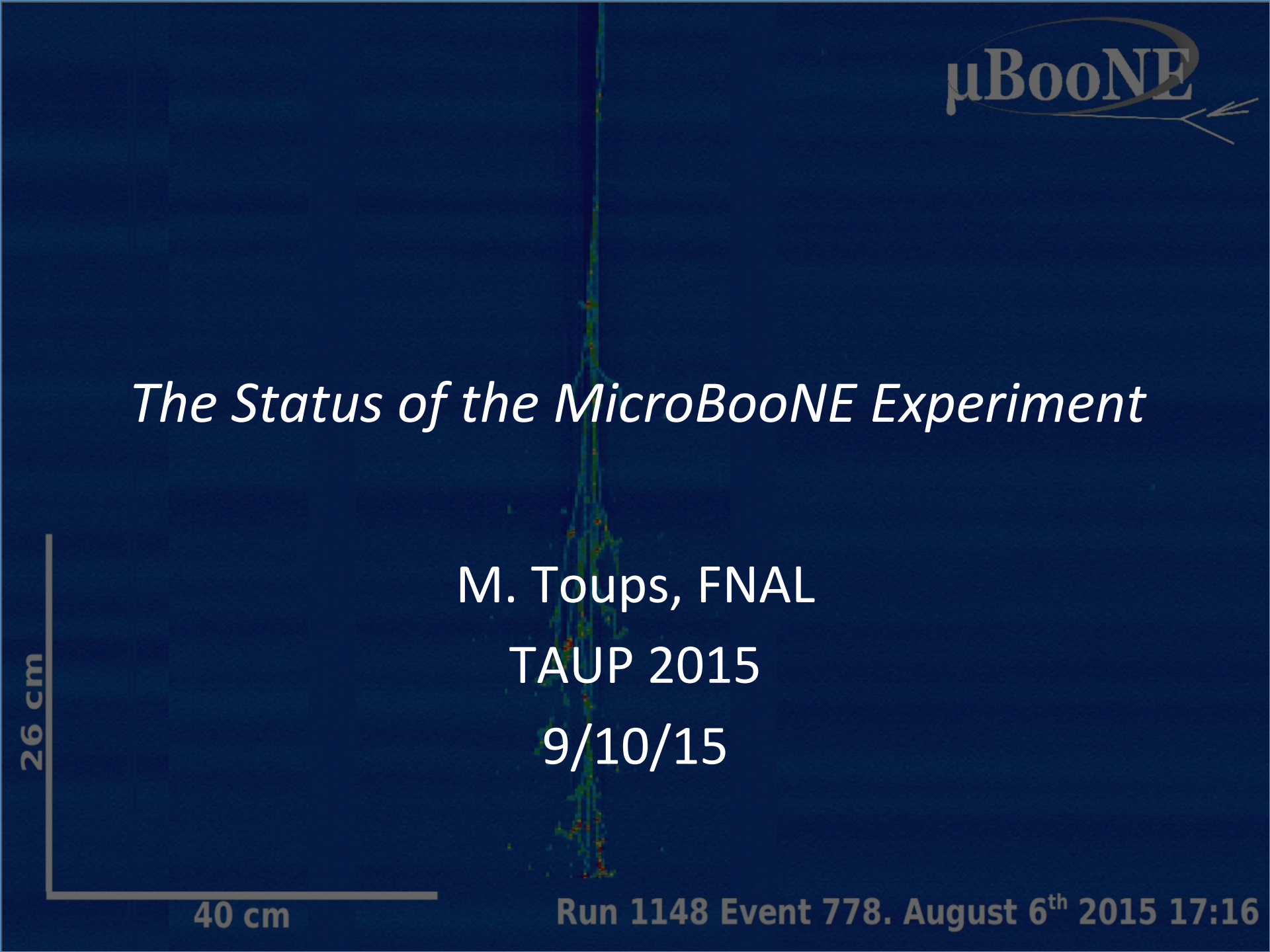
The Status of the MicroBooNE Experiment

M. Toups, FNAL

TAUP 2015

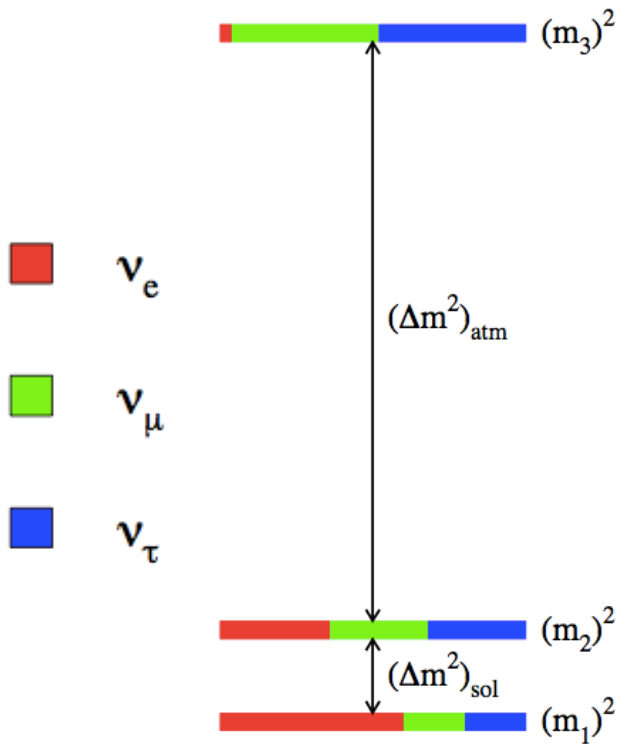
9/10/15



Outline

- Motivation
- The MiniBooNE Low Energy Excess
- The MicroBooNE LArTPC
- MicroBooNE Commissioning
- First Data From the MicroBooNE Detector
- Conclusion

Three-Neutrino Mixing Paradigm



"Normal"
Mass Ordering

$$|\nu_\alpha> = \sum_i U^*_{\alpha i} |\nu_i>$$

Neutrino Flavor Eigenstates | Unitary Mixing Matrix | Neutrino Mass Eigenstates

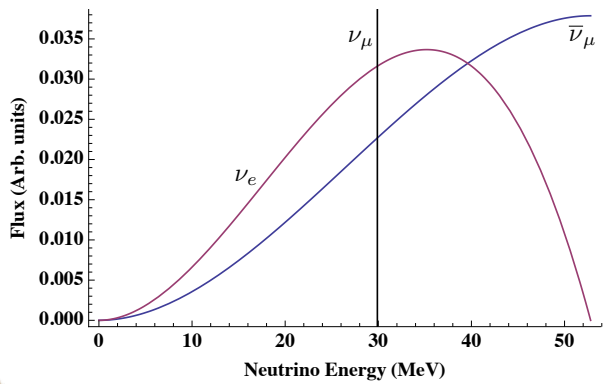
$$|U_{\alpha i}| = \begin{pmatrix} |c_{12}c_{13}| & |s_{12}c_{13}| & |s_{13}e^{-i\delta}| \\ |-s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta}| & |c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta}| & |s_{23}c_{13}| \\ |s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta}| & |-c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta}| & |c_{23}c_{13}| \end{pmatrix}$$

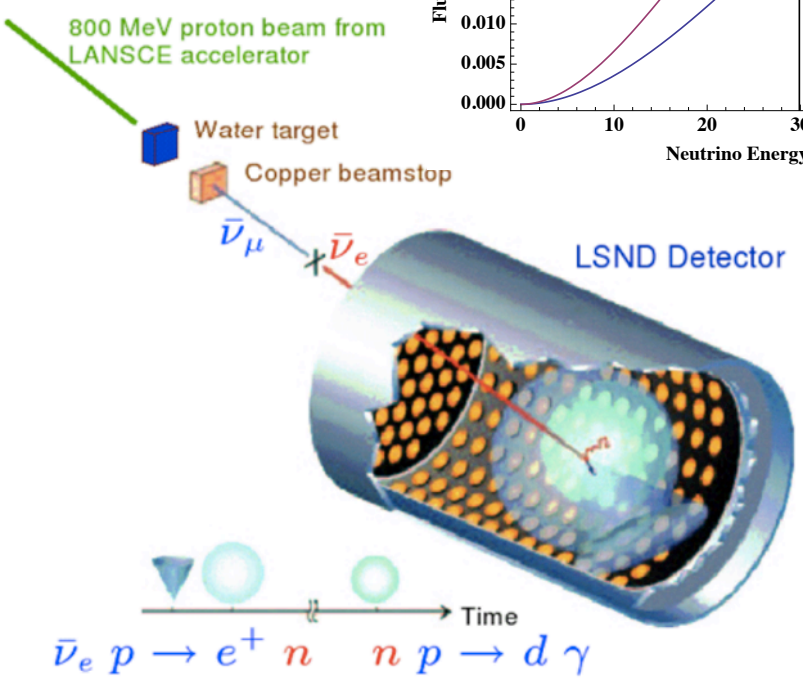
Parameterized by 3 real mixing angles and 1 CP-violating phase

$$s_{ij} = \sin\theta_{ij}$$
$$c_{ij} = \cos\theta_{ij}$$

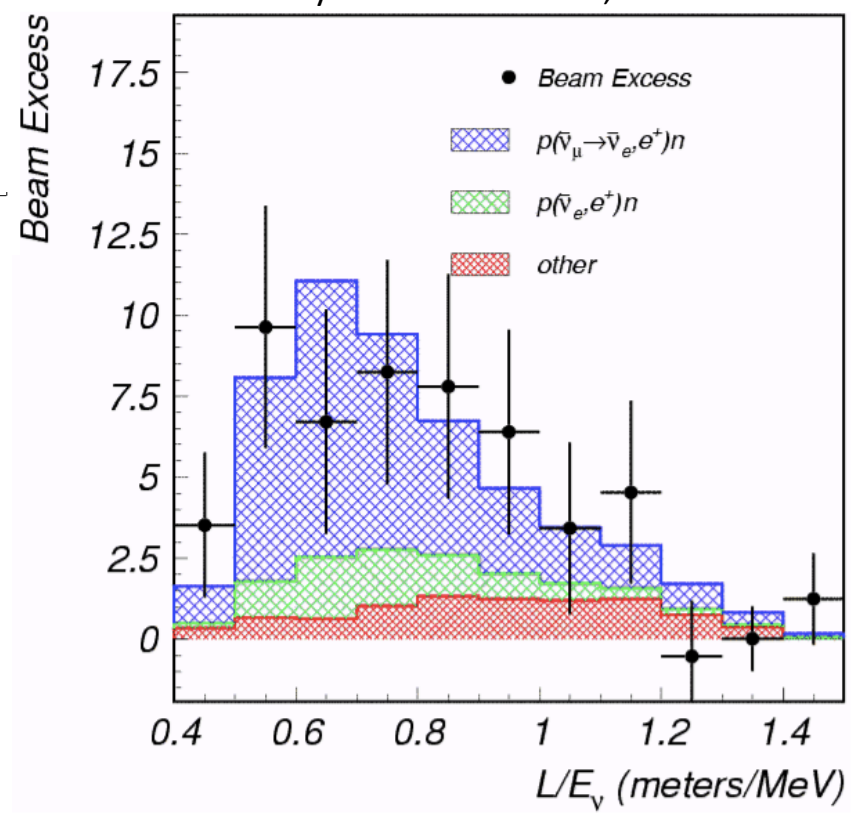
The LSND Experiment

$$P(\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_e) \approx \sin^2 2\theta_{\mu e} \sin^2\left(\frac{1.267\Delta m^2[\mathrm{eV}^2]L[\mathrm{m}]}{E_\nu[\mathrm{MeV}]}\right)$$

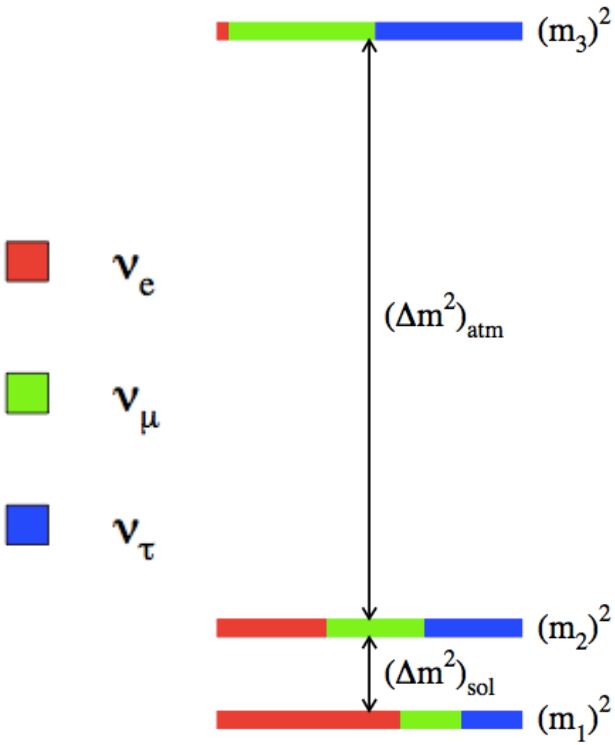




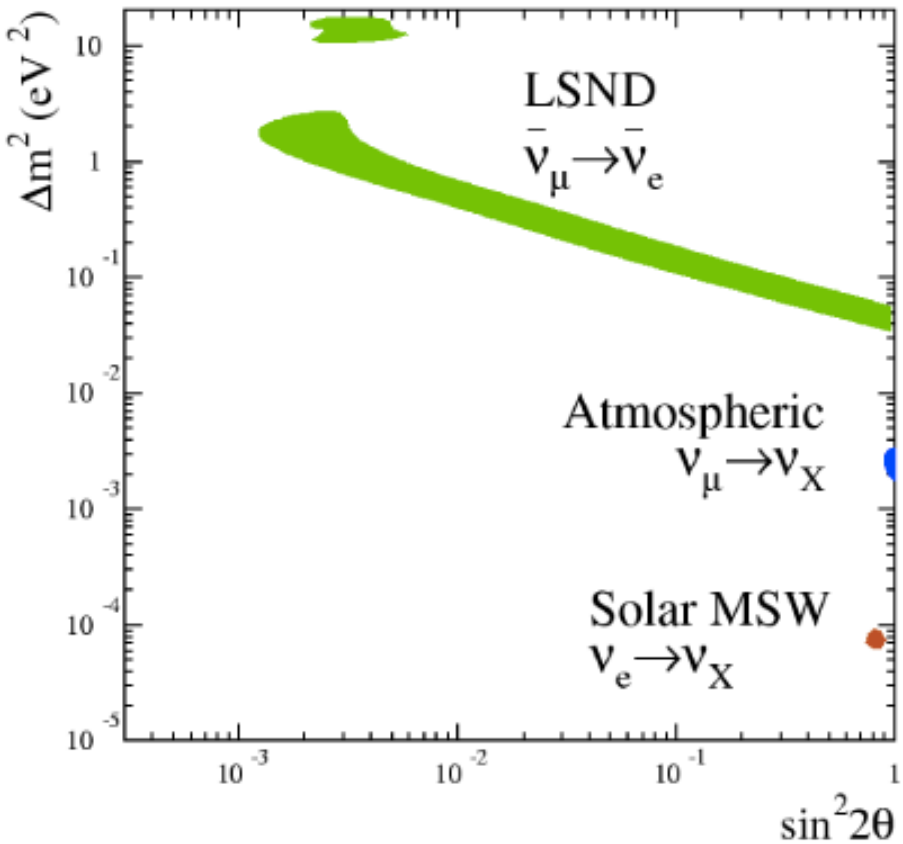
LSND: Phys.Rev.D64:112007,2001



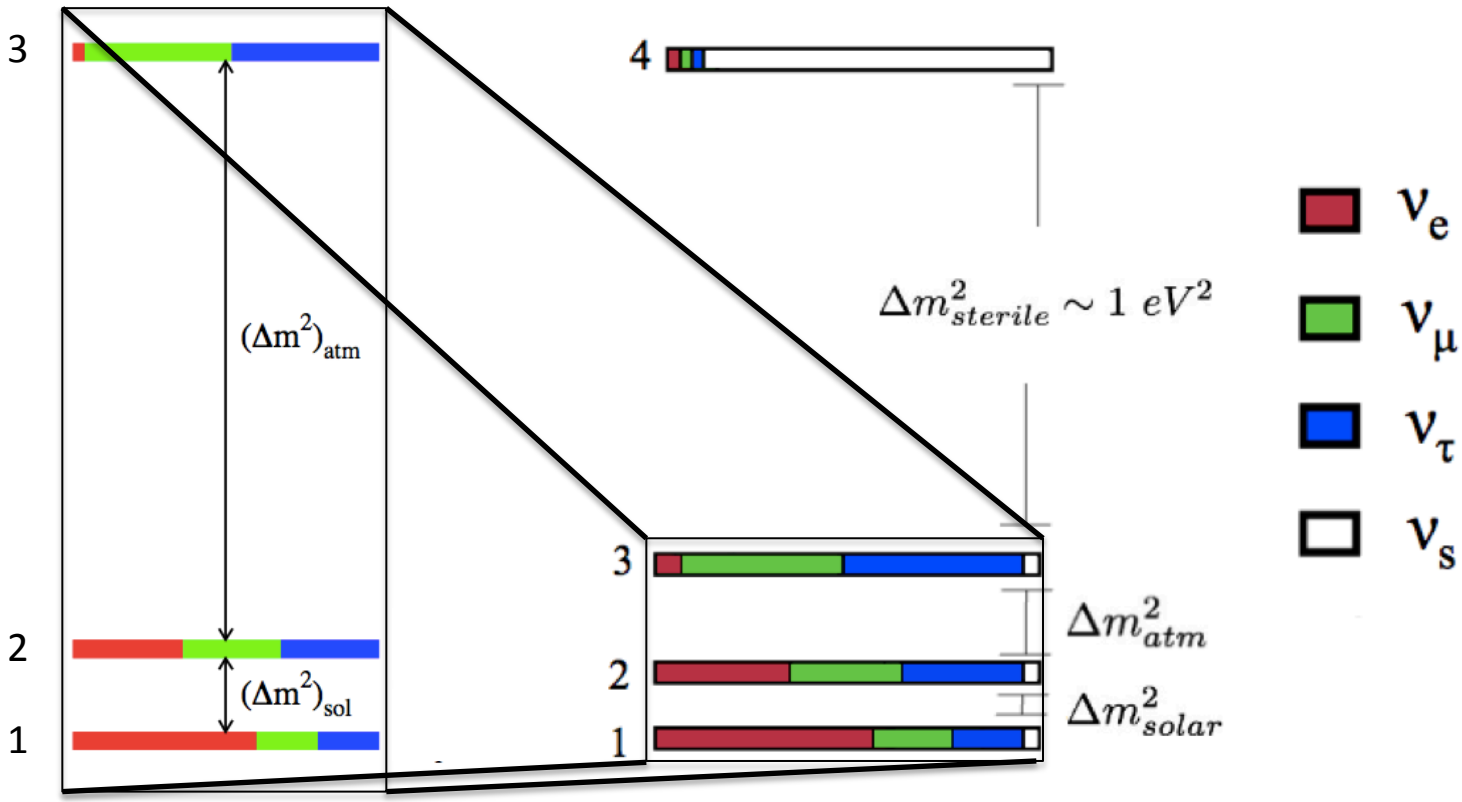
Evidence for Neutrino Oscillations at 3 Different Δm^2



