GANIL : A PROPOSAL FOR A FRENCH HEAVY ION LABORATORY

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Abstract

A detailed study of a multi-accelerator system for heavy ions has been undertaken [(1)]

In the heart of this system are two identical conventionnal separated-sector cyclotrons (SSC1 and SSC2); at the output of SSC1, the ions are stripped, a high charge state is selected and injected into SSC2.

To achieve the beam requirements (intensity and energy spread) both SSC1 and SSC2 use auxiliary cavities to flattop the effective accelerating voltage and, in addition, careful transversal and longitudinal matching of all the stages is necessary

1. Introduction

1.1 Main beam requirements

The GANIL machine should be able to accelerate beams of all elements from carbon up to uranium.

The energy ranges from 100 MeV/nucleon for light particles to 8 MeV/nucleon for the heaviest ions (see Fig. 1) with a smooth variation down to 4 MeV/nucleon.

The maximum intensity which is needed is given by Fig. 2 .

Finally the beam quality (mainly intrinsic energy spread and emittances) has to be high as given by Table I.

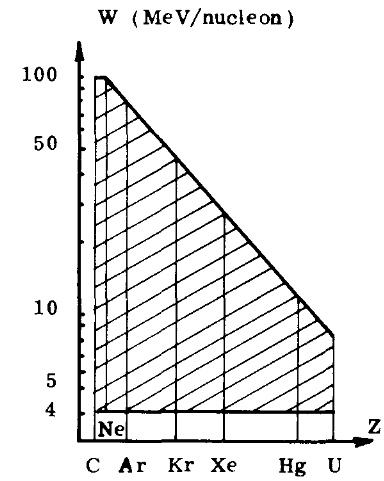

Fig. 1 Beam energy

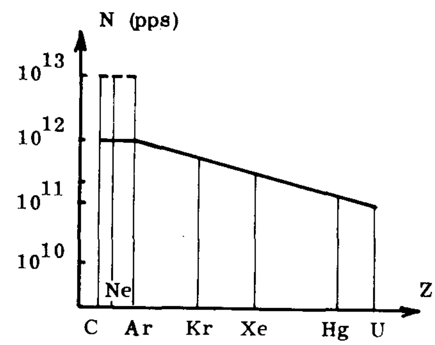

Fig. 2 Beam intensity

- - - high intensity beam
—— high quality beam

Table I - Beam quality

MASS NUMBER A	FLUX (PARTICLES PER SECOND)	ENERGY RESOLUTION $\Delta W/W$	EMITTANCE (mm.mrad at 10 MeV/A) HORIZONTAL	VERTICAL	DUTY FACTOR % MACRO (PIG source)	MICRO
< 60	2.10^{11}	4.10^{-4}	5	50	25	4
	10^{12}	4.10^{-4}	50	50	25	4
	10^{13}	10^{-3}	100	100	25	4
> 60	10^{11}	10^{-3}	100	100	25	4

Proc. 7th Int. Conf. on Cyclotrons and their Applications (Birkhäuser, Basel, 1975), p. 111-116

1.2 Time schedule

The GANIL facility should be in full operation in 1981 or 1982 (assuming the project to be funded in 1976).

This tight time schedule dictates staying within conventional technologies requiring only small extensions of the existing state of the art.

Particularly this is the reason why we have chosen to use classical iron magnets with copper coils - these items having to be ordered during the next year.

2. The two main cyclotrons

Detailed considerations of beam behaviour and machine design features are reported elsewhere in this conference. Let me draw your attention on papers (2) on beam dynamics under space charge conditions, (3) on RF system, (4) on injection and ejection, (5) on beam transfer lines and (6) on injector.

Thus we shall only present here the basic parameters of the project, trace the evolution of our thoughts on main topics and discuss the design philosophy.

2.1 General description

In Fig. 3 we can see a plan view of the accelerator complex.

Both SSC1 and SSC2 are isochronous cyclotrons with four radial bending sectors. Two of the open sections between the magnets are occupied by the fundamental and flat-topping cavities, one by the injection and ejection devices and the fourth by control apparatus and beam probes.

We plan to use a small compact cyclotron Co as an injector for SSC1. As we need only low charge state ions a conventional PIG source, located in the Co magnet gap, will be used.

At the output of SSC1 a foil stripper increases the charge state by a factor of about 4 and the selected charged particles are injected into SSC2.

