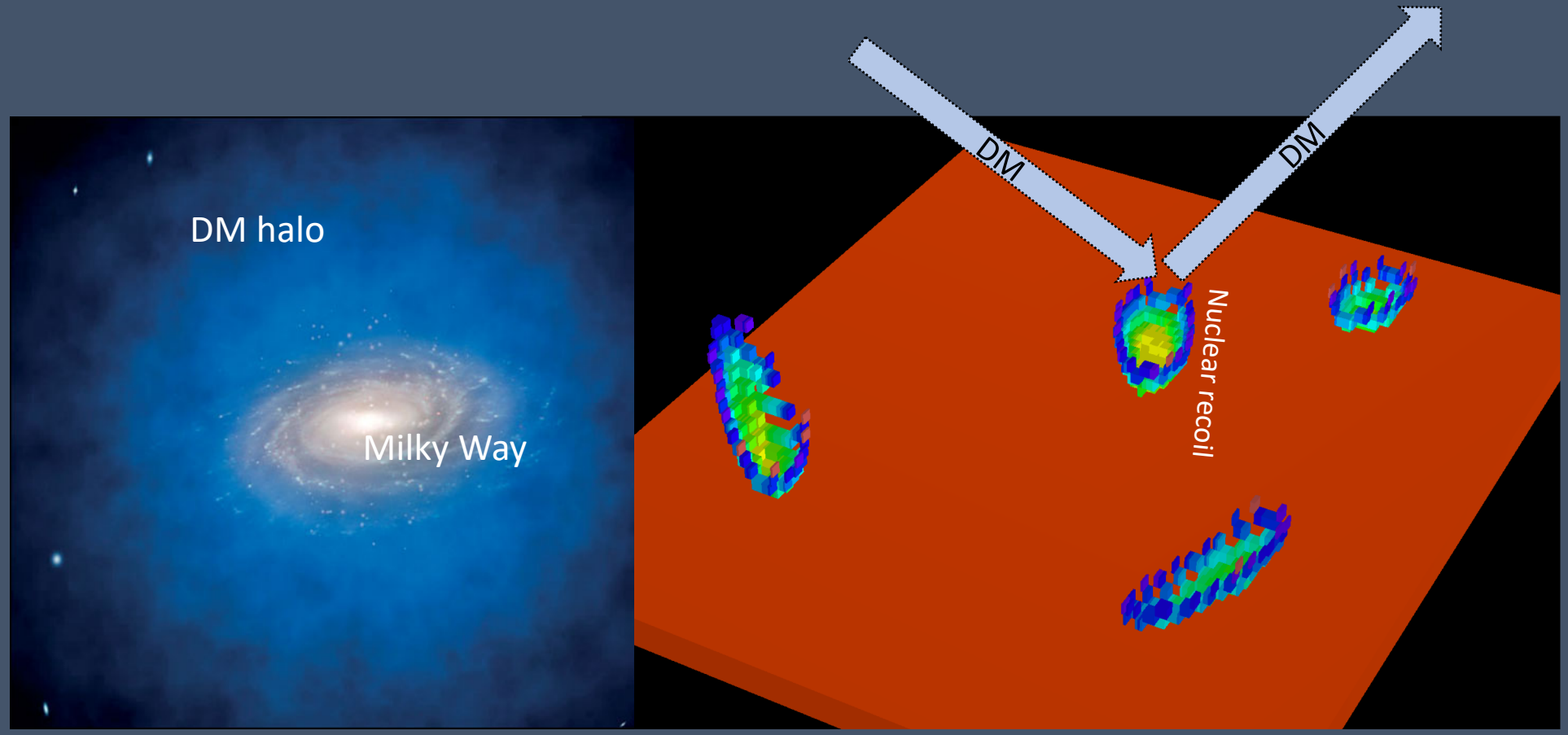
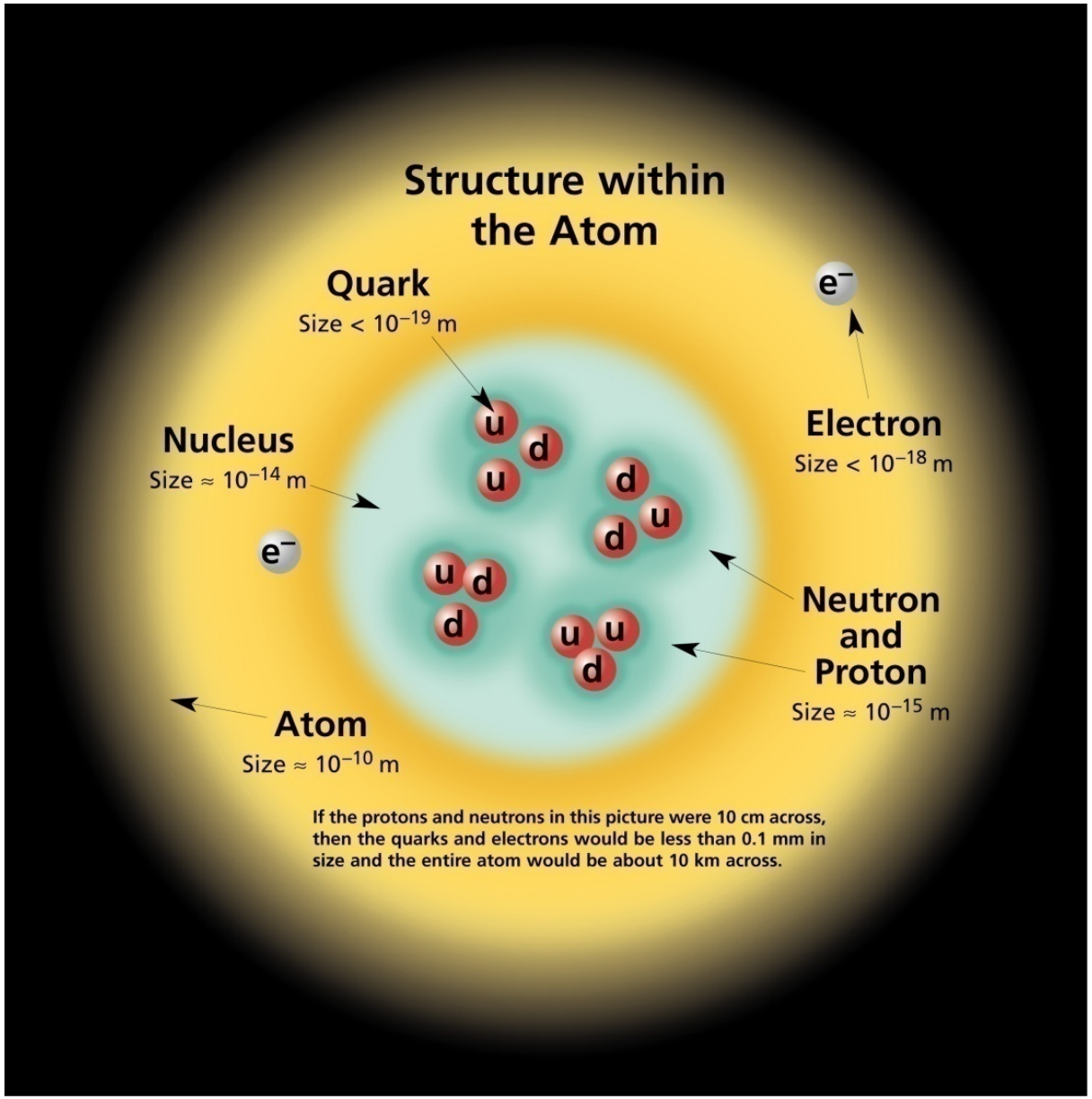
Dark Matter



