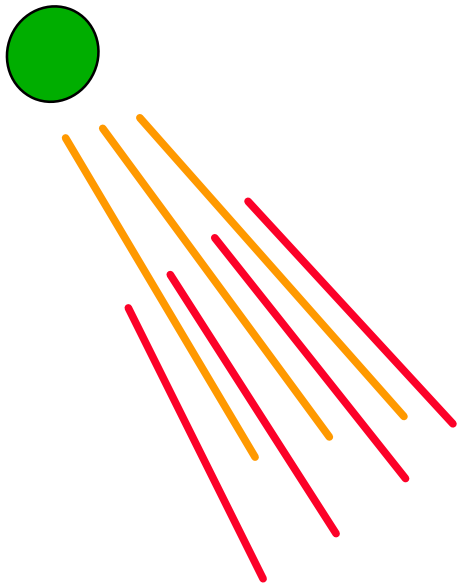
Particle Physics at CMS

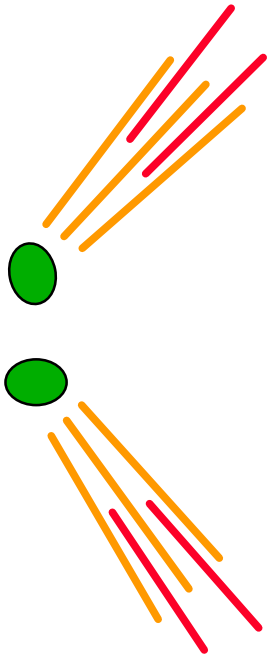
- *What* is it and *why* are we doing it ???
- The theory of everything !
- How do we study particle physics ?
  - Accelerators
  - Detectors
- Demands on detectors and DAQ.



What is Particle Physics & why are we studying it ???

What ?

- Study elementary building blocks of matter, (smaller than about 0.000000000000001 meters !)
- *Understand* forces which arise between them.

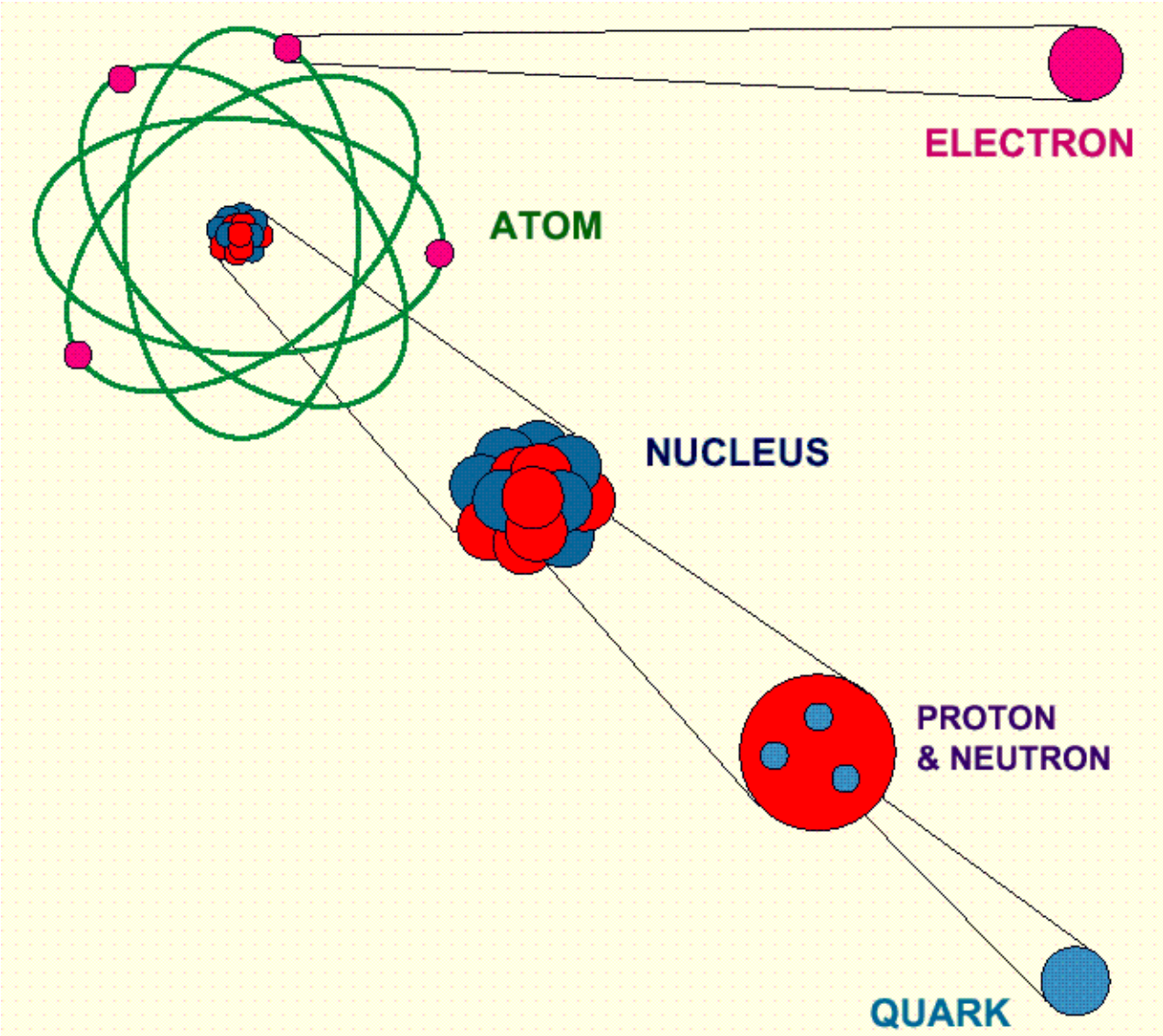


Why ?

- Curiosity driven.
- Fundamental knowledge often proves useful.

  e.g., electron and electromagnetic force.

The Standard Model
Theory of Everything ???



Nuclear atom
-- Rutherford (1909)

Neutron
-- Chadwick (1932)

Quarks
-- SLAC (1968)

The Standard Model
Theory of Everything ???

