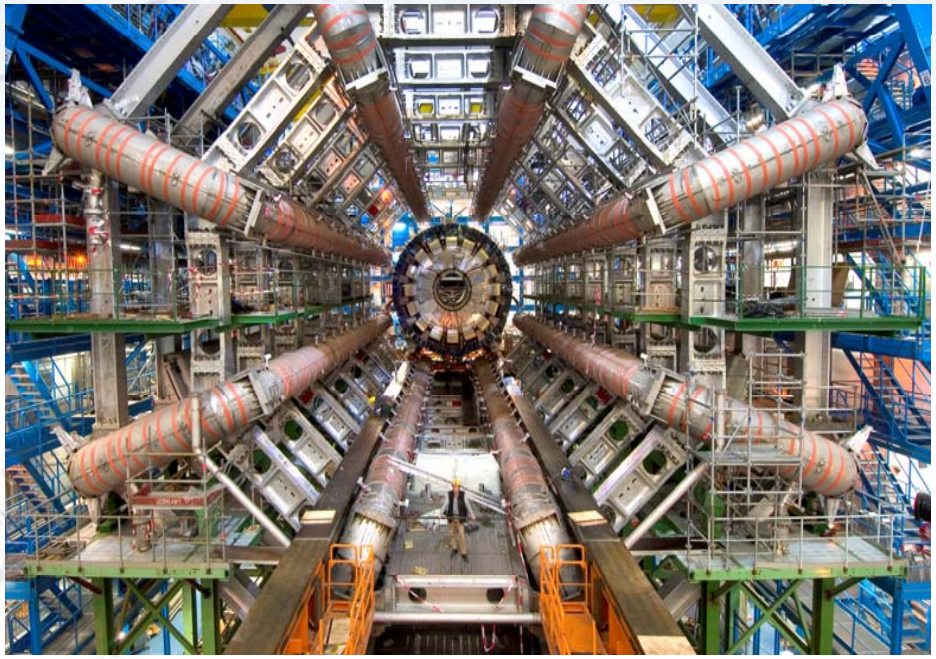
The ATLAS Experiment

An attempt at an What, Why, How, Where, and When guide

Troels C. Petersen (CERN)

- Why are we doing the ATLAS experiment?
- How does one probe such small scales as 10^{-19} meter?
- How does ATLAS detect elementary particles?
- What does it take to build a detector like ATLAS?
- Where is ATLAS situated?
- When will ATLAS run?



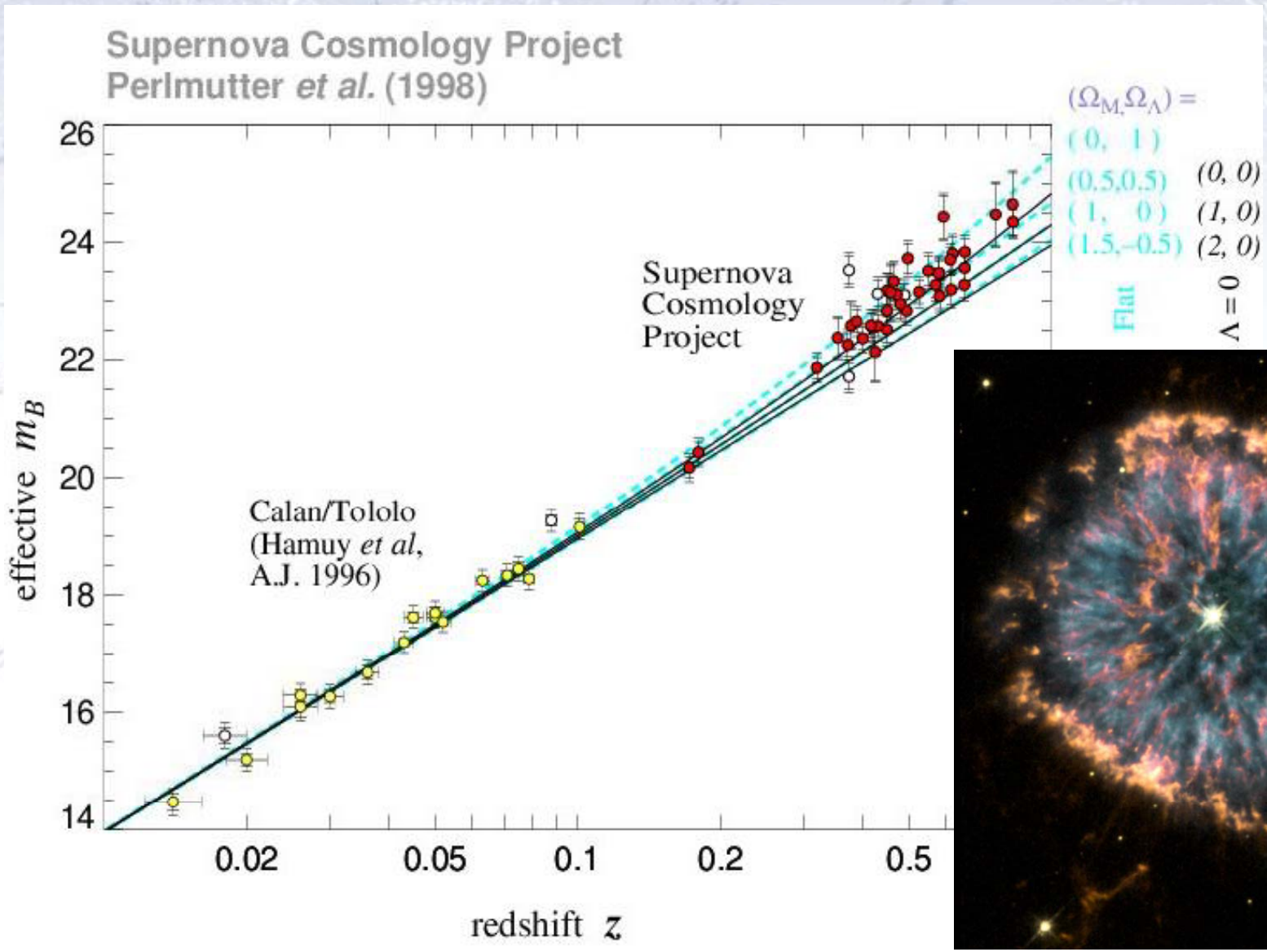
Now the smallest Particles of Matter may cohere by the strongest Attractions, and compose bigger Particles of weaker Virture.... There are therefore Agents in Nature able to make the Particles of Bodies stick together by very strong Attraction. And it is the Business of experimental Philosophy to find them out. [Isaac Newton, Optics (1680)]

Why?

To understand part of this, we have to turn our attention in the other direction, namely cosmology!

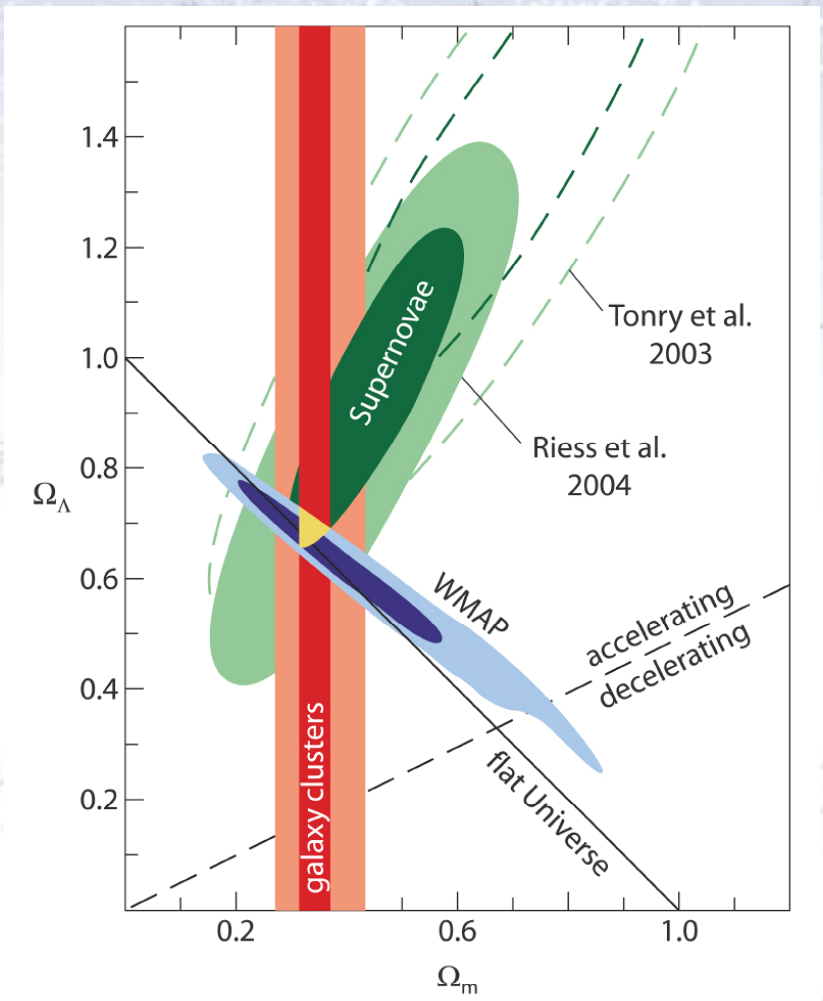
Why?

Latest years research in supernova has told us, that something funny is going on in the Universe!



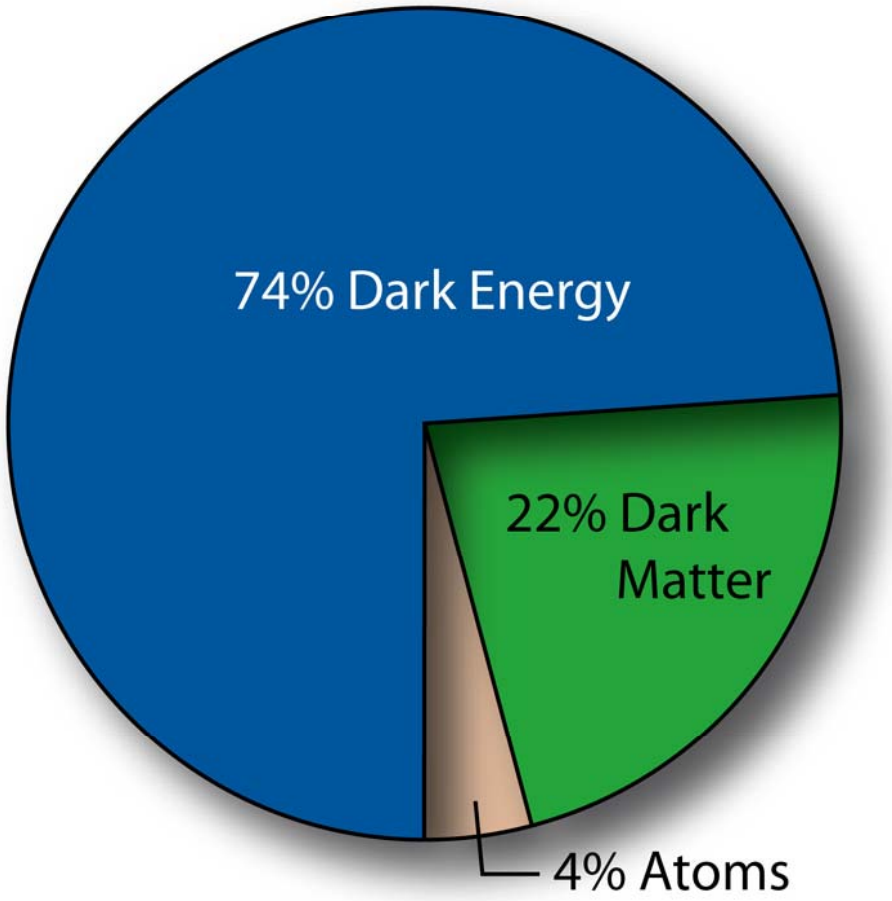
Why?

