MicroBooNE in 10 Minutes

Katrina Miller, on behalf of the MicroBooNE Collaboration

New Perspectives 2019 (Fermilab)

krm29@uchicago.edu

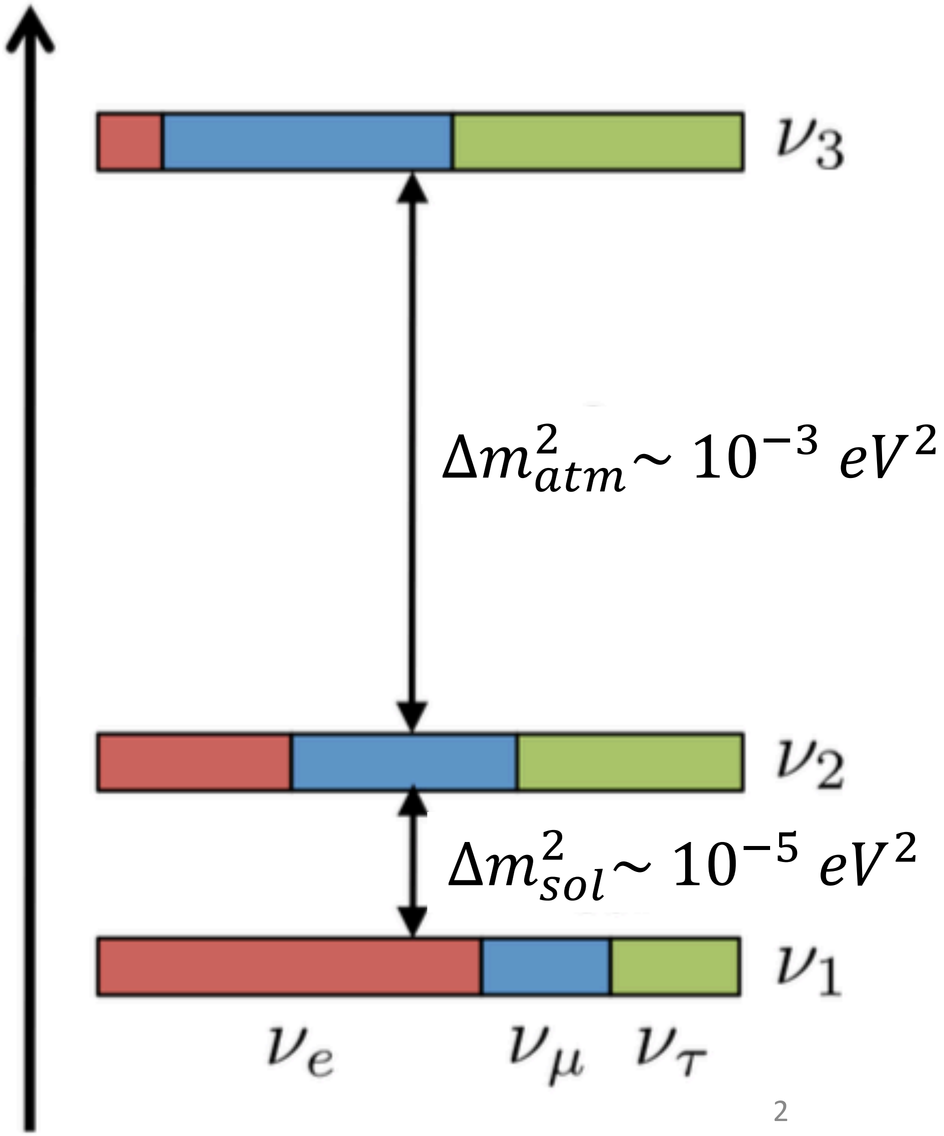
THE UNIVERSITY OF CHICAGO

Neutrino Oscillations

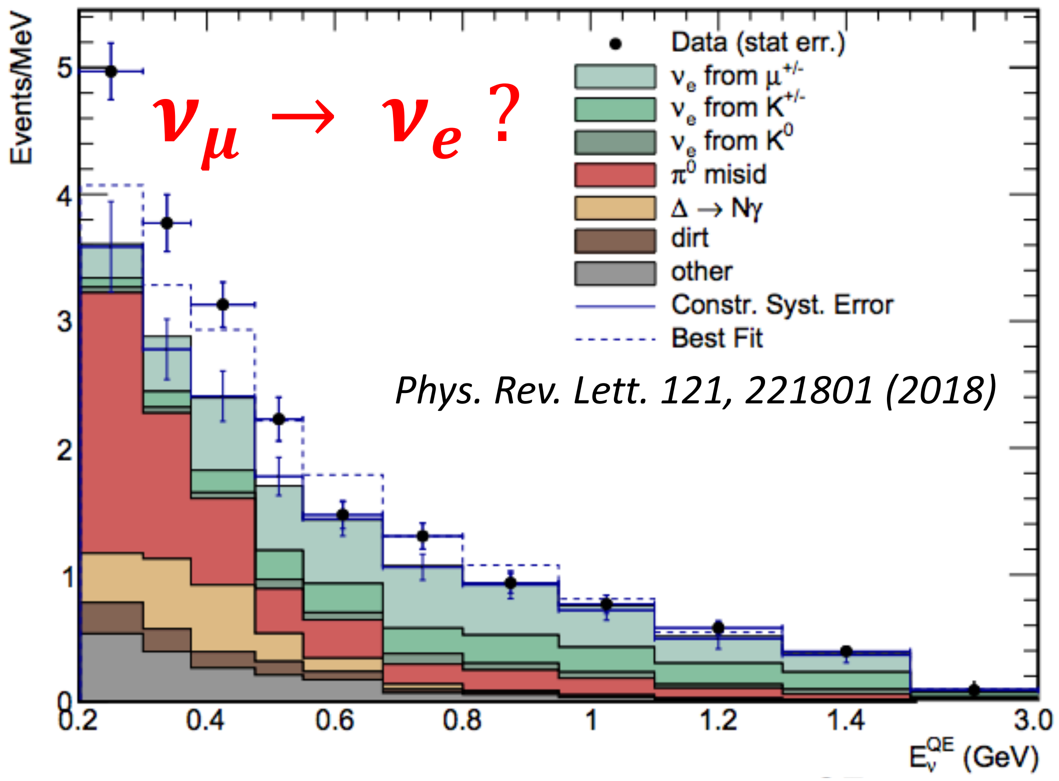
- neutrinos of the Standard Model are massless & come in three flavors:

- discovery of flavor oscillations → *neutrinos have mass!*
- in a two-neutrino approximation, the appearance probability is given by:

$$P(\nu_\alpha \to \nu_\beta) = sin^2(2\theta)\ sin^2\left(1.27\ \frac{\Delta m^2[eV^2]\ L\ [km]}{E_\nu\ [GeV]}\right)$$



MiniBooNE Event Excess (2009-2018)



Short-Baseline Neutrino Anomaly

$$L/E \approx 1\, m/MeV \Rightarrow \Delta m^2 \sim 1\, eV^2$$

- 2001: **LSND** observes excess of EM-like events
  - 3-neutrino model predicts **no oscillations**
  - 3.8σ excess consistent with $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillations
- 2009: **MiniBooNE** reports excess for both ν & $\bar{\nu}$ data with 4.7σ significance
  - different systematics, energy, & event signature
  - *unable to distinguish electrons & photons*

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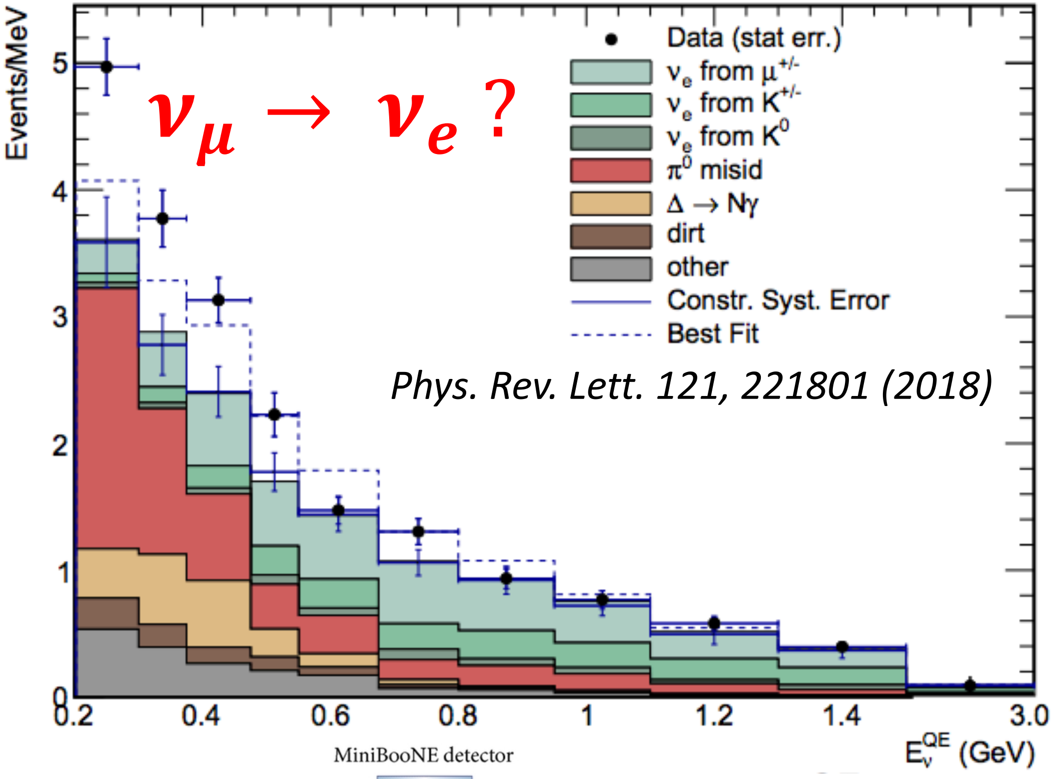

