STATUS OF THE SPIRAL2 PROJECT*

Marek Lewitowicz

on behalf of the SPIRAL2 Project Group and Physics Collaborations

Grand Accélérateur National d'Ions Lourds — GANIL CEA/DSM-CNRS/IN2P3
BP 55027, 14076 Caen Cedex, France

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The SPIRAL2 project at GANIL, one of the ESFRI list and the NuPECC Road Map European research infrastructures, entered recently in the construction phase. In the following, a physics case of the facility, expected performances and main technical parameters of the facility as well as planned new experimental areas and detectors are shortly introduced.

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1. From GANIL/SPIRAL to the SPIRAL2 facility

The GANIL/SPIRAL1 facility [1] (Caen, France) is one of the major Rare (or Radioactive) Ion Beam (RIB) and stable-ion beam facilities for nuclear physics, astrophysics and interdisciplinary research in Europe. Since the beginning of the SPIRAL1 project, it was proposed to enlarge the range of accelerated ions by production of high intensity RIB of fission fragments. This idea, after several years of discussions and an important preliminary study phase was concretized in the SPIRAL2 project [2]. The project is following the European road map for RIB facilities defined by NuPECC (Nuclear Physics European Collaboration Committee), which recommended the construction of two complementary next-generation RIB facilities in Europe: FAIR and EURISOL [4] with SPIRAL2 as an essential intermediate step [3]. The SPIRAL2 facility has entered in its construction phase in 2005 and is supported by the EU FP7 through the Preparatory Phase contract since 2008 (EU contribution of 3.9 MEuros).

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2. Scientific case of SPIRAL2

A complete presentation of the scientific case of the facility, going beyond the scope of this contribution, can be found in the White Book of SPIRAL2, Letters of Intent and Technical Proposals for SPIRAL2 (see Ref. [6]). A major part of the experimental and theoretical research program at the SPIRAL2 facility will be dedicated to nuclear structure and nuclear reaction studies. SPIRAL2 thanks to very high intensities of RIB will give access to a whole range of experiments (from elastic scattering to fusion-evaporation reactions), which are inaccessible with modest intensity beams of first generation RIB facilities. One of the interesting possibilities, which will open with the SPIRAL2 facility is related to the production of a high neutron flux in the energy range from several hundreds of keV up to about 40 MeV. The facility will offer a unique opportunity for material irradiations and cross-section measurements, both for fission-related (notably accelerator driven systems (ADS) and Generation-IV fast reactors) and nuclear fusion-related research.

3. Layout and performances of the SPIRAL2 facility

The SPIRAL2 facility (Fig. 1) is based on a high-power, superconducting linac driver, which will deliver a high-intensity, 40 MeV deuteron beam as well as a variety of heavy-ion beams with mass-to-charge ratio of 3 and energy up to 14.5 MeV/nucleon. A possibility of construction of a second injector for heavy-ions with a mass-to-charge ratio 6–7 is incorporated in the design of facility.

The main RIB production scheme of SPIRAL2 is based on the fast-neutron induced fission of uranium target. Using a carbon converter, a 5 mA deuteron beam and a high-density (up to 11 g/cm^3) 2.3 kg uranium carbide target, the fission is expected to reach a rate of up to 5×10^{13}/s. The intensities of the post-accelerated RIB in the mass range from $A = 60$ to $A = 140$ will be of the order of 10^6 to 10^{10} particles/s (pps) surpassing by one or two order of magnitude existing facilities. Examples of the RIB intensities achievable for the first experiments at SPIRAL2 Phase 2 are shown in Fig. 2 (a full list of the SPIRAL2 beams can be found in [6]). A direct irradiation of the UC_2 target with beams of protons or ^{3,4}He can be used if higher excitation energy leads to higher production rate for a specific nucleus of interest or if much smaller targets with fast release properties are required.

