Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Status of MicroBooNE

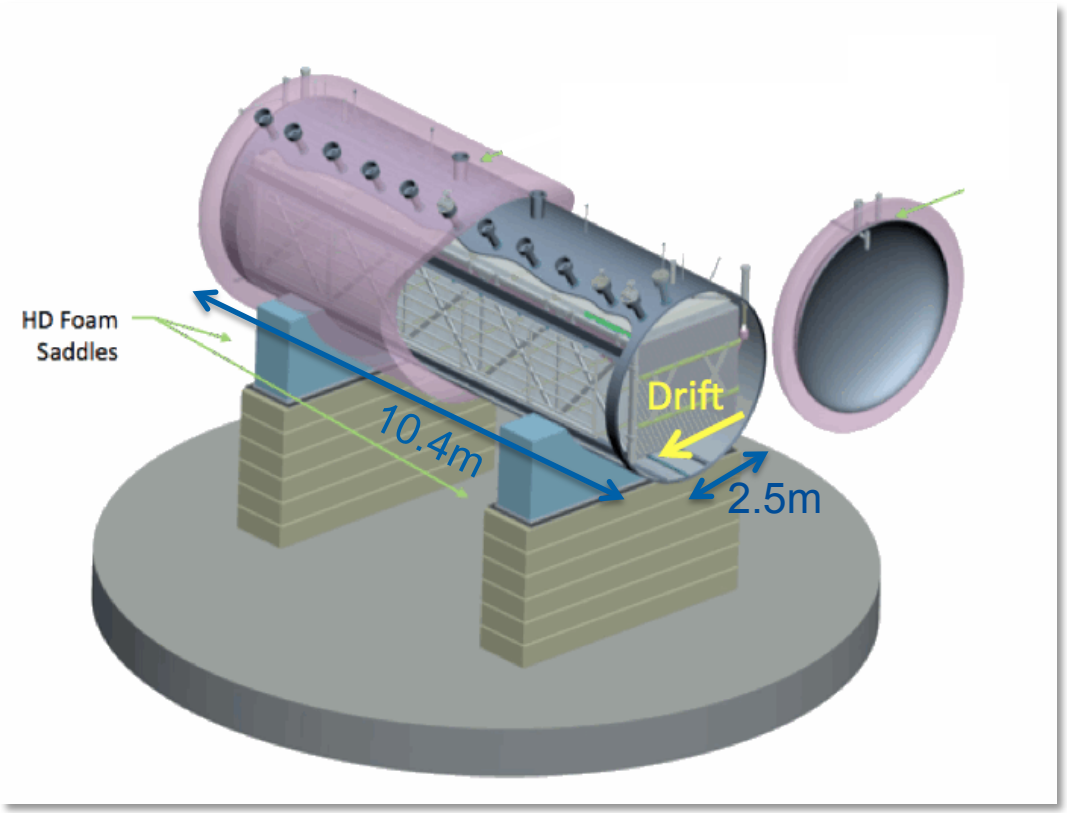
Sam Zeller

PAC Meeting

June 22, 2015

MicroBooNE Experiment

- 170 ton LAr TPC in the BNB
(same beam and approx location as MiniBooNE)



- MicroBooNE kicks off the start of the short-baseline neutrino program

- physics goals:
  - *understand the source of the MiniBooNE low energy excess*
  - *make the 1st measurements of low energy neutrino cross sections in argon*

- technical advancements:
  - *argon fill without evacuation*
    (1st demonstrated in LAPD)
  - *cold front-end electronics*
  - *long drift (2.5m)*
  - *automated reconstruction*
  - *near surface operation*

MicroBooNE Collaboration

University of Bern, Switzerland: M. Auger, A. Ereditato, D. Goeldi, I. Kreslo, M. Lüthi, C. Rudolf von Rohr, T. Strauss, M. Weber
Brookhaven: M. Bishai, H. Chen, J. Joshi, B. Kirby, Y. Li, D. Lissauer, M. Mooney, X. Qian, V. Radeka, C. Thorn, B. Yu, C. Zhang
University of Cambridge: A. Blake, J. Marshall, M. Thomson
University of Chicago: W.M. Foreman, J. Ho, D.W. Schmitz, J. Zennamo
University of Cincinnati: R. Grosso, R.A. Johnson, J. St. John
Columbia University: L. Camilleri, D. Caratelli, V. Genty, D. Kaleko, W. Seligman, M. Shaevitz, K. Terao
Fermilab: R. Acciarri, L. Bagby, B. Baller, B. Carls, F. Cavanna, H. Greenlee, C. James, H. Jostlein, M. Kirby, T. Kobilarcik, S. Lockwitz, B. Lundberg, A. Marchionni, O. Palamara, Z. Pavlovic, S. Pordes, J.L. Raaf, G. Rameika, B. Rebel, A. Schukraft, P. Spentzouris, T. Yang, G.P. Zeller*
Illinois Institute of Technology: R. An, B. Littlejohn
Kansas State University: T. Bolton, S. Gollapinni, G. Horton-Smith, V. Meddage, A. Rafique
Los Alamos: G. Garvey, W. Ketchum, W.C. Louis, G.B. Mills, R. Van de Water
University of Manchester: A. Furmanski, J. Hewes, G. Karagiorgi, R. Murrells, S. Söldner-Rembold, A.M. Szelc
MIT: L. Bugel, J.M. Conrad, B.J.P. Jones, J. Moon, M.H. Moulai, J. Spitz, M. Toups, T. Wongjirad
New Mexico State University: T. Miceli, V. Papavassiliou, S. Pate, K. Woodruff
Oregon State University: H. Schellman, S. Wolbers
Otterbein University: N. Tagg
University of Oxford: G. Barr, M. Bass, R. Guenette
University of Pittsburgh: S. Dytman, N. Graf, D. Naples, V. Paolone
Pacific Northwest National Laboratory: E. Church
Princeton University: K. McDonald
Saint Mary's University of Minnesota: P. Nienaber
SLAC: M. Convery, B. Eberly, L. Rochester, Y-T. Tsai, T. Usher
Syracuse University: J. Asaadi, J. Esquivel, G. Pulliam, M. Soderberg
Virginia Tech: A.M. Ankowski, C.M. Jen, L.N. Kalousis, C. Mariani
Yale University: C. Adams, B.T. Fleming*, E. Gramellini, A. Hackenburg, B. Russell

121 collaborators
24 institutions
(4 non-U.S., 5 nat'l labs)
31 postdocs
24 graduate students

New Institutions and Collaborators

University of Bern, Switzerland: M. Auger, A. Ereditato, D. Goeldi, I. Kreslo, M. Lüthi, C. Rudolf von Rohr, T. Strauss, M. Weber
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+ Lancaster University and University of Michigan, Ann Arbor will be joining our team this summer

Postdoc Placements

- in the last 3 years, 15 of our postdocs have landed their next position - all in particle physics, majority have remained on MicroBooNE (12 out of 15)

(1) Roxanne Guenette, Oxford, STFC Rutherford Fellow
(2) David McKee, Missouri Southern State University, Assistant Professor
(3) Mike Cooke, DOE, AAAS Science & Technology Policy Fellow
(4) Teppei Katori, Queen Mary University of London, Lecturer
(5) Georgia Karagiorgi, Manchester, Lecturer
(6) Bryce Littlejohn, IIT, Assistant Professor
(7) Tingjun Yang, FNAL, Applications Physicist, ND
(8) Zarko Pavlovic, FNAL, Applications Physicist, ND
(9) Andrzej Szelc, Manchester, Lecturer
(10) Eric Church, PNNL, Scientist
(11) Wes Ketchum, FNAL, Associate Scientist, SCD
(12) Andy Blake, Lancaster, Lecturer
(13) Josh Spitz, Michigan, Ann Arbor, Assistant Professor
(14) Thomas Strauss, in negotiations
(15) Matt Toups, in negotiations

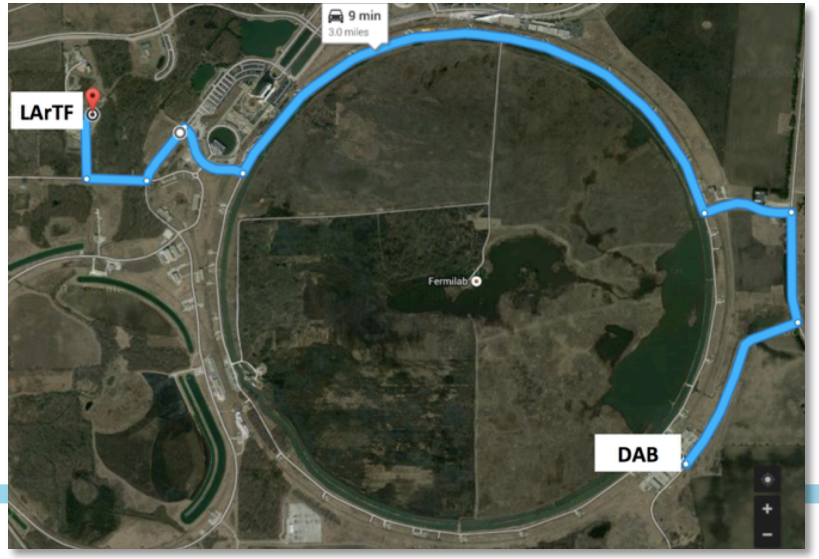
What Have We Been Up To?

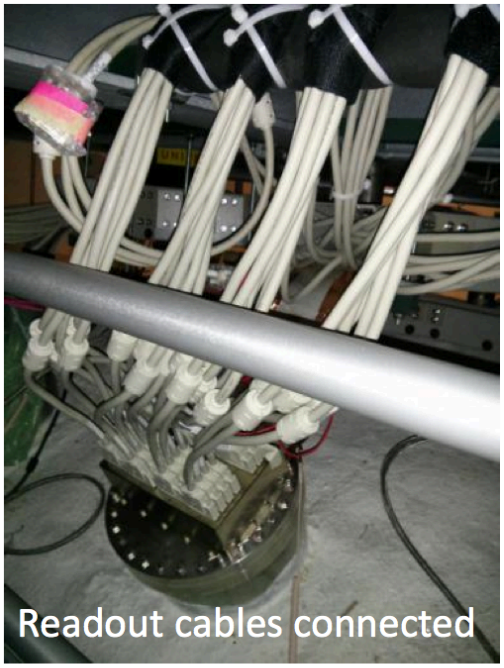
- last time we presented to the PAC:

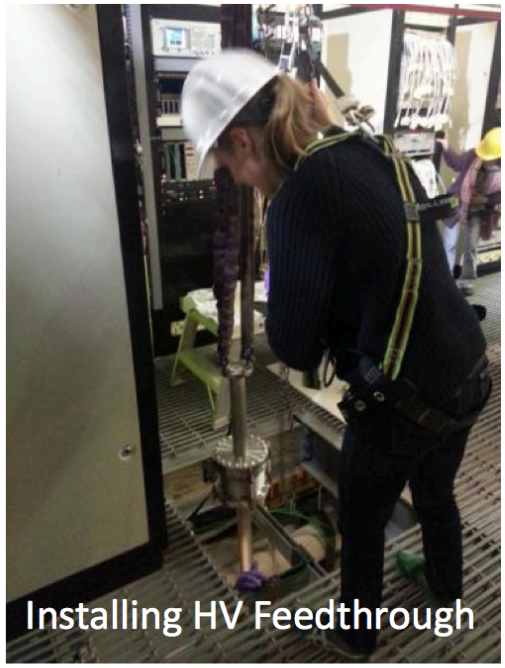
- a lot has happened since then
- a few highlights …

Summer 2014

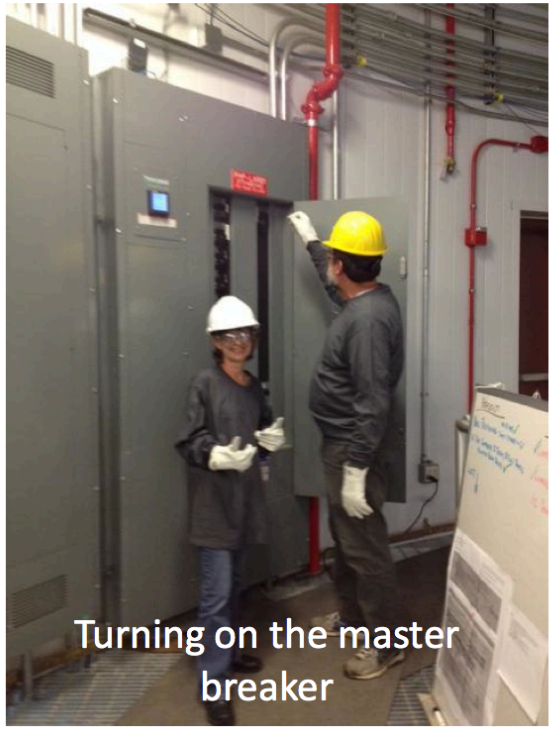
- moved the detector to LArTF




Readout cables connected


Installing HV Feedthrough

Installed ~4 miles of cables


Turning on the master breaker

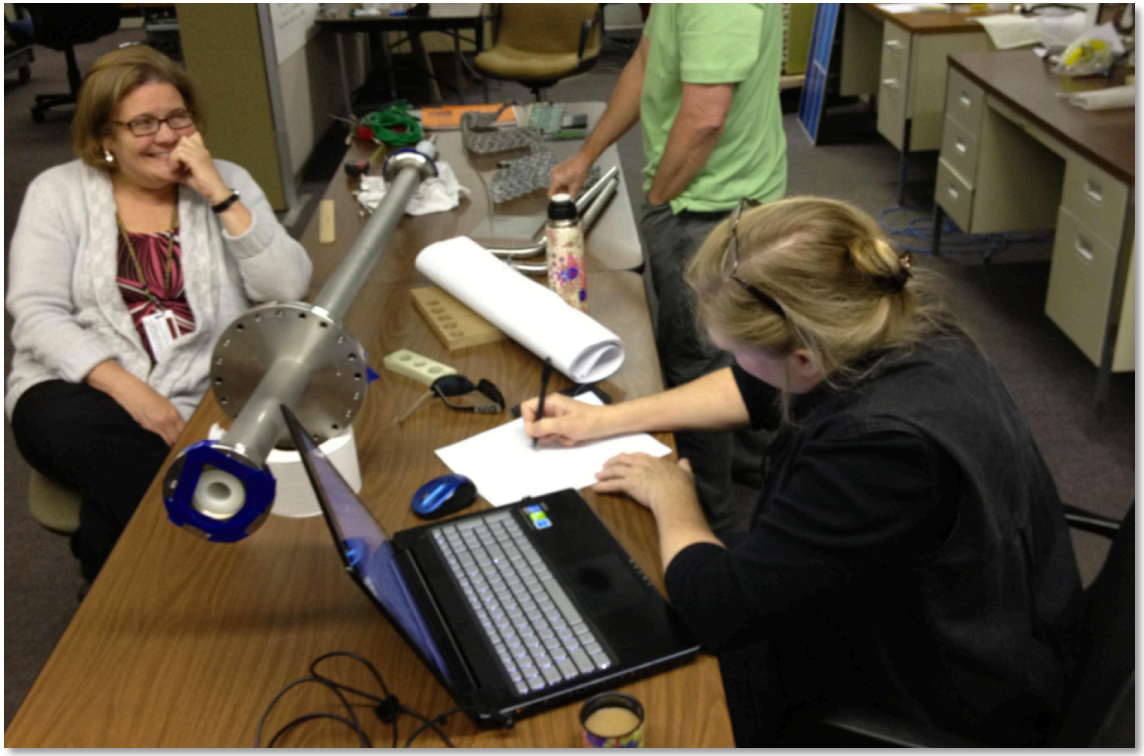
Fall 2014

detector installation completed & ORCs granted

It works!

MicroBooNE Project Completion

- received CD-4 approval on December 22, 2014!

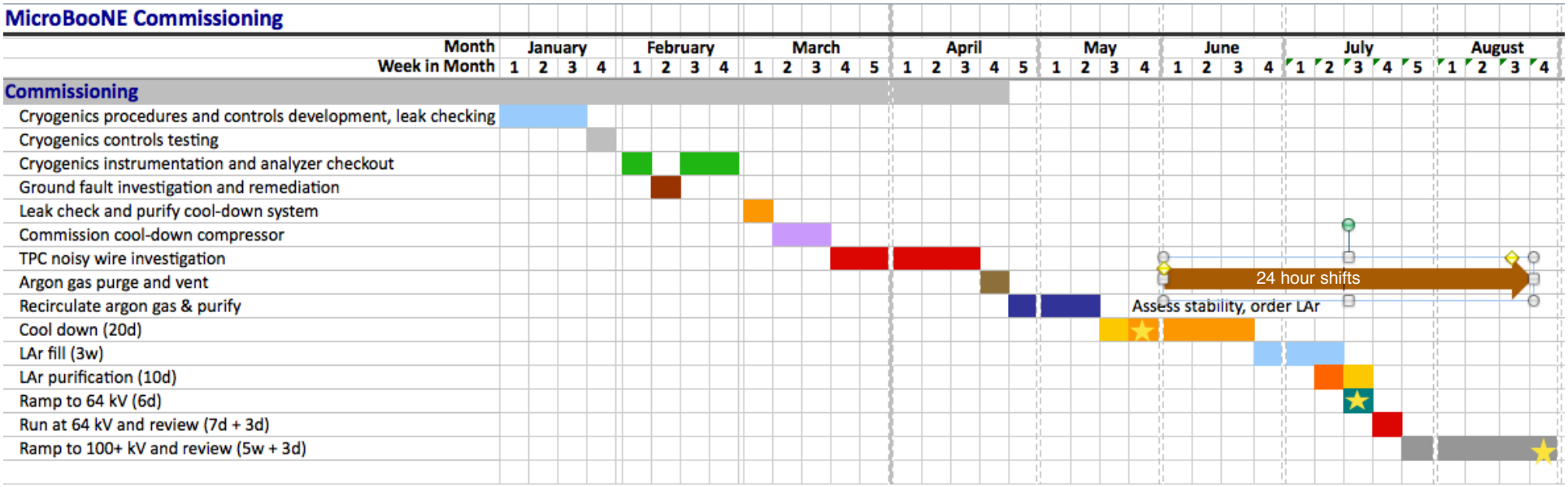


G. Rameika (project manager), C. James (deputy project manager)

- this catches you up, we have now moved on to commissioning …

MicroBooNE Commissioning

- commissioners: Bruce Baller (FNAL), Matt Toups (MIT)



