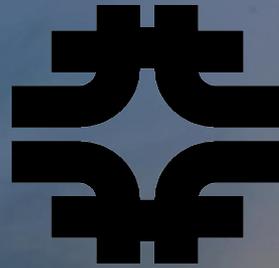


# The LArIAT Experiment

(Liquid Argon Time Projection Chamber In A Testbeam)



**Jonathan Asaadi**

**Syracuse  
University**

**On behalf of the  
LArIAT Collaboration**



# Outline

## • Motivation

- 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

- Optimization of Particle ID
- Electron / Photon Shower Separation
- Non-magnetic Muon Sign Determination
- Study of anti-proton ( $\bar{p}$ ) events in LAr

## • What's to come...

# Motivation

## Understanding LArTPC's Capabilities

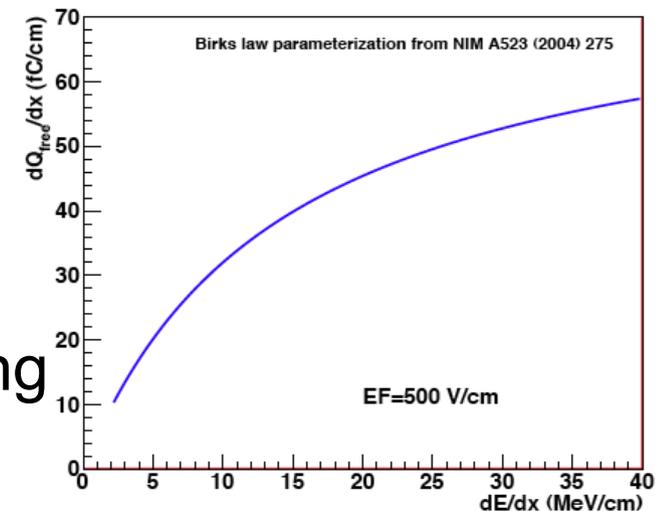
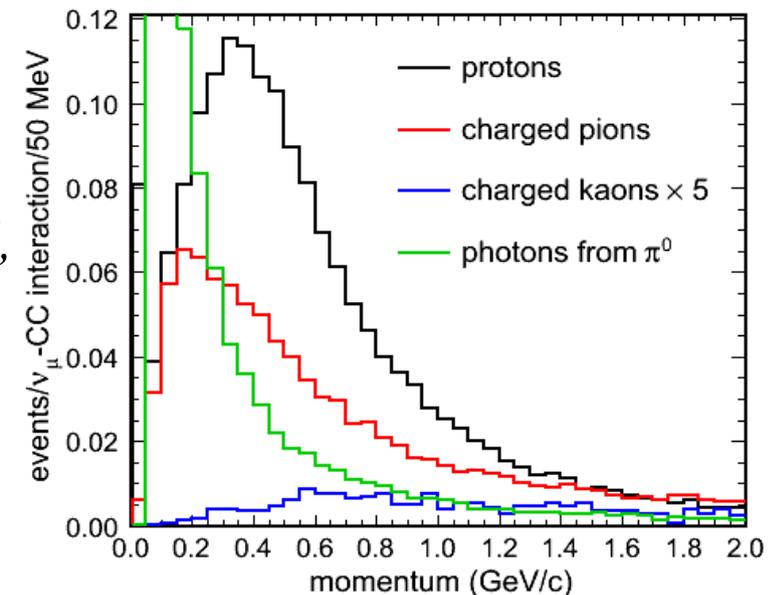
**Calibration** is one of the critical steps to understanding the response of any detector.

*“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.



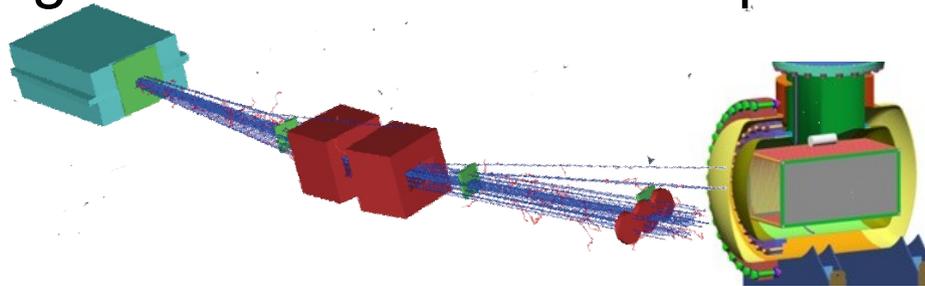
# Motivation

## LArIAT Phase I and Phase II

### Staged LArIAT program at Fermilab

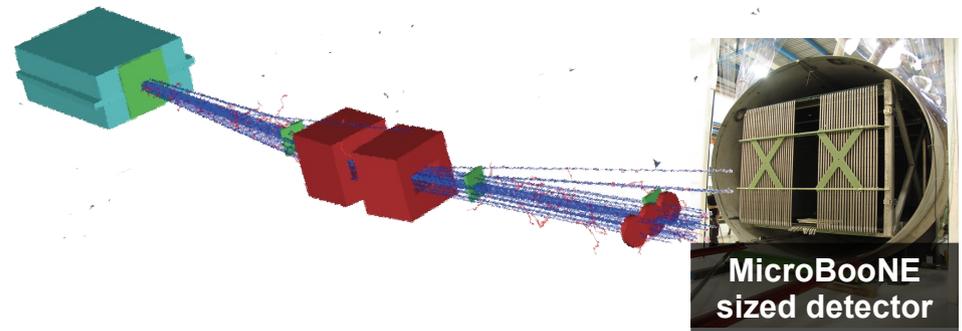
**Phase-I:** Repurpose the ArgoNeuT detector in the upstream end of beamline

