**Subject:** Electrical safety documentation required to obtain ORC approval of PMT vertical slice test stand at PAB

**Introduction:**

The MicroBooNE PMT System Vertical Slice Test (VST) aims to monitor the performance of a sample of the photomultiplier tubes (PMTs) from the optical system of MicroBooNE experiment over a period of several months in liquid argon. The test will incorporate two PMT assemblies and elements of the MicroBooNE readout electronics and data acquisition systems. We seek Operational Readiness Clearance to operate the test stand unattended for this long term system stability test.

**Location:**

The MicroBooNE PMT VST will use the Bo cryostat and two electronics racks at the proton assembly building (PAB), shown in figure 1.

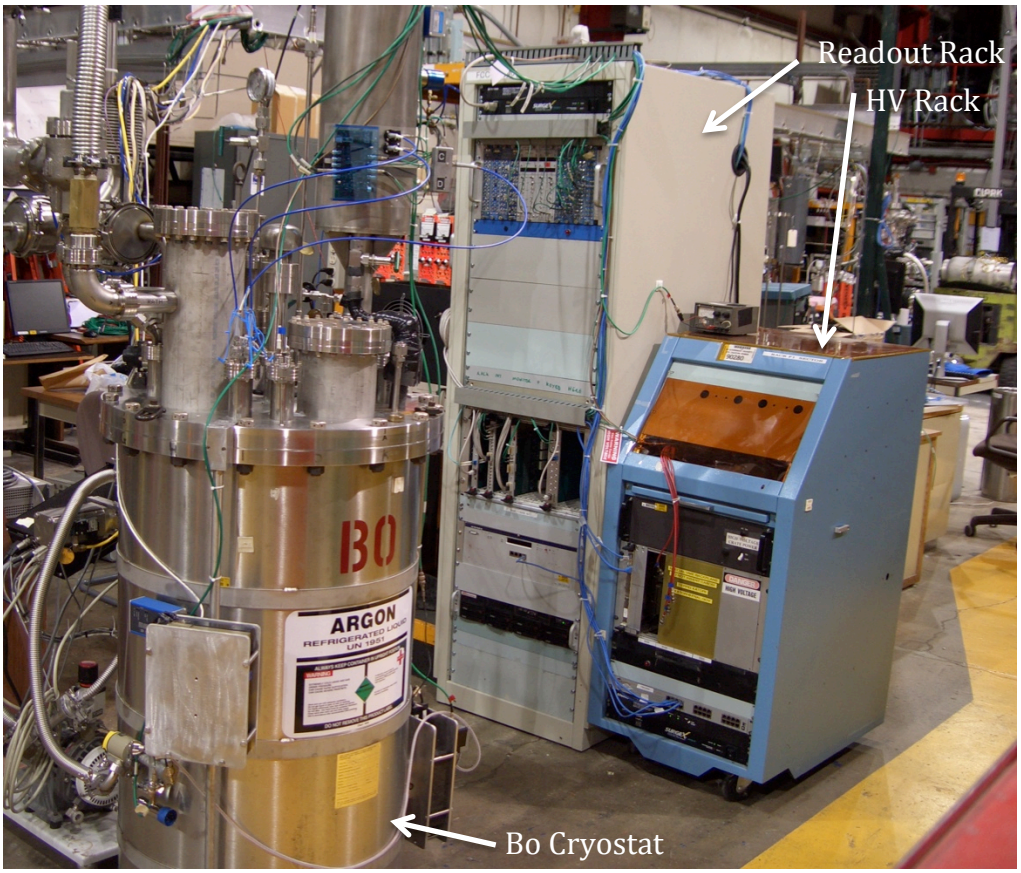



Figure 1: Bo cryostat in situ, with supporting readout and HV racks

## System Description

The Bo cryostat and its supporting cryogenics have already undergone an ORC review and have been run unattended with the Bo TPC. Documentation and references to further information from the previous reviews are given as appendix A. High voltage supplied to the PMTs is provided by a half size HV rack which has also undergone a previous ORC review and has been stably operated with a previous test stand. ORC documentation is attached as appendix B.

