For JINR 2019

1) Mass Production and Quality Tests of a High-Efficiency Cosmic Ray Veto Detector for the Mu2e Experiment

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- Submission: 2019 IEEE Nuclear Science Symposium and Medical Imaging Conference
  Topic: NSS 08 High Energy and Nuclear Physics Instrumentation Systems
- Processing

Abstract

The Mu2e experiment will search for unambiguous evidence of charged lepton flavor violation through observation of the decay $\mu^- + N \rightarrow e^- + N$ with expected single-event sensitivity of 2.9×10^{17}. It requires keeping the cosmic background below 0.25 events over the course of the three-year run. An overall veto efficiency of 99.99% must be achieved by Cosmic Ray Veto (CRV) system enclosing the Mu2e detectors in order to suppress background caused by the cosmic rays. This paper describes the way we achieve such high efficiency alongside CRV modules mass production and quality tests on each steps of production. Over 80 of such modules of different length (from 0.9 to 7.0 meters) and 1-meter width made as a 4-layer sandwich of scintillation counters and aluminum sheets with 64 SiPM on each layer should be produced by summer of 2021. Five of 6-m-long CRV modules were already produced and passed required quality tests. We discuss a way of improving the CRV performance for the 7-meter modules which will suffer from a high neutron fluence (up to 10^{11} neutrons per cm^2).

2) Light yield and radiation hardness studies of scintillator strips with a filler

A. Artikov, V. Baranov, J. Budagov, M. Bulavin, D. Chokheli, Yu. I. Davydov, V. Glagolev, Yu. Kharzheev, V. Kolomoets, A. Simonenko *et al.* *Show all 12 authors*

Nov 30, 2017 - 8 pages

- **Nucl.Instrum.Meth. A930 (2019) 87-94**
- DOI: 10.1016/j.nima.2019.03.087
- NIMA 62032

Abstract (Elsevier)
Detectors based on polystyrene scintillator strips with WLS fiber readout are widely used to register charged particles in many high-energy physics experiments. The fibers are placed into grooves or holes along the strip. The detection efficiency of these devices can be significantly increased by improving the optical contact between the scintillator and the fiber by adding an optical filler into the groove/hole.

3) Radiation Hardness of Scintillation Detectors Based on Organic Plastic Scintillators and Optical Fibers (Review)

Yu.N. Kharzheev (Dubna, JINR)

2019 - 35 pages

- Phys.Part.Nucl. 50 (2019) no.1, 42-76
  Fiz.Elem.Chast.Atom.Yadra 50 (2019) no.1,
- DOI: 10.1134/S1063779619010027

Abstract (Springer)
Scintillation detectors (SD) based on organic plastic scintillators and optical fibers are basic detectors at all modern accelerators and in astrophysics and neutrino physics experiments. In recent years, interest in SD has significantly increased due to the upcoming major upgrade of the LHC and the construction of new accelerators NICA, FAIR, FCC, etc. At the same time, requirements on the stability and reliability of SD operation under new conditions have become stricter, and their fulfillment largely depends on radiation hardness of scintillators, optical fibers, and photodetectors. The review presents the results of the radiation hardness investigations of various scintillators, optical fibers (scintillating, as well as wavelength-shifting and clear), and optical glues used to increase light collection from scintillators by fibers. The influence of various factors (dose, dose rate, type of radiation, scintillator materials, and fluors) on light output, light collection, and transmittance of the irradiated materials and their recovery is considered. Aging of scintillators caused by environmental effects (temperature, humidity) irrespective of radiation is also briefly considered.

4) **Photoelectron Yields of Scintillation Counters with Embedded Wavelength-Shifting Fibers Read Out With Silicon Photomultipliers**

Mu2e Collaboration (Akram Artikov *et al.*) *Show all 24 authors*
Sep 19, 2017 - 12 pages

- Nucl.Instrum.Meth. A890 (2018) 84-95
- DOI: 10.1016/j.nima.2018.02.023
- e-Print: arXiv:1709.06587 [physics.ins-det] | PDF

Abstract (Elsevier)
Photoelectron yields of extruded scintillation counters with titanium dioxide coating and embedded wavelength shifting fibers read out by silicon photomultipliers have been measured at the Fermilab Test Beam Facility using 120 GeV protons. The yields were measured as a function of transverse, longitudinal, and angular positions for a variety of scintillator compositions, reflective coating mixtures, and fiber diameters. Timing performance was also studied. These studies were carried out by the Cosmic Ray Veto Group of the Mu2e collaboration as part of their R&D; program.

5) **Increase in the light collection from a scintillation strip with a hole for the WLS fiber using filling materials of various types**

A.M. Artikov, V.Yu. Baranov, J.A. Budagov, V.V. Glagolev, D. Chokheli, Yu.I. Davydov, V.I. Kolomoets, A.V. Simonenko, V.V. Tereschenko, Yu.N. Kharzheev *et al.* *Show all 11 authors*

Apr 8, 2016 - 5 pages

- **Phys.Part.Nucl.Lett. 14 (2017) no.1, 139-143**
- DOI: 10.1134/S1547477117010058
- e-Print: arXiv:1604.02286 [physics.ins-det] | PDF

Abstract (Springer)
The light collection of extruded scintillation strip samples with the help of WLS fibers placed in a longitudinal hole inside of the plates has been measured. The holes are filled with various liquid fillers. Measurements are performed under irradiation by cosmic muons. A method for pumping a liquid filler with a viscosity of more than 10 Pa s into the strip hole with a WLS fiber inside is devised and successfully tested.

