GANIL STATUS REPORT

M-H Moscatello, E.Baron, C.Barué, C.Berthe, L.David, M. Di Giacomo, P.Dolegieviez, C.Jamet, P.Lehérissier, R.Leroy, F.Loyer, E.Petit, A.Savalle, G.Sénécal
GANIL-DSM/CEA,IN2P3/CNRS, BP 55027, 14076 Caen Cedex, France

Abstract

GANIL operation has been orientated towards an increase of intensities these last years, for production of both radioactive beams by fragmentation through SISSI device and exotic nuclei in the experimental caves, and in view of Spiral start up. Usual running statistics are presented, as well as the operation conditions and results in terms of beam intensities.

Different improvements and equipment renovations have been realized consequently: beam production method developments on the ECR sources, hard-ware renovations, tuning and control programs, development of high intensity beam diagnostics. A review of these works is reported.

1 OPERATION STATISTICS

The GANIL accelerators have reached now a cruise operation schedule with 34 to 35 weeks (5500 hours) of beam production per year, with a 3 month shut-down in winter and 1 month in summer. The beam time is shared between different user categories as shown on Fig.1.

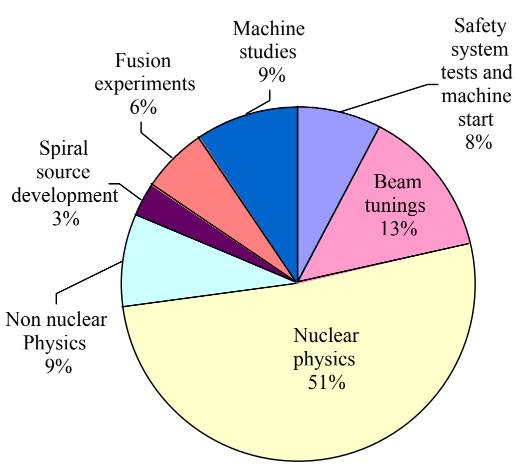

Figure 1: Beam time sharing in 2000

Nuclear Physics experiments use radioactive beams produced in SISSI device during 50% of the time, and the Intermediate Energy Exit, working simultaneously with the main exit, uses about 1800 beam hours per year. Almost one beam change per week(ion and energy) is performed, which leads to a quite high failure rate: around 10% of the total running time, with a large predominance during these last 2 years of failures in RF systems (power components and water leaks in cooling circuits), as presented in Table 1.

Table 1: Failure repartition

Equipment type	Time percentage*
RF systems	42 %
Safety control systems	11 %
Power supplies	6,6 %
PLCs	6,1 %
ECR Sources	5 %

*: the total is not 100% as not all items appear in the table

Nevertheless, the availability yield for physics experiments (i.e. available beam time/scheduled beam time) is maintained around 90%.

2 BEAM INTENSITIES

2.1 High intensity primary beams

The intensity increase in GANIL started a few years ago [1], and even if the final goal of 6 kW has not been reached yet, some high intensity beams are produced in operation and for machine studies. A sample of these beams is given in Table 2. At the exit of CSS2, with high frequencies and for intensities up to 5-6 μA, no tuning problems are met, while for higher intensities, space charge effects may be quite important [2]. At lower frequencies, space charge effects are present from CSS1 (ex: Kr beam).

Table 2: Primary beam intensities

Beam	Energy (MeV/A)	Available intensity (CSS2 exit)
$^{13}C^{3/6}$	75	18 μA- 1.9 10^{13} pps
$^{36}Ar^{10/18}$	95	10,5 μA- 3.6 10^{12} pps
$^{36}S^{10/16}$	77	6,3 μA[1] - 2.5 10^{12} pps
$^{58}Ni^{11/26}$	74	3,6 μA – 8.7 10^{11} pps
$^{86}Kr^{10}$	5,3 (CSS1)	20 μA – 1.25 10^{13} pps

The standard primary beam characteristics are the following:

$$\text{Total } \varepsilon_{H,V} \approx 3 \text{ to } 5\ \pi\text{.mm.mrad}$$

[1] ^{36}S enrichment: 63,4%

CP600, *Cyclotrons and Their Applications 2001, Sixteenth International Conference,* edited by F. Marti

$\Delta W/W$ (half height) $\approx \pm 5.10^{-4}$ to 10^{-3}

2.2 Secondary beams produced in SISSI device

Secondary beams are routinely produced in SISSI device, a set of 2 super-conducting solenoids with a target in between, placed at the entrance of the alpha spectrometer. These beams are usually purified through an achromatic degrader, before being sent to the experimental lines (the obtained intensities are presented in table 3). Their characteristics are the following:

$\varepsilon_{H,V}$: limited to 16 π.mm.mrad (transport line acceptance)

$\Delta W/W$: limited to ±1% by alpha spectrometer acceptance.

