EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
CERN — SL DIVISION

CERN-SL-2001-026 BI

Sensitivity Studies with the SPS Rest Gas Profile Monitor

G. Ferioli; C. Fischer; J. Koopman; M. Sillanoli.

CERN, Geneva – CH

Abstract

During the SPS run in the year 2000 further test measurements were performed with the rest gas monitor.

First, profiles of single circulating proton bunches were measured and the bunch charge progressively reduced, in order to determine the smallest bunch intensity which can be scanned under the present operating conditions. The image detector in this case was a CMOS camera.

Using a multi-anode strip photo-multiplier with fast read-out electronics, the possibility to record profiles on a single beam passage and on consecutive turns was also investigated. This paper presents the results of these tests and discusses the expected improvements for the operation in 2001.

Moreover, the issue of micro channel plate ageing effects was tackled and a calibration system based on electron emission from a heating wire is proposed. The gained experience will be used for the specification of a new monitor with optimised design, to be operated both in the SPS and in the LHC.

Presented at DIPAC 2001 – Grenoble– France

13 – 15 May 2001

Geneva, Switzerland
May 2001

SENSITIVITY STUDIES WITH THE SPS REST GAS PROFILE MONITOR

G. Ferioli, C. Fischer, J. Koopman, M. Sillanoli, CERN, Geneva, Switzerland

Abstract

During the SPS run in the year 2000 further test measurements were performed with the rest gas monitor.

First, profiles of single circulating proton bunches were measured and the bunch charge progressively reduced, in order to determine the smallest bunch intensity which can be scanned under the present operating conditions. The image detector in this case was a CMOS camera.

Using a multi-anode strip photo-multiplier with fast read-out electronics, the possibility to record profiles on a single beam passage and on consecutive turns was also investigated. This paper presents the results of these tests and discusses the expected improvements for the operation in 2001.

Moreover, the issue of micro channel plate ageing effects was tackled and a calibration system based on electron emission from a heating wire is proposed. The gained experience will be used for the specification of a new monitor with optimised design, to be operated both in the SPS and in the LHC.

1 INTRODUCTION

A residual gas ionisation beam profile monitor (IPM) is considered as one of the instruments for measuring the transverse beam size of the proton beams in the SPS and in the LHC. A monitor from DESY has been modified and is under test in the SPS [1][2]. Previous measurement campaigns have shown that adequate accuracy and resolution can be achieved. During 2000 the sensitivity limit of the monitor was probed. It was operated in both a high spatial resolution read-out mode, using a standard CMOS camera, and a high speed read-out mode, employing a miniature photo-multiplier tube with 16 anode strips.

In the LHC the instrument will have to deal with beam intensities varying from one pilot bunch, (5×10^{9} protons), up to 2808 bunches of 1.67×10^{11} protons each (ultimate current): a dynamic range in the order of 10^{5}.

The acquisition speed is another important issue, since the device may also be used to verify the quality of the betatron matching at injection into the SPS and the LHC [3]. For that purpose a single nominal bunch, (1.1×10^{11} protons), should be measured on a turn by turn basis (23.1 μs in the SPS and 88.9 μs in the LHC).

One of the problems encountered, when exploiting IPM monitors, is the ageing of the micro channel plate (MCP). This ageing affects the area of the MCP where the beam is imaged. To track this effect and correct for it, a remote controlled built-in calibration system would be very useful. A method is proposed using a heating wire acting as an electron source. The feasibility of such a correction system has been checked in a dedicated laboratory set-up.

2 SENSITIVITY LIMIT

2.1 High spatial resolution read-out set-up.

In the first half of the 2000 SPS run, a read-out system integrating a standard CMOS camera, with a 25 Hz frame rate associated to CERN designed acquisition electronics, was installed. Beam profiles, integrated over 866 SPS turns, were provided every 40 ms. Figure 1 shows 108 consecutive horizontal profiles acquired during the SPS acceleration cycle, starting at injection.

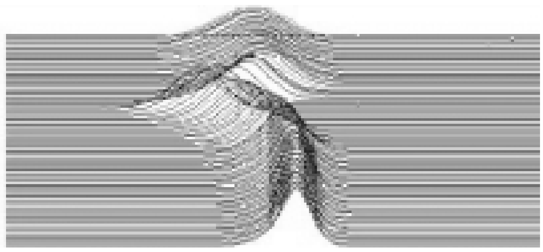


Figure 1: 108 consecutive horizontal profiles of a bunch of 6×10^{10} protons accelerated in the SPS.

