CONCEPTUAL DESIGN OF THE BETA = 0.86 CAVITIES FOR THE SUPERCONDUCTING LINAC OF ESS

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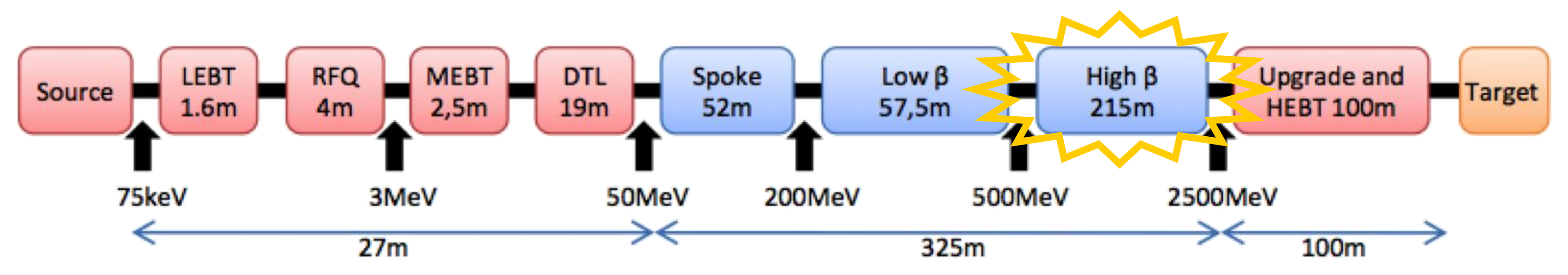
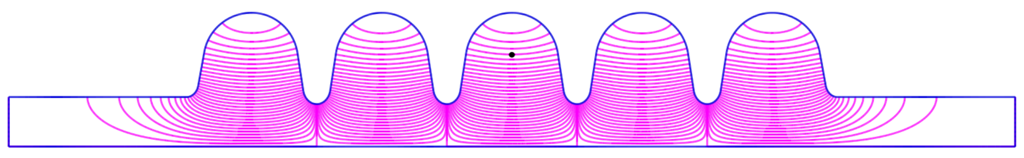
CEA-Saclay is in charge of the design, the fabrication and the tests of the superconducting high beta cavities for the high energy part of the ESS (European Spallation Source) linac. This paper reports the actual status of the RF and mechanical design of these cavities. According to ESS specifications, these cavities will be 5-cells elliptical, with frequency 704 MHz and β = 0.86. They will work in the pulsed mode, with a beam current initially equal to 50 mA.

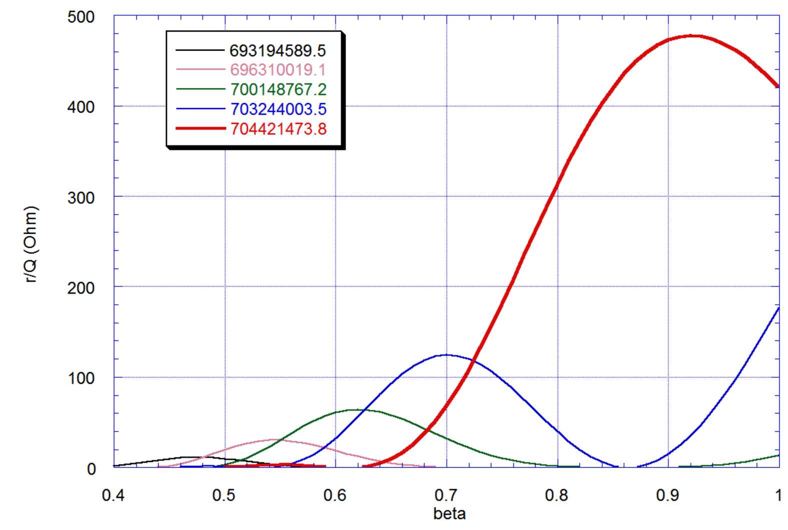
The target accelerating gradient is 18 MV/m on the linac, and 20 MV/m in vertical tests. For the RF design, the cavity efficiency and the peak fields were optimized, while the feasibility of the external coupling with RF power was taken into account. Attention was also paid to the HOM frequencies and impedances and to their future extraction. Coupled RF/mechanical FEM calculations have been carried out and the Lorentz detuning, critical for a pulsed mode cavity, is lowered by the insertion of stiffening rings.



