The MicroBooNE TPC trigger and GPS timing studies

Leonidas N. Kalousis (Virginia Tech.) for the MicroBooNE collaboration
APS meeting, Denver, April 2013
MicroBooNE

- MicroBooNE will be the largest Liquid Argon Time Projection Chamber (LAr TPC) operating in the United States (US).
- The primary objectives of this experiment are:
  - The investigation of the MiniBooNE low energy excess
  - Detailed measurements of neutrino interaction cross-sections and,
  - Study of the background related to proton decay searches in massive LAr detectors; such as LBNE, LBNO and Okinoshima.
- Of course all this effort is expected to further advance the LAr detector concept; a very promising technology well-suited for neutrino physics.
- Additional searches with the MicroBooNE detector include:
  - Burst neutrinos and,
  - Neutrinos from supernova explosions (SN).
Experimental layout

- MicroBooNE (just like MiniBooNE) will be installed along the Booster Neutrino Beam (BNB) in Fermi National Laboratory.

- Placed at a distance of ~470 m from the neutrinos’ creation point in the Liquid Argon Test Facility (LArTF).

- It is expected to start data taking in 2014 and run for 2-3 years in the neutrino mode accumulating $6.6 \times 10^{20}$ POT.

Accelerates protons to 8 GeV
BNB and NuMI beamlines

• Besides BNB MicroBooNE will also receive Neutrinos from the Main Injector beamline (NuMI).
The MicroBooNE TPC

Characteristics:
- ~1.6 ms drift time (~2.5 m drift length)
- 8256 total channels
- Three planes of wires at 3 mm pitch
  - One collection plane at 0° from vertical
  - Two inductions planes at ±60°
- Optical system of 30 cryogenic PMTs

Current status (under construction):
- Field cage already built
- Wire planes constructed
- Cryostat delivered
- The LArTF building will be soon ready

10.4 m × 2.3 m × 2.5 m uniform field of 500 V/cm
170 tons of purified LAr
(active volume 83 m³)
Triggering options

- Neutrinos from the BNB have a well-known timing structure
  - The signal gate is a priori known.
- Besides this, MicroBooNE can also trigger relying on the timing information obtained from the optical system.
  - Contrast to the electron drift times (~ms) light is propagated almost simultaneously (~ns).
- Additionally we are exploring the possibility to “trigger” events according to their signature in the TPC.
- This will be an offline “trigger” termed as the TPC trigger (and will occupy the first part of this talk ...).
- This is an important ingredient for:
  - Cosmic ray studies
  - Studies of background sources relevant for proton decay
Continuous data stream

• Two distinct data streams envisaged in MicroBooNE.
  – Beam events and the SN continuous data flow

SN stream:
• Saved continuously in a disk.
  – Large amount of data
• Stored in a circular buffer and retained there for an hour.
• Develop fast algorithms to select the interesting events

Requirements:
• Robust performance
• Minimize CPU time

One Hard Drive (HD) per section of the TPC
The TPC trigger

- U, V and Y wires overlap in a region of 30-60 cm at the top of each crate.
- Requiring a time coincidence between groups of U, V and Y wires will signal a particle that comes through the top of the TPC.
- Additionally hits in the Y plane only betray vertical going particles (cosmic muons)
- In general, exploit the geometry of the TPC to characterize topologies.
GPS timing

• For the global timing information we use, naturally, a commercial GPS card (Symmetricom PCIe).

• Its software has been modified for our linux machines (Yale).

• A customized firmware developed to cast the Trigger Board (TB) time-stamp (Nevis Labs).
Trigger board time-stamp

I. Consecutive frames of 1.6 ms:

```
  1.6 ms  1.6 ms  1.6 ms  ...
```

II. Every frame consists of 2 MHz samples:

```
  1.6 ms  1.6 ms  

  1.6 ms × 2 MHz = 3200 samples, 0.5 μs
```

III. Samples digitized by 16 MHz clock:

Each sample is split in eight divisions; ultimate graining 62.5 ns
Combine the two functionalites
(Current work at Virginia Tech.)

• The GPS card will “interrupt” normal data taking with a one pulse per second (PPS).

• Consequently the TB will issue its three-fold counter stamp to this external signal.

• Then a combined software will intervene and relate the time of this event to the TB timestamp.
  – Future triggers will also be assigned with the proper timing.

• This will allow:
  – Precise global timing for all data
  – Correlate events with possible SN explosions
Ending themes

• MicroBooNE will be a very beautiful and a multi-purpose detector
• ... and presumably will deliver some equally wide and rich physics results!
• The TPC trigger will be an integral part of the detector and the read-out, allowing to study non-beam events; a rather challenging task.
• When completed, this work could influence and further inspire future and existing LAr TPC detectors.
• MicroBooNE is expected to start data taking in 2014.
• Until then stay tuned!
Thank you!

