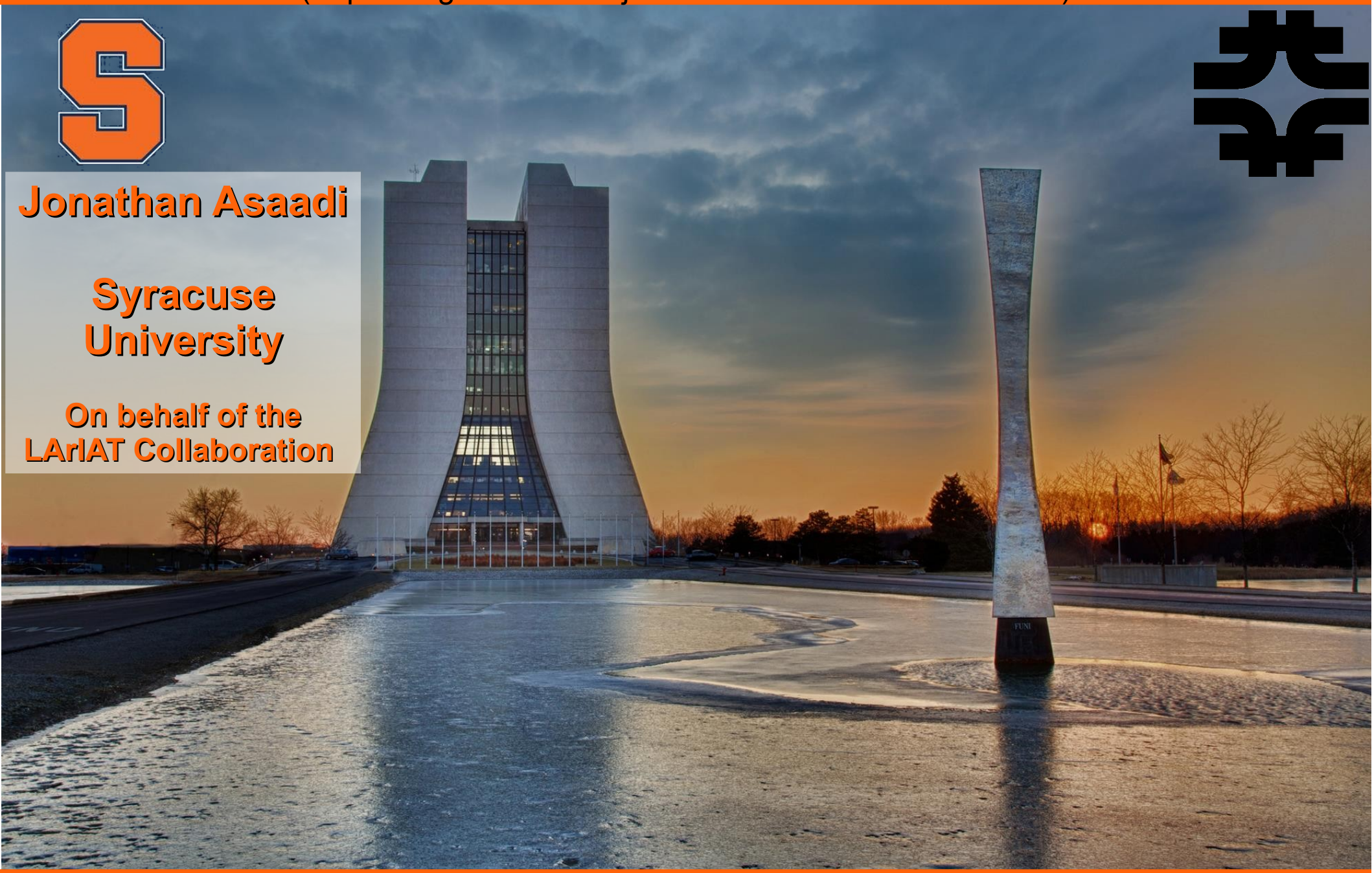
The LArIAT Experiment

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



Jonathan Asaadi

Syracuse University

On behalf of the LArIAT Collaboration

Outline

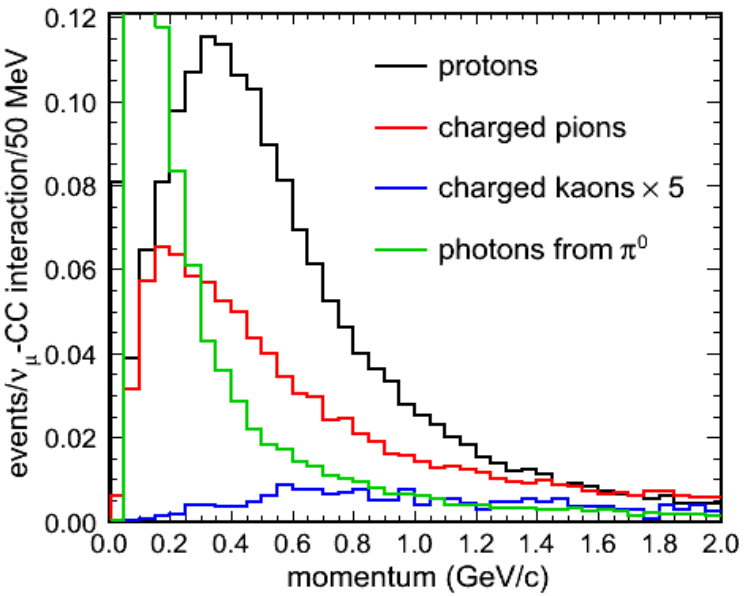
- **Motivation & Plan**
  - Understanding LArTPC's capabilities
  - LArIAT Phase I and Phase II
  - LArIAT in the scheme towards LBNE
- **Tools**
  - Fermilab Test Beam Facility
  - Repurposing the ArgoNeuT Detector
- **Physics Goals of Phase I**
  - Electron / Photon Shower Separation
  - Optimization 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

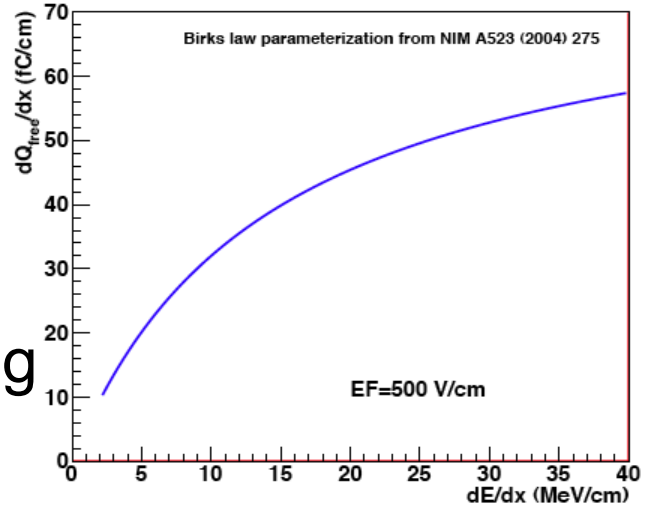
Calibration is one of the critical steps to understanding the response of any detector.

"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.

