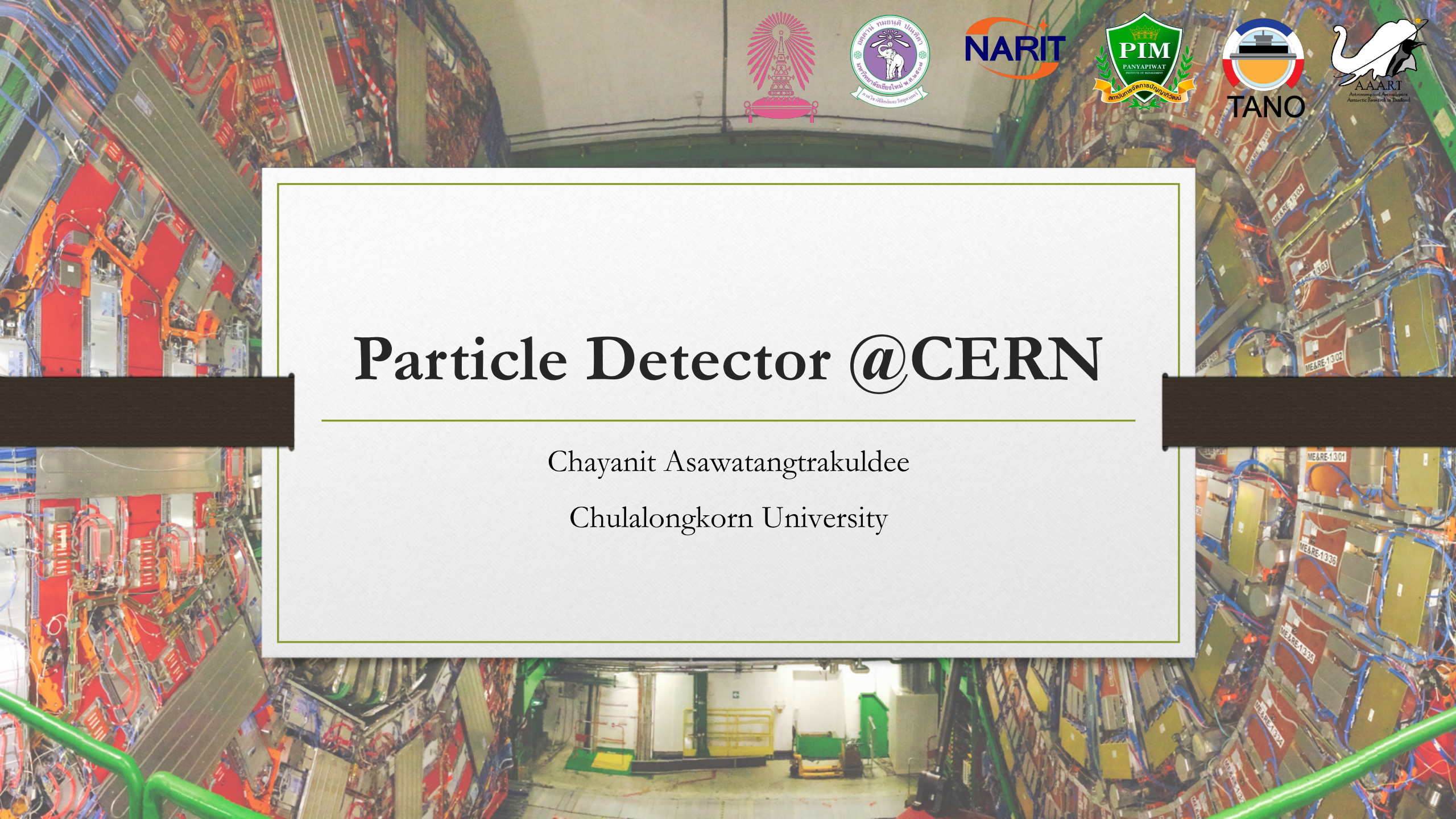


Particle Detector @CERN

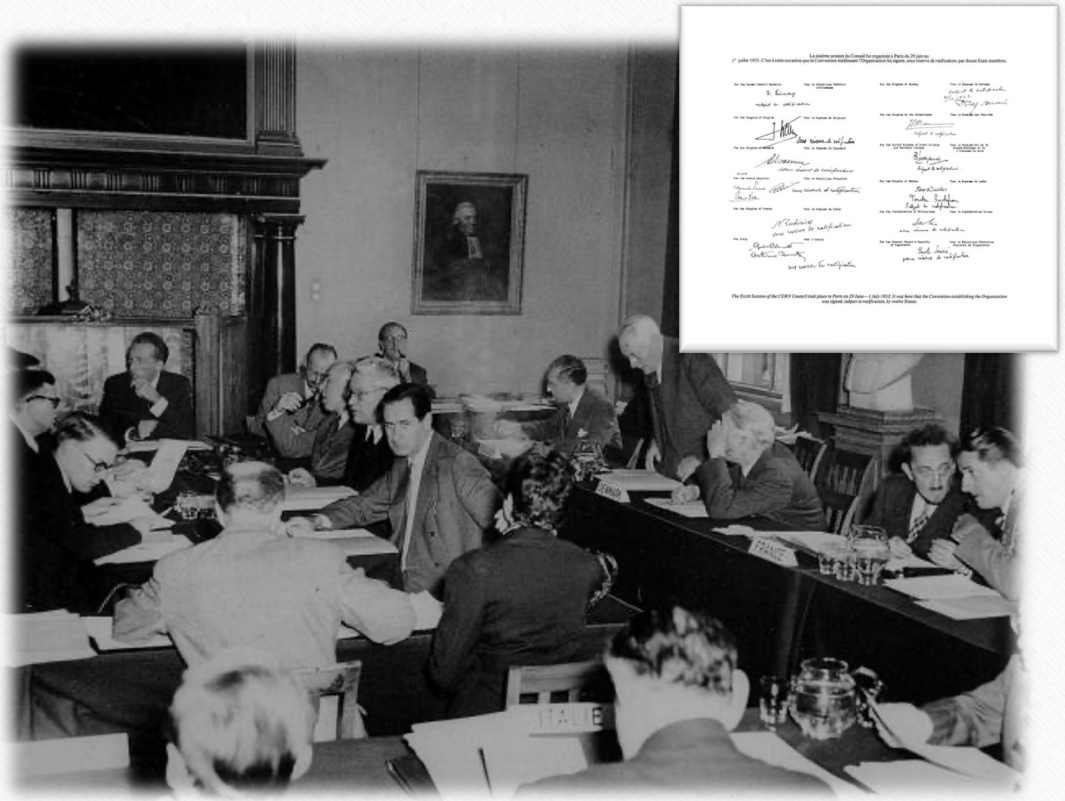
Chayanit Asawatangtrakuldee

Chulalongkorn University

CERN

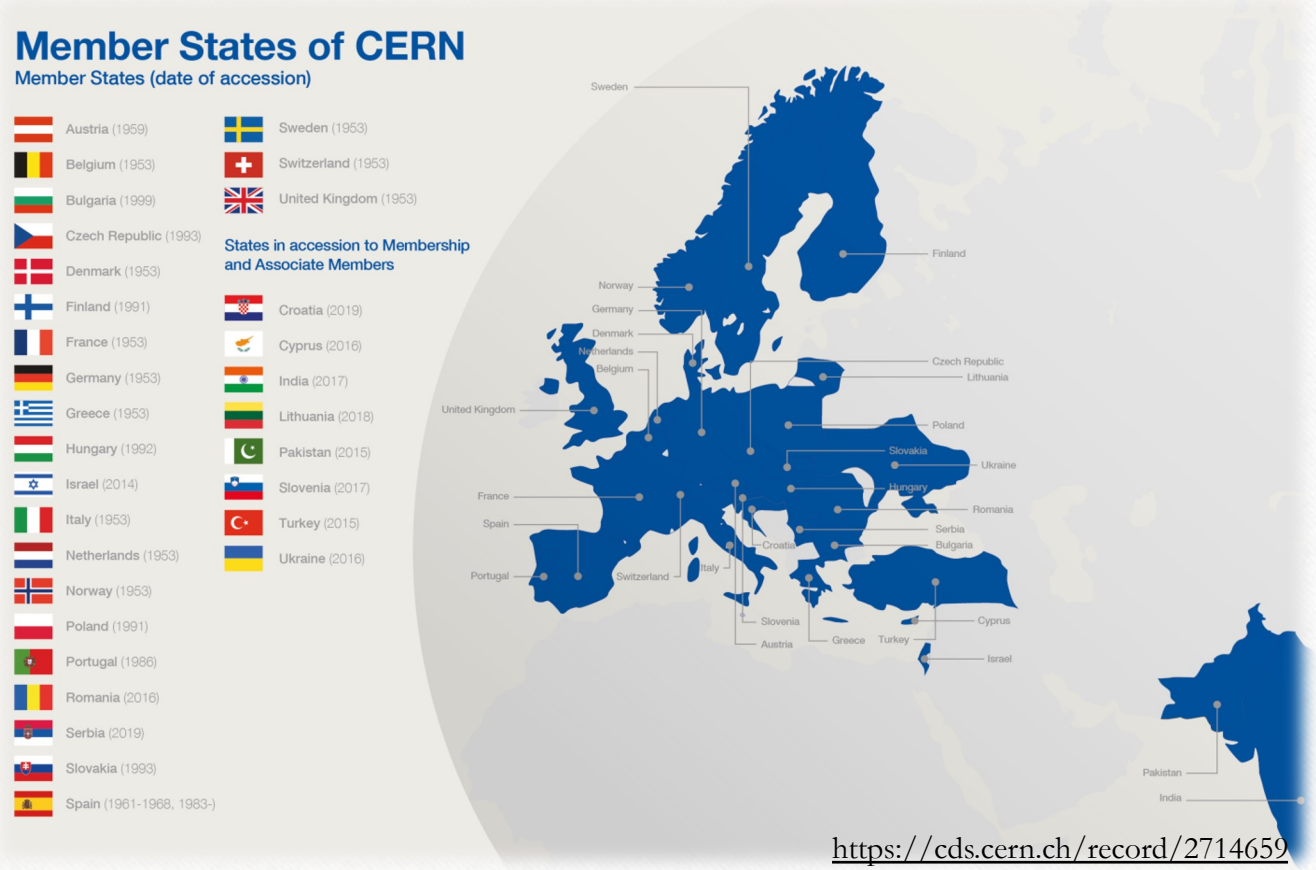
Conseil **E**uropéen pour la **R**echerche **N**ucléaire (1954)

- At the end of the Second World War, European science was no longer world-class
- A handful of visionary scientists imagined creating a European atomic physics laboratory
- At an intergovernmental meeting of UNESCO in Paris in December 1951, the first resolution concerning the establishment of a **European Council for Nuclear Research** was adopted. Two months later, 11 countries signed an agreement establishing the provisional council – the acronym CERN was born
- Geneva was selected as the site for the CERN



CERN

Conseil Européen pour la Recherche Nucléaire (1954)



https://cds.cern.ch/record/2714659

- Today 23 member states
- 10 associated member states (3 in pre-stage to member states)
- 1 to become associated member state
- **Thailand** has an International Cooperation Agreement with CERN since 2018

