INFN - Laboratori Nazionali di Frascati
Servizio Documentazione

LNF-91/003 (P)
18 Gennaio 1991

THE PHOTOMULTIPLIER GAIN MONITORING SYSTEM FOR THE E687 ELECTROMAGNETIC CALORIMETER AT FERMILAB

S. Bianco[4], P. Cantoni[2], A. Cotta-Ramusino[5], L. Daniello[4], M. Enorini[4], F.L. Fabbri[4], P.L. Frabetti[1,2], M. Giardoni[4], V. Giordano[2], S.Meneghini[2], G. Molinari[2], L. Passamonti[4], L. Perasso[3], R. Pilastrini[2], S.P. Ratti[5,6], V. Russo[4], A. Sala-Grabar[3], G. Sola[2], A. Spallone[4], P. Trespi[6], P. Vitulo[5], A. Zallo[4]

1 - Dip. di Fisica dell'Universitá, v. Irnerio 46 I40100 Bologna
2 - I.N.F.N. Sez. di Bologna, v. Irnerio 46 I40100 Bologna
3 - I.N.F.N. Sez. di Milano, v. Celoria 16 I20133 Milano
4 - Laboratori Nazionali di Frascati dell'INFN v. E.Fermi 40 I00044 Frascati
5 - Dip. di Fisica Nucleare e Teorica dell'Universitá, v. A.Bassi 6 I27100 Pavia
6 - I.N.F.N. Sez. di Pavia, v. A.Bassi 6 I27100 Pavia

ABSTRACT

The nitrogen pulsed laser monitoring system for the Outer Electromagnetic calorimeter of the E687 photoproduction experiment, investigating charm and beauty states at the Fermilab Tevatron, is described. The system is reliable, economical and allows a photomultipliers gain stability control as good as 1%.

INTRODUCTION

One of the important issues concerning particle detectors using a large number of photomultipliers (PM) is the monitoring of their stability during a long period of time. In particular, the gain stability is extremely important for sampling calorimeters (both electromagnetic and hadronic) because it directly affects their energy resolution. Since the energy resolution is typically $0.15/\sqrt{E[GeV]}$ $(0.60/\sqrt{E[GeV]})$ for electromagnetic (hadronic) showers, at $100GeV/c$ it can be as good as 1%; thus, in order to reach high performances controlling the gain at the 1% level is mandatory. There are many reasons why the gain of a PM can vary and they are not always predictable; among them, temperature and vacuum changes, thermal and chemical reactions on the material.[1,2] To control the PM gain a known amount of light is usually sent to each PM and the answer is read-out. Several different light sources are available on the market (photodiodes, xenon or krypton lamps and lasers), but not all of them meet the needed characteristics like stability, frequency spectrum, pulse duration and rise-time.

For the control of the Outer Electromagnetic Calorimeter of the E687 photoproduction experiment at the Fermilab Tevatron[3][4], we chose a nitrogen pulsed laser source because it is economical, and it has many of the desirable features i.e. pulse duration, frequency spectrum and repetition rate. In this paper we shall describe the characteristics of the E687 monitor system and the performances obtained over a data taking period.

1. THE E687 NITROGEN LASER MONITOR SYSTEM

The E687 Outer Electromagnetic Calorimeter[5] is a lead acrylic-scintillator (POPOP $C_{24}H_{12}N_2O_2$ doped with 8% naphtalene) sandwich having an area of $\sim (255 \times 205\,cm^2)$ and covering the angular region $(28 \div 142\,mrad)$ in the laboratory system. The calorimeter is highly segmented both laterally ($3.3\,cm$ wide counters) and longitudinally (23 sampling regions organized in 7 independent views oriented at $0°, 90°, \pm 45°$). Light read out for strip counters is either individual or five-fold integrated on ten stage photomultipliers (EMI-9902KB, 20% quantum efficiency at 440 nm, typical gain $\sim 0.5 \cdot 10^6$) at the selected working point. The total number of channels, whose global (counter+PM+ADC effect) stability has to be controlled for short and long term variations during the six months data taking period, is 778. The laser system (fig.1) is composed of a nitrogen pulsed laser, a light diffusion block and optical fibers to each PM.

The light source consists of a laser resonant open cavity[6] (fig.2) triggered by a $21\,KV$ spark gap which excites the nitrogen flowing through the chamber. The HV power supply (fig.3) makes use of a fast transformer (EG&G TR1700) and a SCR diode with grounded cathode in the output circuitry[6]. The maximum operating rate determined by the loading time of the $44\mu F$ capacitor is roughly $1\,Hz$.

The $330nm$ light emitted by the excited nitrogen is collected on one side of the chamber and converted by a $8\,mm$ thick wave length shifter bar of BBQ to a frequency of $440nm$, tuned to the frequency of the light emitted by the acrylic scintillator used in the calorimeter counters. A lucite cylinder drives the light to the focus of a spherical lens machined on the apex of a conical lucite diffusion block (fig.4). At the opposite end of the diffusion block, 50 fiber bundles, each one composed of 25 quartz optical fibers (OPSICA SCF - RADIALL France) $200\mu m$ core diameter, $400\mu m$ silicon cladding and $600\mu m$ vynil protection, are coupled.

The $10m$ long fiber bundles are routed from the diffusion block to tuning boxes, where the light carried by each fiber can be tuned by a regulator connector (fig.5). The desired amount of light to the individual PM can be obtained by changing the distance between the two fiber heads, unscrewing the outer part of the connector.

