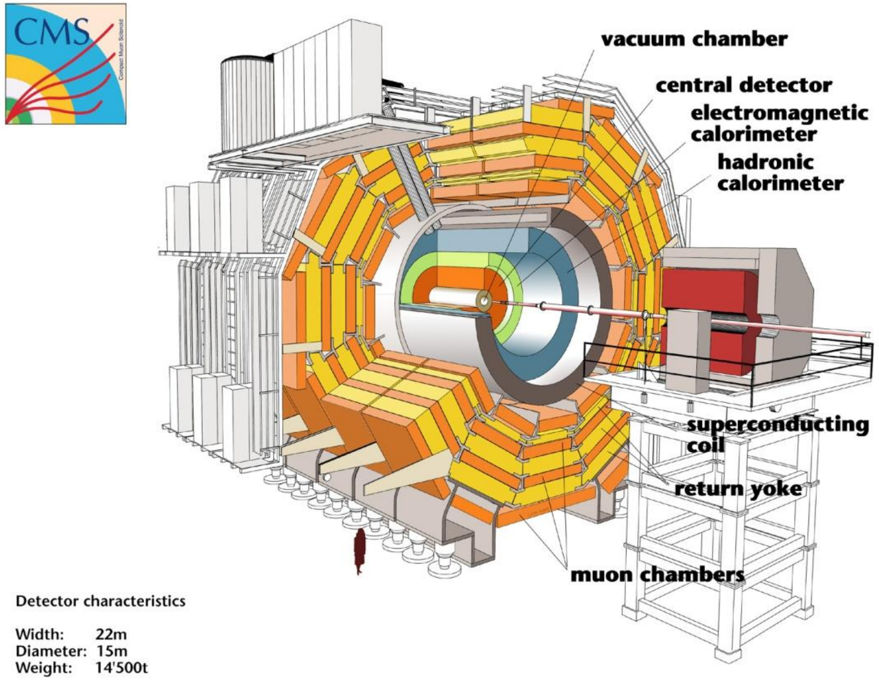
LHCb B decay

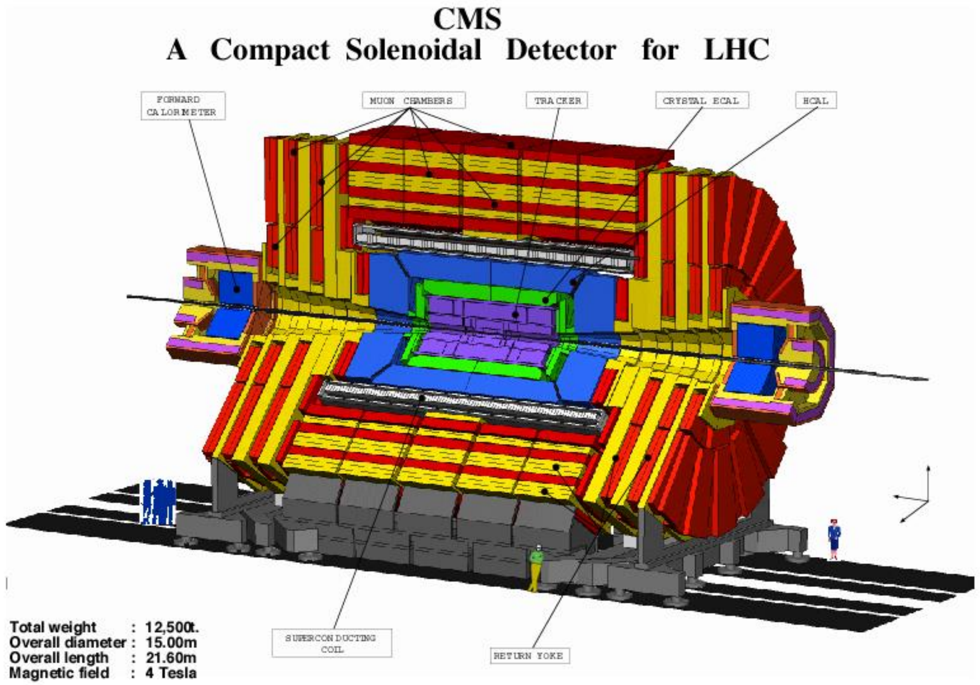


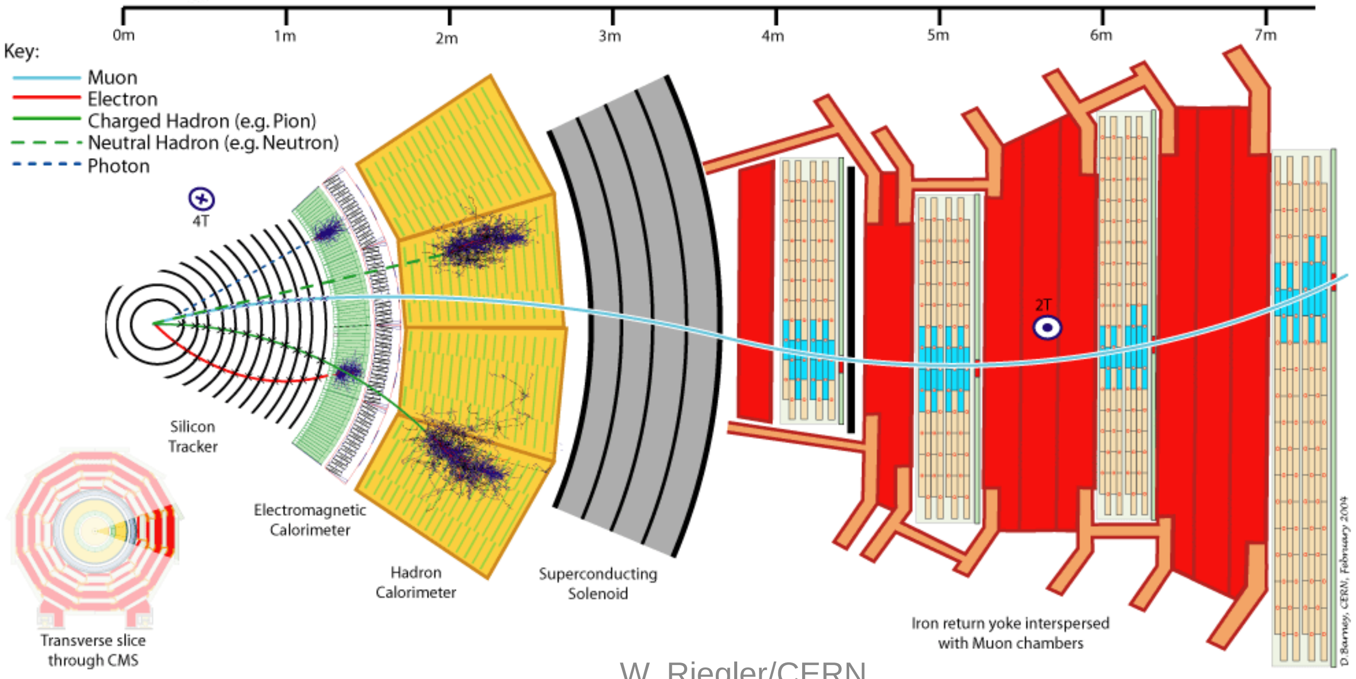

Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
ATLAS
Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding


ACORDE
EMCal
TOF
TRD
PMD
V0
Absorber
Tracking Chambers
Dipole Magnet
Trigger Chamber
HMPID
L3 Magnet
PHOS
ITS
TPC




CMS
vacuum chamber
central detector
electromagnetic calorimeter
hadronic calorimeter
superconducting coil
return yoke
muon chambers
Detector characteristics
Width: 22m
Diameter: 15m
Weight: 14'500t



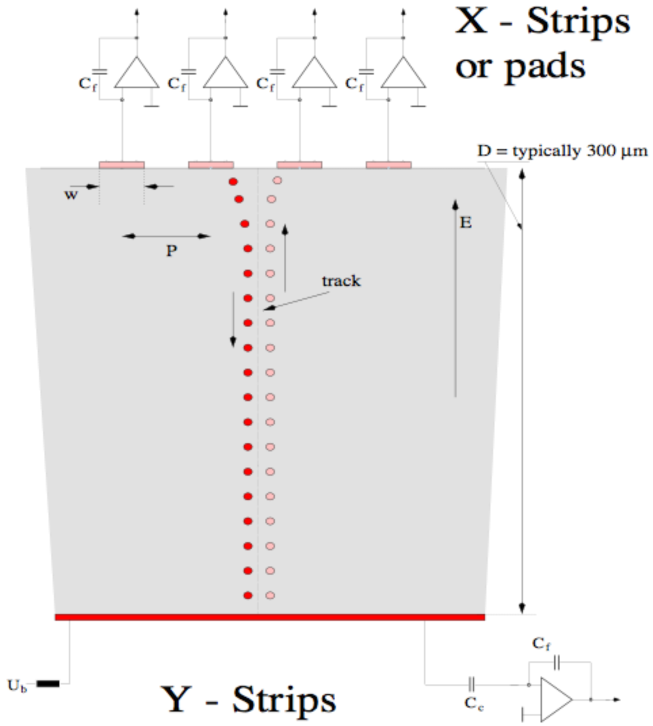


W. Riegler/CERN

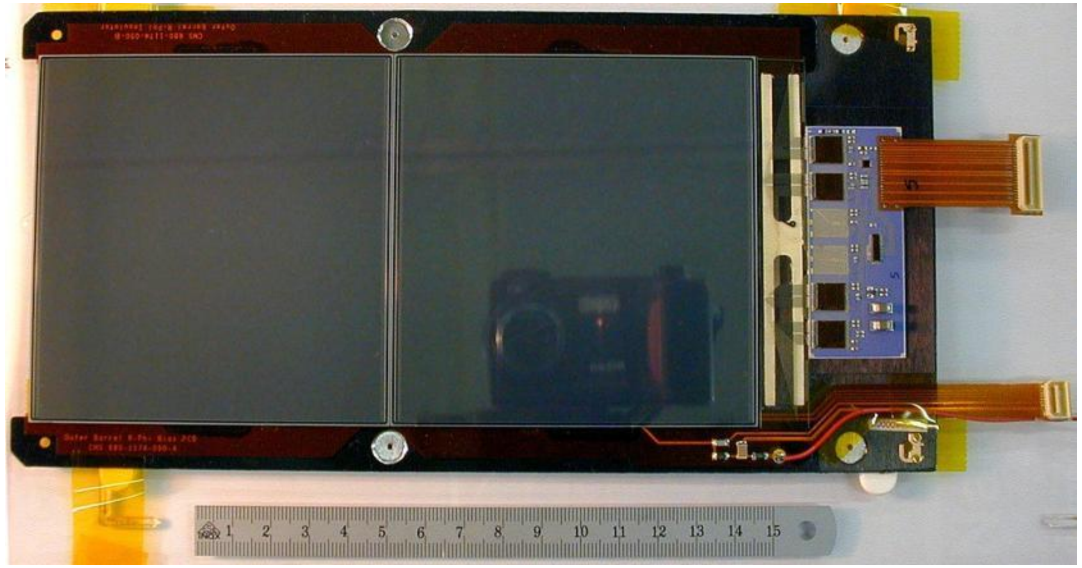
Silicon Strip Detectors

Every electrode is connected to an amplifier →
Highly integrated readout electronics.

