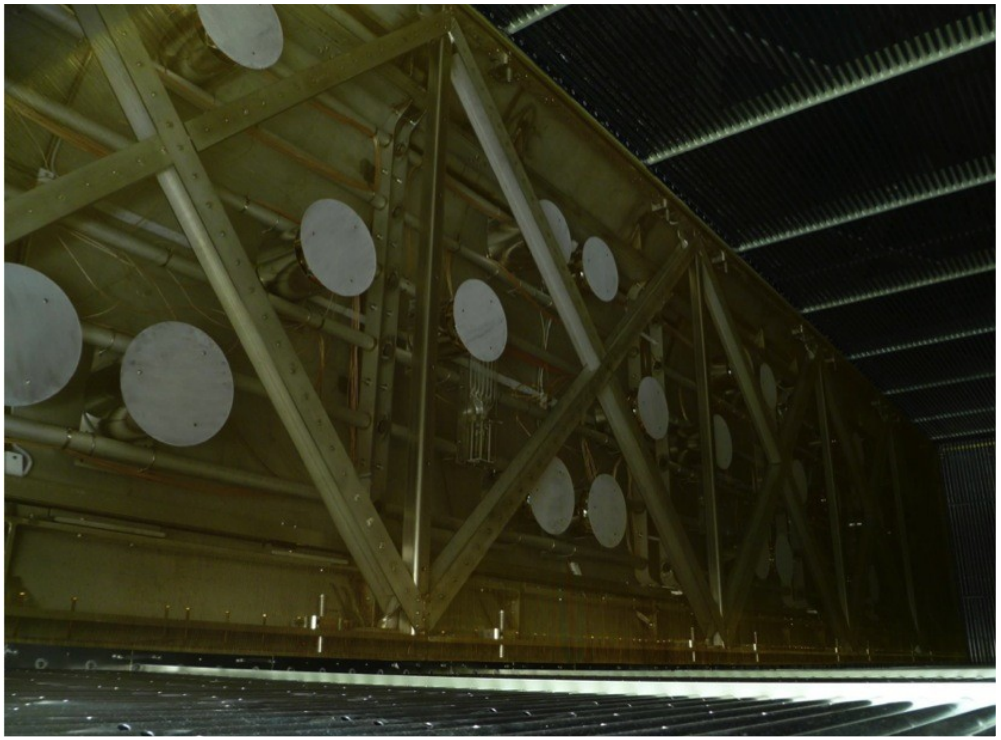


The MicroBooNE Detector

Jonathan Asaadi
University of Texas Arlington

Outline

- **Overview of the MicroBooNE Detector**
  - Time Projection Chamber (TPC)
  - Light Detection System (PMTs)
  - Laser Calibration System (Laser)
  - Auxiliary Detectors
    - Cosmic Ray Paddles
    - Purity Monitors
- **Detector Technology Development**
  - Published Results
- **Performance of the MicroBooNE Detector**
  - Cosmic Ray Commissioning Run
  - First Neutrinos!

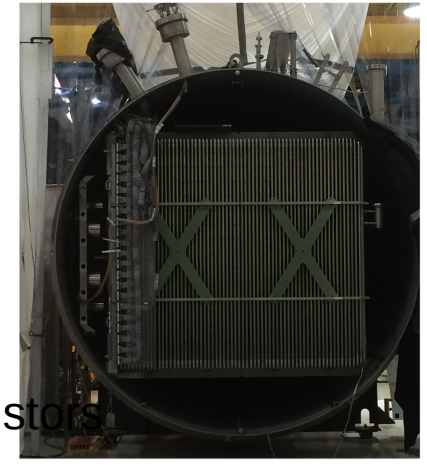
Questions from the charge covered

- **Question 2)**
  - Has it been demonstrated that the detector is ready for physics-quality data taking?
- **Question 6)**
  - Is the proposed detector technology development plan comprehensive and sound to help future neutrino experiments?

Time Projection Chamber (TPC)

Question 2

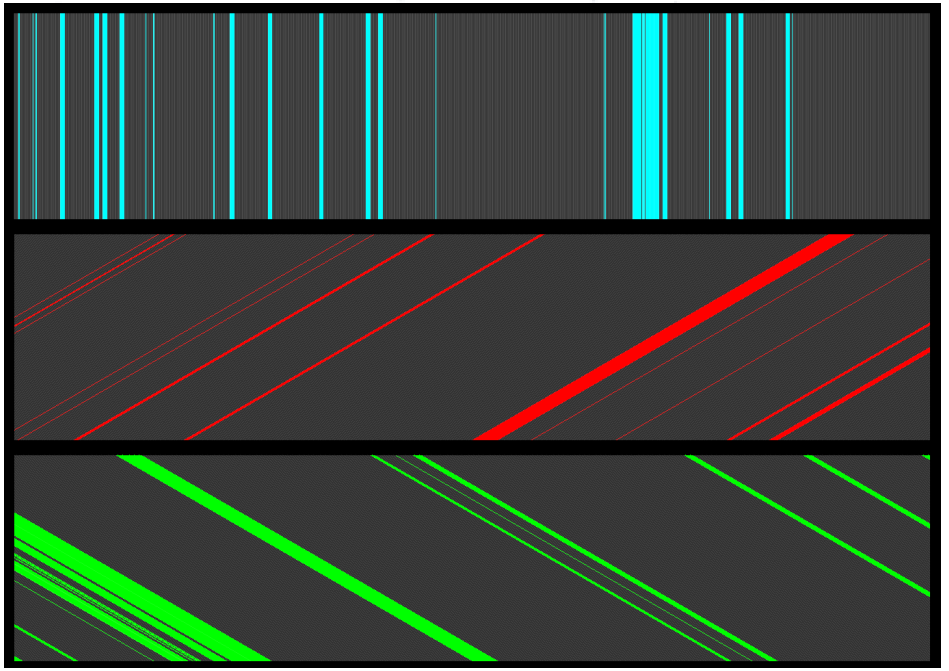
- **TPC Dimensions:**
  - 10.3 m long x 2.3 m tall x 2.5 m wide (drift distance)
  - 89 ton active mass
- **8256 wire channels:**
  - 3 mm wire spacing and plane-to-plane pitch
  - 3456 Collection channels (Y-Plane)
    - Wires oriented w.r.t. the vertical
  - 4800 Induction channels (V & U Plane)
    - Wires oriented +/- 60^{o}
- **High Voltage System**
  - 128 kV HV feedthrough attached to the cathode
  - Voltage divider chain
    - 2 kV drop per field cage protected by varistors over the first 32 filed cage tubes



