THE KIND OF PHYSICS THAT WE DO AT FERMILAB

Cristina Mantilla Suarez - Fermilab

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A little about me

- Born in Quito, Ecuador (Andes mountains). I have seen a Galapagos tortoise but have never been to the islands.
- I liked chemistry and physics in high school but I did not know that being a physicist was possible until my physics teacher told me.
- I got my undergraduate degree from Ecuador's public university (only two colleges offer a degree in physics). My thesis advisor got me in touch with people at Fermilab.

My journey in the US

- Intern at Fermilab @ 2015.
- PhD @ Johns Hopkins (Baltimore, Maryland), 2016 - 2020
- Now I am a Fermilab postdoc. I use accelerator experiments to search for possible dark matter particles and to investigate the properties of the Higgs boson.

Fermilab is located in Batavia, IL.
It was founded by Robert Wilson in 1967.

It is one out of 17 national laboratories founded by the Department of Energy.

Fermilab is a particle physics laboratory.

We also do astronomy and cosmology.

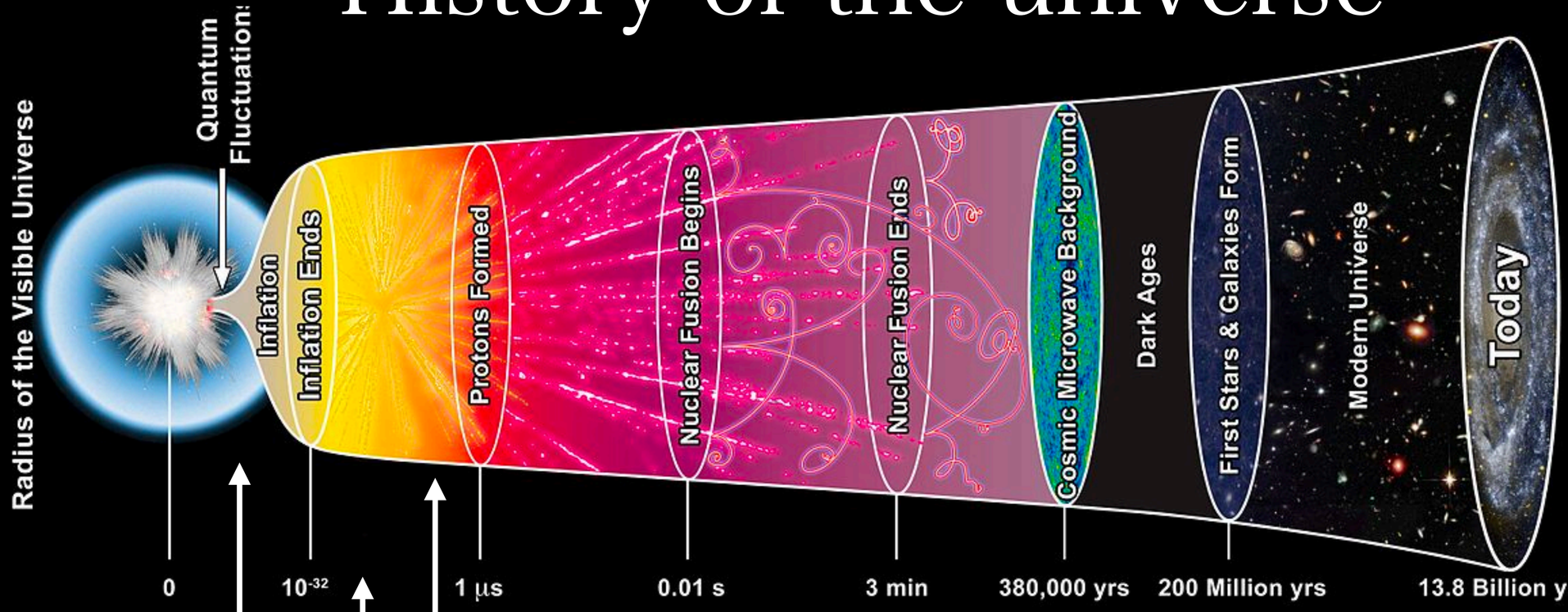
We also develop particle detectors and accelerators, quantum science and technologies. We do theory and experiment.

Where does everything come from?

What is the origin of the universe? What are the components?

We know that the Universe is 13.8 billion years old and that it is expanding (and that this expansion is accelerating).

History of the universe



Very dense

Rapid expansion

Fundamental Interactions

Matter created

Then universe cools down, first atoms form, we see the sign of first electrons, galaxies form, … TODAY

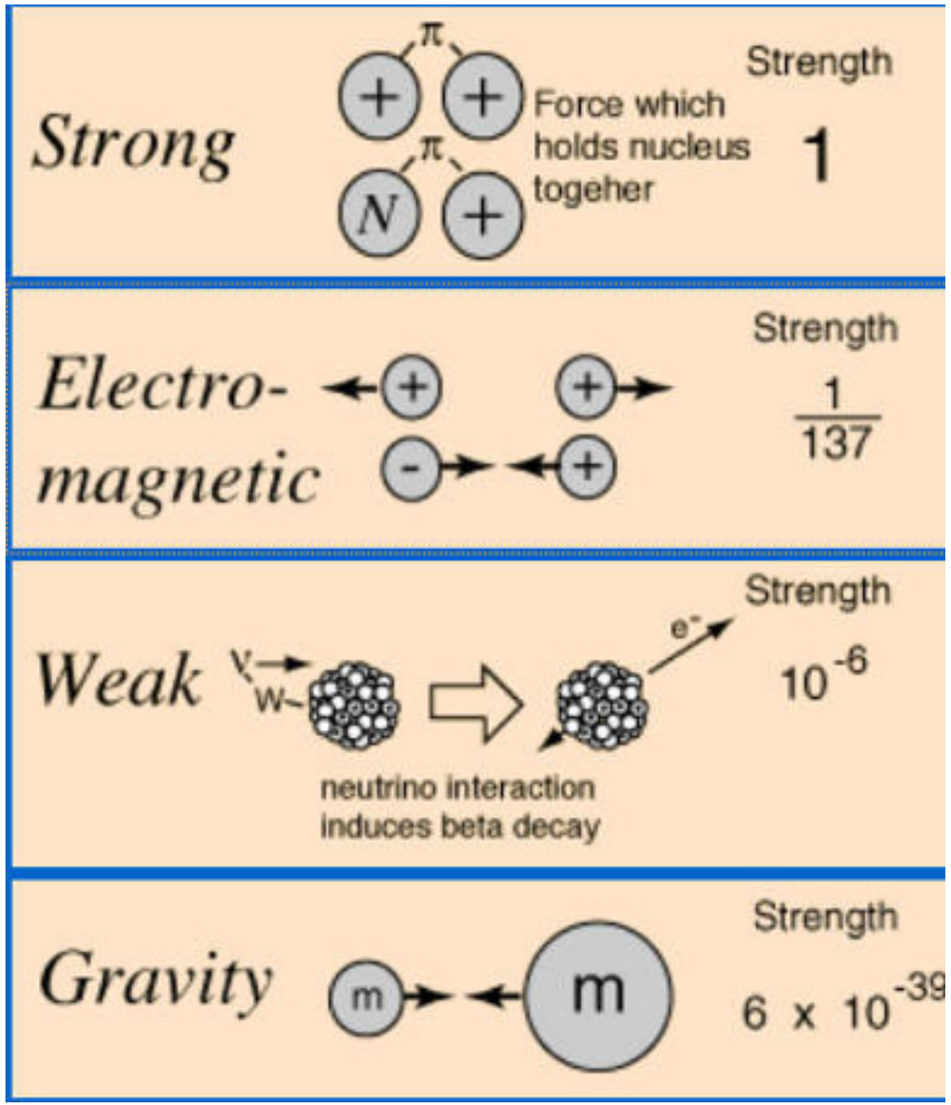
Where does everything come from?

