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Recombination Measurements of the CERF Beam monitor for a 120 GeV/c Hadron Beam

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Abstract

The exact knowledge of the performance of the CERF beam monitor is essential, since it serves to normalize the experimental data to the number of particles in the H6 beam. Therefore a series of studies were started in the calibration laboratory of CERN with radioactive gamma sources [Gsc00a] and at CERF with a mixed hadron beam of p=120 GeV/c and 40 GeV/c [Gsc00b]. Among other things the recombination of the CERF beam monitor for a hadron beam of p=120 GeV/c was investigated for several beam intensities up to 22400 PIC-counts per spill which corresponds to about 5×10^8 beam particles per spill. These experiments have shown that the actual voltage of the PIC U=250 V is, within the uncertainties, in the region of ion saturation. Thus no correction factors due to recombination losses are required for the CERF beam monitor up to the intensities mentioned above.

1 Motivation

The beam at CERF is monitored by a Precision Ionization Chamber (PIC), which is installed about 405 m downstream the T4 production target and a few metres upstream from the secondary target of CERF. It is an open air ionization chamber with cylindrical shape. Its sensitive volume is 0.86 litres (diameter: 185 mm, active length: 32 mm). The exact design of the PIC is described in [Aro93]. The ionization current is fed into a charge digitiser: the charge produced by ionization is collected at a capacitor. Whenever this charge attains a predefined threshold, the capacitor is discharged and issues one count that is a measure of the number of beam particles which have produced this charge.

The PIC serves to normalise the experimental data to the number of particles in the H6 beam. Thus the knowledge of its performance is essential. In the past a series of measurements determined its calibration factor for a 120 GeV/c beam (Γ_{120} = (23264 $\pm$ 988) particles per PIC-count) and a 40 GeV/c beam (Γ_{40} = (24475 $\pm$ 337) particles per PIC-count) [Gsc00b]. Other measurements in the calibration laboratory at CERN have shown that the PIC needs about 2 hours to stabilise, it shows no electronic noise, its response is linear up to air kerma rates $\dot{K}_a$ = 30 mGy/h (the limit of the gamma source) and it shows no leakage currents [Gsc00a].

Also recombination measurements were performed in the CERN calibration laboratory [Gsc00a], which have shown that the PIC is operating within the region of ion saturation for homogeneous gamma irradiation with air kerma rates up to $\dot{K}_a$=30 mGy/h. This corresponds to $\dot{K}_a$=8.3 μGy/s and was the maximum achievable air kerma rate with the available radioactive sources. At CERF the beam consists of hadrons and has beam dimensions of typically a few centimetres and a local dose rate along the beam track of several mGy/s. Since the results obtained from the gamma measurements are not easily adaptable to the H6 environment, recombination measurements were directly performed at CERF under real test beam conditions.

2 Experimental Set-Up

The recombination measurements were performed in May 2000 at CERF. The H6 beam was derived from the T4 target station served by a primary proton beam with a momentum of p=450 GeV/c with typical intensities of several 10^{12} protons per spill. The target was made of a 2 mm$\times$ 160 mm beryllium plate 300 mm long. A schematic plan of the elements of the H6 beam optics and their position can be found in [Amb99]. The momentum of the secondary particles was p=120 GeV/c with a particle composition of 61% pions, 35% protons and

4% kaons at the position of the PIC [Vin99]. The total SPS cycle had a period of 14.4 s with a spill of t=2.37 s. The intensity of the beam was controlled by the two collimators C3 and C5. Saturation curves of the PIC for different H6 beam intensities were recorded. For this purpose the collimator settings were varied in order to obtain PIC count rates between ∼310 and ∼22400 counts/spill (see Table 1).

Table 1: *Parameters during the measurements of the voltage characteristic curves of the PIC.*

Saturation PIC-Rate [ct/spill]	**Beam Fluctuation** [%]	**Settings** Collimator3	Collimator5
∼ 310	2.4	1	3
∼ 6300	7.5	15	20
∼ 10800	3.2	30	20
∼ 16800	5.2	20	15
∼ 19600	4.1	20	20
∼ 22400	3.3	25	25

