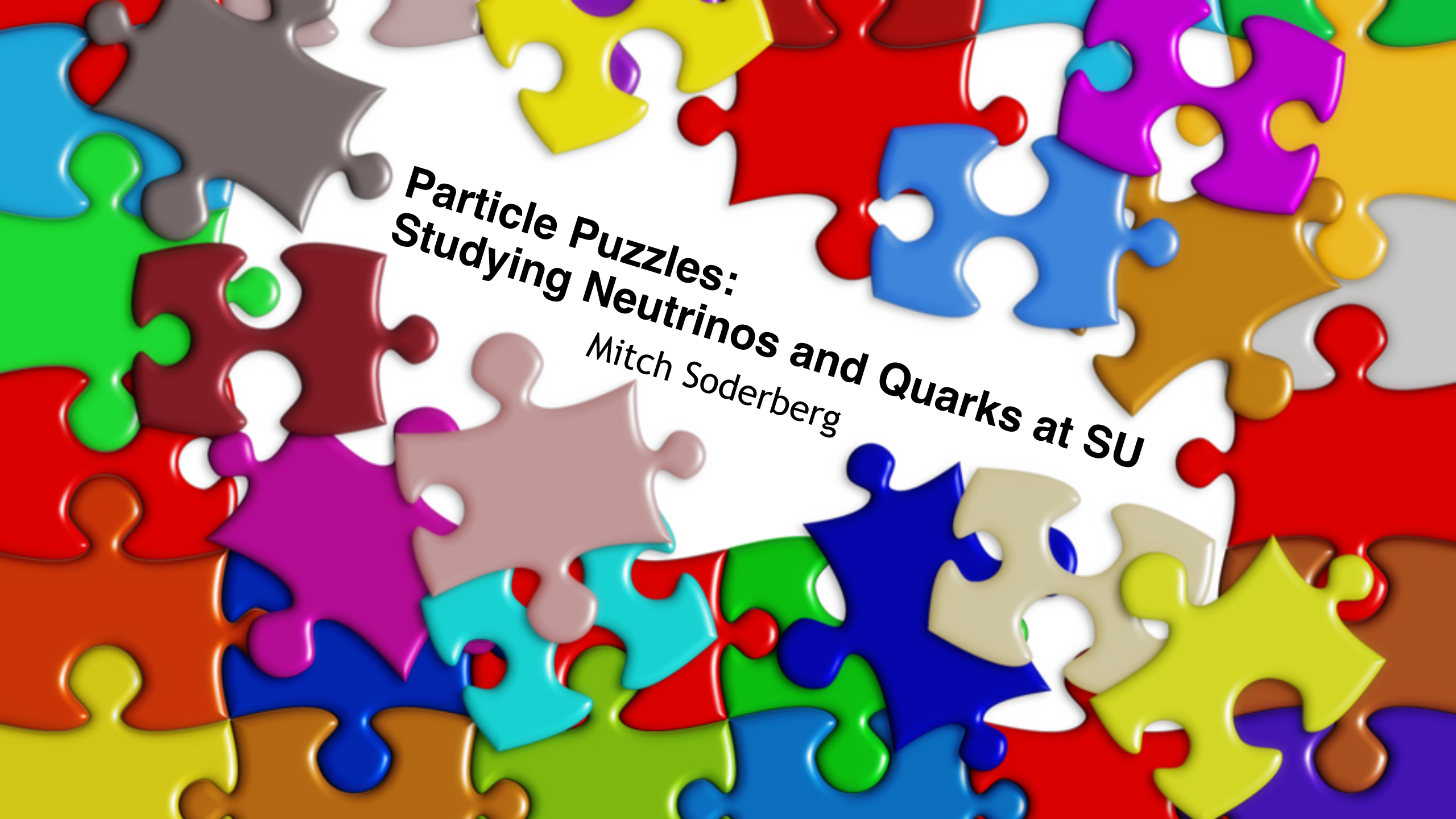

Particle Puzzles:
Studying Neutrinos and Quarks at SU
Mitch Soderberg

Outline:

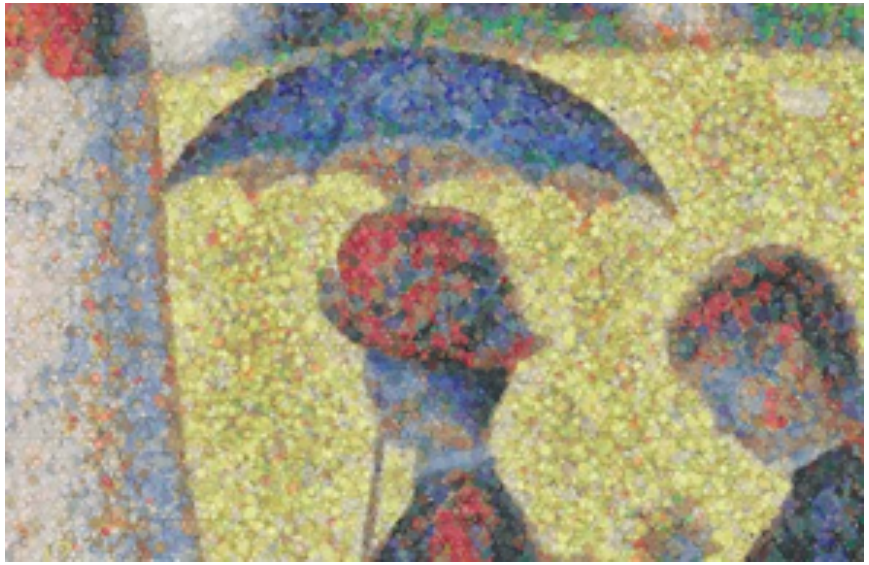
- Particles
- Puzzles
- Neutrinos in 1 slide
- Detecting Neutrinos
- Lightning-quick look at NOvA and LHCb.

Particles

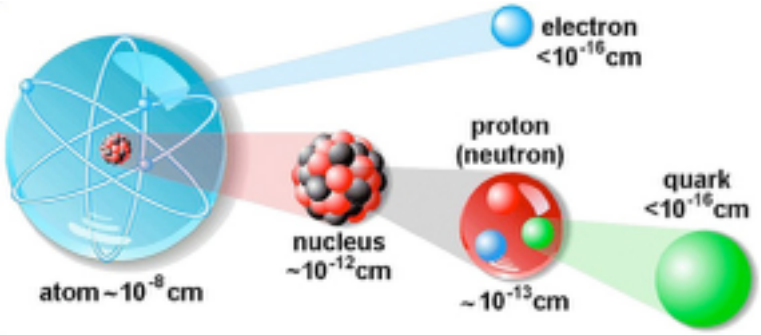
In our field of research, we study unimaginably tiny objects, which in some cases (e.g. neutrinos) have an extreme aversion to our inquiry.

