Intensity control in GANIL's experimental rooms

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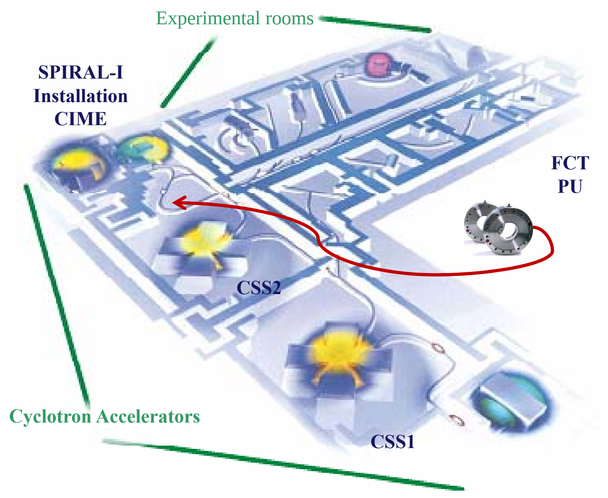
Abstract: the safety re-examination of existing GANIL facilities requires the implementation of a safety system which makes a control of the beam intensity sent to the experimental rooms possible. The aim is to demonstrate that beam intensities stay below the authorized limits defined by the safety GANIL group.

The challenge is to be able to measure by a non-interceptive method a wide range of beam intensities from 5nA to 5µA with a maximum uncertainty of 5%, independently of the frequency (from 7 to 14.5MHz) and the beam energy (from 1.2 to 95MeV.A).

Introduction

GANIL map



A system that controls the beam intensity delivered in experimental rooms in the energy and frequency ranges used at GANIL has to be developed. At the end of the project, seven equipments will be installed in beam lines and experimental rooms. All of them will be classified as EIS (Element Important to Safety). Hence they have to meet a number of requirements in terms of safety, in particular an insurance of well-functioning stronger as possible.

EIS

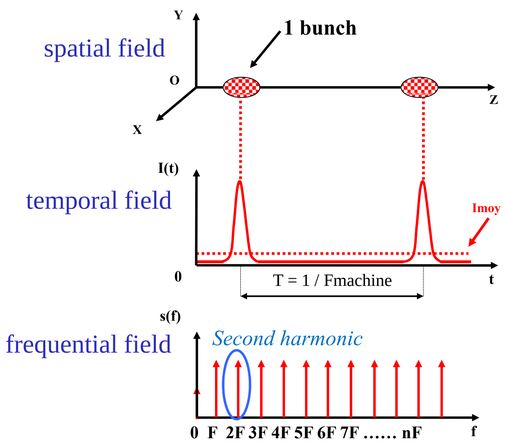
Requirements

The system has to provide a high reliable measure of the beam intensity with a relative precision better than 5% in the range 5nA to 5µA.

The detector response should be independent of :
- •temperature,
- •beam position,
- •energy,
- •frequency,
- •phase extension.

A Quality Assurance Process has to be followed, that involves:
- •characterization of the measurement chain in laboratory and with beam,
- •verification and validation that the system meets specifications,
- •test procedure guides,
- •certified reports,
- •traceability of instruments,
- •Follow-up study, periodic tests...

Feasability study of technical solutions



Two high frequency diagnostics have been selected:
- •**the capacitive Pick-Up (**developed at GANIL)
- •**and the Fast Current Transformer (**Bergoz Instrumentation).

The FCT features are:
- •its large bandwidth (up to 2GHz) ,
- •its high sensitivity (5V/A).

The signal processing consists in measuring the second harmonic of the signal coming from the diagnostic. A relative simple relation exists between the average value of the outgoing signal and its second harmonic (*cf.* CICS system, DIPAC'05, POT028).

Compared to CICS system, We have to deal with two difficulties:
- •the large range of beam intensity (from 5nA to 5µA) requiring sensitivity modifications,
- •the large range of beam energy (from 1.2 to 95MeV.A) since this method is dependent on beam energy.

Characterization of the Fast Current Transformer in laboratory

Laboratory tests were performed at Bergoz Instrumentation and GANIL. The first purpose of these tests was to ensure that the FCT performs to specifications.
- •The uncertainty with temperature and frequency has to be at most equal to 1%.
- •The cutoff frequency has to be at least equal to 200MHz.

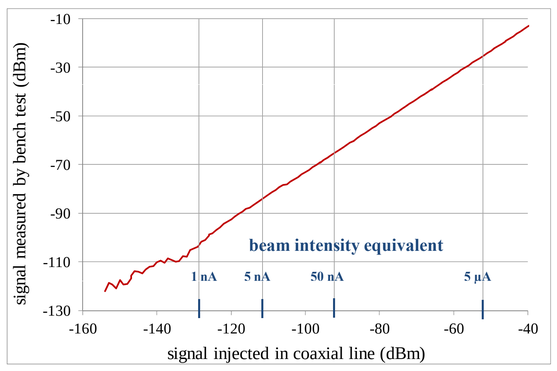
Tests carried out in GANIL aimed at a more detailed characterization.