What is the origin of the universe? What are the components?

How does everything interact?

What are the fundamental forces and what is their strength?

We know that there are four fundamental forces.



Where does everything come from?

What is the origin of the universe? What are the components?

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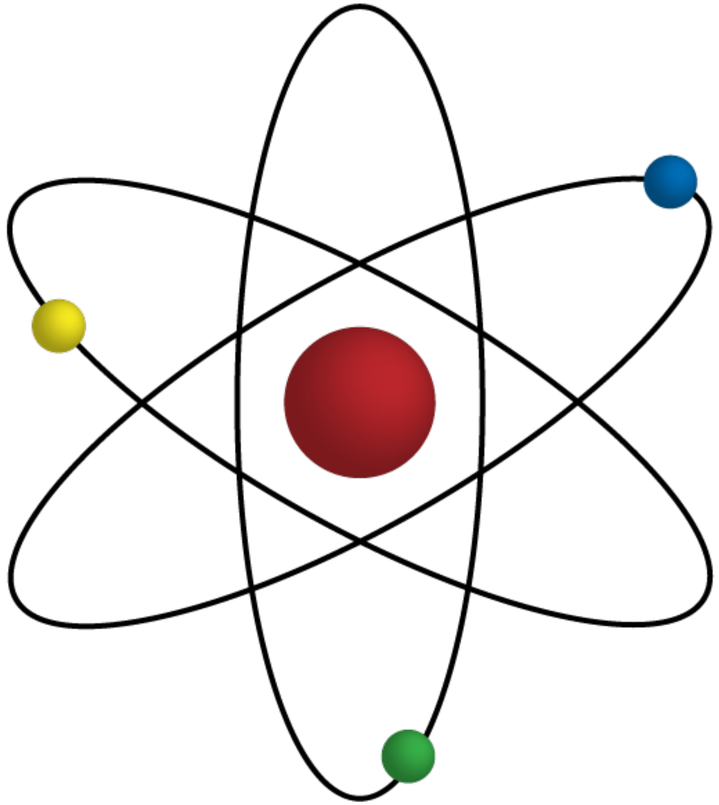
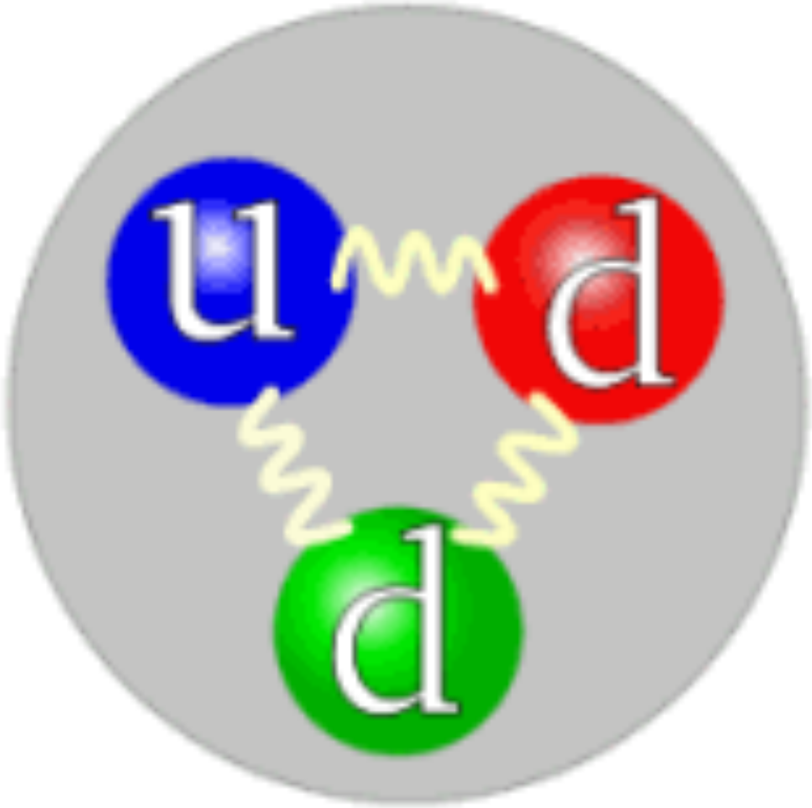
What are the fundamental forces and what is their strength?

What is stuff made off?

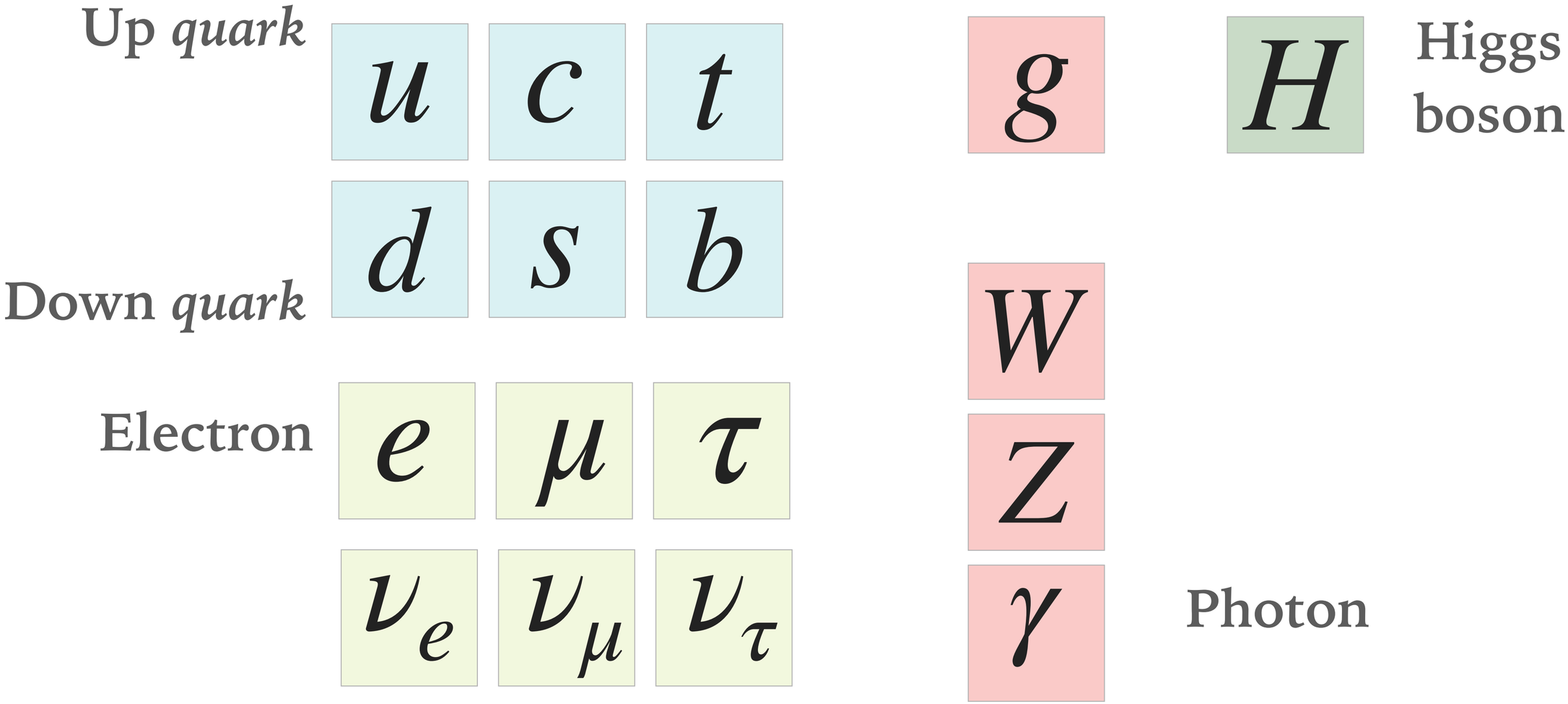
What are the fundamental blocks of our universe (particles)?

