Modernizing Modern Physics

or, disproving the Pauli effect

Summer Seminar 2025

Jason Ho

Physics & Engineering

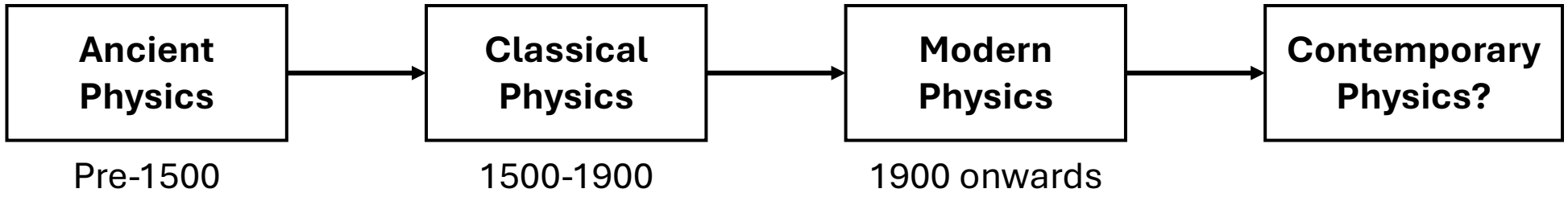
Wolfgang Pauli

The Pauli Effect

The tendency of technical equipment to encounter critical failure in the presence of certain people.

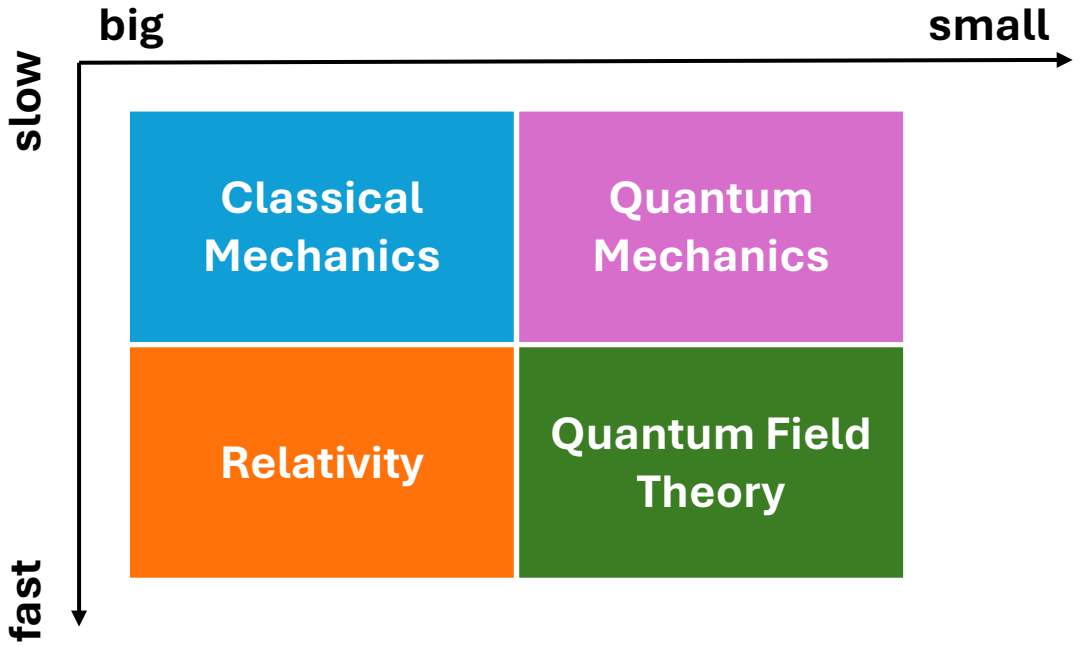
“It is well known that theoretical physicists cannot handle experimental equipment; it breaks whenever they touch it.” – George Gamow

What is **Modern Physics**?



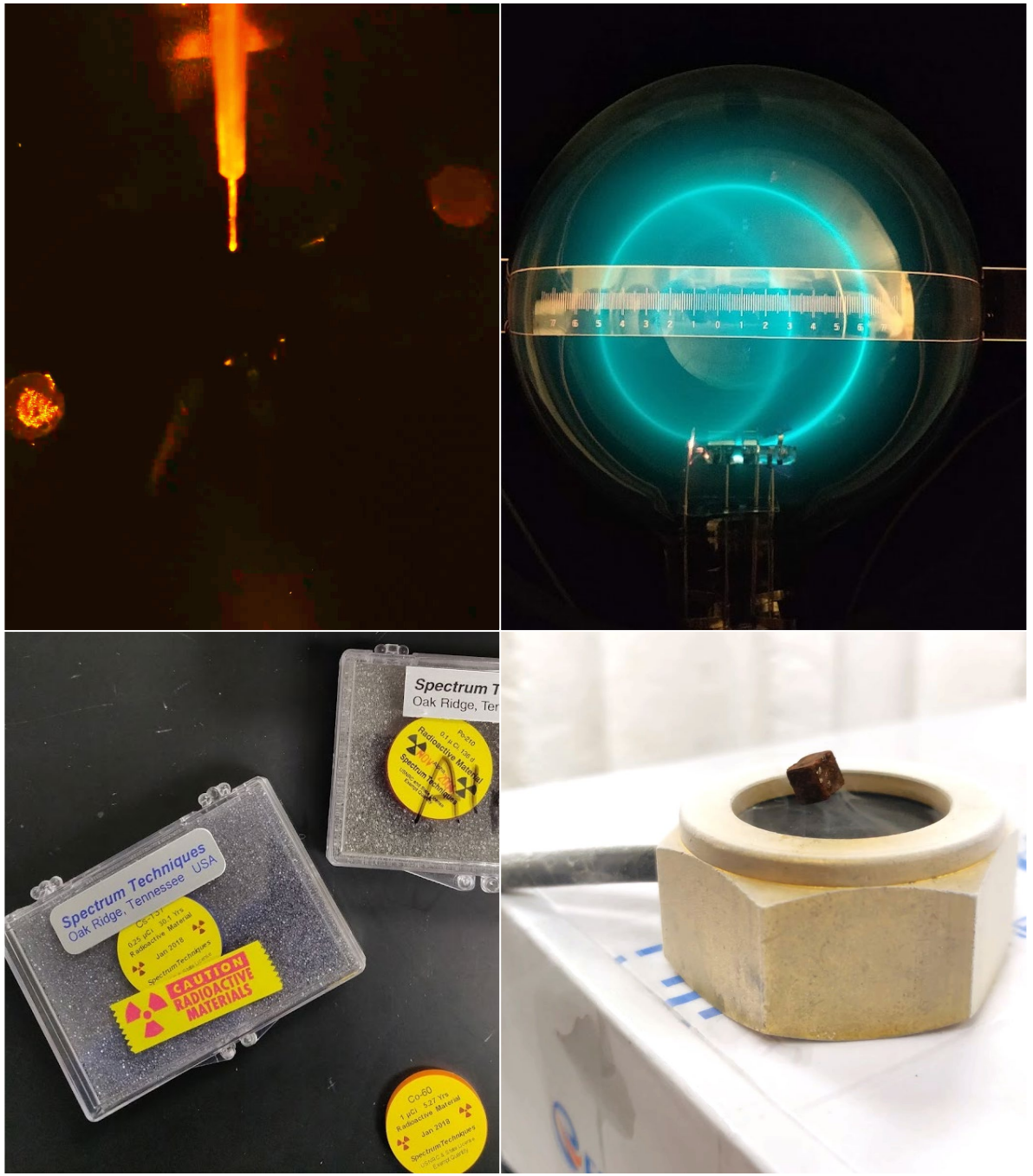
"...it seems probable that most of the grand underlying principles [of physical science] have been firmly established"

