SWELL progress and status

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FCC Week 2023

08 th of June 2023

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- Introduction and context
- Mechanical design and challenges of the 1.3 GHz SWELL cavity (reminder)
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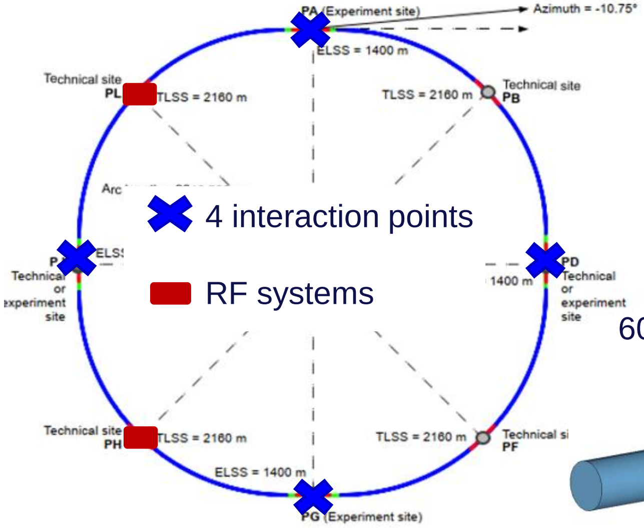
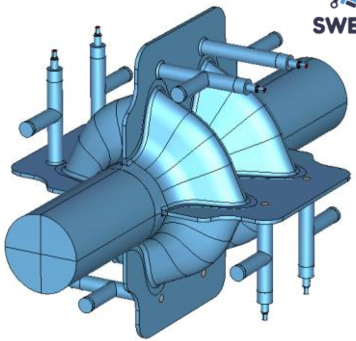
- What’s next ?

RF system for FCCee

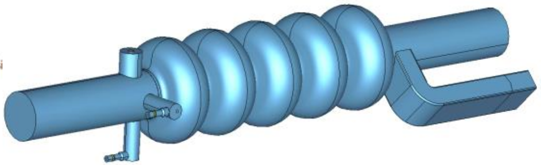
Alternative scenario at 600 MHz

	Energy (GeV)	Current (mA)	RF voltage (GV)
Z	45.6	1280	0.120
W	80	135	1
H	120	26.7	2.08
ttb	182.5	5	11.67





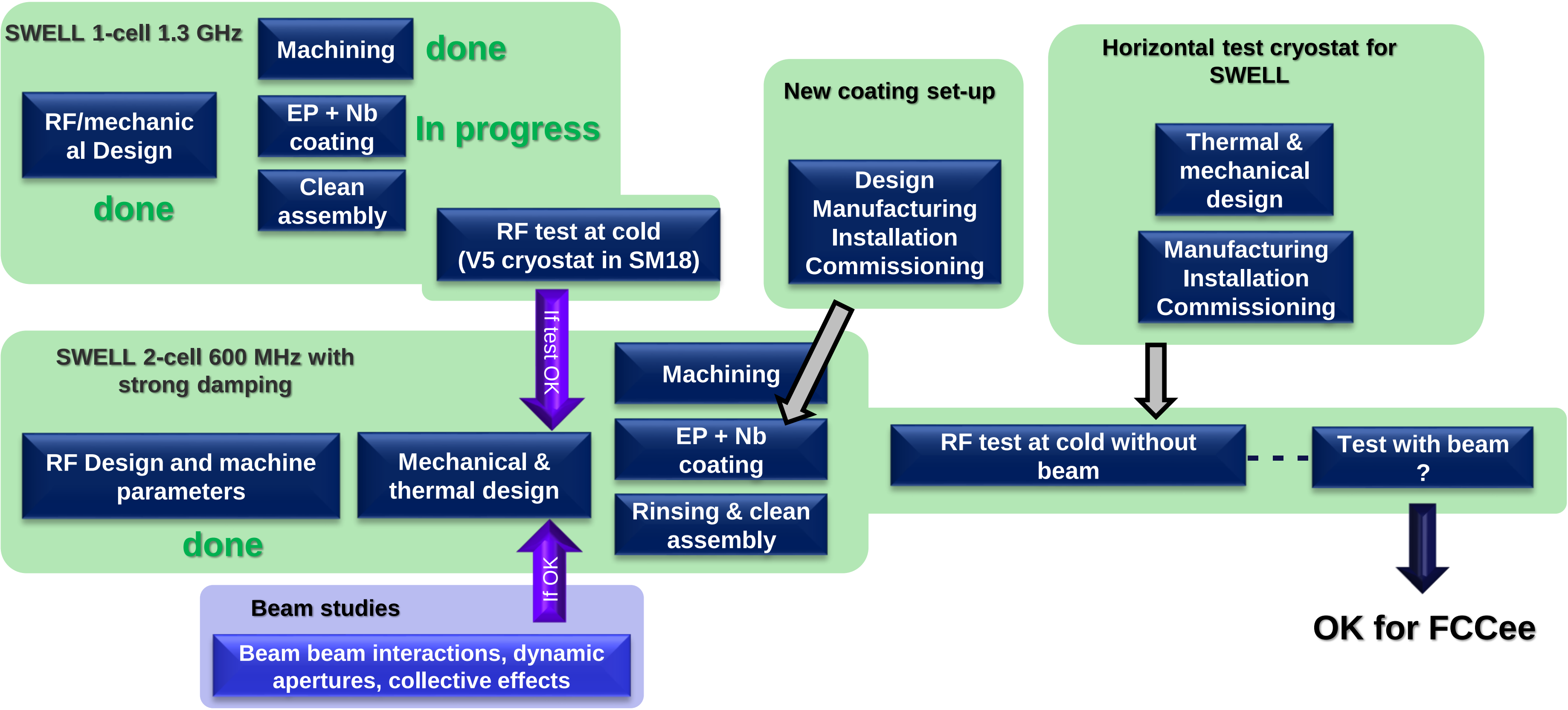
600 MHz 2-cell Nb/Cu for Z, W&H



600 MHz 5-cell bulk Nb for ttb and booster

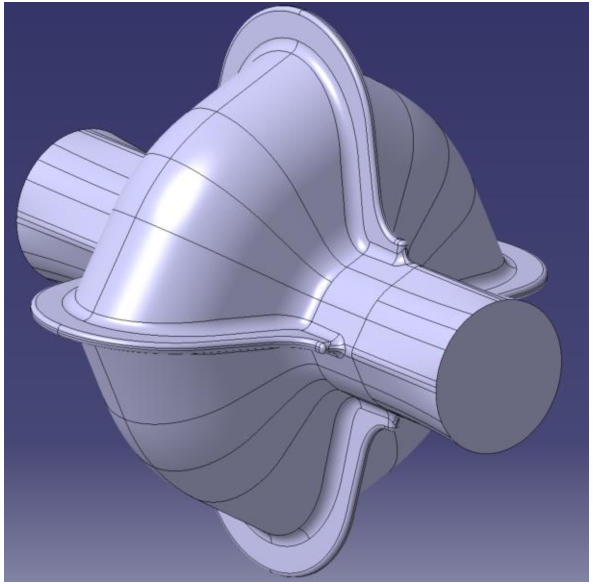
A new optimized RF system with a single operating RF frequency and only two cavity types

