DISCOVERING THE QUANTUM UNIVERSE

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Physical Sciences Breakfast Lecture Series
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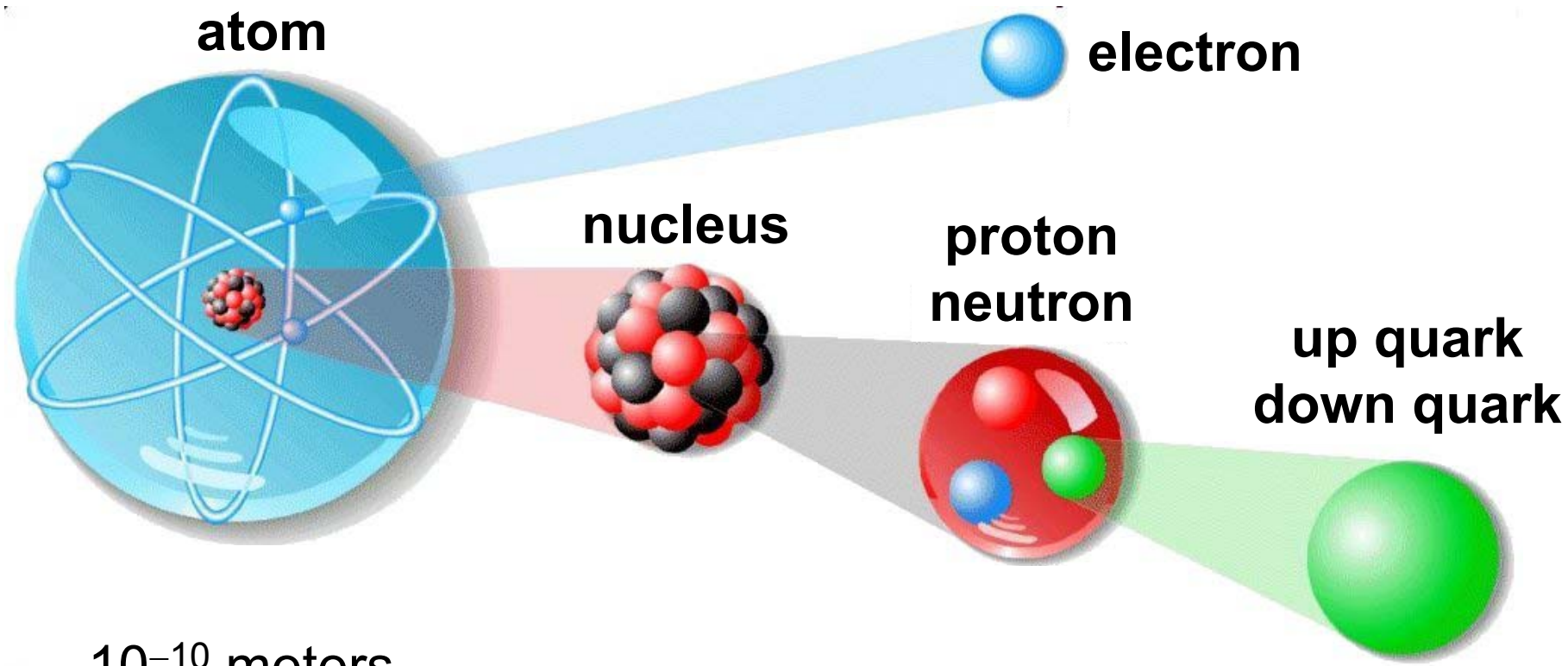
QUANTUM UNIVERSE?

- Quantum theory governs the very small (atoms).
- The Universe is very big.
- What do these have to do with each other?
- In fact, studies of the very small and the very big have become intimately related, and are the focus of an experimental program whose flagship is the Large Hadron Collider.

VERY SMALL: STATUS REPORT

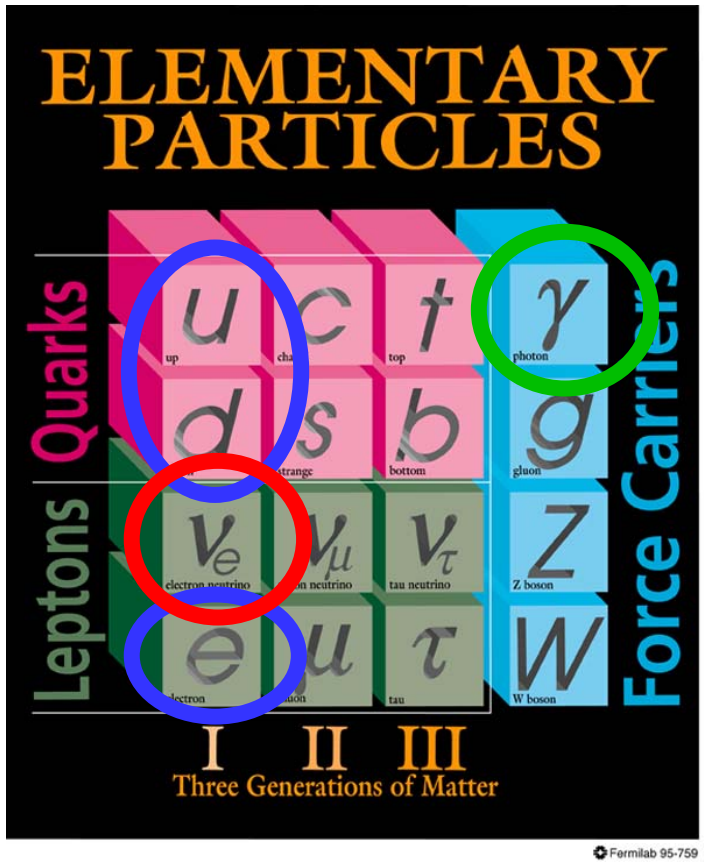


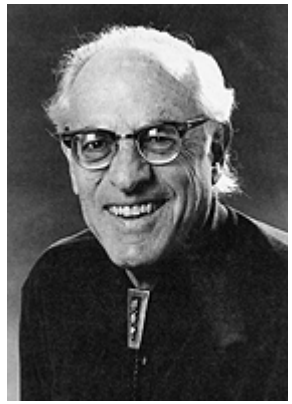
10^{-10} meters (thickness of human hair ~ 10^{-5} m)	10^{-14} meters	10^{-15} meters	$< 10^{-18}$ meters