The characteristics of the laser have been studied during various laboratory tests, using either joulmeter or PM pulse height measurements. In fig.6 we show how the light output depends on the high voltage applied to the spark gap, at constant gas pressure. A plateau is obtained for voltage above 20 KV. The dependence of the laser power on the gas pressure at fixed voltage is shown in fig.7; for pressure values between 1.8 and $2.1\,atm$ the light output is almost constant, while above $2.1\,atm$ sparking becomes erratic. Fig.8 shows the ADC spectrum of the laser light output as seen by a EMI-9902KB PM coupled to a laser output fiber. This measurement is done in about 20 minutes; the laser pulse to pulse variation appears to be $\sim \pm 10\%$, the expected contribution from the PM photostatistics being of order 2%.

The laser stability over a longer period is illustrated (fig.9) by the distribution of the averages of laser pulses (about 300 pulses in each point) for two PM's facing the same optical fiber and kept in a temperature controlled box. The overall variation of the laser pulses mean values during the 50 hour period is $\sim \pm 8\%$, while the percent variations of the two PM's response agree at the 1% level. The periodic behaviour in the laser output (fig.9) is mainly due to temperature variations in the experimental environment ($\pm 10°C$). Similar measurements give no evidence for a dependence of the laser output on atmospheric pressure.

3. THE OE MONITOR SYSTEM AND RESULTS

The Outer Electromagnetic Calorimeter monitoring system is based on periodic control of:

- HV supplies for PM
- pedestals in both ranges of the Lecroy Fastbus ADC A1885
- PM and ADC gains by mean of the N_2 laser source.

PM's high voltages are periodically readout and discrepancies between setting and reading values $\geq 0.3\%$ are stored in a database while an on-line warning is generated. About 10 ADC pedestals and laser pulses are acquired between beam spills. Readings are accumulated in 1-2 hour periods while their mean values, variances and skewness are stored in a database for an off-line use in data analysis. Two PM's facing the same optical fiber are used as reference; they are installed in a temperature controlled box ($\pm 2°C$) and shielded from any beam effect. The N_2 laser is operated in free-running mode at the rate of $1Hz$ and the monitor trigger is generated making use of the coincidence between the two reference PM's. The amplitudes of the laser output pulses are individually set in order to have light pulses corresponding to $\sim$ 2000 ADC channels ($= 200pC$) in low range, equivalent to $\sim$ 2500 photoelectrons. This charge is equivalent to a 10-50 mips signal, depending on the sampling view.

In the offline analysis the average of the laser amplitude distribution over 1-2 hour periods *(runs)* is used to monitor the gain stability of each counter in the calorimeter. The correction algorithm applied to evaluate the gain variation of the ith counter $G(i)_k$ for the kth run, with respect to its reference gain $G(i)_0$, is:

$$G(i)_k = G(i)_0 \left[\frac{1}{2} \left(\frac{< R_1 >_k}{< R_1 >_0} + \frac{< R_2 >_k}{< R_2 >_0} \right) \right] \left(\frac{< P_i >_0}{< P_i >_k} \right) \quad (1.1)$$

where as reference gain $G(i)_0$ we use the gain at the time of physical calibrations; $< P_i >$ and $< R_{1,2} >$ represent the ith counter's and the reference PM's average amplitudes, respectively. This correction is applied after having performed a consistency check which excludes any laser malfunctioning, instability of the reference counters or overfluctuations. This check consists of two criteria:

- $< R_1 >_k$ and $< R_2 >_k$ are required to share a continuous evolutionary trend, indicating that the laser is stably working. Systematic drifts are allowed. When sudden permanent amplitude jumps are common both to the reference PM's and to the calorimeter counters, a new reference run is chosen. The gain variations within reference runs are then cross-checked through the analysis of physical signals (π^0 peak and width, etc).

- The gain variation correction (1.1) is applied only when the condition

$$\left|\frac{<R_1>_k}{<R_1>_0} - \frac{<R_2>_k}{<R_2>_0}\right| \leq 4\%$$

is satisfied, since (fig.9) the reference PM's are in intrinsic agreement better than 3%. This second criterion identifies erratic variations of the reference PM's.

Fig.10 shows the laser pulses variations for a sample of counters over a 100-hour period before applying the correction algorithm, each point being the laser pulses mean value over one run. For each counter in fig.10, pulse height distributions during one monitoring run are plot in fig.11. The gain correction greatly reduces the RMS variance of the distributions (fig.12). The distribution of the RMS variances over one run is shown in fig.13 for 660 counters with and without correction. Similarly, the use of the gain correction greatly reduces the observed time-dependent variations in the raw data (fig.14 to be compared with fig.10). Photomultipliers b) and d) in fig.14 evidenciate a good stability, whereas a) and c) undergo important gain variations, that must be taken into account in the physical analysis. The calorimeter stability over a typical 100-hour period is shown in fig.15, where the percent dispersion of the laser corrected pulse heights mean values for each counter is shown. The distribution is peaked at ~ ±1%, while the average is ±1.4%. Those counters showing a stability worse than ±2.5% (about 6%) must be corrected in the off-line analysis.

3. CONCLUSIONS

We have described the monitoring laser system installed for the control of the counters gain stability of the outer electromagnetic calorimeter in the E687 photoproduction experiment at Fermilab. The laser system is a home made, low cost and sturdy project. The intrinsic laser pulse-to-pulse stability is ~ 10%, while the complete system is capable of controlling the calorimeter counters stability better than 1% over long periods. We have shown that the overall calorimeter stability was quite remarkable during the data taking period: more than 30% of the counters fluctuated less than 1%, while only 6% fluctuated more than 2.5%, thus requiring off-line corrections.

