MicroBooNE

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New Mexico State University

Fermilab Users' Meeting

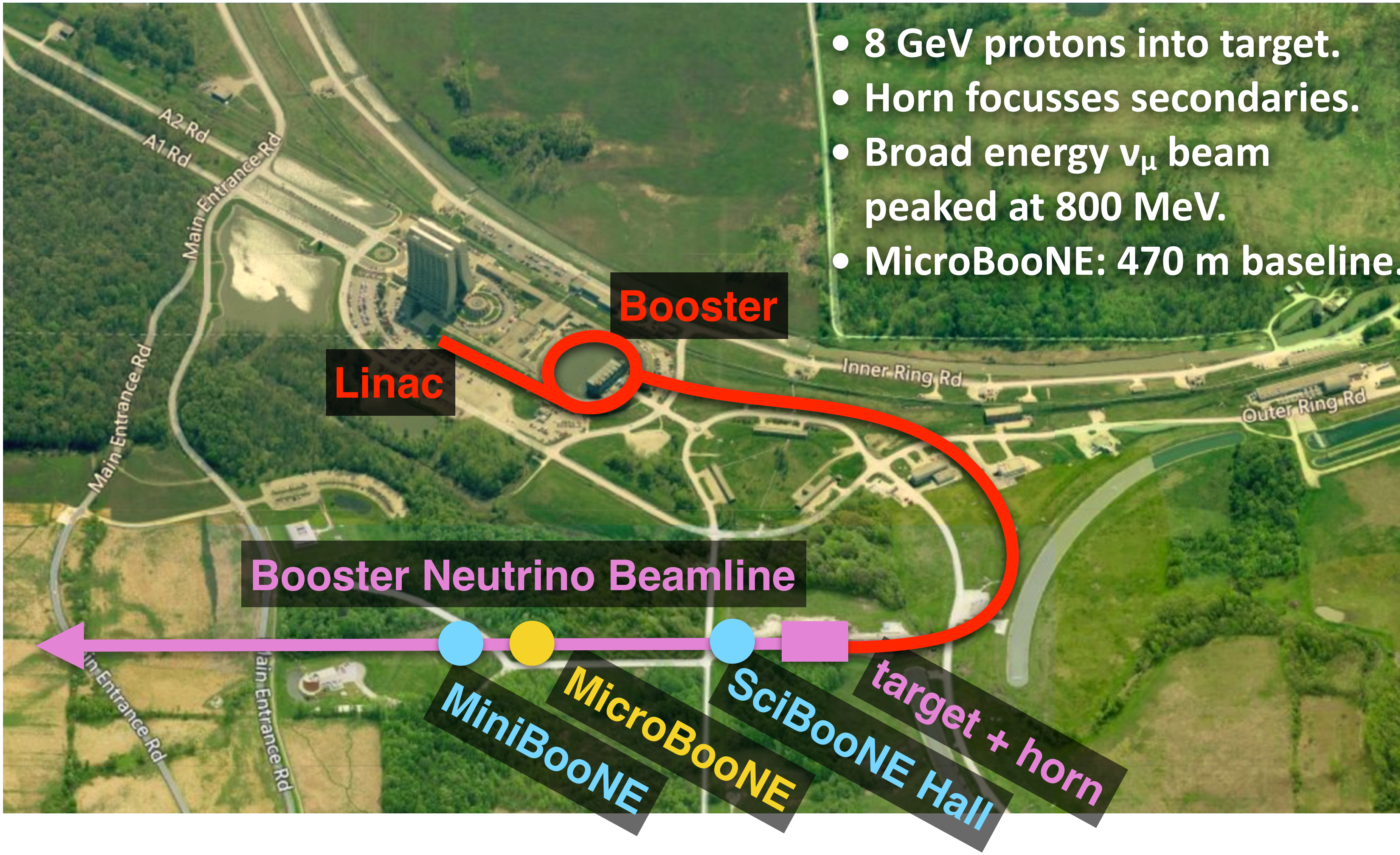
10 June 2015

MicroBooNE Collaboration

- We are commissioning our liquid argon time projection chamber (LArTPC) now.
- Collaboration of 121 people.
  - 31 postdocs
  - 24 graduate students
- 24 Institutions.

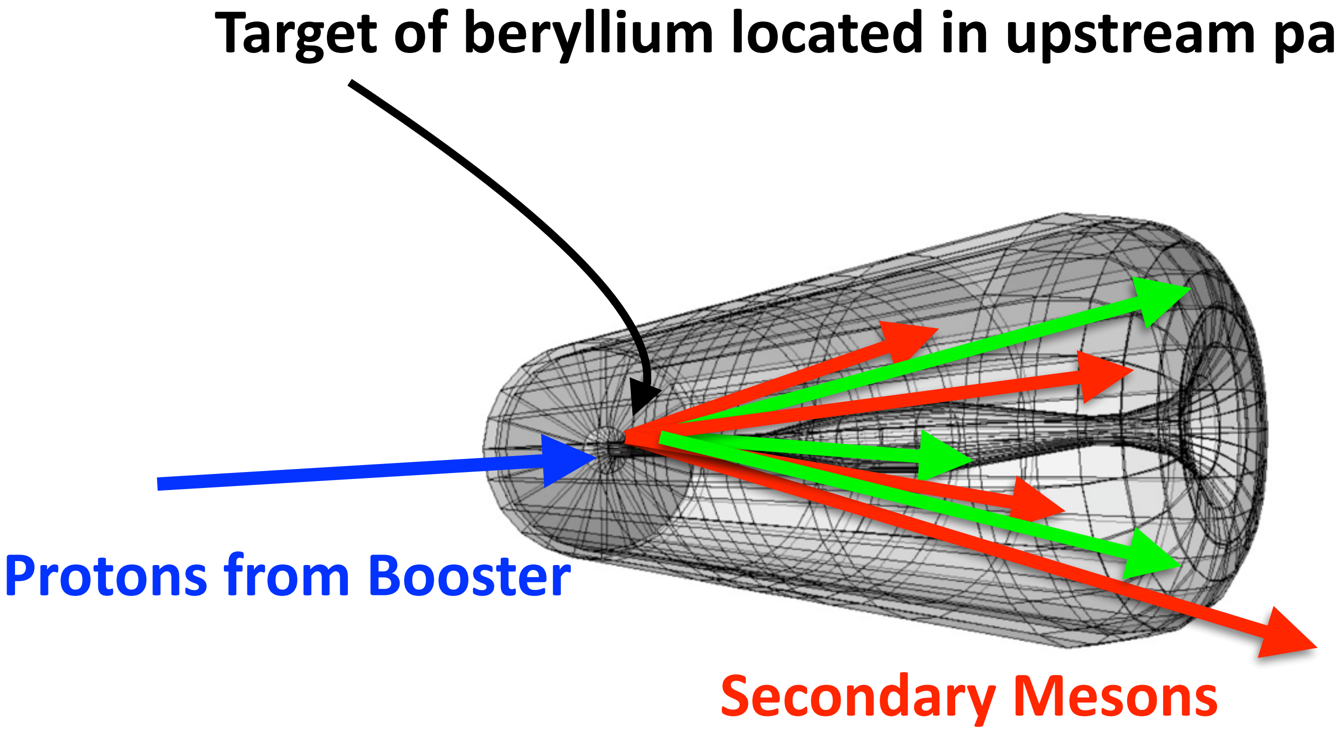
MicroBooNE on the Booster Neutrino Beamline

- 8 GeV protons into target.
- Horn focusses secondaries.
- Broad energy ν_μ beam peaked at 800 MeV.
- MicroBooNE: 470 m baseline.



The BNB horn

- Protons hit beryllium target producing many mesons.



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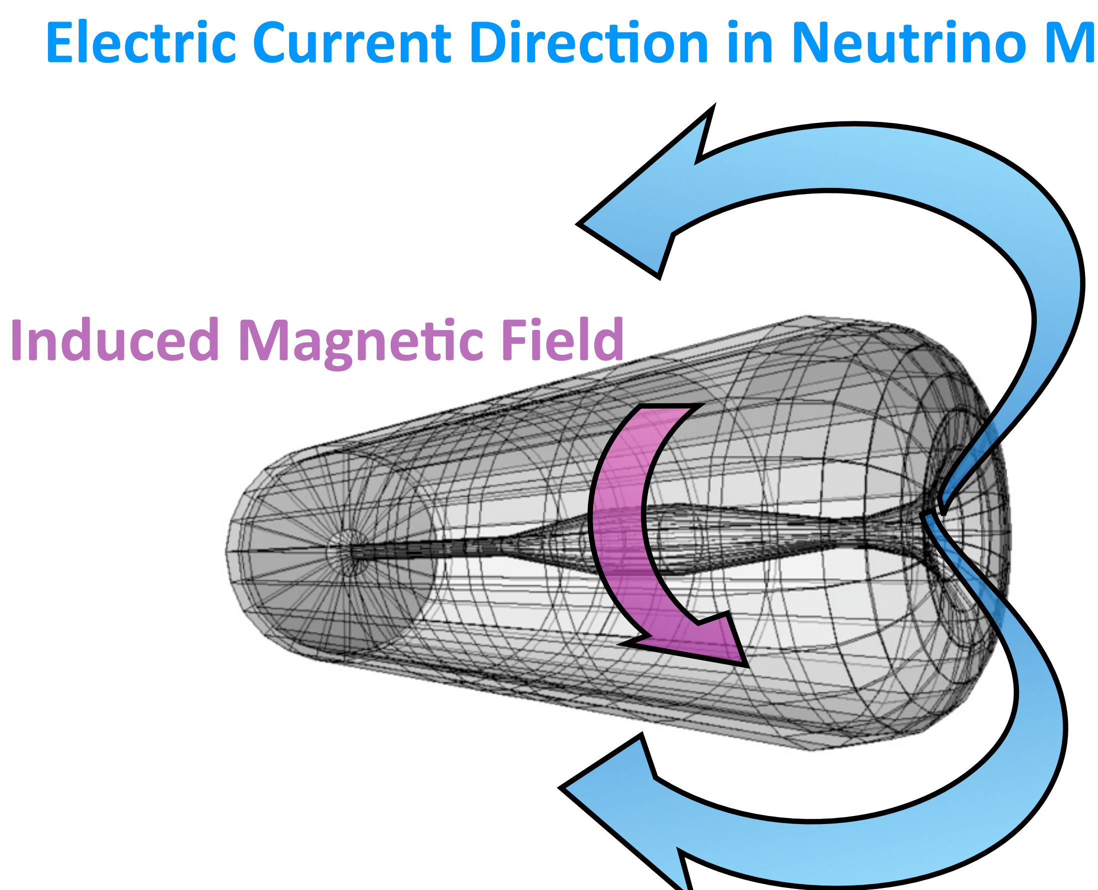
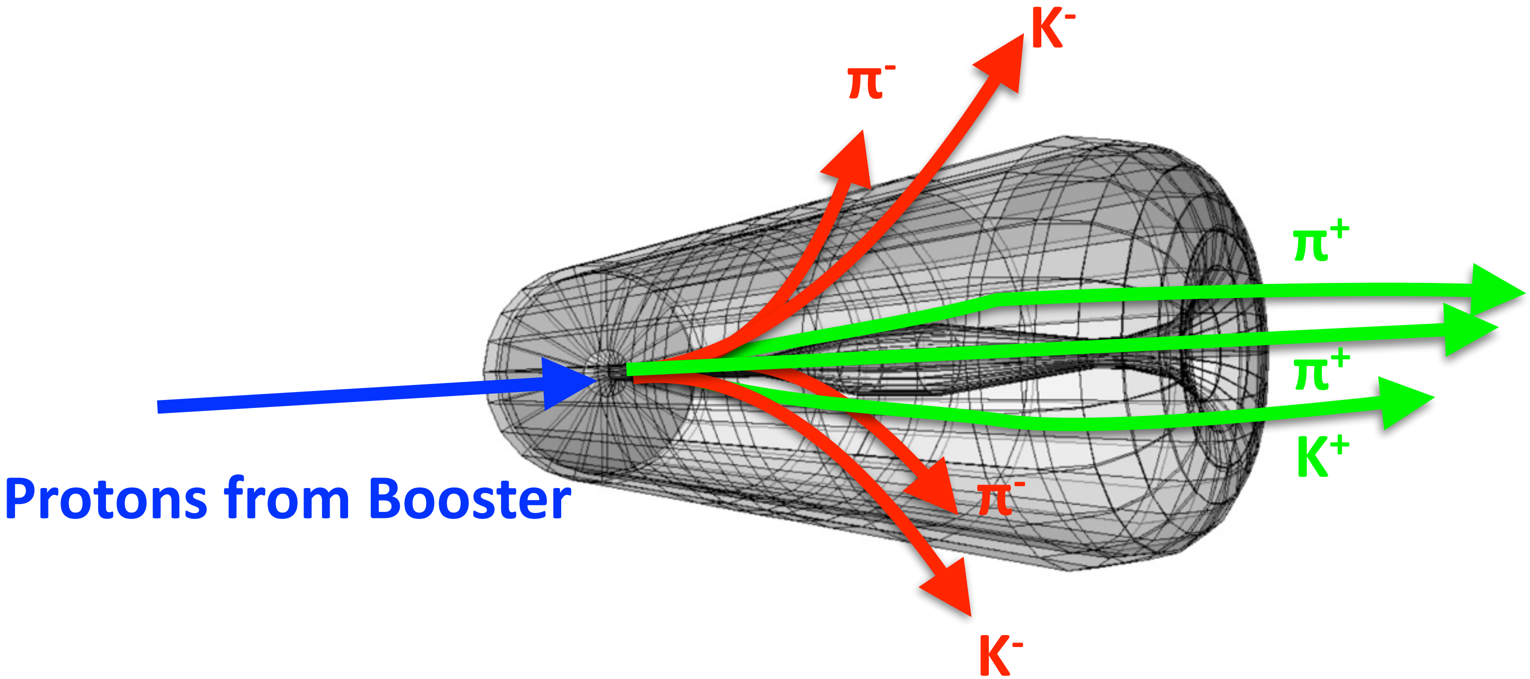


The BNB horn

- Protons hit beryllium target producing many mesons.
- The magnetic field of the horn focuses positive mesons and defocuses negative mesons.