*Quick turnaround, can be ready by Fall 2013*

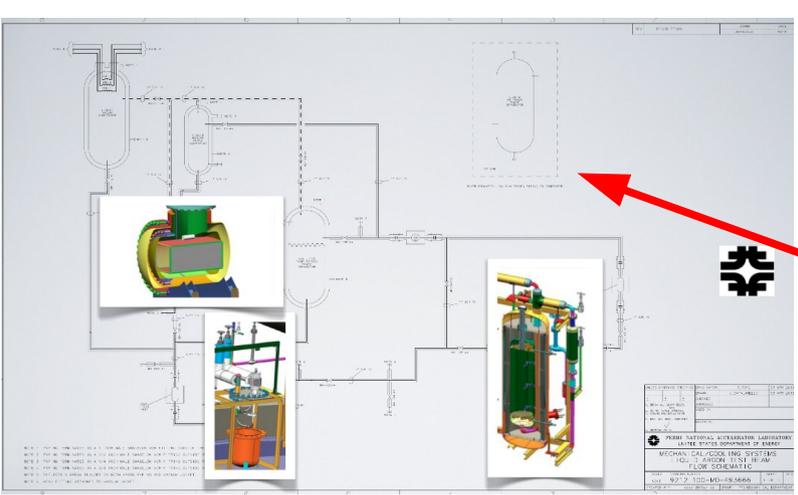


**Phase-II:** Larger LArTPC further downstream

*Design facility for broader, longer-term use*



MicroBooNE sized detector



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

# Motivation

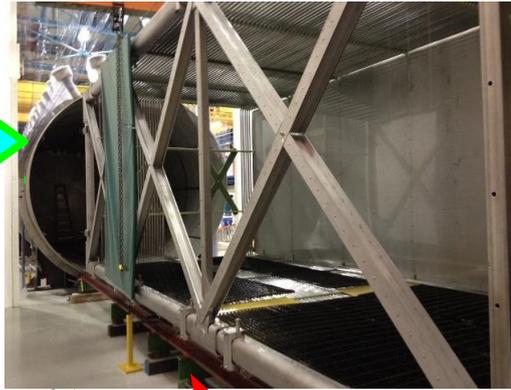
## LArIAT on the path towards LBNE

Neutrino Physics Experiments

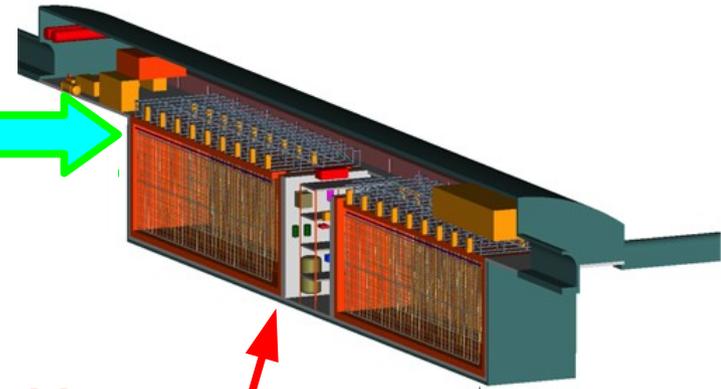
ArgoNeuT



MicroBooNE



LBNE



R&D Detectors



Bo

(Electronics / Readout)



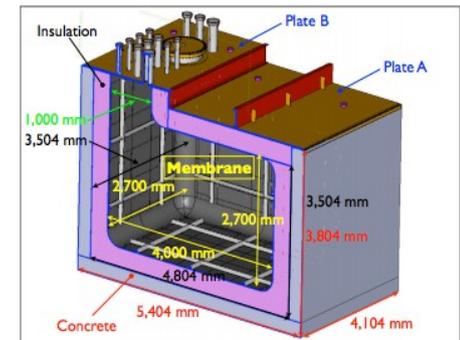
Long Bo in LAPD

(High Voltage, Cold Electronics, Purity)



