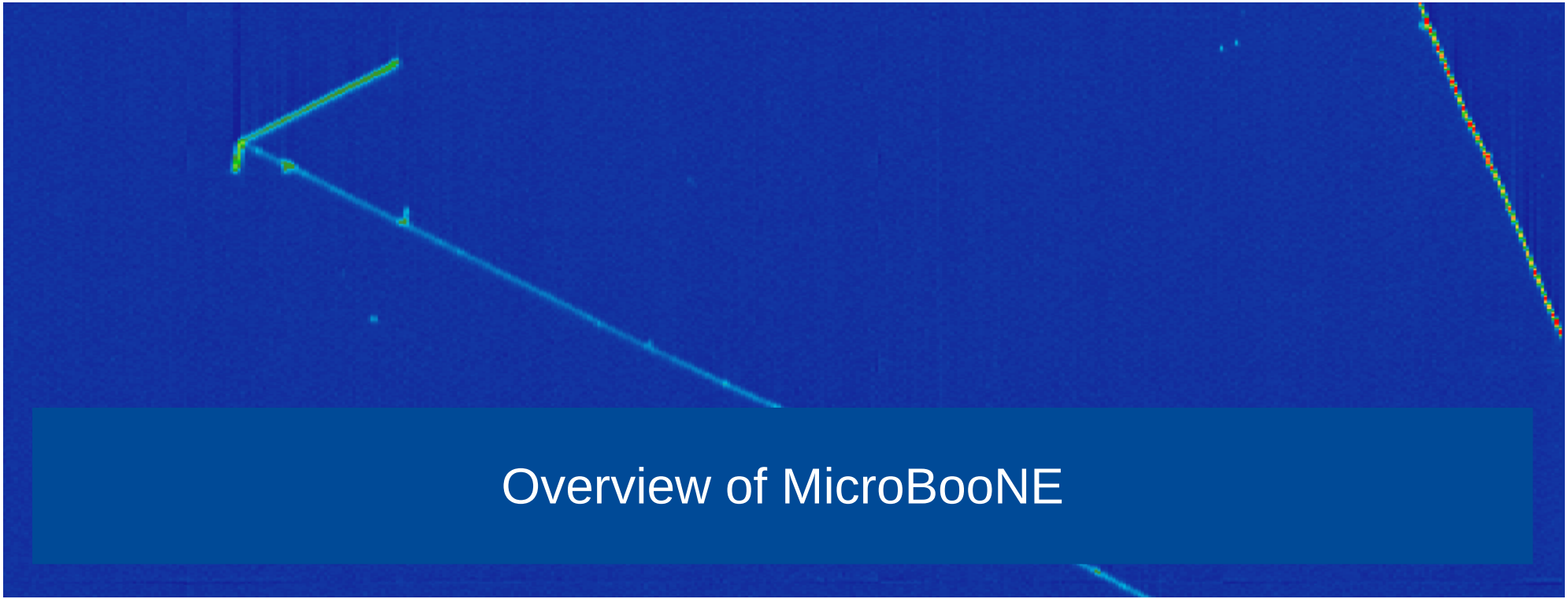


Overview of MicroBooNE

Thomas Mettler on behalf of the MicroBooNE collaboration

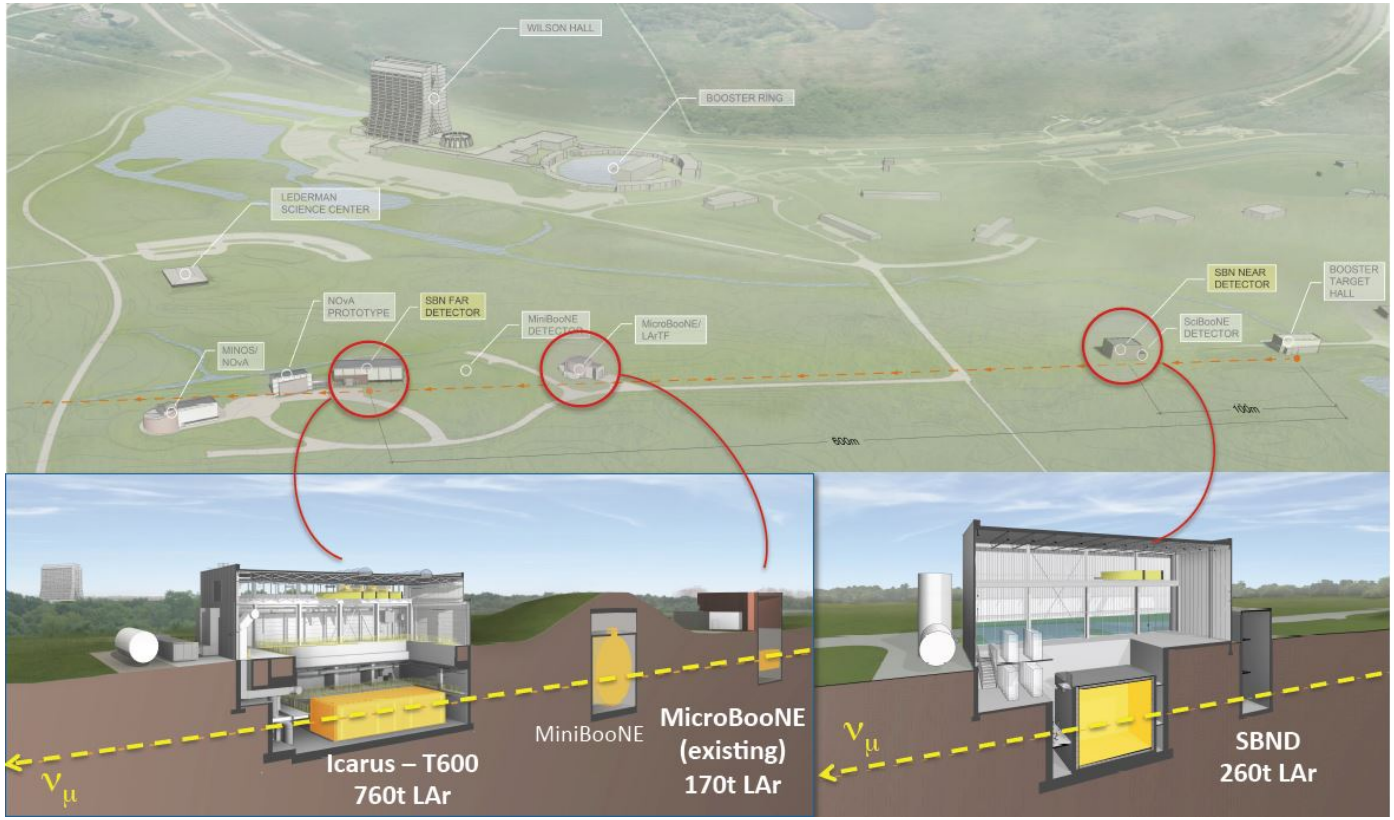
Joint Annual Meeting of SPS and ÖPG, 29 August 2019

UNIVERSITÄT BERN

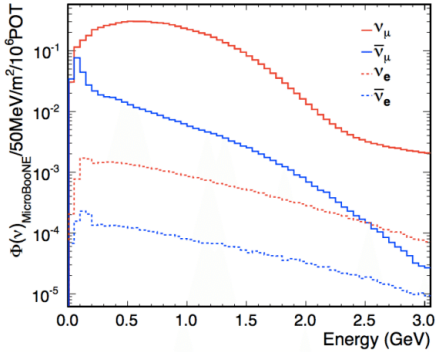
AEC
ALBERT EINSTEIN CENTER
FOR FUNDAMENTAL PHYSICS

LABORATORIUM FÜR HOCHENERGIEPHYSIK
LHEP
UNIVERSITÄT BERN

Short-Baseline Neutrino program



- Three detectors located at different distances (110m, 470m, 600m) in the same baseline
- Same technology
  - Liquid Argon Time Projection Chamber (LArTPC)
- Neutrinos from the BNB beam line
  - Mean energy: 800 MeV
- Offaxis: NuMI beam



