LArIAT
(Liquid Argon in a Test Beam)

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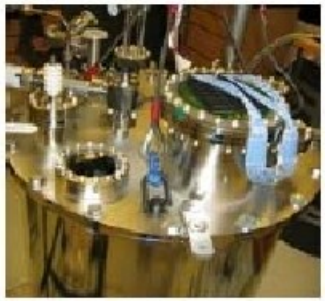
Outline

- The LArTPC in neutrino physics and why do we need to calibrate it?
- LArIAT @ at the Fermilab Beam Test Facility.
- The detector.
- Physics goals.
- Conclusions.

US LAr R&D Program

Yale TPC



Location: Yale University
Active volume: 0.002 ton
operational: 2007

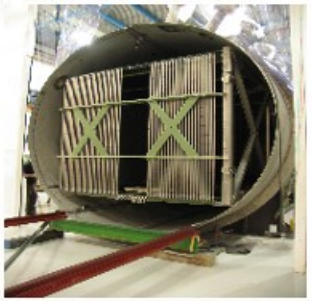
Bo

Location: Fermilab
Active volume: 0.02 ton
operational 2008

ArgoNeuT

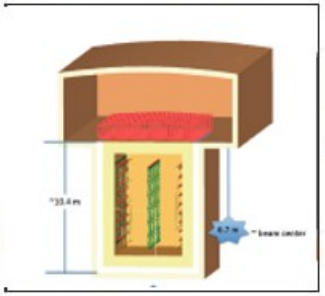
Location: Fermilab
Active volume: 0.3 ton
operational: 2008
First neutrinos: June 2009

MicroBooNE



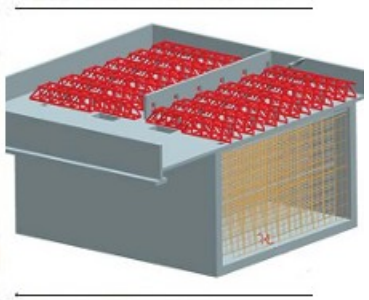
Location Fermilab
Active volume: 0.1 kton
Operational: 2014

LAr1



Location: Fermilab
Active volume: 1 kton
Construction start: 2016?

LBNE



Location: Homestake
Active volume: 10/35 kton
Construction start 202?

Luke

Location: Fermilab
Purpose: materials test st
Operational: since 2008

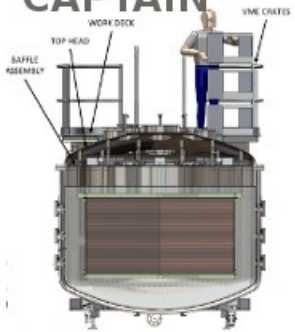
LAPD

Location: Fermilab
Purpose: LAr purity demo
Operational: 2011

LArIAT

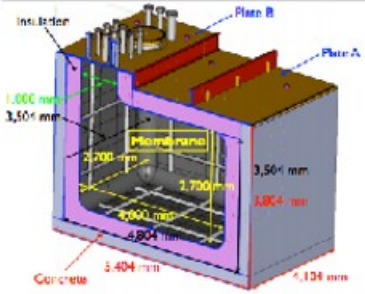
Location: Fermilab
Purpose: LArTPC calibration
Operational: 2014 (phase 1)

CAPTAIN



Location: LANL
Purpose: LArTPC calibration
Operational: 2014

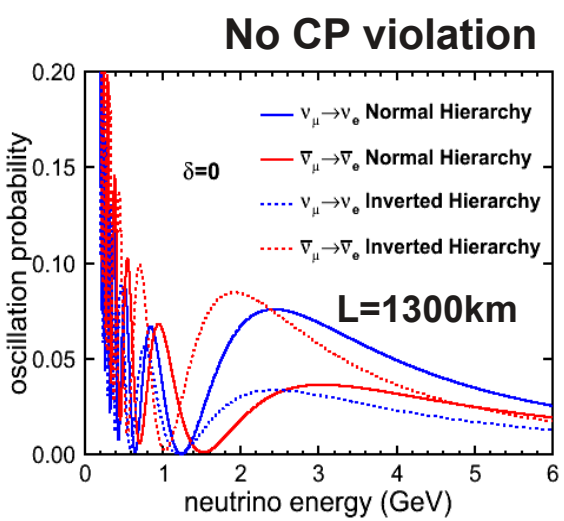
LBNE 35 Ton

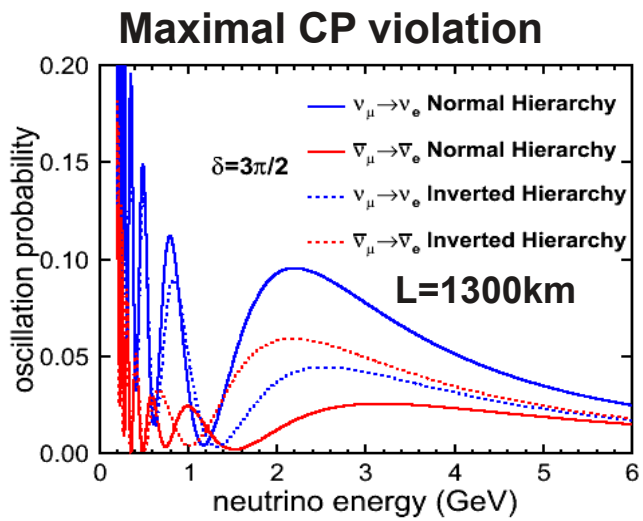


Location: Fermilab
Purpose: purity demo
Operational: 2013

Physics with LArTPCs

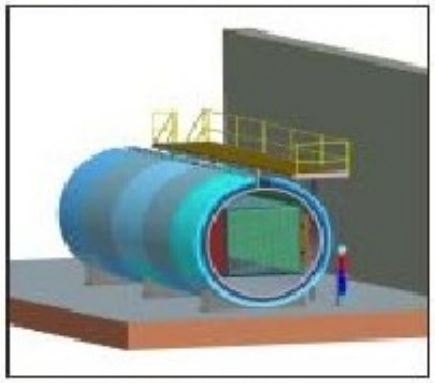
The LArTPC is becoming the go-to technology in neutrino physics



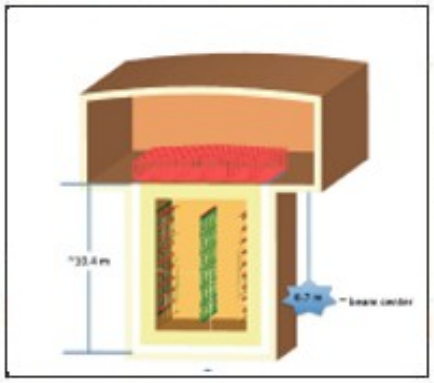


The physics effects we want to measure are becoming more and more subtle. Need to keep errors as small as possible. Increasing statistics is hard! So let's try systematic errors.

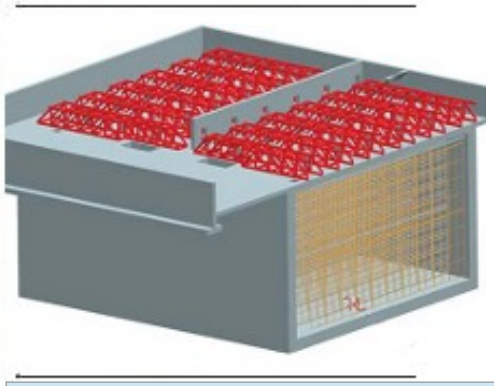
MicroBooNE



LAr1



LBNE



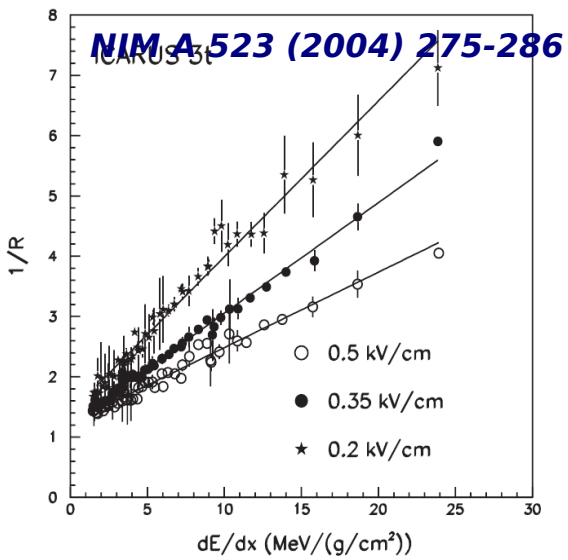
+Several other projects throughout the world