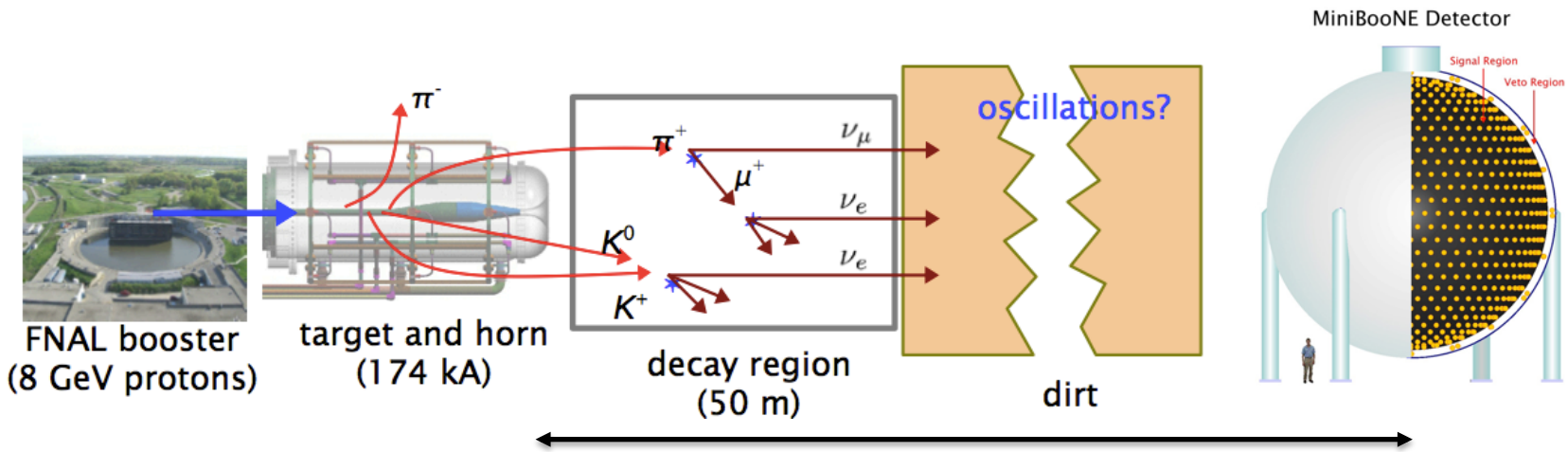
"Normal"
Mass Ordering



A 4th (sterile) neutrino state?

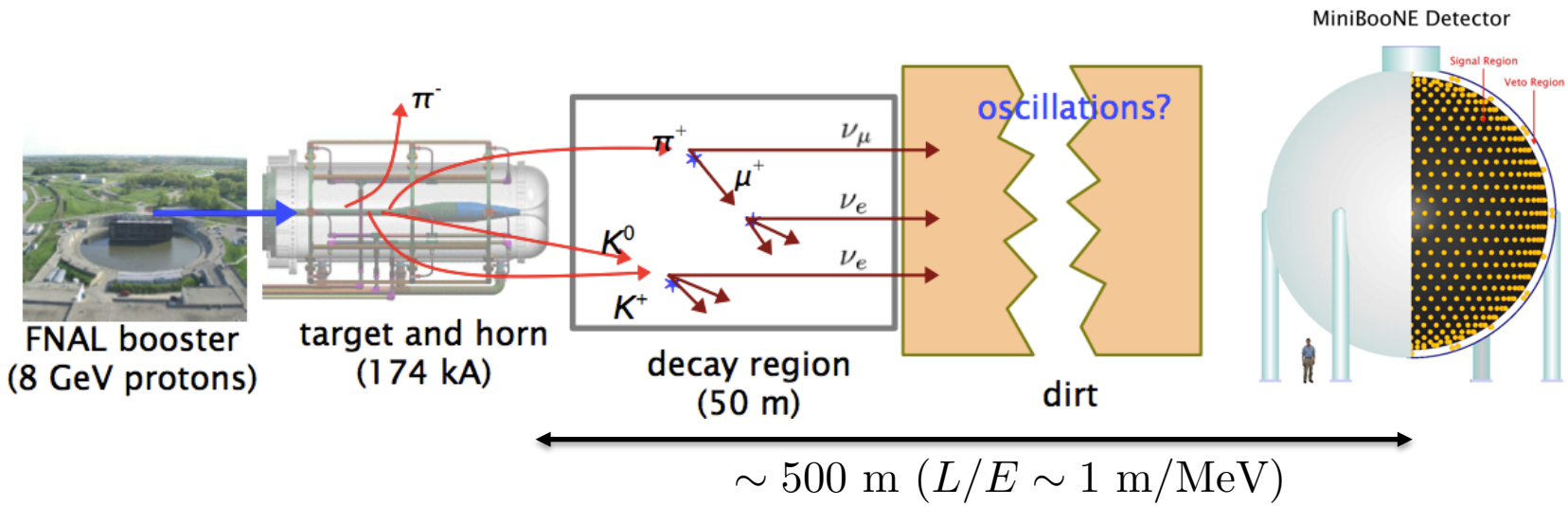


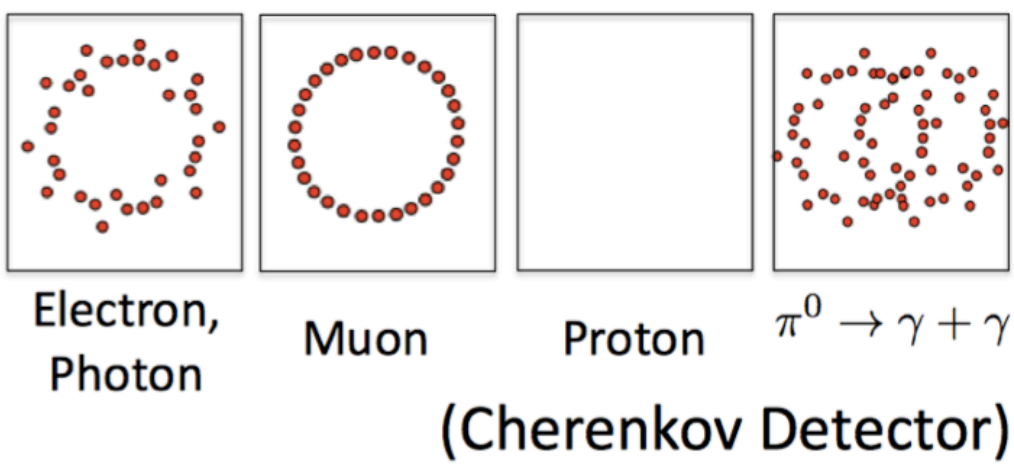
MiniBooNE Experiment



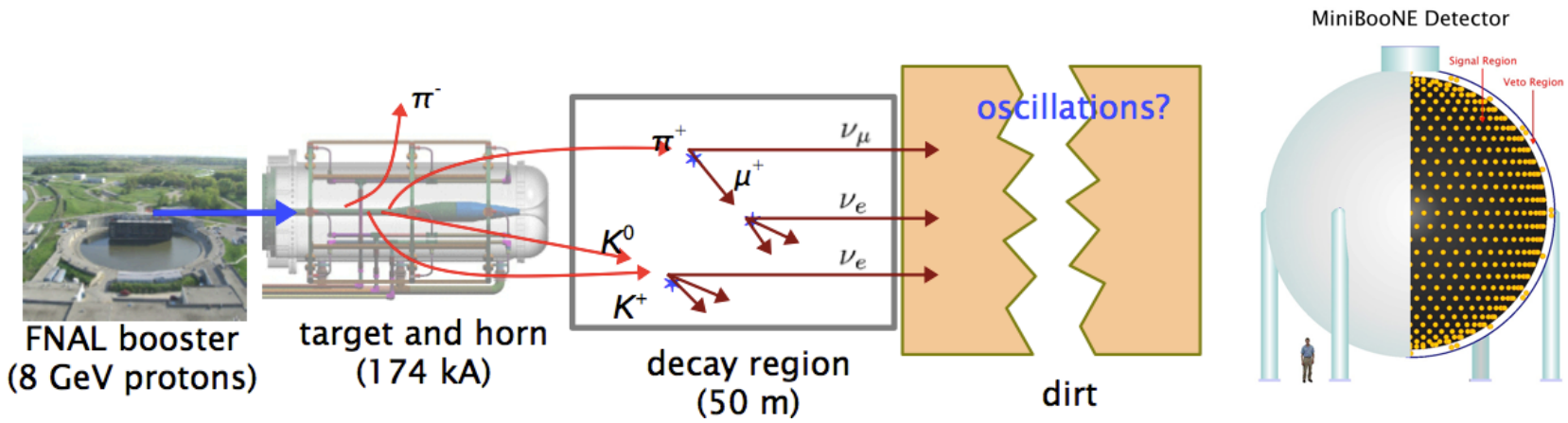
$$\sim 500 \text{ m } (L/E \sim 1 \text{ m/MeV})$$

MiniBooNE Experiment

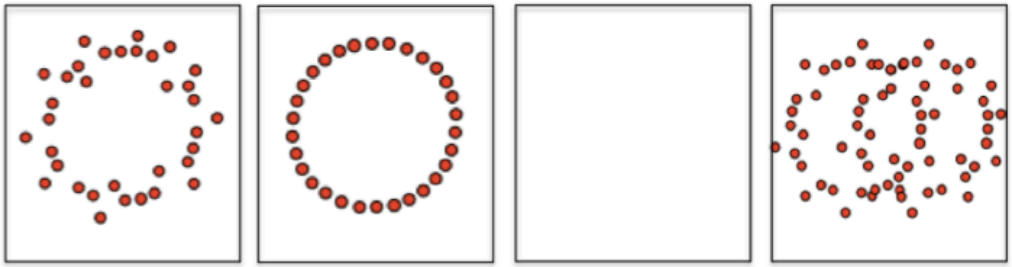




MiniBooNE Experiment



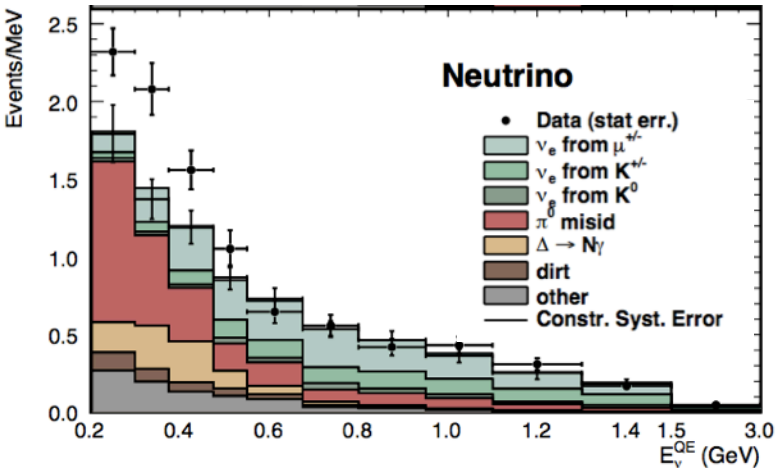
~ 500 m $(L/E \sim 1$ m/MeV$)$



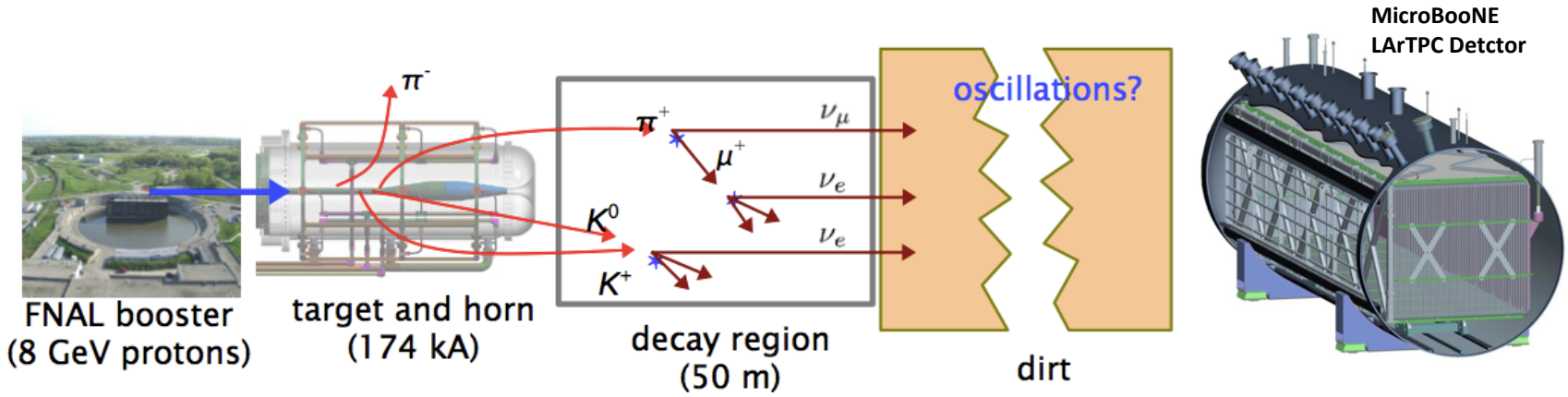
Electron, Photon | Muon | Proton | $\pi^0 \to \gamma + \gamma$

(Cherenkov Detector)

