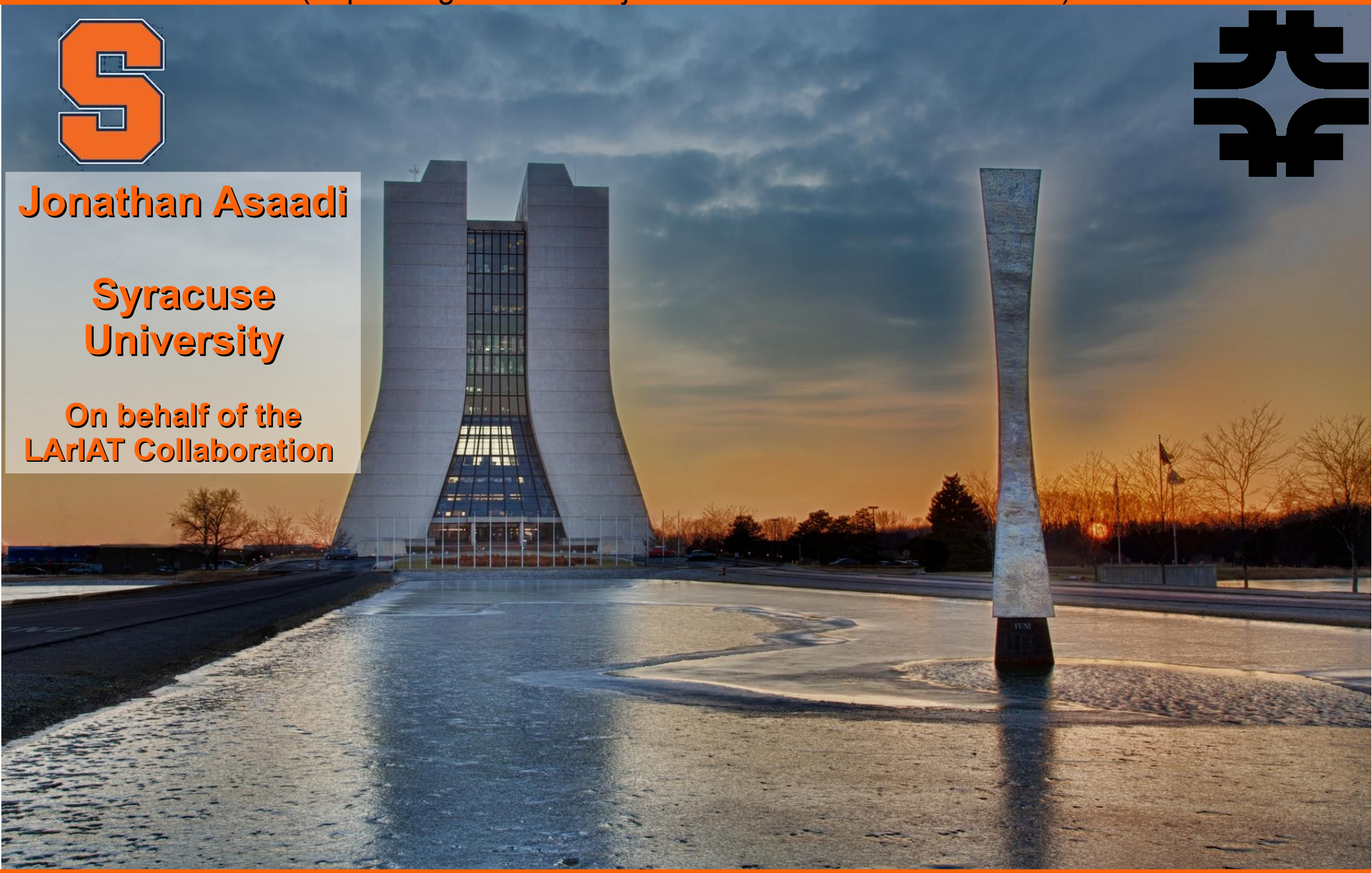
The LArIAT Experiment (T-1034)

(**L**iquid **Ar**gon Time Projection Chamber **I**n **A** **T**estbeam)



Jonathan Asaadi

Syracuse University

On behalf of the LArIAT Collaboration

Outline

- **Motivation & Plan**
  - Comprehensive understanding LArTPC's capabilities
  - LArIAT Phase I and Phase II
  - LArIAT in the scheme towards LBNE
- **Tools**
  - Fermilab Test Beam Facility
  - Repurposing the ArgoNeuT Detector
- **Physics Goals of Phase I**
  - Electron / Photon Shower Separation
  - Optimization of Particle ID
  - Non-magnetic Muon Sign Determination
  - Study of anti-proton ($\bar{p}$) events in LAr
- **What's to come...**

Motivation

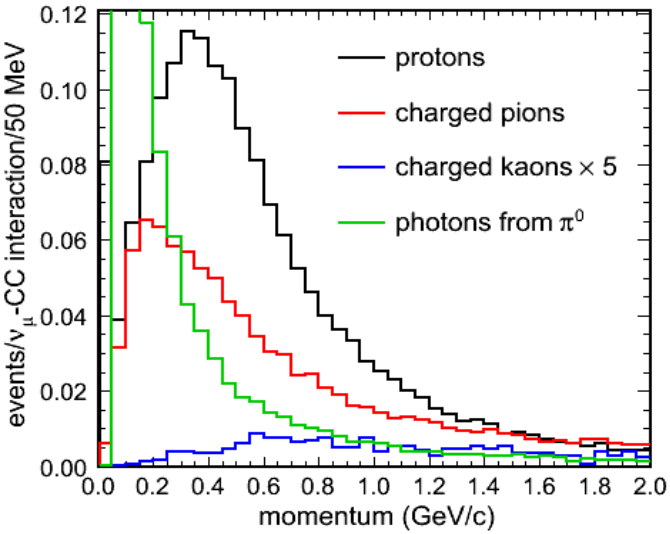
Understanding LArTPC's Capabilities

Calibration is one of the critical steps to understanding the response of any detector.

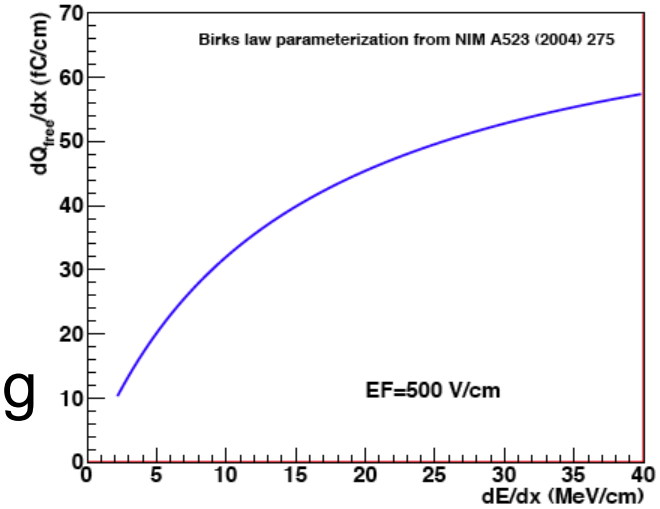
"Every new detector (e.g., trackers, calorimeters, etc...) is (usually) 'calibrated' before physics application."
- Some Physicists

Important question to come out of the 2009 Fermilab-sponsored LAr R&D review:
"*How well known are the **energy resolution** and **particle identification** capabilities of LArTPCs?"*

The LArIAT collaboration was formed to address this question as well as facilitate further characterization of LArTPC performance by placing a LArTPC in a charged particle test beam.



Particle spectra created in neutrino interactions in the NuMI low energy beam, similar to the planned beam from Fermilab to Homestake.



