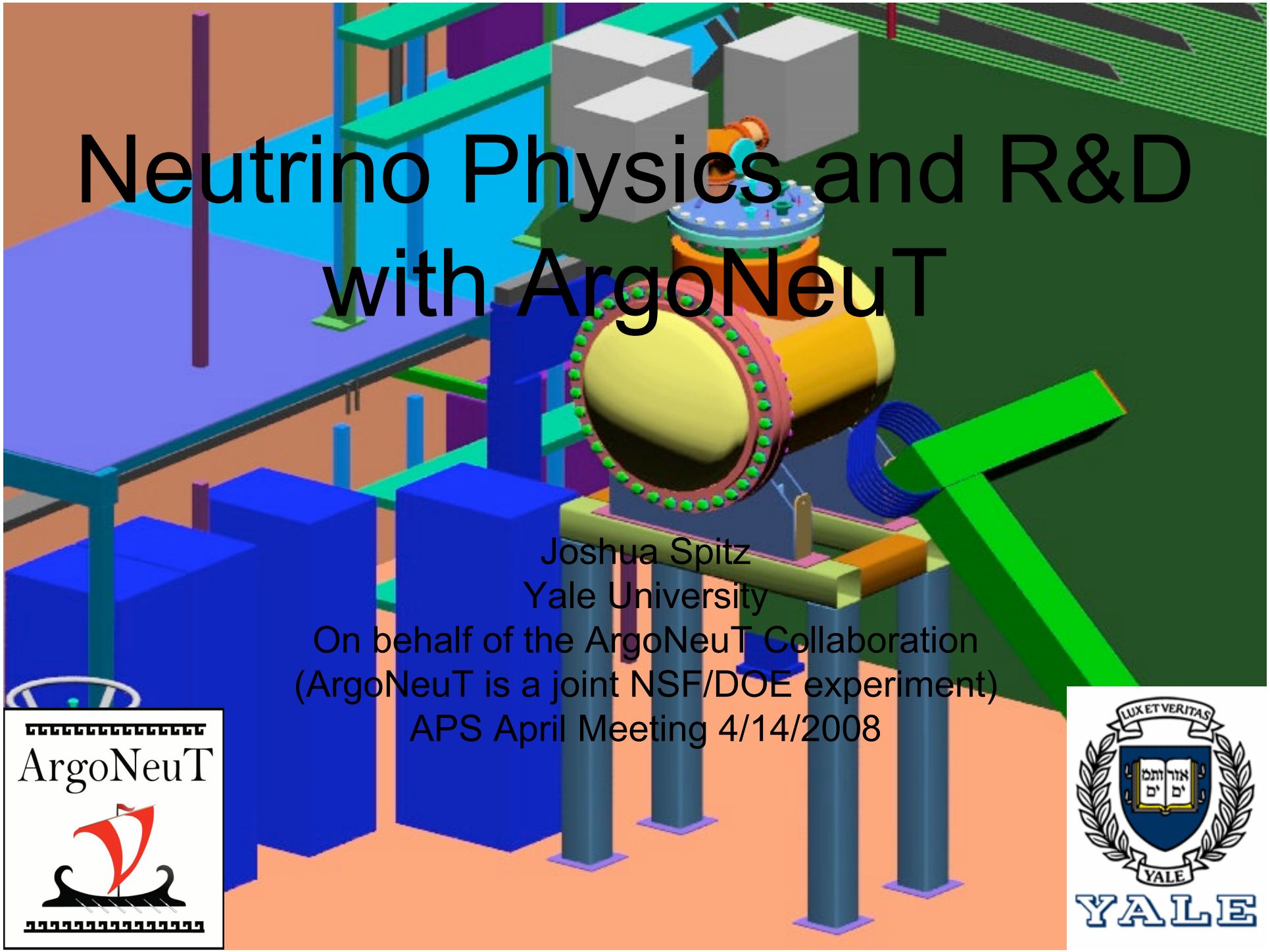
Neutrino Physics and R&D with ArgoNeuT



Joshua Spitz
Yale University
On behalf of the ArgoNeuT Collaboration
(ArgoNeuT is a joint NSF/DOE experiment)
APS April Meeting 4/14/2008

