DQW LHC-series cavities

Discussion: Trim Tuning

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AGENDA

- **Updated target frequency table for DQW SPS-series** cavities (Silvia)
- **Lessons learned** from tuning the DQW SPS-series cavities (Silvia)

- **Target frequency for DQW LHC-series** cavities (All)
  - Jacketed, evacuated, at 2K, delivering 3.4 MV to the LHC beam ~ 400.75 MHz

- **Strategy** (All):
  - Metrology.
  - Symmetric trim tuning, or last is asymmetric?
  - Cavity profile sketch with location of trim edge needed to calculate available trim tuning range

- **Equipment** (Nuria):
  - Clamp
  - Probes
  - Pickup tube

- **Responsibilities** (All):
  - RI and CERN-BNL responsibilities.
  - Non-disclosure agreement.

MINUTES

- Metrology will be provided by RI.
- 3 trimming steps, the third being the last one.
- Symmetric trim tuning: favor symmetry of the cavity; the two welds are performed after machining if finished, sequentially.
- Probes: fabricated by CERN, handled to RI.
- RI is responsible for trim tuning. CERN-BNL is a witness with know-how.
- Non-disclosure agreement.

ACTION ITEMS

Silvia -- Generate a target frequency table for DQW LHC-series cavities:

- ❑ Jacketed, evacuated, at 2K, delivering 3.4 MV to LHC beam ~ 400.75 MHz
- ❑ Include target frequency for each trimming steps
- ❑ Correct units and column label (expected → measured), update LFD

CERN -- Check:

- ❑ if enough load for tuner;
- ❑ desired frequency point if tuner breaks to avoid synchro-betatron sidebands (at 3, 8 kHz);
- ❑ LFD for jacketed CERN SPS-series cavity
- ❑ Cavity profile sketch with location of trim edge needed to calculate available trim tuning range.
- ❑ Clamp: to be prepared by RI, design to be reviewed by CERN-BNL.

Target frequencies for DQW SPS-series [1]

Operation	Expected shift [kHz]	Expected frequency [MHz]	Target frequency [MHz]	Acceptance range [MHz]	Cavity status
Fabrication tolerances (before W03A/B)		N/A			
TUNING: trimming			401.05	±0.10	Clamped, in air at room temperature
Welds W03A/B (transverse shrinkage and penetration depth effects)	-0.89	400.16			
Leak check	0				
TUNING: action on inductive plates (alternative tuning)			400.16	±0.10	In air at room temperature
Bulk BCP (150 um)					
High temperature baking	+0.22	400.38			
Light BCP (30 um)					
Vessel assembly	-0.42	399.96			
TUNING: action on tank plates (pre-tuning)			399.96	±0.05	In air at room temperature
Assembly of HOM filters, pickup and FPC (in 5 mm-longer ports)*	-0.04	399.92			
Cool down with helium vessel (shifts due to ΔT, Δp, $\Delta \varepsilon$)	+0.71	400.63			
RF on (LFD)	-0.3004	400.63			
TUNING: with push/pull system			400.73-400.79	±0.005	In vacuum at 2 K

Measured MHz

- 4 kHz

(Target frequencies updated in Nov. 2017 from measurements; information from pull-push tuning not included.)

Measured LFD for CERN DQW SPS-series ”bare” cavities with cold test stiffening frame was -350 and -400 Hz/(MV)^2 [2], thus -4 kHz for 3.4 MV

(Preference to operate tuner in pulling mode to avoid buckling.)

Lessons learned from DQW SPS-series cavities

1) Deformation during last two welds… found method to tune the frequency back.

2) Main frequency shifts:

Step	Frequency shift (MHz)	
	SPS-DQW-01	SPS-DQW-02
Last two welds	+3.10	+3.11
BCP	+0.14	+0.22
High-T baking	+0.07	-0.001
He tank assembly, welding	-0.42	-0.57
Coupler insertion	-0.04	-0.02
Cool down	+0.71	not available

3) Predicted shifts were underestimated and measured shifts have large deviation, but tuning range was sufficient to tune the frequency back.

