BEAM TEST OF THE FAIR IPM PROTOTYPE IN COSY

C. Böhme, Technical University Dortmund, Germany
J. Dietrich, V. Kamerdzhiev[#], FZJ, Jülich, Germany
P. Forck, T. Giacomini, GSI, Darmstadt, Germany
D. Liakin, ITEP, Moscow, Russia

Abstract

The advanced ionization beam profile monitor is being developed at GSI for the future FAIR facility in collaboration with ITEP and FZ-Jülich. In January 2009 the IPM prototype was installed in COSY-Jülich. After successful hardware test the beam tests followed. The prototype was operated without magnetic field, thus only residual gas ions were detected. An arrangement consisting of an MCP stack, a phosphor screen, and a CCD camera was used to detect ions. We report the first profile measurements of the proton beam up to 2.8 GeV at COSY.

INTRODUCTION

The Ionization Profile Monitor (IPM), currently under development at GSI, is intended to provide fast and reliable non destructive beam profile measurements at the future FAIR machines as well as the existing accelerators at GSI [1]. The ionisation products are guided to a position sensitive detector by transverse electric field. Two modes of operation are foreseen. Ion detection is used to obtain the profiles with high spatial resolution by means of a phosphor screen (PS) and a CCD camera [2]. Detection of electrons is required to allow for turn-by-turn profile measurements. This will be done by using a multichannel photomultiplier [3]. Collection of electrons makes the presence of a guiding magnetic field necessary in order to prevent the electrons from spreading out. The magnetic system is being designed in collaboration with iThemba LABS, South Africa.

THE IPM SETUP AT COSY

The IPM prototype was installed in COSY to study its performance and gain operational experience. It is not equipped with a magnet; hence only ion detection technique can be applied. An arrangement consisting of an MCP stack (100x48 mm^2), a P47 phosphor screen, and a 656×494 pixel CCD camera is used to detect ions. High voltage electrodes provide the electric field for ion extraction. The IPM prototype actually contains two identical units to provide simultaneous measurements in both, horizontal and vertical, planes. Figure 1 shows the design of the IPM prototype installed in the arc downstream of the cooler telescope.

The cameras are read out by a LabView server application running on a PXI based front end. The user interacts with the front end from the accelerator control room by means of a client program running on a PC. Both the server and client applications were developed by a private company according to the GSI specifications.

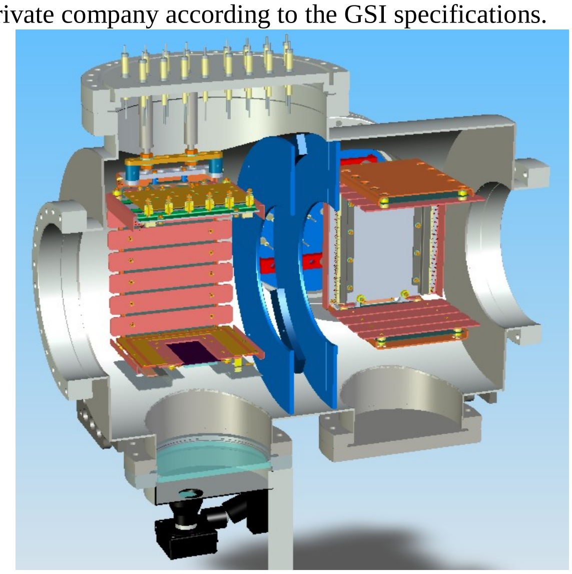

Figure 1: Mechanical design of the FAIR IPM prototype.

In order to be able to monitor and control the aging of the MCPs the monitor is equipped with UV lamps that are capable of homogeneously irradiating the whole MCP surface. This feature is used to correct the detector sensitivity inhomogeneity. Profiles of the polarized and unpolarized proton beams circulating in COSY were measured covering the full energy range of the machine.