TPC current performance

Question 2

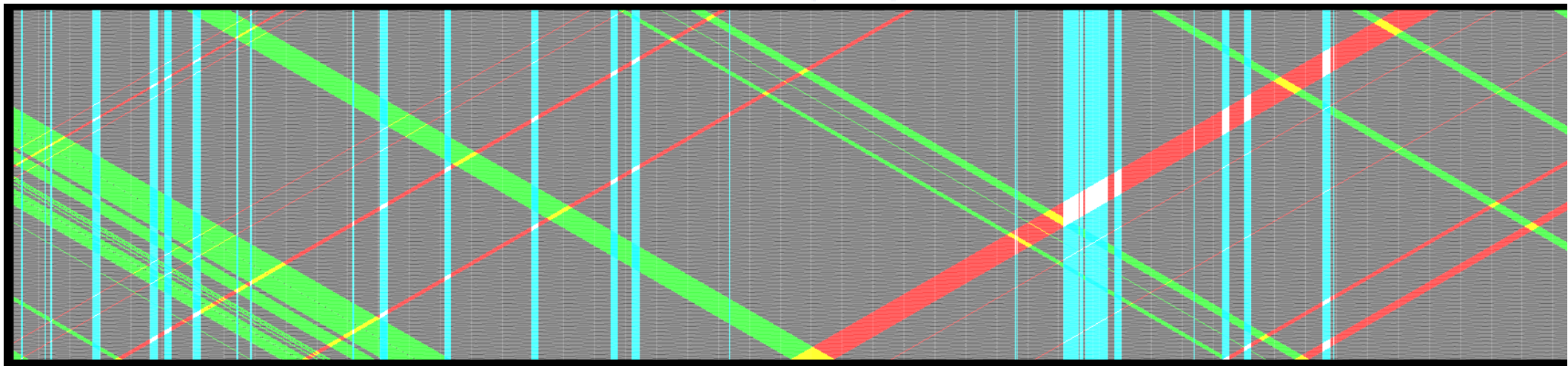
- **Wire Readout**
  - ~90% healthy channels
    - Signal to Noise ~40:1
      (Note: ICARUS reported 10:1)
  - ~10% are unresponsive/unusable
    - ~ 400 Channels in the 1st induction plane
    - ~ 100 Channels in the 2nd induction plane
    - ~ 300 Channels in the collection plane
- **High Voltage**
  - First turned on 3 months ago (initial ramp to 58 kV)
  - Operating stably at 70 kV for ~1.5 months



Unresponsive Channels per plane
1st Induction
2nd Induction
Collection

TPC current performance

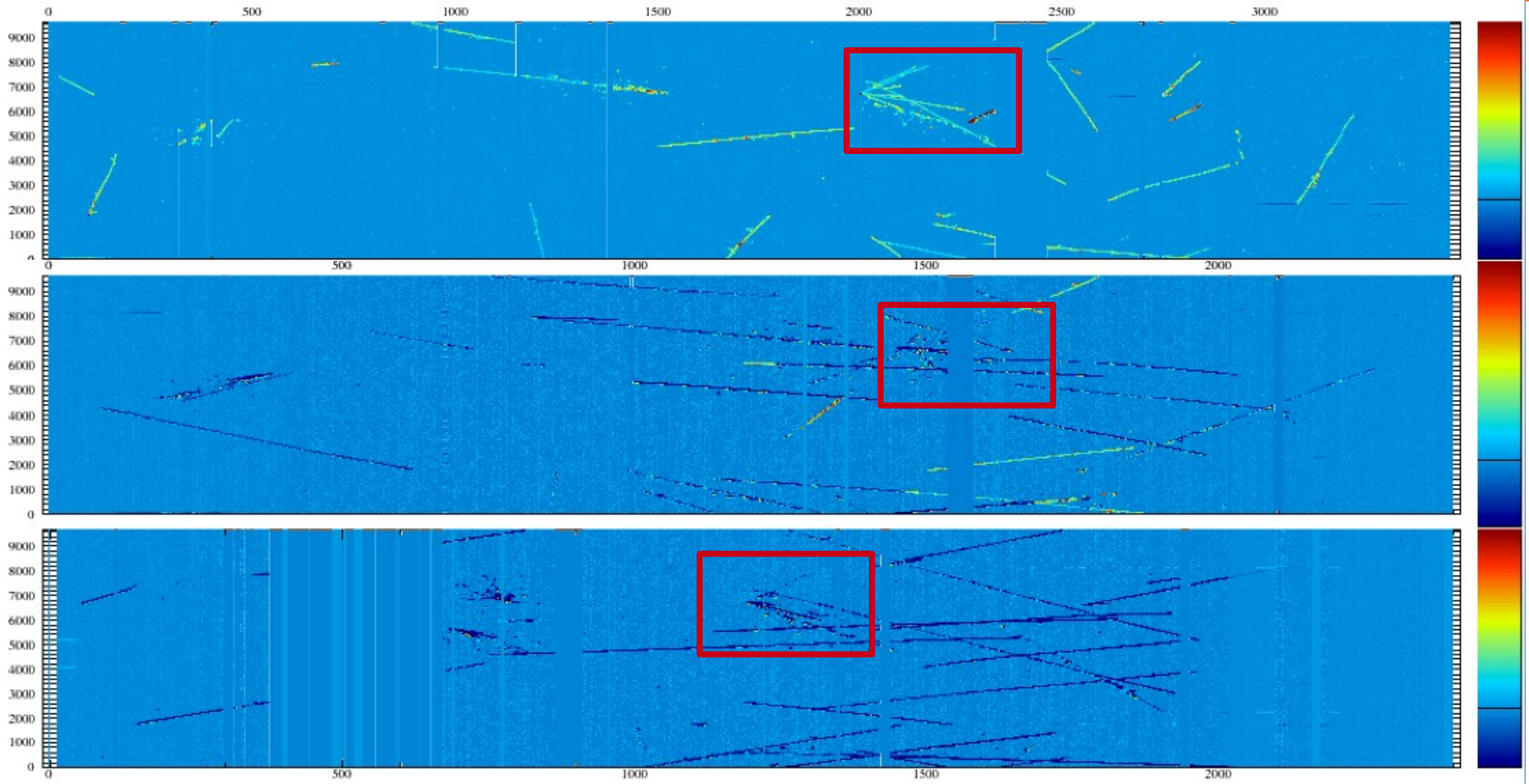
Question 2



- Regions of overlap that have 2 or more planes affected **is a small fraction** of the overall active volume
  - Need 2 planes of wires to do 3d-reconstruction
  - Ongoing work to find solutions to have the reconstruction deal with these regions
    - Continuing work to find remediation in hardware as well

TPC current performance

Question 2



~ 10% of channels non-responsive across all three planes

- Automated reconstruction still able to identify and **select neutrino candidates**
  (See Matt Toups talk for more info)

Remaining electronics noise removed with offline software filters

- One filter which removes correlated noise shown here

Light Detection System (PMTs)

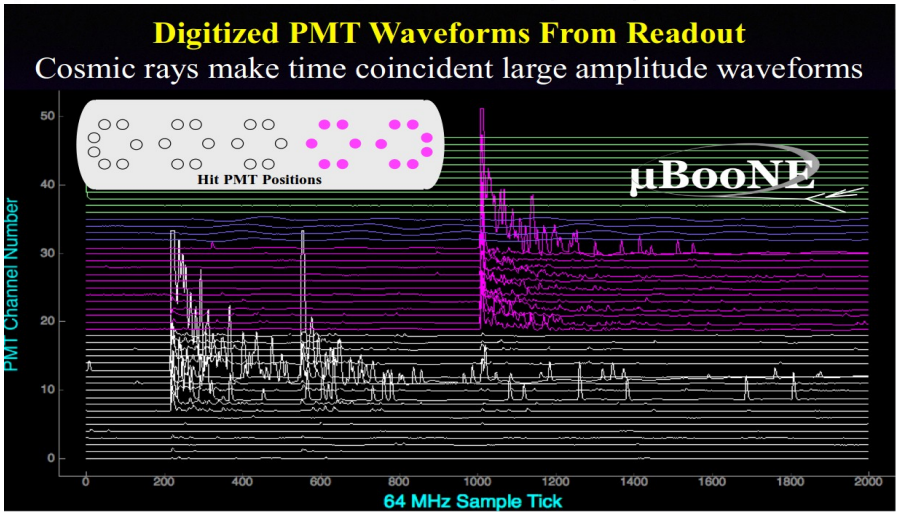
Question 2

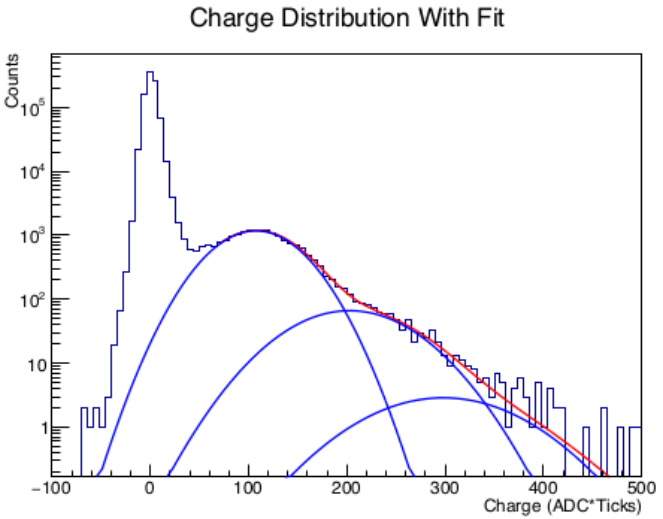
- **32, 8” PMT's**
  - Each with a wavelength shifting acrylic plate located in front of the PMT
  - LED flasher system allows channel-by-channel gain and timing calibration
- **Used as a trigger, cosmic ray veto, and neutrino interaction ID**
- **4 acrylic light guide bars**
  - Each coated in wavelength shifting material

