LHC Crab Cavities
Impedance and Multipole Update

J. A. Mitchell[1, 2]

[1]Engineering Department
Lancaster University

[2]BE-RF Section
CERN

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- SPS DQW antenna was dual function: HOM damper and fundamental mode antenna.
- Functions split because damping geometry coupled to beam (perturbing LLRF signal).

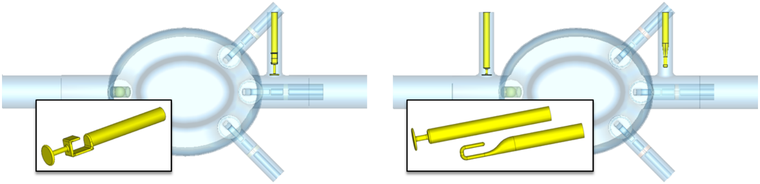
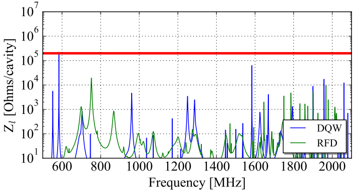
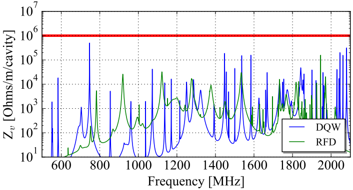
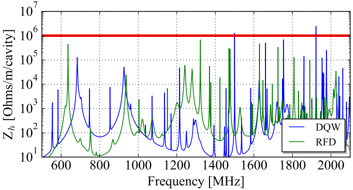


Figure 1: SPS (left) and LHC (right) DQW crab cavities with beampipe ancillaries highlighted.

Crab Cavity Impedance







- DQW model: EDMS No. 2009911 - Alumina ceramics, Nb HF-Damper, Cu Antenna.
- RFD model: EDMS No. 1347072
- RFD was benchmarked with ACE3P results from Z. Li.

Concerning Modes

- Limits: $\perp = 1\,\mathrm{M\Omega/m/cavity}$, $\| = 200\,\mathrm{k\Omega/cavity}$.

f [MHz]	Qe	R_v [kΩ/m]	R_h [kΩ/m]	R_l [kΩ]	Notes
583.59	4381	-	-	243.00	Far from bunch spacing harmonic
960.87	507	-	-	4.70	Close to bunch harmonic. Al_2O_3: R_l + 27% Al_2O_3: Frequency + 0.75 MHz
1500.20	23200	-	2009	-	
1754.40	8522	-	751	-	
1921.98	60600	-	2505	-	Not mesh converged.

Table 1: DQW

f [MHz]	Qe	R_v [kΩ/m]	R_h [kΩ/m]	R_l [kΩ]	Notes
752.06	217	-	-	19.4	9.4 MHz from bunch harmonic. Not simulated with HOM coupler ceramics.

Table 2: RFD

19^{th} and 24^{th} bunch spacing harmonics: 761.52 MHz and 961.92 MHz

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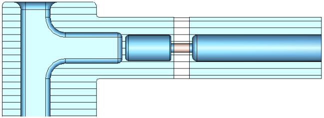
- HL-LHC beam parameters from [1].
- Mode frequency and Q varied: 1000 stochastic variations.
- Limits from SPS DQW measurements.
- Q: factor 0.5→2.0, f: -0.1→0.9%

Cavity	P_{max} (Gaussian) [W]	P_{max} (Binomial) [W]	Mode
DQW	1000	1000	961 MHz
RFD	8500	8200	752 MHz

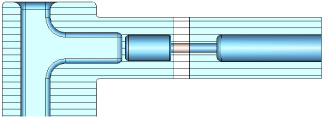
Table 3: Maximum HOM power values.

Average DQW 960 MHz shifts
f: +0.35%, Q: $0.77\times Q_{sim}$
From measured RFD HOM deviations [Berrutti et. al.]
f: +0.342 MHz, Q: $1.26\times Q_{sim}$

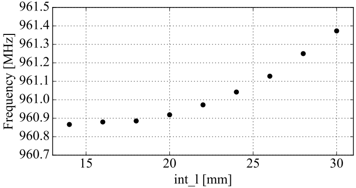
DQW Feedthroughs - Tuning



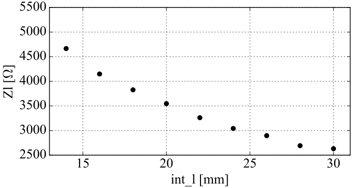
(a) Nominal, int_l = 14 mm



(b) int_l = 30 mm



(c) Frequency



(d) Longitudinal Impedance

Multipole Components

- Last meetings: Questions about b_4 magnitude.
- Re-visited: Issues with CST field export and convergence

  Panofsky Wenzel method did not converge. Lorentz Force does.

