HiLumi
HL-LHC PROJECT

First Test Results of DQW-HOM Coupler Testing

HOM Coupler Design Considerations: LHC

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CERN

Presentation outline

<u>First Test Results of DQW-HOM Testing</u>

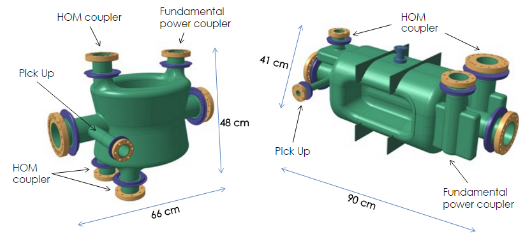
1. SPS crab cavity HOM couplers
2. HOM coupler test boxes
3. L-Bend test box: spectral measurements
4. L-Bend test box: transmission

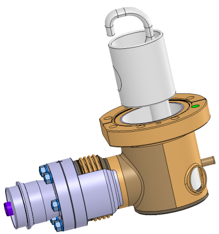
<u>HOM coupler design considerations: LHC</u>

1. LHC considerations for HOM coupler design

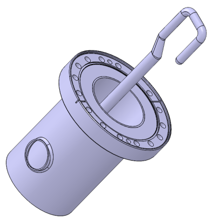
SPS Crab Cavity HOM Couplers

- SPS crab cavities:
  - Double Quarter Wave (DQW)
  - Radio Frequency Dipole (RFD)
- HOM couplers: Transmission path at the HOM frequencies but stop-band for the fundamental mode.

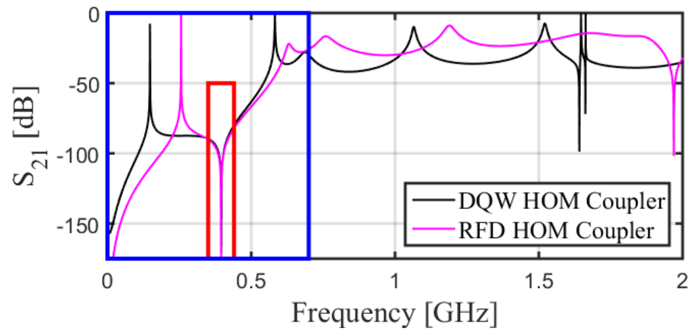




a) SPS DQW HOM coupler

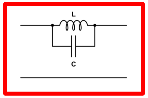


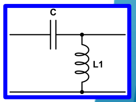
b) RFD HOM coupler



c) Spectral responses of the HOM couplers

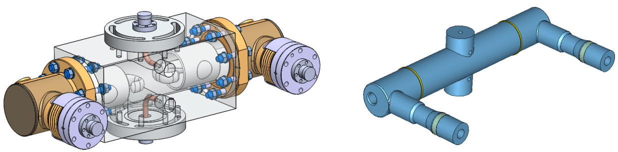
- It is beneficial to know the **spectral response** of the HOM couplers **pre-installation**.



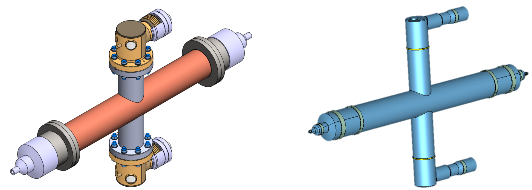


HOM Coupler Test Boxes

- **Aim:** Characterise the transmission and reflection of each coupler and the coupler pairs with respect to the simulated models.
- Test Boxes:



