ArgoNeuT

University/Lab R&D Experience

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Fermilab Workshop on Detector R&D

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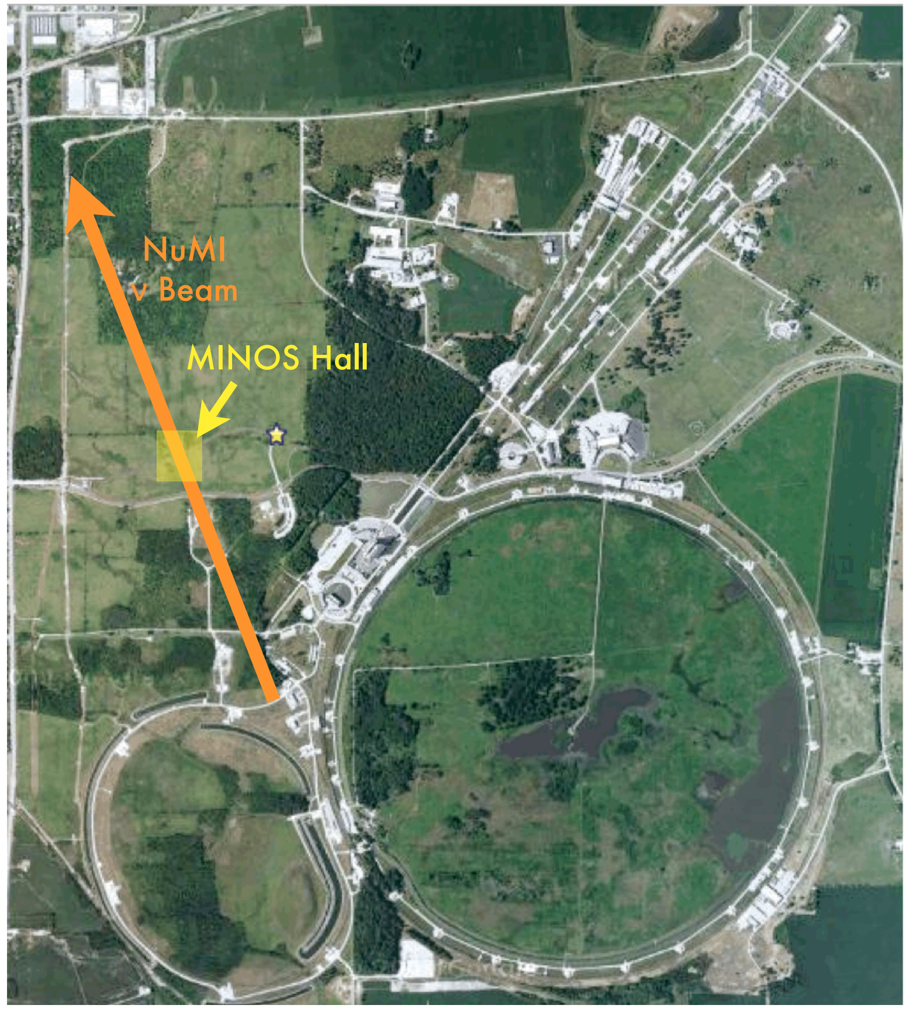
Please also see posters from J. Spitz (ArgoNeuT/MicroBooNE) and T. Yang (LAPD).

ArgoNeuT

- ArgoNeuT (*a.k.a.* - Fermilab T962) features a small liquid argon detector.
- Operated in NuMI beam at Fermilab, upstream of MINOS near detector.
- R&D Goals:
  - Gain experience building/running liquid argon neutrino detectors.
  - Accumulate neutrino/antineutrino events (1st time in the U.S., 1st time ever in a low-E beam).
  - Develop simulation/reconstruction tools useful for future experiments (MicroBooNE/LBNE).
- Collaborating Institutions:
  - University of L'Aquila
  - University of Bern
  - Fermilab
  - Gran Sasso National Laboratory
  - Kansas State University
  - Michigan State University
  - Syracuse University
  - University of Texas at Austin
  - Yale University

