Neutrino Data Analysis with the ArgoNeuT Project

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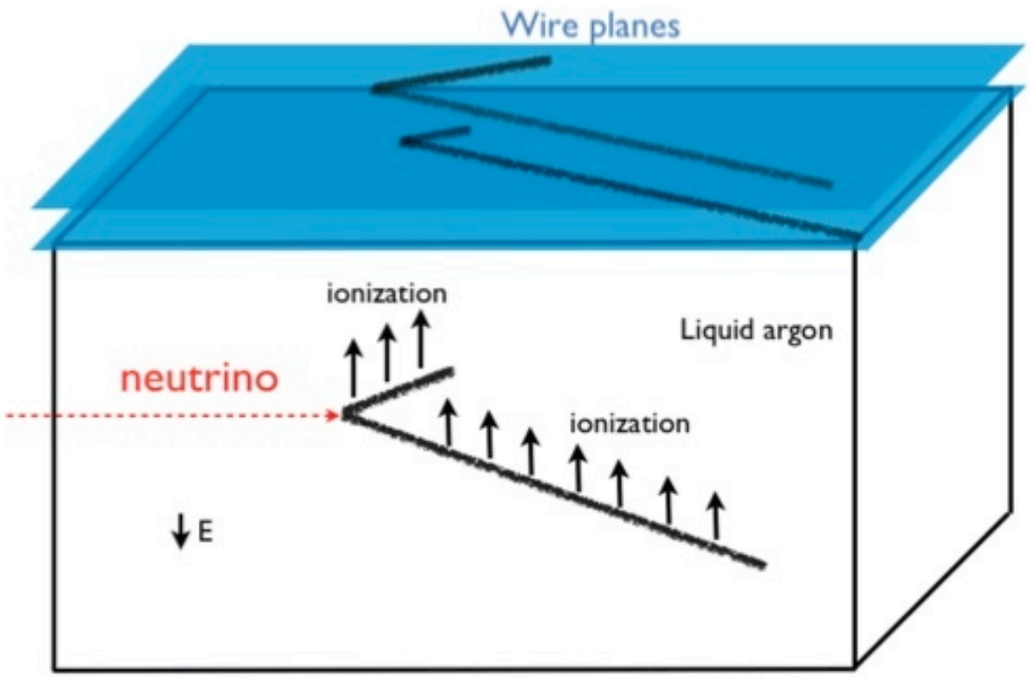
2011 Moriond EW

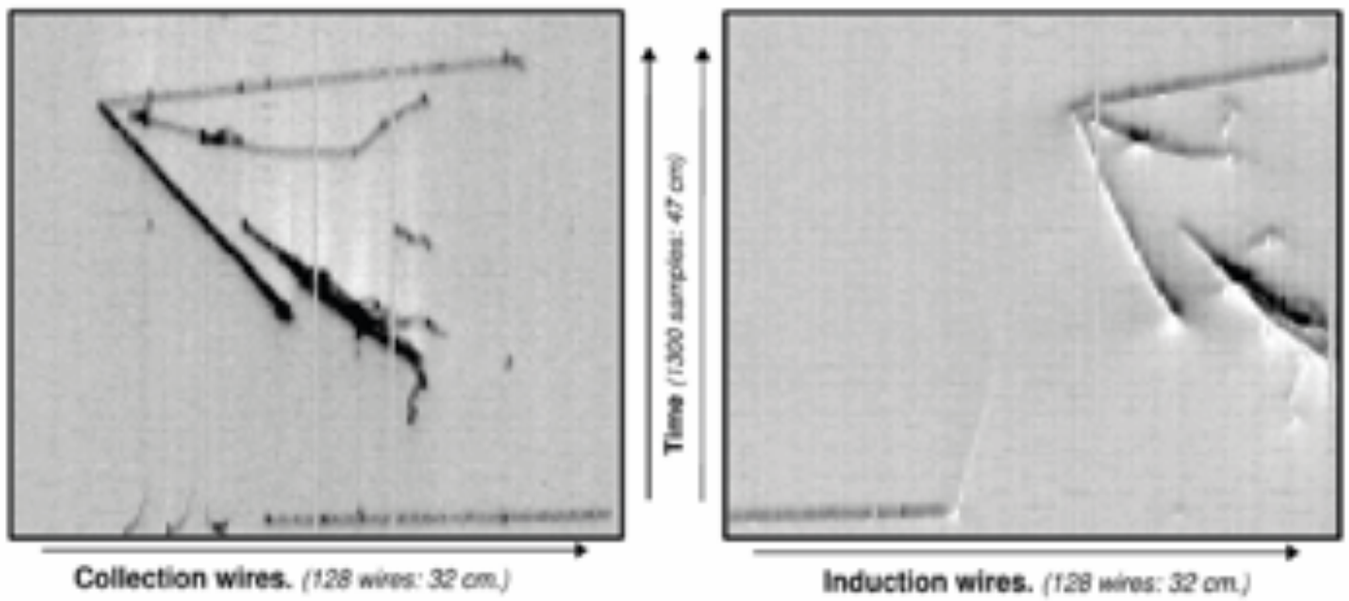
Introduction

- Neutrino experiments growing increasingly larger to achieve desired sensitivities for oscillation physics.
  - Simultaneously want to take advantage of this large detector mass to study important topics like proton decay and supernova neutrinos.
  - Detectors need to be able to accommodate all of these demands.
- Precision measurements of neutrino interaction cross-sections are of great interest also, and will help improve knowledge of neutrino oscillations.
- In this talk I will introduce the Liquid Argon Time Projection Chamber (LArTPC) technique, which is well-suited for this physics, and showing how it has been used on the ArgoNeuT project.

Liquid Argon Neutrino Detectors

- Neutrino interactions in the TPC produce charged particles that ionize the argon as they travel.
- Ionization is drifted along E-field to wireplanes, consisting of wires spaced a few millimeters apart.
- Location of wires within a plane provides position measurements...multiple planes give independent views.
- Timing of wire pulse information is combined with known drift speed to determine drift-direction coordinate.
- Scintillation light also present, can be collected by Photomultiplier Tubes and used in triggering.
- Argon is cheap (1% atmosphere), fairly dense, and a source of abundant ionization/scintillation.





Images from ICARUS* 50-liter TPC.

*Pioneering LArTPC work done by the ICARUS collaboration.

Refs:

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

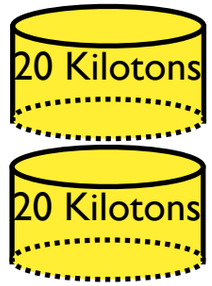
Liquid Argon Efforts at Fermilab

Development focused on scaling LArTPCs to sizes necessary for long-baseline experiment.

Materials / Electronics Test Stand

L.A.P.D.

LBNE



100% R&D

2007-

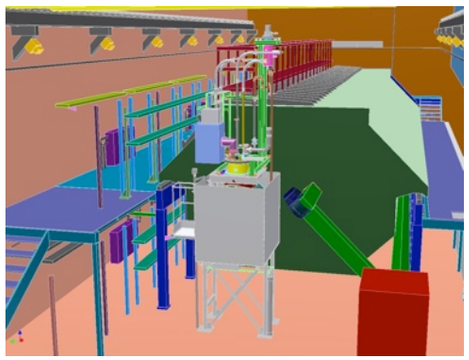
2008-

2011

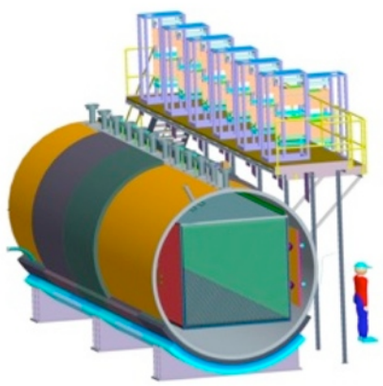
2013

20??