Contrary to what is (high-)schools all over the world, the world is NOT made of atoms! They hardly take part.



Constraining the Cosmological Parametres

ESO PR Photo 18d/04 (3 June 2004)



WHAT!!!

So?

If the Universe is NOT made from atoms, what is it then made of?

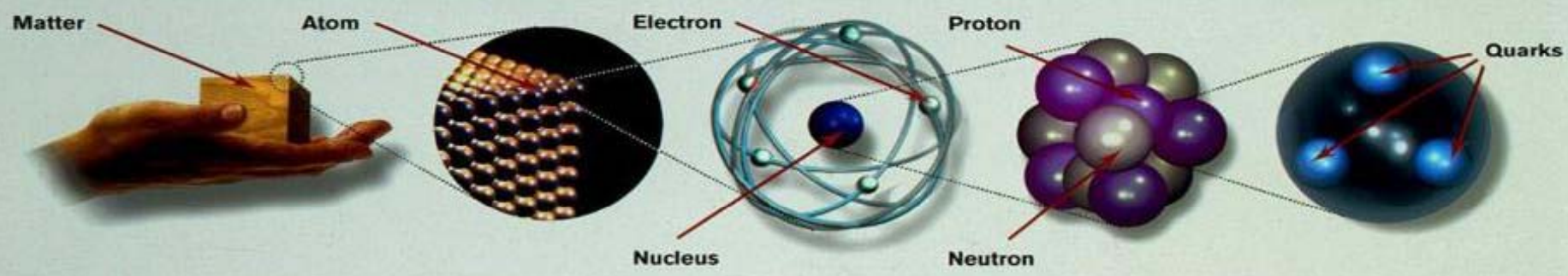
- Dark matter candidates:
  - Black holes (no – way too few).
  - Background radiation (no – way too little).
  - Planets (no – also way too few).
  - Weakly Interacting Massive Particles (WIMPs)…

PERHAPS! Super Symetric Particles!

- Dark energy (don't ask – we have no clue!)

How?

How does one probe such small scales as quarks and leptons? And why the large size of the bloody ring?



Matter particles
All ordinary particles belong to this group

These particles existed just after the Big Bang. Now they are found only in cosmic rays and accelerators

	LEPTONS		QUARKS	
FIRST FAMILY	**Electron** Responsible for electricity and chemical reactions; it has a charge of -1	**Electron neutrino** Particle with no electric charge, and possibly no mass; billions fly through your body every second	**Up** Has an electric charge of plus two-thirds; protons contain two, neutrons contain one	**Down** Has an electric charge of minus one-third; protons contain one, neutrons contain two
SECOND FAMILY	**Muon** A heavier relative of the electron; it lives for two-millionths of a second	**Muon neutrino** Created along with muons when some particles decay	**Charm** A heavier relative of the up; found in 1974	**Strange** A heavier relative of the down; found in 1964
THIRD FAMILY	**Tau** Heavier still; it is extremely unstable. It was discovered in 1975	**Tau neutrino** not yet discovered but believed to exist	**Top** Heavier still	**Bottom** Heavier still; measuring bottom quarks is an important test of electroweak theory

Force particles
These particles transmit the four fundamental forces of nature although gravitons have so far not been discovered

Gluons
Carriers of the strong force between quarks

Felt by: quarks

The explosive release of nuclear energy is the result of the strong force

Photons
Particles that make up light; they carry the electromagnetic force

Felt by: quarks and charged leptons

Electricity, magnetism and chemistry are all the results of electro-magnetic force

Intermediate vector bosons
Carriers of the weak force

Felt by: quarks and leptons

Some forms of radio-activity are the result of the weak force

Gravitons
Carriers of gravity

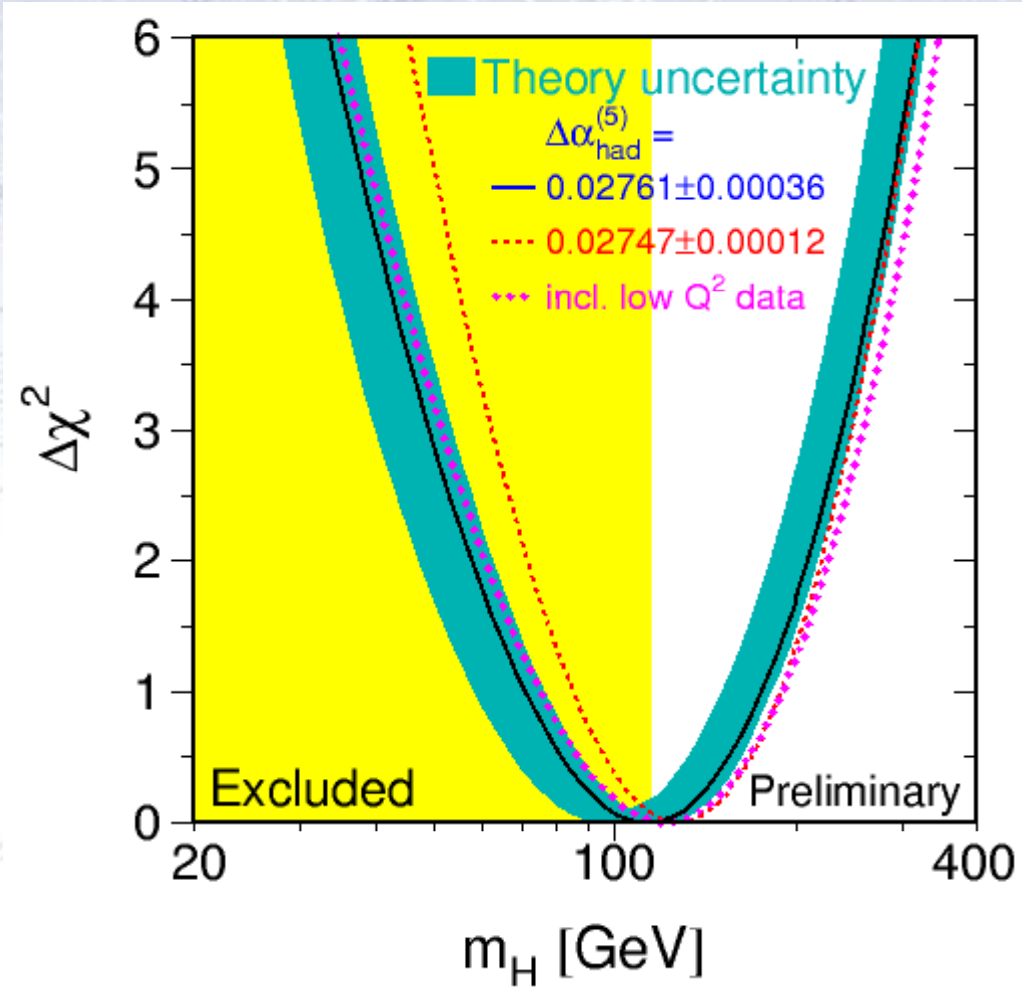
Felt by: all particles with mass

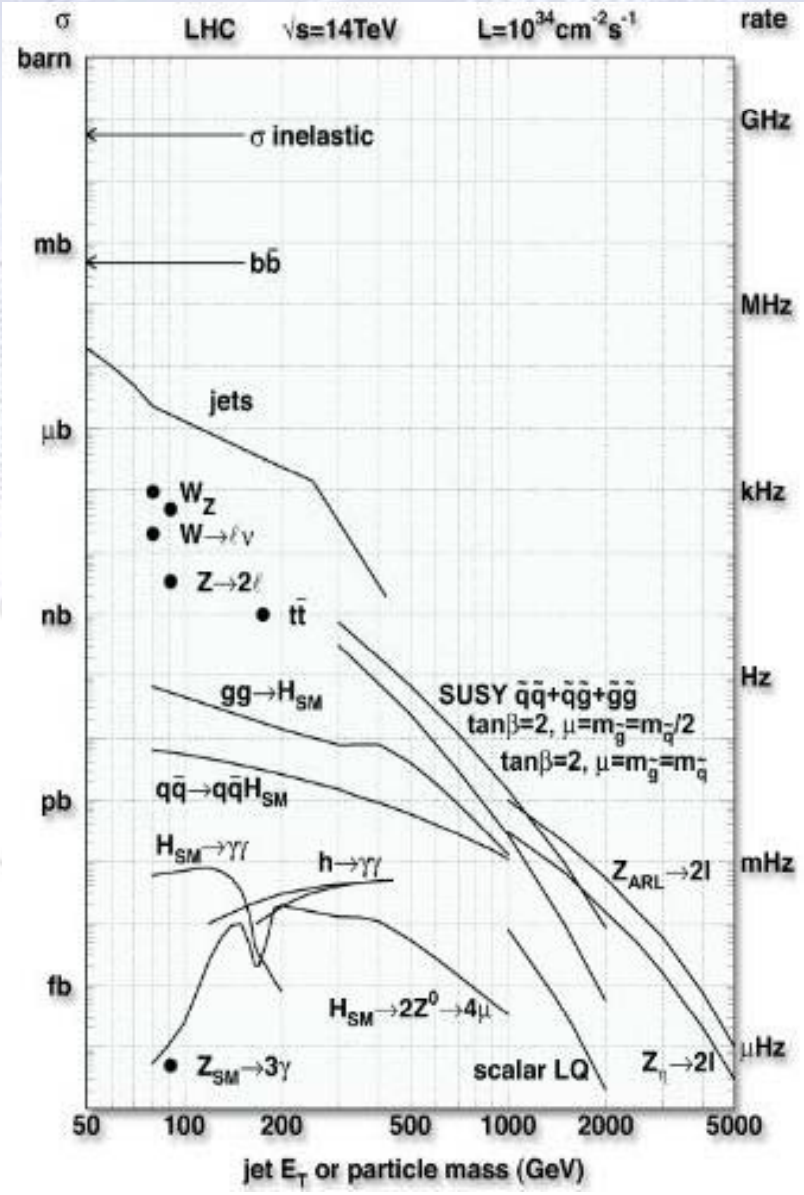
All the weight we experience is the result of the gravitational force

GRAPHICS PETER CROWTHER

What?

What is the ATLAS experiment actually looking for? And how often does it happen?

