Fermilab

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Fabrication and post-fabrication steps for reaching target frequency in spoke cavities

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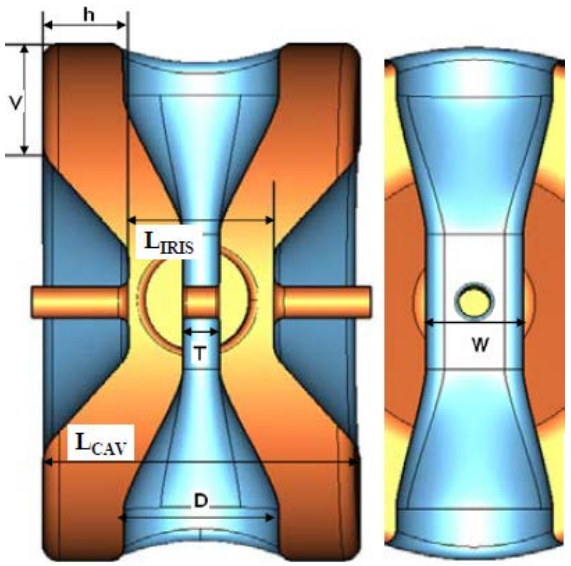
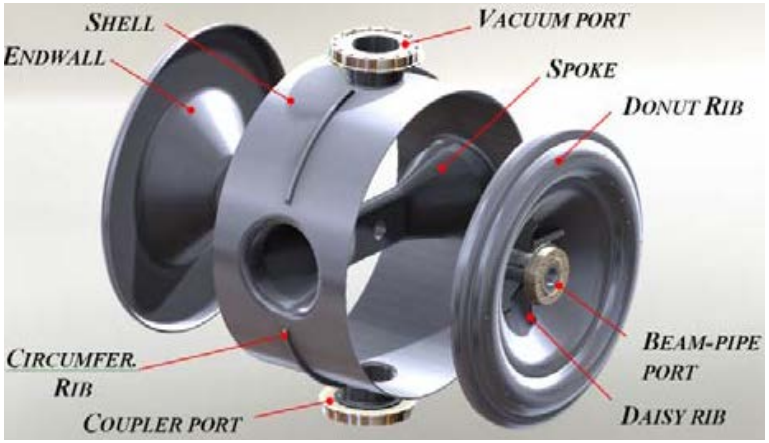
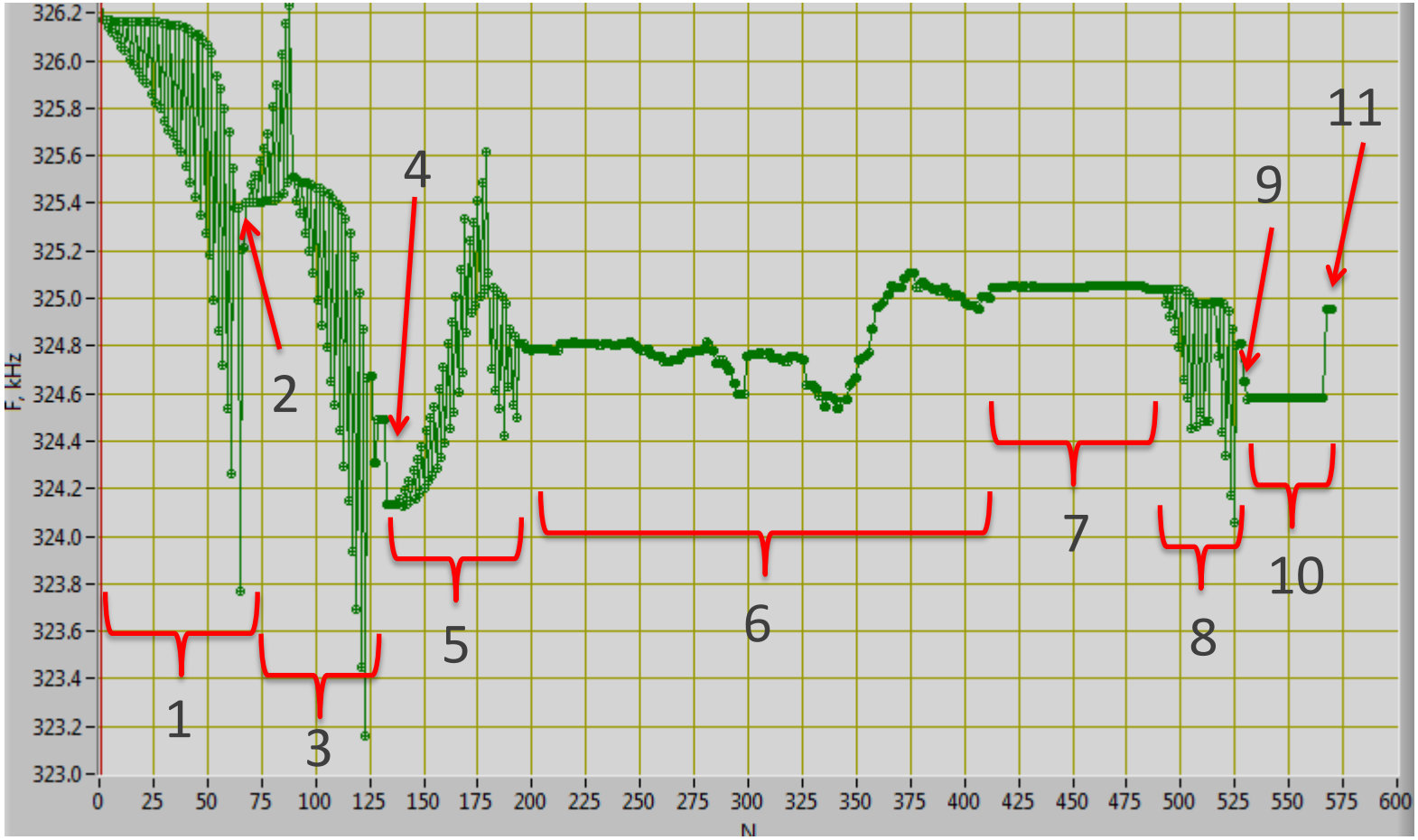
SSR1 operating mode frequency map

