SENSITIVITY STUDIES WITH THE SPS REST GAS PROFILE MONITOR

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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 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 is tackled and a calibration system based on electron emission from a heating wire. 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 actual 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.

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

The acquisition speed is another important issue, since the device may also be used to measure 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 scanned 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

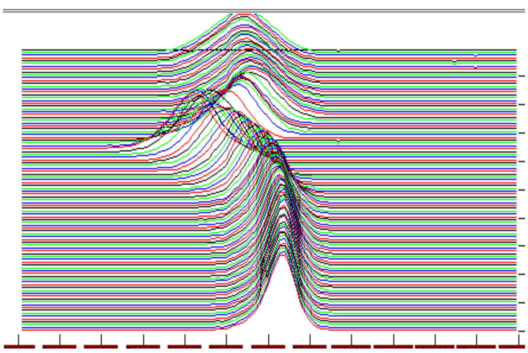

Figure 1: 108 consecutive horizontal profiles of a bunch of 6.10^{10} protons accelerated in the SPS.

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, are then provided every 40 ms,. Figure 1 shows 108 consecutive horizontal profiles acquire during the SPS acceleration cycle.

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 on Figure 2, and the shrinking of the r.m.s. beam size (from1.2 to 0.7 mm) during acceleration can be easily distinguished

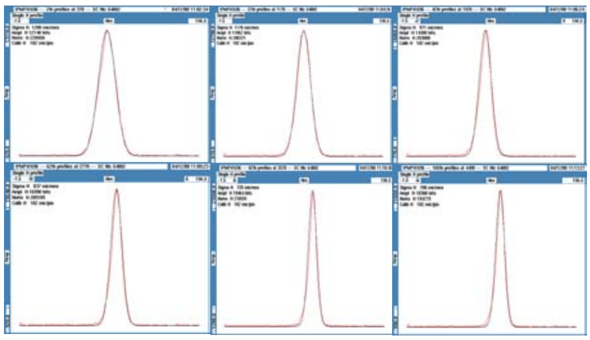

Figure 2: Six horizontal individual bunch profiles of a bunch of 6.10^{10} protons accelerated in the SPS

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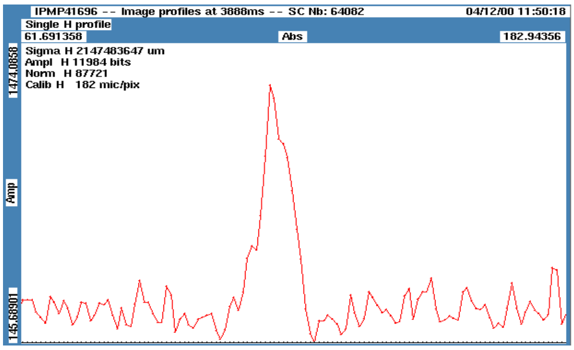


Figure3: Horizontal profile of a bunch of 6.10^9 protons

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, but at the nominal SPS rest gas pressure of 10^{-8} T. The signal, although rather noisy, is still exploitable. This confirms that this set-up is suitable throughout the intensity range of LHC beams. The intensity dynamic range can be handled with several parameters: the MCP gain, the phosphor screen gain, the camera diaphragm opening, and the video gain. A further facility is to locally increase the residual pressure by injection of gas (N2). This will allow 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.

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, expected 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.

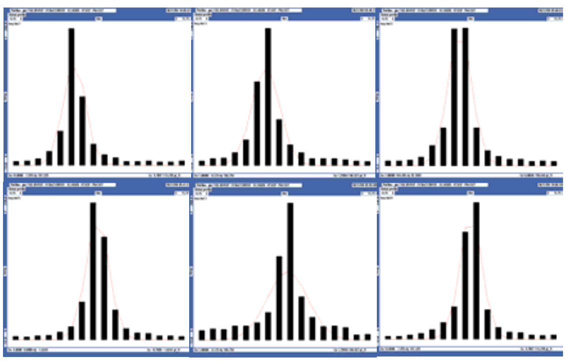


Figure 4: Horizontal profiles of a beam of 1.5 10^{12} protons (40 bunches), on six SPS consecutive turns.

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

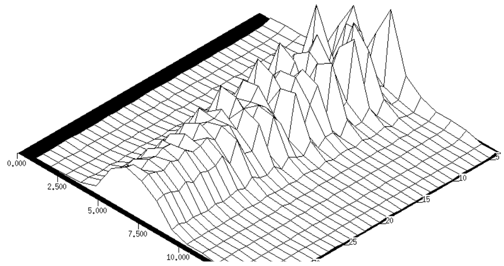
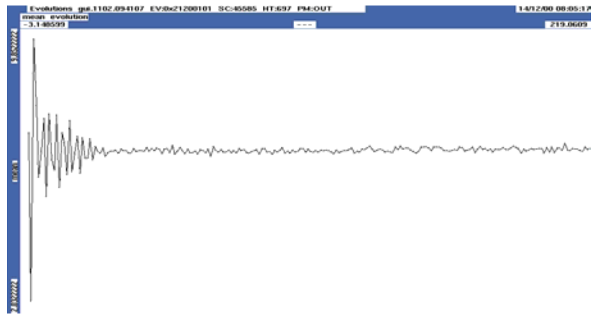