BEAM PROFILE MEASUREMENTS

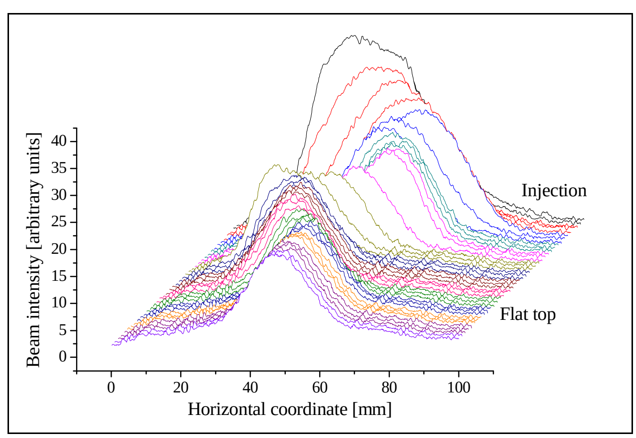

Figure 2: Evolution of the horizontal proton beam profile during injection and acceleration to 1.343 GeV/c. About $3 \cdot 10^9$ polarized protons reached flat top. Time span is 2 s. Corrected for spatial detector sensitivity distribution via UV calibration. 5 pts moving average smoothing was applied.

[#]v.kamerdzhiev@fz-juelich.de

The beam profile measurements were carried out at various proton beam energies. The ion extraction voltage was set to 4400 V, the MCP voltage to 1950 V and the MCP to PS voltage to 3800 V. The accelerator timing system was set up to trigger the IPM data acquisition before the proton injection occurred and stop it at the end of flat top. Figure 2 shows the fast evolution of the horizontal profile of the polarized proton beam during injection and acceleration to 1.343 GeV/c. The behaviour of the vertical profile is shown in Figure 3. One can clearly see particle losses in both planes. However, only horizontal beam motion is observed. The data was recorded at a rate of 20 profiles per second in each plane. ANKE internal target was on [4].

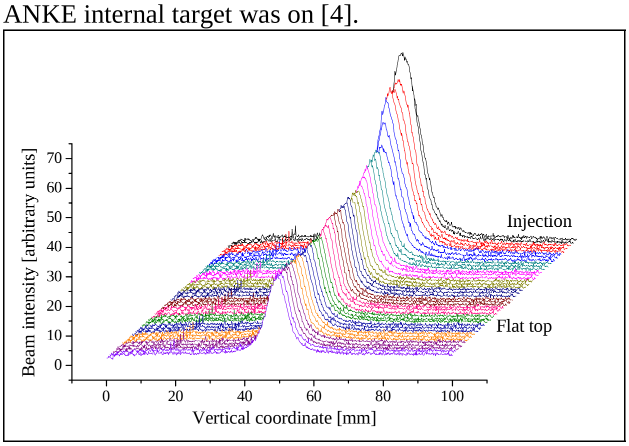

Figure 3: Evolution of the vertical proton beam profile during injection and acceleration to 1.343 GeV/c. About $3{\cdot}10^9$ polarized protons reached flat top. Time span is 2 s.

Figure 4 and Figure 5 show the slow evolution of the horizontal and vertical polarized proton beam profile at 1.343 GeV/c flat top. The beam quality degradation is due to the ANKE internal target which was estimated to be about $3{\cdot}10^{14}$ atoms/cm^2 thick at the time of measurement.

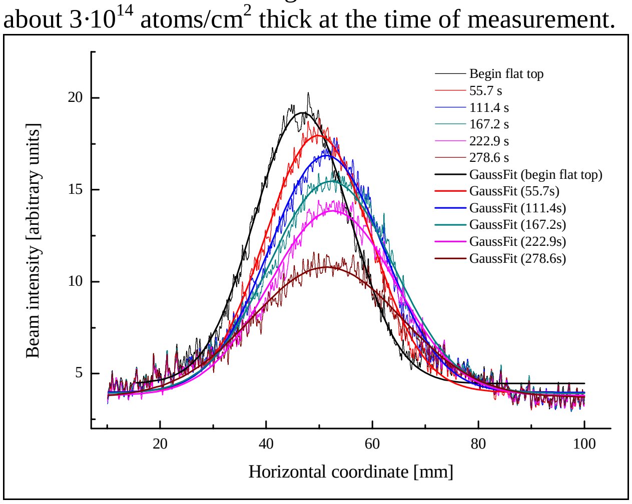

Figure 4: Horizontal profiles of the polarized proton beam at 1.343 GeV/c. The profile measurement started once the flat top was reached. COSY was operating in a 300 s cycle for ANKE experiment. Internal target on.