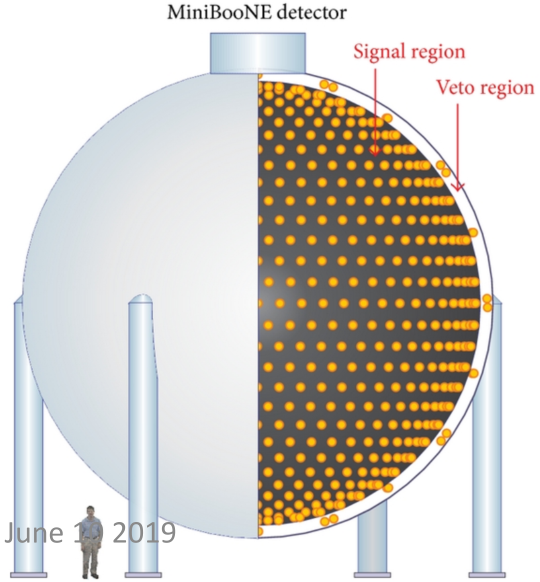

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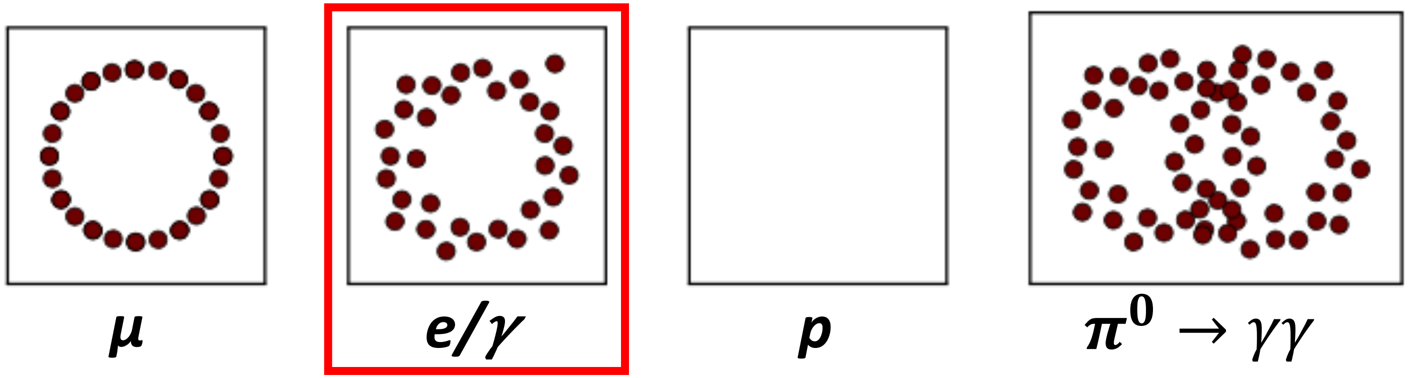
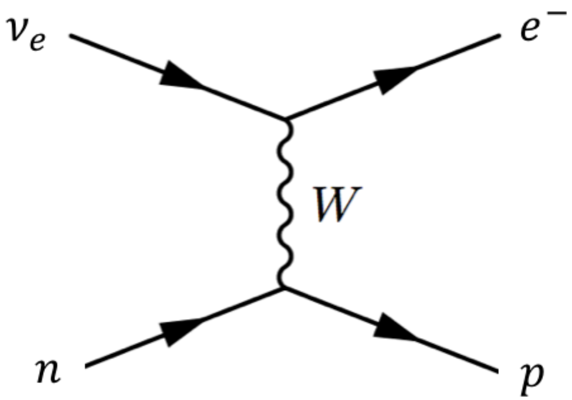
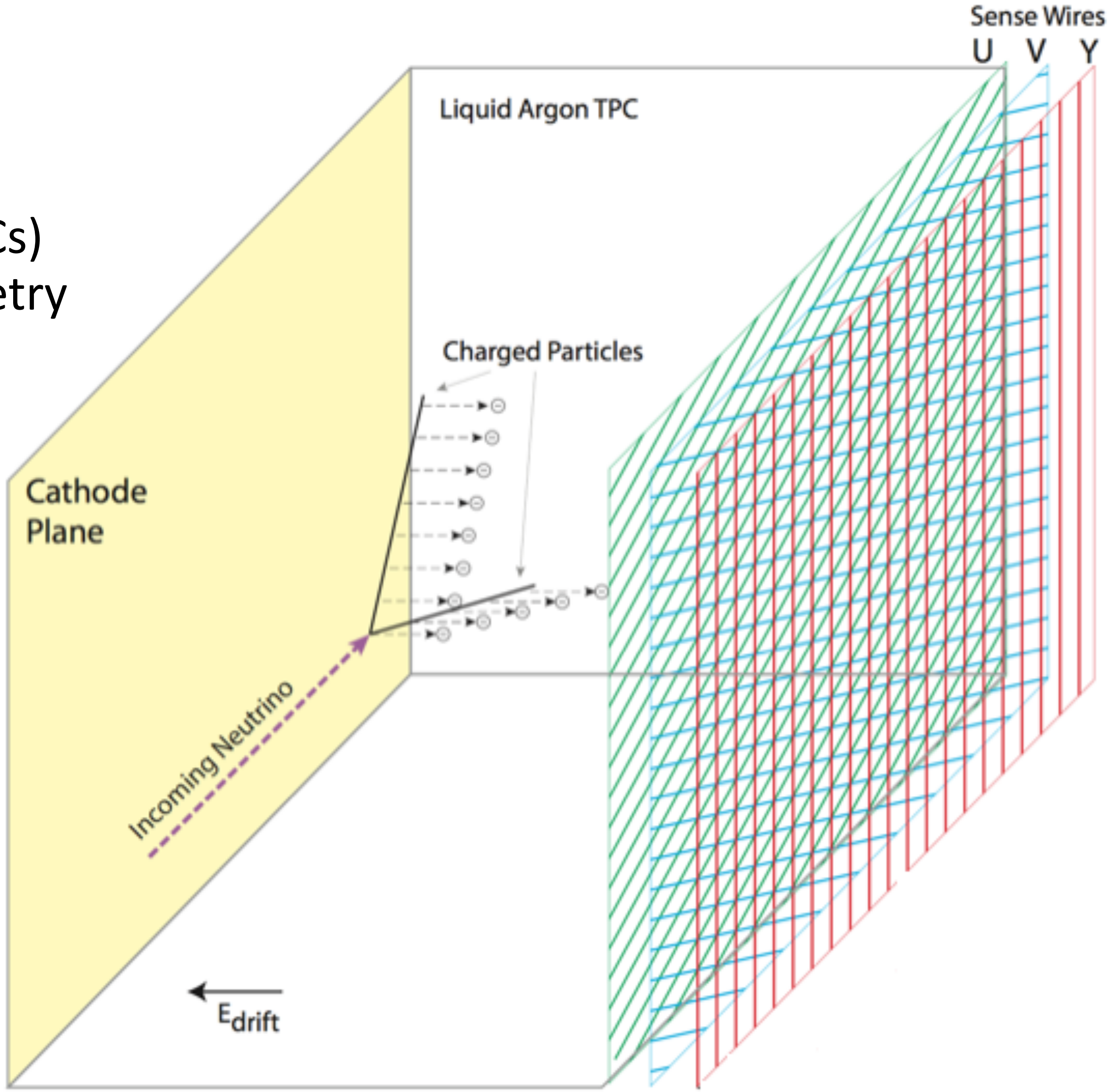


LArTPCs

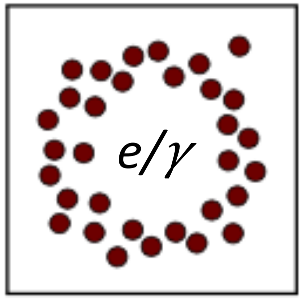
- liquid argon time projection chambers (LArTPCs) give us high quality tracking, imaging, calorimetry



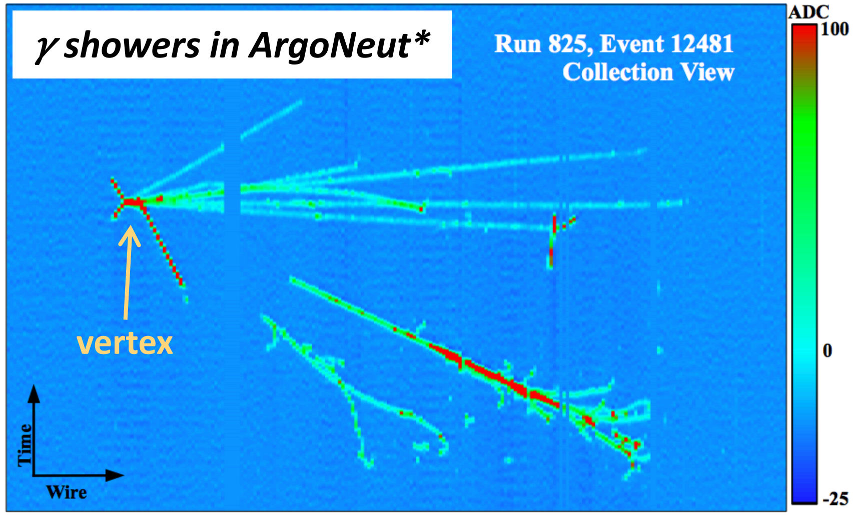
- electric field drifts ionization electrons to anode plane
- scintillation measured with optical detection system $(t = 0)$
- TPCs provide 3D reconstruction of particle trajectories inside the detector

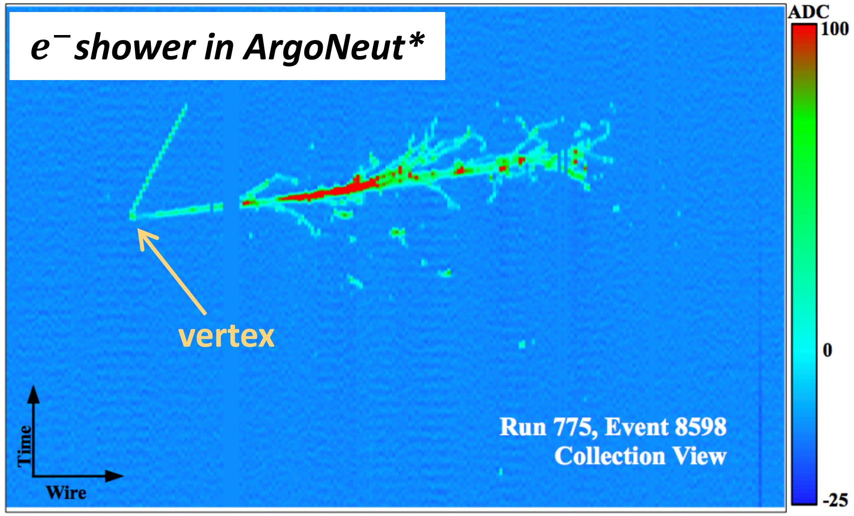


MiniBooNE:

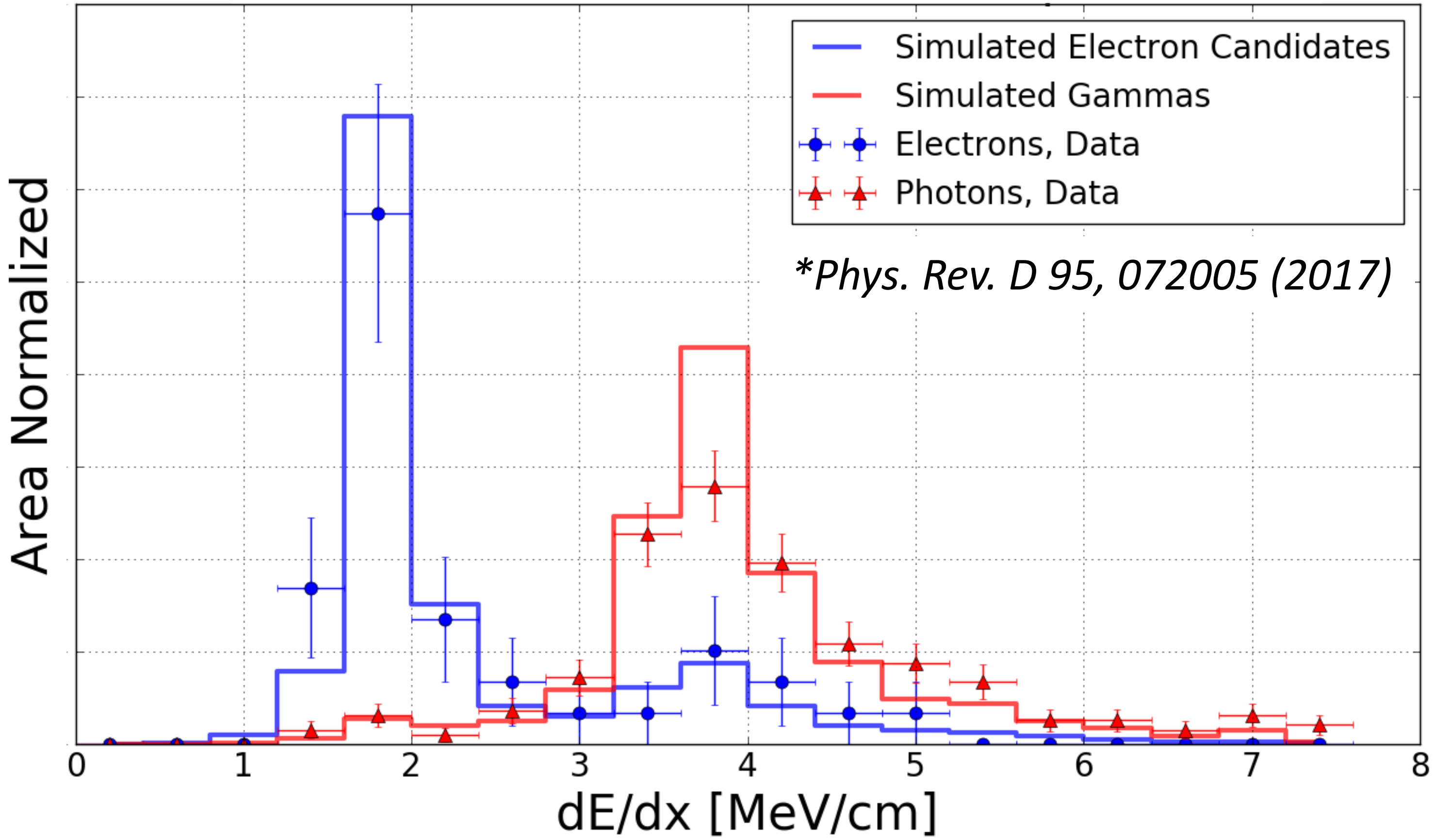


LArTPCs can discriminate electrons & photons—ideal for investigating the short-baseline neutrino anomaly!





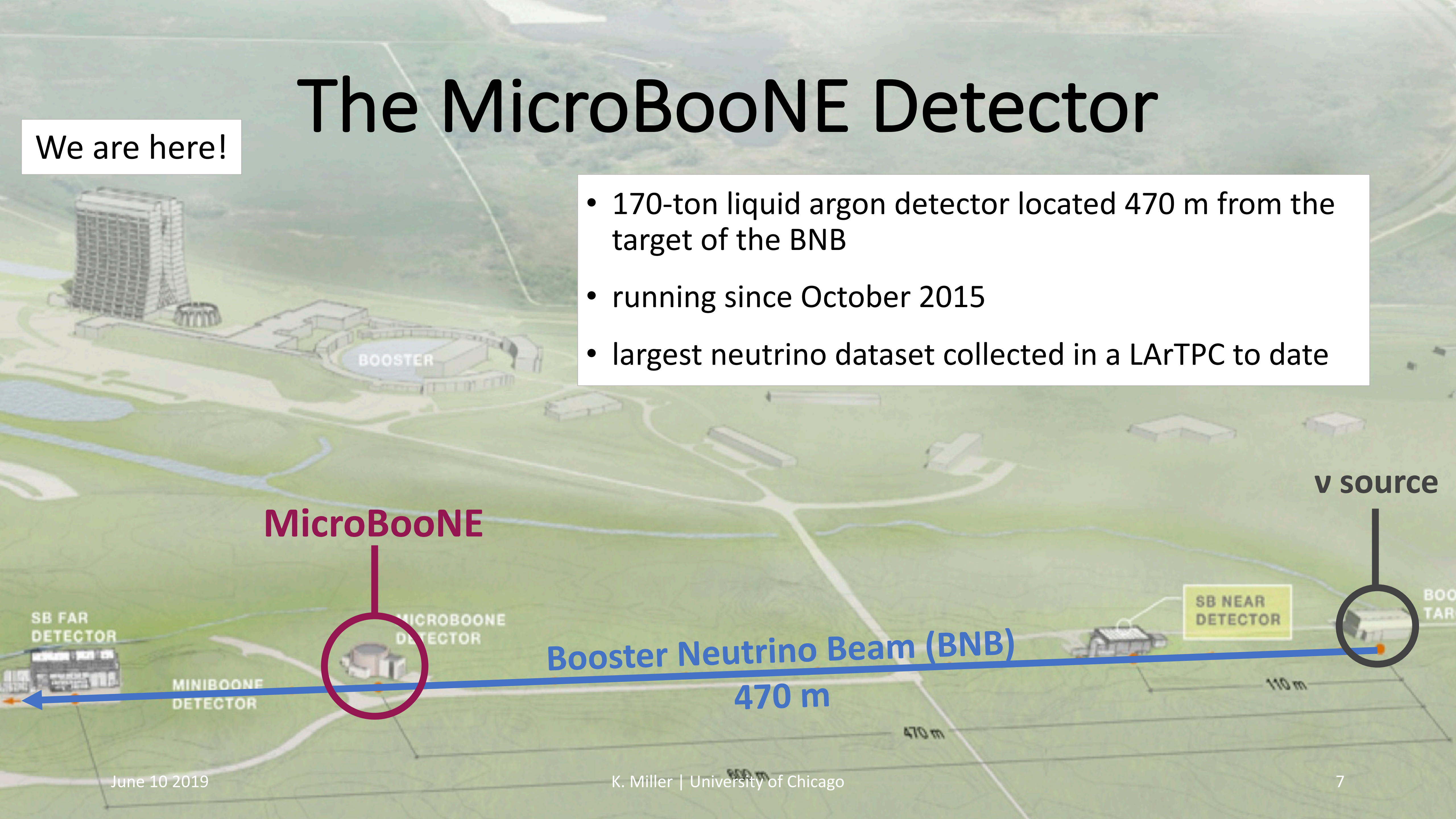
Calorimetric Discrimination of e/γ in ArgoNeut*