ACKNOWLEDGEMENTS

Thanks are due to Milena Boldini, Lidia Maselli, Luisa Sandri and Luisa Vallini who prepared the optical fiber bundles in Bologna. We also thank Giorgio Bernardi and Federico Bertino for their skillful processing of drawings.

REFERENCES

[1] S.Bianco et al. *et al.*, **A STUDY OF SHORT-TERM RATE EFFECT IN PHILIPS XP-2008 PHOTOMULTIPLIER TUBES,** *to appear on Nucl. Instr. and Meth., also* LNF note LNF-90/038(P).

[2] S. Bianco *et al.*, **A COMPUTER-CONTROLLED SYSTEM FOR TESTING LARGE QUANTITIES OF PHOTOMULTIPLIERS TUBES,** INFN note LNF-85/49(R).

[3] P.L. Frabetti *et al.*, **DESCRIPTION AND PERFORMANCE OF THE E687 SPECTROMETER,** *to be submitted to Nucl. Instr. and Meth.*

[4] P.L. Frabetti *et al.*, **MEASUREMENT OF THE D_s^+ AND Λ_c^+ LIFETIMES,** *accepted for publication in Phys. Lett. B (1990), also FERMILAB-Pub-90/158-E.*

[5] S. Bianco *et al.* **THE E687 OUTER ELECTROMAGNETIC CALORIMETER** *to be submitted to Nucl. Instr. and Meth.*

[6] A home-made project derived from an earlier CERN design by R. De Salvo, CERN note 1984.

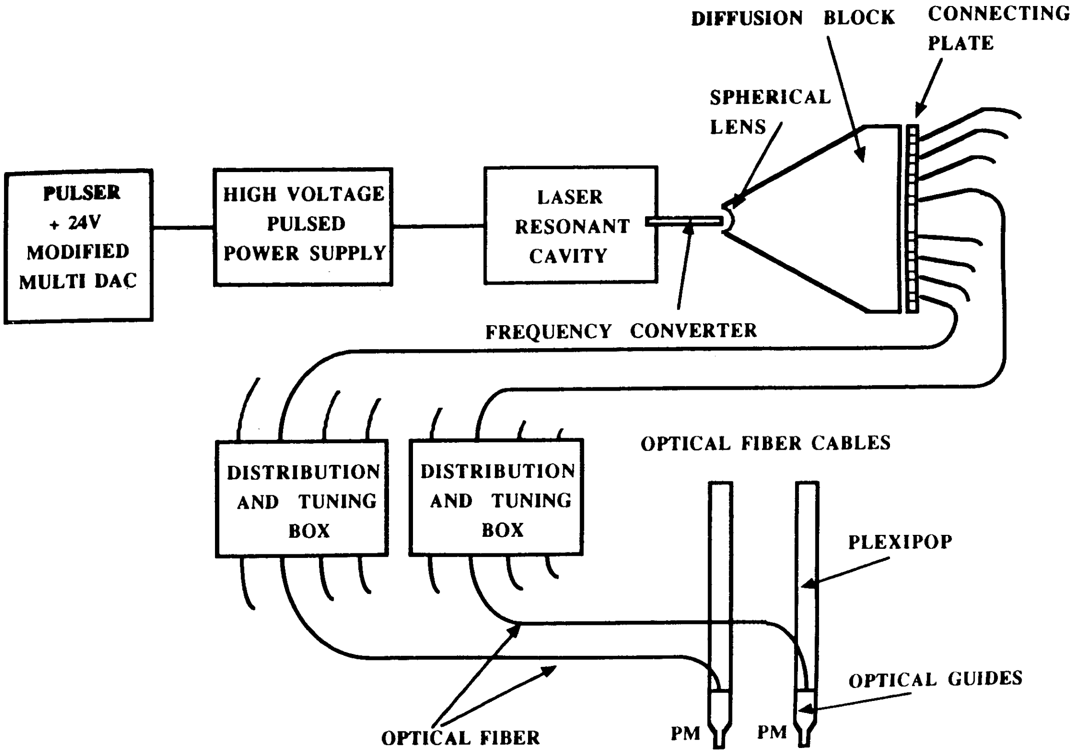

Fig. 1 Hardware schematics of the monitoring system.

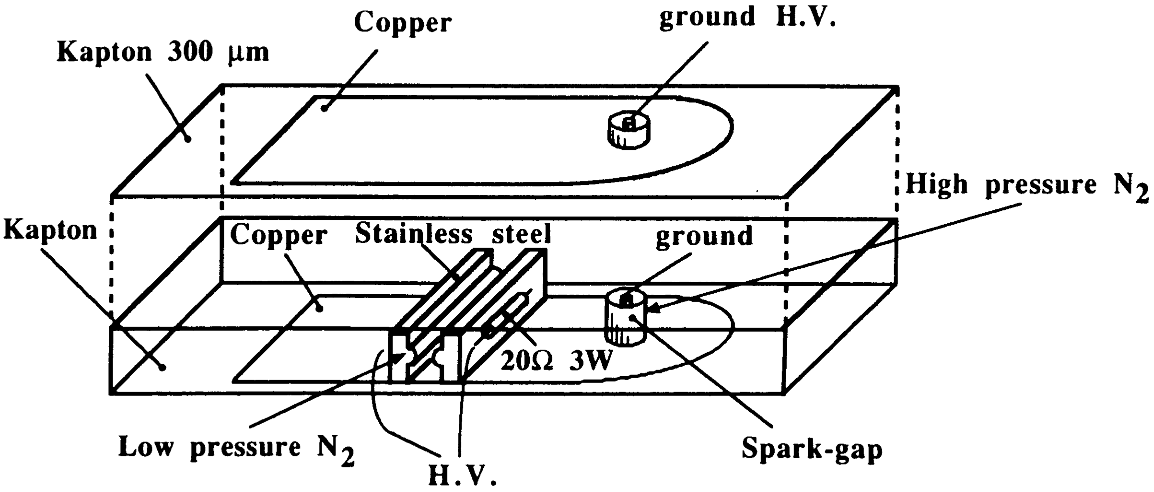

Fig. 2 Laser light source.

