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Recent results on radiation hardness tests of WLS fibers for the ATLAS Tilecal hadronic calorimeter

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Abstract

Three types of fibers, that were candidates to be used in the Tilecal/ATLAS detector were irradiated in a ^{60}Co γ source. The degradation of the light output and attenuation length were measured a few hours and several days after the end of the irradiation. The results are presented. © 2000 Elsevier Science B.V. All rights reserved.

1. Introduction

The Tilecal is a hadronic sampling calorimeter made of alternating layers of steel plates and scintillating tiles. The scintillating tiles are aligned in the (r,ϕ) plane, perpendicular to the beam axis [1–3]. Each tile is read out in its open edges by 1 mm diameter WaveLength Shifting (WLS) fibers that collect the light and transmit it to the photomultiplier tubes (PMTs).

The Tilecal is composed of three major parts: one 5.6 m long central barrel and two extended barrels, each one with about half of the size of the barrel. The particles resulting from the pp interactions will reach the Tile hadronic calorimeter after traversing about 2λ of material. The maximum expected integrated dose in the Tilecal, over 10 years of LHC operation, is about 230 Gy (23 krad) for the barrel region and 360 Gy (36 krad) for the extended barrels.

The Tilecal is being instrumented with Kuraray Y11(200)MSJ fibers. These fibers were chosen in the beginning of 1999, among three candidates proposed by Bicron, Kuraray and Pol.Hi.Tech. Here, we present the irradiation test results for the fibers proposed by the three companies.

2. Experimental conditions

A ^{60}Co source from a radiosterilization facility, "Unidade de Tecnologias de Radiação" of the "Instituto Tecnológico e Nuclear" in Lisbon, was used. The dose rate profile is shown in Fig. 1. The average in the plateau is about 15 Gy/h (1.5 krad/h). In order to have this dose rate and profile, several shieldings of lead and copper are used, as it is described in Ref. [4]. Fibers with length of 200 cm, polished with a diamond cutting machine at both ends, were irradiated [5,6]. Ten fibers of each type (Bicron BCF91A MC, Kuraray Y11(200)MSJ and Pol.Hi.Tech S250-100) were irradiated with a total dose of 1.16 kGy (116 krad) and 8 fibers of each

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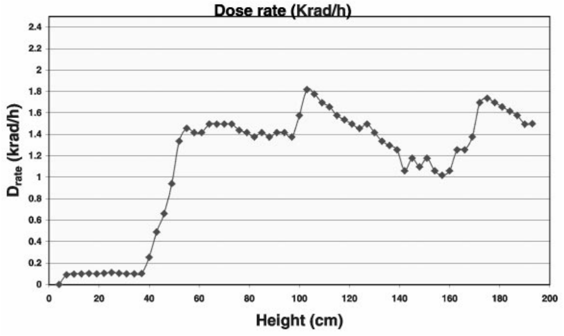

Fig. 1. Dose profile used to irradiate the fibers.

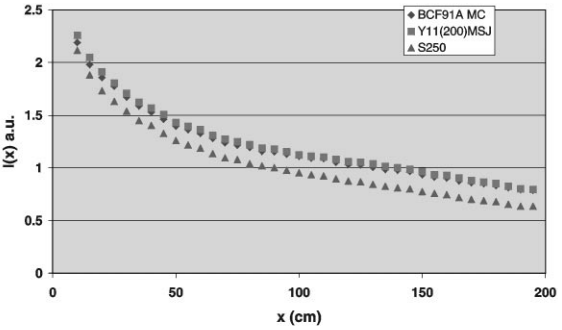

Fig. 2. Light output $I(x)$ as a function of the distance from the readout PMT before the irradiation.

type were irradiated with a higher dose 6.93 kGy (693 krad).

3. Results

The fibers are optically characterized by the light output and the attenuation length. For the Tilecal, the lengths of the fibers span between approximately 70 and 230 cm, and the tiles are readout by the last 20–40 cm of the fibers.

The fibers were measured before the irradiation and 3 times after the end of the irradiation: after 3 h, after one day and after 6 or 10 days.

In order to quantify the degradation in the light output, the following ratio was calculated:

$$\frac{R(x)}{R(30)} = \frac{I_{\mathrm{irr}}(x)/I_{\mathrm{nirr}}(x)}{I_{30}(x)/I_{\mathrm{nirr}}(x)} \tag{1}$$

where I_{irr} is the light output of the fibers after irradiation and I_{nirr} before irradiation. The x is the distance from the PMT and corresponds to the "Height" in the dose profile (Fig. 1). The point at 30 cm is used to normalize the ratio, since the dose is negligible in the region of x smaller than 30 cm.

Fig. 2 shows the light output of the fibers, $I(x)$, as a function of the distance from the readout PMT, before the irradiation. All the values were normalized to $I(140)$ of the Y11(200)MSJ fibers, the fibers that present the higher light output. The results are summarized in Table 1.

The optical properties (light output and attenuation length) of BCF91A-MC and Y11(200)MSJ fibers are very similar with a difference of about 2% in the $I(140)$. The S250-100 fibers have an average light output at 140 cm almost 20% lower than the other fibers. This smaller light output of the Pol.Hi.Tech fibers is in part due to its smaller attenuation length, that is about 50 cm smaller.

