The Status of The MicroBooNE Experiment

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NUFACT11

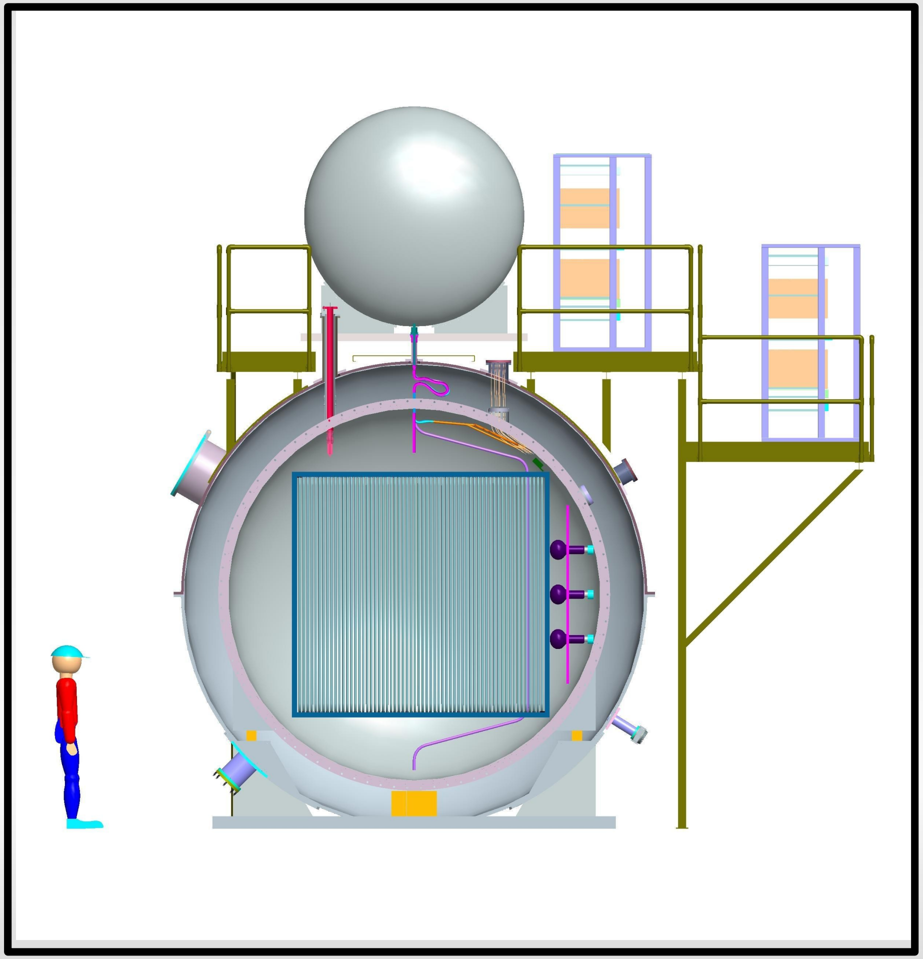
CERN - 1st, 5th and 6th Aug'11

UNIGE - 2nd - 4th Aug'11

MicroBooNE

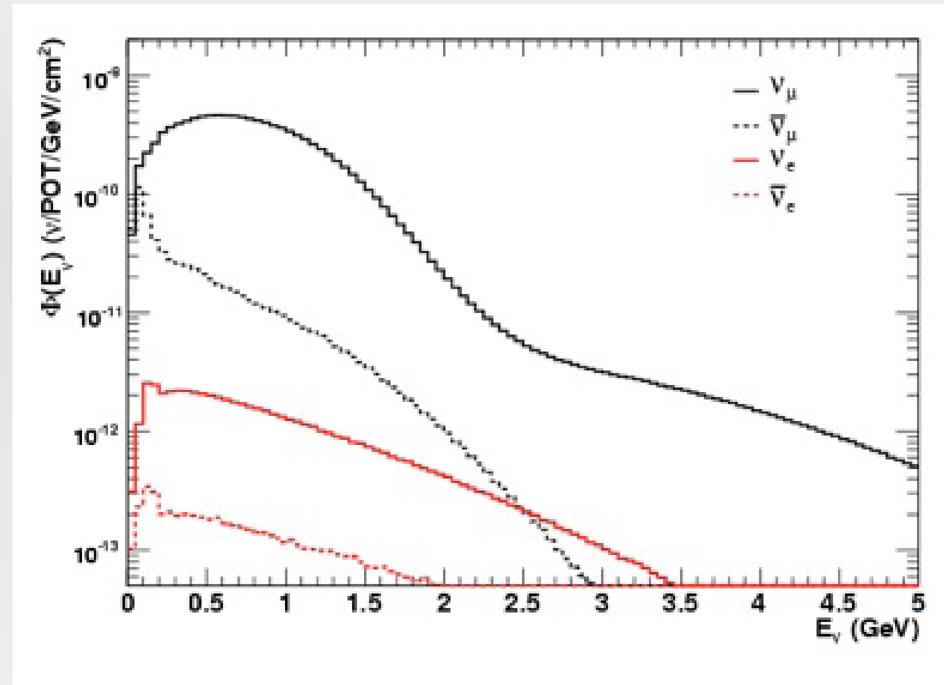
- MicroBooNE is a 170 ton liquid argon TPC detector which will start running at Fermilab in ~2013-2014

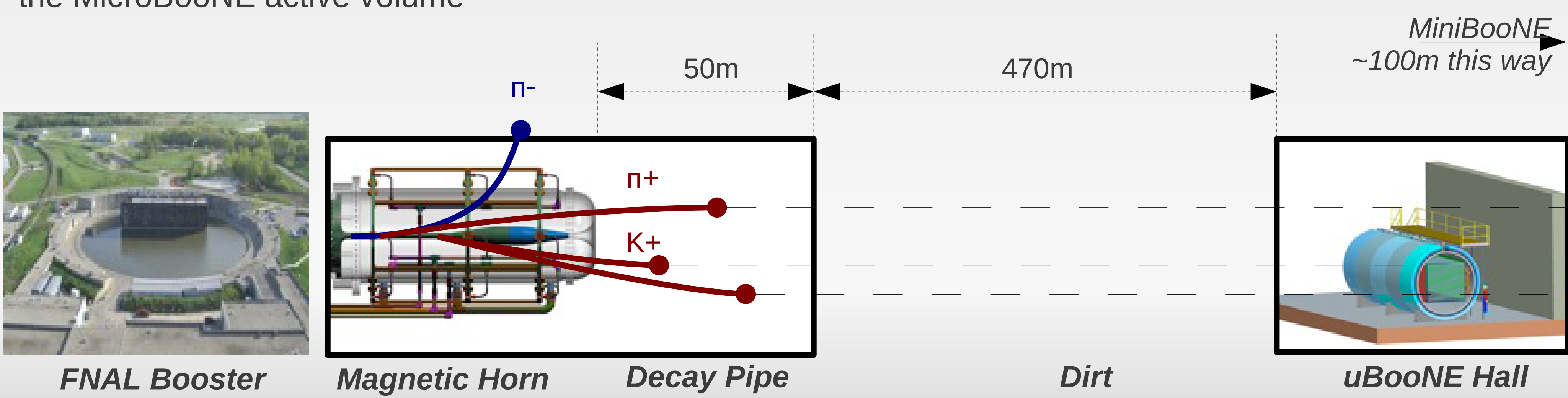
- 2.5 x 2.3 x 10.4 m TPC volume with a 2.5m charge drift
- Corresponds to an active volume of 70 tons (TPC interior volume)
- The total fiducial volume is 60 tons (>35cm from any TPC wall)
- Run plan is to take 6.6×10^{20} POT in the Booster Neutrino Beam (BNB) in neutrino mode
- This represents the highest statistics sample of neutrino interactions collected in liquid argon
- MicroBooNE also has the longest drift distance so far employed in a LArTPC neutrino experiment.



BNB : The Booster Neutrino Beamline

- 8 GeV protons from the FNAL booster impinge upon a beryllium target, producing pions and kaons
- Mesons of a chosen charge are focussed in the beam direction and wrong sign mesons are defocussed, by a 174kA magnetic horn
- Selected mesons and a small wrong sign BG decay in a 50m decay pipe, producing a forward neutrino beam with ~1GeV peak energy
- The neutrinos pass through 470m of dirt and arrive at the MicroBooNE detector hall
- A small fraction of beam neutrinos then interact in the MicroBooNE active volume



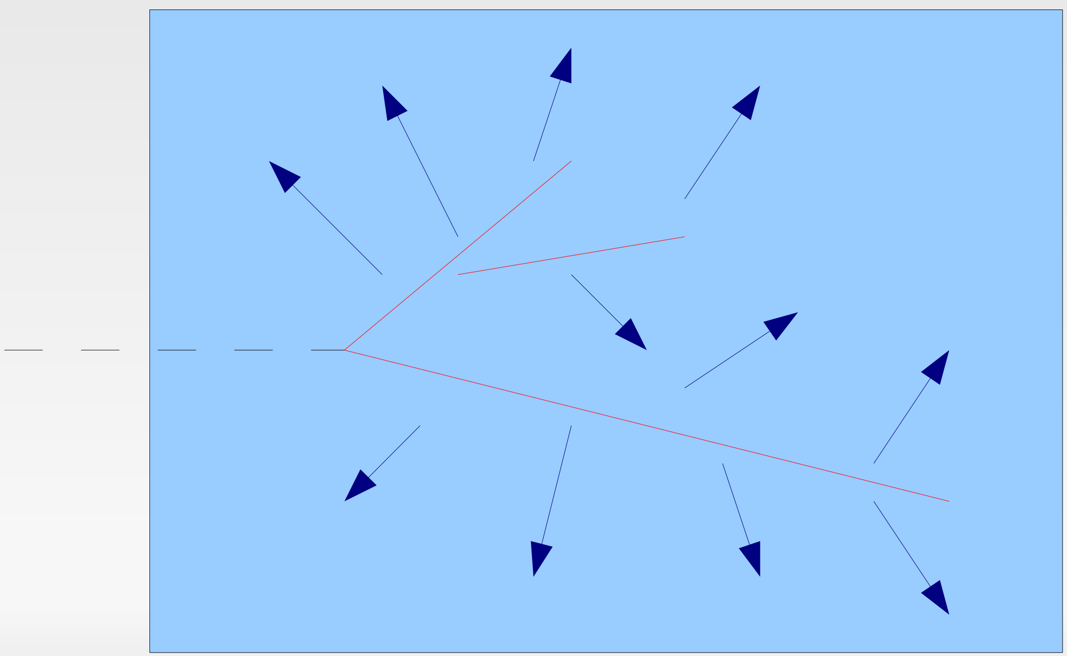


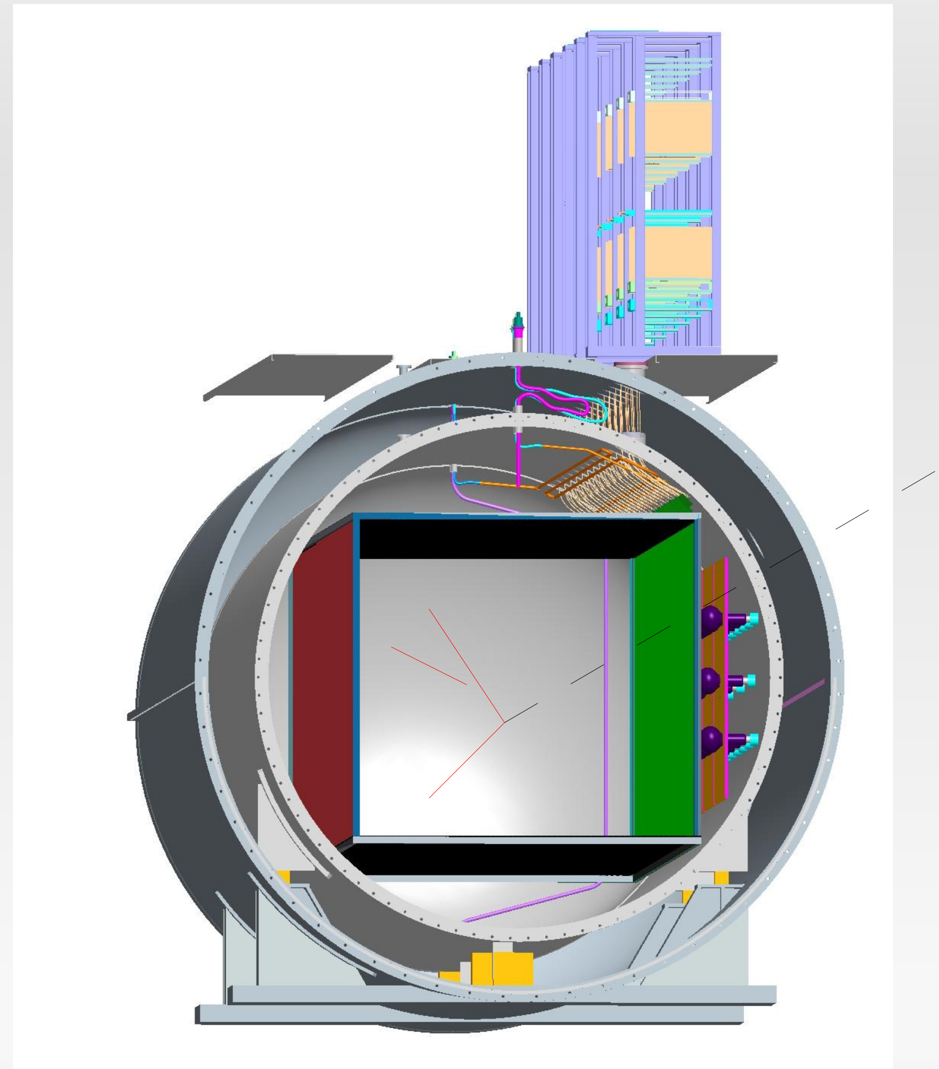
MicroBooNE Sensitive Detectors

A neutrino interaction produces charged and neutral particles which continue through the argon volume