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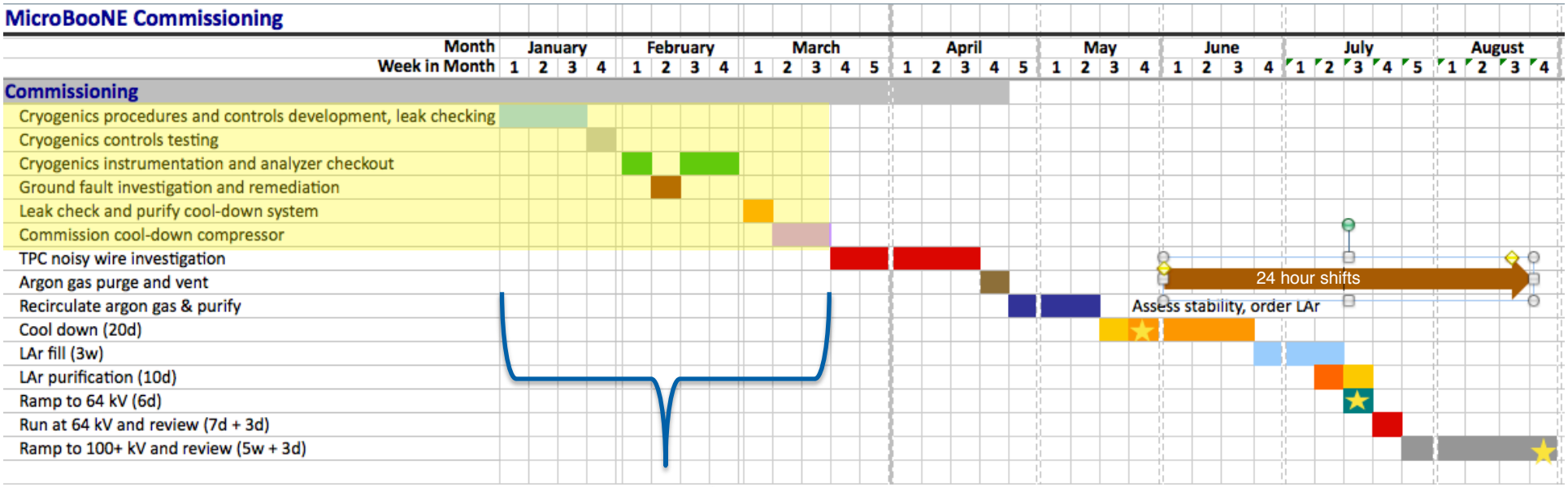
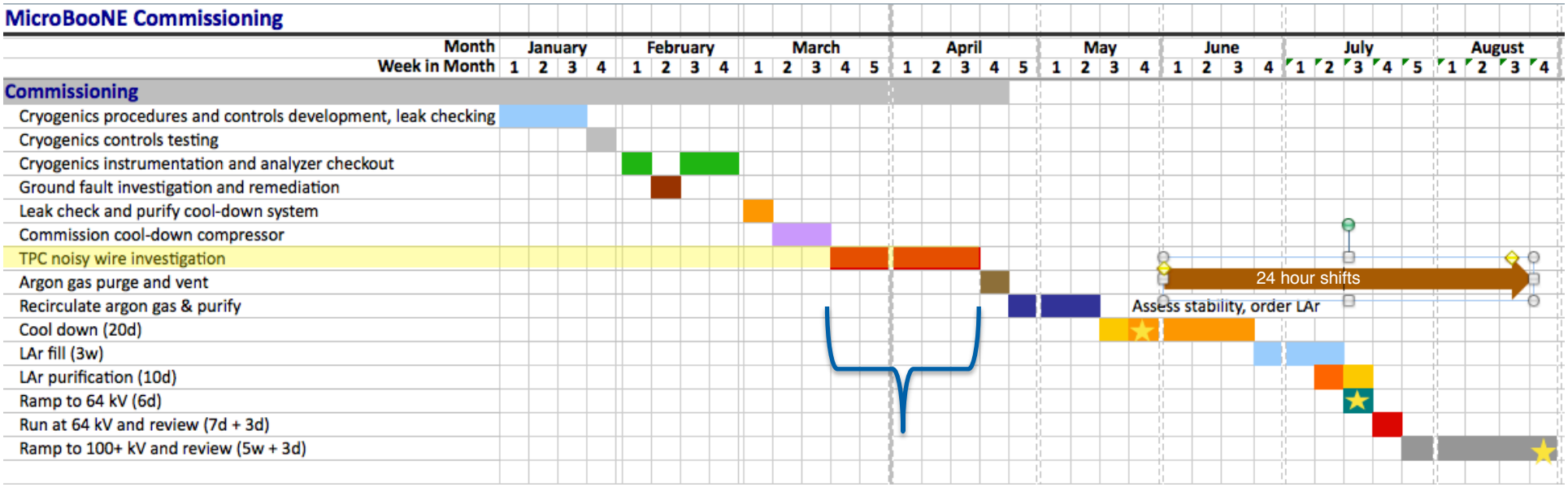


commissioning
our newly completed
cryogenics system

offline computing review
Feb 23-24, 2015

MicroBooNE Commissioning

- commissioners: Bruce Baller (FNAL), Matt Toups (MIT)



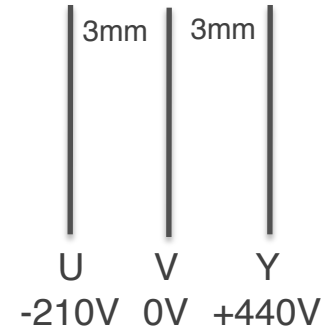
hiatus to investigate
noisy TPC channels

(discovered during one of the checks we scheduled before cooling down)

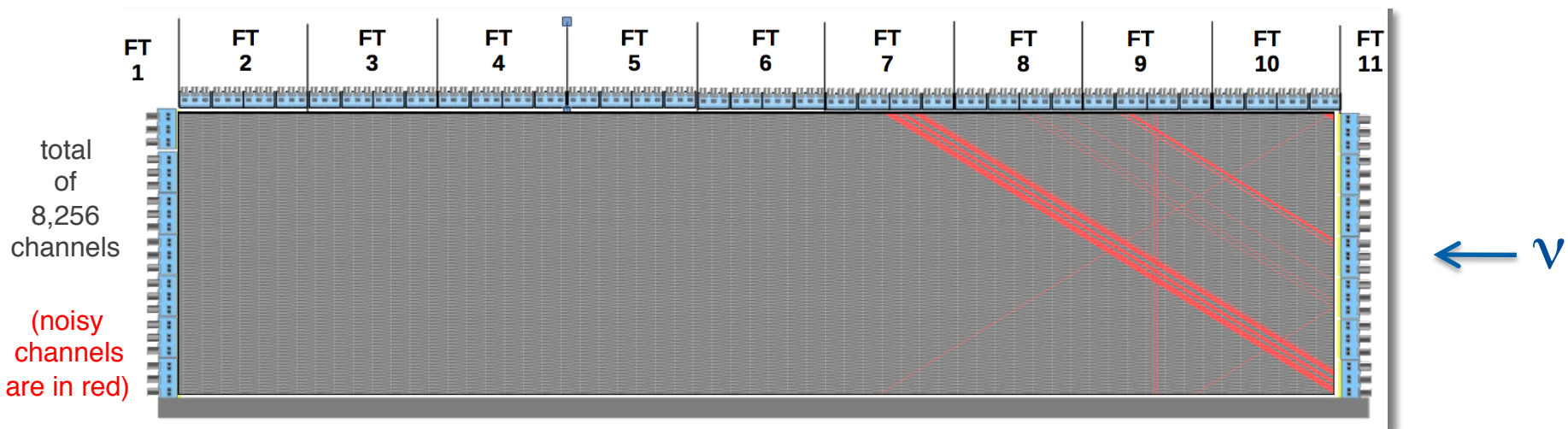
Noise Levels

- in March, discovered 43 TPC channels with above average noise (0.5% of channels) in ramping up the wire bias voltages (in air)
- the impedance measured on the negative bias line for 3 feedthroughs also appeared correlated

  → *touching wire planes? electronics?*
  → *worst case scenario: broken wire(s)?*

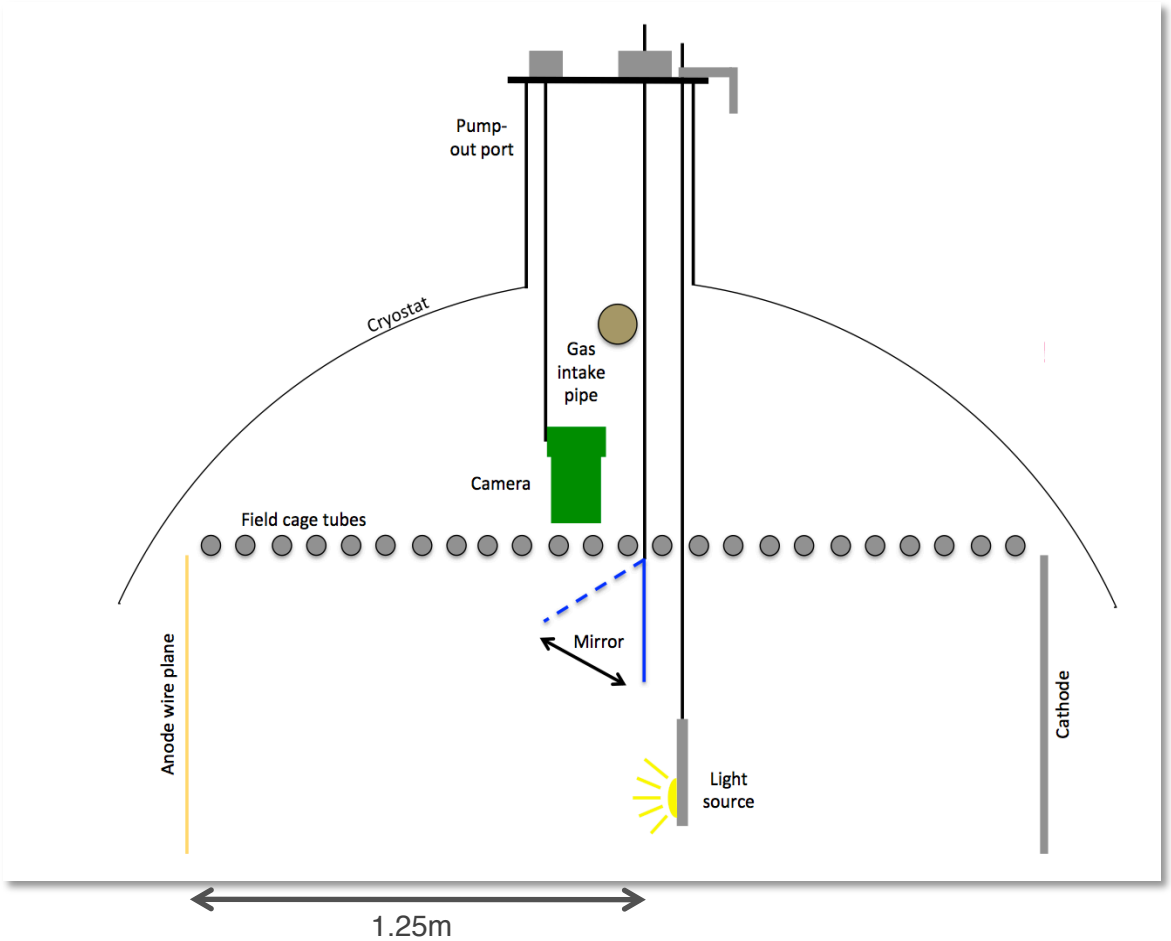


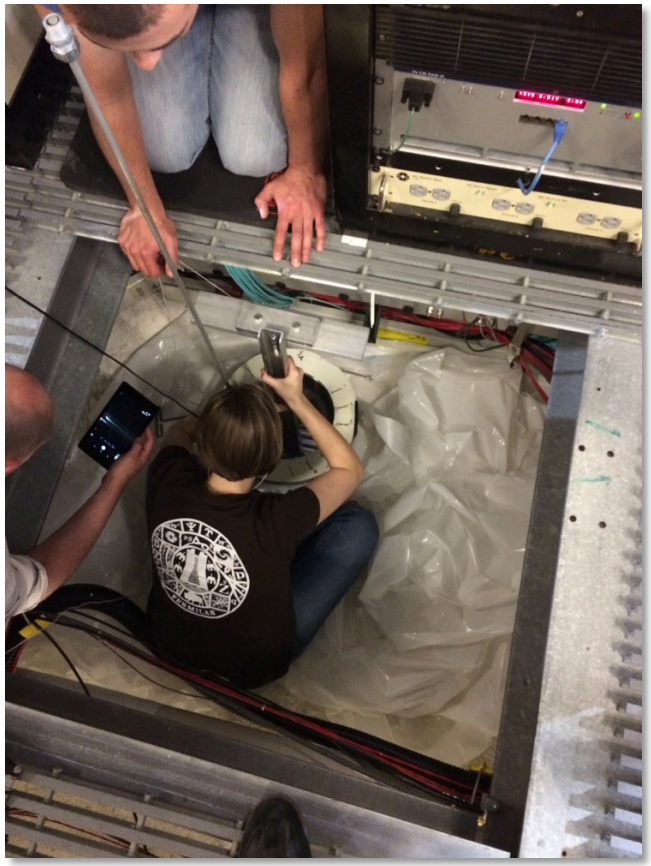
- learned a lot about our detector & electronics



Detector Health Check

- we used a camera, mirror, and light system to view inside the vessel in the region near the noisy channels

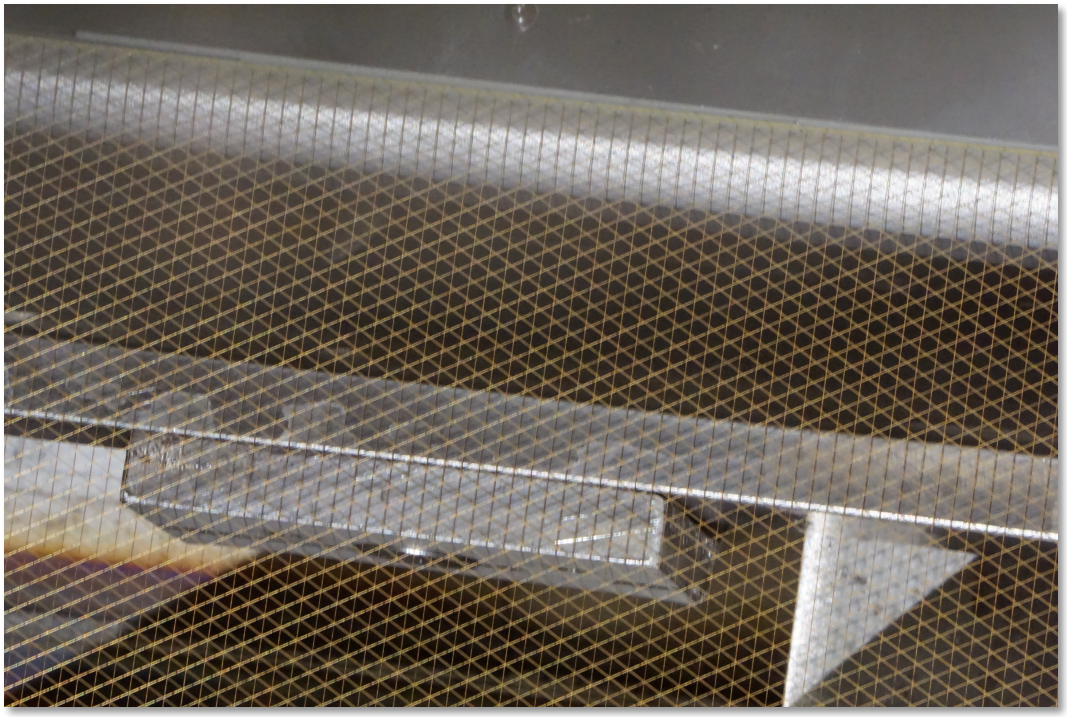




A. Schukraft (FNAL), R. Acciarri (FNAL), B. Carls (FNAL)

Spectacular Images

- teams systematically scanned images



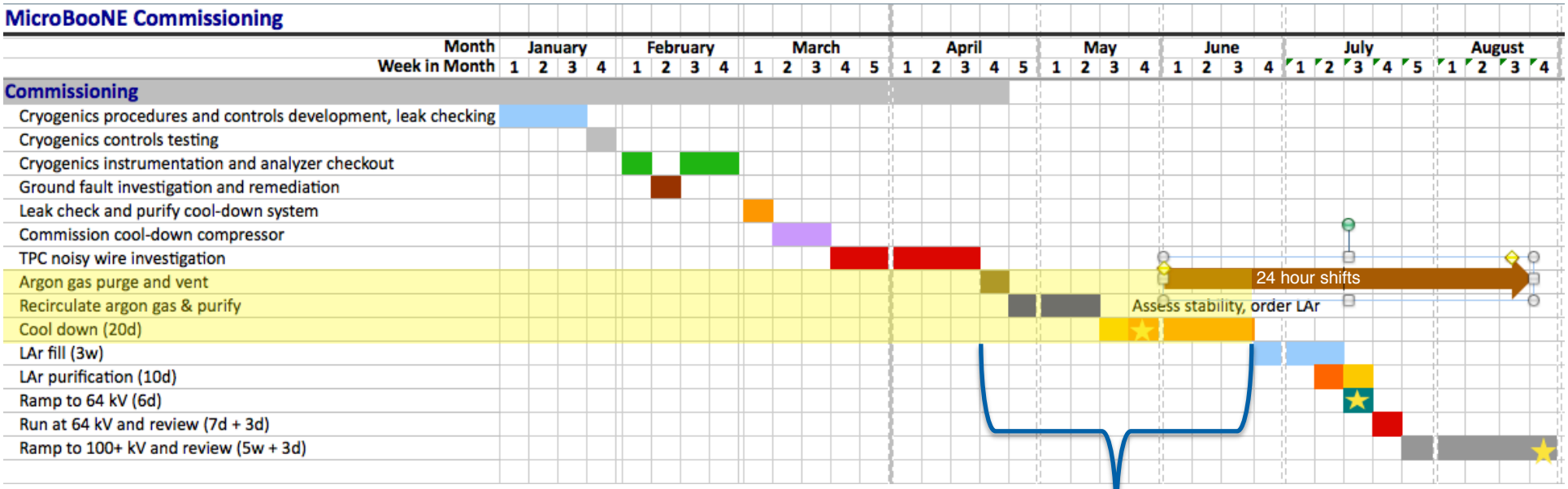
(as viewed from > 4m away)

- no broken wires or anomalies observed, so we proceeded to cooldown

(# of noisy channels has been decreasing as we are cooling down: 43 → ~20 channels)

MicroBooNE Commissioning

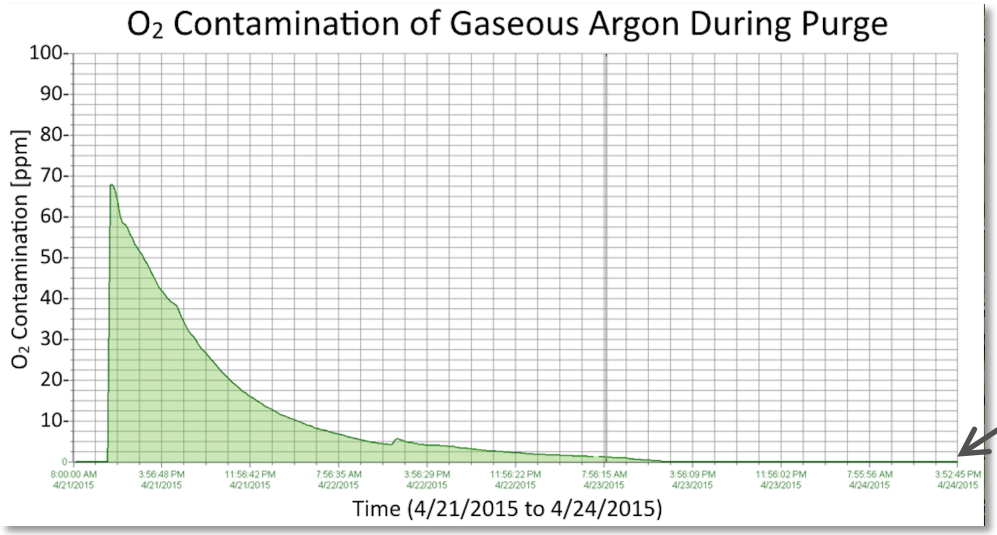
- commissioners: Bruce Baller (FNAL), Matt Toups (MIT)



purge and cooldown
started in mid-April
and finished last week
(we also started shifts)

