# PMT Triggering and Readout for the MicroBooNE Experiment

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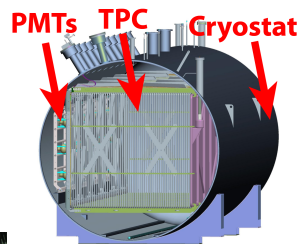## On behalf of the MicroBooNE Collaboration

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Abstract: This poster presents the proposed PMT readout and triggering system that will be used in the MicroBooNE LArTPC experiment. The triggering scheme has been designed to study beam neutrino events as well as fully characterize cosmic rays. In addition, exploration of important physics applications including the use of "late" scintillation light in argon for particle identification and Michel electrons from muon decay will be possible. Various types of triggers and how they will be implemented in the combined PMT+TPC readout electronics system will be discussed.
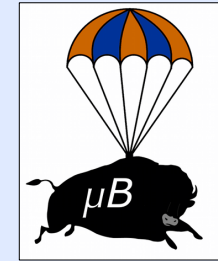
The MicroBooNE PMT System

- 32 8" Hamamatsu PMTs.
- Used for
  - Triggering and event timing information.
  - Reconstruction, cosmic tagging, particle ID, etc.
- PMTs behind TPB coated plates to convert UV scintillation to visible.
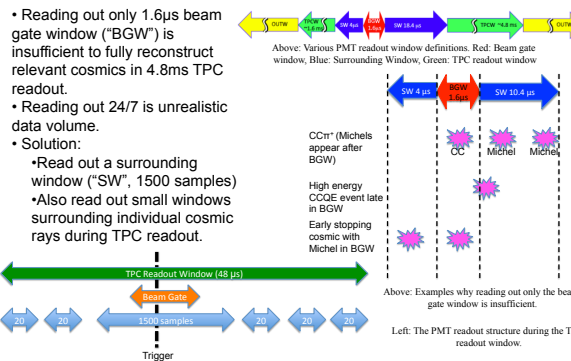- The PMT system determines when the detector (TPC+PMT) is read out.
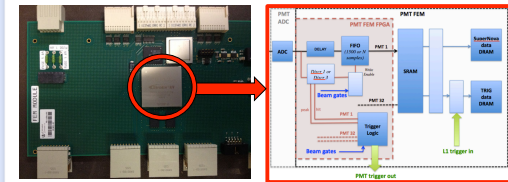

Current Status

- PMTs installed and tested with HV in "dark" cryostat.
- Official DAQ system successfully recorded data.
- HV hardware and software working.
- All PMTs operational.

PMT Readout Goals

- Identify scintillation light emission in coincidence with beam gates.
  - Expected to have 1 in 20 beam-gates satisfy requirement (mostly due to cosmic rays).
  - 1/2500 beam gates will contain a neutrino interaction if no PMT trigger.
- Measure timing and position of background cosmics.
- Measure prompt and late light.
  - Time scales: 6ns and 1.6μs.
  - Related to dE/dx … PID!
  - Need PMT readout to accommodate different time scales.
- See Michel electrons from beam events.
- All while having a manageable data rate.

Above: PMTs help determine which of these is the neutrino among a sea of cosmics.

Above: Excited Ar atom may combine with ground state Ar in an excimer, with two decay pathways; prompt (6 nanosecond) and late (1.6 microseconds)

PMT Readout Structure

- Reading out only 1.6μs beam gate window ("BGW") is insufficient to fully reconstruct relevant cosmics in 4.8ms TPC readout.
- Reading out 24/7 is unrealistic data volume.
- Solution:
  - Read out a surrounding window ("SW", 1500 samples)
  - Also read out small windows surrounding individual cosmic rays during TPC readout.

Above: Various PMT readout window definitions. Red: Beam gate window, Blue: Surrounding Window, Green: TPC readout window

SW 4 μs | BGW 1.6μs | SW 10.4 μs

CCπ+ (Michels appear after BGW)

High energy CCQE event late in BGW

Early stopping cosmic with Michel in BGW

Above: Examples why reading out only the beam gate window is insufficient.