100% Physics



ArgoNeuT

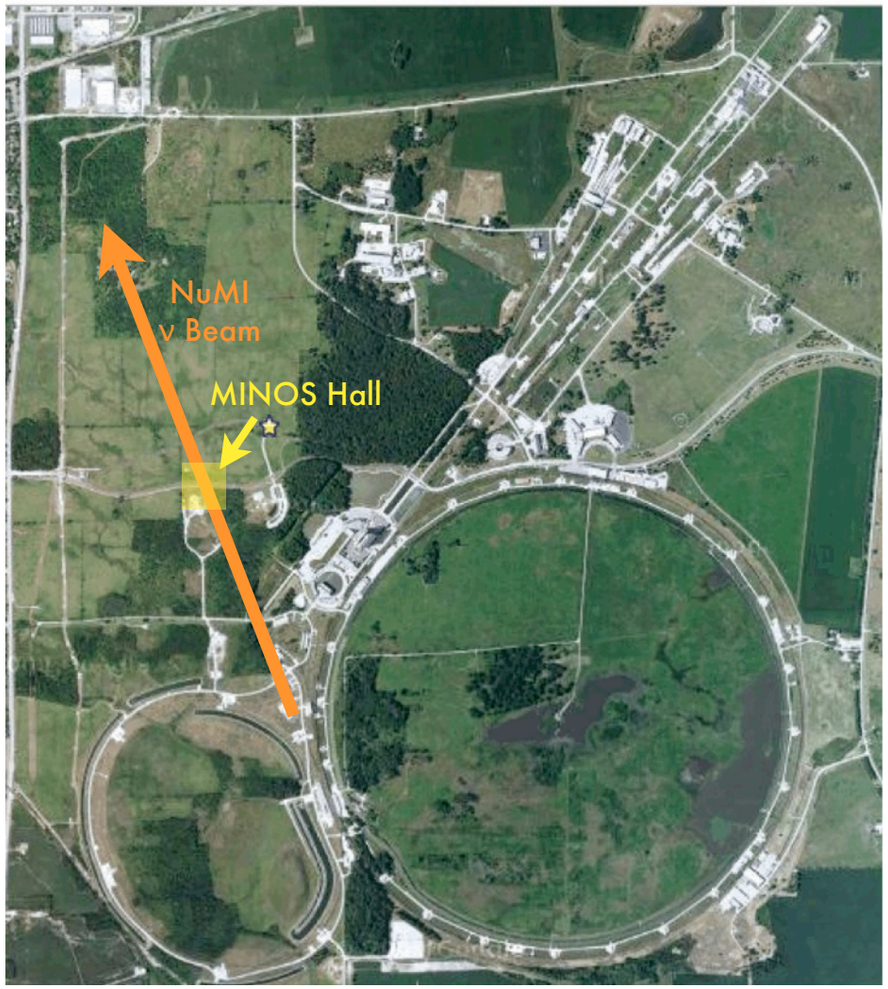


MicroBooNE

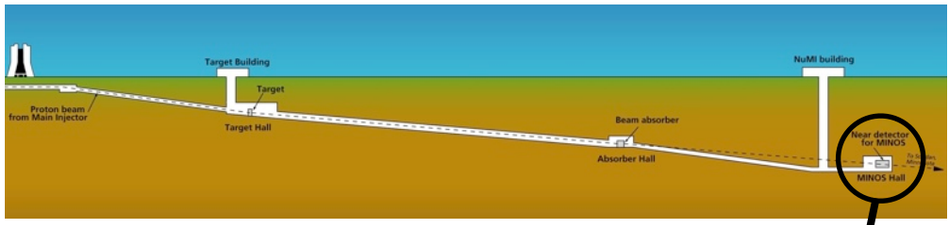
Refs:
1.) *A Regnerable Filter for Liquid Argon Purification* Curioni et al, NIM A605:306-311 (2009)
2.) *A system to test the effect of materials on electron drift lifetime in liquid argon and the effect of water* Andrews et al, NIM A608:251-258 (2009)

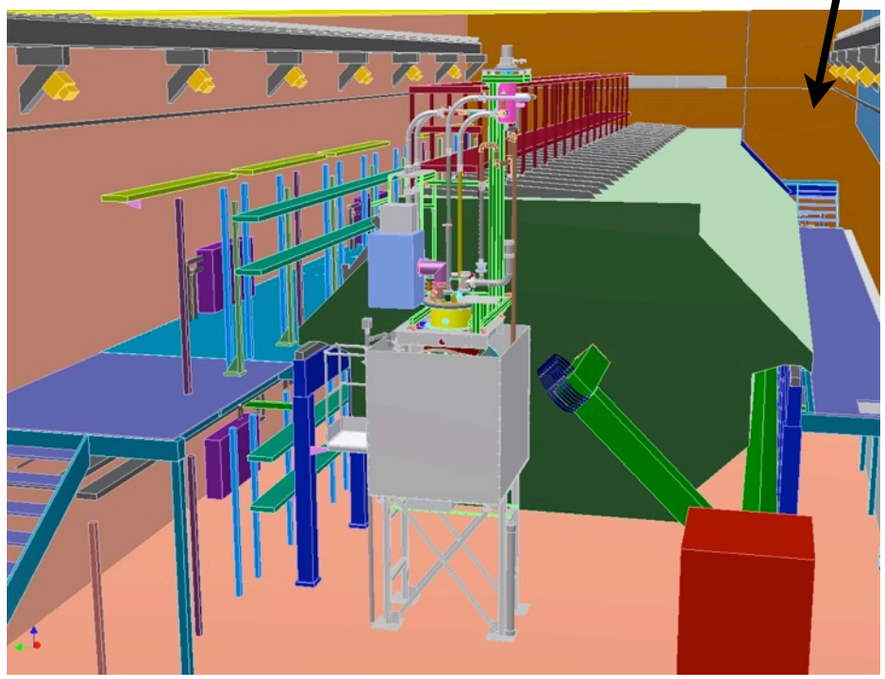
The ArgoNeuT Project

- ArgoNeuT (a.k.a. - Fermilab T962) deployed a ~175 liter LArTPC in a neutrino beam.
- Operated in NuMI beam, upstream of MINOS near detector (to aid in muon reconstruction).
- ArgoNeuT Goals:
  - Gain experience building/running LArTPCs.
  - Accumulate neutrino/antineutrino events (1st time in the U.S., 1st time ever in a low-E beam).
  - Develop simulation/reconstruction tools for LArTPCs and make comparisons with data.