BNB neutrino energy spectrum

The MicroBooNE experiment

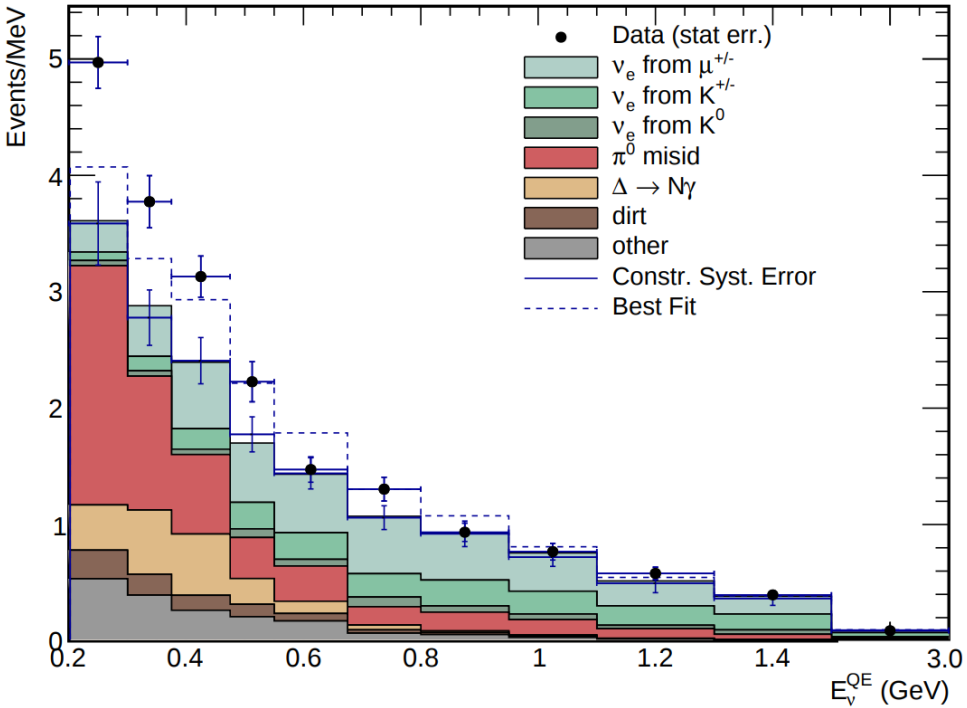
- Physic program:
  - Investigation of the low energy excess (LEE) of electron-like events measured by MiniBooNE
  - Neutrino – Argon cross-section measurements
  - Detector R&D for future LArTPC experiments (e.g DUNE)

Inner view of MicroBooNE cryostat during installation.

fnal.gov

Low energy excess observed by MiniBooNE

- MiniBooNE:
  - Liquid scintillator
  - 800 t of mineral oil
  - Spherical PMT system
- Low energy excess:
  - Excess of low energy electron neutrino like signal
  - 4.7 sigma, + LSND → 6.0 sigma
- Investigation of this excess needs good electron neutrino (e^-) identification from background (γ)

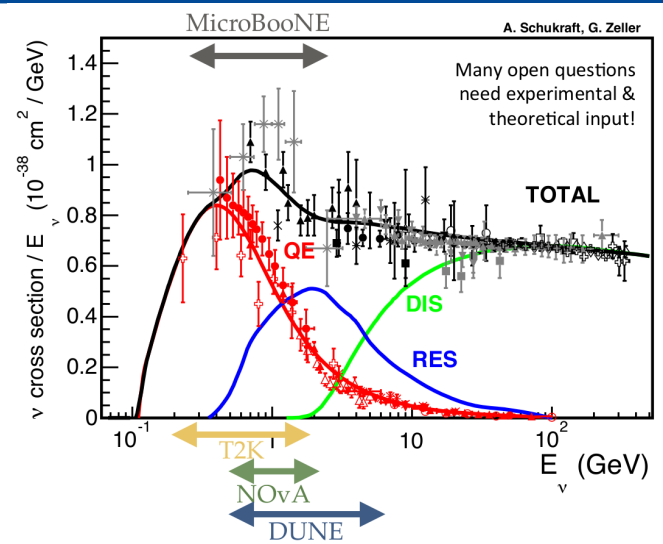


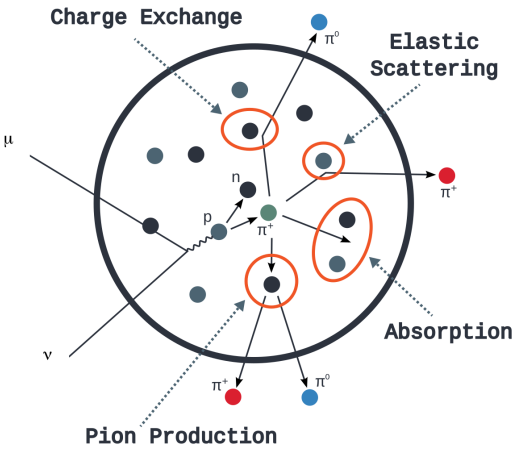
Reconstructed neutrino energy at MiniBooNE

