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M. Contreras, N.D. Giokaris

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M. Contreras
University of Chicago, Chicago, IL 60637

N. D. Giokaris
The Rockefeller University, New York, NY 10021

Abstract

Samples of SCSN23, SCSN81, and SCSN81+Y7 scintillator have been exposed in air to radiation doses of 10 krad, 100 krad and 1 Mrad from a ^{60}Co source. Light yield and attenuation length were measured before and after irradiation. Results on the relative change in light yield and attenuation length vs dose, dose rate and as a function of time are reported.

1 Introduction

There is at present great interest in the response of plastic scintillators to irradiation. Scintillator-based tracking and calorimeter detectors are under consideration for high luminosity accelerators such as SSC and LHC, where the delivered radiation doses over the lifetime of the experiments will be very high. This fact as well as the observation of a significant damage in the scintillator of the beam-beam trigger counters (BBC) of the CDF experiment during the Fermilab 1988-1989 $p\bar{p}$ collider run [1,2], prompted us to perform the measurements reported in this paper. The BBC are two planes of scintillation counters covering from 0.32° to 4.47° with respect to the beam line. Extrapolations based on measurements of the radiation inside the CDF detector during the collider run [3] suggest that the BBC received a dose of less than $\sim$ 10 krad delivered during the 1-year run. A $\times 7$ decrease in attenuation length and 40% decrease in light yield were observed. Yellowing and surface crazing were observed as well. Due to the large number of counters in the BBC system, and the large hit multiplicities involved, the damage had only less than a 1% impact on the overall BBC trigger efficiency [4].

With this motivation, we carried out controlled radiation damage tests to investigate whether the damage observed in the BBC scintillator (SCSN23) was

reproducible. At the same time samples of SCSN81 and SCSN81+Y7 were studied to learn about their relative radiation hardness in order to choose scintillator type for future CDF applications. All the scintillators tested are manufactured by Kuraray Co. [5] and are based on polystyrene. SCSN23 and SCSN81 are blue scintillators. SCSN81+Y7 has wave shifter that causes it to give green light.

In planning this study we decided to concentrate on the effects of overall dose and dose rate on the scintillator attenuation length and light yield. We also decided to look for possible recovery over time. We did not attempt to study the effect of radiation and recovery in different gases, and all measurements were performed in atmospheric air.

2 Experimental Technique

The scintillator samples were bars of 1 cm × 1 cm × 13 cm wrapped along their length with one layer of thin aluminum foil and one layer of black electrical tape. One end of the bar was left clear and the other end was covered by the black tape. The clear end of the scintillator was inserted through a plastic sleeve with a 1 cm × 1 cm slit at its center and pushed in until it touched the photocathode of the photomultiplier tube (PMT). The plastic sleeve was permanently attached to the PMT so that all scintillator bars could be positioned in the same area of the photocathode. We used a two-inch Hamamatsu photomultiplier tube, model R1828-01 with H1949 base assembly, and operated it at 2000 V. The PMT quantum efficiency peaks at 400 nm (blue) with a value of approximately 25% decreasing to about 10% at 550 nm (green). A collimated ^{90}Sr Beta source was positioned along the scintillator at distances to the photocathode in the range 5.5 – 12.5 cm. The DC voltage at the anode of the PMT was read for each position of the source. A 200 nF capacitor was connected in paralell to the digital voltmeter to damp fluctuations and make its reading easy and accurate. The PMT dark current was registered at the beginning and the end of the measurement of each scintillator and had a typical value of 1% of the signal produced by the ^{90}Sr source.