BASIC BUILDING BLOCKS

Atoms

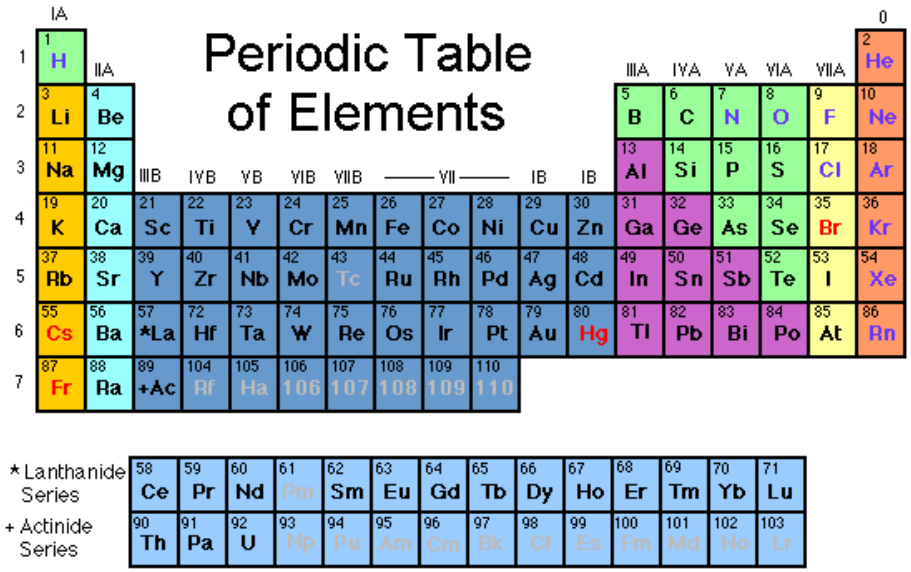
Light



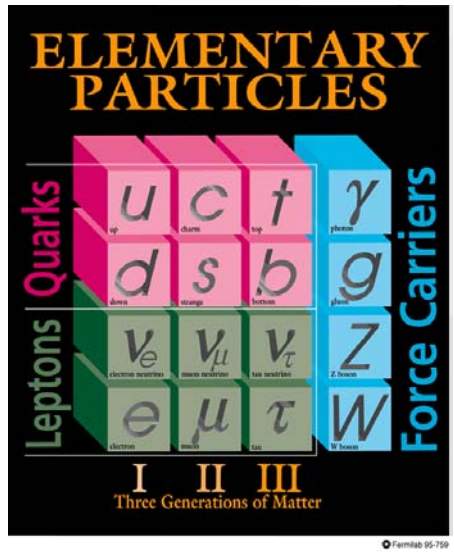


Frederick Reines
1995 Nobel Prize
for the Detection
of the Neutrino

PUZZLES



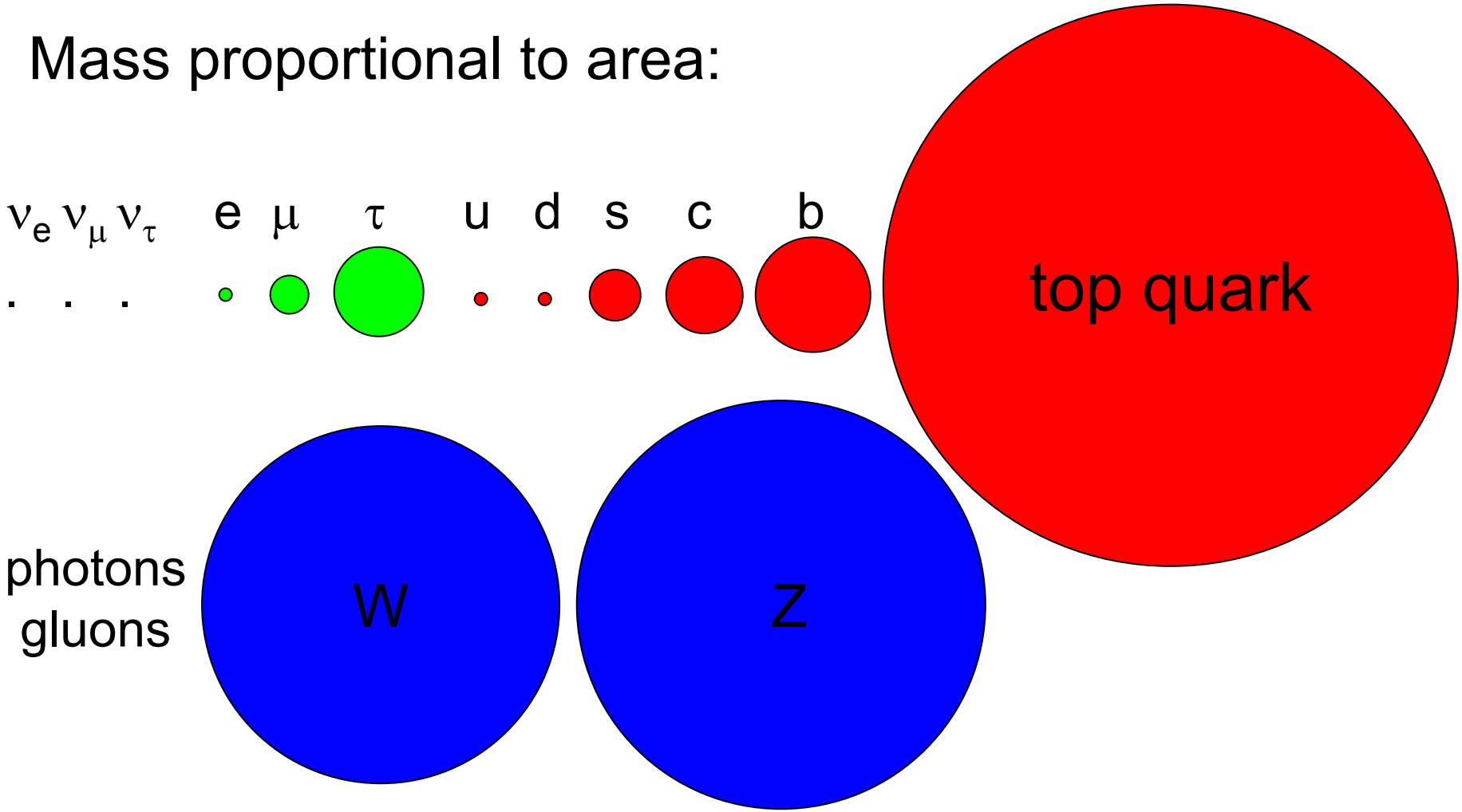
vs.



- Periodic table is…periodic. All atom masses are integral multiples of proton/neutron masses. What about elementary particles?

ELEMENTARY PARTICLE MASSES

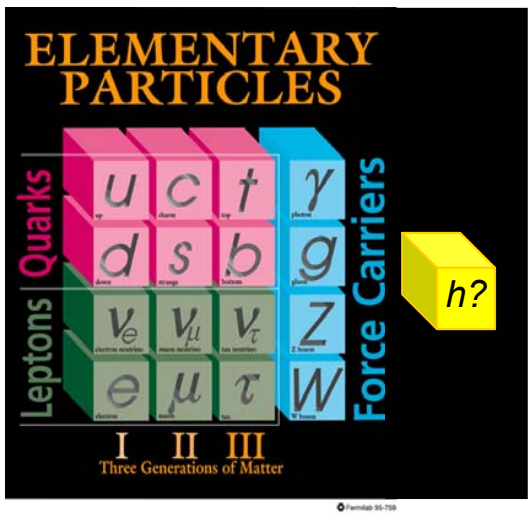
Mass proportional to area:

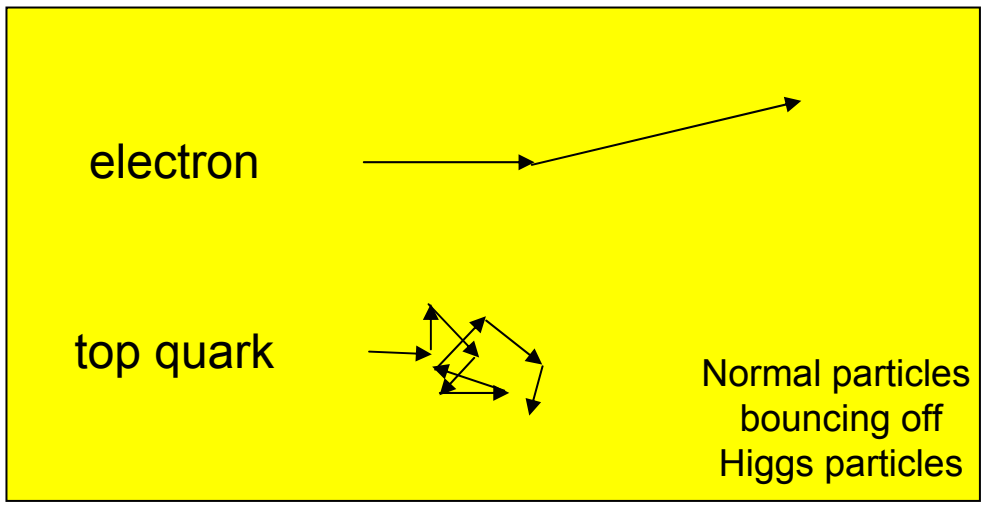


Are these made of something else? Are there more quark-, neutrino-,and electron-like particles?

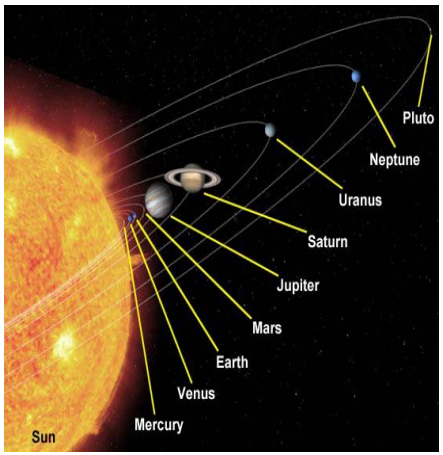
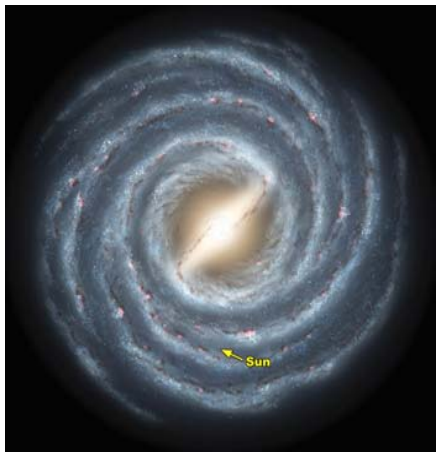
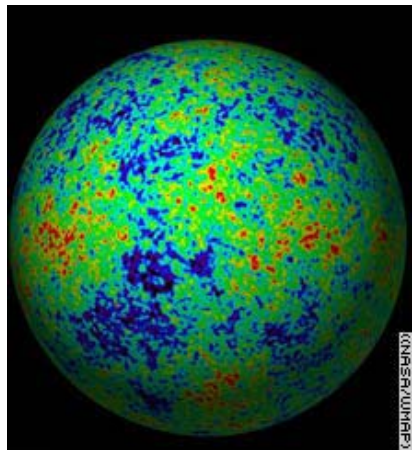
THE HIGGS BOSON

- In fact, with only the known particles, the current theory is incomplete: it predicts that all particles are massless and travel at the speed of light.
- A hypothetical particle, the Higgs boson, beautifully fixes this problem, but we've yet to find it.