CERN Missions

Research : seeking and finding answers to questions about the Universe

Technology : advancing the frontiers of technology

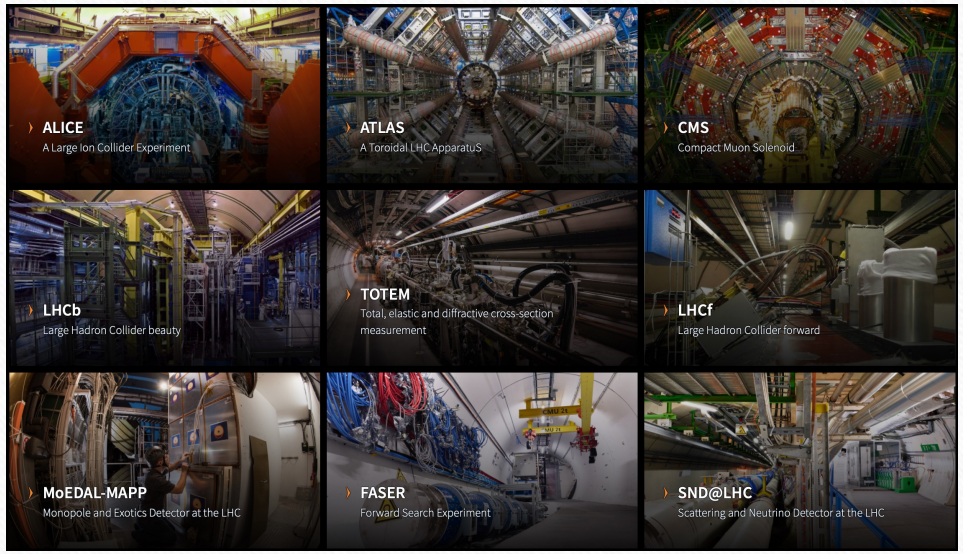
CERN

Education : training the scientists of tomorrow

Collaborating : bringing nations together through science

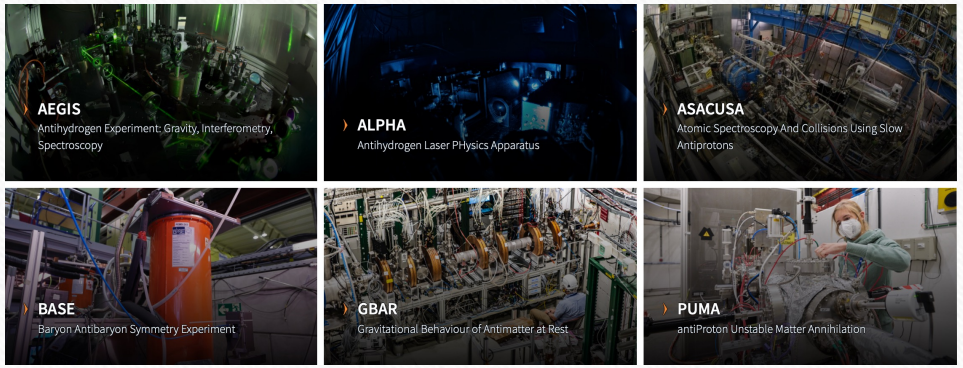
CERN Experiments

LHC experiments

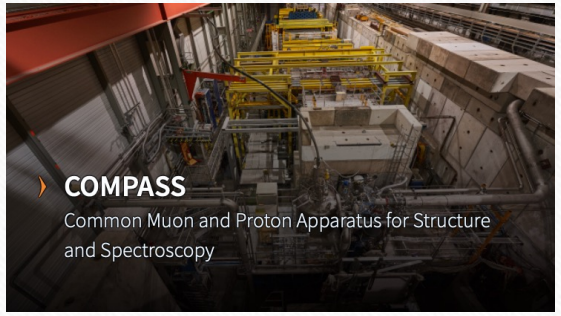


Non-accelerator experiments

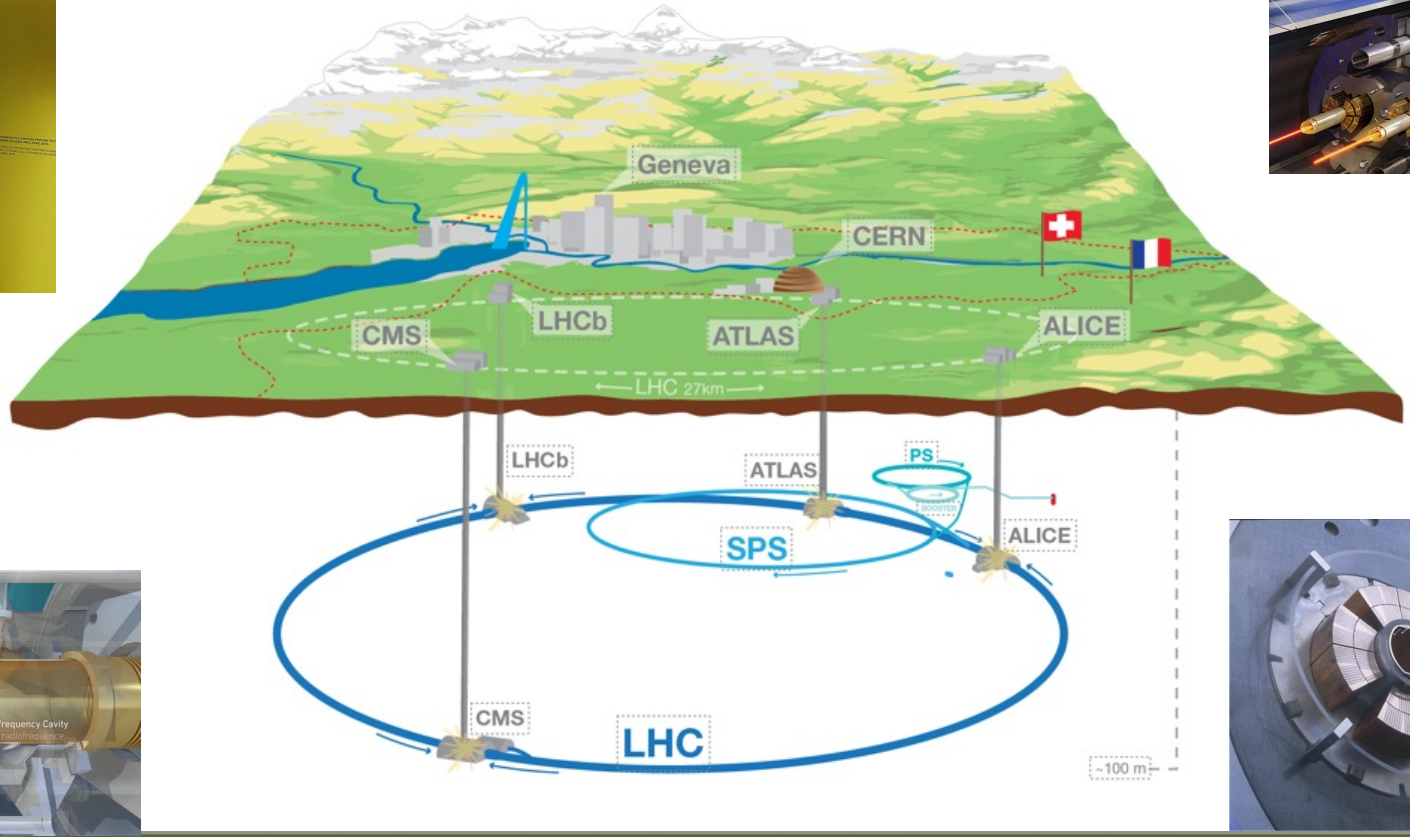
Antimatter experiments

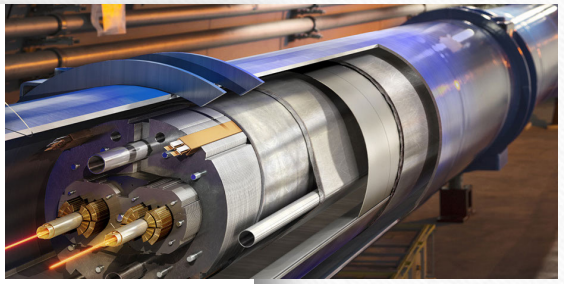


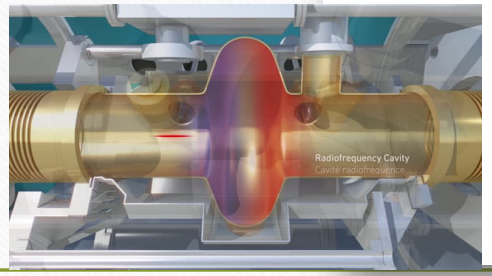
Fixed-target experiments

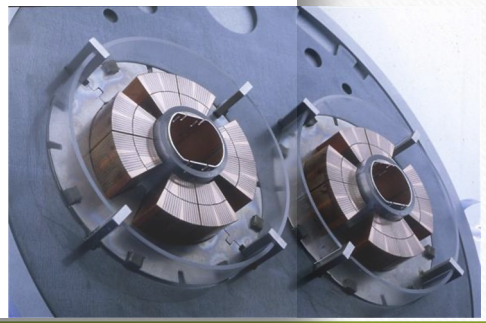


Large Hadron Collider (LHC)









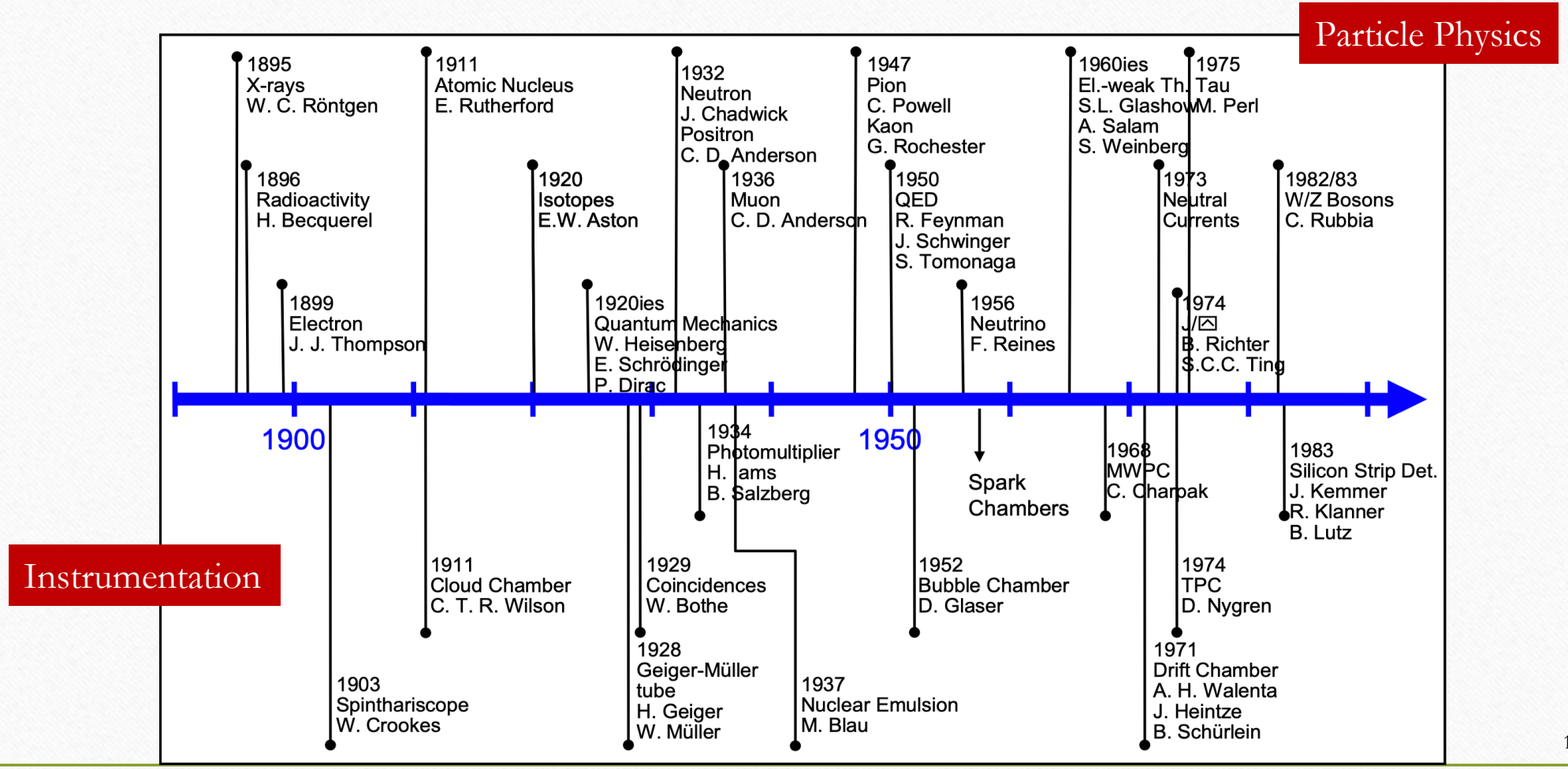
How a Detector works

"Just as hunters can identify animals from tracks in mud or snow, physicists identify subatomic particles from the traces they leave in detectors" -- *CERN*