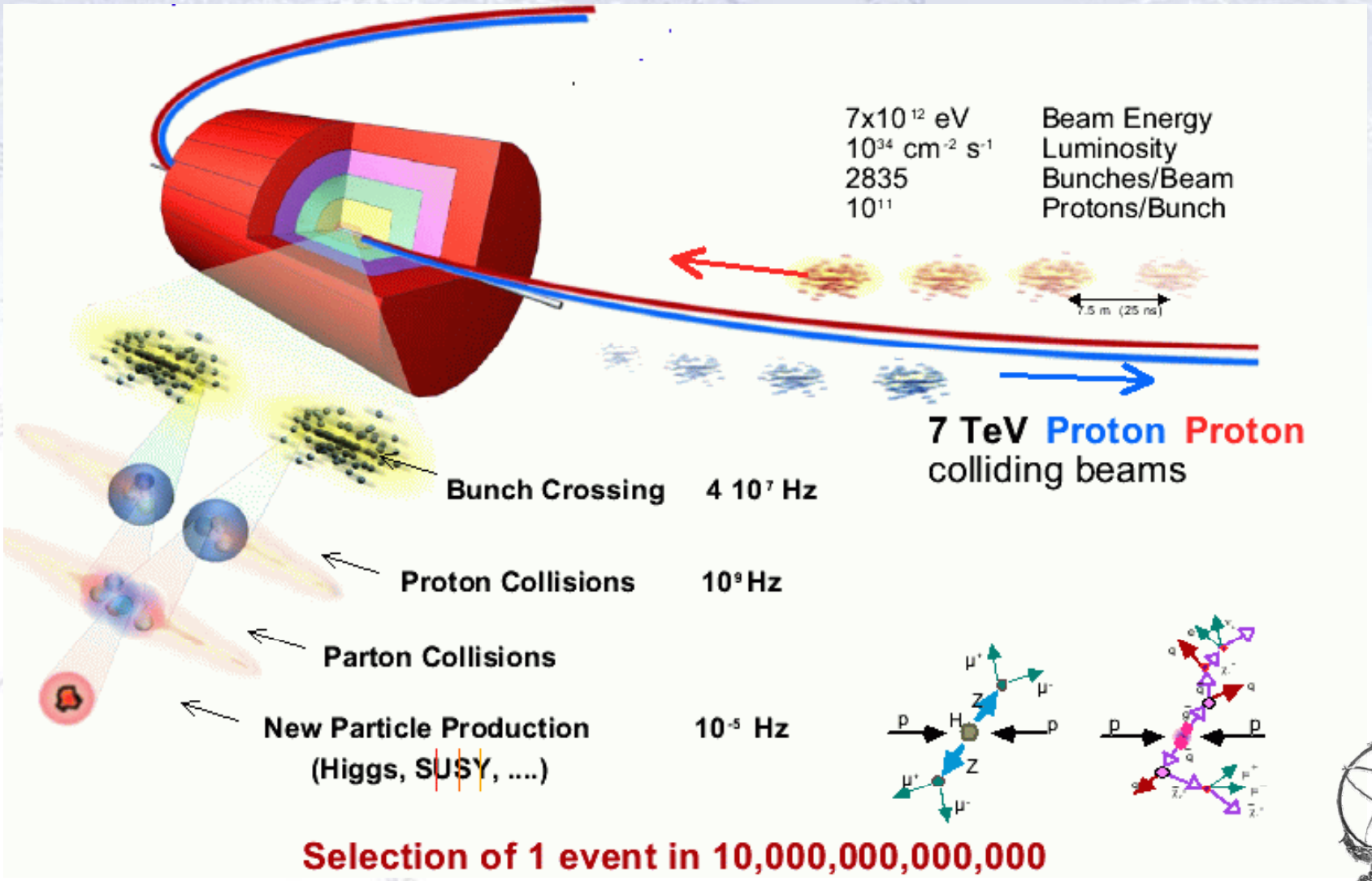




So we know that there is “something” out/in there, looking like a Higgs.

How?

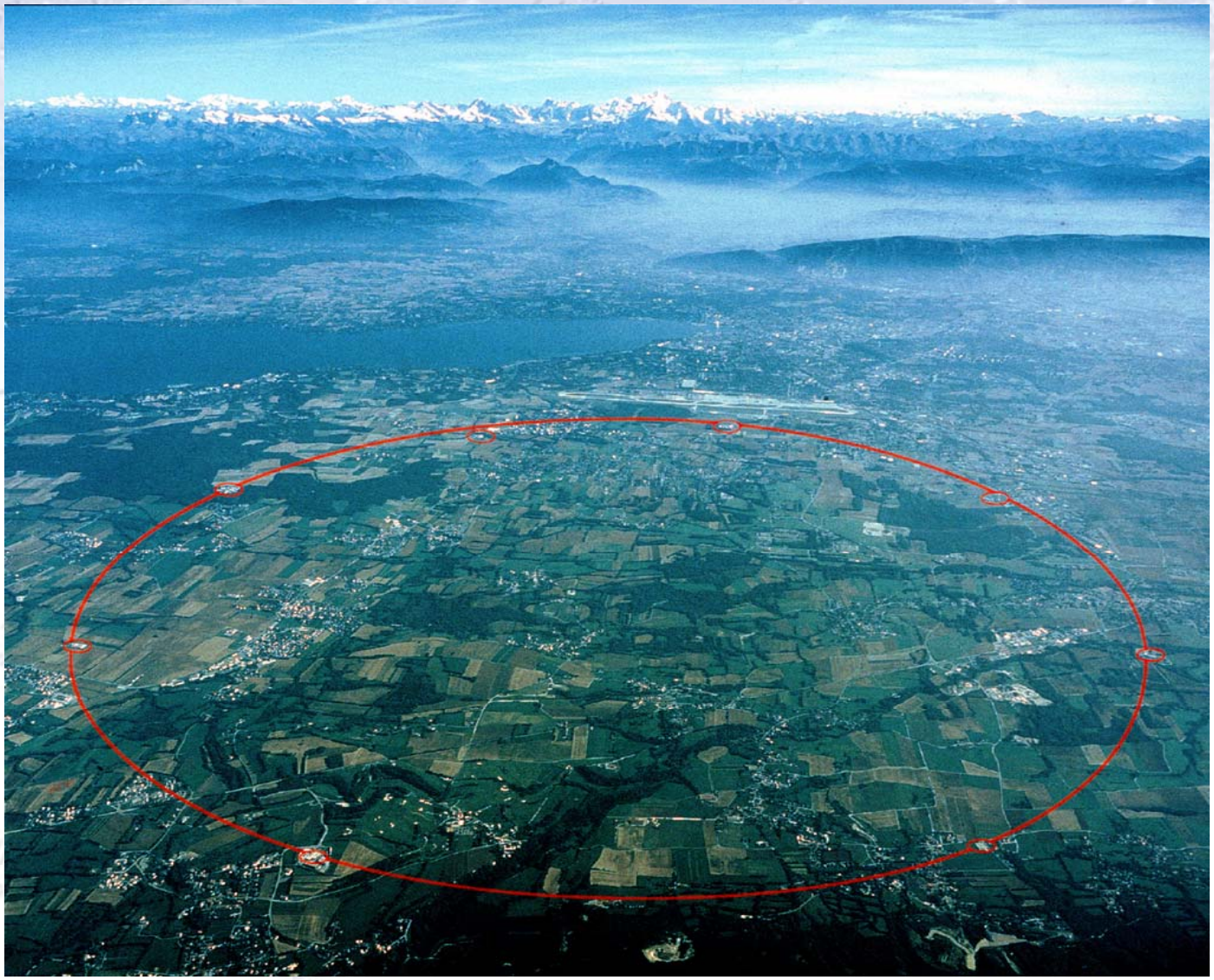
How does one probe such small scales as quarks and leptons? And why the large size of the bloody ring?



This is the very reason why we have triggers!

Why?

Why so large?

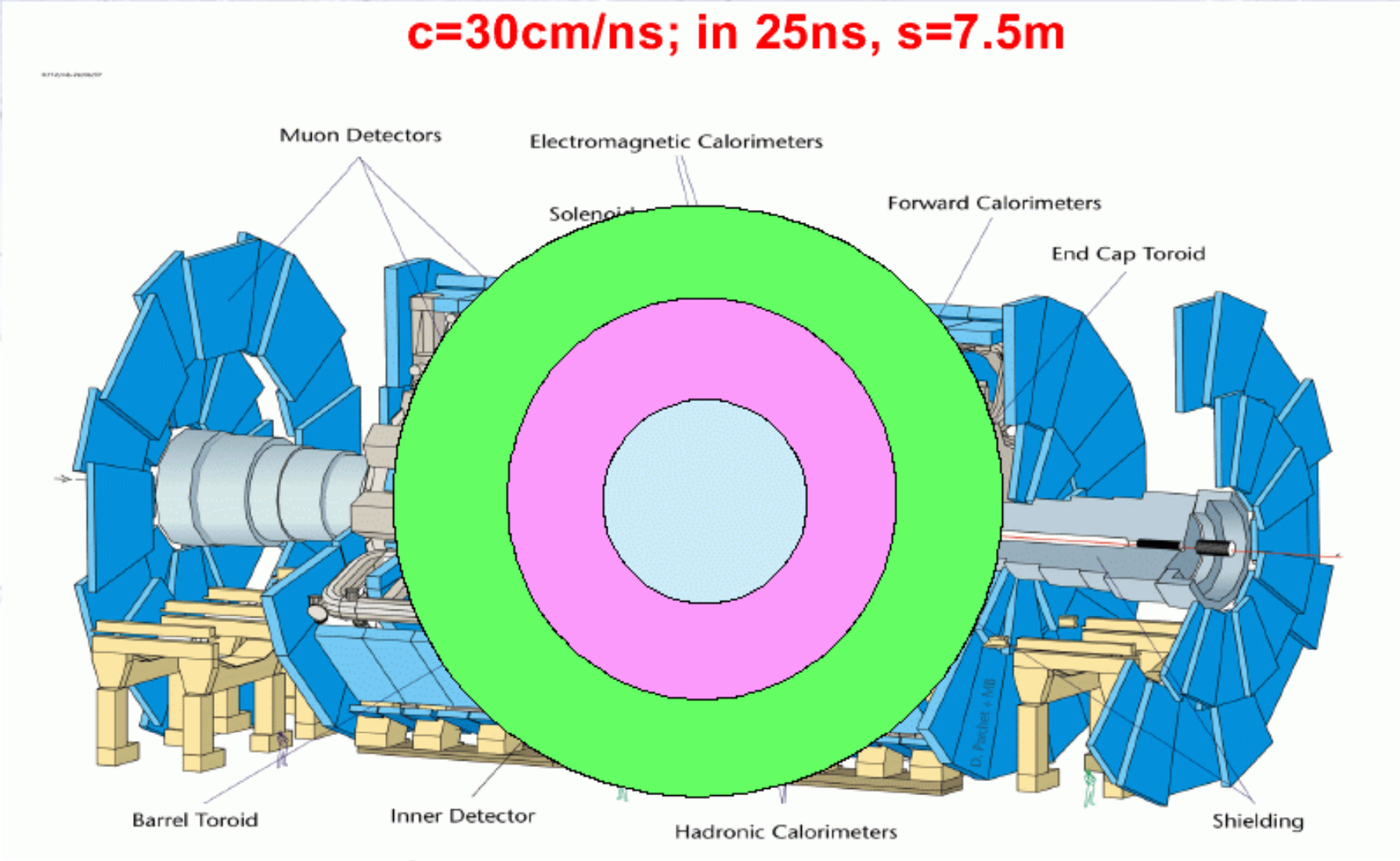


Why?