Thanks to the high intensity heavy-ion beams provided by the driver the neutron-rich fission RIB will be complemented by beams of nuclei near the proton drip-line, provided by fusion-evaporation or transfer reactions. The extracted 1+ radioactive ions will be subsequently injected to the $1+/n+$ charge breeder (ECR ion source) and post-accelerated to energies of up to

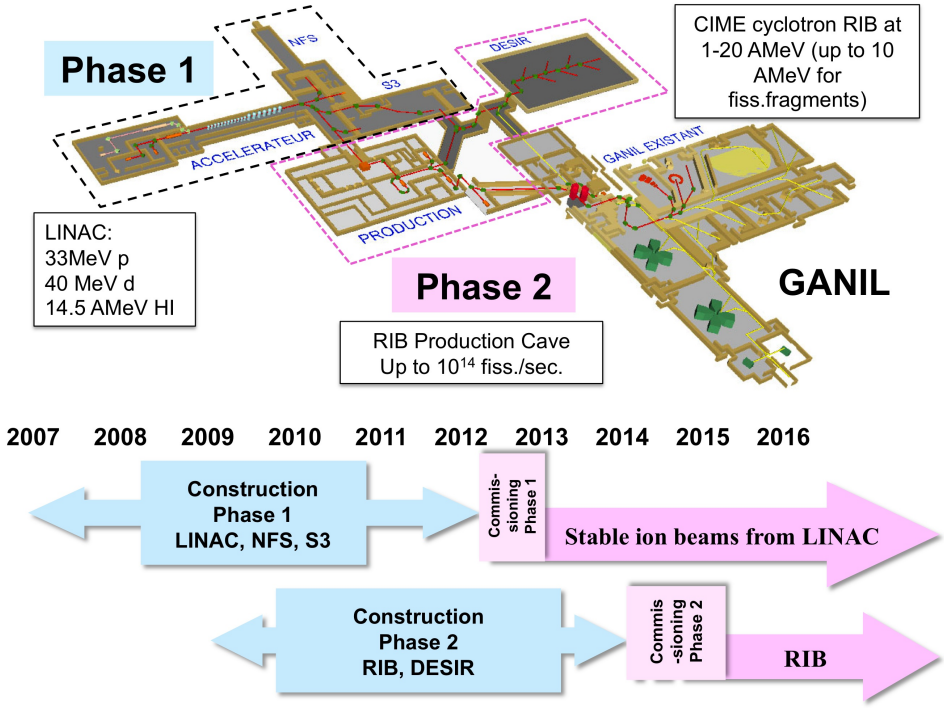

Fig. 1. Upper part: the layout of the SPIRAL2 facility indicating two construction phases. Phase 1 with the LINAC, NFS and S3 experimental halls; Phase2: RIB production building and DESIR experimental hall. The timeline corresponding to the two construction phases is presented in the lower part of the figure.

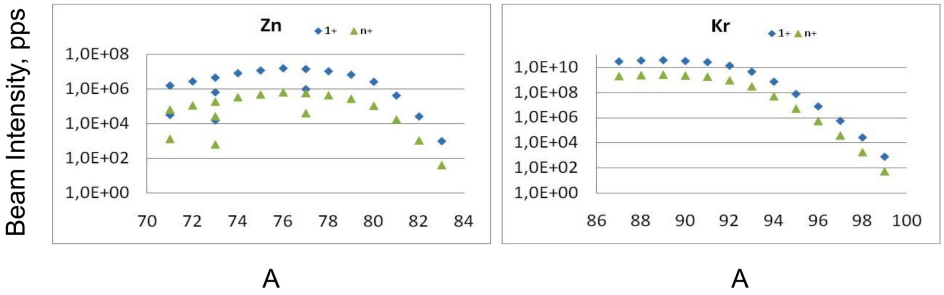

Fig. 2. Examples of post-accelerated (denoted as $n+$) and DESIR (denoted as 1+) RIB of zinc and krypton proposed for SPIRAL2 Phase 2 Day 1 experiments. Note: the nominal SPIRAL2 RIB intensities will reach intensities about 15 times higher than those presented in the figure.

20 MeV/nucleon (up to 7–8 MeV/nucleon for fission fragments) by the existing CIME cyclotron. Thus, using several different production mechanisms and techniques, SPIRAL2 would allow users to perform experiments with a wide range of neutron- and proton-rich nuclei far from the line of stability. The future GANIL/SPIRAL1/SPIRAL2 facility will deliver up to five stable or radioactive beams to different users simultaneously in the energy range from keV to several tens of MeV/nucleon. A civil construction of SPIRAL2 is divided into two phases (Fig. 1). The first one (LINAC buildings and associated experimental AEL, see below) begun end of 2010 with a goal to provide first stable-ion beams in 2013. The second phase (RIB production building and DESIR facility) is aiming for the beginning of operation in 2015. The construction of LINAC is already well advanced with, in particular, the manufacturing and tests of super-conducting cavities, ion sources and beam-line components already successfully accomplished.

