HOM COUPLER ALTERATIONS FOR THE LHC DQW CRAB CAVITY*

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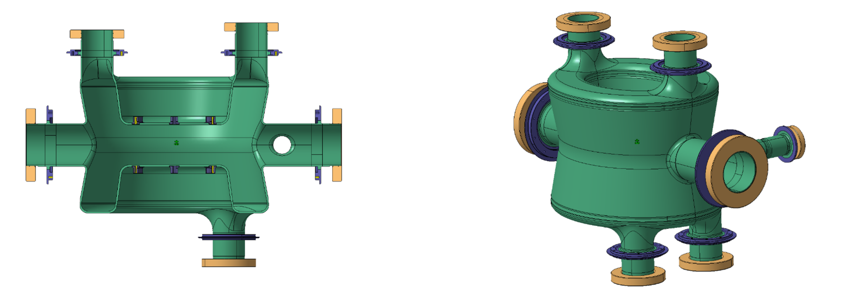
INTRODUCTION

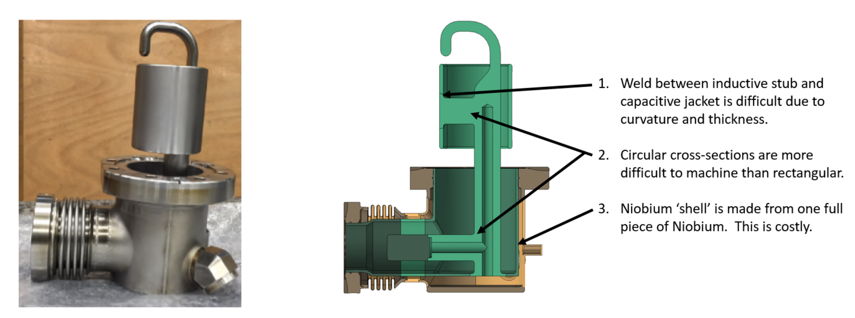
As part of the High Luminosity Large Hadron Collider (HL-LHC) project, 16 crab cavities are to be installed in the LHC in 2025. The two crab cavity designs are the Double Quarter Wave (DQW) and Radio Frequency Dipole (RFD). Preliminary beam tests in the Super Proton Synchrotron (SPS) are planned for both cavity types, with the DQW scheduled for testing in 2018.

The DQW has three identical on-cell Higher Order Mode (HOM) couplers. For the SPS cavity design several geometric constraints exist creating **RF performance limitations.** Additionally, current geometries have proven **difficult to manufacture**. These difficulties risk tolerances not being met and hence a degradation of the RF performance.

Henceforth, the HOM coupler design has been re-visited to asses the feasibility of both improving the damping of the cavity's spectral impedance and easing manufacturing processes, tolerances and costs.

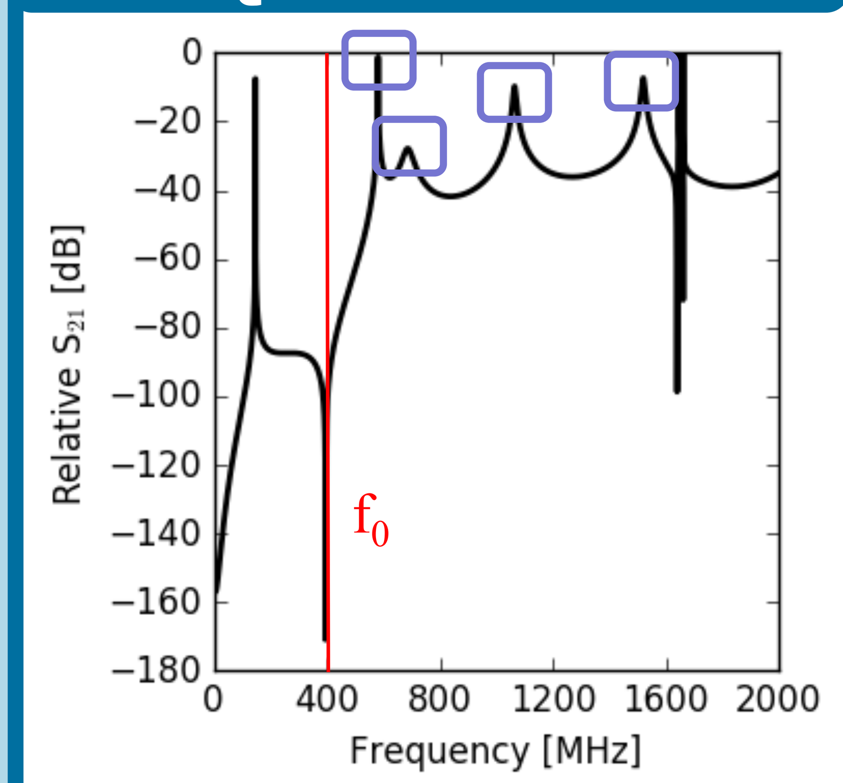


SPS DQW Crab Cavity



HOM Coupler for SPS DQW

SPS DQW HOM COUPLER



If the relative S_{21} is plotted as a function of frequency for the HOM coupler (left), the frequency dependant transmission can be evaluated:

- LC stop-band filter at f_0
- Higher frequency section:
  - Frequency dependant transmission line.
  - **Transmission peaks at filter interaction regions.**

The impedance spectrum can be derived from the Panofsky-Wenzel Theorem [10].

