

Small physics

Big Engineering

Steve Boyd

2013 - A Great year in Particle Physics!

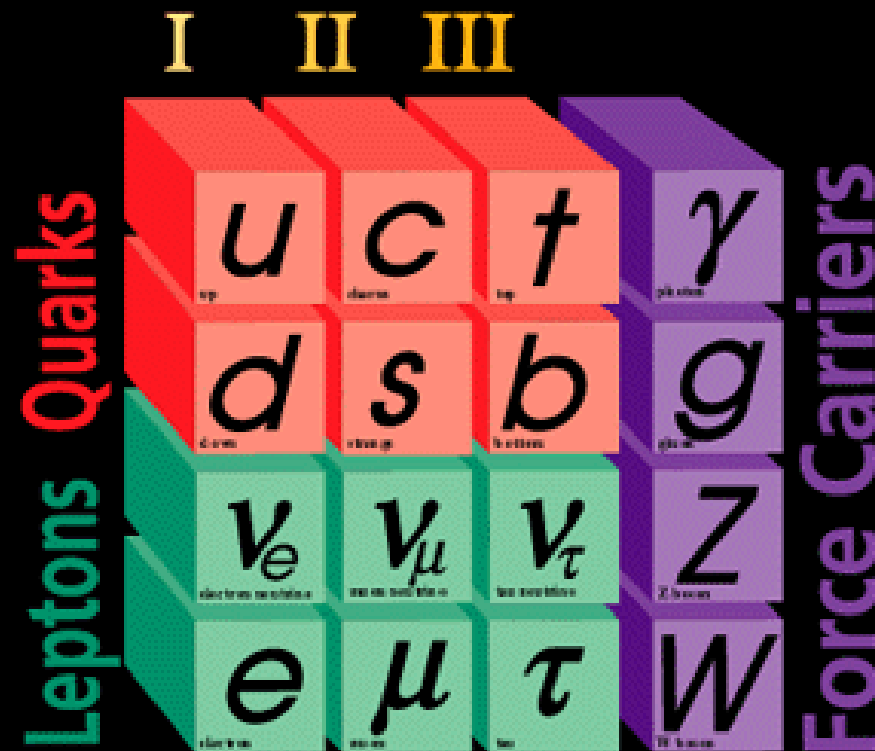


Before the Higgs...



The Standard Model of Particle Interactions

Three Generations of Matter

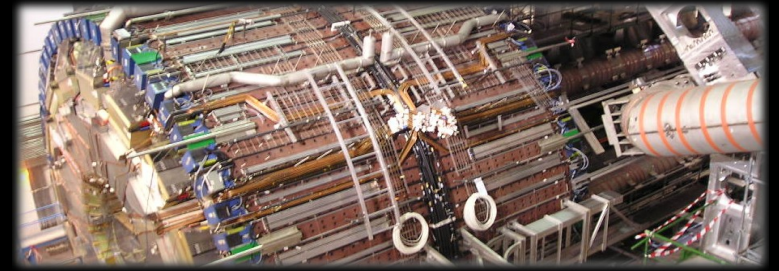


But there's a problem



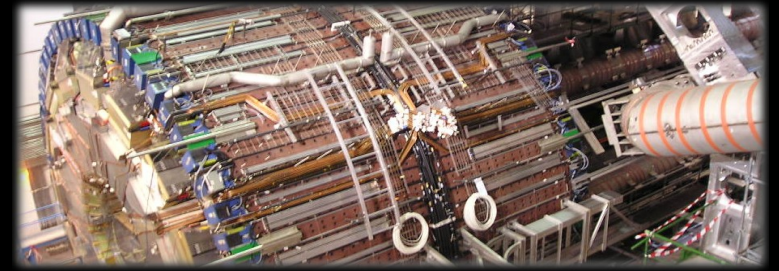
- The Standard Model describes our understanding of the workings of the visible universe to 1 part in a billion
- Except that it predicts that all particles are massless
- This is bad – all particles will move at the speed of light, so there is no time for atoms to form and therefore no you.
- The “Higgs mechanism” was proposed to give mass to particles in 1964
- July 4, 2012 – the Higgs was observed at CERN

The Higgs Mechanism



- Basic Idea : The universe is saturated with a Higgs field and particles interact with excitations of this field in the form of Higgs particles.

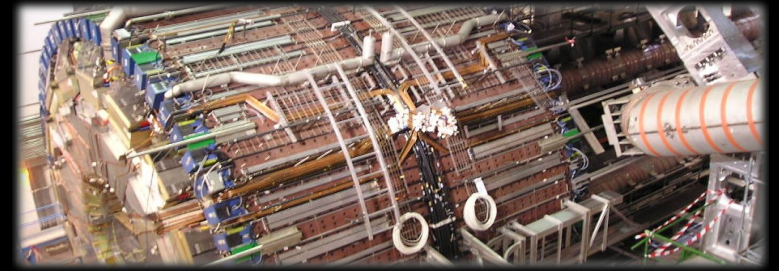
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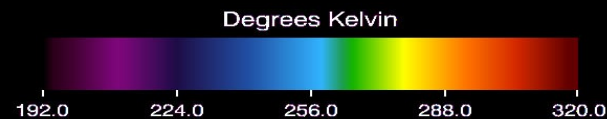
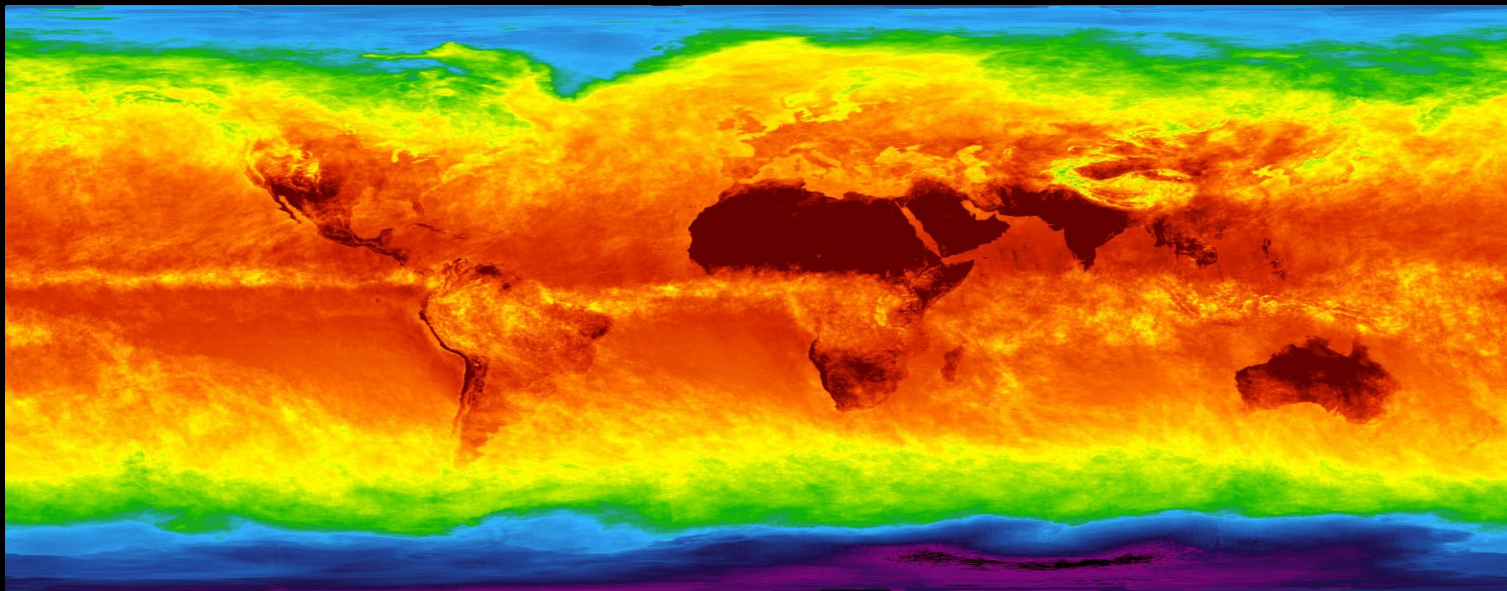


Fields



- A Field is a physical quantity which has a value at every point in space and time

example : temperature field



Fields



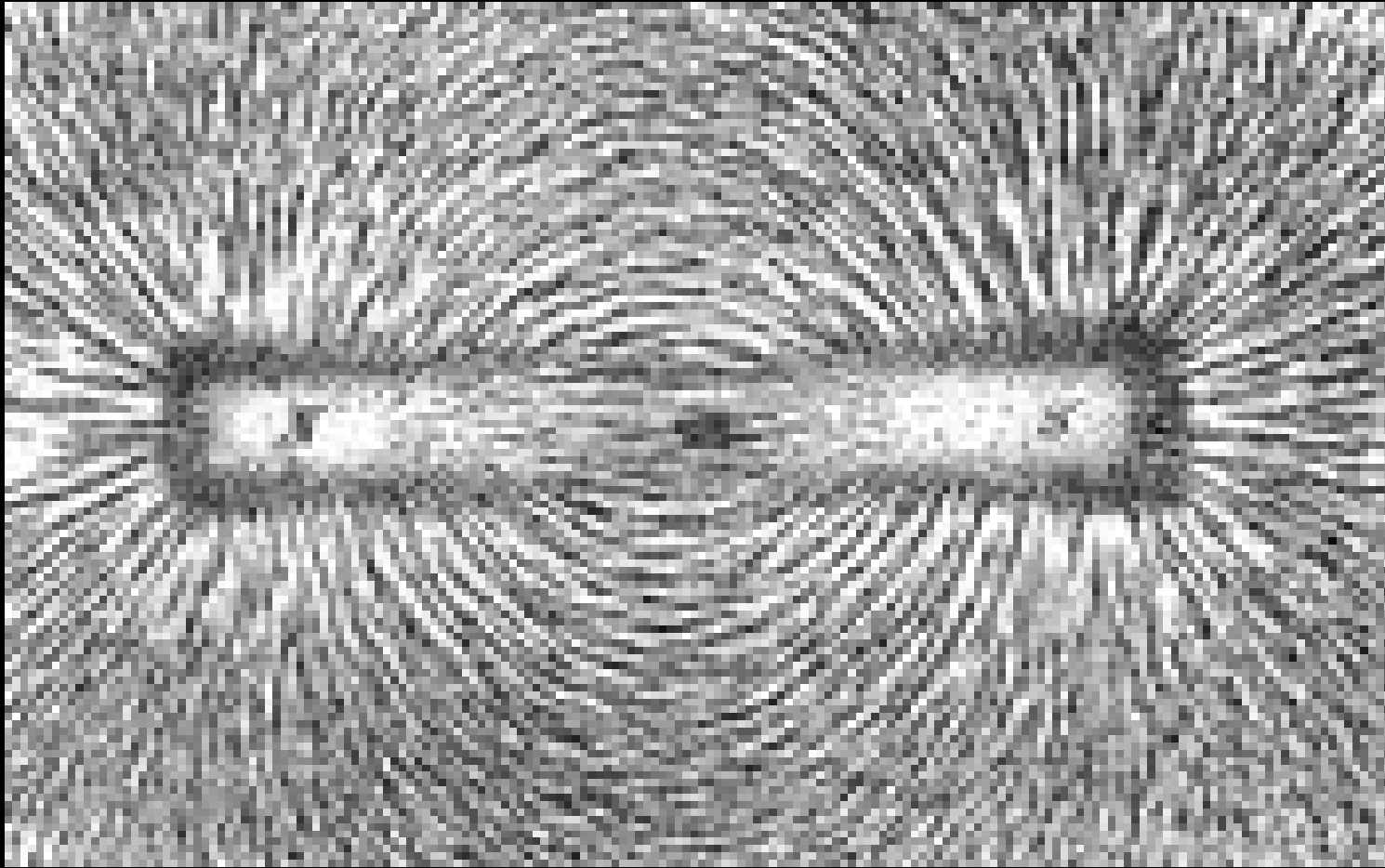
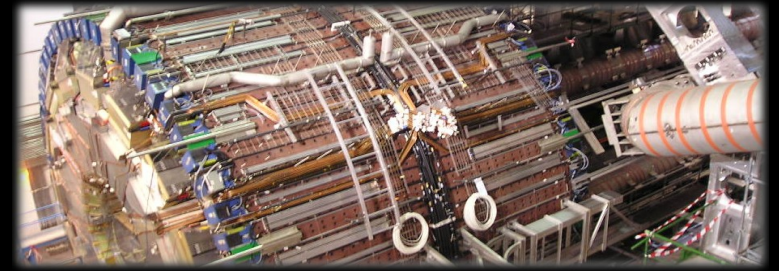
- Fields are the mathematical tools we use to describe reality

Electromagnetic field

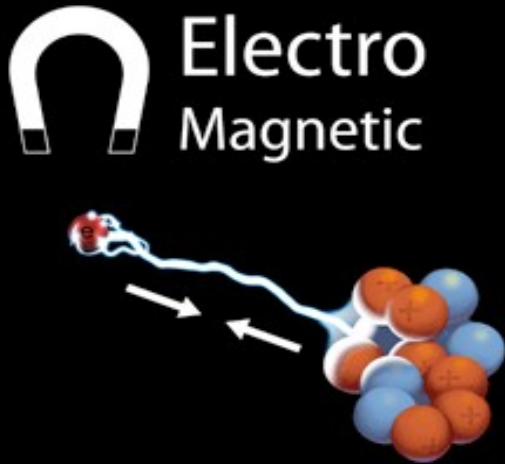
$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\bar{\psi}\not{D}\psi + \text{h.c.} + \bar{\psi}_i \gamma_{ij} \psi_j \phi + \text{h.c.} + |D_\mu \phi|^2 - V(\phi)$$

Electron field

Are fields “real”?



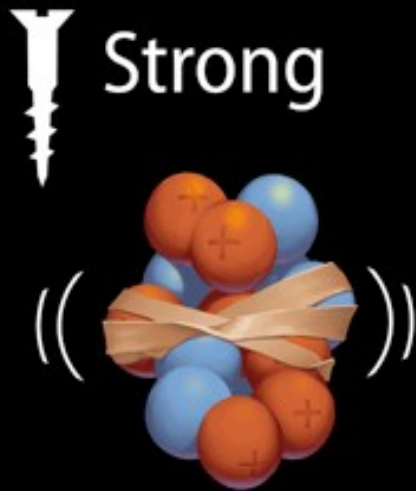
Forces



Electricity
Magnetism



Radioactivity



Keeps nuclei
together



Gravity

Forces & Fields

- Each force is associated with a field

magnetism is associated with the electromagnetic field

- In Quantum Physics, each force is also associated with a particle

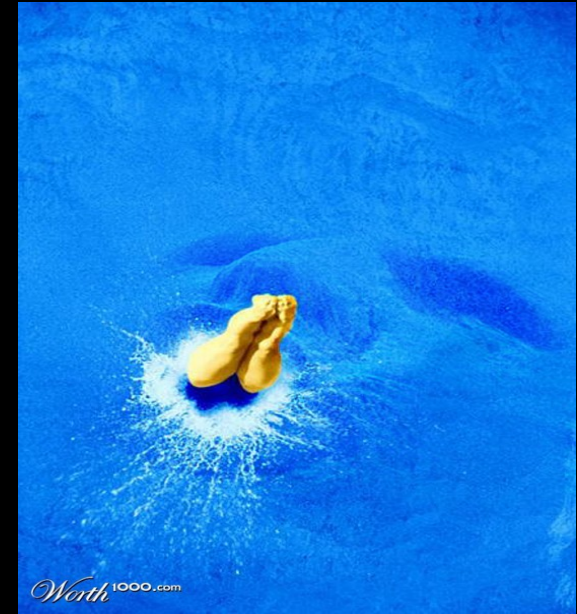
For Electromagnetism this is the photon - the particle of light

- So every field is associated with a particle. In some sense, “particles” are just locations where the relevant field is more concentrated.

