GANIL Scientific Council Report

February 4-5, 2025

Scientific Council Members:

- Amine Cassimi, CIMAP, France
- Wilton Catford, Univ. Surrey, UK
- Anna Corsi, Irfu/DPhN, France
- Dolores Cortina Gil, CSIC Valencia, Spain
- Anne-Marie Frelin, GANIL, France
- Fabiana Gramegna, LNL INFN, Italy
- Ferid Haddad, ARRONAX, France
- Morten Horth-Jensen, FRIB, USA
- Beatriz Jurado, CENBG, France
- Michal Kowal, NCBJ Varsovie, Poland
- Alain Letourneau, Irfu/DPhN, France
- Nathalie Moncoffre, IP2IL EMIR&A, France
- Iain Moore, JYFL, Finland
- Jaromir Mrazek, NPI, Czech Republic
- Christoph Scheidenberger, GSI Darmstadt, Germany
- Daisuke Suzuki, The University of Tokyo, Japan
- David Verney, IJCLab, France

Ex-officio members:

- Chairperson GANIL PAC
- Chairperson GANIL GUEC
- Chairperson Interdisciplinary PAC

1 Preamble

The document summarizes the deliberations of the GANIL Scientific Council, which convened on February 4th and 5th, 2025. It also includes the council's recommendations and an overview of the laboratory's activities over the past year

2 Meeting scenario & agenda

The Scientific Council (SC) deliberations were conducted in a hybrid format, with some members participating online, including Anna Corsi and Fabiana Gramegna. The remaining members attended in person: Amine Cassimi, Wilton Catford, Dolores Cortina Gil, Anne-Marie Frelin, Ferid Haddad, Morten Horth-Jensen, Michal Kowal, Alain Letourneau, Nathalie Moncoffre, Iain Moore, Jaromir Mrazek, Daisuke Suzuki, and David Verney.

The proceedings began with the election of the chair, and Michał Kowal from the National Centre for Nuclear Research in Warsaw was appointed to this role. Following this, Deputy Director Fanny Farget (GANIL management) delivered a presentation summarizing the achievements of the GANIL laboratory over the past year.

The SC had the opportunity to visit several measurement stations, including the S3 spectrometer and the SPIRAL2 LINAC. Then, the session was accessible in general mode to all GANIL employees according to the agenda here.

A series of presentations took place, during which council members actively engaged by asking numerous questions about the presented projects.

Subsequently, a closed session took place, available only to members of the SC, where preliminary summaries of the deliberations were made.

On the following day, the deliberations continued in closed format, focusing on preparing the preliminary version of the report. This was followed by a short briefing where the SC presented its opinions and recommendations to the Deputy Director of GANIL.

3 Scientific Summary of 2024 in GANIL

GANIL is a multi-user, multidisciplinary laboratory conducting research in nuclear physics, nuclear astrophysics, astrochemistry, materials under irradiation, nanostructuration, radiobiology, new therapies, industrial applications, and R&D on accelerators and detectors [1]

3.1 Cyclotrons in 2024

GANIL continued to support a diverse range of nuclear physics experiments in 2024, utilizing its five cyclotrons and multiple experimental rooms. These facilities enable studies with stable and radioactive ion beams across a broad energy spectrum, from below 1 MeV/u to 95 MeV/u. Up to four experiments can be conducted in parallel, facilitating research in various fields.

One of the leading research themes is nuclear fission, including studies on actinide fissioning systems and the transition from asymmetric to symmetric fission in pre-actinides. Experiments with uranium and thorium beams aim to explore new fissioning systems, with detectors such

[1] Industrial applications typically receive 10–15% of the beamtime and generate an annual income of approximately 400 k€, which can be used to support postdoctoral positions and other initiatives.

as VAMOS and PISTA providing precise isotopic identification of fission fragments and mass distributions.

