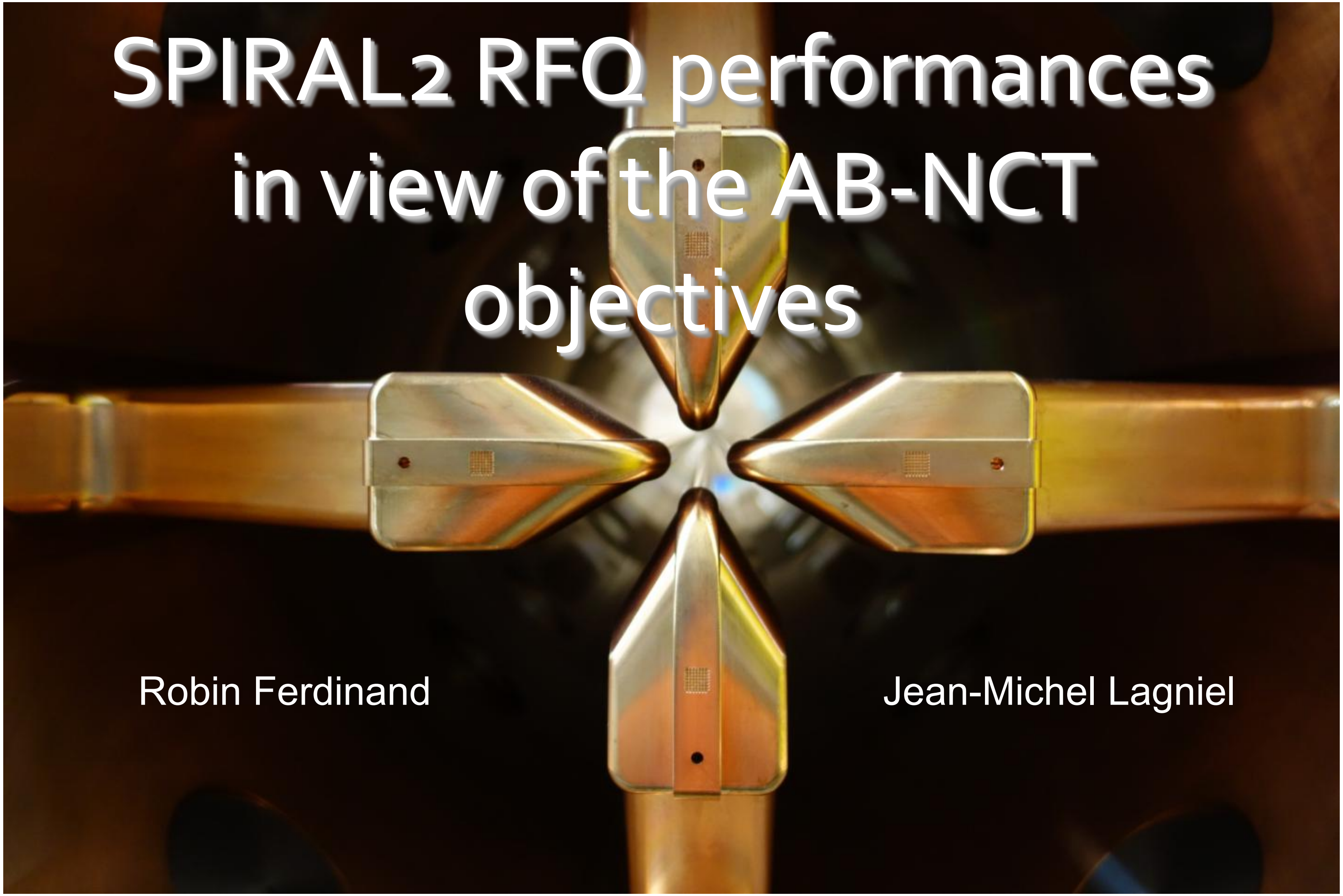
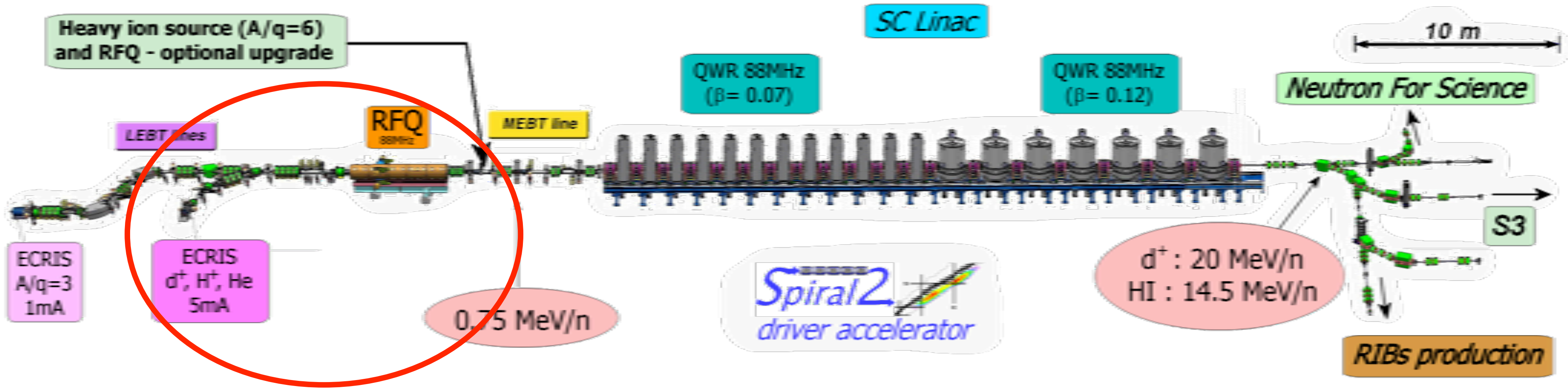
SPIRAL2 RFQ performances in view of the AB-NCT objectives



Robin Ferdinand

Jean-Michel Lagniel

SPIRAL2 Accelerator



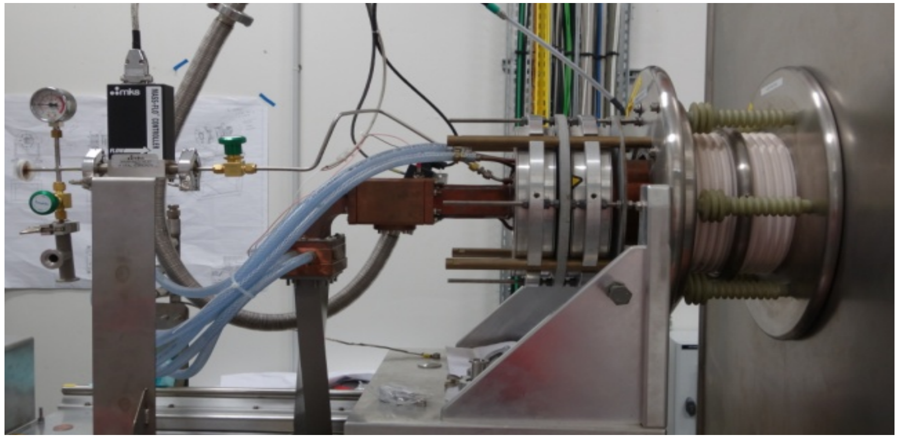
Particles	H+	3He2+	D+	Ions	
Q/A	1	2/3	1/2	1/3	1/6
I (mA) max.	5	5	5	1	1
W_O max. (MeV/A)	33	24	20	15	9
CW max. beam power (kW)	165	180	200	44	48

Total length: 65 m (without HE lines)

Slow (LEBT) and Fast Chopper (MEBT)
RFQ (1/1, 1/2, 1/3) & 3 re-bunchers

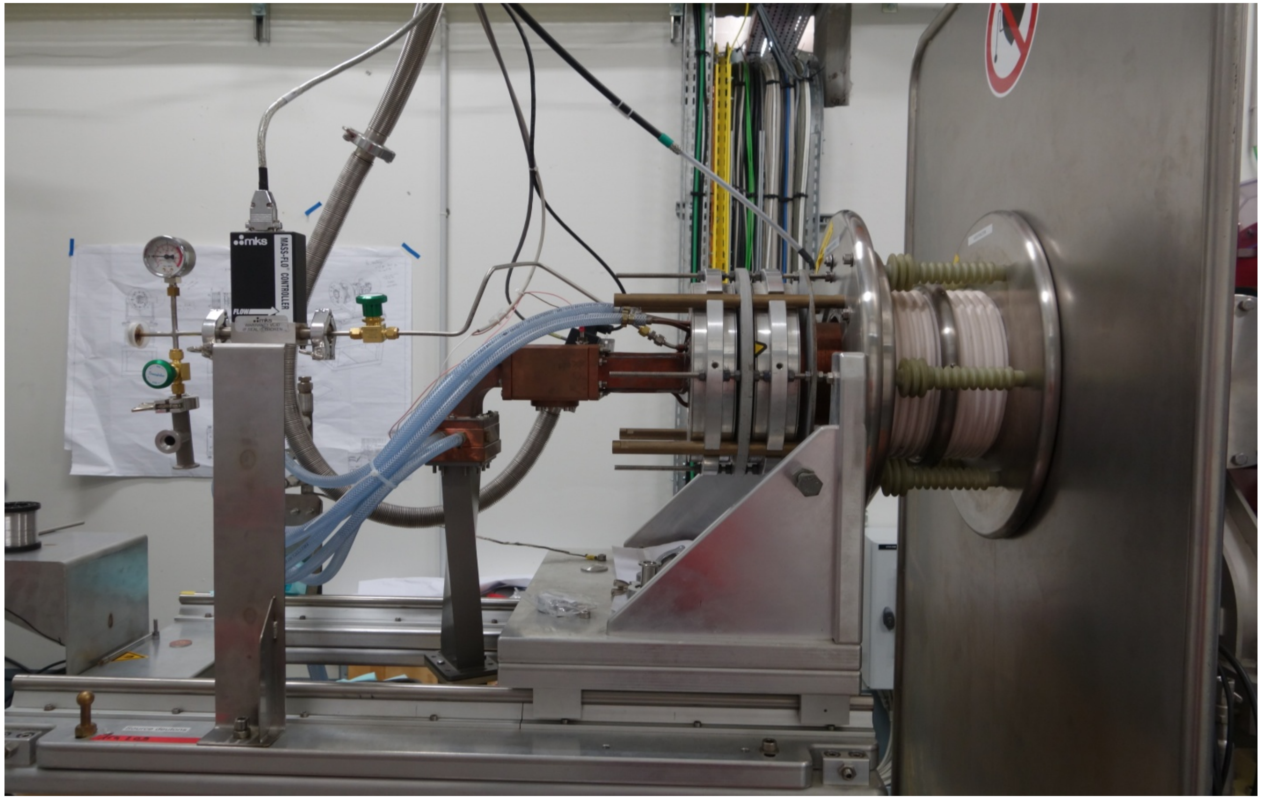
12 QWR beta 0.07 (12 cryomodules)
14 (+2) QWR beta 0.12 (7+1 cryomodules)
1.1 kW Helium Liquifier (4.5 K)
Room Temperature Quadrupoles
Solid State RF amplifiers (10 & 20 KW)
6.5 MV/m max $E_{acc} = V_{acc}/(\beta_{opt}\lambda)$ with $V_{acc}=\int E_z(z)e^{i\omega z/c}dz$.

