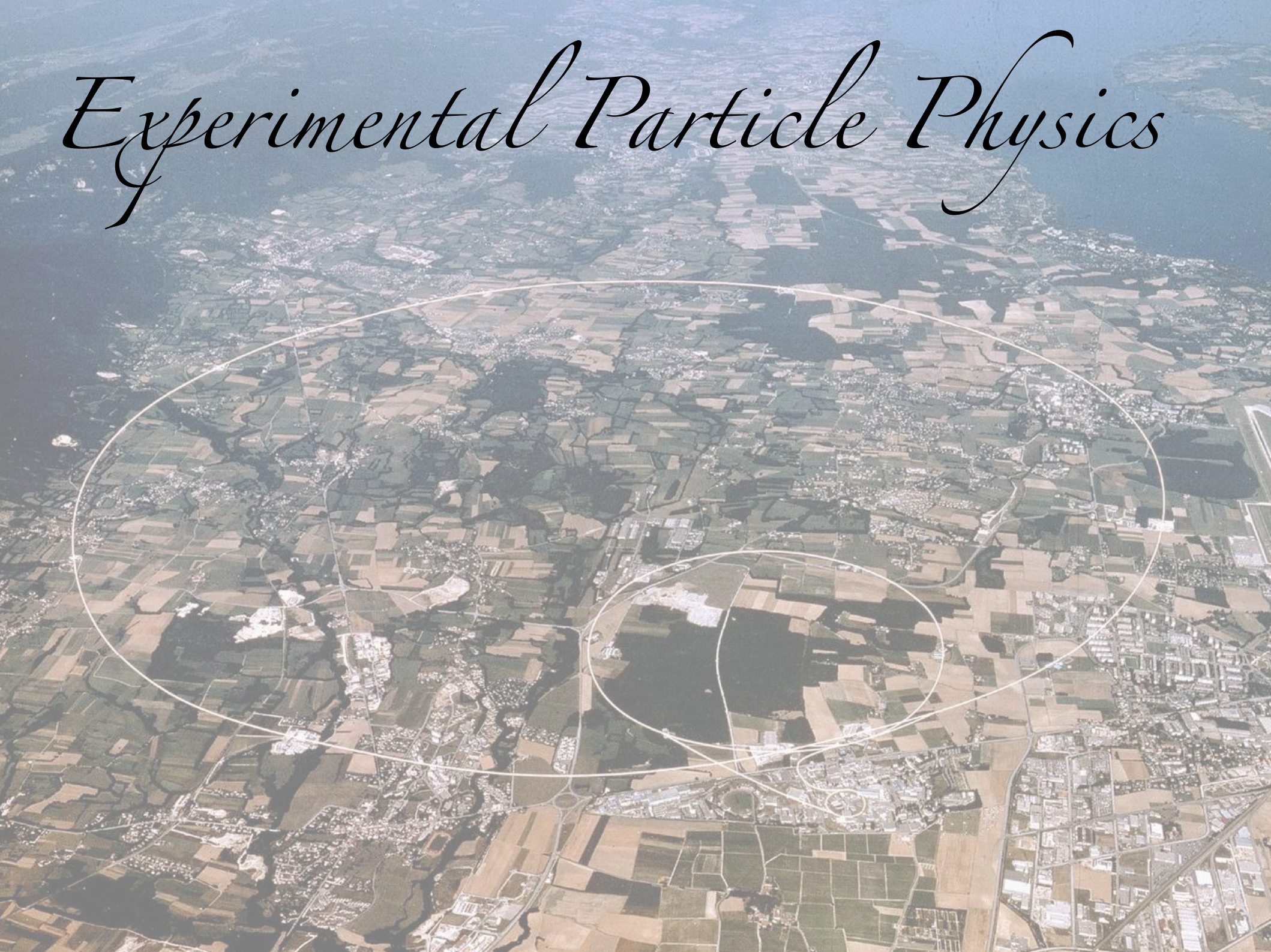


Experimental Particle Physics



Outline

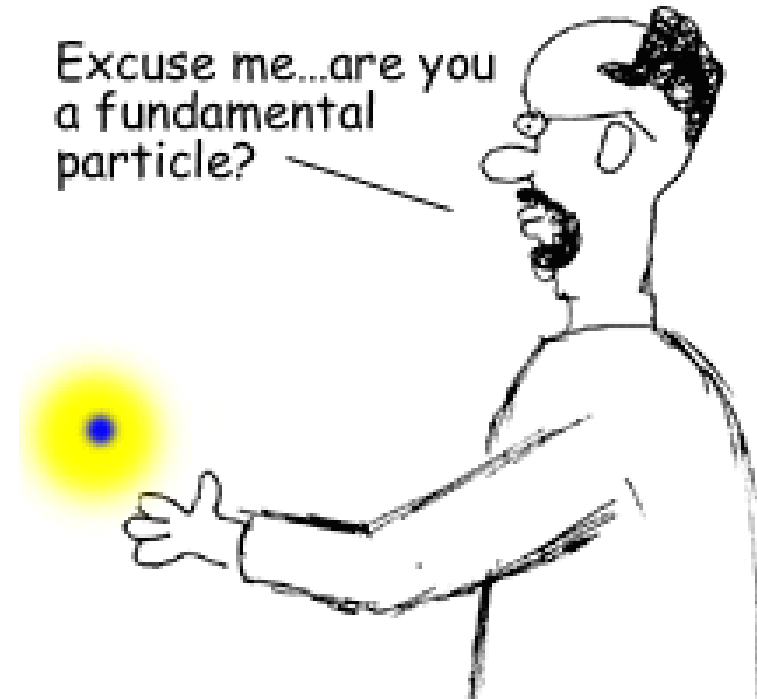
- How small is small?
- What are we trying to learn?
- How we study particles?
- What does Brigitte do all day?

Élémentaire! Mon cher Watson.

Particle physicists seek to understand what are the fundamental building blocs of Nature and how they interact to make up our Universe.

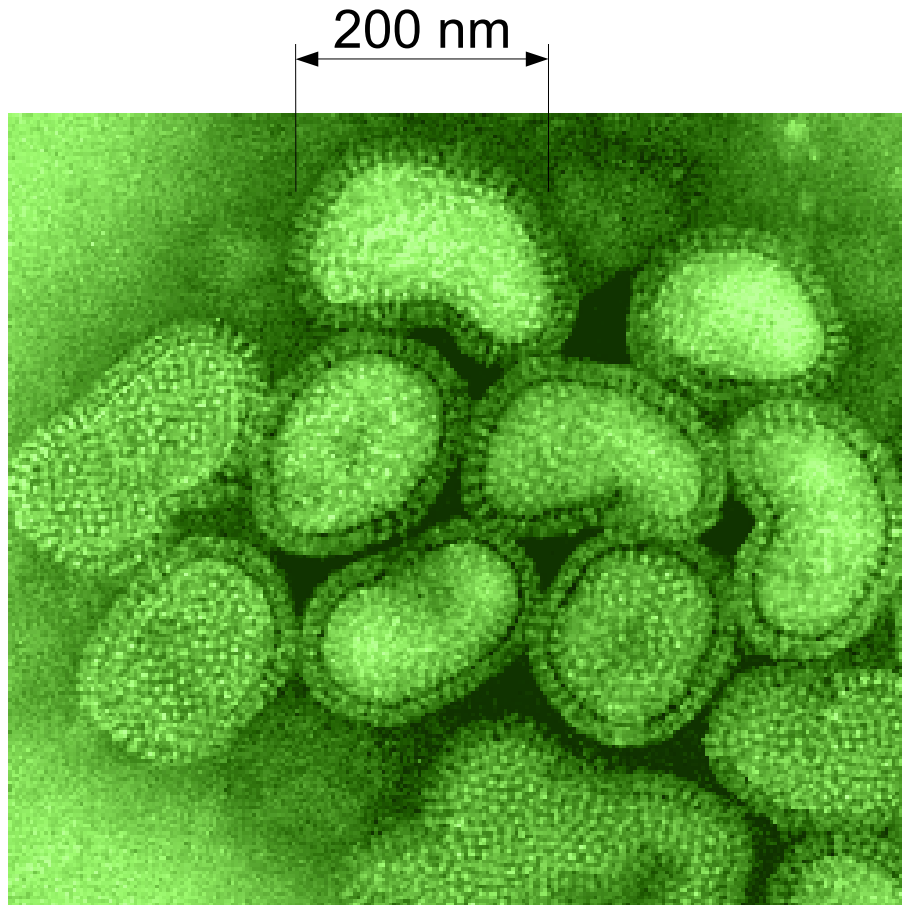


Excuse me...are you
a fundamental
particle?



How small is small?

