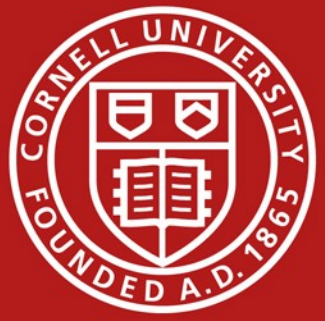
Probe The Unknown Indirectly

-- From Rutherford experiment to beyond



Cornell University

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March 13, 2009

Laboratory for Elementary Particle Physics

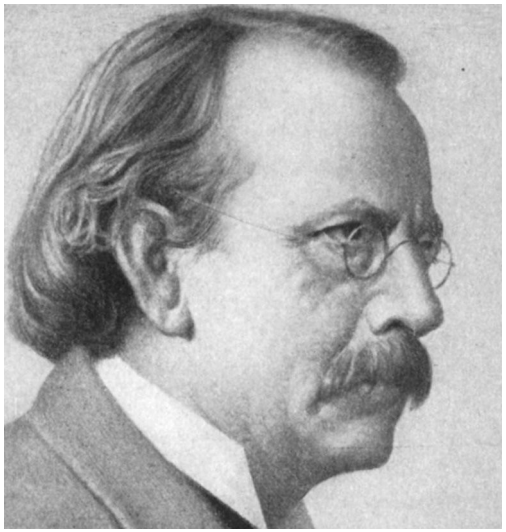
Indirect Measurement

- In everyday life, we learn about things by holding them and looking at them with our eyes
- What if they are too small?

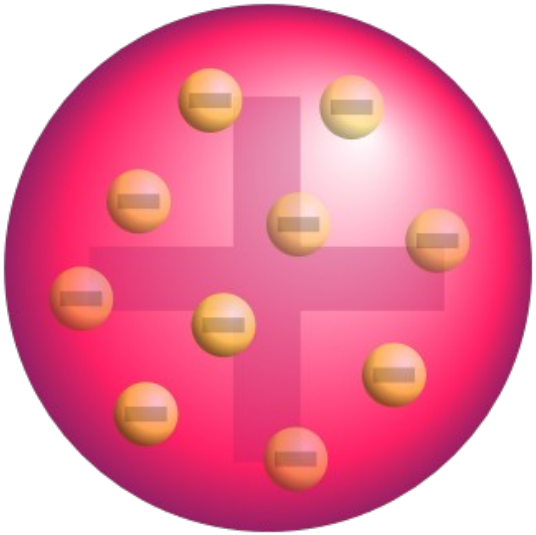
- We need ***indirect*** measurements
- Some tools are familiar such as microscopes, others are not.

- All of them let you draw conclusions about the object that you are measuring

Plum pudding model



- In 1897, J J Thomson discovered the negatively charged particle called electron



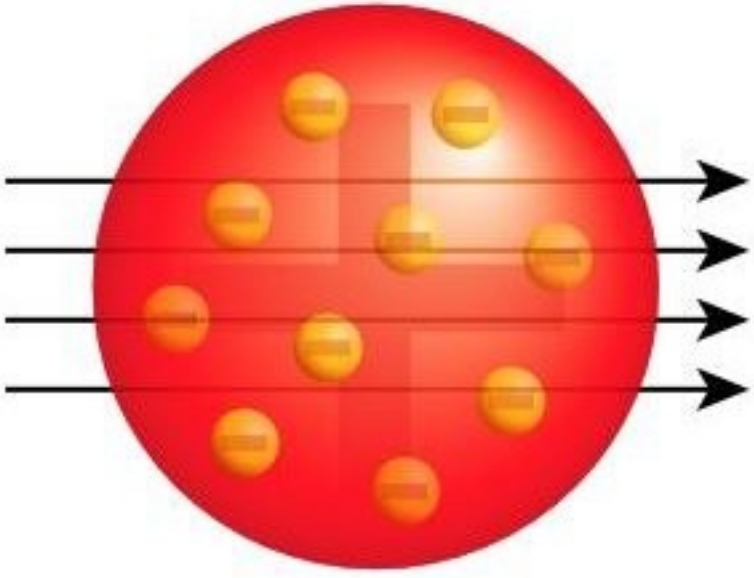
- Constituent of the (neutral) atom
- Theory: blob of positive charge where electrons are embedded

- But: how do you test it?
  - Can't use a ruler: too small -> *Indirect* measurement