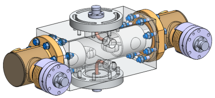
L-Bend

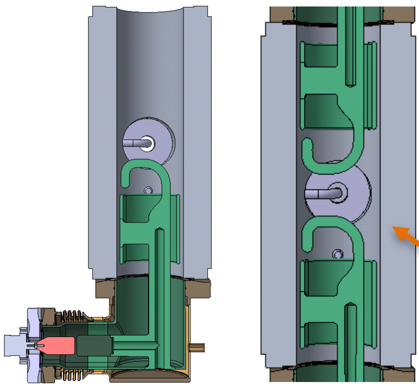


Coaxial chamber

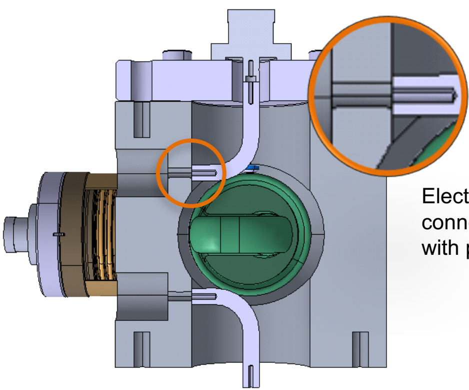
- Understand manufacturing tolerances between the 6+2 couplers.
- *Flange on the coaxial chamber had to be modified to ensure safe adaptation with the HOM coupler flange. Hence no measurements have yet been performed.*

L-Bend Test Box: Measurements





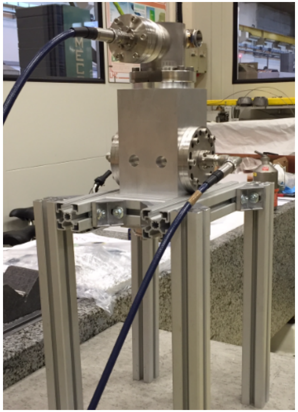
- The L-bend test box uses a **pick-up probe**, with an **electrical connection** to the wall, measure the **transmission response of the coupler**.
- Single coupler measurements can be done on one port, with a blank fixed to the other side.
- Two pick-ups are available for comparison and hence evaluation of alignment/rotational errors.
- The test box can also be used as a means to test the transmission between couplers.
  - This acts as a feasibility study for pre-installation conditioning.

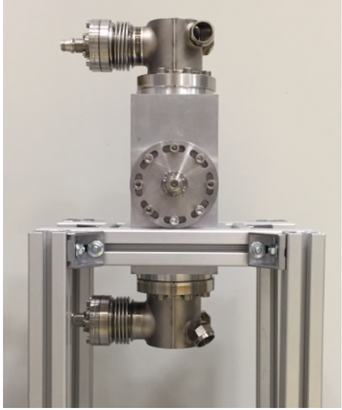


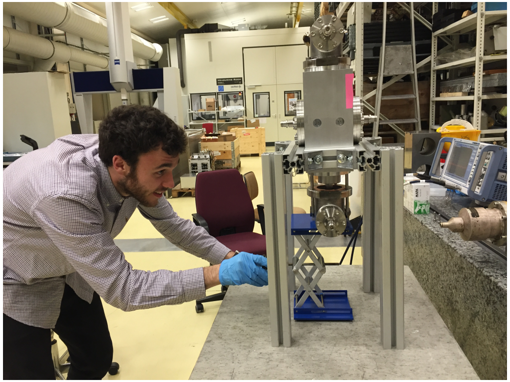
Electrical connection with probe.

- <u>**Initially two HOM couplers were available for test: coupler_2 and coupler_5.**</u>

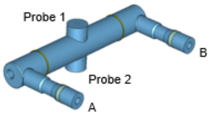
L-Bend Test Box: Measurements



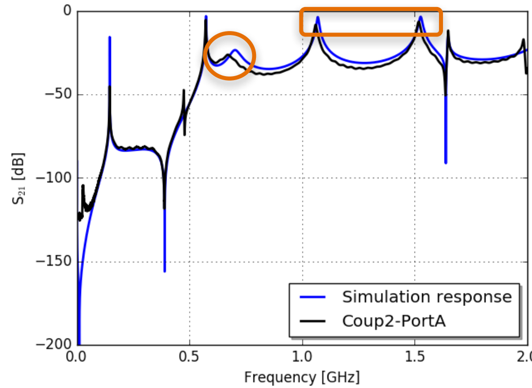


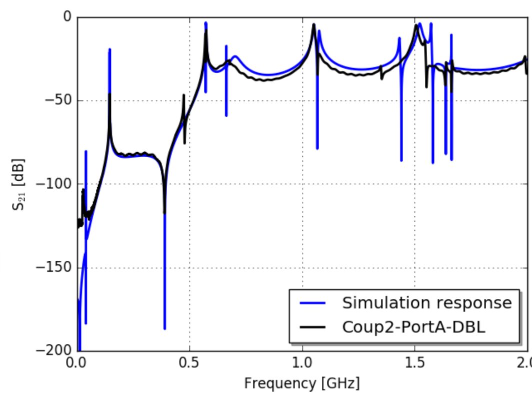


Spectral Response

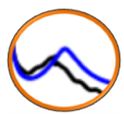


- The spectral response for the HOM couplers was taken from **0-2 GHz**.
- Example plots on the right are for Coupler2 on port A.
  - Single coupler regime.
  - Dual coupler regime (Coupler5 on port B).