A Sunday Afternoon on the Island of La Grande Jatte - Georges Seurat

A painting ~ 10^{2} cm



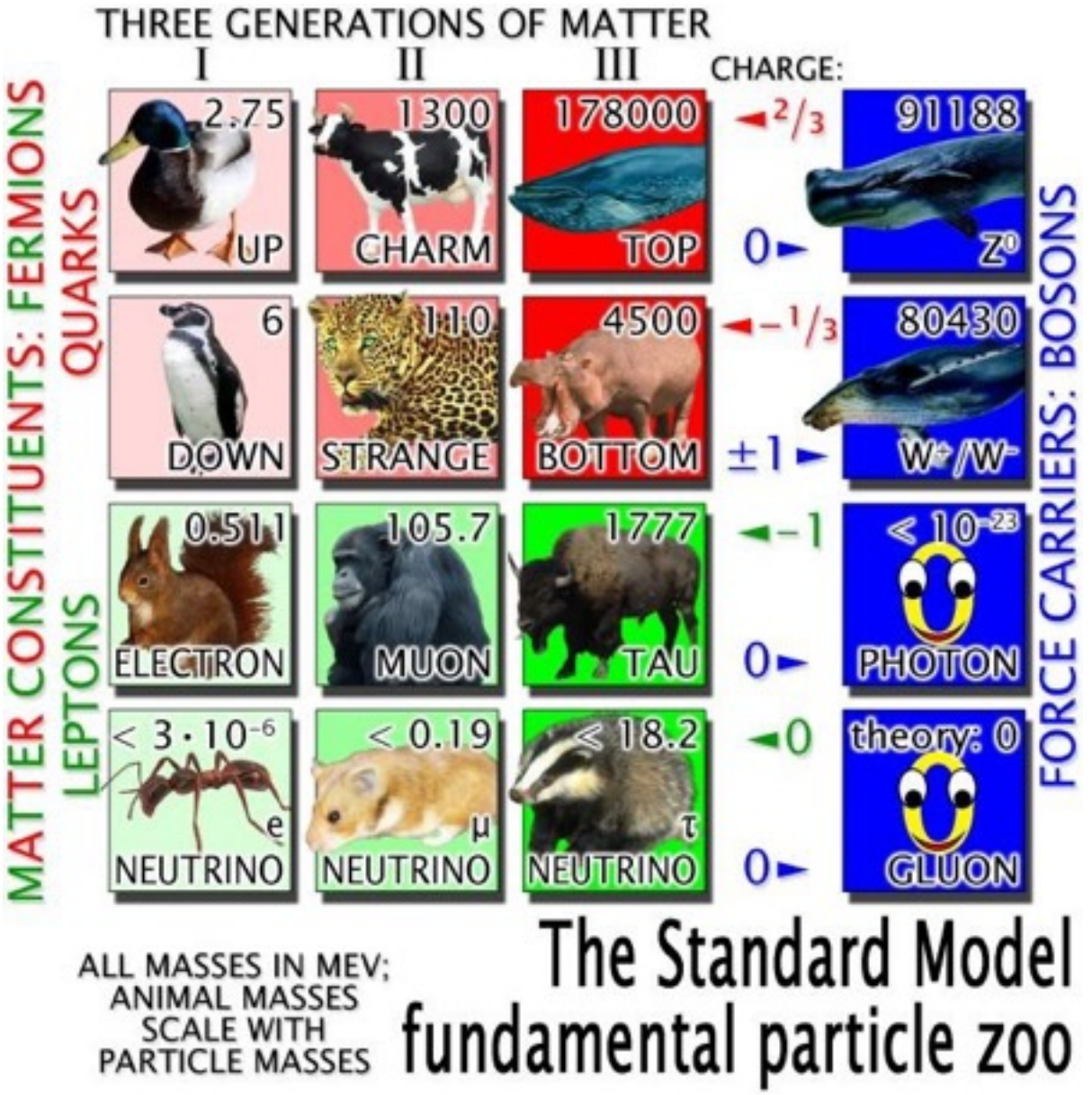
Dots in this painting ~ 10^{-1} cm



Atomic/Subatomic

Particles

- Particle physics explains universe in terms of interactions of subatomic particles.
- Matter seems to be organized in lepton+quark generations, with 3 distinct and increasingly heavier copies. (Puzzle #1: Why 3 copies?)
- We use facilities like CERN and Fermilab, where beams of some of these particles are made, and watch what happens when they interact in our detectors.



Puzzles

- Where did all the antimatter go?
- How many types of neutrinos are there?
- What is the nature of the neutrino?
- Does the proton decay?
- What's the deal with "dark matter"?
- Can we use neutrinos to understand the dynamics of supernovae?