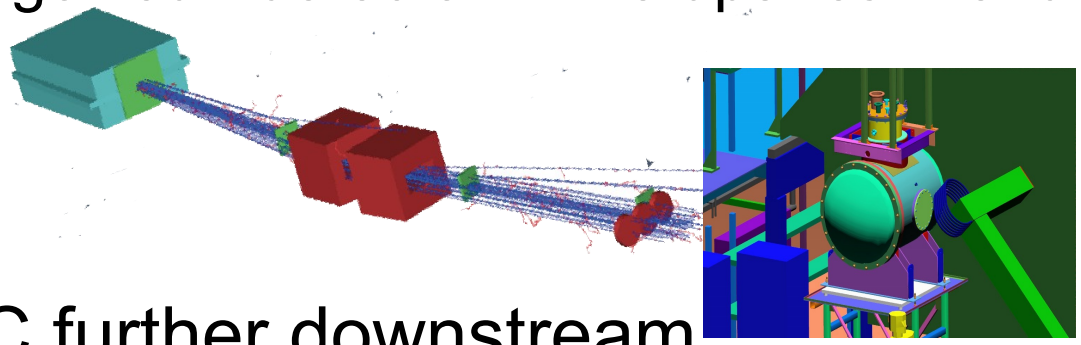
Relationship between the collected ionization charge at the TPC wires and the energy deposited in LAr by incident particles of different types and stopping powers

LArIAT Phase I and Phase II

Staged LArIAT Program at Fermilab

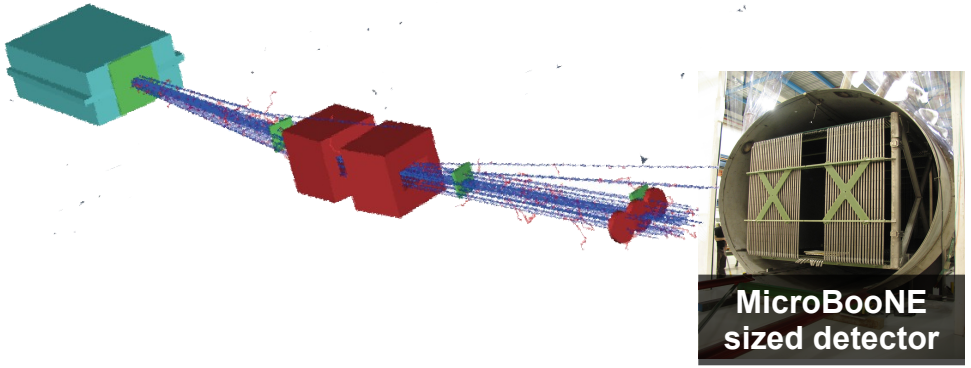
Phase-I: Repurpose the ArgoNeuT detector in the upstream end of beamline

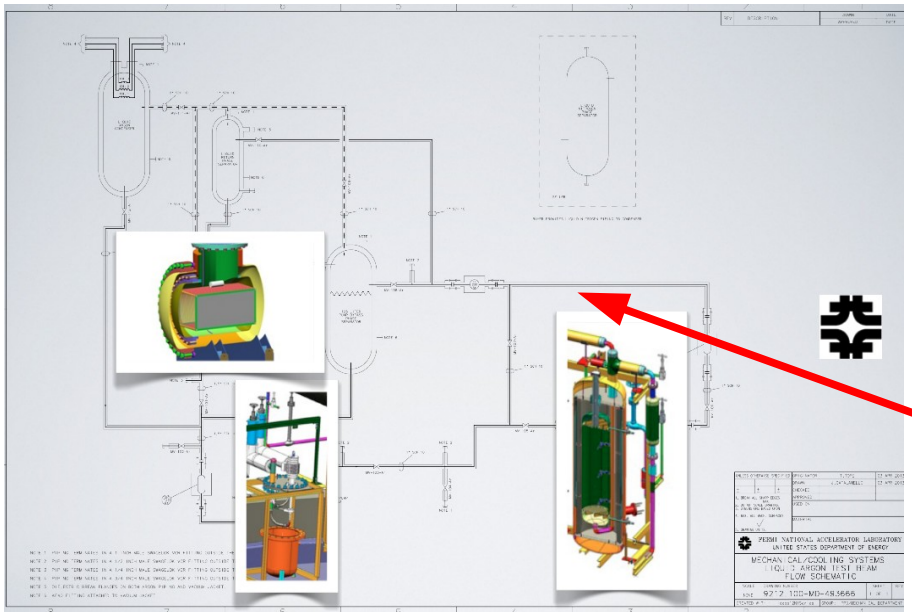
Relatively quick turnaround



Phase-II: Larger LArTPC further downstream

Design facility for broader, longer-term use





One unique cryogenic/purification facility at FNAL designed to operate for both phases

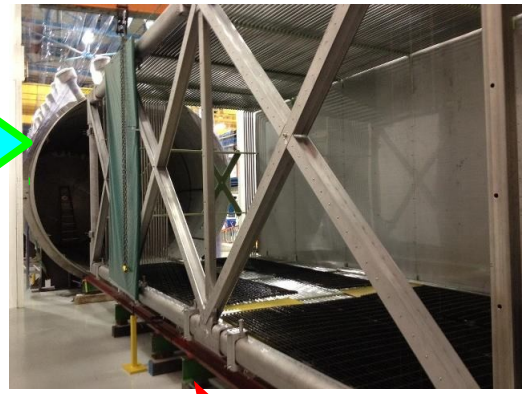
Motivation

LArIAT on the Liquid Argon Roadmap

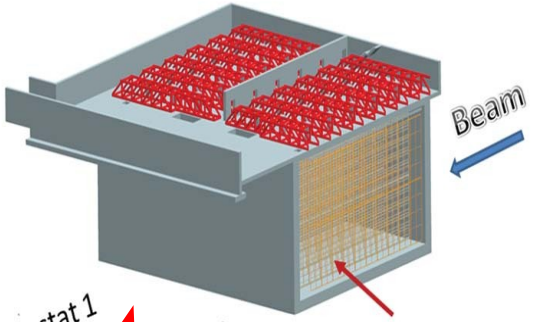
Neutrino Physics Experiments

ArgoNeuT

MicroBooNE



LBNE

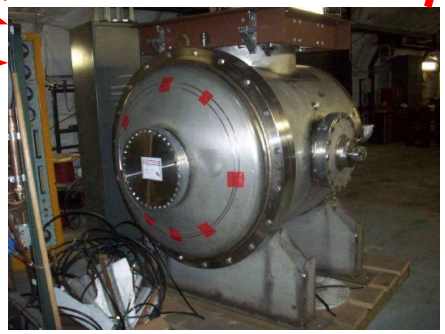


LArIAT provides input to many of the necessary items that will help make MicroBooNE & LBNE successful.

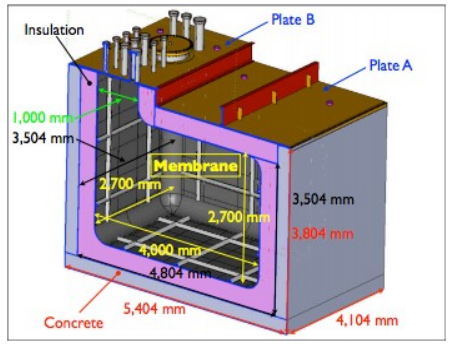
R&D Detectors

Bo
(Electronics / Readout)

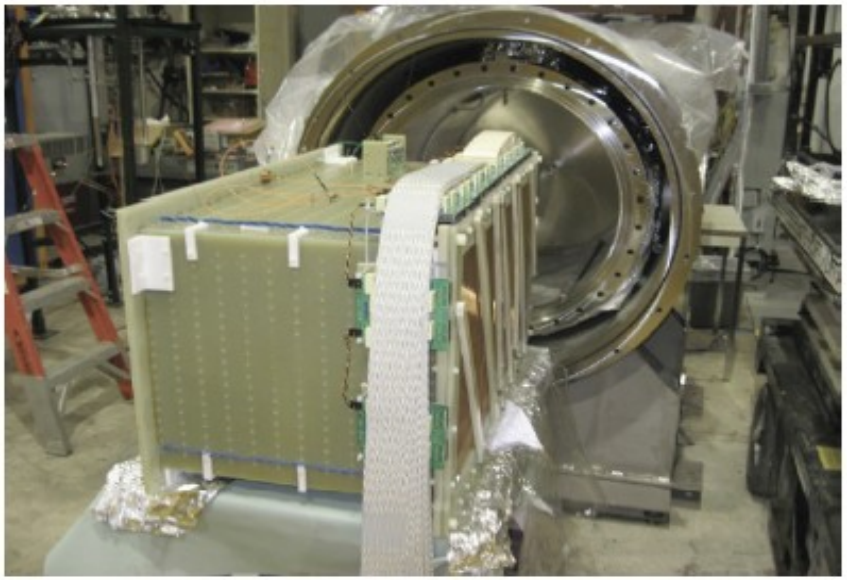
Long Bo in LAPD
(High Voltage, Cold Electronics, Purity)

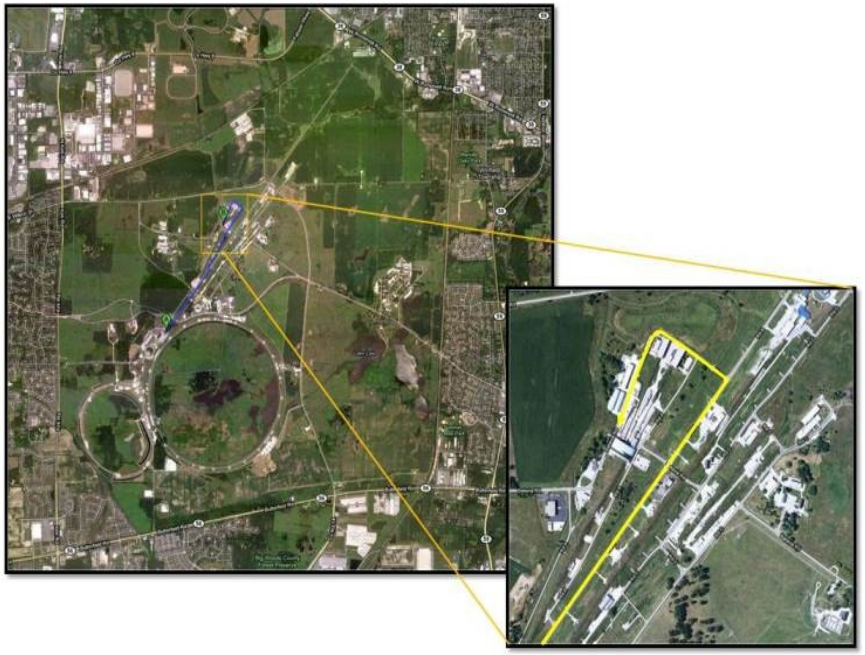


LArIAT
(Detector Response, Particle ID, dE/dX, e/g separation)