SWELL cavity feasibility study & development plan

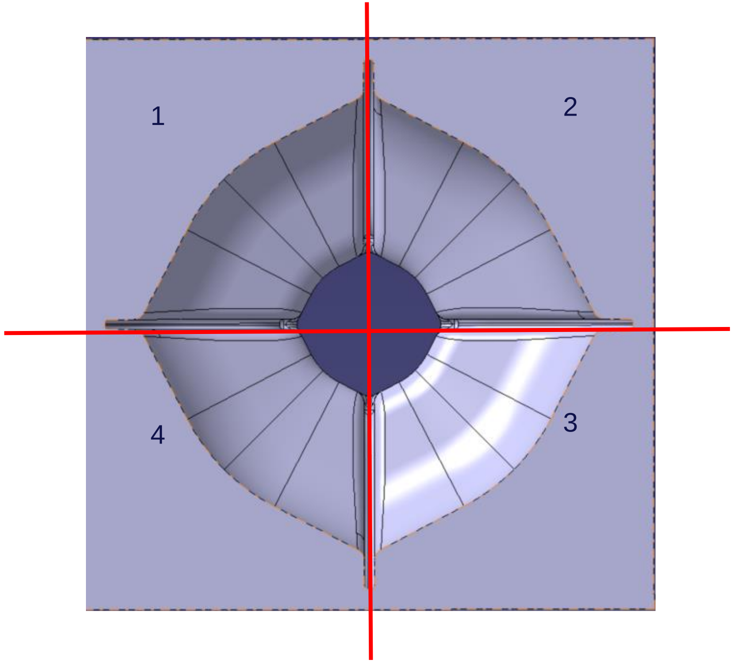


Mechanical design and challenges of the 1.3GHz SWELL cavity (reminder)

RF shape and volume

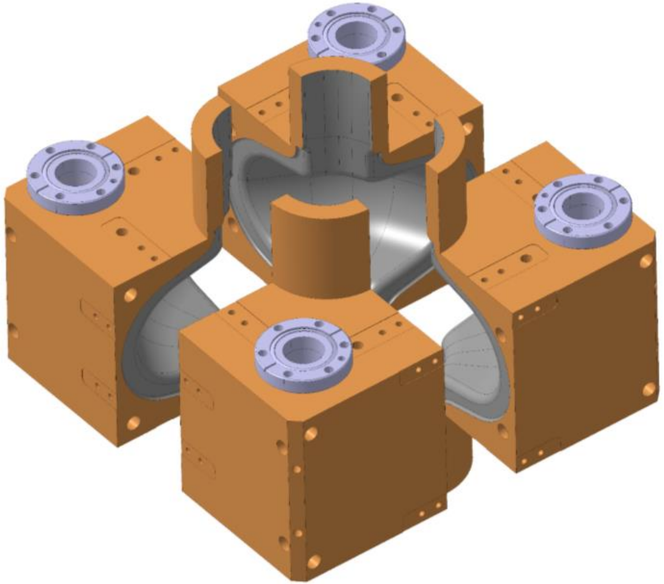


Mechanical shape and volume
4 blocks to be machined independently

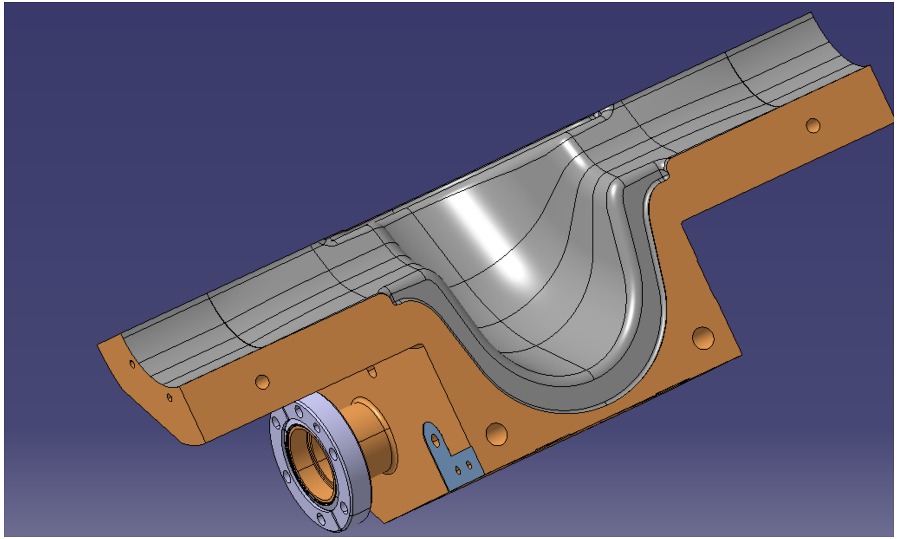


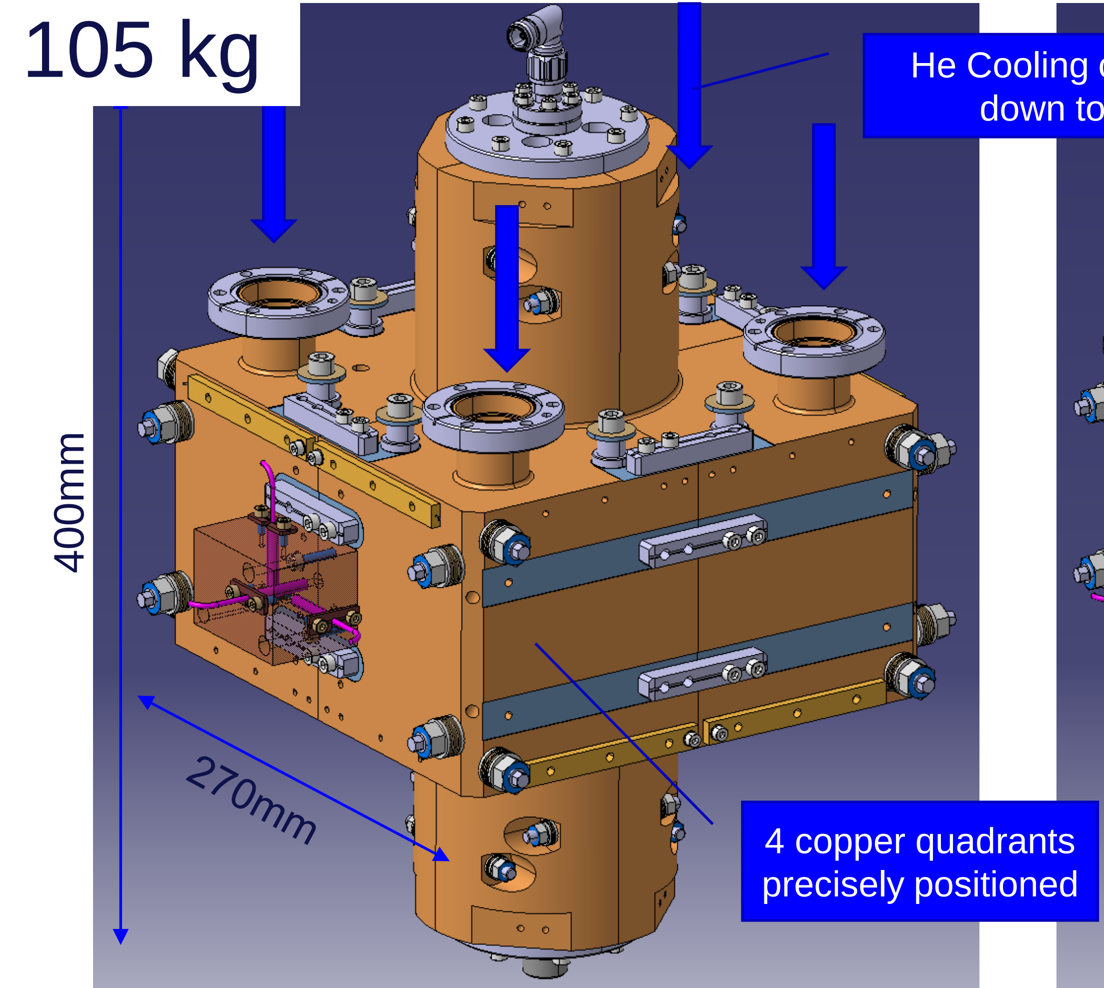
Mechanical design and challenges of the 1.3GHz SWELL cavity (reminder)

