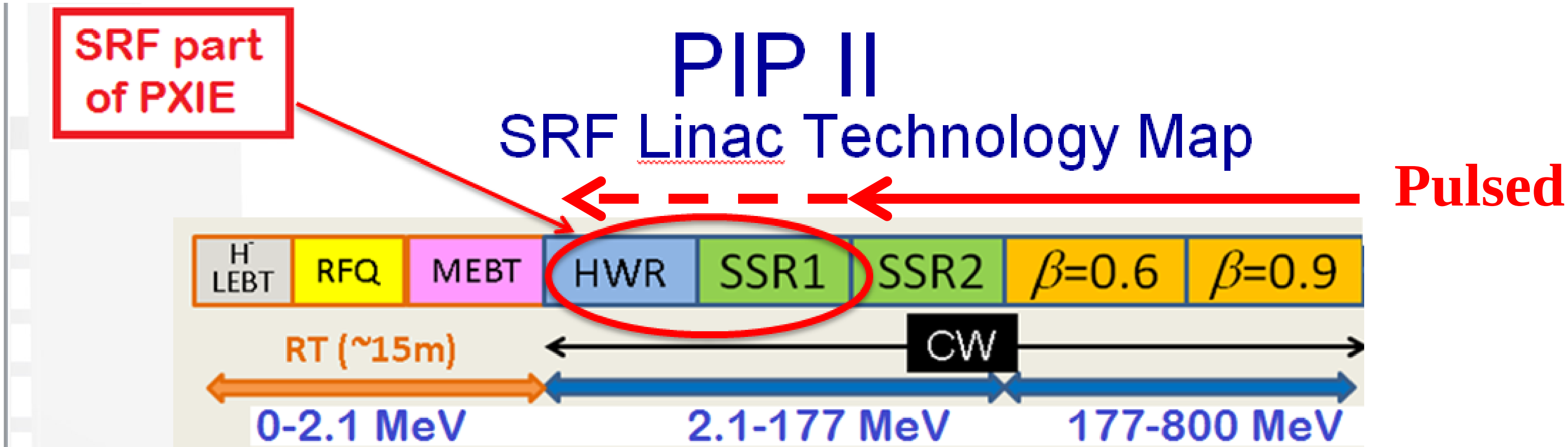
PIP-II 650MHz cavity optimization

Timergali Khabiboulline

Microphonics Workshop, FNAL October 8-9

PIP-II concept



SRF Cavity Type	Freq, MHz	Energy (MeV)	Cav/mag/CM	CM type, length
HWR (β_G=0.11)	162.5	2.1-11	8 /8/1	scscscscscscscsc, 5.3m
SSR1 (β_G=0.22)	325	11-38	16 /8/ 2	csccsccsccsc, 4.8m
SSR2 (β_G=0.51)	325	38-177	35 /21/ 7	sccsccsc, 6.5m
LB 650* (β_G=0.61)	650	177-480	30 /20/5	cccfdccc, 7.1m
HB 650 (β_G=0.9)	650	480-800	24 /6/ 4	cccccc, 9.5m

*3-cavity option is under consideration; CM has no focusing elements.

5 IIFC, July 2014; Slava Yakovlev Fermilab

2 mA pulsed beam with duty factor from 0% to CW operation

Microphonics SRF cavities

Bandwidth and required power optimized for CW (2 mA)

Section	Freq MHz	Maximal detune (peak Hz)	Minimal Half Bandwidth (Hz)	Max Required Power (kW)
HWR	162.5	20	34	4.8
SSR1	325	20	45	5.3
SSR2	325	20	27	17.0
LB650	650	20	29	33.0
HB650	650	20	31	48.5

Microphonics Control Strategies:

- **Adding RF power to compensate for the expected peak frequency detuning.**
- **Minimizing Helium bath pressure peak to peak variations.**
- **Reducing df/dP , the sensitivity of the cavity resonant frequency to in the helium bath pressure.**
- **Reducing Lorenz Force Detuning**
- **Minimizing acoustics from external sources.**
- **Active compensation using a fast tuner driven by feedback from measurements of the cavity resonant frequency.**

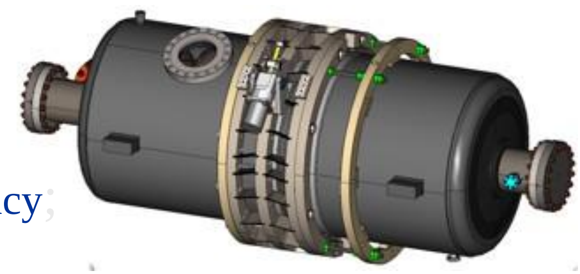
General Issues:

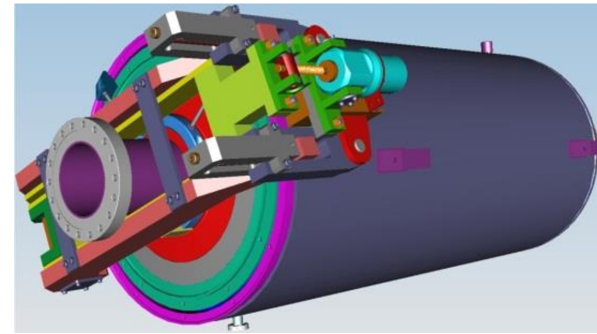
- Low beam loading → narrow cavity bandwidth → microphonics
- Lorentz Force Detuning (LFD) is an issue in a pulsed mode, and should be analyzed for each cavity type
- Future CW operation → cryo-losses → high Q_0 is desired. Technology of the cavity processing based on N-doping is developing

HB650 MHz cavity

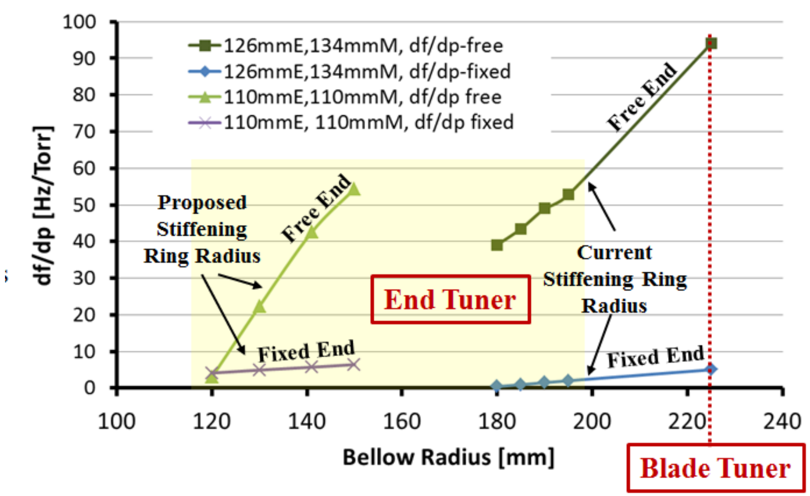
1st design of HB650 cavity was designed for maximum stiffness of the bare cavity