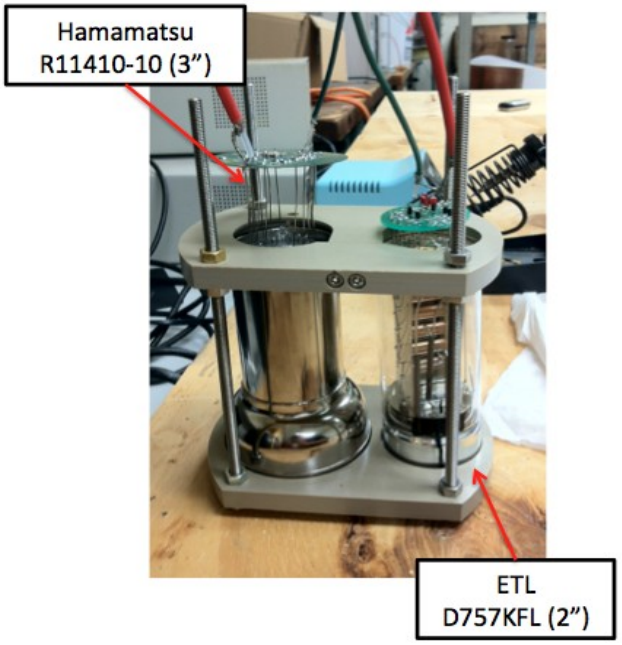


35T Membrane Cryostat
(Purity)

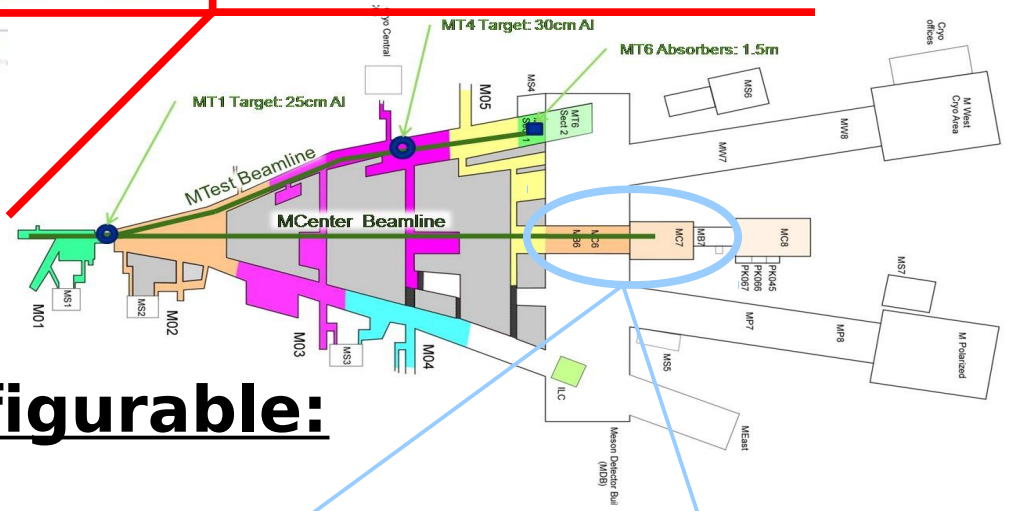




Tools



Fermilab Testbeam Facility



MTest and MCenter are configurable:

Primary beam

Proton Mode: 66-120 GeV protons

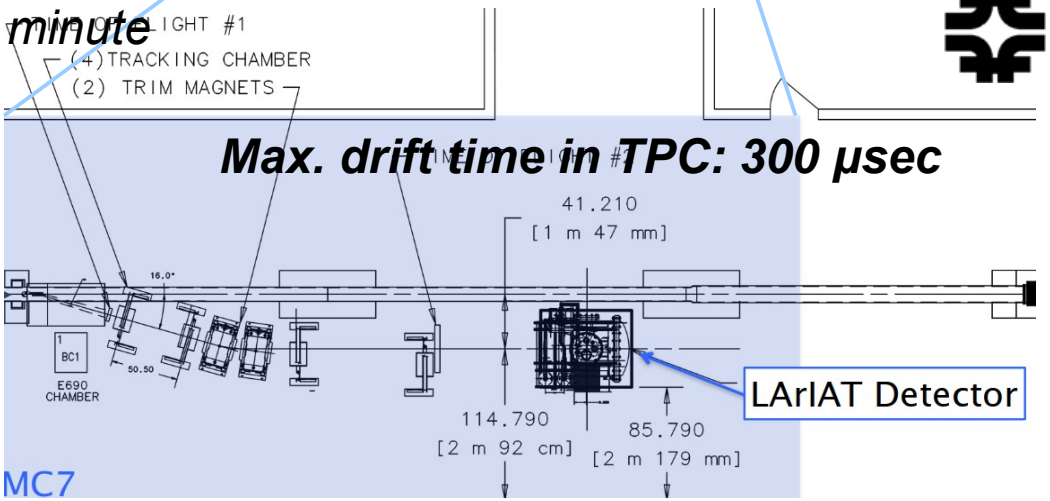
Secondary beam

300k particles/spill max, one 4-second spill per minute
(~30-40 particles crossing detector per spill)

Pion Mode: 8-66 GeV beam
Low Energy Pion Mode: 1-32 GeV beam
Muon Mode: 1-32 GeV beam

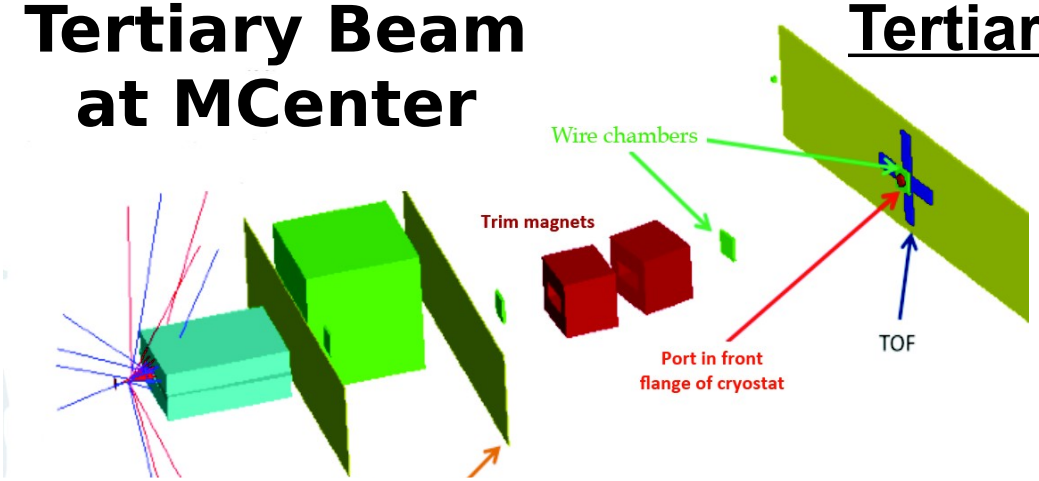
Tertiary beam

Low Energy Pion Mode: 200 MeV - 3 GeV



Fermilab Testbeam Facility

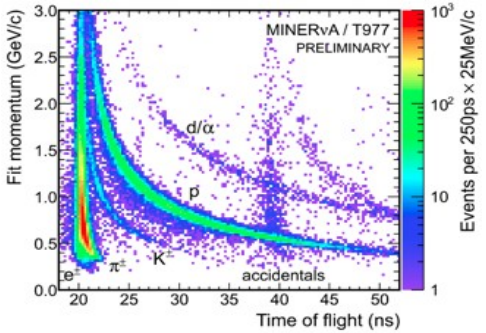
Tertiary Beam at MCenter



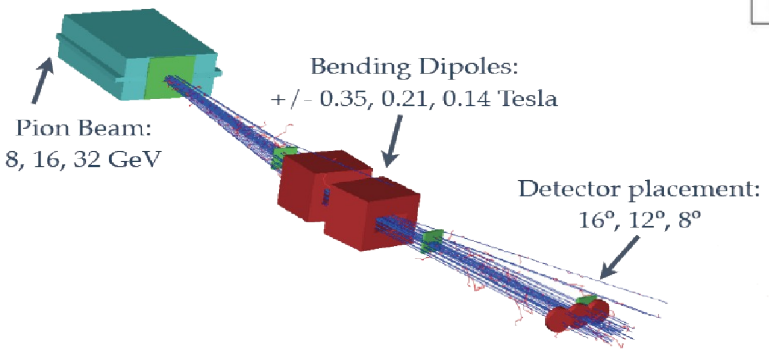
Tertiary beam components have been moved from MTest to MCenter and set up in the same configuration.