MiniBooNE: PhysRevLett.110.161801

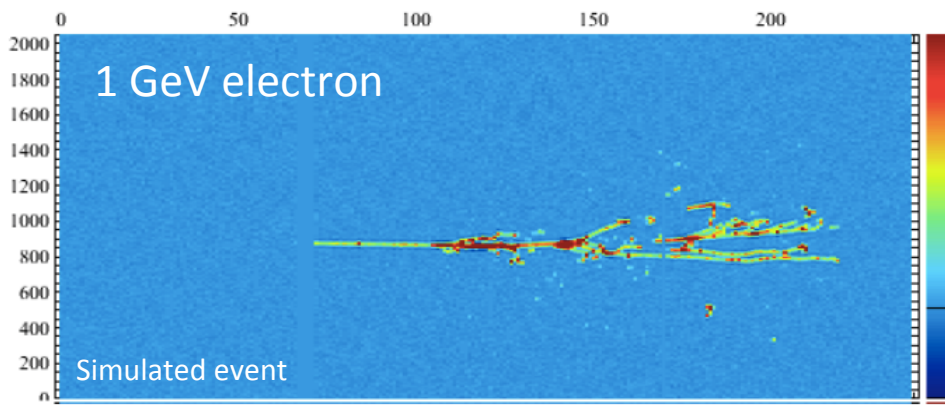


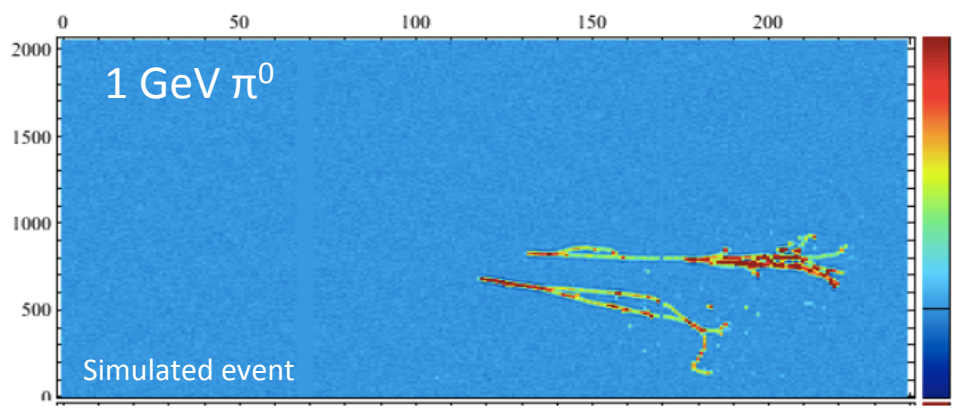
Addressing the MiniBooNE "Low-Energy Excess"



$$\sim 500 \text{ m } (L/E \sim 1 \text{ m/MeV})$$

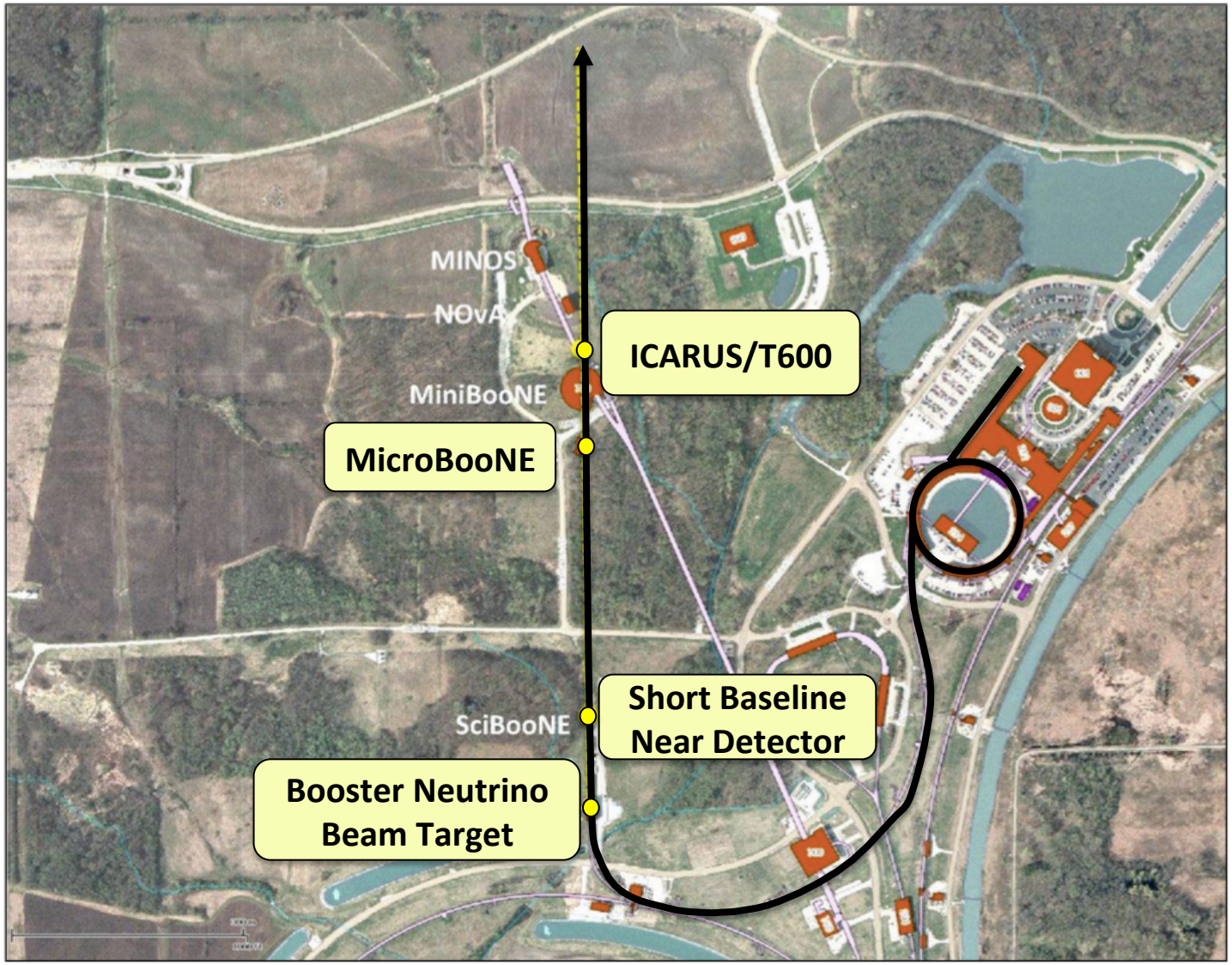
Liquid Argon Time Projection Chamber (LArTPC)