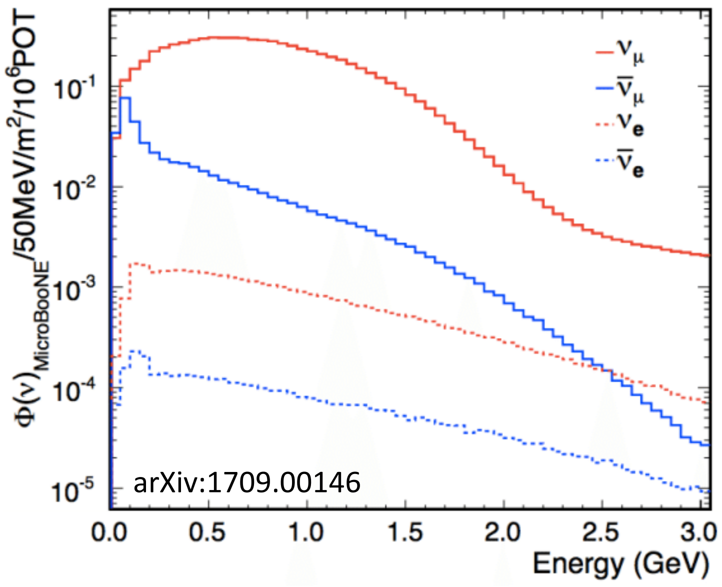
**Phys. Rev. D 95, 072005 (2017)*

The MicroBooNE Detector

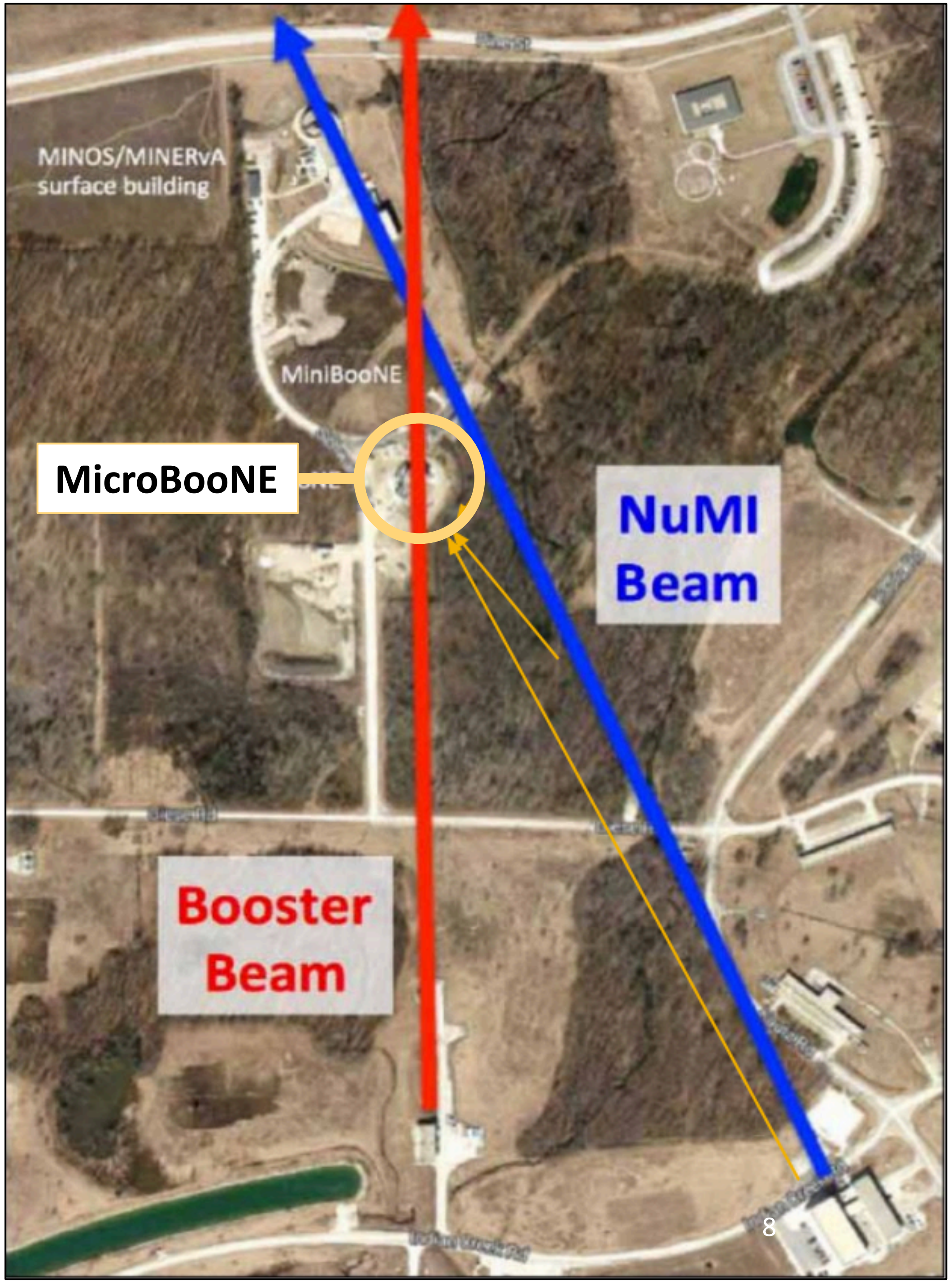
- 170-ton liquid argon detector located 470 m from the target of the BNB
- running since October 2015
- largest neutrino dataset collected in a LArTPC to date



On-Axis BNB Flux @ MicroBooNE



- 8 GeV proton beam incident on a beryllium target
- flux is mostly $\nu_\mu/\bar{\nu}_\mu$ (99.5%) with small amount of $\nu_e/\bar{\nu}_e$ (0.5%)
- $\sim$300,000 ν_μ & $\sim$ 3000 ν_e events observed thus far!



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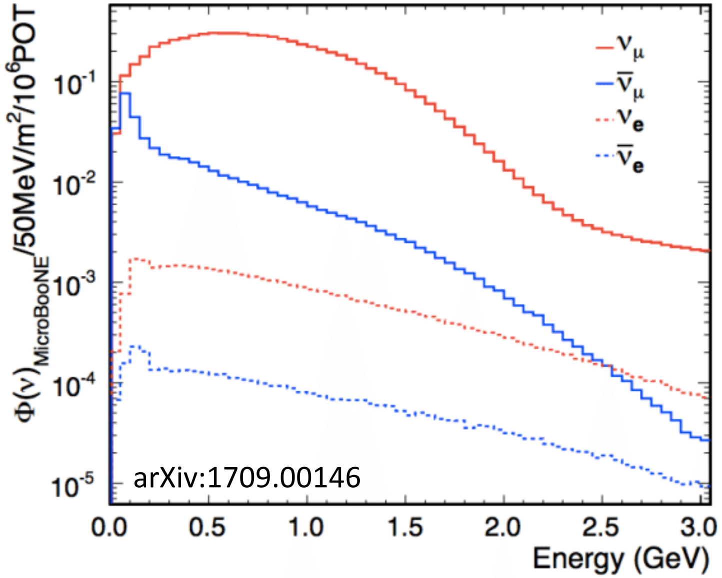

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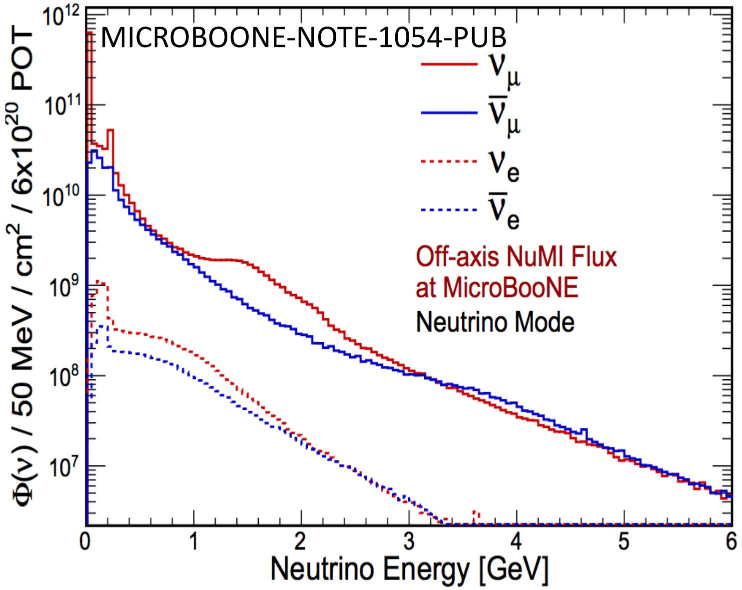
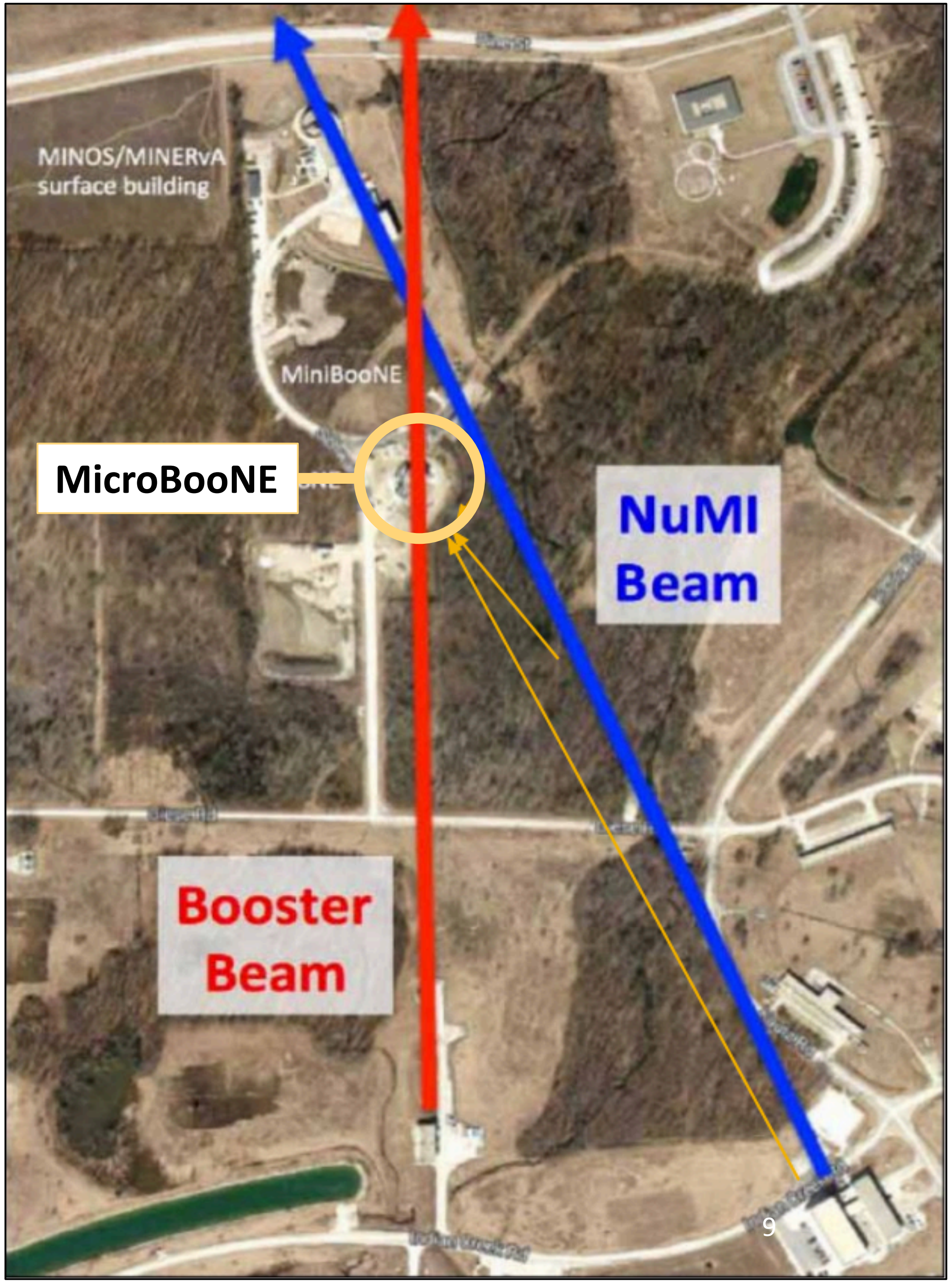
Off-Axis NuMI Flux @ MicroBooNE



