GANIL OPERATION STATUS AND UPGRADE OF SPIRAL1

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Abstract

The GANIL facility (Grand Accélérateur National d'Ions Lourds) at Caen produces and accelerates stable ion beams since 1982 for nuclear physics, atomic physics, radiobiology and material irradiation. Nowadays, an intense exotic beam is produced by the Isotope Separation On-Line method at the SPIRAL1 facility. It is running since 2001, producing and post-accelerating radioactive ion beams of noble gas type mainly. The review of the operation from 2001 to 2013 is presented. Due to a large request of physicists, the facility will be enhanced within the frame of the project Upgrade SPIRAL1. The goal of the project is to broaden the range of post-accelerated exotic beams available especially to all the condensable light elements as P, Mg, Al, Cl, etc. The upgrade of SPIRAL1 is in progress and the new beams would be delivered for operation by the end of 2015.

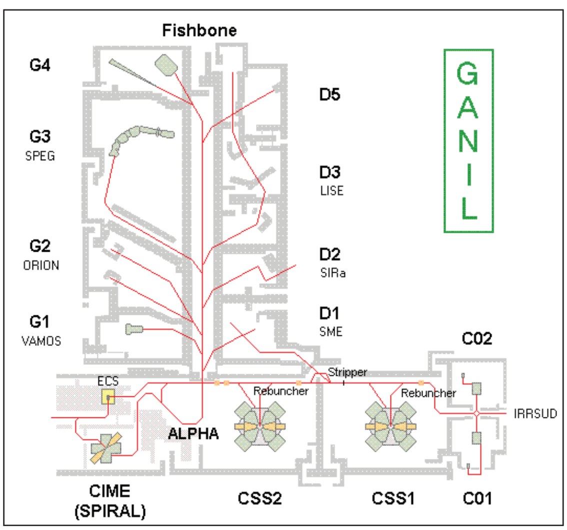

Figure 1: GANIL layout.

OPERATION REVIEW

Multi-beam delivery is routinely done at GANIL using its 5 existing cyclotrons. Up to five experiments can be run simultaneously in different rooms with stable beams (Fig. 1):

1. Beams from C01 or C02 are sent to an irradiation beam line IRRSUD (<1MeV/u).
2. A charge state of the ion distribution after the ion stripping downstream CSS1 is sent to atomic physics, biology and solid states physics line D1 (4-13MeV/u).
3. A high-energy beam out of CSS2 is transported to experimental areas (<95MeV/u).
4. An auxiliary experiments shares the previous CSS2 beam (10% of the pilot experiment time)
5. Finally, stable beams from SPIRAL1 source can be sent to LIRAT (<10 keV/q) or post-accelerated by CIME and used for testing detector for example.

During radioactive beam production with SPIRAL1, the combinations are reduced to the four first (cases 1, 2, 3, 4) and radioactive beam is sent to the experimental areas.

2001-2012 GANIL OPERATION STATUS

Since 2001 (Fig. 2), more than 40000 hours of beam time has been delivered by GANIL to physics, which correspond to 92 % of scheduled experiments.

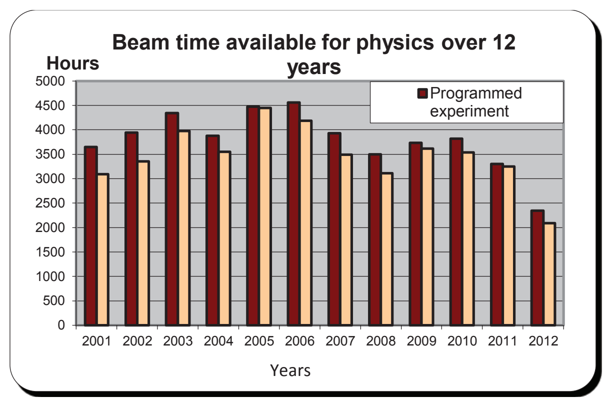

Figure 2: Beam time available for physics over 12 years.

The number of beam delivered per year (Fig. 3) has increased until 2010. Owing to the construction and assembly of the new SPIRAL2 accelerator, the running time has been shrinked to devote more human ressources to the project, in particulier in 2012 with only 2000 hours of running time (instead of 3500 hours per years).

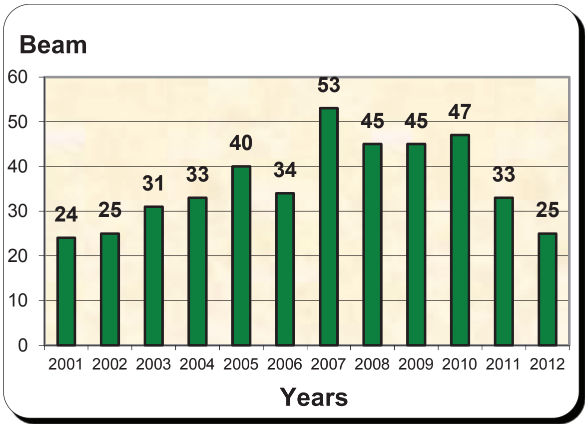

Figure 3: Number of beams tuned between 2001 and 2012.

