A TEN MEGARAD FIBER CALORIMETER

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Abstract: We have built a scintillating fiber based calorimeter which can be made compensating. The calorimeter recovers its original resolution less than one month after receiving a dose of ten megarad via 100 MeV electrons.

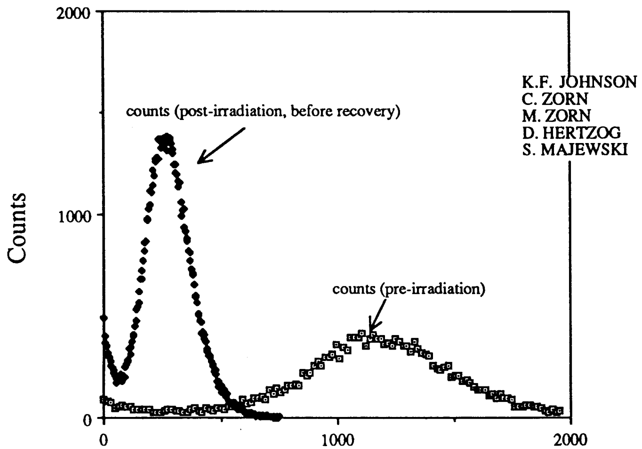
Fewer than ten months ago there were serious reservations about the feasibility of using plastic scintillator-based calorimetry in the SSC environment [1]. It was thought that plastics could not survive the high doses associated with high-luminosity hadron collider environments. The best plastics at that time could survive at most about one megarad dose before yellowing. There has been great progress since then in fashioning plastics which recover their optical and scintillating properties after intense exposure [2]. Little progress has been made, however, in understanding the role of the immediate chemical environment on the recovery. There are, for example, contradictory reports of the effect that oxygen, nitrogen, argon, etc. have on recovery. There is, however, a large body of evidence which suggests that access to oxygen is essential for quick recovery [3].

With this in mind, we have designed, built and tested a very radiation-hard calorimeter. The mechanical design is identical to the Urbana "lasagna" calorimeter [4]. Grooved lead foils alternate with layers of 1 mm. diameter plastic scintillating fibers; the entire assembly is held together with glue, resulting in a lead to scintillator to glue ratio of 40:50:10 (by volume). This is a design which is optimized for use as an electromagnetic calorimeter and can clearly be made compensating simply by changing the lead to scintillator ratio. The fiber chosen was a PTP/3-HF (green emitting) polystyrene fiber with an acrylic cladding which had been shown by us to recover its original attenuation length after a dose of 10 megarad when immersed in air [5]. Access to air was provided by the glue used, a commercial polydimethylsiloxane encapsulant [6], which is exceptionally permeable to air [7]. In addition, this substance is remarkably impervious to radiation. Unlike some glues, it does not attack fiber claddings or significantly alter its optical properties even up to 100 megarads [8].

The block was layered and cured at 60 ^{0}C overnight and then machined to have square faces. A Hamamatsu R1513 green-sensitive photomultiplier tube was connected to the rear of the module via a 2 mm. thick layer of polysiloxane encapsulant. The final dimensions were 9.1 x 8.8 x 19.3 cm^3 (height, width, length). A 100 MeV electron beam at the Illinois microtron was used to measure the energy resolution (at low intensity) and then to irradiate the module (at high intensity $\approx$ 0.5 μA). The module was exposed for 15 minutes until approximately a 10 megarad dose was absorbed in the central region of the module.where the intrinsic resolution was measured. The resolution was immediately remeasured and measured again using an 88 MeV electron beam 3.5 weeks later. Originally the resolution (normalized to 1 GeV) was 7.5%. Immediately after irradiation it worsened to 11% and the light output per GeV dropped by a factor of four (see figure 1). After recovery the resolution at 1 GeV was again found to be 7.5% (figure 2). From previous measurements on this fiber we expect that the loss in light output should have recovered to within 90% of its original value [9]. We intend to repeat these tests more carefully to control for any variations in intensity of the irradiation across the face of the module and to obtain a direct measurement of the reduction in light output.

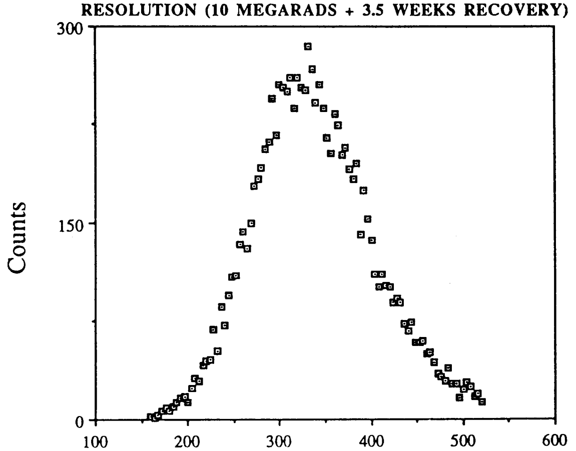
1) D.Groom, Workshop on Calorimetry for the Superconducting Supercollider, March, 1989, Tuscaloosa, Al.
2) S.Majewski et al., ibid.
S.Majewski et al., "Radiation Damage Studies in Plastic Scintillators with a 2.5 MeV Electron Beam", to be published by NIM.
3) U.Holm and K.Wick, IEEE Trans. Nuc. SCI. 36 (1989) 579.
4) D.Hertzog et al., "Tests of Prototype Pb/SCIFI Electromagnetic Calorimeter Modules", Workshop on Scintillating Fiber Developement for the SSC, Fermilab, Nov., 1988.
5) The fibers were supplied by Kyowa Gas Chemical Industries, Tokyo,Japan.
6) Petrarch Systems PS273 encapsulant.
7) B.Arkles, Petrarch Systems Register and Review (1987) 87.
8) Unpublished observations of the authors.
9) S.Majewski et al., "Comparative Study of the Radiation Resistance of Selected Plastic Scintillating Fibers", these Proceedings.

FIGURE 1
PRE- AND POST-IRRADIATION RESOLUTION



Resolutions normalized to 1 GeV are 7.5% and 11% for the pre and post cases.

FIGURE 2
RESOLUTION (10 MEGARADS + 3.5 WEEKS RECOVERY)



Resolution normalized to 1 GeV is 7.5%.
Note that the ADC scale in this figure is not the same as in figure 1.