# The ArgoNeuT and MicroBooNE Experiments at Fermi National Accelerator Laboratory

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on behalf of the ArgoNeuT and MicroBooNE Collaborations
ICHEP 2012

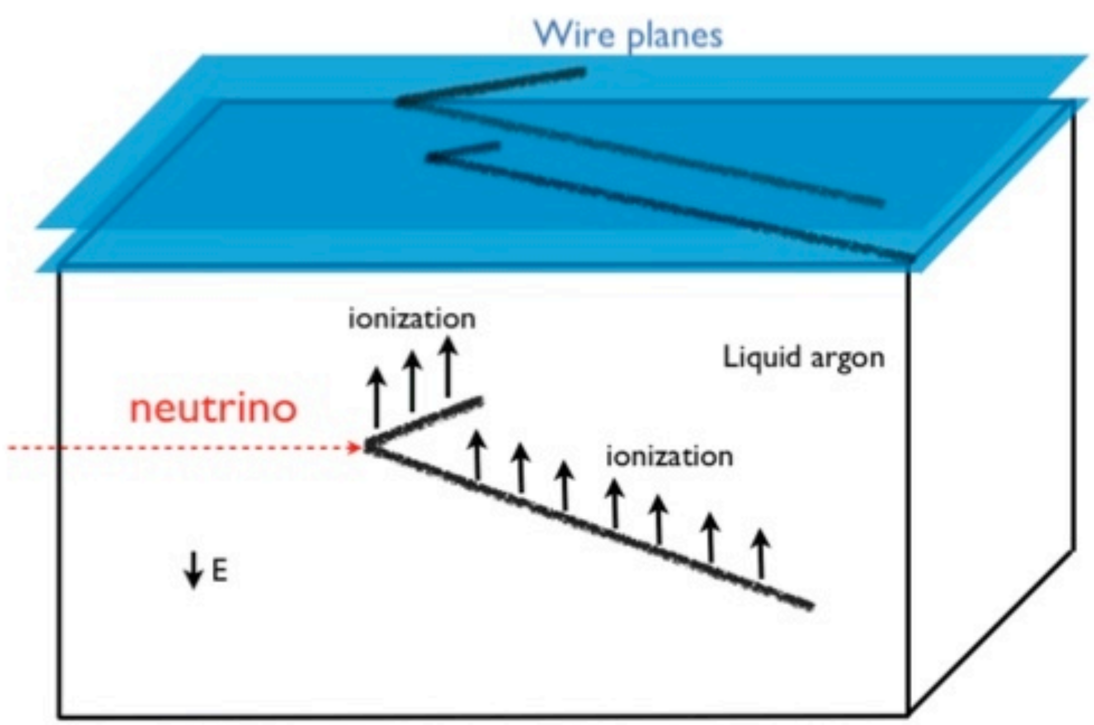
# Introduction

- Liquid Argon Time Projection Chambers (LArTPCs) are imaging detectors that offer exceptional capabilities for studying neutrinos.

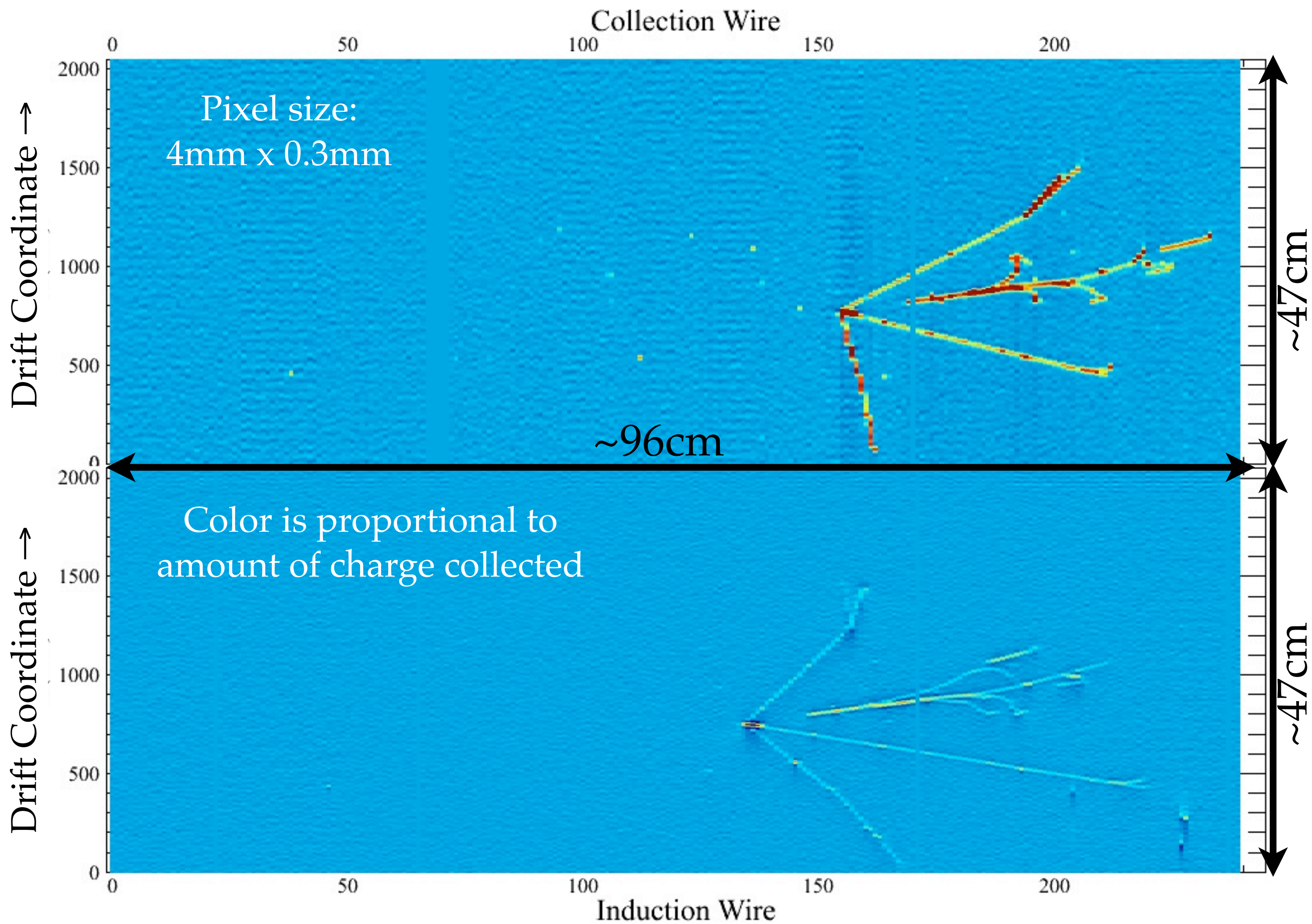
- The ArgoNeuT and MicroBooNE experiments, described in this talk, provide unique opportunities for interesting physics measurements and important LArTPC hardware development.

# Liquid Argon Neutrino Detectors

- Ionization produced in neutrino interactions is drifted along E-field to highly segmented wireplanes.
- Timing of wire pulse information is combined with known drift speed to determine drift-direction coordinate.
- Calorimetry information is extracted from wire pulse characteristics.
- Copious scintillation light also available for collection and triggering.