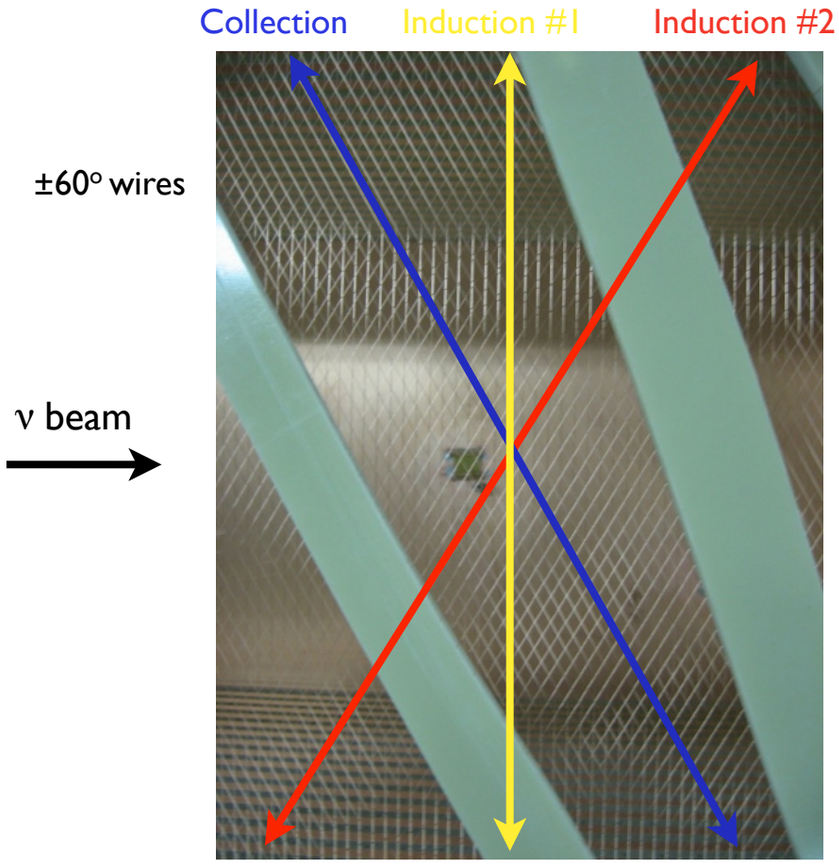
NuMI Beam at Fermilab



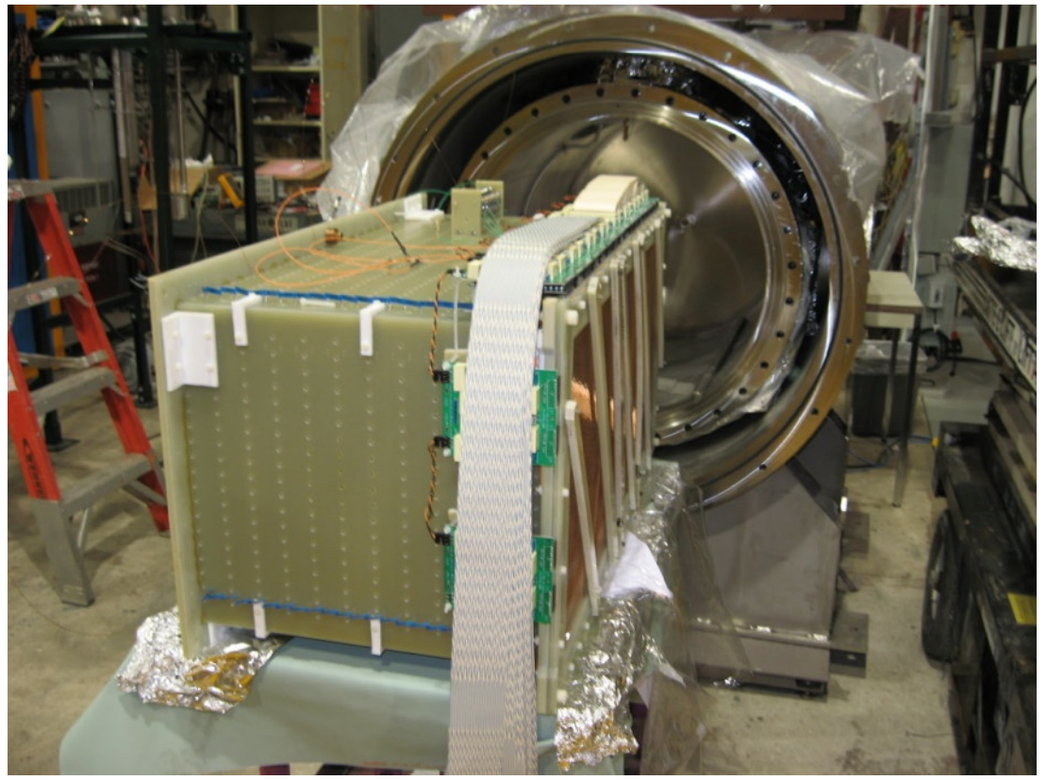


MINOS Hall at Fermilab

ArgoNeuT Detector Details



Wire Orientations

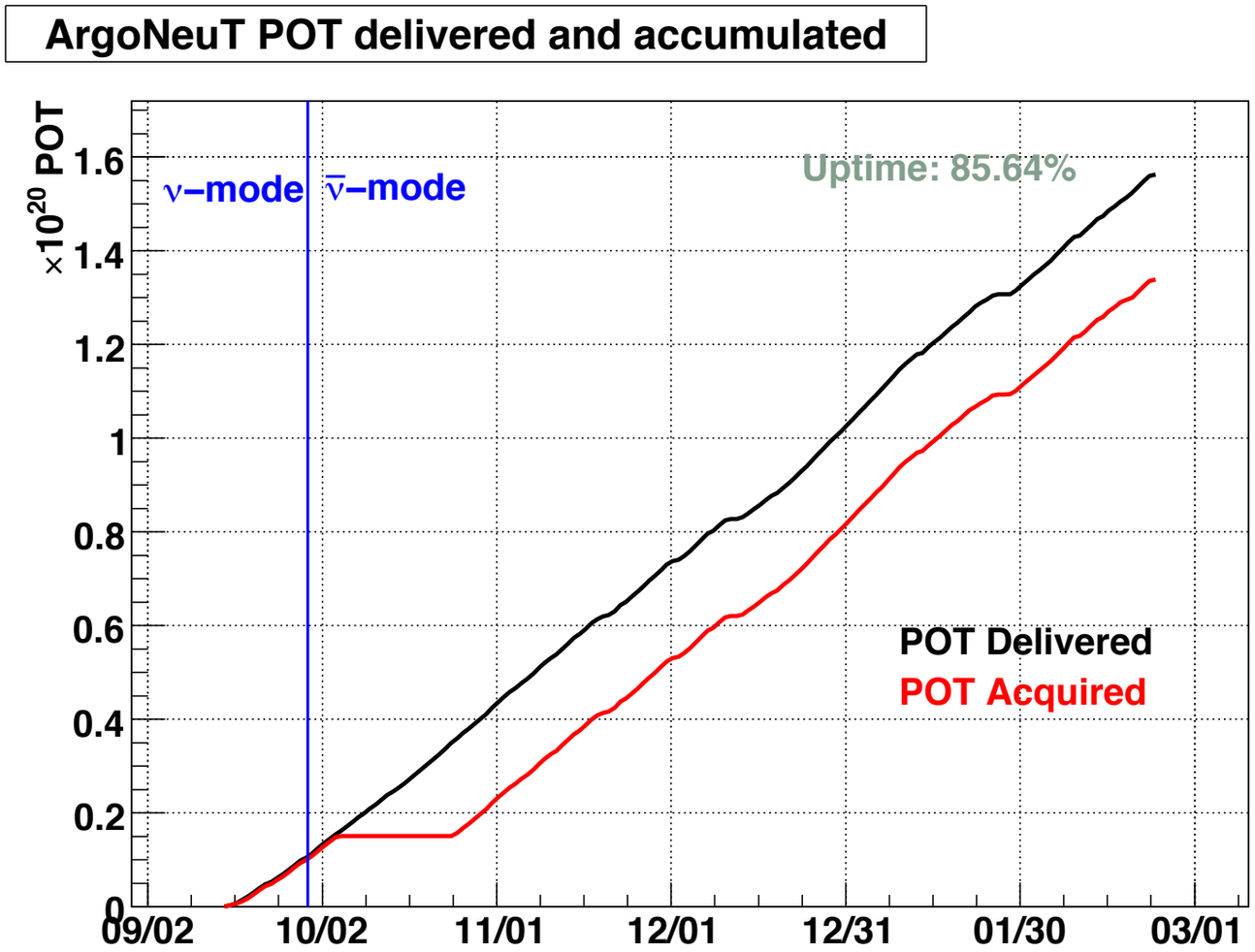


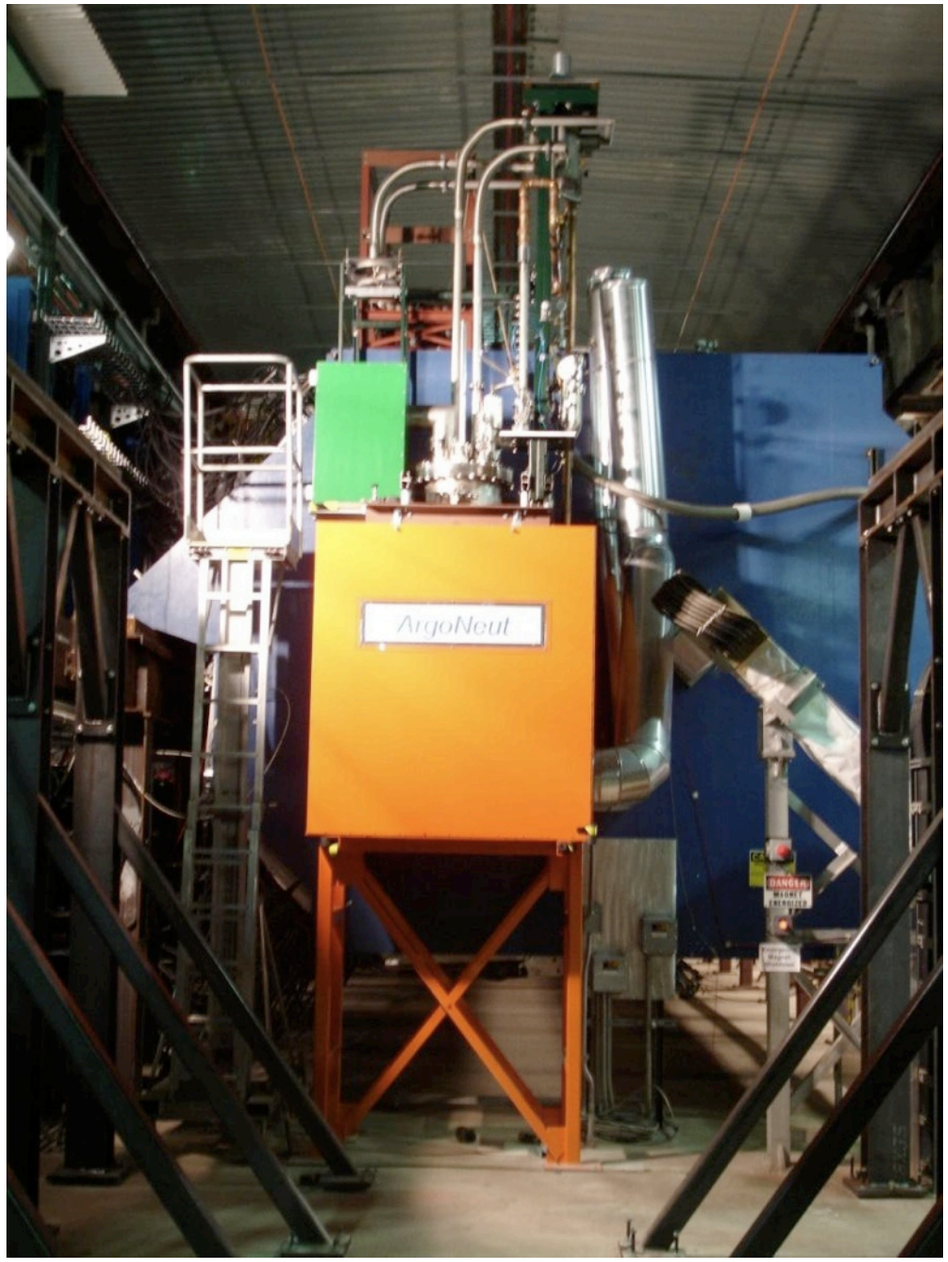
TPC outside cryostat

Cryostat Volume	500 Liters
TPC Volume	175 Liters
# 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 Beamline