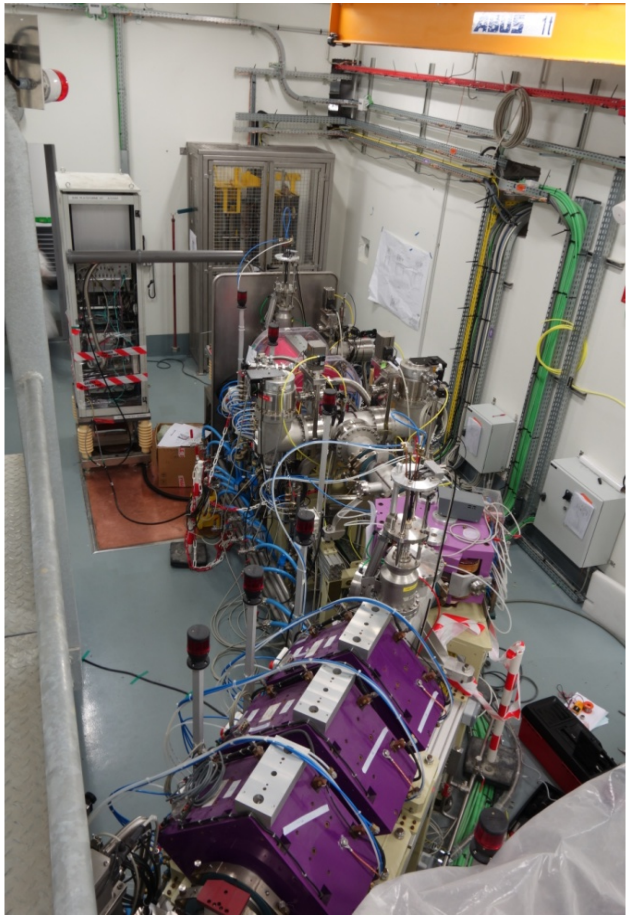
SPIRAL 2 Proton / Deuteron source



Source protons / deutons

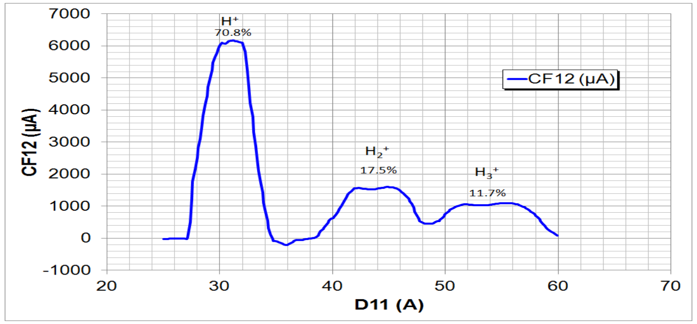
- CW Deuteron source designed for 5 mA CW
  - ECR permanent magnet, developped by CEA-Saclay, derived from SILHI
  - 2.45 GHz < 1 kW
  - Very simple, 2 butons (gas flow and RF power)
  - LEBT to manage H^+/H_2^+ D^+/D_2^+

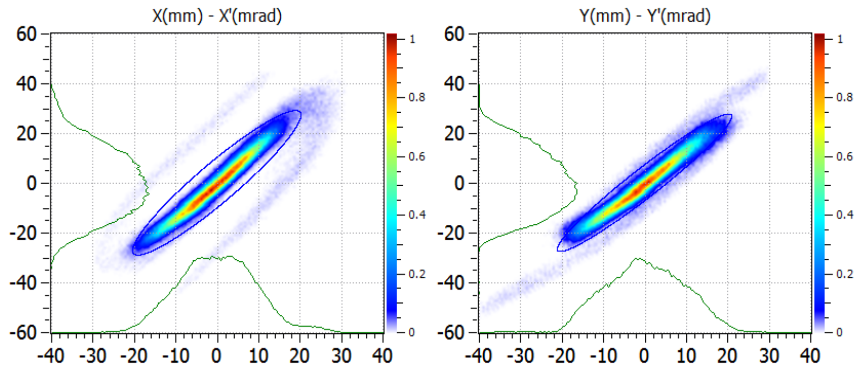


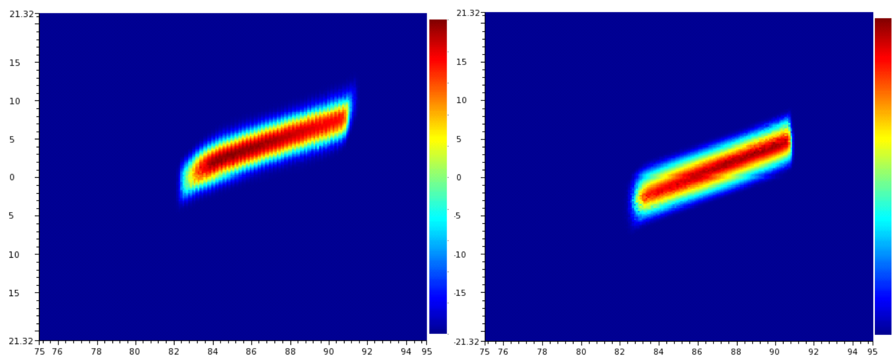


Achieved performances

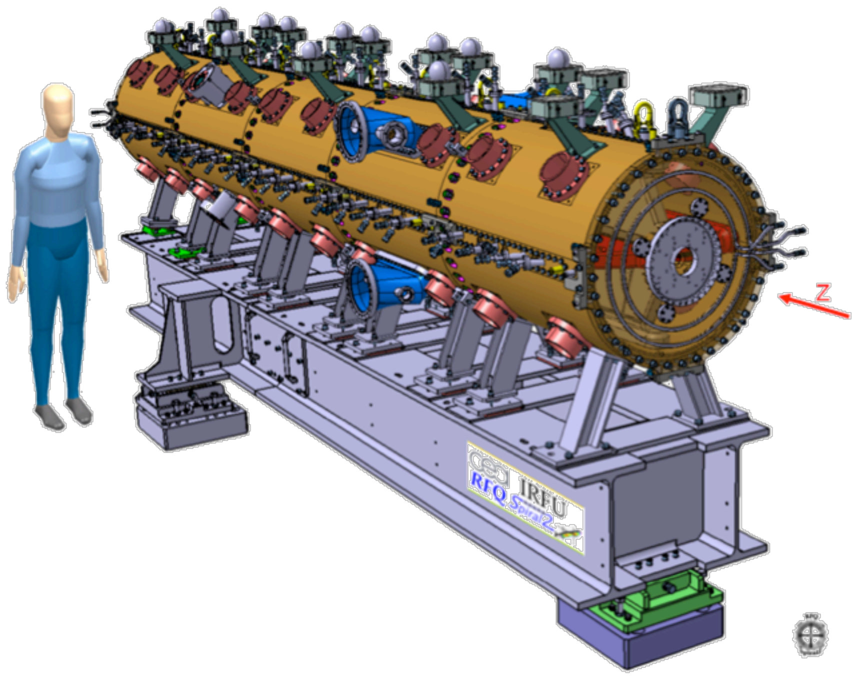
- Up to 14.5 mA at the source exit,
  12 mA @ the lebt end, 79% D+
- Emittances :
  - ε_x = 0.27 π.mm.mrad (rms norm)
  - ε_y = 0.20 π.mm.mrad (rms norm)
  - $\varepsilon_{x,\ \text{slits 3 rms}}$ = 0.13 π.mm.mrad (rms norm)
  - $\varepsilon_{y,\ \text{slits 3 rms}}$ = 0.14 π.mm.mrad (rms norm)
- Emittance reduction ×2 with slits, still 5 mA
- Space charge compensation
  - From 10 time faster than theory
    (750 µs @ 3 10^{-7} mbar),
    to 2 time faster (40 µs @ 1.7 10^{-5} mbar)
- At GANIL so far :
  - 12 mA H^+ at the source exit,
    5.7 mA at LEBT end
  - Same emittances