LArTPC Principle

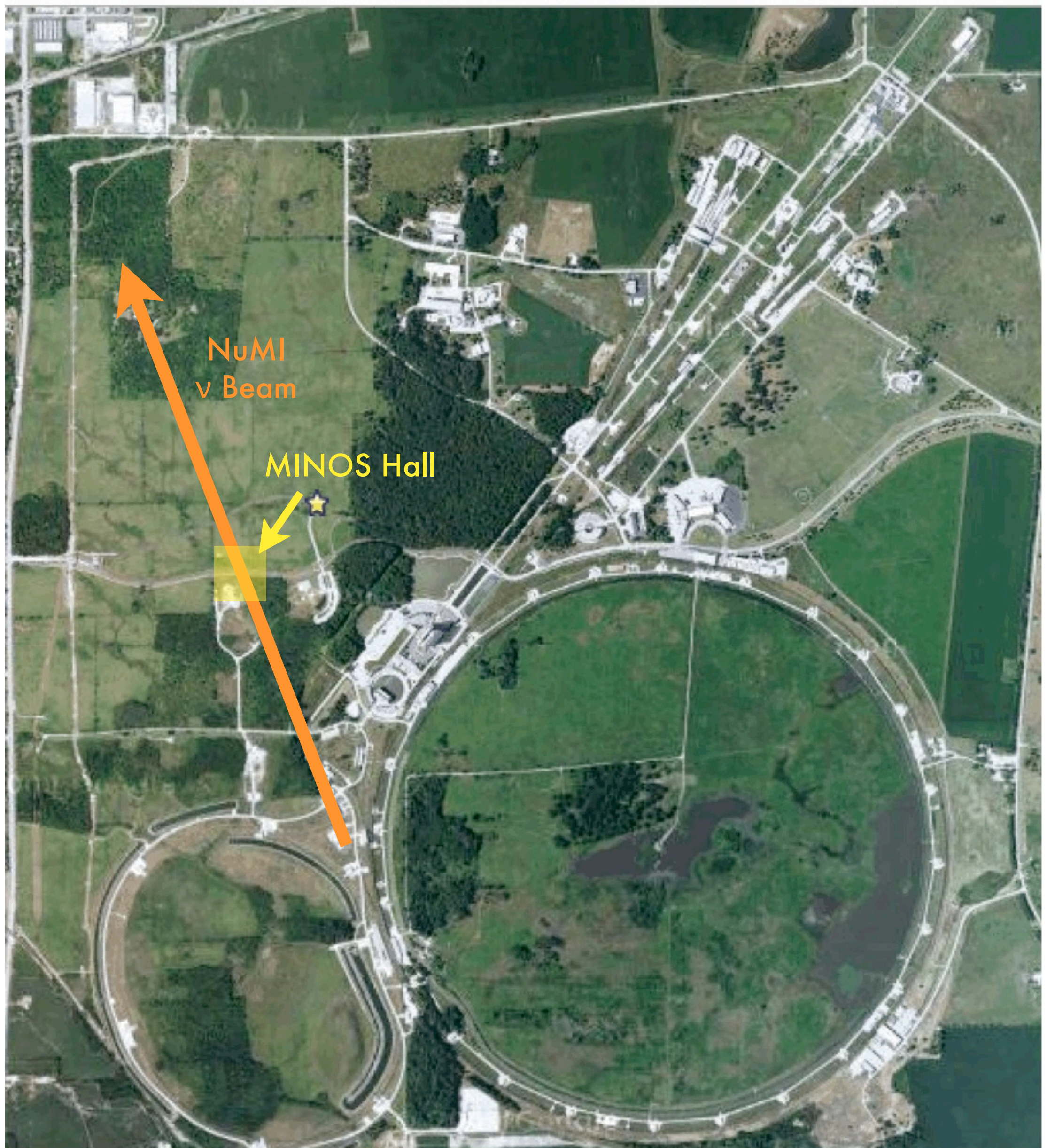



ArgoNeuT Data Event

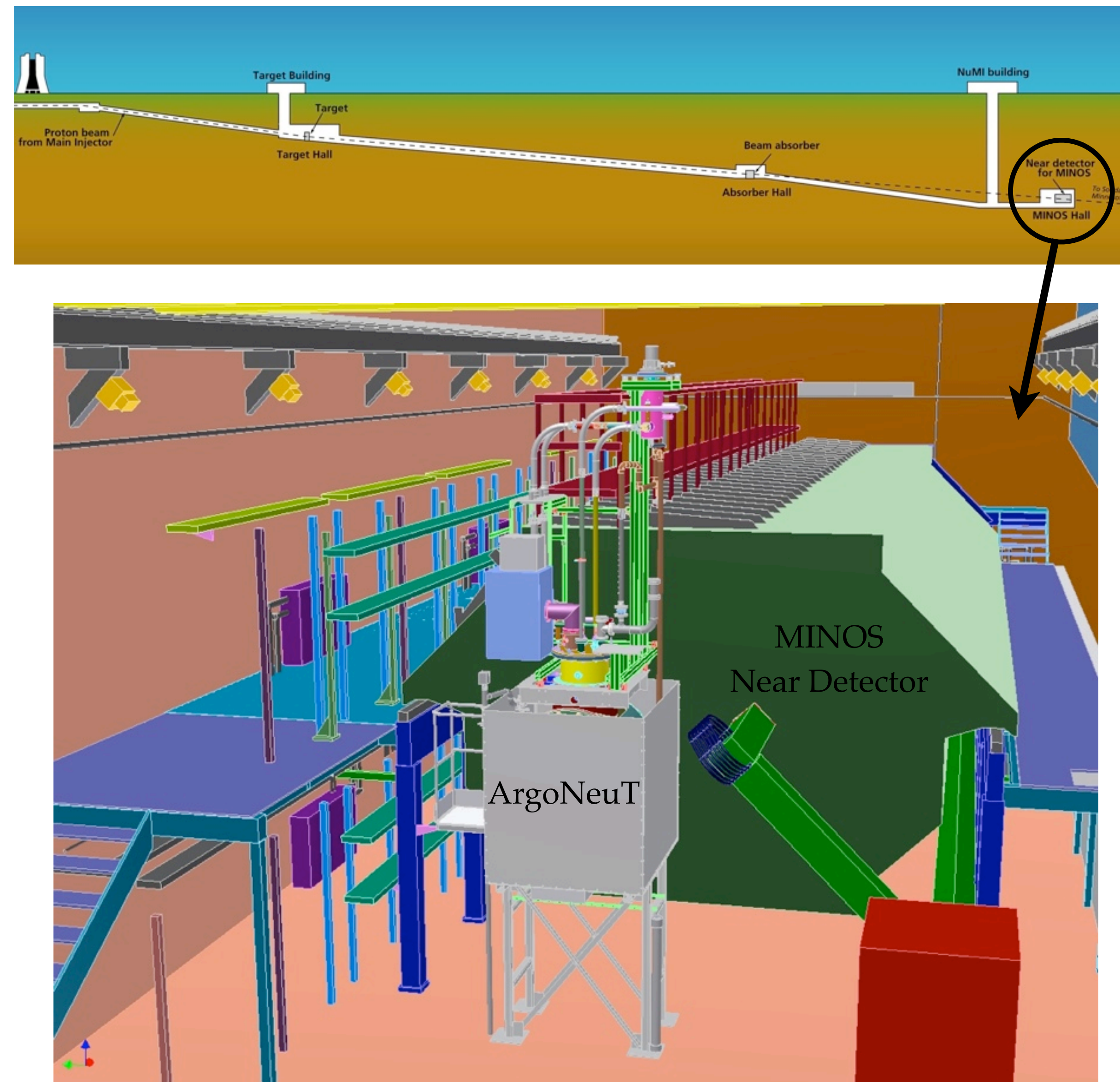

Refs:
1.) *The Liquid-argon time projection chamber: a new concept for Neutrino Detector*, C. Rubbia, CERN-EP/77-08 (1977)

# The ArgoNeuT Project

- ArgoNeuT (a.k.a. - Fermilab T962) deployed a ~175 liter LArTPC in Fermilab NuMI neutrino beam.
- Located directly upstream of MINOS near detector, which is used for full muon reconstruction and sign selection.
- Collected $1.35\times10^{20}$ Protons on Target (POT), predominantly in antineutrino mode.

