SPIRAL2 DIAGNOSTIC QUALIFICATIONS WITH RFQ BEAMS

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The SPIRAL2 accelerator, built on the GANIL's facility, at CAEN in FRANCE is dedicated to accelerate light and heavy ion beams up to 5mA and 40 MeV. The continuous wave accelerator is based on two ECR ion sources, a RFQ and a superconducting LINAC. The beam commissioning of the RFQ finished at the end of 2018.

This poster presents the Diagnostic-Plate installed behind the RFQ, with all associated accelerator diagnostics. Diagnostic monitors, measured beam parameters, results are described and analyzed. A brief presentation of the next steps is given.

INTRODUCTION

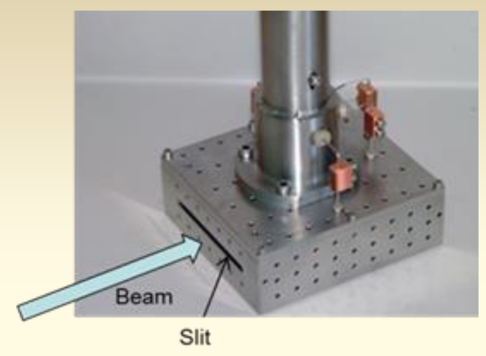
The SPIRAL2 facility is designed to produce deuteron, proton beams with the first ECR source and ion beams with the second source. The acceleration is given by a CW RFQ (A/Q ≤ 3) and a high power superconducting linac.

Beam	P	D+	Ions (1/3)
Max. Intensity	5 mA	5 mA	1 mA
Max. Energy	33 MeV	20 MeV/A	14,5 MeV/A
Max. Power	165 kW	200 kW	43,5 kW

The injector commissioning phase consisted to qualify the RFQ beams with a Diagnostic Plate (D-Plate), from the end of 2015 up to 2018. The D-Plate was removed at the end of 2018 to install the full MEBT at the beginning of 2019.

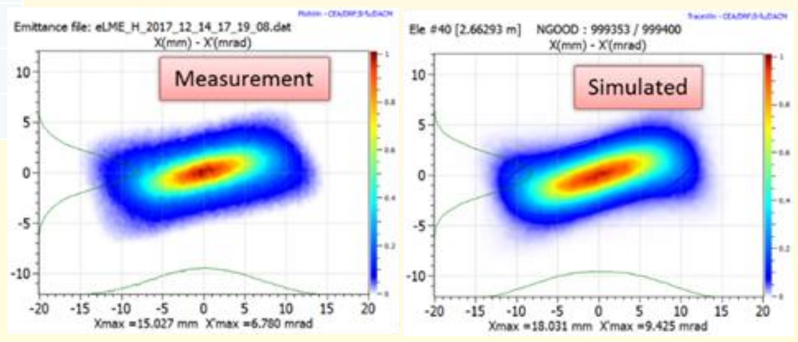
EMITTANCEMETERS

Water cooled scanner emittancemeters also named Allison Scanner are installed in the LEBT and in the D-Plates.



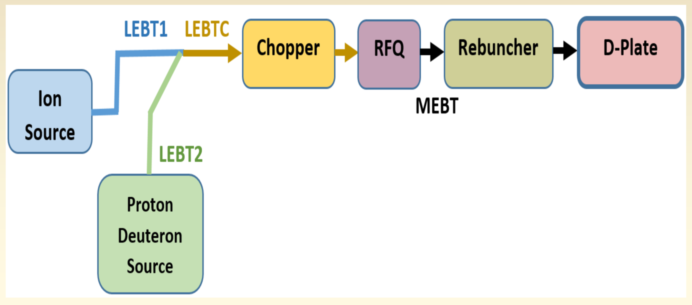
Slit gap	0.12 mm
Max. Deviation Voltage	8 kV
Max. Beam Power Density	1 kW/cm²
Max. Emittance	1 π.mm.mrad
Min. Emittance	0.01 π.mm.mrad
Position accuracy	< 0.1 mm
Angle accuracy	< 0.1 mrad

The emittances are compared with the simulations, like for the 5 mA H+ beam.

