GANIL

Large national heavy ion accelerator

PROBING THE MYSTERIES OF MATTER

GANIL,

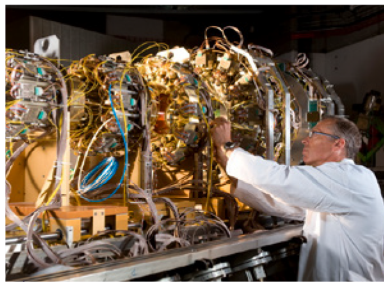
a facility for investigating the heart of matter.

**GANIL is one of the leading laboratories in the world engaged in research with ion beams.
The accelerators, coupled to very high-performance detection instruments, enable researchers from all over the world to conduct unique experiments.**

Cryogenic chambers enclosing the accelerating cavities of the SPIRAL2 superconducting accelerator.

Did you know?

- *The nucleus contains 99.95% of the mass of an atom.*
- *The nucleus, hidden at the centre of the atom, is 100,000 smaller than the atom as a whole. That is like a pea in the centre of a football stadium!*
- *The GANIL ion beams can travel at speeds of up to 120,000 km per second, the equivalent of three round-the-world journeys in just one second!*



INDRA charged particle detector.

Ion beam transport line.

**Experiments in nuclear physics at GANIL aim to provide a better understanding of matter:
the matter all around us, and the matter we are made from.**

How was matter created in the universe?

After the Big Bang, the universe was made up of only two chemical elements: hydrogen and helium. The great diversity of elements making up today's universe is mainly due to the stars. These immense cosmic cauldrons constantly create new atoms, which are ejected into the universe during violent cataclysms, such as supernovae explosions. At GANIL, physicists recreate and study reactions taking place in the stars to better understand both chemical element formation and stellar evolution.

How do the neutrons and protons making up the atomic nucleus interact?

To study the nucleus of the atom, physicists give it rough treatment by hurling it at other nuclei at speeds of several tens of thousands of kilometres per second. The results obtained are startling: nuclei shaped like a lemon or a pear, or with different shapes co-existing for the same nucleus; explosion into multiple smaller nuclei; etc. These experiments test theoretical models that underpin our understanding of atomic nuclei. They also allow the investigation of the forces that ensure the cohesion of the nucleus or that lead to its transformations.

What rules govern "magic nuclei"?

Nuclei appear to be particularly stable and robust when they have 2, 8, 20, 28, 50, 82 or 126 protons and/or neutrons. These are called "magic numbers". However, it seems that so-called «exotic nuclei», i.e. those which do not naturally occur on Earth, do not obey this rule.
At GANIL, physicists study the «magicity» of ever more exotic nuclei.

What are the limits of existence of matter?

Currently, the heaviest element observed in a laboratory – i.e. the one having the most protons and neutrons in its nucleus– **has 118 protons.** Theoretical models predict the existence of even heavier nuclei, containing more than 120 protons. These massive so-called "super heavy" elements can be produced by fusing two nuclei. Thanks to the unparalleled intensities of the SPIRAL2 beams, and efficient experimental equipment, GANIL will be at the cutting edge of the quest for «super-heavy» elements.

Journey to the centre of the machine

To study the atomic nucleus, it needs to be made to interact with other nuclei. GANIL houses several devices capable of producing, accelerating and transporting beams of ions towards a target to cause nuclear reactions.

SPIRAL2

THE SUPERCONDUCTING LINEAR ACCELERATOR
generates very intense beams of particles: this increases the probability of interaction between the accelerated particles and the target nuclei.