We know that there is a given number of elementary particles.

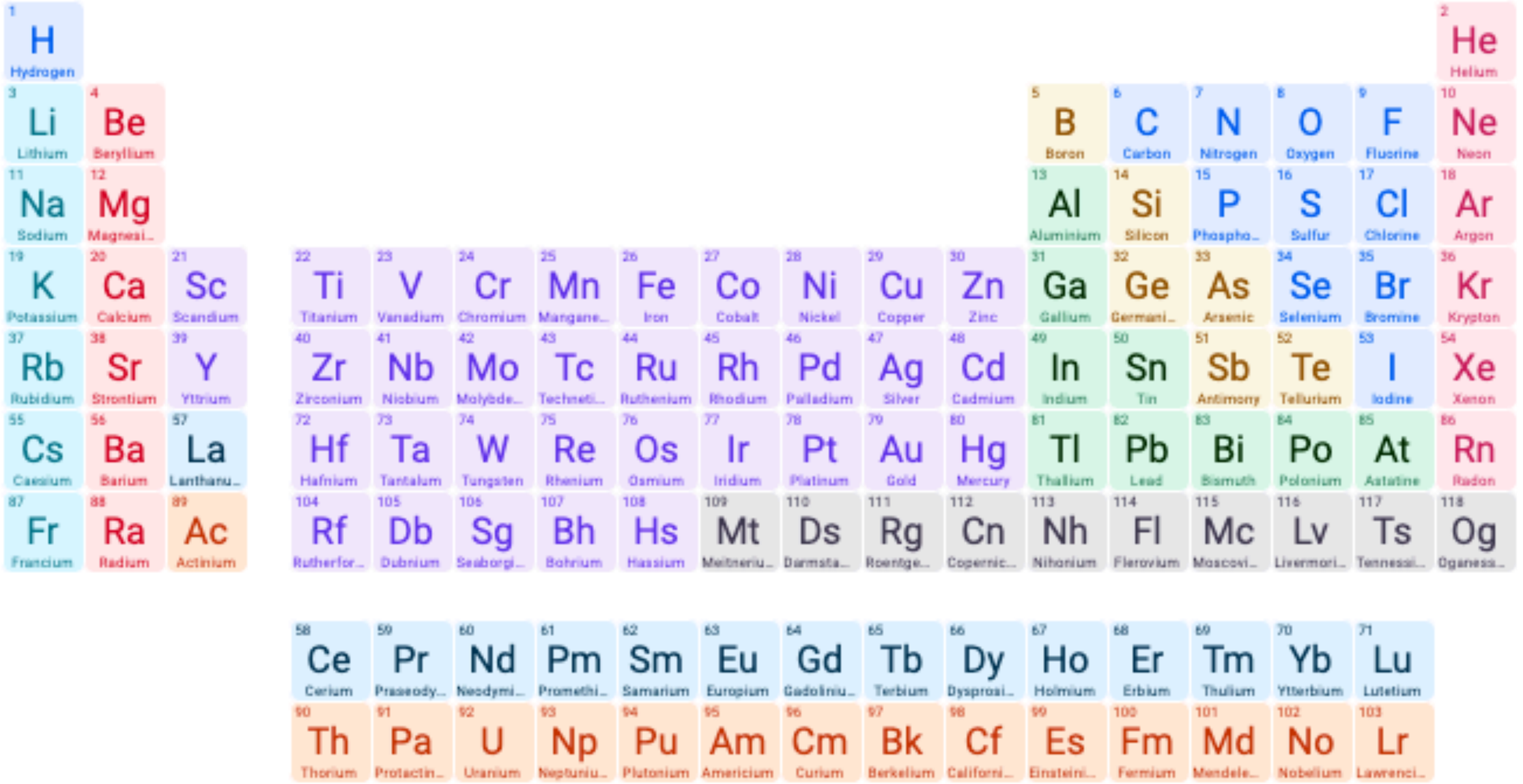




Electrons + Nucleus (protons/neutrons made of up and down quarks)


Up *quark*
u c t
g
H
Higgs boson
d s b
Down *quark*
W
Electron
e μ τ
Z
ν_e ν_μ ν_τ
γ
Photon
Neutrinos

Periodic Table



Fermilab was very involved with discoveries of particles in the last 50 years.