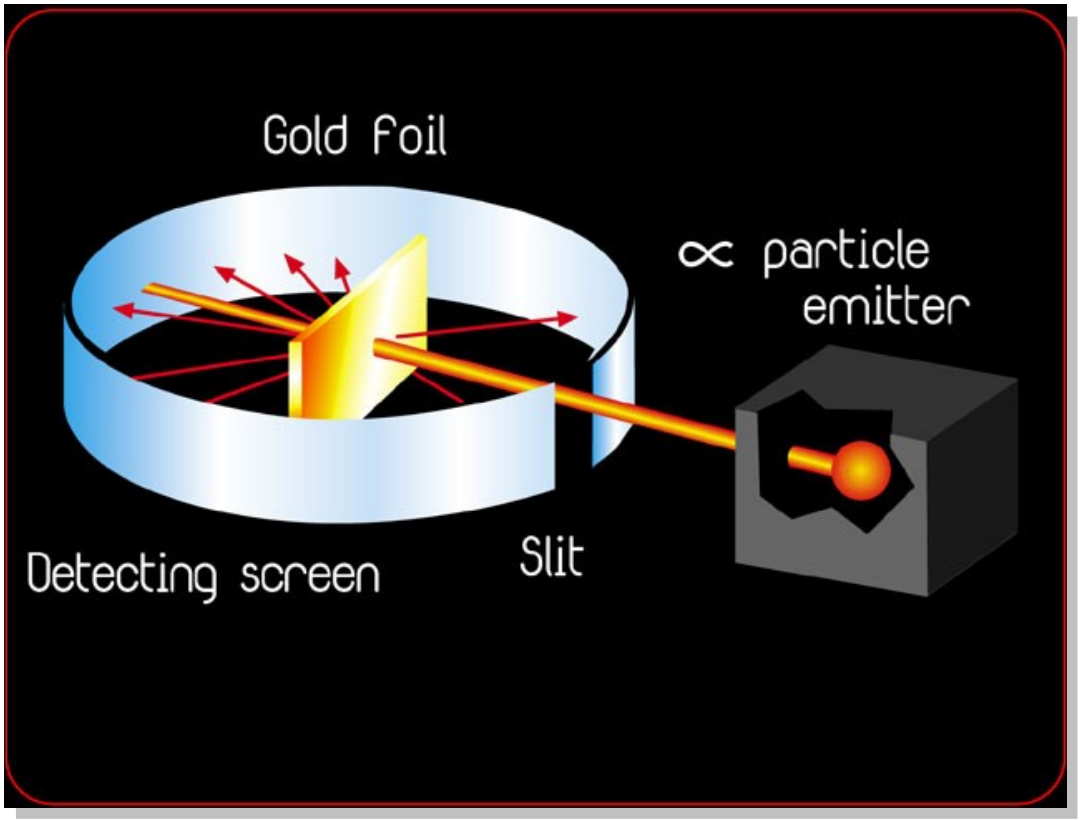
Test Thomson's model

- Ernest Rutherford
  - Hans Geiger
  - Ernest Marsden

- Test plum pudding model
- Find the nature of the atom

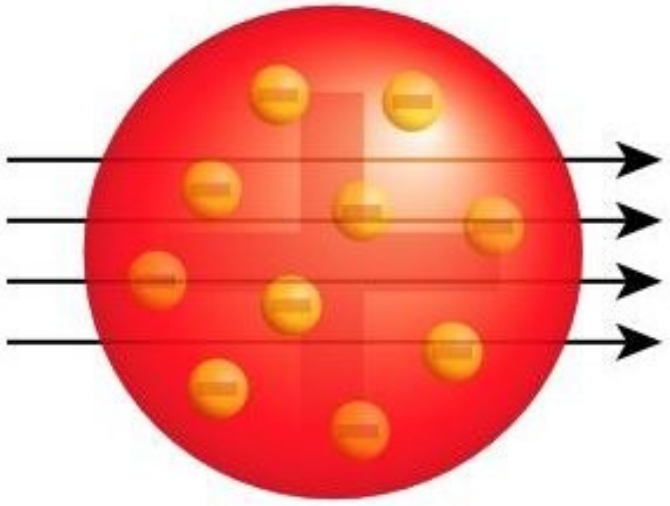


Rutherford experiment - Setup



- shoot “bullets” (positivly charged alpha particle) at target
- see how bullets deflect

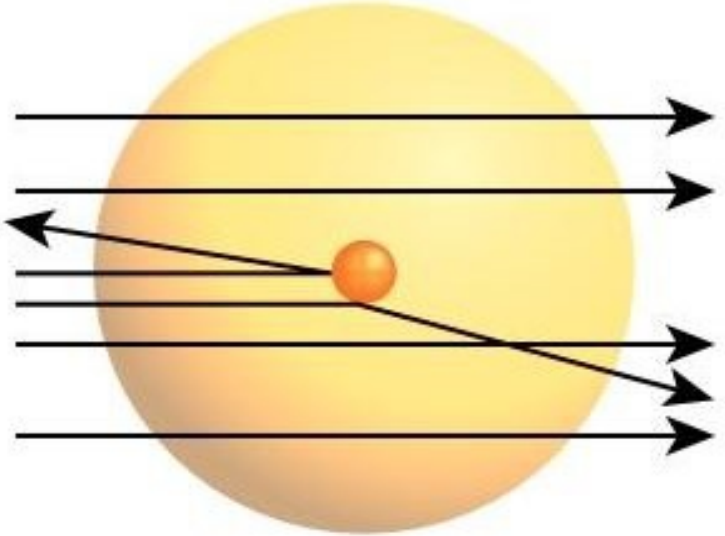
- Expectation: most of them will go right through the foil
- May just deflected a little bit

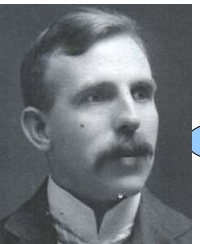


Experiment Results

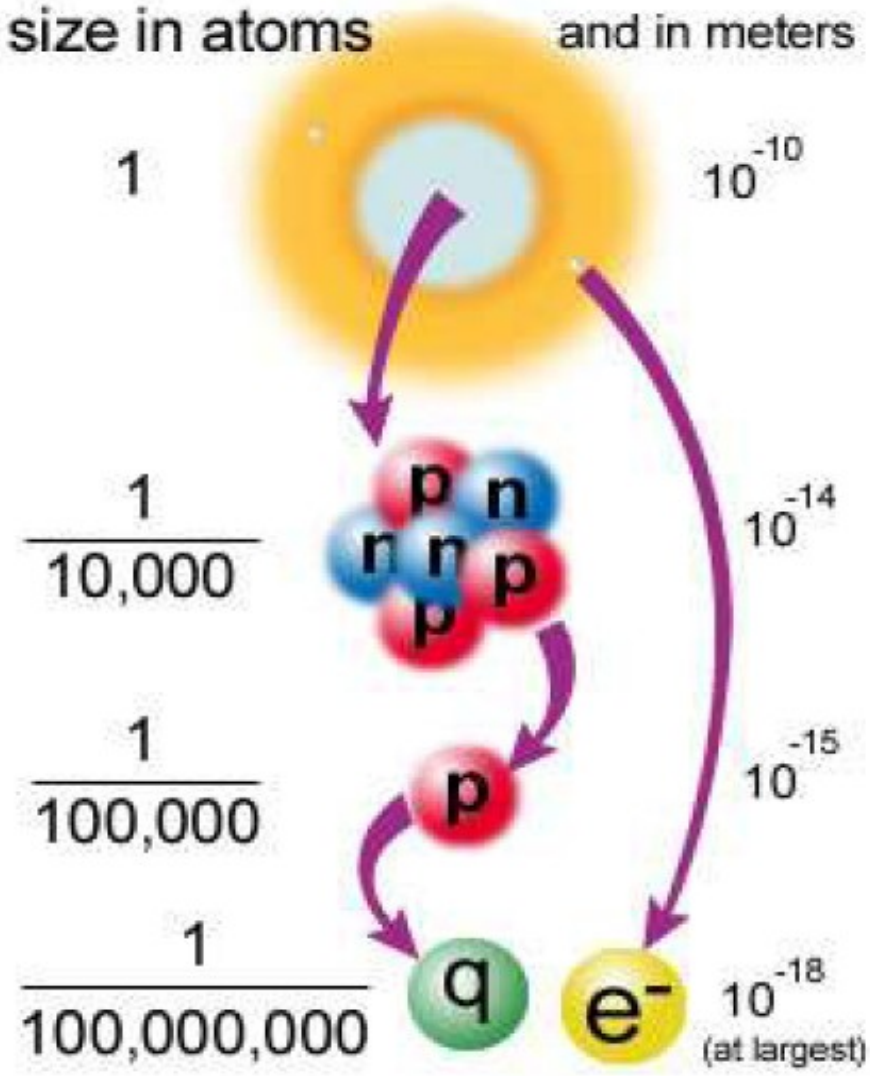
- Most of the data was just as expected: alpha “bullets” went straight through
- Some, however, were deflected right back!