The Higgs Field Idea

- To be “massless” = to travel at the speed of light
- Imagine that the universe is saturated by an energy field.
- Massless particles travel through the field, bouncing back and forth.
- The effect of interacting with the field effectively slows the particle down below light speed – giving the particle a mass.

Light

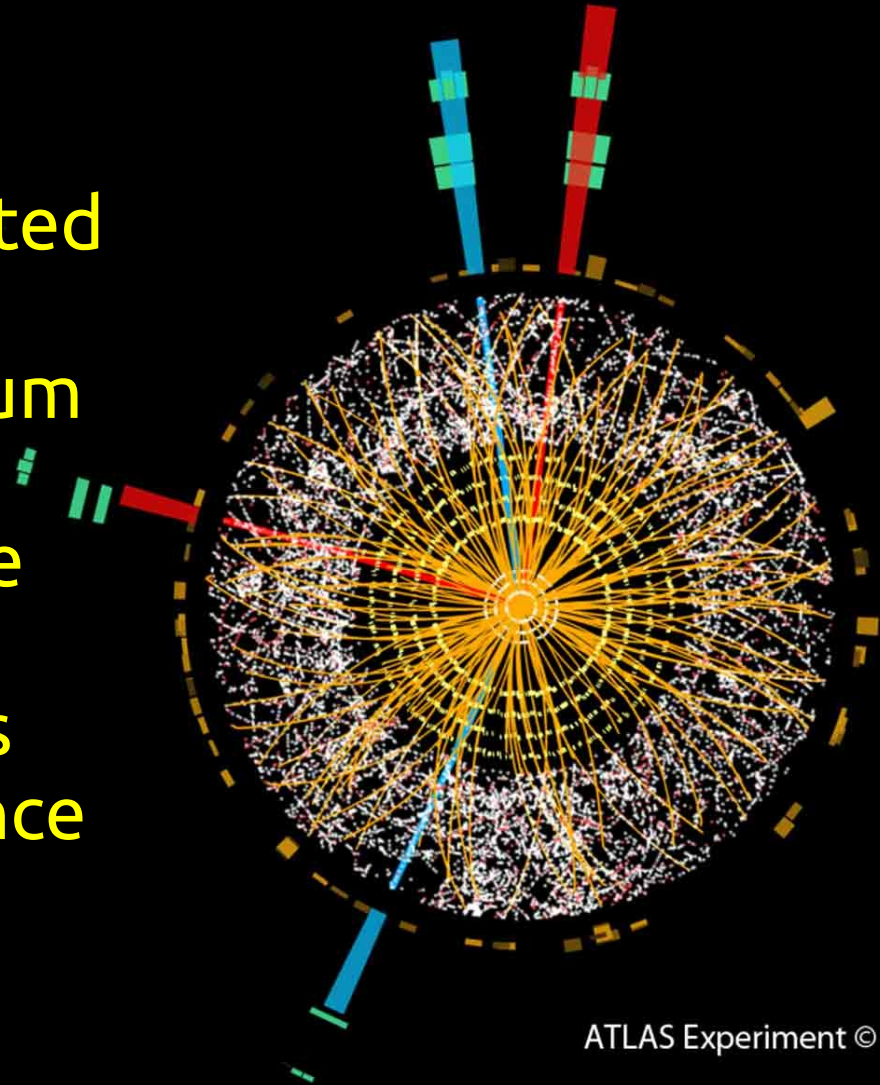


Heavy

The Higgs Boson



- A quantum field is associated with a particle
- The Higgs Field is a quantum field
- So there must be a particle - the Higgs Particle
- The existence of the Higgs Particle implies the existence of the field.



How do we find it?

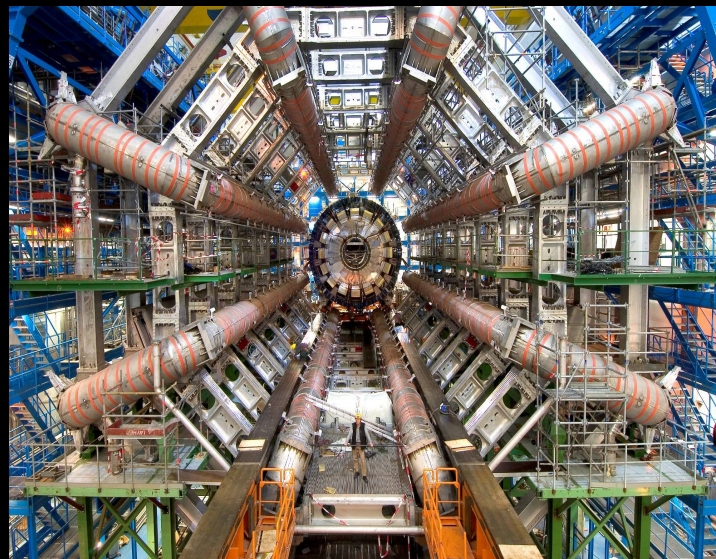


- Particle physics tries to understand the fundamental structure and forces in the universe
- We do this by smashing stuff together at near light speed and observing what comes out : $E = m c^2$

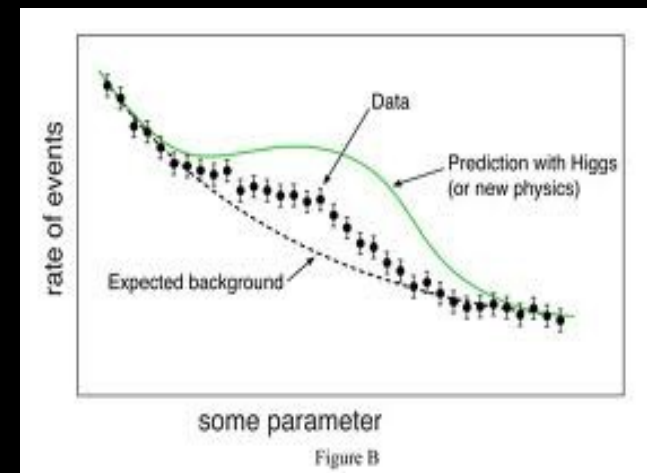
Accelerators



Detectors



Analysis



Finding the Higgs



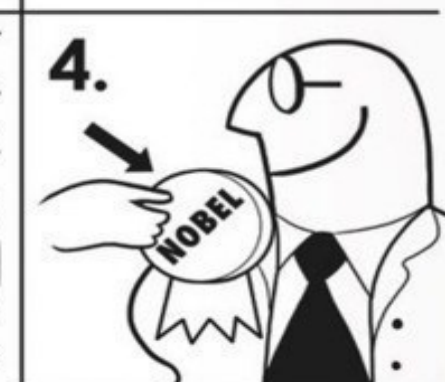
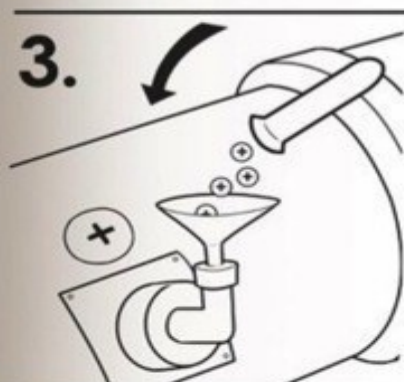
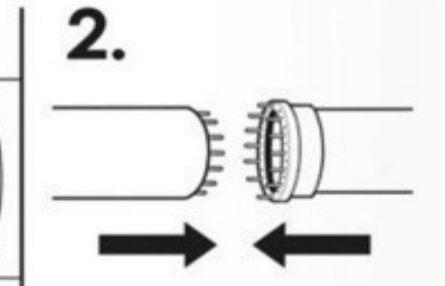
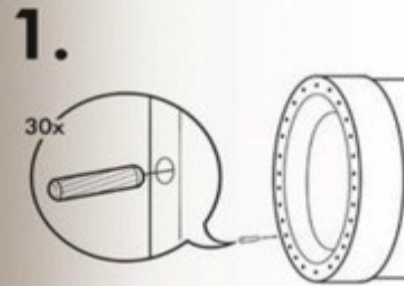
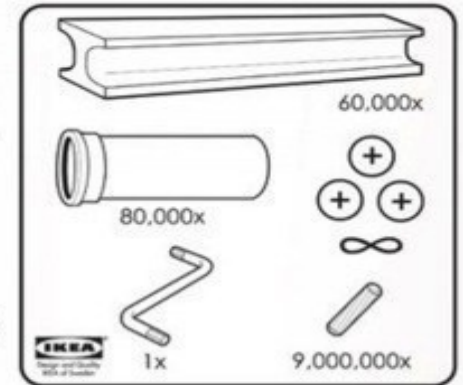
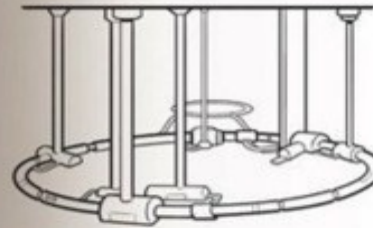
- Most massive particles can decay to lighter ones
- The Standard Model tells us that the Higgs can decay in certain ways

e.g. $H \rightarrow 4 \text{ electrons}$

- I. Smash protons into other protons to form Higgs particles
- II. Look for events with 4 electrons coming from the same place
- III. Measure mass of decaying particle from energy of the visible particles