The scintillator samples were inserted in plastic bags and shipped from Fermilab to the Phoenix Lab of the University of Michigan where they were exposed to a ^{60}Co source. Control pieces (i.e. not exposed to radiation) of each kind of scintillator were kept at Fermilab and were used to check the stability and reproducibility of our measurements. Different sets of samples were irradiated with doses of 10 krad, 100 krad and 1 Mrad, with two different dose rates. A 'fast' dose rate of 1.2 Mrad/hour and a 'slow' dose rate of 10.5 krad/hour were used. The ^{60}Co source activity is supposed to be known to ±5% [6]. However, film measurements [7] suggest that the actual doses could be about 20% lower than what was reported by the Phoenix Lab. The radiated samples were shipped back to Fermilab and the first measurement was performed 24 hours after the end of exposure. The slow dose samples were measured again 1 month after radiation, the fast dose samples

were measured several times in the 3 month period that followed the exposure. The control samples were systematically remeasured on every ocassion.

3 Results

The PMT output voltage (v) vs source-to-photocathode distance (x) data are shown in fig. 1 for three different measurements of the SCSN81 control sample. We obtain the attenuation length (λ) and the light yield (v_0) for each case by fitting the data to the form $v = v_0 \exp(-x/\lambda)$. Fig. 2 shows the values of λ and v_0 obtained from the fits, plotted as a function of time for the same control sample. The average over time of six measurements of the attenuation length and light yield of the control sample for each scintillator type are shown in table 1. We note that the stability of the attenuation length measurements is about 6% and that of the light yield is 2%. These numbers indicate the precision of our measurements. We note that the SCSN81+Y7 (green) scintillator has almost half the light yield of the other two (blue) scintillators, due to the smaller efficiency of the PMT in the green region.

Fig. 3 and 4 show the light yield and attenuation length as a function of time for samples of SCSN81 irradiated with 1 Mrad at doses rates of 1.2 Mrad/hour and 10 krad/hour respectively. The first point ($t = 0$) was taken before irradiation. The second point represents the first measurement after irradiation. We note that, for this sample, no significant change in light yield is observed, that the attenuation length decreased by $\sim$ 40% after irradiation for both the fast and slow dose rates, and that there is no significant recovery observed up to 3(1) months after irradiation for the fast(slow) rate.

It should be noted that the attenuation length we measure can vary significantly from sample to sample of a given scintillator type due to differences in surface preparation and wrapping. Also, due to geometrical light aceptance effects our attenuation length measurement cannot be compared directly with other measurements (e.g. from scintillator fibers). In order to factor out these effects, we use the ratio of attenuation lengths, *after/before* irradiation. A list of the measured ratios is given in table 2 for the different scintillator samples, doses, and dose rates measured. The errors in the ratios were derived from the errors given by the fits to the v vs x data. Up to 100 krad doses there is no significant effect in the attenuation length of any of the three scintillators (except for the SCSN81 100 krad fast rate measurement which has puzzled us). The 1 Mrad dose reduces the SCSN23 and SCSN81 attenuation lengths by about 40%, and has a much smaller ($\sim$ 10%) effect on SCSN81+Y7. Within our errors, we see no clear difference between the fast and low rate results. We plan to investigate the effect of dose rate with more precise measurements in a forthcoming study.

4 Conclusions

We have exposed SCSN23, SCSN81 and SCSN81+Y7 scintillator samples to 10 krad, 100 krad, and 1 Mrad radiation doses from a ^{60}Co source at rates of 1.2 Mrad/hour ('fast') and 10 krad/hour ('slow'). We have seen no significant effect of these doses to the light yield. At 1 Mrad dose the attenuation length of the SCSN23 and SCSN81 scintillators was reduced by $\sim$ 40% and that of the SCSN81+Y7 by $\sim$ 10%. No recovery in the attenuation length of the affected scintillator was observed over a period of 3(1) months after irradiation for the fast(slow) rate. The level of damage observed on the CDF Beam-Beam Counters (SCSN23) was not reproduced by contolled irradiation to doses 100 times larger than what is estimated that the counters received. We are at present beginning a new series of measurements at slower dose rates to investigate possible dose rate effects on the radiation damage to plastic scintillators.

