Search for a Low Energy Excess in MicroBooNE

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Neutrino anomalies and the Low Energy Excess

Anomalies in Short Baseline Neutrino Oscillations

→ Might hide sterile neutrinos -> new physics BSM

- LSND: excess of EM-like events
  Phys. Rev. D 64, 112007

- MiniBooNE: similar EM-like excess
  Phys. Rev. Lett. 121, 221801
  ○ Could not distinguish electrons from photons

- MicroBooNE: LEE is the primary goal
  ○ Is there an excess?
  ○ Origin? Electron-like or photon-like?
Neutrino anomalies and the Low Energy Excess

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Precision measurements of Cross Sections in liquid argon

➔ Improve understanding of nuclear physics in neutrino interactions
➔ Preparation for DUNE
Micro Booster Neutrino Experiment at Fermilab

Two beamlines:

- **BNB**: On axis, 480 m from the production point
  - For the main physics goals of MicroBooNE
  - The heart of the SBN programme, with SBND and Icarus

- **NuMI**: Off Axis (dedicated to NOνA, MINERνA, MINOS)
  - Complementary physics and cross checks
A typical event
A typical event

Color shows deposited charge
A typical event

x-axis [time]  (drift axis)

Color shows deposited charge

Z-axis [m] (beam direction)

NuMI DATA: RUN 10811, EVENT 2549. APRIL 9, 2017.
A typical event

x-axis [time] (drift axis)

Tracks: protons, pions, muons

Color shows deposited charge

Z-axis [m] (beam direction)
A typical event

Electromagnetic shower: electron-like, attached to the main vertex

Color shows deposited charge

x-axis [time] (drift axis)

Z-axis [m] (beam direction)
A typical $\pi^0 \rightarrow \gamma\gamma$ event
A typical $\pi_0 \rightarrow \gamma\gamma$ event

Electromagnetic showers detached from the vertex, photon conversion length $\sim 26$ cm
LEE analysis strategy
Electron-like search:

- Shower attached to the vertex
- $dE/dx$ of one MIP particle at the start of the shower
LEE analysis strategy

**Electron-like search:**
- Shower attached to the vertex
- $dE/dx$ of one MIP particle at the start of the shower

**Photon-like search:**
- Shower detached from the vertex
- $dE/dx$ of two MIP particles at the start of the shower
LEE analysis strategy

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- Shower attached to the vertex
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Photon-like search:
- Shower detached from the vertex
- $dE/dx$ of two MIP particles at the start of the shower
Lee analysis strategy

Some data ready to develop the analyses:

- Open data: 4e19 POT BNB (~3.5%) and 2.4e20 POT NuMI (21%)
- Total data: about 1.13e21 POT BNB and 1.6e21 POT NuMI so far

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- dE/dx of one MIP particle at the start of the shower

Photon-like search:
- Shower detached from the vertex
- dE/dx of two MIP particles at the start of the shower
\( \nu_e \) CC topologies

- **Only one electron: \( \nu_e \) CC 0\( \pi \)0p**
  - Hardest to distinguish from single photon production

- **Additional protons: \( \nu_e \) CC 0\( \pi \)Np**
  - Easier because additional tracks determine vertex
  - It is the channel in which the LEE has been observed

- **Additional pions: \( \nu_e \) CC M\( \pi \)Np**
  - Very complex events
  - Typically higher energies
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Light and charge: remove cosmic rays

Topological and geometrical requirements

Calorimetry: particle ID and energy measurement
Cross check: two sidebands on 3.5% of the total BNB data
NuMI $\nu_e$CC 0$\pi$Np analysis

Cross check the BNB analysis using NuMI
- As many $\nu_e$CC interactions as expected in the full BNB dataset
- Perfect to validate the analysis
NuMI $\nu_e$ CC $0\pi$Np analysis

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$\cos(\theta)$ wrt NuMI beam direction:
- Cosmic rays: flat distribution
- Neutrinos: peak around 1
- Data/Monte Carlo agreement gives us confidence we can tune and cross check the LEE analysis
Conclusions

● Exciting moment for MicroBooNE:
  ○ Collected a huge amount of data
  ○ Solid strategy and demonstration of the LEE analyses

● First Cross section measurements submitted for PRL publication
  ○ CC$\nu_{\mu} \pi_0$: MICROBOONE-NOTE-1032-PUB
  ○ CC$\nu_{\mu}$ inclusive: MICROBOONE-NOTE-1045-PUB

● Strong demonstration of the LEE analysis strategies
  ○ Electron-like search BNB: MICROBOONE-NOTE-1038-PUB
  ○ Electron-like search NuMI: MICROBOONE-NOTE-1054-PUB
  ○ Photon-like search BNB: MICROBOONE-NOTE-1041-PUB

Stay tuned: new results coming soon!
BACKUP
A liquid argon TPC

Two signals:
- Scintillation light, mainly for trigger and event selection
- TPC information: reconstruct the event, tracking and calorimetry
Neutrino Interactions in MicroBooNE

Typical neutrino energy ~ 1 GeV
→ In this energy range interactions with the nuclei are predominant

**Charged current** interactions

Production of a lepton: clear exp signature.

Distinguish different flavours

**Neutral current** interactions

Only nucleus recoil, hard to detect.

No information about the flavour

For the LEE search -> need to distinguish the two flavours, only Charged Current (CC) are of interest!
MicroBooNE during the construction
Electron/photon separation using dE/dx

MicroBooNE In Progress

NuMI 2.345e20 POT

\[ \chi^2 = 13.1, \text{ndf} = 18 \]

Entries / 0.44 MeV/cm

DATA BEAM ON

\( \nu_e \text{CC0\piNp} \)

\( \nu_e \text{CCothers} \)

NC

\( \nu_\mu \text{CC} \)

out of FV

cosmic contaminated
dirt

cosmic

DATA BEAM OFF

Candidate Shower dE/dx [MeV/cm]