Table 3: secondary beams produced by SISSI device

Beam	Energy (MeV/A)	Available intensity*	Primary beam
^{6}He	41	5.10^{5} pps	^{13}C 5µA
^{11}Be	41	2.10^{5} pps	^{13}C 2,5µA
^{32}Mg	52	600 pps	^{36}S 5,8µA

*: after purification by the achromatic degrader

3 BEAM PRODUCTION WITH ECR SOURCES

3.1 Intensity increase program with the ECR ion sources

In 1998, following the High Intensity Transport project and experimenter requests, it was decided to start a program for increasing Ni, Ca, Mg intensities from the ECR sources. At the end of 1999, one ECR4 was transformed in ECR4M (modified magnetic structure, higher performances). The second ECR4 source will be modified in the same way at the end of 2001.

3.2 Iron and Nickel production with MIVOC method

During 1999, constant efforts were put on the development of high intensity Nickel beams, in order to reach one of the most important results in nuclear physics, the discovery of the last doubly-magic nuclei: Nickel-48. In September 1999 four of them were produced and detected at GANIL. A high intensity nickel-58 beam had been produced by the ECR ion source over a long period (10 days), i.e. 50 µA of $^{58}Ni^{11+}$, to get a 3,5 µA $^{58}Ni^{26+}$ on SISSI production target [3]. The MIVOC method (Metal Ions from Volatile Compounds) developed at Jyväskylä [4] was used for the production of this beam. Contrary to other methods, like oven or sputtering, the molecules condensed on the cold walls can be recycled. Therefore, the total ionization efficiency is improved and higher intensity can be obtained. For nickel, the total ionization efficiency is improved by a factor 7 compared to the oven method (7% instead of 1%), i.e. 7 times more intensity is extracted from the source. The best spectrum produced by the ECR ion source during the nickel-48 experiment is shown in Fig. 2.

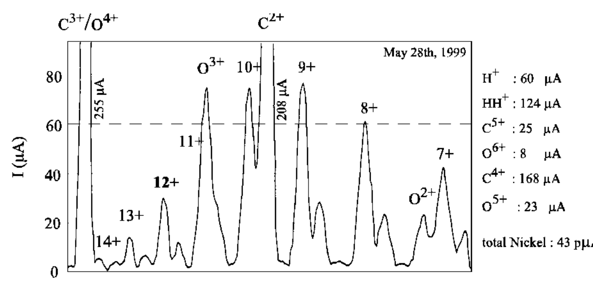

Figure 2. ^{58}Ni spectrum, with 50 µA of Ni^{11+}

3.3 Intensity increase for Calcium beams

Last year, some tests started with natural Calcium, and were carried on during a few weeks at the beginning of this year, with the ECR4 source. The natural Calcium was used under the metallic form, without any oven polarization and Tantalum chamber, and some 30 to 35 µA of $^{40}Ca^{9+}$ were obtained during several tens of hours, with a good stability and a rather low consumption($\leq$ 0.4 mg/h), which is an important criterion if using ^{48}Ca. A run with 60 µA intensity was also performed, but under conditions to be improved for the accelerator operation.

4 ACCELERATOR HARD-WARE RENOVATION PROGRAM

The accelerator renovation program that started a few years ago [7], is based on the 3 main points (major operations are mentioned).