Blade Tuner – scaled ILC:
- High df/dP
- Insufficient tuning efficiency

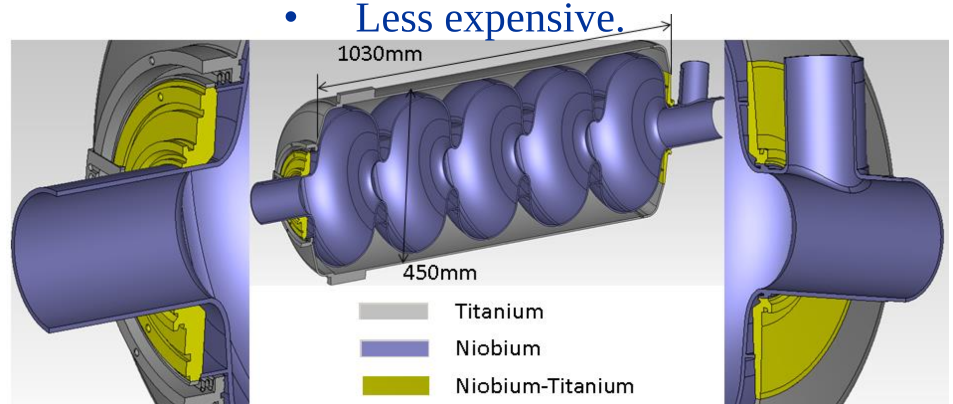




New End Tuner design:
- Low df/dP,
- Mechanical resonance s > 60 Hz;
- Good tunability;
- Less expensive.

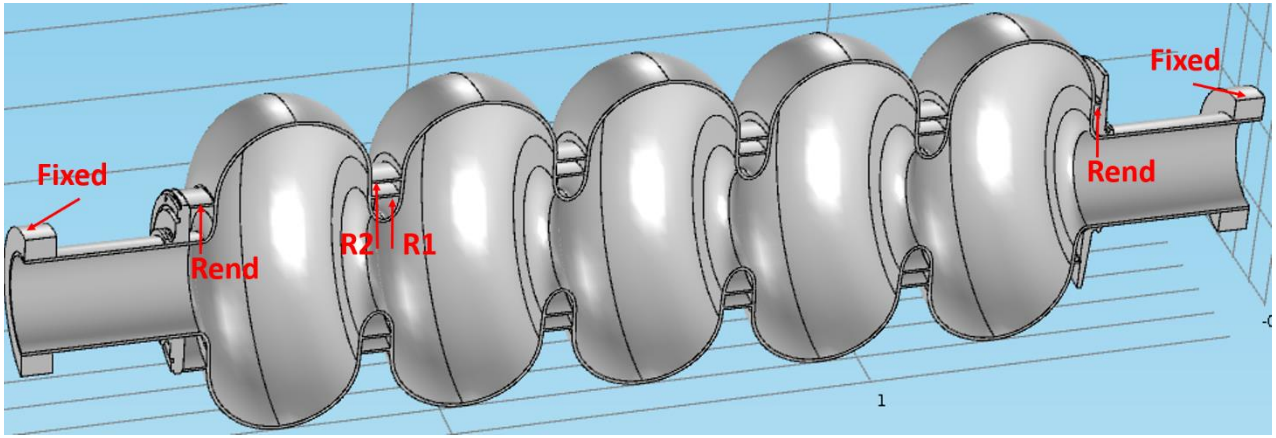


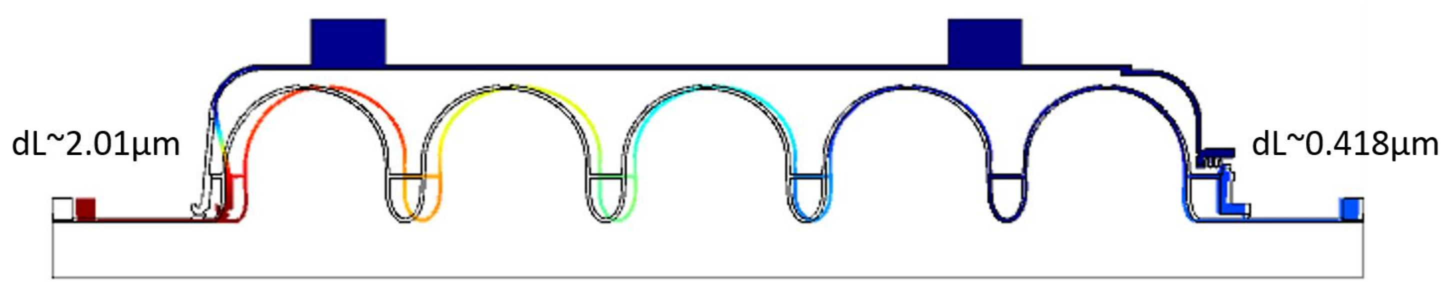
Stiffening rings located to minimize df/dP while maintaining tunability