How to build an LHC

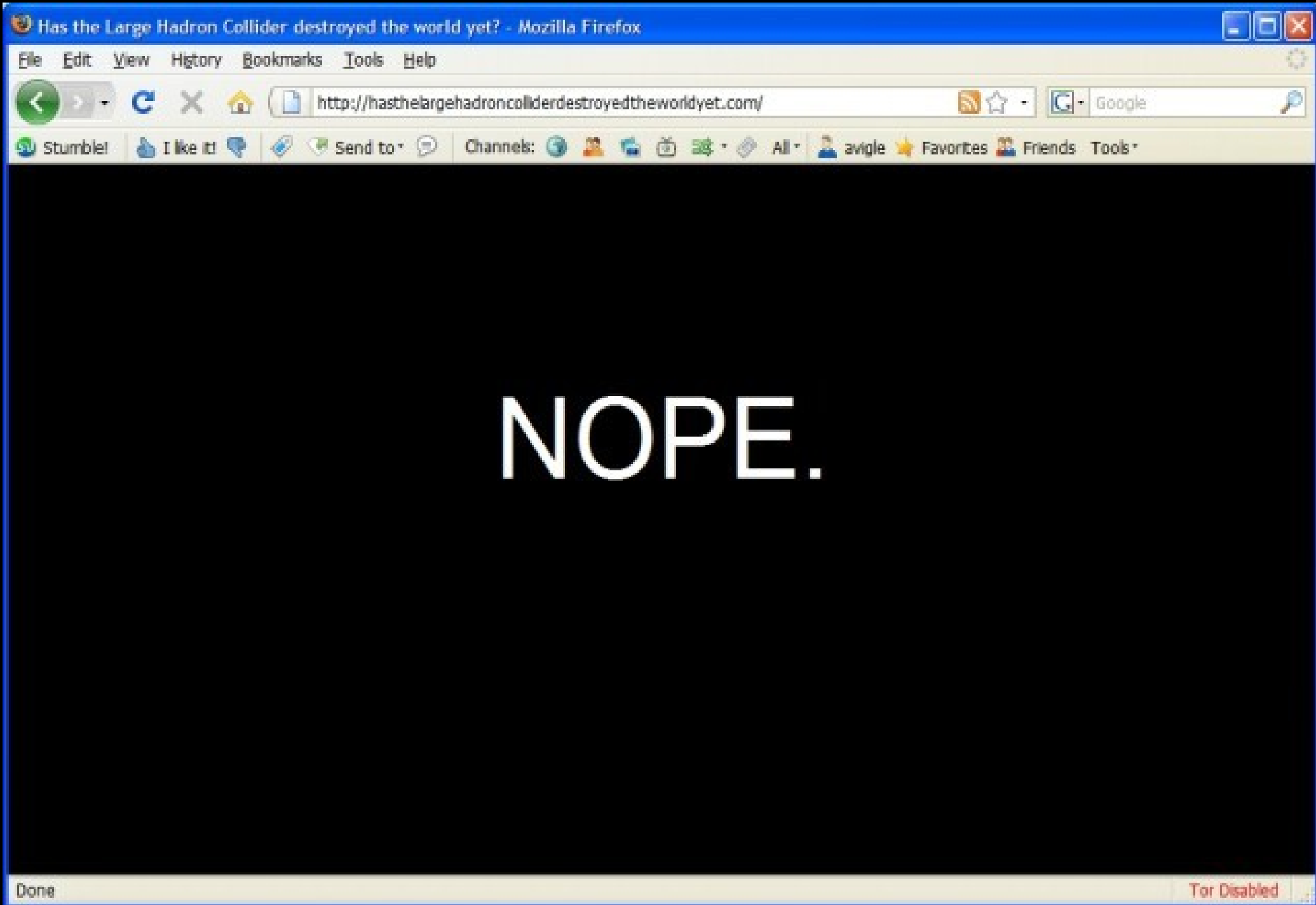
HÄDRÖNN CJÖLIDDER



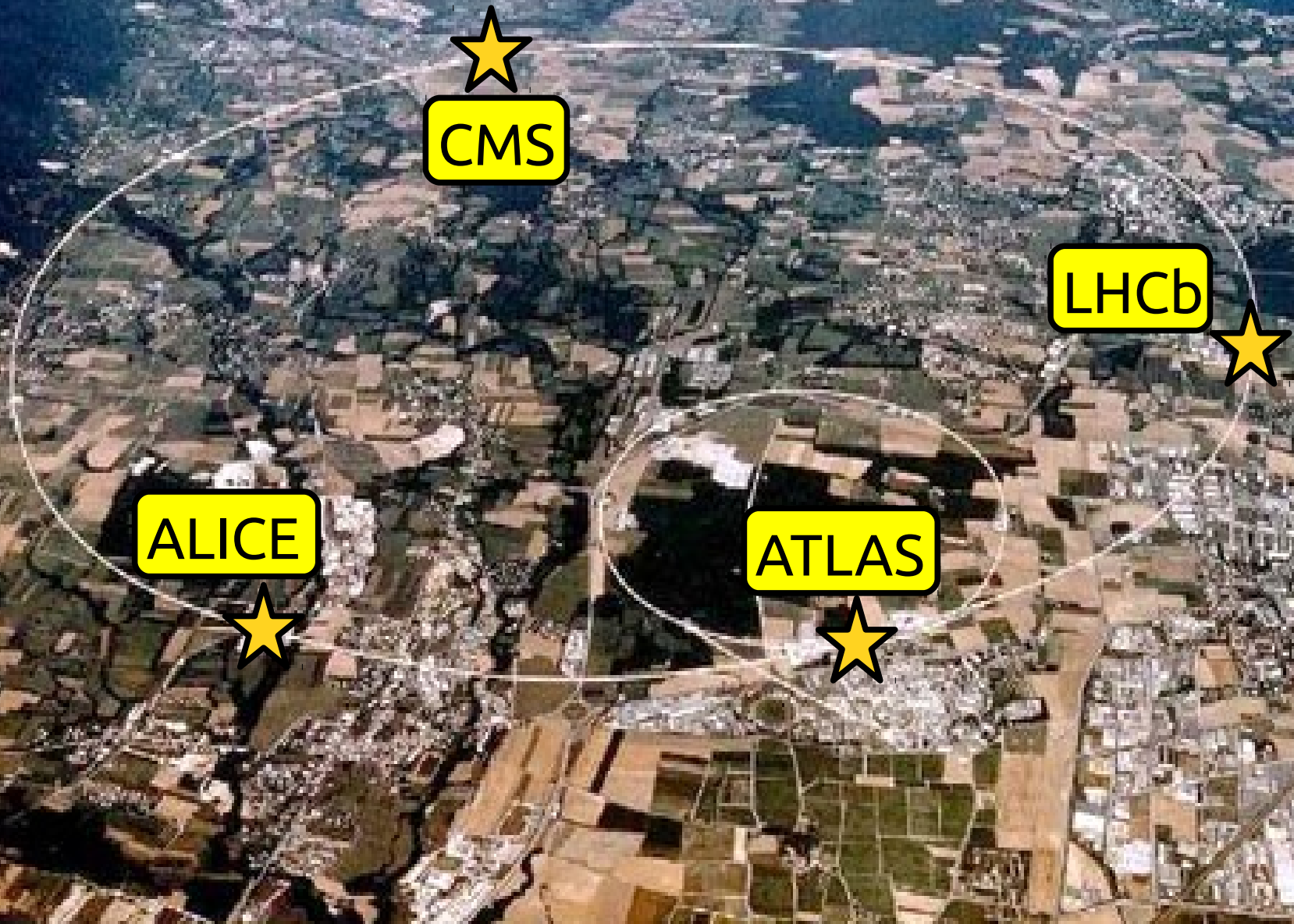
What the news reports said would happen



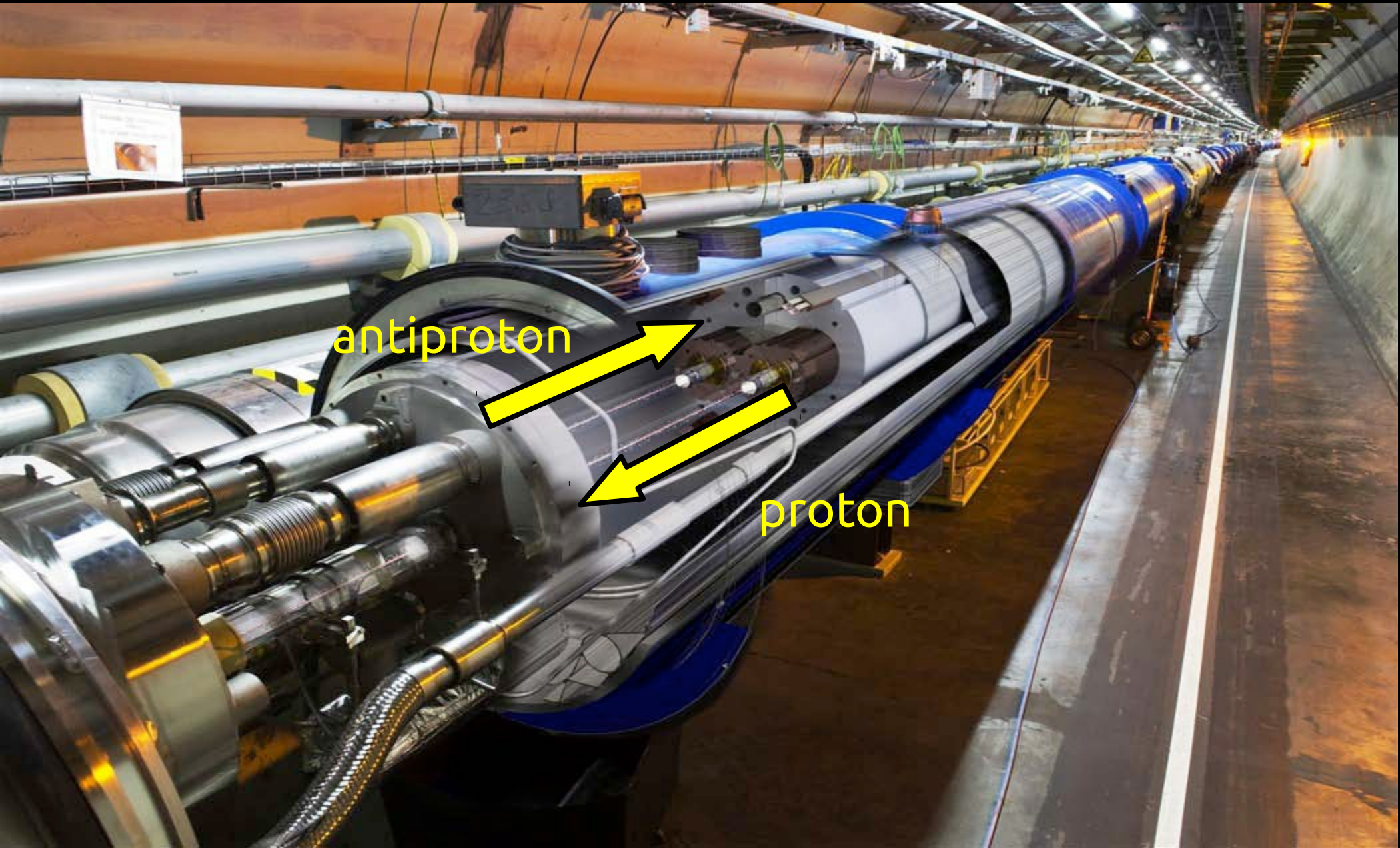
<http://www.hasthelargehadroncolliderdestroyedtheworldyet.com>



Large Hadron Collider



LHC Magnets

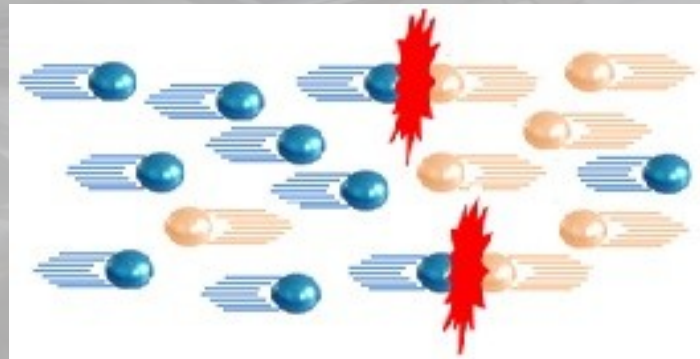


antiproton

proton

LHC Magnets

- ▶ 9,600 superconducting magnets in the LHC ring
- ▶ Cooled to about 1.9 degrees Kelvin
- ▶ Collides bunches of 100,000,000,000 protons together every 50 ns

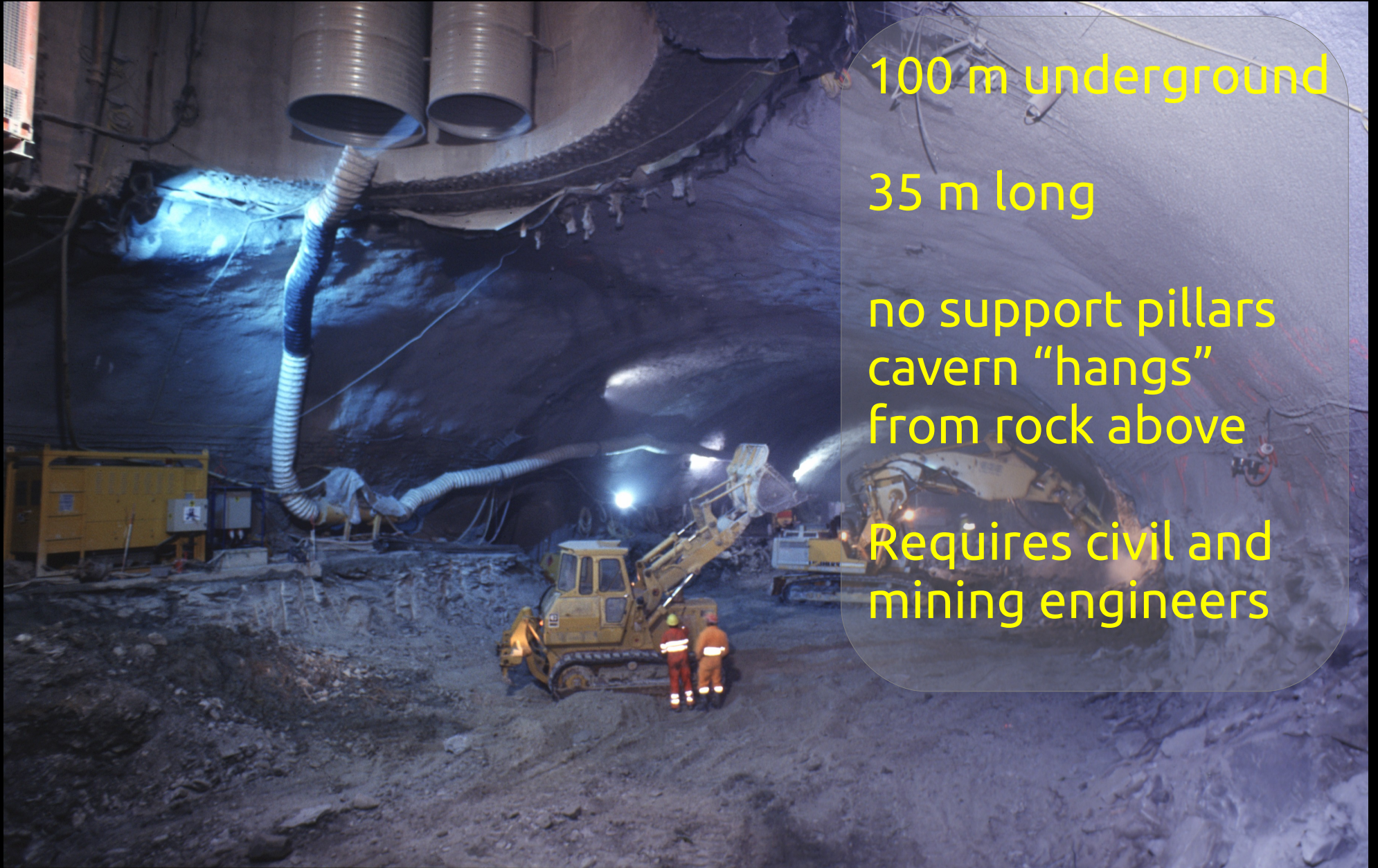


Engineering needed : civil, design, magnet, power, safety, systems and control engineers are all needed to build, design and maintain this accelerator

Detector Caverns



Detector Cavern



100 m underground

35 m long

no support pillars
cavern "hangs"
from rock above

Requires civil and
mining engineers

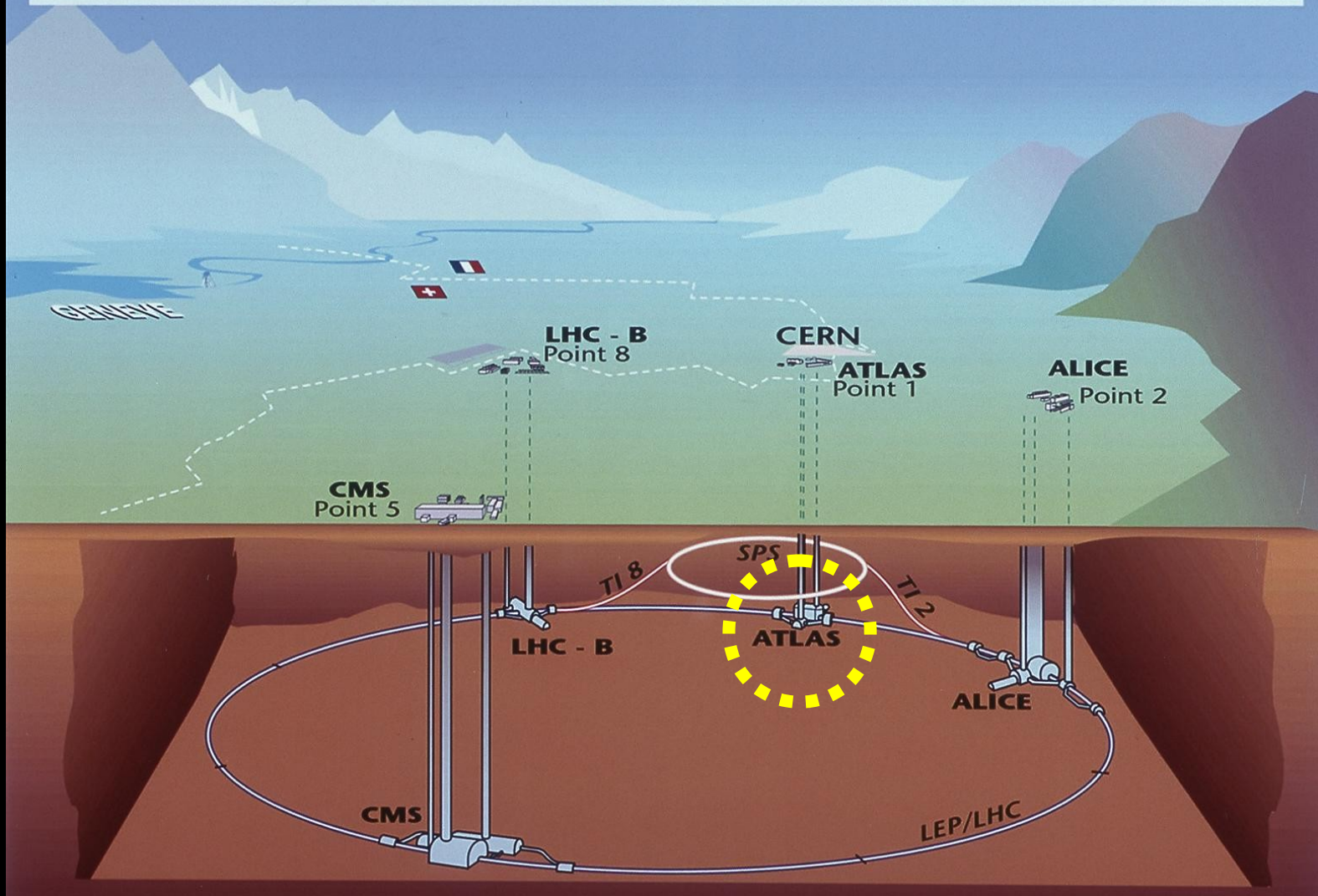
Detector Caverns



Detectors



Overall view of the LHC experiments.

