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FUTURE UPGRADES FOR GANIL

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Abstract

We will present the plans and ideas for the next upgrades as discussed for the GANIL-SPIRAL2 installation in France. Recently, a report "French roadmap for Nuclear, Particle, and Astroparticle physics, along with associated technical developments and applications." were produced. It particularly focused to “The future of GANIL”. This was further enriched through extensive discussions by an international expert committee led by Michel SPIRO. These endeavours aim to push the boundaries of research capabilities at GANIL-SPIRAL2 during the next decades. Since the starting up in 1983, 40 years ago, successful exploitation with stable beams at the cyclotrons of GANIL, the laboratory has continuously evaluated and enhanced its capabilities. The latest evolution was the starting up of the SPIRAL2 facility. Today GANIL, with its state-of-the-art installations, including five cyclotrons, a linear superconducting accelerator, and experimental areas, presents unique opportunities for cutting-edge research. The next upgrades will bring increasing beam intensities, exploring new exotic nuclei.

GANIL YESTERDAY AND TOMORROW

1st physics experiment was conducted at the new facility with stable beams in 1983. 40 years later 4 ECR injectors are operating providing protons to HI beams. The cyclotron complex accelerates the stable C to U beams up to 95 MeV/u. The LISE In-Flight facility (1990), and SPIRAL1 ISOL facility (2001) provide radioactive ion beams at high and low energies for experiments [1]. The SC LINAC, in operation since 2019, provides high energy beams for neutron facility since 2021 [2]. The GANIL facility runs more than 5000 hours yearly.

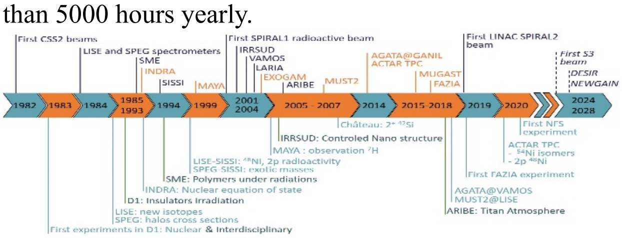

Figure 1: The development projects at GANIL since 1982.

TOMORROW: on-going and financed projects

As a continuous tradition since the start-up of the installation many upgrade projects are on-going as seen in Figure 1. Following the successful commissioning of the SC LINAC, the current major projects are dedicated to the increase in intensity with the development of a new ion source and injector for the SC-LINAC (the NewGAIN project), the construction of a complete new experimental area for radioactive beams of low energy (few tens of keV) experiments and the final installation and commissioning of a new target and separator for the production of super heavy elements. In the upcoming years the following projects will come into operation, all of them are currently in construction, some are already in a installation and start-up phase and all of them are fully financed.

2025 Exploitation of a Super Heavy production installation, S3. [3]

2027 Availability of the A/q=7 post accelerated beams.

2028 Exploitation of a new low energy experimental hall for physics with radioactive ions DESIR. [4]

2031 Start-up of the new high intensity heavy ion injector, the 5th at GANIL accelerator complex. [5]

2033 Finalization of the full refurbishment of the cyclotron complex. With these projects on going there is a well-defined horizon for GANIL up to 2033.

GANIL AFTER TOMORROW – THE FUTURE IN PREPARATION

In 2019, French research institutes carried out an evaluation of GANIL's position in the regional, national, and international research landscape. The report highlight GANIL's unique potential for the production of high-intensity exotic radioactive ions in various fields of fundamental and applied research domains. This potential is due to the uniqueness of GANIL with the capabilities of the SPIRAL2-LINAC facility, coupled to the cyclotron facility gives access to low and high energy experimental areas.

One of the recommendations was the refurbishment of the cyclotron facility, which celebrated 40 years of beams for physics in 2023; the refurbishment programme was partially funded by the French government in 2023 and will be closed by 2033, as mentioned in the paragraph above.

Other recommendations were to continue with the installation and commissioning of the projects mentioned above.

