# ArgoNeuT: A Liquid Argon Time Projection Chamber in a Low Energy Neutrino Beam

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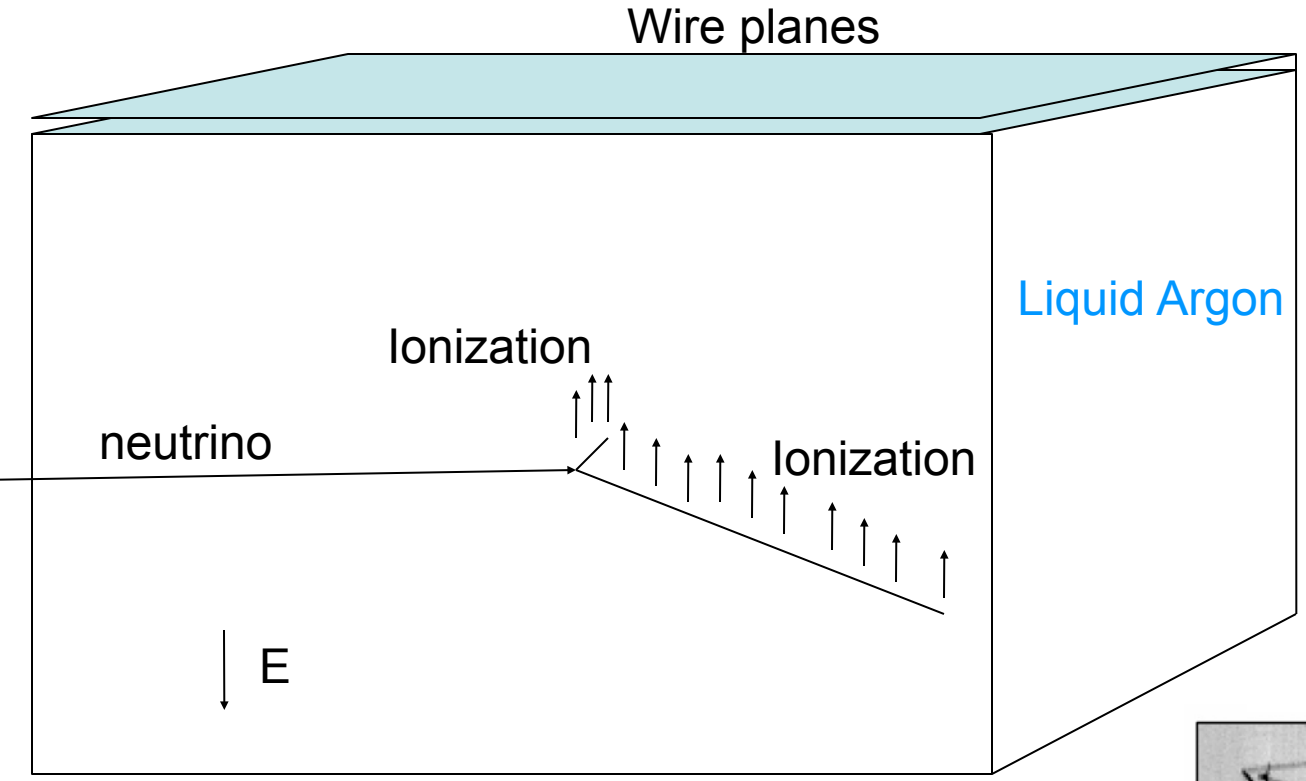
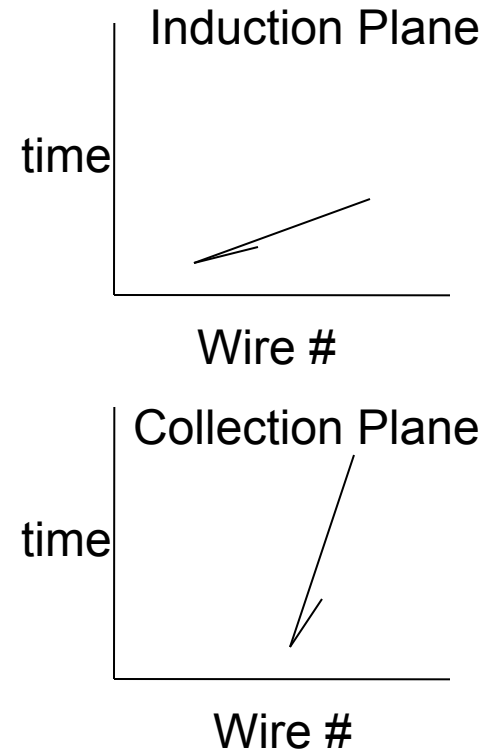
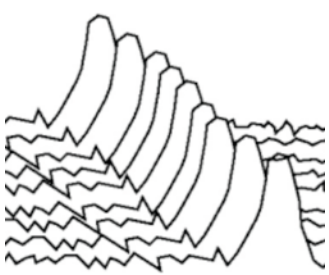
TAUP 7/2/2009

# The LArTPC technique

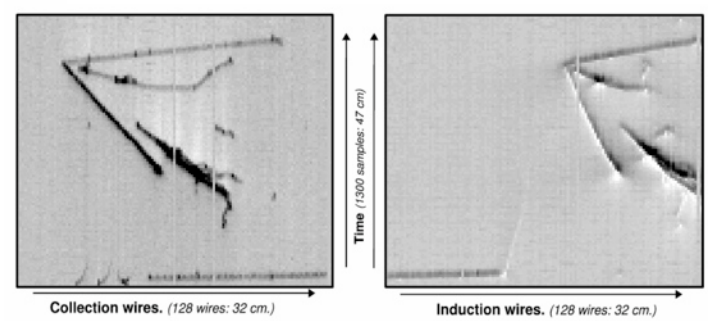


Wire pulses in time give the drift coordinate of the track

Scintillation light can give $t_0$




ICARUS 50L in WANF neutrino beam

induction plane + collection plane + time = 3D image of event (w/ calorimetric info)

