INTENSITY-DISTRIBUTION MONITORS FOR THE SIN EXTERNAL PROTON BEAMS

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The SIN isochronous ring cyclotron accelerates a proton beam to 590 MeV kinetic energy. The design current is 100 µA. High-intensity secondary-particle beams (pions, muons, neutrons, and polarized protons) are produced at two external target stations. Because of the high intensity of the proton beam and the resulting complexity of the local target shielding, a common method of beam monitoring in the target stations (e.g. scintillator plus TV-camera, etc.) is not feasible. Since each target station contains four different target wheels which rotate to avoid excessive heating by the proton beam, one of the target wheels is modified in such a way that is scans the proton beam in a plane perpendicular to its direction. Thereby it provides information of the beam-spot profile and its center of gravity in the horizontal plane (the vertical beam position is somewhat less critical in our case).

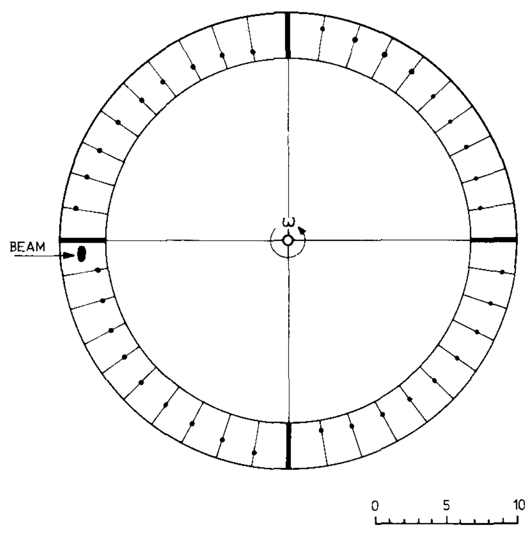

Fig. 1: Design of the special target wheel. A possible beam profile is shown by the black spot on the left between plate and 1st pin. The beam direction is perpendicular to the paper plane.

The system works in the following way. The four quarters of the special target wheel are separated by four molybdenum plates of 25 mm thickness in the beam direction. Between these plates 9 cylindrical pins (r = 1 mm, l = 20 mm) of the same material are fixed at equidistant angles, each displaced by 2 mm in radial direction with respect to its neighbour (see fig. 1). By turning the special target wheel through the beam, protons are scattered and secondary particles are produced both from the plate and those pins which hit the beam. These particles can be detected with scintillation counters outside the vacuum chamber and the local target

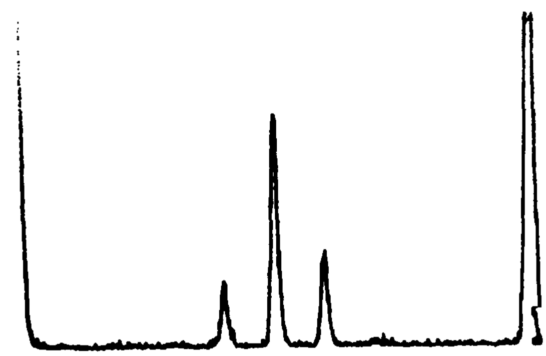

Fig. 2: Profile of the SIN 590 MeV proton beam at the thick-target station detected by the special target wheel. From this picture, the beam spot is seen to be centered with a precision of ± 0.5 mm, and to be 5 mm wide and 7.5 mm high (base widths).

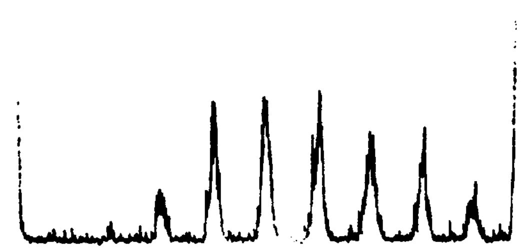

Fig. 3: Same as fig. 2. Here the beam is not yet optimally focussed and centered.

