# Measuring beam losses in the THI project

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**Abstract**

The goal of the THI project (High Intensity Transport) is to upgrade the GANIL facilities by increasing the beam by a factor of 15, at least for light ions.

So the actual $10^{11}$ pps will be boosted to $2.10^{13}$ pps to get 6 kilowatts heavy ion beams at 95 Mev/nucleon.

This higher intensity is required by the radioactive beam facility SPIRAL starting in September 1997, to generate the new nuclear species in the solid target-source (ISOL method).

For the control system, the most important issues are now to tune the accelerators while minimizing the beam losses at each stage of acceleration and when not possible, to have a fast beam loss detection signal.

This system is composed of probes which deliver a signal to stop the beam when there too much intensity lost and when not, a logarithmic value of the beam intensity.

These probes are linked to a front end VME crate on the network, and in the control room, on the workstations, a graphical user interface program displays the beam variations using logarithmic scales.

This program is also used to center the beam while injecting in or ejecting from the main cyclotrons by tuning the steerers, the magnetic elements inside, and the electrostatic deflector to be able to separate and extract the last beam turn.

## 1 Introduction

The THI project consists in upgrading the GANIL facilities, while increasing the beam intensity by a factor around 15, at least for the light ions species up to argon [1].

As an example, an Ar 36 beam now of 7.3 $10^{11}$ pps will become 1.1 $10^{13}$ pps to deliver 6 kilowatts at the output of the second Sector Separated Cyclotron SSC2 with an energy of 95 Mev/Nucleon.

This new intensity is necessary for the SPIRAL project which is the Radioactive Ion Beam facility under construction at Ganil [2] following the ISOL production method. The aim is there to create a sufficient number of exotic nuclei as the production rate in the SPIRAL target/source assembly ranges from 1/10000 to 1/1000000.

The SISSI device which already produces radioactive ion beams using the projectile fragmentation method will also take benefit of the THI project.

The control system must be able to tune the beam while minimizing as much as possible the beam losses at every tuning phase, specially in the Separated Sector Cyclotrons. When these losses happen anyway, the beam has to be stopped very quickly, to protect the vacuum chambers or the beam lines pipes called L2 and L3.

Indeed, for the Ar 36 beam at 95 Mev/Nucleon, the beam power will be 1 kilowatts in the L2 line and 6 kilowatts in the L3 line. Focused on one $cm^2$ of no-cooled stainless steel, this one will reach his fusion point in 120 ms in the L2 line and 40 ms in the L3 line.

## 2 Acquisition electronic

The sensors to be installed for the THI project must cope with two needs. First, they have to deliver a signal proportional to the beam losses and also they have to send a fast response when the beam exceeds predefined thresholds (Survey mode).

### *2.1 The probes [3]*

Before the High Intensity Transport, no diagnostics were used in the beam lines because the beam losses had no consequence on the stainless steel pipes. For this new project, the probes could have been ionization chambers or isolated shields.

The ionization chambers could take advantage on being disposed outside the insertion devices but were not sensible enough at the L2 energy and were too much reactive on radioactivity (   rays) around the SISSI device.

So we decided to use the shields which were already installed to protect the micro-channel profilers.

In the Separated Sectors Cyclotrons, the probes are the same as those previously existing to measure the injection or ejection beam. But the electronic acquisition system had been modified to generate a logarithmic value from the input signal, in such a way to have a better range.

The intensity transformers, already used, have also been connected to this logarithmic electronic system with enough dynamic range to measure both a "standard" ion beam or a "high intensity" one.

### *2.2 The survey mode*

Along the transport lines, the shields are mainly used for threshold detection. If the beam loss is higher than a predefined threshold, then the electronic acquisition generates, in a few milliseconds, a signal to reduce the beam power by activating a chopper.

The other probes in the cyclotrons and the current transformers are only used for measurement without any security threshold linked to.

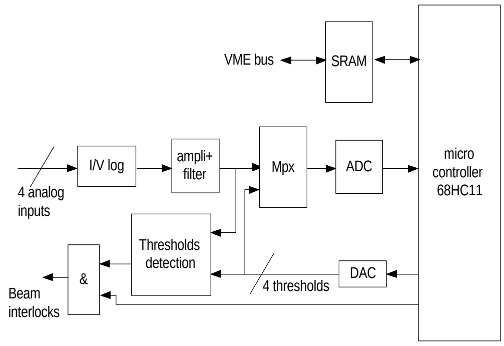
### *2.3 The input signals*

The different probes measure a beam current which is translated in a voltage proportional to the logarithm of the current by a small CMS mezzanine board, plugged on a VME board based on 68HC11 micro controller. An ADC converter translate, within 10 µs, the input range of +/- 10 volts in a 12 bits coded numeric value, stored in a shared memory between the VME bus and the 68HC11.

Each board has 4 input and every input is compared to a threshold sent by the control system through the VME bus and the micro controller. This one can also read back the threshold when asked by the control room.

When the threshold is over, an interrupt is generated on the VME bus, so that the VME processor is able to know which board is concerned and which input has detected the overtake.

The VME crate can send an alarm message to the control room, with the right name of the probe between the four plugged on one board. An other signal is also sent to the beam interlock to reduce the beam intensity.




## 3 Acquisition software

From the control system point of view, the integration of the beam losses measurement entirely follows the hardware and software architectures adopted for the Ganil facility [4] and extended to the Spiral project [5].