These measurements are performed on a single bunch of 6×10^{10} protons, (half the nominal LHC intensity). Profiles are very well defined, as can be seen in Figure 2, and the shrinking of the r.m.s. beam size (from 1.2 to 0.7 mm) during acceleration can be easily distinguished.

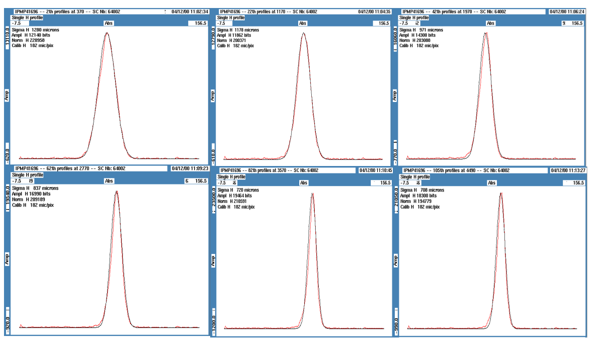


Figure 2: Six horizontal individual bunch profiles of a bunch of 6×10^{10} protons accelerated in the SPS.

The profile of a bunch of 6.10^{9} protons, nearly an LHC pilot bunch, is displayed in Figure 3. This measurement was performed with all gains set at maximum, while maintaining the nominal SPS rest gas pressure of 10^{-8} hPa. The signal, although rather noisy, is still exploitable.

This confirms that this set-up is suitable for transverse profile measurements throughout the full intensity range of LHC beams. The large dynamic range can be handled with by acting on several parameters: the MCP gain, the phosphor screen gain, the camera lens diaphragm opening, and the video gain. A further possibility is to locally increase the residual gas pressure by injection of gas (N2). This will allow for precision measurements at low beam intensities, (pilot bunches), in the LHC where the residual pressure will be lower than in the SPS by at least one order of magnitude.

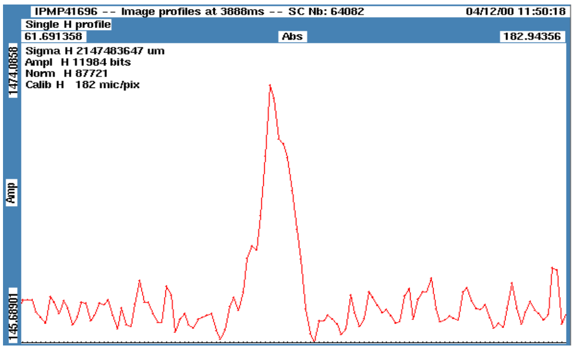


Figure 3: Horizontal profile of a bunch of 6×10^{9} protons.

2.2 High speed read-out set-up.

In the second half of the SPS run a Photo Multiplier Tube (PMT) with 16 anode strips and dedicated, CERN designed, high speed acquisition electronics [4], were associated to the IPM. The phosphor used was of the P46 type, claimed to have a decay time of 0.3 µs down to 10% and 90 µs down to 1%. This set-up allowed for profile measurements at the SPS beam revolution frequency (43.3 kHz). Such profiles measured at injection on 6 consecutive SPS turns, with good definition, are represented in Figure 4.

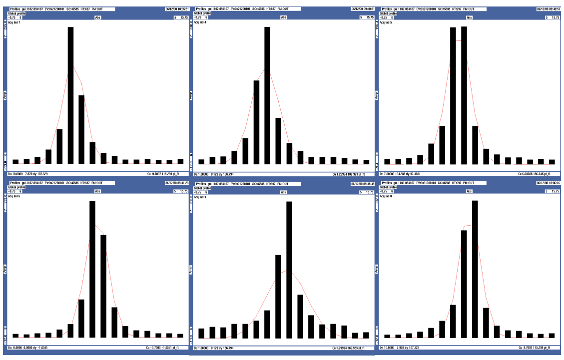


Figure 4: Horizontal profiles of a beam of 1.5×10^{12} protons (40 bunches), on six consecutive SPS turns.

