GANIL STATUS REPORT

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ABSTRACT

Following the OAE (augmentation of energy) modification[1] and the installation of the SME[2] (medium energy facility) the accelerator has been operating for three years with the new ECR source (CAPRICE IIB at 10 GHz). Results obtained with new beams, metallic beams and the first tests with the new injector[3] system using an ECR source installed on a 100 kV platform are given.

1. INTRODUCTION

The GANIL (Grand Accélérateur National d'Ions Lourds) has been operating at Caen since 1983. This national facility is widely opened to the International Nuclear Physics Community.

The accelerating system provides the physicists with ion beams from carbon (E_{max} = 100 MeV/u) up to uranium (E_{max} = 25 MeV/u). The intensity varies from 1.5 x 10^{12} pps for carbon to 1 x 10^{9} pps for uranium (see below).

2. STATISTICS OF OPERATION

The OAE increased the energy of the ion beam as well as its intensity. A new ECR source called ECR3 has been operating since 1989.

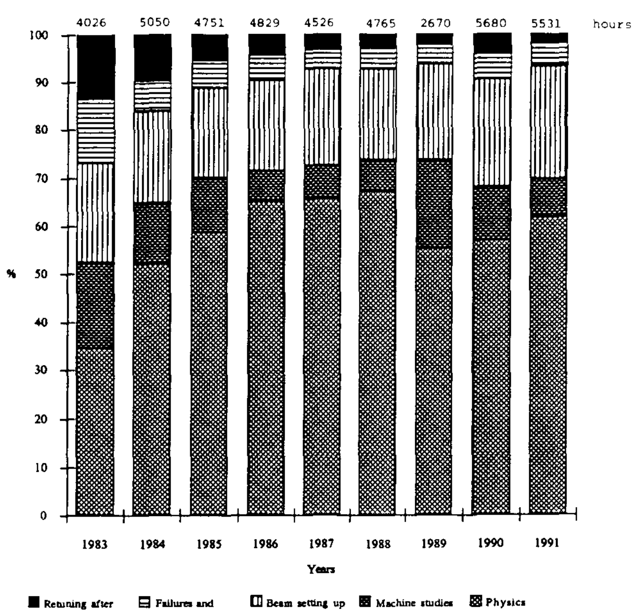


Figure 1

Figure 1 shows how the total running time (41 828 hours) has been shared for 9 years between physics, industrial applications, machine and new beam studies, initial settings and beam tunings, failures and maintenance during operation, and retuning.

Out of a total time of 41828 hours, 28614 hours were available (24284 were effectively used on target and 4 330 hours for machine studies and new beam developments), 2169 hours were used for beam retunings and 2467 hours in equipment failures.

The operation efficiency during experiments has grown regularly up to 90%.

The number of metallic ions to be tuned has increased, during the last three years. Fifty experiments have been performed at high energy in 1991. Fig 2 and 3 show the experimental caves time sharing.

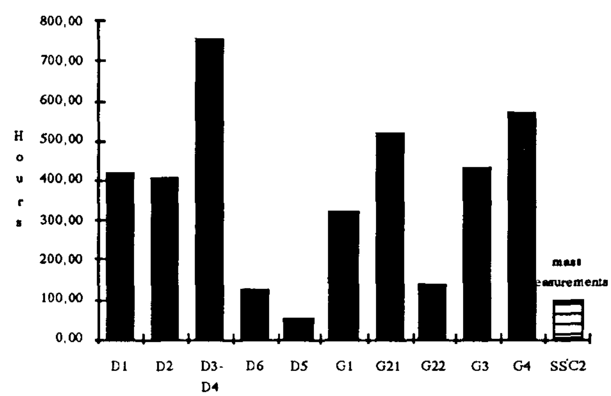


Figure 2

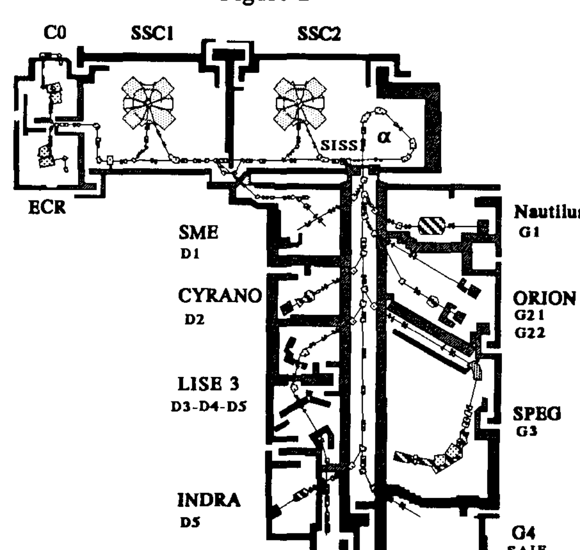


Figure 3

3. Beam characteristics

Table 1 shows the ion beams and their characteristics accelerated up to June, 1992. They were produced with the ECR3 source (10 GHz), except tantalum which was produced with the ECR4 source (14.5 GHz).