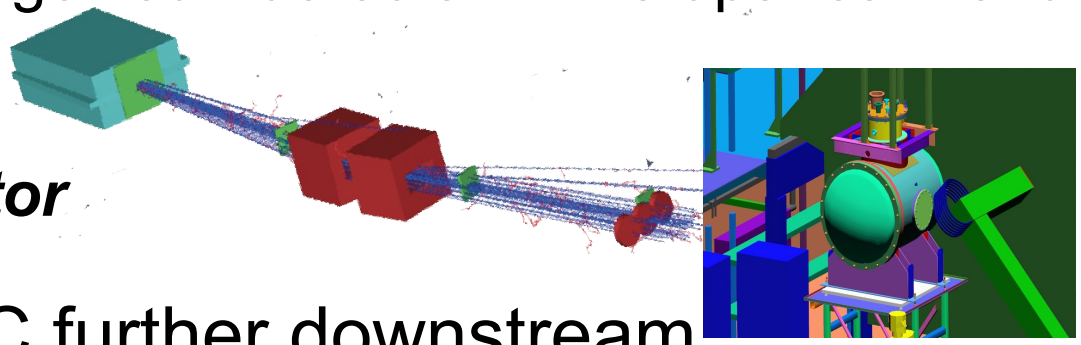


LArIAT Phase I and Phase II

Staged LArIAT Program at Fermilab

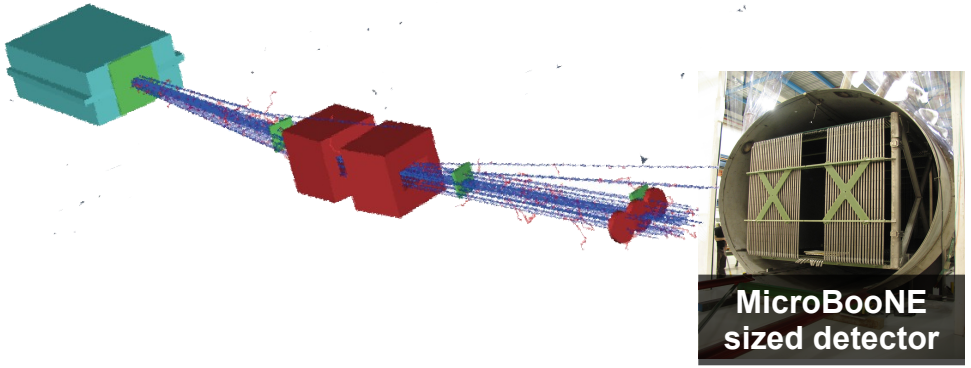
Phase-I: Repurpose the ArgoNeuT detector in the upstream end of beamline

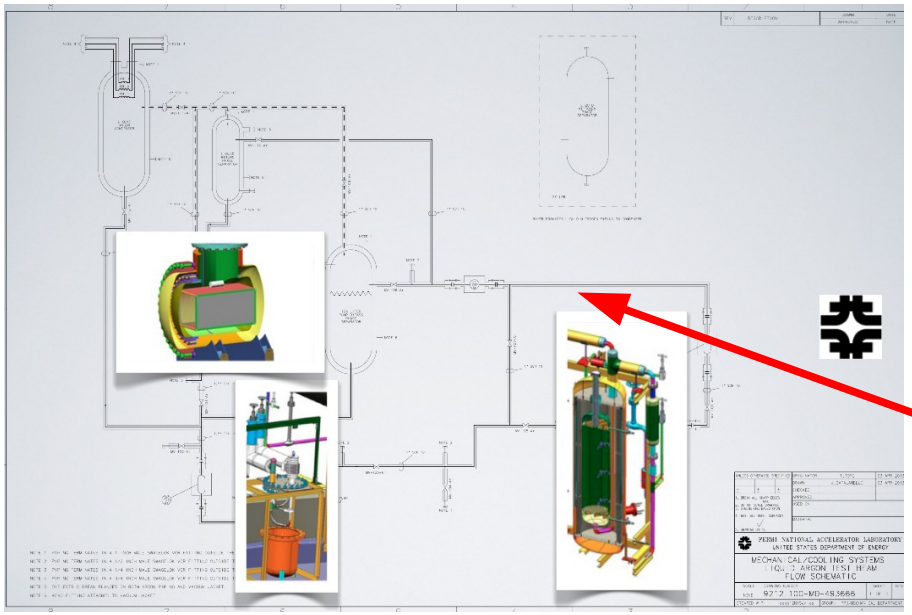
Quick turnaround, no need to design new detector



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

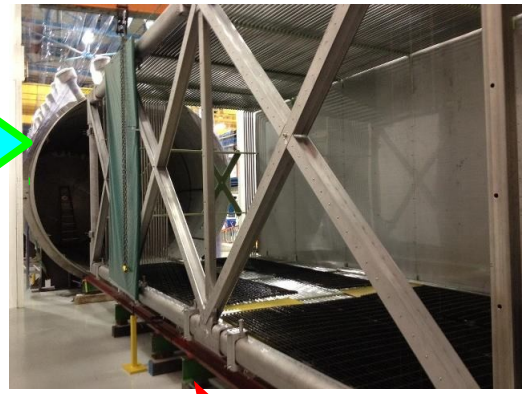
LArIAT on the path towards LBNE

Neutrino Physics Experiments

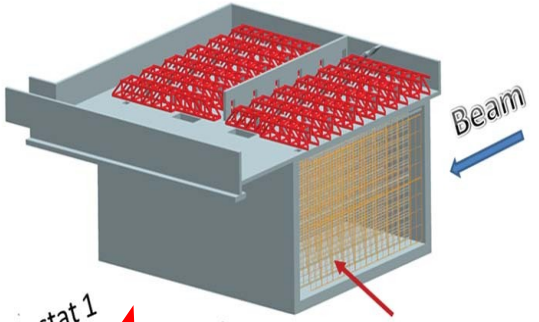
R&D Detectors

ArgoNeuT

MicroBooNE



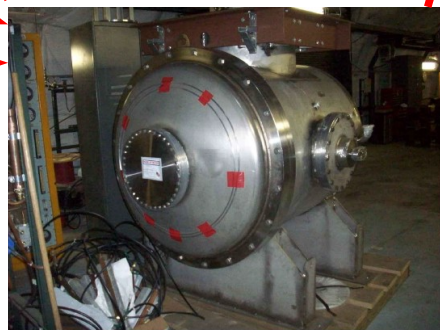
LBNE



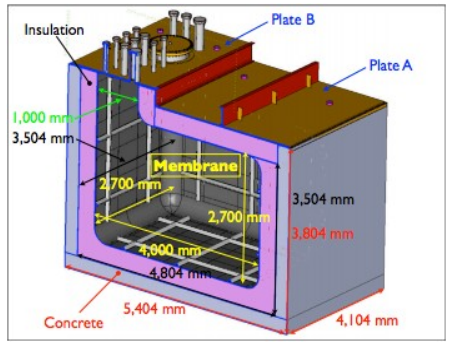
LArIAT provides input to many of the necessary items that will help make MicroBooNE & LBNE successful.

Bo
(Electronics / Readout)

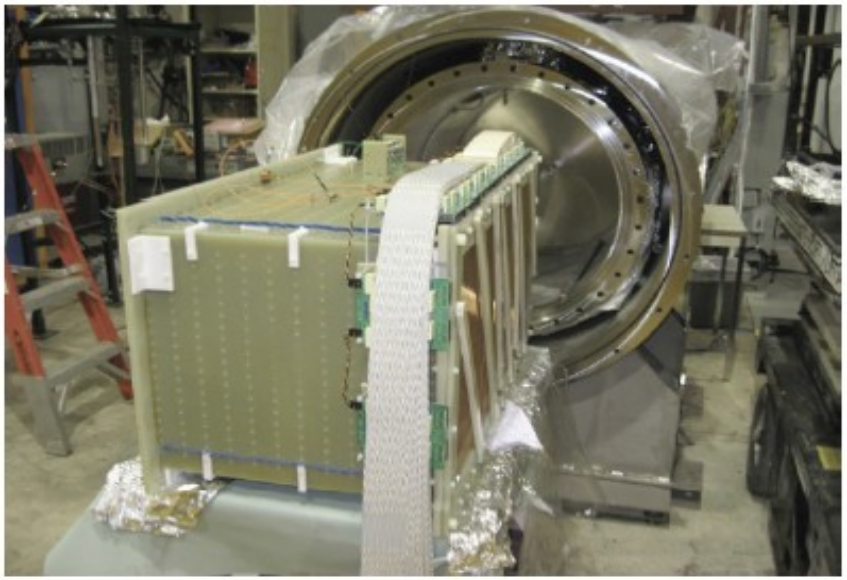
Long Bo in LAPD
(High Voltage, Cold Electronics, Purity)