### *3.1 Logarithmic handler*

In every front end crate, every input-output board is controlled by a driver according to the hardware. At an upper level, a handler manages the function the board has to perform as seen from the equipment. So, a protocol Jbus board will be driven by a "Jbus" driver, and will be used either by a power supply handler to control power supplies, either by a stepping-motor handler to manage motors. So, a logarithmic handler has been defined to process the new sensor class as described in section 2.

### *3.2 Alarms*

When one threshold is overtaken, an interrupt is generated and the driver reads the status of the board to know which input had been activated . Then it sends an alarm message with this input number to an alarm server process that is running on the database computer. This alarm is displayed on an X terminal in the main control room and stored in the alarm database. So it will be possible to read it back afterwards, if it is necessary to compare it with other events.

### *3.3 User interface*

For people involved with the tuning programs on the workstations, a software user interface has been written in Ada to send commands to the front end crate.

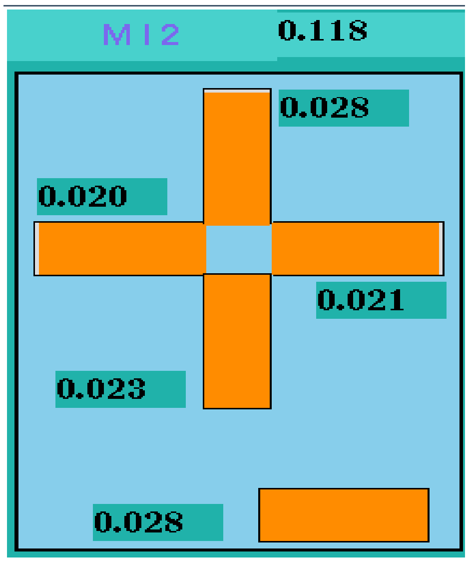
Ada is used for all our control software, on the real time crate but also on the workstations for the graphical user in terfaces.

The beam losses software interface contains all the commands that can be received by the handler. Some of them are only used for the survey mode : alarm test, alarm reset, thresholds read and write. The "read status" command is used in the survey mode to know the input number which triggered an alarm and in the measure mode to check the input channel. The "read input" command is only used in the measure mode to perform the acquisition.

## 4 Display software

### *4.1 Beam losses in the cyclotrons*

On the workstations, the tuning program allows to switch between a display mode and a control panel from which the operator can drive the steerers and the magnetic injection or ejection devices.




Also the operator has to choose on which cyclotron he wants to work and if he will tune the beam injection or ejection . Before starting the acquisition, the electronic noise can be suppressed with the offset button.

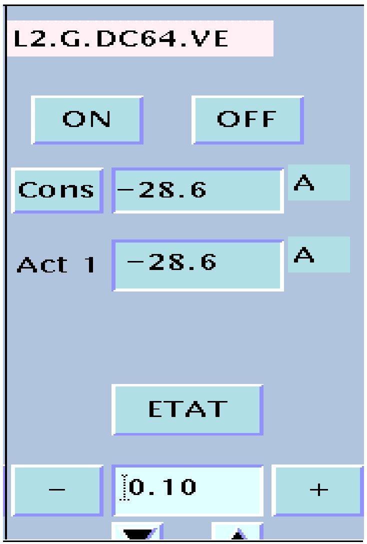
Most of the injection and ejection devices have four sensors (top, bottom, right and left). These probes are displayed on the screen within a cross shape (see above), with the numeric values beside. The more important the losses are, the more the cross shape is filled.

The summation of all the losses is displayed over each cross and the beam intensities at injection and ejection are always shown beside of the cyclotron name.

### *4.2 Injection and ejection centering*

In command mode, the bottom side of the screen displays all the devices used to control the injection or the ejection of the beam. That includes two steerers, four magnetic devices inside the cyclotron and two motors to move the electrostatic deflector. Each of them is controlled by a panel like the one below.

With this panel, all the devices can be started, stopped, set to a value entered either by keyboard or by incremental steps.




*4.3 The collimators*

When the high intensity beam is sent on the radioactive ion source SISSI, the defining slits of the spectrometer could be highly activated and have to be protected.

Therefore three collimators have been installed in the L3 line, before the slits. They are water-cooled to support the beam intensity and are disposed on propellers to be introduced in for high intensities and moved out for standard beams.

They are considered as security devices and so controlled by the program already in use for the beam stops and pepperpots.

*4.4 Future developments*

This program doesn't allow automatic tuning while injecting or ejecting the beam. The human operator has to manually set the magnetic devices, watch the beam losses and increase or decrease the current in the steerers.

At the same time, automatic tuning programs have been written for beam adaptation and for beam alignment.

Once the alignment program successfully operational, the next step will be a link between the alignment algorithm and the centering controls in a way to perform an automatic centering for injection into the cyclotrons.

In parallel, a new program is under way to organize and to manage the tuning modes for accelerating high intensity beams. This program will allow the operator to set the Ganil machine within a predefined procedure by tuning step by step the source, the injector, the SSCs at low intensity and then switching to the high intensity. The beam intensities and throughputs will be displayed from the main panel of the application being acquired from the measurement system presented here.

## 5 References

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[4] "Controlling the GANIL from an Operator workstation", L. David, E. Leorché, C. Maugeais, M. Ulrich. Proceedings of the 4th European Particle Accelerator Conference, London, Great-Britain, June 1994.

[5] "Extending the GANIL control system for the Spiral project", E. Leorché and the Ganil control group. 10th Real Time Conference, Beaune, France, September 1997.