All ion beams from SSC1 are available for the SME with energy ranging from 4 to 13 MeV/nucleon.

Beam intensities shown are those adjusted on target according to the experiment requirements.

The power of the ion beam at the output of the SSC2 is, for the time being, deliberately limited to 400 Watts, to ensure the safety of the equipment.

Other beam energies have been obtained by decreasing the velocity after the SSC2.

Exotic ion beams of ^{14}O at 70 MeV/u and ^{12}N at 65 MeV/u were produced by fragmentation of the primary ion beam in front of the high energy spectrometer.

Light ion beams (p, d, α) as well as exotic ion beams can be produced at various energies for detector calibration purpose.

Other ion beams have been tuned without changing the magnetic field up to the stripper.

Pencil beams with a diameter less than 0.5 mm on target are available.

Parallel ion beams for channelling are also available, with a diameter of 3 mm and a divergence smaller than 0.1 mrad.

The time structure of the beam[4] can be reduced by tuning SSC2 as a rebuncher. The method consists in increasing the magnetic field over the last 50 turns, with one or two trim-coils.

Mass of elements can be measured with a high level of resolution, using the GANIL cyclotron SSC2 as an Accelerator-Mass Spectrometer System[5].

ION/M	Charge state before and after stripping	RF Frequency (MHz)	Maximum energy (MeV per nucleon)	Maximum intensity on target (6) (measured)		Beam characteristics (measured)		
				pps x 10^{11}	enA	± ΔW/W half height (10^{-3})	Bunch timing half height ns	Intensity enA
C 12	3/6	13.45	96.3	20.5	2000	0.30	-	173
N 14	3/7	13.45	95	18.75	2100			
O 16	4/8	13.45	95	15.6	2000			
(5)O 17	4/8	12.75	84	9.8	1250			
(1)O 18	4/8	12.2	76	16.4	2100	0.64	0.2	6
Ne 20	3/10	9.893	48	21.87	3500	0.32		
(4)Mg 24	7/12	13.45	95	1.88	360			
(1)Ar 36	10/18	13.45	95	2.8	800		0.3	10
Ar 40	7/17	11.77	70	3.67	1000	0.79	0.5	340
Ca 40	6/19	10.1347	50.4	1	300			
(2)Ca 48	8/19	11	60.3	2.78	800		0.3	360
Ni 58	10/26	11.651	68.5	1.92	800		< 1	180
(5)Ni 64	10/26	11.061	61	0.72	300			
(4)Zn 64	11/29	12.42	79	0.2	100		< 0.8	10
(3)Kr 84	14/33	11	60	2.8	1500	0.59	0.6	900
(1)Kr 86	14/34	11	60	1.10	600			
(4)Nb 93	14/33	8.075	31	0.53	280		1.8	250
(4)Ag 107	18/38	8.71	36.4	0.2	120			
(4)Ag 109	18/38	8.55	35	0.2	120		1.5	80
(5)Te 125	17/38	7.55	27	0.03	16			
(2)Xe 129	18/44	9.52	44	1.09	800	0.90	0.2	18
(2)Xe 132	18/45	9.649	45.4	0.61	440	0.6		
(4)Gd 155	19/47	8.672	36.1	0.05	40	0.5		
(4)Gd 157	19/47	8.562	35.1	0.03	25	0.5		
(4)Ta181a	24/55	8.66	36	0.34	300			
(4)Pb 208	23/56	7.82	29	0.049	45	0.61	< 1.9	30
(4)U 238	24/58	7.13	24	0.01	10	0.32	1	5

(1) enriched 99% ; (2) enriched 70% ; (3) enriched 90% ; (4) natural ; (5) enriched 50% ; (6) for light ion beams. the intensity is voluntarily reduced according to the radiation level

Table 1

$^{238}U^{24/58+}$ was accelerated in October 1991 for the first time for experiments. The beam characteristics are presented below :

ECR3 source (CAPRICE IIB)	Material UO_2 Gas : neon
Intensity before analysis in axial injection	2.6 eμA U^{24+}
SSC1 output energy	3.72 MeV/u
Charge state in SSC2	58+
Carbon stripper	100 μg/cm^2
SSC2 output intensity	1 x 10^9 pps
Half bunch length	less than 1 ns

4. MEDIUM-ENERGY BEAM FACILITY (SME)

An unused charge state of the beam stripped between SSC1 and SSC2 can be sent into a new experiment room dedicated to atomic and solid state physics.

