THE CYREN PROJECT: REFURBISHMENT OF THE GANIL CYCLOTRONS FACILITY

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Abstract

For over 40 years, the GANIL facility has been supplying stable beams (carbon to uranium, 60 keV/A to 95 MeV/A) and low- and high-energy radioactive ion beams for fundamental, applied and industrial research from a set of 5 cyclotrons.

Since 2010, the maintenance and refurbishment of the cyclotrons has been reduced to a bare minimum due to the SPIRAL2 construction and compliance work following the mandatory safety review from French safety authorities. Consequently, the failure rate has increased over the years.

The outlined exceptional scientific and industrial program presented by the users of the facility is requesting GANIL to guarantee its operation over the next 20 years or more. Therefore an ambitious renovation program, the CYREN (CYclotrons RENovation) project, was launched in 2024.

This article covers the progress of the project. It details the challenges encountered, which are partly due to the diversity of the different installations and their unique equipment. The project encompasses the five cyclotrons, beam lines, associated experimental caves, building infrastructure, technical utilities, and safety, security, and radiation protection systems.

INTRODUCTION

The GANIL cyclotron facility [1] delivers high-intensity stable beams up to uranium, as well as exotic nuclei produced via both in-flight fragmentation through the LISE separator and the ISOL (Isotope Separation On-Line) technique through the SPIRAL1 facility. Radioactive beams from SPIRAL1 can be used directly or re-accelerated while preserving high optical quality. The GANIL cyclotron facility, without SPIRAL2, is a multi-beam facility, capable of operating up to 4 simultaneous beams: IRRSUD, SME (medium energie), CSS high energy and CIME [2]. Figure 1 shows the cyclotrons facility with the associated experimental halls.

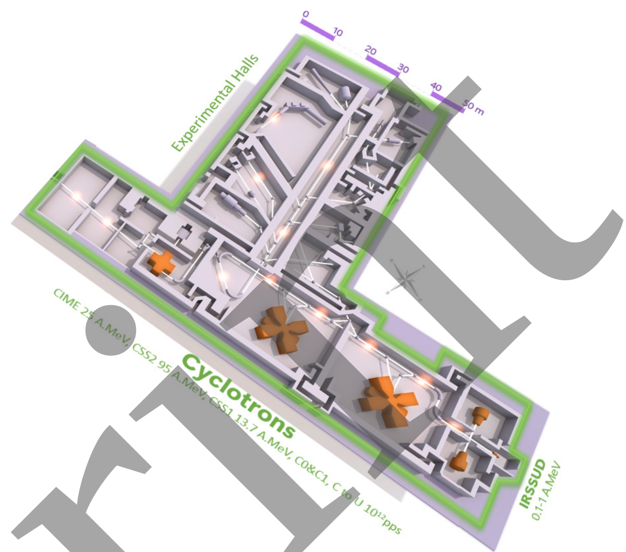

Figure 1: GANIL cyclotron facility.

CURRENT CONTEXT AND SCIENTIFIC OBJECTIVES

Since the start of its operation in 1983, GANIL has carried out regular refurbishment works on its equipment, enabling this research infrastructure to remain operational to this day. Since 2010, renovation work has been significantly reduced due to the redeployment of human and financial resources towards the construction of the SPIRAL2 facility and the implementation of the action plan resulting from the first safety review [3].

This minimal renovation and the aging of the facility, GANIL is now facing difficulties. It includes ther obsolescence of an ageing stock of equipment (some datesback to its construction), and difficulties to maintain and operate. The human resources required to handle the volume and complexity of repairs are becoming difficult to manage, posing a threat to the smooth operation of the cyclotrons. Figure 2 illustrates beam downtime trend. User satisfaction follows the same trend.

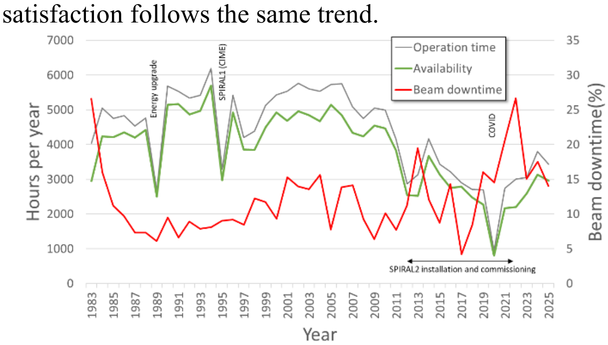

Figure 1: Cyclotrons beam availability and failure rate.