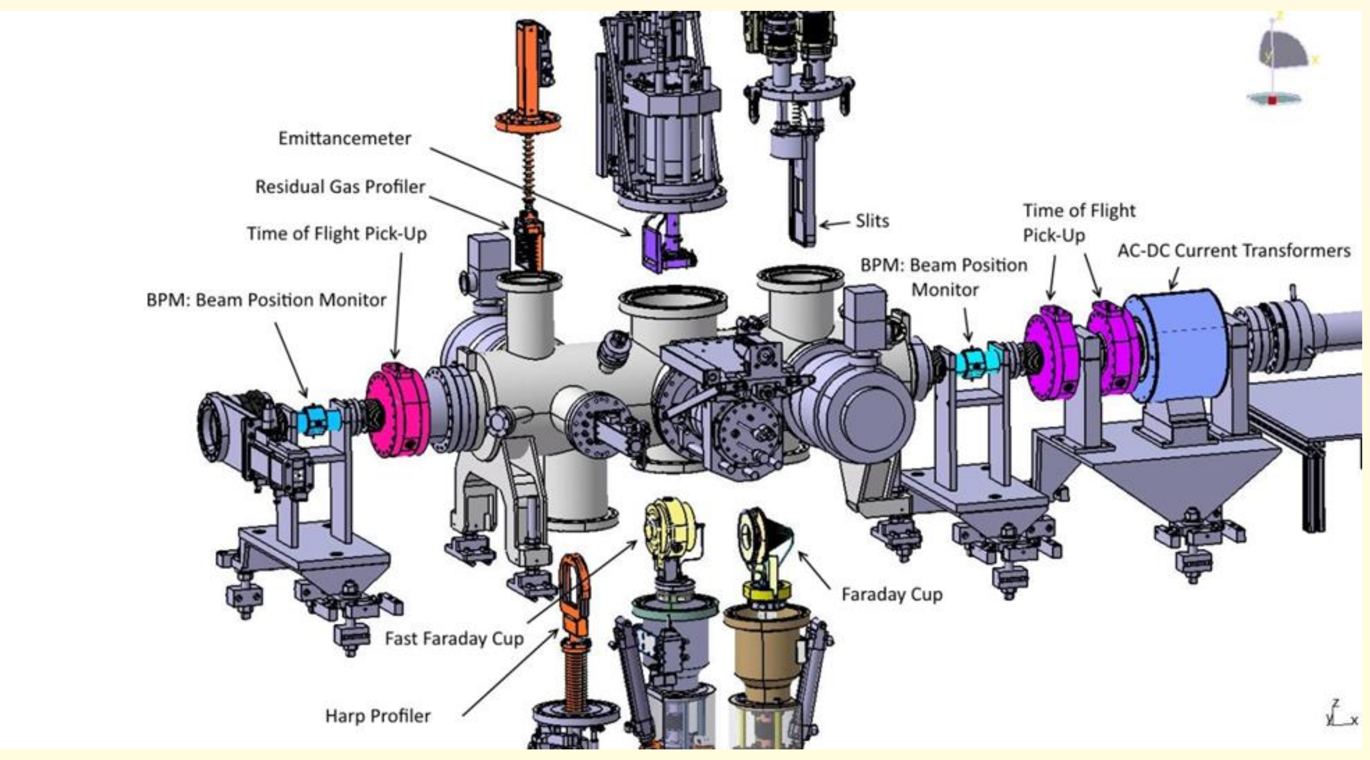


INJECTOR AND D-PLATE DESCRIPTION

The D-Plate (named BTI in French: Intermediate Test Bench) was defined to characterize the beams from the RFQ and also to qualify the SPIRAL2 diagnostic monitors.



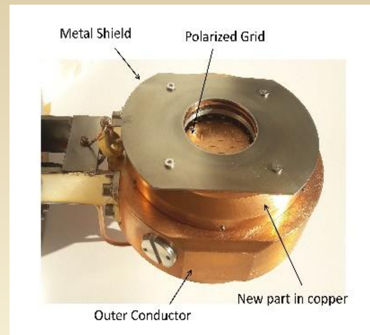
- Intensities with Faraday cups, ACCT and DCCT
- Transverse profiles with classical multi-wire profilers and ionization gas monitor (MIGR)
- H and V transverse emittances with Allison type scanners,
- Energies with a Time of Flight (TOF) monitor
- Phases with the TOF and 2 BPMs,
- Longitudinal profiles with a Fast Faraday Cup (FFC) and a Beam Extension Monitor (BEM)
- Beam position and ellipticity (σ_x^2-σ_y^2) with the BPMs



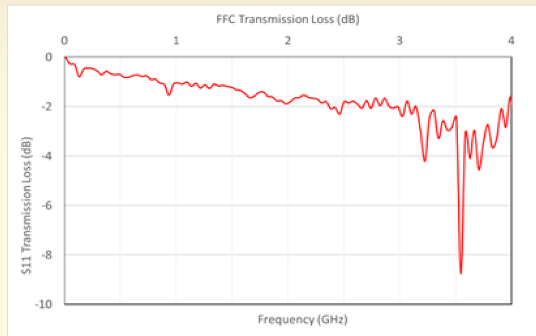
LONGITUDINAL BUNCH MEASUREMENTS

Two different diagnostics were developed to measure longitudinal profiles:
- Fast Faraday Cup (FFC)
- Bunch Extension Monitor (BEM)

The FFC is a coaxial Faraday with the outer conductor, cooled by water, and the inner conductor cooled by conduction via tree ceramic rods.

