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A NEW INJECTION METHOD FOR CYCLOTRONS

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Principle (Fig. 1)

As indicated in a previous paper,[1] it seems possible to inject a charged particle beam up to the center of a cyclotron in the median plane of the machine. It is necessary to cancel the Lorentz force at every point, i.e. to compensate the magnetic force by a proportional electric field E, perpendicular to the magnetic field B and to the direction of the trajectory :

$$E = \frac{v}{c} \cdot B = \frac{2W_{kin}}{r_o} \qquad (1)$$

where r_o would be the radius of curvature of the particle in the field B (without electric field) for the kinetic energy W_{kin}, which depends on the local potential seen by the particle.

If (1) is not exactly fulfilled, one can obtain a curved path. If a straight path is desired, the hamiltonian [2] shows that the orbits are stable in the (y, z) plane perpendicular to the mean equilibrium orbit, if :

$$\left(\frac{\partial E_y}{\partial y}\right)_o - v\left(\frac{\partial B_z}{\partial y}\right)_o > 0 \qquad (2)$$

$$(E_y)_o^2 - \frac{2W_o}{e}\left(\frac{\partial E_y}{\partial y}\right)_o + \frac{p^3}{em^2}\left(\frac{\partial B_z}{\partial y}\right)_o > 0 \qquad (3)$$

This indicates that, even for a constant magnetic field, the electric field has to be varied in the plane perpendicular to the mean direction of the beam, and thus (1) can be verified only at one "point" in the (y,z) plane (the equilibrium orbit). The inequalities (2) and (3) insure respectively vertical and horizontal focusing. For low speeds (a few keV) one can always neglect the magnetic terms and use (1) to simplify these equations :

$$\frac{(E_y)_o}{r_o} > \left(\frac{\partial E_y}{\partial y}\right)_o > 0. \qquad (2')(3')$$

These inequalities define the "region of stability" of the system.

Realization

We used three different systems whose cross-sections (y-z) are given in figure 2. The first one is made by two plates (±) and two bars which allow us to obtain a large region of stability (AB on fig. 2). This system unfortunately cannot be used for a machine in which the z = 0 plane must be kept free for the accelerated beam. The two other systems fulfil this condition.

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Results

1. The first system was used to check the instabilities. It ran correctly over an 80 cm long path, along which the magnetic field increased from 1800 to 9000 gauss. One sees on figure 3 very marked oscillations for the detected intensity which indicate that the mean "straight" path is not obtained. It seems that small field defects (generally at the entrance to the field) are enough to excite coherent oscillations.

The beam of 5.4 keV produced by a Van de Graaff type ionizer was followed by an Einzel-lens ; the emittance at the entrance of the system was roughly 10 milliradians × 3 mm, and the intensity was 6-8 μA. A variation of ± 3 mm around the optimum position at the entrance produced a 30% decrease of the intensity. Taking into account the difficulties resulting from the perturbations introduced by the detector itself, the transmission factor seems greater than 20%. Figure 4 shows this system.

2. The second system did not give good results, probably because the region of stability was too small to be compatible with even small defects in the entrance channel. The beam was lost after 21 cm.

3. The third one will be soon realized and should give better results, the stability area being similar to that of the first one. We shall also improve the entrance channel of the system to avoid oscillations of large amplitude.

Acknowledgment

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References

1. R. Beurtey and J. Thirion, Nucl. Instr. Methods 33 (1965) 338.
2. H. L. Hagedoorn and P. Kramer (Private Communication).

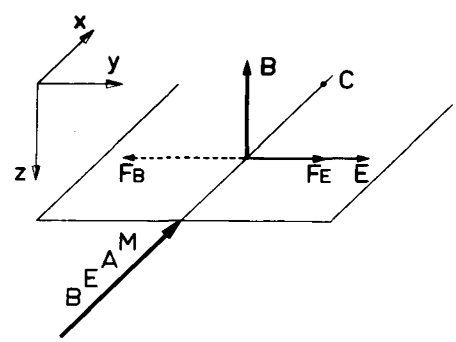

Figure 1.

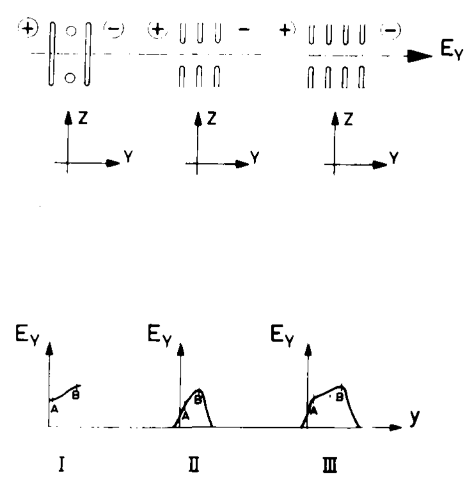

Figure 2.

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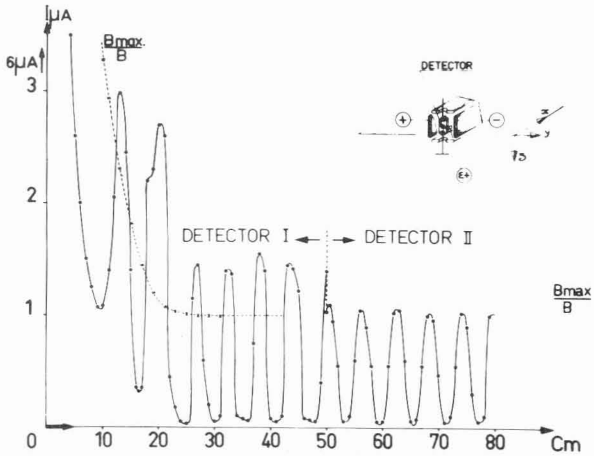

Figure 3.

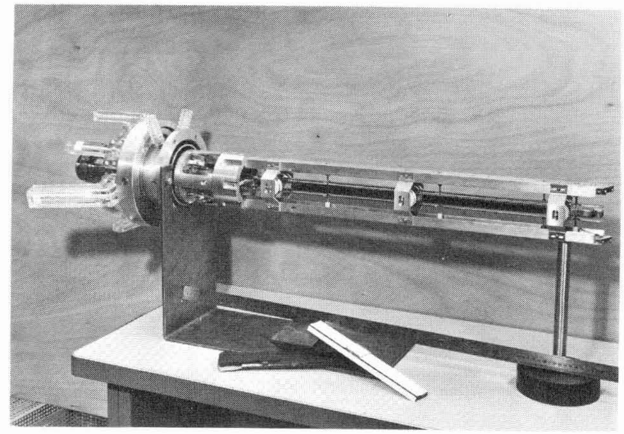

Figure 4.

DISCUSSION

GRUNDER: How big is the emittance of the polarized ion source?

BEURTEY: Our ionizer is very similar to that of Glavish.

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