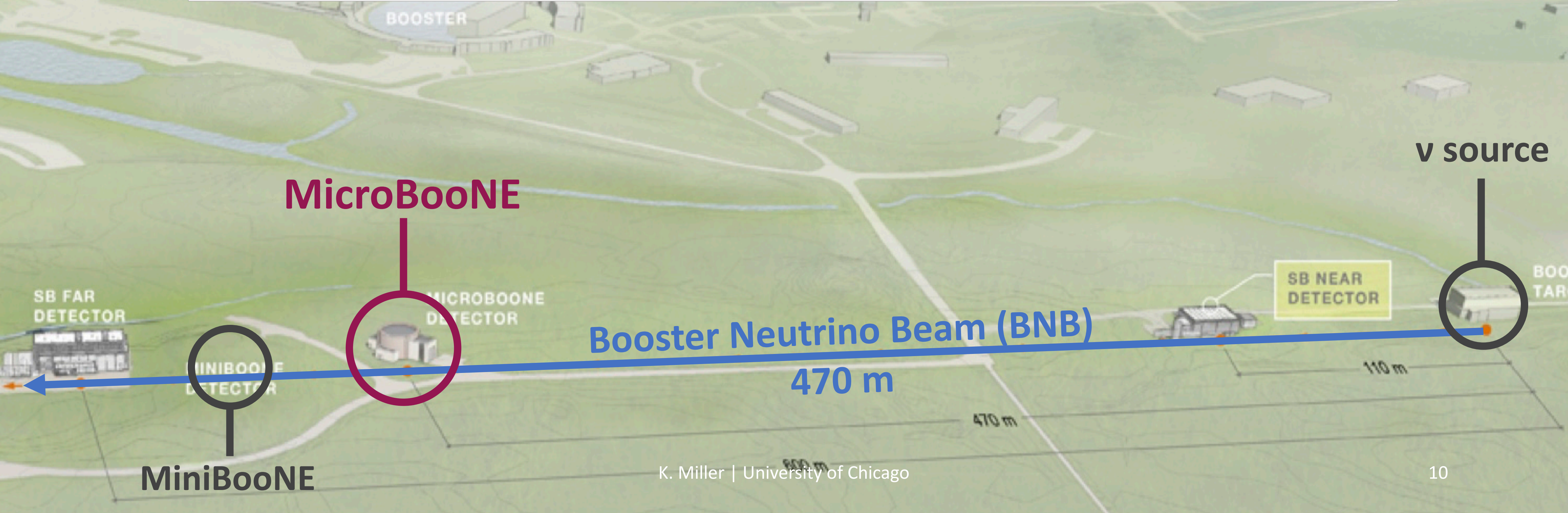
- MicroBooNE sits 8° off-axis from NuMI beamline
- 120 GeV proton beam incident on a graphite target
- higher intrinsic $\nu_e/\bar{\nu}_e$ flux ($\sim$5%)



The MicroBooNE Detector

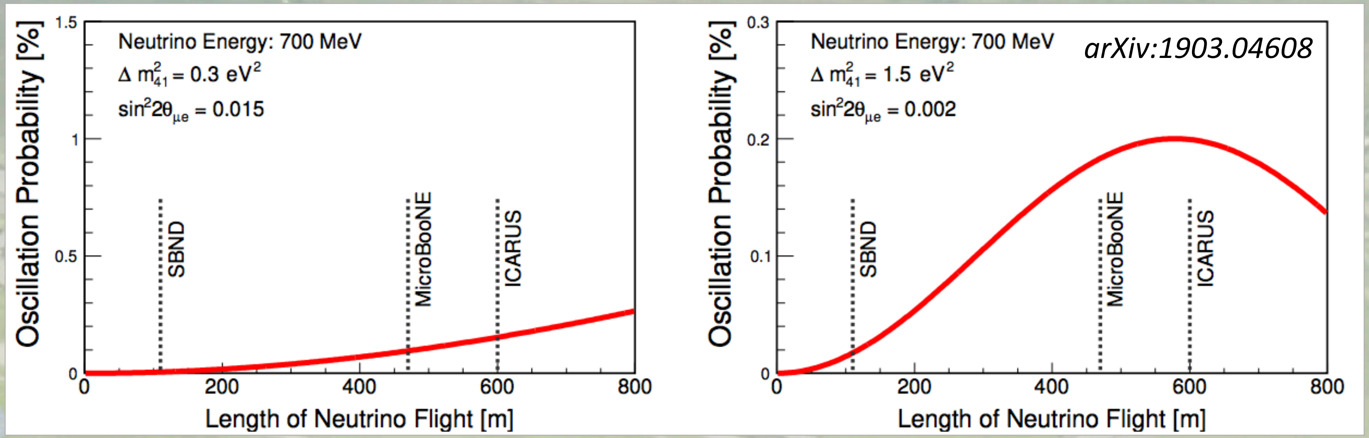
The Physics Program:

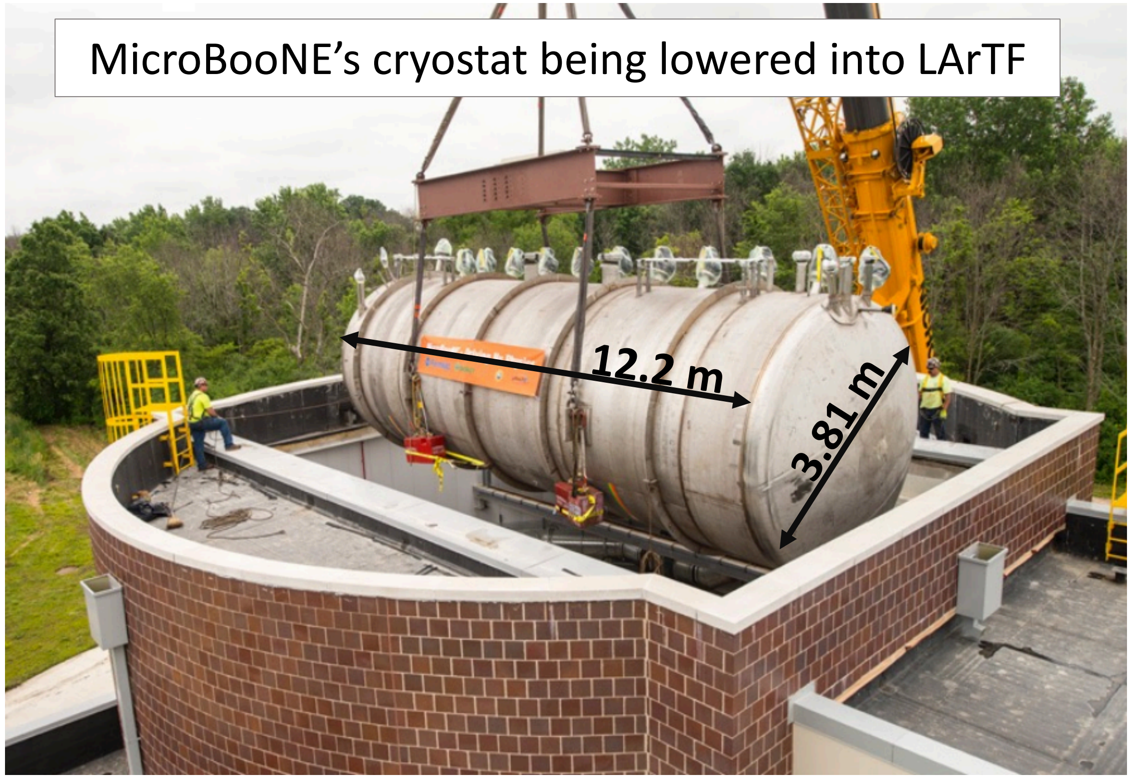
- Investigate the EM-like event excess previously reported by MiniBooNE
- Study various neutrino interactions in LAr & measure low-energy cross sections
- R&D for future long-baseline experiments (DUNE)



