MicroBooNE Status
Fermilab PAC

Bonnie Fleming for the MicroBooNE Collaboration

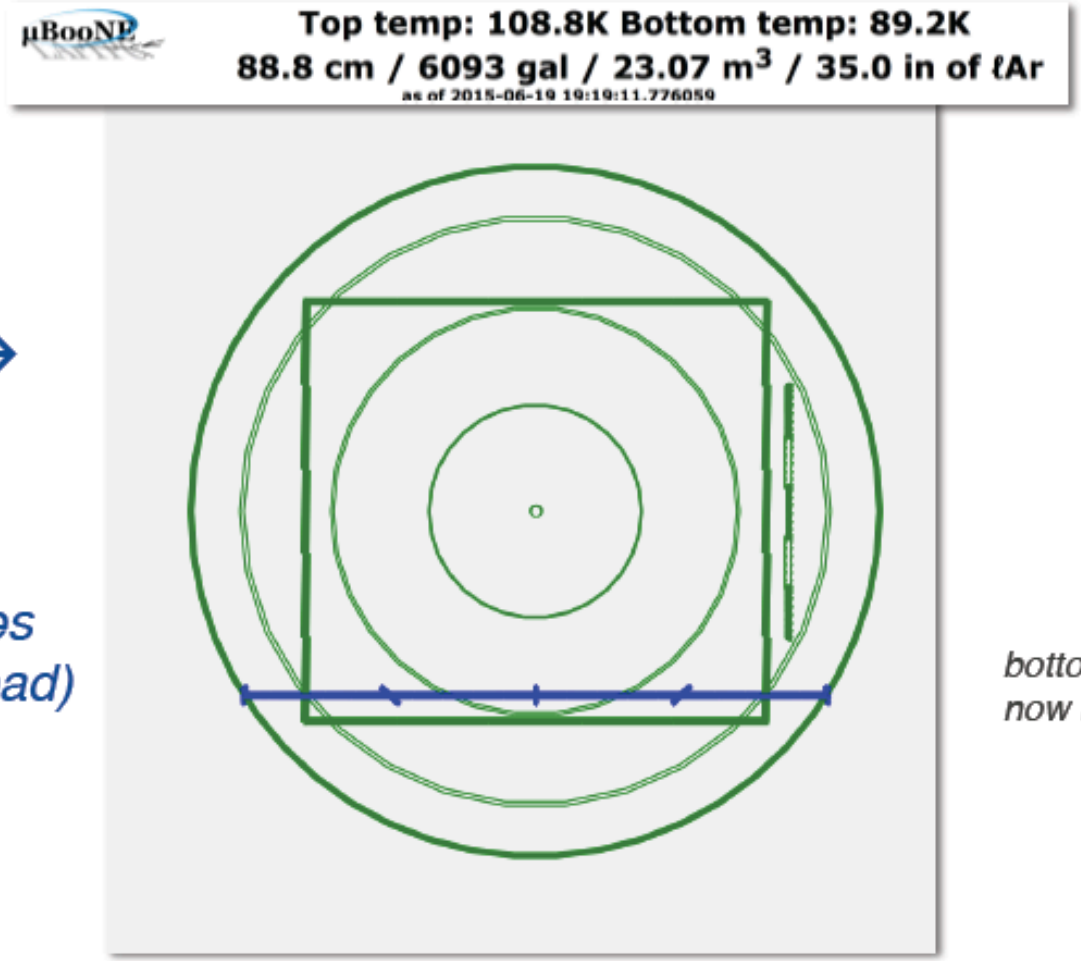
Outline

- Where we were at the last PAC
- LAr Fill and Commissioning
- First cosmics and first laser events
- Start of beam
- First neutrinos
- Operations
- Physics Tools development
- Physics Analysis status and plans
- Recent ORR review and outcome
- Collaboration organization in Operations

Where we were at the last PAC meeting…..

- after the first 2 truckloads →

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



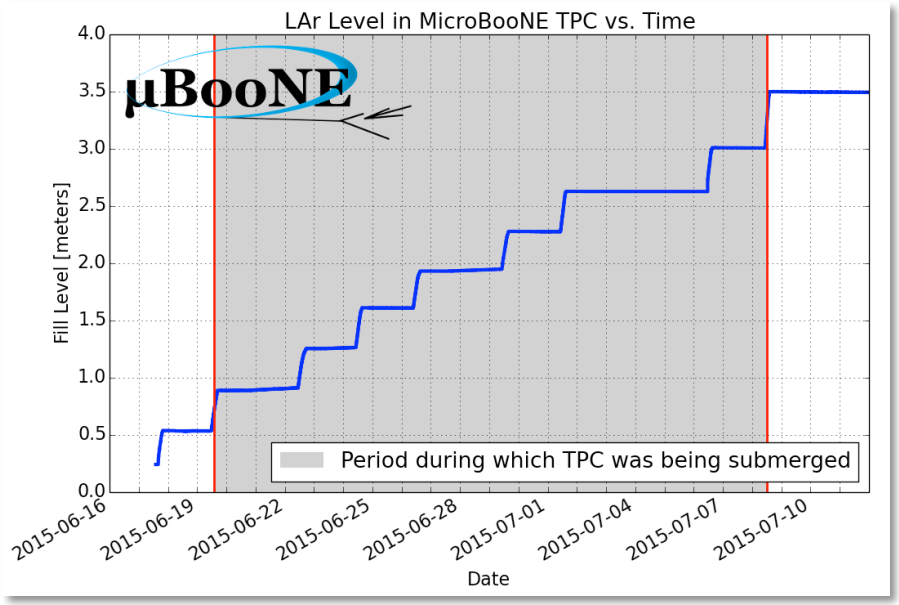
bottom of the TPC is now immersed in liquid

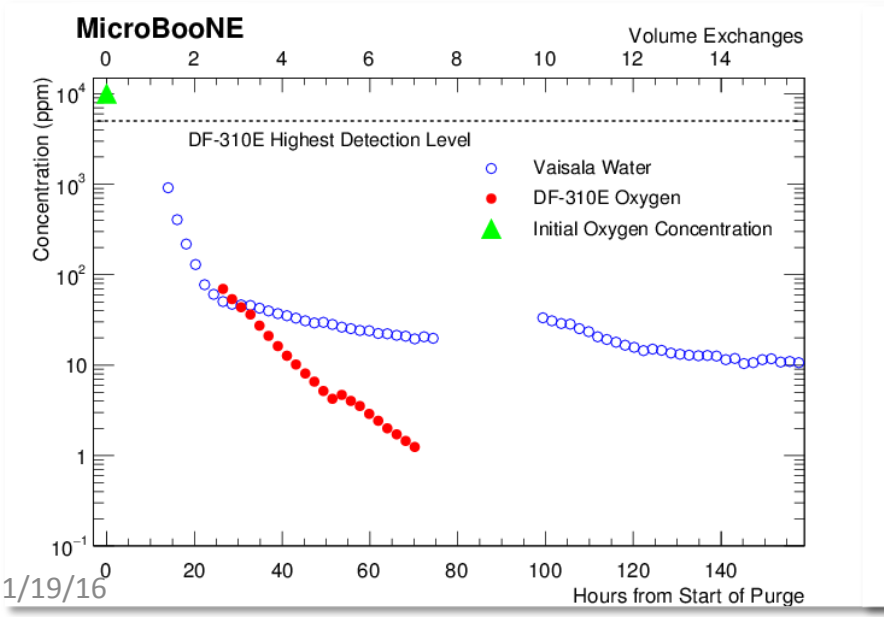
http://argo-microboone.fnal.gov/FillLevel/

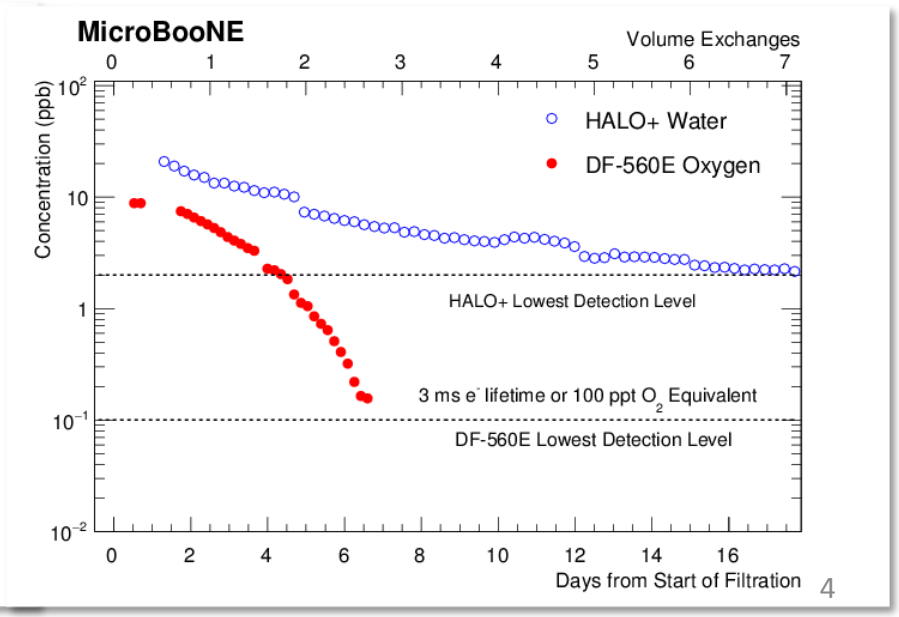
Very successful LAr fill and purification

(purity critical for electron drift)

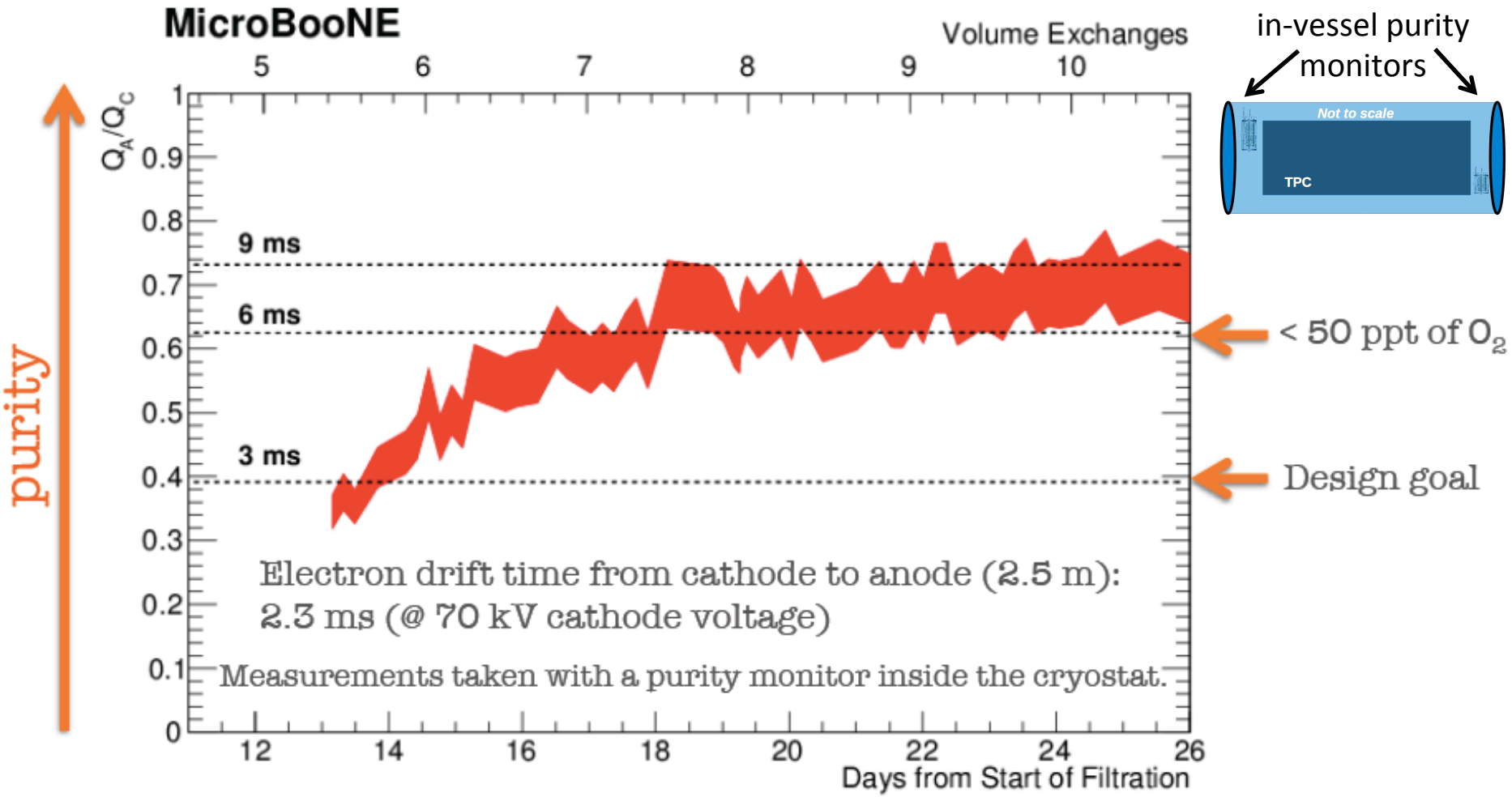
- Argon delivery: O_2 (N_2) contamination x10 (x300) better than spec
- After purification, electronegative contaminants x2-3 lower than design