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Working groups have been established to analyse the situation and to identify the scientific prospects of the facility. The scientific communities have confirmed their need for cyclotron beams for a broad research programme. A white paper has been published outlining the wealth of planned research studies , including nuclear physics, industrial applications and interdisciplinary physics [4]. The future DESIR facility, currently under construction and due to come online in 2028, will also require the use of these beams. Furthermore, French and European space industry players set out additional demands for irradiating and testing electronic components intended for use in space (e.g. SAGA project : Space Applications at GANIL Accelerators).

In light of these very promising research prospects, the CEA and the CNRS, after preliminary studies in 2022 launched the CYREN project in 2024, with the aim of ensuring, for at least 20 years, the long-term viability of the beam production capacity of the GANIL facility (from the cyclotrons to the reaction target).

This project should optimise the allocation of human resources for maintenance activities after the cyclotrons have been refurbished

CYREN PROJECT DEVELOPEMENT

Initially, the operational experts reviewed the age of the equipments, their reliability, the availability of spare parts, obsolescence and contingency plans in the event of breakdowns. Subsequently, breakdown statistics and their impact on the availability of the system were considered.

Water leaks, quickly became apparent as a frequent, significant beam downtime problem that was rapidly increasing in frequency (Fig. 3).

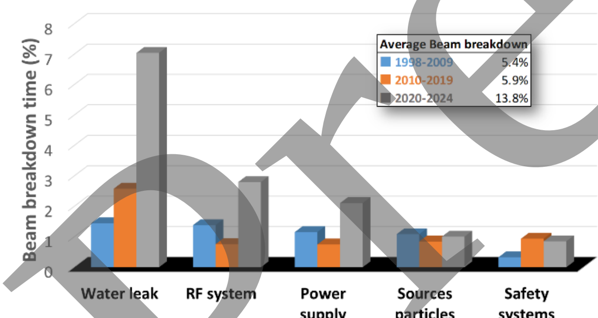

Figure 2: Evolution of cyclotron breakdown over time for the 5 main sources.

Since the 80s, and at a significantly increased rate since the 2000s, the accelerator HF cavities in the two CSS cyclotrons have been subject to leaks from their cooling circuits, resulting in major repairs (3 to 15 days of beam downtime due to leaks in the cavities, see Figure 3). Until now, the leaks have always been more or less easily accessible for repair.

In order to prevent the risk of longer shutdown caused by a major leak that could not be repaired, various scenarios are considered to replace and/or repair some or all RF cavities.

The feasibility of such an operation has been studied. The creation of new cavities and the construction of the associate test bench were examined and evaluated. The workload and costs were very high in relation to a failure rate inside CSS that did not increase since 2000 (Fig. 4).

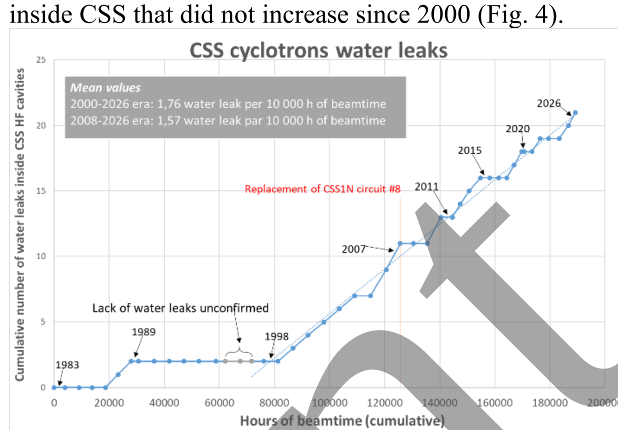

Figure 4: Statistics of water leaks inside CSS cyclotrons since 1998.

It was therefore decided, given a limited budget, to partially refurbish the cavities at the level of the outer casings (Fig. 5), where more than 50% of the leaks are concentrated.