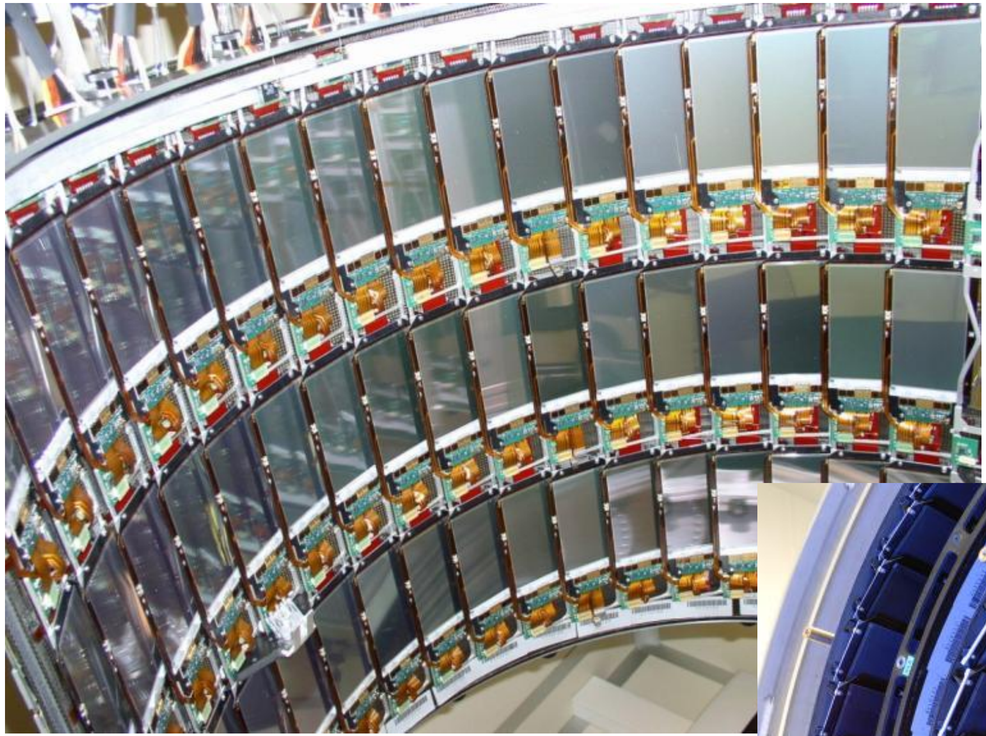
Two dimensional readout is possible.

