Diagnostic System Dedicated to the Radioactive Ion Beams at the SPIRAL Facility

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In order to be able to tune the CIME cyclotron and the associated beam lines with the radioactive ion beams, dedicated diagnostic sytems have been built. This equipment will be described in details. The first tests with reduced intensity stable beams will also be reported.

1 Introduction

The SPIRAL Radioactive Ion Beam (R.I.B.) Facility has already been described elsewhere [1]: it is designed to postaccelerate through a K265 isochronous cyclotron the R.I.B.'s which are produced by the ISOL method, in a target hit by the present GANIL beam, boosted in intensity [2]. The R.I.B.'s will be accelerated in a wide range of energy (2. to 25. MeV/A) and intensity (from a few pps up to 5.10^8 pps).

The cyclotron and beam lines will be pretuned with a known stable beam, and a shift of frequency and/or magnetic field applied [3] for the R.I.B. Diagnostics working with normal stable beams are implemented [4], but nevertheless a possibility of checking the correct tuning with dedicated diagnostics has been felt necessary. This sytems will be described as well as the results of preliminary tests with reduced intensity stable beams.

The current measurement electronics has been made sensitive (down to a few pA): it is based on a logarithmic amplifier [5].

2 Low energy Beam Line

As the mass selection in the injection line [1] is rather moderate (R=200), the beams out of the target will not be enough separated. It is then of limited interest to implement dedicated diagnostics systems unless the radioactive ions are detected through their radioactive decay: this is the reason why a identification station, based on measurement of radioactive properties, is being installed in the beam line: the beam can be directed towards it with a switchyard. This station is described in details elsewhere [6] and will be extremely useful in measuring the production rate of the R.I.B.'s (the one of interest as well as the others) prior to the acceleration.

3 Cyclotron

It is important to tune the isochronism of the cyclotron for the desired radioactive specie, this is why the cyclotron will be equipped with two radial probes:

- a normal intensity one, but equipped with a retractable plastic scintillator, in the valley between the two parts of the electrostatic deflector [4],
- a dedicated one, in a hill, with silicon detectors and associated preamplifiers.

It should be pointed out that both probes are equipped with a vacuum lock and carry a NMR probe for precise mesurement of the magnetic field and control when a shift of magnetic field is made.

The purpose of the scintillator is the measurement of the phase and the phase width of the beam(s), the plastic scintillator being rather robust and, if the intensity is sufficiently reduced, one can insert the Si, for identification ($E.\Delta E$), energy and energy dispersion measurement. If the scintillator can withstand without damage (and still counts) rates up to 10^6 pps, the maximum rate accepted by the encoders being a few 10^4 pps, the phase measurement is limited to that rate. However the maximum rate the silicon detector can accept is 10^3 pps, so that caution is mandatory for its use.

As far as the scintillator is concerned, the light is transmitted to a photomultiplier located outside the magnetic field through a liquid optical fiber. Experiments using the GANIL CSS2 have been performed with this set up [7] and demonstrated the usefulness and capability of such a device, but also that the required minimum of energy to trigger the electronics is around 1 to 2 MeV/A, according to the mass. Also mass measurements with CSS2 has also demonstrated the diagnostics power of silicon detectors inside a cyclotron [8].

4 Medium Energy Beam Line

Different low intensity diagnostics equipments will be implemented at different locations of the line:

- ionization chambers [9] for profile measurements, the working intensity of these devices ranges from 10^2 up to 10^7 pps, intensity where the secondary emission profile monitors are effective. Those ionization chambers are very rugged and the same electronics as for the SEM profile monitor are used,
- scintillators, on a 3-position actuator, so that if the scintillator gets accidentely burnt, it is moved to the next position for the beam to hit new scintillating material,
- Si detectors ($E.\Delta E$) for the correct tuning of the Alpha spectrometer, particularly in case of separation of isobars, by energy loss in a thick target.

Diagnostics boxes, with a silicon detector, a scintillator and an ionization chambers will be located just at the exit of the cyclotron and right after the Alpha spectrometer, while an ionization chamber will be, in addition, at the object point of the spectrometer.