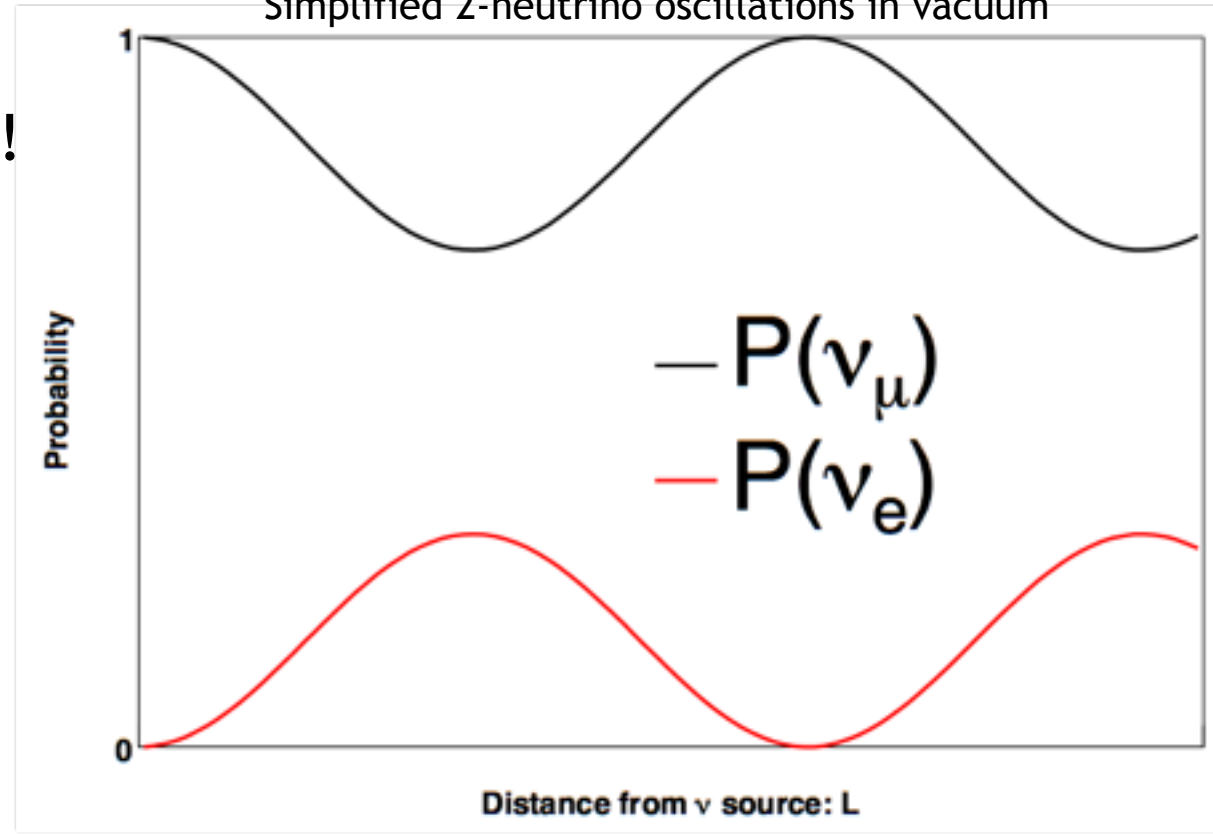
Supernova 1987A

We are trying to answer BIG questions!

Neutrinos in 1 slide

- Neutrinos "oscillate" among the 3 SM flavors as they travel. Quantum mechanics in action!
- Oscillations imply neutrinos must have mass!
- Neutrinos are electrically neutral and only participate in the Weak interaction, which combined with their incredibly small mass makes them **extremely unlikely** to interact with matter.

Simplified 2-neutrino oscillations in vacuum



$$\mathrm{P}_{osc} = \sin^2(2\theta)\sin^2(1.27\frac{\Delta m^2 L}{E})$$

Detecting Neutrinos

- The technology: **Liquid Argon Time Projection Chamber**
- Detector immersed in vat of highly purified liquid argon.
- Like launching a satellite or rocket…don't necessarily get a second chance to fix! Lots of R&D to verify the launch is a success!

Another example of pointillism!