– Albert A. Michelson, 1894

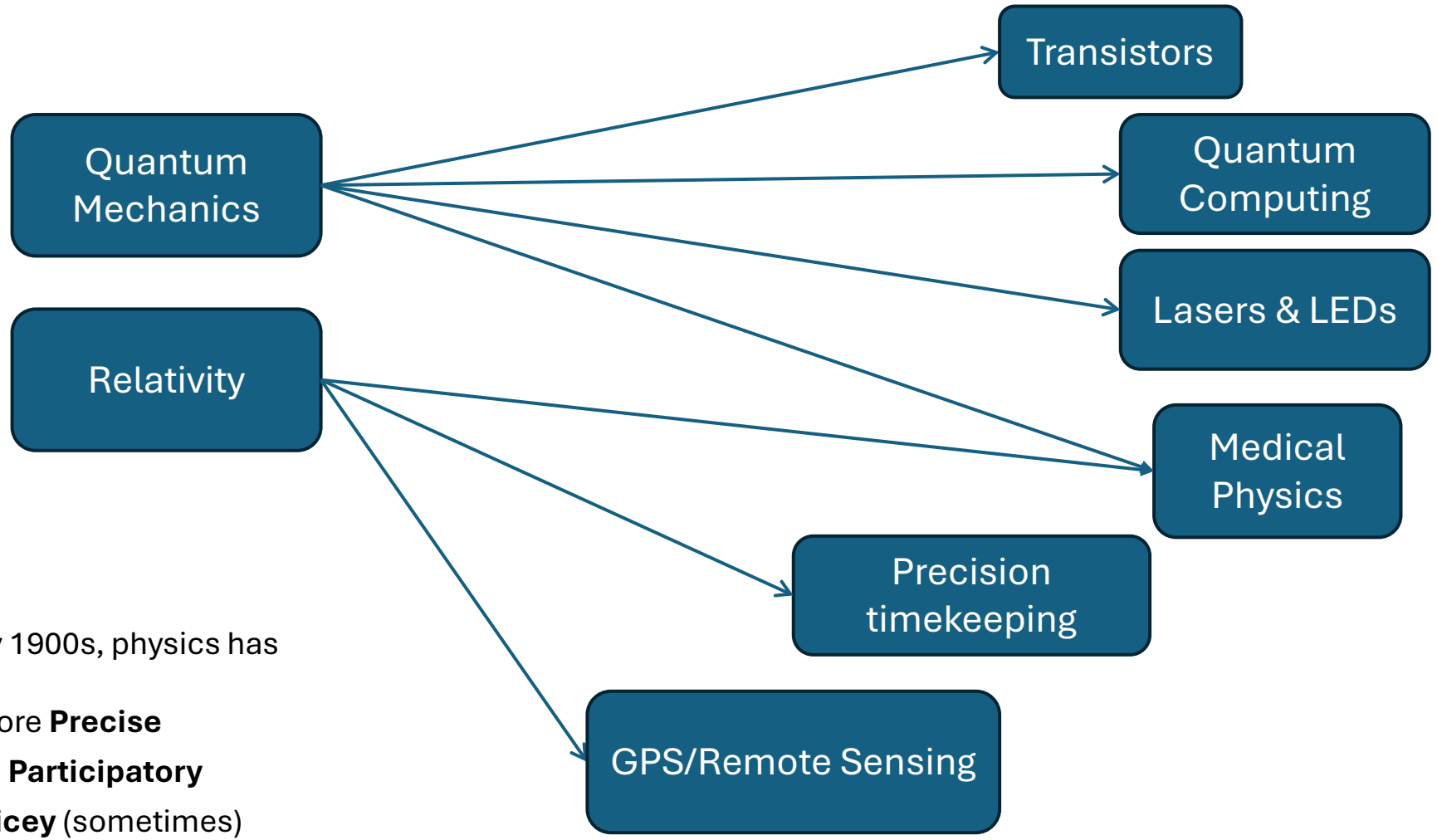


What is **PHYS337**?

- Introduction to concepts in Modern Physics
- In the lab: observe modern physics concepts in action
  - Incorporate computational tools in analysis
  - Build expertise with technical equipment
  - Tackle larger, more complex experiments



Keeping the Modern in Modern Physics



Since the early 1900s, physics has become…

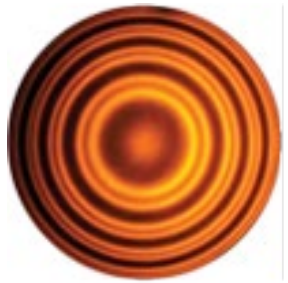
More **Precise**

More **Participatory**

Less **Pricey** (sometimes)

ALPhA Immersions

- **A**dvanced **L**aboratory **Ph**ysics **A**ssociation
- Goal is “to support and enhance advanced experimental physics education”
- 630 enrolled participants over the past 15 years