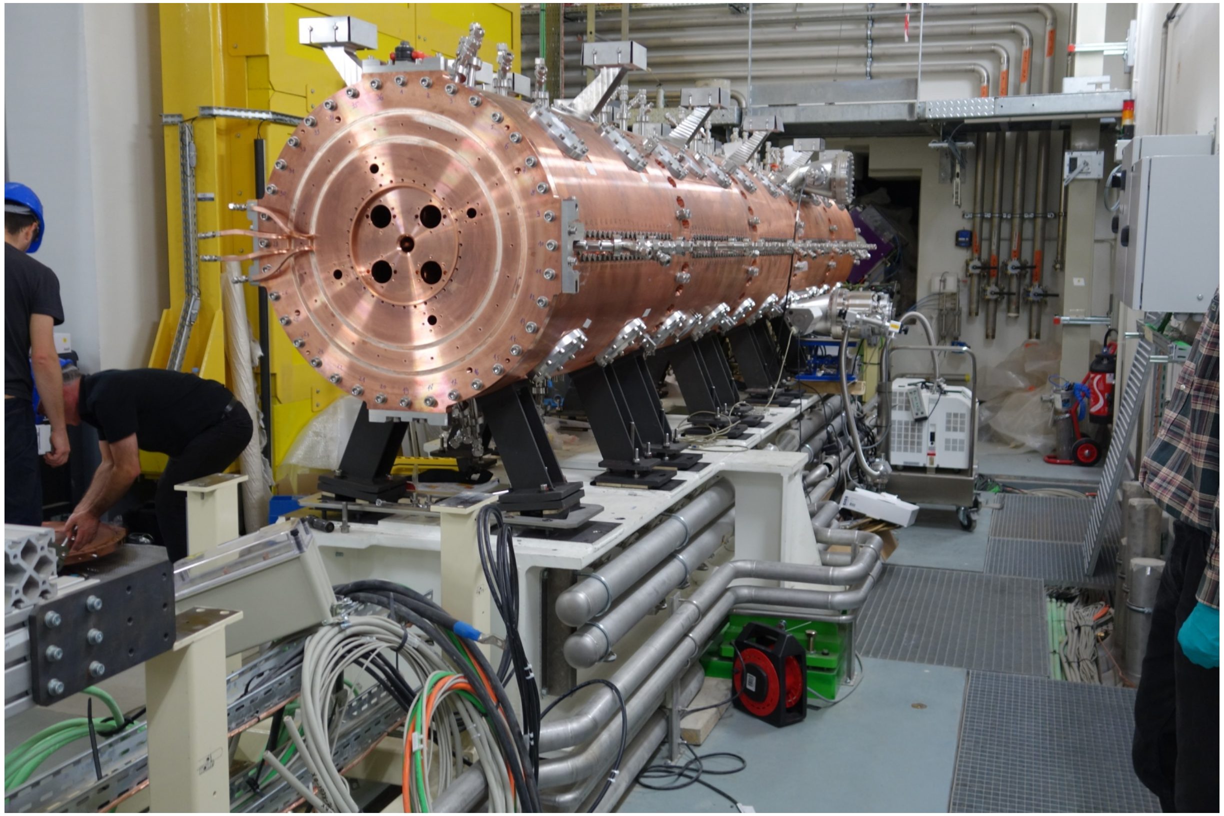


SPIRAL 2 RFQ

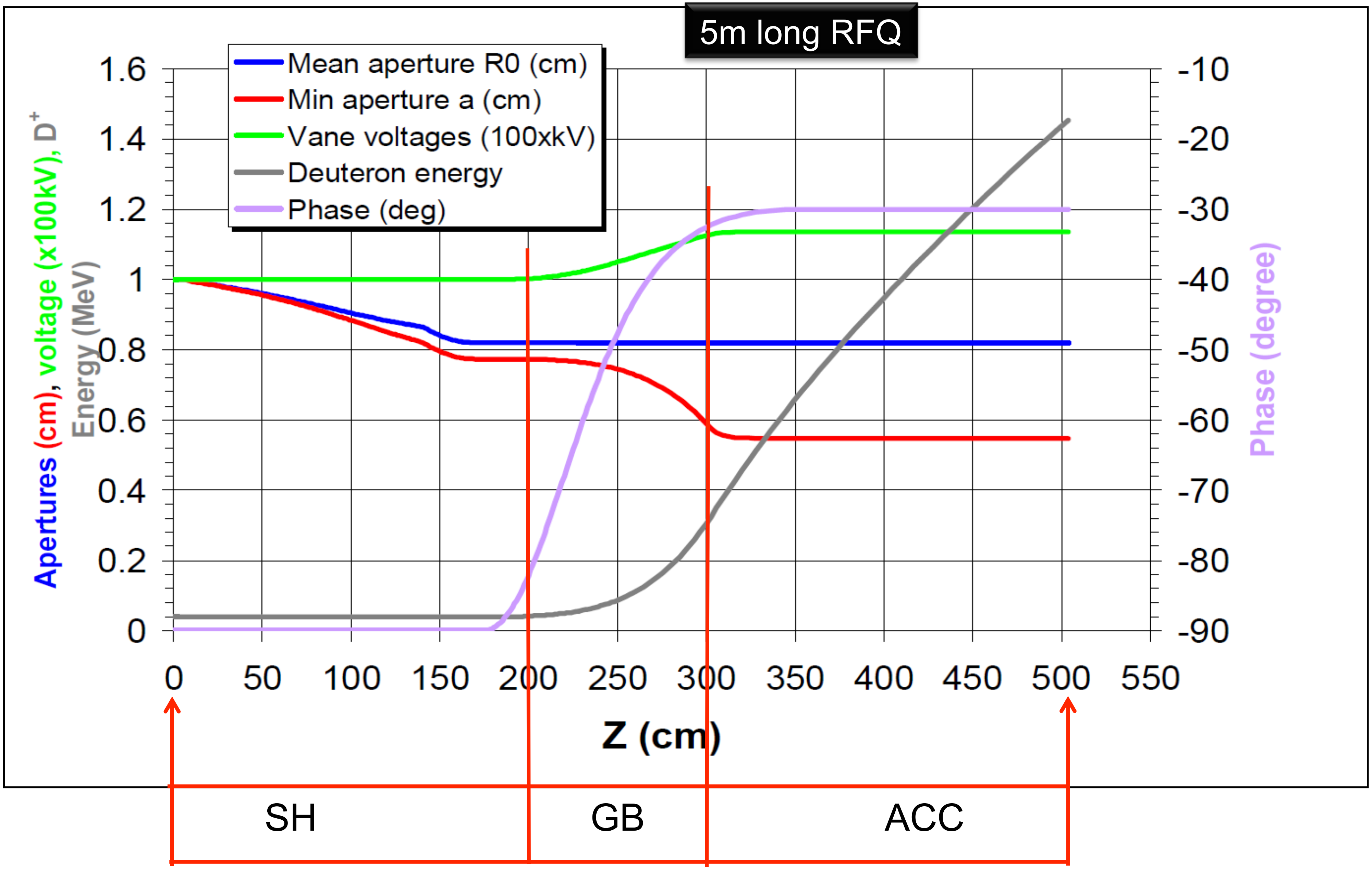


SPIRAL2 RFQ requirements

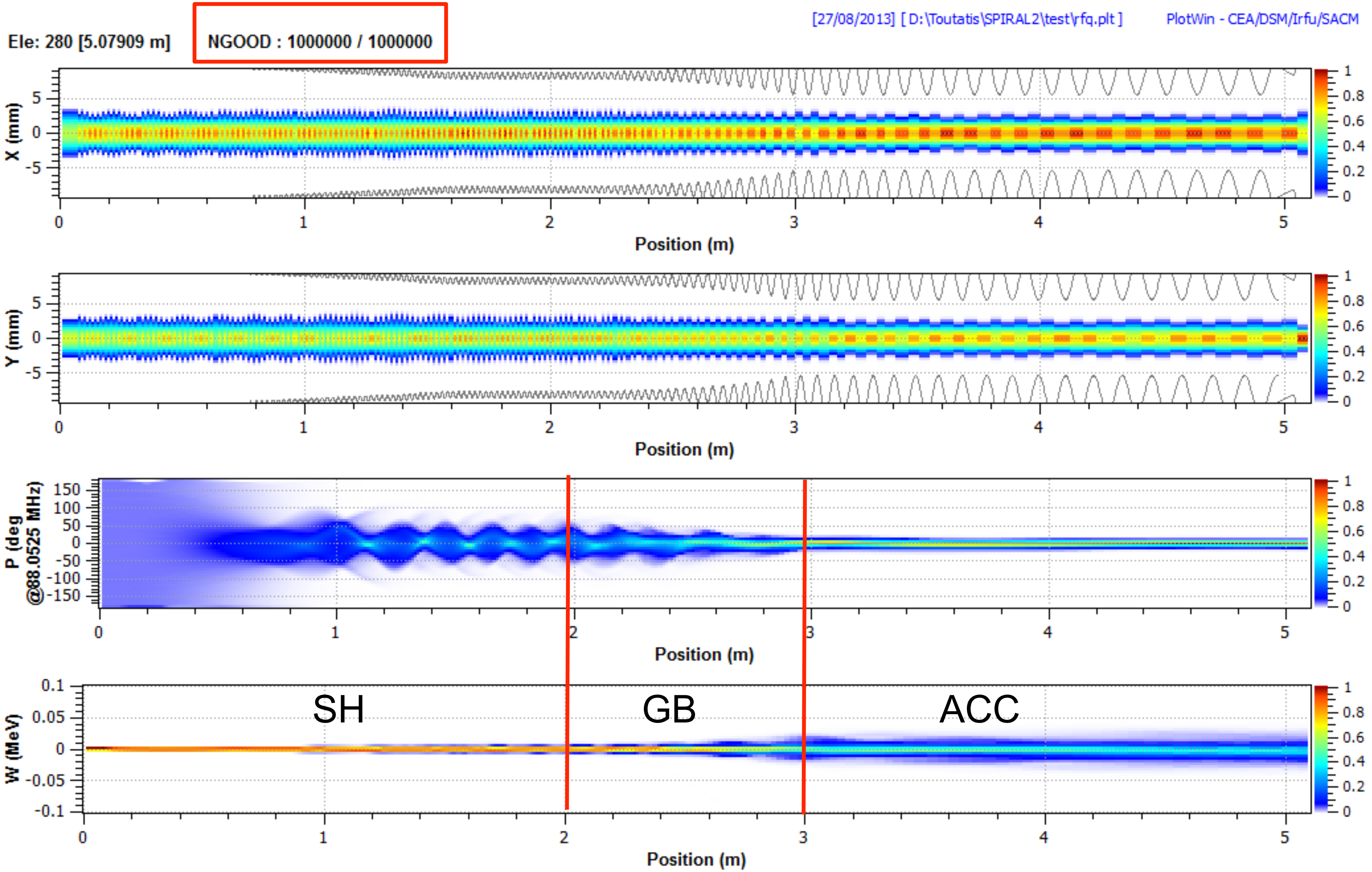
- From 20 keV/A at 0.734 MeV/A
- 5 mA H^+, 5 mA D^+, or 1 mA Q/A=1/3
- 88.05 MHz, 4-vanes, > 99% transmission



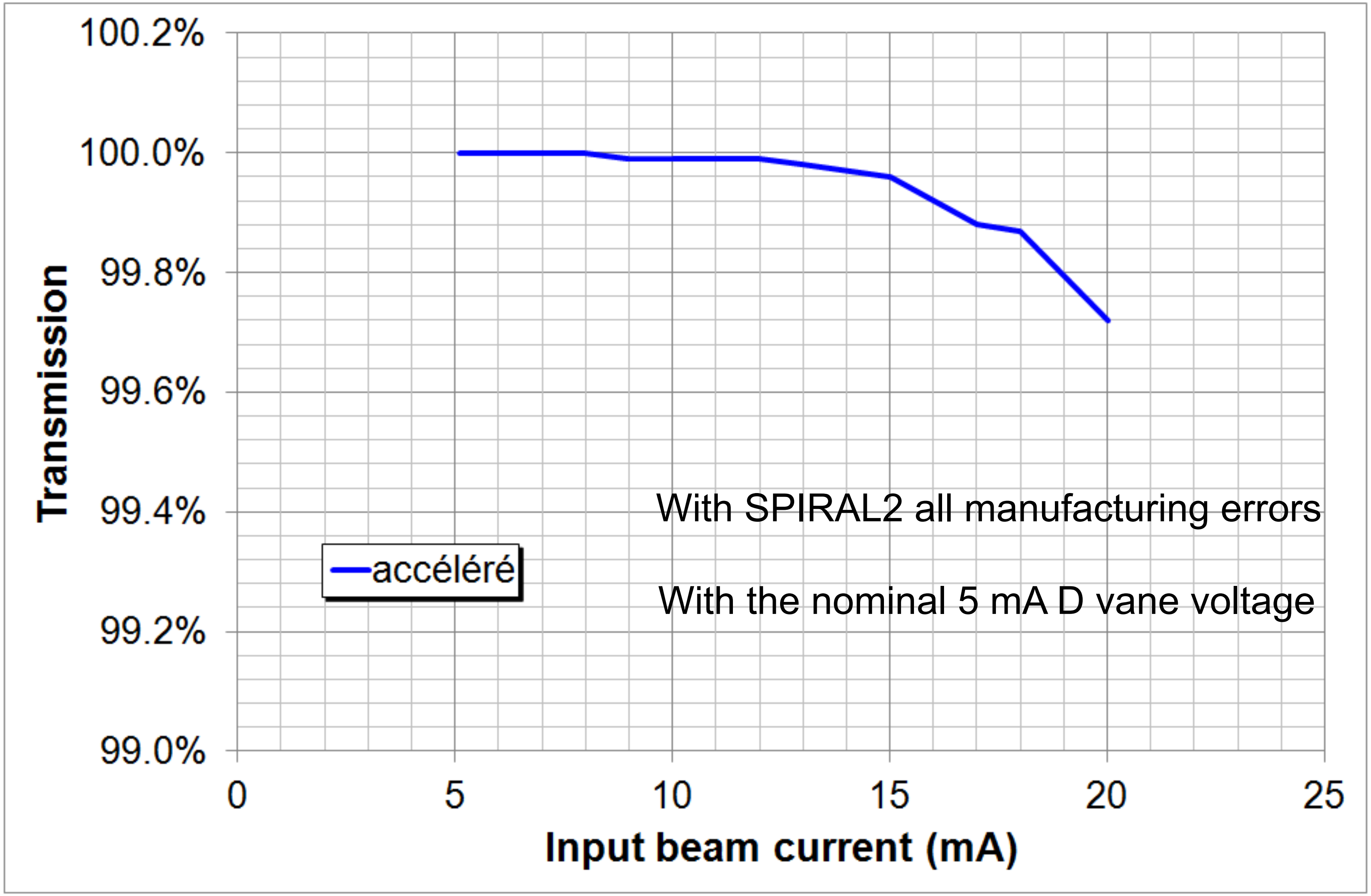
Design


5m long RFQ
Mean aperture R0 (cm)
Min aperture a (cm)
Vane voltages (100xkV)
Deuteron energy
Phase (deg)
Apertures (cm), voltage (x100kV), D+ Energy (MeV)
Phase (degree)
Z (cm)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
50
100
150
200
250
300
350
400
450
500
550
SH
GB
ACC

