MEASUREMENT UNCERTAINTY ASSESSMENTS OF THE SPIRAL2 ACCT/DCCT

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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.

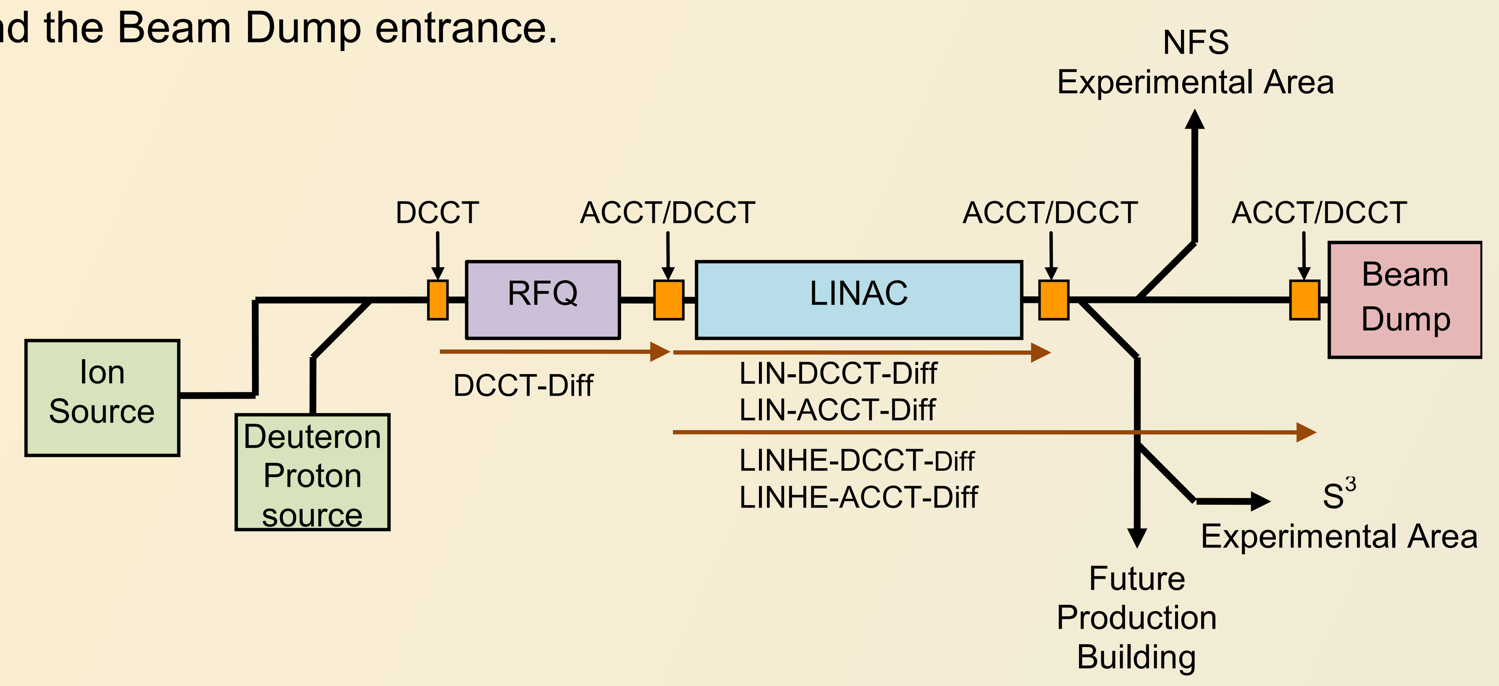
BEAM INTENSITY AND TRANSMISSION CONTROLS

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.