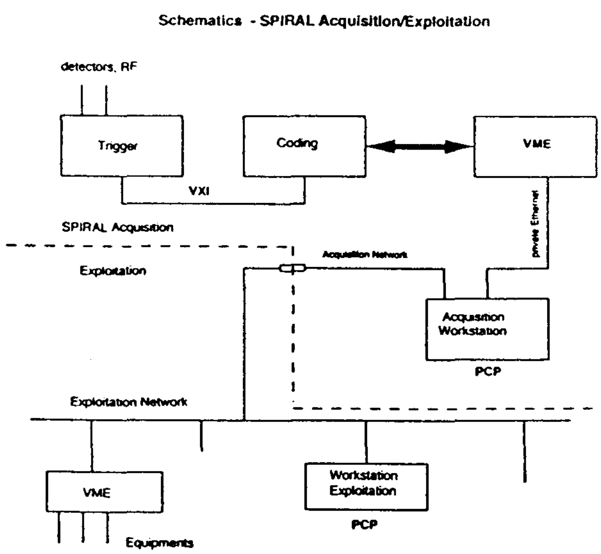

Figure 1: Principles of Acquisition

5 Acquisition

To be able to use these diagnostics which are in fact standard nuclear detectors, we have chosen to take advantage of the GANIL experience on data acquisition and treatment [10]. All the detectors will be hooked to a common acquisition. The principle is shown on figure 1. We will be able for the final version to use the new generation of trigger that the GANIL Acquisition Group is developing. But as the data should be used to tune cyclotron and beam lines, ways of communication have to be established between the acquisition world and the standard Control System of SPIRAL. For example, data on phase measurements have to be extracted from the spectra given by the detectors and transmitted to the automatic isochronism tuning task which normally takes the data from the phase probes. In addition, the position of each radial probe must be correlated on a real time basis: the position is digitized when a particle triggers the electronics. Data may be taken "on the fly" or step-by-step in order to adjust to the particle flux. The "START" signal is given by triggered event on the detector and the "STOP" by the RF.

6 Stable Beam Tests

For the tests, a limited version of the acquisition is set up, with CAMAC and VME crates for the control and digital conversion. The following detectors only have been installed:

- scintillator on the valley radial probe, a fast plastic scintillator BC418 from Eurisys, ϕ 15 mm, the width seen by the beam being 14 mm,
- silicon detector on the hill radial probe. We will use a 300 μm thick, 15x15 mm^2 detector from Eurisys, with only 0.5 mm of dead area on one side, because of the small turn separation,
- right at the exit of the cyclotron, a 300 μm thick, ϕ 11 mm Si detector mounted on an actuator, also from Eurisys.

The beam intensity is reduced by a pepperpot (1/10 000) and by closing the slits at the object point of the Low Energy beam line selecting magnet. The high sensitivity of the current measurement allows the secure setting of this low intensity: beams of, say, 10 pA are obtained on the radial probe by closing the slits, and hence inserting the pepperpot puts the final intensity well below the lethal rate for the scintillator. Counting on the scintillator is then a way to control the insertion of the silicon detector.