The motion of the charged particles liberates charge from the surrounding argon (**ionization**) and produces light (**scintillation**)

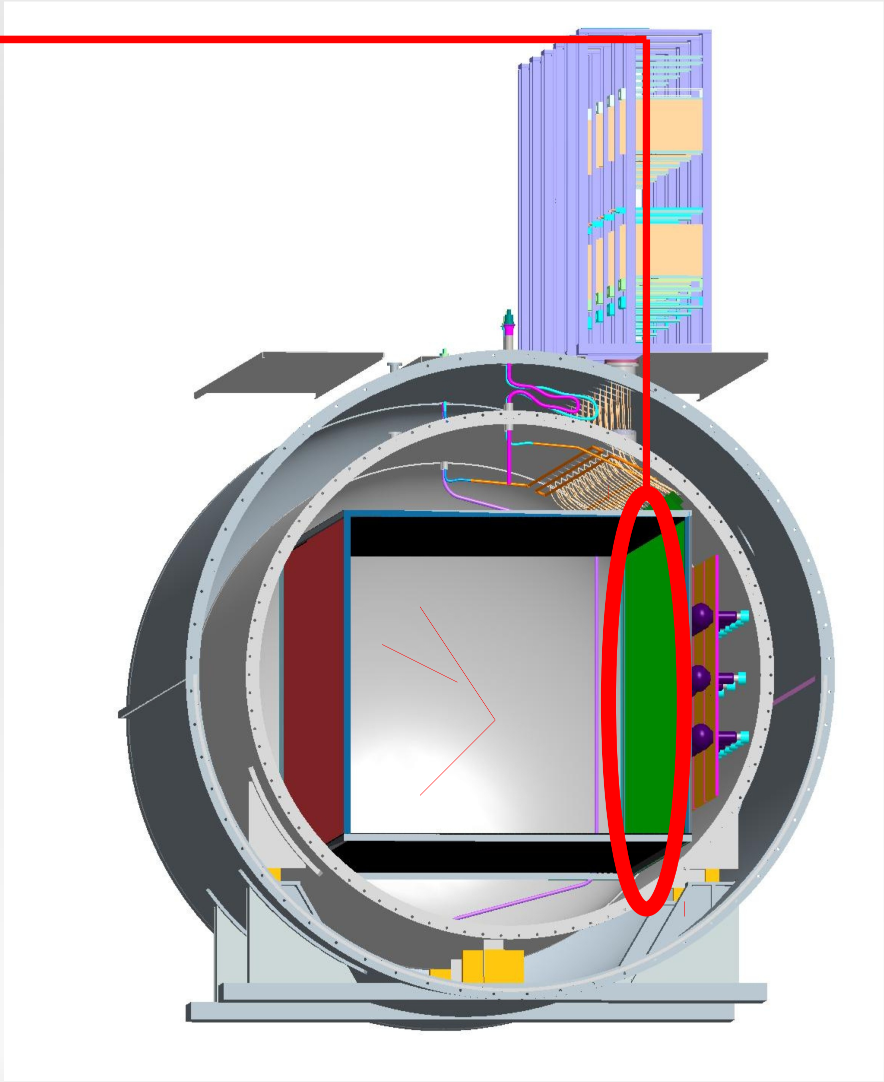
MicroBooNE measures both of these signals





MicroBooNE Sensitive Detectors

1 – TPC System



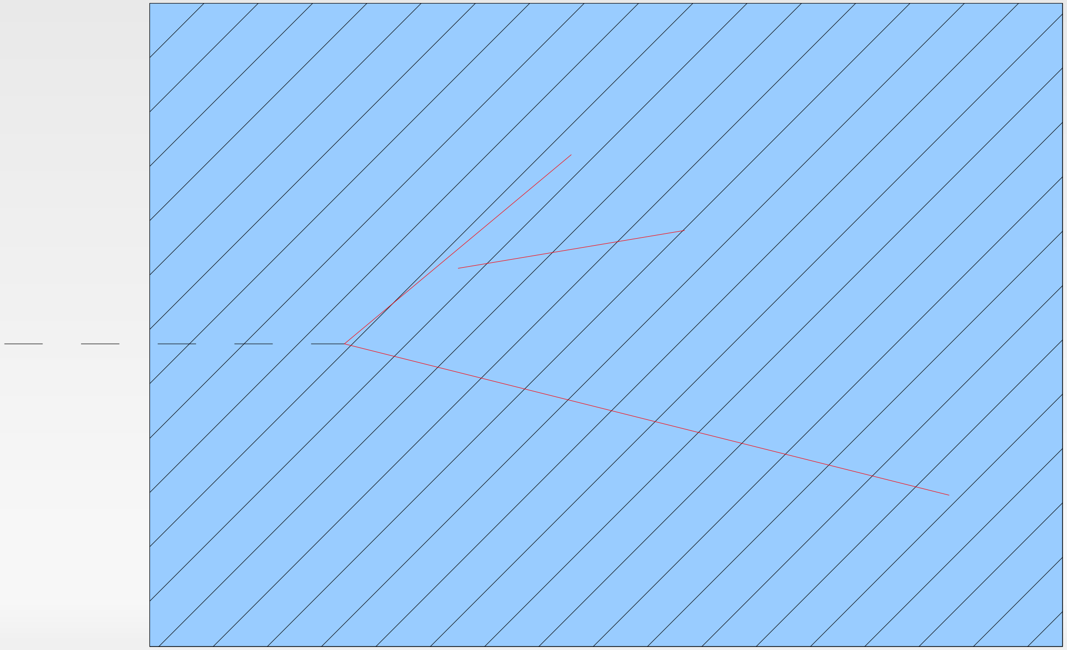
MicroBooNE Sensitive Detectors

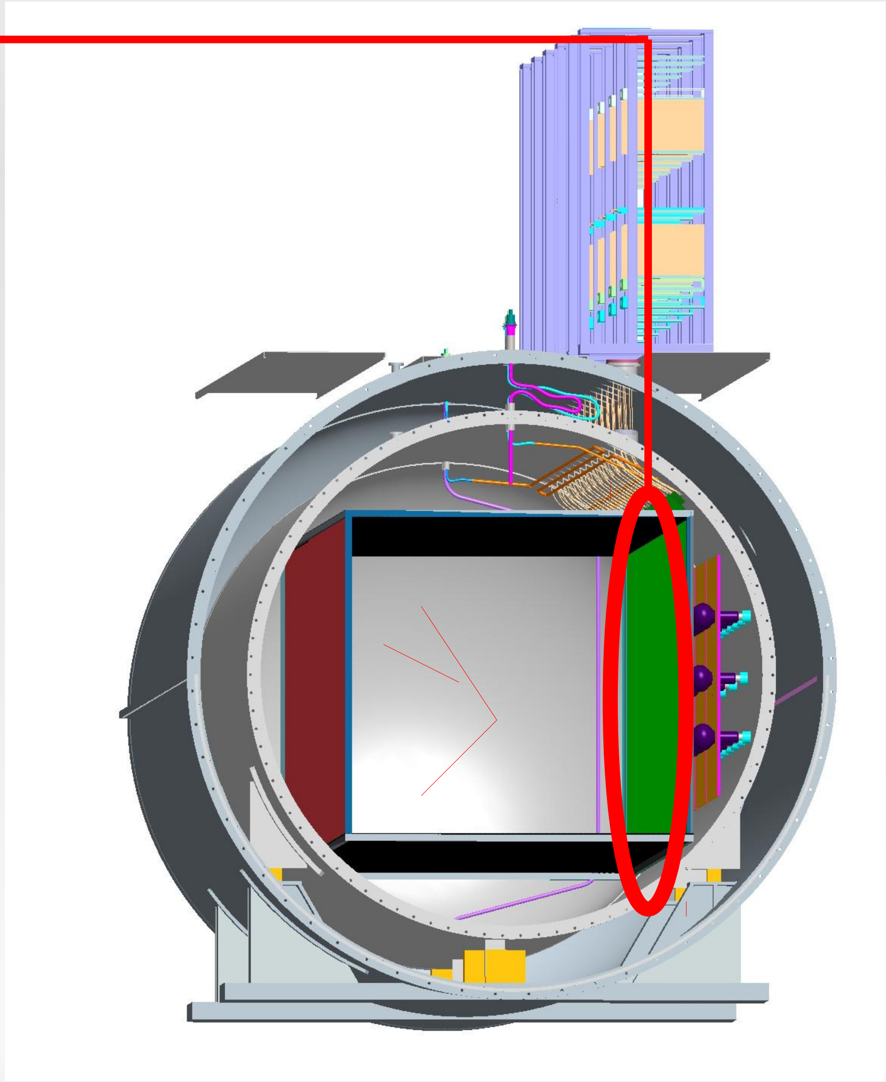
1 – TPC System

Charge drifts in a strong E field (500 V/cm)

At the x=0 end of the TPC there are three crossed wire planes which detect the charge

Using both spatial and temporal information, reconstruct a 3d image of the event in question