Beam size and position oscillations following injection can be observed in Figure 5, (time axis from upper right to down left corner). Figure 6 represents the associated average position oscillation with a maximum excursion of ±3mm.

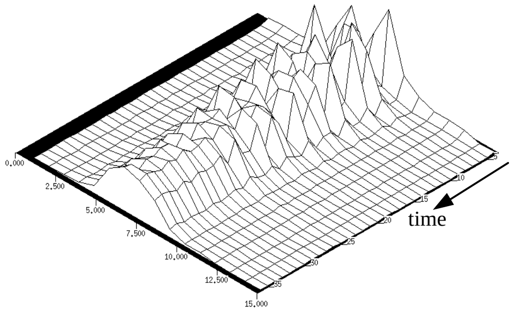


Figure 5: Profiles measured on 37 consecutive turns after injection of a beam of 1.5×10^{12} protons (40 bunches).

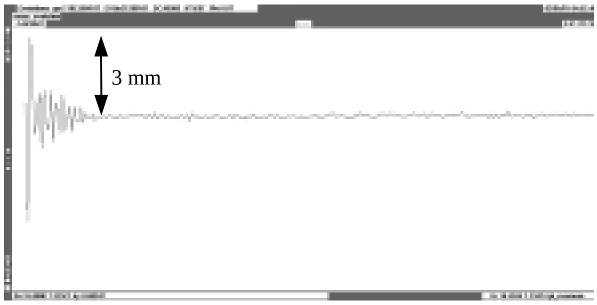


Figure 6: Corresponding oscillations in average position (±3mm maximum amplitude).

The previous measurements were carried out with a beam of 1.5×10^{12} protons consisting of 40 bunches. They were repeated with a single bunch of 3.5×10^{10} protons. Results are displayed in Figure 7. The signal is somewhat noisier, with a few random spikes, but it is still exploitable.

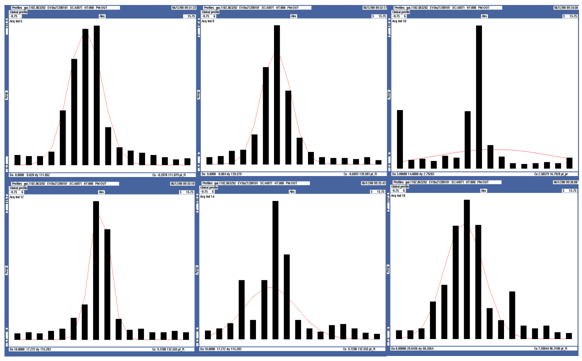


Figure 7: Horizontal profiles of a bunch of 3.5×10^{10} protons, on six consecutive SPS turns.

The evolution of the bunch size measured over 195 SPS turns just after injection is represented in Figure 8. A blow-up of about 5 mm, created deliberately, is clearly observed on the rms value.

One drawback of this high speed read-out system was its low spatial resolution. Both position oscillations and beam-size variations had to be coped with. A range of 50.5 mm at the beam level was covered with the 16 channels of the PMT, resulting in a resolution of 3.16 mm/strip. Reducing this range to 40 mm should be acceptable. Moreover, a new design is under way that

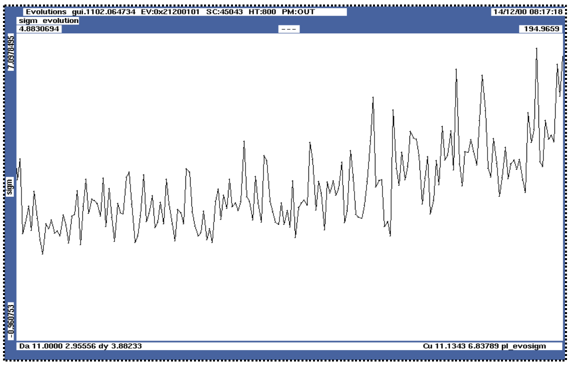


Figure 8: Evolution of the horizontal rms value of a bunch of 3.5×10^{10} protons over 195 turns.

