NIMA 382 BRR MURTHY GRACY

FERMILAB-PUB-97-523

NIM-A
MS No. 382 (4 pages)
Date 3/1/98

TYPESET FROM AUTHOR'S DISK

ELSEVIER

Nuclear Instruments and Methods in Physics Research A 000 (1998) 000–000

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

Research for a fiber detector for CDF Run II

M. Atac[a,*], F. Bedeschi[b], G. Berchiesi[b], E. Cocca[b], B. Di Girolamo[b], M. Incagli[b], S. Leone[b], D. Lucchesi[b], N. Parashar[b], D. Pieroni[b], N.B. Wallace[a]

[a] *Fermi National Laboratory, MS 222, P.O. Box 500, Batavia, IL 60510, USA*
[b] *INFN sezione di Pisa, I-56100 Pisa, Italy*

Abstract

In the course of research and development of a fiber detector for CDF Run II we have made measurments of the light yield increase due to fiber mirroring, and both the noise and rate capability of visible light photon detectors (VLPCs). We found the reflection coefficient, $R = 0.65 \pm 0.01$ could be obtained using aluminum sputtering. We also found that both the noise level and the rate capability of the VLPCs were acceptable for use in CDF for collider Run II.

1. Introduction

The new generation of high luminosity hadron collider experiments require tracking detectors which outperform the standard gas volume tracking detectors used previously. As part of the CDF upgrade project a scintillating fiber tracker, Intermediate Fiber Tracker (IFT), was proposed for the intermediate tracking region of the CDF-II detector.

The proposed IFT consisted of 6 layers of mirrored 600 μm thick scintillating fibers, coupled to high quantum efficiency cryogenic photon sensors Visible Light Photon Counters (VLPCs) [1,2] via clear fibers.

As part of the research and development phase of this project we investigated the use of mirroring to improve light yield, the noise level of the VLPCs, and the rate capability of VLPCs.

2. Fiber mirroring

Fibers with aluminum sputtered on one end were exposed to a Sr^{90} source at various points along their length. The variation of the photocurrent in a PMT was fit as a function of source position using a exponential function modified to include a reflection coefficient R. The fiber end was blackened and the measurement repeated. The mirroring produced a reflection coefficient $R = 0.65 \pm 0.01$; the data are plotted in Fig. 1.

x (an)

3. Readout electronics measurements

The expected signal sizes of the fibers, the QE and gain of the VLPCs made it convenient to use

*Corresponding author.

0168-9002/98/$19.00 © 1998 Elsevier Science B.V. All rights reserved
PII S0168-9002(97)00856-5

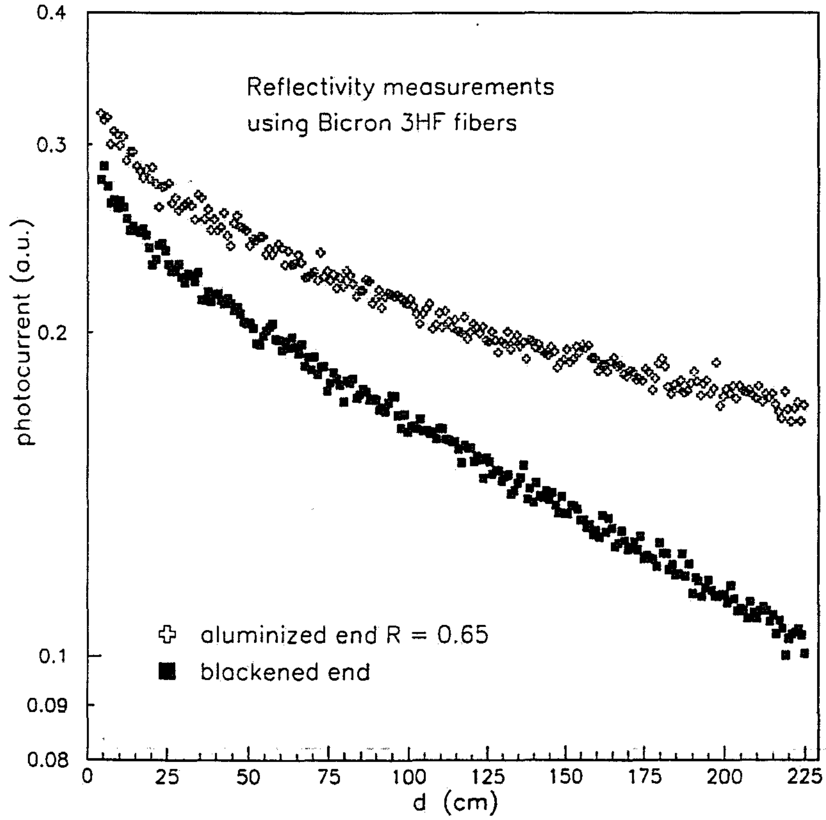

Fig. 1. Comparison of the light yield for scintillating fiber with an aluminized end and a blackened end.

the SVX3 readout chip, which was developed for silicon detector applications [3]. The necessity of a bias voltage for the VLPCs and the need to AC-couple the system resulted in a readout chain as shown in Fig. 2.