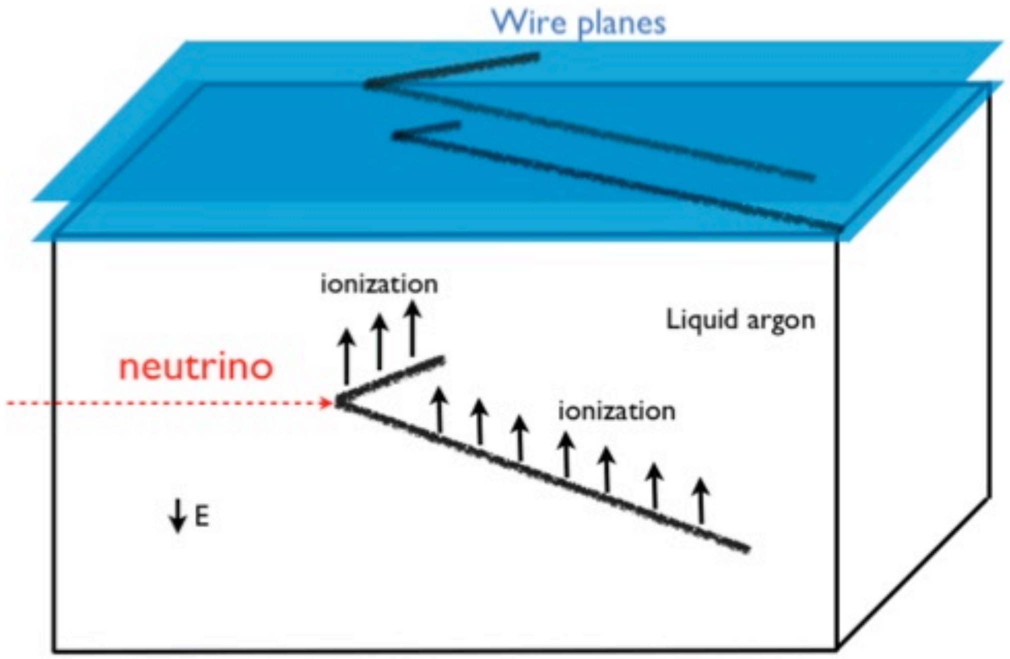


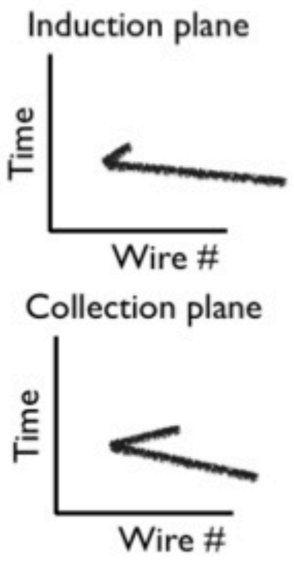
NuMI Beam at Fermilab

ArgoNeuT in front of MINOS Near Detector

Liquid Argon Detection Principle

- LArTPC = Liquid Argon Time Projection Chamber
  - Charged particles produced in a neutrino interaction ionize the argon as they travel through the TPC (55k e^-/cm for a MIP).
    - 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 at differing angles provide independent views.
        - Timing of wire pulse information is combined with drift speed to determine drift-direction coordinate.
          - Scintillation light also present, can be collected by Photomultiplier Tubes and used in triggering.





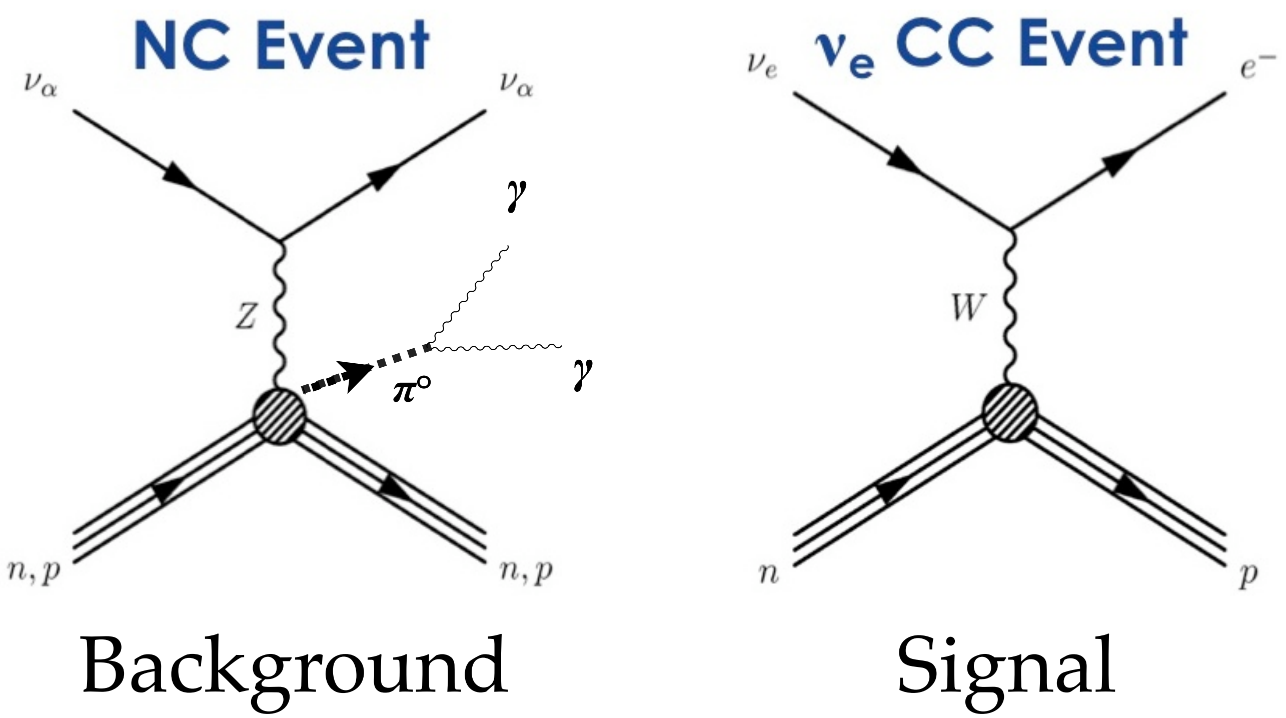
	He	Ne	Ar	Kr	Xe	Water
Boiling Point [K] @ 1atm	4.2	27.1	87.3	120.0	165.0	373
Density [g/cm^3]	0.125	1.2	1.4	2.4	3.0	1
Radiation Length [cm]	755.2	24.0	14.0	4.9	2.8	36.1
dE/dx [MeV/cm]	0.24	1.4	2.1	3.0	3.8	1.9
Scintillation [γ /MeV]	19,000	30,000	40,000	25,000	42,000	
Scintillation λ [nm]	80	78	128	150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

