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MEASUREMENTS OF THE ENERGY SPREAD OF THE EXTERNAL PROTON BEAM AT THE CERN SC

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The energy spread of the external proton beam is one of the important parameters of the proposed (p,2p) experiment[1]. An upper limit of 5 MeV was established in an earlier measurement[2]. In order to get a more precise value, we have done some measurements by means of part of the ISOLDE-beam elements, two collimators, a secondary-emission chamber and a small 1x1 cm^2 scintillator counter (see figure 1).

As the bending took place in the vertical plane it was essential to collimate the vertical emittance in such a way that the dispersion due to the bending magnet became as pronounced as possible. The collimator in position A had the internal dimensions 4 x 14 x 20 mm^3 for height, width and depth respectively. The corresponding figures for the B-collimator were 2 x 10 x 50 mm^3.

In the first measurement (I) only the A-collimator was used and a focus in position C was obtained by means of LA1, LA2 and LA3. In the second measurement (II) the B-collimator was added in order to limit further the vertical width of the source. In the third (III) and final measurements the three quadrupole magnets were switched off.

The total number of protons transmitted to the focus at C was found by means of the secondary-emission chamber. The focus was scanned by using the 1 x 1 cm-scintillator attached to a 56 AVP, whose current was integrated and read on a DC instrument. The beam profile was also found from Ilford K5 emulsions.

Results

Before the first measurement we adjusted slightly the computed quadrupole currents to get optimum yields from the scintillation counter at C.

The adjusted current settings were:

$$I(LA1) = \downarrow 40A,\ I(LA2) = \uparrow 40A,\ I(LA3) = \uparrow 22A,\ I(MP1) = 642A.$$

An emulsion exposure of this focus is shown in figure 2b and the vertical width as judged from the picture is 4,5cm. The intensity was $3{,}6 \times 10^{10}$ p/sec for an extracted beam intensity of $1{,}5 \times 10^{11}$ p/sec.

After the second collimator had been installed in position B the beam distribution at C was scanned vertically by changing the current of MP1 and horizontally by displacing the scintillation counter. This set of plots is shown in figure 3. The curves are trapezoidal with a maximum half width of 6,5A. The peak value of each distribution curve is not dramatically dependent on the horizontal position. The total beam intensity was $1{,}3 \times 10^{9}$ p/sec.

In the last measurements, when only the two collimators and MP1 were used the total intensity was not measurable. The emulsion exposure in figure 2a shows a vertical beam width of 2,5 cm. The vertical scan by means of MP1 is shown in figure 4 from which a half width of 7A is found.

Discussion

We shall only be interested in vertical beam extensions as the pictures and the plots indicate that there is little correlation between energy and horizontal position. The transformation between vertical extent at C and magnet current bite is:

$$dZ_c = \frac{L\varphi}{B} \frac{dB}{dI}\, dI,$$

where L means distance between MP1 and image. By using the measured values of B vs.I in ref. 3 and putting the deflexion angle $\varphi = 27°$, we get $dZ_c = 0{,}53\ dI$. The trapezoidal distribution for case II in figure 3 corresponds thus to a FWHM of 3,5 cm and the one for case III in figure 4 to 3,7 cm. As the slopes have widths of approximately 1 cm we assume that the real distributions are rectangular with widths of 2,5 and 2,7 cm, the trapezoidal shape being due to the scan with the 1 cm-scintillator. The 2,7 cm in case III checks very well with the picture in figure 2a.

The FWHM of the measured distribution $\Delta Z_c = (\Delta Z_{c_1}^2 + \Delta Z_{c_2}^2)^{\frac{1}{2}}$

is composed of one part due to the finite source width a,

$$\Delta Z_{c_1} = M.a_1$$

and one part due to the dispersion

$$\Delta Z_{c_2} = \frac{L\varphi}{p\beta} \Delta E,$$

where ΔE is FWHM of the energy spread and

$$\frac{L^{\varphi}}{p\beta} = 0,76 \text{ cm/MeV}.$$

In case I a = 0,4 and the magnification factor M as found from the TRAMP programme is 7,5, which gives $\Delta Z_{c_1} = 3$ cm.