HB650 MHz cavity

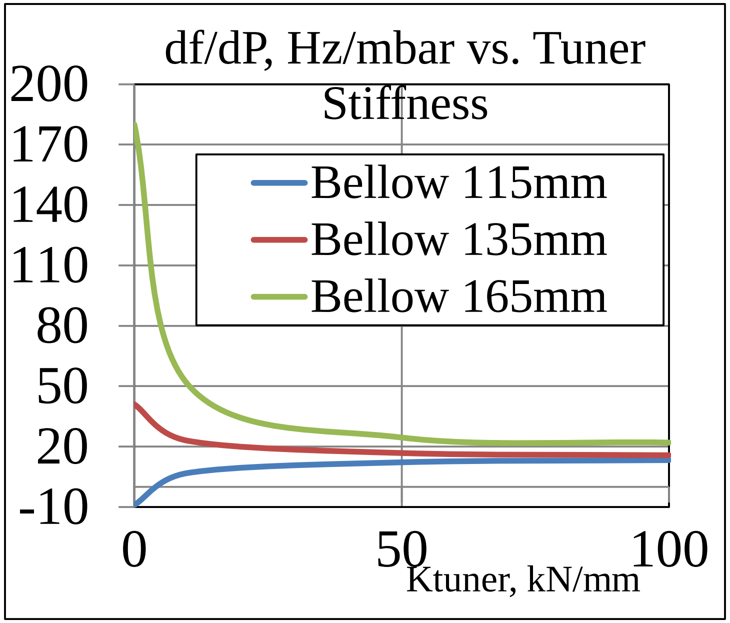
Bare and dressed cavity optimization

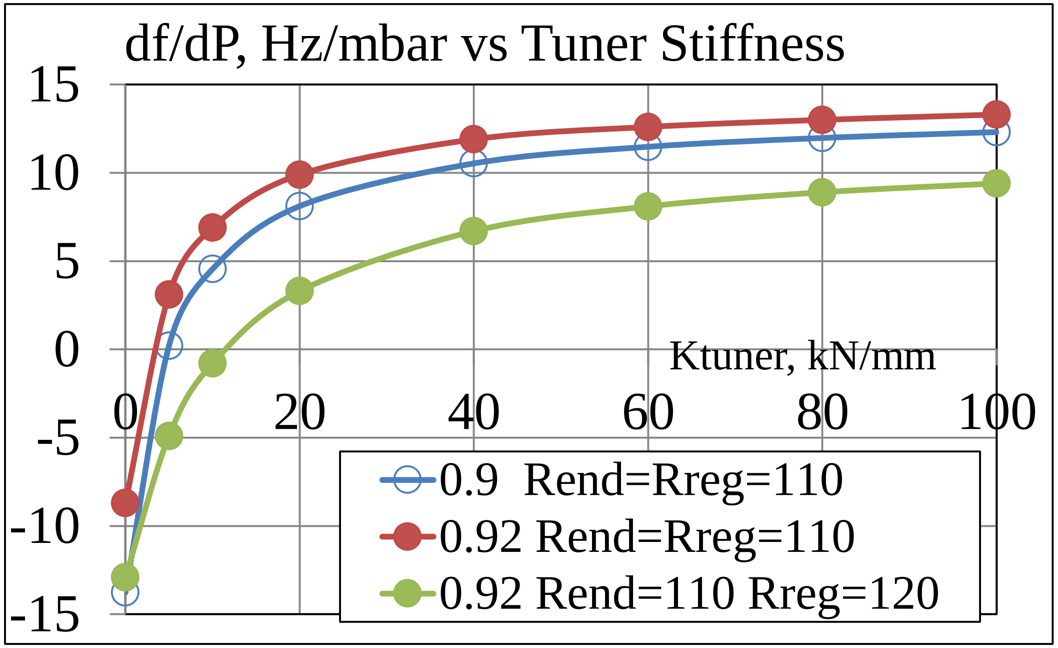




HB650 MHz cavity

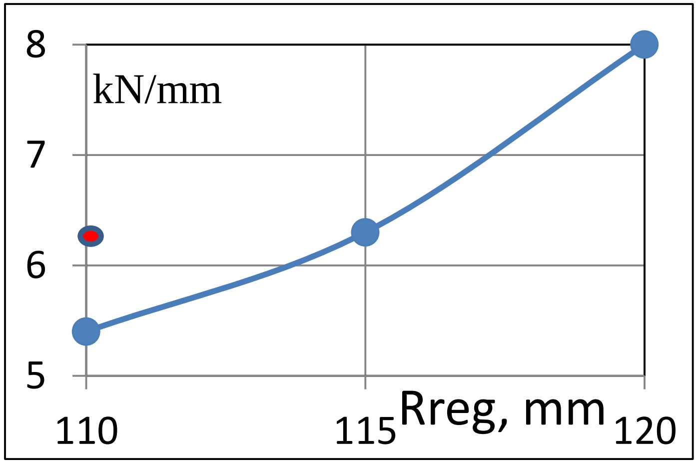
df/dP optimizations of new design for end lever tuner





Stiffness of β=0.92 cavity kN/mm vs. Radius of the Regular stiffening ring

- Stiffness of β=0.9 cavity



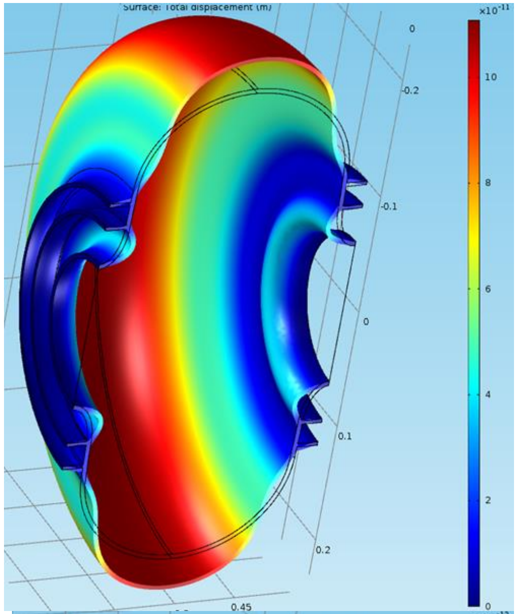
Lorenz force detuning

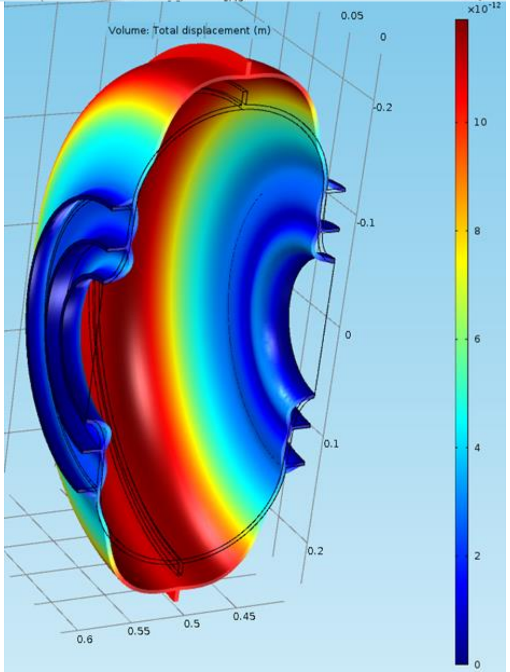
Upper Ring R2=125mm
Stiffness ~10 kN/mm
Lower Ring R1=85 mm
LFD ~ 0.352 Hz/(MV/m)^2

