MicroBooNE

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MicroBooNE Collaboration

- We are commissioning our liquid argon time projection chamber (LArTPC) now.
- Collaboration of 121 people.
  - 31 postdocs
  - 24 graduate students
- 24 Institutions.
MicroBooNE on the Booster Neutrino Beamline

- 8 GeV protons into target.
- Horn focuses secondaries.
- Broad energy $\nu_\mu$ beam peaked at 800 MeV.
- MicroBooNE: 470 m baseline.
Protons hit beryllium target producing many mesons.
The BNB horn

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Electric Current Direction in Neutrino Mode

Induced Magnetic Field
The BNB horn

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- The magnetic field of the horn focuses positive mesons and defocuses negative mesons.
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- The magnetic field of the horn focuses positive mesons and defocuses negative mesons.
- 50 m decay pipe for $\pi^+$ and $K^+$ decay to primarily $\mu^+$ and $\nu_\mu$. 

Diagram: Protons from Booster, Protons hit beryllium target, produce many mesons. The magnetic field of the horn focuses positive mesons and defocuses negative mesons. 50 m decay pipe for $\pi^+$ and $K^+$ decay to primarily $\mu^+$ and $\nu_\mu$. 

The BNB horn

- Protons hit beryllium target producing many mesons.
- The magnetic field of the horn focuses positive mesons and defocuses negative mesons.
- 50 m decay pipe for $\pi^+$ and $K^+$ decay to primarily $\mu^+$ and $\nu_\mu$.
- Layers of steel and concrete absorb charged particles.
- Result $\rightarrow \nu_\mu$ beam!
Accelerator Division has successfully replaced the BNB horn and is in the process of commissioning it.

- Horn had been in service since 2004.
- Horn had been pulsed 400M+ times (twice its design, setting a world record!)

Decision was made to replace horn after several cooling lines became clogged last year.

The new filtering system is now more robust against introducing debris.
MicroBooNE on the Booster Neutrino Beamline

- 8 GeV protons into target
- Horn focuses secondaries
- MicroBooNE: 470 m baseline
- Broad energy $\nu_\mu$ beam peaked at 800 MeV
1. Neutrinos from beam interact with an argon atoms.
2. Charged particles from the interaction excite/ionize surrounding LAr.
3. Scintillation light detected by photomultiplier tubes (PMTs) (∼few ns).
4. Ionization electrons drifted by electric field to collect on wires (1.6 ms).
### Why liquid argon?

<table>
<thead>
<tr>
<th></th>
<th>He</th>
<th>Ne</th>
<th>Ar</th>
<th>Kr</th>
<th>Xe</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point [K] @ 1atm</td>
<td>4.2</td>
<td>27.1</td>
<td>87.3</td>
<td>120</td>
<td>165</td>
<td>373</td>
</tr>
<tr>
<td>Density [g/cm³]</td>
<td>0.125</td>
<td>1.2</td>
<td>1.4</td>
<td>2.4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Radiation Length [cm]</td>
<td>755.2</td>
<td>24</td>
<td>14</td>
<td>4.9</td>
<td>2.8</td>
<td>36.1</td>
</tr>
<tr>
<td>dE/dx [MeV/cm]</td>
<td>0.24</td>
<td>1.4</td>
<td>2.1</td>
<td>3</td>
<td>3.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Scintillation [γ/MeV]</td>
<td>19,000</td>
<td>30,000</td>
<td>40,000</td>
<td>25,000</td>
<td>42,000</td>
<td></td>
</tr>
<tr>
<td>Scintillation λ [nm]</td>
<td>80</td>
<td>78</td>
<td>128</td>
<td>150</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>Approx. Cost [$/kg]</td>
<td>52</td>
<td>330</td>
<td>5</td>
<td>330</td>
<td>1200</td>
<td></td>
</tr>
</tbody>
</table>

- Heavy target.
- Cheap.
- Transparent to drifting electrons.
- Transparent to own scintillation light.
  - Strict limits on impurities to maintain these transparencies.
What do collisions look like?

- Example of an event from Fermilab’s ArgoNeuT LArTPC.
Inside of MicroBooNE

- Ultra purified liquid argon.
  - Impurities continuously filtered and monitored.
- Requirements to drift a MIP track 2.5 m (or else the e⁻ is absorbed!)
  - < 100 ppt O₂ equivalent
- Requirements for photon detection (or else the γ is absorbed!)
  - < 1 ppm N₂

Sharks need to smell at least 1 ppm blood to hunt its prey!
Inside of MicroBooNE

- **Strong electric field**
  - $-120$ kV across 2.5 m drift distance.

- **Large drift distance $\rightarrow$ more target volume per instrumentation area $\rightarrow$$\$$ efficient**

- **Challenges:**
  - LAr purity
  - High voltage

Longest drift distance in a $\nu$ beam!
Inside of MicroBooNE

- Three wire planes to sense ionization electrons.
  - 8,256 wires!

3 mm pitch
Inside of MicroBooNE

- 32 PMTs to collect scintillation light.
  - Provide trigger, drift time.

Liquid argon is invisible to its own scintillation light.
Publications already growing!

- Proposals for hardware and physics.
- Technical investigations.