This is in fair agreement with the photograph in figure 2b. As we have nothing but a photograph for this case we are not able to say anything about the energy resolution.

In case II a = 0,2 and this makes $\Delta Z_{c_1} = 1,5$cm. As ΔZ_c from the previous was found to be 2,5 cm we compute by means of the formula above $\Delta E = 2,6$ MeV.

The distribution of a beam, that has passed two collimators with widths a_1 and a_2 a distance l_1 apart, is after a distance l_2 from the last collimator trapezoidal with a FWHM:

$$\Delta Z_{c_1} = 2a_1 \cdot \frac{l_2}{l_1}.$$

In case III we thus find $\Delta Z_{c_1} = 1,75$ cm and as ΔZ_c was 2,7 cm we compute $\Delta E = 2,8$ MeV. We think this last figure is a better estimate of the energy resolution, as we are not dependent on the magnification factors of the quadrupoles.

It should be remembered that we have selected a rather small fraction of the vertical phase space picked out by means of the collimators and that the measured energy spread is valid for this "bite". It is no reason to believe that there exists any correlation[4] between energy spread and position in vertical phase space so we take our measured figure of 2,8 MeV as a value valid for the

whole beam. This figure can be considerably improved by using a collimator to confine the vertical source width of the beam and by using an energy-selective collimator in front of BM2. The most ideal position of the source-defining collimator would probably be inside the machine. A factor of 5-10 improvement on the present value should be quite easy. The loss of intensity ought to be the energy improvement ratio squared.

