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

\[ |\nu_\alpha > = \sum_i U_{\alpha i}^* |\nu_i > \]

Neutrino Flavor Eigenstates Unitary Mixing Matrix Neutrino Mass Eigenstates

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

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

\[ s_{ij} = \sin \theta_{ij} \]
\[ c_{ij} = \cos \theta_{ij} \]
The LSND Experiment

\[ P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e) \approx \sin^2 2\theta_{\mu e} \sin^2 \left( \frac{1.267 \Delta m^2 [eV^2] L [m]}{E_\nu [MeV]} \right) \]
Evidence for Neutrino Oscillations at 3 Different $\Delta m^2$

"Normal" Mass Ordering
A 4\textsuperscript{th} (sterile) neutrino state?
MiniBooNE Experiment

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

FNAL booster (8 GeV protons) → target and horn (174 kA) → decay region (50 m) → oscillations? 

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

Electron, Photon
Muon
Proton

$\pi^0 \rightarrow \gamma + \gamma$

(Cherenkov Detector)
MiniBooNE Experiment

FNAL booster (8 GeV protons) -> target and horn (174 kA) -> decay region (50 m) -> oscillations? -> dirt

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

Electron, Photon
Muon
Proton

$\pi^0 \rightarrow \gamma + \gamma$

MiniBooNE: PhysRevLett.110.161801
Addressing the MiniBooNE “Low-Energy Excess”

Liquid Argon Time Projection Chamber (LArTPC)

LArTPC = “Modern Bubble Chamber” with 3D track reconstruction
Aerial View of Fermilab Site

- MicroBooNE
- ICARUS/T600
- Booster Neutrino Beam Target
- Short Baseline Near Detector
LArTPC Detector

Cathode

LAr Bulk

Anode wires

e.g. Muon

E-field

\[ \text{Ar}_2^* \rightarrow e^- \rightarrow e^- \rightarrow \text{Ar}_2^* \rightarrow e^- \rightarrow e^- \rightarrow \text{Ar}_2^* \rightarrow e^- \rightarrow e^- \rightarrow \text{Ar}_2^* \rightarrow e^- \rightarrow e^- \rightarrow \text{Ar}_2^* \]

M. Toups -- TAUP 2015
LArTPC Detector

Cathode

LAr Bulk

Anode wires

Prompt light emission occurs over O(ns)

E-field

e.g. Muon

4/28/15

M. Toups -- TAUP 2015
LArTPC Detector

Cathode

LAr Bulk

Anode wires

PMTs

Prompt light emission occurs over $\sim$0(ns)

e.g. Muon

$E$-field
LArTPC Detector

Cathode

LAr Bulk

Anode wires

Electron drift at constant velocity over O(ms)

e.g. Muon

PMTs

M. Toups -- TAUP 2015
Electron drift at constant velocity over $O(\text{ms})$
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

TPB-coated acrylic plate

128 nm light

450 nm light

PMT
MicroBooNE Goals

• Address MiniBooNE low energy excess
• $\nu$ 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


Brookhaven: M. Bishai, H. Chen, J. Joshi, B. Kirby, Y. Li, D. Lissauer, M. Mooney, X. Qian, V. Radeka, C. Thorn, B. Yu, C. Zhang

University of Cambridge: J. Marshall, M. Thomson

University of Chicago: W.M. Foreman, J. Ho, D.W. Schmitz, J. Zennamo

University of Cincinnati: R. Grosso, R.A. Johnson, J. St. John


Illinois Institute of Technology: R. An, B. Littlejohn

Kansas State University: T. Bolton, S. Gollapinni, G. Horton-Smith, V. Meddage, A. Rafique, S. Shrestha

Lancaster University: A. Blake, D. Devitt

Los Alamos: G. Garvey, W.C. Louis, G.B. Mills, R. Van de Water

University of Manchester: A. Furmanski, J. Hewes, G. Karagiorgi, R. Murrells, S. Söldner-Rembold, A.M. Szlec


University of Michigan, Ann Arbor: J. Spitz

New Mexico State University: T. Miceli, V. Papavassiliou, S. Pate, K. Woodruff

Oregon State University: H. Schellman, S. Wolbers

Otterbein University: N. Tagg

University of Oxford: G. Barr, M. Bass, R. Guenette

University of Pittsburgh: S. Dytman, N. Graf, D. Naples, V. Paolone

Pacific Northwest National Laboratory: E. Church

Princeton University: K. McDonald

Saint Mary's University of Minnesota: P. Nienaber

SLAC: M. Convery, B. Eberly, L. Rochester, Y-T. Tsai, T. Usher


Virginia Tech: A.M. Ankowski, C.M. Jen, L.N. Kalousis, C. Mariani

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 $\Rightarrow$ 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
Liquid argon deliveries far exceeded purity specifications:

- $O_2 < 1$ ppm
- $N_2 < 3$ ppm
PMT HV Turned on Same Day

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

Run 1147 Event 0. August 6th 2015 16:59

Raw cosmic data – no noise filtering
Electromagnetic Shower

Raw cosmic data – no noise filtering

24 cm
40 cm

Run 1153 Event 40. August 6th 2015 21:07

-58 kV
Candidate Muon and Decay Electron

Raw cosmic data – no noise filtering

Run 1149 Event 158. August 6th 2015 17:52
Cosmic muons with delta rays

Run 1153 Event 13. August 6th 2015 21:02

Raw cosmic data – no noise filtering
First UV Laser Calibration Tracks

Raw laser + cosmic data – no noise filtering

-58 kV

Run 1306 Event 134. August 10th 2015 11:03
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.