PROGRESS REPORT AND FIRST OPERATION OF THE GANIL INJECTOR

P. ATTAL, A. BACKOUCHE, M. BAJARD, E. BARON, L. BEX, M.P. BOURGAREL, G. CARDIN, J. DEVILLE, B. LENOBLE, M.VOISIN and R.F. GROUP.

GANIL BP 5027 14021 CAEN Cédex (France) Tel : (31) 94 81 11 Telex : 170533 F

Abstract.- In April 1981 the construction of the K = 30 injector cyclotron was achieved, and the first beam was accelerated on the 4th harmonic mode. Results of measurements are reported. Characteristic measurements such as emittance, phase width, radial beam density are presented and compared to the theoretical calculations.

1. Introduction.- The Ganil injector (Co) has been described in previous conferences |1.2| and thus only a short summary of its features is given, with more developments about the central region for which a special care has been taken. Details of principal elements are given in the references quoted.

The injector mechanical design started in 77 and its construction that followed, is now completed. The first beam was accelerated in May 81 and ejected at the end of June. Since this period, we have been dividing the time between an investigation of the proper injector capabilities - internal emittance and phase width measurements, acceleration of ions produced by gas or sputtering - and the work in the beam lines.

2. Main Features.- Co is essentially a small flatpole cyclotron (K ≃ 30) operating on RF harmonic numbers 4 and 8 in the 45-550 Kev/A energy range. In addition it has to have the capability to inject light ions up to Argon into SSC2 in the 0.5 - 3.5 Mev/A energy range, on harmonic numbers 1 and 2. The use of these harmonics requires 4 very different central regions and the simplest design appeared to have one dee for each harmonic. Thus the design has been based on a very easy access to the central region : as shown on figure 1, the RF cavity can be moved backwards (with 1mm clearance) allowing to remove the dummy-dees from the ground plates and to disconnect the dee from the fork that prolongs the coaxial line. A view of this last one is given, figure 2, when the constructor SEIV was assembling the RF cavity in January 81. The waved structure of the capacitive panels appears on this picture. More details are given in Ref.3 on the RF preliminary design, current and power requirements.

Let us remember, that 2 movable capacitive panels, one on each side of the waved line, allow covering the 6.5 to 14 MHz frequency range. One can see, on figure 1 the second panel, not yet assembled to the cavity and its waved structure. The accuracy obtained on these profiles and on their assembly is better than ± 2mm.

The measured capacitive panels distances versus frequency shows a good agreement with computations. The maximum expected dee voltage is 90 KV at 14 MHz. Until now we never tried to obtain this maximum since we have been operating at 9.52 MHz with Ar^{4+} for the tests in the beam lines, but we have reached the corresponding maximum voltage, i.e. 65 KV, after conditionning during 3 hours only. More details are given in Ref. 4 on the RF Regulation System.

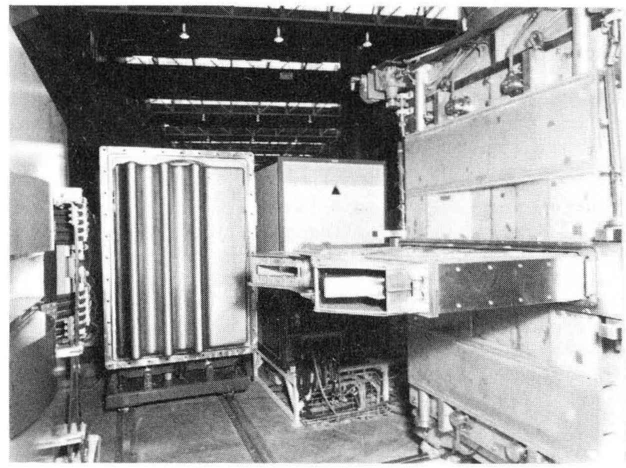

Fig. 1 : View of the RF cavity.

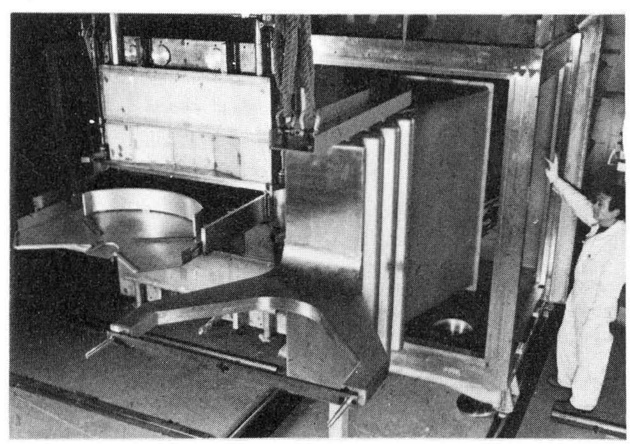

Fig. 2 : RF Line assembly.