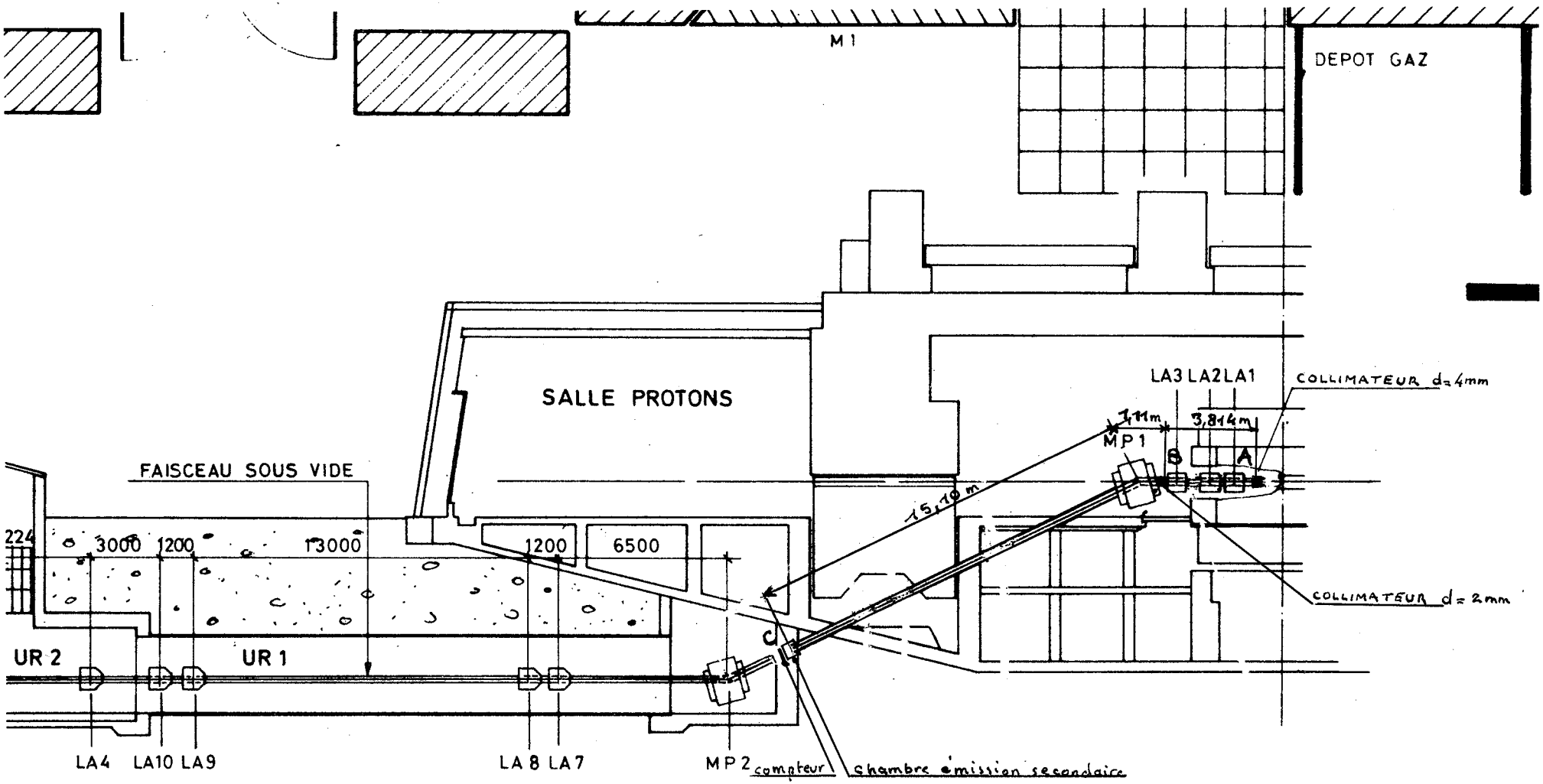
REFERENCES

1) A. Johansson, G. Tibell et al.: Proposal for a study of the (p,2p) reactions at 600 MeV, PH III-67/29, 8 June 1967.

2) The ISOLDE beam, MSC Internal Report, M-12, May 1967.

3) E. Braunersreuther: Magnetic Field Measurements of MP1. N° 4, published by the MSC Division, 2 August 1967.

4) S. Lindbäck, Private communication.