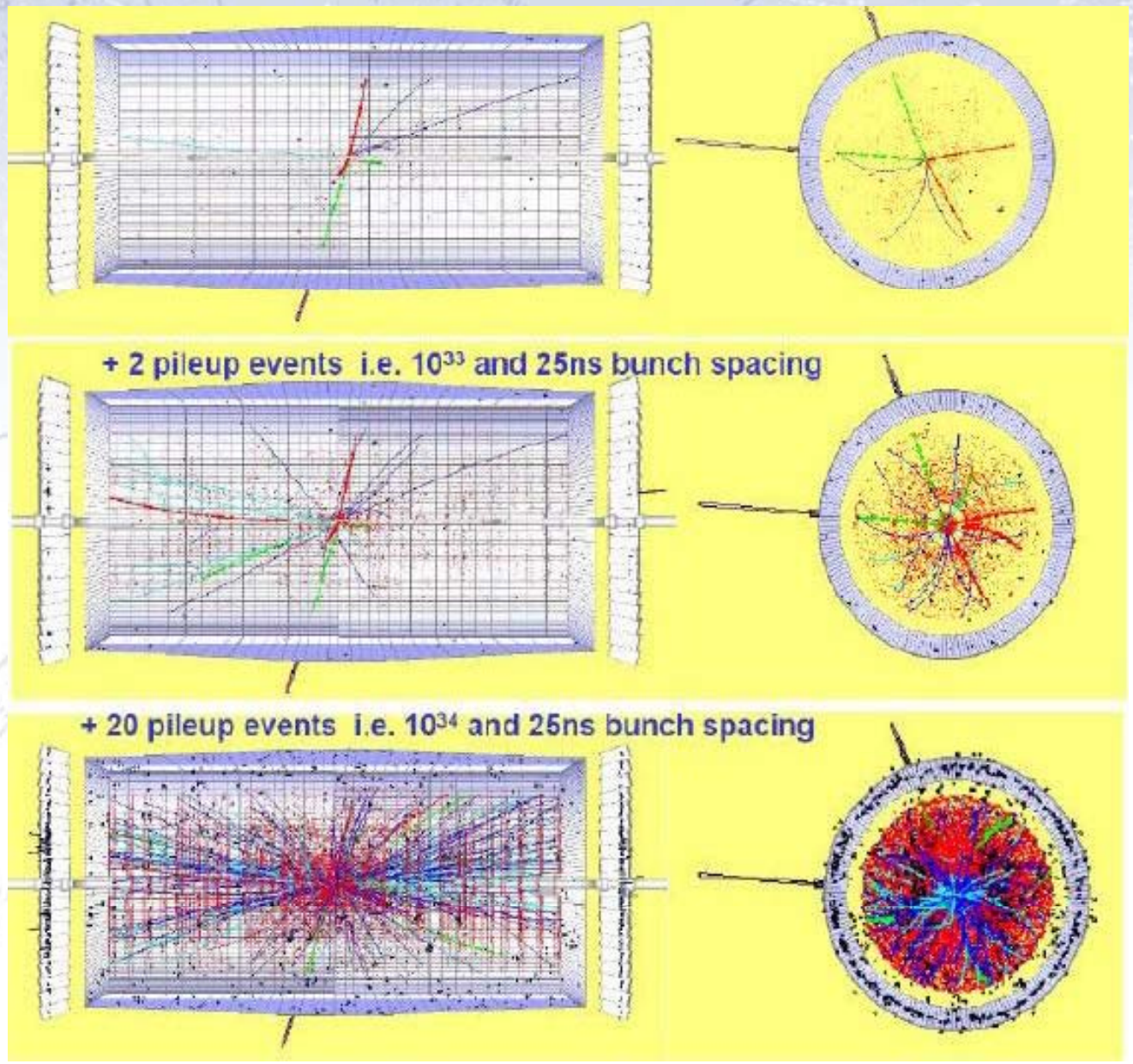
Why so large?

How Fast?

How fast does the detector response have to be? And to know what signals belonged to an event?



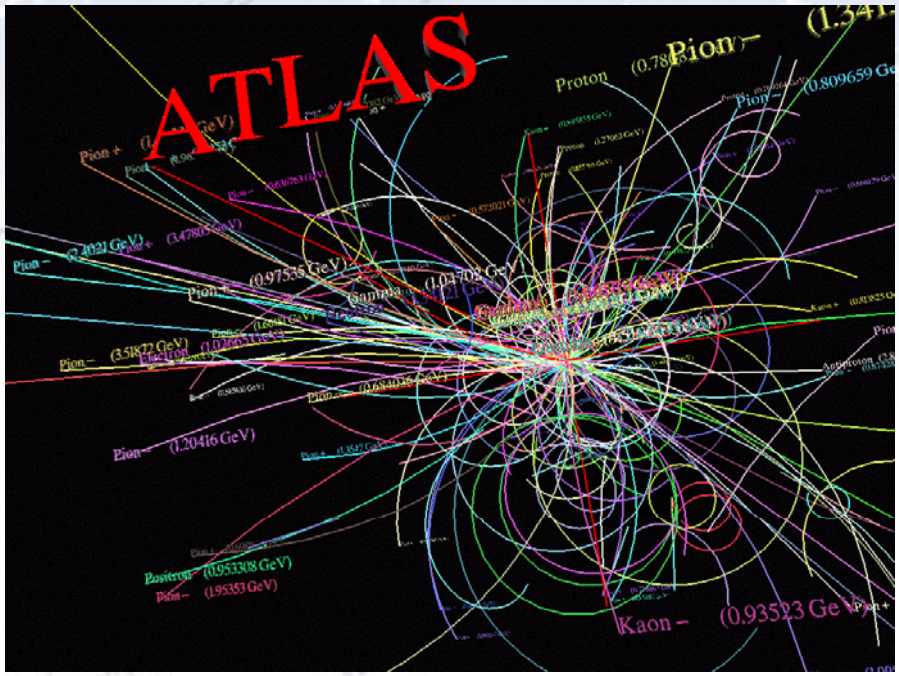
What (a mess).


+ 2 pileup events i.e. 10^{33} and 25ns bunch spacing
+ 20 pileup events i.e. 10^{34} and 25ns bunch spacing

So…

In order for ATLAS to work, the detector has to be:

- Very fast.
- Radiation hard.
- Precise.
- Redundant.
- Hermetic.
- Robust.
- Aligned.
- Cheap!!!



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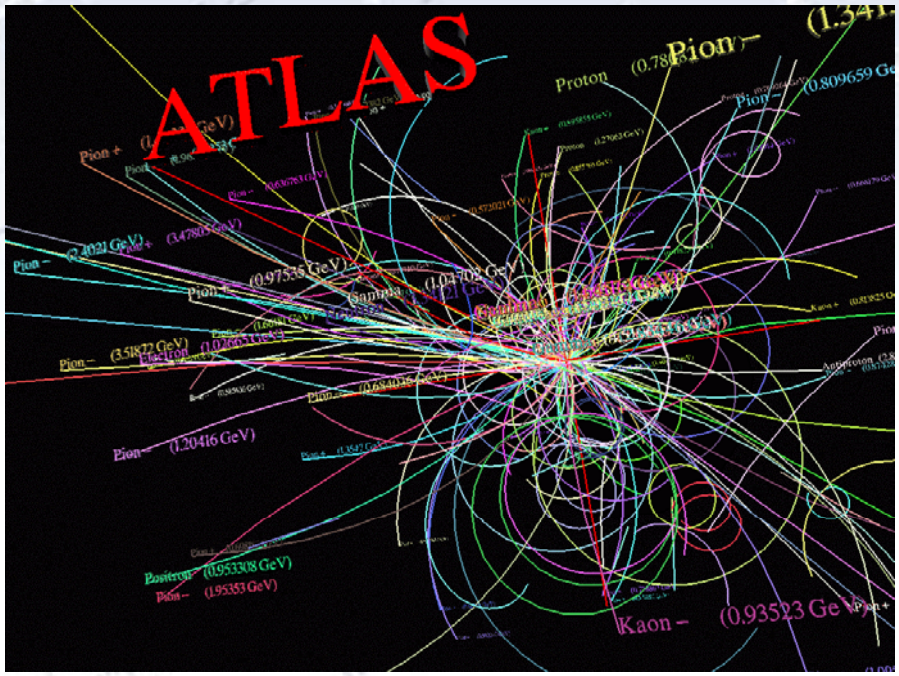
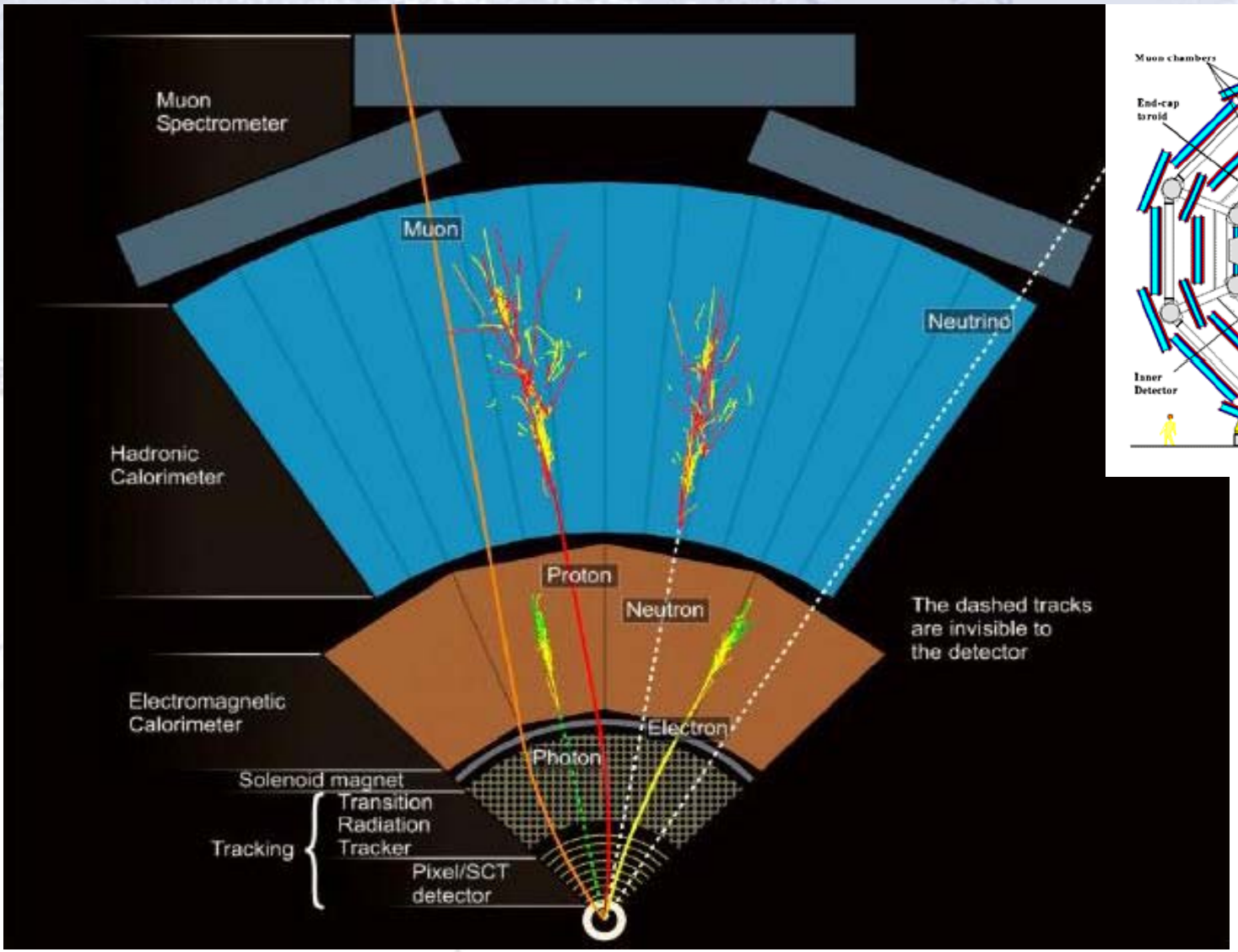


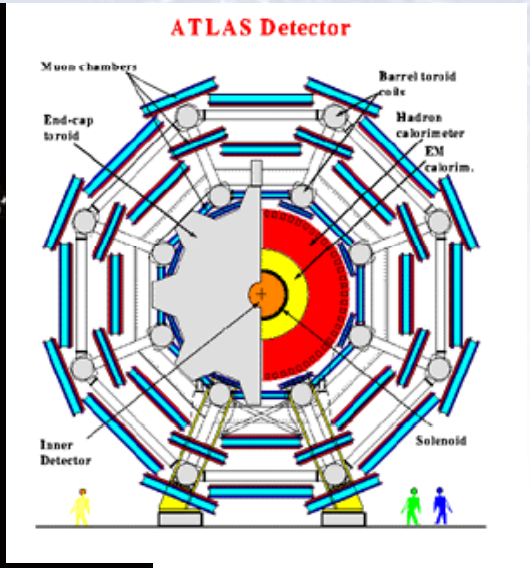
Haha… no such thing as an ideal detector!!!

