neutrino interactions in MicroBooNE

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Invisibles19 Workshop
Booster Neutrino Beam

The MicroBooNE Experiment

~99.5% $\nu_\mu$

MicroBooNE Preliminary
The MicroBooNE Detector

A Liquid Argon Time Projection Chamber: ionization charge + scintillation light

Combine topological & calorimetric information from 3 planes to get full 3D reconstruction of neutrino interaction.
\( \nu \)-Argon Cross Sections in MicroBooNE

- \( E_\nu \sim 0.8 \text{GeV} \)
- \( \nu \)-Ar cross sections useful for
  - nuclear effects
  - testing generators
  - \( \nu \) flux & energy for oscillations experiments.

**Booster Neutrino Beam**

\[ \nu_p \rightarrow \nu_\mu \rightarrow W^+ \rightarrow \mu^- + \nu \]

**Target**

\[ n \rightarrow p + \Delta + \pi^0 \]

**NuMI**

\[ \nu_e \rightarrow e^- + W^+ \rightarrow e^- + p^+ \]
\( \nu \) CC inclusive

**Signal:** interactions with a neutrino-induced muon.

I. Cosmic rejection [1\( \nu \) every 15k cosmic rays]:

- Use scintillation light as trigger
- Check if coincident with beam spill
- Track selection

II. Neutrino vertex & track selection

- Fiducial volume, topological & calorimetric selection

arXiv:1905.09694
First single & double differential cross-section measurement on Argon at low energy
[paper on arXiv, submitted to PRL]

\[\nu_\mu \text{ CC inclusive}\]

- Compared to 4 generator models
- Full angular & momentum coverage
Signal: interactions with a neutrino-induced muon that produce a single $\pi^0$.

I. Cosmic rejection
II. Neutrino vertex & track selection
III. Shower reconstruction & $\pi^0$ event selection

→ first fully automated EM shower reconstruction in a LArTPC.

*Phys. Rev. D 99, 091102(R) (2019)*
Scaling of final state interactions in GENIE
agreement across deuterium, carbon, argon.

Differential cross-section measurement with
higher efficiency underway.
Summary

MicroBooNE is a LArTPC @ Fermilab’s SBN program.

Physics: neutrino oscillations & neutrino-Argon cross sections.

Recent results: single & double differential cross sections in $\nu_\mu$ CC channels [inclusive, $\pi^0$].

In progress: $\nu_\mu$ CC Np, $\nu_\mu$ CC $K^+$, $\nu_e$-Ar cross section,...
Thank you!
Backup
LSND & MiniBooNE anomalies

observed an excess of electromagnetic events on a scale of $\Delta m^2 \sim 1$eV$^2$!

oscillation signal from additional sterile neutrino [electron-like]

OR

unknown photon background [photon-like]?

“low energy excess”

2. FERMILAB-PUB-18-219, LA-UR-18-24586
\textbf{e/\gamma separation in MicroBooNE}

Both electrons & photons produce electromagnetic showers.

\textbf{e/\gamma separation based on:}

- Distance from neutrino vertex
- Stopping power \([dE/dx]\)

MicroBooNE can solve the “low energy excess” puzzle.
$\nu_\mu$ CC inclusive

arXiv:1905.09694
Total cross-section measurement on Argon at low energy
[paper published in PRD, 2019]
Signal: interactions with a neutrino-induced muon that produce at least 1 proton & no mesons.

I. Cosmic rejection [1ν every 15k cosmic rays]
II. Neutrino vertex & track selection
III. Proton identification

→ LArTPC’s can detect protons at lower momenta than scintillator detectors [~47 MeV].
$\nu_e$ with NuMI

- Higher $\nu_e$ content than BNB.
- Can use as cross-check for $\nu_e$ search in BNB.
nuclear effects

➔ Argon nucleus is large
  ➞ sensitivity to nuclear effects
➔ electroweak nuclear physics
  ◆ short range correlations
  ◆ meson-exchange currents
  ◆ relative phase approximation

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<th>Model element</th>
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<th>GENIE Alternative</th>
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