# Why Argon?

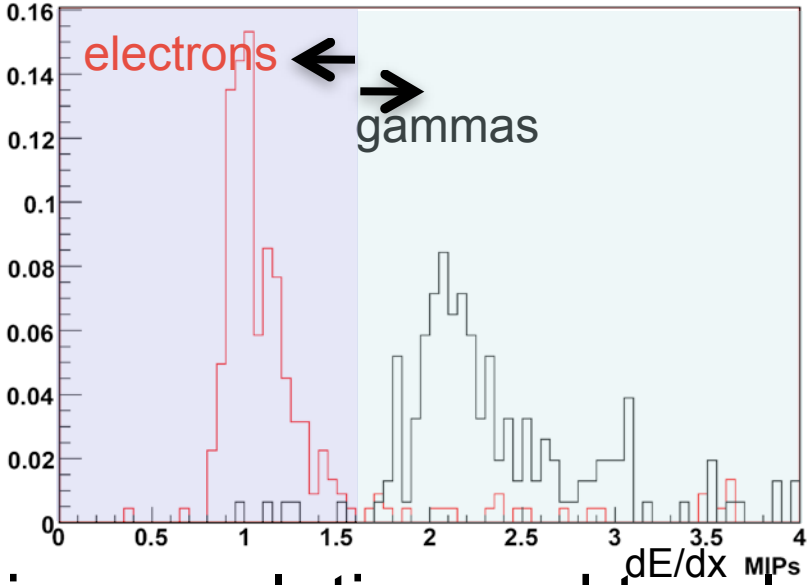
| | He | Ne | Ar | Kr | Xe |
|---|---|---|---|---|---|
| Boiling Point [K] @ 1atm | 4.2 | 27.1 | 87.3 | 120.0 | 165.0 |
| Density [g/cm$^3$] | 0.125 | 1.2 | 1.4 | 2.4 | 3.0 |
| Radiation Length [cm] | 755.2 | 24.0 | 14.0 | 4.9 | 2.8 |
| Scintillation [$\gamma$ /MeV] | 19,000 | 30,000 | 40,000 | 25,000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

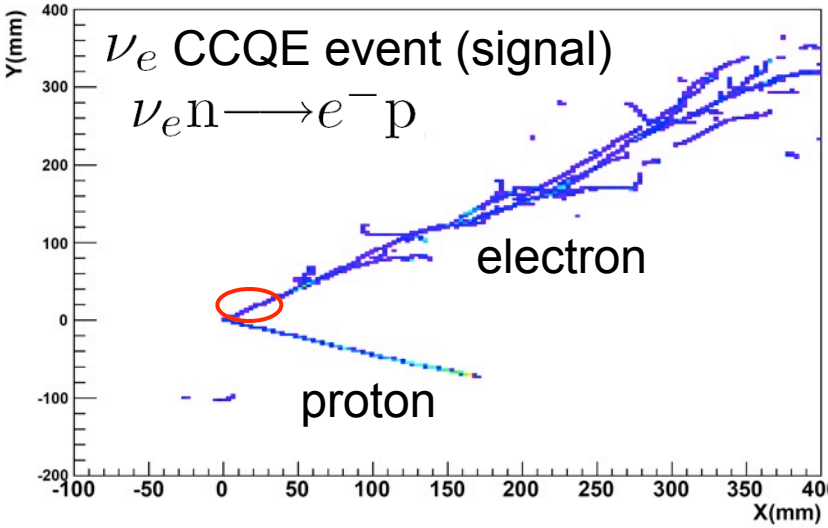
Expensive

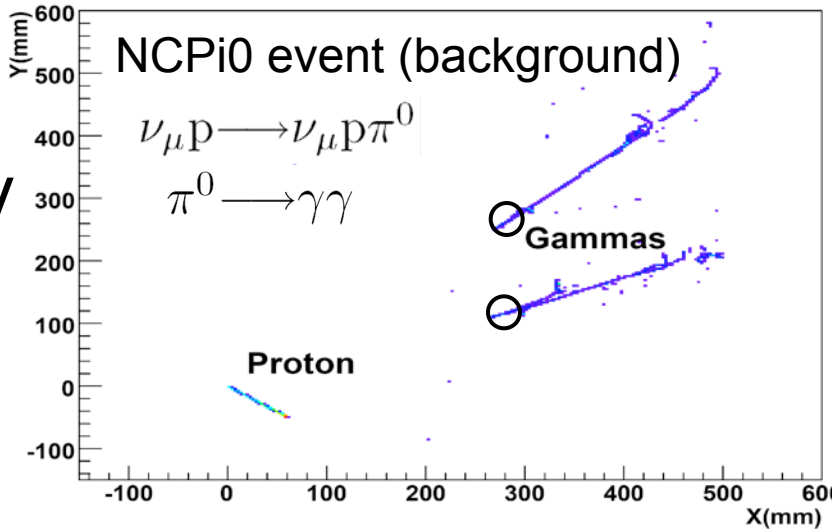
# What's so great about LArTPCs?

## -dE/dx

- Monte Carlo studies show that LArTPCs can identify electron/gamma tracks with >90% efficiency.
- Extremely important for tagging $\nu_e$ correctly




## -Position resolution and topology

- Pixel size in ArgoNeuT= (4.0 x 4.0 x 0.3) $mm^3$

## -Low energy threshold

- Detection of particles with energy as low as 15 MeV.