Upper Ring R2=125mm
Stiffness ~10 kN/mm
Lower Ring R1=80 mm
LFD ~ 0.365 Hz/(MV/m)^2

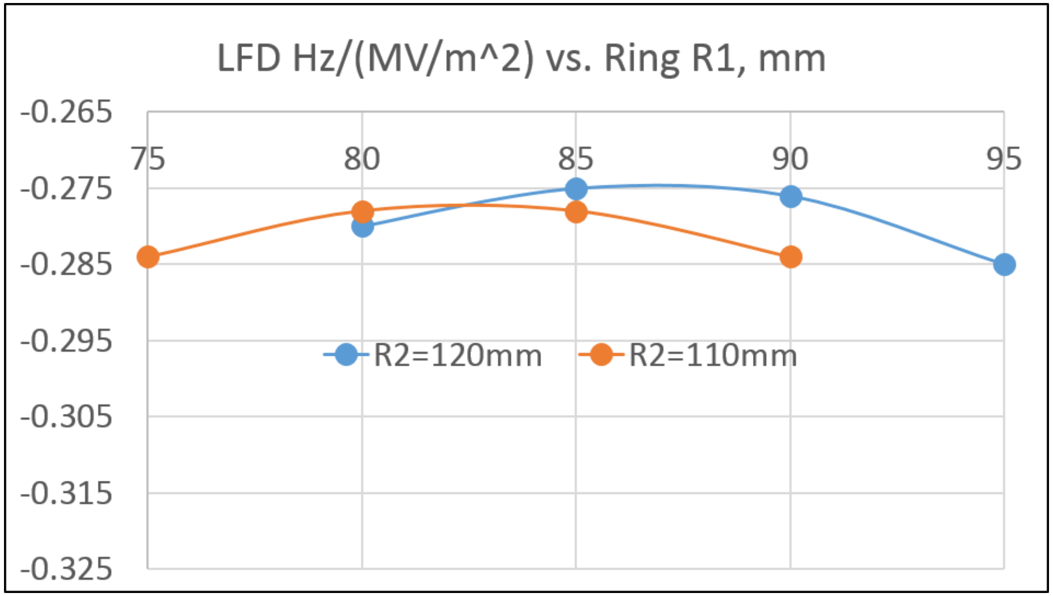
Upper Ring R2=125mm
Stiffness ~10 kN/mm
Lower Ring R1=90 mm
LFD ~ 0.38 Hz/(MV/m)^2

Upper Ring R2=125mm
Stiffness ~10 kN/mm
Lower Ring R1=85 mm
LFD ~ 0.316 Hz/(MV/m)^2

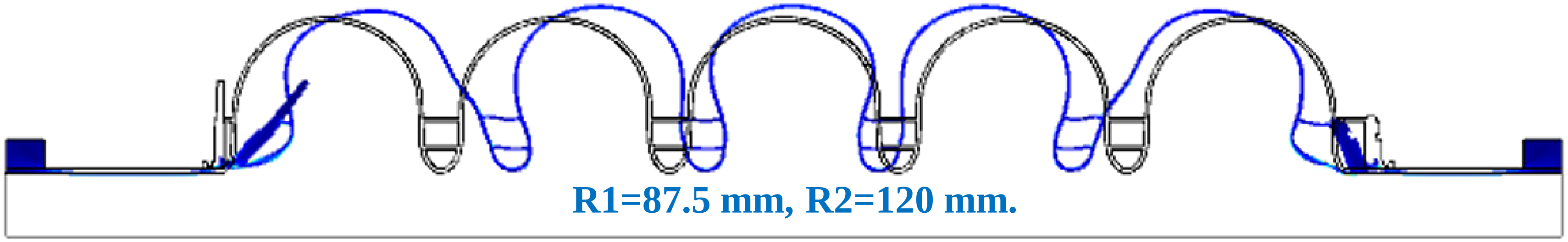




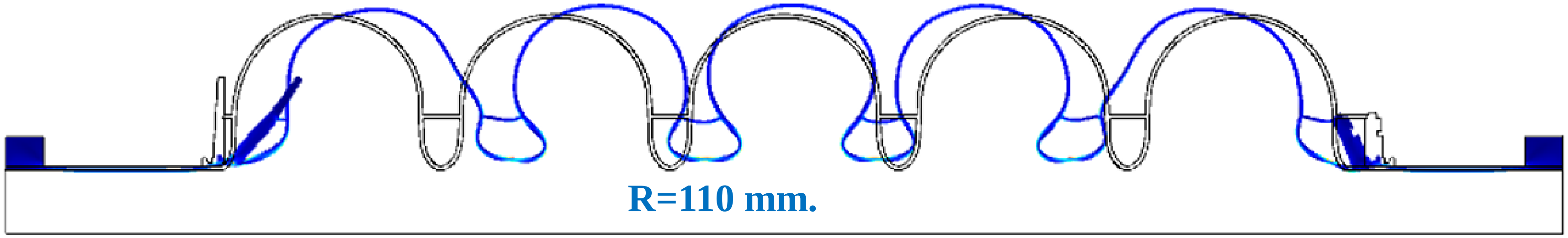
HB650 MHz bare cavity LFD.



For 2 rings LFD~-0.275 Hz/(MV/m)^2 for 1 ring LFD~-0.38 Hz/(MV/m)^2. Because the difference in LFD value for one and two rings options is not essential and the complexity of production of the cavity with two rings is high enough, we decided to use one ring option and redesign the end groups of original Helium vessel.