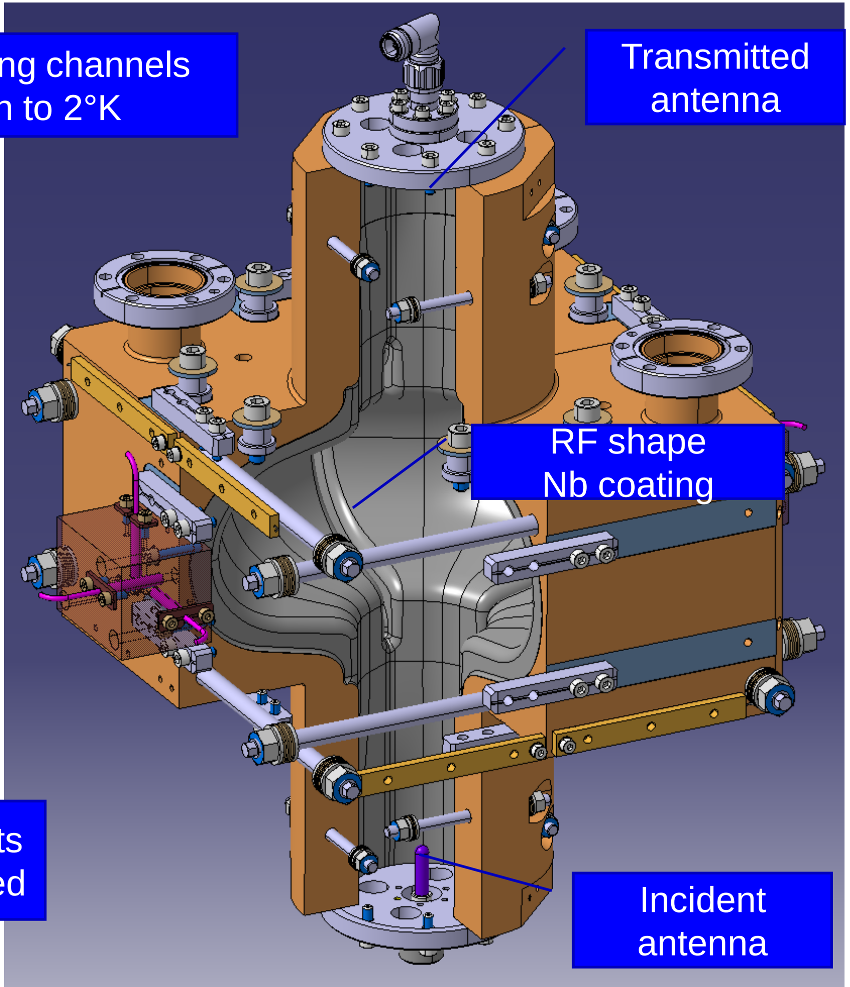
Four Nb coated copper blocks precisely assembled together



Each block is precisely machined on a 5 axis CNC machine.




105 kg
400mm
270mm
He Cooling channels down to 2°K
4 copper quadrants precisely positioned