THE PARTICLES AND THEIR DISCOVERY

Positron, e^+ – 1932

Muon, $\mu^\pm$ – 1937

Pion, π^0, $\pi^\pm$ – 1947

Kaon, K^0, $K^\pm$ – 1947

Lambda, Λ^0, $\Lambda^\pm$ – 1947

Antiproton, p – 1955

Electron anti-neutrino, ν_e – 1956

Muon neutrino, ν_μ – 1962

Xi, Ξ^0, $\Xi^\pm$ – 1964

J/Ψ – 1974

Tau, $\tau^\pm$ – 1975

Upsilon, ϒ / b quark– 1977

Gluon, g – 1979

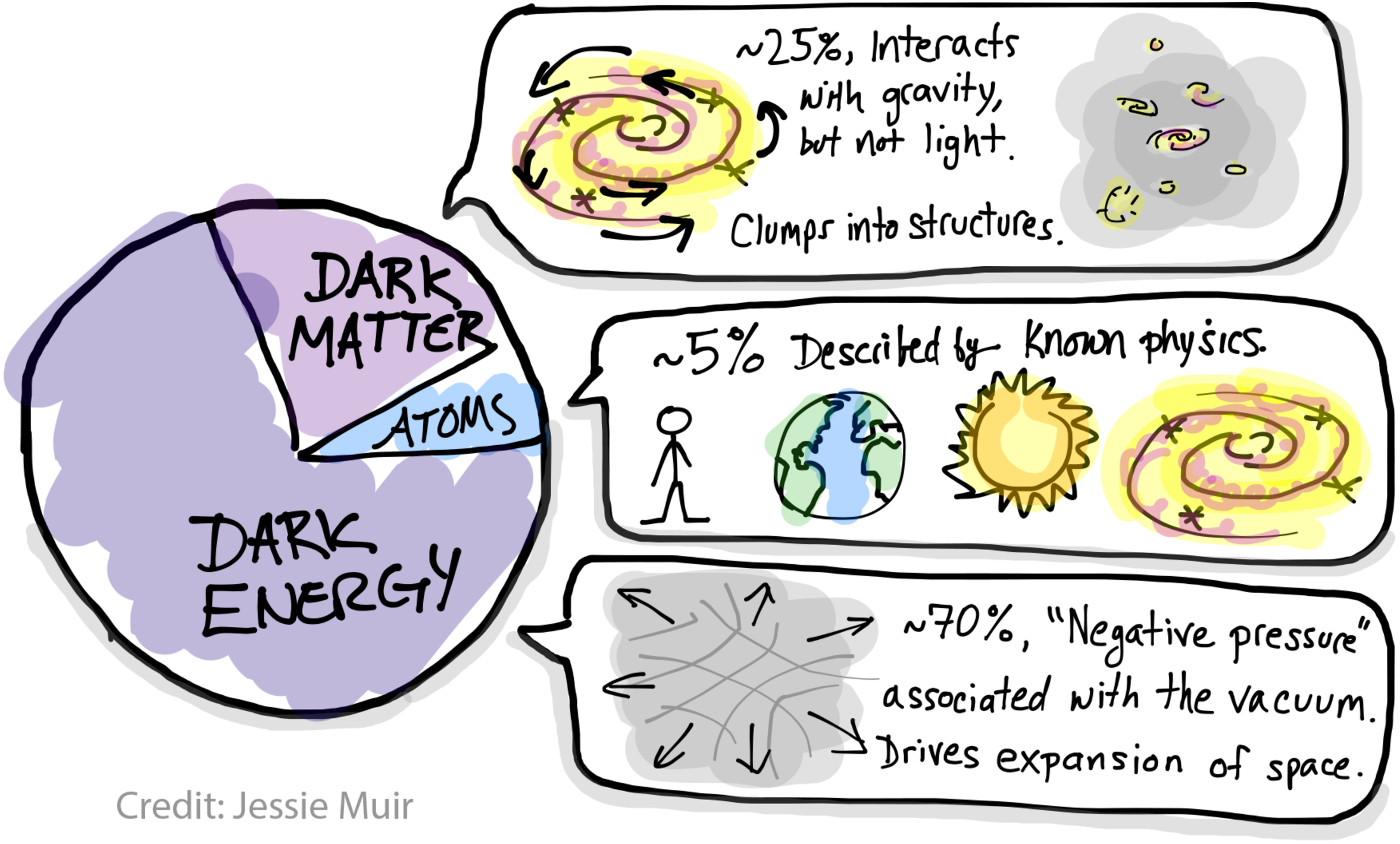
Z and W bosons, Z^0, $W^\pm$ – 1983

Top quark, t – 1995

Tau neutrino, ν_τ – 2000

Higgs Boson, h – 2012

What are some open questions?

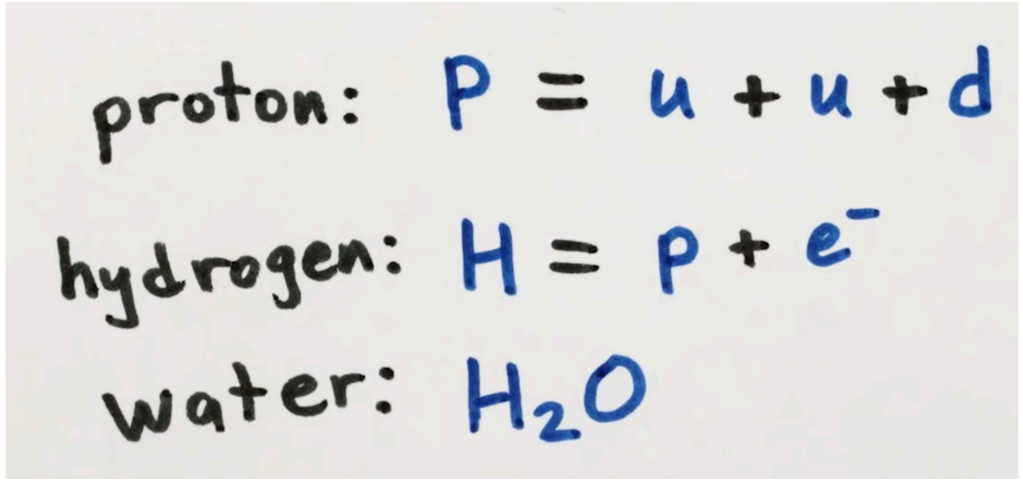


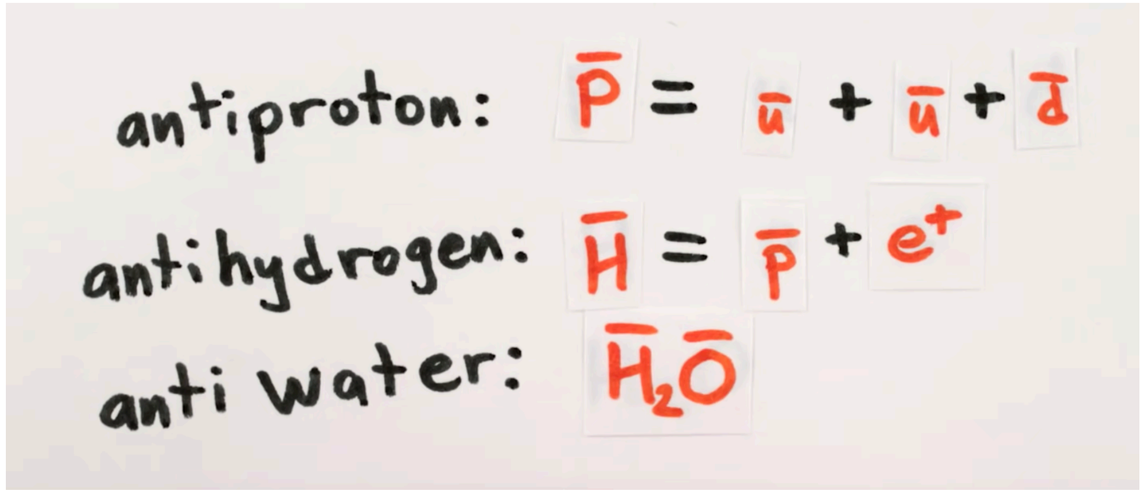
Credit: Jessie Muir

We know that **dark matter** exists because of astrophysical and cosmological measurements. We know that it interacts gravitationally. **We would like to know what dark matter, is it heavy, is it light?**

Also, we would like to understand **dark energy**: a term used to describe the mechanism responsible for the accelerated expansion of the universe. **What is causing the universe's expansion to accelerate?**

You may have heard of anti-matter too. Anti-matter is a type of matter that simply has opposite electrical charge.