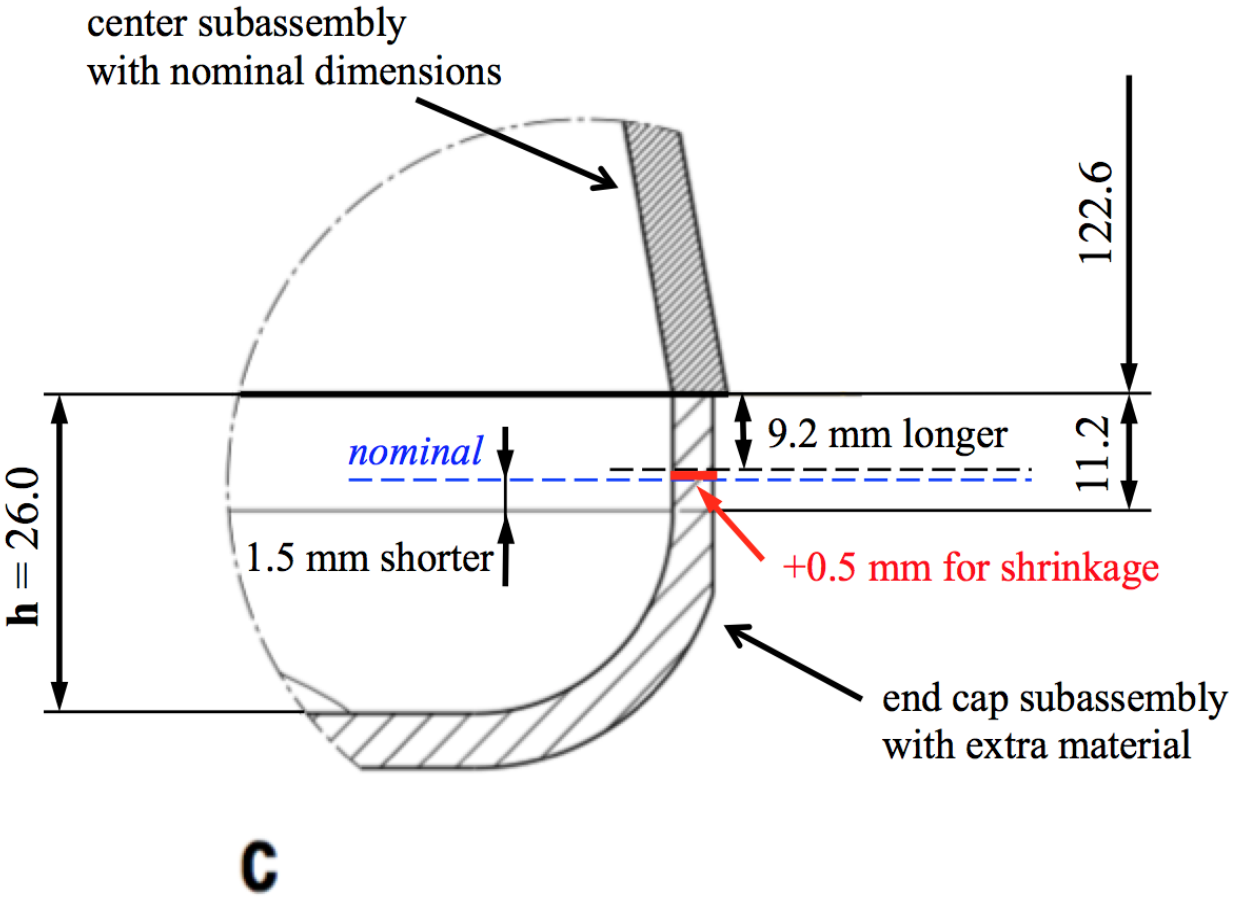
Tuning methods, range

Tuning method	Tuning sensitivity (MHz/mm)	Minimum frequency step (MHz)	Minimum tuning step (mm)	Tuning range (MHz)	Range limit (mm)
Trimming	Increases from 0.7 to 1.0 with trimming	±0.5	±0.5 Nb machining	(+13, -2)	(+9.2, -2.0)
Alternative tuning	1.2	-0.1	-0.08	-2.4	2.0
Pre-tuning in tank (at warm)	0.77 – 0.94 (calculated)	±0.025	±0.025 Control screws	±0.684	±0.8 Stress in NbTi
Push-pull tuning (at cold)	0.318	±0.000018	±0.00006	±0.508	±1.6 Stress in Nb

