Tests of the radiation hardness of scintillators in a high energy proton-proton collider environment

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Abstract

Radiation damage to the attenuation length and light output of scintillating materials may depend not just on the deposited energy, but also on the dose rate and the types and energies of the interacting particles. We present the results of measurements of the damage to several different types of scintillating materials irradiated in the CMS collision hall during running with a center-of-mass eneryg of 13 TeV at the Large Hadron Collider. The materials received a doses ranging from xxx over a period of xxx months. The light output was measured at several intermediate doses.

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

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1. Introduction

Radiation damage to the attenuation length and light output of scintillating materials may depend not just on the deposited energy (dose), but also on the dose rate and the types and energies of the interacting particles. We present the results of measurements of the damage to several different types of scintillating materials irradiated in the CMS collision hall at the Large Hadron Collider (LHC) during its operation at a center-of-mass energy of 13 TeV during 2015. The materials received a doses ranging from xxx over a period of xxx months. Their light output was measured at several intermediate doses. Irradiation in the collision hall of a running high energy proton-proton collider allows access to very low dose rates that would not be affordable at reactors, electron linacs, and ^{60}Co sources, with the particle type and energy spectrum most appropriate for those designing detectors for hadron colliders.

In-situ tests are of particular interest, as several experiments have found unexpected large radiation damage in operation compared to expectations based on irradiations using reactors, linacs and ^{60}Co sources. In the CDF experiment, scintillators placed close to the beam line received much larger damage than expected [1]. During 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 [2]. Studies of the radiation hardness of scintillator tiles prior to installation in the detector, using an electron linac and ^{60}Co sources, indicated an exponential reduction in light output with accumulated dose, with a exponential constant of around 7 Mrad [3, 4]. However, although the dose received by the CMS tiles was small compared to this number, significant light loss was observed [5]. Experiments using scintillator at HERA, however, saw damage consistent with expectations [6].

One possible explanation is dose rate effects. Several studies have shown larger damage for the same dose at lower dose rate both for light self absorption before annealing and initial light output [7, 8, 9, 10, 11, 12, 1, 13].

Another possible explanation is damage that is dependent on particle type and energy. Most studies [8, 14, 15, 16] need to recheck these papers. also missed 2 have found equivalent damage from protons, neutrons and gammas when kerma factors [17] are taken into account.

2. Irradiation conditions

For irradiation, samples were placed in the CMS collision hall on the structure that housed the CMS CASTOR [18] forward calorimeter, 14.3 m away from the CMS interaction point. They were held in fiber glass holders (Figure 1) suspended in an Aluminum box (Figure 2). Parts of the samples are as close as 22 mm to the beam pipe. The temperature in the box i don't know The atmosphere was i don't know

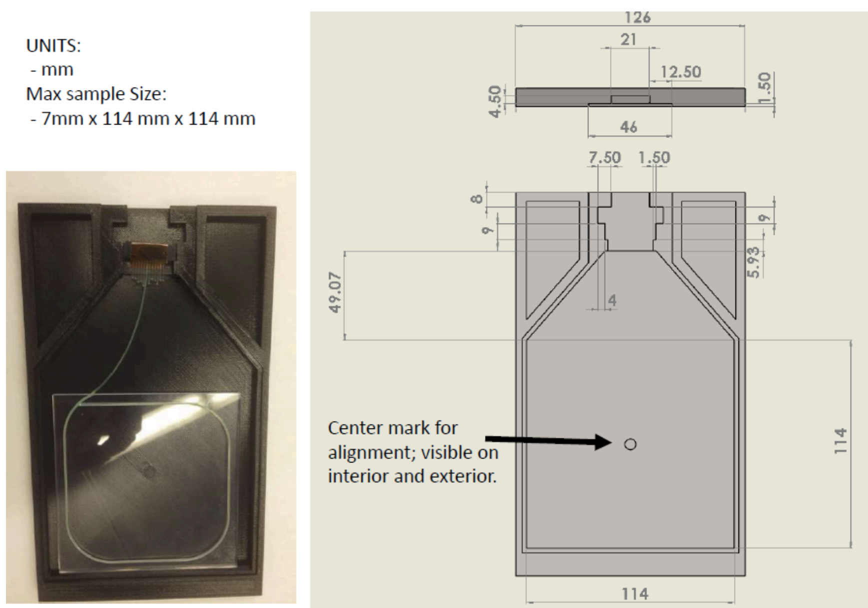

Figure 1: Design for fiber glass holder used for irradiations.

The dose was measured using FWT-60-00 Radiochromic dosimeters (thin films) by Far West Technology, RADMON detectors produced by CERN PPD,

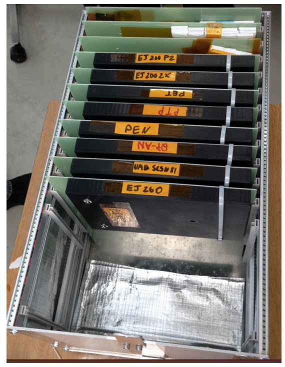

Figure 2: Design for Aluminum box holding samples.

and using Silicon Diodes. The FWT dosimeters are attached directly to the scintillator samples.

The samples were installed during June of 2015. The samples were removed and measurements were made on put dates here.

3. Tile designs

put description of tested tiles here

4. Measurement techniques

The light output before and after irradiation in the CMS collisions hall was measured using two different ways.

In the primary method, the response of the scintillator was measured using a columnated beta source which one?. A SiPM (Hamamatsu I don't know) was used as the photodetector. The scintillator was placed in a dark box, and a clear fiber was used to connect it to the photodetector, outside the box. The resulting current was measured using a Keithley 2001 or 6487 picoameter. The SiPM was calibrated by plotting the dark current versus bias voltage and locating the break down voltage. The data was taken with a bias voltage one volt above the breakdown. The temperature was also monitored.

A secondary measurement used the light output produced by cosmic rays. Scintillator-based counters above and below the tile were used for triggering. No attempt was made to select minimum ionizing (mip) muons. The muons were thus of low energy and produce more light than mips. The same SiPM was used for the photodetector.

5. Results

6. Conclusions

We presented results on radiation damage to scintillating materials in

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