10^{-7} m virus

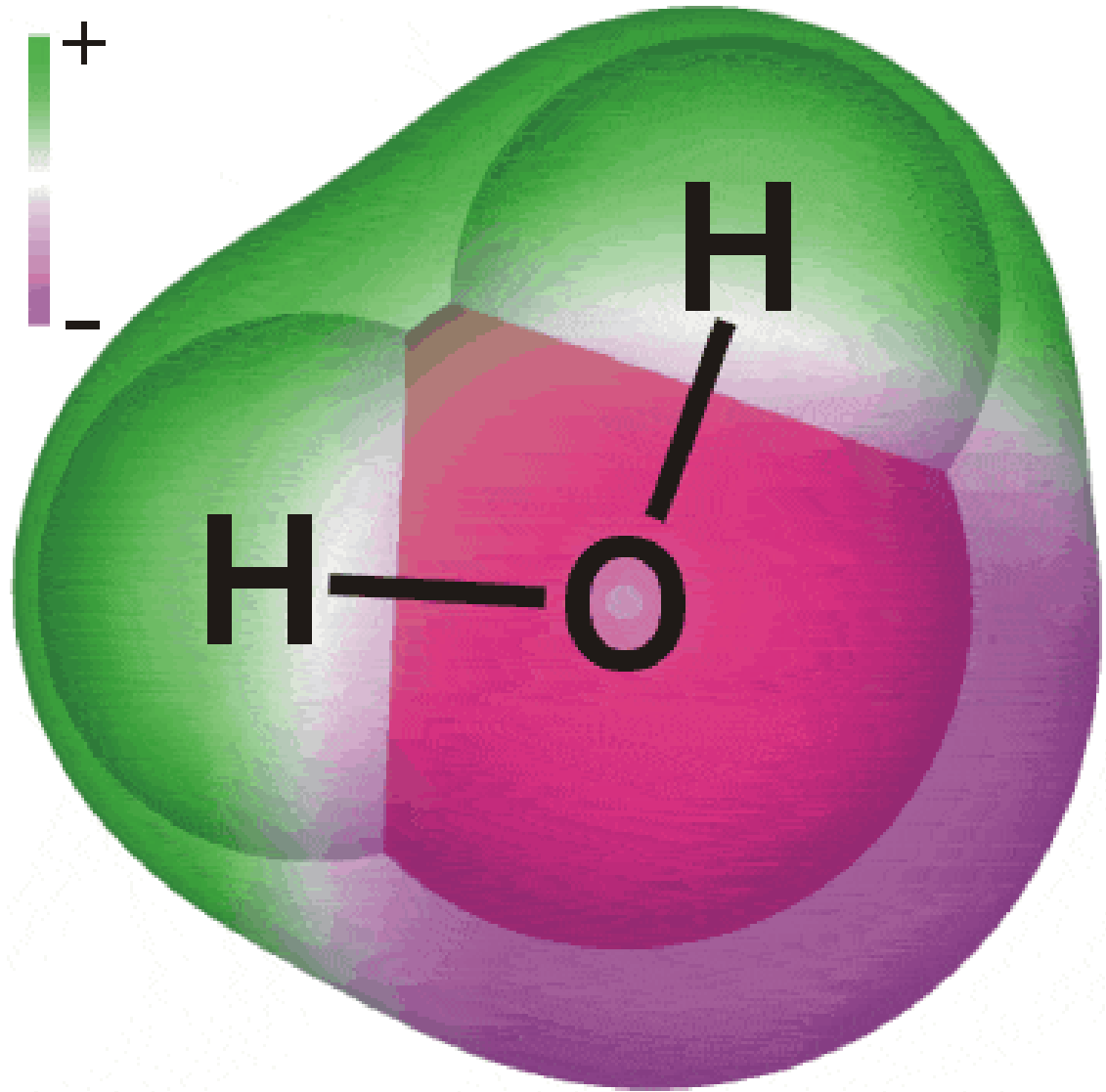


virus de l'influenza

How small is small?

10^{-7} m virus

10^{-9} m molecule



How small is small?

10^{-7} m

virus

10^{-9} m

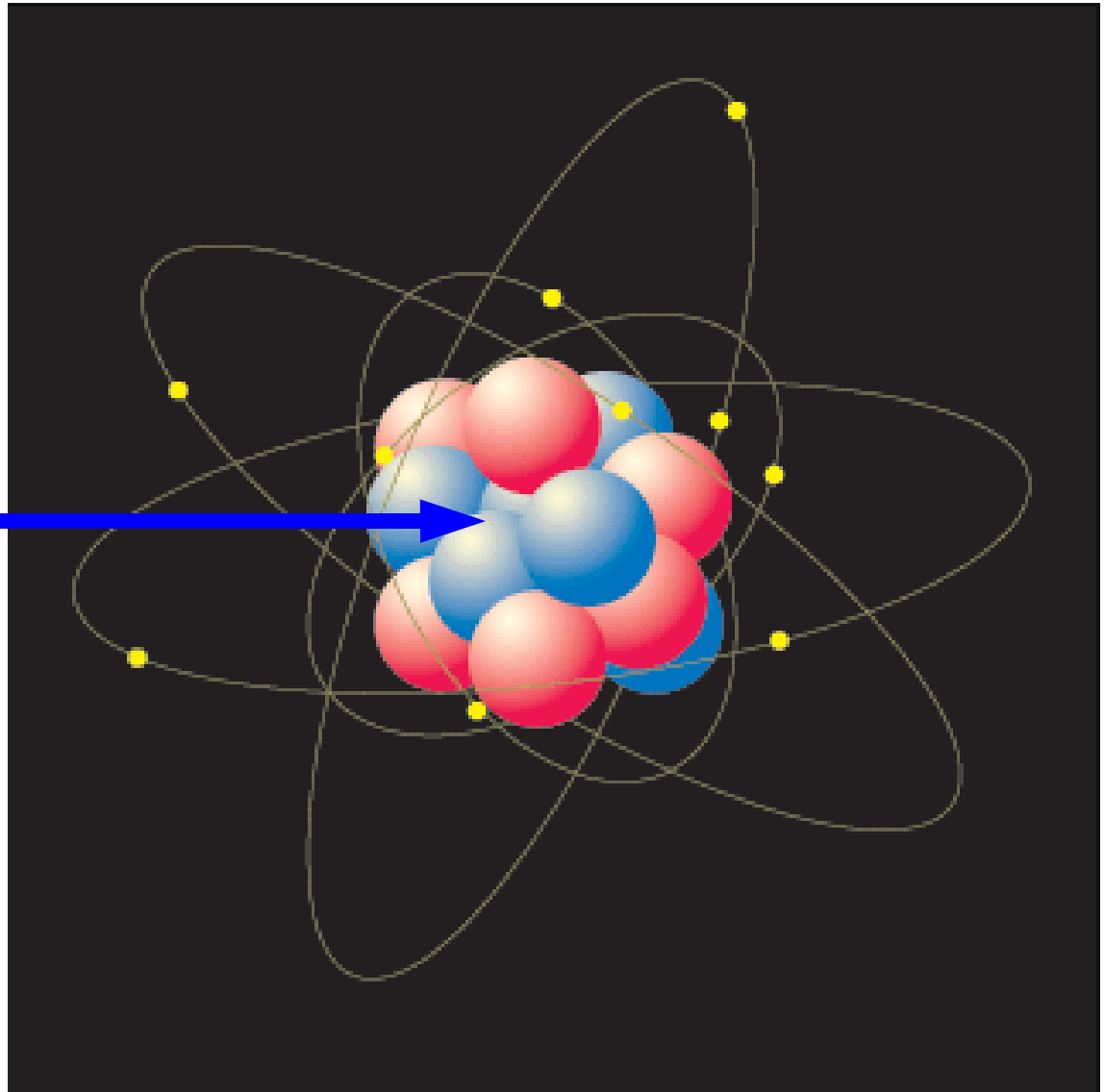
molecule

10^{-10} m

atom

10^{-14} m

nucleus



How small is small?

10^{-7} m virus

10^{-9} m molecule

10^{-10} m atom

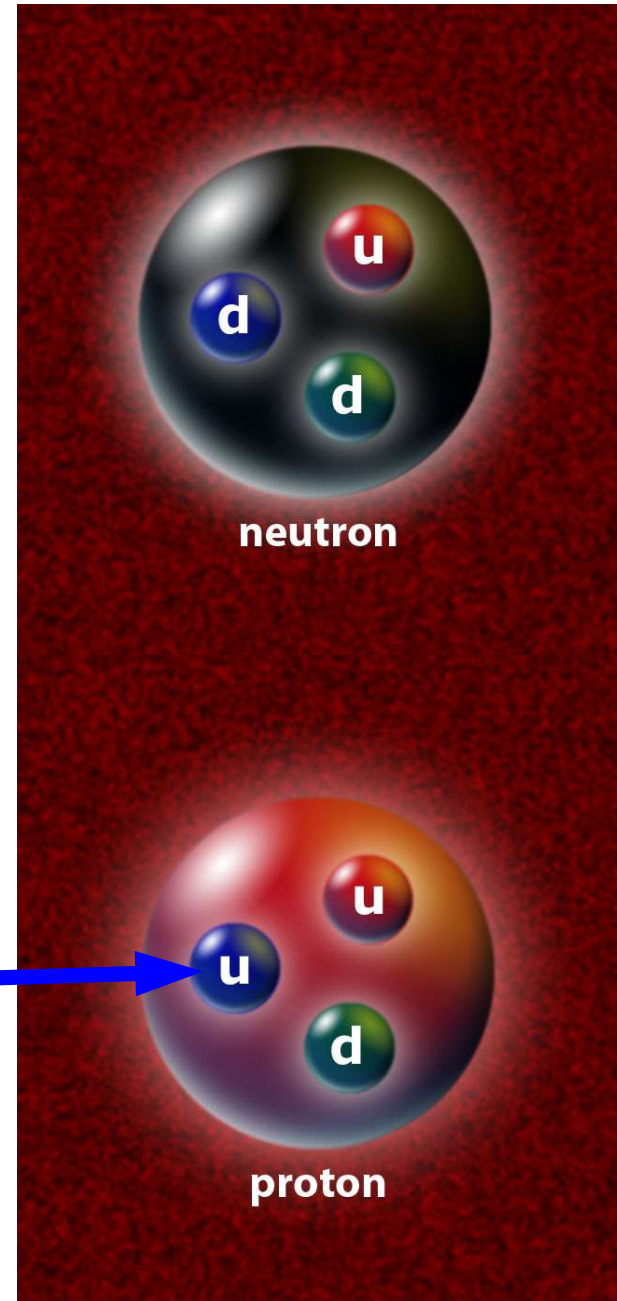
10^{-14} m nucleus

10^{-15} m proton/neutron

$<10^{-18}$ m

quarks

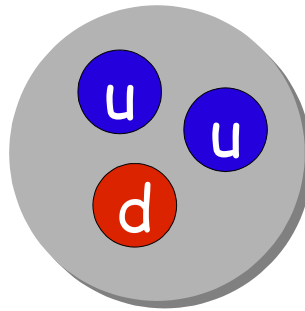
?