It should be noted that the VLPCs draw a much higher current than a silicon detector (on the order of μA), thus shot noise becomes an important factor in signal-to-noise performance.

We measured both the noise and the rate capability using 32 channels of HISTE-V VLPCs (48 channel chips) housed in a cassette cooled to between 5 and 13 K. Since the SVX3 was not available at the time, we read out the VLPCs using a QPA02 hybrid preamplifier and a LECROY AD2249 CAMAC ADC. The detector bias current was measured using a Keithley 485 Picoammeter.

3.1. Noise Measurements

The total noise, σ_{total}, in the system can be written as

$$\sigma_{total} = \left(\sigma^2_{pre-amp} + \frac{4KT}{R_{bias}} \tau_{int} + \alpha^2 I_{bias} \tau_{int} + \beta^2 I^4_{bias} \tau_{int} \right)^{1/2} \quad (1)$$

where $\sigma_{pre-amp}$ is the intrinsic noise of the preamplifier, K the Boltzmann constant, T the temperature of the VLPC in degrees Kelvin, R_{bias} the value of the bias resistor, I_{bias} the bias current, τ_{int} the integration time, α the coefficient for the shot noise, and β a coefficient for a second-order noise term related to the gain stage of the VLPCs.

We took data at several bias currents, temperatures, values of R_{bias}, and integration times. Using these data we measured a thermal noise contribution consistent with the bias resistor used. We also measured $\alpha^2 = (2.2 \pm 0.5) \times 10^7\,\mathrm{pC}^{-1}$ and $\beta^2 = (2.0 \pm 0.5) \times 10^{10}\,\mu\mathrm{A}^{-4}\,\mu\mathrm{s}^{-1}$. We measured the total noise for τ_{int} of 107 and 370 ns (which correspond to the two Run II beam crossing times of 132 and 396 ns) to be 3500 and 6800 electron, respectively. This can be compared to an expected signal of $2.4 \pm 0.4 \times 10^5$ electrons for the HISTE-V VLPCs.

3.2. Rate capability measurements

In order to measure the behavior of the VLPC as a function of light pulse rate we pulsed the VLPC cassette using two green LEDs driven by independent pulsers. This system allowed us to have constant light output through the entire pulsing frequency range. The timing for the system is shown in Fig. 3. We used the 2249 with an integration time of 60 ns, which is close to the actual integration time of the SVX2/SVX3 chip.

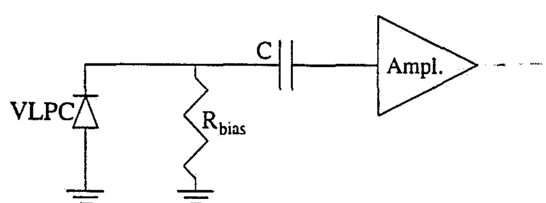

Fig. 2. A single channel of the fiber readout electronics with blocking capacitor, C, and bias resistor R_{bias}.

For each frequency point we performed two measurements:

- We synchronized the ADC gate on LED1 and took data.
- We synchronized the ADC gate to LED2 and took data. The light output is kept small to allow an accurate measrement of $\bar{n}_e$.

The data were analyzed by measuring $\bar{n}_e$ for LED1 and multiplying the result by the pulse rate to give the equivalent rate in photoelectrons/s (pe/s). We then measured $\bar{n}_e$ for LED2. This gave a determination of the gain. The normalized results of the quantum efficiency (QE) as a function of the equivalent rate for two different temperatures are shown in Fig. 4.

The QE falls by 10% at 10^6 pe/s and by roughly 20% at 2×10^6 pe/s, the decrease in gain is slighlty larger. Similar results were obtained for the HISTE-VI series of VLPCs by the D0 collaboration [4]. The variation in loss with respect to temperature leads us to believe that the QE loss is related to the pixel relaxation time.

4. Conclusions

Our studies of both the detector elements and the electronics gave no indication that the IFT was unsuitable in the CDF Run II environment. The use of fiber mirroring gives a sizable signal which can be observed with a single photon detector like the VLPCs. The VLPCs provide enough rate capability so that the expected occupancy at CDF during Run II does not pose a serious problem for the detection and readout electronics.