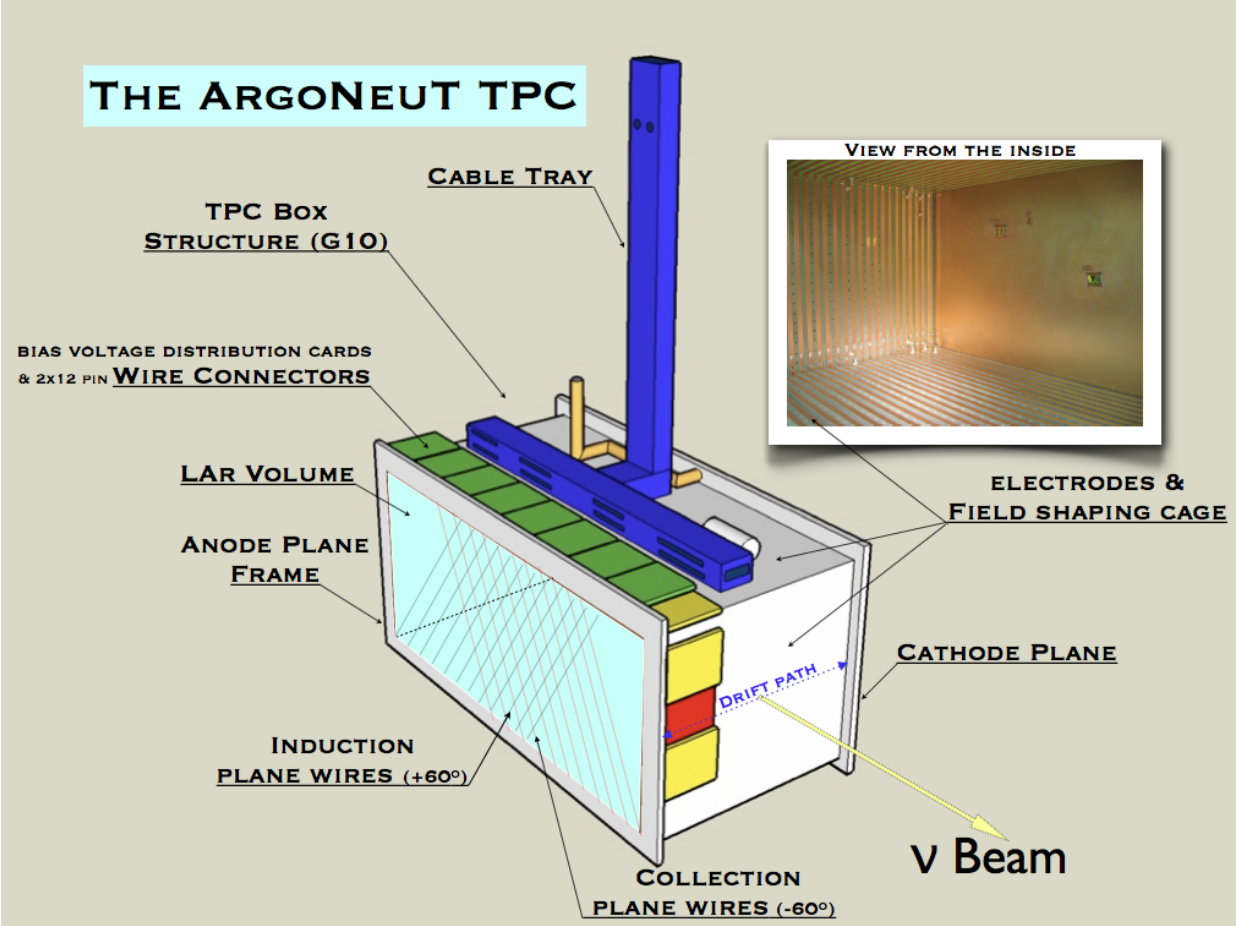


NuMI Beam at Fermilab



MINOS Hall at Fermilab

# ArgoNeuT: Detector Details

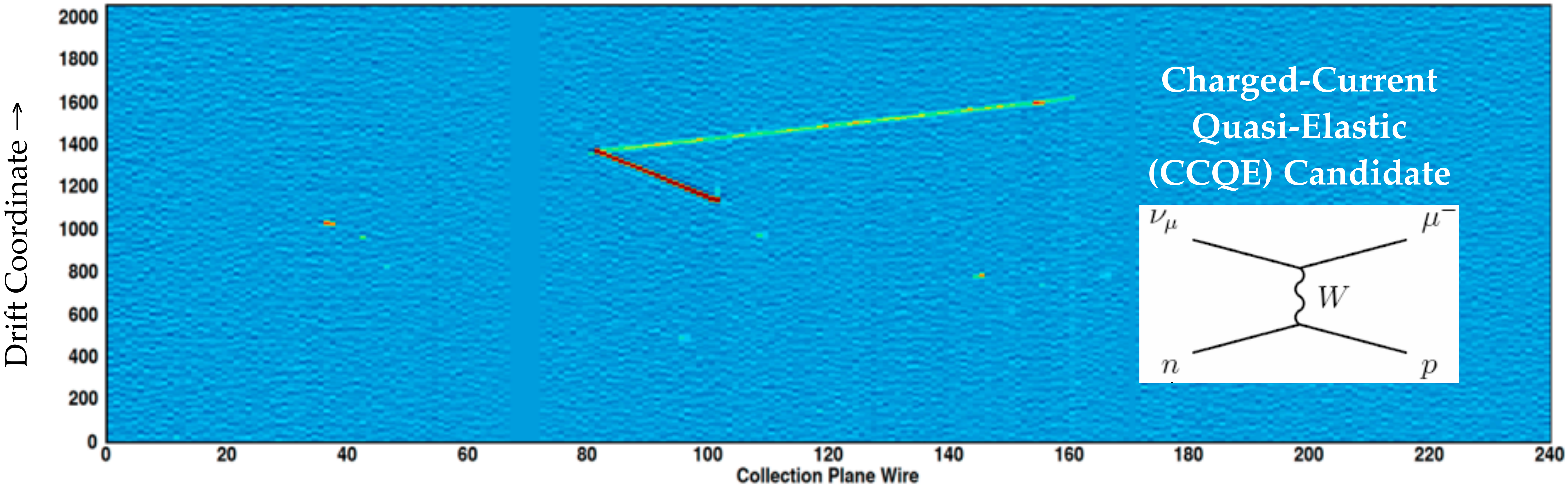


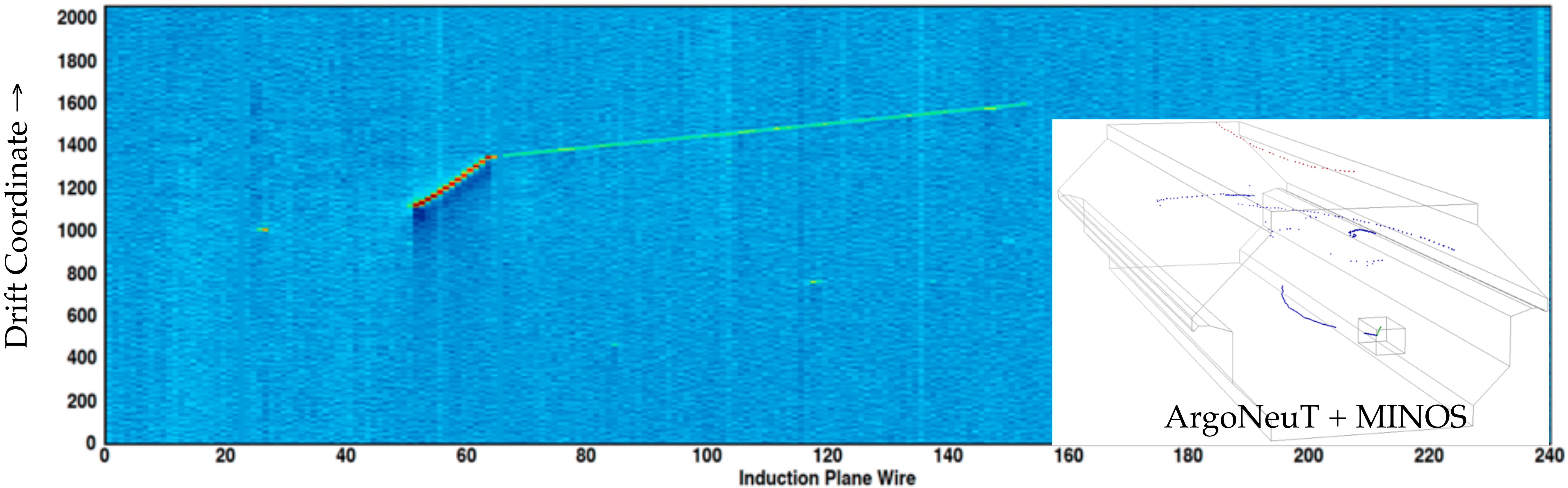

| | |
|---|---|
| Cryostat Volume | 500 Liters |
| TPC Volume | 175 Liters (90cm x 40cm x 47.5cm) |
| # Electronic Channels | 480 |
| Electronics Style (Temp.) | JFET (293 K) |
| Wire Pitch (Plane Separation) | 4 mm (4 mm) |
| Electric Field | 500 V/cm |
| Max. Drift Length (Time) | 0.5 m (330 μs) |
| Wire Properties | 0.15mm diameter BeCu |


ArgoNeuT in the NuMI Tunnel

**Refs:**
**1.)** ***The ArgoNeuT detector in the NuMI low-energy beam line at Fermilab*, C. Anderson et al., arXiv:1205.6747**

# ArgoNeuT Data Event

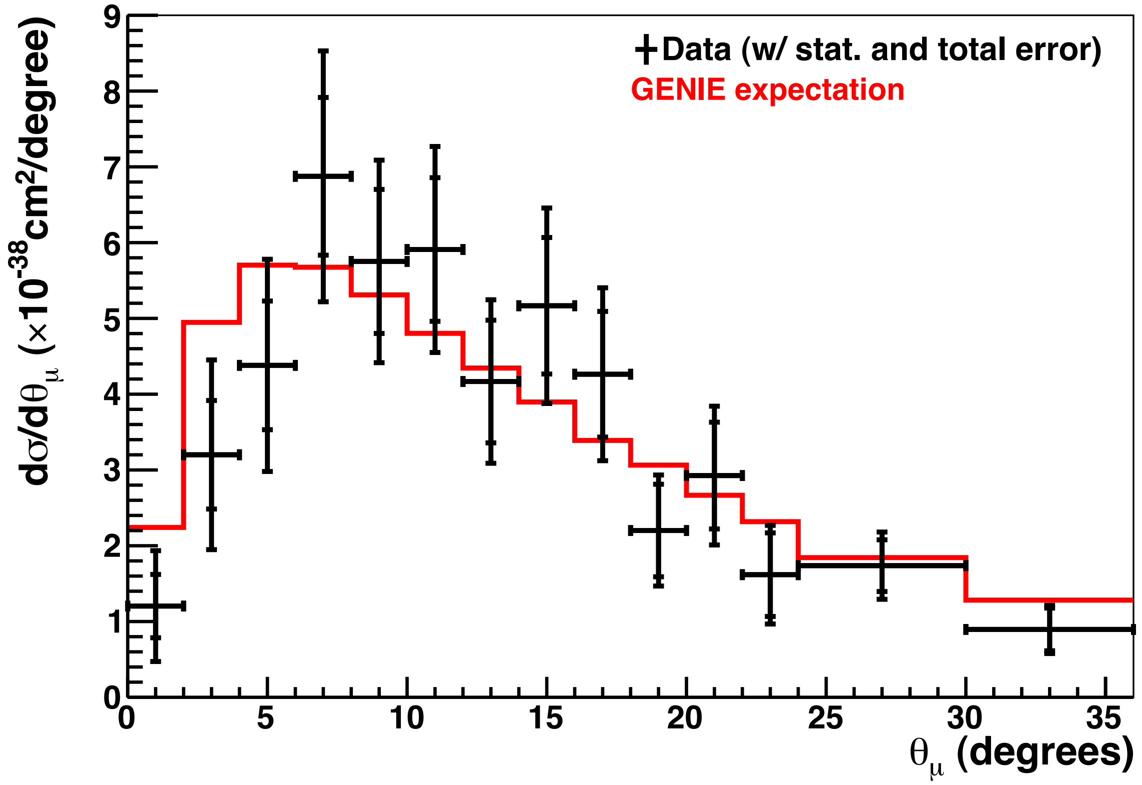


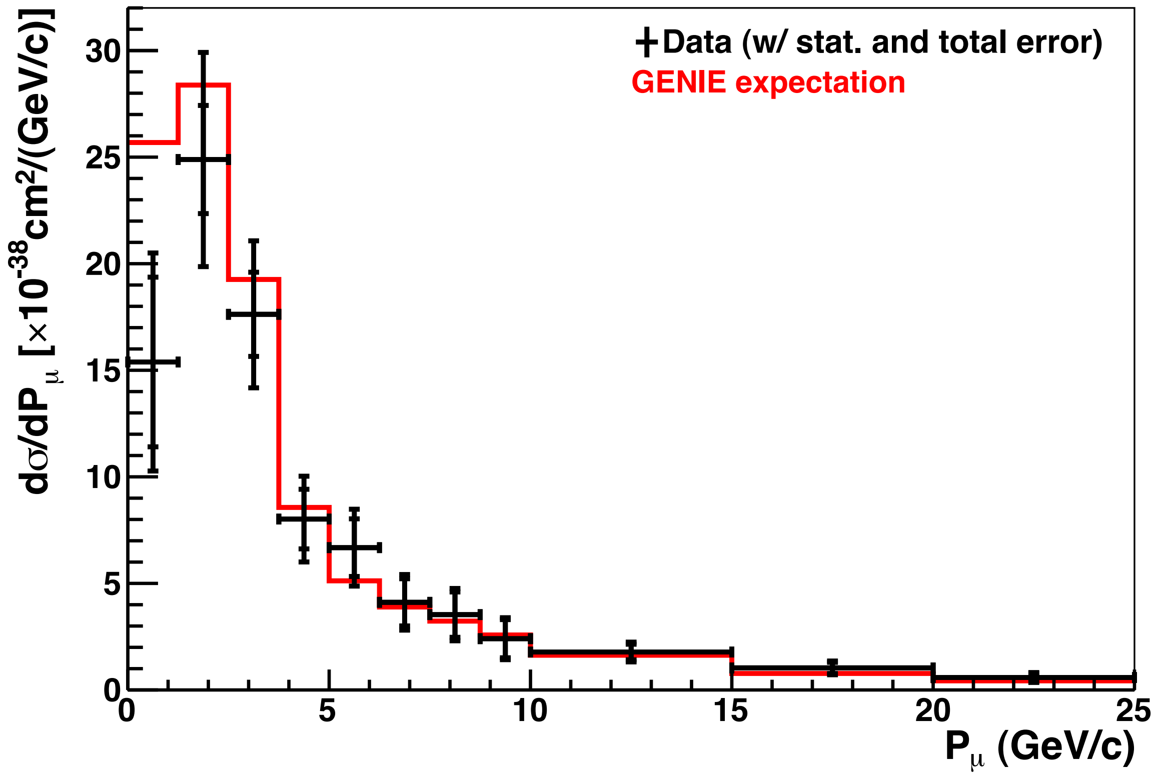



# ArgoNeuT: Physics

- First Results: Using **2 weeks** of neutrino-mode data ($8.5\times10^{18}$ POT), the differential cross-section for inclusive charged-current muon neutrino production was measured.
- Analysis Selection:
  - Track originating within ArgoNeuT fiducial region.
  - Match to corresponding track in MINOS near detector.
  - MINOS track is negatively charged.
- First such measurement on Argon!