PMT Current Performance

Question 2

- **All 32 channels are operational**
  - System has been taking data since LAr fill was complete (July 2015)
- **System is being calibrated**
  - Single Photo-electron response measured for all 32 channels
  - Larger than expected light rate has been observed (potential source currently being investigated)
  - System timed in and used to identify neutrino candidate events!



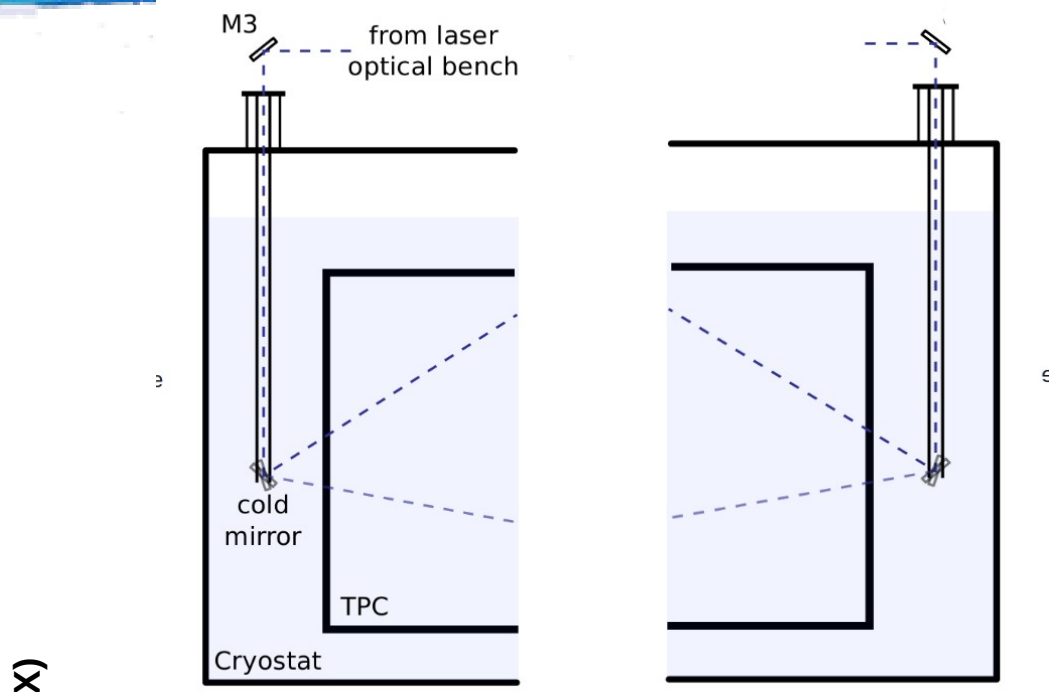


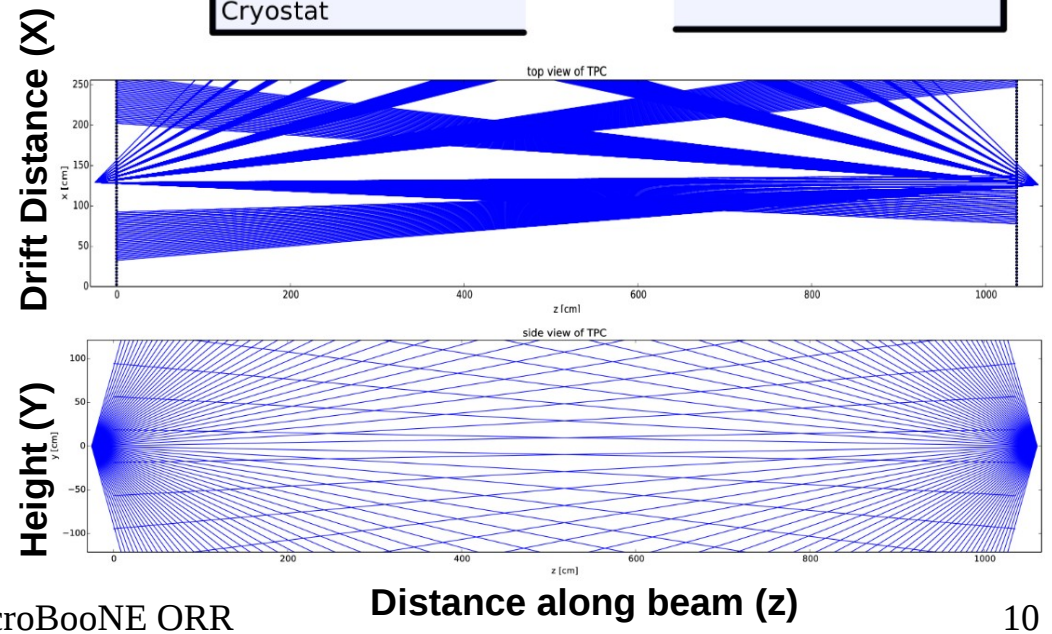
More details on the performance of the PMT system to come in Taritree's talk

Laser Calibration System

Question 2

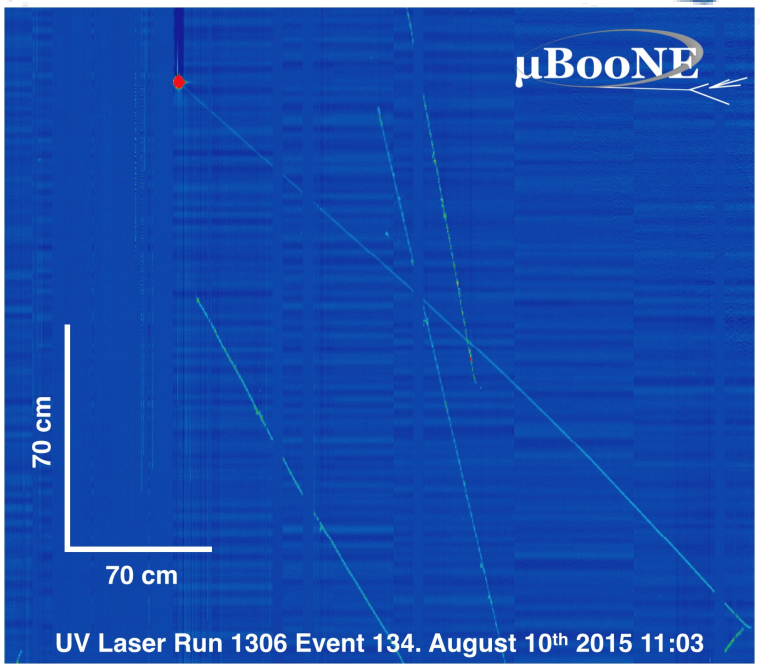
- **Nd:YAG 266 nm laser calibration system installed to allow for mapping of field distortions**
  - e.g. Non-uniform fields caused by the build up of space-charge
- **Two lasers located upstream and downstream allow for shots to be taken across the TPC**