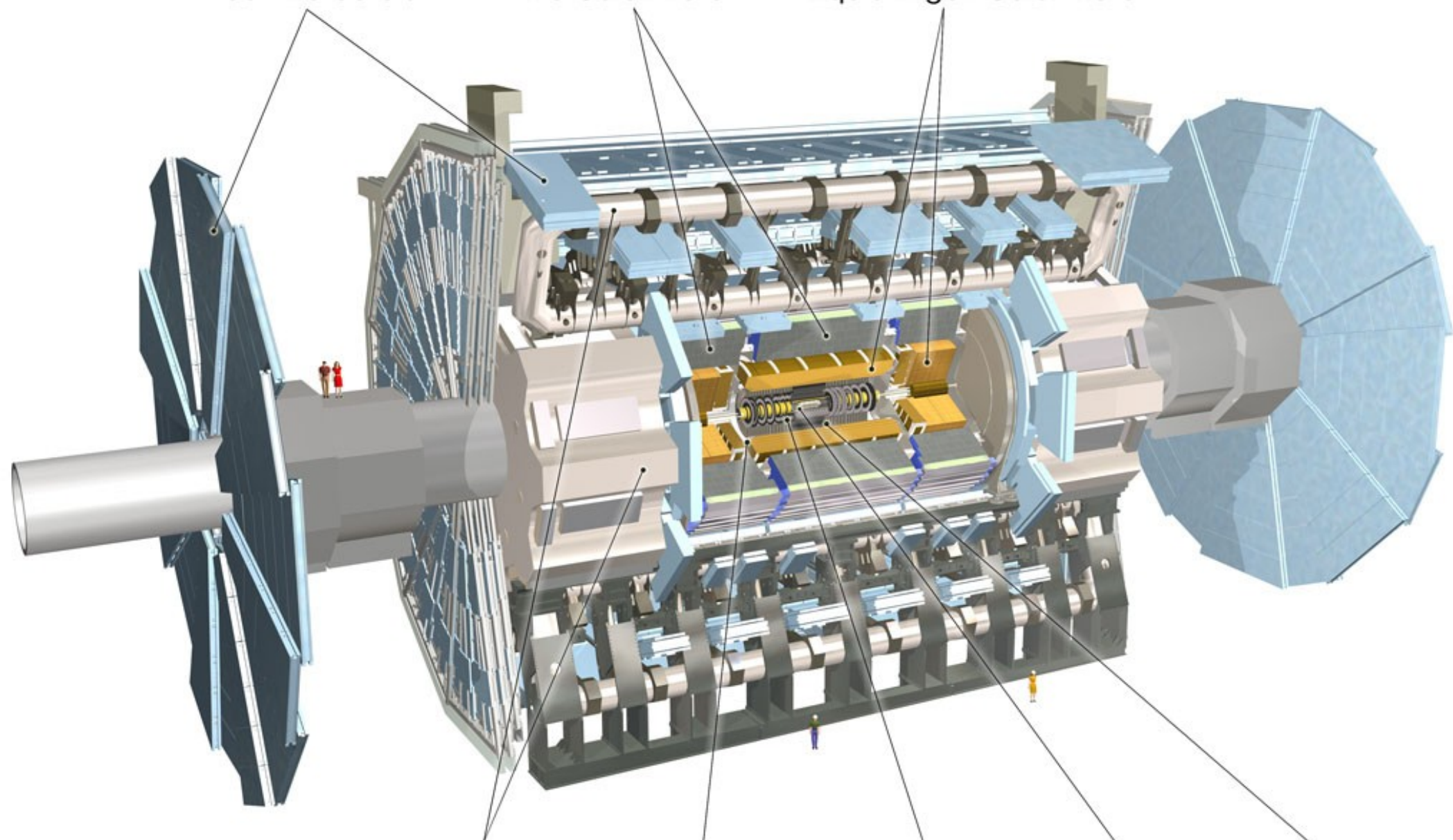




Muon Detectors

Tile Calorimeter

Liquid Argon Calorimeter



Toroid Magnets

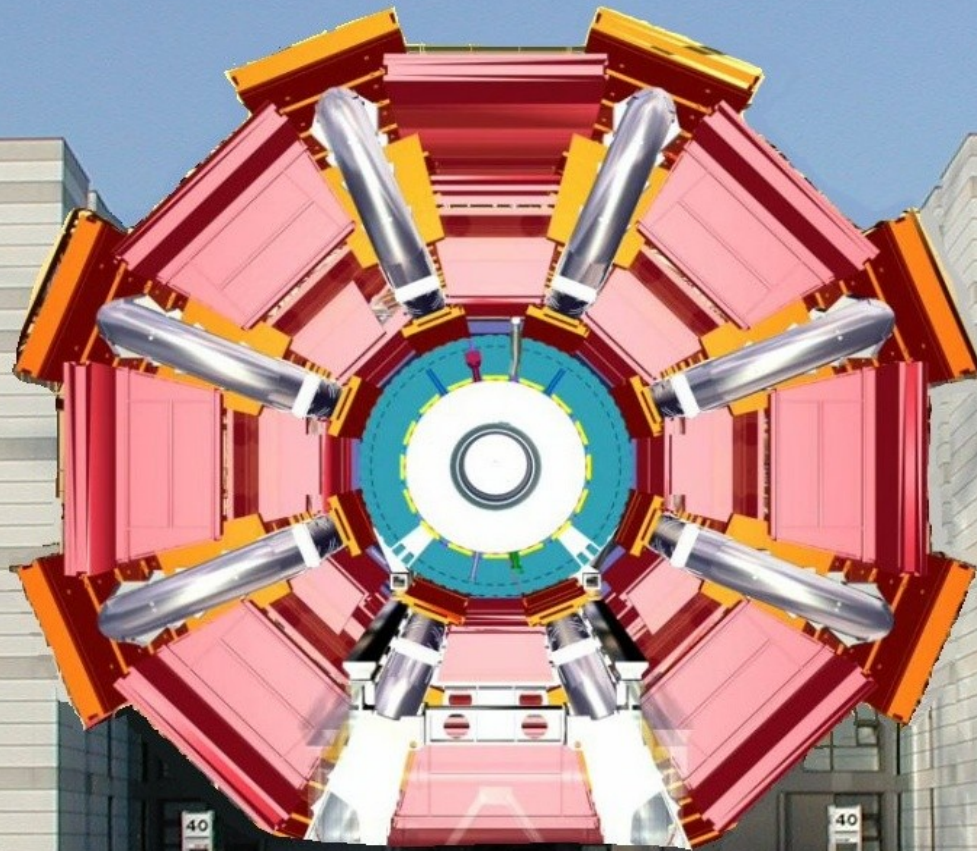
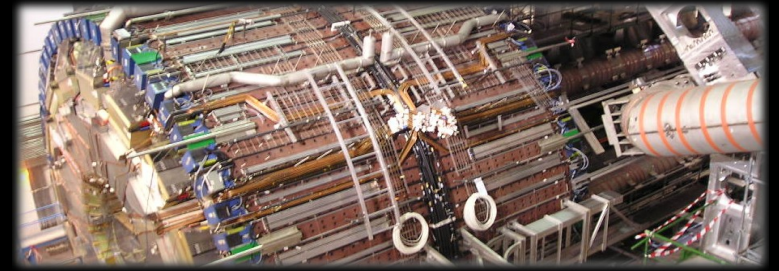
Solenoid Magnet