Constituents of matter:

Quarks: u d c s b t

- Quarks are sociable

-- always found in groups of 2 or 3 (p, n, $\pi^{\pm}$...)

Leptons: e ν_e μ ν_μ τ ν_τ

- Leptons are loners ...

The Standard Model
Theory of Everything ???

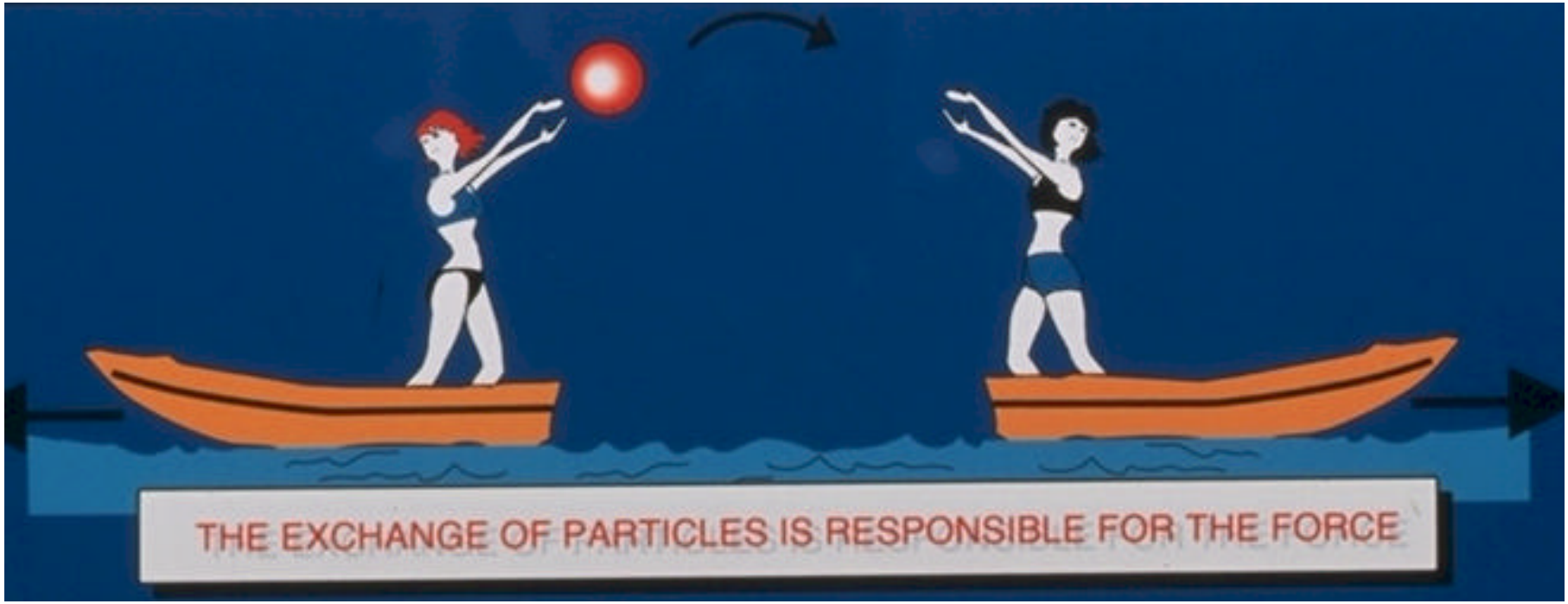
Force Particles:

Gravity: G

Electromagnetic: γ

Strong Nuclear: g

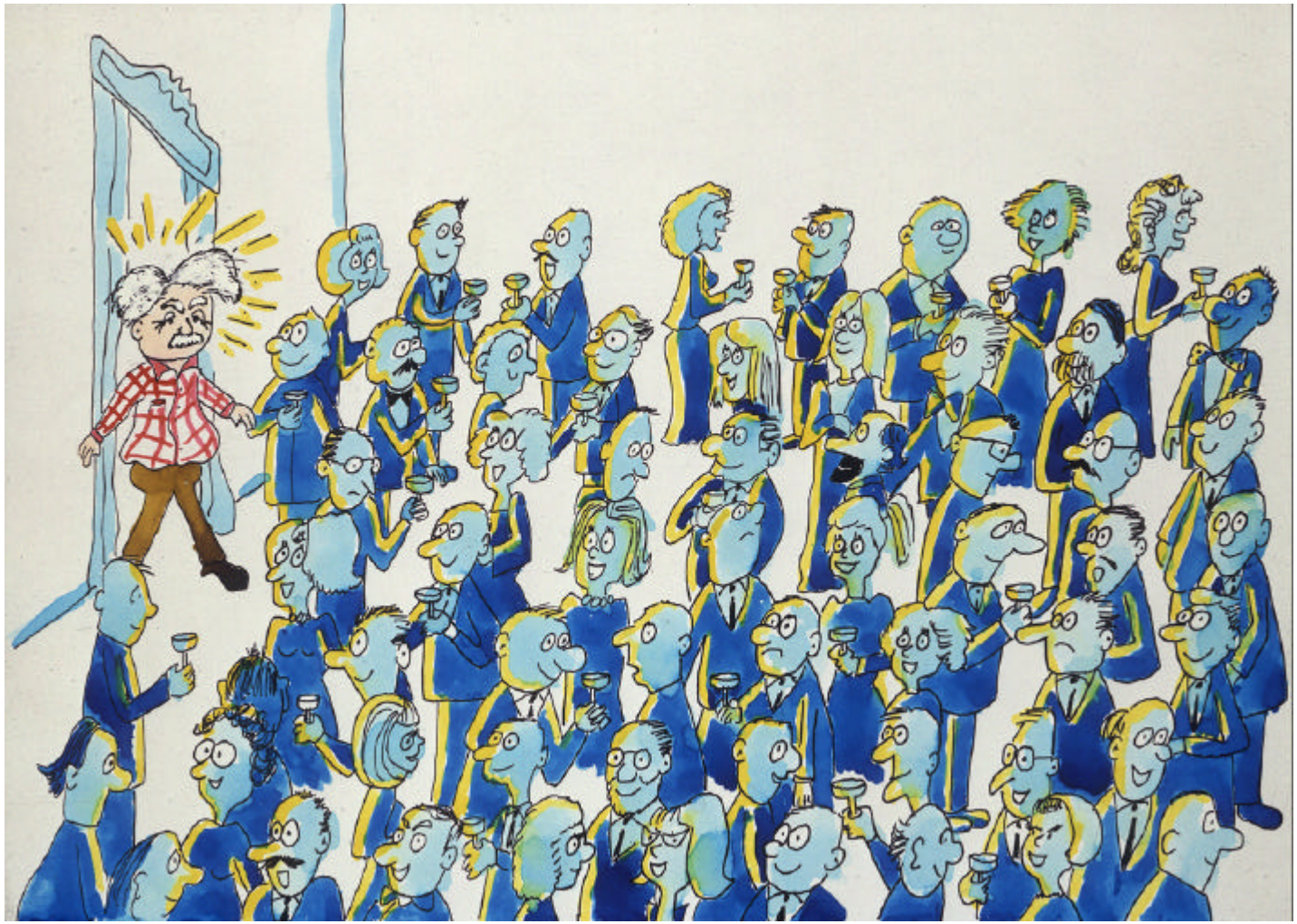
Weak Nuclear: $W^{\pm}$ Z



The Standard Model
Theory of Everything ???

