SECONDARY BEAM OVERVIEW AND LOW CURRENT MEASUREMENTS OF SPIRAL1 AND SPIRAL2 FACILITY

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Abstract

Since 2001, radioactive beams have been accelerated in the CIME cyclotron of the SPIRAL facility at GANIL. In order to tune low intensity and low energy beams in the transport line, low current measurements and an identification stations have been used.

For the new project SPIRAL2, the production of high intensity radioactive beams will be based on fission of uranium target induced by neutrons.

These exotic particles will be produced, ionized, selected in a dedicated production building and transported to the existing CIME cyclotron for post-acceleration.

The beam diagnostics, required for the production facility allow a pre-tuning with a stable beam followed by an extrapolation of the tuning to the radioactive beam. Some diagnostic devices may also be used for equipment protections and for the safety systems.

This proceeding describes the present secondary beam diagnostics in the SPIRAL1 facility and the future secondary beams diagnostics foreseen by the SPIRAL2 project. These low current, low energy beams are/will be produced by the ISOL Method.

GANIL ACCELERATOR

GANIL which means "Great National Accelerator of Heavy Ions" is located in the town of CAEN, France. The complete accelerator installation is composed by five cyclotrons. Two ion sources and two compact cyclotrons produce and accelerate two ion beams at an energy around 1MeV/A for the lightest beam. One of the two beams is accelerated by two separated sector cyclotrons up to 95 MeV/A. The facility delivers a wide spectrum of high intensity ion beams ranging from ^{12}C to ^{238}U.

The primary beam at the exit of SSC2 can be sent directly through an alpha spectrometer toward experimental rooms. This beam can also be driven, since 2001, in the SPIRAL1 facility to produce secondary radioactive beams.

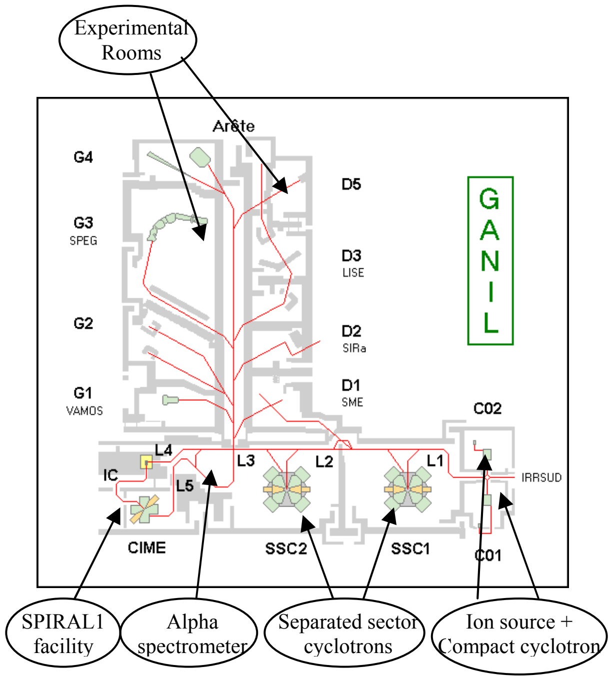

Figure 1: GANIL Accelerator Layout

SPIRAL1 FACILITY

The primary beam from SSC2 with a current up to 15µA, is driven trough the HEBT line on a thick carbon target.

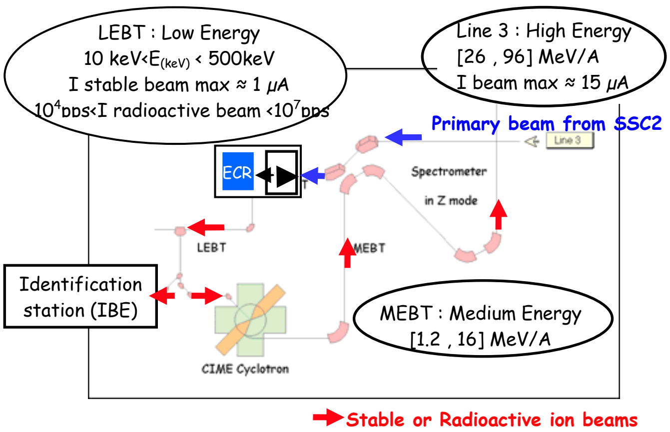

Figure 2: SPIRAL1 Layout

The production of atoms is done by projectile collisions on a thick carbon target. Then atoms are ionized by an ECR ion source.

The stable beams at the source exit have an intensity value up to 1µA. The radioactive beam intensity is included between 10^4 pps and 10^7 pps.

