

# DUNE in 10 Minutes

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New Perspectives  
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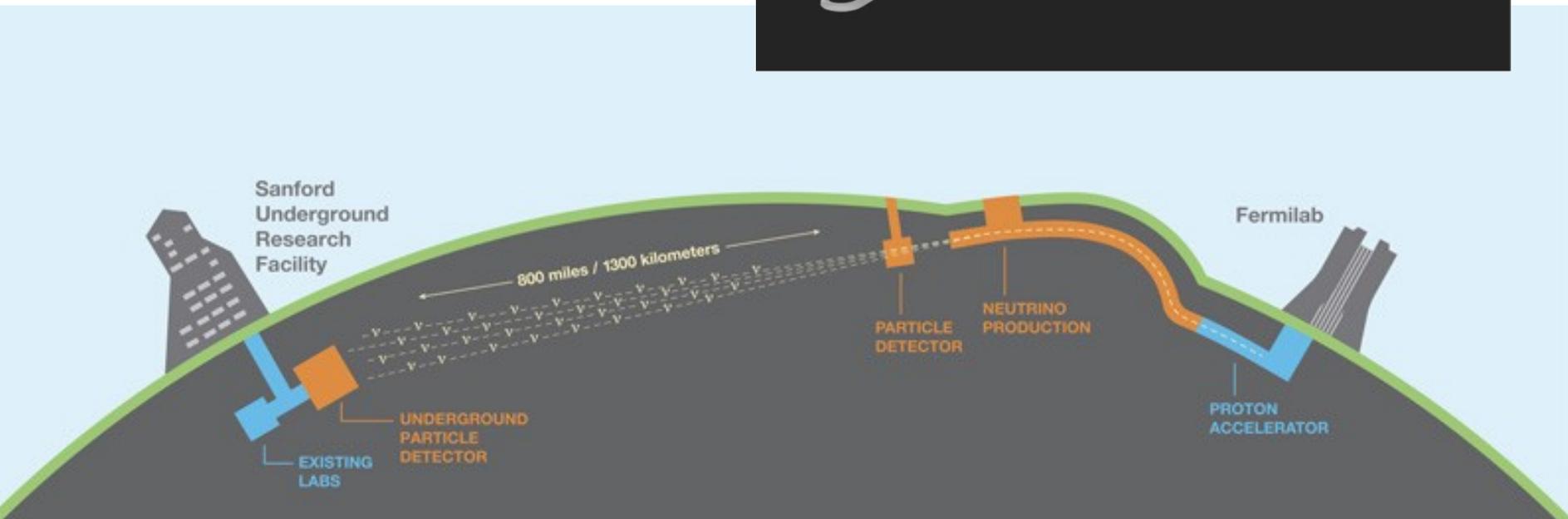
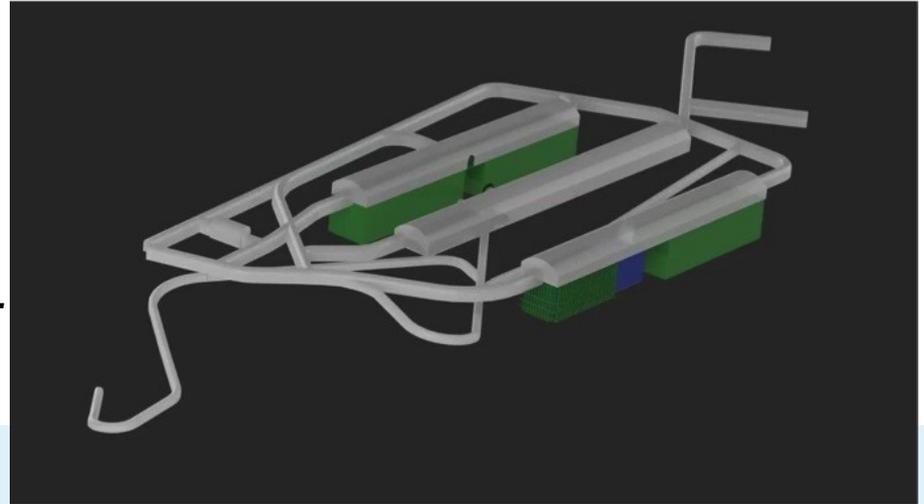
# What is DUNE?

- Deep Underground Neutrino Experiment
  - Liquid Argon (LAr) based neutrino experiment
  - Beamline originating at Fermilab, with far detector at Sanford Underground Research Facility in Lead, SD
    - 1300 km baseline
- “Small Particles, Big Science”
  - [https://www.youtube.com/watch?v=AYtKcZMJ\\_4c&feature=youtu.be](https://www.youtube.com/watch?v=AYtKcZMJ_4c&feature=youtu.be)