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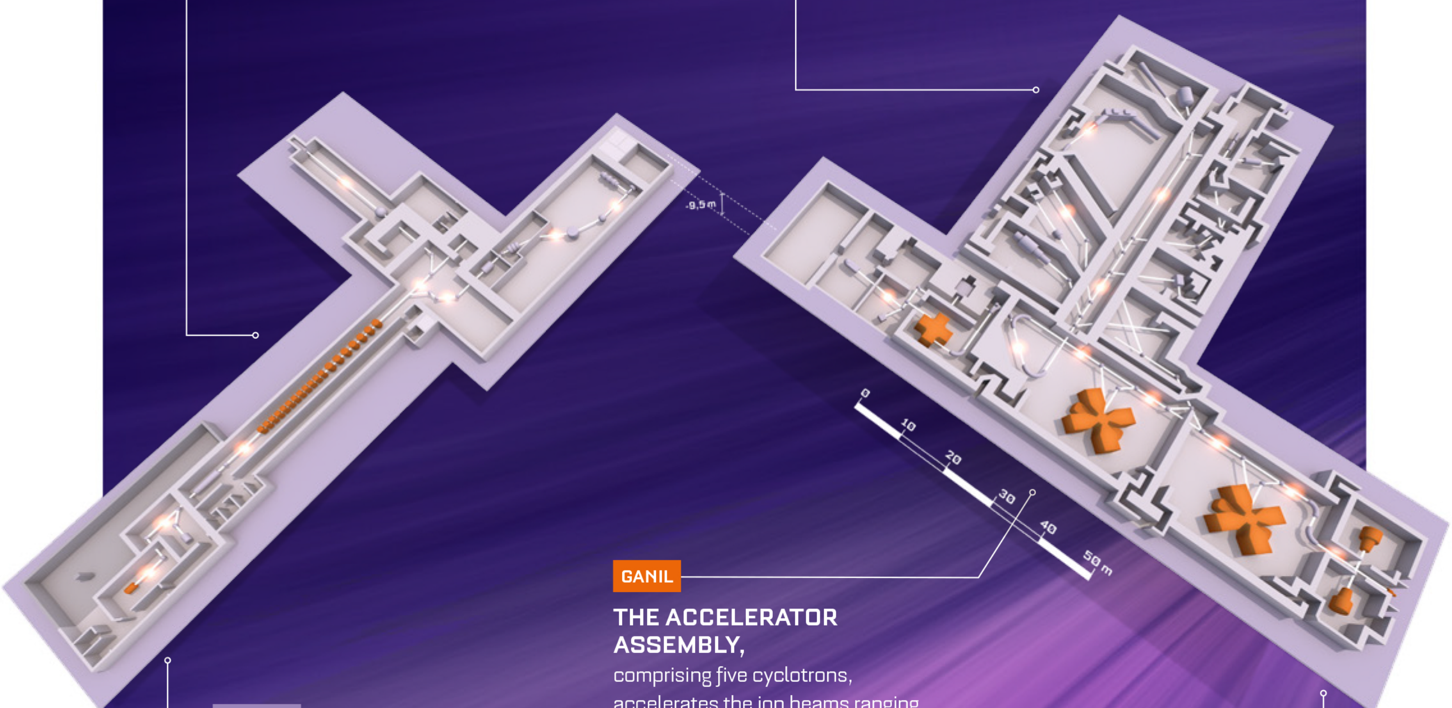
THE EXPERIMENTAL ROOMS
house very sophisticated detection and measurement systems for observing the reactions produced by collisions between the ion beam and a target.



SPIRAL2

THE SPIRAL2 ION SOURCES
can produce a wide range of particles, including very light ones such as deuterons or protons.

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THE ACCELERATOR ASSEMBLY,
comprising five cyclotrons, accelerates the ion beams ranging from carbon-12 to uranium-238 at different energies depending on the experiment.
Carbon-12 ions for instance can reach up to 120 000 kilometers per second, i.e. more than one third of the speed of light.

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THE SOURCES
produce the ions that are then formed into beams and accelerated.

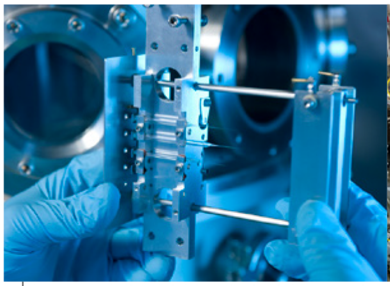
SAFETY OF THE FACILITIES

A team of safety and security specialists is responsible for risk prevention on the site and for environmental protection.

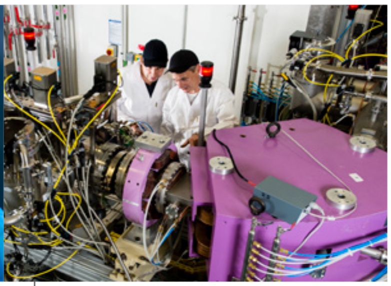
They ensure the safety of staff and due compliance with regulations governing the operation of GANIL as a "basic nuclear facility".

GANIL,

A team of experts and cutting-edge equipment



Sample holder used by CIMAP for applied materials research.



Magnetic devices guiding the ion beams.