LArIAT

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



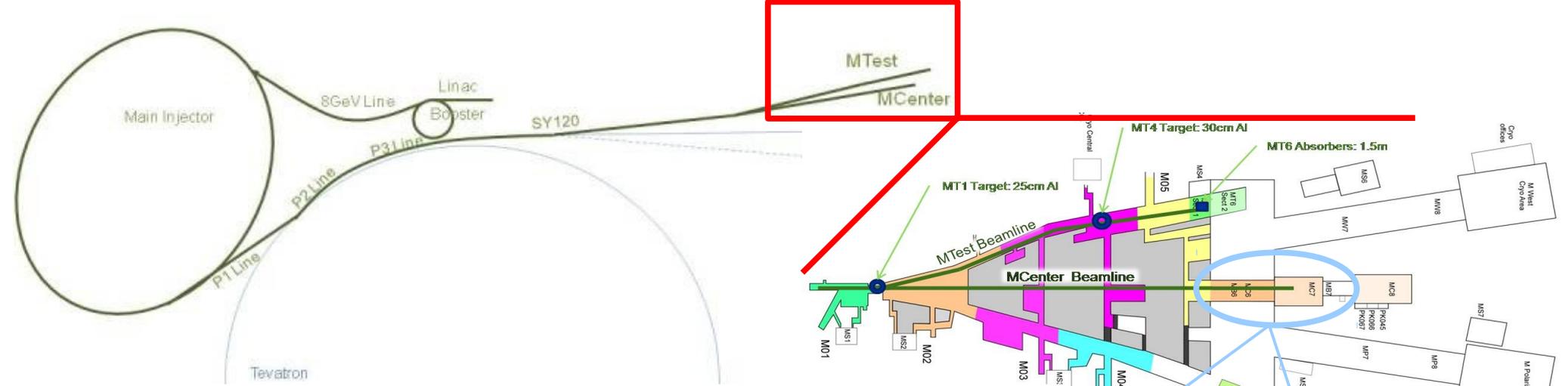
35T Membrane Cryostat

(Purity)

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

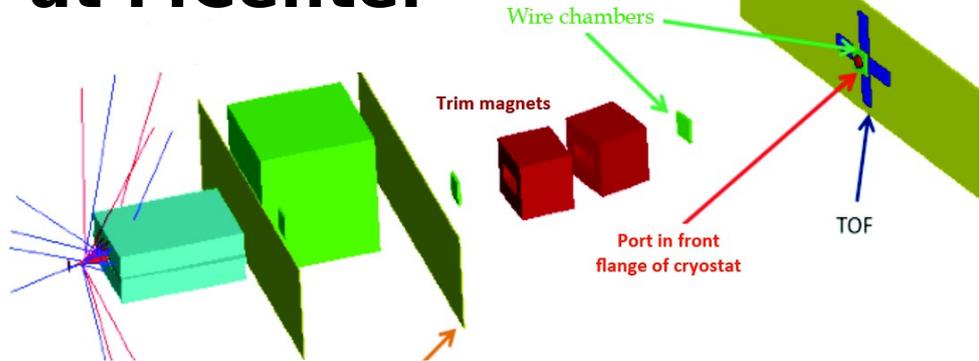


# Fermilab Testbeam Facility



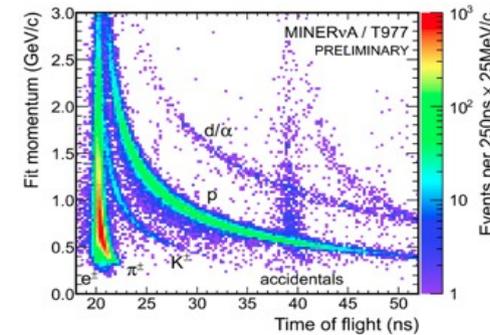
# Fermilab Testbeam Facility

## Tertiary Beam at MCenter



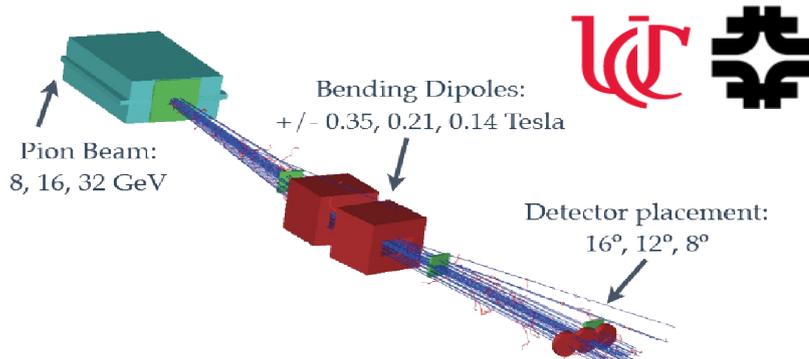
## Tertiary beam (identical to MINERvA beam test):

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



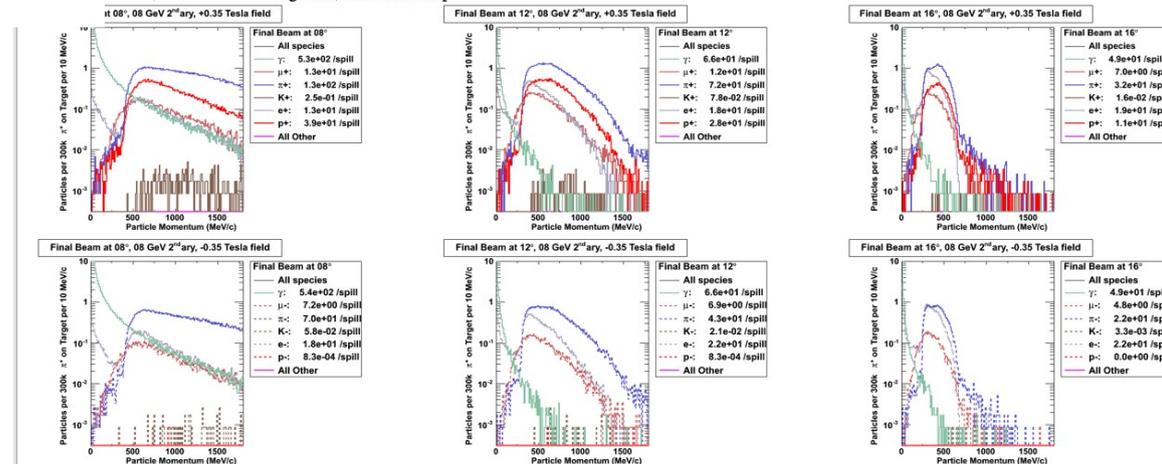
*Tertiary beam composition as measured in MINERvA calibration run at MTest*

