INTRODUCTION

The GANIL Scientific Council (SC) met February 1-2, 2024, in a hybrid format. During the first day of the meeting, the SC heard an update detailing on-going activities from Deputy Director Fanny Farget, which was followed by presentations of on-going activities and possible future initiatives. Attending the meeting for the SC in person were Amine Cassimi, Anne-Marie Frelin, Jérôme Giovinazzo, Férid Haddad, Michal Kowal, Alain Letourneau, Iain Moore, Jaromír Mrázek, R.G. Pillay, David Verney, and Robert Tribble (chair). On-line were Anna Corsi, Fabiana Gramegna, Rituparna Kanungo, and Christoph Scheidenberger. Also attending was the PAC Chair, Stephan Oberstedt. The previous SC meeting was held also as a hybrid meeting in January, 2023.

It has been a busy and prosperous year for GANIL since the last SC meeting. Last year we reported on the progress of using the LINAC for a very successful campaign of research at NFS. This facility will continue to lead the development of new science for SPIRAL2 into the near future. Consequently, upgrades to the target at NFS to allow for higher beam current should be undertaken. Following up on the report last year of the successful acceleration of a heavy-ion beam in the LINAC, work this past year has been devoted to producing a substantial increase in beam power through the machine. The impressive results bode well for the future operation of SPIRAL2. It is critical, however, to move forward with the commissioning of S^3, which is central to much of the nuclear physics program being planned for SPIRAL2. Given its importance, a session at the SC meeting was devoted to the commissioning activities and a report from the SC on this effort is given below.

Two other major efforts related to SPIRAL2 are also progressing—DESIR and NEWGAIN. Following the recent announcement by the French Ministry of 40 M Euro of new funding for projects, they should proceed on schedule. The present plans from the GANIL management are to use about half of this new funding to complete DESIR and NEWGAIN. The other half will be used to initiate the project of Cyclotron renovations—CYREN. The SC recognizes that potential conflicts might arise among the competing priorities for laboratory resources, which include successfully commissioning S^3, completing the construction for DESIR and NEWGAIN, and beginning the ambitious program for CYREN. The SC views the commissioning of S^3 as vital for the long term program of research at GANIL. If additional resources are needed to make this happen, it should be a priority of the lab management to find them, possibly by slowing other priority activities.

In addition to the new project funding, GANIL has made progress on increasing its workforce. Additions have been made both to the permanent staff and also to the contract, or term, staff. These additions are much needed in order to continue the progress toward realizing SPIRAL2 and also to begin work on CYREN.

Last year, GANIL management discussed plans to develop simultaneous operation of the Cyclotrons and the LINAC. More details were presented at this meeting about how such simultaneous operation would be staged. The program appeared to be well thought out. The SC encourages moving toward the schedule that was presented in order to optimize the use of the facility. As was noted in last year's report, the GANIL facility with its high-energy heavy-ion beams is one of the best in the EU for carrying out irradiations of electronics for space applications.

It appears that this effort is growing. In the future, it might be possible to use a larger share of time when simultaneous operation of the cyclotrons and LINAC is in place. The SC asked the management to develop a business plan for this effort to establish a charging scheme that provides the resources for staff to maintain such a broader program, and support for maintenance that would be needed to make a larger amount of beam time available. This plan still is needed.

Overall, the SC is supportive of a stronger visiting scientist program for GANIL. This should include all areas from theory, to experiment, to technical support. This is a possible way to improve the size of the workforce using a different mechanism.

One particular area of the lab staff that is undergoing change is the theory group. Retirements and the lack of new staff additions could create a sub-critical group. **The SC recommends that the lab develop a plan to ensure that the group remains strong into the future and present this at the next SC meeting.** As a positive sign, it is good to see that there is external interest in the theory effort as indicated by the number of visiting scientists who are coming to GANIL to work with the group.

Following a discussion of each initiative presented to the SC, a list of recommendations from the 2024 meeting are summarized here:

General:

- **The SC recommends that the lab develop a plan to ensure that the theory group remains strong into the future and to present this at the next SC meeting.**

S^3 commissioning:

- **The GANIL management should be prepared for decisions on prioritization in case of major disruptions due to the fragility and technical risk associated with the superconducting systems. This may mean additional financial resources will need to be re-allocated.**
- **The commissioning period of the spectrometer is critical to ensuring the success of this flagship SPIRAL-2 scientific program. This will require the performances of the diagnostics and beam suppression capability are demonstrated, necessary for a proper understanding of the ion – optical behavior of this complex device. Within the two-year commissioning period, the SC recommends the beam time and scheduling is optimized to ensure the continuous evaluation of the spectrometer sub-systems and overall performance.**
- **The SC expresses its interest to follow the ongoing developments of the commissioning phase.**

CYREN:

- **The SC recommends technical and financial evaluations of setting up a test bench for rf systems as part of CYREN.**
- **The SC recommends that the pre-project working group closely work with the different communities to evaluate the impact of CYREN technical choice implementations on their scientific programs**.