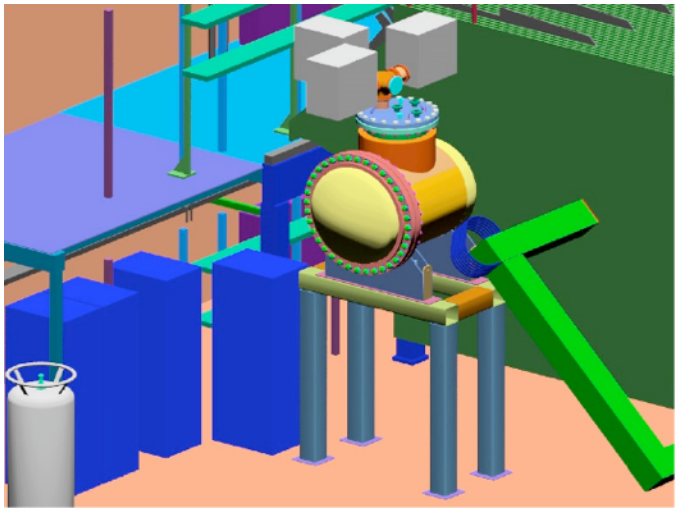
## -Always live

## -Appear scalable to kton-level

# Overview of ArgoNeuT

- ArgoNeuT (NSF/DOE project) is the first Liquid Argon TPC (LArTPC) to go in a “low energy” neutrino beam (NuMI on-axis, peaking at ~3GeV).
- We will see 10000s of (anti-)neutrino events in the 170L TPC.
- ArgoNeuT was filled with LAr on 5/8/2009

- Goals:
  - Research and Design for future LArTPCs (MicroBooNE, long baseline neutrino oscillation, proton decay, …)
  - Beautiful, bubble-chamber-like event displays
  - Demonstrate particle ID (e.g. electron/gamma separation) capabilities of LArTPCs with dE/dx
  - Physics…