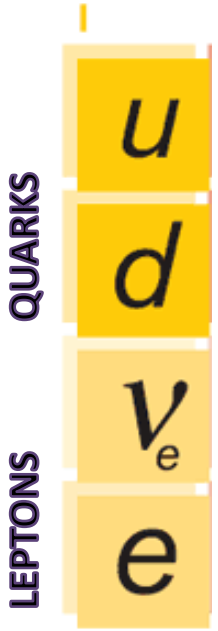
Sven Vahsen, University of Hawaii

Ordinary Matter

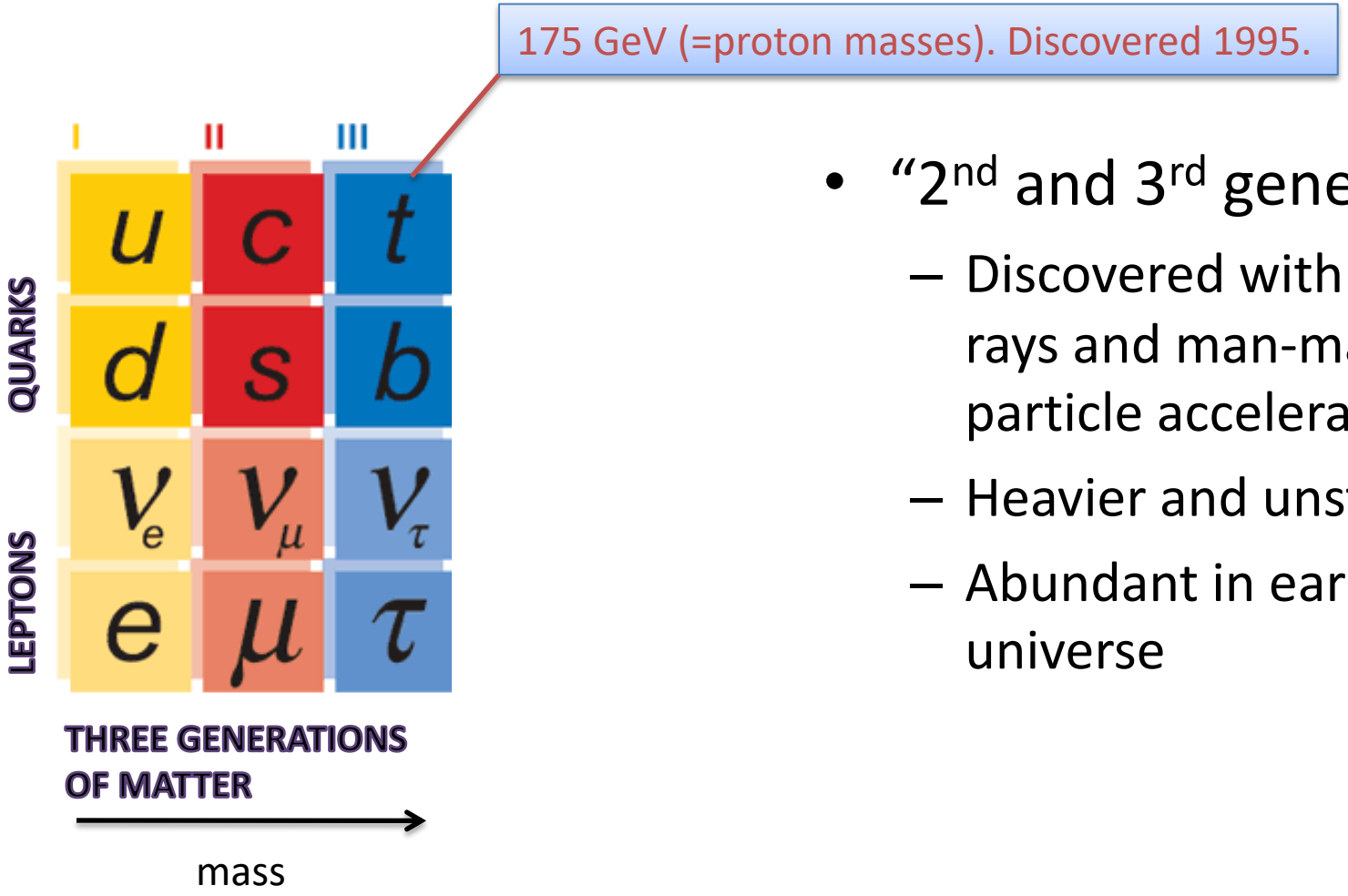
- Ordinary matter consists of atoms
- Atoms consist of three types of elementary particles
  - Up quark
  - Down quark
  - Electron
- In radioactive decays, also the electron neutrino is produced
  - υ_e



Ordinary Matter

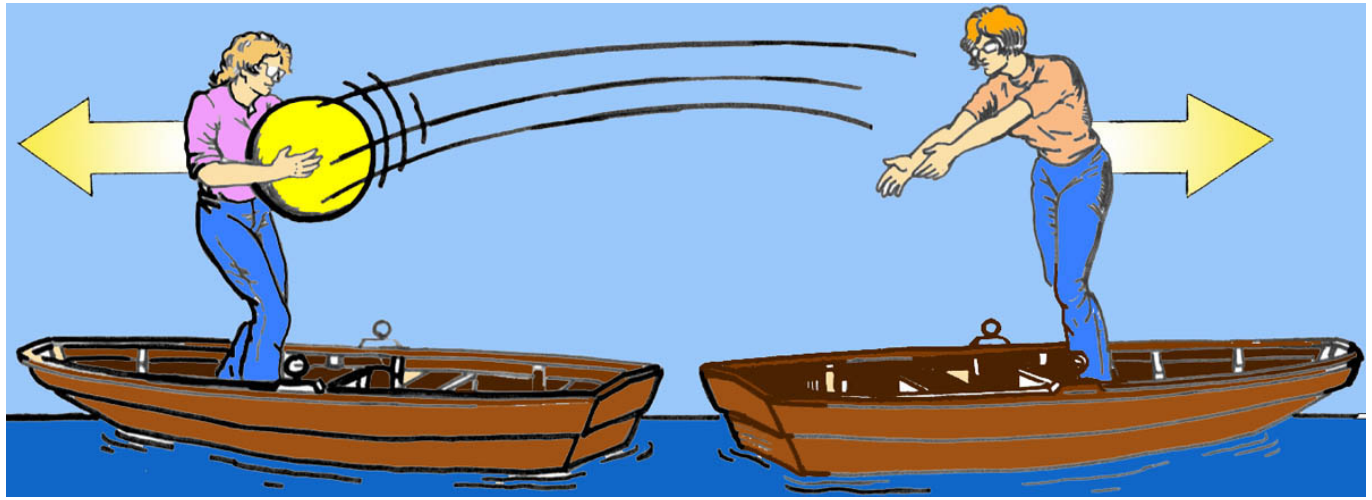


Three generations of particles

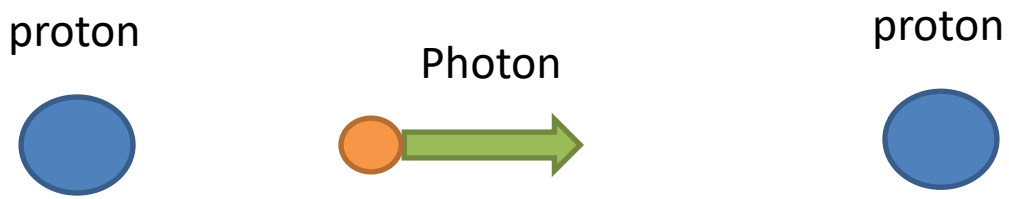


- "2nd and 3rd generation"
  - Discovered with cosmic rays and man-made particle accelerators
  - Heavier and unstable
  - Abundant in early universe

What are the Force of Nature?



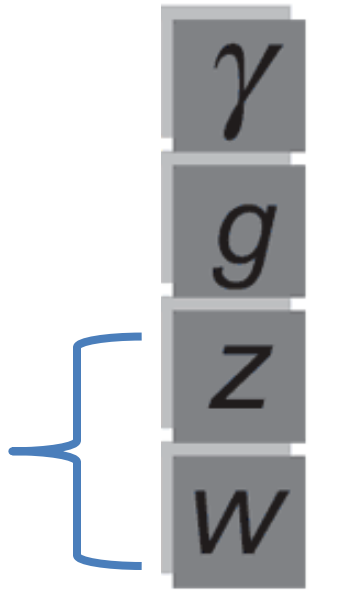
Even *forces* are due to elementary particles!



The Four Forces of Nature

- Four types of forces - each has it's own force carrier particles

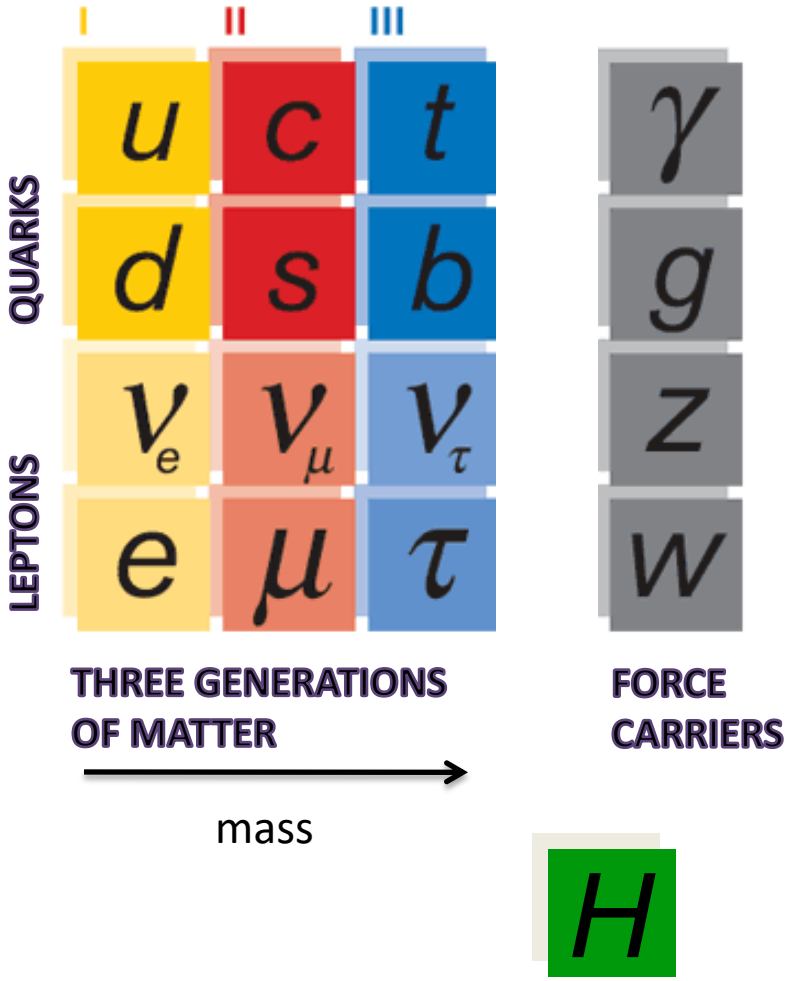
- Electromagnetic interaction
- Strong nuclear force
- Weak Nuclear force