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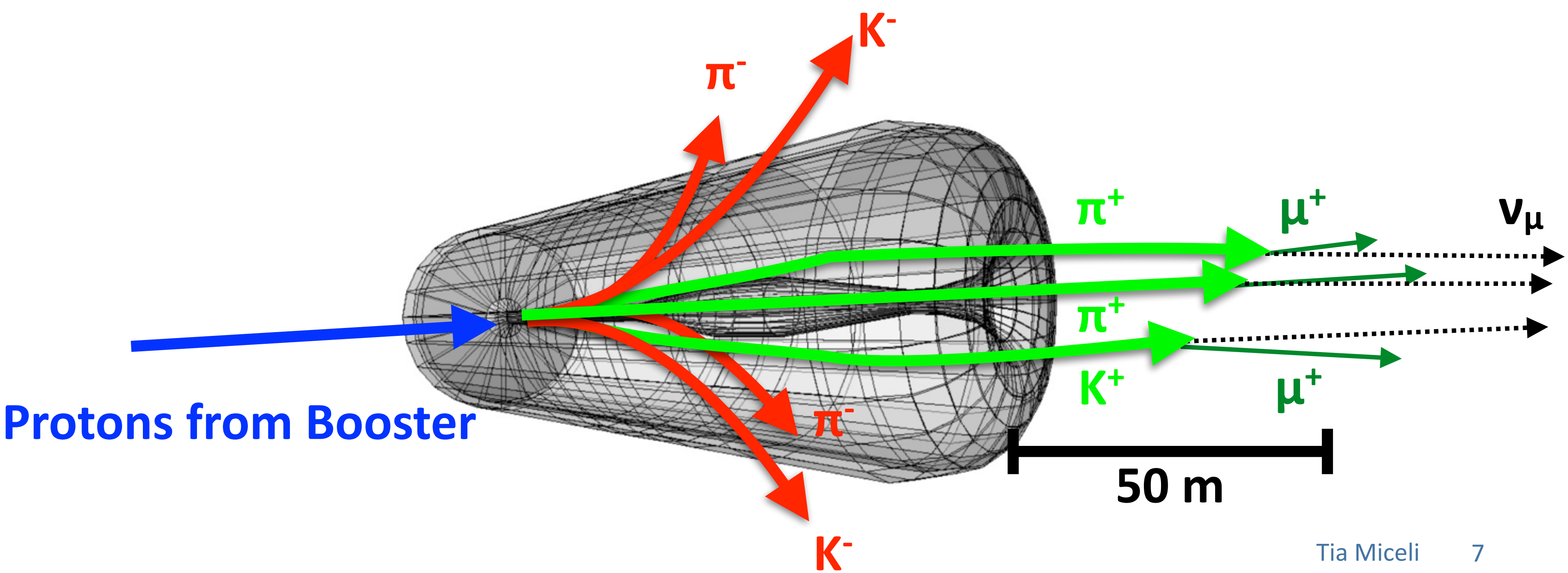
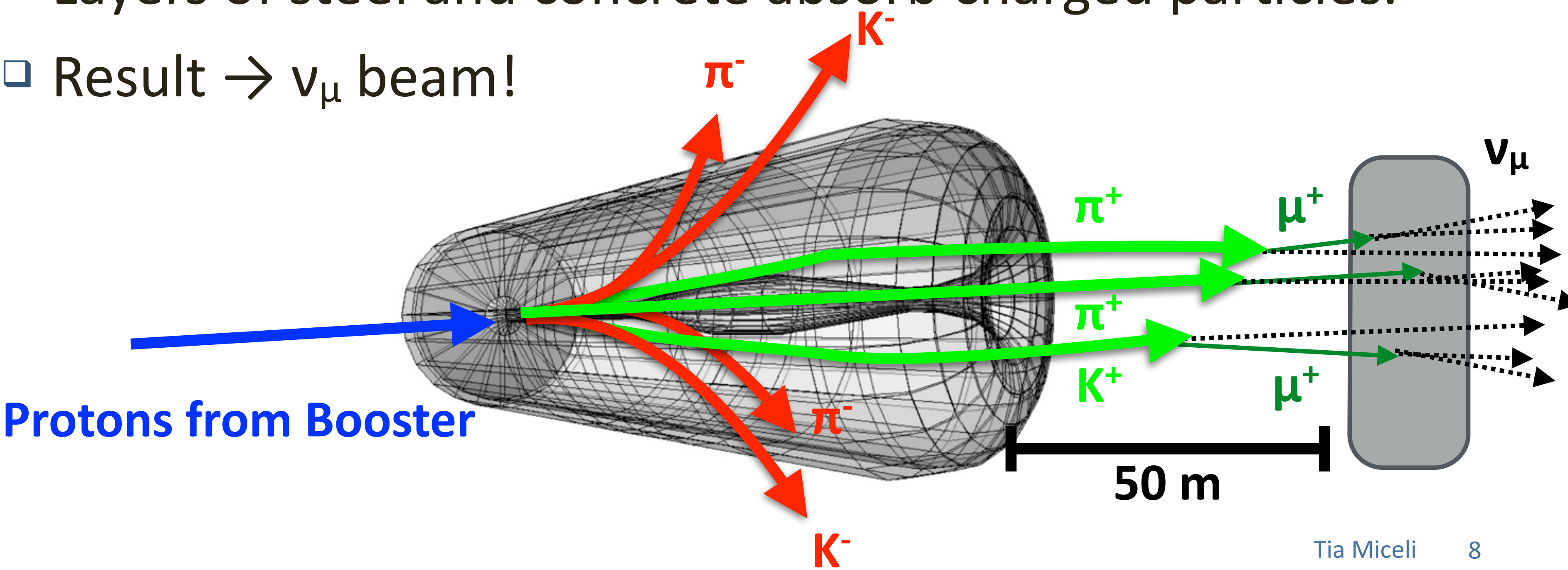
- 50 m decay pipe for π^+ and K^+ decay to primarily μ^+ and ν_μ.



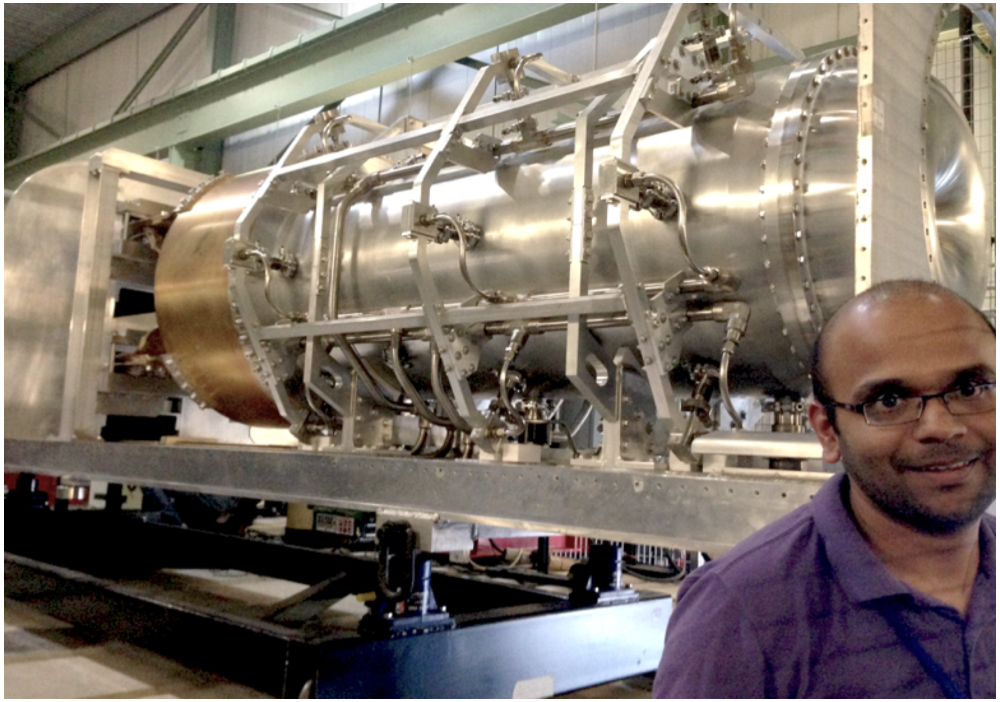
The BNB horn

- Protons hit beryllium target producing many mesons.
- The magnetic field of the horn focuses positive mesons and defocuses negative mesons.
- 50 m decay pipe for π^+ and K^+ decay to primarily μ^+ and ν_μ.
- Layers of steel and concrete absorb charged particles.
- Result → ν_μ beam!



BNB horn replacement

- Accelerator Division has successfully replaced the BNB horn and is in the process of commissioning it.
  - Horn had been in service since 2004.
  - Horn had been pulsed 400M+ times (twice its design, setting a world record!)
- Decision was made to replace horn after several cooling lines became clogged last year.
- The new filtering system is now more robust against introducing debris.