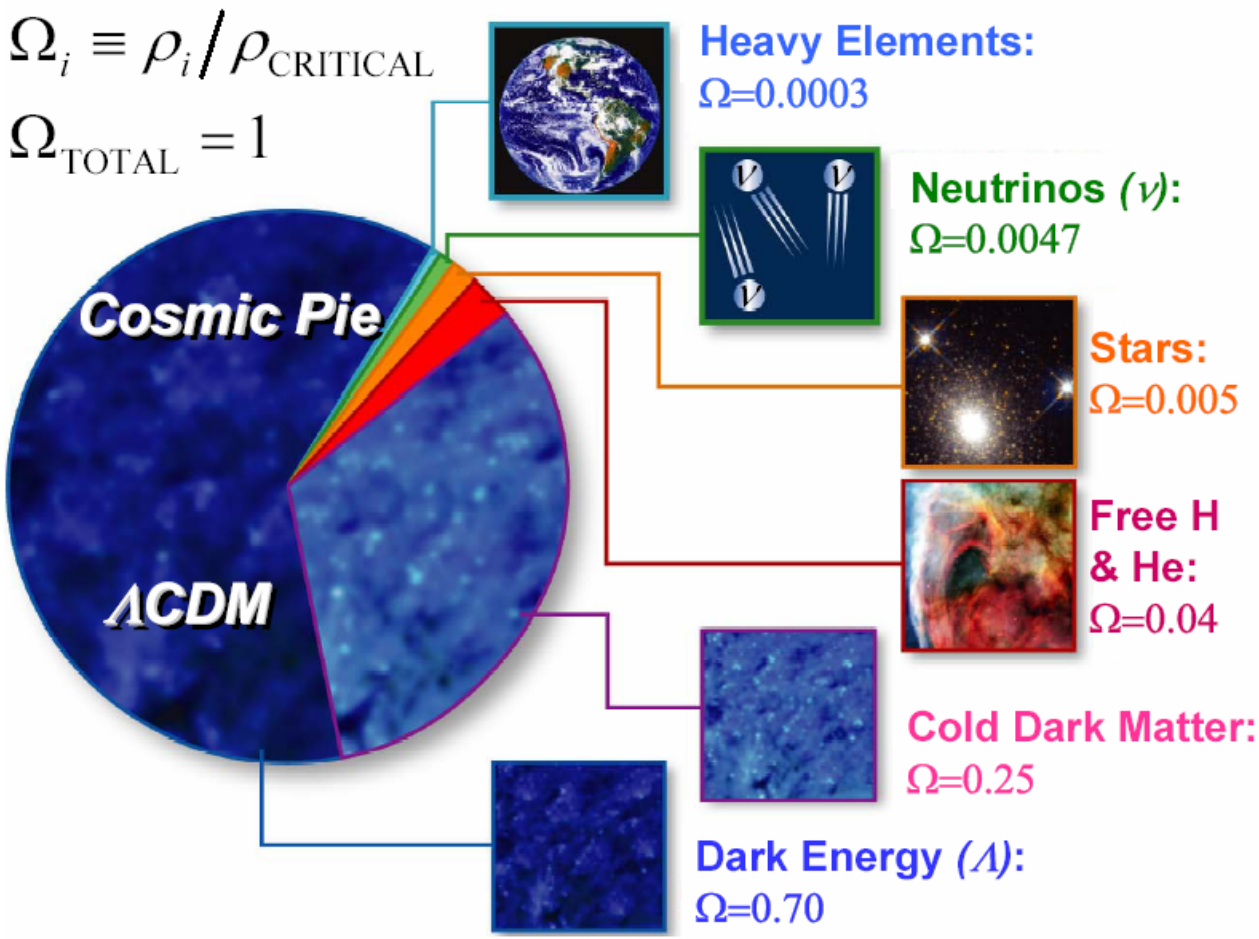




VERY BIG: STATUS REPORT

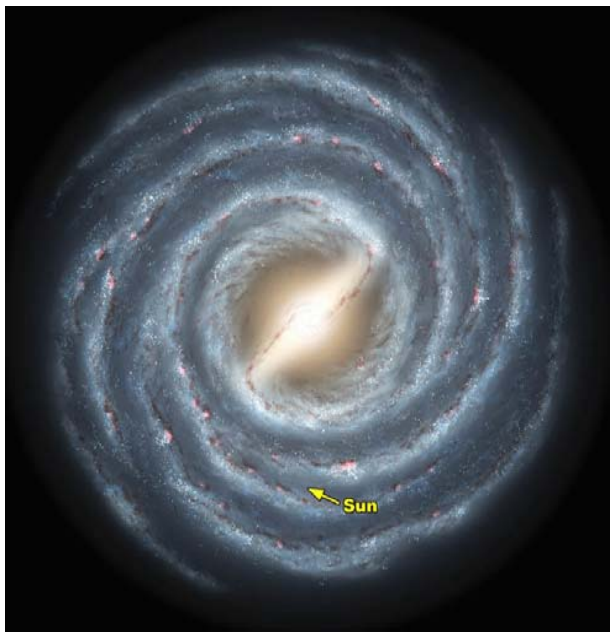
solar system	galaxy	galactic cluster	universe
			
10^{12} meters	10^{17} meters	10^{23} meters	$> 10^{26}$ meters

COMPOSITION OF THE UNIVERSE

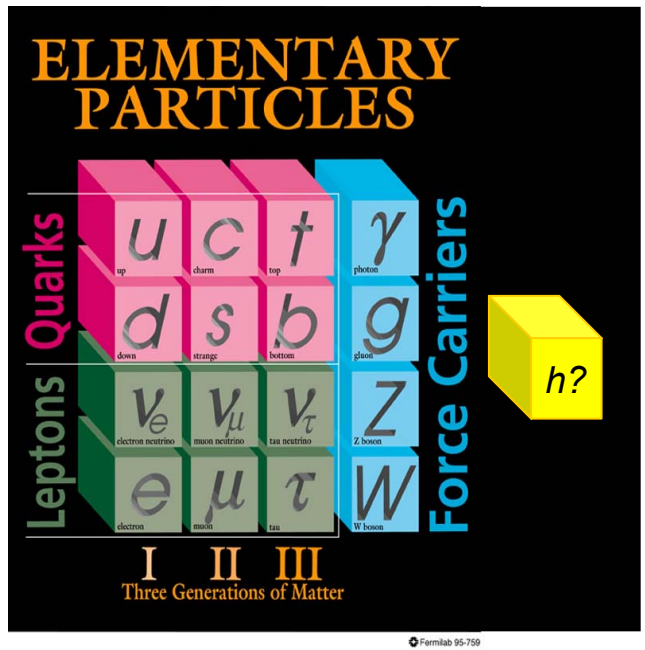


PUZZLES

- What is dark matter? It is required to understand why galaxies don't fly apart, but it can't be any of the known particles.



vs.



EXTRA DIMENSIONS

- How many dimensions are there?