Figure 4 shows the statistic running of the machine over 11 years. As we can see, 66.4 % of beam time is dedicated to Physics and 12% for machine tuning.

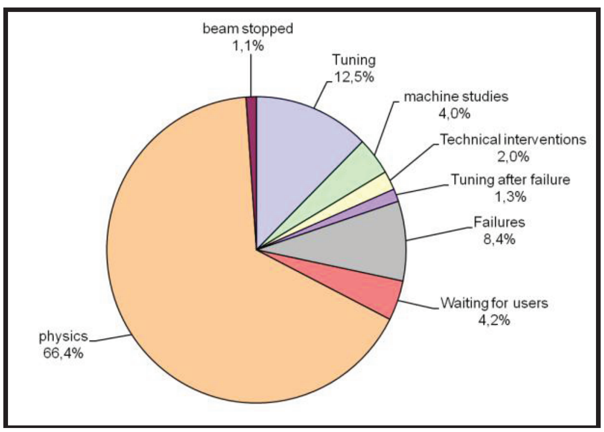

Figure 4: Statistic running of the machine between 2001 and 2012.

UPGRADE SPIRAL1

The first Isotope Separator On Line System installed at GANIL, named SPIRAL1, has delivered radioactive ions for 11 years. Radioactive atoms produced by fragmentation of swift heavy ions (up to 95 MeV/u) on a carbon target are ionized in a multi-charged ECR ion source before being post-accelerated in a cyclotron. Due to the design of the target ion source system (TISS), mainly gaseous ions are produced. To satisfy the request of physics community in extending the choice of ions to those made from condensable elements, with masses up to Xe, an upgrade of SPIRAL1 has been undertaken. Beams and technical options considered during the prospective phase have been sorted out. A schematic of the ongoing upgrade is presented in Fig. 5. Surface ionization, FEBIAD (Forced Electron Beam Induced Arc Discharge) or ECR (Electron Cyclotron Resonance) ion sources [1, 5] will be installed in the production cave after its modification to provide 1+ beam of condensable elements. Out of the cave and after mass separation, a Phoenix charge breeder will be installed on the present low energy beam line to increase the charge of the radioactive ions from 1+ to N+ for post-acceleration [2].

The upgrade of SPIRAL1 and its technical environment need to conform the stringent regulation requirements as explained below.

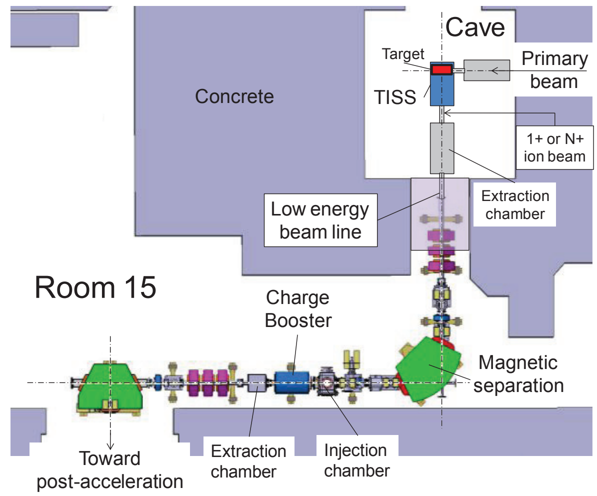

Figure 5: Schematic of the SPIRAL1 upgrade.

NEW BEAMS VERSUS NEW TISS

New elements will be mainly produced by fragmentation of primary beam ions on a graphite target. Thus most of the masses and atomic numbers will generally not be higher than those of the primary beams available at GANIL. The elements to be produced can be divided in three groups:

1- alkali elements and rare earth elements (Li, Na, K, Rb and Sr). The elements could be ionized in an existing TISS, already tested on line at GANIL on a test bench but it needed some optimizations before being used in the cave.

2- metallic ions (Mg, Al, Ca, Sc, Cr, Mn, Co, Ni, Cu, Zn, Ga, Ge, As and Se). They will be produced by association of a carbon target with a FEBIAD of VADIS (Versatile Arc Discharge Ion Source) type developed at CERN (Fig. 6). This association indicates good performances for the TISS and yields have been measured favorably for Mg, Al, Cl, K, Mn, Cu and even Fe ions [3]. The technical design ought to be pursued, mainly for improving the setup reliability because there is still a weakness concerning the connection tube to the hot target to the FEBIAD ion source which should be solved before being used in the SPIRAL1 cave. The final version should be ready by end of September 2013 and tested off-line for checking the ionization efficiencies..