Tertiary beam (identical to MINERvA beam test):

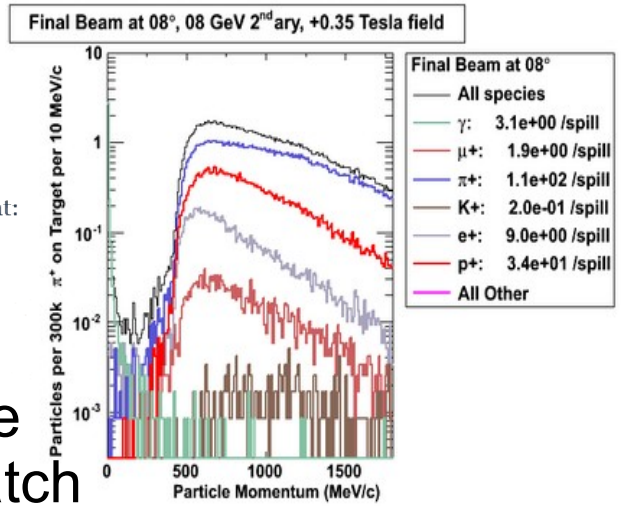
- Cu target in secondary beam
- Collimator at 16 degrees
- Pair of trim dipole magnets
- MWPCs for tracking

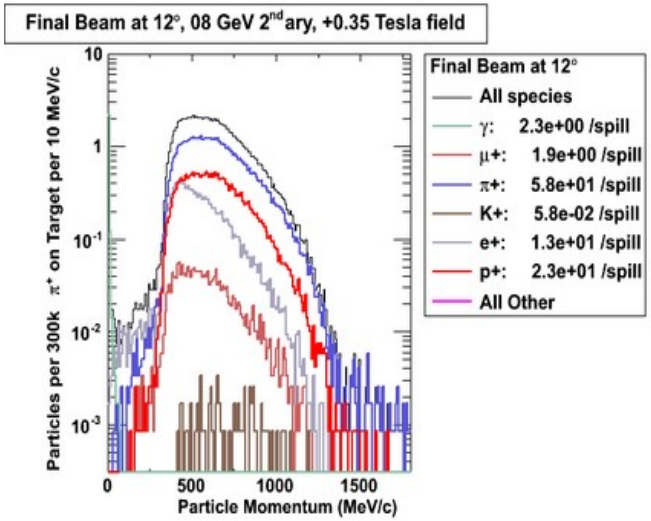


Tertiary beam composition as measured in MINERvA calibration run at MTest



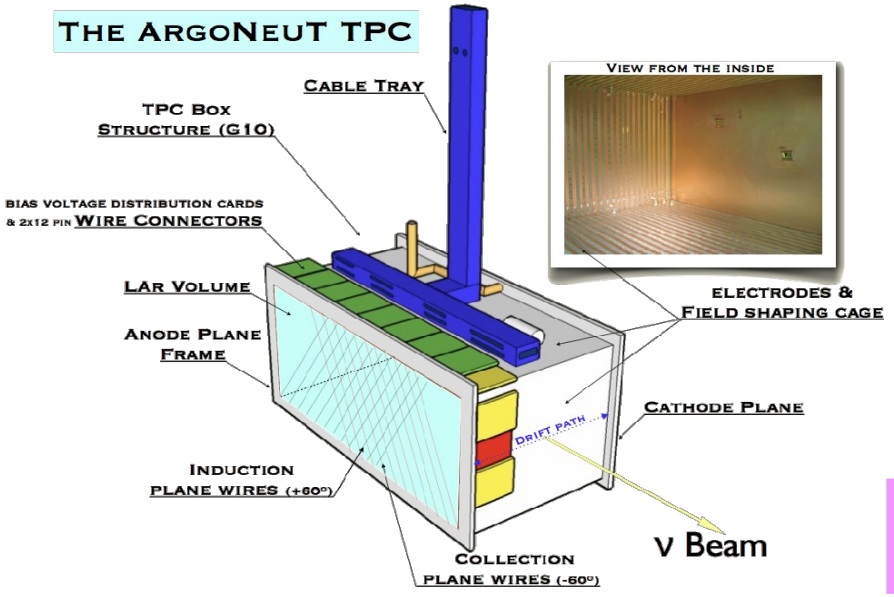
Studies indicate we can tune the beam configuration to better match the spectrum from neutrino beams

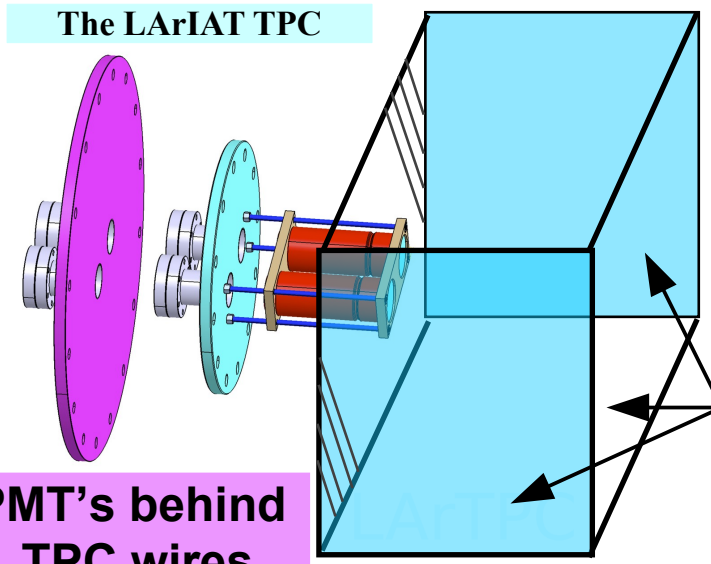




Repurposing the ArgoNeuT Detector

Modifying the TPC



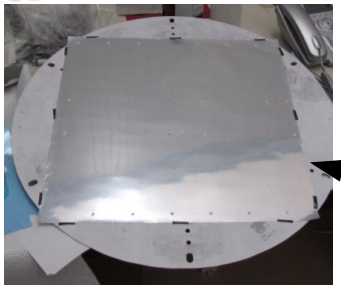


PMT's behind TPC wires

Two cryogenic PMTS

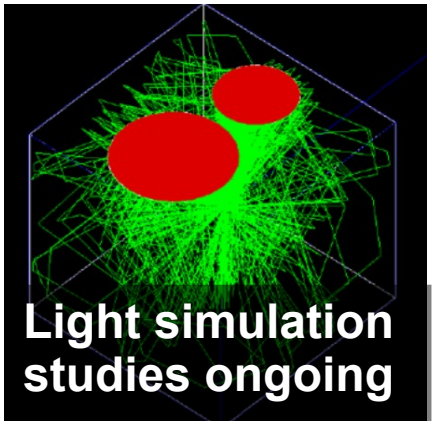
- one 3" high QE (30%)
- one 2" standard QE (20%)

Wavelength shifting reflector foil lining the TPC to give uniform light yield



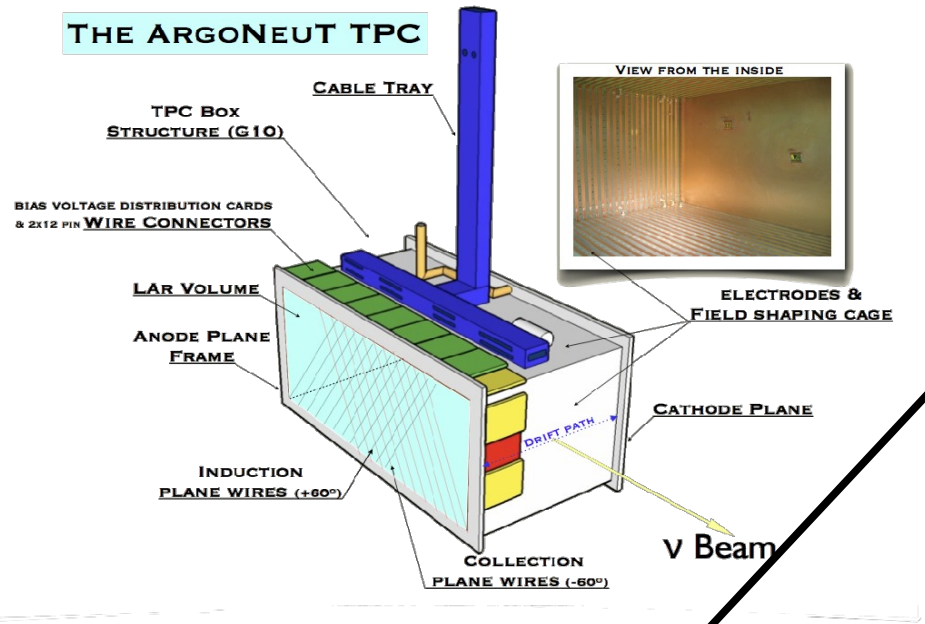
Applying TPB to the reflective foil that will line the inside of the LArIAT TPC