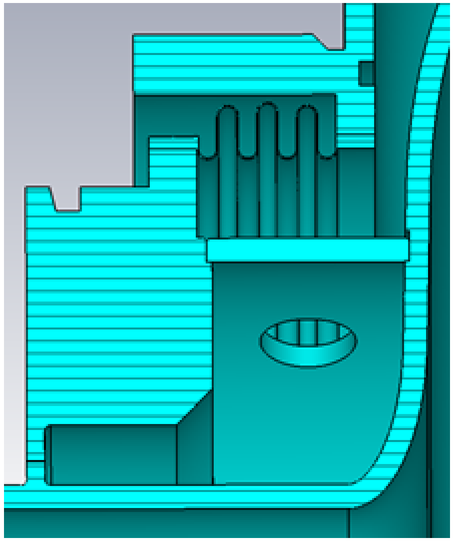


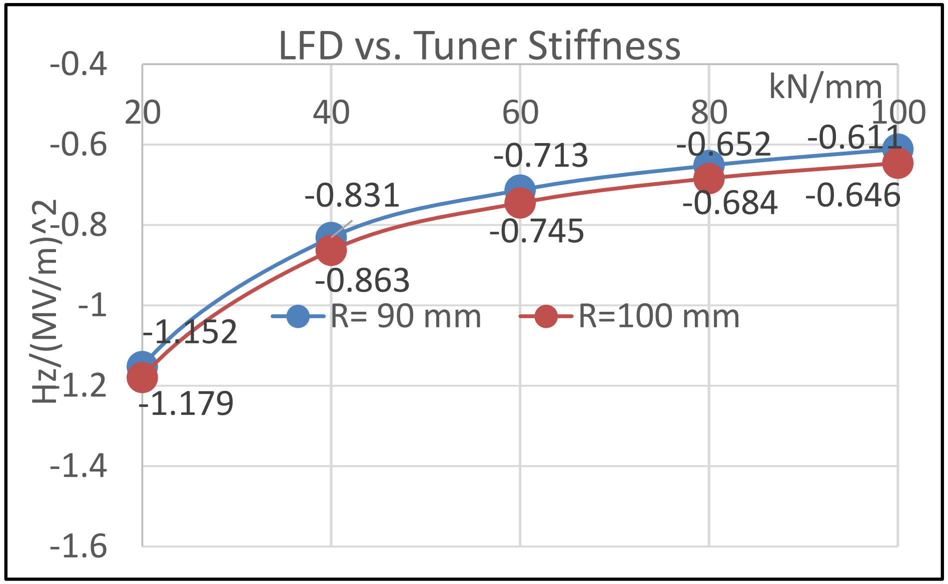
R1=87.5 mm, R2=120 mm.

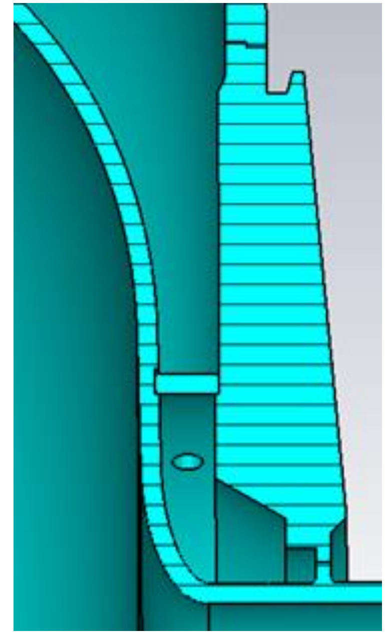


R=110 mm.