- Gravity

G

Putting it all together



- Theoretically described by “Standard Model” of particle physics since early 1970s
- Standard Model predicted Higgs Boson

Questions:

How can you see matter?

What is happening when you see…

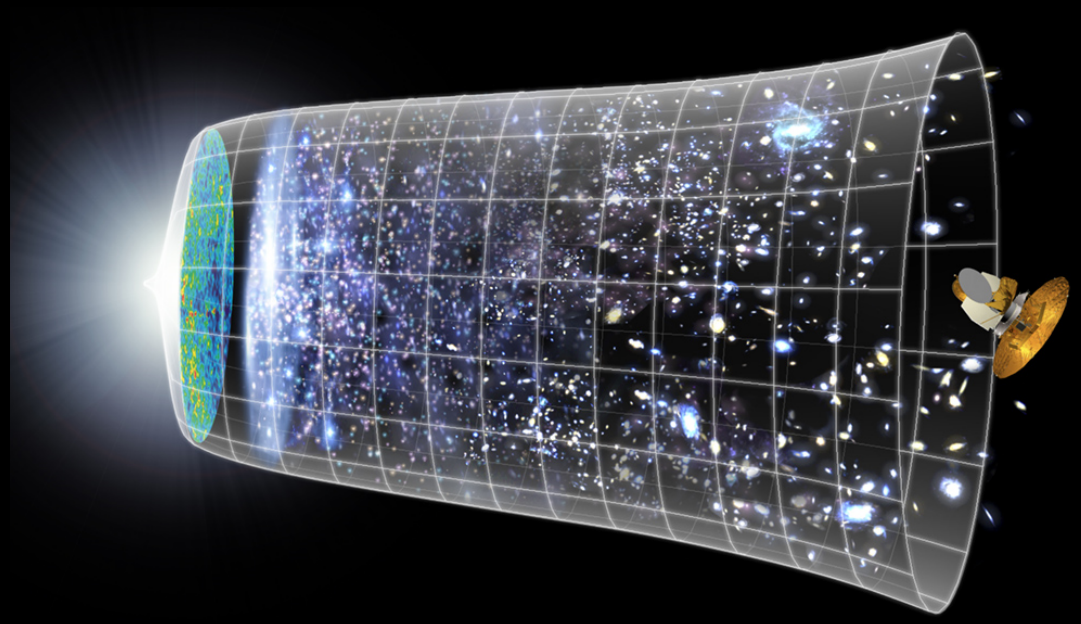
…the sun?

…other students?

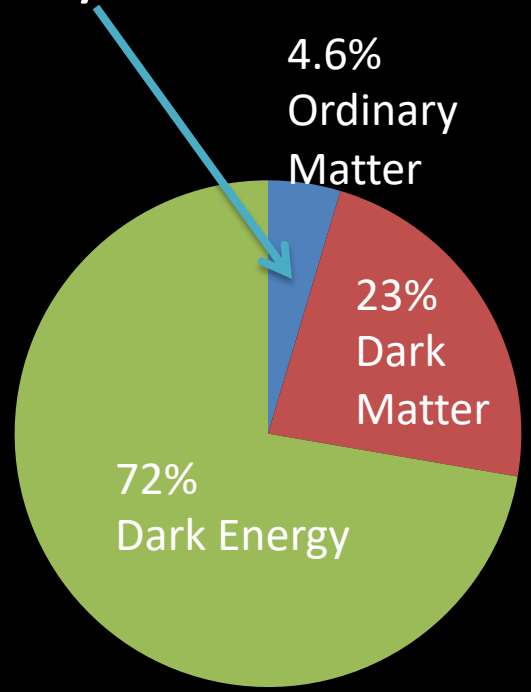
…yourself in a mirror?

…a dark object?

Things we cannot see with photons



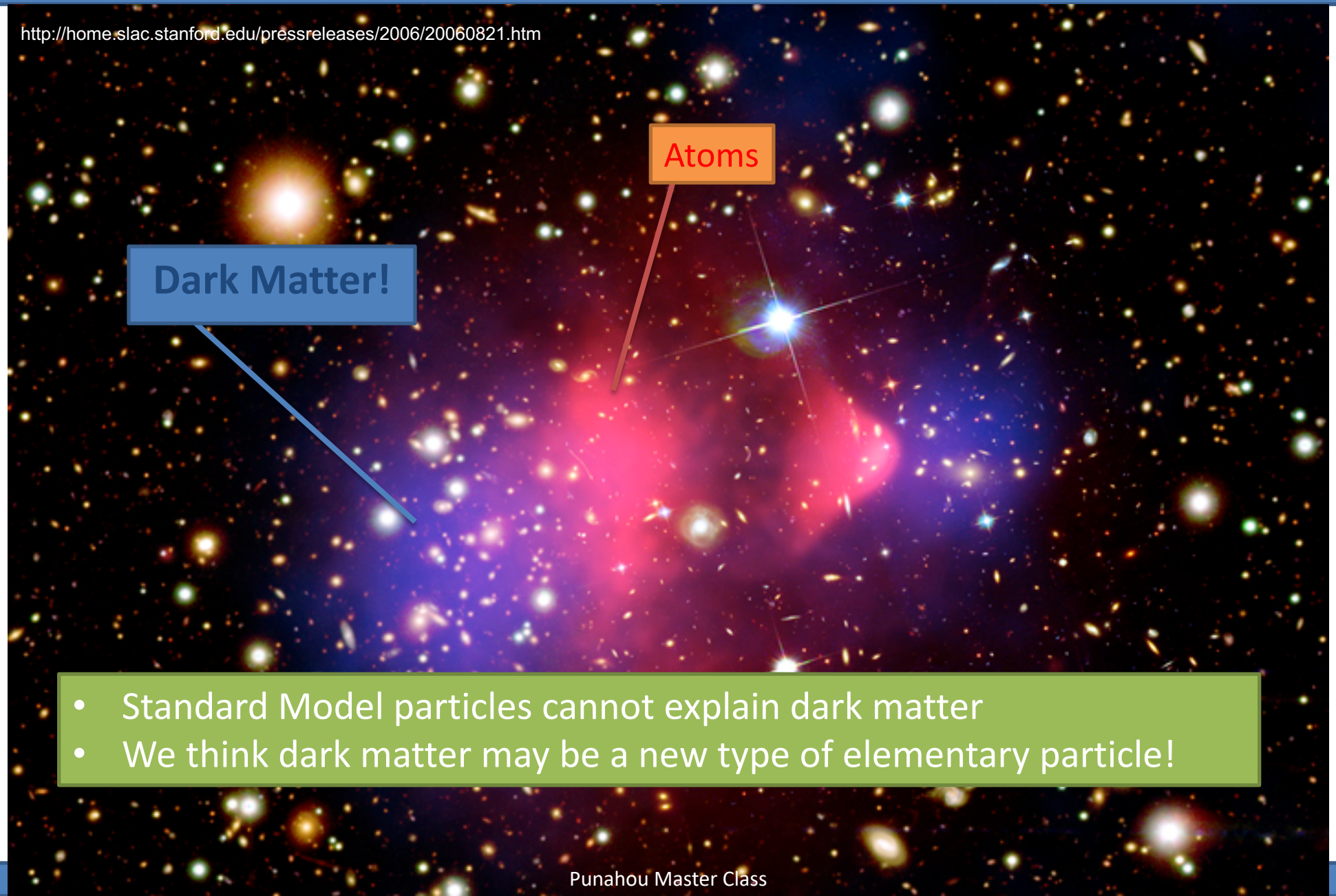
- Only 5% of energy in the universe due to ordinary matter



Question:

Is dark matter… dark?