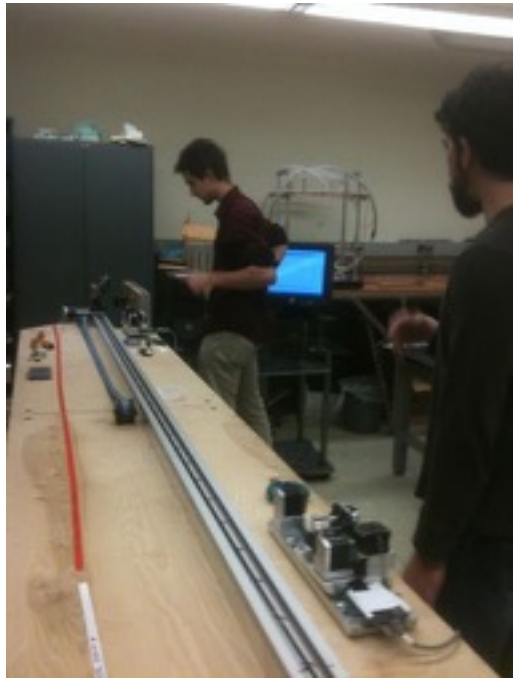
75 cm

Run 3493 Event 41075, October 23rd, 2015

Run 3469, Event 53223

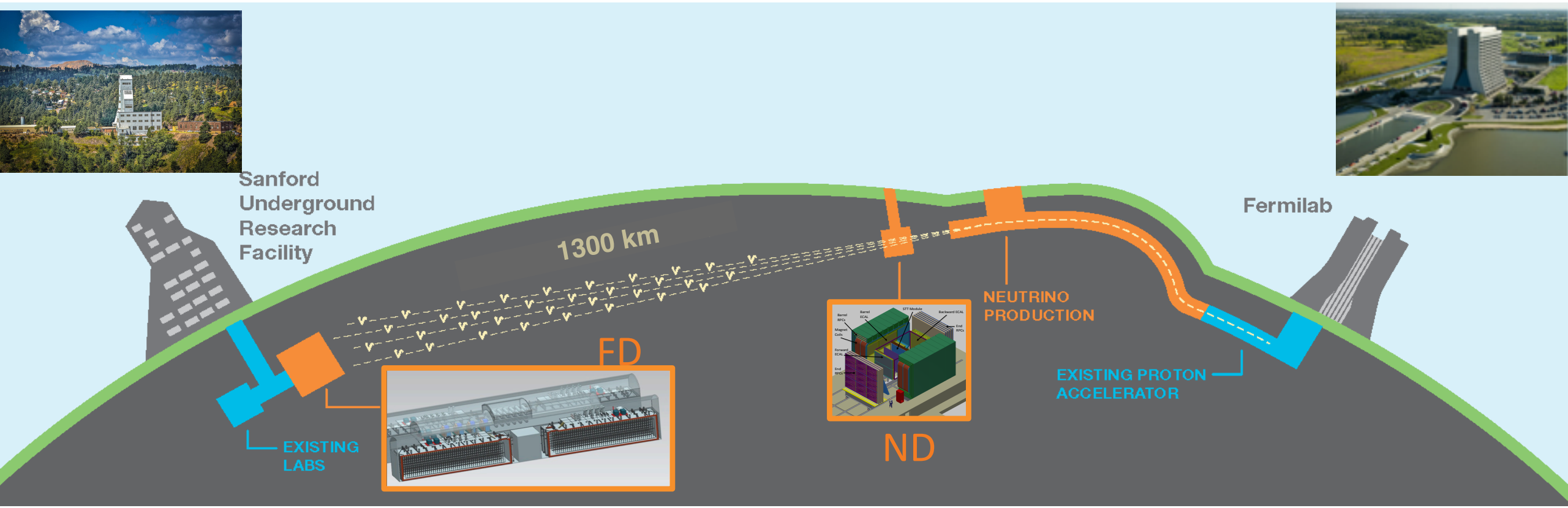
Detecting Neutrinos

- **Recent undergraduate projects:**
  - Production of >3000 wires for MicroBooNE TPC.
  - Design/build Cold Box setup to study detector components.
  - Creating LabView programs to measure TPC wire tension.
  - Studies of radioactive Ar-39 levels in liquid argon detectors.
  - 3D printing prototype components for next-generation detectors.
  - Creating software tools for event visualization.
- **Looking for students with interests in:**
  - Using GPU farm at SU to classify neutrino data.
  - Reviving vacuum system for use in detector testing.
  - Participate in construction of next-generation experiment (SBND).
  - Labview/Python/etc… coding for lab work.
  - Developing material for outreach.