However, for 20 years people have been thinking, planning, designing, testing, building a realistic detector.

How?

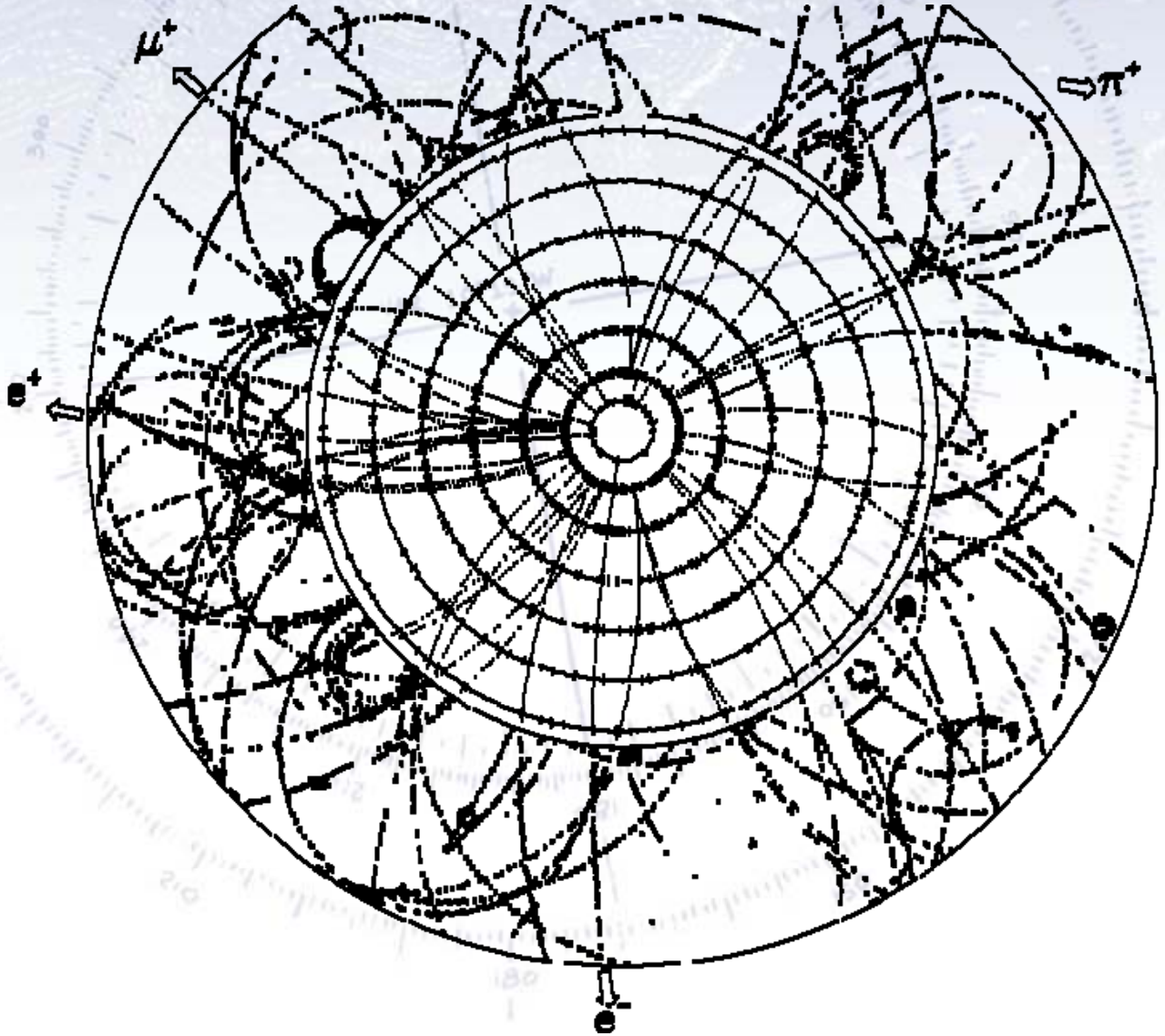
How does an experiment like ATLAS detect elementary particles? And what are we up against?

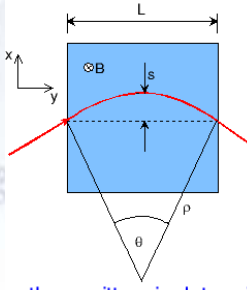




How

How does ATLAS do tracking?





$$p_T = qB\rho$$

$$p_T\ (\mathrm{GeV/c}) = 0.3B\rho \quad (\mathrm{T\cdot m})$$

$$\frac{L}{2\rho} = \sin\theta/2 \approx \theta/2 \;\rightarrow\; \theta \approx \frac{0.3L\cdot B}{p_T}$$

$$\Delta p_T = p_T \sin\theta \approx 0.3L\cdot B$$

$$s = \rho(1-\cos\theta/2) \approx \rho\frac{\theta^2}{8} \approx \frac{0.3}{8}\frac{L^2 B}{p_T}$$

the sagitta s is determined by 3 measurements with error $\sigma(x)$:

$$s = x_2 - \frac{x_1 + x_3}{2}$$

$$\left.\frac{\sigma(p_T)}{p_T}\right|^{meas.} = \frac{\sigma(s)}{s} = \frac{\sqrt{\frac{3}{2}}\sigma(x)}{s} = \frac{\sqrt{\frac{3}{2}}\sigma(x)\cdot 8 p_T}{0.3\cdot BL^2}$$

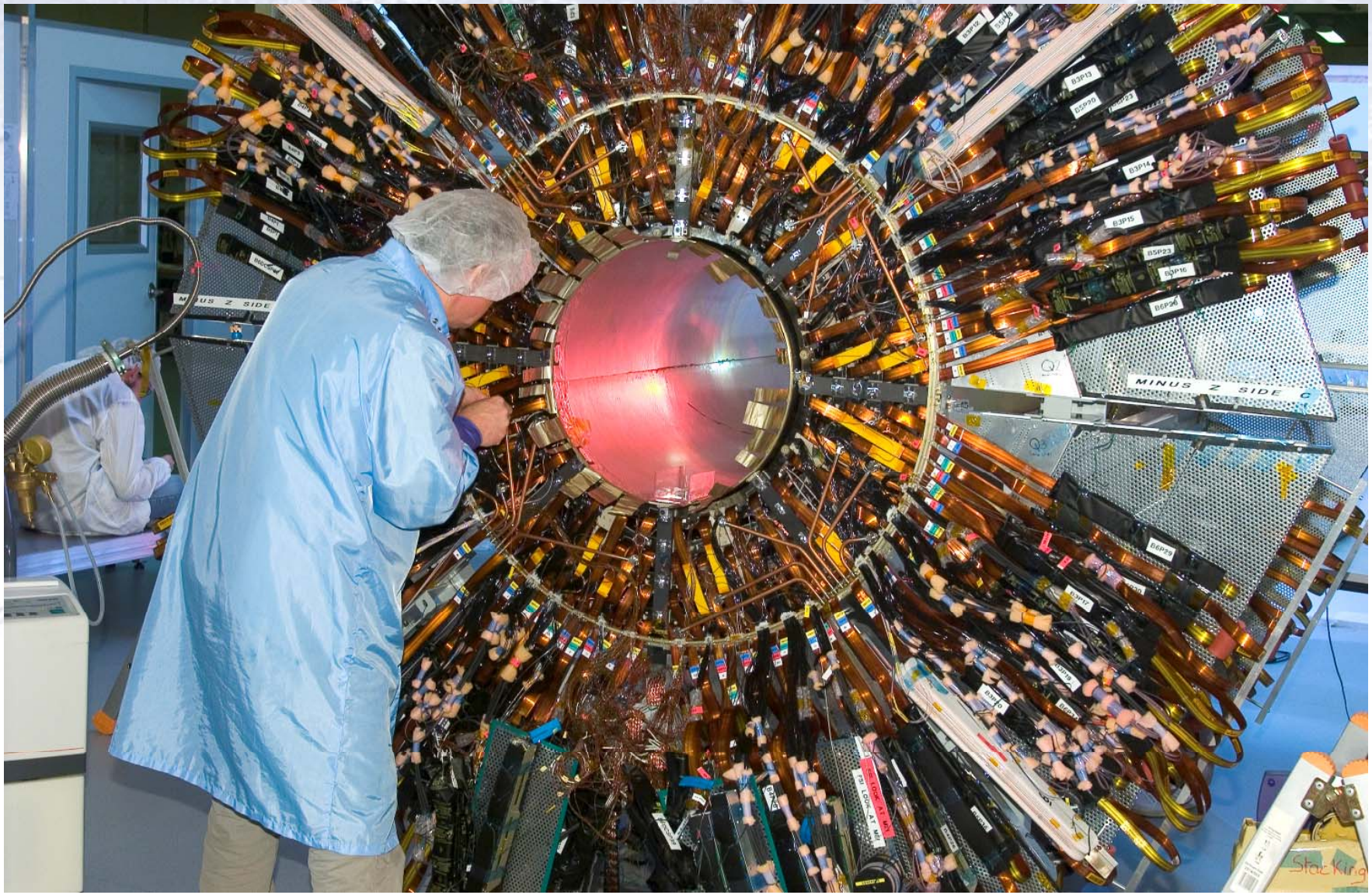
for N equidistant measurements, one obtains

(R.L. Gluckstern, NIM 24 (1963) 381)

$$\left.\frac{\sigma(p_T)}{p_T}\right|^{meas.} = \frac{\sigma(x)\cdot p_T}{0.3\cdot BL^2}\sqrt{720/(N+4)} \qquad (\text{for } N \geq \approx 10)$$

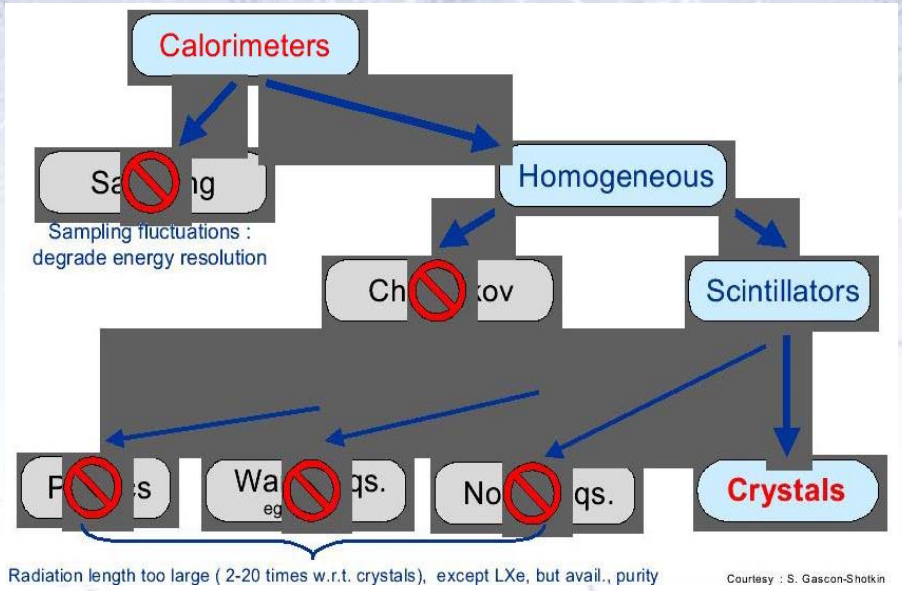
What?

