EDMS No. 404492

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

Technical Inspection and Safety Division

Technical Note
CERN-TIS-2003-016-RP-TN

Inter-comparison of the CERF beam monitors

E. Dimovasili, M. Magistris and M. Silari

Abstract

The beam monitoring at H6 is performed by a 1 liter volume Precision Ionisation Chamber (PIC) and since 2002 by a second chamber of the same type but 3 liter volume (BIG PIC). The number of beam particles is also recorded by a scintillation counter, Trigger4; a control of its operation is performed every year before the start of each CERF run. This note provides the efficiency curve of Trigger4 measured in Aug 2003, a new inter-comparison between the PIC and the BIG PIC and an expression for the counts of Trigger5/6 (scintillators counting the muons downstream of the CERF area) versus PIC-counts.

CERN, 1211 Geneva 23, Switzerland
23 October 2003

1. Introduction

This note discusses the results of measurements carried out at the CERF (the CERN-EU high-energy Reference Field) [Mit02] facility during the August run in 2003 (28^{th} August–3^{rd} September). These measurements include tests for the verification of the calibration factor of the standard Precision Ionisation Chamber (PIC) by inter-comparison with the Trigger4 scintillator in the H6 beam line and cross-comparison of the efficiencies of the two PIC chambers (the standard PIC and the BIG PIC).

The BIG PIC stands as the back-up instrument of the PIC. It has been submitted to extensive performance tests in the past so as to be ready for use in case of any future failure of the PIC [Dim02]. This note compares the response of the two chambers at several beam intensities and verifies their inter-calibration factor.

The Trigger4 is one of the scintillators installed in the H6 beam line very close to the PIC. A routine check of the operation of the PIC is done before each CERF run by means of Trigger4 [Els98, Gol99, Gsc00, Eft02]. The characteristics of Trigger4 are given in [Eft02].

The Trigger5 and Trigger6 are two scintillation counters located 15 m downstream of the iron beam dump installed at the end of the CERF area. These counters measure the muons produced by the pion component of the beam, and thus provide an indirect measurement of the beam intensity.

2. Measurements and results

I. Efficiency measurements of Trigger4

A routine check of the PIC calibration factor is performed with the following procedure. The PIC-counts are read out online via a LabView program running on a PC. A certain number of cycles are preset and the PIC-counts during this period are accumulated. At the same time, the reading of Trigger4 is received directly by the SPS beam-control program, using the following commands:

From the main menu
eanorth> TRUNK/STATUS/FILES/TUNE/DETECTORS/ACCESS//INDEX/INFOS//
Type: TUNE
MEAS
TRIGGER
4
USE

The beam cycle lasts 16.8 s while the spill extraction lasts 4.8 s (August 2003). After selecting a number of beam cycles, the Trigger4 counts the beam particles and after the last cycle the beam-control program gives the average number of particles. An estimation of the calibration factor is obtained from the ratio of the average number of particles to the average PIC-counts.

The first measurements showed a big deviation from the known calibration factor, i.e. 31,000 instead of the expected ~23,000 particles per PIC-count. The reason of such discrepancy was an inappropriate high voltage (HV) of the photomultiplier of Trigger4 (-1.85 kV). By varying the HV of the photomultiplier and recording the counts of the scintillator, it was found that a good operating HV value (i.e., in the middle of the so-called “plateau”) is -1.73 keV (figure 1).