  a) 3

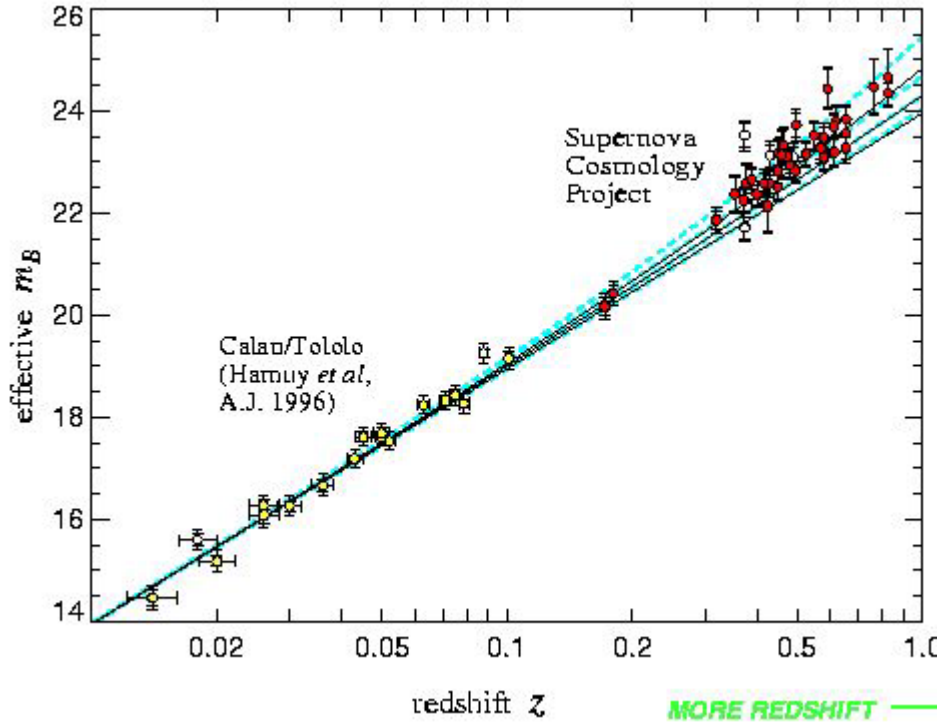
  b) 4

  c) 10

  d) 11

  e) none of the above

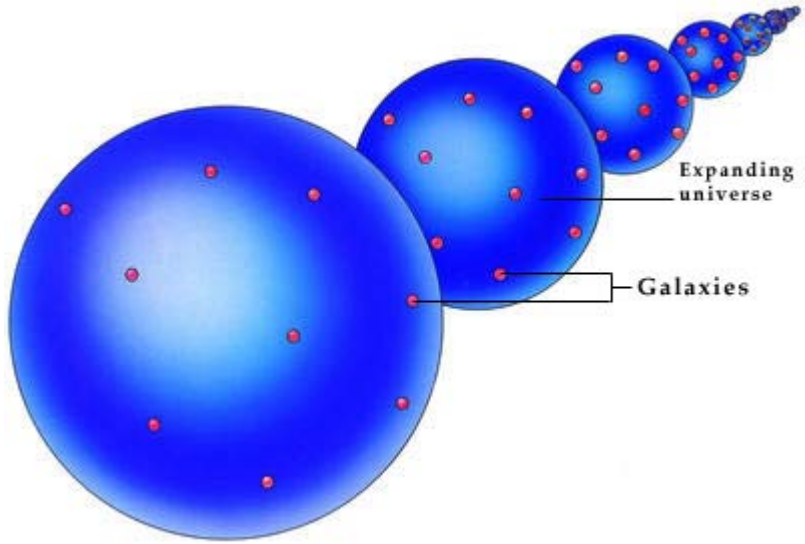
Edwin Hubble



Hubble (1929): The universe is expanding

Small Dimensions

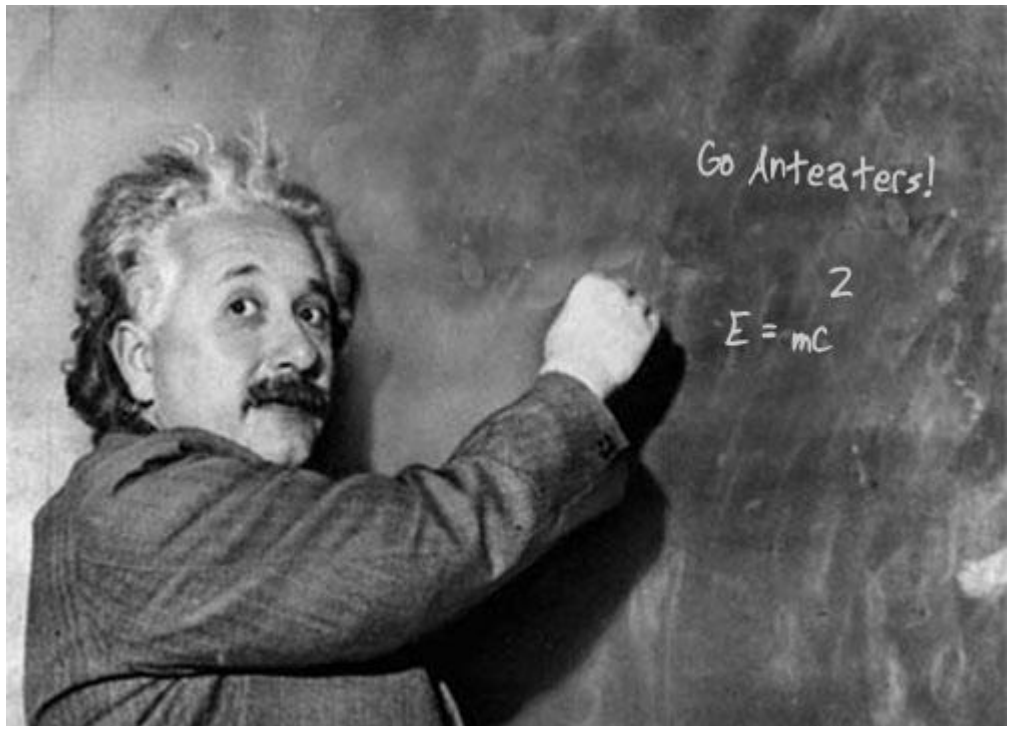
- The universe does not expand into space – space itself expands
- Extrapolating back, space was small – the Big Bang



- Other dimensions could exist but still be small. Some theories even *require* extra spatial dimensions. For example, string theory requires 6 more.

$E = mc^2$

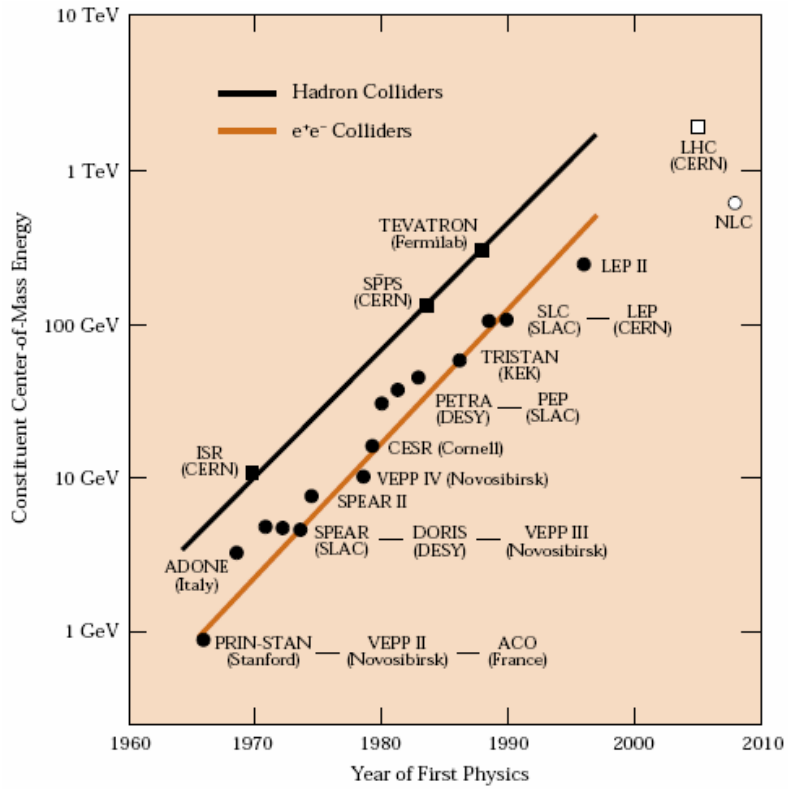
- Many of these questions involve hypothetical particles. How can we investigate them?
- Einstein: $E = mc^2$. Energy can be transformed into mass.



- To make new, heavy particles, simply smash together known particles at high energy.

PARTICLE COLLIDERS

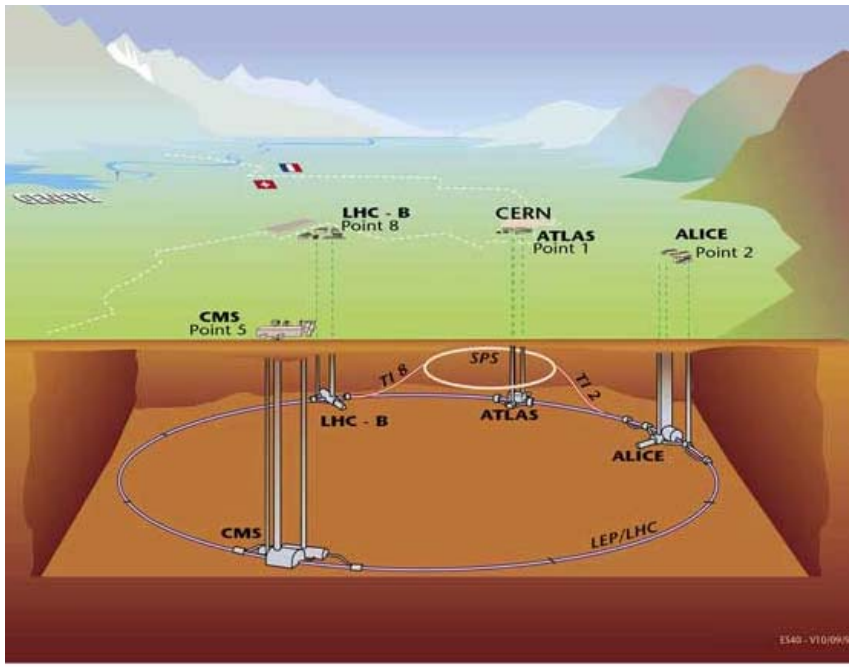
E. O. Lawrence's Cyclotron (1930s)



