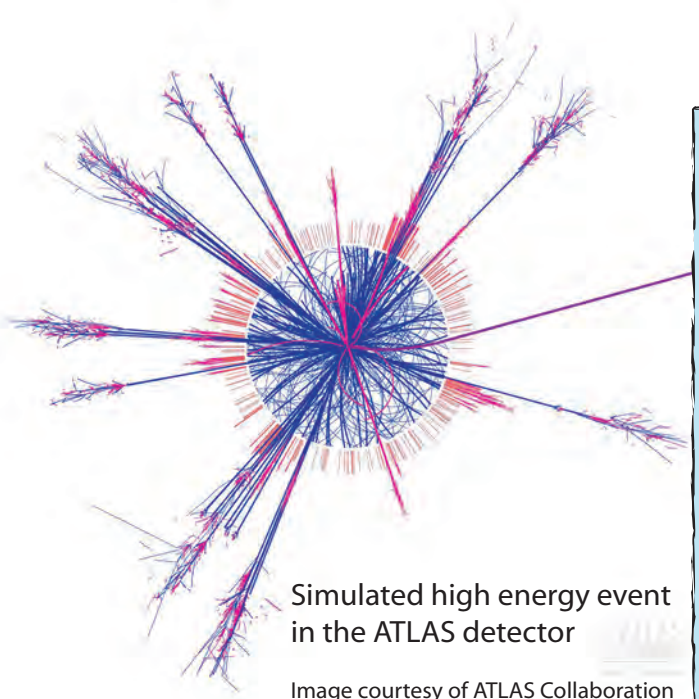
Cracking Open the Universe



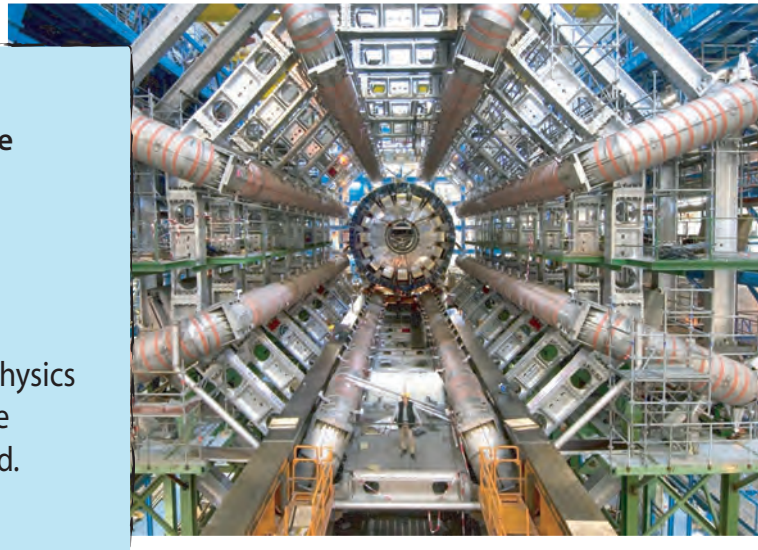
Simulated high energy event
in the ATLAS detector

Image courtesy of ATLAS Collaboration
www.atlas.ch

James Brau
Knight Professor of Natural Science
Graham Kribs
Assistant Professor of Physics
Eric Torrence
Associate Professor of Physics

UO particle physicists will explain the new physics discoveries expected with the start-up of the Large Hadron Collider in Geneva, Switzerland.

7:00 pm, Friday, September 12, 2008
150 Columbia Hall, 1215 E. 13th Ave.
346-4898 for details



ATLAS detector
Image courtesy of ATLAS Collaboration www.atlas.ch

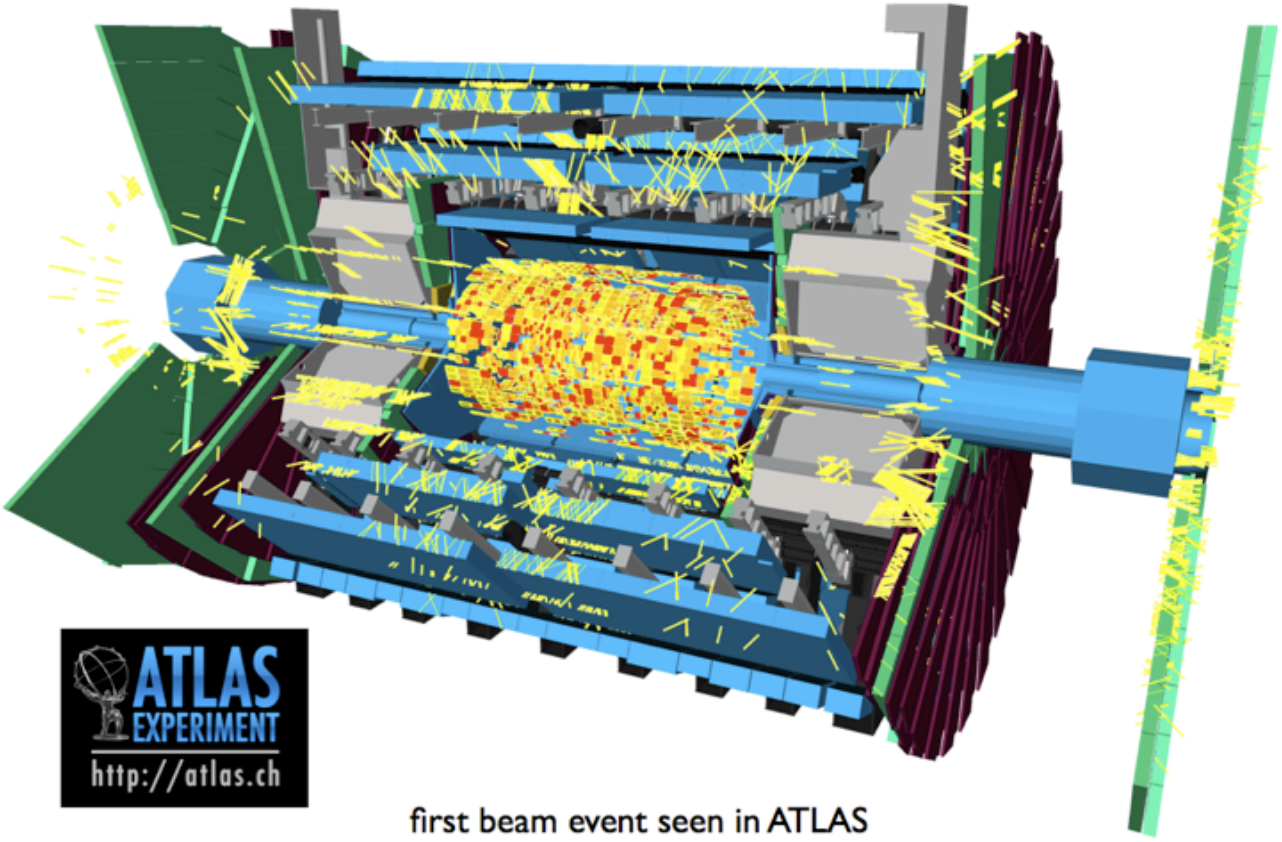
The World of Physics is about to change! This week, the Large Hadron Collider (LHC) in Geneva, Switzerland is beginning first beam operations. The ATLAS experiment at the LHC, conducted by a virtual United Nations of 37 countries, including UO physicists, will soon be exploring a crack into the fabric of the universe. Physicists expect this entirely new frontier in particle physics to bring discoveries of the relationship between electricity and magnetism and radioactive decay, the origin of the mass of fundamental particles, and unification of all forces in nature. As LHC physicists enter the expansive new Terascale frontier, even unexpected new phenomena may be discovered. Our very understanding of matter and energy, space and time, will be transformed by the LHC. Come early to get a good seat.

UNIVERSITY OF OREGON

Public Welcome
Admission Free

September 10, 2008

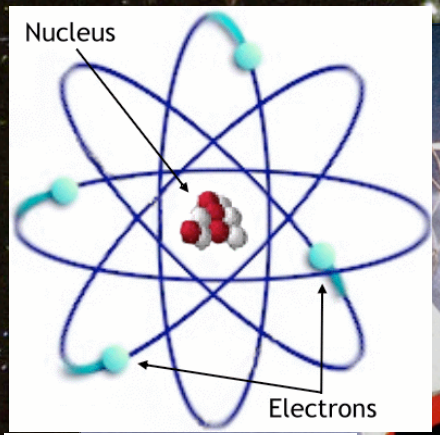
First Beam at Large Hadron Collider



first beam event seen in ATLAS

Particle beams were transported around the 17 mile ring in both directions

The Universe is Made of Particles



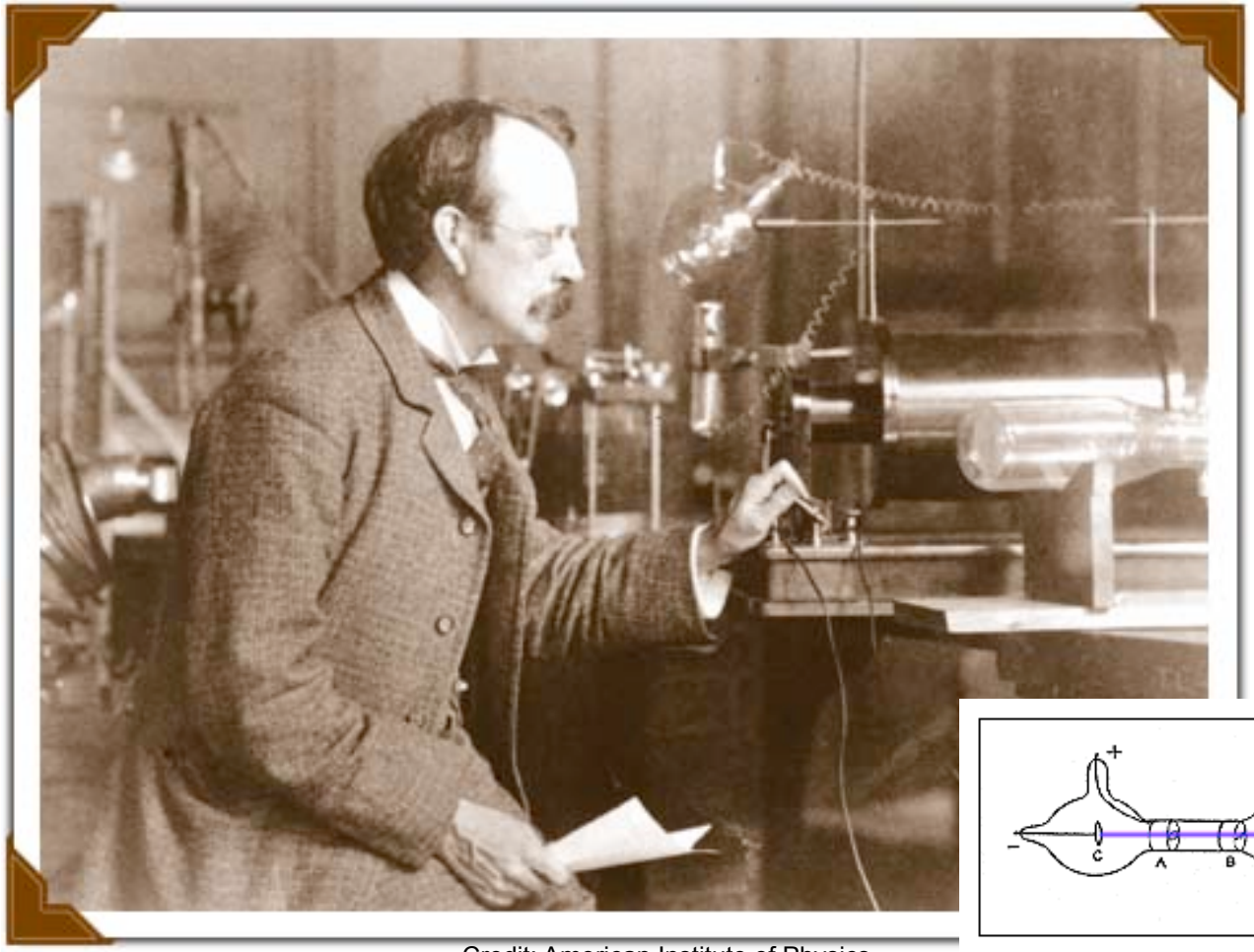
THE ATOM

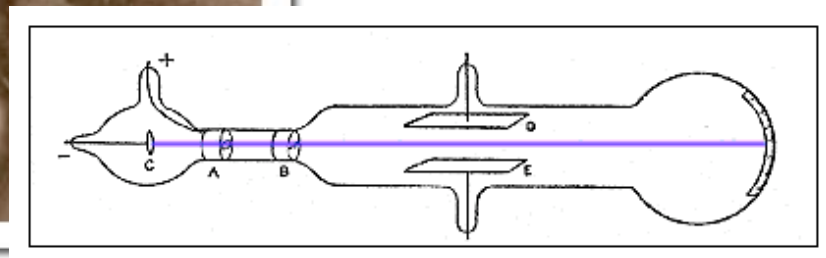
- Investigating the particles reveals the fundamental structure of the Universe and matter within it

TONIGHT'S PROGRAM

- What are some highlights of particle physics history?
- What is the purpose of the Large Hadron Collider? - G. Kribs
- How do we do experiments at the LHC? - E. Torrence
- What are the unanswered questions from the audience?

1897 - J.J. Thomson - Electron





Credit: American Institute of Physics

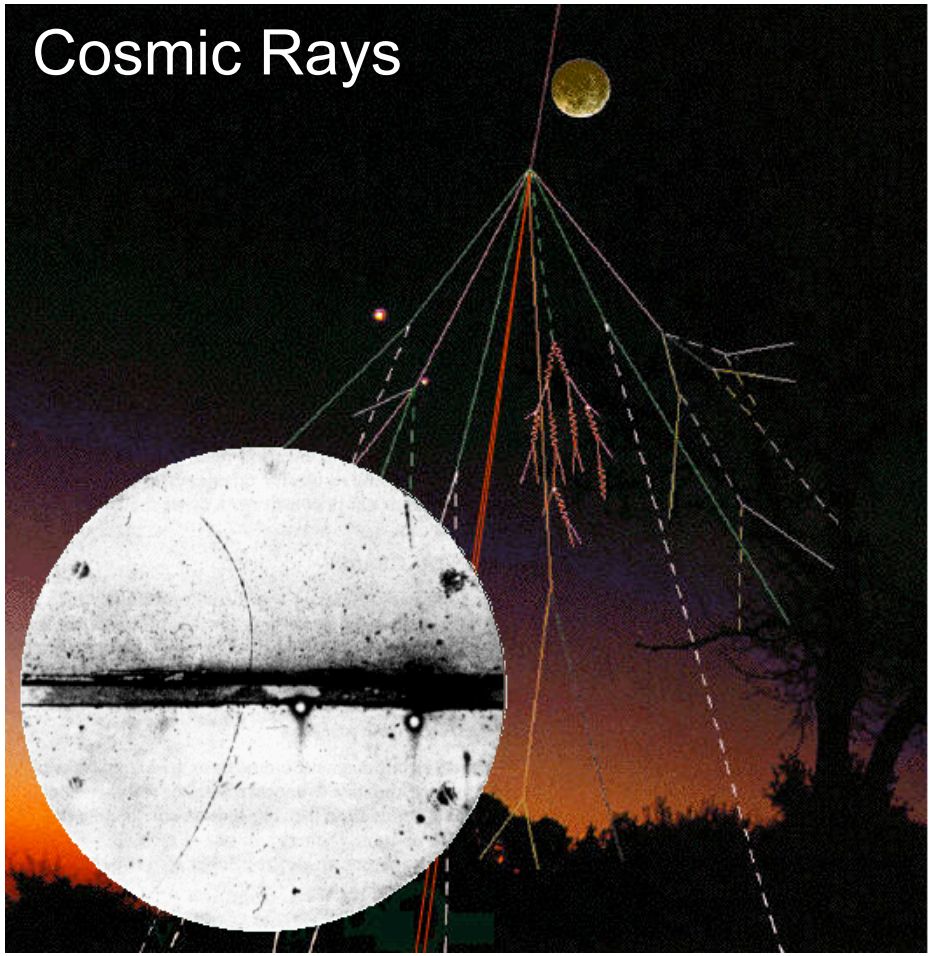
J.J. Thomson, Speaking in 1934

Could anything at first sight seem more impractical than a body which is so small that its mass is an insignificant fraction of the mass of an atom of hydrogen? -- which itself is so small that a crowd of these atoms equal in number to the population of the whole world would be too small to have been detected by any means then known to science.