5 Acknowledgements

We want to thank Prof. Kuni Kondo of Tsukuba University for providing the scintillator samples. Thanks go to Ken Gray of Fermilab for preparing the samples and to Robert Blackburn of the Phoenix Lab of the University of Michigan for doing the irradiation.

References

1. N. Giokaris, *Radiation Damage of the CDF Beam-Beam Counters During the 1988-89 Fermilab Collider Run*, to be published in the proceedings of the Workshop on Radiation Hardness of Plastic Scintillators, Tallahassee, Florida, March 19-21, 1990.

2. N. Giokaris, *BBC Inefficiencies : Evidence from the Data and Bench Measurements*, CDF Internal Note 1214.

3. R. Yarema, *Radiation Measurements Inside the CDF Detector*, Fermilab TM-1610.

4. N. Giokaris, *E*W BBC Efficiency from L0 Query Runs*, CDF Internal Note 1213.

5. Kuraray Co., Ltd., Shuwa Higashi-Yaesu Building, 9-1, 2-Chome, Hatchobori, Chno-ku, Tokyo, 104 Japan.

6. Robert Blackburn, Phoenix Laboratory, University of Michigan. Private communication.

7. Kurtis Johnson, Florida State University, Tallahassee. Private communication.

Scintillator Type	Avg. Att. Length (cm)	Avg. Light Yield (Volts)
SCSN23	65.4 ± 6%	21.6 ± 2%
SCSN81	73.2 ± 5%	18.1 ± 2%
SCSN81+Y7	29.4 ± 6%	11.0 ± 3%

Table 1: Average attenuation length and average light yield of the control samples.

Dose	Dose Rate	SCSN23	SCSN81	SCSN81+Y7
10 Krad	1.2 Mrad/hour	0.92±0.05	0.95±0.06	0.96±0.09
100 Krad	"	1.15±0.24	0.69±0.12	1.07±0.07
1 Mrad	"	--	0.67±0.04	0.90±0.06
100 Krad	10.5 Krad/hour	1.14±0.11	0.99±0.13	0.88±0.07
1 Mrad	"	0.59±0.11	0.55±0.07	0.83±0.06

Table 2: Attenuation length ratios *after/before* irradiation.

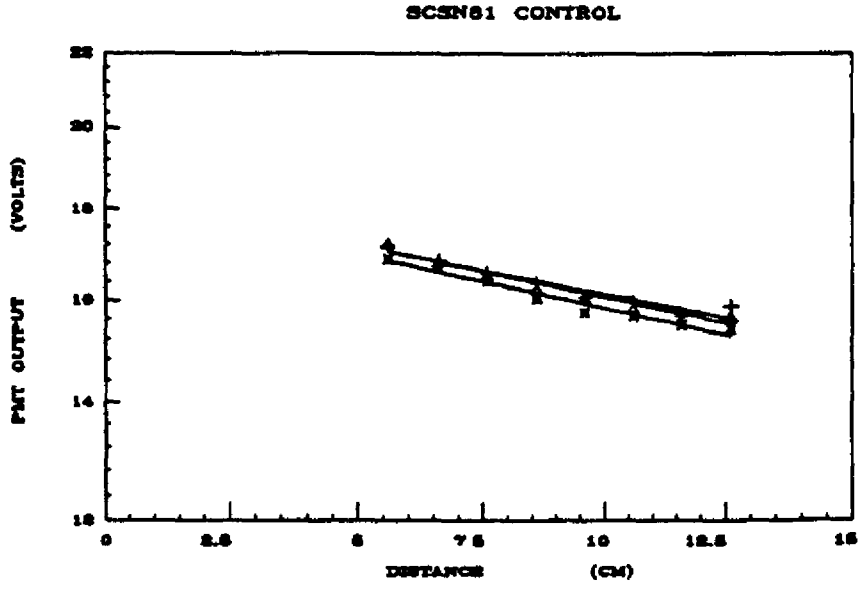


Figure 1: Photomultiplier output as a function of source-to-photocathode distance, for three sets of measurements of the same SCSN81 control sample. The vertical scale is logarithmic.