But, antimatter is so rare that it costs $62.5 trillion per gram to produce it! **Why is there more matter than antimatter?**

There are also other questions that may keep us up at night. The list includes but is not limited to:

Are there other new forces/new particles?

Is one particle more special than the other: examples are the Higgs boson, the muon particles, the neutrinos?

What else can we learn from astrophysics objects about inflation/dark energy/dark matter?

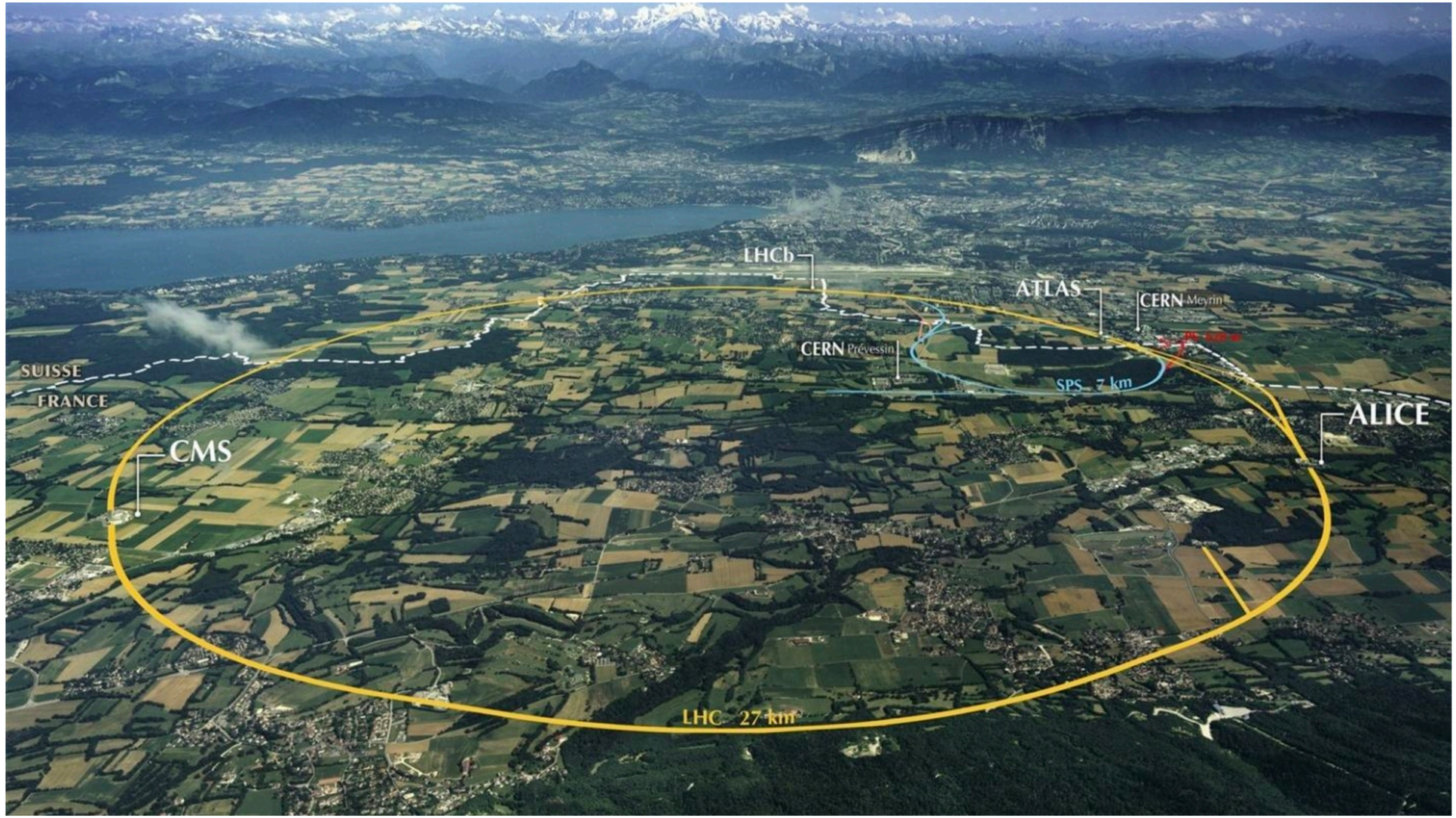
What does Fermilab do now?

Use accelerators

Tevatron

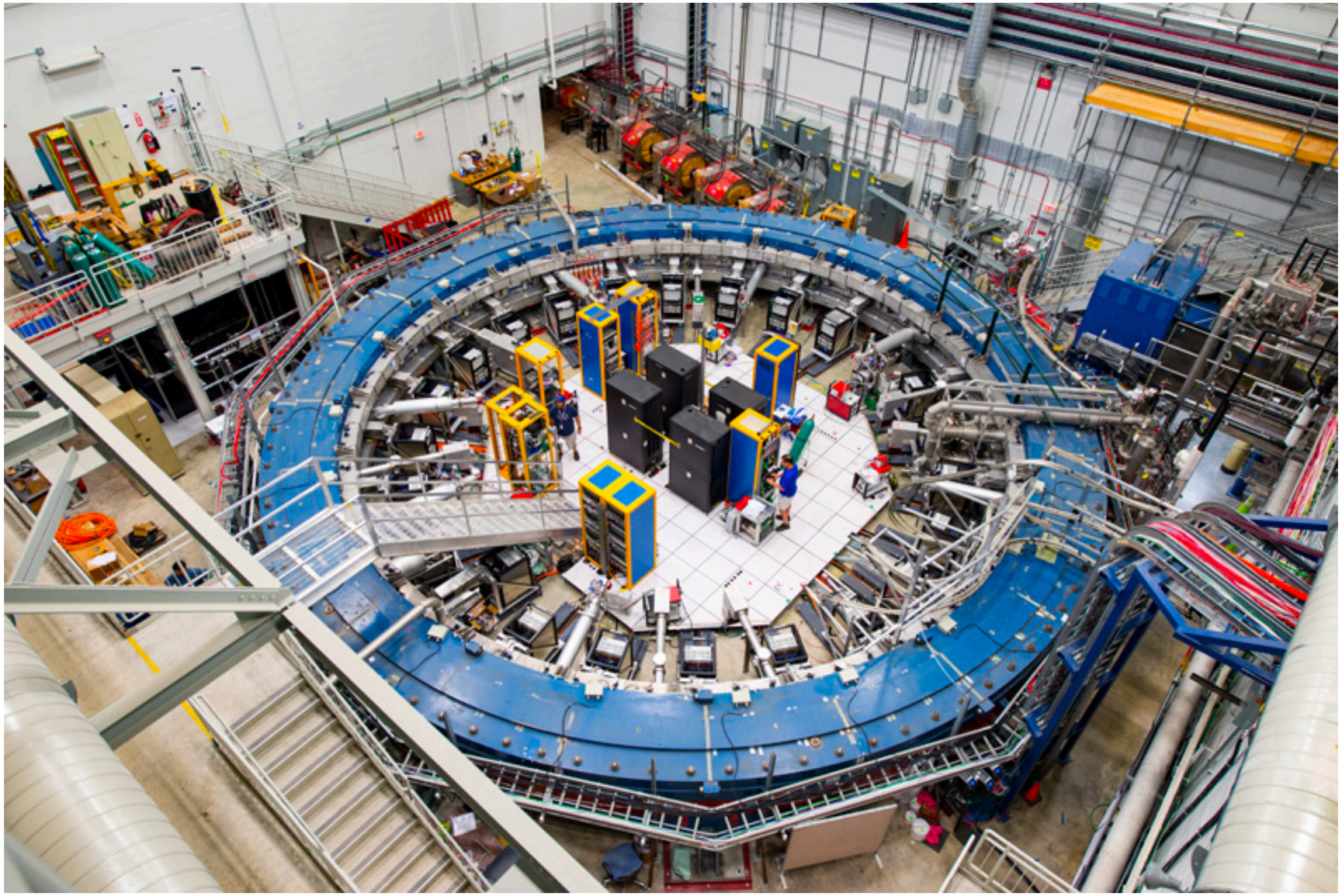
Particle accelerators are machines that use electric and magnetic fields to bring particles to very high speeds, and collide particles to produce other particles.