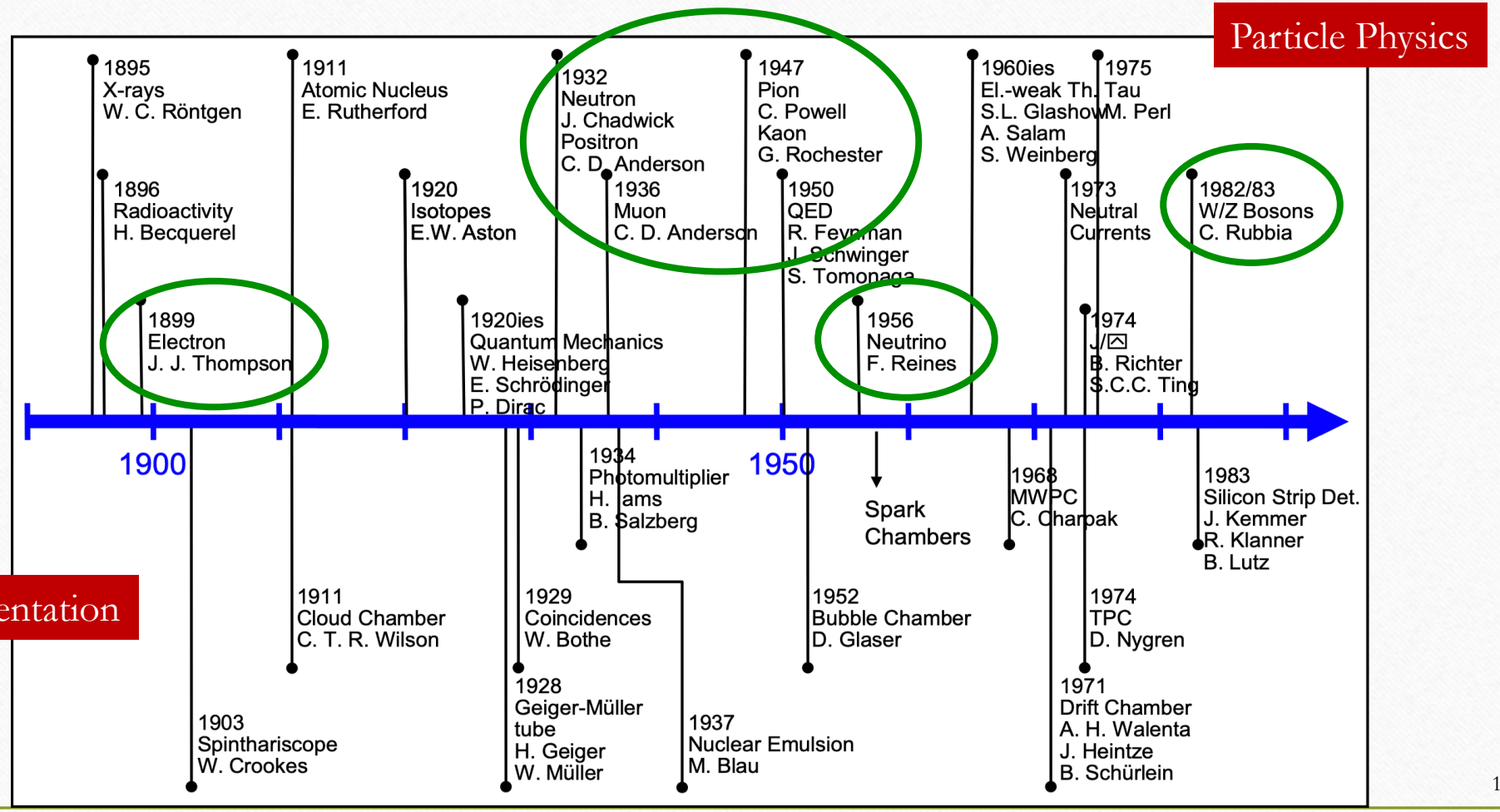
Detectors @CERN

- **Tracking devices**
  - reveal the paths of charged particles as they pass through and interact with suitable substances
  - record tiny electrical signals that particles trigger and reconstructed the patterns of tracks by a computer program.
- **Calorimeters**
  - measures the energy a particle loses as it passes through
  - perform two different tasks -- stopping particles and measuring energy loss
- **Particle-identification detectors**
  - by measuring a particle's velocity and combine with momentum measured in the tracking devices, helps to calculate a particle's mass and therefore its identity.

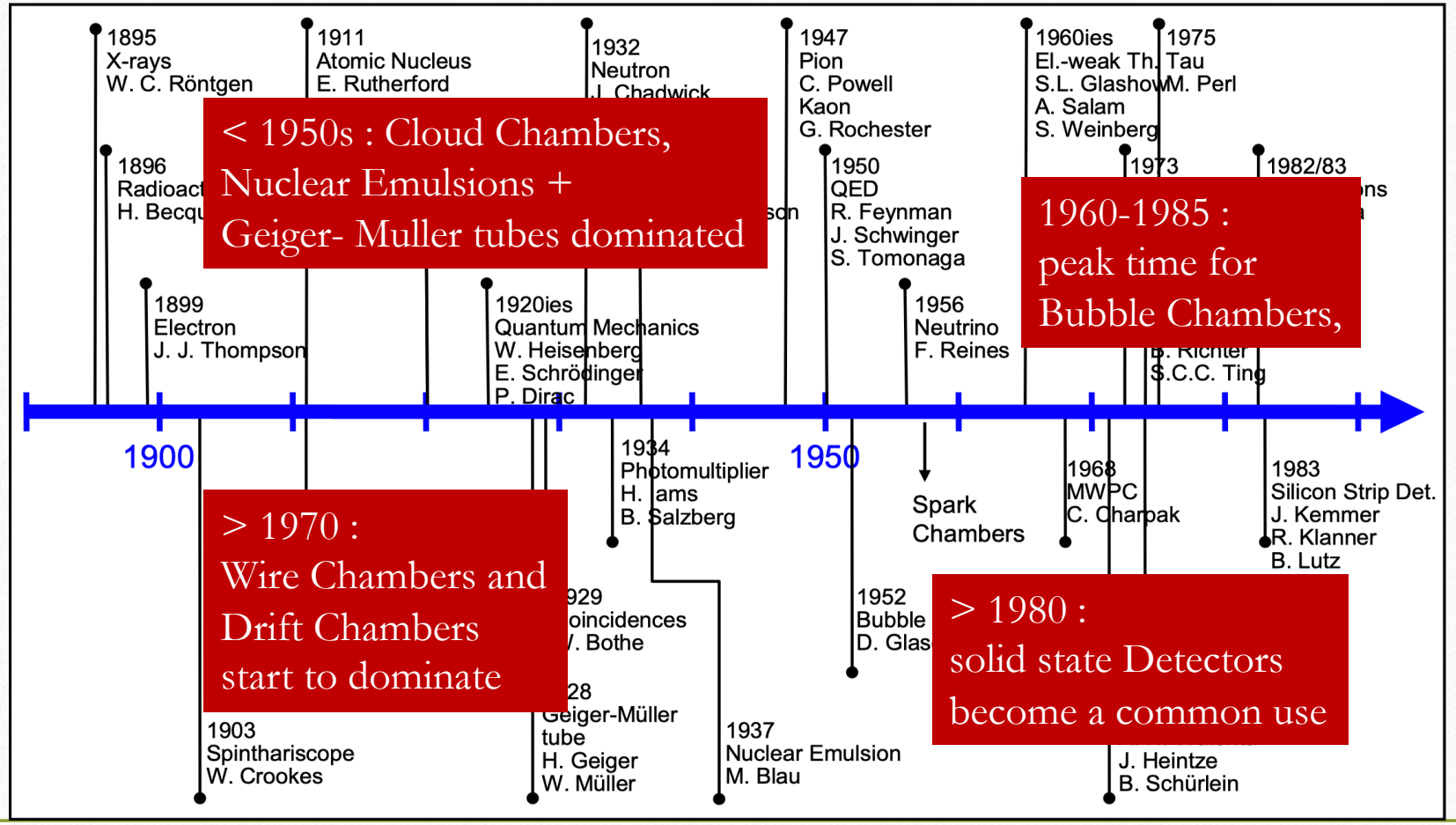
A Chronology



A Chronology

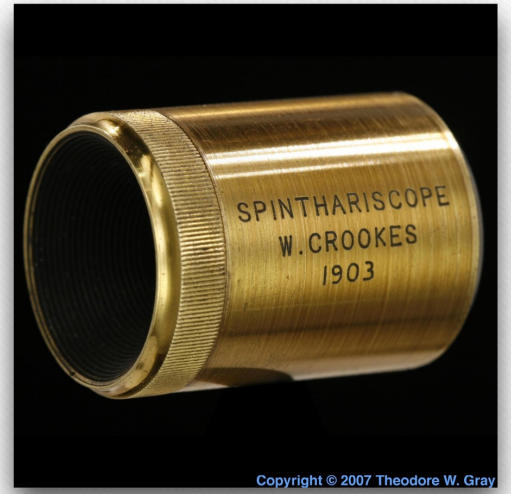


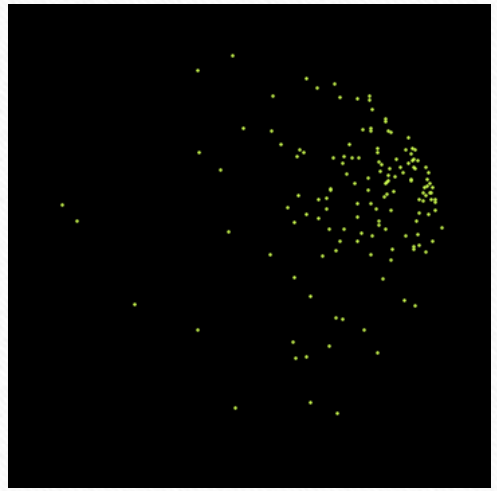
A Chronology



Spinthariscope (1903)

- Invented and beautifully named by **William Crookes** in 1903, is a device for seeing individual atoms or at least, seeing the death of individual atoms



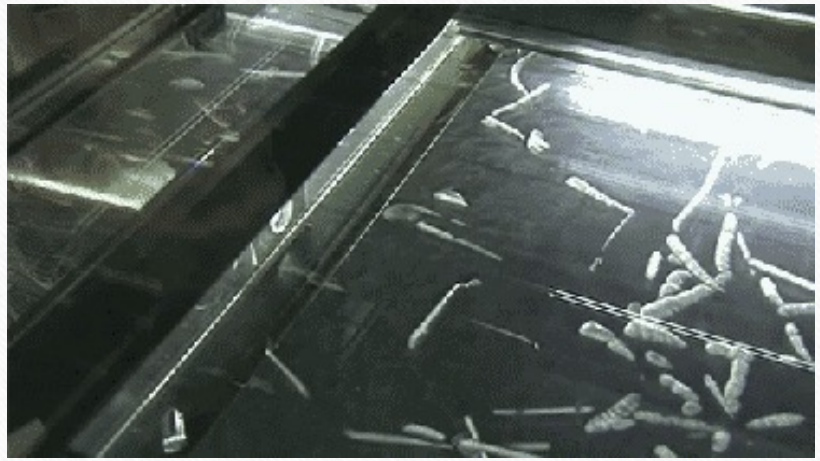


- Consist of a small screen coated with **zinc sulfide** affixed to the end of a tube, with a tiny amount of **radium salt** suspended a short distance from the screen and a lens on the other end of the tube for viewing the screen. Crookes named his device after the Greek word 'spintharis', meaning **"a spark"**

Credit : https://blog.wolfram.com/2007/10/30/a-thousand-points-of-light/

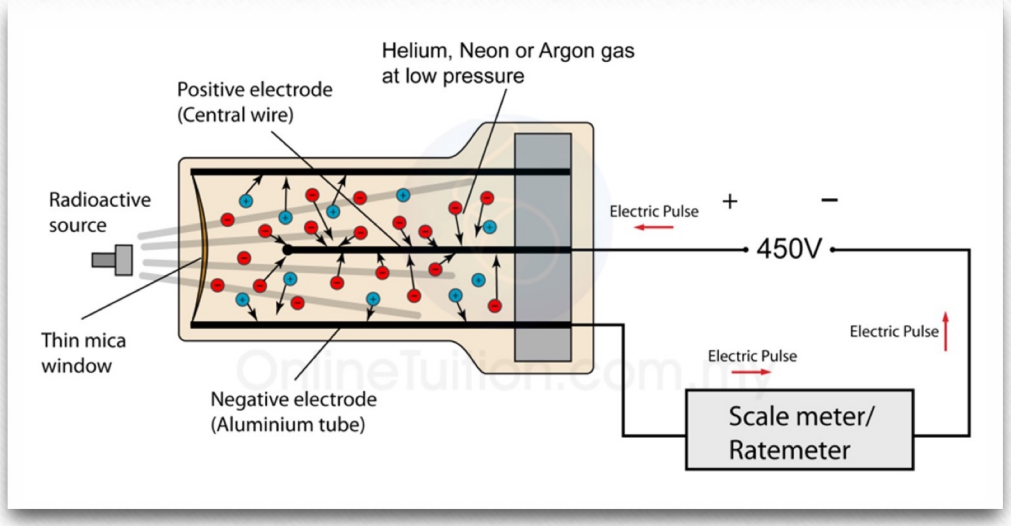
Cloud Chamber (1911)

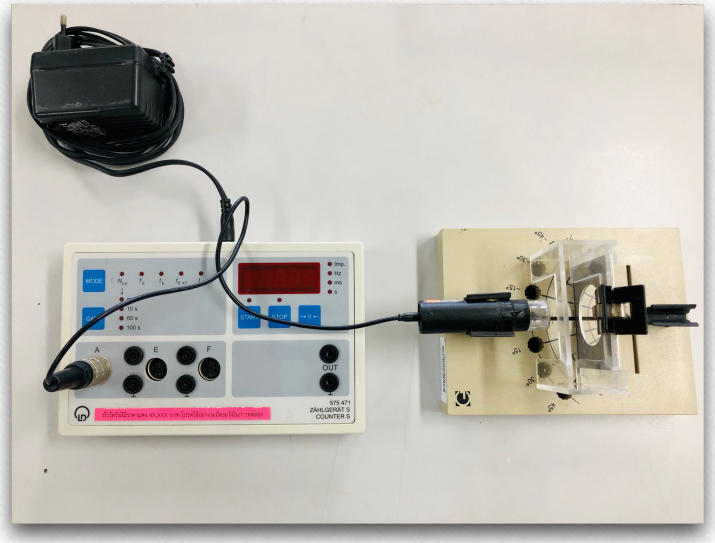
- Originally developed to study formation of rain clouds
- Passage of charged particle would condense the vapor into tiny droplets, making the particle's path → their number being proportional to dE/dx
- The discoveries of positron in 1932 and muon in 1936, both by Carl Anderson (awarded a Nobel Prize in Physics in 1936), used cloud chambers



Charles Thomson Rees Wilson
(1869–1959)
Nobel Prize in 1927

Geiger–Müller Tube (1928)





- The Geiger-Müller tube (1928 by Hans Geiger and Walther Müller)
  - Tube filled with inert gas (He, Ne, Ar) + organic vapor (alcohol)
  - Avalanche process : exponential increase of electrons (and ions)