I PA 02
H

COUPE ISOLDE

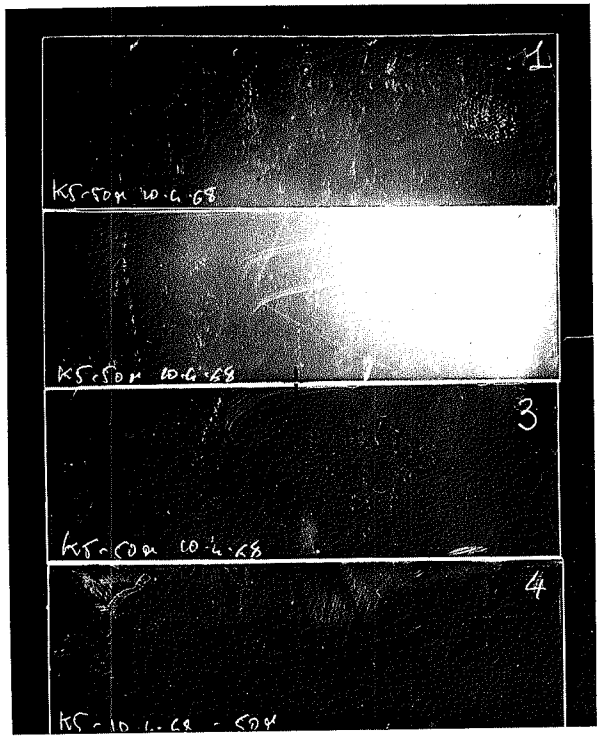
0 1 2 3

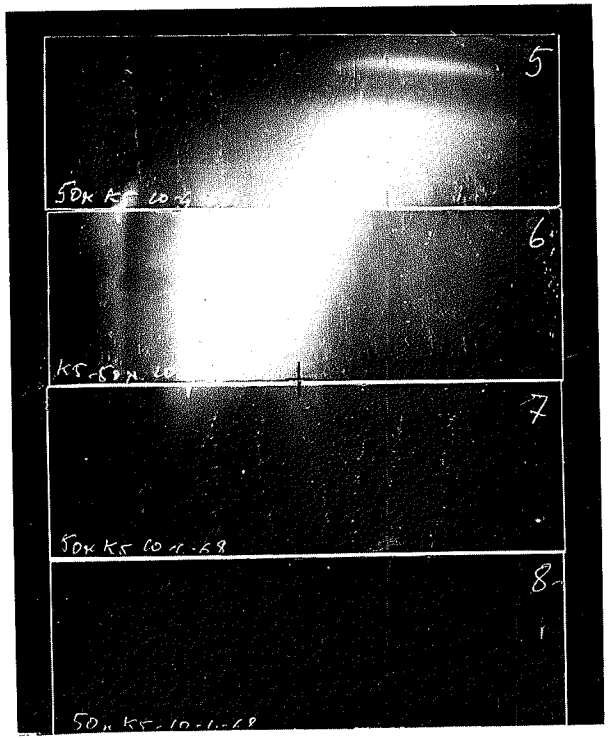
MESURE ΔP/P -1014168

Figure 1

BEAM PROFILE in front of MP2

Figure 2





a/ 2 COLLIMATORS ONLY

b/ 1 COLLIMATOR + QUADRUPÔLES

+ = THE CENTRE OF THE VACUUM TUBE

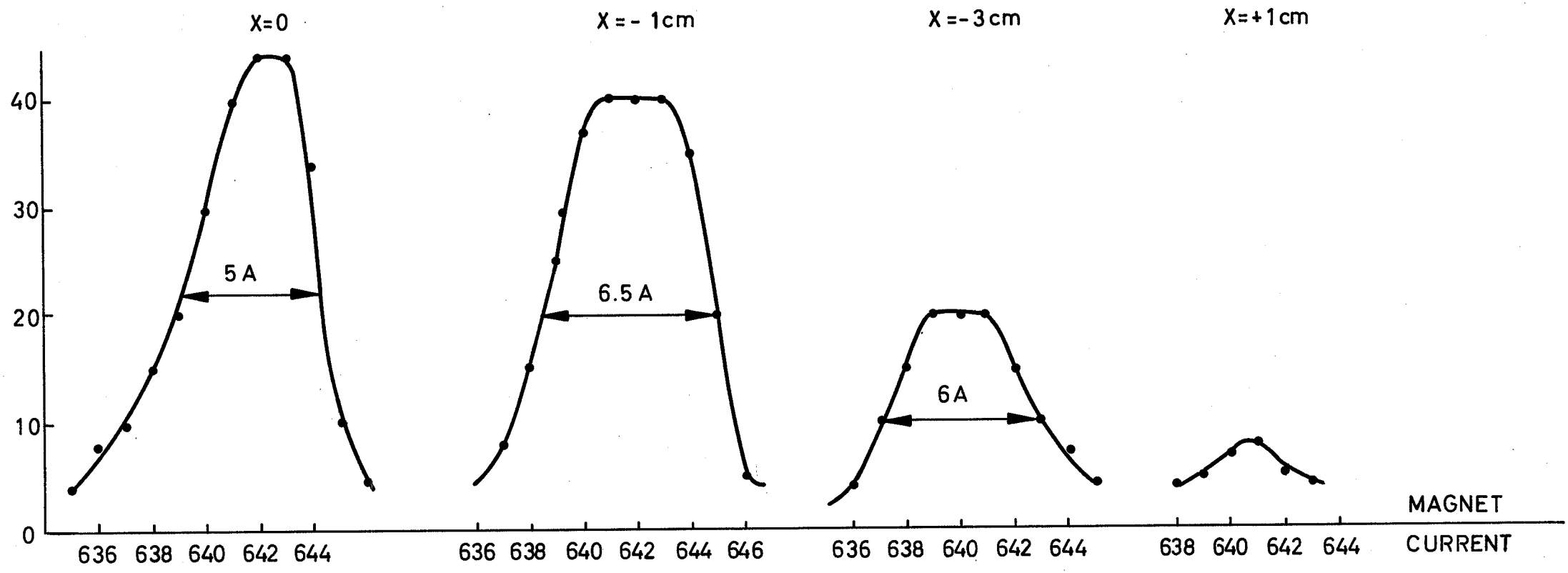


FIG. 3 1x1-cm scintillator reading as function of current in MP 1. for various positions in the horizontal plane.

Totale intensity $=1.3 \times 10^9$ P/sec . Elements used were : A - collimator, LA 1, LA 2 , LA 3 , MP 1.