$$\frac{\partial\sigma(u_i)}{\partial u} = \frac{N_{\text{measured},i} - N_{\text{background},i}}{\Delta u_i \; \epsilon_i \; N_{\text{targ}} \; \Phi}$$



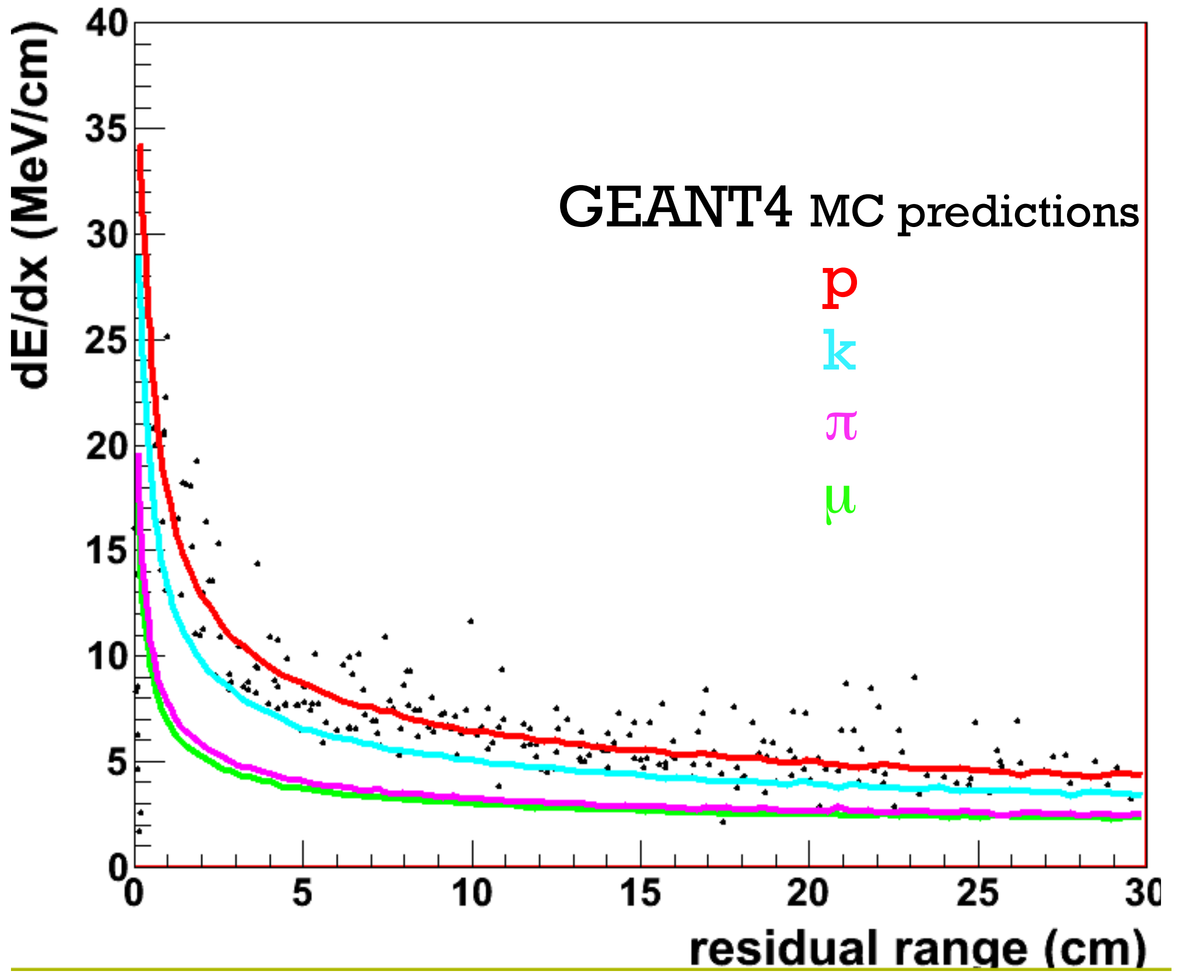



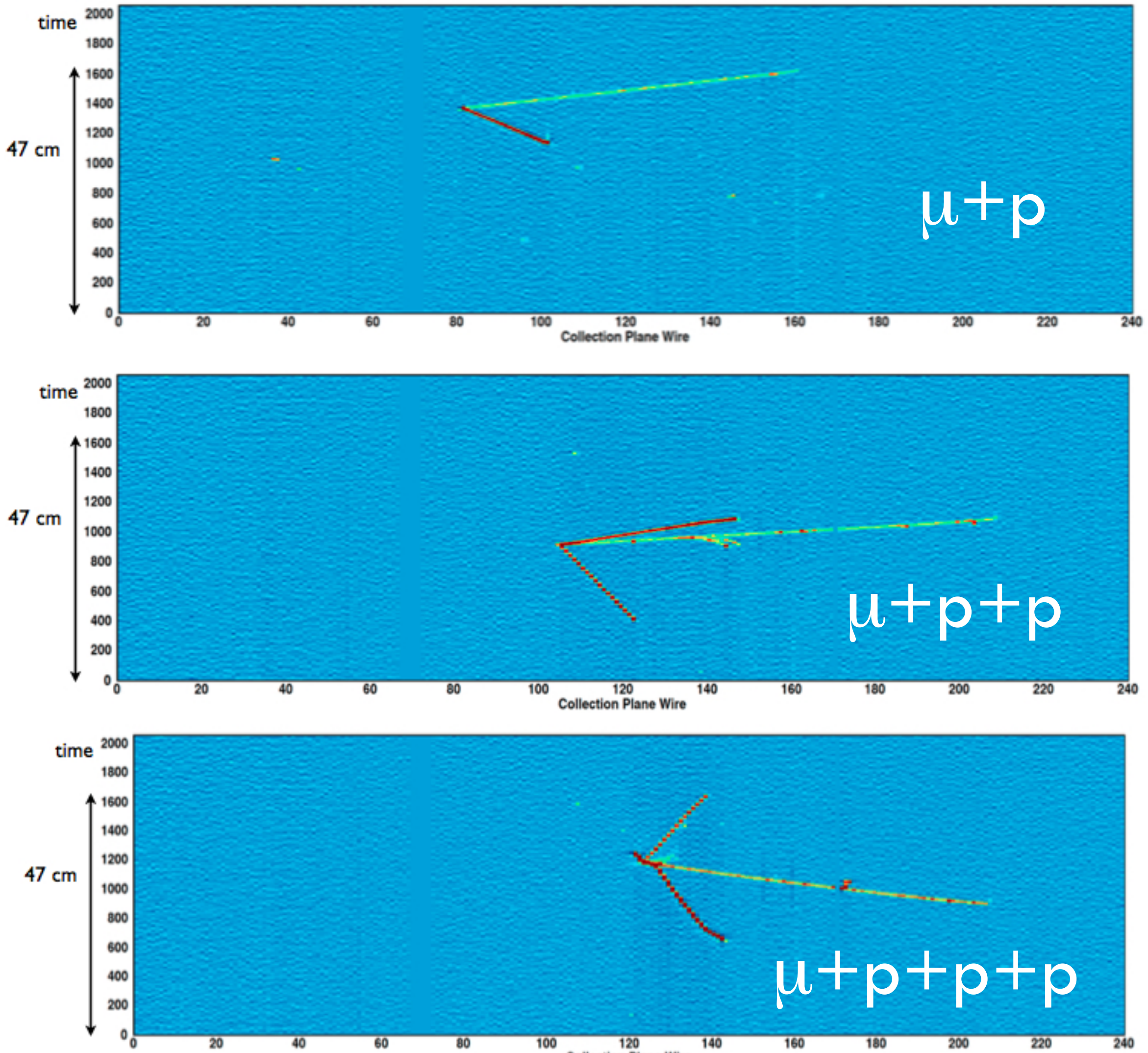

Inclusive CC cross-section

Refs:
1.) *First Measurements of Inclusive Muon Neutrino Charged Current Differential Cross Sections on Argon*, C. Anderson et al., PRL 108 (2012) 161802, arXiv:1111.0103

# ArgoNeuT Physics

- Analyses in Progress:
  - Charged-Current Inclusive cross-section in antineutrino mode.
  - Charged-Current Quasi-Elastic exclusive analysis.
  - Stopping Protons to measure recombination behavior.
  - Hyperon Production
  - Initial measurements of dE/dx Particle ID effectiveness.
- Multinucleon Correlations, producing additional final-state activity, should be observable/measurable in ArgoNeuT.