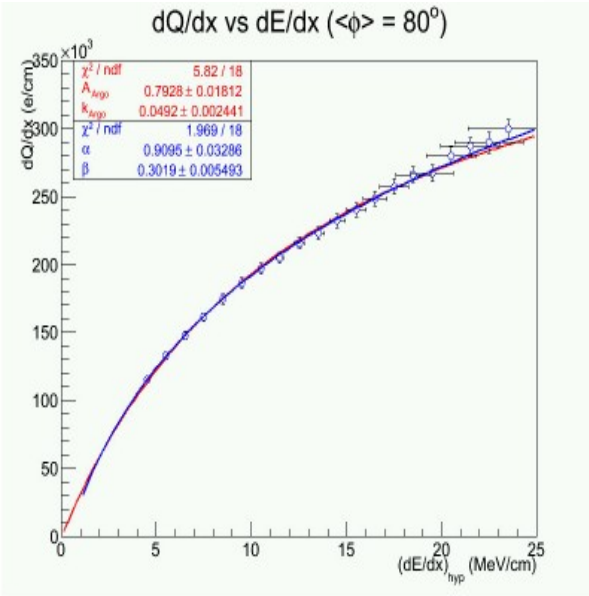
MiniBooNE excess	Sterile neutrino(s)	CP violation, Mass Hierarchy

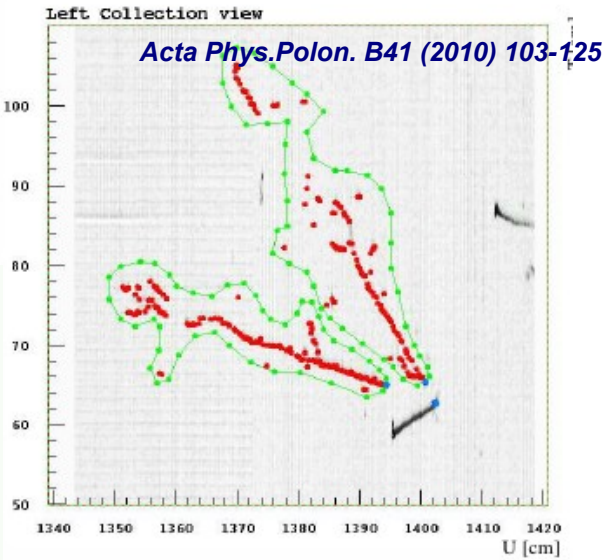
LArTPC Calibration

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

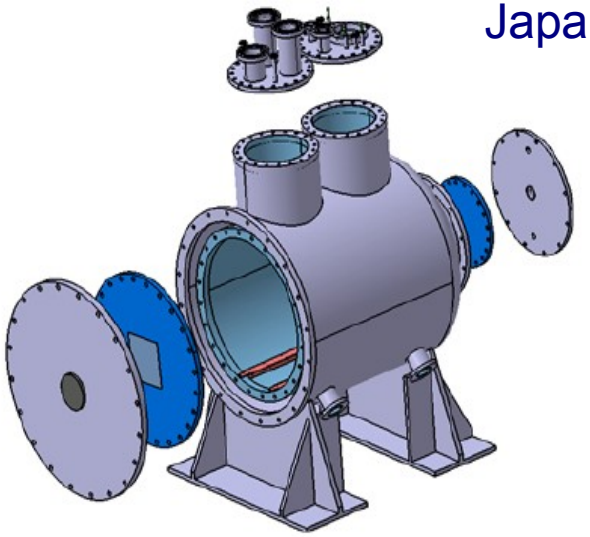
Surprisingly, there haven't been many dedicated calibrations of LArTPCs.







T-32 experiment in Japan

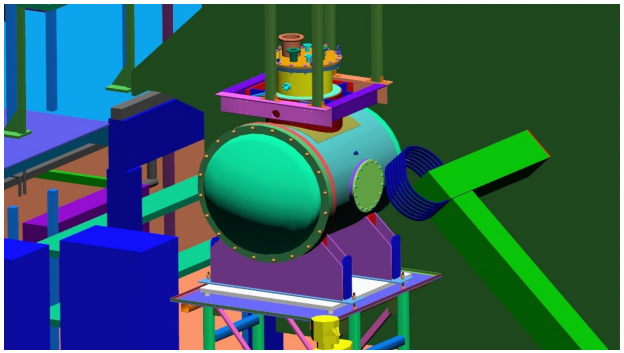


Understanding parameters like energy resolution and particle ID capabilities will allow future experiments to lower their systematic errors which may prove essential in precision measurements they are aiming at.

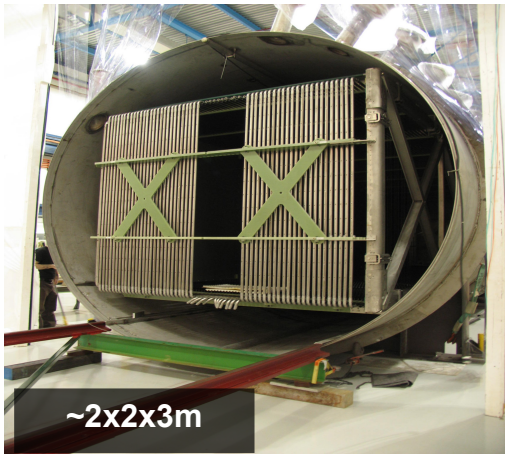
The LArIAT program @ FNAL

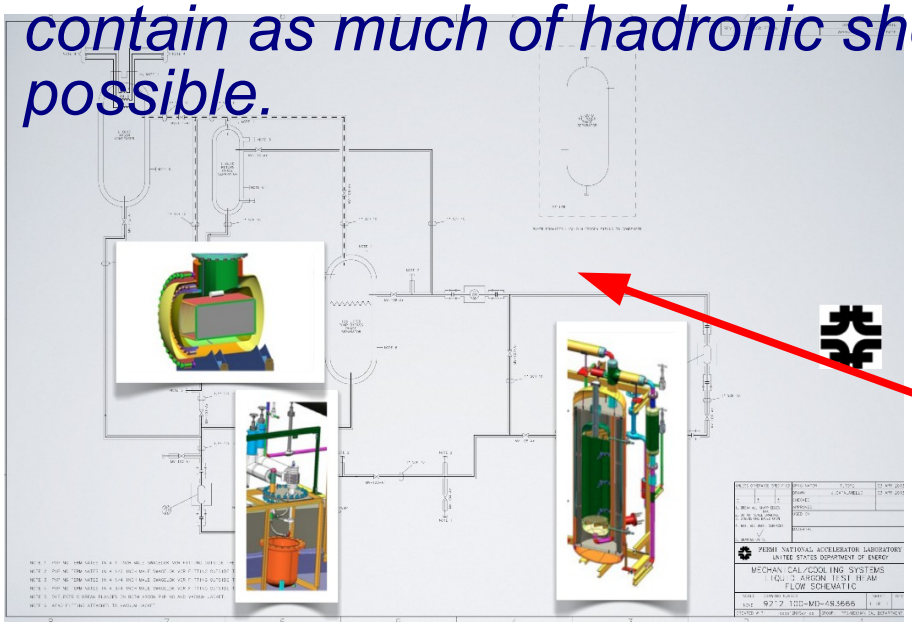
Setting up a test facility to calibrate and test LArTPCs and their components using a beam of charged particles

Phase-I: Reuse the ArgoNeuT detector with small modifications – *should allow relatively quick operation* – planned start of data taking: spring 2014



Phase-II: Larger LarTPC - *Design facility for broader, longer-term use. Sized to contain as much of hadronic showers as possible.*





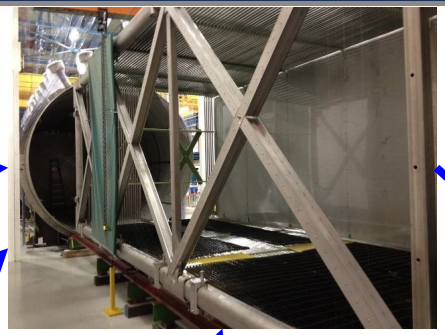
One unique cryogenic/purification facility at FNAL designed to operate for both phases and to allow future tests of LAr detectors

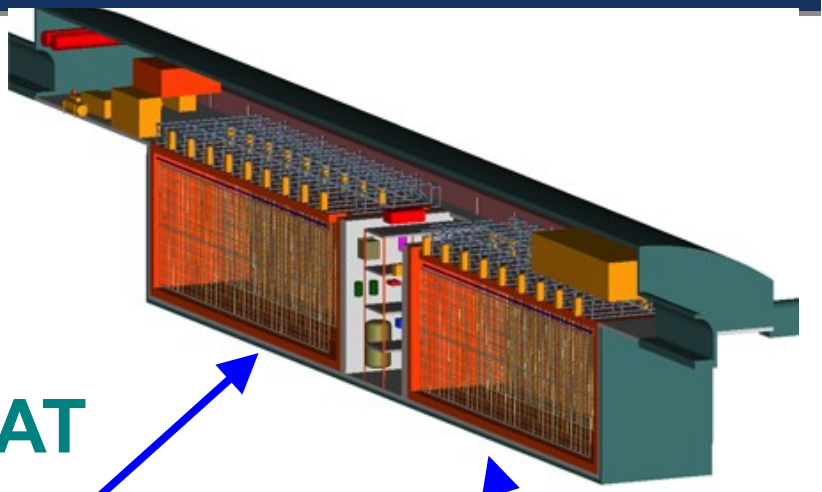
Working toward LBNE

Physics

ArgoNeuT

MicroBooNE





LARIAT

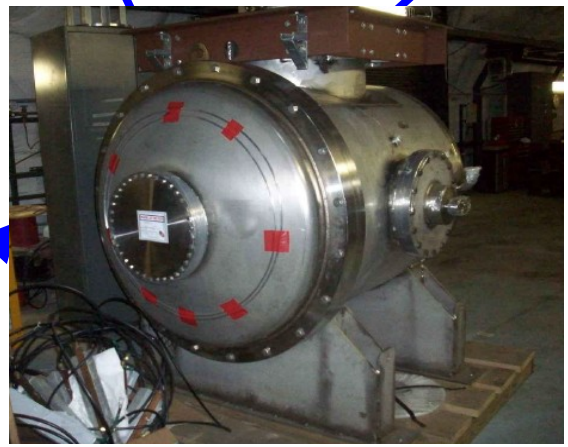
R&D

Bo

Electronics, readout, cold elec.

