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GANIL and the SPIRAL2 project

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Abstract. Based on a multibeam high intensity driver (5 mA of deuterons, 1 mA of heavy ions) a detailed project study for Spiral2 was started in November 2002 in a large collaboration. Fission rates of up to 10^{13}/s will be possible with standard density UC ($2.3\,\mathrm{g/cm^3}$), and up to 10^{14}/s with high density ($11\,\mathrm{g/cm^3}$) UC. Fission may be induced either by neutrons from a converter, or with direct beams. The multibeam driver will allow other high intensity beams, with energies up to 14 MeV/nucleon for $A/Q = 3$. The radioactive ions will be accelerated by the existing CIME cyclotron, with energies of 1.7–25 MeV/nucleon.

PACS. 29.17.+w Electrostatic, collective, and linear accelerators – 29.25.-t Particle sources and targets

Based on the LINAG (LINear Accelerator at GANIL) Phase 1 conceptual design [1,2] and the European RTD (Research for Technical Development) program [3], a two years detailed design study of a facility for the production of high intensity secondary beams, mainly by the ISOL method, named SPIRAL2, was started in November 2002 in a large collaboration. The multibeam driver will allow various production modes to reach various regions of the nuclear chart (see fig. 1). Radioactive isotope beams can be produced via the fission process, with the aim of 10^{13} fissions/s, induced in a UC_x target by fast neutrons from a C converter [4] using a 5 mA deuteron beam of 40 MeV. With the use of high density UC_x ($11\,\mathrm{g/cm^3}$) the fission rate can reach 10^{14}/s. In this case the fission products are coming from ^{239}U at an excitation energy of about 25 MeV, that is optimal for the production of neutron-rich nuclei in the main fission bumps (region 1 of fig. 1). Higher excitation energy fission products that populate a much broader range, including region 4 on the chart can be obtained by direct bombardment of a fissile target with a heavier beam, such as He, Li, C, ... The driver is made of the following main elements: the primary beam is produced in high-performance ECR sources, and accelerated by a RFQ cavity and independent phase superconducting resonators. Energies up to 14.5 MeV/nucleon and intensities of 1 mA will be possible for $A/Q = 3$, with present technologies up to Ar-Ca. Further upgrade will be possible.

The recently commissioned cyclotron CIME will perform the post acceleration in the SPIRAL2 project. It allows acceleration of heavy ions in the energy range of 1.7 MeV/nucleon up to 25 MeV/nucleon, depending on the A/Q. For fission fragments and with present performances of an ECR charge booster, optimal energies would be of the order of 8 MeV/nucleon. Yield calculations of fission fragments (see, *e.g.*, [5] and references cited) with the Monte Carlo codes (LAHET + MCNP + CINDER, see references in [5]) for a 5 mA deuteron beam of 40 MeV energy in a carbon converter, followed by a UC_x target have been performed. The expected radioactive beam intensities (after diffusion, effusion, ionisation and acceleration) are for some examples: ^{78}Zn, $8 \cdot 10^6$/s; ^{91}Kr, $8 \cdot 10^{10}$/s; ^{94}Sr, 10^{10}/s; ^{123}Cd, 10^9/s; ^{132}Sn, $3 \cdot 10^9$/s; ^{140}Xe, $8 \cdot 10^{10}$/s. The in target production yields are those calculated using the $11\,\mathrm{g/cm^3}$ UC_2. The Arrhenius coefficients used in

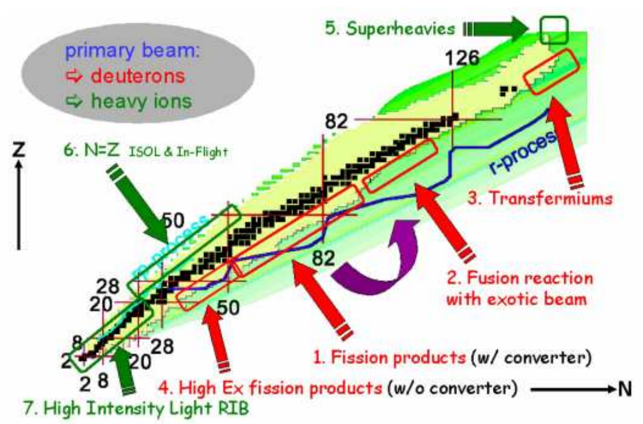

Fig. 1. The different domains on the nuclear chart covered by the SPIRAL2 project (see text).