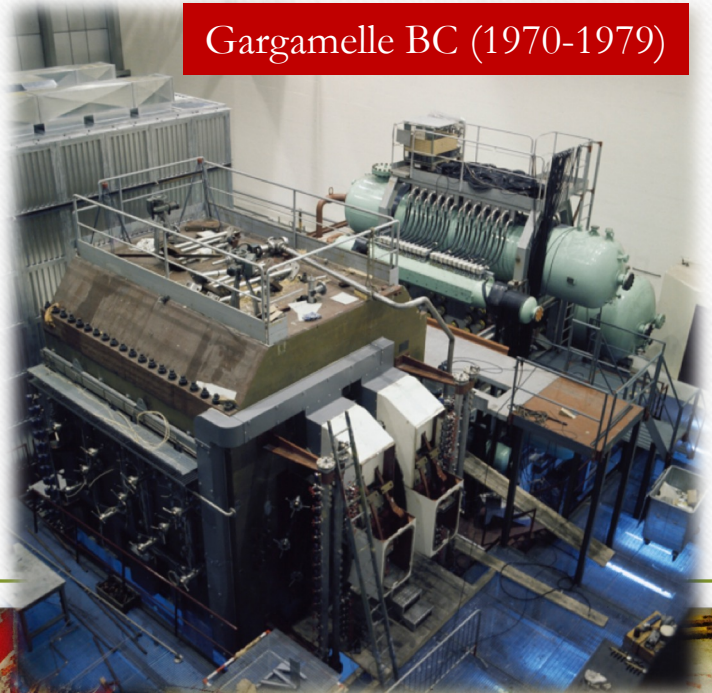
Bubble Chamber (1952)

Credit : https://en.wikipedia.org/wiki/Bubble_chamber

- Instead of supersaturating a gas with a vapor one would superheat the liquid
- A particle leave a trail of ions along its path → make a liquid boil and form gas bubbles around ions

Donald A. Glaser
Nobel Prize in 1960

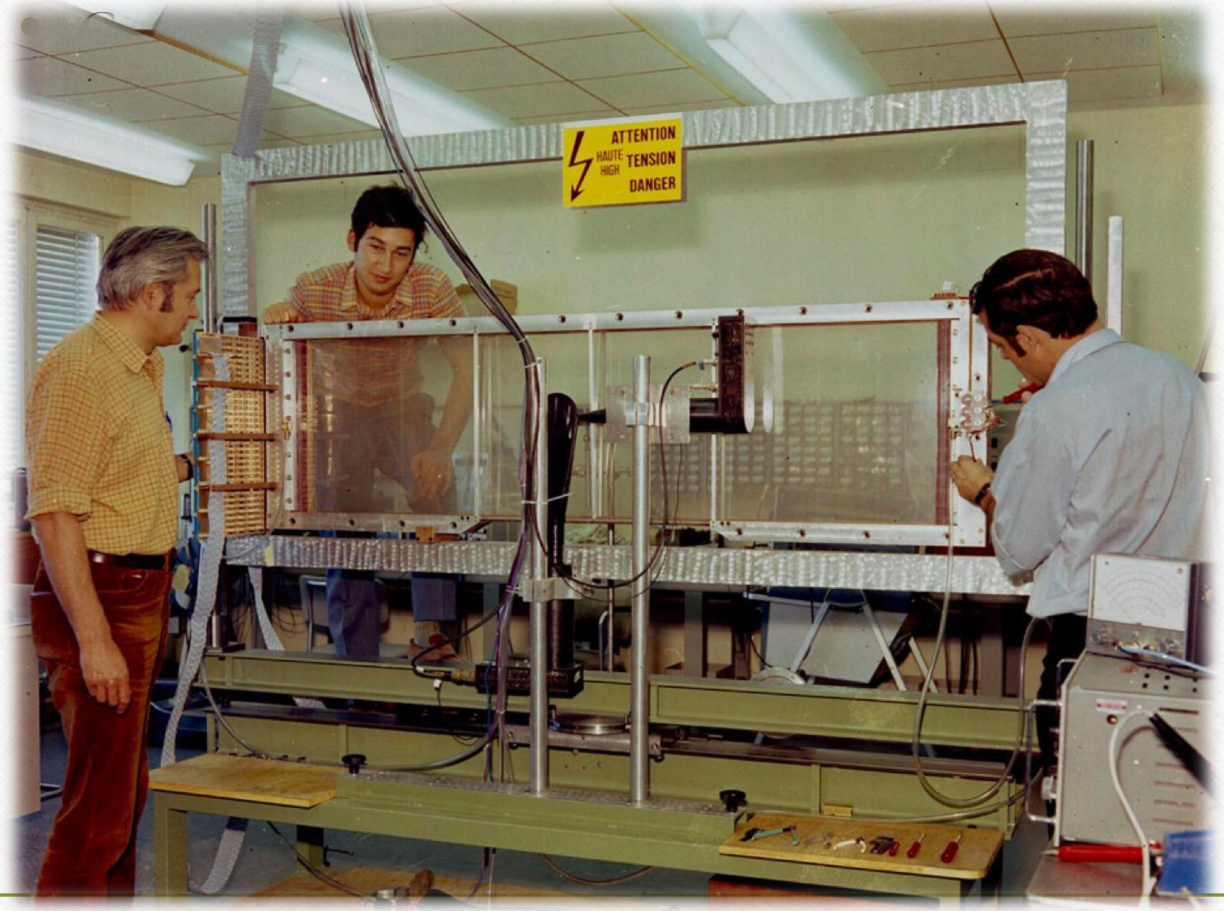
Big European Bubble Chamber (BEBC)1973-1984



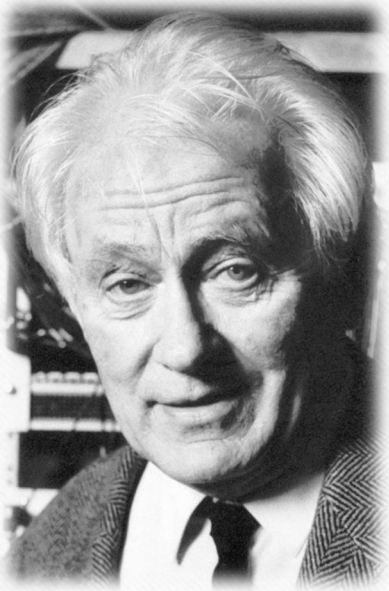
Gargamelle BC (1970-1979)

MWP Chambers (1968)

Credit : https://home.cern/news/news/experiments/fifty-years-charpak-revolutionised-particle-detectors



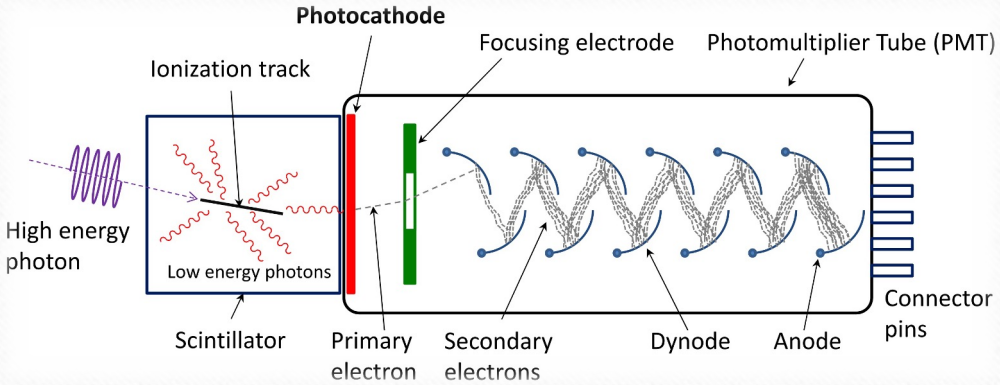
- Multi Wire Proportional Chambers (MWPC)



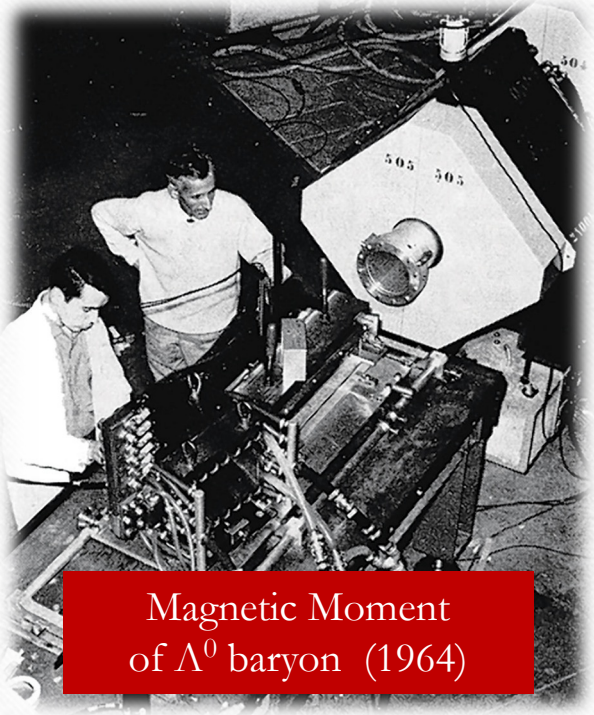
Georges Charpak
(1924–2010)
Nobel Prize in 1992

Some more…

Photomultiplier tube
Harley Iams & Bernard Salzberg (1934)



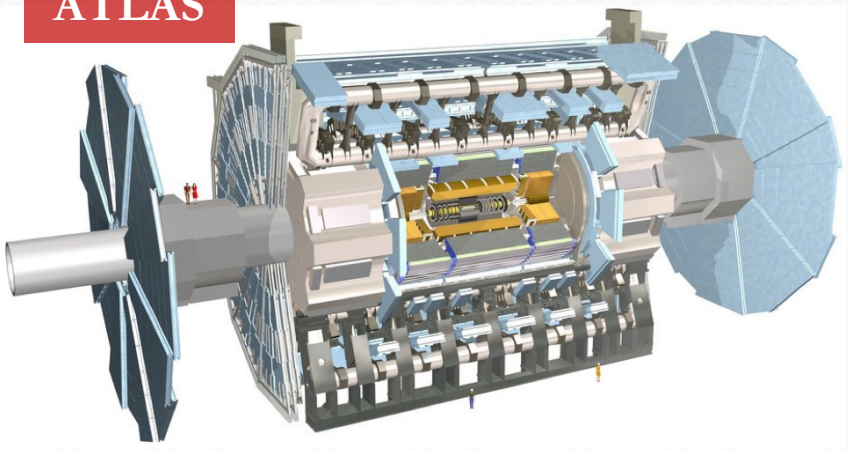
Nuclear Emulsions
Marietta Blau (1937)



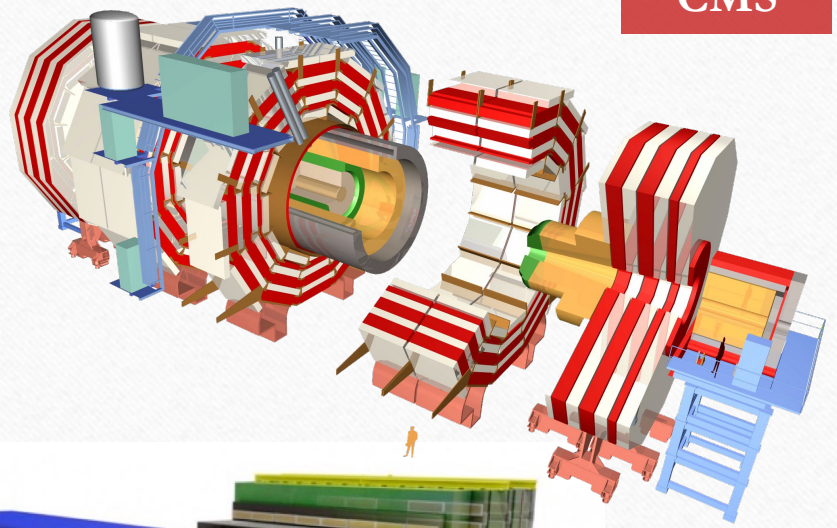
Credit : https://cerncourier.com/a/nuclear-emulsions/