Study Proton collisions



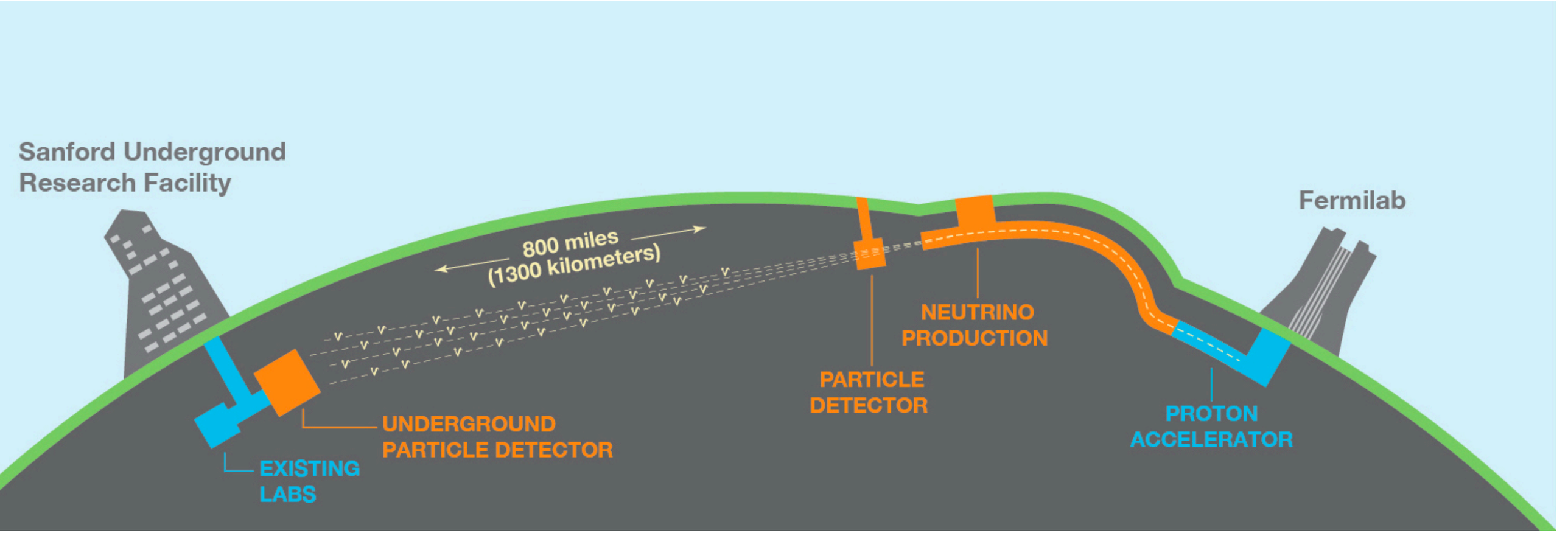
The Large Hadron Collider

Study Muons and their properties



The g-2 /mu2e experiments

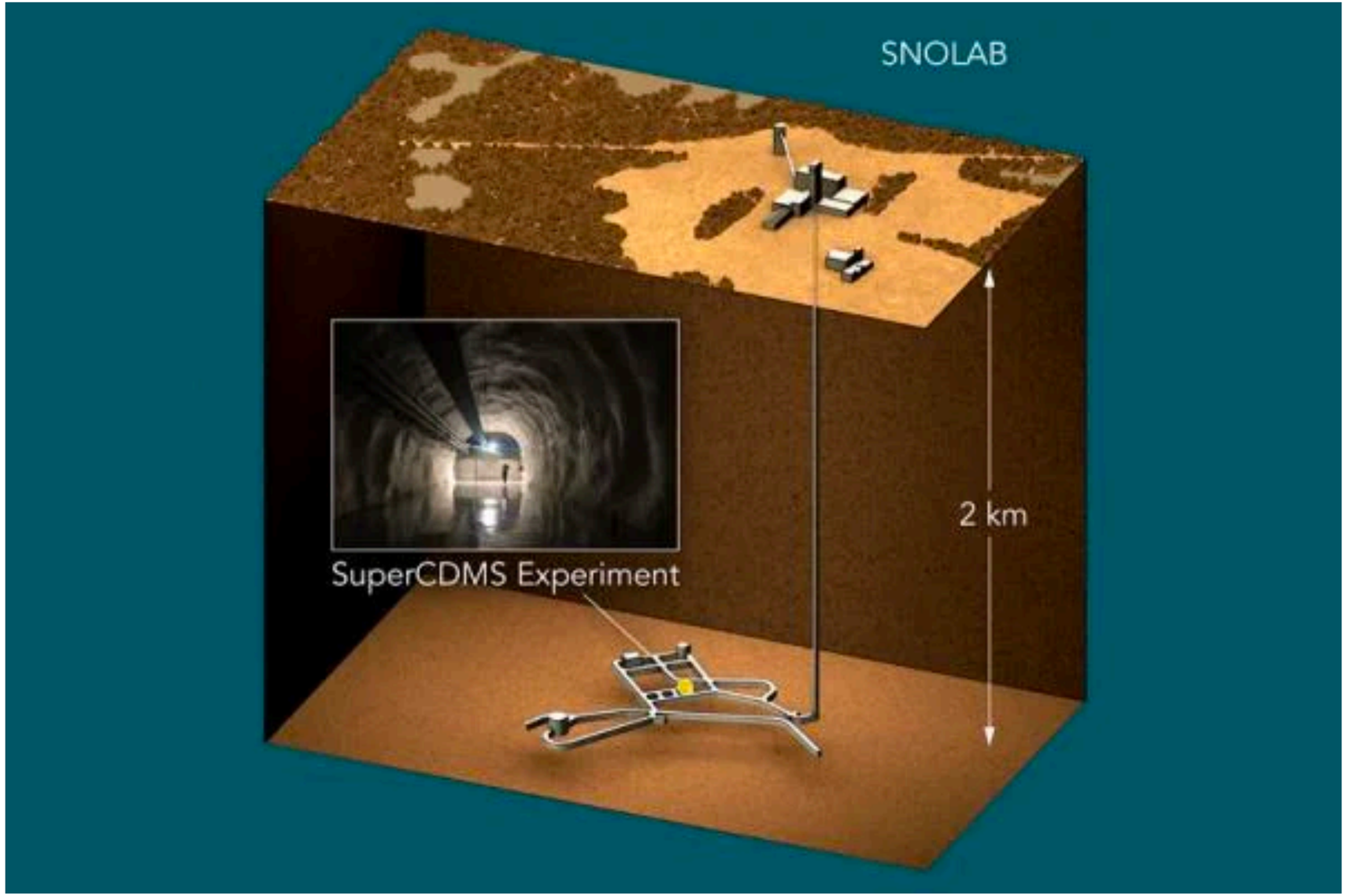
Study Neutrinos and send them through very long paths



