Lessons Learned from Production of Custom Optical Readout Modules for the ICARUS Experiment

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Abstract

Suppression of cosmic ray backgrounds is crucial to the measurement of neutrino oscillations using the ICARUS detector in the Short-Baseline Neutrino program at the Fermi National Accelerator Laboratory. A Cosmic Ray Tagger subsystem is under construction that provides almost complete solid angle coverage of the Liquid Argon Time-Projection Chambers. We present the fabrication process and quality control measures for the silicon photomultiplier-based Optical Readout Modules (ORM) that will read out the 860 m^2 side-walls constructed from repurposed veto detector modules from the former MINOS experiment.

Introduction

The ICARUS experiment requires a fully instrumented Cosmic Ray Tagging (CRT) system. For the sides of the CRT, scintillator panels formerly used by the MINOS experiment were enlisted. A new readout system needed to be created, spurring the creation of the Optical Readout Modules. Each module has ten Hamamatsu s14160-3050HS Multi-Pixel Photon Counters, or MPPCs, each of which reads out two fibers from the MINOS modules. Each MPPC is only 3 mm x 3 mm, so a tight tolerance is required on their alignment. To instrument the full side CRT subsystem, 268 Optical Readout Modules are needed for full readout of all modules. Modules were produced by a team of undergraduate students, then handed to myself for Quality Control checks for alignment of the light sensors as well as checks of their photoresponse in a dark box before being shipped to Fermilab for further testing and installation.

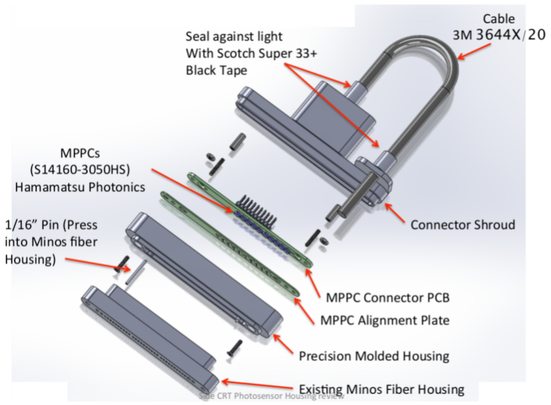

Figure 1: An exploded view of an Optical Readout Module, designed by engineer David Warner.

ORM Production

Our team at Colorado State used a stencil to apply solder paste to a printed circuit board, then placed the Multi Pixel Photon Counters onto the board using a vacuum tool to minimize damage to the devices. An alignment plate maximized placement accuracy, in order to hit a tolerance of 0.15 mm. The devices were then baked in a soldering oven, had a 20-pin connector soldered onto the back, then placed into their precision injection-molded housings.

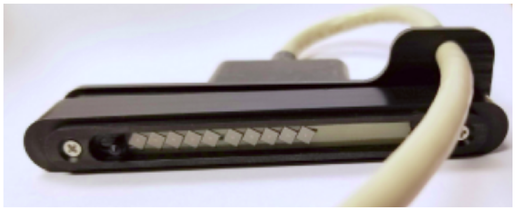

Figure 2: An Optical Readout Module in its housing.

Measuring Light Sensor Alignment

Tests for MPPC alignment were crucial early on, as there was a need to see if the injection molded housings were able to keep alignment within the tolerance limit. In the middle of production, there was a need to change the alignment plates used in production to maximize precision across the housings, which was a success. Alignment was measured with a Coordinate Measuring Machine, which allows for measurement precision of 0.002 mm.

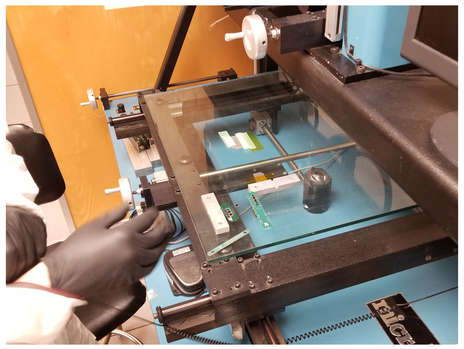

Figure 3: An example of CMM being used to measure light sensor positions.