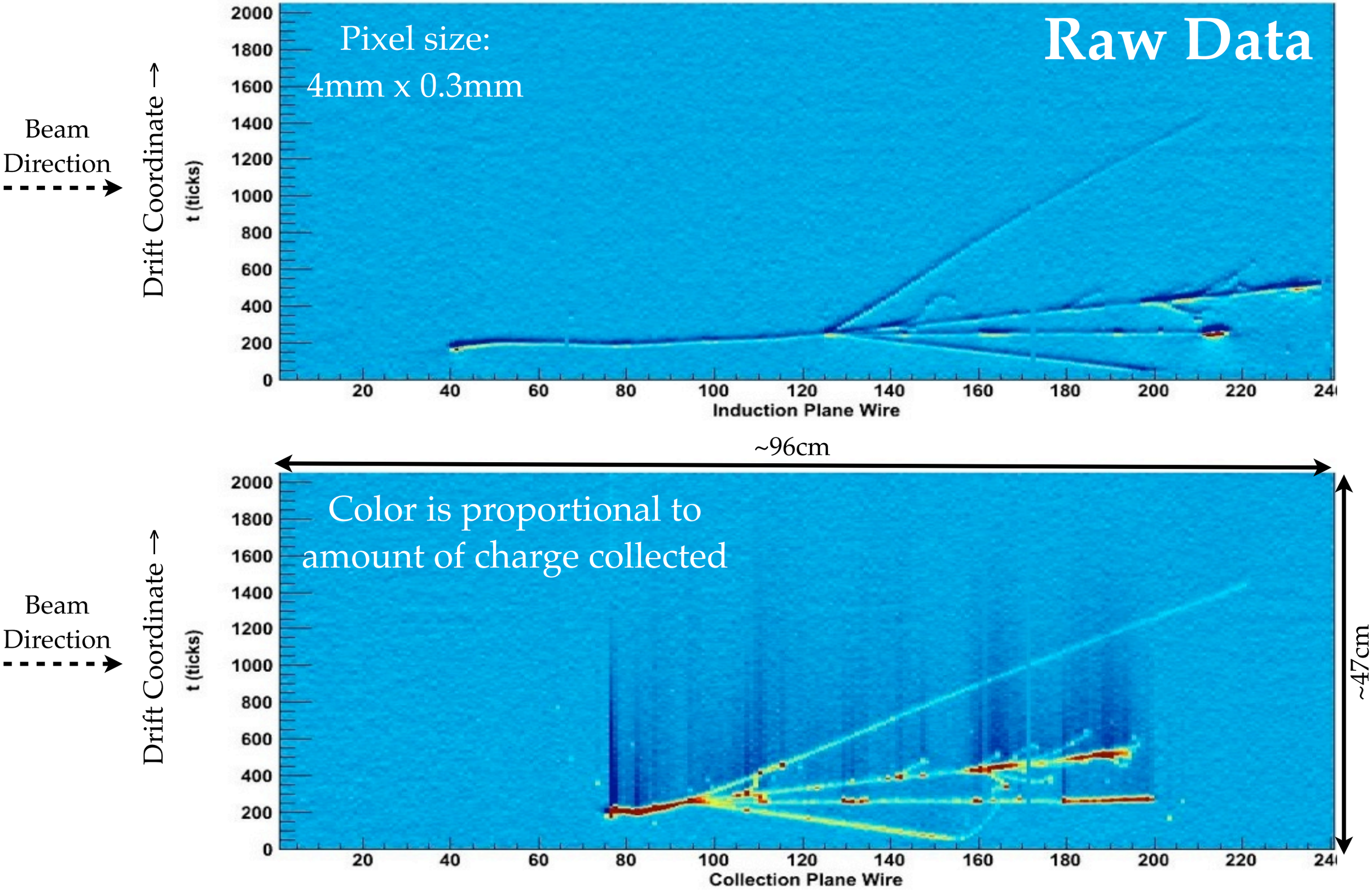
- Physics run lasted from Sept. 2009 through Feb. 22, 2010, mostly in antineutrino mode.
- Accumulated 1.35E20 Protons On Target (P.O.T.).
- Now focusing on developing tools to analyze data and extract physics results.



