Fabrication of a High-Efficiency Cosmic Ray Veto Detector for the Mu2e Experiment

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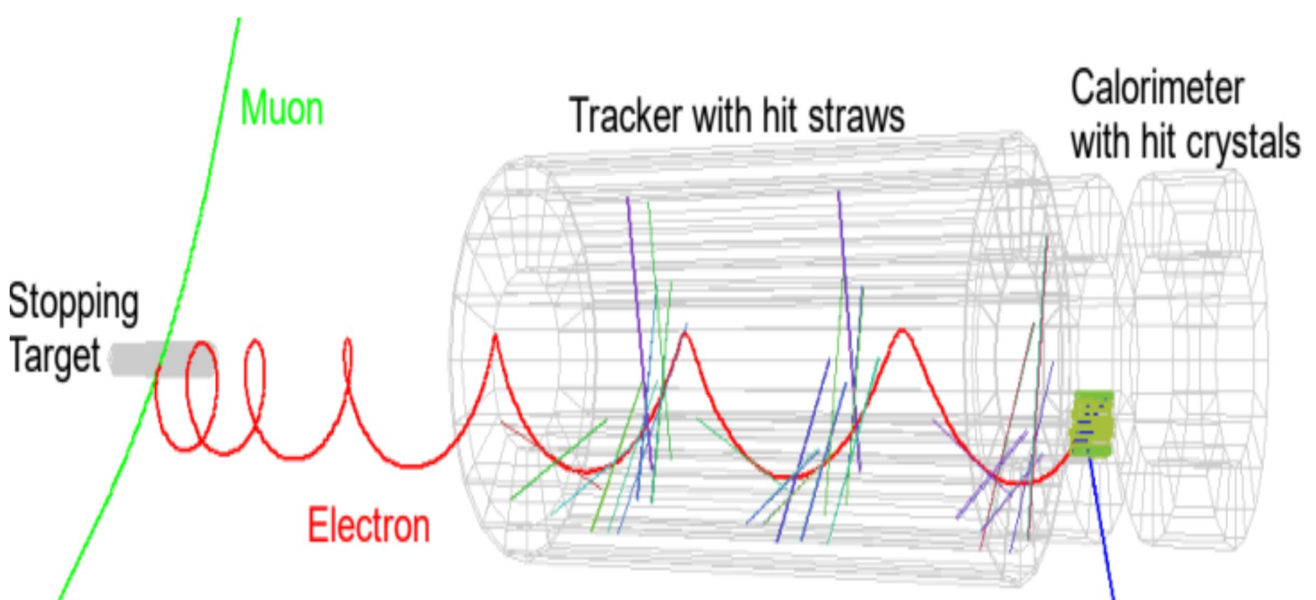
On behalf of the Mu2e Collaboration

A Cosmic Ray Background

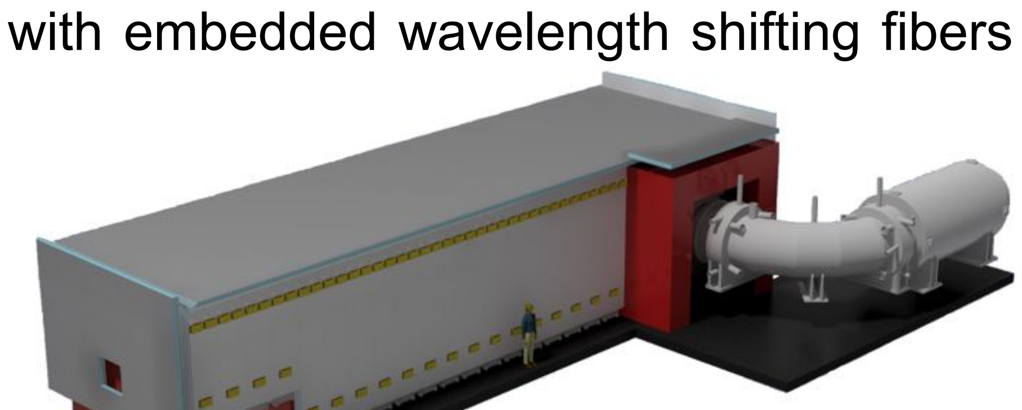
- The Mu2e experiment will search for unambiguous evidence of charged lepton flavor violation through the observation of muon-to-electron conversion in the presence of a nucleus.
- In Run 1 (2025-2026), ~10^{17} muons will be stopped on an Al target. A search result 1,000 times more sensitive than the world's current best result is expected.
- Over 15,000 cosmic-ray muons are expected to pass through the detector every second, producing a signature-like event about once per day.
- In order to keep the background be <1 event over the course of the run, an overall veto efficiency of 99.99% must be achieved.



A simulated cosmic ray background event.

The Cosmic Ray Veto

- The Cosmic Ray Veto (CRV) encloses the detector in order to detect background cosmic rays.
- It is composed of four layers of extruded polystyrene scintillator counters with embedded wavelength shifting fibers read out by SiPMs.