- Trimming of shell length in order to reach goal frequency and beta, - 0.37(0.345) MHz/mm
- Final trimming before last shell welding
- Welding and leak check, df ~ -0.2 MHz
- Finished bare cavity pre-tuning if needed
- BCP and 600C heat treatment, df ~ 0.2 MHz
- 120C bake and cold tests, df ~ 0.0 MHz
- Pre-tuning before helium vessel
- Transition ring welding, df ~ -0.5 MHz
- Helium vessel welding, |df| < 0.2 MHz
- Final tuning of dressed cavity - 0.46 MHz/mm
- At room temperature air inside 324.6 MHz
- At 2K in vacuum 325.1 MHz
- 2K operating conditions, frequency tuned by slow tuner to 325.0 MHz





SSR1-107 operating mode frequency history



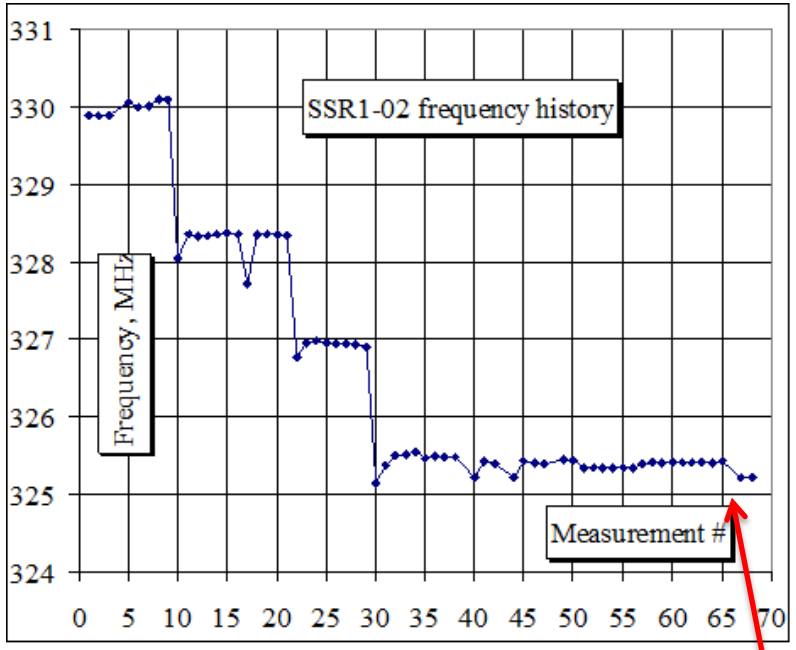
1- pre-tuning, 2- BCP, 3-tuning, 4- ring welding, 5- tuning, 6-dressing, 7- leak check and pressure test, 8- tuning with dummy tuner, 9- cavity pumped down, 10- tuner installation, 11- insulating pumping, vacuum everywhere in STC.

SSR1 main production steps changing frequency

- Frequency control during welding of the cavity
- Non-elastic tuning of finished bare cavity
  - Stretching cavity
  - Compressing cavity
- Transition ring welding
- Helium Vessel welding
- Final tuning of dressed cavity

SSR1 frequency control during welding of the cavity

- End-walls manufactured per drawings
- Shell manufactured with extra length
- Pre-tuning of cavity assembly before welding
  - Cavity assembly measurements
  - Trimming 30-70 % of calculated extra length
  - Repeat this step if frequency is too high
- Welding of one end-wall to the shell
- Measure assembly frequency & length and calculate weld shrinkage and dl for trim
- Final trimming of shell by calculated amount
- Welding of last end-wall to shell joint