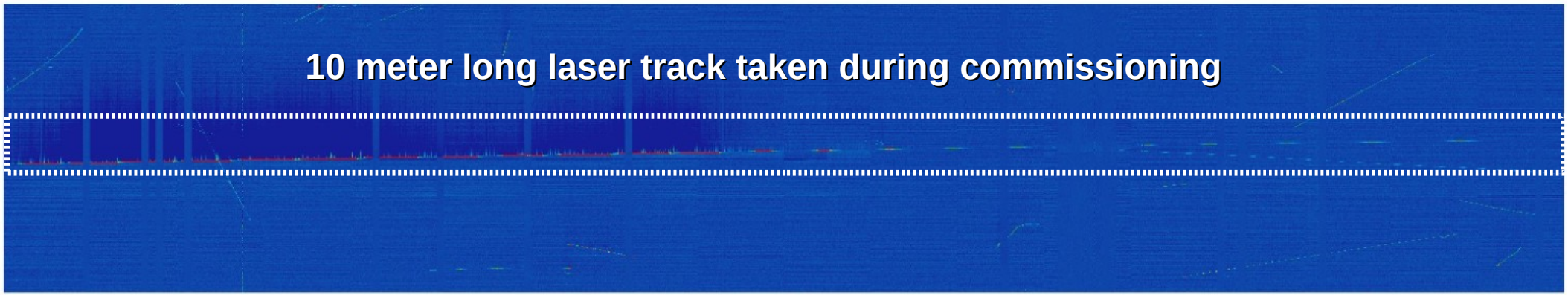




Performance of Laser Calibration

- **Laser system is operational**
  - Mapping of laser locations inside the TPC complete
  - Calibration run plan developed with the operations team



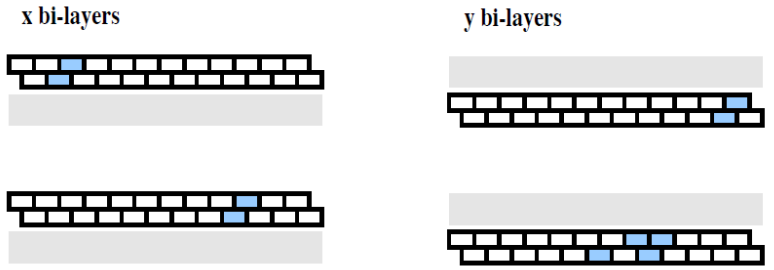


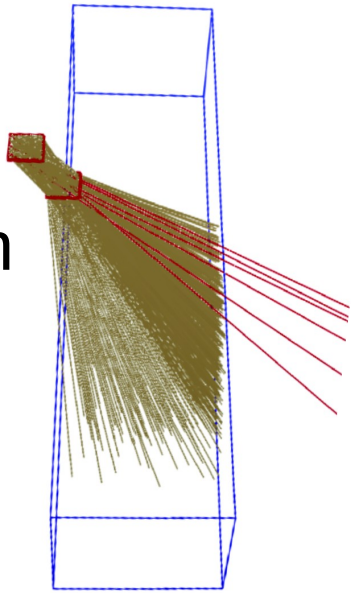
See Mike's talk for more details on Laser calibration

Auxiliary Detectors (CR Paddels)

Question 2

- **Two bi-layer cosmic ray paddle systems allow us to trigger on the coincidence of the external cosmic system**
  - Allows for multiple physics studies using the known location of a track entering the TPC
    - Light / Trigger studies
    - Purity / Diffusion studies
    - Tracking and calorimetry efficiency studies

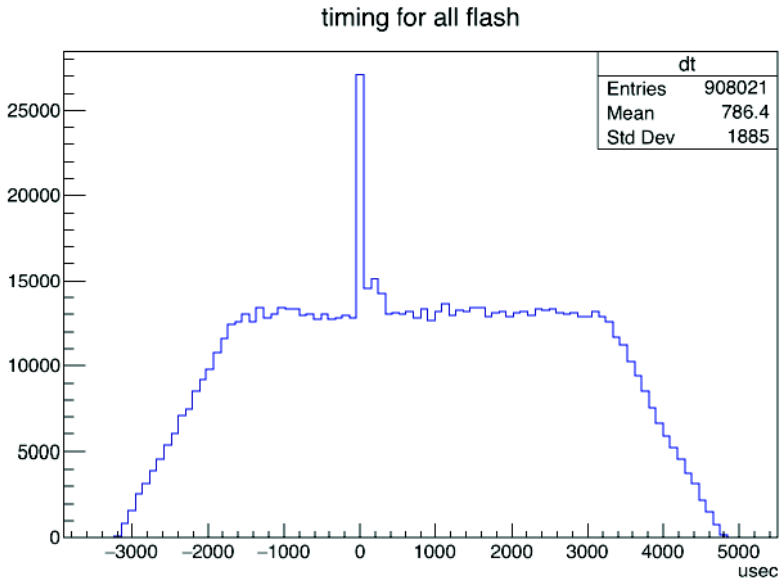


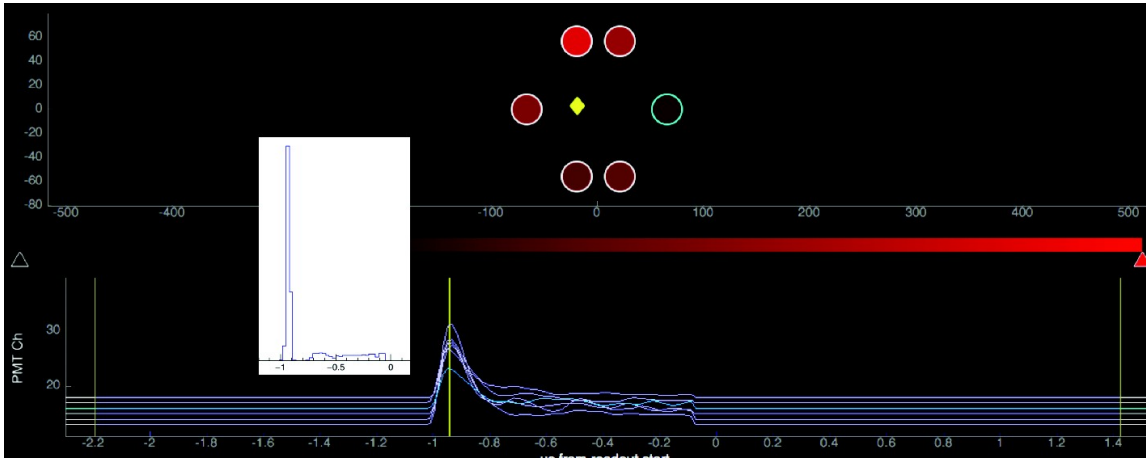


Auxiliary Detectors (CR Paddles)

Question 2

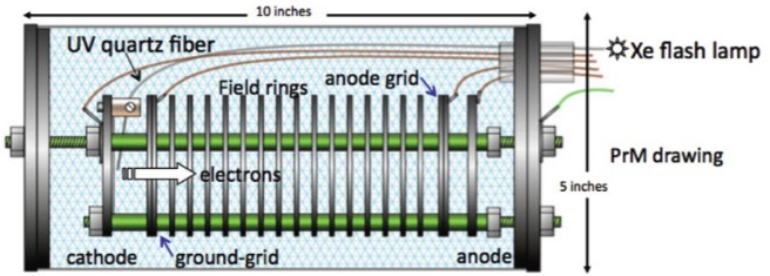
- **Show CR Paddle system used to trigger the readout**
  - Peak of light seen around the trigger corresponding to the muons seen by the CR Paddles
  - Geometric location of the light readout confirms the system is working as expected