SCT Tracker

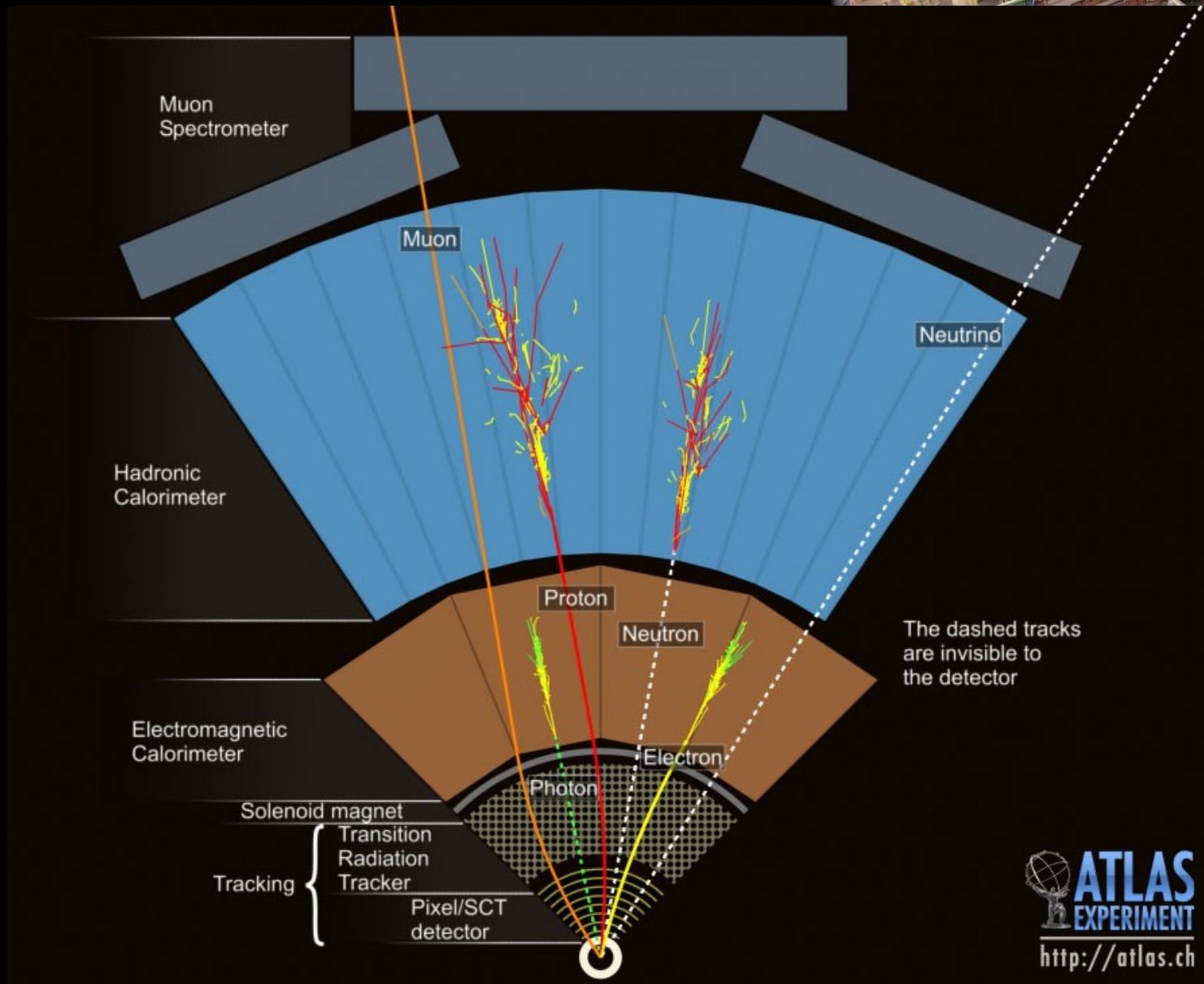
Pixel Detector

TRT Tracker

The ATLAS Experiment



How it works





BOOSTER

1.4 GeV

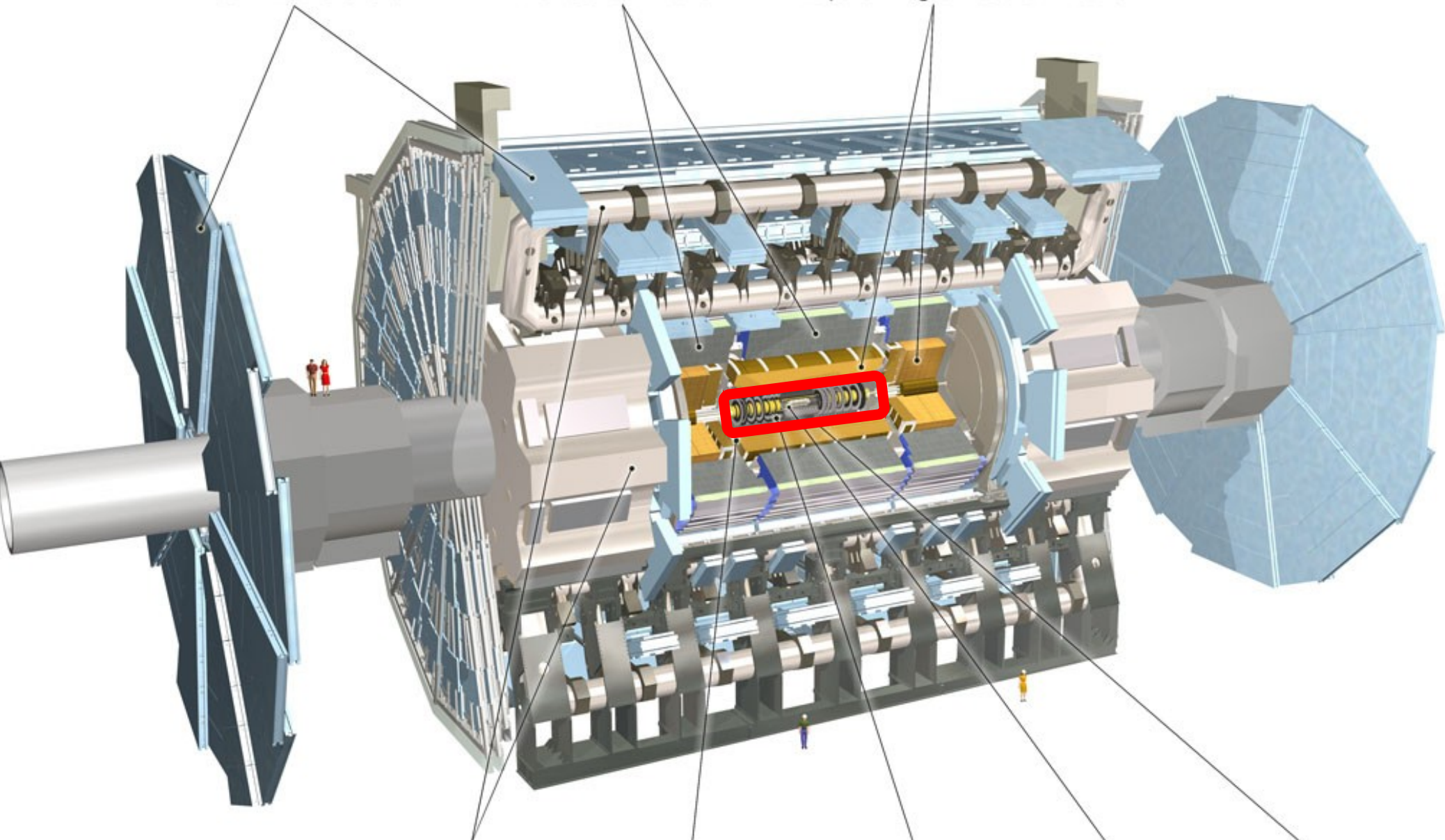
 157m



Muon Detectors

Tile Calorimeter

Liquid Argon Calorimeter



Toroid Magnets

Solenoid Magnet

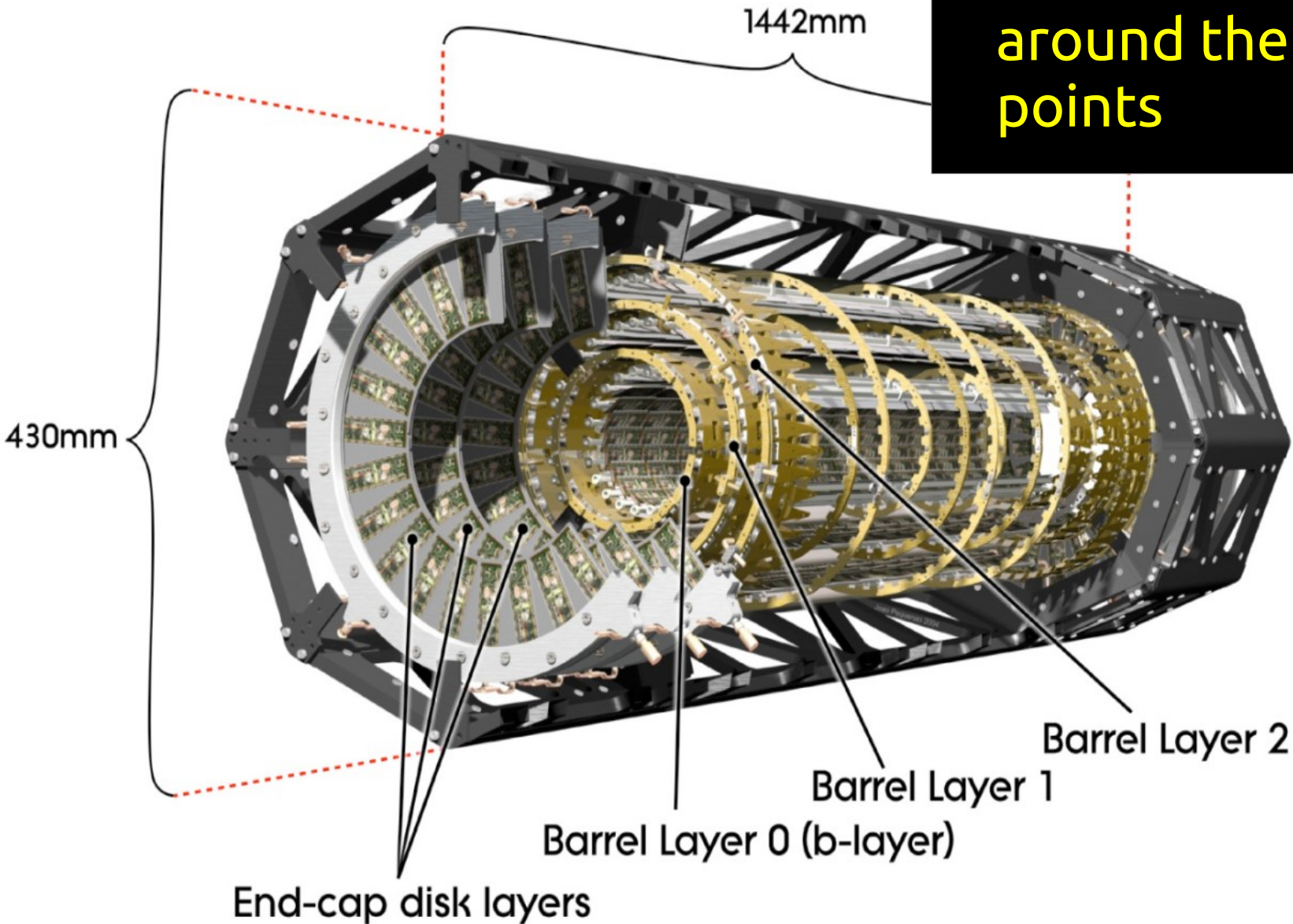
SCT Tracker

Pixel Detector

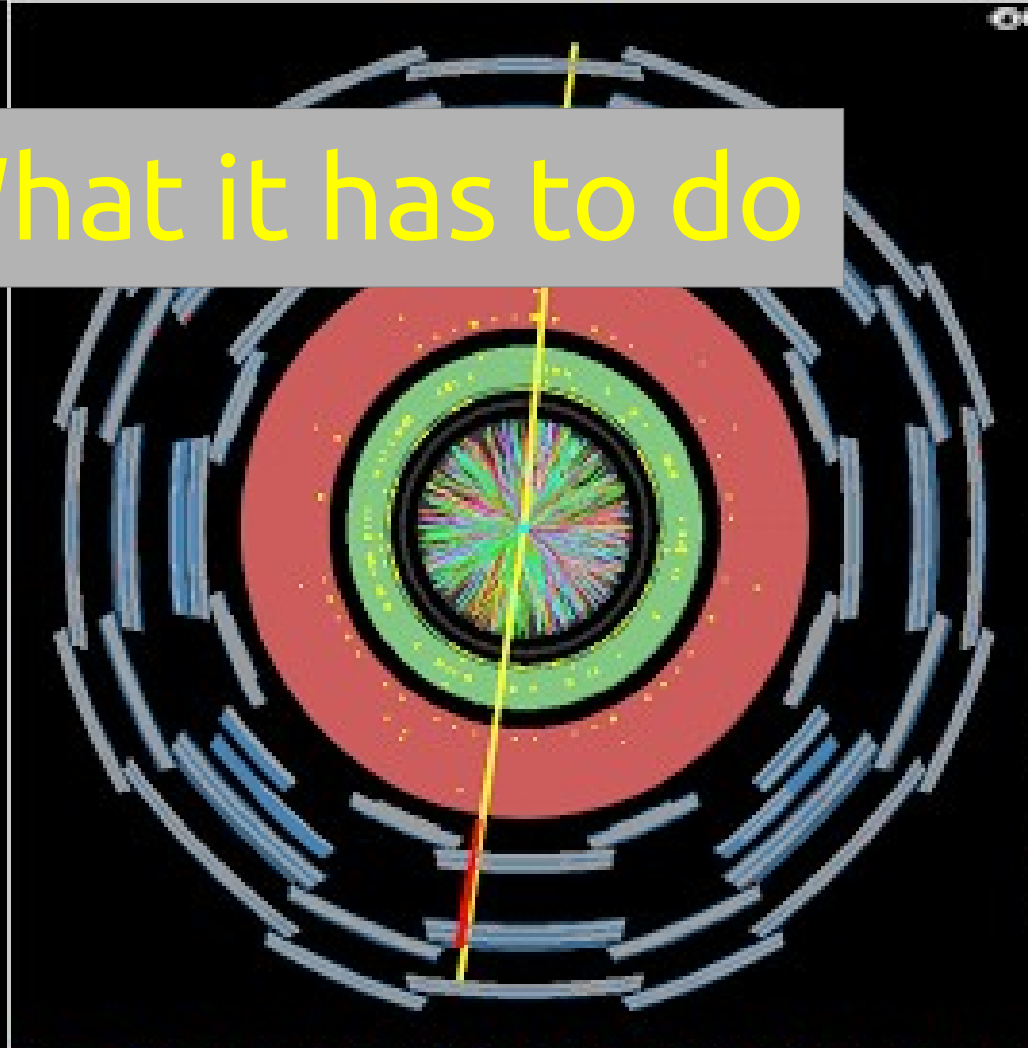
TRT Tracker

SCT

- Central Tracker
- 20,000 36 cm^2 silicon sensors
- In the ATLAS core around the collision points

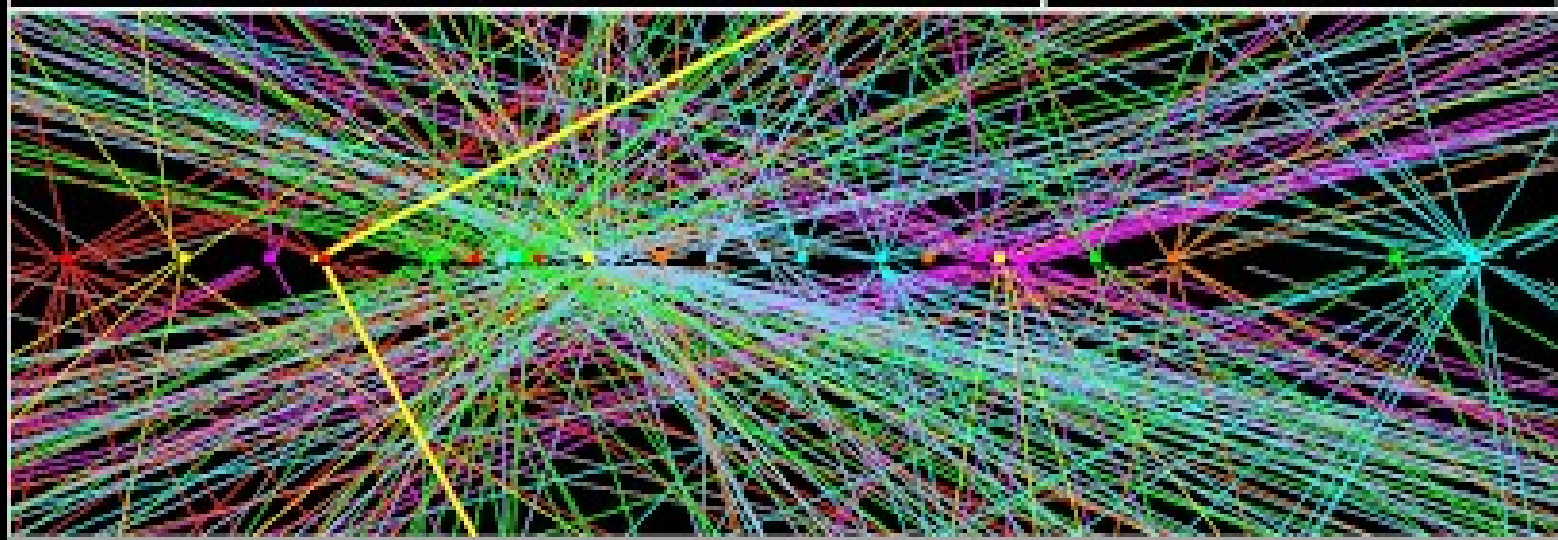
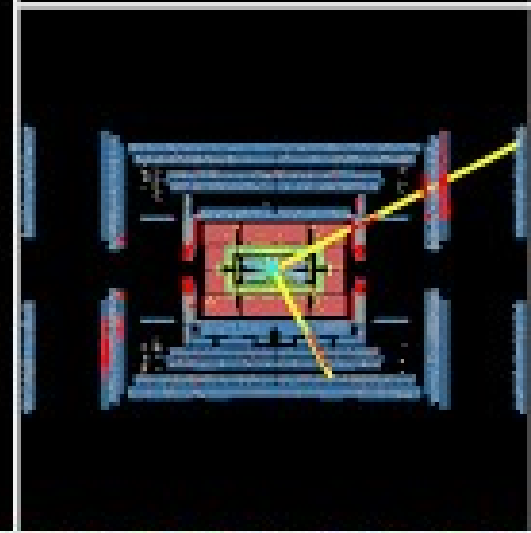


What it has to do



 **ATLAS**
EXPERIMENT

Run Number: 261283, Event Number: 24151616
Date: 2012-04-15 16:52:58 CEST

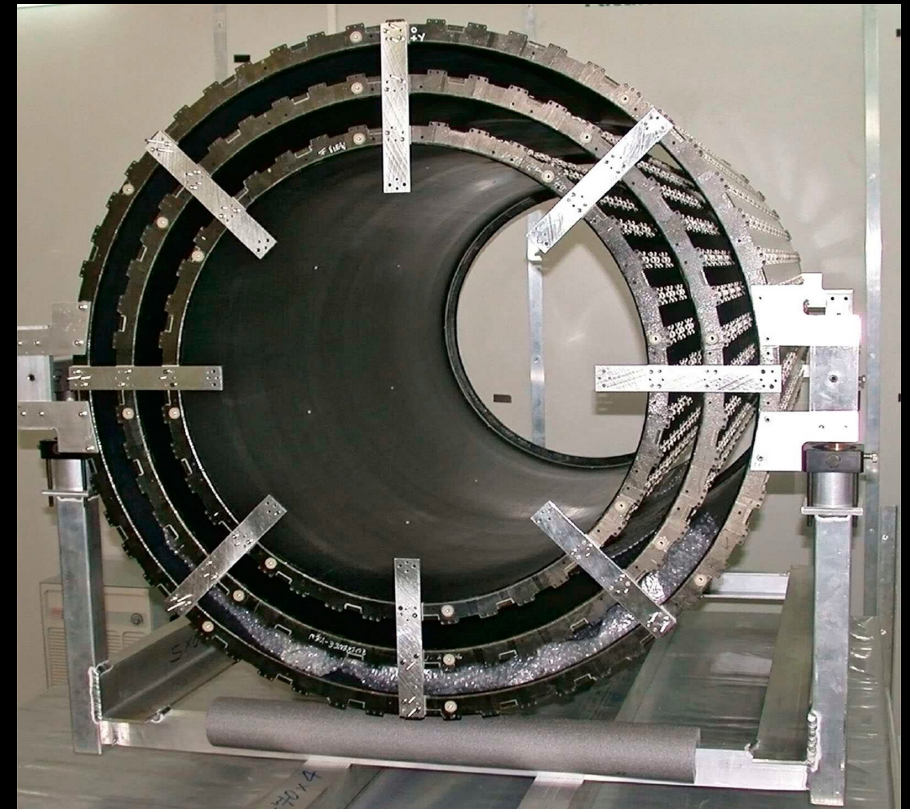
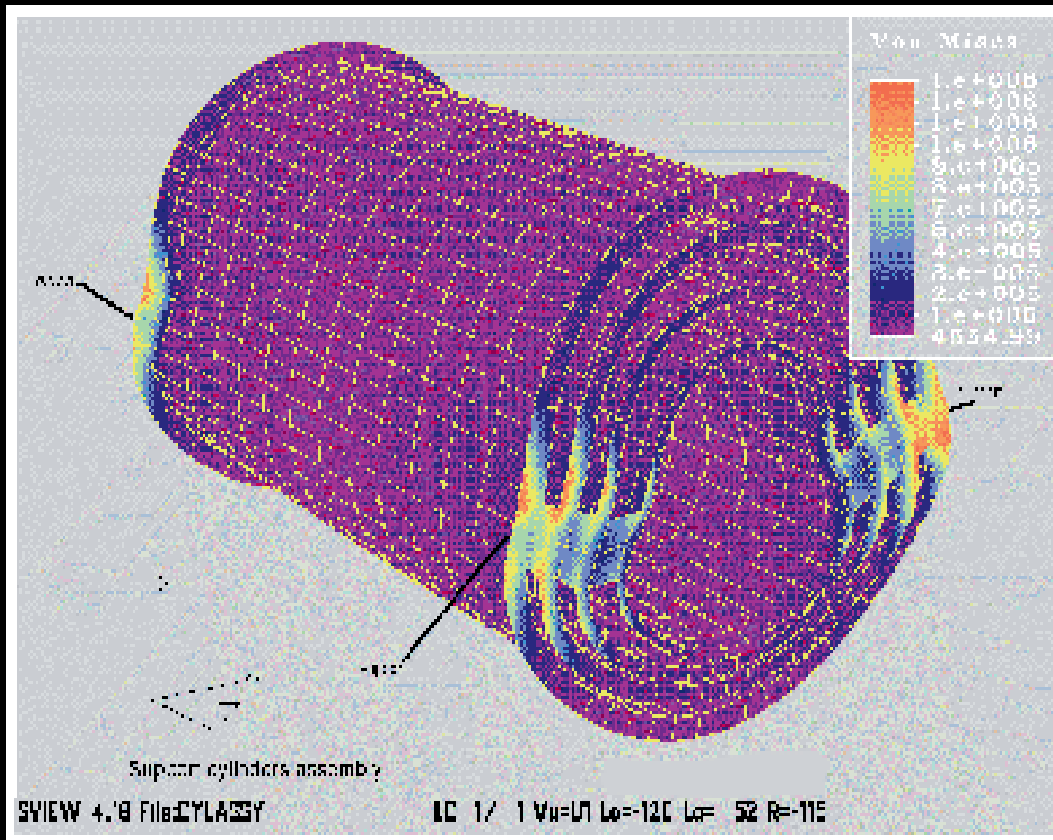


