10 Minutes in DUNE

Richie Diurba

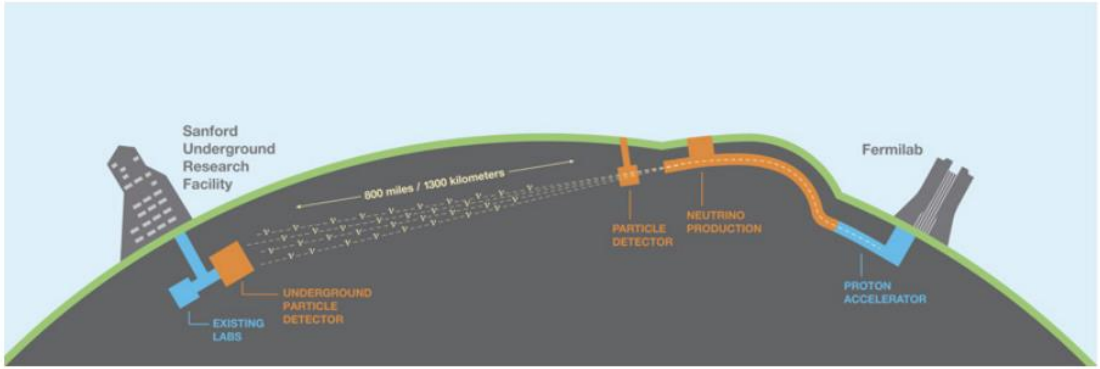
New Perspectives 2019

Neutrinos and Nucleons

- Answer a multitude of neutrino questions
  - Determine mass hierarchy ($m_3 > m_1$ or $m_3 < m_1$)
  - Search for CP violation
  - Precision measurements of PMNS matrix

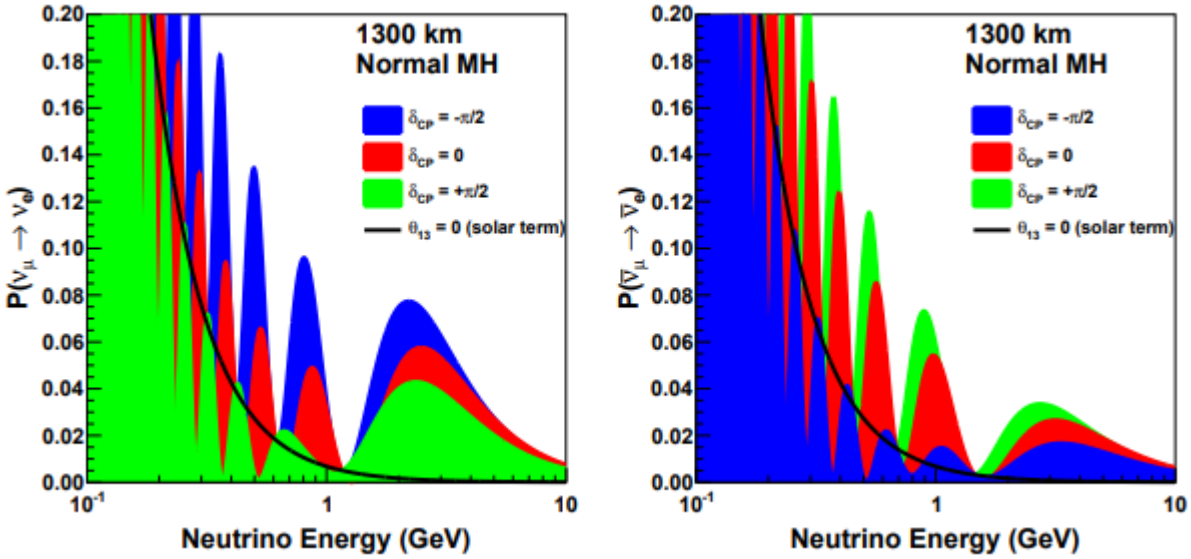
$$\begin{bmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{bmatrix} = \begin{bmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{bmatrix} \begin{bmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{bmatrix}.$$

- Search for precision BSM events, most notably proton decay
- Observe SN neutrinos



Neutrino Mixing

- Measure mixing in appearance and disappearance studies
  - Example: Muon neutrino to electron neutrino