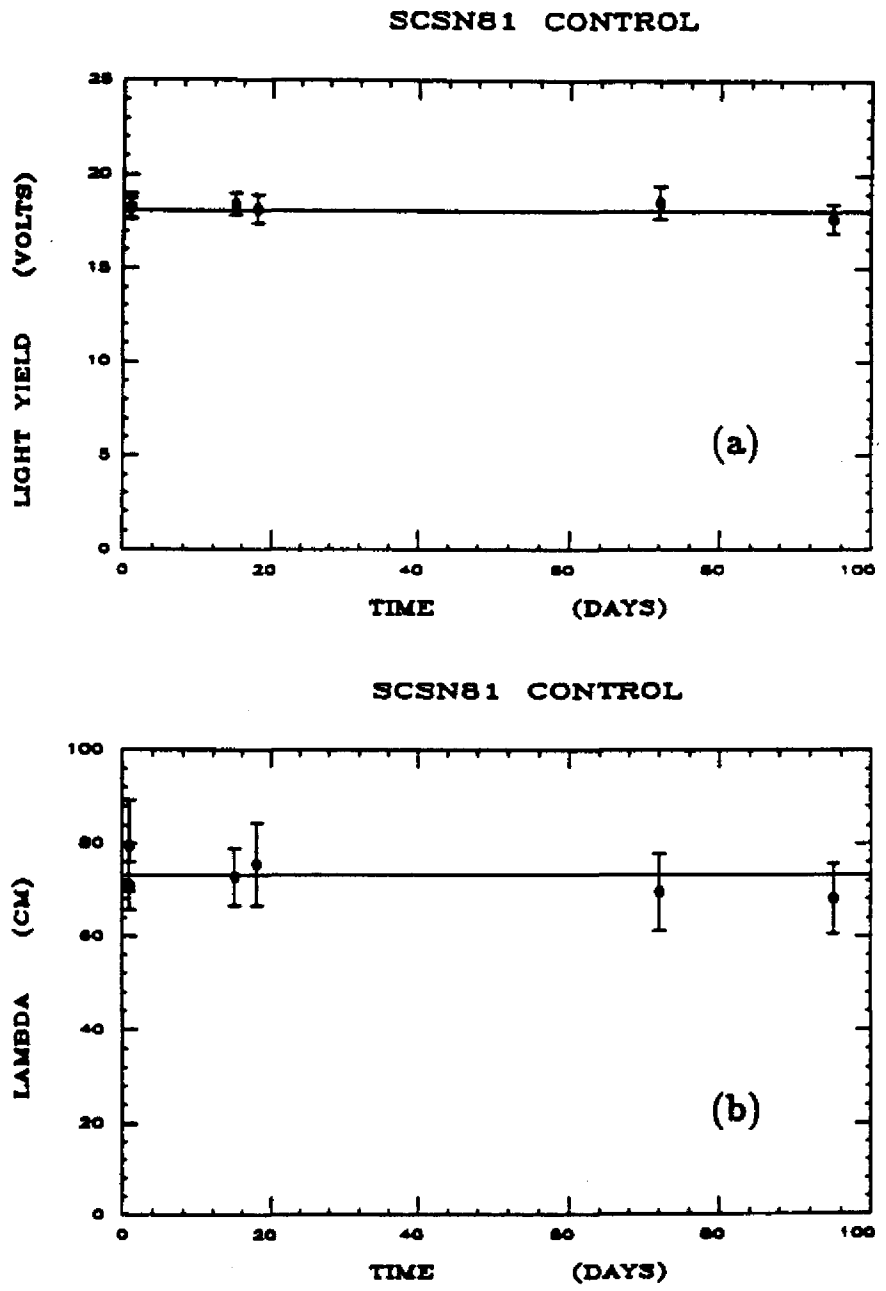
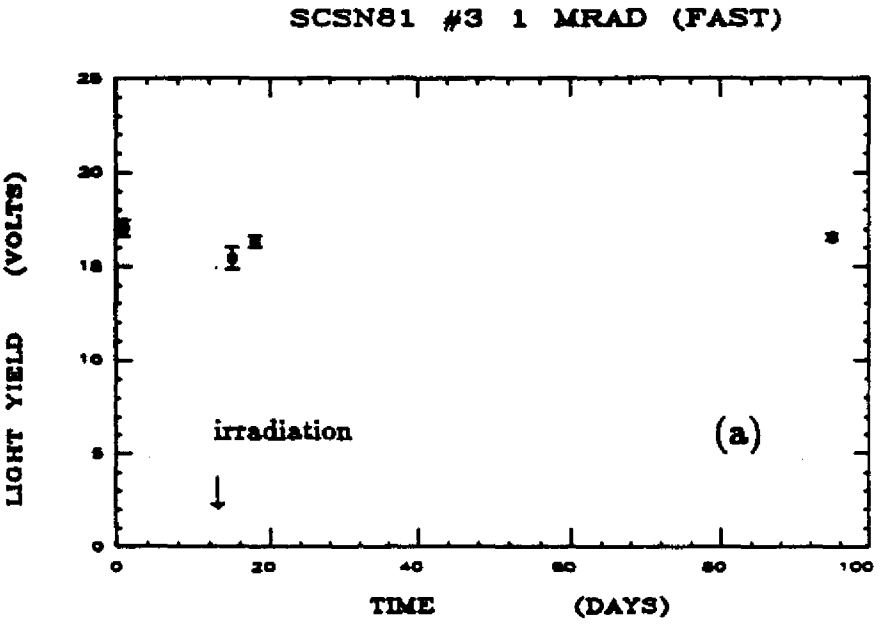