The novel parts of the system which we will describe in detail in this document include a new readout rack, an LED pulser module, a cosmic ray paddle detector, and an oscilloscope and monitor setup. We have also added an argon level / HV interlock to the HV crate to ensure that the PMT voltage is dropped before the PMT bases can be exposed to gaseous argon.

### *Readout Rack*

The readout rack houses a Koi Computer server, a rack mounted keyboard and monitor, an Ortec model 401A NIM crate with a model AEC-320.9 power supply (Appendix C). The NIM Bin is cooled by an AD Ayre Amplifier model 5106BB rack mounted fan, all of which are commercial products. The Readout Rack also incorporates a custom designed MicroBooNE style readout crate powered by a commercially available Wiener power supply and cooled by a rack mounted fan unit. Close ups of the NIM crate, readout crate, rear view of the server, Weiner power supply, and readout rack are shown in figure 2.

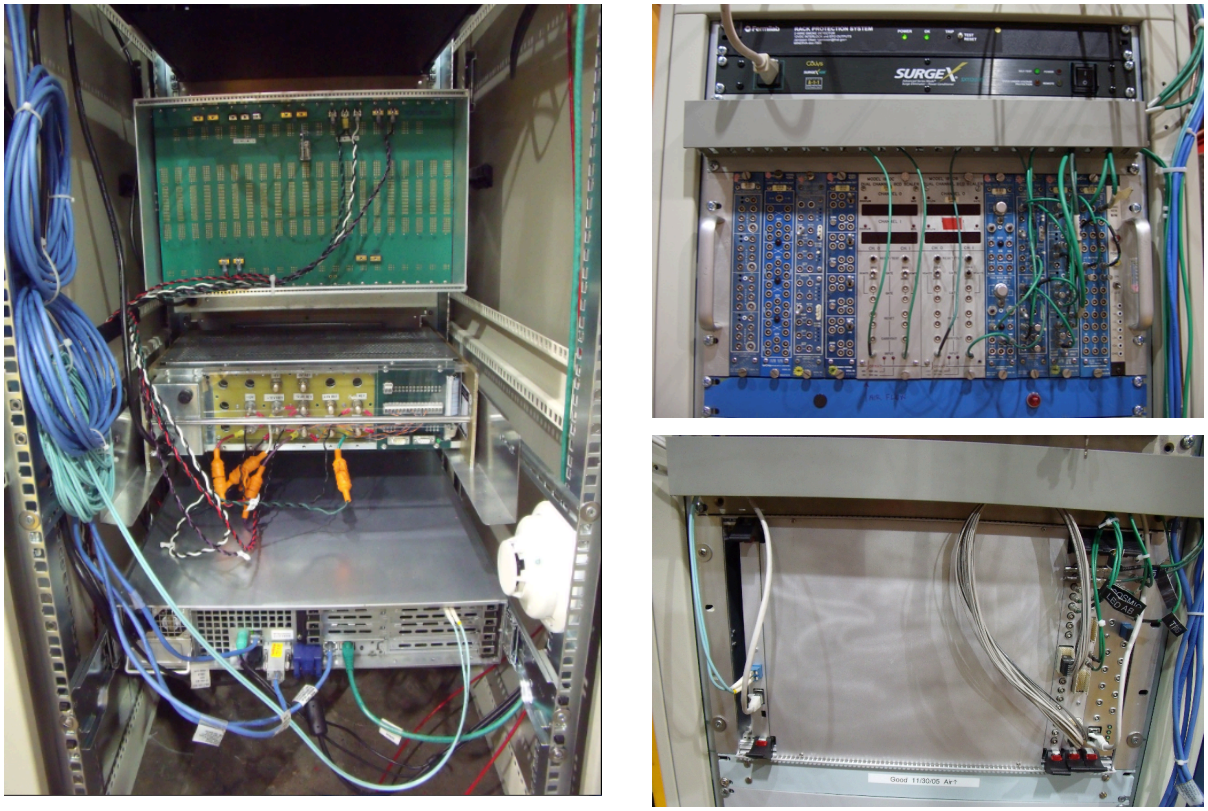


Figure 2. Left: Rear view of readout crate, Weiner power supply, server. Right top: NIM crate. Right bottom: Front view of readout crate.