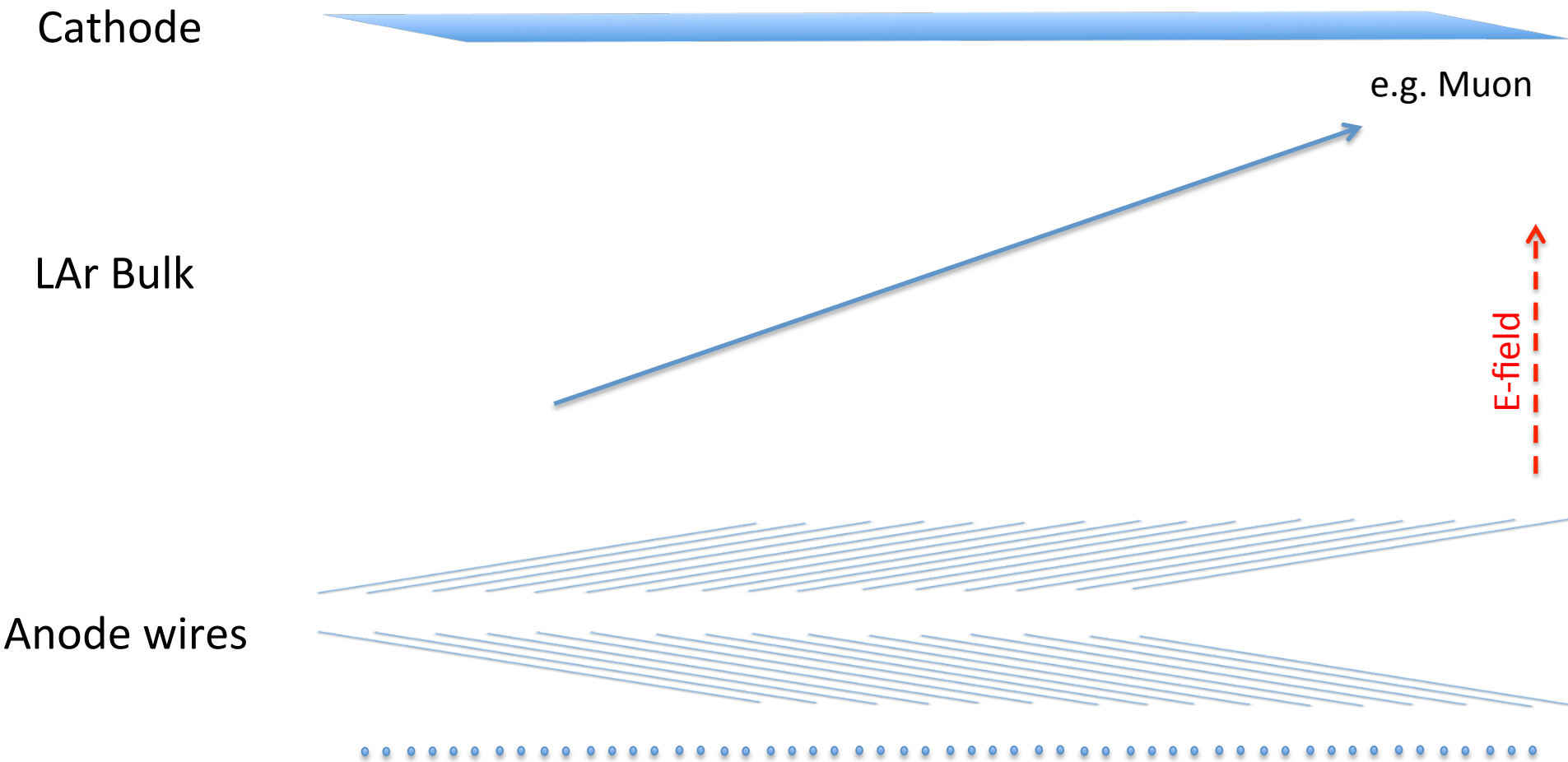


LArTPC = "Modern Bubble Chamber" with 3D track reconstruction

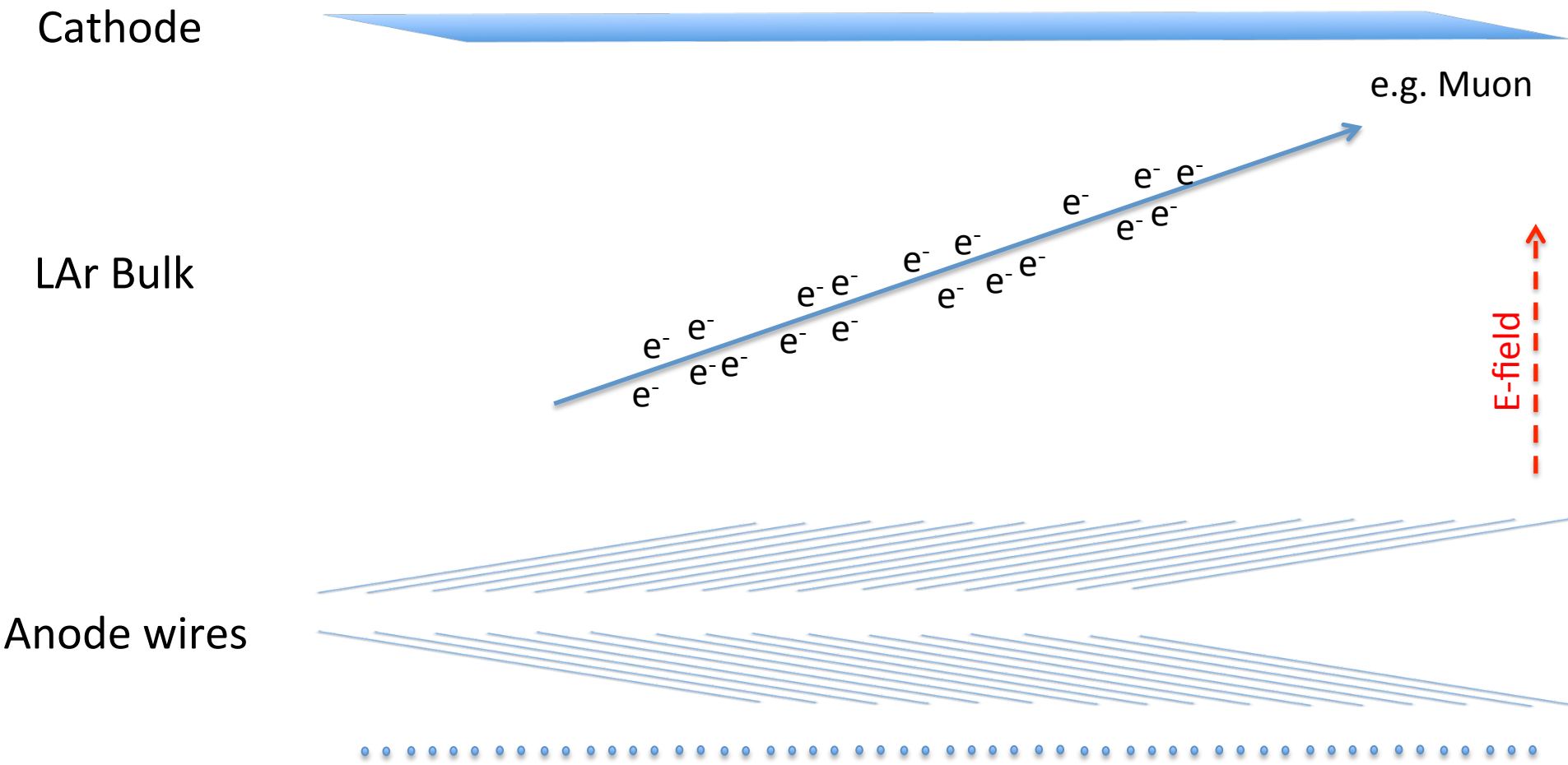
Aerial View of Fermilab Site



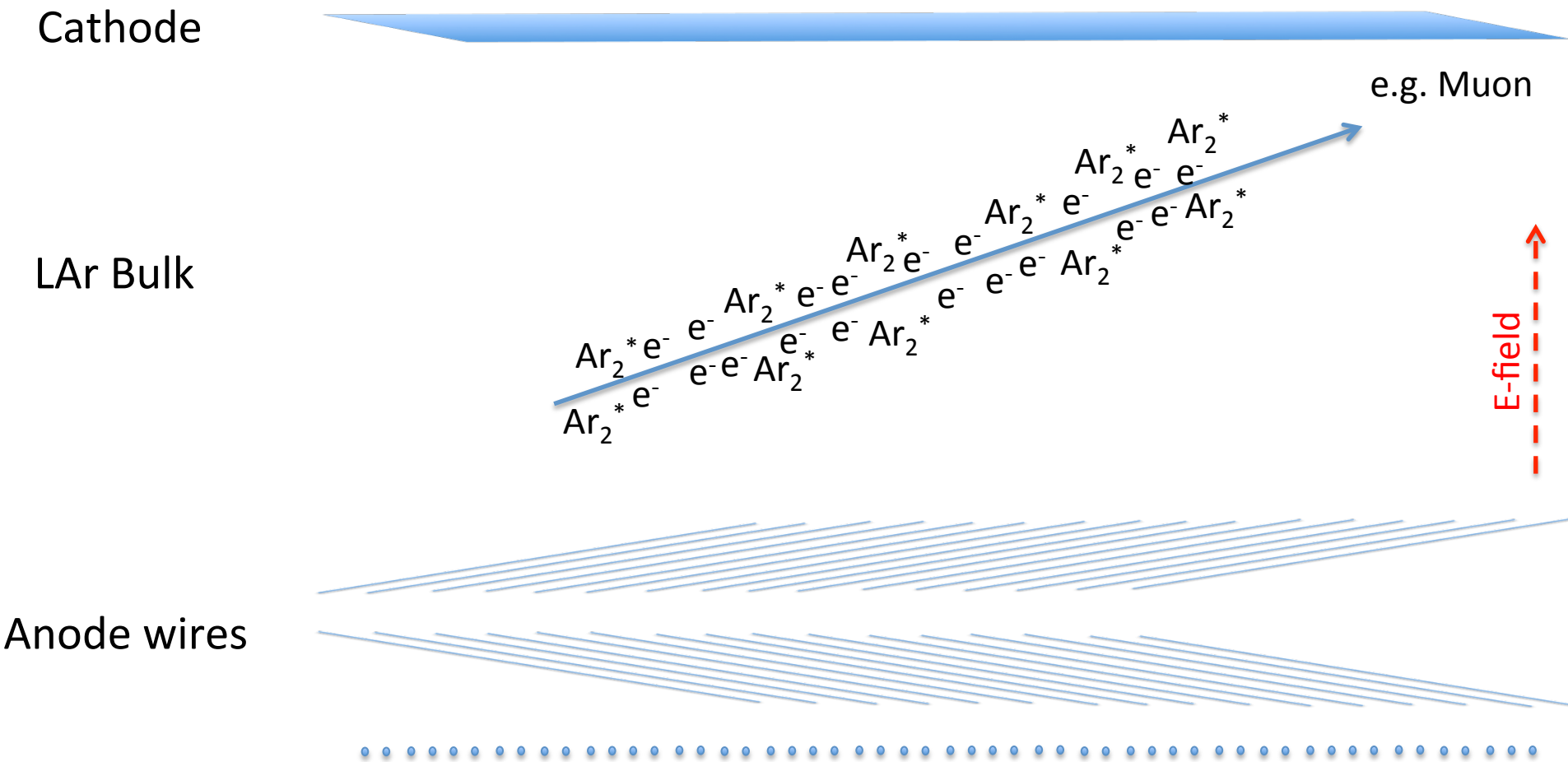
LArTPC Detector



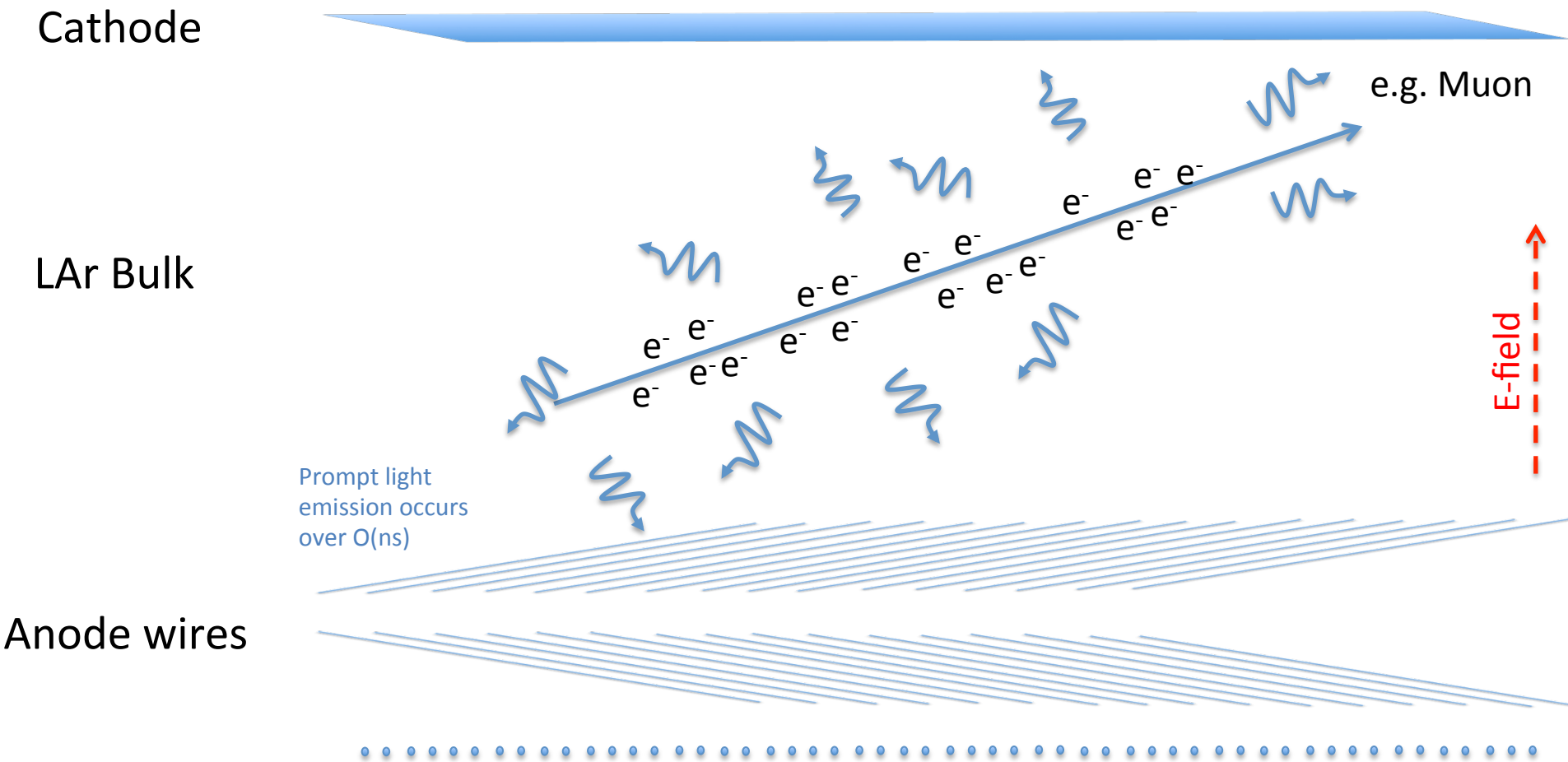
LArTPC Detector



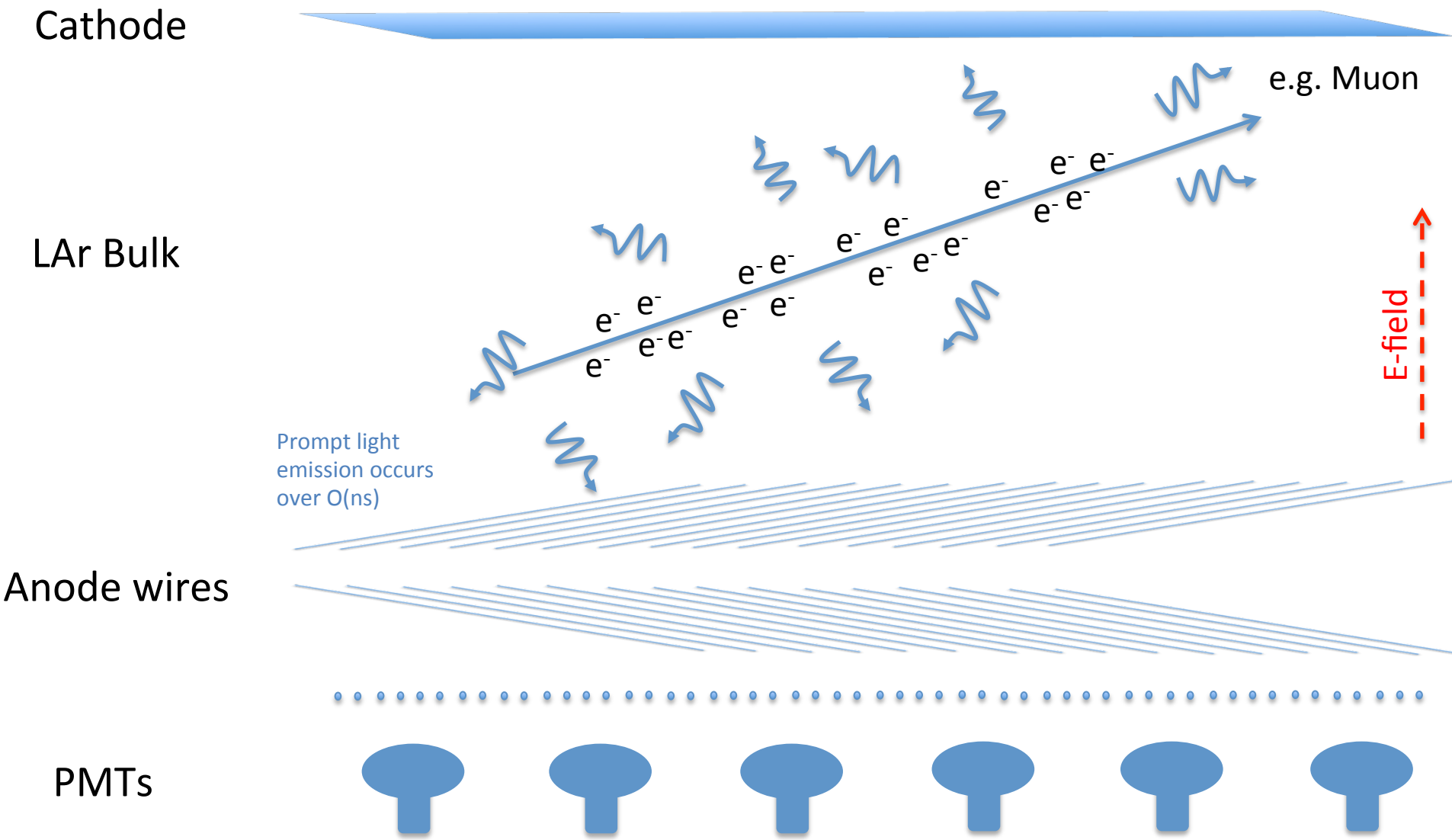
LArTPC Detector



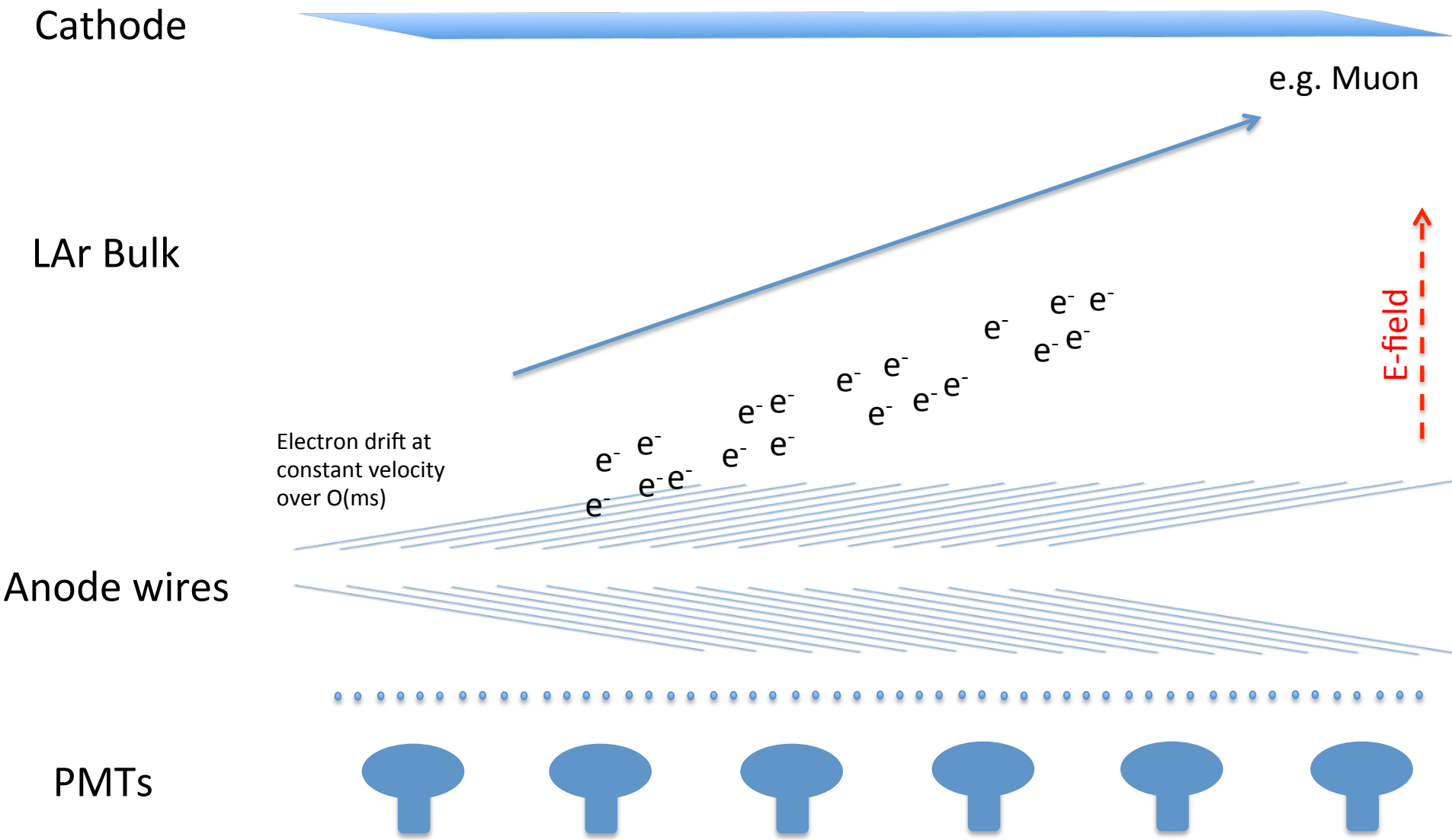
LArTPC Detector



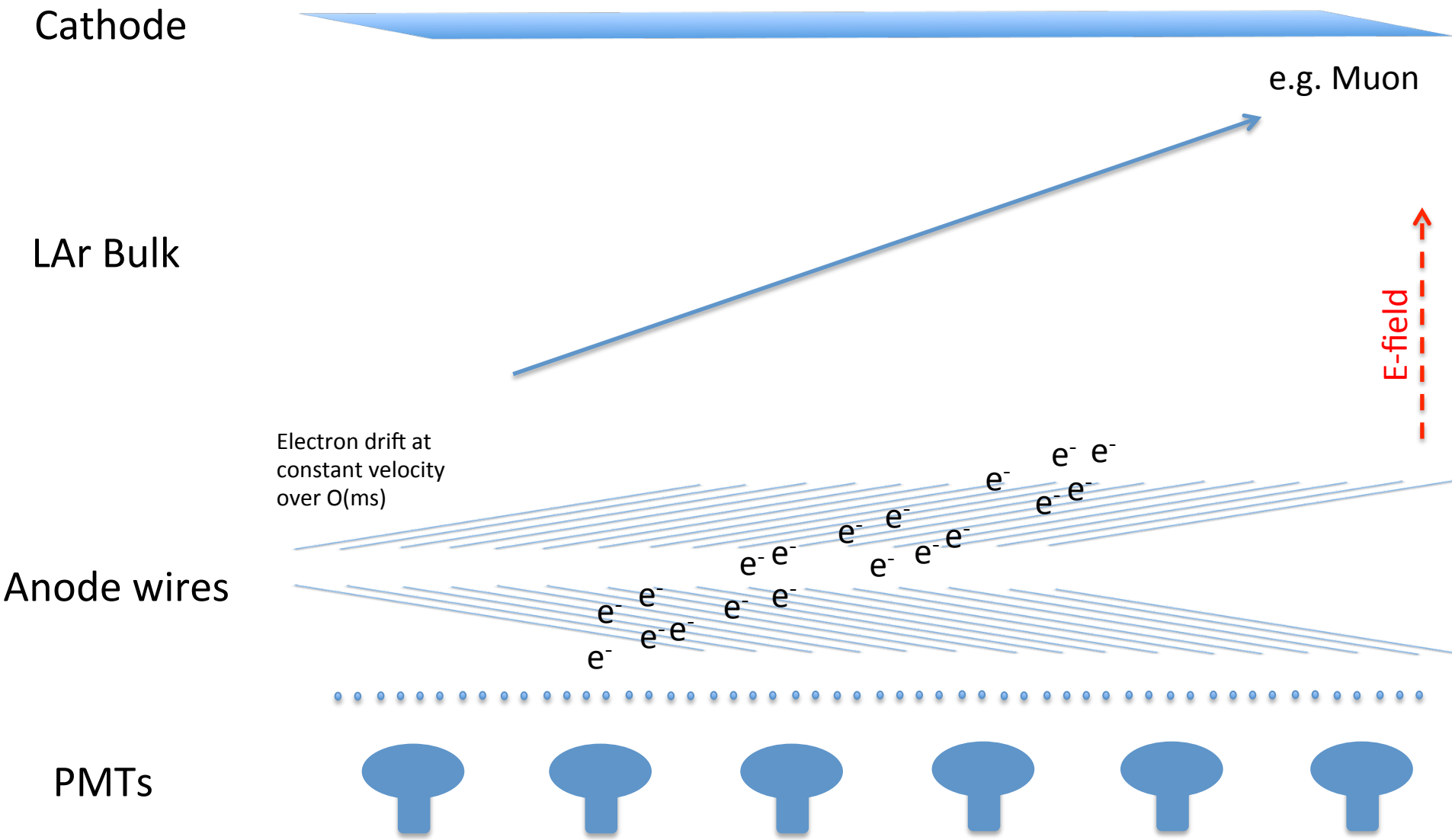
LArTPC Detector



LArTPC Detector

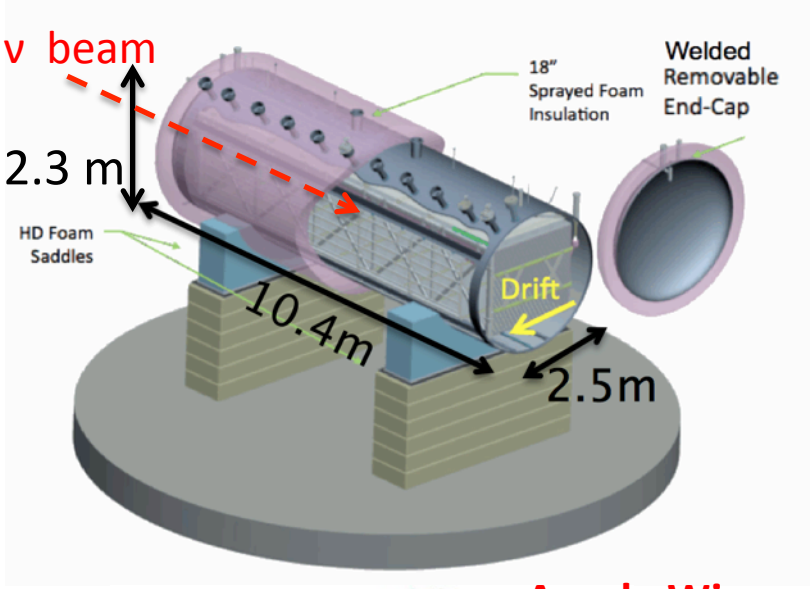


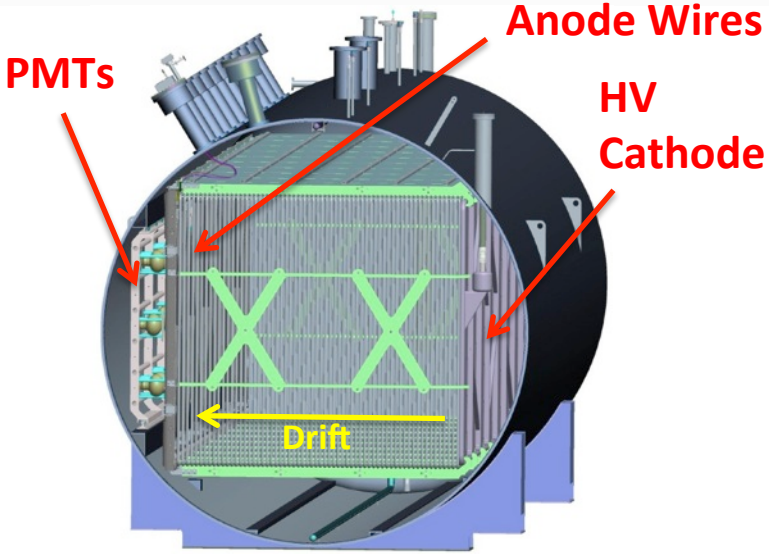
LArTPC Detector



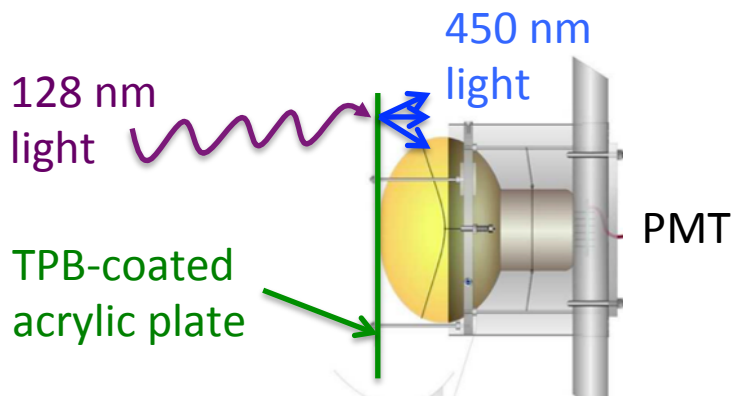
The MicroBooNE Detector

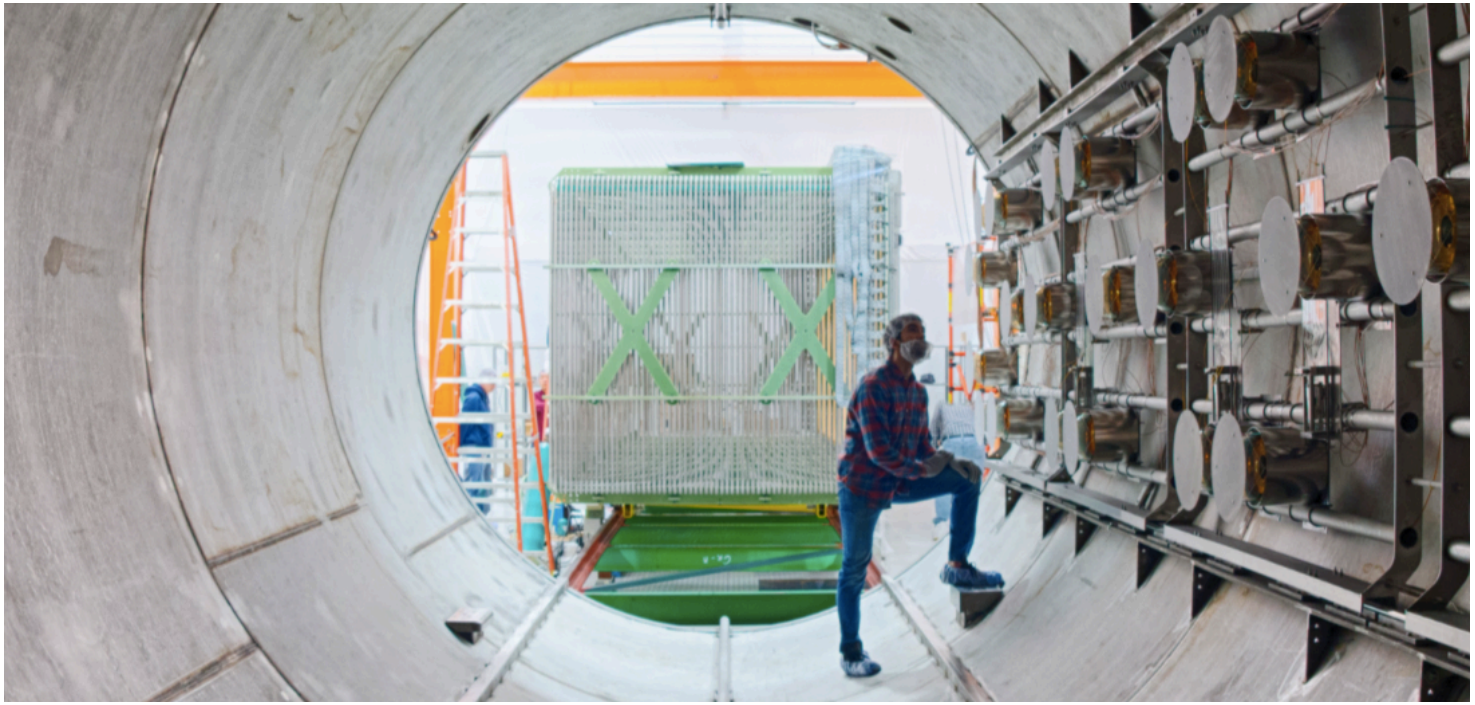
- 170 ton LArTPC (total mass)
- 8256 wires (3 mm pitch)
  - 3456 collection channels (oriented vertically)
  - 4800 induction channels (oriented at ±60˚)
- 32 8” Cryogenic PMTs + 4 light guide “paddles”
- UV laser calibration system
  - 2 ports: upstream, downstream (maneuverable heads)
- Purity monitors
- External muon tagger system





LAr Light Detection in MicroBooNE

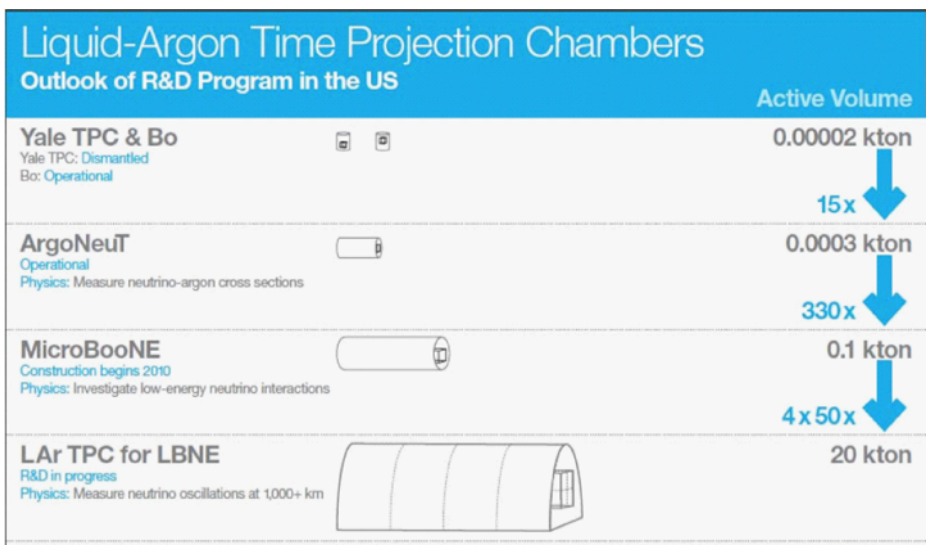


