THE GANIL INJECTOR

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Abstract

A description is given of how to make a small compact cyclotron suitable for the injection of Carbon to Uranium ions beams into the GANIL separated sector cyclotrons.

1. GENERAL DISCRIPTION

1.1. Why a compact cyclotron as an injector ?

The Ganil injector |1| should provide heavy ions beams with the following characteristics (table 1) :

Table 1

Energy range		15-390 keV/nucleon
Maximum intensity	light ions	$\sim 10^{14}$ p.p.s.
	heavy ions	$\sim 10^{13}$ p.p.s.
Bunch phase width		15°
Energy spread		± 0,5%
Emittance at max. energy	radial	50π mm.mrad
	vertical	200π mm.mrad

In addition, the use of a single separated sector cyclotron (SSC) to accelerate light ions (up to argon) requires injection energies ranging from 0.25 to 2.9 MeV/nucleon. In order to achieve these performances, the choice was made of a small compact cyclotron (C_o) working with a conventional internal PIG source. The reasons for this choice are two fold : i) the design and operation of such a machine are well-known techniques and ii) an equivalent insulated platform would require an accelerating voltage of more than 4 MV. However a D.C. injector will be carefully examined in view of the adaptation of an eventual new type of ion source.

1.2. Main parameters of Co.

Identical RF frequencies were adopted for the three components of the machine :

$$F(C_o) = F(SSC1) = F(SSC2)$$

Hence, the injection conditions into SSC1 (conservation of the velocity and of the magnetic rigidity) lead to choose the extraction radius R_{oe} ,magnetic field B_{oe} and RF harmonic number h_o such that :

$$R_{oe} = \frac{R_{1i}}{2} \ , \ B_{oe} = 2\bar{B}_{1i} \ \text{ and } \ h_o = \frac{h_1}{2} \ , \text{ where}$$

the subscripts 0 and 1 refer to C_o and SSC1 respectively (e = extraction , i = injection). Table 2 summarizes the main parameters of C_o .

Table 2

Energy constant K	25
Extraction radius	0,375 m
Magnetic field range	0,8 - 1,9 T
RF frequency range	5,8 - 13.4.MHz
harmonics numbers (C_o+SSC1) :	1 and 2
(C_o+SSC1+SSC2) :	4 and 8
Two 60° dees - 6 cm aperture	

Figure 1 shows the C_o working chart for a few ion species.

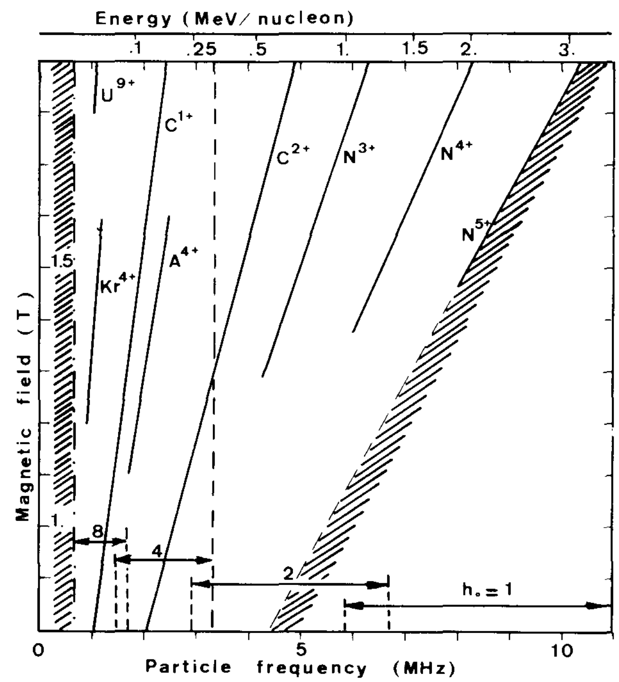

Fig. 1 Working chart of C_o

1.3. Central geometries.

The use of four harmonics requires different ion source azimuthal positions for the four modes of operation |2| , such that the starting phase is always negative. Besides, in order to avoid large adjustements of the source radius, and to keep a fixed radius for the electrostatic deflector, a constant orbit geometry was adopted. Due to the use of several charge states, a voltage variation of 30 to 110 kV only is necessary to cover the whole energy range. Fig. 2 shows the four central region arrangements designed with the method discussed in ref. |2| .