Magnetic measurements |5| during Spring 80, showed a good agreement with computation |6|. After measuring the induction and the gradient given by the iron and by each of the 6 trimcoils, at 12 main field levels between 6 KG and 19 KG, a program computed the set of currents to fit the Vz = 0.1 theoretical curve, from 20 cm radius to extraction. Then measurements were resumed to control the corrected fields and to add some field levels from interpolated values. Thus a final grid (19 sets of currents) was introduced in the computer and a program allows to compute the operation values. Experience showed that this method followed by an adjustment of the main current of about 1 to 210^{-3}, is good enough to obtain the beam.

The ion source rod can be moved in 2 directions |7| and is microprocessor controlled |8|. The Pig ion source has been tested |9| for 3 years on a bench and results about intensities, emittance and lifetime are given at this conference |10|. The cyclotron acceptance vs. the SSC beam requirements, leads to reduce these currents by about a 50 to 100 factor.

The present version of the extraction consists of an 55° electrostatic channel followed by a 30 cm long electrostatic quadrupole |11|. The originally designed focusing magnetic channel gives too much perturbation on the internal beam, since, on this small machine, the difference between internal and extracted beam, does not exceed 10cm. As it was possible, in this energy range, to focus with an electrostatic system, we designed a 3 cm diameter quadrupole with 13KV maximum voltage (35 KV in "solomode"). Nevertheless some difficulties appear when we operate with a pressure higher than 1.10^{-6} Torr: high current flows are generated by permanent plasmas between the electrodes due to the joint effect of a positive voltage and magnetic field (Penning discharge).

Two cryogenic vacuum pumps (6500 l/s each) consisting of a 20°K cold surface surrounded by a 80°K radiation shroud with LN^2, are located on the cavity ($8m^3$). A 3500 l/s turbomolecular pump on the vacuum chamber ($\simeq 1m^3$) takes care of the H, He and Ne Gases. The typical pumpdown shows that a 1.10^{-6} Torr pressure is obtained after 2 hours and the limit pressure obtained, 5 to 7.10^{-8} after 15 hours, is better than the required one.

Co will be shortly computer controlled |12|. Actually it is easily operated "in local" with microprocessors which drive the RF amplifier, the main magnetic field, the probe and the ion source, etc....

3. Central Region on 4th harmonic.- The large number of publications on this subject allowed us to design the central regions by following the classical method (computations assuming a narrowgap, then an uniform electric field, and finally with a model in an electrolytic-tank).

Transit times with harmonics 4 and 8 requires to reduce the source to puller distance (d) and to study carefully the first gaps geometry.

The parameter $\chi h^2 = 2(d/Ro)^2$ where Ro is the initial radius, has been chosen equal to 0.5 for keeping a convenient value (less than 11 Kv/mm) of the electric field and a good starting phase (-40°). Secondly it has been seen that "posts" are necessary on the first turn due to the transit time and that it is better to keep "posts" on the 2th turn too, to avoid the strong effects of the electric field on the vertical focusing. Thirdly, the dee angle on the first turn has been optimized to obtain the maximum energy gain and to reduce the center displacement (Xc, Yc coupling).

The figure 3 shows the 4th harmonic orbit pattern with the geometry of the central region, and the figure 4 shows the orbit centres positions for different starting phases and for different momenta.

Specifications for Co can be met only if the centers of the horizontal orbits are located in a $20mm^2$ area around the cyclotron centre ; the RF phase width is then 15° the energy spread is limited to 1% and the emittance is approximatly equal to 30 ¶ mm-mrad.