# ArgoNeuT Collaboration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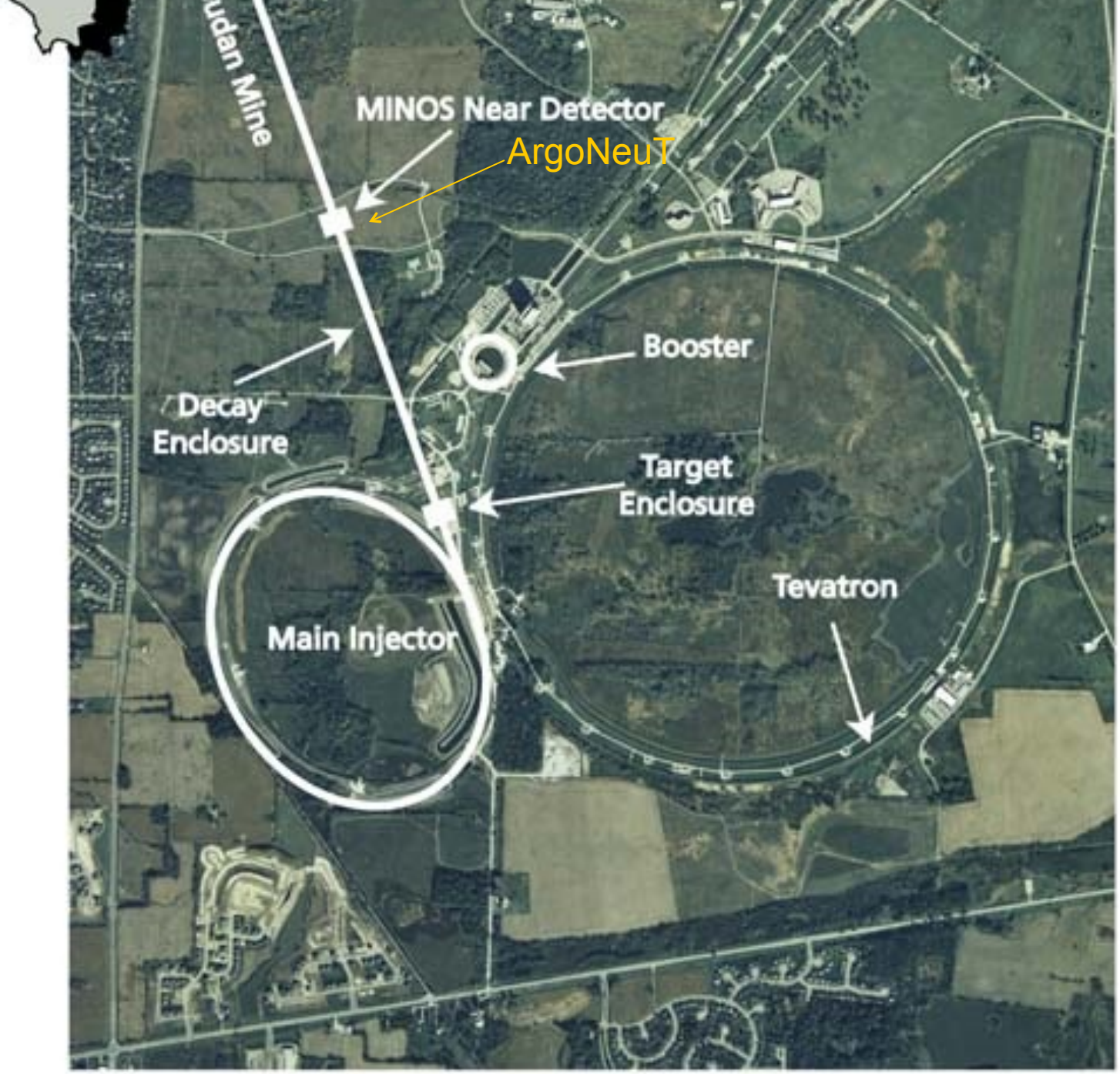


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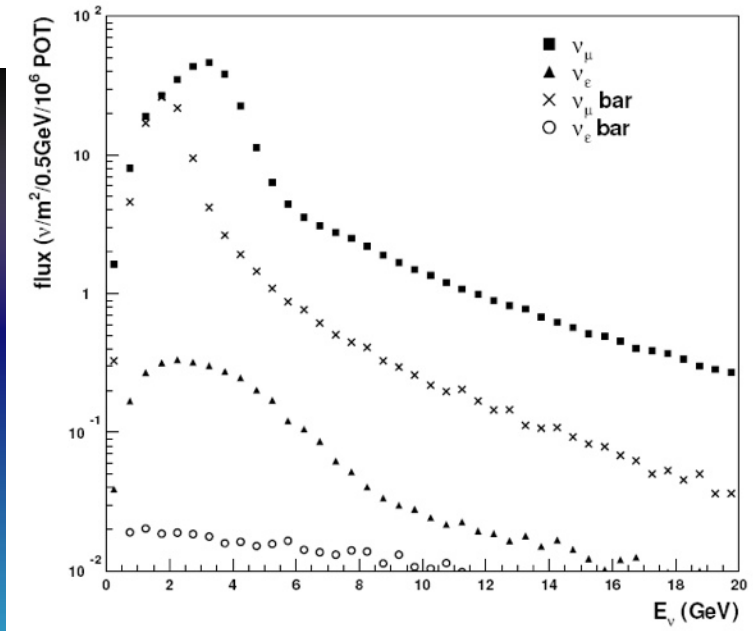
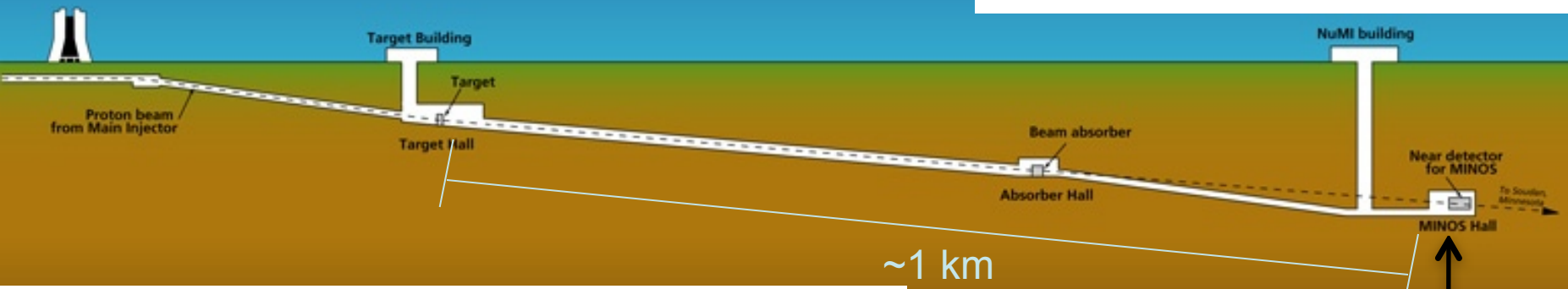
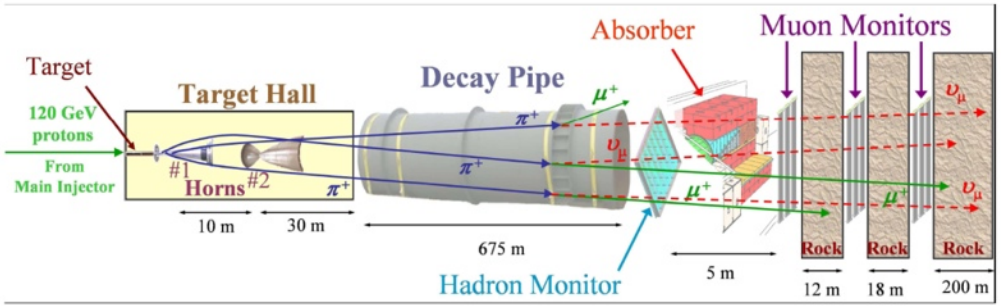
# NuMI Tunnel Project