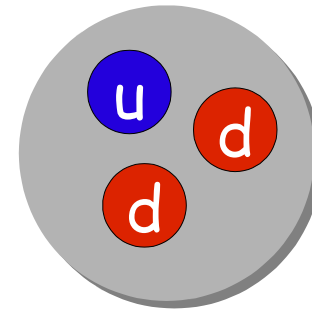
What is matter made of?



electron



proton

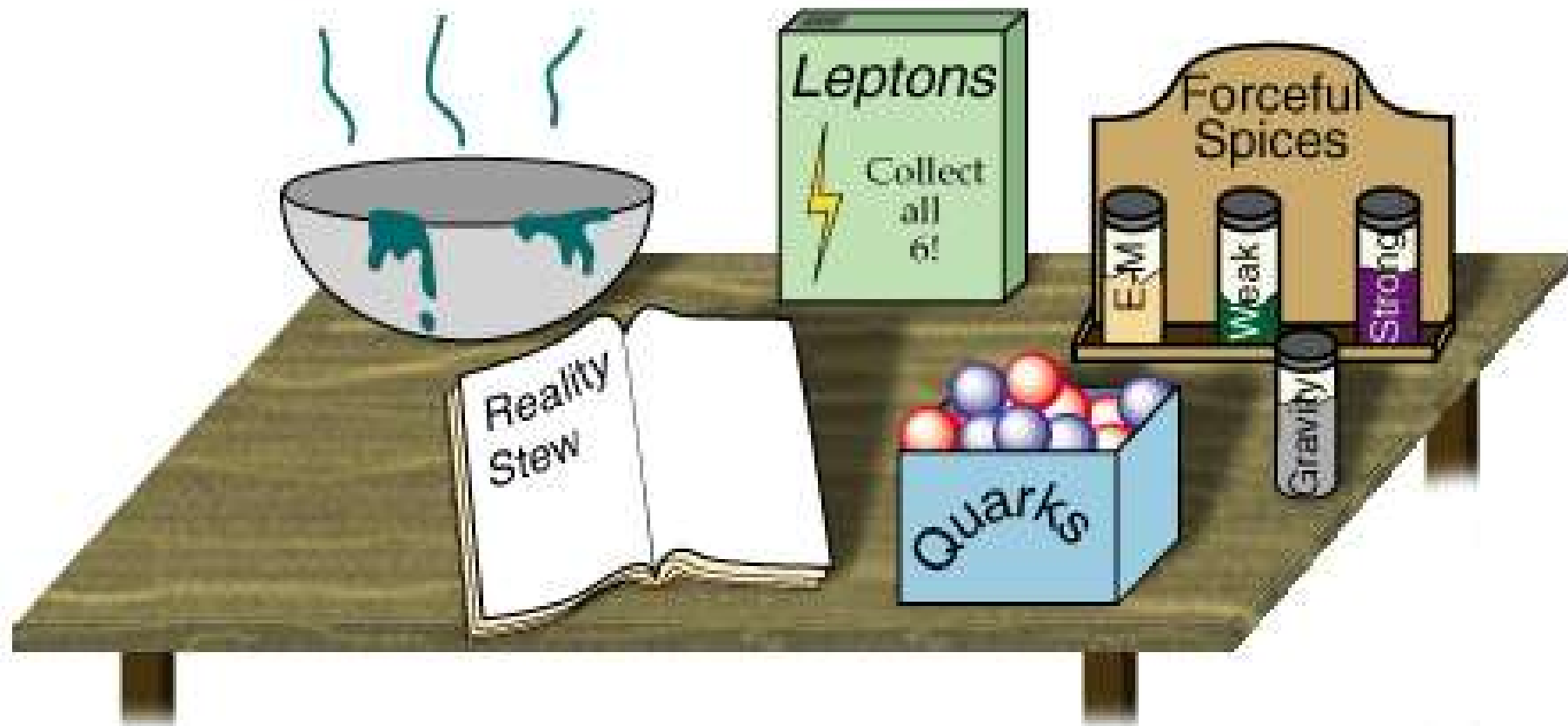


neutron

The ingredients of the Univers

Matter particles (6 quarks, 6 leptons)

Force carrier particles (4)



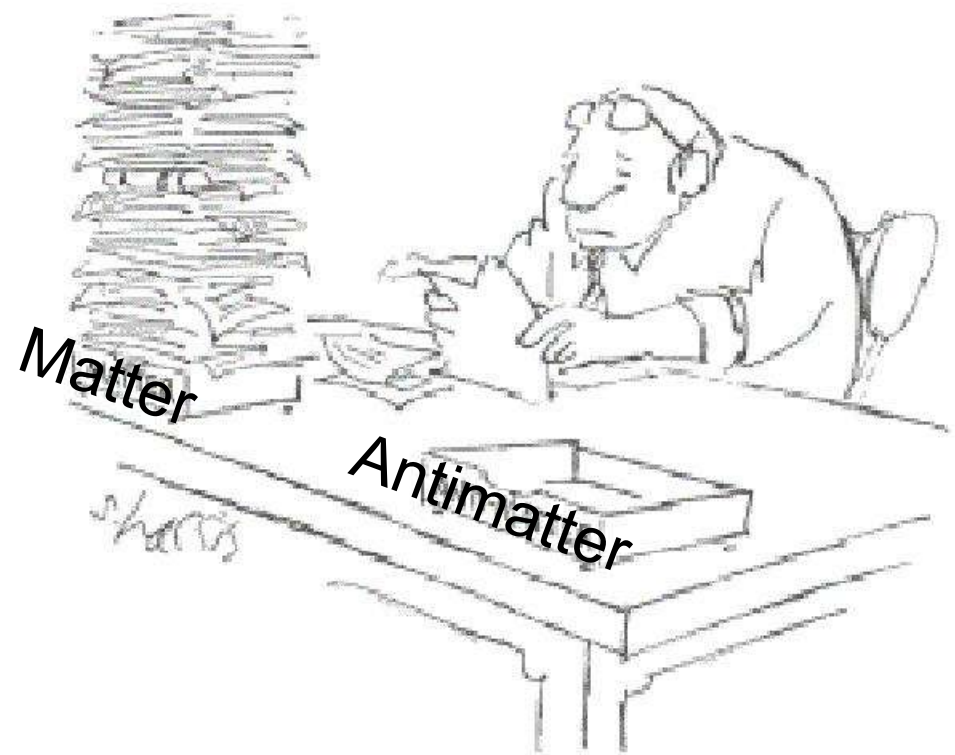
What are we trying to understand?

- Origin of mass
- No unified description of all forces including gravity
- What is the Dark matter of the Univers?



What are we trying to understand?

- “What's the matter with anti-matter?”



- Matter behaves slightly differently than anti-matter (CP violation)

How do we study elementary particles?

Use a giant “microscope”: a particle accelerator



How do we use a particle accelerator?

Instructions:


- 1) Fill accelerator with a large number of particles that travel in opposite directions.
- 2) Accelerate these particles to the highest possible energy.
- 3) Bring beams of particle traveling in opposite directions into collision.
- 4) Take “pictures” of what comes out of these collisions
- 5) Analyze billions of “pictures” to study how nature works.



Why does that work?

$$E = mc^2$$


Energy



Mass

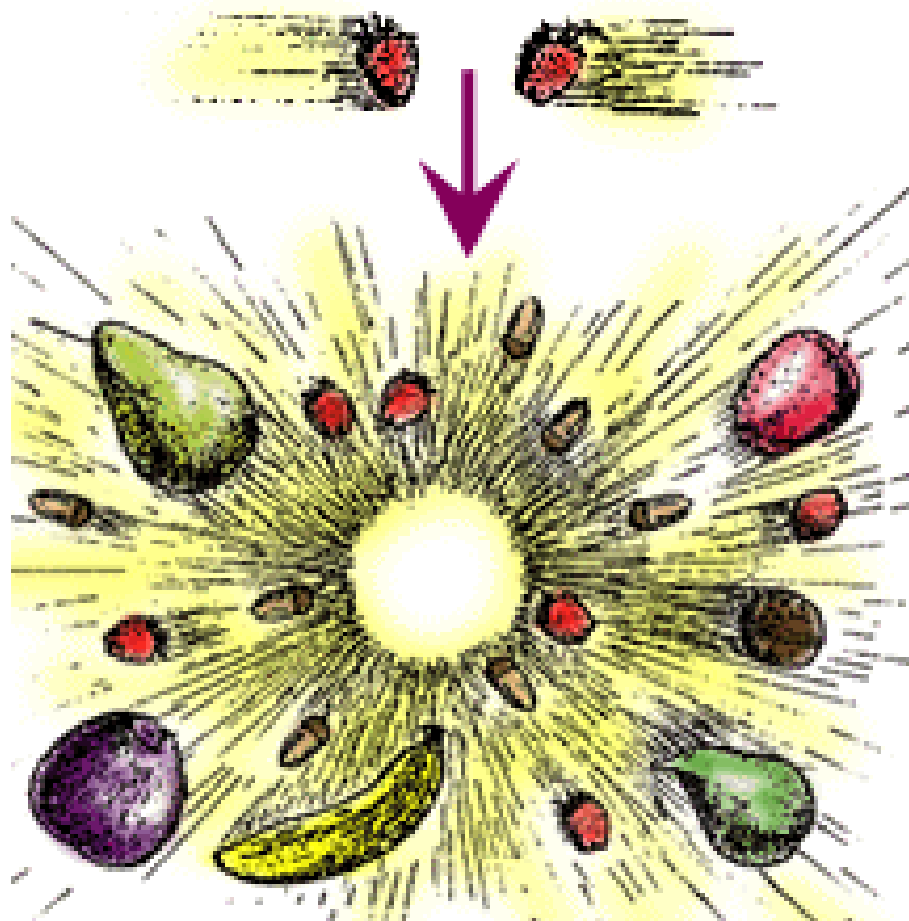


Speed of light
(3×10^8 m/s)