Impedance Calculations

The following formulae and schematics, derived from the Panofsky-Wenzel theorum, show how the transverse impedance was calculated.

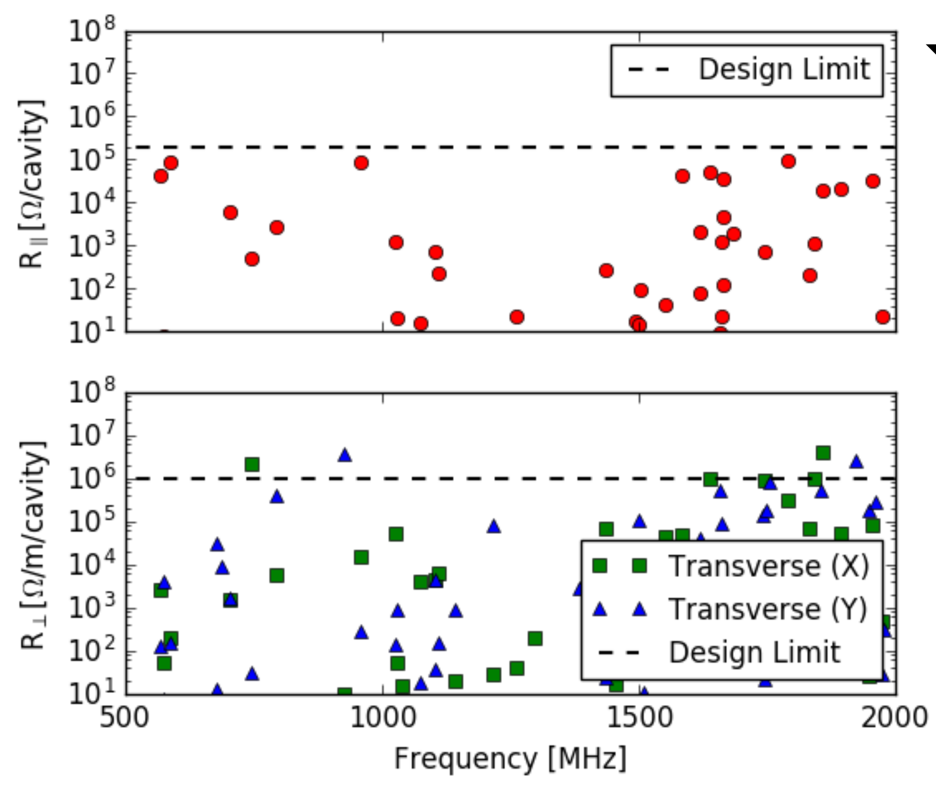
$$(R/Q)_{\perp(x,y)} = \frac{1}{2\omega U}\cdot\left(\frac{c}{\omega}\left|\frac{dV_z}{d(x,y)}\right|\right)^2 \quad (1)$$

$$R_{\perp(x,y)} = (R/Q)_{\perp(x,y)}\cdot Q_{ext}\cdot\frac{\omega}{c} \quad (2)$$

For longitudinal impedance, the following calculations are applied:

$$(R/Q)_z = \frac{1}{2\omega U}\cdot|V_z|^2 \quad (3)$$

$$R_z = (R/Q)_z\cdot Q_{ext} \quad (4)$$



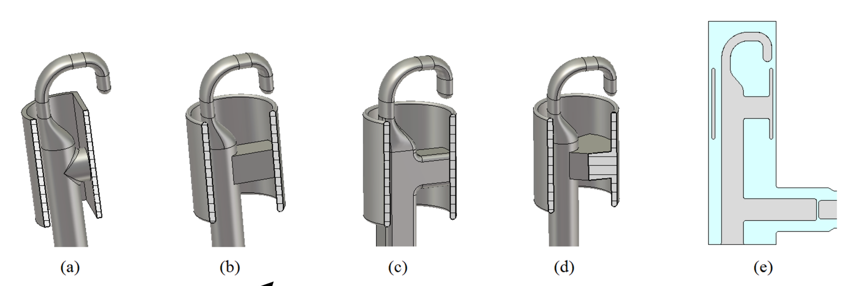
PARAMETRIC INVESTIGATION

SPS Coupler Geometric Problems:

1. The section joining the jacket to the central shaft is very difficult to weld due to access restraints, curvature and thickness.
2. Circular cross sections with blended sections can prove difficult to machine to tolerance.
3. The Niobium jacket surrounding the bend section of the coupler is very expensive to manufacture as it needs to be machined from one piece of Niobium.