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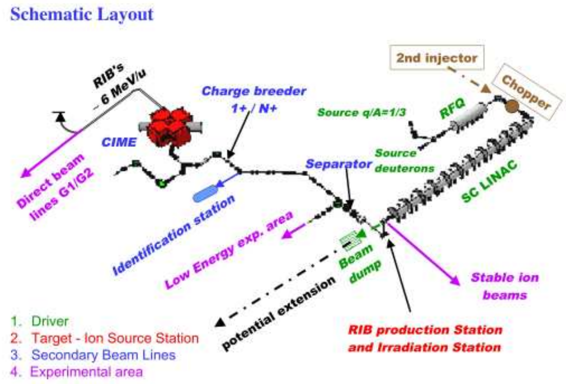

Fig. 2. General layout of the SPIRAL2-project. Ions coming either from a deuteron ion source, or a high performance heavy ion source are first bunched and accelerated up to 0.75 MeV/nucleon in a room temperature RFQ. The superconducting Linac accelerates up to 40 MeV for deuterons, or 14 MeV/nucleon for $A/Q = 3$. The beams may be used directly, or in a RIB-ISOL production station. After selection, the ISOL beams can be used at TIS-energy and, simultaneously, can be re-accelerated by the existing CIME cyclotron.

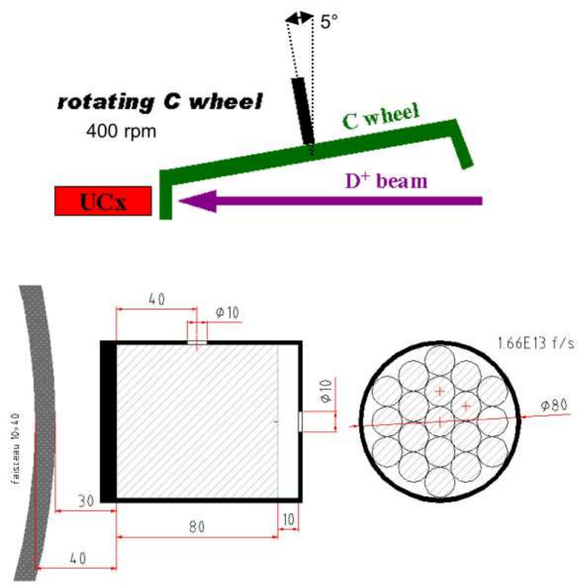

Fig. 3. Scheme for the deuteron-to-neutron converter and the fission product target. In the upper part a general view of the system is shown, in the lower part a front and side view of the UC_x container is shown, with dimensions in mm.

this calculation were supposed to be the same as for C and Ta, both tabulated in the literature. The assumed 1+ and 1+/N+ ionisation efficiencies are adopted as 90% (1+) and 12% (1+/N+) for Kr and Xe, 30% (1+) and 4% (1+/N+) for Zn, Sr, Sn, I and Cd. The assumed acceleration efficiency in the CIME cyclotron is 50%. The

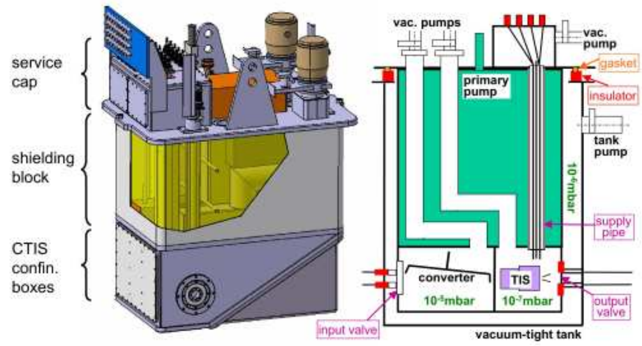

Fig. 4. Scheme of the plug system for the converter and the TIS (Target Ion Source) for fission products.

region $N = Z$ (region 6 on fig. 1) will be accessible via the fusion-evaporation process, using the high intensity heavy ion beams of the LINAG. Light radioactive nuclei (region 7) can be produced using either neutron induced reactions or appropriate light heavy ion induced reactions. It was estimated that 10^{13}/s of ^{6}He can be produced. Regions 2, 3 and 5 will come in reach using fusion evaporation reactions induced by secondary beams. The general scheme of the project is shown on fig. 2. The target ion-source system must be carefully optimized to achieve the highest possible production rates for the secondary beams, together with a long lifetime for all components in the highly radioactive environment. The scheme of the converter and the target is shown on fig. 3.

The high radioactivity that will result from the neutrons from the converter and the fission products, needs a very careful design for handling all parts in a safe way, acceptable with present safety rules. A design similar to the plug system at TRIUMF-ISAC was adopted. It is shown schematically on fig. 4.

The green light for the construction is expected by mid-2005 from French funding agencies.

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