Photoresponse Measurement

To determine photodetector response, modules were placed inside a dark box, approximately 1 meter away from an LED being driven by a pulser. Our main goal in these tests was to measure a gain and a light yield under three different conditions, as well as monitor the "dark rate" (a value proportional to the 'inherent noise' of the modules) of the modules, looking for any outliers in response.

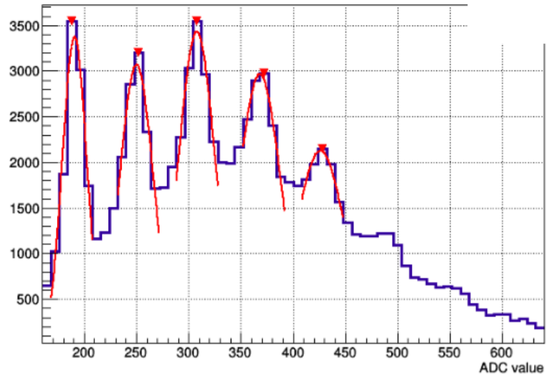

Figure 4: By obtaining spectra like that above, an equivalence between the ADC counts from our front-end electronics readout and photoelectron peaks provided a "gain" to convert between the two units.

Results of Quality Control Checks

The gains and light yields can be compared across runs to check for stability; Figures 5 and 6 provide examples of this. Figure 7 shows a histogram of all channels' deviations from nominal, we were able to succeed with less than 10 modules failing this check out of the 361 produced. Overall, we were able to tag 17 of the 361 modules as unfit for installation from tests at CSU, and installation is now underway at Fermilab.

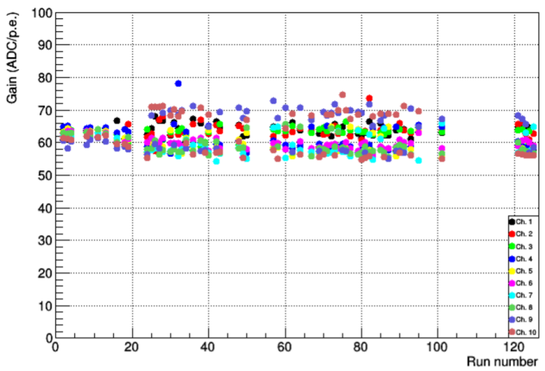

Figure 5: Gain stability of a given dark box position across different modules.

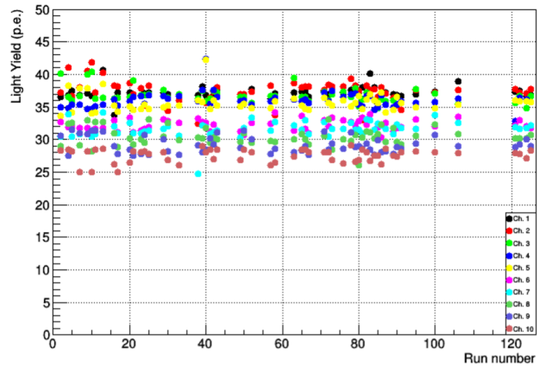

Figure 6: Light yield stability of a given dark box position across different modules.

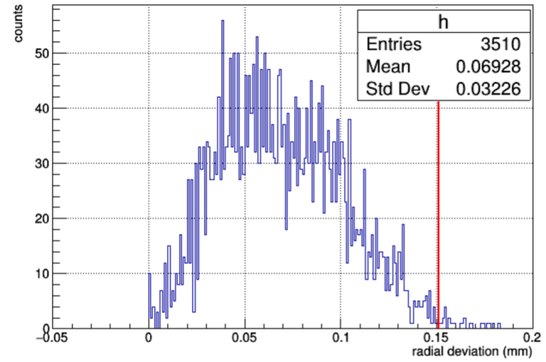

Figure 7: Histogram of all channels' deviation in position from the nominal position on the module. The red line in the plot marks the tolerance level for any individual MPPC.

Lessons Learned

Taking time in advance to plan for such a project is a must; any and all time spent planning pays dividends in the long run. Detailed records of tests being done should be kept, especially in the early phase. During the planning phase for the full production run, every note of early tests is incredibly useful. Record keeping should also be considered a crucial pillar of and production effort.

Acknowledgements

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