GANIL's ion beams to serve also multidisciplinary research

The quality of the laboratory's ion beams make them remarkable tools for different fields of basic and applied research: atomic physics, material physics and radiobiology. Approximately 30% of the facility operating time is dedicated to such multidisciplinary research.
The Jules Horowitz campus, where GANIL is situated, hosts part of CIMAP (research centre for ions, materials and photonics) and LARIA (research laboratory for radiobiology with accelerated ions).
GANIL has also provided beams to France Hadron physicists as part of the ARCHADE program focused on research for the treatment of cancer by hadrontherapy.

Capitalizing on equipment and research at GANIL

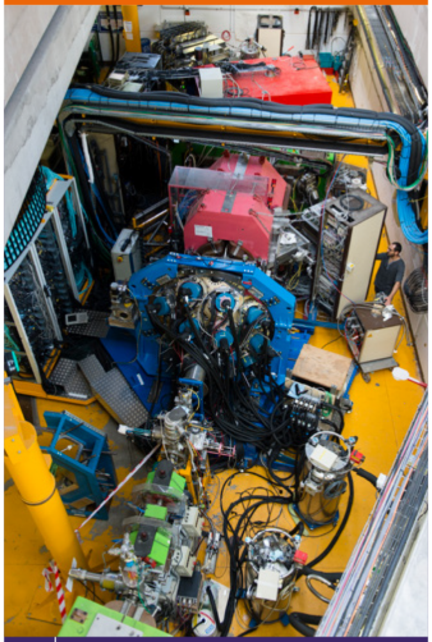
GANIL's ion beams are used for industrial applications: manufacturing microporous membranes, irradiating electronic components used in satellites (research and development, tests, etc.).
The laboratory relies on the scientific and technical expertise of its staff in order to promote partnerships with industry, in particular in the form of patent licences, transfer of know-how and research cooperation agreements.

A team serving research

The running of GANIL relies on the expertise of various technicians and engineers working at the facility. These include, among others, staff dedicated to creating and transporting ion beams, preparing and ensuring proper running of experiments, including the data acquisition systems.
Research teams propose experiments using state-of-the-art technologies. Some of the required developments are carried out at GANIL in collaboration with experimentalists and engineers from other laboratories.
The experimental and theoretical physicists work closely together to compare the theory with the results of experiments.
The smooth operation of the entire facility, and its accessibility to users, is ensured by the administrative personnel working alongside the scientific and technical staff.
In all, nearly 280 people are employed in GANIL's different departments.

Did you know?

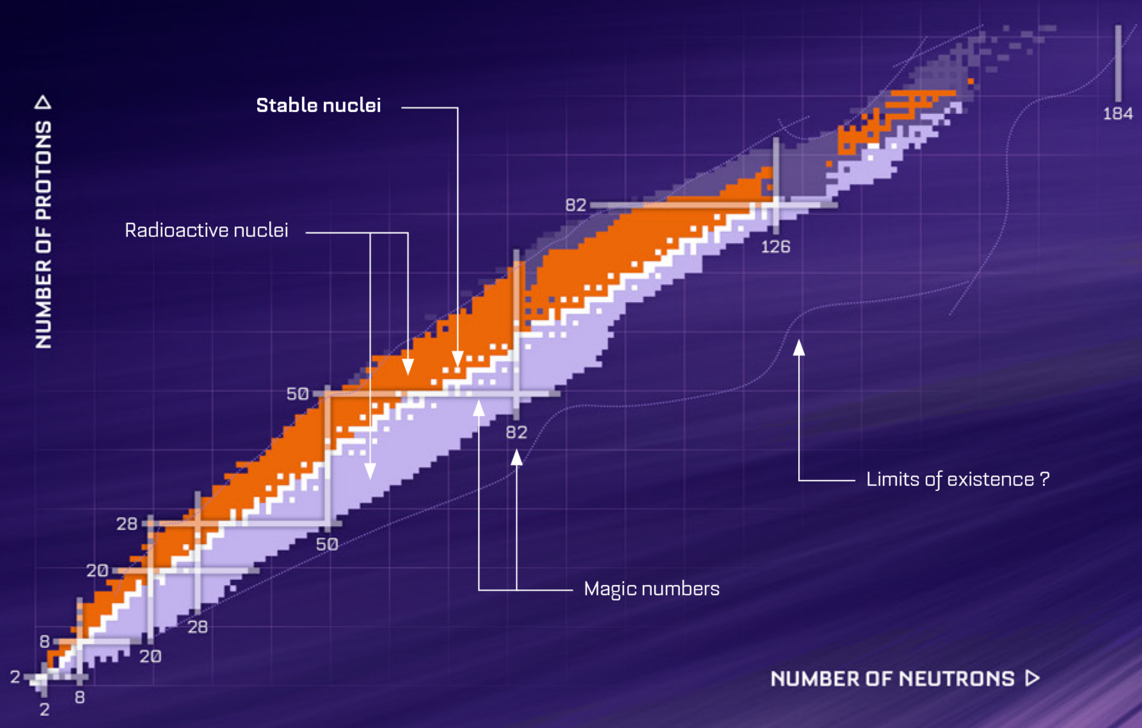
- *An atom is electrically neutral; it has the same number of electrons (negative charges) and protons (positive charges). To accelerate it, it needs to be transformed into an electrically charged ion by removing a few electrons from it.*
- *The components of the nucleus (protons and neutrons) are not motionless! They continually move at 30,000 km per second.*
- *Since its first operation in 1983, GANIL has witnessed the discovery of more than 100 nuclei never previously observed!*
- *The density of the nucleus is such that a nucleus the size of a thimble would weigh 200 million tonnes!*



