

# GANIL Status Report

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### Abstract

This paper deals with the present status<sup>[1]</sup> of the heavy ion accelerator GANIL. The performance of the accelerator is described in terms of machine availability for physics experiments and ion diversity. GANIL is now preparing for the near future in accelerating very high intensity beams and radioactive beams.

## 1. INTRODUCTION

GANIL has been for ten years at the forefront of the physics with medium energy heavy ion beams. Recently new equipment aimed to increase the beam intensity have been installed and are now in operation :

- The new injector system using an ECR4 source implanted on a 100 kV platform<sup>[2]</sup>.
- SISSI (Source d'Ions Secondaires à Supraconducteurs Intenses)<sup>[3]</sup> located on the beam line L3 at the output of SSC2.

In order to satisfy the growing interest for the physics with radioactive beams, the SPIRAL project (Système de Production d'Ions Radioactifs et d'Accélération en Ligne)<sup>[4]</sup> has been approved. The completion of SPIRAL is planned for the end of 1998. For this project a very intense beam (6 kW) is needed. The THI project (Transport des Hautes Intensités)<sup>[5]</sup> will adapt GANIL to very high-intensity beams limited in the range extending from helium to argon.

## 2. OPERATION STATISTICS

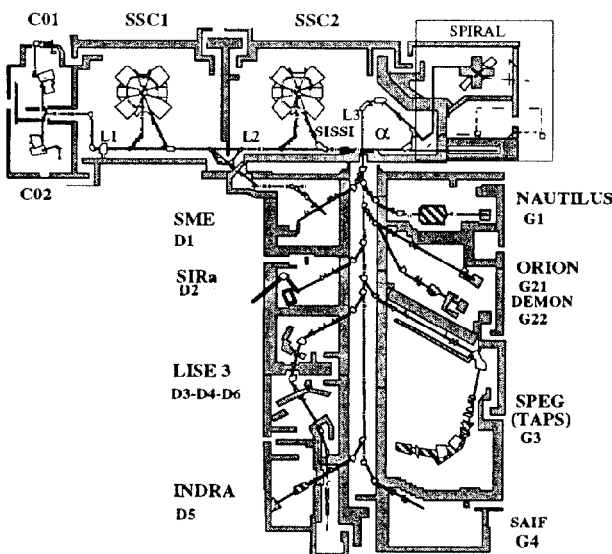


Figure 1

The GANIL cyclotrons with the new project SPIRAL and the experimental caves are shown figure 1.

Items	Time sharing per year (hours)	
	1992	1993
Physics	3594	3212
Machine and new beam studies	240	601
Beam set up	1035	1152
Failures and maintenance	273	237
Retuning after failure	191	190
<b>Total time per year</b>	<b>5333</b>	<b>5413</b>

Beam number	29	31

Table 1

Table 1 shows how the beam time has been shared during the years 1992 and 1993. The machine availability for physics experiments is approaching 90%. Three experiments can be performed at the same time : one with the SME (Sortie Moyenne Energie) at the SSC1 energy and two others at the SSC2 energy. The charge state of the ions delivered to the SME is 1, 2 or 3 units lower than the one accelerated in SSC2, depending on the mass.

## 3. BEAM CHARACTERISTICS

- Beams produced with ECR sources and accelerated up to now :

<sup>3</sup> He	<sup>12</sup> C	<sup>13</sup> C	<sup>14</sup> N	<sup>16</sup> O	<sup>17</sup> O	<sup>18</sup> O
<sup>20</sup> Ne	<sup>24</sup> Mg	<sup>36</sup> Ar	<sup>40</sup> Ar	<sup>40</sup> Ca	<sup>48</sup> Ca	<sup>52</sup> Cr
<sup>58</sup> Ni	<sup>64</sup> Ni	<sup>64</sup> Zn	<sup>84</sup> Kr	<sup>86</sup> Kr	<sup>93</sup> Nb	<sup>107</sup> Ag
<sup>109</sup> Ag	<sup>112</sup> Sn	<sup>125</sup> Te	<sup>129</sup> Xe	<sup>132</sup> Xe	<sup>154</sup> Sm	<sup>155</sup> Gd
<sup>157</sup> Gd	<sup>158</sup> Gd	<sup>181</sup> Ta	<sup>298</sup> Pb	and	<sup>238</sup> U	

- Energy range :  $24 \text{ MeV/u} < W < 95 \text{ MeV/u}$
- Emittances :  $E_H \text{ and } E_V \leq 5 \pi \text{ mm.mrad}$
- Energy dispersion measured at half height :  $0.3 \cdot 10^{-3} < \frac{\Delta W}{W} < 1.9 \cdot 10^{-3}$
- Bunch length at half height :  $0.3 \text{ ns} < \Delta t < 1.9 \text{ ns}$   
 depending on the RF frequency which ranges from 7.13 to 13.45 MHz

Table 2 gives a sample of ion beams recently accelerated.