# What is DUNE?

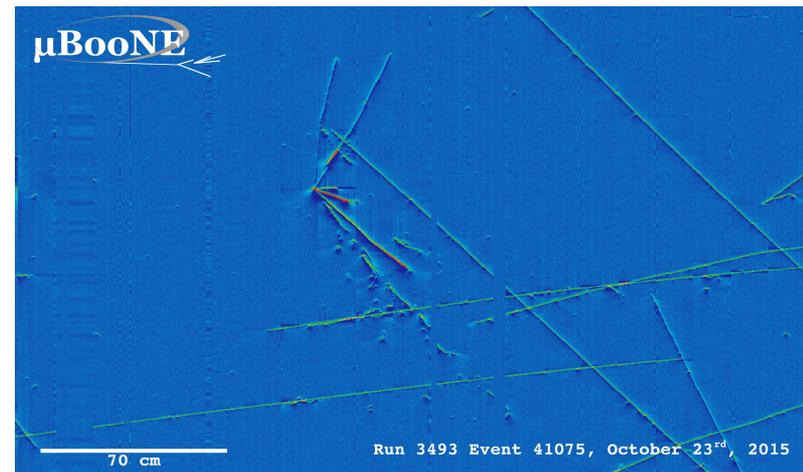
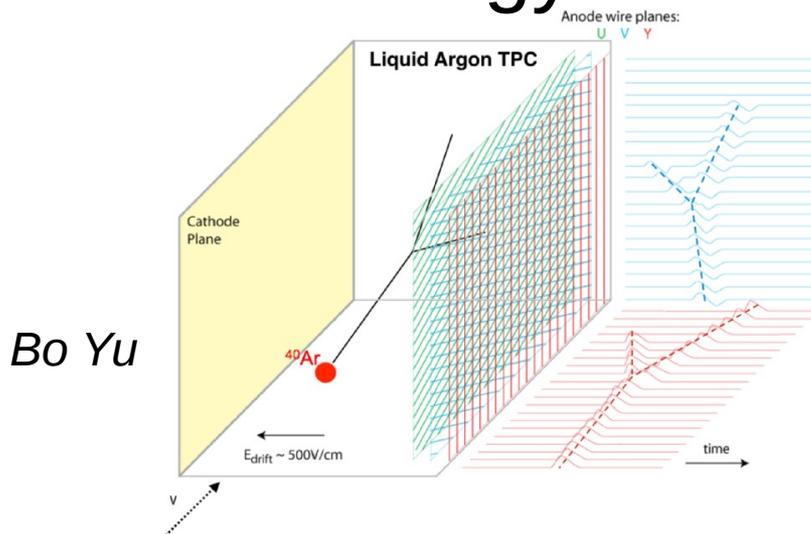
LBNF/DUNE

*Depiction of the layout at the Sanford Underground Research Facility, showing areas capable of housing four large LAr detector modules.*



# The DUNE Detectors

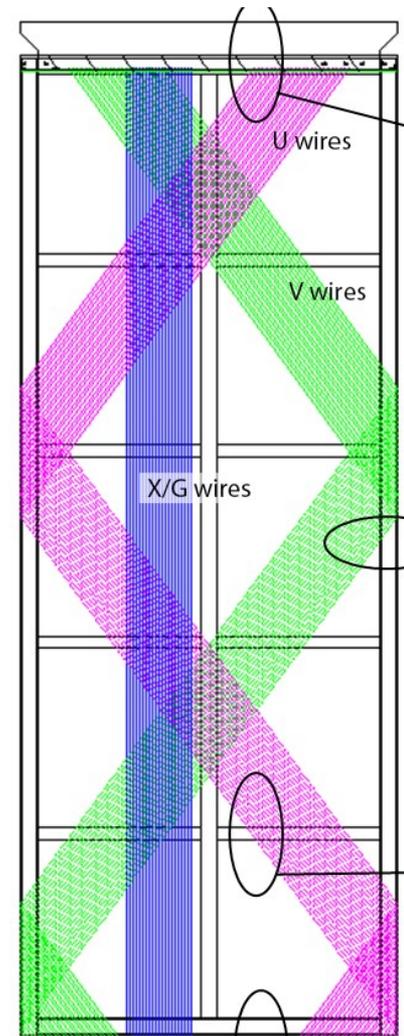
- Far detector design is LAr time-projection chamber (TPC)
  - Multiple technologies under consideration (single-phase, dual-phase)
- Technology example: Single-phase TPC