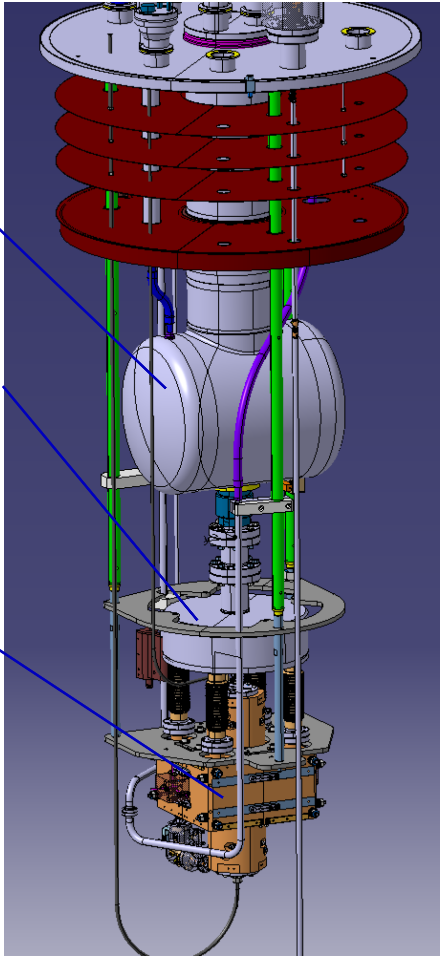

Transmitted antenna
RF shape Nb coating
Incident antenna

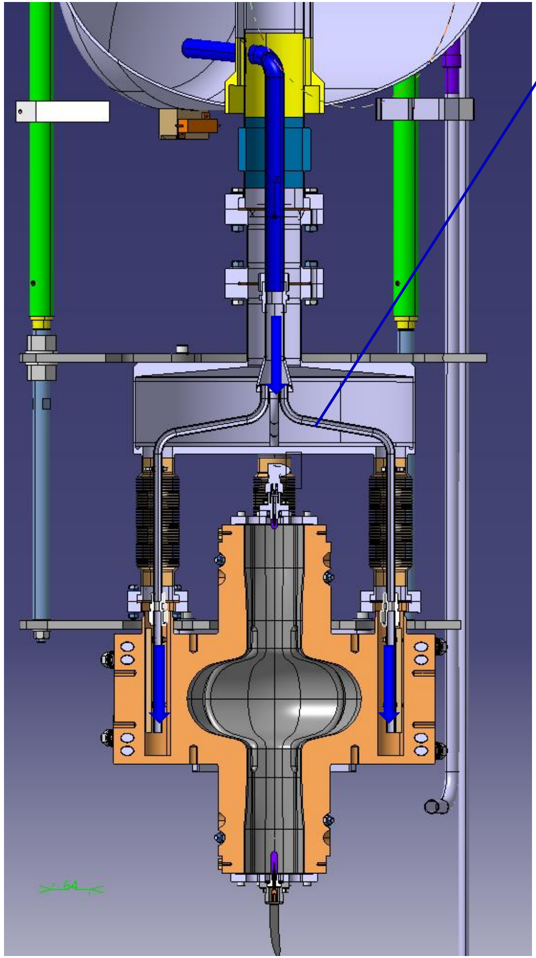
V5 insert

He reservoir

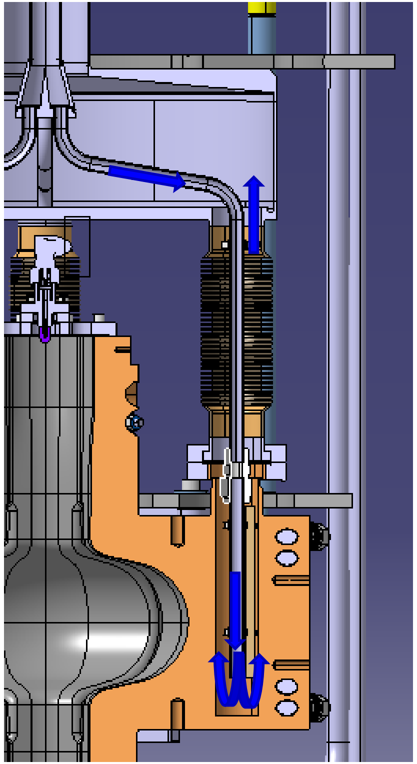
He gas collector

Swell cavity



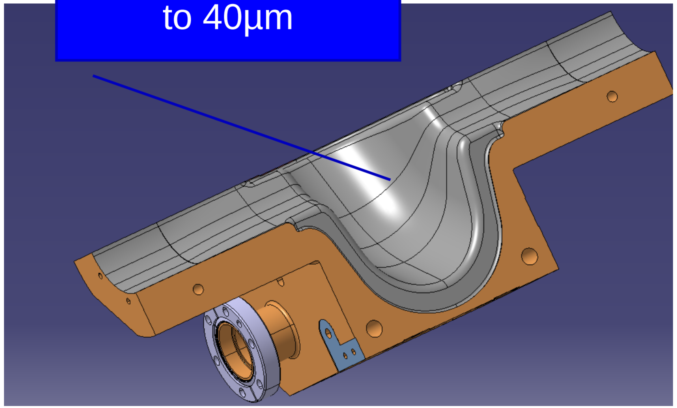


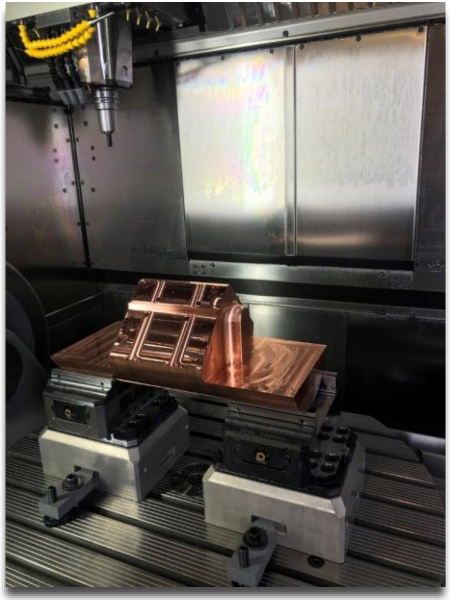
4 cooling channels



Fabrication and assembly challenges

Each quadrant needs to be precisely machined and positioned.

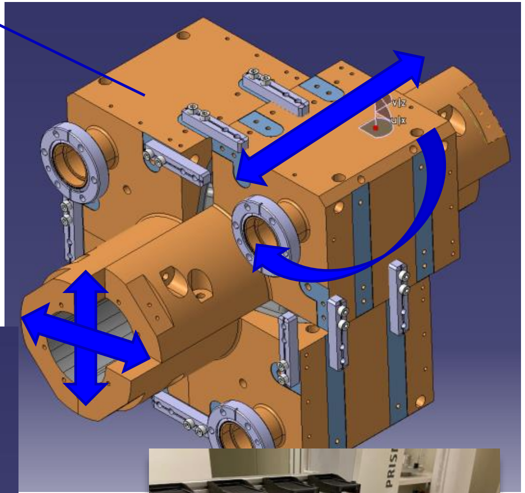




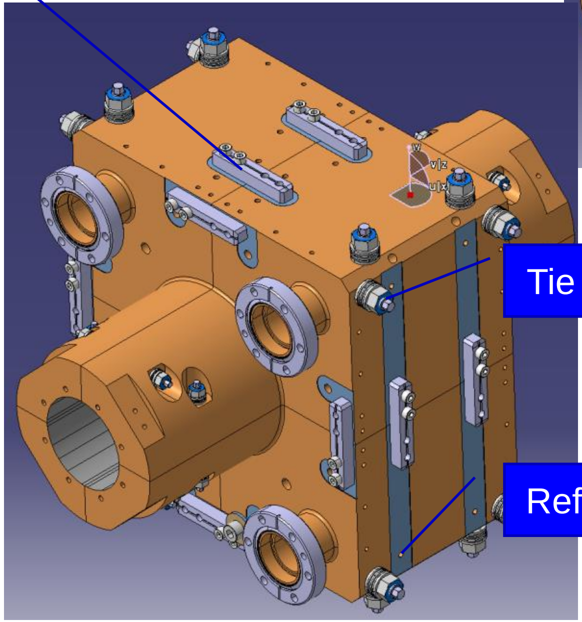
1 -Reference surfaces are machined after the cavity has been aligned and tightly assembled with tie rods.

2 – Reference surfaces will be used to find back the position for final assembly after coating using alignment keys.