Ion mass and charge states	Energy (MeV per nucleon)	Beam current on target (enA)
$^{12}\text{C}^{3/6}$	96.3	2000
$^{13}\text{C}^{3/6}$	75	2400
$^{14}\text{N}^{3/7}$	95	2100
$^{18}\text{O}^{4/8}$	76	2100
$^{20}\text{Ne}^{6/10}$	95	2000
$^{24}\text{Mg}^{7/12}$	95	360
$^{36}\text{Ar}^{5/17}$	44	800
$^{48}\text{Ca}^{8/19}$	60.3	800
$^{52}\text{Cr}^{10/23}$	75	250
$^{58}\text{Ni}^{12/26}$	68.5	800
$^{64}\text{Zn}^{13/29}$	79	100
$^{86}\text{Kr}^{14/34}$	60	600
$^{93}\text{Nb}^{14/33}$	31	280
$^{109}\text{Ag}^{18/38}$	36.4	120
$^{112}\text{Sn}^{22/45}$	63	100
$^{125}\text{Te}^{17/38}$	27	16
$^{129}\text{Xe}^{18/44}$	44	800
$^{154}\text{Sm}^{20/46}$	32.1	230
$^{158}\text{Gd}^{19/47}$	34.7	50
$^{181}\text{Ta}^{23/57}$	39.5	40
$^{208}\text{Pb}^{23/56}$	29	45
$^{238}\text{U}^{24/58}$	24	10

Table 2

The ion charge states are given for the ions selected at the ion source and after the stripper located in the beam line L2.

#### 4. MEDIUM-ENERGY BEAM FACILITY (SME)

In 1993 approximately 2100 hours have been delivered to perform 66 experiments of atomic and condensed matter physics. Very heavy ions (e.g. Pb, U) are particularly requested by condensed matter physicists. A sample of these ions is given in table 3.

Ion	Energy (MeV/u)	Beam current on target (enA)
$^{13}\text{C}^{5+}$	9.05	50
$^{36}\text{Ar}^{17+}$	13.6	1100
$^{48}\text{Ca}^{18+}$	9.0	150
$^{155}\text{Gd}^{45+}$	5.53	535
$^{208}\text{Pb}^{53+}$	4.38	70
$^{238}\text{U}^{55+}$	3.73	40

Table 3

#### 5. MACHINE AND TECHNICAL STUDIES

The topics recently investigated are mainly related to :

- The THI project

- Detection of very low beam losses using an ionization chamber.

- Transmission and acceleration of  $^{129}\text{Xe}^{46+}$  in SSC2.

- Measurement of the radiation level in order to protect electronic components at the location of the rebuncher (R2) which will be installed between the two SSC.

- Transmission through the first part of the machine (C01) of an argon beam ( $^{36}\text{Ar}^{10+}$ ). A current of 32  $\mu\text{A}$  ( $2 \cdot 10^{13}$ pps) has been accelerated by the C01 injector. If accelerated by SSC2, the power of this beam would be 6 kW.

• The SPIRAL project

- Construction of an on line isotopic separator test bench called SIRa (Séparateur d'Ions Radioactifs)<sup>[6]</sup> in order to test the feasibility of the production of multicharged radioactive ion beams.

Firstly the transmission efficiency of a production target coupled with an ECR ionizer has been studied with secondary ions produced in the  $\alpha$  spectrometer. The first test consisted in the production of an  $^{35}\text{Ar}$  beam ( $T_{1/2} = 1.78$  s) by interaction of a GANIL standard  $^{36}\text{Ar}$  beam with a carbon foil located in the  $\alpha$  spectrometer. This  $^{35}\text{Ar}$  beam is then conducted in the D2 cave on a graphite target heated at  $1800^\circ\text{C}$ . Atoms of  $^{35}\text{Ar}$  are desorbed from the target, ionized in an ECR source and finally accelerated.

Secondly, the production of  $^{35}\text{Ar}$  and  $^{34}\text{Ar}$  in the SIRa target was studied.

Similarly the production of  $^{17,18,19}\text{Ne}$  isotopes has also been investigated with a  $^{20}\text{Ne}$  primary beam.

- Measurement of dose rates<sup>[7]</sup> from a target irradiated under normal accelerator operating conditions, in order to calculate heavy ion and neutron induced radiation levels for radiological protection.

#### 6. NEW BEAM DEVELOPMENTS

• In order to extend from carbon to helium the mass range of elements accelerated, a 200 enA beam of  $^3\text{He}$  has been performed at 95 MeV per nucleon.