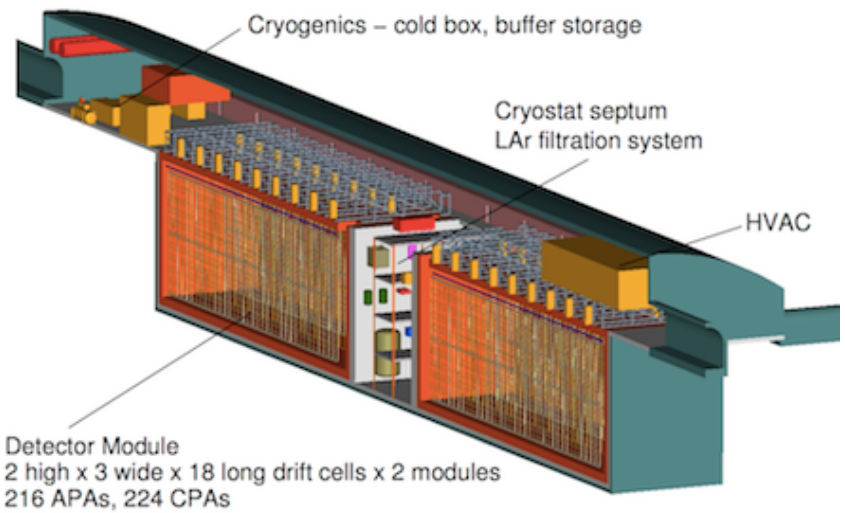


MicroBooNE Goals

- Address MiniBooNE low energy excess
- ν cross section measurements on Argon
- R&D for future LArTPCs
  - Long drift length (2.5 m)
  - Cold electronics (CMOS ASICs in LAr)
  - LAr fill without evacuation (GAr purge)

Related to scalability





MicroBooNE Collaboration

*spokespeople

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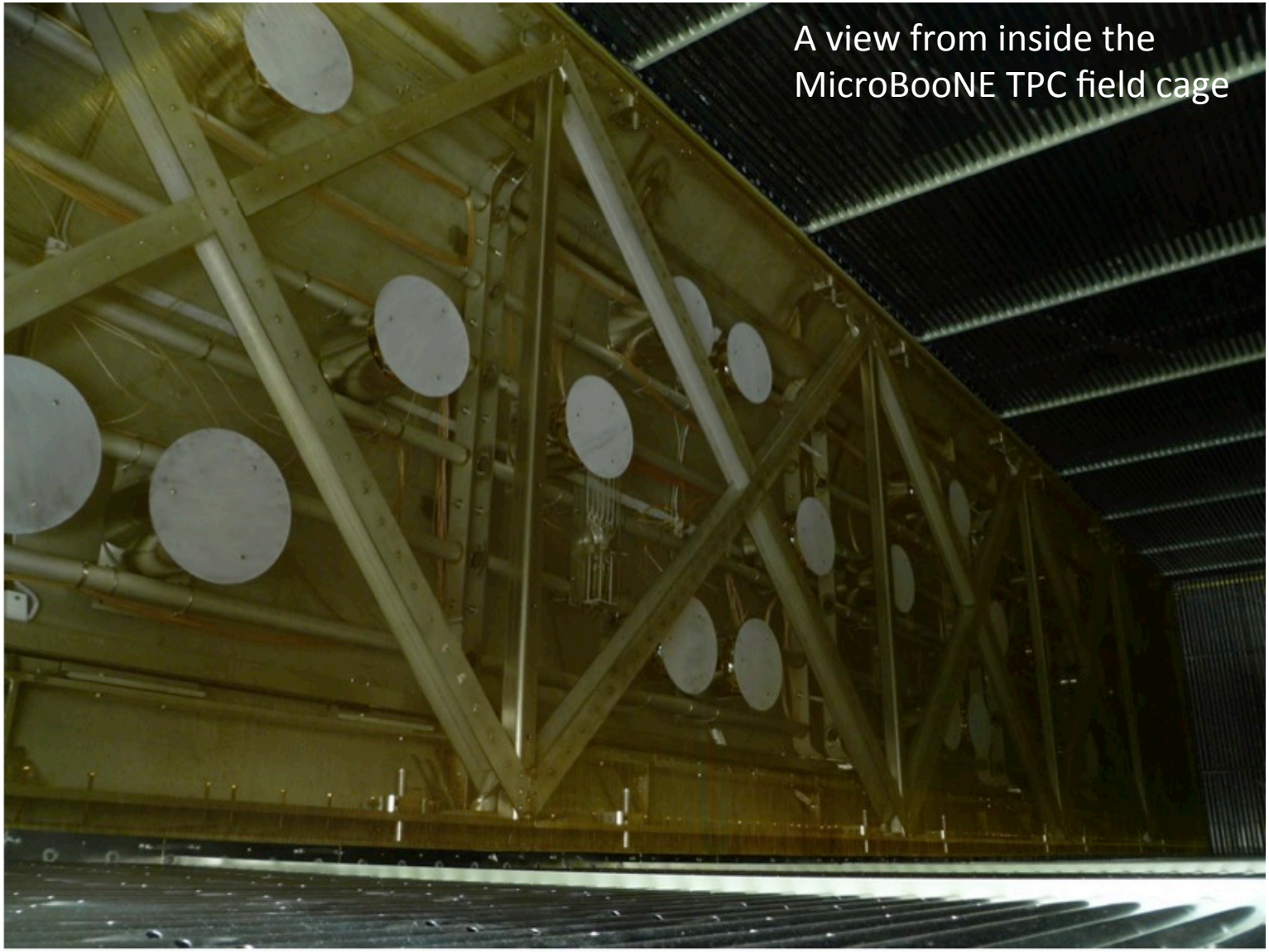
Yale University: C. Adams, B.T. Fleming*, E. Gramellini, A. Hackenburg, X. Luo, B. Russell, S. Tuflani

125 collaborators,
26 institutions (5 non-U.S.)
29 postdocs
24 graduate students

Inserting the MicroBooNE TPC


A view from inside the
MicroBooNE TPC field cage

Transporting the MicroBooNE Detector to the Booster Neutrino Beam

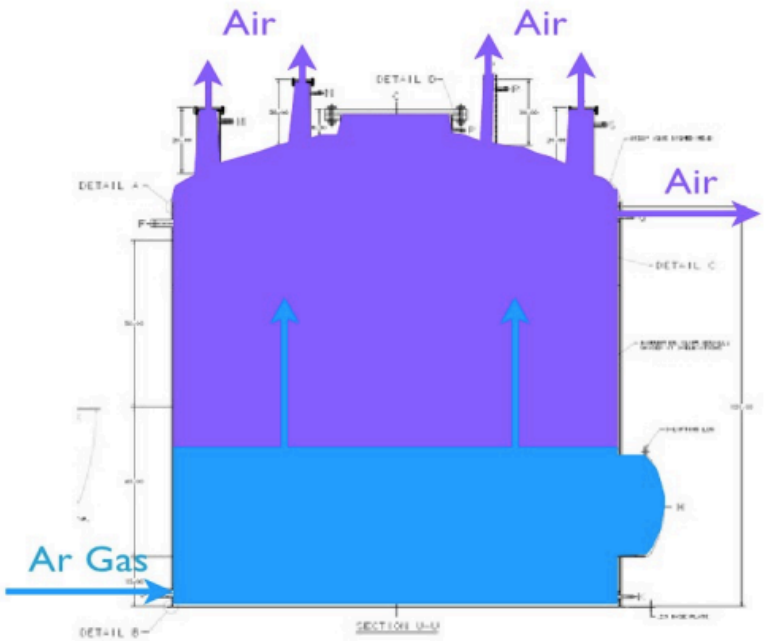
June 23, 2014

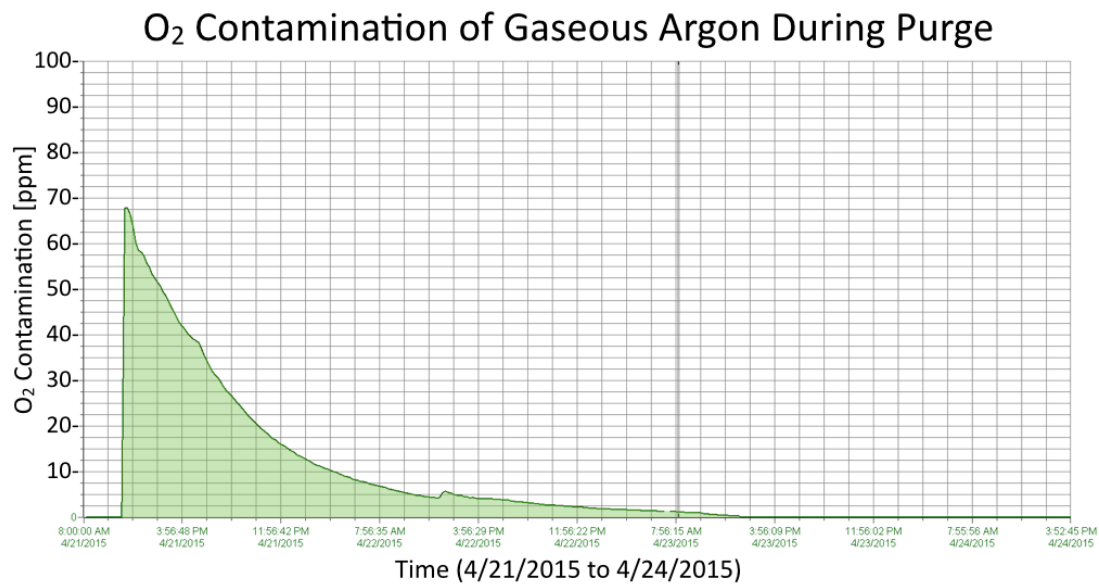
Installing the Detector at LArTF

Foam insulation applied to the outside of the cryostat—readout electronics racks installed on platform above

Detector components, installed, cabled up, and granted final safety clearance Dec. 2014

MicroBooNE "Piston Purge"