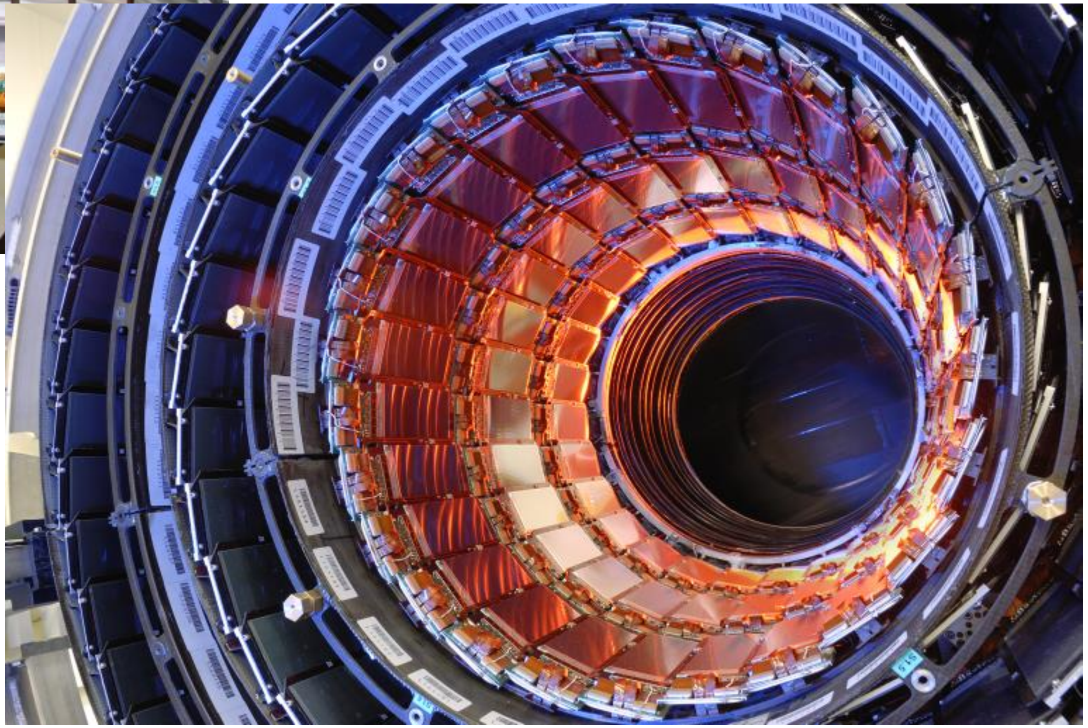


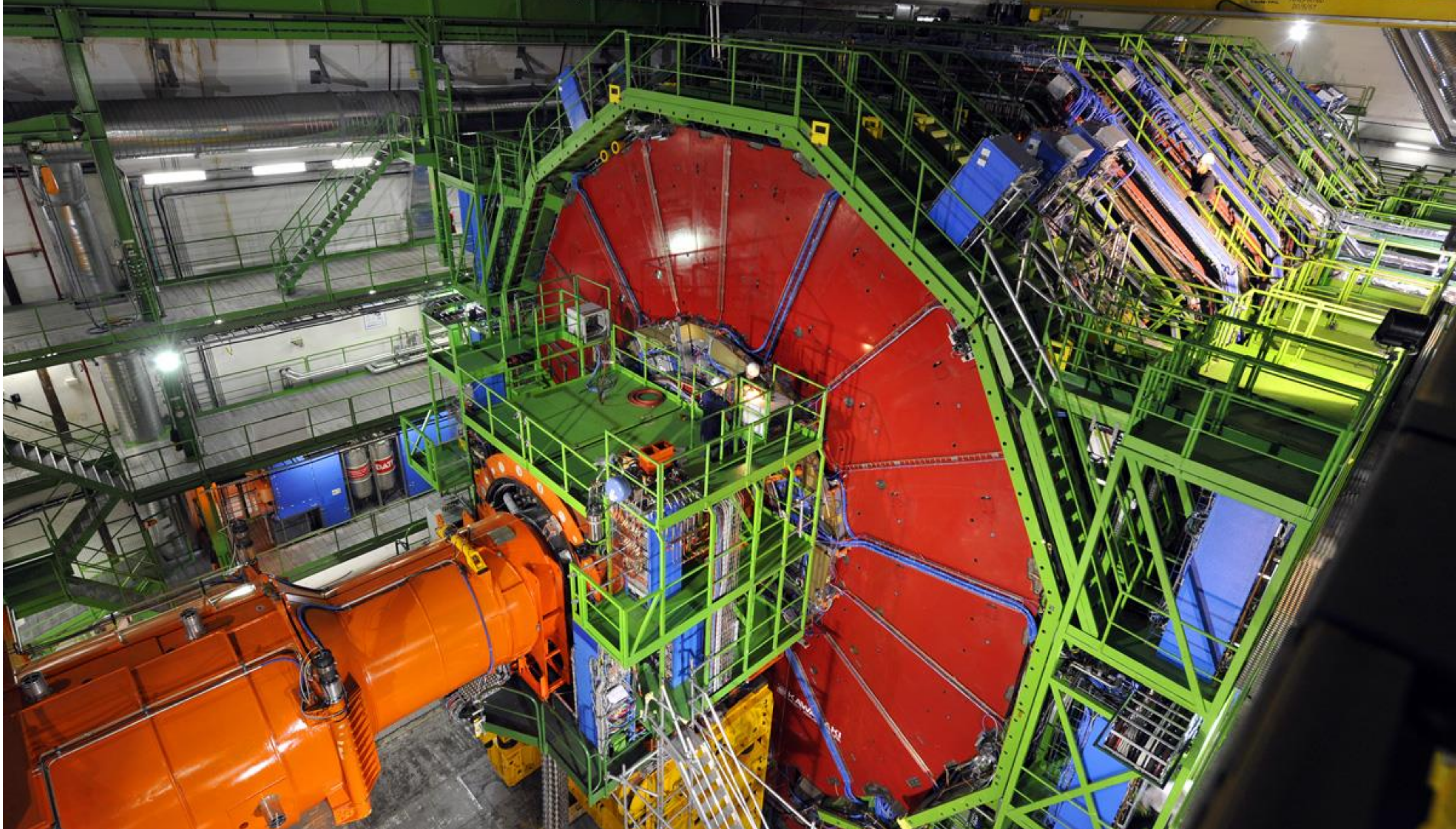
CMS Outer Barrel Module

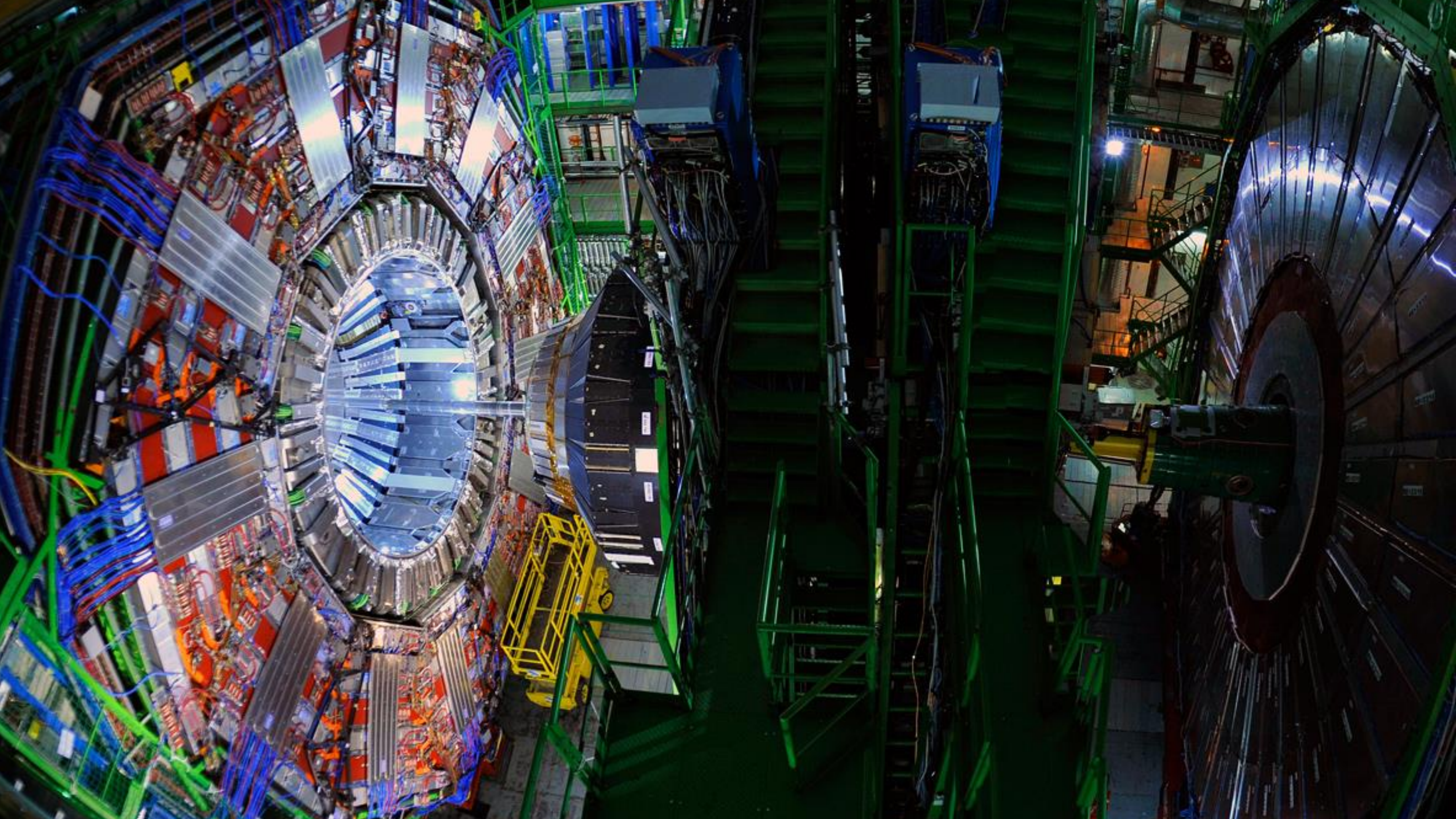


Silicon Strip Detectors

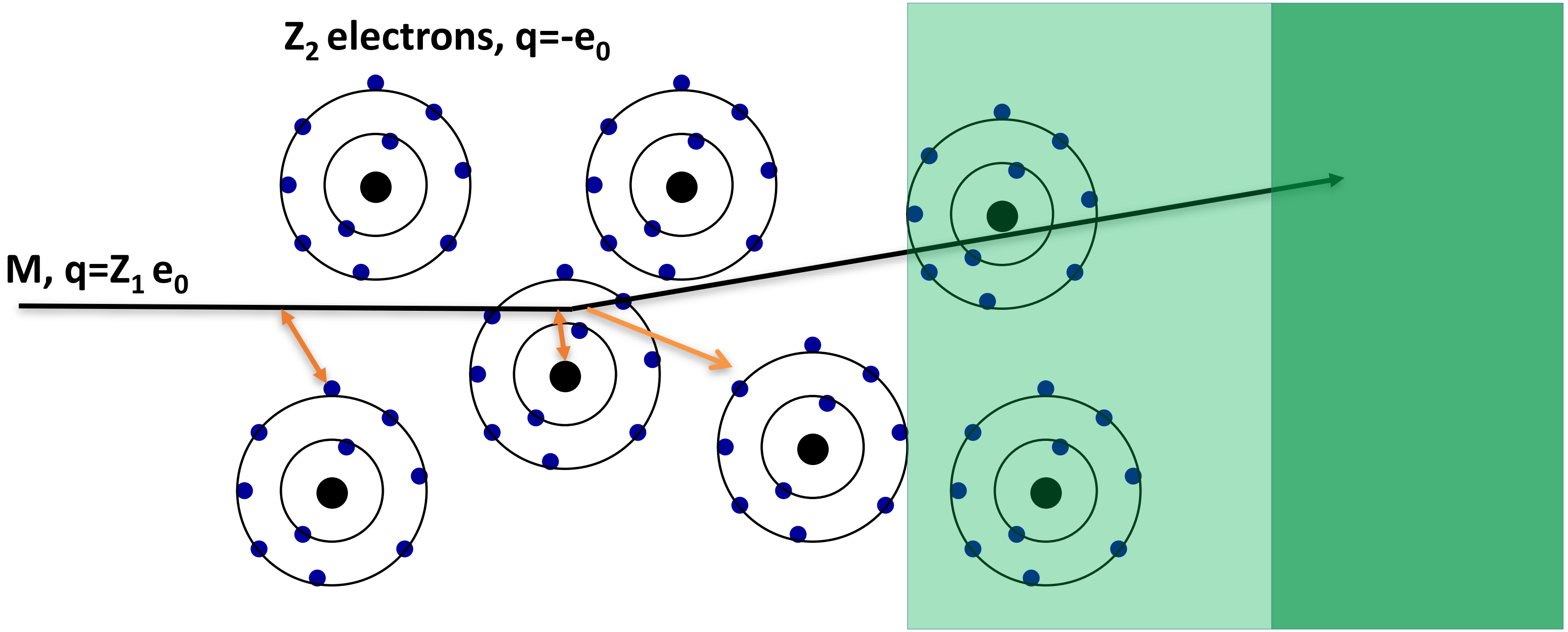








Electromagnetic Interaction of Particles with Matter

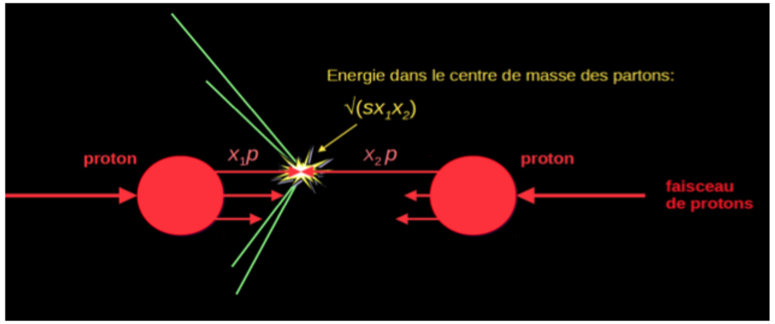


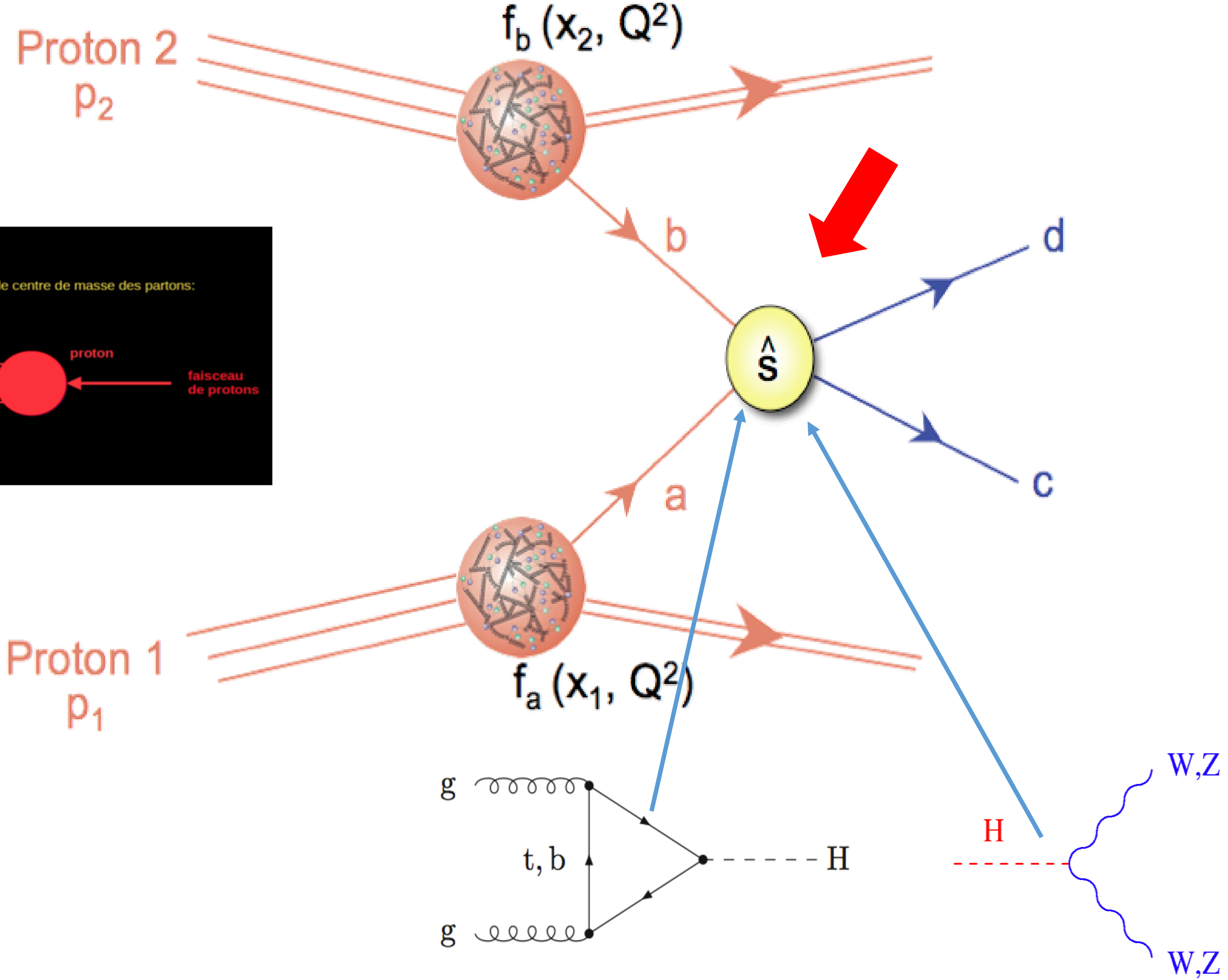
Interaction with the atomic electrons. The incoming particle loses energy and the atoms are excited or ionized.

Interaction with the atomic nucleus. The particle is deflected (scattered) causing multiple scattering of the particle in the material. During this scattering a Bremsstrahlung photon can be emitted.