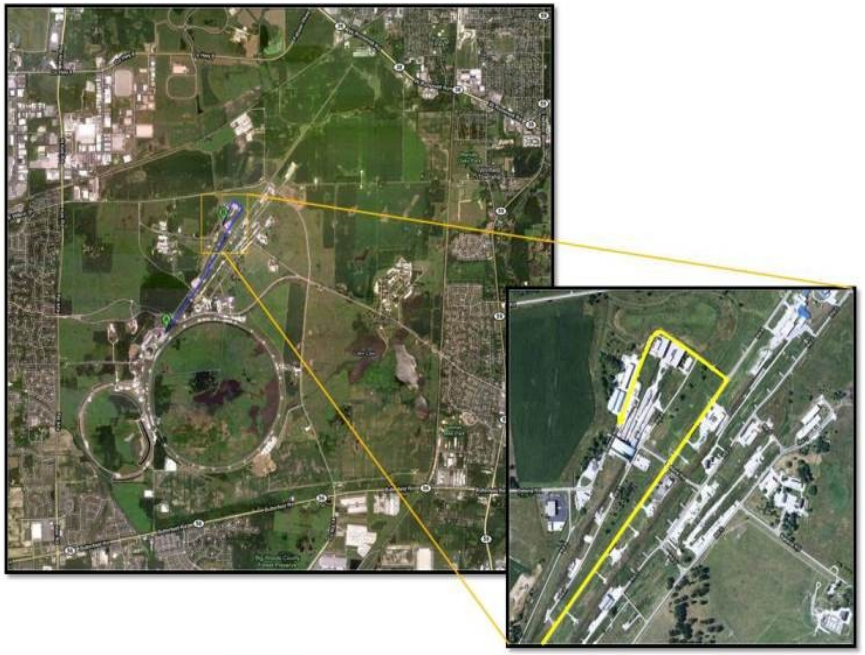


LArIAT
(Detector Response, Particle ID, dE/dX, e/g separation)

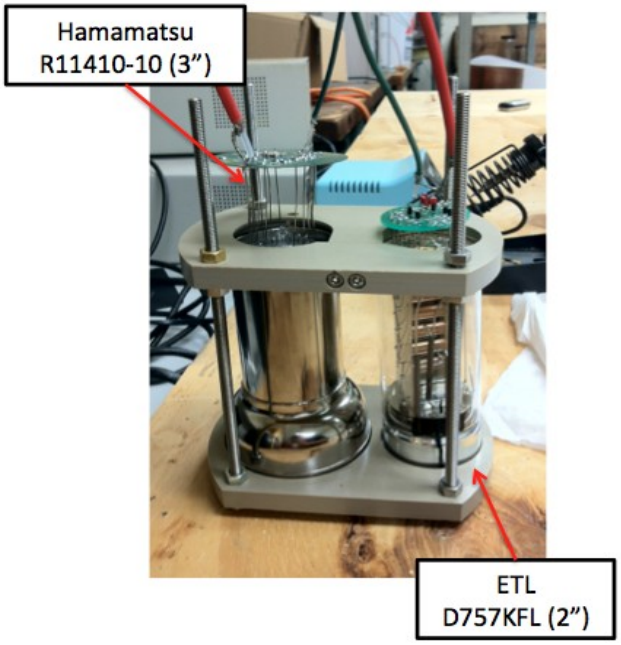


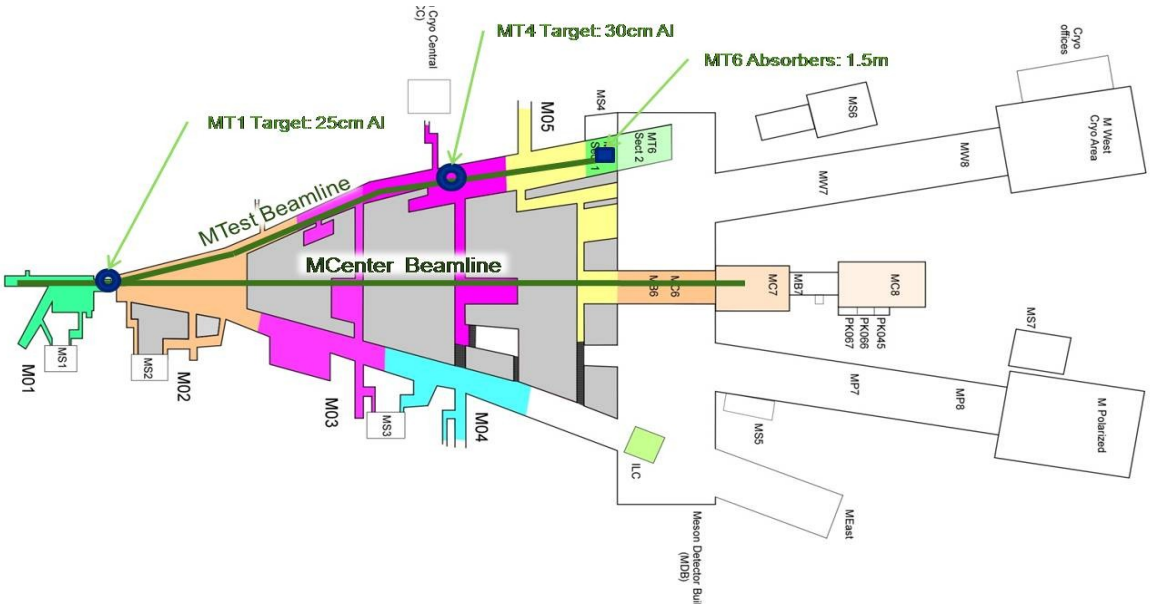
35T Membrane Cryostat
(Purity)