arXiv:1805.12028v2

Neutrinos in Argon

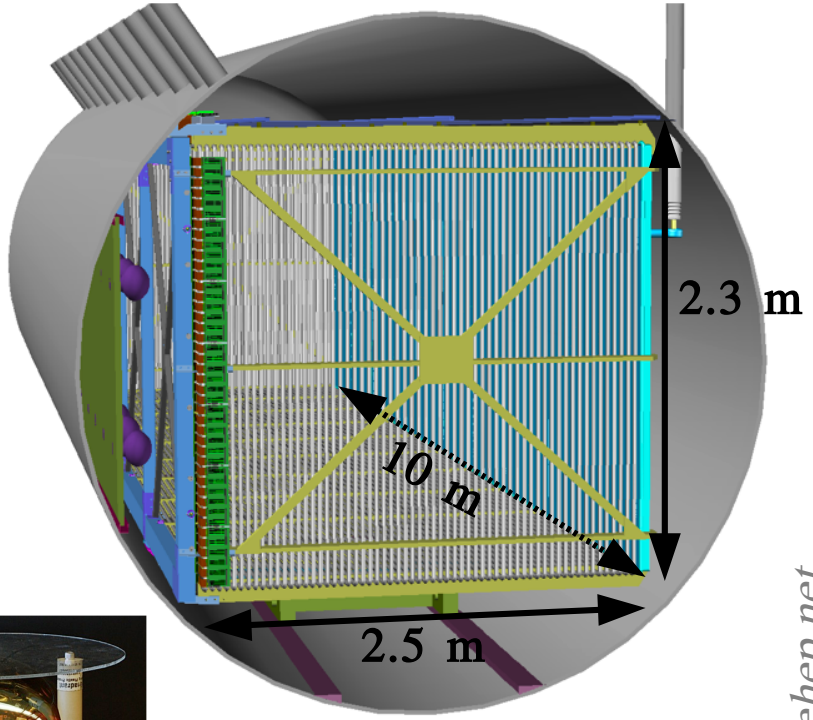
- MicroBooNE reconstruct neutrino-Argon interactions with different channels
  - Quasi-elastic (QE)
  - Resonance (RES)
  - Deep inelastic (DIS)
- Neutrino – Nucleus interaction
  - Only “see” what leaves the nucleus
  - Final-state interactions (FIS)
  - Nucleon correlations
  - Nuclear model
- For precise modeling, precise measurements are needed!