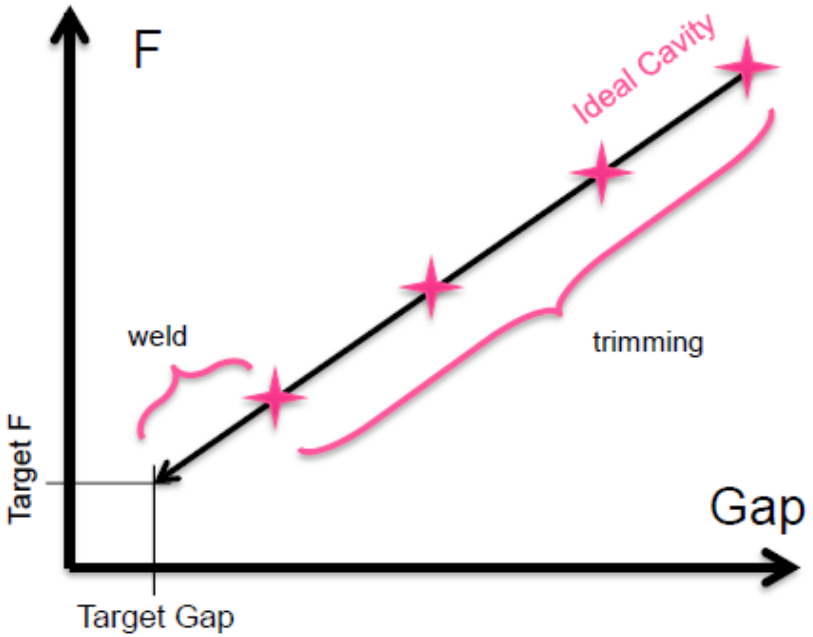


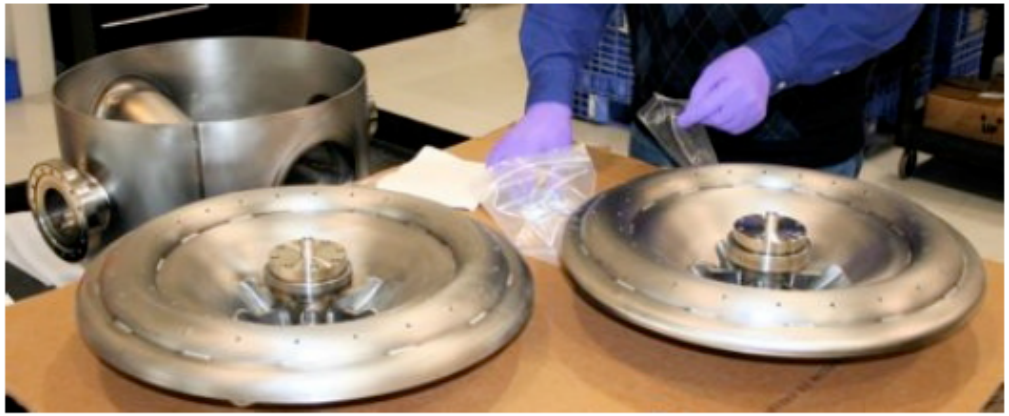
Leak check shifted frequency by -0.2 MHz. Done at manufacturer site before work hardening

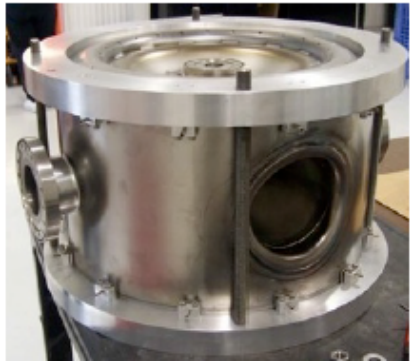
SSR1 shell trimming before final weld

- Frequency is adjusted by trimming the outer conductor incrementally, before final equator welds.
- Ideal cavity will hit target frequency and gap size

Operation	Shift (kHz)	Freq. (MHz)
End-wall Welding	Negligible	323.975
BCP (120-150 μm)	+ 160	324.135
BCP (20-30 μm)	+ 40	324.175
Ring + Jacketing	+ 500	324.675
BCP (20-30 μm)	+ 40	324.715
Cool-down	+ 385	325.100
Tuner Engaged	- 100	325.000