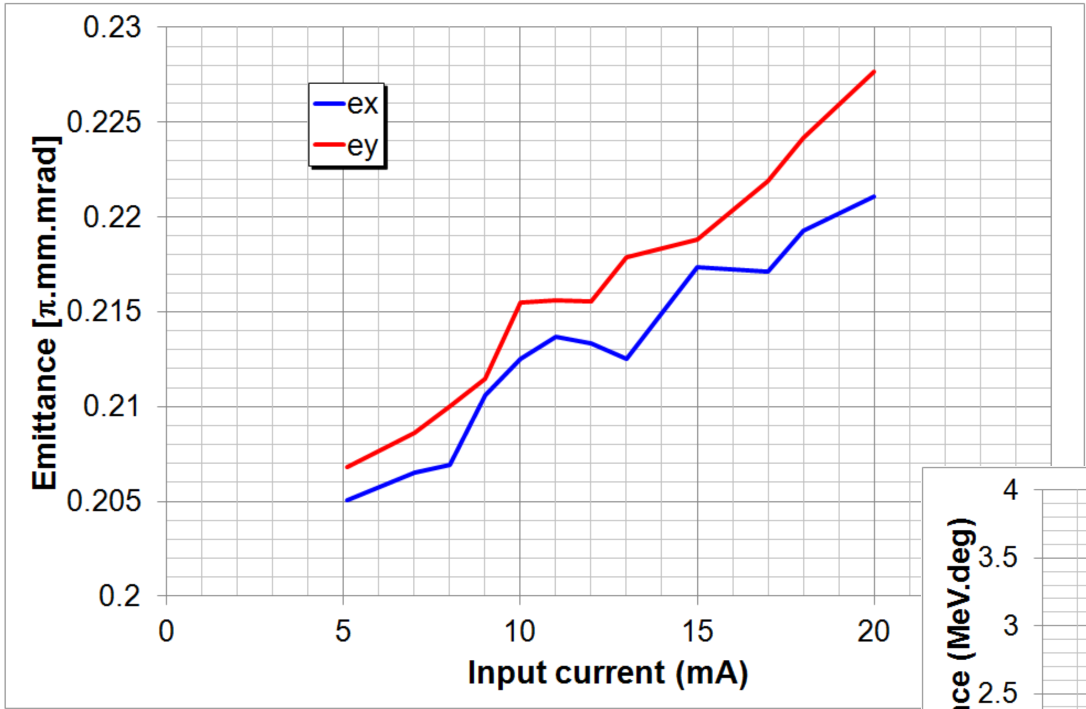
Beam dynamique



AB-NCT objectives

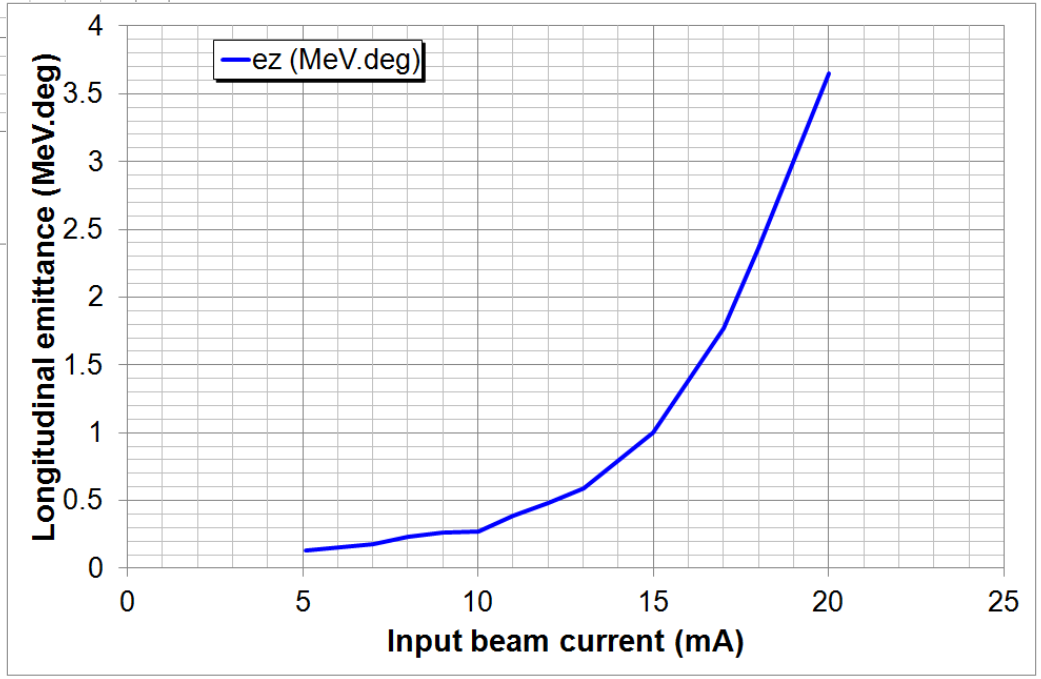


Associated output emittances



With SPIRAL2 all manufacturing errors

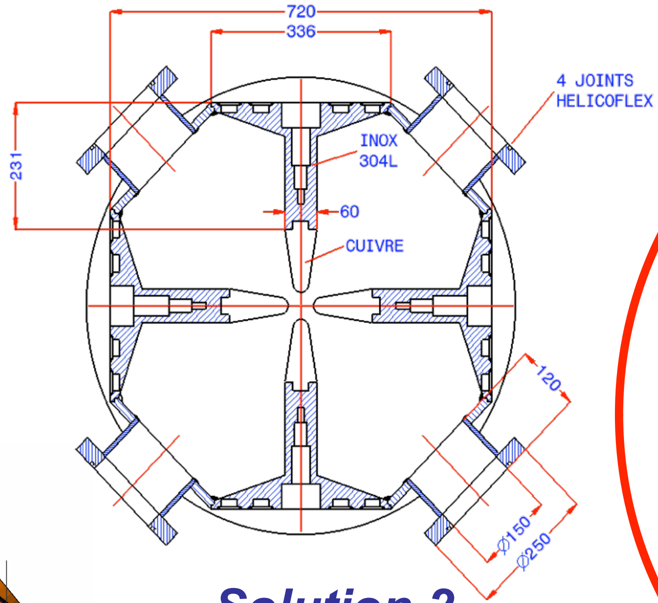
With the nominal 5 mA D vane voltage



Seems ok up to 10mA

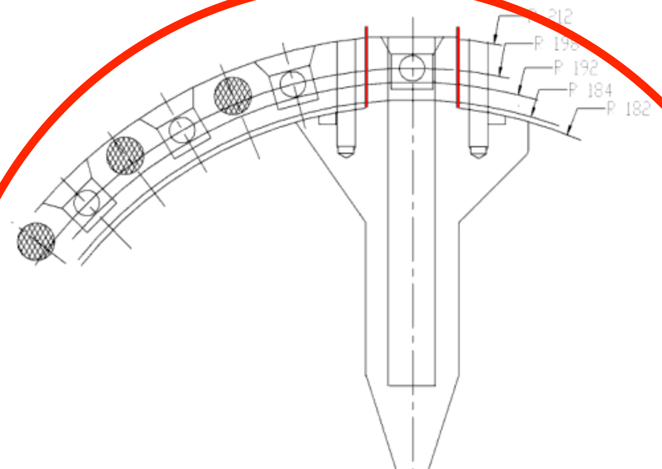
The RFQ solutions types

- We estimated the associate cost and technical risk of the following solutions



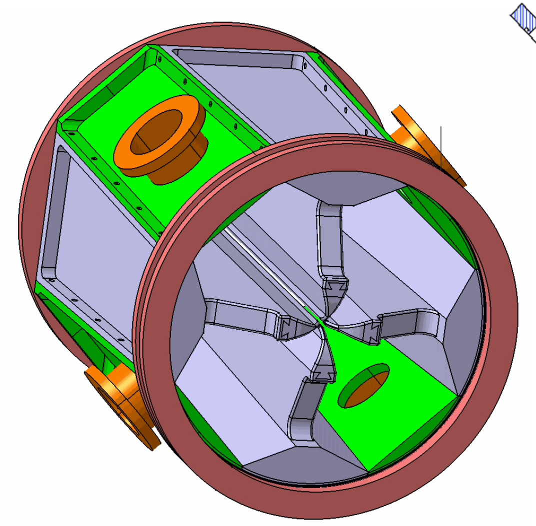
Solution 2

Copper plated
Stainless steel
88 MHz



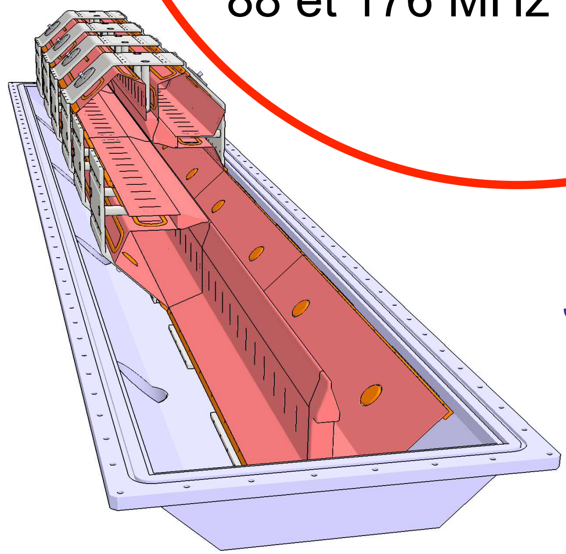
Solution 3

Assembly process
88 et 176 MHz



Solution 1

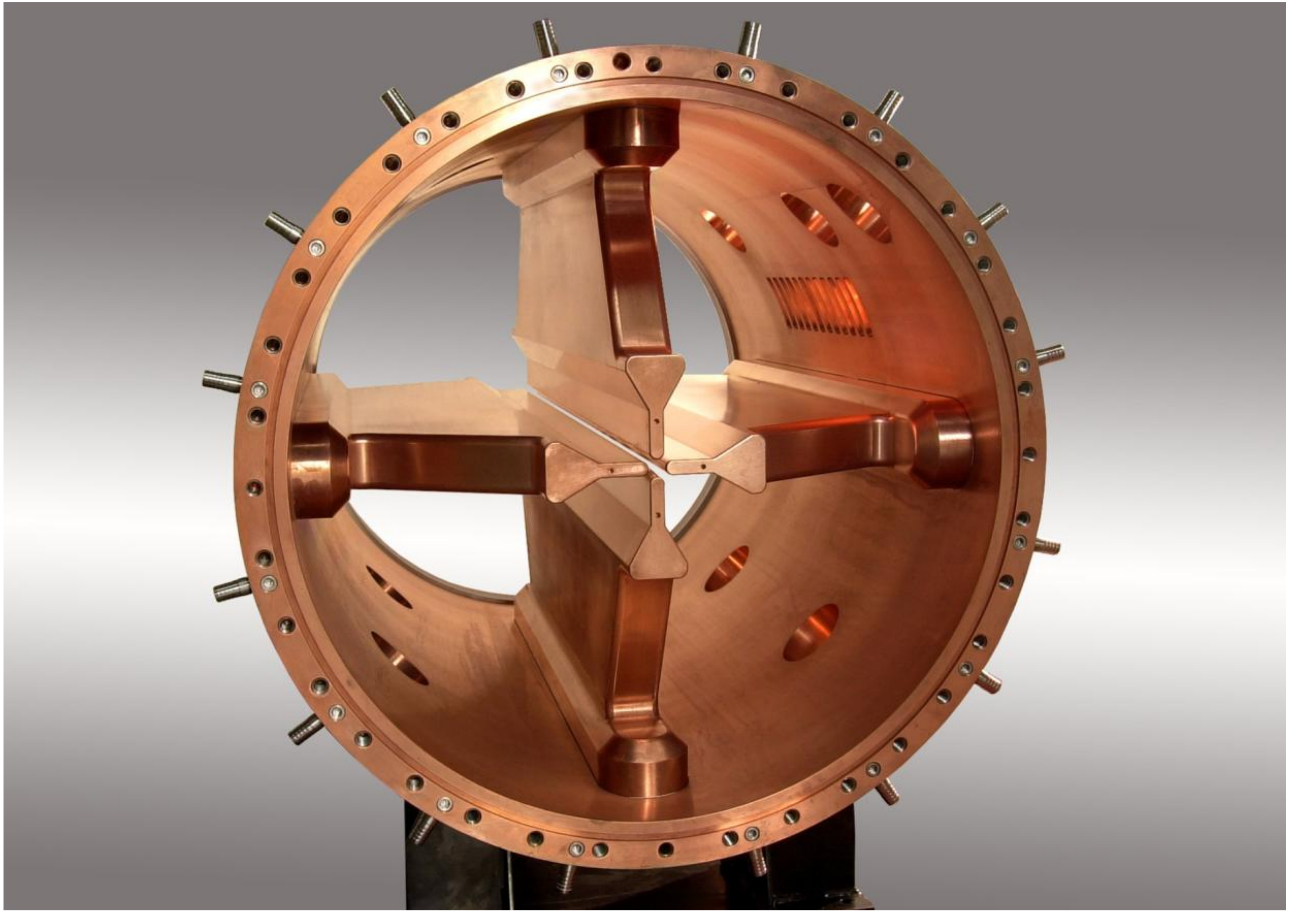
OFE copper (welded, brazed…)
88 and 176MHz



