# Description of the infrastructures

# Grand Accélérateur National d’Ions Lourds

**Location of the infrastructures:** Caen, FRANCE

**Web site address:** http://www.ganil-spiral2.eu/

**Annual operating costs (excl. investment costs) of the infrastructure (€):** 11 M€ (GANIL without manpower), 29 M€ (including manpower)

## Description of the infrastructure GANIL-SPIRAL2:

GANIL-SPIRAL2 is one of the major nuclear physics facilities in the world with SPIRAL2 selected at the ESFRI list. The accelerator complex delivers four different beams for users:

* High-intensity stable beams, from Carbon up to Uranium between ~ 1 MeV to 95 MeV/nucleon,
* Very high-intensity light beams such as p, d, Helium …
* Wide range of high-intensity exotic beams produced either in flight with the LISE and S3 (from ~2024) fragment separators or with the ISOL method at the SPIRAL1 facility,
* And neutron beams with Neutron for science (NFS) since 2020.

The infrastructure consists of the following parts:

* Two injector cyclotrons right after two ECR ion sources, which can be operated in parallel.
* The IRRSUD beam line allowing to use low-energy beams from any of these injectors.
* CSS1: separated-sector cyclotron number 1 (delivers beams in the energy range 5-15 MeV/nucleon).
* CSS2: separated-sector cyclotron number 2, fed by CSS1, to reach the maximum beam acceleration (E=30-100 MeV/nucleon).
* SPIRAL 1 provides low energy radioactive beams (30 keV) at the LIRAT facility. These beams can also accelerated by the CIME cyclotron at 2-25 MeV/nucleon. This facility is unique in Europe.
* SPIRAL 2 Phase 1 (first PAC approved experiments in 2021): Superconducting LINAC is accelerating beams (with the highest worldwide intensity) from protons to heavy-ions with A/Q=3 in the energy range from 0.75 MeV/u to 20 MeV/u. The future A/Q=7 injector (~2028) will further sustainably increase the intensity of heavy ion beams at the

**The Associated research instrumentation with GANIL/SPIRAL2**

In the GANIL experimental halls, a variety of experimental infrastructure is fully available to all users with local technical support provided to physicists, engineers, and technicians. To be mentioned:

* VAMOS is a large acceptance spectrometer and is used for various types of experiments: direct and deep-inelastic reactions for new spectroscopy studies of exotic nuclei, fusion-evaporation reactions, etc. The focal-plane detection system will undergo a significant upgrade in the coming years.
* The LISE III spectrometer, which separates projectile fragments from an enormous flux of incident unreacted beam, focuses and unambiguously identifies these fragments using several types of detectors. LISE is also used for Atomic Physics experiments.

Two new experimental halls with corresponding instrumentation have been built at SPIRAL 2 Phase 1 that will open new opportunities: Neutrons For Science (NFS) facility (commissioned in 2019-2020) and Super Separator Spectrometer (S3) for nuclei far from stability (to be operational in ~2024). The Decay, Excitation, and Storage of Radioactive Ions (DESIR) hall is expected to be commissioned around 2026.

Other detectors at GANIL, designed for investigations on exotic nuclei and highly excited nuclei are:

* The EXOGAM high efficiency array of germanium detectors for gamma-ray spectroscopy.
* MUST2/TIARA: set-ups consisting of Si detectors for the study of direct reactions.
* ACTAR TPC: an active target and time projection chamber constructed with funds of an ERC starting grant (2013-2018). It is essential for experimental studies of nuclear structure and rare decay modes.

Other detectors are: INDRA and FAZIA 4π multi-detectors for charged particles, the Chateau de crystal scintillator array for γ rays, and the Neutron wall.

In addition, three beam lines with dedicated equipment are now available for Atomic and Condensed Matter Physics, at low energy (around 1 MeV/nucleon), at medium energy (after CSS1) and at high energy (95 MeV/nucleon). A dedicated beam line is devoted to industrial beam applications, and to biological research. In total (including low and medium energy beams), between 50 and 60% of GANIL beam time is allocated to interdisciplinary and applied research to tackle major societal challenges including cancer therapies, medical radioisotopes and energy.

The laboratory has access to the major computer centers of the CNRS (CC IN2P3 in Lyon) and the CEA. It is located in an active academic environment, the EPOPEA science and innovation park.

**Services currently offered by the infrastructure:** All stable and rare isotope beams and all experimental areas at GANIL-SPIRAL2 are open to external users. Each area has both a technical and a scientific coordinator, who act as liaisons with the outside users. They provide assistance to the users with regards to setting up and performing the experiment. In 2021, GANIL provides around 9 months of beam time. The GANIL users community gathers around 900 physicists, among which 300 are from EU (non-national). International users contribute actively to funding and construction of all major experimental devices. The average number of scientific publications related to GANIL experiments is around 120 per year.

**Description of work**

Modality of access under this proposal to GANIL-SPIRAL2 fully meets the requirements for open access to international users. Access has to be asked by submitting a written proposal. An additional application form has to be submitted by the users interested in the EC support. Preliminary contacts with the responsible of the facility of interest must be established in advance in order to ascertain the feasibility of the experiment and to comply with the scientific scheduling and safety rules. Local research groups are in charge of the above-mentioned experimental facilities and the users are independent in all the activities allowed by safety rules. The duration of a user’s stay can range between a few days for the short solid-state physics experiments to several weeks for long nuclear physics experiments or campaigns of experiments. Each experiment is attributed a DOI number. Data taken at GANIL are managed according a dedicated Data Management Plan according EU standards.

**Support offered under this proposal by GANIL-SPIRAL2**:

A number of main services are offered to users, including: 1) engineering project service and mechanical machine shops, 2) vacuum laboratories, 3) cryogenics and superconductivity laboratory, 4) target laboratory, 5) detector laboratory, 6) accelerator division. At GANIL-SPIRAL2 Users Executive Committee (GUEC) specifically ensures that user teams receive maximal support; it oversees the adequacy of the physics equipment for experimental programs. Important logistics support includes: 1) canteen and cafeteria service, 2) rooms for guests and users, 3) library and documentation service.

GANIL-SPIRAL2 covers from its own budget all additional expenses not covered by the unit cost (that means more than 90% of the full cost) of all fundamental research experiments performed at the facility.

**Outreach to new users of GANIL-SPIRAL2:**

Information on GANIL-SPIRAL2 and on internal meetings relevant to users is available online https://www.ganil-spiral2.eu and widely announced via extended mailing lists.

• All workshops and conferences organized by GANIL/SPIRAL2 are also widely advertised by email distribution, and information posted on the websites. In addition, surveys are made when decisions have to be taken involving the scheduling of beam time or developing of new beams.

• For industrial applications, outreach is achieved via an active participation in the RADECS association that gathers companies and beam providers, and also through participation in related conferences.

• The number of users will increase with the new facility SPIRAL2 Phase 1 and the associated new beams and detection systems.

All GANIL-SPIRAL2 users are registered and this allows for an easy monitoring of their number on a year-by-year basis.

**Review procedure under this proposal:**

Proposals to conduct an experiment at GANIL-SPIRAL2 are evaluated and ranked by a Program Advisory Committee (PAC) mainly from institutions abroad. During the public sessions, proposals for experiments are presented by their spokespersons. The evaluation process by the PAC is based entirely on the criteria of scientific excellence. The selection of international users benefitting from the TA support is also based solely on scientific merit and is communicated to the spokespersons. Up to now, all experiments fulfilling TA criteria could benefit from the TA funds, with a special attention to new users and users from countries where such infrastructure is not available, and to young scientists, PhD students and postdoctoral fellows.