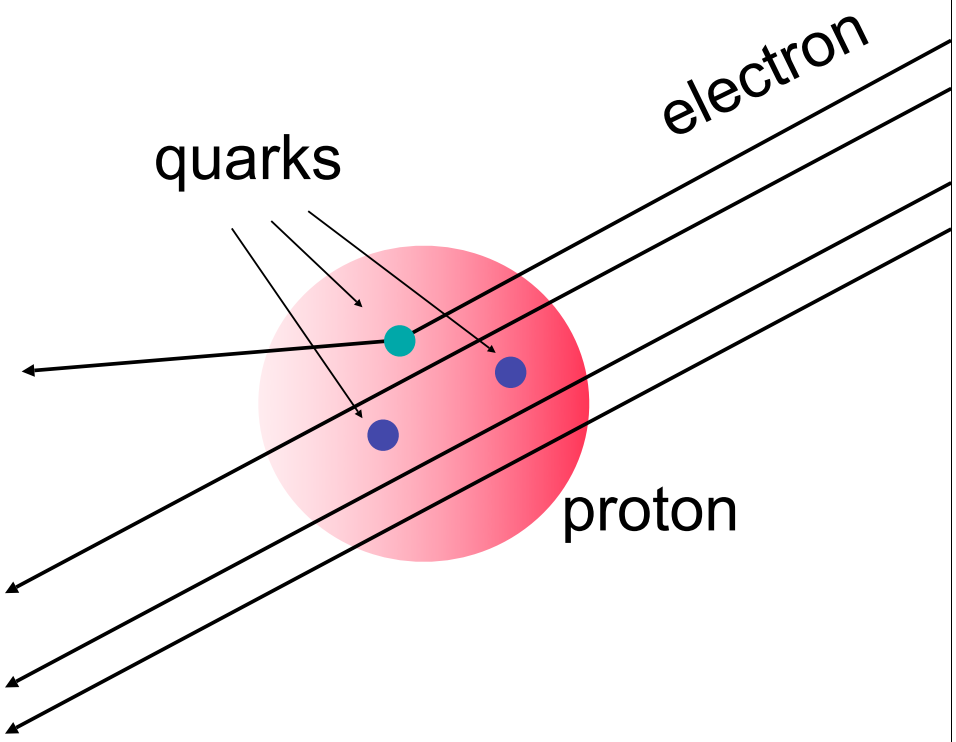
Credit: American Institute of Physics

From the soundtrack of the film, Atomic Physics

1932 - Discovery of Anti-Matter



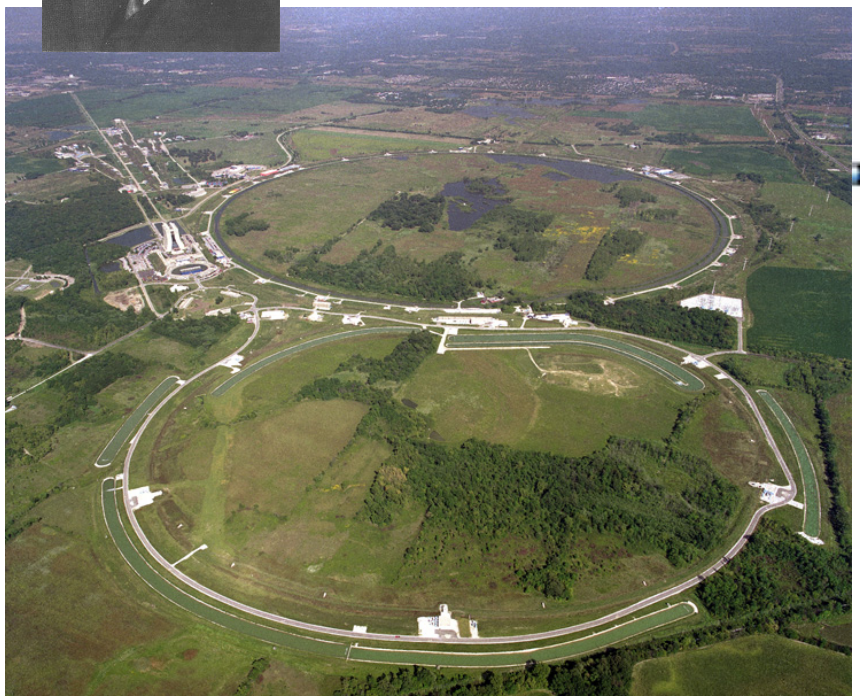
1969 - Quarks discovered (inside atomic nucleus) Stanford

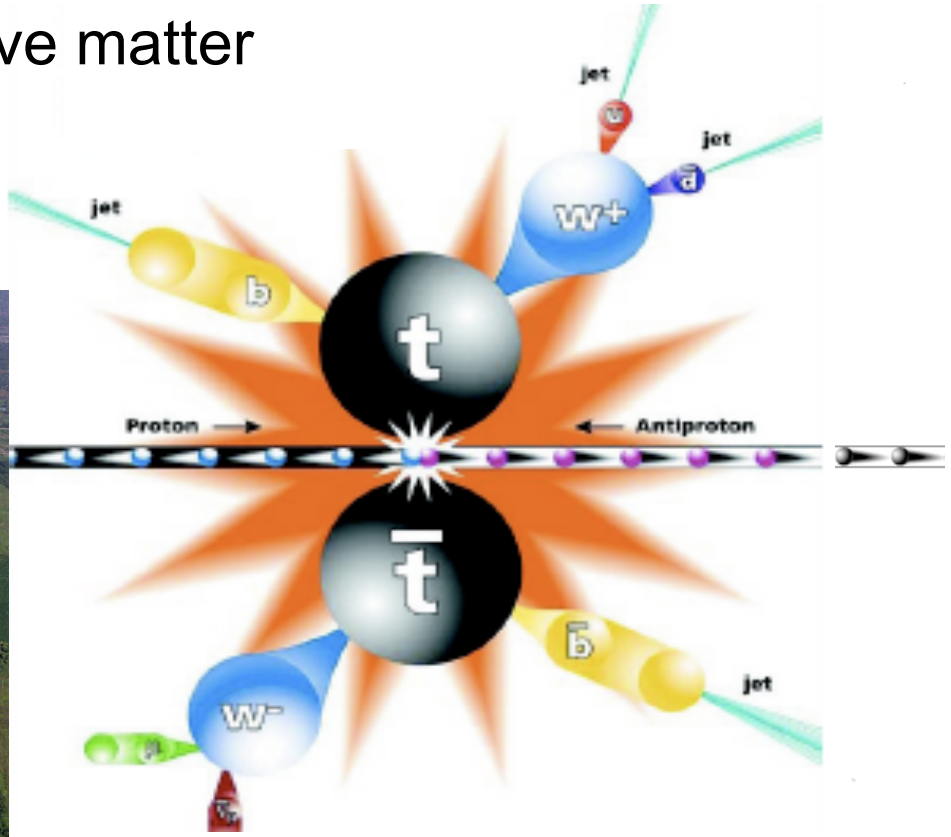


1995 - Top Quark Discovered at Fermilab

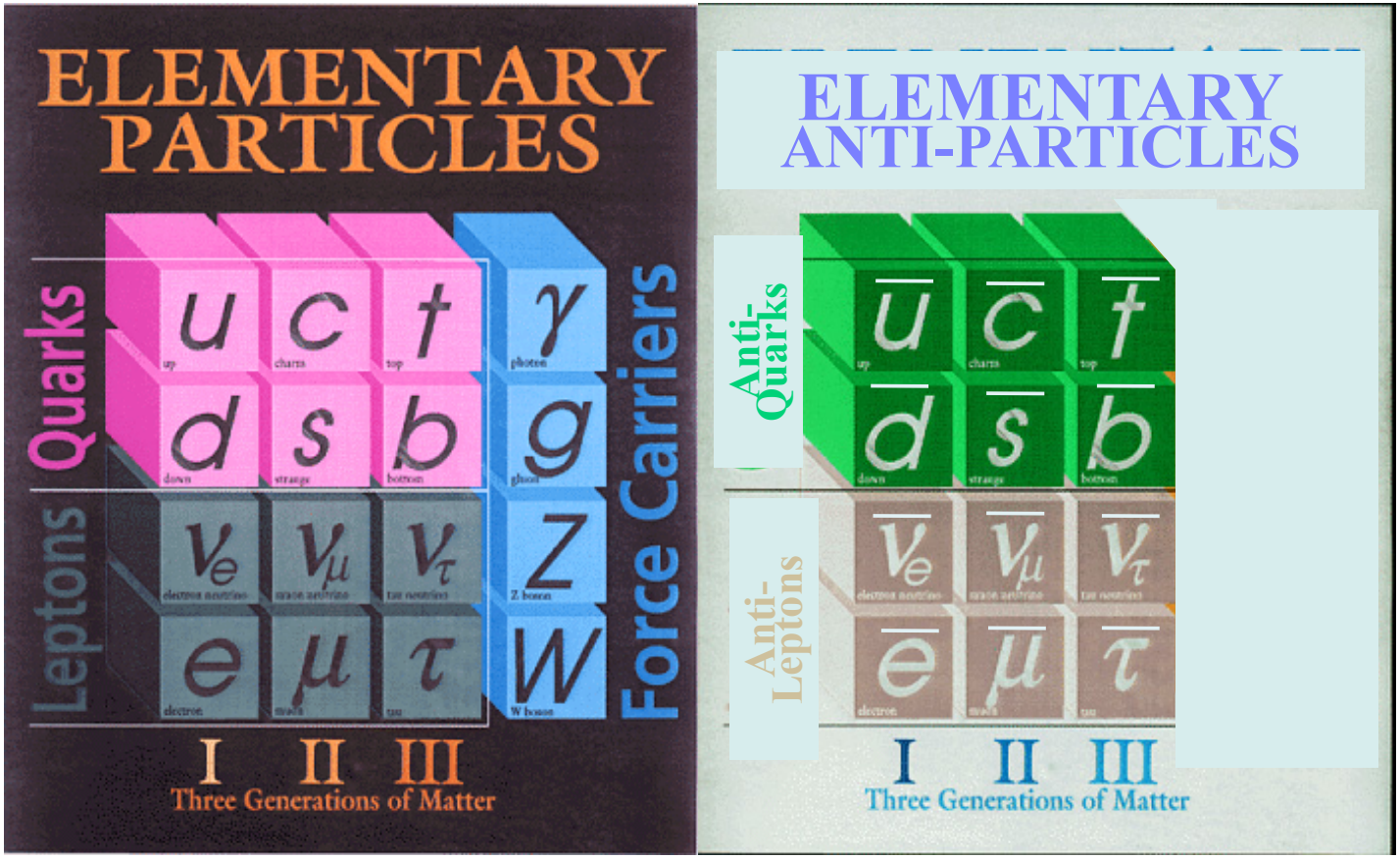
Creation of massive matter

$(E=mc^2)$





Building Blocks of Nature



Next Energy Frontier

- Terascale

  Energy = 1,000,000,000,000 electron-volts

  – Equivalent to trillions of household batteries

  – Controlled voltage of tens of thousands of lightning bolts

- Scientific Goals at Terascale

  – Origin of Mass

  – Symmetries of Forces

  – Dark Matter

The Large Hadron Collider(LHC)

Largest machine in the world

Fastest racetrack on the planet

Emptier than space in the Solar System

Hottest spots in the galaxy, but even **colder** than outer space

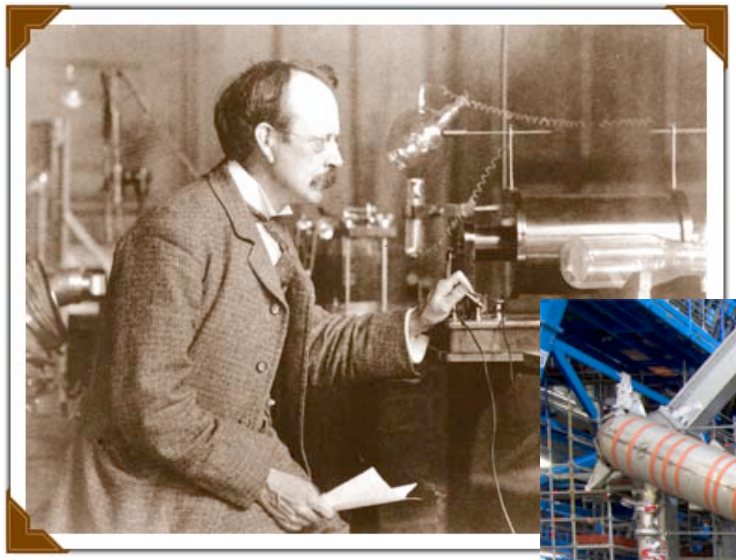
Biggest and **most sophisticated** detectors ever built

Most powerful supercomputer system in the world

The Large Hadron Collider(LHC)

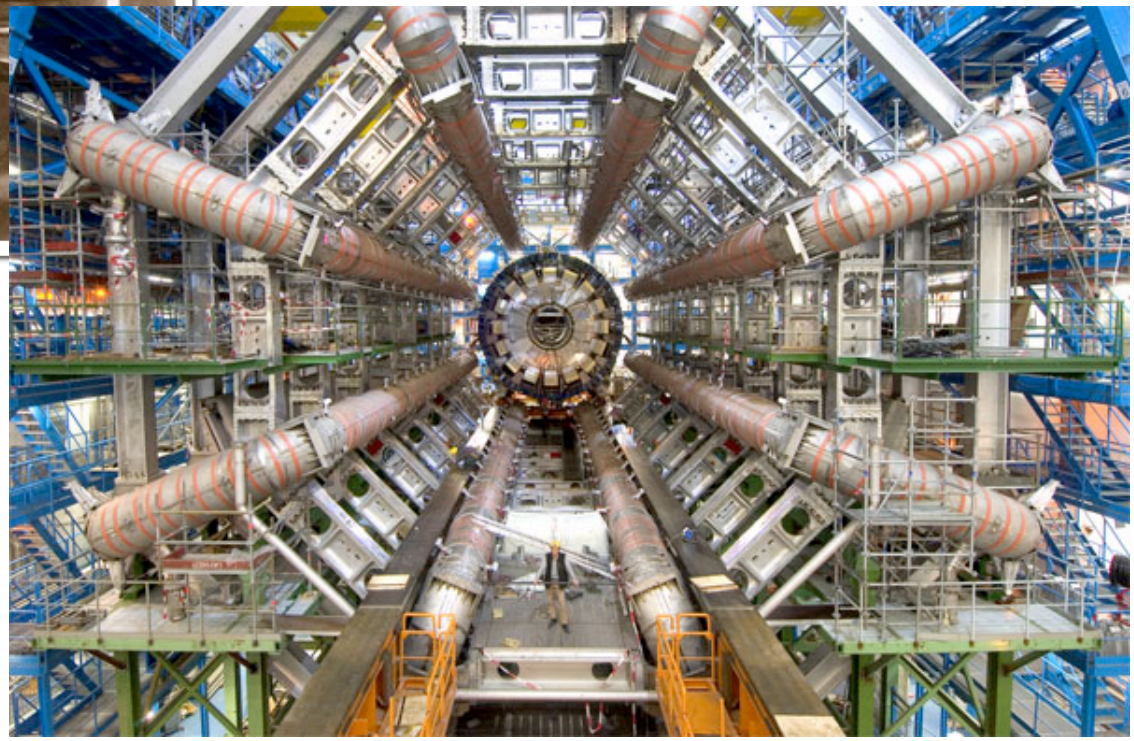
- 17 mile circumference
- 9300 Magnets
  - 1600 Superconducting (–456^{o} F)
- Collision energy
  - 14,000,000,000,000 eVolts
- Energy in beams
  - 362 MegaJoules
    - 747 Jumbo Jet on take-off
  - 10,000 MJ in magnets
- Particle Collision rate
  - 600,000,000/second

From kilo-electron-volts to the Terascale



1897
Discovery of
the Electron

2008 +
Discovery
of ??????



Now, Two Experts on the LHC

- Physics Goals of the LHC
  - Graham Kribs

    UO Assistant Professor of Physics

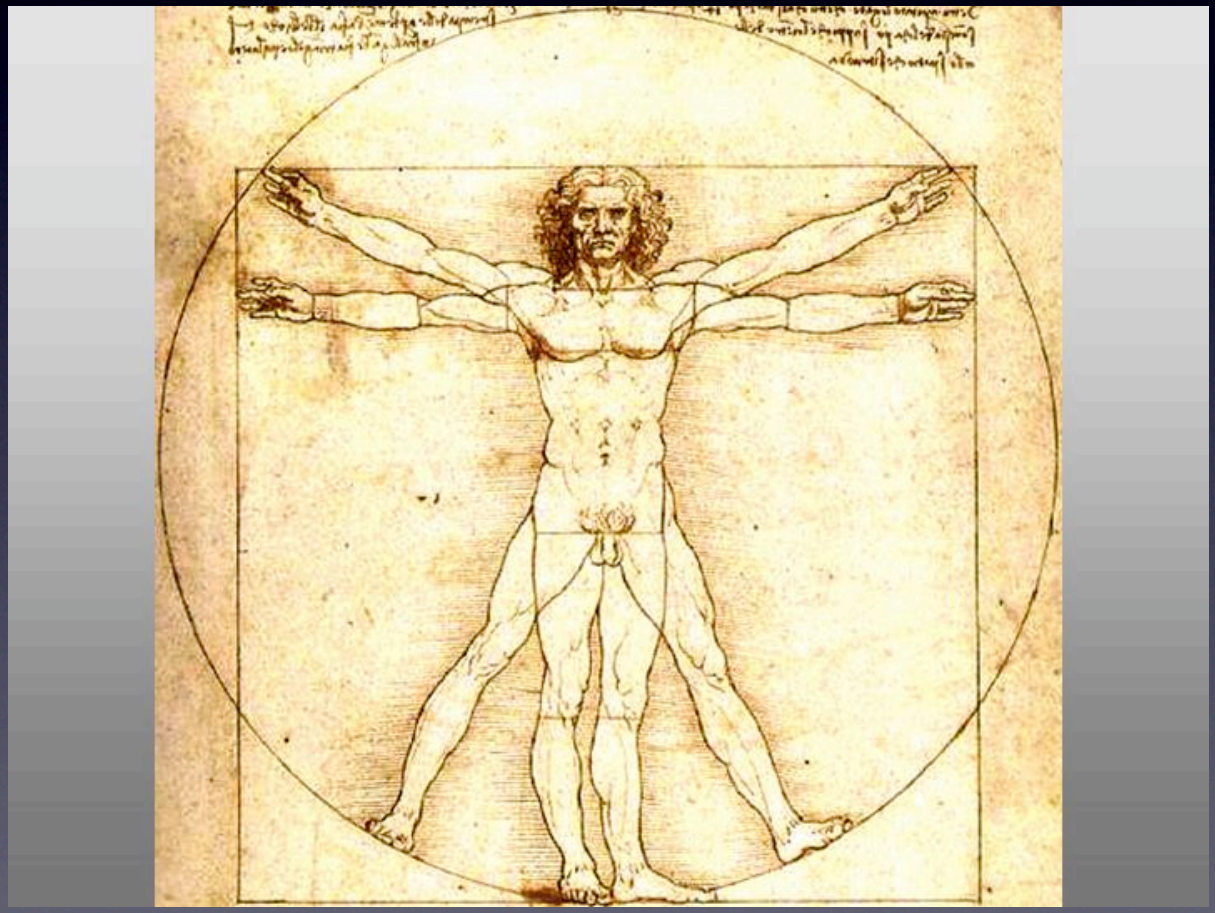
- Experiments at the LHC
  - Eric Torrence

    UO Associate Professor of Physics

- Then - Questions and Discussion

The BIG questions...