AGATA spectrometer coupled with VAMOS spectrometer.

Chart of nuclei

Around 300 stable atomic nuclei exist in a nature.
More than 2800 have been produced in laboratories to date and more than 5000 have yet to be discovered.



GANIL,

A major facility serving French, European and international research.

GANIL is an economic interest group (GIE). The Centre national de la recherche scientifique (CNRS - national scientific research centre) **and the Commissariat à l'énergie atomique et aux énergies alternatives** (CEA - the French atomic and alternative energy commission) **are the laboratory's two regulatory authorities.**

The SPIRAL2 facility was selected in 2006 by ESFRI, the European Strategy Forum on Research Infrastructures, as a project of scientific excellence.

SPIRAL2 linear accelerator.

GANIL's local roots

Normandy's local authorities and GANIL have pursued a policy of promoting scientific research for many years with a view to increasing the appeal and competitiveness of the Normandy region.

The Normandy Region, the Calvados Department, the Caen-la-mer urban district and the City of Caen support many of GANIL's projects, including SPIRAL2 which was partly financed by these public entities.

Siting GANIL in Normandy has profoundly modified the region's scientific development, as demonstrated by the development of a first-rate scientific cluster around GANIL, comprising higher education and research establishments.

An international scientific community

Every year GANIL receives several hundred researchers and engineers to collaborate on scientific experiments and projects.

In total, nearly 700 researchers from 65 laboratories in 30 different countries come to GANIL every year to conduct experiments or attend seminars.

European and international agreements with numerous countries favour exchanges of researchers between laboratories. The research projects are developed at GANIL in conjunction with international scientists or with European fundings.

laboratoire commun CEA/DRF · CNRS/IN2P3

SPIRAL2 facility at GANIL

New research prospects.

The SPIRAL2 facility offers GANIL new research prospects thanks to very intense ion and neutron beams, allowing notably to study the properties of hitherto unknown atomic nuclei.

The linear accelerator

The SPIRAL2 LINAC (LINear ACcelerator) **can accelerate lighter nuclei** (protons, deuterons, helium) **than the GANIL cyclotrons,** thereby extending the research done until now. It also accelerates heavy ions up to nickel, at intensities 10 times higher than those currently available. This gain in intensity opens up new prospects, like the discovery of new atomic nuclei.

Experimental rooms

- **Neutrons For Science (NFS):**

The protons and deuterons (nuclei made up of one proton and one neutron) **accelerated by the SPIRAL2 LINAC can be used to generate extremely intense and quite unique neutron fluxes.** These beams of neutrons are used in the NFS room for experiments in nuclear physics and applied research (energy, electronics, etc.).

- **Super-Separator-Spectrometer (S^3):**

In nuclear physics, S^3 allows among other things the study of super-heavy elements, so called because they are much heavier than uranium, the heaviest naturally-occuring element found on Earth. S^3 could produce and study the properties of hitherto unknown chemical elements, which would extend the periodic table of Mendeleiev. EQUIPEX quality-certified facility (Equipment of Excellence).