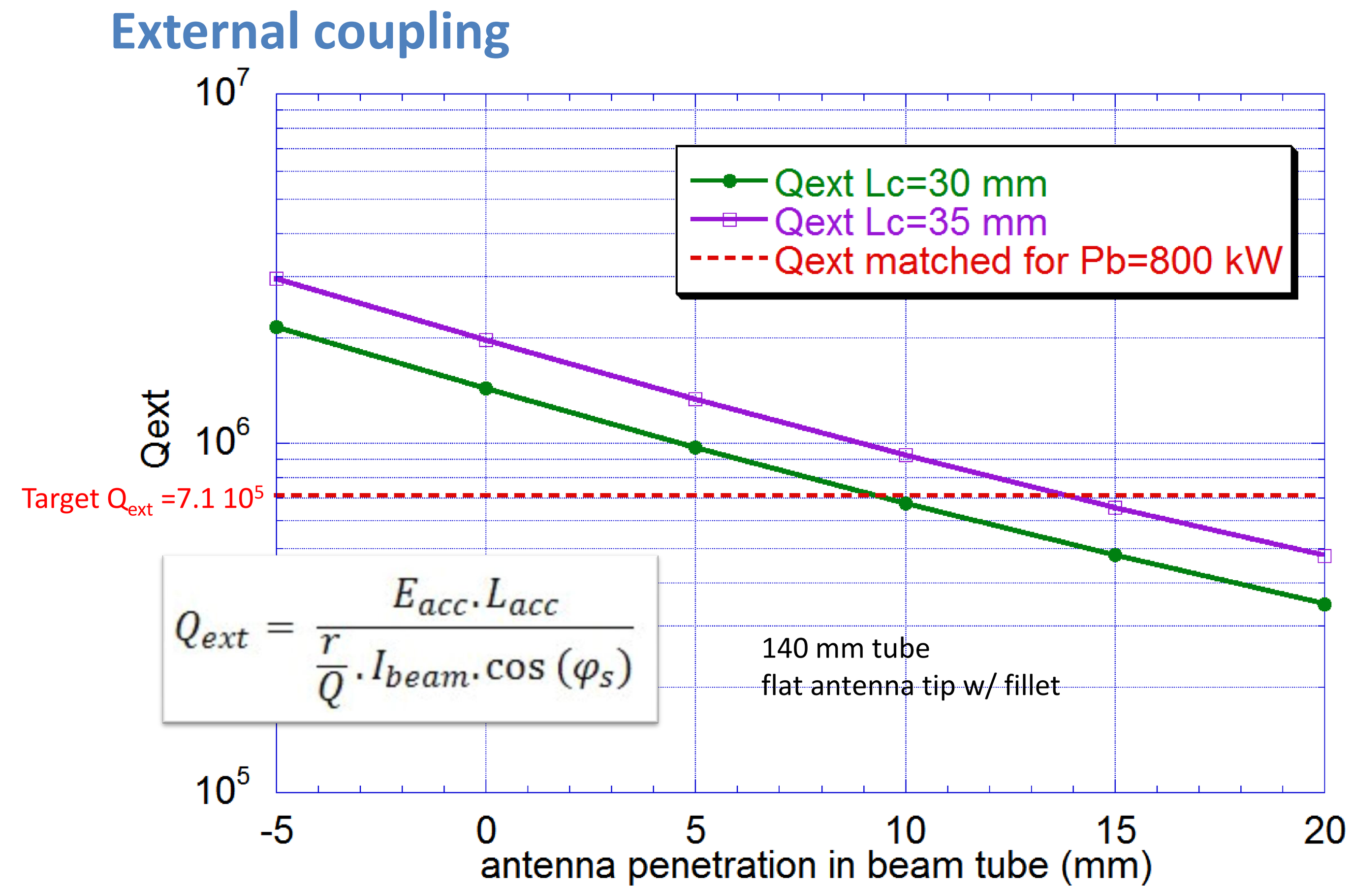
ESS DESIGN PARAMETERS	
RF frequency	704.42 MHz
Cavity geometrical beta	0.86
Operating Temperature	2 K
Accelerating gradient	18 MV/m
Q_0	6 10^9
Maximum surface E field	40 MV/m
Average pulse current	50 mA
Peak RF power	900 kW
Repetition frequency	14 Hz
Beam pulse length	2.86 ms