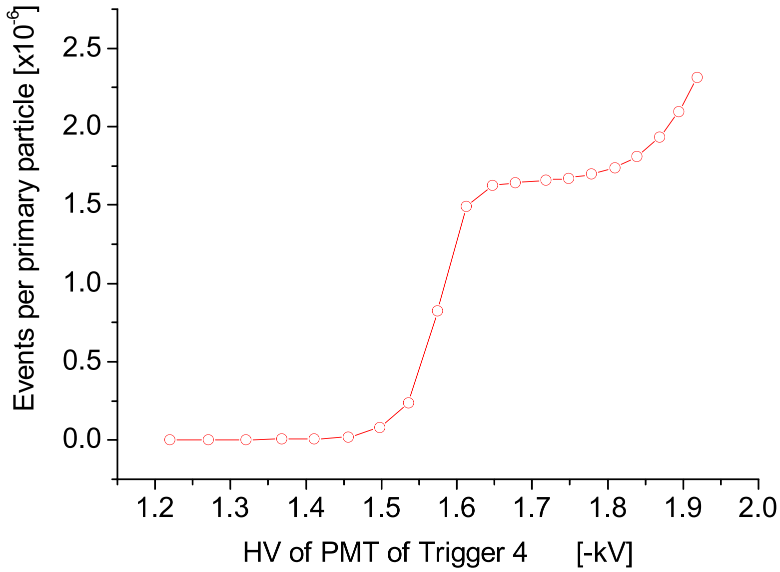

Figure 1. Characteristic curve of the Trigger4 scintillator. Events on Trigger 4, normalized to the protons on T4 production target, as a function of high-voltage (HV) of the photomultiplier (PMT).

With the HV set to the new value of -1.73 kV, the counts per spill of Trigger4 were recorded for different apertures of collimators C3 and C5, and compared to the counts per spill of the PIC (table 1).

Table 1. Ratio of Trigger4-counts over PIC-counts for different beam intensities.

PIC-counts per SPS spill (mean over 5 cycles)	Trigger4 response per SPS spill (mean over 5 cycles)	Ratio (Trigger4-counts / PIC-counts)
74	1,697,103	23,058
165	3,742,178	22,625
294	6,521,542	22,197
458	9,953,216	21,732
653	13,853,153	21,221
1,160	23,141,498	19,943
2,132	33,055,128	15,503

As noted in the past [Gsc00], Trigger4 is not reliable above about 1,700 PIC-counts per spill, because in this region the limit of the photomultiplier is reached. Results in table 1 show that at ≈300 PIC-counts per spill it is already important to correct the response of the scintillator for dead time losses.

In order to check if these data are consistent with the usual calibration factor of 23,000 particles per PIC-count, the Trigger4 response was corrected for dead time losses. When calculating the effects of dead time the entire detector system must be taken into account. There are two models for dead time behaviour: paralyzable and nonparalyzable response [Kno89]. The expressions of the recorded count rate m as a function of the "true" interaction rate n and the system dead time τ are:

$$m = n\, e^{-n\tau}, \quad \text{paralyzable model,} \tag{1}$$

and

$$m = \frac{n}{1 + n\,\tau}, \quad \text{nonparalyzable model.} \tag{2}$$

Each element of a detector system usually has its own dead time, which can be extendable (paralyzable model) or non extendable (nonparalyzable model) [Leo87]. The two models predict the same first-order losses and significantly differ for high true event rates (i.e., higher than $1/\tau$). Since we do not have any information about the detector components and their dead times, data analysis was done with both models. We assume that they represent the two extremes of the experimental set up and our true set up lies in between [Gsc00].

The data presented in table 1 have been normalized to a spill length of 4.8 s to obtain the recorded count rate m for Trigger4, the PIC-counts per second (the "true" count-rate n) and their ratio Γ. The dead time of the system and the ratio Γ have been estimated by fitting the experimental data with expressions 1 and 2, as shown in figure 2.

Taking the mean value of the calibration factors obtained from the two fitting models [Gsc00], we get Γ=23,640. This value is consistent within 3% with the calibration factor in use of 23,000 particles per PIC-count.