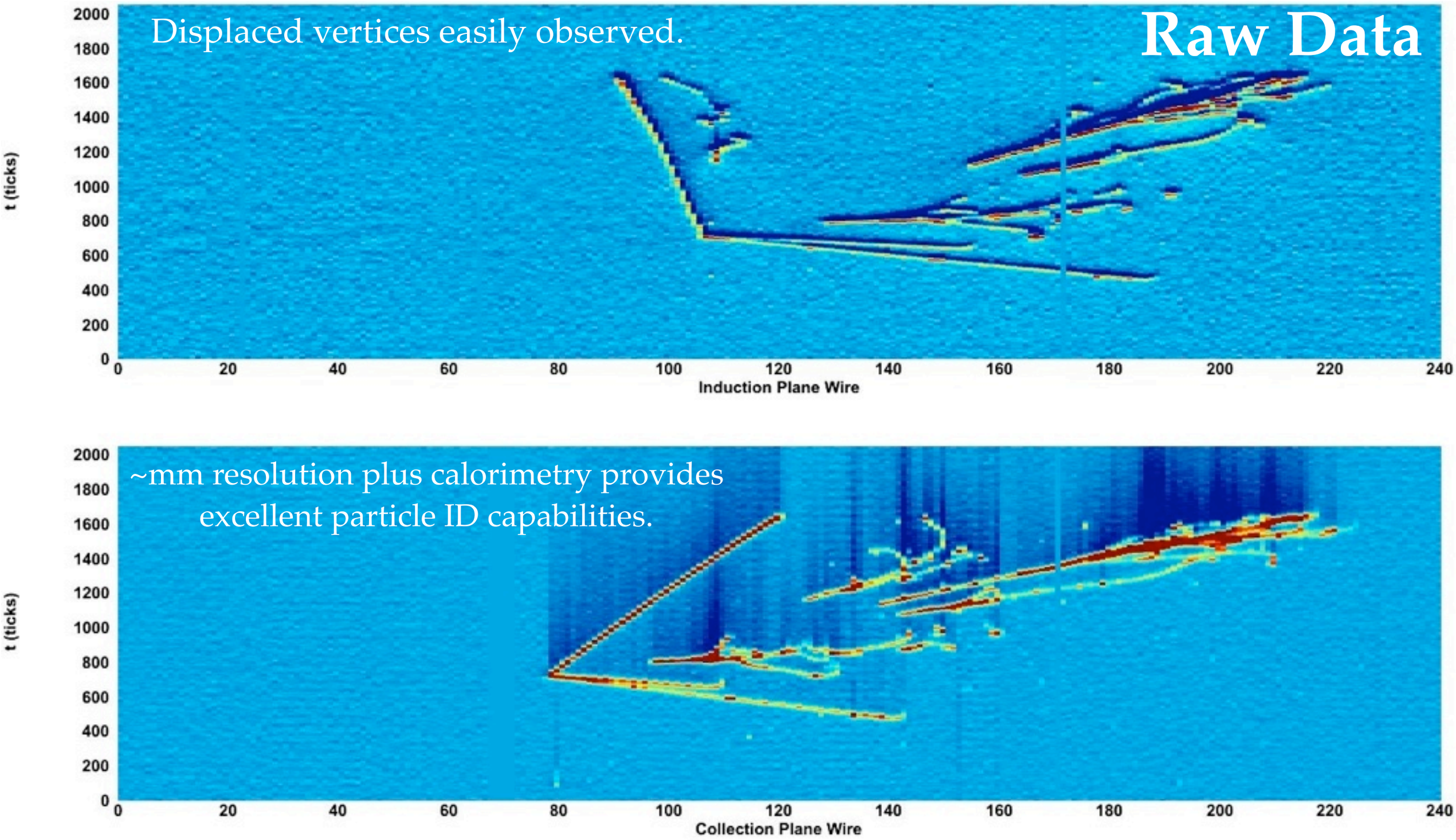


ArgoNeuT in the MINOS Hall

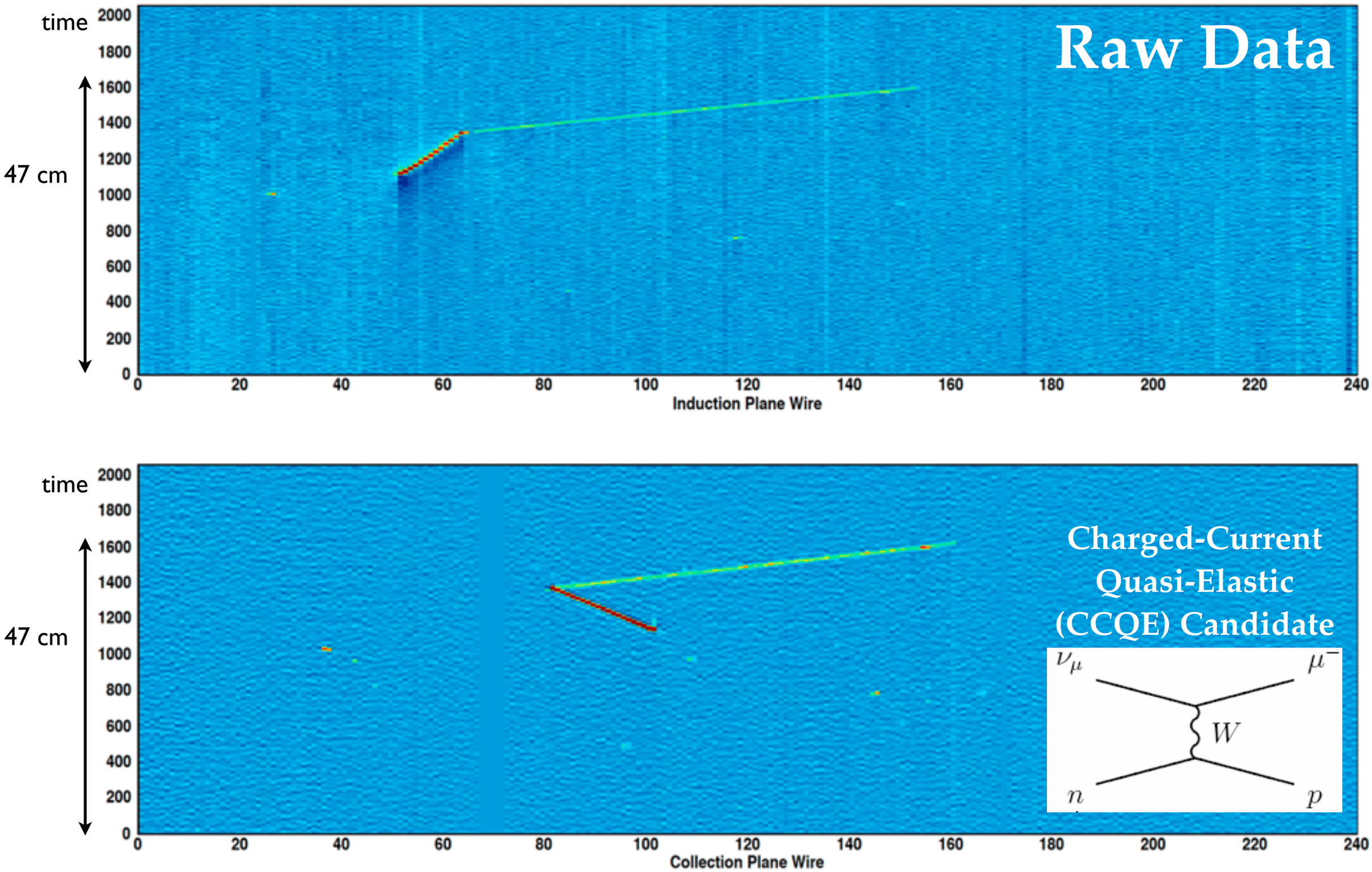
ArgoNeuT Event



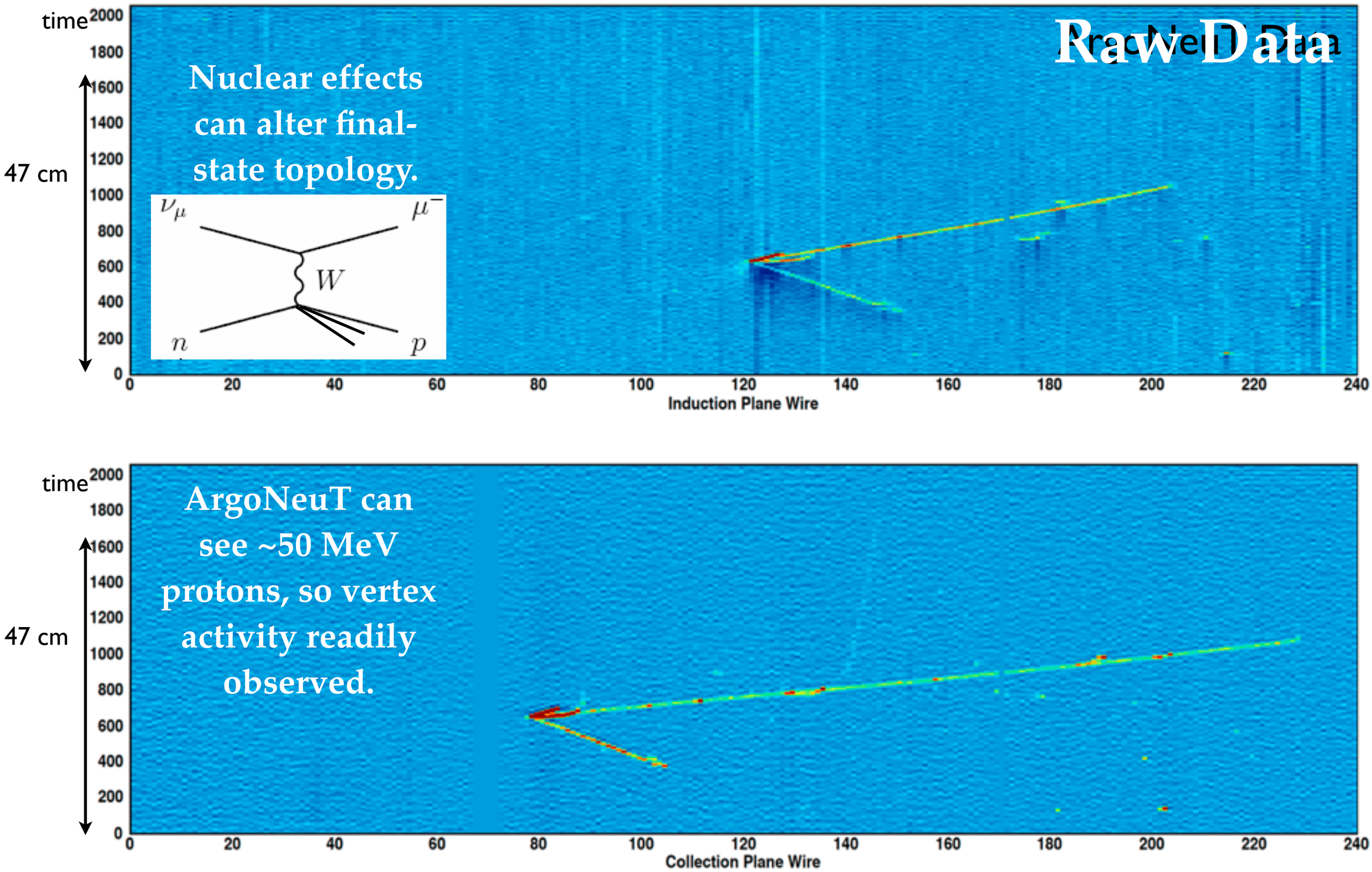
ArgoNeuT Event



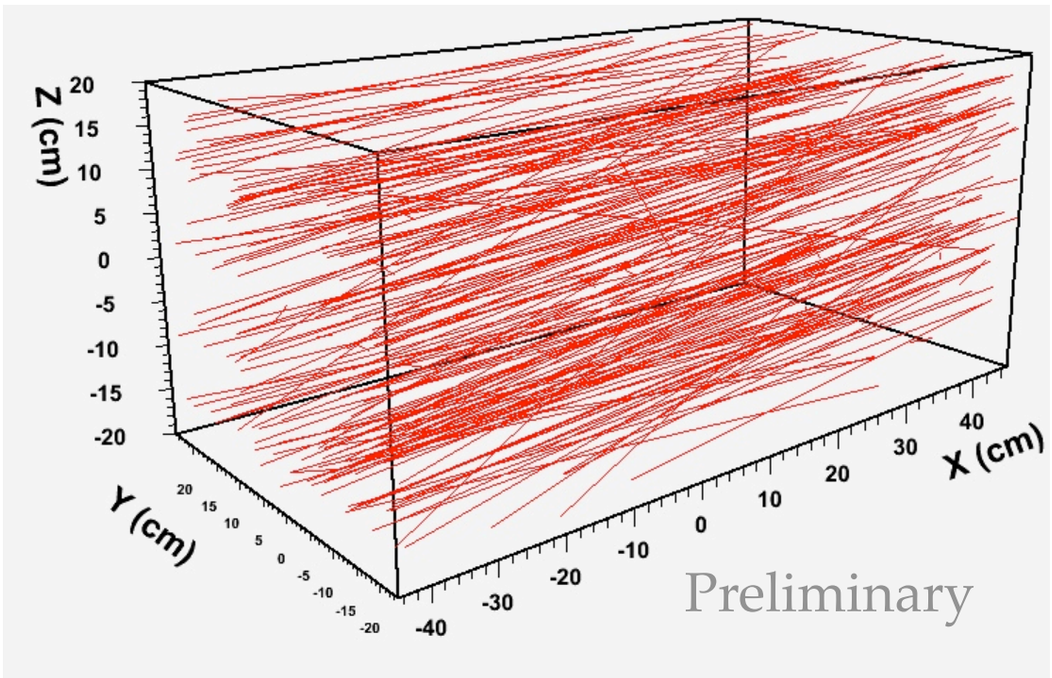