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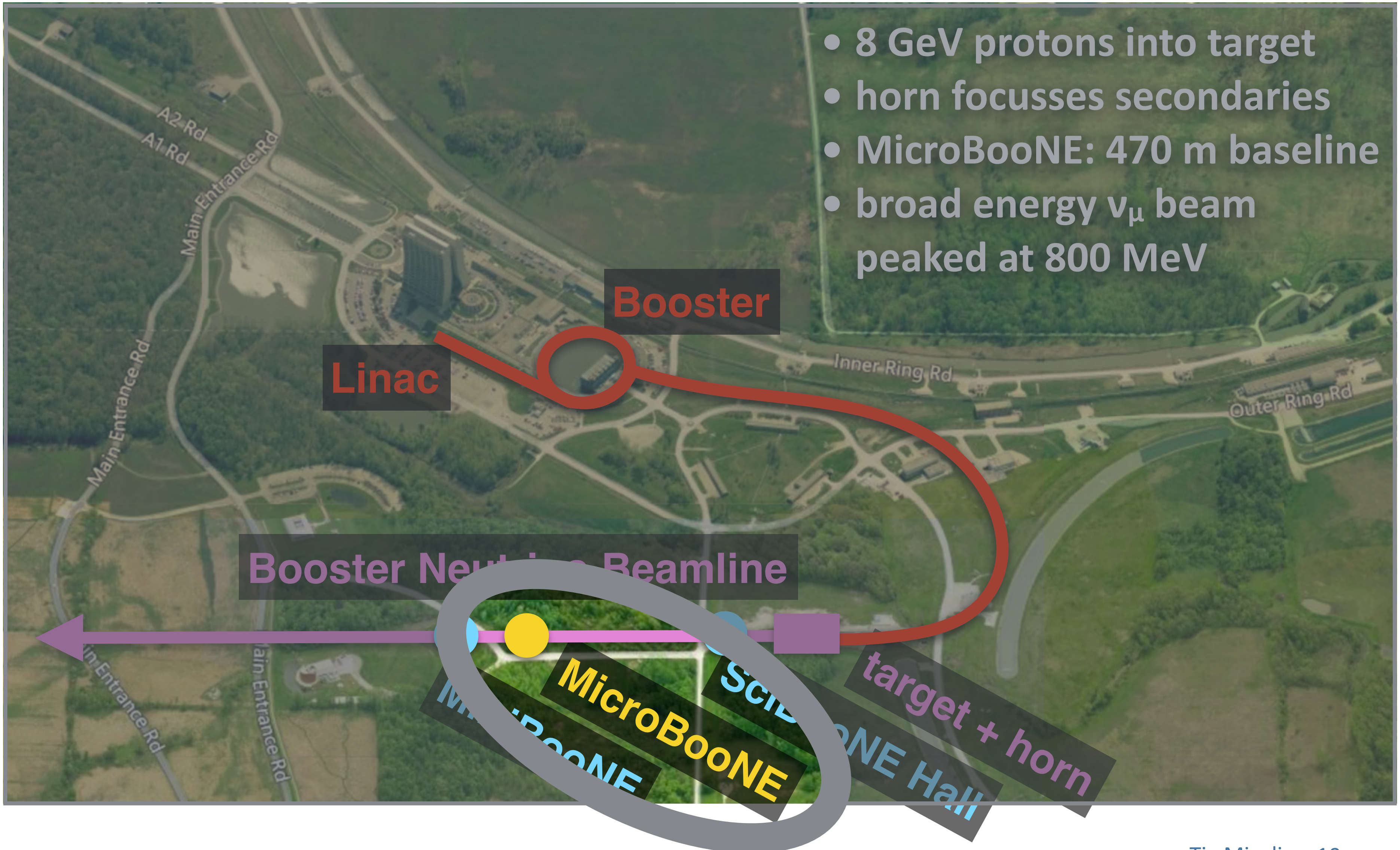
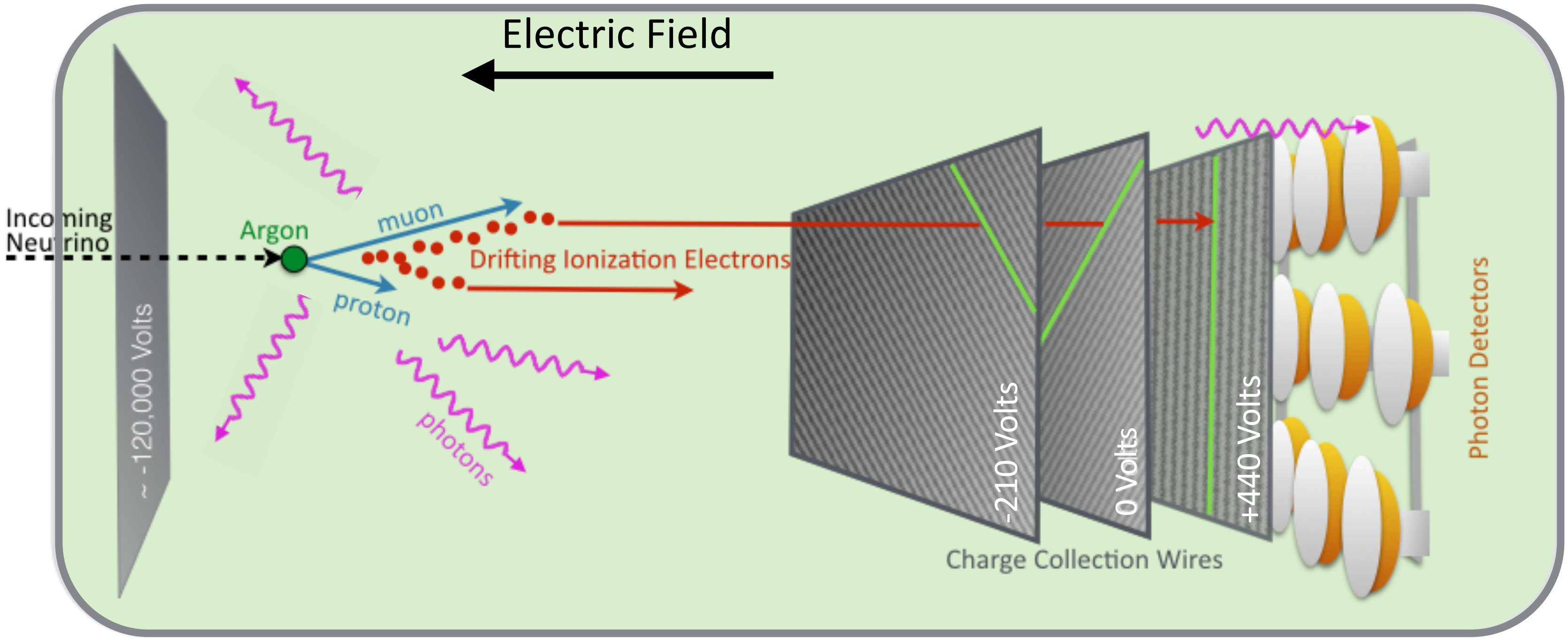


MicroBooNE- 170-ton LArTPC

1. Neutrinos from beam interact with an argon atoms.
2. Charged particles from the interaction excite/ionize surrounding LAr.
3. Scintillation light detected by photomultiplier tubes (PMTs) **(~few ns)**.
4. Ionization electrons drifted by electric field to collect on wires **(1.6 ms)**.



Inside MicroBooNE

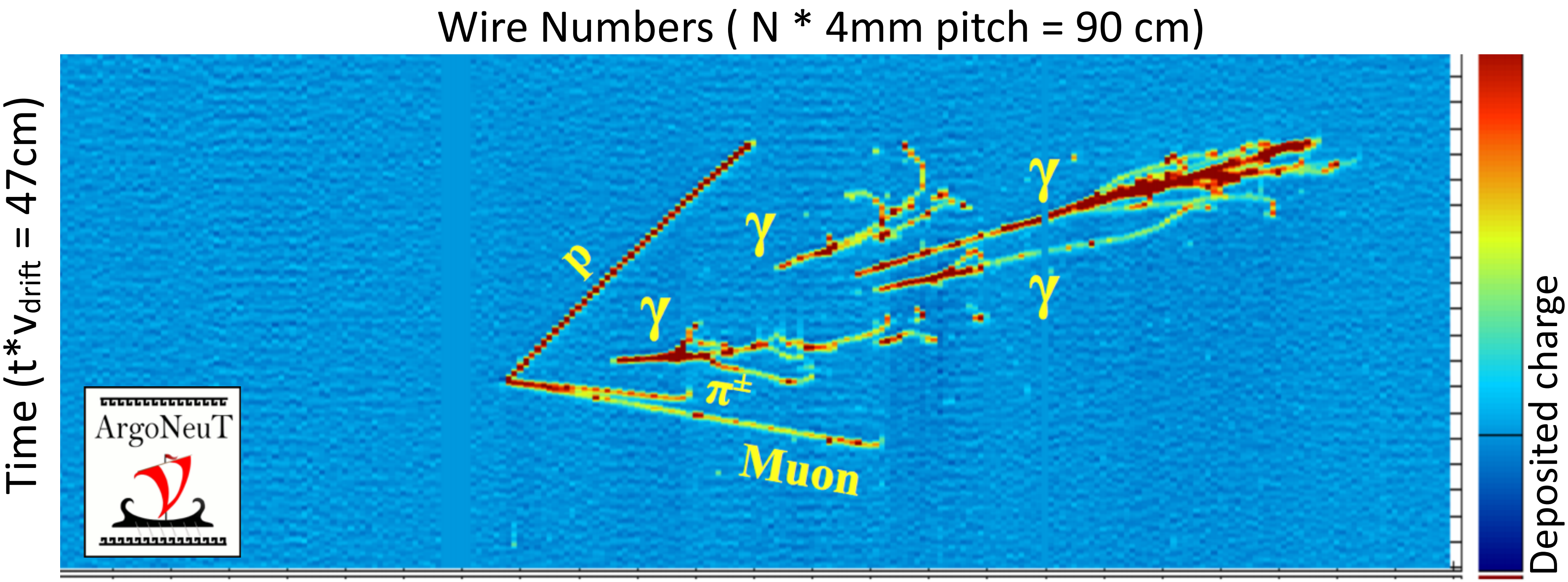
Why liquid argon?

Courtesy of M. Soderberg	He	Ne	Ar	Kr	Xe	Water
Boiling Point [K] @ 1atm	4.2	27.1	87.3	120	165	373
Density [g/cm^3]	0.125	1.2	1.4	2.4	3	1
Radiation Length [cm]	755.2	24	14	4.9	2.8	36.1
dE/dx [MeV/cm]	0.24	1.4	2.1	3	3.8	1.9
Scintillation [γ/MeV]	19,000	30,000	40,000	25,000	42,000	
Scintillation λ [nm]	80	78	128	150	175	
Approx. Cost [$/kg]	52	330	5	330	1200	

- Heavy target.
- Cheap.
- Transparent to drifting electrons.
- Transparent to own scintillation light.
  - Strict limits on impurities to maintain these transparencies.

What do collisions look like?

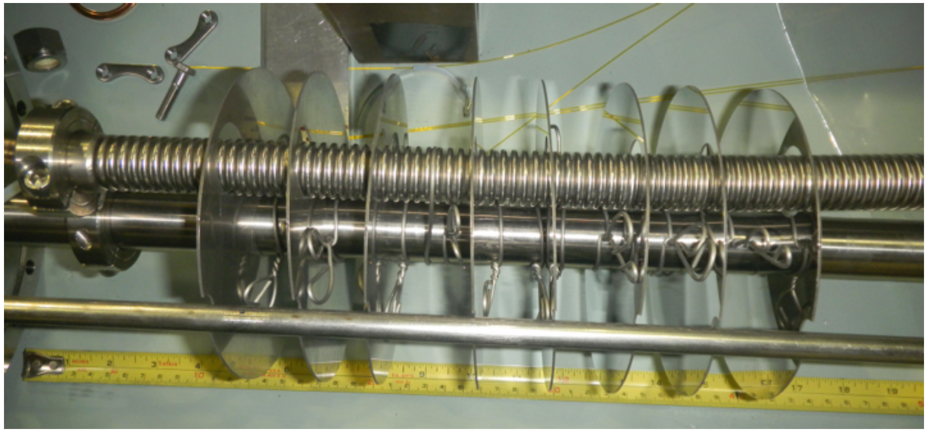
- Example of an event from Fermilab's ArgoNeuT LArTPC.



Inside of MicroBooNE

- Ultra purified liquid argon.
  - Impurities continuously filtered and monitored.
- Requirements to drift a MIP track 2.5 m (or else the e^- is absorbed!)
  - < 100 ppt O_2 equivalent
- Requirements for photon detection (or else the γ is absorbed!)
  - < 1 ppm N_2

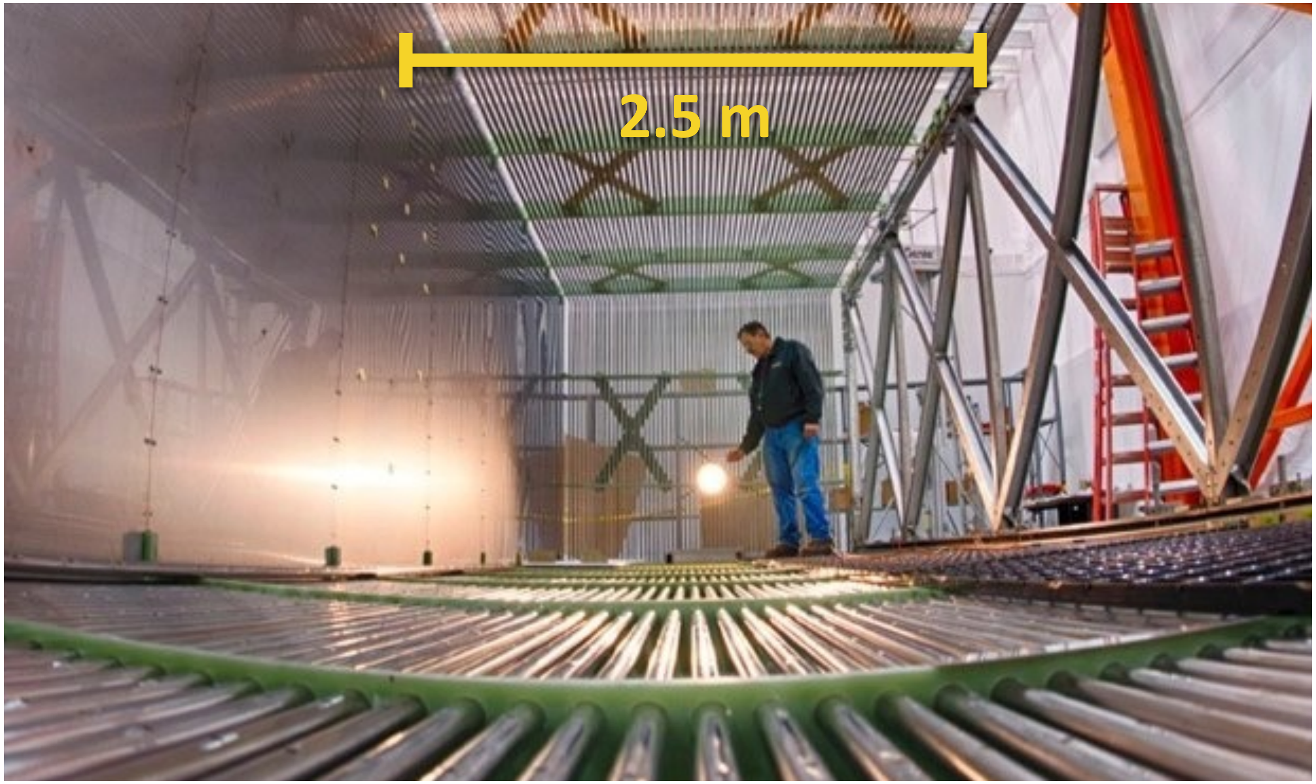
Purity Monitor Drift Region



Sharks need to smell at least 1 ppm blood to hunt its prey!