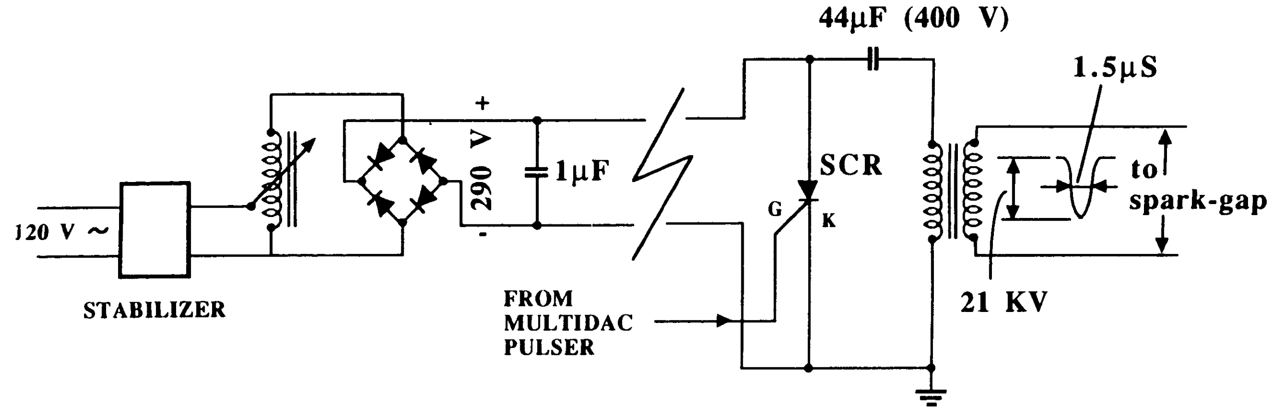

Fig. 3 High voltage power supply.

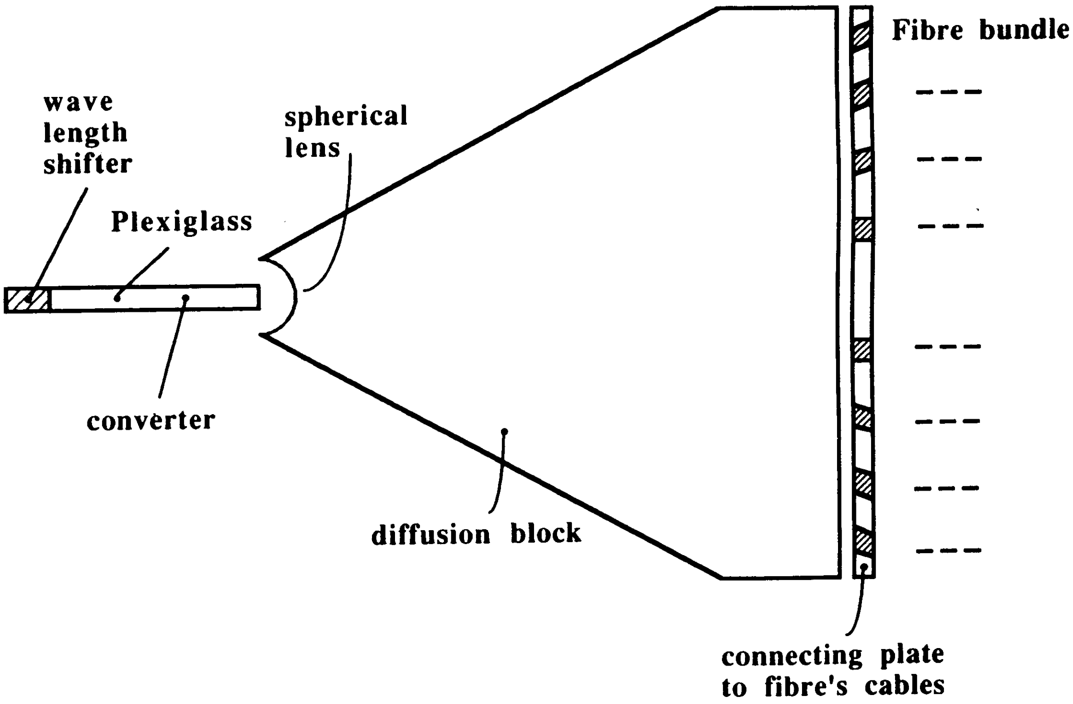

Fig. 4 Converter and light diffusion block.

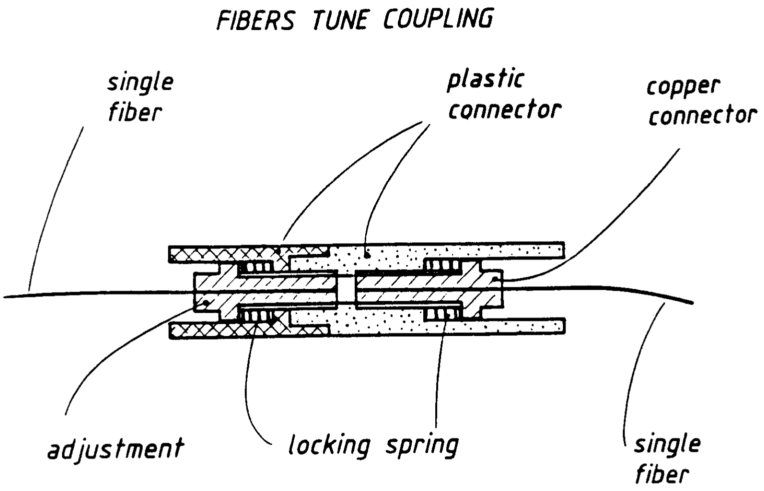

Fig. 5 Tuning box connector.