In addition to fission studies, GANIL is engaged in nuclear structure research, particularly around neutron-rich and exotic nuclei. Investigations into the clustering properties of light nuclei beyond alpha clustering are being carried out using reactions with ^{10}Be beams. These studies contribute to a deeper understanding of the formation and decay of exotic nuclear states.

Beyond fundamental nuclear physics, GANIL hosts radiobiology, material irradiation, and astrophysics experiments. Research at LISE includes hadron therapy studies with lithium and carbon beams, while ARIBE supports experiments in molecular physics and laboratory astrophysics. Over 58 experiments are planned on facilities such as IRRSUD, SME, and D1 HE, with additional research on radiation protection and new ion sources.

3.1.1 CYREN

The CYREN project continued its renovation efforts, extending the operational lifespan of GANIL's cyclotrons. Significant upgrades were made to beamline diagnostics, improving reliability and beam intensity control. By the end of 2024, GANIL's upgraded cyclotrons successfully delivered a new high-intensity ^{40}Ar beam for experimental physics applications.

3.2 SPIRAL2-LINAC

SPIRAL2 LINAC provides high-intensity beams of **5 mA, 33 MeV** protons, **5 mA, 40 MeV** deuterons, and **1 mA, <14.5 MeV/u** heavy ions.

The accelerator consists of multiple sections, including ECR ion sources, an RFQ (Radio Frequency Quadrupole), and superconducting linac structures. It has demonstrated the feasibility of operating at 200 kW power, ensuring high transmission efficiency. The first heavy ion beams, such as ^{36}Ar and ^{40}Ar at 7 MeV/nucleon, have been successfully accelerated with an efficiency of 98%.

SPIRAL2 supports multiple experimental rooms, including the Neutrons for Science (NFS) area, the DESIR facility for low-energy radioactive ion manipulation and studies of exotic nuclei, and the S3 (Super Separator Spectrometer) for high-precision nuclear structure studies.

3.3 NEWGAIN

The NEWGAIN injector at GANIL is designed to achieve record-breaking ion beam intensities, significantly enhancing current capabilities. The table presents intensity projections for different ions for 2023, 2028, and beyond 2030, showing a steady increase in beam power.

Beams of ^{1}H are expected to reach 375 µA by 2028. Intensities of ^{4}He will increase from 10 µA in 2023 to 45 µA in 2028. Beams of ^{36}Ar and ^{40}Ar are projected to reach 100 µA and 45 µA, respectively, in 2028. ^{40}Ca and ^{48}Ca beams are expected to rise to 30 µA and 10 µA, contributing to nuclear physics research[2]. ^{78}Kr and ^{129}Xe beams will achieve intensities of 10 µA and 3 µA, respectively.

Other heavy ion beams, including ^{132}Sn, ^{238}U, and ^{18}O, show promising projections, with intensities improving significantly over time. Several elements have expected intensity increases beyond 2030, though estimations for some ions are still pending.

[2] The issue regarding the availability of ^{48}Ca has been addressed, ensuring that planned experiments can proceed without delays.

3.4 NFS

The Neutrons for Science (NFS) facility at GANIL provides a dedicated experimental area for neutron-based studies, utilizing a collimated neutron beam at 0° and a time-of-flight (TOF) hall for high-precision measurements. The facility supports multiple research programs, including studying pygmy dipole resonances in ^{140}Ce, aiming to understand low-energy nuclear excitations relevant to nuclear structure and astrophysics.

The MEDLEY detector system is employed for investigations into light ion production, focusing on reaction mechanisms and particle energy distributions. Neutron-induced reactions for nuclear energy applications are also studied through $(n, xn\gamma)$ cross-section measurements, providing critical data for nuclear reactor modeling and safety assessments.

The REPARÉ project at NFS also works on optimizing neutron-induced production pathways for ^{211}At, a crucial isotope for targeted alpha therapy in oncology. Structure studies on neutron-rich isotopes such as ^{56}Ni using $(n, 3n)$ reactions offer new insights into nuclear shell evolution and neutron excess effects.

