RECENT IMPROVEMENTS AND NEW POSSIBILITIES OF THE GANIL FACILITY

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Abstract

The results of the machine improvements recently achieved : ECR source, new injector[1], and medium energy output are presented . The measured characteristics of all the recently accelerated beams are summarized, featuring results obtained with metallic ions : ^{40}Ca, ^{48}Ca, ^{58}Ni, ^{64}Zn, ^{157}Gd, ^{238}U. Specific beams can be tuned : very short bunch length, parallel beam for channeling experiments, special beam line focusing for secondary particles. Finally, new developments are mentioned : axial injection at 100 kV, high intensity secondary beam production and new operational facilities are described.

I. INTRODUCTION

The GANIL (Grand Accélérateur National d'Ions Lourds) is beeing operated 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} p.p.s for carbon to 7 x 10^8 p.p.s for uranium (see below).

In conjonction with the upgrading of the accelerator, much efforts have been put in the design and the construction of major experimental set-ups: two Spectrometers SPEG and LISEIII and several 4 π detectors for neutrons, gammas and charged particles (ORION, TAPS, NAUTILUS, INDRA)(figure 1).

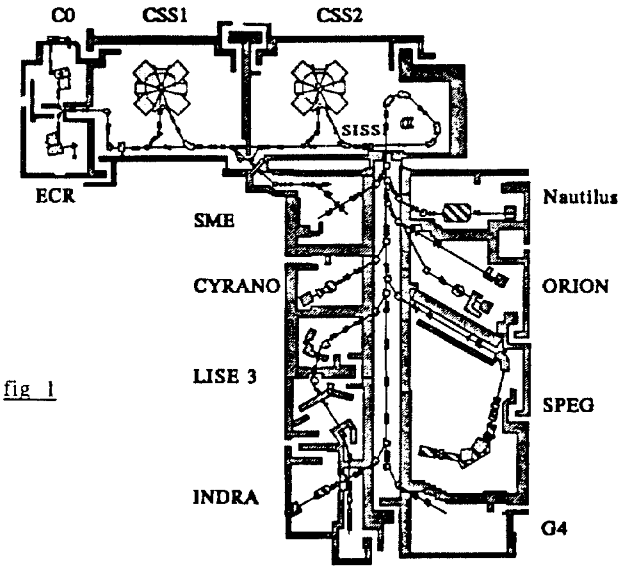

fig 1

II. RECENT IMPROVEMENTS

After the O.A.E. modification (Opération Augmentation d'Energie)[2] energy and intensity have been increased.

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
O 16	4/8	13.45	95	15.6	2000			
(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		
(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			
(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)Ta 181	23/57	9.055	39.5	0.044	40	0.64	1.4	40
(4)Pb 208	23/56	7.82	29	0.049	45	0.61	< 1.9	30
(4)U 238	24/59	7.13	24	0.0068	6.4		< 1.7	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

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Table 1 shows the ion beams and their characteristics accelerated up to April 1st, 1991 with the source called ECR3 (CAPRICE IIB). For light ion beams, the intensity is voluntarily reduced according to the radiation level and allowed beam power (400 watts).

The beam time devoted to the heavy and specially heavy metallic elements occupies the main part of the total beam time (64%).

1. *Medium-energy beam facility* (S.M.E.)[3]

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

In 1990 approximately 1400 hours of beam have been delivered consisting of :
$^{16}O^{7+}$, $^{16}O^{8+}$, $^{36}Ar^{17+}$, $^{40}Ar^{14+}$, $^{40}Ca^{18+}$, $^{48}Ca^{18+}$, $^{58-64}Ni^{25+}$, $^{64}Zn^{27+}$, $^{84-86}Kr^{32+}$, $^{129-132}Xe^{42+}$, $^{208}Pb^{53+}$.
energy range : 3.5 to 13.5 MeV/u
emittance : 10 π.mm.mrad in both planes
number of experiments : 38

2. *New radiation safety control system*

A new control system called UGSII (Unité de Gestion des Sécurités) which is more flexible and more evolutive than the old one has been installed and is working satisfactorily since February 1990. The system is VME processed.

3. *Mass measurements with the GANIL cyclotrons*[4]

An original method of mass measurements using the GANIL cyclotrons as an Accelerator-Mass Spectrometer System was suggested in order to reach a higher level of resolution. The main idea is to make use of the specific features of the GANIL cyclotron SSC2 to extend the time of flight. Secondary nuclei are produced by nuclear reactions between SSC1 and SSC2 and reaccelerated in SSC2.

4. *Time structure of the beam*[5]

A new method is being developed to reduce the length of the pulses. It consists in tuning SSC2 as a rebuncher, by increasing the magnetic field over the last 50 turns, with one or two trim-coils.

Due to the drift to the experimental room, the longitudinal emittance ellipsoid rotates and reaches its minimum phase length (chromatic width) when arriving in the room(the drawback of this method is of course an increase of the energy dispersion, the total area of the longitudinal emittance ellipsoid remaining constant). For example, the pulse length decreases from 400 ps (FWHM) in the spectrometer (see fig 1) to 215 ps in LISE, that is a 60 m drift length.