Mitigations

1. A flat section on the capacitive jacket.
2. Rectangular profile with rounded edges.
3. Larger distance from the inner conductor bend to the end of the Niobium shell.

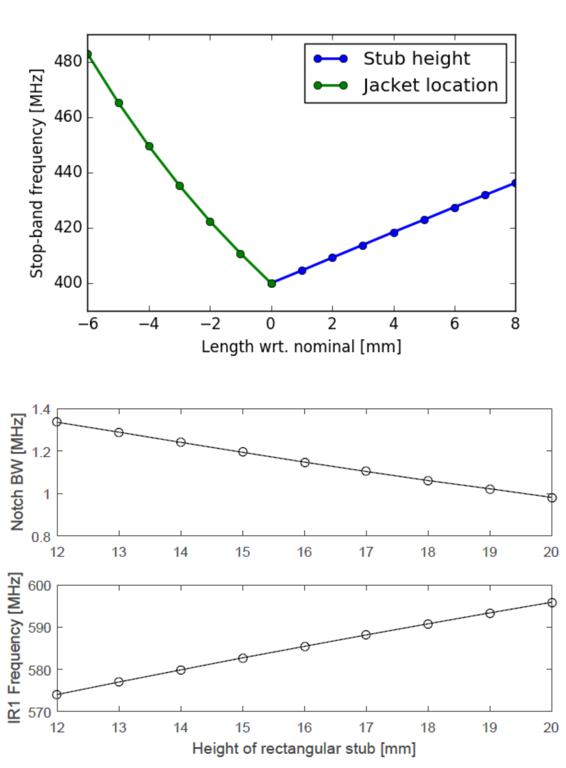


Several geometric changes were implemented on the HOM coupler to **reduce the manufacturing difficulty**. Parametric variation allowed the effect on several aspects of the HOM couplers RF performance to be analysed.

With the new changes - full parametric variation study. This gave 'weighting-factors' for the effect of each control parameter on each of the performance values:

- Stop-band frequency and amplitude.
- Stop-band bandwidth at -100dB.
- Frequency and amplitude of interaction regions 1-4.

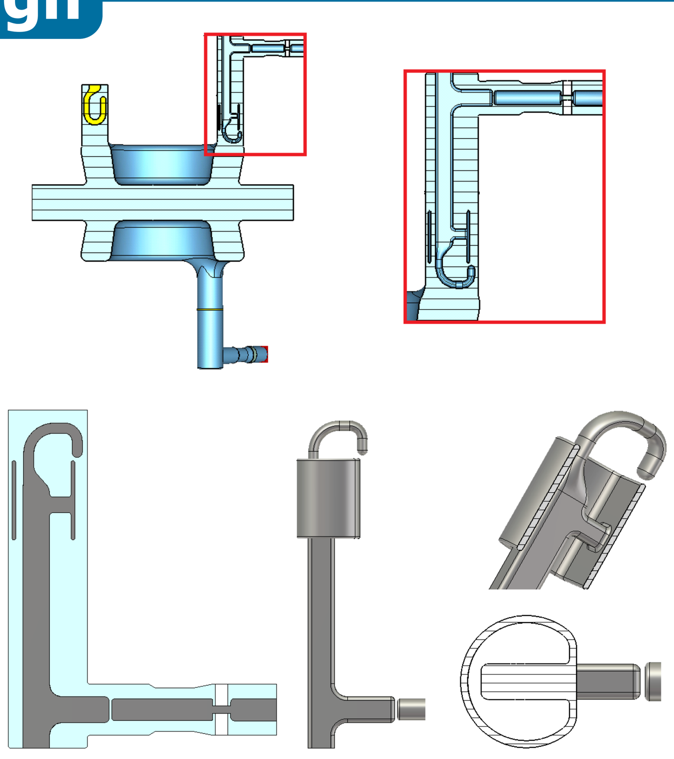
Examples of the parametric weighting factors are shown here.



