Liquid scintillator tiles for high radiation environments

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Abstract

Future experiments in high energy and nuclear physics may require large, inexpensive calorimetery that can operate to doses of 50 Mrad or more. We present the results of a study of a scintillator tile based on EJ-309 liquid scintillator using cosmic rays, test beam, and ^{60}Co irradiations that shows little degradation of output under irradiation.

Keywords: organic scintillator, liquid scintillator,, radiation hardness, calorimetry

1. Introduction

Sampling calorimeters using plastic scintillator tiles with wave length shifting fibers, such as the CDF plug calorimeter [1] and the CMS barrel[2] and endcap hadron calorimeters[3], are popular due to their low cost and ease of construction. Plastic scintillator is available commercially from companies like St. Gobain and Eljen. When irradiated, however, the performance of plastic

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scintillator and wave length shifting fibers deteriorate; light self-absorption (yellowing) increases and light output decreases. The resulting loss of light output has been studied [4][5]. Generally, the light output decreases exponentially with dose, with an decay constant on order of a few Mrad. Future high energy and nuclear experiments, however, may have to operate in environments that will deliver doses of tens of Mrad. In this paper, we present the design and optimization of a liquid scintillator tile, based on EJ-309 liquid scintillator, that can operate in thie kind of environment.

2. Tile design

Our tile is based on EJ-309 scintillator, from Eljen Technology, which uses naphthalene as the substrate with wavelength shifting additives. It has a light output that is 75% of anthracene, a wavelength of maximum emisison of 424 nm, a refractive index of 1.57 and a flash point of 144°C. The low flash point is important for its suitability for a collider environment.

The design of tile to hold the liquid needs to consider light collection efficiency, light collection uniformity, and cost. The container should not leak and there should not be interactions between the container and its contents that degrade the light output over time or compromise the integrity of the container. Figure 1 shows the mechanical construction of our prototype. The case is made of aluminum. Two transparent support tubes with outer diameter of 2 mm run through the liquid and can hold either wavelength shifting fiber or liquid wavelength shifter. The support tube is sealed to the case with a viton fluoroelastomer o-ring. The thickness of the top and bottom Aluminum plates is 0.5 mm. The total internal volume is 88x88x4 mm. The inner surface of the contain is a lapped and polished Al6061 available for a McMaster Carr. The material comes with a plastic coating that can be used to maintain its mirror quality during the machining process and then removed before the welding step.

Several variations on this design were constructed. For the default design, the thickness of the liquid is 4 mm. A version with a 6 mm thickness was also made. Tthe support tubes were quartz with an inner diameter of 1.3 mm and were used with Kuraray Y-11 fiber (doping of 200 ppm), double clad. Quartz tubes with an outer diameter of xx and an inner diameter of yy were also used with liquid wave length shifter from Eljen, which is not yet a commercial item, but has an emission maximum from between 481 and 492 nm and a decay time between 2 and 8 ns. The solvent was the same as that used for EJ-309. Sapphire tubes were also tested with both liquid and plastic wavelength shifter.

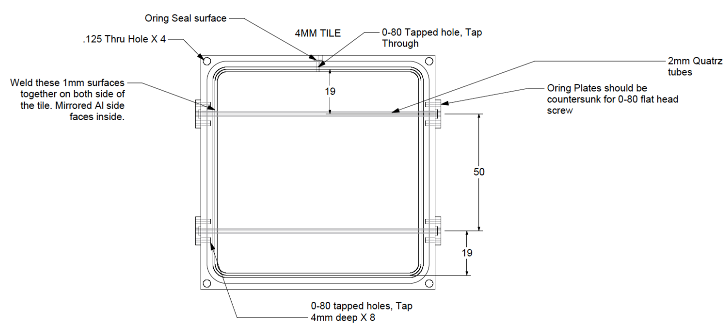

Figure 1: Mechanical design of a liquid scintillator tile. Units are mm.

3. Test beam results

The light yield and uniformity of the tiles was measured in the H2 test beam facility at CERN using 120 GeV muons.

4. Light yield dependence on tile parameters and comparison with simulation

We use the GEANT4 [6] package to simulate the optics of our tile.

5. Radiation hardness tests

Several different tests were made using irradiations with a ^{60}Co source lcoated at the University of Maryland. Performance of the tile under irradiation in a proton-proton collision environment will be the subject of a future paper.

6. Conclusions

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