CAVITY RF PARAMETERS	
Bpk/Eacc [mT/(MV/m)]	4.3
Epk/Eacc	2.2
G [Ohm]	241
Cell to cell coupling	1.8 %
π and 4π/5 mode separation	1.2 MHz
r/Q [Ohms]	477
L_{acc} = Ngap.β.λ/2 [m]	0.915
Cell wall angle	> 8°

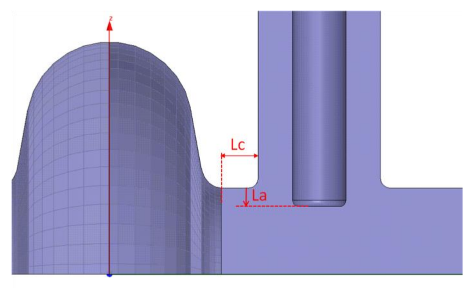




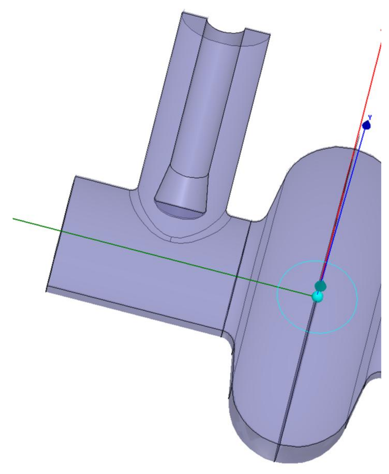
External coupling



$$Q_{ext} = \frac{E_{acc}.L_{acc}}{\frac{r}{Q}.I_{beam}.\cos(\varphi_s)}$$

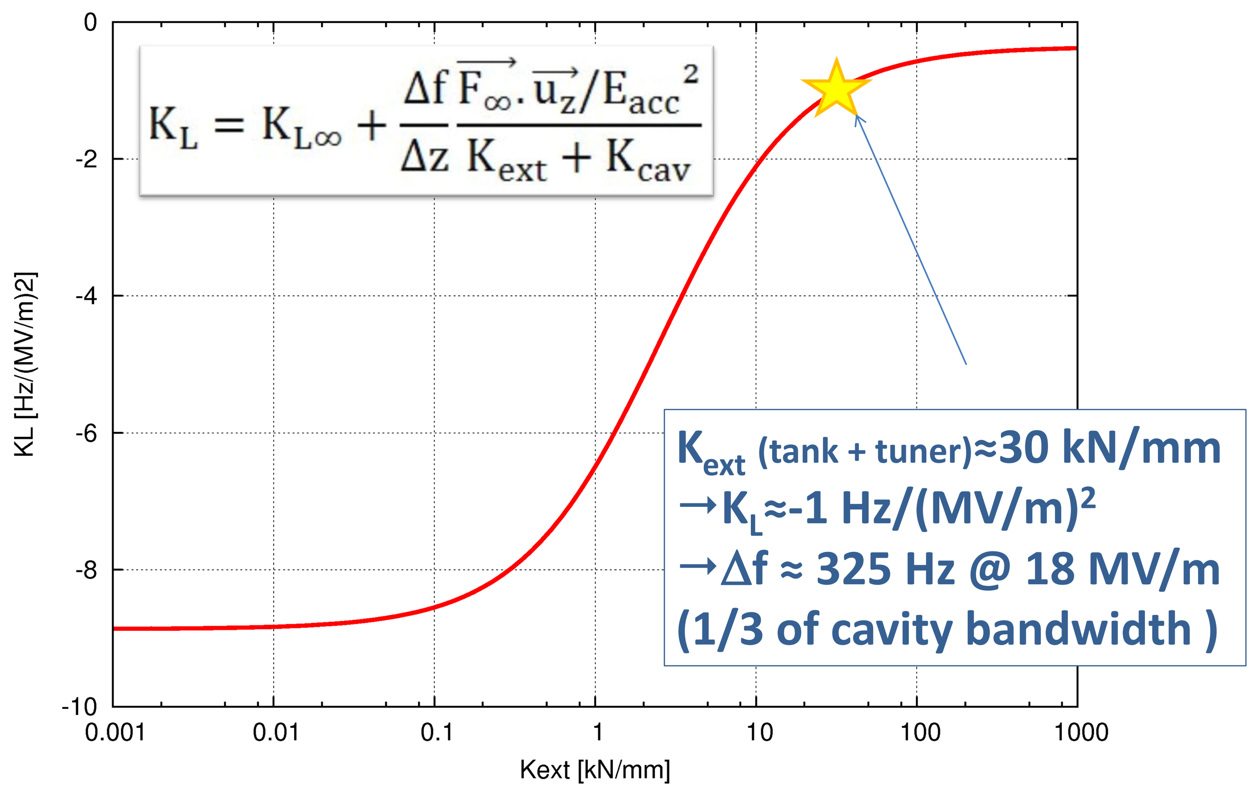


- Lc can be reduced to 30 mm (Ti vessel option)
- Using a conical tip decreases Qext by~15% for a given antena penetration