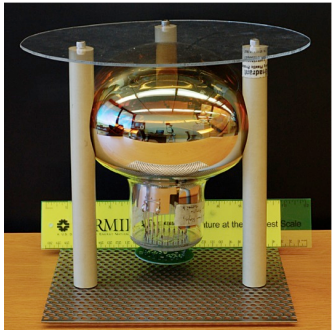




The MicroBooNE detector

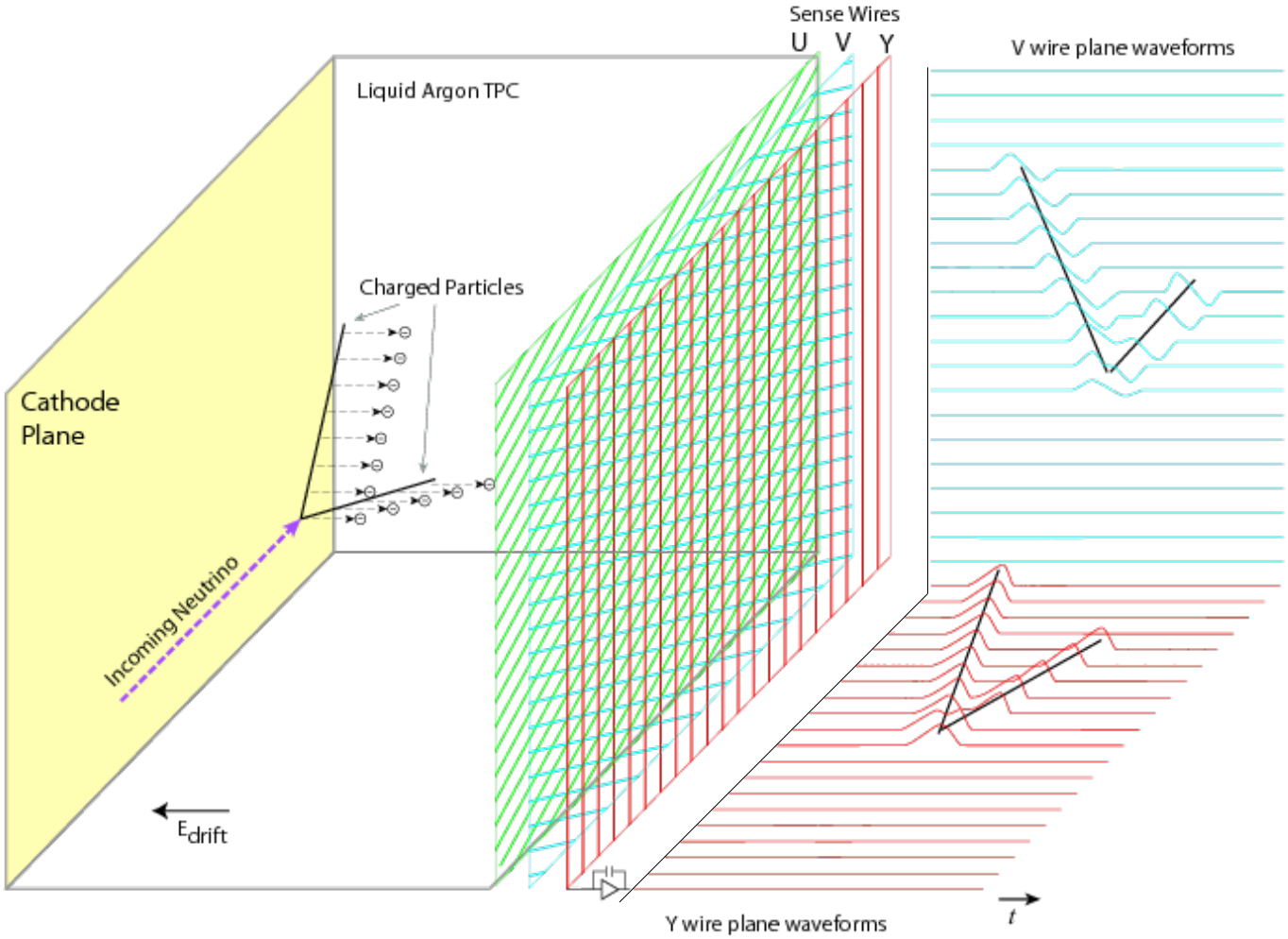
- 170 t liquid Argon, 85 t active
- Time Projection Chamber:
  - Charge readout:
    - 8256 wires
    - 2 induction planes (+- 60 Deg)
    - 1 Collection plane
  - E-field: 70 kV over 2.5 m drift
  - 2.3 ms drift time
- Optical readout
  - 32 PMTs with TPB coated plate
  - Behind anode wire plane
  - Triggering and T0 determination



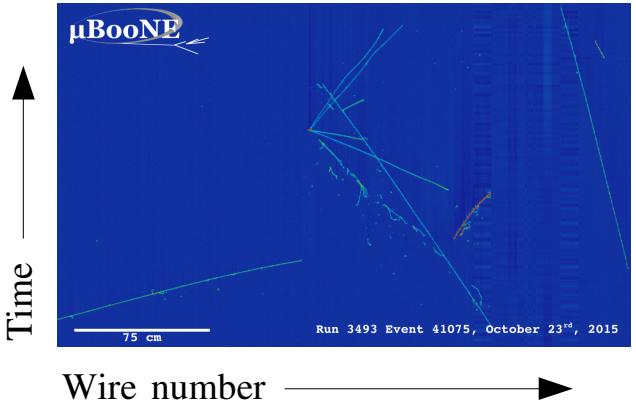


inspirehep.net

Detection principle of LArTPC

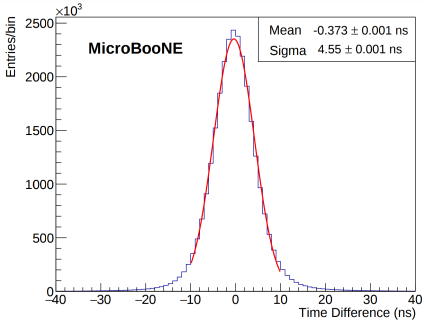


- Neutrino interaction produces charged particles
- These ionize the LAr and produce scintillation light, the ionized electrons drift to the anode, the light is detected by PMTs
- Drifted electrons induces a signal in the induction planes U and V and are then absorbed in the collection plane Y
- Drift time of the electrons determines distance from anode
- Combined information results in a 3D reconstructed object