Radioactive beams can be driven either in an Identification station either in the CIME cyclotron. The energy range available, at the exit of CIME, goes from 1.2 MeV/A to 25 MeV/A.

SPIRAL1 TUNING

Tunings are done by three stages.

1 Tuning with a stable beam

The initial tuning of LEBT, CIME and MEBT is realised with a stable beam delivered by the ion source. (Allow the use of classic diagnostics)

2 Shift of electrical and magnetic fields

Electrical and magnetic values are changed by a factor depending of the ratio Q/M of stable ions and Q/M of radioactive ions. The frequency or the magnetic field is shifted in the CIME cyclotron.

3 Controls of the radioactive beam

The radioactive beams are controlled by:

- Germanium detector in the LEBT (Identification Station)
- Silicon detectors in the CIME cyclotron
- Gas profilers in the MEBT

LEBT DIAGNOSTICS

1 Beam current measurements

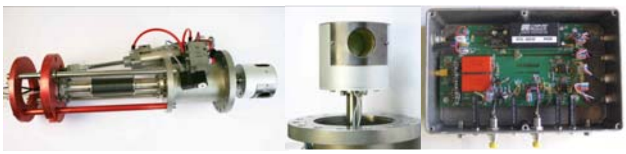

Figure 3: Faraday Cup & Logarithmic Converter

Faraday cups and logarithmic converters are designed for low beam current measurement. The intensity range is included between 10^7 to 10^{14} pps in correspondence to around 1pAe to 1mAe.

The principle of a logarithmic converter is to give a proportional voltage to the logarithm of the current. In the SPIRAL case, the voltage is equal to zero for a current of 10 nAe and two volts correspond to a factor of ten on the input current.

$$V = 2\log\frac{I}{I_0} \qquad \text{With } I_0=10\text{nAe}$$

Faraday cups with log. electronics are easy to use without gain switch but the sensitivity is limited by the reverse current in diodes and Ibias influence of amplifier.

2 Beam Profile measurements

(See the DITANET proceeding of J.L. Vignet)

3 Radioactive beam diagnostics

An identification station characterises the radioactive ions. In the vacuum chamber, a faraday cup, a plastic detector and a silicon detector are installed or can be installed and behind the chamber a germanium detector is available to measure gamma rays.

Ions can also be implanted onto a tape and be transported to the front of a remote germanium detector. This system gives the possibility to count gamma ray for long life radioactive ions with a germanium detector.

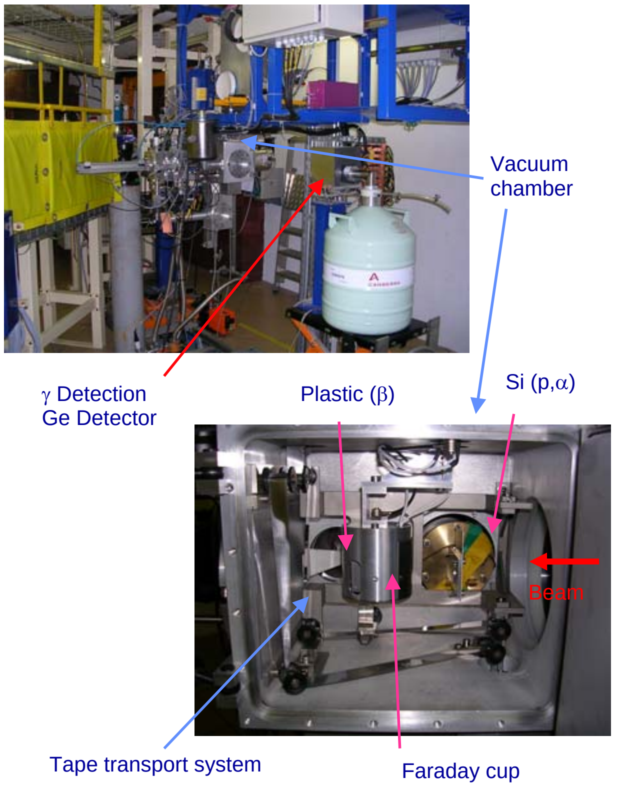

Figure 4: IBE setup

These detectors are used by physicists during dedicated studies. In general, the germanium detector is only used for the beam counting. In this case, the beam is stopped and gamma rays produce by the radioactive ions are detected by a Germanium detector.

$$I_{beam} = \frac{Disintegration\_number}{Efficiency}$$

The beam current is proportional to the disintegration number and the efficiency. An estimation of the beam current can be done.

This station enables to identify radioactive species and estimate the number of ions but with a complicated use.

SPIRAL2 PROJECT

The SPIRAL2 project consists in building a new facility near the GANIL accelerator in order to produce new exotic beams in the GANIL experimental rooms.