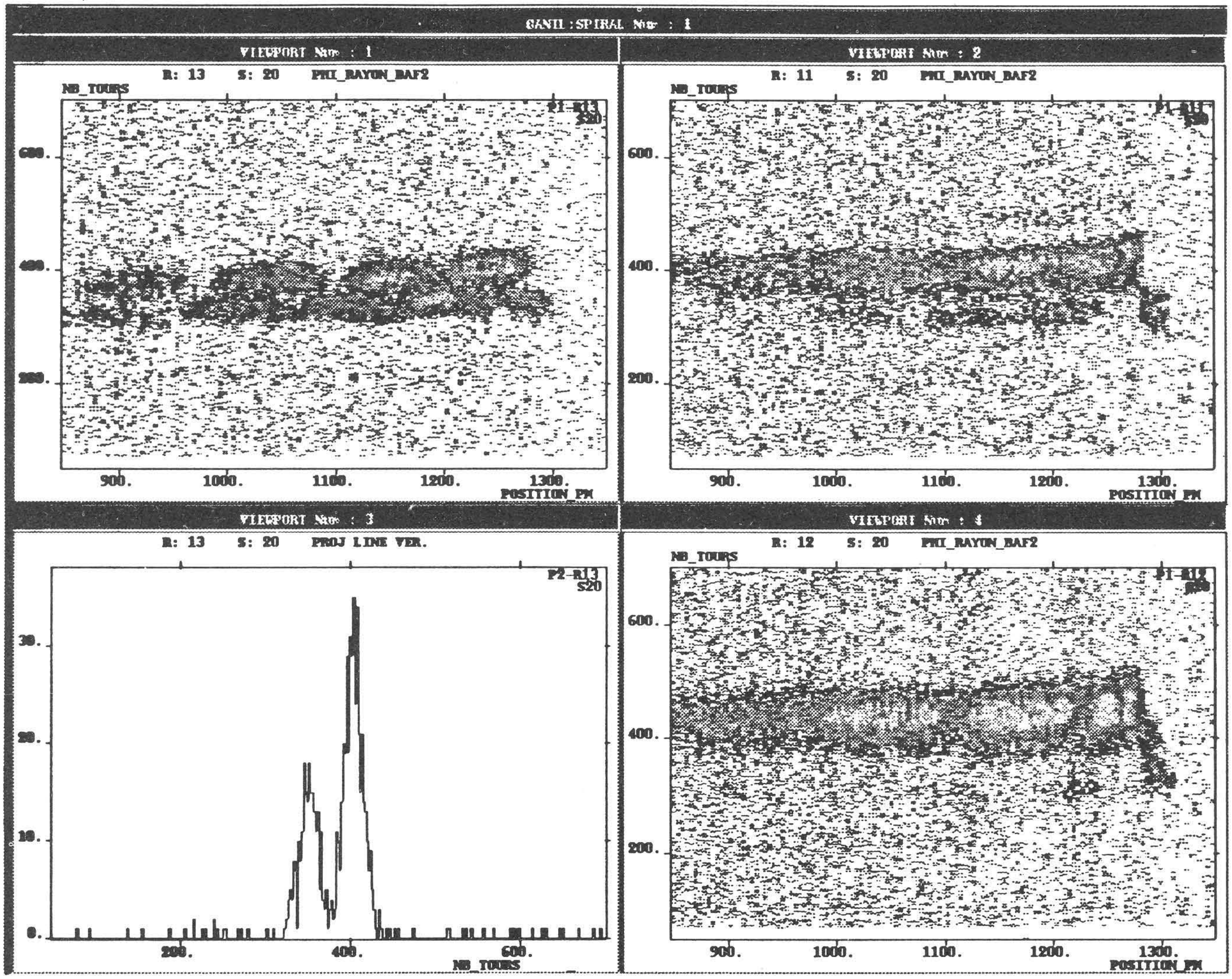

Figure 2: Examples of spectra obtained by scanning the radial probe. The total phase width of the beam is around 25°. These spectra were taken for different RF voltages. At the lower left corner, an example of a projection in the top left spectrum, is shown. The display of such a slice is possible at any probe location.

6.1 Scintillator tests

The intensity has been reduced as described and the phase and phase extension has been measured with the $^{18}_{8}O^{4+}$ beam (around 11 MeV/amu at extraction). Examples of spectra are shown on figure 2. It allowed a better insight on what was happening during the beam loss[11], in particular showing that the beam was perfectly isochronous. The background was very high because of a poor light transmission, due a loose contact between the scintillator and the light guide, that will be fixed.

6.2 Silicon detector tests

A silicon detector, sensitive to the vertical position has been mounted. Unfortunately, it was partially damaged, because it was too close to the circulating beam. In particular the energy measurement was not reliable. When the beam tests will restart, a new detector will be installed and better protected from the normal intensity beam. However, current measurement (counting) and vertical sensitivity could be used to help diagnose the CIME beam loss prior to extraction [11].

7 Conclusion

SPIRAL will be equipped with detectors allowing the fine tuning of both the cyclotron and the beam lines, from intensity ranging from a few pps up to the normal intensity. The stable beam allowed us to test most of the diagnostic systems and procedures that will be used for the radioactive ion beams, with the exception of the identification station, that needs to await the R.I.B.'s. Production and acceleration of R.I.B.'s are expected during the first semester of 99. Nevertheless the stable beam tests must continue to improve the operation (and the protection) of the diagnostics, in particular, more work has to be done to extract the right information from the spectra in order to tune the cyclotron in an userfriendly way. These detectors provide detailed information about the beam properties and, since they are available, can be used with stable beams, but with a dependable intensity reduction, i. e. using pepperpots and not by emittance limitation through slits.

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