Liquid scintillator tiles for high radiation environments

Alberto Belloni[a,*], Mahnegar Amouzegar[a], Jeff Calderon[a], Sarah C. Eno[a], Kenichi Hatakeyama[f], Kevin Pedro[e], Geng Yuan Jeng[a], Joshua Samuel[a], Elmer Sharp[d], Young Ho Shin[a], Zishuo Yang[a], Yao Yao[a], Sung Woo Youn[c]

[a] *Dept. Physics, U. Maryland, College Park MD 30742 USA*
[b] *Eljen Technology, 1300 W. Broadway, Sweetwater, Tx 79556 USA*
[c] *Institute for Basic Science, Center for Axion and Precision Physics Research, IBS Center for Axion and Precision Physics Research Room 4315, Department of Physics, Natural Science Building (E6-2), KAIST, 291 Daehak-ro, Yuseong-gu, Daejeon 305-701, South Korea*
[d] *Elmer Sharp Engineering, 7007 Leesville Blvd. Springfield, VA 22151*
[e] *Fermi National Accelerator Laboratory, Batavia, IL, USA*
[f] *Baylor University, Waco, Texas, USA*

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.

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 [**?**], are popular due to their suitable performance at a reasonable cost. Plastic scintillator is available commercially from companies like Kuraray, St. Gobain, and Eljen. When irradiated, however, the performance of plastic scintillator deteriorates; light self-absorption (yellowing) increases and light output decreases. The resulting damage has been studied for most common plastics[1], [2], [3], [4],[5],[6],[7],[8]. Generally,

*Corresponding author
Email address: `abelloni@umd.edu` (Alberto Belloni)

the light output decreases with 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, and is based on naphthalene 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. It's 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. Figure 1 shows the mechanical construction. The case is aluminum. Two transparent support tubes with outer diameter of 2mm 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.

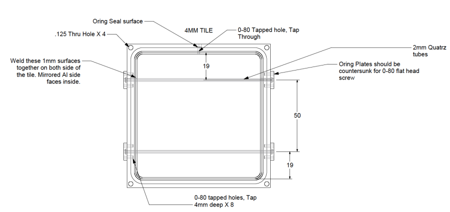

Figure 1: Mechanical design of a liquid scintillator tile. Units are mm.

3. Tile Simulation

We use the GEANT4 package

4. Test beam results

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

6. Radiation hardness tests

Performance of the tile under irradiation in a proton-proton collision environment will be the subject of a future paper.

7. Conclusions

8. Acknowledgements

The authors would like to thank Randy Ruchti of Notre Dame for providing the capillaries and Yasar Onel's group at the University of Iowa for help with the test beam. This work was supported in part by U.S. Department of Energy Grant YYYYY.

References

[1] U. Holm, K. Wick, Radiation stability of plastic scintillators and wave-length shifters, Nuclear Science, IEEE Transactions on 36 (1) (1989) 579–583. `doi:10.1109/23.34504`.

[2] K. Wick, D. Paul, P. Schrder, V. Stieber, B. Bicken, Recovery and dose rate dependence of radiation damage in scintillators, wavelength shifters and light guides, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 61 (4) (1991) 472 – 486. http://dx.doi.org/http://dx.doi.org/10.1016/0168-583X(91)95325-8 `doi:http://dx.doi.org/10.1016/0168-583X(91)95325-8`.

URL http://www.sciencedirect.com/science/article/pii/0168583X91953258

[3] B. Bicken, U. Holm, T. Marckmann, K. Wick, M. Rohde, Recovery and permanent radiation damage of plastic scintillators at different dose rates, Nuclear Science, IEEE Transactions on 38 (2) (1991) 188–193. doi:10.1109/23.289295.

[4] B. Bicken, A. Dannemann, U. Holm, T. Neumann, K. Wick, Influence of temperature treatment on radiation stability of plastic scintillator and wavelength shifter, Nuclear Science, IEEE Transactions on 39 (5) (1992) 1212–1216. doi:10.1109/23.173180.

[5] G. Buss, A. Dannemann, U. Holm, K. Wick, Radiation damage by neutrons to plastic scintillators, Nuclear Science, IEEE Transactions on 42 (4) (1995) 315–319. doi:10.1109/23.467829.

[6] B. Wulkop, K. Wick, W. Busjan, A. Dannemann, U. Holm, Evidence for the creation of short-lived absorption centers in irradiated scintillators, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 95 (1) (1995) 141 – 143. http://dx.doi.org/http://dx.doi.org/10.1016/0168-583X(94)00435-8 doi:http://dx.doi.org/10.1016/0168-583X(94)00435-8.
URL http://www.sciencedirect.com/science/article/pii/0168583X94004358

[7] A. Bross, A. Pla-Dalmau, Radiation damage of plastic scintillators, Nuclear Science, IEEE Transactions on 39 (5) (1992) 1199–1204. doi:10.1109/23.173178.

[8] V. Hagopian, I. Daly, Radiation damage of fibers, AIP Conference Proceedings 450 (1) (1998) 53–61. doi:http://dx.doi.org/10.1063/1.56958.
URL http://scitation.aip.org/content/aip/proceeding/aipcp/10.1063/1.56958