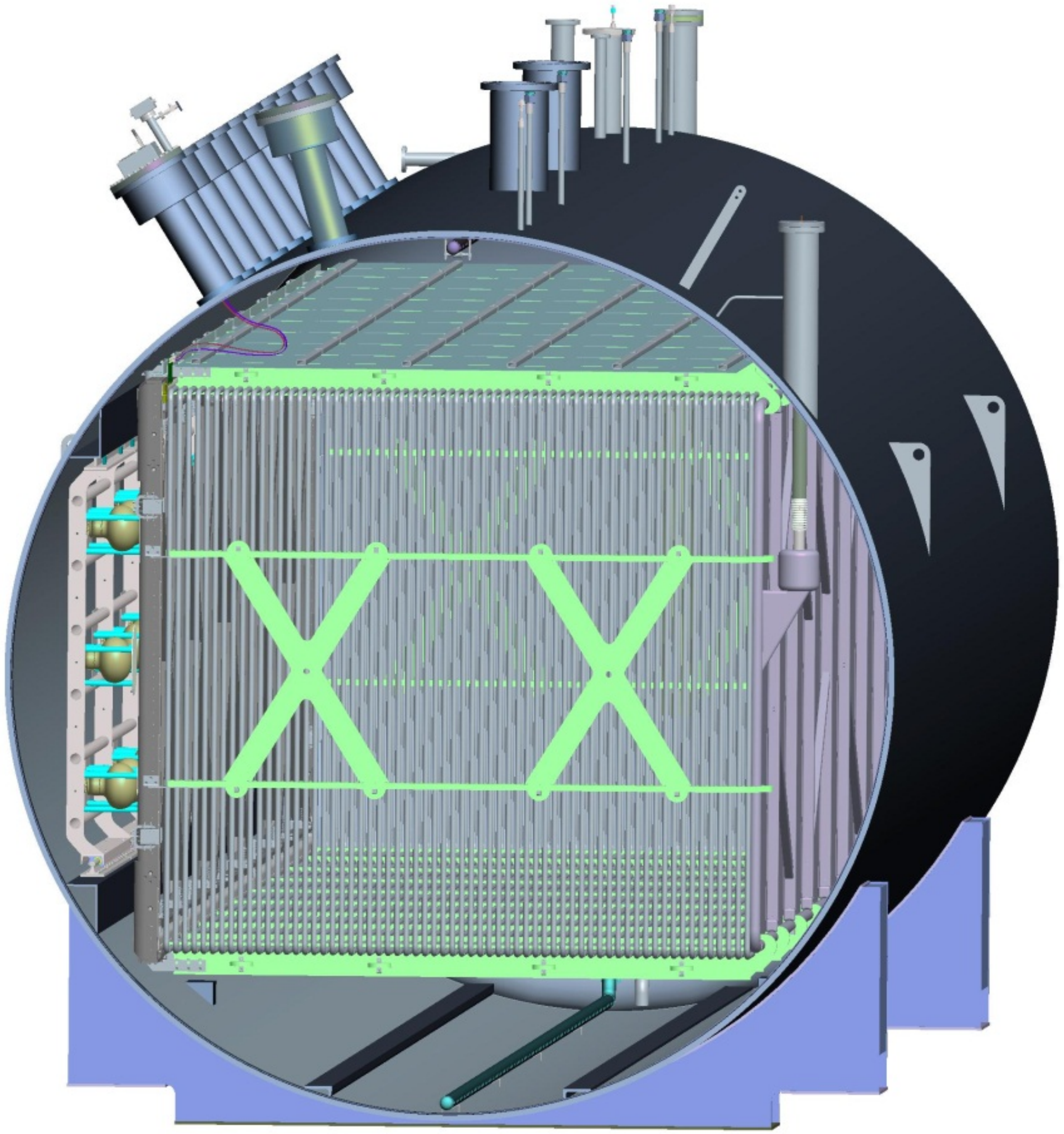

Refs:


1.) Analysis of a Large Sample of Neutrino-Induced Muons with the ArgoNeuT Detector, C. Anderson et al., arXiv:1205.6702

# The MicroBooNE Experiment

- MicroBooNE will operate in the Booster neutrino beam at Fermilab starting in early 2014.
- Combines timely physics with hardware R&D necessary for the evolution of LArTPCs.
  - MiniBooNE low-energy excess
  - Low-Energy neutrino cross-sections
  - Cold Electronics (preamplifiers in liquid)
  - Long drift (2.5m)
  - Purity without evacuation.

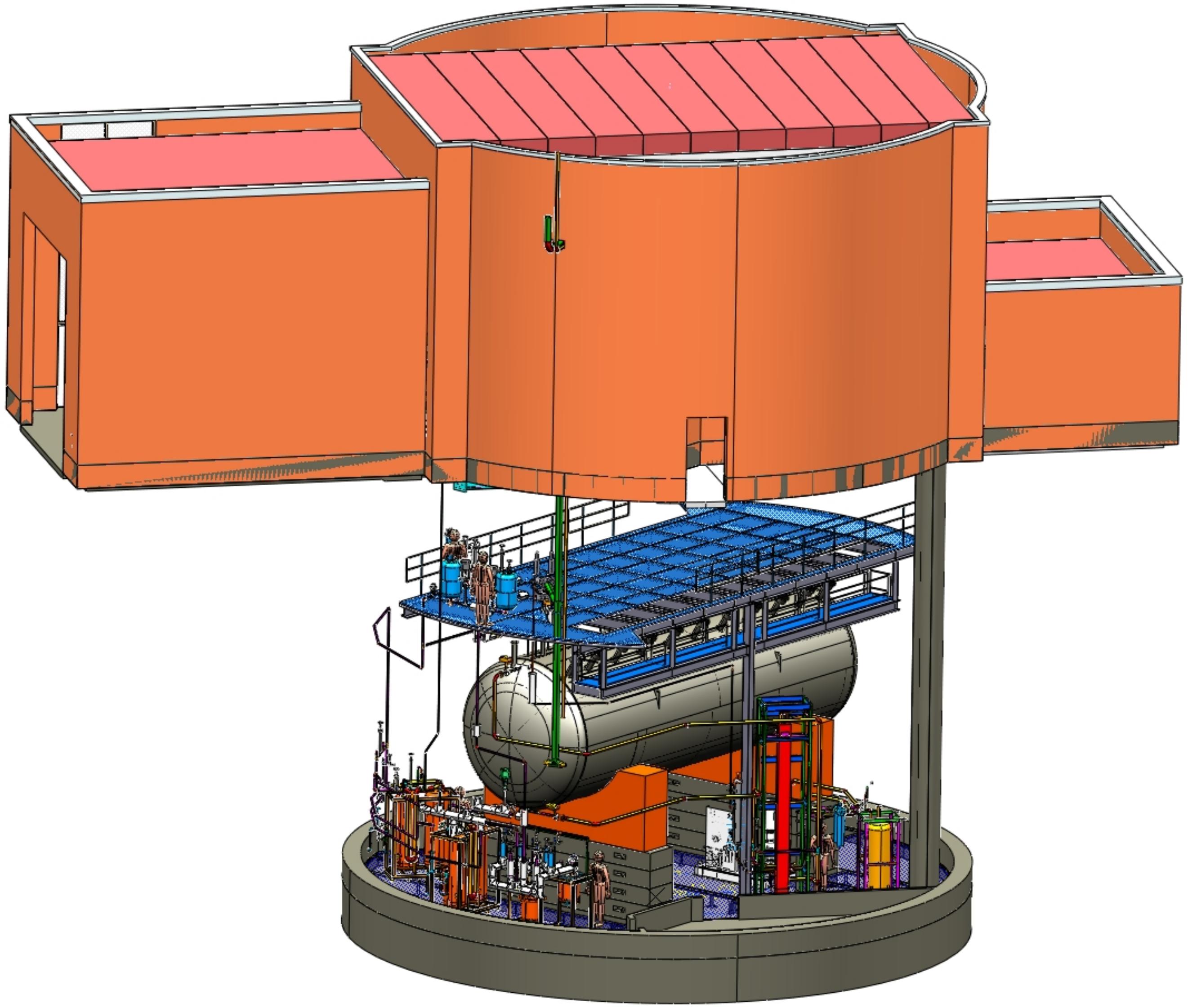
Booster Neutrino Beam at Fermilab


MicroBooNE Detector

# MicroBooNE: Detector Details

- MicroBooNE will be located in new Liquid Argon Test Facility (LArTF), just upstream of MiniBooNE location.
- Building construction is well underway.