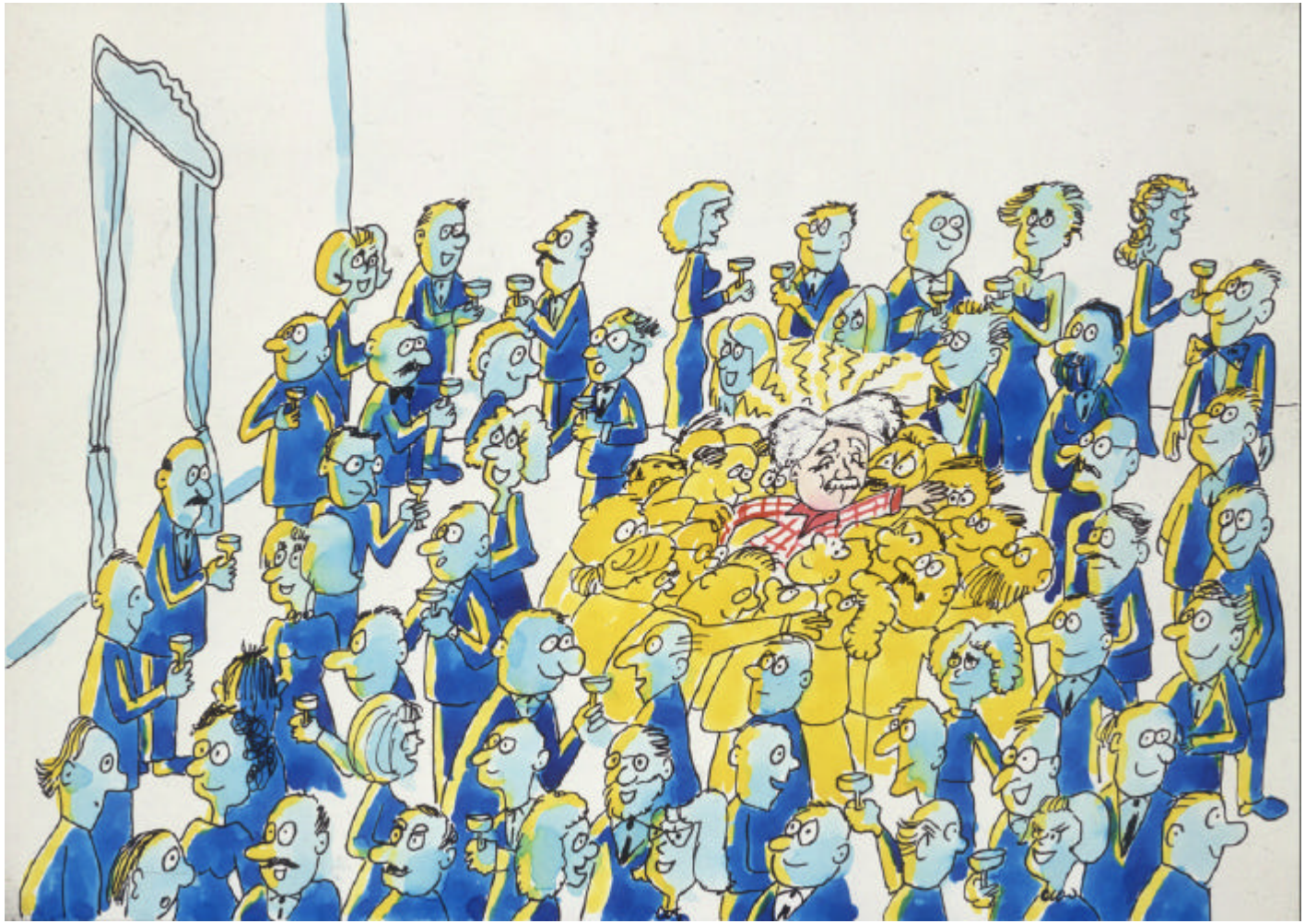
Higgs Particle

-- Giver of Mass

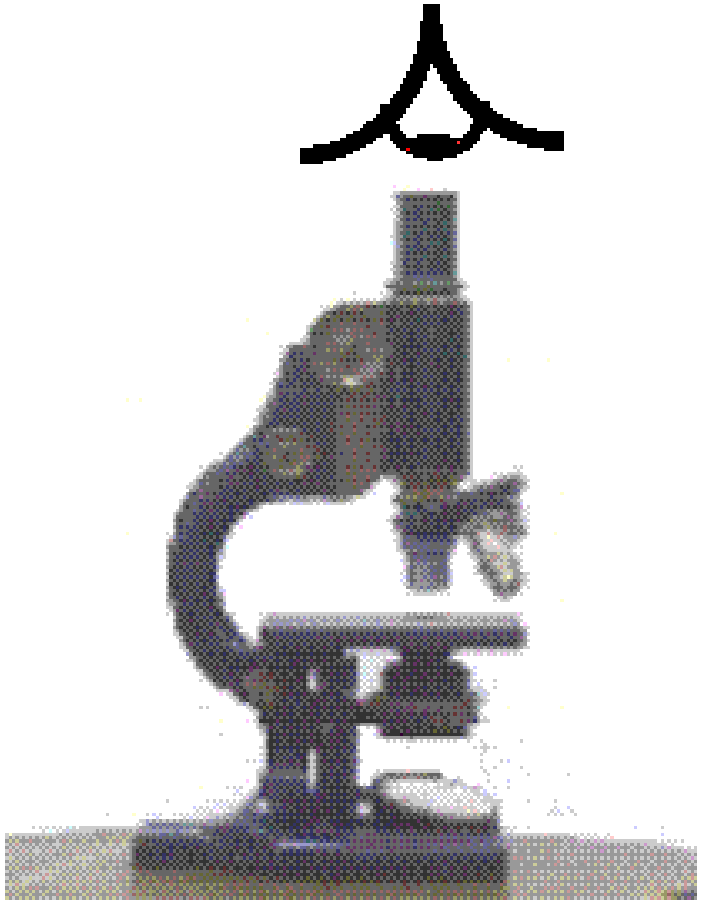


The Standard Model
Theory of Everything ???

Higgs `field' clusters around other particles.



How do we study particle physics ? Accelerators !

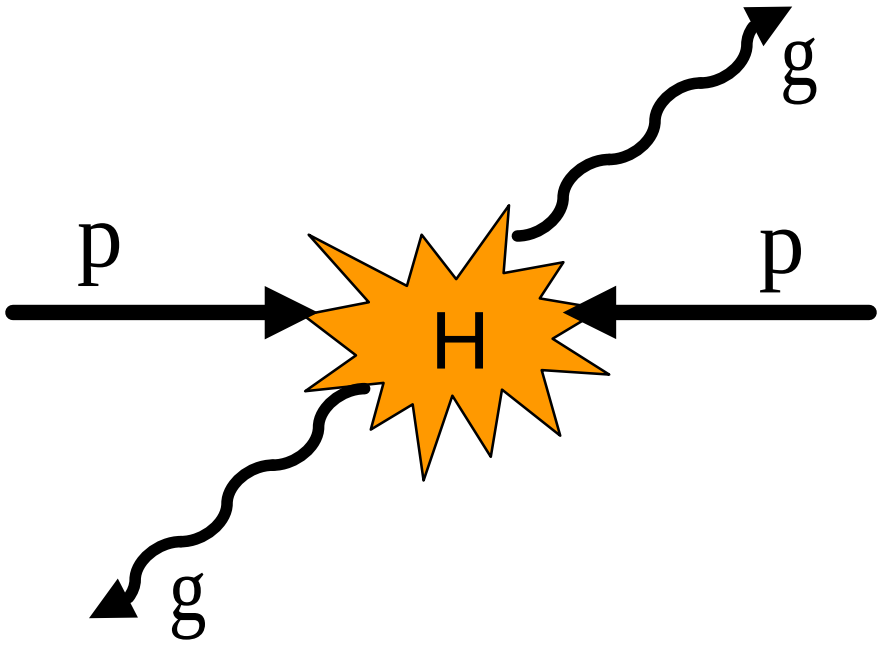


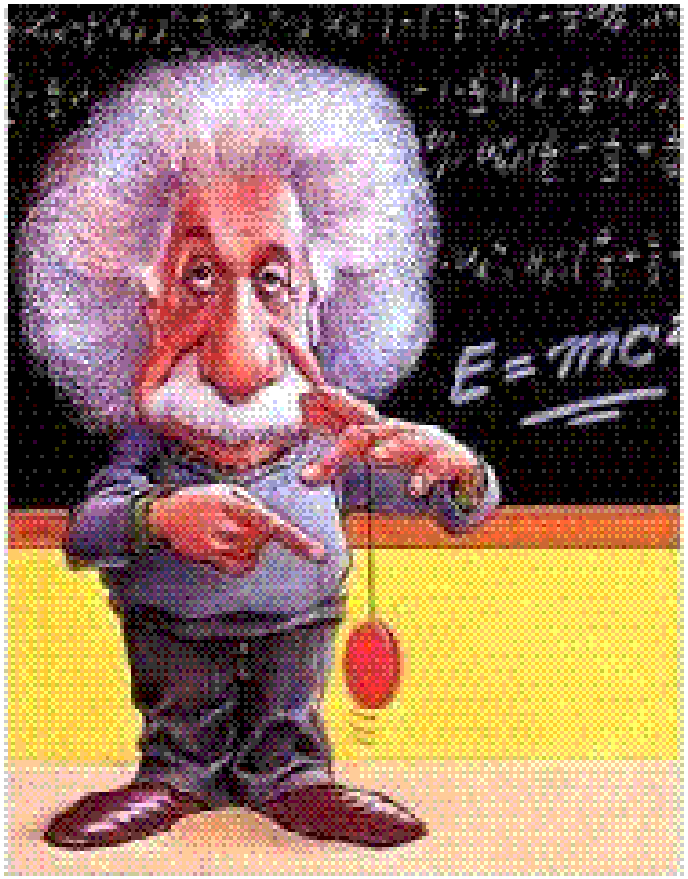
Can't see things smaller than wavelength of probe radiation. ($\lambda \sim 1/E$).

Object	Size	Probe
Bacteria	10^{-6} m	Visible light
Molecule	10^{-8} m	Electron microscope
		e (0.000001 GeV)
Nucleus	10^{-14} m	e/p (0.01 GeV)
LHC	10^{-17} m	p (14000 GeV)

How do we study particle physics ? Accelerators !