Finally, the FALSTAFF detector system is dedicated to high-precision analysis of fission fragments from ^{235}U neutron-induced fission, contributing to a deeper understanding of fission fragment mass distributions and energy spectra.

3.5 DESIR

The DESIR (Decay, Excitation, Storage of Radioactive Ions) facility achieved significant progress in 2024, successfully completing key infrastructure and beamline optimizations. A major milestone was the approval of €40M in funding, which will support the enhancement of beam purification techniques and the extension of isotope selection capabilities, ensuring higher precision in nuclear structure measurements. The first beams from SPIRAL1 and S3 will undergo rigorous purification processes, with expected impact on improving the accuracy of nuclear mass and decay studies. Additionally, DESIR expanded its international collaborations through a new agreement with JYFL-ACCLAB at the University of Jyväskylä in Finland, further strengthening its role in global research on exotic nuclei and fundamental interactions.

3.6 S^3

In 2024, the S3 spectrometer successfully delivered its first experimental beam, marking a crucial milestone in its commissioning phase. Extensive optimization efforts have enhanced its capability for isotopic separation and high-resolution identification of superheavy elements, solidifying its role as a key instrument for studying exotic nuclei. A breakthrough was achieved by observing neutron-deficient actinide isotopes, providing valuable insights into nuclear stability and advancing the understanding of fundamental nuclear properties. Furthermore, the S3-LEB (Low Energy Branch) was equipped with state-of-the-art spectroscopy tools, enabling precise measurements of rare nuclear states and expanding research opportunities in nuclear structure and reaction dynamics.

4 Progress from 2023

- Compared to 2023, the commissioning of SPIRAL2 has made significant strides, particularly with the LINAC producing increased beam power and stability.

- S3, which was in early development last year, has successfully delivered its first experimental beam, marking a crucial milestone.
- DESIR, awaiting funding and technical approval in 2023, has secured financial backing and infrastructure improvements, ensuring progress towards its first experiments in 2028.
- The CYREN project has moved from planning to implementation, with renovations beginning to extend the operational life of GANIL's cyclotrons.
- The increased workforce at GANIL has contributed to faster development timelines and better resource allocation for the simultaneous operation of cyclotrons and the LINAC, a key concern in 2023.
- Industrial and medical applications have expanded, particularly in high-intensity beam testing for space electronics and hadron therapy research.

These advancements highlight the substantial progress made at GANIL in 2024.

5 Evaluation of specific projects presented in the open session

A detailed discussion of each presentation is provided below, with attention given to their strengths and weaknesses, along with recommendations highlighted in bold.

Theory @ GANIL

Speaker: David Boilley (GANIL)
Duration: 1h 30min

The scientific council is deeply impressed by the GANIL theory group's activity. Over many years, the group has contributed to the development of theoretical approaches to complex nuclear few- and many-body problems, spanning from nuclear structure and reaction problems to studies of dense matter as expected in dense objects like neutron stars. Its legacy and international standing are of the highest quality, and many of its theoretical findings have contributed significantly to the experimental program at GANIL, as well as to the nuclear physics community worldwide.

The group's productivity, its contribution to the education of new talents, and its role in advancing theoretical models for nuclear experiments are outstanding. The scientific council strongly advises GANIL to continue supporting an active theory group, ensuring the recruitment of new talents when necessary to maintain and strengthen the field of nuclear theory at GANIL.

Recommendations

1. Given the current age distribution, the council recommends that GANIL initiate discussions with the theory group, in close collaboration with the University of Basse-Normandie, French funding agencies, and other theory groups in France, to develop a strategic plan for recruiting new talents. These efforts should focus on

reinforcing and expanding the theoretical expertise that has made GANIL's theory group internationally recognized.