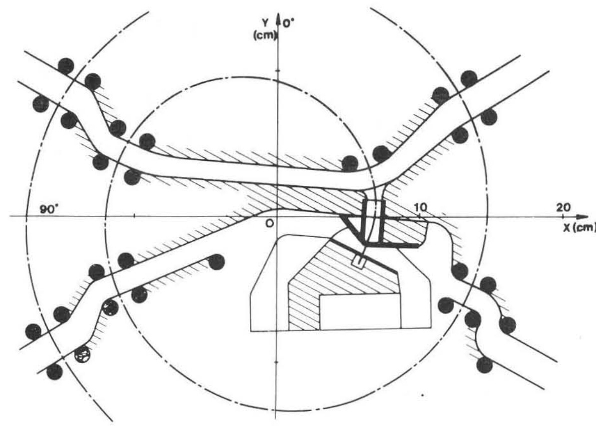

Fig. 3: Central geometry (h = 4)

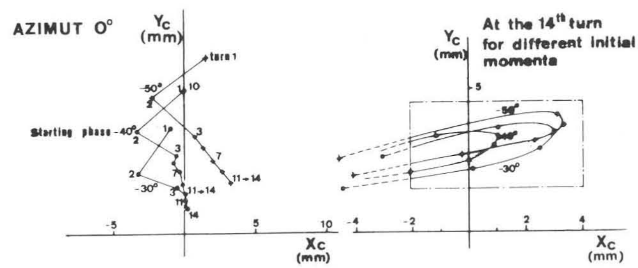

Fig. 4: Position of the orbit centres.

Figure 5 illustrates how the horizontal acceptance varies with starting phase (this acceptance corresponds to the allowed area for the orbit centres).

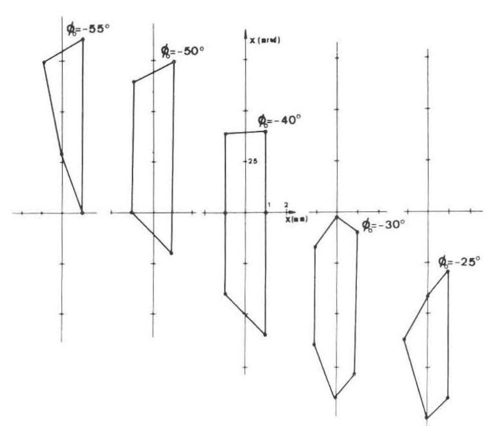

Fig. 5: The horizontal acceptance depends on the starting phase.

Three radial slits or posts, on the first, third and eighth turns, allow to eliminate particules having an energy spread greater than 1%. Computations show that these slits can reduce mainly energy spread and emittance but have a smaller effect on the phase extension.

4. Beam Behaviour.- For the first operation, we have accelerated successively on the 4th harmonic :

C^{2+}	(33 KV)	Beam current	: 1 to 5µAe	0.276 Mev/A
N^{2+}	(46 KV)	Beam current	: 1 to 5µAe	0.276 Mev/A
Ar^{4+}	(56 KV)	Beam current	: 1 to 3µAe	0.250 Mev/A
Cu^{6+}	(59 KV)	Beam current	: 0.3µAe	0.250 Mev/A

Figure 6 is a typical current distribution obtained on a differential probe. It shows a good agreement between computed and experimental beam positions to an accuracy of approximately 1 mm, after adjustment of the dee voltage and main magnetic field. With a small output slit (20 x 0.85 mm) on the ion source, the total beam width is 6 to 7 mm and 2 or 3 mm at half-height. This last one increases to 4 or 5 mm with a larger output slit (20 x 1.5 mm). Losses on the 5 first turns are due to the phase and vertical acceptance - since the radial slits are limiting also the vertical beam extension to 20mm. The axial current distribution, measured on a 3 finger probe, shows a coherent vertical oscillation of about 4 mm amplitude, noticed already on the 2th turn. Several attempts to diagnose the reason have been carried out unsuccessfully.

On the Figure 6, it can be seen also the deflected beam, just after the electrostatic channel (10mm wide). Due to the beam properties, an 100% efficiency is achieved. A wire profil probe, located at the entrance of the beam line allows to adjust the electrostatic quadrupole and the beam position.

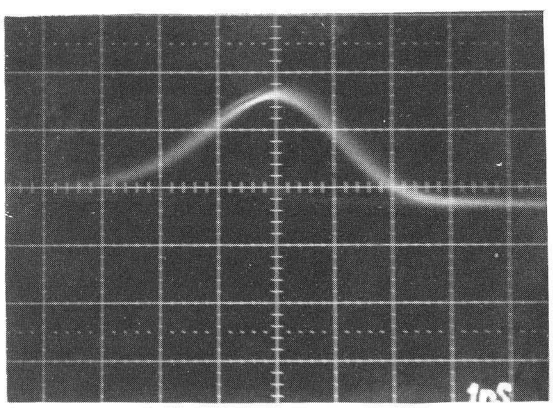

Fig. 7: phase extension (Scale : 3°.4/cm)

A destructive coaxial phase probe gives the phase extension on the last turn before extraction. Figure 7 shows that experimental values are very close to computations.