Another reason why high energies needed: $E = m c^2$



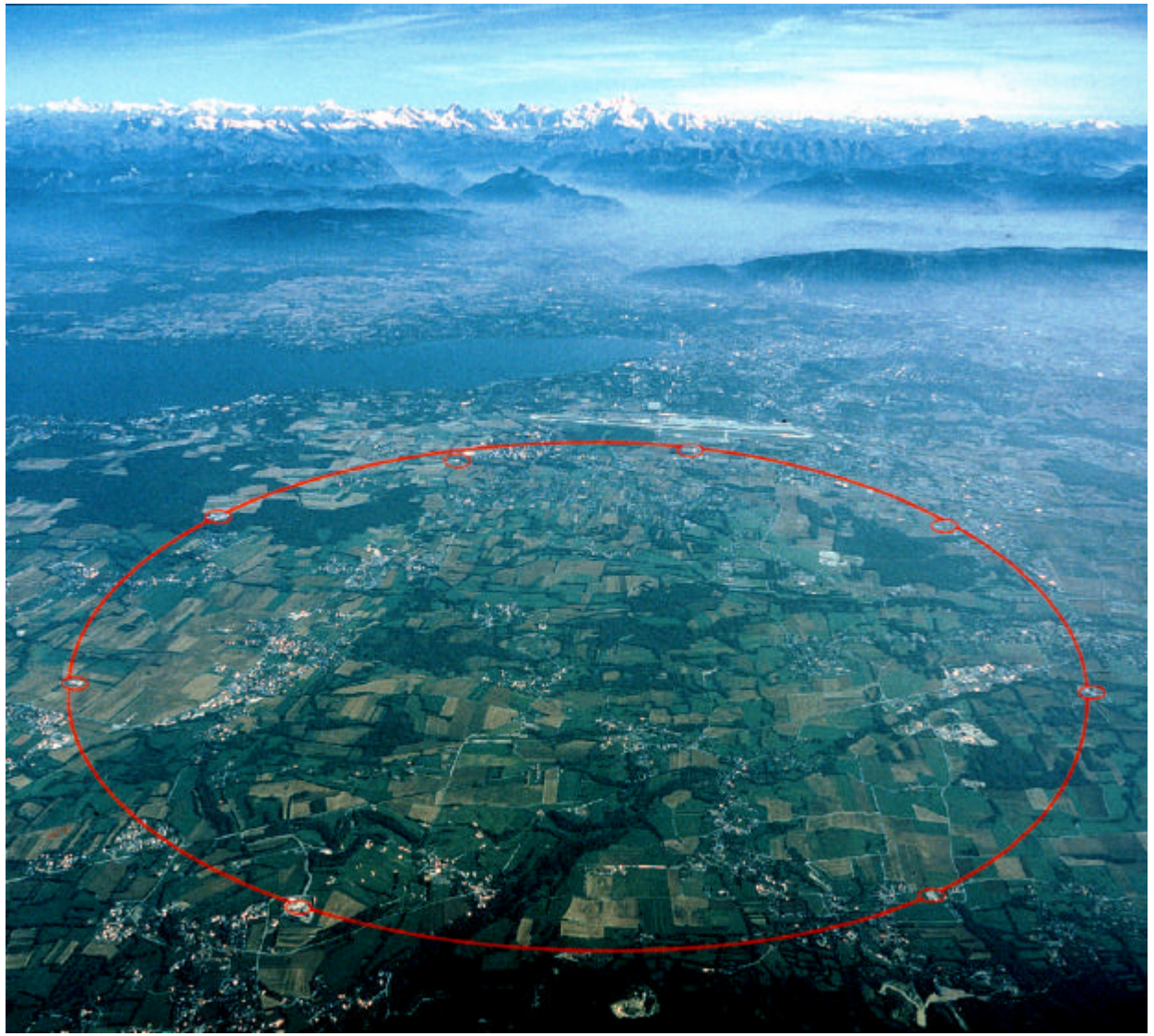


How do we study particle physics ? Accelerators !