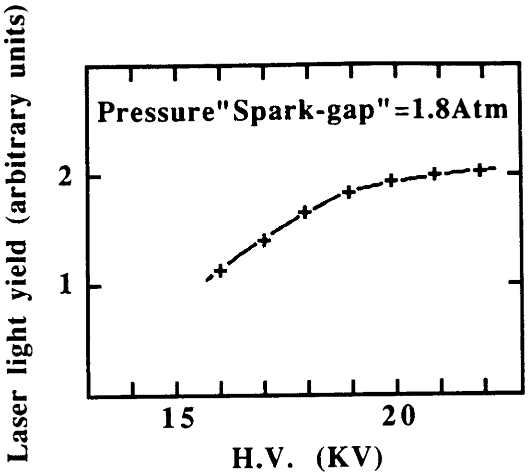

Fig. 6 Laser light yield dependence on the high voltage applied to the spark gap.

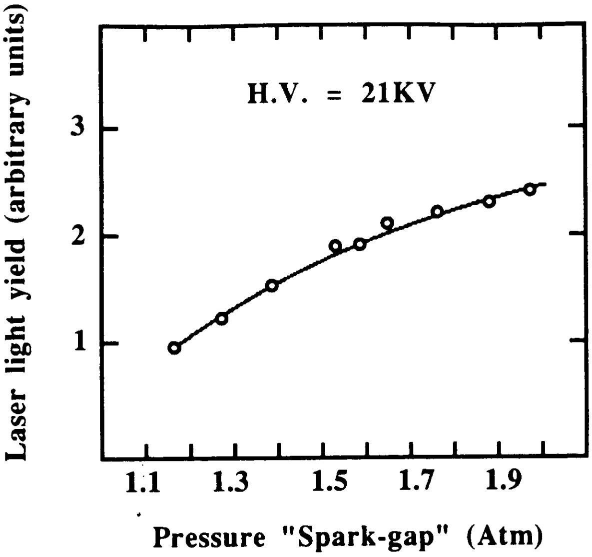

Fig. 7 Laser light yield dependence on the gas pressure in the spark gap.

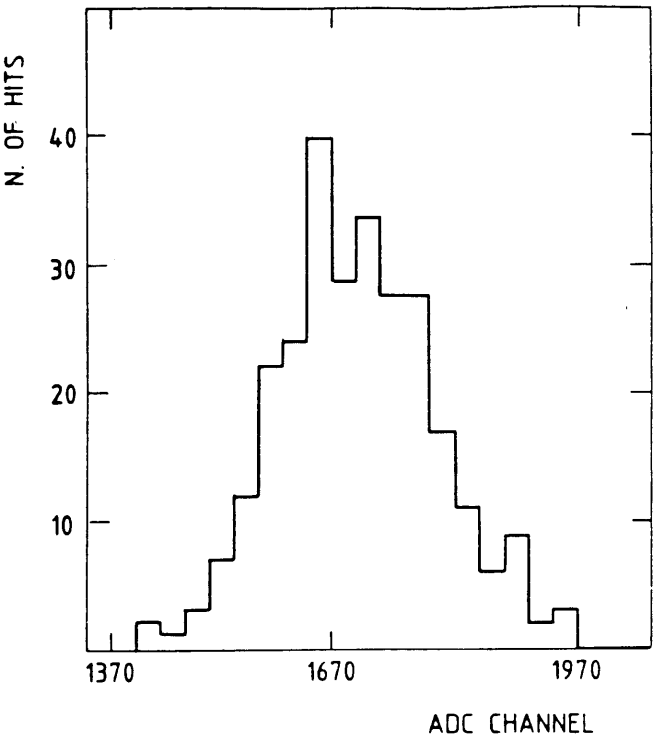

Fig. 8 Pulse-to-pulse variation of the laser light output.