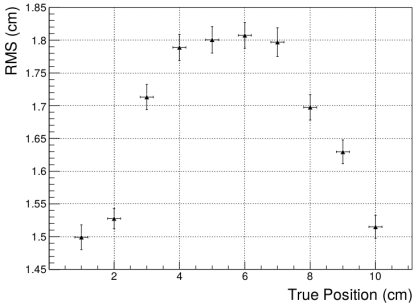
Cosmic Ray Tagger

- Developed and produced @ University of Bern
- Implemented for cosmic removal and detector physic studies
- Installation completed in January 2017
- Time resolution O(ns)
- Spatial resolution < 2cm
- Self triggering and continuously running



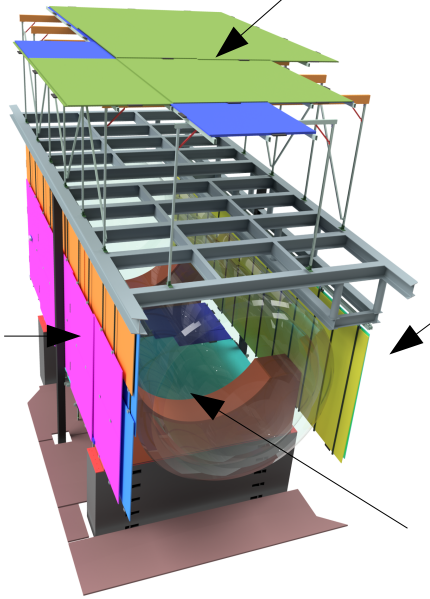
Time difference between 2 layers

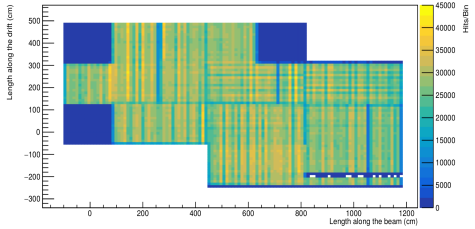
JINST 14, P04004 (2019)

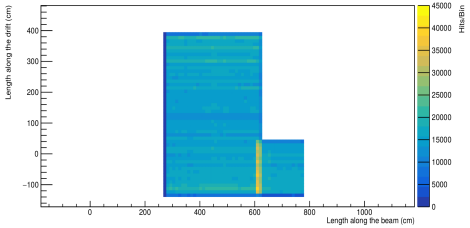


Position resolution

10.3390/instruments1010002 (2017)



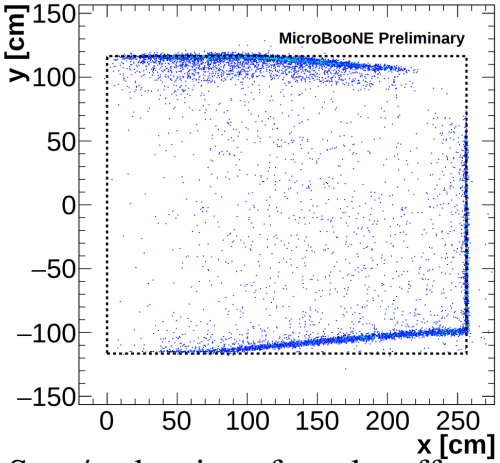




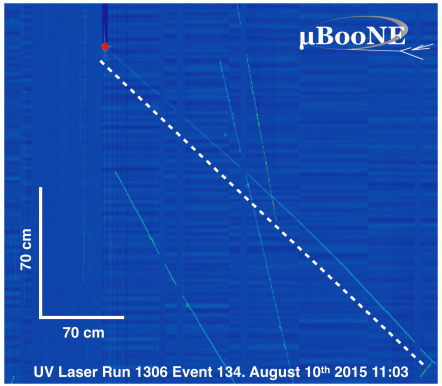
Number of reconstructed CRT hits in each plane

Laser calibration system

- Developed and produced @ University of Bern
- Accumulated positive ions in the LAr can distort the E-field → Space Charge Effect
  - Distorted tracks
- Using straight laser tracks, the distortion can be measured and the E-field can be recalculated
- Improves momentum calculation using multiple scattering
- Improves the energy deposition measurement dE/dx