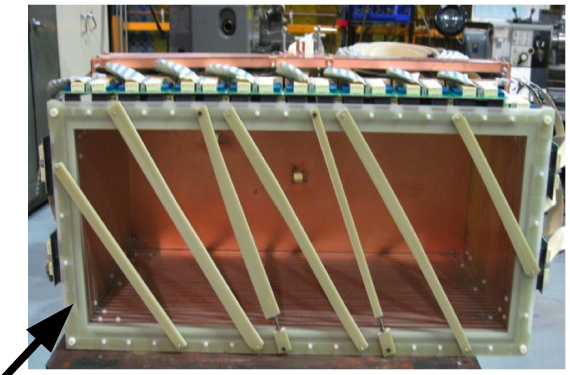
Light collection system in LArIAT allows further exploration of the relationship between energy deposited and charge collected as well as between the energy deposited and light collected.



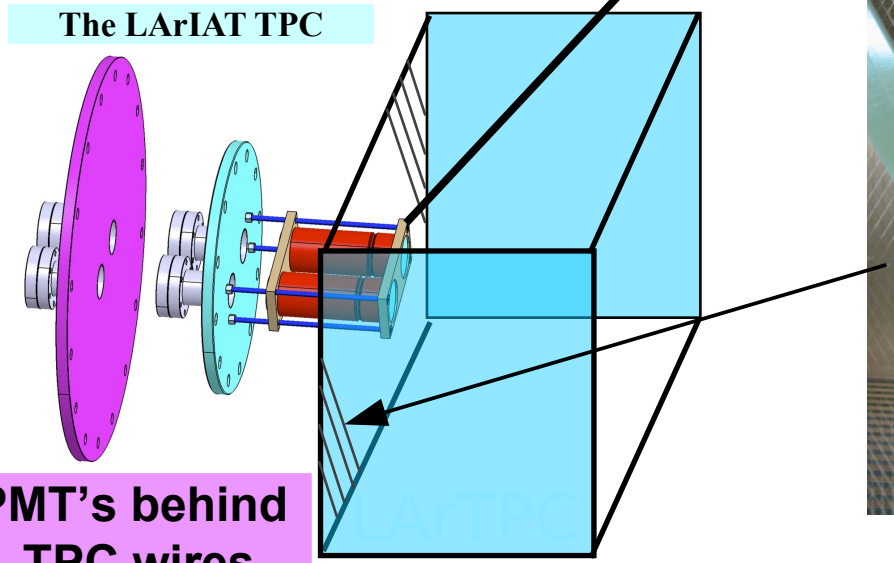
Repurposing the ArgoNeuT Detector

Modifying the TPC





Modify the existing TPC wire frame support structure in order to remove any interference with the PMT's

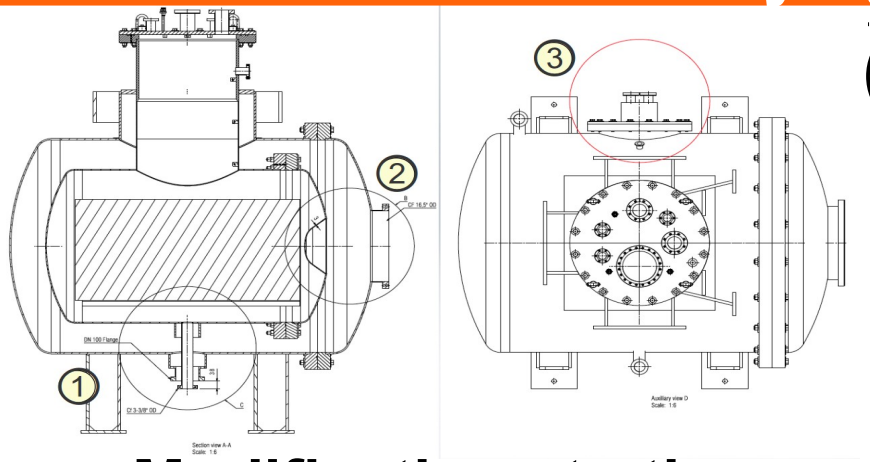


PMT's behind TPC wires

Additionally, we plan to restring the existing wire planes which have been in place since the ArgoNeuT era

Repurposing the ArgoNeuT Detector

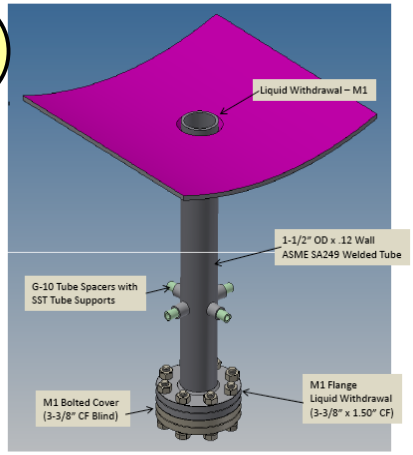
Modifying the Cryostat



Modifications to the ArgoNeuT Cryostat

1) **Better Purity:** Bottom port added for cryogenic circulation pumping on the liquid
2) **Beam Window:** Modify the front flange to allow for charged particle beam
3) **Light Collection:** Modify a port for the cryogenic PMTs

1



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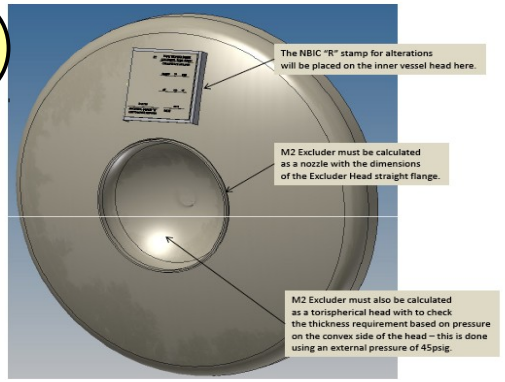

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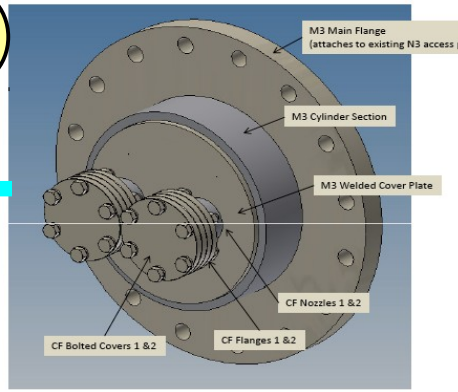
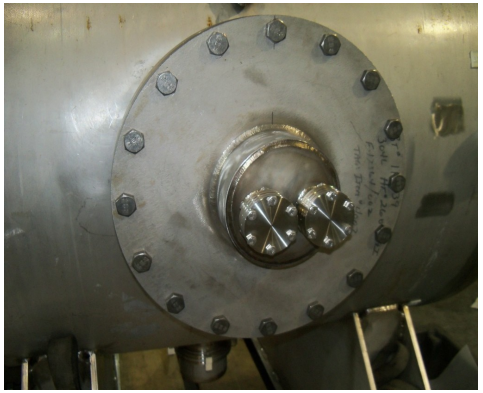
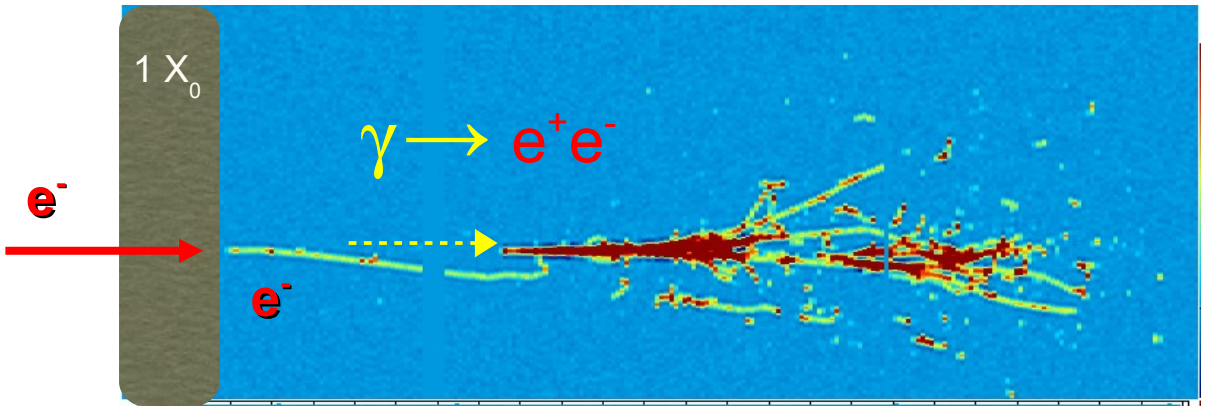