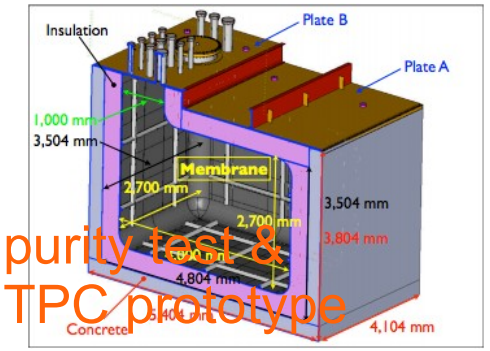
Long Bo

HV,cold elec.,purity



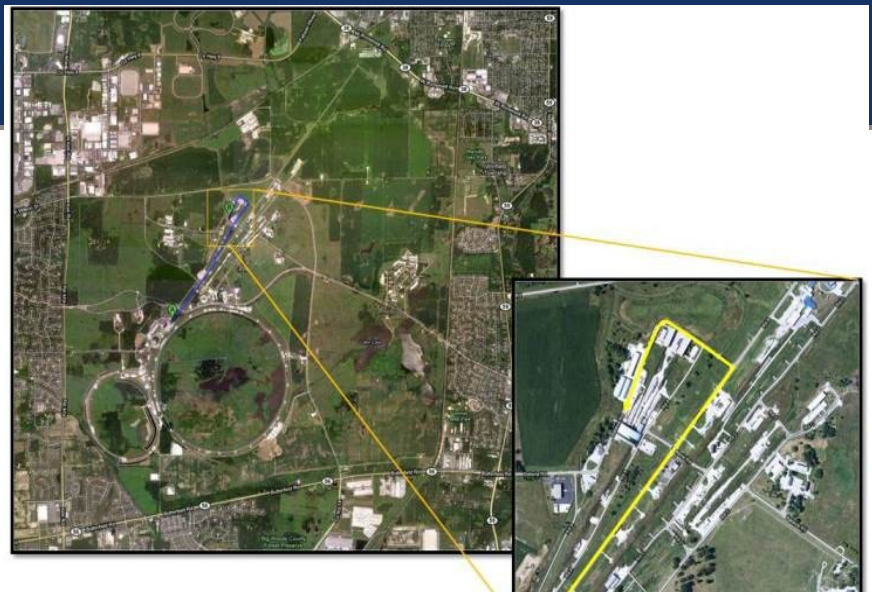
LARIAT

35t membrane cryostat



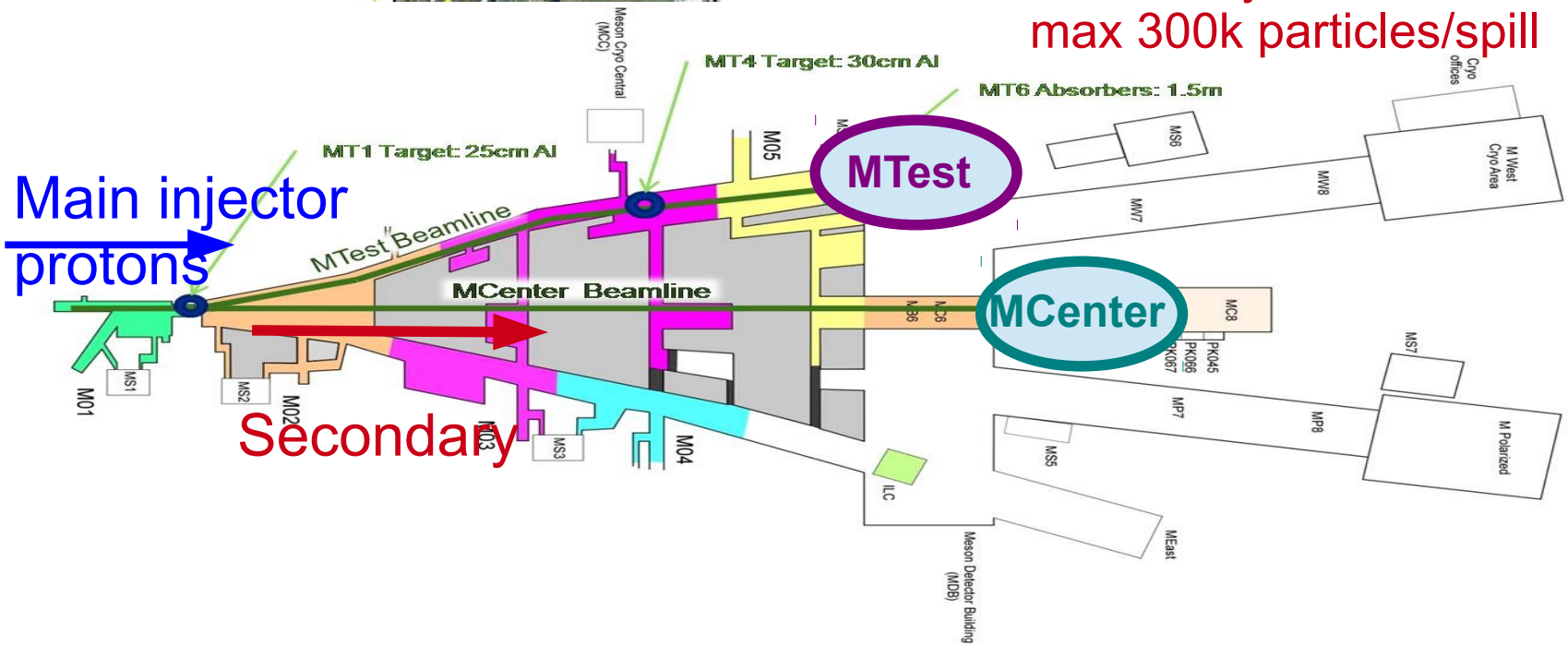
purity test & TPC prototype

Fermilab Testbeam Facility



LArIAT will run in MCenter – allows long term occupation (as opposed to MTest).

Main Injector
One 4s long spill per minute
Secondary beam
max 300k particles/spill

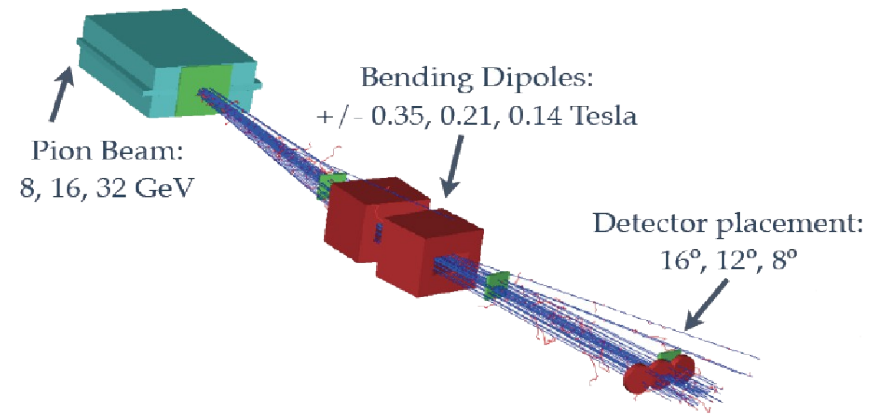


Beam Optimization

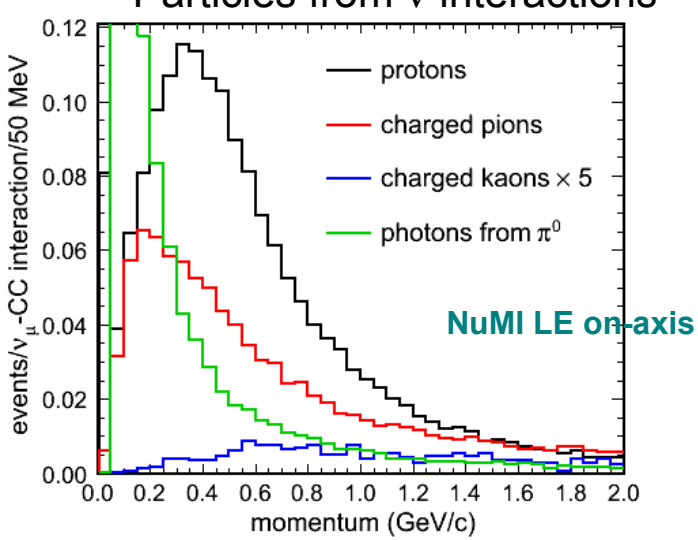
We will use a Tertiary beam (identical to MINERvA beam test).