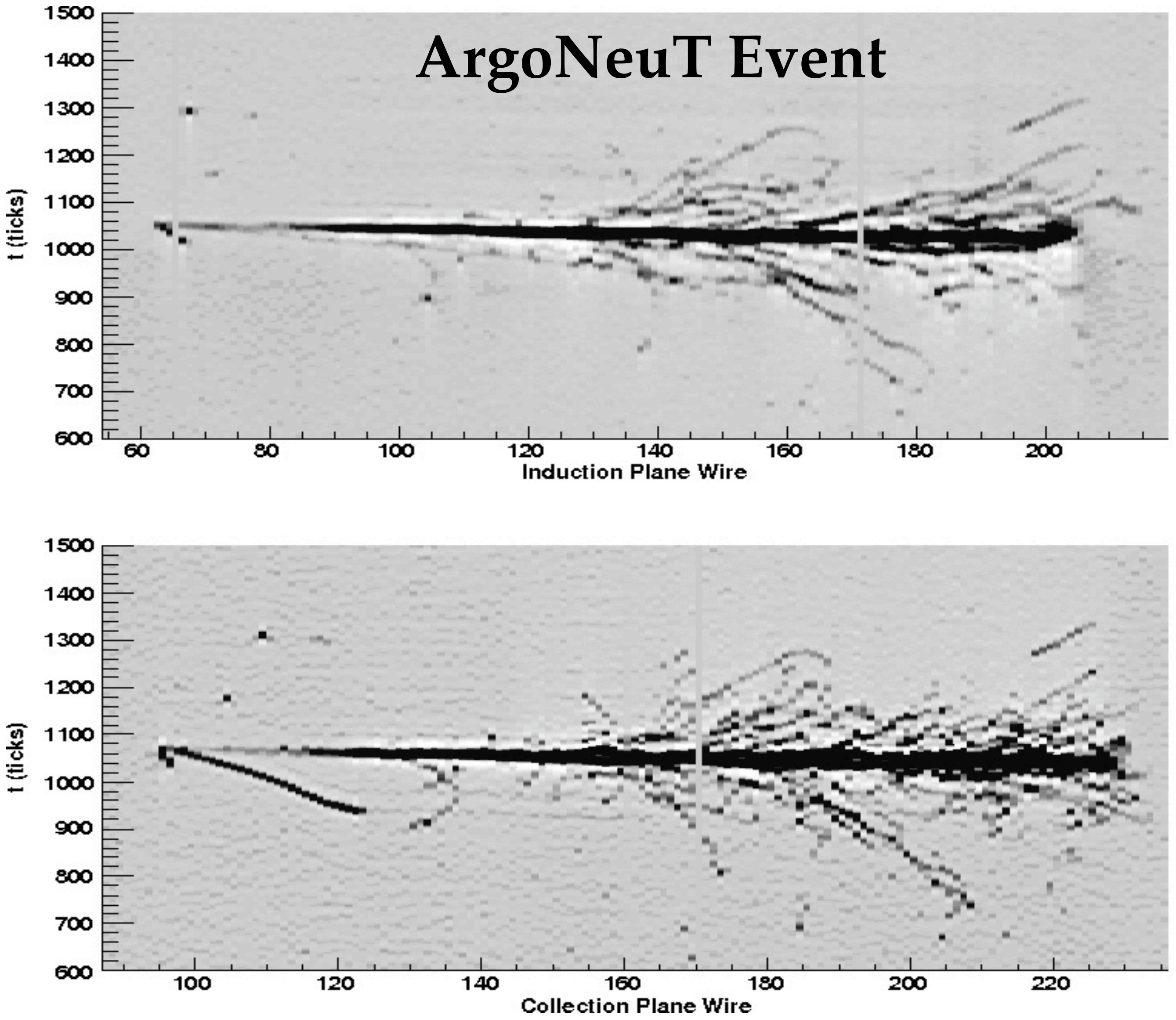
Refs:
1.) *The Liquid-argon time projection chamber: a new concept for Neutrino Detector*, C. Rubbia, CERN-EP/77-08 (1977)

LArTPCs for Neutrino Physics

excellent e/γ separation → superior background rejection

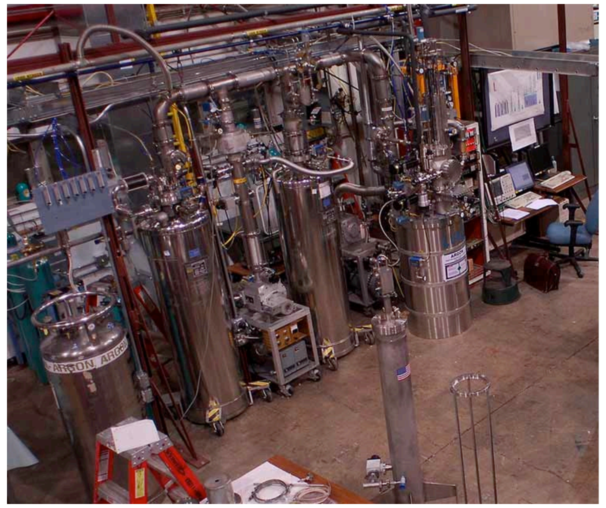
- Particle identification comes primarily from dE/dx (energy deposited) along track.
  - Millimeter wire spacing provides many measurements of dE/dx for even short tracks
- ν_e appearance: Excellent signal (CC ν_e) efficiency and background (NC π^0) rejection
  - Topological cuts will also improve signal/background separation
- LArTPCs appear scalable to large sizes.
- Beautiful, bubble-chamber like events!