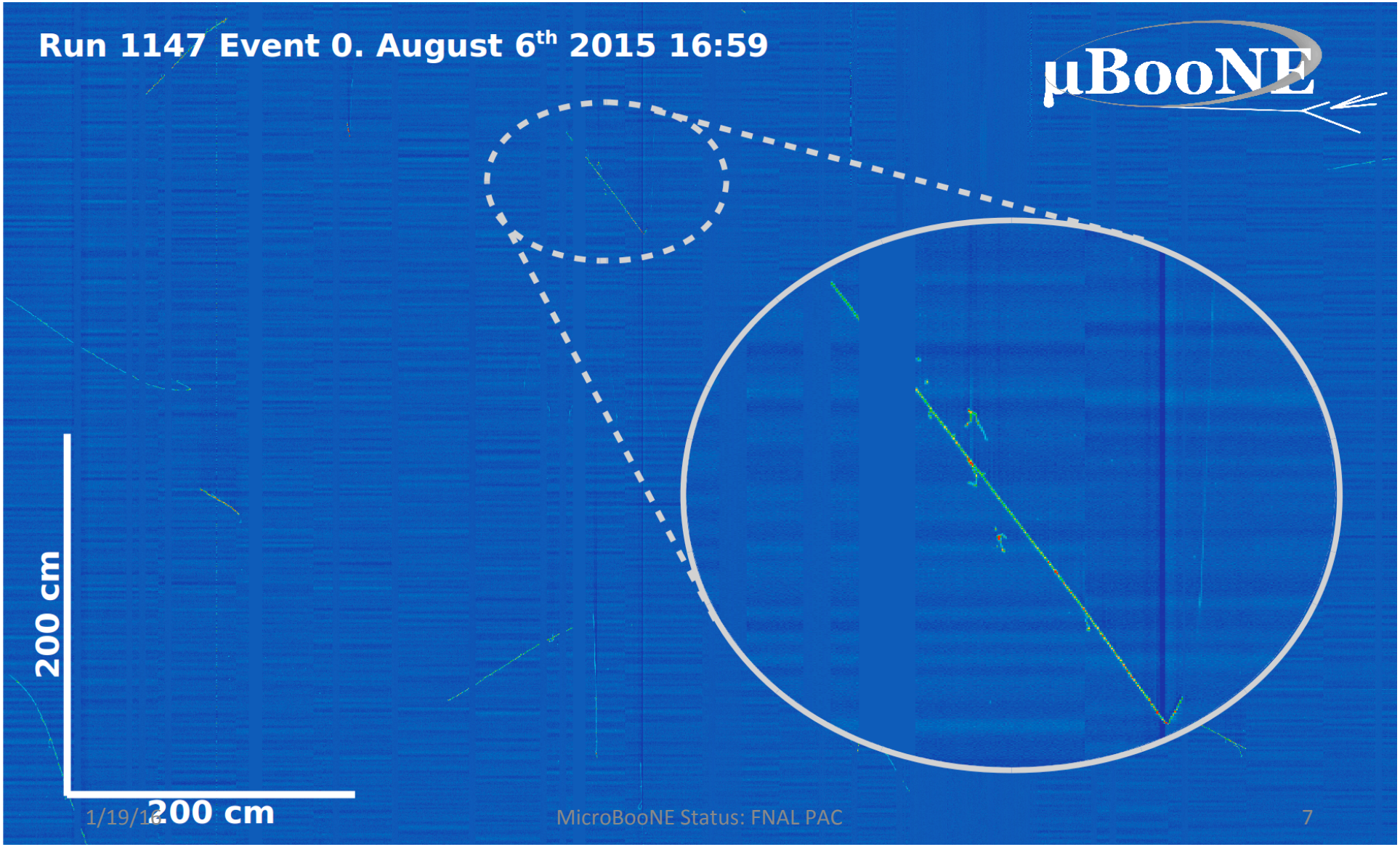
Liquid Argon purity after two week purification process



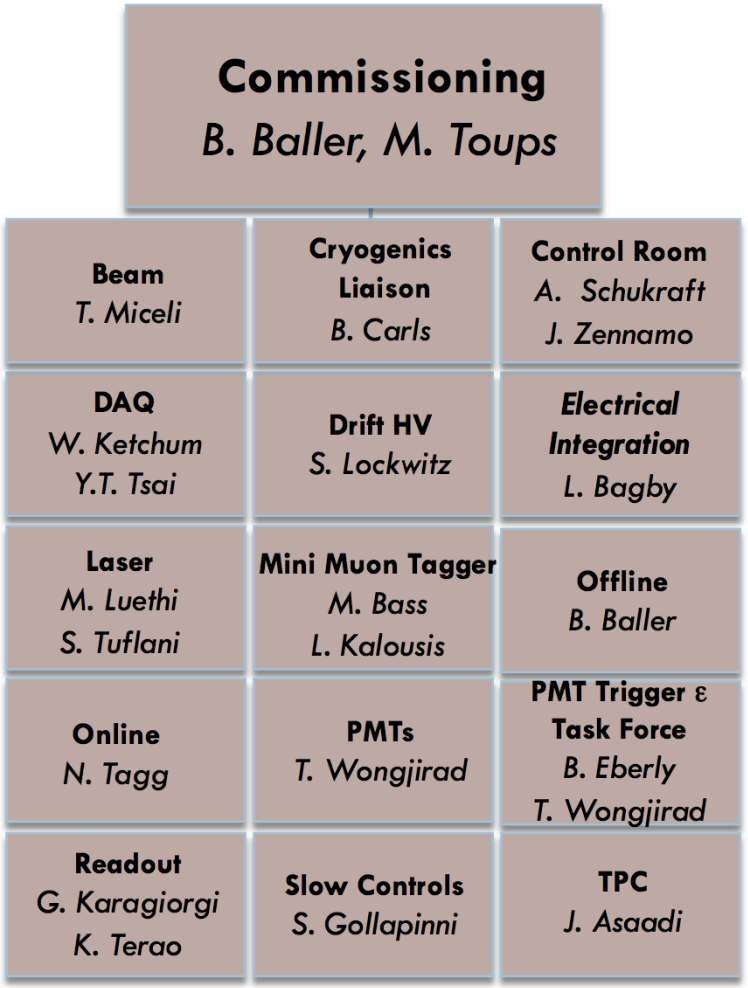
Achieved (surpassed!) one of our main development goals: Good LAr purity without evacuation of a fully instrumented cryostat

Ramping up Drift HV!

The detector works! Cosmic images from soon after fill and purification in August



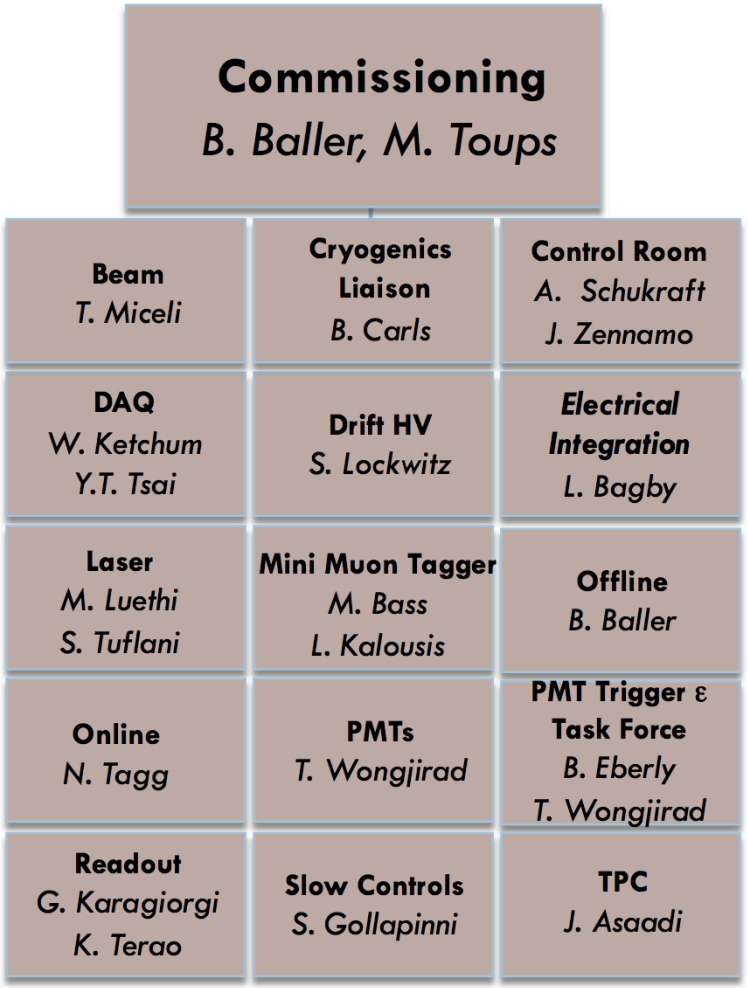
Commissioning



Organization:

- 15 commissioning teams to bring up all the systems, largely postdoc led
- Full Internal Commissioning Review (Sept 24-25, 2015) with technical notes, presentations, and reviewers
- Commissioning is complete as of October for all sub-systems except for the PMT trigger where planned commissioning takes place over first three months of data taking