Related Publications by MicroBooNE Collaborators:

- L.F. Bagby et al., "Breakdown Voltage of Metal Oxide Resistors in Liquid Argon", JINST 9, T11004 (2014)
- R. Acciarri et al., "Liquid Argon Dielectric Breakdown Studies with the MicroBooNE Purification System", JINST 9, P11001 (2014)
- A. Blatter et al., "Experimental Study of Electric Breakdown in Liquid Argon at Centimeter Scale", JINST 9, P04006 (2014)
Physics Goal 1: Investigate MiniBooNE Excess

- MiniBooNE saw an excess of low-energy $\nu_e$-like and $\bar{\nu}_e$-like events.
- Cherenkov detectors, such as MiniBooNE, cannot distinguish between a Cherenkov ring from $e$ or $\gamma$.
- We want to determine the source of this electromagnetic excess.

![MiniBooNE Electron Neutrino Energy](image)

*Antineutrino*
- Data (stat err.)
- $\nu_e$ from $\mu_\tau$
- $\nu_\tau$ from $K^{+/-}$
- $\nu_\mu$ from $K^0$
- $\pi^0$ misid
- $\Delta \rightarrow N\gamma$
- dirt
- other

*Neutrino*
- Events/MeV
- $E_{\nu}^{QE}$ (GeV)

**Figure 1** (color online). The antineutrino mode (top) and neutrino mode (bottom) event excesses as a function of energy. Other backgrounds from external neutrino interactions are similar in both the neutrino and antineutrino flux estimates, uncertainties due to nuclear effects, and uncertainties in detector modeling and reconstruction. These include uncertainties from variations of parameters. These include uncertainties in detector stability, beam and spatial cuts to isolate these events whose vertex is near the edge of the detector and point towards the detector.
Physics Goal 1: Investigate MiniBooNE Excess

- MicroBooNE’s LArTPC technology was specially chosen for its excellent e/γ identification capabilities.
Physics Goal 1: Investigate MiniBooNE Excess

- If excess is due to photons:
  - MicroBooNE will make the first measurements of a novel photon production mechanism.
  - This mechanism would then need to be included in MC generators and this would impact all future $\nu_e$ appearance experiments!

- If excess is due to electrons:
  - Is MicroBooNE seeing oscillations of a new sterile neutrino!?
  - Some other novel production mechanism?
Physics Goal 2: Cross-section measurements

- We will make high-statistics measurements of neutrino-argon cross-sections.
Physics Goals 3 & 4

- MicroBooNE’s supernova data stream buffers all of the MicroBooNE data to be read out if SNEWS gives an alert.

- MicroBooNE also serves as an excellent tool to study background to proton decay experiments
  - Cosmogenic kaons:
    \[ K^0_L + p \rightarrow K^+ + n \]
Physics Goal 5: Collaborate on SBN program

- MicroBooNE serves as the first of Fermilab’s three-detector Short Baseline Neutrino (SBN) oscillation program.
  - More details on this in the following talk from Joseph.
Technical Goals

- Test LArTPC technology at a scope and scale to inform the design and operation of future, larger LArTPCs.
- Develop extensive reconstruction algorithms to be used by all LArTPCs at Fermilab.
  - 1660+ commits in uboonecode
What have we been up to this year?
What have we been up to this year?

Well, another one of our collaborators won the **Fermilab Physics Slam**... but besides that...

<table>
<thead>
<tr>
<th>Fermilab Physics Slam Winners</th>
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<tbody>
<tr>
<td>Accelerators</td>
</tr>
<tr>
<td>Dark Energy Survey</td>
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<tr>
<td>MicroBooNE</td>
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<tr>
<td>Others</td>
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</tbody>
</table>
The Built MicroBooNE Detector Moved: June 23, 2014

Massive MicroBooNE particle detector moved into place; will see neutrinos this year

30-ton MicroBooNE neutrino detector is gently fed into the Liquid-Argon Test Facility at Fermilab on Monday, June 23. The detector will be the centerpiece of the MicroBooNE experiment, which will study ghostly particles called neutrinos. Photo: Fermilab
Cryostat was insulated with 16” of spray foam.

Welded pipe assemblies to the cryostat.

Last year, summer students helped build cables.

Over the next months, we connected up the detector and electronics racks.

- 6.2 km of cable deployed!
- Yes, those labels will never fall off!

Electronics Racks Installed: Sep-Nov 2014

- Racks of electronics successfully passed the partial Operational Readiness Clearance (ORC).
  - Brought over from D0 and installed on top of cryostat at LArTF.
- After installation at LArTF, racks passed full ORC review.

All piping was installed, welded, leak checked, insulated, and is now starting to run.
- Nearly 200 m of piping was installed!
Bern Collaborators installed UV Laser System in December.

Since MicroBooNE will have a high cosmic ray flux, we expect ions to build up near the cathode plane.

UV laser allows us to map E-field and correct our tracking software.
The DOE MicroBooNE Project consisted of:

- Design, fabrication, and installation of the MicroBooNE detector

All signatures collected for Critical Decision 4 (CD-4) on December 22!

Moved onto “operations phase”.
Successful data acquisition tests using our new control room at ROC West.

- 20 TB of noise data already collected!

To give confidence that the wires were healthy after our big move, we imaged inside the cryostat. Looks great!
Purge air out of cryostat by injecting gaseous argon from the bottom.

- Thanks to LAPD for pioneering our procedure!

O₂ Contamination of Gaseous Argon During Purge
The argon gas is cooled by running it through a liquid nitrogen heat exchanger.

- We will start filling the detector with liquid argon in ~2 weeks.
- It will take ~3 weeks to fill (170 tons of liquid argon ~12 truck loads).

Average Cryostat Temperature
Shifts Started!: June 1, 2015

- Currently monitoring our subsystems from ROC West.
  - Running the Data Acquisition System recording and analyzing noise data during cool-down and filling (only 2 weeks away!).

- We are excited to collect our first physics data!
We are very thankful for all of our supporters!