ArgoNeuT Event



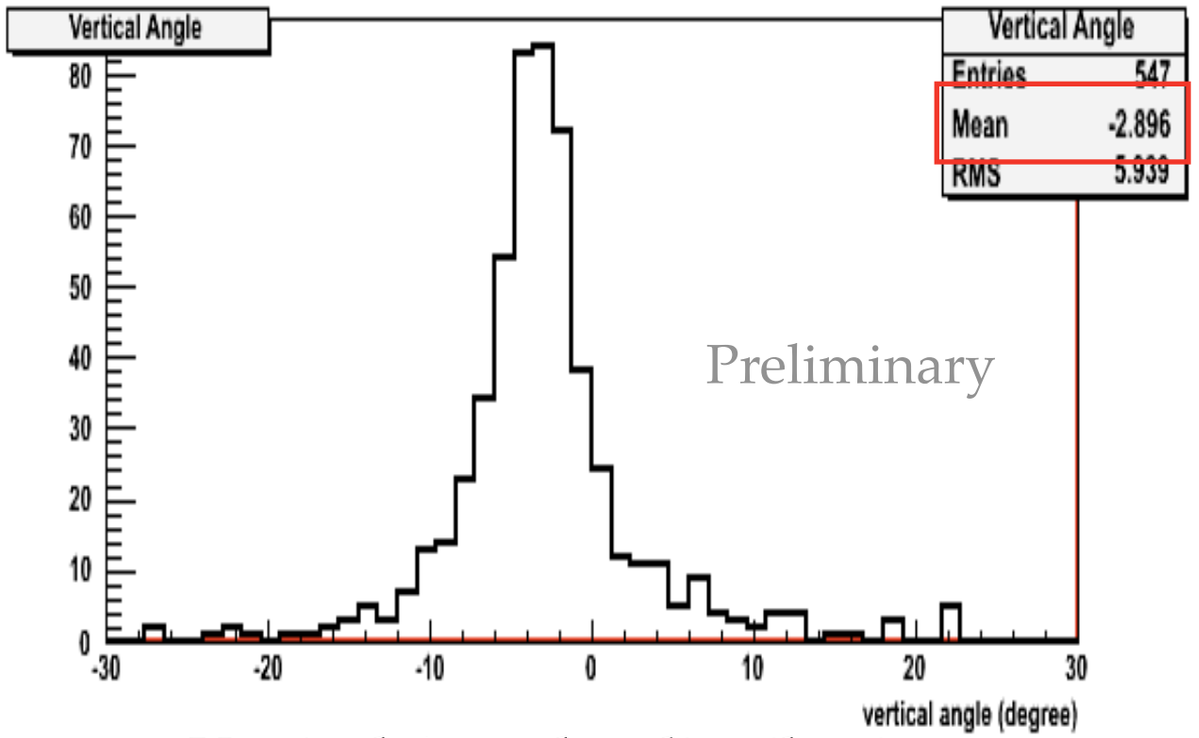
ArgoNeuT Event



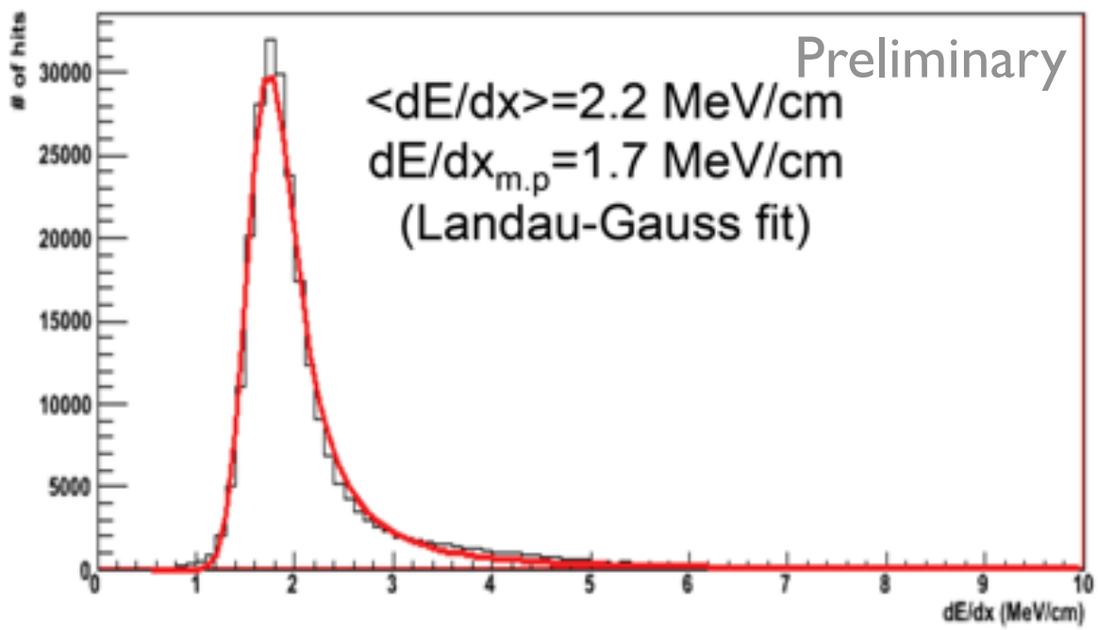
LArTPC Reconstruction: Muons



3D Reconstructed muons from a few hours of running.