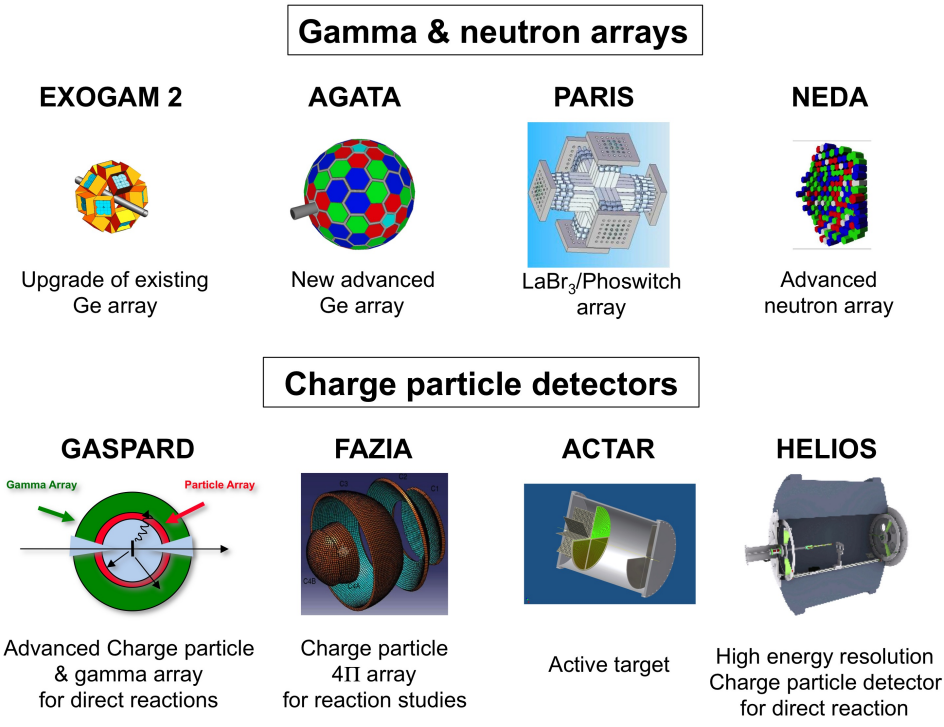

Fig. 3. New detectors to be used at SPIRAL2. Upper part: gamma and neutron arrays, lower part charge particles arrays and detectors. The GASPARD array combine high-efficiency detections of charge particles and gamma rays which might be achieved using PARIS, EXOGAM2 and AGATA arrays in particular.

4. New experimental areas and new detectors for SPIRAL2

The SPIRAL2 project contains two new experimental areas. One dedicated to the experiments with high intensity stable beams delivered by linac (Aires Experimentale du LINAC — AEL) containing Neutrons For Science hall and S3 (Super Separator Spectrometer) hall and one devoted to research program with low energy RIB called DESIR (Decay, Excitation and Storage of Radioactive Ions). A set of existing detection systems at GANIL such as the magnetic spectrometer VAMOS, the 4Π gamma-array EXOGAM/EXOGAM2 and AGATA as well as charged particle detectors like MAYA, MUST 2 and TIARA will be enriched by new and innovative detection systems (ACTAR, FAZIA, GASPARD, PARIS, HELIOS). Several existing detection systems and the existing experimental area will be adapted to take a full benefit of the high intensity (up to 10^{11} pps) RIB [6].

5. Conclusions

The SPIRAL2 construction cost (without detectors) of 200 MEuros is shared by the French funding agencies CNRS/IN2P3 and CEA/DSM, the regional authorities of Basse-Normandie and international partners. Following recommendations of ESFRI [5], the baseline project as well as new dedicated detectors are supported the EU FP7 through the Preparatory Phase contract. The civil construction of the SPIRAL2 Phase 1 begun in the end of 2010. The construction of the driver accelerator is close to be completed. The detailed definition of the RIB production building, of the experimental areas and of the dedicated detectors is entering in the detailed phase. The first beams are expected to be delivered by SPIRAL2 in 2013. The full GANIL/SPIRAL1/SPIRAL2 facility will serve a community of about 700–800 users.

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