The electronic setup is composed of an amplifier and a Lock-In Amplifier (Stanford Research Systems SR844). A coaxial line developed at GANIL modeled the beam.

Lock-In Amplifier "SR844"

coaxial line

	specifications	measurements
lower cutoff frequency	< 200kHz	6.485kHz
upper cutoff frequency	> 200MHz	267.575MHz
cumulative uncertainty	< 1% on 5-45ºC and 14-29MHz	0.76% on 25-45ºC and 14-29MHz



Signal simulation

The FCT achieves its measurement via the beam magnetic field while the PU measures the intensity via the beam electric field. The electric and magnetic field-line distributions depend on the beam energy. Hence a study on the energy sensitivity of the electromagnetic field was conducted.

On table below is presented the second harmonic variation in the range of energy for CSS1, CSS2 and CIME cyclotrons.

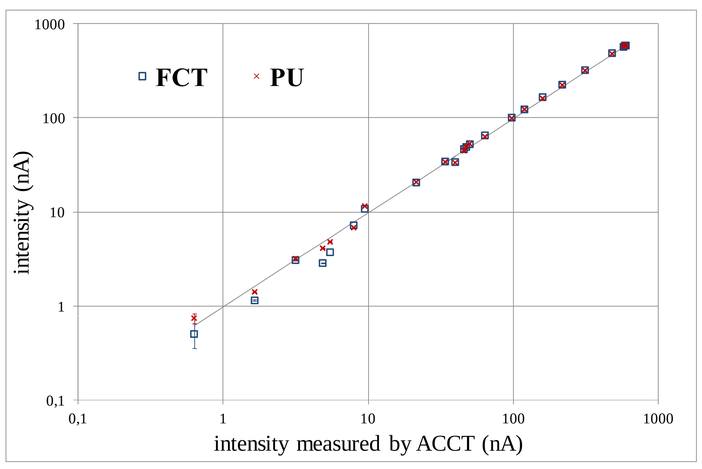
cyclotron	energy range (MeV.A)	frequency range (MHz)	second harmonic variation	
			FCT	PU
CSS1	[4; 13]	[7; 14]	0.007%	0.07%
CSS2	[24; 95]	[7; 14]	0.01%	0.1%
CIME	[1.2; 25]	[9.6; 14.5]	0.9%	8%

The FCT is ten time less sensitive to energy variations than the PU.

Tests with Beam

A prototype of each diagnostics, FCT and PU, has been set on beam line. In the PU measurement chain, the high input impedance of the amplifier is used.

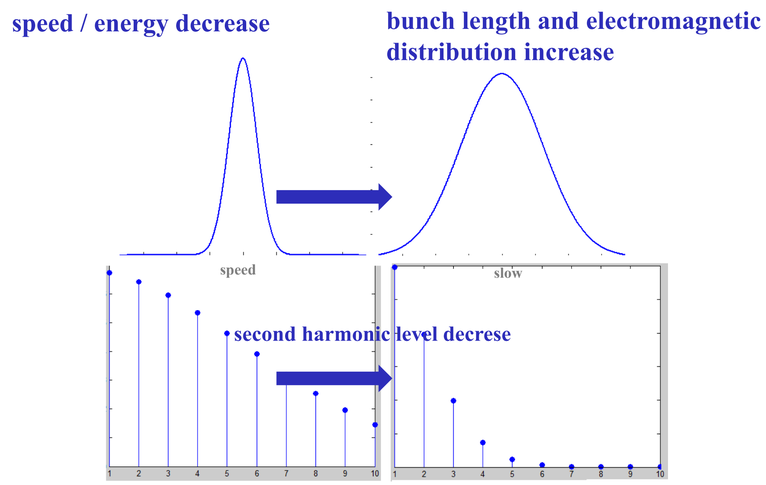
The aim is to reduce the beam intensity to 1nA and evaluate linearity, sensitivity and uncertainty of the measurement chain. The major disadvantage of these beam tests is the reference diagnostic. This diagnostic, an AC current transformer used in routine at GANIL, is worse in terms of linearity and sensitivity than diagnostics to be characterized.



on [1nA; 500nA]	non-linearity error	maximum uncertainty*
FCT	1.54%FS	1.7%
PU	1.15%FS	1.8%

*This uncertainty is composed of diagnostic and beam uncertainties.

One important purpose of beam tests is to characterize the energy sensitivity of FCT and PU. A decrease of beam energy leads to a rise of the bunch length which leads to a second harmonic level decrease. A correction, *a posteriori,* of the second harmonic is thus possible. For now, only three energy values have been tested. More beam tests are required to realize this correction. Beam tests are scheduled for the end of this year 2013.



Conclusion

A safety system based on a beam diagnostic involves a Quality Assurance Process. A feasibility study has already been done; simulations and tests in laboratory have also been performed. It remains the characterization with beam. Some beam tests have been realized in July and other are scheduled for the end of the year 2013. The choice of the equipment will depend on the intensity range required and which should be decided soon.