Table 1
Optical properties of each type of WLS fibers before the irradiation. Average light output at 140 cm and RMS, average attenuation length (L_{att}) and RMS, for ten fibers of each type. The values are normalized to I_{140} of the Y11(200)MSJ fibers

Fiber type	I_{140}	RMS (%)	L_{att} (cm)	RMS (%)
BCF91A MC	0.98	9.6	280	9.5
Y11(200)MSJ	1.00	1.8	280	1.6
S250-100	0.81	5.7	230	5.6

Table 2
Relative light output at $x = 140$ cm, for total doses of 1.16 and 6.93 kGy

Fiber type	$\frac{R(140)}{R(30)}$ for 1.16 kGy			$\frac{R(140)}{R(30)}$ for 6.93 kGy		
	0 days	1 day	10 days	0 days	1 day	10 days
BCF91A MC	0.83	0.86	0.85	0.54	0.56	0.56
Y11(200)MSJ	0.87	0.92	0.91	0.71	0.72	0.74
S250-100	0.60	0.70	0.81	0.52	0.55	0.64

Table 2 and Fig. 3 show the ratio $R(140)/R(30)$ for the three types of irradiated fibers. An average degradation smaller than 15% can be seen for the Y11(200)MSJ fibers in the first measurement, a few

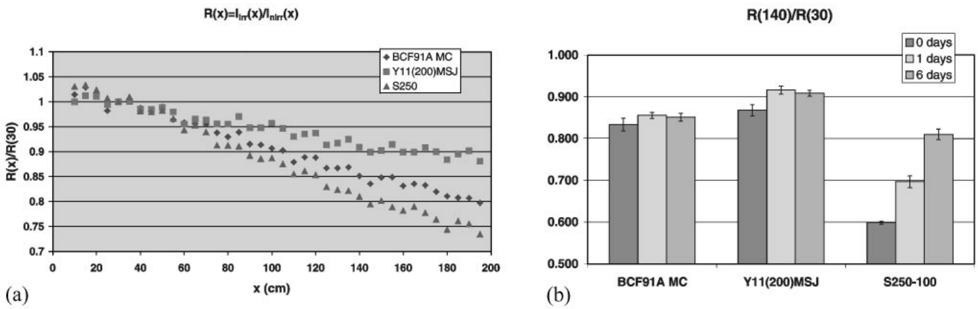

Fig. 3. Irradiation with a total dose of 1.16 kGy. (a) Ratio of the light output after and before irradiation ($R(x)/R(30)$) as a function of the distance from the PMT, after 6 days of recovery. (b) Relative light output given by $R(140)/R(30)$ recovering as a function of the time.

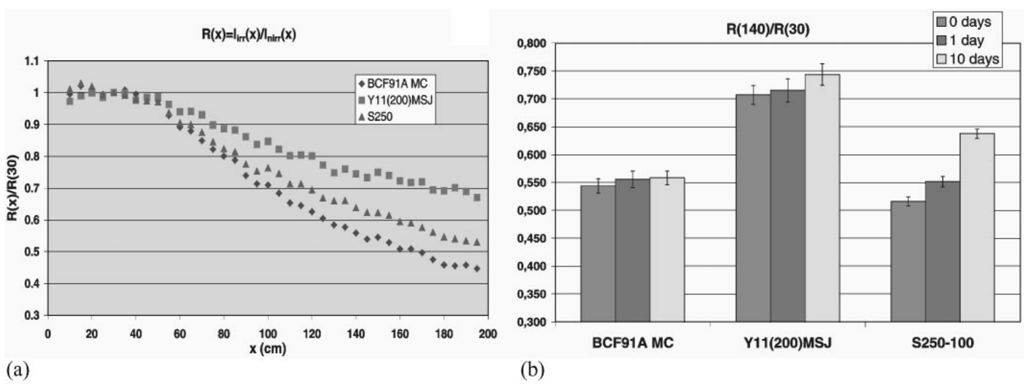

Fig. 4. Irradiation with a total dose of 6.93 kGy. (a) Ratio of light output after and before irradiation ($R(x)/R(30)$) as a function of the distance from the PMT after 10 days of recovery; (b) Relative light output given by $R(140)/R(30)$ recovering as a function of the time.

hours after the end of the irradiation with a total dose of 1.16 kGy. The other two types of fibers show a larger degradation: about 17% for the BCF91A-MC fibers and 40% for S250-100 fibers.

A recovery in the light output is seen for all the fibers. At the end of the irradiation after the 6th day, it is 2% and 4% for Bicron and Kuraray fibers, respectively, and about 20% for the Pol.Hi.Tech fibers.

For the irradiation with a total dose of 6.93 kGy, the results are shown in Fig. 4 and Table 2. The Bicron and Pol.Hi.Tech fibers present a decrease in the light output of about 45–48% a few hours after the irradiation, while Kuraray fibers have a lower degradation of about 30%. As for the lower dose irradiation, the Bicron and Kuraray fibers present a slight recovery of a few percent, while the recovery in the light output of the Pol.Hi.Tech fibers 10 days after the end of the irradiation is about 12%.

4. Summary

Three types of fibers, Bicron BCF91A-MC, Kuraray Y11(200)MSJ and Pol.-Hi.Tech S250-100 were submitted to irradiations with total doses of 1.16 and 6.93 kGy.

The Kuraray fibers always show the best properties (light output and attenuation length) before and after irradiation. The loss in the light output for these fibers at a few hours after the end of the irradiation is about 13% for the lower dose (1.16 kGy) and less than 30% for the higher dose (6.93 kGy). The recovery in the light output of these fibers is a few percent in both cases.

The Bicron fibers present similar average optical properties before irradiation, but with larger fiber-to-fiber fluctuations. When submitted to the lower dose, these fibers have a slightly lower damage than the Pol.Hi.Tech fibers and slightly higher than the Kuraray fibers, but 10 days after the end of the irradiation they present the highest decrease in the light output when submitted to the higher dose. The Pol.Hi.Tech fibers are the most severely damaged a few hours after the end of the irradiation, but they recover partially in the following days.

Acknowledgements

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