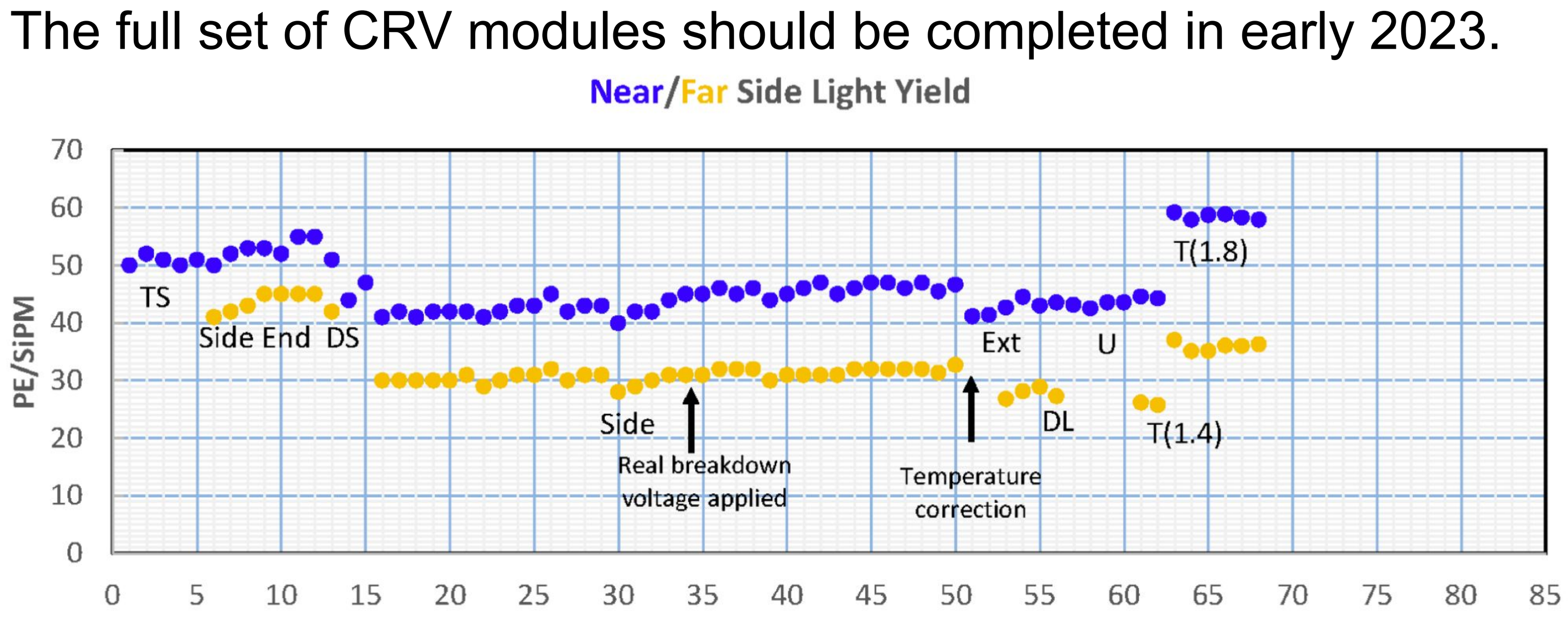


The CRV enclosing the detector solenoid.

- Layer coincidences produce a veto in offline analysis with an estimated total deadtime of ~5%.
- The CRV design was optimized for excellent muon veto efficiency and minimal deadtime in a high-intensity environment.

Production Status

- The completed CRV will consist of ~5500 counters in 83 modules.
- As of August 1, 2022, over 2500 out of 2700 production di-counters have been assembled.
- 68 out of 83 modules have been fabricated.
- The full set of CRV modules should be completed in early 2023.

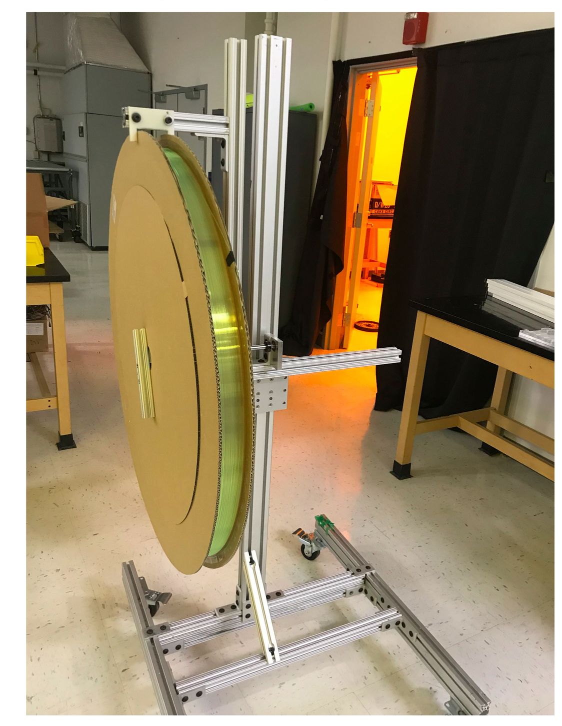


The average light yield (in units of photo-electrons) for all of the counters in each production module as measured using cosmic-ray muons.