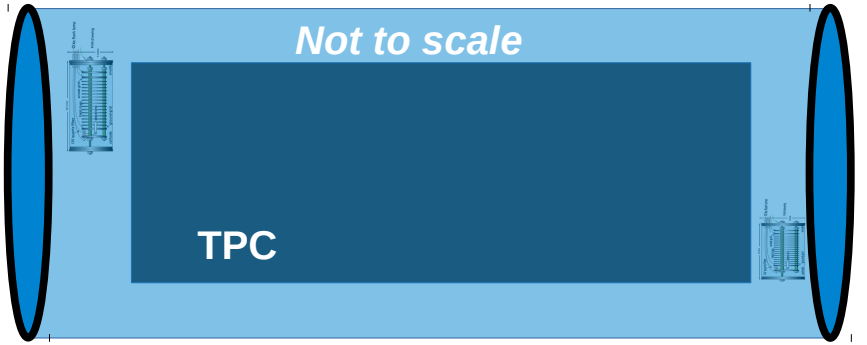


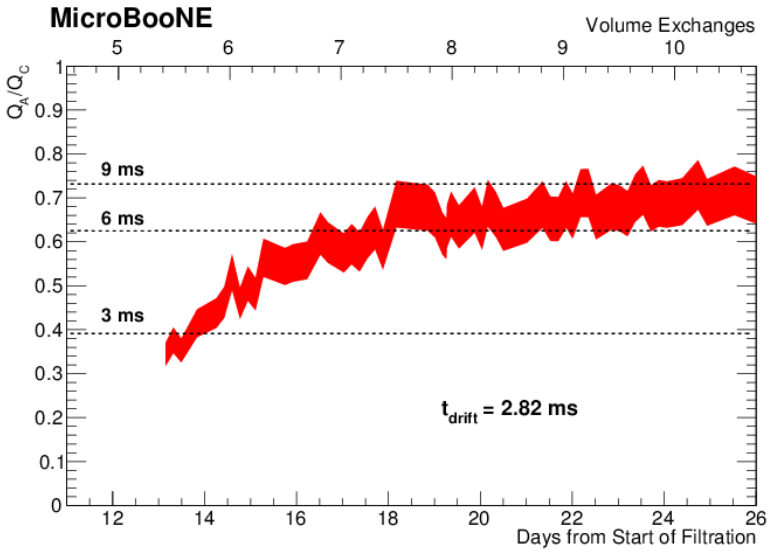


Auxiliary Detectors (Purity Monitors)

- **Purity monitors are tiny little TPCs with a quartz fiber-optic cable which brings in a flash from a UV light**
  - Measure the amount of charge loss during the drift to extract the electron lifetime
- **We have two inside the cryostat (short/long)**
  - One additional purity monitor inline
- **Measurements of our purity show we have achieved greater than two times our design purity**







Detector Technology Development

Question 6

- 13 Publications related to LArTPC Detector R&D before the deployment of MicroBooNE
- 2 PhD thesis and 1 Undergraduate Thesis

Publications/Documents by the MicroBooNE Collaboration:

- MicroBooNE TDR from CD3b review (February 2012)

MicroBooNE Theses:

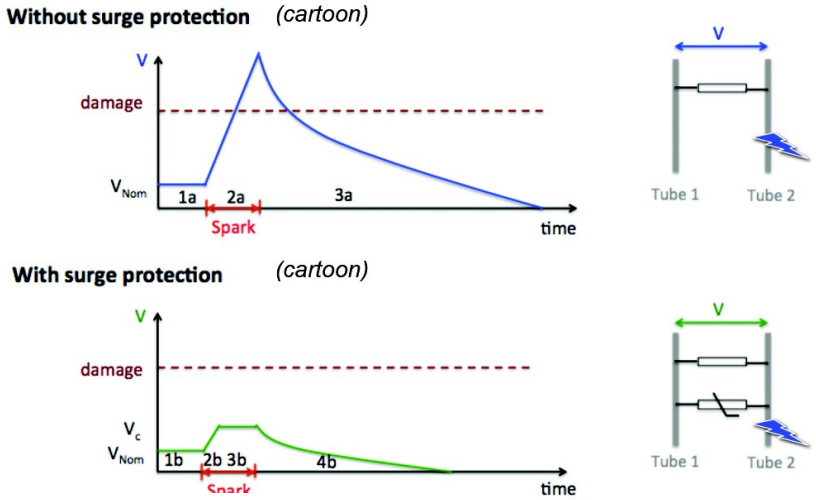
- Ben Jones, Sterile Neutrinos in Cold Climates, MIT, Ph.D. thesis, September 2015
- Christina Ignarra, Sterile Neutrino Searches in MiniBooNE and MicroBooNE, MIT Ph.D. thesis, September 2014
- Christie Chiu, Liquid Argon Scintillation Light Quenching Due to Nitrogen Impurities: Measurements Performed for the MicroBooNE Vertical Slice Test, MIT, B.S. in physics, June 2013

Related Publications by MicroBooNE Collaborators:

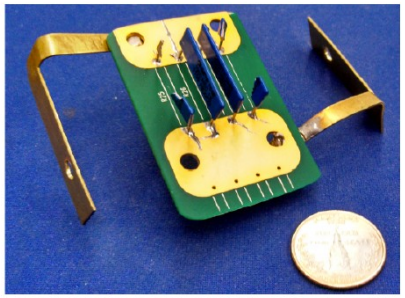
- B. Carls *et al.*, "Design and Operation of a Setup with a Camera and Adjustable Mirror to Inspect the Sense Wire Planes of the TPC Inside the MicroBooNE Cryostat", JINST 10, T08006 (2015)
- J. Conrad *et al.*, "The Photomultiplier Tube Calibration System of the MicroBooNE Experiment", JINST 10, T06001 (2015)
- L.F. Bagby *et al.*, "Breakdown Voltage of Metal Oxide Resistors in Liquid Argon", JINST 9, T11004 (2014)
- R. Acciarri *et al.*, "Liquid Argon Dielectric Breakdown Studies with the MicroBooNE Purification System", JINST 9, P11001 (2014)
- A. Ereditato *et al.*, "First Working Prototype of a Steerable UV Laser System for LAr TPC Calibrations", JINST 9, T11007 (2014)
- J. Asaadi *et al.*, "Testing of High Voltage Surge Protection Devices for Use in Liquid Argon TPC Detectors", JINST 9, P09002 (2014)
- M. Auger *et al.*, "A Method to Suppress Dielectric Breakdowns in Liquid Argon Ionization Detectors for Cathode to Ground Distances of Several Millimeters", JINST 9, P07023 (2014)
- A. Blatter *et al.*, "Experimental Study of Electric Breakdown in Liquid Argon at Centimeter Scale", JINST 9, P04006 (2014)
- T. Briese *et al.*, "Testing of Cryogenic Photomultiplier Tubes for the MicroBooNE Experiment", JINST 8, T07005 (2013)
- B.J.P. Jones *et al.*, "Photodegradation Mechanisms of Tetraphenyl Butadiene Coatings for Liquid Argon Detectors", JINST 8 P01013 (2013)
- B.J.P. Jones *et al.*, "A Measurement of the Absorption of Liquid Argon Scintillation Light by Dissolved Nitrogen at the Part-Per-Million Level", JINST 8 P07011 (2013)
- C.S. Chiu *et al.*, "Environmental Effects on TPB Wavelength-Shifting Coatings", JINST 7, P07007 (2012)
- A. Ereditato *et al.*, "Design and Operation of ARGONTUBE: a 5m Long Drift Liquid Argon TPC", JINST 8, P07002 (2013)