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



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

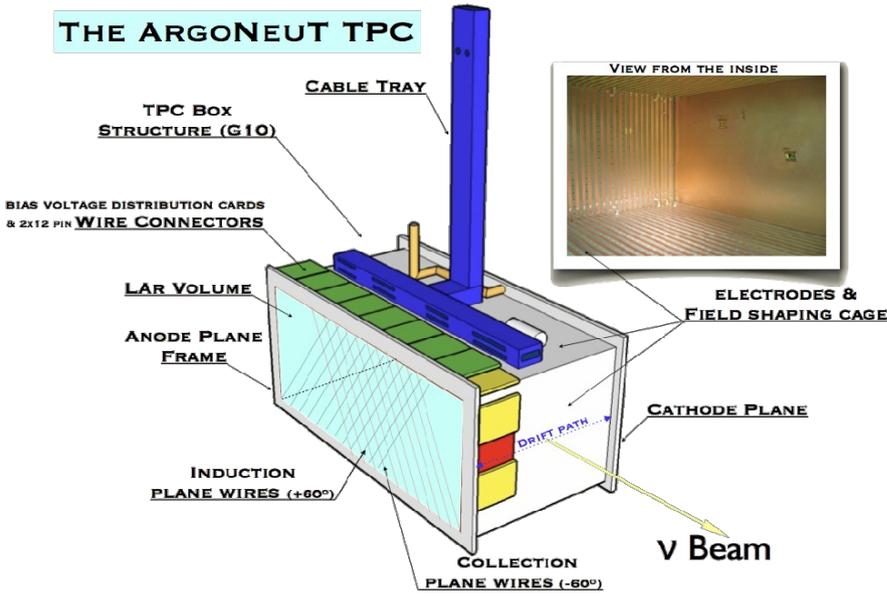
- beam, 0.35 Tesla bending field, three detector placements



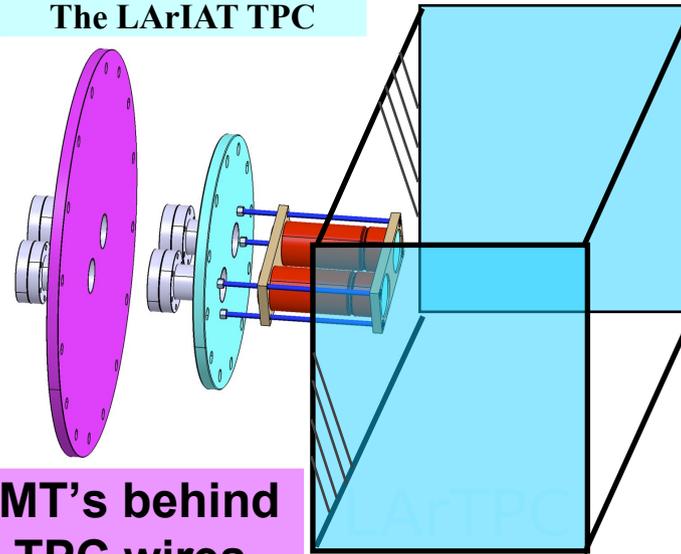
# Repurposing the ArgoNeuT Detector

## Modifying the TPC

THE ARGONEUT TPC



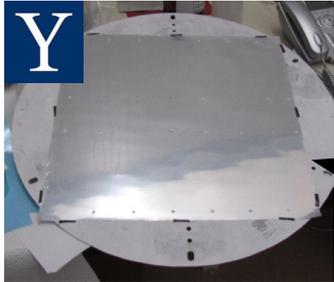
The LArIAT TPC



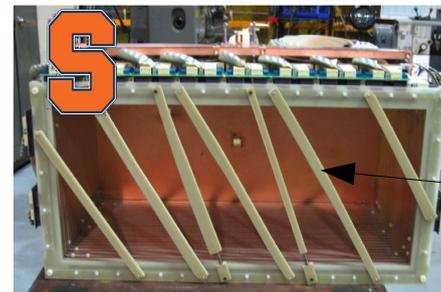
**Two cryogenic PMTS**

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

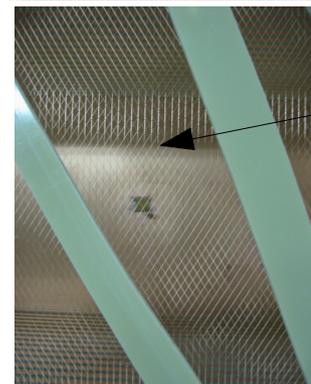
**w/ wavelength shifting reflector foil lining**