Technological advances

The SPIRAL2 project involves the development of ever more sophisticated technologies.
For LINAC, new superconducting accelerator cavities have been developed to deliver an unprecedented level of performance.
The development of new detectors for the SPIRAL2 project is driving technological innovations, with potential spin-offs in industry and health.

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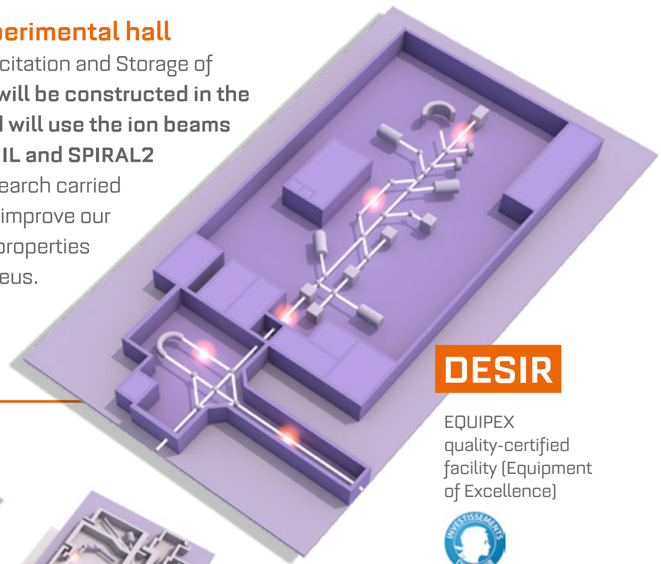
Development prospects

A new ion source for the SPIRAL2 LINAC is under study.

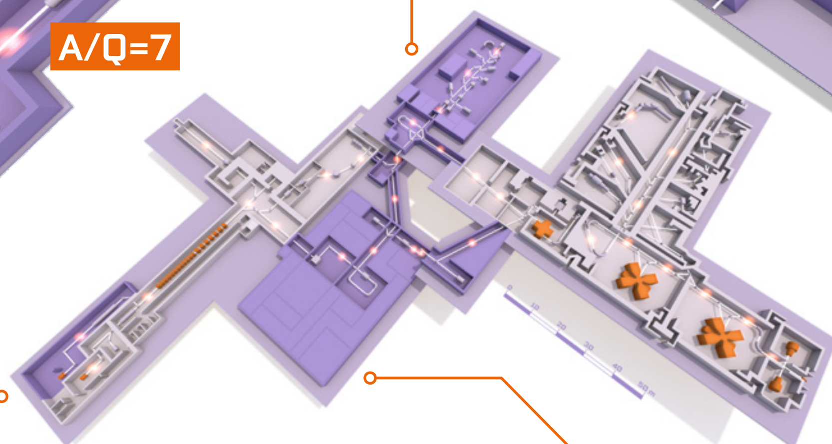
It will further increase the intensity of the ion beams generated by SPIRAL2 and boost its international competitiveness.

The DESIR experimental hall

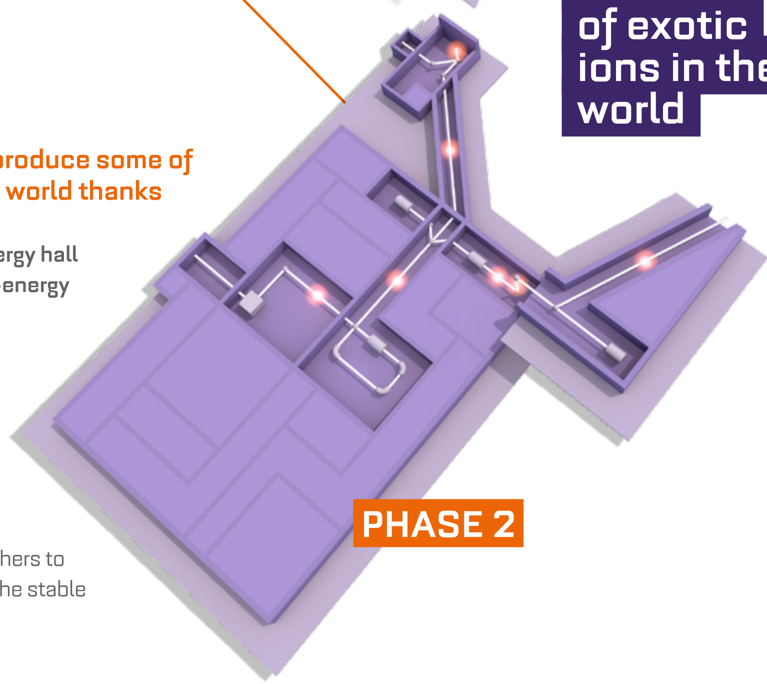
(Disintegration, Excitation and Storage of Radioactive Ions) **will be constructed in the coming years and will use the ion beams produced by GANIL and SPIRAL2 facilities.** The research carried out in this hall will improve our knowledge of the properties of the atomic nucleus.