These first three recommendations have been incorporated into GANIL’s long-term financial plans and are being implemented. Furthermore, the committee recommended that the studies on the production of highly intense fission fragments as planned at the beginning of the SPIRAL2 project [6], but put on stand-by in 2013, should be restarted. In 2013 the SC-LINAC and its infrastructure were under construction. The accelerator was designed to operate as a primary beam driver for the production of very intense radioactive ion beams. The current operation uses two ECR ion sources for p, d and H.I. beams, capable of providing up to 200 kW of beam intensity with the light beams.

Production of exotic ions

The vision is to complete the construction and add several target stations designed to use the high intensity proton, deuteron and heavy ion beams, the target station

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should be ready to use the beams provided by the NewGAIN injector, which is foreseen to provide 15pµA beams up to 7MeV/u.

The production mechanisms for the required high intensity exotic ion beams are of several types. Light proton and/or deuteron beams will be used on a Uranium carbide target or via a neutron target to access neutron rich fission fragments near the driplines. Another target station will be designed to use heavy ion beams into a gas target or onto a thin target to access products from Multi-Nucleon Transfer (MNT) or fusion evaporation reactions. The use of an electron beam onto a Uranium carbide target would open up the possibility of producing fission fragments using the photo-fission principle. To optimise the availability of the exotic beams three separate production cells are proposed. The three methods described above (neutron induced fission, MNT reactions and photo-fission) will induce a high radiotoxic background, the three production units are separated into different areas, which allows to perform maintenance for one target while another target is in use. This will limit the exposure for the personnel, although it would be a more expensive installation initially, since a larger volume is needed a gain can be made in reducing the robotics for maintenances. Although the SPIRAL2 SC-LINAC will have three ion sources to produce the primary beams, there are only one SC-LINAC for the acceleration. In order to increase the availability of the exotic beams for the fundamental, applied or industrial set-ups, the study to install a separate electron driver as a 6th injector at GANIL will start. The electron injector should provide a 40 MeV electron beam of a few hundred µA to a few mA.

Radioactive ion beam transport

The exotic beams produced will be extracted at energies of a few tens of keV, and transported to one of the GANIL's experimental areas. The first meters of the beam lines after production and extraction will be designed with one or more mass separation steps depending on the maximum production rate and the acceptable background around the beam transport lines further down the line. Due to French environmental and nuclear regulations, theses beam lines won't be accessible during operation.

These beam lines will be combined into a common beam transport section of electrostatic transport lines, such as those designed and built for the DESIR facility [7] and should be accessible for maintenance without major delays. The transport lines going to the DESIR experimental area will access the lines just before the constructed High Resolution Separator (HRS). The HRS, two 90° magnets coupled with a 48 pole electrostatic corrector has already demonstrated separation capabilities with a mass separation $\Delta M/M$ of 20 000 [8] and will provide unique separated fission fragment beams to the experimentalists.

The other option is to direct the beams to the cyclotron experimental areas for post-acceleration. Prior to the post-acceleration the A/q =1 ratio must be reduced to increase the efficiency. Studies at ANL have shown the efficiency of using an Electron Beam Ion Source Charge Breeder (EBIS-CB) for heavier short-lived isotopes [9]. With the existing CIME cyclotron energies of 5-10 MeV/u should be achieved. There is a scope to develop a new post-accelerator, probably a superconducting cyclotron, which would allow energies of 50-70 MeV/u to be achieved. The higher energies open up the possibility of using the post-accelerated beams as secondary beams impinging on a thin target.

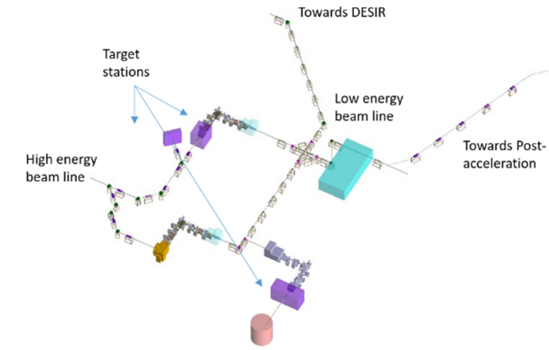

Figure 2: The new installations at GANIL. With the High Energy beam lines of SPIRAL2. The 3 production cells. In the lower left part is the electron accelerator.