ARIBE:

- **The SC recommends the laboratory continue to support the work associated with ARIBE.**
- **The renewal of this agreement [with the French regulatory commission for proper shielding] is mandatory to maintain the activity of ARIBE and is essential since major engagements were taken in several projects such as the PEPR ORIGIN for the development of the MIRRPLA platform and the realization of a very ambitious research program.**

SHEXI:

- **The committee recommends supporting the development, implementation and use of the SHEXI demonstrator. As a follow up, the collaboration should outline how they intend to construct the full detector system**.

ACTAR TPC at TRIUMF:

- **The SC recommends that the GANIL management consider supporting this program [to use ACTAR at TRIUMF].**

Individual reports for each of the areas reviewed by the SC are given below.

Commissioning plan for the S^3 project

The S^3 spectrometer is a flagship facility of GANIL that will bring unique science capabilities for stopped beam physics, including laser spectroscopy and mass measurements. The scientific community of S^3 consists of 27 laboratories from 11 countries. S^3 will have two main experimental setups available for physics campaigns, namely the SIRIUS detector setup used mainly for heavy element decay studies, and the LEB for laser spectroscopy and mass measurements, used for studies of proton dripline and N=Z nuclei, as well as for heavy and super-heavy element research. Techniques to be applied at the LEB include high-resolution in-gas jet laser spectroscopy, an MR-ToF mass spectrometer (PILGRIM) and a high-performance alpha and conversion electron decay detector (SEASON).

The SC appreciated the efforts of the two scientific communities around SIRIUS and LEB to undertake initial commissioning campaigns of their respective infrastructure (in part offline at GANIL and LPC Caen, as well as online at GANIL). The performance of the devices as indicated in the report are sufficient to begin commissioning at the S^3 spectrometer.

The SC were presented with a two-year strategy for commissioning the separator – spectrometer, expected to start in 2025. This will take place in three phases:

1. Optical commissioning phase. This uses dedicated diagnostics along the spectrometer and at the focal plane and is expected to last 1-3 months. SIRIUS or LEB can be at the focal plane but will not be used for data taking.
2. Scientific commissioning phase. This plan is aimed to optimize the beam rejection and the transmission for different relevant kinematics. The goal is to reach the required

performance in the converging mode for Day 1 experiments. Some beam time will be used to test the high-resolution mode which is important for the scientific program of SIRIUS.

3. The third phase is to commission the two experimental setups which will take place in parallel with the second phase. The aim is to have a full setup ready for experiments.

The commissioning scenario is based on the beam time plan proposed by the GANIL management, with a goal of gradually increasing the beam time while having parallel operation of the cyclotrons and the LINAC. The SC were informed that the S^3-UCC has agreed upon a detailed commissioning scenario for 2025-26, with the strategy of alternating between the setups of LEB and SIRIUS. The reasoning behind installing the LEB first was motivated by the initial commissioning of the converging mode. Several reactions have been proposed to test different ion – optical settings of the spectrometer, with the potential for scientific output prior to day 1 science.

The status of the commissioning of the spectrometer was presented to the committee. Several problems were identified which are critical risks to the ongoing commissioning in 2024. These include cold box turbine issues and a non-satisfactory cool down sequence. An investigation into these problems continues with Air Liquide. An action plan for 2024 was presented to the SC, with longer periods for cryogenic tests, a taskforce organization and an external expert group implemented. Moreover, problems have been identified in at least one of the superconducting magnets. The SC recognizes these as current risks to the project.

The SC appreciated the efforts of the management to resource required isotopic material for the future scientific program. The SC urges GANIL management to work with local industry when possible to secure the needed isotopes for future operation.

The SC has the following recommendations for S^3 commissioning.

- **The GANIL management should be prepared for decisions on prioritization in case of major disruptions due to the fragility and technical risk associated with the superconducting systems. This may mean additional financial resources will need to be re-allocated.**
- **The commissioning period of the spectrometer is critical to ensuring the success of this flagship SPIRAL-2 scientific program. This will require the performances of the diagnostics and beam suppression capability are demonstrated, necessary for a proper understanding of the ion – optical behavior of this complex device. Within the two-year commissioning period, the SC recommends the beam time and scheduling is optimized to ensure the continuous evaluation of the spectrometer sub-systems and overall performance.**
- **The SC expresses its interest to follow the ongoing developments of the commissioning phase.**

CYREN

The CYREN project is important for the future of GANIL, for the production of SPIRAL1 RIBs, the interdisciplinary activities, to trigger new industrial applications (e.g. SAGA project) and is crucial to maintain GANIL at the forefront of medium-energy heavy-ion science.