EQUIPEX quality-certified facility (Equipment of Excellence)



Producing some of the most intense beams of exotic ions in the world



The ultimate aim of SPIRAL2, phase 2, is to produce some of the most intense beams of exotic ions in the world thanks to a dedicated production building.

These beams will be transported to the DESIR low-energy hall or post-accelerated by GANIL's cyclotron for medium-energy ions (CIME) before being sent to one of the existing experiment halls. Researchers will thus benefit from all the existing infrastructure, with its detection, acquisition and data processing systems.

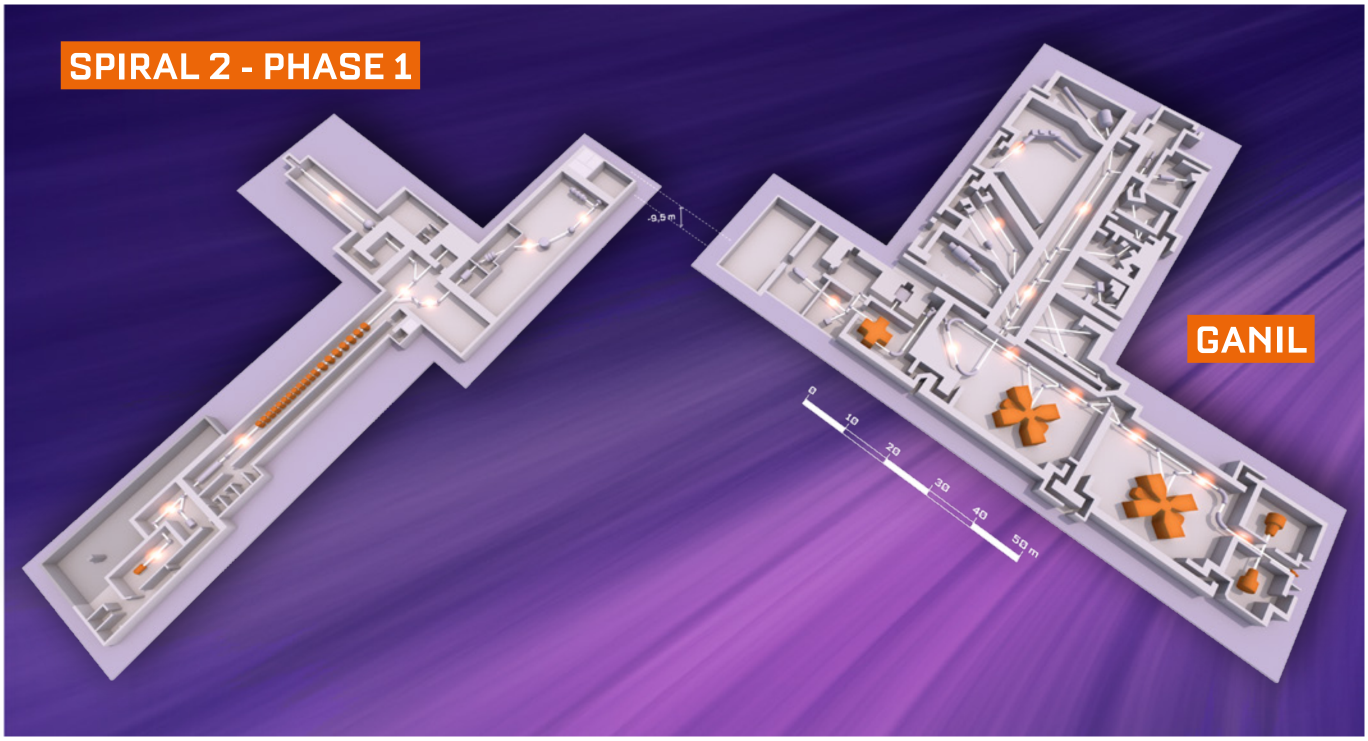
In parallel, a new generation of more efficient detectors is under construction as part of several European collaboration programs.