Electron beam – radioactive ion beam collisions

The committee also recommended that a facility be built in which radioactive ions would collide with an electron beam. This will implement the study of an electron accelerator to provide a new probe of exotic nuclei. Scattering of the electrons on to the radioactive ion beams (e-RIB) will allow to complement the studies made by direct reactions using the new re-acceleration complex. It would provide a rich and unique flagship programme at GANIL in the long term future. Feasibility studies could be initiated soon given the strong interest shown.

IMPLEMENTATION AT GANIL

The implementation of the infrastructure for production of the ion beams and the future e-RIB installation have been studied. The use of the high energy beams of the current SC-LINAC installation, the connections to the low and high energy experimental areas imposes the geographical installation of the infrastructure as shown in Figure 3.

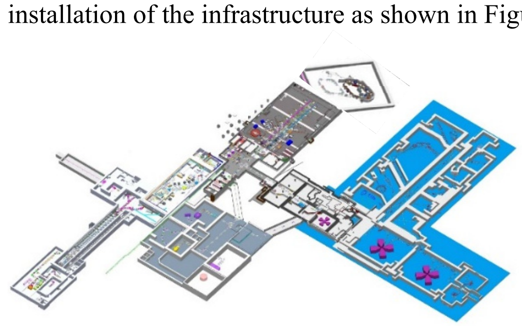

Figure 3: Installation at the GANIL site.

The installation for e-RIB electron accelerator should be performed around the DESIR building to avoid long transfer lines.

A preliminary implementation with identification of maintenance and operational areas have been performed. This study allows to do a preliminary financial estimation

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of the construction. During the design study of the infrastructure, maintenance procedures and operational conditions an optimisation will be foreseen.

TECHNICAL REQUIREMENTS

For the construction of the final installation developments need to be conducted for:

- Fission targets,
- Neutron converter,
- MNT Gas targets,
- The retreatment procedures for the production targets after irradiation.
- In addition the construction is necessary for:

An electron beam injector providing 40 MeV / 3mA

- 50-60 m of high energy beam transport.
- 150 m of low energy beam transport (<60 keV)
- A charge breeder for radioactive ions.
- A SC post-accelerator for 70MeV/u beams
- A synchrotron for the reactions of radioactive ions with e— beam of 500MeV with a luminosity of 1030-31
- An installation for low energy radioactive ion / electron beam collisions.
- A new infrastructure to host all of this at the site of GANIL
- Regarding the beam diagnostics, control devices for the installation and vacuum techniques, the same techniques and devices as installed at the existing facilities will be adopted and therefore no further developments are identified at this stage.

TIMELINE

The project timeline for the full project until construction are planned to span over the next decade. Fundamental proof of principles for the production methods are still required. Currently the project is in a first evaluation phase of technical requirements, identification of needs of human and financial resources. Ones the technical requirements for the production methods are identified the technical studies of the implementation will start.

We foresee that the conceptual design phase that will start in 2026. According to French regulations and authorisations a dialog with the authorities are put into place from the beginning of the project.

The first step of administrative authorisation for a modification or construction of a new facility is to have a validation for the foreseen operational conditions in regards to environmental and radiological impacts. This exchange is performed based on hypothesis of the future installation and will lay the grounds on the design conditions to implement during the detailed design study. The finite solutions and techniques to meet the requirements are to be presented in a later stage. Taking this into account this new upgrade could be constructed within the next 10-15 years giving great opportunities for the science of fundamental physics.

CONCLUSION

An ambitious programme has been identified for GANIL over the next decades. Although the timeframe for the new facility presented here is very long, it will fit into the ongoing development and installation plans for the current projects, which will provide beams for new physics from now until the 2030's.

Although 10-15 years may seem a long time it is the usual development time for any major facility upgrade, but what we are proposing here is to start development now to ensure continuity in the constructions.

We have shown that GANIL will continue to provide an infrastructure for fundamental research as well as applied science and industrial research with stable and radioactive beams.

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