LHC Detectors

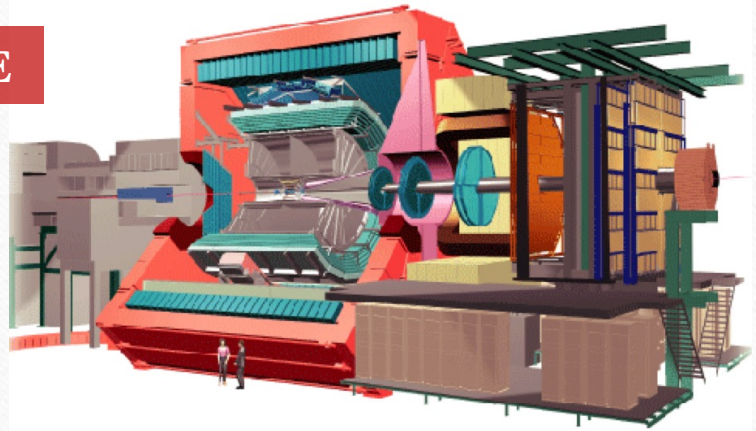
ATLAS



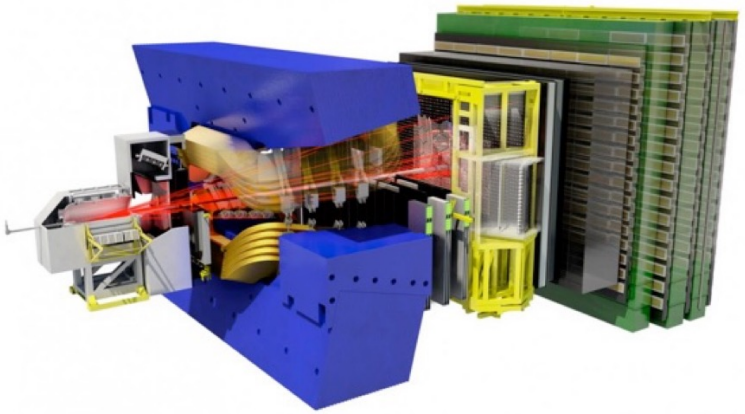
CMS



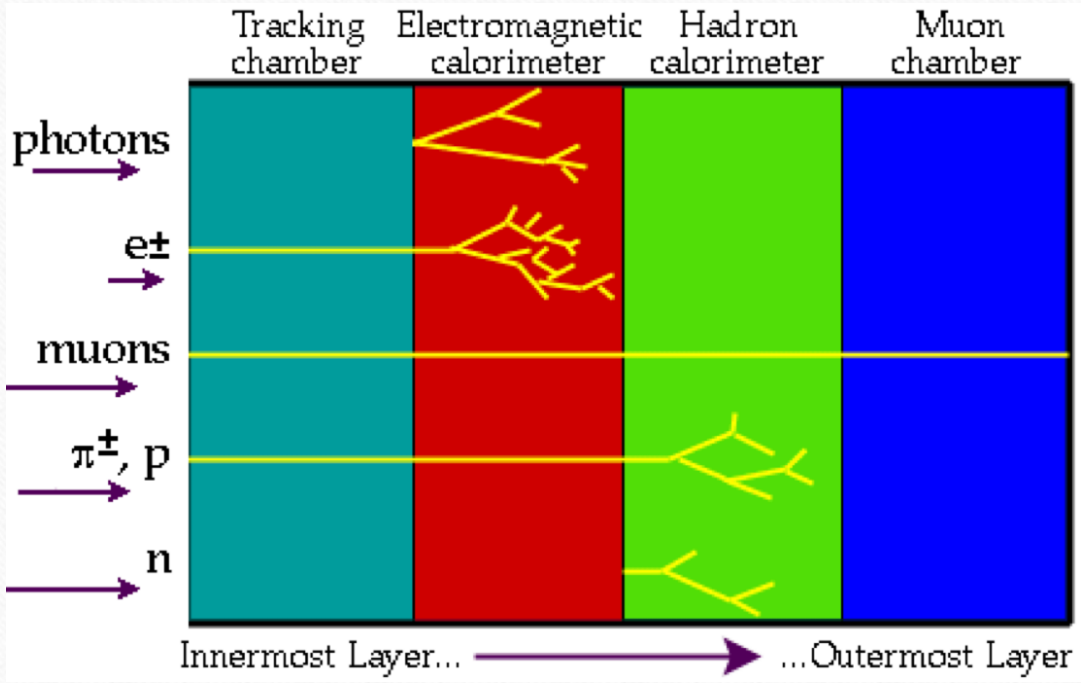
ALICE

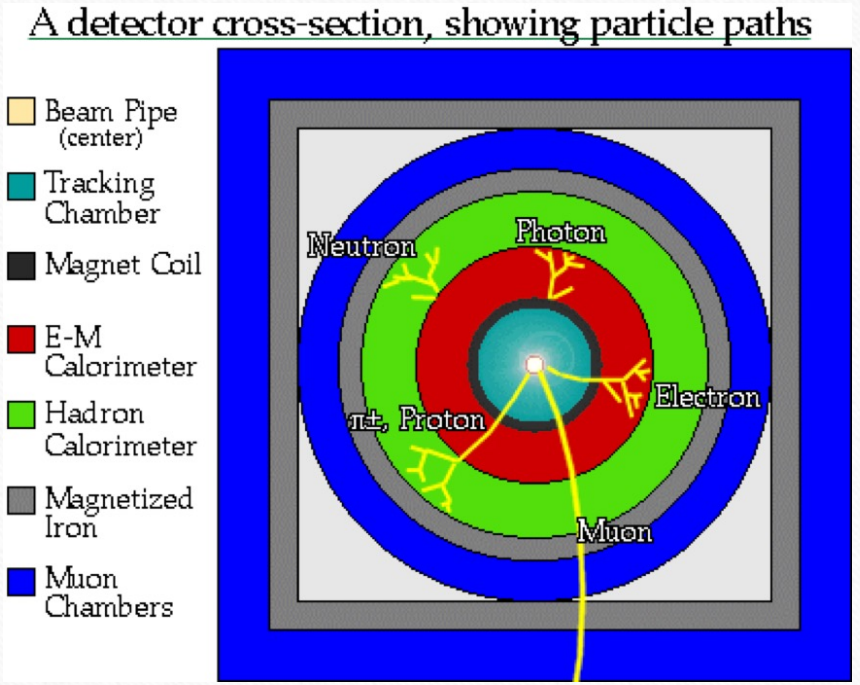


LHCb



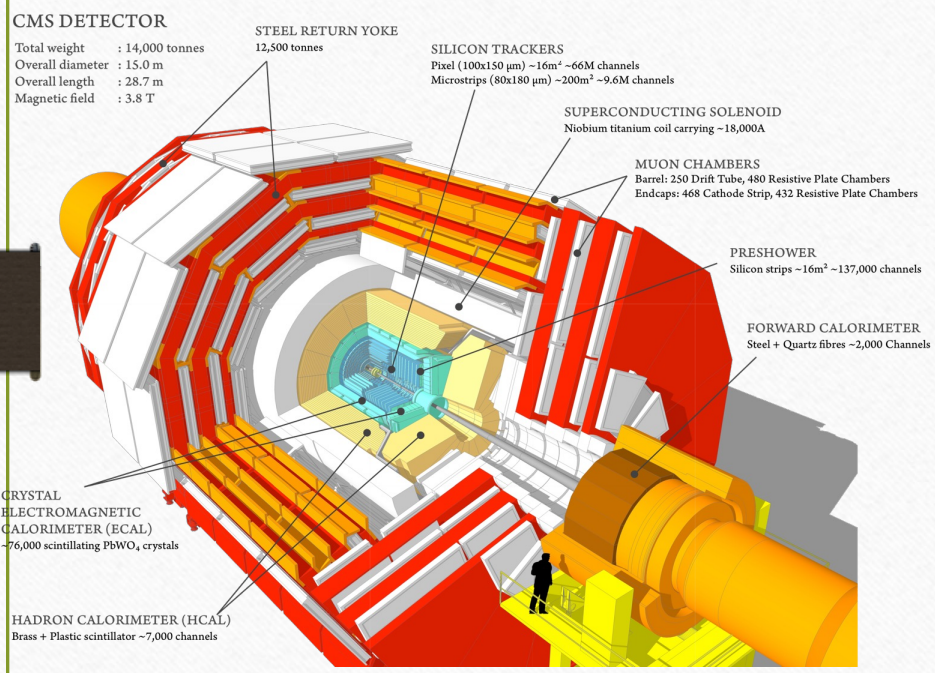
Detectors @CERN

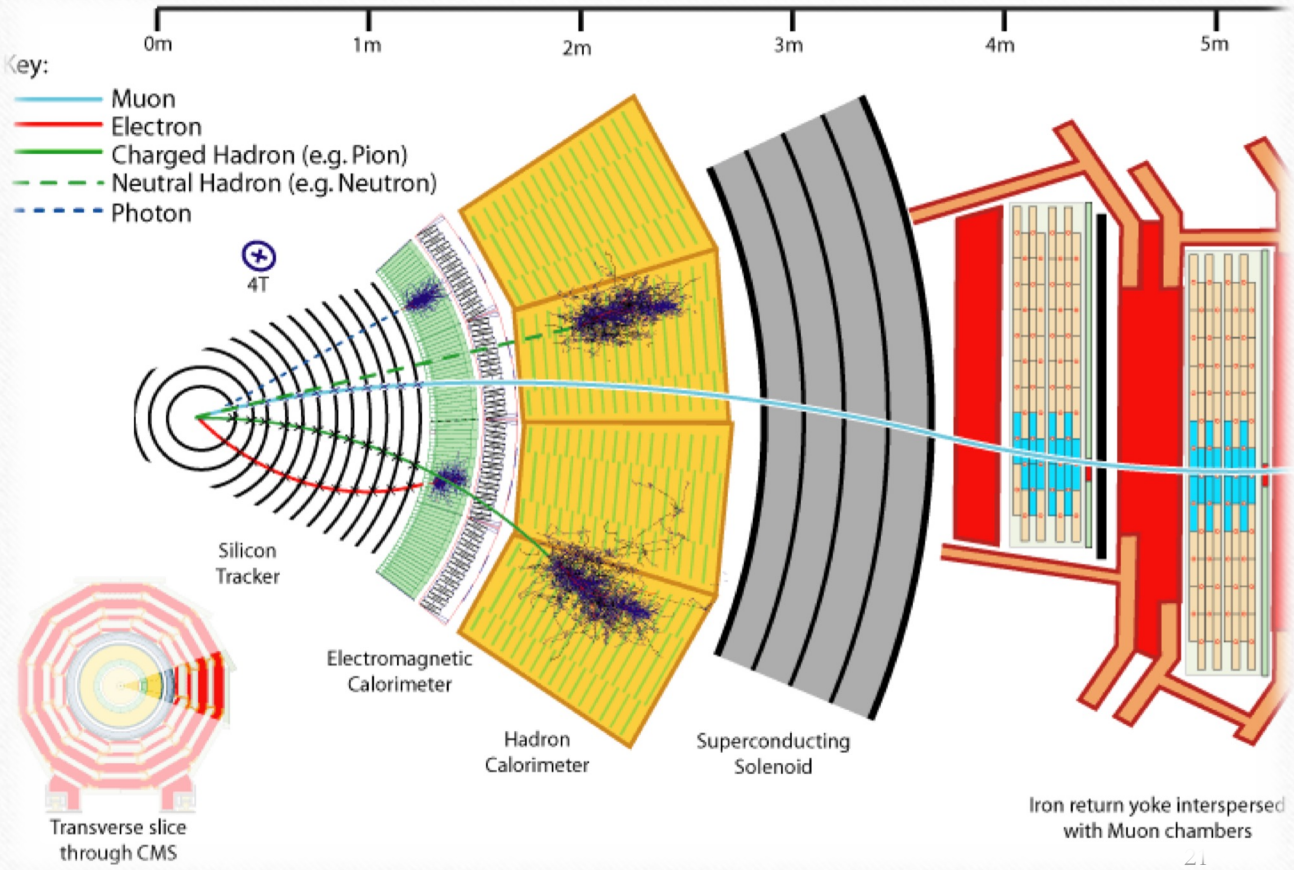




- Not all particles are detected, some leave the detector without any trace (neutrinos), some escape through not sensitive detector areas (holes, cracks for e.g., water cooling and gas pipes, cables, electronics, mechanics)

Compact Muon Solenoid (CMS)