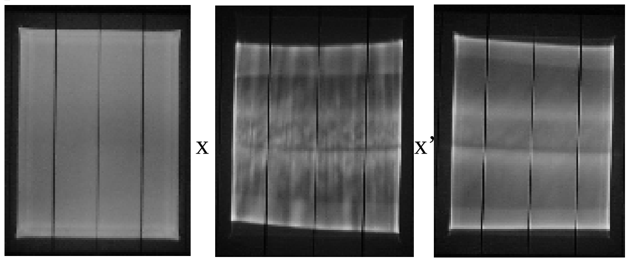
uses a PMT with 32 channels. Hence, the optics of the system can be modified to reach a resolution of 1.25 mm/strip.

3 MCP CALIBRATION SYSTEM.

One recurrent problem with instruments employing micro channel plates is ageing. MCP's lose gain after having delivered a certain amount of charge, resulting in erroneous measurements. To correct for this phenomena a built-in remote controlled electron source could be employed. This source must deliver a uniform and, even more important, stable distribution of electrons onto the MCP input face. One of the most simple electron sources is a glowing wire. Applying an electrical extraction field with sufficient strength will induce enough energy to the liberated electrons to excite the MCP.

A laboratory set-up was built to test the principle. Inside a windowed vacuum tank, a wire made of an alloy of Tungsten (75%) and Rhenium (25%), with a diameter of 50 µm, was stretched in a 80 mm wide supporting fork. This fork was placed on a carriage allowing the distance between MCP-input and wire to be varied from 5 mm to 60 mm. A DC voltage was applied to the wire ends inducing a current of 0.5 A, causing the wire glow red. Behind the wire and around the input face of the MCP, two large parallel plates were mounted to ensure the uniformity of the extraction field. A voltage of a few tens of Volts was applied on the wire with respect to the plate behind it in order to reject the emitted electrons towards the MCP. An extraction field of several hundreds of Volts was applied between the wire and the MCP input, thus giving enough energy to the electrons to excite the MCP. The phosphor behind the MCP was of the P46 type and could be observed through the window.

The first results are encouraging. Figure 9(a) shows an image of the light density distribution from the phosphor obtained with the glowing wire at a distance of 60 mm from the MCP input face. The distribution looks fairly homogeneous. The exercise has been repeated a few weeks later under the same conditions. No alteration of the pattern was observed, indicating that the distribution may be reproducible with time. Ageing of the wire should not be an issue, since it is operated only for very short periods of time.



(a) (b) (c)

Figure 9: Light density distributions from the phosphor.

One of the problems encountered in this set-up was an erratic emission pattern along the wire in the xx' direction, Figure 9(b), clearly observable when it was placed at 5mm from the MCP input face. Neither polishing nor cleaning the wire in a solvent cleared the problem. Heating the wire for some minutes at a very high temperature, the wire was then lighting up white, did, however, improve the emission pattern: Figure 9(c).

The obtained light density distribution is not homogeneous enough yet to be used as an absolute calibration system. A peak to peak modulation of about 25% can be measured. It should be sufficient, however, to track the ageing of the MCP. Using two or more wires in parallel at some distance may improve the uniformity of the light distribution. The principle of this system will be integrated into a new IPM design, under preparation, to be installed next year in the SPS.

4 CONCLUSION.

The tests carried out in the SPS during the year 2000 with the rest gas monitor, show that it will probably be possible to acquire profiles down to the LHC pilot bunch level (5×10^{9} p). In the turn by turn mode, an improvement of the resolution by a factor of 2.5 is expected, in order to also use the device for injection matching studies.

A future rest gas monitor design will incorporate two parallel heating wires, emitting electrons, to track and correct for the ageing of the micro channel plate.

REFERENCES

[1] Fischer, C., Koopman, J., Measurements made in the SPS with a Rest Gas Profile Monitor by collecting Electrons, BIW 2000, Boston, USA, May 2000.

[2] K. Wittenburg, Emittance measurement in the Proton Accelerator in DESY, Emittance in Circ. Accel., KEK 95-7, Sept. 1995.

[3] Bovet, C., Jung, R., A new Diagnostic for Betatron Phase Space matching at Injection into a circular Accelerator, EPAC '96 Sitges, Spain, Jun 1996.

[4] Ferioli, G. et Al., Beam profile measurements at 40 MHz in the PS to SPS transfer channel, DIPAC'99. Chester, UK, May 1999.