Inside of MicroBooNE

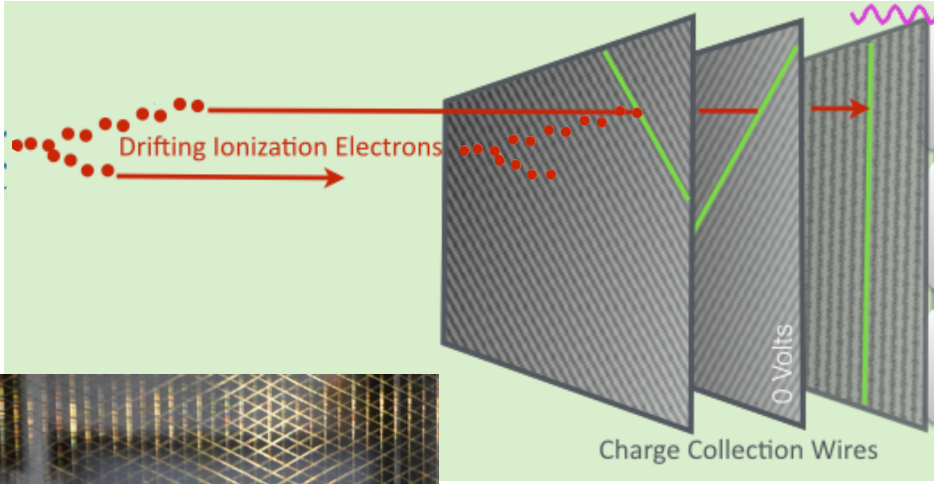
- Strong electric field
  - −120 kV across 2.5 m drift distance.
- Large drift distance → more target volume per instrumentation area → $$ efficient
- Challenges:
  - LAr purity
  - High voltage

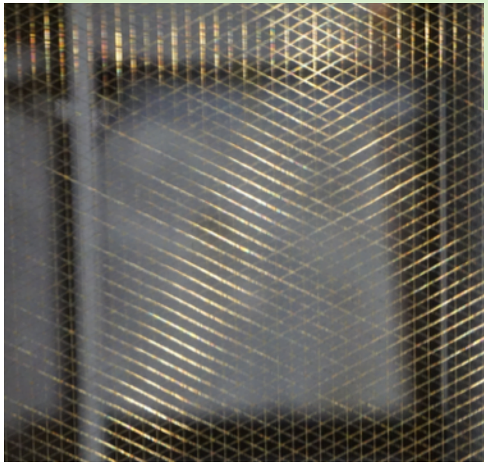


Longest drift distance in a ν beam!

Inside of MicroBooNE

- Three wire planes to sense ionization electrons.
  - 8,256 wires!

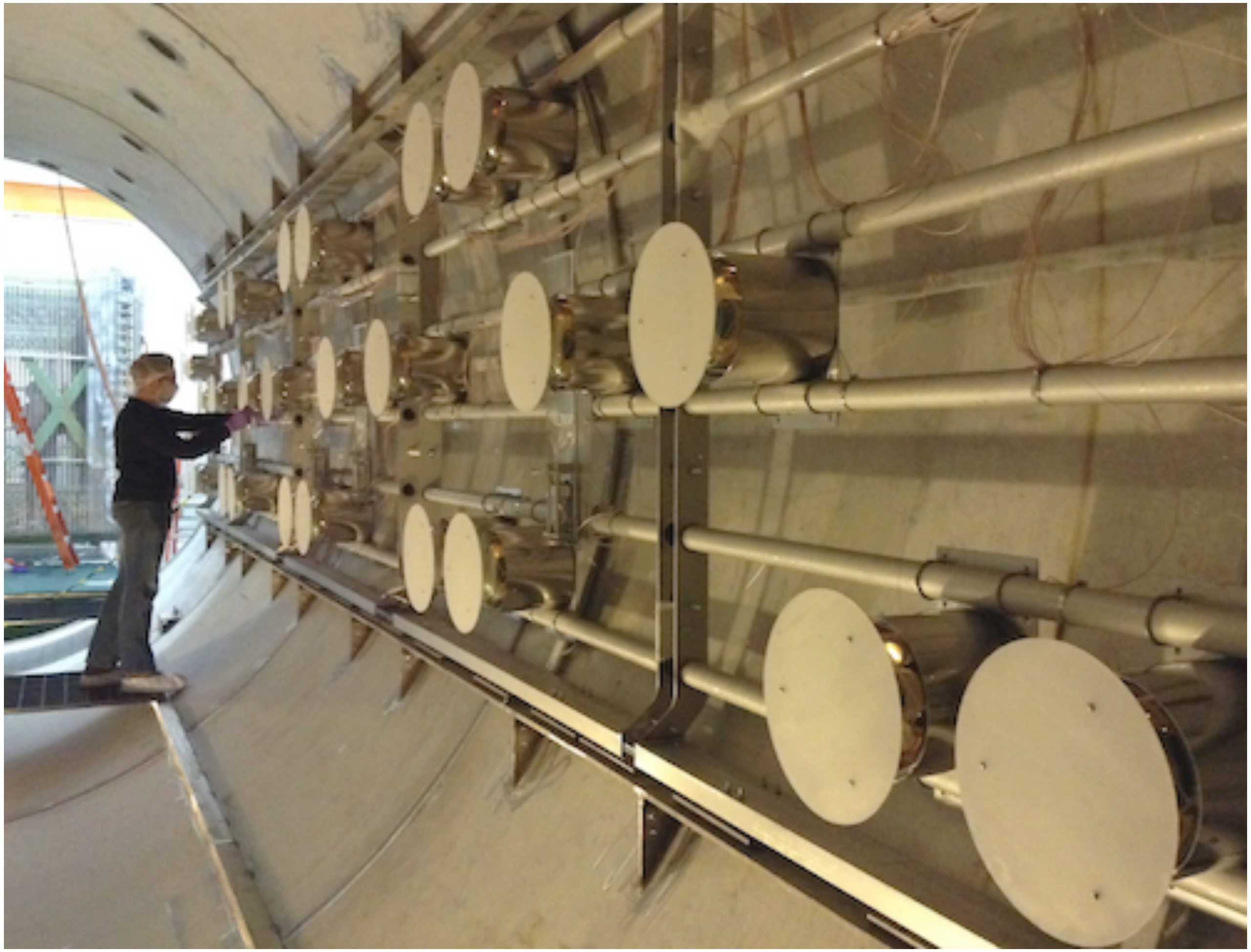


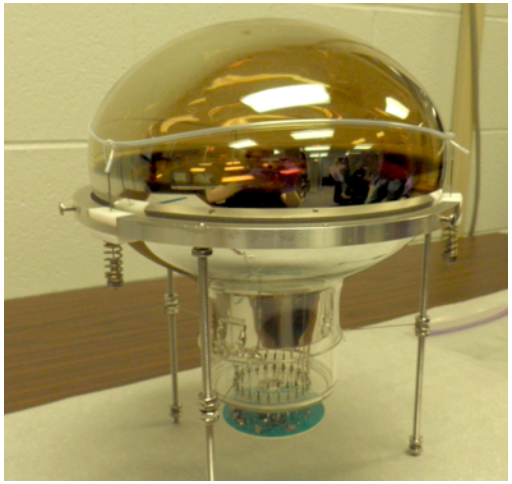


3 mm pitch

Inside of MicroBooNE

- 32 PMTs to collect scintillation light.
  - Provide trigger, drift time.





Liquid argon is invisible to its own scintillation light.

Publications already growing!

- Proposals for hardware and physics.
- Technical investigations.

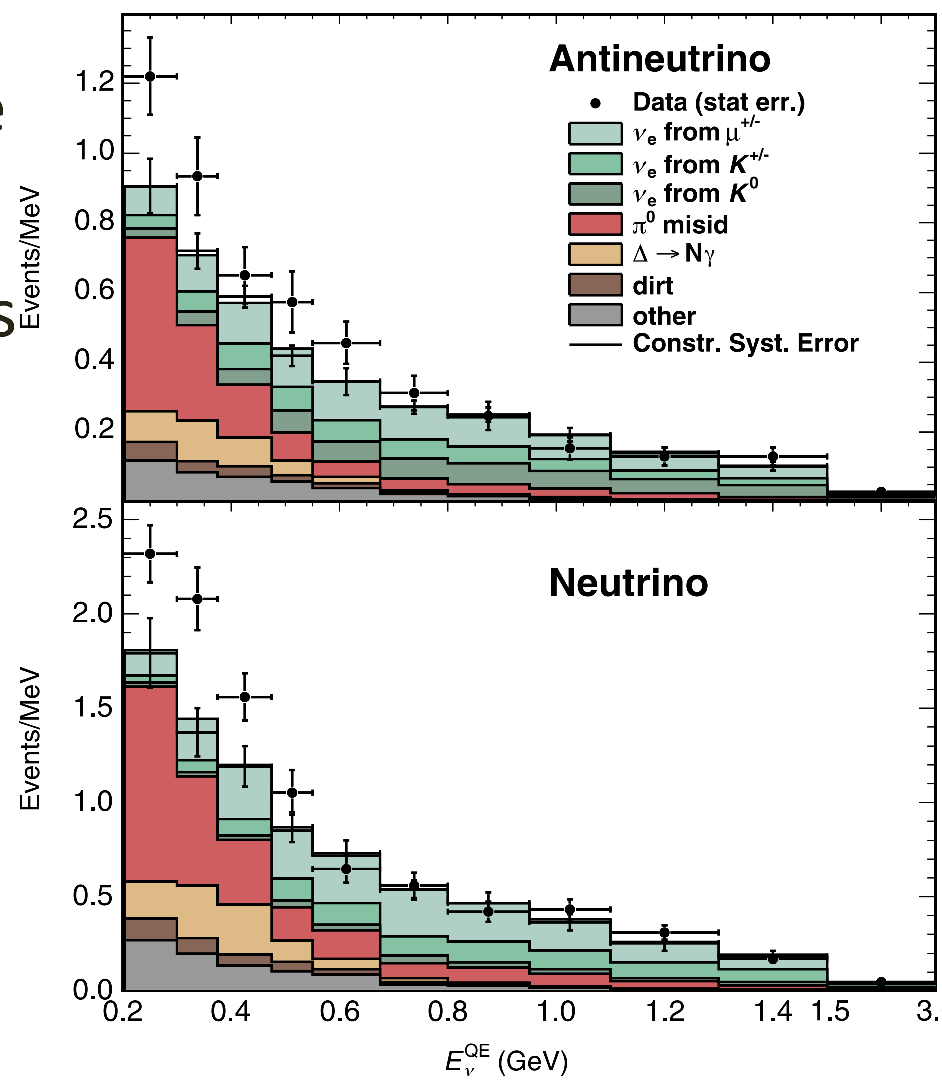
Related Publications by MicroBooNE Collaborators:

- 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)

Physics Goal 1: Investigate MiniBooNE Excess

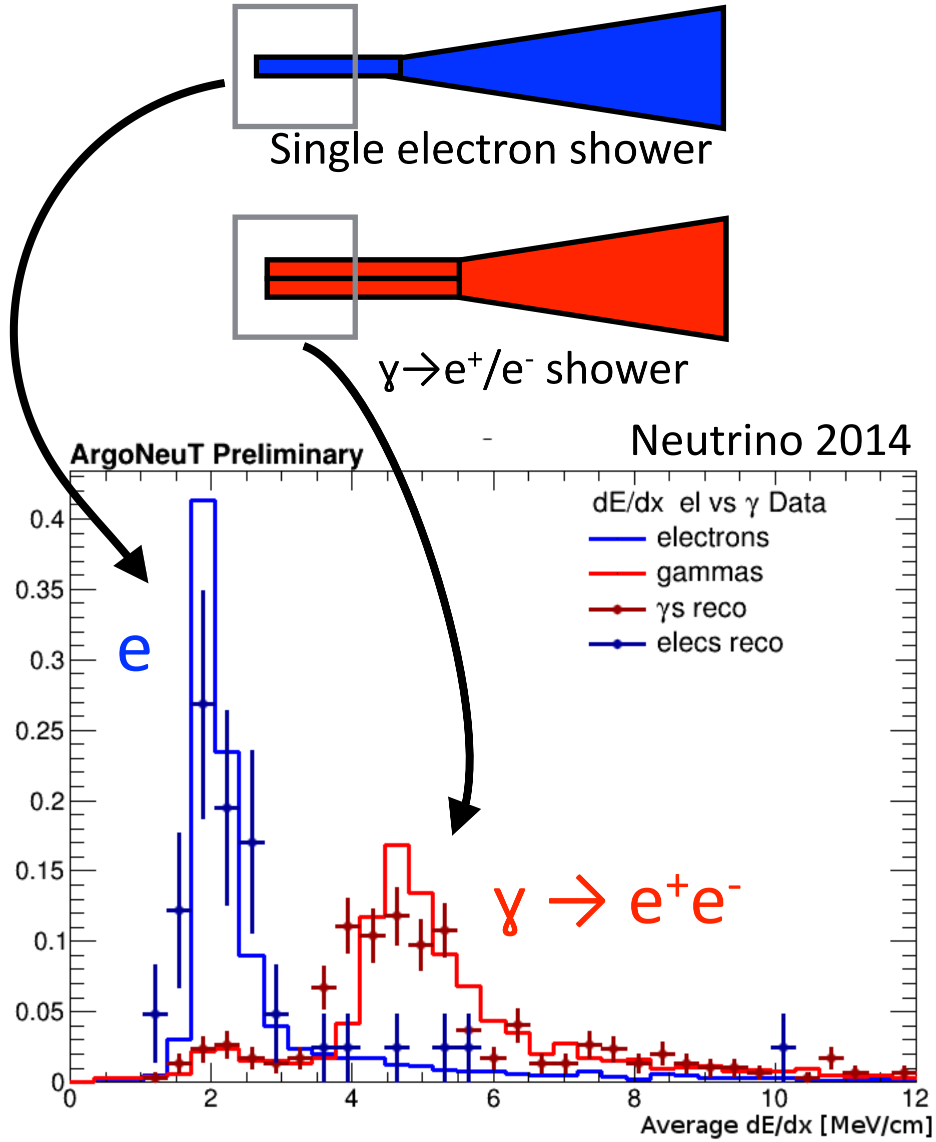
- MiniBooNE saw an excess of low-energy ν_e-like and $\bar{\nu}_e$-like events.
- Cherenkov detectors, such as MiniBooNE, cannot distinguish between a Cherenkov ring from e or γ.
- We want to determine the source of this electromagnetic excess.