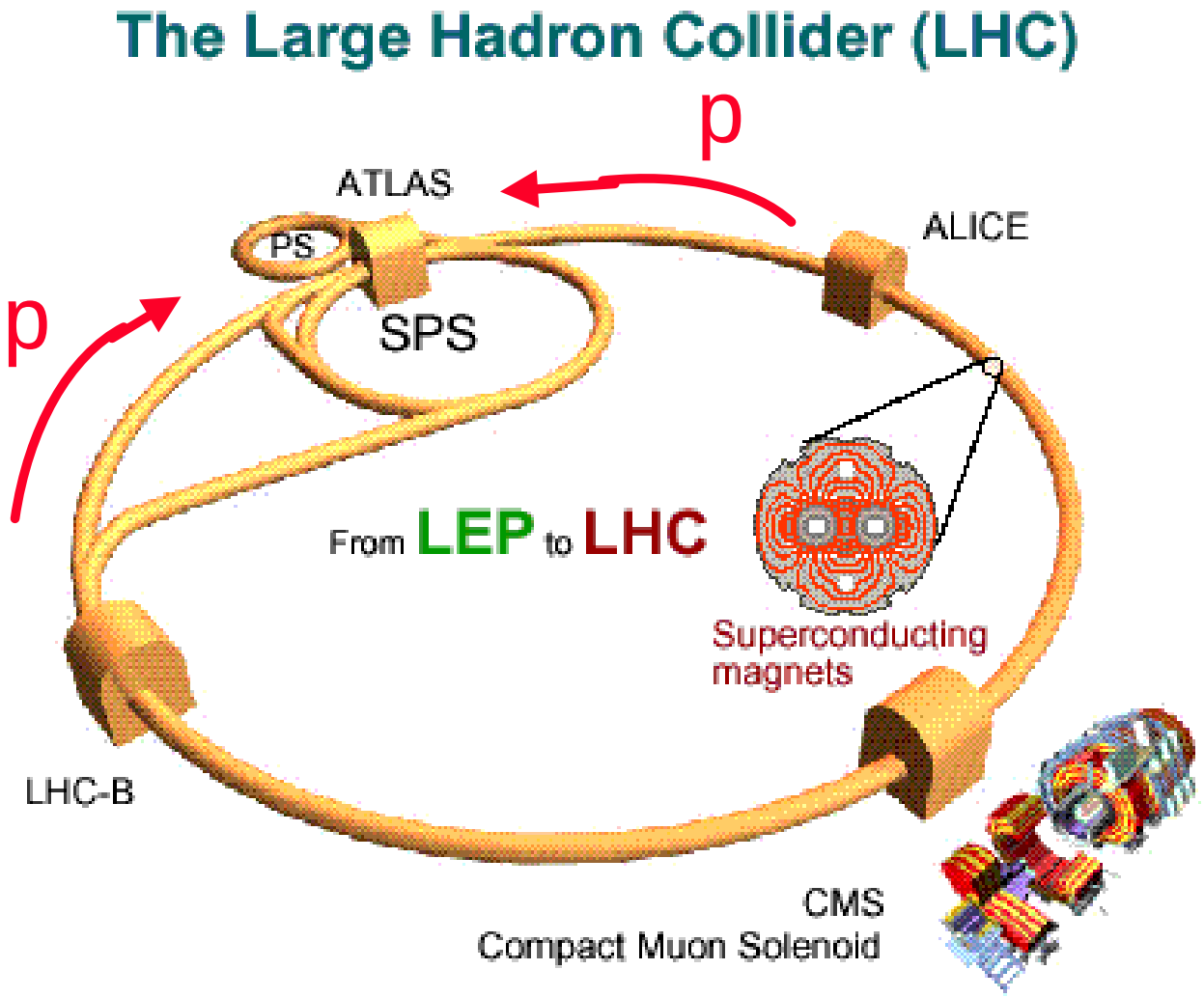
LHC collider

built at CERN

by 2006.



How do we study particle physics ?
Accelerators !



E = 14 TeV

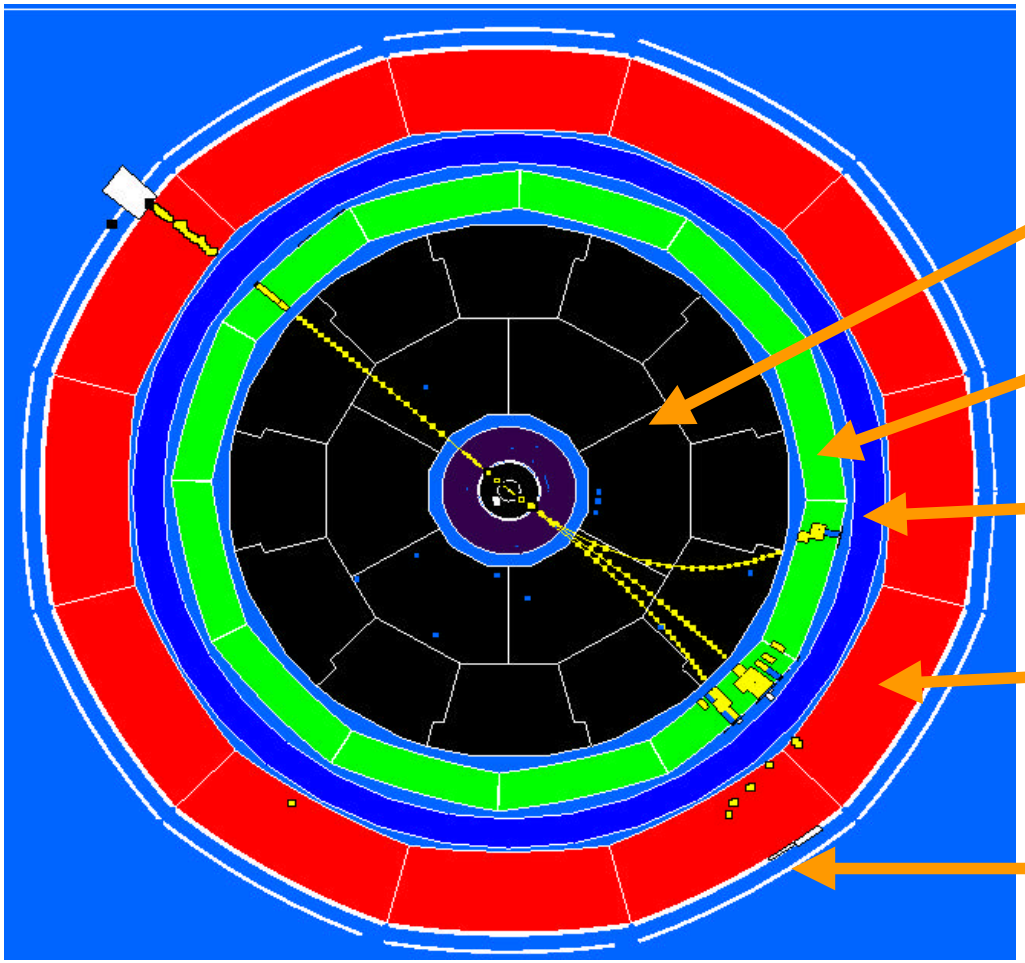
High Energy ?

(No, ~ energy of a household fly.)

But all in proton 0.000000000000001 meters across !