Proc. 7th Int. Conf. on Cyclotrons and their Applications (Birkhäuser, Basel, 1975), p. 132-134

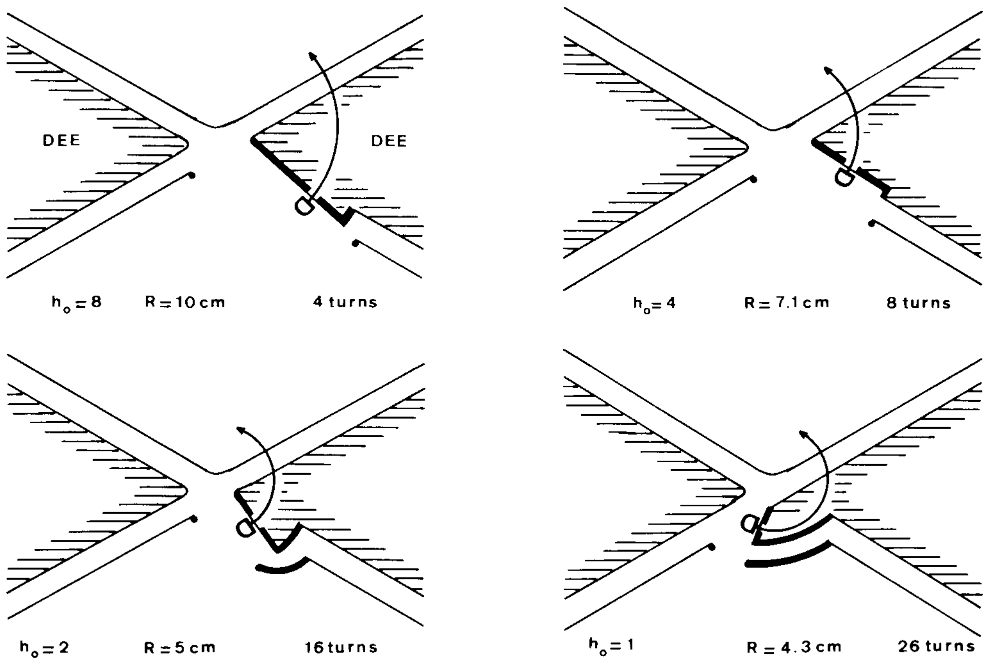

Fig.2 The central geometries

2. Beam dynamics

2.1. Median plane motion.

Optimum starting conditions at the puller slit (phase ϕ_o , angular divergence α_o and coordinates x_o , y_o) providing a well-centered reference trajectory were determined using M. Reiser's method |2| and orbit calculations with the programme TRIWHEEL |3| . The coupling between ϕ and α is shown on figure 3 : for a ±0.5% energy spread at the C_o output , $\Delta\phi$ = 15° for a given α and $\Delta\alpha$=60 mrad for a given ϕ. The total acceptance, for the required output conditions, is about 150 mrad for the divergence and 30° for the phase ; for a 3 mm-wide puller slit, 450 mm mrad are accepted. However , after acceleration, the particles are bunched within 15° RF and the emittance becomes 45 πmm mrad.

These calculations were made with a flat magnetic field and a uniform electric field in the gaps. We are presently looking more carefully into the dynamics with electrolytic tank measurements for the electric fields and computed (programme POISSON |4|) magnetic fields with adequate shimming on the poles to avoid the saturation effects.

2.2. Vertical motion.

Since the number of turns is small (from 4 to 26), our philosophy is to try to keep a simple magnetic field configuration by controlling the vertical motion by electrical focusing only over the first revolutions. A slightly decreasing magnetic field would take over for the last turns.

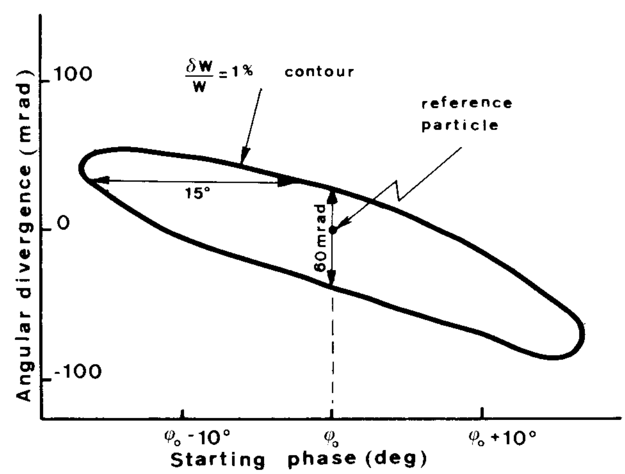

Fig. 3 The coupling between starting phase and divergence at the puller slit

Fig 4 shows the results of the first studies using the thin lens approximation. Curve 1 was drawn with electrical focusing only in a flat magnetic field and a 840 mm mrad vertical emittance at the puller : the beam fills the whole dee aperture; a weak negative gradient (curve 2) provides enough focusing.