Physics Goals

Electron / Photon Shower Separation

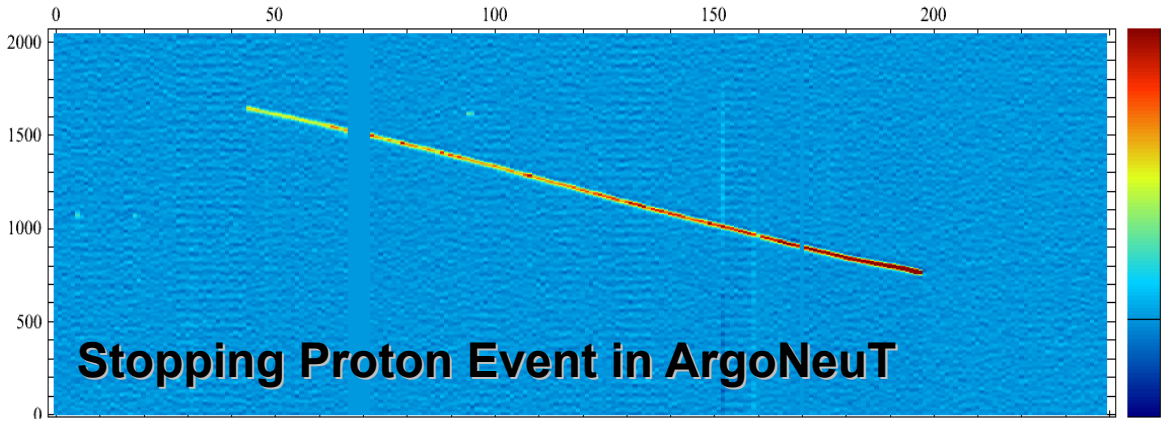


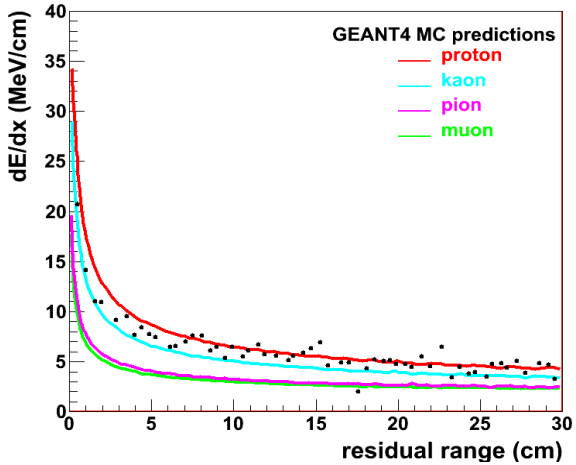
LArIAT's large electron (e) tagged event sample will **experimentally measure** separation efficiency and sample purity for e-induced vs. photon (γ)-induced showers in a liquid argon TPC:

- e/γ separation is a **key feature of LArTPC technology**

- **Only initial part of the shower is necessary** for e-γ separation, making LArIAT Phase-I an ideal place to measure separation power experimentally and compare to simulation

Optimization of Particle ID





High-statistics test beam data will allow LArIAT to **experimentally determine** many of the Particle ID parameters relevant to neutrino oscillation experiments and proton decay searches:

- Proton ID, proton-to-Kaon separation (Rejection/Efficiency)

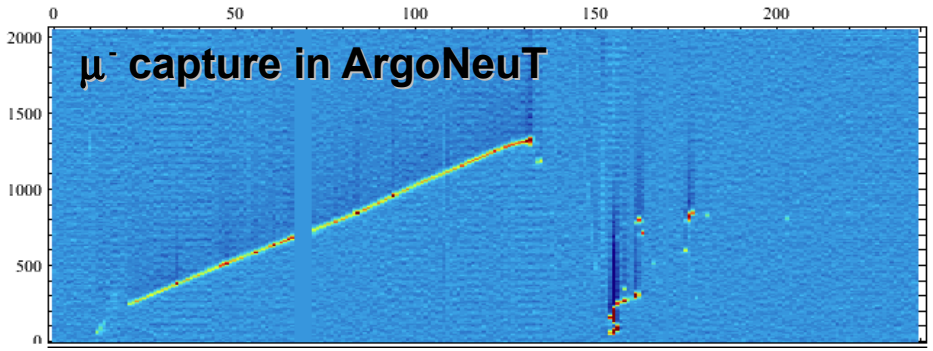
- Kaon ID, Kaon-to-π/μ separation (Rejection/Efficiency)

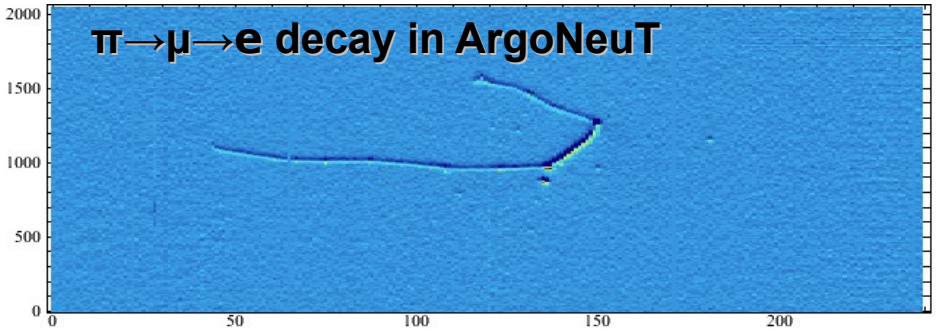
- dE/dx vs Residual Range for contained tracks

Using testbeams (unlike neutrino beams) you know which particles you are inputting into the detector and thus test your ID

See B. Baller's Talk from Saturday
"Results from the analysis of highly ionizing stopping protons in the ArgoNeuT detector"

Non-Magnetic Muon Sign Determination





Charge sign determination (w/o a magnetic field) can be obtained for particles which stop inside a LArTPC using statistical analysis

– μ^+ decay only with an e^+ emission of a known energy spectrum

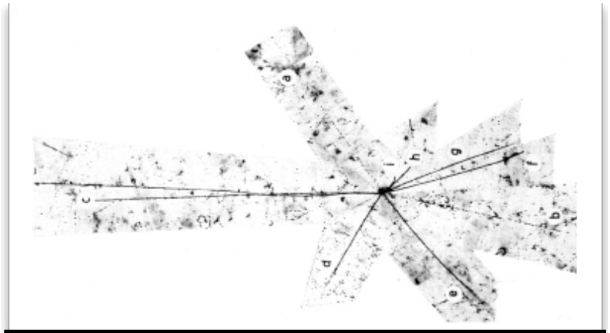
– μ^- capture on a nuclei (~ 75%, followed by a γ/n emission) or decay (~25%)

Systematic study of μ- capture in LAr has never been performed

LArTPC sign determination capability has yet to be explored.

Beams with tunable polarity will provide **data for direct measurement of the sign separation** efficiency (and purity) for muons and pions

Study of $\bar{p}$ events in LAr



Antiproton Star Observed in Emulsion*

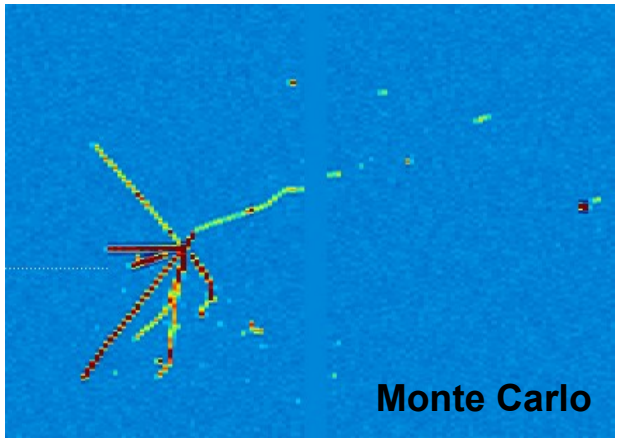
O. Chamberlain, W. W. Chupp, G. Goldhaber, E. Segrè, and C. Wiegand, *Radiation Laboratory, Department of Physics, University of California, Berkeley, California*

and

E. Amaldi, G. Baroni, C. Castagnoli, C. Franzinetti, and A. Manfredini, *Istituto di Fisica della Università, Roma Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Italy*