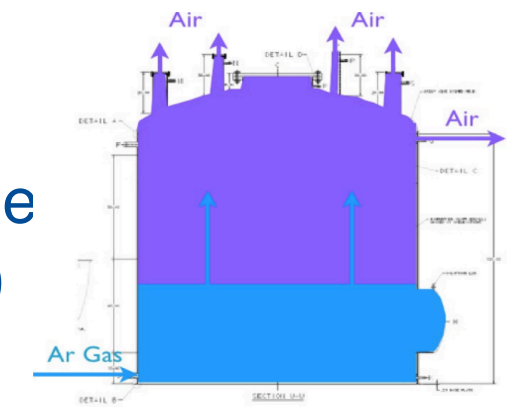
Purge and Cooldown

- warm cryostat filled with air → cold cryostat filled with LAr

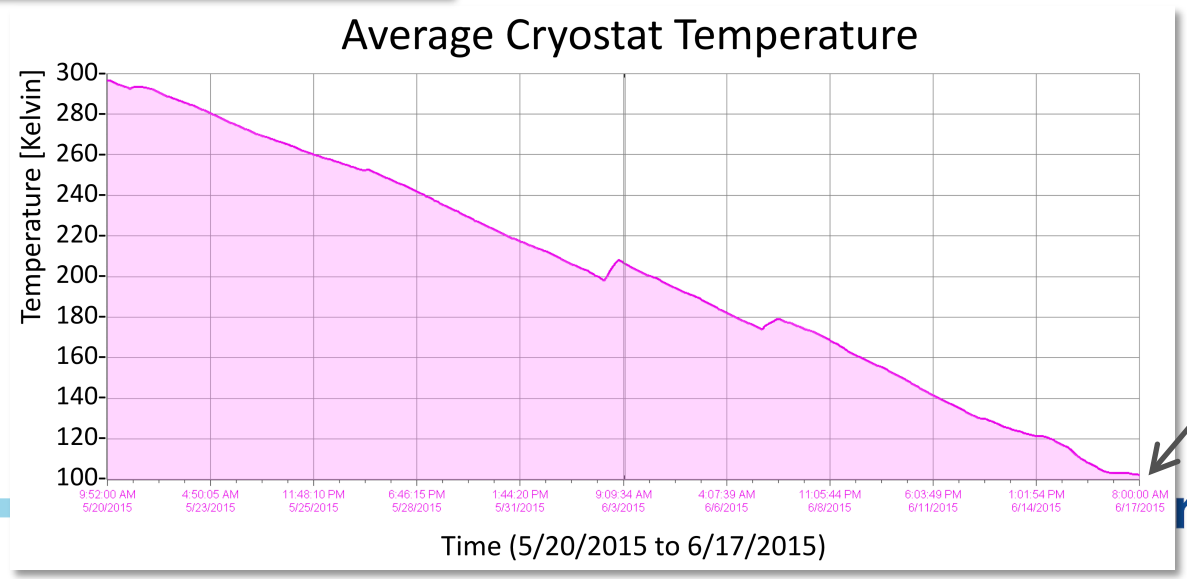


← gaseous argon purge (ala LAPD)

20 ppb O_2



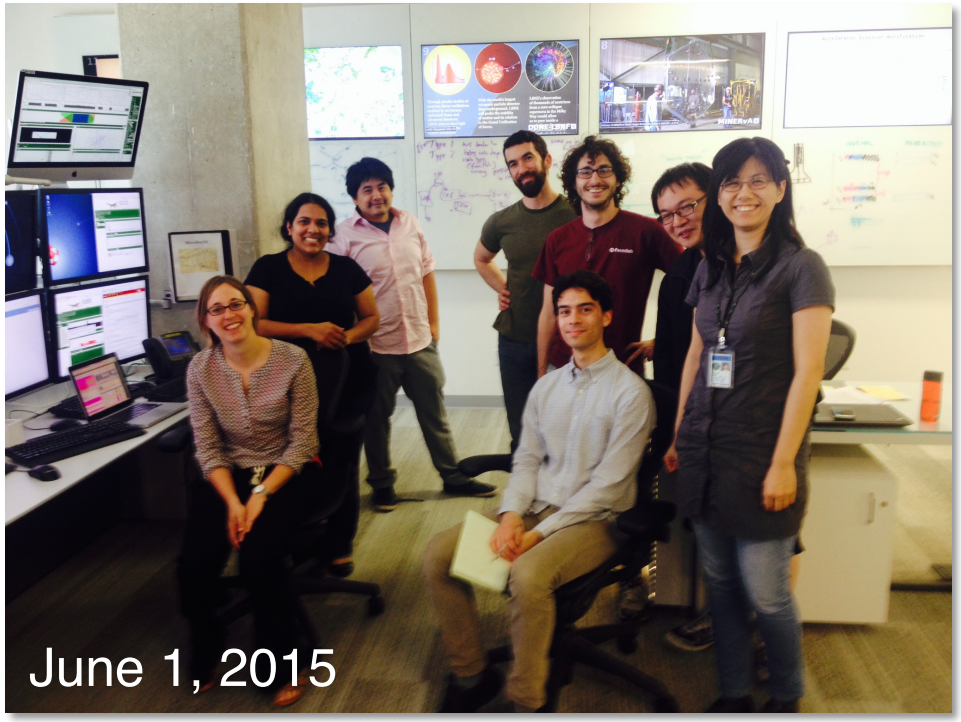
cooldown → (~8K/day)



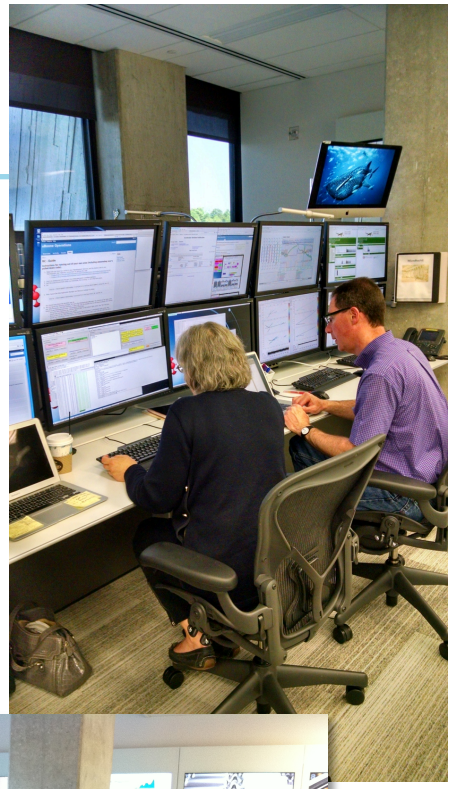
last week

MicroBooNE Shifts

- 24/7 shifts started on June 1, 2015 *(> a month before detector turn-on)*
  - operations meetings every Monday 10am
  - BNB/AD meetings every Monday 11am



A. Schukraft (FNAL), S. Gollapinni (KSU), T. Wongjirad (MIT), J. Asaadi (Syracuse), J. Zennamo (Chicago), K. Terao (Columbia), D. Caratelli (Columbia), Y-T. Tsai (SLAC)

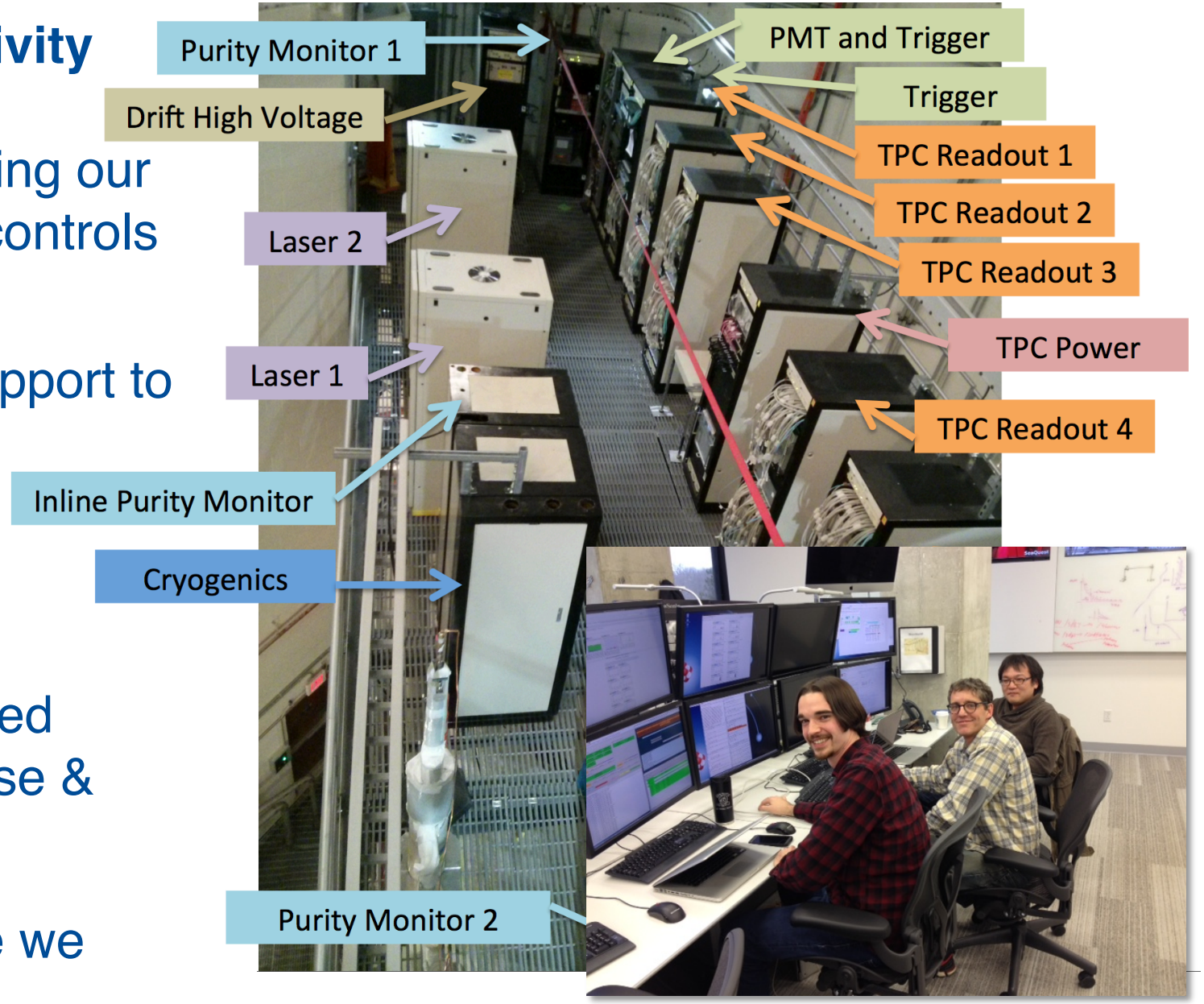


D. Torretta (ND), Kurt Bierry (SCD)

N. Tagg (Otterbein), Y-T. Tsai (SLAC), W. Ketchum (LANL),G. Lukhanin (SCD)

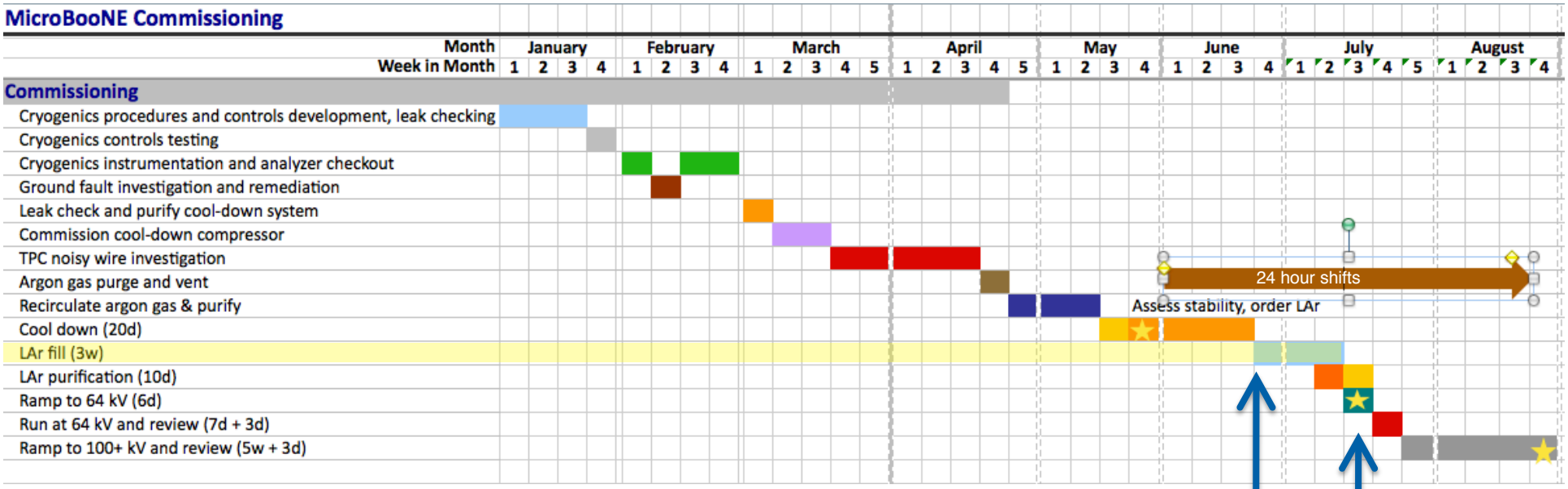
A lot of Activity

- fully exercising our DAQ, slow controls
- shifters are providing support to the ND cryo team & taking daily noise runs
- have collected 27 Tb of noise & pulser data
- making sure we are ready!



W. Ketchum (LANL), E. Church (PNNL), K. Terao (Columbia)

MicroBooNE Commissioning



we are here

turn on HV

We Are Filling with Liquid Argon!

- <u>we started filling with liquid argon last Wednesday</u>
- we have received 2 truckloads so far, 3rd arrived this morning will take 9 truckloads, 3 weeks to fill; Mon-Wed-Fri delivery
- last delivery is currently scheduled for July 8th
- important demonstration that we can secure a large volume (>3,000 gallons) of high purity LAr

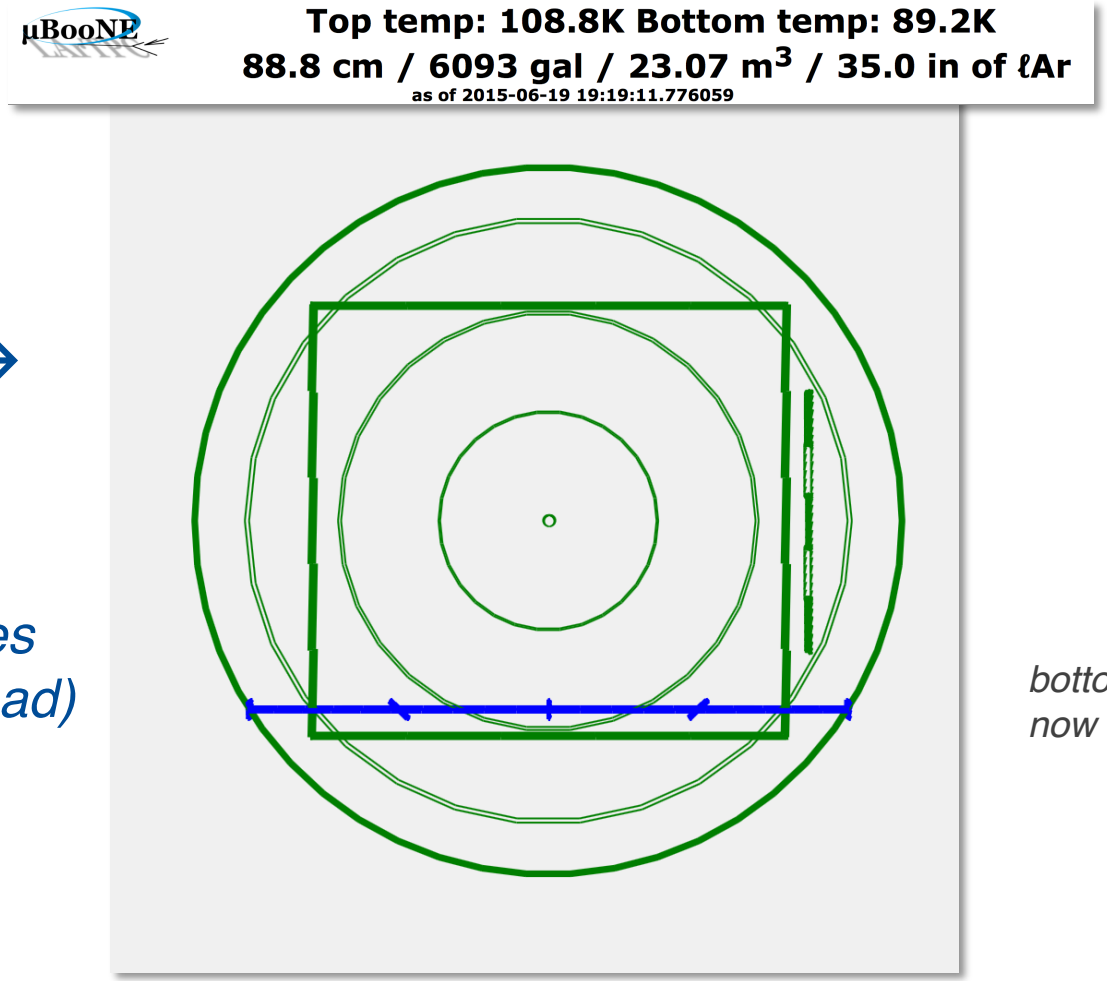
<u>first 2 deliveries</u>:
O_2: 90 ppb (spec: < 1ppm)
N_2: 10 ppb (spec: < 3ppm)

first truck load of LAr to MicroBooNE
June 17, 2015

Current LAr Fill Status

- after the first 2 truckloads →

(each load is ~3,000 gallons of LAr and takes 8 hours to unload)

