Interdisciplinary research

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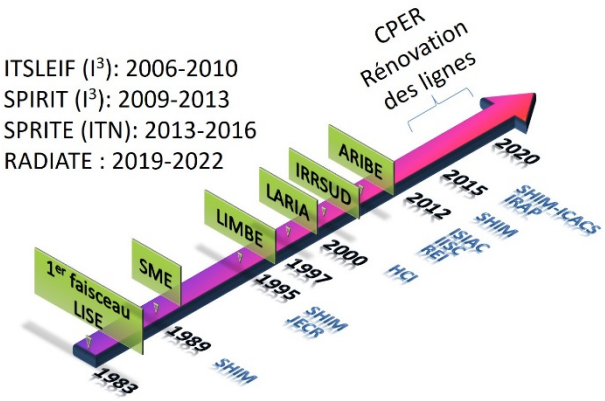
Since the creation of GANIL, the use of swift heavy ions by communities other than nuclear physics has been considered. Thus the CIRIL laboratory was created to host interdisciplinary experiments. In 1989, the construction of the medium-energy line (SME) renewed the interdisciplinary research, by allowing the addition of about 3000 hours of beam time for material irradiation and collision physics to the 10% of high-energy beam time. Since then, the GANIL beamline possibility was greatly enriched first with the creation of a multicharged low-energy ion line in 2000 (LIMBE, which has evolved since 2005 with the ARIBE installation having several beam lines), and then the IRRSUD line (2002) which takes advantage of the presence of two compact cyclotrons (the "free" cyclotron is used for interdisciplinary research. The ion energy of this beamline is exactly those of fission products and the lowest energy allows having high electronic stopping power but without activation of the samples, which makes easier the characterization after irradiation).



The vast majority of available equipments (as examples, we can cite ISOC, PELLICAEN, IGLIAS, CHEXPIR, ALIX, CASIMIR, COLIMACON) were unique in the world when they were started up. Due to their successes, they have been duplicated on other installations and consequently they contribute to increase the international reputation of the GANIL beams.

All these developments (beamline and in-situ instruments) permit a constant increase of the research topics and users, with around one hundred of new authors per year in publication related to experiment at GANIL (in interdisciplinary research). On average, around 70 experiments/year spread over nearly 3000 hours of operation (about 150 experimenters from national, European and international scientific communities) are hosted. Every year, requested beamtime is about 2 or 3 times more important than the available beamtime. The CIRIL platform has been able to anticipate the development of scientific practices by being a major player in national or international networks (PAMIR, NEEDS, EMIR, France hadron, LEIF, ITS LEIF, SPIRIT, RADIATE) and by optimizing human and financial investments resulting in significant spinoffs for innovation and research in both the French and international research landscape. A very broad variety of fundamental research and applications is performed at GANIL facility.

Each community on the major research field in interdisciplinary research have deposited a contribution. In the following, we go over the main scientific domains using GANIL beam lines and for each of them we present some recent highlights or "hot" questions for which GANIL beamtime would be necessary.

- Material Science: Recent progresses in numerical simulations and the access of advanced nano-scale characterization techniques (Equipex GENESIS, in-situ instrument) have allowed a better description and a better comprehension of the mechanisms of damage creation in materials for nuclear applications and the prediction of long term evolution under alpha irradiation of organic materials present in nuclear waste packages and the related confinement matrices (geopolymers, bitumen or those to come). Very recently, irradiation of 2D materials or topologic insulators has become a strong research topic leading to very promising results on the efficient use of ion irradiation to improve their properties. Demands for track-etched membranes for the Ion Track Technology are in constant grow due to the increasing interest in high value-added devices for environment and lab-on-chips applications deriving from their functionalization.
- Astrophysics: GANIL is a precious and unique tool to perform laboratory simulations of expected radiation effects in icy space environments, showing how to detect them and what observations to search for. It could significantly contribute to prepare future space missions like the ESA JUICE or the NASA Europa Clipper (exploration of the Jovian moons) as well as to interpret the future data for which the GANIL has a unique position in the international community. This is also true for telescope-based observations either from the ground (VLT on Kuiper Belt Objects) but also from the future space telescope JWST for which ESA and European scientists are engaged.
- Radiobiology: Hadrontherapy is a direct application of the use of ions beams in medical treatments of cancer. Thanks to the quality of the beams and of the infrastructure (GANIL, CIRIL platform and state-of-the-art equipment's in the LARIA lab), researches are progressing in the domain, and users still need beam time regularly and for several years to reach the goals and further improve radiation biology knowledge. The ARCHADE project in Caen reflects the success of GANIL in this field. Even after the possibility of using H beam (and in future C beam) at these new facility, the GANIL ion beams will remain necessary, for instance for exploring LET effect.
- Atomic Physics: The availability of intense and stable ion beams of high optical quality on French Large Scale Accelerator Facility (GANIL and soon SPIRAL2) opens new challenging opportunities to probe a variety of systems of prime importance for applications and basic research(Fit-FISIC experimental program).

Advantages of GANIL and requirements for interdisciplinary research

The main advantage of GANIL is that several users can have access to a large choice of ions and a wide range of energies (SME, ARIBE, IRRSUD and HE) at one place and to many unique online experimental devices. They can vary the linear energy transfer as well as the electronic to nuclear stopping power ratio. The variety, the versatility and the accessibility of GANIL's ion beams open a huge amount of opportunities to different scientific communities as well as to industrial applications.

The requirements to maintain the dynamism of the different communities (100 new authors per year) are the following:

- the availability of the beam lines of actual GANIL have to be guaranteed (at least 6 month per year) and new on-line experiment have to be proposed. For instance, a new EPR (electronic paramagnetic resonance) spectroscopy would be particularly useful for studying metal complexes or organic radicals and to better understood the formation of intermediate species under irradiation.

- In the EMIR&A network, we have also point out that it would be very interesting to expand the possibilities of beams at GANIL by adding an accelerator with an intermediate energy range between that of ARIBE and that of IRRSUD, with the possibility of in-situ RBS measurements and dual beam irradiations coupling “low” and “high” energy beam line.

- The time-resolved experiments would also strongly benefit from a unique equipment of GANIL known as the “suppresseur de paquets” (a pulse selector) which is not operational anymore (too old technology) but would be if great interest if an up-to-date version could be rebuilt. This new version could benefit from the development of the same kind of device which is under study for SPIRAL 2.

- The scientific communities will remain attentive to the new possibilities that will be offered by the new developments of GANIL (SPIRAL2, NFS, DESIR, interdisciplinary room, ….) to enlarge the possibility for interdisciplinary research.

- To conclude, in order to maintain a high level of quality in welcoming experiments at GANIL beamlines in interdisciplinary research fields, it is necessary to guarantee a reasonable amount of manpower (technicians, engineers, researchers) in the CIRIL platform.

We are confident that GANIL/CIRMAP/CIRIL can expand its role as a pioneer and pacemaker of accelerator-based, non-nuclear physics in the decades to come by making the right strategic decisions and implementing appropriate measures.