Commissioning Highlights



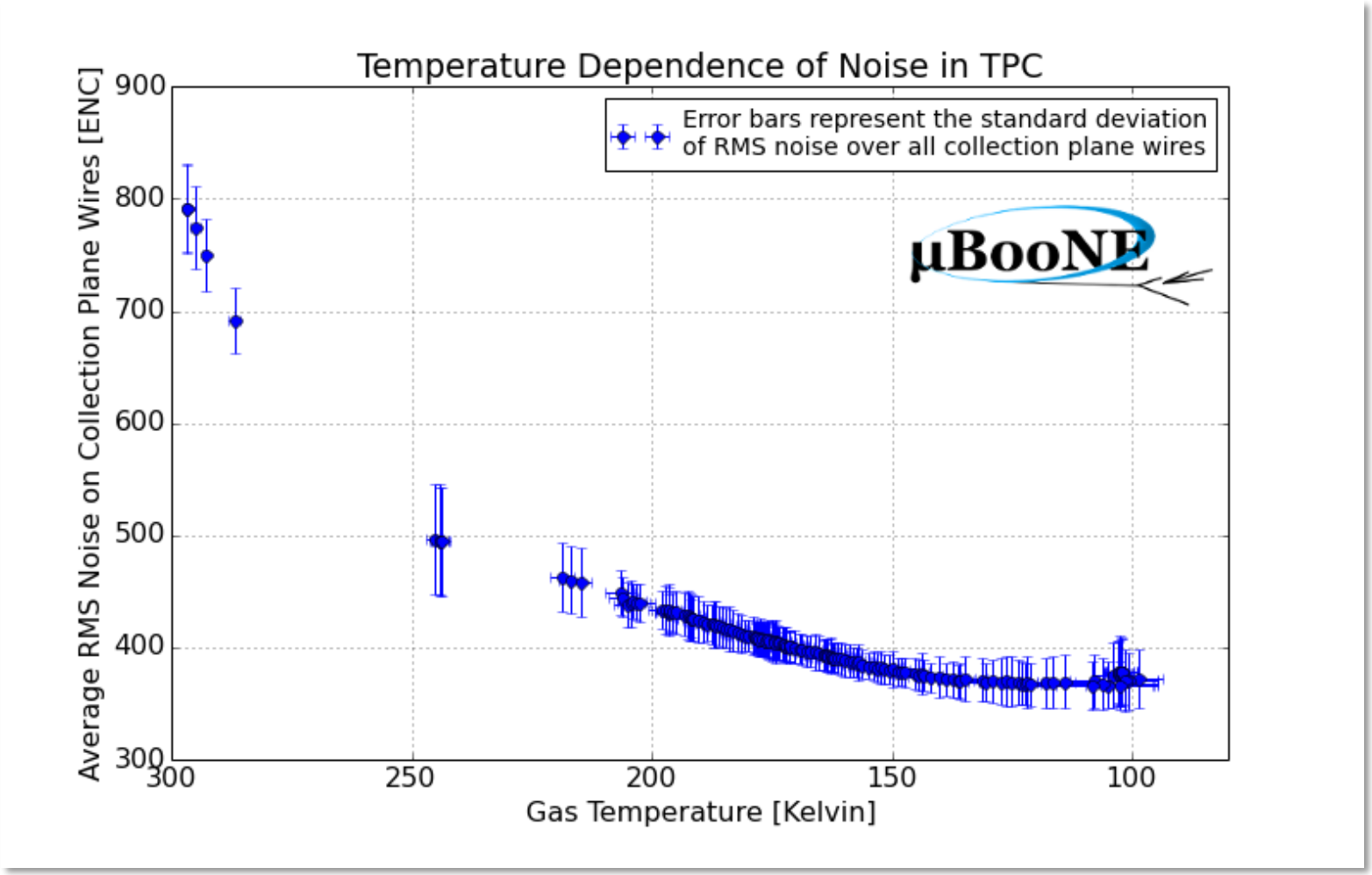
TPC and Readout:

- 90% of channels operational
- Three wire planes – redundant so even with 10% of channels non-operational, we have >95% of the detector with 2-plane readout
- Non-operational wires largely due to: (1) unresponsive channels associated with ASICs in a bad state or (2) consecutive channels grouped by ASIC or wire carrier board that are unresponsive

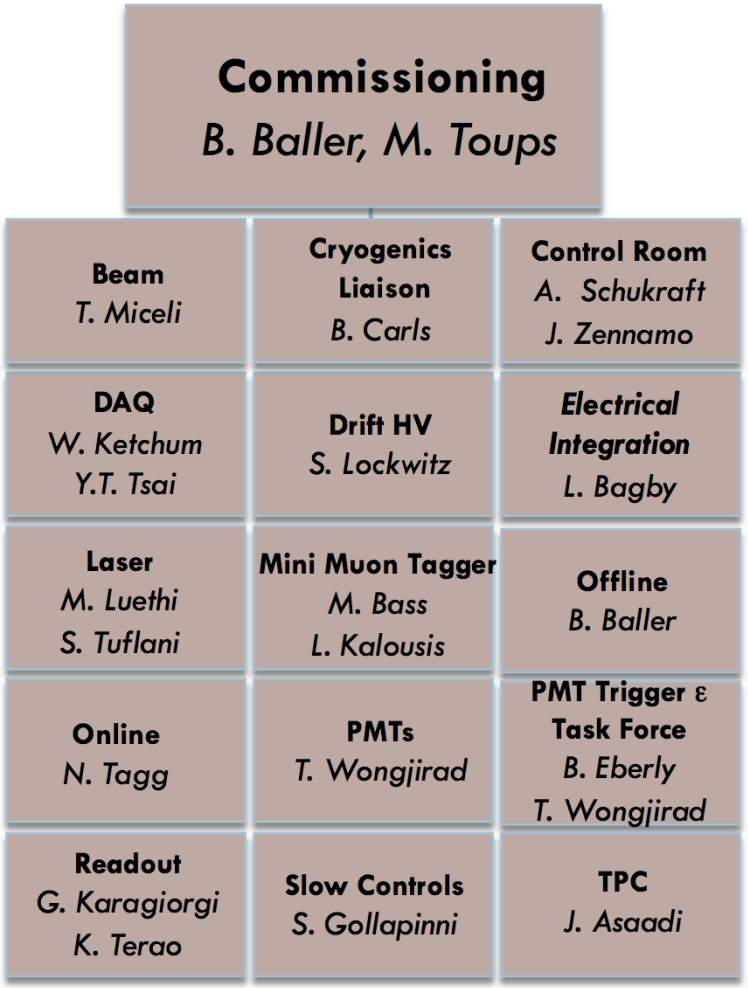
Cold Electronics:

- Excellent performance at liquid argon temperatures
- Signal to Noise of 40:1 (ICARUS: 10:1)

Cold Electronics Performance



Commissioning Highlights



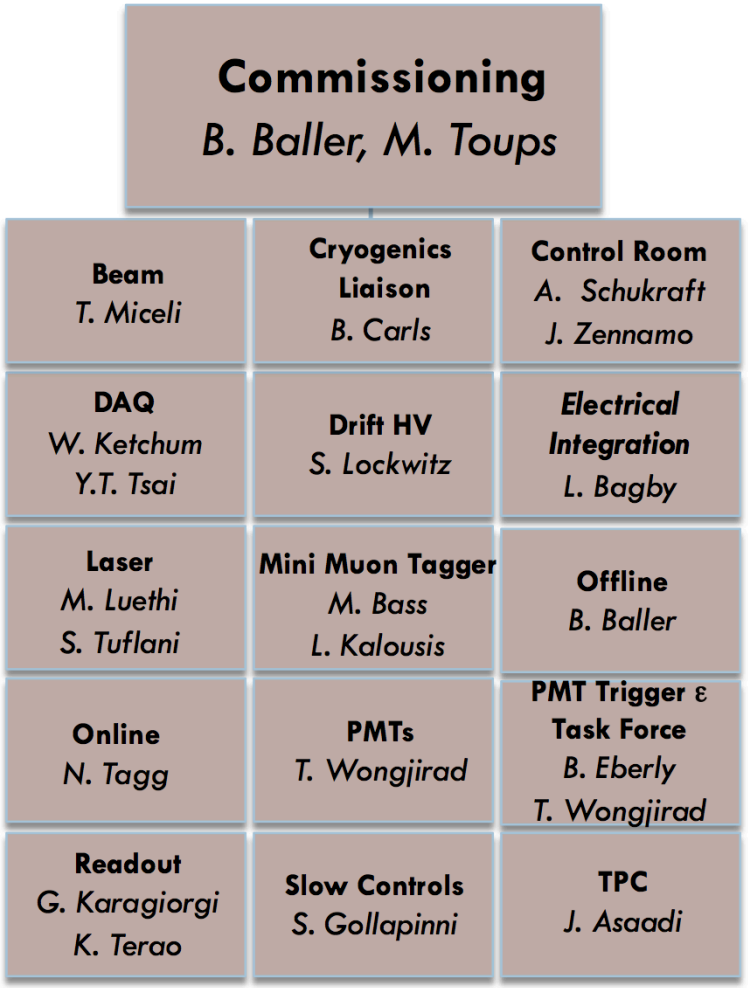
DAQ:

- Excellent performance typically running at >97% uptime (when receiving beam)
- Typically running at ~6Hz, tested up to 10Hz (5 Hz BNB + 0.7 Hz NuMI + ~0.2 Hz external triggers)

Electrical Integration:

- Comprehensive noise studies to understand and eliminate noise sources. Some eliminated (chirpiness), others mitigated in software

Commissioning Highlights



Drift High Voltage:

- Running at 70kV – below our design voltage but ok given our excellent purity

PMTs:

- All operational and running at design voltages – first to come online!

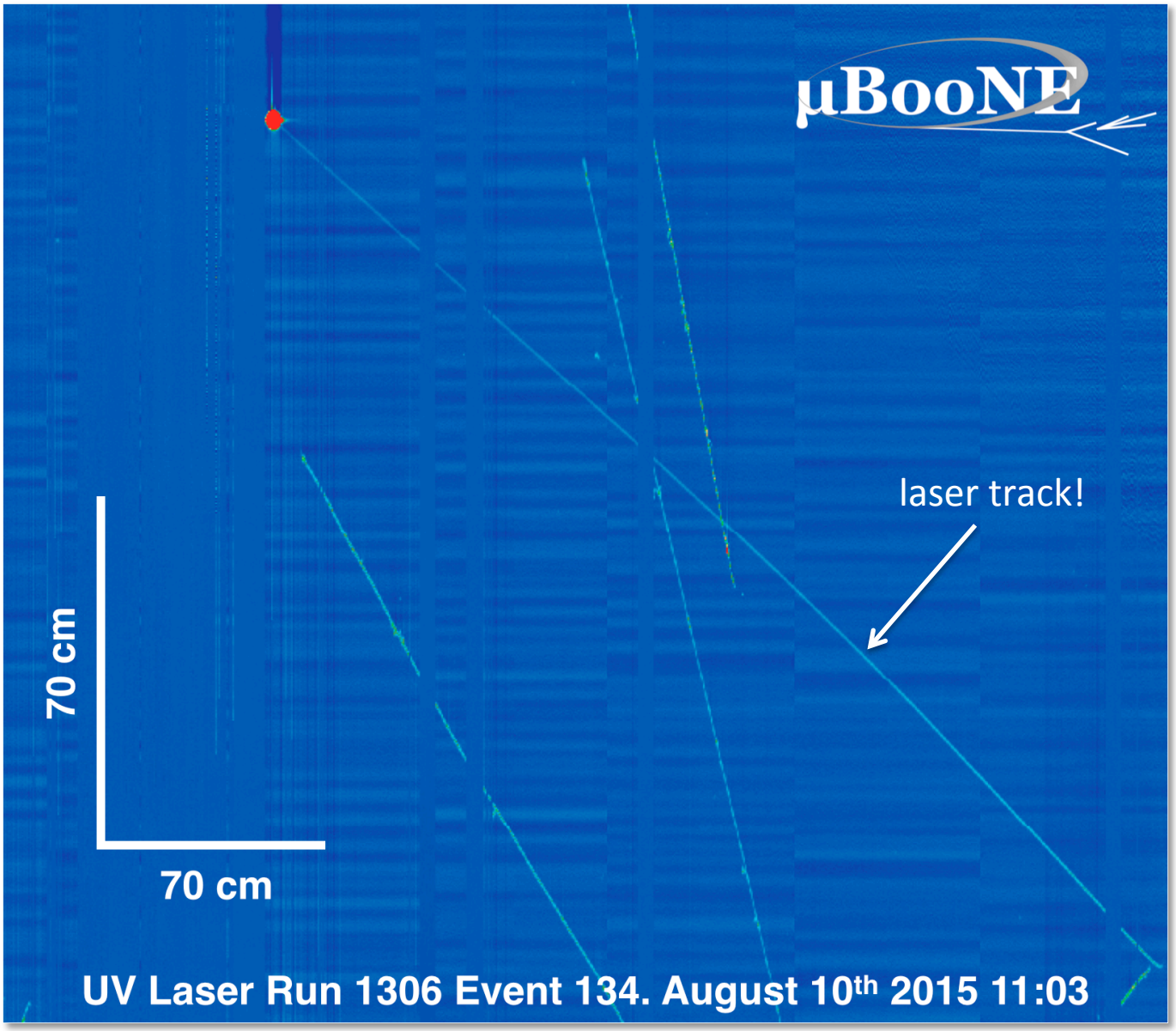
Mini Muon Tagger System:

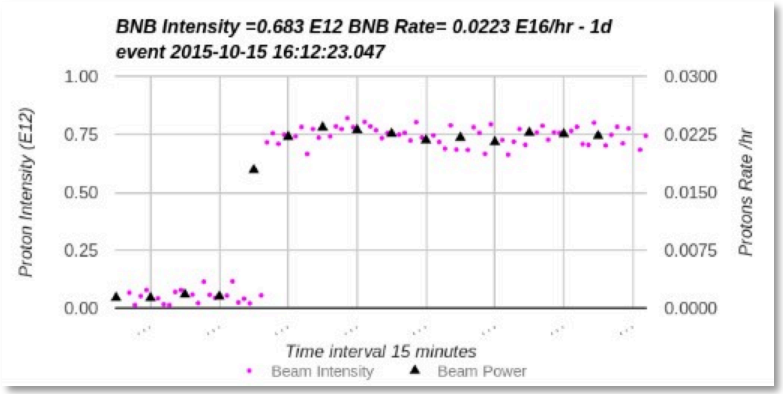
- Fully Operational – regular runs made with the tagger for calibration data

Laser system:

- Operational – images coming up!

The Laser works! First laser tracks from early August…



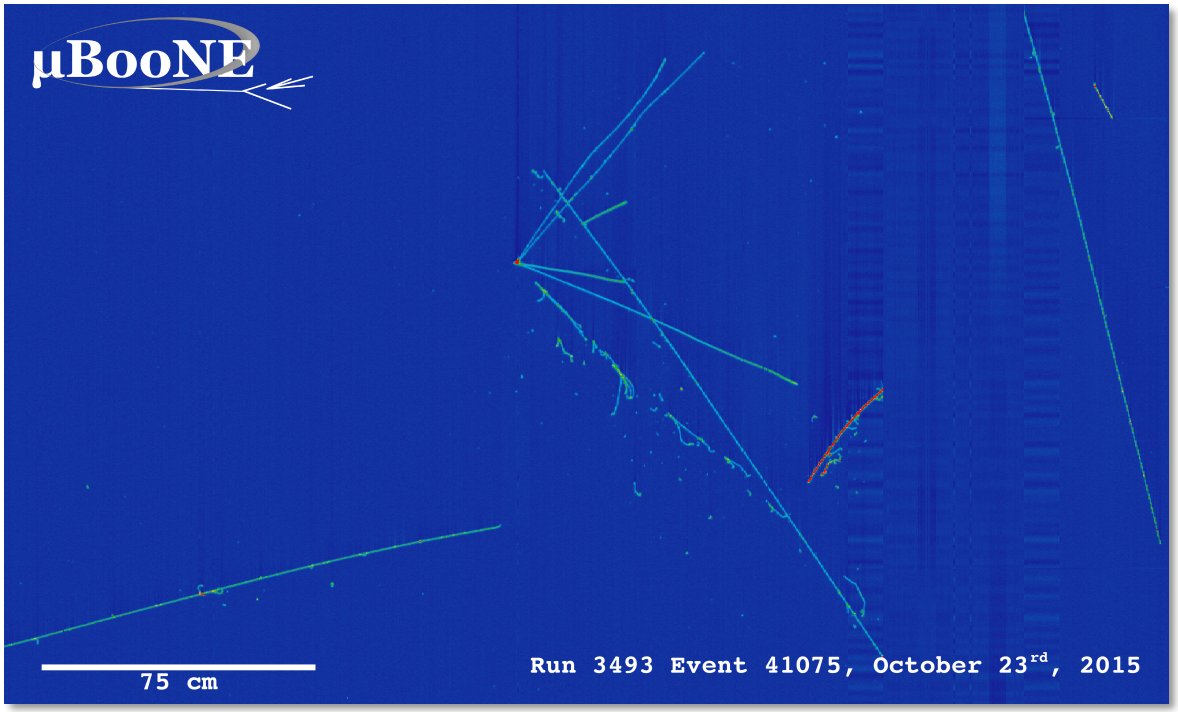


First Neutrinos on October 15th

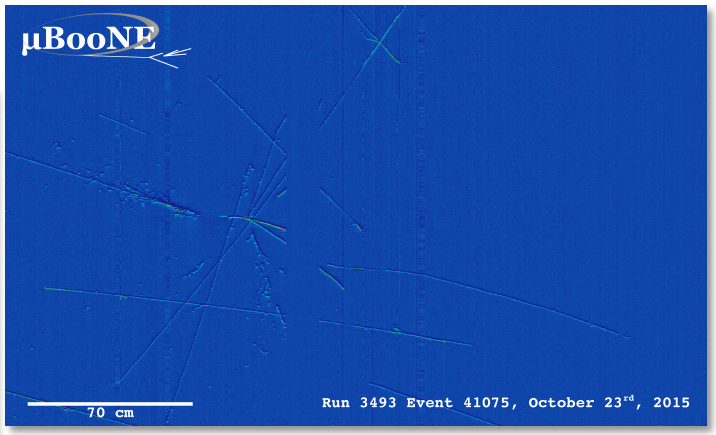
Press release for first neutrinos on November 2, 2015

(exactly 8 years to the day → proposal to the PAC *MicroBooNE's Birthday…)*

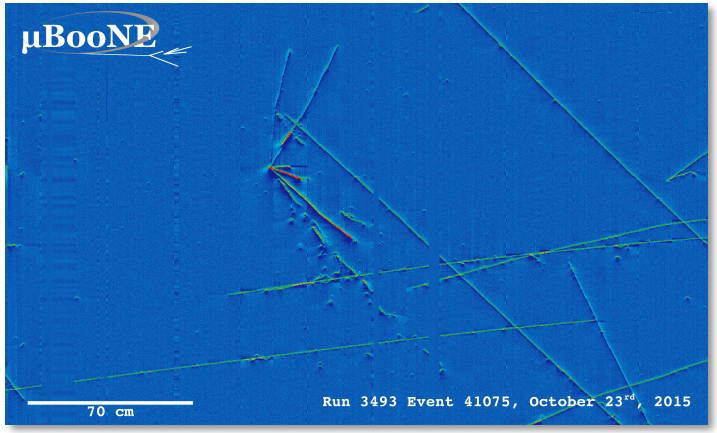
collection plane:

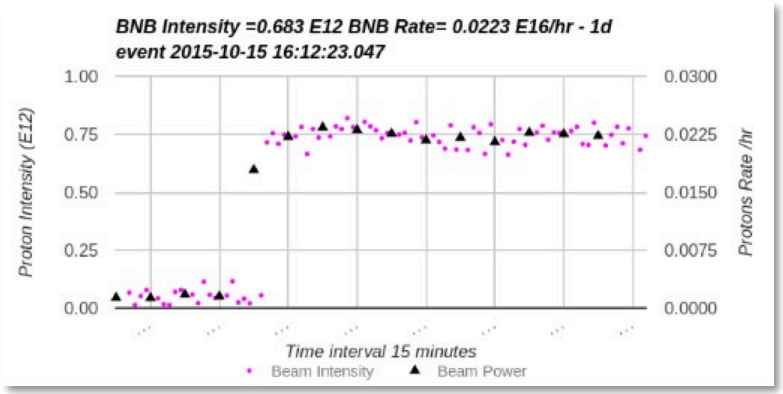


induction plane 1:



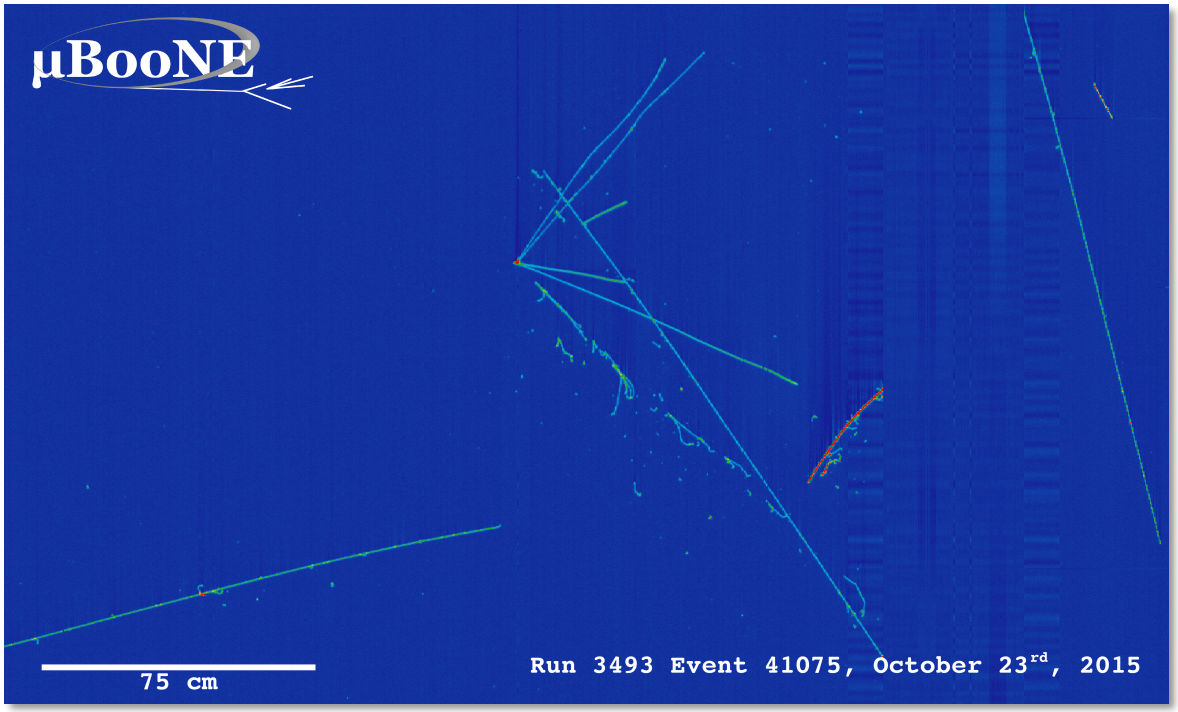
induction plane 2:





neutrinos identified using fully automated event filter and 3D reconstruction

collection plane:

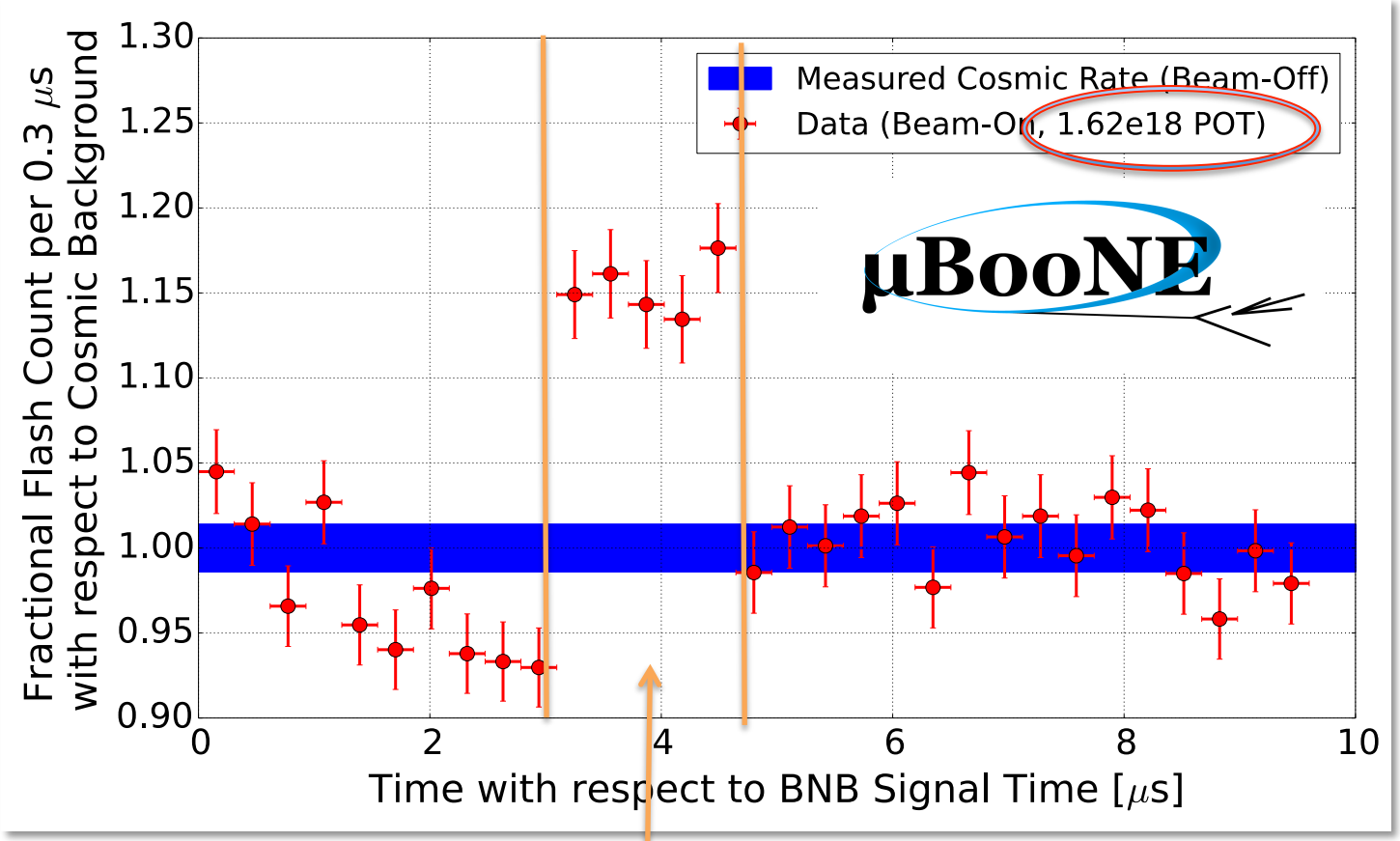


• <u>ingredients</u>:

- Optical reconstruction
- Noise removal
- TPC Hit extraction
- 2D reconstruction (clusters)
- 3D track reconstruction
- Cosmic removal based on optical flashes and track geometry
- Vertex reconstruction

more events here: http://www-microboone.fnal.gov/first-neutrinos/index.html

We see neutrinos in the time of the beam window of the BNB



1.6 microsecond BNB beam spill

Recent Operational Readiness Review (Nov 23-24, 2015)

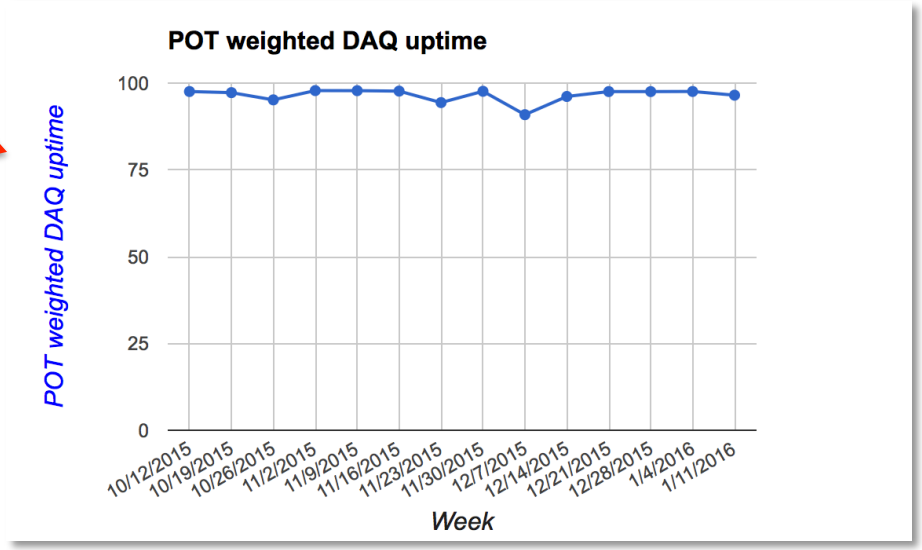
"We would like the committee to review the preparations for running, plans for maintenance & operations of the detectors, and data taking and analysis, including the current status of the detector, the status of the online and offline software, and the run plan.``

Committee chaired by Doug Glenzinski. 9 reviewers from both inside and outside Fermilab. Successful review. We are addressing the review recommendations.

e.g.: suggestion to implement a "loose" trigger in software instead of in hardware ASAP (even before we fully understand the PMT trigger efficiency)
We are doing this!

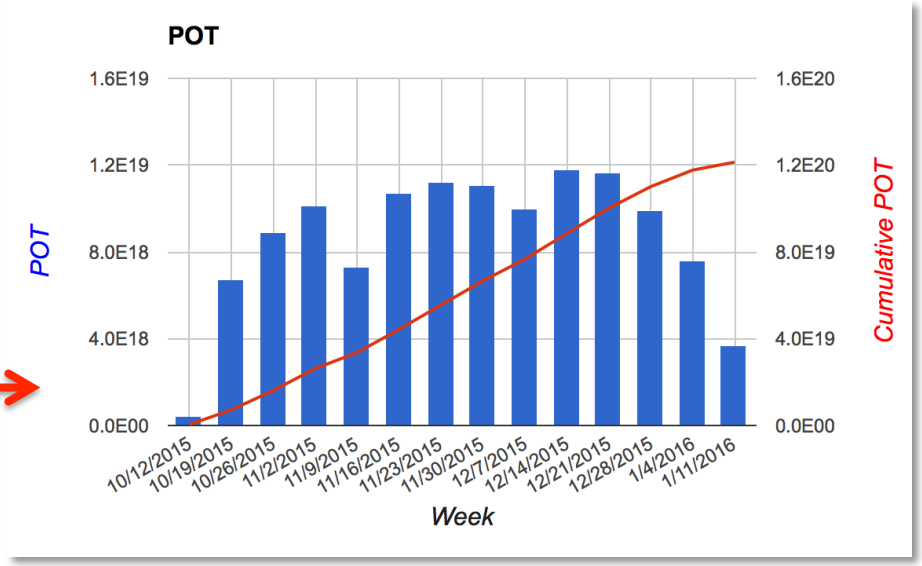
Stable Operations

- Excellent detector and DAQ uptime



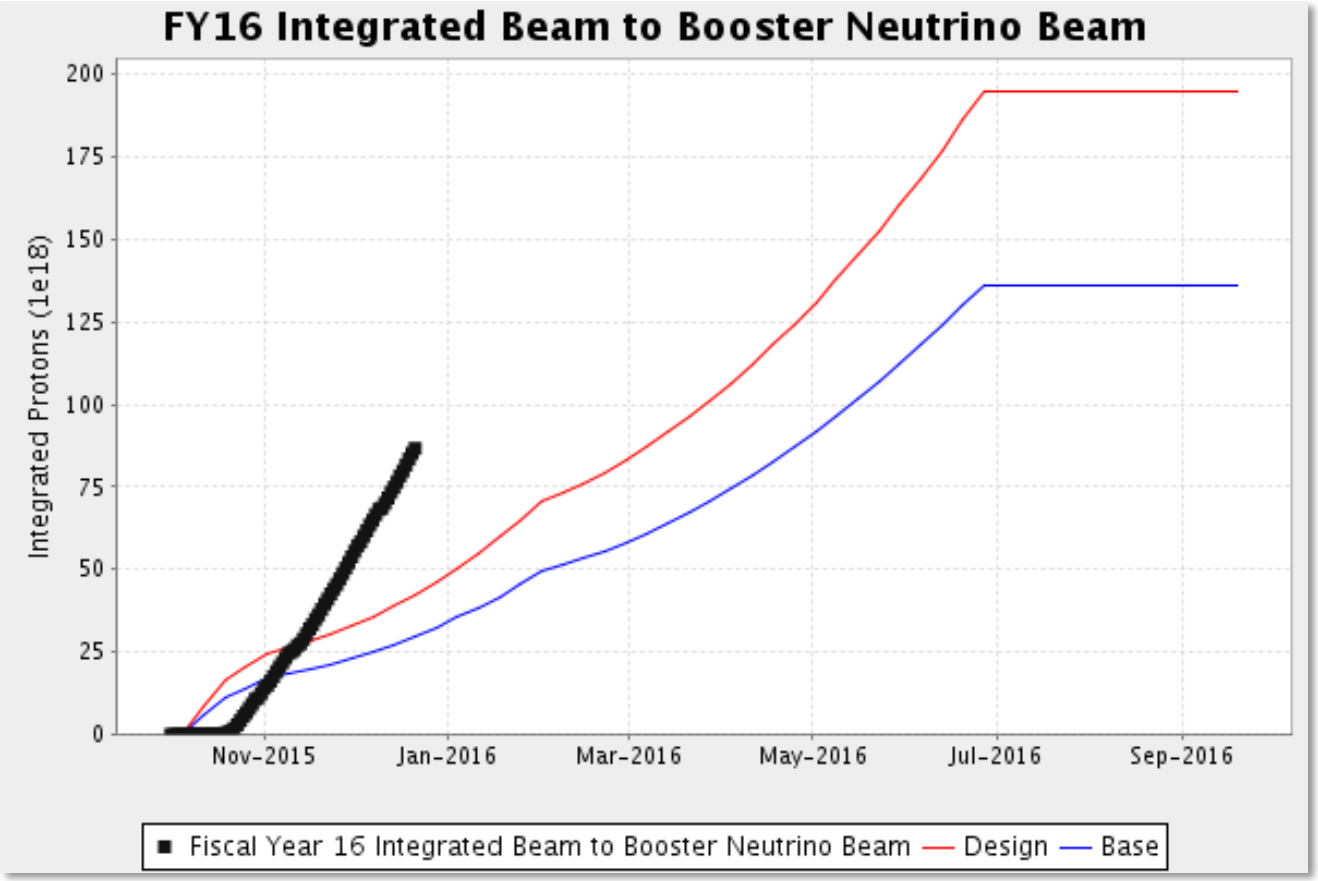
- Collecting significant POT – months of 5 Hz running due to extended commissioning of slip stacking in the Main Injector