The accelerator is divided in 3 main parts, an injector, a superconducting linac and a high energy line. The injector part is composed of a deuteron/proton line, an ion line (LEBT), a RFQ and a MEBT line. Two kinds of superconductivity cavity are used for the Linac (β=0.07,

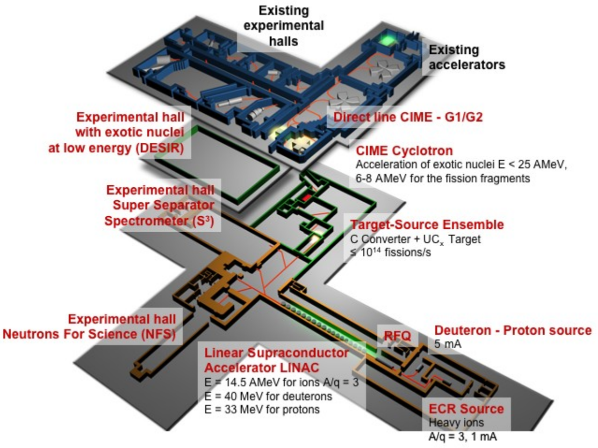

Figure 5: SPIRAL2 layout

The beam energy will be up to 14.5MeV/A for ions, 40MeV for deuterons and 33 MeV for protons. The beam intensity is foreseen to be up to 1mA for ion beams and 5 mA for deuteron beams. At the Linac exit, the beam could be sent in experimental halls NFS and S3.The third possibility will be to drive the deuteron beam in a target source system to produce radioactive beams.

RADIOACTIVE BEAM SECTION

The primary beam arrives on a carbon wheel in which the deuterons are broken. The neutrons, without electric charge, go through the converter and produce radioactive atoms by fission of an uranium carbide target.

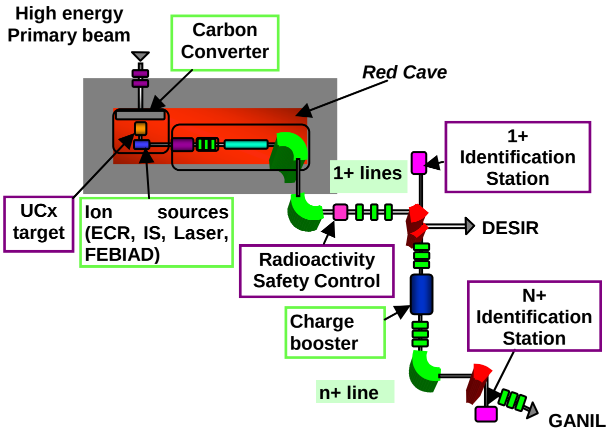

Figure 6: RNB general scheme

Mono-charged secondary beams are selected in the 1+ beam line, used for low energy experiment or multi ionized to be post accelerated in the existing Ganil.

The red cave is an unauthorized area where all interventions will be done by remote controls with robots. A safety system has to control the beam radioactivity at the exit of the red cave.

TUNING AND CONTROL METHODS

The tuning principle of the SPIRAL2 beams consists in a pre-tuning with a stable beam, followed by an extrapolation to the radioactive beam (SPIRAL1 method).

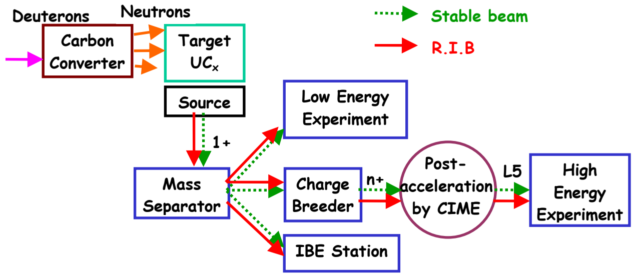

Figure 7: Stable beam tuning and R.I.B. tuning

The radioactive beams will be controlled at special points and indentified in identification stations.

BEAM CURRENT MEASUREMENTS

A new electronic device will be needed to measure low beam currents. The choice is to use linear I/V converters with different gains for measuring current under 0.1 pA.

- Two I/V converters will be tested in 2010:
  A new commercial I/V: FEMTO DDPCA-300
  Very High Dynamic Range: Sub-fA to 1 mA
  Transimpedance Gain Switchable from 10^4 to 10^{13} V/A
- A GANIL I/V prototype with the amplifier LMP7721. The typical input bias current is 3fA

R.I.B. CONTROL

The R.I.B (Radioactive Ion Beams) control is foreseen with the use of devices containing implantation foil and semiconductors to measure the beam radioactivity (gamma radiation) and control the transmission in the beam lines.