Proc. 7th Int. Conf. on Cyclotrons and their Applications (Birkhäuser, Basel, 1975), p. 358-360

shielding either near the proton channel or in a secondary beamline. Because of the very high counting rates a current-integration method is used where one monitors the current analogue signal from the anode. This current is converted to a voltage and displayed on a storage scope. The signals from one target quarter consist of one big peak produced by the thick plate which is used as a trigger signal, and smaller peaks from each pin which touches the beam. The number of the small peaks gives information about the horizontal size and intensity distribution of the beam spot, their width gives the vertical extension. From the distribution of the small peaks one can determine the center of gravity in the horizontal plane. A calibration of the time base for the estimation of the vertical beam-spot size is given by the peak-to-peak distance on the oscilloscope screen.

Fig. 2 shows the photomultiplier signal of a 1 µA proton beam of 590 MeV kinetic energy. The beam size is :

$x = (5 \pm 0.5)$ mm,
$y = (7.5 \pm 0.5)$ mm.

More than 90 % of the beam intensity are in this spot. Fig. 3 shows a beam which is not optimally focussed and centered. The extensions here are:

$x = (16 \pm 1)$ mm,
$y = (8 \pm 0.5)$mm.

The center of gravity in this case is shifted to the right by about 2 mm.

To measure the intensity distribution of the proton beam outside the target shielding one uses a somewhat simpler mechanism. L. Rezzonico[1] developed a profile monitor in which a tungsten plate of 1 mm width and 10 mm length in beam direction is moved through the beam. The mechanism is shown in Fig. 4. Rezzonico detects the intensity distribution of the SIN low energy beams ($E \leqslant 72$ MeV) by stopping the particles in this plate and measuring the resulting current as a function of the position of the plate, known from a linear potentiometer. In the 590 MeV proton beam one can use the same system. However, the protons are not stopped in the tungsten plate at this energy. If one detects the current from the tungsten plate, the resulting signal is very small and the range of application is limited to currents of more than 100 nA. On the other hand, by measuring the beam spill from the tungsten plate with the above mentioned scintillation counters or electron multiplier counters again using a current integration method, one obtains a much better signal to noise ratio. With this system tests have been made and it was found to be applicable for beam currents between 1 nA and at least 1 mA. Fig. 5 and 6 show the horizontal and vertical intensity distribution of the SIN external proton beam at 1 µA behind the thick target, measured

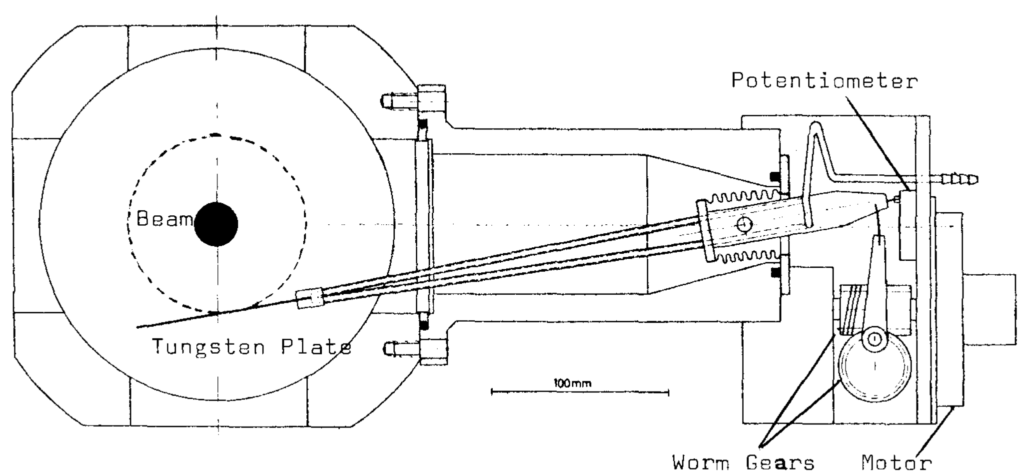

Fig. 4:

Mechanism of the SIN standard profile monitor MHP.