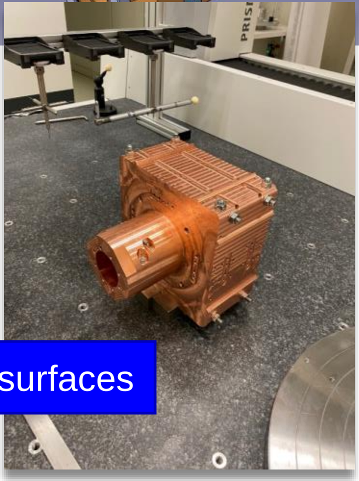
4 blocks aligned in metrology thanks to fiducial surfaces on the outside of the cavity (5µm)



Alignment keys



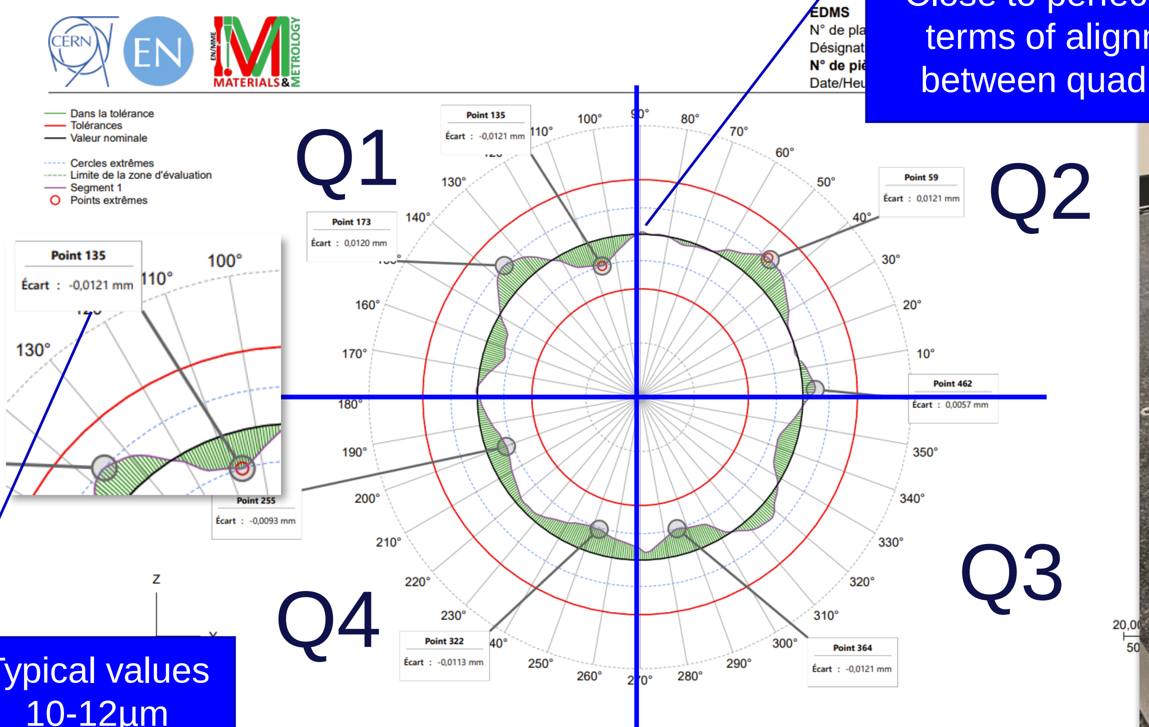
Tie rods



Reference surfaces

Machining and alignment completed

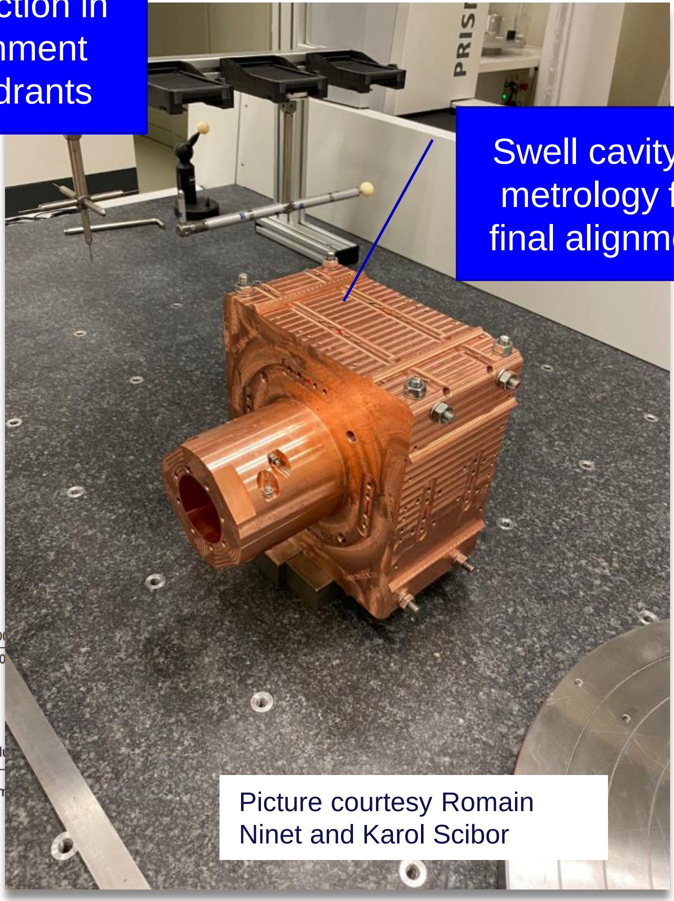
Close to perfection in terms of alignment between quadrants



Typical values 10-12µm

		Valeur mesurée	Limite supérieure	Points	Filter type	Lc	upr	Probe radius	Vmess[mm/sec]	Evalu
O	CIRC-X+	0,0242	0,0500	459	Passe-bas Spline	-	50 -	4,9999	5,000	Elém

