ISBN: 978-3-95450-205-9 doi:10.18429/JACoW-Cyclotrons2019-MOA03

STATUS REPORT ON GANIL AND UPGRADE OF SPIRAL1

O. Kamalou, P. Delahaye, M. Dubois, A. Savalle, GANIL, CEA-DSM/CNRS-IN2P3, Caen, France

Abstract

The GANIL facility (Grand Accélérateur National d'Ions Lourds) at Caen is dedicated for acceleration of heavy ion beams for nuclear physics, atomic physics, and radiobiology and material irradiation. Nowadays, an intense exotic beam is produced by the Isotope Separation On-Line method at the SPIRAL1 facility since 2001. New demands from the physics community motivated the upgrade of this facility in order to extend the range of post-accelerated radioactive ions. A 2 MEuro project allowed the profound modification of the facility and the commissioning was achieved in 2017. The status of this facility and the last results will be presented. The review of the cyclotron operation from 2001 to 2019 will be presented as well.

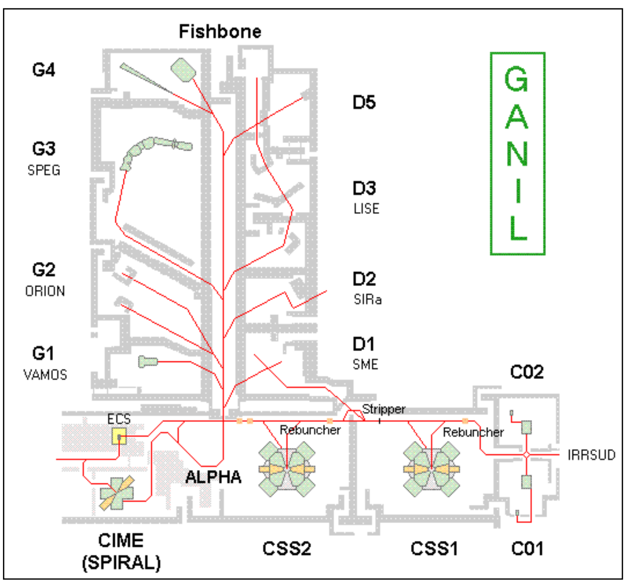

Figure 1: GANIL Layout.

OPERATION REVIEW

Multi-beam delivery is routinely done at GANIL using its 5 existing cyclotrons (Fig. 1):

1. Beams from C01 or C02 are sent to an irradiation beam line IRRSUD (<1 MeV/A)0.
2. A charge state among the ion distribution after the ion stripping foil downstream CSS1 is sent to atomic physics, biology and solid states physics line D1 (4 - 13 MeV/A).
3. A high-energy beam out of CSS2 is transported to experimental areas (< 95 MeV/A), for nuclear physics and previous applications.
4. 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 two first cases are still possible, CSS2 beam is sent toward the SPIRAL1 target, and radioactive beam is sent to the experimental areas.

In addition, Ion sources are available in "hall D" building for atomic physics at very low energy.

2001-2019 GANIL OPERATION STATUS

Since 2001 (Fig. 2), more than 56000 hours of pilot beam time has been delivered by GANIL to physics, which correspond to 93% of scheduled experiments.

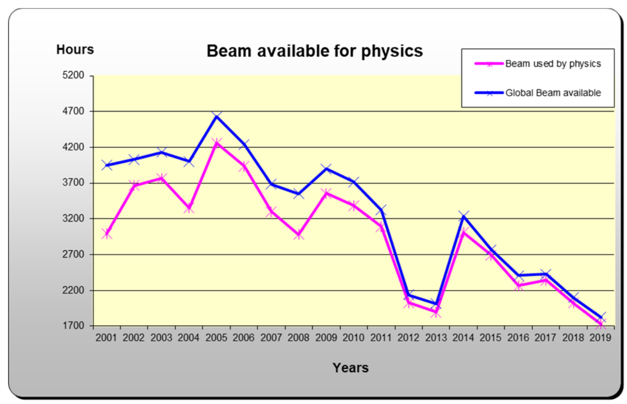

Figure 2: Beam time for physics.

In average, the number of beams delivered per year has increased until 2010. Owing to the construction and assembly of the new SPIRAL2 accelerator and upgrade of SPIRAL1, the running time has been shrinking to devote more human resources to the project SPIRAL2, in particular in 2012 and 2013 with only 2000 hours of experiments time (instead of 3500 hours per years).

Figure 3 shows the statistic running of the machine over 19 years. 67.8% of beam time is dedicated to Physics and 12.6% for machine tuning.

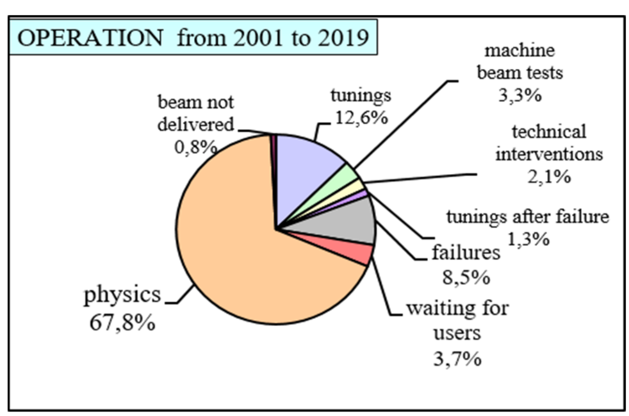

Figure 3: Statistic Running.

