Performance of scintillator tiles with different doping concentrations after irradiation

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Abstract

The performance of plastic scintillator degrades when exposed to radiation. We present results on the degradation of light output of scintillator tiles with embedded wavelength shifting fibers when irradiated by a ^{60}Co source for a variety of concentrations of the primary and secondary dopant. Tiles made from a blue scintillator with blue-to-green wavelength shifting fiber and for green scintillator with green-to-orange wavelength shifting fiber are presented.

Keywords: organic scintillator, radiation hardness, calorimetry

1. Introduction

Sampling calorimeters using plastic scintillator tiles with wavelength-shifting (WLS) fibers as the active element have been part of hadron collider experiments since the mid 1990's, when the CDF plug calorimeter was constructed[1]. Both the CMS Barrel[2] and Endcap[3] calorimeters use a similar design. Prolonged exposure of plastic scintillator to ionizing radiation, however, can result in damage: light self-absorption (yellowing) increases and the transfer efficiency of the initial excitation of the polymer to the dopants combined with the probability of radiative decays for the dopants ("initial light output") can lessen. During

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the running of the LHC from its commissioning in 2009 through 2012, the CMS detector was exposed to an integrated luminosity of 25 fb^{-1}. Parts of the CMS endcap calorimeter are estimated to have received doses of 0.1 to 0.2 Mrad[4]. Studies of the radiation hardness of scintillator tiles prior to installation in the detector using an electron linac and ^{60}Co sources indicated an expoential reduction in light output with accumulated dose, with a expoential constant of around 7 Mrad[5, 6]. However, although the dose received was small compared to this number, significant light loss was observed [7].

The effect of radiation on plastic scintillator is known to depend both on dose and dose rate[8, 9, 10, 11, 12, 13, 14]. The increased self-absorption immediately after exposure is larger at high dose rate. After exposure, interactions with oxygen that diffuses into the plastic decreases the initial damage, and the "permenant" damage after a recovery time (typically a month) is usually indepenent of dose rate. Some studies, however, indicate that permenent damage to the initial light output depends on dose rate[15] and that increasing the dopant concentration can help alieviate this[16, 8]. Since the dose rates insitu at hadron collider experiments are much lower than those used for reactor and linac tests, this may be part of the explanation for the higher-than-expected damage to the CMS tiles.

In addition, many studies have shown that induced self-absorption is stronger at short wavelengths and thus scintillators that produce green light should be more radiation resistant than the more common blue scintillators [17, 8, 14]. Dose rate effects may therefore be smaller for such scintillators.

In this paper, we present measurements of ratio of the light output before and after irradiation for tiles based on two different types of plastic scintillator manufactured by Eljen corporation, EJ-200 (a blue scintillator, similar to BC-408 from Bicron corporation) and EJ-260 (a green scintillator, similar to BC-428), before and after irradiation by a ^{60}Co source for doses of 50, 30, 10, 4, and 2 Mrad at various dose rates and for different concentrations of the primary and secondary dopant.

2. Tile design

We tested two different tile designs. Both used scintillator with dimensions of 10 cm x 10 cm x 4 mm. A blue-to-green multi-clad WLS fiber from Kuraray Corporation (Y-11) with a diameter of 1mm was used for with the EJ-200. A green-to-orange multi-clad WLS fiber from Kuraray Corporation (S-type O-2) with a dye concentration of 100 ppm and a diameter of 1 mm was used with the EJ-260. Aluminum was sputtered onto one end of the fiber to increase the light output. A square "σ"-shaped groove similar to that used for the CMS tiles with machined into the plastic, and the fiber was inserted into the groove. The tiles were wrapped with a tyvek covering, held together with tape.

3. Results

4. Conclusions

5. Acknowledgements

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