DESIR at SPIRAL2/GANIL

B. Blank, CENBG, scientific coordinator for the DESIR collaboration

The DESIR (Desintégration, Excitation et Stockage des Ions Radioactifs = Decay, excitation and storage of radioactive isotopes) is presently in its final design study at GANIL and construction is scheduled to start before the end of 2021 to become GANIL's low-energy ISOL facility with the start of its radioactive beams program beginning of 2024.

Research at DESIR [1)] will include radioactive decay studies, laser spectroscopy and experiments with different trapping devices, allowing high-precision measurements to be performed with ultra-pure samples. The experimental program at DESIR will tackle questions concerning the structure of atomic nuclei, questions linked to the nucleosynthesis and the energy production in different stellar environments, and to the nature of fundamental interactions. Research subjects will also include interdisciplinary research linked to energy production and treatment of radioactive waste, to nuclear medicine, to atomic physics and, possibly, to condensed and soft matter physics.

For these purposes, different sub-collaborations within the DESIR collaboration have started the design and construction of experimental equipment or embarked in the upgrade of existing devices. Two Penning-trap facilities, PIPERADE (at CENBG) and MLLTRAP (at IJCLab), are in their commissioning phase in order to perform mass measurements, in-trap decay studies or to serve for trap-assisted studies where the traps are used to clean and store radioactive samples before being sent to the experiment. An existing Paul trap, LPCTrap to become the MORA device (at LPC Caen and GANIL), will be upgraded to a much higher detection efficiency and to enable experimenters to send a laser beam into the radioactive sample stored in the trap for studies of parameters of the weak interaction and its possible extensions. Laser spectroscopy set-ups inspired by ISOLDE's CRIS or MIRACLS devices are envisaged to study nuclear properties like spins, deformation and single-particle structure observables through magnetic and quadrupole moment measurements by exciting the configuration of atomic electrons of nuclei of interest that couples via the hyperfine interaction to the structure of the atomic nucleus. Another collinear laser spectroscopy set-up, LINO, is presently tested at ALTO/IJCLab. This set-up can also be upgraded for decay studies of polarised nuclei in order to determine spin and parity of the nuclear states involved in the beta decay. Finally, a large number of smaller set-ups are readily available to investigate the decay properties of atomic nuclei. These set-ups consist typically of plastic scintillators for β-particle detection, germanium detectors for γ-ray detection, and/or silicon detectors for proton or α-particle detection. Set-ups like BEDO (IJCLab) or Silicon-Cube (CENBG) have already been used in a number of experiments in other facilities. Particular devices for radioactive decay studies are total absorption γ-ray spectrometers, TAGS. Different versions of these devices exist in Europe and are ready to move to DESIR. A proposal for the construction of a new device exists at SUBATECH Nantes, which is devoted to the characterization of nuclear deformation and to constrain the evaluation of the decay heat and the antineutrino flux of nuclear power plants.

[1] see e.g. the contribution on weak-interaction studies

This large panoply of experimental studies requests more or less all nuclei of the Segré chart of radioactive isotopes. These nuclei are produced by different means depending on their characteristics: light (up to mass A=40 or 50) are efficiently produced by fragmentation reactions with SPIRAL1. To enlarge the scope of nuclei available, an ambitious R&D program is necessary as each element requires a specific development. However, refractory elements are not accessible to the technique used at SPIRAL1. Heavier nuclei and in particular nuclei from refractory elements will be produced by S^3 and its low-energy branch LEB [2)]. The main reaction type to be used will be fusion-evaporation reactions for the production of proton-rich, heavy and super-heavy nuclei, but deep inelastic or multi-nucleon transfer reactions can also serve for the production of moderately neutron-rich isotopes. The most neutron-rich nuclei will be unfortunately not available at GANIL/SPIRAL2 due to the lack of a production facility based on nuclear fission. This is the biggest shortcoming of GANIL for the future DESIR facility.