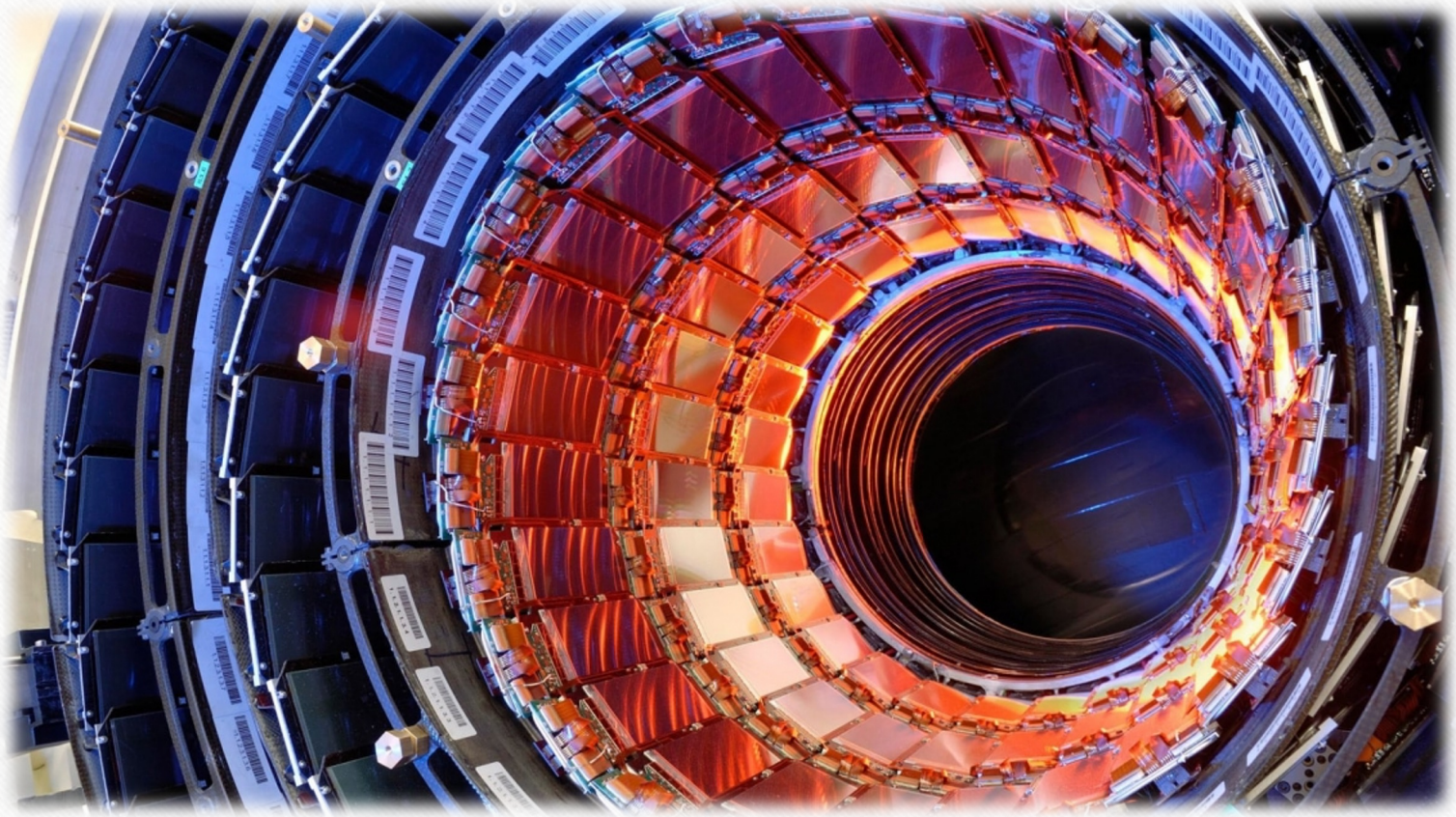




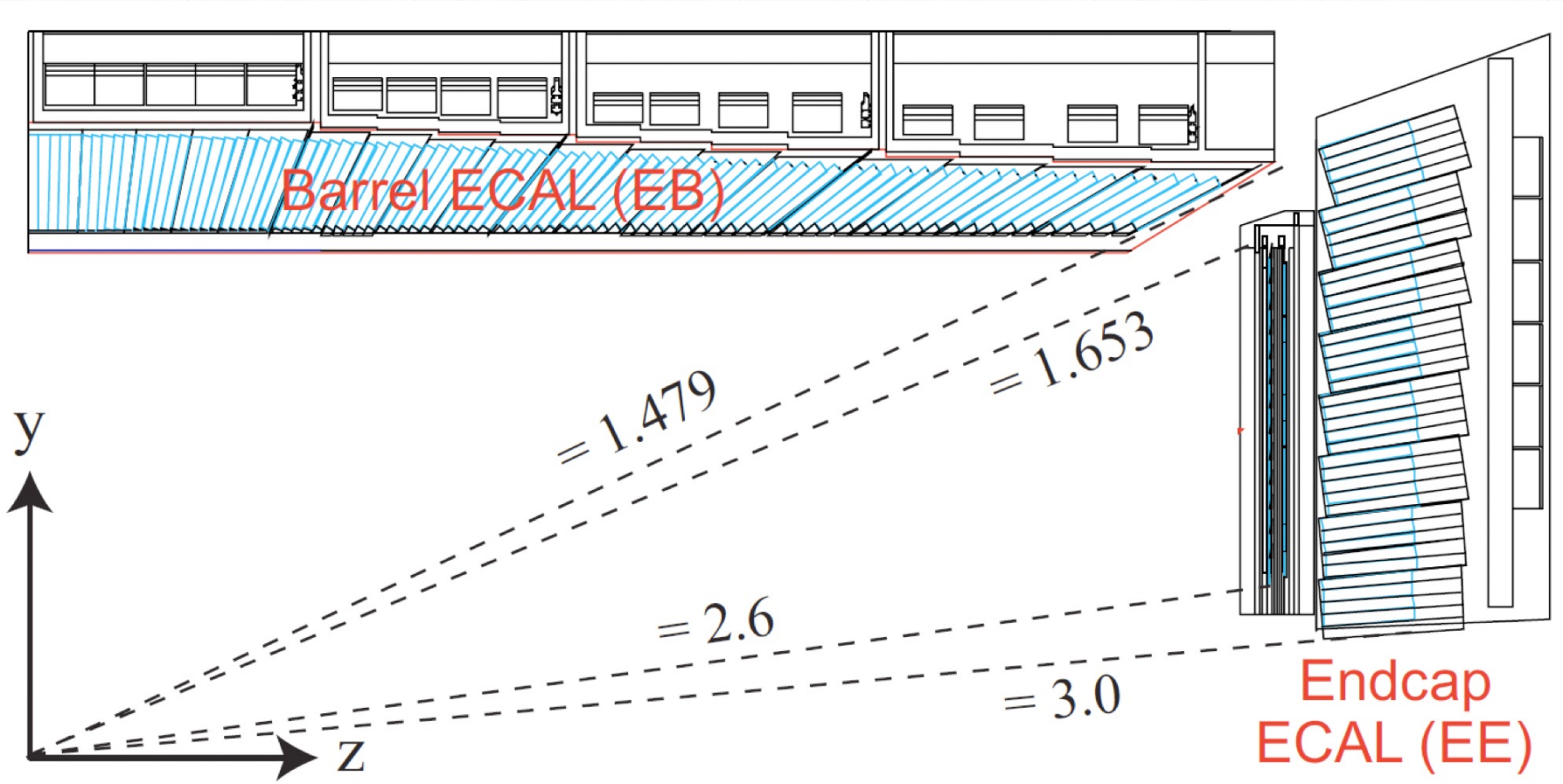
Tracker

- Records the paths taken by charged particles by measuring their positions at number of key points
- 4 inner layers of Pixel detector (Phase I)
- 10 outer layers of Silicon Strips detector

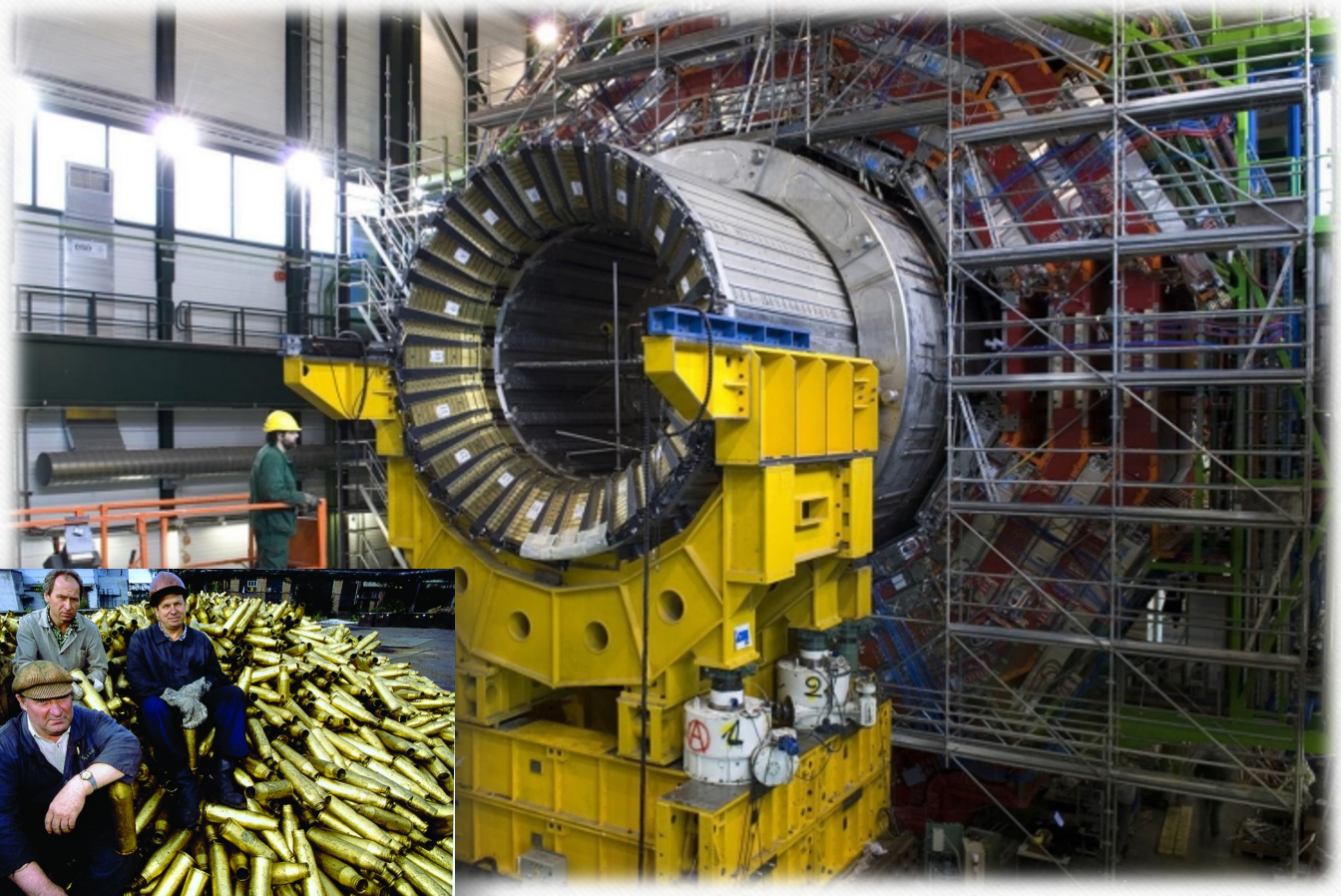
Credit : https://cms.cern/detector/identifying-tracks



Electromagnetic Calorimeter (ECAL)



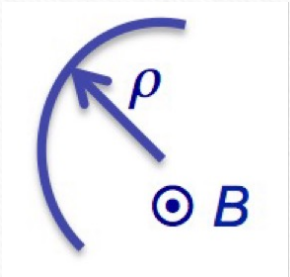
Hadronic Calorimeter (HCAL)



- HCAL measures the energy of hadrons, particles made of quarks and gluons
- A sampling calorimeter (material that produces the particle shower is distinct from the material that measures the deposited energy)
- Alternating layers of **absorber** and fluorescent **scintillator** materials that produce a rapid light pulse when the particle passes through

Solenoid Magnet (4 T)

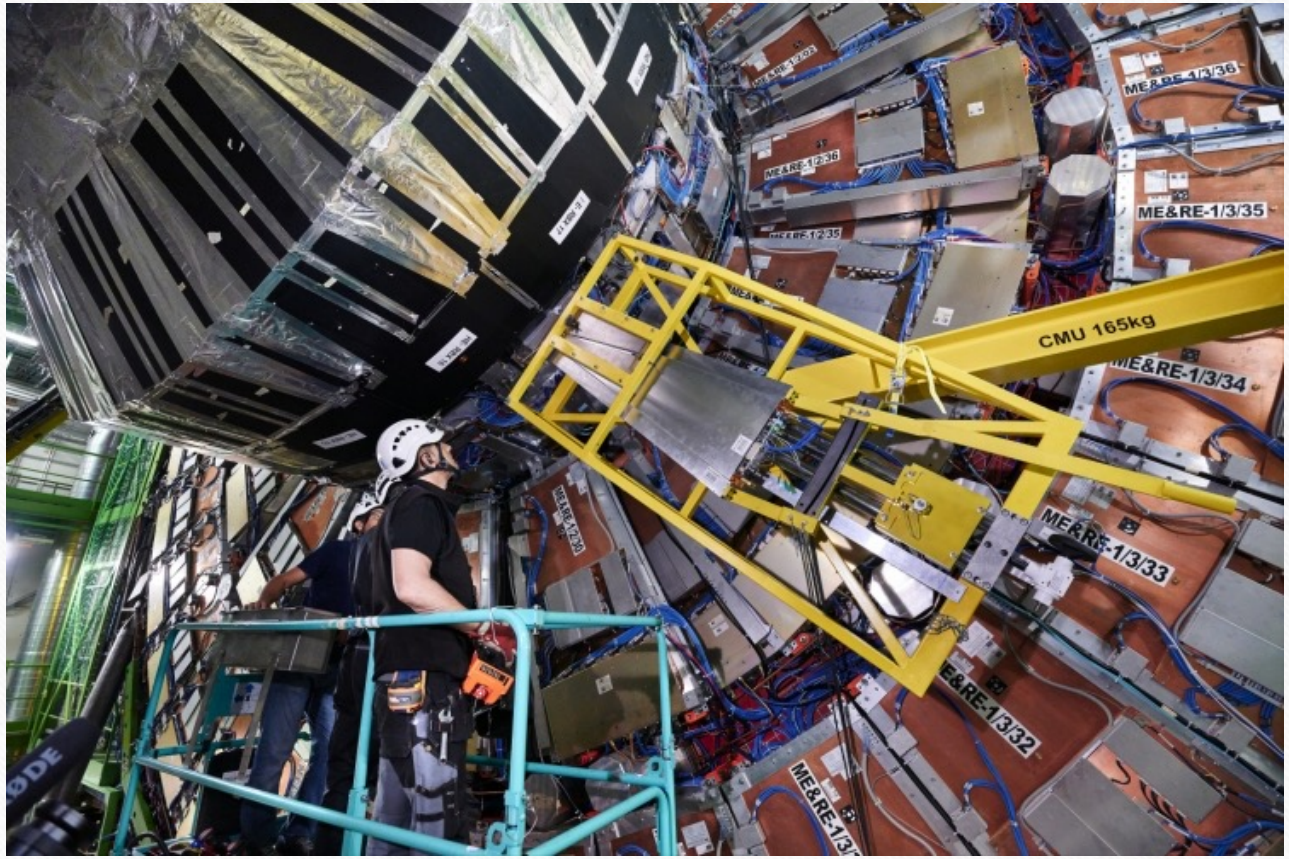
- Charged particles are deflected by magnetic field