***Readout crate electronics***

***Add information regarding all custom electronics in the Readout Rack. Custom cards within the PMT crate include Shaper, Controller, Trigger, FEM, and backplane. Custom designed cards outside of crate include the PCIe card housed in the KOI.***

***The preproduction Engineering Design Review documents for all crate custom cards are here http://www-ppd.fnal.gov/EEDOffice-w/Projects/MicroBoone/EDR/Round_1.html***

***The review Findings and Approval report is the first item under the first heading. Please use the same card names as those in the spreadsheet for easy reference.***

***The EDR findings for the PCIe card states that if the non-fused PCIe card is used, an additional smoke sensor needs to be mounted above the card and tied into the Rack Protection System.***

***This approach was used for the D0DAQ test stand, found here, http://www-ppd.fnal.gov/EEDOffice-w/Projects/MicroBoone/EDR/Test_Stands/B102412_Bagby_D0DAQ_TS.pdf***

***and also implemented in the PMT readout Rack.***

***LED Pulser module***

The LED pulser board was designed by Sten Hansen (Fermilab) and its technical specifications can be found in appendix D. It is connected via RG174 cables with LEMO connectors to four LEDs mounted on "postage stamp" boards, also described in the appendix. The LED boards and pulser board are mounted on a perspex backplane which is attached to the Bo condenser tower with a bracket, and optical fibers run from the LED housings to the cryostat fiber feedthroughs. The pulser is connected by a commercial USB cable, routed above the walkway between the readout rack and cryostat, to the Koi Computer server in the readout rack. The board is protected by a blue plastic cover, which is screwed down onto the backplate. The pulser, "postage stamp" boards and LED housings are shown in figure 3.

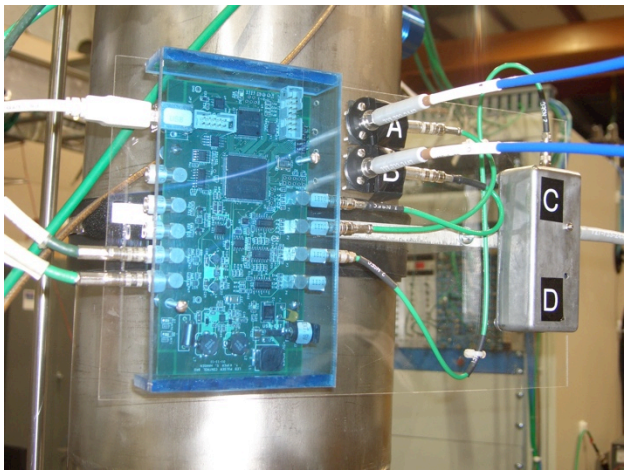



Figure 3. Pulser board, “postage stamp” boards and LED housings

***Cosmic Paddle Assembly***

The cosmic ray paddles are powered by a 12V Hewlett Packard 6216A Power Supply which sits on top of the HV mini-rack. The spec sheet for the power supply is given as appendix E. It provides power to two sets of cosmic ray paddles, comprised of 1 inch PMTs with Hamamatsu Cockroft Walton bases optically coupled to scintillator blocks. The power supply and one cosmic paddle are shown in figure 4. Documentation from these bases and PMTs are provided in appendix F.

Figure 4. left : Cosmic paddle power supply, right: cosmic paddle assembly

***Scope and Monitor Setup***

A Tektronix TDS5054B scope and ACER monitor sit on a desk to the right of the readout crate to be used as an alternative mode of data acquisition. These are shown in figure 5. Both are commercial products. The specification sheet for the scope is given in Appendix G.