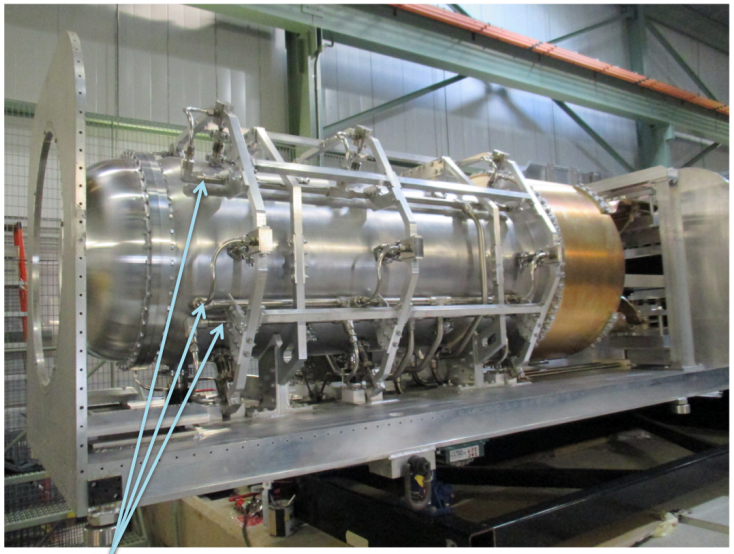


bottom of the TPC is now immersed in liquid

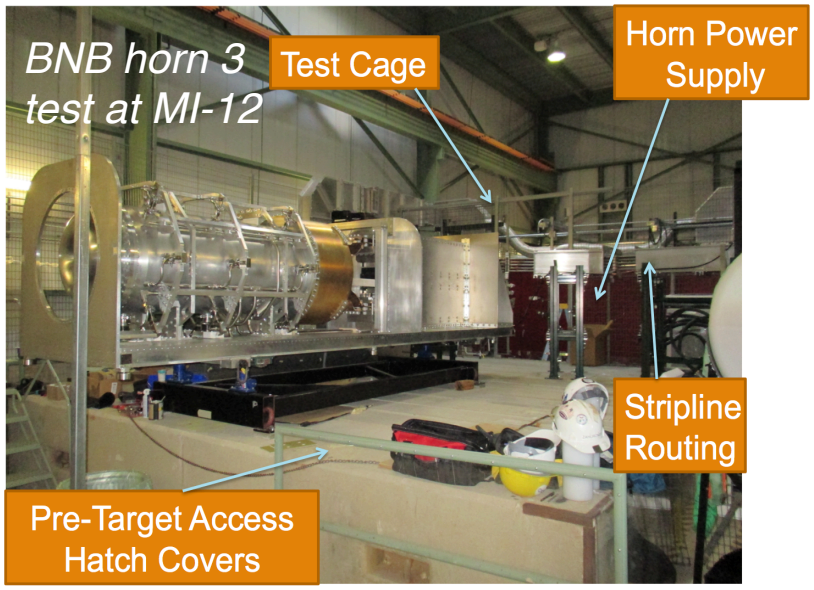
http://argo-microboone.fnal.gov/FillLevel/

BNB Horn Replacement

- we replaced the BNB horn
- horn #2 and target had been in service since Oct 2004, pulsed >400M times (world record)
  - *in November 2014, 2 of the 4 operational water headers became clogged, efforts to unclog them were unsuccessful*
- decided to replace the horn
- MicroBooNE will start our run with a new horn; we are approved to run MiniBooNE to provide a rate check



Water spray nozzle headers (Beam left side)



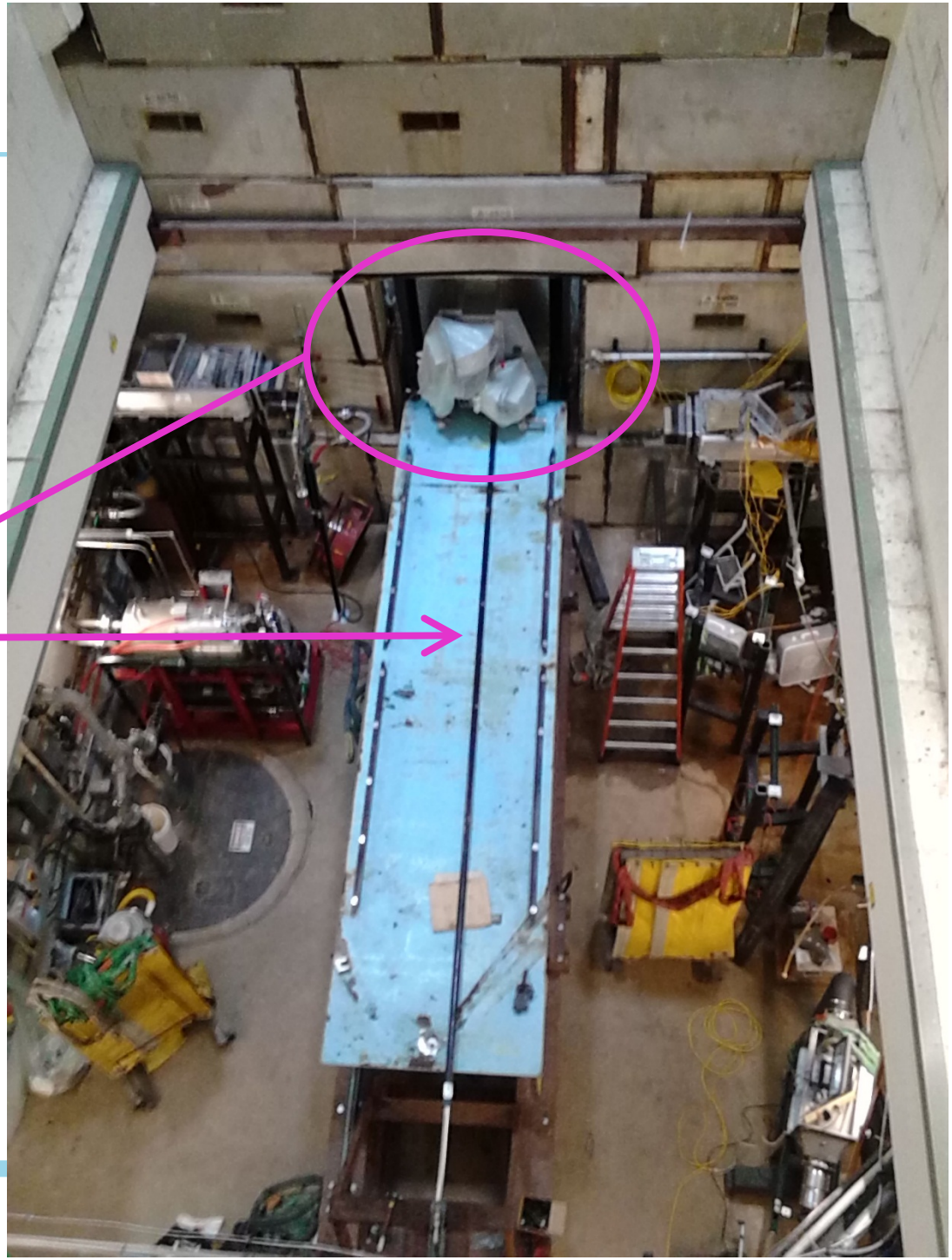
BNB Horn Replacement

- horn #3 is in!
- final walk-through was on Friday, AD will start commissioning this week

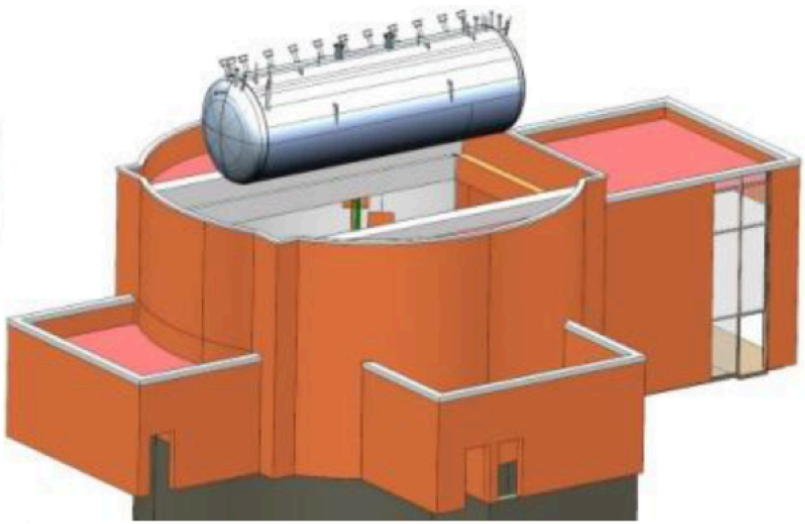
horn in target pile

platform for sliding horn into the target pile

- plans for a new BNB interlock are in place
  - *this will allow us to run BNB when NuMI is down*
  - *x5 more beam to μB*
- see Mary Convery's talk



From Drawing to Reality



"drawing"

"reality"

- transition from "drawing" to "reality" for detector construction & installation is now complete
- next, we need to the same for data taking & physics analyses

MicroBooNE Team

Institutional Board
Chair: G. Horton-Smith

Spokespeople
B. Fleming, G. Zeller

Neutrino Division:

Experimental Liaison Officer (ELO)
B. Lee
D. Torretta (deputy)

Cryogenics
B. Norris

Computing Sector:

Computing Sector Liaison
M. Kirby

Commissioning
B. Baller, M. Toups
(Run Coordinator: M. Toups)

- **Beam** *T. Miceli*
- **Calibration** *B. Carls, T. Strauss*
- **Cryogenics Liaison** *B. Carls*
- **Control Room** *A. Schukraft, J. Zennamo*
- **DAQ** *W. Ketchum, Y.T. Tsai*
- **Electrical Integration** *L. Bagby*
- **HV System** *S. Lockwitz*
- **Laser** *M. Luethi*
- **Muon System** *M. Bass, L. Kalousis*
- **Online** *N. Tagg*
- **Offline** *B. Baller*
- **PMTs** *T. Wongjirad*
- **Readout** *G. Karagiorgi, K. Terao*
- **Slow Controls** *S. Gollapinni*
- **TPC** *J. Asaadi*

Analysis Tools & Computing
E. Church, H. Greenlee

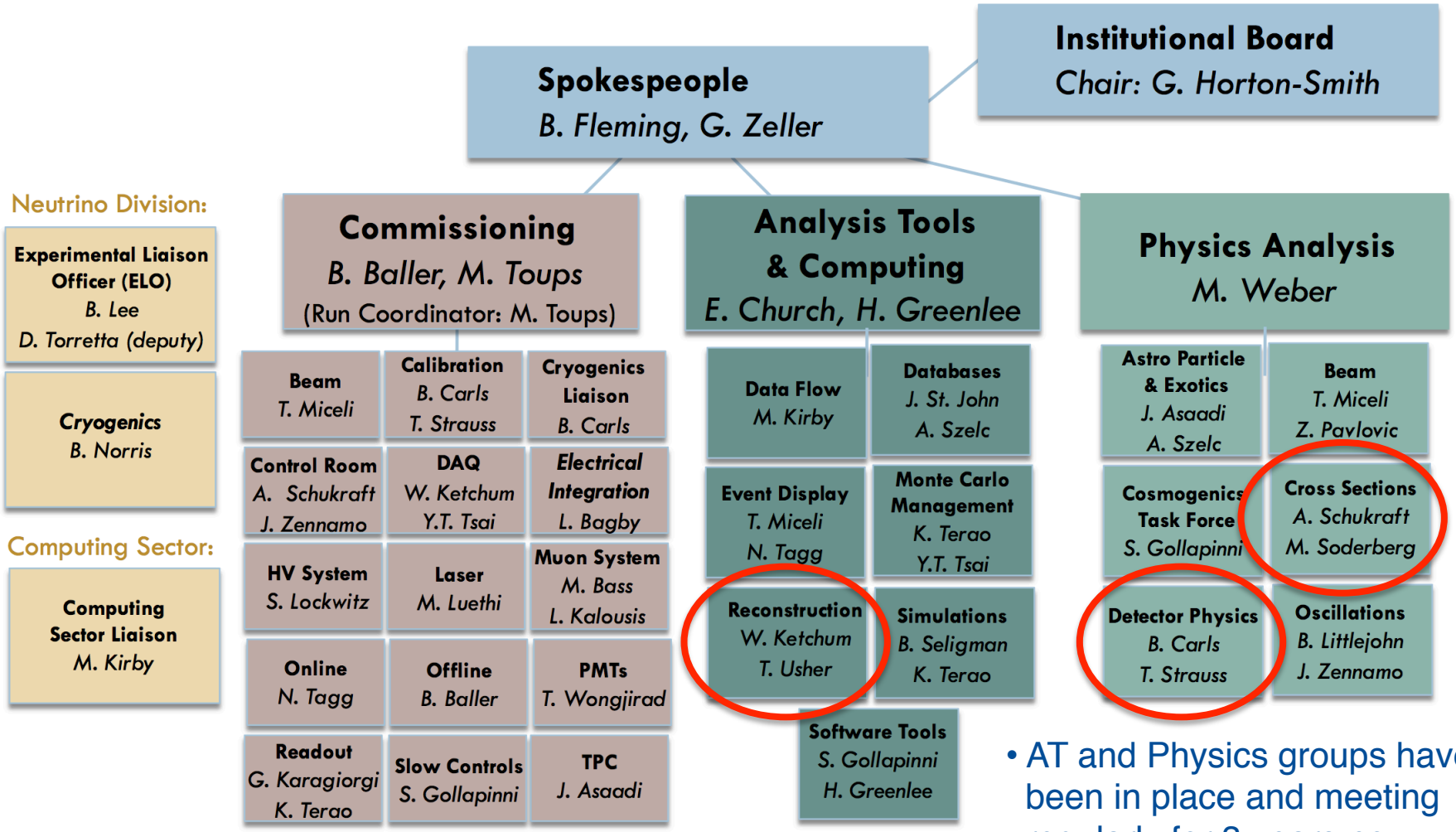
- **Data Flow** *M. Kirby*
- **Databases** *J. St. John, A. Szelc*
- **Event Display** *T. Miceli, N. Tagg*
- **Monte Carlo Management** *K. Terao, Y.T. Tsai*
- **Reconstruction** *W. Ketchum, T. Usher*
- **Simulations** *B. Seligman, K. Terao*
- **Software Tools** *S. Gollapinni, H. Greenlee*

Physics Analysis
M. Weber

- **Astro Particle & Exotics** *J. Asaadi, A. Szelc*
- **Beam** *T. Miceli, Z. Pavlovic*
- **Cosmogenics Task Force** *S. Gollapinni*
- **Cross Sections** *A. Schukraft, M. Soderberg*
- **Detector Physics** *B. Carls, T. Strauss*
- **Oscillations** *B. Littlejohn, J. Zennamo*

- "team approach": commissioners are responsible for providing an operating system + documentation
- AT and Physics groups have been in place and meeting regularly for 3 years now
- June 25: conveners retreat

MicroBooNE Team



- "team approach": commissioners are responsible for providing an operating system + documentation

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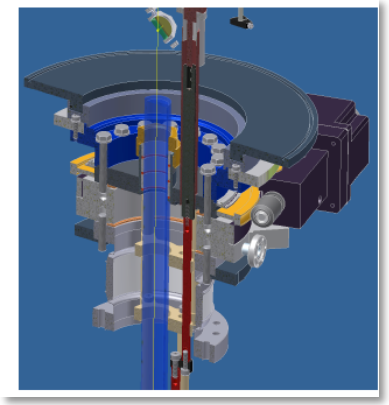
First Things First

- we will spend some time first understanding and calibrating our detector

  - *electronics calibration*
    (gain, noise, linearity, cross-talk)
  - *LAr purity, e^- lifetime*
    (purity monitor, thru-going muons)
  - *UV laser field maps*
  - *recombination*
  - *diffusion & space charge effects*
  - *energy scale*
  - *light collection & triggering*



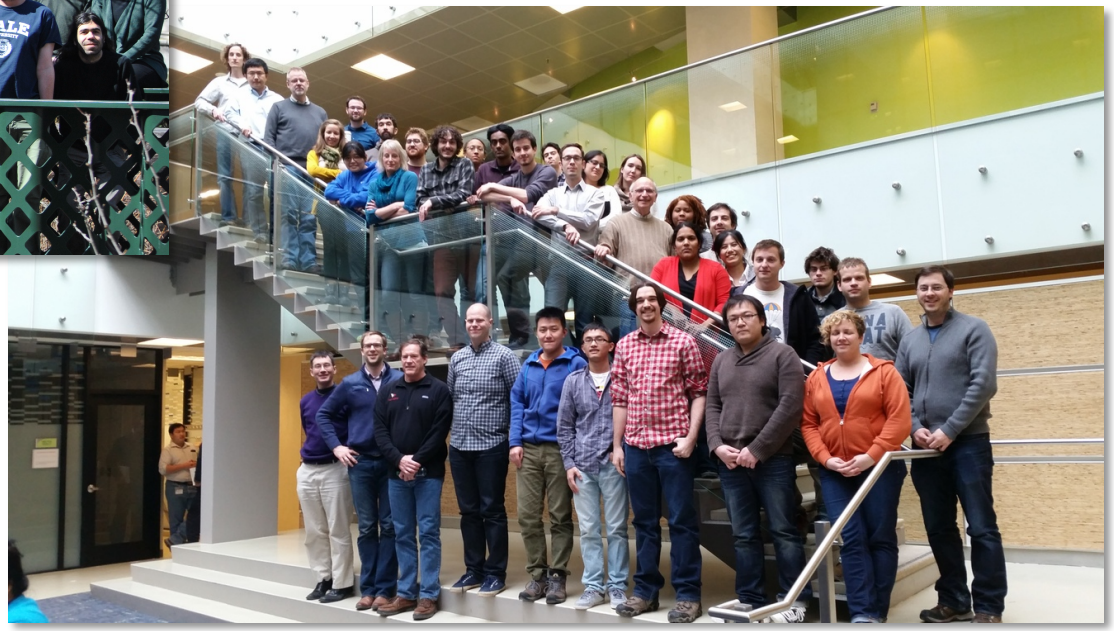
- this is where much of our focus is right now
- crucial ingredients to our neutrino physics measurements

Reconstruction Retreats

Yale, March 17-21, 2014

- MicroBooNE comprises ~70% of all contributors to LArSoft

IIT, January 5-9, 2015



- work closely with SCD to advance these tools and methods

Offline Readiness Review

- charge: the MicroBooNE spokespeople and SCD management ask the committee to review and evaluate the offline computing software and infrastructure readiness of the experiment for successfully carrying out planned commissioning and physics analysis tasks

Committee

- Adam Lyon
- Andrew Norman
- Burt Holzman
- Jim Amundson
- Jim Kowalkowski
- Jon Paley
- Marc Mengel
- Parag Mhashilkar
- Peter Shanahan
- Tom Junk
- Oliver Gutsche (chair)

Agenda (ReadyTalk: 9135693)

Day 1: February 23 - WH 1 East:

8:30 - 9:00: Executive Session
9:00 - 9:45: Experiment and Physics Overview - Herbert Greenlee (30+15) (Slides)
9:45 - 10:15: Online Systems and DAQ - Eric Church (25+5) (Slides)

10:15 - 10:30: Coffee Break

10:30 - 10:50: MC Workflows - Yuntse Tsai (15+5) (Slides)
10:50 - 11:10: Data Workflows - Mike Kirby (15+5) (Slides)
11:10 - 11:30: Data Handling - Herbert Greenlee (15+5) (Slides)
11:30 - 12:00:

12:00 - 13:00: Lunch - working lunch for committee
13:00 - 13:15: Executive Session

13:15 - 13:40: Databases - Jason St. John (20+5) (Slides)
13:40 - 14:05: Larsoft - Erica Snider (25+5) (Slides)
14:05 - 14:35: Reconstruction - Wes Ketchum (25+5) (Slides)
14:35 - 14:55: Event display - Tracy Usher (15+5) (Slides)
14:55 - 15:25: Simulation - Bill Seligman (25+5) (Slides)