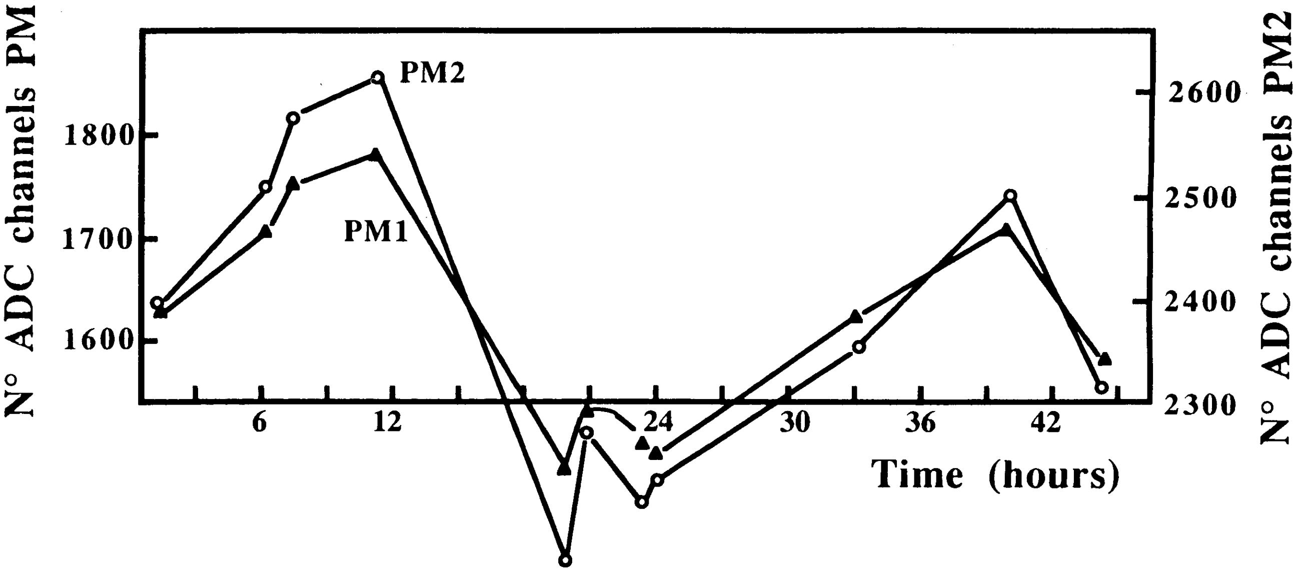

Fig. 9 Response (ADC channels) of the reference PM's to the laser light over a 50 hour period.

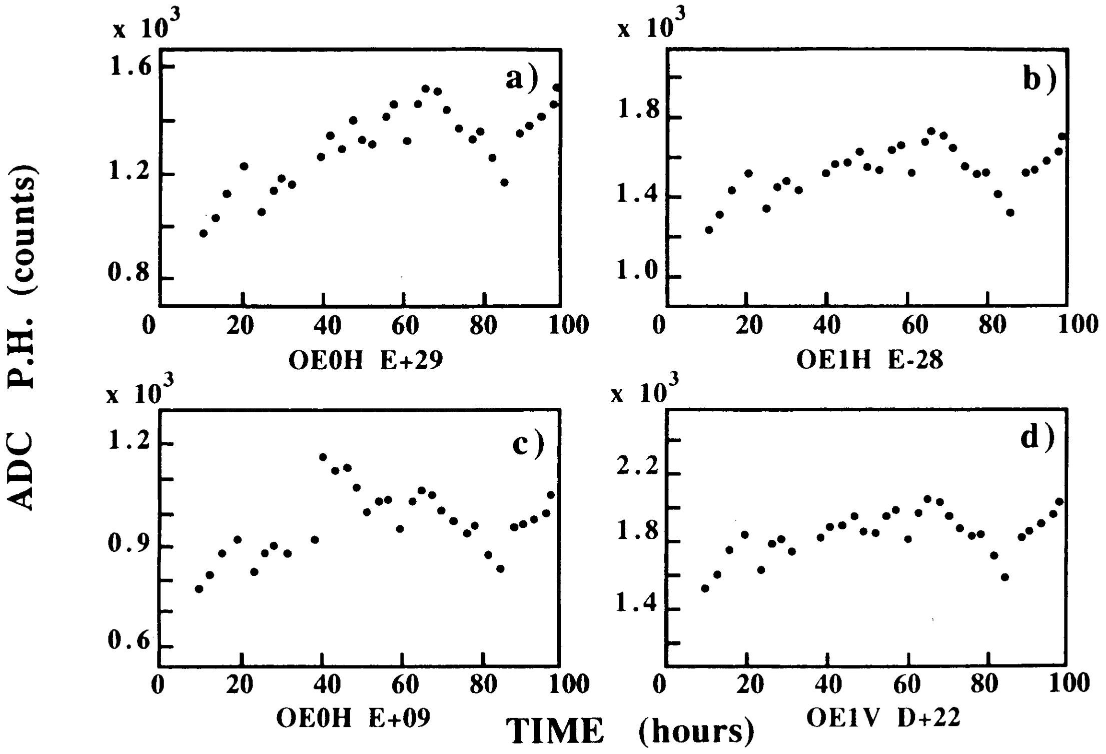

Fig. 10 Laser pulses variations for four OE counters over a 100 hour period.