Solution 4

Skirt RFQ
88 MHz

The prototype

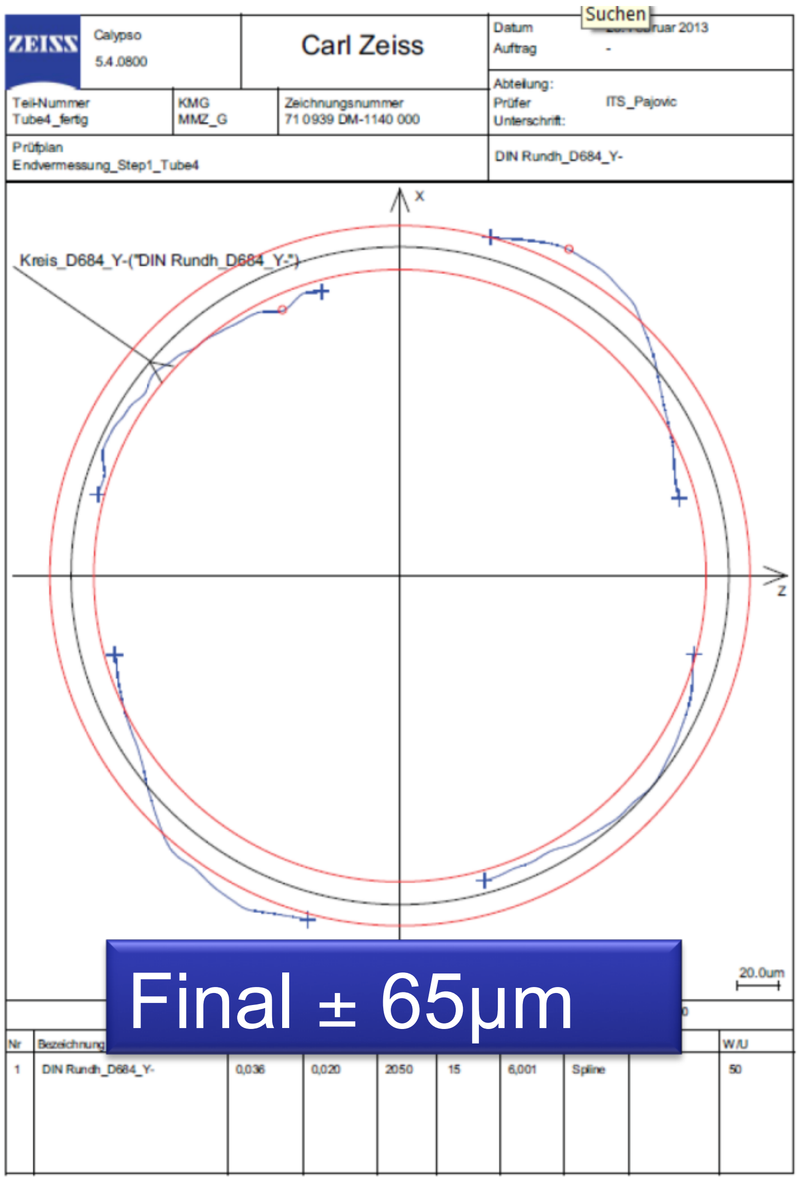


RFQ Fabrication

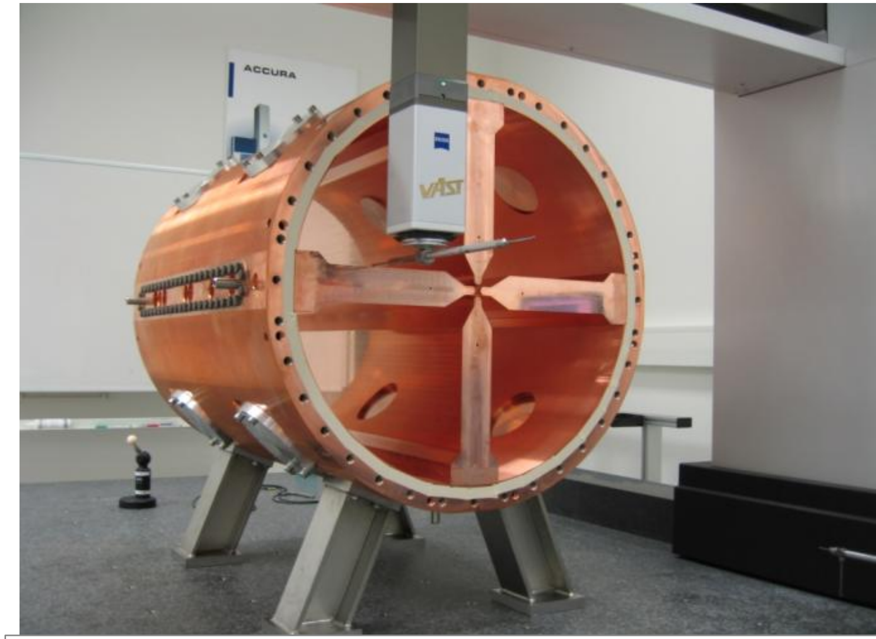
Vanes

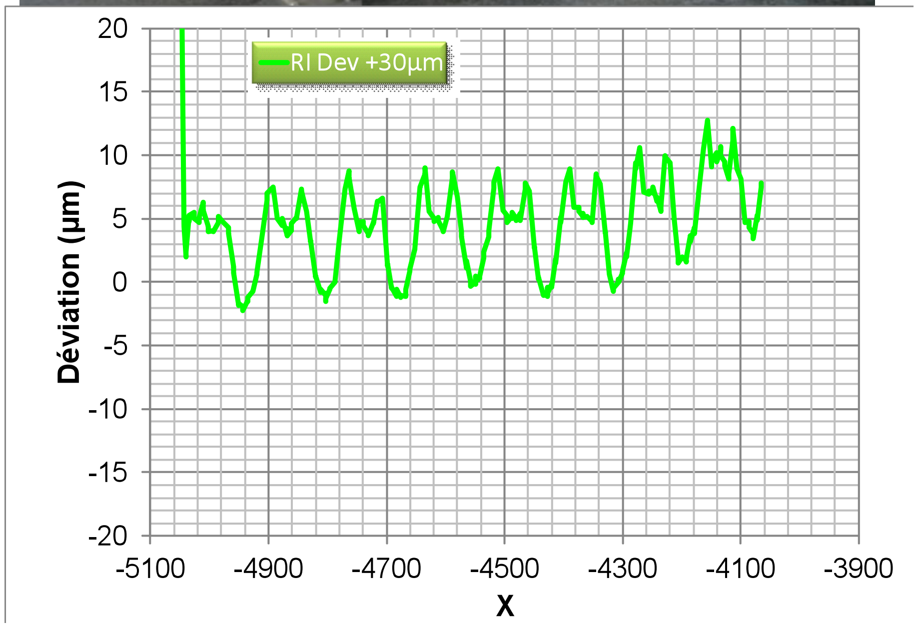
External 1-m long tubes

Measurements



Final ± 65µm





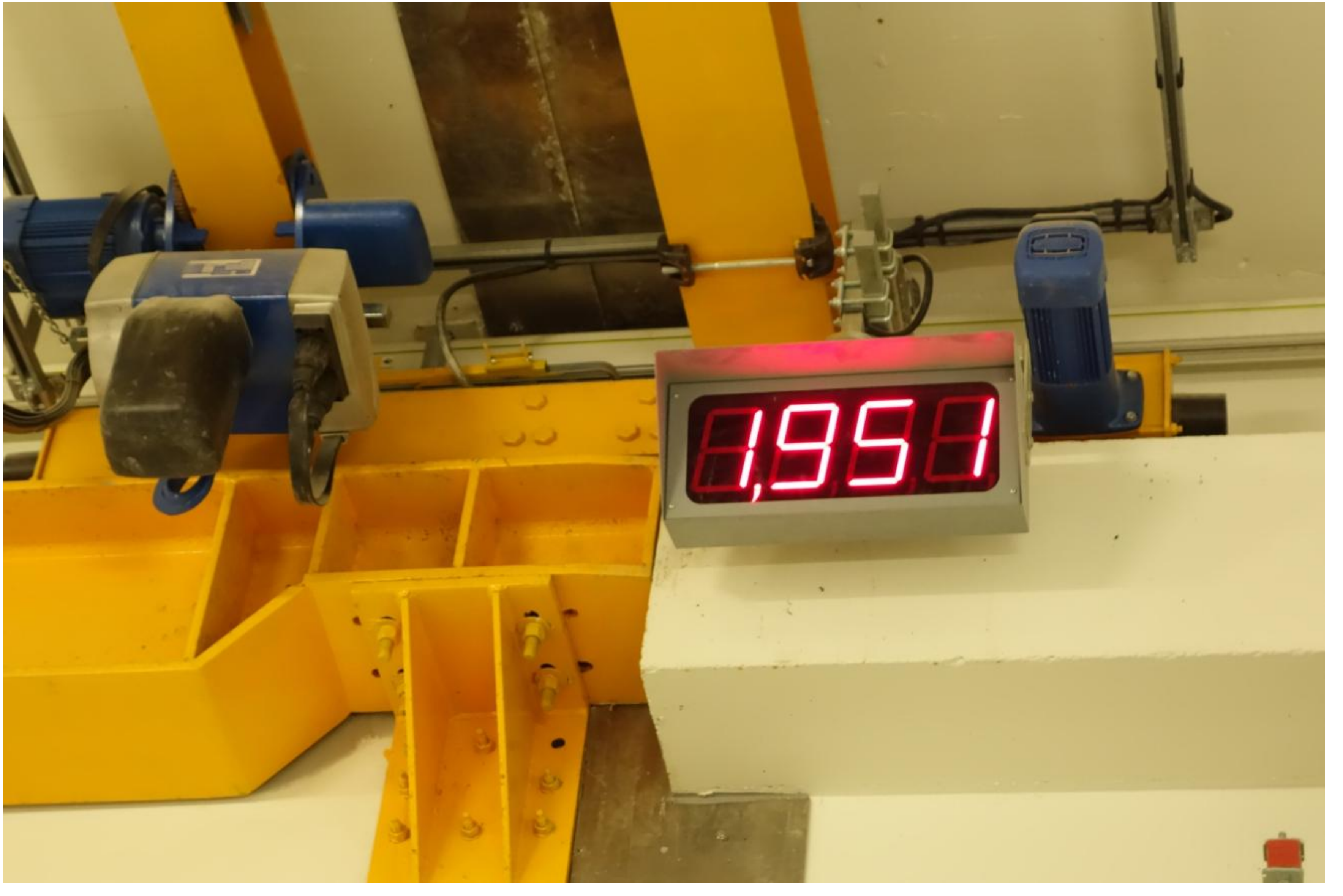
RFQ assembly

Transport and Storage

Vacuum joins preparations

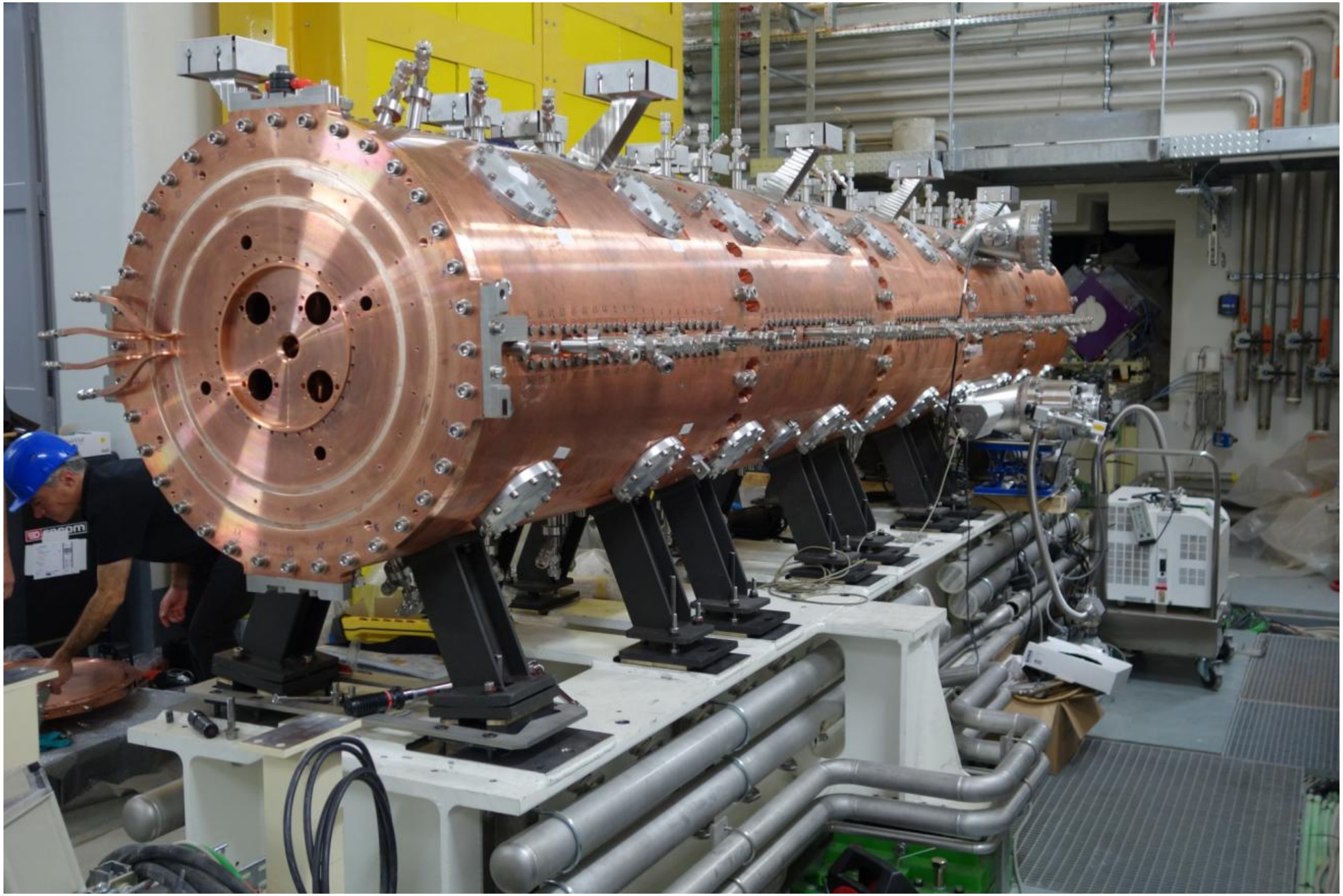