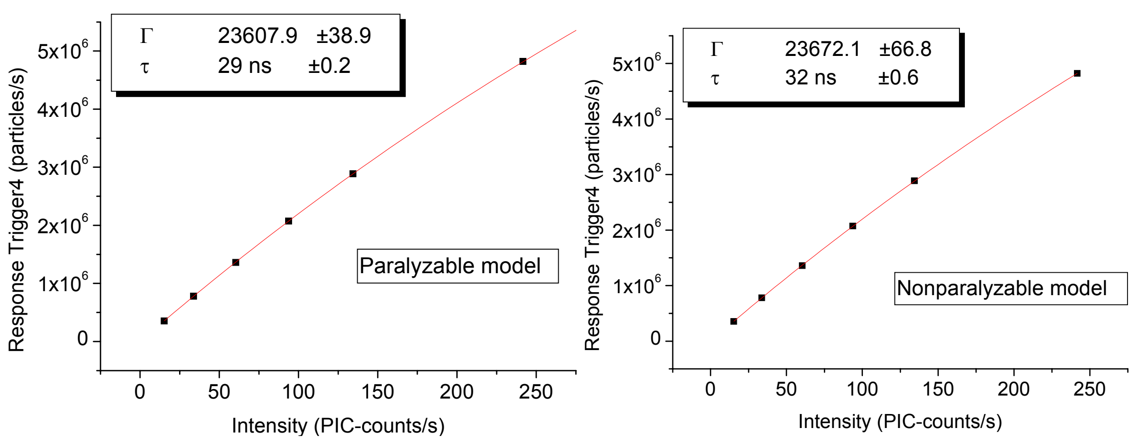

Figure 2. Measured count rate by Trigger4 as a function of the "true" count rate as given by the PIC (symbols). The solid line is a fit according to the paralyzable model (left) and the nonparalyzable model (right).

II. Inter-calibration of the PIC and BIG PIC

The efficiencies of the PIC and the BIG PIC have a correlation factor which is approximately equal to 3 [Dim02]. For the verification of this factor new measurements were performed at CERF with intensities varying from about 70 PIC-counts/spill to 4,000 PIC-counts/spill. The raw data are shown in table 2.

Table 2. Raw data of the PIC and BIG PIC for different beam intensities.

Approximate beam intensity (PIC-counts/spill)	Total PIC-counts in 5 cycles	Total BIG PIC-counts in 5 cycles	BIG PIC-counts / PIC-counts
75	366	1,090	2.98
165	815	2,447	3.00
290	1,469	4,419	3.01
460	2,290	6,907	3.02
645	3,264	9,843	3.02
1,160	5,802	17,472	3.01
1,780	8,884	26,734	3.00
2,480	9,880	29,571	2.99
3,280	16,516	49,426	2.99
4,060	20,349	61,081	3.00

From table 2 one sees that the ratio between the readings of the BIG PIC and the PIC ranges from 2.98 at low beam intensity (75 PIC-counts/spill) up to 3.02 at ~500 PIC-counts/spill. These variations are well within the experimental uncertainties and in agreement with the factor found previously [Dim02].

III. Measurements of Trigger5 and Trigger6

The response of the PIC was compared with the reading of the scintillation counters Trigger5 and Trigger6, installed downstream of the CERF area. The Trigger5 and Trigger6 measure the muons produced by the pion component of the beam that is roughly proportional to the beam intensity in the H6. Because the muon flux is about three orders of magnitude lower than the beam intensity, it allows monitoring over a wider intensity range than Trigger4 [Els98]. The response of the scintillation counters versus PIC-counts is shown in figure 3 for different beam intensities.