Detecting Neutrinos

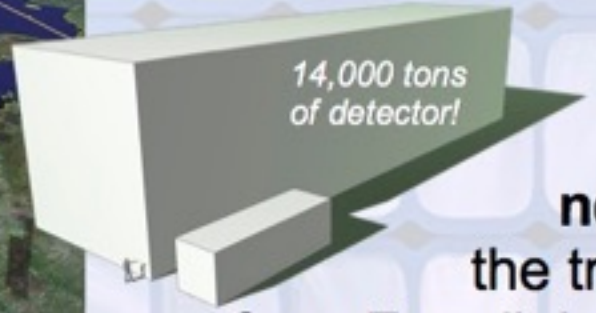
DUNE: DEEP UNDERGROUND NEUTRINO EXPERIMENT



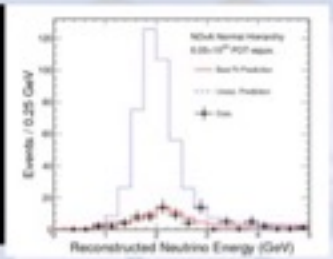
The definitive BIG neutrino experiment. <10 years from scheduled start of operations…seems far away, but it isn't.

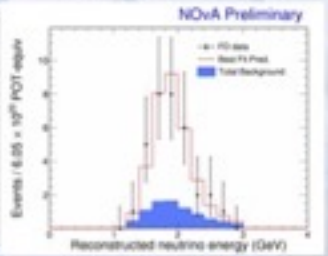
Prof. Denver Whittington

NuMI Off-axis ν_e Appearance



NOvA measures the details of **neutrino oscillation** by observing the transmutation of **muon neutrinos** from Fermilab (Illinois) into **electron neutrinos** at the far detector (Minnesota).





Flavor Oscillation

Denver is looking for interested undergraduates to work with him!

You Can Help

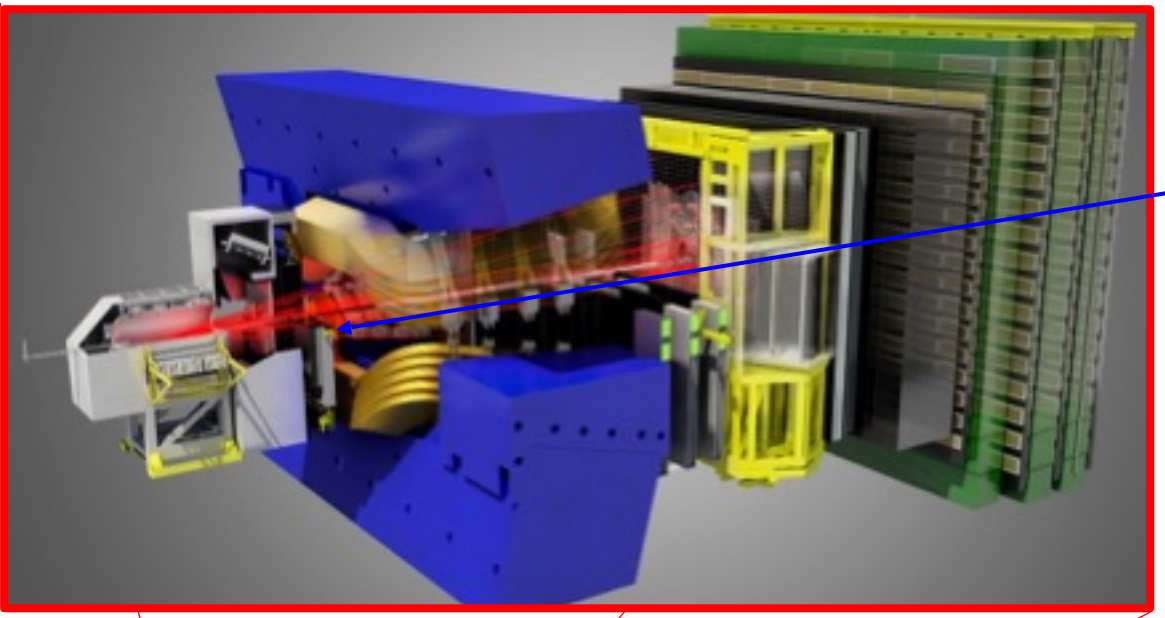
- Can we better distinguish what other particles are in each event?
- What new approaches can we use to improve neutrino energy measurements?
- How can we better filter out non-neutrino noise?