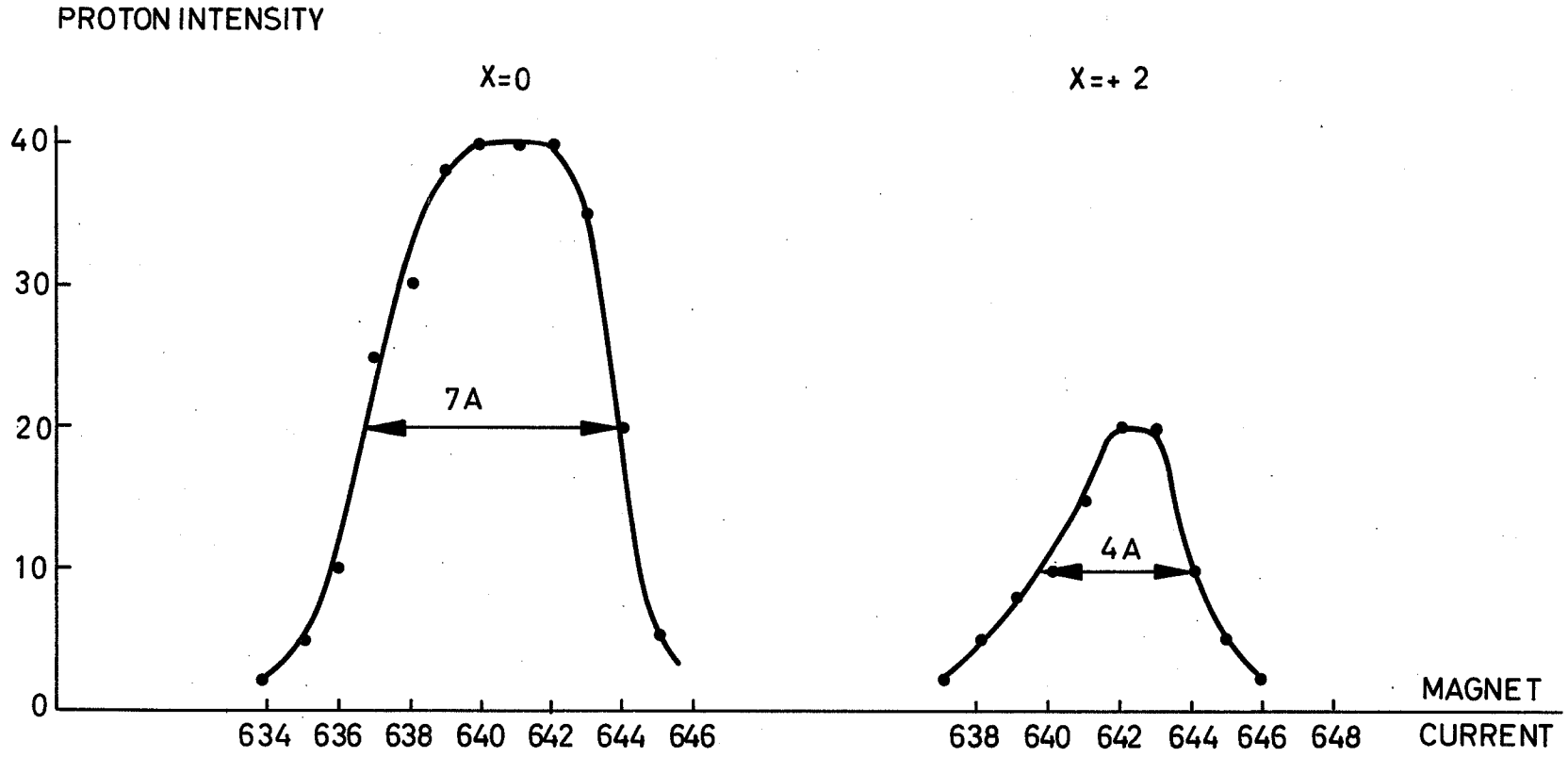


FIG. 4 Same as in fig.3: Beam elements used were: A - collimator, B - collimator, MP 1.