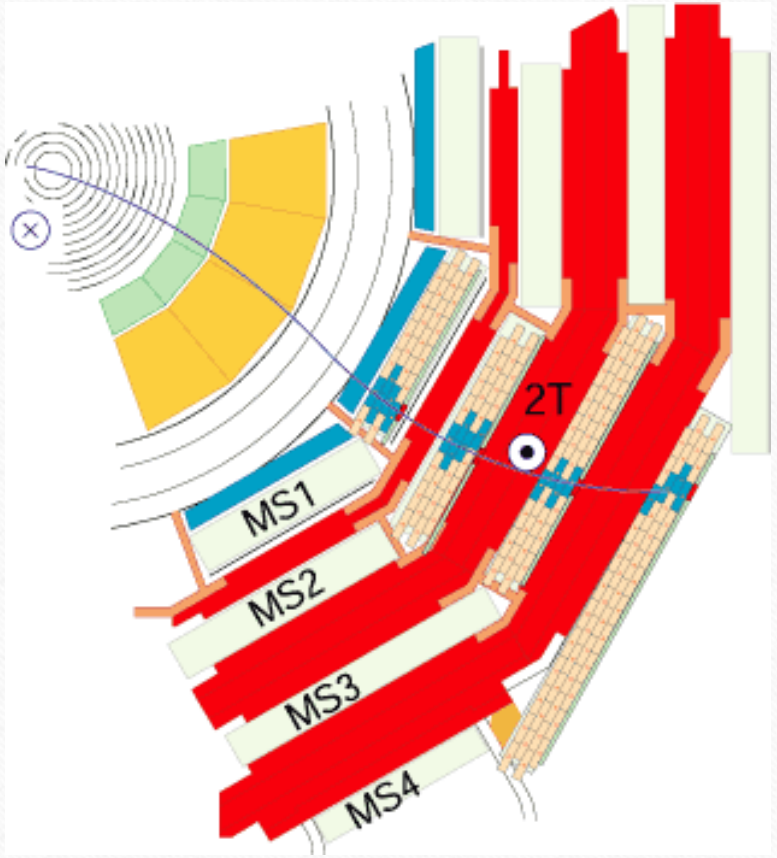


$$\rho = \frac{p_T}{q|B|} = \frac{\gamma m_0 \beta c}{q|B|}$$

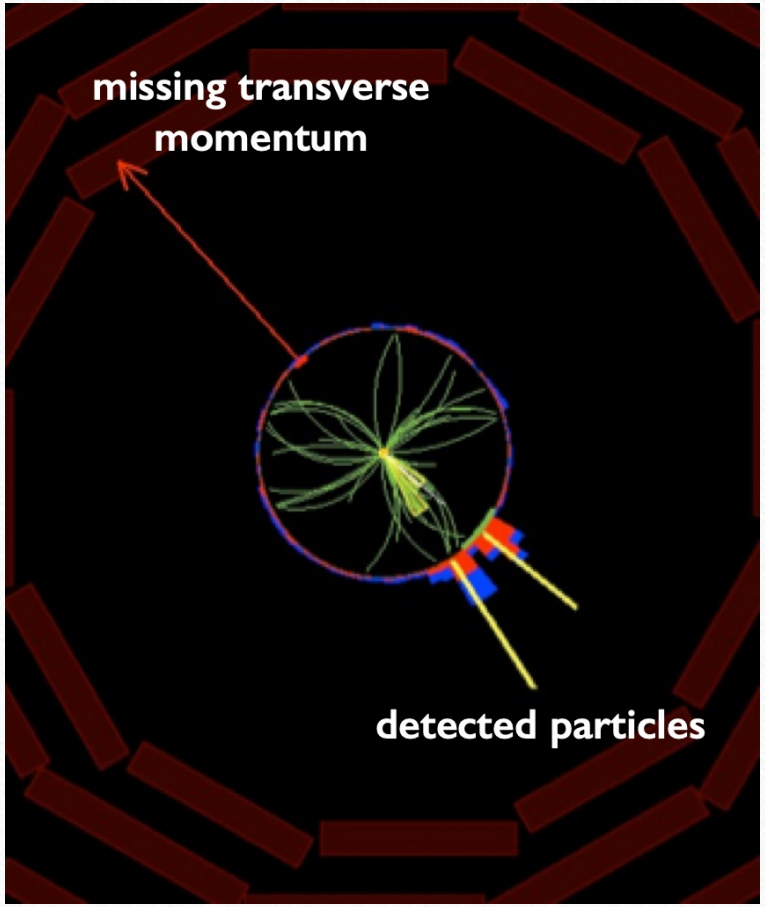
- By measuring the radius of curvature, we can determine the momentum of a particle
- If we can measure also β (velocity) independently we can determine the particle mass and identify it

Muon Chamber





Any undetected particles?

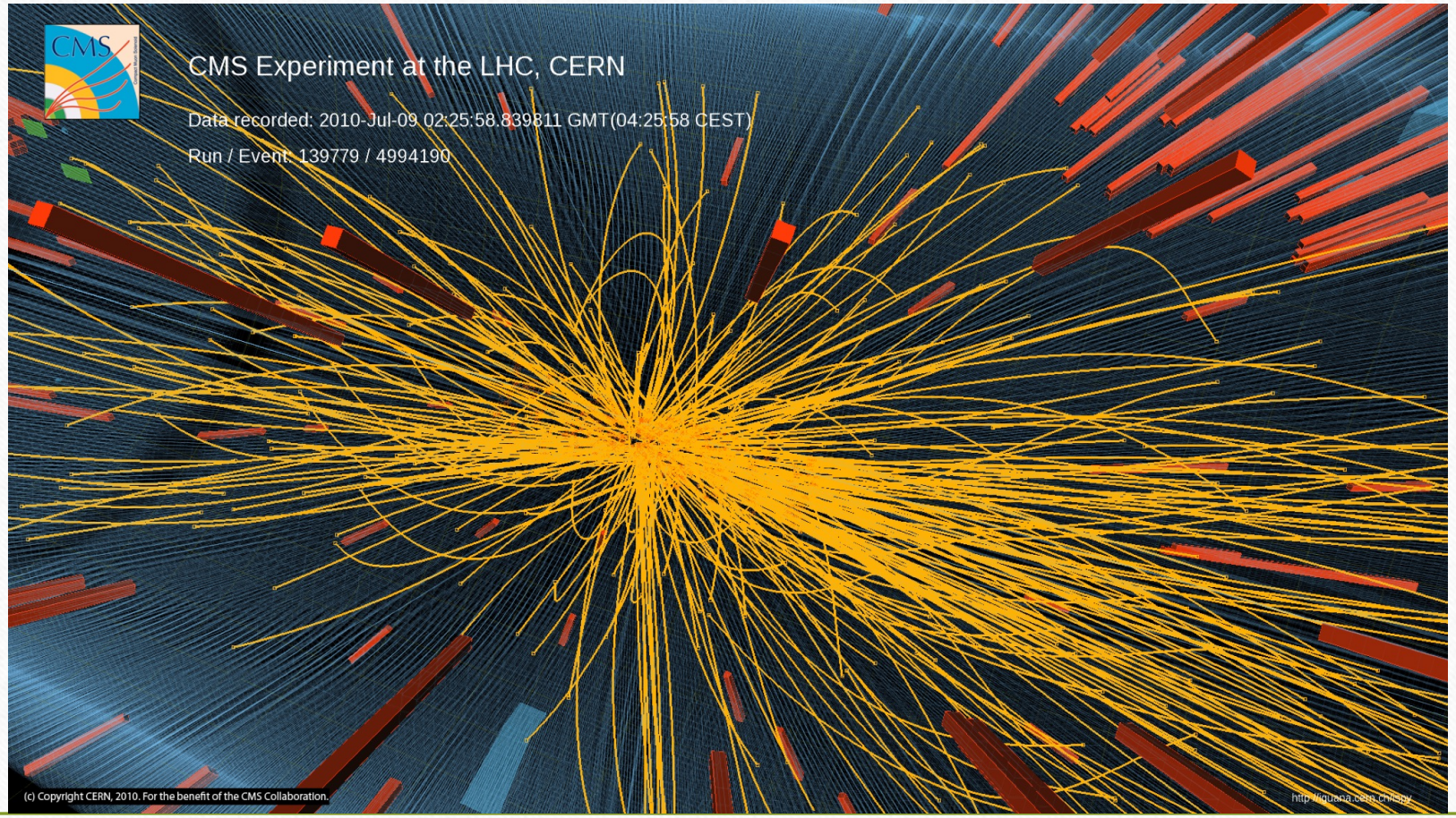


- Onion-like shape detector to avoid missing particles but still…
- In collider experiment, we detect this kind of particle indirectly from the momentum imbalance in the plane perpendicular to the beam direction. This quantity known as missing transverse momentum
- What we do is summing up all visible energy and momentum, then attribute missing energy and momentum to neutrino or undetected particles

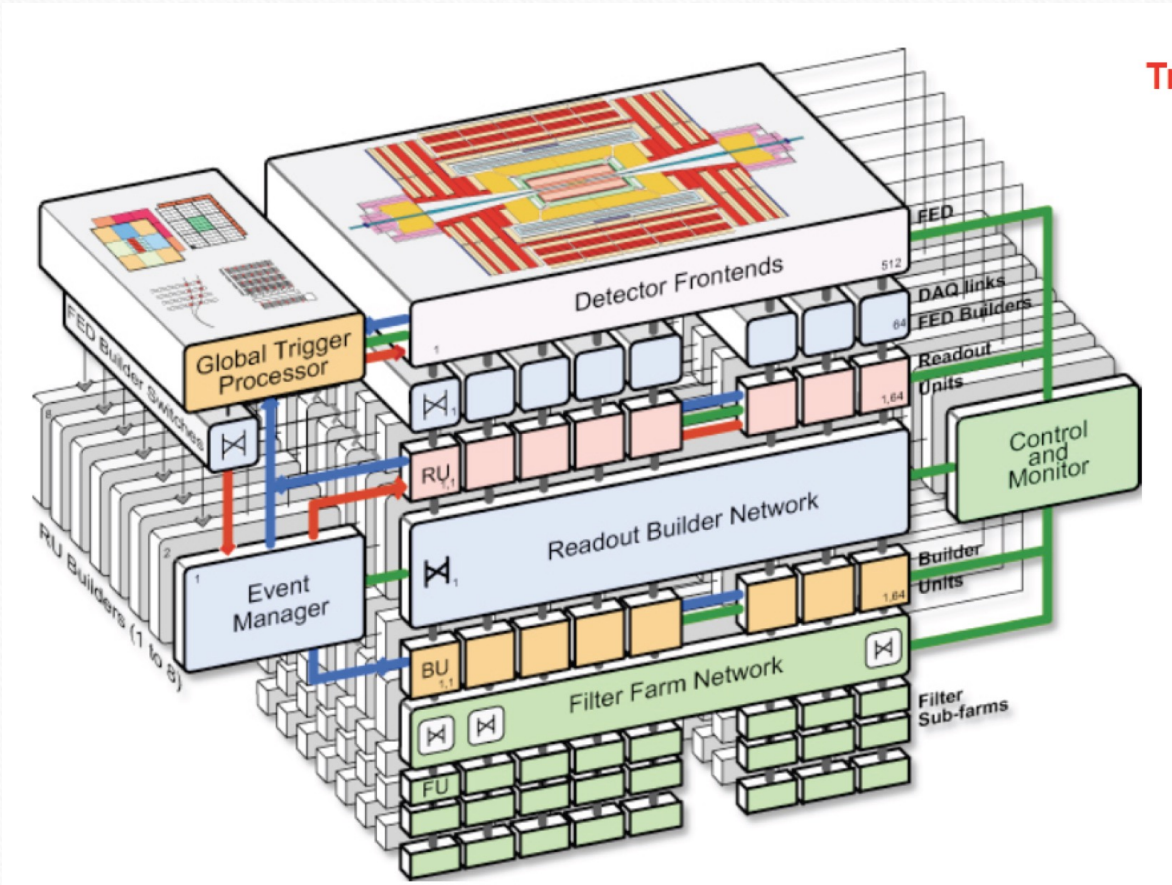
Every 25 ns

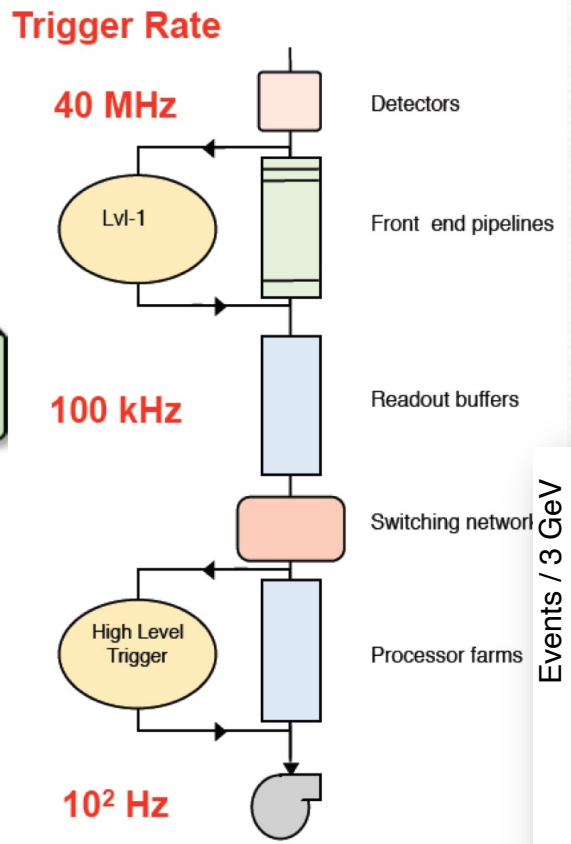
- 40M events per sec
  - 2 MB/events
  - 80 TB/sec
- **Impossible** for storage and CPU to process all events
- We need pre-selection based on physics of interest