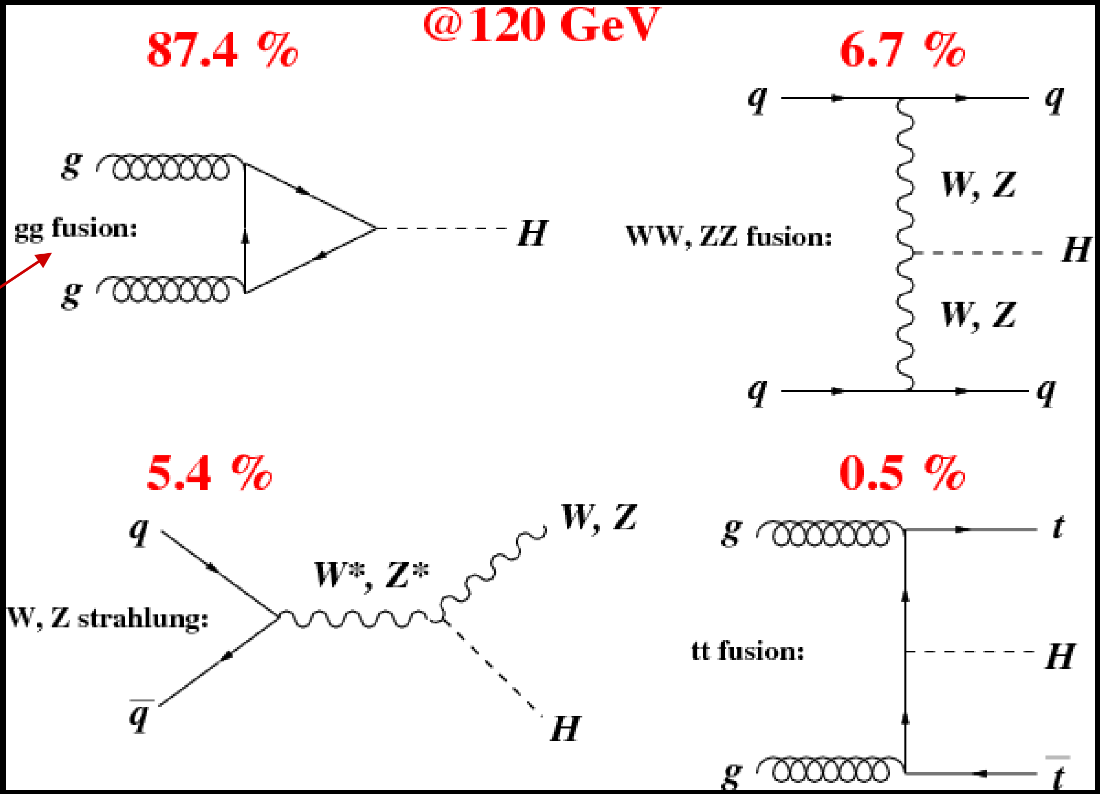
In case the particle's velocity is larger than the velocity of light in the medium, the resulting EM shockwave manifests itself as Cherenkov Radiation. When the particle crosses the boundary between two media, there is a probability of the order of 1% to produced and X ray photon, called Transition radiation.

Higgs boson at the LHC - production and decay

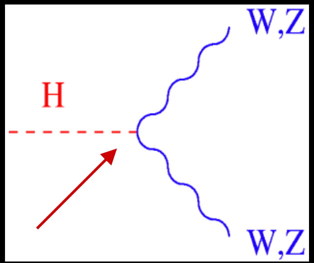


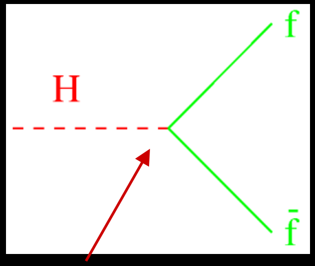


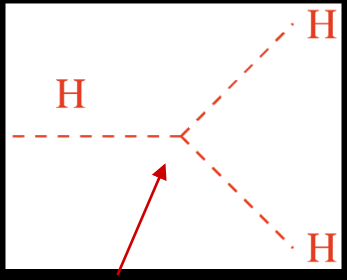
The various Higgs production mechanisms and decay modes

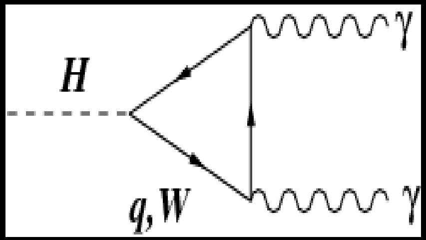


indirect coupling to gg,
top in the loop









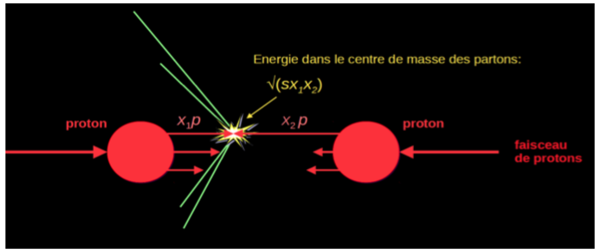
$g_{HVV} = 2m_V^2/v$
$g_{HWW} = g\ m_W$

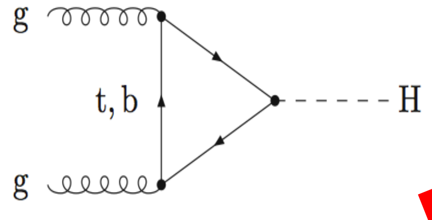
$g_{Hff} = m_f/v$

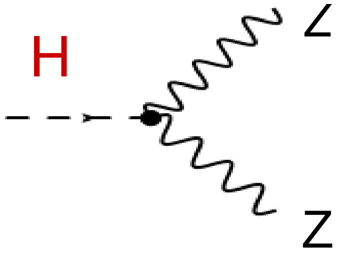
$g_{HHH} = 3m_H^2/v$

indirect coupling to $\gamma\gamma$

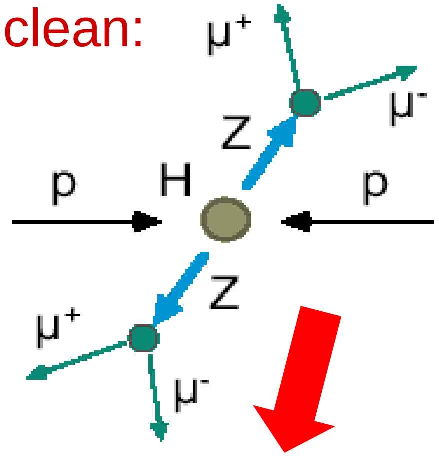
Production and detection of the Higgs in CMS

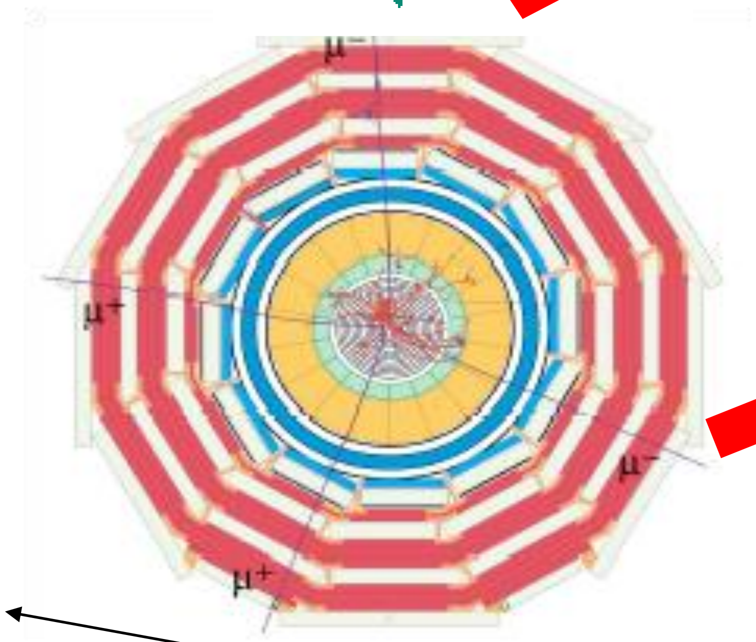




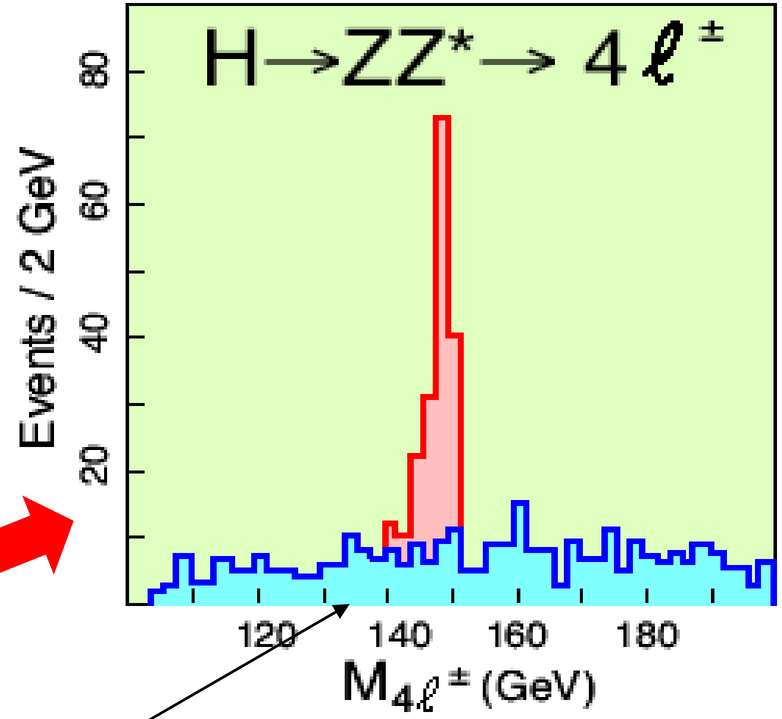


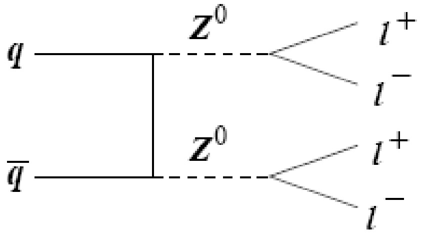
very rare collision 1 in 10^{15}, but clean:





Expectations for signal and background if the Higgs has a mass ~ 150 GeV





Electroweak ZZ background

Feynman inspired art

a construction manual

Andy Charalambous in collaboration with CERN HST Programme 2017

Fig.1: Coreen, 2012

1. Introduction

When I left school I went to work as a technician for the Physics and Astronomy department at a university in London. I trained as an engineer and spent many years designing and building equipment for the research groups there. My interest in science grew as I worked with these groups and got a better understanding of the science they were researching. I loved my job because it gave me so much insight into the science involved.