What are we made of?



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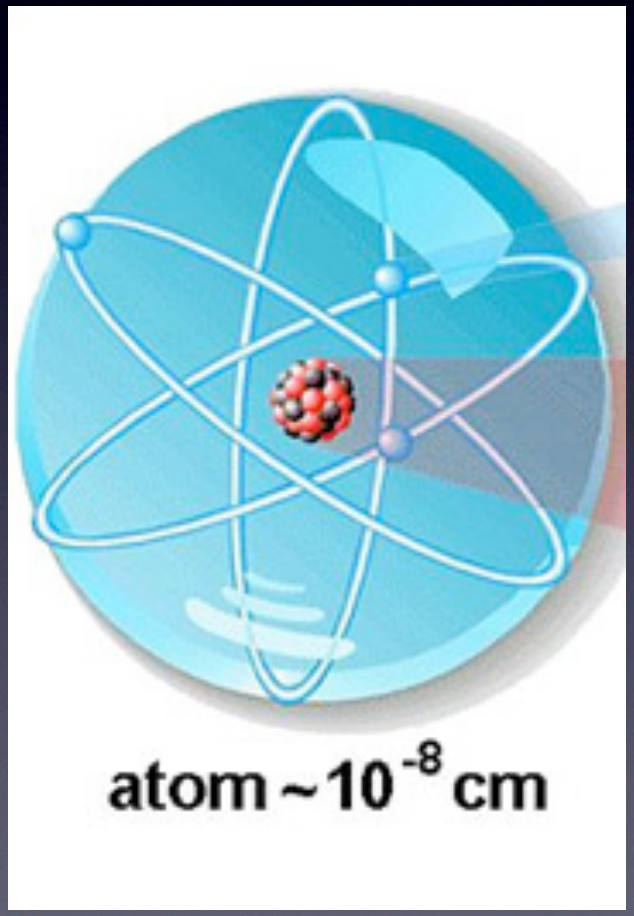
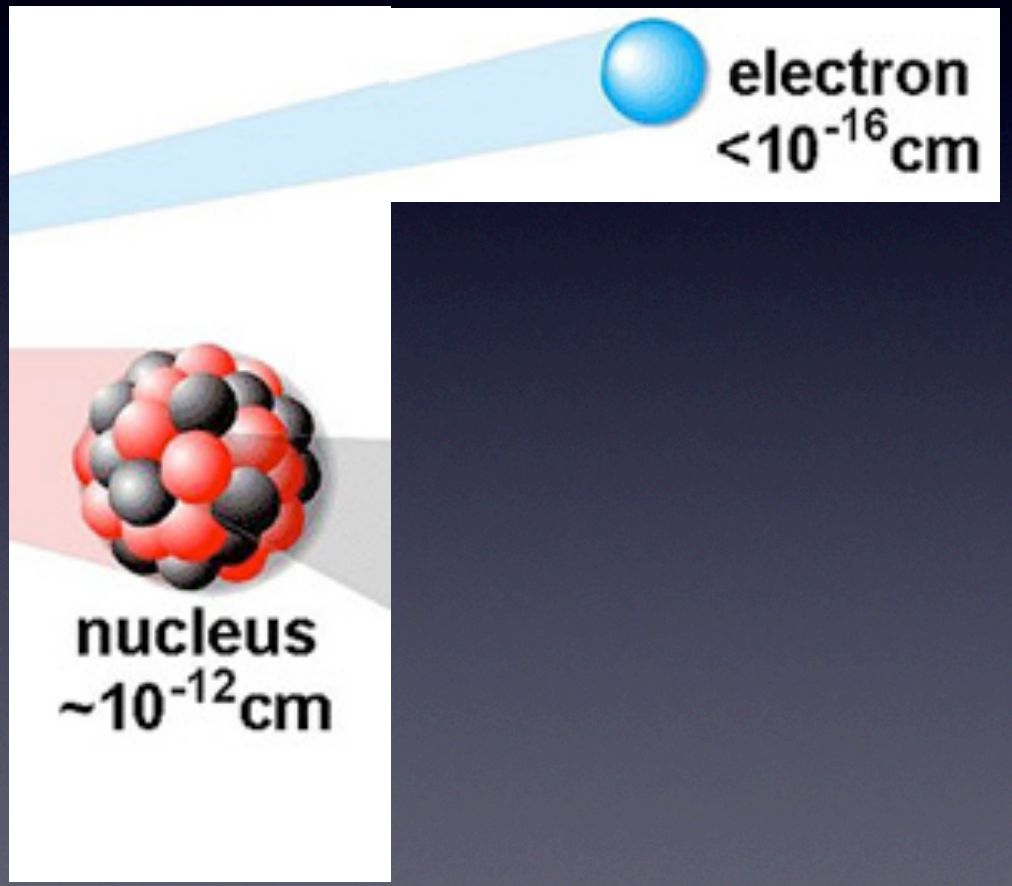
What are we made of?



The BIG questions...

What is matter made of?



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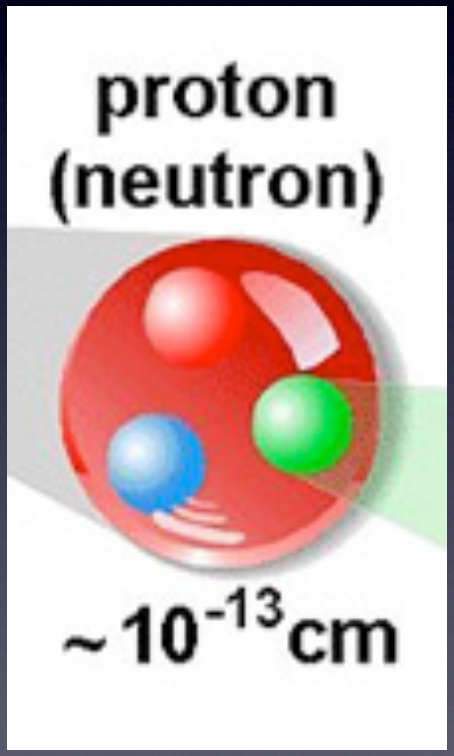

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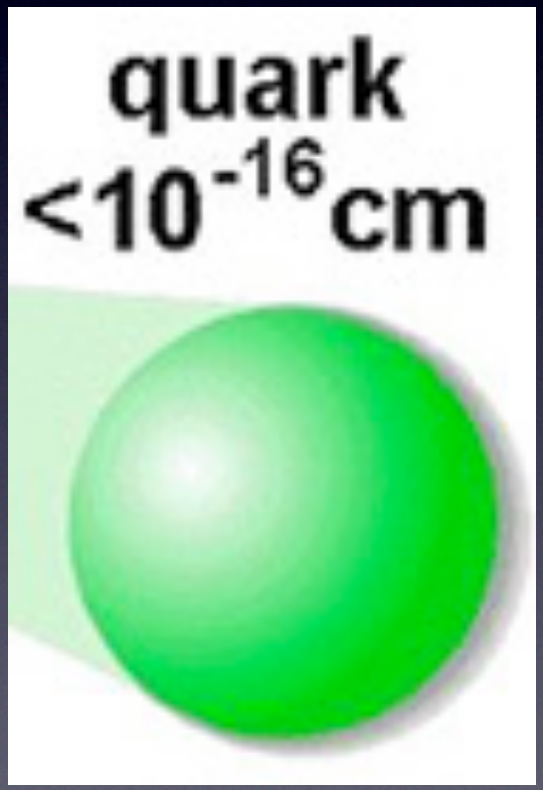


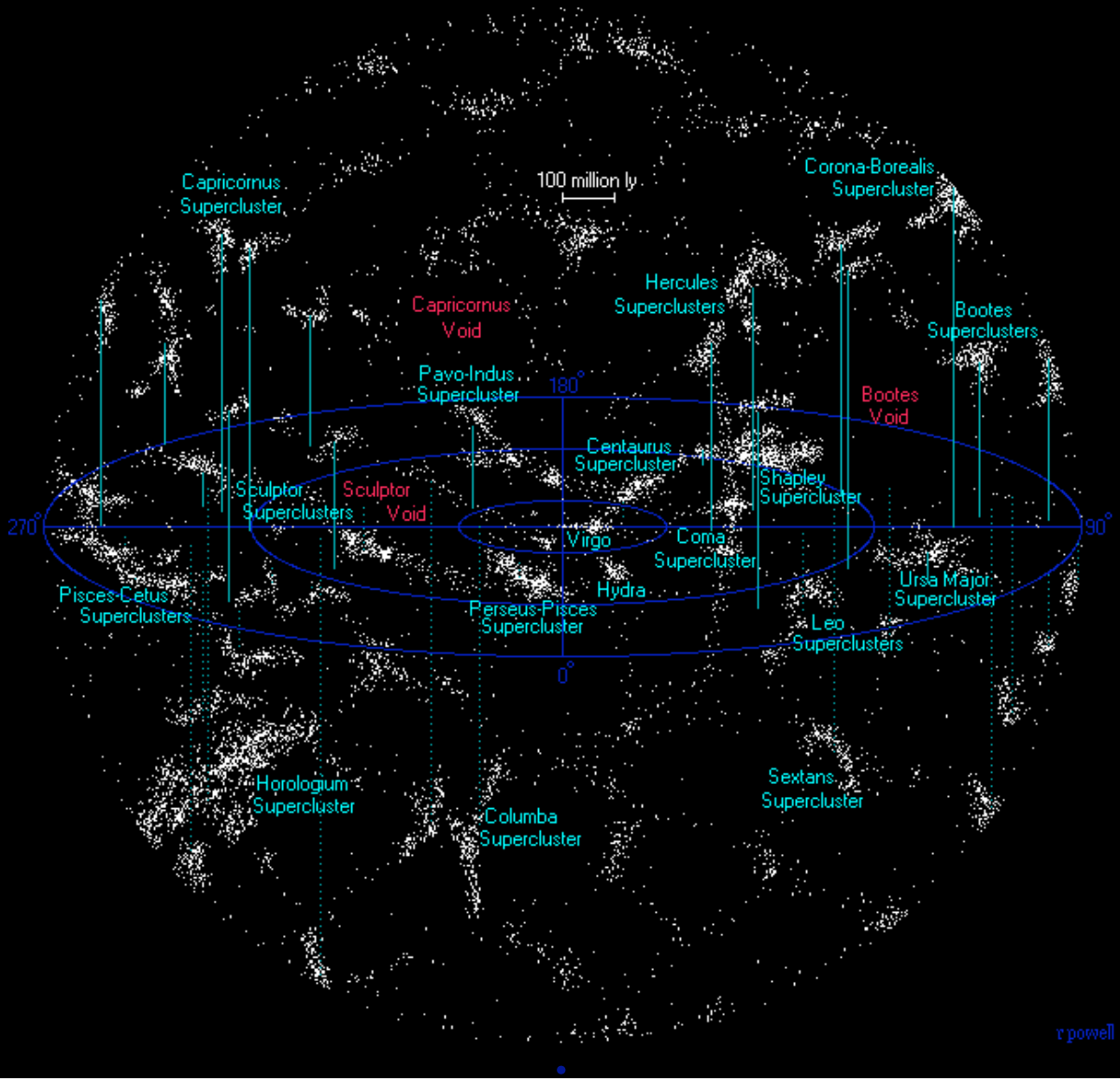
The BIG questions...

What is matter made of?

The BIG questions...

What is the Universe made of?

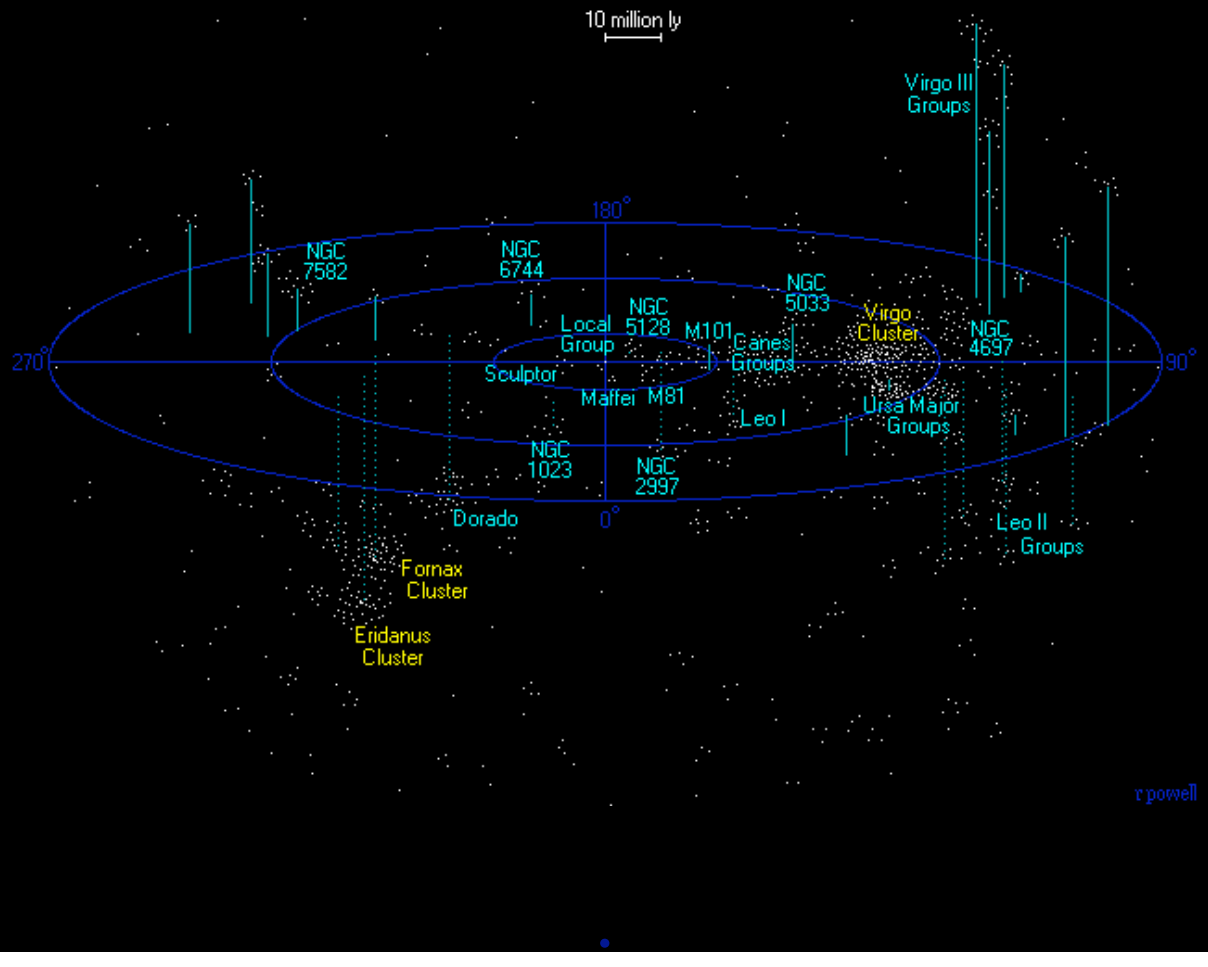
1 billion light years



The BIG questions...

What is the Universe made of?