Fermilab Liquid Argon Activities

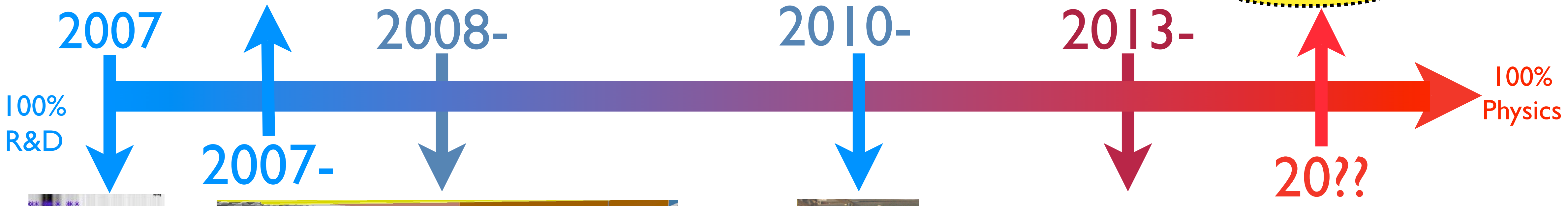
Materials Test Stand

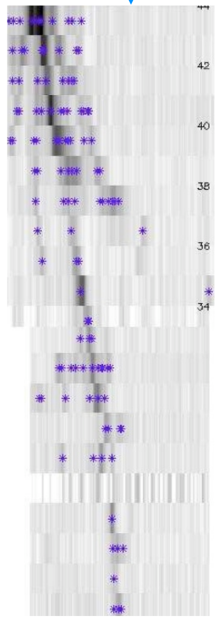


Electronics Test Stand

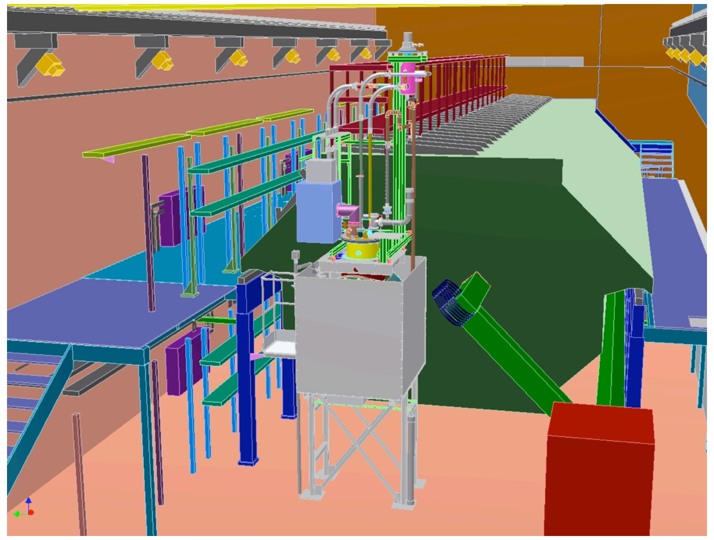
Lots of activity to develop this technology for large scales necessary for long-baseline neutrino physics.

