MicroBooNE Status

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Miami 2017
MicroBooNE: Goals

- Study the MiniBooNE excess of low energy neutrino events
  - MiniBooNE saw a ~3σ $\nu_e$-like excess between 200 and 600 MeV
  - In tension with global 3+1 model fit
  - Systematic error on par with statistical error

- Main area of improvement:
  - $e^-/\gamma$ separation

- Will use same neutrino source
  - Fermilab’s Booster Neutrino Beam (BNB)
  - Primary mode: $\nu_\mu$ with some intrinsic $\nu_e$

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**Neutrino**

<table>
<thead>
<tr>
<th>Phys. Rev. Lett. 102</th>
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<tbody>
<tr>
<td>101802</td>
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**Antineutrino**

<table>
<thead>
<tr>
<th>Phys. Rev. Lett. 105</th>
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<tr>
<td>181801</td>
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LArTPCs

\( \mathbf{E} \)-field, \( e^-\) drift

- Charge absorption during drift is low for pure Argon

Image courtesy of MicroBooNE collaboration [https://www-microboone.fnal.gov/](https://www-microboone.fnal.gov/)
LArTPC 3-Plane Data

Particle tracks project onto wire planes

Planes at an angle to each other

Time

Wire

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PMTs to collect Light

- Argon produces scintillation light
- Plane projection requires $T_0$ tagging
  - For MicroBooNE:
    - max drift time: 1.6ms
    - Required to break degeneracy between drift direction and time
- Can also use as a trigger condition
  - Require minimum summed P.E.
Particle ID from calorimetry AND spatial topology

dQ/ds (after signal processing)

Run 3493 Event 41075, October 23rd, 2015
170 Tonne LArTPC
- 85 Tonne active volume

3 planes
- 2 Induction planes @ 3256 wires
- 1 Collection Plane @ 3600 wires

Readout window
- 9600 digitizations (or time ticks) total
- 4.8 ms (~3x drift length of TPC)

MicroBooNE: R&D

Liquid-Argon Time Projection Chambers
Outlook of R&D Program in the US

<table>
<thead>
<tr>
<th>Chamber</th>
<th>Active Volume</th>
<th>Details</th>
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<tbody>
<tr>
<td>Yale TPC &amp; Bo</td>
<td>0.00002 kton</td>
<td>Yale TPC: Dismantled, Bo: Operational</td>
</tr>
<tr>
<td>ArgoNeuT</td>
<td>0.0003 kton</td>
<td>Operational, Physics: Measure neutrino-argon cross sections</td>
</tr>
<tr>
<td>MicroBooNE</td>
<td>0.1 kton</td>
<td>Construction begins 2010, Physics: Investigate low-energy neutrino interactions</td>
</tr>
<tr>
<td>LAr TPC for DUNE</td>
<td>20 kton</td>
<td>R&amp;D in progress, Physics: Measure neutrino oscillations at 1,000+ km</td>
</tr>
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</table>

Final goal
Replicate proven technology, Physics: Search for CP violation in neutrino sector

N x 20 kton

US HEP Emphasis for the next 15 years

- Requires experience in scaling LArTPC technology
- Shares much of the same technologies and personnel as current generation experiments

Source: http://www.dunescience.org/
Other Physics

► Cross Section Measurements
  ■ Requires low energy threshold and efficiency
  ■ Good spatial reconstruction

► Supernova
  ■ Sensitive to 5-50 MeV neutrinos.
  ■ Expect 100 $\nu_e$ interactions / kiloton mass.

► Heavy Sterile neutrinos
  ■ Signal will show as “delayed” neutrinos from beam

► Proton decay
  ■ Not expected to be seen in MicroBooNE
  ■ Development of analysis methods

$p \rightarrow K^+ \bar{\nu}$
The SBN Program

- MicroBooNE
  - Flagship detector (currently operating)
- Icarus
  - Delivered to Fermilab (in installation)
- SBND
  - Under construction/design

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SBN Program Goals

Image: arXiv:1705.06561v1
Boost Neutrino Beam (BNB)

- Flux uncertainty in CC$\pi^{0,+}$ is roughly 10% (PRD83 2011)
- Flux uncertainty in CCQE is 8.66% (PRD81 2010)

Plots: uBoone Public Note 24
Backgrounds

- Expect ~11 cosmic tracks per neutrino trigger
- Matching to PMT flashes reduces this, but lowers detection efficiency

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<tr>
<th>Cut</th>
<th>Survival Fraction (Overall / Relative)</th>
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<tr>
<td>&gt; 1 Flash with &gt; 50 PE</td>
<td>25%/25%</td>
</tr>
<tr>
<td>Candidate vertex in FV</td>
<td>55%/14%</td>
</tr>
<tr>
<td>Flash matched to longest track</td>
<td>29%/4.0%</td>
</tr>
<tr>
<td>Track Containment</td>
<td>49%/1.9%</td>
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MicroBooNE Public Note 1005
Cosmic Ray Tagger

- 10.8 cm panels readout by WLS->MPPCs
- About 85% coverage
- At least 2 layers on each side with opposing orientations

Actual detector hall CRT wall
Analysis Workflow

Electronics Processing

PMT Flash Reconstruction

Pandora

Wirecell

Deep Learning
Signal Processing

Steps:
- Electronics deconvolution
- Filtering of low frequency voltage regulator noise
- 32 Hz HV power supply noise filter
- 900 kHz burst noise filter
- Peak signal to noise ratio (PSNR) below

JINST 12, P08003 (2017).

Waveform Type | U Plane PSNR | V Plane PSNR | Y Plane PSNR
--- | --- | --- | ---
Raw Data | 6.6 | 5.7 | 19.5
After Noise Filtering | 22.3 | 16.2 | 37.9

MicroBooNE After noise removal
Cuts based analysis routine
- Groups hits into clusters, tracks and showers
- Performed in 2 passes
  - Cosmic tuned reconstruction
  - Neutrino tuned reconstruction
    - Includes vertex finding, track shower discrimination and PID

MICROBOONE-NOTE-1015-PUB
Wirecell

- Utilizes 3D tomography to reconstruct full event
- Has an internal electronics deconvolution
- Performs similar cut based analysis from 3D objects.
Deep Learning

- Utilizes 2D Convolutional Neural Networks to classify whole image
- Analysis chain also has semantic segmentation network for pixel tagging
- Currently works on 1p+1l topologies
- Framework can also be used in other analysis, but requires network to be re-trained
Due to E-field from neighboring “pixels”, tracks seem to squeeze and bow.

Effect is understood, and using tracks tagged as cosmics, a mitigation method is being developed.

MICROBOONE-NOTE-1018-PUB
Michel Electron Reconstruction

- Benchmark analysis
  - High efficiency and purity sample produces a number of known events

- arXiv:1704.02927
Current Status

- MicroBooNE has been taking data since 2015
  - Taken roughly 6.0E20 of the target 6.6E20
- Currently working on analyses for the neutrino low energy excess (LEE)
- Also working on cross sections and other physics such as proton decay

My term as RunCo!
Conclusions

- MicroBooNE is moving towards a low energy excess result
  - Trifurcated analysis approach
  - Several analyses completed
- The SBN program is coming up with Icarus in the near future and SBND not far off
  - Will further constrain neutrino phase space
- We have demonstrated that LArTPCs are a feasible, scaled technology for neutrino physics
- Currently paving the path for DUNE
Backups