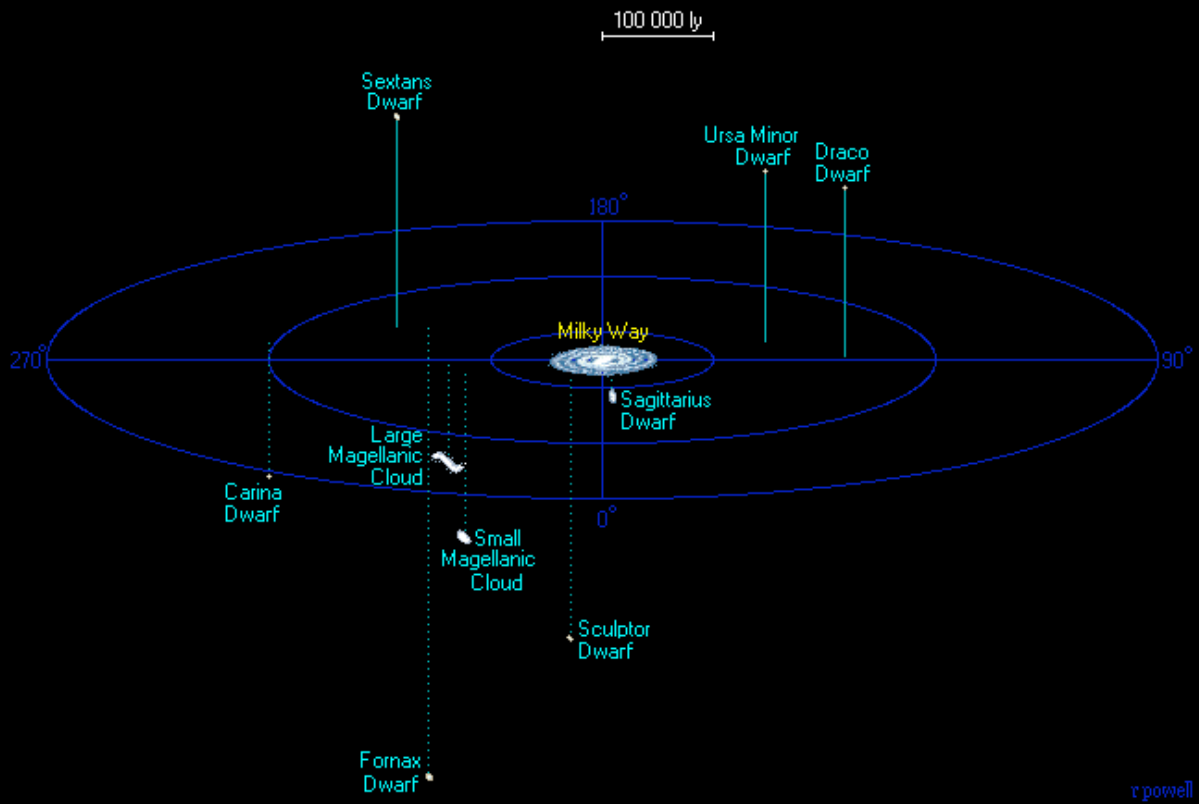
100 million light years



The BIG questions...

What is the Universe made of?

1 million light years



The BIG questions...

What is the Universe made of?

100000
light years

The BIG questions...

How does it all fit together?

The BIG questions...

for LHC:

What are we made of?

How do particles get mass?

What is the Universe made of?

What is dark matter?

How does it all fit together?

Do the forces unify?

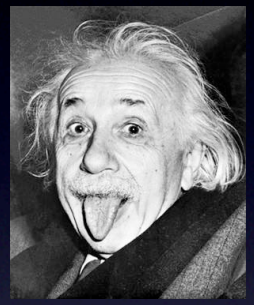
Part I

How do particles get mass?

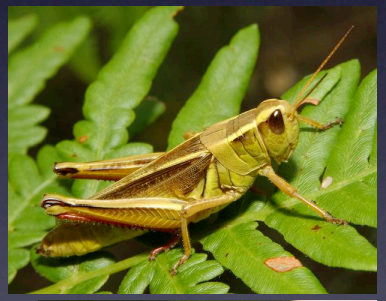
Over the last century, particle physicists have found elementary particles with a huge range of mass:

Animal Kingdom

100 humans

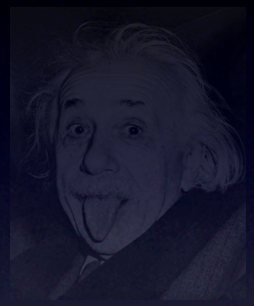


1 human



10^{-6} humans = 0.000001 humans

10^{-10} humans = 0.0000000001 humans



Particle Kingdom

top quark	180 protons
proton	1 proton
electron	10^{-3} protons
neutrino	10^{-10} protons

Just like all animals started from a tiny cell and grew....

The Universe began very hot and very small

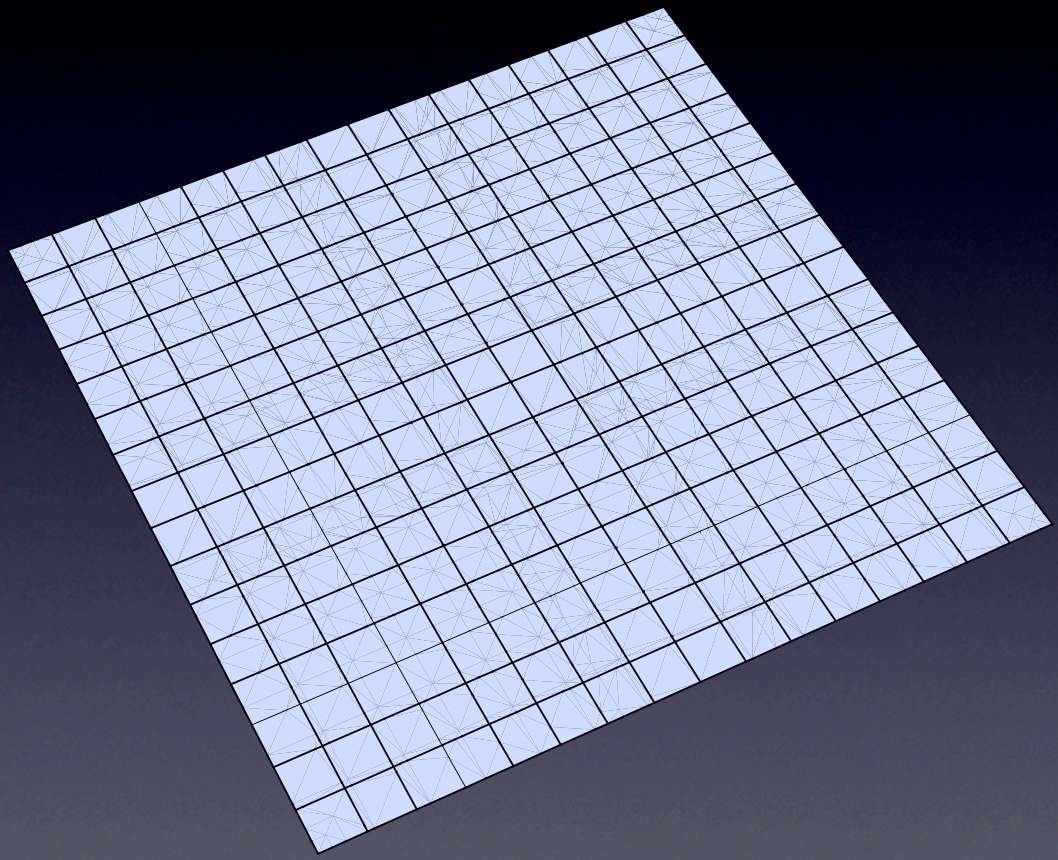
All particles were without mass

After it cooled, the Universe underwent a "phase transition" after which almost all particles became massive

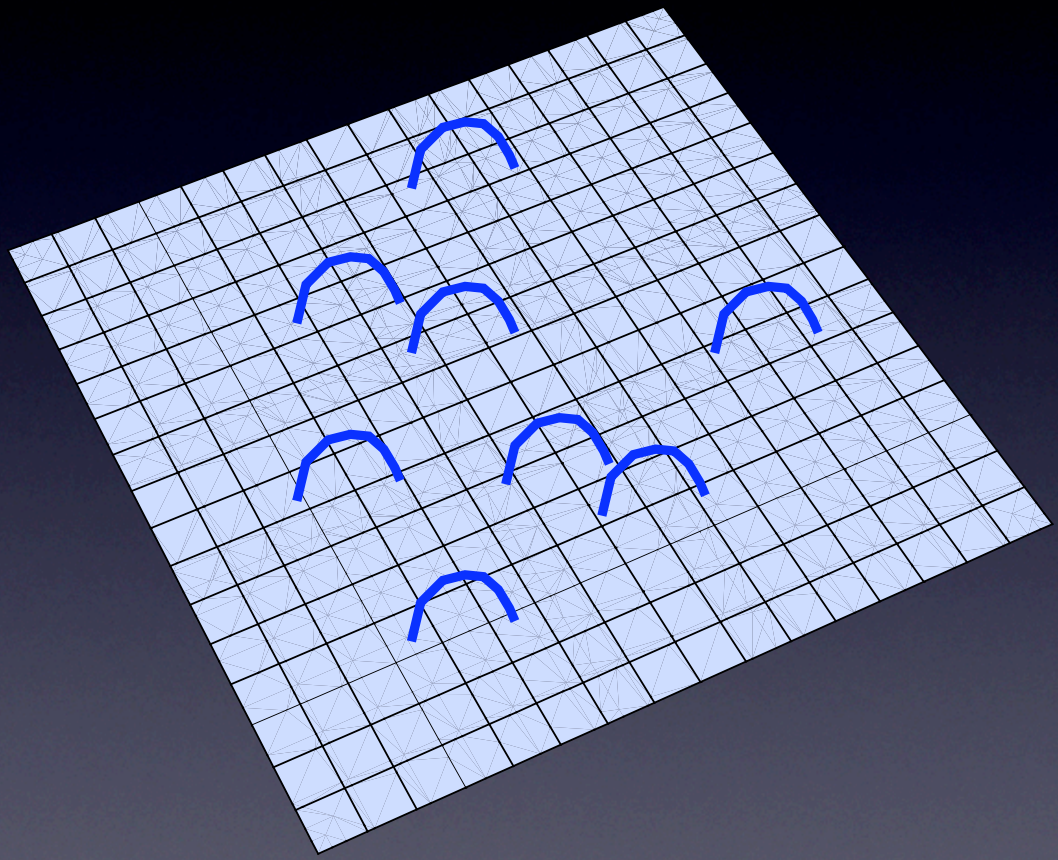
Hot gas →

Hot gas → Liquid water → Cold ice

In the early Universe, *empty space itself* underwent a kind of phase transition.

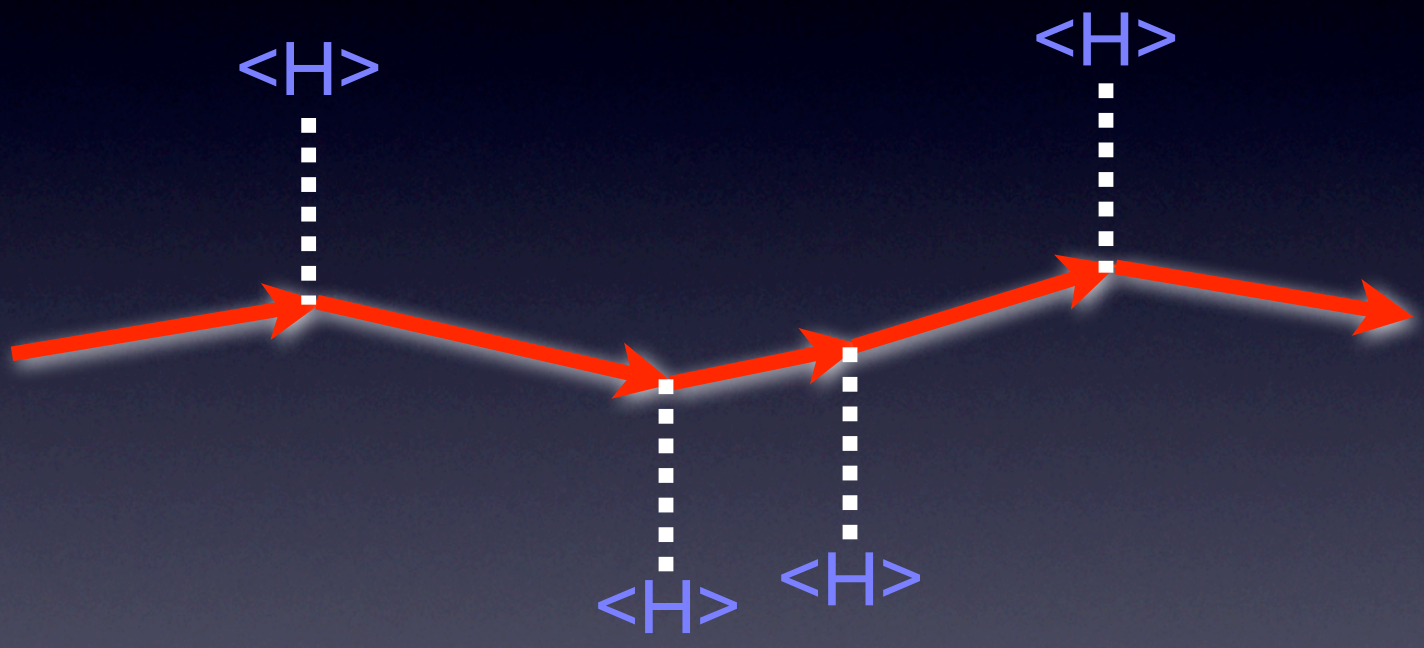


This is because empty space
is not empty at all!



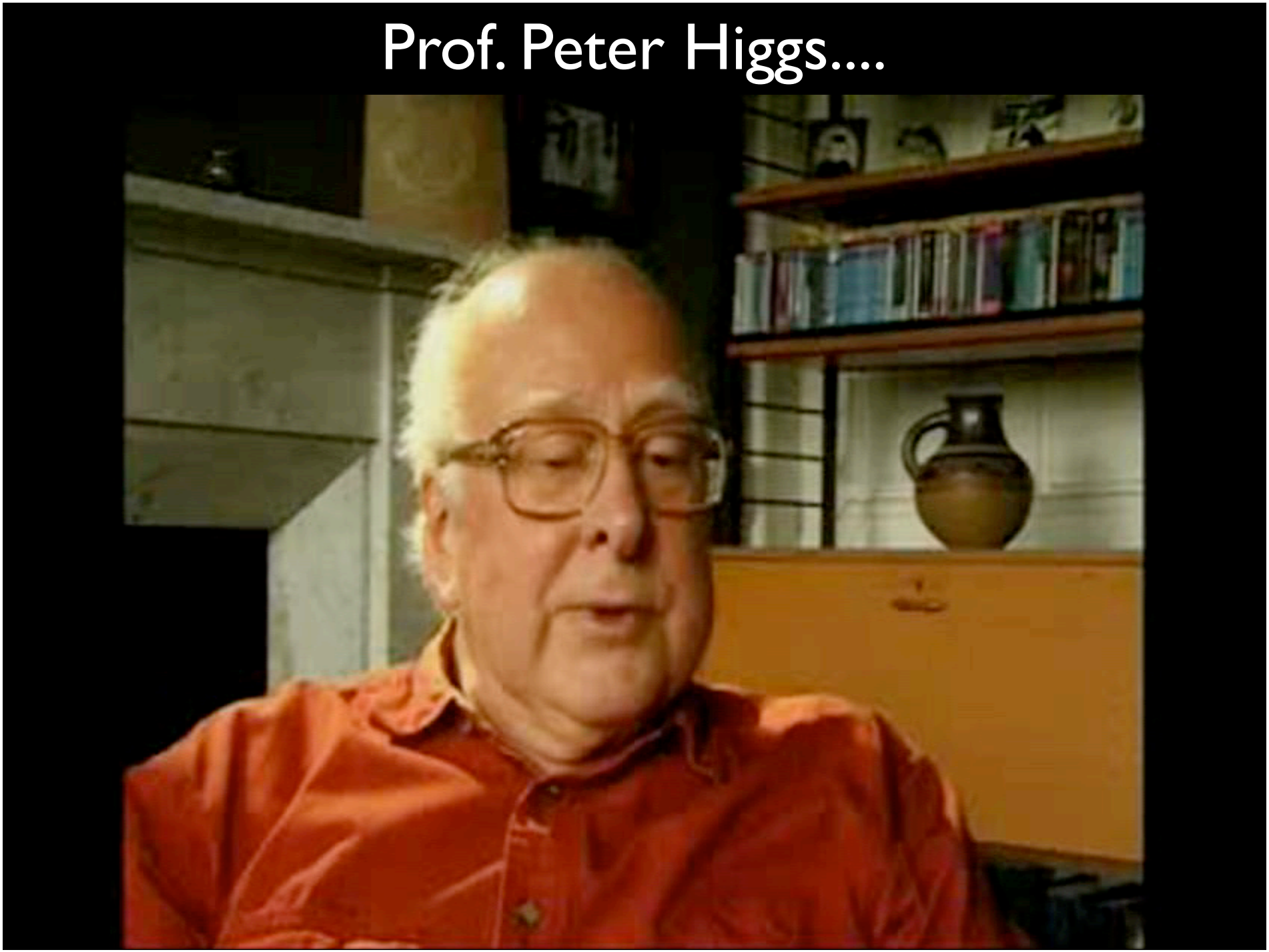
It is filled with a sea of "virtual particles"

Massive particles "feel" the phase transition of empty space by bumping into virtual particles



called "Higgs bosons"

Prof. Peter Higgs....



The central goal of the LHC
is to find the Higgs boson.

Its discovery will revolutionize our
understanding of one of the most
basic quantities of physics: MASS!