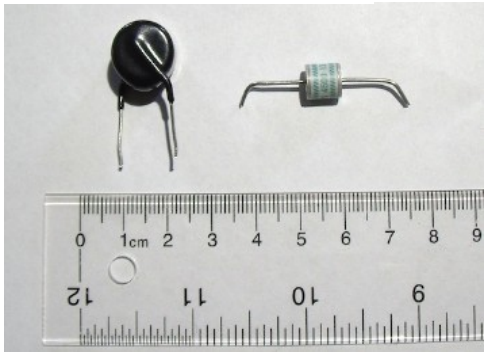
Surge Protection in LAr

Question 6

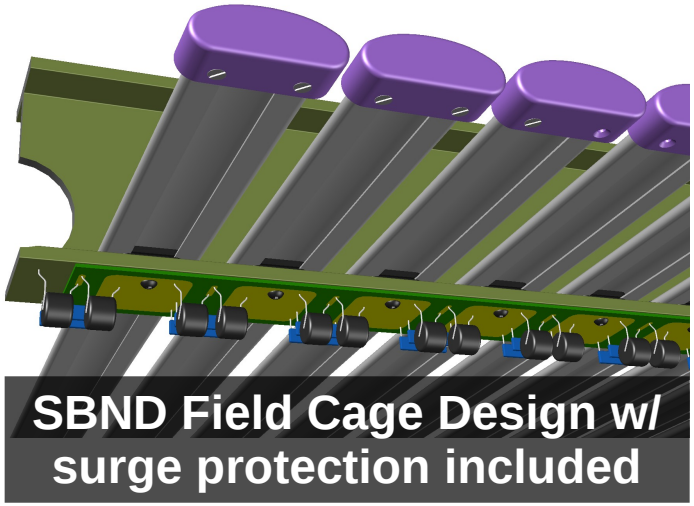


Typical failure mode:





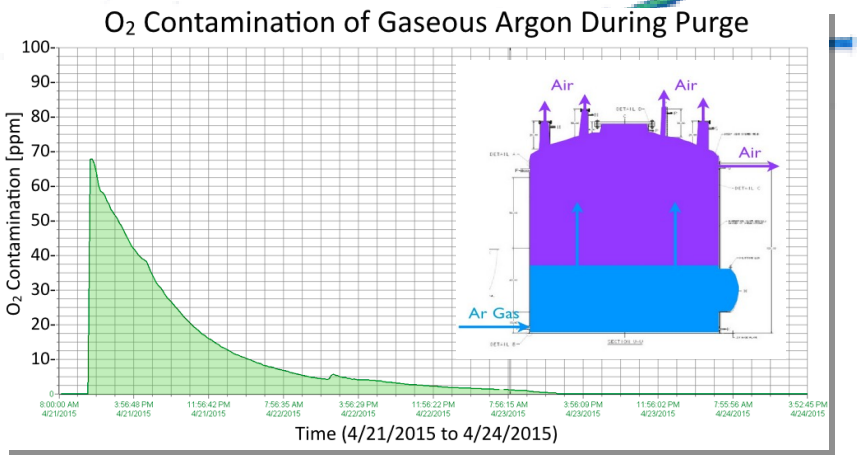
- **Sudden and unexpected breakdown in LArTPCs can cause an over-voltage condition**
  - This can lead to permanent damage of detector components
- **In order to remediate this risk, we evaluated and deployed surge arrestor devices within the voltage divider chain**
  - Gas Discharge Tubes
  - Varistors
- **Both solutions are now used in operating LArTPC experiments (MicroBooNE and LArIAT) and planned to be used in SBND**

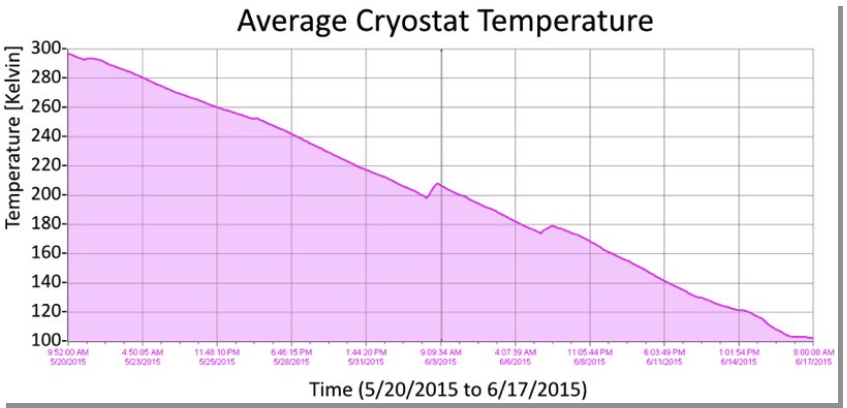


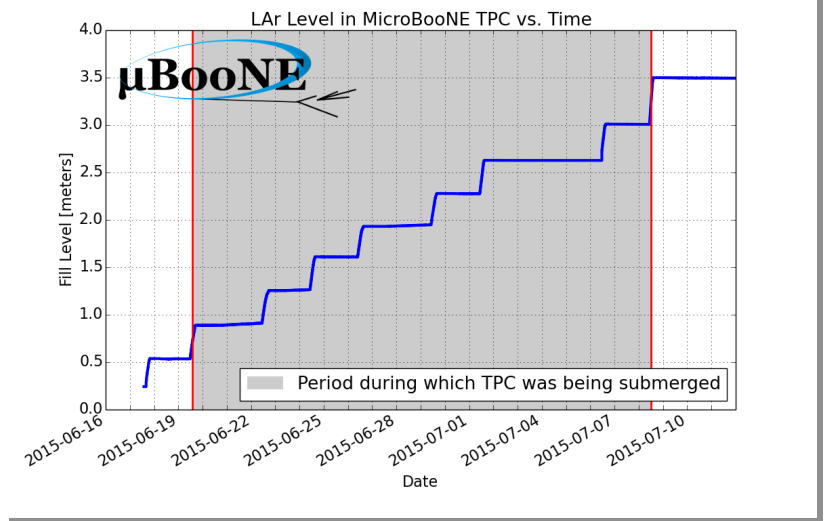
SBND Field Cage Design w/ surge protection included

Performance of the MicroBooNE Detector

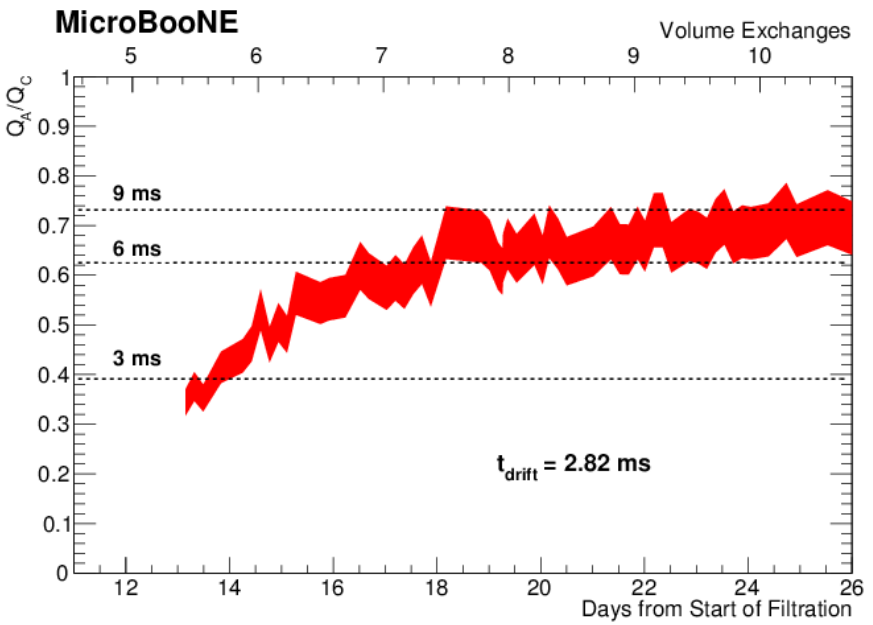
Question 2/6







- **Step 1: Purge w/ gaseous argon**
  - O_2 contamination reduced by two orders of in 10 volume exchanges
  - First time this technique used in a fully instrumented LArTPC experiment
    - Vessel evacuation not necessary!
- **Step 2: Slowly cool to LAr temperatures**
  - Cool to 100 K over 28 days
- **Step 3: Fill with liquid argon**
  - 9 tanker trucks to fill the detector
- **Step 4: Recirculate and purify**
  - Achieved 3x design purity
    - Allows for operation at lower (safer) drift voltage