MicroBooNE

# The DUNE Detectors

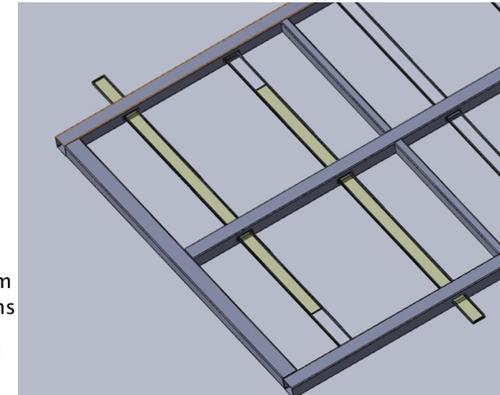
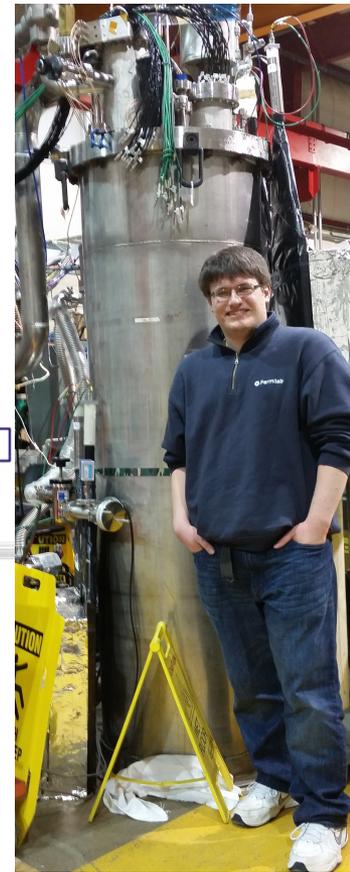
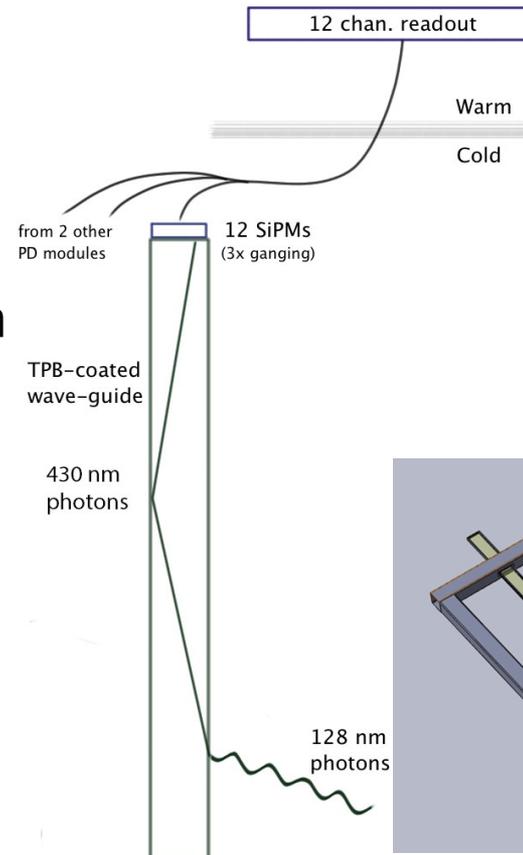
- DUNE single-phase TPC design:
  - Horizontal drift field
  - Four planes of wires in anode assembly
    - Grid plane shields wires behind from charge elsewhere in TPC volume
    - 2 induction planes ( $\pm 35.7^\circ$  from vertical)
      - These are sensitive to charge coming from both sides of anode
    - Vertical collection plane disambiguates signal volume
  - Provides high resolution tracking, calorimetry, and particle identification via  $dE/dx$



# The DUNE Detectors

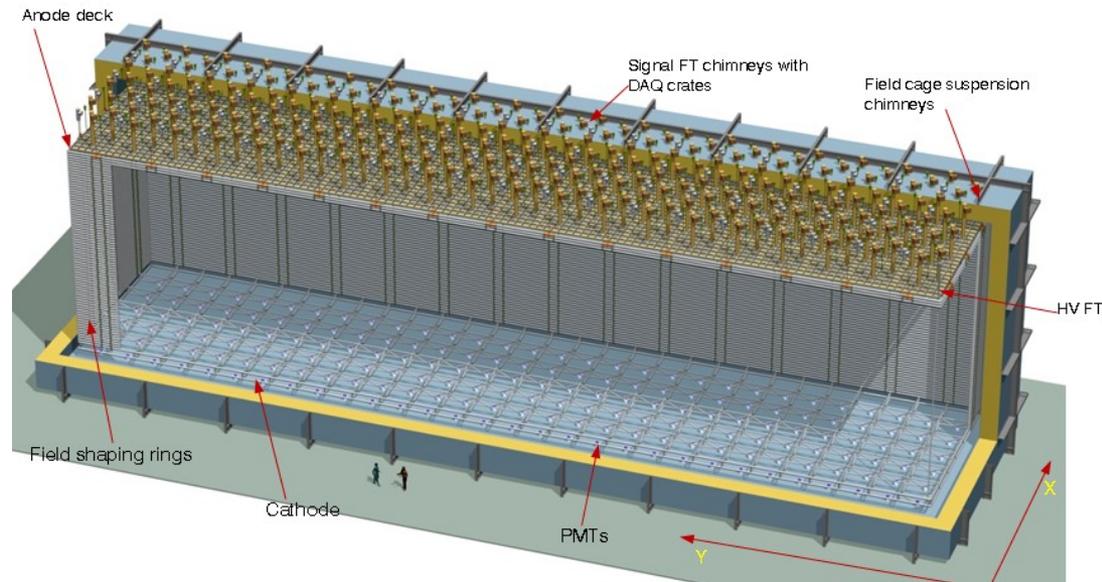
- Photon Detection

- LAr scintillates: 128nm
- Precise event time
  - Resolution of t-0 relative to TPC time  $< 1 \mu\text{s} \rightarrow \sim\text{mm}$  spatial resolution in direction of drift
- Detection system
  - $\lambda$ : 128nm  $\rightarrow$  visible
  - Light-guides transport  $\gamma$
  - Silicon photomultiplier readout



# The DUNE Detectors

- DUNE dual-phase TPC design
- Vertical drift field
  - Electrons extracted from liquid phase to gas phase
  - Avalanches in gas phase amplify signal → higher S/N
  - Two collection planes: x and y
- PMTs beneath cathode collect light