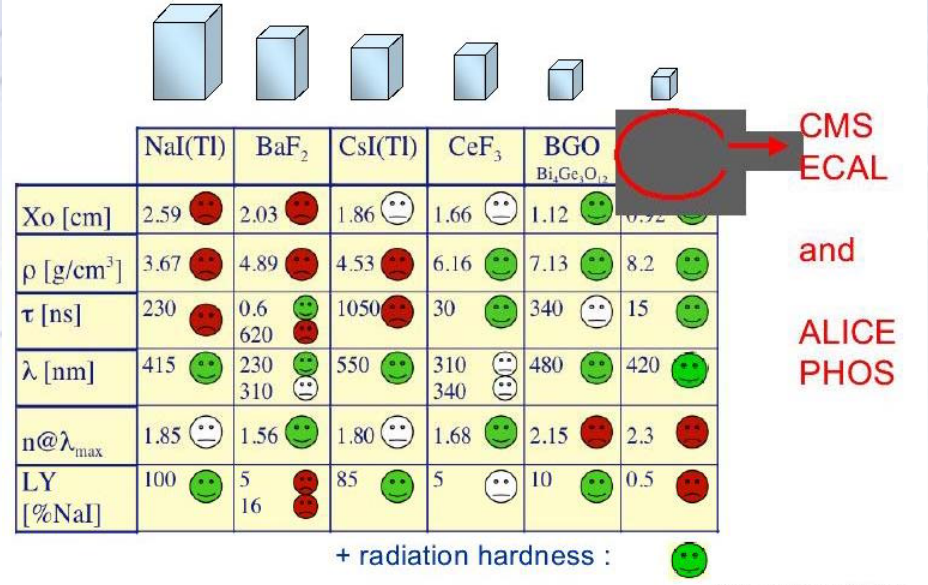
What does a real tracking detector look like? And what to take into account when building such things?

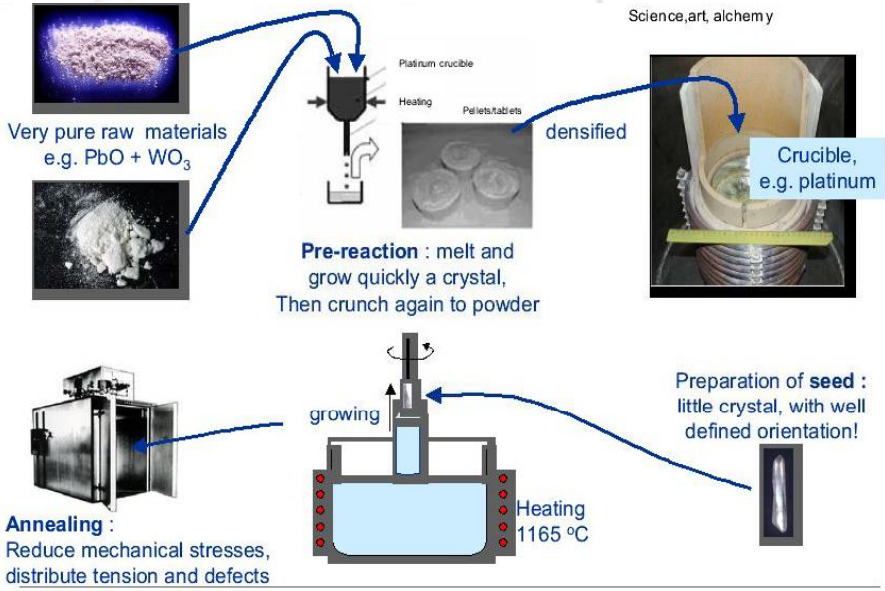


How?

How does CMS (the competitor experiment to ATLAS) do calorimetry?



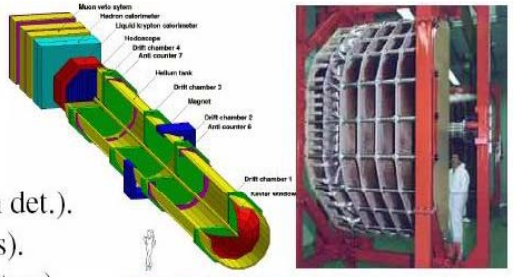




Sometimes it is desirable to use strange (and expensive) materials, such as:

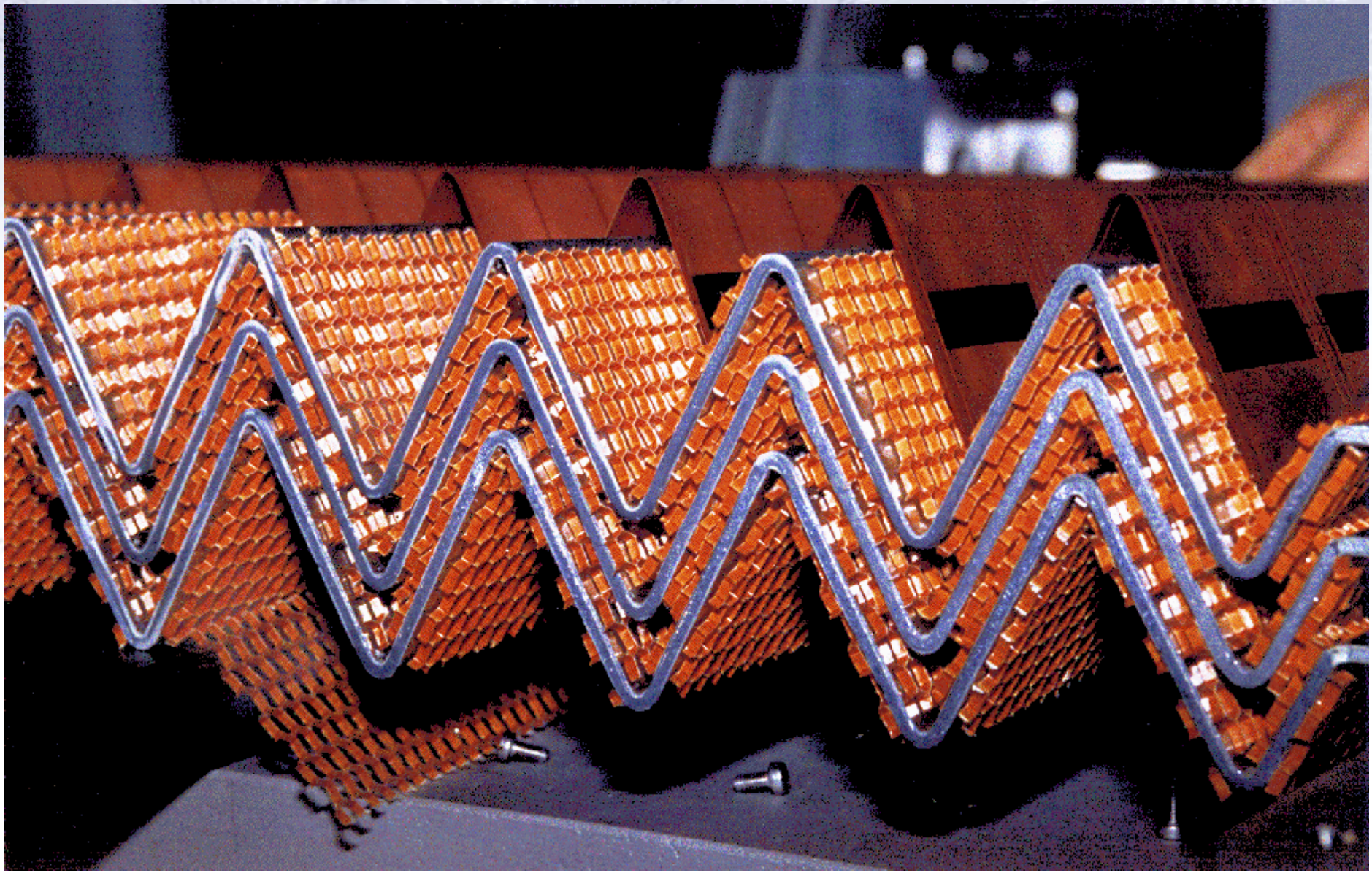
- Diamonds (target & radiation det.).
- Liquid Crypton (Calorimeters).
- Depleted Uranium (Calorimeters).
- Gold (Drift chambers & electronics).
- Silicon (vertexing and tracking).
- Deuterium (neutrino detection).

The uranium (Zeus & NA44) and the deuterium (SNO) can be "loaned".



How?

How does ATLAS do calorimetry?



Where?

The actual ATLAS detector is situated deep underground precisely in the middle of the LHC ring.

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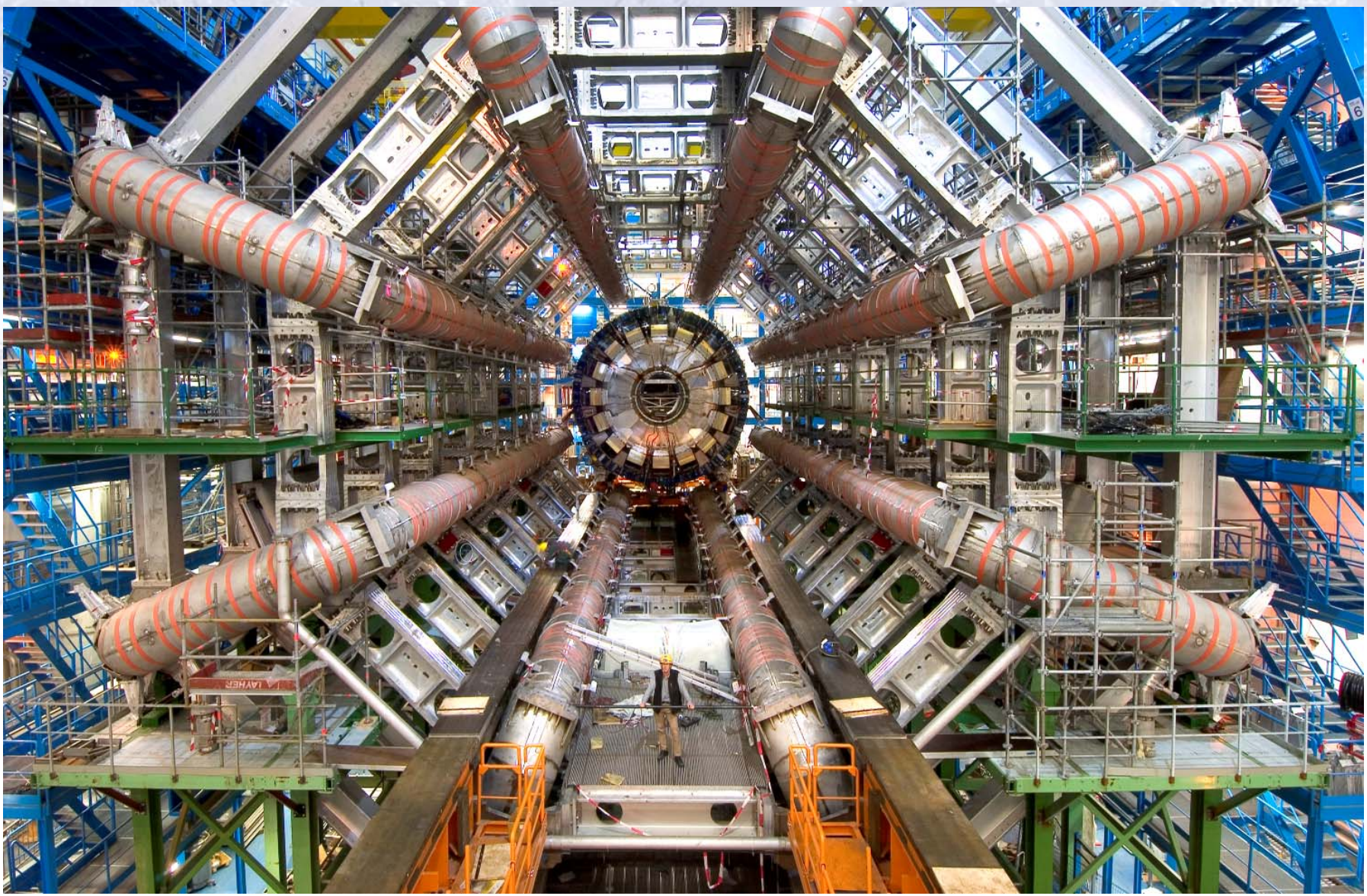

Where?