It was almost as incredible as if
you fired a 15-inch shell
at a piece of tissue paper
and it came back and hit you.





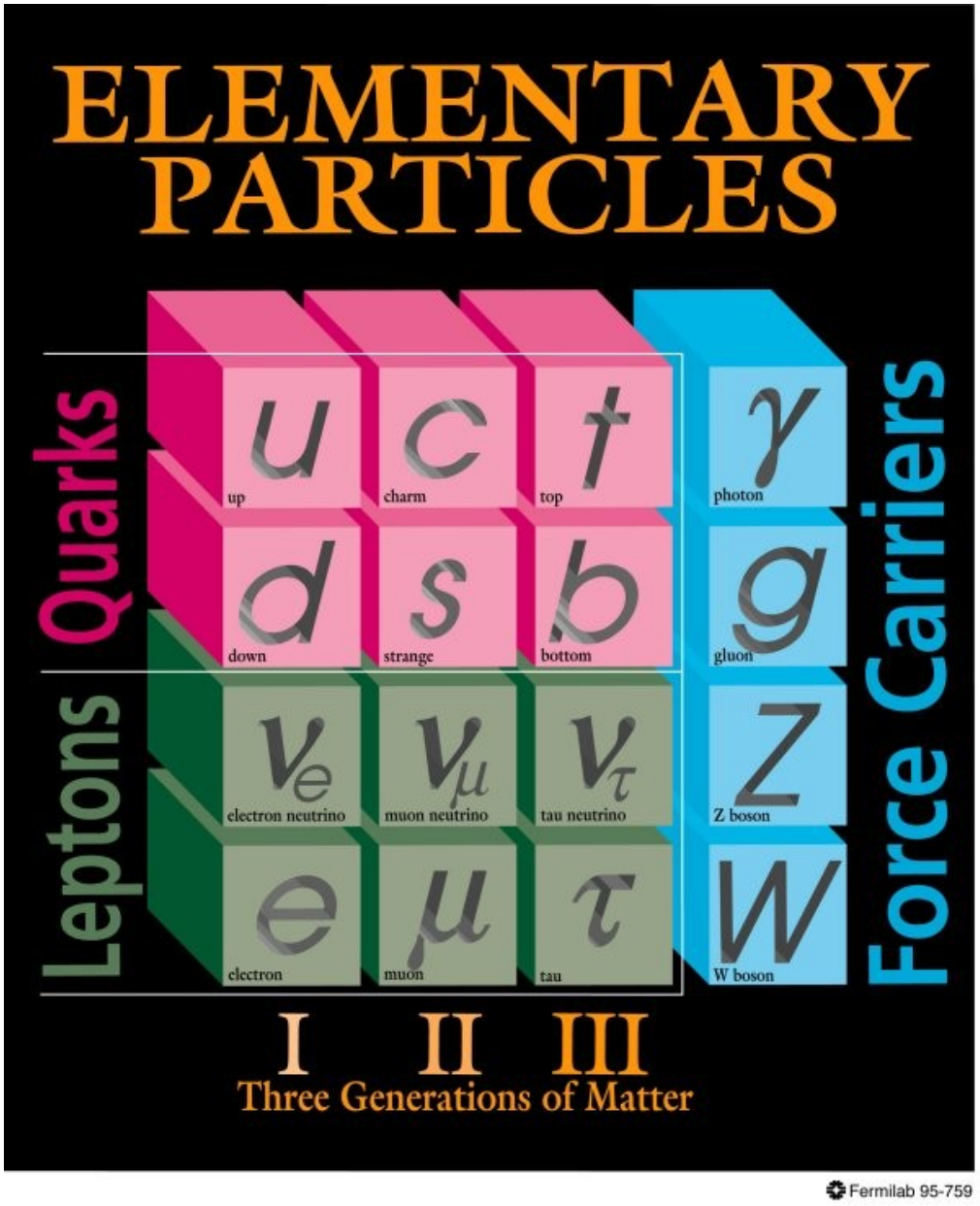
Beyond Rutherford ...



- Atoms
- Nucleus
- Protons and Neutrons
- Quarks
- .... ?

- What is the world made of ?
- What holds it together ?

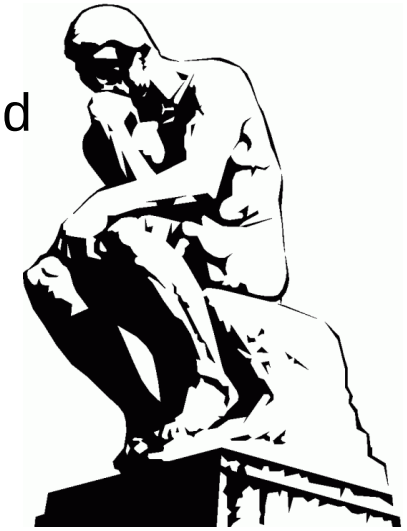
The Standard Model



A theory of :