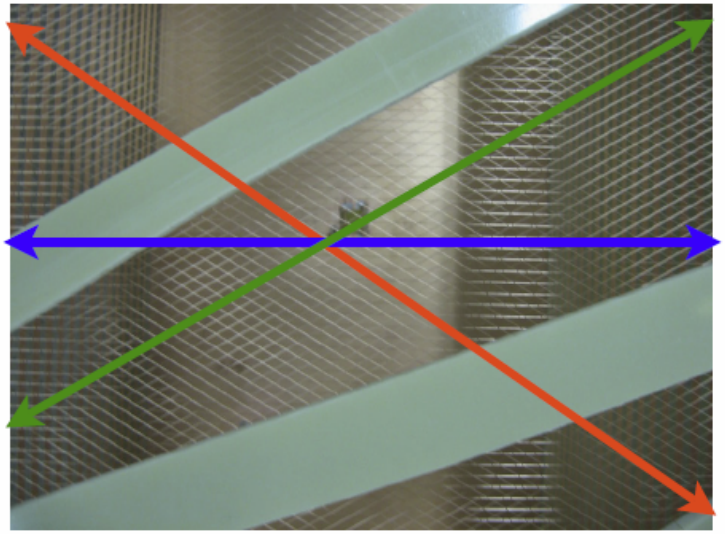



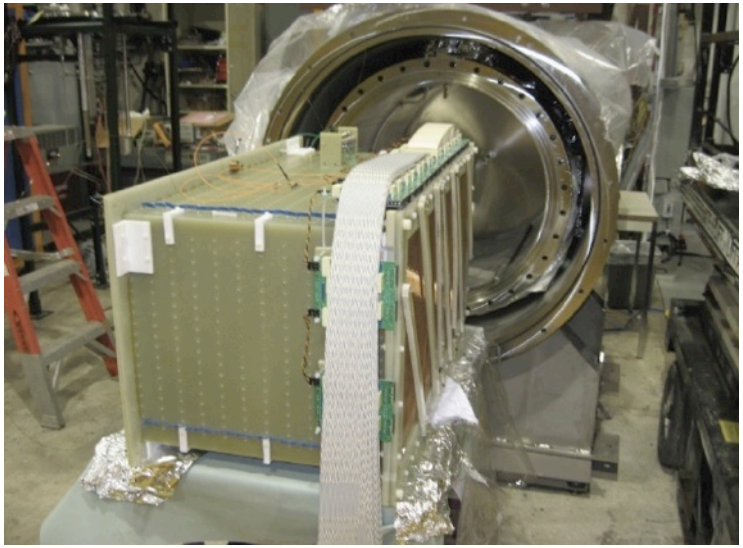

ArgoNeuT



# ArgoNeuT TPC specs.

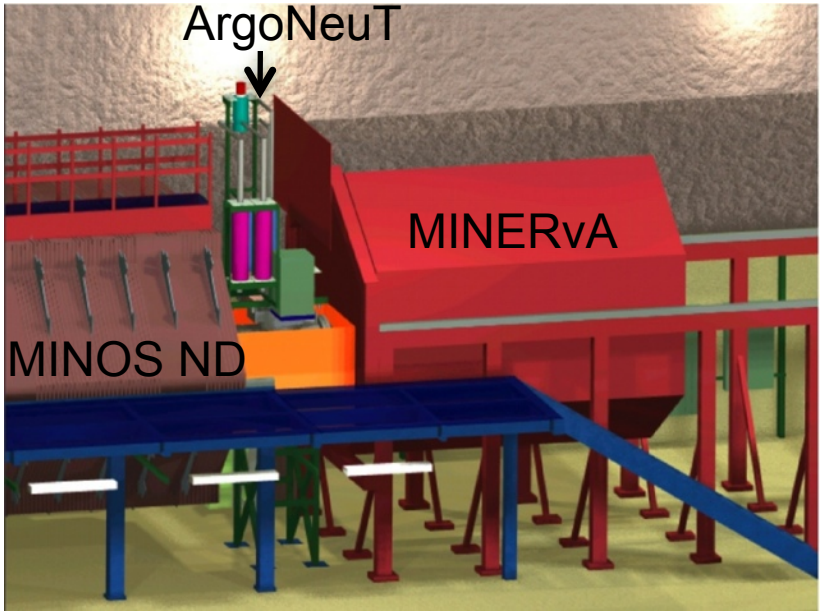
- ~170 L volume
- 4 mm wire spacing
- 480 channels (240 channels/plane)
- 2048 samples over 400 $\mu$s (per spill)
  - ArgoNeuT uses the beam as a trigger.
- ~50 cm drift distance
- ~500 V/cm field