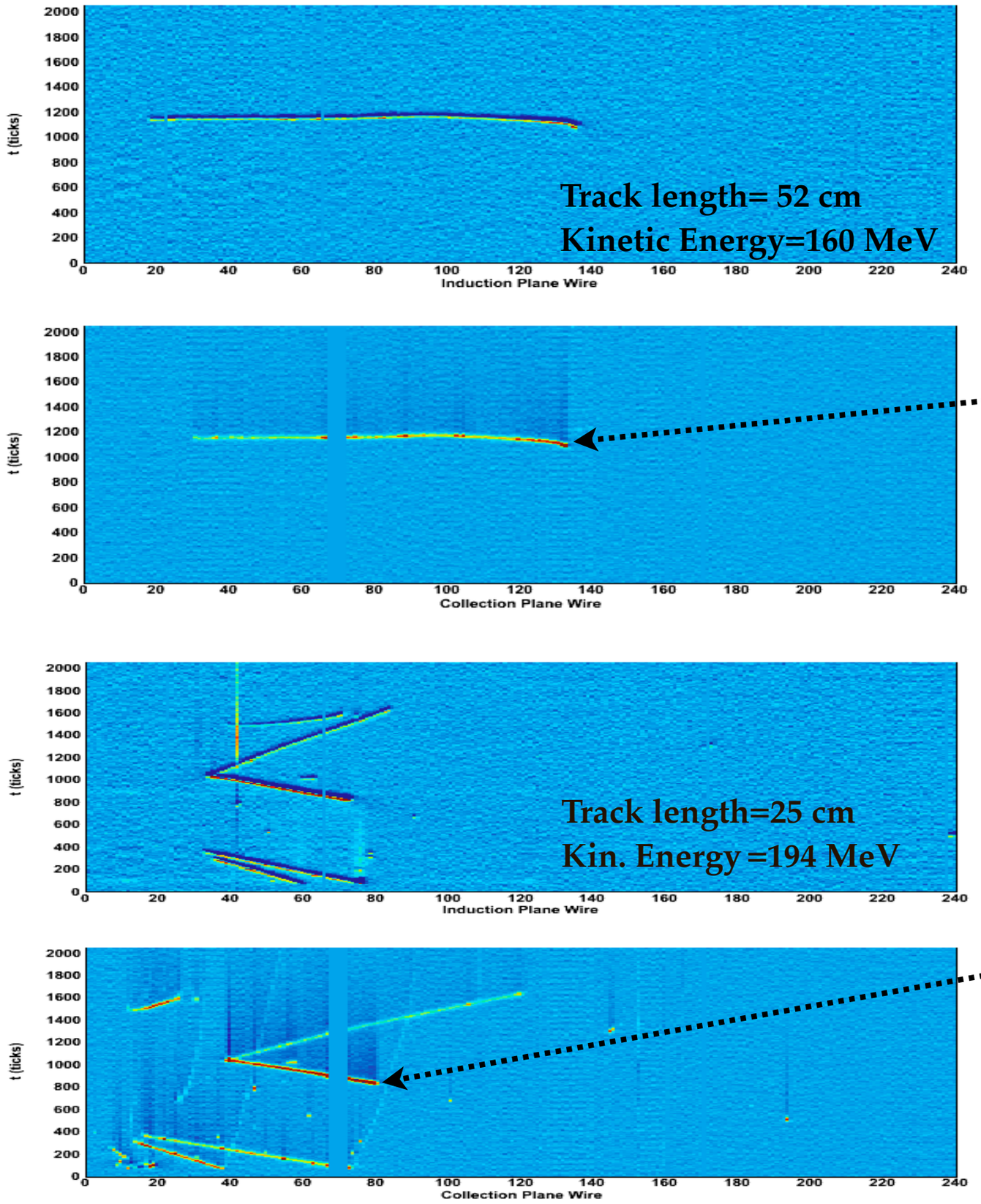


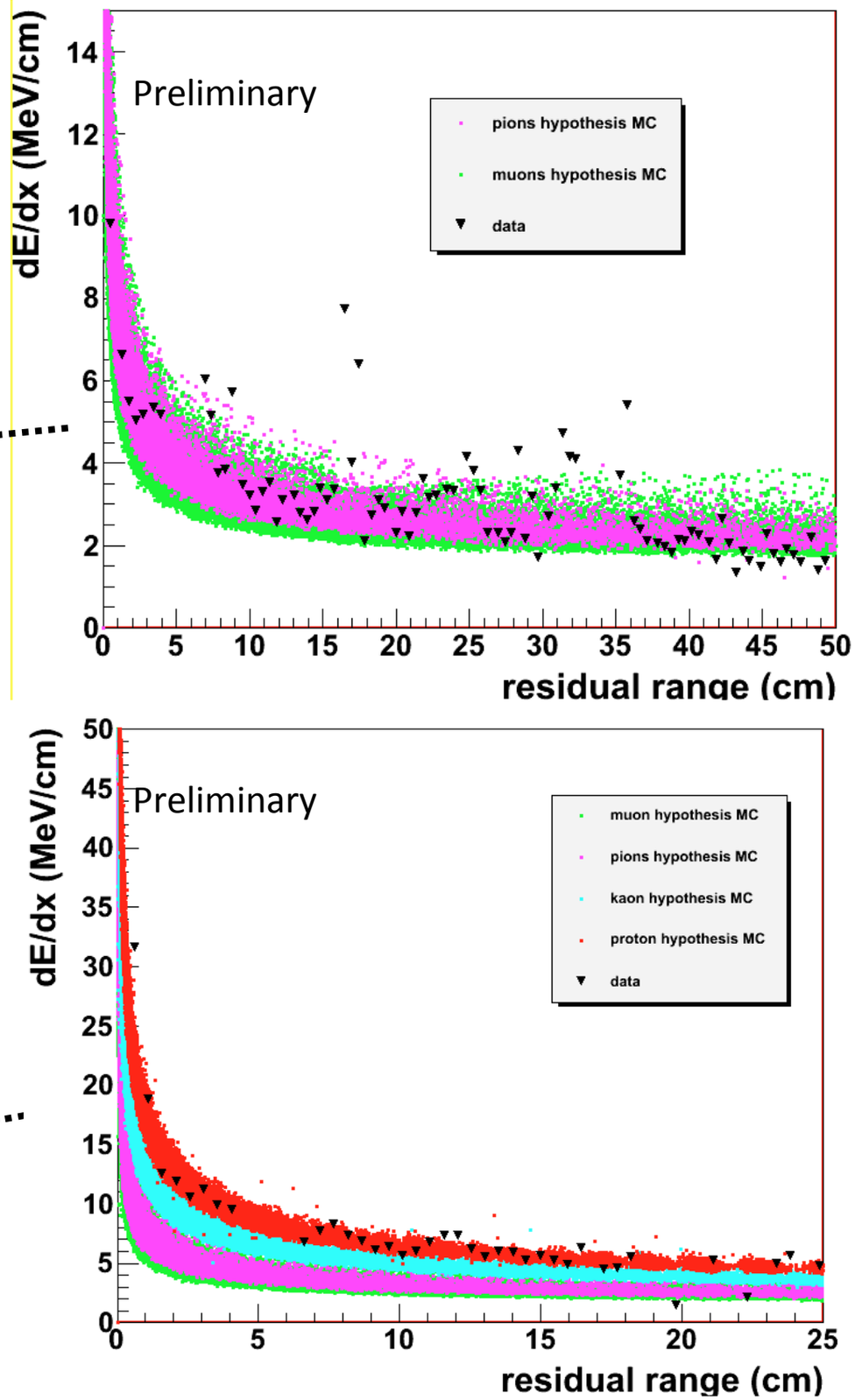
Vertical Angular distribution... NuMI Beam is at -3º



dE/dx distribution for muons.