The main characteristics of the GANIL accelerators are given in Table II :

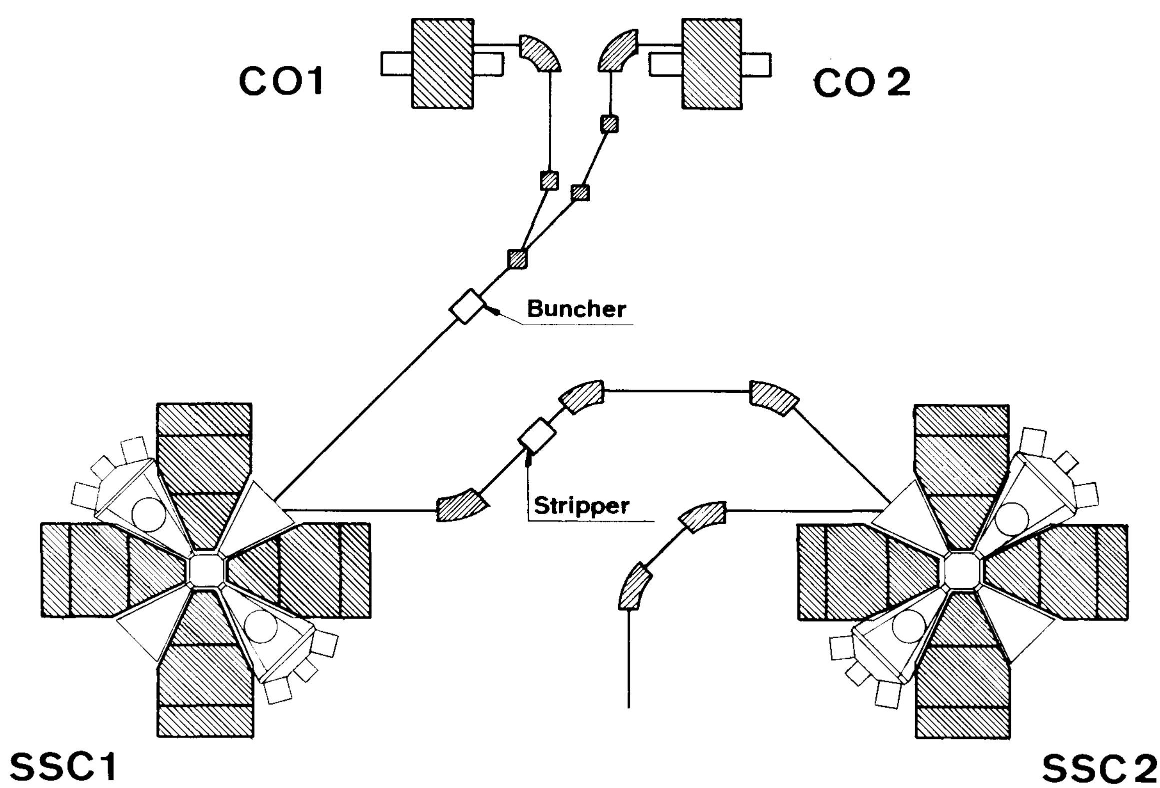

Fig. 3 GANIL accelerators

TABLE II - PARAMETERS OF GANIL

	C_o	SSC1	SSC2
1 - Orbit			
Energy constant K	25	400	400
Number of sectors N	1	4	4
Sector angle 2α		52°	52°
Mean injection radius R_i		0.75 m	0.75 m
Mean extraction radius R_e	0.375 m	3 m	3 m
Energy ratio W_e/W_i		16	16
Betatron wave numbers		$\nu_x \sim 1.07-1.20$ $\nu_z \sim 0.86-0.73$	$\nu_x \sim 1.07-1.20$ $\nu_z \sim 0.86-0.73$
Beam envelope modulation m_e		$m_{ex} \sim 1.4-1.5$ $m_{ez} \lessapprox 1.1$	$m_{ex} \sim 1.4-1.5$ $m_{ez} \lessapprox 1.1$
RF phase acceptance	15°	15°	15°
2 - Magnets			
Magnet gap	20 cm	10 cm	10 cm
Maximum field	1.91 T	1.6 T	1.6 T
Main coil power	150 kW	600 kW	600 kW
Iron weight	$\sim$ 54 t	1600 t	1600 t
Main coil copper weight	4 t	16 t	16 t
Number of trimming coils		35	35
3 - RF cavities			
Number of dees	2	2	2
Dee angle	60°	28°	28°
Peak RF working voltage	110 kV	250 kV	250 kV
RF power (per dee)	25 kW	100 kW	100 kW
Fundamental resonator tuning range	5,8-13,4 MHz	5,8-13,4 MHz	5,8-13,4 MHz
Harmonic (RF/orbit frequency)			
High energy beam	4	8	2
Low energy beam	8	16	4
Flat-topping harmonic		3,4,5	3,4,5
4 - Vacuum			
Operating pressure	10^{-6} Torr	5.10^{-8} Torr	3.10^{-7} Torr