Particle collisions

During a collision, the kinetic energy of colliding particles is converted to mass to form new massive secondary particles. This is how we can create unstable massive particles and study their properties.



Particle Accelerators



Tevatron

- Location: Chicago, USA
- Size: **5 km** circumference
- Operation: 1992-now
- **proton-antiproton** collisions
- Collision energy = **2 TeV**
- # collisions / s = **3 MHz**
- 99.999956% speed of light
- 60,000 turns / s

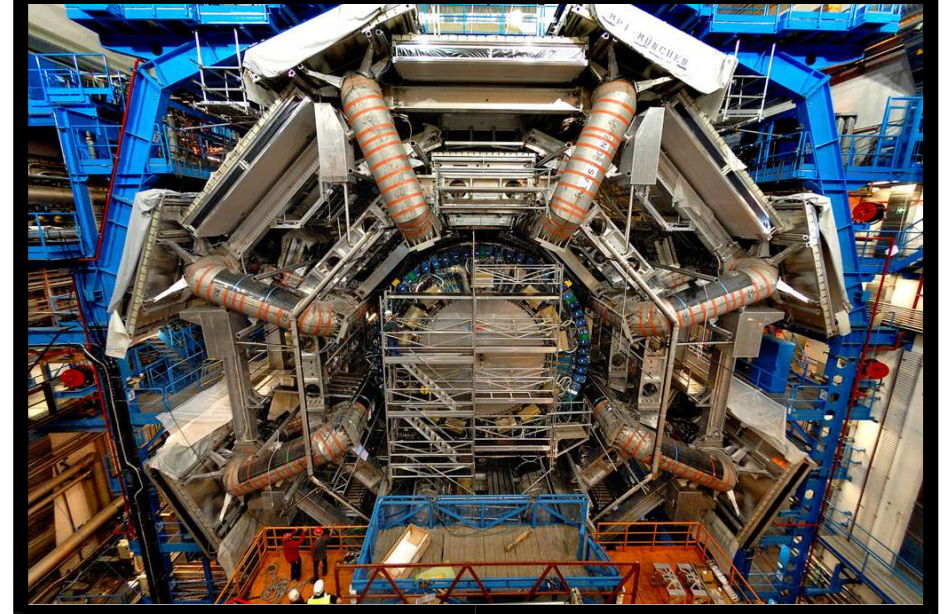


Large Hadron Collider (LHC)

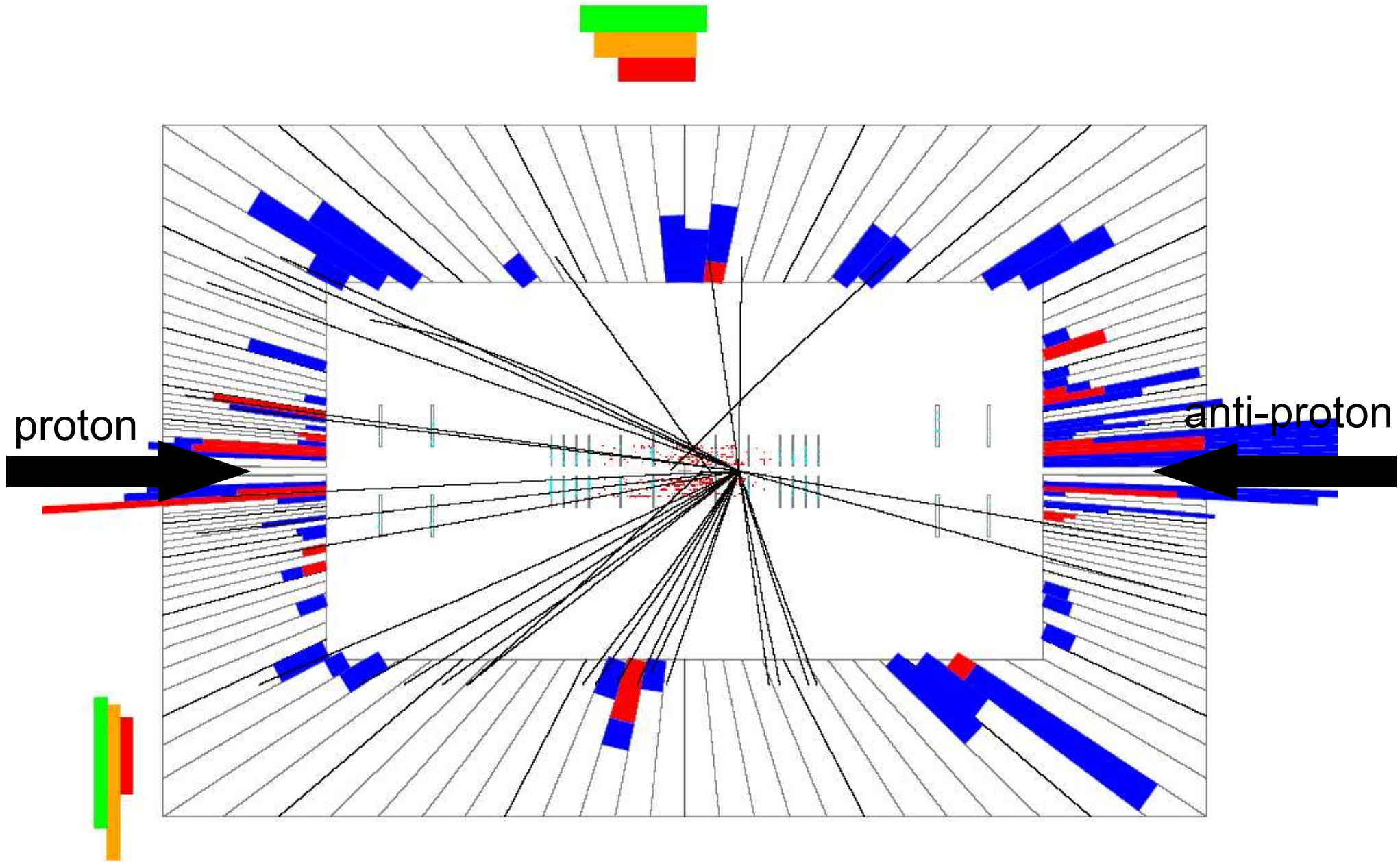
- Location: Geneva, Switzerland
- Size: **27 km** circumference
- Operation: 2007-future
- **proton-proton** collisions
- Collision energy = **14 TeV**
- # collisions / s = **1 GHz**
- 99.9999991% speed of light
- 11,000 turns / s

How to “see” what happens in a collision?