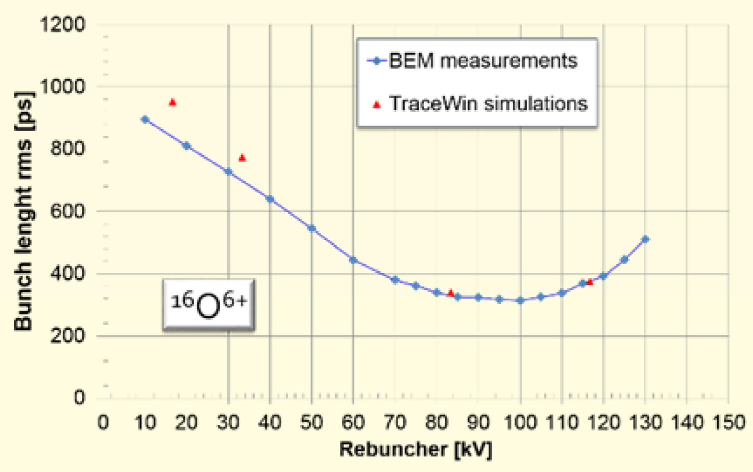


Several modifications have been tested to improve the shield connection and optimize the return loss.
The front part which supports the grid and the shield is now made of copper instead of insulating.
The new return loss, with an attenuation of 4 dB at 3 GHz, is much better. Its installation in the MEBT is planned in September 2019.



Bunch Extension Monitor (BEM) is based on the registration of X-rays emitted by the interaction of the beam ions with a thin tungsten wire. The estimated temporal resolution gives σ = 47 ps.

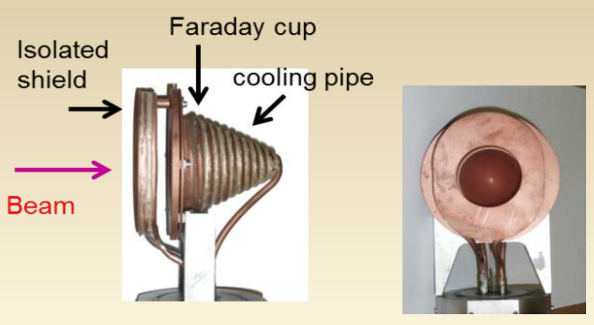
Measurements have shown good agreement with simulation data.



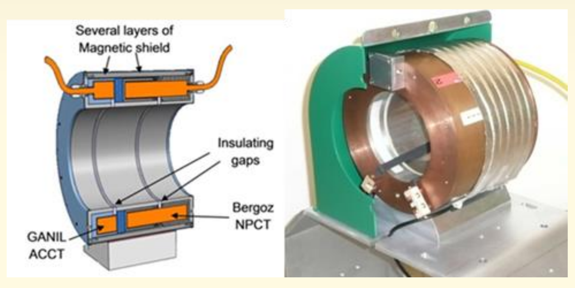
Current measurements on the wire was tested. These option permits to measure beam distribution on the axis of wire insertion and make positioning of wire in the beam center.

INTENSITY MONITORS

The water cool Faraday cup is the MEBT FC.
- Aperture of 60 mm
- Maximum beam power of 3kW
- Maximum power density of 2600W/cm²



An ACCT-DCCT bloc is installed at the end of the D-Plate.
- DCCT (New PCT from Bergoz Company)
- ACCT: Nanocrystalline torus with turns ratio of 300:1



Two intensity measurements are available:
- Average: Measured and controlled with a special electronic
- Peak :Intensity measured in a time zone defined by users

All the intensity monitors can be tested separately with the same test signal. A current generator and a distributor are controlled remotely to inject the current of test.