ArgoNeuT

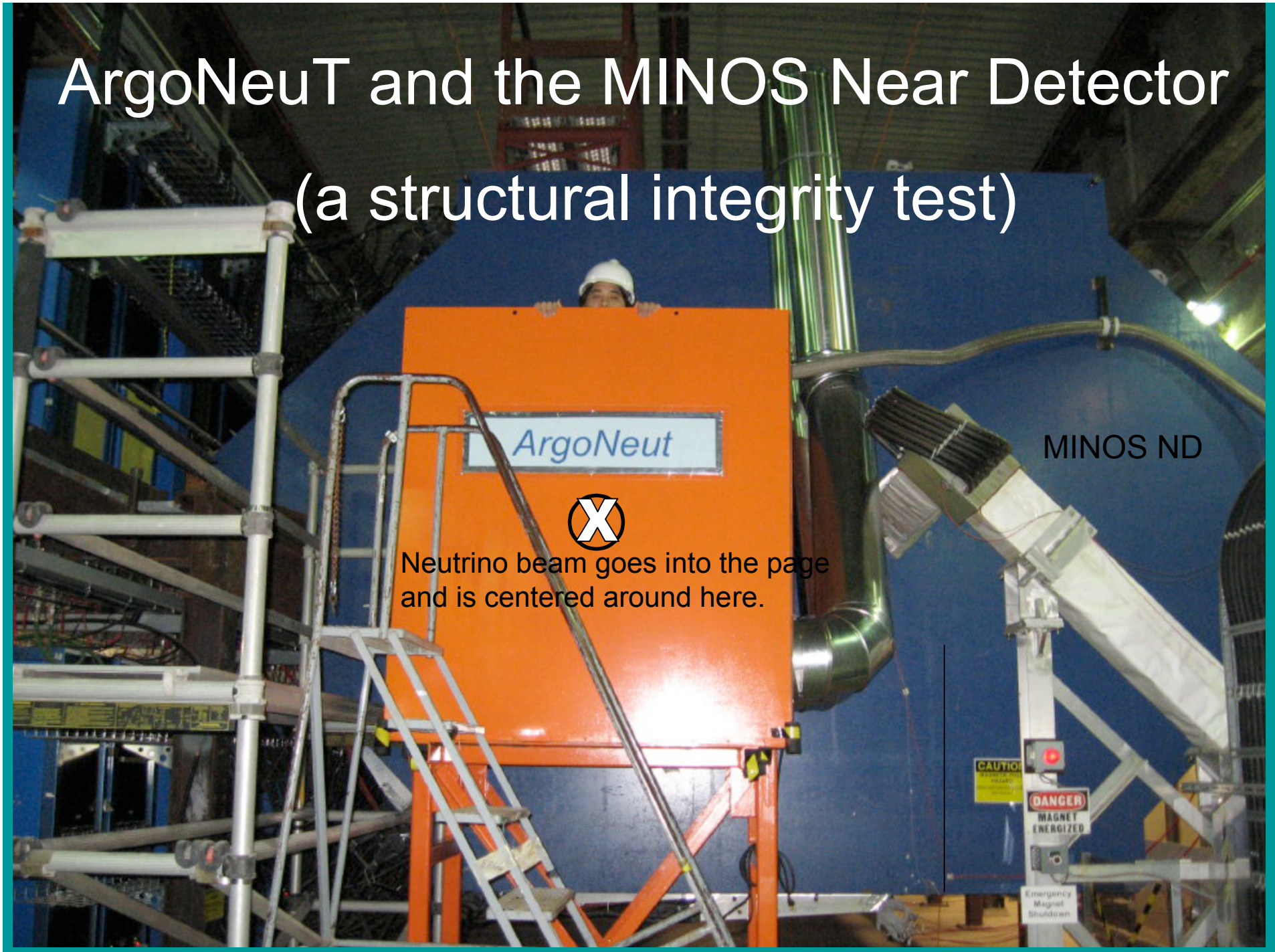
YALE

Overview of the Experiment

- ArgoNeuT is the first Liquid Argon TPC (LArTPC) to go in a "low energy" neutrino beam (NuMI on-axis, peaking at ~3GeV). The first neutrino events are expected quite soon.
- We will see ~45000 neutrino events in the 170L TPC in ~180 days (Phase 1) of running.
  - In Phase 2, ArgoNeuT (w/ PMT) will move in front of MINERvA and run for xxx days.
- Goals:
  - Research and Design for future LArTPCs (MicroBooNE, long baseline neutrino oscillation, proton decay, …)
    - Argon purity, electronics, detector design and construction, etc.
    - Simulation and reconstruction framework
  - Beautiful, bubble-chamber-like event displays
  - Demonstrate particle ID (e.g. electron/gamma separation) capabilities of LArTPCs with dE/dx
  - Physics…

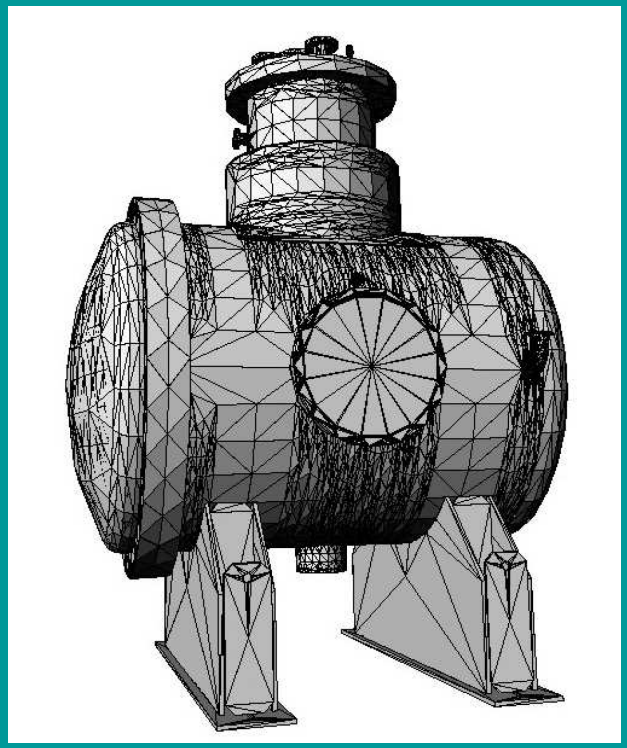
ArgoNeuT and the MINOS Near Detector

(a structural integrity test)



The Cryostat

ArgoNeuT Collaboration



F. Cavanna
University of L'Aquila

B. Baller, C. James, G. Rameika
Fermi National Accelerator Laboratory

M. Antonello, R. Dimaggio, O. Palamara
Gran Sasso National Laboratory

C. Bromberg, D. Edmunds, P. Laurens, B. Page
Michigan State University

S. Kopp, K. Lang
The University of Texas at Austin

C. Anderson, B. Fleming*, S. Linden, M. Soderberg, J. Spitz
Yale University

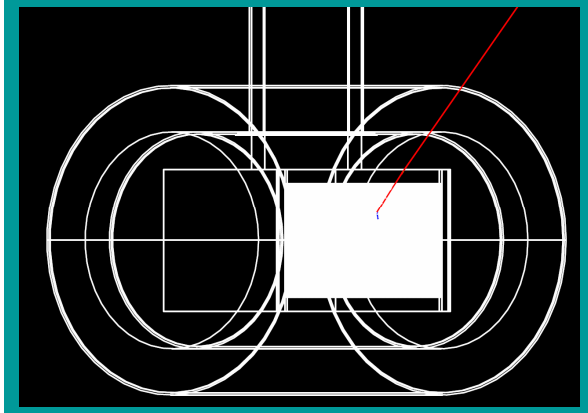
The Monte Carlo tree

gnumi near detector flux

CRY cosmic ray generator

GENIE neutrino generator (modified for LAr)