Water circuit validations

1-m long weight



Linac tunnel crane

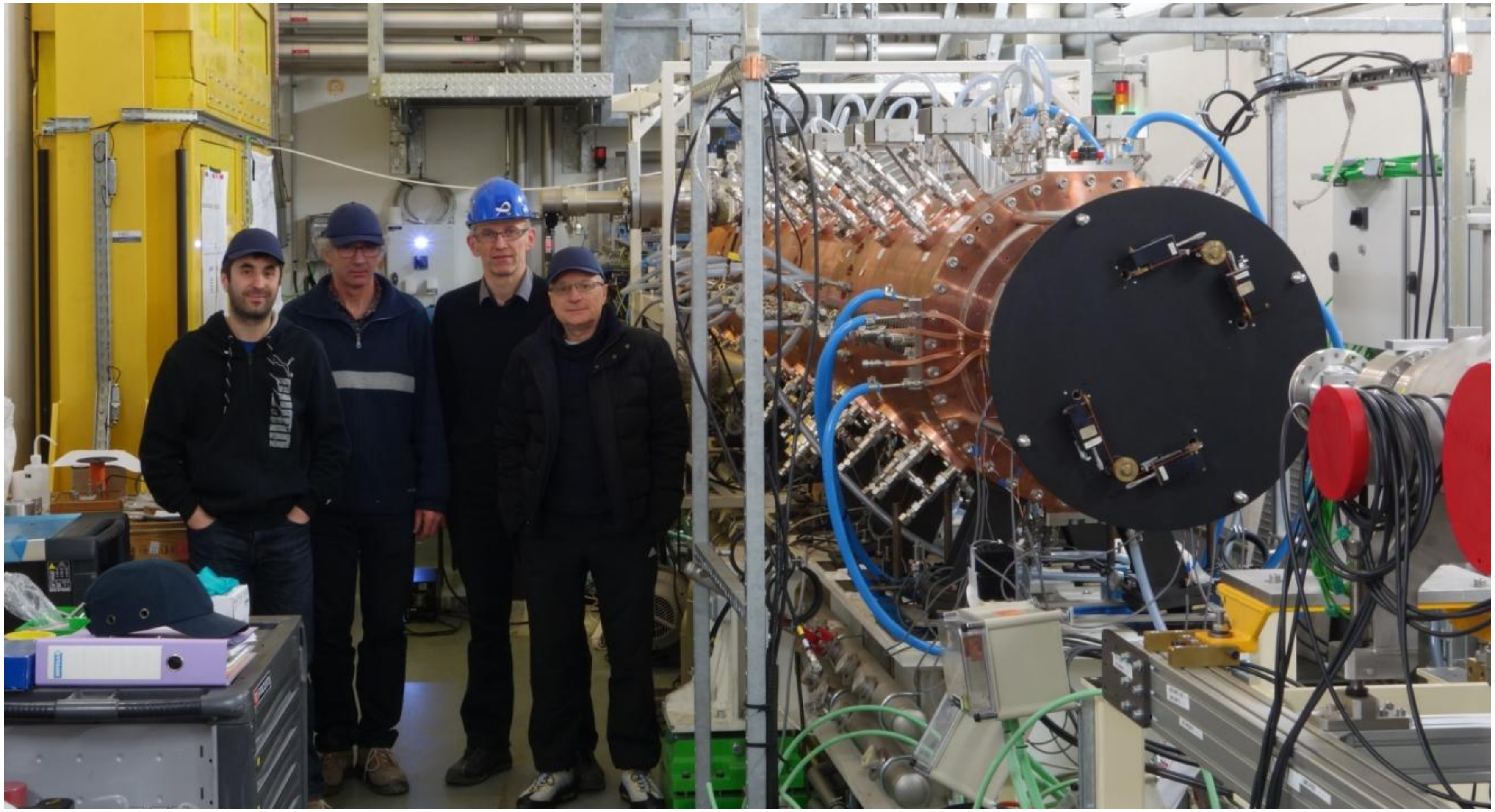
Assembled and alligned



RF tuning of the RFQ cavity

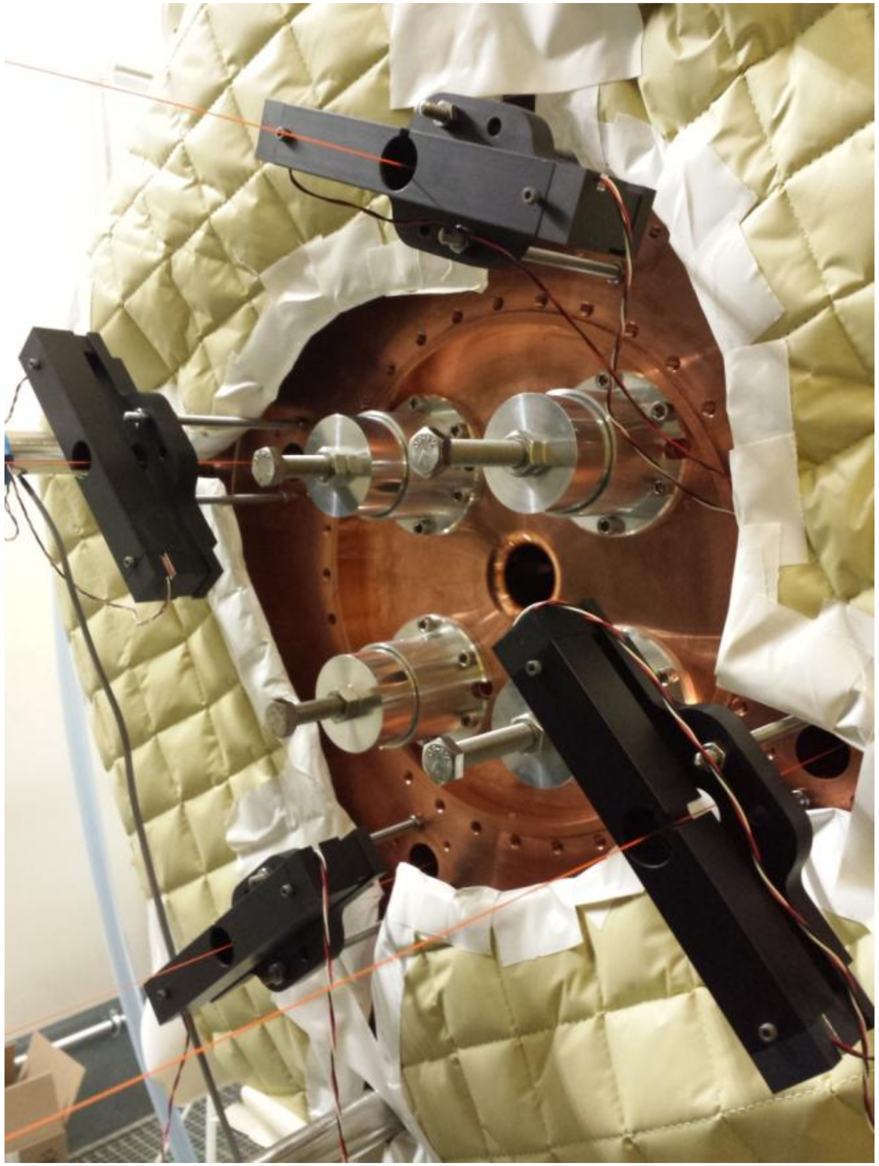
Quadrupolar (not dipolar)
Longitudinal law
Bead pull

Tuners measurements

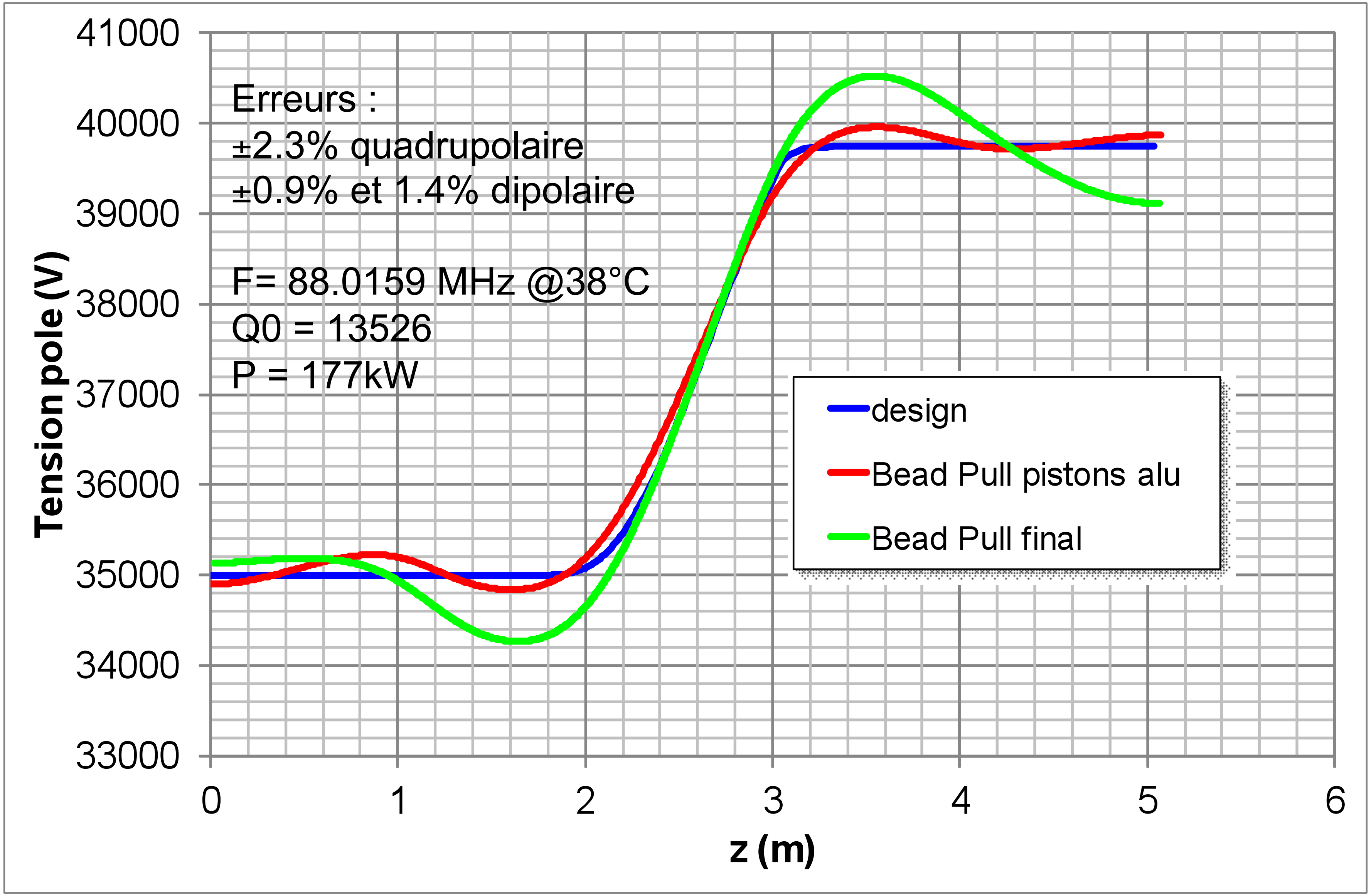


- Get the voltage law
- Compensate the manufacturing errors (+/- 65 µm) and assembly (+/-100 µm)