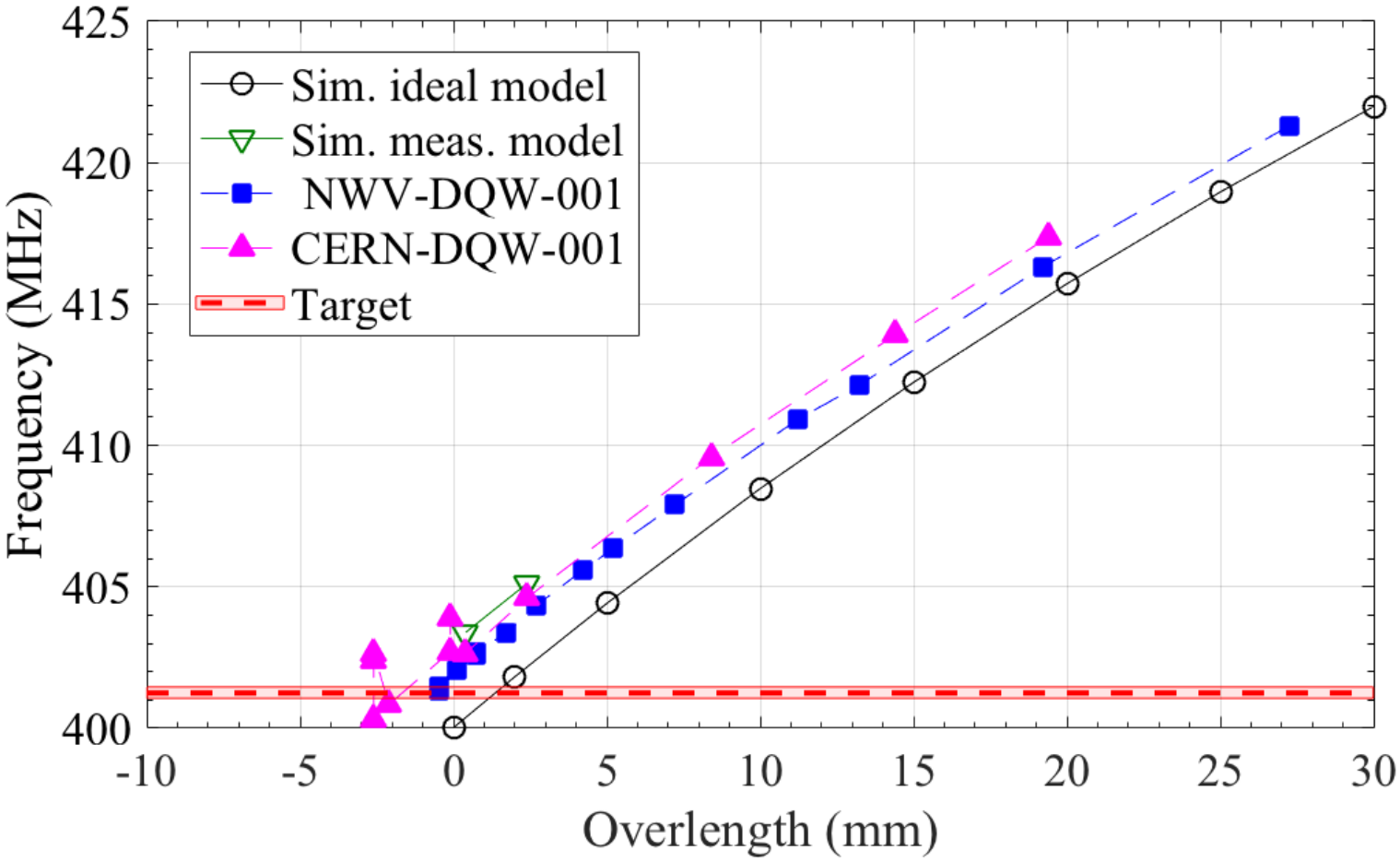
Tuning methods, range

- Before the three last subassemblies of the cavity are welded together: **trim tuning** to correct from frequency deviations resulting from cavity profile within manufacturing and assembly tolerances.
- After leak check and before surface treatment preparatory for cavity cold rf test (that is, before light BCP): **action on the inductive plates** of the cavity to correct deviations due to welding, leak check and eventually, bulk BCP and high temperature baking.