ALPhA
Advanced Laboratories

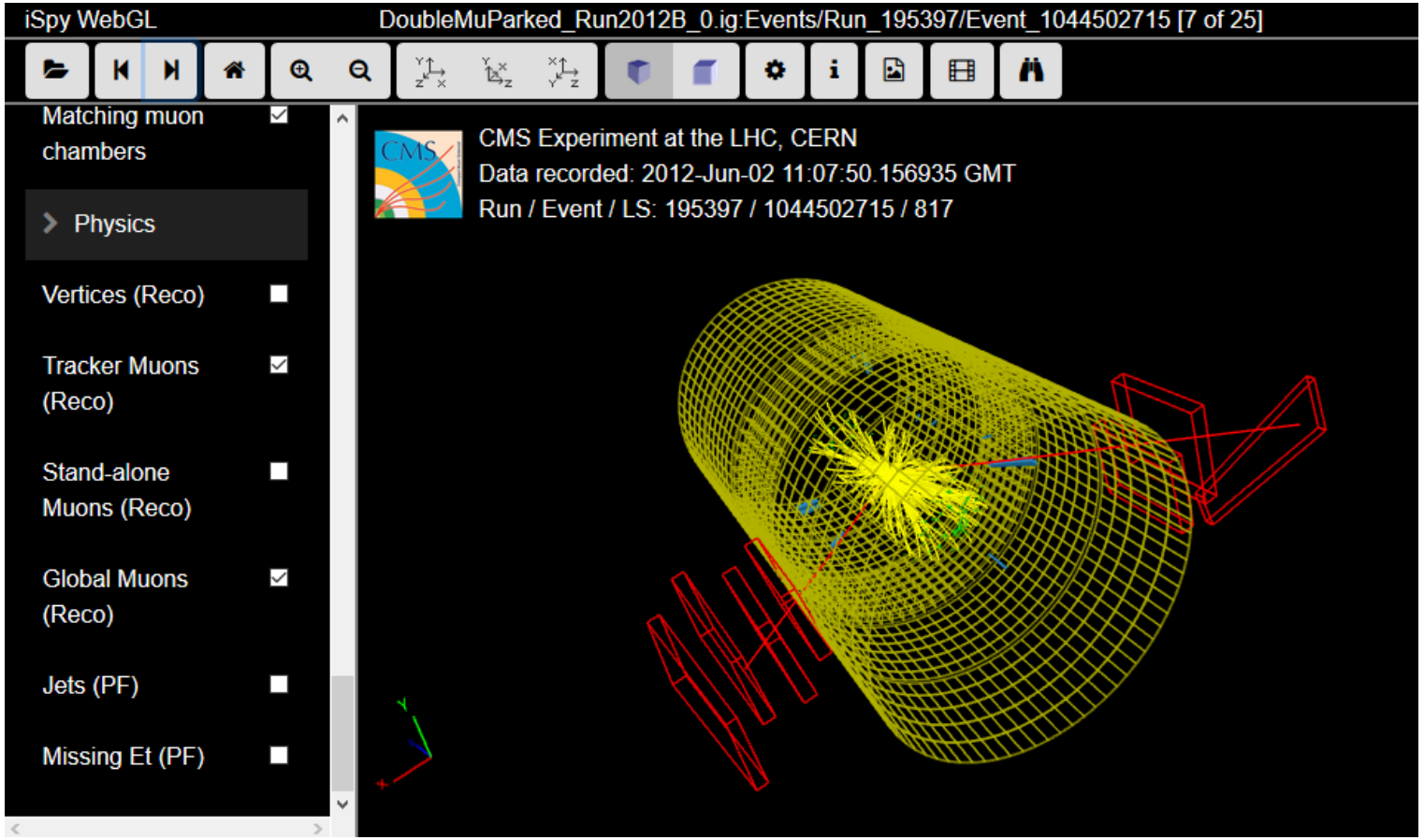
https://advlab.org/

2021	2024	2025
Particle Data Lab	Quantum Optics	Dark Matter

Particle Data Lab

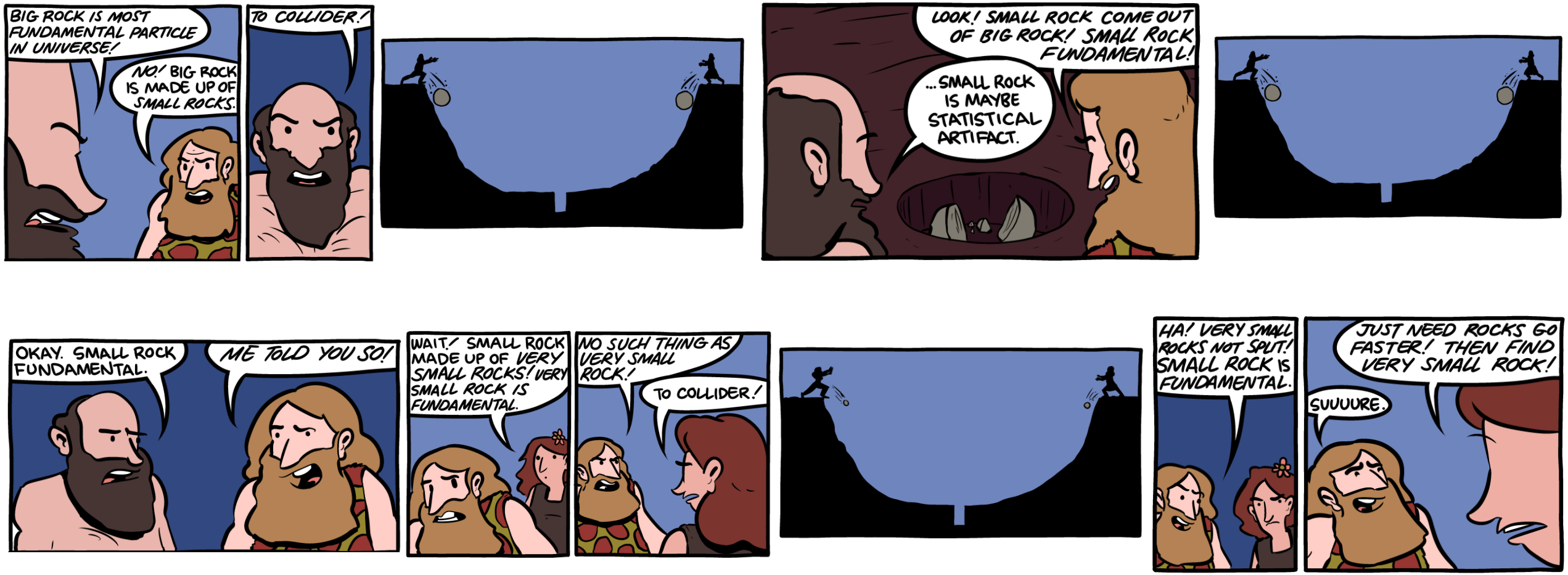
Dr. Julie Hogan, Bethel University

Participating in “big physics”



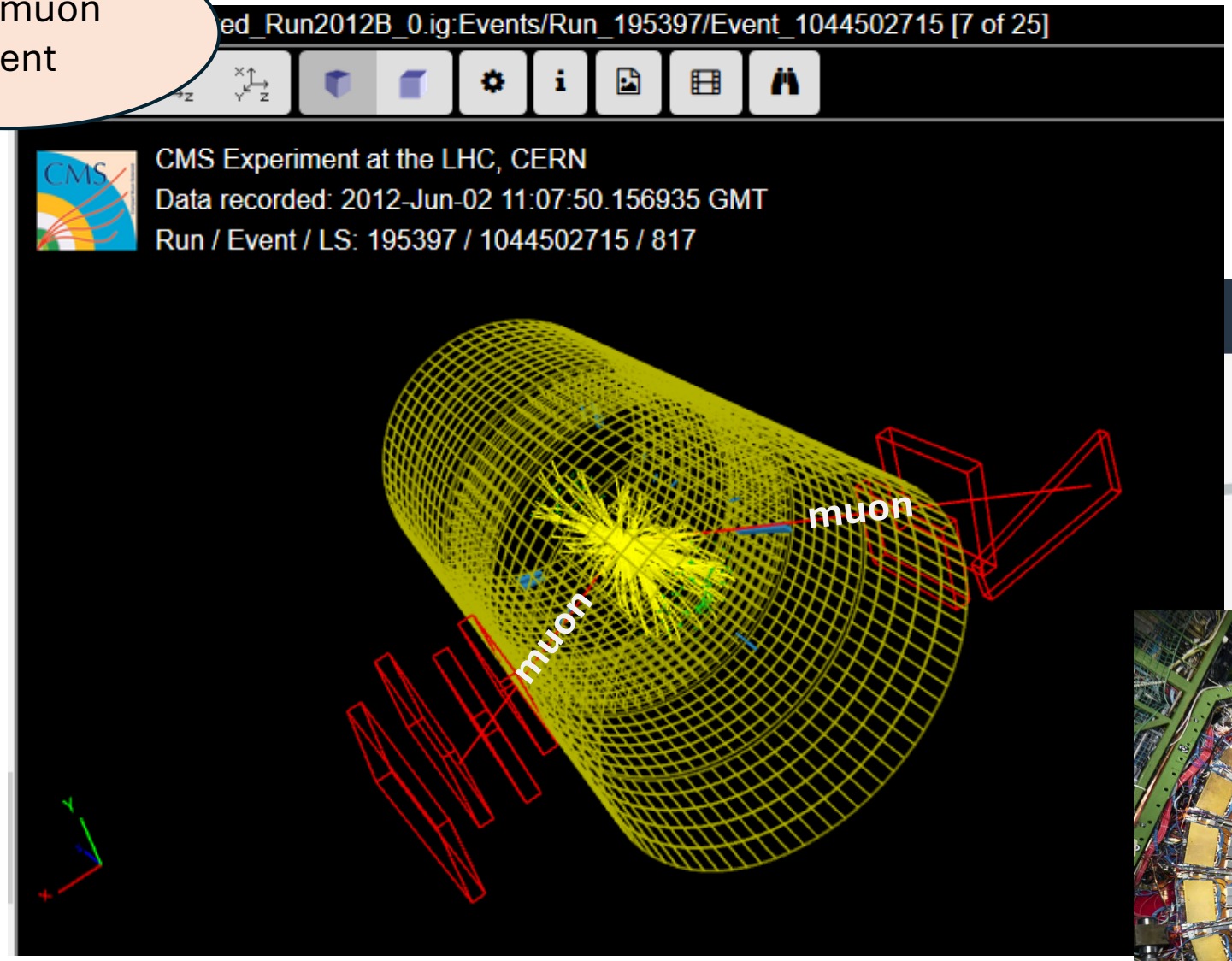
How do particle accelerators work?

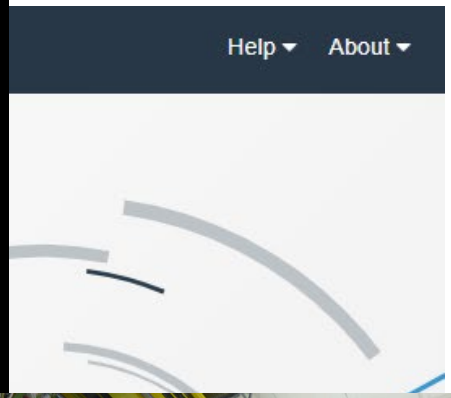
Take two known things, smash them together, and look at what pieces come out the other end.