Results picture courtesy Bartosz Bulat

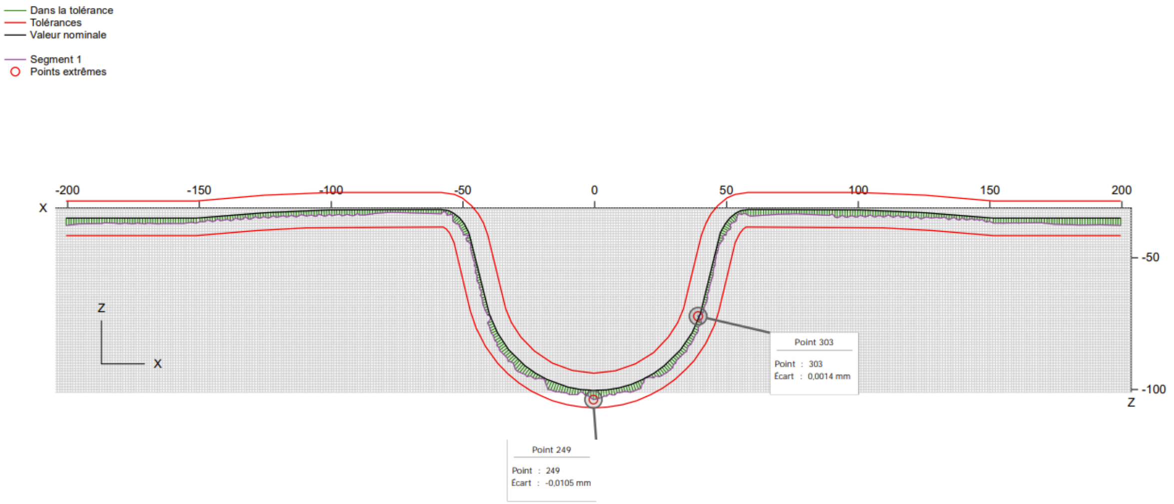


Swell cavity i metrology fo final alignme

Picture courtesy Romain Ninet and Karol Scibor

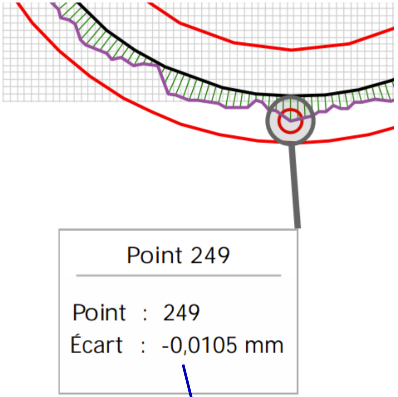
Outstanding machining precisions

EDMS	**2732101**
N° de plan	FCCACS1GRCA0004
Désignation	SWELL 1.3GHz 1/4 CAVITY -BEFORE ELECT…
N° de pièce	**FCCACS1GRCA0004-2**
Date/Heure	06/05/2022 11:51



Best Fit	Translation	Rotation
X	0,0000	0,0000
Y	0,0000	0,0000
Z	0,0000	0,0000

Nom	Valeur mesurée	Limite supérieure Limite inférieure	Points	Filter type	Lc	Probe radius	Vmess[mm/sec]	Evaluation method
Forme profil8	0,0209	0,0400 0,0000	499		-	1,4903	3,000	Direction vecteur nominal

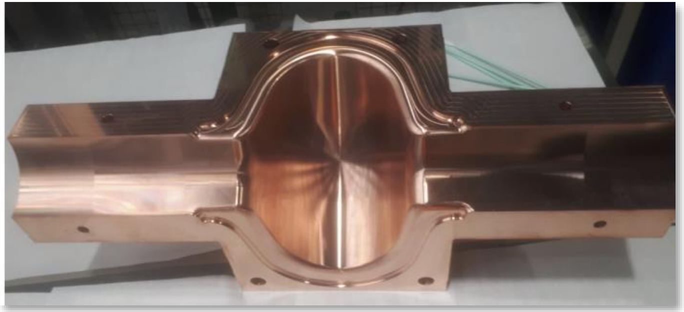


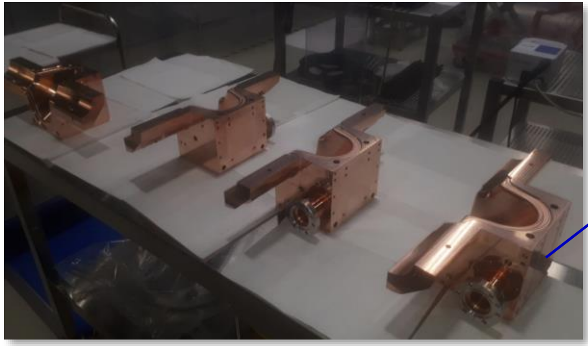
Typical values 10-12µm

Results picture courtesy Bartosz Bulat

Preparation of the 1.3 GHz SWELL measurements.

Collection of all the components (cleaned for clean room assembly)

