

Four instrumentation chains with AC and DC Current Transformers (ACCT-DCCT) will equip the lines of SPIRAL2 facility to measure the beam intensity and line transmissions. These measures are essential to tune and supervise the beam, to assure the thermal protection of the accelerator and to control that the intensities and transmissions are below the authorized limits. As such, the uncertainties of measurement chains must be taken into account in the threshold values. The electronic has been designed with high requirements of quality and dependability by following different steps; from prototyping, the qualification through an Analysis of Failure Modes and Effects Analysis (FMEA) until final fabrication.

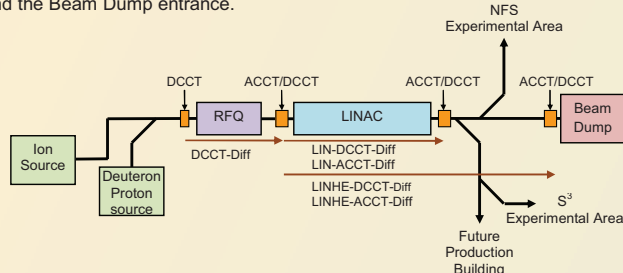
## BEAM INTENSITY AND TRANSMISSION CONTROLS

The SPIRAL2 facility at GANIL in France is planned to accelerate deuteron, proton and heavy-ion beams with a RFQ and a superconducting linear accelerator.

Beam	P	D+	Ions(1/3)
Max. Intensity	5mA	5mA	1mA
Max. Energy	33MeV	20MeV/A	14.5MeV/A
Max. Power	165kW	200kW	43.5kW

Beam specification

A DCCT bloc is set up at the entrance of the Radio Frequency Quadrupole (RFQ) and three ACCT/DCCT blocs will be installed at the Linac entrance, the Linac exit and the Beam Dump entrance.

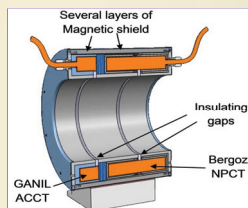


Beams Intensities and transmissions

## MEASURING CHAIN DESCRIPTION

### ACCT-DCCT bloc

- DCCT : Bergoz NPCT-175-C030-HR
- ACCT : GANIL's Electronic Group  
Nanocrystalline torus & winding of 300 turns
- Shielding layers (Armco, Mu-metal and copper) protect the sensors from external electromagnetic fields.
- Shield plate between ACCT and DCCT minimize the disturbance produced by the DCCT magnetic modulator on the ACCT.



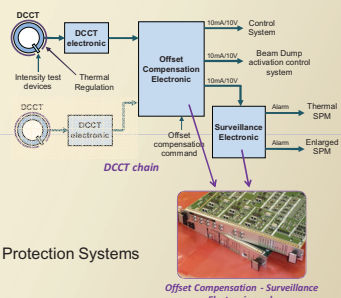
ACCT-DCCT bloc section

### DCCT measuring chain

DCCT sensor is maintained @40°C

"Offset Compensation" card:

- sets the zero point, with a manual command before each start of new beam tuning
- generates the transmission signal (difference of two intensity signals)
- distributes the intensity and transmission signals



Offset Compensation - Surveillance Electronic cards

### ACCT measuring chain

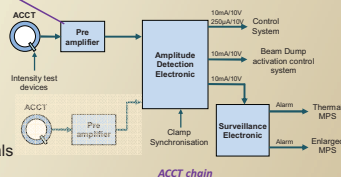
"Pre amplifier" is a couplant to tension convertor. It is placed as close as possible to the transformer for minimize the noise but outside the linac room to be protected of the radioactive effects.



Pre amplifier

"Amplitude detection" card :

- regenerates the DC signal non-transmitted by the ACCT ("clamping" function)
- generates beam intensity and transmission signals
- distributes the intensity and transmission signals



ACCT chain

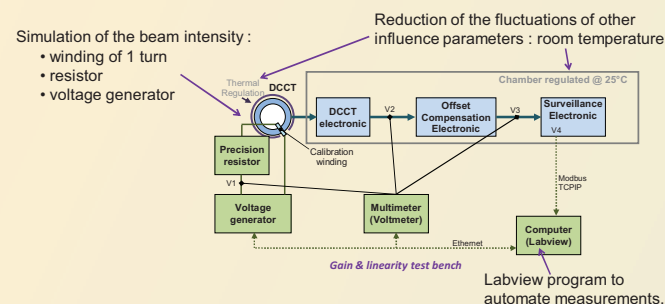
"Surveillance" card : same as DCCT chain.