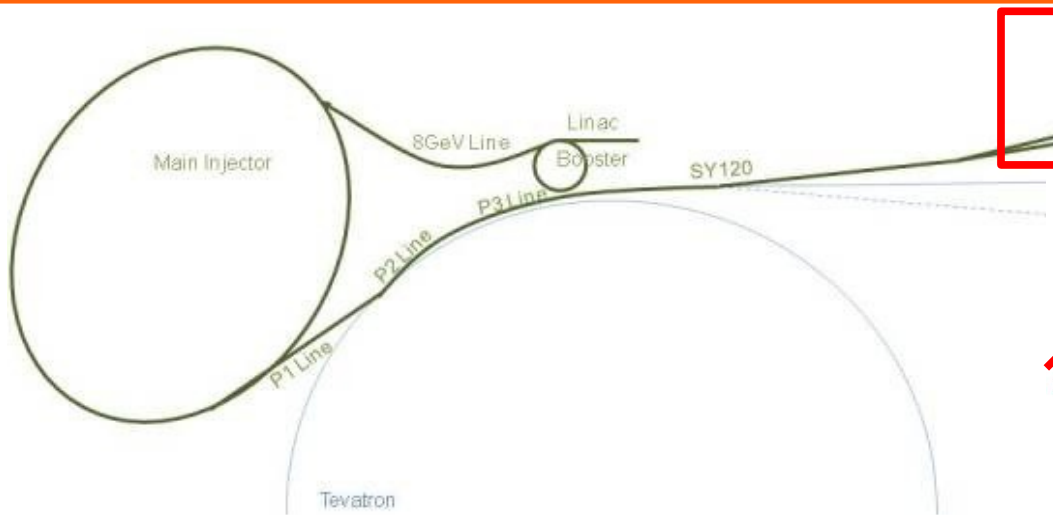


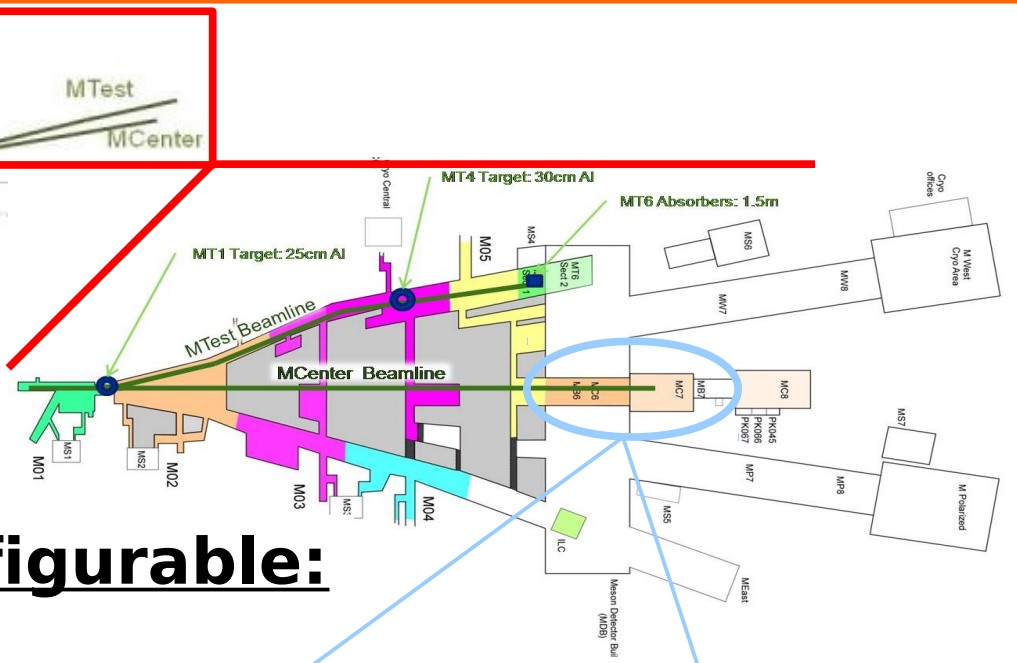
Tools


Hamamatsu
R11410-10 (3")
ETL
D757KFL (2")


MT4 Target: 30cm Al
MT6 Absorbers: 1.5m
MT1 Target: 25cm Al
MTest Beamline
MCenter Beamline
M01
M02
M03
M04
M05
MS1
MS2
MS3
MS4
MS5
MS6
MS7
MC7
MC8
MB7
MP7
MP8
MW7
MW8
ILC
MEast
M Polarized
M West
Cryo Area
Cryo offices
Meson Detector Bui
(MDB)

Fermilab Testbeam Facility





MTest and MCenter are configurable:

Primary beam

Proton Mode: 66-120 GeV protons

Secondary beam

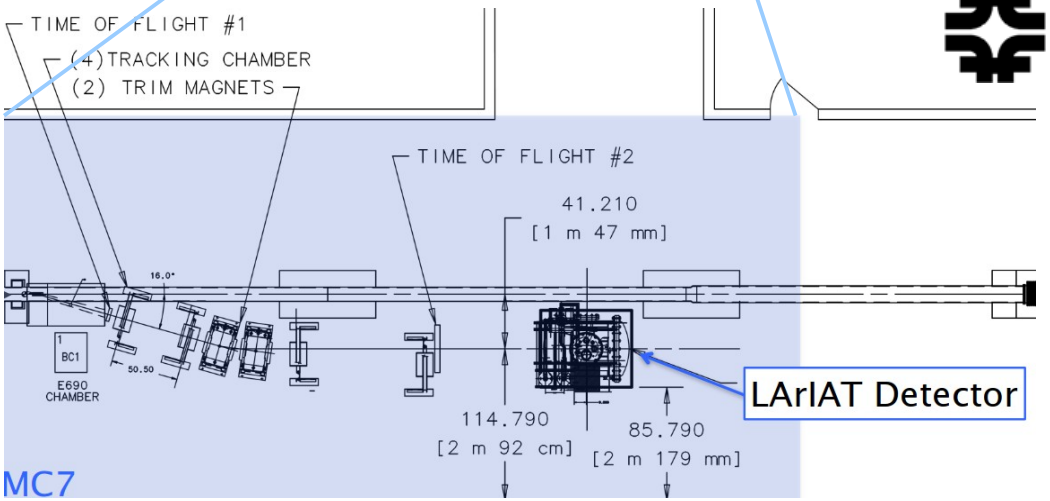
Pion Mode: 8-66 GeV beam

Low Energy Pion Mode: 1-32 GeV beam

Muon Mode: 1-32 GeV beam

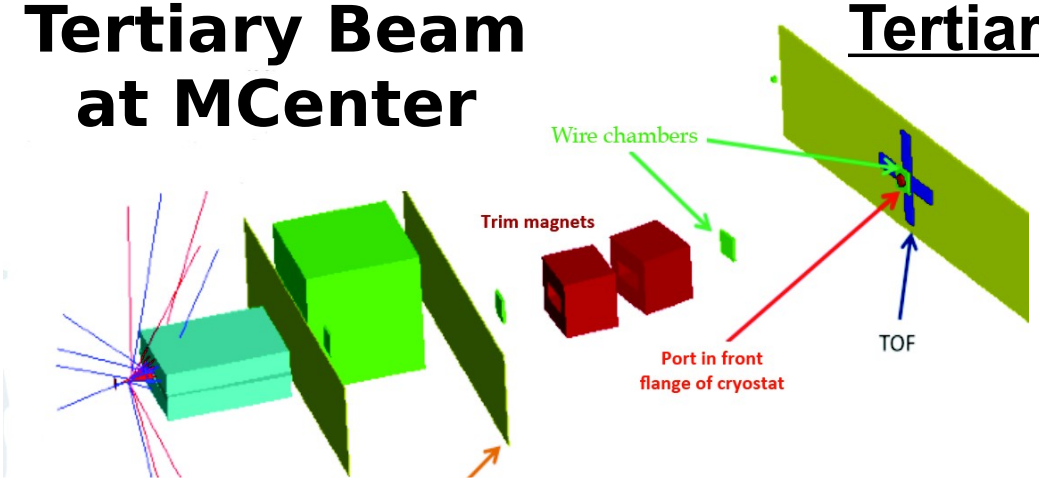
Tertiary beam

Low Energy Pion Mode: 200 MeV - 3 GeV



Fermilab Testbeam Facility

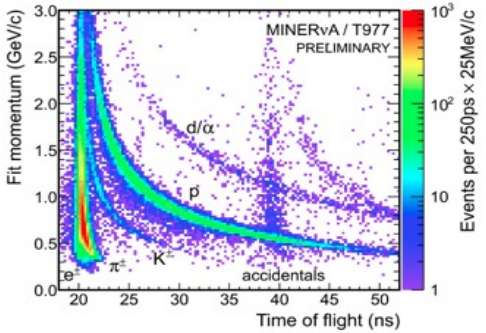
Tertiary Beam at MCenter



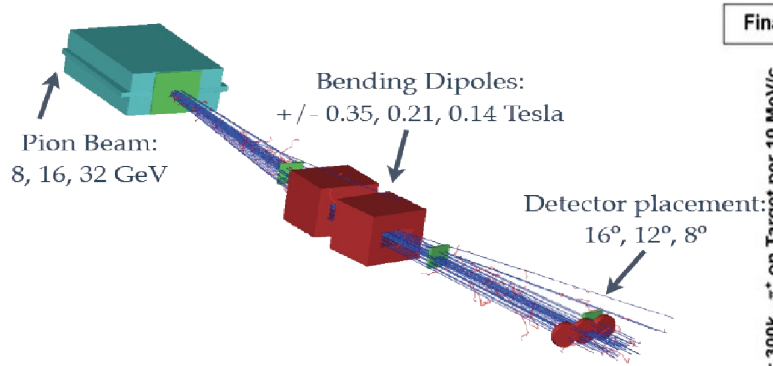
Tertiary beam components have been moved from MTest to MCenter and set up in the same configuration.