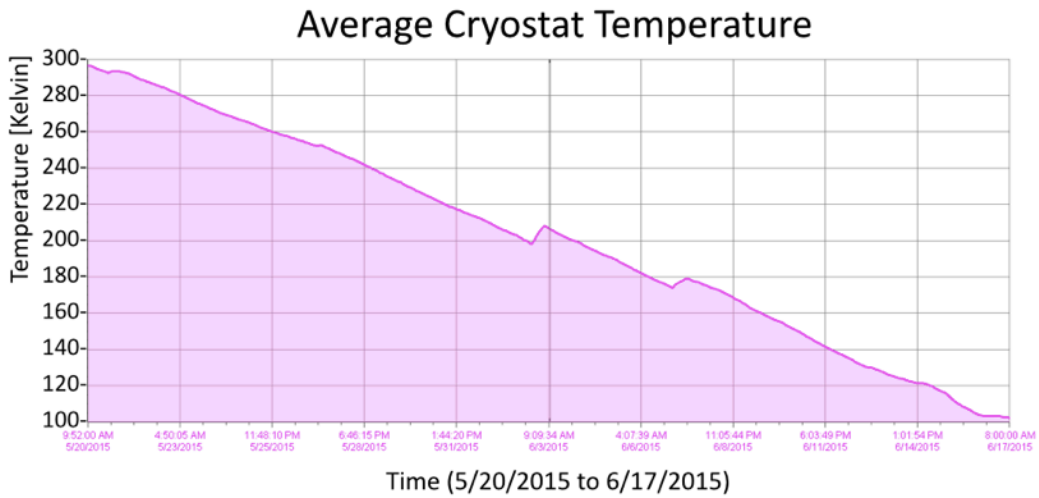




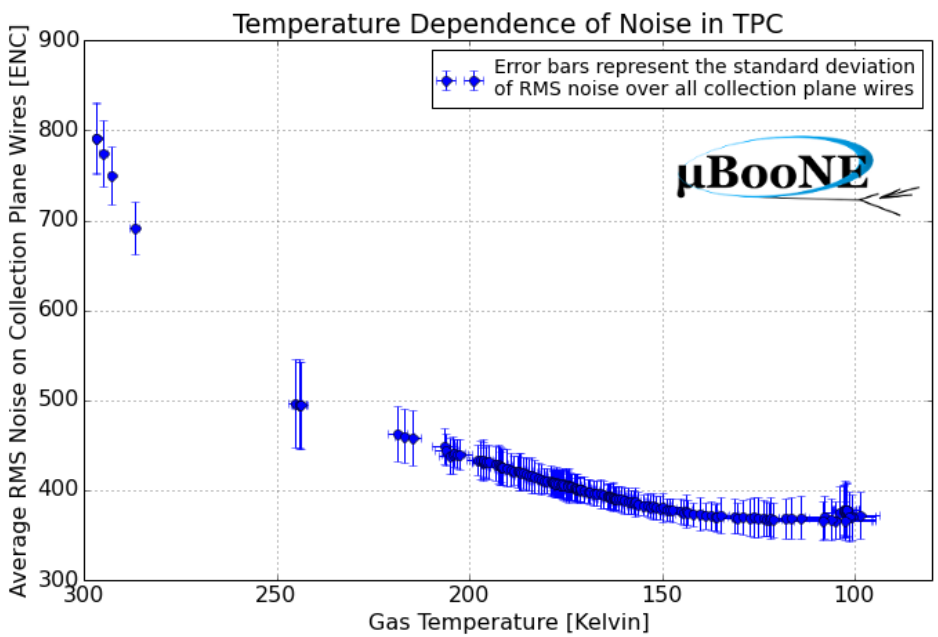
Reduced O_2 from 70 ppm ⇒ 20 ppb
over the course of 300 volume exchanges

Vessel evacuation not necessary to reach high purity

Gaseous Argon Cool-down

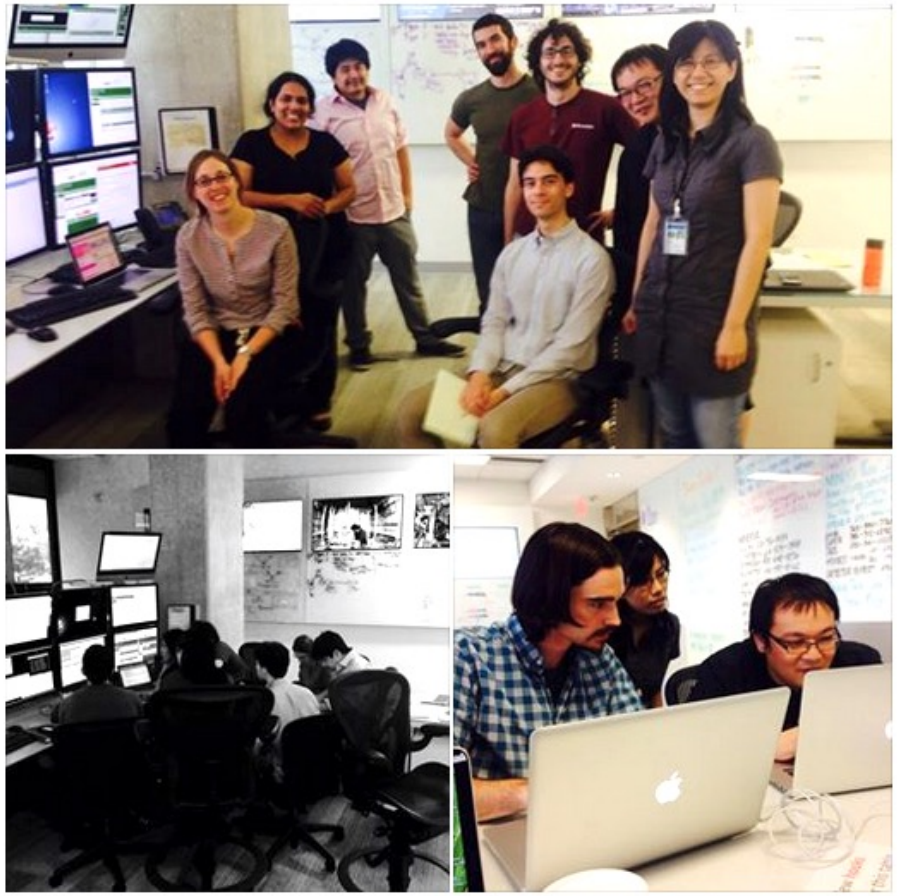


Detector cooled down before introduction of liquid Argon

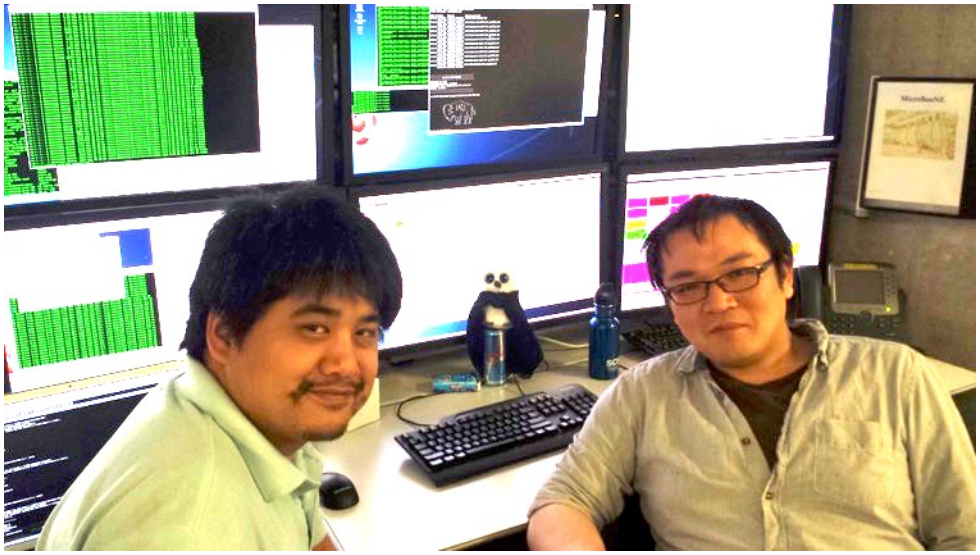


ASIC noise decreases as expected during gaseous Argon cool-down

MicroBooNE shifts started June 1, 2014



First MicroBooNE shift!



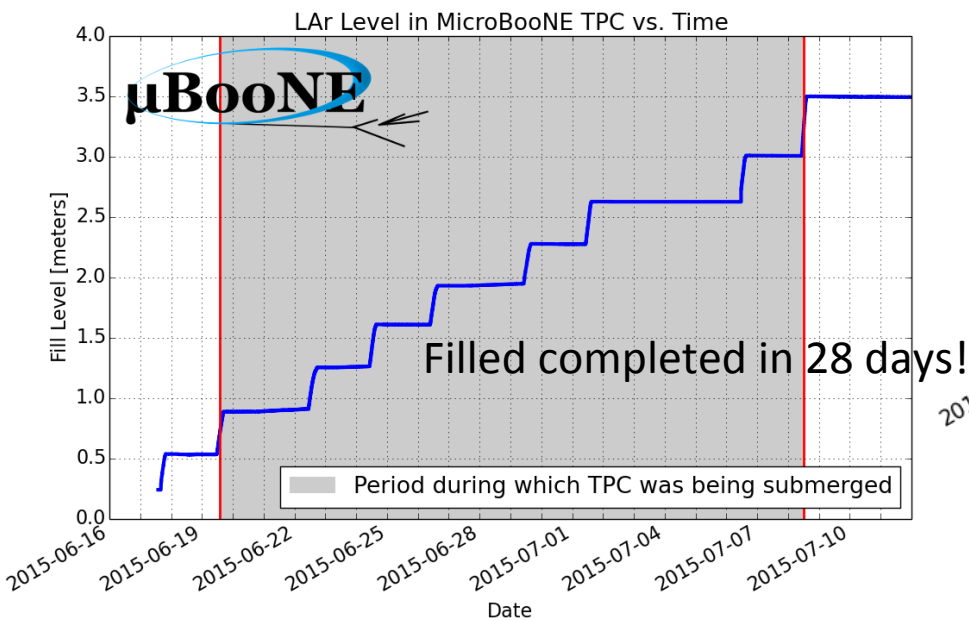
Critical systems operational

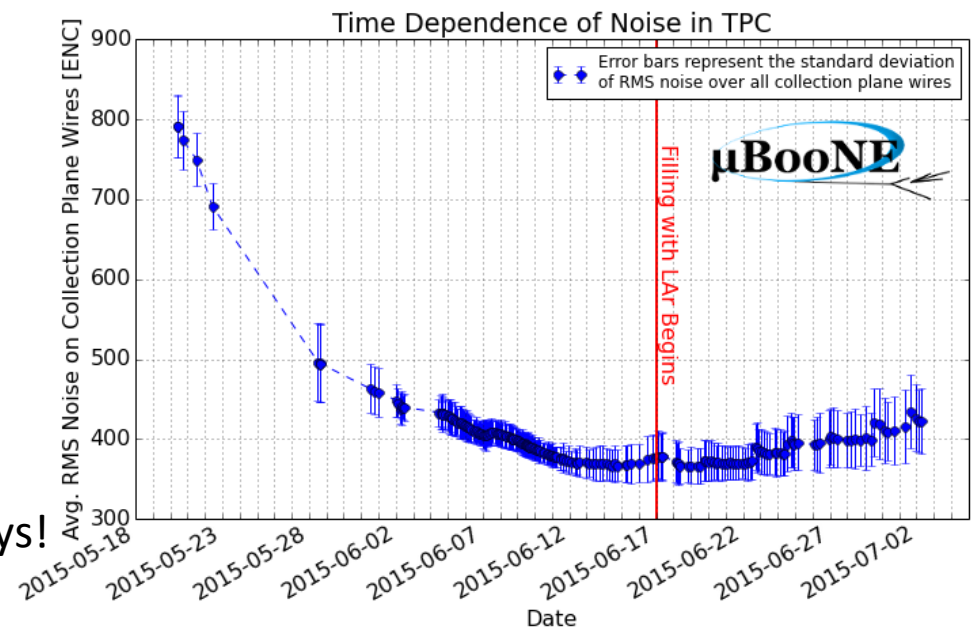
- DAQ
- Online monitor
- Data management
- Slow controls

MicroBooNE Filling with Liquid Argon

Liquid argon deliveries far exceeded purity specifications:

- $O_2 < 1$ ppm
- $N_2 < 3$ ppm

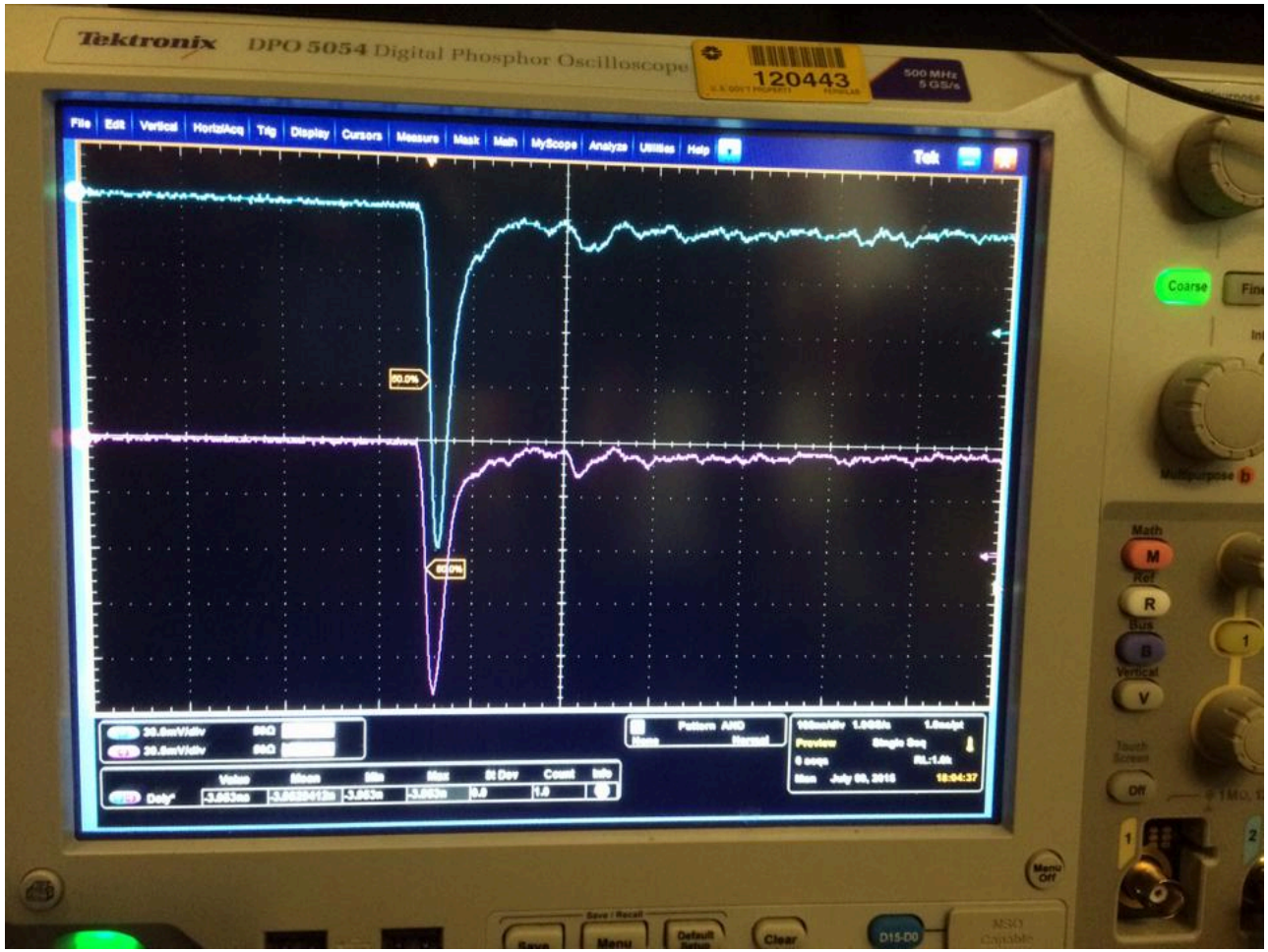




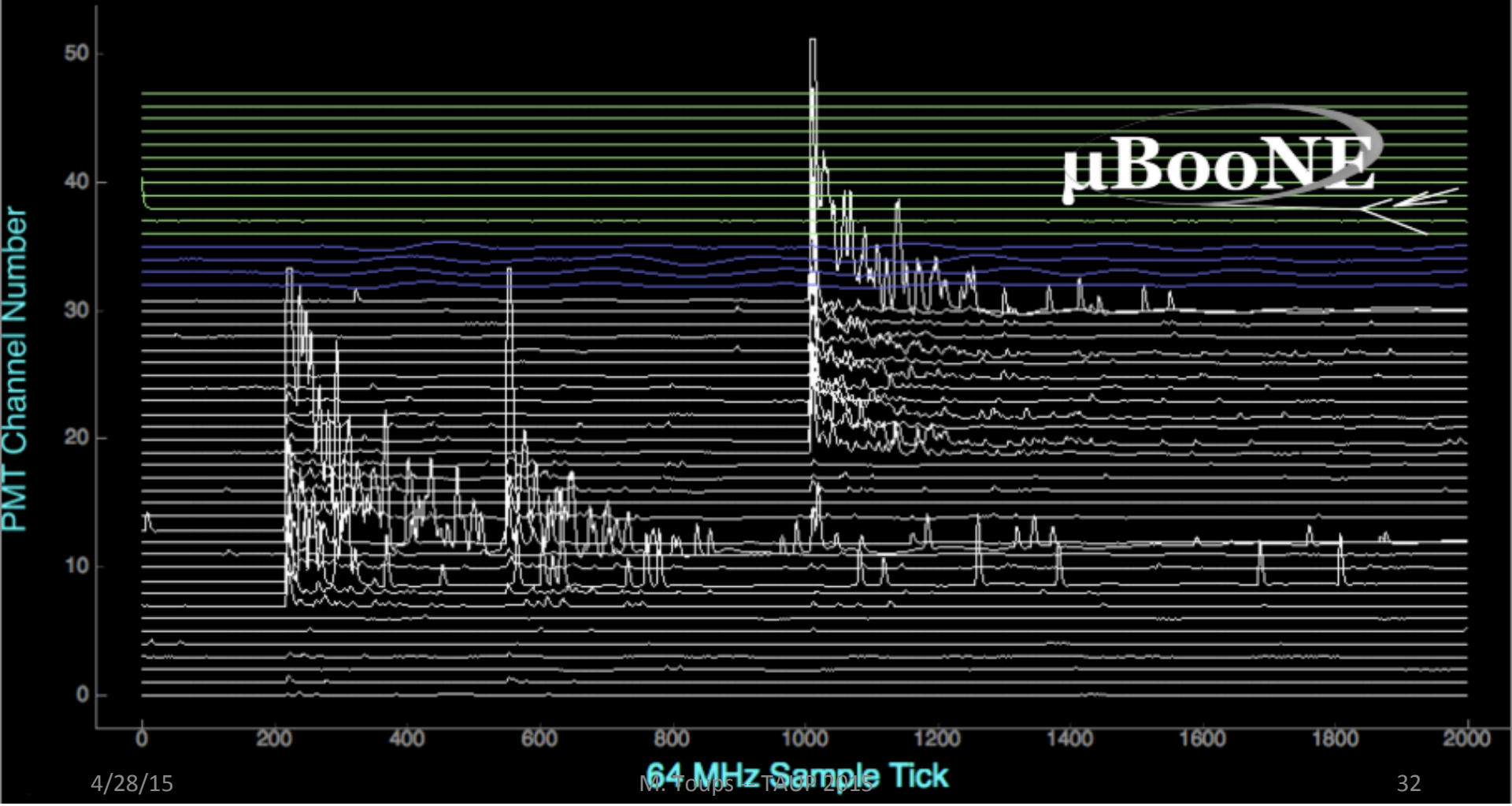
ASIC noise increases as expected with introduction of dielectric (LAr)