These data have been completed by radial emittance measurements on the internal beam : since orbits are separated, a movable slit has been introduced on the 13th turn and the current peak has been registered with the differential probe. Results are given in detail at this conference (10) and shows an horizontal emittance of about 30 ¶ mm-mrad can be expected for the required intensities.

5. Conclusion.- The next step is the final design dee for the 8th harmonic and the tests in the machine. The good agreement between the results and the computations on the 4th harmonic make us rather confident for this more difficult central geometry.

References

(1) The Ganil injector. Seventh international conference on cyclotrons p. 132.

(2) The Ganil injector design.Eighth international conference on cyclotrons p. 1944

(3) C. Bieth - A. Joubert - C. Pagani. Ganil injector RF system 79 R/024/HF/06

(4) B. Ducoudret, A. Joubert, F. Labussière ; GANIL RF Systems : feedback control systems and electronics. Ninth International Conference on cyclotrons, Caen, September 81.

(5) M.P. Bourgarel - E. Baron. Magnetic measurements on Co. 80N/109 /IS/05

(6) M.P. Bourgarel-Pole profil and Trimcoils design 78N/178/IS/11

(7) M.P. Bourgarel- P. Attal. Ion Source rod mechanism design. 80R/140/IS/07.

(8) L.Bex, M. Bajard, G. Cardin, J. Deville, M.P. Bourgarel- INPUT-OUTPUT ion source program 81R/048/IS/04

(9) L.Bex, G. Cardin- Ion source performances on the bench 80R/153/IS/09.

(10) Ganil status Report. This Conference.

(11) E. Baron - the electrostatic deflector. 79R/038/IS/02.

(12) M. Bajard - M.P. Bourgarel - B. Piquet- Some aspects of the Co control system. 81N/077/IS/06.

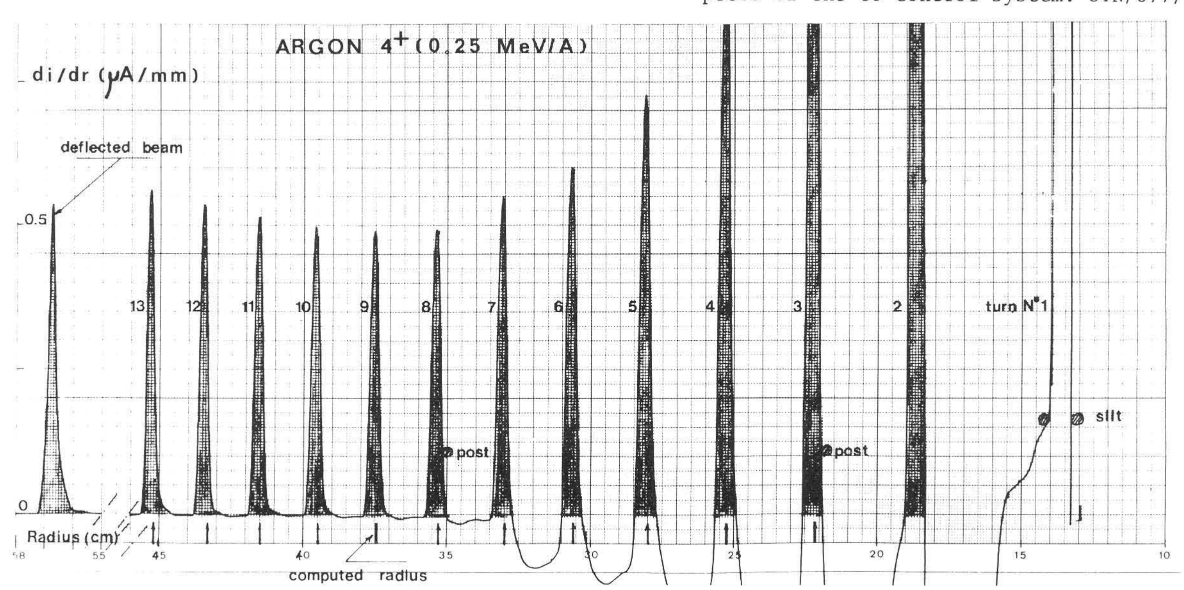

Fig. 6 : Current distribution obtained on a differential probe.