We are in the process of optimizing the beam configuration to obtain a spectrum of charged particles closely resembling that of future neutrino experiments.

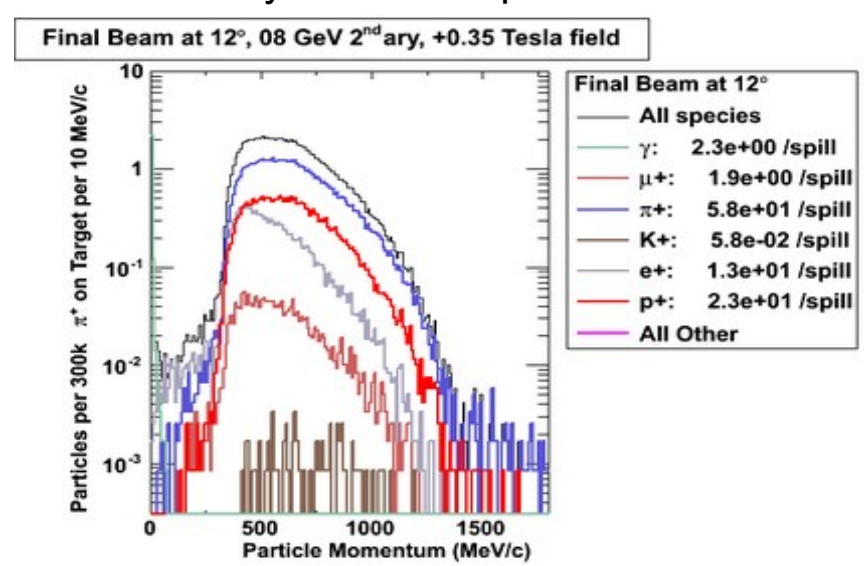
Tertiary Beam at MCenter



Particles from ν interactions

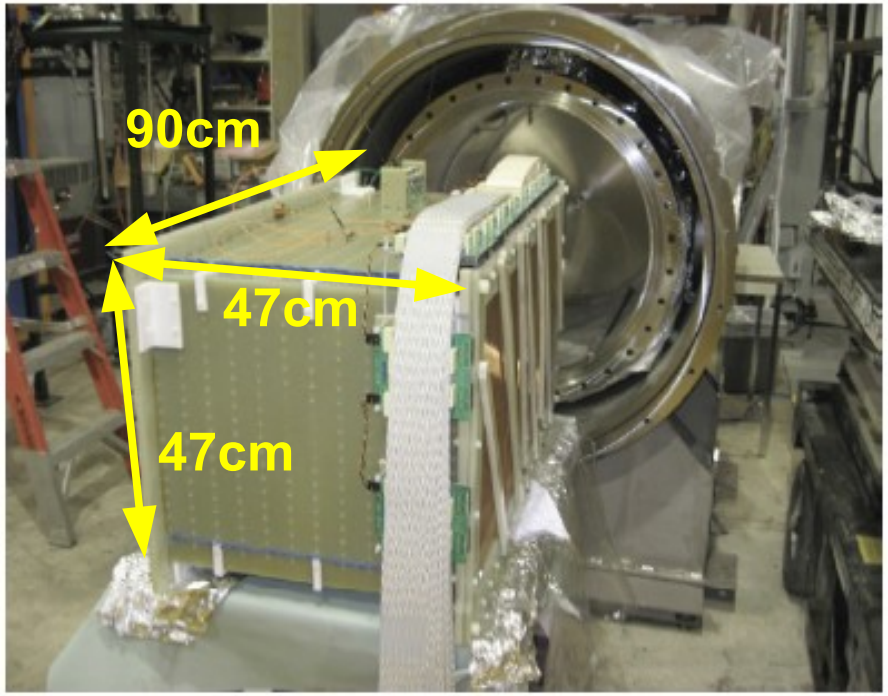


Tertiary Beam composition



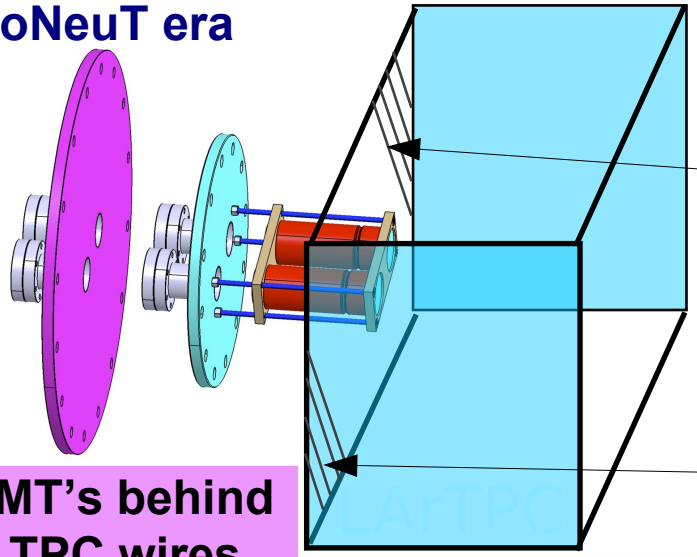
The Detector

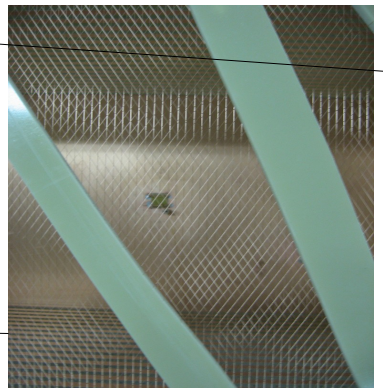
- LArIAT will reuse the ArgoNeuT cryostat and TPC (see ArgoNeuT talk) – allows for relatively quick return time.
- Modifications to cryostat and TPC are needed.
- The detector will have a light collection system.

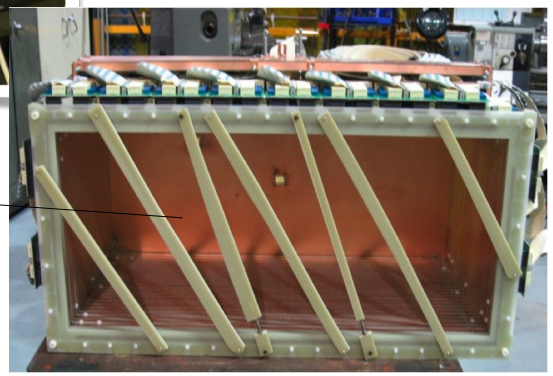


Cryostat and TPC modifications

- **Beam Window flange and excluder**
- **Side Flange for PMT feedthrough.**
- **Bottom flange to allow a liquid recirculation system.**
- **Modify the existing TPC wire frame support structure in order to remove any interference with the PMTs**
- **Planning to restring the existing wire planes which have been in place since the ArgoNeuT era**