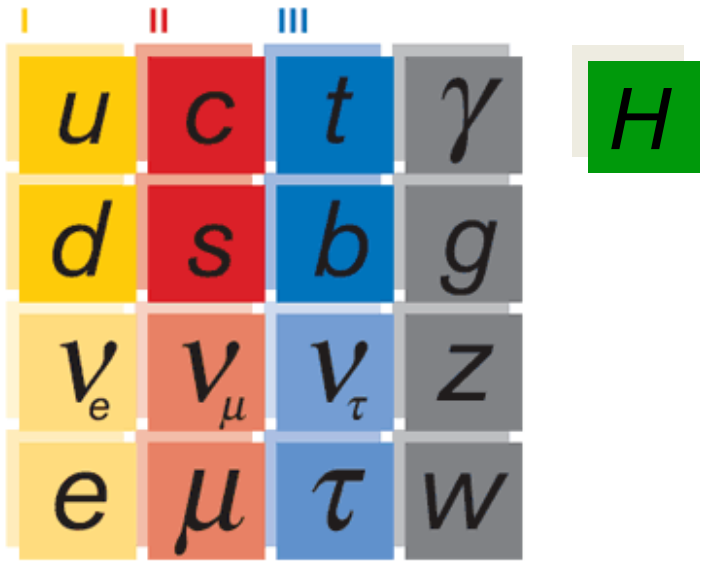
What does the Dark Matter consist of?

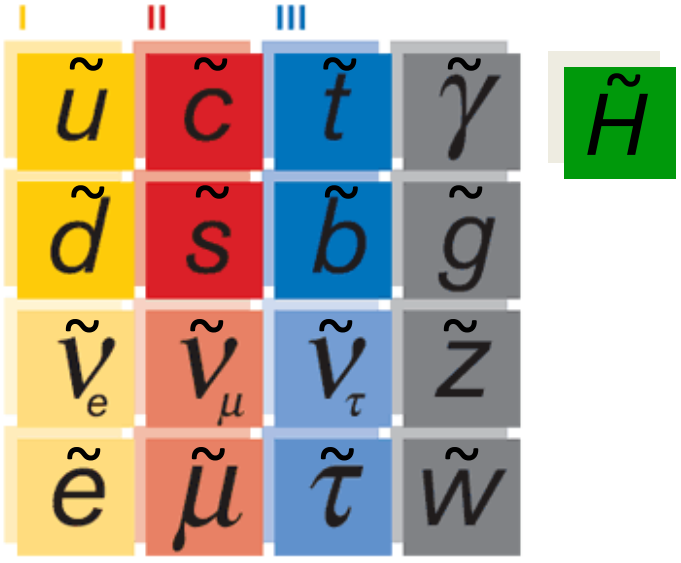


- Standard Model particles cannot explain dark matter
- We think dark matter may be a new type of elementary particle!

Supersymmetry

- We may need to extend the standard model





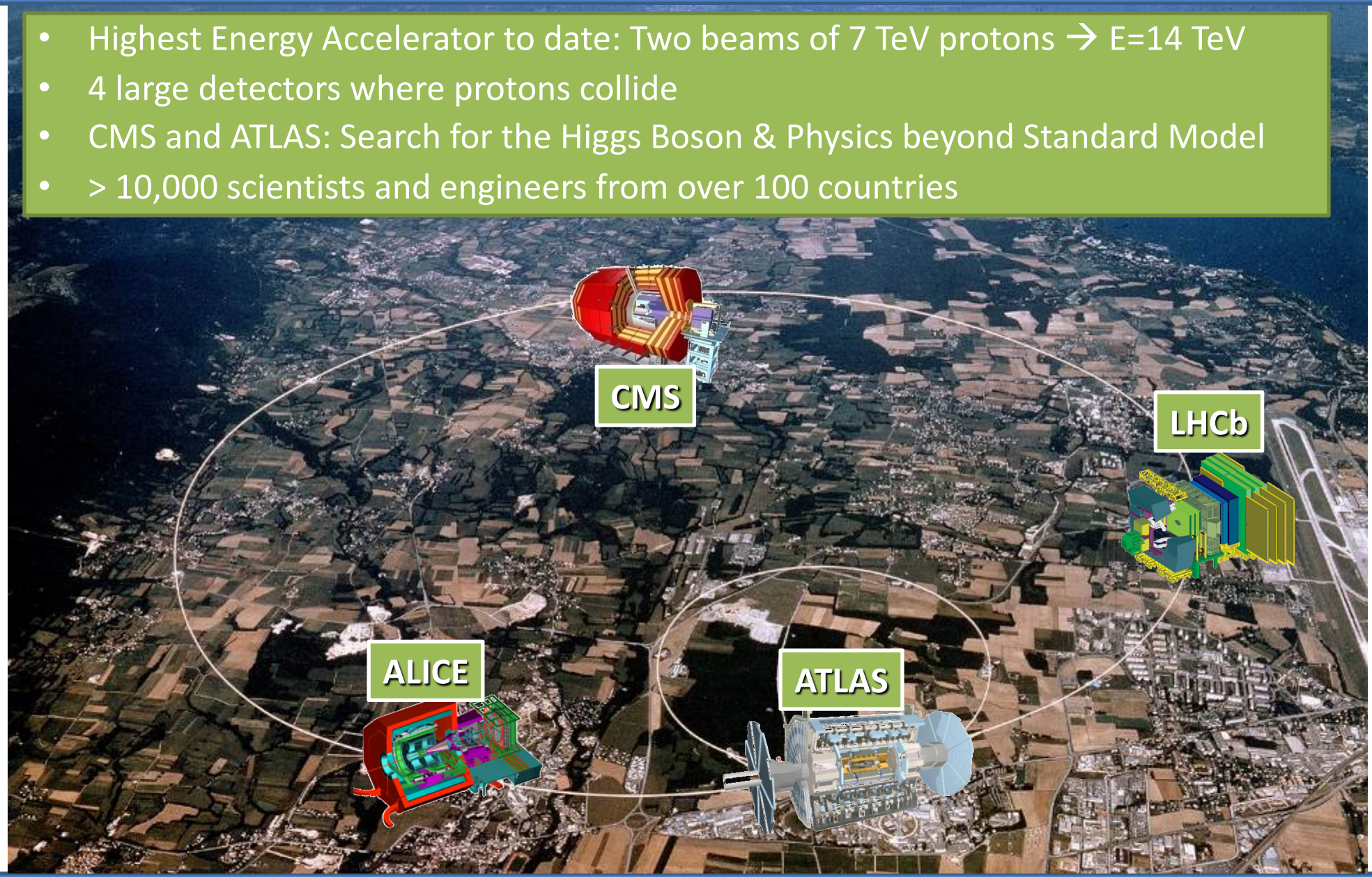
Supersymmetry predicts new particles.
Including dark matter particles!

How can we test this *hypothesis*?

1. Produce dark matter with particle accelerators
2. Try to directly detect dark matter
3. Observe decays of dark matter into visible particle

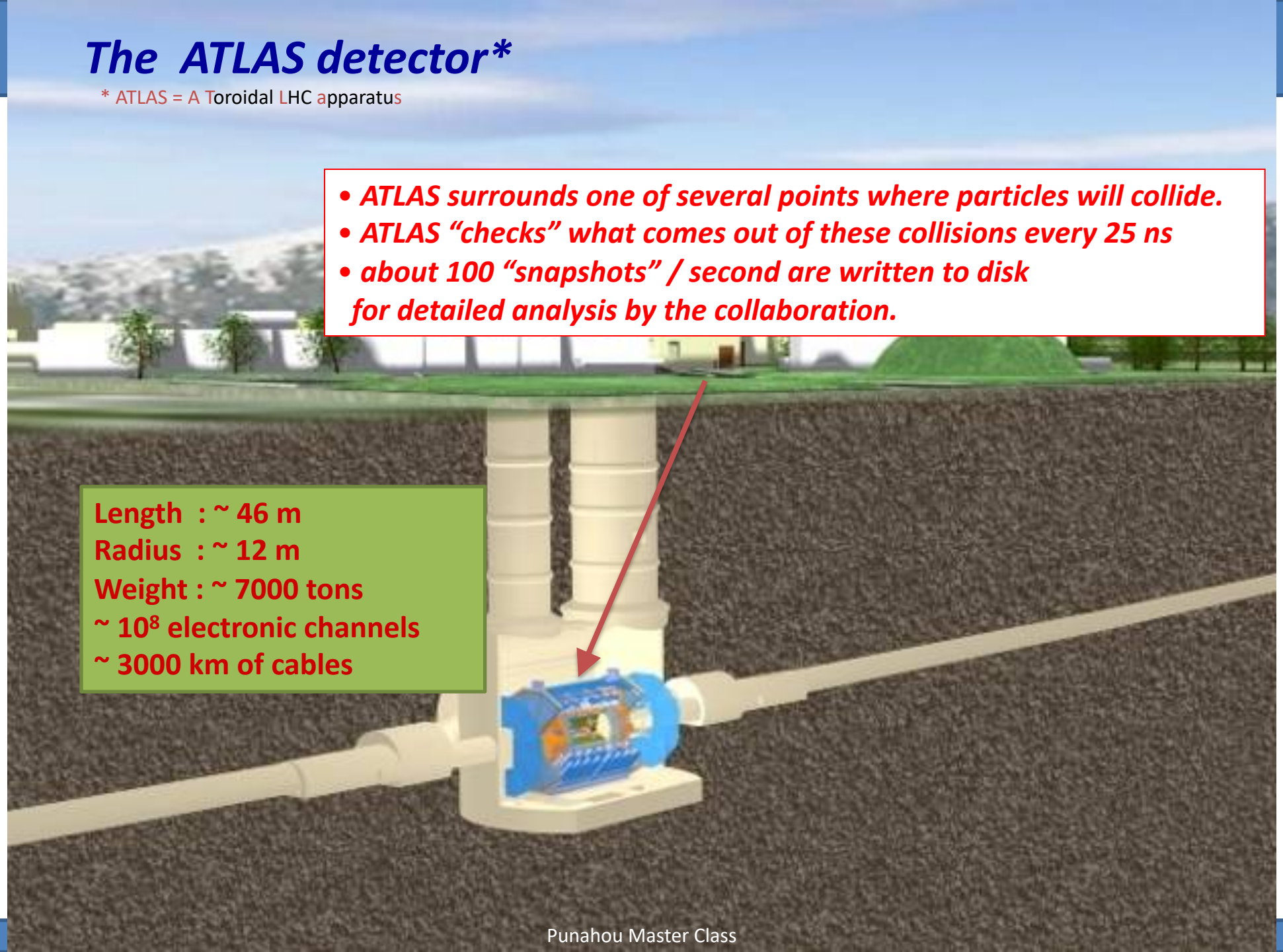
The Large Hadron Collider (LHC)