- MicroBooNE has collected a total of 1.2×10^{20} POT from the BNB since we started data-taking on October 15, 2015



BNB Performance

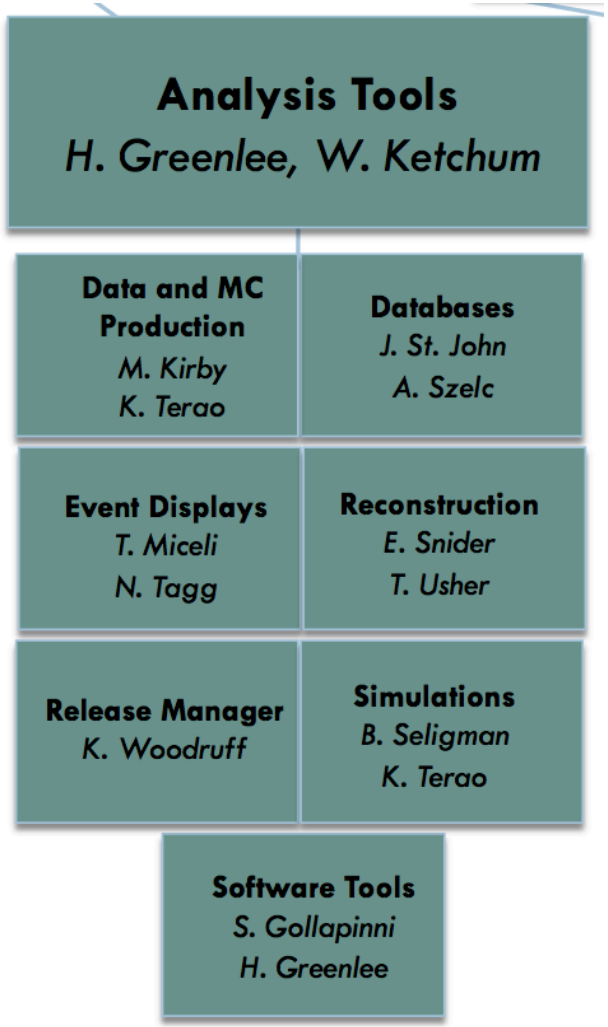
- Booster has been running extremely well. MicroBooNE is typically receiving BNB at 5 Hz, 4.5×10^{12} p/pulse. Expect reduction in BNB intensity as NuMI slip stacking is commissioned.



Lots of beam means lots of writing data to tape….

- During 3 month planned PMT trigger commissioning period, save all data to tape: 120TB a week. With SCD's help we have been able to keep up this rate but need to implement the PMT trigger very soon to have manageable rates
  - to take the stress off tape writing
  - Limit time spent re-running the data for analysis
- Challenges in implementing a PMT trigger: Observe higher than expected PMT rates in the detector – still working to understand this
  - "PMT trigger efficiency task force"
  - "Radon task force" (really a "rates task force")
- Plan: Implement loose trigger, tight trigger soon after this

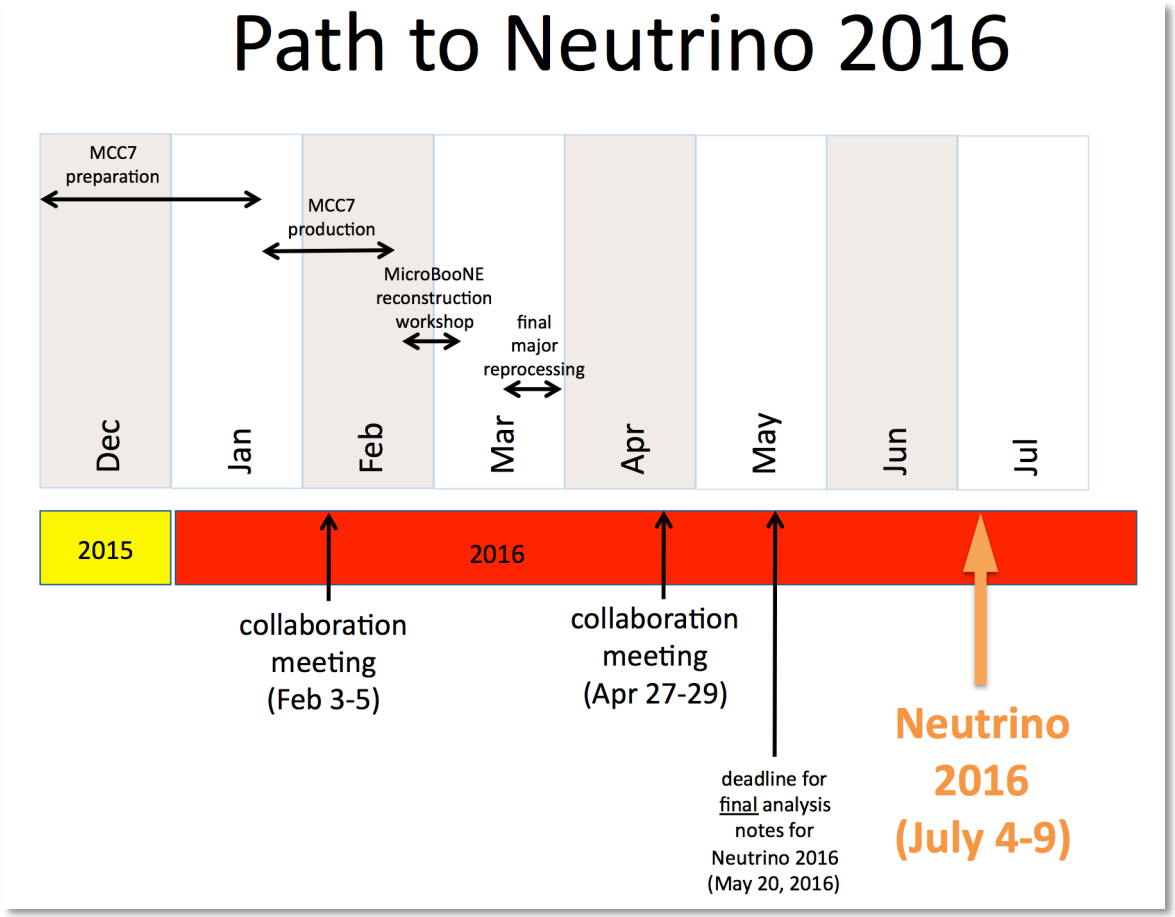
Analysis Tools Development



- Lots of development in
  - Tracking
  - Cosmic removal
  - Vertex Finding
  - Shower reconstruction
  - …..
- MCC7 production starts this month (Monte Carlo generation)
- Annual MicroBooNE Reconstruction Workshop planned for Feb 29-Mar 4 at University of Michigan

Analysis Tools development aligned with Physics Analysis plans

Physics Analysis Plans



Physics Analysis
M. Weber, M. Toups

Astro Particle & Exotics
J. Asaadi
Y-T. Tsai

Beam
T. Miceli
Z. Pavlovic

Cross Sections
S. Gollapinni
A. Schukraft

Detector Physics
B. Carls
J. Joshi

Oscillations
B. Littlejohn
J. Zennamo

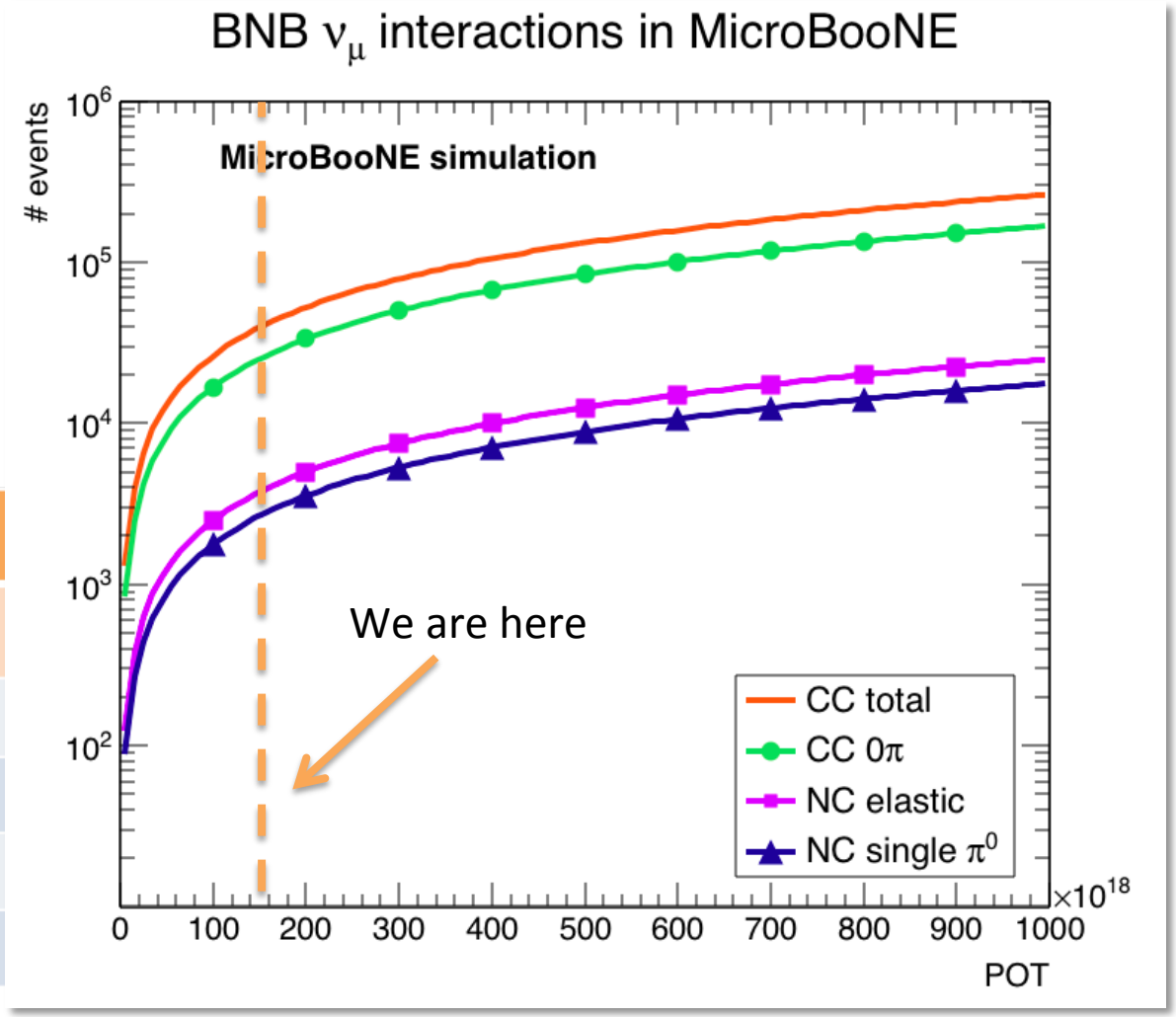
First CC Inclusive Cross Section Measurement
full end to end MC analysis with fully automated reconstruction