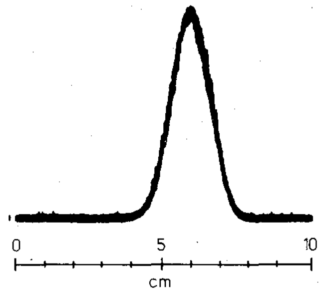

Fig. 5: Horizontal intensity distribution of the SIN external proton beam behind the thin target.

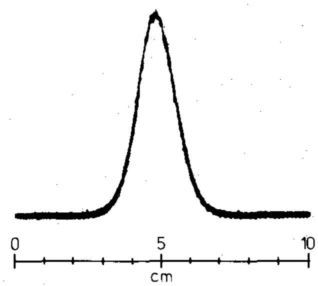

Fig. 6: Vertical intensity distribution of the SIN external proton beam behind the thin target.

with the mechanic system shown in Fig. 4 and an electron multiplier detector some 10 meters away just beside the vacuum pipe. The optimum distance is between 2 and 5 meters.

Fig. 7 shows the horizontal intensity distribution of a 1nA SIN 590 MeV accelerated polarised proton beam from our polarised ion source in front of the thin target.

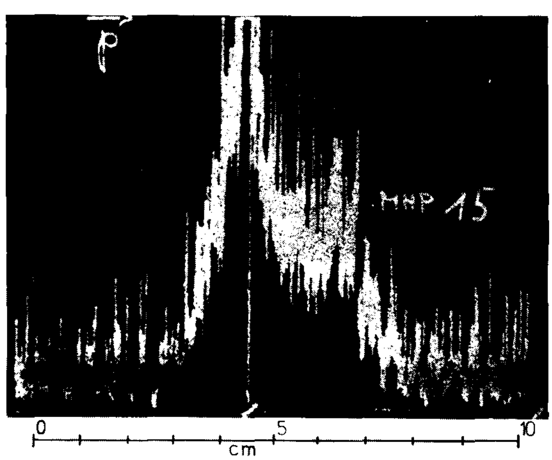

Fig. 7: Horizontal intensity distribution of a 1nA 590 MeV SIN polarised proton beam from the polarised ion source in front of the thin target.

For beam currents below 1nA, for instance in the SIN scattered proton beam, the system of measuring the intensity distribution was again modified. Here one moves a 1 mm wide plastic scintillator plate through the beam. The light produced in the scintillator is guided in lucite rods outside the vacuum chamber. Fig. 8 and 9 show the horizontal and vertical intensity distribution of a 20 pA beam in the SIN scattered proton channel at the temporary target. Further tests showed that this monitor works very well down to beam intensities of 1 pA, while below 0,1 pA the quality of the measurements was poor but a beam of 0,01 pA ($\hat{=} 6 \cdot 10^4$ protons/sec) was still observable.

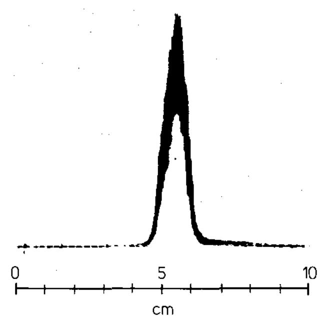

Fig. 8: Horizontal intensity distribution of the SIN scattered proton beam at the temporary target.

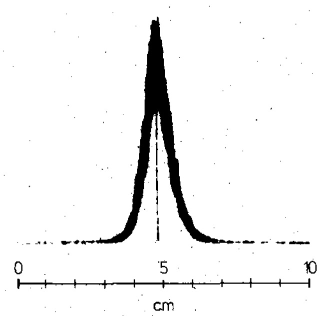

Fig. 9: Vertical intensity distribution of the SIN scattered proton beam at the temporary target.

Reference:

1) L. Rezzonico, SIN TM-09-26