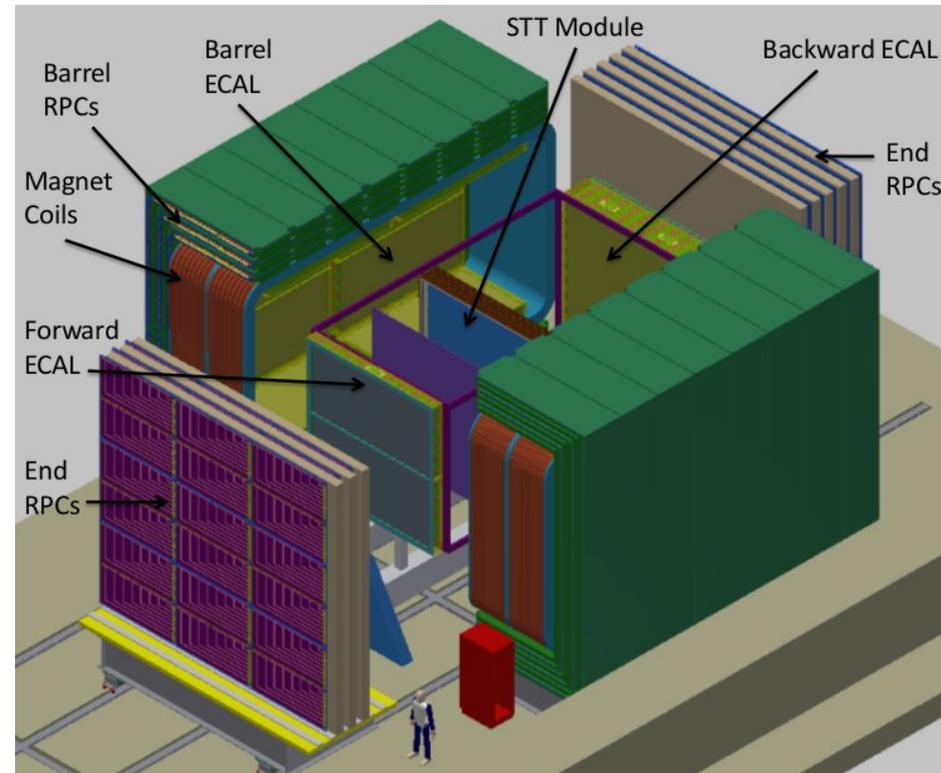


# The DUNE Detectors

- The ND reference design is a fine-grained tracker with a straw-tube tracker
  - Provides high-resolution tracking
  - Nuclear targets to examine neutrino interactions
    - Argon
    - Calcium
    - Graphite: Measure  $\nu$ -C, then use  $\nu$ - $(C_3H_6)_n$  [polypropylene] with a statistical subtraction to find  $\nu$ -p
- EM calorimeters around tracker region

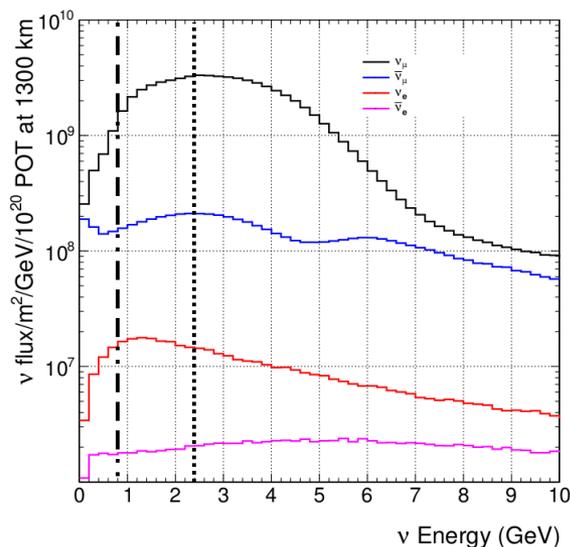
# The DUNE Detectors

- Muon identifiers
- Magnetic field for charge/momentum measurement
- LAr TPC and gaseous argon TPC options are being explored (would cancel some errors)

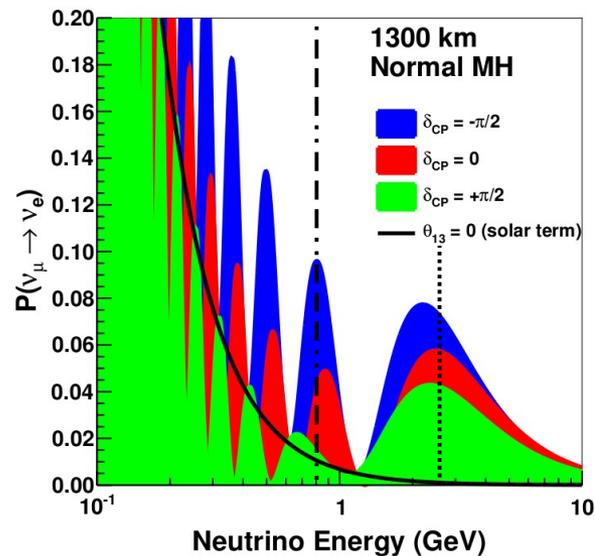


# DUNE physics program

- Beamline originating at Fermilab
- Optimization studies to get the best design
  - Talk by Monica Avila on beam focusing parameters.