The acquired profiles agree well with the expected ones and are nicely fitted with a Gaussian, except for some tails in horizontal plane and peaks in the vertical plane (not shown in Figure 5 for readability reasons).

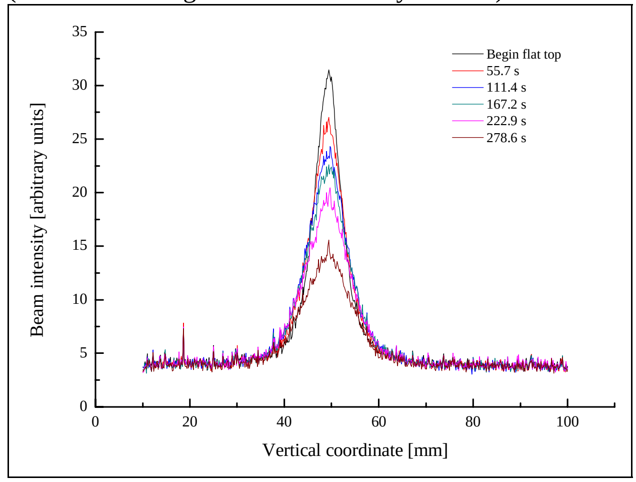

Figure 5: Vertical proton (polarized) beam profiles at 1.343 GeV/c flat top. Recorded during a 300 s COSY cycle with ANKE internal target on.

The profile integrals calculated by the client application agree very well with the beam current measured by the beam current transformer (BCT) (see Figure 6).

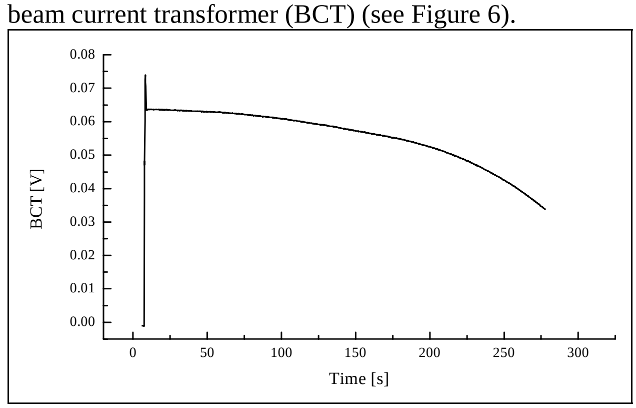

Figure 6: Beam current transformer signal.

EXPERIENCE AND CHALLENGES

Figure 7 shows the horizontal beam (unpolarized protons) image as seen by the CCD camera on the PS. The image width corresponds to the full width (100 mm) of the P47 screen. The beam is intentionally offset to optimize extraction. The unexpected light spot in the centre (horizontally) on the lower edge of the PS may be explained by light reflection. However, it is not yet clear whether it takes place in the glass substrate of the screen or is a result of multiple reflections in the vacuum chamber.

Figure 8 shows the vertical beam image. There are indications that the vacuum window may be contributing to the light reflection. The edges of the PS seem to appear twice in the camera image. This could be due to the light reflection from the screen holder as well. These issues require further investigation and dedicated studies. For example, it would be very useful to study the phenomena mentioned above by varying the beam position at the IPM location. This would allow for better understanding of geometrical dependencies and eventually, identifying the origin of the problem.

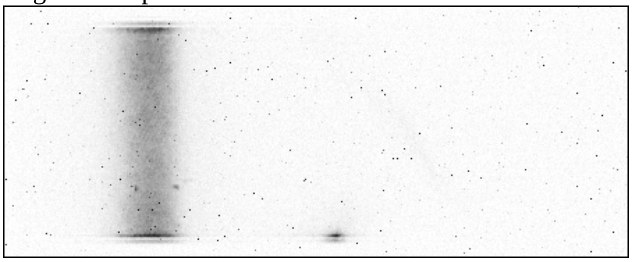

Figure 7: Horizontal beam image as seen by the camera on the PS. The greyscale image is inverted for better readability.

The camera images were cropped using the client application, prior to profile calculation to prevent the phenomena, taking place on the PS edges, from distorting the profiles.