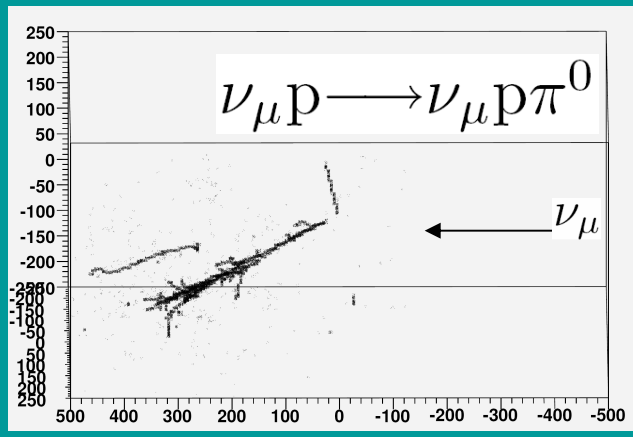
Nuance neutrino generator (modified for LAr)



Event initial conditions

e.g.

ArgoNeuT Geant4



Event

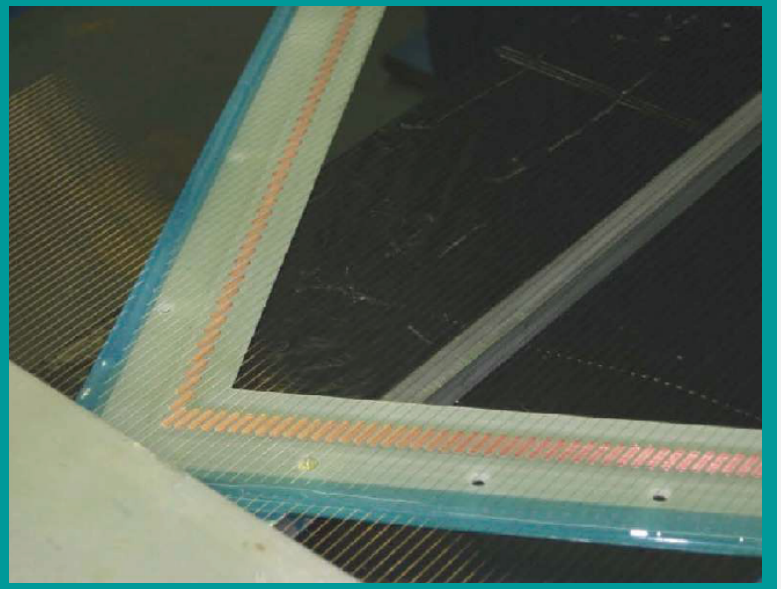
MC Steps
Interaction product info
Particle ID
Energy
Momentum vector
…

MC Truth
Initial neutrino info
Energy
Momentum vector
…

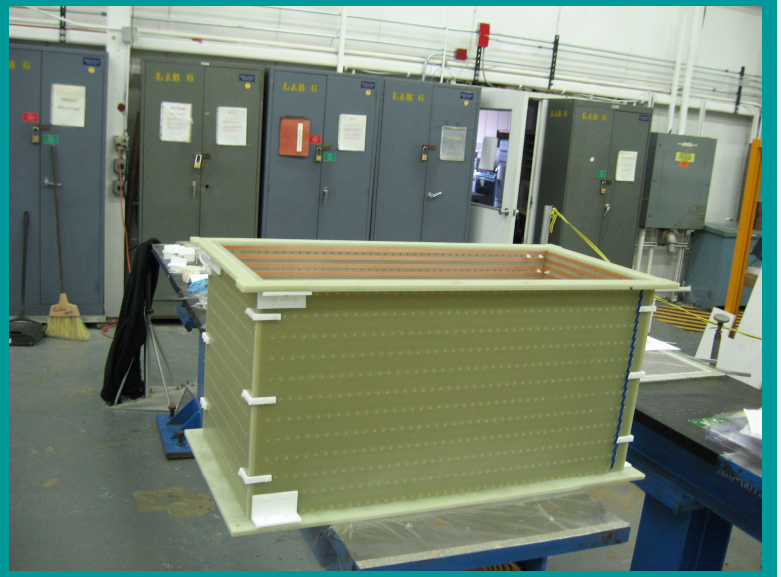
Hits->Digits->Wires
Wire # (position)
Charge (energy deposit)
Time