- Solved. Benchmarked with K. Papke's code.

SPS DQW (Dressed)					
		b1	b2	b3	b4
LF	Re	33	6	1498	1026
	Im	0	-2	19	-383
LHC DQW (Dressed)					
		b1	b2	b3	b4
LF	Re	33	6	1488	1048
	Im	0	-2	21	-292
LHC RFD (Dressed)					
		b1	b2	b3	b4
LF	Re	34	0	-458	128
	Im	0	0	-74	55

Table 4: Evolution of b_n in units of mT/m^{n-1}. Values correspond to a transverse deflecting voltage of 10 MV and are evaluated with 64 points around the azimuth at a radius of 30 mm.

- TDR: Limit of b_4 was 1000 units.
- TDR: Limits pending for higher components.

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Conclusions

- DQW HOMs: two horizontal modes 2.5 times over threshold.

- Worst case HOM Power in DQW (1000 W - very pessimistic) is more likely. But it is manageable.
- Heat load in RFD could be problematic (8 times threshold), f-shift is unlikely - measure during upcoming manufacture.
- Damping and tuning method for DQW 960 MHz mode.

- Multipoles: b4 are now more realistic → in limits. Limits for b5?

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Appendix

960 MHz Mode Shift

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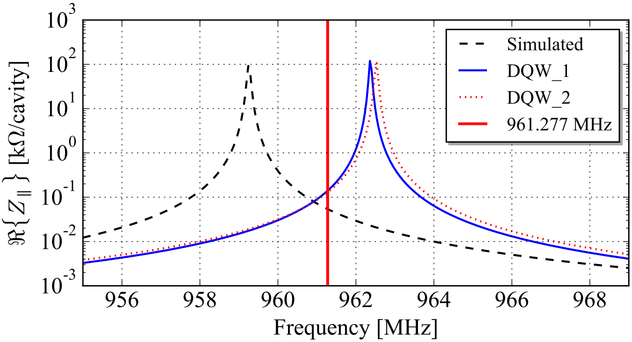


Figure 4: Measured impedance spectra in SPS.

Multipole Components

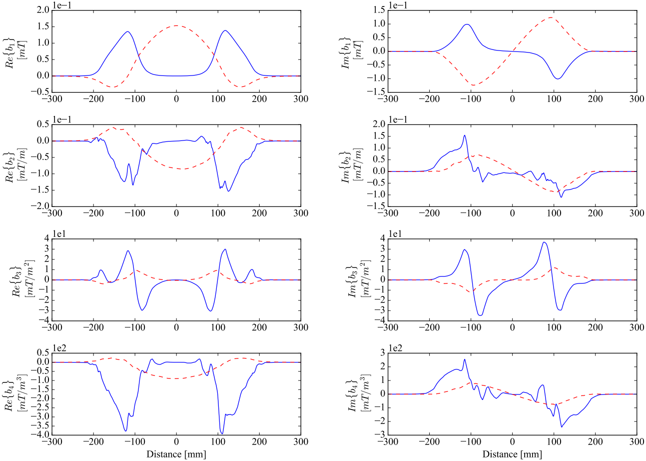
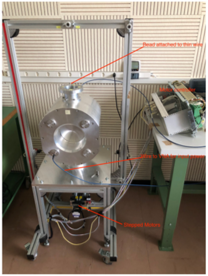


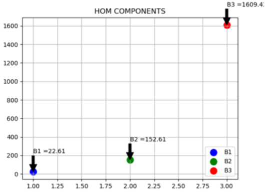
Figure 5: Multipole coefficients as a function of longitudinal position. Panofsky-Wenzel and Lorentz Force decomposition methods shown in blue and red dashed lines respectively.

Multipole Measurements

- Measurement technique developed on aluminium prototype (PoP design).
- TDR: Limits pending for higher components.



α_{radius}	b_1	b_2	b_3
20mm	31.97	0.18	1049.03
30mm	32.08	2.87	1184.75



- Work from and detailed in the summer student report by P. Gapais.

- 1500 MHz mode Q can be reduced using a more complex HOM damper.
- Probe material still under investigation - if copper can bring down by 25%.

- 1920 MHz mode is under investigation. I see a decrease in Q with mesh convergence, beam-pipe length and without ports.
- There are also big differences between broadband and narrow band solvers.

References

R. Tomas, Presentation: Parameter update for the nominal HL-LHC : Standard , BCMS , and 8b + 4e Current HL-LHC Parameters table, in *26th HL-LHC TCC*, 2017.