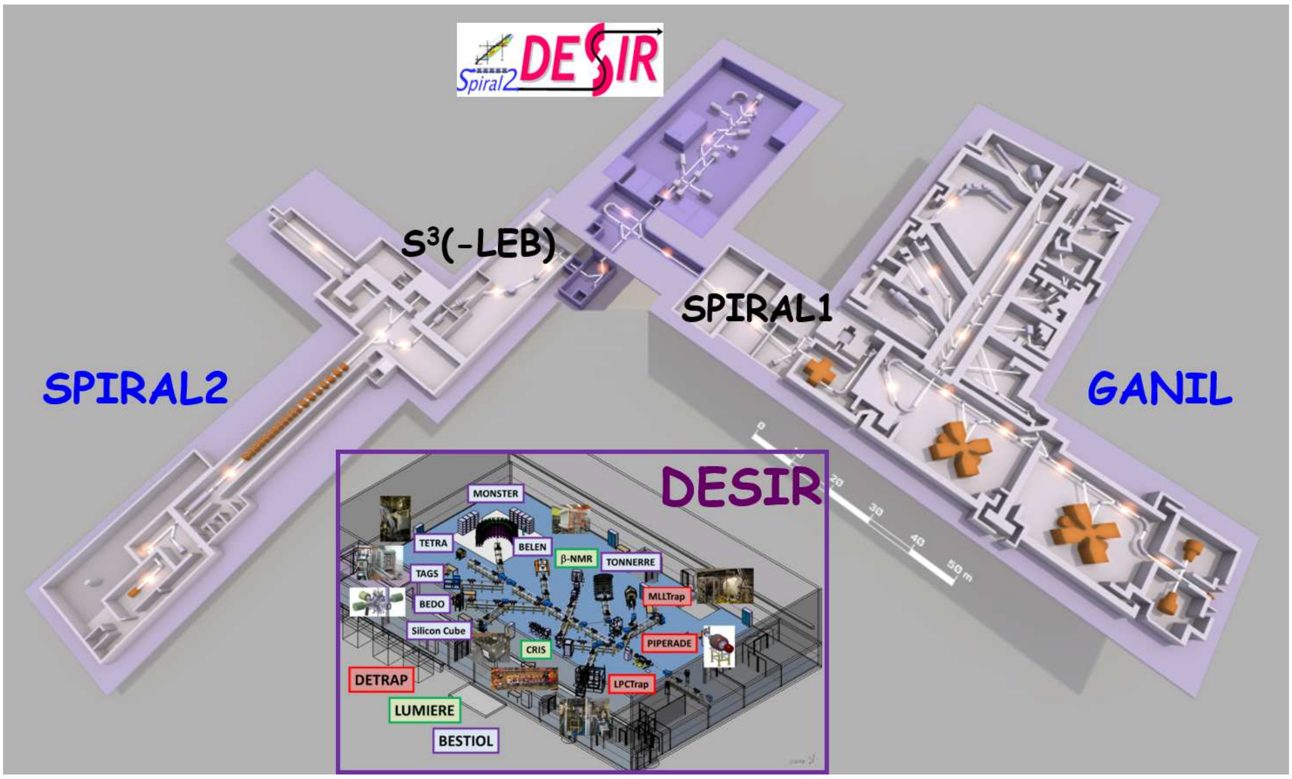
None of the production means of exotic nuclei just laid out is able to produce pure samples as required for most experiments. Even laser ion sources, which ionise selectively certain elements, produce inevitably e.g. alkali elements, which are “surface-ionised”. Therefore, at installations like ISOLDE, certain experiments are not feasible, not because the production rate of the isotope of interest is too small, but because the amount of contamination of unwanted nuclei is so high that it can no longer be handled. This is the reason, why at DESIR a particular emphasis was put on beam quality and purity. The DESIR facility will be equipped with a sequence of three devices to achieve isotopically or even isomerically clean beams. The first stage will be a high-resolution mass separator HRS presently in its commissioning phase at CENBG. This separator, equipped with a high-current RFQ cooler developed at LPC Caen, will have the highest resolution ever achieved with such devices ($m/\Delta m$ > 20000). It will yield an overall modest resolution compared to the following devices, however, the time needed for the separation is just the time of flight through the separator (a few µs). The next step will be a multi-reflection time-of-flight mass separator (MR-TOF-MS), based on the PILGRIM device developed at GANIL for S^3-LEB, which has more than a factor of 10 higher resolving power, but the separation time is much longer (typically 10 ms) and space charge effects limit its loading capabilities. Finally, PIPERADE has not only been designed as a mass spectrometer, but in particular as a mass separator and storage device of large capacitance. Its mass resolving power is increased by about another factor of 10 compared to an MR-TOF-MS, while the separation time increases roughly by the same amount. With the newly developed PI-ICR method even nuclear isomers will be separated if the isomer excitation energy is higher than a few tens keV. Being a double Penning trap, PIPERADE can use its first trap to efficiently separate the isotopes of interest from contaminants and continuously store them in the second trap before sending the accumulated samples to an experiment in the DESIR hall. These different separation devices can be used in a sequence or independently. Together with the state-of-the-art experimental equipment these separation devices will make DESIR a world-class facility, especially once neutron-rich fission fragments become available. SPES at Legnaro has put the emphasis on accelerating fission fragments, while no large-

[2] see contributions about a new A/Q=7 injector for the LINAC in “SPIRAL2 as a radioactive ion beam facility” and in particular in “RFQ injector A/Q = 7 for the production of exotic nuclei using fusion-evaporation and multi-nucleon transfer reactions”

scale low-energy facility is planned. Therefore, when fission fragments will be available, SPIRAL2/DESIR will be unique and complementary to the developments foreseen at SPES.

The DESIR facility will provide all elements needed to efficiently prepare radioactive ion beams (RIB) for their use in an e^- - RIB collider, as proposed in a different contribution [3)]. The separation devices and the cooler and buncher devices (like the GPIB, the General-Purpose Ion Buncher, an RFQ cooler and buncher to be installed at the entrance of the DESIR hall) will allow to send isotopically clean and bunched samples with a very good emittance to such a collider.

To summarise: the future low-energy ISOL facility DESIR will be operational beginning of 2024 at GANIL. A large number of equipment is presently under construction or in the planning phase. A particular emphasis has been put on efficient beam preparation and cleaning, as contamination limits the performances of other facilities. The purification devices, together with state-of-the-art experimental equipment, are probably the strongest assets of the new DESIR facility. However, in terms of production capabilities, the lack of a source of neutron-rich nuclei will strongly hamper the possibilities in terms of nuclear physics, astrophysics and applied nuclear physics research. Therefore, the construction of a powerful fission source is the most urgent request of the DESIR collaboration. We underline in addition that the production of exotic nuclei with SPIRAL1 has to be kept in operation until another facility at GANIL provides similar or higher intensities of light nuclei.



GANIL-SPIRAL2 by 2024 with the new DESIR facility receiving radioactive ion beams at very low energy from the SPIRAL1 and S^3-LEB production sites.

---

[3] see contribution about a possible e^- - RIB collider in "SPIRAL2 as a radioactive ion beam facility"