We use a fancy camera that takes 3D pictures: particle detector

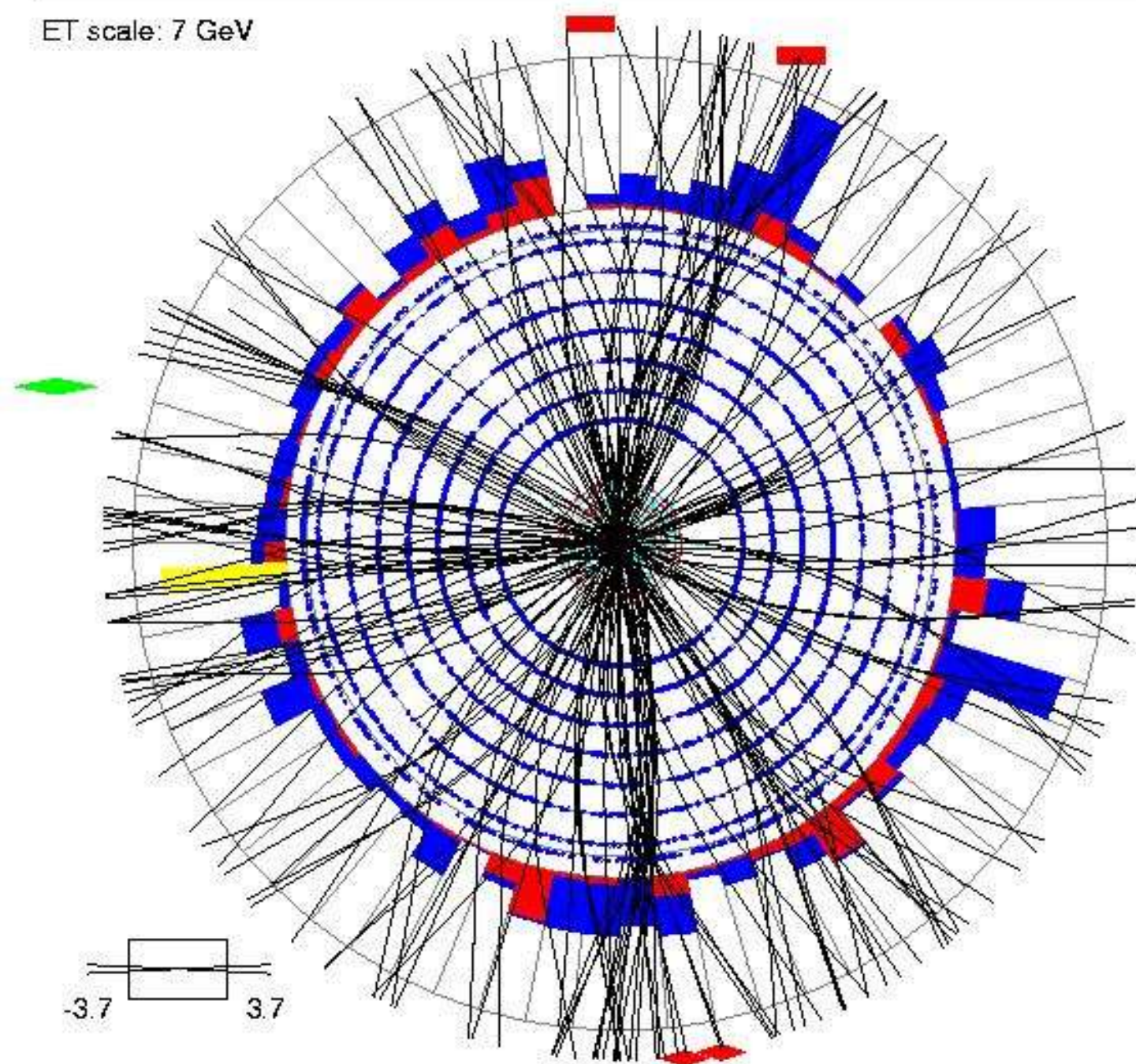


A “picture” of a collision



A “picture” of a collision

ET scale: 7 GeV

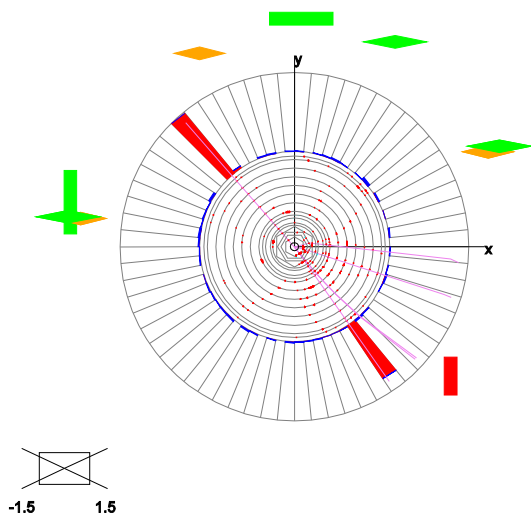


Particle Identification

Electron

Run 142673 Event 1349366 Fri Feb 22 14:32:35 2002

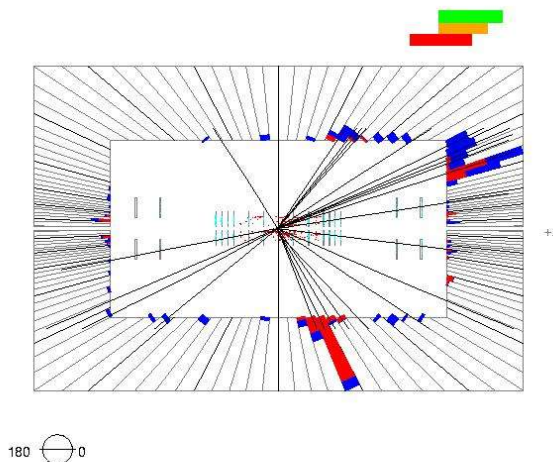
ET scale: 41 GeV



Muon

Run 180748 Event 40093638 Sun Aug 31 20:18:03 2003

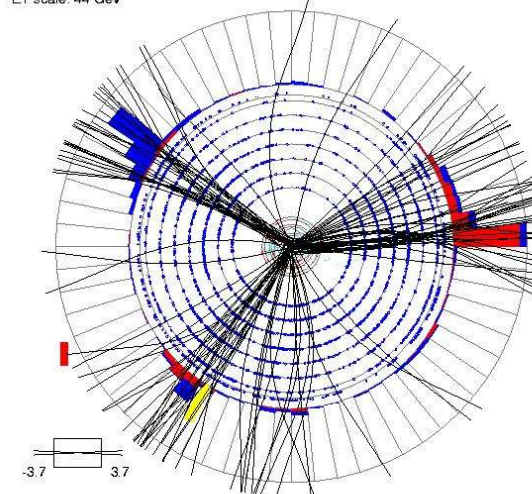
E scale: 26 GeV



Quark

Run 180748 Event 36431869 Sun Aug 31 19:02:55 2003

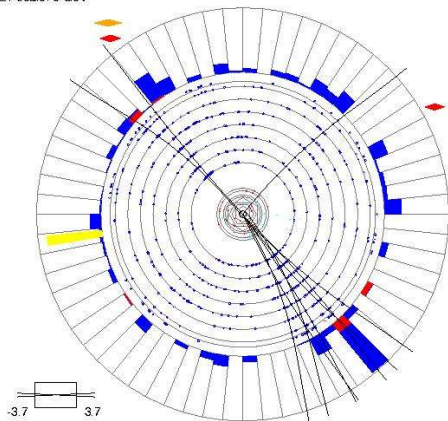
ET scale: 44 GeV



Neutrino

Run 180748 Event 34291340 Sun Aug 31 18:13:41 2003

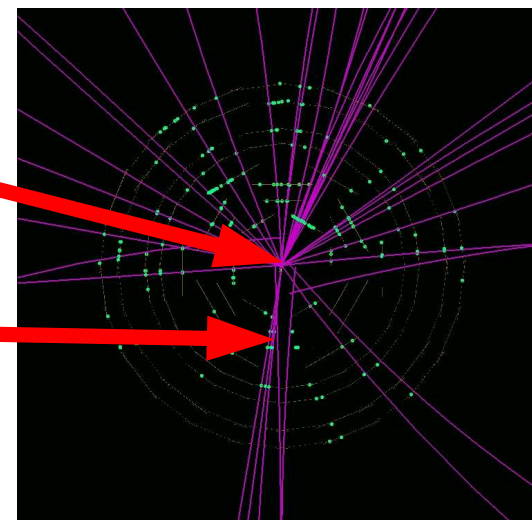
ET scale: 6 GeV



Bottom quark

primary
vertex

secondary
vertex



Putting it all together



Animation

Examples from my research

1- Detector construction/commissioning:

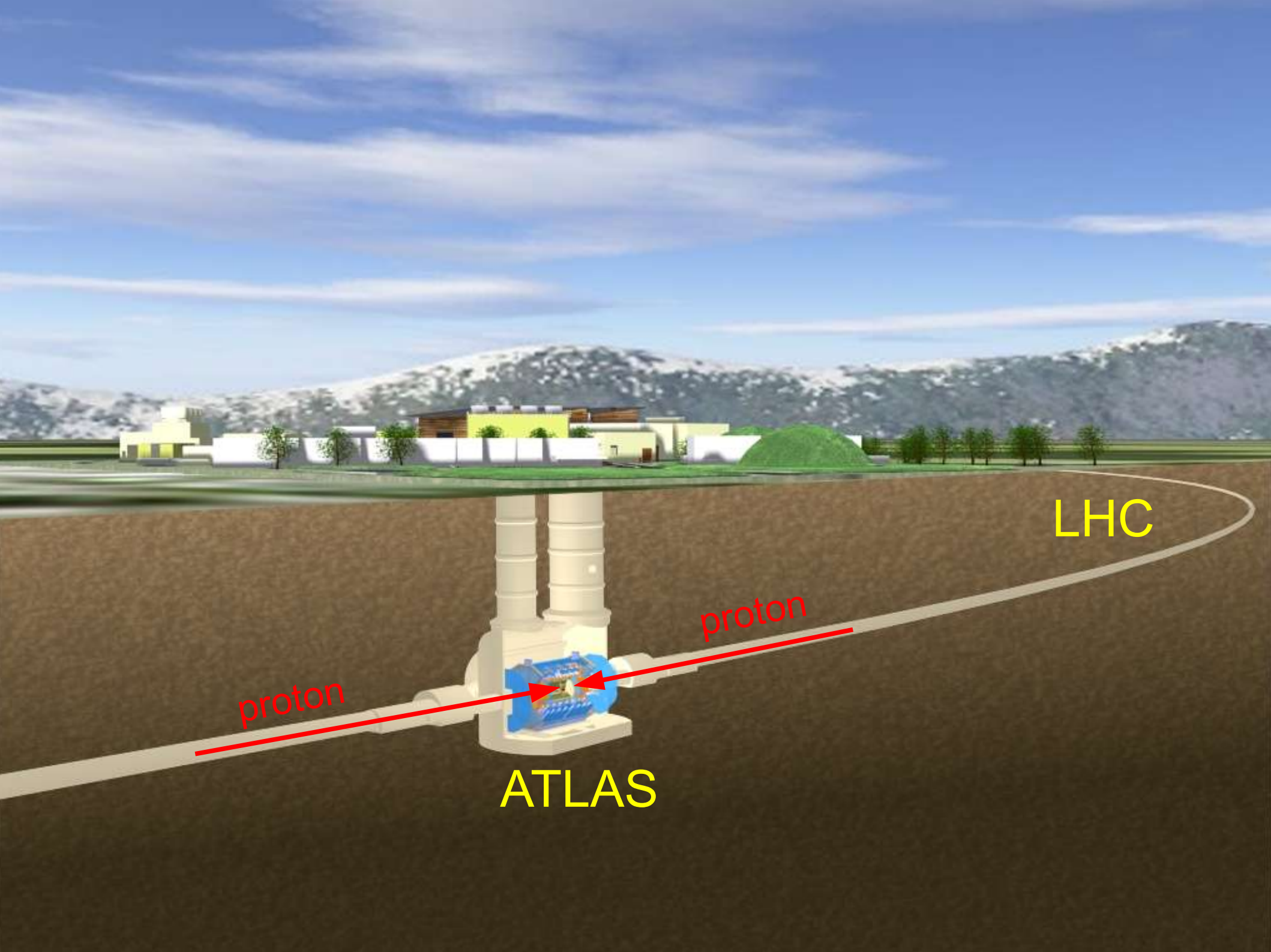
ATLAS trigger commissioning

2- Analysis of data

Top quark studies using the DZero experiment



Large Hadron Collider



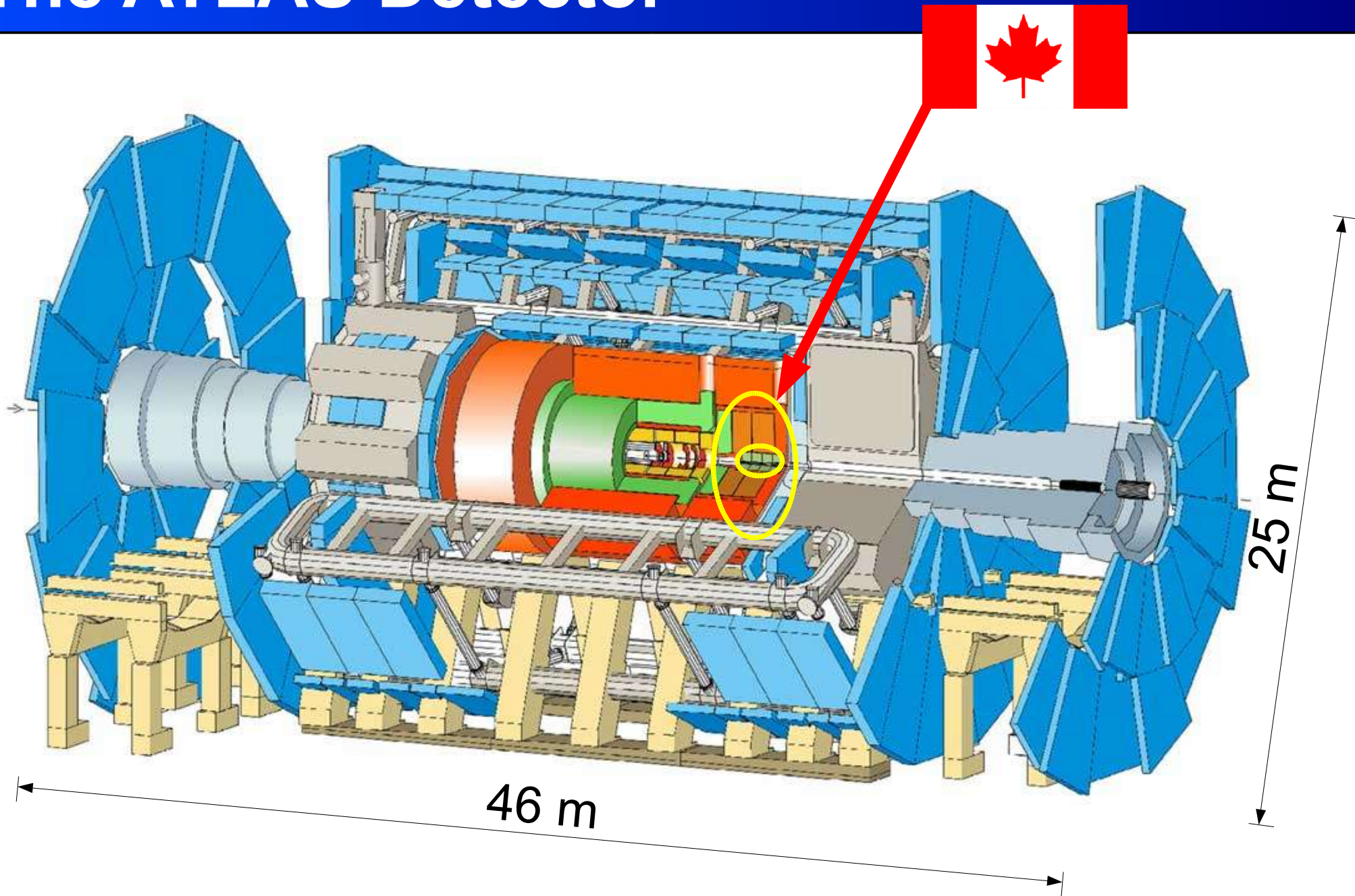
LHC

proton

proton

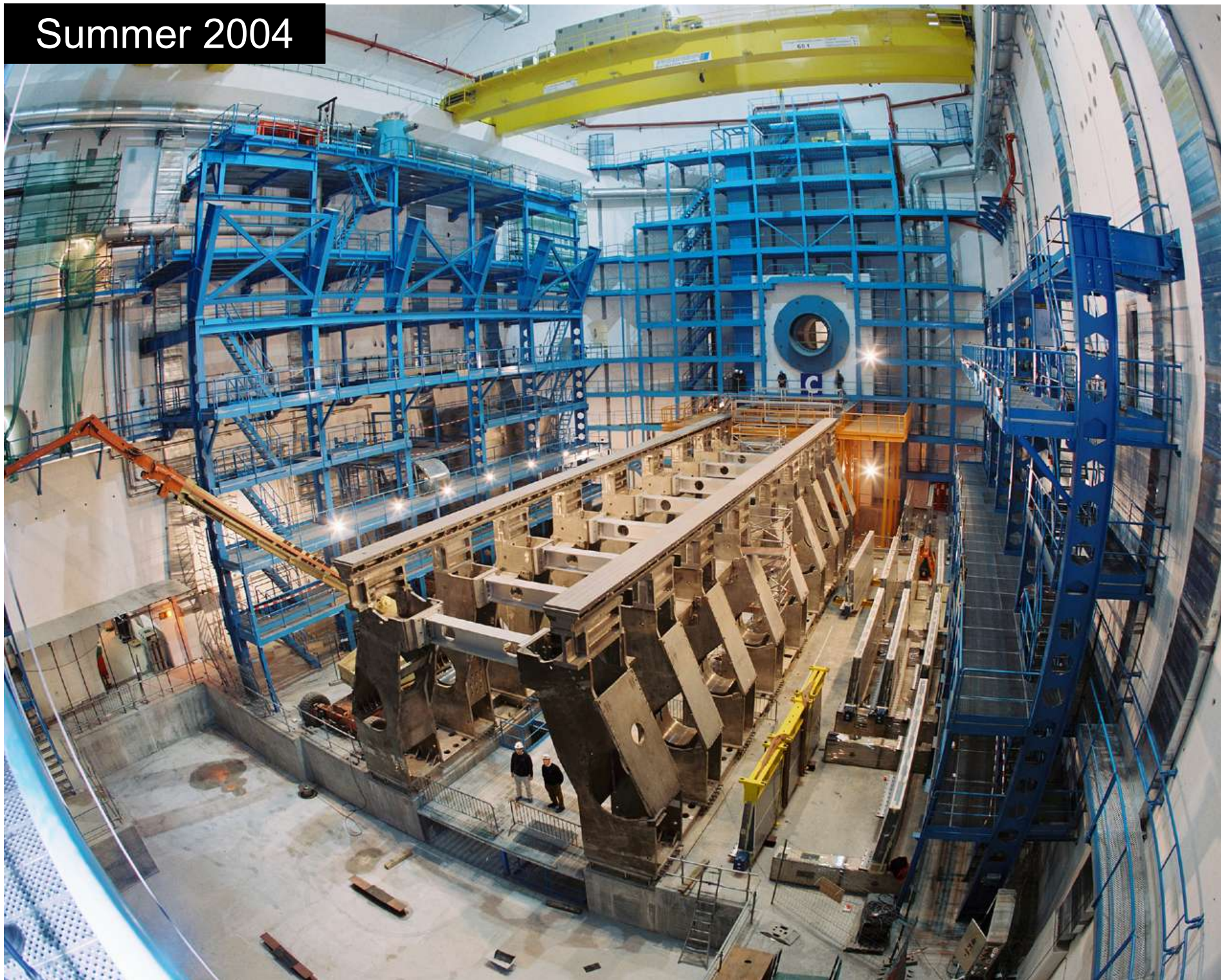
ATLAS

The ATLAS Detector

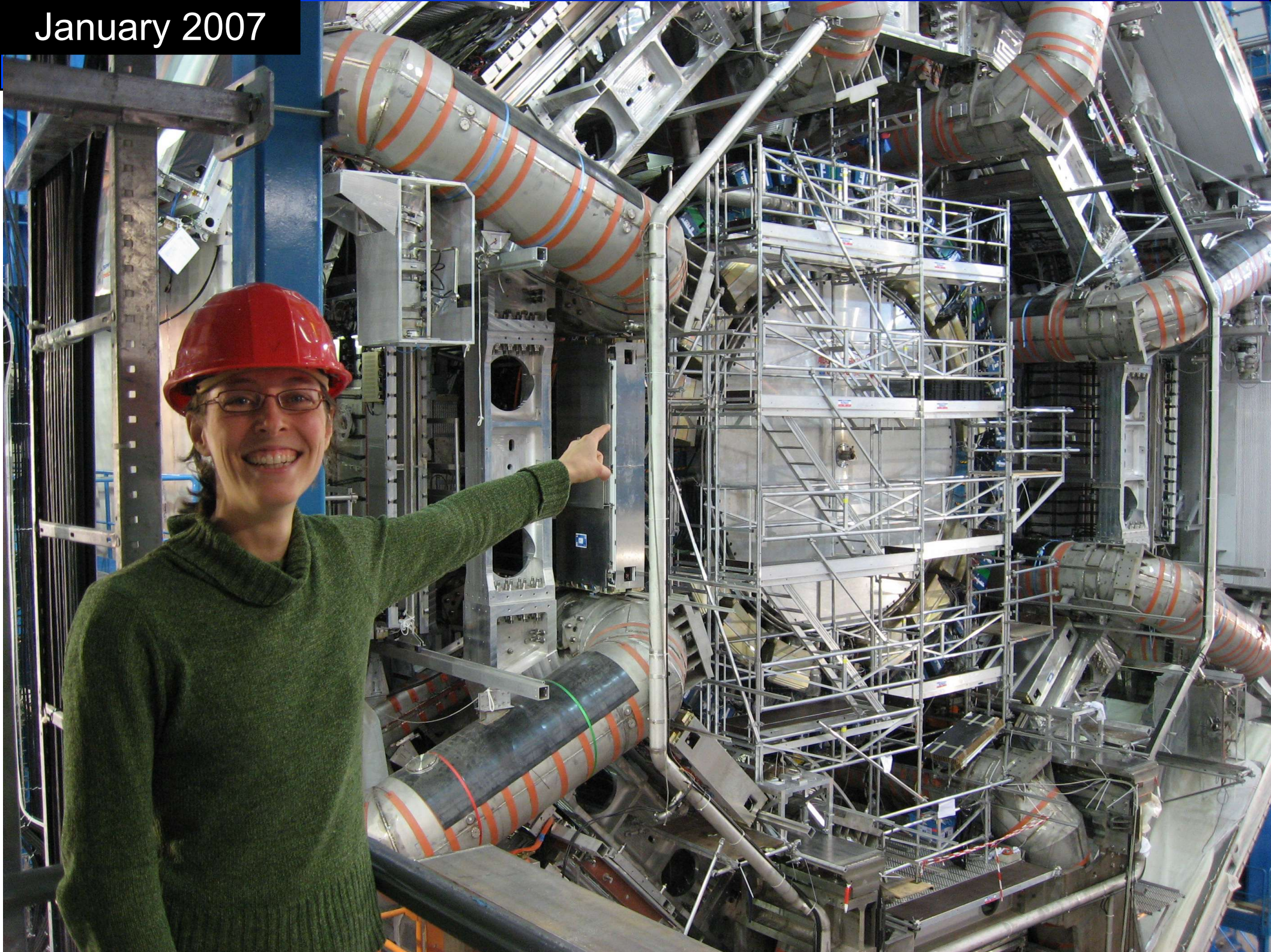


Weight = 7000 Tons

Summer 2004

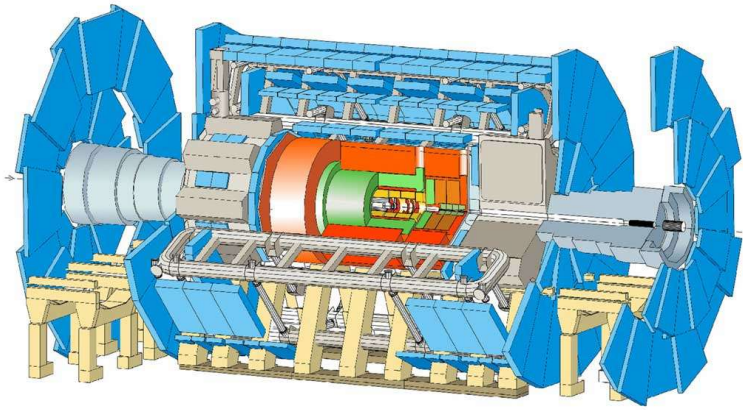