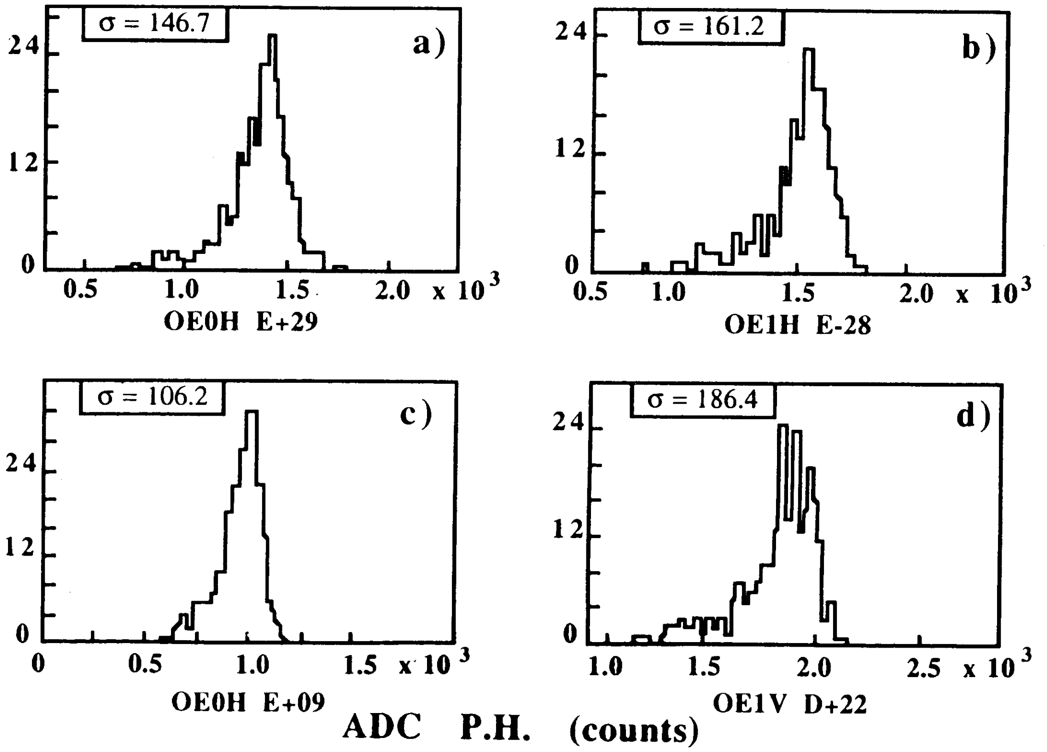

Fig. 11 Pulse height distributions in a monitor run for the counters in fig.10.

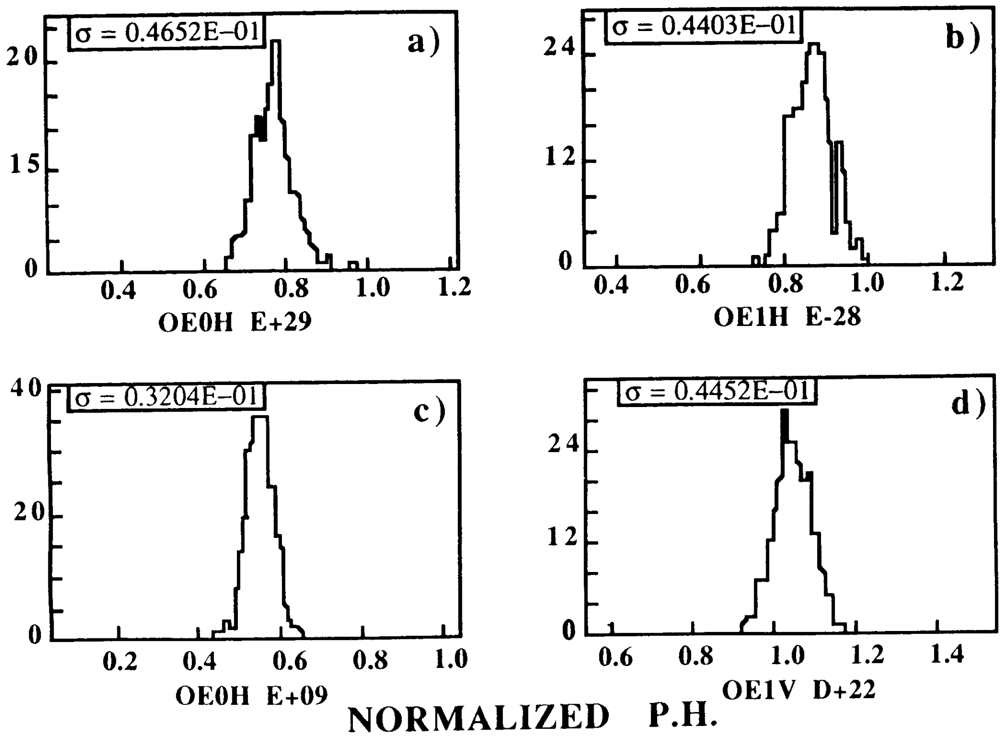

Fig. 12 Normalized pulse height distributions in a monitor run for the counters in fig.10.

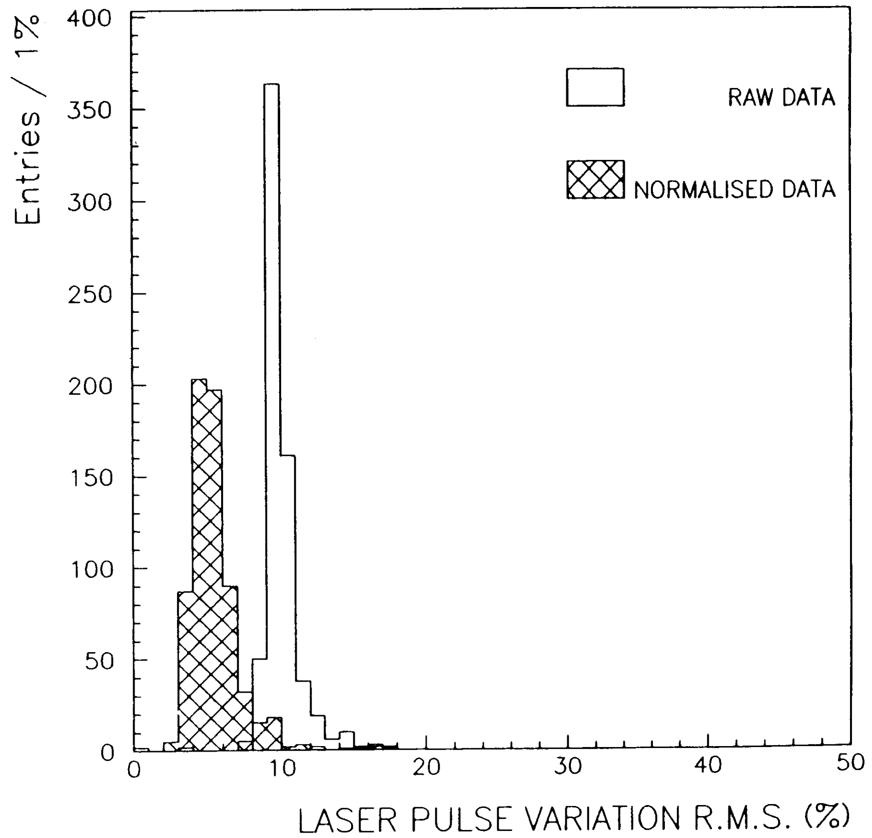

Fig. 13 Distribution of laser pulse heights RMS variances before and after (cross-hatched) normalization.