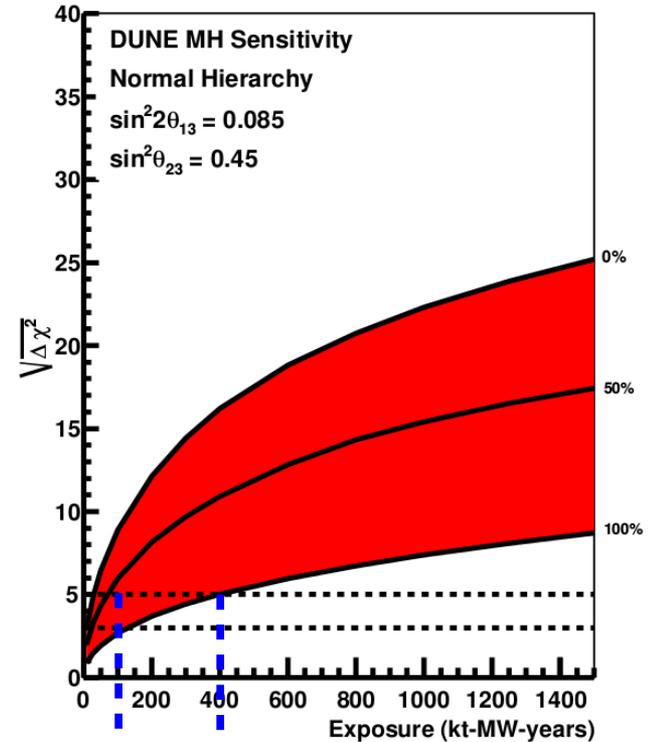
Reference focusing system and  
120 GeV protons



Neutrino appearance probabilities

# DUNE physics program

- Oscillation physics:
  - Measure CP-violating phase ( $\delta_{CP}$ )
  - Determine the neutrino mass hierarchy (sign of  $\Delta m_{31}^2$ )
  - Characterize  $\theta_{23}$  and its octant
  - Measure  $\sin^2(2\theta_{13})$
  - Use beam primarily, and also atmospheric neutrinos



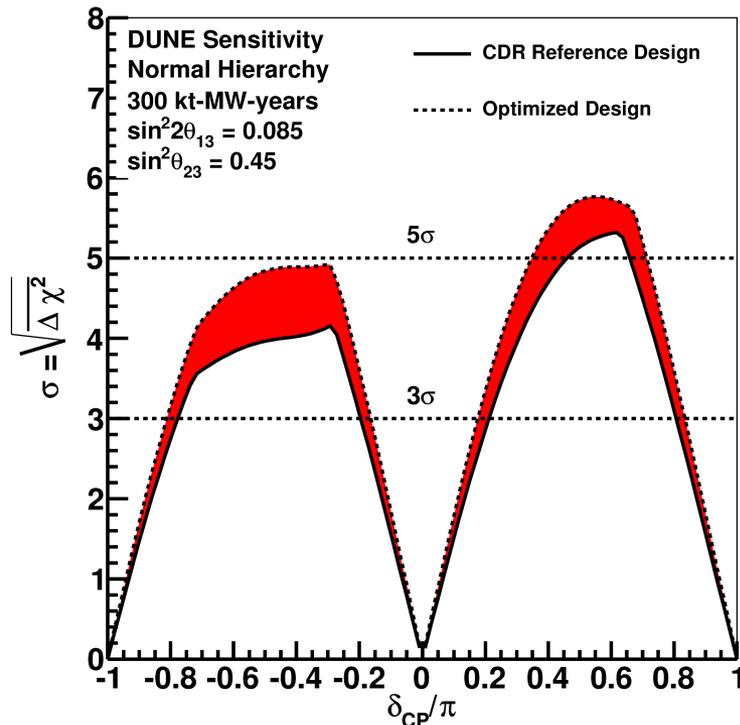
*For any CP phase with reference beamline, 10 years of exposing 40kt to 1MW beam gives  $\sim 5\sigma$  determination (both hierarchies very similar)*