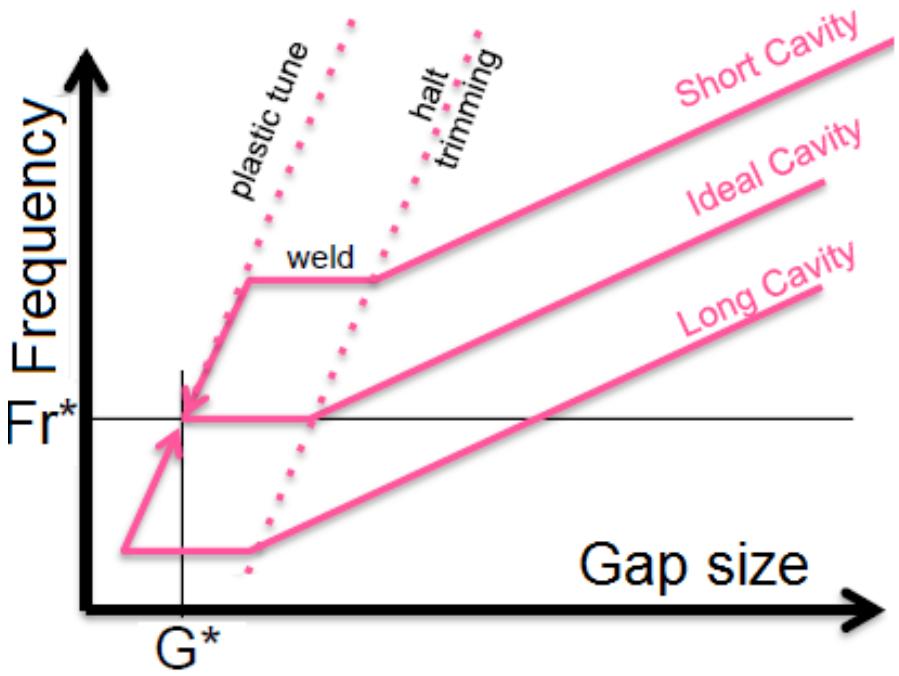


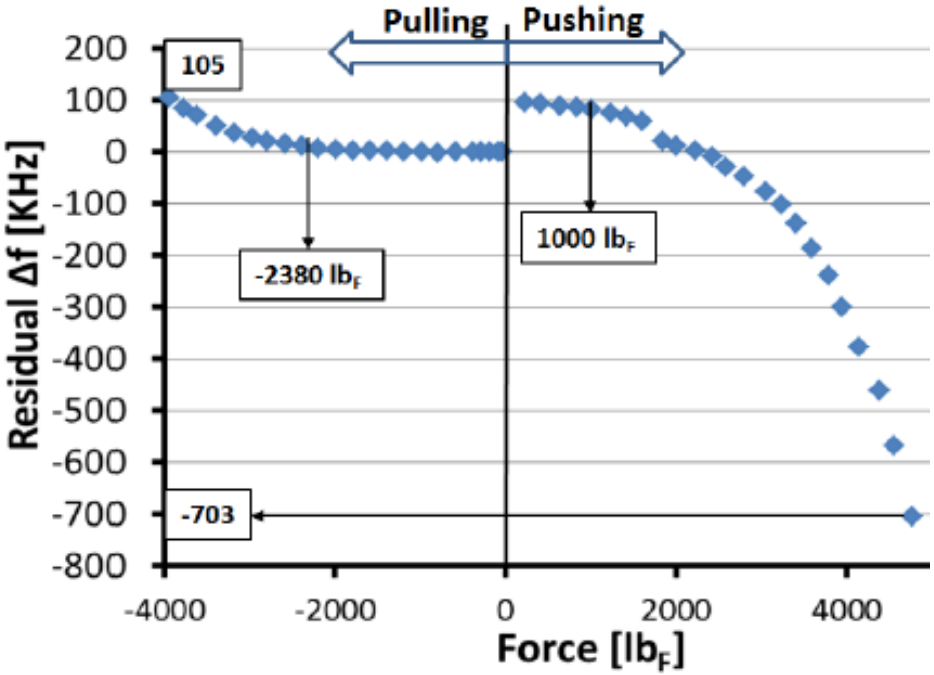


SSR1 trimming and plastic tuning

- Frequency AND gap size can be achieved by using wisely the plastic tuning process.
- Trimming should be interrupted at the crossing of the "halt trimming" line, not at a fixed frequency

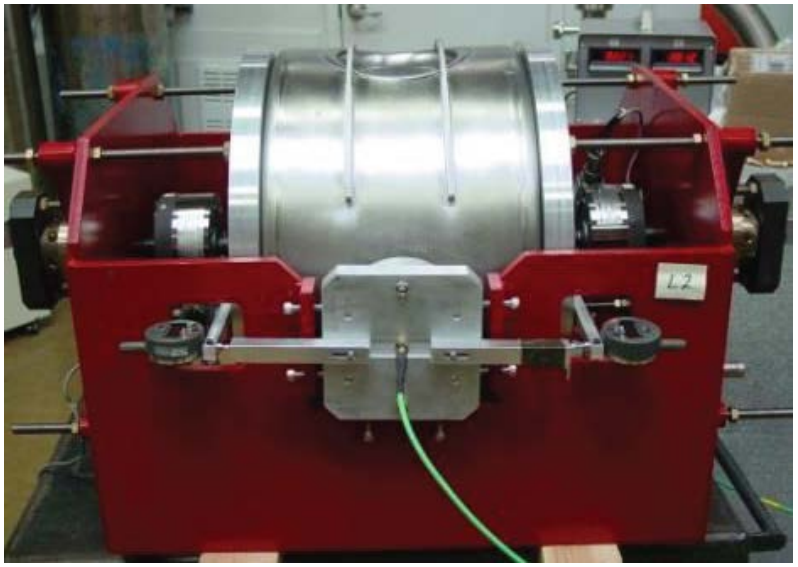
kHz/mm	measured (avg)
trimming	345 (320-370)
plastic tune	465
elastic tune	585