- **Replacement of obsolete components or equipment, impossible to repair, in order to avoid accelerator shutdown:**
  Replacement completed:
  SCANDITRONIX NMR probes by METROLAB's
  VAX work-stations by Alpha's
  APS programmable controllers by SIEMENS's
  Compressors for SSC cryogenic pumping by CTI's
  Replacement in progress:
  CAMAC by VME (RTVAX then POWERPC)
  APS + JCAM10 by SIEMENS PLCs for the RF local control system
  Stepping motor control by micro-step system
- **Reliability improvement, by replacing aged (but working) components:**
  Replacement completed:
  Experiment area magnet relay-based switching grid by PLC

Network upgraded to Fast Ethernet with Gigabit upper link

Replacement in progress:

Magnet power supply components

Low level electronics for the RF amplifier high voltage power supplies

- **Improvement of the whole accelerator performances, needed for the Transport of High Intensity and Spiral projects:**

Completed:

Renovation of the control room

In progress:

Power supply interfaces renewed

Analogic beam feedback converted to digital

Beam instrumentation improvement (replacement of LF current transformers by RF ones, new bunch length probes)

Planned:

Monogap linear buncher to be built

Beam chopper to be transformed for more safety and to perform high intensity reduction factor (1/1000).

It is clear that these 3 types of renovations may overlap for some equipment, and the priorities may evolve every year, according to the priorities that might be changed (if some failures become important on some equipment, for instance).

5 HIGH INTENSITY BEAM DIAGNOSTICS

Developments of high intensity diagnostics started with the High Intensity Transport Project, beginning with the spiral wire beam profile monitors [5]. In 2000, 9 spiral monitors were installed on L1 line, replacing the secondary electron emission profile monitors, and are now used routinely.

The front-end diagnostic of CSS2 electrostatic deflector was also improved, as the safety of CSS2 is mainly based on it. The copper blade protecting the deflector septum blade was modified in order to dissipate 600 W (direct cooling by water circulation), and the measured current fluctuations on this diagnostic were attenuated by a low polarization of the copper blade. Nevertheless, the disturbances associated with the high voltage still exist, and one has to improve this point to ensure a total safety concerning beam losses in CSS2.

More generally, non-interceptive diagnostics must be developed for the measurements of the high intensity beam characteristics (longitudinal in particular)

6 AUTOMATIC TUNING PROGRAMS

After beam matching and beam centering automatic tuning programs [6], new automatic tuning or measurement programs were produced:

- beam energy measurement at the exit of each cyclotron (one has to transport the beam in the nearest spectrometer)
- achromatism measurements in different sections (and automatic correction in most of the sections)
- emittance (transversal and longitudinal) measurements, that are mainly used during machine studies
- automatic injection in CSS1 and CSS2, which consists in centering the beam in all the magnetic and electrostatic channels of the injection systems.

7 IRRSUD BEAMLINE CONSTRUCTION

IRRSUD is an irradiation line which uses low energy beams from injector cyclotrons C01 or C02, for applied physics and industrial applications as nanotechnologies, material evolution under irradiations. This line was built in 1999 and 2000, according to the accelerator beam time schedule; it is ready now to operate, just waiting for the Safety Authority authorization.

8 CONCLUSION

GANIL has been operating with higher intensity beams for 2 years now, mainly for secondary beam production in SISSI device and in experimental areas. The continuing efforts on beam production with ECR sources and equipment renovations should bring the accelerator to still higher performances, especially for the start of SPIRAL facility, that should occur in a very near future.

REFERENCES

[1] E.Baron et al.- Experience with high intensity operation of the GANIL facility. Proceedins of the 15th Int. Conf. On Cyclotrons and their Applications. Caen, France (1998), p385-387

[2] E.Baron et al., High intensity heavy ion beams for exotic nuclei production at GANIL. Proceedings of this conference.

[3] C.Barué et al., Metallic ion developments at Ganil, 14th International Workshop on ECR Ion Sources, ECRIS99, CERN, Geneva, p111-115.

[4] H. Koivisto et al., 13th International Workshop on ECR ion sources, College Station, Texas, p. 167 (1997).

[5] E.Petit et al, Recent developments for beam intensity increase operation, Proceedins of the 15th Int. Conf. On Cyclotrons and their Applications. Caen, France (1998), p290-292

[6] A.Savalle et al, Automatic beam tuning at GANIL, Proceedins of the 15th Int. Conf. On Cyclotrons and their Applications. Caen, France (1998), p560-563

[7] F.Loyer et al, Status Report on the GANIL renovation program, Proceedings of the 14th Int. Conf. on Cyclotrons and their Applications, Cape Town, South Africa (1995), p74-77