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

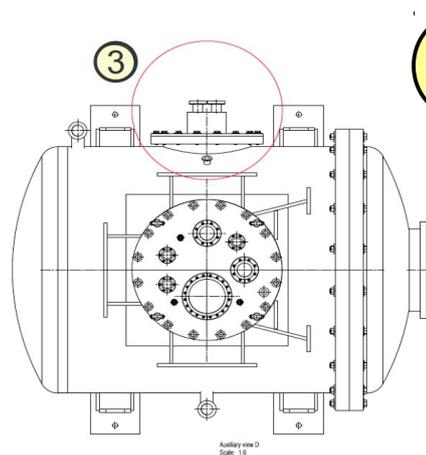
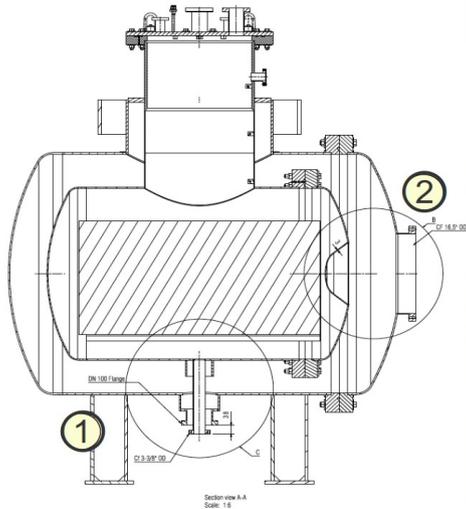


**Modify the existing TPC wire frame support structure and restring the wire planes**

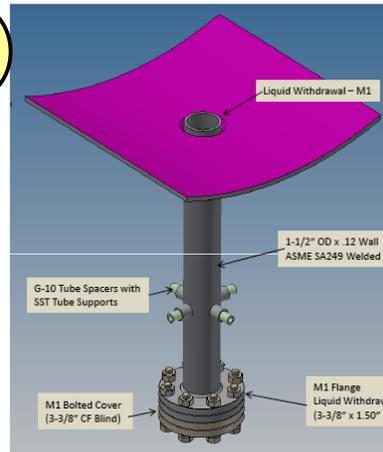


# Repurposing the ArgoNeuT Detector

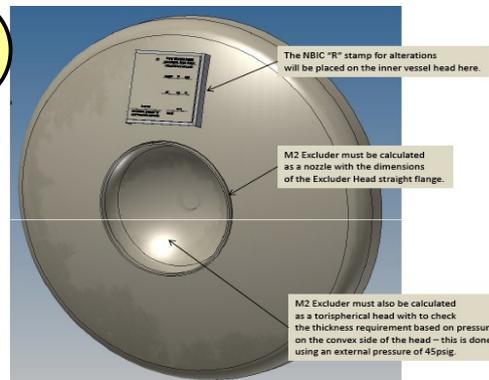
## Modifying the Cryostat



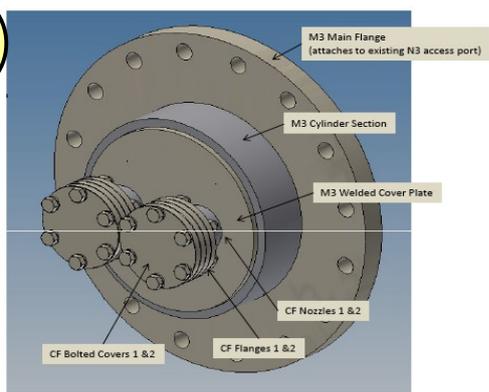
1



2



3



### 3 Modifications to the ArgoNeuT Cryostat

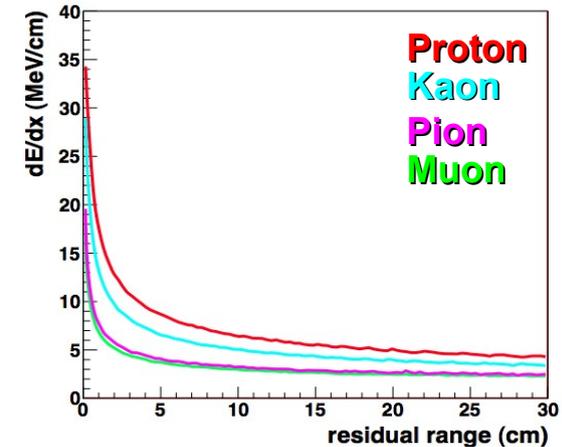
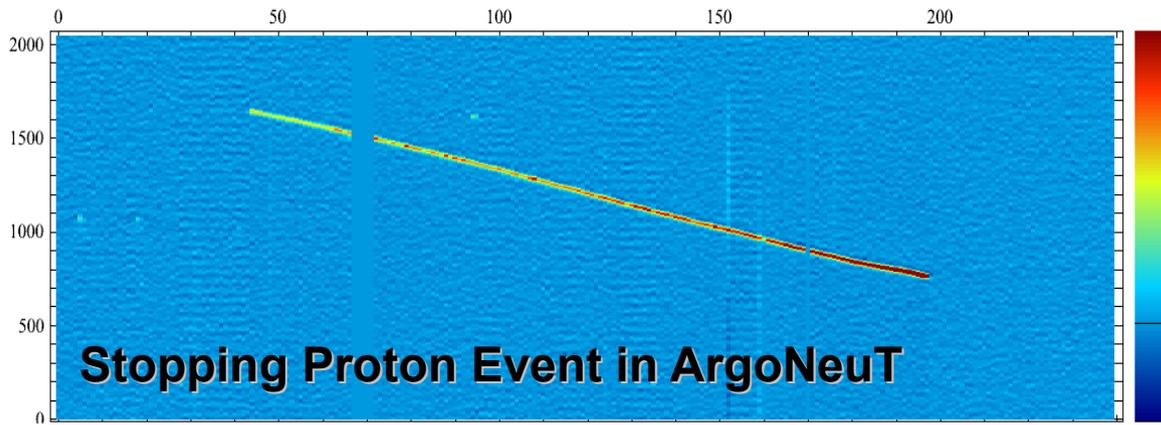
- 1) Bottom port modified for cryogenic circulation
- 2) Modify the front flange to allow for charged particle beam
- 3) Adding port for the cryogenic PMTs



ArgoNeuT cryostat w/ modifications back at FNAL!