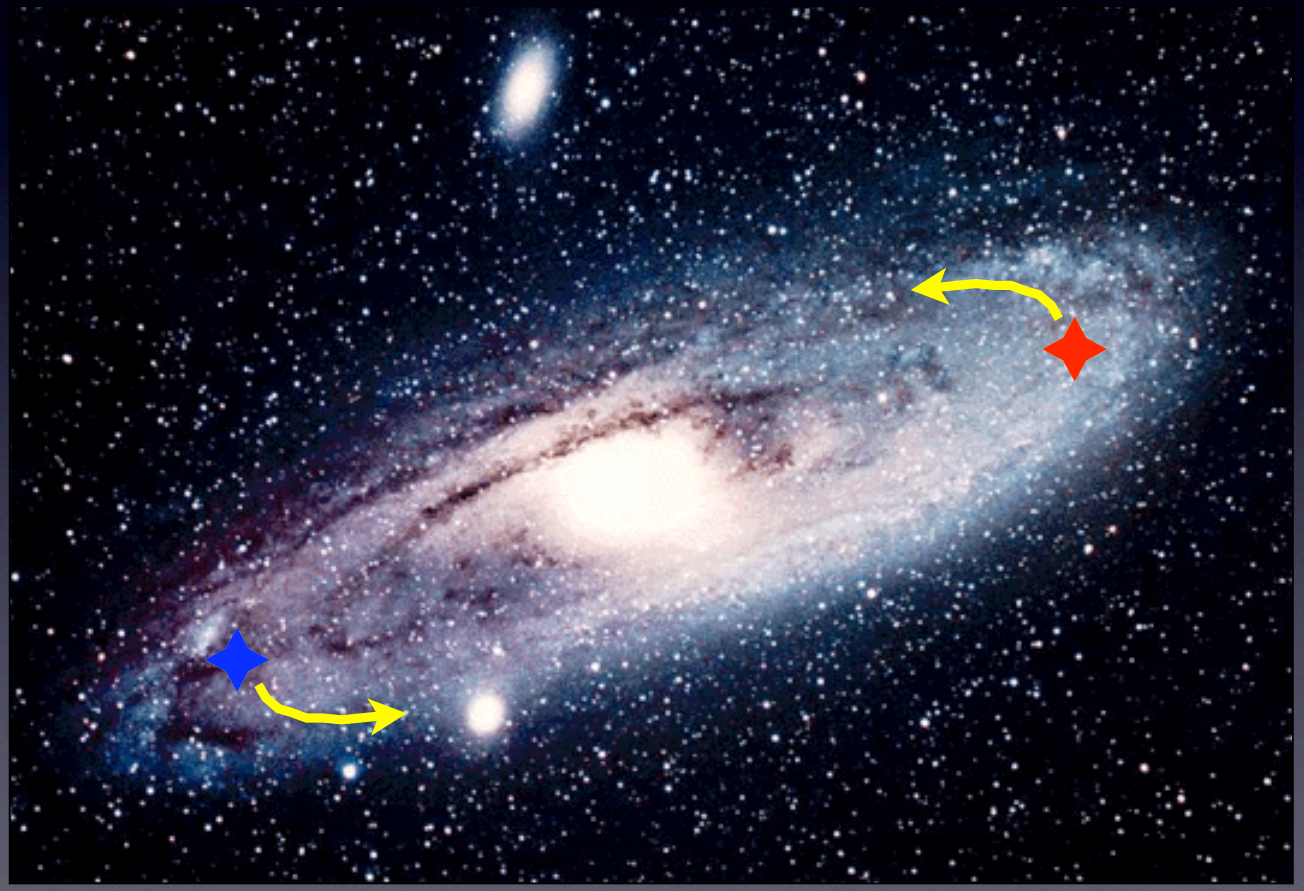
Part II

What holds galaxies together?

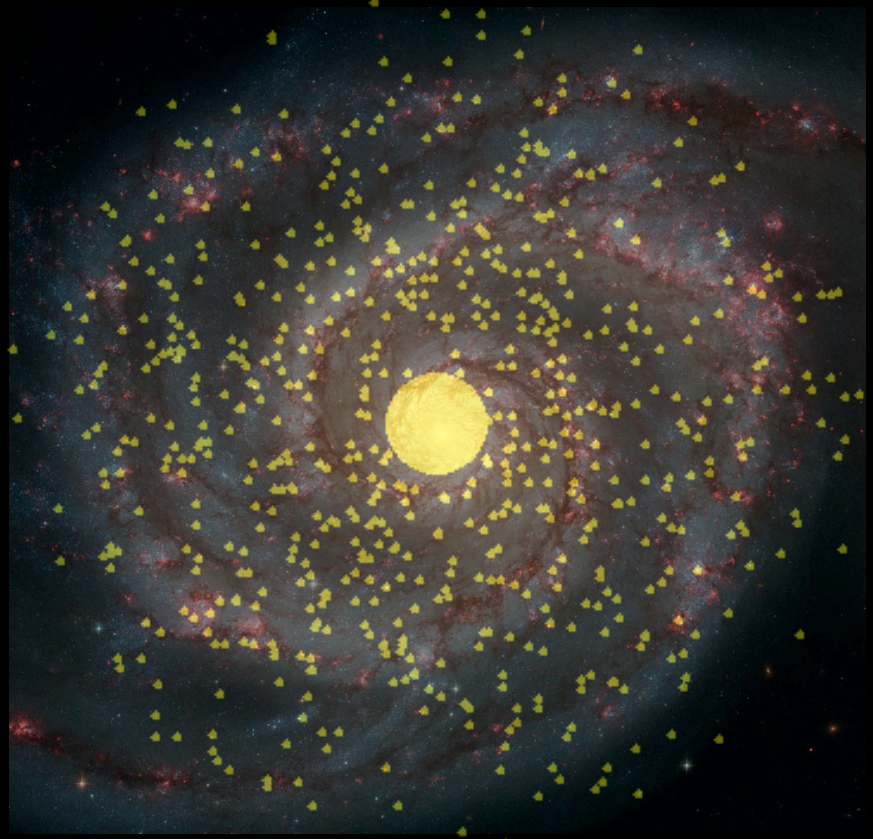
What is dark matter?

Vera Rubin pioneered observations of galactic motion

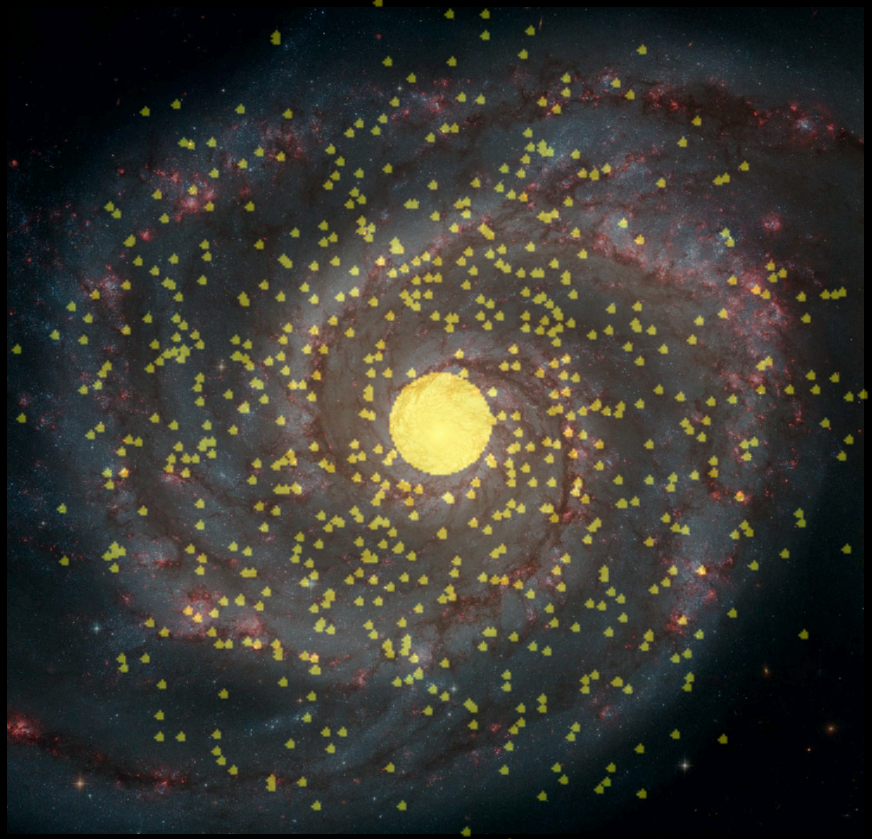
Velocities of spiral arms determined through light "blue-shifting" or "red-shifting"



Expected...



Actually observed...

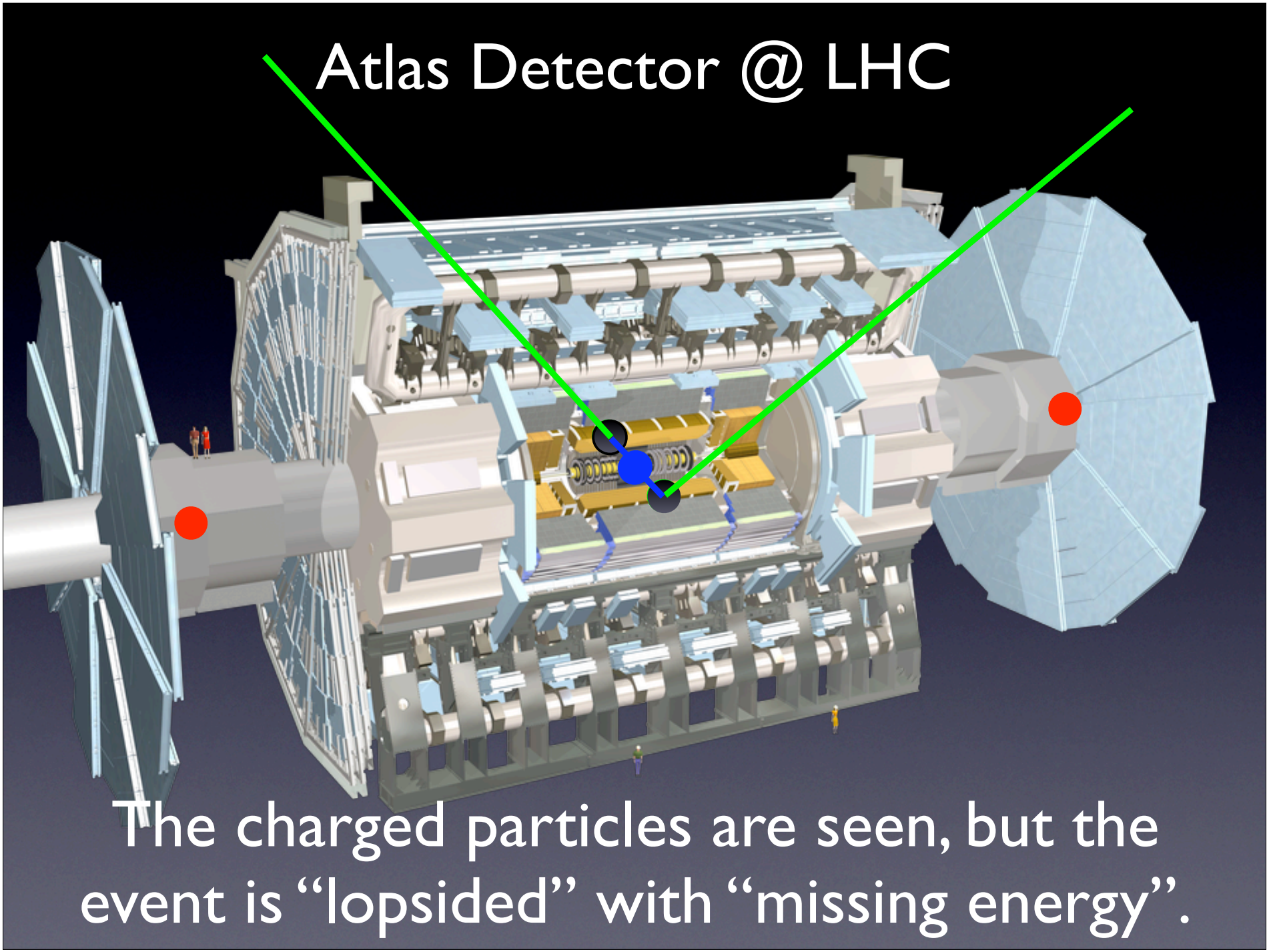


Missing Mass: Dark Matter

We think dark matter is made of heavy, weakly-interacting particles

But if dark matter is so dark, how could the LHC see it?

Atlas Detector @ LHC



The charged particles are seen, but the event is “lopsided” with “missing energy”.

Goals of LHC: Wrapup

Higgs boson: origin of mass

Dark Matter: holds galaxies and Universe together

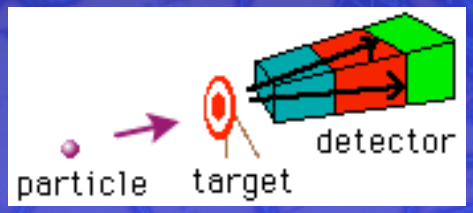
New Physics: search for the unknown!


How do we see
any of this?

Particle Physics Experiments

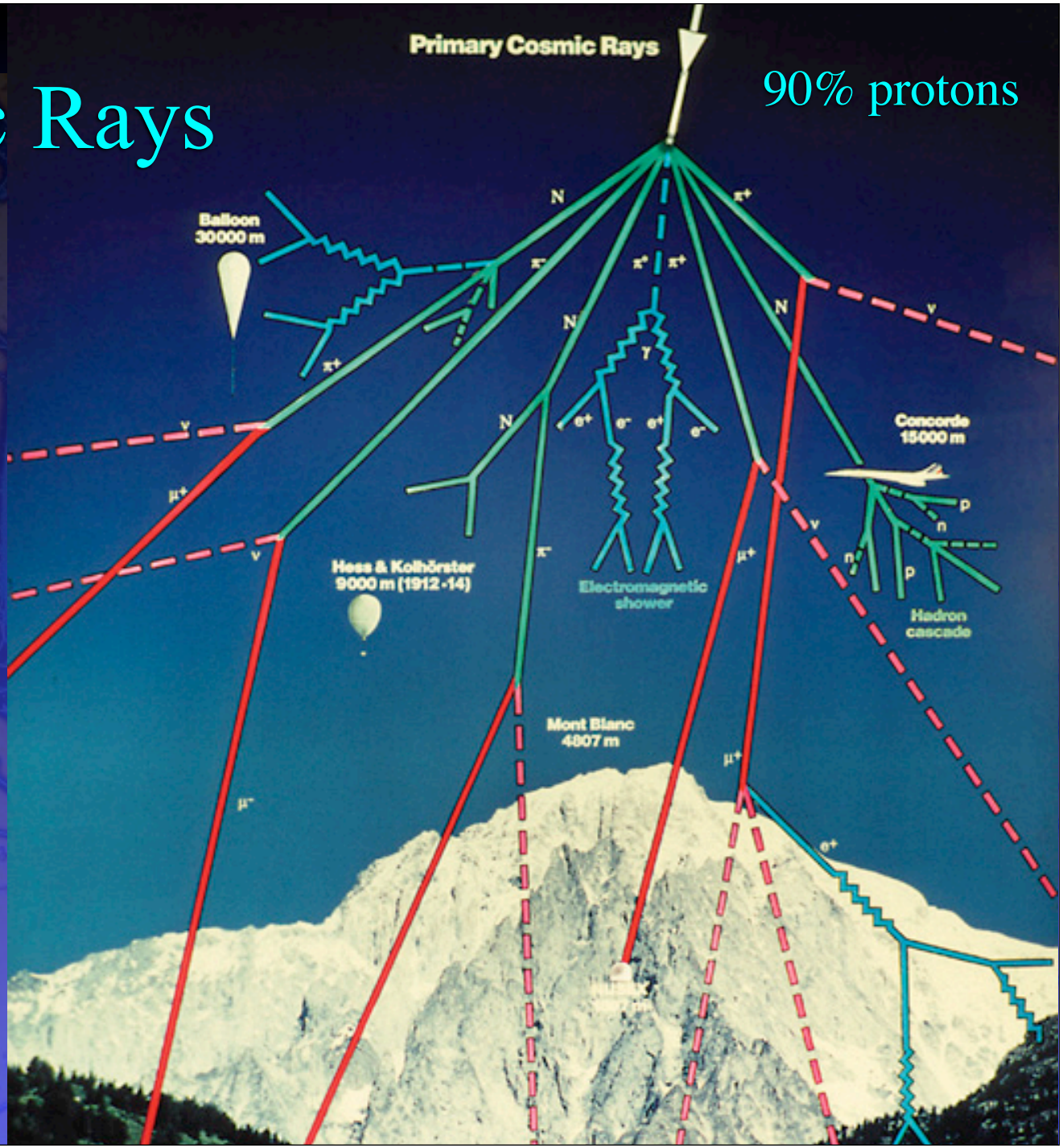
- Source of High Energy Particles
- Target to collide with
- Detector to see the results