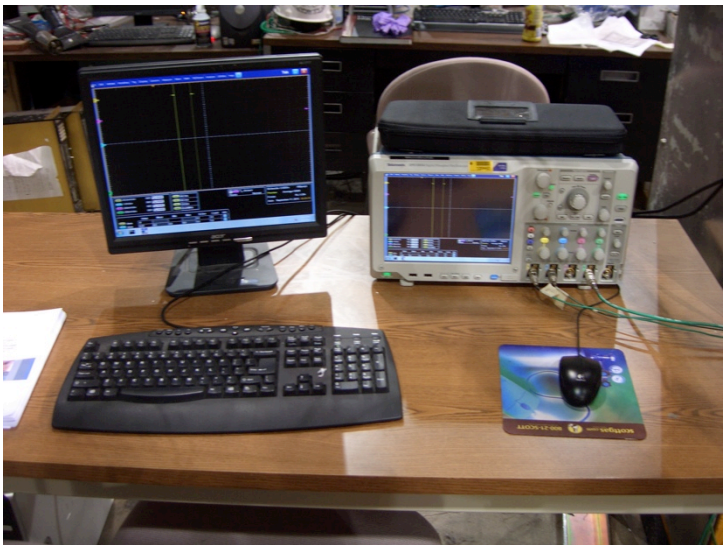


Figure 5. Oscilloscope and monitor

**AC Distribution**

The AC distribution diagram for the system is shown in figure 6. All incoming AC power is supplied from the same circuit to the AC sockets in the readout rack. A 12AWG cable delivers power from here to the HV mini rack (whose AC distribution is shown in the figure and described in more detail in appendix B). A second 12 AWG cable delivers power to the rack mounted SurgeX SX1120RT Surge Suppressor AC Distribution unit. The specifications for the SurgeX can be found in Appendix B. The SurgeX supplies switched power to the rack mounted NIM crate (fused at 5A), Weiner power supply (fused at 16A) and Koi Computers server, as well as the external Hewlettt Packard DC power supply (fused at 0.5A). It provides unswitched output through the back panel to the rack mounted keyboard and monitor, and through the front panel to a commercial Tripp-lite power splitter which runs the oscilloscope and monitor.

