A new method for particle identification in liquid argon

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On behalf of the MicroBooNE collaboration

NuPhys 2019
December 16th, 2019
Micro Booster Neutrino Experiment at Fermilab

→ Short baseline neutrino experiment
→ Physics goals:
  ◆ Investigate the anomalous excess of low energy events observed by MiniBooNE
  ◆ Detailed measurements of neutrino interactions
→ Technology:
  ◆ Liquid argon time projection chamber - R&D towards new detectors, like SBND and DUNE

Booster Neutrino Beam

MicroBooNE

L ~ 470 m

E_\nu ~ 1 GeV
A liquid argon TPC - in theory
A liquid argon TPC - in theory
A liquid argon TPC - in theory
A liquid argon TPC - in practice
A liquid argon TPC - in practice

μBooNE

x-axis [time]
(drift direction)

Z-axis [m]
(beam direction)

30 cm
Run 3493 Event 27435, October 23rd, 2015
A liquid argon TPC - in practice

Color shows deposited charge

x-axis [time]
(drift direction)

Z-axis [m]
(beam direction)
A liquid argon TPC - in practice

Color shows deposited charge

Track-like particles

x-axis [time] (drift direction)

Z-axis [m] (beam direction)
A liquid argon TPC - in practice

Bubble chambers-like detectors...
A liquid argon TPC - in practice

Bubble chambers-like detectors...  ...with calorimetric capabilities
Particle identification

Particle 1: proton or muon?

Particle 2: proton or muon?

Particle 3: proton or muon?
Ionisation from the Bethe-Bloch theory
Ionisation from the Bethe-Bloch theory
Ionisation from the Bethe-Bloch theory

MicroBooNE

- $dE/dx$ (MeV g$^{-1}$ cm$^2$)

- $\beta\gamma = p/Mc$

- $\text{H}_2$ liquid
- He gas
- Fe, Al, C
- Sn, Pb

- Muon expectation
- Proton expectation
- MIP expectation
Ionisation from the Bethe-Bloch theory

**Graph 1:**
- For various materials (H$_2$ liquid, He gas, Fe, Al, C, Sn, Pb), the graph shows the energy loss per unit length ($-dE/dx$ in MeV g$^{-1}$cm$^{-2}$) as a function of the relativistic factor ($\beta \gamma = p/Mc$) and the muon momentum (GeV/c).

**Graph 2:**
- The MicroBooNE graph illustrates the energy loss spectrum with different expectations: Muon Expectation, Proton Expectation, and MIP expectation.
- The graph plots the energy loss per unit length ($dE/dx$ in MeV/cm) against the residual range (cm), with data points showing the distribution for various momenta (GeV/c).
From 2D images to 3D reconstruction

- U plane
- V plane
- Y plane
From 2D images to 3D reconstruction

3d reconstruction
From 2D images to 3D reconstruction

For each point:
- $dE/dx$
- Residual range
- Location
- Direction

Calorimetry

3d reconstruction
How to exploit all this information?
How to exploit all this information?

Model the dE/dx distribution taking into account detector anisotropies
How to exploit all this information?

Model the dE/dx distribution taking into account detector anisotropies

Combine the measurements of the three planes in the optimal way
How to exploit all this information?

Model the dE/dx distribution taking into account detector anisotropies

Combine the measurements of the three planes in the optimal way

Correct the simulation to match the data
How to exploit all this information?

Model the dE/dx distribution taking into account detector anisotropies

Correct the simulation to match the data

The Calorimetry Likelihood Project

Combine the measurements of the three planes in the optimal way
Stop by my poster to learn more!
(Or look for me during the coffee breaks!)
Do you want to know the answer?

Particle 1: proton or muon?

Particle 2: proton or muon?

Particle 3: proton or muon?
BACKUP
Typical neutrino energy $\sim 1$ 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
Shower-like event

Electron showers

Photon showers