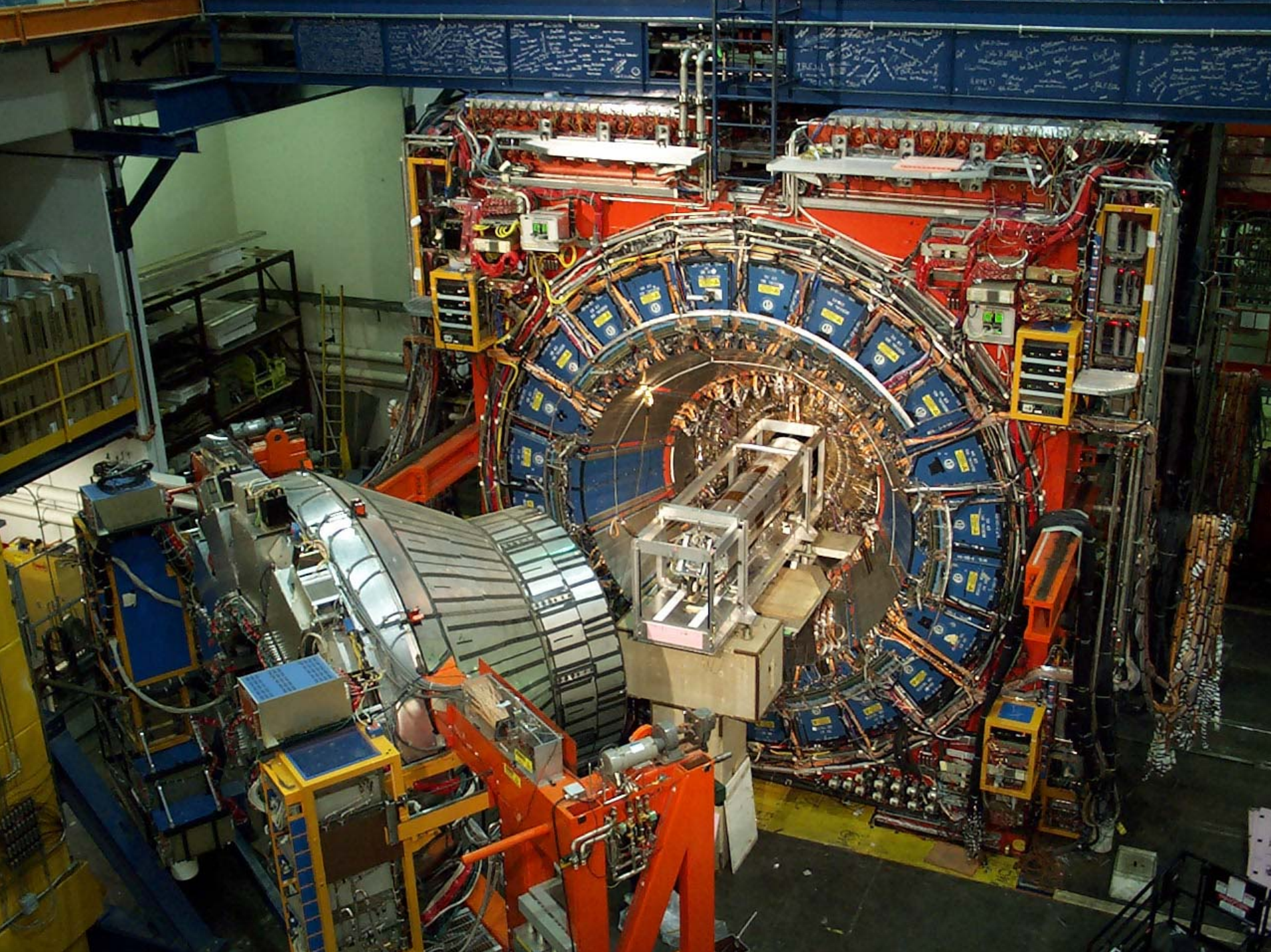
Livingston Plot: Moore's Law for Particle Colliders