When I left that job and started as an artist I found that the excitement of science was something I didn't want to move away from. So, I decided to use science as the inspiration for my art. Most of the art I make comes from some bit of science that has seeded an idea. Science is a tool for letting us see our world more clearly, and for me it also inspires my work. By the way, I have not moved very far from the university I worked at. I am Artist in Residence for the Astronomy group and the High Energy Physics groups there, as well as being part of the art@CMS project run by Michael Hoch at CERN.

High School Teacher Programme 2017

Orders of Magnitude – Potato Powered Cosmos

a construction manual

Rachael Nee in collaboration with HST Programme 2017

1. Introduction

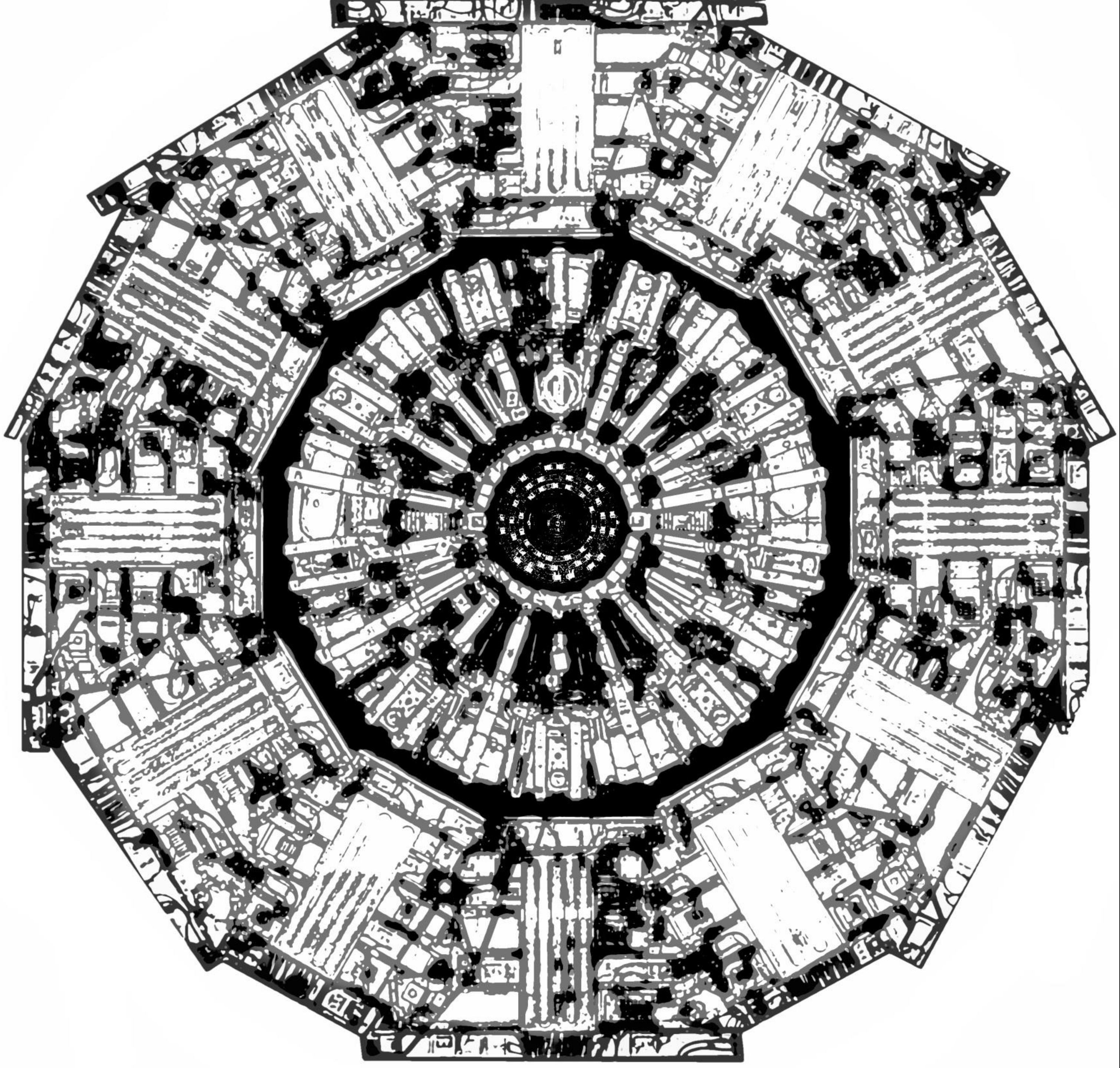
This booklet is written for science and art teachers with the aim of interdisciplinary learning. It assumes no knowledge of the other disciplines subject. In it you will read about the art installation from both the science and art viewpoints and how to reconstruct it. This becomes a jumping off point for the development of new artworks by High School students, with questions along the way.

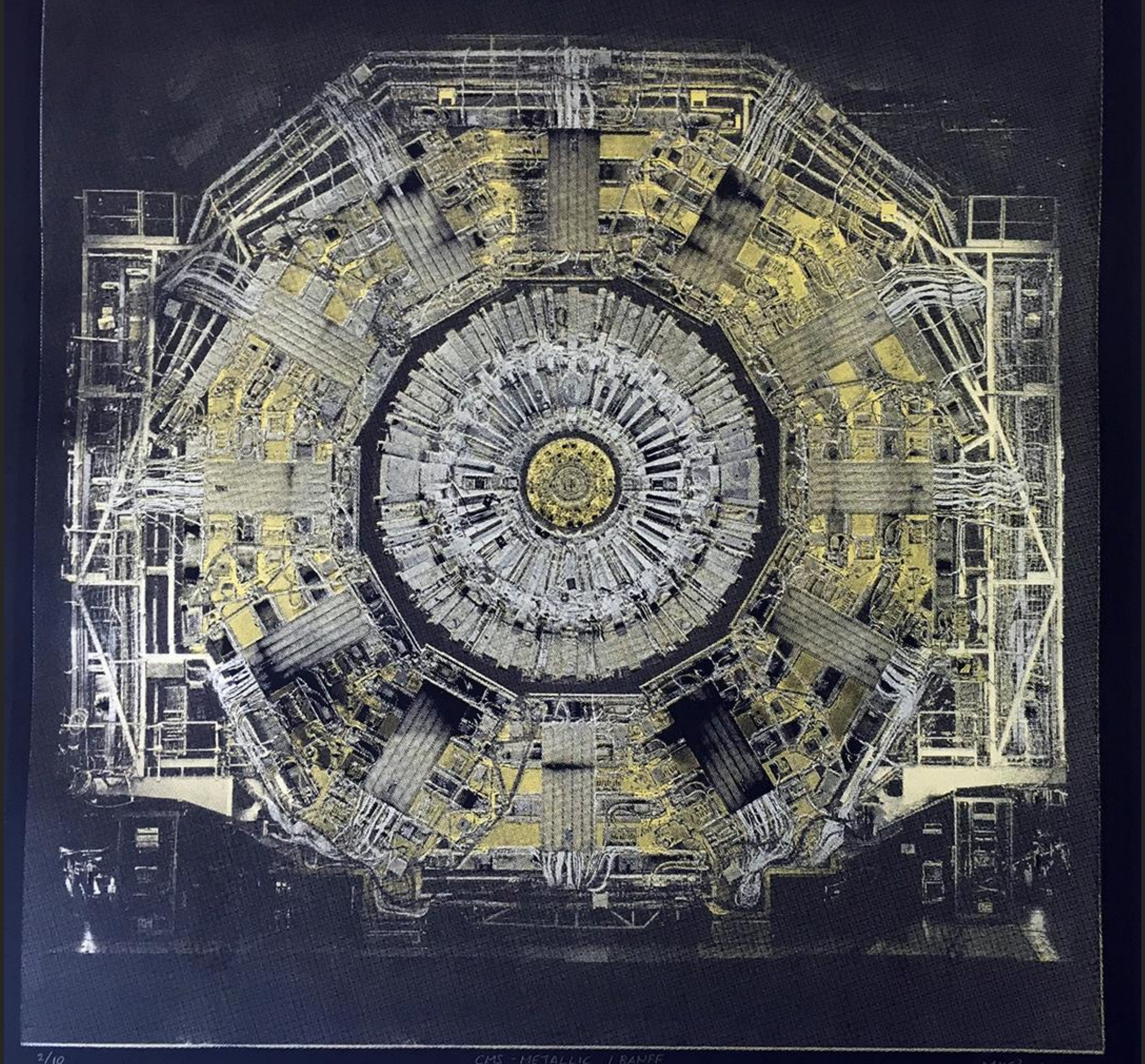
Science and contemporary art have different end goals; however, they also have a lot in common. Both contemporary art and science have similar methodologies involving; investigation, research, testing out of ideas and theories through experiment. They share imagination, curiosity, quest for knowledge and are forms of inquiry. When successful both allow the world to be seen in new ways.