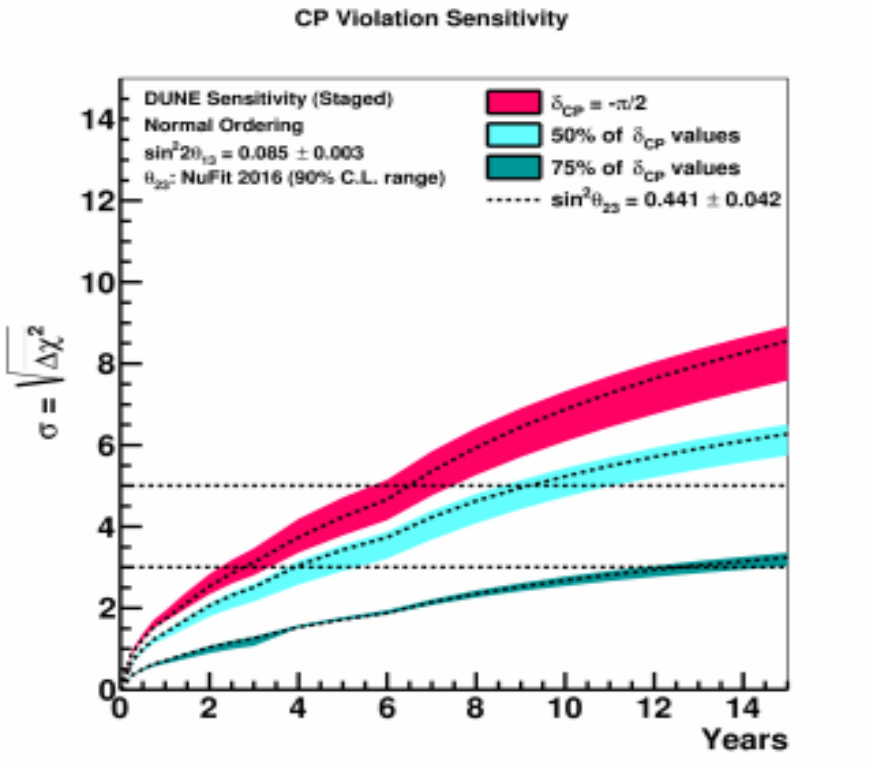


$$P(\nu_\mu \to \nu_e) \simeq \sin^2\theta_{23}\sin^2 2\theta_{13}\frac{\sin^2(\Delta_{31}-aL)}{(\Delta_{31}-aL)^2}\Delta_{31}^2$$
$$+ \sin 2\theta_{23}\sin 2\theta_{13}\sin 2\theta_{12}\frac{\sin(\Delta_{31}-aL)}{(\Delta_{31}-aL)}\Delta_{31}\frac{\sin(aL)}{(aL)}\Delta_{21}\cos(\Delta_{31}+\delta_{\rm CP})$$
$$+ \cos^2\theta_{23}\sin^2 2\theta_{12}\frac{\sin^2(aL)}{(aL)^2}\Delta_{21}^2,$$

From DUNE CDR (1512.0614)

CP Violation

- Key analysis that young scientists will help immensely.



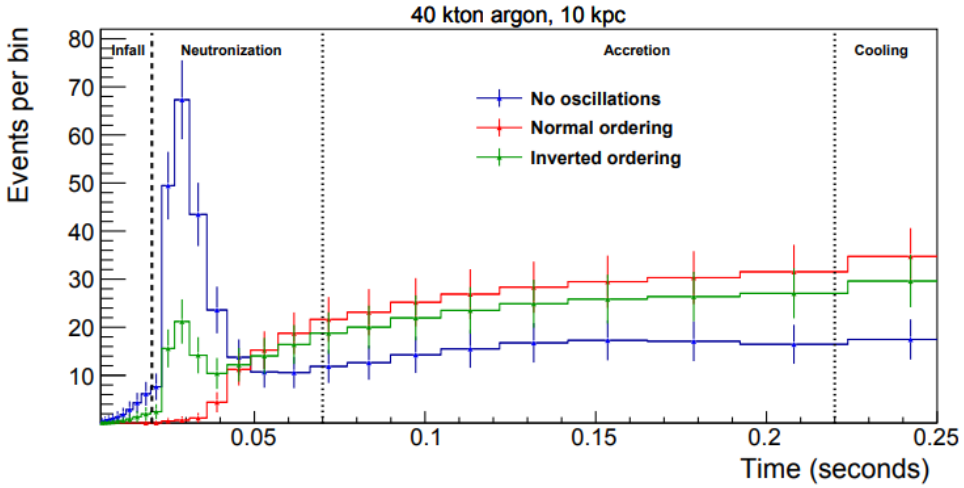
Physics milestone	Exposure (kt · MW · year)	Exposure (years)
1° θ_{23} resolution ($\theta_{23} = 42^\circ$)	29	1
CPV at 3σ ($\delta_{CP} = -\pi/2$)	77	3
MH at 5σ (worst point)	209	6
10° δ_{CP} resolution ($\delta_{CP} = 0$)	252	6.5
CPV at 5σ ($\delta_{CP} = -\pi/2$)	253	6.5
CPV at 5σ 50% of δ_{CP}	483	9
CPV at 3σ 75% of δ_{CP}	775	12.5
Reactor θ_{13} resolution ($\sin^2 2\theta_{13} = 0.084 \pm 0.003$)	857	13.5