- Highest Energy Accelerator to date: Two beams of 7 TeV protons → E=14 TeV
- 4 large detectors where protons collide
- CMS and ATLAS: Search for the Higgs Boson & Physics beyond Standard Model
- > 10,000 scientists and engineers from over 100 countries



The ATLAS detector*

* ATLAS = A Toroidal LHC apparatus

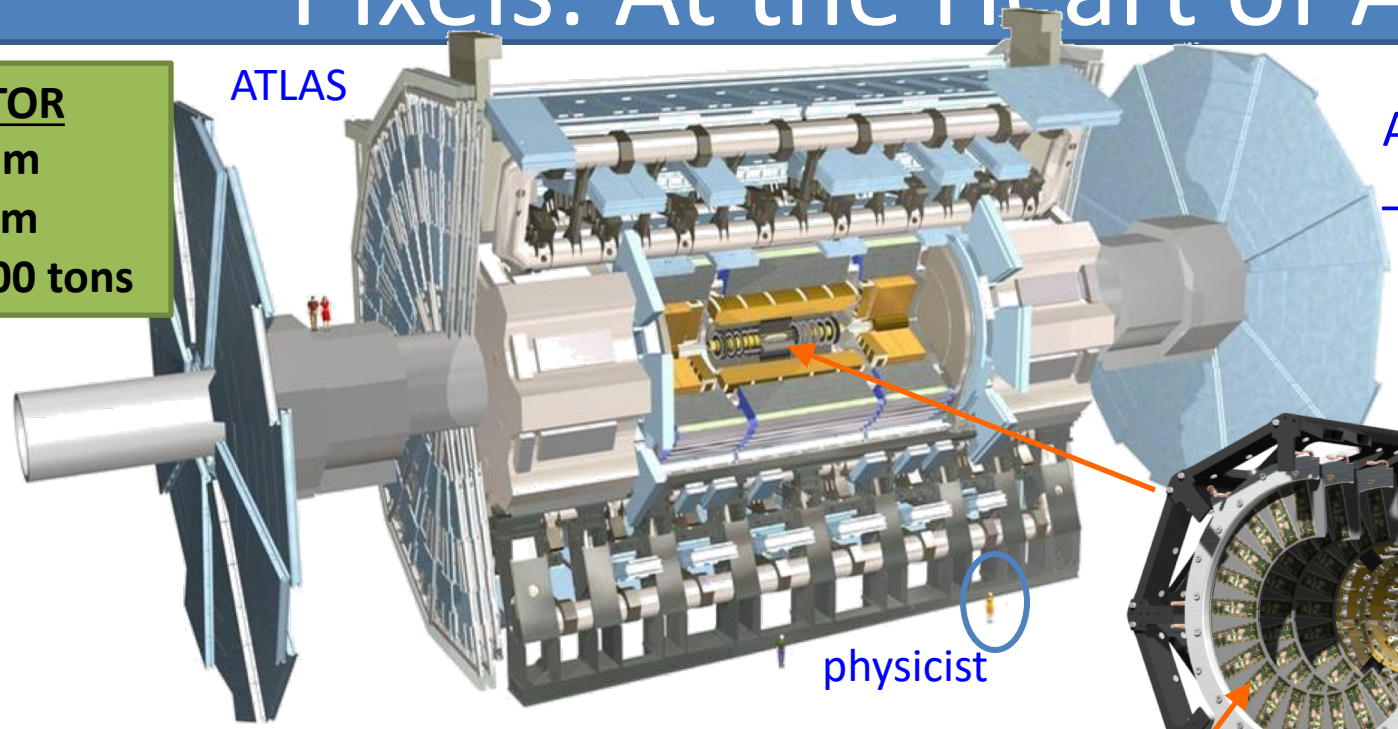


- *ATLAS surrounds one of several points where particles will collide.*
- *ATLAS "checks" what comes out of these collisions every 25 ns*
- *about 100 "snapshots" / second are written to disk for detailed analysis by the collaboration.*

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~ 10^8 electronic channels
~ 3000 km of cables

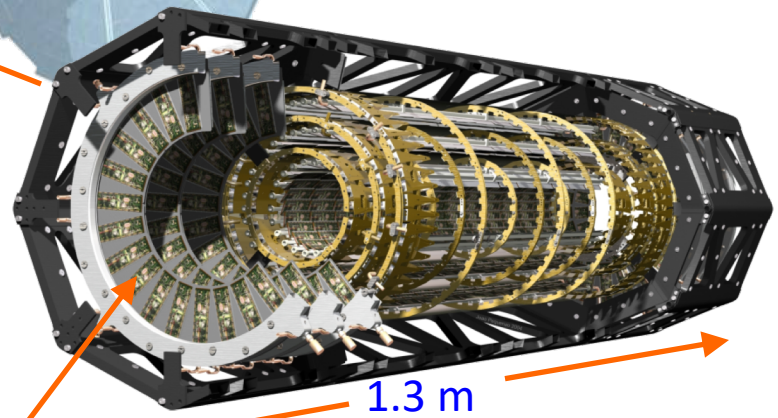
Pixels: At the Heart of ATLAS

ATLAS DETECTOR
Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons



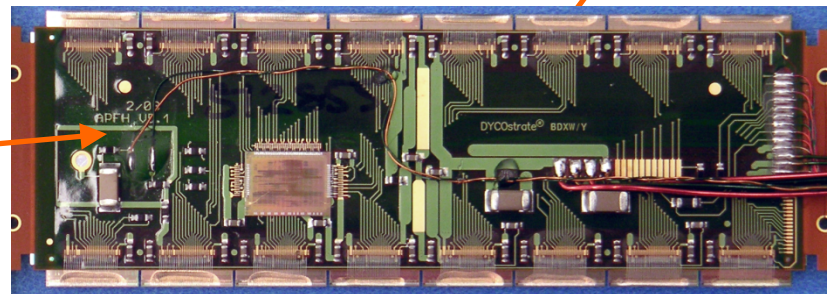
ATLAS Pixel Detector

– Innermost tracking detector, surrounding beam pipe



16 FE Chips

6 cm



Pixel

x46080

50 x 400 µm

Detection of charged particles takes place in 1744 identical *ATLAS Pixel Modules*

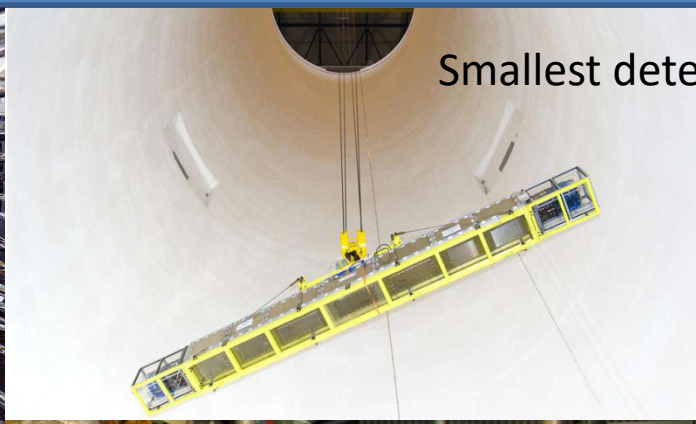
1744 modules x 46080 pixels = 80 million channels!