Improved reliability of the cyclotrons is a key point for the future operation, and to achieve the ambitious program of continuous increase of the available beam time by parallel operation mode. This will strongly benefit the rich and diverse scientific community around GANIL and open the path towards increased industrial application without jeopardizing the scientific ambitions. The SC points out the necessity of an improved maintenance level after refurbishment to guarantee future continuous operation over 20 years.

Obtaining funds for the so called "baseline scenario" is a good first step but does not solve the in-cavity leakage issues. The SC supports any endeavor to complete the funding and move towards the "complete scenario". The reason for that is not only to secure reliable long-term operation but also to take advantage of the fact that the expertise for the production of cavities has been identified and may disappear.

This complete scenario goes along with the question of the setting up of a test bench to minimize the impact on the operation and the availability of the beam for the users. **The SC recommends technical and financial evaluations of setting up of such a test bench as part of CYREN**. The SC would like to have a reevaluation of the beam time schedule for up to years 2030's in case such a complete scenario would be implemented (also considering 2 sub-scenarios with or without a test bench).

The SC recognizes that the impact of failures on the cyclotrons do not impact equally the various GANIL communities and physics programs: e.g. SME, fission at VAMOS, LISE and SPIRAL1. For that reason, **we recommend that the pre-project working group closely work with the different communities to evaluate the impact of CYREN technical choice implementations on their scientific programs**.

The SC acknowledges the potential strength of the nuclear physics and interdisciplinary research programs allowed by CYREN, but it would be desirable to strengthen these programs during the pre-project phase in order to define priorities and longer-term perspectives. It is therefore important to associate each scientific community to this elaboration, including in particular the DESIR community in view of the definition of a SPIRAL1 beam development scenario.

ARIBE

ARIBE is the low-energy ion beam facility at GANIL-SPIRAL 2, operated by CIMAP, which enables users to develop interdisciplinary projects via the iPAC GANIL portal.

The experimental program at ARIBE involves fundamental research projects related to astrophysical, biological or environmental issues. When it comes to astrophysical ices, ARIBE

ions are ideally suited to simulate solar wind species. These experiments are often carried out in collaboration with international space projects, which undoubtedly contribute to GANIL's high visibility. What is notable as well is to see the extent to which the instrumental developments carried out around ARIBE on astrophysics or cluster physics projects can federate international teams. Access to the beam via the European RADIATE network also contributes to this. The aim of understanding the fundamental mechanisms that govern our environment, as well as the growth processes of complex molecules, are ambitious projects that contribute, for example, to understanding the origins of life. The development of *in situ* instruments such as FTIR and mass spectrometry is a real strength. The possibility of opening up ARIBE beams to the EMIR&A research infrastructure network for the study of materials could be considered. It is true that other EMIR&A facilities offer beams of similar energies (JANNuS Orsay, JANNuS Saclay), but their availability is limited. Access to ARIBE beams would be a great opportunity for the materials community.

The outlook of ARIBE is promising. In particular, the development of the new MIRRPLA platform for the study of synergistic multi-beam effects opens the way to a number of highly original collaborations. The prospect to access to new ions is also attractive and constitutes a high demand of users. Moreover, ARIBE is highly complementary of the other beam lines operated by CIMAP for the interdisciplinary program, offering beam energies from keV to GeV, which makes the attractiveness of GANIL unique in this field. It also presents the advantage to be run independently from cyclotrons operation, allowing performing experiments all year long.

Recommendations:
The research performed at ARIBE is very important for the interdisciplinary users of GANIL and contributes to attract diverse scientific communities. Consequently, **we recommend continuing to support the work associated with ARIBE**. If it's not already the case, ARIBE should be fully considered as a beam line of GANIL (similarly to D1 which is operated by CIMAP and occasionally receive help from GANIL staff).

Of particular note is the renewal of the agreement with the French nuclear safety agency in 2026. The safety interlock chain has to be renewed, and a new shield designed, given the need for a public zone around the ion source. This has a cost and requires support from GANIL safety staff, which already has an important workload. Nevertheless, **the renewal of this agreement is mandatory to maintain the activity of ARIBE and is essential since major engagements were taken in several projects such as the PEPR ORIGIN for the development of the MIRRPLA platform and the realization of a very ambitious research program.**

The SHEXI Demonstrator

The high-intensity LINAC providing dc-beams together with the S^3 separator-spectrometer will become operational soon for experiments with deep inelastic reactions at Coulomb-barrier energies, including super-heavy element research. This next-generation facility and its experimental program will be a flagship in Europe in the coming years. S^3 is equipped with novel instrumentation that emerges from existing facilities and the experience gained in recent experiments. The present project is seen is this context: it is proposed to develop and implement a

very efficient, large-area demonstrator for the detection of characteristic x-rays emitted from super-heavy nuclei produced at S^3 and to upgrade SIRIUS.