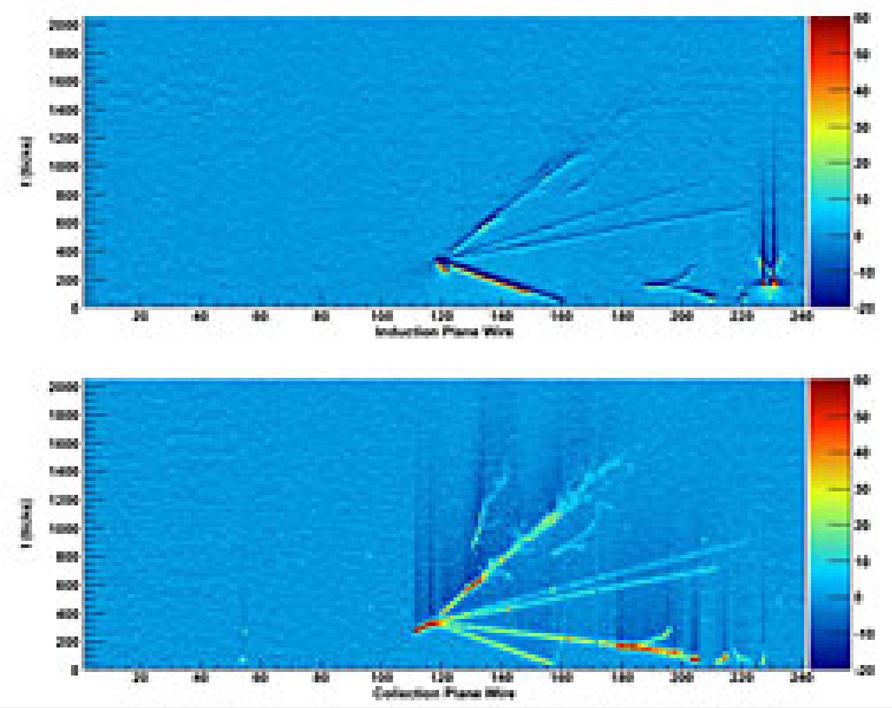
MicroBooNE Sensitive Detectors

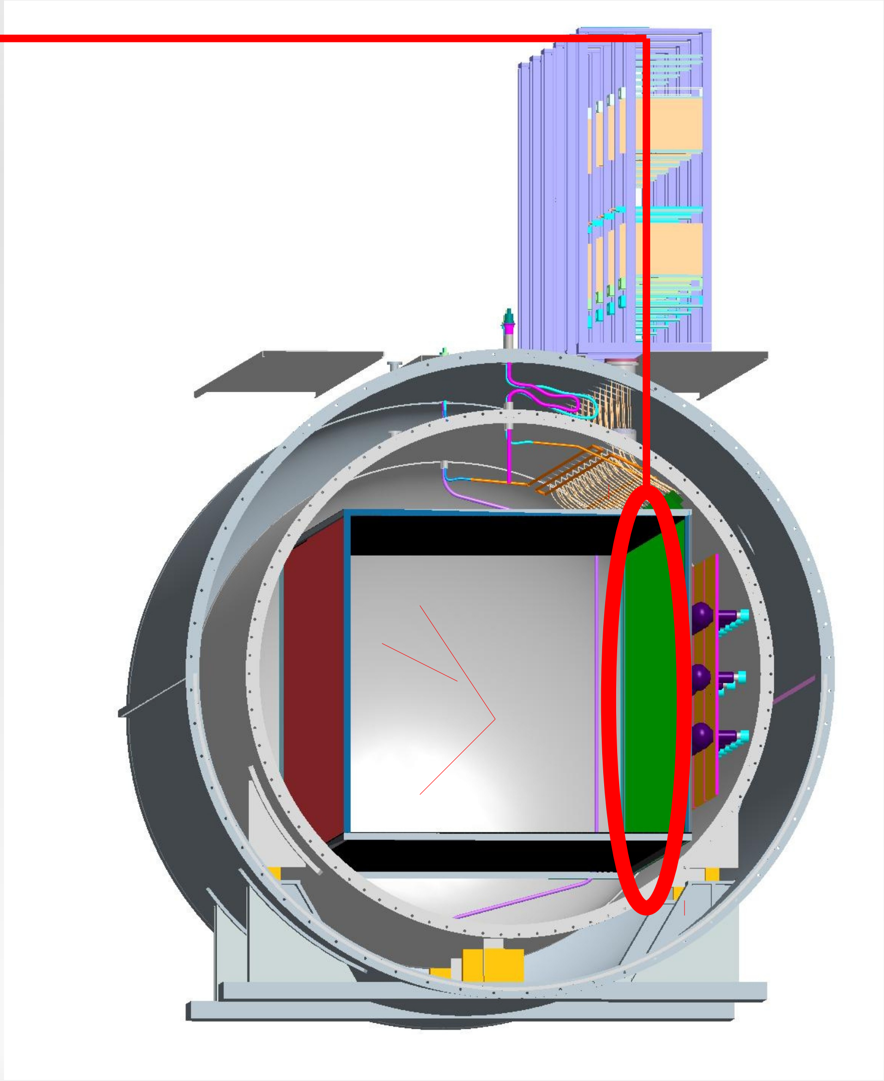
1 – TPC System

MicroBooNE improves on ICARUS by having a 2.5m drift (for kiloton scales we would like to go even higher)

It has 3 wire planes with 3mm pitch at 3 different angles

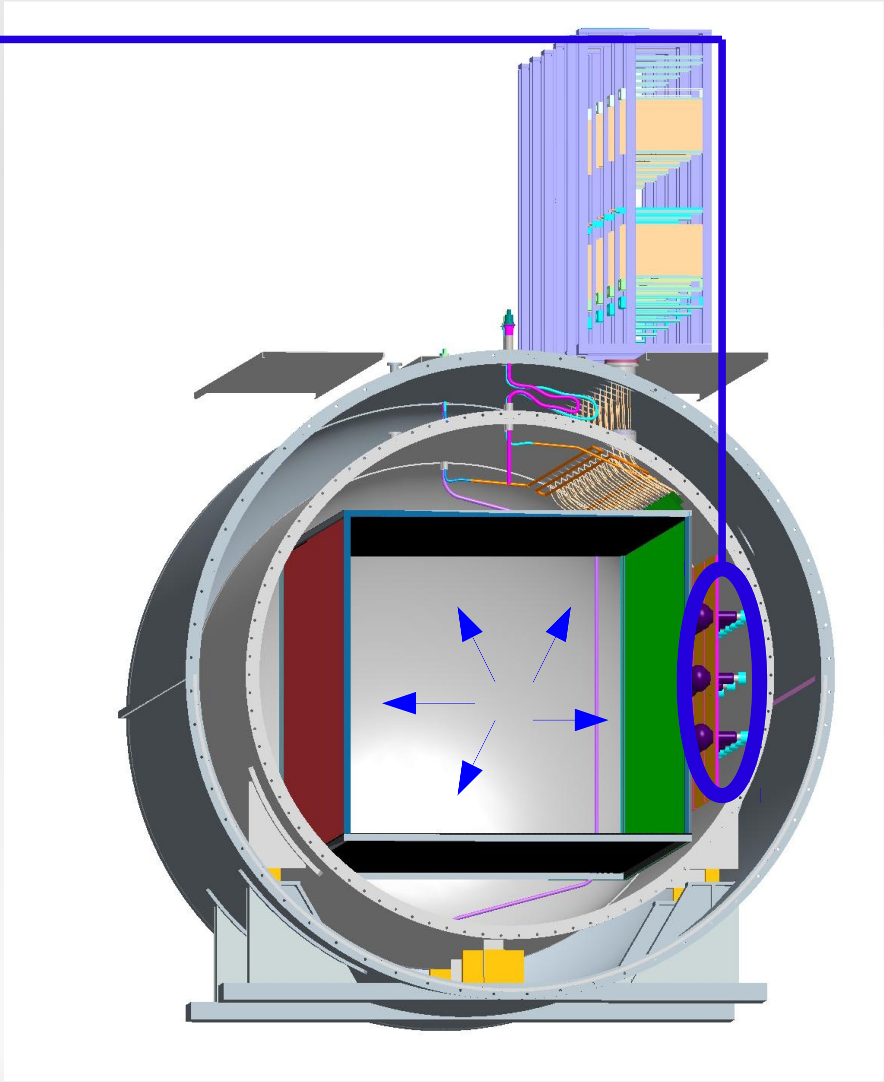
Below is an event display from ArgoNeuT, a much smaller liquid argon prototype TPC at Fermilab





MicroBooNE Sensitive Detectors

2 – Optical System

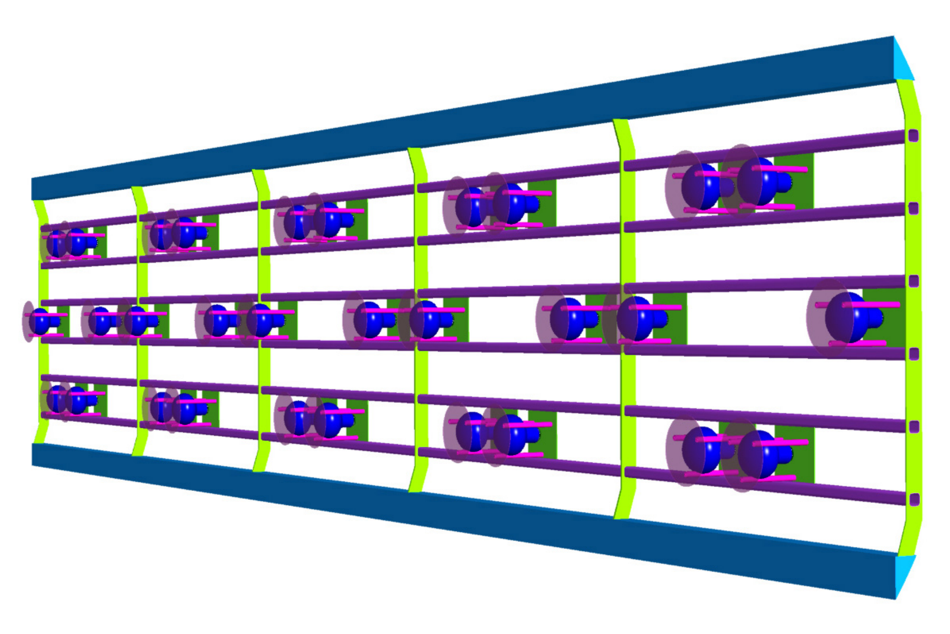


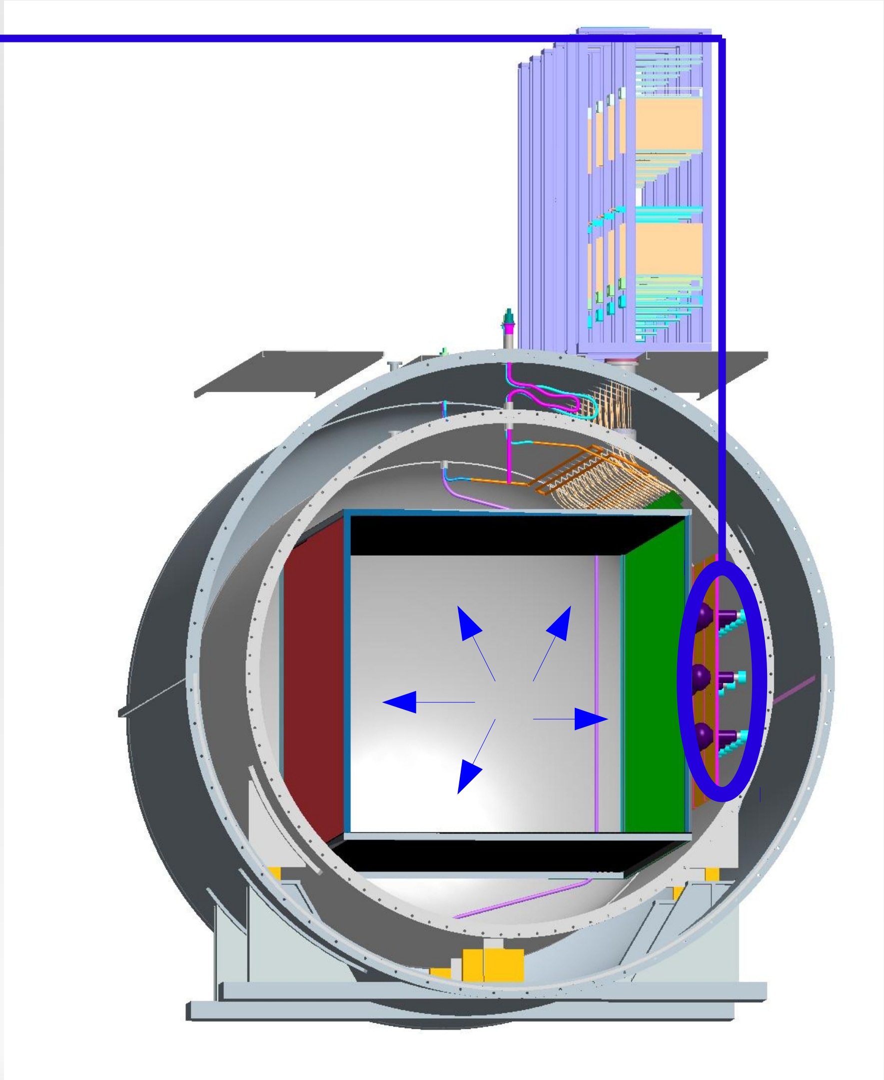
MicroBooNE Sensitive Detectors

2 – Optical System

The primary importance of the optical systems is for triggering. Scintillation light has a strong prompt component so can provide detailed timing information

But optical information can also contribute to reconstruction





Motivations for the Experiment:
1 – The MiniBooNE Anomalies

The MiniBooNE experiment was proposed in order to explore an anomalous $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ appearance signal reported by the LSND collaboraion.