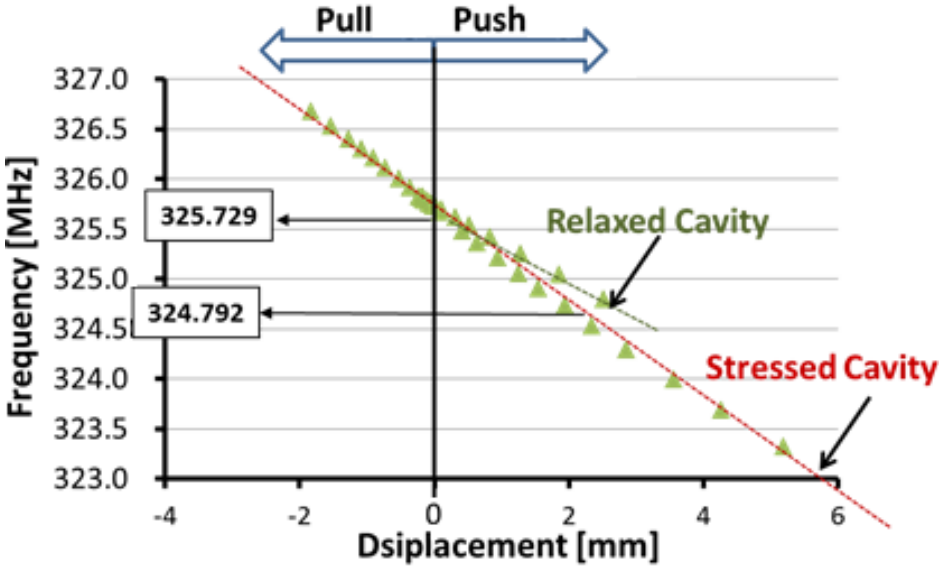


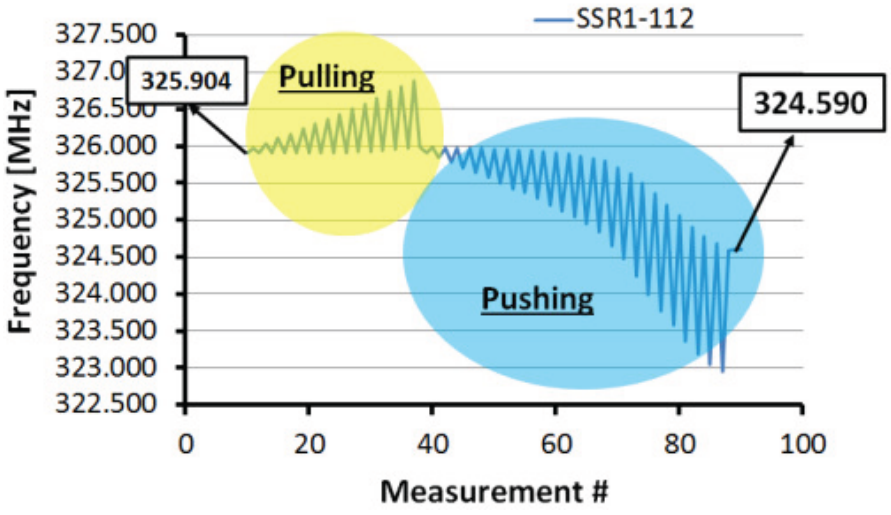


SSR1 tuning of bare cavity

- Elastic df/dl simulated is 0.54 MHz/mm and measured of 0.53(0.585) MHz/mm.
- Non-elastic df/dl 0.37(0.465) MHz/mm.
- Elastic tuning range increased from 0.6 MHz to 1.5 MHz after work hardening
- Pull before Push if tuning frequency df<0.2 MHz for work hardening