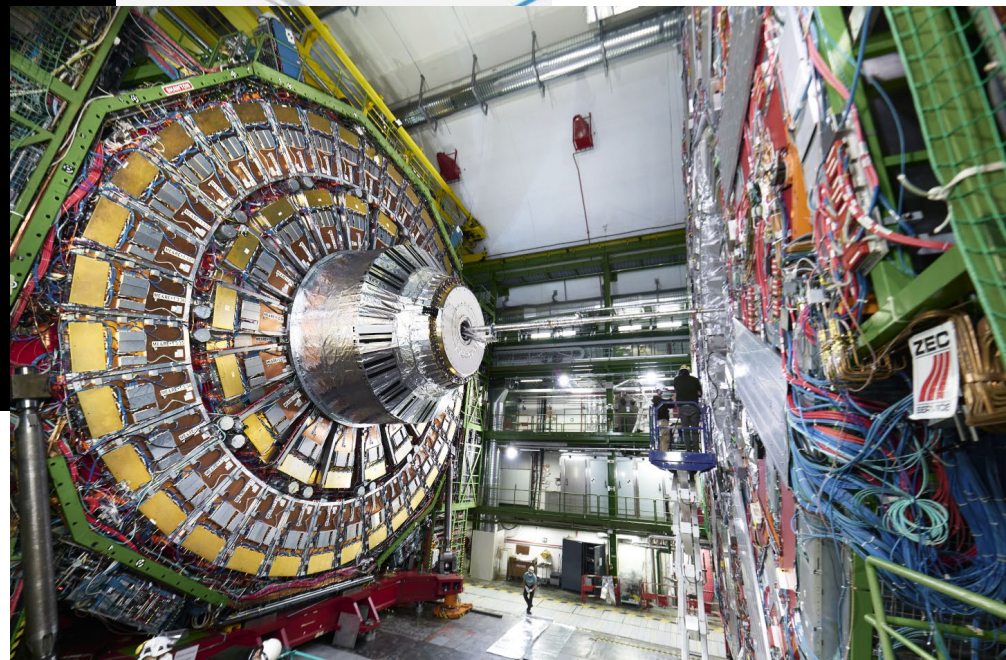


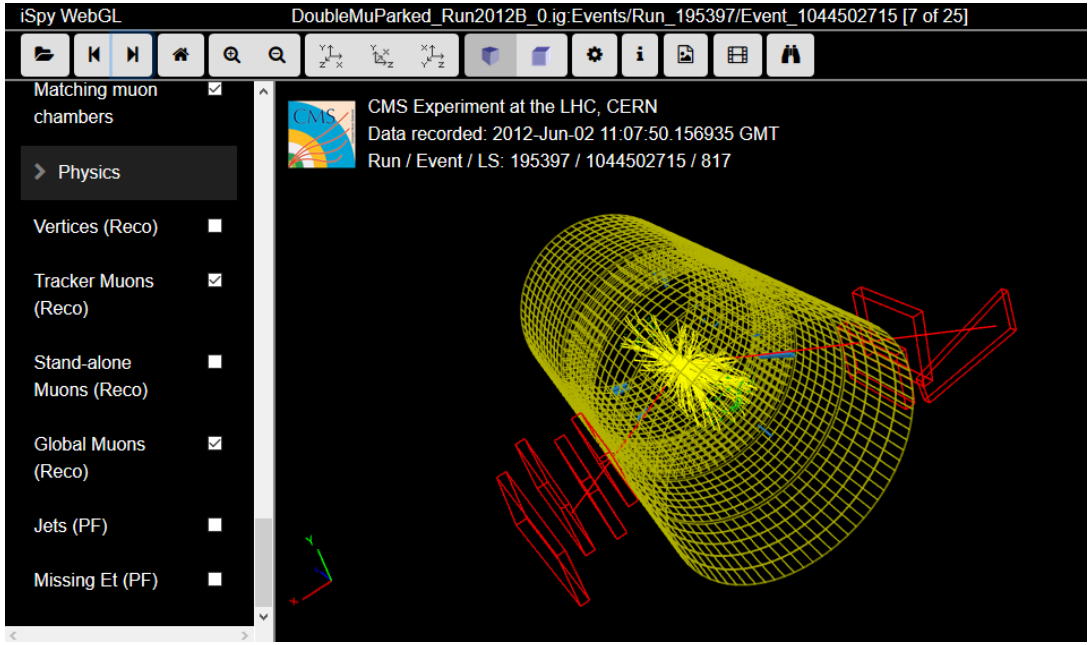
http://www.smbc-comics.com/comic/2014-11-25