## UNCERTAINTY EVALUATIONS

For evaluate the total uncertainties, all the influence parameters should be identified and quantified. Several test benches were set up to characterize these parameters.

### One of test benches : Gain & linearity

Requirement : Not redefine the total uncertainty values when an electronic card is replaced for maintenance reasons. => evaluation of maximum uncertainty with all cards combinations (with electronic spares)



Optimizations of the measurement uncertainties associated with the bench :

- > Ratios of measured voltages by a single multichannel multimeter
- > Beam intensity : measurement of output voltage of the generator & precision resistor
- > Reduce the measurements : dividing the chain in 3 parts and take into account the maximum uncertainties of each part.

### Study and design stage

The first uncertainty evaluations on the prototype electronics have guided the development of ACCT/DCCT chains. The main influences were the subject of specific studies.

Influence parameters	Technical solution
Room temperature on DCCT sensor	Regulation system to stabilize the transformer temperature.
External Electromagnetic Field	Three shielding layers protect the sensors. Definition of PCB EMC design rules for the electronic cards
Disturbances between AC and DC sensors.	A vertical shield plate is installed between the sensors to minimize the effect of DCCT magnetic modulator on the ACCT.
ACCT Low Drop	Choice of the nanocrystalline torus with winding of 300 turns. Implementation in preamplifier a function to decrease the resistance value of ACCT winding. Clamp function triggered in the middle of the time off.

### Validation and qualification of chains in the definitive version

All the uncertainty values were calculated from laboratory measurements.

Average Intensities			
Sources of uncertainty	ACCT	DCCT	
Gain & Linearity	0.04%	0.45%	
Sensor Temperature	-	13μA <sup>(1)</sup>	
Electronic Temperature	-	23μA <sup>(2)</sup>	
Noise <sup>(3)</sup>	10mA	2μA	
Clamp	2.5μA	-	
Initialization Offset with surveillance cards	50mA	5μA	
Gain & Linearity of surveillance cards	0.35%	0.35%	
<sup>(1)</sup> DCCT range 20mA - Thermal regulation at 40°C ±0.5°C			
<sup>(2)</sup> Ambient temperature range: 18° - 31°C			
<sup>(3)</sup> Noise measured in laboratory			
Average Transmissions			
Sources of uncertainty	ACCT	DCCT	
Gain & Linearity on the intensity	0.035%	0.12%	
Gain & Linearity on the loss	0.04%	0.45%	
Sensors Temperature	-	26μA	
Electronic Temperature	-	9μA <sup>(1)</sup>	
Noise	15mA	3μA	
Clamp	4μA	-	
Initialization Offset with surveillance cards	75mA	7μA	
Gain & Linearity of surveillance cards	0.35%	0.35%	
<sup>(1)</sup> Temperature difference of electronics: 5°C max.			

### Total uncertainty values

Intensity uncertainty			Transmission uncertainty		
Beam Intensity	1 ACCT	1 DCCT	Beam Intensity	Transmission Loss	Uncertainty
5mA	±23μA	±82μA	5mA	250 μA	±7μA ±52μA
1mA	±7μA	±51μA	1mA	250 μA	±7μA ±48μA
50μA	±3μA	±43μA	50μA	50 μA	±5μA ±45μA

Total uncertainties will be taken into account in the threshold values, to ensure that intensities and the transmissions don't exceed the operating ranges authorized.

The overall chain ACCT-DCCT is manufactured, validated and will be installed on the accelerator before the end of the year 2016. The characterization and the qualification should continue on site without and with beam. For example, the influence of the external magnetic fields should be quantified with SPIRAL2 in operating. The qualification will finish by tests with the other interfaced systems. Mainly, the response times between beam overrun and its cut off must be verified.