15:25 - 15:35: Coffee Break

15:35 - 16:00: User report - Sowjanya Gollapinni (20+5) (Slides)
16:00 - 16:25: LarLite - Kazuhiro Terao (20+5) (Slides)
16:25 - 16:50: Porting LarLite -> Art - Andrzej Szelc (20+5) (Slides)

17:00 - 18:00: Executive Session
18:00: submit questions to MicroBooNE

Day 2: February 24 - Snake Pit WH2NE

8:30 - 9:00: Executive Session
9:00 - 9:20: Summary - Herb Greenlee/Eric Church (15+5) (Slides)
9:20 - 10:00: MicroBooNE presents Answers to Questions (Slides)

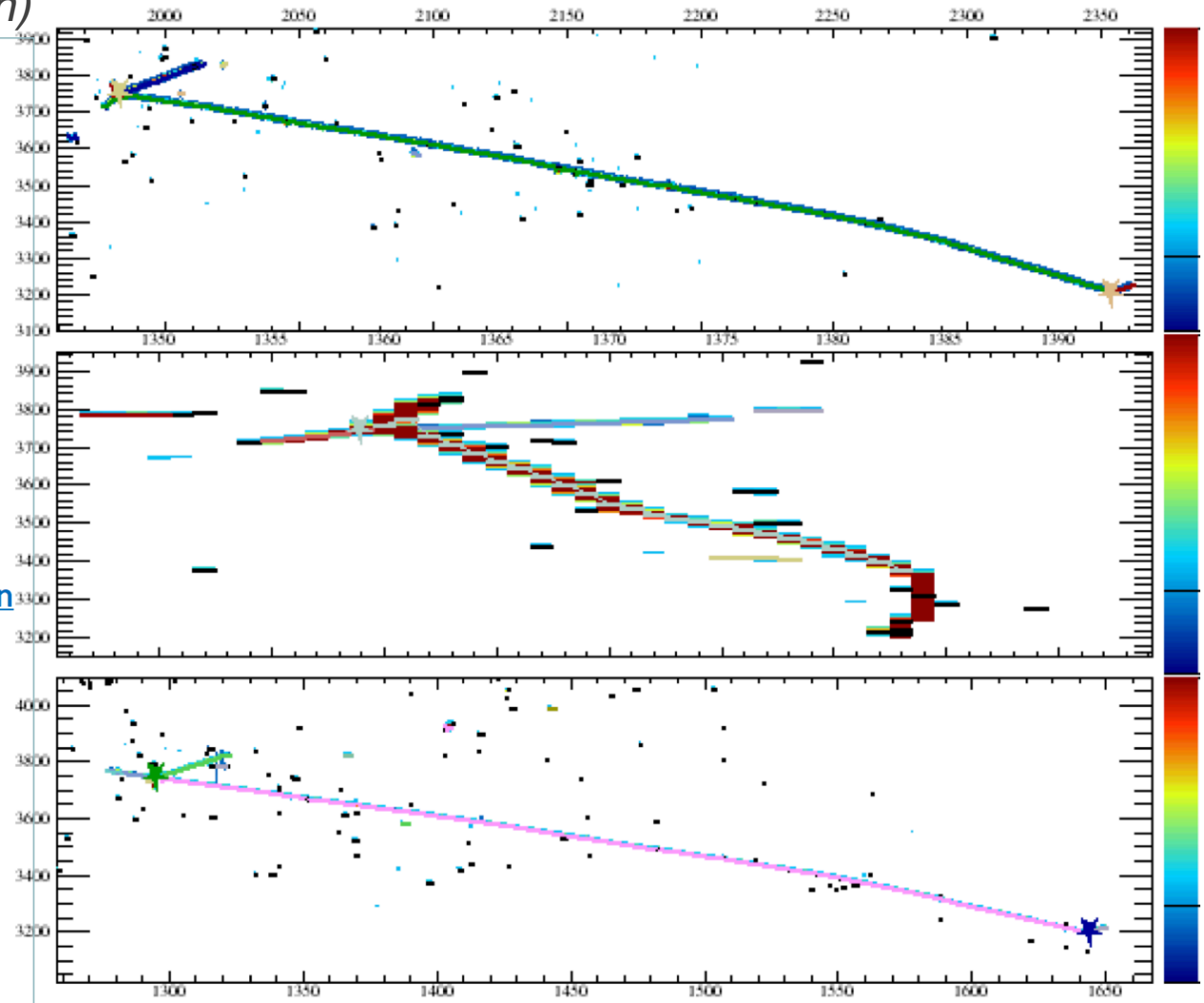
10:00 - 10:30: Coffee Break
10:30 - 11:30: Executive Session
11:30 - 12:30: Close-Out

- Feb 23-24, 2015
- 21 page report
- continuing to incorporate new SCD tools and working through RLS
- new support from SCD as a result

Reconstruction: 2D

(simulation)

Enu 1102 MeV
386 MeV muon
EP2 = 0.94
E = 0.95
P = 0.99
Plane 0
61 MeV proton
EP2 = 0.83
E = 0.83
P = 1.0
Plane 1
128 MeV proton
EP2 = 0.85
E = 0.85
P = 1.0
Plane 2
85 MeV proton
EP2 = 0.80
E = 1.0
P = 0.8

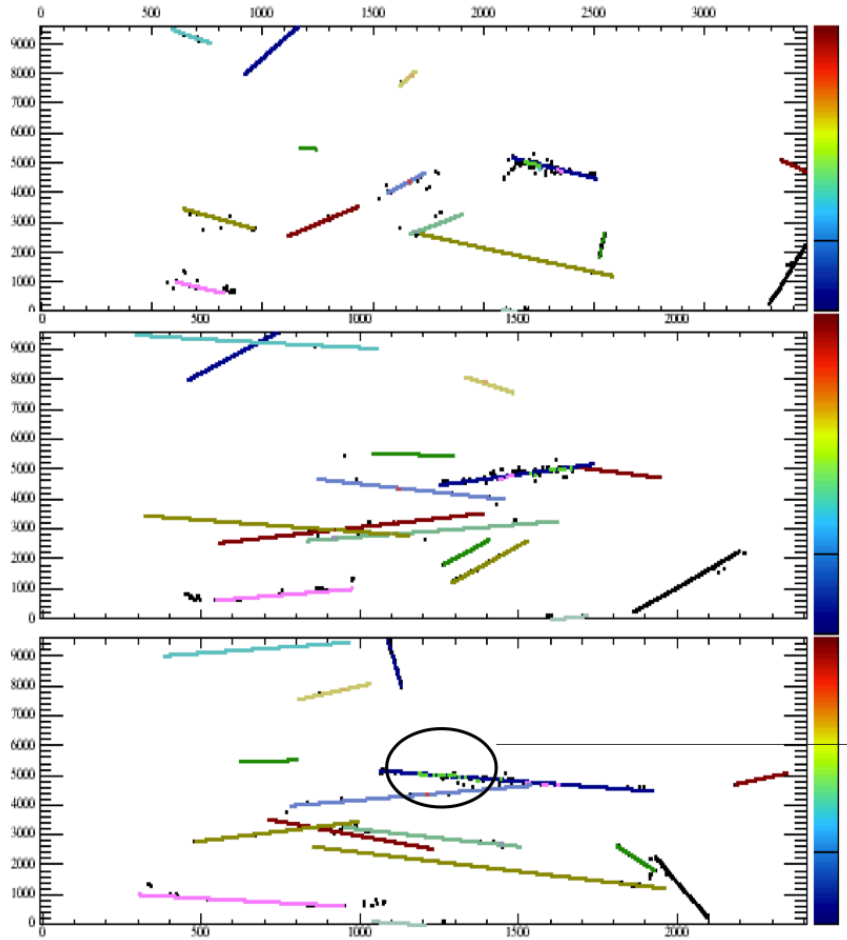


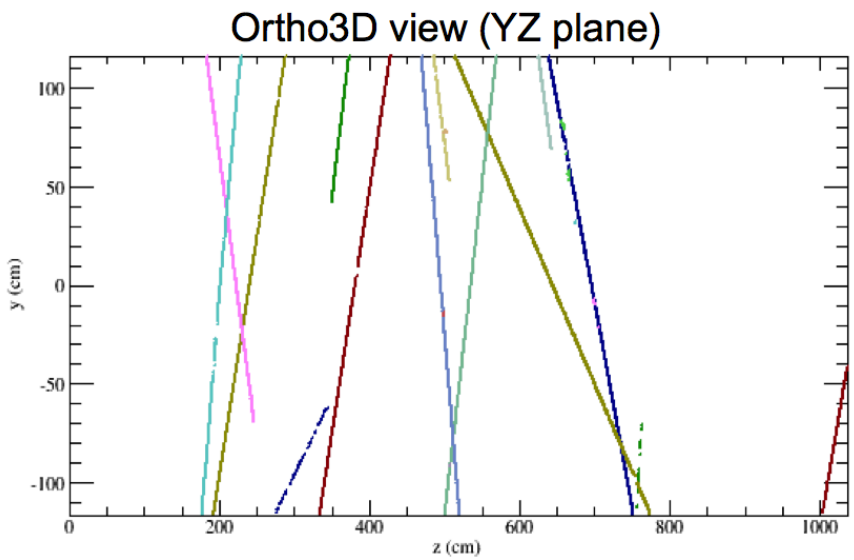
- will show what we're trying to accomplish thru some pictures
- straight tracks
- "cluster crawler"

(colors don't match in each of the views because the tracks have not yet been matched in 3D)

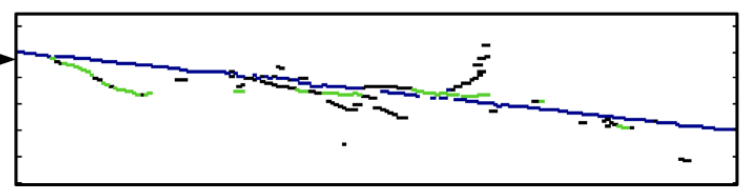
Reconstruction: 3D

- example of a particularly busy event …





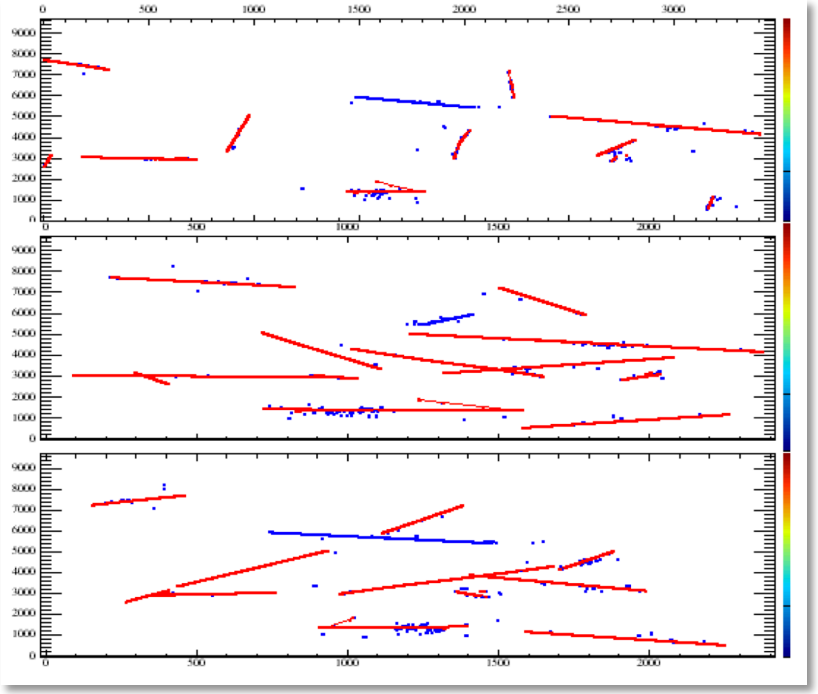
(simulation)



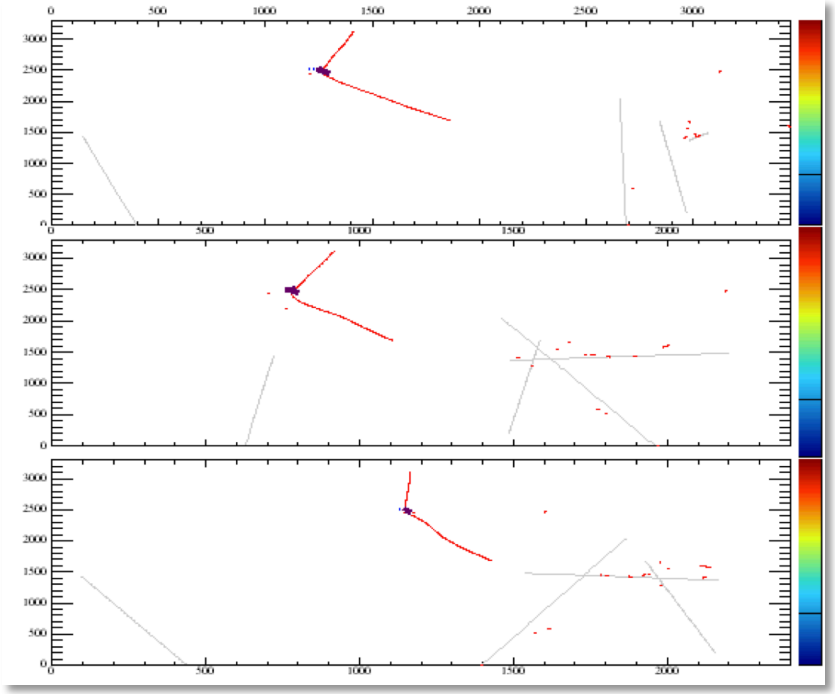
Deltas (green stuff) stitched together as one track

Cosmic Rays

TPC geometry



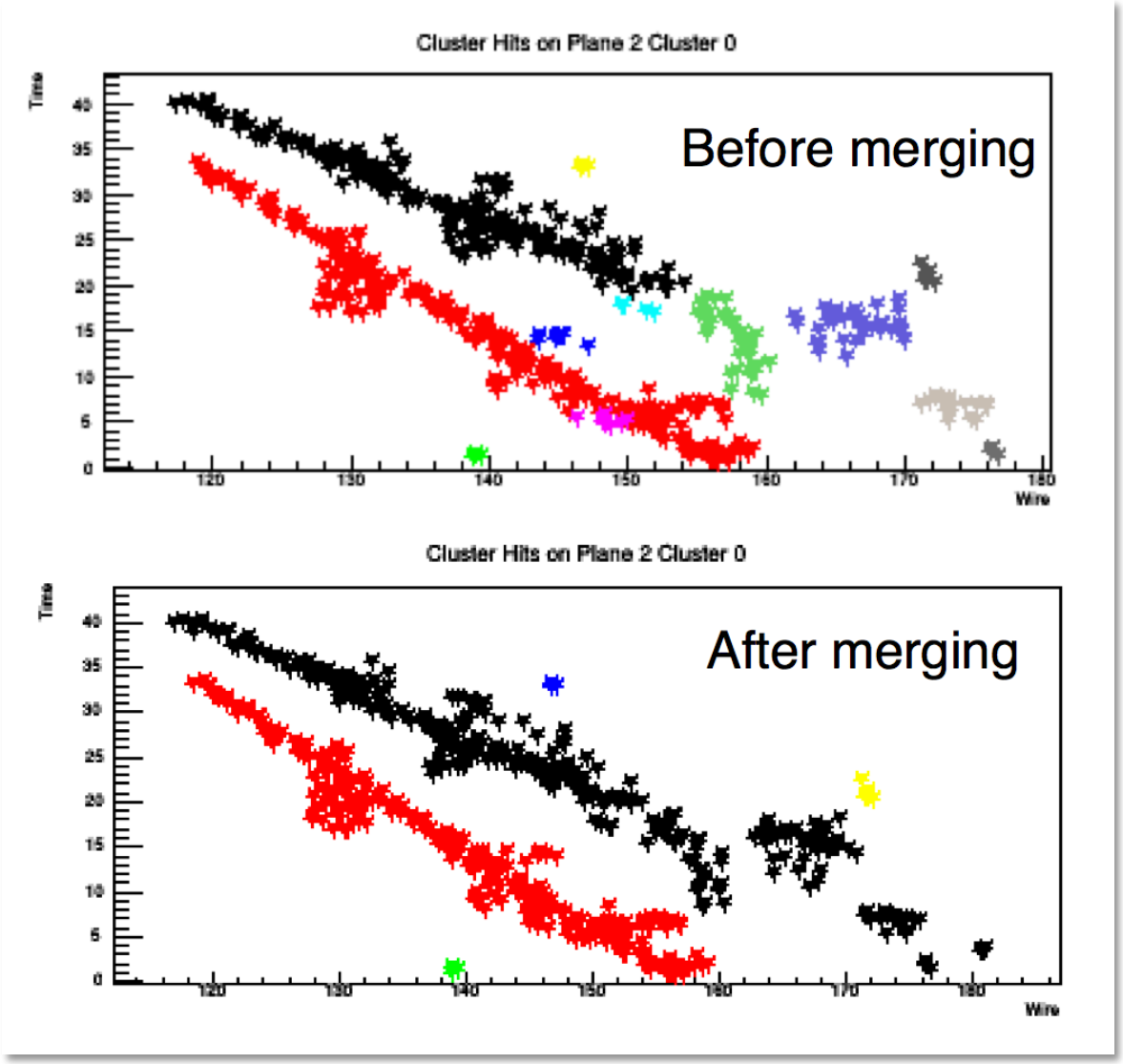
TPC info + PMT timing



(simulation)

- beam events are accompanied by cosmics (1.6μs beam spill, 1.6ms drift window)
- software in place to reconstruct and tag cosmics

Reconstruction: Electromagnetic Showers



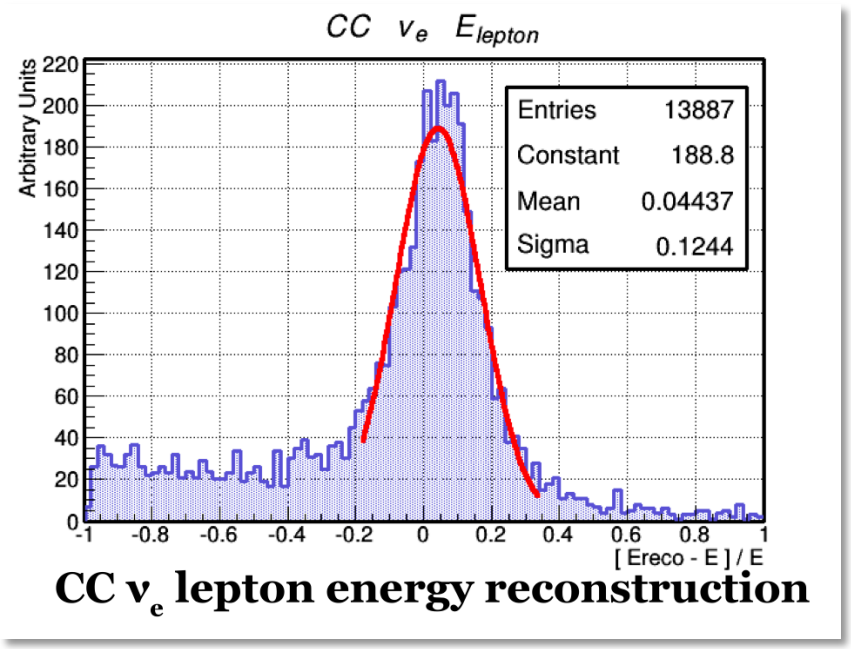
- it's one thing to reconstruct straight tracks