Reduction of K_L with stiffening rings

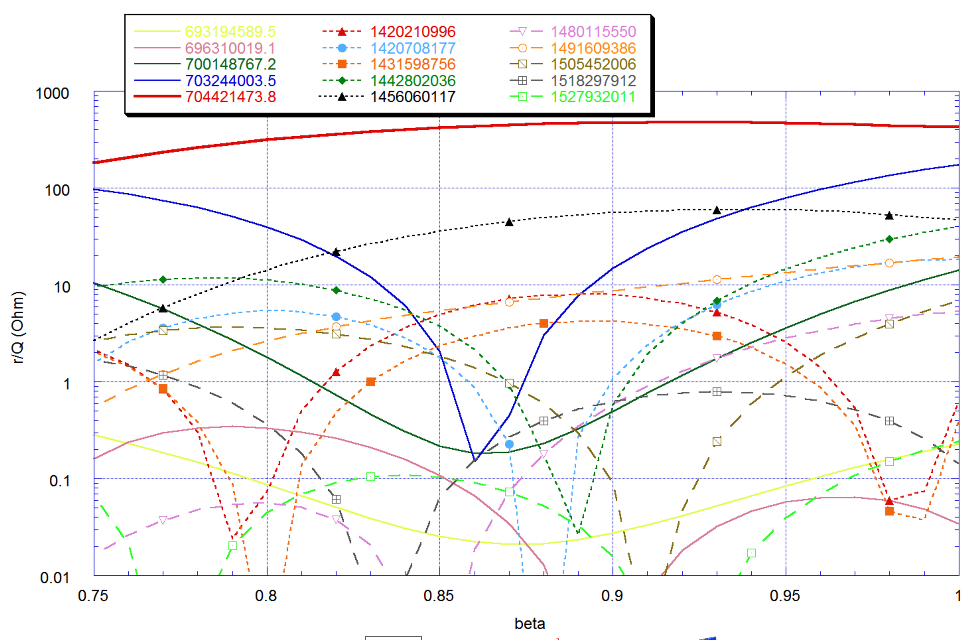
MECHANICAL PARAMETERS	
Nominal wall thickness [mm]	3.6
Cavity stiffness Kcav [kN/mm]	2.59
Tuning sensitivity Δf/Δz [kHz/mm]	197
KL with fixed ends [Hz/(MV/m)²]	-0.36
KL with free ends [Hz/(MV/m)²]	-8.9
Pressure sensitivity KP [Hz/mbar] (fixed ends)	4.85

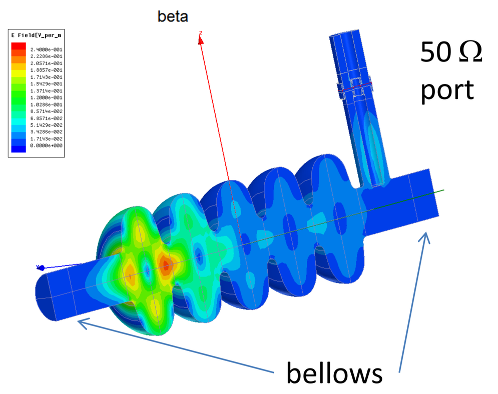


$$K_L = K_{L\infty} + \frac{\Delta f}{\Delta z} \frac{\overrightarrow{F_\infty}.\overrightarrow{u_z}/E_{acc}^2}{K_{ext}+K_{cav}}$$

K_{ext} (tank + tuner)≈30 kN/mm
→K_L≈-1 Hz/(MV/m)²
→Δf ≈ 325 Hz @ 18 MV/m
(1/3 of cavity bandwidth)

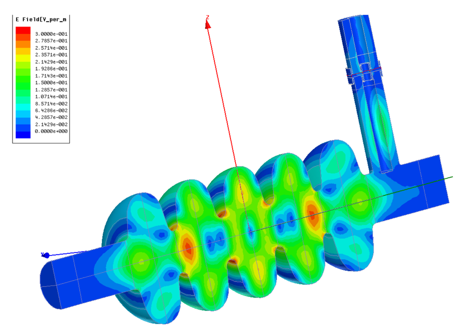
Monopole modes below 1.64GHz (TM01 cut-off frequency for Ø140 mm tube)