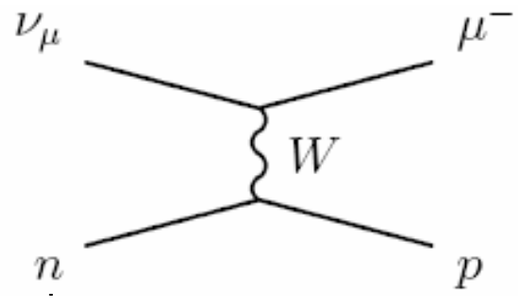
Calorimetry





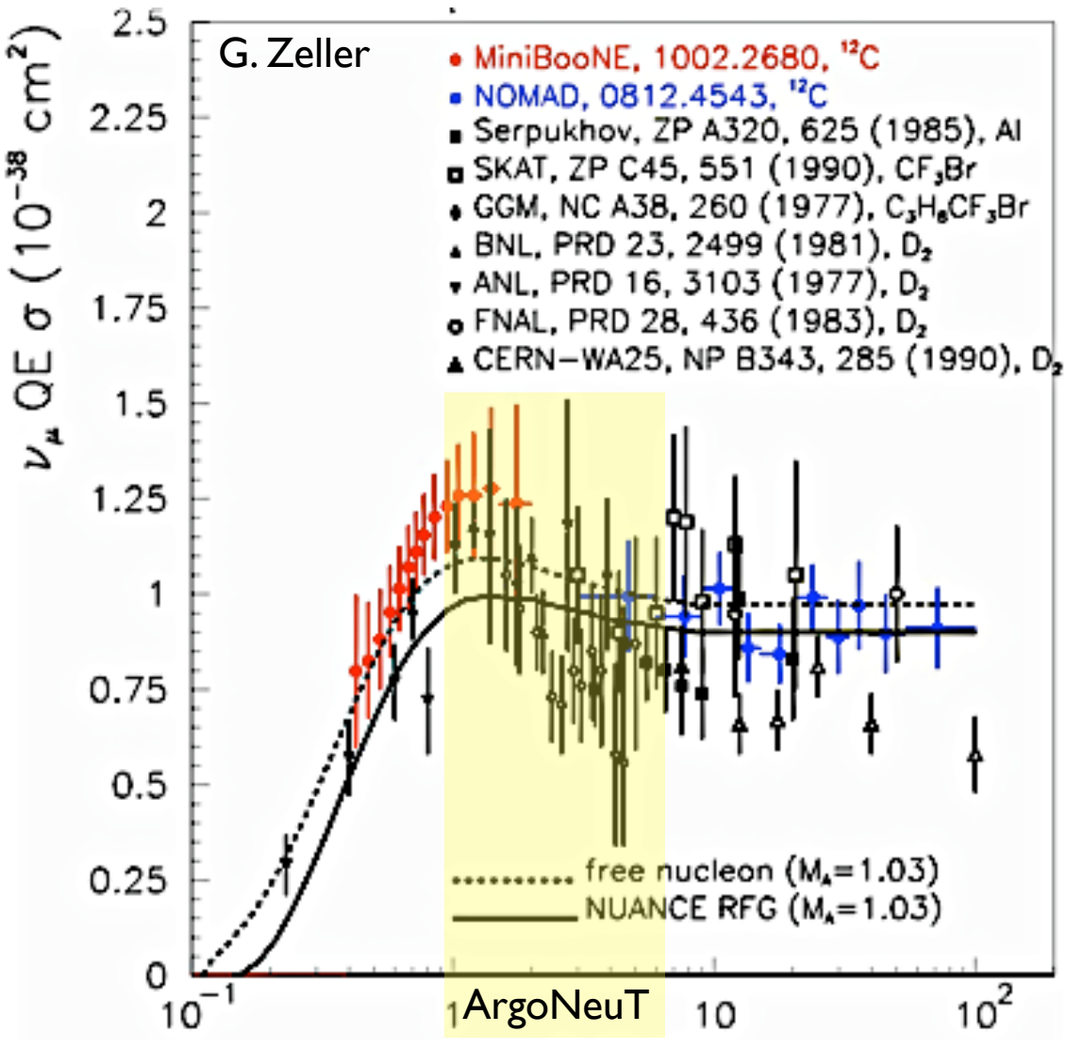
ArgoNeuT Physics Prospects

- CCQE interaction is the "golden channel" for GeV-scale neutrino oscillation experiments.
- CCQE cross-section uncertainty over most of the relevant energy range is large.
  - recent MiniBooNE and NOMAD measurements differ by ~30%
  - neither detector is able to fully resolve "vertex activity" associated with CCQE events, so definition of "CCQE" is ambiguous.
- Using ArgoNeuT's low-energy threshold and tracking capabilities, we will include vertex activity and measure cross-sections for CCQE-like (anti)neutrino events from 1-5 GeV



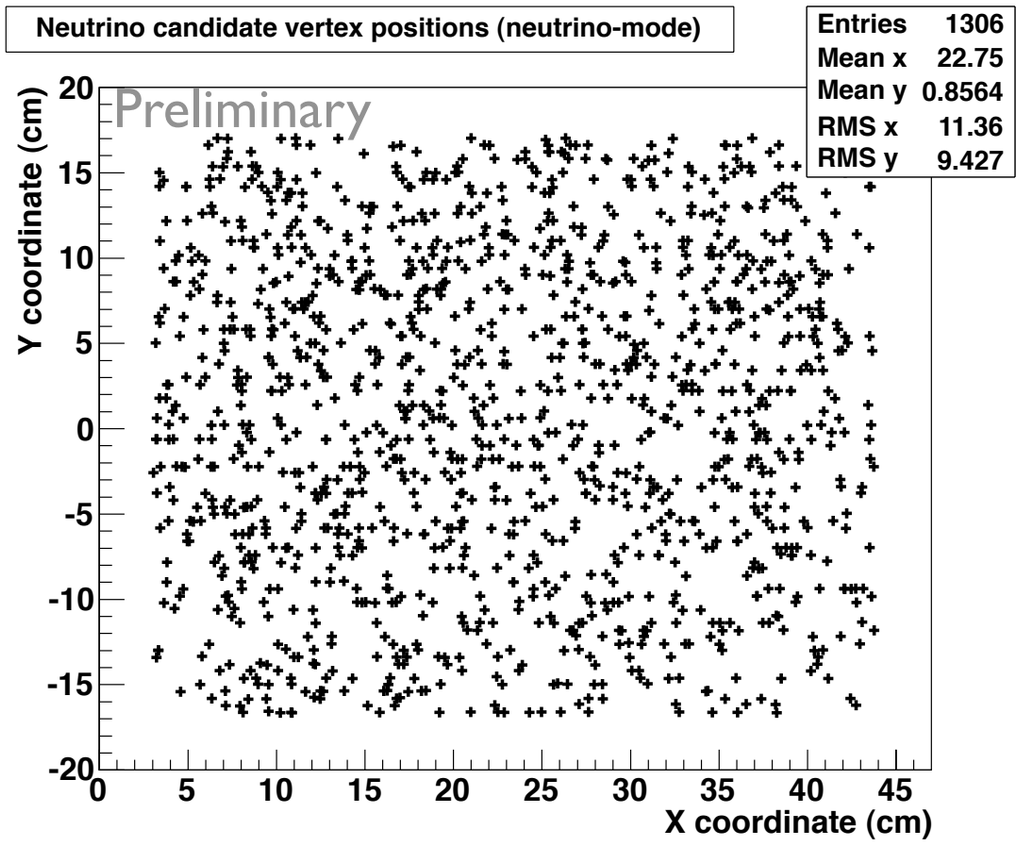
Reaction	#events in AV (~1.35E20 POT)
ν_μ CC	~6600
$\overline{\nu}_\mu$ CC	~4900
ν_μ CCQE	~600
ν_e CC	~130

Expected event sample in ArgoNeuT

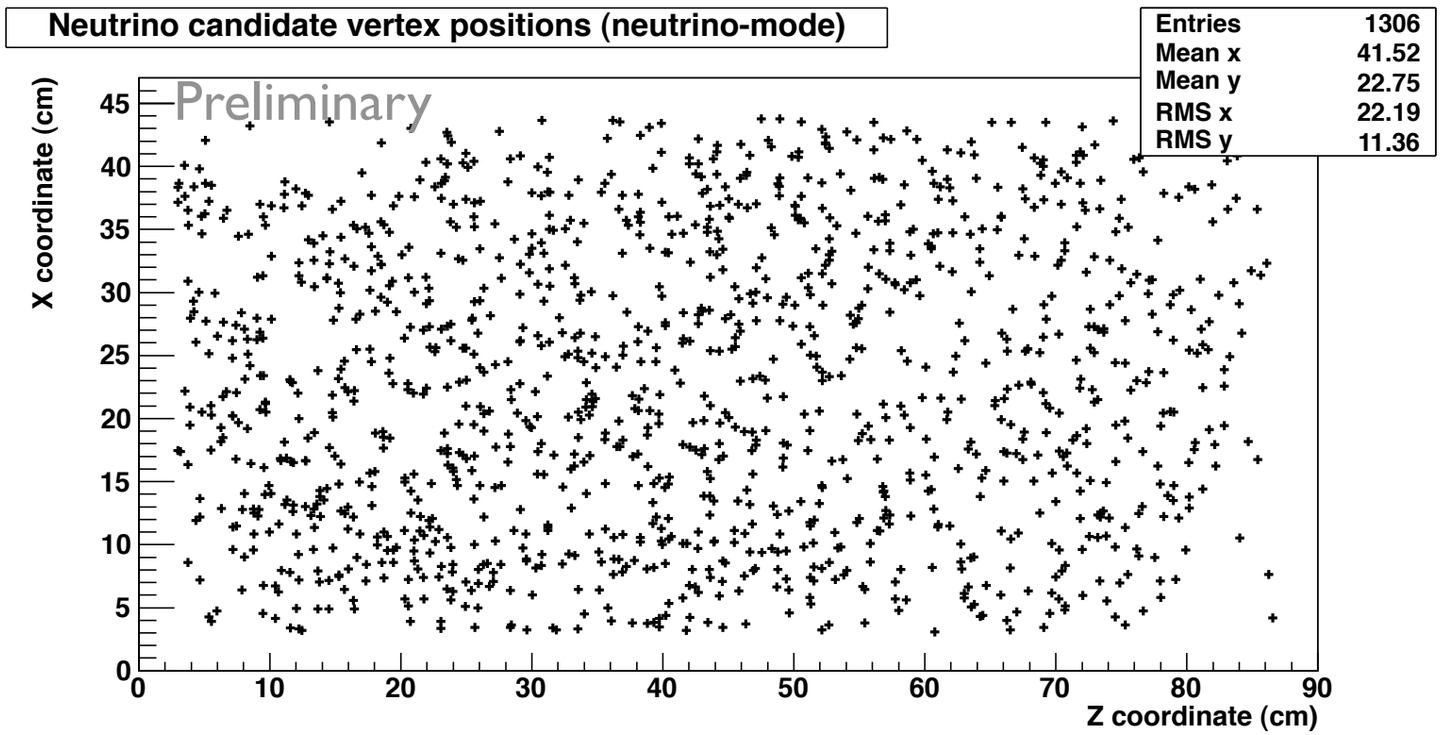


ArgoNeuT Physics Prospects

- Current focus is on analyzing the ~2 weeks of neutrino-mode data.
- Combination of software and human scanning has been performed to identify "Neutrino" and "Maybe Neutrino" events.
- Using the "Neutrino" sample, we can use 3D reconstruction and calorimetry to select events with 2 tracks (one proton, one muon), consistent with CCQE-like signature.
- Using MINOS information we can separate this CCQE-like sample by muon charge.



Beam View



Top View

Conclusions

- LArTPC is very attractive technology for neutrino physics due to combination of scalability and precision tracking/calorimetry.
- ArgoNeuT is a 175-liter LArTPC that ran in the NuMI beam at Fermilab.
- Currently developing software tools (which will be reused by MicroBooNE/LBNE) to perform complete analysis of data.
- **Expect first results analyzing charged-current quasi-elastic like events later this year.**