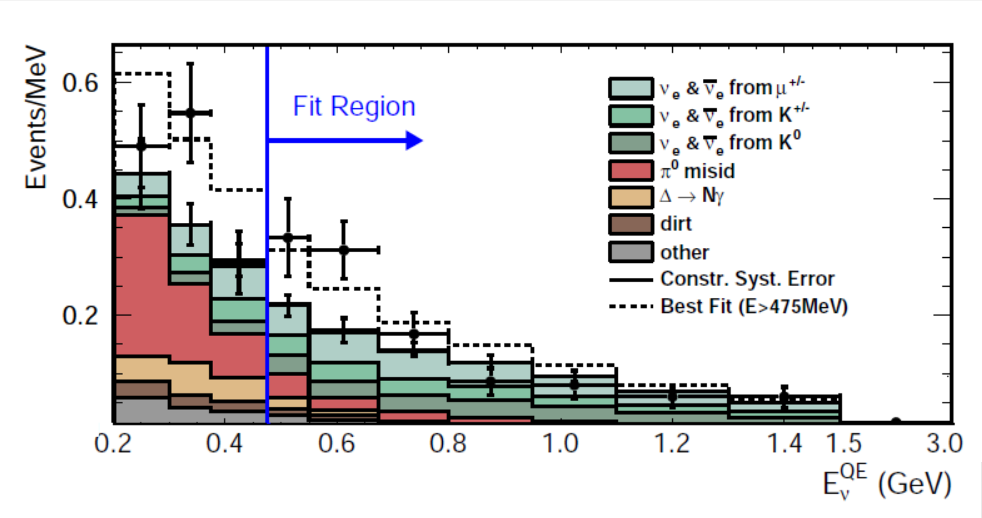
Possible explanations for this anomalous appearance include the existence of a hypothetical sterile neutrino, which contributes to oscillations but does not participate in the weak interaction.

MiniBooNE was designed to run in the same L/E range as LSND with larger L and E.

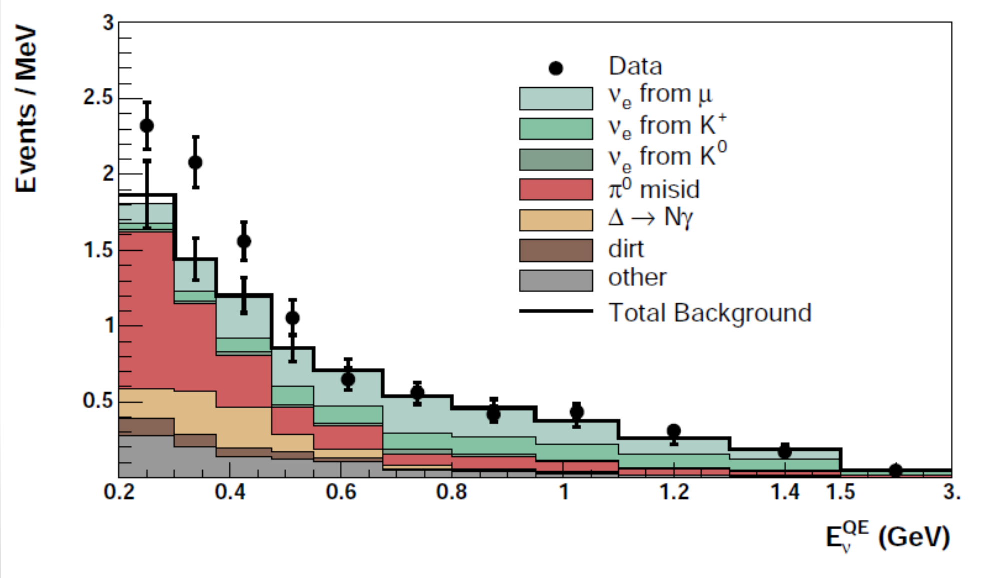
Key observations:

- No evidence for large Δm^2 oscillations was observed in neutrino mode
- In antineutrino mode, an anomalous appearance signal was observed, but is not compatible with the LSND signal in the (3+1) sterile neutrino hypothesis
- In both modes, an additional anomalous appearance signal was observed at low energies

MiniBooNE Antineutrino Mode



MiniBooNE Neutrino Mode



Motivations for the Experiment:
1 – The MiniBooNE Anomalies

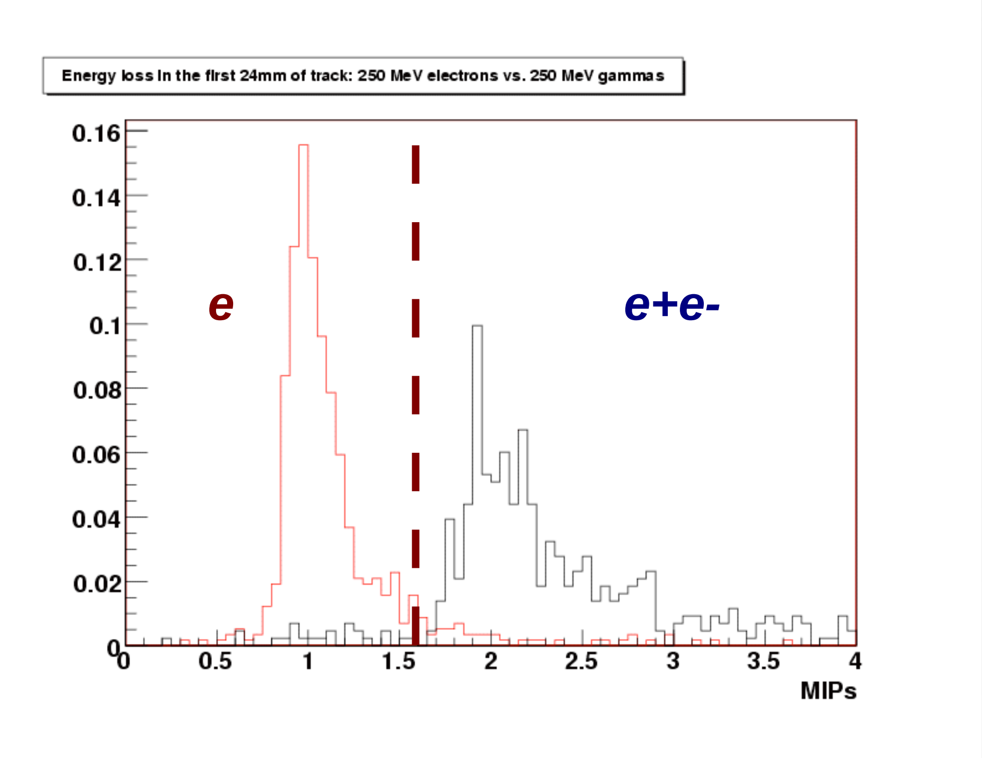
The low energy excess has a significance of 3σ and covers the energy range 200-475 MeV

Proposed explanations involve a single electron or photon production in a neutrino scattering event.

Cerenkov detectors such as MiniBooNE detector cannot distinguish between photon and electron tracks.

The excellent PID capabilities of a liquid argon detector make this distinction possible, based on the dE/dx of a single track vs that from an e+e- pair.

MicroBooNE expects to observe a 5σ (4σ) signal if the source of the low energy anomaly is due to electrons (photons), including both statistical and systematic uncertainties.

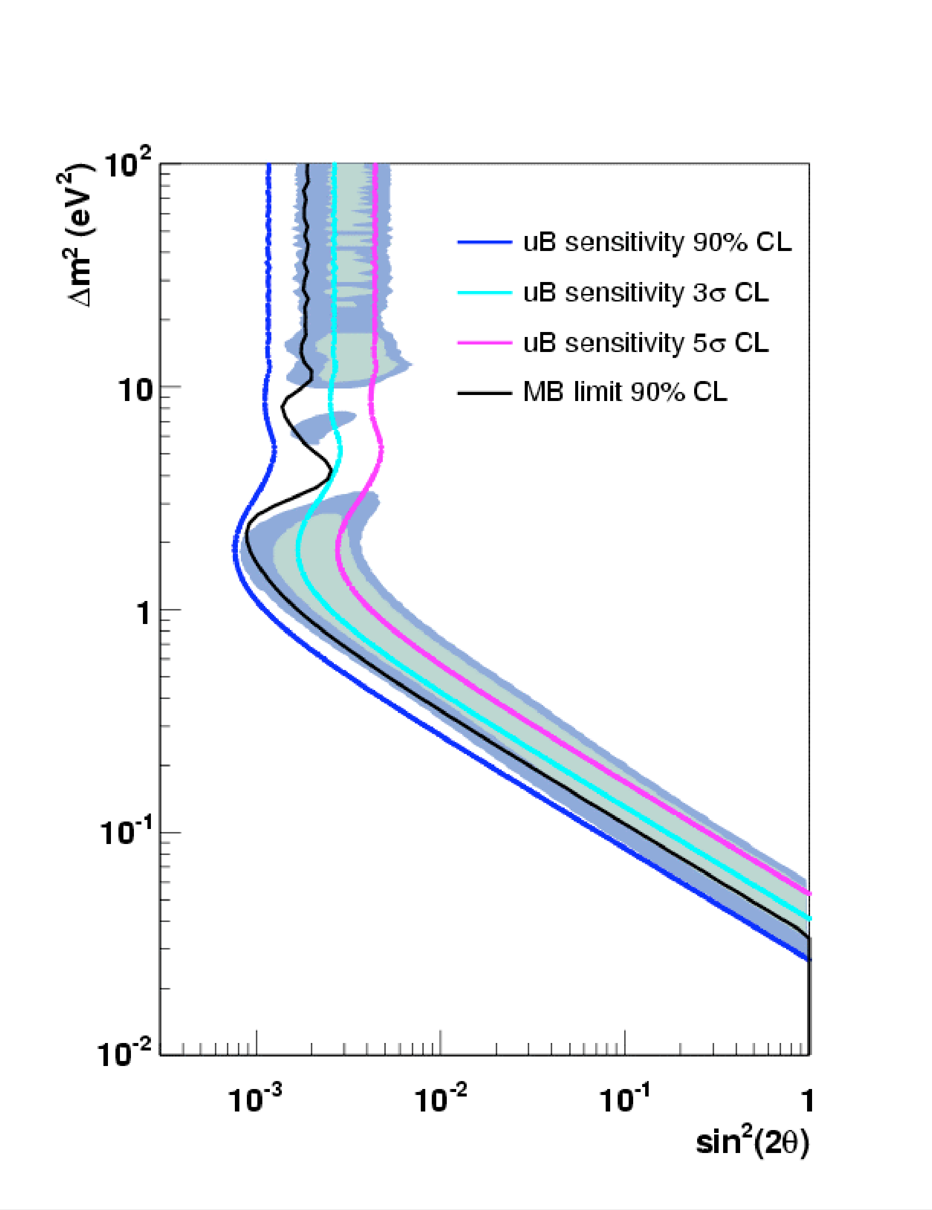


Motivations for the Experiment:
1 – The MiniBooNE Anomalies

As well as the low E excess, MicroBooNE will also explore high Δm^2 oscillations suggested by LSND and MiniBooNE's antineutrino mode running.

Despite being a factor of 5 smaller in volume, MicroBooNE can provide a measurement of ν_e appearance competitive with MiniBooNE.

This is due to greatly reduced backgrounds provided by the superior particle ID capabilities of a LArTPC detector.



Motivations for the Experiment:
2 – Cross Sections on Argon

MicroBooNE will be able to make world leading measurements of neutrino cross sections on Ar.

These measurements are relevant to future neutrino, dark matter and proton decay experiments, and many are theoretically interesting in their own right.