LBNE



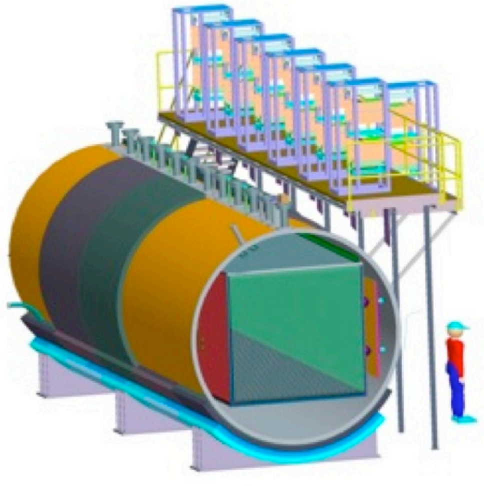


Yale Tracks



ArgoNeuT

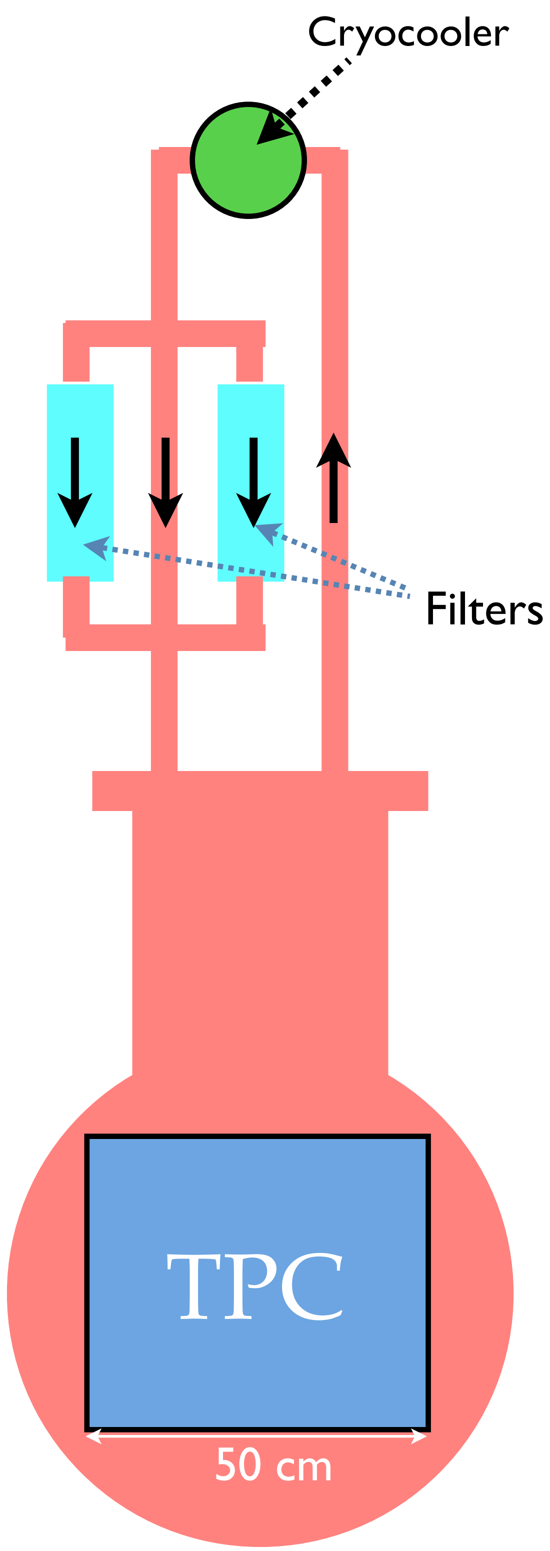
LAr Purity Demonstrator

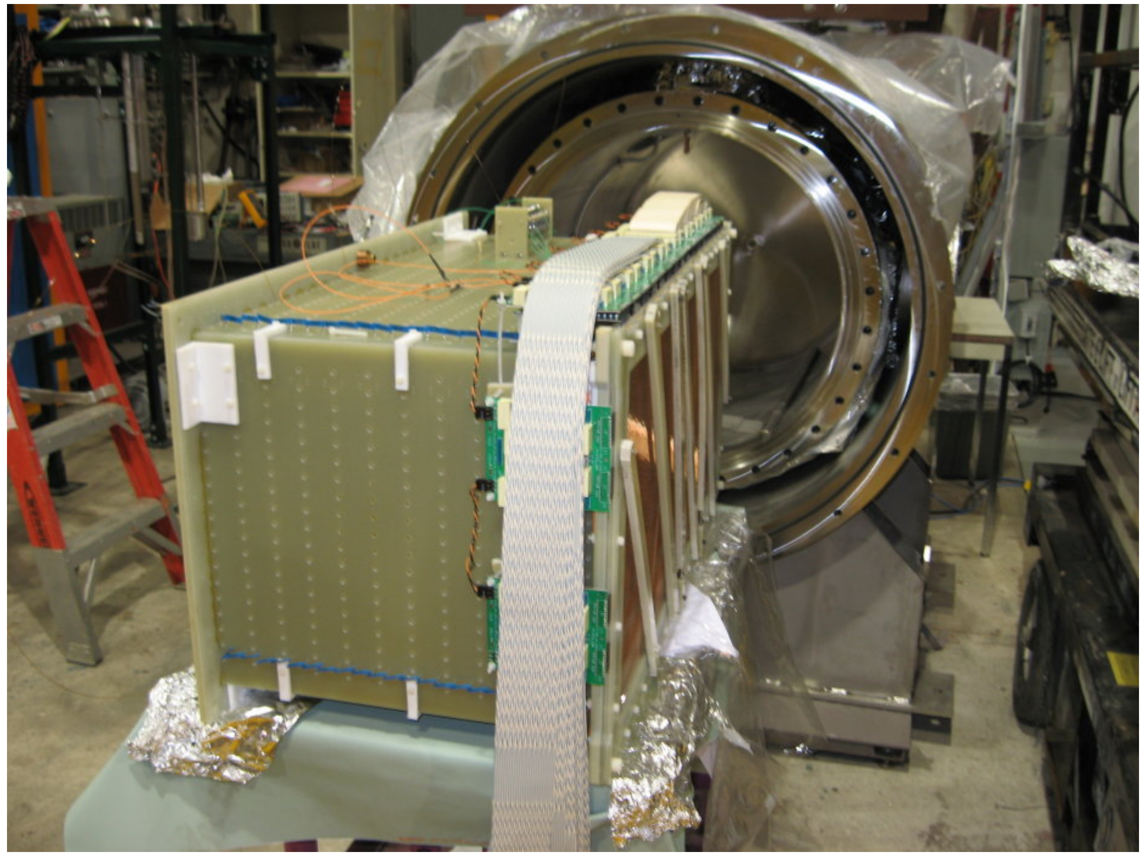


MicroBooNE

ArgoNeuT: Parameters

Cryostat Volume	500 Liters
TPC Volume	175 Liters
# Electronic Channels	480
Wire Pitch	4 mm
Plane Separation	4 mm
Electric Field	500V / cm
Max. Drift Time	330μs
Wire Properties	0.15mm diameter BeCu





TPC outside of cryostat

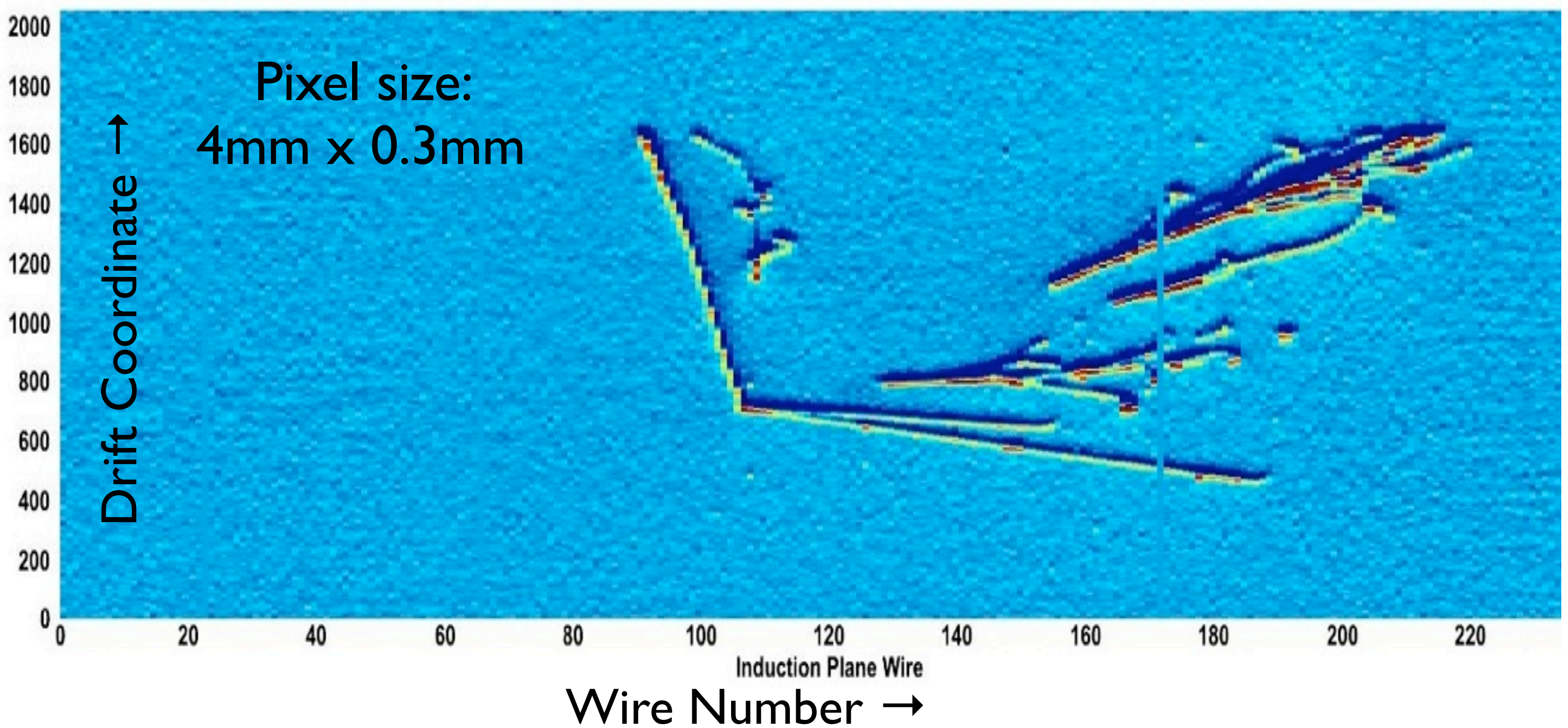
- Continuously circulate liquified argon through filters to purify (i.e. - to remove electronegative contaminants).
- 300W cryocooler utilized to condense boil-off argon gas.
- Custom low-noise electronics built to read out 480 channels.
- Vacuum-jacketed ~500 liter cryostat built for ArgoNeuT.

