# SIMULATION AND MEASUREMENTS OF CRAB CAVITY HOMS AND HOM COUPLERS FOR HL-LHC*

J. Mitchell† [1,2], R. Apsimon[2], G. Burt[2], T. Jones[2], N. Shipman[1,2], Lancaster University, Lancaster, UK
I. Ben-Zi, B. Xiao, S. Verdú Andrés, BNL, Upton, NY 11973, USA
R. Calaga, A. Castilla, A. Macpherson, E. Montesinos, A. Zalewska, CERN, Geneva, Switzerland
T. Powers, H. Wang, JLAB, Newport News, VA 23606, USA
[1]also at CERN, Geneva, Switzerland, [2]also at the Cockcroft Institute, Daresbury, UK

## 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.

Here, simulation and measurements of the SPS DQW HOM coupler spectral analysis are presented along side first measurements of the dressed cavity HOMs.

**HOM Coupler Test-Boxes**
Analyse full spectral response of DQW HOM couplers

**Comparison with Simulation**

**Are the Damping Deviations Predictable?**

**VTF Spectral Measurements**
For two cavities with HOM couplers

**Cavity Mode Characterisation**

**Comparison with Simulation**

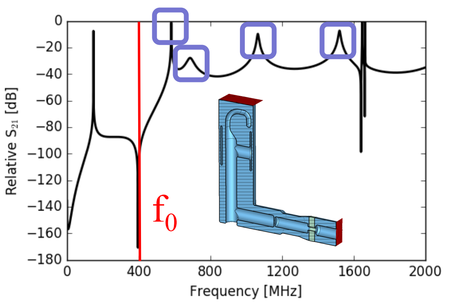
## TEST-BOX MEASUREMENTS

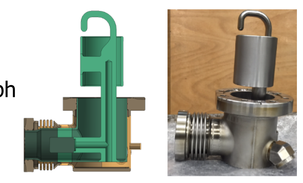
**Goal of test boxes:**
- Analyse frequency dependant transmission response of HOM couplers.

**Two test boxes designed:**
- L-Bend Transmission
- Coaxial Chamber

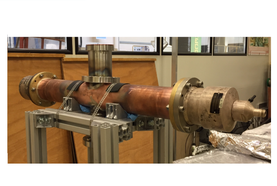
L-Bend Transmission used to measure each SPS DQW HOM coupler.

**Transmission response of the DQW HOM Coupler:**

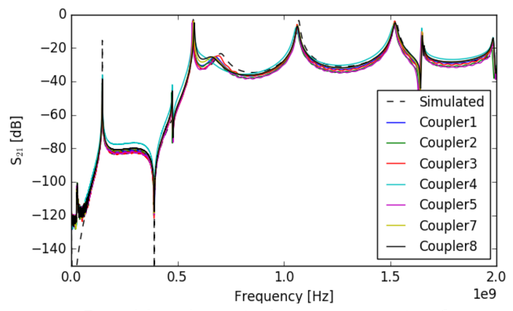


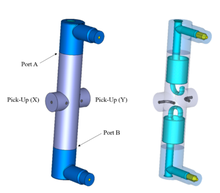
CAD cross-section (left) and photograph of SPS DQW HOM coupler.



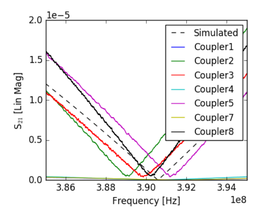
Coaxial chamber (left) and L-bend transmission (right) test boxes.




Broad-band spectral measurements of each HOM coupler.



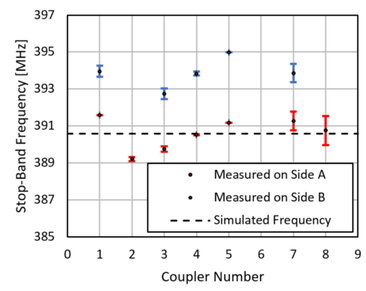

L-bend test box vacuum model.