• Studies for new beams are essentially related to ions produced from solid materials, which partial vapour pressure must be of the order of  $10^{-2}$  mbar in the plasma chamber of the ECR source. Some pure elements (e.g. Mg, Cr, Ni, Zn, Sn and Te) are evaporated by means of an oven electrically heated at a maximum temperature of  $1500^\circ\text{C}$ ; others requiring higher temperature (e.g. Nb, Sm, Gd and U) are evaporated by the plasma from a 3 mm diameter rod of oxide. The second method is used to evaporate refractory metal (e.g. Ta and W).  $^{48}\text{Ca}$  is obtained from reduction of calcium oxide by aluminium in an oven.

#### 7. OPERATION WITH THE TWO INJECTORS

The compact injector cyclotron C01 is equipped with an axial injection and an ECR4 source (14.5 GHz) installed on a high voltage platform (100 kV). After hardening electronic equipment against electromagnetic perturbations generated by high voltage breakdown of the accelerating tube, this injector

is routinely operating with  $^{36}\text{Ar}$ ,  $^{58}\text{Ni}$ ,  $^{112}\text{Sn}$ ,  $^{154}\text{Sm}$ ,  $^{181}\text{Ta}$  and  $^{208}\text{Pb}$  beams.

The second injector C02 equipped with an axial injection and an ECR3 source (10 GHz) at 25 kV will be modified in December 1994. The ECR3 source will be replaced by an ECR4 delivering higher charge states and higher extracted current.

#### 8. OPERATION WITH THE NEW ACCELERATOR CONTROL SYSTEM

The new computer control system is conducting the heavy ion accelerator GANIL since the beginning of 1993 and has reached a state of routine operation. It was carried out to supersede the obsolete initial system and to cope with the harsh experimental conditions required by the very high intensity beams envisioned for the next future. A three-layer distributed architecture has been adopted. An ETHERNET local area network (LAN) links the basic components: a VAX/VMS cluster, XWINDOWS interfaced operator consoles, VAXELN driven CAMAC crate controllers and programmable logic controllers for front end controls. Data management with the INGRES relational database management system (RDBMS), as well as operating software written in ADA language have also been adopted.

Current activities are channelled along two main axes:

- hardening the control system, to ensure reliable and efficient accelerator controls,
- increasing the functional capabilities of control applications (e.g. on-line parameter calculation, beam profile displays, ...), as well as extending the scope of RDBMS applications.

In the near future, the new control system will have to supply appropriate software tools to meet the severe operation conditions needed to the acceleration of very high intensity beams and radioactive beams.

#### 9. SISSI : A NEW TOOL FOR RADIOACTIVE BEAMS

The high energy beam from SSC2 is focused with a superconducting solenoid ( $B_{\text{max}} = 11.8 \text{ T}$ ) on a rotating target over a  $0.125 \text{ mm}^2$  cross section, producing a high energy secondary beam with a large angular divergence which is focused by another superconducting solenoid. The secondary ions are usually produced inside a cone having an half-aperture of 80-100 mrad. This angle is reduced to 5-10 mrad by the second superconducting solenoid, matching the acceptance of the beam line L3. Thus the most part of the secondary beam produced in the target can be transmitted. This device is operating since March 1994.

Using a  $^{112}\text{Sn}$  beam delivered by the GANIL cyclotron, at the energy of 63 MeV per nucleon, in conjunction with this high acceptance device SISSI, proton rich nuclei in the region of  $A = 100$  have been produced and subsequently analysed by the LISE3 spectrometer. As a result the doubly magic nucleus  $^{100}\text{Sn}$  was identified with 11 events recorded during 44 hours.

#### 10. THE SPIRAL PROJECT

This device consists of collecting and ionizing the radioactive ions formed by the interaction of the GANIL primary beam with a thick target, then separating them, subjecting them to post acceleration and, finally, reinjecting them in the spectrometer which is ahead of the beam distribution line going to the experimental areas.

At the beginning of 1994 a group has been formed to study and construct SPIRAL. For this project a very high-intensity beam is needed (for example  $1.1 \cdot 10^{13}$  pps of  $^{36}\text{Ar}$  at 95 MeV/u producing a 6 kW beam power). The THI project will provide the transport of this very high-intensity beam produced by the C01 injector to the L3 beam line downstream of SSC2 with an improved transmission factor.

This last operation consists of the construction of a rebuncher (R2) in the L2 beam line which conducts the beam from SSC1 to SSC2 and of the adaptation of all the machine for operation at a high intensity.

#### 11. CONCLUSION

The accelerator GANIL has been delivering heavy ion beams for physics experiments since 1983. Its performances have been continuously improved in terms of beam availability (90%) and stability owing to the new control system. The demand for metallic ions is increasing and a development in this field is needed for ion sources.

Very high-intensity beams and radioactive beams are now under development.

For the running of the machine emphasis is put on :

- operation with two injectors alternatively,
- optimization of secondary beams produced with SISSI and use of its target as an energy degrader for primary beams,
- computer program development for automatic tuning of parts of the machine.

#### 12. REFERENCES

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