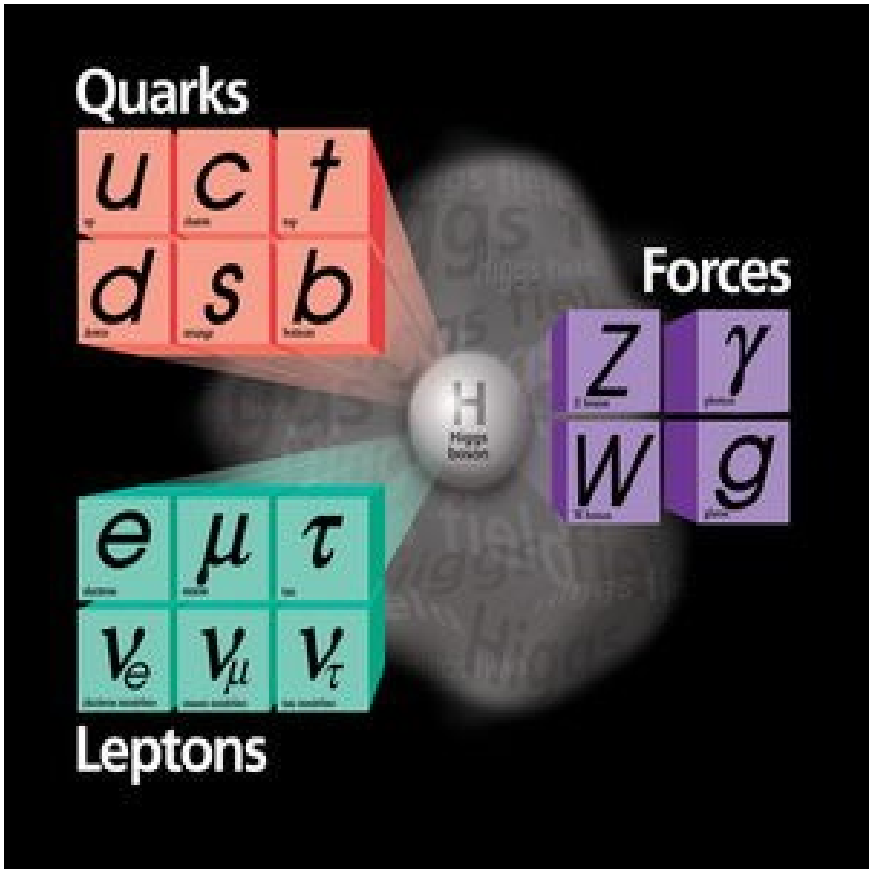
- elementary particles
- fundamental interactions

- What is the world made of ?
- What holds it together ?



Still puzzles left ...

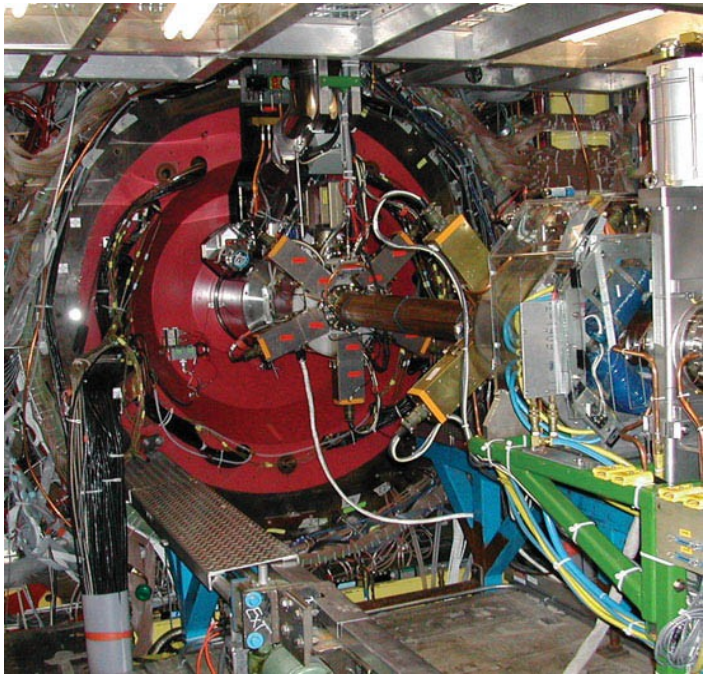
- Why are there three generations of particles?
- Does the Higgs boson really exist?
- High Precision Frontier
- High Energy Frontier



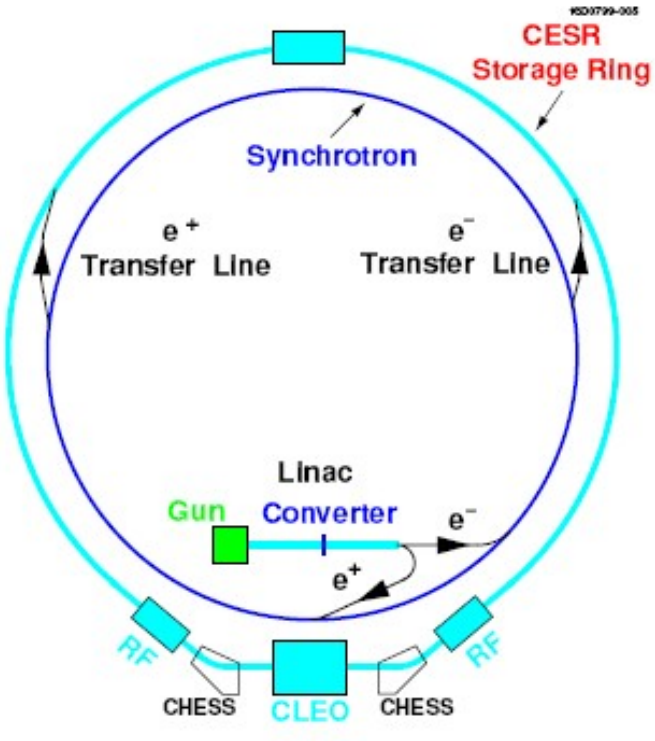
A Precision Frontier Experiment

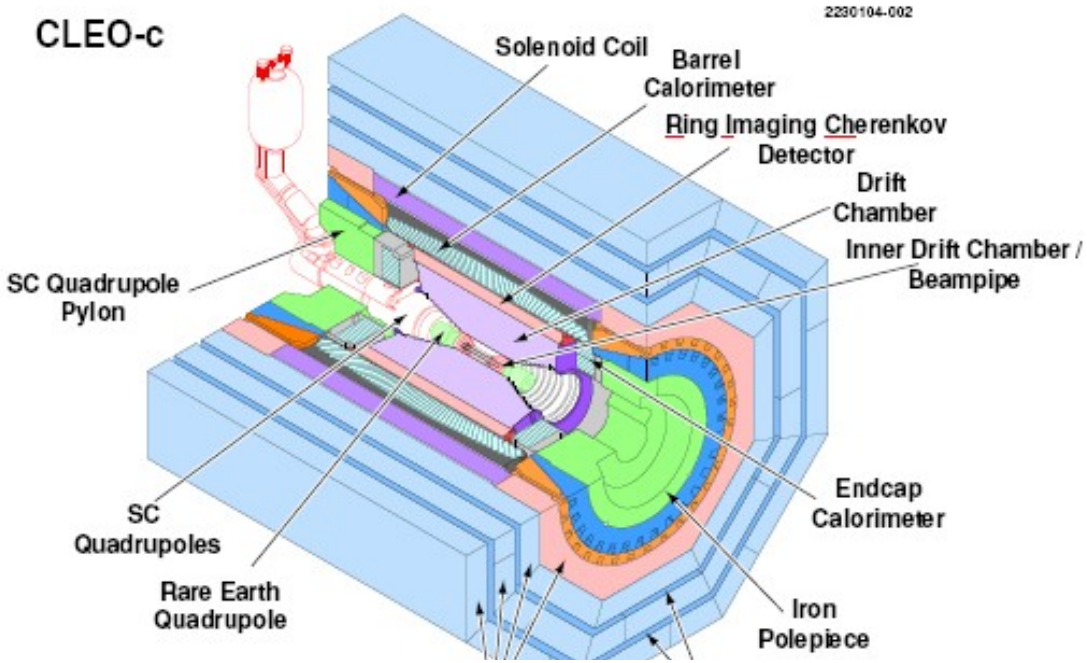
Cornell Electron Storage Ring (CESR)