# Physics Goals

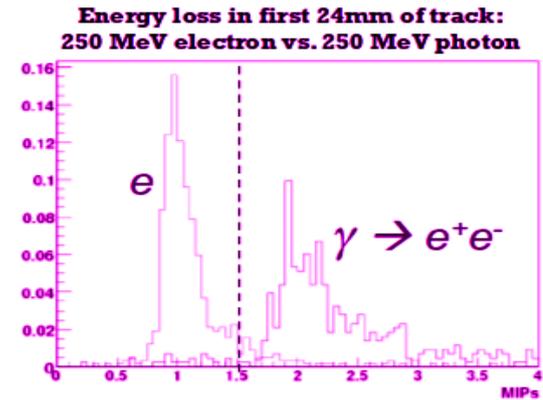
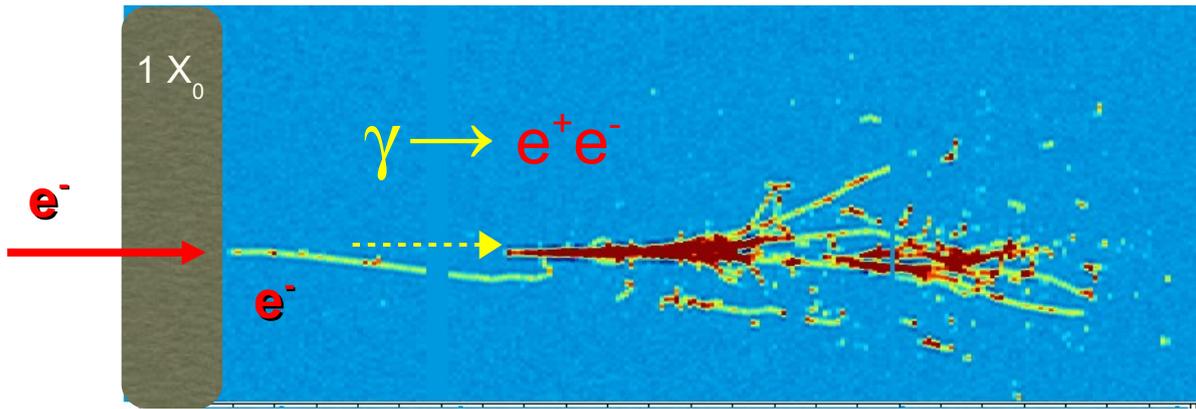
# Optimization of Particle ID



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- $\pi/\mu$  separation (Rejection/Efficiency)
- $dE/dx$  vs Residual Range for contained tracks

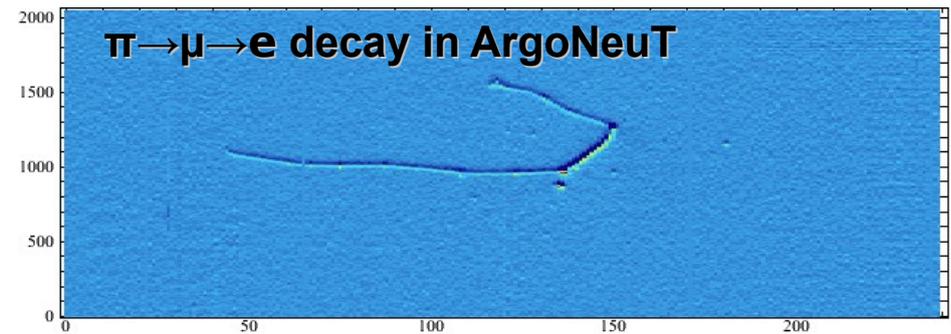
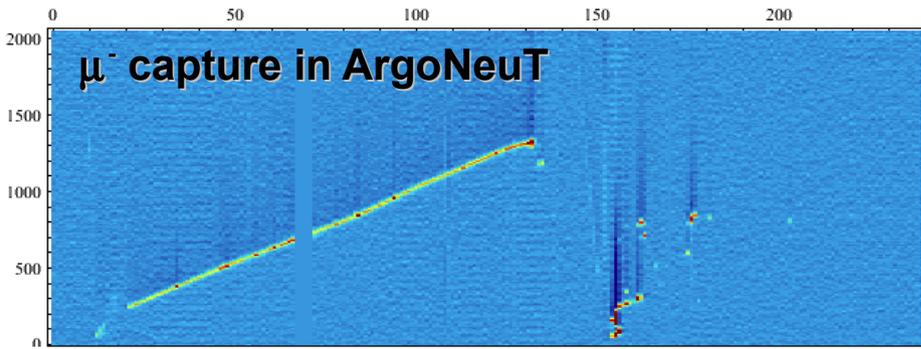
# Electron / Photon Shower Separation