More sophisticated computations form actual electric field maps are in progress; although approximate calculations |5| to evaluate the space charge effects have shown that the intensity requirements are below the limits, an attempt is

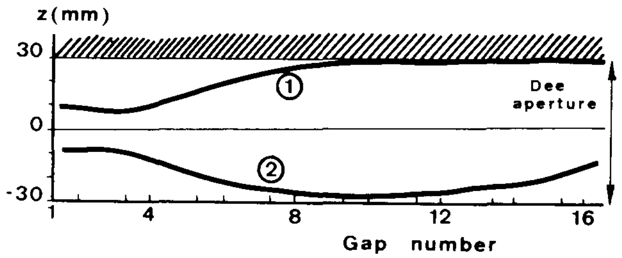

Fig.4 Vertical focusing without (1) and with (2) magnetic field gradient.

being made to take these effects into account (programme CLOTHO).

2.3. Experimental studies

A model of the C_0 is being prepared at CERN *) to test the validity of the calculations for high-intensity beams. Two central geometries are planned, along with phase and internal emittance measuring devices. The hope is also to achieve proper phase width and vertical focusing by suitable posts and slits.

*) Whe are greatly indebted to Dr E.G. Michaelis and the CERN-MSC Division for their collaboration and help in this work.

3. Technology

A sketch of the injector is shown on fig.5. The central part of the dee carrying the puller will have to be movable , as well as the position and orientation of the ion source body. The even and odd harmonics impose both push-pull and push-push operation of the dees . The maximum foreseen dee voltage will be 110 kV ($\frac{\Delta V}{V}$ $=10^{-3}$) .

In the worst case (uranium at low energy), the required pressure in the vacuum chamber is of the order of 5.10^{-7}torr.

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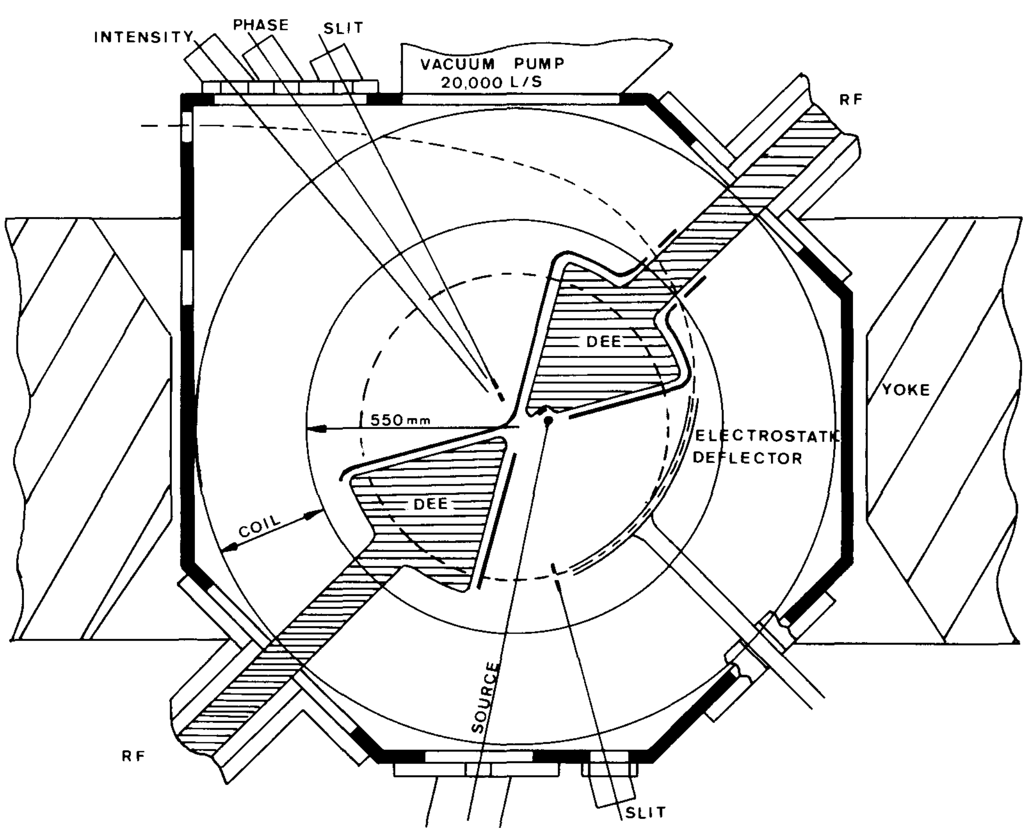

Fig.5 Schematic view of the injector