Overview of MicroBooNE

Thomas Mettler on behalf of the MicroBooNE collaboration
Joint Annual Meeting of SPS and ÖPG, 29 August 2019
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 ($\nu_e$) identification from background ($\gamma$)

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
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 physics studies
- Installation completed in January 2017
- Time resolution O(ns)
- Spatial resolution < 2cm
- Self triggering and continuously running

Time difference between 2 layers

Position resolution

JINST 14, P04004 (2019)
10.3390/instruments1010002 (2017)
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 \( \frac{dE}{dx} \)

JINST 9 T11007, (2014)

Start/end point of tracks affected by space charge effect

Straight UV laser track in MicroBooNE
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 $\nu_\mu$ CC
  - 130’000 $\nu_\mu$ 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
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 $\nu_\mu$ charge current cross section

- First inclusive cross section on Argon at GeV scale
- Only requires a muon track in the final state
  - $\nu_\mu + Ar \rightarrow \mu + \text{(other particles)}$
- 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

\[
\sigma = 0.693 \pm 0.010 \text{ (stat.)} \pm 0.165 \text{ (syst.)} \times 10^{-38} \text{ cm}^2
\]
\( \nu_\mu \text{ CC } \pi^0 \)

- Also require electromagnetic shower → CC \( \pi^0 \) cross section measurement
  - LAr detectors has benefits over other techniques
  - e/\( \gamma \) separation
  - Shower reconstruction
- \( \pi^0 \) mass reconstruction → allows precise energy calibration
- \( \pi^0 \) (\( \gamma \)) is background for electron neutrino interactions

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

*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!