*Bulk of CP values at  $5\sigma$  by 2.5 years for 40kt in a 1MW beam*

# DUNE physics program

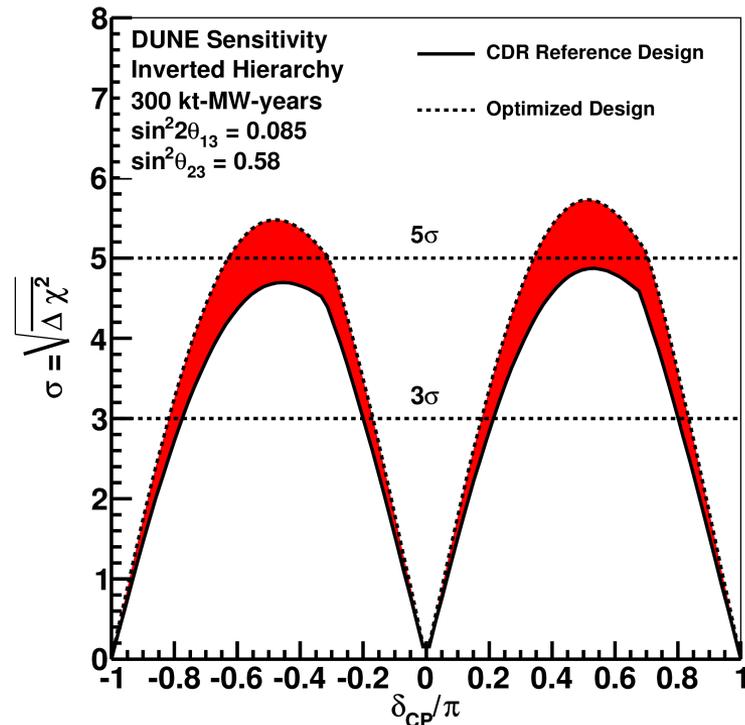
## Normal Hierarchy

CP Violation Sensitivity



## Inverted Hierarchy

CP Violation Sensitivity

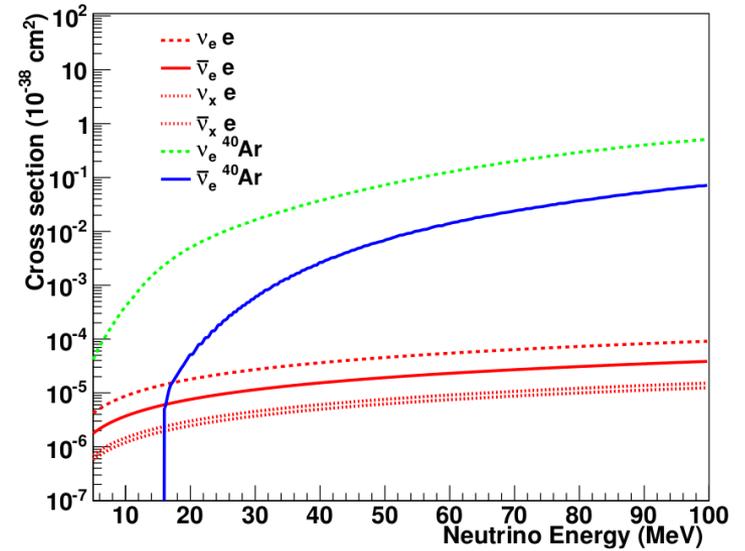
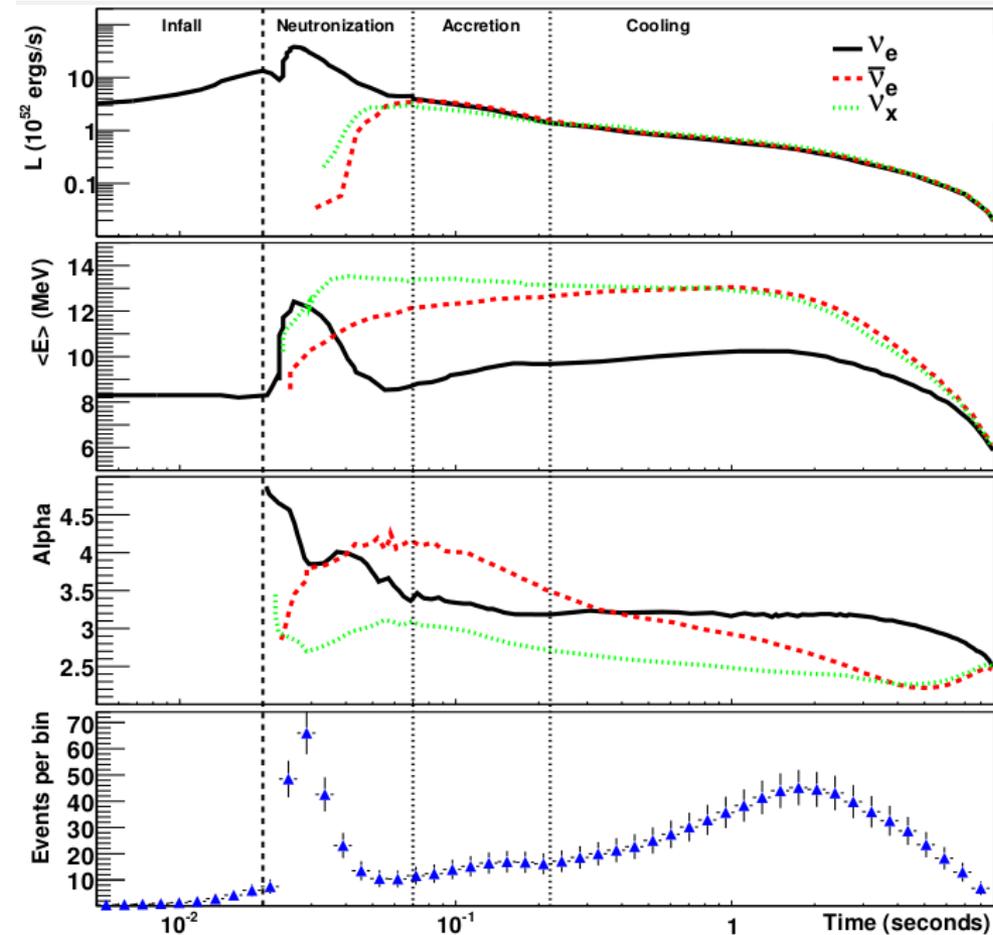


*Significant discovery potential for CP violation*

# DUNE physics program

- Supernova (SN) physics:
  - SN1987A gave first look at neutrinos from SN. Want to be ready to observe more from the next nearby SN
  - LAr especially sensitive to  $\nu_e$  CC ( $\nu_e + {}^{40}\text{Ar} \rightarrow e^- + {}^{40}\text{K}^*$ )
  - Supernovae will have a time-dependent flux as different stages occur. Look for features:
    - Black hole formation would cause abrupt cutoff
    - Turbulence and shock-wave effects
- Also look for proton decay to test GUT
  - A particularly good mode in LAr TPCs:  $p \rightarrow K^+ \bar{\nu}$