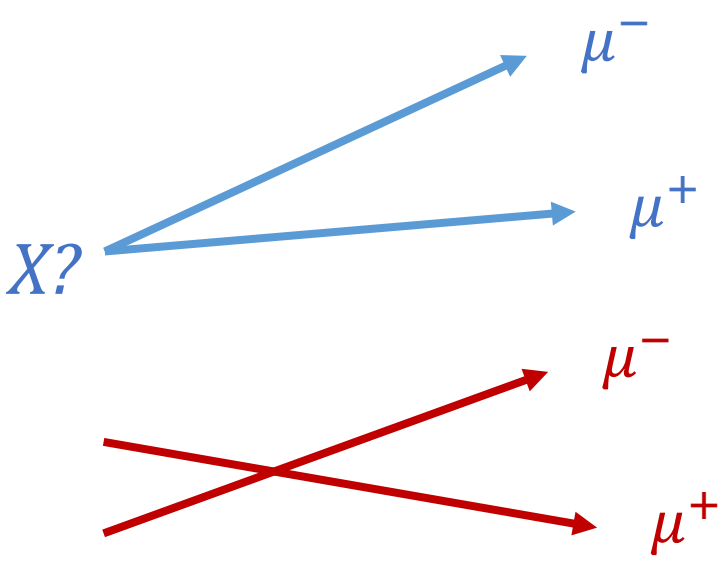
Two-muon event

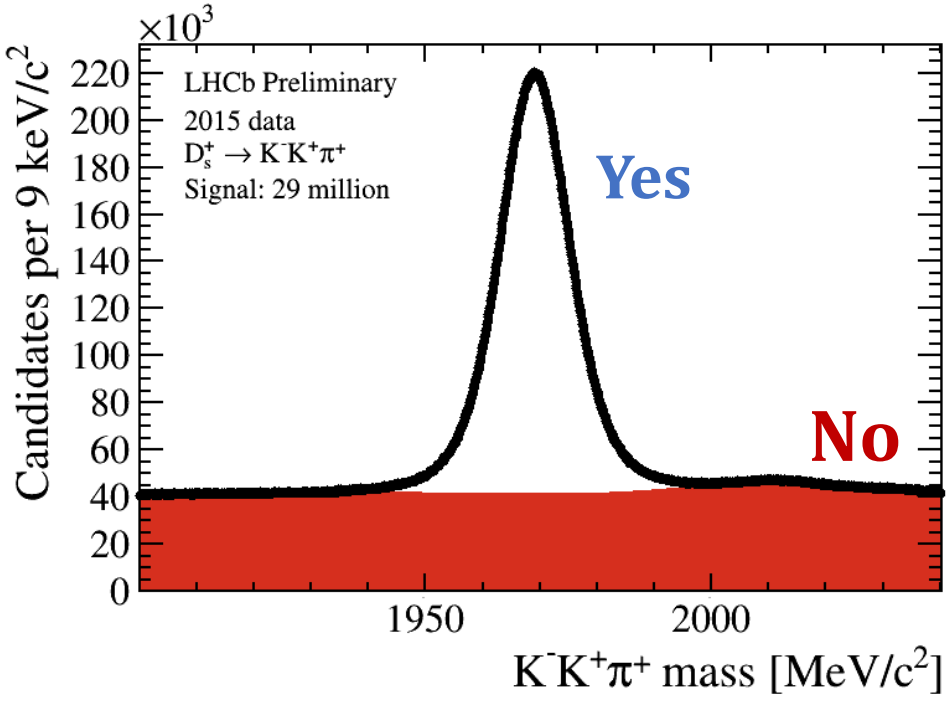




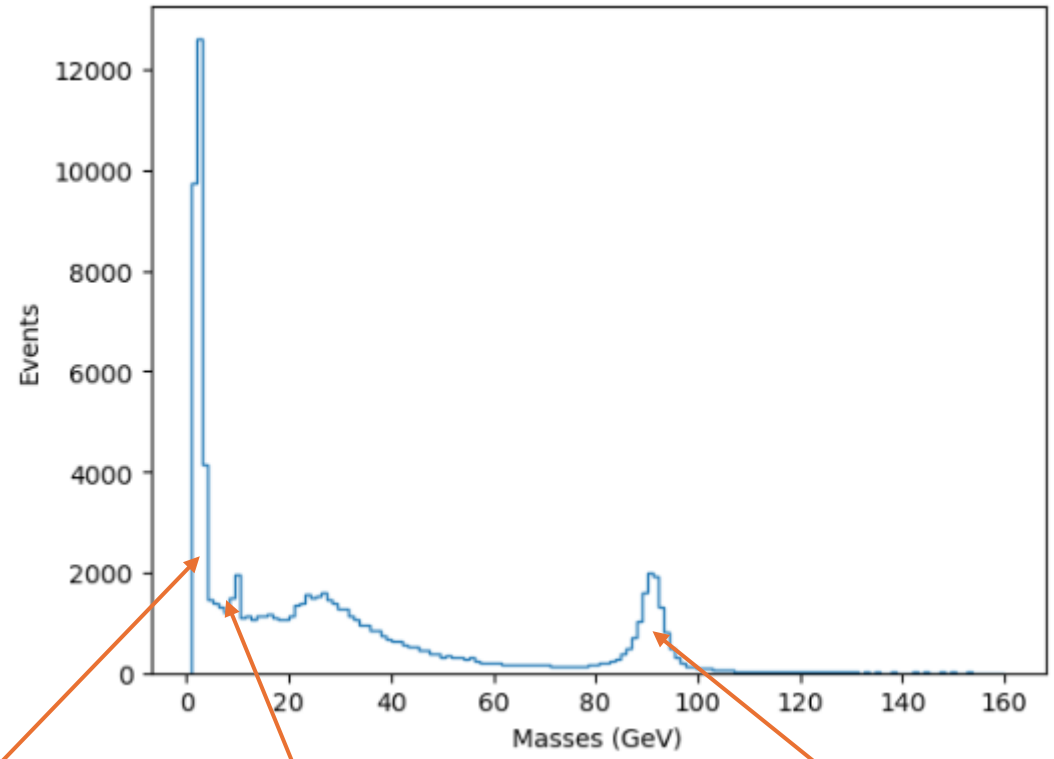



iSpy WebGL
DoubleMuParked_Run2012B_0.ig:Events/Run_195397/Event_1044502715 [7 of 25]
Matching muon chambers
Physics
Vertices (Reco)
Tracker Muons (Reco)
Stand-alone Muons (Reco)
Global Muons (Reco)
Jets (PF)
Missing Et (PF)
CMS Experiment at the LHC, CERN
Data recorded: 2012-Jun-02 11:07:50.156935 GMT
Run / Event / LS: 195397 / 1044502715 / 817


X?
μ^-
μ^+
μ^-
μ^+


$\times 10^3$
Candidates per 9 keV/c^2
LHCb Preliminary
2015 data
$D_s^+ \to K^-K^+\pi^+$
Signal: 29 million
Yes
No
$K^-K^+\pi^+$ mass [MeV/c^2]

Sharp “resonances” in the event data typically is a signal of a particle



J/ψ (3.0 GeV)

Υ(9.46 GeV)

Z boson (90 GeV)

Students use Python to

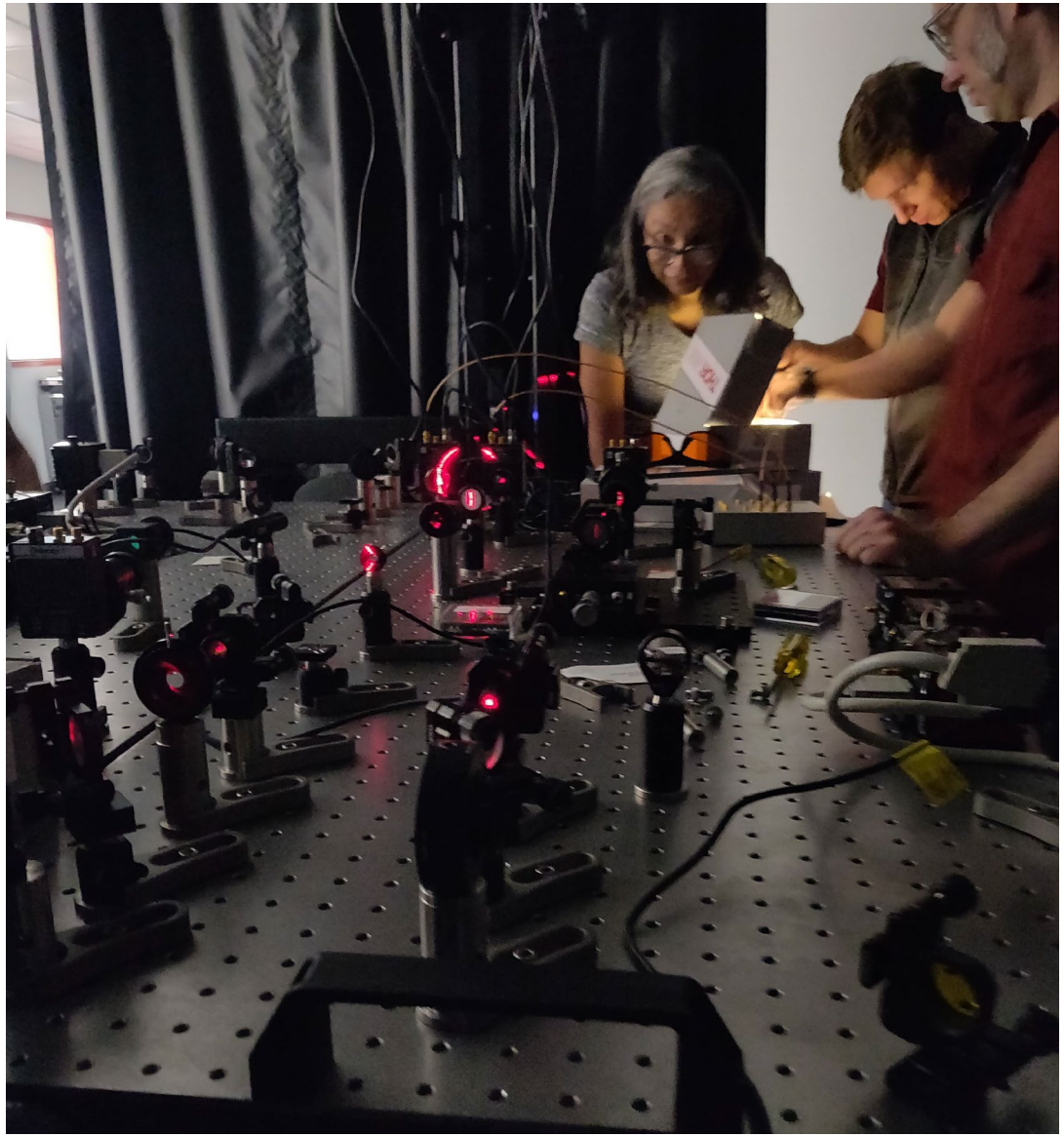
- Reconstruct and plot raw histograms
- Fit data and subtract background
- Fit signal and analyze (and identify) particle

Has been implemented in **PHYS337,** Undergraduate Research onboarding.

