Recent results and future prospects of MicroBooNE

Rachel Carr • MIT • for the MicroBooNE collaboration
International Symposium on Neutrino Frontiers
ICISE, Quy Nhon, Vietnam • July 16, 2018
The **MicroBooNE** experiment at Fermilab

A liquid argon time projection chamber (LArTPC) to study neutrino interactions in **micro** detail

Rachel Carr, for MicroBooNE
The **MicroBooNE** experiment at Fermilab

A liquid argon time projection chamber (LArTPC) to study neutrino interactions in *micro* detail

**MicroBooNE cryostat**

**Event display**

Rachel Carr, for MicroBooNE
MicroBooNE physics goals

Study neutrino-argon interactions, key to CP violation & mass hierarchy measurements in future LArTPCs

Identify origin of anomalous low-energy electron neutrino-like events in MiniBooNE

Example of interaction in the complex argon nucleus

Evidence of a sterile neutrino? … or … ?

Aguilar-Arevalo et al. (MiniBooNE collaboration), arXiv:1805.12028
MicroBooNE physics goals

Study **neutrino-argon interactions**, key to CP violation & mass hierarchy measurements in future LArTPCs

Identify origin of **anomalous low-energy electron neutrino-like events** in **MiniBooNE**

+ **broad program of other physics**, including:
  - Supernova neutrinos
  - Nuclear structure
  - Exotic BSM signatures

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Flux is mainly $\nu_\mu$ with $\langle E \rangle = 800$ MeV

$< 10^{-2}$ contribution from intrinsic $\nu_e$

MicroBooNE: beam data since 2015

Today's results come from 6 months of data

(1.6 $\times$ $10^{20}$ protons on target)

Booster Neutrino Flux Prediction at MicroBooNE

85 tons of liquid argon in TPC (170 tons in cryostat)

Drift time: up to 2.3 ms

3 planes of wires: 8192 in total

32 photo-multiplier tubes

MicroBooNE LArTPC
Novel signal processing techniques

Noise filtering & low-level signal processing
Ionization electron signal processing in single phase LArTPCs. Part I & II, JINST 13 P07006 & 07007 (2018)

Multiple approaches to event reconstruction & cosmic ray removal
(see refs. in later slides)
A charged current $\nu_\mu$ event in data

Run 3469 Event 53223, October 21st, 2015
How many charged particles emerge from the nucleus in $\nu_\mu$-Ar interactions?

**NEW RESULT:** Comparison of Muon-Neutrino-Argon Multiplicity Distributions Observed by MicroBooNE to GENIE Model Predictions


**GENIE simulations of charged particle multiplicity agree with data within 2$\sigma$**

MEC = meson exchange current (populates multi-nucleon final states)
TEM = transverse enhancement model (larger transverse QE form factor)
First $\nu_\mu$-Ar CC inclusive cross section

First absolute cross section from MicroBooNE: Charged current $\nu_\mu$ on argon, inclusive of all interaction modes & final states

such as...

$\nu_\mu + p \rightarrow W + \mu$ + all other CC $\nu_\mu$
First $\nu_\mu$-Ar CC inclusive cross section

First absolute cross section from MicroBooNE:
Charged current $\nu_\mu$ on argon, inclusive of all interaction modes & final states

... as function of reconstructed $\mu$ momentum:

... as function of reconstructed $\mu$ angle:

NEW RESULT: First Muon-Neutrino Charged-Current Inclusive Differential Cross Section Measurement for MicroBooNE Run 1 Data

First $\nu_\mu$-Ar CC inclusive cross section

A foundational result for $\mu B$ cross sections—-and easy to cross compare:

--- Global $\nu_\mu$ CC inclusive data ---

- MINERvA, PRD 95, 072009 (2017)
- T2K, PRD 93, 072002 (2016)
- T2K (Fe) PRD 90, 052010 (2014)
- T2K (CH) PRD 90, 052010 (2014)
- T2K (C), PRD 87, 092003 (2013)
- ArgoNeuT PRD 89, 112003 (2014)
- ANL, PRD 19, 2521 (1979)
- BEBC, ZP C2, 187 (1979)
- BNL, PRD 25, 617 (1982)
- CCFR (1997 Seligman Thesis)
- CDHS, ZP C35, 443 (1987)
- GGM-PS, PL 84B (1979)
- IHEP-ITEP, SJNP 30, 527 (1979)
- IHEP-JINR, ZP C70, 39 (1996)
- MINOS, PRD 81, 072002 (2010)
- NOMAD, PLB 660, 19 (2008)
- NuTeV, PRD 74, 012008 (2006)
- SciBooNE, PRD 83, 012005 (2011)
- SKAT, PL 81B, 255 (1979)
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NEW RESULT:
First $\nu_\mu$-Ar CC inclusive cross section as function of reconstructed $\mu$ angle:

MicroBooNE Data (Stat.⊕Syst.)

GENIE Cross Section

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MicroBooNE Preliminary

An absolute cross section from MicroBooNE:
Charged current $\nu_\mu$ on argon, inclusive of all interaction modes & final states


First $\nu_\mu$-Ar CC inclusive cross section as function of reconstructed $\mu$ angle:

MicroBooNE Data (Stat.⊕Syst.)

GENIE Cross Section
Probing exclusive channels: CC $1\pi^0$

First measurement of charged current single $\pi^0$ production in $\nu_\mu + Ar$

NEW RESULT: First Measurement of Muon Neutrino Charged Current Single Neutral Pion Production on Argon with the MicroBooNE LArTPC

Probing exclusive channels: CC $1\pi^0$

$\pi^0$ mass peak shows good shower energy resolution:

**MicroBooNE Preliminary**

1.62e20 POT

Simulation Normalized to Data
- (Data-Backgrounds)
- $\nu_\mu$ CC $\pi^0$
  - Energy Resolution: $2\% \oplus 15\%$\sqrt{E}$
  - Angular Resolution: 1%
Exploring the MiniBooNE anomaly

MiniBooNE excess of electron neutrino-like events = ?

Unclear in MiniBooNE, a Cherenkov detector....

A task for the MicroBooNE LArTPC, using $e/\gamma$ separation

dE/dx

R. Acciarri et al. (ArgoNeuT collaboration), arXiv:1610.04102

Electron, photon  Muon  Proton  $\pi^0 \rightarrow \gamma\gamma$
Exploring the MiniBooNE anomaly

Developing multiple pathways to low-energy $\nu_e$ signal:

Electron-neutrino selection and reconstruction in the MicroBooNE LArTPC using the Pandora multi-algorithm pattern recognition


Convolutional Neural Networks Applied to Neutrino Events in a Liquid Argon Time Projection Chamber, JINST 12, P03011 (2017)
The **MicroBooNE** experiment

Studying neutrinos in *micro* detail with a Fermilab Booster Neutrino Experiment

Rachel Carr, for MicroBooNE
The **MicroBooNE** experiment

Studying neutrinos in *micro* detail with a Fermilab **Booster Neutrino Experiment**

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**boon**¹

/boon/

*noun*

1. a thing that is helpful or beneficial.

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Today, shared recent results… Many other helpful, beneficial results to come!
Thank you