Large Hadron Collider
18 miles in circumference
Operation begins in 2007

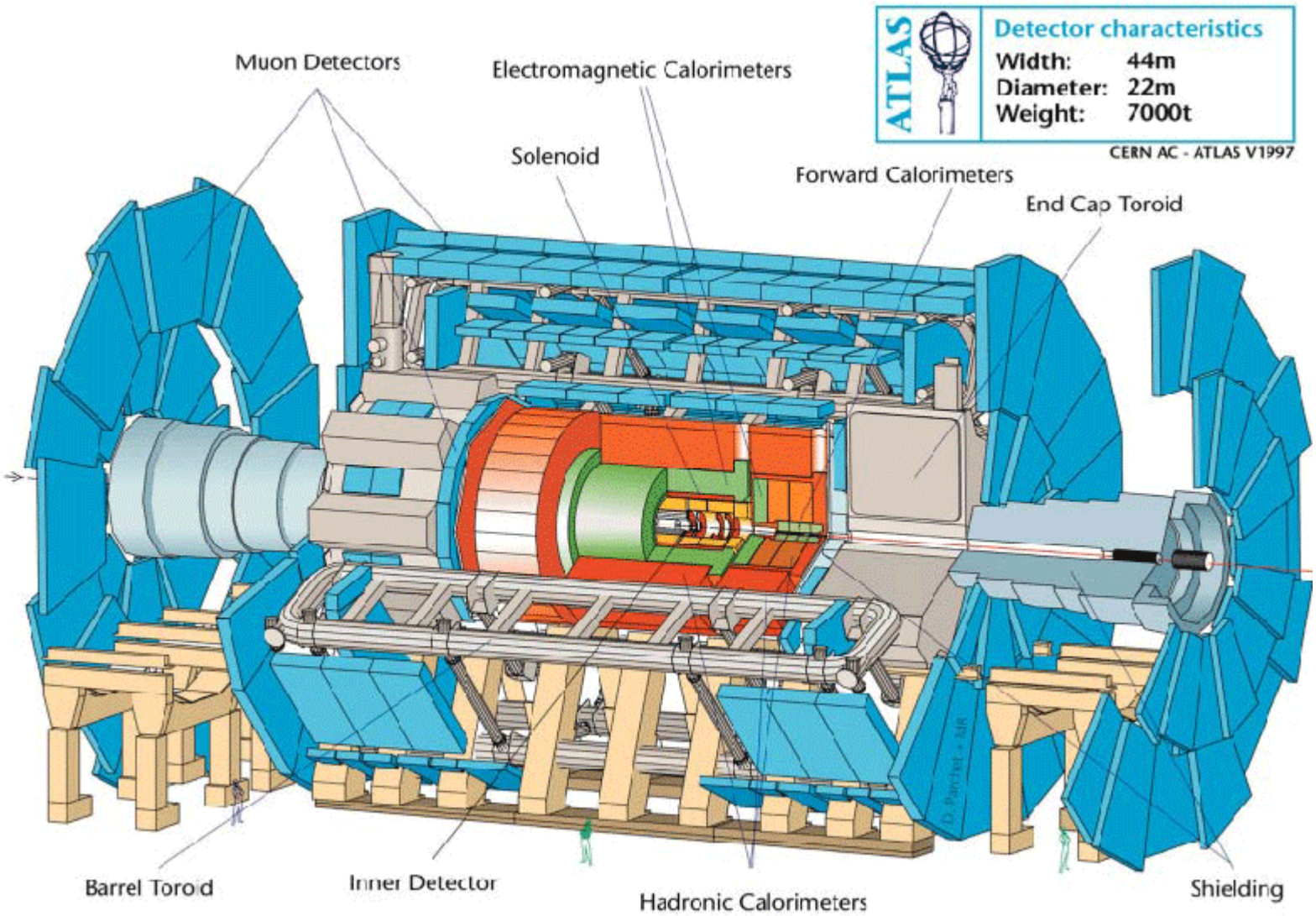
The Accelerator



Two proton beams rotate in opposite directions 100 m underground in Geneva on the French-Swiss border. The beams collide at 4 interaction points, which are surrounded by detectors.



LHC Detectors



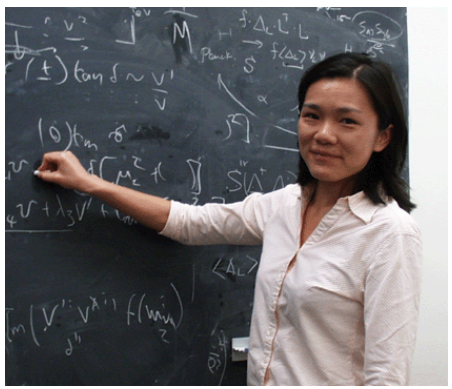
UCI Faculty Working on the LHC

Theorists

Jonathan Feng

Arvind Rajaraman

Yuri Shirman



Mu-Chun Chen

Experimentalists

Andy Lankford

Daniel Whiteson

Anyes Taffard

UCI @ ATLAS

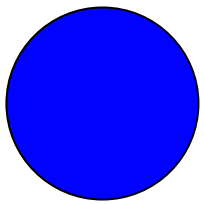
- The main UCI experimental responsibilities are in triggering and data acquisition.
- Data acquisition: the data collected by each detector is
  - 1 Terabyte/second
  - 10,000 Encyclopedia Britannicas/second
  - 10 Libraries of Congress/minute
  - 3 300GB hard drives/second
  - 100 full length DVD movies/second
  - 10,000 times the rate your computer can store data

UCI @ ATLAS

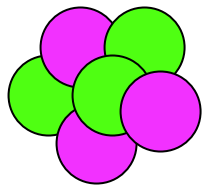
Triggering: finding needles in haystacks

LHC AS MICROSCOPE

High beam energies → short wavelengths. The LHC will provide extremely high resolution to probe substructure.



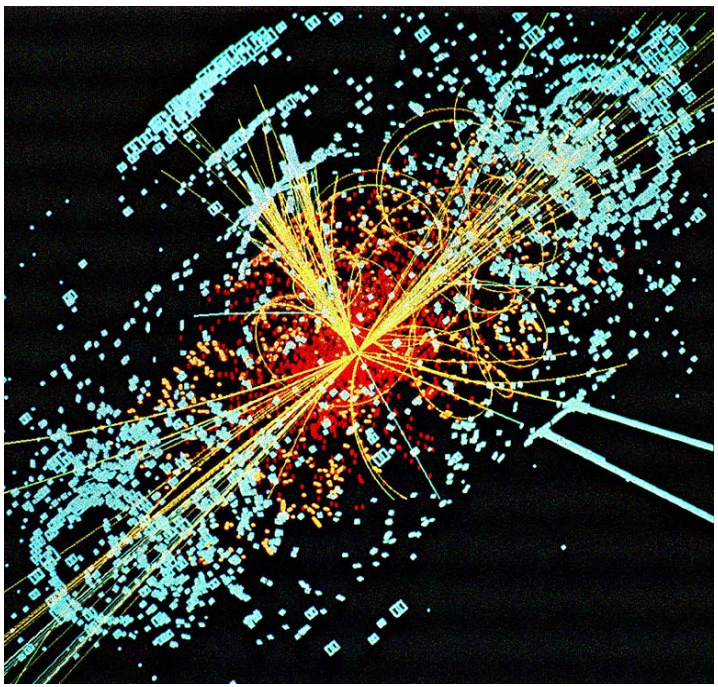
Quark seen by current colliders (low resolution)

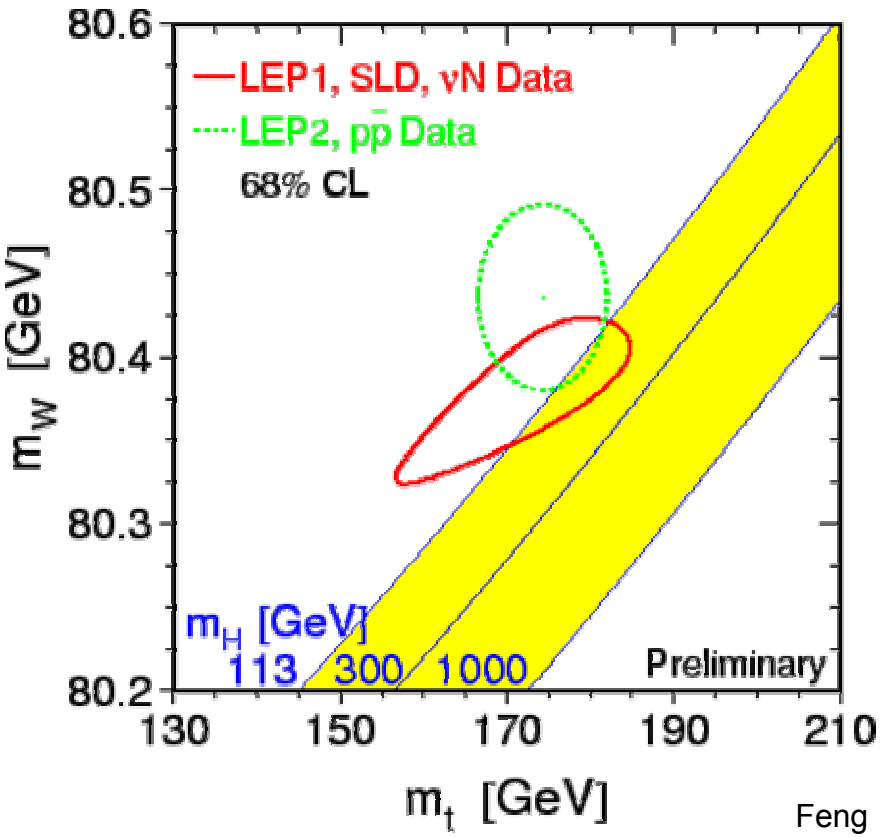


Quark seen by the LHC (high resolution)