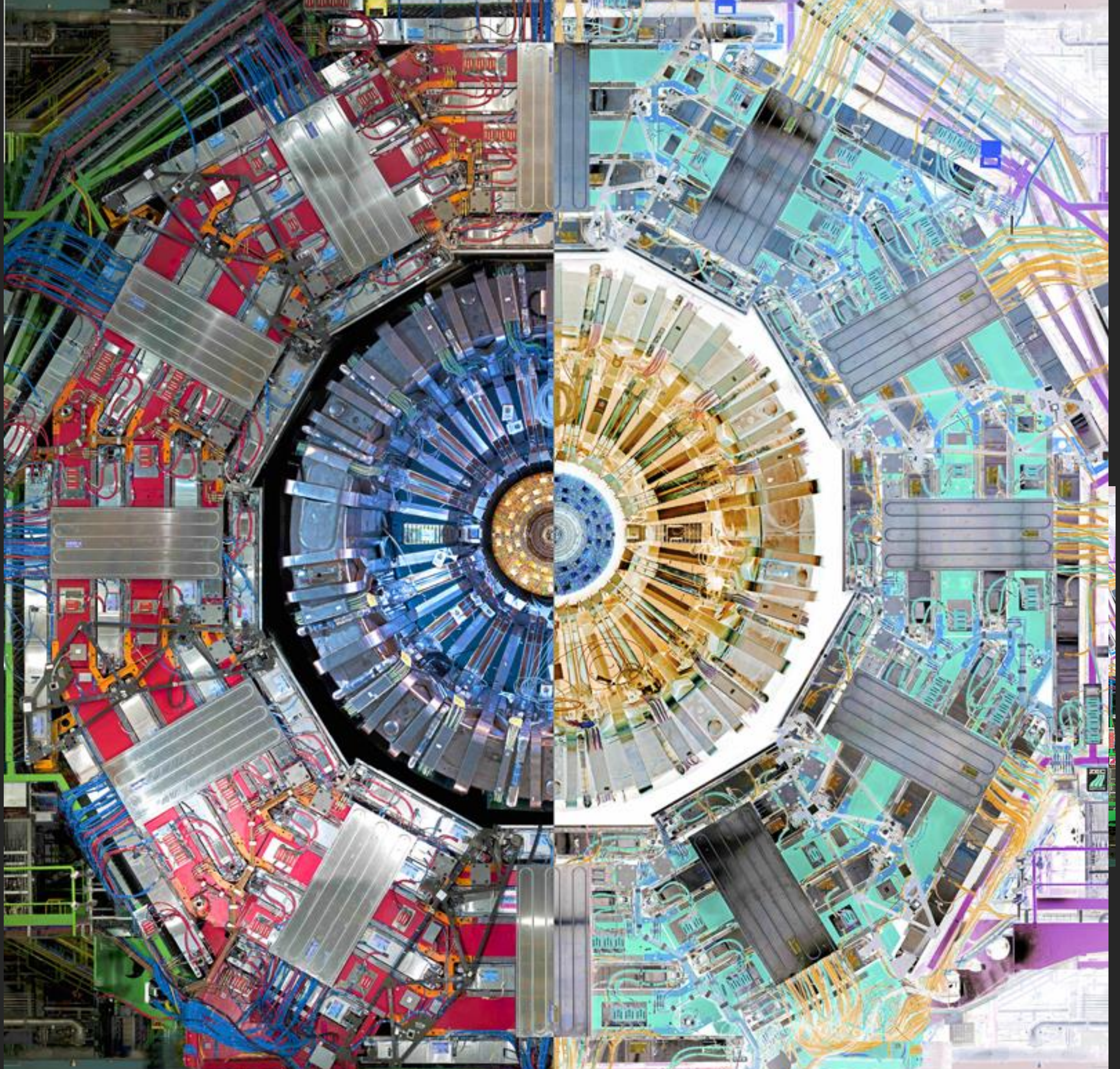
High School Teacher Programme 2017

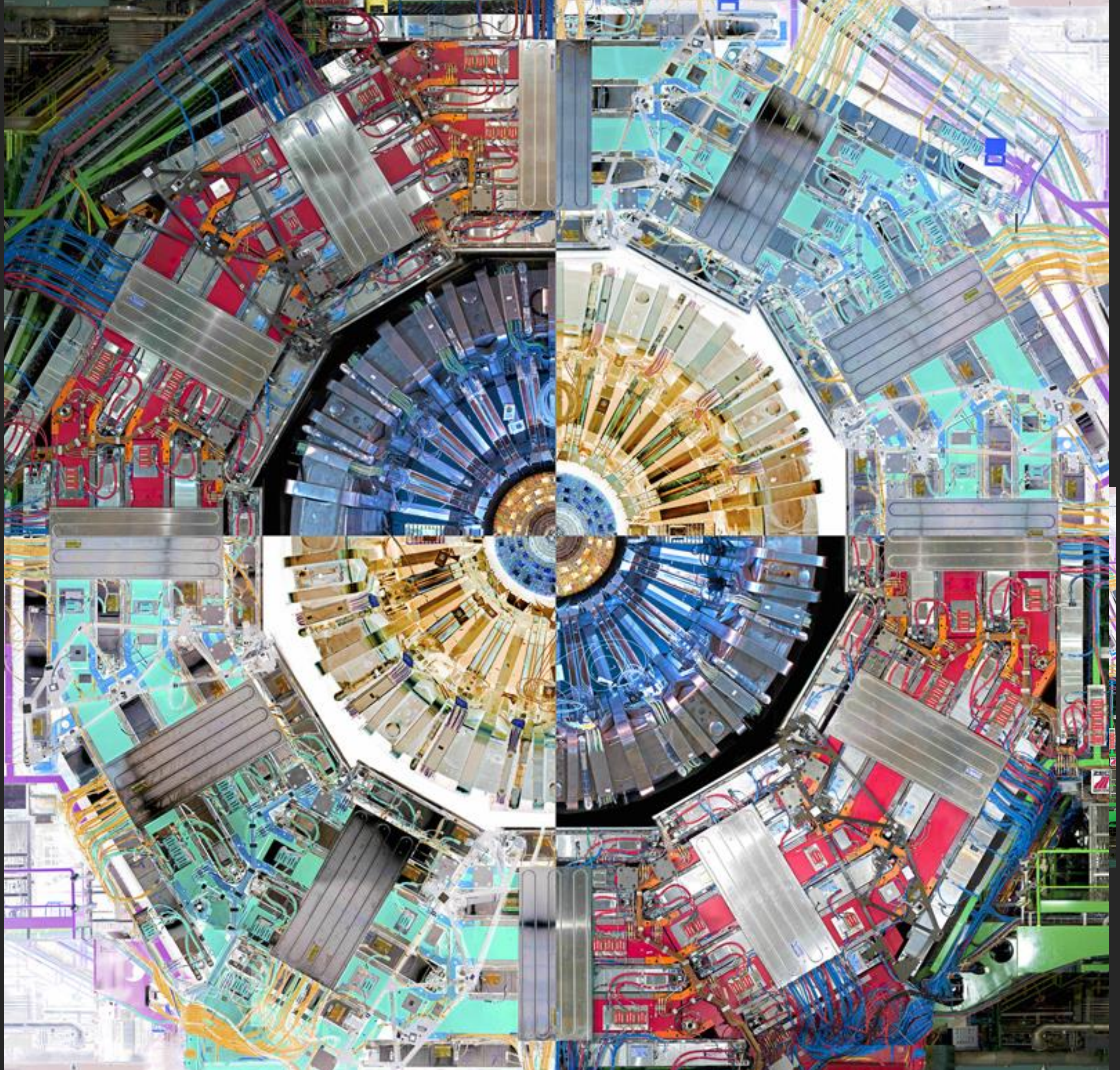
“Where do we come from? What are we? Where are we going?”

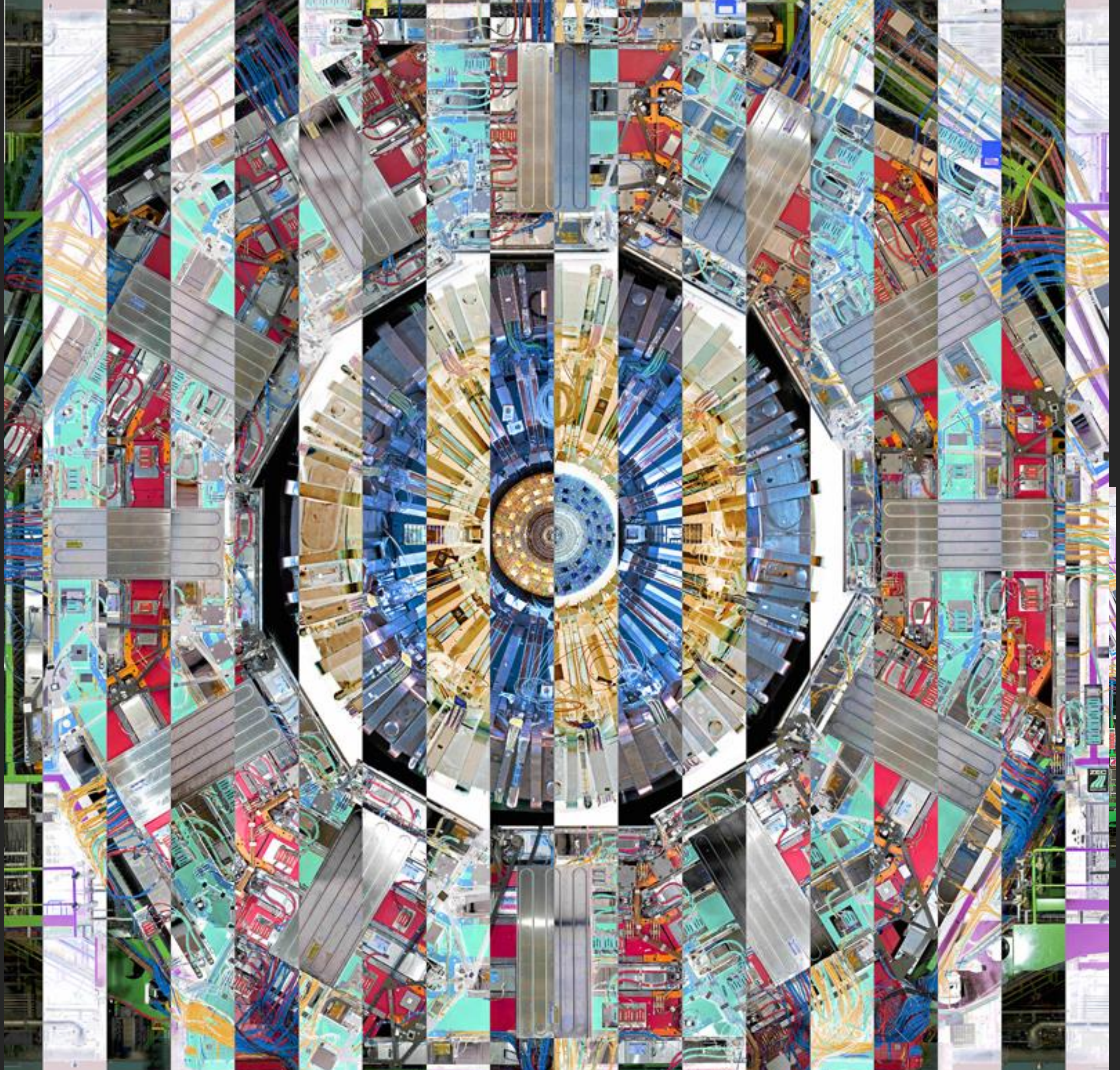
The aim of particle physics, CERN & the LHC:
What is the Universe made of ??