For each collimator setting data were taken for the voltages U=25 V, 50 V, 100 V, 150 V, 200 V, 300 V, 400 V and 500 V. Additionally, the number of primary protons on the T4 target was recorded in order to correct the PIC reading due to beam intensity fluctuations. However, the measurements were performed in a period of very stable beam conditions. The half difference between the maximum and minimum beam intensity during the data acquisition of each saturation curve ranged between 2.4% and 7.5%. For each voltage setting up to five PIC responses per spill and the respective proton intensities on T4 per spill were recorded. In order to correct slight beam fluctuations, the quantity

$$\left\langle \left. \frac{PIC - count/spill}{p_{T4}/spill} \right|_{V} \right\rangle \cdot \left. \langle p_{T4}/spill \rangle \right|_{collset} \tag{1}$$

is plotted in Figure 1 as a function of PIC voltage and beam collimator setting. It is the average of the PIC count rates ($PIC-count/spill$) normalised to the proton rate on T4 ($p_{T4}/spill$) for one voltage setting, multiplied with the mean proton rate for each collimator setting. The uncertainty derives from error propagation of the single standard deviations.

Figure 1 shows clearly that the nominal voltage setting of the PIC U=250 V is, within the uncertainties, in the region of ion saturation for all measured H6 beam

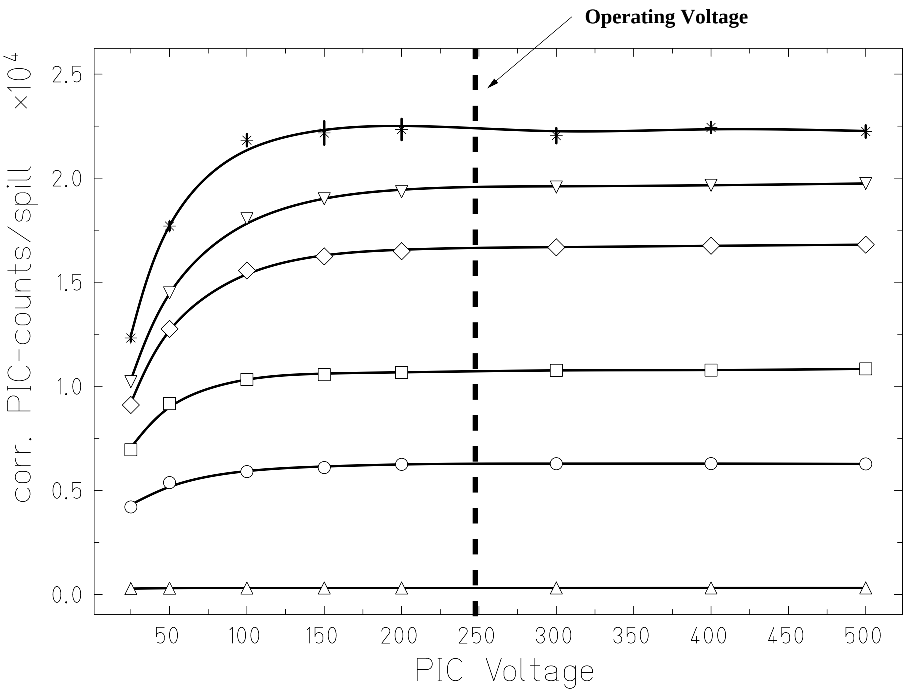

Figure 1: *Voltage characteristic curves of the PIC for different beam intensities, i.e different collimator settings (symbols) as given in Table 1. The PIC count rate is corrected for slight beam fluctuations.*

intensities. Thus up to about 22400 PIC counts per spill, which corresponds to about $5{\times}10^8$ beam particles per spill, no correction factors due to recombination losses are required for the CERF beam monitor. The 'classical way' of evaluating ion saturation, a plot of 1/I vs. 1/V [Kno79], was not possible due to the beam intensities fluctuations.

3 Conclusions

The exact knowledge of the PIC performance is essential, since it serves to normalise the experimental data to the number of particles in the H6 beam. Therefore a series of measurements were started at CERF and at the calibration laboratory at CERN to determine the calibration factor for two different beam momenta [Gsc00b] and other relevant parameters like the warm-up time, electronic noise, linearity and possible existing of leakage currents [Gsc00a]. Recombination measurements of the PIC were first performed in the calibration laboratory with radioactive gamma sources of air kerma rates up to $\dot{K}_a$=8.3 μGy/h [Gsc00a] and then at CERF with a hadron beam of up to $5{\times}10^8$ beam particles per spill and dose rates up to several mGy/s (never reached during normal CERF runs).

All those measurements have shown that the nominal voltage setting of the PIC U=250 V is, within the uncertainties, in the region of ion saturation. Thus no correction factors due to recombination losses are required for the CERF beam monitor.

References

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