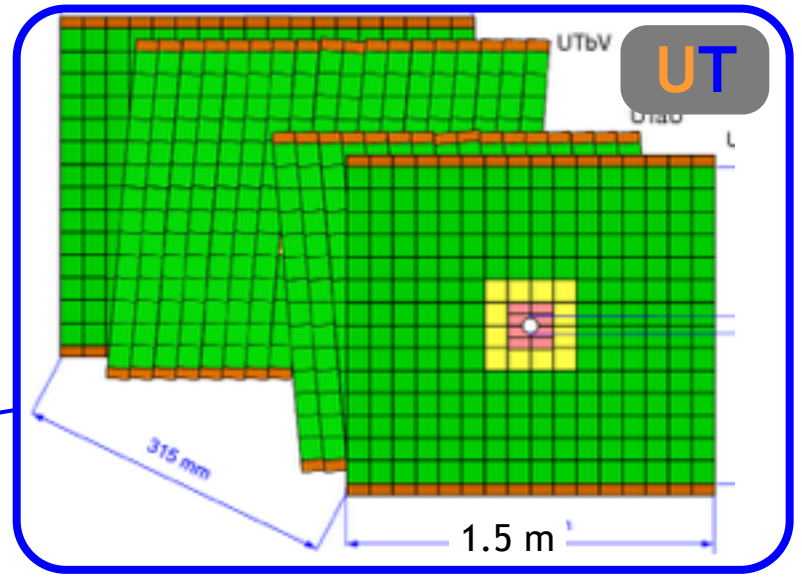
LHCb Experiment at CERN

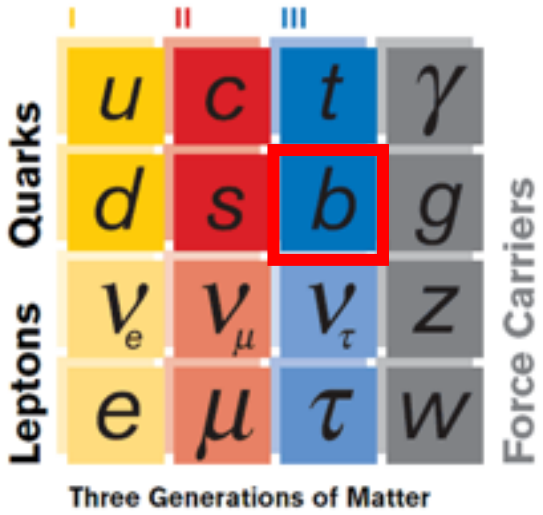
Prof. Marina Artuso | Prof. Steve Blusk | Prof. Matt Rudolph | Prof. Tomasz Skwarnicki | Prof. Sheldon Stone











- Goal is to uncover **deeper theory of matter** through precision study of **beauty** quarks.
- **2019-2021**: Major upgrade of LHC experiments
  - SU LHCb group in charge of building a new detector (**UT**).
  - Opportunities for undergraduate participation, independent study, etc.
    (can contact Prof. Steve Blusk, sblusk@syr.edu)

LHCb Experiment at CERN

http://hep.phy.syr.edu/~raym/UGP/index.htm

LHCb group has a very nice page describing undergraduate projects at SU.
Check it out!