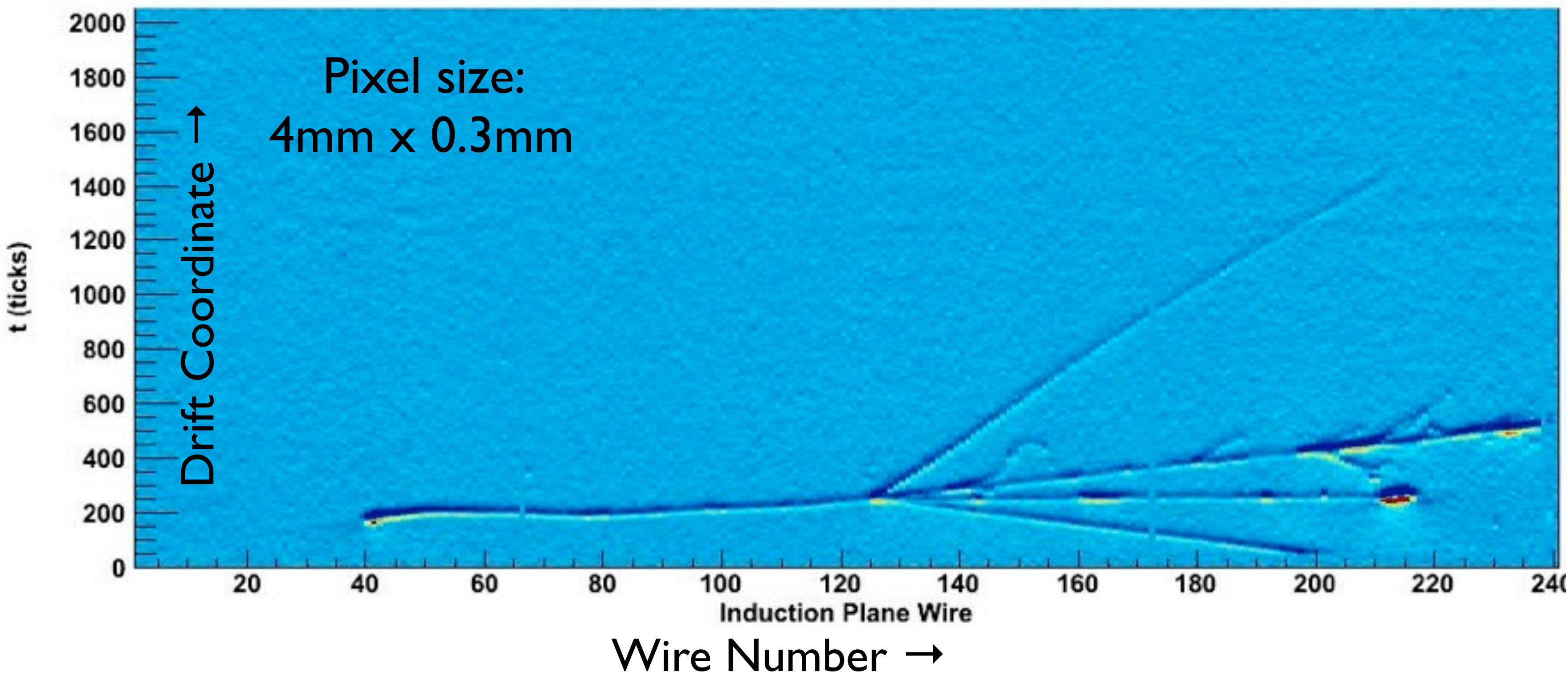
Refs:

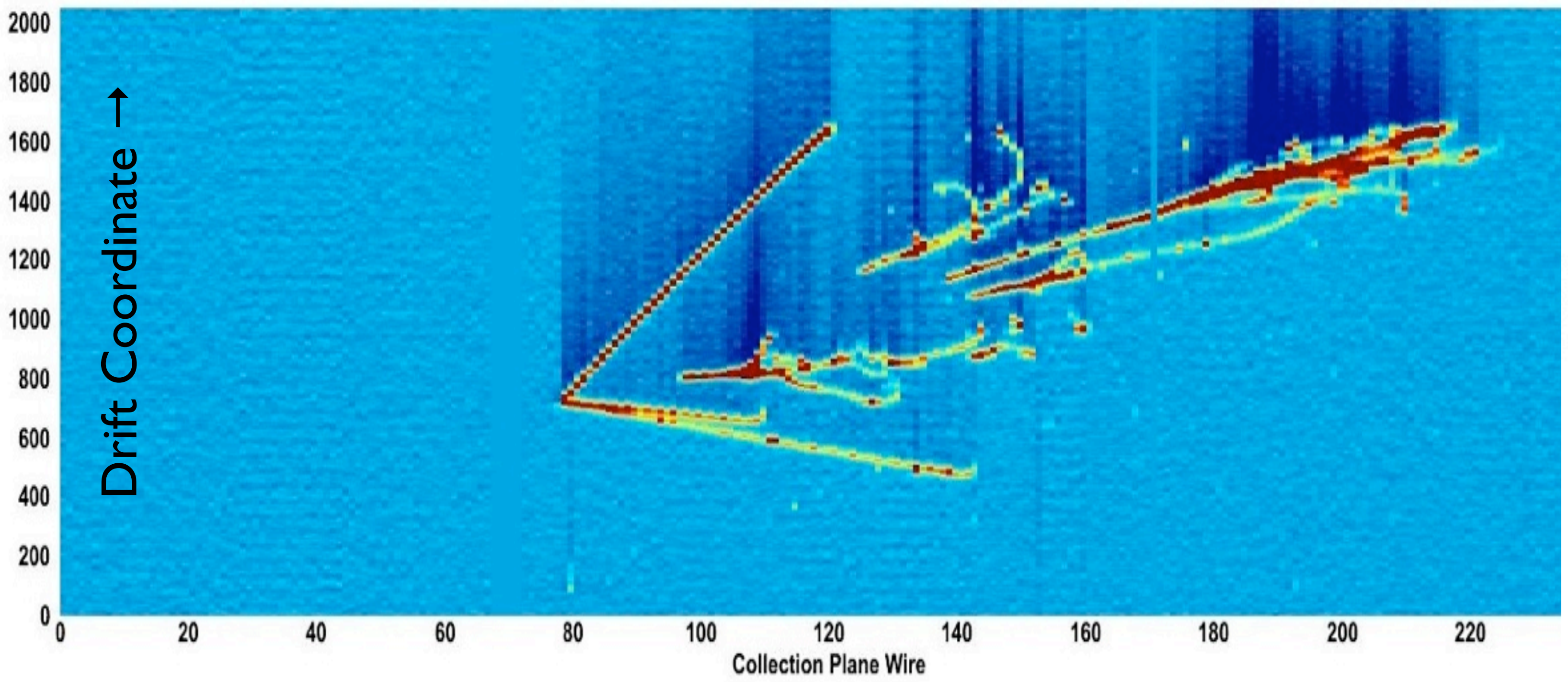
1.) *A Regenerable Filter for Liquid Argon Purification*, A. Curioni *et. al*; NIM A 605 (2009) 306-311