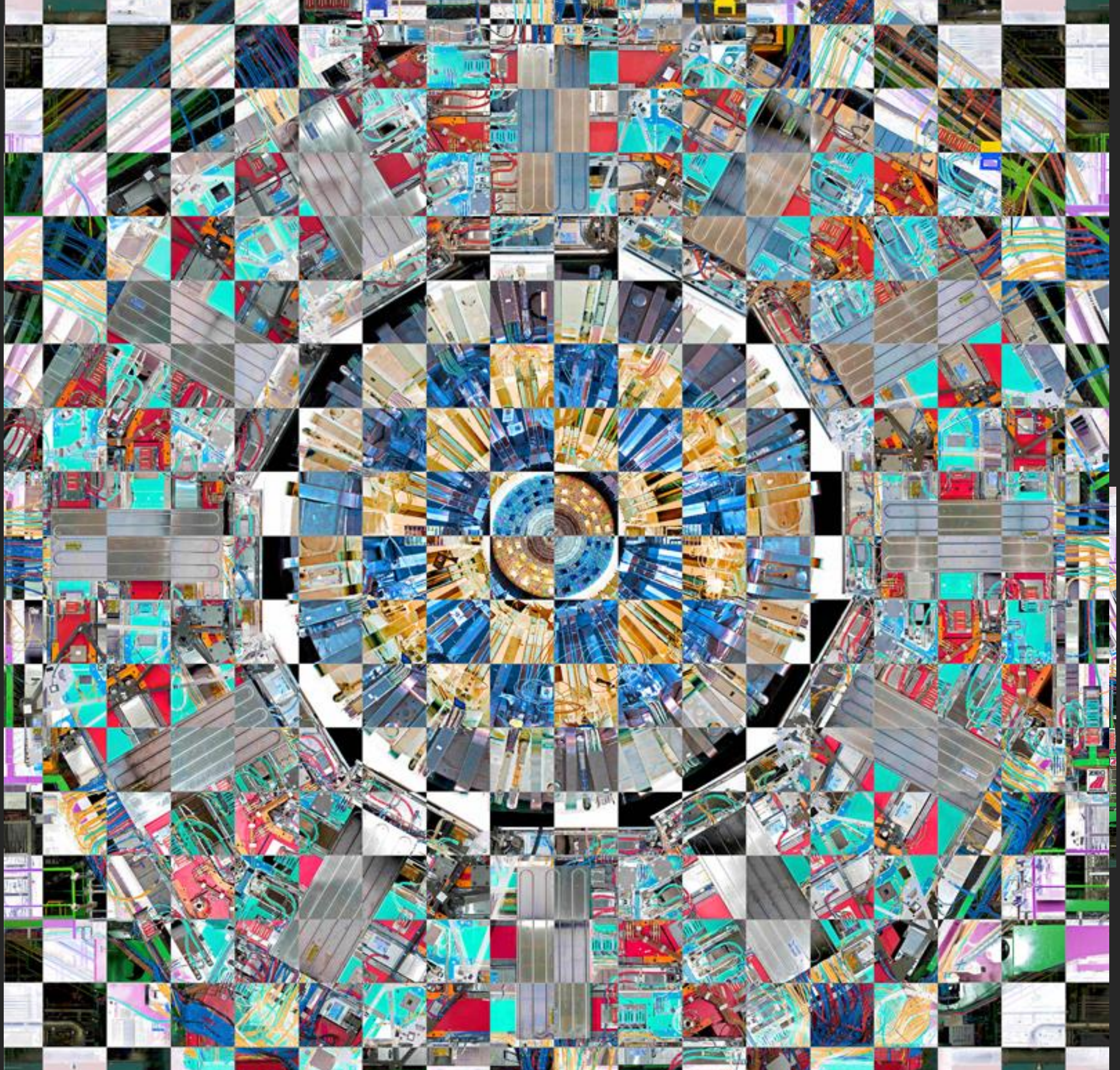


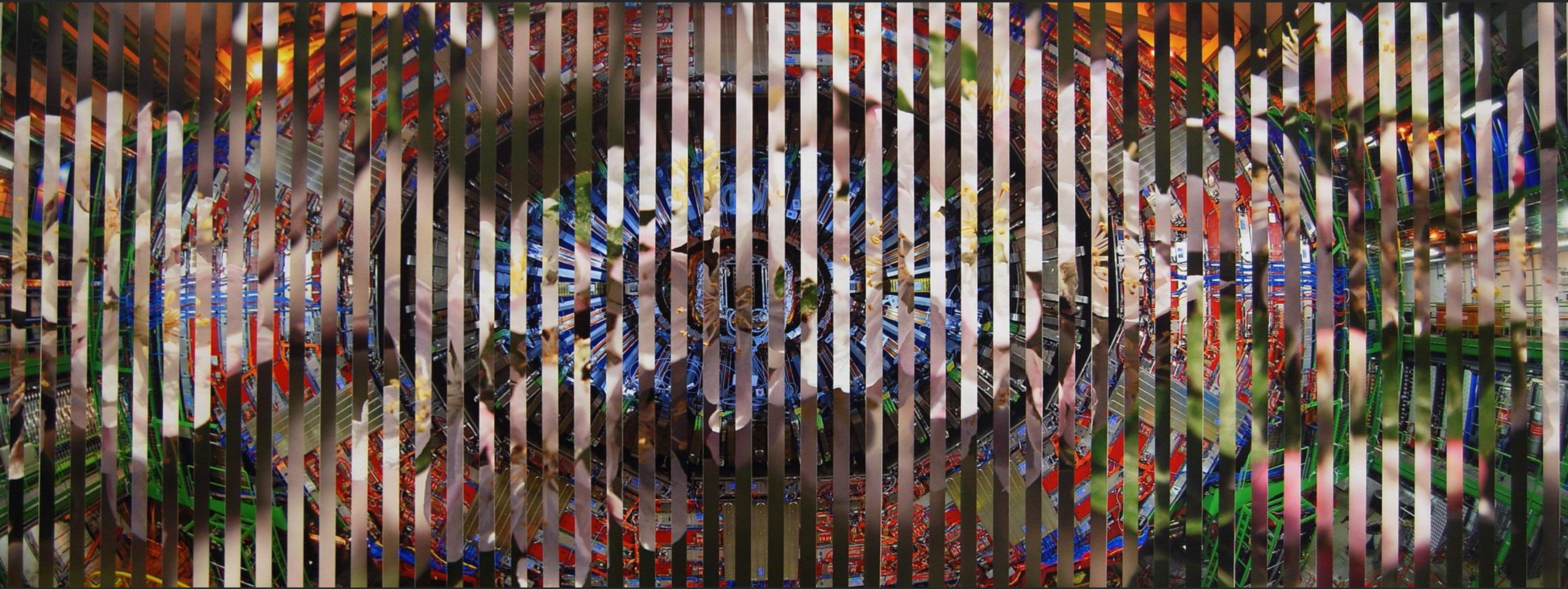

2/10
CMS - METALLIC / BANFF

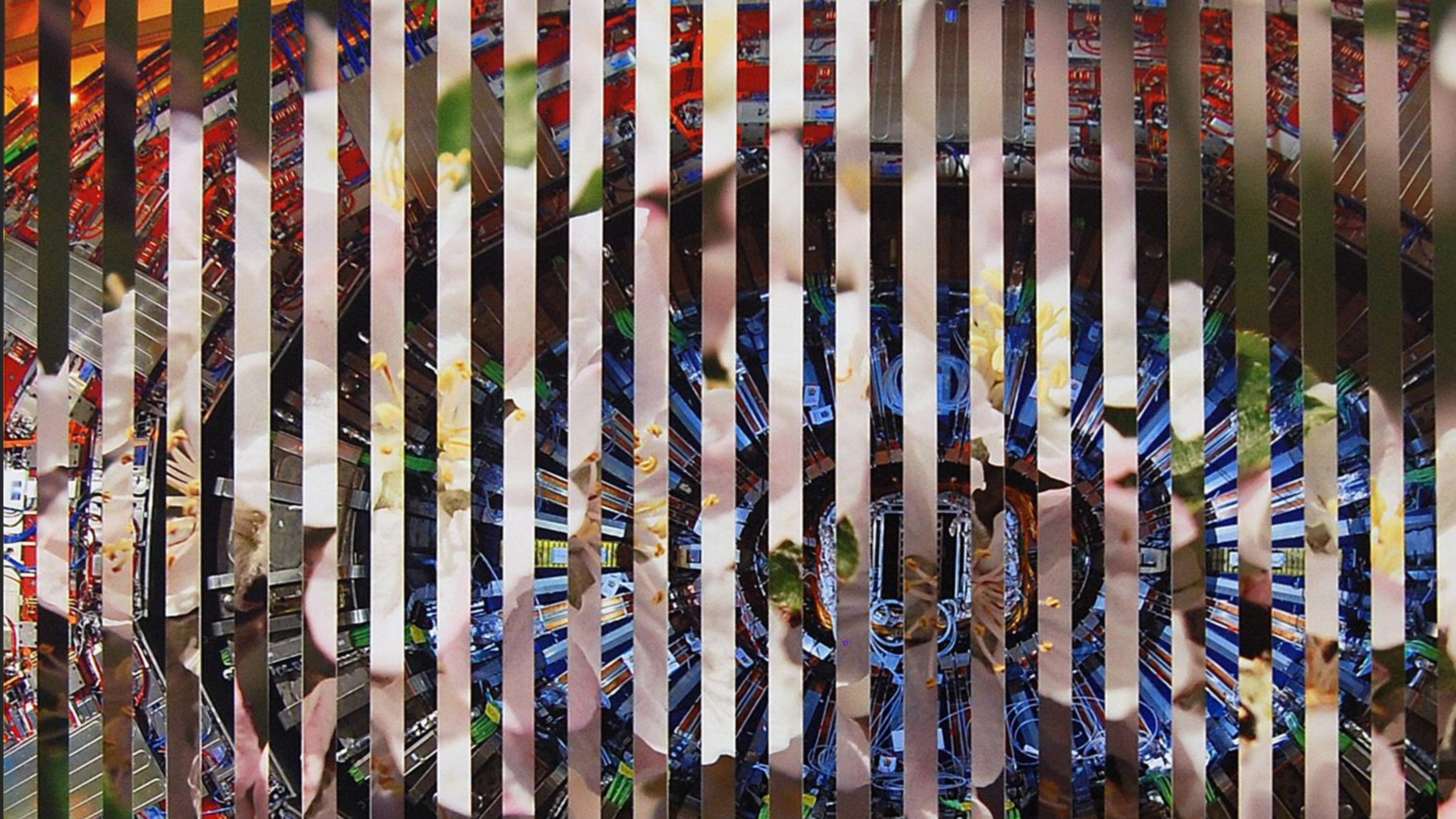


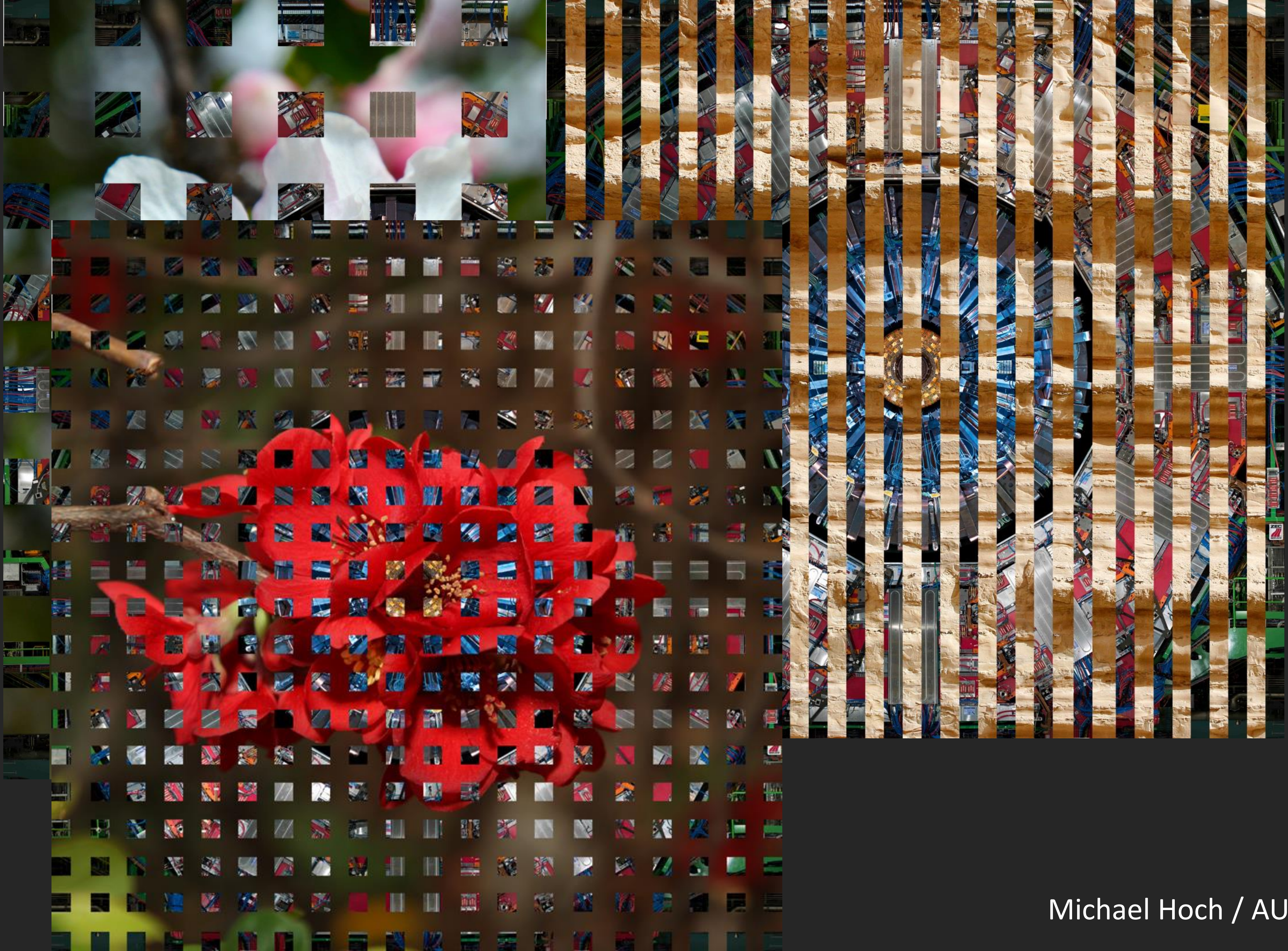




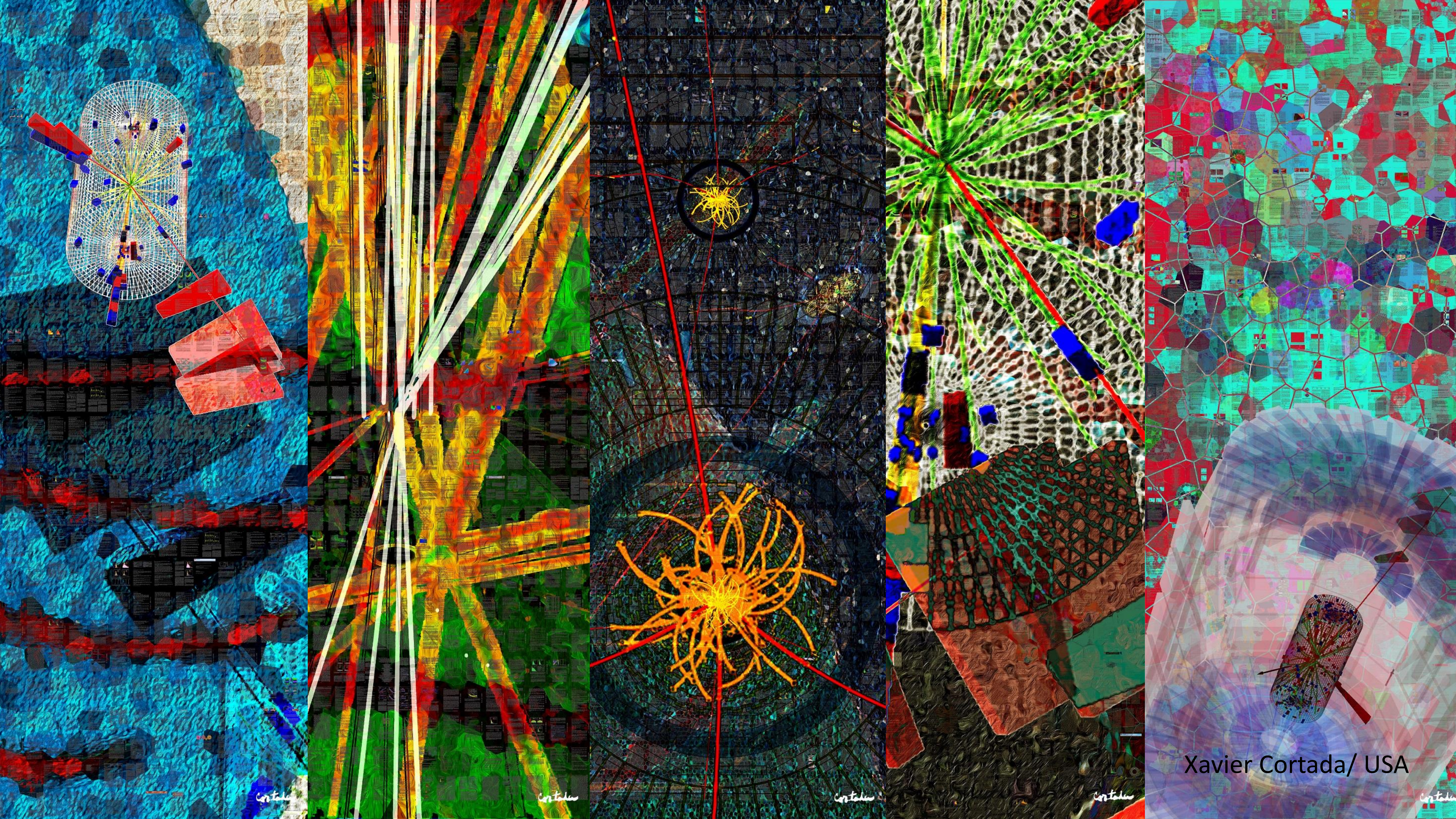