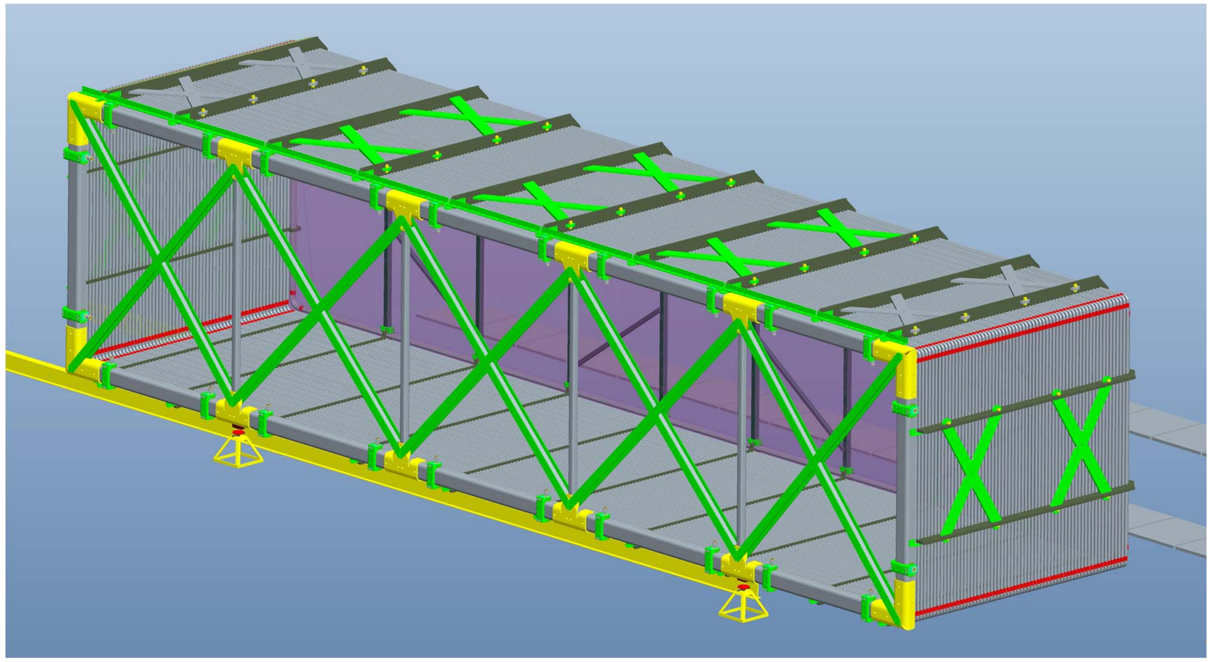
Liquid Argon Test Facility: June 2012



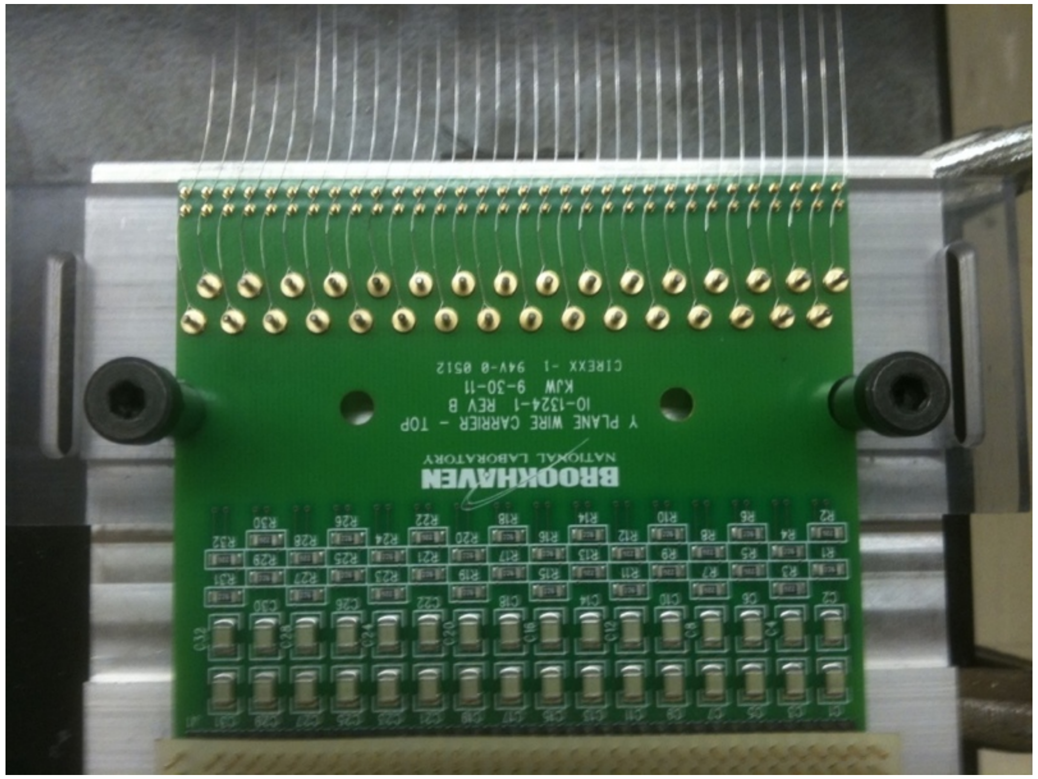
MicroBooNE Layout

# MicroBooNE: Detector Details

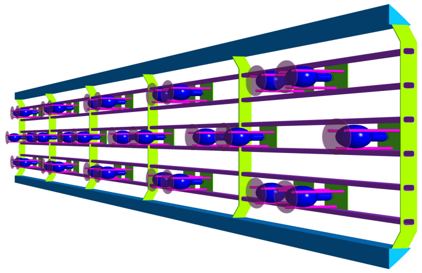
| | |
|---|---|
| Cryostat Volume | 150 Tons |
| TPC Volume (l x w x h) | 89 Tons (10.4m x 2.5m x 2.3m) |
| # Electronic Channels | 8256 |
| Electronics Style (Temp.) | CMOS (87 K) |
| Wire Pitch (Plane Separation) | 3 mm (3mm) |
| Max. Drift Length (Time) | 2.5m (1.5ms) |
| Wire Properties | 0.15mm diameter SS, Cu/Au plated |
| Light Collection | ~30 8” Hamamatsu PMTs |



TPC



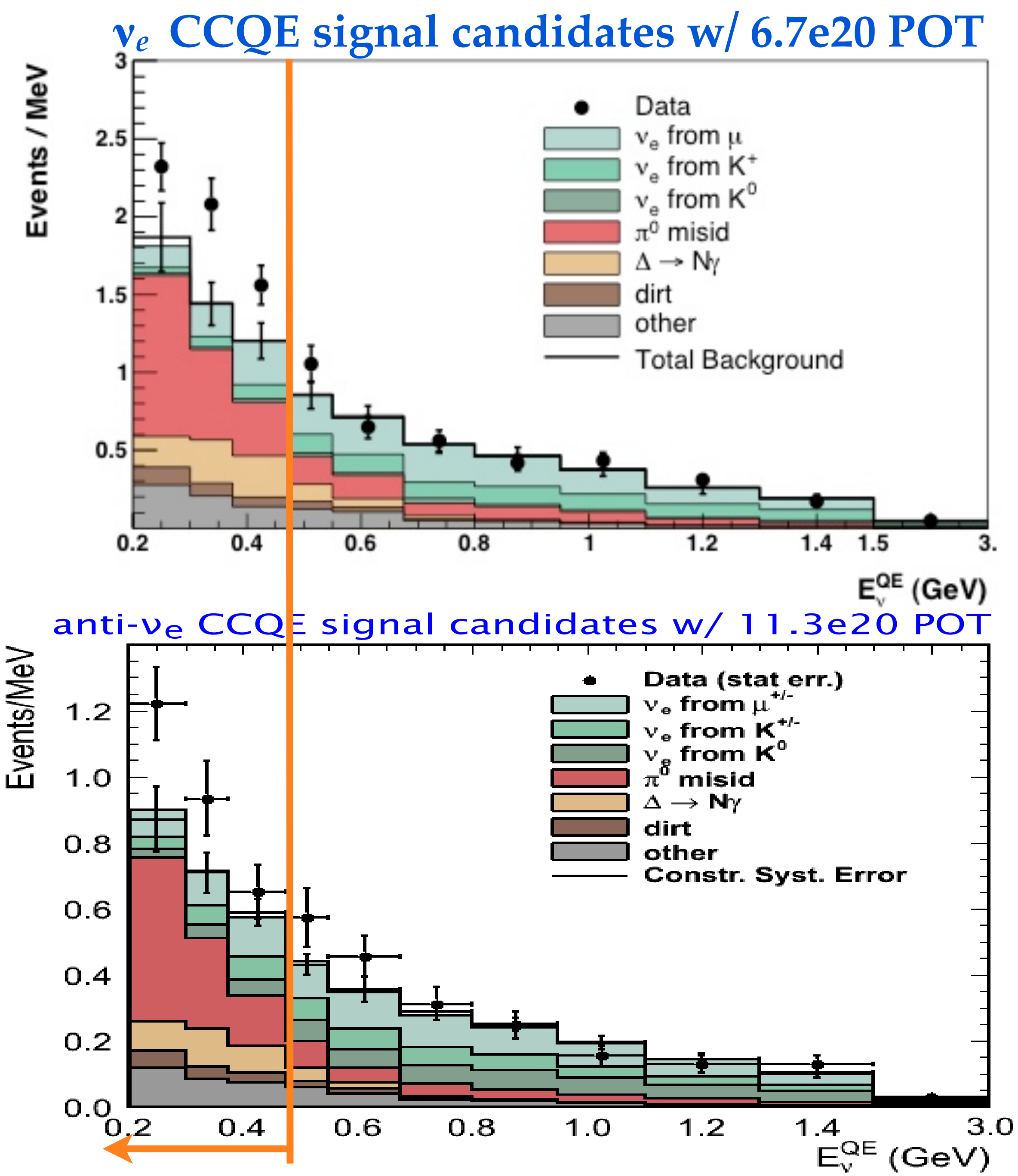
Collection Plane Wire Assembly



Teppei Katori and MicroBooNE PMTs:
IUPAP Young Scientist Prize Winner.
See his talk on Tue., July 10!

# MicroBooNE: Physics

- Address the MiniBooNE low energy excess
  - MiniBooNE is a Cerenkov detector that looks for $\nu_e$ appearance from a beam of $\nu_\mu$
  - Does MicroBooNE confirm the excess?
  - If confirmed, is the excess due to an electron-like or gamma-like process?




MiniBooNE $\nu_e$ Appearance Result

MiniBooNE Result Excess
(200-475 MeV)

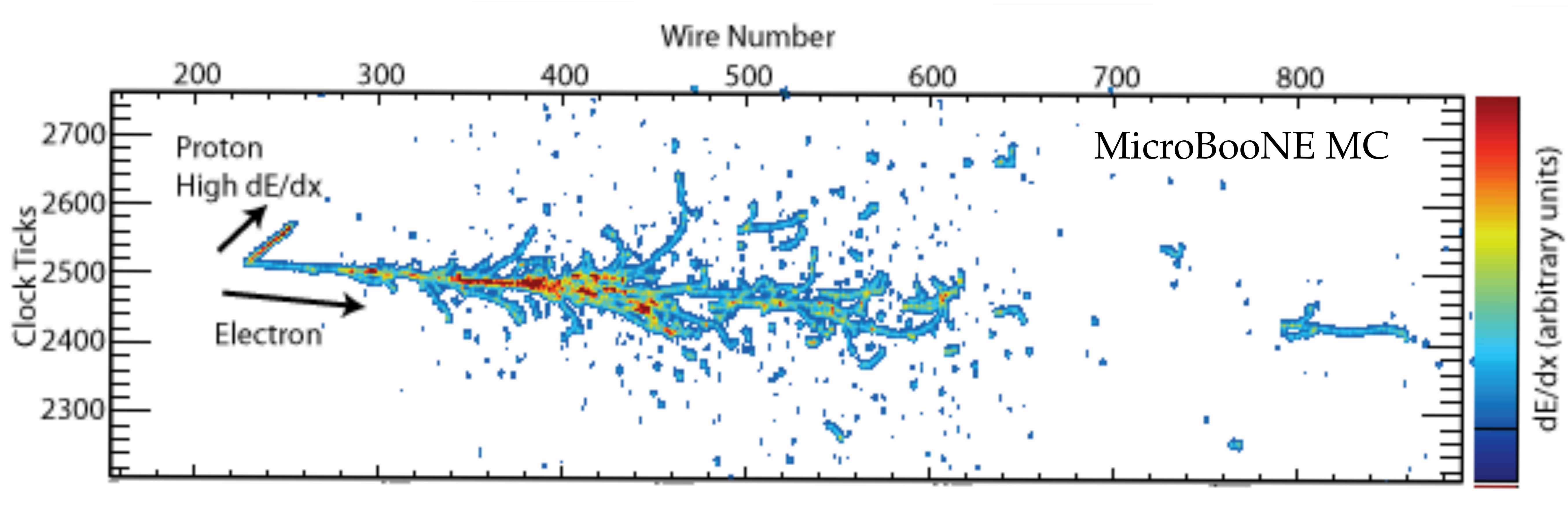
Neutrino: 128.8±43.4 events

AntiNeutrino: 57.9±21.6 events


Refs:
1.) *Unexplained Excess of Electron-Like Events From a 1-GeV Neutrino Beam* MiniBooNE Collaboration, Phys. Rev. Lett. 102, 101802 (2009)
2.) *Updated Oscillation Results from MiniBooNE*, Chris Polly, Neutrino2012 Presentation

# MicroBooNE: Physics

- Prove effectiveness of electron/gamma separation technique (*e.g.* - using dE/dX information), and exploit to characterize any observed MiniBooNE-like “low-E” excess signals.
- Low Energy Neutrino Cross-Section Measurements: CCQE, NC $\pi^o$, $\Delta \rightarrow N\gamma$, etc...
- Study backgrounds relevant for Proton Decay searches in larger detectors (*e.g.* - Kaon production), and develop SuperNova analysis capabilities.
- Probe the Strange Quark content of Proton.
- Continue development of automated reconstruction (building on ArgoNeuT’s effort).