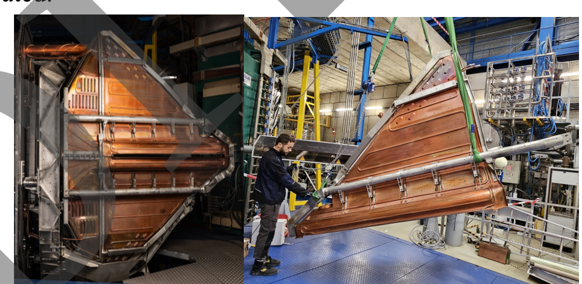

Figure 5: HF cavity and cooled outer casings of a CSS cyclotron.

Another action was implemented to reduce water corrosion in the cooling circuits, following the example of the Paul Scherrer Institute cyclotron facility. This involves the planned installation of a outgassing system to remove oxygen and carbon dioxide, the main agents causing water corrosion in copper [5].

In addition to the degassing systems installed on the most critical cooling circuits, the monitoring of the demineralised water treatment to a pH above 7 will be monitored.

Beyond water leaks caused by corrosion and erosion, the project assessed and ranked all components involved in beam delivery. Criticality, based on the impact of a failure and the probability of failure rate was established and help us to define the technical scope. This involves refurbishing components to address obsolescence or ensuring there are sufficient spare parts in certain cases.

TECHNICAL SCOPE OF THE PROJECT

The technical scope of the project encompasses three major components of the cyclotrons GANIL facility:

- Infrastructure and associated facilities: buildings, electrical distribution and harmonic filters, refrigeration and IT infrastructure.

- Accelerator processes: vacuum systems, beam instrumentation and diagnostics, magnetic field coils, cooled equipment, HF systems, power converters and NMR systems, automation, control systems and the Injector 2 ion source.
- Nuclear safety systems: human access management (UGA), beacon management (UGB) and the radiation monitoring panel for neutron and gamma beacons

TECHNICAL PROGRESS

The refurbishment of the 16 air extraction towers in the cyclotron and experimental buildings (Fig. 6) was achieved in 2025.

Figure 6: Installation of the new air extraction towers.

The renovation of the roofs and vents for smoke extraction is scheduled for 2026.

The control system for the 90 kV high-voltage power substation has been replaced, along with an inverter for the safety systems.

A call for tender for a contractor for the cooling system renovation (air cooling tower, primary and secondary circuits, heat exchangers, pumps, instrumentation, O_2 and CO_2 outgassing system, etc.) is undertaken.

Roll out of the complementary and new network infrastructure are underway.

Plans are being considered to refurbish some of the magnetic ejection systems of the CSS cyclotrons

The three-year program to refurbish 300 power converters for the magnets started this year.

Plans to upgrade more than 30 programmable logic controllers (PLC) are currently underway.

Partial refurbishments of the HF amplifiers for the cavities are under consideration, as are upgrades to diagnostic and motorization systems.

The renovation of the cyclotron control command system, is necessary due to the obsolescence of VME cards and since the support for the MOTIF/XRT graphics technology has been discontinued. A four-year renovation [6] of 32 I/O controllers and 51 human-machine interfaces is currently being prepared.

The high-voltage platform of the C02 injector needs to be renovated (electrical engineering, instrumentation, automation), the studies are currently underway. This upgrade paves the way for the potential introduction of a new, high-performance source, for which funding has not yet been secured.

More than 50% of the work on upgrading the vacuum systems (primary and secondary pumping, gauges, etc.) has been completed.

The studies on the refurbishment of the security systems for access control in the shielded enclosures are currently being finalized. Cybersecurity risks associated with the upgrading of increasingly interconnected network infrastructures are being addressed with the utmost care.

Following a temporary insulation fault in a main magnetic field coil of a CSS cyclotron, a preliminary study for a replacement scenario has been launched

CONCLUSION

In conclusion, the 40 years old GANIL cyclotron facility remains unique in terms of variety and simultaneous beams, covering a wide range of particles, energies and intensities. Since 2010, performance in terms of reliability and availability has slowly declined, while demand from users (both scientific and industrial) is strong in the short and medium term.

The CYREN project aims to restore more than 20 years of fruitful years of beam production, scientific experiments and industrial applications in response to this challenge.

Funding for this project is secured, and it was launched in 2024. The laboratory's internal human resources commitment is around 150 Full Time Equivalents (FTEs).

Studies and renovation work have begun. This ambitious refurbishment programme is scheduled to run from 2024 to 2031, with construction work limited to 4 to 6 months per year in order to ensure a minimum level of beam production for users each year.

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