Fixed Target



Colliding Beam

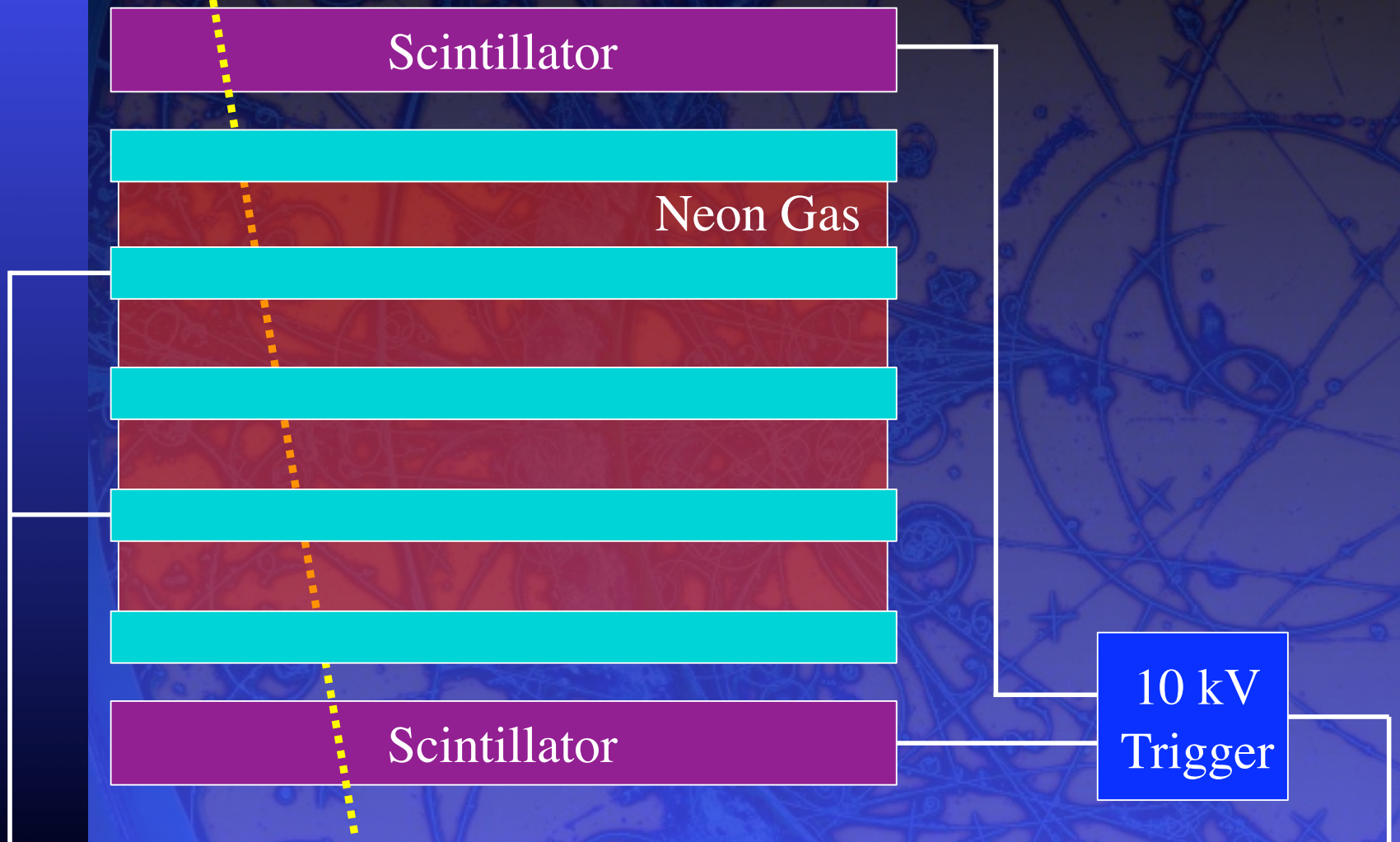
Cosmic Rays



Discovered 1912
by Victor Hess

Mostly muons
at sea level

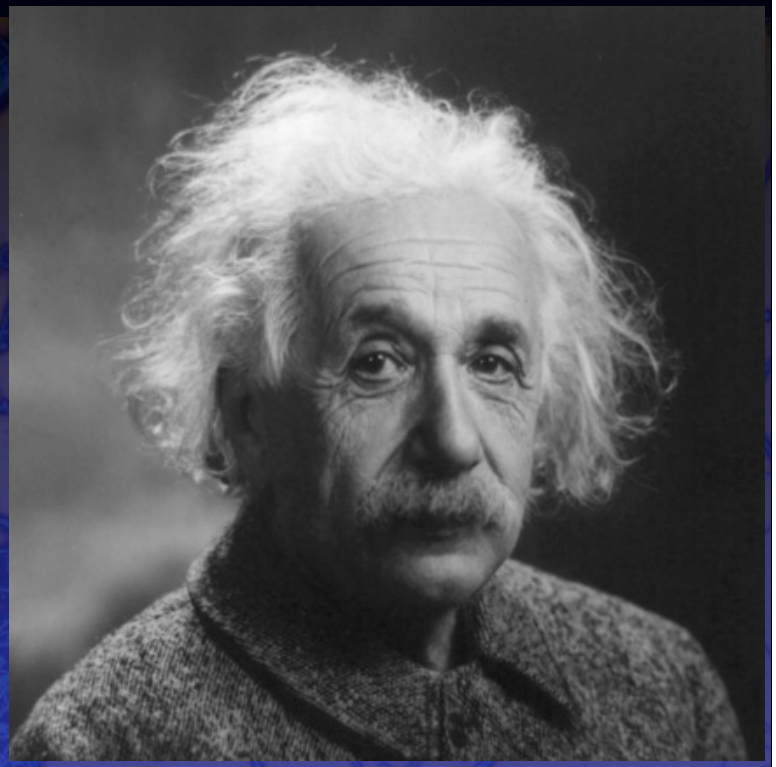
Spark Chamber



Built by Matt Langston - University of Oregon student

Why High Energy?

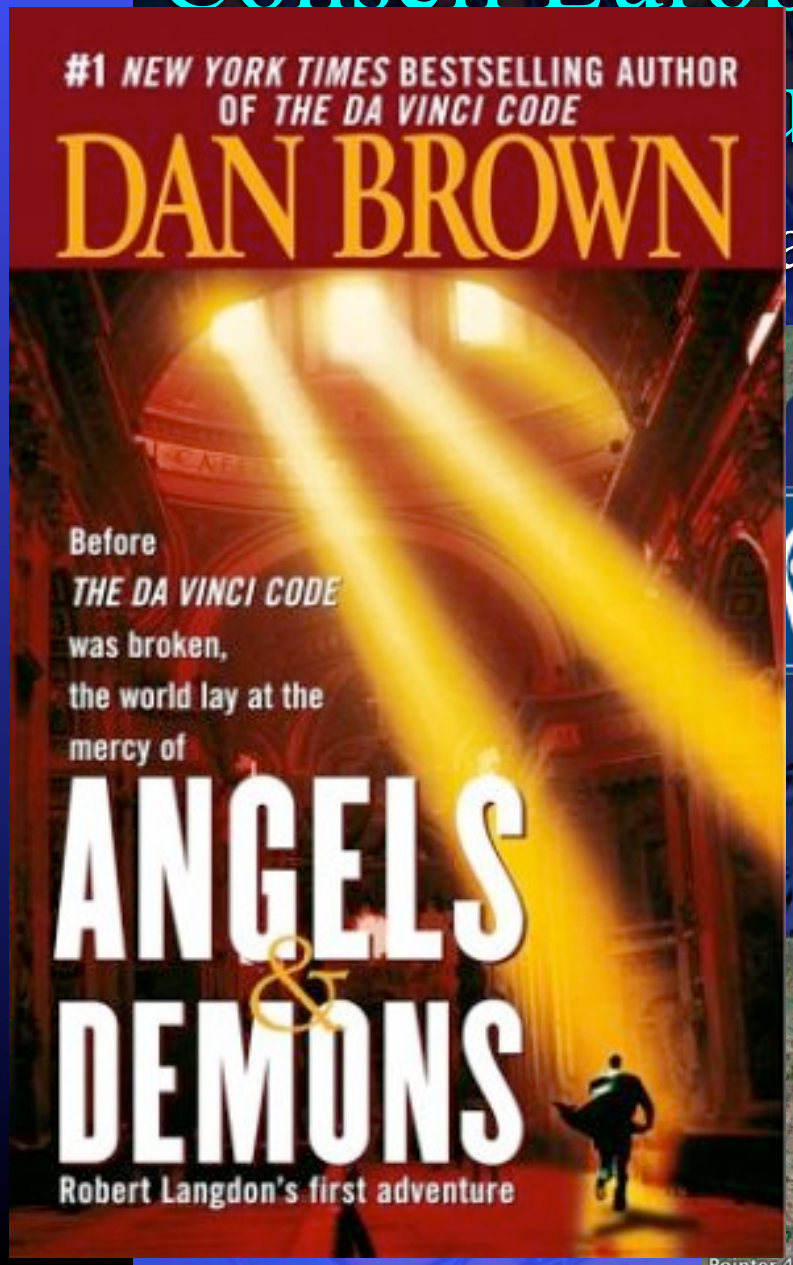
$$E = mc^2$$



High Energy $\longrightarrow$ High Mass

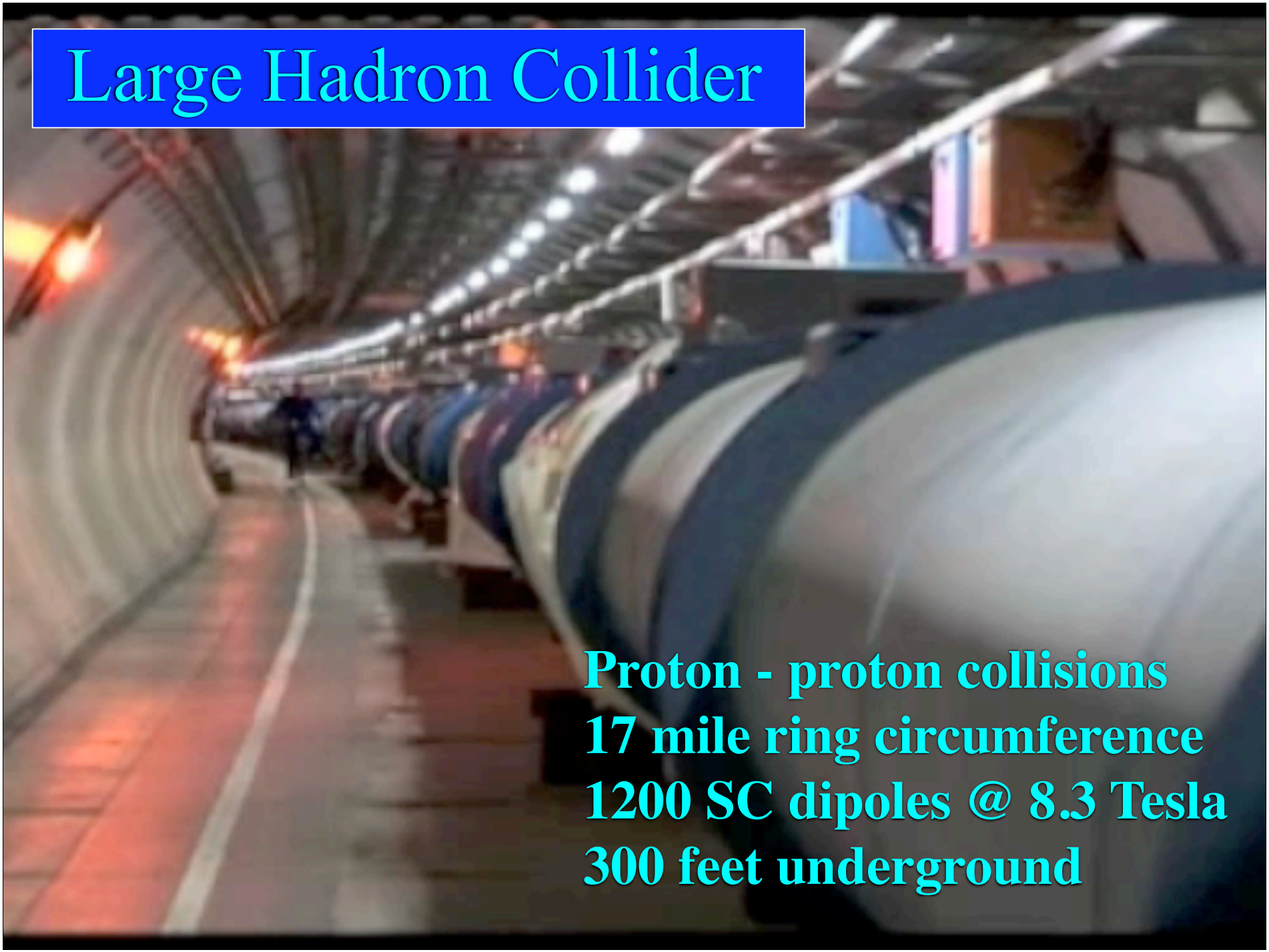
Conseil Européen pour la ucléaire (CERN)

atory for Particle Physics)