Evidence of the stability of such a tuning was established but a reproducible procedure has to be developed by calculation of the parameters taking into account the room where the beam is sent.

5. *Pencil beam*

A pencil beam with low divergence and cross section can be obtained by reducing emittance (0.05 π..m.mrad in both planes). The intensity can be also reduced to a few p.p.s by closing energy spread slits. The beam diameter is less than 0.5 mm on target.

6. *Acceleration of uranium ions*

$^{238}U^{25/58+}$ was accelerated at 24 MeV/u for the first time before OAE. 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^{25+}
Energy before SSC1	3.72 MeV/u
Charge state in SSC2	58
Carbon stripper	150 μg/cm^2
Intensity before SSC2	8.5 x 10^8 p.p.s
Half bunch length	less than 1.7 ns

7. *Parallel beam for channeling*

GANIL is an unique tool to carry channeling experiments. Beams with a diameter of 3 mm and a divergence smaller than 0.1 mrad can be delivered. Channeling is directly observed by a decrease of nuclear reaction production when the beam is aligned with one of the crystal axes. In addition, two new objectives were recently reached using calibrated Al foils to strip the initial beam and/or to slow it down. These foils were placed before the emittance slits and the alpha spectrometer ; with a 3.x 10^{10} p.p.s incoming Xe beam, 3.x 10^6 p.p.s of Xe^{52+} are available, and the energy is varied from 42 MeV/u to 32 MeV/u by 0.4 MeV/u steps. Only half an hour is needed to change the energy and to reproduce the channeling conditions by an automatic procedure.

8. *Secondary beam production*

A 4.x 10^5 p.p.s , 70 MeV/u ^{14}O beam has been produced by fragmentation of 95 MeV/u, 1.5 x 10^{12} p.p.s ^{16}O ions traversing a 3.6 mm thick ^{12}C target.

The composition of the beam selected within the acceptance of the high resolution spectrometer was :
^{17}F - 12% ; ^{16}O - 25%, ^{15}O - 25% ; ^{14}O - 9% ; ^{14}N - 4%, ; ^{13}N - 3% ; C, Be, B - 21%.

During that experiment the primary beam power has been voluntarily limited to 400 W for the safety of the accelerator components.

III. NEW PROJECTS

In the near future four major improvements will be achieved in order to get a considerable increase of the intensity.

1. *New high intensity injection system*[6]

In order to increase the beam intensities for metallic and heavy ions delivered by the GANIL injectors, a new injection system has been designed. It consists of a new 14.5 GHz ECR source installed on a 100 kV platform. Injector C01 has also been modified. The ECR source is working now and the completion of this system is planned for July 1991.

2. *O.A.I operation* (Opération Augmentation d'Intensité)

The goal of this operation is to adapt all the accelerator components (vacuum chambers, septa, beam diagnostics, ...) to a beam power of about 5 to 10 kW.

3. *SISSI project*[7]

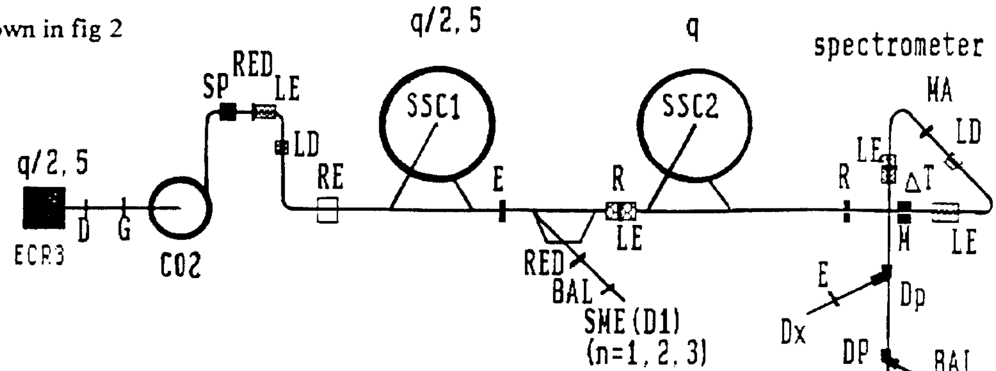
The objective of this project is to increase the transmission of the secondary products by a factor of 50 with respect to the present set-up ; the main component is a pair of high magnetic field solenoids (11 T) providing a large angular acceptance (80 mrad).

4. *Computer control system renewal*[8]

This control system is being renewed to meet the increasing demands of the accelerator operation. The new system is planned to be operational by the end of 1992. It is composed of distributed powerful processors (VAX 6410, µVAX 3800) federated through Ethernet and flexible network wide database access, VME standard front-end microprocessors, enhanced color graphic tools and workstation based operator interface.

IV. Operational Facilities

The operational facilities are shown in fig 2



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 kHz
LD : energy spread limitation
LE : emittance limitation (down to 0.05 π.mm.mrad in both plans H and V)
Δt : time structure measurement

fig 2

SME : medium energy beam facility with two beam lines in room D1 at SSC1 energy

V. Conclusion

The number of additions, modifications and improvements shows that GANIL is in the process of a constant upgrade enlarging the field of physics which can be investigated with a cyclotron facility.

VI. References

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