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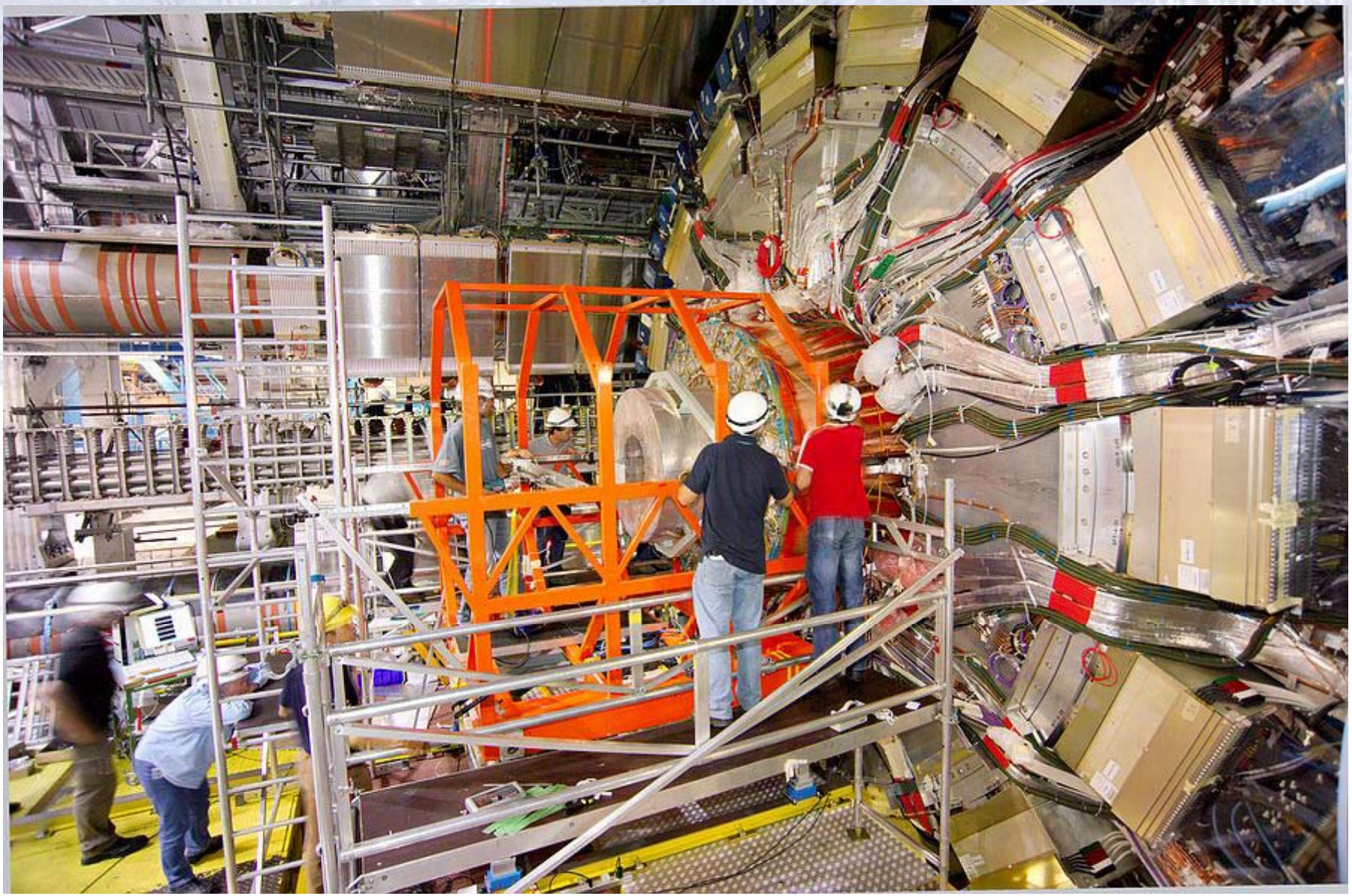
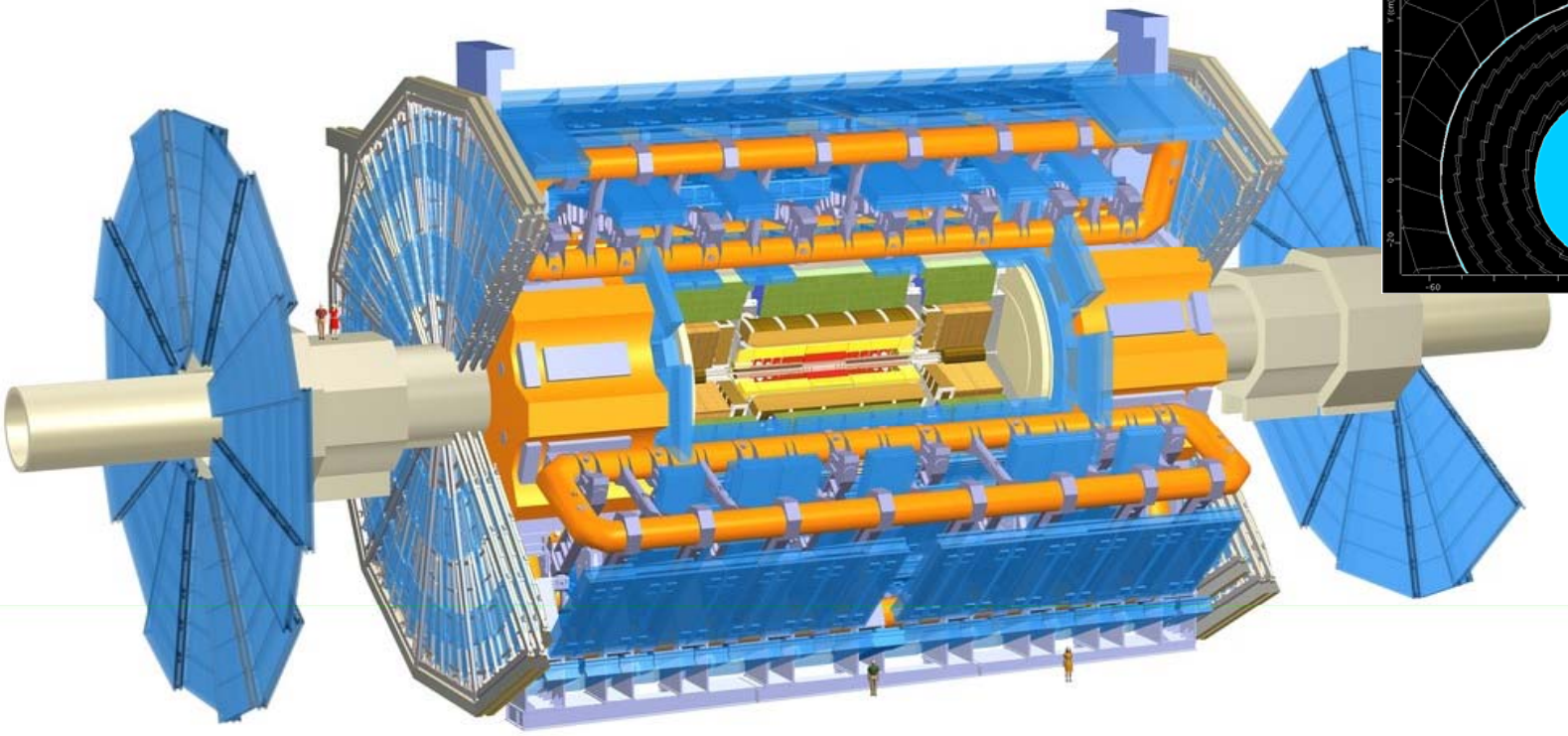
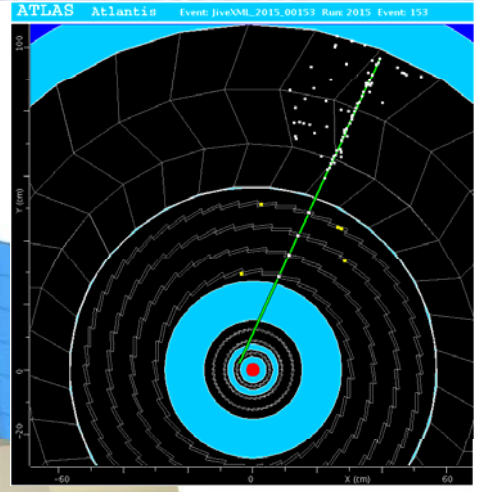
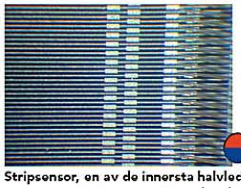


What?

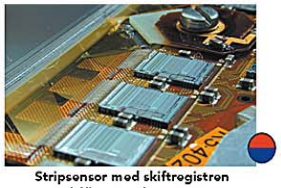
What is the current situation, how much can we see, and what is going on down there?







Stripsensor, en av de innersta halvledarsensorerna. Stripparna, 80 µm breda backspända dioder med bondtrådar till höger.



Stripsensor med skiftregistren som håller signalerna i 2,5 µs

EM, elektromagnetiska kalorimetern, uppbyggd av veckat kretskort

Kryogeniska kärlet som innehåller inre solenoiden

Ändring till inre kryogeniska kärlet

Elektromagnetiska kalorimetrarna monteras i kryogeniska kärlet
Foto: CERN

Två bilder av änd-toroidens kryogeniska kärl, dels från utsidan, dels från insidan. Utan lock.

Kryogenisk fabrik för tillverkning av Helium II till dipolen

Tryckkärl i den kryogeniska fabriken
Foto: CERN

Provlinje för dipolrör
Foto: CERN

Två dipolrör kopplas ihop

Dipolrörets ände. Vakuumkärlet ytterst, sedan det heliumfyllda kärlet. Den massiva biten i mitten är magneten, med de två strålrören sida vid sida.