Specifying the SCT

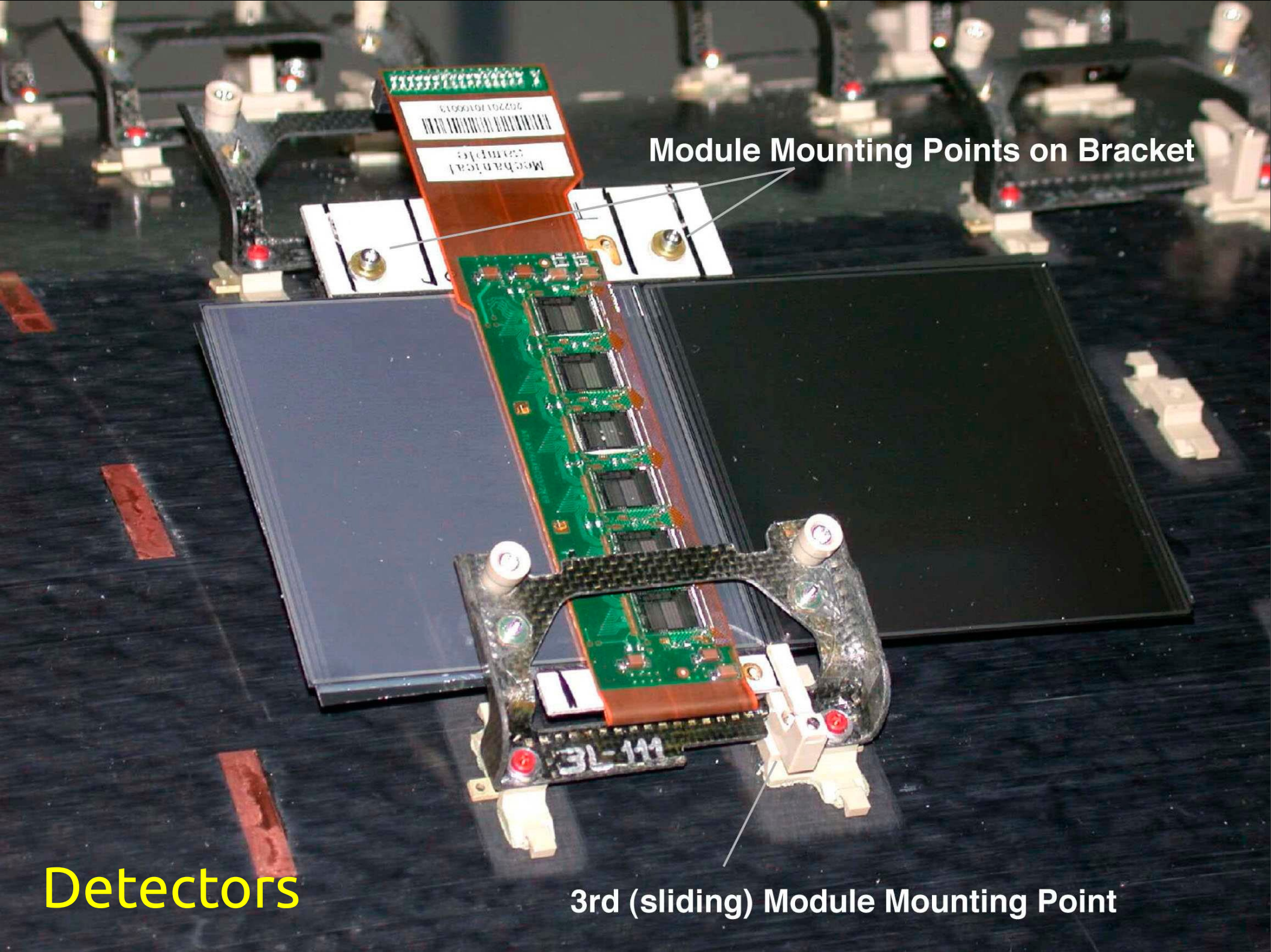


- Position of all elements known to 50-100 μm
- Mechanical and Electronic stability across temperature range from -15° to $+30^\circ$
- Maximum load deformation of support structure less than 20 μm
- Minimum mass
- Radiation Hard
- 20,000 semiconductor detectors with low power dissipation and low noise.
- Robust – there are very opportunities to open up and fix things

Support Barrels



- Carbon fibre skins on a plastic reinforced honeycomb structure



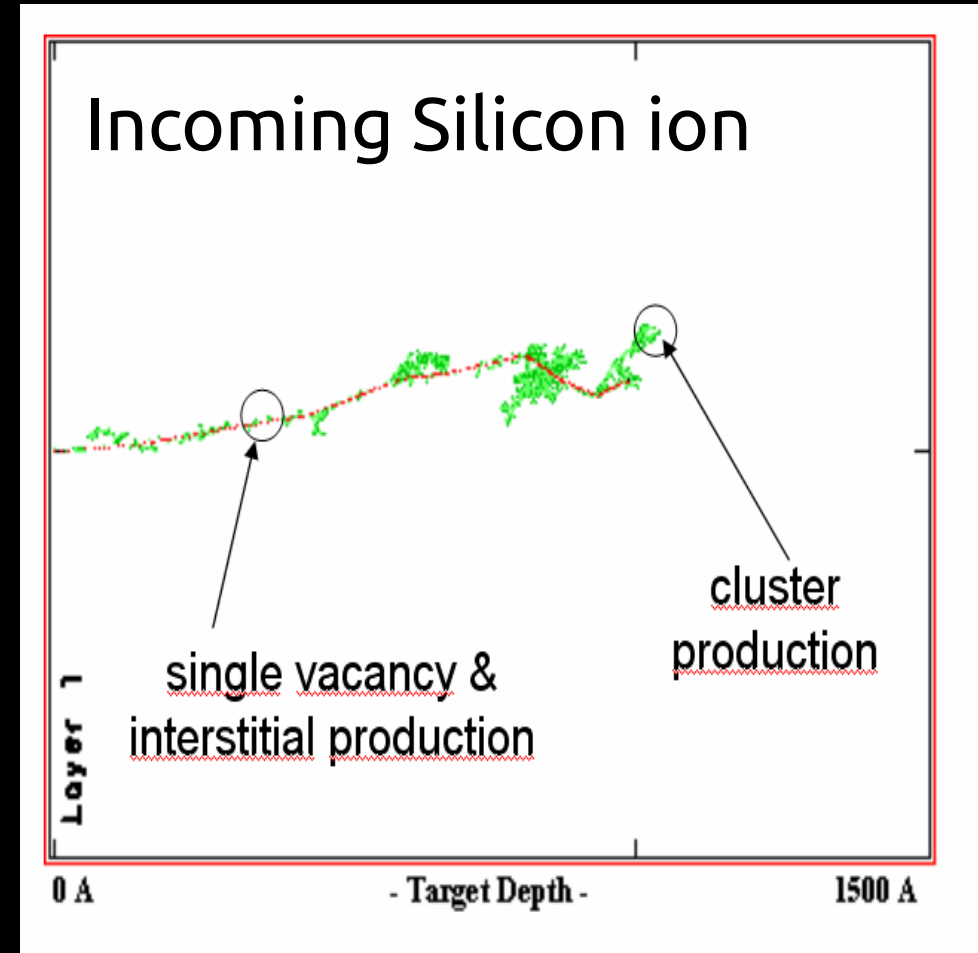
Module Mounting Points on Bracket

Detectors

3rd (sliding) Module Mounting Point

Radiation

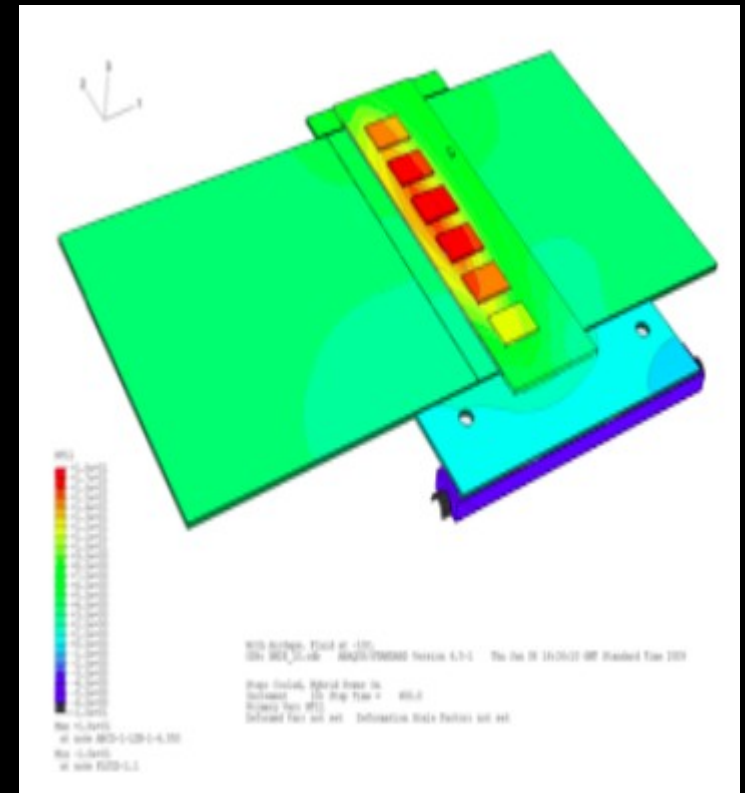
- SCT is very close to the beam collision point.
- Accumulated dose about 1,000,000 times that of maximum recommended annual dose for you or me
- Materials and Electronic engineering needed
- Radiation kills detectors
 - “leakage” current increases
 - detector heats up
 - causing leakage current to increase
- thermal management is very important.



Cooling



- Sensors are sensitive to temperature but require power in a constrained, closed environment in the ATLAS core.
- Sensors maintained at -7°C
- Lots of simulation work and iteration needed to specify cooling system