2. The council values the strong collaboration between the theory and experimental groups at GANIL and recommends that the theory group maintain its close involvement in the experimental program and future research directions. This engagement should particularly focus on fission, studies of heavy and superheavy nuclei, and nuclear reaction mechanisms, ensuring theoretical contributions remain integral to GANIL's scientific strategy.

3. To support GANIL's long-term theoretical ambitions, the council strongly encourages the development of a national recruitment and funding strategy. This should involve partnerships with national agencies, universities, and other research institutions across France to enhance collaborative efforts in nuclear physics. A key proposal is to actively participate in the creation of a theory alliance similar to FRIB-TA in the USA, fostering a more integrated and cooperative theoretical research environment.

HINA (Highly Charged Ions for Nuclear Astrophysics)

Speaker: Sarah NAIMI (IJCLab)
Duration: 50min

The HINA project focuses on the study of Highly Charged Ions (HCI). Beyond its relevance to nuclear physics, understanding atomic processes in HCI has significant implications for various scientific disciplines and technological advancements, including fusion research and the interpretation of astrophysical spectra. The feasibility of the project appears promising; however, a detailed evaluation of the performance of the HINA device is still required. The team has substantial expertise in trapping devices and storage rings and collaborates closely with experts from Max Planck Institutes.

The project requires funding of 400,000 euros, which includes support for a two-year postdoctoral position. The spokesperson has applied for an ANR grant for the second time to secure additional resources. Globally, very few facilities specialize in this area, and the method using traps offers a complementary approach to ion beam storage rings by enabling the study of light ions. Research on Highly Charged Ions is highly relevant to astrophysics and applied fields such as energy storage.

Recommendations

1. The SC recommends that the GANIL management should encourage the HINA collaboration to initiate technical discussions with the DESIR collaboration regarding the potential integration of HINA. Such discussions would facilitate synergies between research groups and optimize the use of existing infrastructure.

2. The Scientific Council acknowledges the strong scientific potential of the HINA project, particularly in enhancing the DESIR physics program. The proposed EBIT trap and the development of an original physics program on rare decays would provide a unique addition to DESIR, currently lacking such capabilities.

3. Several aspects of the project require further development, including demonstrating the efficiency of the EBIT as a charge-breeder, strengthening the collaboration network, and stabilizing funding sources.

4. The Scientific Council appreciates the efforts made by the spokesperson in securing funding through the ANR grant and encourages the GANIL management to continue supporting this initiative to ensure long-term project viability.

Tape stations @ DESIR / IDEAS3 / SEASON

Speakers: Iolanda Matea Macovei (IPN Orsay), Vladimir Manea (IJCLab, Orsay), Marine Vandebrouck (CEA Saclay DPhN)
Duration: 1h 20min

Tape stations @ DESIR / IDEAS3

The identification stations IDEAS3 and DESIR IDS have been assigned high priority, as the identification of beams from S3 and DESIR is essential from the earliest phase of their operation. GANIL should actively support the development, installation, and operation of these test stations to ensure the success of their experimental programs.

Recommendations

1. For other decay test stations at DESIR, the Scientific Council encourages the GANIL Directorate to motivate users to establish a unified Working Group (WG) dedicated to the test stations of DESIR and S3-LEB. This WG should focus on discussing physics cases, coordinating strategies, and establishing a clear delivery timeline.

2. The Scientific Council considers it essential for GANIL to maintain competitiveness in the field of spectroscopy with radioactive ion beams. A strategic roadmap should be developed based on the Working Group's discussions, ensuring an optimized allocation of resources and a structured development plan.

3. Regarding resource management, the Scientific Council recommends that the GANIL Directorate take the initiative in coordinating a shared pool of equipment for beta decay studies to maximize resource availability. This pool should include Ge detectors, ancillary detectors, electronics, and other essential components.

4. The Scientific Council highlights the availability of the European Ge detector pool as a valuable resource that should be leveraged. The Directorate is encouraged to maintain communication with the Working Group and provide regular updates regarding decisions related to equipment coordination and resource allocation.