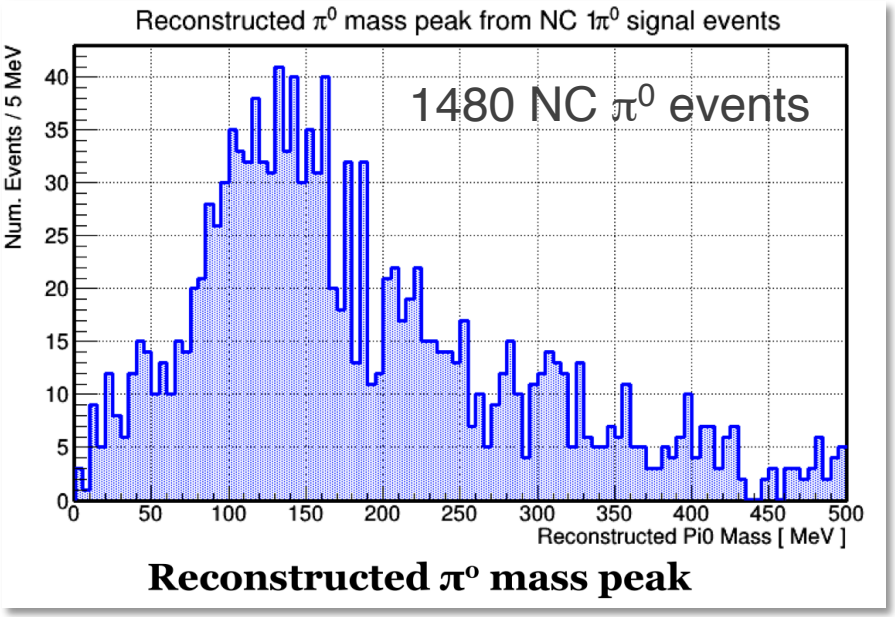
  → showers are more complex

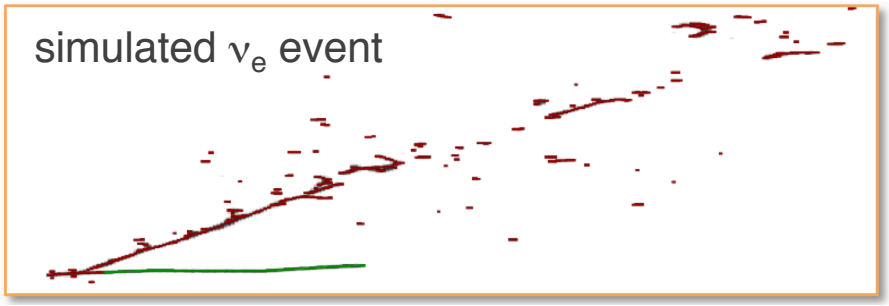
(simulation)

On the Path to First Physics

- we are exercising the complete path; examples from MCC6:



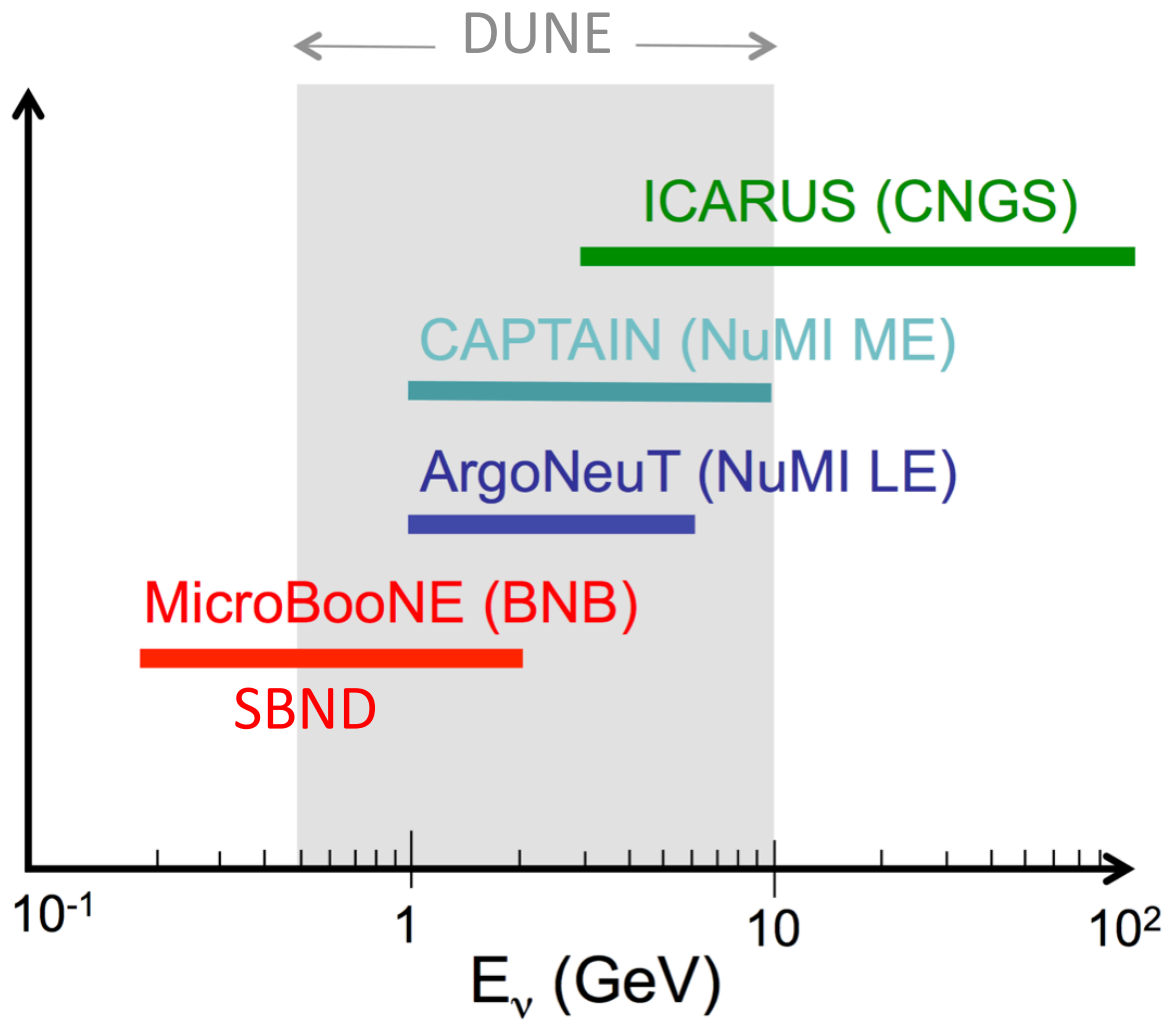




(simulation)

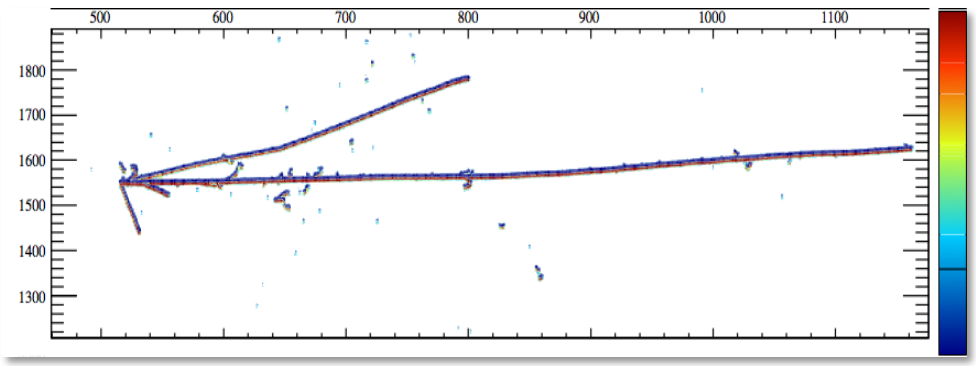
LAr-Based Neutrino Experiments

- μB (and SBND!) will extend our coverage to lower ν energies
- this is an important energy region where MiniBooNE (& others) have revealed the presence of completely neglected nuclear effects

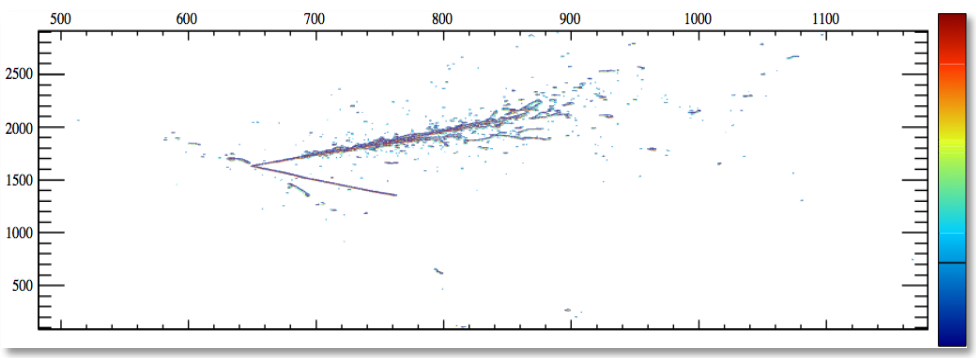


Neutrino Interactions

- MicroBooNE will build off of what we've already learned in MiniBooNE *(same beam)* & ArgoNeuT *(same technology)*



(simulated ν events in MicroBooNE)



- will make the 1st σ_ν measurements in argon at low energy (E_ν ~1 GeV)
- these analyses will benefit from well-known BNB flux

Aguilar-Arevalo et al., PRD 79, 072002 (2009)

- expect to collect ~1,500 ν_μ CC events/month from the BNB in the first year

(ArgoNeuT-sized sample in first few months)

Training the Next Generation of LAr Experts

- we are extremely fortunate to have a lot of students & postdocs who are actively participating in detector commissioning and getting us ready for first data with this new detector

M. Mooney (BNL),
J. Joshi (BNL),
Y. Li (BNL)

S. Gollapinni (KSU), D. Caratelli (Columbia),
D. Kaleko (Columbia)

M. Moulai (MIT),
Georgia Karagiorgi (Manchester),
Aleena Rafique (KSU)

Learning A Lot As We Go

- 12 papers produced during the construction of MicroBooNE

Related Publications by MicroBooNE Collaborators:

- 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.*, "Evironmental 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)

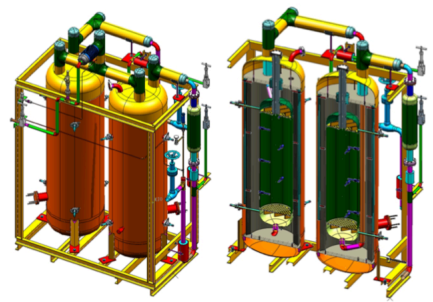


Figure 32. Three-dimensional renderings of a MicroBooNE filter skid. The left drawing shows the full skid, while the right drawing shows a cut-away of the vessels.

system are sealed using spiral-wound graphite gaskets. Smaller connections are made with VCR fittings with stainless steel gaskets.

11.2 Nitrogen Refrigeration

11.3 Controls and Purity Monitoring

Argon contaminations ranging between 300 and 50 ppt oxygen equivalent can be measured using double-gridded ion chambers, henceforth referred to as purity monitors, immersed in liquid argon. The design of the purity monitors was based on the design presented in Ref. [75].

Reference [?] gives a thorough description of the purity monitors, the data acquisition hardware, and the data acquisition software used in LAPD. MicroBooNE uses the same type of purity monitors, and the same data acquisition hardware and software.

A measure of the electronegative impurities can be made by examining the fraction of electrons generated at the cathode that subsequently arrive at the anode (Q_A/Q_C) after a drift time t. The ratio of (Q_A/Q_C) can also be interpreted as an electron lifetime, τ, such that

$$Q_A/Q_C = e{-}t/\tau. \quad (11.1)$$

The MicroBooNE cryogenics and purification system uses three purity monitors of varying lengths. One purity monitor with a drift distance of 50 cm sits in a vessel just downstream of the filters and is used to monitor filter effectiveness. Two purity monitors, one with a drift distance of

– 45 –

(MicroBooNE detector paper is currently in preparation)

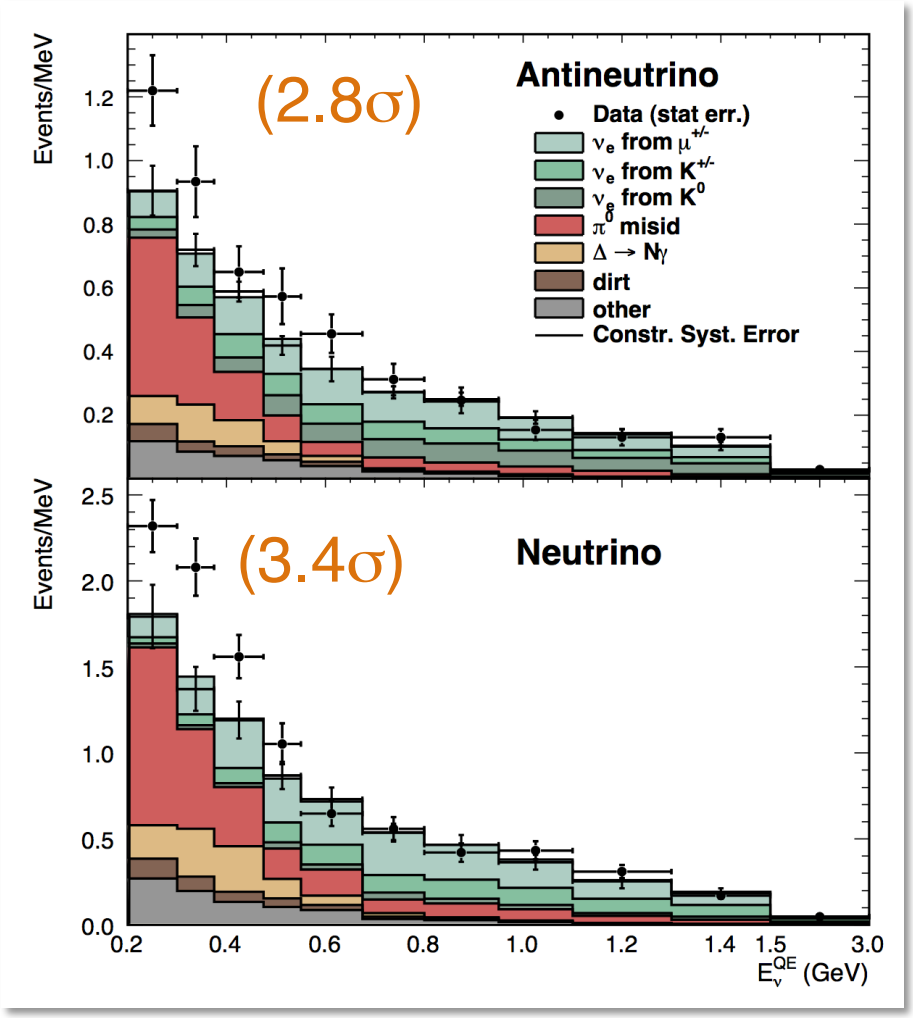
Summary

- detector construction/installation is now complete and we are commissioning: LAr fill in progress, detector turn-on in late July
- we will spend this summer commissioning with cosmics and look forward to our first neutrinos in October ($2x10^{20}$ POT/year)
- well-established analysis groups
- reconstruction is in good shape (but need to validate with data)
- 24/7 shifts have started
- our team of 55 graduate students and postdocs is eager and ready for first data!

-- we have the tools and the team in place --

Backups

MiniBooNE



Aguilar-Arevalo, PRL 110, 161801 (2013)

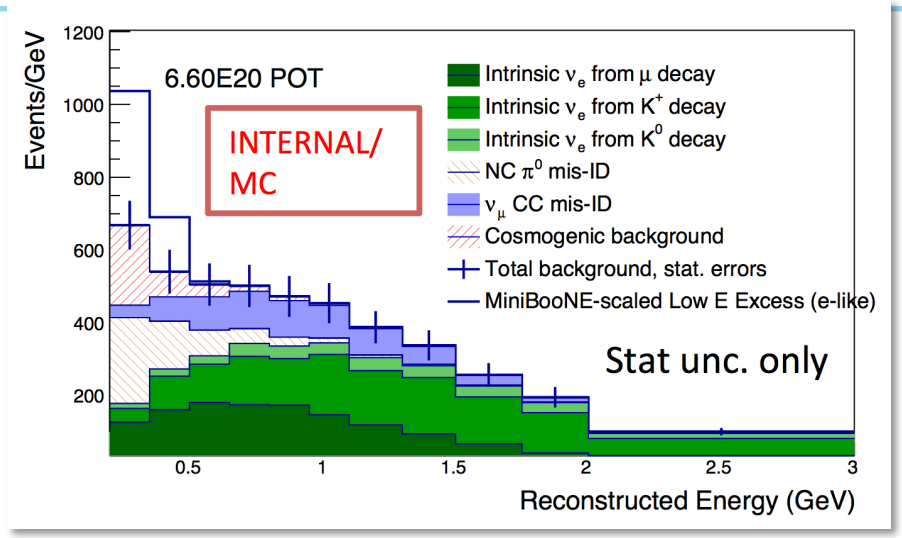
- published its final $\nu_\mu \rightarrow \nu_e$ oscillation results in 2013
  - *6.46E20 POT in ν mode*
  - *11.3E20 POT in anti-ν mode*
- observed an excess of low energy events in both modes
- source of excess is still unknown

→ MicroBooNE!