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In 2019 (April to July), the pilot beam time was 64%, the failure rate is 16% (highest value till 2013).

WATER LEAK NORTH RF CAVITY CSS1 AND BEAM TUNNING

In the past 2 years, the GANIL facility has encountered water leak problems mainly on the RF cooling circuits (an example given in Fig. 4 for CSS1 North cavity which is happening in 2018).

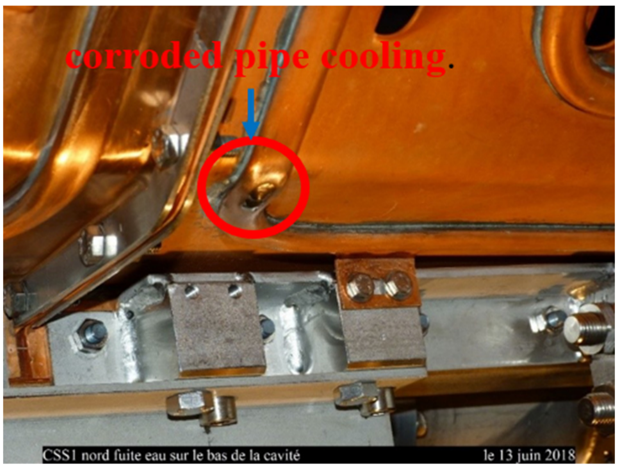

Figure 4: Corroded Pipe Cooling.

Instead of undertaking a water leak reparation, which would have caused a one-week time loss for experiment, the CSS1 cyclotron was tuned with one cavity as we can see in Fig. 5. Without North cavity, the magnetic fields should be decreased in the sectors D and A and increased in the sectors B and C. The optimized magnetic field for easy beam ejection could not be achieved in this degraded configuration. The beam time tuning was increased by a factor 3. Nevertheless, we managed to tune the CSS1 with only one cavity with 90% of efficiency for 16O at 95 MeV/A.

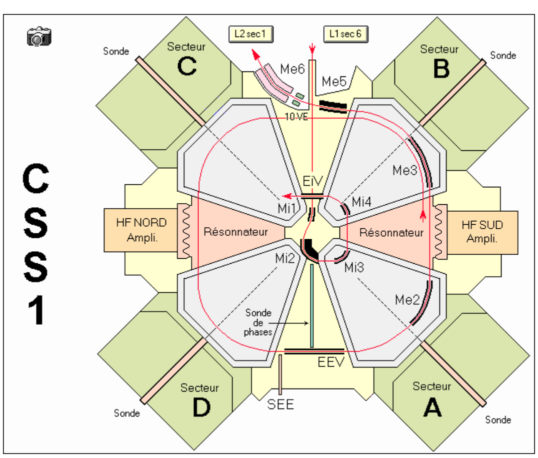

Figure 5: CSS1 Cyclotron.

SPIRAL1 UPGRADE

The first version of the Isotope Separator On Line System installed at GANIL, named SPIRAL1, has delivered radioactive ions for 13 years. Radioactive atoms produced by fragmentation of swift heavy ions on a carbon target are ionized in the Nanogan ECR multi-charged ion source before being post-accelerated in a cyclotron. The cyclotron energy is 1.2 to 25 MeV/A using harmonics 2 to 6. Several beams of gaseous elements (He, N, O, F, Ne, Ar, Kr) was produced for nuclear physics.

Due to the design of the Target Ion Source System (TISS), mainly gaseous ions were produced so far. To satisfy the request of physics community for extending the choice of ions to those made from condensable elements, with masses up to Xe, an upgrade of SPIRAL1 has been undertaken [1]. Beams and technical options considered during the prospective phase have been sorted out. A schematic of the ongoing upgrade is presented in Fig. 6.

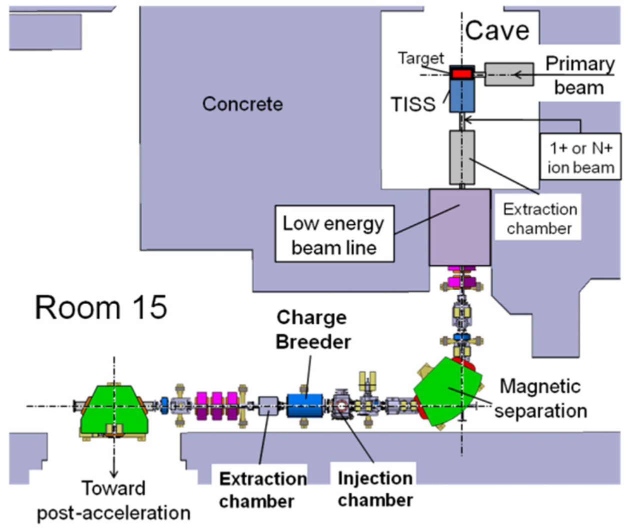

Figure 6: SPIRAL1 Upgrade Layout.