"Trigger system"



Dealing with Big Data

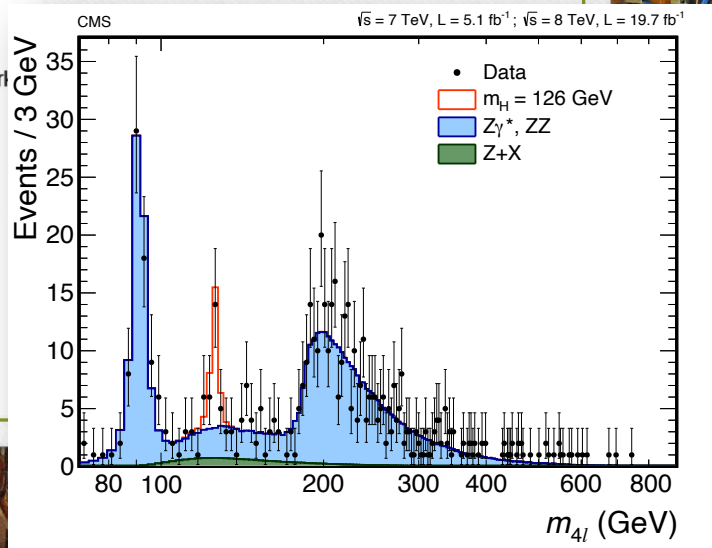




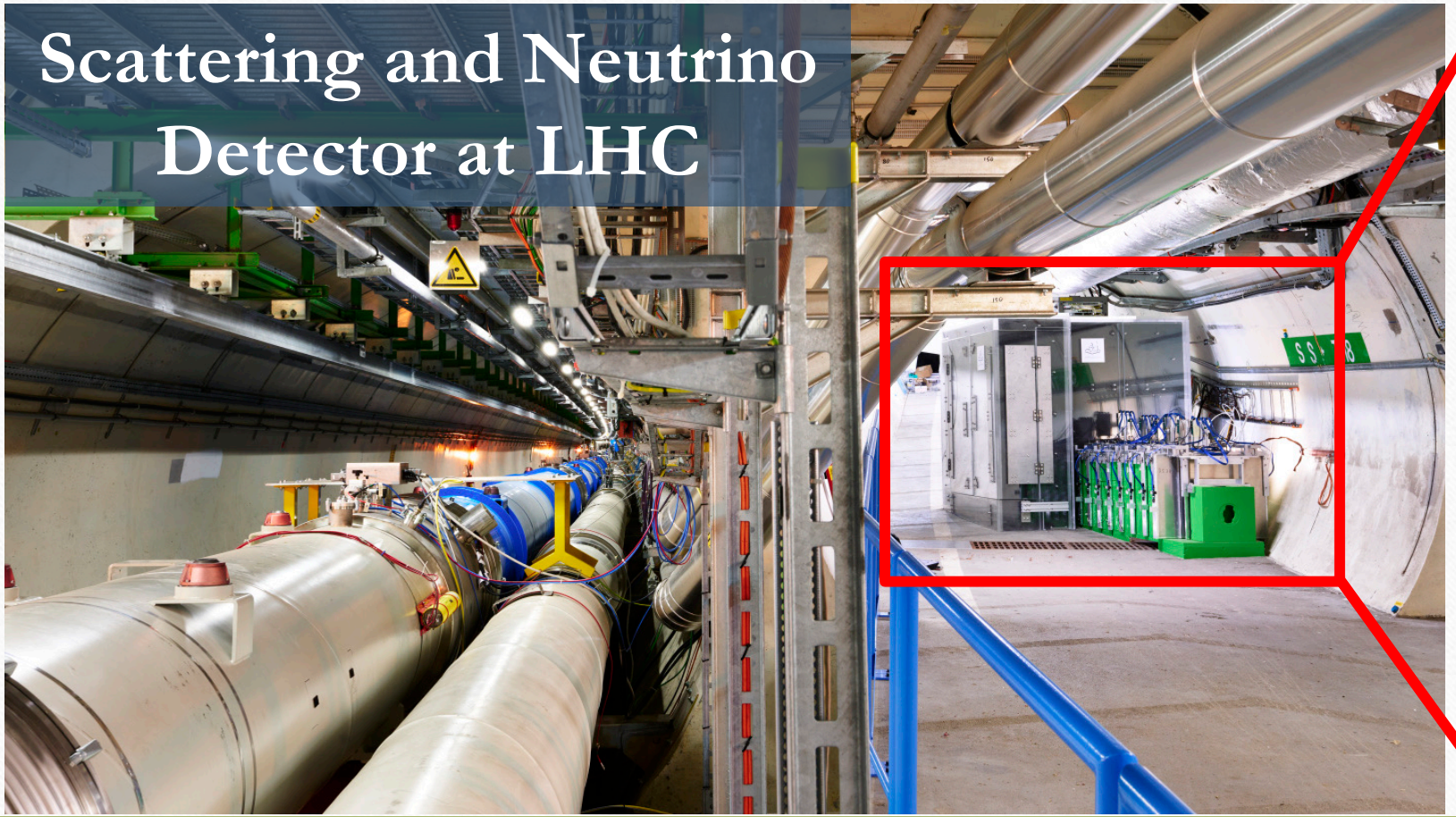
L1 Trigger

High Level Trigger

Physics Analyses



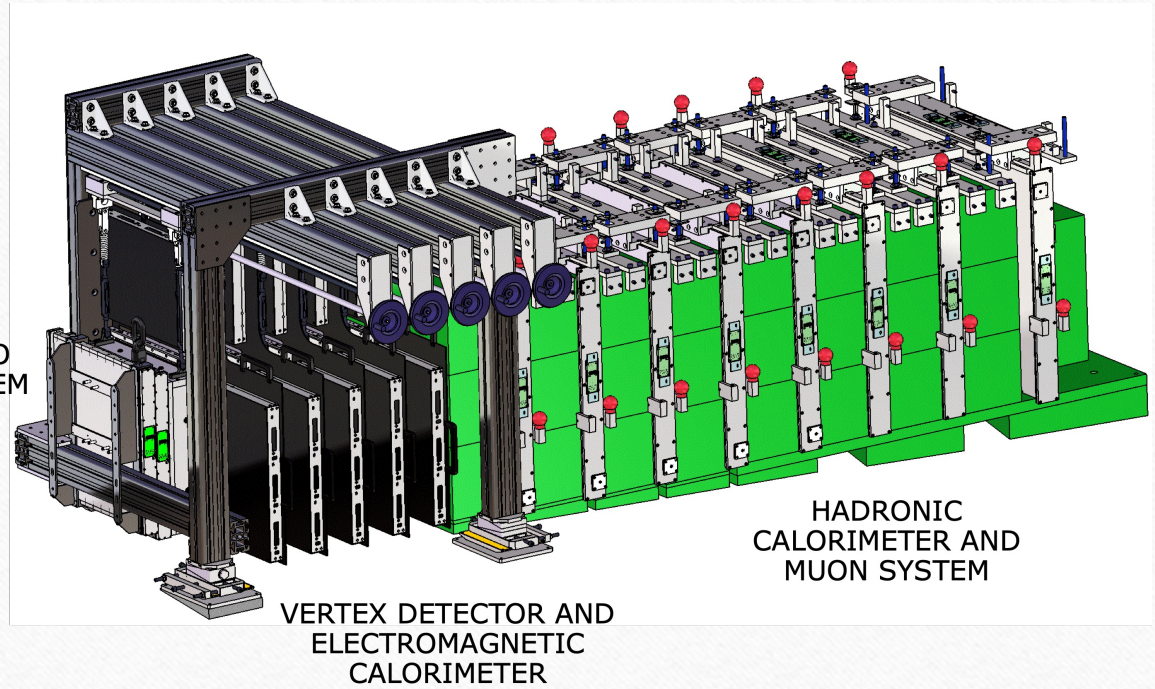
Neutrino Detectors at LHC



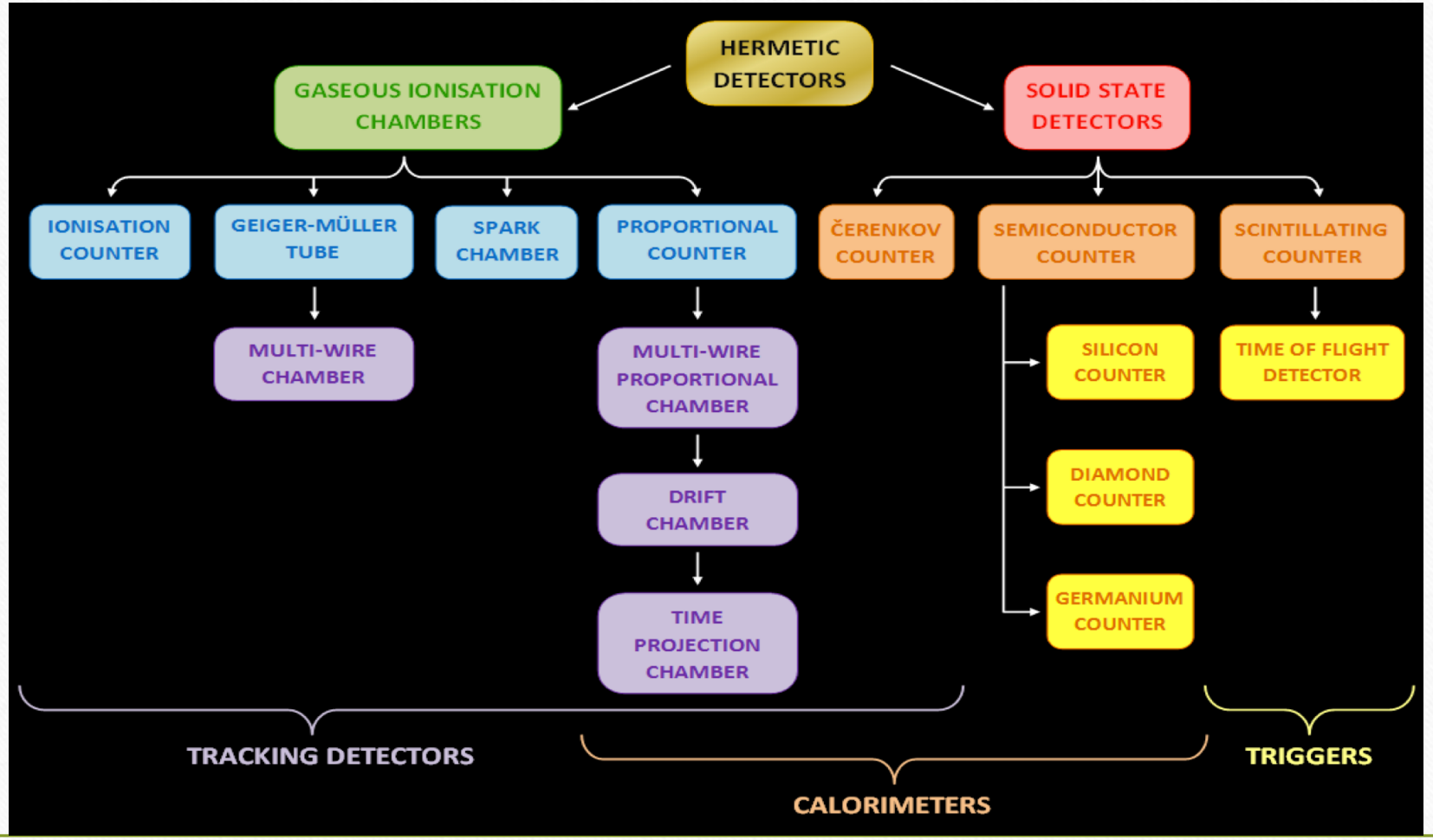
- The SND@LHC is located underground close to the ATLAS experiment, in an unused tunnel that links the LHC to the Super Proton Synchrotron
- A hybrid detector optimized for the identification of three neutrino flavors and for the detection of feebly interacting particles

Neutrino Detectors at LHC

- **VETO SYSTEM:**
  - tag penetrating muons
- **VERTEX DETECTOR + EM CAL:**
  - Emulsion cloud chambers (Emulsion + Tungsten) for neutrino interaction detection
  - Scintillating fibers for timing information and energy measurement
- **HAD CAL + MUON SYSTEM:**
  - iron walls interleaved with plastic scintillator planes for fast time resolution and energy measurement



Take-Away



Credit : http://upload.wikimedia.org/wikipedia/commons/c/c0/Detectors_summary_3.png