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

- $e/\gamma$  separation is a **key feature of LArTPC technology**
- **Only initial part of the shower is necessary** for  $e$ - $\gamma$  separation, making LArIAT Phase-I an ideal place to measure separation power experimentally and compare to simulation

# 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

–  $\mu^+$  decay only with an  $e^+$  emission of a known energy spectrum

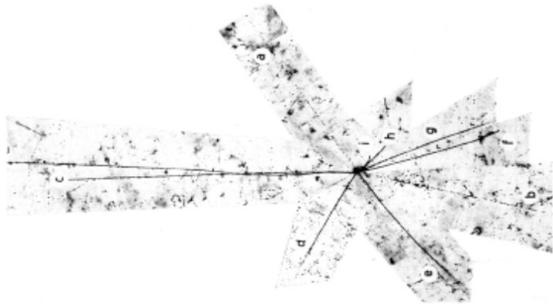
–  $\mu^-$  capture on a nuclei ( $\sim 75\%$ , followed by a  $\gamma/n$  emission) or decay ( $\sim 25\%$ )

*Systematic study of  $\mu^-$  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\*

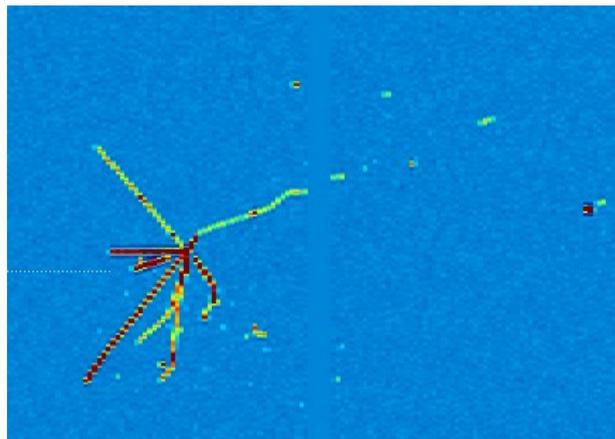
O. CHAMBERLAIN, W. W. CHUPP, G. GOLDHABER, E. SEGRÈ, AND  
C. WIEGAND, *Radiation Laboratory, Department of Physics,  
University of California, Berkeley, California*

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

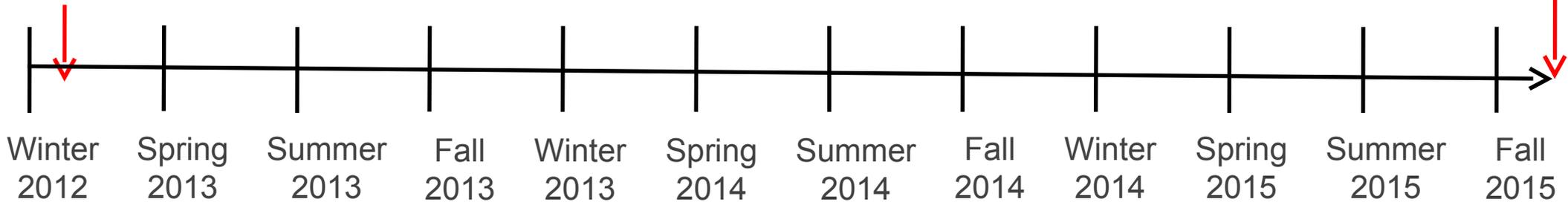
- $\pi^\pm$ ,  $\pi^0$ ,  $K^\pm$ , etc.. multiplicity in hadron stars can be accurately determined utilizing LAr imaging detector capabilities.
- This information is very relevant for  $n$ - $\bar{n}$  oscillation searches at future large LArTPC detectors.



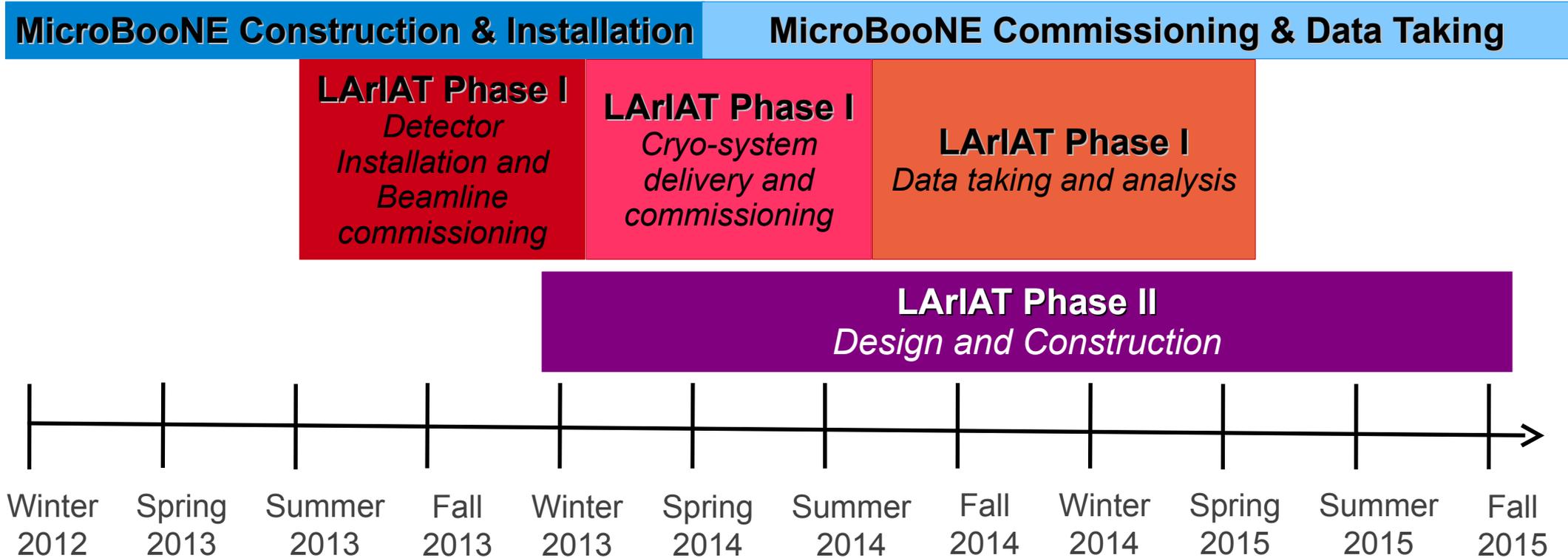
# What's to come...

