A BEAM PROFILE MONITOR USING THE IONIZATION OF RESIDUAL GAS

J.M. Schippers and H.H. Kiewiet *
Kernfysisch Versneller Instituut
Zernikelaan 25, 9747 AA Groningen
the Netherlands

ABSTRACT

A non intercepting beam-profile monitor for the beam-guiding system of AGOR has been designed and tested successfully. By detecting the ions created by the beam in the residual gas, a one dimensional intensity distribution of the beam is obtained. The device is suitable for a wide range of beam intensities, but especially at beam intensities below several nanoAmps it has proven to be much more sensitive than e.g. scintillation screens.

1. INTRODUCTION

A new monitor that measures the beam-intensity profile in one direction and without intercepting the beam, has been designed and tested. It is designed to be suitable for all AGOR beams. After testing a prototype version[1] also experiments with the version that will be mounted in the actual beam pipe had to be performed. Especially the life time of the device during realistic operation conditions was tested during the last months of operation of the Philips cyclotron at KVI.

2. OPERATION PRINCIPLE

The residual gas beam-profile monitor (RG-BPM) uses the ions that are created by beam particles traversing the residual gas in the beam tubes. The ions are extracted from the beam tube with a homogeneous electric field and drifted towards a pair of micro channel plates (MCP's) acting as a charge multiplier. The electrons generated in the MCP's are collected on strips parallel to the beam, so that a position sensitive readout is obtained in a direction perpendicular to the beam. By varying the amplification of the MCP's the signal magnitude can be changed, so that a large dynamic range is achieved.

It can be shown that the MCP's should operate with an amplification larger than 4×10^4 for a 200 MeV proton beam of 1 nA traversing a residual gas of $10^{-7} - 10^{-6}$ mbar. The produced ions (about 135 ions s^{-1} cm^{-1}) will then give a final signal current of at least 1pA. Since the amplification factor of MCP's can be set from 1 to 10^6, this current can be measured quite easily.

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At several positions along the beam lines the desired accuracy of beam position measurements is 0.3mm, so that the drift field has to be very homogeneous. For the prototype[1] this was rather easy to achieve; the final design discussed here, however, has to be mounted in a standard reference block in the beam pipe. The inner diameter of such a block is only 65 mm so that detailed calculations on the field shaping had to be performed.

3. DESCRIPTION OF THE DESIGN

In Fig.1. a drawing is shown of the RG-BPM. The drift field of 0.5 kV/cm is created by the field shaping electrodes: copper strips, evaporated on a flexible printed circuit board, shaped as the inner side of the vacuum chamber. A resistor chain provides the correct voltage on the strips. A free aperture of 55 mm is available for the beam. To allow convenient assembly the length of the strips has been limited by the length of the reference blocks (10 cm). Field calculations show that the field lines in the central region (length of 2 cm) are not distorted more than approx. 1 mm. Therefore the limit on the position resolution will be approximately 1 mm. However, if necessary this can be improved by using longer field shaping electrodes.

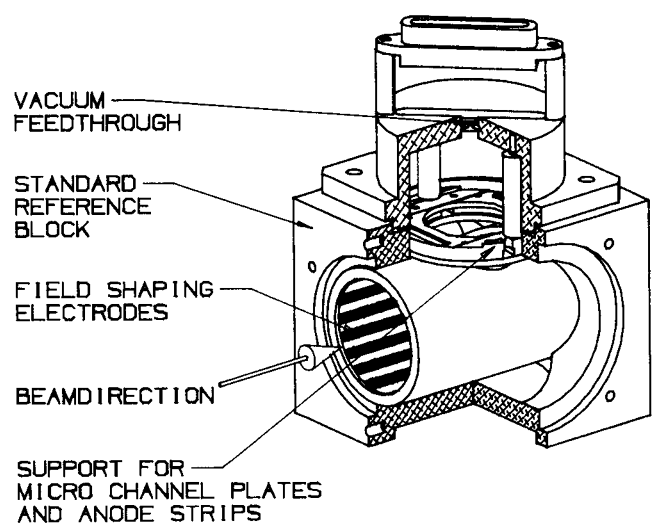

Fig.1. The Residual gas beam-profile monitor, mounted in an accurate position-reference block of the AGOR beam line.