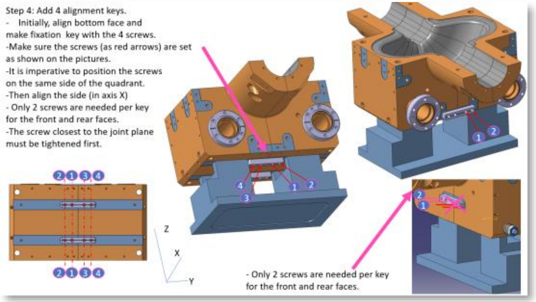


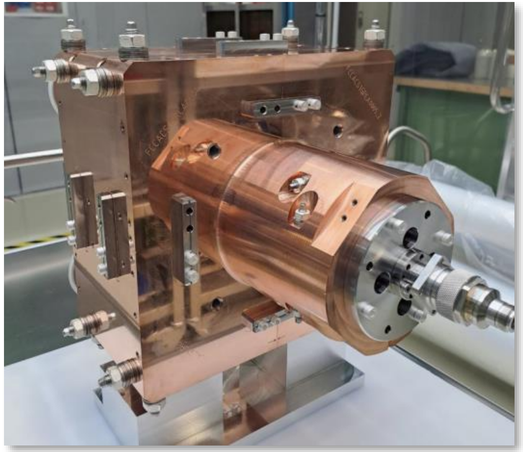


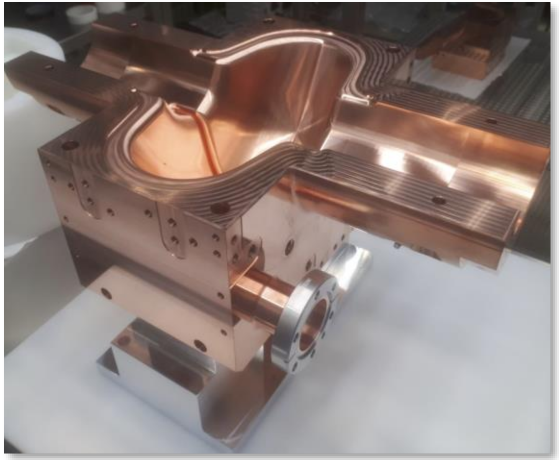
Quadrants

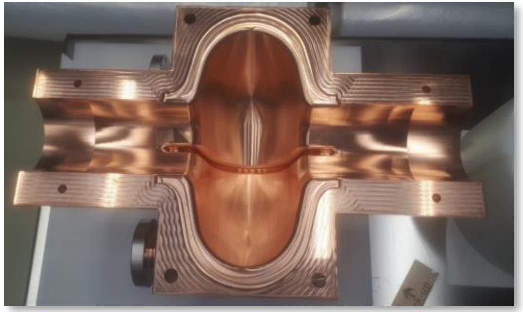
Handling tooling

Blank assembly test of the cavity – following strict assembly process

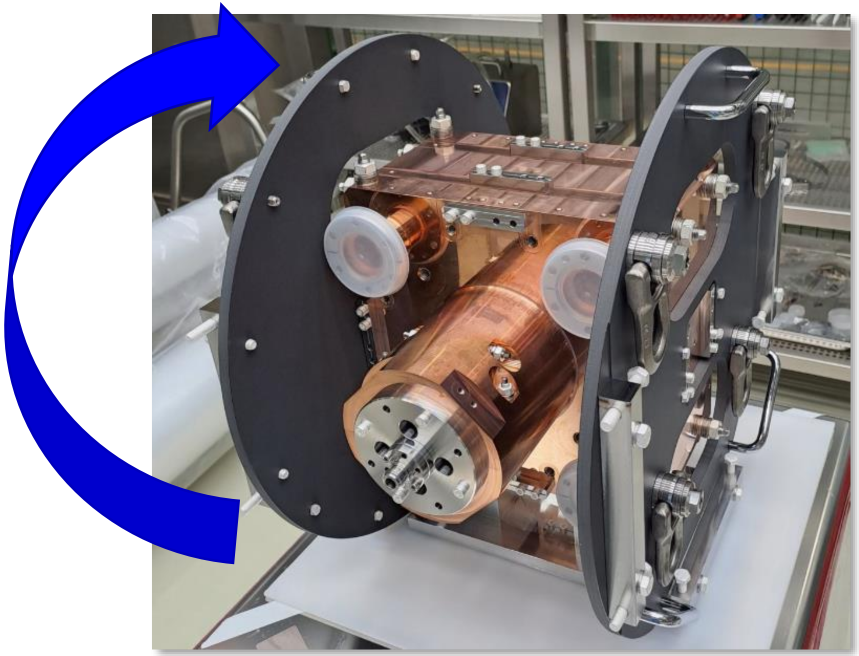




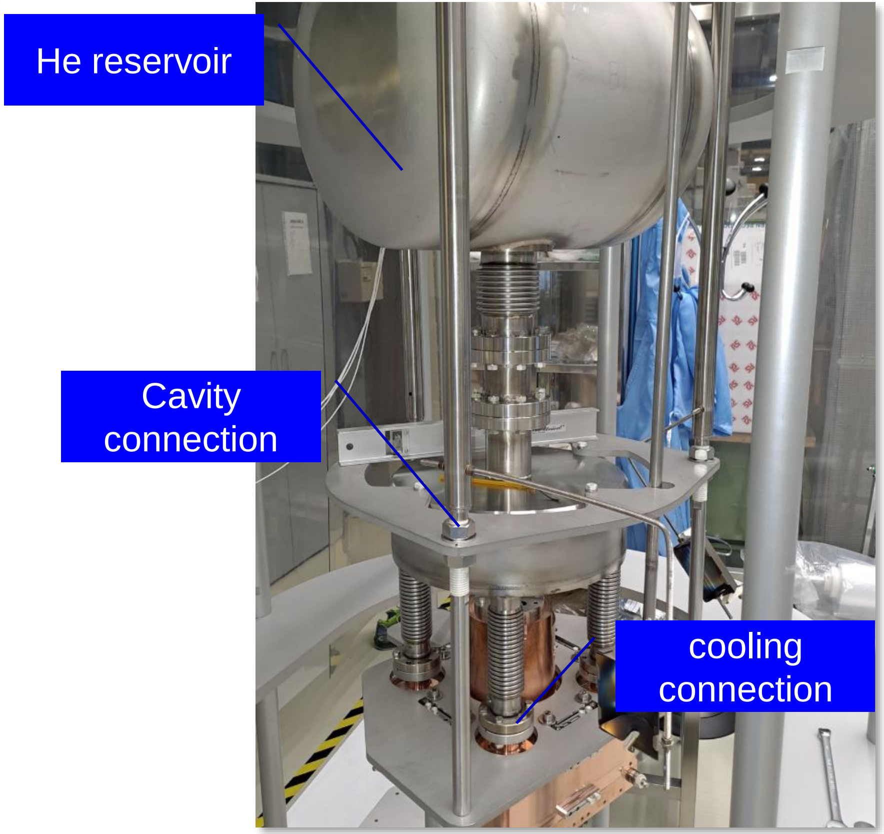




Rotation of the cavity to installation position for cryostating in V5 insert



Connection of the cavity to V5 insert



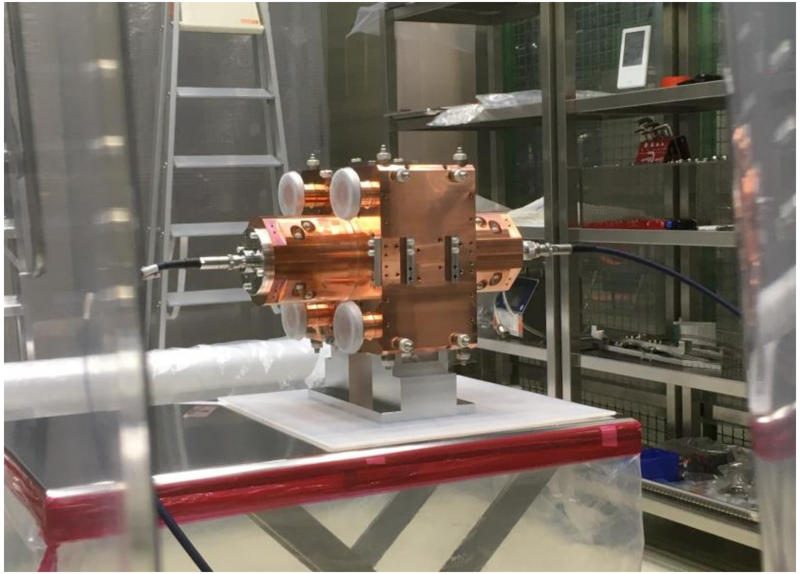
SWELL 1.3 GHz warm RF measurements

Expected frequency sensitivity parameters (calculated with CST)

Parameters		Calculated values
Frequency at 4.5 K under vacuum of nominal geometry	F1	1.301 011 11 GHz
Frequency at 20 °C under vacuum of nominal geometry	F2=F1/1.00324	1.296 809 44 GHz
Frequency shift between 20 °C and 4.5 K	F2 – F1	4 201.67 kHz
Frequency sensitivity to uniform material removal by chemistry		+12.824 kHz/um
Frequency at 20 °C under vacuum with 50 mm overthickness	F3	1.297 450 65 GHz
Frequency shift at 20 °C under vacuum between nominal geometry and 50 mm overthickness	F3 – F2	641.2 kHz
Frequency with 50 mm overthickness in air at normal conditions 20°C, 50% humidity, 1015 mbar	F4=F3/sqrt(e_{air}) =F3/1.0003229	1.297 031 84 GHz
Frequency shift between vacuum and air at normal conditions 20°C, 50% humidity, 1015 mbar	F3 – F4	418.81 kHz