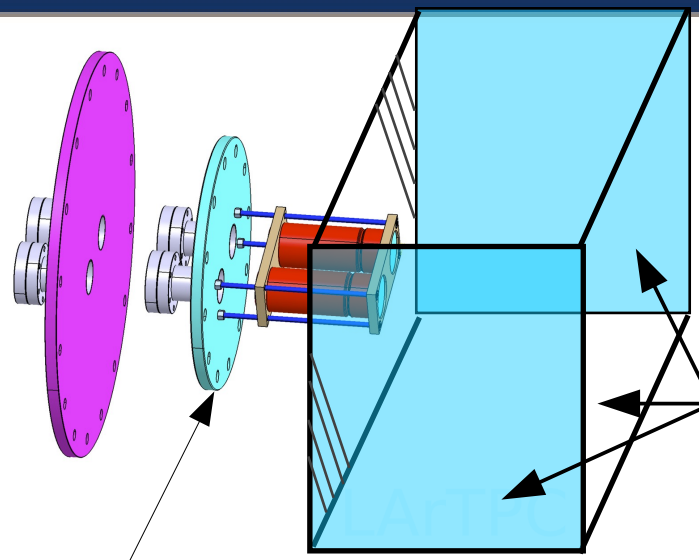




PMT's behind TPC wires

The Light Readout System

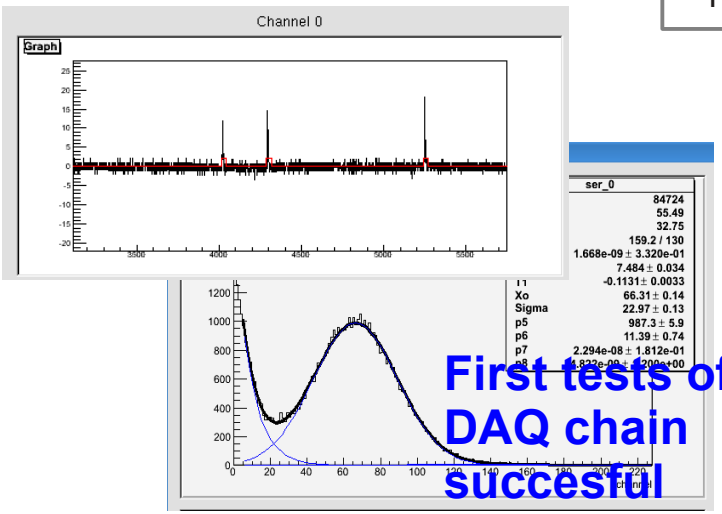
- We want to collect much more light than typical neutrino experiments using argon and digitize it fast enough to differentiate fast and slow light
- This will be achieved by lining the inside of the chamber with TPB coated reflector foil.
- Read out with fast digitizer, 1GS/s sampling



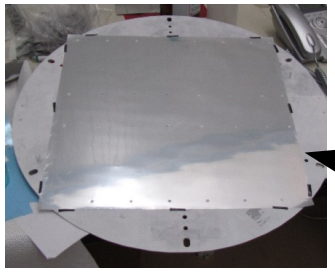
Two cryogenic PMTS
- one 3” high QE (30%)
- one 2” standard QE (20%)