Four channels of particular interest:

Neutrino – Proton elastic scattering
Measure Δs and improve sensitivity of dark matter searches

Kaon production in neutrino scattering
Proton decay background in a giant detector

Coherent Pion Production
Theoretical tension between CCPi+ and NCPi0 production measurements

Photon production in low E scattering
And possible first conclusive measurement of nue cross section in 0.1-10 GeV range

Expected event counts in MicroBooNE
6.6×10^{20} POT, neutrino mode.

production mode	# events
CC QE ($\nu_\mu n \to \mu^- p$)	60,161
NC elastic ($\nu_\mu N \to \nu_\mu N$)	19,409
CC resonant π^+ ($\nu_\mu N \to \mu^- N \pi^+$)	25,149
CC resonant π^0 ($\nu_\mu n \to \mu^- p \pi^0$)	6,994
NC resonant π^0 ($\nu_\mu N \to \nu_\mu N \pi^0$)	7,388
NC resonant $\pi^\pm$ ($\nu_\mu N \to \nu_\mu N' \pi^\pm$)	4,796
CC DIS ($\nu_\mu N \to \mu^- X$, $W > 2$ GeV)	1,229
NC DIS ($\nu_\mu N \to \nu_\mu X$, $W > 2$ GeV)	456
NC coherent π^0 ($\nu_\mu A \to \nu_\mu A \pi^0$)	1,694
CC coherent π^+ ($\nu_\mu A \to \mu^- A \pi^+$)	2,626
NC kaon ($\nu_\mu N \to \nu_\mu K X$)	39
CC kaon ($\nu_\mu N \to \mu^- K X$)	117
other ν_μ	3,678
total ν_μ CC	98,849
total ν_μ NC+CC	133,580
ν_e QE	326
ν_e CC	657

Motivations for the Experiment:
3 – Selected Non-Accelerator Physics Topics

- The MicroBooNE experiment is surface based, so the options for nonaccelerator physics are limitted. However, MicroBooNE can contribute to two notable areas of non-accelerator physics:

- ***Burst Supernova Neutrino Detection***
  Despite its small size, a burst supernova in our galaxy is likely to give more events in MicroBooNE than all those detected from 1987A in total

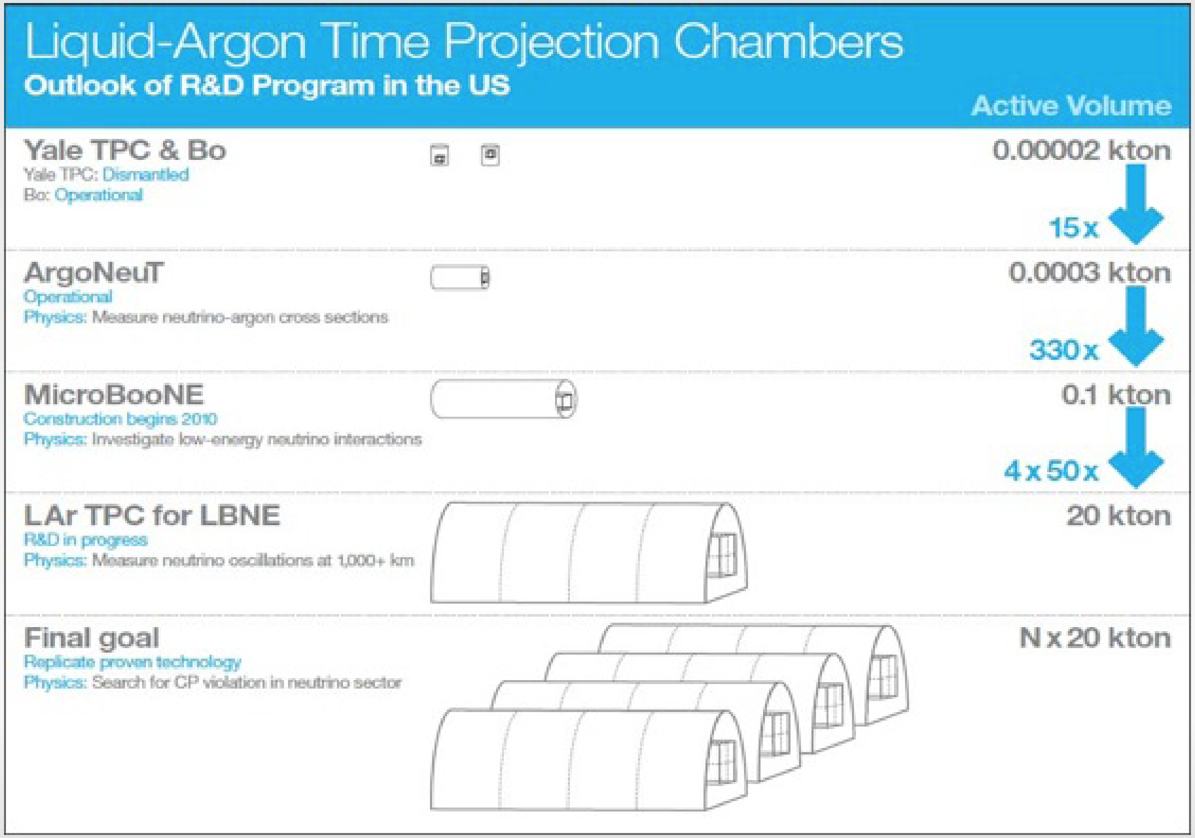
- ***Proton Decay Background Measurements***
  Cosmogenic kaons from cosmic rays are a likely source of background for proton decay searches. MicroBooNE will collect a high statistics and well defined sample of such events due to its surface position and excellent PID capabilities.

Motivations for the Experiment:
A – LArTPC Development

LArTPCs have excellent event reconstruction and particle ID capabilities, and have been proposed as a technology for future giant liquid argon neutrino and rare event detection experiments.

MicroBooNE will help answer many questions about the feasibility of LArTPCs for giant LAr experiments and provide contributions to

- Understanding the effectiveness of electron / photon separation techniques in LAr
- Development of analysis tools for event reconstruction in a liquid argon TPC
- Scalability of electron drift length for a large detector
- Performance of cold electronics in a liquid argon TPC
- Maintainance of argon purity and electron lifetime in large detector
- Contributions from optical systems to event reconstruction capabilities and triggering in a neutrino beam
- Development of a cost scaling model for future experiments

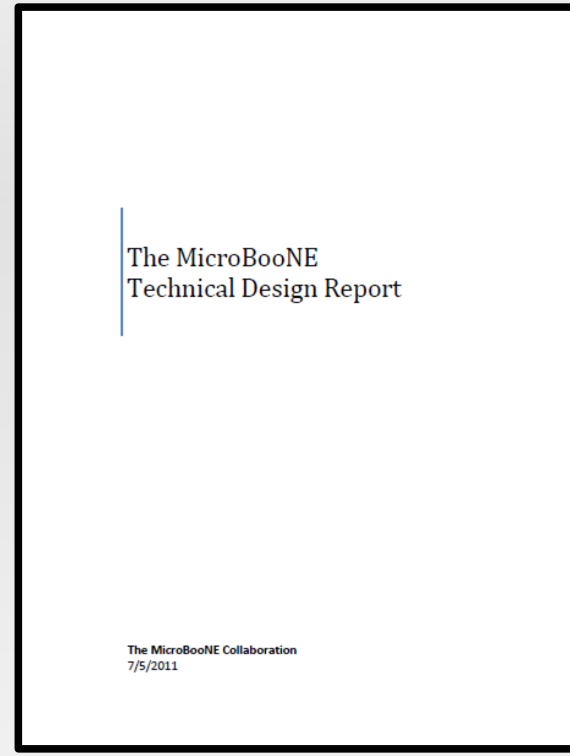


Project Status

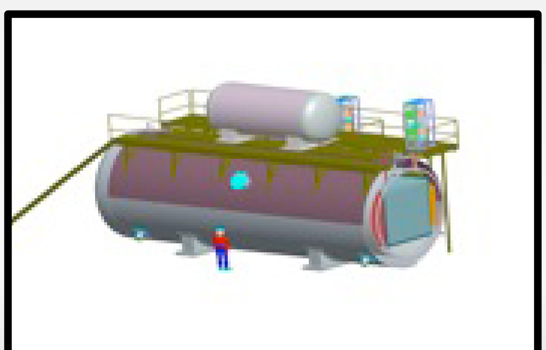
- ***2007*** - Proposed to Fermilab PAC
- ***2008*** - Stage 1 Approval
- ***2009*** - Passed Fermilab CD-0 Review
- ***2010*** - Passed Fermilab CD-1 Review
- ***~now*** - Fermilab CD-2/3A Review

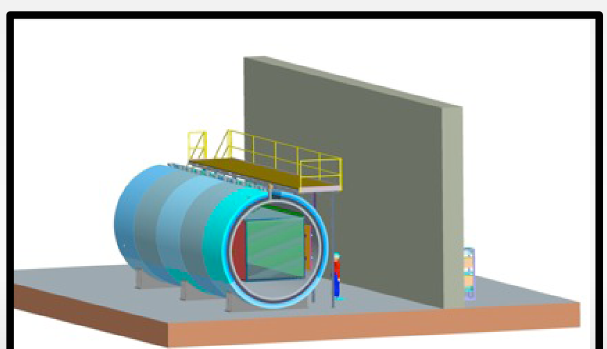
As soon as CD-2/3A is passed, construction begins.

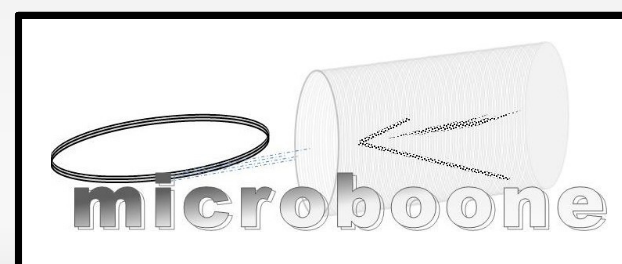
- ***Late 2013*** - Fill and purify detector
- ***Early 2014*** - Expected first neutrinos