- After helium vessel assembly: **pre-tuning in helium vessel** to correct from cavity deformations induced by helium tank assembly.
- For installed and operative cavity: **push-pull tuning** to shift cavity frequency during operation with different energy beams and to allow cavity transparency and provide a tool to mitigate bunch instabilities.

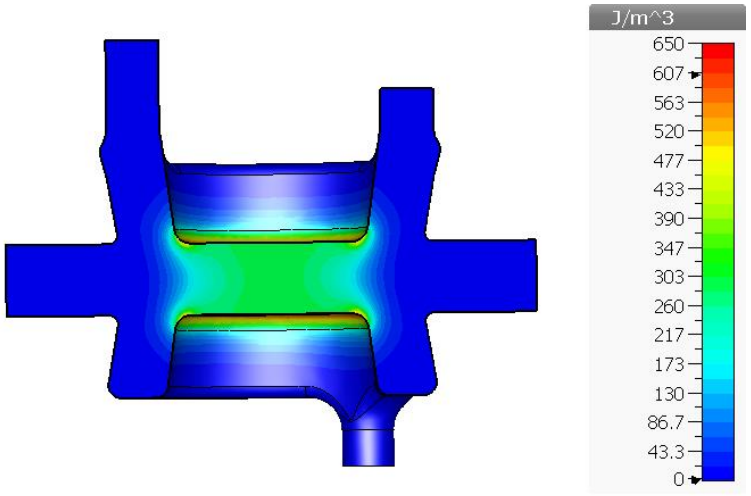
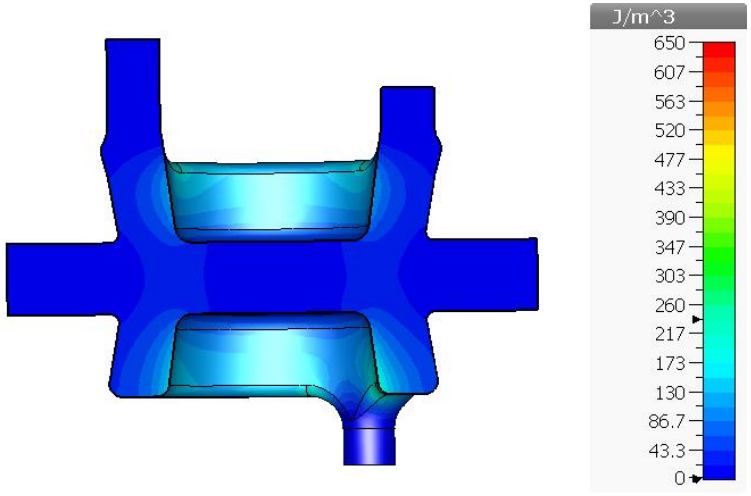
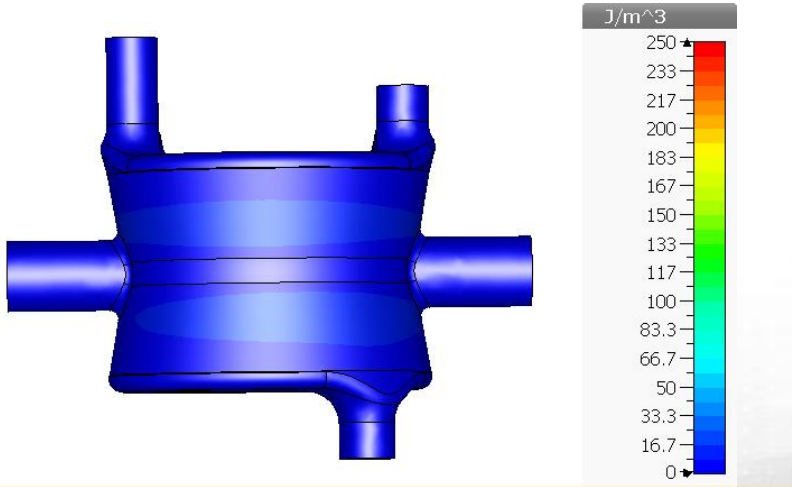
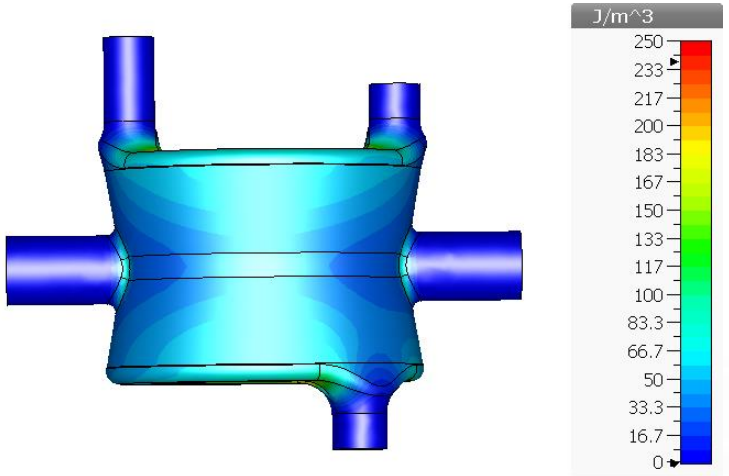
Trim tuning