The Nova, (MicroBoone + SBND), DUNE experiments

Search for dark matter

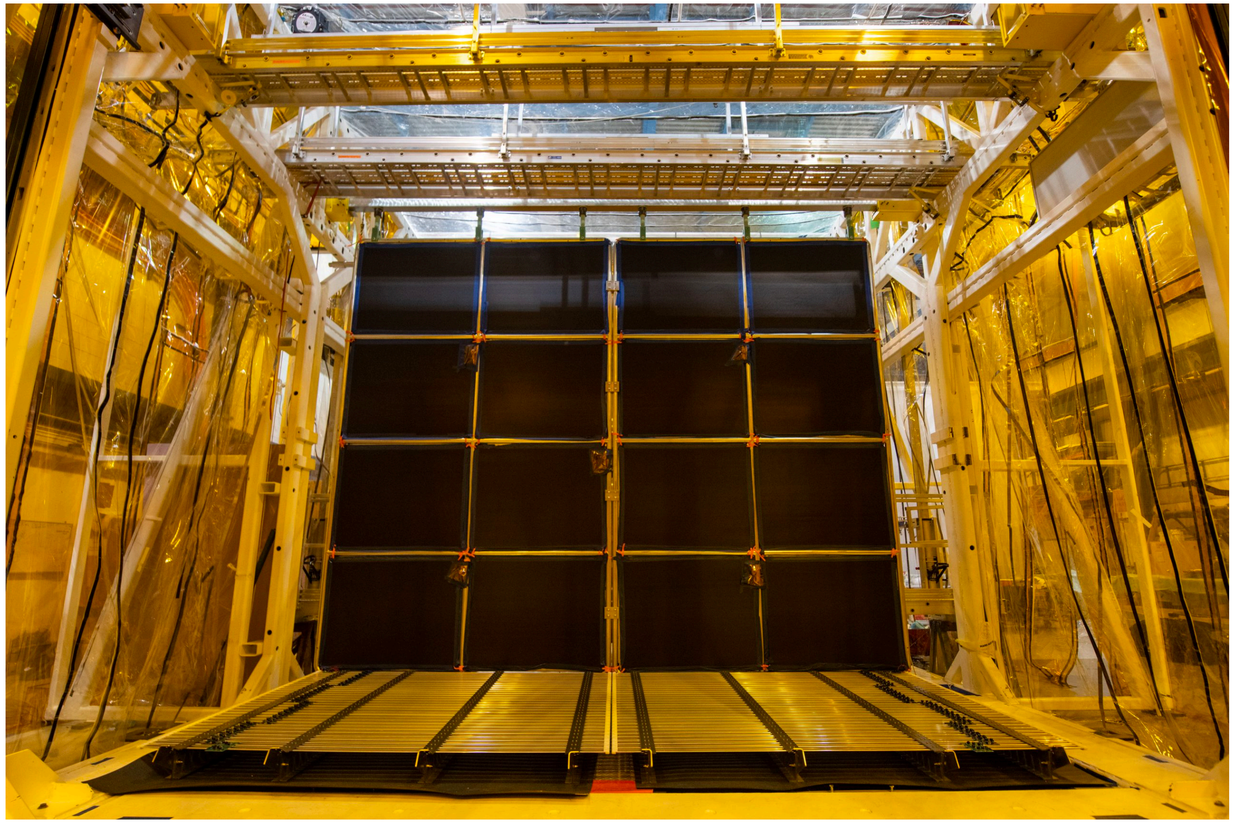
The SuperCDMS, Sensei, Oscura, ADMX, LDMX experiments



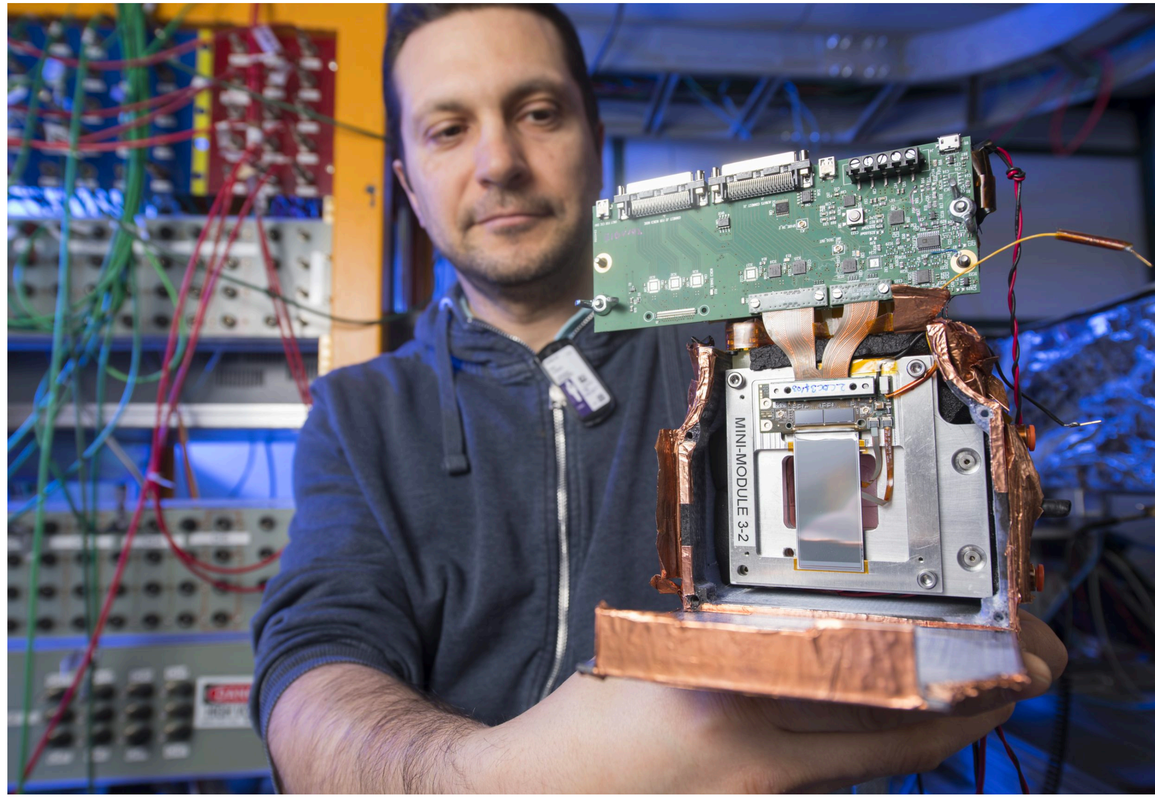
Explore astrophysical objects and perform cosmological measurements