+2 SiPMs

Wavelength shifting reflector foil

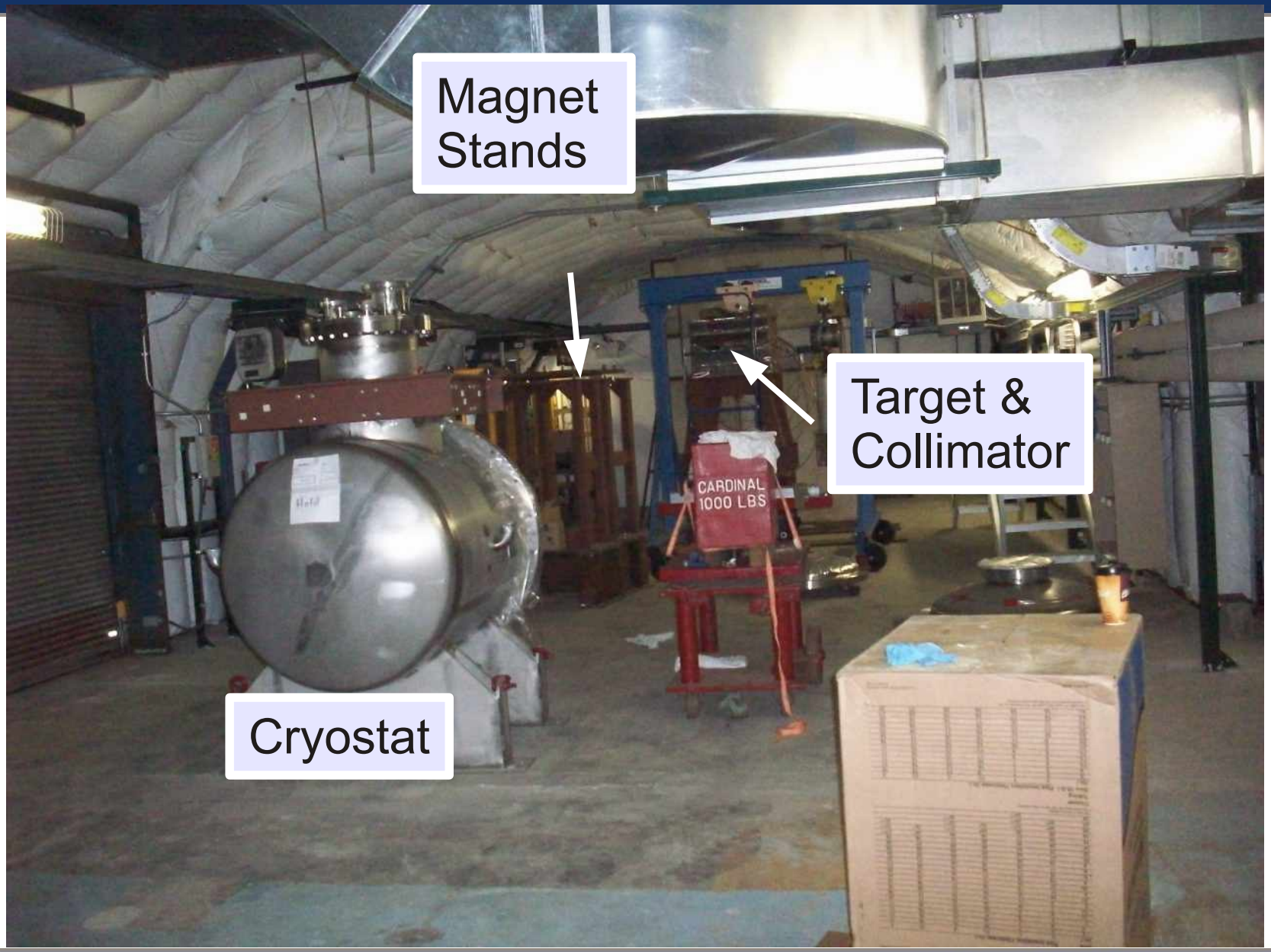


First tests of DAQ chain succesful

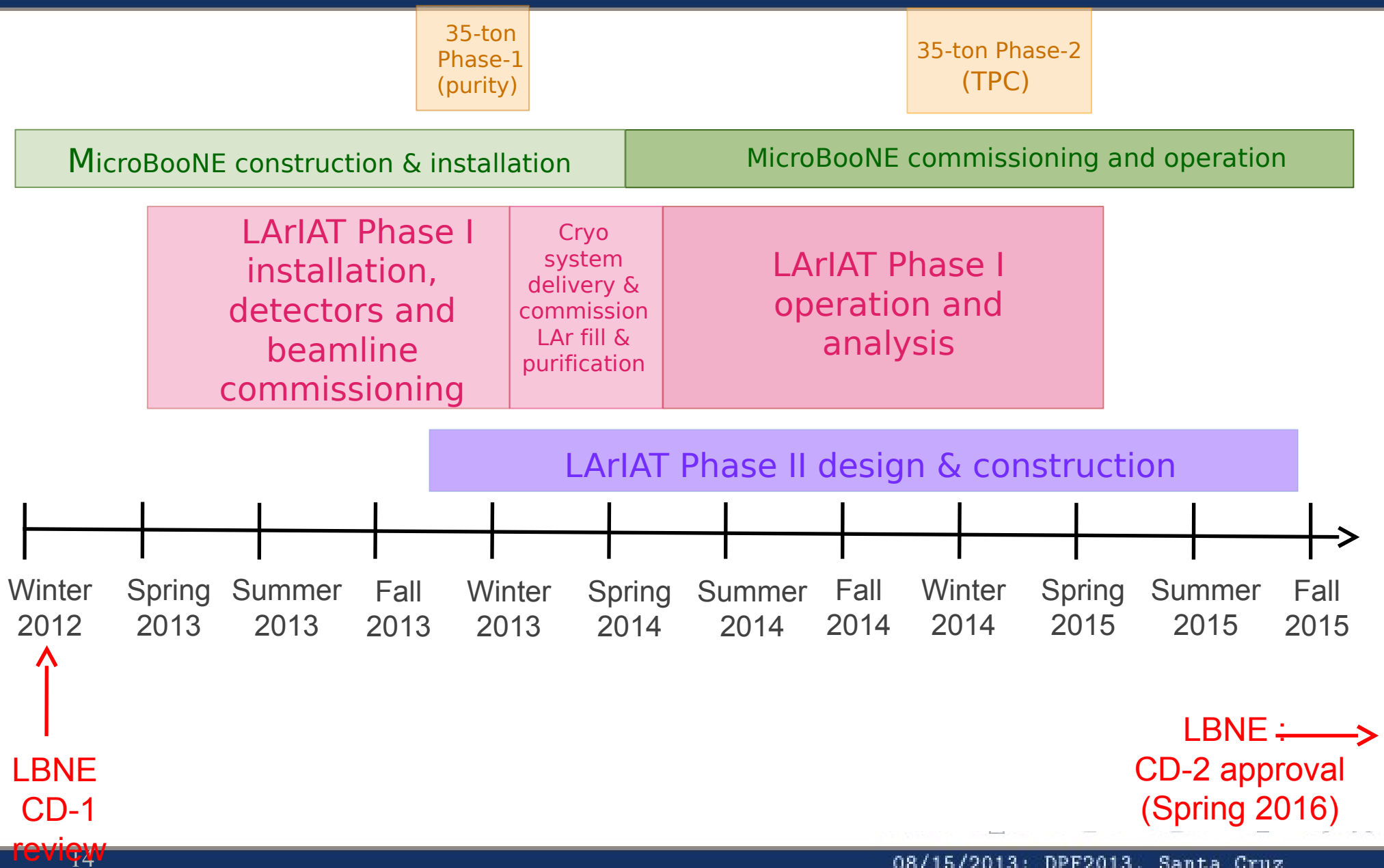


Applying TPB to the reflective foil that will line the inside of the LArIAT TPC

Experiment setup in progress



LAr R&D Timeline

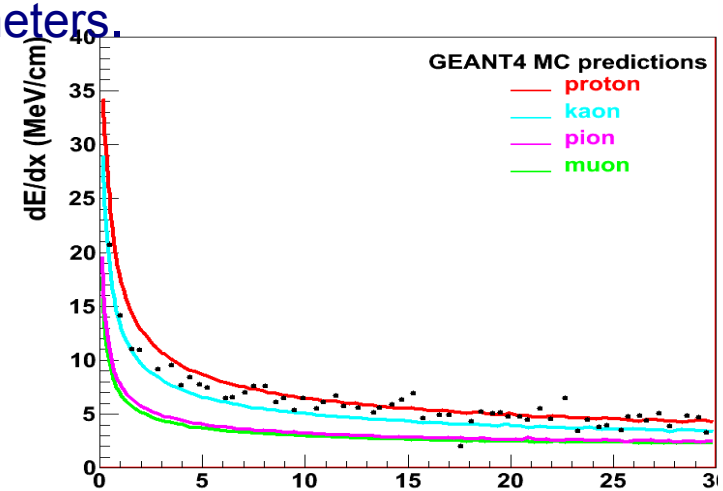


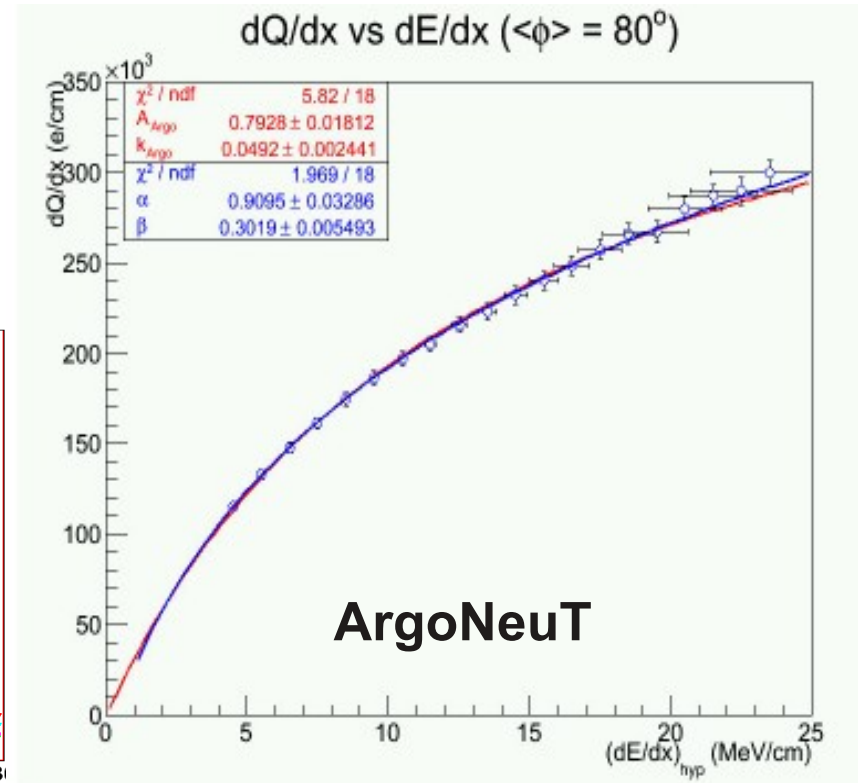
LArIAT physics goals

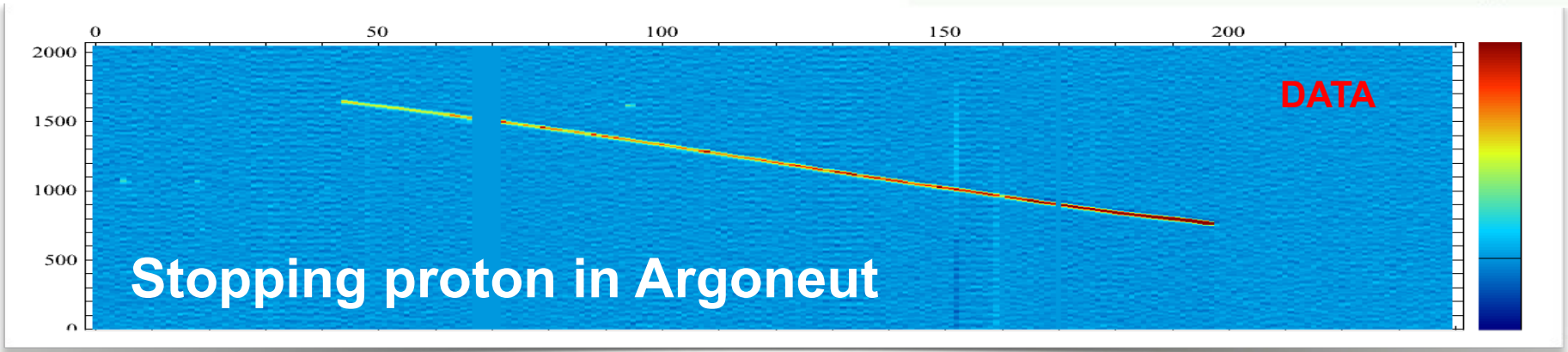
- Optimizing the particle ID:
  - For protons, kaons and pions measuring the recombination factors.
  - For electrons and gammas measuring the dE/dx separation.
- Non-magnetic muon sign determination.
- Anti-proton event studies.
- Testing new technologies!
- Phase 2: Continue studies from phase 1.
- EM and hadronic shower containment studies.

Visible energy calibration

- **dE/dx** measurement provides particle ID and energy.
- It depends on the electron recombination in LAr.
- By studying the dQ/dx of stopping tracks of known energy we can precisely determine the recombination parameters.