Figure 2: a) Light yield vs time and b) attenuation length vs time, for the SCSN81 control sample.



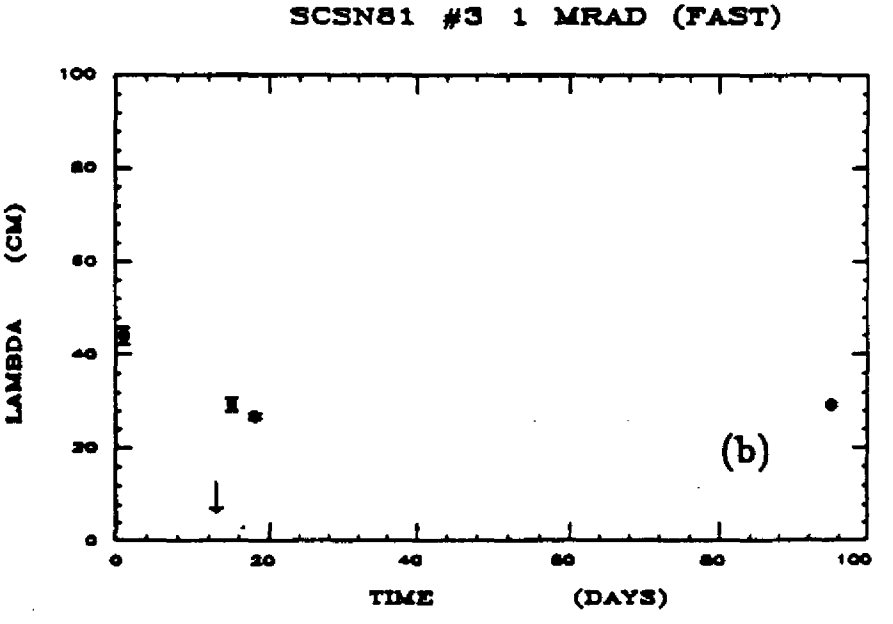
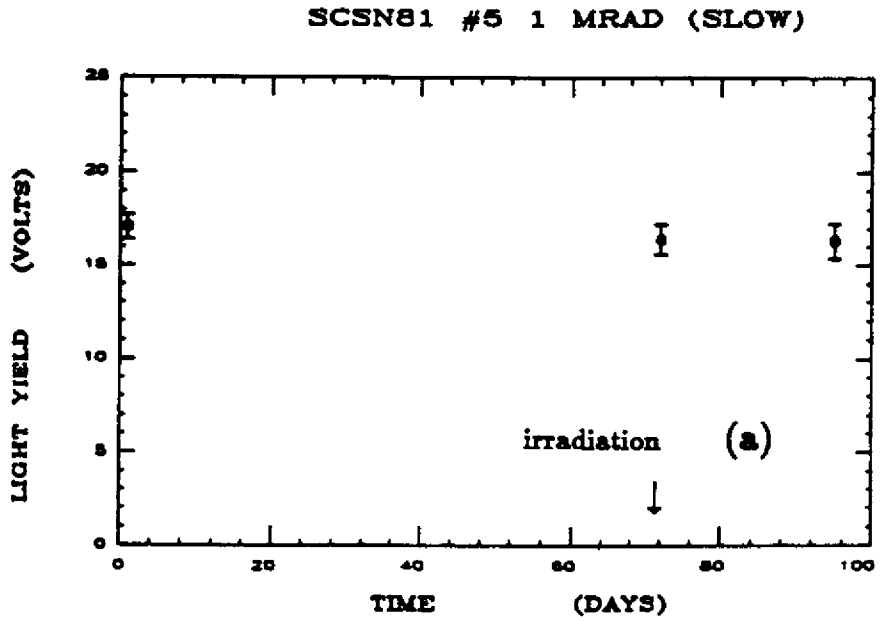