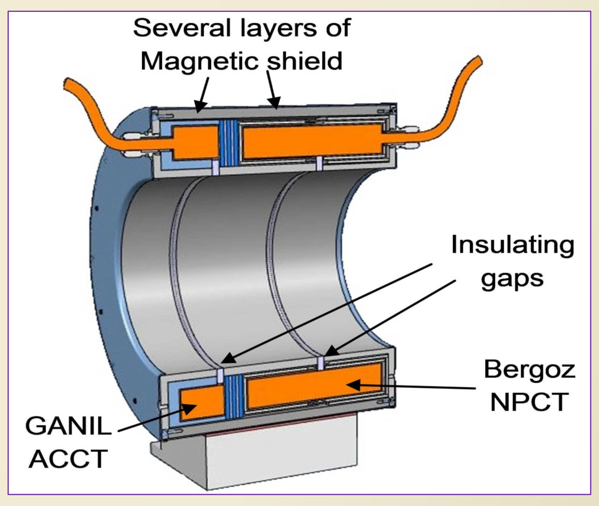


Beams Intesnities and transmissions

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.

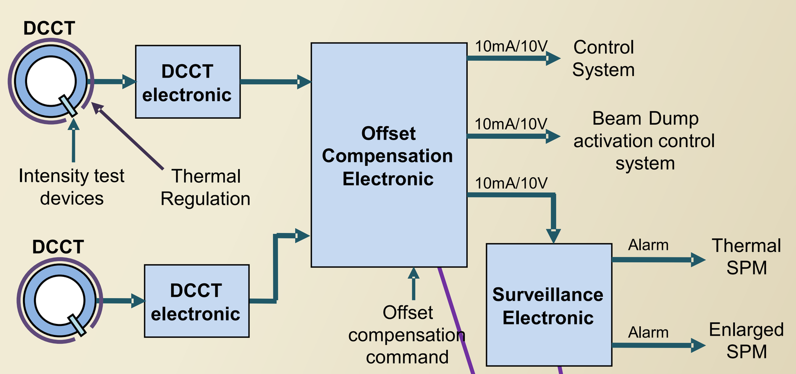


ACCT-DCCT bloc section

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



DCCT chain

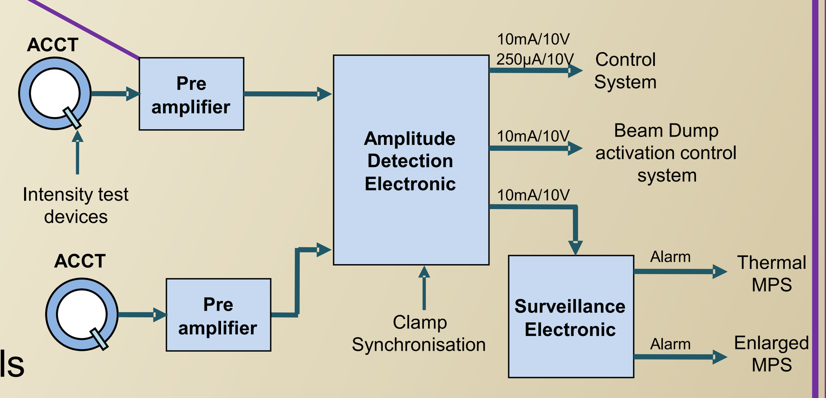
"Surveillance" card :
- carries out moving averages of input signal
- compares it to thresholds
- sends alarms in case of overtake to the Machine Protection Systems

Offset Compensation - Surveillance Electronic cards

ACCT measuring chain

"Pre amplifier" is a courant 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