With Faraday cups, the average transmission deviations are under 0.2%, and with peak measurements around 1%.
- ACCT : Noise 20nA / Clamp 5µA / Offset 100nA
- DCCT : Noise 4µA / Offset saturation 30µA

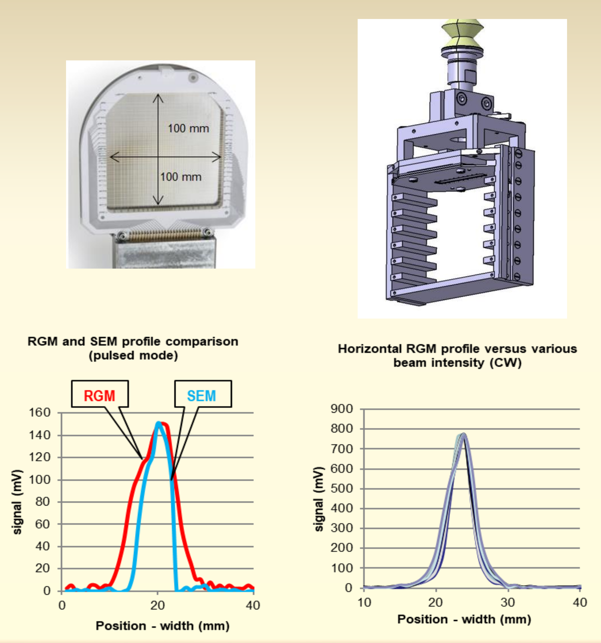
The difference between ACCT and DCCT is around 0.2% with a beam intensity of 4,5 mA. Transmission measurements give an RFQ efficiency close to 100%.
Thresholds and alarms managements with the Machine Protection System (MPS) were tested.

TRANSVERSE PROFIL MONITORS

Two different kinds of profile monitor were installed:
- A "classical", multi-wire profilers
- A residual gas profiler.

The multi-wire profiler is composed of 47 wires with a constant spacing of 1mm. The wire diameter is 150µm.
The Residual Gas Monitor (RGM) were tested with pulsed and CW proton beams at currents up to 5 mA .

A size increase of 30% was observed on the RGM profiler compared to the SEM profile and an increase of 12% with a beam intensity of 1mA in comparison of 0.28 mA.



PHASE & ENERGY MONITORS

Time Of Flight (TOF) monitor is dedicated to calculate the beam energy by measuring beam Phases. Three phase probes are installed on the D-Plates. Phase measurements and energy calculations were also done with the 2 BPM probes.
Helium beam:
- RFQ voltage: 80kV
- Re-buncher voltage: 90 kV,
- RFQ Beam Energy: 727 keV/A.

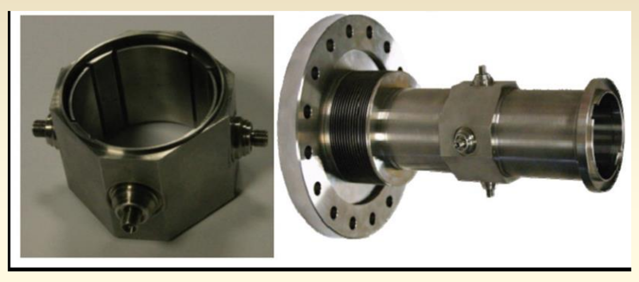
Energy variations with a 360° scan phase of the rebuncher:
- 686 keV/A to 784 keV/A.

The maximum energy difference measured between TOF probes is 0.05%, below the accuracy requirement of 0.1%.
Between TOF and BPM probes, the maximum difference is 0.2% which is also acceptable.

POSITION & ELLIPTICITY MONITORS

The electronic modules, were designed to measure position, ellipticity and phase parameters at two frequencies:
- the fundamental (h1=88.0525 MHz)
- the second harmonic (h2=176.105 MHz)

The transverse ellipticity corresponds to ($\sigma_x^2 - \sigma_y^2$).
σ_x, σ_y : the standard deviations of the transverse size.



Slits were scan to change the beam positions and beam ellipticities.
Rotations of the four BPM signals were applied on the electronic inputs .
Main tests consisted to compare BPM measurements at different rotations and at the two frequencies.
The BPM position comparison gives differences within the requirements of ±150 µm.
The global ellipticity differences were higher than ±1.2 mm² asked.
The analyzes showed :
- Differences of the four input return losses
- Cross-couplings in the modules with small signals (under -60 dBm).

Hardware and software corrections were applied in the first semester of 2019.
New tests are planned in the MEBT in September.

CONCLUSION

All SPIRAL2 diagnostic monitors were tested and qualified on the D-Plate.Transmissions, transverse and longitudinal emittances were compared to the Tracewin simulations with success. Measurements are very close to simulations with the tested reference beams.
The tests made it possible to check and improve the operation of the measurement and monitoring chains, especially the diagnostic chains used by the Machine Protection System (ACCT-DCCT and TOF). Improvements were also applied after the D-Plate dismantling on the FFC and BPM.
On July 7, the French Nuclear Safety Authority gives the authorization to start the RF conditioning of the 19 cryomodules and to begin the beam commissioning. The MEBT commissioning started on July in parallel with the start of the linac cavities. The beam is expected before the end of 2019 in the linac, new steps for the diagnostic commissioning.