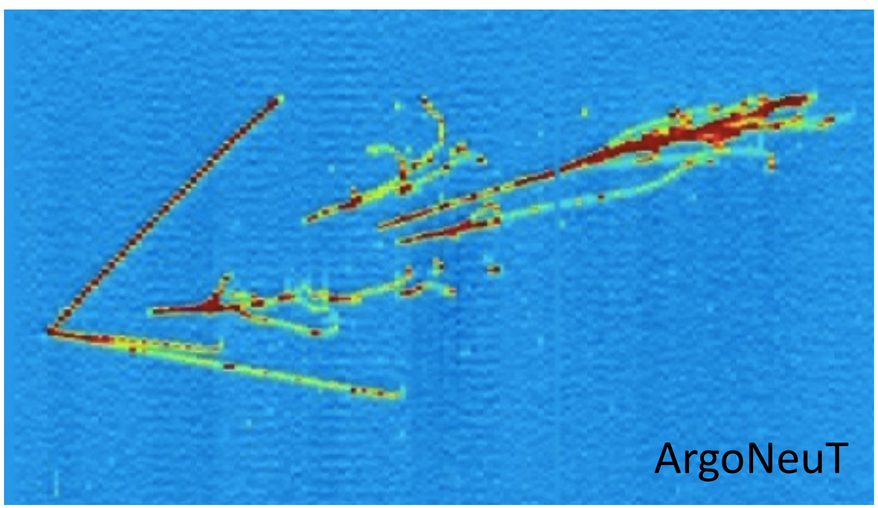
MiniBooNE Electron Neutrino Energy



Physics Goal 1: Investigate MiniBooNE Excess

- MicroBooNE's LArTPC technology was specially chosen for its excellent e/ɣ identification capabilities.





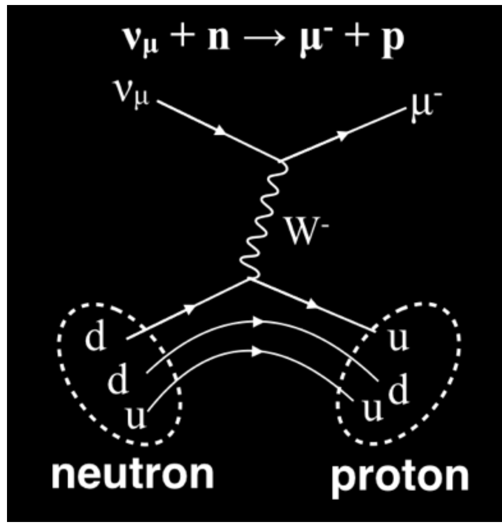
Physics Goal 1: Investigate MiniBooNE Excess

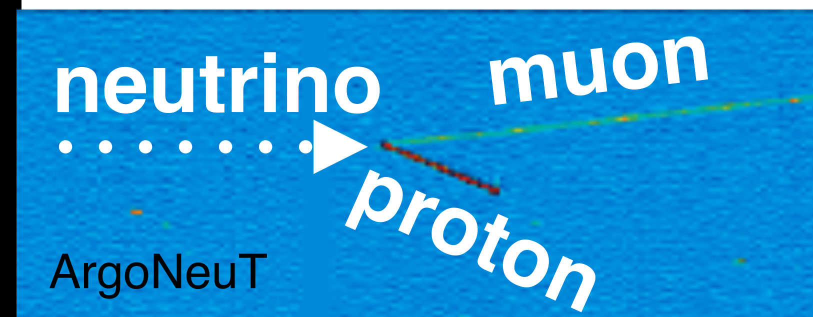
- If excess is due to photons:
  - MicroBooNE will make the first measurements of a novel photon production mechanism.
  - This mechanism would then need to be included in MC generators and this would impact all future ν_e appearance experiments!
- If excess is due to electrons:
  - Is MicroBooNE seeing oscillations of a new sterile neutrino!?
  - Some other novel production mechanism?

Physics Goal 2: Cross-section measurements

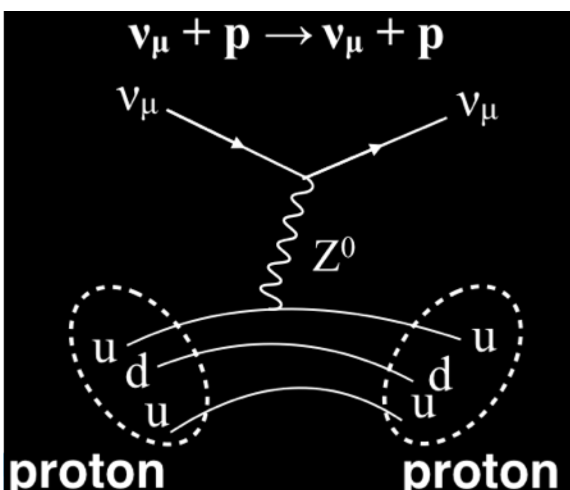
- We will make high-statistics measurements of neutrino-argon cross-sections.

Charged Current





Neutral Current



… and many more complicated topologies…

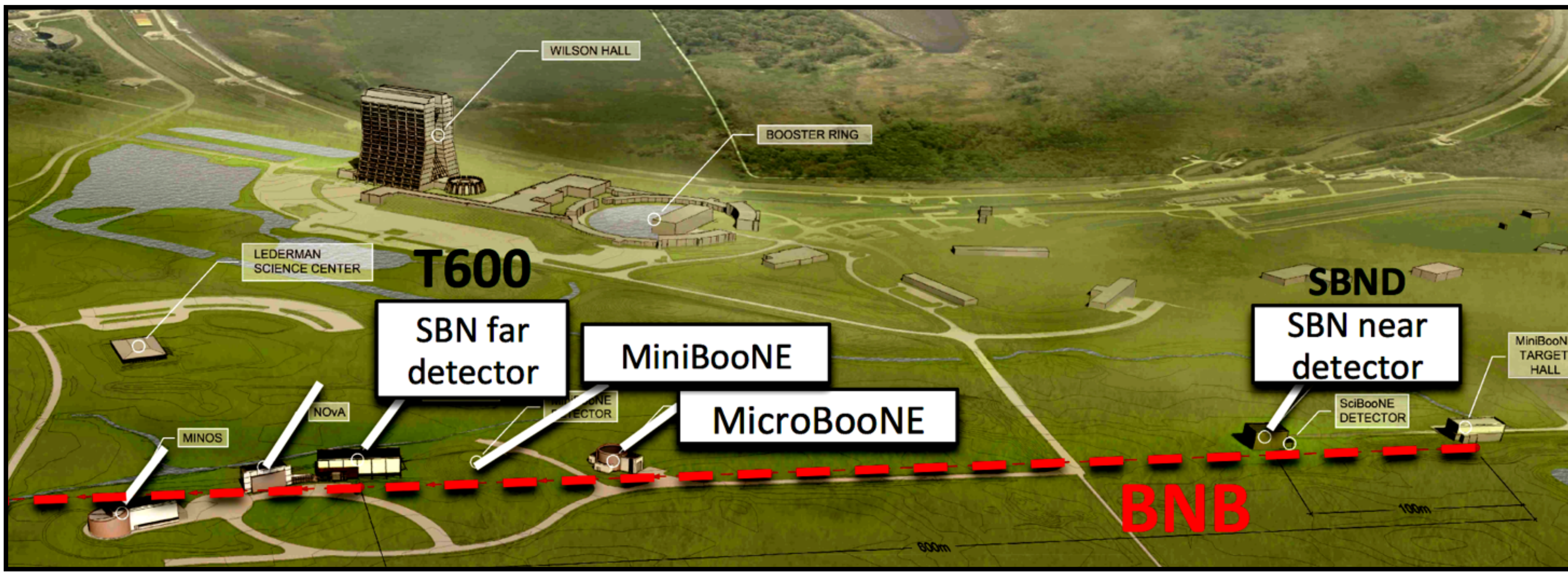
Physics Goals 3 & 4

- MicroBooNE's supernova data stream buffers all of the MicroBooNE data to be read out if SNEWS gives an alert.
- MicroBooNE also serves as an excellent tool to study background to proton decay experiments
  - Cosmogenic kaons: $K^0_L + p \rightarrow K^+ + n$

$$p \xrightarrow{?} K^+ + \bar{\nu}$$

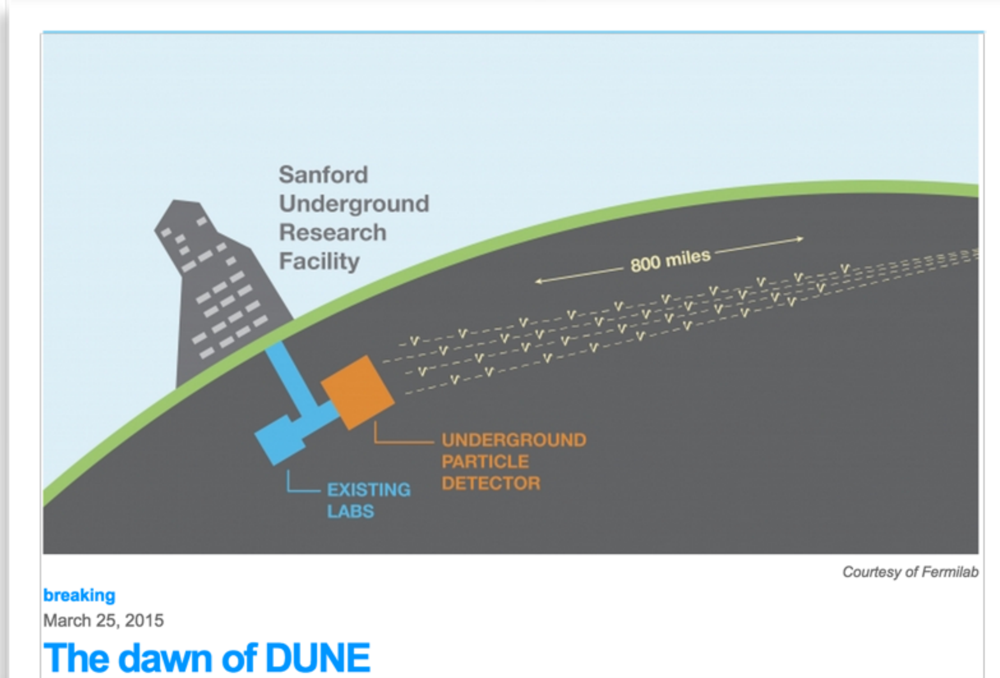
Physics Goal 5: Collaborate on SBN program

- MicroBooNE serves as the first of Fermilab's three-detector Short Baseline Neutrino (SBN) oscillation program.
  - More details on this in the following talk from Joseph.

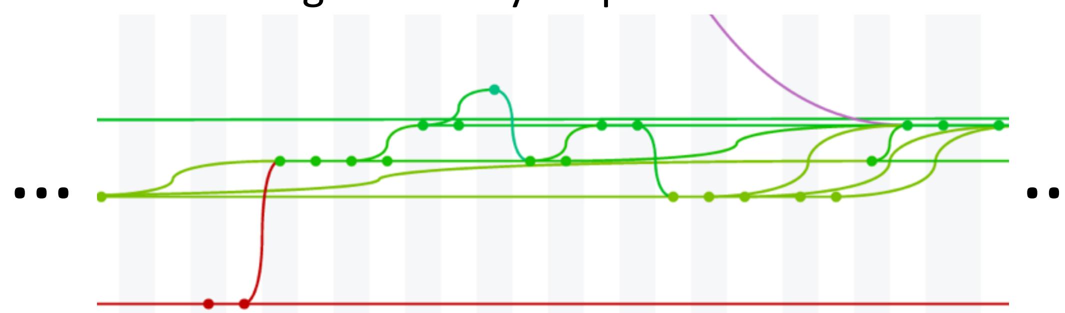


Technical Goals

- Test LArTPC technology at a scope and scale to inform the design and operation of future, larger LArTPCs.
- Develop extensive reconstruction algorithms to be used by all LArTPCs at Fermilab.
  - 1660+ commits in uboonecode



Selected git “subway map” of branch commits



What have we been up to this year?

