LBNE Water Cherenkov Electronics

Preliminary Working Specifications

This document provides an initial list of specifications as input for a cost estimate. It is intended to separate:

- *requirements* which are necessary to achieve the basic physics goals of the detector
- *desirable features* which enhance the physics of the detector, but which should be proven by *Monte Carlo* simulation to be sufficiently valuable to include
- *implementation details* which do not directly affect the ability to achieve basic physics and should ultimately be left to the judgment of engineers

Assumptions

These specifications make some basic assumptions (which are kept to a minimum). A large (>100kT) water volume is instrumented with a 10^4 – 10^5 large round photomultiplier tubes (PMT). Tubes may be equipped with light-collecting reflectors or wavelength-shifting plates.

Measurements are event-oriented, where an "event" is defined loosely as a cluster of photo-electrons (pe) viewed by a group of PMTs within a time window (≤ 1μs).

Requirements

To support the basic physics goals of the detector, the requirements are few and easily-stated. The requirements proposed below are somewhat more stringent than the minimum but are expected to be easily achievable.

PMT Signal Measurements

The following measurements must be made on the signal received by each PMT.

Quantity	**Defined as**	**Precision**	**Accuracy**	**Full Scale**	**Notes**
Precision Time	$t_{PMT} - t_0$ (trigger)	0.2ns	1ns	1μs	Limited by PMT resolution
Absolute Time	$t_0 - t_{BEAM}$	100ns	100ns	?	For LB event ID
UTC Time	$t_0 - t_{GPS}$	1ms	1ms	n/a	For astronomy
Charge (npe)	PMT Q with gate	0.2ps	1pe (lo)	1000 pe	Could be non-linear scale

For the time measurement, time-walk correction of some sort is assumed (*i.e.* constant-fraction or zero-crossing discriminator).

The t_0 mentioned above is assumed to be a hardware trigger signal. If a "readout every hit" architecture is selected, this may be a pure software construct. It is intended to illustrate that the timing requirements within an event are more stringent than the absolute timing with respect to an outside reference.

Trigger

Two basic triggers are foreseen:

PMT multiplicity – Trigger when a real-time sum of the number of PMTs above a per-channel threshold within a defined time window exceeds a programmed value.

Energy – Trigger when a real-time sum of the total charge seen by all PMTs within a defined time window exceeds a programmed value. Calibration factors may need to be applied to match PMT gains.

Analog, digital or pure software triggers are acceptable. The width, programmability and required precision of the time window must be defined.

Calibration

A scheme must be provided for in-situ calibration and testing of the following characteristics of each front-end channel:

1. Time measurement
    - Zero offset from trigger
    - Slope in counts/ns
2. Charge measurement
    - Pedestal
    - Slope in counts/pC

The calibration scheme should provide sufficient precision and accuracy to verify that each channel meets the specifications described in this document.

Readout

A readout system must be provided to capture PMT hit data in response to a trigger and deliver the event data to disk. As the expected rate of background and signal events for most physics processes is very low, the requirements for the readout system are largely driven by desired burst capability to handle nearby supernovae. Suggested specifications for the readout system are given below.

Individual channel dead-time	< 500ns after each hit	keep dead time < 0.5% per tube for worst-case 10kHz noise rate
Number of hits buffered per channel	2 minimum	handle μ decay electron in same PMT
Time to empty channel buffers after trigger	100 μs	

High Voltage

High voltage power must be provided to each PMT. The detailed requirements depend on the details of the PMT and base, but an initial list is given below.

Voltage Setting – per PMT	1500-2500V 1V accuracy 0.5V precision	(Channels may be grouped with limited adjustment range within a group)
Ripple	< 100mV at PMT base	
Current capability	3mA maximum per PMT	
Voltage readback	1V accuracy 0.5V precision	
Current readback	1uA accuracy, precision	
Over-current trip	100uA resolution for setpoint	Disable PMT output, can reset by software

Reliability / Maintenance

The electronics must be robust, stable and reliable. Access for servicing must be provided. Specifications must be determined for MTTF (mean time to fail) and MTTR (mean time to repair) for all components of the system.

Desirable Features

Below is a list of items which are not required to meet the basic physics goals of the detector but which might enhance it's performance. Each will be considered only if a defensible case can be made for it's inclusion.

- Low/zero deadtime
- Pulse shape analysis (could be waveform recording or other method)
- Software/programmable trigger

- Increased dynamic range in pulse height or time measurement
- others?