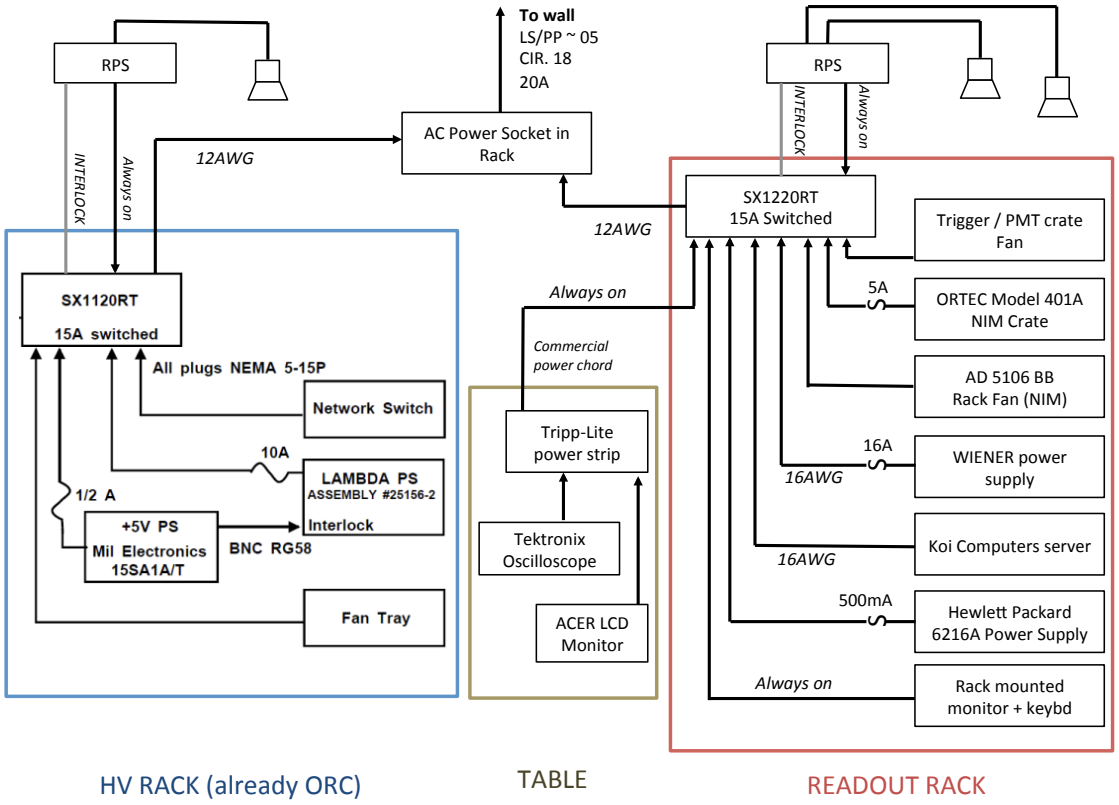


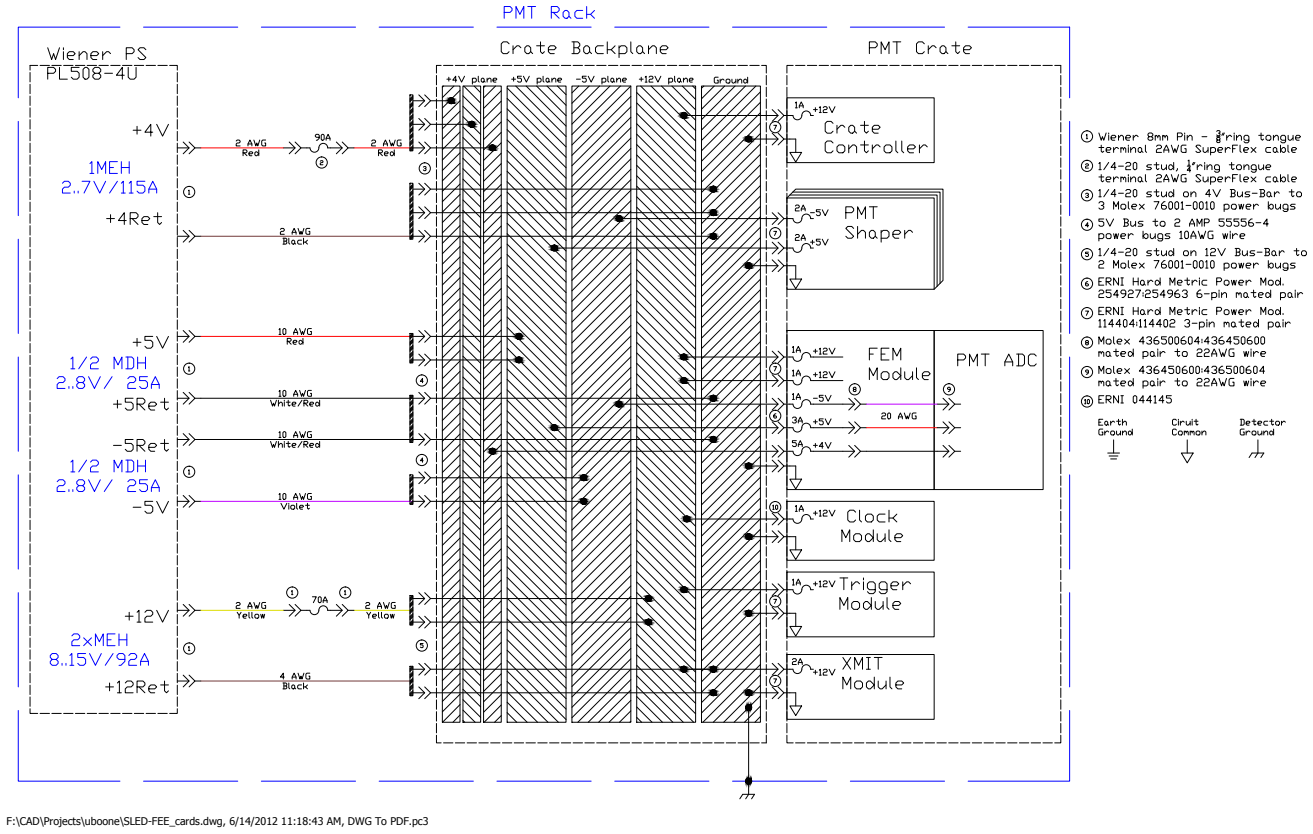

Figure 6. AC distribution and rack protection scheme for Bo racks

## DC Distribution

The DC power for the readout rack is provided by the Weiner power supply through four twisted pair cables, at +5V, -5V, +4V and +12V, and is shown diagrammatically in figure 7.