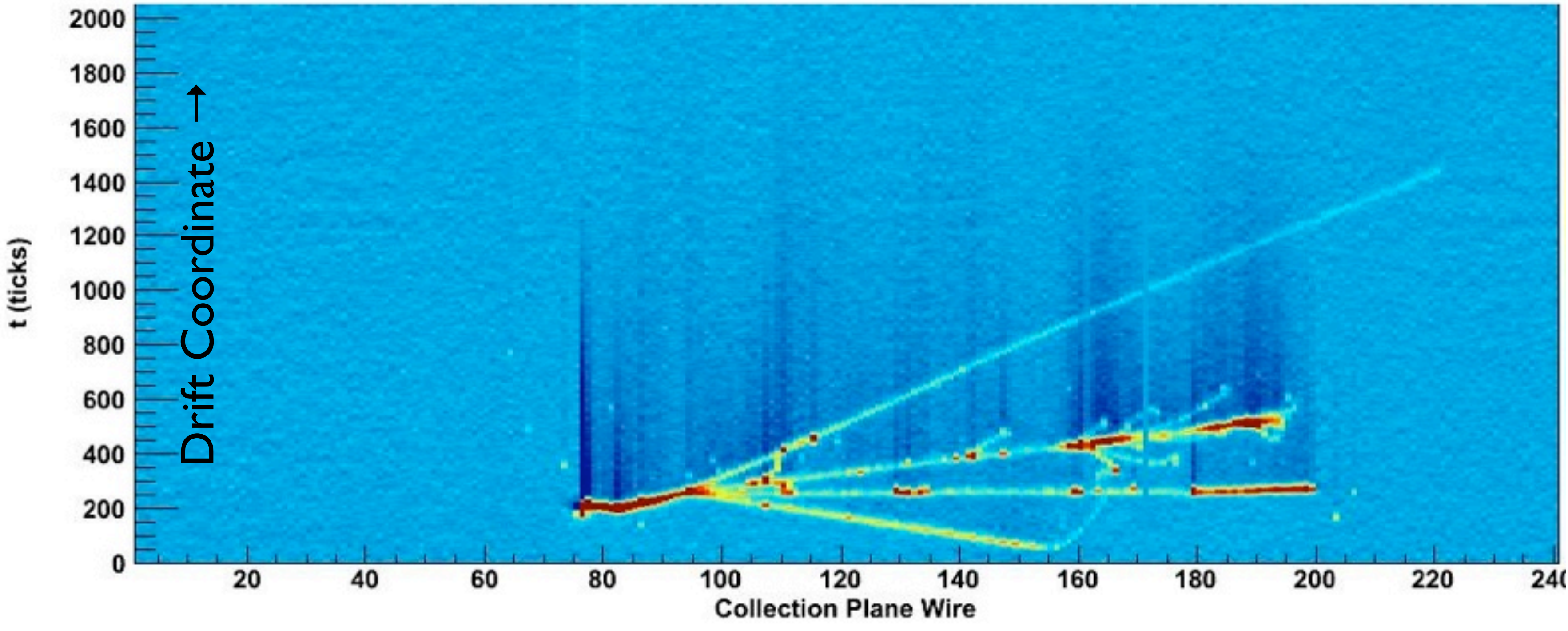
2.) *A System to Test the Effects of Materials on the Electron Drift Lifetime in Liquid Argon and Observations on the Effect of Water*, R. Andrews *et. al*; NIM A 608 (2009) 251-258