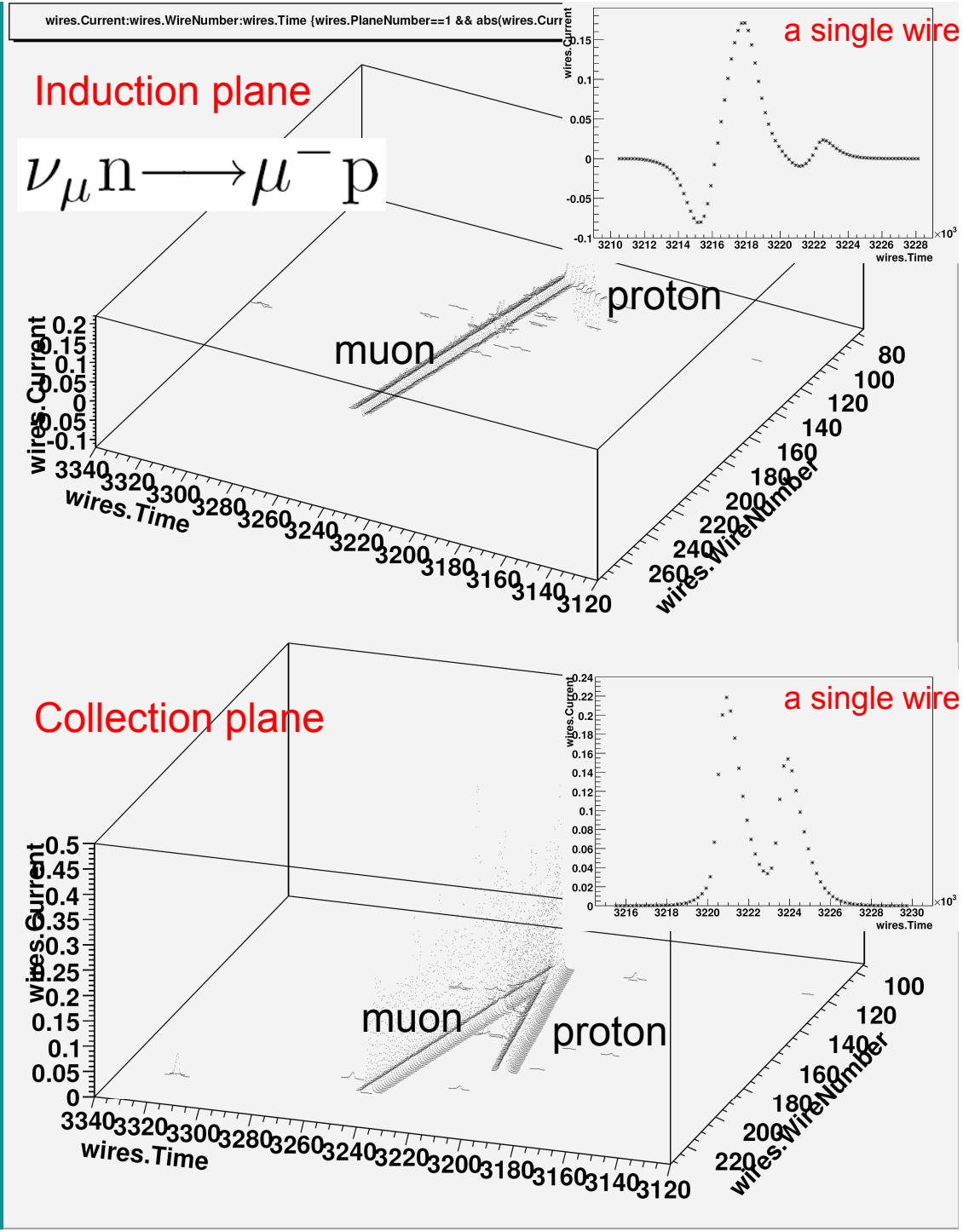
e.g.

4 mm wire spacing (240 channels/plane)