The MicroBooNE
Technical Design Report

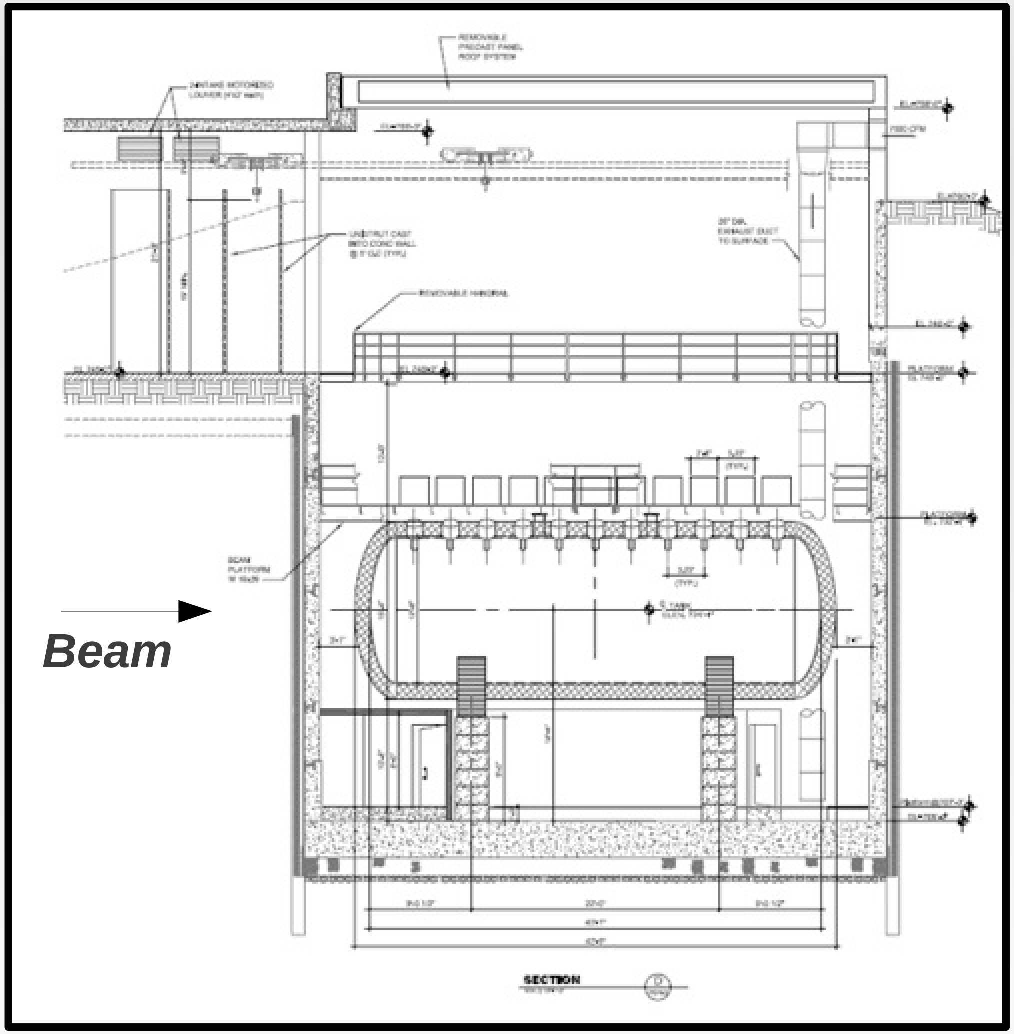
The MicroBooNE Collaboration
7/5/2011



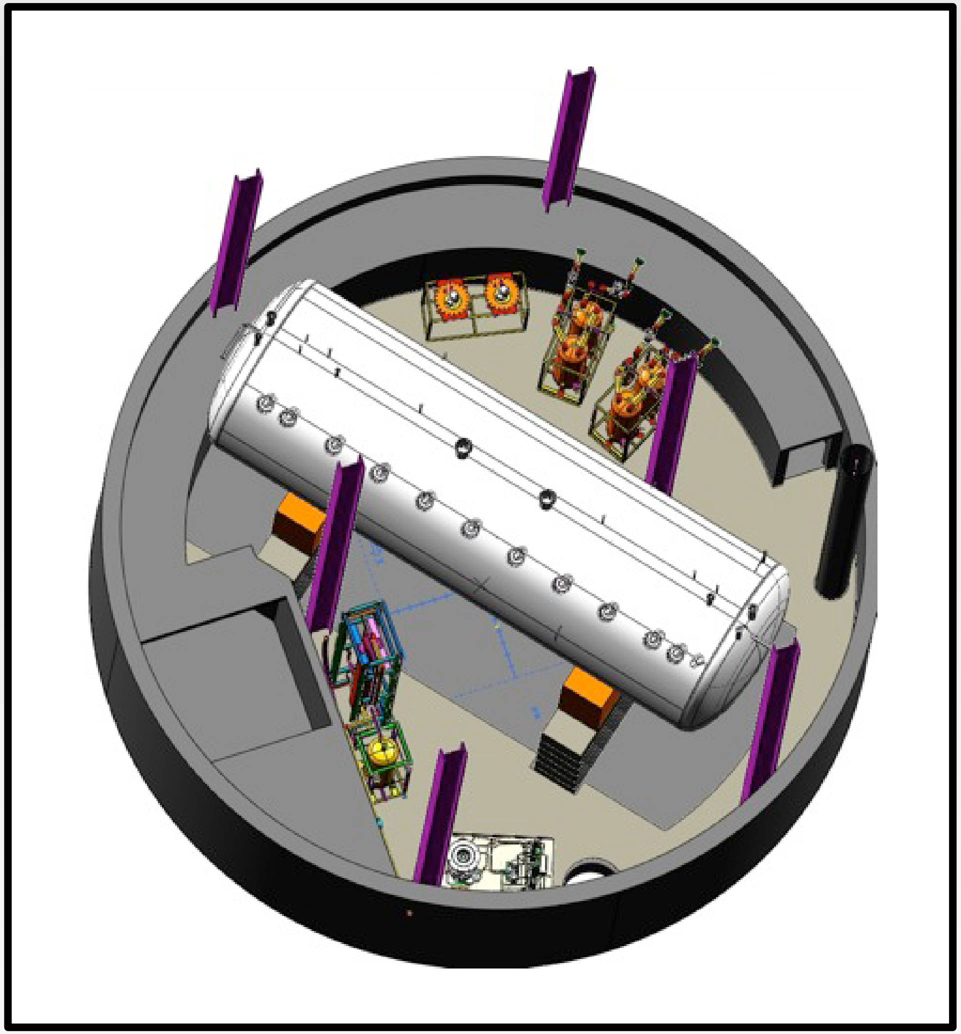




Infrastructure

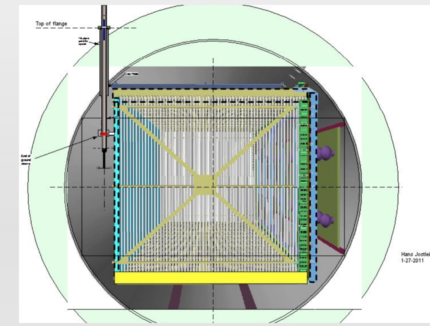


Detector and hall cross section along beam axis, side view



3D view of detector enclosure

TPC System

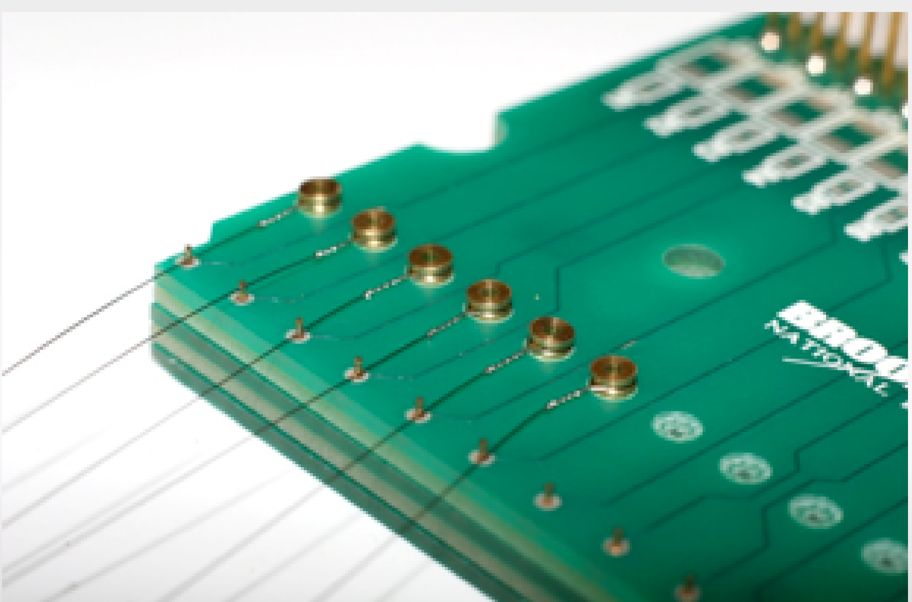


- The TPC system consists of three wire planes, each with 3mm pitch

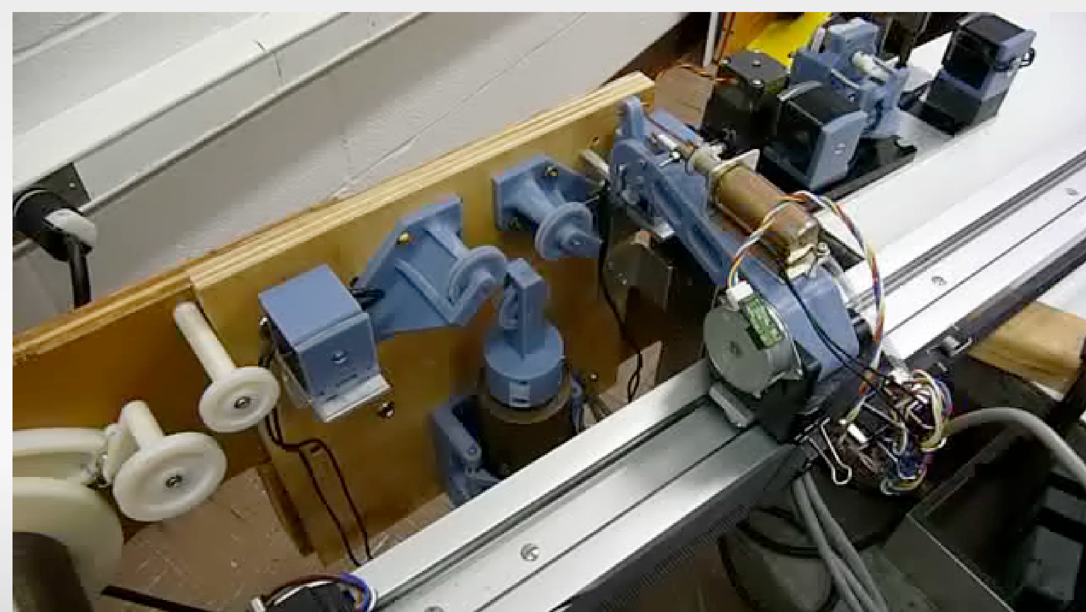
Y	*Vertical*	*3456 wires*
U	*$+60^\circ$*	*2400 wires*
V	*-60°*	*2400 wires*

- Wires are attached to the TPC frame by a ferrule fixed onto a wire carrier board at both ends
- This summer, we have begun stringing wireplanes for the TPC system using an automated wire winding machine at BNL

Carrier board attachments

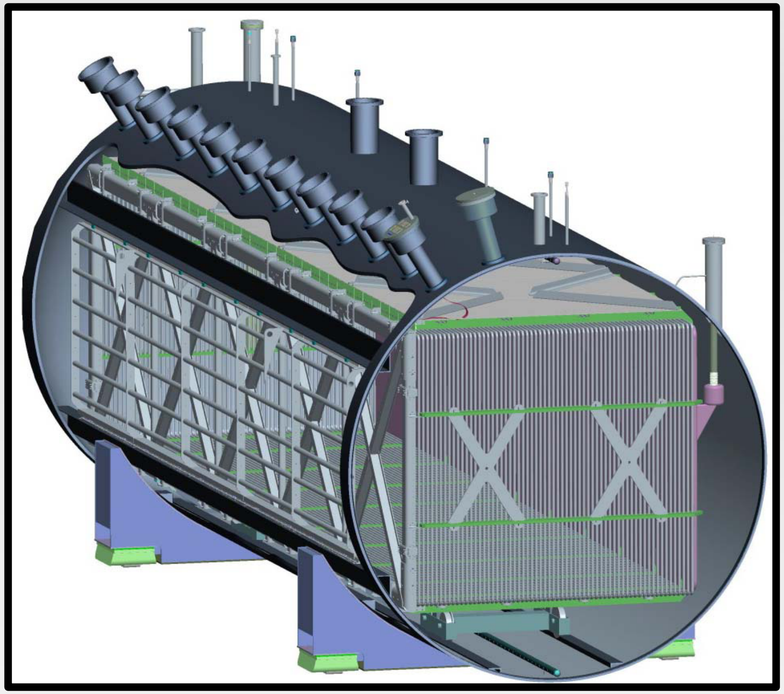


Wire winding machine

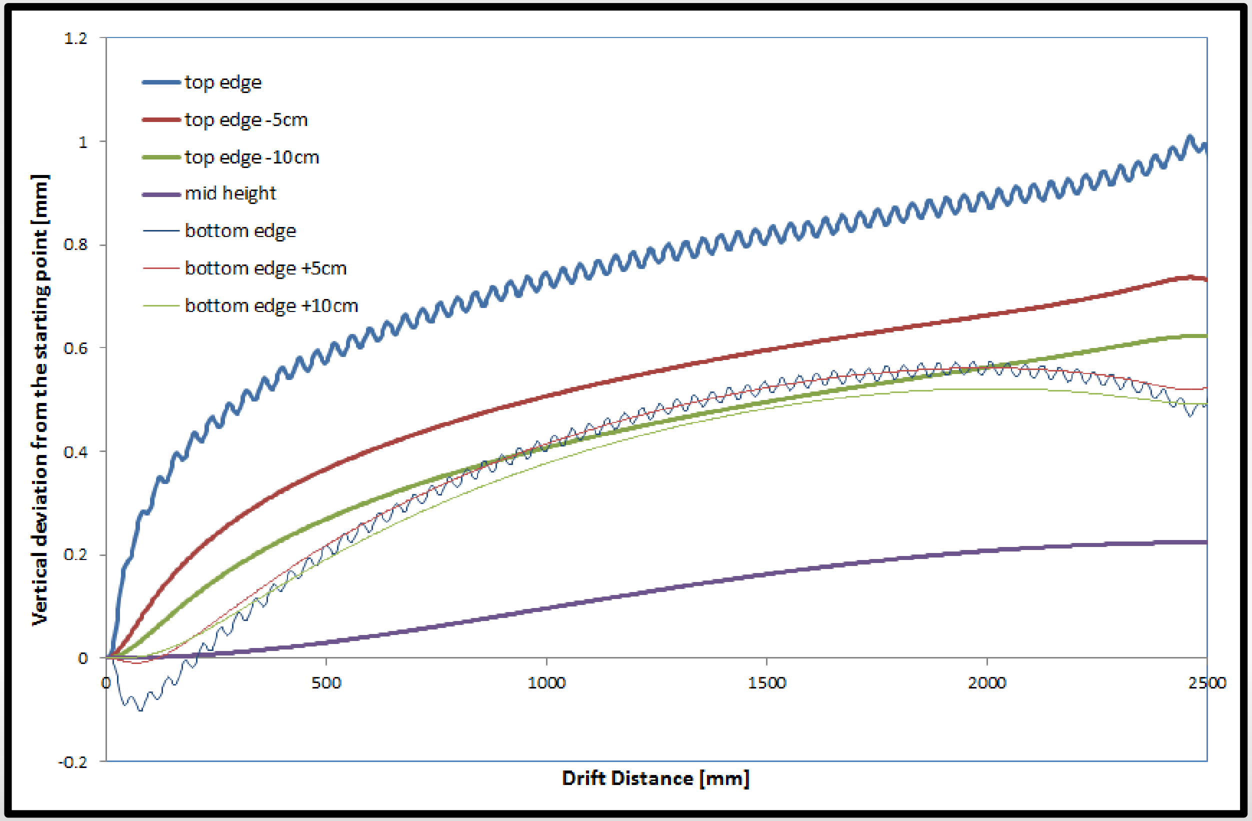


Drift Field Uniformity

Picture of TPC and field cage in situ



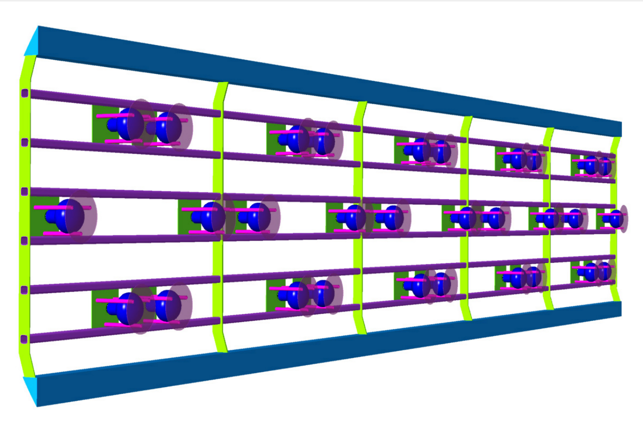
Error in charge position introduced by field nonuniformities for several charge trajectories