Quantum Optics

Dr. Brandon Mitchell, West Chester University
Eric Kurywczak, Thorlabs

Precision measurements of light



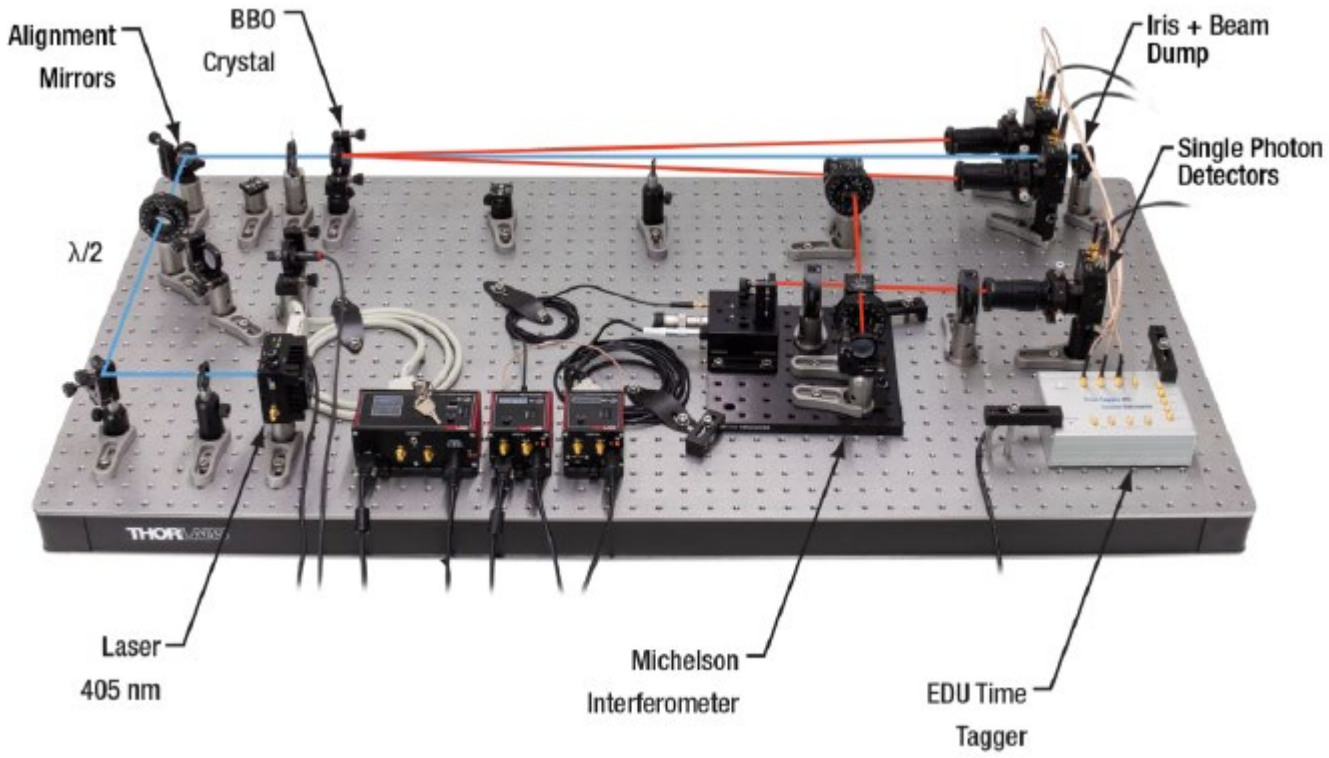
How can we see quantum mechanics in the lab?

Light provides a good playground to examine quantum behavior

- Create and test a source of single photons
- Measure wave interference with a single photon
- Demonstrate how measurement changes an entangled photon

How can we see quantum mechanics in the lab?

Light detectors with picosecond resolution (10^{-12}s) allow for the detection of single photons



Students develop

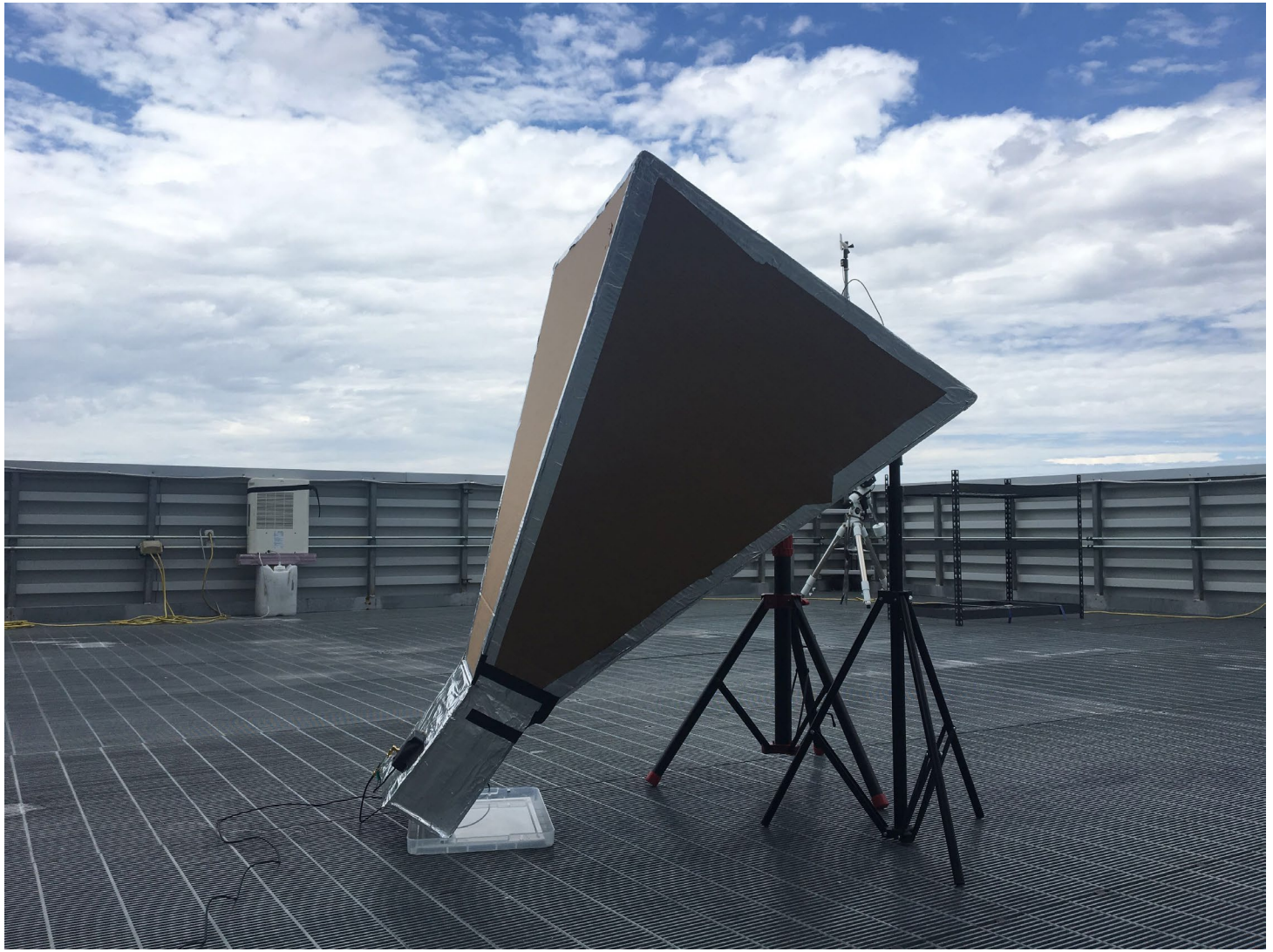
- expertise with industry-grade optical equipment.
- hands-on expertise with key quantum mechanical concepts such as entanglement and measurement.
- …lots of patience and understanding of modern precision experiments.

Has been (partially) implemented in **PHYS380**

Gathering Evidence for Galactic Dark Matter

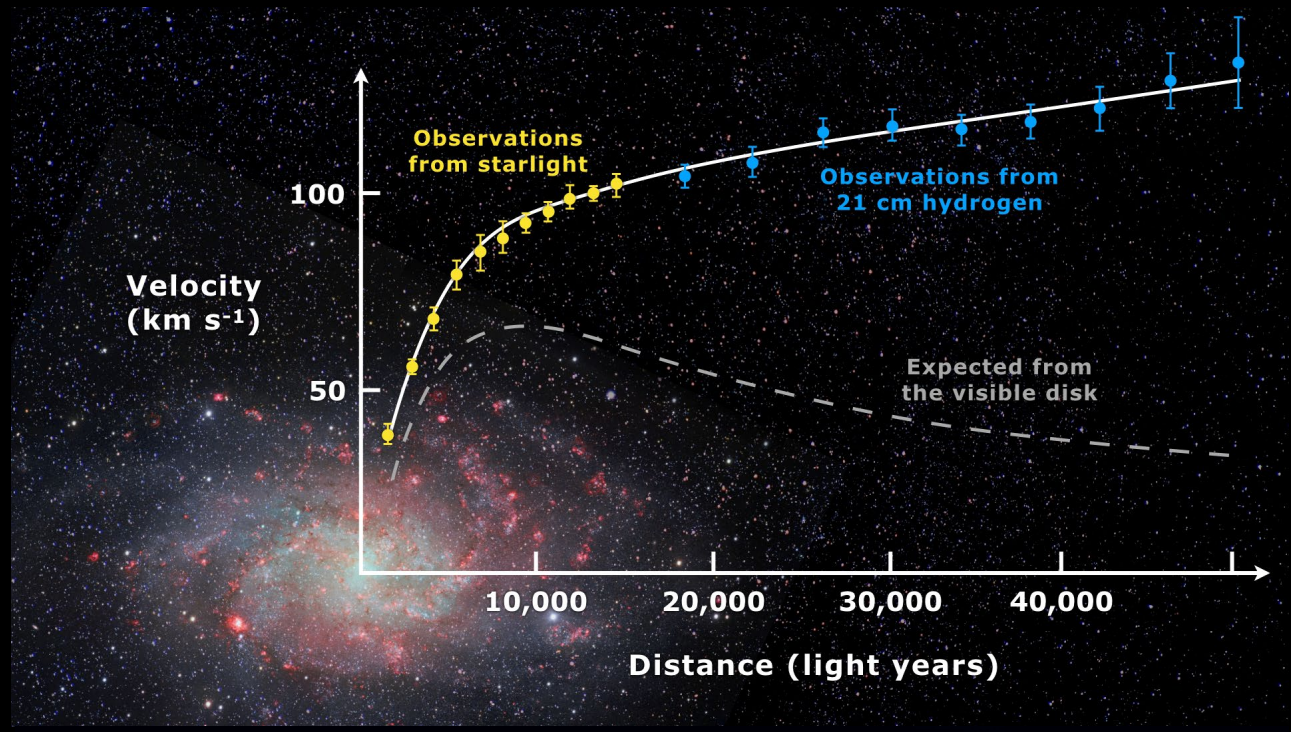
Dr. Adam Beardsley, Winona State University
Dr. Lindsay Berkhout, McGill University
Dr. Danny Jacobs, Arizona State University