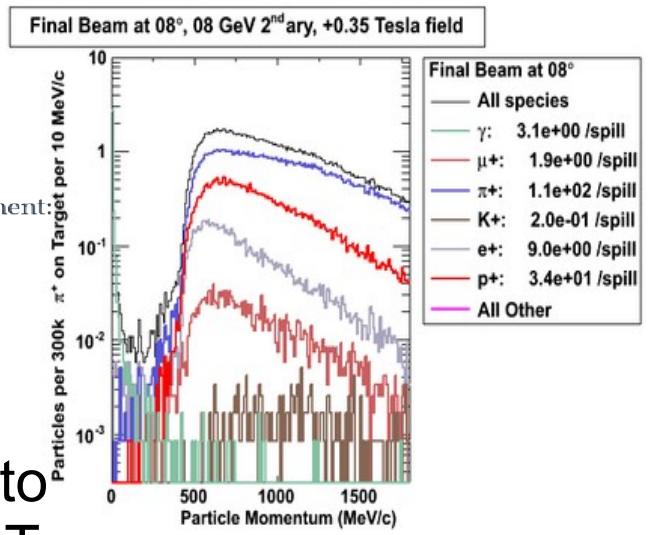
Tertiary beam (identical to MINERvA beam test):

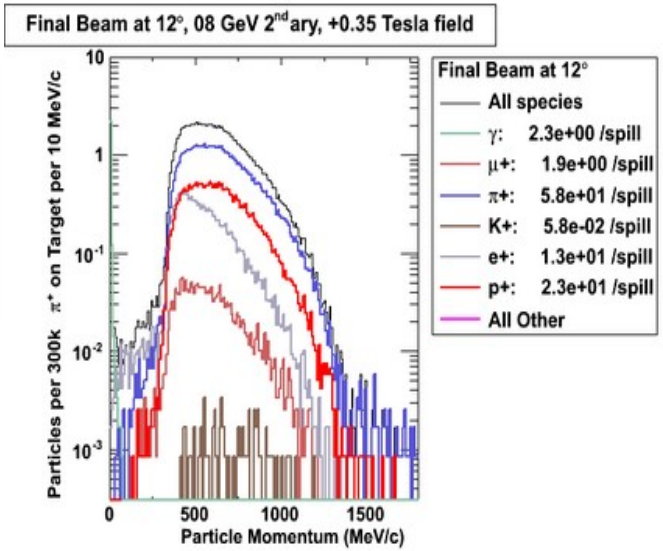
- Cu target in secondary beam
- Collimator at 16 degrees
- Pair of trim dipole magnets
- MWPCs for tracking



Tertiary beam composition as measured in MINERvA calibration run at MTest



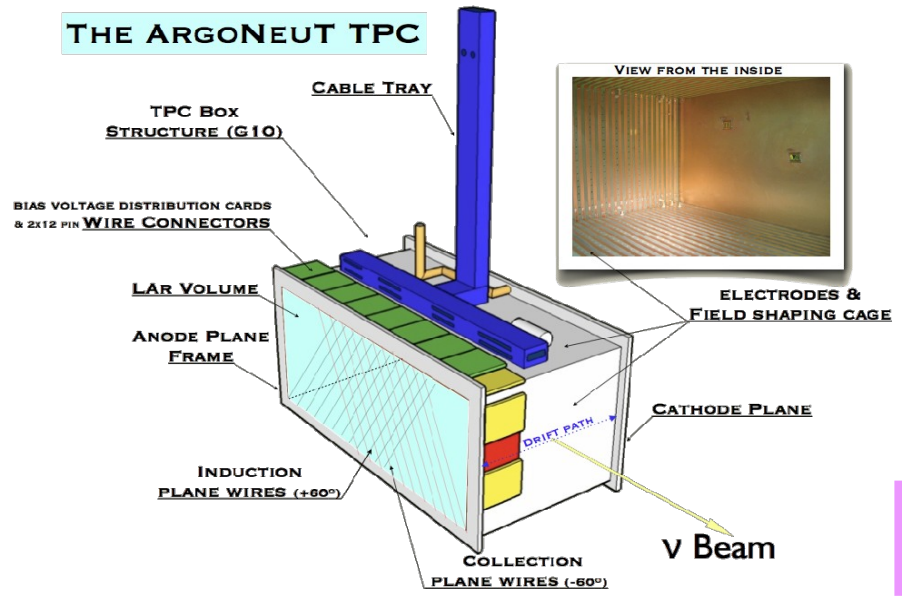


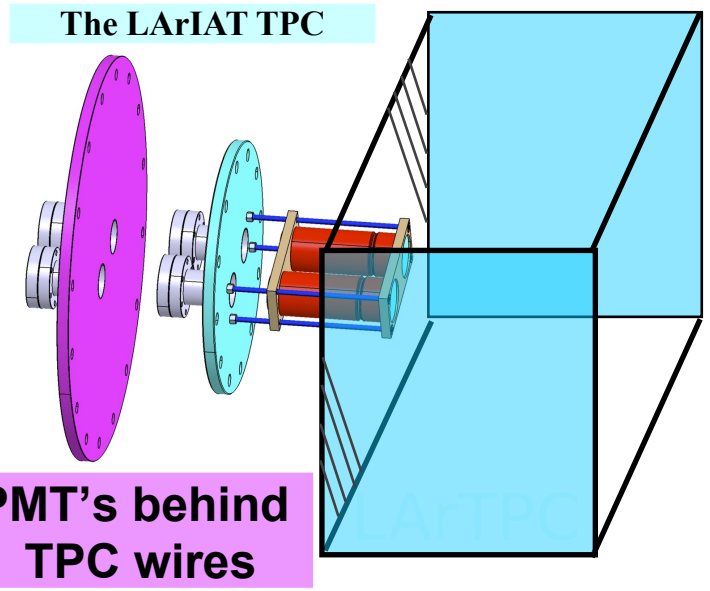


Simulation studies indicate we can improve our configuration to better meet the needs of LArIAT

Repurposing the ArgoNeuT Detector

Modifying the TPC



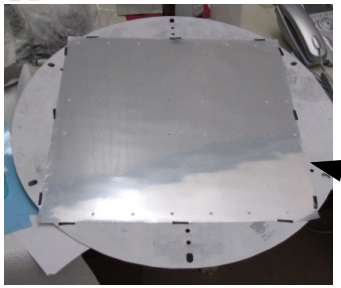


Two cryogenic PMTS

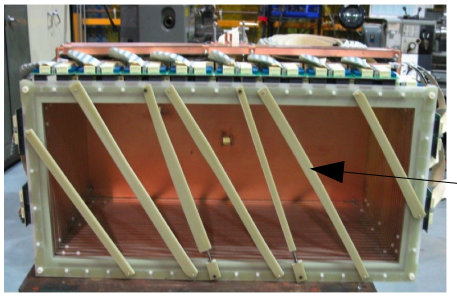
- one 3” high QE (30%)
- one 2” standard QE (20%)