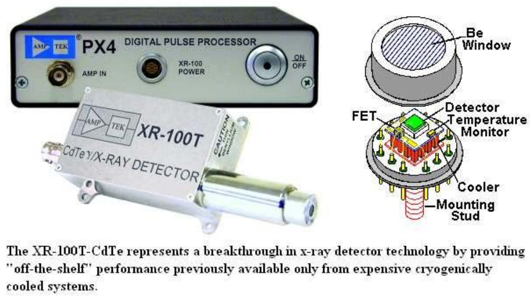

Figure 8: CdTe detector

This CdTe detector is under development at Ganil (resolution: 0.8 % FWHM at 662 keV).

IDENTIFICATION STATIONS

The goal of the Identification Stations will be:

- to identify the radioactive ions by their characteristic radioactive decay
- to measure the intensity of the nucleus of interest and the contaminants
- to enable an optimization/tuning of the target-ion source and the charge-breeder system

The developments and realisations will be done by the LPC Laboratory from CAEN.

RADIOACTIVITY SAFETY CONTROL

An intensity control of the continuous radioactive beam is necessary in a range of 10^9 to 10^{13}pps (100pAe to 1µAe) at the exit of the red production cave.

This control must ensure that the radioactivity and the associated contamination never reach a maximum rate in the production building and Ganil.

Beam intensity measurement is a possibility, three solutions are studied, and each one requires a beam modulation.

Beam Current Transformer

The best measurement resolutions at GANIL with these sensors are of the order of nAe ($\approx 10^{10}$ pps). The minimum threshold value is fixed ten times bigger than the resolution ($\approx 10^{11}$ pps). This resolution can't respond for the safety control needs.

Pick-Up

The modulated beam produces pick-up signal amplitudes proportional to the beam intensity.

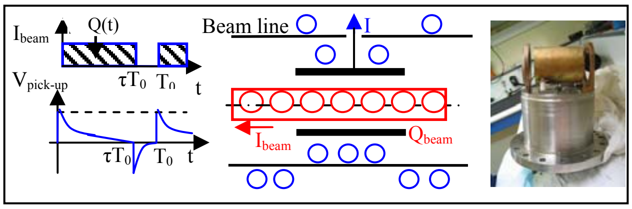

Figure 9: Views of the GANIL pick-up.

$$|Q_{\text{pick-up}}| = |Q_{\text{beam inside the pick-up}}| = I_{\text{beam}} * \text{time}_{\text{inside the pick-up}}$$

The beam charge inside the pick-up is equal to the product of the beam intensity by the time done to go through the pick-up.

$$V_{pick-up} = \frac{Q_{pick-up}}{C} = \frac{1}{C}.I_{beam}.\frac{L}{v}$$

L: Pick-up length
v: beam velocity

Measurements were done with a preamplifier and a lock-in amplifier Stanford Research SR830 at a frequency around 10kHz.

The best measurement resolutions for these sensors at low energy (20keV) are of the order of 10nAe ($\approx 10^{11}$pps). A threshold value under $\approx 10^{12}$ pps can't be guaranteed.

Faraday Cup Associated With a Fast Electro-static Deflector

A device equipped with an electrostatic deflector and a low intensity Faraday cup enables to measure a part of the beam current. This electrostatic deflector could deflect, for example, at a frequency of 1kHz, with a useful ratio for measurement of 5 %, leaving 95 % of the continuous beam for the users (Fig. 10).

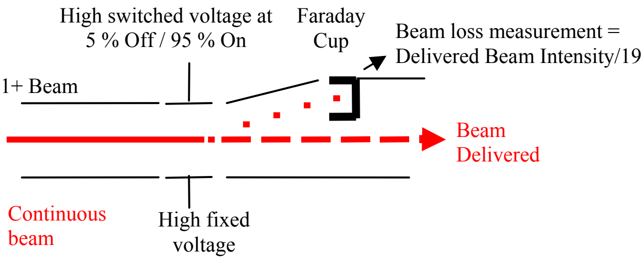

Figure 10: Faraday cup associated with a fast electrostatic deflector.

In this case, a Faraday cup resolution of 1 pAe, by guaranteeing the "deflector" function, provides an indirect resolution of 20 pAe on the beam users. This device could control and guaranty in all circumstances a user beam threshold of about 200 pAe ($2*10^9$ pps). This solution gives a sufficient sensitivity.

CONCLUSION

The feedback of the GANIL and SPIRAL1 operation contributes to define the beam tuning methods and to design diagnostics.

However, all diagnostics in the RIB facility will have to operate in a new and strong nuclear environment. Diagnostics will have to be simple, robust, and reliable.

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