IONISATION BEAM PROFILE MONITOR AT THE COOLER SYNCHROTRON COSY-JÜLICH

V. Kamerdzhiev, J. Dietrich, Forschungszentrum Jülich GmbH, Germany

Abstract

For beam profile measurements, a residual-gas ionisation beam profile monitor using a position sensitive micro channel plate (MCP) detector was developed and installed at the cooler synchrotron and storage ring COSY.

Since COSY operates with beam intensities up to 10^{11} protons/deuterons and a vacuum of 10^{-11} - 10^{-9} mbar, there is a high risk of detector damage. The aging of the channel plates was investigated by means of scanning electron microscope and energy dispersive x-ray microanalysis. Different implemented detector protection mechanisms are discussed. Profile measurements with electron cooled beams are reported.

INTRODUCTION

To optimise the performance of an accelerator precise measurements of many beam parameters are required. To determine the actual charge distribution inside the beam and to find the value of beam emittance non destructive beam profile measurements are needed. One of the known techniques [1] relies on the ionisation of residual gas by the beam particles. A device utilising this principle was installed in the COSY ring [2,3].

DESIGN

Between two electrodes a parallel ion drift field is maintained. Residual gas ions are drifted onto MCP chevron assembly that provides an electron multiplication factor up to 10^7 [4]. The secondary charge produced from each ion is collected by a wedge and strip anode (see Fig. 1) [5].

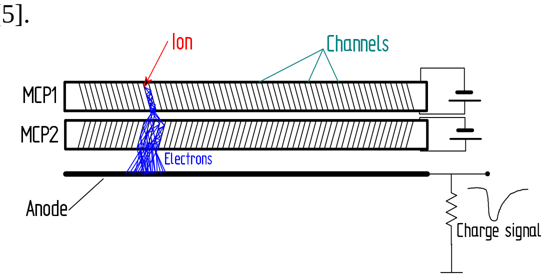

Figure 1: Position sensitive detector.

The charge signals from each electrode are first converted into time signals which are then digitised. A PC running CoboldPC software [6] is used for data readout, analysis and visualisation. The detector and the readout method used allow the measurement of position of separate residual gas ions and are especially suitable for low and medium intensity beams. The images of higher contrast compared to the phosphor screen approach are achievable [6].

Position sensitive anode

A position sensitive wedge-and-strip anode is placed on a 2 mm thick ceramic substrate of 65 mm outer diameter with germanium layer on the opposite side (see Fig. 2). The anode consists of three electrodes called by their geometry wedge, strip and meander.

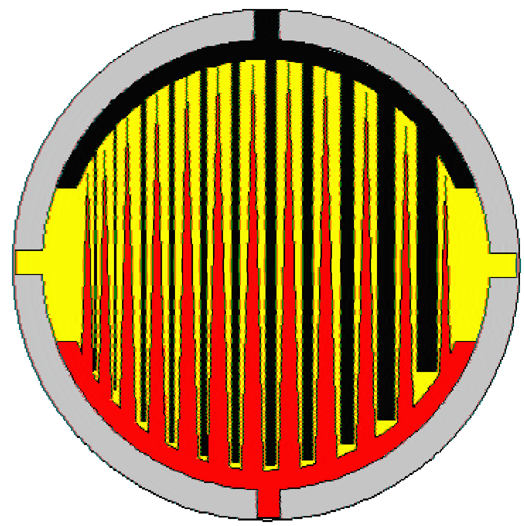

Figure 2: Wedge-and-Strip Anode.

Since this is a charge coupled device, secondary electrons leaving the MCP assembly hit the germanium layer and induce a signal on the anode structure (see Fig. 1) [7]. The charge of secondary electron cloud is distributed over all electrodes. To determine the position of cloud's centre of mass i.e. the residual gas ion coordinates one should measure the charge on each electrode independently and compute x and y values using the formulae:

$$x = \frac{Q_s}{Q_s + Q_w + Q_m};$$

$$y = \frac{Q_w}{Q_s + Q_w + Q_m}$$

where Q_s, Q_w and Q_m are measured charges on strip, wedge and meander respectively. As one can see in Fig. 2 the equations are derived just from the geometry of the anode structure.

Electronics

The charge-to-time converter is based on the LeCroy's MQT 300AL chip [3,8] which utilises a Wilkinson dual slope converter. The time signals are transported to control room where a time-to-digital converter (TDC) and a PC are installed. The TDC is connected to the computer via internal ISA card [6,9].

Software

As mentioned above CoboldPC program [6] is used for data acquisition, analysis and visualisation. The program has a modular structure and can be easily adopted for different hardware and data analysis algorithms i.e. other detector types.