# DUNE physics program



Channel	“Livermore” model events	“GKVM” model events
$\nu_e + {}^{40}\text{Ar} \rightarrow e^- + {}^{40}\text{K}^*$	2720	3350
$\bar{\nu}_e + {}^{40}\text{Ar} \rightarrow e^+ + {}^{40}\text{K}^*$	230	160
$\nu_x + e^- \rightarrow \nu_x + e^-$	350	260
<b>Total</b>	<b>3300</b>	<b>3770</b>

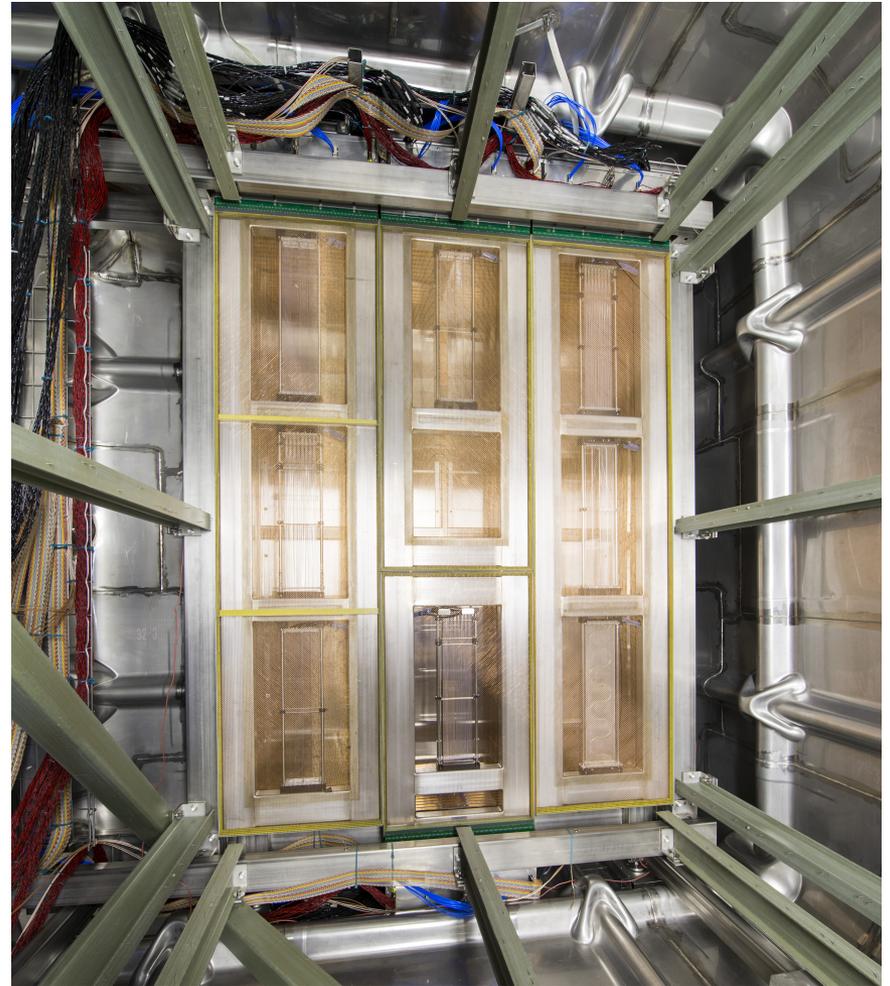
*40kt of LAr, supernova at 10kpc*

# DUNE physics program

- ND measurements include:
  - Electron neutrino and antineutrino content in beam
    - Ratios of electron (anti-)neutrinos to muon (anti-)neutrinos
  - Measure flux using  $\nu$ -e scattering (to about 2.5%)
  - Measure cross-sections related to  $\nu$ -Ar scattering
  - Model-independent measurements of nuclear effects
    - The subtraction of carbon results from polypropylene
  - Weak mixing ( $\sin^2\theta_w$ ) with NC processes
    - DIS:  $\nu N \rightarrow \nu X$ ; Elastic:  $\nu e^- \rightarrow \nu e^-$ ,  $\nu p \rightarrow \nu p$ ; Coherent  $\rho^0$  production
    - Different momentum transfers, can test running

# Path to realizing DUNE

- 35-ton prototype
  - Took place at Fermilab
  - Phase I: engineering test of cryostat
  - Phase II: operational test with TPC and PD elements
  - See talk by Karl Warburton in next session for more details