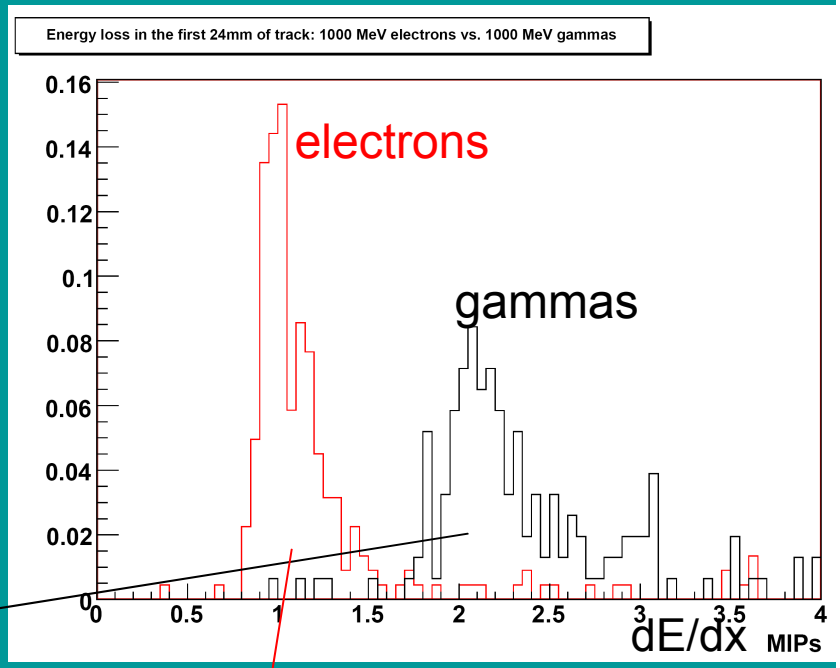
The TPC

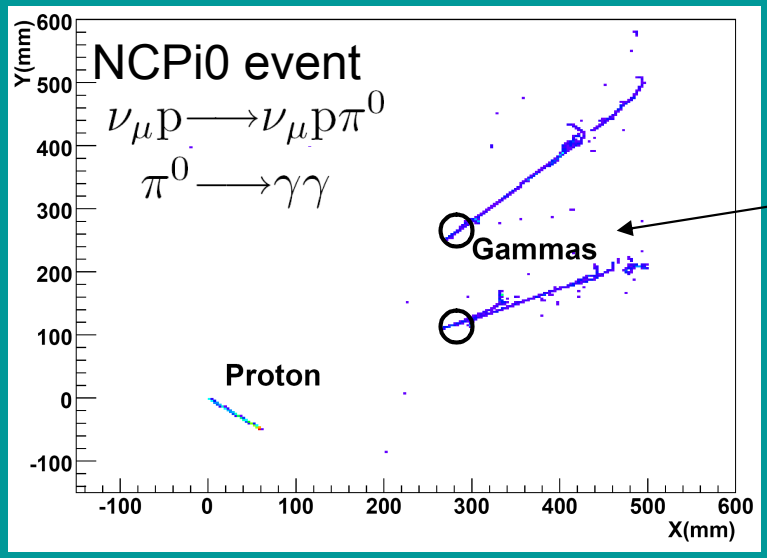


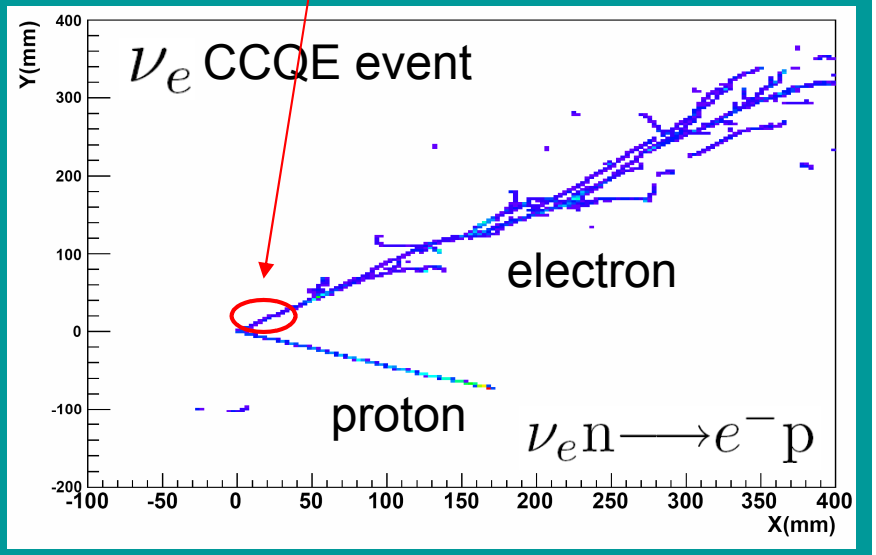


Particle tagging with dE/dx

- ArgoNeuT will demonstrate the LArTPC's ability to ID particles with dE/dx and topology.
- Monte Carlo studies indicate that LArTPCs can tag electron/gamma events with >90% efficiency.
- Extremely important for tagging ν_e
  - Backgrounds: NCPi0, radiative delta decay $\Delta \rightarrow N\gamma$





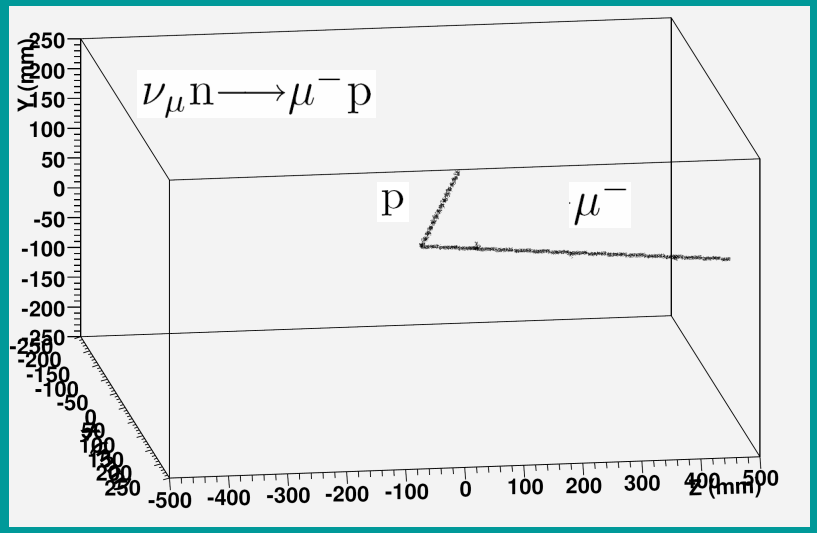


Mis-ID of an NCPi0 event (w/o dE/dx):

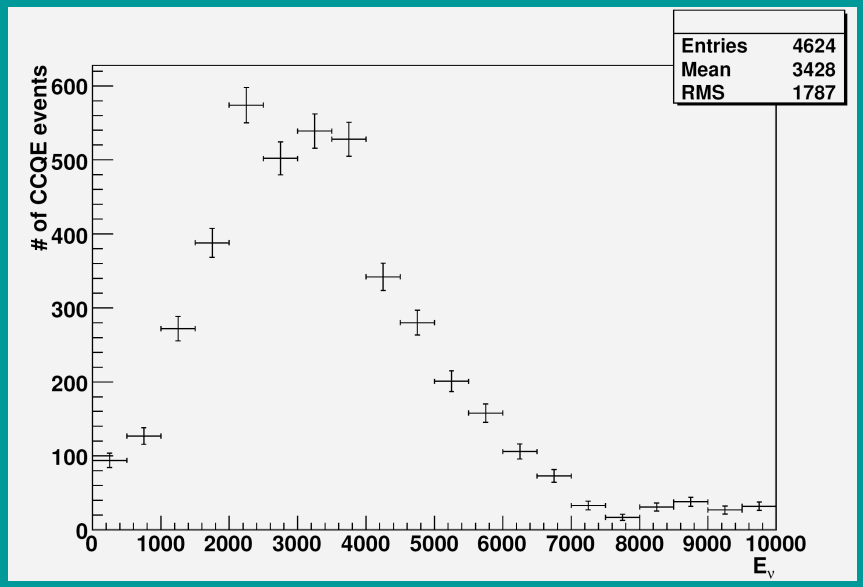
- One gamma converts outside detector
- Two gammas appear to be one track
- One gamma is absorbed by photo-nuclear interaction
- A gamma converts close to event vertex

Physics…

- Using dE/dx and LArTPC resolution, ArgoNeuT will be able to identify and separate event-types with high efficiency.
- CCQE events in ArgoNeuT may provide a measurement of the axial vector mass (M_A).
  - The main background (CC1pi+) will be tagged with high efficiency
  - We will use MINOS to catch muons and may be able to make a CCQE cross-section measurement on argon (which will help with M_A).



– Δ_s measurement?