TPC Readout Window (48 μs)

Beam Gate

20 | 20 | 1500 samples | 20 | 20 | 20

Trigger

Left: The PMT readout structure during the TPC readout window.

PMT Electronics

Splitter
High gain (90%)
Warm cables
HV Feedthrough
Cold cables
GAr
HV in
Low gain (10%)

Fan out to TPC crates and PMT FEM

PMT Crate
PMT Trigger
Shaper | ADC | FEM | XMIT | Trigger Board

PMT Base
LAr

Readout to DAQ PC

- High and Low gain extends dynamic range of ADC.
- Two readout streams
  - Triggered neutrino readout.
  - Continuous supernova readout.

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Pulse from an LED-flashed PMT in the "dark" cryostat, read out through the full PMT readout electronics system.
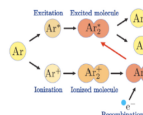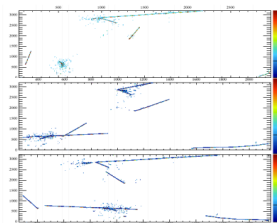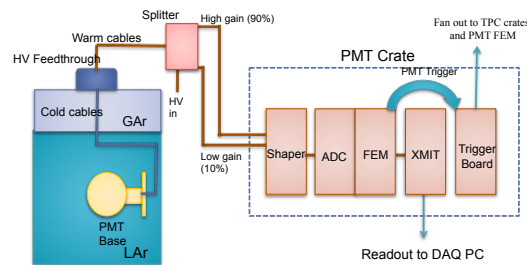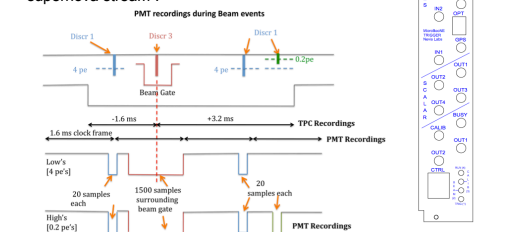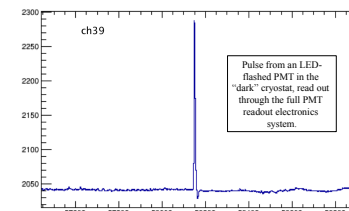
Triggering with PMTs

Above: A picture of a PMT front end module (FEM). Input from shaper boards comes in from below. The top attaches to a crate backplane.

Above: A schematic of the FPGA on the PMT FEM, with a portion dedicated to trigger logic.

- PMT system determines when the detector (TPC+PMT) is read out.
- *Readout Conditions* (to read out the PMT FEM buffer memory) include:
  - Discriminator level 0 (low-threshold, for good timing) plus discriminator level 1 (higher-threshold, used outside of BGW with required Discr0 precondition to tag cosmics).
  - Readout sizes are either 1500 samples or 20 samples for Disc0/1 fires.
- If a trigger is formed, these data are read out to the DAQ system.
- *PMT Trigger Conditions* (to form a PMT trigger) include:
  - Pulse amplitude on a single PMT.
  - Summed coincidences on multiple PMTs.
  - Delayed coincidences (Michel electrons).
- Data meeting conditions are continually read out to a "supernova stream".

PMT recordings during Beam events

Discr 1 | Discr 3 | Discr 1
4 pe | Beam Gate | 0.2pe
-1.6 ms | +3.2 ms | TPC Recordings
1.6 ms clock frame | PMT Recordings
Low's [4 pe's]
20 samples each | 1500 samples surrounding beam gate | 20 samples each
High's [0.2 pe's] | PMT Recordings

Above: The readout structure for a possible beam gate event, for one PMT. 1500 samples surrounding a beam gate are always read out in every PMT, and 20 samples surrounding cosmics in individual PMTs.

Above: Triggerboard front-panel with inputs from PMT system, beam gates, laser calibration systems, etc.

- Types of triggers available include:
  - Beam event trigger (Beam PMT trigger in coincidence with Beam Gate).
  - Cosmic PMT trigger (occurs in "OUTW").
  - External trigger.
  - DAQ-issued calibration trigger.
  - Random trigger (to study backgrounds).
- PMT Readout is essentially deadtime-less!