Low momentum anti-protons in the beam (even at a small rate) will allow the first study of hadron star topology from p-$\bar{p}$ annihilation at rest in Argon

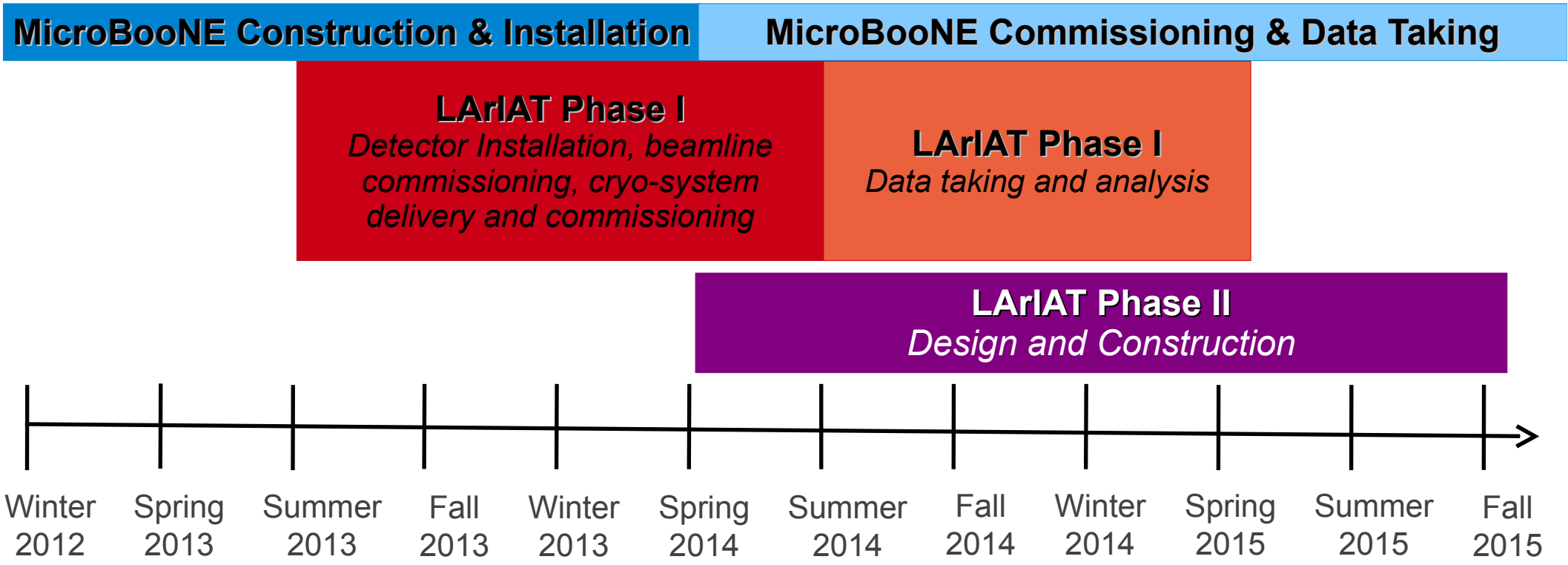
- $\pi^{\pm}$, π^{0}, $K^{\pm}$, etc.. multiplicity in hadron stars can be accurately determined utilizing LAr imaging detector capabilities.



- This information is very relevant for n-$\bar{n}$ oscillation searches at future large LArTPC detectors.

What's to come...

Timeline
(Best projection)



- Modified Cryostat now at MCenter
- TPC modifications starting at Fermilab soon
- MCenter beamline on schedule for operation in Summer 2013

Conclusions

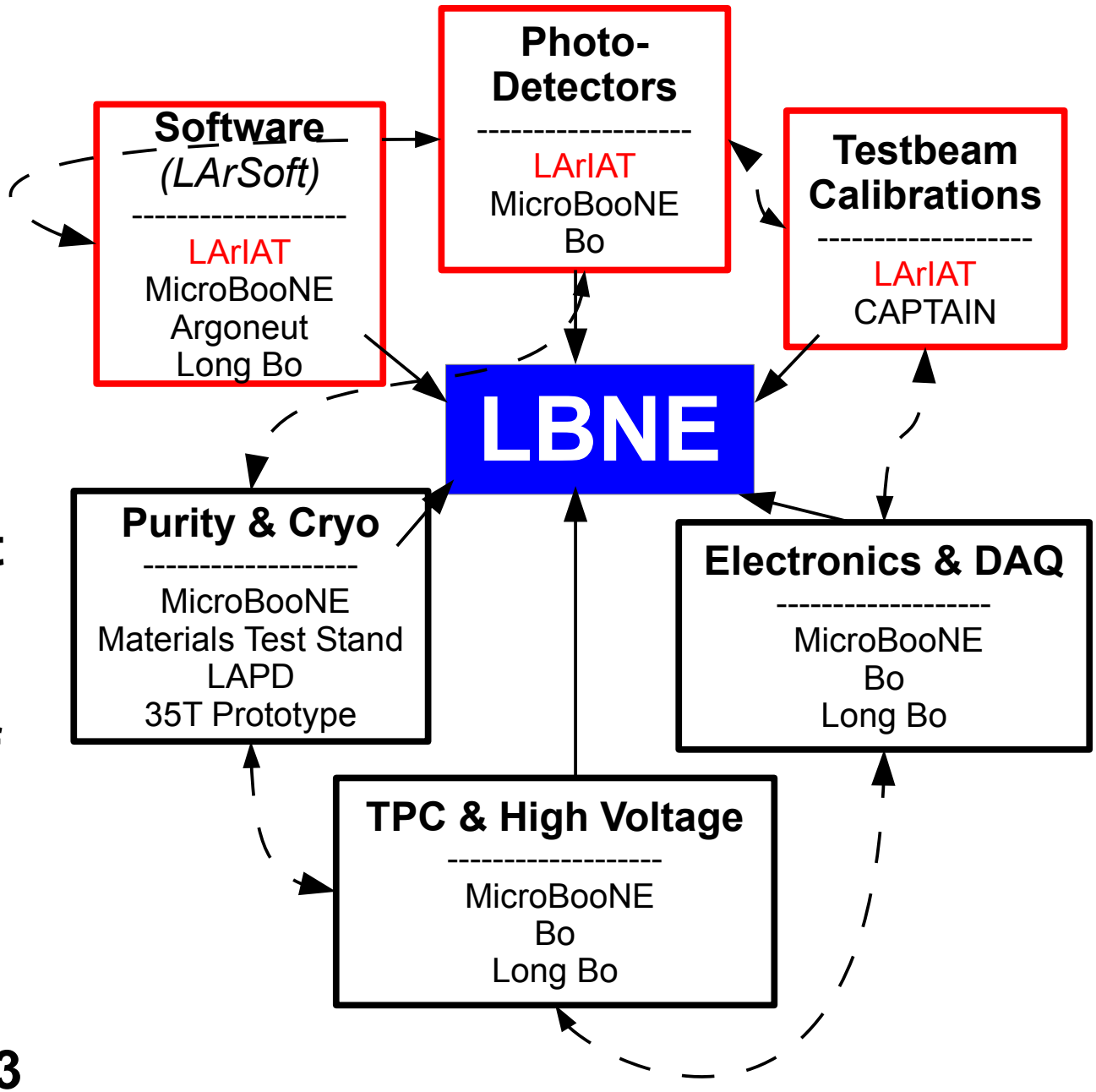
LArIAT is an important component of Liquid Argon detector R&D

A consensus in LAr community deems it necessary!

Interesting and robust set of R&D/physics goals

Well aligned with goals of MicroBooNE & LBNE

Off to a good start with lots of momentum heading into summer 2013



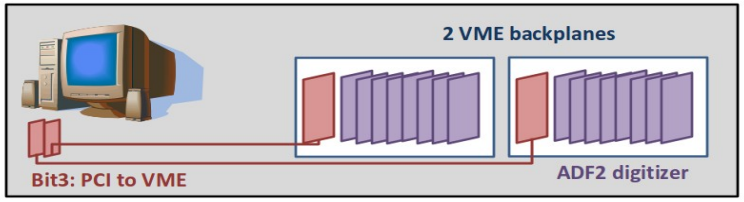
The LArIAT Collaboration:

Fermilab *J. Raaf, B. Rebel, R. Acciarri, P. Adamson, B. Baller, A. Hahn, D. Jensen, M. Kirby, H. Lippincott, A. Marchionni, K. Nishikawa, M. Stancari, G. Zeller*
Yale *B.T. Fleming, F. Cavanna, E. Church, O. Palamara, A. Szelc*
Syracuse U *M.Soderberg, J. Asaadi*
William and Mary *M. Kordosky, P. Vahle*
Michigan State U *C. Bromberg, D. Edmunds*
U Texas Austin *K. Lang, J. Huang*
U Texas Arlington *J. Yu, A. Farbin, S. Park*
U Chicago *D. Schmitz*
U Cincinnati *R. Johnson, J. St. John*
U Minnesota Duluth *A. Habig, R. Gran*
U College London (UK) *R. Nichol, J. Thomas*
Imperial College London (UK) *M. Wascko*
Manchester U (UK) *J. Evans, P. Guzowski*
U of L'Aquila and INFN Gran Sasso Lab (It) *F. Cavanna*, O. Palamara** (*presently at Yale)
Boston U *E. Kearns*
LSU *F. de Maria Blaszczyk, W. Metcalf, N. Tzanov*