LBNE  
CD-1  
review

LBNE milestone:  
CD-2 approval  
(Spring 2016)



# Rough Timeline



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

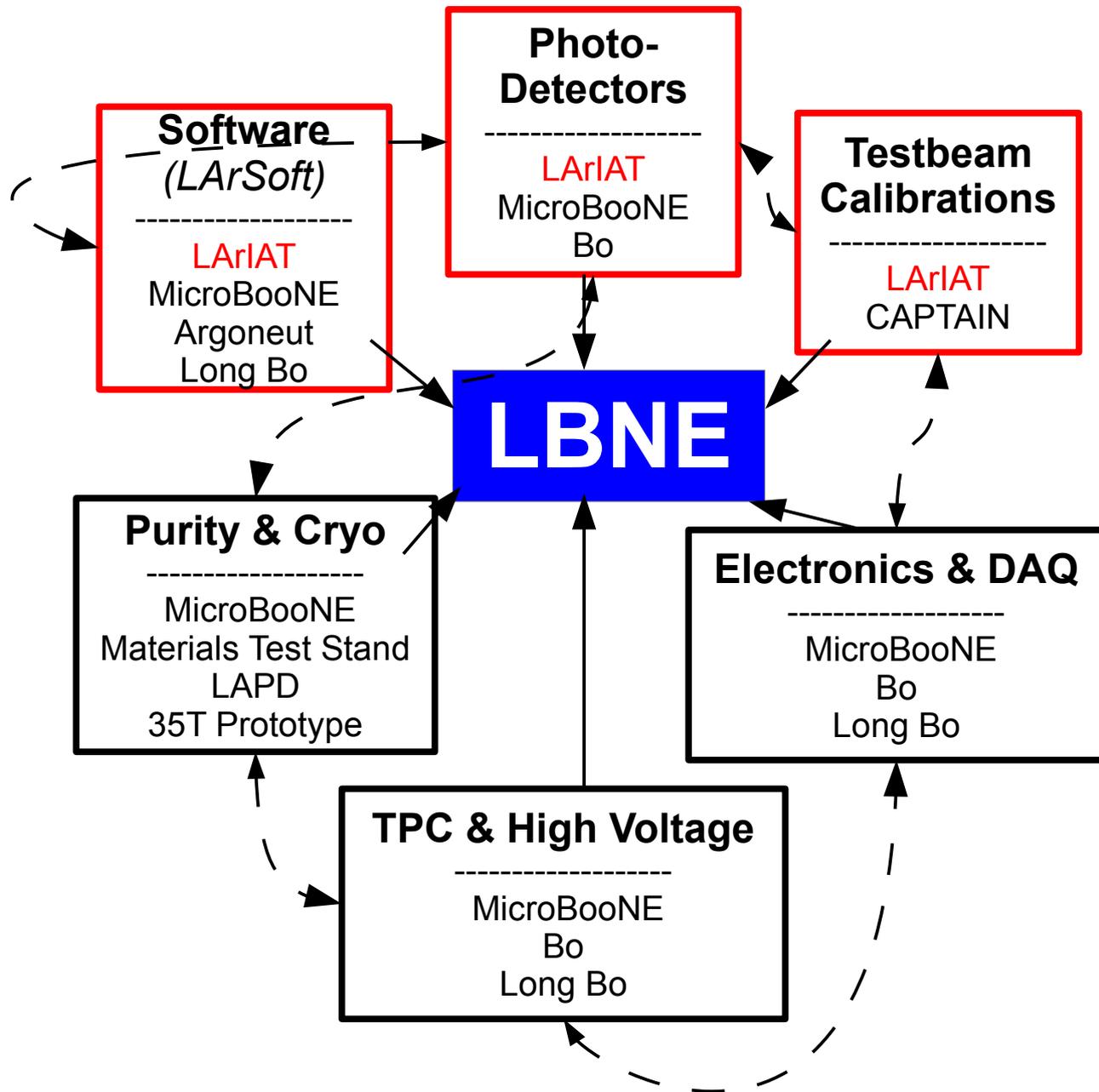
# Conclusions

**LArIAT is an important component of LAr detector R&D**

**A consensus in LAr community deems it necessary!**

**Well aligned with goals of LBNE**

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





Thank You

# Backup Slides