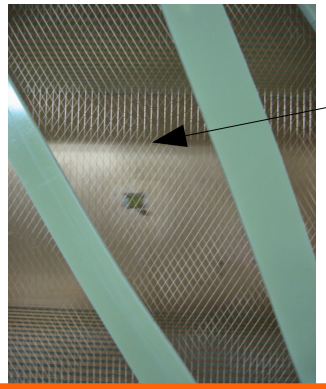
w/ wavelength shifting reflector foil lining

PMT’s behind TPC wires



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

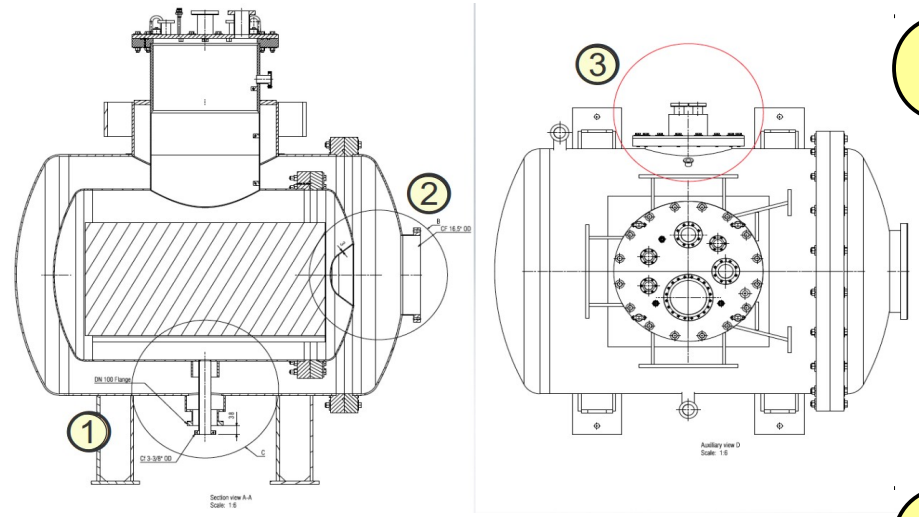




Modify the existing TPC wire frame support structure and restring the wire planes

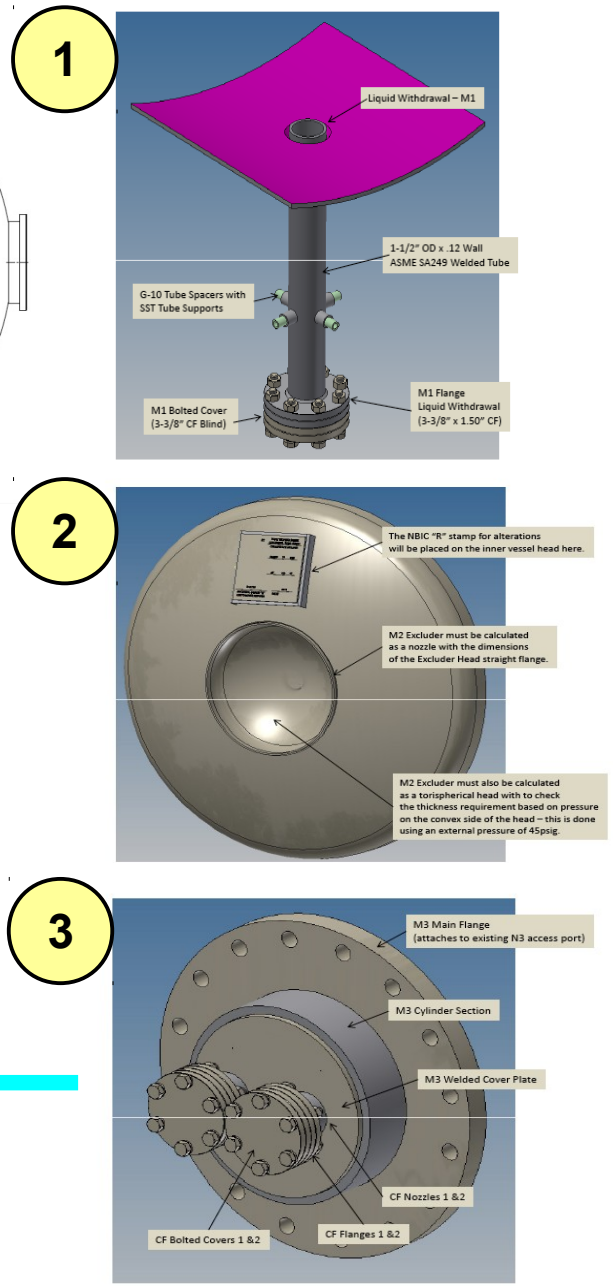
Repurposing the ArgoNeuT Detector

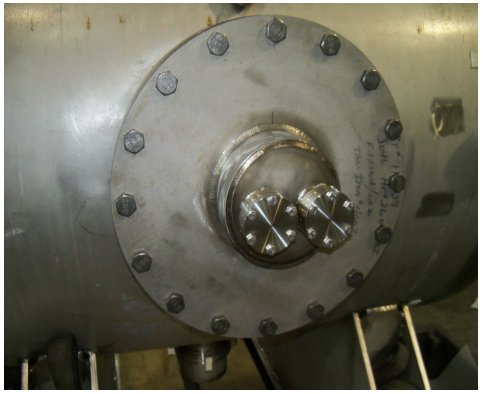
Modifying the Cryostat



3 Modifications to the ArgoNeuT Cryostat

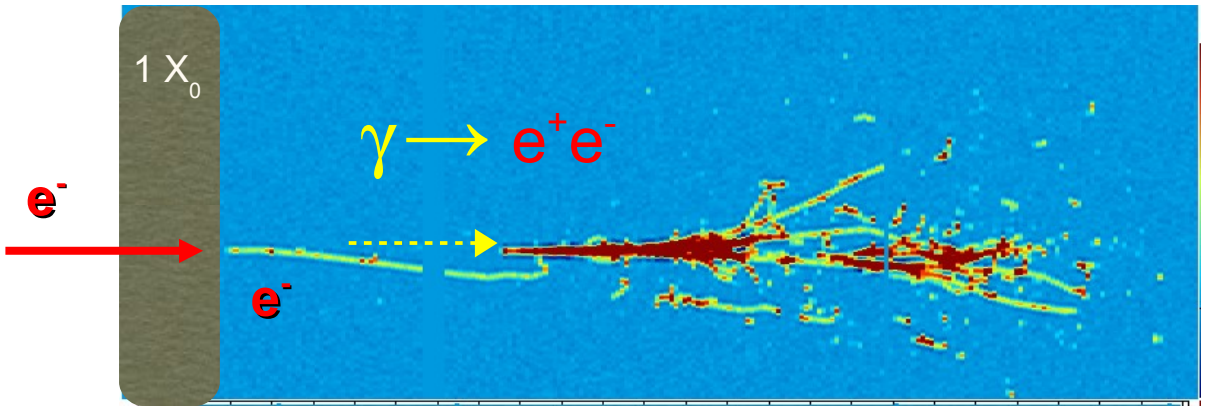
1) Bottom port modified for cryogenic circulation
2) Modify the front flange to allow for charged particle beam
3) Adding port for the cryogenic PMTs