The MCP's (Galileo; active area ∅ =42 mm), are mounted in a chevron geometry on top of the tube with the field shaping electrodes. A position sensitive anode is mounted on top of the upper MCP. It consists of 40 strips, 0.9 mm wide and spacing 0.1 mm, etched on a printed circuit board. The MCP's were operated at 600-800V each, resulting in a total gain of $10^4 - 10^6$.

Each anode strip was connected to a current to voltage amplifier.[2)] The outputs of the amplifiers are multiplexed, digitized and sent to a BitBus line via a micro controller acting as an interface. Presently a PC interfaced to the BitBus system is used for displaying the beam profiles. Ten times per second the screen is refreshed and a new profile is made visible. If the statistics is very poor, an average over many cycles can be made and background subtraction is also possible. The conversion gain of the ADC can be adjusted from the PC. With this set of electronics also the beam-profile monitors normally used ("harps": 48 wires, spacing 1 mm, on which the secondary emission current is measured) are read out, allowing a nice flexibility.

4. PERFORMANCE

Tests on a prototype[1)] have already shown that the signal height is in agreement with the expected values mentioned in section 2. The final version of the RG-BPM has been tested during a half year of the normal beam-time program with the Philips cyclotron at the KVI. Measurements on various beams at different intensities (0.1-200 nA) have been performed.

The detector was mounted in a reference block 50 cm before a harp and a viewing screen, so that beam profiles could be compared. A quadrupole doublet 1.5 m before the RG-BPM was used for adjustment of the beam size. The gas pressure in the beam pipe was usually 10^{-6} mbar. Typical convenient signal currents were in the order of several times 10 pA per nA beam current, summed over all strips.

The result of a measurement of a beam profile, taken with the RG-BPM is shown in Fig.2. The position resolution has been measured by comparing the widths of the peaks obtained from the RG-BPM and the harp, taking into account the beam divergence. Usually a resolution of about 2 mm FWHM was found.

During its half-year operation the dependence of the operating characteristics on the strength of the drift field, the amplification and beam intensity, as well as the time dependence of its characteristics have been studied systematically. It was found that the device has a constant behaviour approximately 10-20 min after switching on. Therefore a continuous operation mode is necessary.

The sensitivity of the RG-BPM has been clearly demonstrated at low beam currents. The cyclotron operators frequently used the RG-BPM in cases where the viewing screens gave a poor (or no) image.

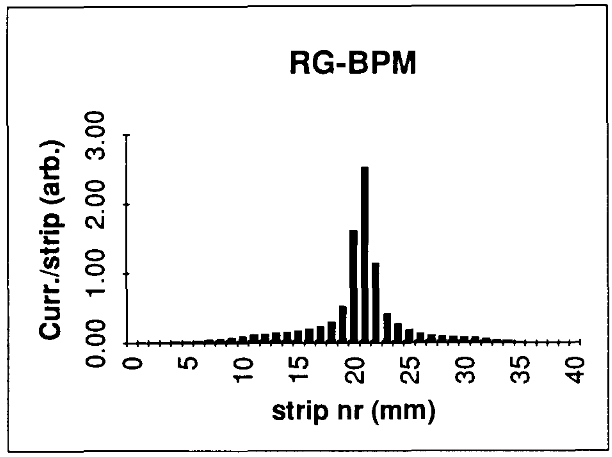

Fig.2. A beam profile, measured with the RG-BPM. The beam width was approx. 2 mm FWHM.

5. CONCLUSIONS

The beam-profile monitor based on the principle of the detection of ions created in the residual gas in the beam lines has shown to be a reliable device, suitable for all AGOR beams, especially at low intensities. Several of these profile monitors will be installed in the AGOR beam lines.

An advantage of such a non interceptive beam profile measurement, is that the amount of neutron- and gamma radiation created during the measurements is minimized. This may be very important for some of the nuclear physics studies planned with AGOR; we have experienced that even the radiation produced by other types of monitors, e.g. harps, contributes significantly to the background observed in experiments using neutron- or gamma ray detectors. Furthermore we have observed that beam particles scattered from the wires of a harp, dominate the background in several measurements at zero degree, performed with a magnetic spectrograph. Therefore they will be mainly used as last-profile measuring devices, installed before the target stations. An on-line continuous monitoring of the target spot is then possible, without interference with the experiments.

6. REFERENCES

1) J.M. Schippers, H.H. Kiewiet and J. Zijlstra, Nucl. Instr. and Meth. A310 (1991) 540.
2) Ch. Olivetto, AGOR internal report NT-DIA-29-09-88