January 2007





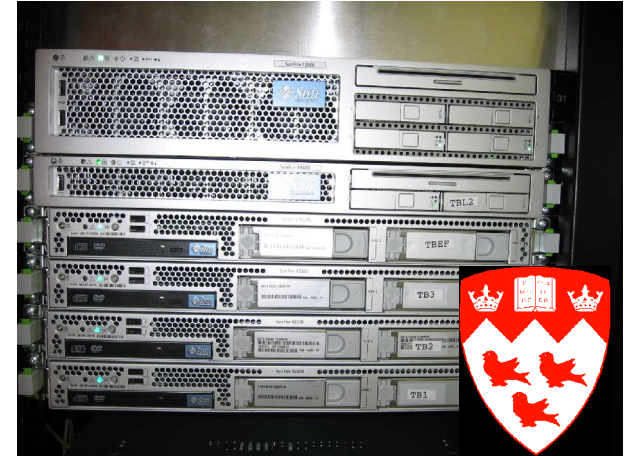
ATLAS Trigger System



1 billion collisions
per second



Trigger System



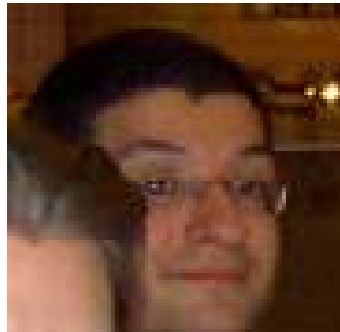
200 "photos"
per second



Dr Chris Potter



Marc-Andre Dufour



Dr Cibran Santamarina

3.2 PB data / year
(4.6 Million CD = 695 year of music)



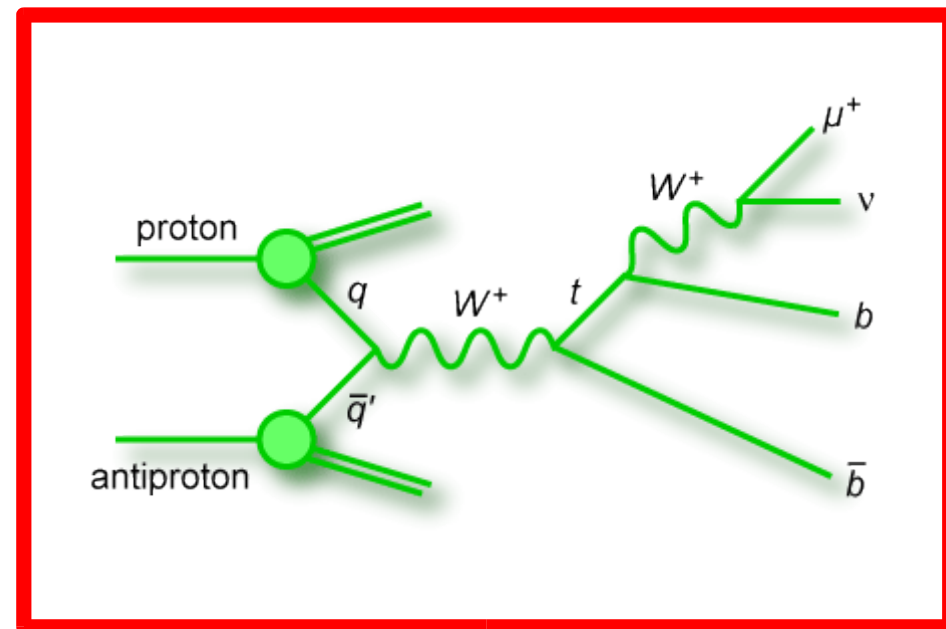
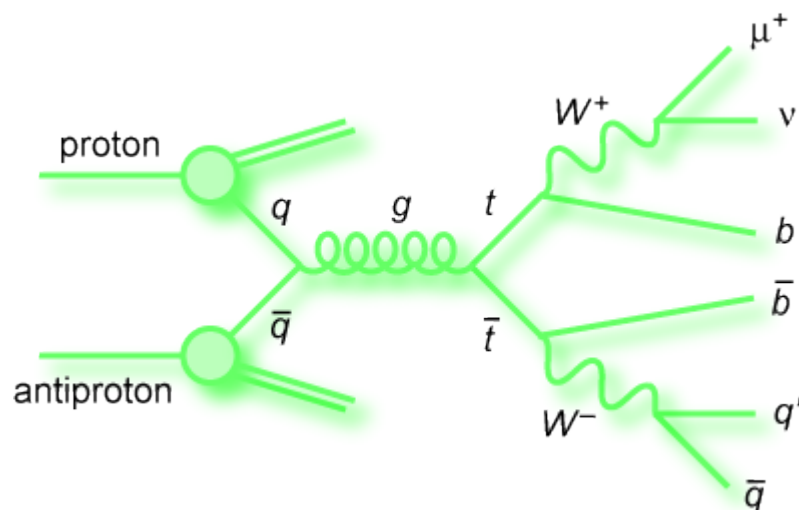
Data Analysis