Physics Goals

Electron / Photon Shower Seperation

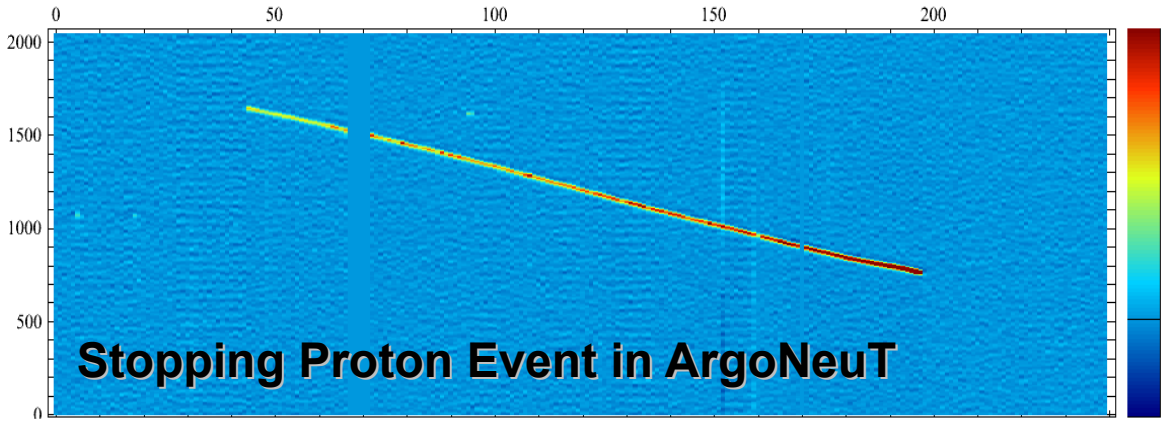


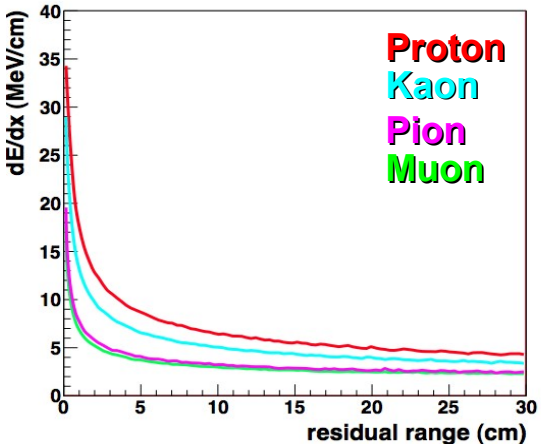
LArIAT's large electron (e) tagged event sample will **experimentally measure** separation efficiency and sample purity for e-induced vs. photon (γ)-induced showers in a liquid argon TPC:

- 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:

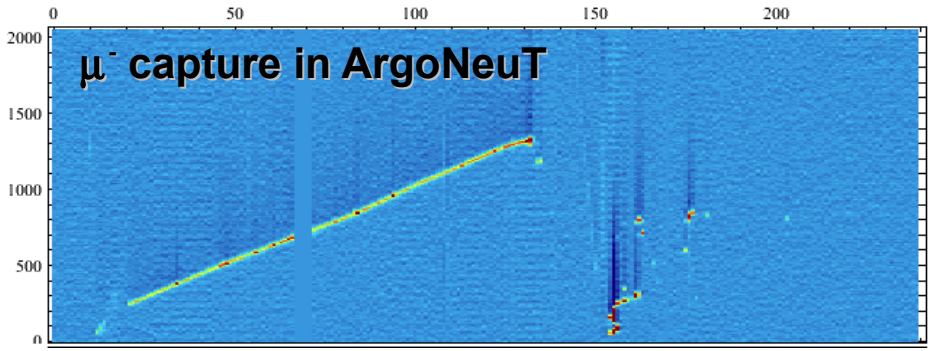
- Proton ID, proton-to-Kaon separation (Rejection/Efficiency)

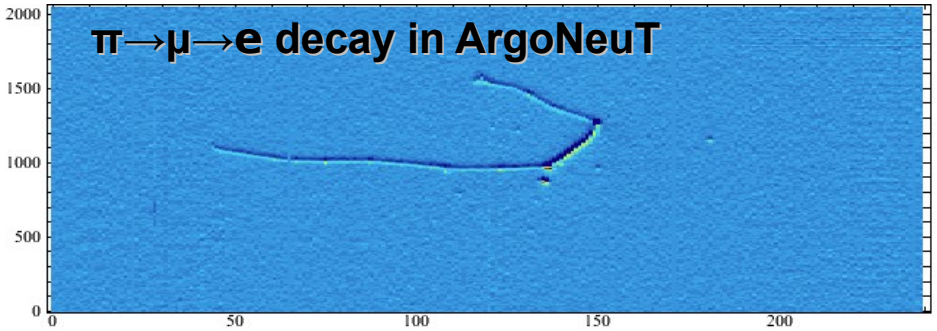
- Kaon ID, Kaon-to-π/μ separation (Rejection/Efficiency)

- dE/dx vs Residual Range for contained tracks

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

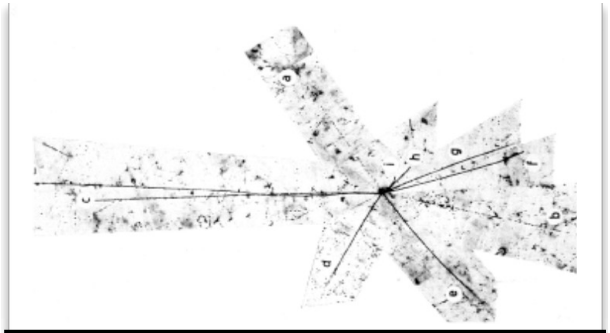
– μ^- capture on a nuclei (~ 75%, followed by a γ/n emission) or decay (~25%)

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

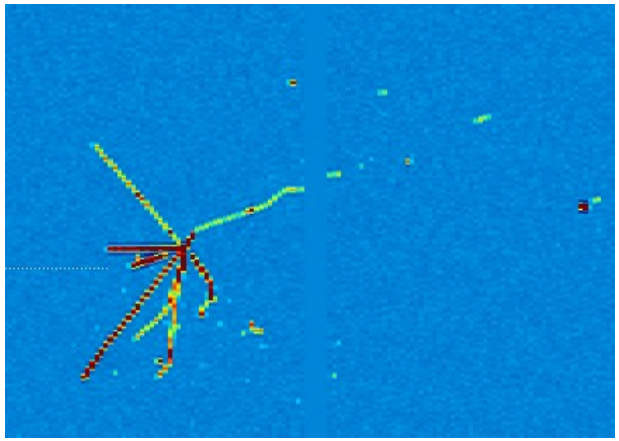


Antiproton Star Observed in Emulsion*

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*

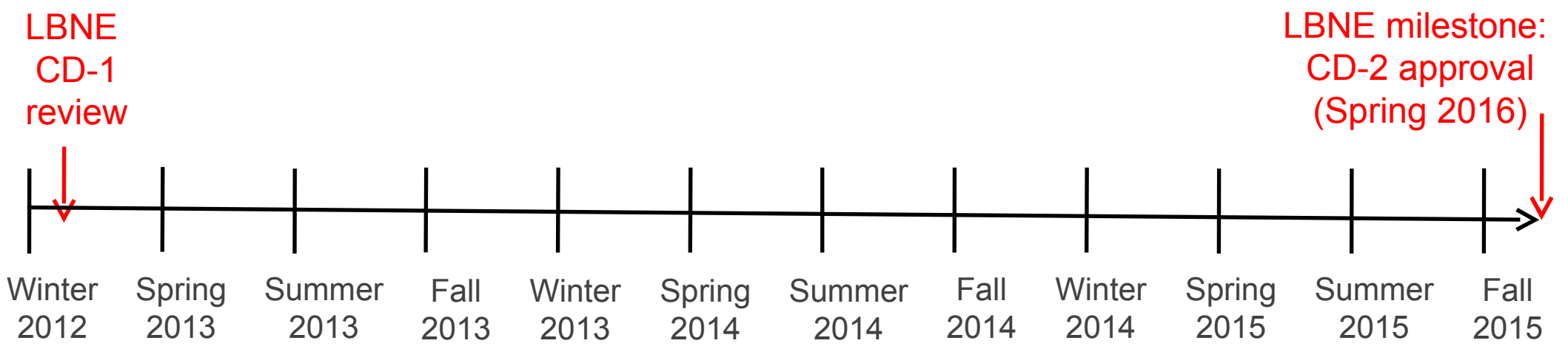


Low momentum anti-protons in the beam (even at a small rate) will allow the first study of hadron star topology from p-$\bar{p}$ annihilation at rest in Argon