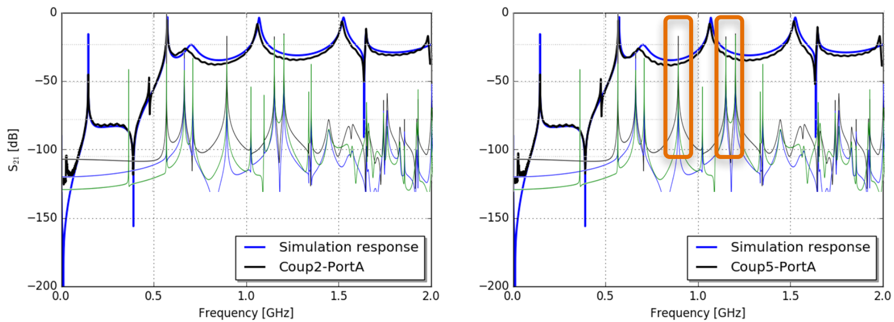


- Spectral conclusions for coupler_2
  - 0.6 – 0.7 GHz peak: lower frequency and amplitude

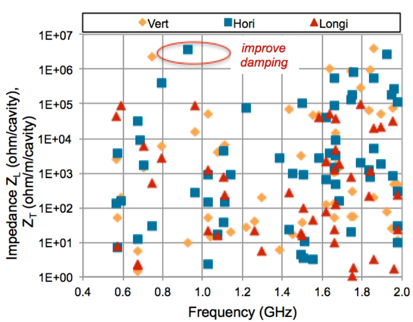


  - Lower frequency for the two interaction regions.

Comparison with Impedance Spectrum



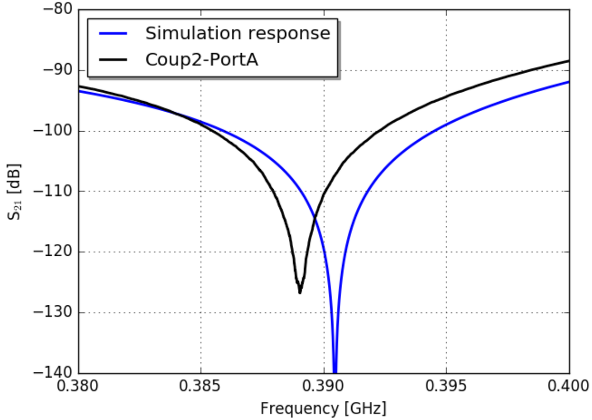
- The on-axis impedance spectrums superimposed for visualisation.
- For both HOM couplers, the 0.6 – 0.7 GHz peak and interaction regions are higher in frequency.
- Reduced damping is observed in the three high impedance modes highlighted.

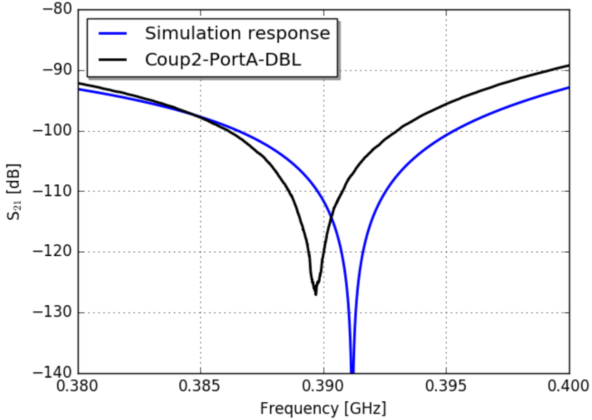


- Although the damping is only slightly reduced. The 980 MHz mode is high and damping of this mode should be maximised.
- Graph on left is courtesy of B. Xiao and BNL. **See talk by Qiong Wu.**
- This is also discussed later in this presentation.