SWELL 1.3 GHz warm RF measurements

Measurement results

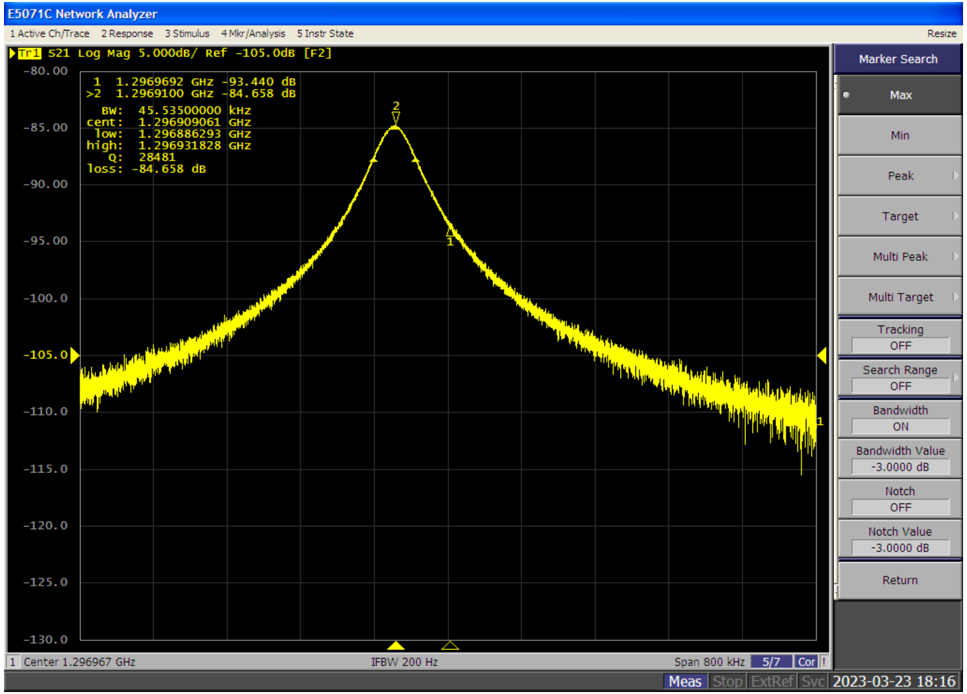


with 50 mm overthickness

L input antenna [mm]	L transmitted antenna [mm]	f_{meas} [GHz]	f_{meas} [GHz] normalized at 20°C under vacuum	$F_{calculated}$ at 20 °C [GHz] normalized at 20°C under vacuum	$DF_{meas/calc}$ [kHz]
45	17.5	1.2969123	1.2973742	1.29745065	**-76.435**
53.5	17.5	1.2969110	1.2973729		**-77.736**
61	17.5	1.2969109	1.2973728		**-77.836**
65	17.5	1.2969101	1.2973720		**-78.636**
71	17.5	1.2969106	1.2973725		**-78.136**
75	17.5	1.2969091	1.2973710		**-79.636**
80	17.5	1.2969090	1.2973709		**-79.736**

The average frequency deviation $\Delta F_{meas/calc}$ is about -78 kHz which corresponds to an error of 6e-5 or 0.006 %

SWELL 1.3 GHz warm RF measurements



The Q factor is measured at -3 dB from the maximum of the S_{21} parameter amplitude and is **28481**.

At ambient temperature, the total Q factor is dominated by the losses in the cavity given by the Q_0 of the resonator. The Q_0 factor is defined as $Q_0 = \frac{G}{R_S}$ with:

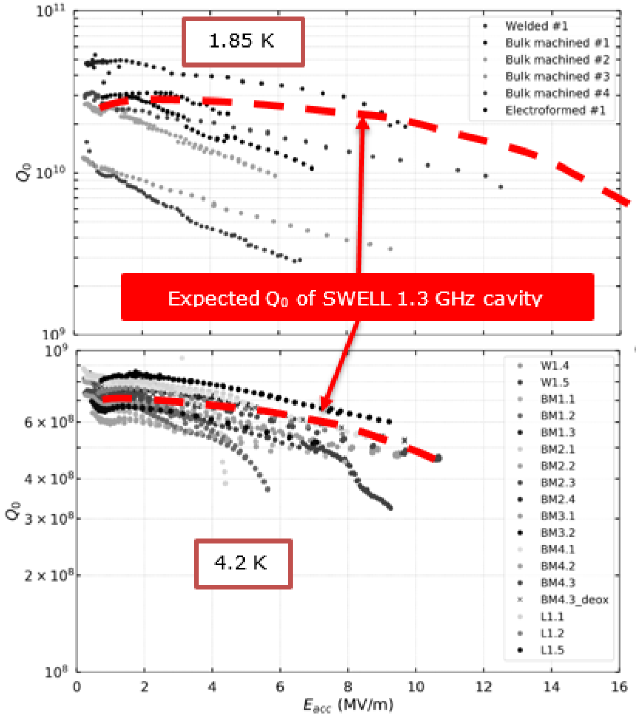
$$R_S = \frac{1}{\delta\sigma} = \frac{1}{\sqrt{\frac{1}{\sigma\pi f \mu_r \mu_0}}\sigma} = \sqrt{\frac{\pi f \mu_r \mu_0}{\sigma}}.$$

With $\sigma = 59.4e6\, S/m$ for pure OFHC copper, the surface resistance is $R_S = 9.284\, m\Omega$ at f=1.29696 GHz. With a geometric factor of $G = 265.5\,\Omega$, the intrinsic quality factor is $\boldsymbol{Q_0 = 28600}$, which is in agreement with the measurements.

→ no RF leakage occurs in the contact areas of the quadrants. the mechanical alignment of the quadrants is very good.

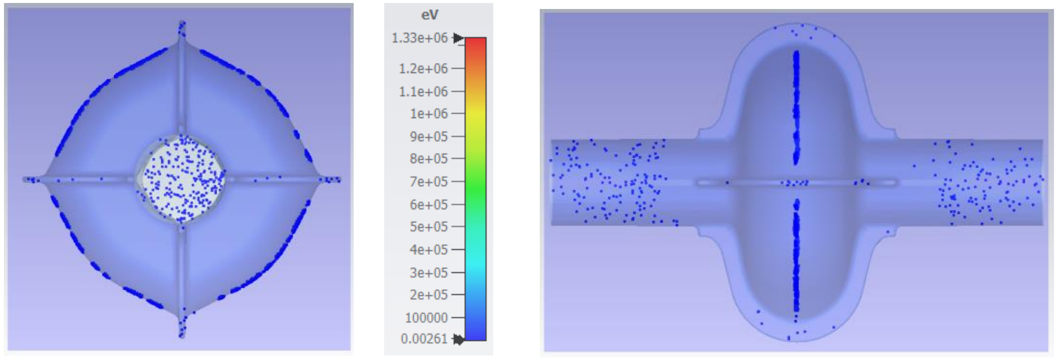
Next steps

- Blank assembly of toolings for surface treatments of the quadrants
- Degreasing, electropolishing and HiPIMS Niobium coating of the quadrants
- In parrallel, cryogenic test of the cryostat insert (without the cavity) in SM18
- **HPR, clean room assembly of the cavity and preparation of the insert**
- **RF test at 4.5 K and 2 K <u>before end of 2023</u>**



Multipacting studies by LPSC – IN2P3 Grenoble

Y. Gomez Martinez, M. Meyer, F. Bouly, A. Plaçais (IPAC2023)



Thank you for your attention

Questions ?

Acknowledgements

Gloria Bellini, Olivier Brunner, Ivan Karpov, Igor Syratchev, Rama Calaga, Heiko Damerau, Eric Montesinos, Frank Gerigk, Ofelia Capatina, Marc Timmins, Said Atieh, Guillaume Rosaz, Walter Venturini Delsolaro, Vittorio Parma, Mathieu Therasse, Shahnam Gorgi Zadeh, Joanna Sylwia Swieszek, Karol Scibor, Leonel Ferreira, Torsten Koettig, Graeme Burt

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