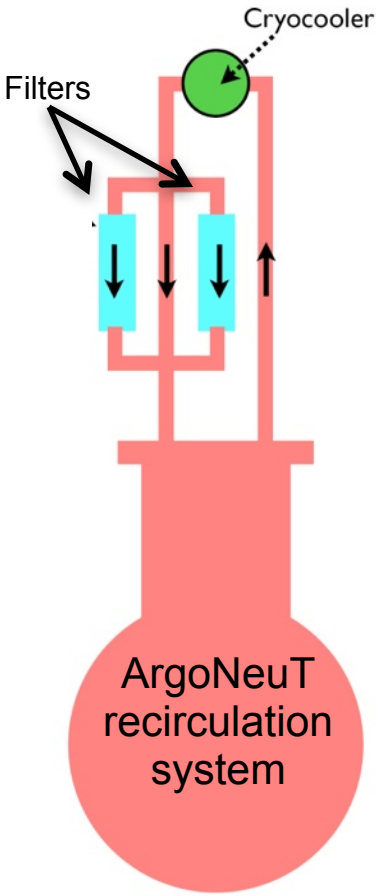




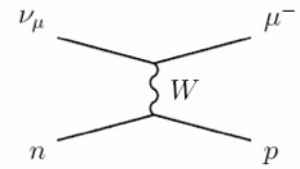
# The trip underground

MINOS ND
ArgoNeut


ArgoNeuT
MINERvA
MINOS ND

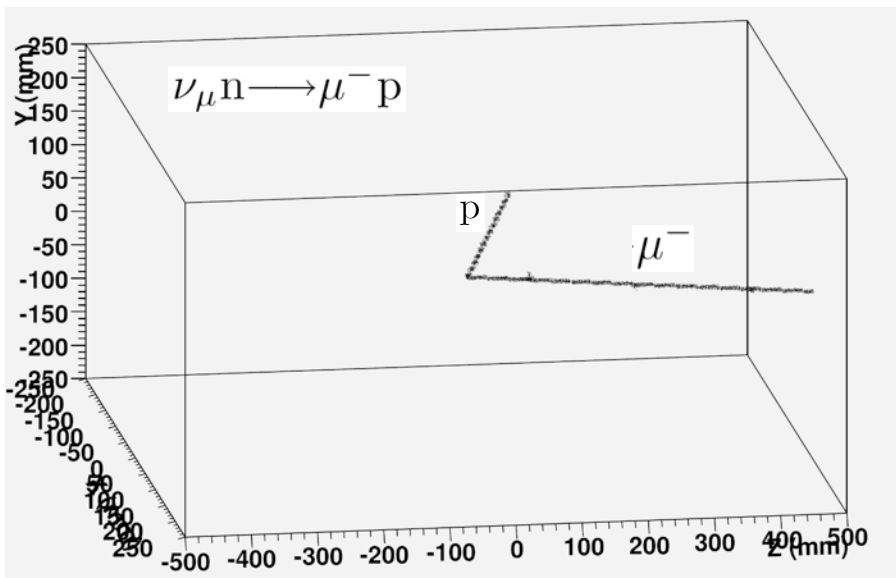

Cryocooler
Filters
ArgoNeuT
recirculation
system

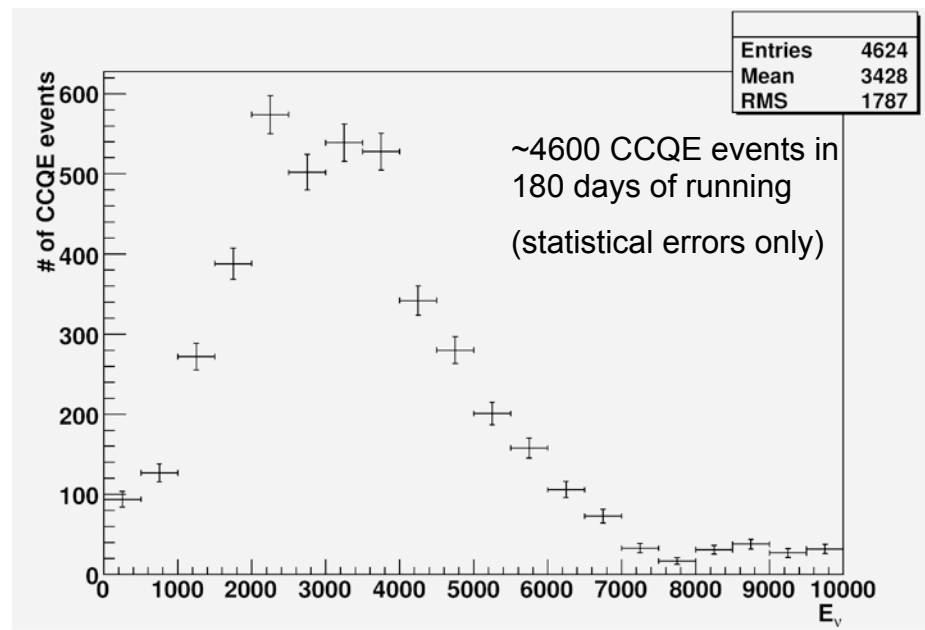
# Charged-Current, Quasi-Elastic (CCQE) events in ArgoNeuT




- CCQE is considered the "golden mode" for all accelerator-based neutrino oscillation experiments.
- There are a few reasons for this:
  - The cross section is comparatively high at low (0.5-5 GeV) energy.
  - The events are simple. There are only two final-state particles with both particles easily identified and reconstructed.

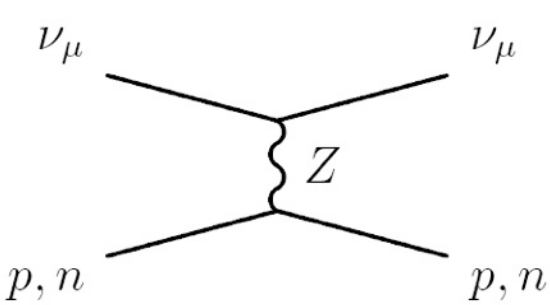
- Using dE/dx and LArTPC position/energy resolution, ArgoNeuT will be able to identify and separate (CCQE-like) event-types with high efficiency.



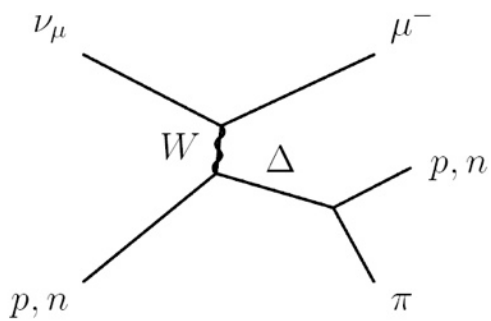



# Other physics with ArgoNeuT

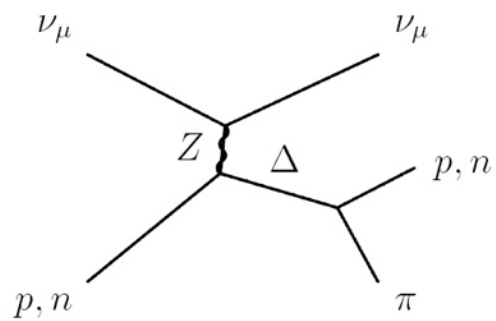
| Event type | # of events in 180 days | Notes |
|---|---|---|
| $\nu_\mu$ CC | 28800 | |
| $\overline{\nu}_\mu$ CC | 2520 | |
| $\nu_e$ CC | 540 | Use dE/dx to tag electron |
| NC | 9720 | |
| $\nu_\mu \mathrm{n} \longrightarrow \mu^- \mathrm{p}$ (CCQE) | 4680 | ~50% proton containment. Will use MINOS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




Neutral current elastic (NCE)