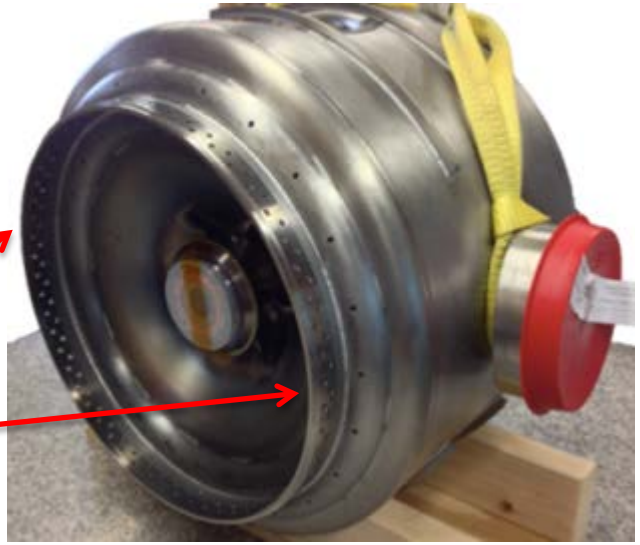






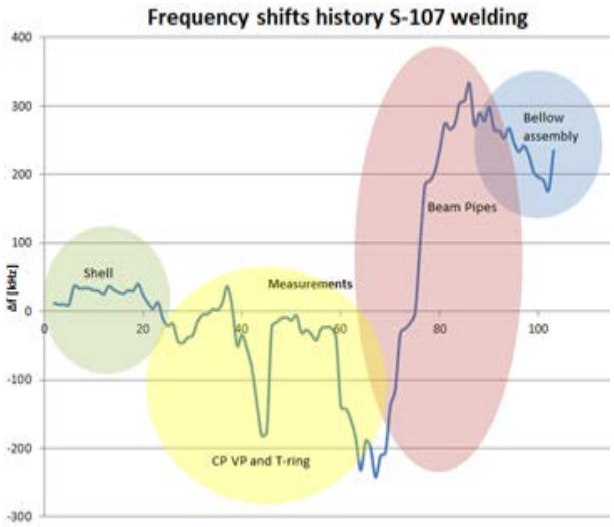
SSR1 transition ring welding

- SSR1 cavities are welded to a ring that will serve as a connection in between one of the cavity wall and helium vessel, this is called transition ring.
- The weld shrinkage affects the resonator frequency bringing it down since the beam tube moving in reducing the gap, and thus affects the field flatness as well.
- The frequency shift induced has been monitored on several SSR1 cavities, taking measurements before and after the weld, overall the shift ranged from -460 to -500 kHz.



SSR1 helium vessel welding

- SSR1-107 has been welded into a helium jacket, SSR1-109 and 108 are being welded right now, process still on going.
- The vessel is welded on the side ports, transition ring and on both beam pipes, one of them is attached to a bellow. All of the welds mentioned have an affect on the frequency except the one on the bellow side.
- The first cavity showed an overall positive frequency shift due to the welding on the transition ring side beam pipe, $\Delta f \approx 240$ kHz.
- A critical step was welding and centering of the side ports since they get displaced by the shrinkage on transition ring welds.
- Cavity and vessel are shown in the picture on top, the frequency history of SSR1-107 during welding is reported in the figure on the bottom right.



Final tuning of dressed cavity

- Final tuning of the dressed SSR1 cavity is necessary to compensate an uncertainty of frequency shift during dressing
- Stiffness of end walls are different therefore only bellows side was tuned