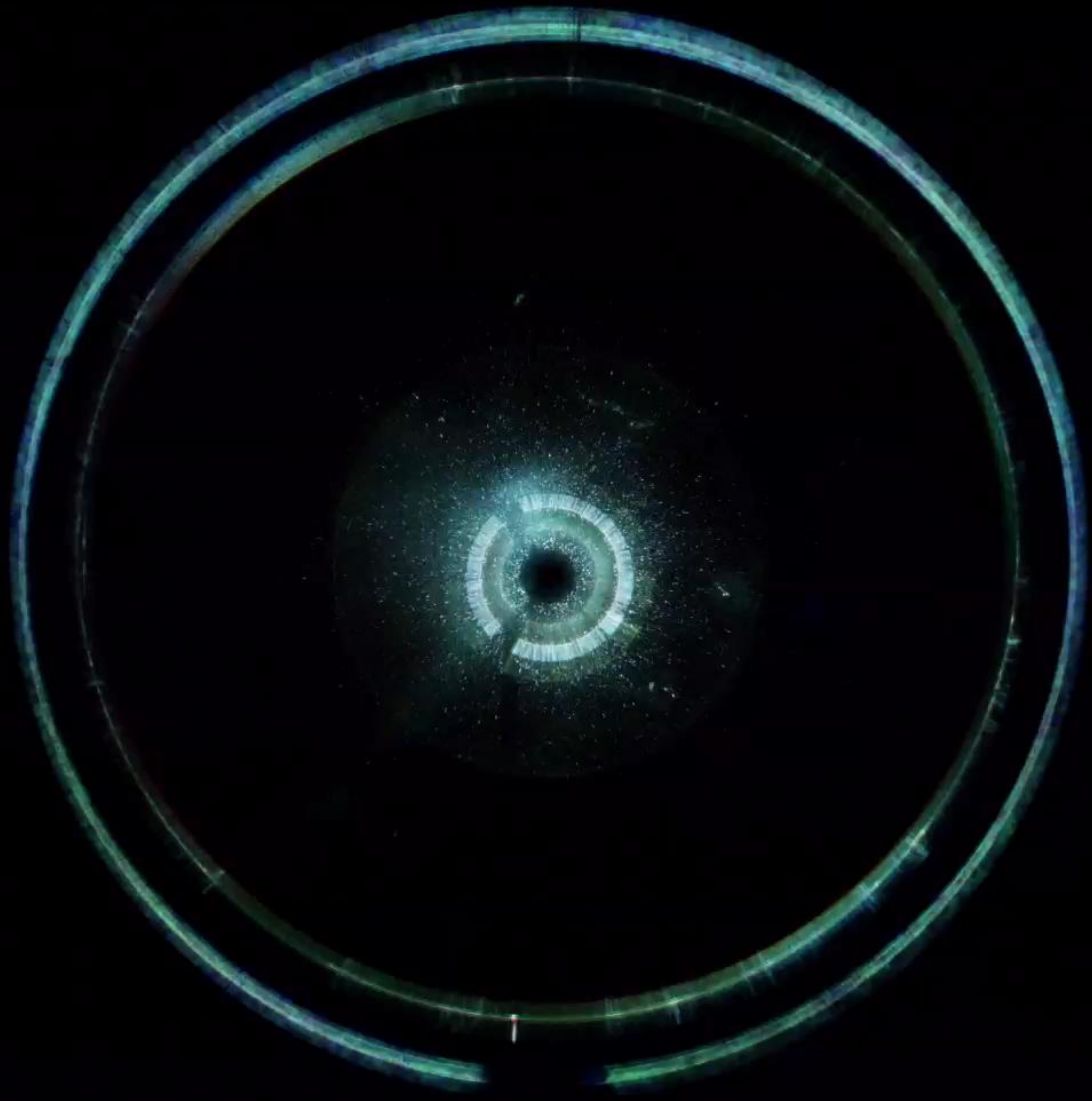




Michael Hoch / AUT


Xavier Cortada/ USA

Rachael Nee / UK



Chris Henschke /AUS

Thank you for you attention

Portal.opendiscoveryspace.eu/creations

Michael.Hoch@cern.ch