From DUNE Interim Design Report (1807.10334)

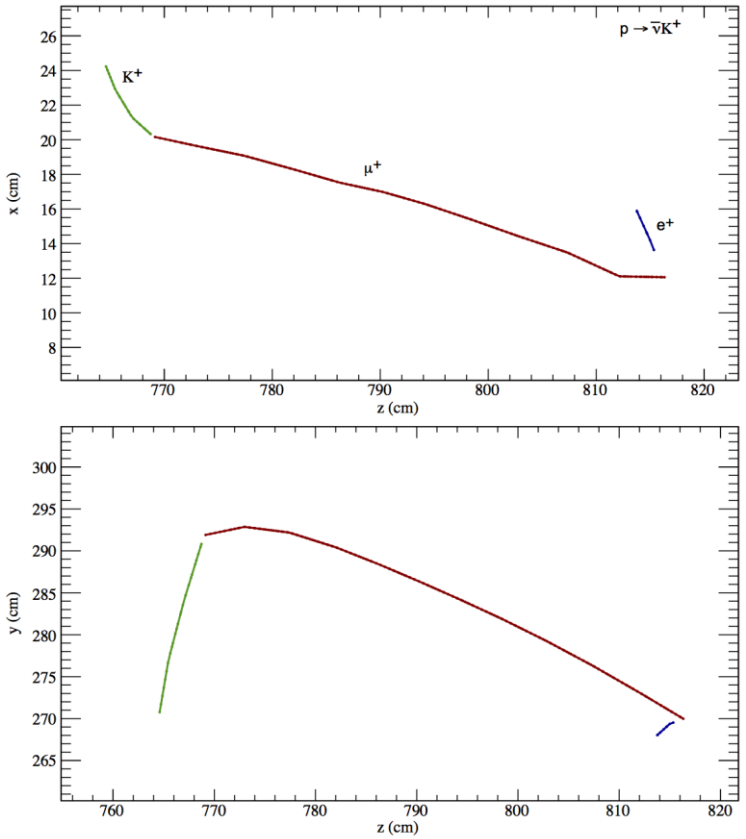
Precision Physics

- DUNE also hopes to see a SN, if they happen, and look for proton decay.

Electron neutrino events during a SN



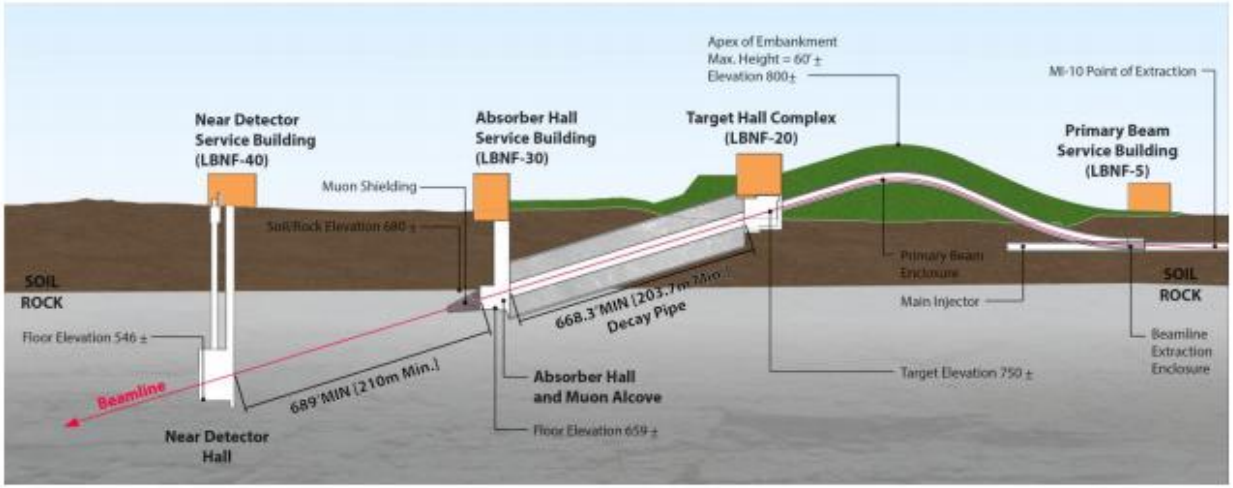
Proton decay golden mode (p->K+v)