In 1991 approximately 1500 hours of beam have been delivered consisting of :
$^{14}N^{6+}$, $^{16}O^{7+}$, $^{16}O^{8+}$, $^{24}Mg^{11+}$, $^{20}Ne^{9+}$, $^{36}Ar^{17+}$, $^{40}Ar^{14+}$, $^{40}Ca^{18+}$, $^{48}Ca^{18+}$, $^{58-64}Ni^{25+}$, $^{64}Zn^{27+}$, $^{84-86}Kr^{32+}$, $^{93}Nb^{31+}$, $^{107}Ag^{36+}$, $^{129-132}Xe^{42+}$, $^{155}Gd^{45+}$, $^{181}Ta^{55+}$, $^{208}Pb^{53+}$, $^{238}U^{55+}$.
energy range : 3.5 to 13.5 MeV/u
emittance : 10π.mm.mrad in both planes
number of experiments : 50
for example : intensity of $^{208}Pb^{53+}$ was 2.4 10^{10} pps at 4.4 MeV/u.

5. MACHINE AND TECHNICAL STUDIES

The topics recently investigated were :

- charge distribution after stripping in order to increase the intensity of Ar^{16+}, Ar^{17+}, Ar^{18+} as a function of the carbon foil thickness,
- beam transmission through vacuum,
- longitudinal emittance measurements at the ouput of SSC1 or SSC2,
- reduction of the time structure of the beam,
- supervision of the temperature and voltage measurements of the RF cavities,
- supervision of the programmable logic sequencer controlling the vacuum between the SSC2 and the experimental areas,
- operation logs and statistics viewing. This application read the INGRES database by means of the graphic query language (GQL) to feed an EXCEL application,
- acceleration of light ions at high intensity.

Two tests have been carried out with a $^{20}Ne^{6+}$ beam which was produced by the ECR4 source installed on a 100 kV platform, driven into the new axial injection and accelerated by the C01 cyclotron.

Results are presented here after :

- **Source analysis**

. 65 to 95% of the analysed beam was concentrated, depending on the platform voltage, within a transverse emittance of 60 π.mm.mrad which corresponds to the admittance of the C01 injection system.

- **Beam intensity**

	Injected into C01	Extracted from C01
$^{20}Ne^{6+}$	36 eμA(3.75 10^{13}pps)	24 eμA(2.5 10^{13} pps)

NB : 60 to 70% of the extracted beam is within the acceptance of the SSC1.

In June 1992 this beam was accelerated by SSC1 and ejected at maximum energy. The power of this beam accelerated by SSC2 would exceed by 5 times the maximum value permitted by the safety of the equipment.

6. NEW BEAM DEVELOPMENTS

They are essentially related to ions produced from solid materials. The ECR source is operated both by a sputtering and by an electrically heated oven methods. The second one allows us to obtain stable intensity of Zn, Nb, Mg, Cr, Ca, Ag, Pb ions. Now the Lu ion production is under development.

7. OPERATION WITH THE NEW INJECTOR

The new injector of the GANIL facility[6] (new ECR source operating at 14.5 GHz installed on a 100 kV platform, new axial injection and modified C01 cyclotron) is now running for the operation.

The $^{181}Ta^{24/57+}$ was accelerated at the energy of 36 MeV/nucleon. The availability of the beam for experiments was 100% :

ECR4 source (14.5 GHz) $^{181}Ta^{24+}$	Material tantalum Gas : oxygen
Intensity after analysis in axial injection	8 eμA (60 π x 60π mm.mrad)
C01 output intensity	5 eμA
SSC1 input intensity	2.2 eμA (40 π x 40π mm.mrad) and $\frac{\Delta W}{W} = \pm 5\%$
SSC1 output intensity	1.8 eμA (24+)
Carbon foil	180 μg/cm^2
SSC2 output intensity for the users	0.3 eμA (55+)