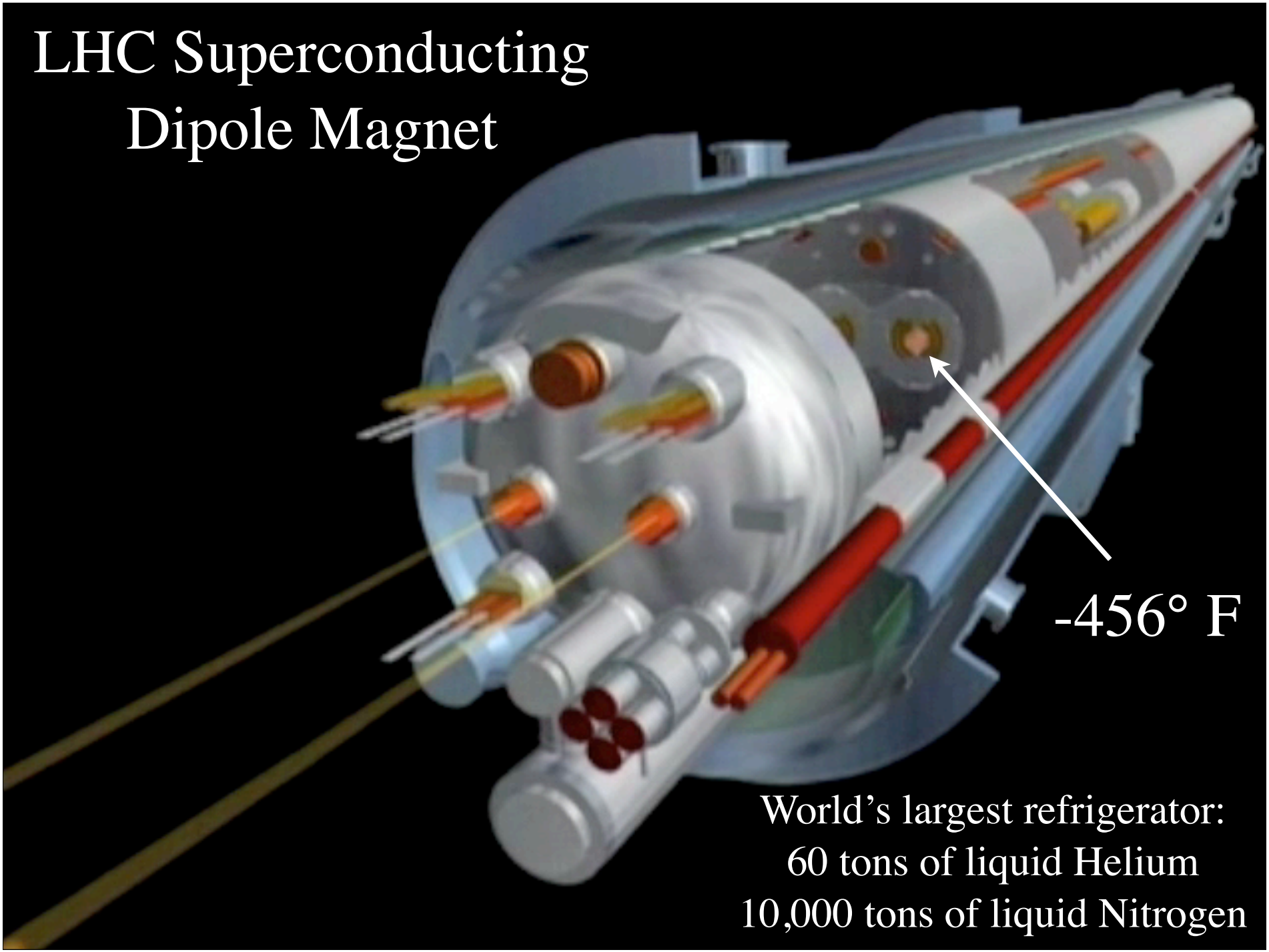



ATLAS

Large Hadron Collider



LHC Superconducting Dipole Magnet



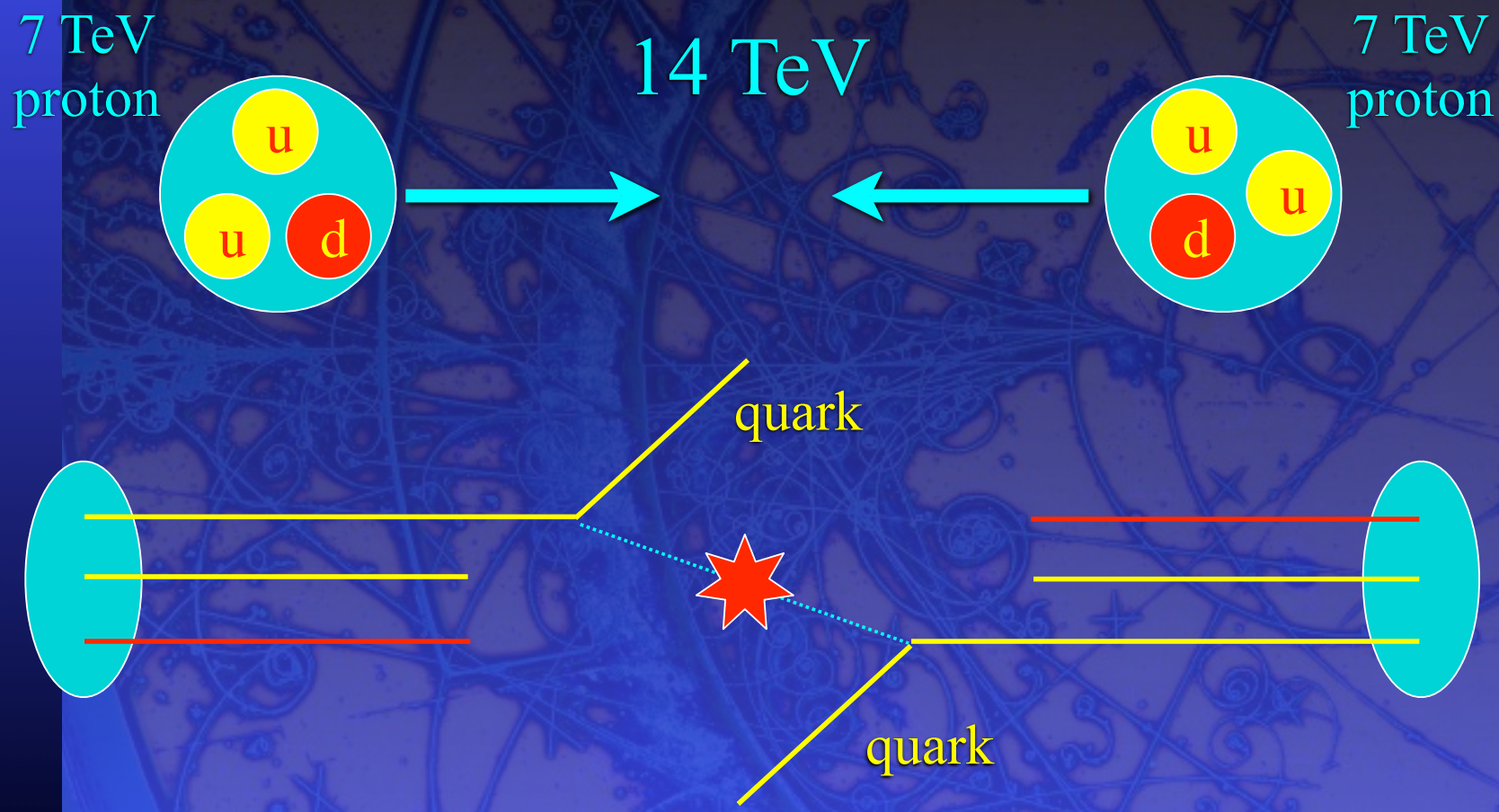
World's largest refrigerator:
60 tons of liquid Helium
10,000 tons of liquid Nitrogen

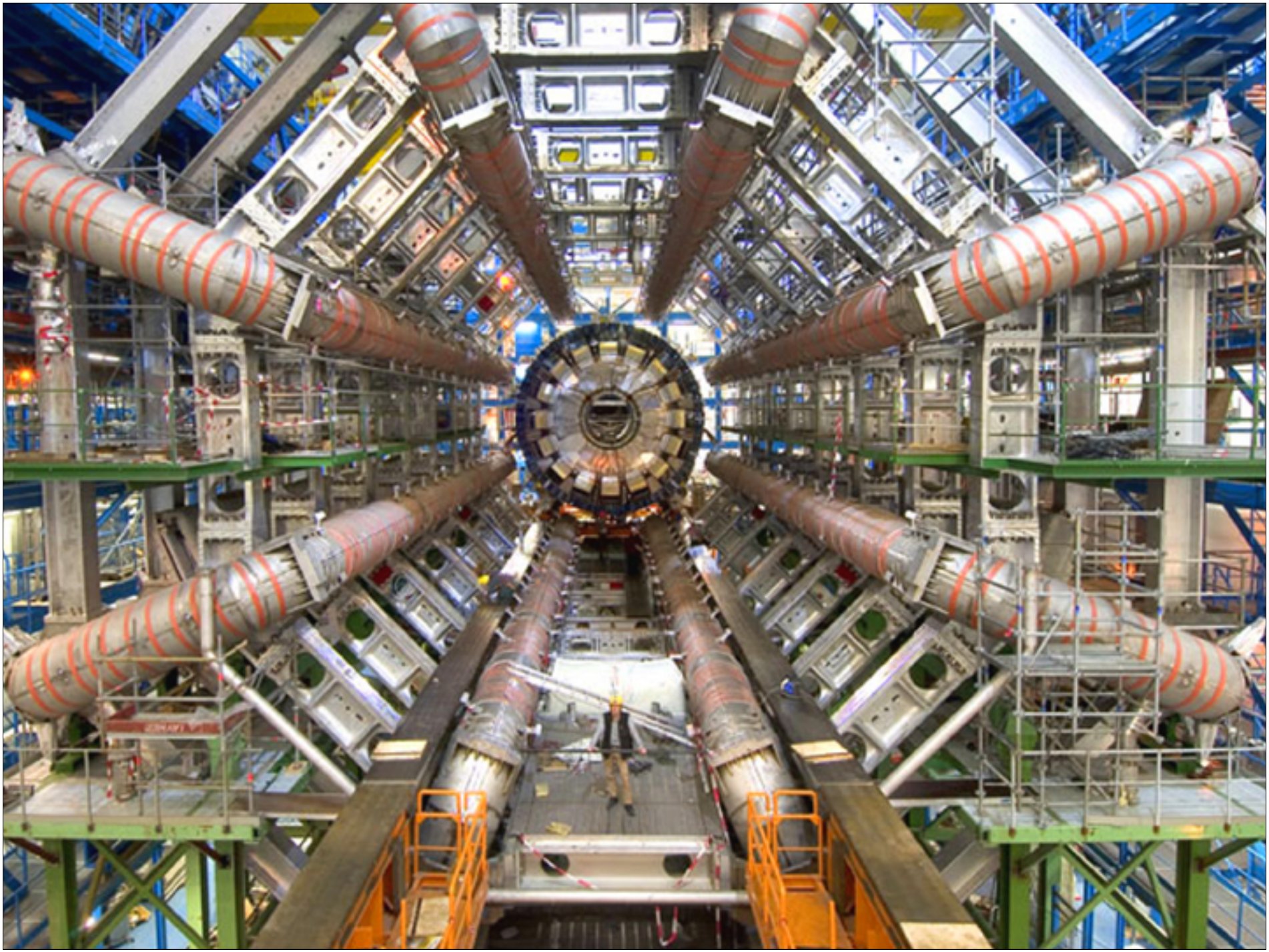
What is 14 Tera-electronVolts?

- 14 TeV = 14,000,000,000,000 eV
- 14 TeV = 14,925 proton mass
- 7 TeV proton travels at 99.9999991% c
- LHC Beam stores 700 MegaJoules
  (enough energy to melt 1000 lb of copper)

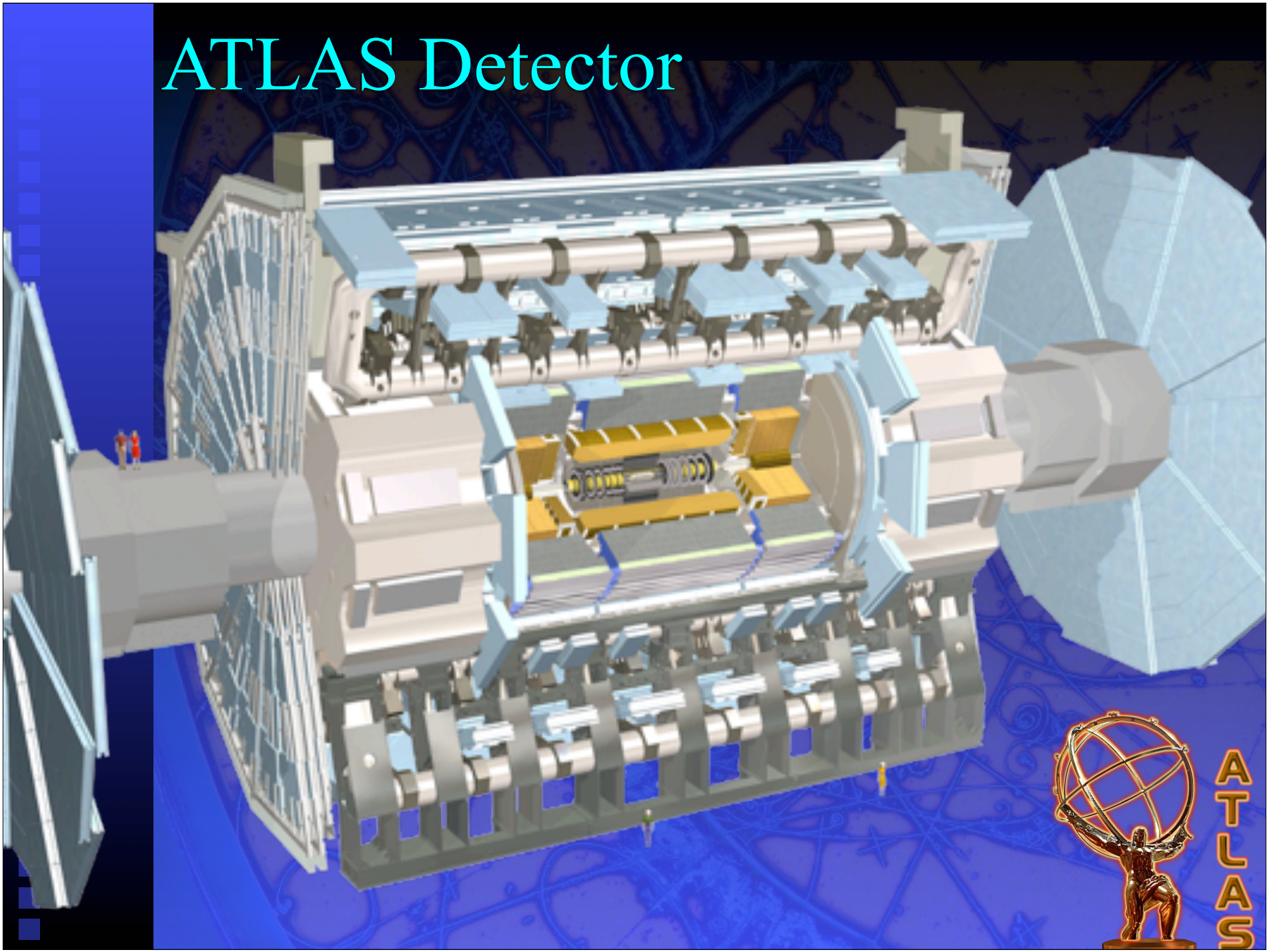
300 MegaJoules

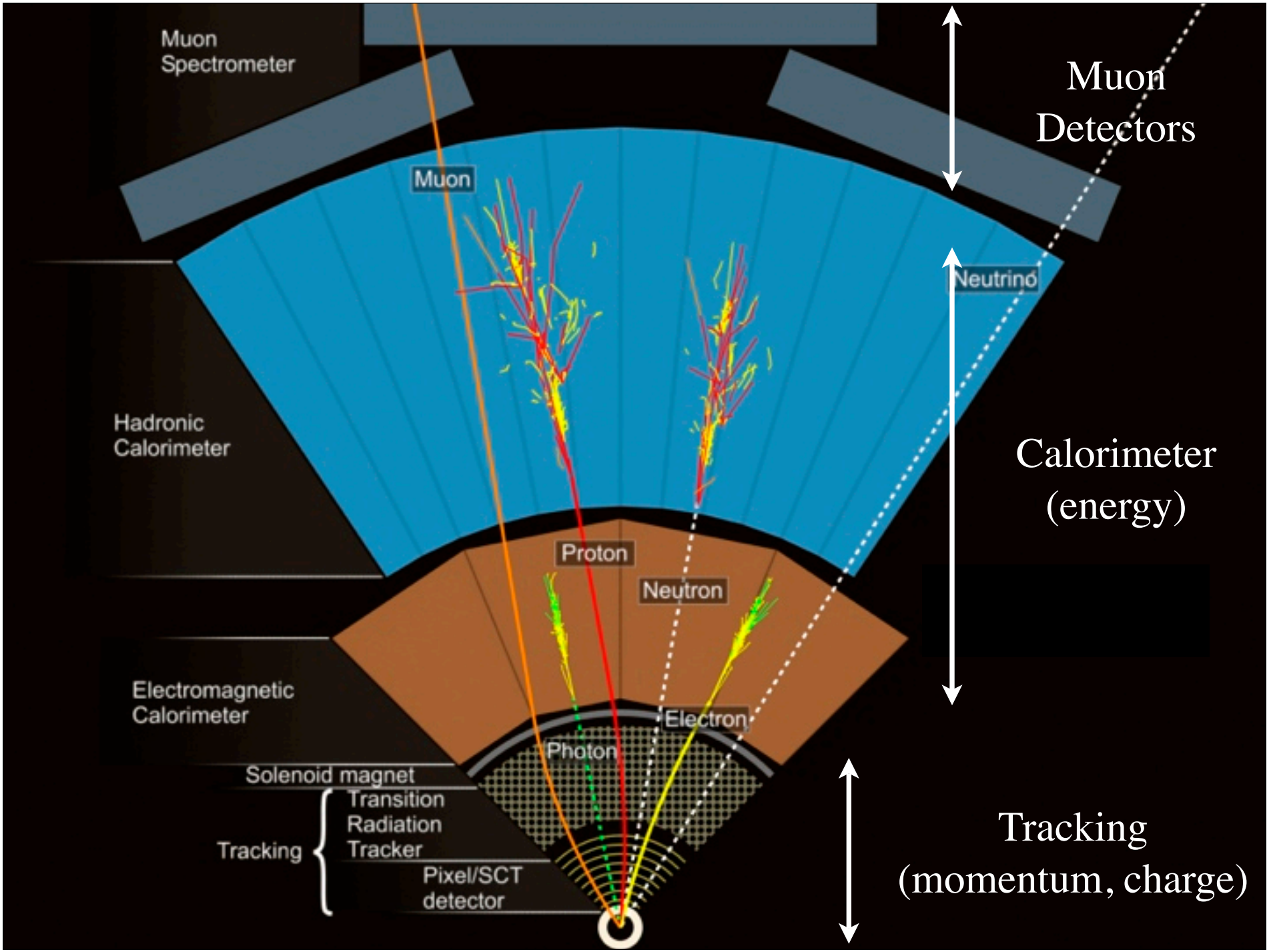
Quark Collider!