PMT HV Turned on Same Day

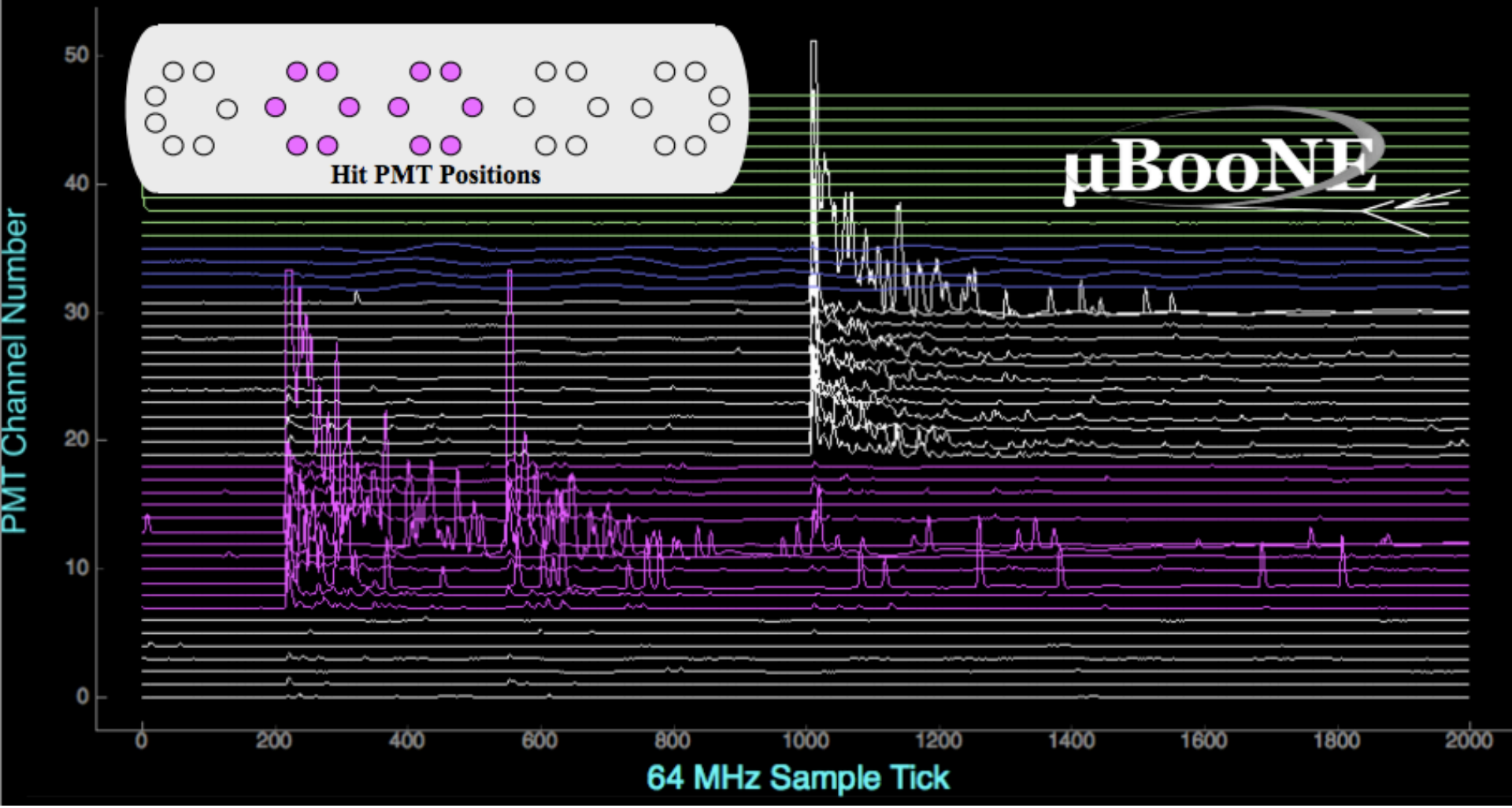
We couldn't help ourselves: coincident pulses seen on adjacent PMTs