FERMILAB-PUB-06/475-E

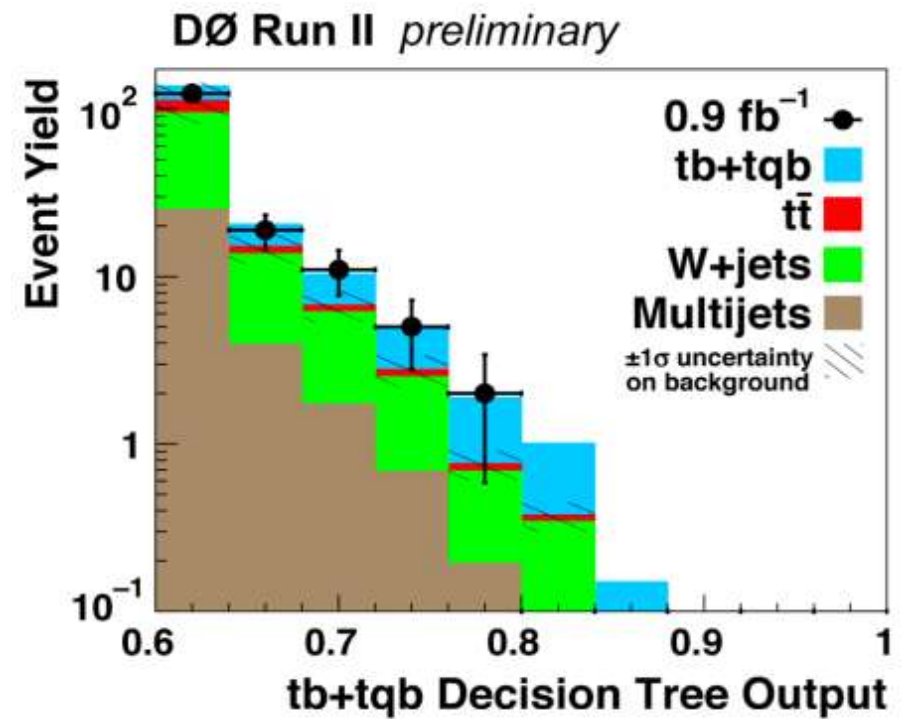
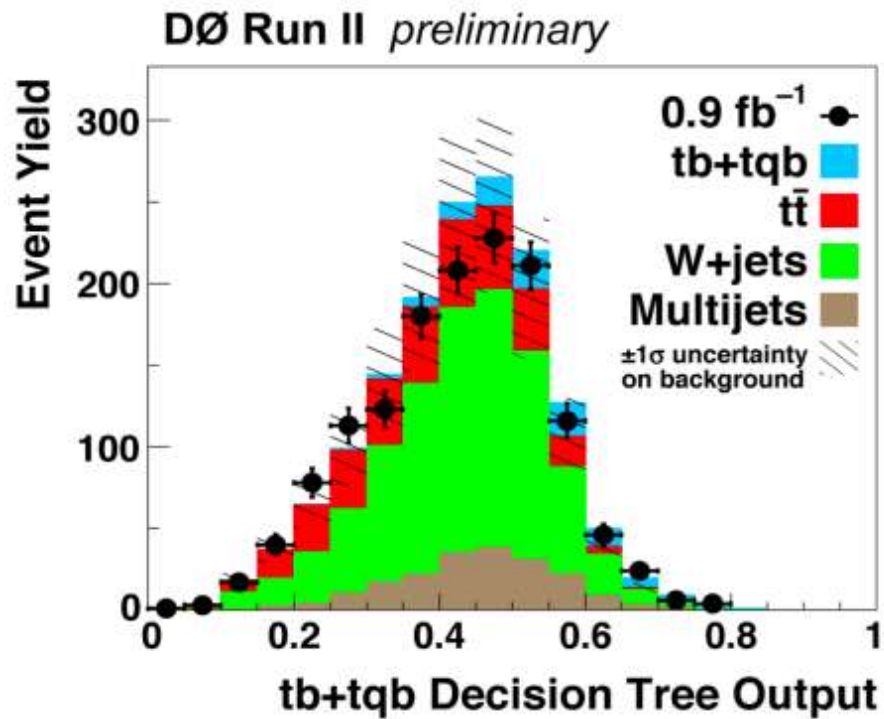
Evidence for production of single top quarks and first direct measurement of $|V_{tb}|$

The D0 Collaboration presents first evidence for the production of single top quarks at the Fermilab Tevatron $p\bar{p}$ collider. Using a 0.9 fb^{-1} dataset, we apply a multivariate analysis to separate signal from background and measure $\sigma(p\bar{p} \rightarrow tb + X, tqb + X) = 4.9 \pm 1.4 \text{ pb}$. The probability to measure a cross section at this value or higher in the absence of signal is 0.035%, corresponding to a 3.4 standard deviation significance. We use the cross section measurement to directly determine the CKM matrix element that describes the Wtb coupling and find $0.68 < |V_{tb}| \leq 1$ at 95% C.L. within the standard model.

PACS numbers: 14.65.Ha; 12.15.Ji; 13.85.Qk



First evidence for single top quark



Gustavo Kertzscher



Dr Chris Potter

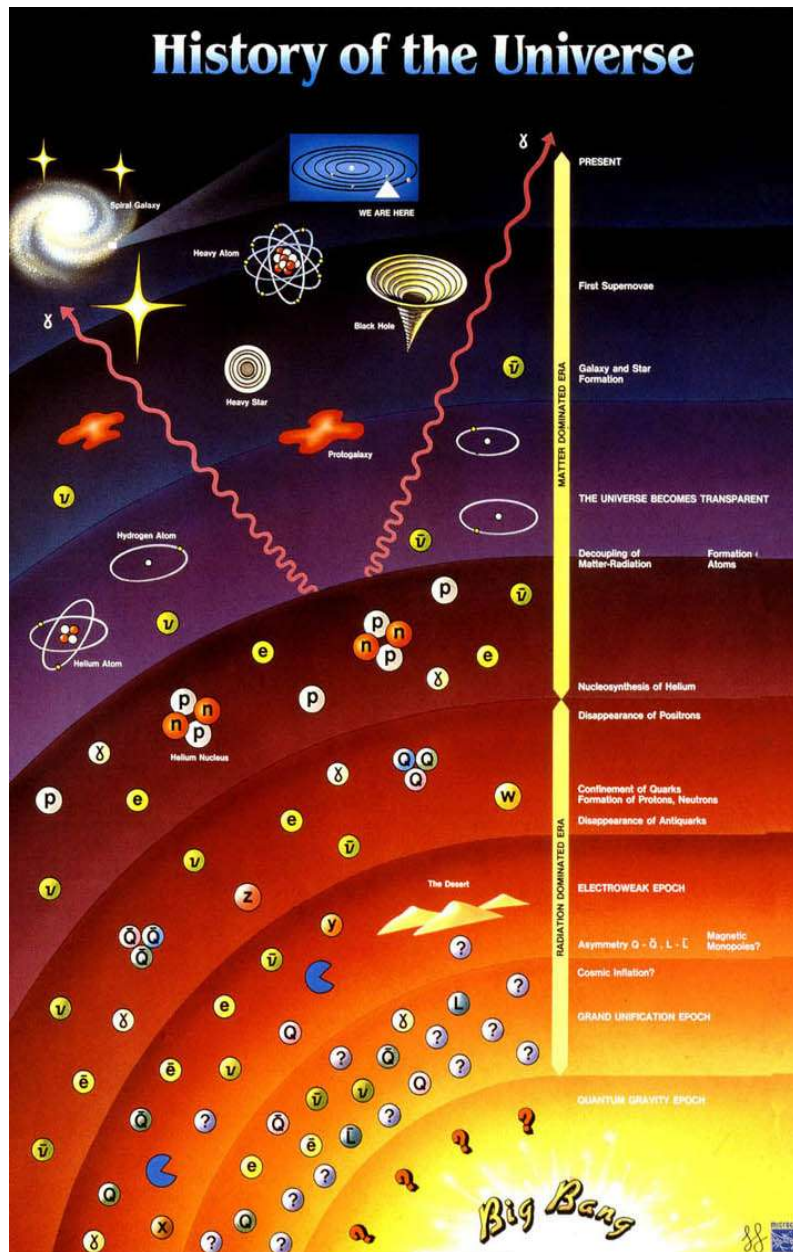


Camille
Belanger-Champagner

An aerial photograph of a rural landscape, likely a valley or plain, showing a dense network of agricultural fields in various shades of green and brown. A large, thin white circle is drawn around a central area of the landscape, which includes a small town or village. A smaller, thin white circle is drawn around a specific area within the larger circle, possibly highlighting a point of interest. The text "Questions?" is overlaid in the center of the image.

Questions?

Recreating the Early Universe



13.7 billion years

NOW

1 billion years

Stars form

300,000 years

Atoms form

180 seconds

Nuclei form

10^{-10} seconds

Protons/Neutrons form

1×10^{-12} s

10^{-34} seconds ?

Quarks differentiate

?? Before ??

LHC Tunnel



Centre Européen de Recherche Nucléaire





ATLAS International Collaboration

1850 Physicists & engineers
150 Universities & laboratories
34 Countries



Alberta
Carleton
McGill
Montréal
Regina
Simon Fraser
Toronto
TRIUMF
UBC
Victoria
York