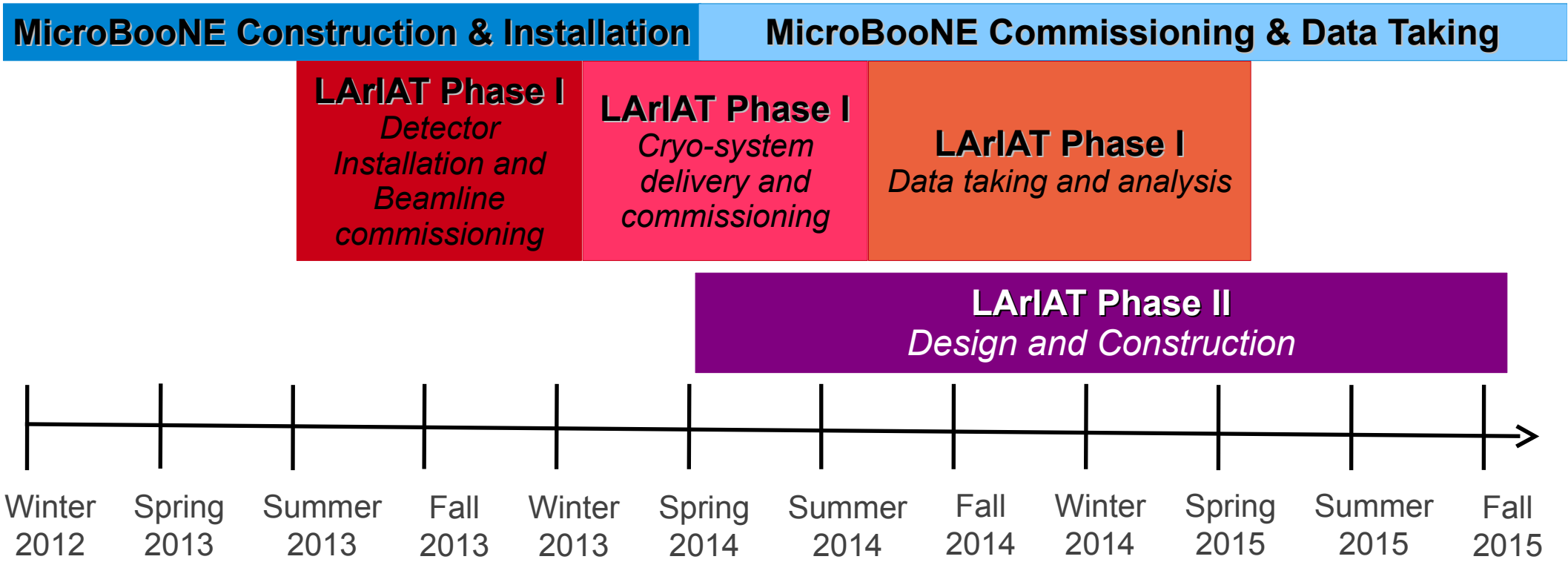
- $\pi^{\pm}$, π^{0}, $K^{\pm}$, etc.. multiplicity in hadron stars can be accurately determined utilizing LAr imaging detector capabilities.

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

What's to come...



Rough Timeline
(All dates subject to modification)



- Modified Cryostat now at MCenter
- TPC modifications starting at Fermilab soon
- MCenter beamline on schedule for operation in Summer 2013
- Manpower available this summer for detector installation and beamline commissioning

Conclusions

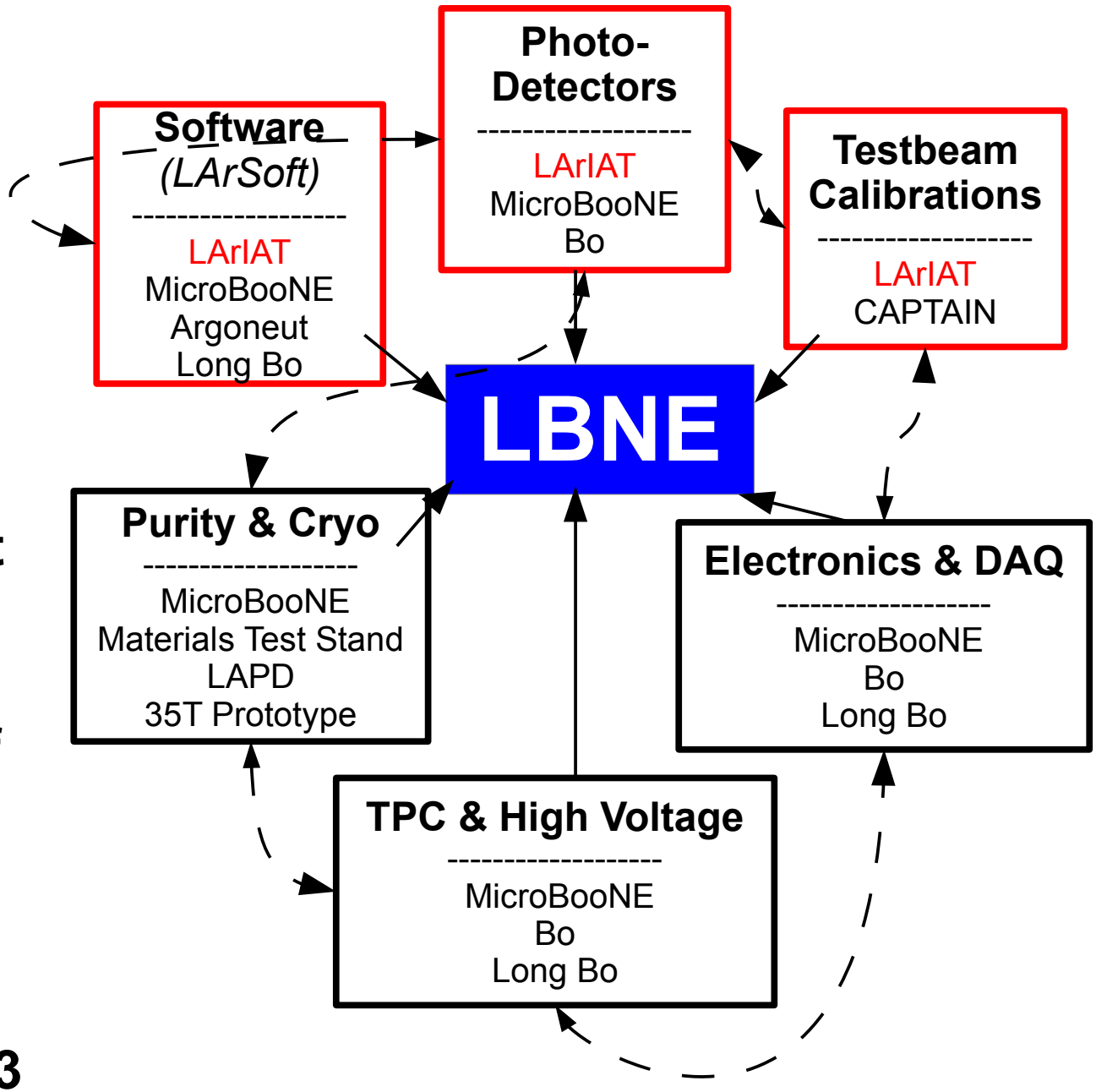
LArIAT is an important component of Liquid Argon detector R&D

A consensus in LAr community deems it necessary!

Interesting and robust set of physics goals

Well aligned with goals of MicroBooNE & LBNE

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



Thank You

Backup Slides