1420.3 MHz

Closest mode to the 2nd harmonic of 704.42 (12MHz apart)



1456.0 MHz

Highest impedance HOM monopole

FIRST MONOPOLAR BAND		
Frequency (MHz)	Max. r/Q (Ohm)	Q
1420.3	8	1.58 10^5
1421.9	17	4.30 10^3
1431.7	4	3.22 10^4
1442.8	29	3.30 10^4
1456.0	60	4.41 10^4

The RF window of the power coupler is included in the HFSS computations

The low Q of HOMs is explained by losses on copper surfaces of the power coupler and inter-cavity bellows, and transmission through the RF window. The matched termination on the power coupler coaxial line

None of monopole mode below cutoff need extra damping

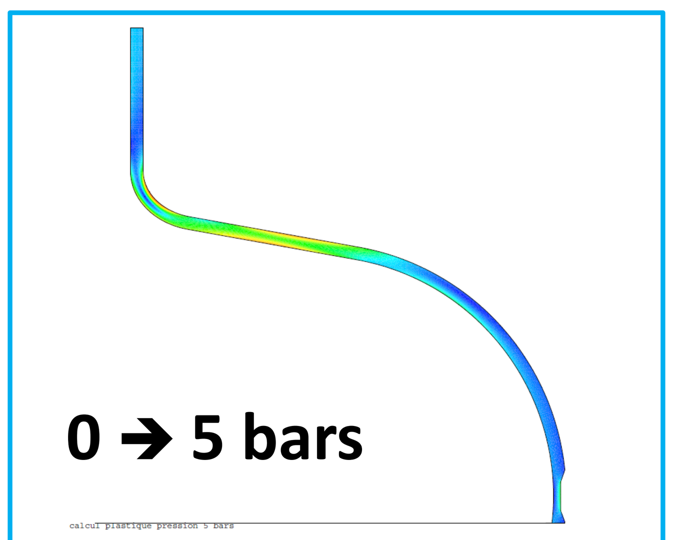
SECOND MONOPOLAR BAND		
Frequency (MHz)	Max. r/Q (Ohm)	Q
1480.1	5	1.98 10^4
1491.5	17	1.33 10^4
1431.7	4	1.40 10^4
1518.2	4	1.87 10^4
1527.9	0.2	4.57 10^4

Pressure certification test : mechanical calculations

We foresee a pressure test of the He tank/cavity will be carried out for certification

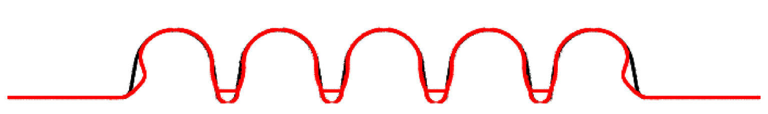
Simulation of cavity deformation with a *plastic* model, 3.6 mm thickness

- The differential pressure is cycled : 0-5-0 bars
- external rig used to maintain cavity length : fixed ends
- max residual deformation after 1 cycle : 7µm for 1 cycle, detuning 560 Hz



0 ➔ 5 bars

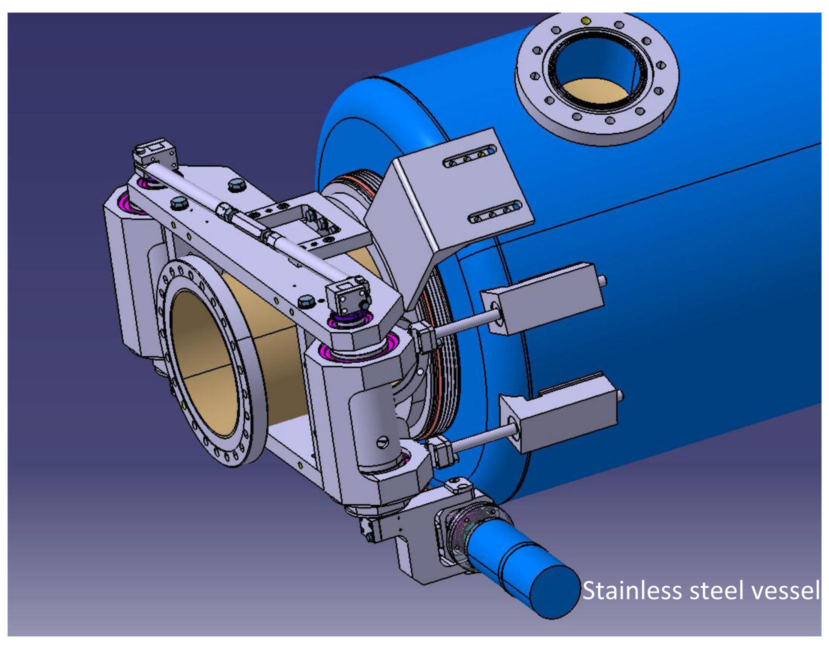
Max VM stress	Max. deformation	Delta f
54 Mpa	0.235 mm	33.9 kHz