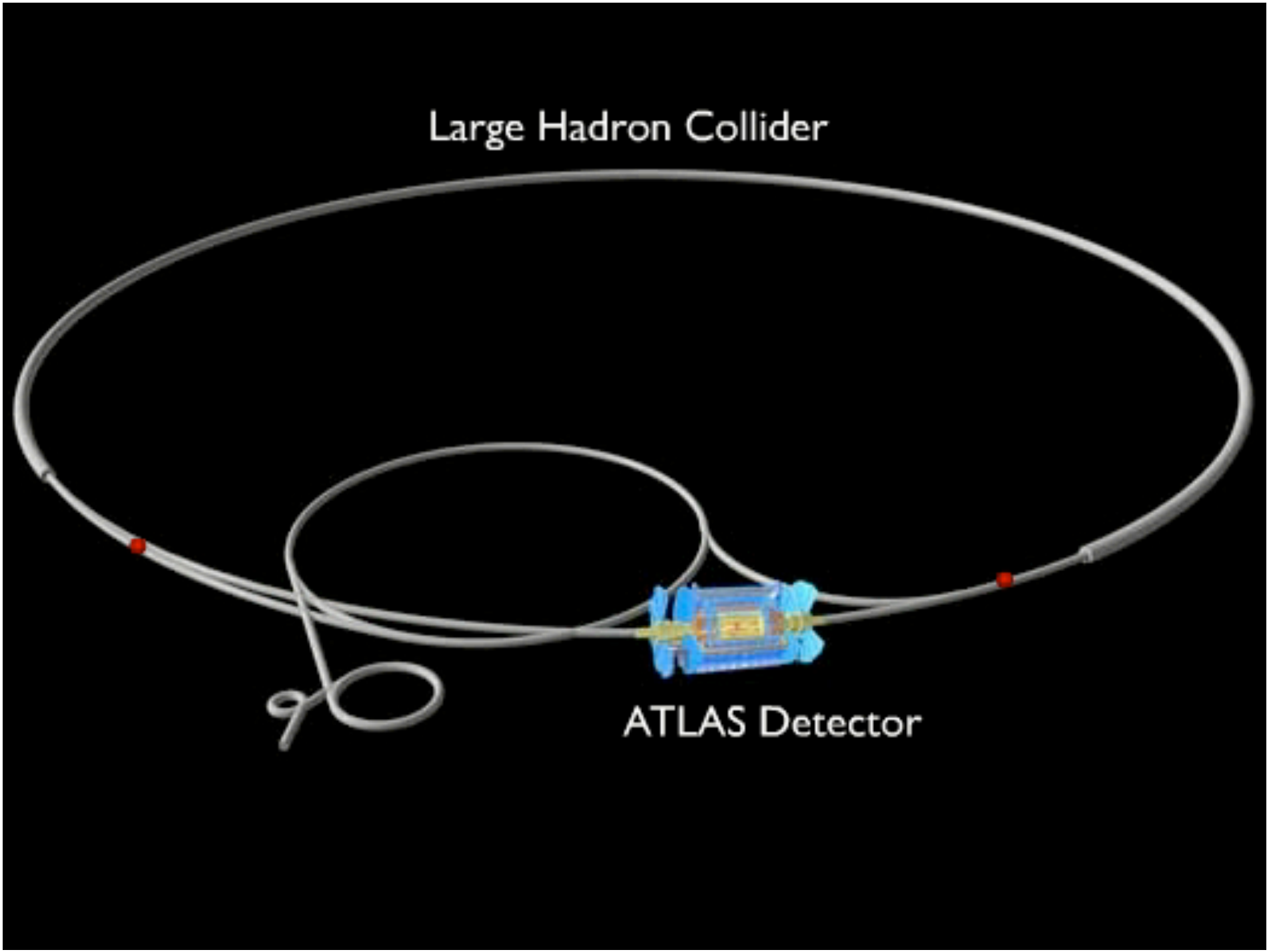


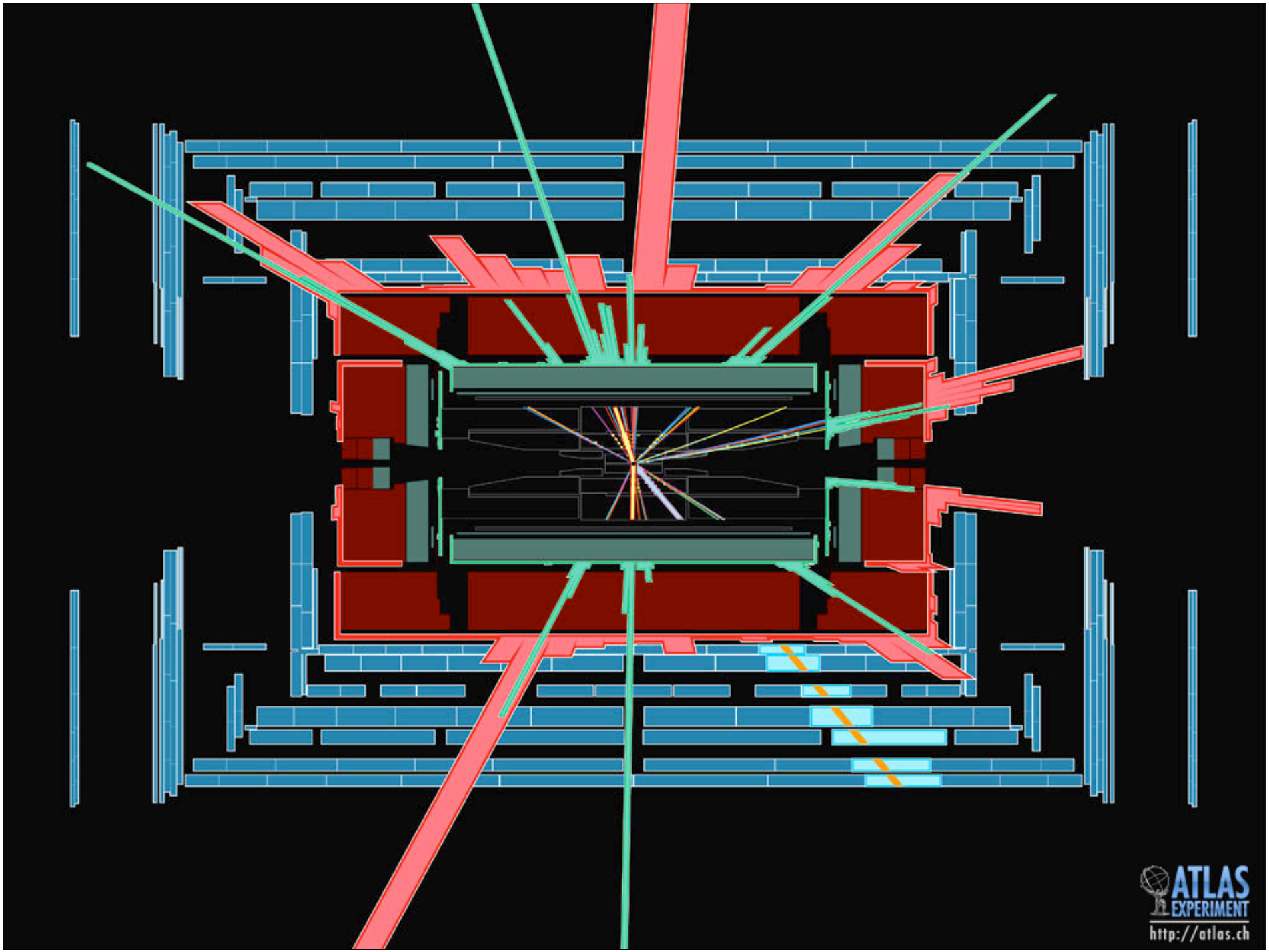


ATLAS Detector

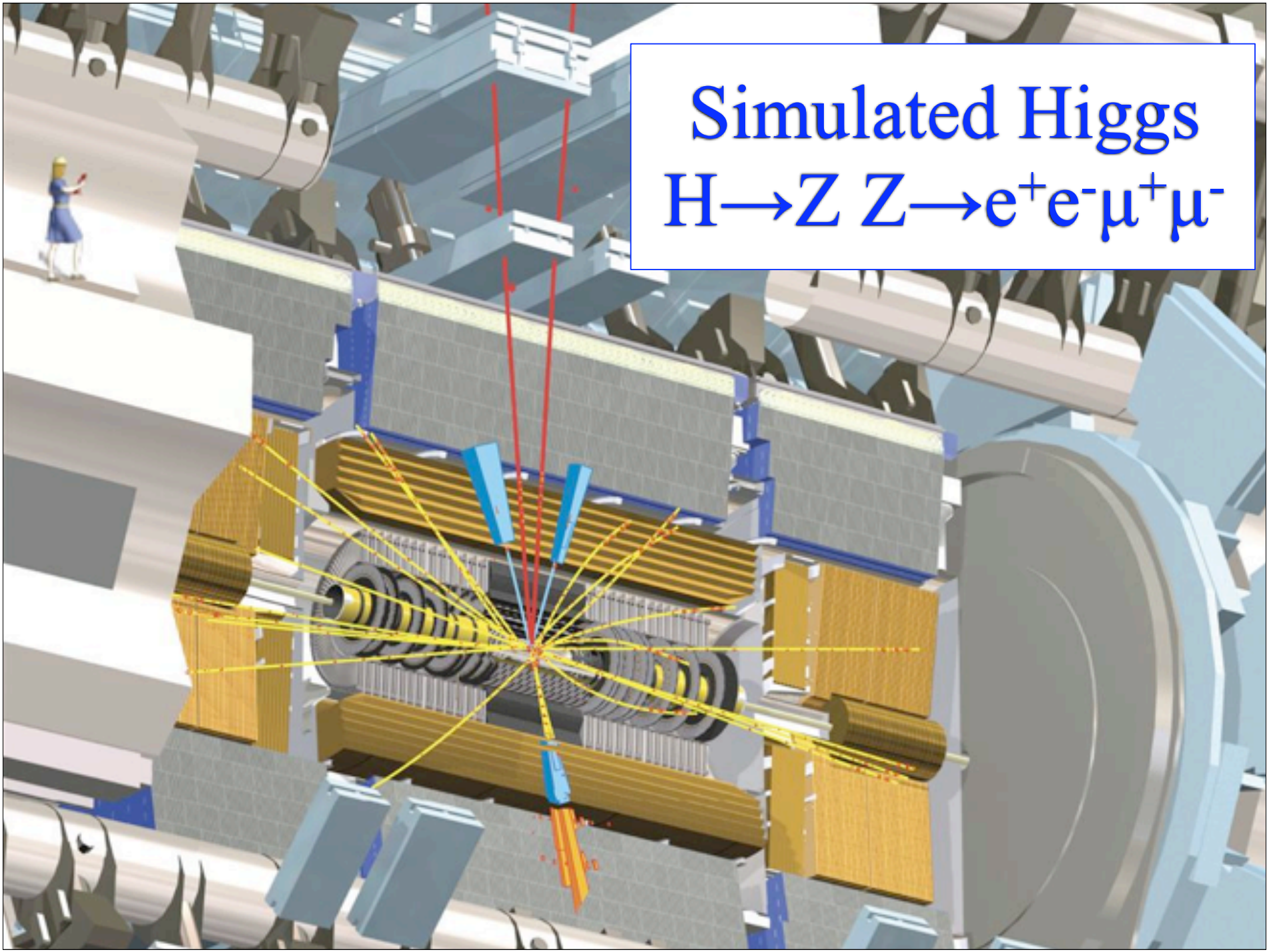


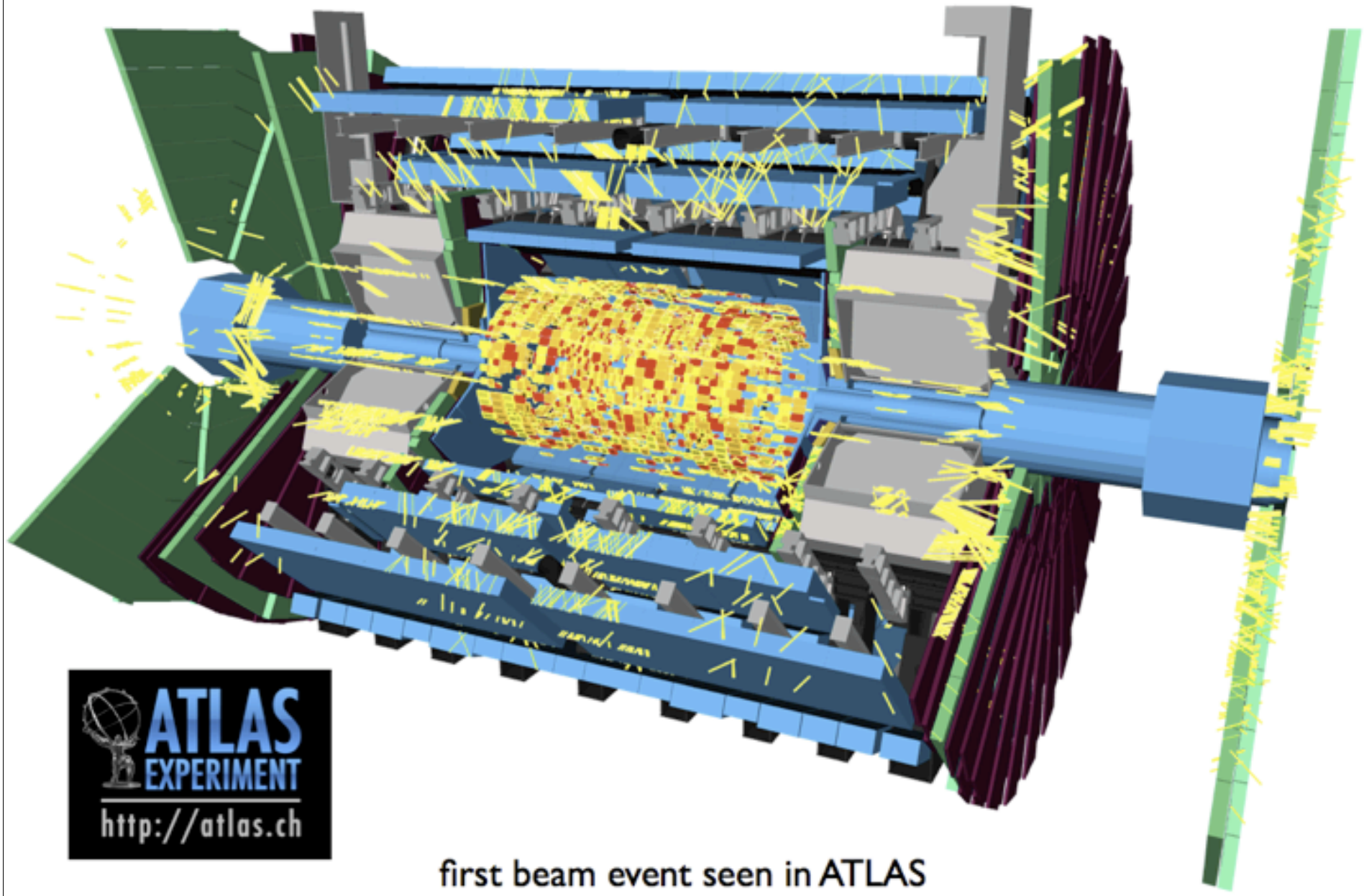

Muon
Spectrometer
Muon
Detectors
Muon
Neutrino
Hadronic
Calorimeter
Calorimeter
(energy)
Proton
Neutron
Electromagnetic
Calorimeter
Electron
Photon
Solenoid magnet
Transition
Radiation
Tracker
Tracking
Pixel/SCT
detector
Tracking
(momentum, charge)


Large Hadron Collider
ATLAS Detector


ATLAS
EXPERIMENT
http://atlas.ch

Data Processing


Simulated Higgs
H→Z Z→e+e-μ+μ-



first beam event seen in ATLAS

September 10, 2008

Comments from Around the World

LHC project leader Lyn Evans,
"It's a fantastic moment. We can now look forward to a new era of understanding about the origins and evolution of the universe."

Nigel S. Lockyer, Director of Canada's TRIUMF laboratory.
"One short trip for a proton, but one giant leap for mankind! TRIUMF, and indeed all of Canada, is delighted to bear witness to this amazing feat."

Atsuto Suzuki, Director of Japan's KEK laboratory,
"This is a historical moment."

Vinod C. Sahni, Director of India's Raja Ramanna Centre for Advanced Technology
"It has been a fascinating and rewarding experience for us."

Pier Oddone, Director of Fermilab.
"The completion of the LHC marks the start of a revolution in particle physics."

United Nations Secretary General, Ban Ki-moon,
in a recent visit to CERN
"I am very honored to visit CERN, an invaluable scientific institution and a shining example what international community can achieve through joint efforts and contribution.

I convey my deepest admiration to all the scientists and wish them all the success for their research for peaceful development of scientific progress."

J.J. Thomson, Speaking in 1934 about the Electron

"Could anything at first sight seem more **impractical** than a body which is **so small** that its mass is an insignificant fraction of the mass of an atom of hydrogen? --which itself is **so small** that a crowd of these atoms equal in number to the population of the whole world would be too small to have been detected by any means then known to science."

Credit: American Institute of Physics

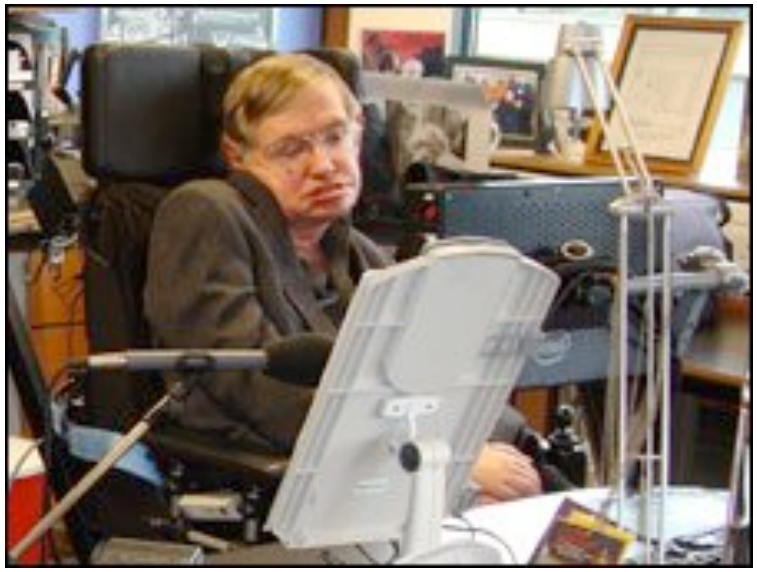
From the soundtrack of the film, Atomic Physics

Comments from Around the World

Throughout history, people have studied pure science from a desire to understand the universe, rather than practical applications for commercial gain. But their discoveries later turned out to have great practical benefits.

It is difficult to see an economic return from research at the LHC, but that doesn't mean there won't be any.

source: bbc.co.uk



Stephen Hawking

Practical Applications from Fundamental Research in Nuclear and Particle Physics

- Diagnostic Instrumentation for Medical Applications
- Cancer Therapy
- Radioactive isotopes in medicine
- Biomedicine and Drug Development
- Superconducting Wire and Cable in Magnetic Resonance Magnets and Power Transmission Lines
- Nuclear Power
- Monitoring Nuclear Waste
- Synchrotron radiation light sources
- Computing advances, the GRID
- World-wide Web


Google

The Future of the LHC

- This year - 2008
  - collide 5 TeV ⊕ 5 TeV beams
  - collect data
- Next year - 2009
  - collide 7 TeV ⊕ 7 TeV beams
  - collect data
- by 2010
  - sensitivity to discoveries of new physics
    - –Higgs boson, Dark Matter, Extra Dimensions, Microscopic Black Holes?

More HEP Information

particleadventure.org

interactions.org

www.uslhc.us

atlasexperiment.org

www.cern.ch