8. REJUVENATION OF THE COMPUTER CONTROL SYSTEM[7]

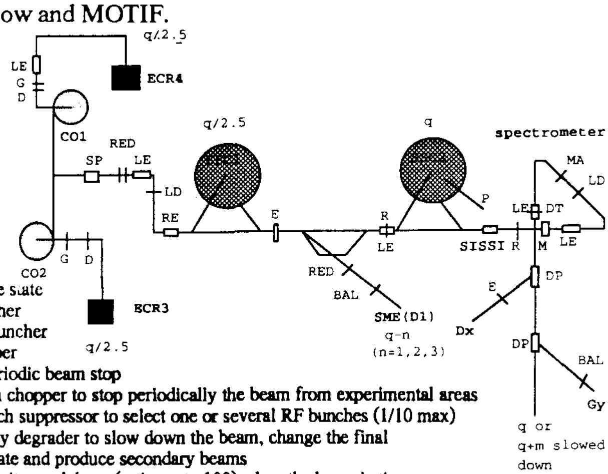
Rejuvenation of the control system of GANIL is under way to fulfil the increasing requirements of the accelerator operation which aims at providing the physicists with a wider range of ion beams under flexible and reliable conditions. The distributed architecture adopted exhibits three functional levels federated by an Ethernet local area network (LAN) :

- The Host Level provides a general purpose and powerful environment for software developments, off-line calculations, database management, and simulation. It relies on a VAX6000-410 computer, linked to video terminals, and workstations VS4000 for colour graphics displays. Connection to other facilities of the GANIL and to remote laboratories via wide area networks (WAN) are available.

- The Realtime Control Level is devoted to human interface for accelerator controls. Man-machine interaction is accomplished via operator consoles, supervision systems, and graphic field terminals. This level is based on a μVax 3800 cluster, workstations VS4000 and Xterminals to benefit from the enhanced graphic capabilities.

- The Equipment Level performs low level controls. It makes use of -Front end controllers : CAMAC controllers (K.3968 from KINETIC SYSTEMS) and VME controllers (VME300 from AEON) to run applications under the VAXELN O.S. - Programmable logic controllers (PCL) : S5-135U from SIEMENS, and PB400 from APRIL. CAMAC and VME front end controllers, as well as the SIEMENS PLC are directly linked to the controls Ethernet.

To achieve productive and dependable software, VMS for VAX processors and VAXELN for real time controls are chosen. ADA (as major programming language), Fortran and C are adopted. Assembly language is relinquished. In addition to the VMS environment and LAN softwares, important packages are used : - The INGRES RDBMS from ASK/INGRES which complies with the SQL standard and encompasses the W4GL 4th generation language for NON-realtime database management (realtime database being hosted in the μVAX3800 and fragmented into dedicated live database to be down loaded into the front end controllers), - the IMAGIN family from SFERCA for PLC supervision, - Xwindow and MOTIF.



q : charge state
G : buncher
RE : rebuncher
E : stripper
MA : periodic beam stop
D : beam chopper to stop periodically the beam from experimental areas
SP : bunch suppressor to select one or several RF bunches (1/10 max)
R : energy degrader to slow down the beam, change the final charge state and produce secondary beams
M : intensity modulator (ratio up to 100) when the beam is time shared between two experiments
DP : pulsed dipole to establish the beam in 0.5 sec
RED : intensity reduction grid to reduce intensity by 5 or 25 while conserving emittance
BAL : beam sweeping from 4 Hz to 7 Hz
LD : energy spread limitation
LE : emittance limitation (down to 0.05 π.mm.mrad in both plans H and V)
Δt : time structure measurement
SME : medium energy beam facility with two beam lines in room DI at SSC1 energy

A specific software layer was designed to match the accelerator environment and to support its controls. This so called GANICIEL layer is quite transparent to the users and is built upon the industry softwares. It makes widely use of the client-server model and takes into consideration the distributed architecture.

Main effort is, by the time being, mainly devoted to coding the GANICIEL and user software. The future control system is planned to be operational by spring 1993.

9. SISSI PROJECT[8]

The aim of this project is to increase the transmission of the secondary beams by a factor of 50 with respect to the present set-up; the main component is a pair of high magnetic field solenoids (11 T) providing a large angular acceptance (80 mrad). Both the SPEG and LISEIII spectrometers should take advantage of this improvement (better mass resolution). It should be completed in 1993.

10. CONCLUSION

After three years of operation with high energies and high intensities the demand is still strong both for light and heavy ions like C, N, O... Ta, PB, U. The demand is increasing for metallic ions Mg, Ni, Nb, Ag, Te, Lu, Gd, Ta, Pb, U.

The new high intensity injector system is operating since June 1992. The completion of the high resolution 4 π detector for light charged particles and nuclei detection INDRA[9] is scheduled for the end of 1992.

Medium-energy beams, diverted after the stripper have been permanently available (1500 hours a year) for non-nuclear physics since December 1989.

A study group is now investigating the spallation production of secondary beams by heavy ions.

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