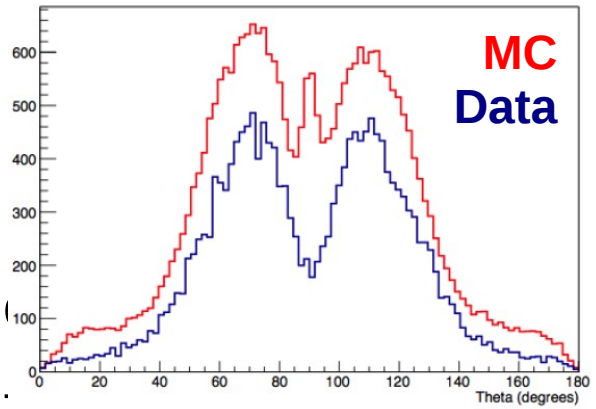


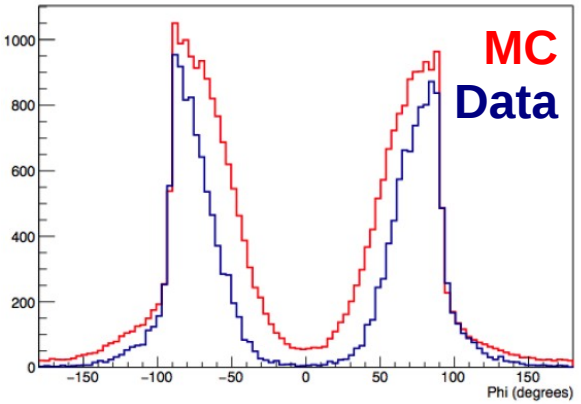
Performance of the MicroBooNE Detector

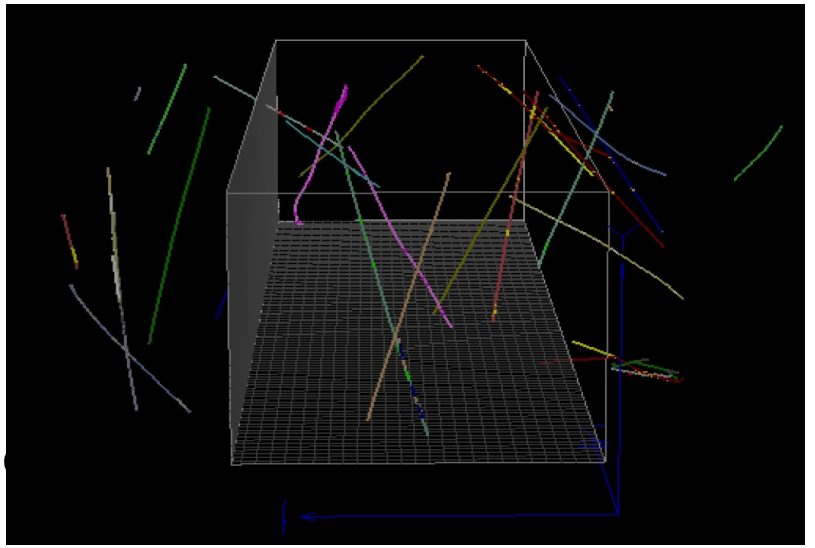
Question 6

E-field	Expected (Lower bound: CRY Upper bound: CORSIKA)	KalmanHit (measured)	Pandora-based (measured)
-58 kV	8.3 – 12.1	8.35 +/- 0.18	7.75 +/- 0.18
-70 kV	7.6 – 11.0	8.07 +/- 0.14	7.35 +/- 0.14

- **Cosmic ray running at -58 kV & -70 kV**
  - Observed cosmic ray rates consistent with early MC predictions
- **Provides a large data sample to vet low level reconstruction performan**
  - Using cosmic ray data taken this summer to vet predicted cosmic ray rates and kinematics obtained from various generators
  - Investigations into the details are ongoing



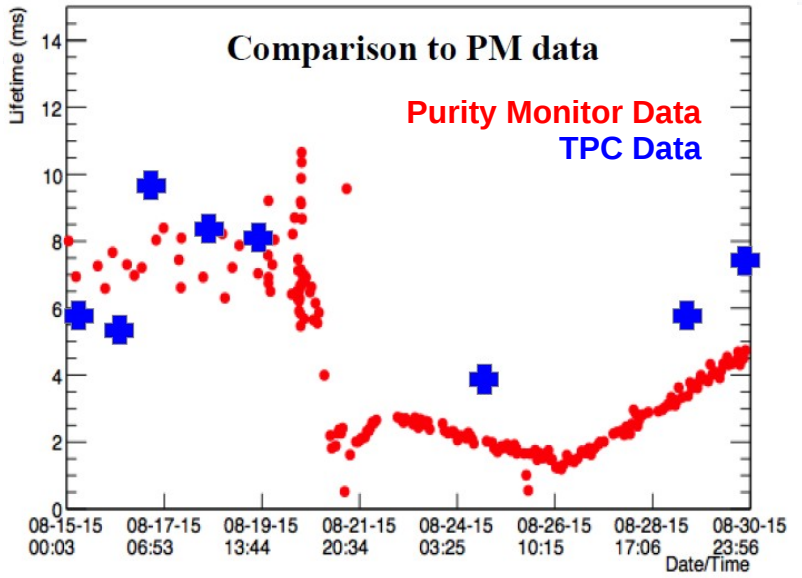


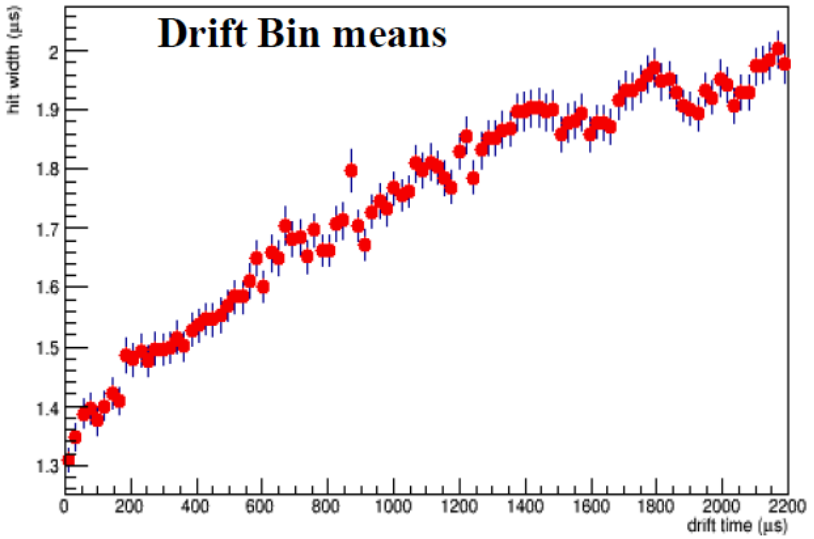


Performance of the MicroBooNE Detector

Question 6

- **Beginning to do physics measurements using the cosmic ray data**
  - Purity measurements using reconstructed TPC tracks
    - Shows good agreement with the purity monitor data
  - Diffusion studies
    - Evidence of increasing hit width as a function of drift distance (consistent with diffusion)