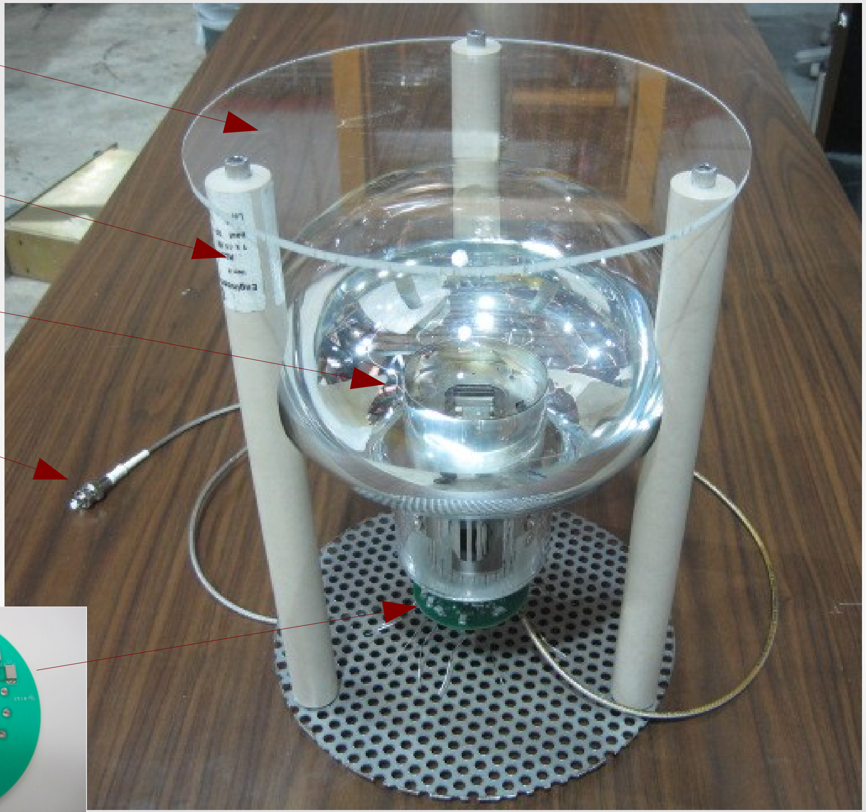
Optical System

- The Optical system is comprised of 30 x 8” cryogenic PMTs, mounted behind wavelength shifting plates.
- PMT assemblies are arranged on a support rack behind the wire planes
- This summer we will construct, test and characterize the 30 PMT units for the experiment in cold conditions, using cryogenic test stands at FNAL.

Optical Support Rack



PMT Assembly (mechanical model)



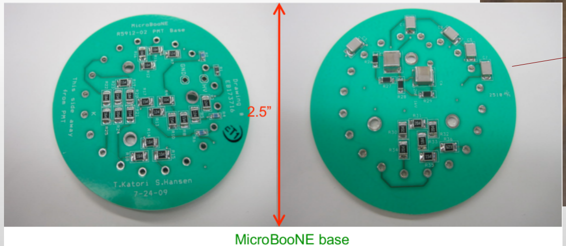
TPB coated acrylic plate

PEEK supports

8” Cryogenic PMT

Combined HV and Signal Cable

Specially designed cryogenic base



Purity and Cryogenics

- MicroBooNE incroporates a complicated system of cryogenics to maintain argon purity, temperature and uniformity.
- **Cryo system specifications:**

  Electronegative impurities in LAr can absorb free charges during the drift to the wire planes.

  Dissolved oxygen and water levels <100ppt

  Impurities quench scintillation light production.

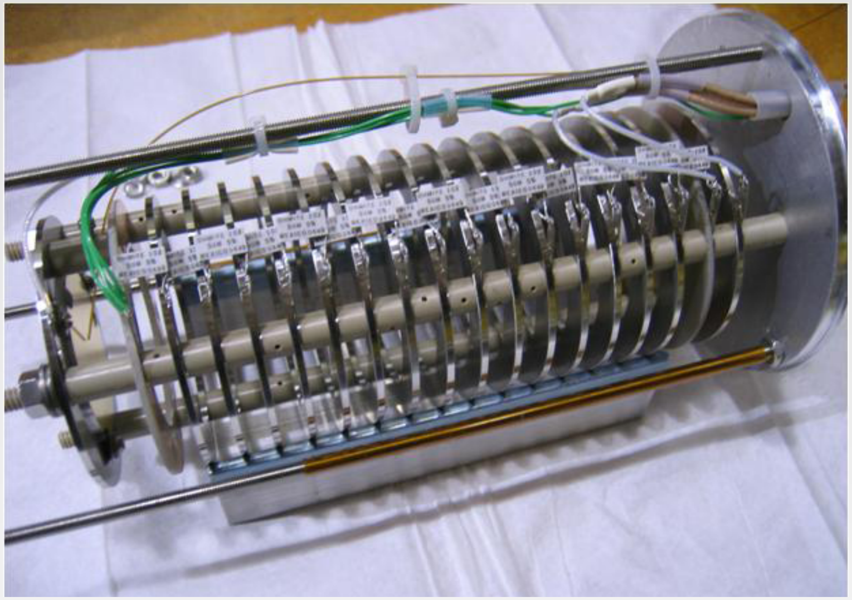
  Nitrogen level maintained <2ppm

  Temperature differences lead to nonuniformity of drift velocity and hence image distortion

  Temperature uniformity ensured to < 0.1 K

- Constant argon purification is employed to combat outgassing from the cryostat
- Temperature is maintained by an LN2 refrigeration system
- Electron lifetime onitors both in cryostat and circulation system constantly records purity

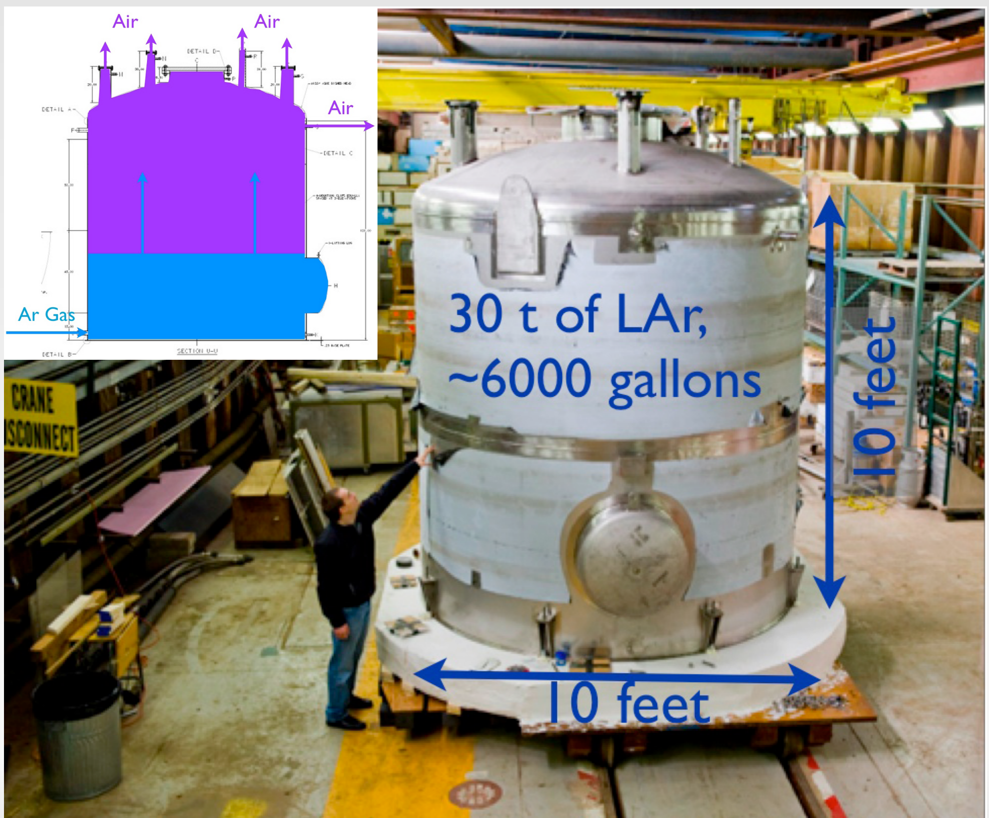
LAr Purity Monitor



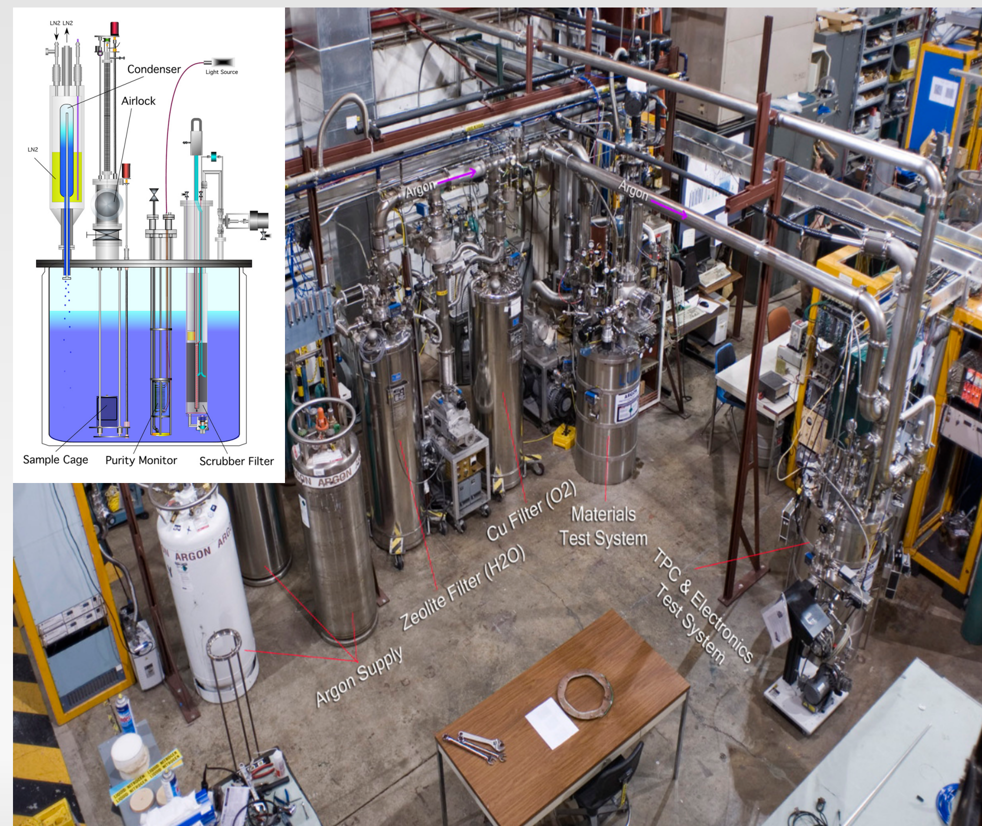
Supporting Experiments

- Fermilab has several test stands and R&D experiments running to improve our ability to achieve, maintain and monitor LAr purity