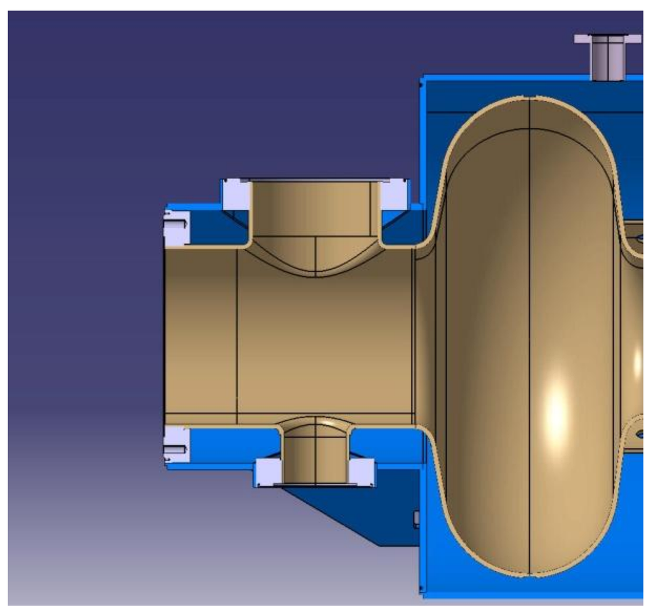
0 ➔ 5 bars ➔ 0

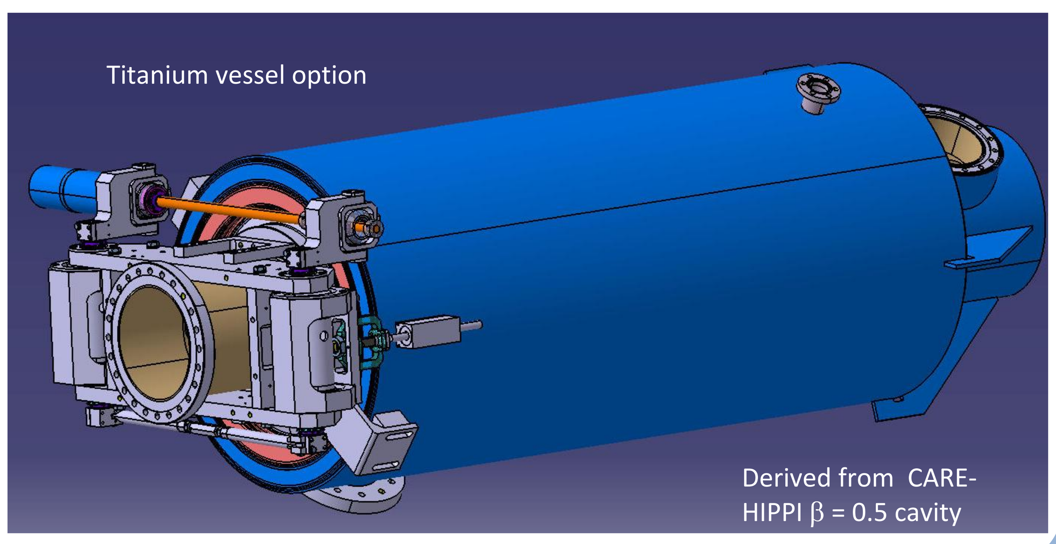
Max. residual deformation	Residual detuning
6.7 µm	-563 Hz

Helium tank and tuner integration



Nb RRR>250
NbTi flanges, Al Hex seals





- Saclay V type
- 1 piezo
- Planetary gearbox (1/100e)
- Piezo preload at 2K is independant of the cavity springback force