Measurement of the $\nu_e + \bar{\nu}_e$ Charged Current Inclusive Cross Section on Argon in MicroBooNE

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New Directions in Neutrino-Nucleus Scattering (NDNN)
NuSTEC Workshop
Importance of the $\nu_e$-Ar cross section

• MicroBooNE + SBN Program + DUNE
  → Employ Liquid Argon Time Projection Chambers (LArTPCs)

• Primary signal channel for these experiments is $\nu_e$– Ar CC interactions

Building a Picture of $\nu_e$ Interactions

ArgoNeuT is the first measurement made on argon

$\nu_e \rightarrow e$

Sample of 13 selected events

Phys. Rev. D 102, 011101(R) (2020)

A handful of measurements on other nuclei in the hundred MeV to GeV range

$\rightarrow$ Gargamelle

$\rightarrow$ T2K

$\rightarrow$ MINER$\nu$A

ArgoNeuT


Other
What are we measuring?

• Total $\nu_e + \bar{\nu}_e$ Charged Current (CC) inclusive cross section

• Signature: the neutrino event contains at least one electron-like shower
  - No requirements on the presence (or absence) of any additional particle
  - Do not differentiate between $\nu_e$ and $\bar{\nu}_e$

Inclusive channel is the most straightforward channel to compare to predictions
• Measurement is performed using the MicroBooNE LArTPC

• Features of a LArTPC detector:
  → Precise calorimetry
  → $4\pi$ acceptance
  → Low detection thresholds
The NuMI Beam

- 120 GeV proton beam
- Off-axis to MicroBooNE
- Majority of selected neutrinos originate from target direction
The NuMI Beam

- Flux has a significant fraction of electron neutrinos

\[ \langle E_{\nu_e + \bar{\nu}_e} \rangle \sim 905 \text{ MeV} \]

\[ E_{\nu_e + \bar{\nu}_e} > 250 \text{ MeV} \]
Electron-Photon Separation

- Key backgrounds in this analysis are NC $\pi^0$ and $\nu_\mu$ CC $\pi^0$

- Classify the electron-induced shower as the shower with most hits: “leading shower”
  
  → Apply requirements e.g. distance to vertex and dE/dx on this shower to identify if it is electron-like or photon-like
Electron-Photon Separation

• Demonstrate the **first fully automated discrimination of electron and photon induced EM-showers** in a LArTPC

• Utilize the energy loss per cm ($dE/dx$):

  - **Electrons**: $dE/dx$ near the start of a EM-shower is ~ 2 MeV/cm

  - **Photons**: $dE/dx$ near the start of a EM-shower is ~ 4 MeV/cm
$\nu_e + \bar{\nu}_e$ Cross Section Measurement

• First $\nu_e + \bar{\nu}_e$ measurement using the NuMI beam from MicroBooNE
  → 214 selected events

• Final selection purity of 39% and efficiency 9%

• Total cross section is in agreement with the GENIE v2, GENIE v3 and NuWro generators

arXiv:2101.04228
• Next generation of analysis in progress using improvements to simulation
  → Significantly reduced cosmic backgrounds (largest contribution in this analysis)
  → Reduced uncertainties, improved efficiency
  → Coming soon: differential cross section as a function of the outgoing lepton energy and angle!
Thanks for Listening!

24 cm

18 cm

24 cm

18 cm

NuMI Data Run 6419 Subrun 2 Event 138

NuMI Data Run 6352 Subrun 34 Event 1716

NuMI Data Run 5092 Subrun 69 Event 3484

NuMI Data Run 5385 Subrun 40 Event 2048