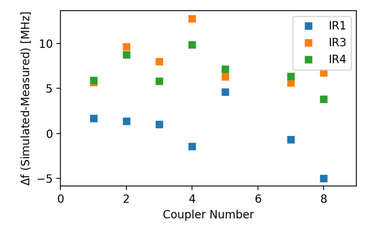


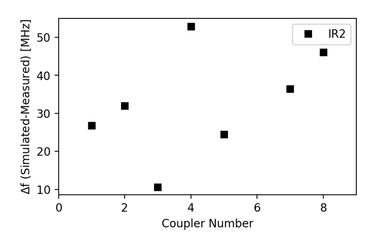

Spectral analysis of the stop-band frequency.

### Analysis

Frequency of the stop-band and interaction regions could then be compared to that of the simulated test box response.



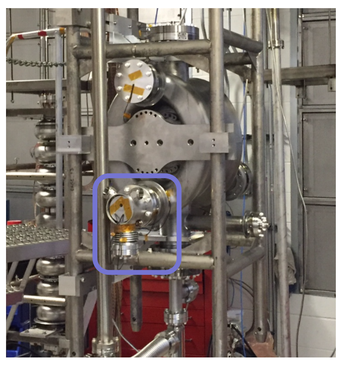




## CAVITY MEASUREMENTS

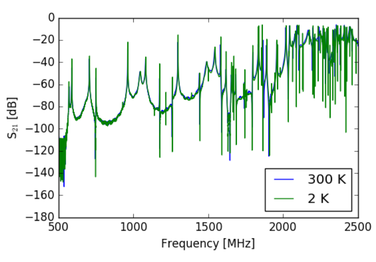
**NWV-DQW-001: JLAB**
With one HOM coupler on FPC Side

Test at JLAB had one HOM coupler (coupler 5) on the FPC side of the cavity.

Full spectral analysis measured and the frequency and Q of each mode measured at 300 K and 2 K.



NWV-DQW-001 before test.
Single HOM coupler is shown.

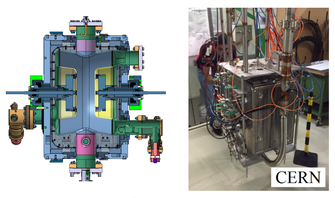



$S_{21}$ measured from 500 MHz to 2.5 GHz (cut-off frequency = 2 GHz)

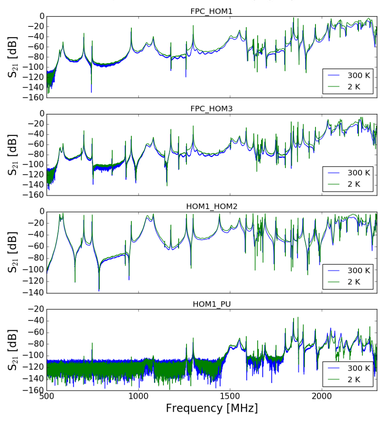
**CERN-DQW-001: CERN**
Three HOM couplers and helium vessel

Test at CERN of partially dressed CERN-DQW-001. Same procedure as that for the JLAB test was followed, however now with more transmission measurement combinations.

For both tests, all spectra were taken in segments of either 300 or 500 MHz with 10,000 points.




Cross section of partially dressed cavity model (left and courtesy of S. Barriere) and photo before test (right).



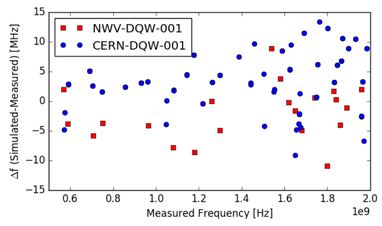

Examples of $S_{21}$ measurements from 500 MHz to 2.3 GHz (cut-off frequency = 2 GHz)

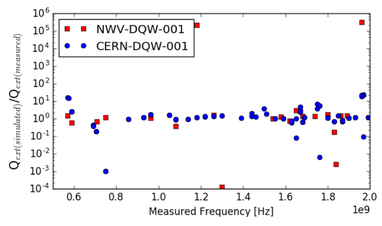
**Comparison with Simulations in CST MWS**

Following the measurements, comparison with eigenmode simulations carried out in CST MWS [3] were possible.

