SPIRAL 2 Commissioning Status

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With thanks to the SPIRAL 2 team
1- SPIRAL 2 facility (Phase 1) presentation
2- Injector commissioning (Sources and RFQ)
3- SC linac status
4- Summary
-1- SPIRAL 2 Facility

4 levels  7,200 m²

More than 100 rooms
-1- SPIRAL 2 Facility   - 9.50 m (beam level)

Neutron for Science (NfS)
Time of Flight experimental hall (28 x 6 m)
Neutron beam collimator
d+Be or p+7Li neutron source

Free room for a future
Q/A = 1/7 injector

Superconducting LINAC

Q/A = 1/3 ECR source
p and d ECR source

.75 MeV/u RFQ

Beam line to SPIRAL 2 Phase 2

Beam dump
Location for possible LINAC extension and new experimental areas

Super Separator Spectrometer (S3)
Experimental hall
SPIRAL 2 building site preparation

January 2011
-1- SPIRAL 2 construction

2011 +3.5 years : September, 2014
-2- SPIRAL 2 injector commissioning

Free space for the future A/Q = 7 injector connection

RFQ
1 < A/Q < 3

Medium Energy Beam Transfer Line

Fast shopper (Bunch selector)

18 GHz  60 kV
LPSC Grenoble

ECR Ion Source
D⁺, p

2.45 GHz 40 kV IRFU Saclay

0.75 MeV/u RFQ
-2- SPIRAL 2 p/d source commissioning

First beam at GANIL
December 19, 2014

Protons
Issue = noise (emittance growth)
First beam  (230 μA Argon 9+)  July 10, 2015

Test
He 4 2+   A/Q = 2
D beam forbidden!
-2- SPIRAL 2 p/d and HI source commissioning

Long period stability (6 mA CW)

Ability to extract 11 mA CW from the p source => 6 mA proton beam

Beam intensity and emittance control using 6 H and 6 V slit systems

Emittance measurements f(I) July + August + Sept

0.2 π mm mrd rms norm.
Voltage law (bead-pull) measurements + adjustments (40 plungers) OK March 2015
Max error = 2.3 % on the quadrupolar mode (+3 % longitudinal emittance increase)
Expected transmission = 99.7 %
RFQ cabling
Cooling / tuning system tests
rf amplifiers tests / load
4 x 60 kW rf amplifiers (tubes / 4 x 3 kW solid state preamplifier)
  DB electronica (Padova, Italy)

First campaign mid October 2015 (~ 2 weeks)
  Pulsed mode, multipactor issues at low level
  Procedure adjustments / adjustment of the feedback loop coefficients

Second campaign November 2015 (~ 3 weeks) with 3 amplifiers
  rf power ramp-up up to CW, November 6 : 38 kV CW (2 amplifiers)
    November 23 : $A/Q = 2$ field = 75 kV CW (89 kW )
    End November : 85 kV CW (with 3 amp / 4)

  4 amplifiers needed for the $A/Q = 3$ field = 113 kV (180 kW => 4 x 45 kW)
2015, December 03, 9h26: First RFQ beams (Protons)
RFQ in CW rf operation (up to 50 kV)  Pulsed beam 200 $\mu$A, 200 $\mu$s, 2 Hz
5 mA with 100% transmission at the end of the working day
(SPIRAL 2 nominal beam current)
First CW proton beam: December 18, 2015: 2.3 mA
First 5 mA CW proton beam: December 23, 2015

100% transmission
Fine tuning using the RFQ vacuum

A/Q = 2 beam up to 1.5 mA $^4$He$^{2+}$
February 25, 2016: First pulsed beam, 250 μA
First CW beam: June 04, 2016 ~ 1 mA
Transmission > 99%

Proton & A/Q = 2: RFQ always operated CW from the rf point of view
rf operation stable and reliable (with 3/4 amps, up to 80 kV)
3 main objectives for the commissioning

1 = Measure the RFQ beam characteristics, including the longitudinal emittances using a rebuncher + FFC & BEM

2 = Debug / measure the performances of the diagnostics (BTI)

3 = Prepare the Superconducting LINAC commissioning measuring the beam characteristics for the different commissioning phases (low current)
-2- SPIRAL 2  RFQ A/Q > 2 rf conditioning

**A/Q = 3**

**A/Q = 2**

**MTTR**

Amplifiers:
20 min to restart (delays)

+ Field ramp up:
40 to 90 min (slow feedback)

V max achieved today
96 kV  CW
114 kV  15% duty cycle
Issue # 1 = rf amplifiers reliability / availability

Availability: one short period with 4 amps, 3/4 amps most of the time, 2/4 today

MTBF too short (over protections?)

MTT Repair / Restart too longs (spares / shorter delays?)

Issue # 2 = LLRF

LLRF: amplitude and phase control of 4 amps coupled to one RFQ cavity

Variable frequency mode unavailable

Variable frequency mode implemented based on internal I/Q vector rotations of the 4 signals

Amplifier issue? (differences between the 4 amps, delayed response, nonlinearities…)

LLRF issue?
Issue #3 = RFQ cavity tuning loop

Very difficult to tune at high power … Too slow … Unstable

- Long water lines
- 3-Way valve response time = 30 s
- Long delay
- Stability = Long time constant (> 2 D)
- Slow response of the cavity tuning loop
- Slow rf power ramp-up
Wide range of particles, intensities, energies, duty-cycles (CW up to single bunch)
Today: 12/12 CM-A + 6/7 CM-B aligned and connected to their valve boxes
18 / 20 hot-section installed
All the valve-boxes have been “re-fabricated” (mechanical errors, cryo. leaks…)

- 2 cryomodules with cryogenic leaks
Cryogenic system (1,300 W equivalent 4.5 K) installed, first liquid helium in July 2015
One solid state amplifier / cavity
Up to 20 kW

Amplifiers, feeders, circulators, LLRF and interlock PLC have been tested independently, installed in the building and interconnected
-2- SPIRAL 2

HEBT line installation

JM Lagniel

HB 2016, Malmö, Sweden

July 5, 2016
Good advances of the SPIRAL 2 project since January 2011 !!!

- Both light and heavy ion sources working very well
- RFQ working well with protons and A/Q = 2 ions (He and O)
- RFQ conditioned up to 96 kV CW ➢ A/Q = 2.4 ions
- RFQ improvements
  - rf amplifiers (reliability)
  - LLRF (variable freq. loop)
  - Tuning system (faster and stable)
- Superconducting linac : first cooling down this week
  (cooling down of all the valve-boxes + 2 cryomodules)
- The installation and commissioning progresses are limited by the availability of the GANIL team
  Operation of the GANIL “cyclotron facility” in //
- First linac beam beginning 2017