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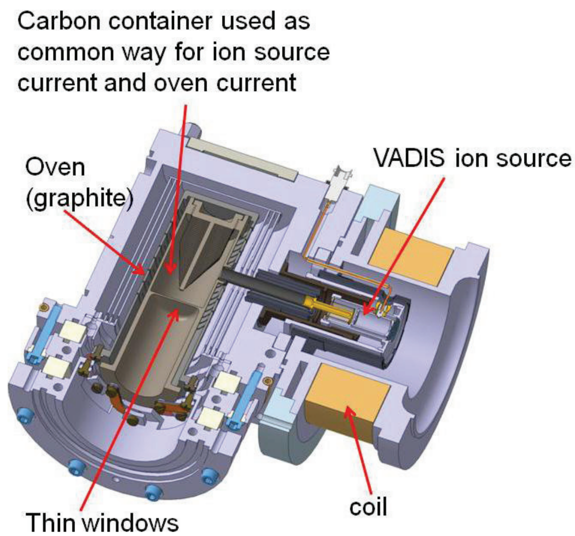

Figure 6: TISS made by association of a graphite target with a VADIS FEBIAD ion source.

3- non-metallic ions, halogen and rare gas ions (He, Ne, Ar, Kr, O, C, P, Cl and Br). Multi-charged ions from rare gases, C and O are currently produced using the ECR ion source of SPIRAL1 updated to enhance the ionization efficiencies.

Because the singly-charged ion sources are shorter than the present NANOGAN III ECRIS along the low energy beam line axis, a chamber containing optical elements will be installed to transport and adapt the 1+ beams to the present low energy beam line.

Some elements heavier than the projectiles will be produced by fusion-evaporation reactions, at lower beam energies. Using heavier target material than graphite will also be possible and beneficial in a 2^{nd} step.

CAVE UPGRADE

The cave of SPIRAL1 has been successfully modified during 2013 to receive the new TISSs. Now, not only multi-charged radioactive ions could be directly produced in the cave for post acceleration but also mono-charged radioactive ions thanks to specialized TISS allowing high ionization efficiencies. The main advantages are a higher purity of the beam of interest owing to a pre-separation of the singly charged ions in the first magnetic dipole and production of higher charge states which will allow heavier elements to be injected in the post accelerator (cyclotron) and thus higher final energy.

The modifications have mainly been made on the support of the TISS, the equipments situated on the HV platform and on the services. The new upgrade of TISS ion source called Nanogan III has been installed and tested with stable beam. This new version is more efficient with lower masses: for example the Ne^{4+} is ionized with an efficiency of 13.9% compare to the previous one of 8.7%. Experiments with radioactive beams are scheduled in September 2013 concerning the production of Ne radioactive ions.

CHARGE BOOSTER

An important part of the upgrade consists in the installation of the charge breeder on the low energy beam line (room 15), after the mass separator. It is a commercial version of the Phoenix charge breeder designed by LPSC, GRENOBLE, and constructed by Pantechnik. It runs routinely at TRIUMF [4] The possibility to make the 1+ and existing N+ beams going through the booster when it is off has been taken into account. This function is essential when the beam delivered by the TISS is directly used, *i.e.* without charge breeding, either for post-acceleration or in the experimental beam line LIRAT (Ligne d'Ions Radioactifs A Très basse énergie). The breeding efficiency increases generally with the ion masses but recent studies have demonstrated that is not so true [5]. Recent results obtained at the ANL lab have shown high breeding efficiencies for light masses especially for Na case: $^{23}Na^{8+}$ 10.1%. This efficiency in general for light masses could be increased by improving the vacuum into the charge breeder. The charge breeder, its injection and extraction chambers are under assembly off-line; vacuum measurements will be done by the end of 2013. Beyond mass higher than ~100, the transport between the TISS and the charge breeder must be made at low extraction voltage, due to the limit of the magnetic rigidity of the mass separator, which limits the transport efficiency. Thus the preferential mass range of SPIRAL1 upgrade goes from ~10 to ~100. The infrastructure is under modifications; a contractor has been employed to study and carry on the nuclear ventilation upgrade, the new accesses to the rooms 15 and the surrounding ones as well as the fire safety enhancement. All this work will be achieved at the end of 2015. Only afterwards, the installation of the booster will start and taking into account the commissioning period, the first new radioactive beam will be provided to physicist at the end of 2015.

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