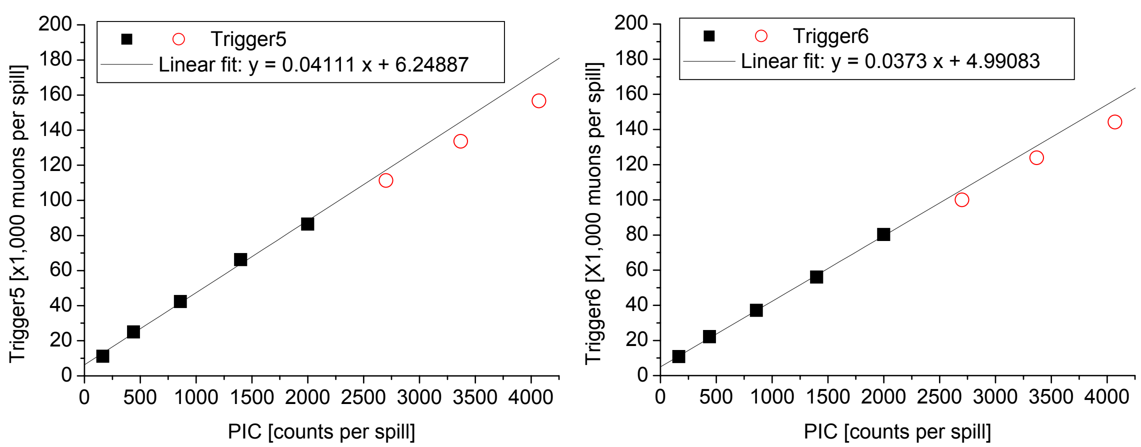

Figure 3. Response of Trigger5 (left) and Trigger6 (right) versus PIC-counts. The straight line is the fit in the range of linearity (squares).

The experimental points in figure 3 were fitted by a linear function in the non-saturated range. The data points above 2,000 PIC-counts (about 10^5 muons) were excluded from the fit because at these intensities the Trigger5 and Trigger6 start to saturate. If we calculate the average of the linear fits shown in figure 3, we obtain an expression that gives the expected number of Trigger5/6-counts ($T_{5/6}$) as a function of the PIC-counts (P):

$$T_{5/6} = (0.039205 \pm 0.0011) \cdot P + 5.61985 \pm 1.25. \qquad (3)$$

Expression 3 compares well with the expression that was calculated in July 1998 [Els98] for correcting the response of Trigger4 up to 2,000 PIC-counts per pulse:

$$T_{5/6} = 0.04078 \cdot P + 4.57536. \qquad (4)$$

3. Conclusions

During the CERF run in August 2003, measurements were performed to verify the calibration factor of the CERF beam monitor, to record the efficiency curve of Trigger 4 and to check the range of the linear correlation between PIC-counts and Trigger5/6-counts.

By varying the HV of the Trigger4 photomultiplier, it was found that the plateau region of the Trigger4 has shifted since last year. A good operating point (i.e., in the middle of the plateau) is now -1.73 kV.

Trigger4 has proved to be reliable to perform calibration tests for intensities below 2,000 PIC-counts per spill, if the appropriate corrections for dead-time losses are made. Measurements taken during the CERF run are consistent with the calibration factor in use (23,000 particles per PIC-counts), the correlation factor between the PIC and BIG PIC (~3) and the expected Trigger5/6-counts per PIC-counts within the experimental uncertainties.

4. Acknowledgements

The authors wish to thank Bruno Chauchaix from the AB/ATB group for his help with the set up of the beam line and Jens Spanggaard from the AB/BDI group for providing the HV scan of the Trigger4. We are also indebted to Stefan Roesler and Chris Theis for useful comments and discussions.

5. References

[Dim02] E. Dimovasili and M. Silari, *Beam and reference field monitoring during the 2002 CERF runs*, CERN/TIS-2002-033-RP-TN (2002).

[Eft02] I. Efthymiopoulos, A. Mitaroff and M. Silari, *Efficiency measurements of the Trigger4 beam monitor in H6*, CERN/TIS-RP/TN/2002-027 (2002).

[Els98] K. Elsener, M. Heilmann and M. Silari, *Verification of the calibration factor of the CERF beam monitor*, CERN/TIS-RP/TM/98-22 (1998).

[Gol99] N. Golnik, M. Silari and T. Otto, *On the use of a recombination chamber for radiation measurements in CERN-EU high energy reference radiation fields*, Radiation Protection Dosimetry Vol. 86, No. 3, pp. 175–179 (1999).

[Gsc00] E. Gschwendtner, A. Mitaroff and L. Ulrici, *A new calibration of the PIC monitor in H6*, CERN/TIS-RP/IR/2000-09 (2000).

[Kno89] G. Knoll, *Radiation detection and measurement*, Wiley Edition (1987).

[Leo87] W. Leo, *Techniques for nuclear and particle physocs experiments*, Springer (1987).

[Mit02] A. Mitaroff and M. Silari, *The CERN-EU high-energy Reference Field (CERF) facility for dosimetry at commercial flight altitudes and in space*, Radiation Protection Dosimetry 102, 7-22 (2002).