CONCLUSION – A Proposed Design

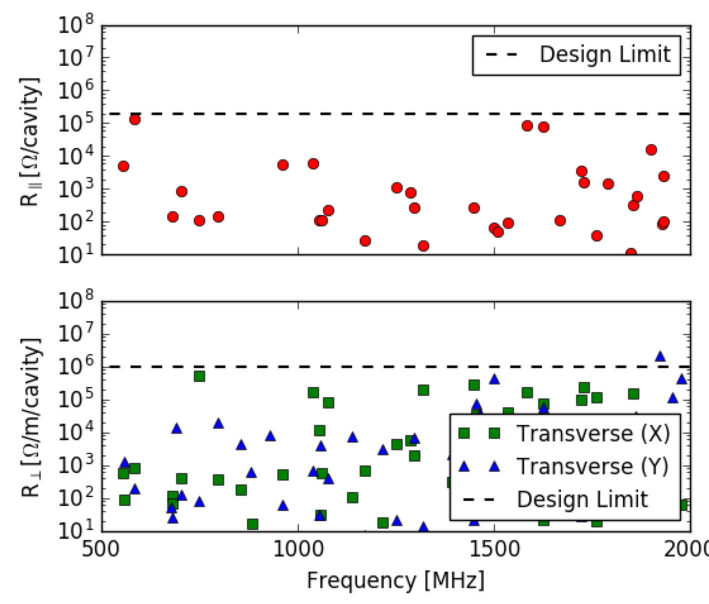
Design Alterations:

- A flat section on the capacitive jacket.
  - Better welding of the stub section.
- Rectangular cross-section throughout.
  - Less time consuming and simpler manufacture.
  - LC filter induction variation which is not inhibited by the shaft width.
- Longer overall length.
- Raised 'elbow' section.
  - Allowing extrusion of the outer Niobium jacket.



RF Performance:

- Final design impedances were all below the design limit apart from mode at 1920 MHz (transverse-y).
  - Impedance limit increases with frequency and thus the impedance of this mode is actually within threshold.
  - Further investigation of this mode and benchmarking in other EM codes.
- First interaction region of HOM coupler has larger bandwidth than before
  - At expense of notch bandwidth (8.6 times smaller).
  - Square profile stub tuning from test-box response.



REFERENCES AND AKNOWLEDGEMENTS

REFERENCES

[1] R. Calaga, S. Belomestnykh, J. Skaritka, Q.Wu, and B. Xiao, "A DOUBLE QUARTER-WAVE DEFLECTING CAVITY FOR THE LHC", No. 284404, (Shanghai, China), pp. 2408–2410, Proceedings of IPAC201

[2] R. Calaga, "CRAB CAVITIES FOR THE LHC UPGRADE", No. 2, Proceedings of Chamonix 2012 workshop on LHC Performance, 2012.

[3] B. Muratori and T. Pieloni, "Luminosity Levelling techniques for the LHC", (CERN, Geneva, Switzerland), pp. 177–181, Proceedings, ICFA Mini-Workshop on Beam-Beam Effects in Hadron Colliders BB2013), 2014.

[4] O. Bruning and L. Rossi, *The High Luminosity Large Hadron Collider: The New Machine for Illuminating the Mysteries of Universe*, vol. 1. Switzerland,Geneva: World Scientific, 2015.

[5] B. Xiao, L. Alberty, S. Belomestnykh, I. Ben-zvi, R. Calaga, C. Cullen, L. Hammons, Z. Li, C. Marques, J. Skaritka, S. Verdú-andres, and Q. Wu, "CYOGENIC TEST OF DOUBLE QUARTER WAVE CRAB CAVITY FOR THE LHC HIGH LUMINOSITY UPGRADE", (Richmond, VA, USA), pp. 3630–3633, Proceedings of IPAC2015.

[6] S. Verdú-Andrés, J. Skaritka, Q. Wu, and B. Xiao, "OPTIMIZATION OF THE DOUBLE QUARTER WAVE CRAB CAVITY PROTOTYPE FOR TESTING AT SPS", (Paris, France), pp. 995–997, Proceedings of SRF2013.

[7] R. Calaga and B. Salvant, "Comments on Crab Cavity HOM Power", tech. rep., CERN, 2015.

[8] Computer Simulation Technology, CST STUDIO SUITE, Bad Nauheimer Str. 19, D-64289 Darmstadt, Germany, http: //www.cst.com.

[9] Massively parallel electromagnetic ACE3P Simulation Suite, https://portal.slac.stanford.edu/sites/ard_ public/acd/.

[10] H. Padamsee, J. Knobloch, and T. Hays, *RF Superconductivity for Accelerators*. Wiley,Weinheim, 2008.

[11] J. A. Mitchell, R. Apsimon, G. Burt, A. Tutte, R. Calaga, A. Macpherson, and E. Montesinos, "LHC CRAB CAVITY COUPLER TEST BOXES", pp. 2248–2250, Proceedings of IPAC2015.

[12] J. A. Mitchell, G. Burt, and R. Calaga, "SIMULATION AND MEASUREMENTS OF CRAB CAVITY HOMS , COUPLERS AND MULTIPOLES FOR HL-LHC", This Proceedings.

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