Frequency and external Q factor changes were compared. For the external Q factors, the ration of simulated to measured was taken. This gave an idea to the magnitude of the expected difference.

**Comparative Plots:**




If the frequency shift of the mode was greater than half the distance from the simulated mode frequency to it's neighbour; incorrect modal comparison.

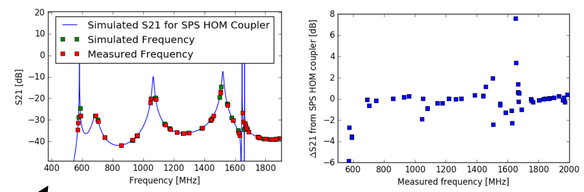
## CONCLUSIONS AND COMPARISONS

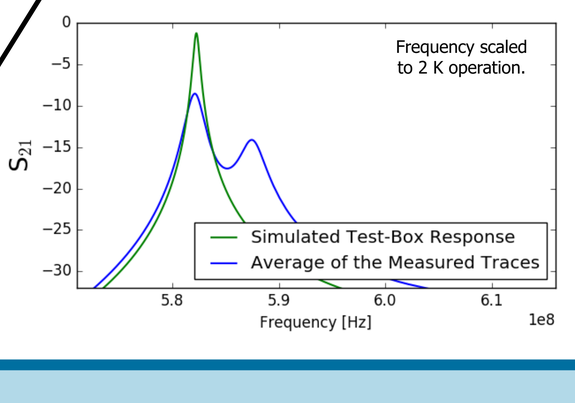
Test-Boxes
- Measured the spectral response of all HOM couplers to be used on the cavity.
- Compared the broad-band transmission response of each coupler.
- Compared the deviation of stop-band and interaction region frequencies to simulated values.

Cavity Tests
- Full spectral measurements of both the NWV-DQW-001 and CERN-DQW-001 partially dressed cavity tests taken.
- Individual HOM measurements for each mode.
- Comparison of mode characteristic between measured and simulated.

**Comparisons for CERN-DQW-001 Results**
*Can deviations in damping be predicted?*

1. A large increase in external-Q at 749 MHz was observed from measurements.
   - This was predicted by the test-box responses by the consistent decrease of the frequency of IR2.
2. First two modes - where the HOM coupler response is a sharp peak, the external-Q decreases.
   - If the change in HOM coupler $S_{21}$ is taken for the mode frequency shift– **reduction in damping predicted**.
   - If test-box measurements are scaled to 2K frequencies, peak broadening is seen which explains the increase for the second mode.
   - Still reduction of initial mode (but to lesser extent) – mode coupling ratios to be incorporated.

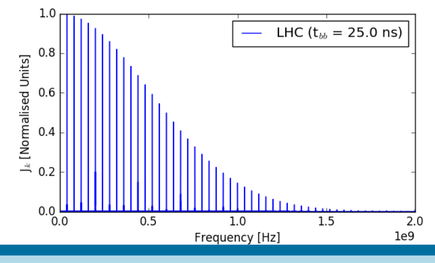



## FUTURE ANALYSIS

With the measured frequency and external Q-factor data from CERN-DQW-001, the change in HOM power as a result of the beam spectrum will be evaluated.

In addition to different bunch types, tolerance studies on both mode frequency and beam parameters can then be applied and the effect of theses changes on HOM power evaluated.




## REFERENCES AND AKNOWLEDGEMENTS

**REFERENCES**

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[3] Computer Simulation Technology, CST STUDIO SUITE, Bad Nauheimer Str. 19, D-64289 Darmstadt, Germany, http:// www.cst.com.
[4] Niowave Inc., http://www.niowaveinc.com/.
[5] A. Castilla, "FIRST HIGH-Q VALIDATION OF CRAB CAVITIES FOR STRING ASSEMBLY AT CERN", This Proceedings.
[6] J. Mitchell, G. Burt, and R. Calaga, "HOM COUPLER ALTERATIONS FOR THE LHC DQW CRAB CAVITY", This Proceedings.

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† **j.a.mitchell@lancaster.ac.uk**