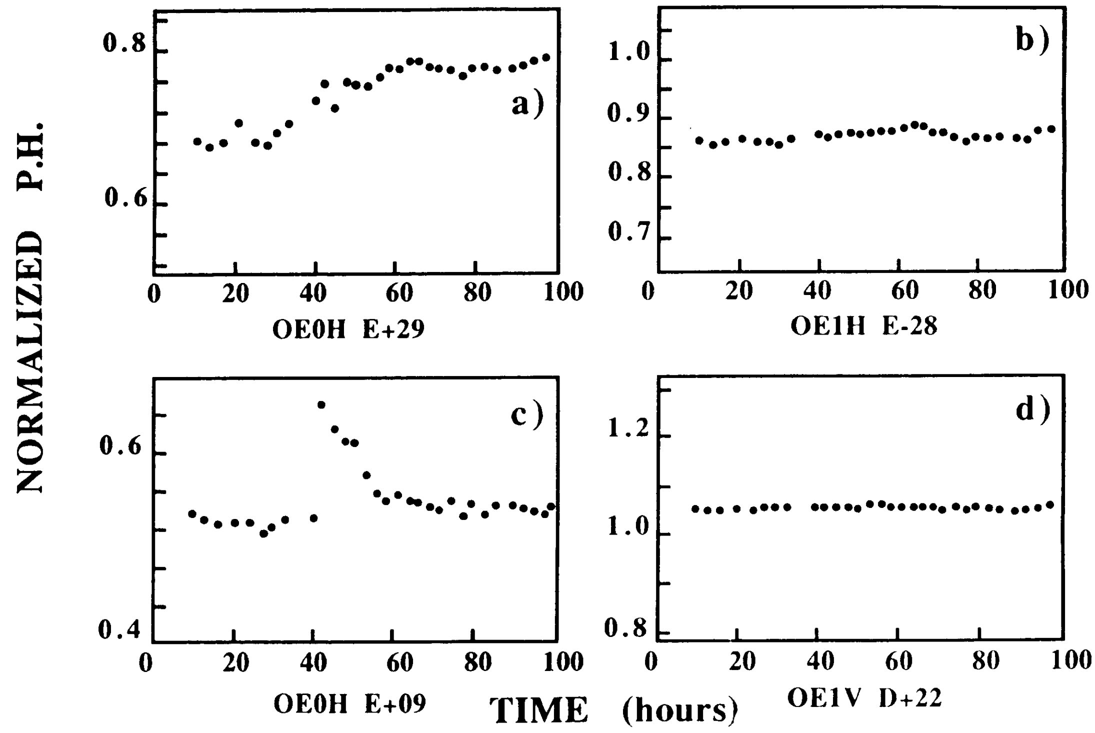

Fig. 14 Laser pulse heights variations over a 100 hour period after normalization for the counters of fig.10.

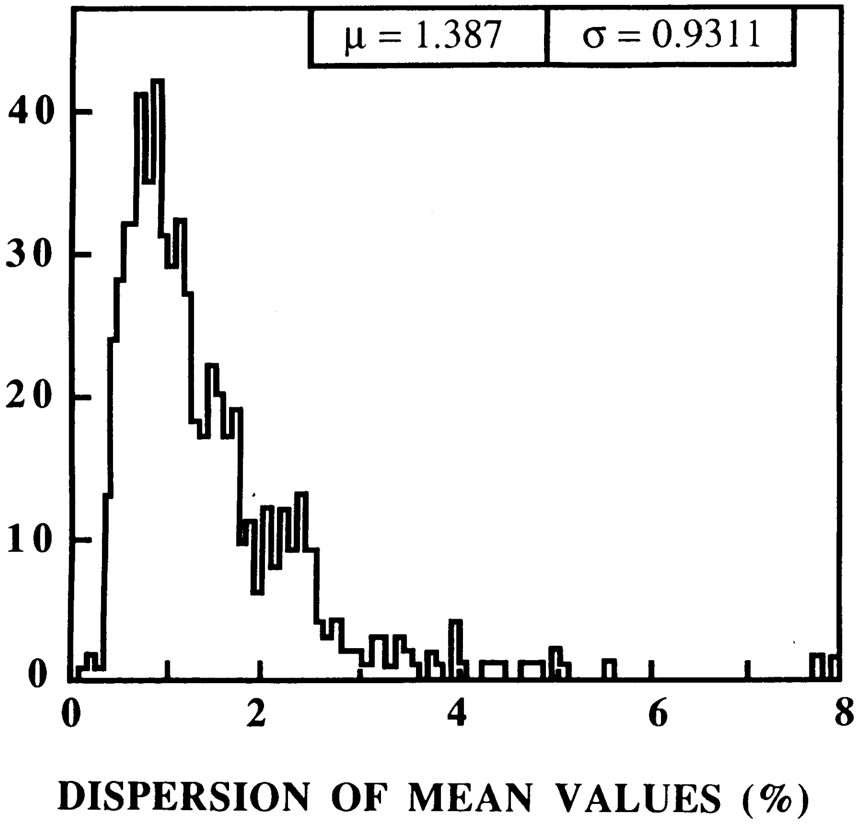

Fig. 15 Percent dispersion of the laser normalized pulse heights over a 100 hour period.