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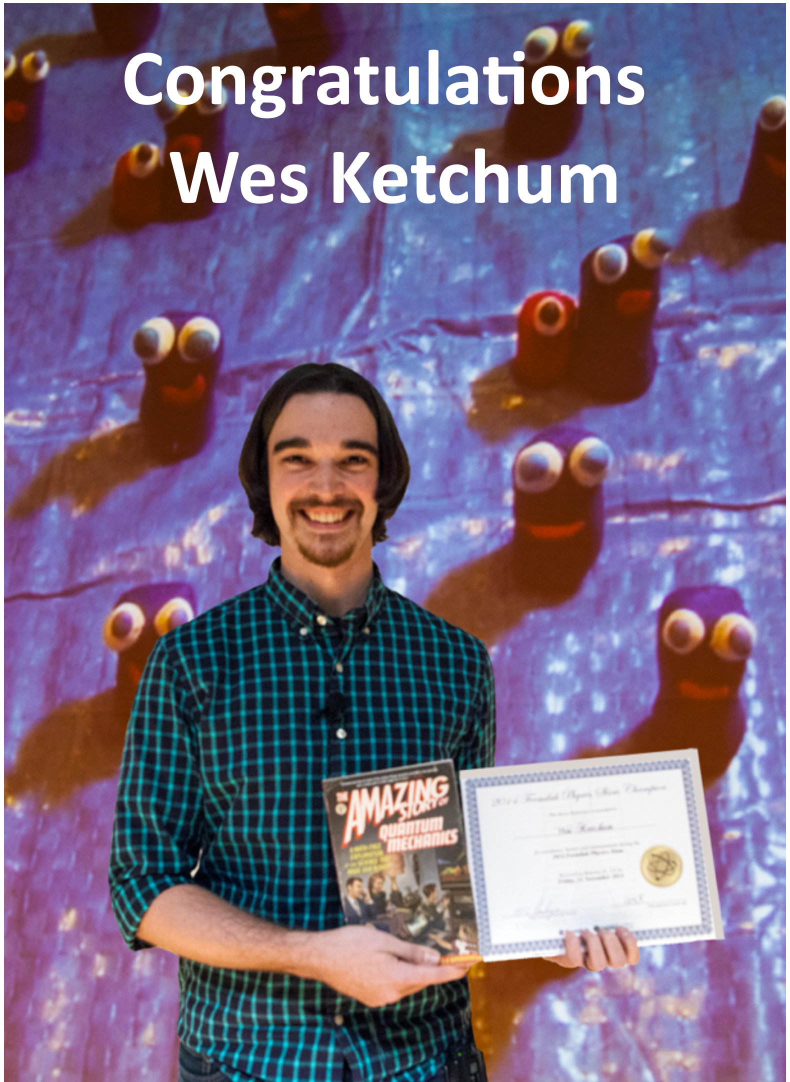
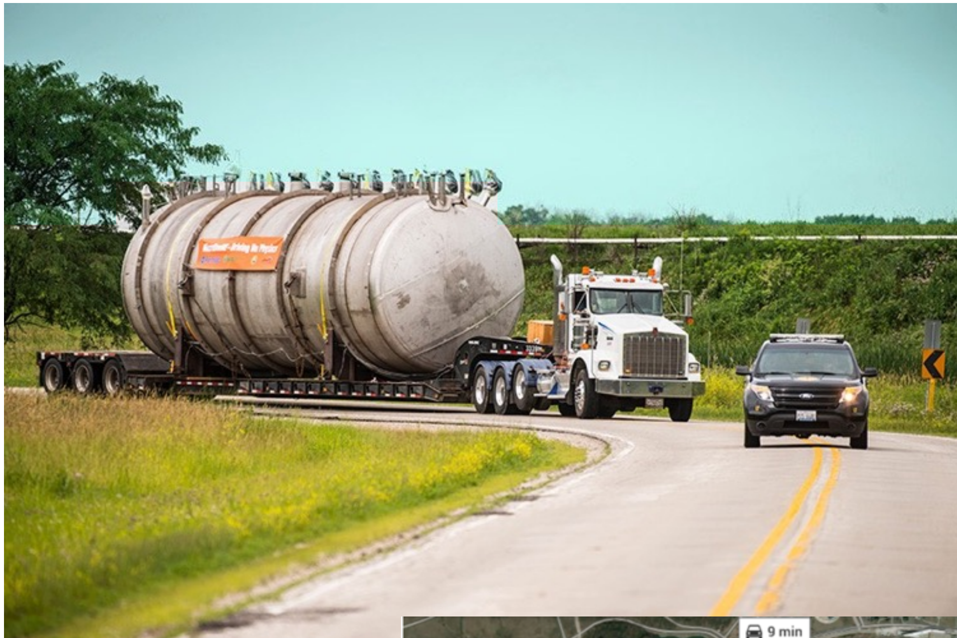


Well, another one of our collaborators won the **Fermilab Physics Slam**… but besides that…

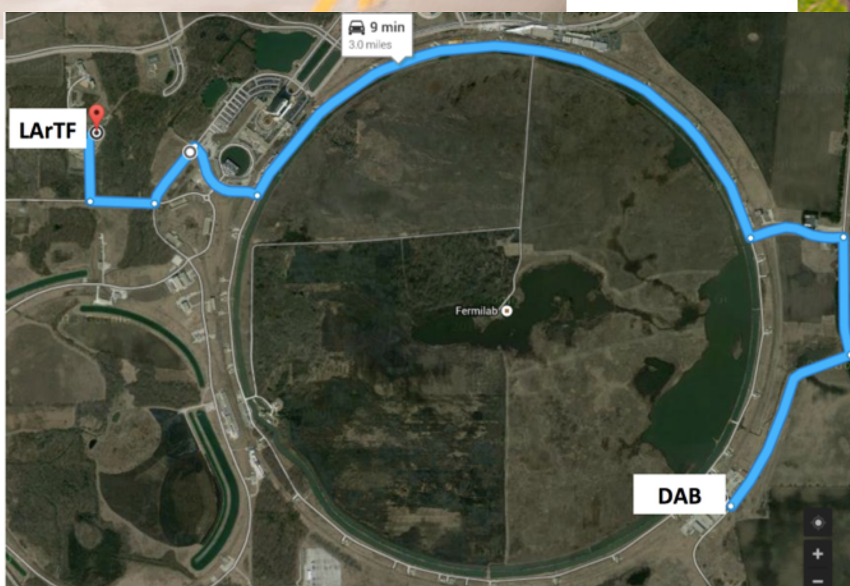
Fermilab Physics Slam Winners	
Accelerators	1
Dark Energy Survey	1
MicroBooNE	2
Others	0

The Built MicroBooNE Detector Moved: June 23, 2014



Press Release **Fermilab Today**

Massive MicroBooNE particle detector moved into place; will see neutrinos this year



30-ton MicroBooNE neutrino detector is gently
red into the Liquid-Argon Test Facility at
ilab on Monday, June 23. The detector will
me the centerpiece of the MicroBooNE
riment, which will study ghostly particles called
inos. *Photo: Fermilab*

MicroBooNE Insulation Installed: July 21-29, 2014

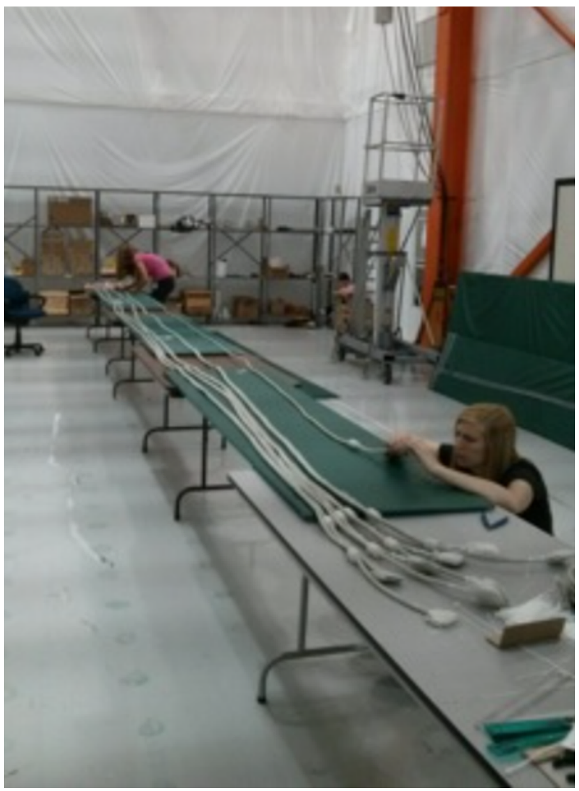
- Cryostat was insulated with 16” of spray foam.

- Welded pipe assemblies to the cryostat.

http://www-microboone.fnal.gov/aem/talks/uBAEM20140811.pdf

Cabling up MicroBooNE: Summer-Fall 2014

- Last year, summer students helped build cables.



- Over the next months, we connected up the detector and electronics racks.
  - 6.2 km of cable deployed!
  - Yes, those labels will never fall off!

http://www-microboone.fnal.gov/aem/talks/uBAEM20140811.pdf

Electronics Racks Installed: Sep-Nov 2014

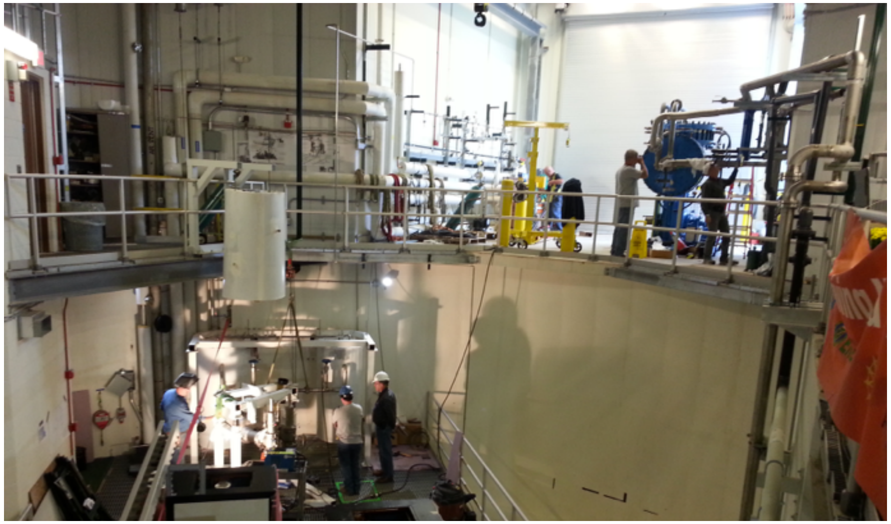
- Racks of electronics successfully passed the partial Operational Readiness Clearance (ORC).
  - Brought over from D0 and installed on top of cryostat at LArTF.
- After installation at LArTF, racks passed full ORC review.

http://www-microboone.fnal.gov/aem/talks/MicroBooNE_AEM_08Sep2014.pdf

http://www-microboone.fnal.gov/aem/talks/AEM_111714.pdf

Cryogenics Installation: Summer-Fall 2014

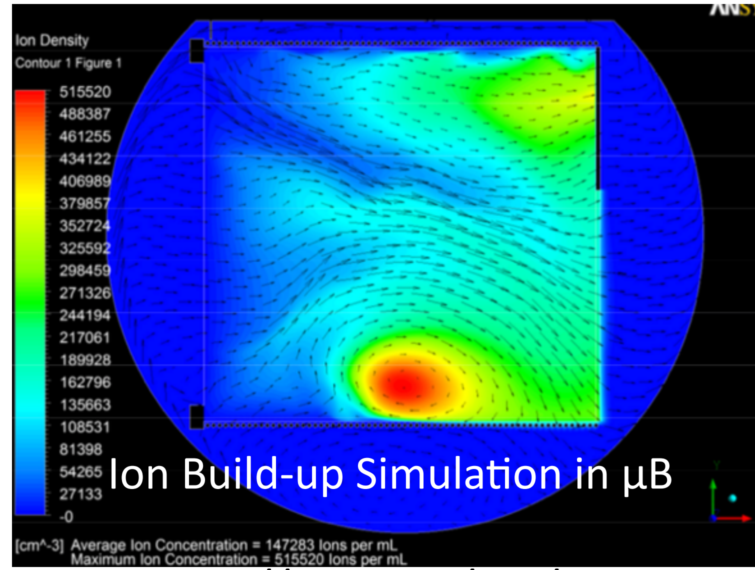
- All piping was installed, welded, leak checked, insulated, and is now starting to run.
  - Nearly 200 m of piping was installed!