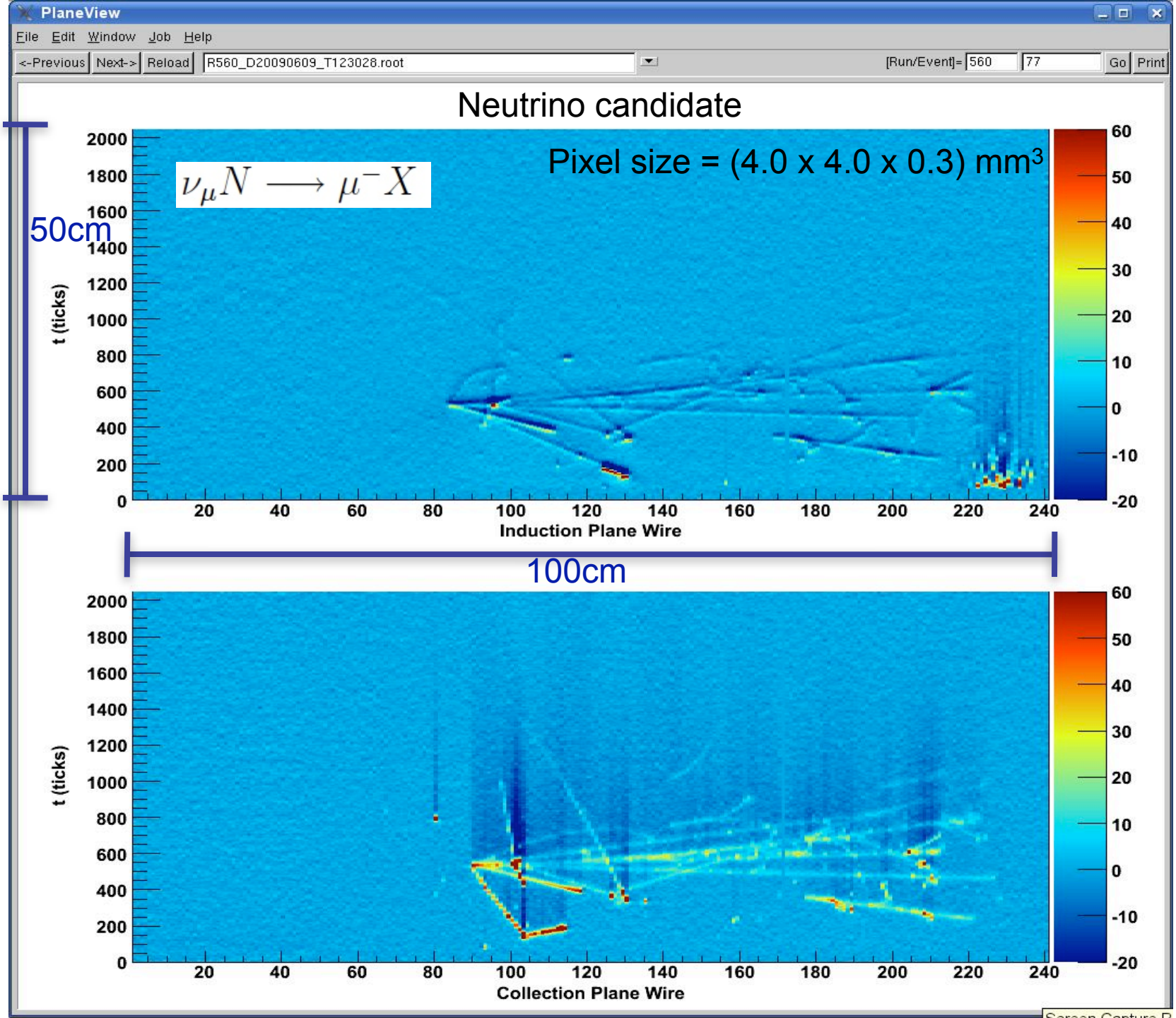

Charged current resonant (CCpi)