SEASON

The presentation by SEASON highlights the critical need for resonance ionization spectroscopy and high-resolution decay spectroscopy of heavy and superheavy elements produced at S3. The physics case is well-defined, and the necessary device is already largely in place. SEASON is designed to complement IDEAS3, which focuses on neutron-deficient nuclei, and PILGRIM, which enables mass measurements. The collaboration demonstrated intense preparation and a clear understanding of the specific requirements for implementation at S3/SPIRAL2, leaving a positive impression on the Scientific Council.

Recommendations

1. The collaboration requires support from the "Techniques d'acquisition" group to implement NUMEXO2, and the Scientific Council strongly supports this request. However, it is noted that a potential scheduling conflict may arise if SIRIUS is allocated time at S3 while SEASON is based in Jyväskylä. This issue should be carefully managed.

2. Many other projects for DESIR and S3 will likely require simultaneous support from the Acquisition group, and the Scientific Council recommends that the GANIL management ensure proper coordination to address these overlapping needs effectively.

3. The collaboration has demonstrated strong cooperation with S3 management and planning. Given this, GANIL is expected to provide suitable support upon the detector's arrival in February 2025 to facilitate its successful integration.

4. The collaboration has established solid connections with Jyväskylä, where commissioning and complementary experiments can be conducted. The Scientific Council considers this an assurance that the program will be effectively implemented at S3. The project aligns well with the unique capabilities of SPIRAL2/S3 and is expected to yield significant scientific results.

Implantation of LRC (Laser Resonance Chromatography) @ GANIL

Speaker: Mustapha Laatiaoui (GANIL)
Duration: 50min

Laser Resonance Chromatography (LRC) is a novel technique that complements other laser-based spectroscopic methods in the study of nuclear structure properties of rare isotopes. The Scientific Council was informed that this method will be implemented at S3 to explore transition metals beyond nobelium, particularly the superheavy elements starting with lawrencium, for which atomic spectroscopy information is currently unavailable. Atomic spectroscopy is a crucial gateway toward fundamental nuclear structure studies, allowing the extraction of charge radii, electromagnetic moments, and nuclear spins.

In the LRC approach, ions are optically pumped using pulsed lasers from the ground state to an excited state, which subsequently decays into a metastable state. The resulting electronic configuration is imprinted on the mobility on the ion that can be exploited in a drift tube towards a particle detector. If the resonant excitation is successful, the excitation frequency can be probed by detecting multiple peaks in the arrival time distribution of ions.

The project is structured into three Work Packages: the first focuses on an offline development program to enhance the efficiency of the existing apparatus, the second aims to develop a new Online Chromatography setup for operation at the S3 Low Energy Branch, and the third is dedicated to proof-of-concept investigations.

Recommendations

1. The Scientific Council found the proposed scientific cases to be highly relevant to the S3 facility. The high yields expected for heavy and superheavy elements can be effectively utilized in an ambitious research program with significant scientific impact.

2. The Scientific Council acknowledges the current limitations in manpower following the recent appointment of the spokesperson. However, it strongly recommends the urgent integration of the project into the existing S3-LEB community to ensure that adequate human resources are allocated. This will be essential for meeting the ambitious project timeline and achieving the expected research objectives.

6 Summary

The Scientific Council gave a very positive evaluation of the laboratory's activities in 2024. Most of the plans and objectives set in the previous year have been successfully implemented or are currently in progress, reflecting significant advancement.

However, the Council also highlighted a fundamental challenge affecting various aspects of the laboratory's operations: GANIL does not have control over the hiring of physicists (particularly on the CNRS side) or the selection of funded projects, yet it is still required to provide full support for all community activities. This includes ensuring the necessary staff and experimental resources are available. While this paradoxical situation is not new, it continues to present obstacles to the laboratory's future planning—an issue that may warrant formal recognition.

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