ArgoNeuT Neutrino Event Examples





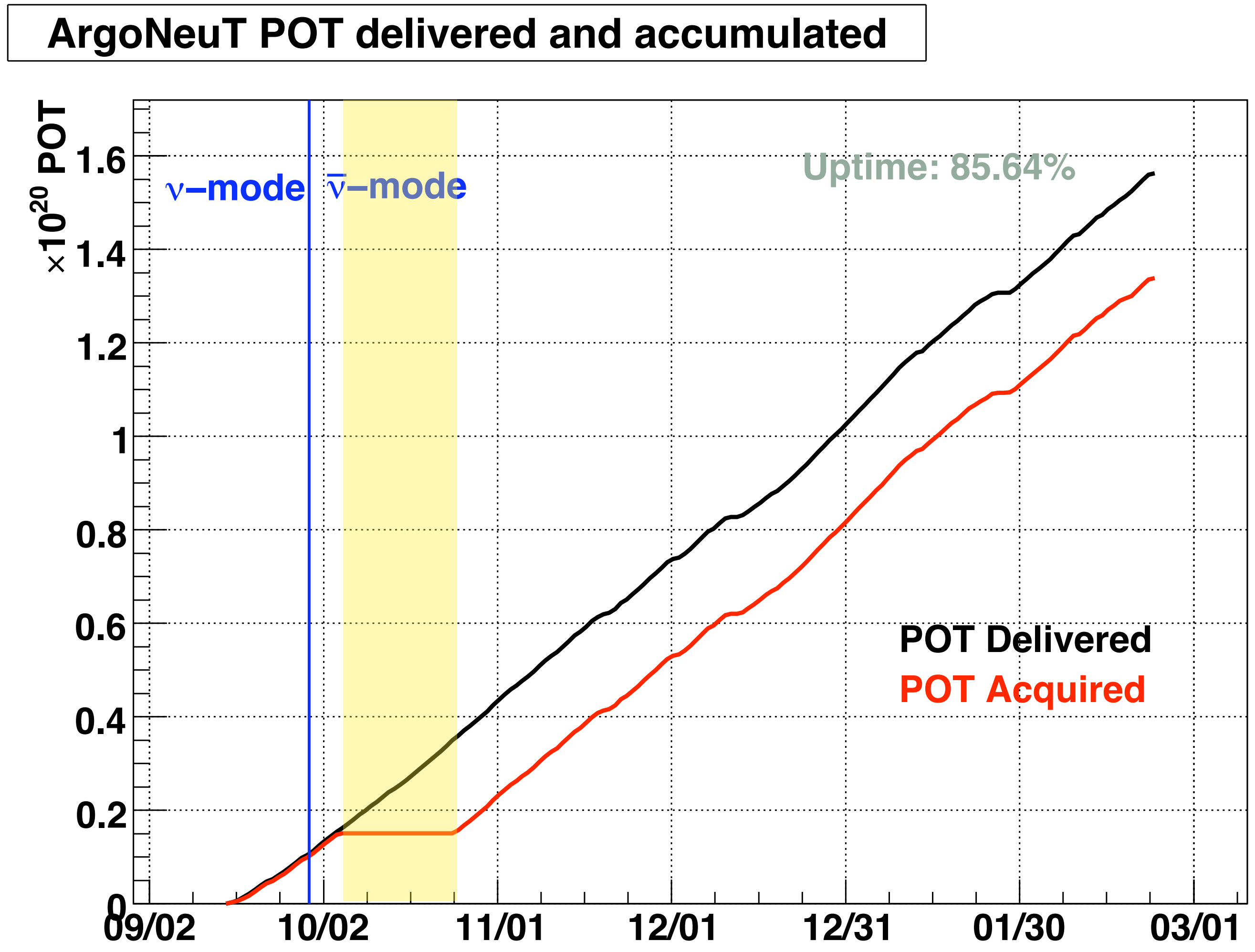




University / Fermilab R&D Experience for ArgoNeuT

How Did It Come About?

- 2006: Bonnie Fleming receives NSF Career Grant to operate small LArTPC at Fermilab in NuMI location where PEANUT (Fermilab T952) had run previously.
- 2007: Fermilab MOU for T962 is approved. Design/construction of detector begins.
- Summer 2008: Commissioning run at the Proton Assembly Building.
- Spring 2009: Detector moved into NuMI tunnel and prepared for operations.
- Spring 2009 - Feb. 2010: Operations in NuMI beam, predominantly in antineutrino mode after summer 2009 shutdown. 1.35×10^{20} Protons on Target (POT) collected.
- Spring 2010: Detector removed from NuMI and taken to Lab F for a vacation.
- Present Day: Data Analysis



Data Taking: Sept. 2009-Feb. 2010

What Made it Successful?

- Funding from NSF/DOE a huge part of making this project possible.
- A major reason for any success we have had is because of the support we received from Fermilab engineers/technicians/staff.
    - Fermilab personnel helped significantly with:
        - TPC fabrication
        - Cryogenic design/fabrication
        - Process controls monitoring system design/fabrication
        - Safety analysis
        - Installation/logistics
        - Computing
- Another reason for success would be the combination of R&D with neutrino data that should lead to real physics results.
    - Opportunities for publications (PRL, PRD, NIM, etc...) obviously very important for young collaborators...enables them to participate.
- The combination of lab and university collaborators was very important. Fermilab collaborators provided invaluable assistance in navigating the Fermilab system (administrative details, requesting resources, etc...)...we would have been clueless without them. Fermilab also provided infrastructure most universities would never have (wire-winding machines, cryogenic engineers, etc...).

Challenges? Advice?

- ArgoNeuT was a rather large test project, and being a test (T) instead of an experiment (E) had its advantages and disadvantages
  - Advantage: Allowed for fairly rapid development (i.e. - minimum of reviews)
  - Disadvantage: Meant we were at the bottom of the priority list for resources (welders, techs, engineering, etc...) compared to experiments.
- Some other minor things:
  - Develop relationships with the local lab personnel as soon as you can, they will be your best resource for getting things done.
  - For a long time I was making small purchases every day for ArgoNeuT...and I needed the materials immediately. Doing this through Fermilab PO system was far too slow, so I relied almost exclusively on my Yale purchasing-card.

How Has the Experience Carried Over?

- First results from ArgoNeuT will appear within the next year, and will provide valuable evidence of performance capabilities of LArTPCs in the neutrino energy range of interest.
- Reconstruction/Simulation software development that is significantly driven by ArgoNeuT collaborators doing data analysis will be reutilized in future LArTPC experiments (MicroBooNE, LBNE).
- Interest from international institutions has developed, and hopefully will help enable future collaborations.
- The safety analysis done for ArgoNeuT in the NuMI tunnel has been referenced by folks at DUSEL looking into future cryogenic detector (neutrinos/dark matter) installations underground.