The combination of these new production and research facilities will enable a wide-ranging community of researchers to probe the properties of atomic nuclei very different from the stable nuclei that make up our environment.

A Norman project supported by local and international partners

The SPIRAL2 project was made possible thanks to the participation of the European Union, the French State, CNRS, CEA, the Normandy Regional Council, the Calvados department, the Caen La Mer urban district and Caen City Council.
In total, 23 countries have collaborated on the project: Germany, Belgium, Bulgaria, Spain, Finland, Greece, Hungary, Italy, Poland, Czech Republic, Romania, United Kingdom, Russia, Sweden, Switzerland, China, South Korea, India, Israel, Japan, Turkey, Canada and the United States. **Twenty or so bilateral agreements have been signed in this respect since 2002.**

Industrial Applications
with GANIL-SPIRAL2 facility



GANIL Ion Beams

GANIL ION BEAM MAINLY USED FOR RADIATION TESTS

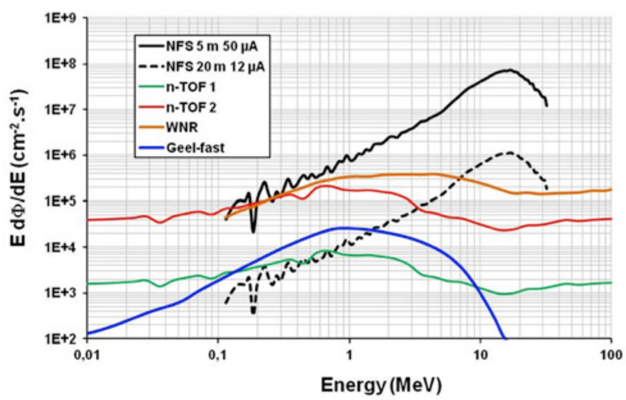
Ion	Energy (MeV/u)	LET MIN (MeV.cm²/mg)	Range (μm)	LET MAX (MeV.cm²/mg)	Range (μm)
^{36}Ar	27	5,4	445	9,9	113
^{86}Kr	60	11,0	1223	42,1	27
^{129}Xe	50	26,5	685	64,3	35
^{208}Pb	29	72,7	258	97,6	64

SPIRAL2 Ion Beams

Ion beams: protons up to ^{58}Ni, ^{78}Kr available in the SPIRAL2 facility and in the NFS area for industrial applications and radiation tests

- Protons up to 33 MeV
- Deuterons up to 20 MeV/u
- Ions (q/A=3) up to 14,5 MeV/u
- Intensity limited to 50 μA for proton and deuteron beams
- Intensity for heavier ions: depend on the ion mass and ion source capability with a minimum of a few tens of μA.

SPIRAL2 Neutron Beams



Comparison of the neutron flux of NFS with 3 other facilities: n-TOF, WNR and GELINA. The fluxes of NFS are presented at 5 m and 20 m.

The length of the TOF area allows either high-intensity flux (5 m) or high-resolution (20 m) measurements. The average neutron fluxes in the TOF area (5 m and 20 m) are very competitive in comparison with other facilities like n-TOF at CERN, WNR at Los Alamos and GELINA in Geel, in the 1-35 MeV energy range.

The neutron flux in the converter room, 5 cm downstream the converter, is higher then 5.10^{11} n/cm²/s when using the beryllium converter. This very high flux can be used to measure very small reaction cross-sections by activation techniques, or irradiate very small samples for instance.