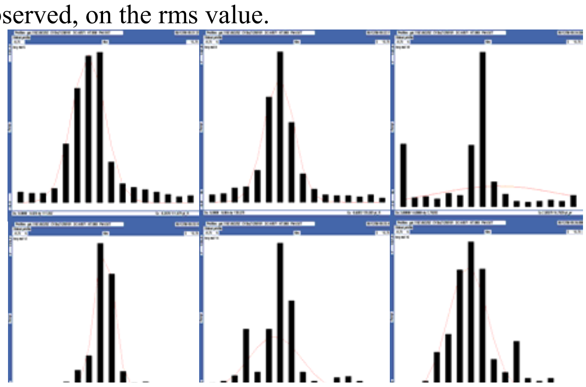
Figure 5: Profiles measured on consecutive turns at injection of a beam of 1.5 10^{12} protons (40 bunches)

Figure 6: Horizontal profiles measured on consecutive



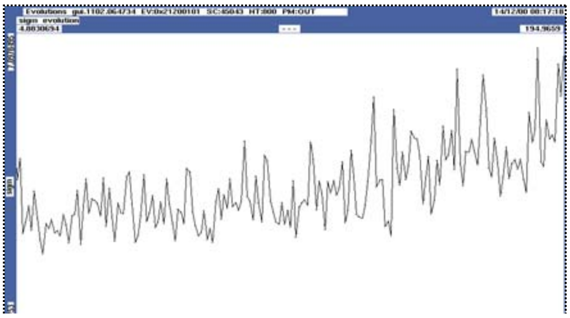
The previous measurements were carried out with a beam of 1.5×10^{12} protons made of 40 bunches. They were repeated with a single bunch of 3.5×10^{10} protons. Results are displayed in Figure 7. The signal is somewhat noisier with a few random spikes, but it is still exploitable.

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 read-out system set-up was its low spatial resolution. Both position oscillations and beam-sizes variation had to be coped with. and a range of

50 mm was covered at the beam level with the 16 channels of the PMT, resulting in a resolution of 3.1mm/strip. Reducing this range to 40 mm should be possible. Moreover, a new design is under way that uses a PMT with 32 channels. Hence, the optics of the system can be modified to reach a resolution of 1.25 mm/strip, i.e an improvement of the resolution by a factor 2.5.



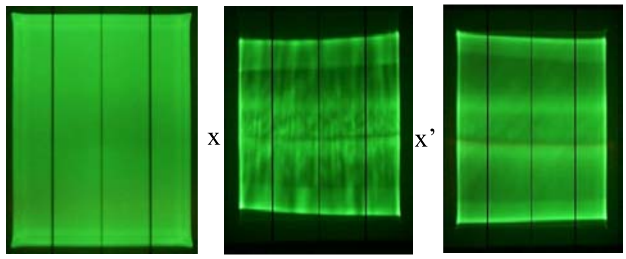
3 MCP CALIBRATION SYSTEM.

One recurrent problem with instruments employing micro channel plates is ageing, MCP's loosing gain after having delivered a certain amount of charge. The gain drop follows the charge delivering pattern and is most of the time non-uniform, resulting in erroneous measurements. To overcome this problem, it would be very helpful to dispose of a built-in remote controlled calibration system that can be used at any time. For this purpose an electron source could be employed. This source is must deliver a fairly 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 of sufficient strength will give 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 thickness of 50 µm, was stretched in a supporting fork (80 mm wide). This fork was placed on a carriage allowing the distance between MCP-input and the wire to be varied from 5 to 60 mm. A DC voltage was applied to the wire ends inducing a current of 0.5 A, making the wire glow red. Behind the wire and around the input face of the MCP, 2 large parallel plates were mounted to ensure the uniformity of the extraction field. A low voltage was applied, (a few tens of Volts), 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 laboratory set-up was designed such as to resemble as much as possible the actual IPM structure.

The first results are encouraging. In Fig. 9(a) a picture is shown of the light density distribution from the phosphor obtained with the glowing wire at a distance of



(a) (b) (c)

Figure 9: Light density distributions from the

60 mm from the MCP-input. The distribution looks fairly homogeneous. The observations have been repeated an interval of a few weeks 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.

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

Another issue is the deformation of the hot wire, causing it to emit in a non-uniform way. This was solved by adding a compensating spring.

Although the obtained light density distribution is not homogeneous enough yet (a peak to peak modulation of about 25% can be measured) to be used as an absolute calibration system, 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 distribution. The principle of this system will be integrated into a new IPM design, under preparation to be installed next year in the SPS.

REFERENCES

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[3] K. Wittenburg, Emittance measurement in the Proton Accelerator in DESY, Emittance in Circ. Accel., KEK 95.

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