RESULTS

Vertical profiles of electron-cooled and uncooled proton beam have been measured (see Fig. 3). At the moment of data acquisition there were about $1.3{\cdot}10^{9}$ protons at 45 MeV in the ring. Residual gas pressure was measured to be 10^{-9} mbar.

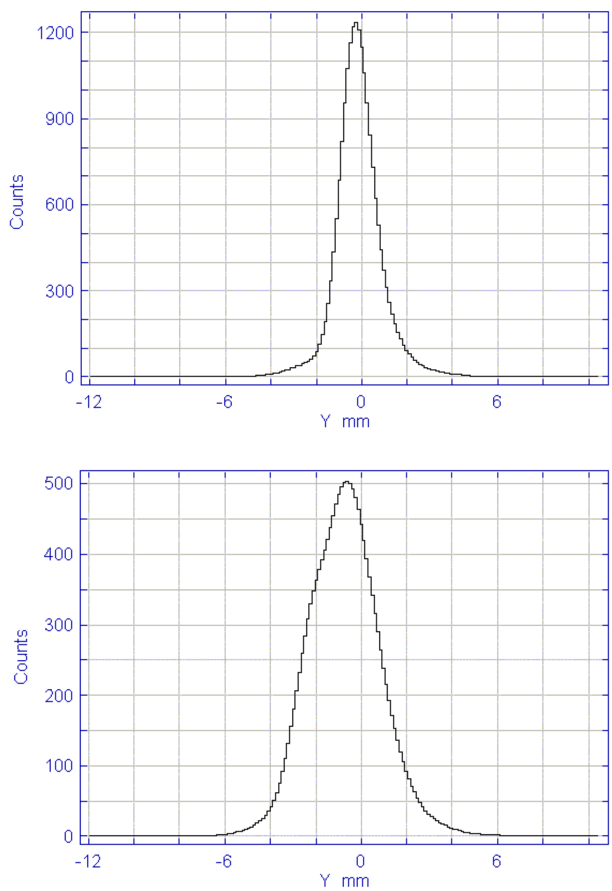

Figure 3: Profile of a cooled (upper trace) and an uncooled (lower trace) proton beam.

As one can see the density of the electron cooled beam is higher compared with the uncooled one (see fig. 4). The profile of the cooled beam meets the expectation and corresponds good to the H^0 profile measured simultaneously. However the width of the uncooled beam seems to be too small. Unexpected aperture limitations could be the reason for this discrepancy [10].

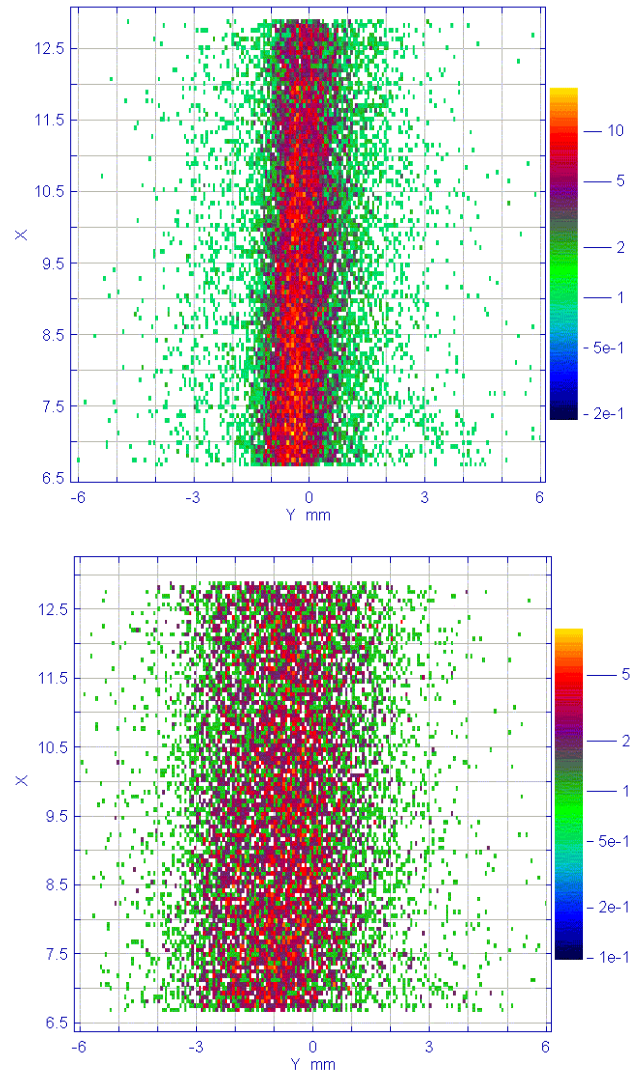

Figure 4: 2D image of a cooled (upper image) and an uncooled (lower image) proton beam.