Start/end point of tracks affected by space charge effect

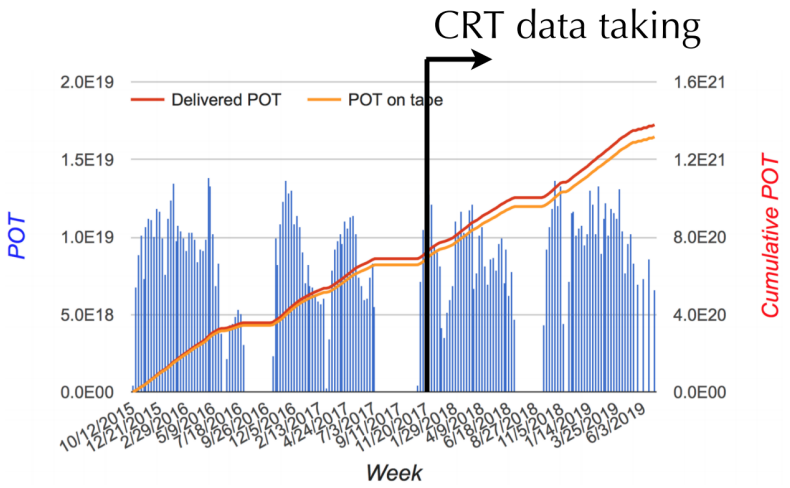


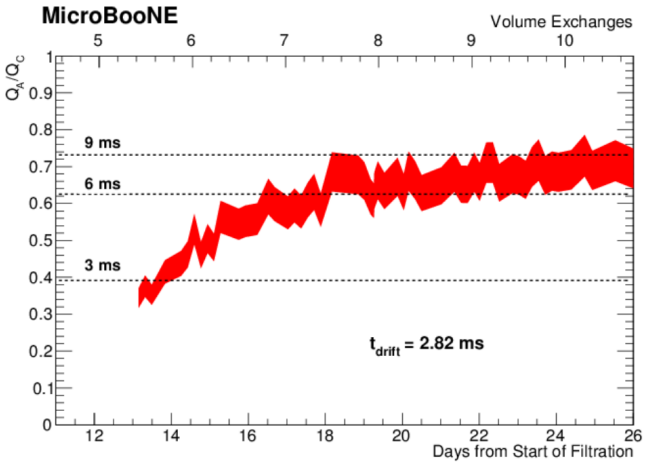
Straight UV laser track in MicroBooNE

JINST 9 T11007, (2014)

The MicroBooNE operation

- Taking data since 2015
  - Longest running LArTPC now
  - 96% detector + DAQ up time
- 13.4 e20 POT on tape of BNB
  - 340'000 ν_μ CC
  - 130'000 ν_μ NC
- Reached purity level is higher than the design requirement
  - Drift distance: 2.5 m
  - Drift time: 2.3 ms
  - Reached life time: > 6 ms





MICROBOONE-NOTE-1003-PUB

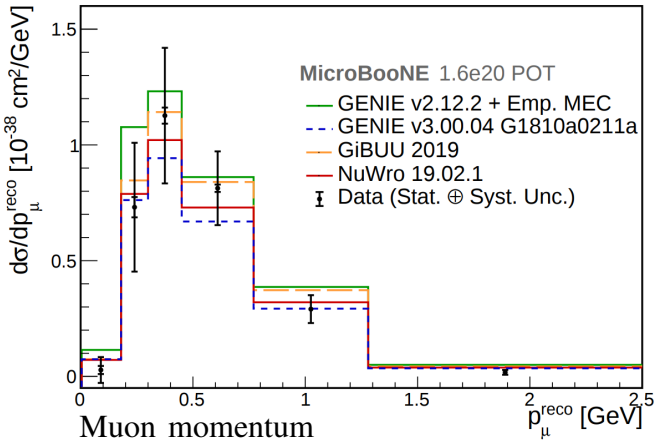
Results

- Detector studies:
  - Calibration of the Charge and Energy Response
  - Design and Construction of the MicroBooNE Cosmic Ray Tagger System
  - Rejecting Cosmic Background for Exclusive Neutrino Interaction Studies
  - A Deep Neural Network for Pixel-Level Electromagnetic Particle Identification
  - Ionization Electron Signal Processing in Single Phase LAr TPCs
  - ...
- Physics studies:
  - First Measurement of Inclusive Muon Neutrino Charged Current Differential Cross Sections
  - First Measurement of Muon Neutrino Charged Current Neutral Pion Production
  - Comparison of Muon-Neutrino-Argon Multiplicity Distributions
  - ...
- See out web page for more: MicroBooNE publications