~4600 CCQE events in 180 days of running

$$\frac{\nu p \rightarrow \nu p}{\nu_\mu n \rightarrow \mu^- p}$$ or $\nu p \longrightarrow \nu p$ cross section

~50% proton containment

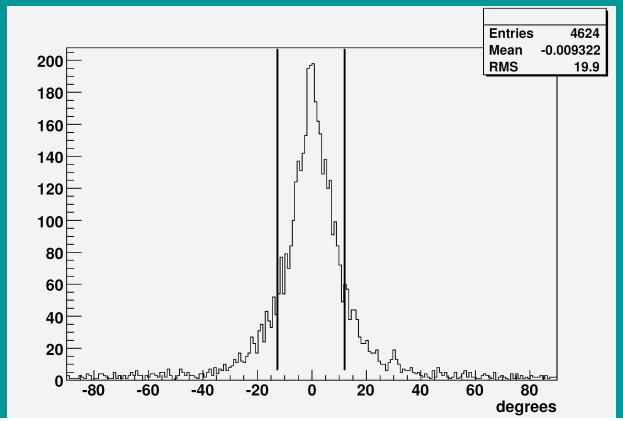
Event rates

Phase 1

Note that ArgoNeuT will move in front of MINERvA for phase 2 and run for xxx more days

Event type	# of events in 180 days	Notes
ν_μ CC	28800	
$\overline{\nu}_\mu$ CC	2520	
ν_e CC	540	Use dE/dx to tag electron
NC	9720	
$\nu_\mu n \longrightarrow \mu^- p$ (CCQE)	4680	~50% proton containment. Will use MINOS ND for muons. Cross-section? M_A?
$\nu_\mu N \longrightarrow \nu_\mu N$ (NCE)	1420	~50% proton containment. Separating neutron and proton events? Cross-section? Δ_s?
$\nu_\mu N \longrightarrow \mu^- N \pi^+$ (CCpi+)	5490	Use dE/dx and topology to tag this channel (CCQE background)
$\nu_\mu n \longrightarrow \mu^- p \pi^0$ (CCpi0)	1850	Use dE/dx and topology to tag this channel (CCQE background)
$\nu_\mu N \longrightarrow \nu_\mu N \pi^0$ (NCpi0)	1370	Low event containment (rad length in Argon is 14 cm). Use dE/dx and topology to tag gamma

Muon angle with respect to beam axis



ArgoNeuT

MINOS ND

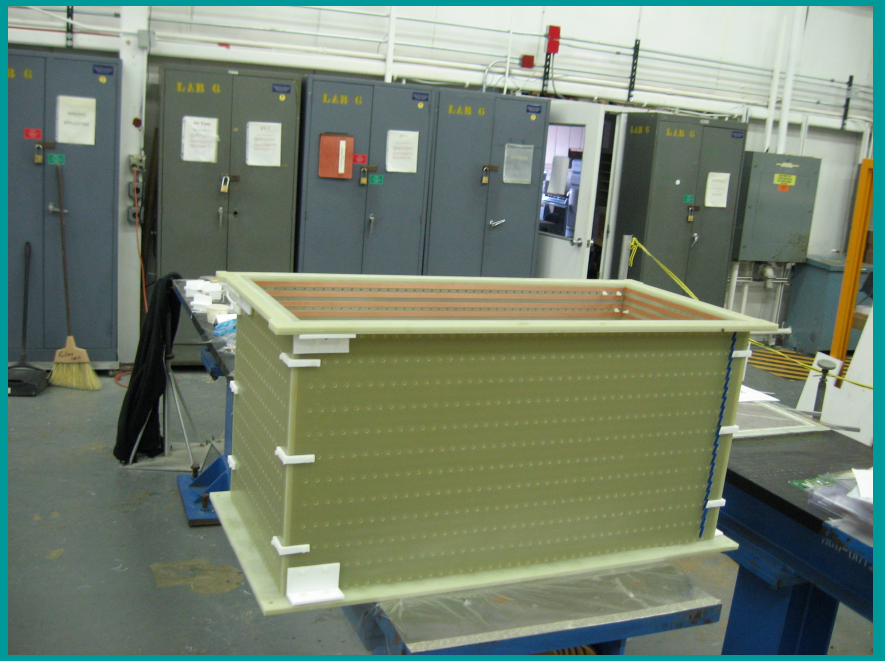
Take home

- ArgoNeuT is an R&D-oriented LArTPC that will begin taking data in the NuMI beamline soon.
- The detector will see >45000 neutrino events in a wide variety of channels.
- Measurements of CCQE and NC-elastic cross sections on LAr are possible with ArgoNeuT.
- The LArTPC's ability to image neutrino events with high resolution and tag with high efficiency (dE/dx) will be demonstrated.

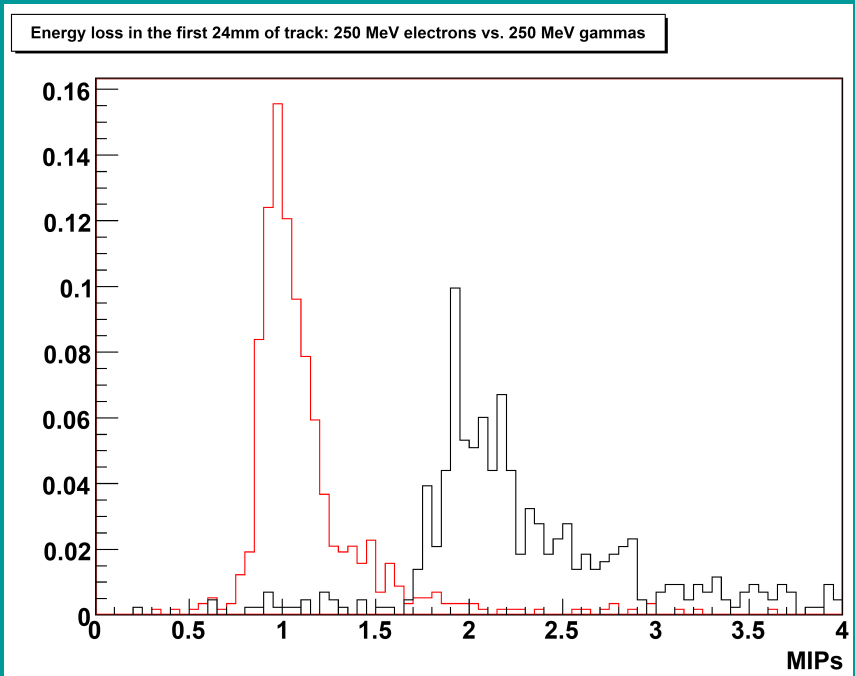
R&D on the road to CP violation, θ_{13}, proton decay, …