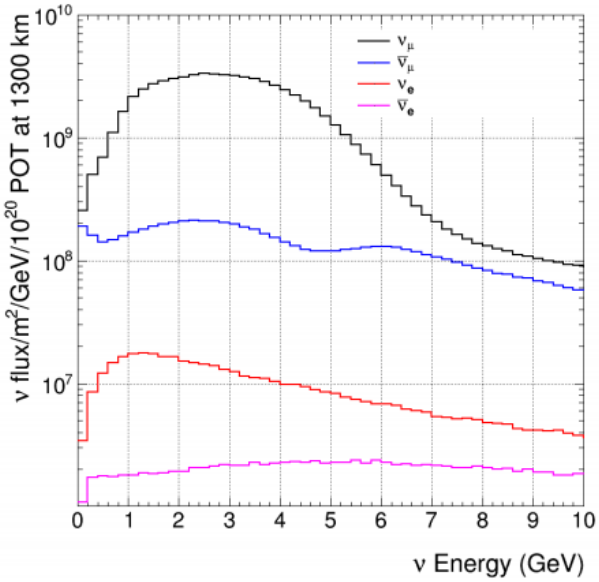


Left is from DUNE Interim Design Report (1807.10334)

Beam

- PIP-II proton beam generates high-intensity neutrino beam through collisions
  - 1.2 MW at turn-on, upgradable to 2.4 MW