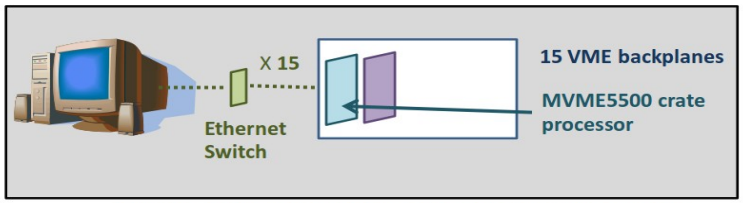
Thank You

Backup Slides

DAQ & Trigger

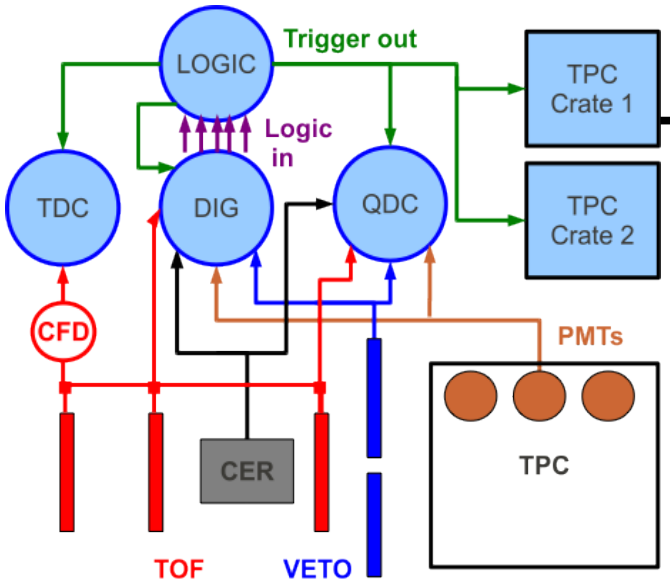


ArgoNeuT: 1.0(0.5) sec to readout 1 event at 200(400) ns/sample



4/5/2013

LArIAT: <0.06 sec to readout 1 event at 400 ns/sample



Non-trivial change: Improve DAQ rate by factor of >10

Existing ArgoNeuT readout system DAQ rate: ~1 Hz

Expected good trigger rate at FTBF: ~ 5-10Hz (~20-40 particles/spill in 4 second spill once per minute)

Speed increase 1:

Implement block data transfers for ADF2 readout x2-4 speed increase.

Speed increase 2:

Move from serial to parallel readout of ADF2 cards x8 speed increase

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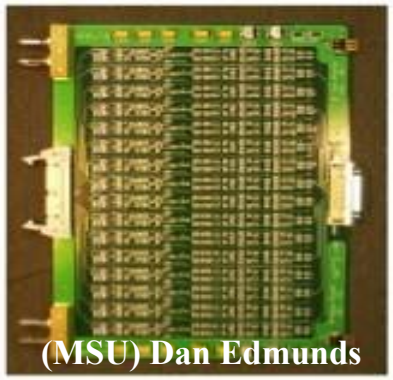
Existing DAQ crate controllers already accommodate an input signal to trigger on the neutrino beam spill and/or internal PMT signals

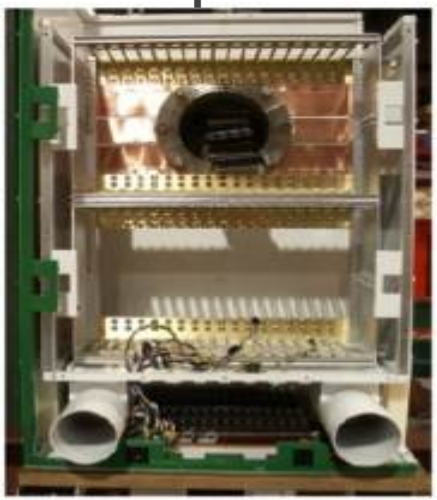
- Use this feature to collect good beam events & reject events with pileup
- Feed information from beam ToF counters, Cherenkov counters, PMTs in vessel, & veto counters into 12-bit digitizer.
- Digitizer will discriminate signals by pulse shape, then send fast logic pulses to FPGA-equipped logic module to test for one or more trigger conditions & enable FEM readout

Electronics

Warm preamp



Preamp card file



ArgoNeuT

480 channels of warm preamp

Signals are a few fC !

Coherent noise fears

Use double shield box, Feed-thru inside box, forced air cooling

Completely disassembled when removed from NuMI

ArgoNeuT was an R&D project over 6 years ago, superceded by 2 generations of cold electronics with significantly better S/N.

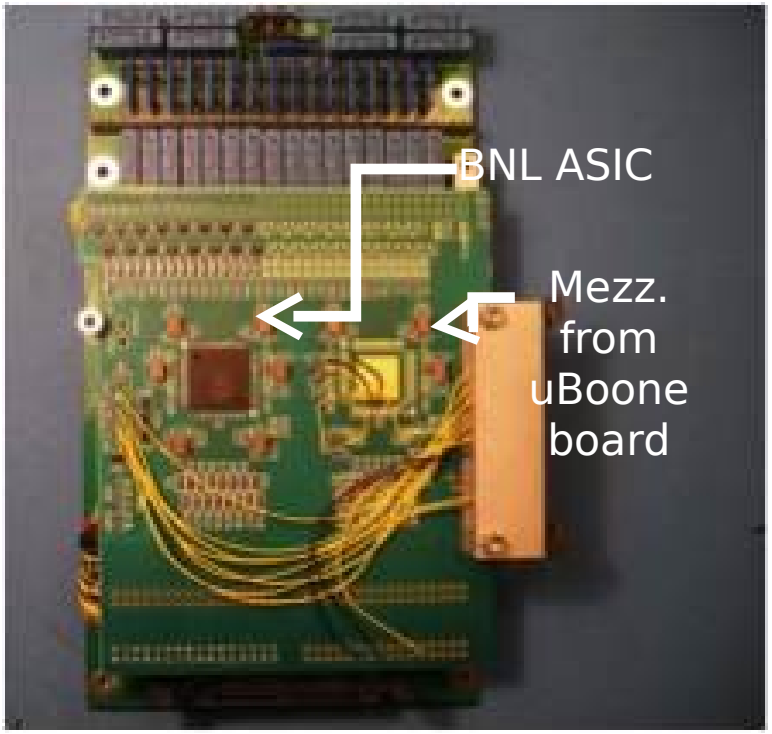
Cryostat provides hermetic shielding of cold preamps from external coherent noise.

Disassembly of old shielding box and removal from NuMI was not performed with the intention of reassembly.

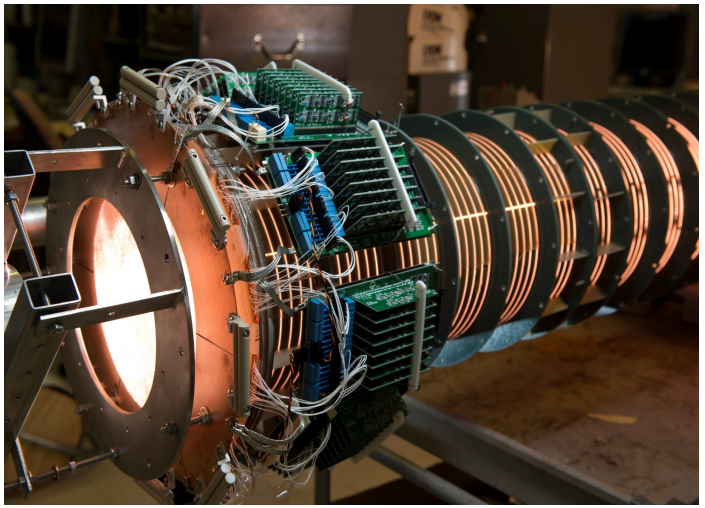
Extensive testing of warm preamps would be required.

Cables must be replaced to avoid water contamination.

Electronics



Modified one MSU 16-channel card to use a BNL ASIC. Installed on the central induction plane



Components

TPC mounted preamp motherboards and cables to feed-thru
Preferred use of 36 BNL ASIC chips (excess MicroBooNE production)
Warm receiver/power for preamps and driving long twisted-pair cables
ADF2 digitizers reprogrammed for 400 ns sampling and fast readout
DAQ software to collect ADF2 data and write to disk