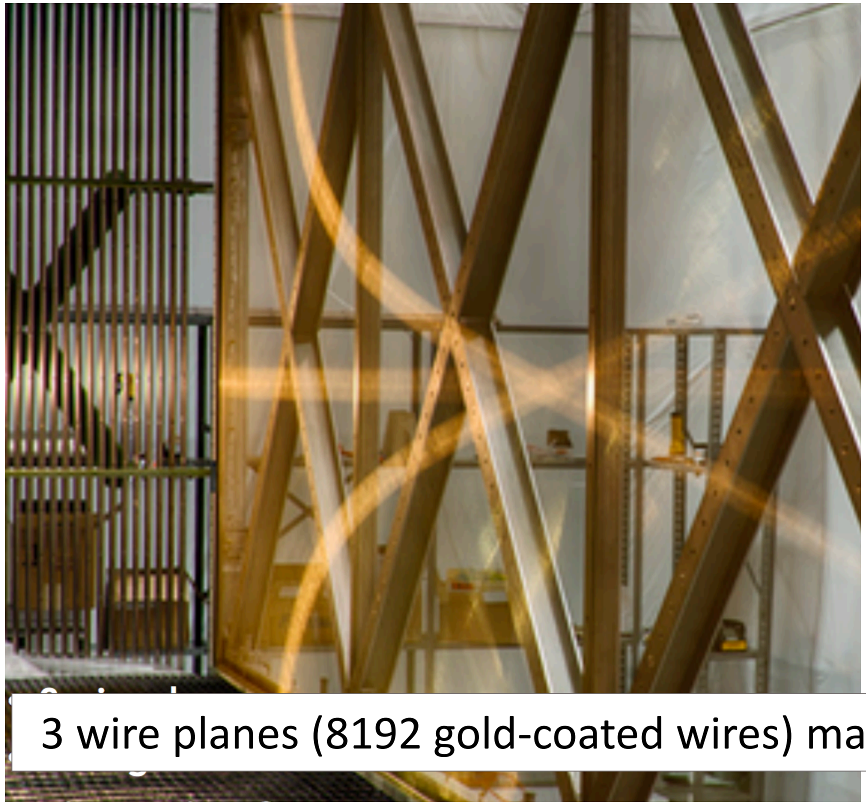
The MicroBooNE Detector

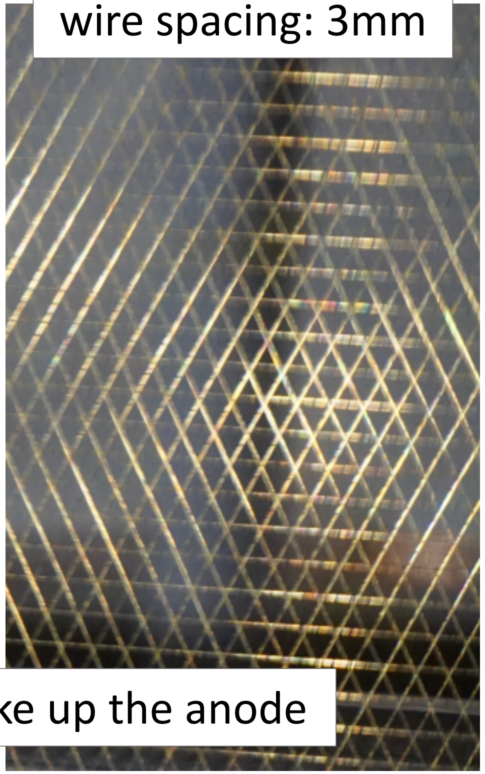
One of three LArTPCs making up the Short-Baseline Neutrino (SBN) Program!





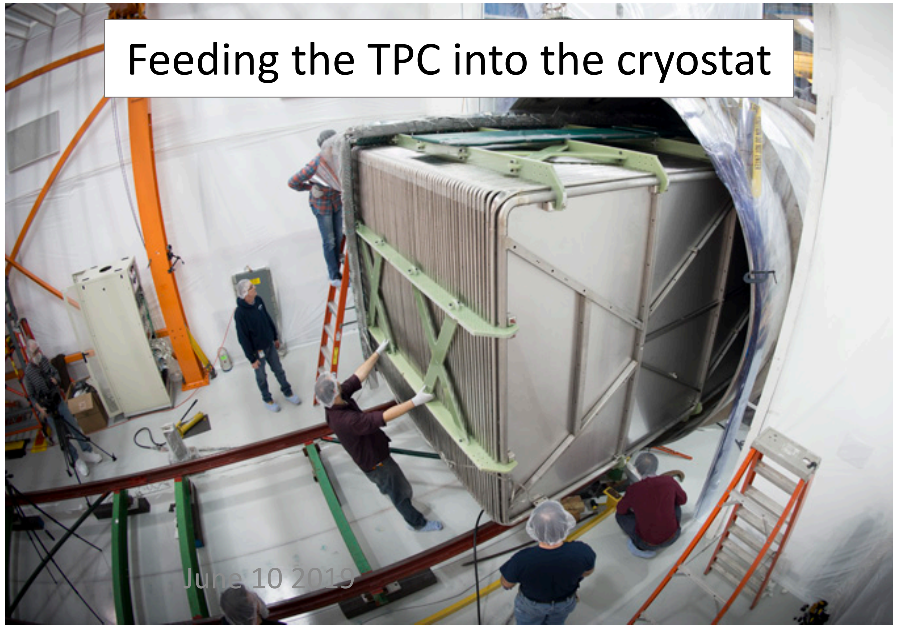
MicroBooNE’s cryostat being lowered into LArTF



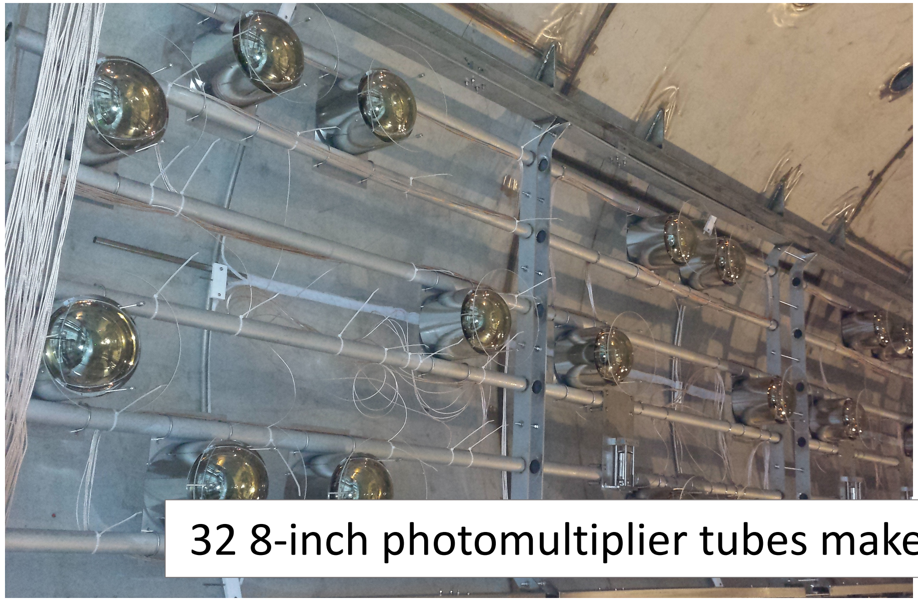


wire spacing: 3mm

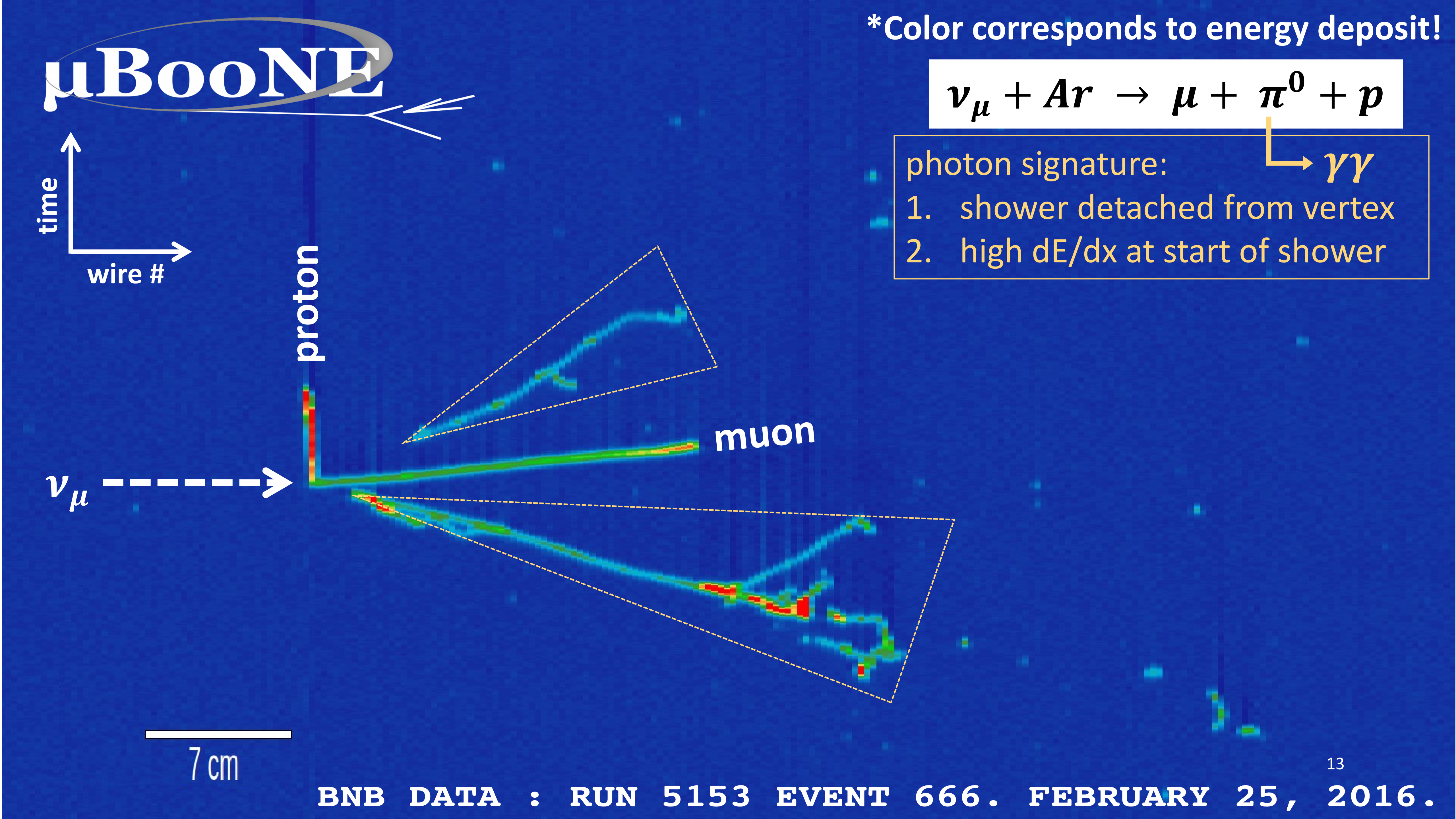
3 wire planes (8192 gold-coated wires) make up the anode