EXPERIENCE

The lifetime of micro channel plates and the ionisation event rate are crucial issues for the profile measurement of intense proton beams. Regular monitoring of MCP condition, e.g. gain distribution and detection efficiency is necessary to provide reliable beam profile measurements. Despite we used Long-Life™ MCPs aging effects such as an inhomogeneous distribution of the gain over the surface have been observed. For monitoring and online calibration purposes an α-source has been fixed on the flange opposite to the one the detector is mounted on. So the detector can be illuminated with α-particles. Different detector protection mechanisms such as moveable (pneumatic driven) protection screen and MCP high voltage triggering were implemented to improve detector lifetime and performance. MCPs with inhomogeneous gain distribution have been investigated by means of scanning electron microscopy and energy dispersive x-ray microanalysis (EDX) [11].

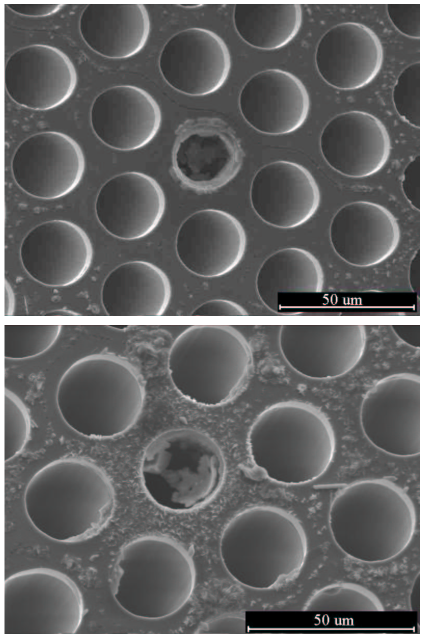

Figure 5: MCP surface seen by scanning electron microscope.

Small damaged regions on the MCP surface faced to the anode were found. Elementary composition on this regions was determined using EDX.

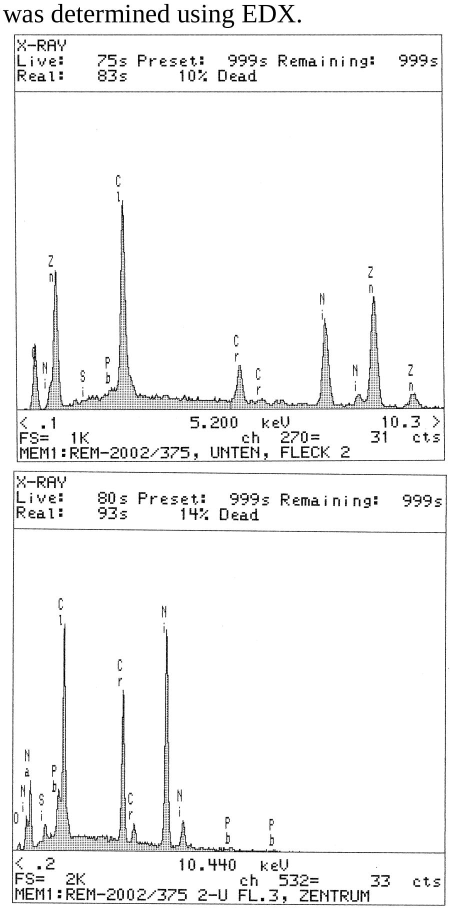

Figure 6: Energy dispersive x-ray microanalysis of the MCP surface.

We still do not properly understand the interrelation between the inhomogeneous gain distribution and damaged regions also the origin of *Cl* on the surface.

ACKNOWLEDGEMENTS

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REFERENCES

[1] K. Wittenburg, Strahlprofilmonitore für den HERA-Protonenring, DESY HERA 1986-06.

[2] M. Schulz-Rojahn, Messung von Strahlprofilen am internen COSY-Protonenstrahl mittels Restgasionisation, Doctor’s thesis, Bonn, 1998.

[3] V. Kamerdzhiev, Diploma thesis, FZ Jülich, 2000.

[4] J.L. Wiza, Microchannel Plate Detectors, Nucl. Instr. and Meth. 162 (1979) 587-601.

[5] O. Jagutzki, J.S. Lapington, L.B.C. Worth, U. Spillmann, V.Mergel, H. Schmidt-Böcking, Position sensitive anodes for MCP read-out using induced charge measurement Nucl. Instr. and Meth. A 477 (2002) 256-261.

[6] http://www.roentdek.com/.

[7] J.S. Lapington et al., Spatial resolution limitations of microchannel plate/conductive charge division readout devices, Nucl. Instr. and Meth. A 273 (1988) 663-666.

[8] LeCroy MQT 300A datasheet.

[9] http://www.acam.de/.

[10] H.J. Stein, private communication.

[11] R. Schneider, Prüfbericht Institut Fresenius, Dresden, 2002.