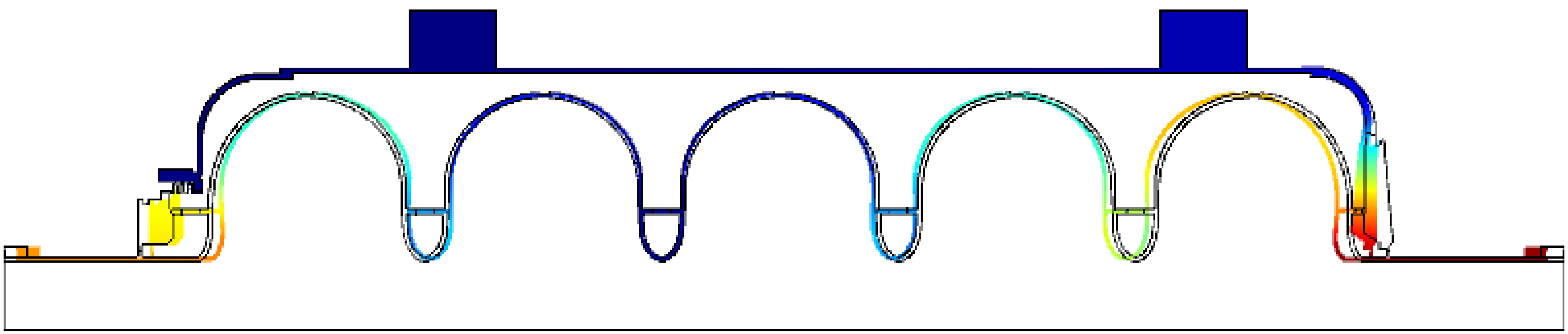
LFD for HB650 MHz dressed cavity



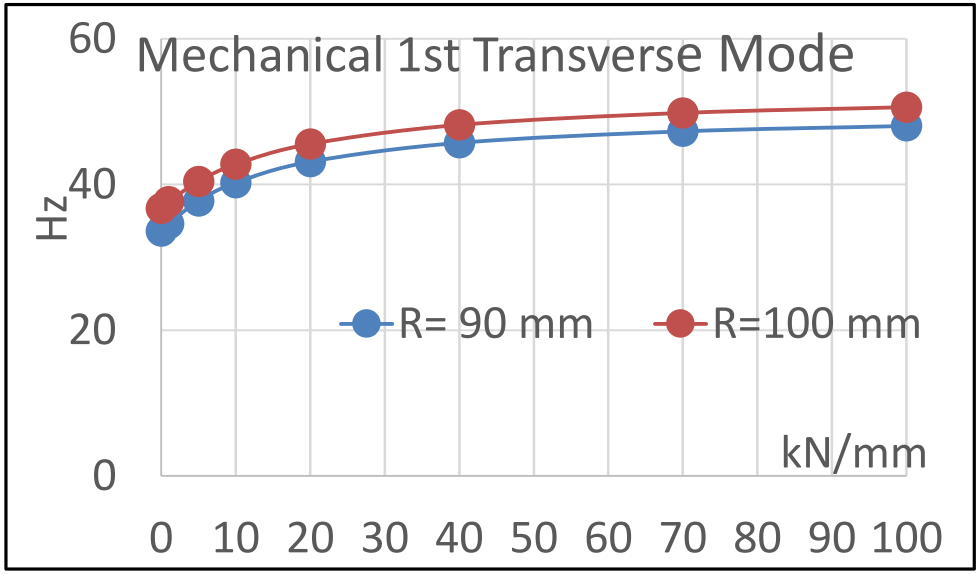


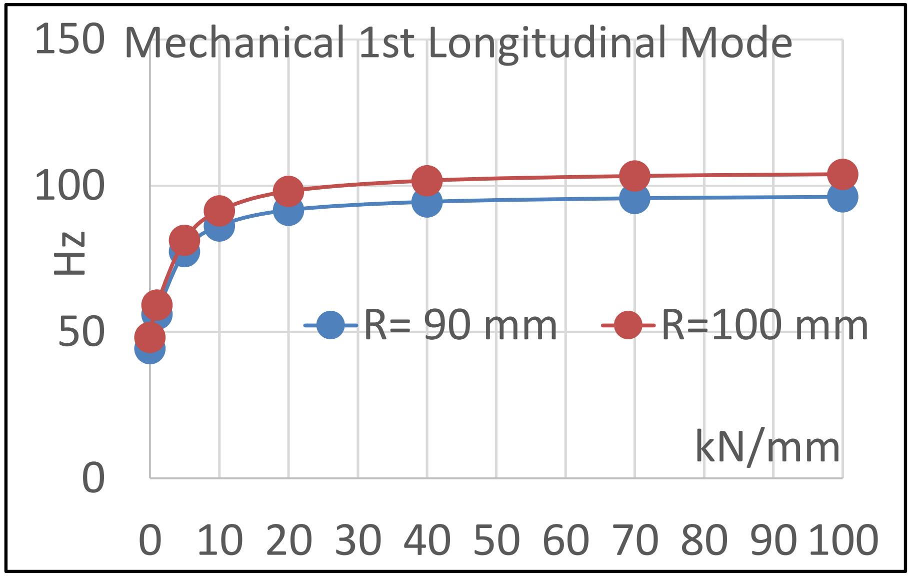


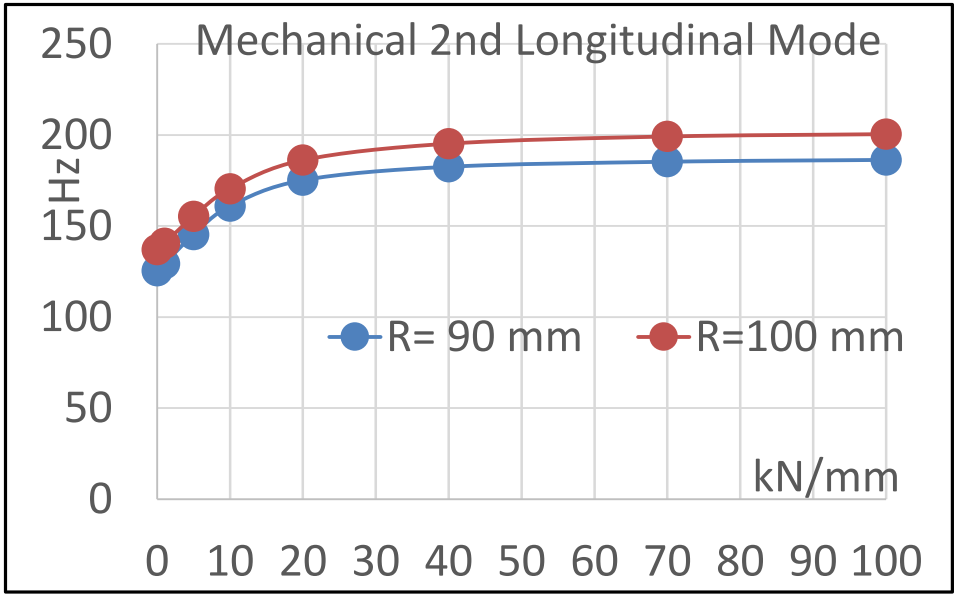
LFD 90 mmm vs. 100 mm for dressed cavity