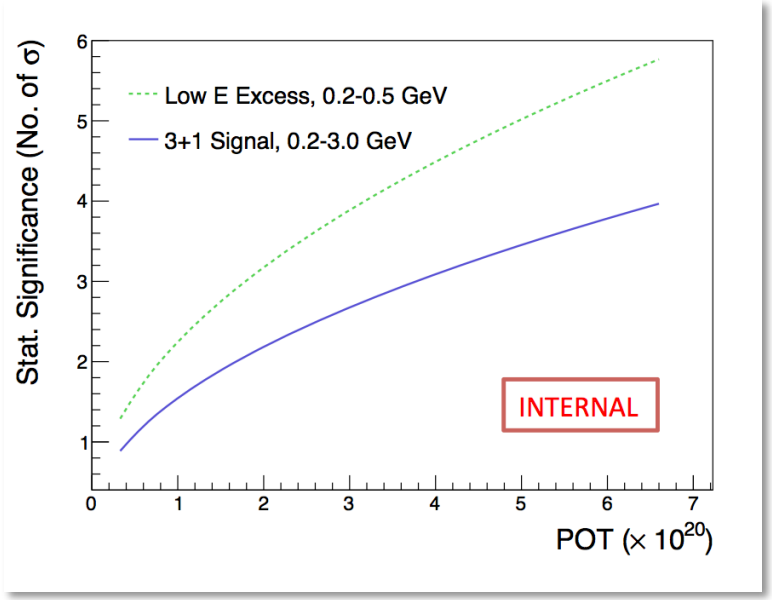
(T. Miceli)

Low Energy Excess in MicroBooNE

- need data to validate NC π^0 and cosmogenic background estimates



- significance of:
  - low energy excess 0.2-0.5 GeV
  - 3+1 signal (Δm^2=0.43, $\sin^2 2\theta$=0.013) 0.2-3.0 GeV



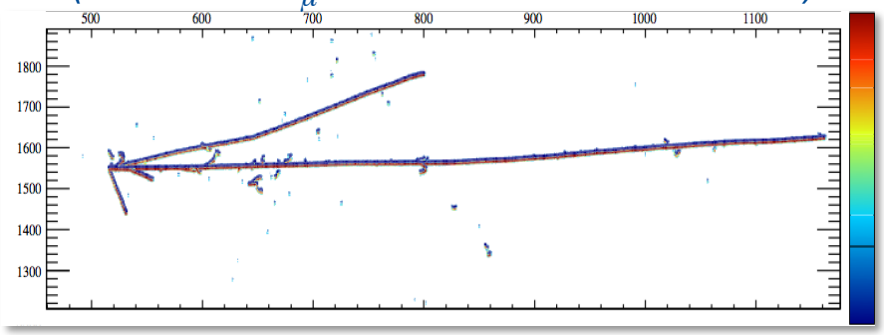
Neutrino Interactions in Argon

- neutrino interaction measurements in argon are a direct input to the future long-baseline neutrino program (DUNE)

- BNB: 2nd oscillation maximum

MicroBooNE → SBND

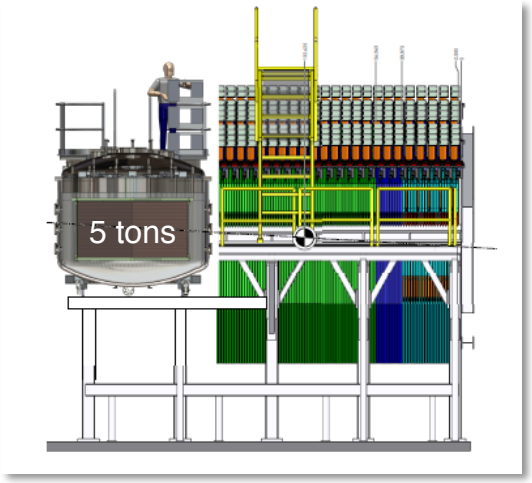
(simulated ν_μ CC event in MicroBooNE)



- MicroBooNE: ~100k ν_μ CC events
- SBND: ~3M ν_μ CC events (6.6E20 POT)

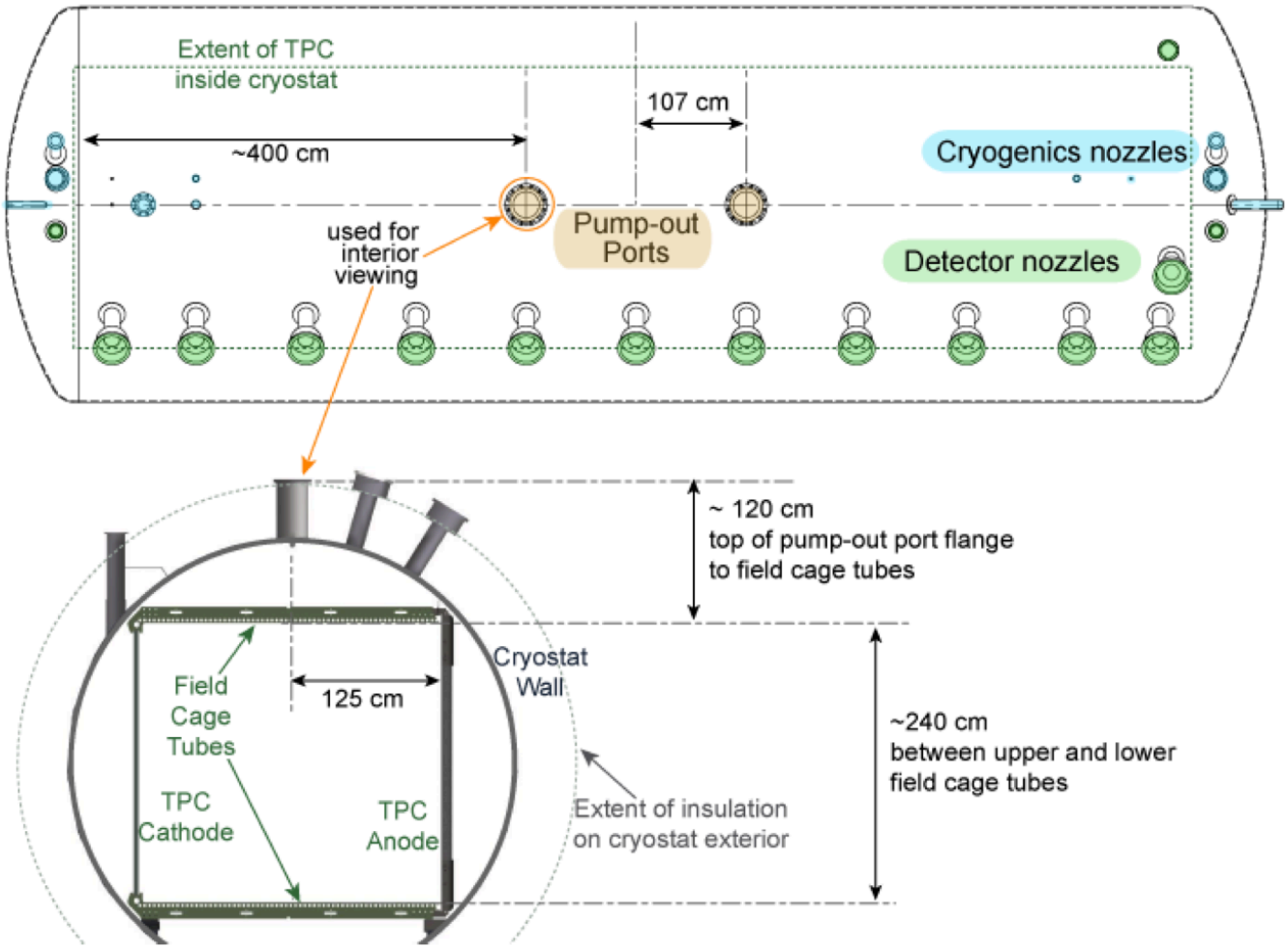
- NuMI: 1st oscillation maximum

ArgoNeuT → MINERvA-CAPTAIN

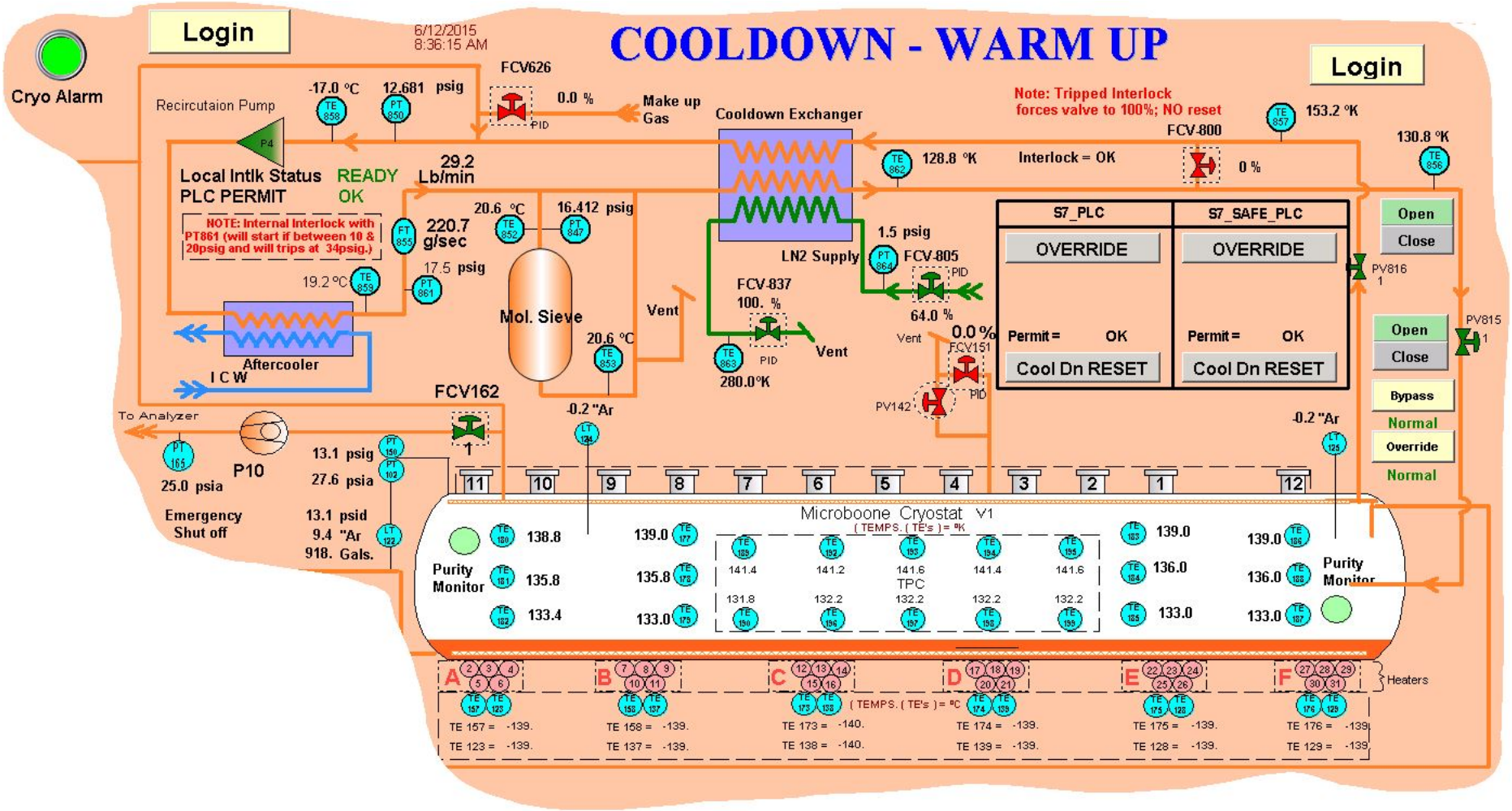


- ArgoNeuT: ~2k ν_μ CC events
- CAPTAIN: >500k ν_μ CC events (6E20 POT)

Aerial View

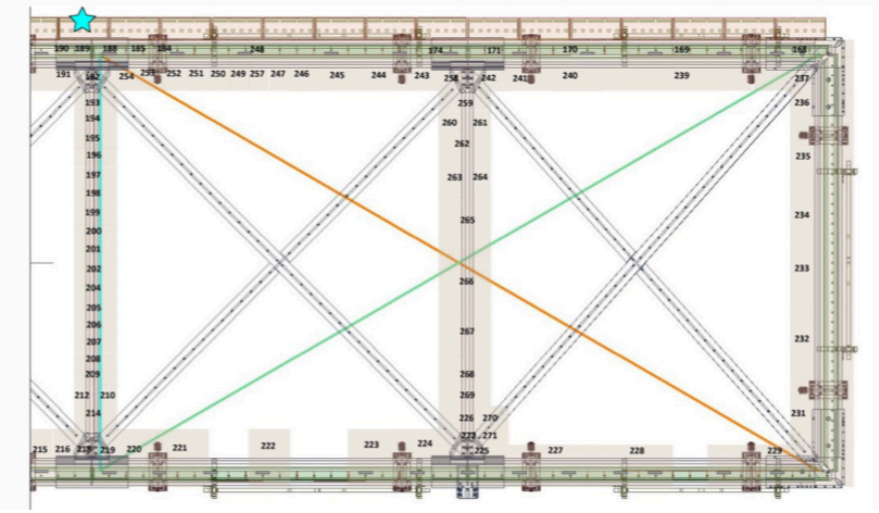

Extent of TPC
inside cryostat
~400 cm
107 cm
Cryogenics nozzles
used for
interior
viewing
Pump-out
Ports
Detector nozzles
~ 120 cm
top of pump-out port flange
to field cage tubes
Cryostat
Wall
Field
Cage
Tubes
125 cm
TPC
Cathode
TPC
Anode
Extent of insulation
on cryostat exterior
~240 cm
between upper and lower
field cage tubes

MicroBooNE Cryogenics System



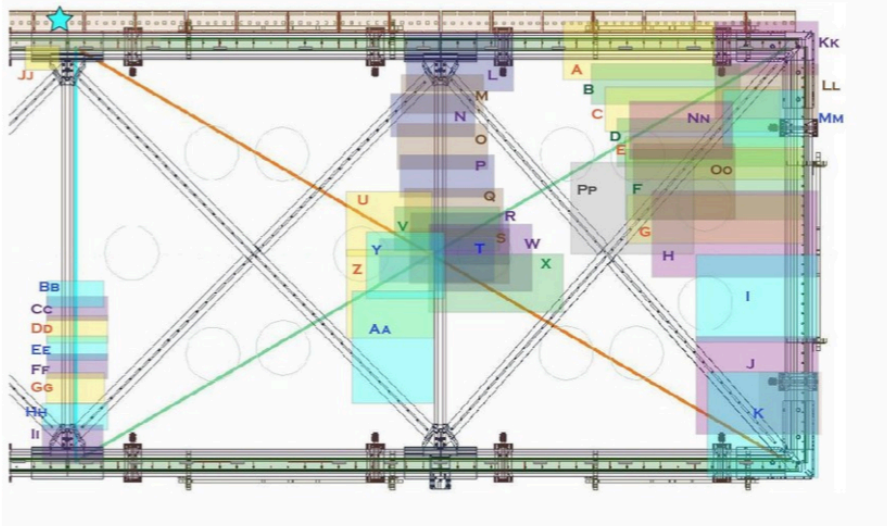
Detector Health Check

- we used a camera, mirror, and light system to view inside the vessel in the region near the noisy channels