Goal: Be ready for data analysis with our first 6 months of data

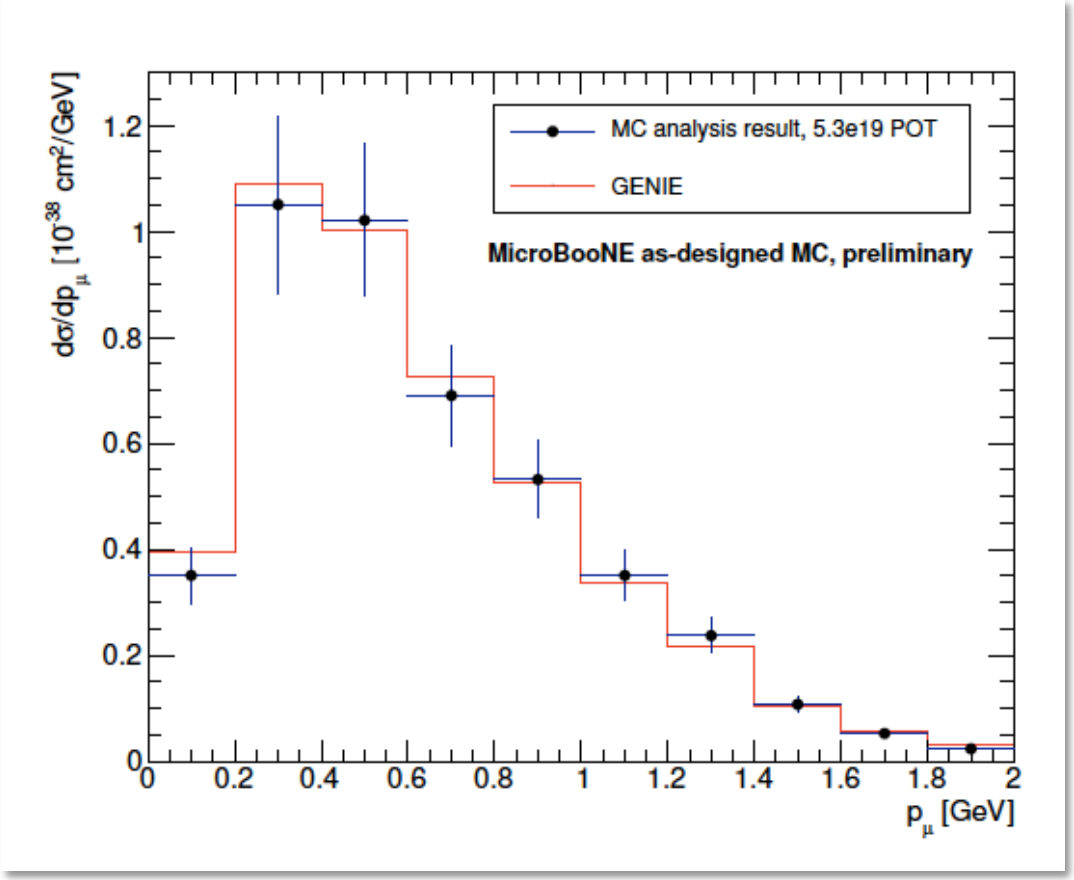
1 month μB data taking

~ entire ArgoNeuT data set

	1e20 POT (~6 months)
(note: we've already collected 1.2 x 10^{20} POT!)	**numu**
	87 tons active volume
CC inclusive	26226
CC 0 pi	16757
NC elastic	2493
NC single pi0	1771



MC-based study with fully automated event reconstruction single differential neutrino cross section sensitivity



- ingredients:

- Optical reconstruction
- Noise removal
- TPC Hit extraction
- 2D reconstruction (clusters)
- 3D track reconstruction
- Cosmic removal based on optical flashes and track geometry
- Vertex reconstruction

- Momentum reconstruction based on track length
- Initial estimates of systematic uncertainty included

Cosmic background removal

- Cosmics do represent a significant background
  - Advances in cosmic models since proposal stage – we know more now
  - Lower drift HV than reference → longer drift time → more cosmogenic backgrounds

from SBN proposal: rates of cosmic backgrounds after topological cuts applied

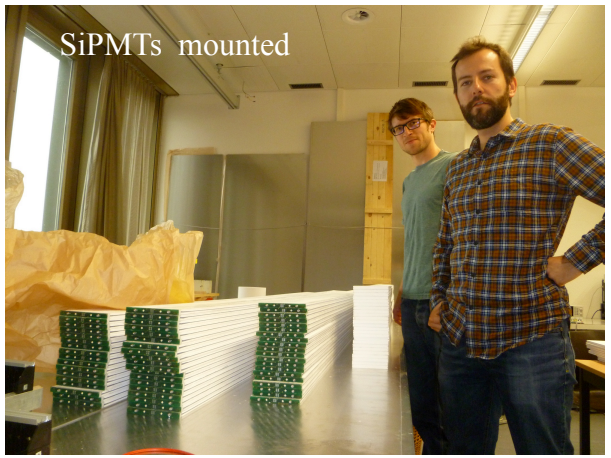
Interaction description	Timing Cat.	Topology Cat.	$E_\gamma > 200$ MeV, Pair prod $E_e > 200$ MeV, Compton, ν_e		
			LAr1-ND	μBooNE	ICARUS
Total Cosmogenic γ backgrounds			146	88	164
Intrinsic ν_e CC			15,800	413	1,500

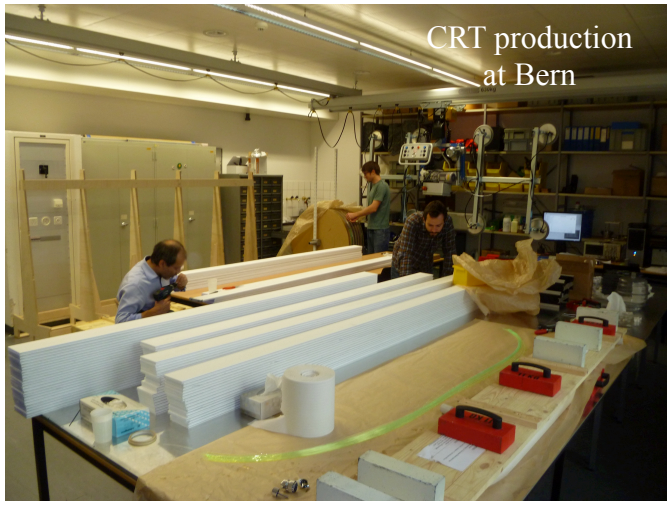
Factor of 5!

Cosmic background removal solutions

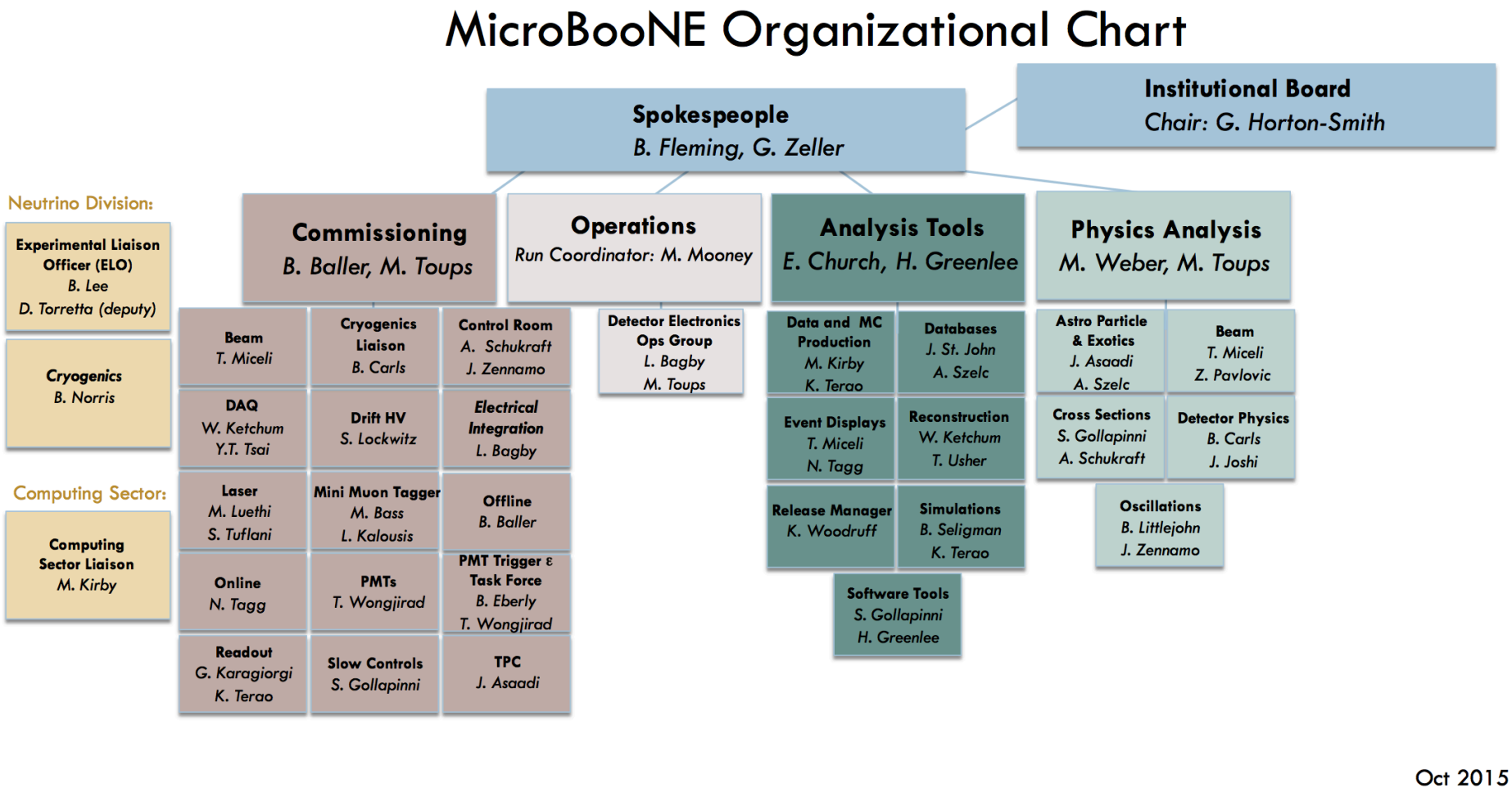
- Reduction: Can be reduced with overburden (building was designed to support an overburden). Working with the lab to find funds to install.
- Tagging: Can be well-measured with a tracker: small tracker already running has shown us how valuable this can be. Bern is supplying a larger muon tracking system. Working with the lab to find funds to install.