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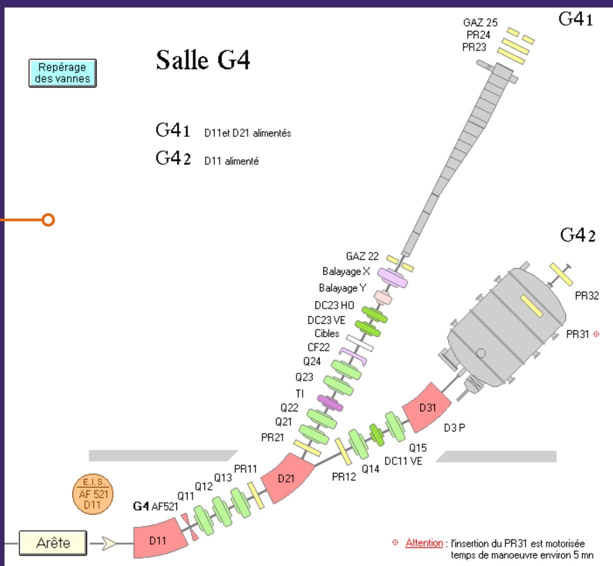
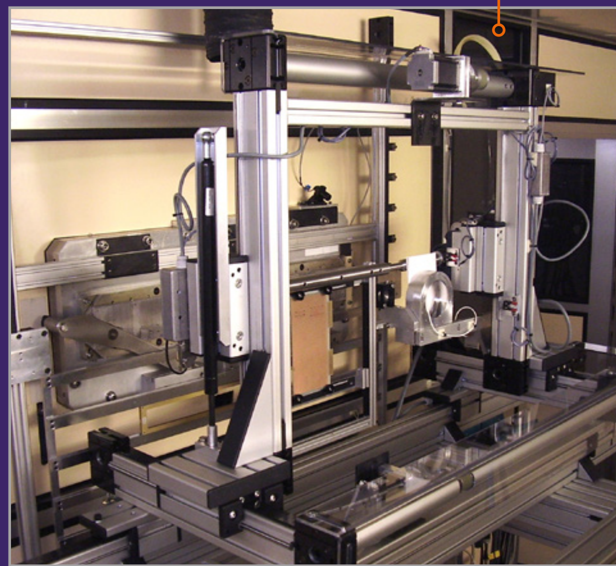
GANIL Facility

IRRADIATION BEAM LINE

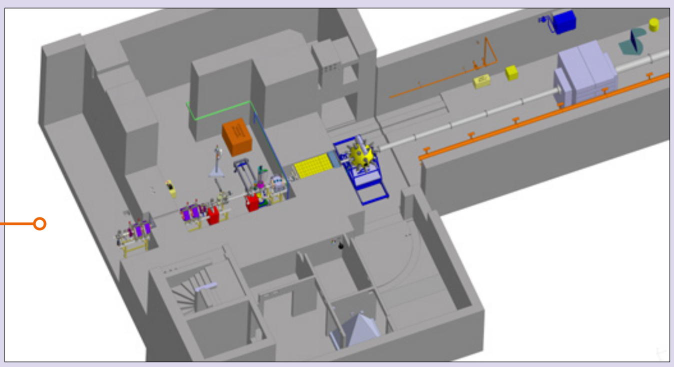


SAMPLE IRRADIATION DEVICE

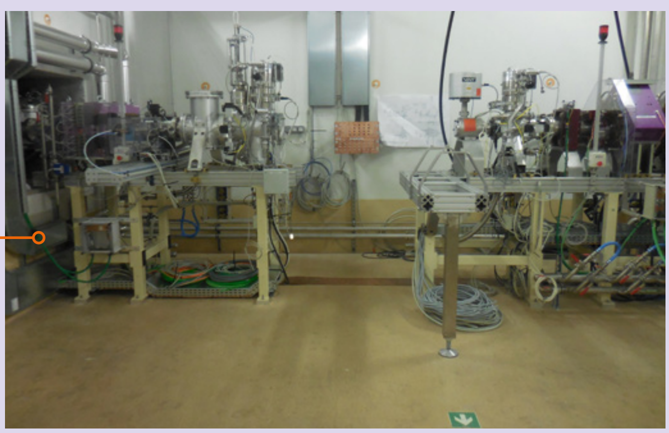


SPIRAL2 Facility

CONVERTER AND TOF AREA



NEUTRON FOR SCIENCE AREA



Beam scheduling for industrial applications

For a standard operation year, around 30 to 40 Units of Time (1 UT=8 hours) dedicated to industrial applications

These last four years, global beam time offer much lower, due to the construction of the SPIRAL2 facility (doesn't allow to operate GANIL accelerators at full time, and the beam time dedicated to industrial applications is somewhat shorter)

GANIL facility: Studies in progress in order to give the possibility in the future to produce microporous membranes with the CIME cyclotron, in order to allocate more beam time for space industry applications, from which demand is higher that beam availability.

SPIRAL2 beam scheduling under study, as well as the new organization to be defined in the GANIL laboratory to run as much as possible both facilities GANIL and SPIRAL2 simultaneously

First experiments in NFS cave in 2019

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