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Extra details and information

BACKUP SLIDES
MiniBooNE low-energy excess

200 MeV < $E_{\nu}$ < 1250 MeV

**Neutrino mode:**
- Data: 952 events
- Background: $790.0 \pm 28.1 \pm 38.7$
- Excess: $162.0 \pm 47.8$ (3.4 $\sigma$)

**Antineutrino mode:**
- Data: 478 events
- Background: $399.6 \pm 20.0 \pm 20.3$
- Excess: $78.4 \pm 28.5$ (2.8 $\sigma$)

**Combined:**
- Excess: $240.3 \pm 34.5 \pm 53.6$
- 3.8 $\sigma$ statistical significance

Tension below 475 MeV
Limitations of the 2$\nu$ model?
Misidentified backgrounds?
e/γ discrimination
G. Karagiorgi, Current and Future Liquid Argon Experiments, NuInt 2012

Flux estimate: $\nu_\mu$ running in BNB

- $\nu_\mu$
- $\bar{\nu}_\mu$
- $\nu_e$
- $\bar{\nu}_e$

Intrinsic $\nu_e$: 0.5%
Wrong-Sign $\nu$: 6%

Expected event rate for BNB $6.6 \times 10^{20}$ POT
60 ton fiducial volume

<table>
<thead>
<tr>
<th>production mode</th>
<th># events</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC QE ($\nu_\mu n \rightarrow \mu^- p$)</td>
<td>60,161</td>
</tr>
<tr>
<td>NC elastic ($\nu_\mu N \rightarrow \nu_\mu N$)</td>
<td>19,409</td>
</tr>
<tr>
<td>CC resonant $\pi^+$ ($\nu_\mu N \rightarrow \mu^- N \pi^+$)</td>
<td>25,149</td>
</tr>
<tr>
<td>CC resonant $\pi^0$ ($\nu_\mu n \rightarrow \mu^- p \pi^0$)</td>
<td>6,994</td>
</tr>
<tr>
<td>NC resonant $\pi^0$ ($\nu_\mu N \rightarrow \nu_\mu N \pi^0$)</td>
<td>7,388</td>
</tr>
<tr>
<td>NC resonant $\pi^+$ ($\nu_\mu N \rightarrow \nu_\mu N' \pi^+$)</td>
<td>4,796</td>
</tr>
<tr>
<td>CC DIS ($\nu_\mu N \rightarrow \mu^- X, W &gt; 2$ GeV)</td>
<td>1,229</td>
</tr>
<tr>
<td>NC DIS ($\nu_\mu N \rightarrow \nu_\mu X, W &gt; 2$ GeV)</td>
<td>456</td>
</tr>
<tr>
<td>NC coherent $\pi^0$ ($\nu_\mu A \rightarrow \nu_\mu A \pi^0$)</td>
<td>1,694</td>
</tr>
<tr>
<td>CC coherent $\pi^+$ ($\nu_\mu A \rightarrow \mu^- A \pi^+$)</td>
<td>2,626</td>
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<tr>
<td>NC kaon ($\nu_\mu N \rightarrow \nu_\mu K X$)</td>
<td>39</td>
</tr>
<tr>
<td>CC kaon ($\nu_\mu N \rightarrow \mu^- K X$)</td>
<td>117</td>
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<tr>
<td>other $\nu_\mu$</td>
<td>3,678</td>
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<tr>
<td>total $\nu_\mu$ CC</td>
<td>98,849</td>
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<tr>
<td>total $\nu_\mu$ NC+CC</td>
<td>133,580</td>
</tr>
</tbody>
</table>

$\nu_e$ CC:
- Total $\nu_e$ CC: 326
- $\nu_e$ QE: 657

Also “sees” NuMI beam: Off-axis

Expected rates from upgraded NuMI beam (200kW, 6E20POT/yr)
1 yr, 60 ton fiducial volume

Higher energy beam
+ increased $\nu_e$ content

- 40k $\nu_\mu$ CC
- 8k anti-$\nu_\mu$ CC
- 2k $\nu_e$ CC
- 400 anti-$\nu_e$ CC
- few 100’s of $\Lambda^0$s
LArTF chronicles

January 2012

February 2012

March 2012

July 2012

January 2013

March 2013
TPC cage construction
Arrival of the cryostat
GPS at DAB

Symmetricom Bc637PCIe

cost ~ 3k $
~ 10^2 ns accuracy

GPS antenna placed at the roof of D-zero assembly building