The modern "Rutherford experiment" - CLEO

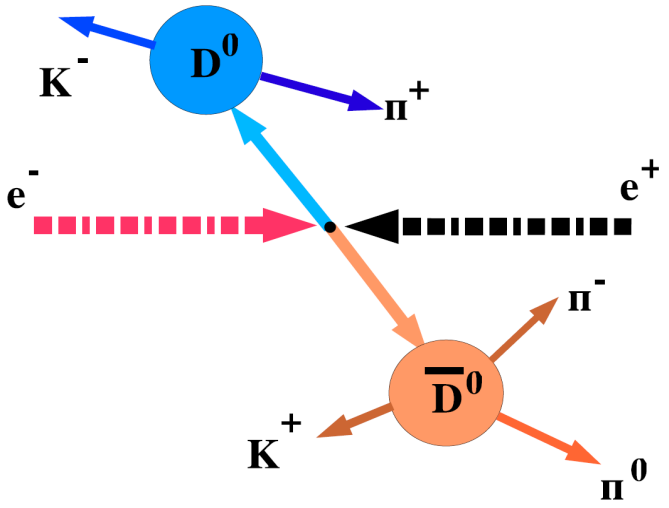


CESR and CLEO





Collide electron and positron to study b-quark and c-quark

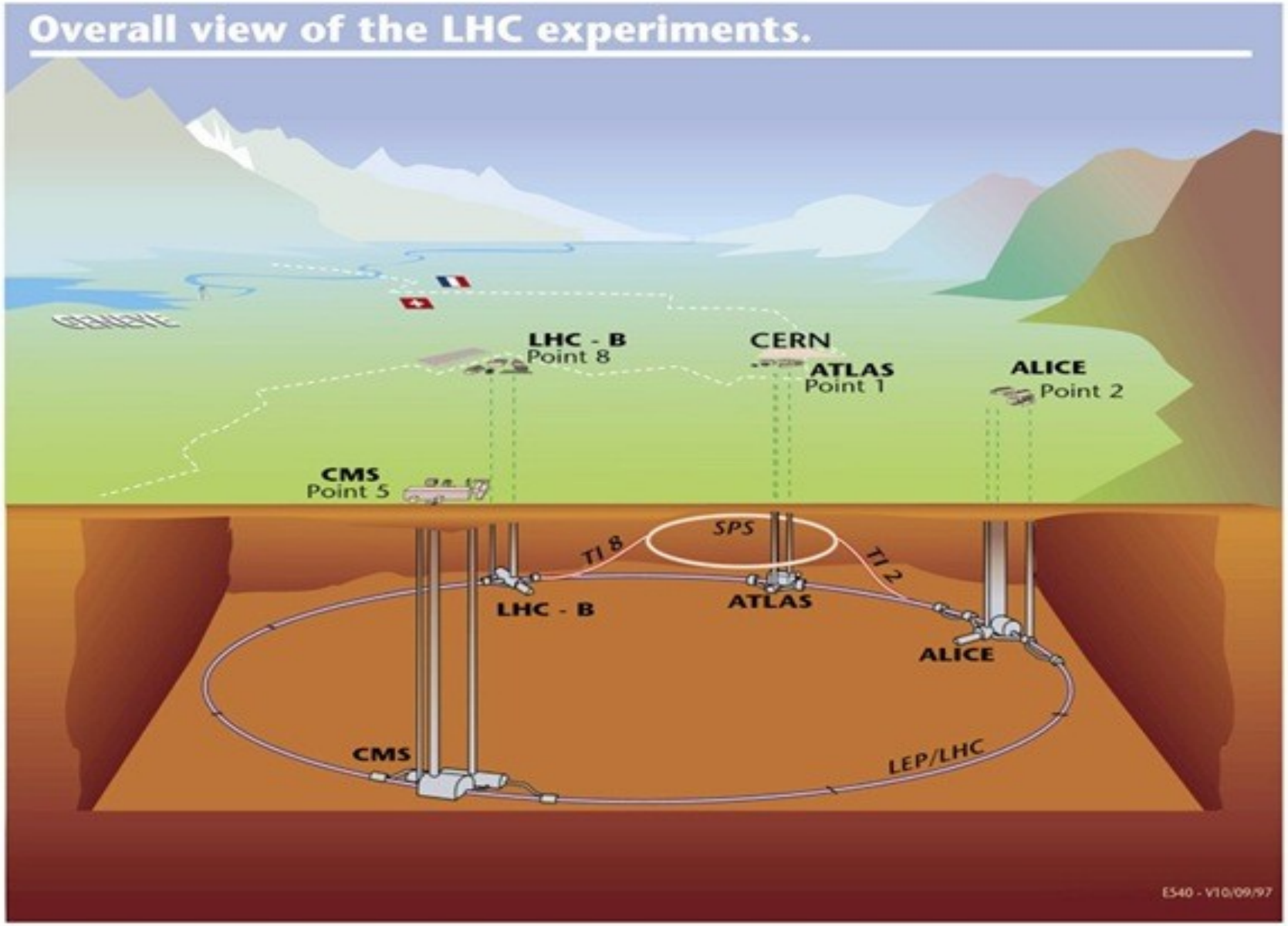


High Energy Frontier - LHC

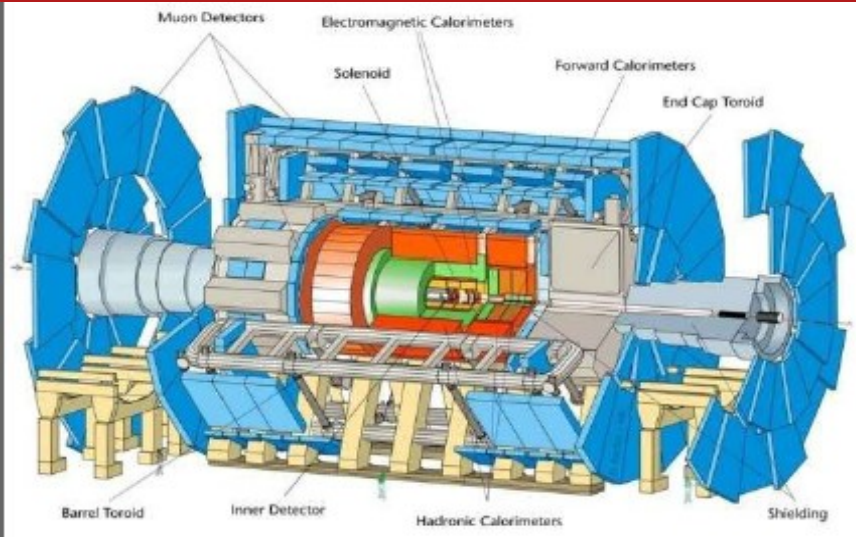
The Large Hadron Collider:

- Cross the boder of France and Switzerland
- Circumference: 27 km (17 miles)
- The internal pressure: 10^-13 atm