The Hewlett Packard DC power supply provides 12V DC via RG58 to a potential divider box at the first cosmic paddle assembly. From here a few volts is supplied to each PMT paddle. A Cockroft Walton base on each then steps this voltage up to 1000V to power the 1 inch PMTs. The current limit on the HP power supply is 0.5mA.

DC power is provided to the LED pulser board by a commercial USB cable from the Koi Computers server. The USB standard dictates that the voltage supplied is between 4.45 and 5.25V, and the maximum drawable current is less than 500mA. The pulser board has a 300mA resettable fuse. Pulses of a few volts in size and few nanosecond width are delivered to the postage stamp boards via RG174 cables with LEMO connectors.



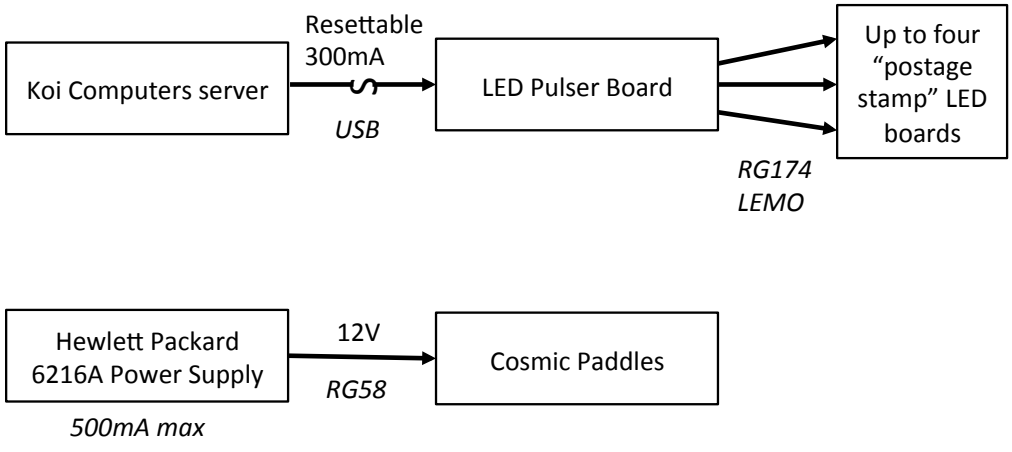




Figure 7. DC Distribution diagrams.
top: readout rack, mid: pulser board, bottom: cosmic paddles

**Voltage Cable Testing:**
The only high voltages carried in the system are within the HV mini rack, and between the splitter boxes housed in that rack and the commercial HV feedthrough flange in the Bo cryostat lid. We will high voltage rated red RG58 cables between the HV rack and splitters, and between the splitters and cryostat feedthrough. Internally to Bo we use RG316 cables, which have been HV tested up to 8kV. An engineering note presenting this test is provided in appendix H.

**Cooling:**
Forced air cooling is provided by a fan tray located under the NIM crate and a fan tray located under the MicroBooNE readout crate. Forced air cooling is also provided for the HV track by a fan tray under the VME crate.

**Fire Protection:**
The readout rack is fully enclosed and will be operated with the top covered and rack access door closed. Any empty rack slots are covered with spacers, the unused slots in the readout crate are covered with panels, and there are no unused slots in the NIM crate. Rack Protection is provided with a Rack Protection chassis design by Jamieson Olsen. This chassis is described in Appendix B.
Upon detection of smoke, the interlock to the SurgeX AC distribution unit is dropped, whereby AC to the all switched components is dropped.

The HV rack has its own smoke detector and interlock, described in more detail in its ORC report, with all details to be found in Appendix B.

***Linda to describe level monitor interlock here.***

**Shock Hazard:**

Details of the shock hazard analysis for the HV mini-rack can be found in appendix B.

# Supporting Documentation

A) Attached signed ORC form for Bo and Luke - 6 pages
See also : http://lartpc-docdb.fnal.gov/cgi-bin/ShowDocument?docid=265&version=36

B) HV Mini Rack ORC - 21 pages
C) NIM power supply spec sheet - 1 page
D) Pulser board and postage stamp shematics - 8 pages
E) Hewlett Packard 12V power supply spec - 1 page
F) Hamamatsu Cockroft Walton base spec sheet - 4 pages
G) Tektronix scope spec sheet - 24 pages
H) RG316 and RG180 cable HV testing - 3 pages