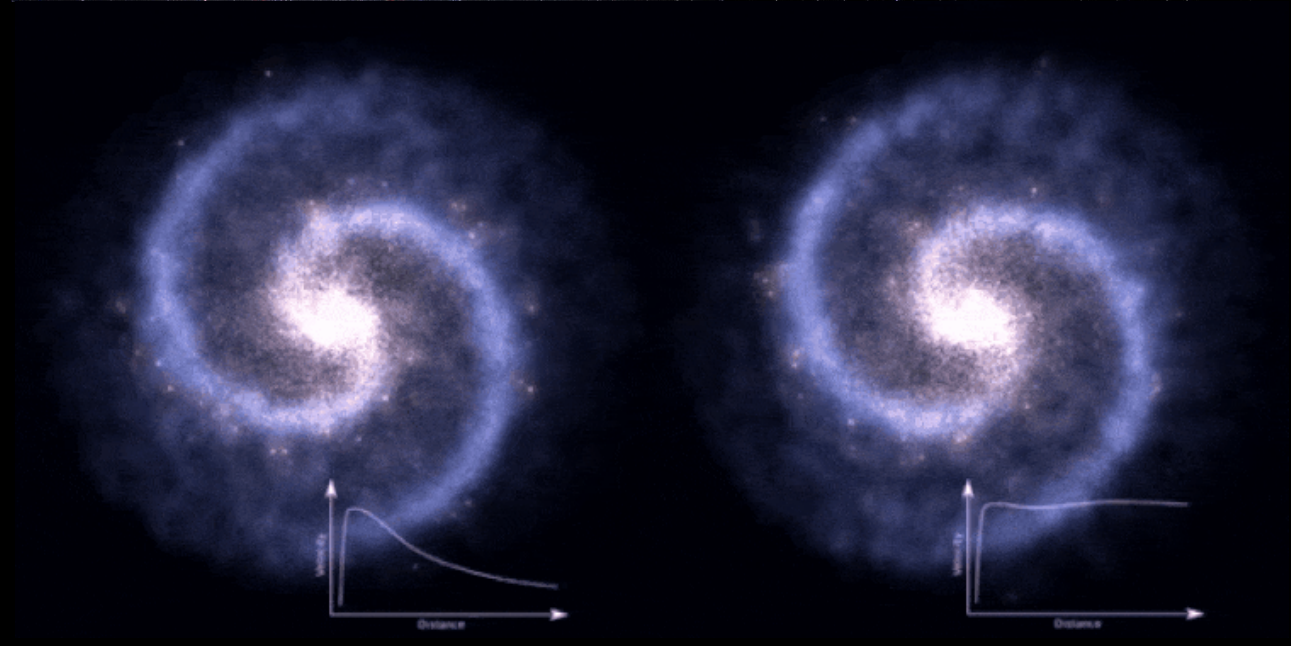
Modern astronomy measurements at low **prices**



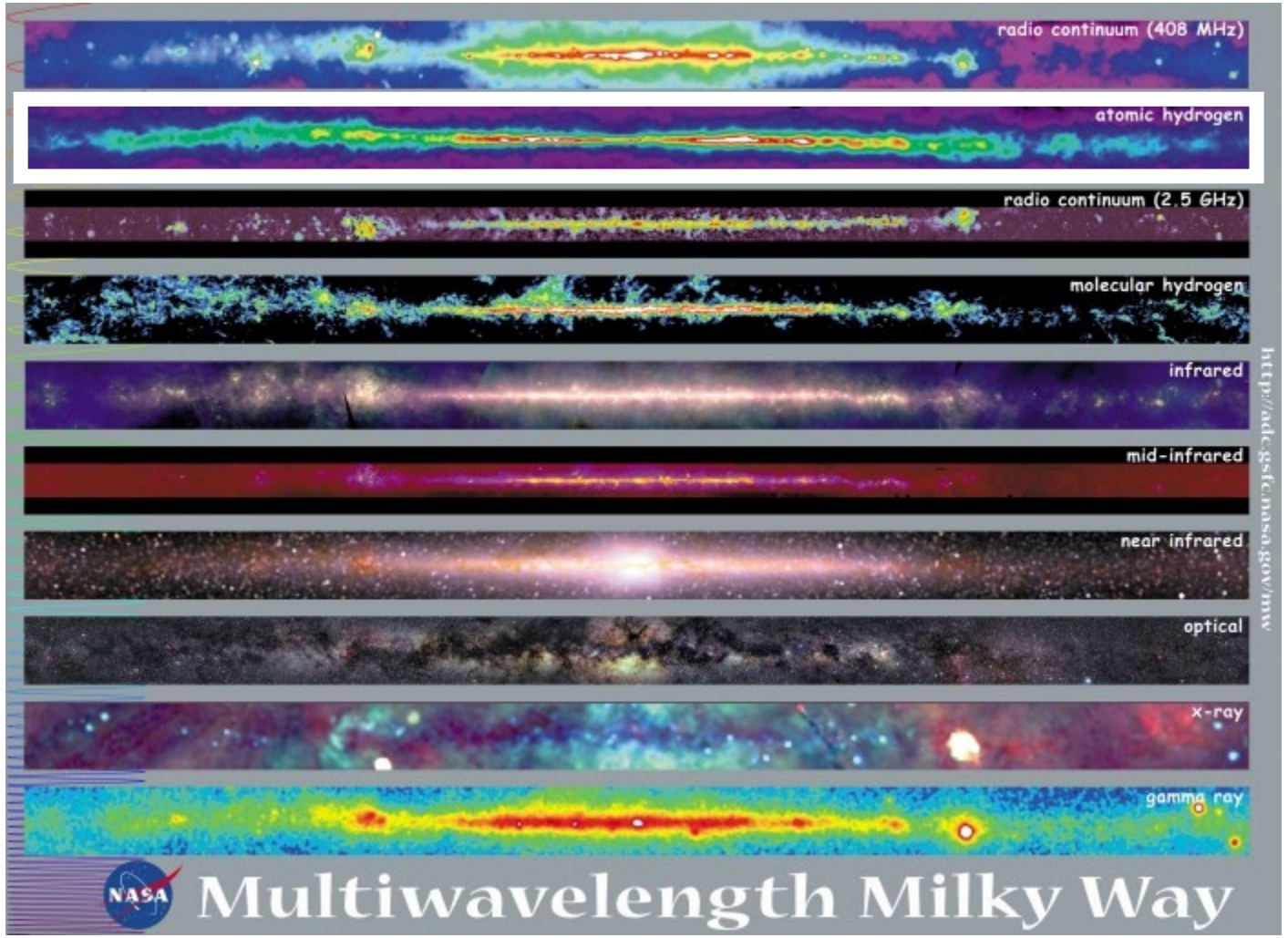
What is dark matter?