Figure 3: a) Light yield vs time and b) attenuation length vs time, for a sample of SCSN81 irradiated with 1 Mrad at a dose rate of 1.2 Mrad/hour.



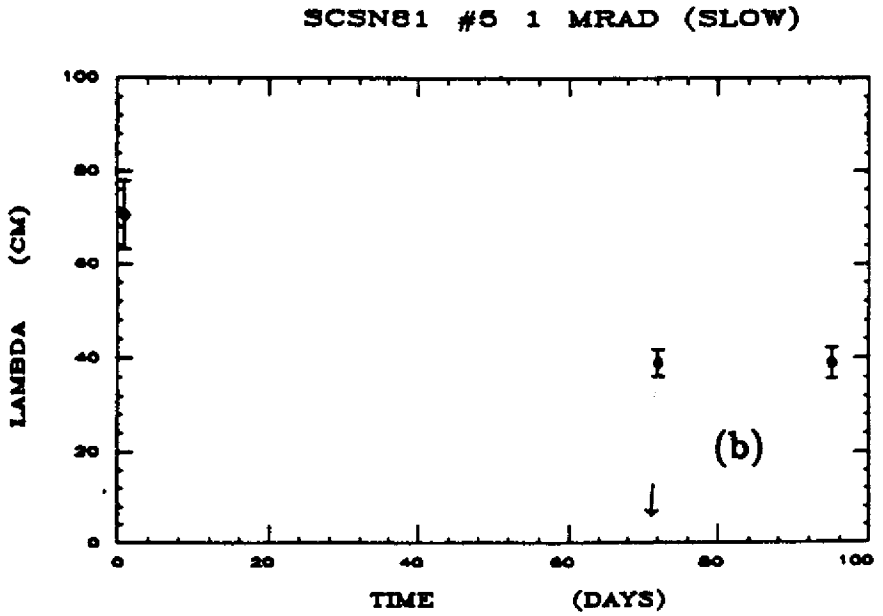


Figure 4: a) Light yield vs time and b) attenuation length vs time, for a sample of SCSN81 irradiated with 1 Mrad at a dose rate of 10.5 Krad/hour.