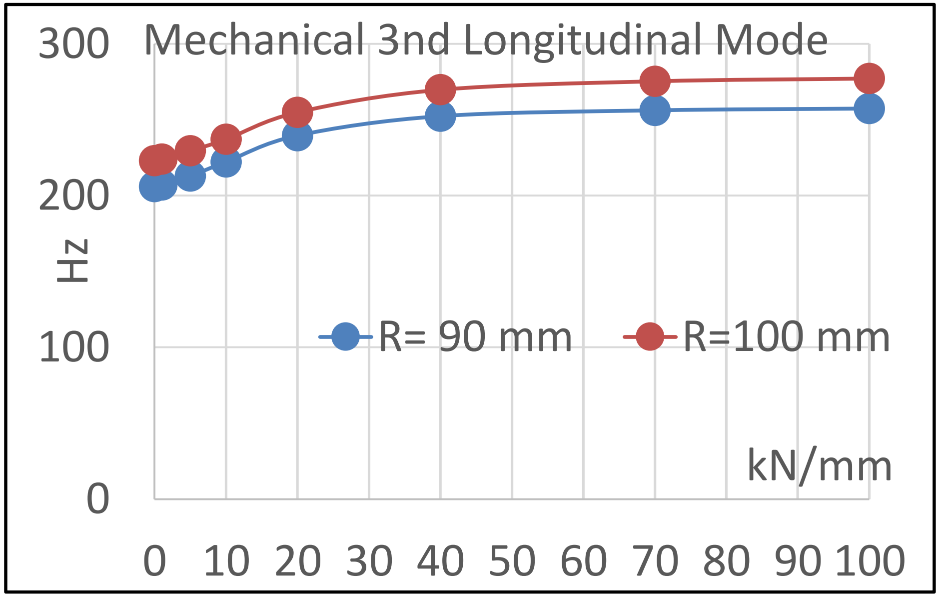


Mechanical resonances HB650 MHz dressed cavity

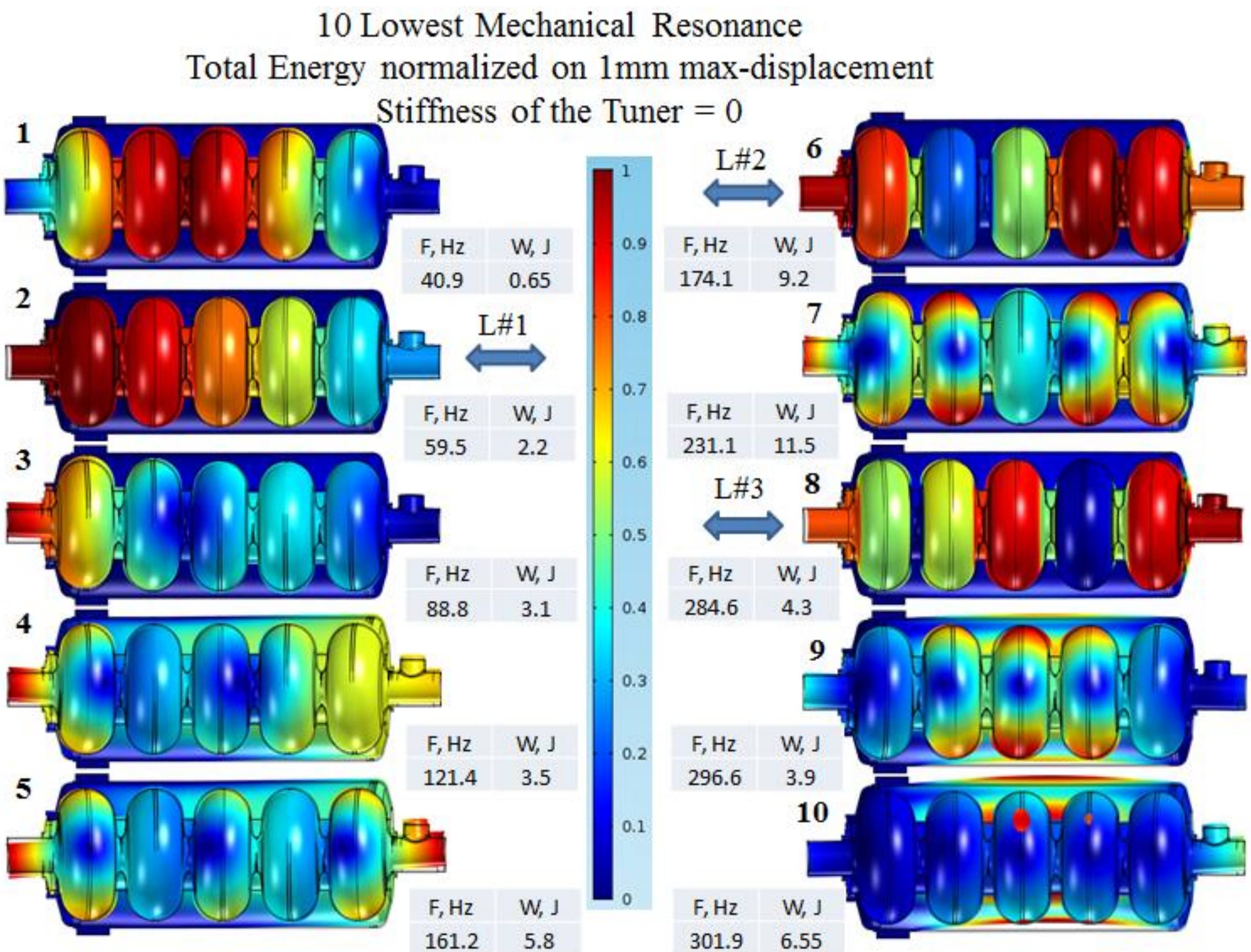




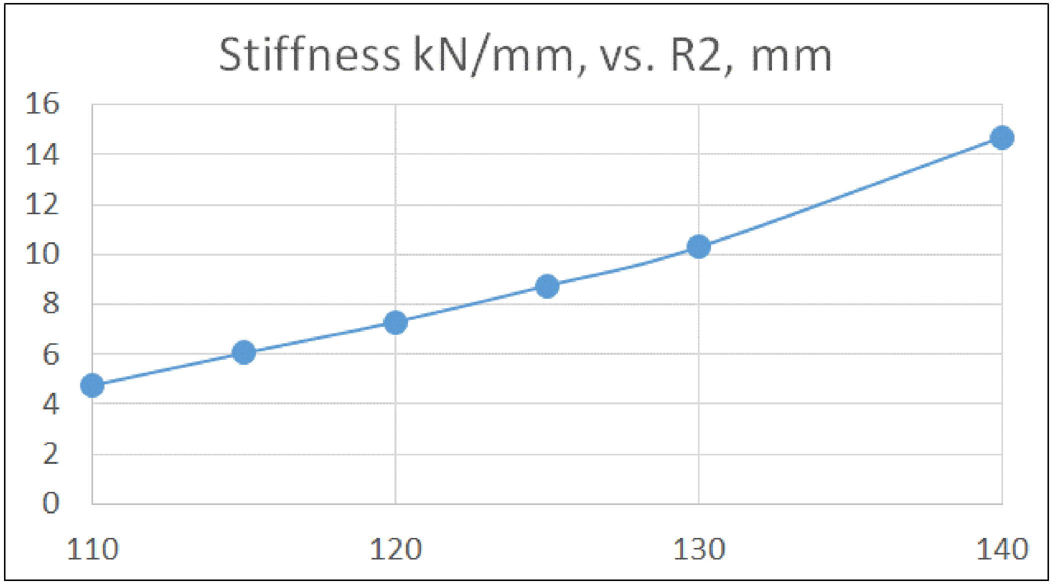




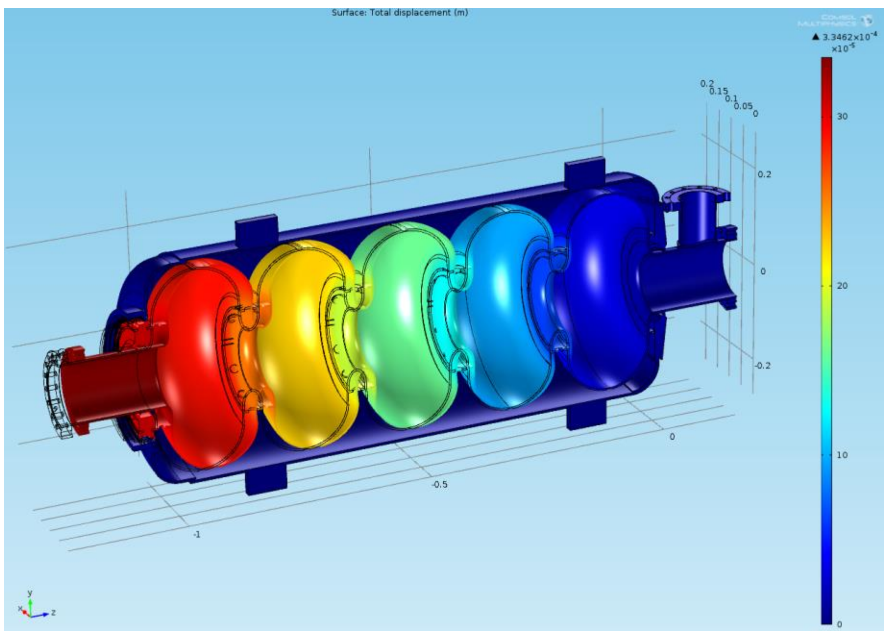
HB650 MHz cavity



HB650 MHz cavity stiffness



R2,mm	Stiffness kN/mm
110	4.75
115	6.2
120	7.3
125	8.75
130	10.3
140	14.7



Cavity Stiffness vs stiffening ring diameter

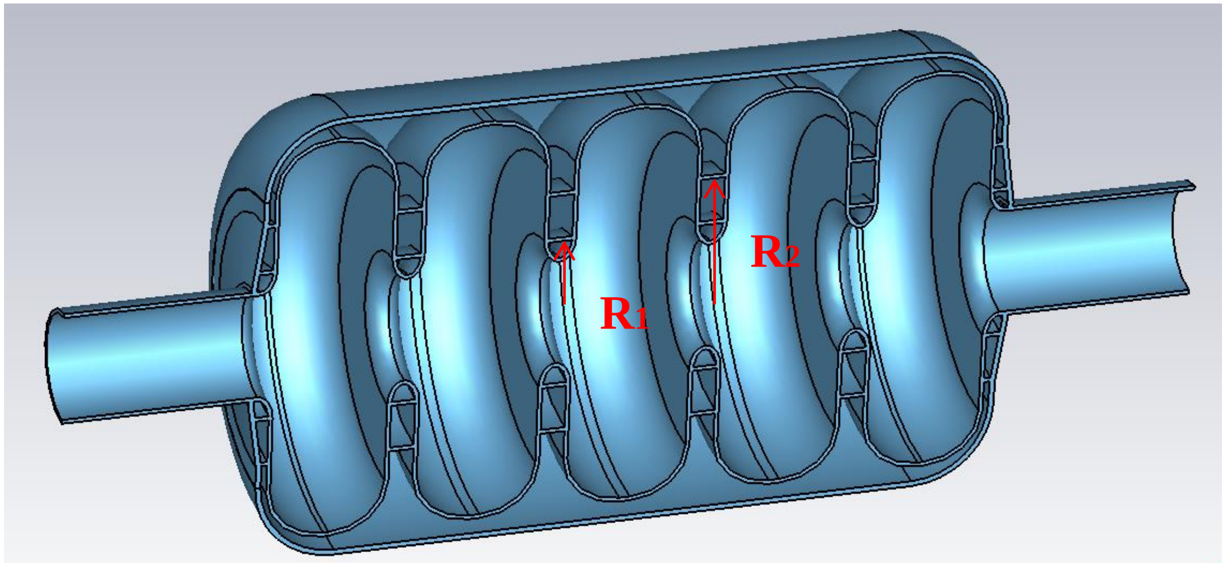
R=100 mm, ΔL ~ 334 μm
Stiffness ~ 3.0 kN/mm

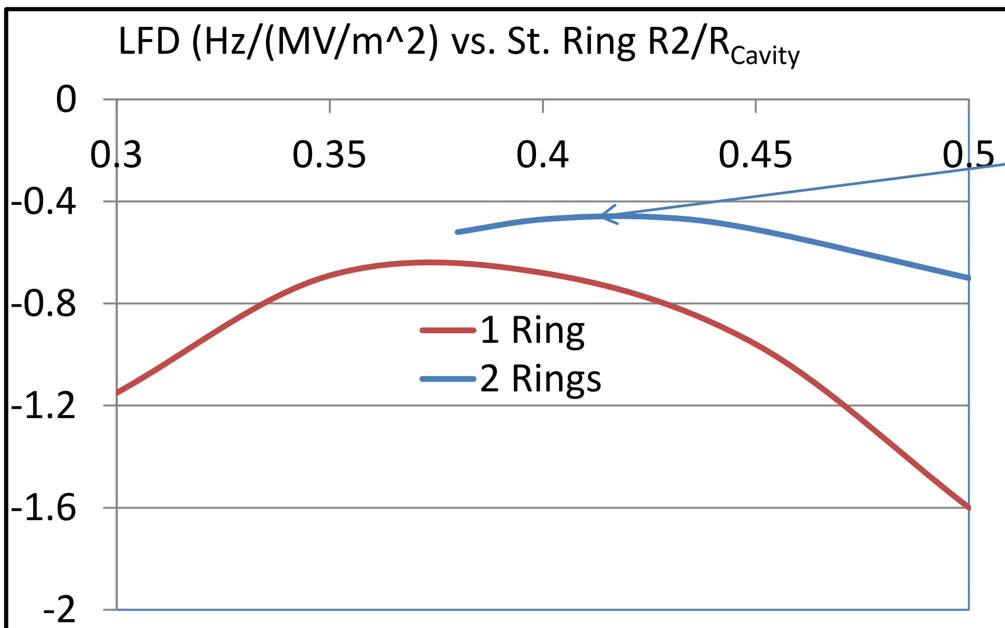
LB650 MHz cavity

Cavity operational and test requirements

Parameter	Value
Max Leak Rate (room temp)	< 10^{-10} atm-cc/sec
Operating gradient	16.5 MeV/m
Maximum Gain per cavity	11.6 MeV
Q_0	>1.5x 10^9
Maximum power dissipation per cavity at 2 K	24 W
Sensitivity to He pressure fluctuations	< 20 Hz/Torr
Field Flatness	Within ±10%
Multipacting	none within ±10% of operating gradient
Operating temperature	1.8-2.1 K
Operating Pressure	16-41 mbar differential
MAWP	2 bar (RT), 4 bar (2K)
Max RF power input per cavity	33 kW (CW, 2 mA)

LFD in LB650 cavity for PIP II





Cavity Stiffens
~2.7 kN/mm

Stiffness of the LB650 cavity is even lower compared to stiffness of the HB650 cavity

The Scope of EM-Mechanical design work

- Minimize a sensitivity to microphonics due to He pressure fluctuations (df/dP) and mechanical vibrations
- Minimize a Lorentz Force Detuning (LFD) coefficient
- To keep the stiffness and tuning sensitivity at suitable level to allow for tuning.
- Keep provision for slow and fast tuner integration.
- Dressed cavity has to be qualified in 5 different load conditions by stress analysis

1. Warm Pressurization
2. Cold operation at maximum pressure
3. Cool down and tuner extension
4. Cold operation at maximum pressure and LHe weight
5. Upset condition – Insulating and beam vacuum failure