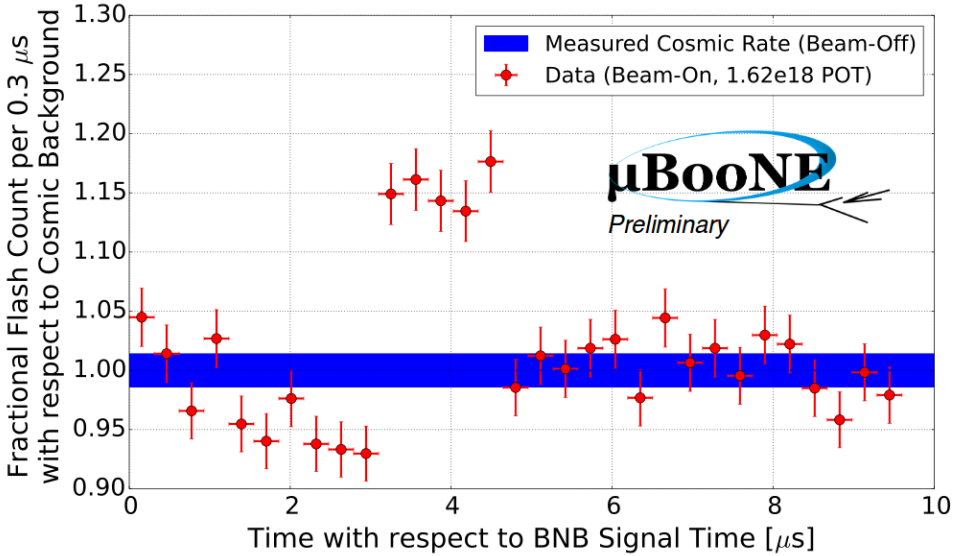




Performance of the MicroBooNE Detector

Question 6

- **October 15th 2015 we begin to receive beam from the Booster**
  - Neutrino ID task force has been hard at work for a few months in preparation
  - Trigger and light system are timed in for neutrino
- **Fully automated event selection is applied to neutrino data**
  - Clear excess of light seen in time with the beam
  - Excess of events observed (above background) using TPC + light selection
  - November 2nd 2015 MicroBooNE announces first neutrino candidates observed



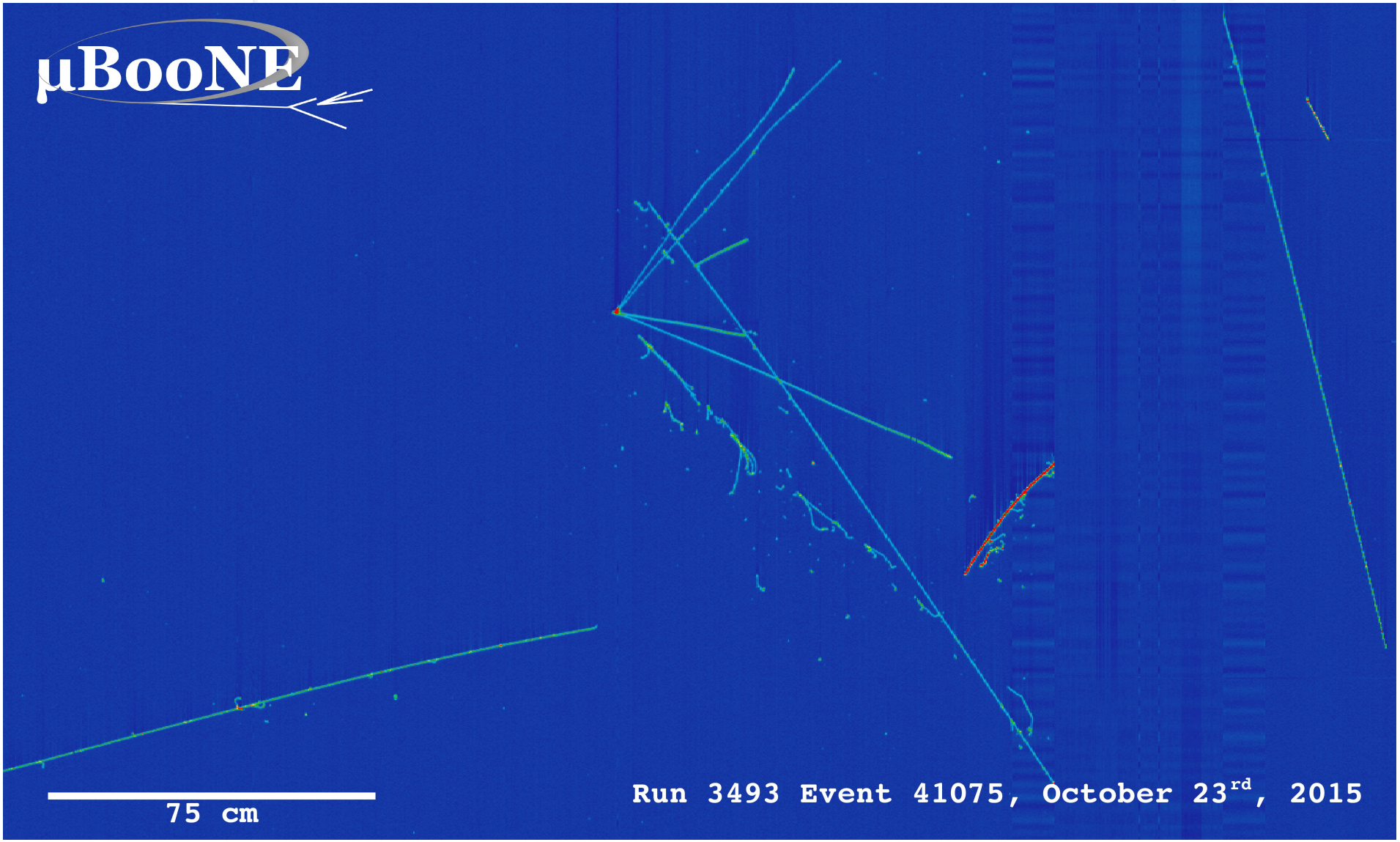
First ν identification

MicroBooNE Preliminary
1.86E18 POT, BNB

Number of events	Automated event selection Optical + 3D-based	Automated event selection Optical + 2D-based
Non-beam background (expected)	4.6 ± 2.6	385 ± 24
Total observed	18	463

See Matt's talk for more details on first neutrinos

Neutrinos!!!!



See Matt's talk for more details on first neutrinos

3-d Neutrinos!!!!

http://www.phy.bnl.gov/wire-cell/bee/set/f3161aa9-7370-48f6-9cb5-5f7a28515104/event/14/?theme=light

One place to see preliminary 3-d neutrino visualization (not used for analysis)

See Matt's talk for more details on first neutrinos

Conclusions

- **MicroBooNE is now in physics data taking mode**
  - Successful commissioning of the system concluded September 2015
  - First neutrinos observed using fully automated readout and reconstruction of LArTPC data
  - All sub-sytems operational and involved in data taking
- **Many high level and foundational measurements underway using the data collected thus far**
  - e.g. Neutrino Identification, purity measurements w/ TPC, diffusion measurements w/ TPC, measuring the cosmic ray flux at LArTF, etc....
- **Number of publications related to detector technology development**
  - Impact of the lessons learned from MicroBooNE already in the LArTPC community
- **Public notes related to early physics and detector commissioning to be released**
  - http://www-microboone.fnal.gov/publications/publicnotes/index.html

Backup Slides

TPC current performance

Question 2