The objective is to develop a state-of-the-art detection system sensitive to L X-rays (20 – 30 keV). Characteristic x-rays are a fingerprint of the atomic number of a nucleus, since the x-ray energy is proportional to the atom's nuclear charge Z. The proposed demonstrator shall have sufficient energy resolution to distinguish neighboring elements and thus unambiguously identify the atomic number of a super-heavy nucleus. The immediate goal is to implement a proof-of-principle detector.

The purpose, namely the unequivocal atomic number identification of the super-heavy elements in the observed isolated region of the nuclear chart, is a pressing issue in nuclear physics. Besides the application to identify super heavies, this improvement is critical for understanding the nature of electromagnetic radiation, thereby allowing a deeper understanding of the quantal structure of nuclei, for instance untangling complex decay cascades involving many converted transitions, such as those from high-K isomers; it also enables the determination of transition multi-polarities from sub-shell conversion coefficient ratios. As such, it will address fundamental questions of nuclear stability and nuclear structure at the outskirts of the chart of nuclei.

The complete system is expected to offer ten times higher detection efficiency and a twentyfold improvement in intrinsic resolution compared to SIRIUS. The enhanced resolution and unrivaled low thresholds of the novel SHEXI detection system will significantly increase the resolving power of the array for Internal Conversion Electron (ICE) spectroscopy. Consequently, SHEXI is expected to significantly advance our understanding of nuclear structure in the Fm-No-Rf-Sg region. The production and study of elements in the mentioned No-Rf-Sg region will be challenging and rely on the availability of beam intensities of a few pμA of ^{48}Ca provided by NEWGAIN.

The SC sees that GANIL will continue to play a pivotal role in advancing fundamental physics and addressing key questions of modern nuclear physics. In particular, success in the field of super-heavy element research and related spectroscopic experiments will position GANIL as a co-leading laboratory alongside with Dubna and its new SHE factory. In this context, the committee considers this detector an important asset for the new facility. To provide unambiguous element tagging via characteristic x-rays - a unique feature of SHE experiments worldwide - should become a routine feature of this new facility. The commitment and contribution from external researchers and their infrastructures (IJCLab, ATOMKI) is an opportunity for the SHE activity of GANIL and will further strengthen the collaborative efforts.

The committee recommends supporting the development, implementation and use of the SHEXI demonstrator. As a follow up, the collaboration should outline how they intend to construct the full detector system.

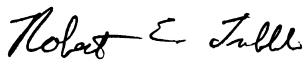
ACTAR TPC at TRIUMF

The GANIL Scientific Council commends the ACTAR Collaboration for initiating a very successful science program with the ACTAR TPC. It is a versatile, powerful detector system that has started delivering a wide suite of important results. It is impressive to see the list of 5 experiments performed during 2019-2022, noting that this overlaps with the unusually difficult period of COVID19 pandemic restrictions. The merit of the detector is its ability to detect very low-energy particles with high efficiency, good angular and position resolution and 3D track reconstruction of each reaction event. The device therefore plays a vital role in the studies of short-lived exotic nuclei, especially for inverse kinematics reactions and rare particle emitting decay channels. The team has made steady progress with the instrumentation and data analysis algorithms for a successful science program.

To maximize the scientific output from ACTAR the collaboration has proposed a few key experiments at TRIUMF in Canada. These were carefully chosen projects where the beam conditions needed are not available at GANIL. Therefore, this presents a good opportunity of a close collaboration between GANIL and TRIUMF. These proposals have been reviewed by the TRIUMF experiments evaluation committee and all 3 experiment proposals with ACTAR have been approved with high priority.

The committee feels that this is a timely unique window of opportunity for best science outcome with the proposed ACTAR campaign at TRIUMF. Therefore, **the SC recommends that the GANIL management consider supporting this program.** The committee suggests the ACTAR collaboration consider having more flexibility in the period the detector can remain at TRIUMF, for example a few months longer, in discussion with the laboratory. This will allow having more suitable conditions for beam scheduling. The committee suggests having a student or postdoc associated with GANIL to also work on the data analysis of any of these experiments.

Submitted on behalf of the Scientific Council by,



Robert E. Tribble, Scientific Council Chair
March 23, 2024