2.2 Coupling of the three stages

As the required beam must be intense and of good quality we have to carefully match the longitudinal and transversal beam emittances of the three cyclotrons connected in series.

In particular each bunch ejected from a machine should be synchronously captured by the following one ; this is conveniently achieved by using the same RF frequency for the three stages.

This coupling scheme imposes geometrical constraints on lengths of injection and ejection orbits and also leads to high harmonic numbers in SSC1 (especially for low energy heaviest ion beams for which fortunately we need lesser requirements - see Table I) thus requiring tight tolerances for this machine.

2.3 Beam dynamics

As said before, extensive results of computer codes will be presented in this conference (2). Let us only summarize the main results of this study :

2.3.1 The feasibility of the accelerators with the required beam intensity and quality as described in Chap. 1 has been proven, the phase width of the bunches along the three stages being 15° in RF.

2.3.2 The space charge is not a serious problem for the required intensities. The only noticeable effect concerns the longitudinal phase plane in which the energy spread is somewhat increased. Moreover it has been found praticable to compensate this defect by a proper phase shifting of the flat-topping waveform (7). Fig. 4 demonstrates the influence of space charge forces

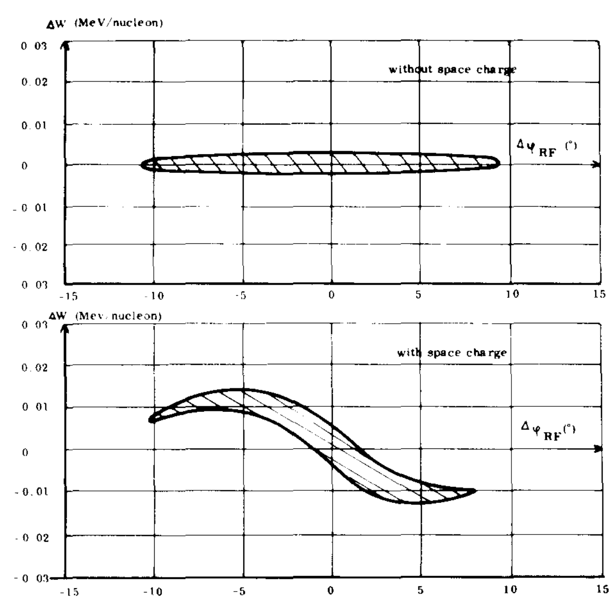

Fig. 4 Space charge in SSC1

(without phase compensation) in the low energy machine for a beam of 12 C^{2+} ions, 6.10^{14} p.p.s. accelerated to 6 MeV/nucleon.

2.3.3 The constructional tolerances required for preserving the quality of the accelerated beam (mainly its energy spread) are very tight (due to the high harmonic number : 16 in SSC1 for lower energies and the large number of turns :440 in SSC2 for high energy beams) but achievable.

As an example Fig. 5 shows in the case of a high frequency flat-topping waveform (k = 4) the degradation of the beam energy spread at the SSC2 output due to errors in flat-topping phase and amplitude. One can see that the maximum tolerances are of the order of ± 0.3° for the phase and $\pm$ 3.10^{-2} for the relative amplitude.