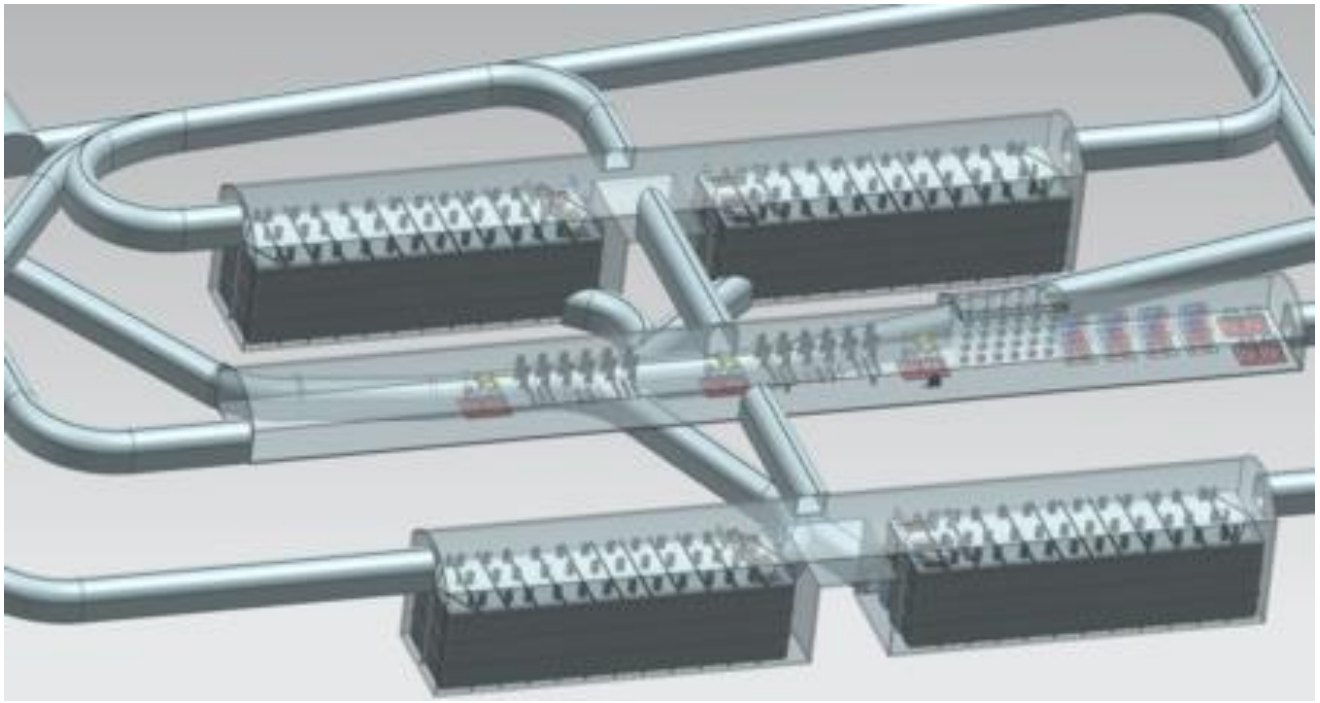


From DUNE CDR (1601.05471)

Design neutrino flux at far detector in neutrino mode

Far Detector

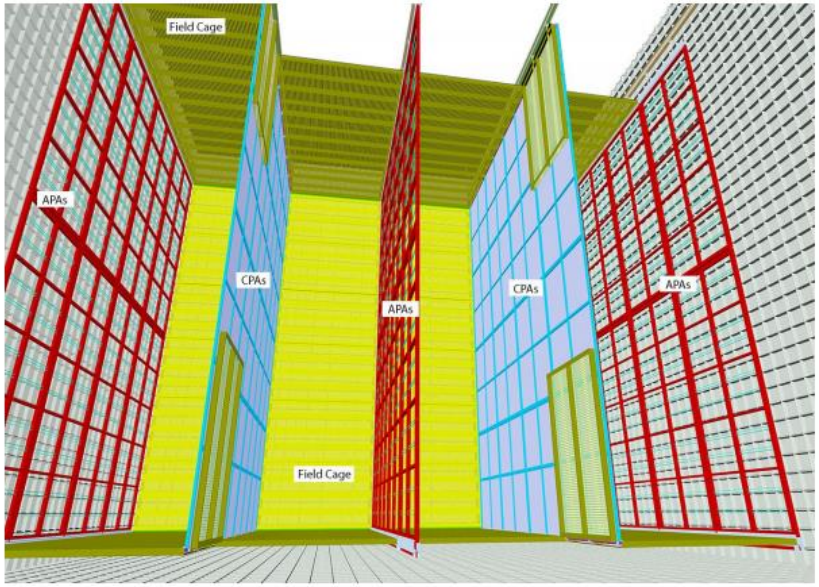
- Four modules (2 single phase, 1 double phase, and 1 TBD)
  - 40 kiloton fiducial volume
  - 1,300 kilometres from beam, 1,475 meters underground

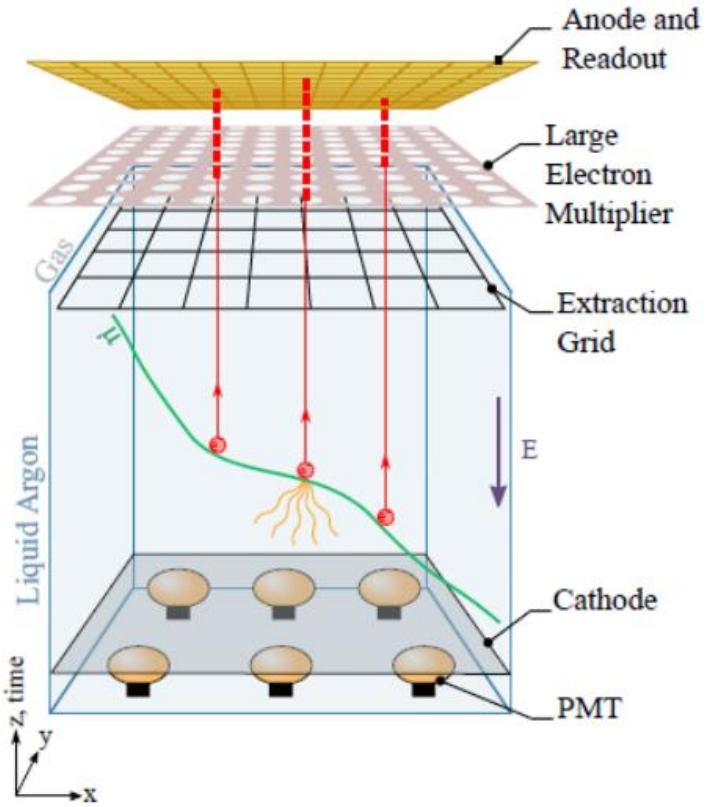


From DUNE CDR (1601.05471)