Example CCQE $\nu_e$ event simulated in MicroBooNE Collection Plane (zoomed in view)

# Conclusions

- LArTPCs are powerful detectors for studying neutrinos.
- ArgoNeuT data analysis is ongoing. First results published, and we will have more results later this year using full data sample.
- MicroBooNE construction is in progress, and operations will begin in early 2014. MicroBooNE will carry out an extensive physics program, including search for MiniBooNE low-energy excess.

# Thanks

## ArgoNeuT Collaboration

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## MicroBooNE Collaboration

- Brookhaven Lab H. Chen, S. Duffin, J. Farrell, F. Lanni, Y. Li, D. Lissauer, G. Mahler, D. Makowieki, J. Mead, V. Radeka, S. Rescia, J. Sondericker, C. Thorn, K. Wu, B. Yu
- Columbia University L. Camilleri, R. Carr, G. Cheng, C. Chi, G. Karagiorgi, C. Mariani, B. Seligman, M. Shaevitz, B. Sippach, B. Willis
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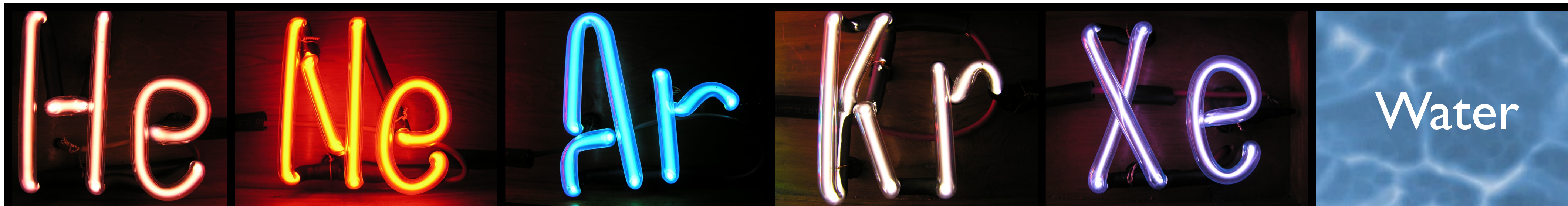
- Syracuse University M. Asaadi, M. Soderberg
- University of Cincinnati R. Grosso, R. Johnson, B. Littlejohn
- University of Texas at Austin S. Kopp, K. Lang, R. Mehdiyev
- Yale University C. Brasco, E. Church, B. Fleming, R. Guenette, E. Klein, A. Szelc

# Back-Up Slides

# Why Noble Liquids for Neutrinos?

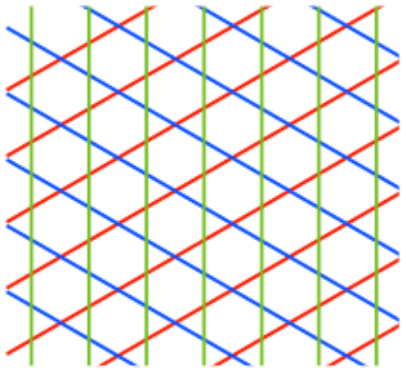
- Abundant ionization electrons and scintillation light can both be used for detection.
- If liquids are highly purified (<0.1ppb), ionization can be drifted over long distances.
- Excellent dielectric properties accommodate very large voltages.
- Noble liquids are dense, so they make a good target for neutrinos.
- Argon is relatively cheap and easy to obtain (1% of atmosphere).
- Drawbacks?...no free protons...nuclear effects.

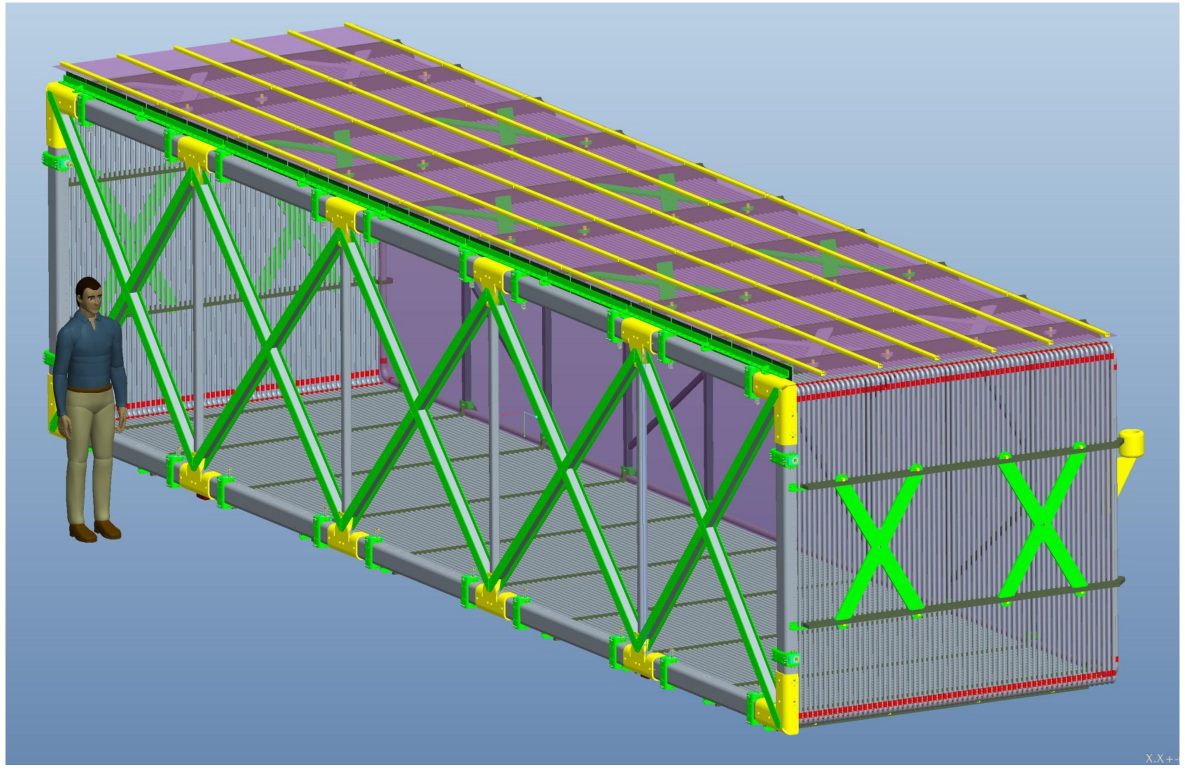



| | He | Ne | Ar | Kr | Xe | Water |
|---|---|---|---|---|---|---|
| Boiling Point [K] @ 1atm | 4.2 | 27.1 | 87.3 | 120.0 | 165.0 | 373 |
| Density [g/cm$^3$] | 0.125 | 1.2 | 1.4 | 2.4 | 3.0 | 1 |
| Radiation Length [cm] | 755.2 | 24.0 | 14.0 | 4.9 | 2.8 | 36.1 |
| dE/dx [MeV/cm] | 0.24 | 1.4 | 2.1 | 3.0 | 3.8 | 1.9 |
| Scintillation [$\gamma$/MeV] | 19,000 | 30,000 | 40,000 | 25,000 | 42,000 | |
| Scintillation $\lambda$ [nm] | 80 | 78 | 128 | 150 | 175 | |