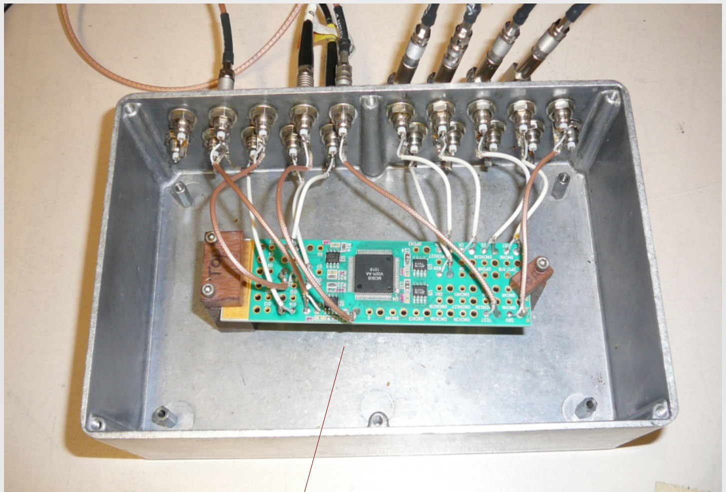
LAPD

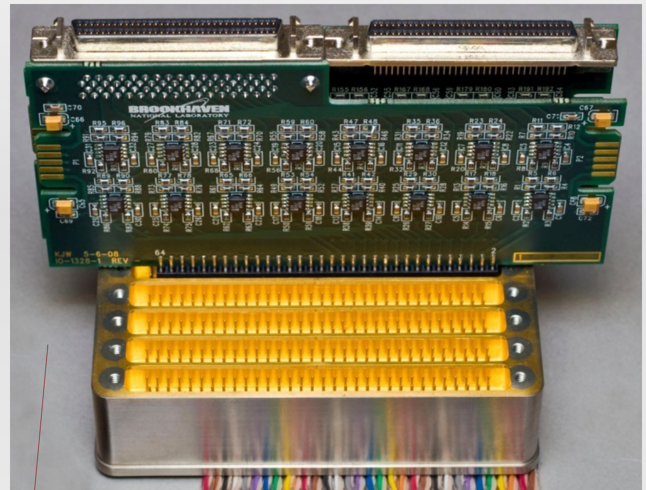


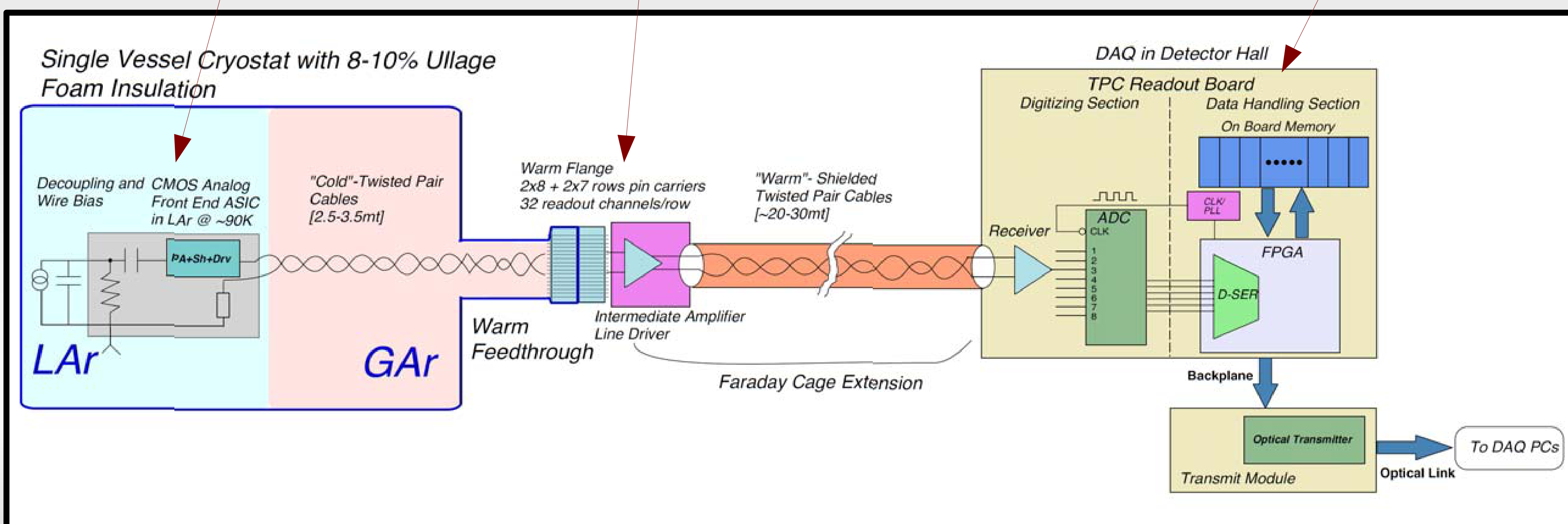
Materials Test Stand



MicroBooNE TPC Electronics

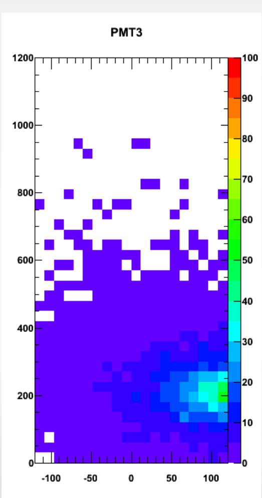


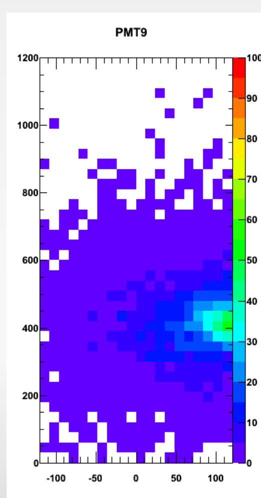


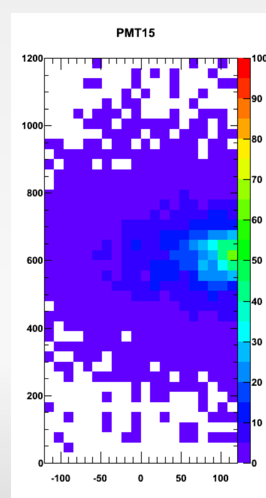


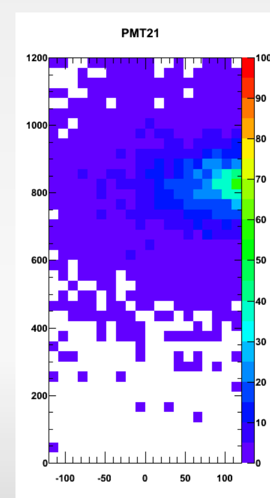
Offline Software

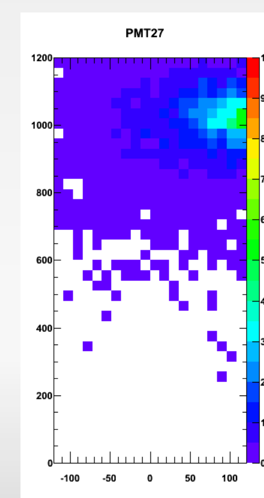
- All simulation, reconstruction and analysis tasks for MicroBooNE are performed in the open source LArSoft framwork. Currently LArSoft is used by the ArgoNeuT, MicroBooNE, LBNE experiments and some Fermilab test stands.
- **Internal and external event generators**, including GENIE for neutrino interaction simulations and CRY for cosmic ray events
- **Full Geant4 TPC simulation** in place for modelling the response of the TPC system, including charge losses and diffusion during drift
- **Optical simulations** have been implemented for MicroBooNE, which is the first LArSoft experiment with an optical system
- **3D TPC reconstruction** is at an advanced stage for the ArgoNeuT 2 wire plane detector. These methods are now being generalized to 3 planes for MicroBooNE. Optically augmented reconstruction methods are also under investigation



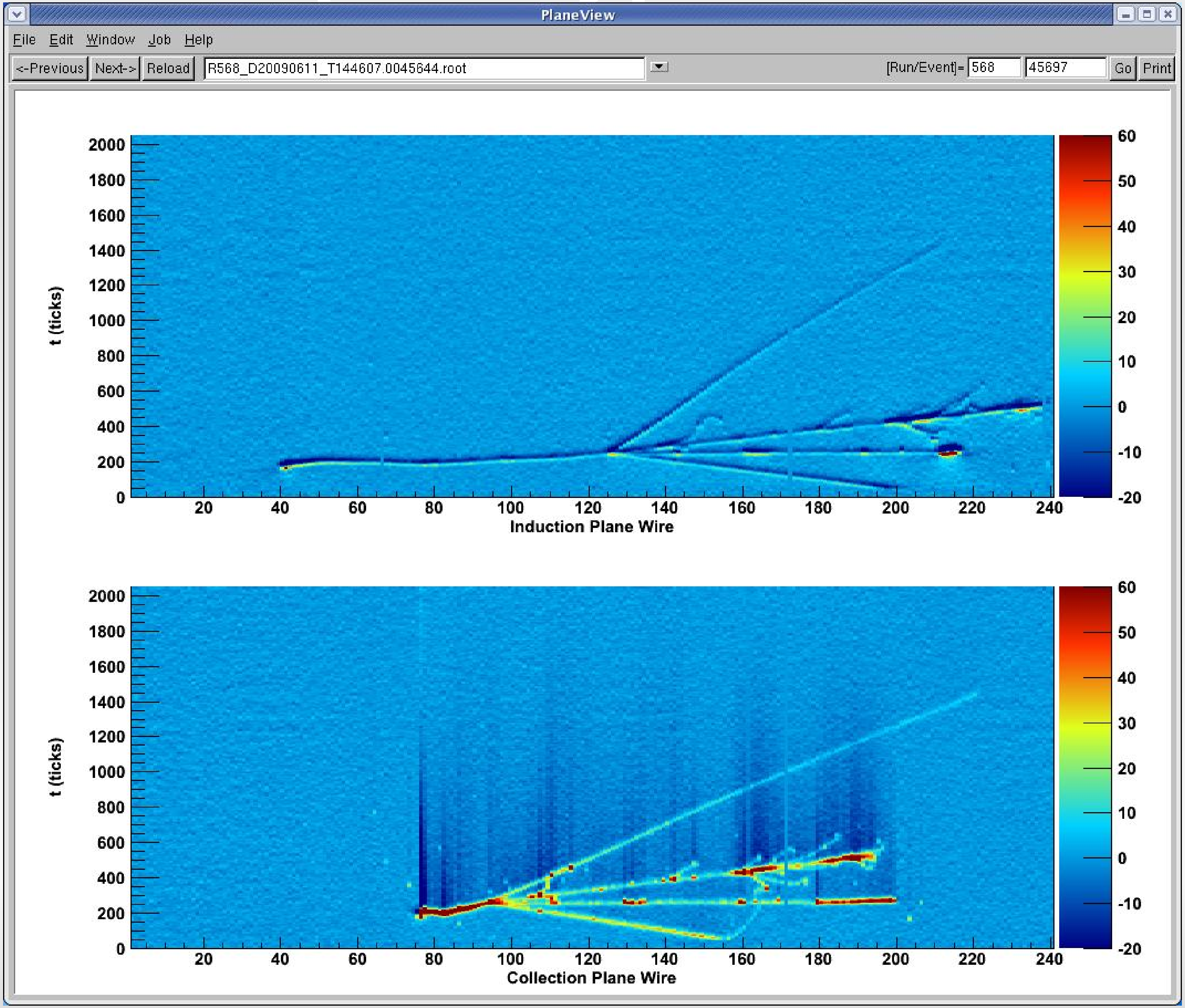








An Event Display from the ArgoNeuT prototype



Summary

- The MicroBooNE LArTPC experiment is set to begin taking data in the Booster Neutrino Beamline at FNAL in late 2013
- The detector includes a 3-plane TPC and a 30 PMT optical system in a 170 ton liquid argon cryostat
- The experiment has a diverse program of short baseline neutrino physics including investigation of the MiniBooNE anomalies, a range of low energy cross section measurements and burst supernova neutrino detection
- The project is currently undergoing the Fermilab CD-2/3A review, after which construction will begin
- This summer will see construction and testing of sensitive PMT and TPC system components
- Complete engineering designs are in place for all cryogenics, cryostat and support components and electronics
- We hope to begin measuring beam neutrino interactions with a completed detector in early 2014