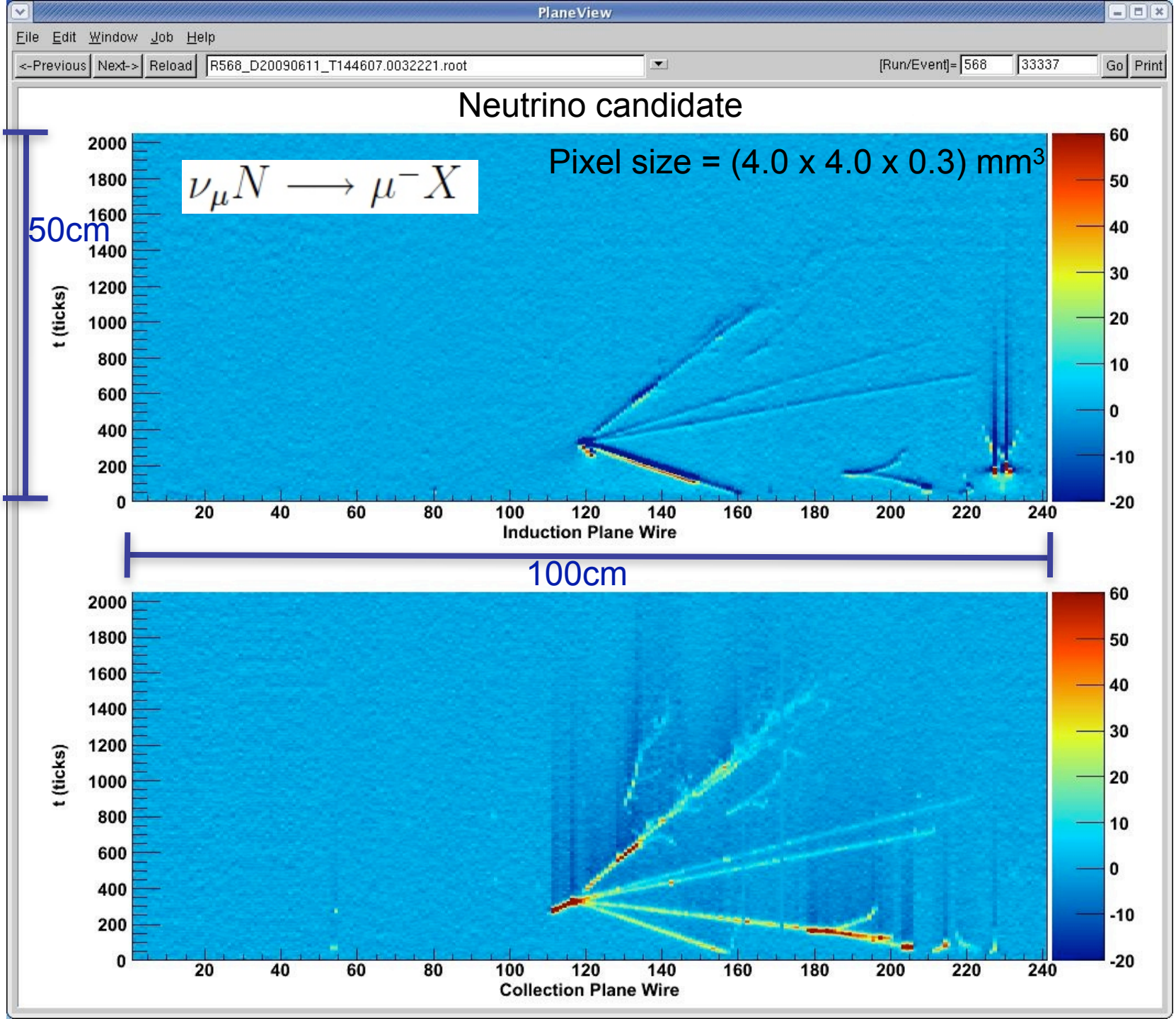


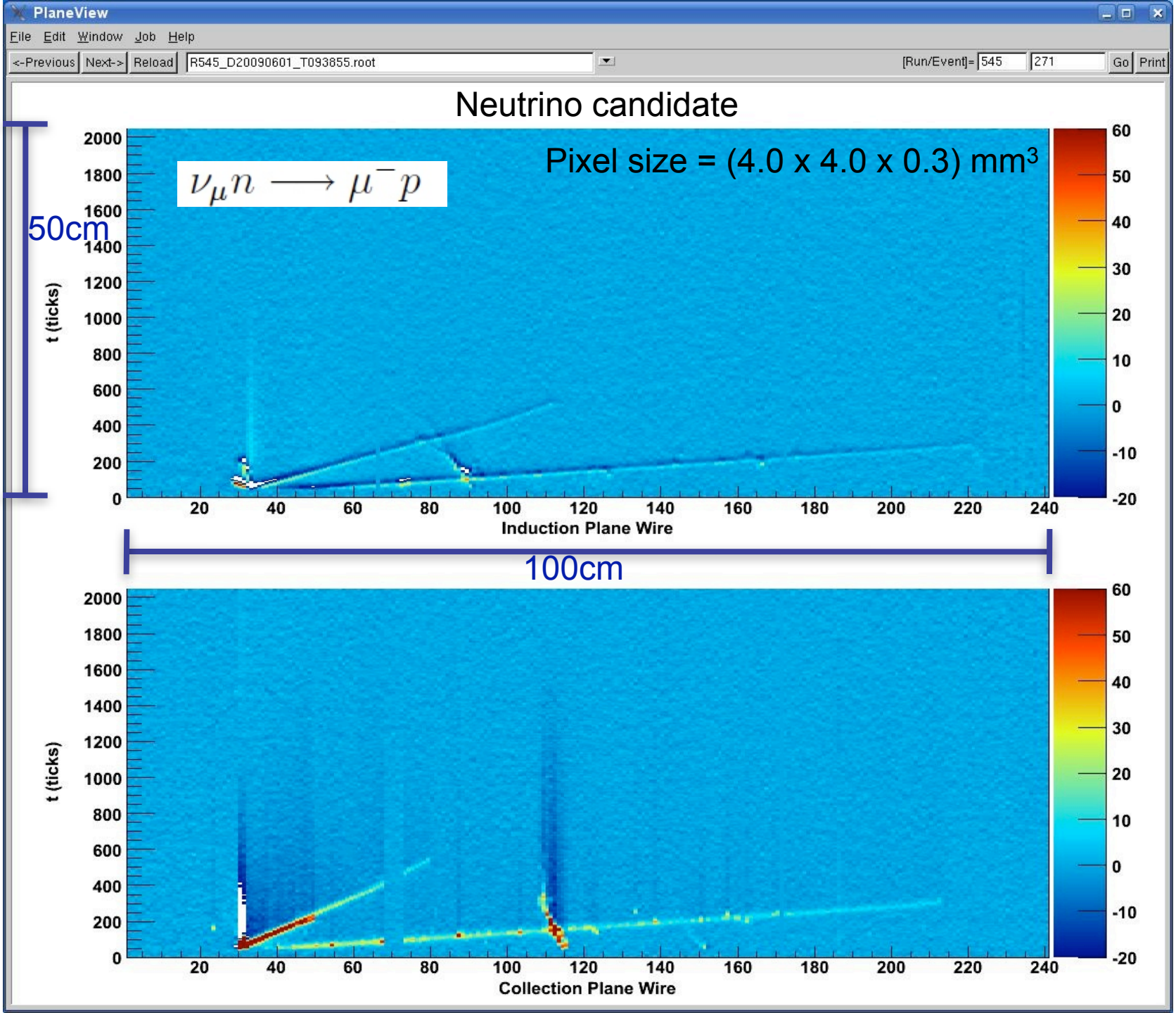

Neutral current resonant (NCpi)

# ArgoNeuT Event Displays!

(preliminary)


PlaneView
File Edit Window Job Help
<-Previous Next-> Reload R560_D20090609_T123028.root
[Run/Event]= 560 77 Go Print
Neutrino candidate
Pixel size = (4.0 x 4.0 x 0.3) mm3
$\nu_\mu N \longrightarrow \mu^- X$
50cm
t (ticks)
Induction Plane Wire
100cm
t (ticks)
Collection Plane Wire


PlaneView
File Edit Window Job Help
<-Previous Next-> Reload
R568_D20090611_T144607.0032221.root
[Run/Event]= 568 33337 Go Print
Neutrino candidate
$\nu_\mu N \longrightarrow \mu^- X$
Pixel size = (4.0 x 4.0 x 0.3) mm$^3$
50cm
t (ticks)
Induction Plane Wire
100cm
t (ticks)
Collection Plane Wire


PlaneView
File Edit Window Job Help
<-Previous Next-> Reload R545_D20090601_T093855.root
[Run/Event]= 545 271 Go Print
Neutrino candidate
Pixel size = (4.0 x 4.0 x 0.3) mm3
$\nu_\mu n \longrightarrow \mu^- p$
50cm
t (ticks)
Induction Plane Wire
100cm
t (ticks)
Collection Plane Wire

# Take home

- ArgoNeuT is a R&D-oriented LArTPC that is currently taking data in the NuMI beamline at Fermilab.
  - The detector will see 10000s of (anti-)neutrino events in a wide variety of channels.
  - We will make a CCQE cross section measurement, among other physics.
  - The LArTPC's ability to image neutrino events with high resolution and tag with high efficiency (dE/dx) will be demonstrated.
- MicroBooNE (170 ton) is an approved LArTPC-based experiment that will begin taking data in the BNB and NuMI off-axis beams in 2011-2012.
  - Important physics and R&D!
  - Not discussed in this talk.

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