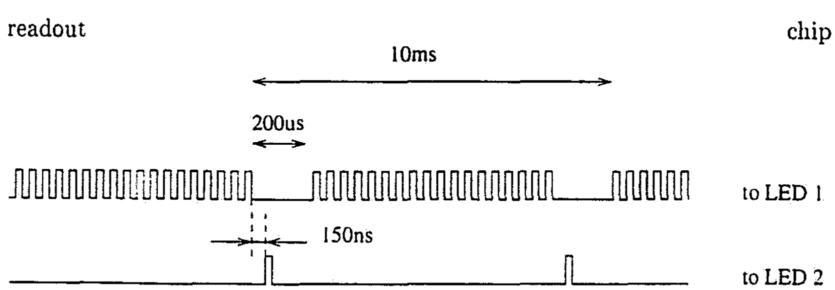

Fig. 3. Timing diagram for the two LEDs.

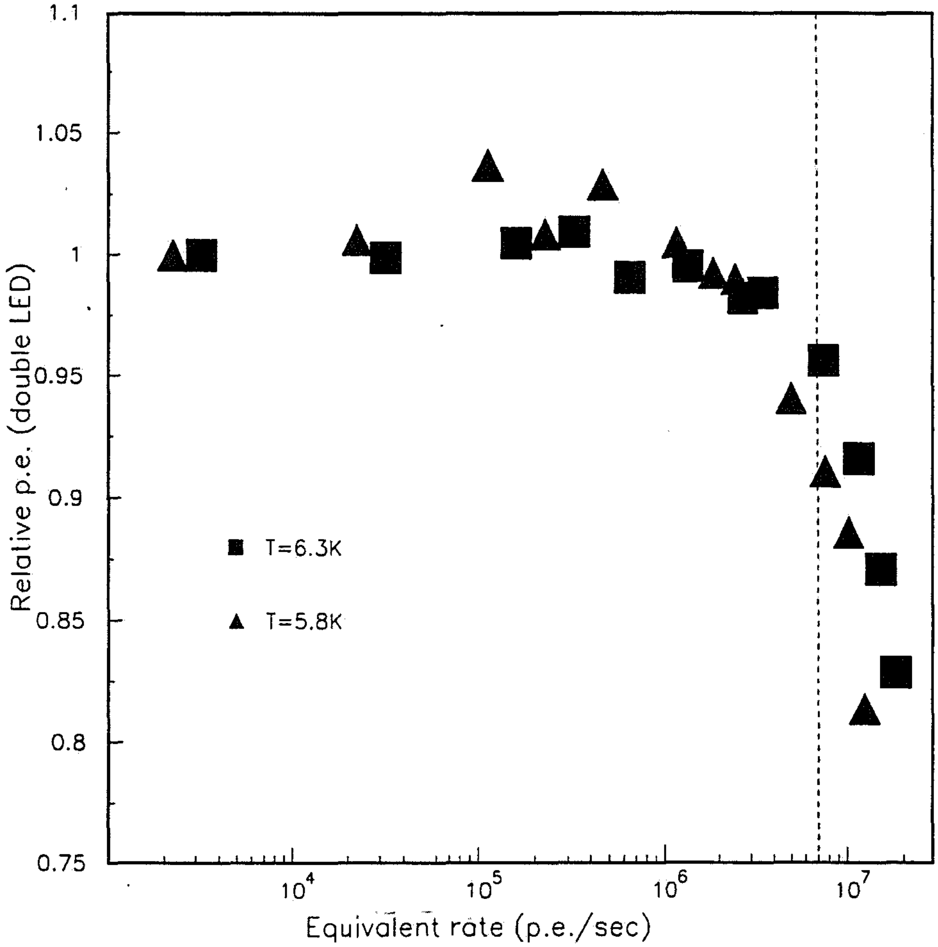

Fig. 4. QE versus rate at $V_{bias} = 6.5$ V; the temperature is indicated in the plots. The vertical dashed line indicates the equivalent rate for the maximum expected Tevatron luminosity in Run II (5×10^{32})

References

[1] M. Atac et al., Nucl. Instr. and Meth. A 320 (1992) 155.

[2] P. Stapelbroek, Visible Light Photon Counters for scintillating fiber applications, SCIFI93 Workshop on Scintillating Fiber Detectors.

[3] T. Zimmerman et al., A dead-timeless chip for silicon detectors, Nucl. Instr. and Meth. These proceedings.

[4] A. Bross, private communication.