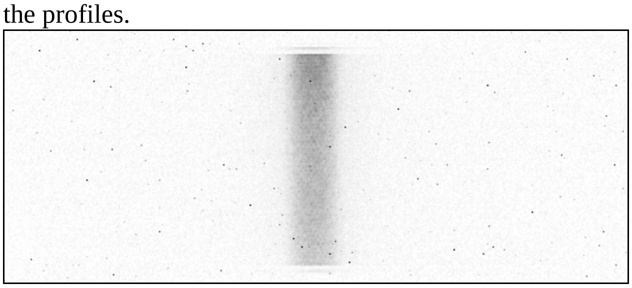

Figure 8: Vertical beam image as seen by the camera on the PS. The greyscale image is inverted for better readability.

The accumulated radiation damage of the CCD chips needs to be characterized quantitatively in order to be able to develop modes of operation assuring the longest possible lifetime. Summing the brightness values for all pixels while there is no beam in the machine and the IPM HV is off could provide a simple and robust way of monitoring the camera condition. A sophisticated algorithm for bad pixel correction is already built into the front end software.

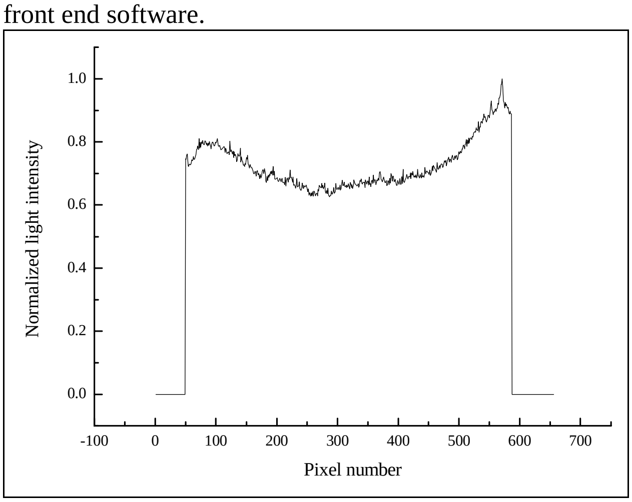

Figure 9: An example of the detector sensitivity distribution measured by illuminating the MCP surface with UV light and observing the PS light with the camera.

The UV lamps (120 nm wavelength) installed in the IPM have proven themselves very useful for monitoring and correction for the detector sensitivity distribution.

Vacuum problems due to operator errors at the early stages of testing showed the necessity to have built-in safety features in the HV power supply control software. Such software was developed and commissioned at FZ-Jülich. The program checks the user input against a series of plausibility criteria. In addition the user is not required to provide the absolute voltages on the electrodes. Instead, physical values, like MCP voltage or MCP to PS voltage are used. These measures made the IPM operation more user friendly and safe.

SUMMARY

The IPM prototype developed by GSI for the future FAIR accelerators was installed in COSY for testing. The monitor was used to measure horizontal and vertical profiles of polarized and unpolarized proton beams in the intensity range of 10^9 to $3 \cdot 10^{10}$ particles in the ring. The data was recorded at a rate of 20 profiles/s in each plane at all beam energies available at COSY. Though all the results reported in this paper are preliminary, they demonstrate that the IPM delivers accurate online beam profile data and can be operated safely and reliably. The values of the profile integrals calculated by the IPM software agree very well with the BCT measurements. The observed evolution of horizontal and vertical proton beam profile throughout the accelerator cycle appears to be consistent with internal target operation and the location of the IPM in the ring.

Undoubtedly, the advanced IPM will be very useful for future beam studies at COSY e.g. beam cooling and injection optimization.

Even though the available software is still under development it allowed for reliable data acquisition and simple analysis.

We plan to replace the PXI based front end with an industrial PC equipped with a fast network card capable of supporting two Gigabit Ethernet cameras generating 200 frames/s each.

REFERENCES

[1] M. Schwickert et al., “Beam Diagnostic developments for FAIR” DIPAC09.

[2] T. Giacomini et al., “Development of a residual gas profile monitor with high resolution and fast readout”, BIW04.

[3] D. Liakin et al., “A Counting Module for an Advanced Ionization Profile Monitor”, EPAC08.

[4] S. Barsov et al., “ANKE, a new facility for medium energy hadron physics at COSY-Jülich”, NIMA, 462, 3, 21 April 2001.