center subassembly
with nominal dimensions
122.6
9.2 mm longer
11.2
nominal
h = 26.0
1.5 mm shorter
+0.5 mm for shrinkage
end cap subassembly
with extra material
C

Trim tuning


Sim. ideal model
Sim. meas. model
NWV-DQW-001
CERN-DQW-001
Target
Frequency (MHz)
Overlength (mm)
425
420
415
410
405
400
-10
-5
0
5
10
15
20
25
30

Stored energy density in a DQW SPS-series

	Electric - U_E	Magnetic – U_H
In middle plane		
In outer wall		

REFERENCES

[1] S. Verdú-Andrés, *"Target frequencies for a DQW cavity",* EDMS 1569809 v.3 (Nov. 8, 2017): https://edms.cern.ch/document/1569809/3

[2] A. Castilla-Loeza, *"CERN DQW Tests Summary",* presented at the 7th HL-LHC Collaboration Meeting, 13-16 Nov. 2017, CIEMAT (Madrid, Spain).

Predicted shifts were underestimated

- Low predictability but cavity is easy to tune.
- Tuning system implemented to correct weld effect offers enough range to bring cavity to target frequency.

Operation [CERN-001]	**Frequency [MHz]**	**Frequency shift due to operation [kHz]**	
		Expected	Measured
Last welds (W03A/B)	402.69	-890	+1250 / +1850
Leak check	402.39	0	-237
Alternative tuning	400.27		
Bulk BCP (150 um)	400.51	-127	+230
Bake 650 C for 24 h	400.58	0	+67
Light BCP (30 um)	400.59	-24	+14
Stiffening frame assembly	400.59	0	0
Evacuation: $\Delta\varepsilon$	400.69	+134	+100
Evacuation: $\Delta p + \Delta\varepsilon$	400.26		
Cooldown	401.20	+609	
Warm cavity, vented, no stiff. frame	400.51		
Alternative tuning	400.09		