New targets (Nb, SiC,..) and new type of Surface ionization, FEBIAD (Forced Electron Beam Induced Arc Discharge) or ECR (Electron Cyclotron Resonance) ion sources [2, 3] can now be operated thanks to the modification of the production cave to provide 1+ beam of condensable elements. After mass separation the 1+ beam is injected into a Phoenix charge breeder, inserted in the low energy beam lines. The increase of charge state of the radioactive ions from 1+ to N+ for post-acceleration enables to access energy up to 25 MeV/A using the CIME accelerator.

The new TISS was tested at nominal power (1200W of 36Ar at 95 MeV/A) in the SPIRAL 1 beam lines in December 2013. The first scientific results obtained at SPIRAL 1 with a FEBIAD source was published [4, 5]. The integration of the charge breeder and the beam line modification were achieved between 2013 and 2016.

In 2017, the charge breeder and beam line off-line commissioning was started. The whole system was validated (performance, beam optics) by the end of 2017 [6].

In April and May 2018, the SPIRAL1 upgraded facility was ready for radioactive ion beam production. A beam of 95 MeV/A of 20Ne first impinged on the SPIRAL1 target

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for the production of a 17F beam at 10 MeV/A for the E750 experiment. The FEBIAD source failed after 6 hours of target irradiation. At that time, the failure was attributed to shortcut of the anode insulator [7], which was possibly caused by a deposition of direct C vapors generated by the primary beam impinging on the target. To fix this issue, a helical chicane was inserted in the transfer tube to stop the vapors from the irradiated target to the insulator (Fig. 7).

Figure 7: Helical Chicane Photo.

In 2019, the 40Ca, 95 MeV/A primary beam was sent to SPIRAL1 carbon target. An isomeric beam of 38 mK at 9 MeV/A was produced successfully and accelerated by the CIME cyclotron for E737 experiment. More than 5×10^5 pps of 38 K was sent to the experimental room for nuclear physics during two weeks. Following the experiment, a yield check showed degraded performances for the production of 33Cl, 23Mg and 25Na beams compared to 2013. We suspected the chicane to slow down significantly the release of these isotopes. The chicane was removed in an ultimate test with the FEBIAD TISS in 2019, with a primary beam of 36Ar at 95 MeV/A. For this last test, other tricks than the chicane were used to prevent deposition of C vapors on the insulators: a local screening of the insulators was improved, and Repieces, less conductive than the original Mo pieces, were used for the connection of the fragile insulators to the hot body of the anode. Once the chicane removed, we could measure as expected yields compatible with the measurements done in 2013.

The mass resolving of CIME cyclotron allow us to purify the beam in many cases for light element (A < 20). For heavier masses, and especially around 56Ni, which triggers a considerable scientific interest, a case by case study has to be done. In the coming years, the test of different stripping foils behind CIME to separate masses delivered from the FEBIAD TISS, and reaccelerated by CIME to energies of 10-12 MeV/A, will be investigated in details.

REFERENCES

[1] P. Jardin *et al.,* "Status of the SPIRAL I upgrade at GANIL", *Rev. Sci. Instrum.,* vol. 83, p. 02A911, Feb 2012. doi:10.1063.1.3672435

[2] S. Sundell *et al.,* "Ion source with combined cathode and transfer line heating", *Nucl. Instrum. Methods Phys. Res., Sect. B*, vol. 70, pp. 160-164, Aug. 1992. doi:10.1016/0168-583X(92)95926-I

[3] R. Vondrasek *et al.,* "Improved charge breeding efficiency of light ions with an electron cyclotron resonance ion source", *Rev. Sci. Instrum*., vol. 83, p. 113303, Nov. 2012. doi:10.1063.1.4768533

[4] J. Grinyer *et al., "*High-precision half-life measurements of the T=1/2 mirror beta decays 17F and 33Cl*", Phys. Rev. C,* vol. 92, p. 045503, Oct. 2015. doi:10.1103/PhysRevC.92.045503

[5] J. Grinyer *et al.,* "High-precision half-life measurement for the isospin T= ½ mirror β^+decay of ^{21}Na", *Phys. Rev. C*, vol. 91 p. 032501, Mar. 2015. doi:10.1103/PhysRevC.91.032501

[6] L. Maunoury *et al*., "SPIRAL1: A Versatile User Facility", in *Proc. 23th International Workshop on ECR Ion Sources (ECRIS'18)*, Catania, Italy, Sep. 2018, pp. 29-33. doi:10.18429/JACoW-ECRIS2018-MOC4

[7] P. Delahaye *et al.,* "New exotic beams from the SPIRAL1 upgrade"*, Nucl. Instrum. Methods Phys. Res., Sect. B,* to be published. doi:10.1016/j.nimb.2019.04.063