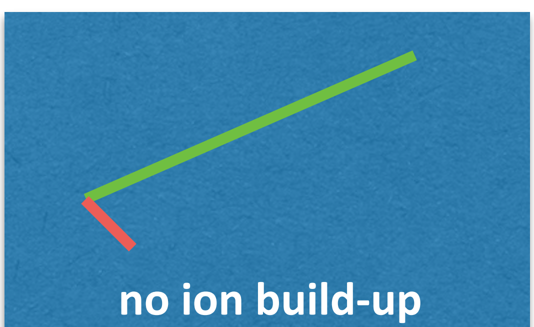
http://www-microboone.fnal.gov/aem/talks/aemMicroBooNE120814.pdf

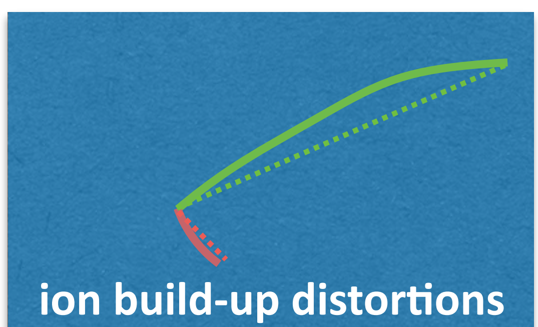
UV Laser System Installed: Dec 2014

- Bern Collaborators installed UV Laser System in December.
- Since MicroBooNE will have a high cosmic ray flux, we expect ions to build up near the cathode plane.
- UV laser allows us to map E-field and correct our tracking software.



http://arxiv.org/abs/1406.6400



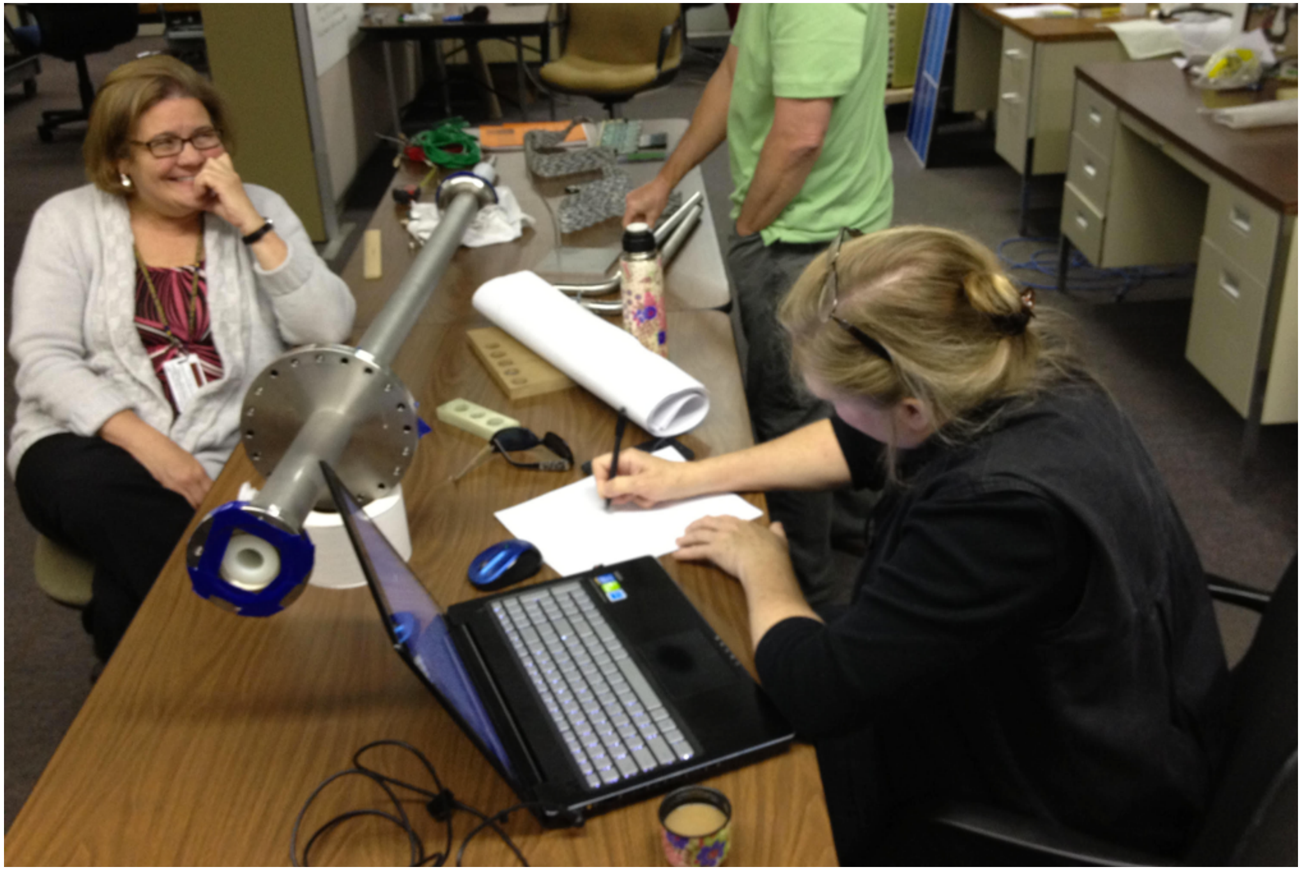


Feature **Fermilab Today**

UV laser calibration system installed in MicroBooNE

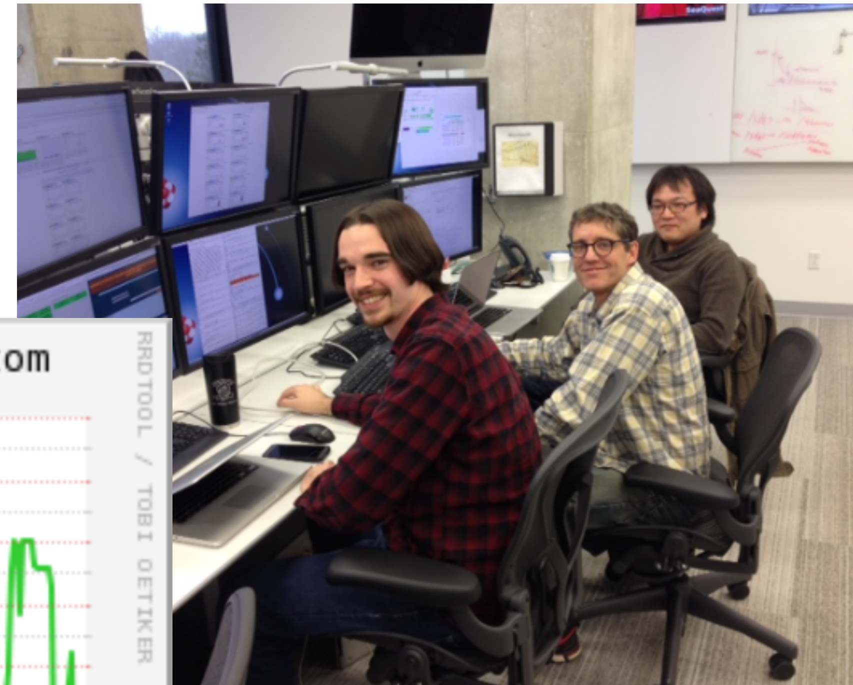
DOE MicroBooNE Project Complete!: Dec 22, 2014

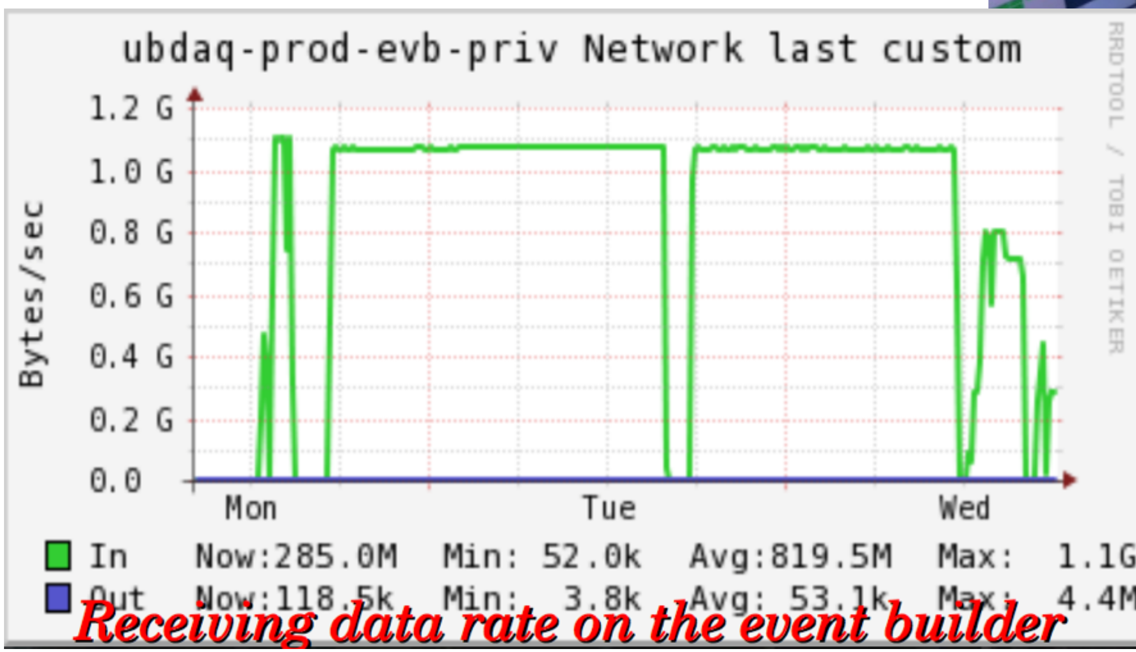
- The DOE MicroBooNE Project consisted of:
  - Design, fabrication, and installation of the MicroBooNE detector
- All signatures collected for Critical Decision 4 (CD-4) on December 22!
- Moved onto "operations phase".



Commissioning Phase Noise Data: March/April 2015

- Successful data acquisition tests using our new control room at ROC West.





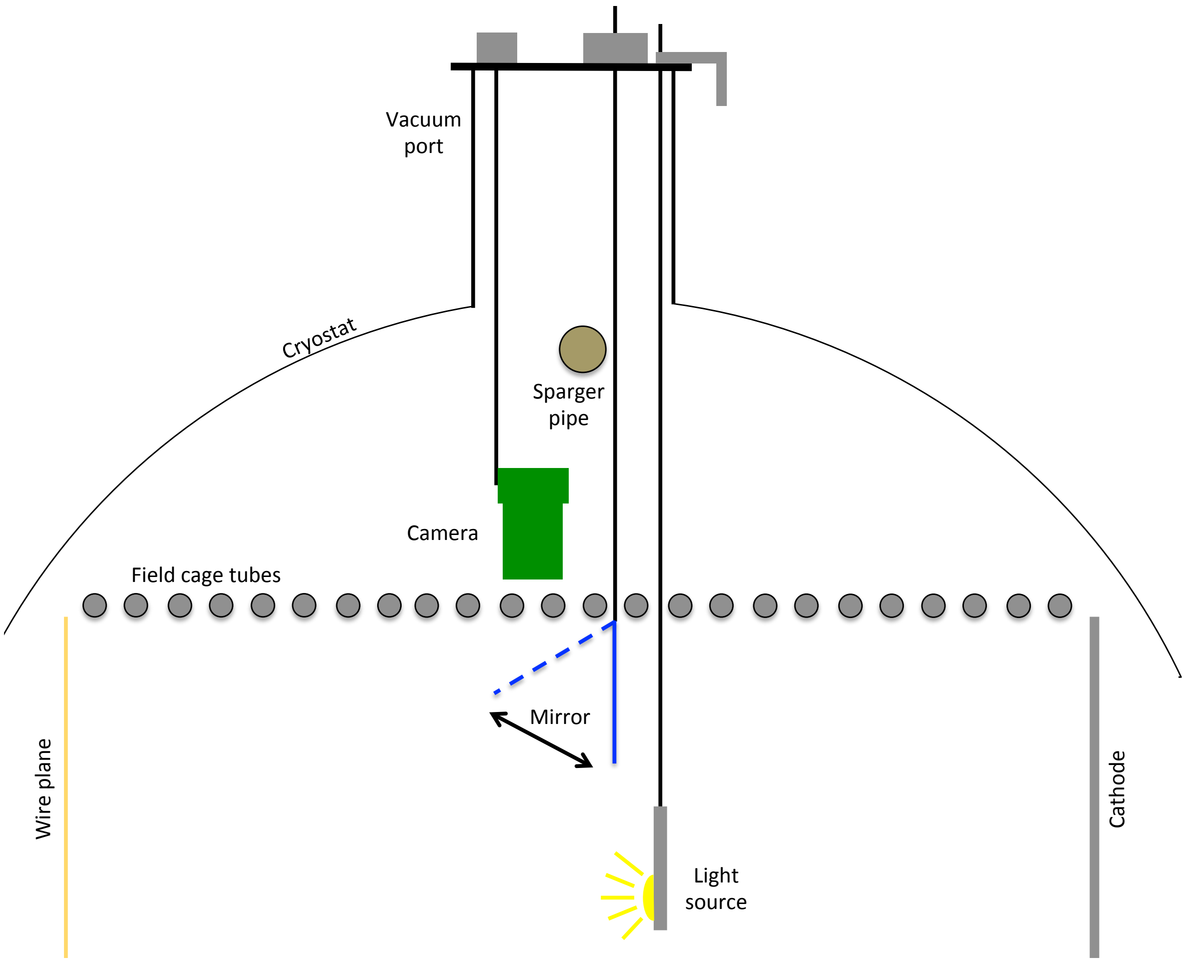
- 20 TB of noise data already collected!