readout boards ready and tested

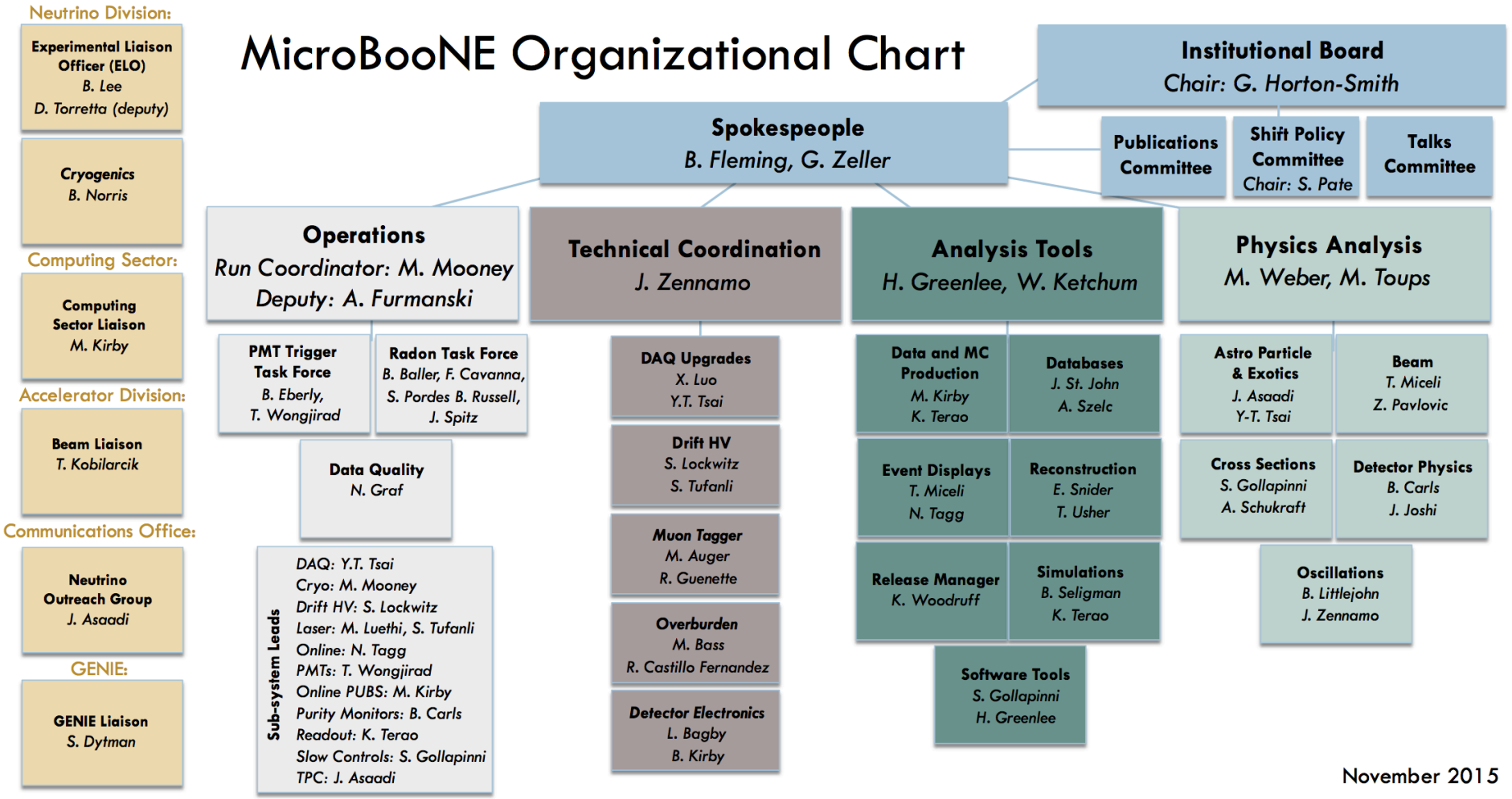

SiPMTs mounted


CRT production at Bern

Organizational chart from last PAC meeting



Moved from Commissioning to Operations



Jan 2016

MicroBooNE Collaboration

University of Bern, Switzerland: M. Auger, A. Ereditato, D. Goeldi, I. Kreslo, D. Lorca, M. Lüthi, C. Rudolf von Rohr, J. Sinclair, 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: J. Jan de Vries, J. Marshall, M. Thomson, J. Weston

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, J. Crespo, V. Genty, D. Kaleko, W. Seligman, M. Shaevitz, K. Terao

Fermilab: R. Acciarri, L. Bagby, B. Baller, B. Carls, F. Cavanna, R. Castillo Fernandez, H. Greenlee, C. James, H. Jostlein, W. Ketchum, M. Kirby, T. Kobilarcik, S. Lockwitz, B. Lundberg, A. Marchionni, C. Moore, O. Palamara, Z. Pavlovic, S. Pordes, J.L. Raaf, G. Rameika, A. Schukraft, E. Snider, P. Spentzouris, T. Strauss, M. Toups, T. Yang, G.P. Zeller*

Illinois Institute of Technology: R. An, B. Littlejohn, D. Martinez

Kansas State University: T. Bolton, S. Gollapinni, G. Horton-Smith, V. Meddage, A. Rafique, S. Shrestha

Lancaster University: A. Blake, D. Devitt, A. Lister, J. Nowak

Los Alamos: G. Garvey, W.C. Louis, G.B. Mills, R. Van de Water

University of Manchester: D. Cianci, A. Furmanski, J. Hewes, C. Hill, G. Karagiorgi, R. Murrells, D. Porzio, S. Söldner-Rembold, A.M. Szelc

MIT: L. Bugel, J.M. Conrad, O. Hen, J. Moon, M.H. Moulai, T. Wongjirad

University of Michigan, Ann Arbor: J. Mousseau, J. Spitz

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, A. Laube, R. Soleti, M. Del Tutto, R. Guenette

University of Pittsburgh: S. Dytman, N. Graf, L. Jiang, D. Naples, V. Paolone, A. Wickremasinghe

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. Esquivel, P. Hamilton, G. Pulliam, M. Soderberg

University of Texas at Arlington: J. Asaadi

Tubitak Space Technologies Research Institute, Turkey: F. Bay, B. Kocaman, M. Kopru

Virginia Tech: C.M. Jen, C. Mariani

Yale University: C. Adams, B.T. Fleming*, E. Gramellini, A. Hackenburg, X. Luo, B. Russell, S. Tuflani

146 collaborators
28 institutions (6 non-U.S.)
36 postdocs
35 graduate students

*spokespeople

Some Statistics

some statistics on the collaboration:

- 48% are young people *(71 students & postdocs)*
- 40% are on-site at FNAL *(most of the students & postdocs are based at FNAL)*
- 24% are from non-U.S. institutions *(Switzerland, Turkey, and the U.K.)*

we've had a growth spurt recently …

- 8 new institutions added over the past year – most by cell division
  (IIT, Lancaster, Manchester, Michigan, Oregon State, PNNL, Tubitak, UT Arlington)
- 31 new collaborators joined MicroBooNE in the last 4 months
  (this includes 15 graduate students, 12 postdocs, 4 senior scientists)

Postdoc Placement

- 17 of our postdocs have landed their next position, all in particle physics; majority have remained on MicroBooNE (13/17)

(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, FNAL, Associate Scientist, TD
(15) Matt Toups, Associate Scientist, ND
(16) Jonathan Asaadi, UT Arlington, Assistant Professor
(17) Leonidas Kalousis, Vrije Universiteit Brussel, Research Associate

- 9 University (5 non-U.S., 4 U.S.)
- 6 U.S. lab
- 1 U.S. government
- 1 second postdoc

Summary

- Successful commissioning of the detector!
  - Cryogenics and purification systems came up beautifully: running with a purity 2-3 times better than our design purity
  - Cold electronics performing with a signal/noise of 40:1
- In stable operations
  - Entire Detector running well with excellent uptime
  - Taking lots of data: collected 1.2x 10^{20} POT so far …
- Near implementation of our PMT trigger to reduce data rates
  - Still investigating rates on PMTs
- Preparing analysis tools and physics analyses aimed at Neutrino 2016
- *We ask the PAC to support our request to the lab to find support for the muon tagger system and for overburden: with what we now know about cosmics and with our longer drift time, these items are more critical to the success of our experiment*

Backups

MicroBooNE has been putting out a steady stream of results …

Editorial Boards

Active	Analysis	Group	Team	EB	Date created	Public Note / Publication
*	Cosmic ray studies in MicroBooNE	"Overburden" task force	Sowjanya G.	Georgia K., Donna N.	Dec 2015	
	NumuCC inclusive cross section study based on simulation	Xsec	Anne S.	Xin Q., Mike S.	Oct 2015	DocDB-4994
	Electronegative concentration and electron lifetime		Ben C., M. Zuckerbrot	Josh S, Brian R.	Sept 2015	DocDB-4928
	First neutrino events	Reco	Anne S., Andy F.	Dave S., Andrzej	Sept 2015	DocDB-4903
	Nucleon Decay	APE	Elena G.	Jen R., Eric C.	Aug 2015	DocDB-4765
	Noise vs. Fill Level	Commissioning	David C.	Bryce L., Vittorio P.	July 2015	DocDB-4717

shown at:

NuInt15

NNN 2015

NuInt 2015

TAUP 2015

TAUP 2015

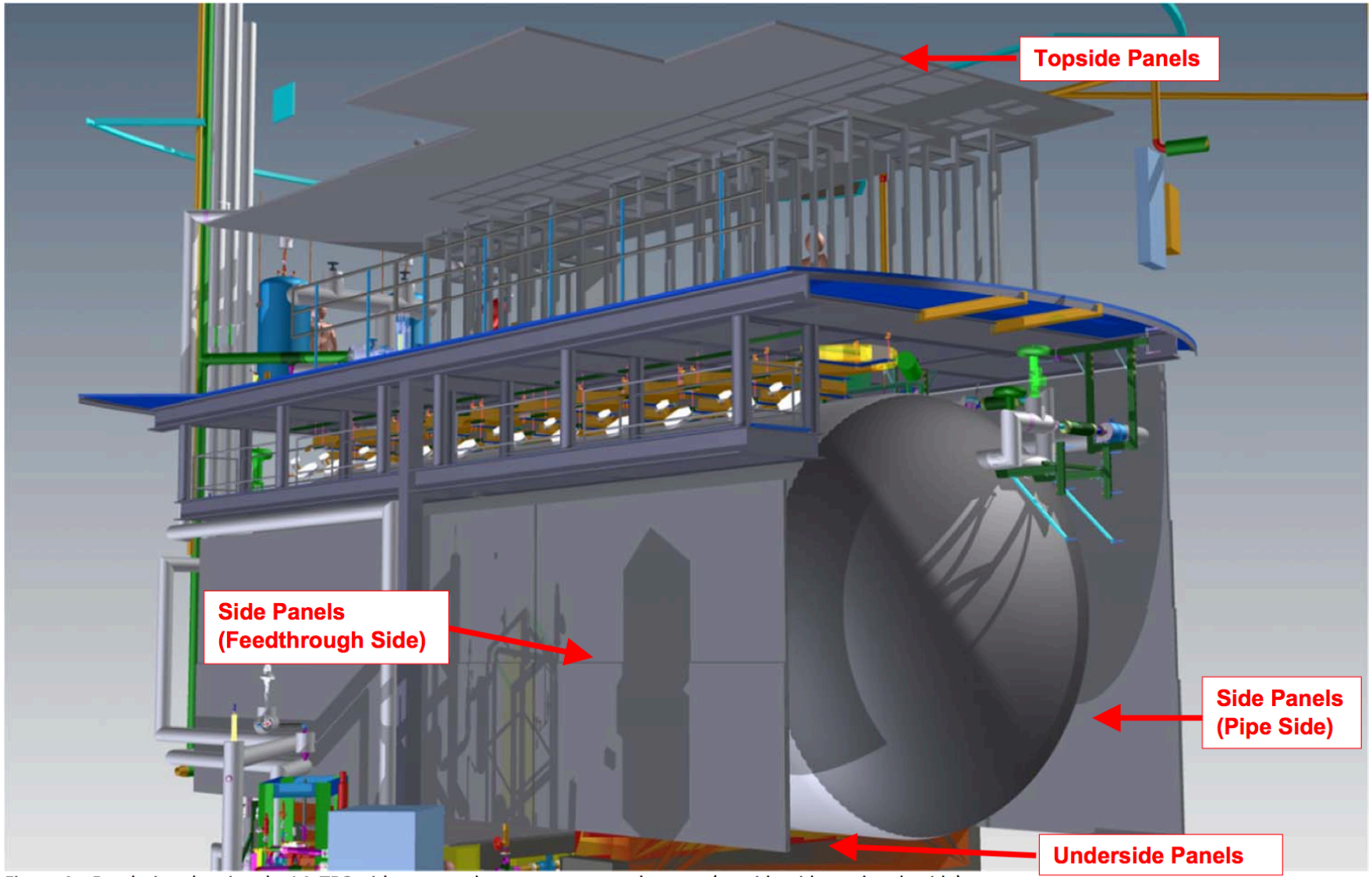


Figure 4 – Rendering showing the LArTPC with proposed muon tagger panel groups (topside, side, and underside).