ACCT chain

"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

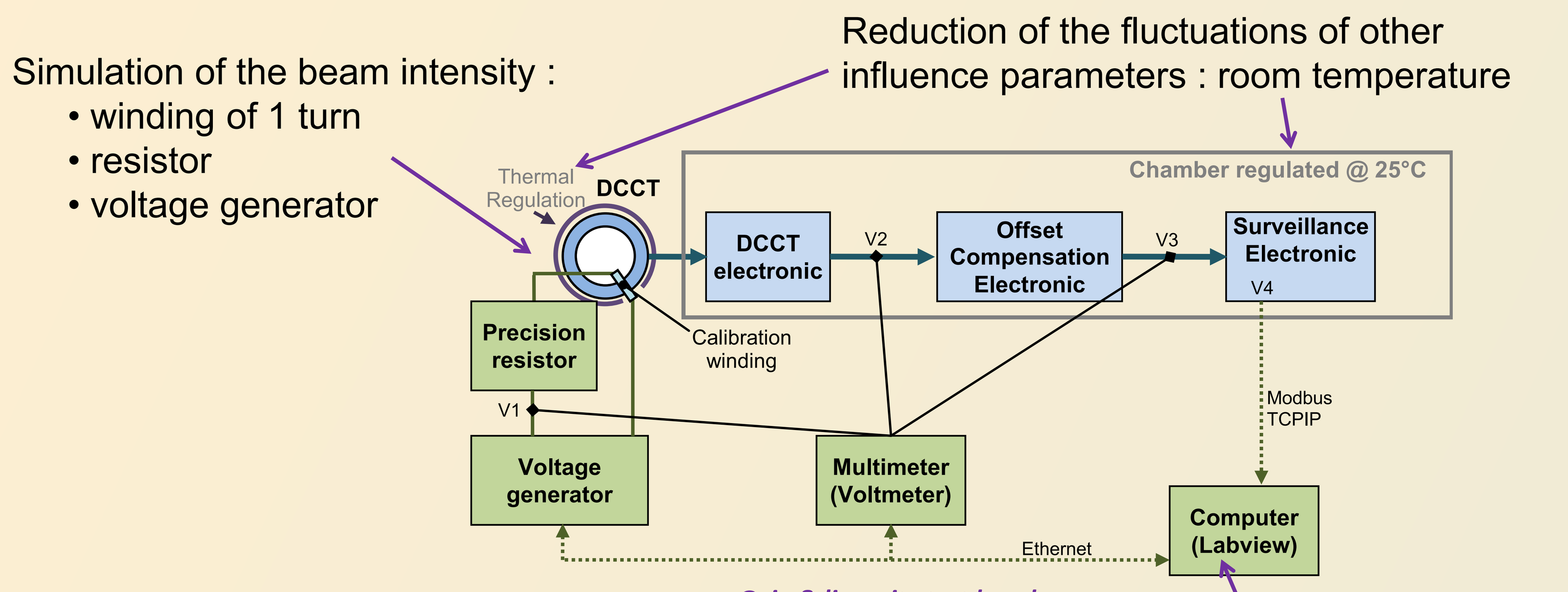
"Surveillance" card : same as DCCT chain.

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)



Gain & linearity test bench

Labview program to automate measurements.

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 trigged 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(1)
Electronic Temperature	-	23µA(2)
Noise(3)	10nA	2µA
Clamp	2.5µA	-
Initialization Offset with surveillance cards	50nA	5µA
Gain & Linearity of surveillance cards	0.35%	0.35%

(1) DCCT range 20mA -Thermal regulation at 40°C ±0.5°C
(2) Ambient temperature range: 18° - 31°C
(3) Noise measured in laboratory

Predominant sources of uncertainty
DCCT : temperature & noise
ACCT : noise on the clamp function surveillance linearity

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(1)
Noise	15nA	3µA
Clamp	4µA	-
Initialization Offset with surveillance cards	75nA	7µA
Gain & Linearity of surveillance cards	0.35%	0.35%

(1) Temperature difference of electronics: 5°C max.

Total uncertainty values

Intensity uncertainty

Beam Intensity	Uncertainty	
	I ACCT	I DCCT
5mA	±23µA	±82µA
1mA	±7µA	±51µA
50µA	±3µA	±43µA

Transmission uncertainty

Beam Intensity	Transmission Loss	Uncertainty	
		ΔI ACCT	ΔI DCCT
5mA	250 µA	±7µA	±52µA
1mA	250 µA	±7µA	±48µA
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 extern 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.