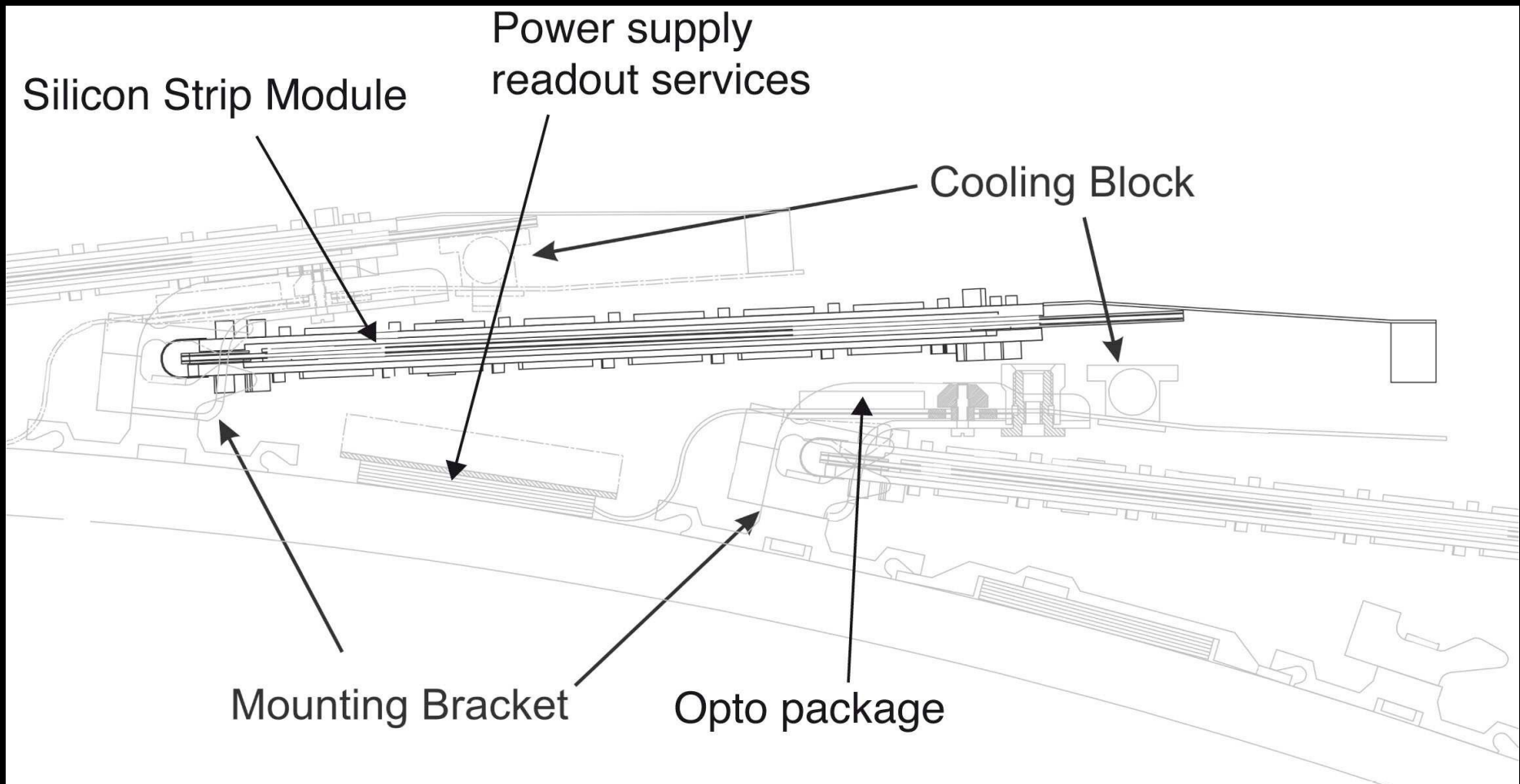


Detector Mounting

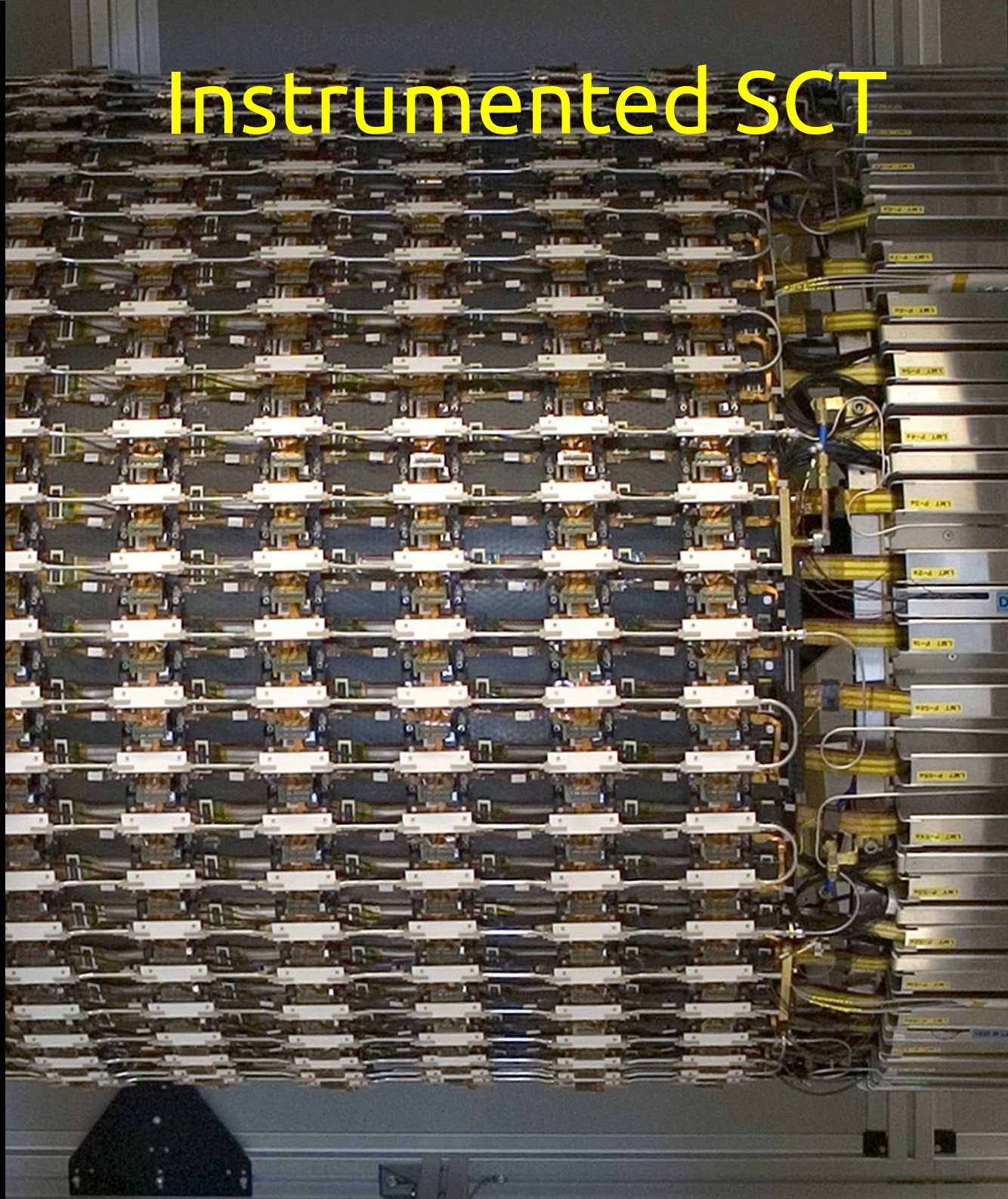


Must have total coverage of the barrels

Also need to get power and cooling in and signals out



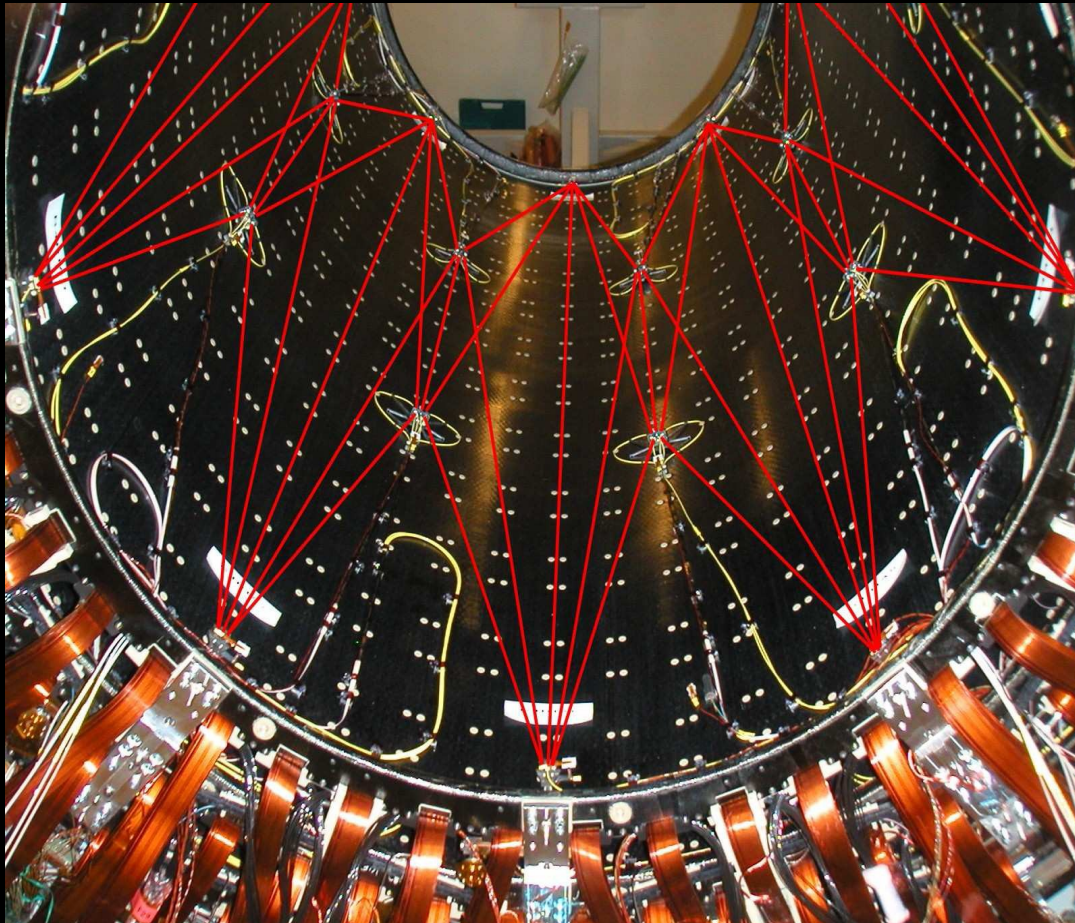
Instrumented SCT



Monitoring



- Monitoring of SCT in operation is very important



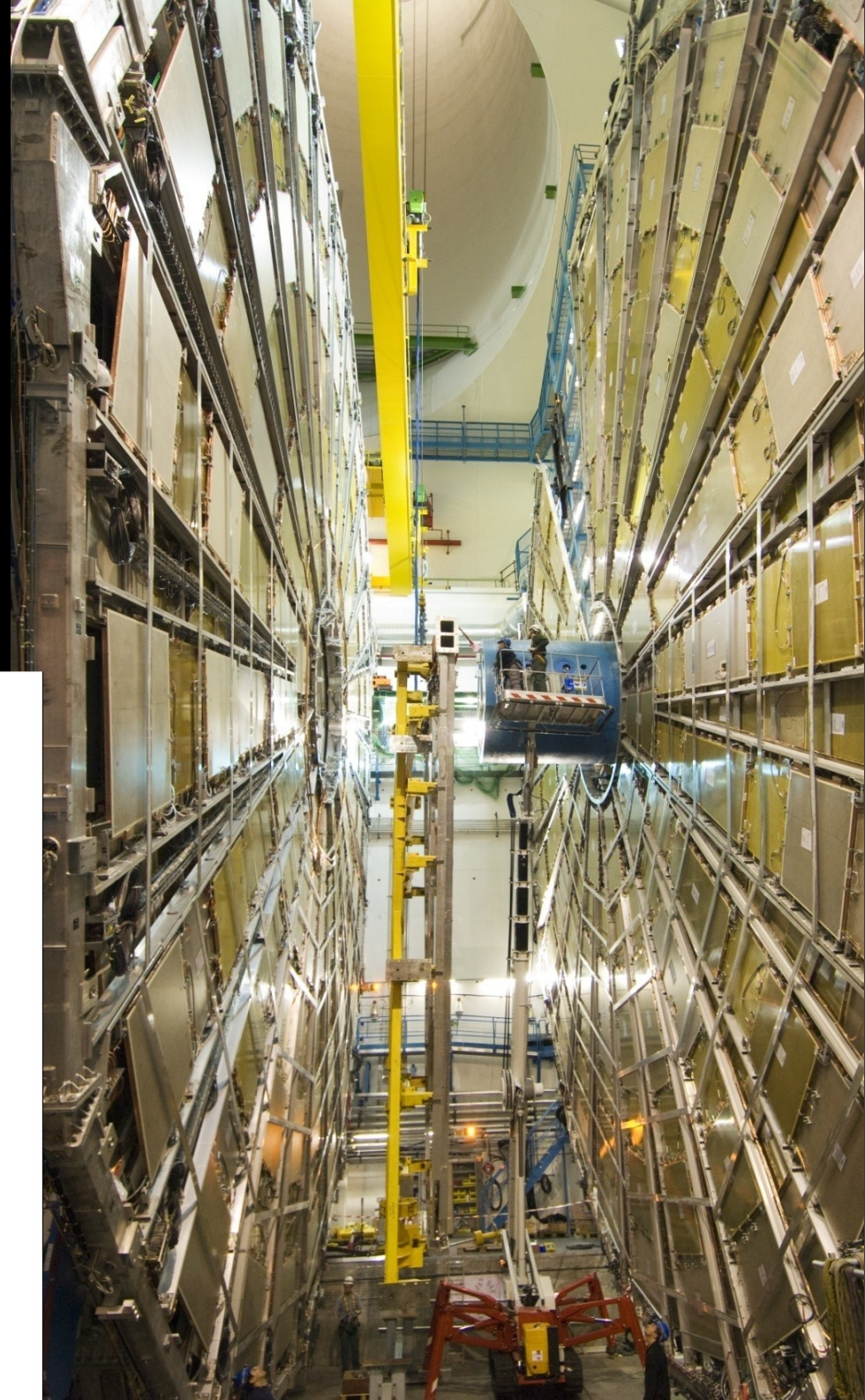
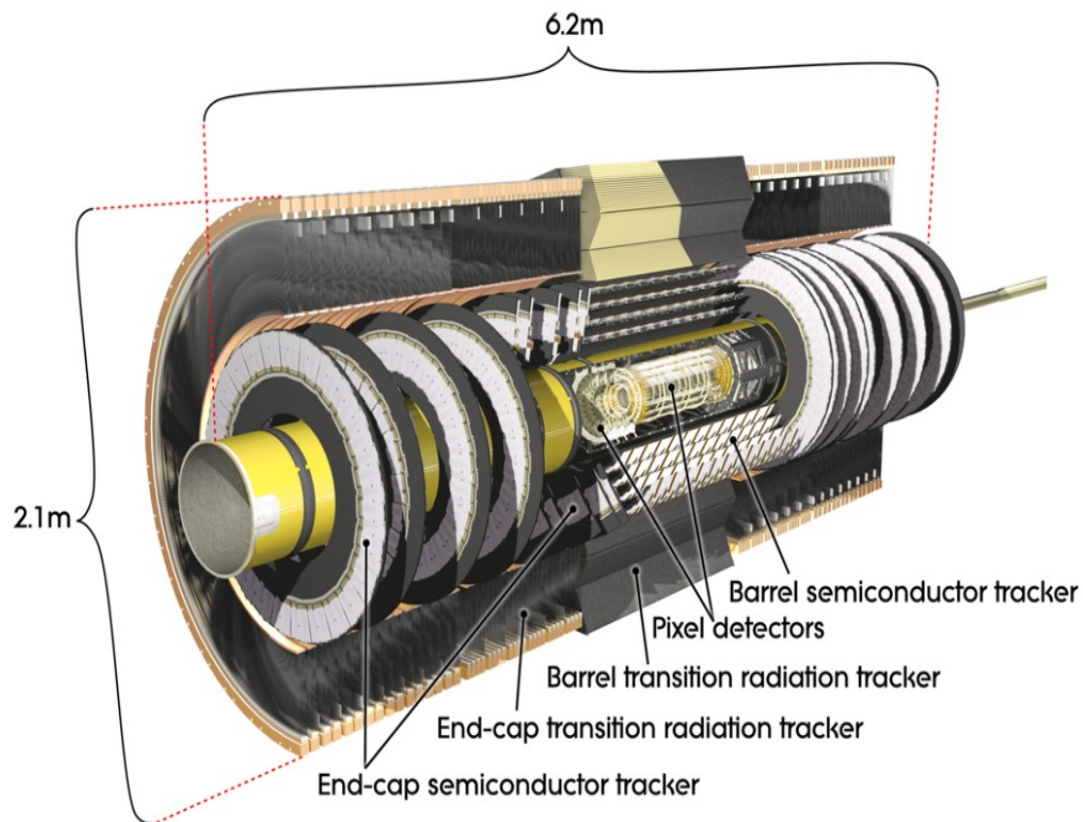
- Module position & shape
- Temperature
- Humidity

Adding services



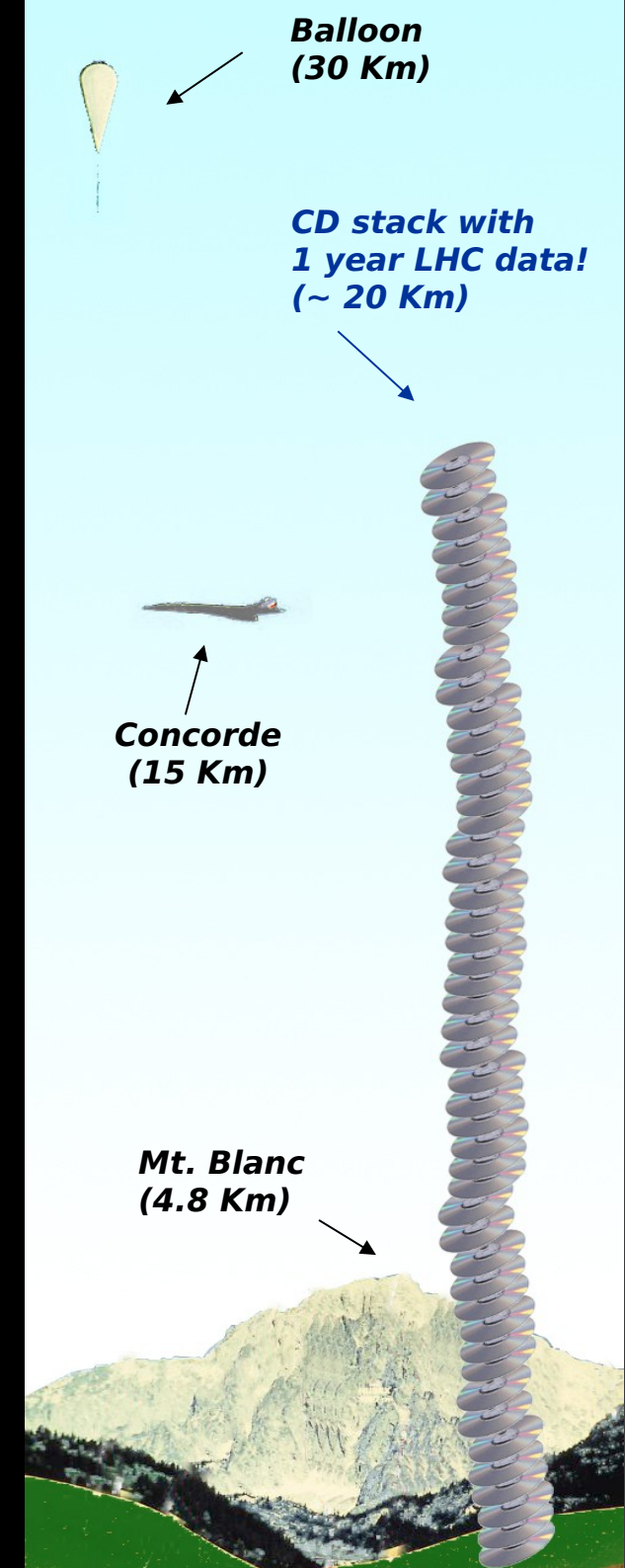
Installation

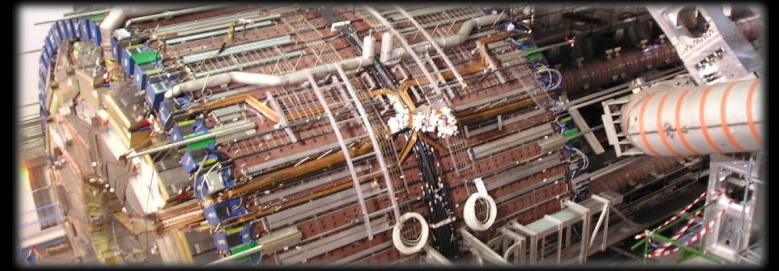
- ▶ SCT is installed in ATLAS
- ▶ Must integrate with the services that serve the entire detector