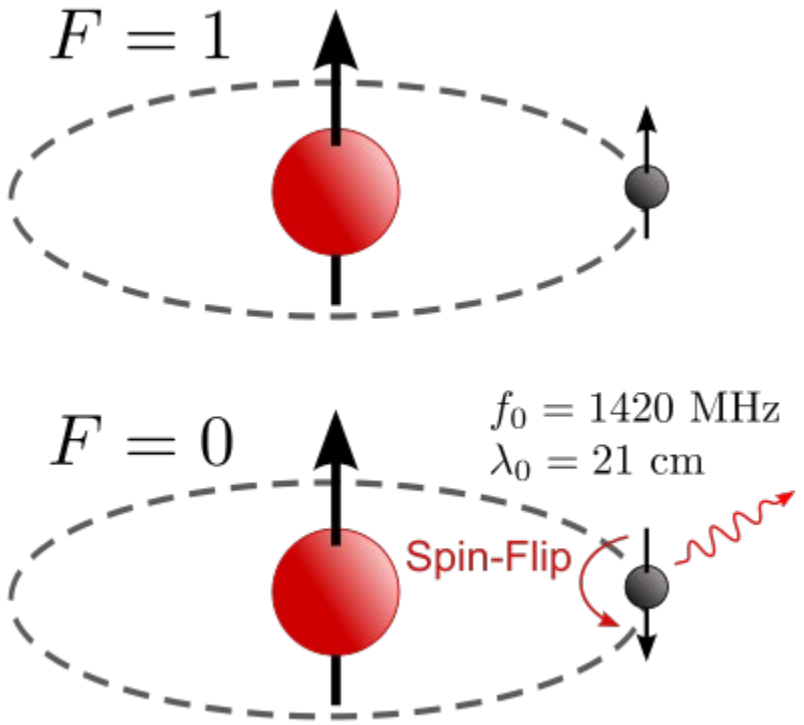
In 1978, **Vera Rubin** discovered that galaxies rotate faster than expected based on the visible matter they contain. This led to the idea that some unseen substance—now called dark matter—**must be adding extra mass.**



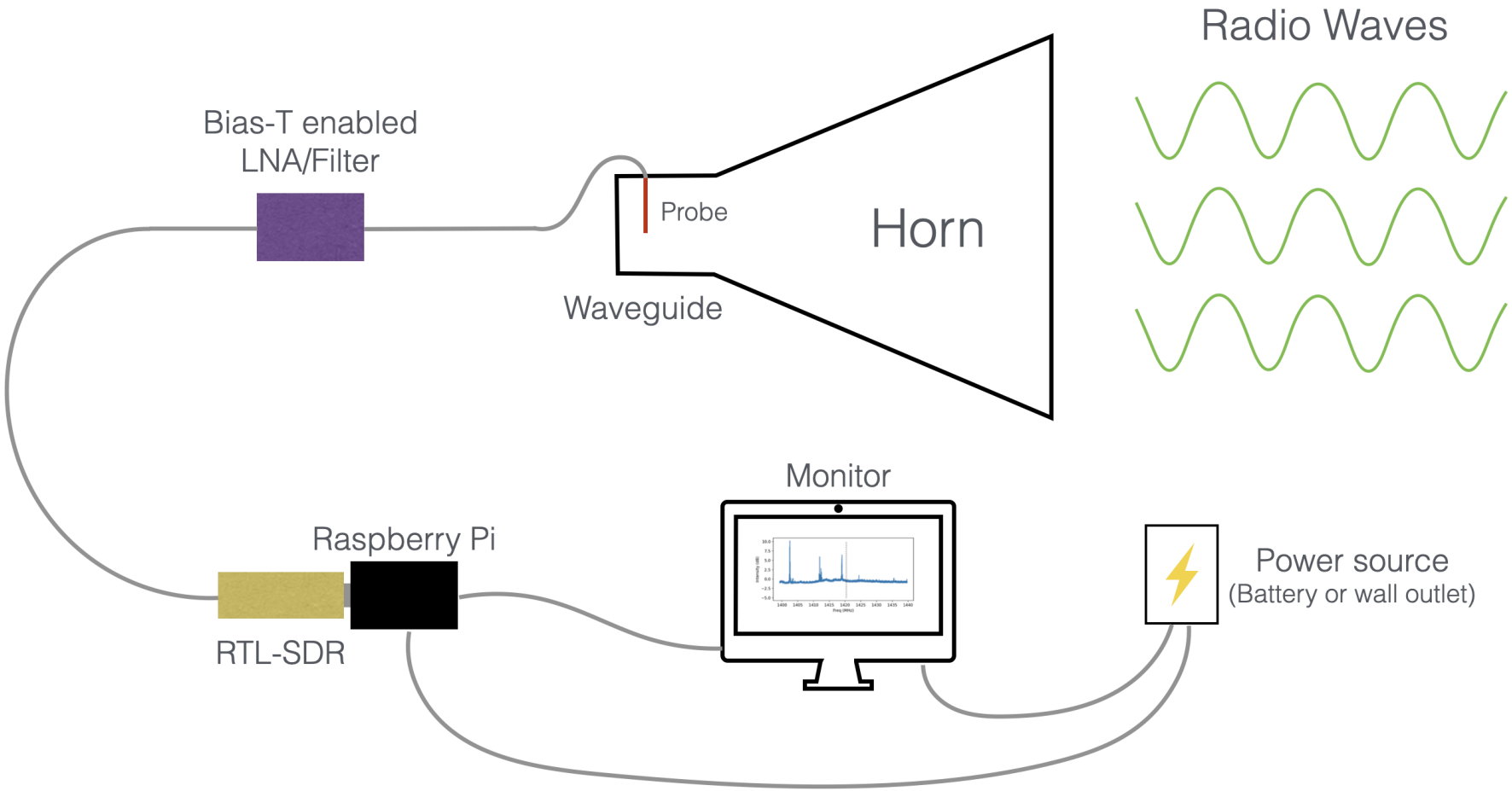


Gathering Evidence for Galactic Dark Matter





Gathering Evidence for Galactic Dark Matter



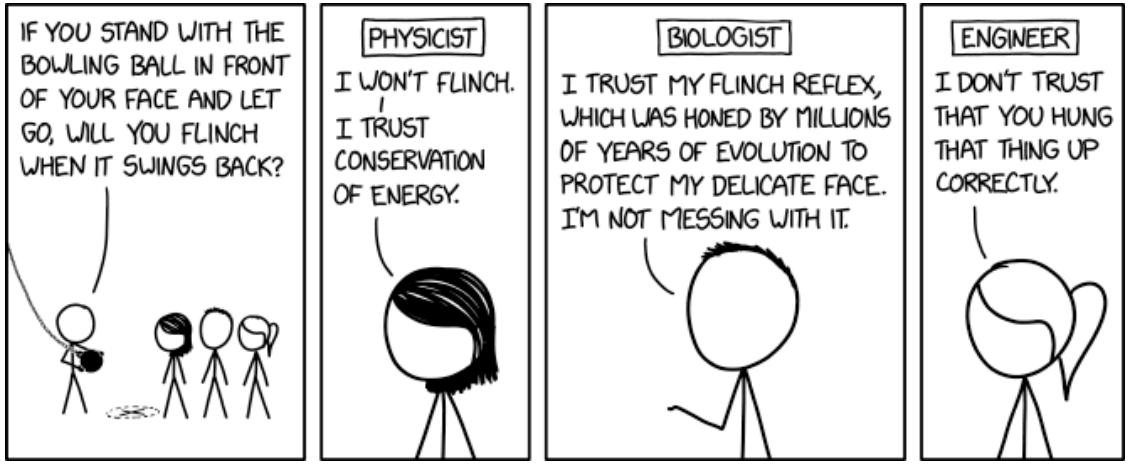
Gathering Evidence for Galactic Dark Matter

Expectations:

- Radio-frequency electronic design and Raspberry Pi interface will **appeal to electrical engineers and tinkerers-at-heart**
- Another opportunity to **draw on student's programming experience** for data cleaning and analysis
- Grounding a cosmic mystery (dark matter) in an accessible method of data collection will **spark interest in open problems in physics.**

Summary

- ALPhA Immersions provide creative, engaging advanced lab experiences by physicists who care about upper-level physics instruction.
- Including contemporary experiments into Modern Physics helps students imagine what physics today looks like
- The Pauli Effect is real, but surmountable.



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