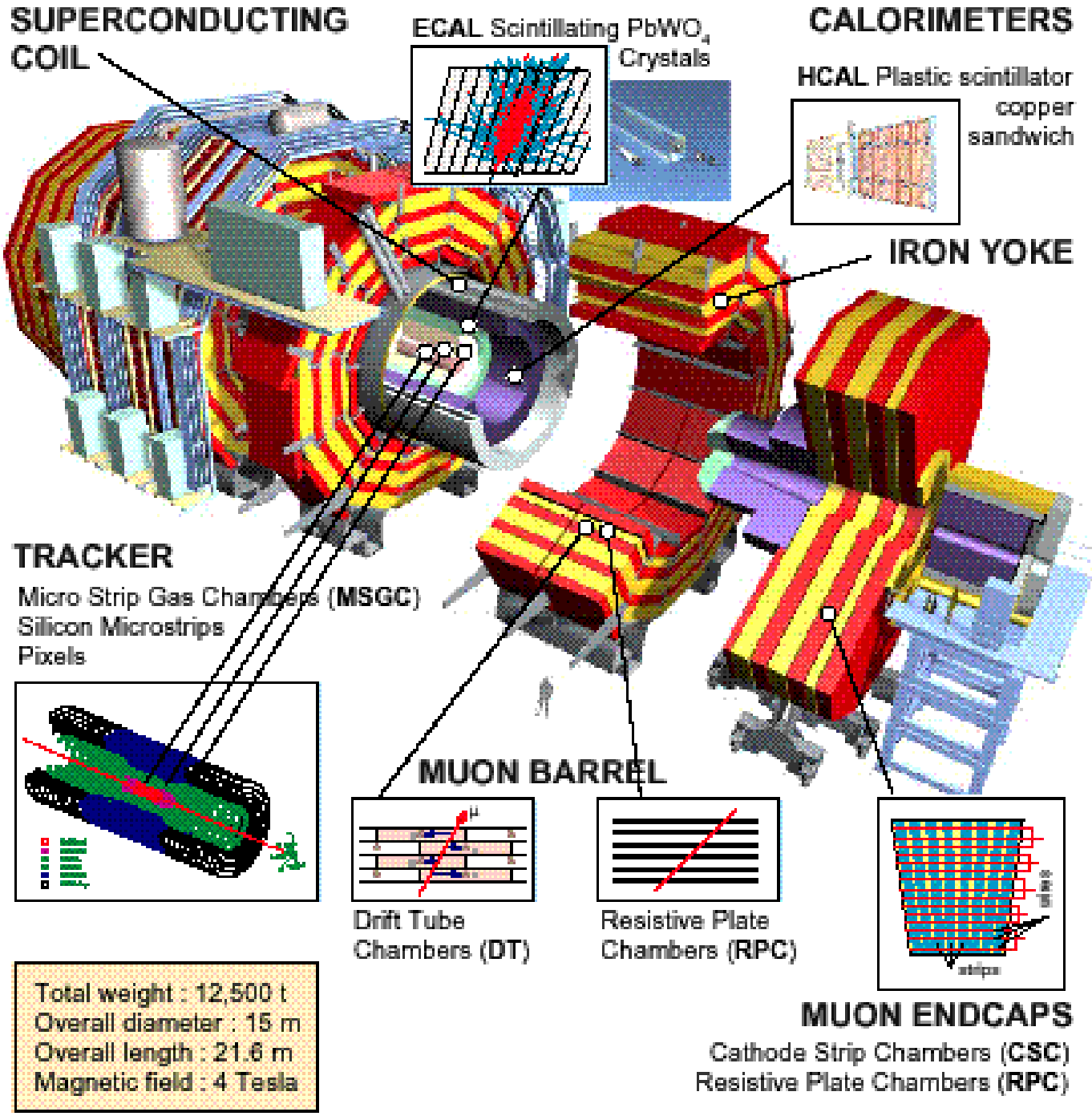
How do we study particle physics ? Detectors !

Detectors at colliders are cylindrical with several layers.

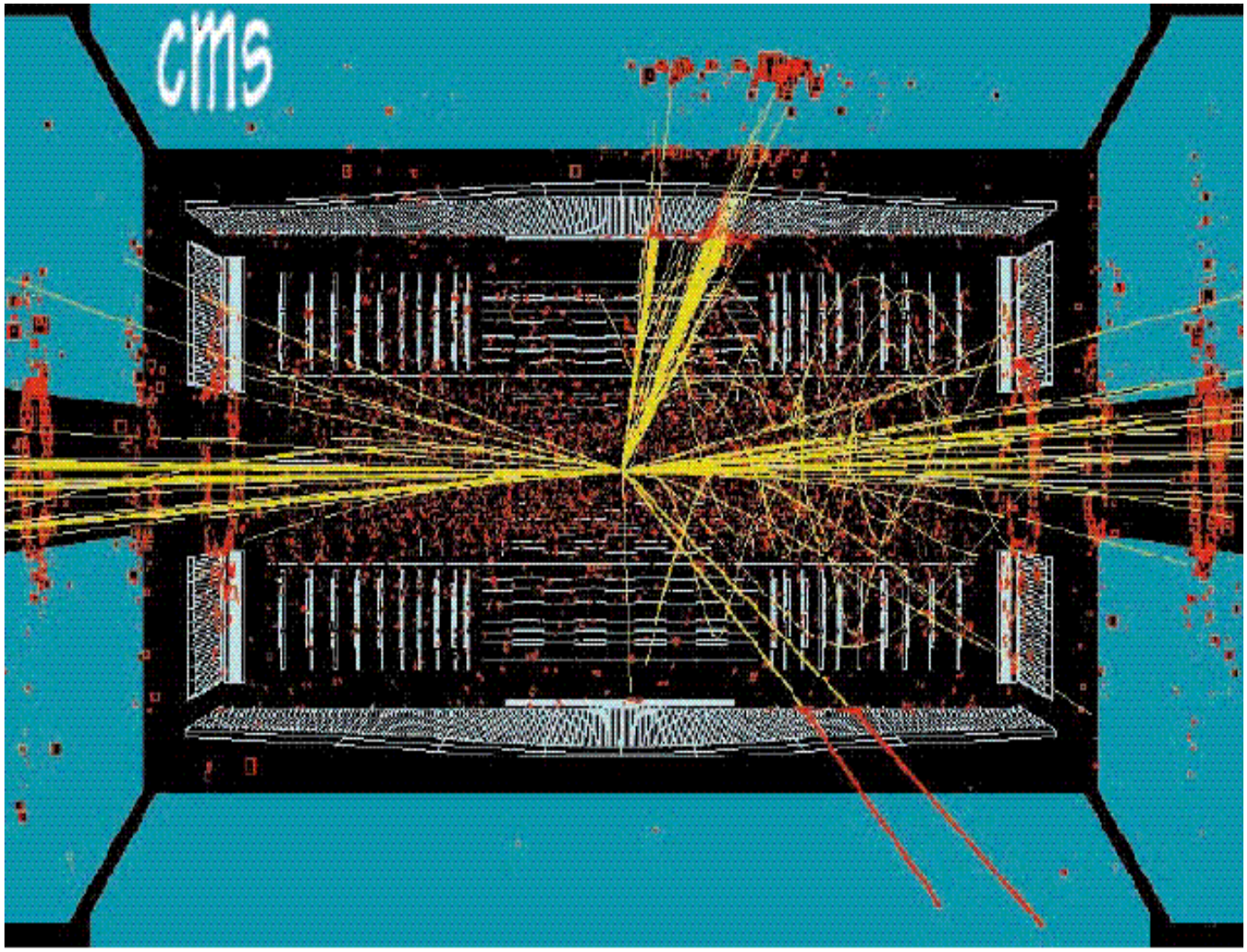


The **CMS** detector for the **LHC** collider.