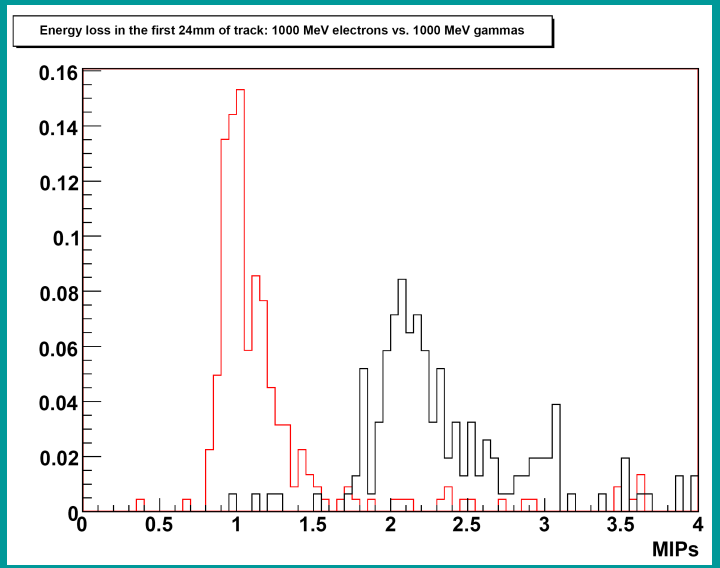
Backup: TPC specs.

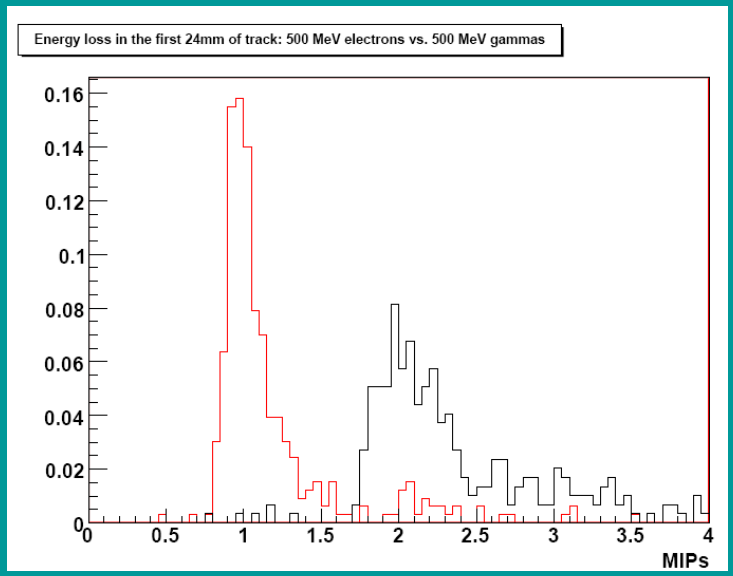
- ~170L volume
- 4mm wire spacing
- 480 channels (240 channels per plane)
- 2048 samples over 400microseconds (per spill)
- ~50cm drift distance
- ~500V/cm field
- Collection and induction wires are at 60degress.