Data Catching

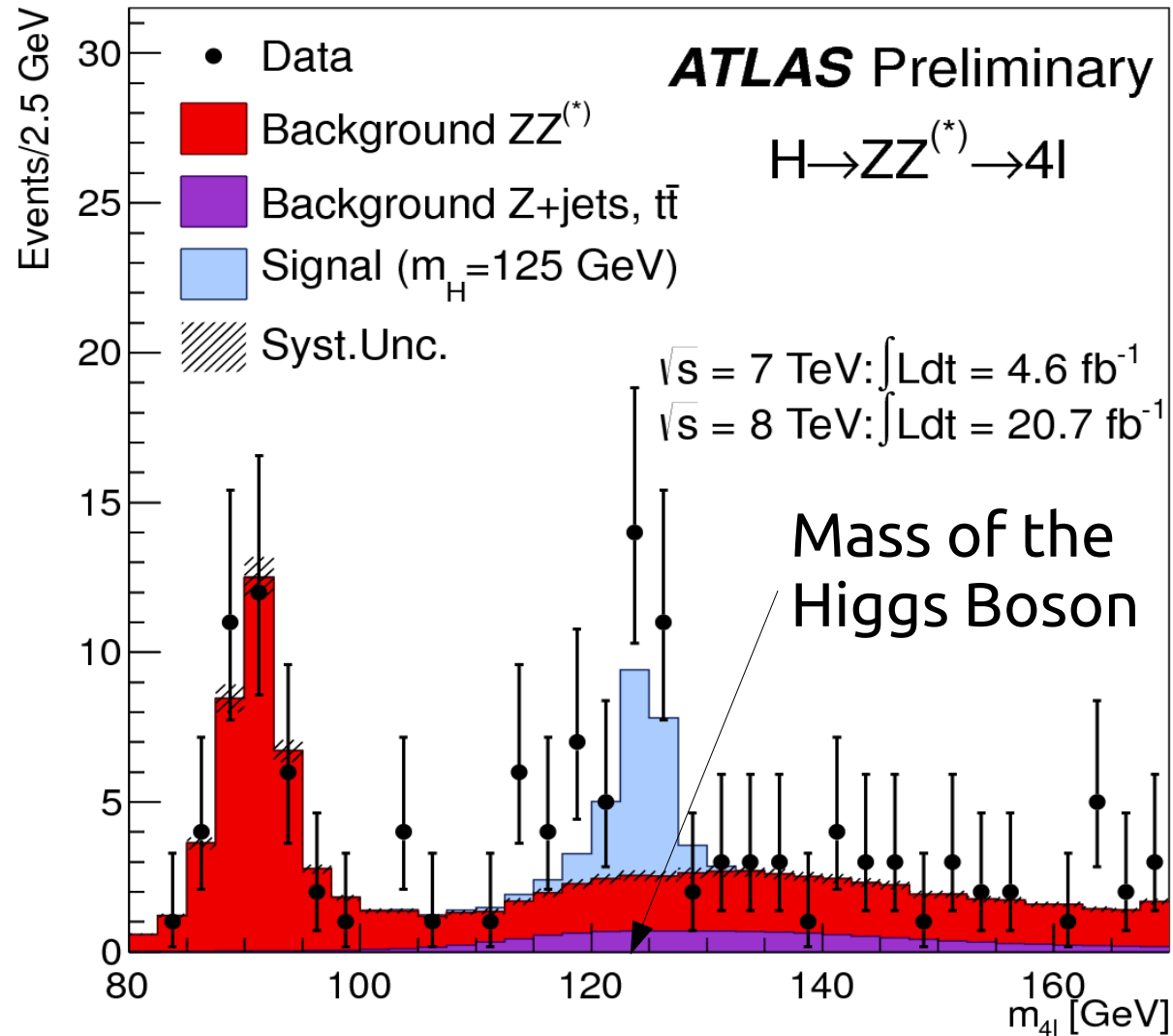
- Raw data rate from ATLAS would fill 100,000 DVDs a second.
- Data is filtered through hardware and software “Trigger Farms” to look for interesting things
- Final data rate 3200 Tb/year
- Trigger farms use electronics engineers and programmers to design and build the components that (quickly) decide whether an event is kept or not.





What do we get for all this work?

A new view of the universe



Comments



- An experiment like ATLAS, and the LHC itself, could not have been built without the expertise of hundreds of engineers and technicians.
- These experiments represent cutting edge *physics*.
- They also represent cutting edge *engineering*. There are 10 times more engineers and technicians at CERN than there are research physicists.

How do I get involved?

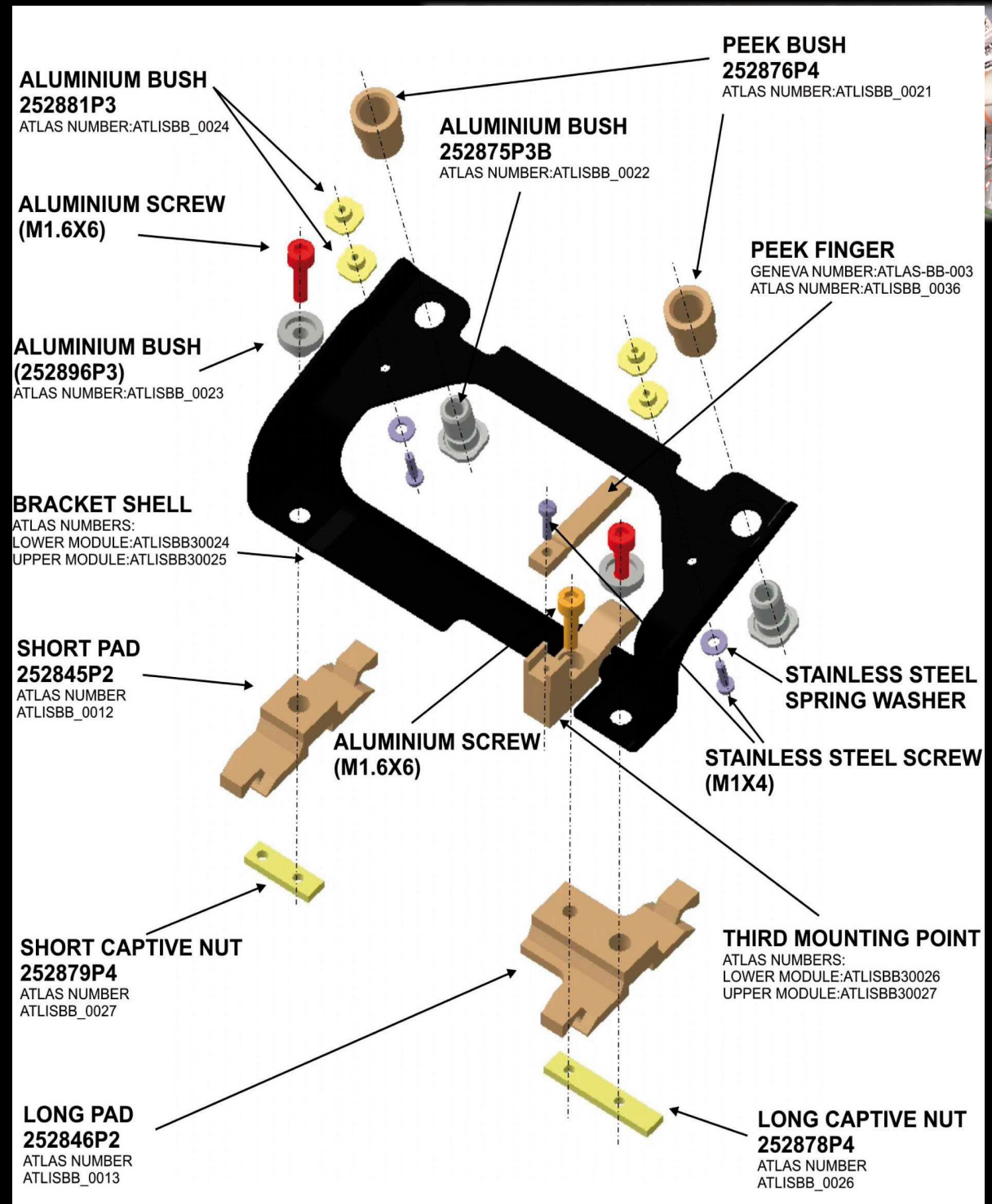


- Go to university and
 - Get a degree in Engineering or Computing
 - Or Physics + a Masters in Engineering discipline
 - Or a Physics/Eng degree then a CASE PhD
 - Try a work placement at a national lab during the degree
- Or go to a University Technical College
 - Get an Advanced Diploma in Engineering or BTEC
 - Follow up with experience in industry or apply for targeted training schemes

e.g. CERN offers a Technician Training Scheme for talented technicians

Mounting blocks

- Even the mounting blocks require specification, design, fabrication and quality assurance tests



The God Particle



The God Particle



A\$VP
Cocky

Resolved Question

[Show me another »](#)

Athiests: they found the God particle, doesn't that prove God exists!?

look at that, God is proven with your precious little science stuff, checkmate stoopid athiests!

2 months ago

[Report Abuse](#)



Nick

Best Answer - Chosen by Voters

Damnit! You got us... well, pack it up, boys...

Edited 2 months ago

[Report Abuse](#)

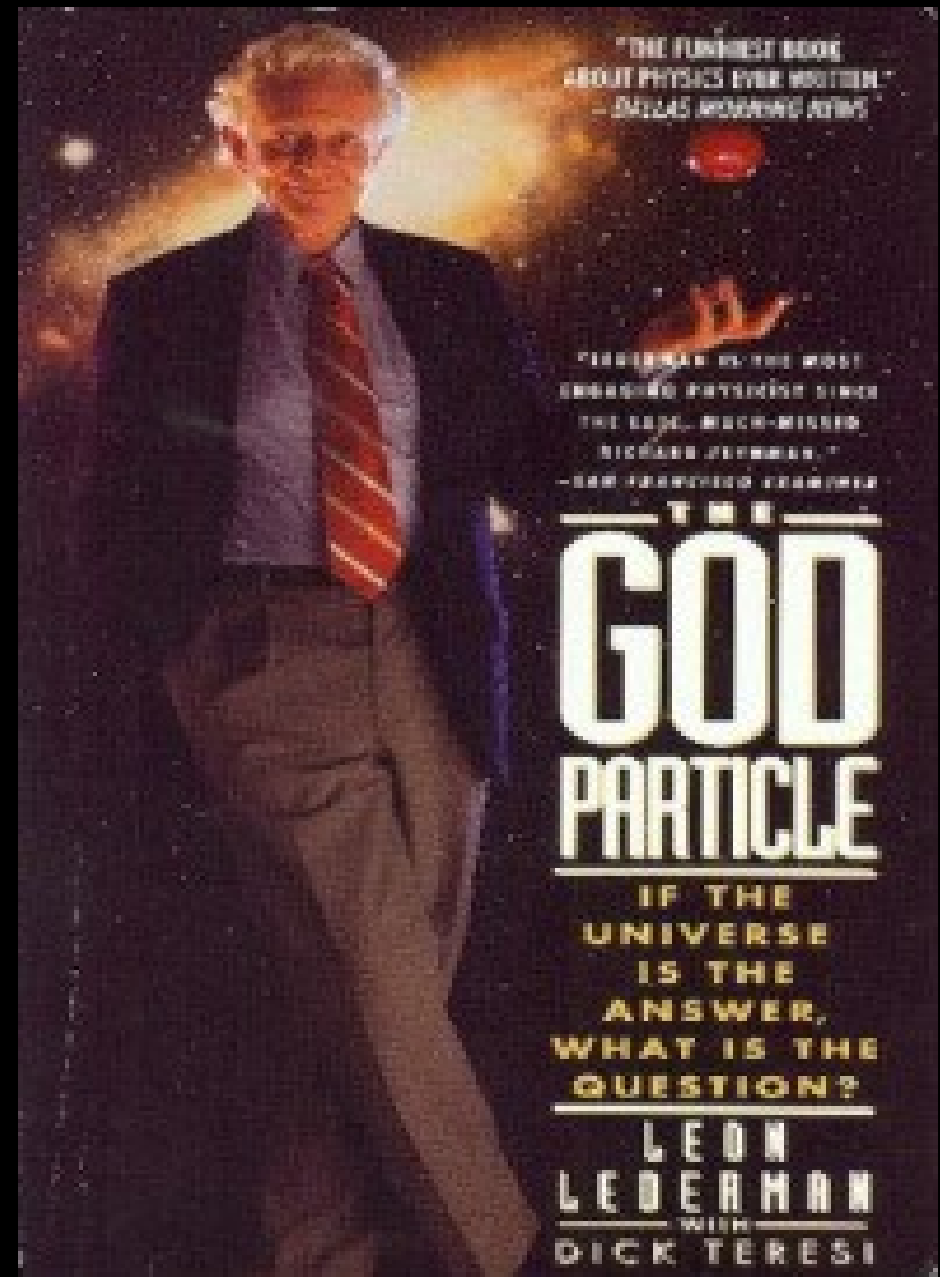
 67% 2 Votes

4  0 

The God Particle

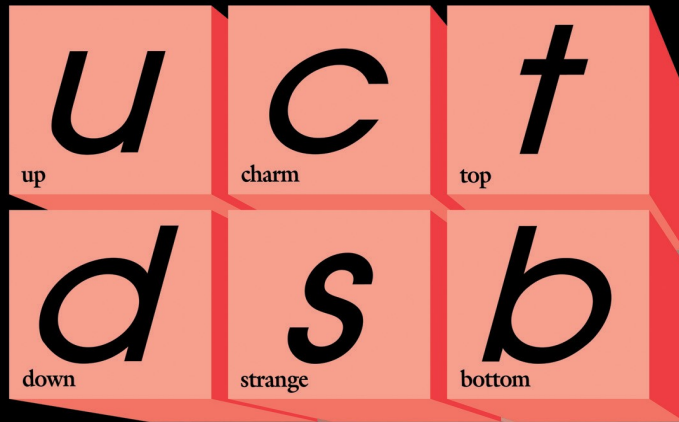
Please stop

- The Higgs particle has nothing to do with theology
- Unfortunately it's a good sound bite and keeps getting used

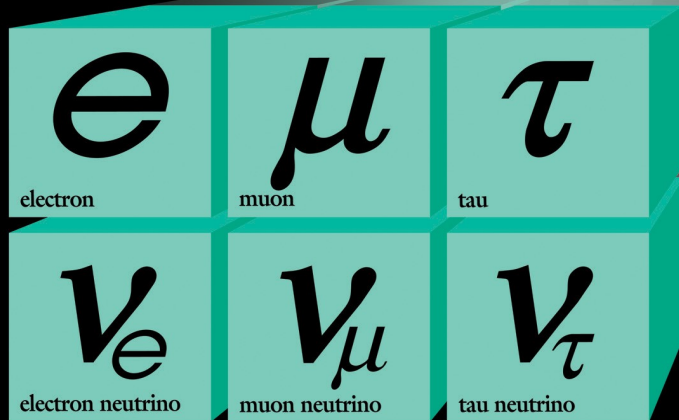
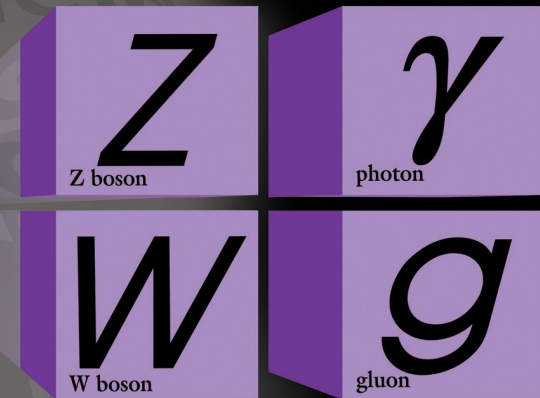


The Particle Zoo

Quarks



Forces



Leptons