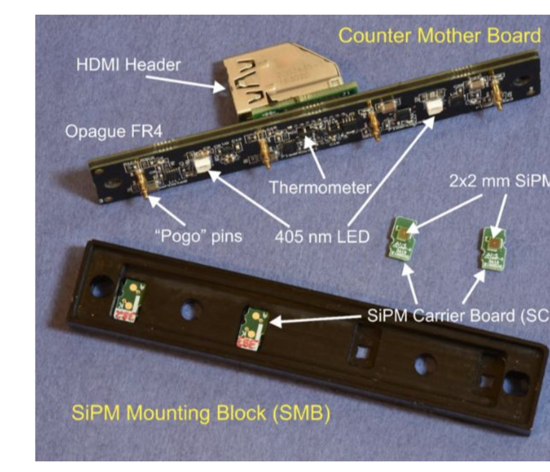
Counters, Fiber, SiPMs

- Counters are extruded planks of polystyrene coated with titanium dioxide and fabricated at the NICADD facility at Fermilab.
- Two co-extruded holes house wavelength shifting fibers which transport photons to photo detectors at the ends of the counters.
- Silicon photomultipliers (SiPMs) detect photons from the fibers.

Several crates full of extruded scintillator.



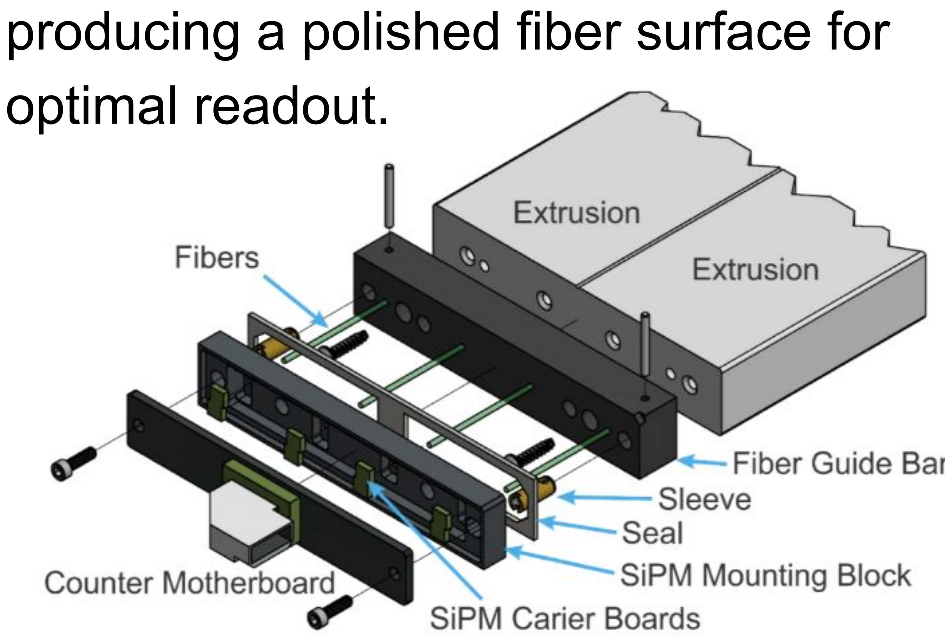
A spool of wavelength shifting fiber.



Components of the counter readout manifold.

Di-counter Construction

- Counters are cut to length and two counters are joined with epoxy to form di-counters.
- Fiber is then fed through each channel and Fiber Guide Bars (FGB) are screwed onto the scintillator face.
- Once dry, each FGB face is flycut, producing a polished fiber surface for optimal readout.



Blow-up of di-counter readout.

Drying di-counters.

Assembled di-counters.

Module Assembly

- Prior to assembling into modules, aluminum tape is wrapped around the interface of the scintillator and FGB of each di-counter.
- Four layers of eight di-counters are glued together with aluminum sheets sandwiched in between.
- A vacuum bag is used to compress the module components while the epoxy sets overnight.

Packing a module for shipment.

A module under vacuum bag.

Acknowledgements

We are grateful for the vital contributions of the Fermilab staff and the technical staff of the participating institutions. This work was supported by the US Department of Energy; the Istituto Nazionale di Fisica Nucleare, Italy; the Science and Technology Facilities Council, UK; the Ministry of Education and Science, Russian Federation; the National Science Foundation, USA; the Thousand Talents Plan, China; the Helmholtz Association, Germany; and the EU Horizon 2020 Research and Innovation Program under the Marie Sklodowska-Curie Grant Agreement Nos. 101006726, 734303, 822185, and 858199. This document was prepared by members of the Mu2e Collaboration using the resources of the Fermi National Accelerator Laboratory (Fermilab), a U.S. Department of Energy, Office of Science, HEP User Facility. Fermilab is managed by Fermi Research Alliance, LLC (FRA), acting under Contract No. DE-AC02-07CH11359.