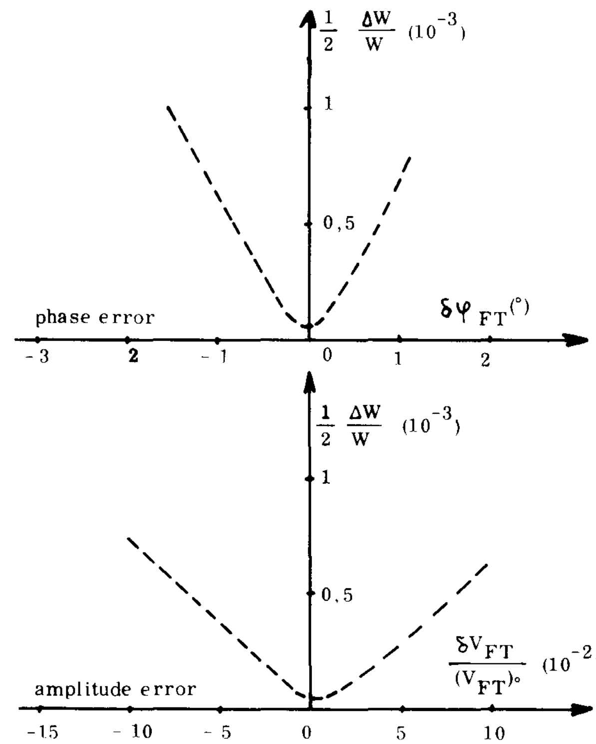

Fig. 5 Flat-topping tolerances in SSC2 for a 100 MeV/nucleon 12 C^{6+} beam

In addition we found that with 35 trim-coils in SSC1 and SSC2 the field mapping was good enough to match the large range in energy and particle mass with a resultant isochronism error of $\pm$ 2° in RF.

3. Experimental areas

The high energy beam extracted from SSC2 will be shared by the means of a septum beam splitter and distributed to the measurements rooms along a "fish-bone" transport beam line (see Fig. 6 and 7).