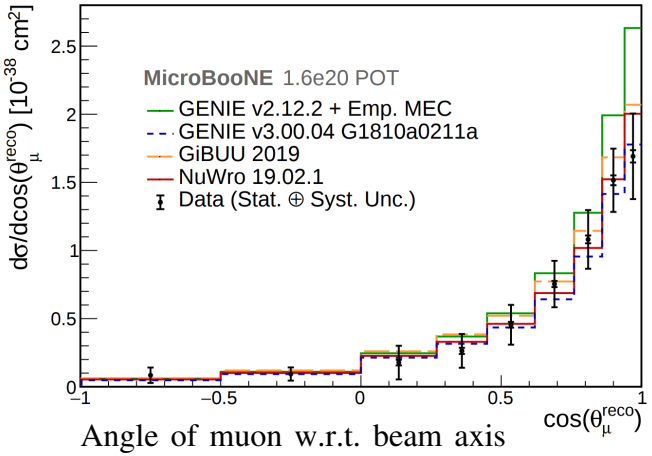
Inclusive ν_μ charge current cross section

- First inclusive cross section on Argon at GeV scale
- Only requires a muon track in the final state
  - $\nu_\mu + Ar \rightarrow \mu +$ (other particles)
- High efficiency and purity channel
  - Input for more exclusive channels
  - Constrain the electron neutrino signal
- Biggest challenge is the cosmic rejection
  - Improvement with CRT in future analysis
- Comparison with different generators
  - Nuclear effects and final state interaction models can be tested

$$\sigma = 0.693 \pm 0.010\,(\text{stat.}) \pm 0.165\,(\text{syst.}) \times 10^{-38}\ \text{cm}^2$$



Muon momentum reconstructed multiple scattering

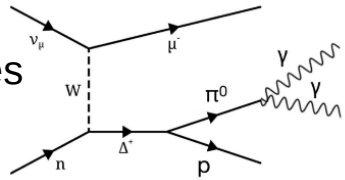


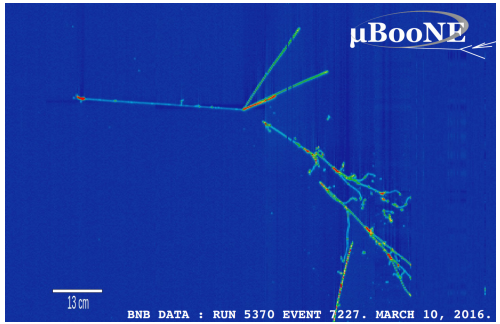
Angle of muon w.r.t. beam axis

arXiv:1905.09694

ν_μ CC π^0

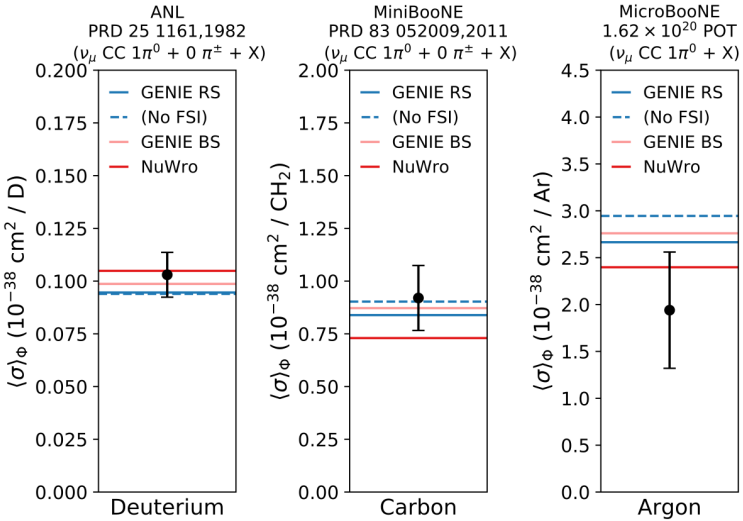
- Also require electromagnetic shower → CC pi0 cross section measurement
  - LAr detectors has benefits over other techniques
  - e/γ separation
  - Shower reconstruction





- π^0 mass reconstruction → allows precise energy calibration
- π^0 (γ) is background for electron neutrino interactions

$$\langle\sigma\rangle_\Phi = 1.9 \pm 0.2\ (\text{stat}) \pm 0.6\ (\text{syst}) \times 10^{-38}\ \frac{\text{cm}^2}{\text{Ar}}$$



Phys. Rev. D99, 091102(R) (2019)

Conclusion

- MicroBooNE is successfully taking data since 2015
- Fully automated event reconstruction
- LAr TPC technology has improved through the experience of MicroBooNE
- First physics results are out, more are coming soon, stay tuned!