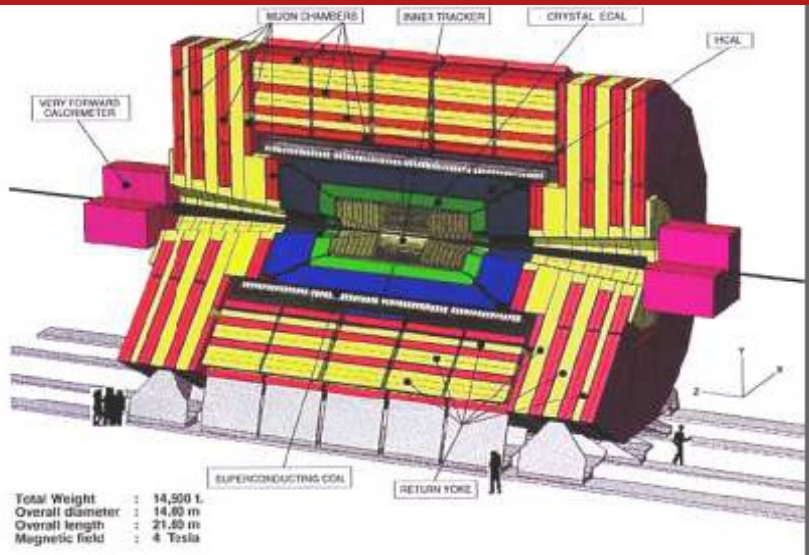
Below 100 meters …



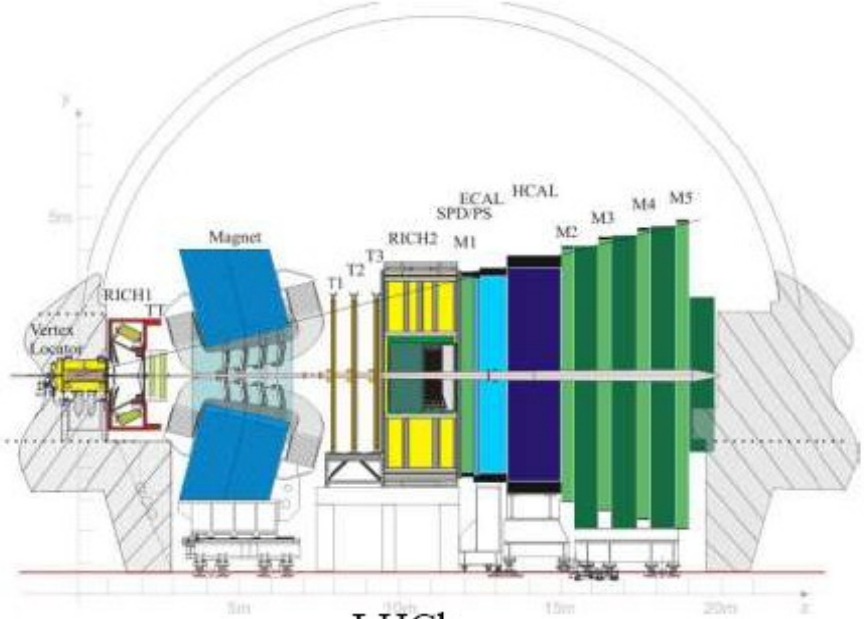
The Four Experiments on LHC



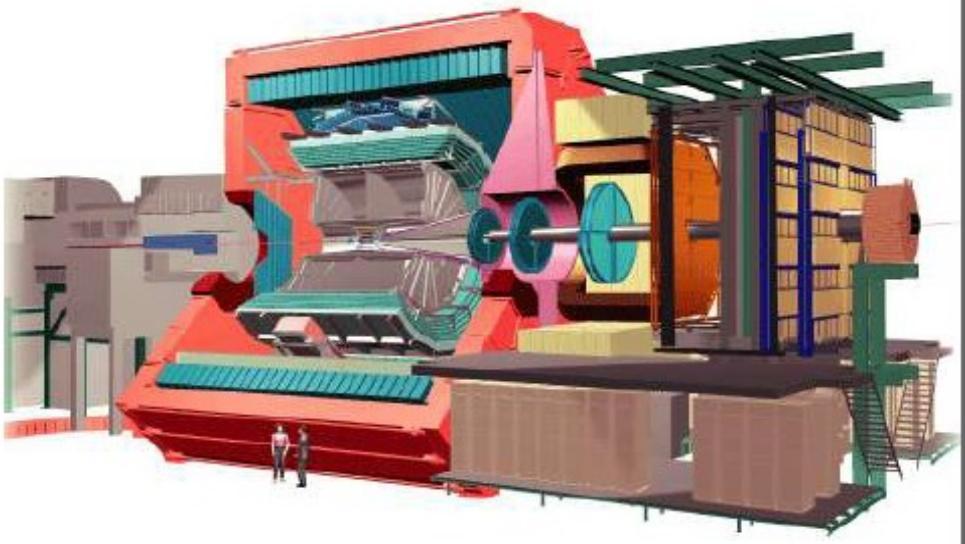
ATLAS – A Toroidal LHC Apparatus