How to transport a Muon System

How to transport a pixel detector

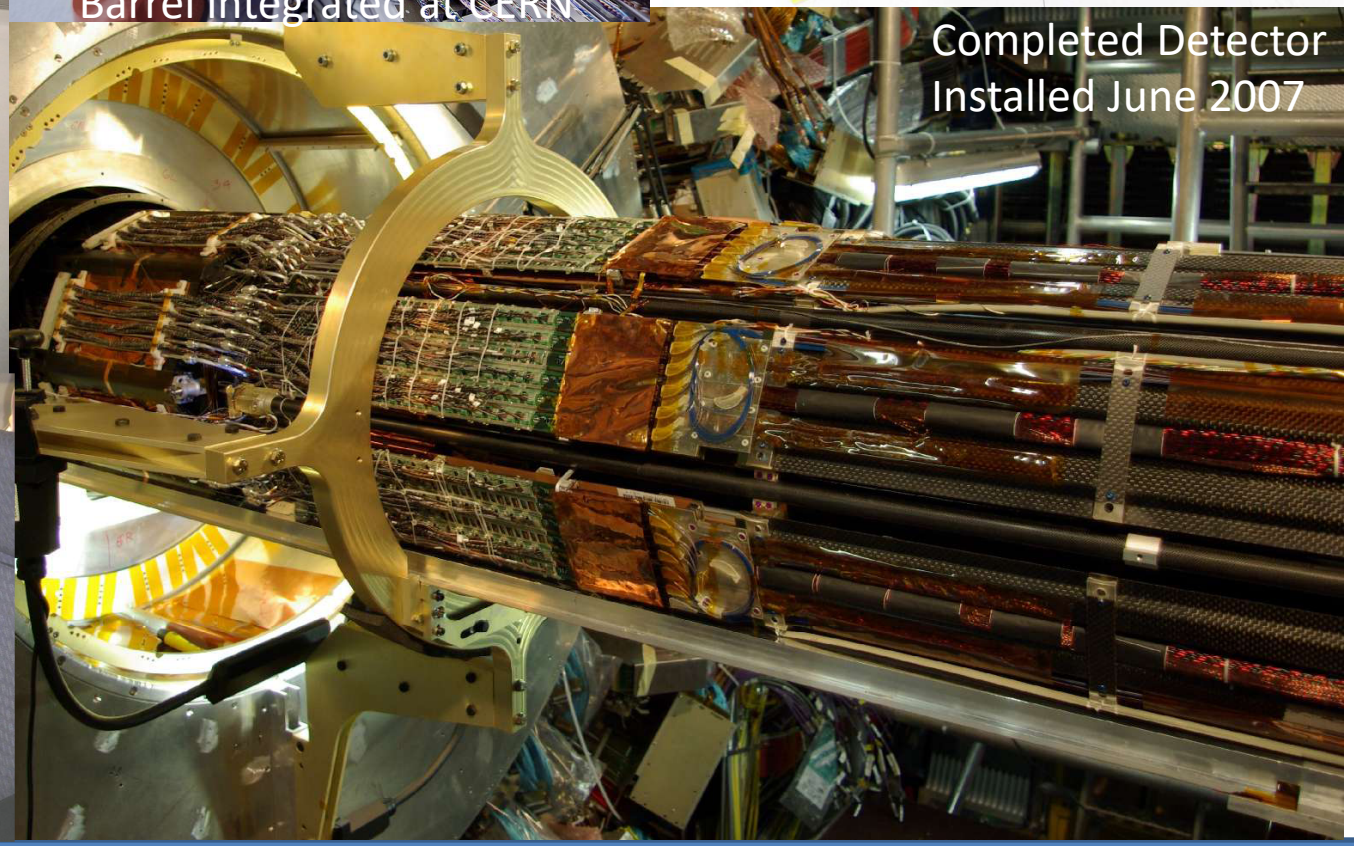
Endcaps integrated at Berkeley Lab

Barrel integrated at CERN



Smallest detector in ATLAS

On the way to CERN!



Completed Detector Installed June 2007

LHC Construction

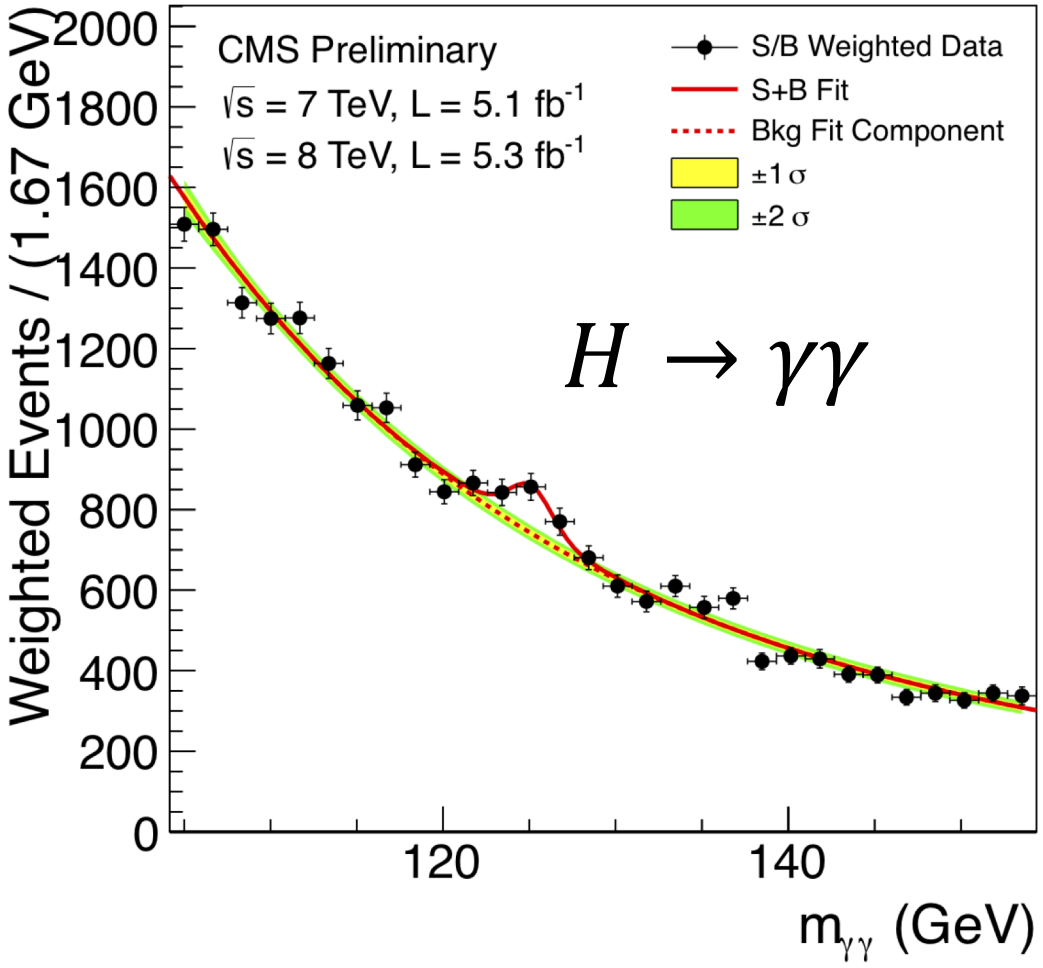
- 7-TeV protons kept in orbit by superconducting magnets
- 8.33T, cooled by superfluid Helium at 1.9K