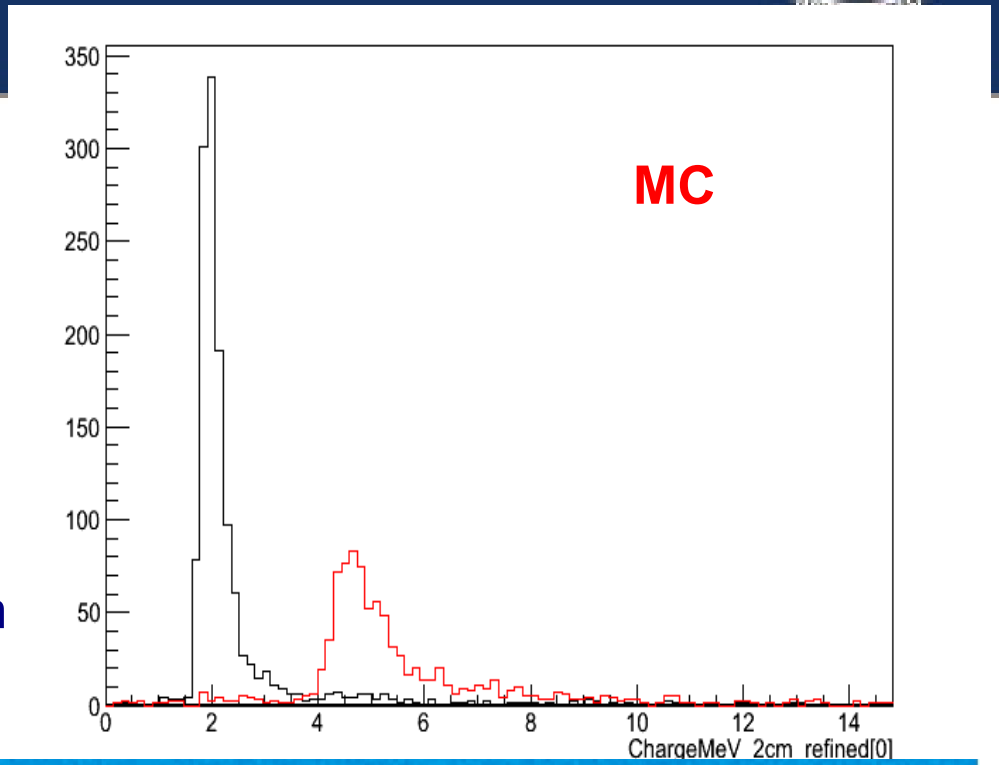






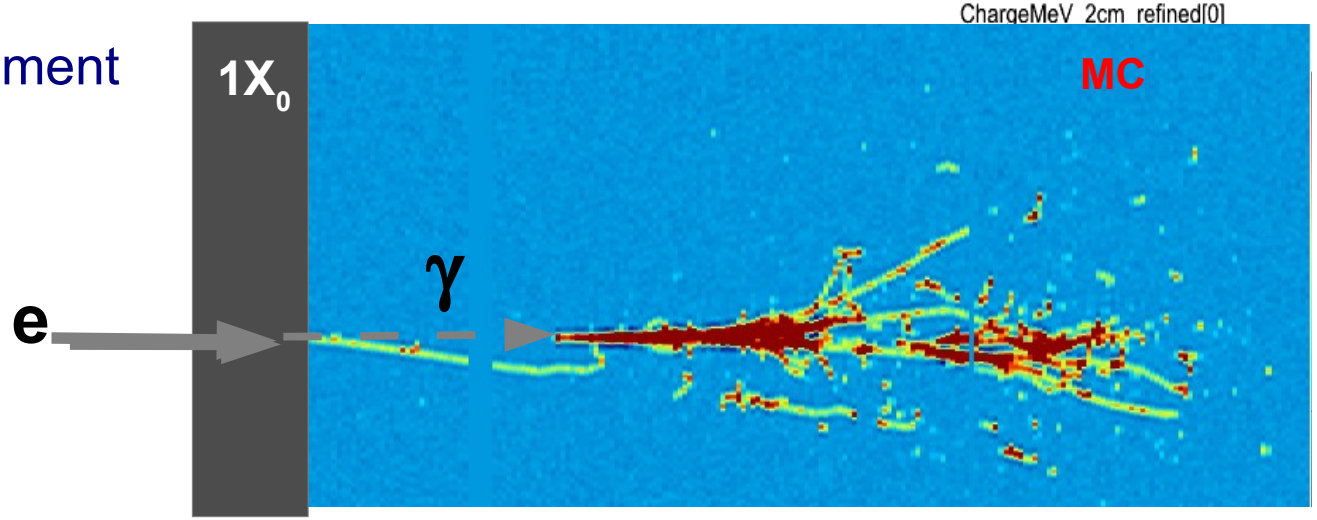
Gamma/electron separation

Crucial for separating ν_eCC signal from π^0 background coming from NC interactions.

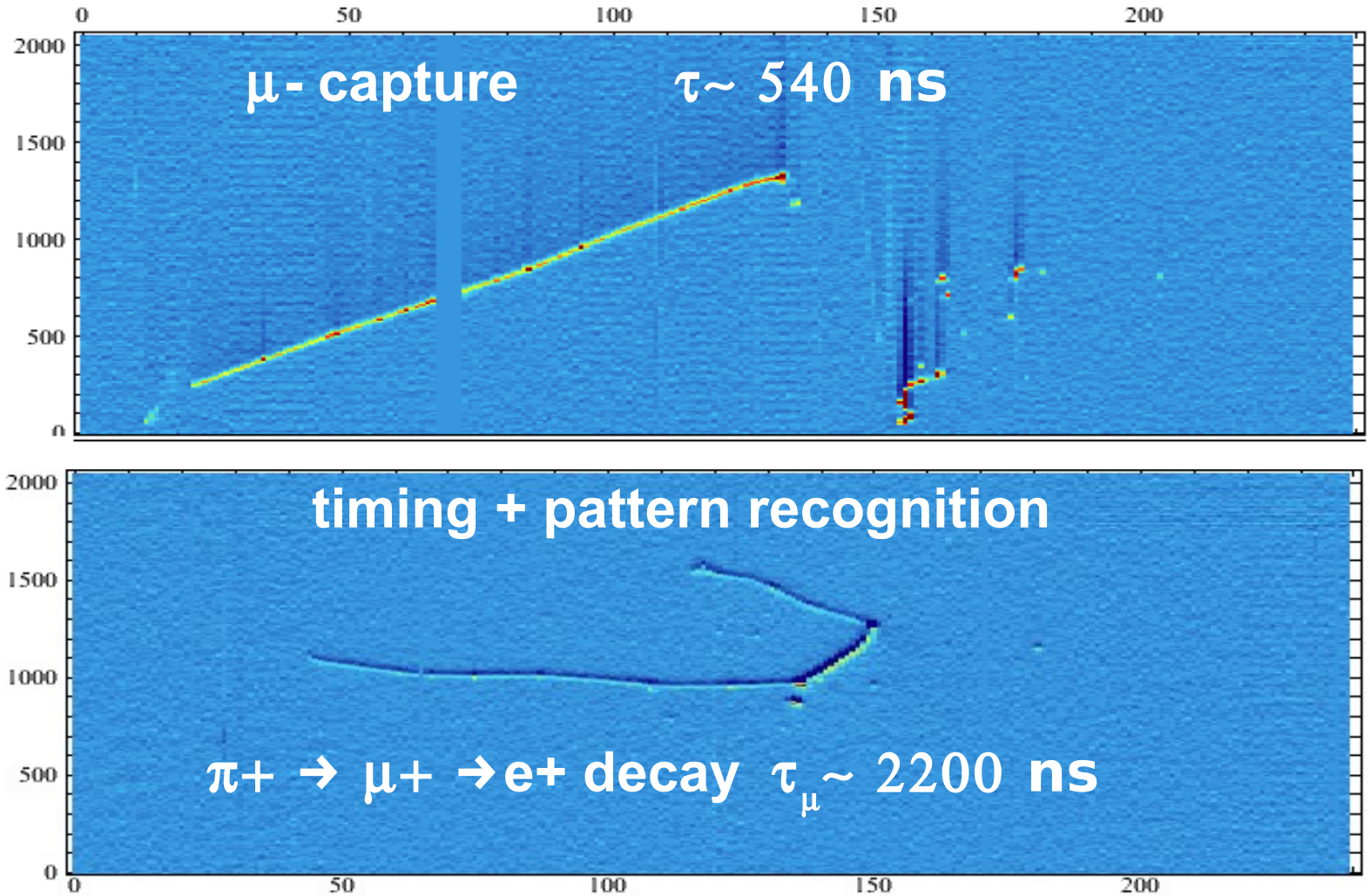


Electrons are found in beam.
Photons generated via brehmsstrahlung in $1X_0$ pre-shower disk.