CMS – Compact Muon Solenoid



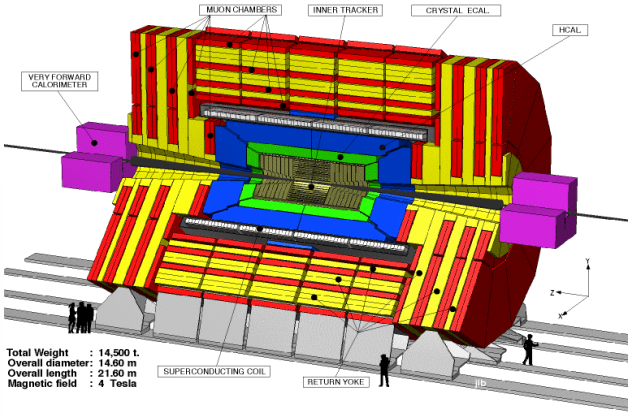
LHCb

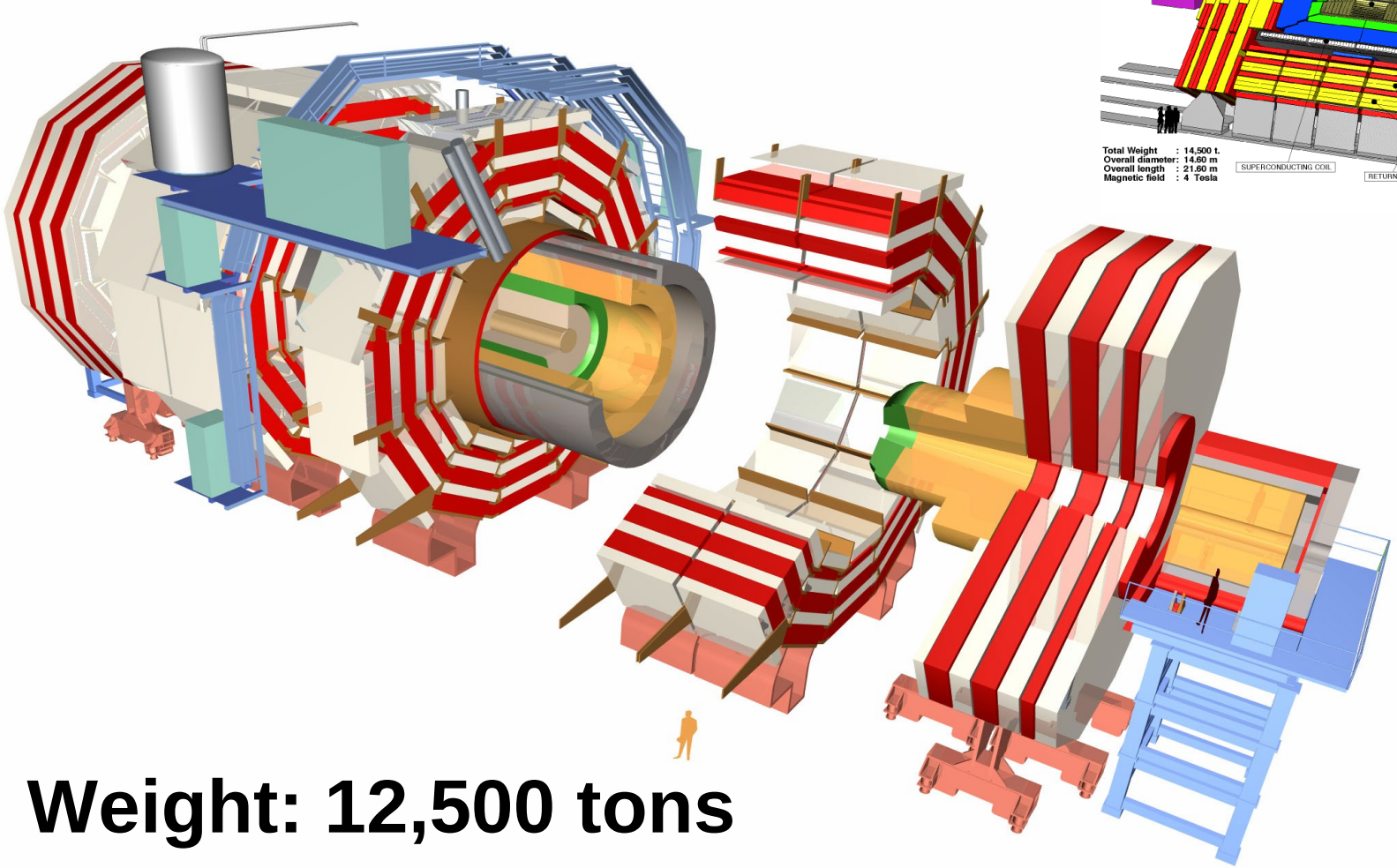


ALICE – A Large Ion Collider Experiment

The Compact Muon Solenoid (CMS)