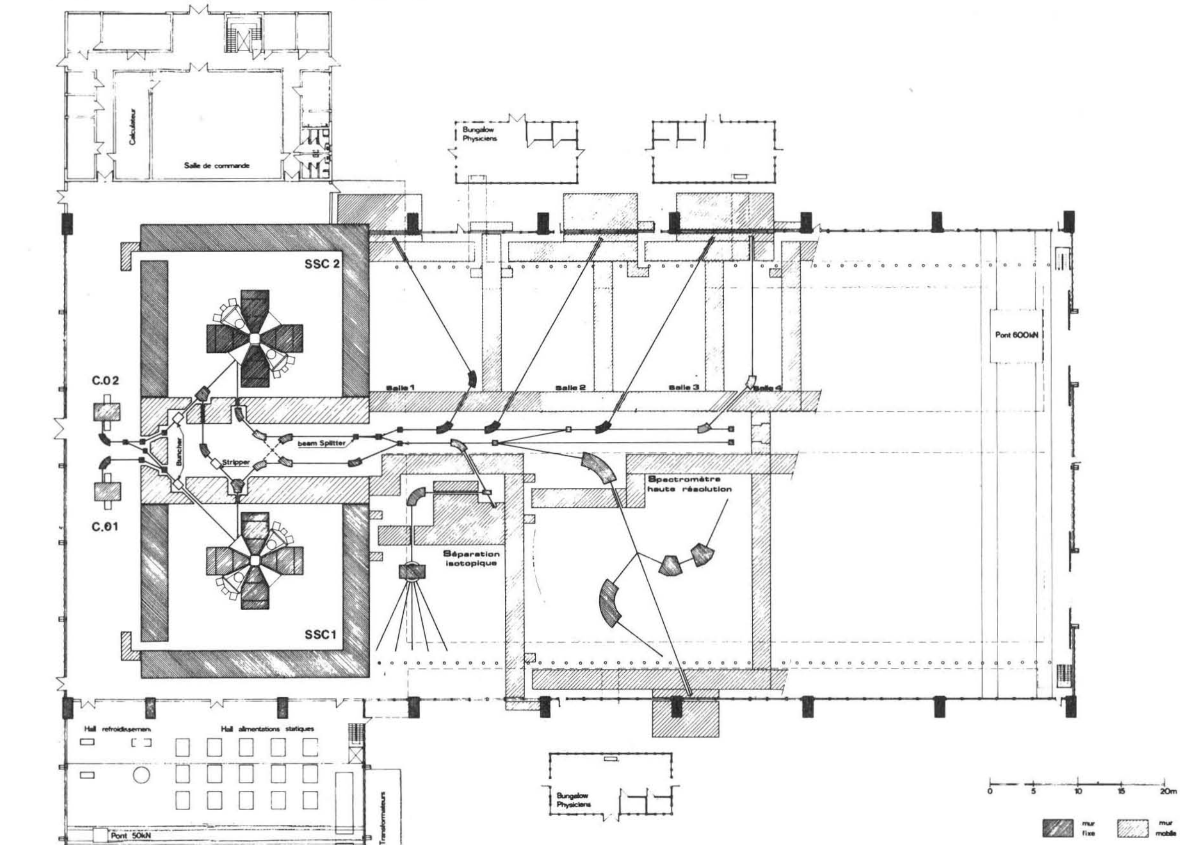

Fig. 6 Plan view of GANIL

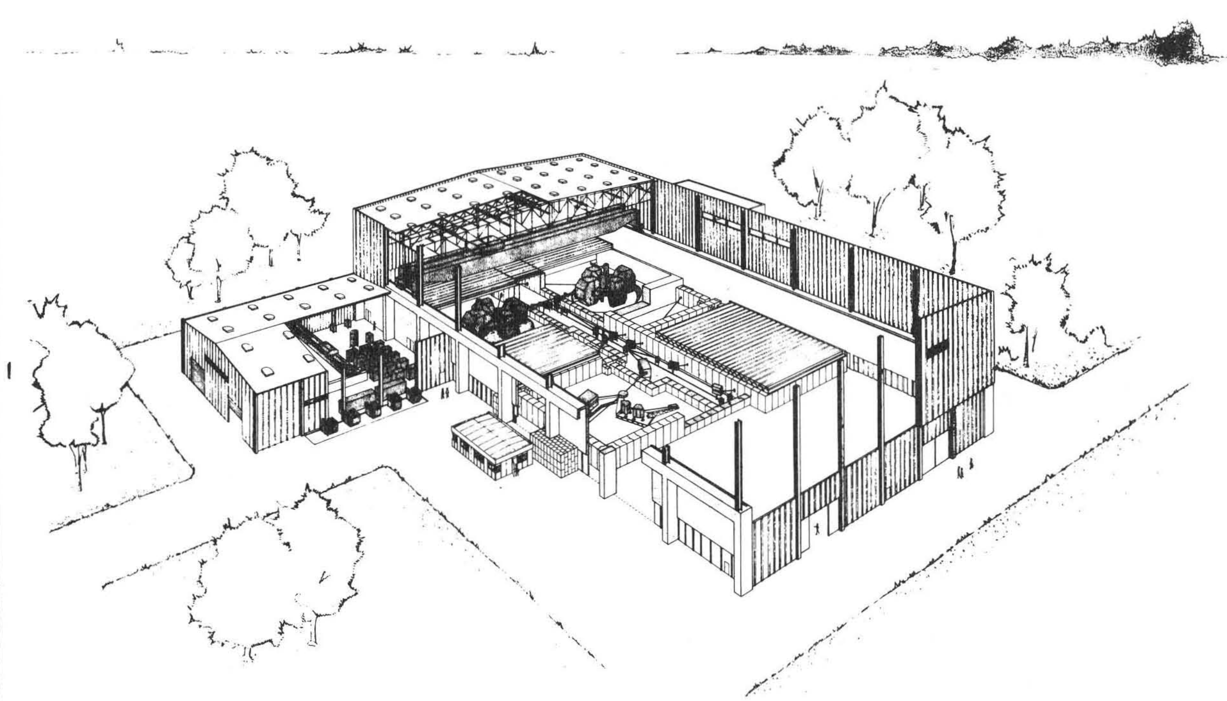

Fig. 7 Cut-away view of GANIL

As an alternative mode of operation we can use SSC1 and SSC2 simultaneously and independently when only medium energy light ion beams are needed (for instance $^{14}N^{5+}$ at 45 MeV/nucleon or $^{40}Ar^{6+}$ at 9 MeV/nucleon). Therefore the output of the second injector cyclotron C_0^2 is also connected to the input of SSC2 and likewise the beam accelerated in SSC1 can be switched directly to the experimental area at the output of SSC1 (see Fig. 6).

4. Current status and conclusion

The major part of the theoretical studies on the GANIL project is now available ; the others will be completed during this year.

Models of magnet and accelerating cavity have been ordered and are presently under construction ; they will be tested in 1976 . Also the performances of the injector cyclotron will be evaluated on the adaptated CERN - MSC micro-cyclotron which has been kindly placed at the GANIL disposal for the next year.

Then we shall be ready to begin the construction of the machines if they are funded at that time.

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