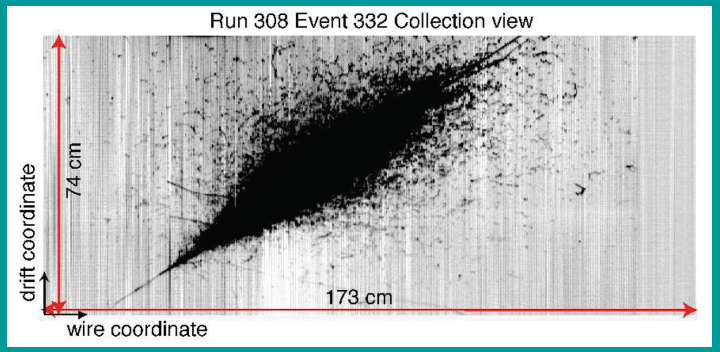
Backup: dE/dx at various energies

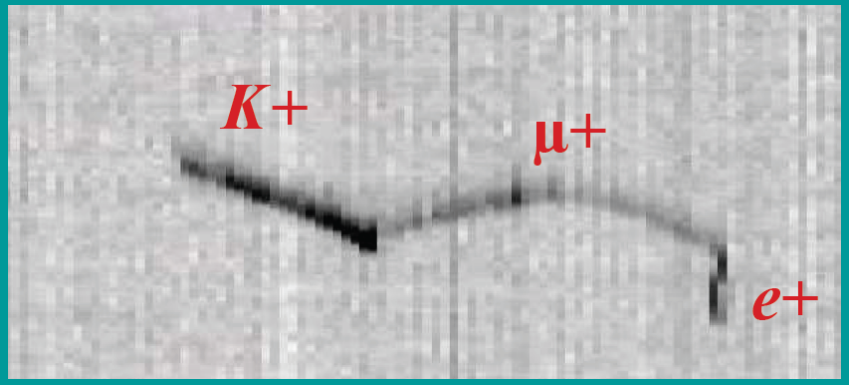


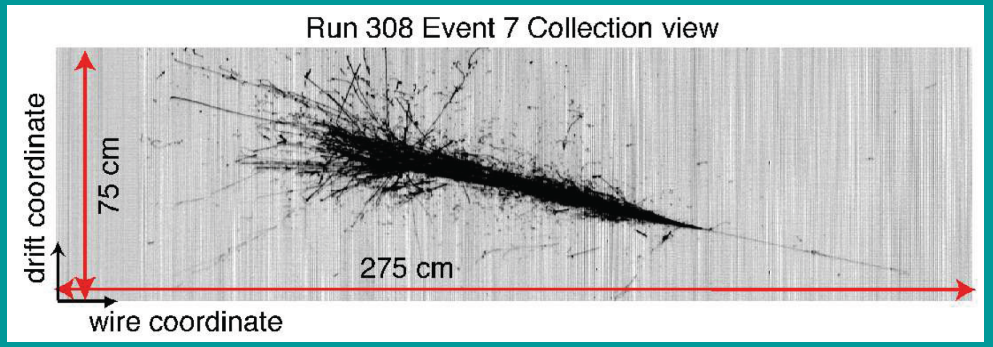




Backup: LAr event displays

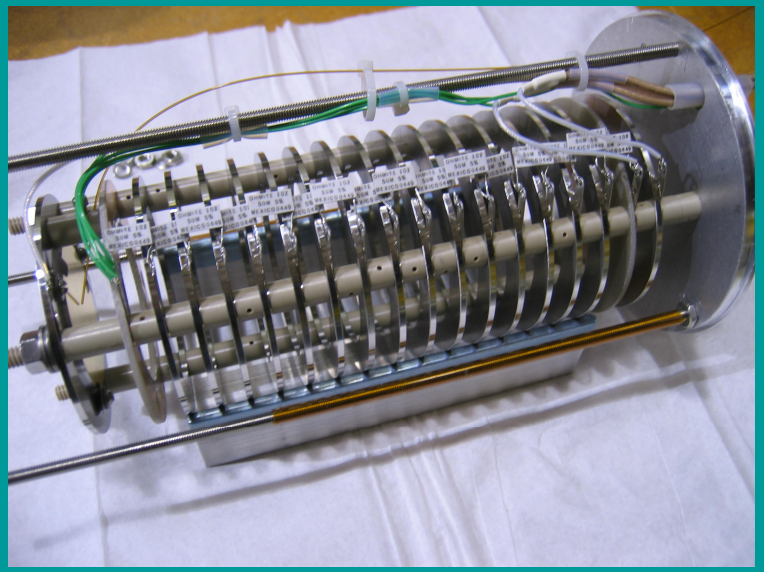


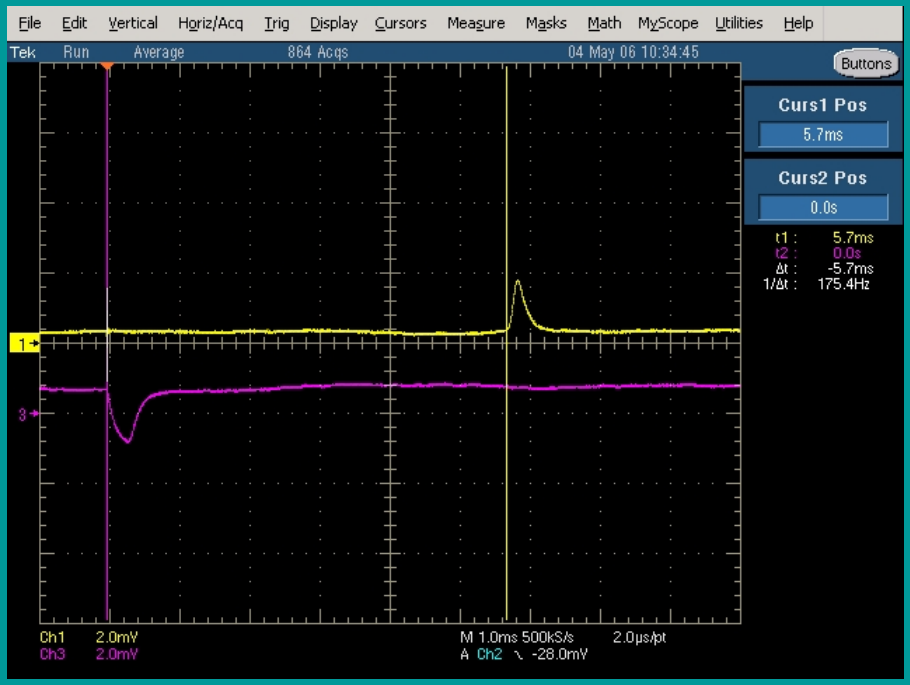




ICARUS T600

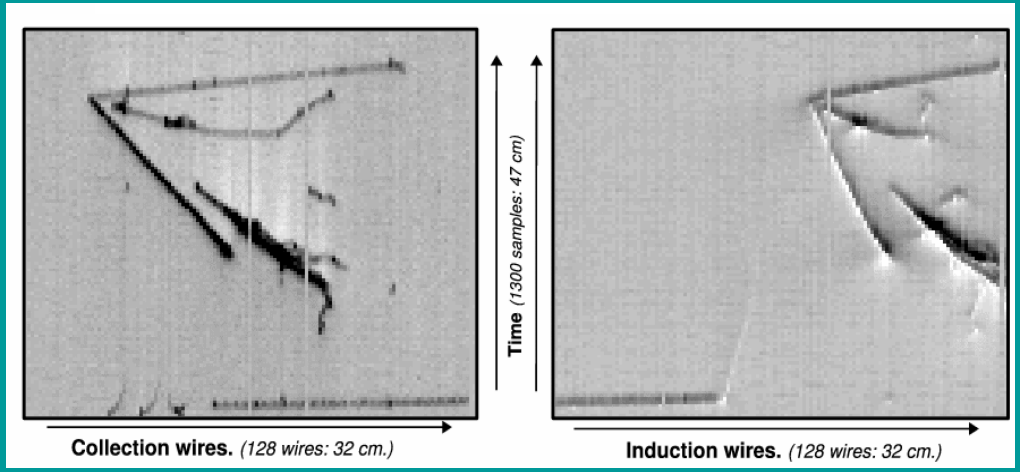
Backup: Purity Monitor





Backup: ArgoNeuT is the first LArTPC to go in a “low energy” neutrino beam

- The ICARUS collaboration exposed a 50L LArTPC to the WANF neutrino beam (mean energy=24 GeV).



- ICARUS will expose the T600 detector to the CNGS (mean energy=17 GeV) beam in the summer.