Dipolar mode tuning



Measured final voltage law



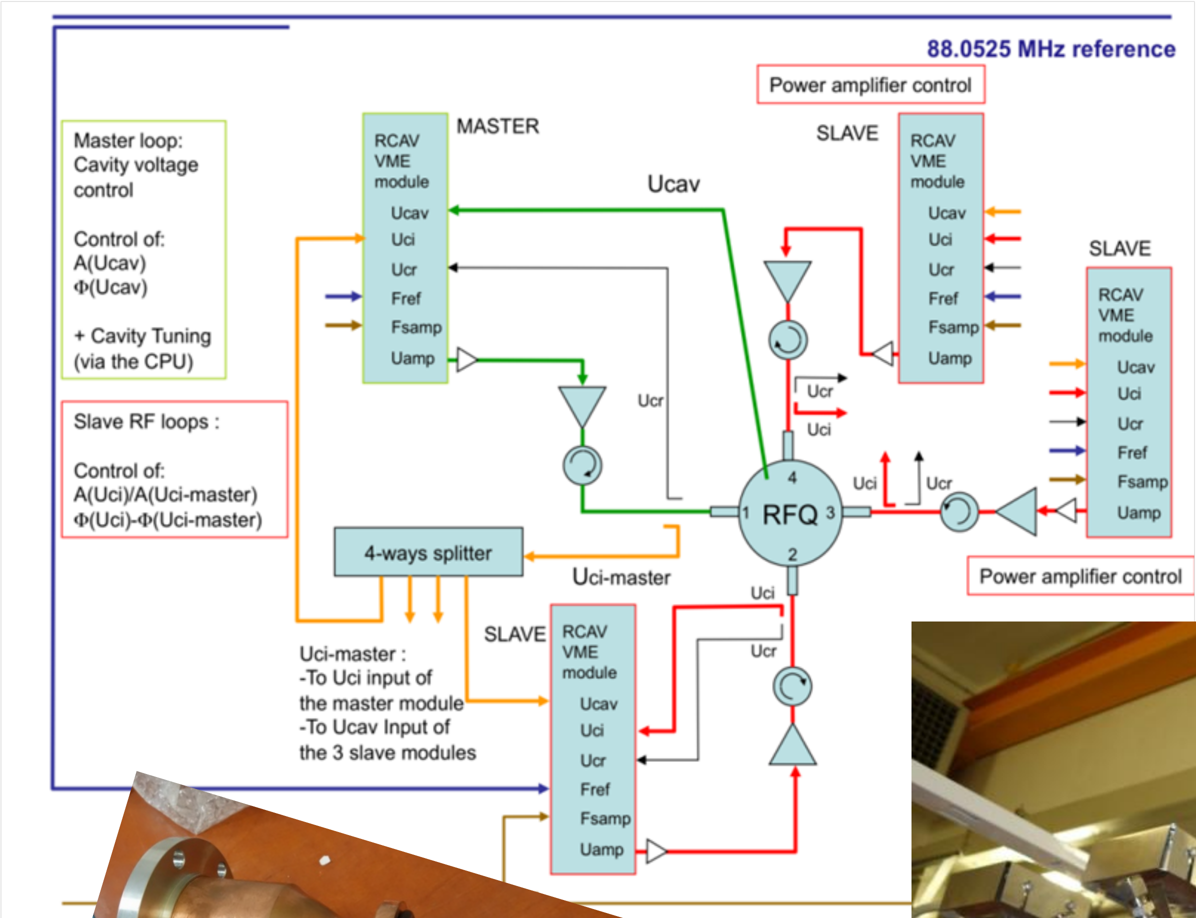
RFQ utilities

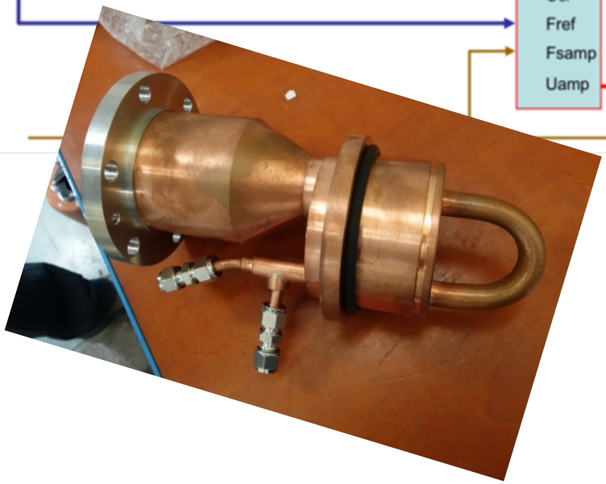
RF and LLRF

4 x 60 kW RF amplifiers

LLRF

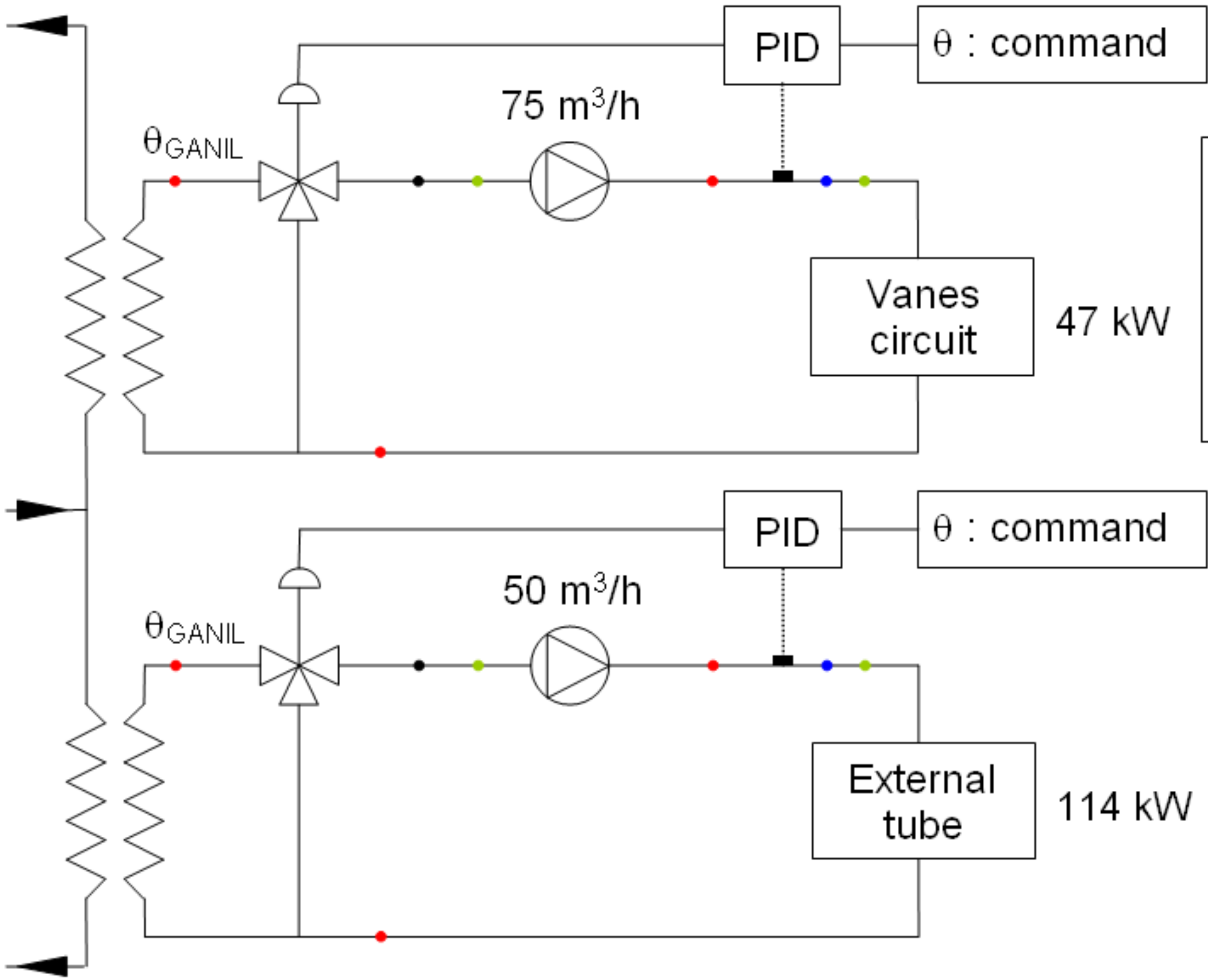
RF Power

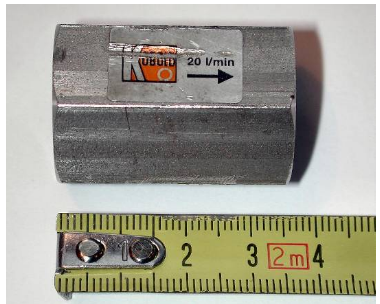




- 4 x 60 kW amplifiers
- 177 kW for SPIRAL2
- Needs for D^+ beams :
  - 90 kW in cavity
  - 2 amplifiers only

Water cooling circuits



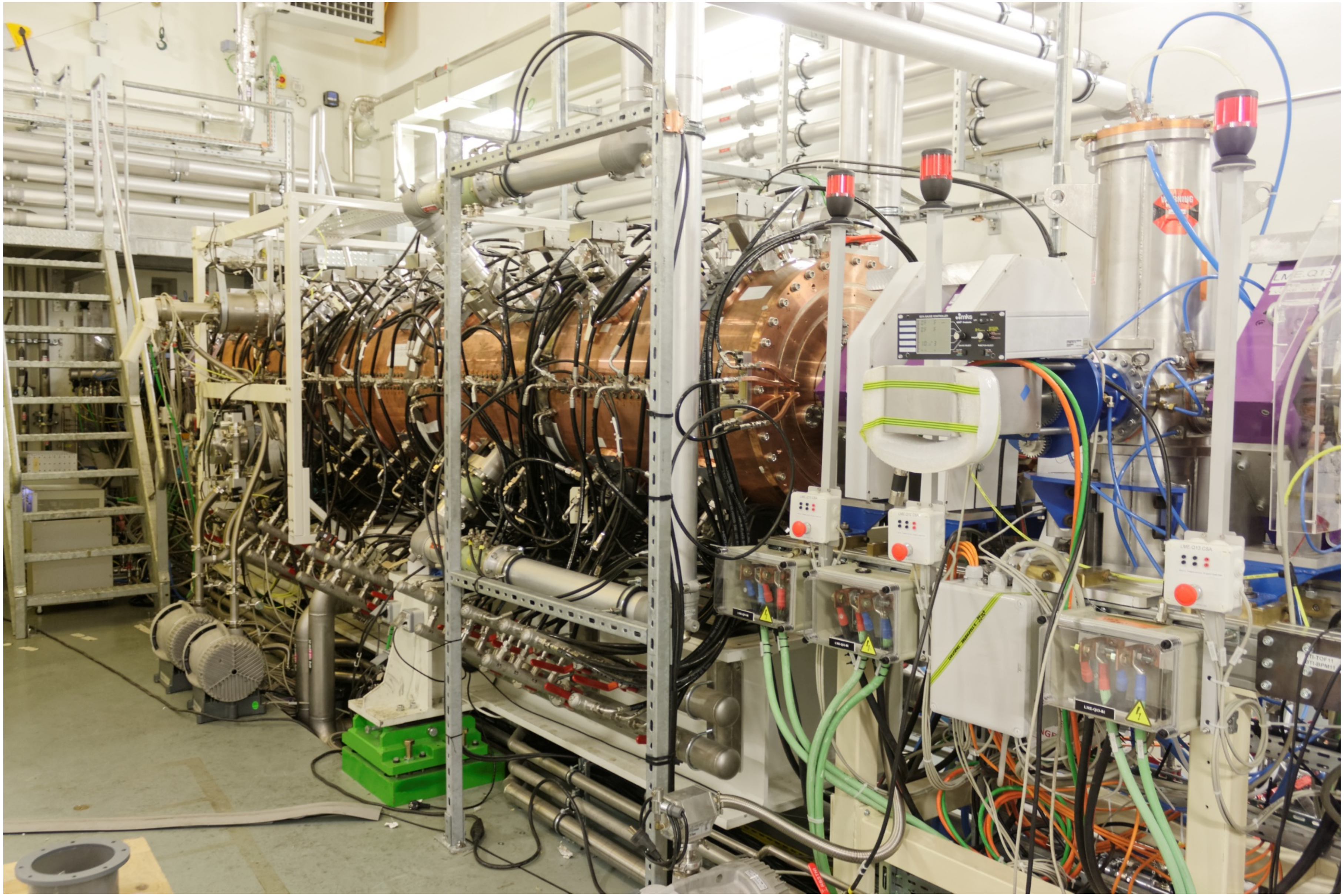


SPIRAL2 skids

Regulation to about +/- 0.1 °C

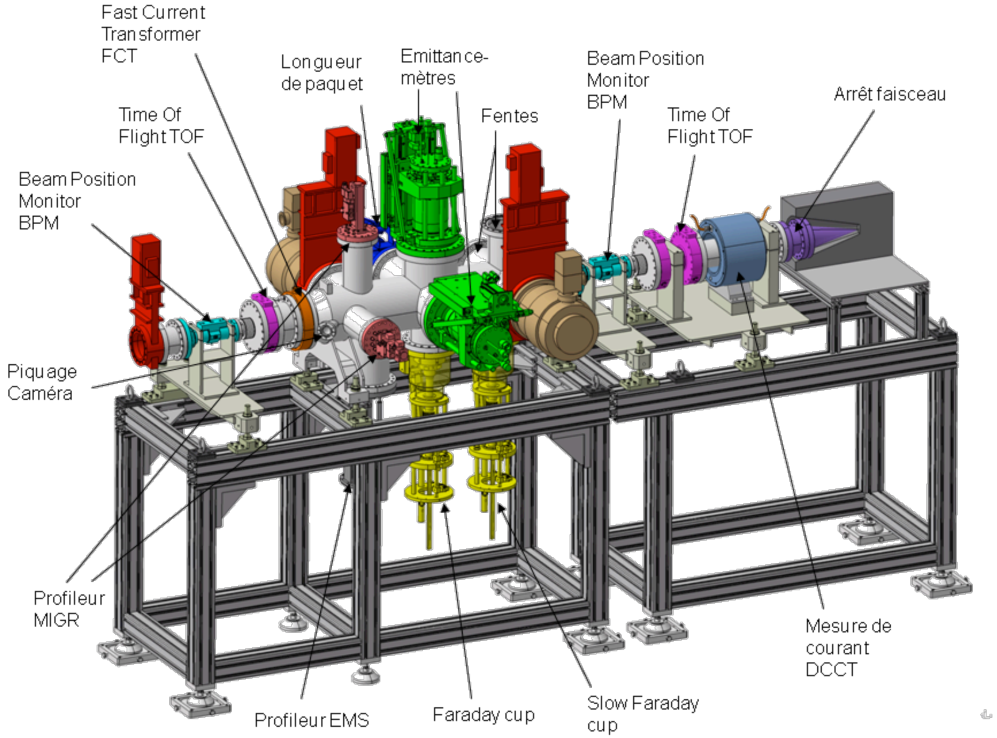
RFQ
Concluding remarks

Today



RFQ qualification

- Cavity RF conditionning
  - @ water cooling PIDs
  - @ LLRF
  - @ RF amplifiers
- Vane voltage meas.
  - X measurements
- Beam characteristics
  - Transmission vs Kilpatrick
  - Measurements vc Computation
  - With proton first
  - $^{4}He^{2+}$, $^{18}O^{6+}$, Metallic ions, Deutons



With the « Injector Test Bench » to qualify the RFQ beam and control the diagnostic performances

Cost and planning @ AB-NCT

- Cavity about 2 M€ all included (water, vacuum, supports)
- RF : about 720 k€ can be reduced for the D+ only option to probably about 400k€

- Manufacturing
  - Call for tender : 1 year
  - Manufacturing : 2 years
  - Installation : 1 year
  - RF conditionning and beam tests : 6 months