1st Survey

http://www-microboone.fnal.gov/public/TPC_Wires/index.html

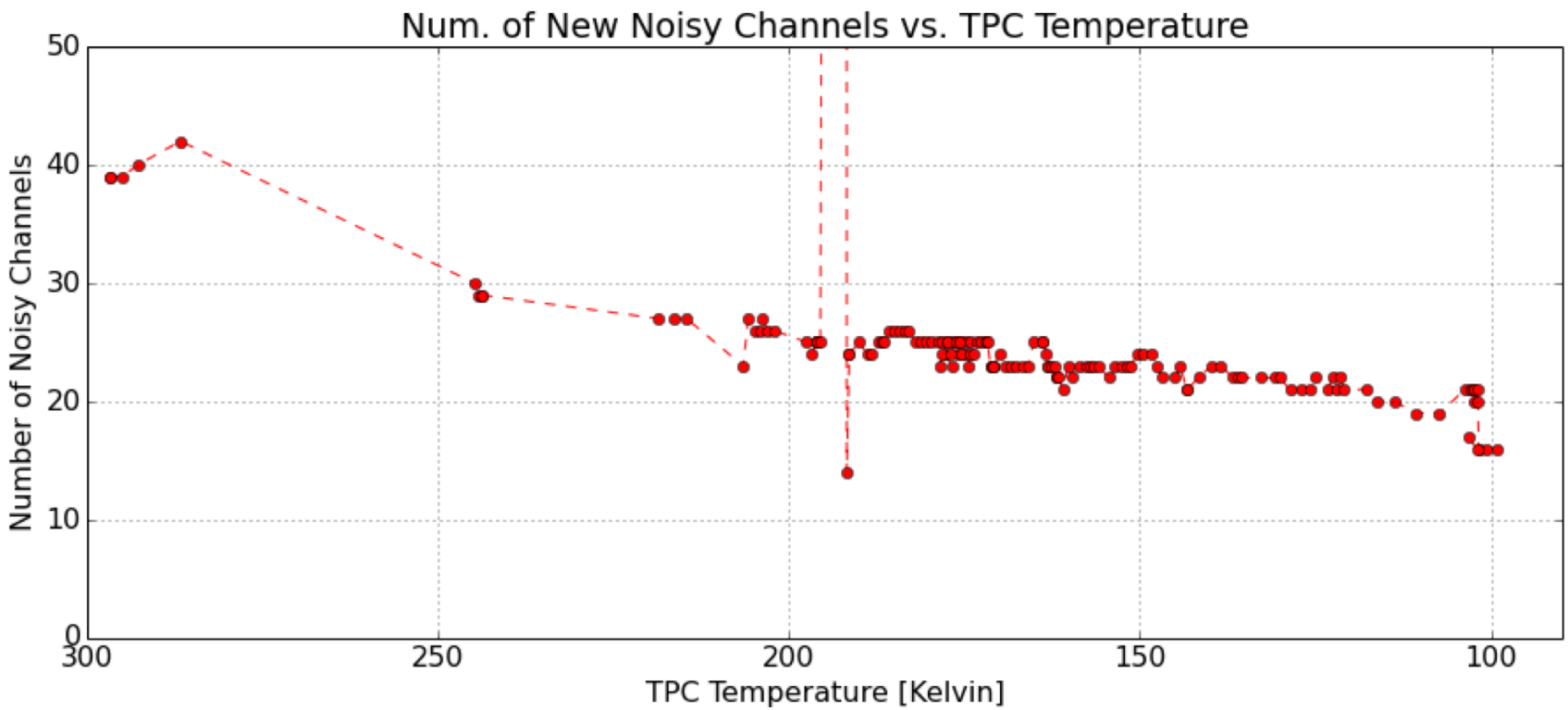


2nd Survey

http://www-microboone.fnal.gov/public/TPC_Wires/second_survey.html

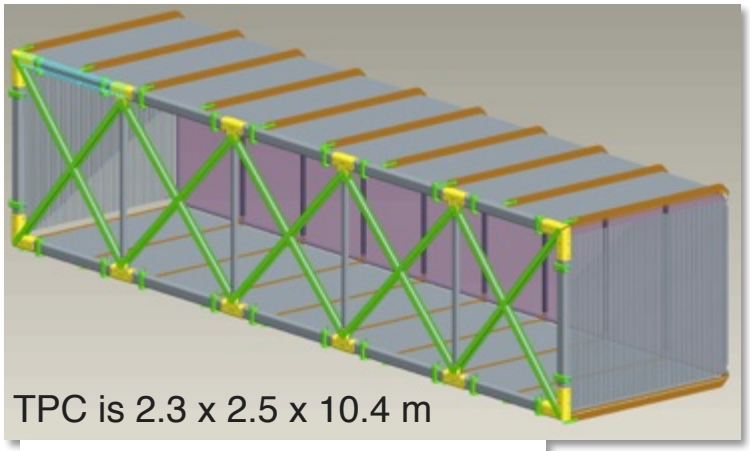
- teams systematically scanned photos

Channels With Above Average Noise

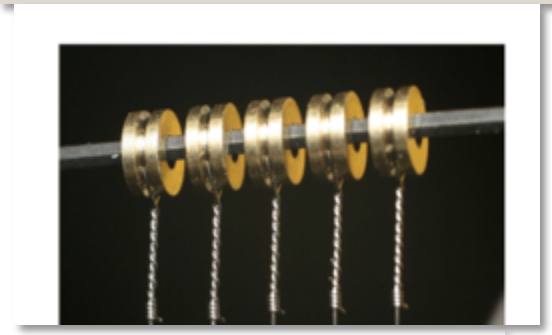


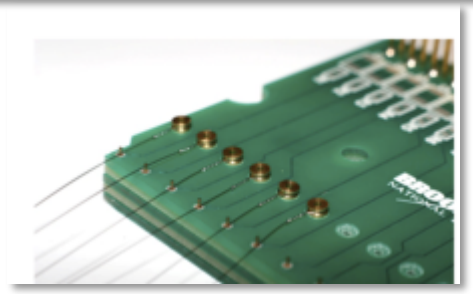
Readout Wires

- TPC drifts and reads out ionization electrons



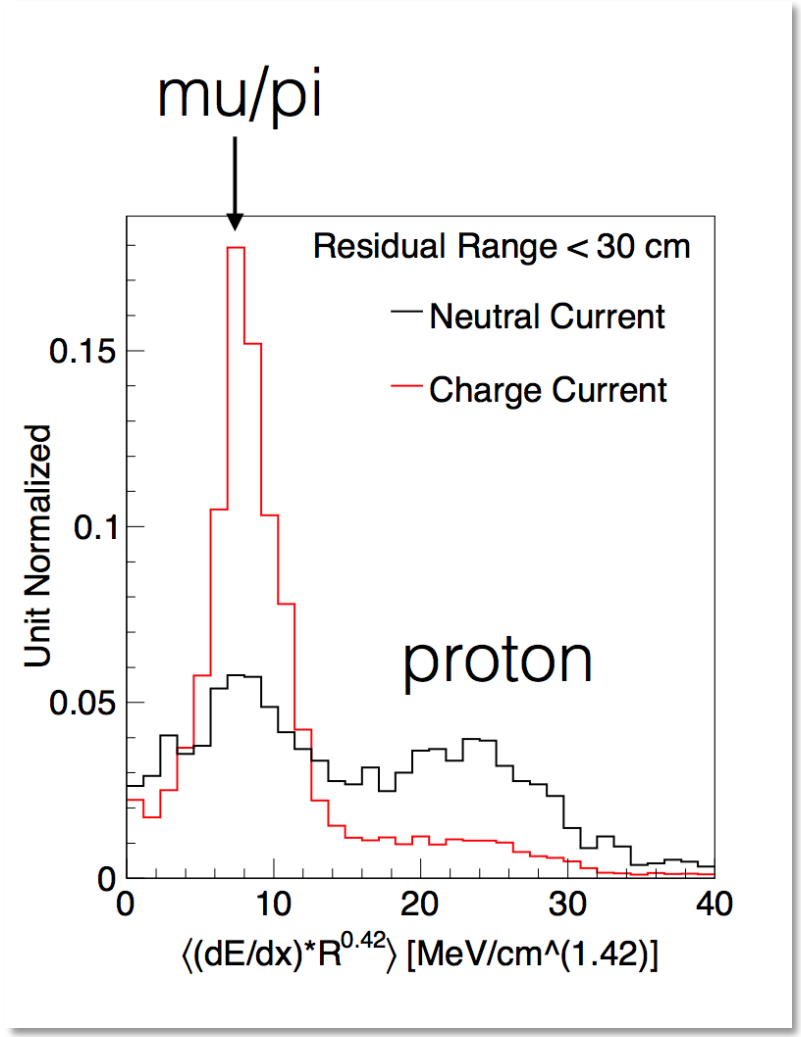
- three wire planes (U,V,Y)
  - 3mm wire spacing
  - wires are 150 micron, stainless steel coated with copper and a gold flash
  - wires under 0.7 kg tension
  - total of 8,256 wires



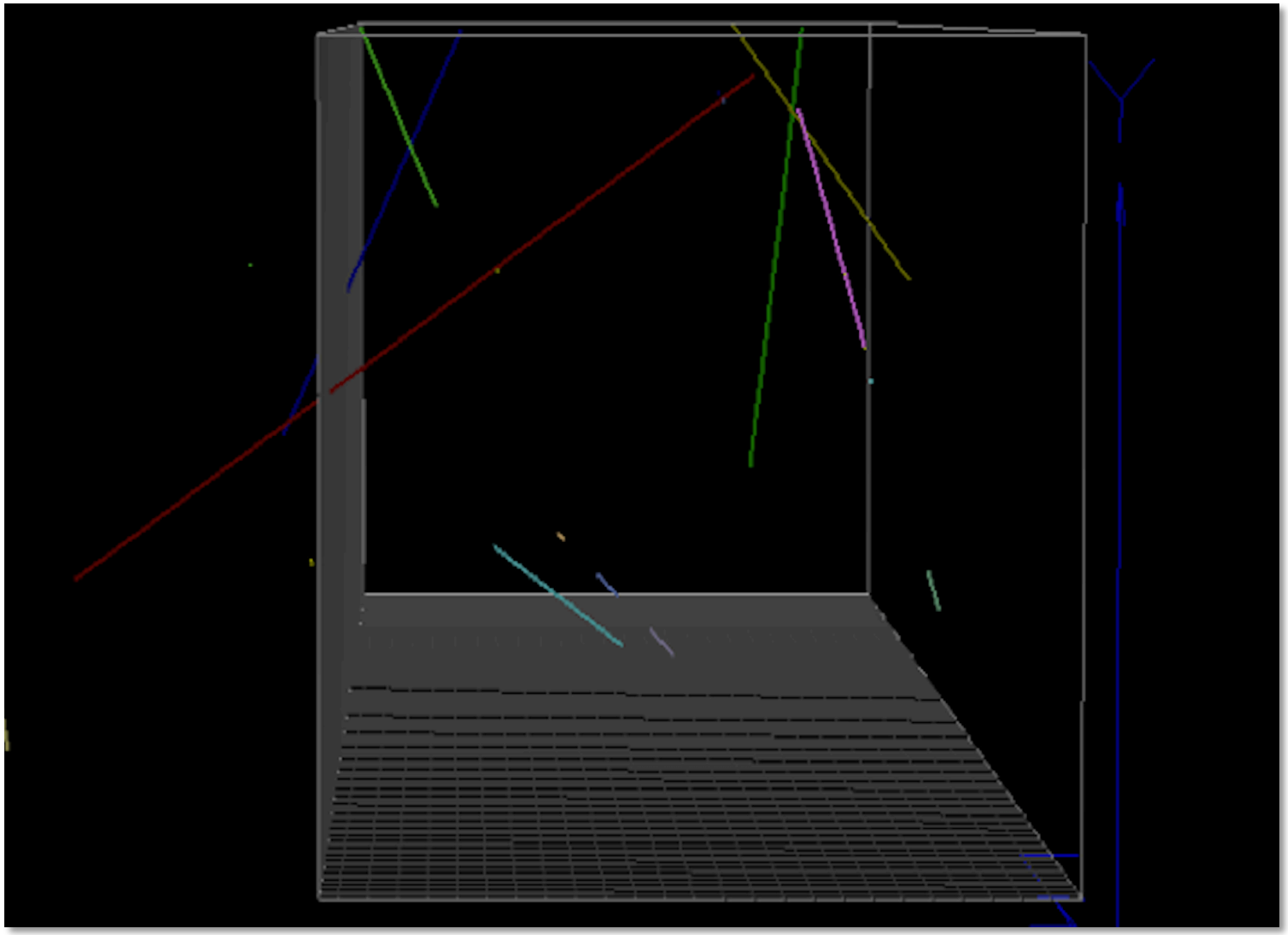


Calorimetry and Particle ID

- using dE/dx vs. residual range to do particle ID
- fit dE/dx to different particle hypotheses



3D Tracking



CC 0π

	CC 0 pion
1.5×10^{19} POT	2550
1×10^{20} POT	16997
2×10^{20} POT	33994
6.6×10^{20} POT	112180

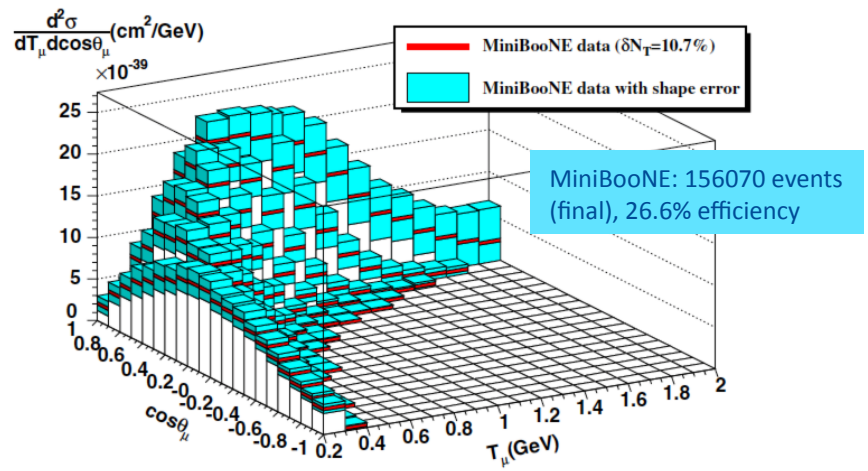
(87 tons, 100% efficiency)

Why is this interesting?

- Hope to gain a clearer understanding of nuclear effects in neutrino scattering
- Comparisons to MiniBooNE data show significant deficiencies in present generators

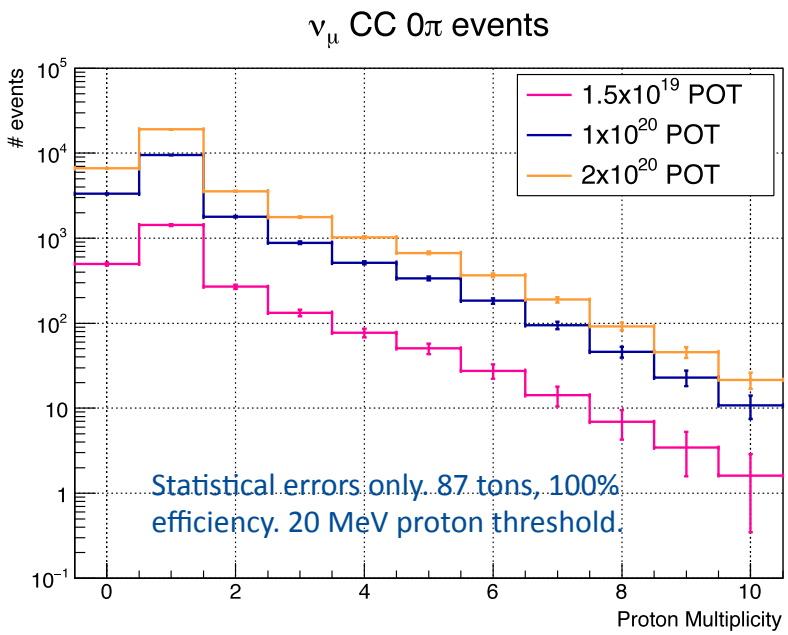
ArgoNeuT is measuring CC 0π cross sections single differential and proton multiplicity with ~ 900 events

ultimate goal: double differential cross sections ala MiniBooNE



MiniBooNE: 156070 events (final), 26.6% efficiency

Phys. Rev. D81 092005 (2010)



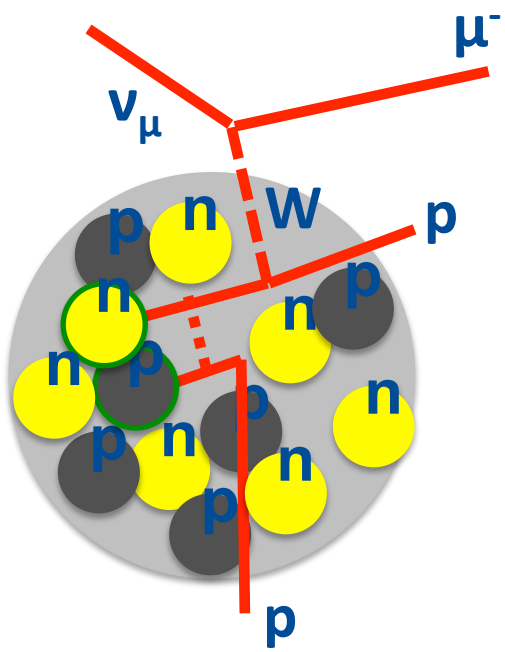
proton multiplicity

This is a very important study in order to understand nuclear effects. LArTPCs are the perfect detector for these studies, MiniBooNE could not measure this.

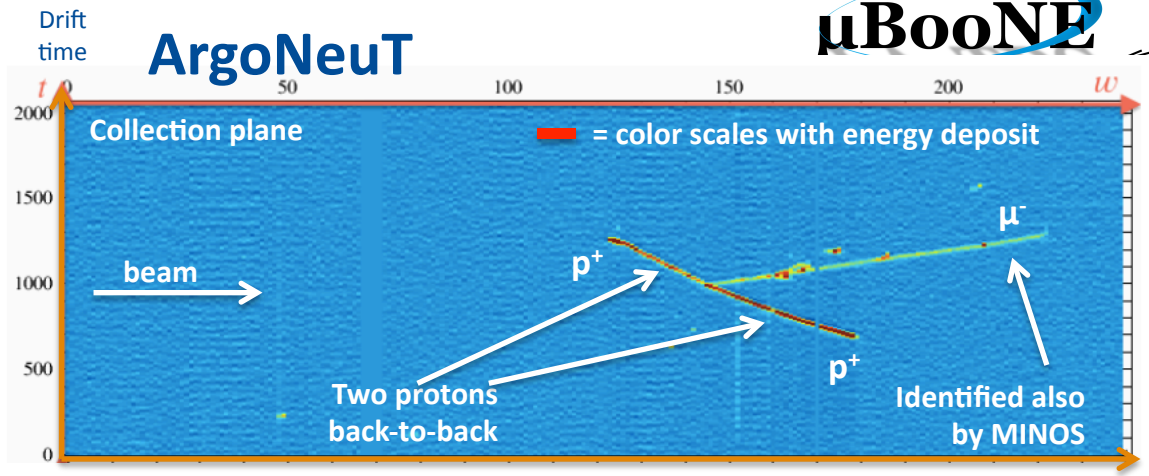
1μ + 2p

Why is this interesting?

- golden channel to study nucleon-nucleon correlations and FSI



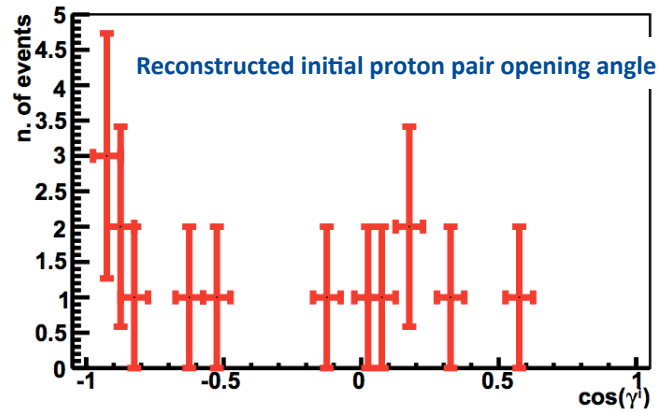
ArgoNeuT



Phys. Rev. D90, 012008 (2014)

ArgoNeuT had 30 ($1\mu^- + 2p$ events total), 5 with back-to-back protons. Not enough statistics to study models.

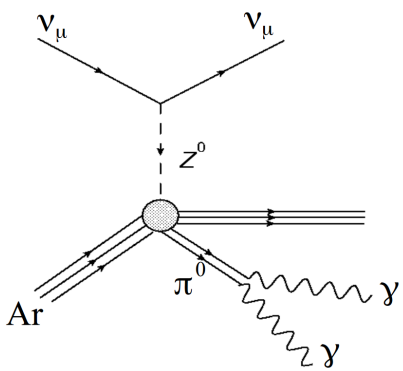
	$1\mu^- + 2p$
1.5×10^{19} POT	269
5×10^{19} POT	896
1×10^{20} POT	1791
2×10^{20} POT	3582
6.6×10^{20} POT	11820

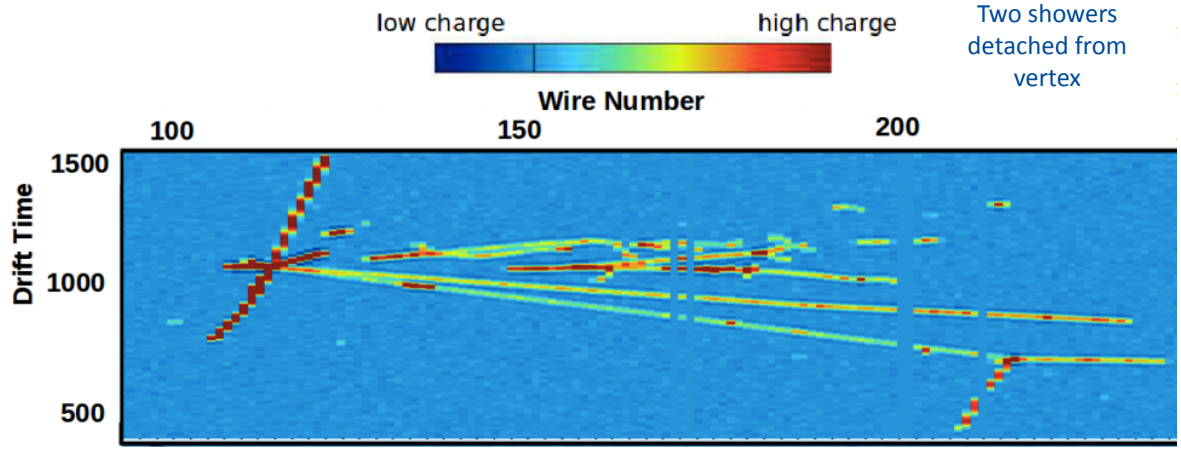


MicroBooNE will provide a more rigorous test of theoretical models

(87 tons, 100% efficiency)

NC π^0





Two showers detached from vertex

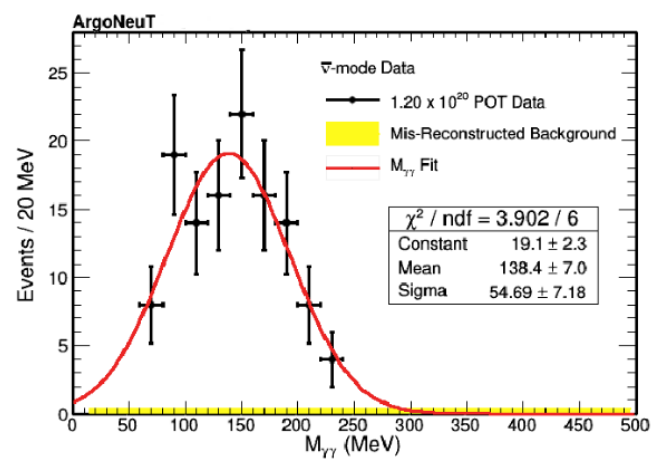
ArgoNeuT NC single π^0 candidate event

Why is this interesting?

- This is an important background for ν_e appearance searches if one of the photon-induced showers is not reconstructed
- The π^0 mass peak is a calibration signal
- Very different pion absorption in argon compared to carbon targets – first chance to measure these effects!

	NC single π^0
1.5×10^{19} POT	266
5×10^{19} POT	886
1×10^{20} POT	1771
2×10^{20} POT	3542
6.6×10^{20} POT	11688

requirement that the showers be fully contained will further reduce these projected statistics



ex. ArgoNeuT had 123 NC single π^0 candidate events for this measurement