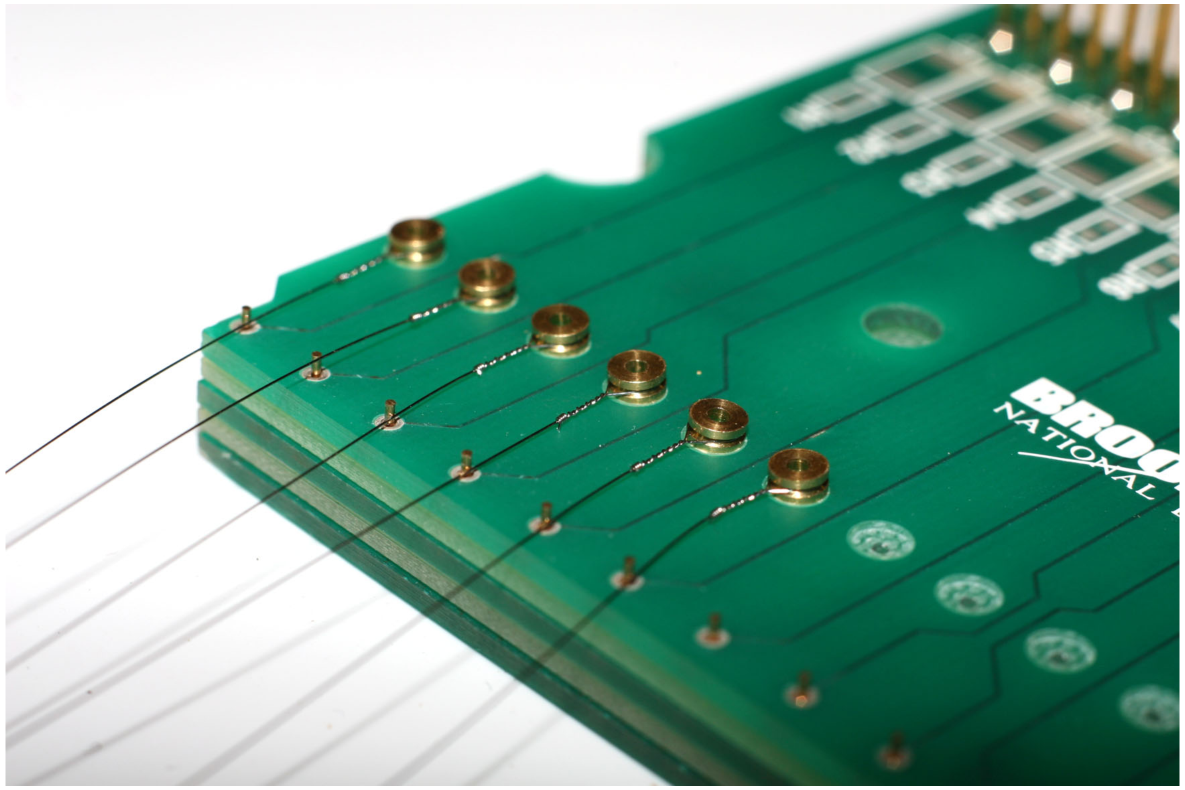
# MicroBooNE: TPC

- TPC has 3 instrumented wireplanes (Two Induction at +/-60 from vertical, One Collection with vertical wires).
- Cathode is held at -125kV, setting up 500V/cm drift field.
- Wires are individually terminated around brass ferrules, then positioned on wire carriers.





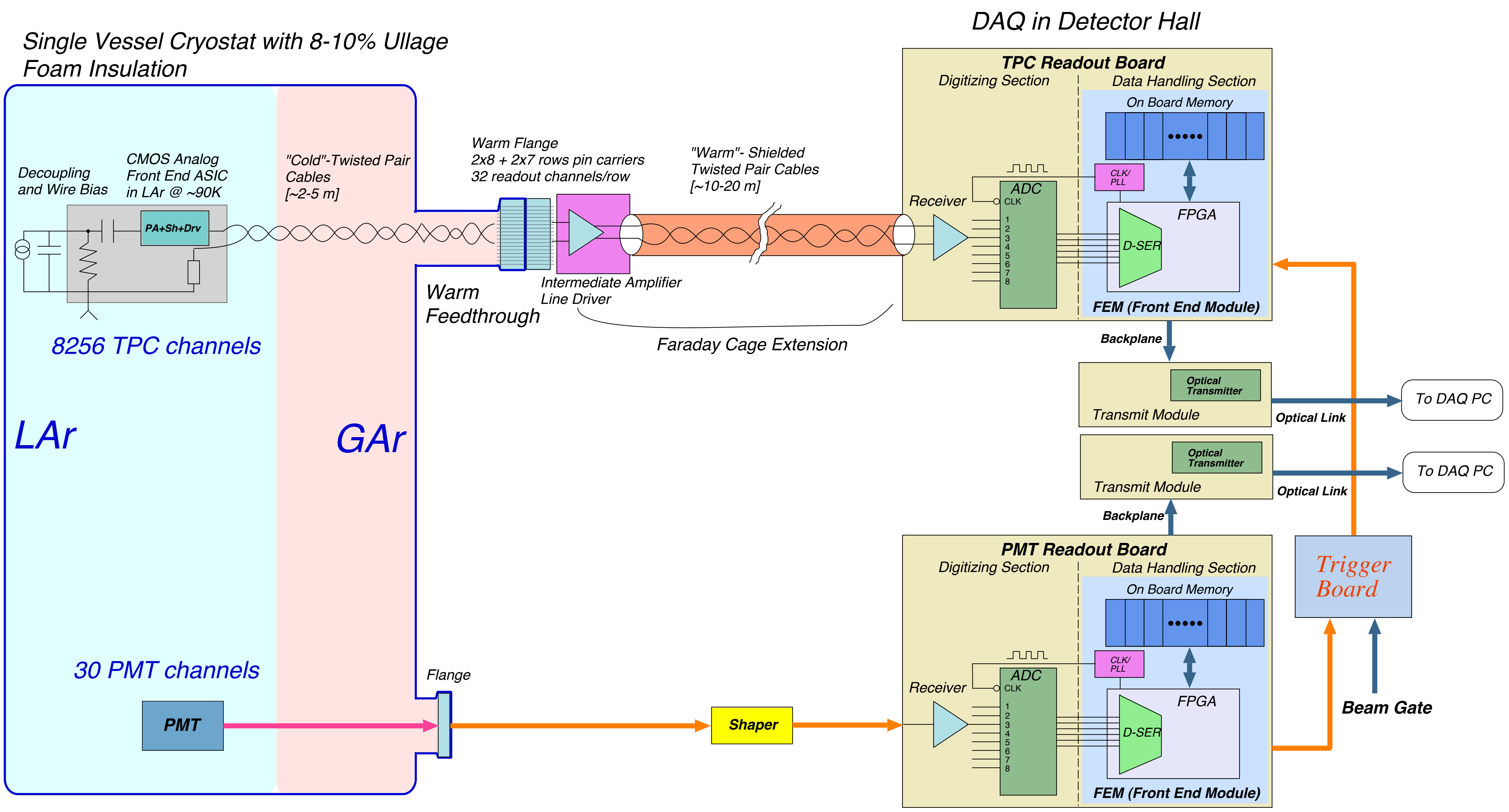
Schematic of MicroBooNE TPC



Prototype wires and wire carrier boards.

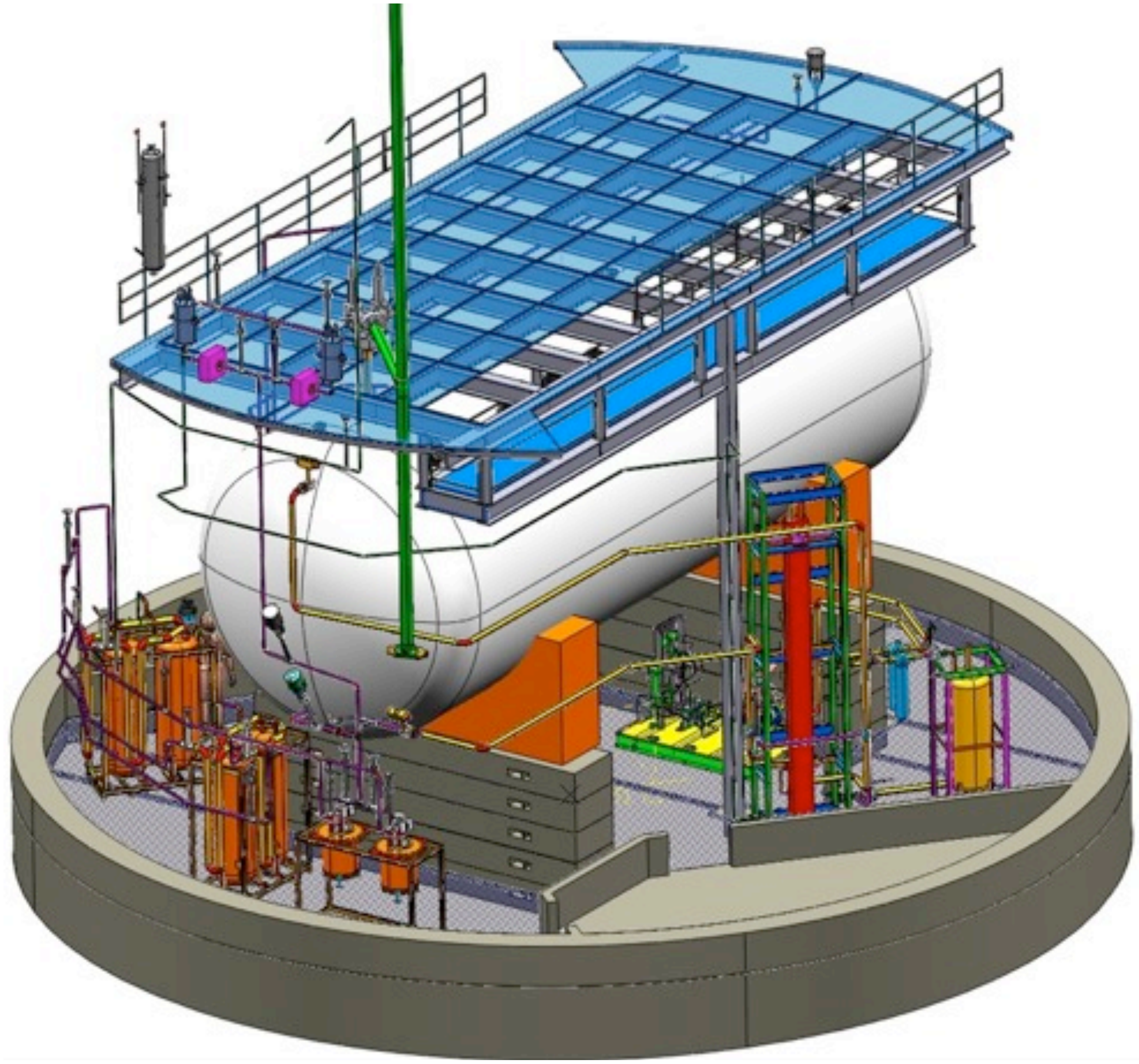
# MicroBooNE: Electronics

- CMOS preamplifiers located in liquid, attached to TPC.
- 12-bit ADCs sampled at 2MHz (i.e. - 500ns per sample) for 4.8ms (x3 drift window).
- 1-hour data buffering for Supernova detection signal from SNEWS.



# MicroBooNE: Cryogenics

- Cryogenic system consists of filters/pumps/etc... for circulating and purifying LAr.
- Cryostat is evacuable (though the plan is not to evacuate) and foam insulated.



Schematic of MicroBooNE Layout

LAPD @ Fermilab

# ArgoNeuT Data Event