Lowering one of 1232 di-pole magnets

… after installation 100 m under ground

First Beams Circulated September 9th 2008

2012 Higgs Discovery!



Higgs announcement seminar on 4 July 2012

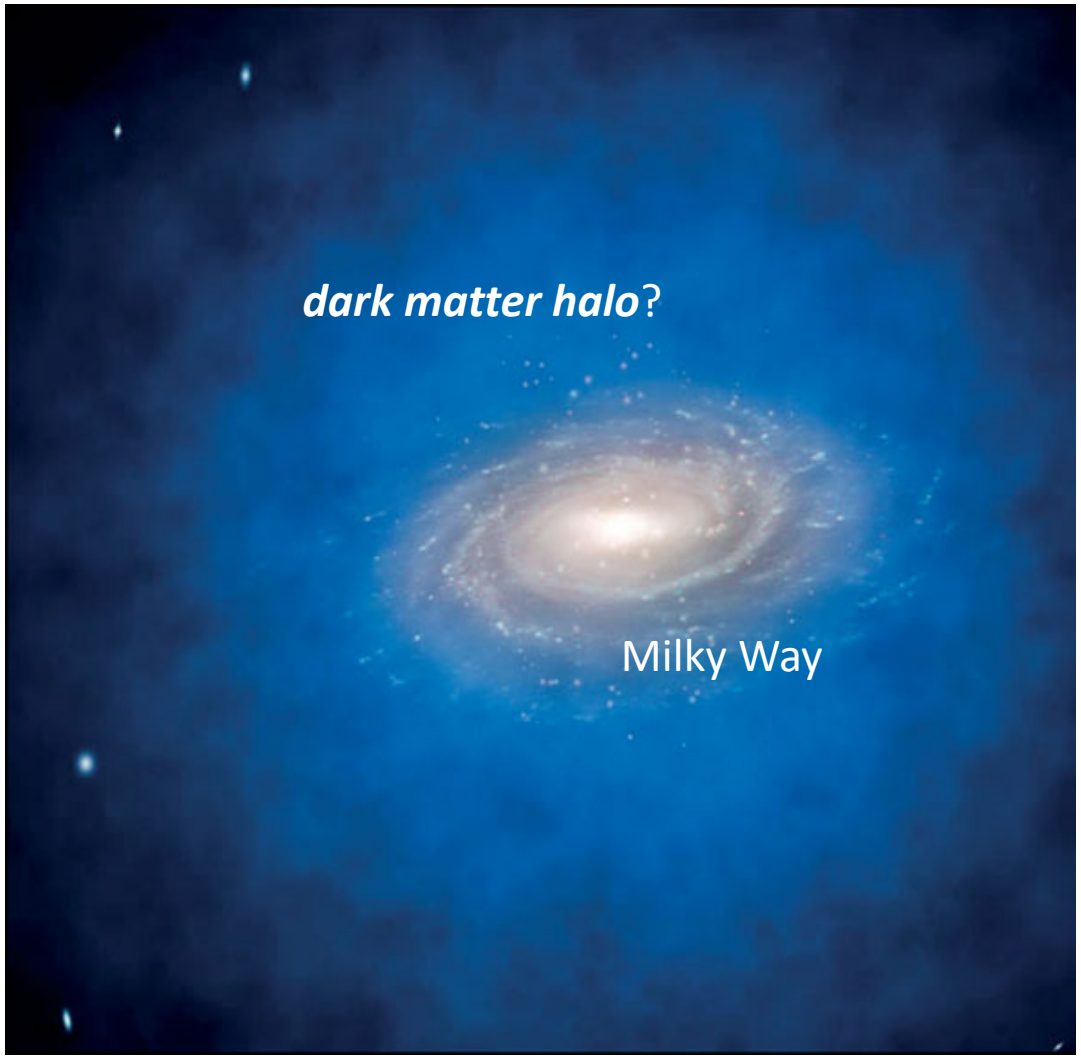
Nobel prize in 2013

So far, we have not detected dark matter
at the Large Hadron Collider…

How can we test this *hypothesis*?

1. Produce dark matter with particle accelerators
2. Try to directly detect dark matter
3. Observe decays of dark matter into visible particle

Are We Surrounded By Dark Matter?



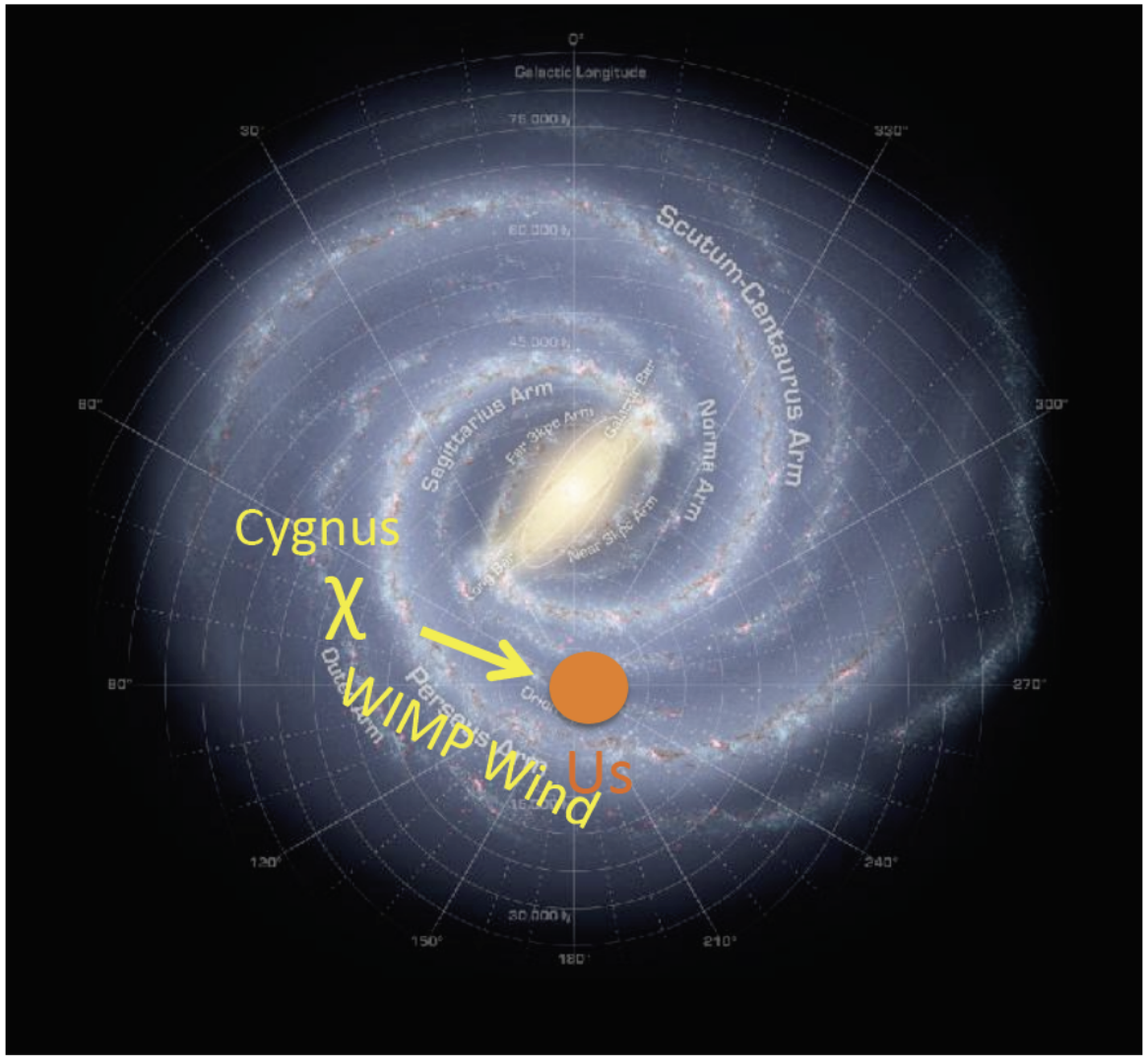
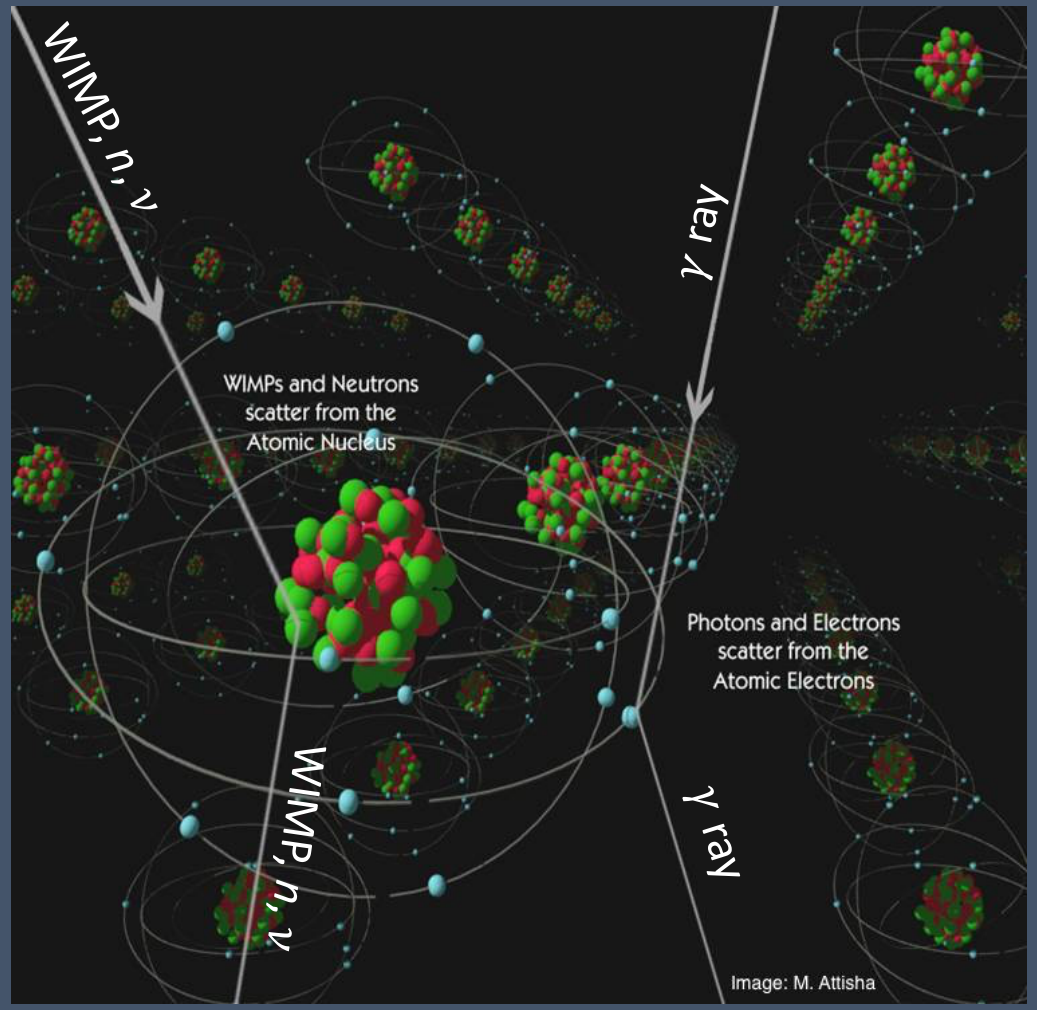