The DES, Rubin LSST, CMB-S4

Build particle detectors

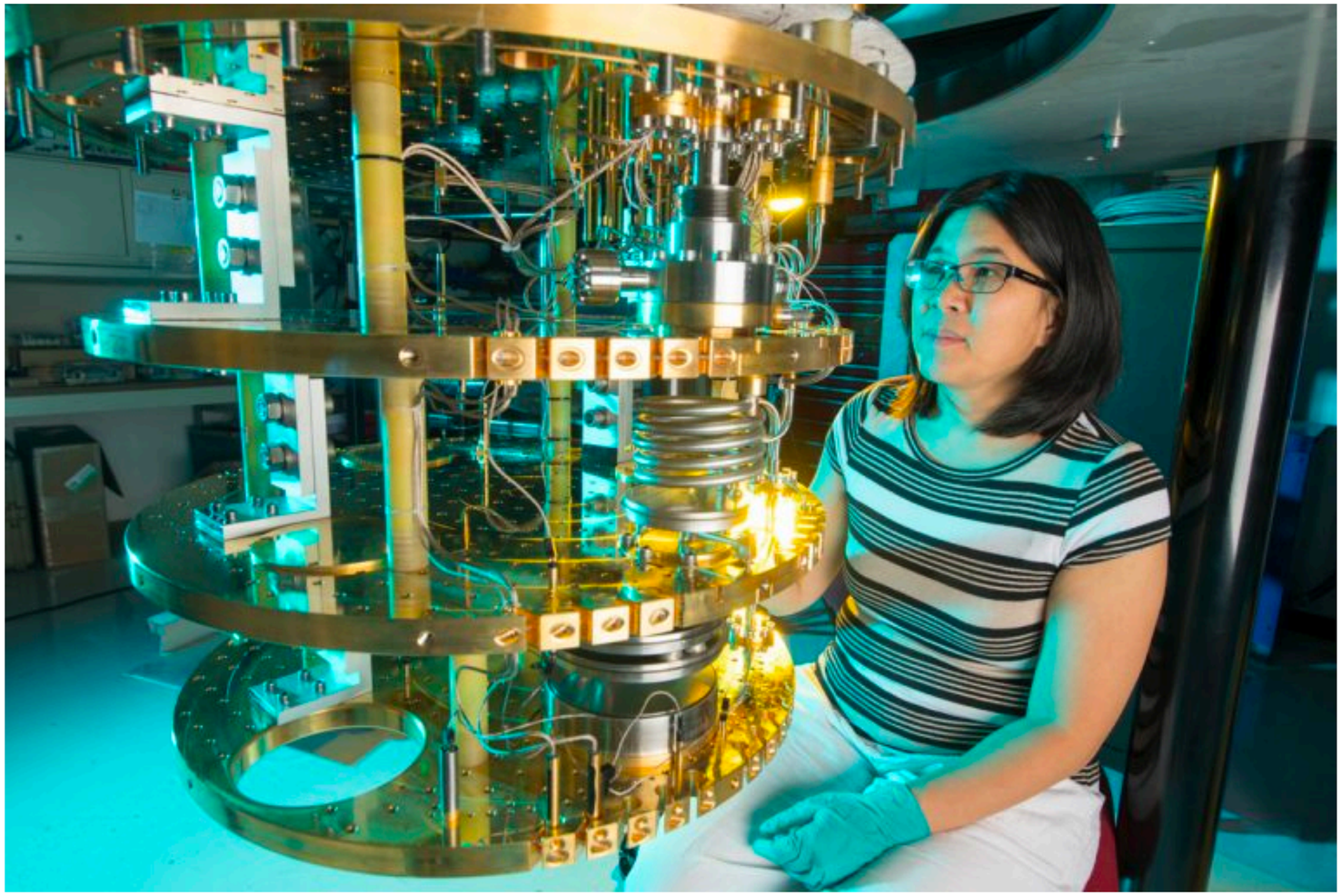


As big as a tank filled with liquid argon.



As small as a silicon strip.

Use quantum computing for sensing, communication and electronics



Dilution refrigerator for a dark matter detector that will detect qubits.

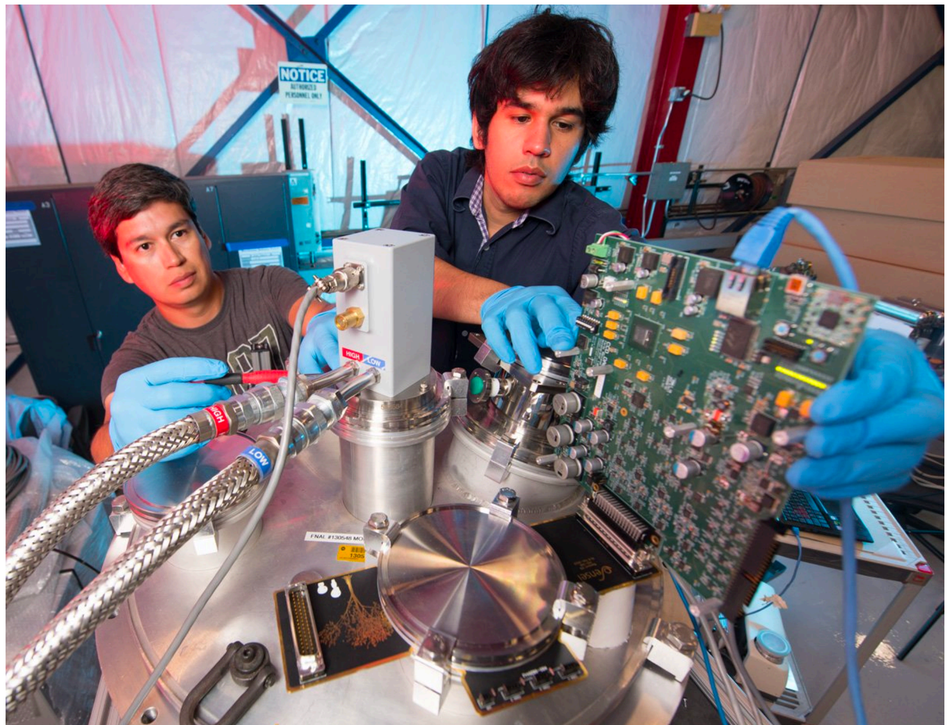
Scientists focus on developing theories developing particle detectors, and understanding the data from the particle detectors.

Scientist Monica Nunes from Brazil

Scientist Minerba Betancourt from Venezuela

Engineers (Electrical/Mechanical and others) can focus on making electronics that can readout detector data.

They can design and test electronics, design fluid, cooling, and mechanical systems that allow detectors/accelerators to work.



Engineers Claudio Chavez Blanco/Christian Torres Hermosa from Paraguay

Computing Scientists develop software and manage modern computing systems to make sure that data can be stored and analyzed in an effective way.

But, what do particle/astrophysics/ computing scientists, electrical and mechanical engineers/technicians **actually do?**