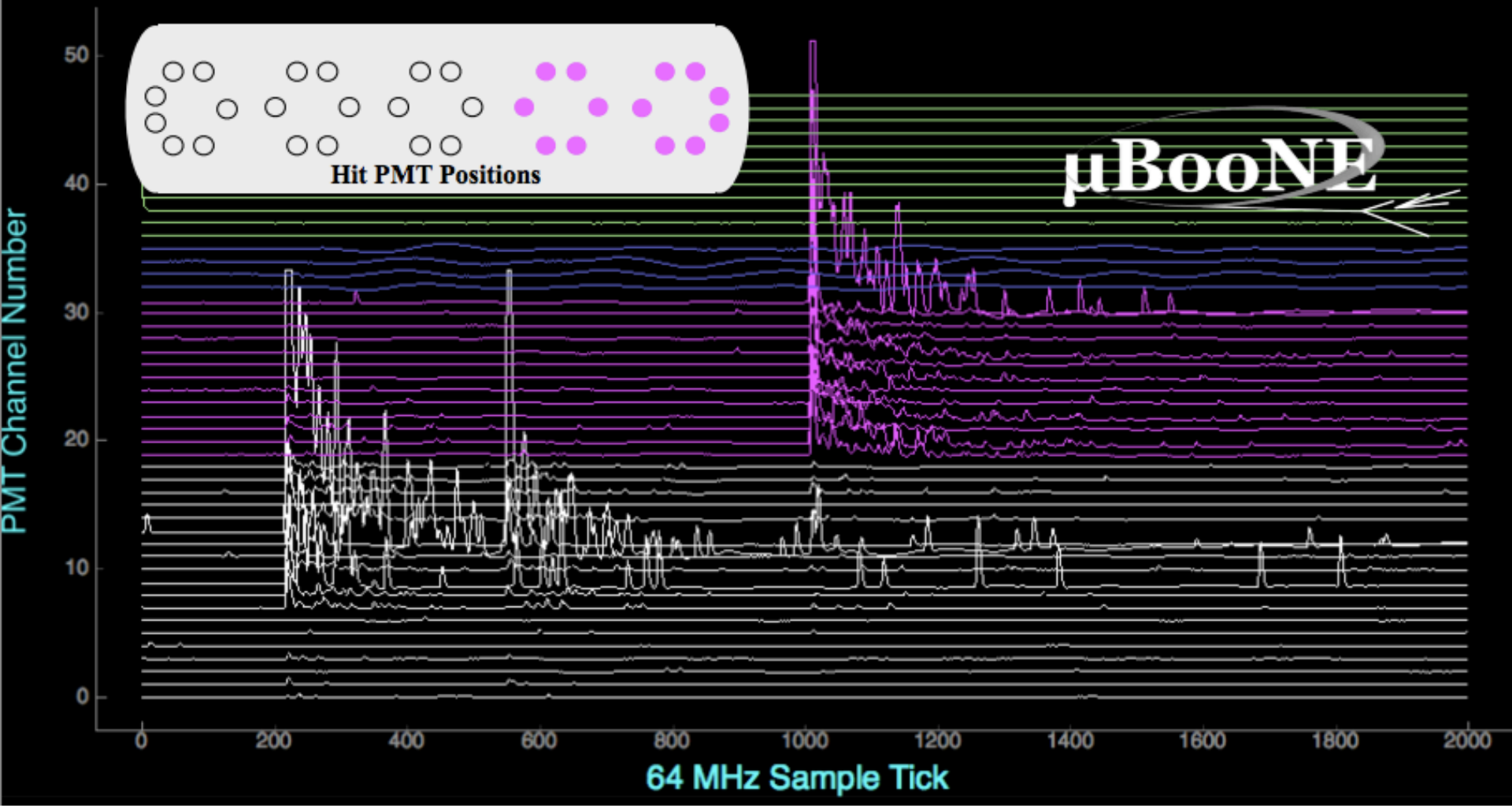
Days After Filling



Days After Filling



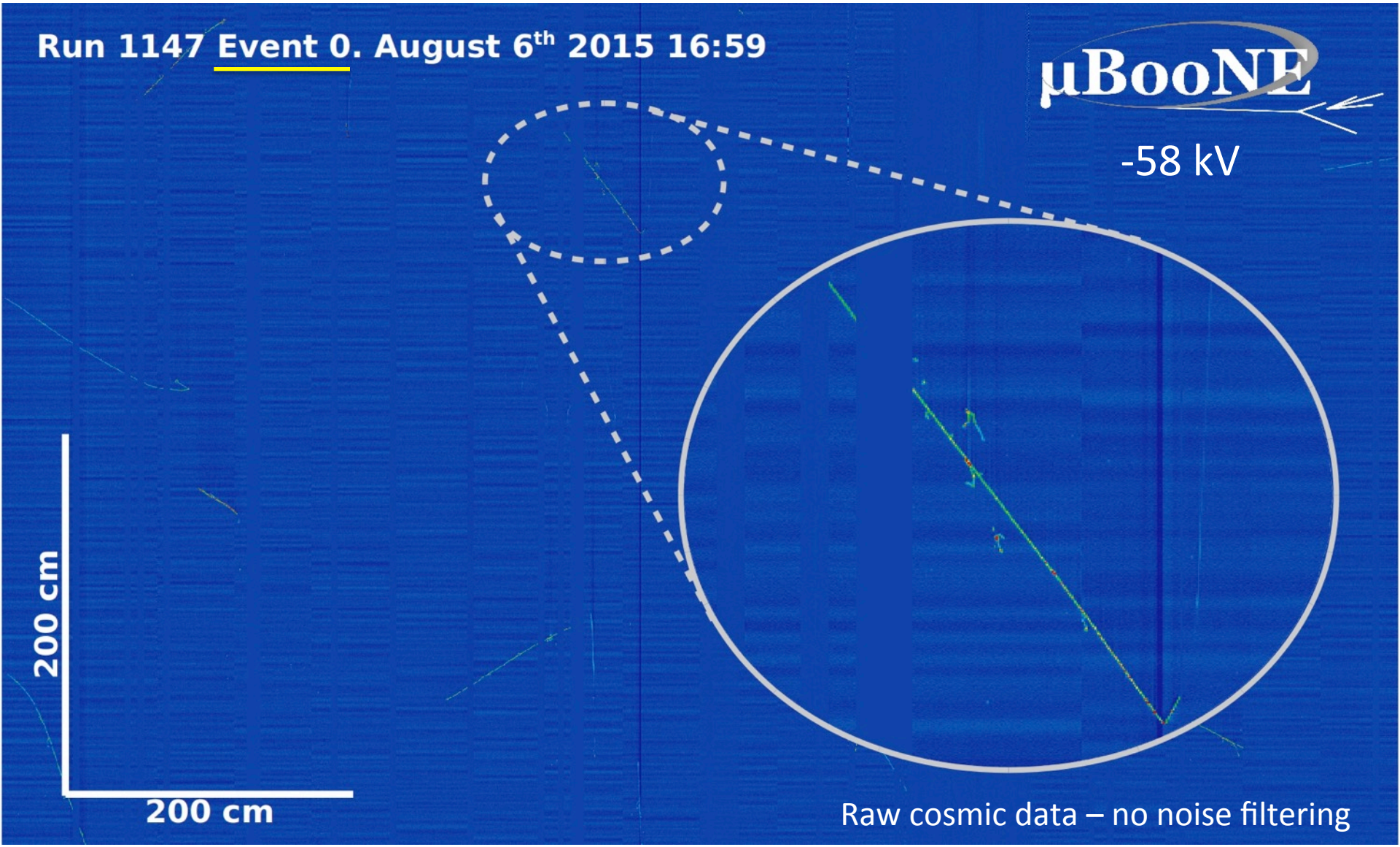
Days After Filling



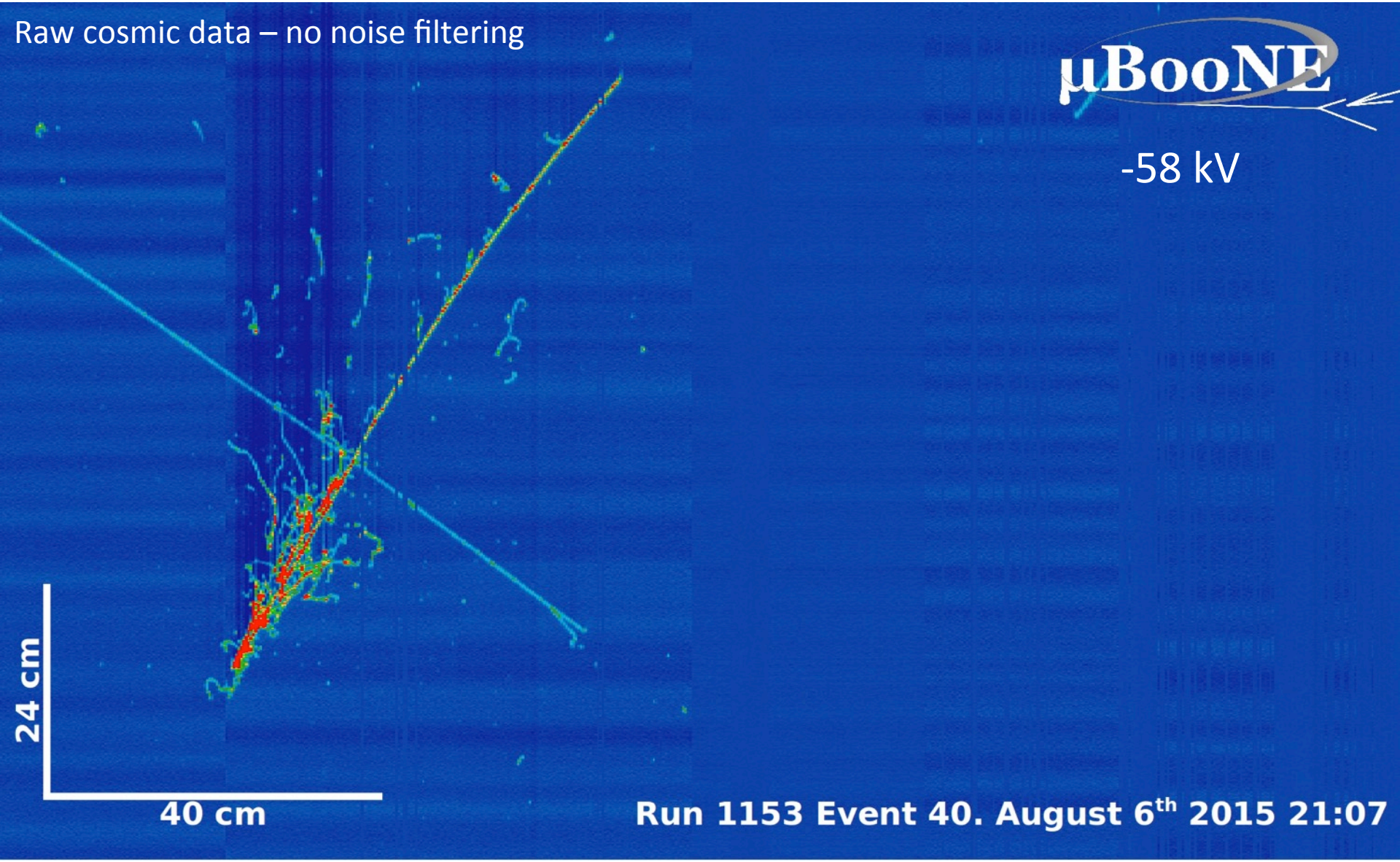
Time to ramp the drift HV: 8/6/15

MicroBooNE controls in the remote operations center at Fermilab

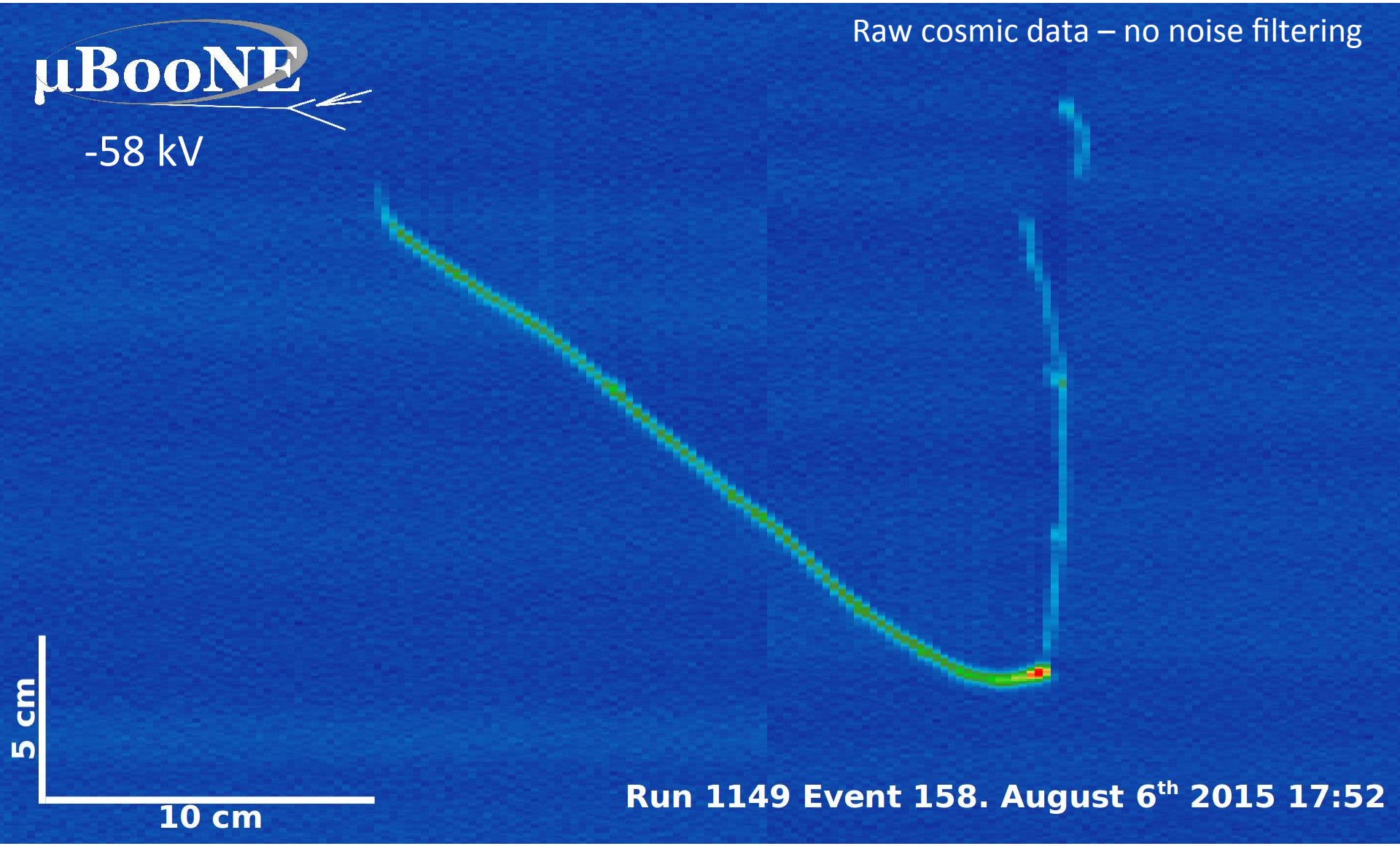
First Tracks in the MicroBooNE Detector!



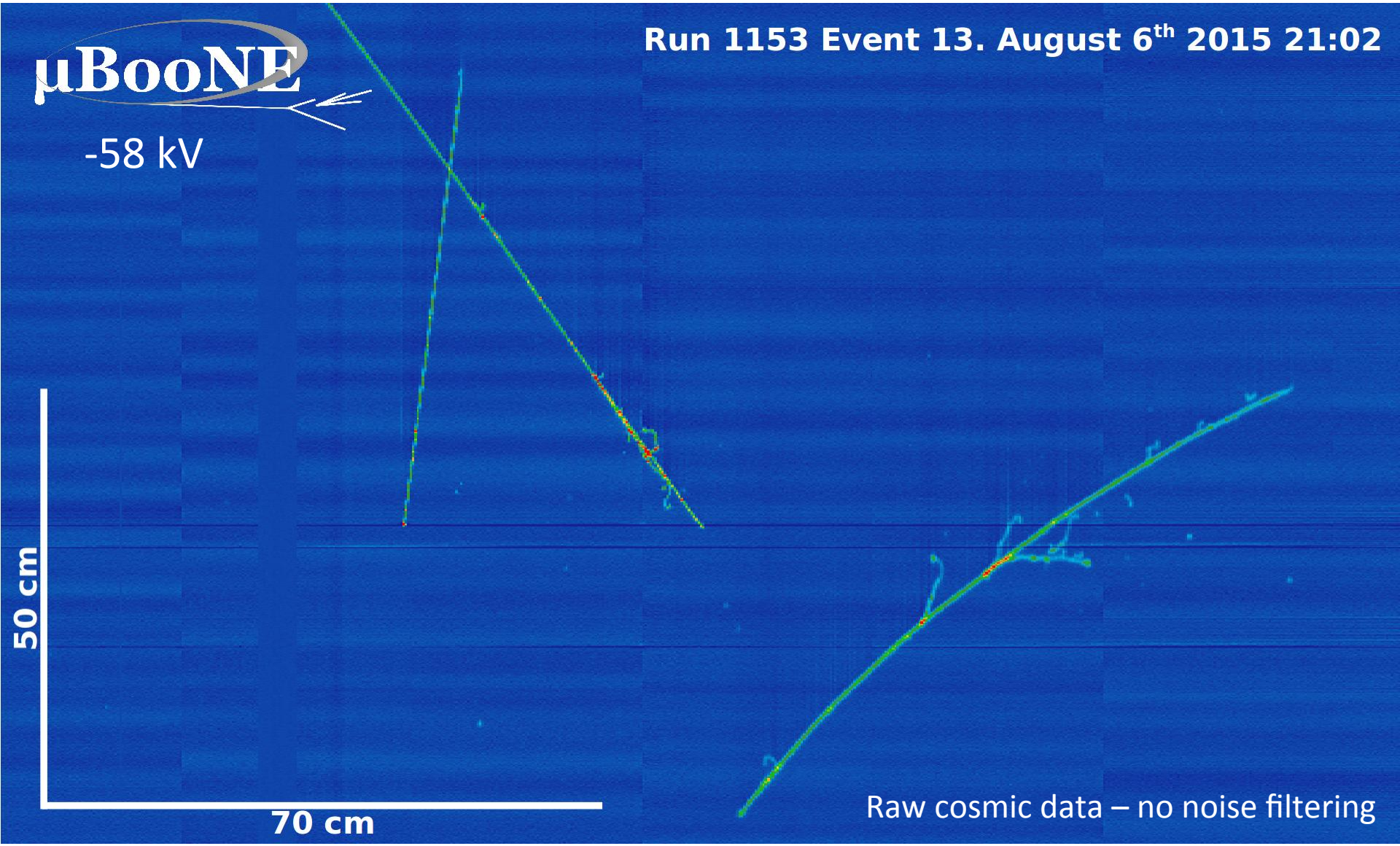
Electromagnetic Shower



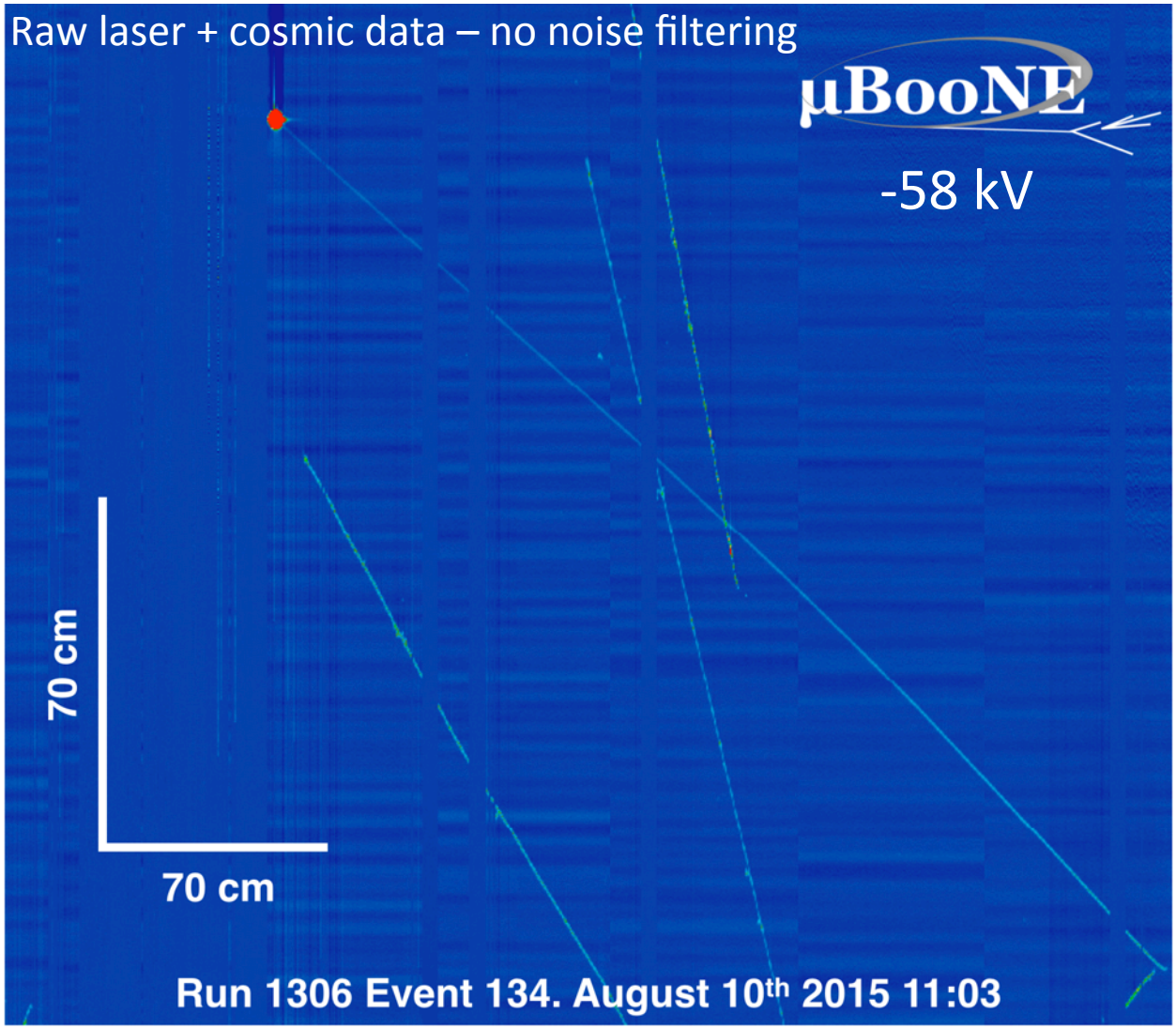
Candidate Muon and Decay Electron



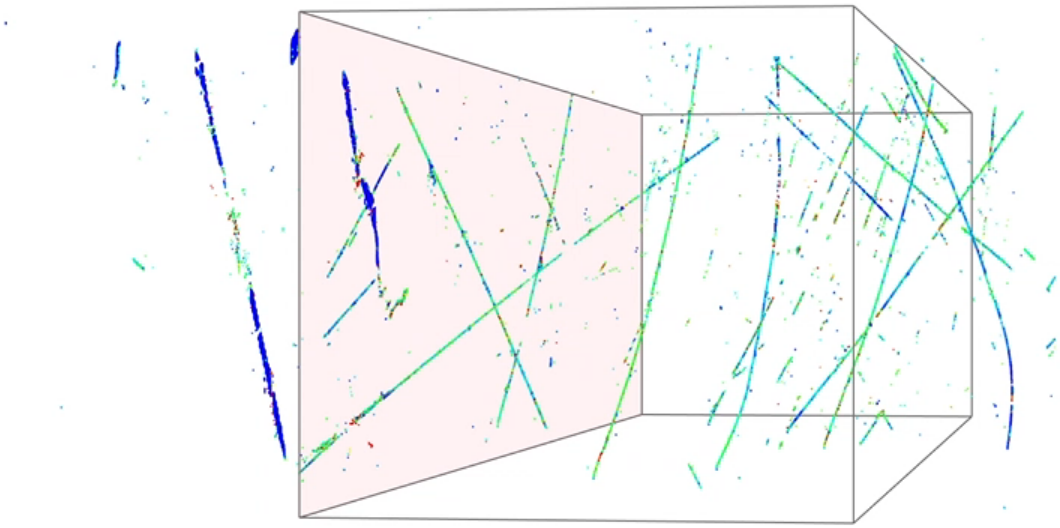
Cosmic muons with delta rays



First UV Laser Calibration Tracks

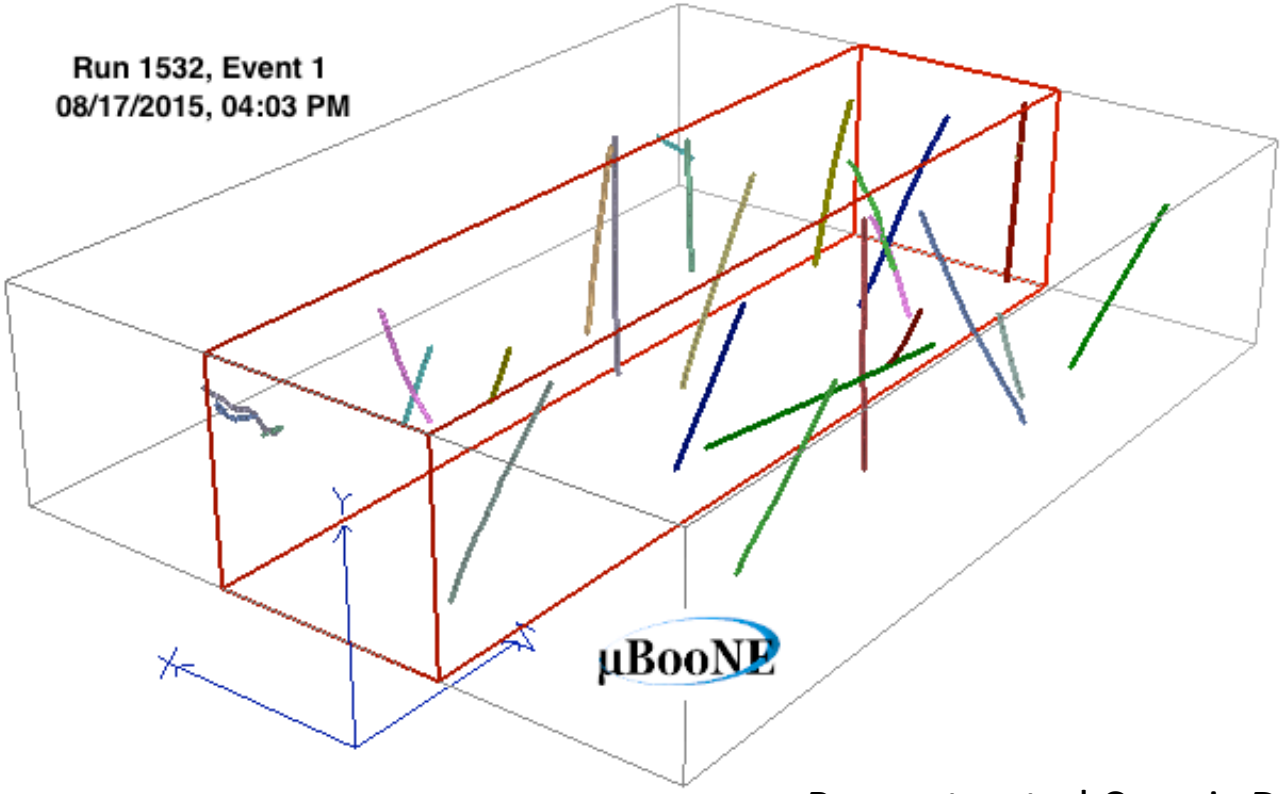


Next Steps: 3D Hit Reconstruction



Reconstructed MicroBooNE Cosmic Data at -58 kV

From There to Track Reconstruction



Reconstructed Cosmic Data at -70 kV

Summary

- MicroBooNE commissioning proceeding well
  - Major subsystems are now operational
  - First TPC tracks and PMT pulses seen in the detector
  - UV laser calibration system operational
- Big push to tune software and reconstruction tools on cosmic data
- MicroBooNE is now in operations mode with 24/7 shifts
- Working to be ready for Booster Neutrino Beam delivery at 5 Hz starting in October
- Very exciting time—new LArTPC neutrino data around the corner!

Thanks for your attention!


End.