6) Optimization of light yield by injecting an optical filler into the co-extruded hole of the plastic scintillation bar

A. Artikov, V. Baranov, Ju. Budagov, D. Chokheli, Yu. Davydov, V. Glagolev, Yu. Kharzheev, V. Kolomoetz, A. Shalugin, A. Simonenko *et al.* *Show all 11 authors*

Apr 8, 2016 - 14 pages

- **JINST 11 (2016) no.05, T05003**
- DOI: 10.1088/1748-0221/11/05/T05003
- e-Print: arXiv:1604.02260 [physics.ins-det] | PDF

Abstract (IOP)
The light yield of 2-m long extruded scintillation bars (strips) are measured with cosmic muons as a function of the distance for different options of the light collection technique. The strips with a 2.6-mm diameter central co-extruded hole were made of polystyrene with the 2% PTP and 0.03% POPOP dopants at ISMA (Kharkov, Ukraine). It is shown that the optical transparent BC-600 or CKTN-MED(E) resin injected by a special technique into the co-extruded hole with a 1.0-mm or 1.2-mm Kuraray Y11 (200) MC wave-length shifting (WLS) fiber in it improves light collection by a factor of 1.6–1.9 against the ``dry'' case.

7) Scintillation counters in modern high-energy physics experiments (Review)

Yu.N. Kharzheev (Dubna, JINR)

2015 - 51 pages

- **Phys.Part.Nucl. 46 (2015) no.4, 678-728**
  Fiz.Elem.Chast.Atom.Yadra 46 (2015) no.4,
- DOI: 10.1134/S1063779615040048

Abstract (Springer)
Scintillation counters (SCs) based on organic plastic scintillators (OPSs) are widely used in modern high-energy physics (HEP) experiments. A comprehensive review is given to technologies for production of OPS strips and tiles (extrusion, injection molding, etc.), optical and physical characteristics of OPSs, and methods of light collection based on the use of wavelength-shifting (WLS) fibers coupled to multipixel vacuum and silicon PMs. Examples are given of the use of SCs in modern experiments involved in the search for quarks and new particles, including the Higgs boson (D0, CDF, ATLAS, CMS), new states of matter (ALICE), CP violation (LHCb, KLOE), neutrino oscillations (MINOS, OPERA), and cosmic particles in a wide mass and energy interval (AMS-02). Scintillation counters hold great promise for future HEP

experiments (at the ILC, NICA, FAIR) due to properties of a high segmentation, WLS fiber light collection, and multipixel silicon PMT readout.

8) Performance of Scintillator Counters with Silicon Photomultiplier Readout

Mu2e Cosmic Ray Veto Group (A. Artikov *et al.*) *Show all 17 authors*

Nov 1, 2015 - 11 pages

- Conference: C15-08-04.

Presentation at the DPF 2015 Meeting of the American Physical Society Division of Particles and Fields, Ann Arbor, Michigan, August 4-8, 2015DPF2015-350

- e-Print: arXiv:1511.00374

Abstract (arXiv)
The performance of scintillator counters with embedded wavelength-shifting fibers has been measured in the Fermilab Meson Test Beam Facility using 120 GeV protons. The counters were extruded with a titanium dioxide surface coating and two channels for fibers at the Fermilab NICADD facility. Each fiber end is read out by a 2*2 mm^2 silicon photomultiplier. The signals were amplified and digitized by a custom-made front-end electronics board. Combinations of 5*2 cm^2 and 6*2 cm^2 extrusion profiles with 1.4 and 1.8 mm diameter fibers were tested. The design is intended for the cosmic-ray veto detector for the Mu2e experiment at Fermilab. The light yield as a function of the transverse and longitudinal position of the beam will be given.

9) Fermilab Testbeam Facility Annual Report – FY 2015

M.G. Albrow (Fermilab), D. Anderson, A. Apresyan (Caltech), A. Artikov (Dubna, JINR), L.C. Bland (Brookhaven), A. Bornheim (Caltech), B.C.K. Casey (Fermilab), F. Cavanna (Fermilab & INFN), D. Chokheli (Dubna, JINR), H.J. Crawford (UC, Berkeley) *et al.* *Show all 55 authors*

Nov 2015 - 30 pages

- DOI: 10.2172/1251186
- FERMILAB-TM-2615-DI

Abstract
This Technical Memorandum (TM) summarizes the Fermilab Test Beam operations for FY 2015. It is one of a series of annual publications intended to gather information in one place. In this case, the information concerns the individual experiments that ran at FTBF and are listed in Table TB-1. Each experiment section was prepared by the relevant authors, and was edited for inclusion in this summary.