Liquid Argon Detectors

- Single Phase (left) and Dual Phase (right)





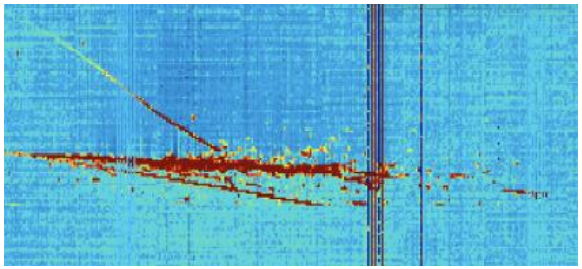
From DUNE Interim Design Report (1807.10334)

ProtoDUNE

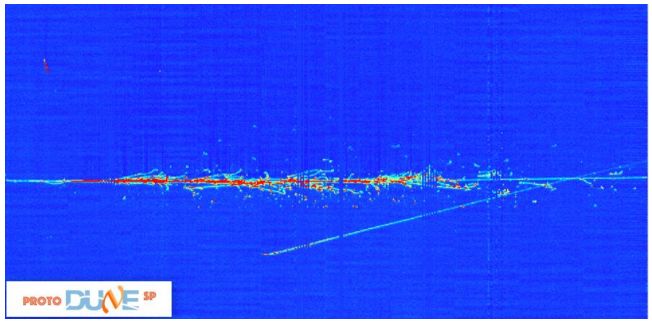
- Two prototype detectors, one of each phase, at CERN.
- Key Goals
  - Research and development on construction of TPCs
  - Use a test beam to understand tracking and calorimetry of protons, pions, and kaons in LAr
- SP-v1 ended beam run late 2018
  - Already seen 4 million triggers
- DP will start shortly

ProtoDUNE Single Phase

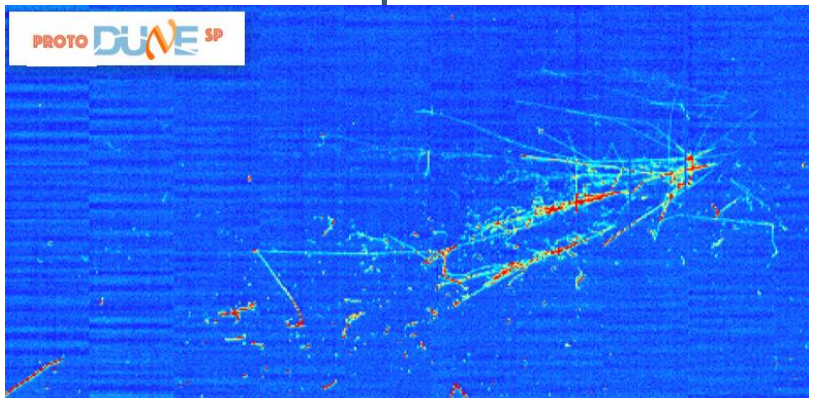
- Saw beam from September to November in 2018
  - Currently running in cosmic mode
- Triggered 4 million times
- Plan to operateProtoDUNE-SPv2 next year
  - Build “module 0” for DUNE Far Detector
  - Collect more test beam particles
- Publications planned for end of 2019



Pion to two photons



High energy muon with bremsstrahlung



Hadronic shower from cosmic ray

Summary

- DUNE is a long term neutrino oscillation experiment intended to solve the mass hierarchy problem, make precision measurements of the PMNS matrix and measure CP violation using a 1.2 MW neutrino beam.
  - Secondary goals to look for SN neutrinos and proton decay
- ProtoDUNE currently runs at CERN with a Single Phase operating and a Dual Phase coming soon.
- Tons of research and development, physics, software tasks open to grad students and postdocs.

12:00	**Cold Electronics Readout System for the ProtoDUNE-SP LAr-TPC**	*Mrs. Maura SPANU*
	One West, Fermi National Accelerator Laboratory	12:00 - 12:15
	Michel electron reconstruction in ProtoDUNE	*Dr. Aleena RAFIQUE*
	One West, Fermi National Accelerator Laboratory	12:15 - 12:30
	Overcoming Neutrino Interaction Mis-modeling with DUNE-PRISM	*Dr. Luke PICKERING*
	One West, Fermi National Accelerator Laboratory	12:30 - 12:45