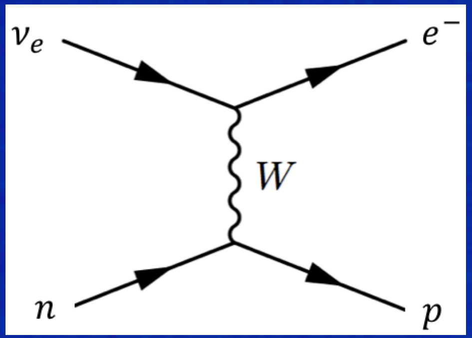
Feeding the TPC into the cryostat

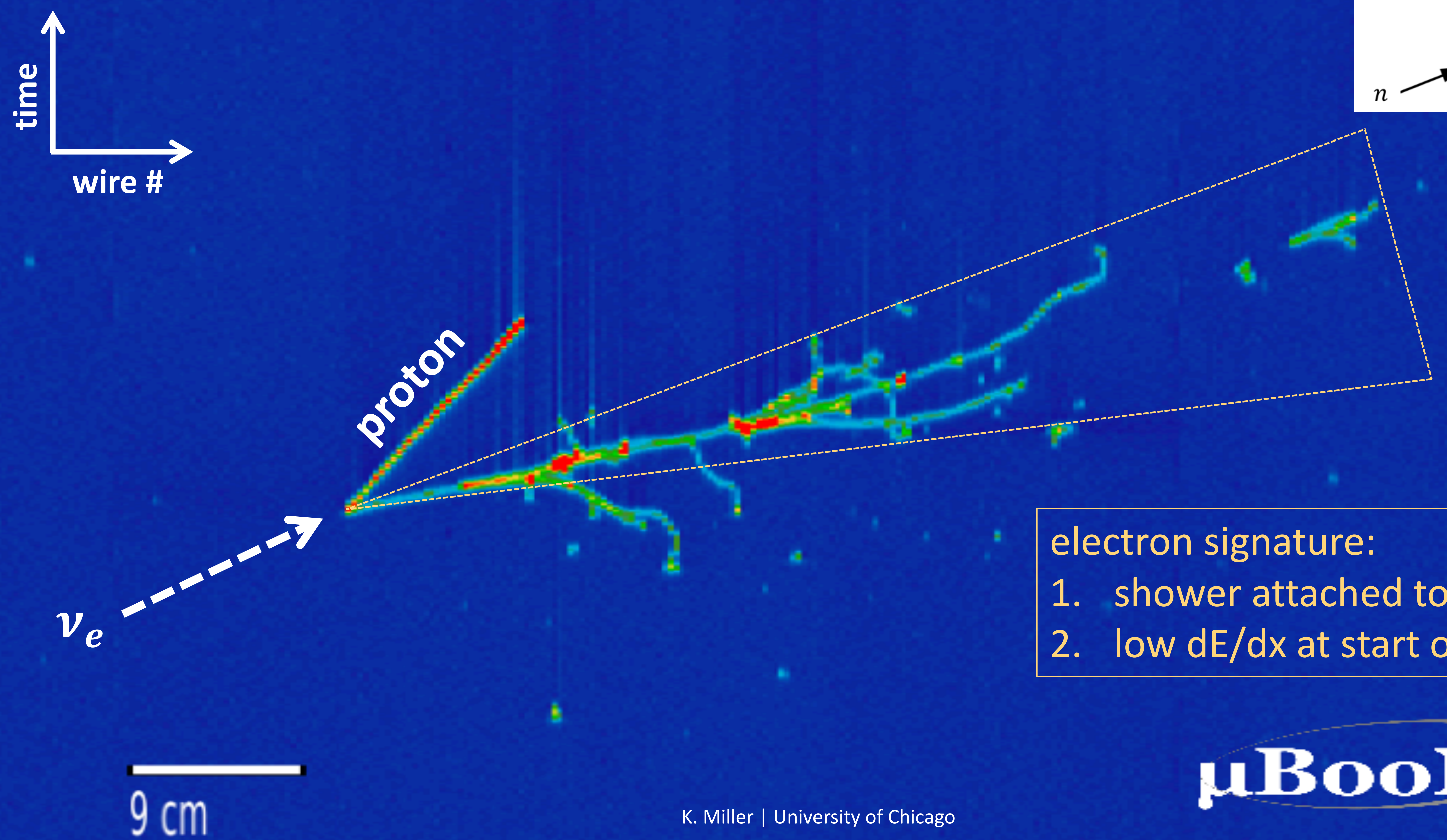


32 8-inch photomultiplier tubes make up the light collection system


µBooNE
*Color corresponds to energy deposit!
$\nu_\mu + Ar \rightarrow \mu + \pi^0 + p$
$\gamma\gamma$
photon signature:
1. shower detached from vertex
2. high dE/dx at start of shower
time
wire #
proton
muon
ν_μ
7 cm
BNB DATA : RUN 5153 EVENT 666. FEBRUARY 25, 2016.

NuMI: Run 5280 Subrun 66 Event 3329





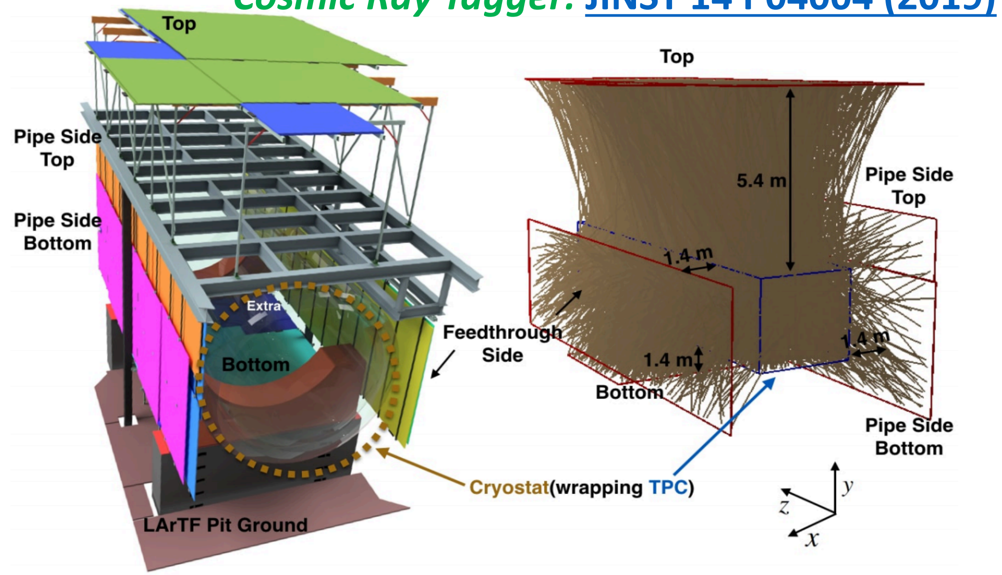
electron signature:

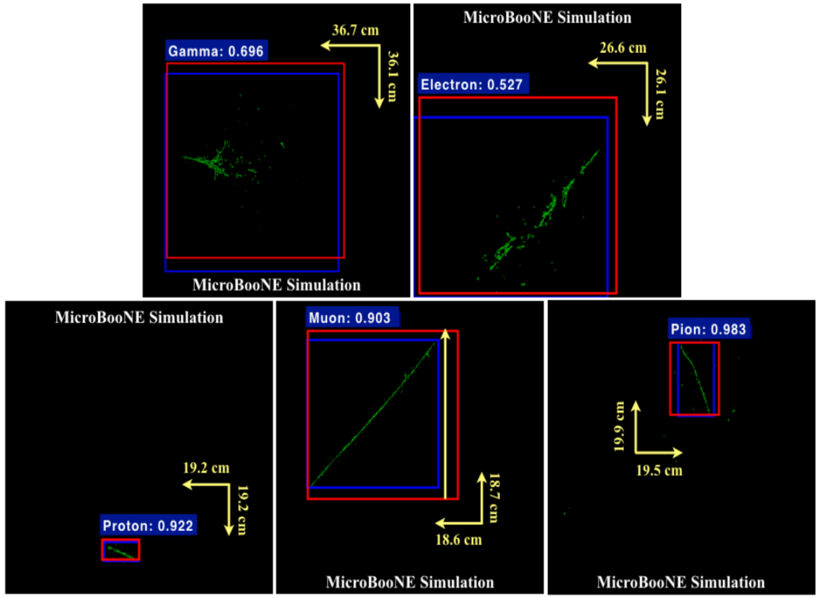
1. shower attached to vertex
2. low dE/dx at start of shower

MicroBooNE's Physics Program:

- **R&D for future LArTPCs**
- ν-Ar interactions & cross sections
- EM-like event excess at $L/E \approx 1\, m/MeV$

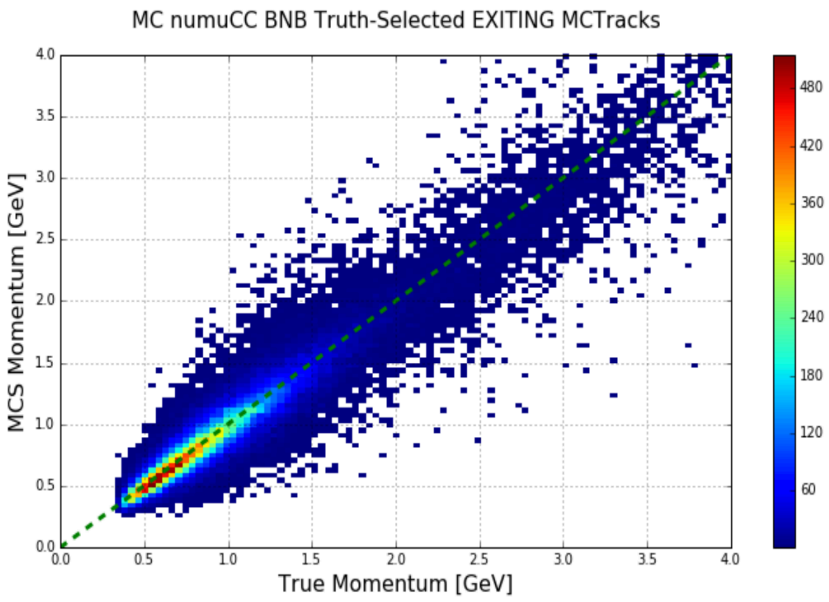
Cosmic Ray Tagger: JINST 14 P04004 (2019)

