First Deep Learning based Event Reconstruction for Low-Energy Excess Searches with MicroBooNE



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MicroBooNE

- Study low E v_e appearance
- Measure v-Ar cross section
- R&D for LArTPC technology for the SBN program and DUNE
- 8 GeV protons on Be target (BNB)
- 470 m baseline
- (2.6x2.3x10.4)m³ fiducial volume
- 85 tons active mass of liquid Ar
- 3 planes of sense wires



Low Energy Excess

MiniBooNE :

1.0

0.5

0.2

0.4

- 3σ excess v_e appearance [200-500] MeV
- Compatible with a 3+1 model lacksquare
- Tensions with LSND and ICARUS
- Could be linked to systematic lacksquareuncertainties, e/γ mis-ID

➡ MicroBooNE :

- LArTPC : good e/γ separation
- Dominated by CCQE 1L1p events
- Constrain intrinsic 1e1p background with 1µ1p





Vertex Finding

• Neural Network :

tick

- Semantic Segmentation Network
- track/shower pixel labeling
- OpenCV tools to find vertex seeds
 - defect points of convex hulls
 - PCA line crossings
- Scan tracks around seeds to find best position





valu

pixel ADC

Office of

Science

Track Reconstruction

Neutrino

Data (stat err.)

Constr. Syst. Error

1.4 1.5

 $\square v_{a}$ from μ^{\dagger}

 \sim v_{e} from $K^{+\prime}$ ve from K

π⁰ misid

1.2

(2013)

161801

3.0

10⁻¹

Neutrino

10⁻³

Search started from 3D vertex position

08

 E_{v}^{QE} (GeV)

- Stochastic search in near-by 3D-space
- Once reached the end of a track, remove pixels and iterate search from vertex
- Self diagnostic tool to remove failed reconstructions



μBooNE

Simulation

Preliminary

uBooNE

Simulatior

Preliminar

1150

Science & Technology

Facilities Council

wire number

1100

 $sin^2 2\theta$

10⁻¹

Ó



Reconstructed Example

8000 value Ę μBooNE μBooNE **U** plane Simulation pixel ADC ADC Simulation Preliminary 7500 7500 **Preliminary** 10² 10² 7000 7000 6500 6500 6000 6000 1100 1200 1300 1200 1300 1400 1100 1400 8000 8000 ADC value valu tic **µBooNE µBooNE** V plane time Simulation Simulation ADC Preliminary 7500 7500 Preliminary 10² Xd 10² 20 7000 7000 6500 6500

Performances



$$E_{\nu}^{\text{visible}} = \mathrm{KE}_p + \mathrm{KE}_\mu + m_\mu + B$$

MicroBooNE Simulation Preliminary 1µ1p





Fermilab U.S. DEPARTMENT OF ENERGY

- Reconstruct µ and p KE from lengths
- Visible energy resolution ~4%
- Reconstruction aimed at low energy events

FNSNF SOCIETY

THE ROYAL

• First use of Neural Networks to reconstruct neutrino interactions in LArTPC