Do not need shower containment

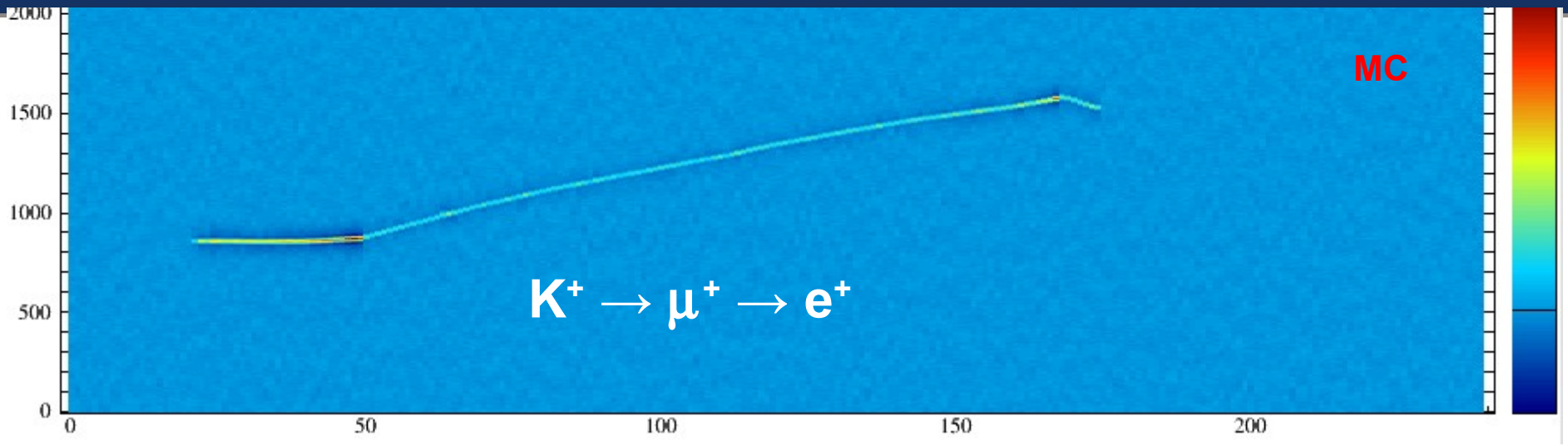


Muon Sign Determination



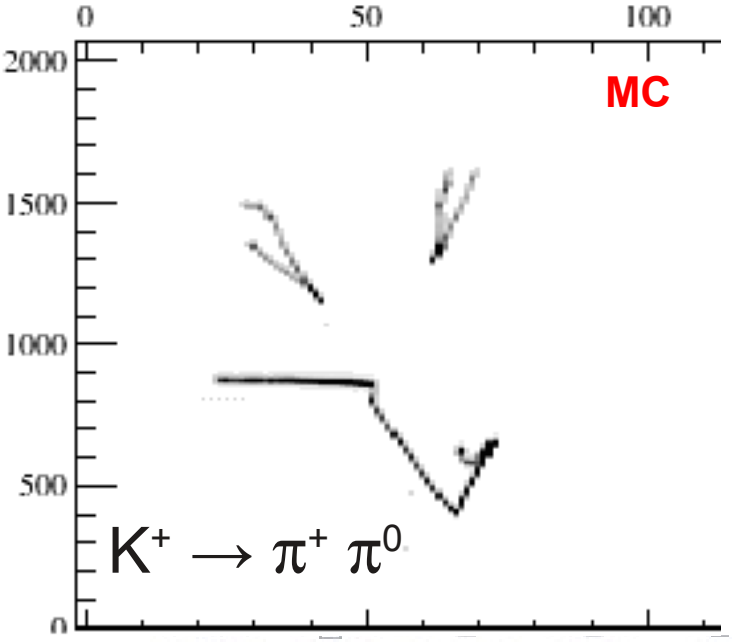
76% μ- undergo capture, 24% decay resulting in different topologies:
Non magnetic sign determination possible!

$K^{\pm}$ reconstruction

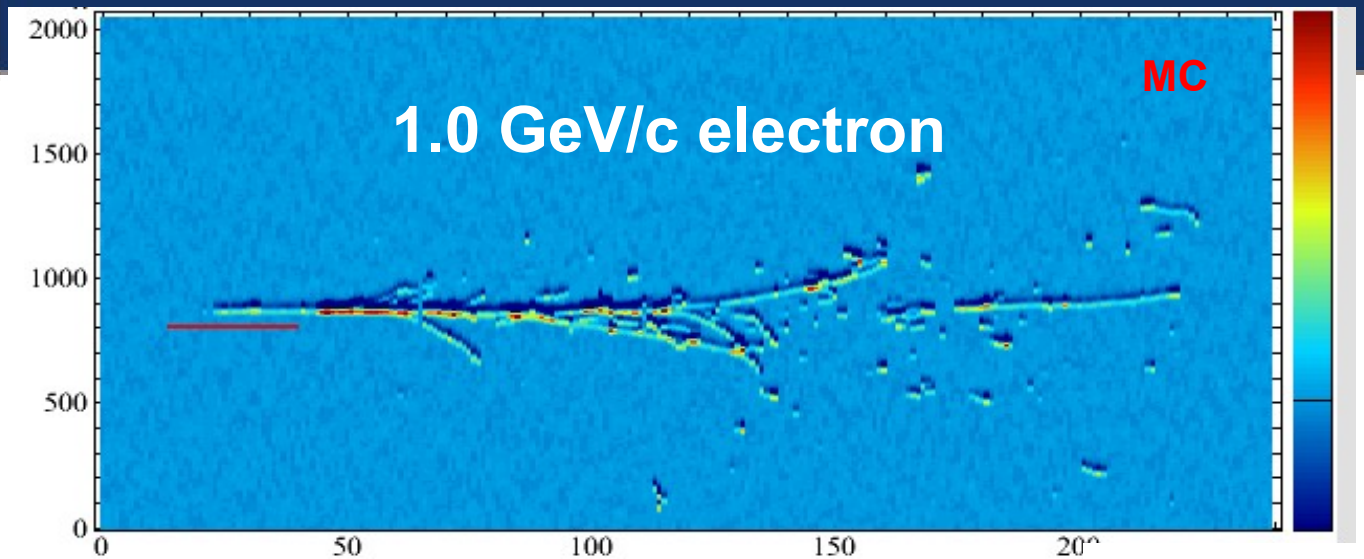


Kaon dE/dx to differentiate from Protons.

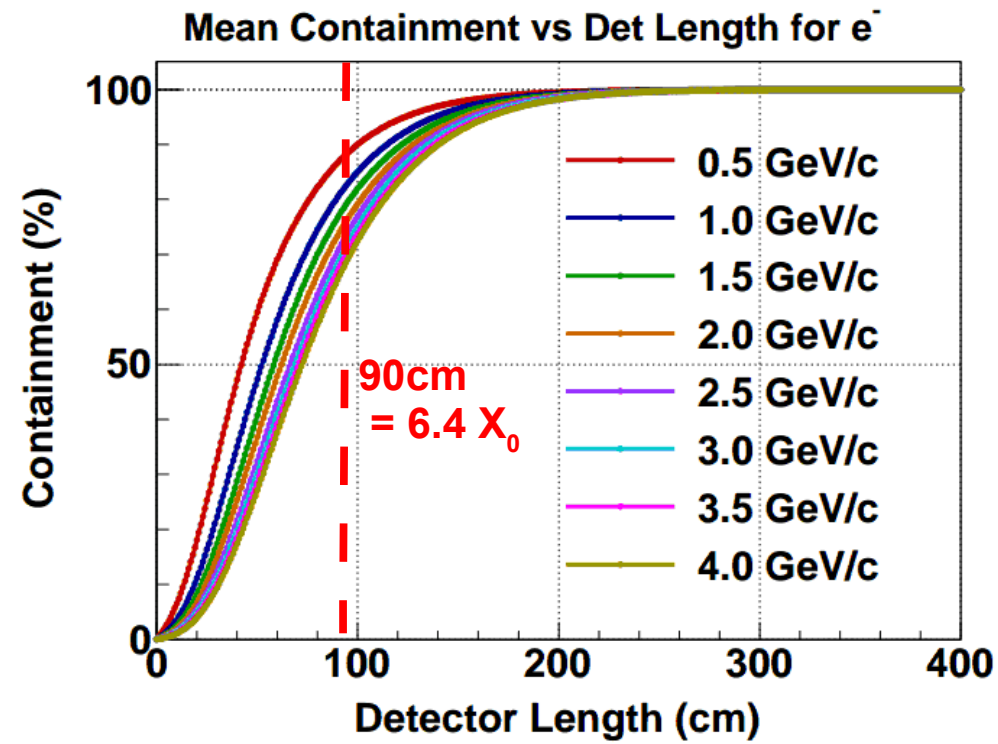
Will provide insight into possible proton decay topologies.



Energy measurements



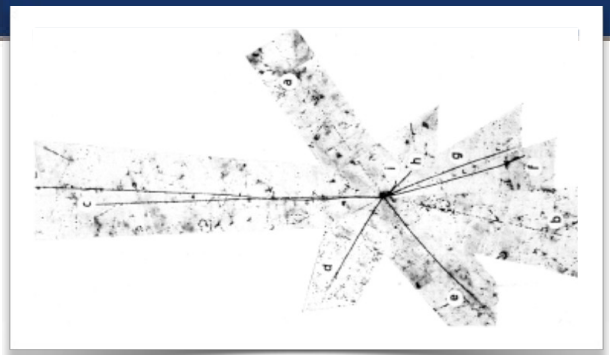
Benchmark MC



<u>Electrons</u>
~80% containment
for p <1 GeV/c
<u>Stopping range</u>
protons p<1 GeV/c

This will be done better
in phase II

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

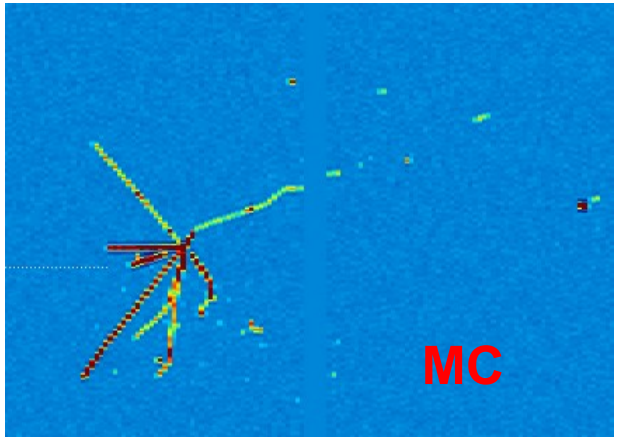


Antiproton Star Observed in Emulsion*

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 underground LArTPC detectors.

Summary

- LArIAT is an important component of the LAr R&D program
- It has a rich physics program that will enhance the capabilities of future neutrino detectors.
- Well aligned with MicroBooNE and LBNE in terms of time and particle energies.
- Phase I will start taking data next spring!
- Phase II will provide a testing ground for LArTPC technology in the future.

Thank You!

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