ATLAS
A Toroidal LHC Apparatus
Ett av de fyra experimenten runt LHC
Large Hadron Collider
vid CERN i Genève i Schweiz

Flytande helium till supraledare 4 K

Flytande Ar + O_2 + CO_2 till TRT 89,3 K

Flytande helium II till supraledare 2 K

Vakuum för termosflaskan kring LHC

Acceleratorringen LHC Supraledande dipolrör. Ringen är 27 km i omkrets.

Avböjnings-dipol 16V= 8.000A

48 kW

Inre solenoid 16V= 8.000A

Änd-toroid 16V= 24.000A

Yttre toroid 16V= 24.000A

26 vakuumpumpar för termosar kring solenoider

85 ventiler

Uppvärmning vid quench

67 vakuumgivare

700 temperaturgivare

600 trådtöjningsgivare

44 meter

120 meter

25 ns. Det ligger en händelse på var 7,5:e meter av ledningen.

RPC, ????, utvalda triggkanaler
MDT, Monitored drift tubes
40 MHz klocka till detektorer med interna skiftregister
SCT, Semiconductor tracker
Pixelbaserad detektor
Hadron-kalorimeter
EM, Elektromagnetisk kalorimeter 1 GB/s 128 kanaler
TRT, Transition tracker
CSC, ???
TGC, ????, utvalda triggkanaler

protoner, 99,999991 % av c

Totalt 130.000 optiska fibrer

Totalt 180.000.000 enskilda sensorer

Indata 40 MHz Peta-byte/s

Signaler utvalda för trigg

Klocka 40 MHz

Nivå 1: triggning. Ett beslut tar 2,5 µs
Beslutslogik
Nivå-komparator
Skiftregister 2,5 µs
75 kHz
75 kHz 120 GB/s

Nivå 2 Ett beslut tar 10 ms
Indata för beslut
Utklockning
Minne 10 ms
Utläsning
2 kHz
2 kHz 3 GB/s

Nivå 3 Ett beslut tar ~0,1 s
Indata för beslut
Händelse-filter
Utklockning
Minne 100 ms
Utläsning
200 Hz
300 MB/s

Linuxcluster för mönsterigenkänning

Switch

Lagring
RAID

Forskarnas arbetsstationer

Kommandogivning
MCS, Magnet-kontroll-system
Ethernet

Underjordiskt kontrollrum

PC som gateway mot CAN-bussen

CAN-buss

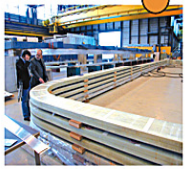
I/O-kort

Koncentrator

PLC

Supraledande toroider

Inre supraledande solenoid

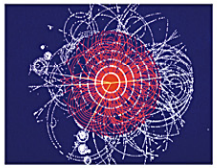


Supraledarna till yttre toroid ingjutna i glasfiber, men utan aluminiumhölje

Vakuumkärl i titan till yttre toroid. Supraledarna ska läggas i och en övre halva svetsas på.

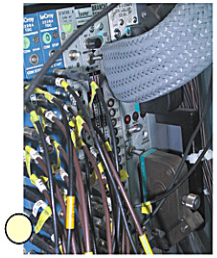
Gigabitswitch

En array av linuxmaskiner



Det som alla väntar på: Higgs-sönderfallet (gula linjer)
Foto: CERN

Signalmottagare från sensorer. De svarta ledarna är nanosekund-kompenserade

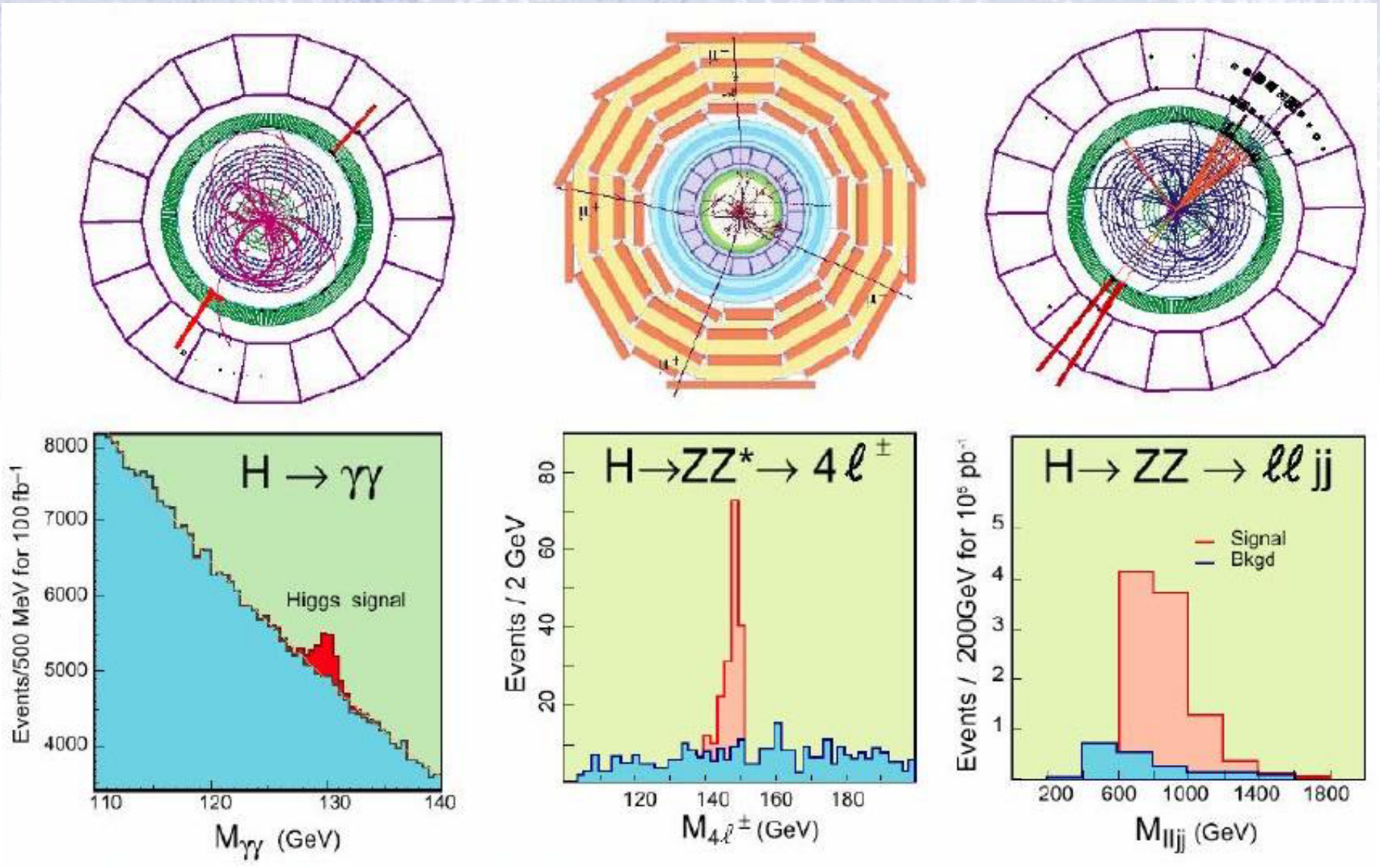


Signalmottagare, detalj med de olika mätkorten i en kortrack

Triggkretsar i nivå ett
Foto: CERN

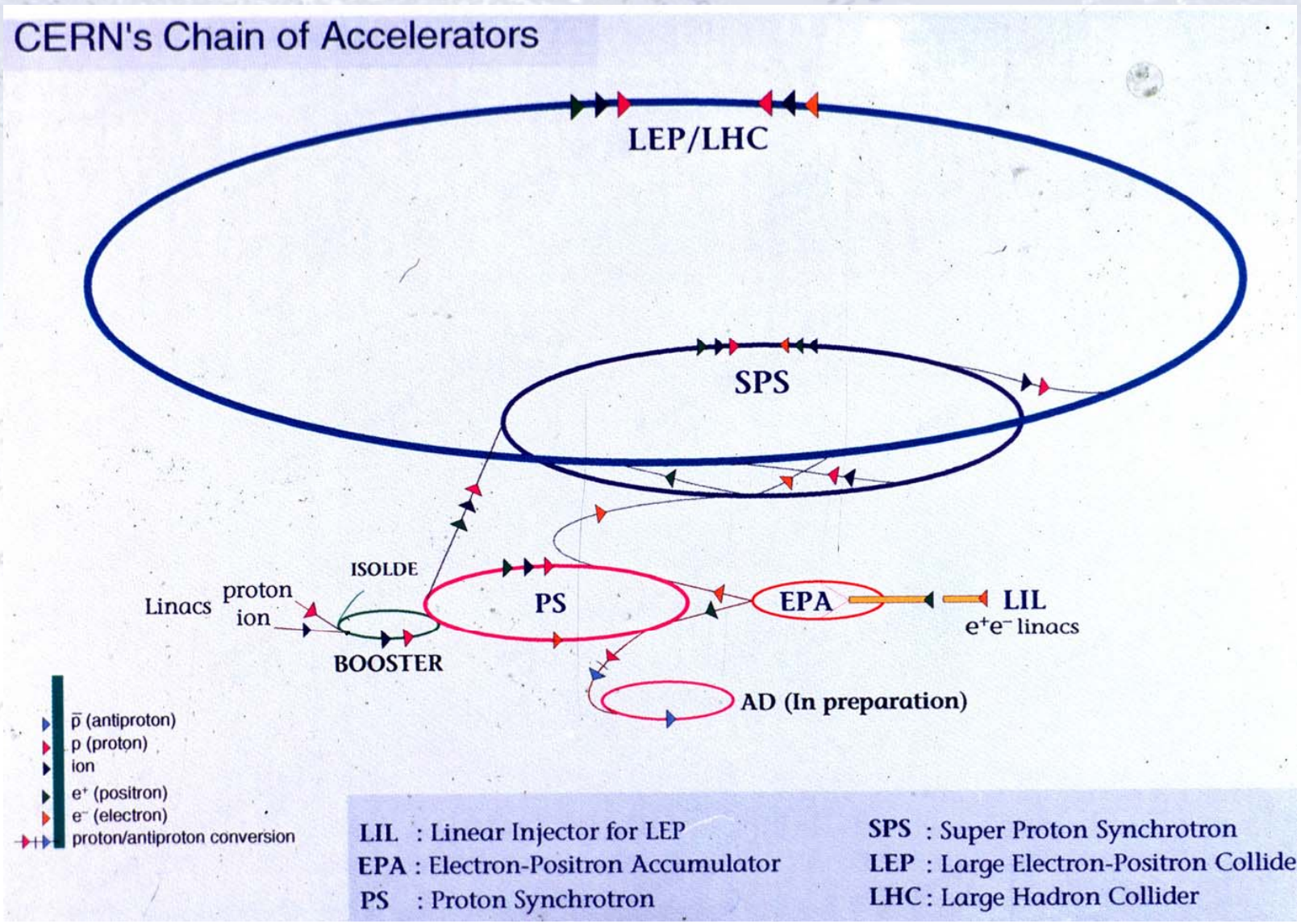
What?

What do we expect to see? What does Higgs events look like, and how does one search for the Higgs?



When?

When will the ATLAS experiment take place? Well, that depends on the accelerator(s), mainly LHC.



So…

- ATLAS is near completion and starting to take cosmics.
- So far, no devastating problems have been encountered.
- The “LHC hype” is starting to spread.
- 5000+ researchers like boys at Christmas.

I’m proud to be part of ATLAS,
and look forward to showing you.