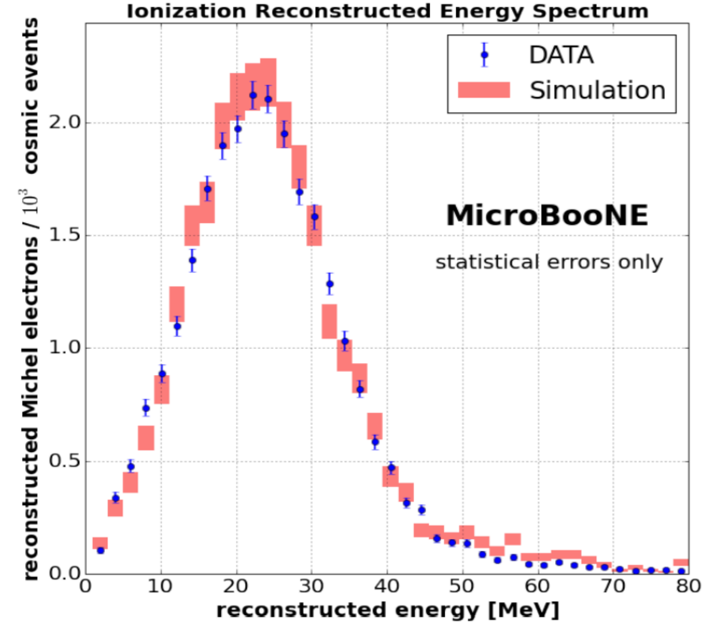




Convolutional Neural Networks Applied to ν Events in a LArTPC: JINST 12 P03011 (2017)

Muon Momentum Using Multiple Coulomb Scattering: JINST 12 P10010 (2017)





Michel Electron Reconstruction: JINST 12 P09014 (2017)

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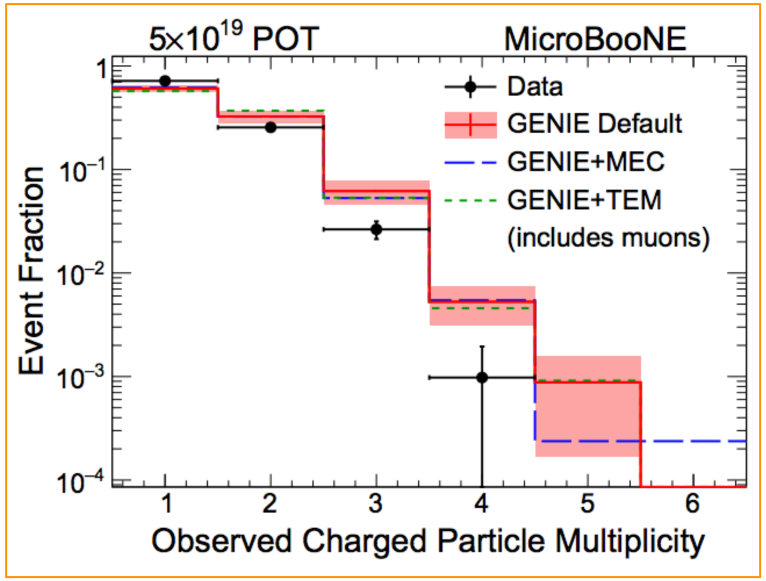
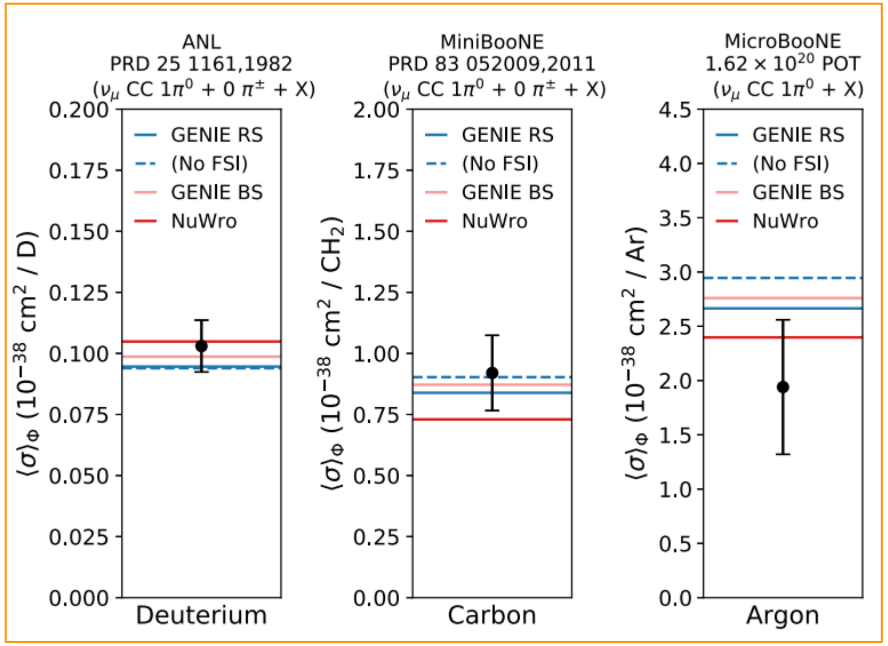
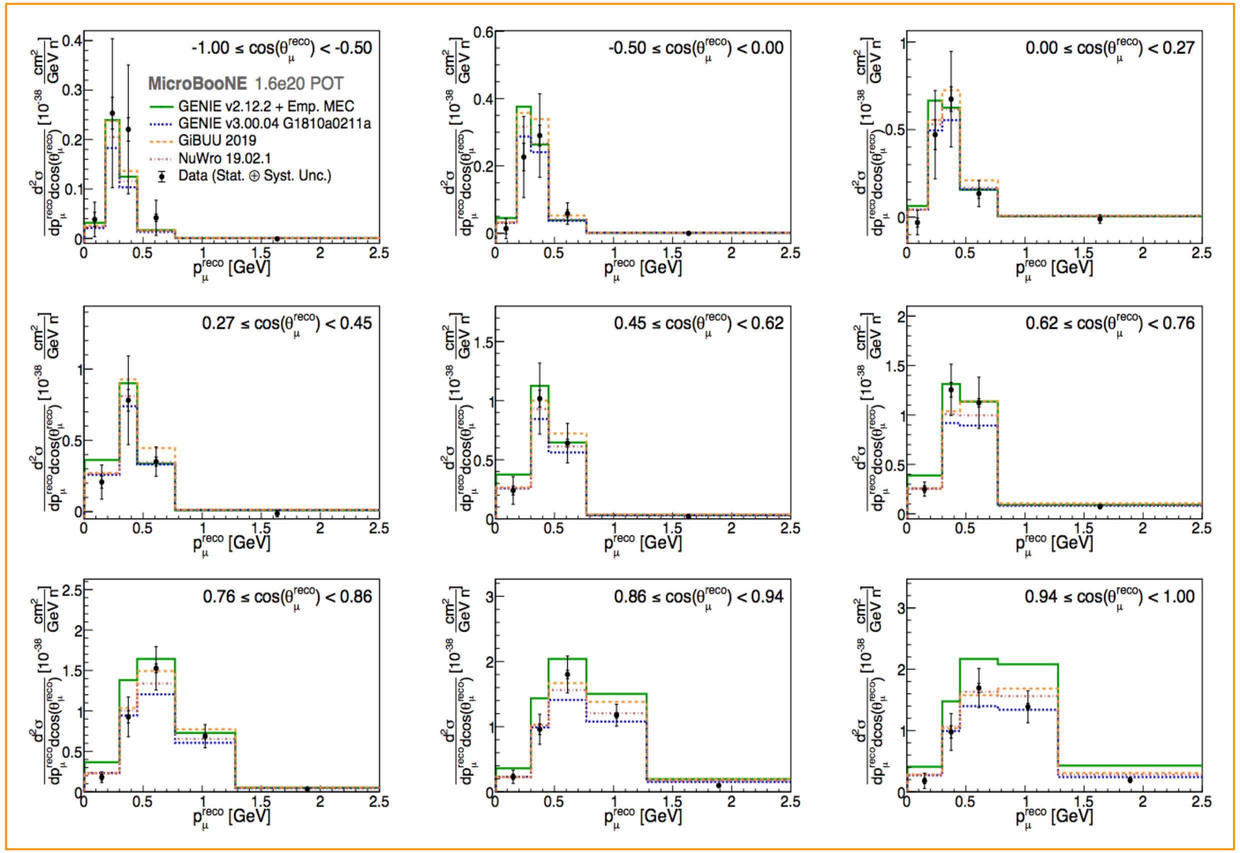
- EM-like event excess at $L/E \approx 1\, m/MeV$

Charged Particle Multiplicity: Eur. Phys. J. C79 248



ν_μ Charged Current π^0 Production on Ar: Phys. Rev. D99, 091102(R)





Inclusive ν_μ Charged Current Differential Cross Section: arXiv:1905.09694

New Perspectives Talks:

Progress towards the extraction of exclusive ν_μ-^{40}Ar cross sections with a single proton using the MicroBooNE LArTPC detector - Afroditi Papadopoulou

Towards the measurement of the charged-current ν_e inclusive cross-section on argon in MicroBooNE using the NuMI beam - Krishan Mistry

Chimera Events in the MicroBooNE Experiment - Polina Abratenko

User's Meeting Posters:

Constraining the Neutral Current π_0 Background for MicroBooNE's Single-Photon Search - Andrew Mogan

MicroBooNE's Continuous Readout - Iris Ponce

MicroBooNE's Search for a Single Photon Low Energy Excess Under a Neutral Current $\Delta \rightarrow N\gamma$ Hypothesis - Kathryn Sutton

Systematic Studies for the Single Photon Analysis at MicroBooNE - Gray Yarbrough

Search For Heavy Neutral Leptons in the MicroBooNE LArTPC - Owen Goodwin

MeV Scale Physics in MicroBooNE - Avinay Bhat

Triggering Efficiency in MicroBooNE - Vincent Basque

Searching for Short-Range Correlations in ^{40}Ar with MicroBooNE - Samantha Sword-Fehlberg

Thank you, & stay tuned for more exciting physics!