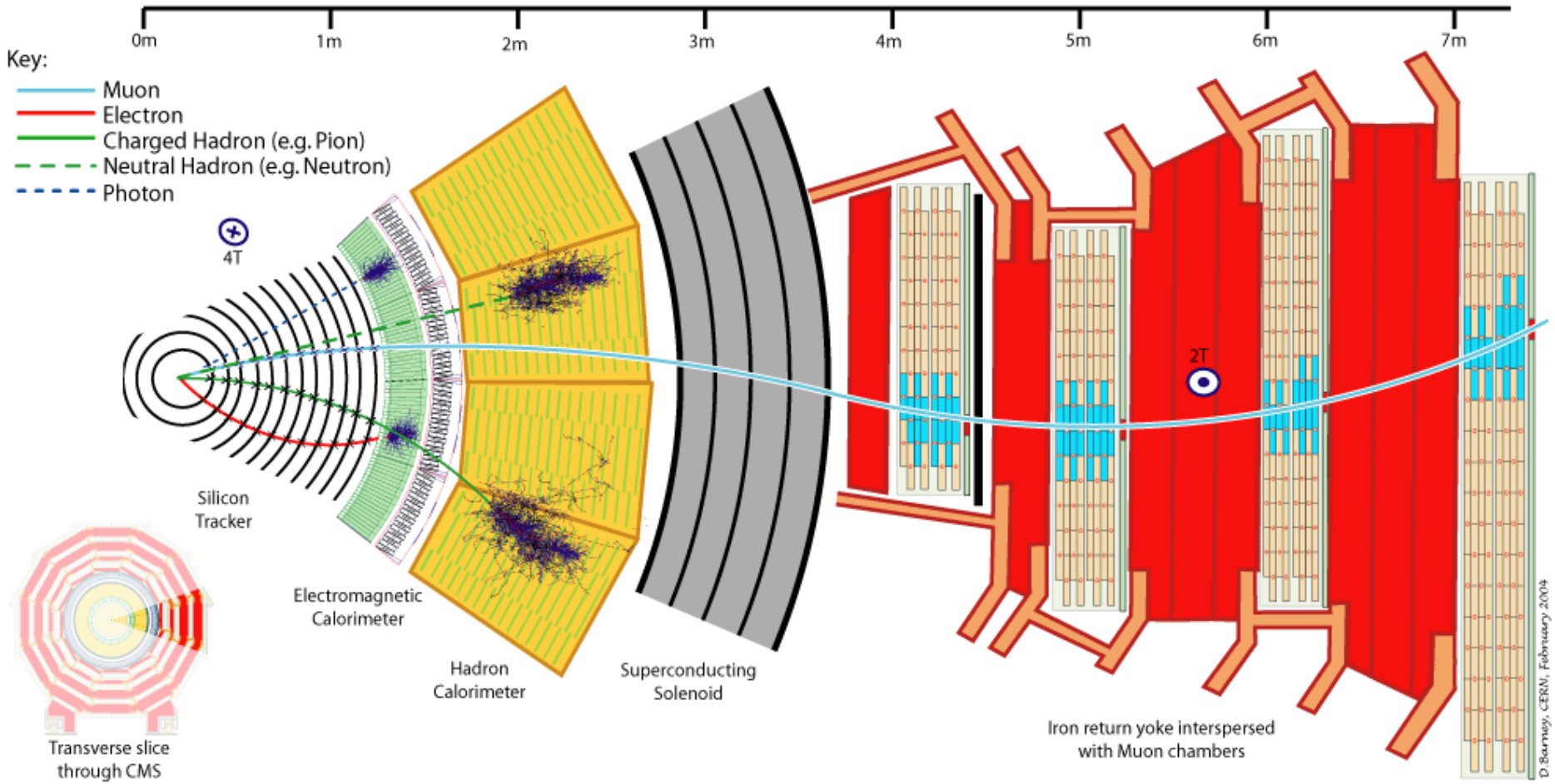
Size: 21m (L) 15m (W) 15m (H)





Weight: 12,500 tons

Tracks and Showers on CMS



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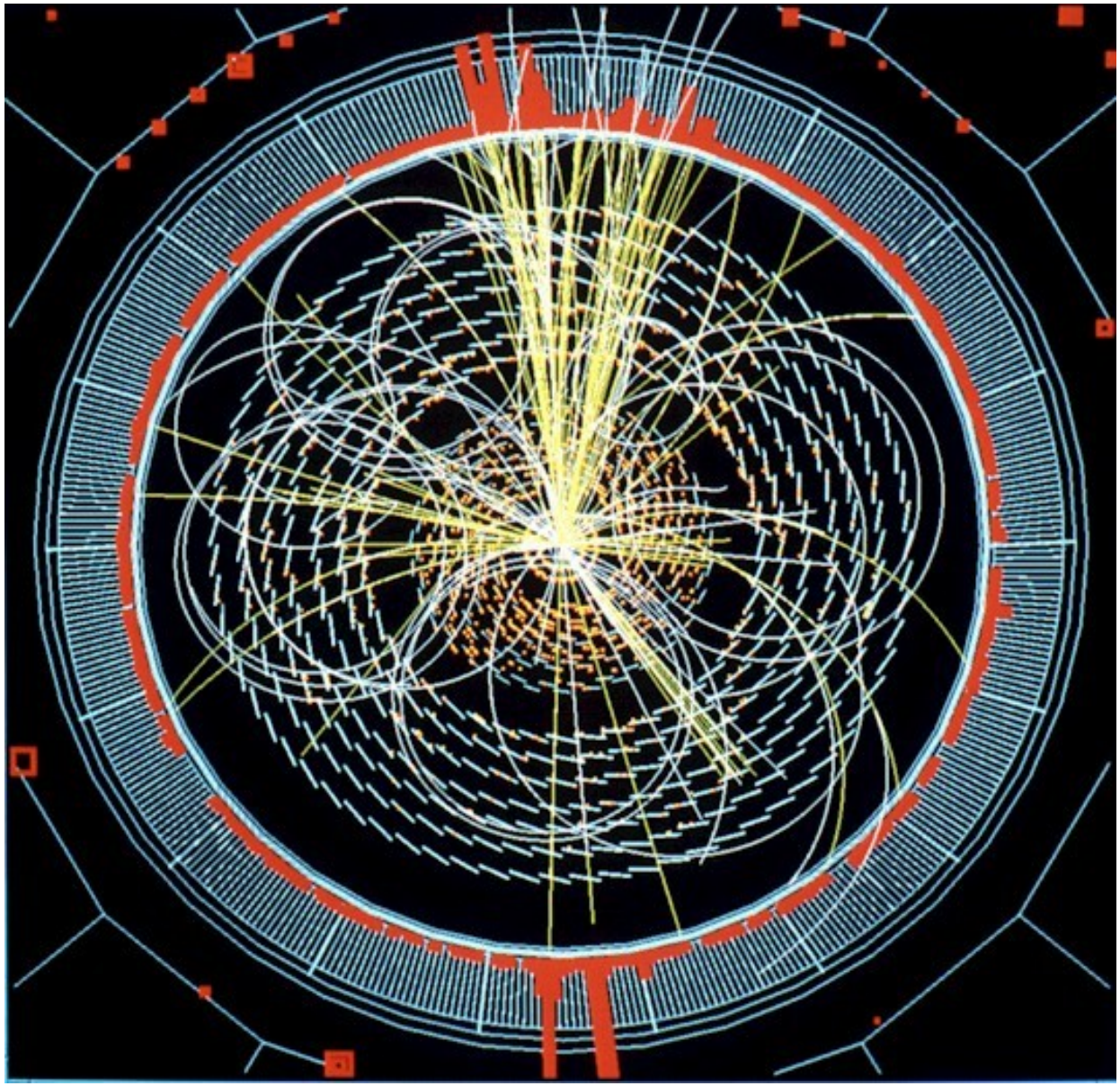
A Higgs Particle Simulation in CMS



Summary

- Rutherford experiment tell us another way of observing our world – indirect measurement
- The same method is used in the modern particle physics experiment – both for higher precision and higher energy frontier
- It's an exciting time for particle physics and let's share this with our students!

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Acknowledgement

- Prof. Jim Alexander
- Prof. Anders Ryd
- Prof. Peter Wittich
- Souvik Das
- Lora Hine
- CLEO and CMS collaborators