MicroBooNE

Motivation
Concept
Construction

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Neutrino Oscillation

\[ P(\nu_\mu \rightarrow \nu_e) = \sin^2 2\theta \sin^2(1.27 \Delta m^2 \frac{L}{E}) \]

- \(\Delta m^2\) gives the oscillation frequency.
- \(L\) is the flight length of the neutrino.
- \(E\) is the energy of the neutrino.
- Different experiments probe different regions of L/E phase space.
Motivation: Resolving Short Baseline Oscillation $\nu_\mu \rightarrow \nu_e$ Anomalies

Unexpected excess in LSND, $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

$\Delta m^2 \sim 1 \text{ eV}^2$ signal shown in blue

Excesses also seen by MiniBooNE $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

[hep-ex/0104049] [PRL 110, 161801 (2013)]
Is it oscillations?
3+1 gives a poor fit to existing data (ν vs. ¯ν disagreement)
Fits want at least 3+2

What’s the cause of the MiniBooNE excess?

Is it...
electron-like → oscillations
photon-like → an unknown background
a combination of electron and photon signal

The MiniBooNE Cherenkov detector cannot distinguish e from γ
The MiniBooNE Design

FNAL booster (8 GeV protons) → target and horn (174 kA) → decay region (50 m) → oscillations? → MiniBooNE Detector

~ 500 m

Electron, Photon
Muon
Proton
\( \pi^0 \rightarrow \gamma + \gamma \) (Cherenkov Detector)
An alternative: the LArTPC detector

LArTPC = “Modern Bubble Chamber” with 3D track reconstruction
The key is the $e/\gamma$ separation using early-track $dE/dx$! Demonstration this idea works from the ArgoNeuT LArTPC data:

**ArgoNeuT data**

- EM showers attached to vertex
- EM showers separated from vertex

*ArgoNeuT is a very small LArTPC that ran in the NuMI beamline at FNAL*
How the MicroBooNE LArTPC addresses the anomalies:

Same beamline, but 100 m upstream of MiniBooNE
Very different detector – LArTPC trades statistics for systematics
Initially address whether the MiniBooNE excess was $e$ or $\gamma$:

**Electron-like signal**

**Photon-like signal**

In the next phase become a part of an LArTPC based SBL program...
Fermilab LAr SBN Program

[Fermilab-Proposal-1053]

Lar1ND just Approved!

NOW!

MicroBooNE (470m)

SBN-FD (600m)

Soon

Lar1ND (100m)
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MicroBooNE…

A 170 ton state-of-the-art liquid argon time projection chamber, to run at Fermilab in 2015
How does a liquid argon time projection chamber work?

High Voltage, (−128 kV)

LAr (at 87 K)

2.5 meter

3 view wire chamber
Neutrino events occur in the argon.
Scintillation light from the event is observed by tubes behind the wire planes.

High Voltage, \((-128 \text{ kV})\)

6 ns timescale
ionized electrons drift slowly toward the chambers

2.5 msec drift in μBooNE

High Voltage, (−128 kV)
electrons produce signals by induction in first 2 wire planes, collected on 3rd
Uses of the TPC:  Track reconstruction, Calorimetry, PID

Example: $\pi^0 \Rightarrow 2 \gamma$

LArTPC provides rich information about particle interaction

Example proton track from ArgoNeuT data
Use of light collection: Cosmic Ray Rejection

Connect light flash to track, Was it in-time?

<table>
<thead>
<tr>
<th>Induction Plane</th>
<th>Collection Plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plane 1</td>
<td>Time 1.6 ms</td>
</tr>
<tr>
<td>Plane 2</td>
<td>Wire number ≈ 10 m</td>
</tr>
</tbody>
</table>
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The TPC

- Dimensions:
  - 10.3 m long x 2.3 m tall x 2.5 m wide
  - 80 t fiducial volume, 170 t total
- 8256 wire channels
  - 3456 Collection channels
- Wires oriented w.r.t. the vertical
  - 4800 Induction channels
- Wires oriented +/- 60°
The Light Collection

- 32 cryo PMTs
- Each with wave length shifting plates in front

TPB-coated acrylic plate

128 nm light

450 nm light
Inserting TPC
December 2013

Putting end cap on...
Summer 2014
Load the detector on a truck, Drive it around the Tevatron Ring...

... lower it into the building...
... coat it with insulation...  

... and install electronics.
• Finish the LAr piping
• Cool and fill with LAr
Thank you.