LHC AS HIGGS HUNTER

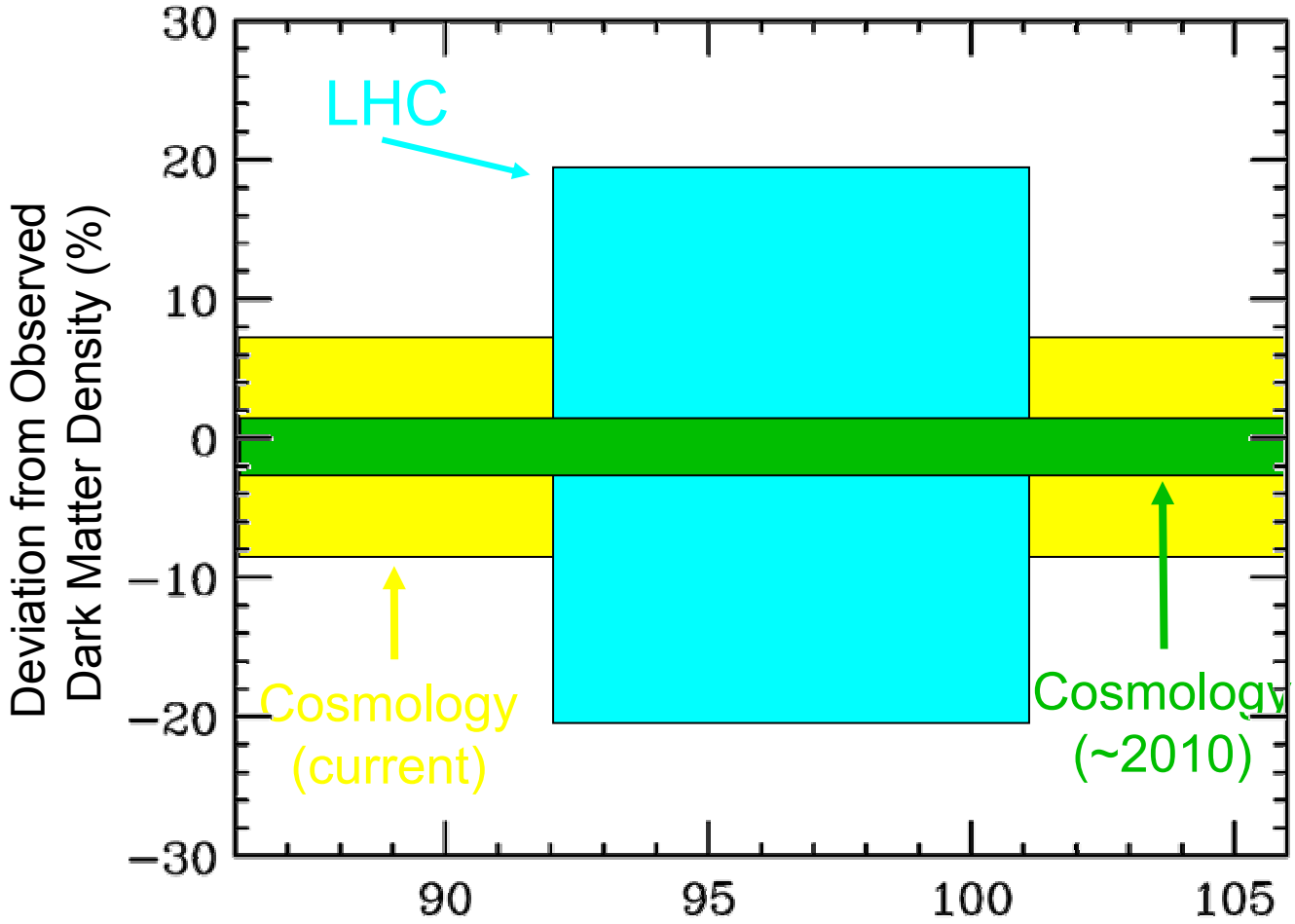
The LHC will discover the Higgs boson – if it's there!





LHC AS TIME MACHINE

The LHC will produce energies last seen 1 picosecond (10^{-12} s) after the Big Bang, and may produce dark matter particles.

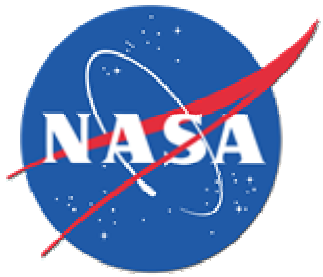


LHC SOCIOLOGY

In each experiment, ~2000 collaborators from ~40 countries (and growing)

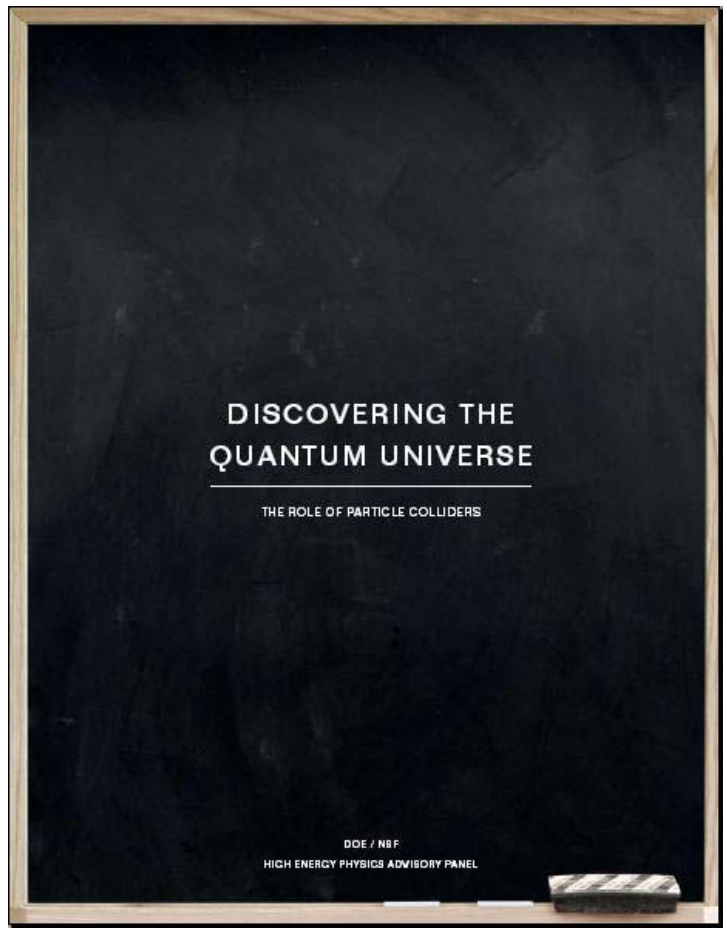
The procedure for sharing data and credit is not completely clear and is a topic of heated debate

ACKNOWLEDGMENTS



UCIrvine
University of California, Irvine

HEPAP Subpanel colleagues



Available at registration desk and at
http://interactions.org/quantumuniverse/qu2006/