Image: NASA/Adler/U. Chicago/Wesleyan/JPL-Caltech

We can also try to directly detect Dark Matter

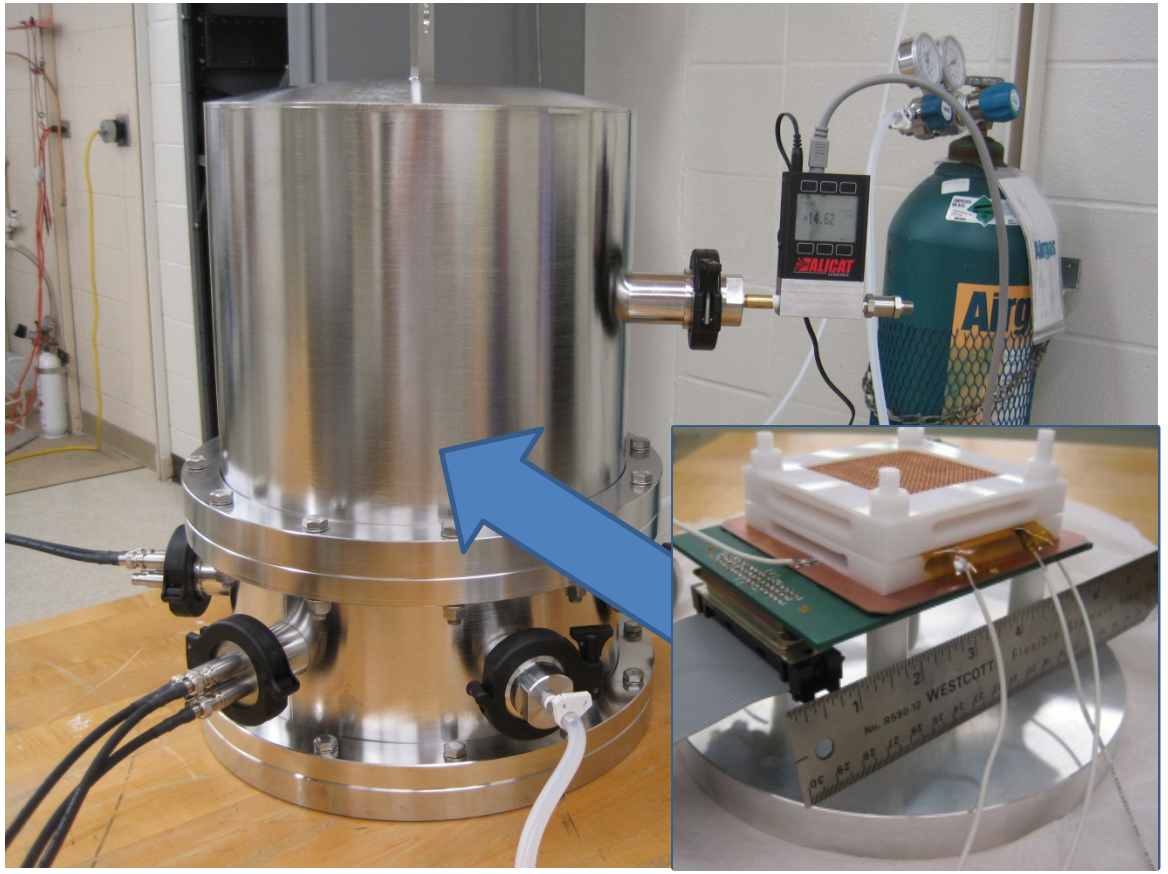


- Huge detectors, Looking for 1 “blip” per year!
- Very clean, to avoid false detection from radioactivity
- Underground, to avoid false detection from cosmic rays

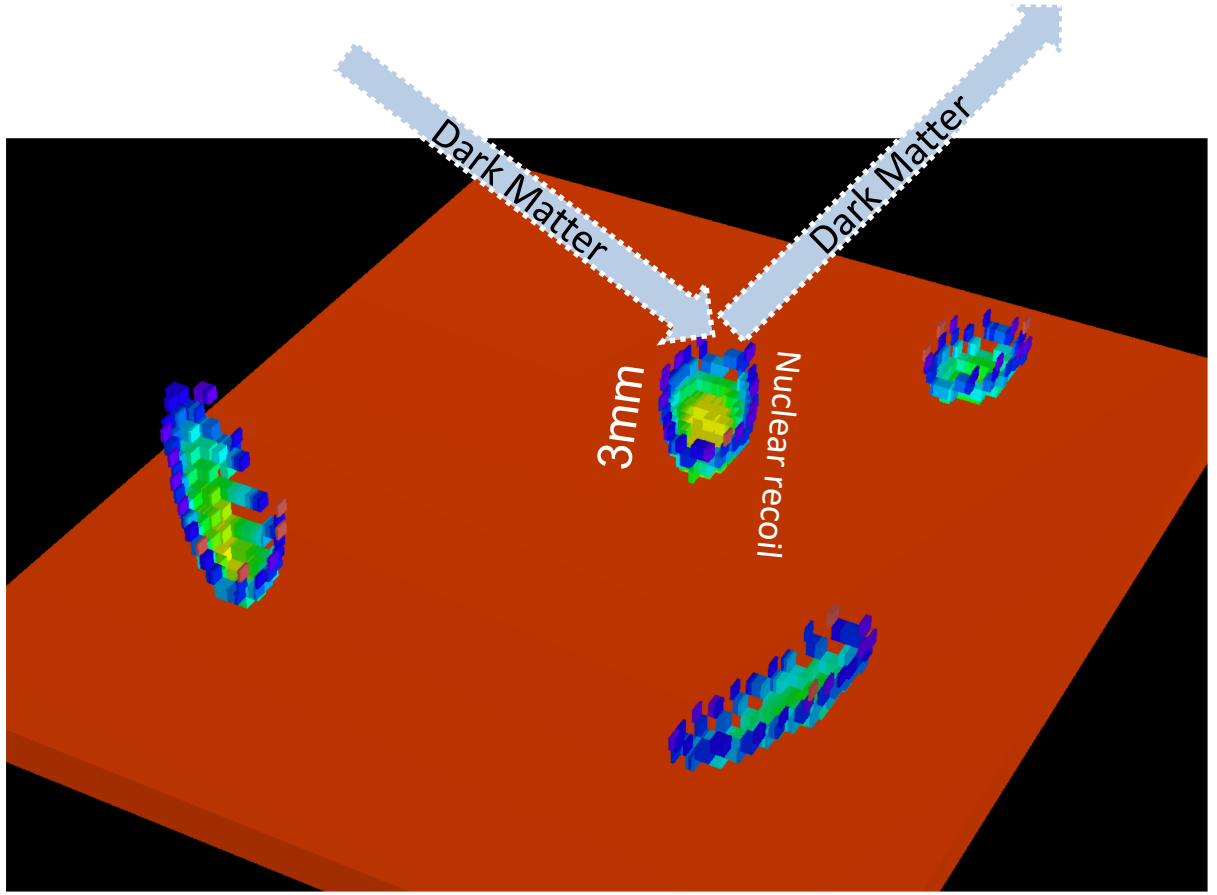
D^3 - Directional Dark Matter Detector

I'm working on this!

Prototype detector at UH Manoa



This is how I want to detect it!



If this works, I'd like to build a dark *matter telescope* in the future, to see where the dark matter comes from!

Questions?