It is HUGE, to measure high energy particles produced.



Demands on Detectors and DAQ



At CMS, many particles from each p-p collision.

So need fine granularity.

⇒ 100000000 readout channels !

So use zero suppression.

Demands on Detectors and DAQ

- LHC collides bunches of protons 40 000 000 times per second ! Why ?

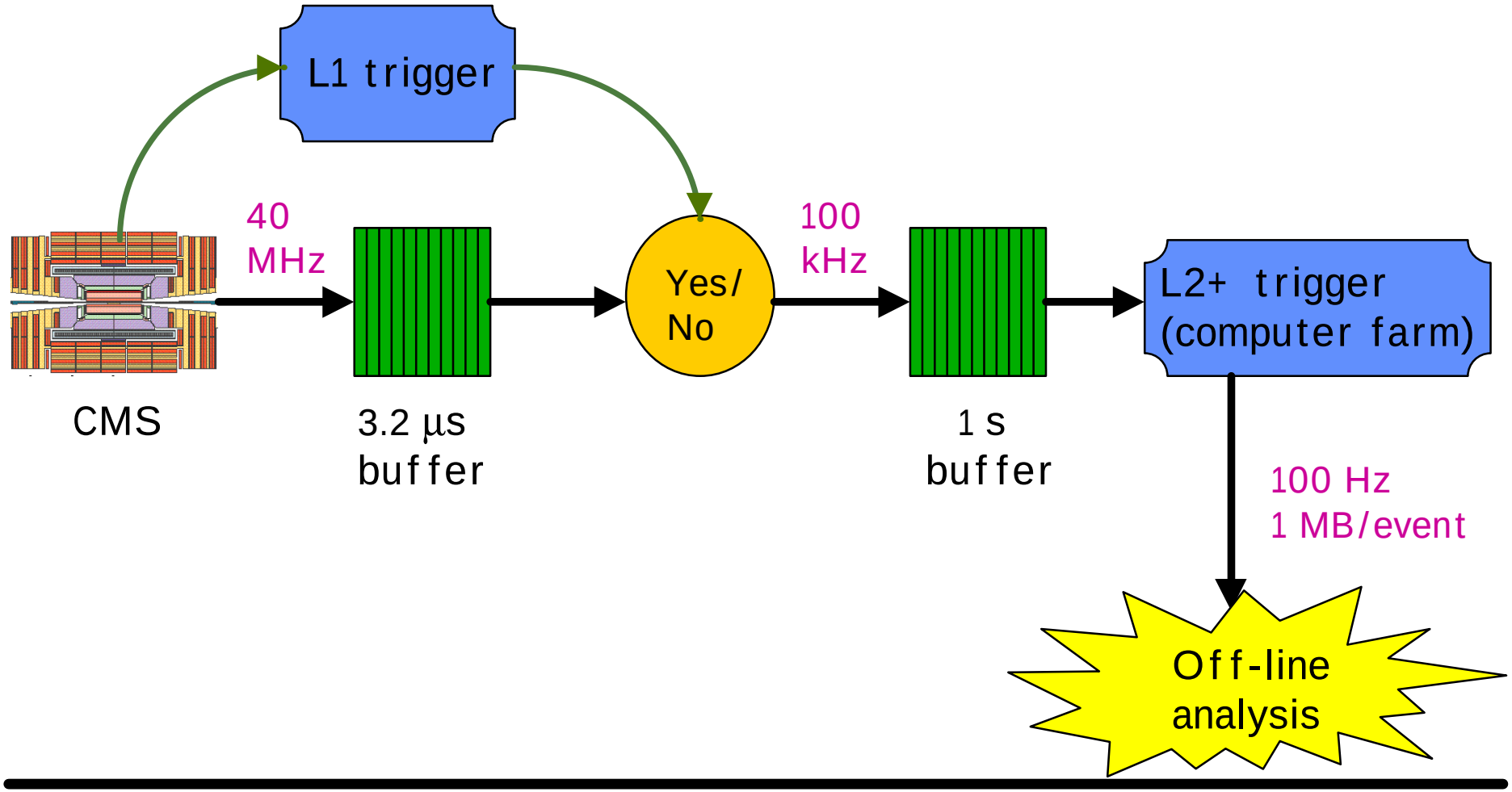
- Even at this rate (10^{16} p-p collisions year), collect only 1000 Higgs $\rightarrow \gamma\gamma$ per year.

- How do we find small number of Higgs in large number of p-p collisions ? It's worse that finding a needle in a hay-stack: Needle ~ 5 mm^3 & Hay-stack ~ 50 m^3

So, needle : hay-stack only 1 : 10^{10} !

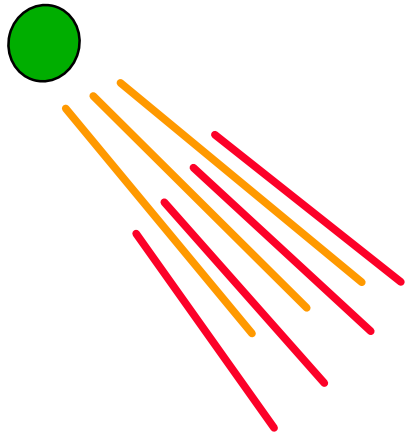
Demands on Detectors and DAQ

Use triggers and off-line data analysis to find interesting events.



Conclusions

- You've had a small introduction to our "Theory of Everything" !



- And seen why particle physicists use accelerators and detectors.

- The detectors are huge, with many channels. The readout electronics must cope with huge data rates.

$\Rightarrow$ We're very glad ID/ED help us build them !