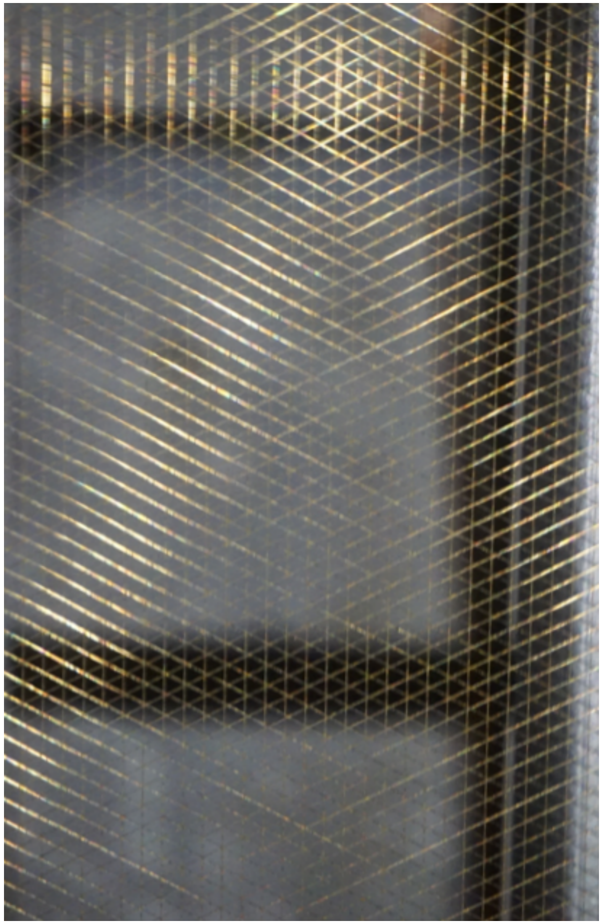
http://www-microboone.fnal.gov/aem/talks/AEM_MicroBooNE_020915.pdf

http://www-microboone.fnal.gov/aem/talks/AEM_MicroBooNE_20015_03_09.pdf

Seeing Inside the Cryostat: April 2015

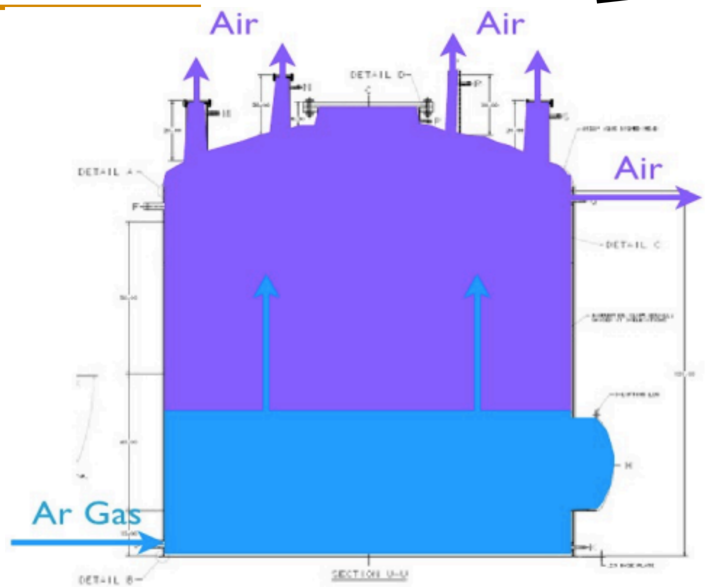
- To give confidence that the wires were healthy after our big move, we imaged inside the cryostat. Looks great!

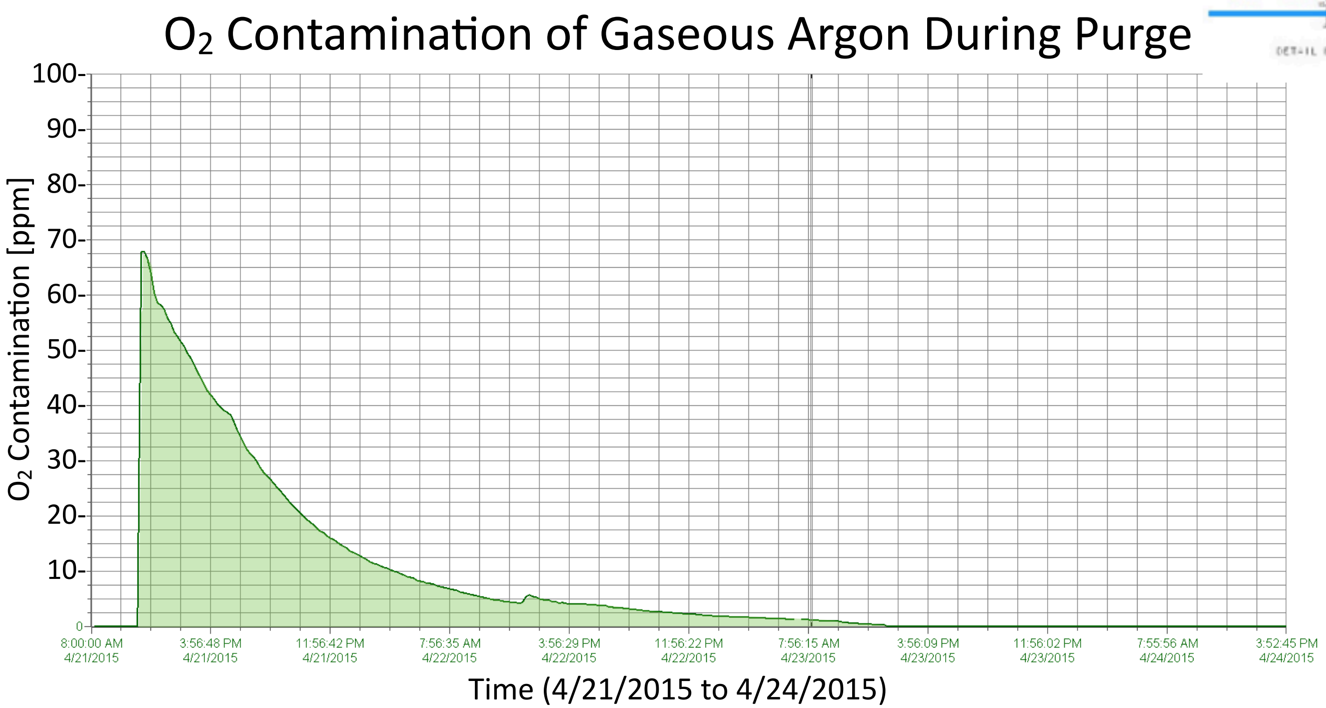




Cryostat Purge: April 2015

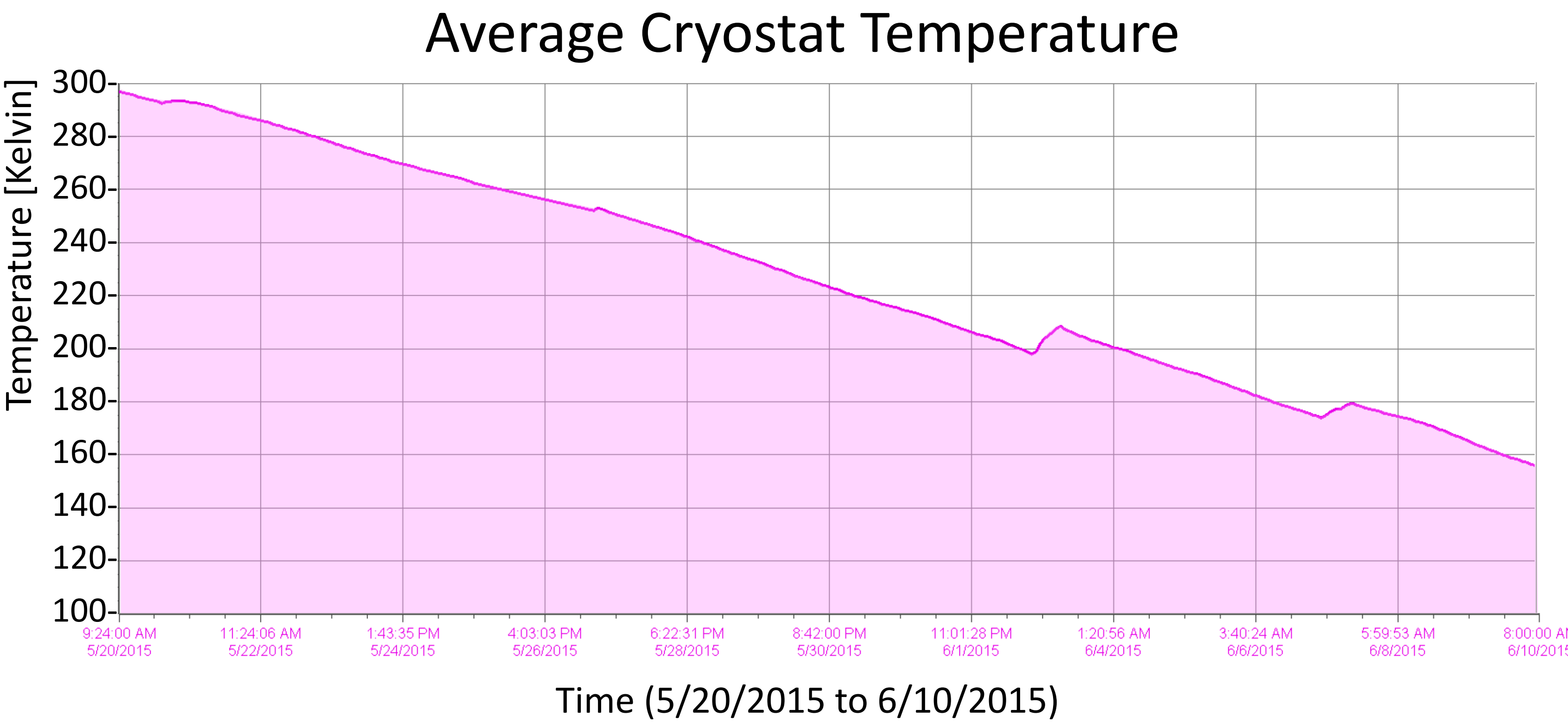
- Purge air out of cryostat by injecting gaseous argon from the bottom.
  - Thanks to LAPD for pioneering our procedure!





Cool-down: May 2015

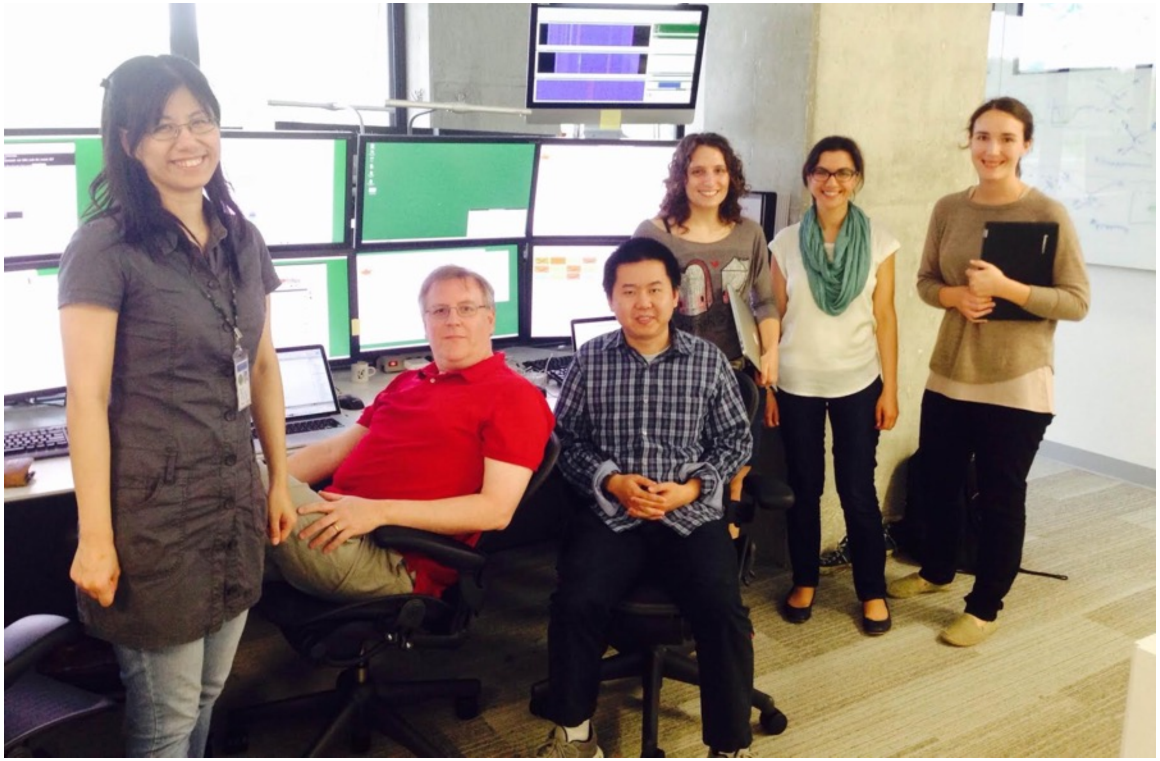
- The argon gas is cooled by running it through a liquid nitrogen heat exchanger.
  - We will start filling the detector with liquid argon in ~2 weeks.
  - It will take ~3 weeks to fill (170 tons of liquid argon ~12 truck loads).



Argon condenses at 87 K

Shifts Started!: June 1, 2015

- Currently monitoring our subsystems from ROC West.
  - Running the Data Acquisition System recording and analyzing noise data during cool-down and filling (only 2 weeks away!).
- We are excited to collect our first physics data!



Thanks!

We are very thankful for all of our supporters!