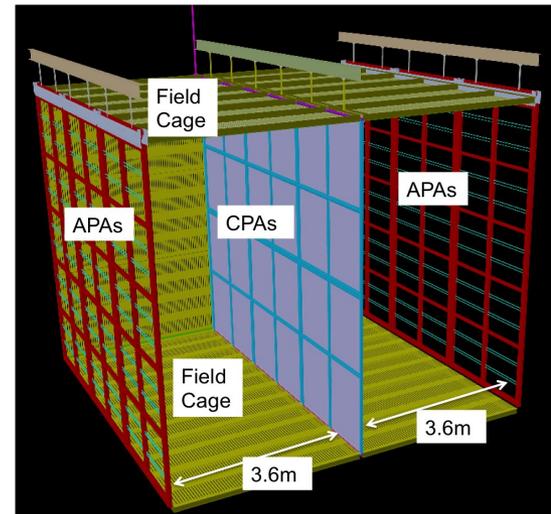
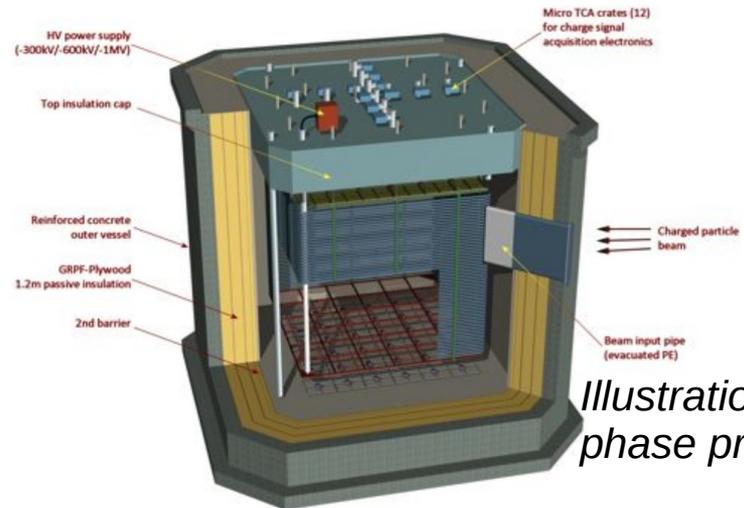


*Fermilab VMS: 15-0257-06*

# Path to realizing DUNE

- ProtoDUNE detectors

- Test single and dual phase designs in a test beam at CERN
- Validation of technologies for both designs
- Feedback on performance capabilities, e.g. calorimetry for electrons/hadrons

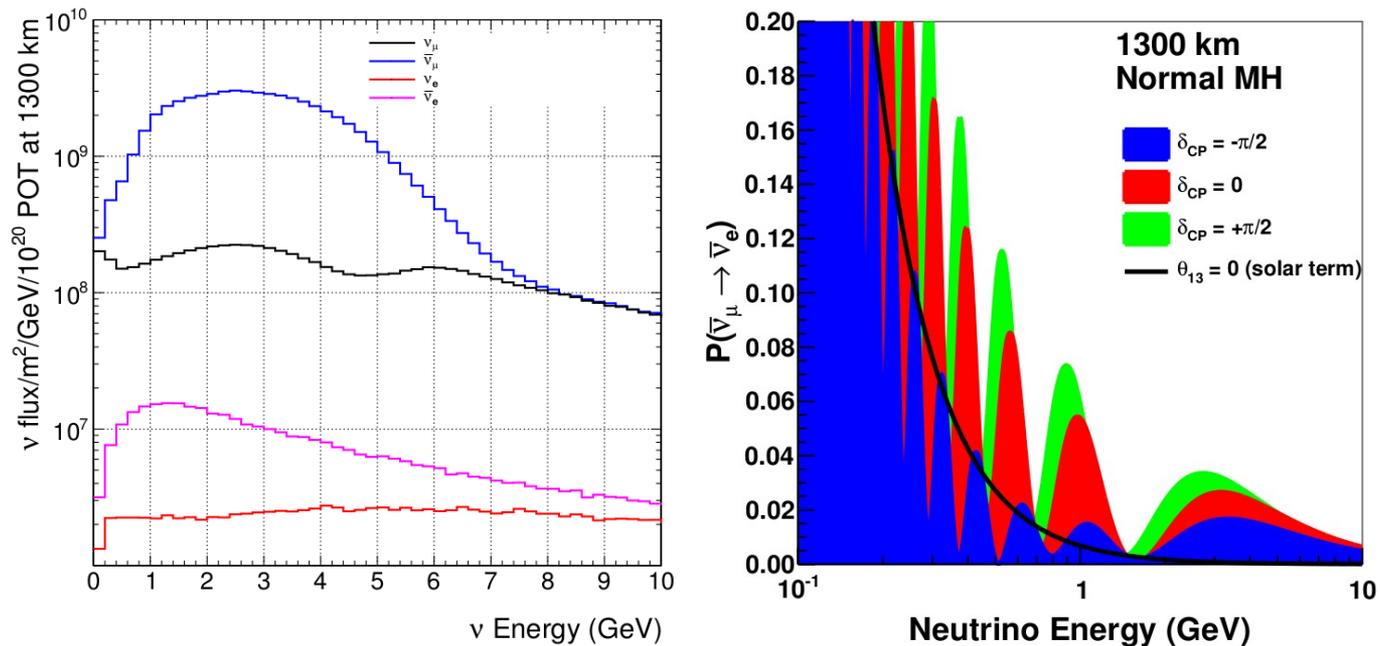


# Exciting things on horizon!

- Many opportunities for young people to get involved in detector development and physics analyses
- More information:
  - DUNE Conceptual Design Report volumes
    - arXiv: 1601.05471, 1512.06148, 1601.05823, 1601.02984
  - Other DUNE-related talks here at New Perspectives
  - DUNE-related posters at the Users Meeting
  - Talk by Daniel Cherdack Thursday at Users Meeting

# Backup

# DUNE physics program



*Reference focusing system and 120 GeV protons  
(antineutrino mode) and appearance probabilities*