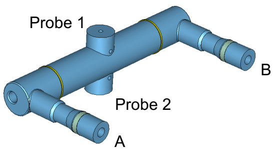
Stop-Band Response

- The stop-band filter was then measured for each coupler.
- Examples of the simulated and measured test box response:



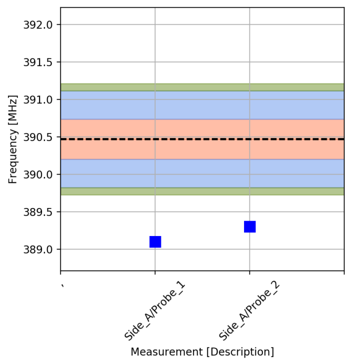


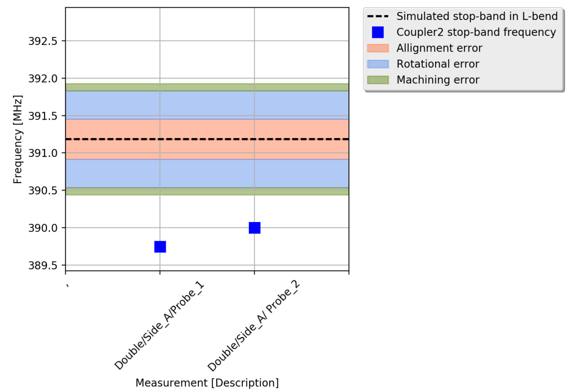
Stop-Band Frequency



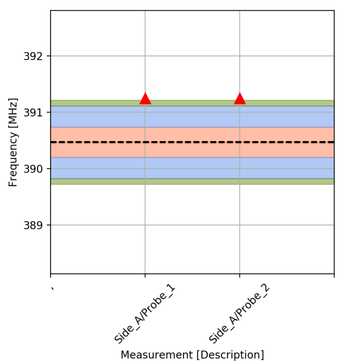
Single coupler | Two couplers

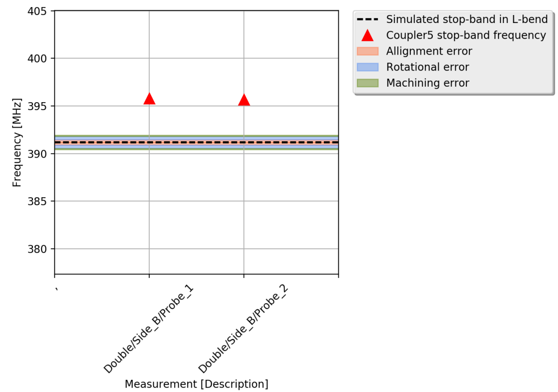
Coupler_2



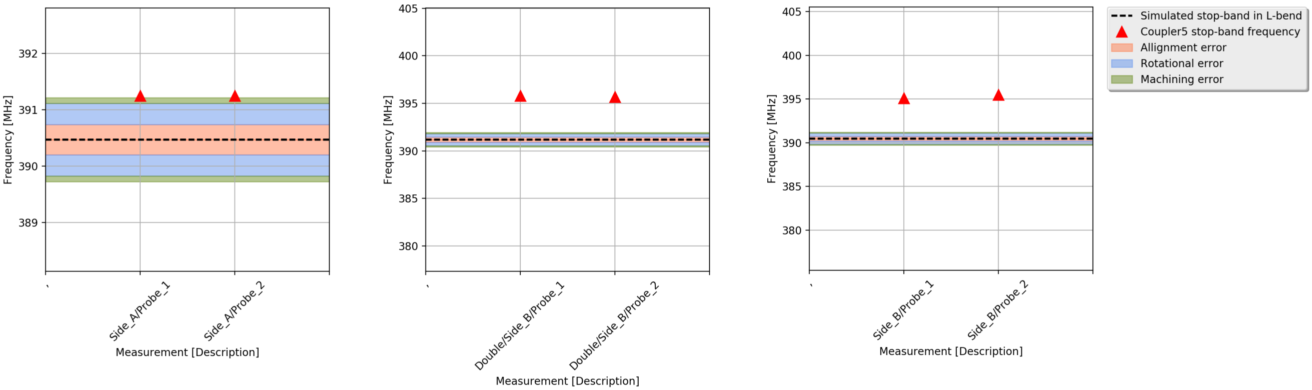


Coupler_5





Port Differences: Coupler_5 measurements



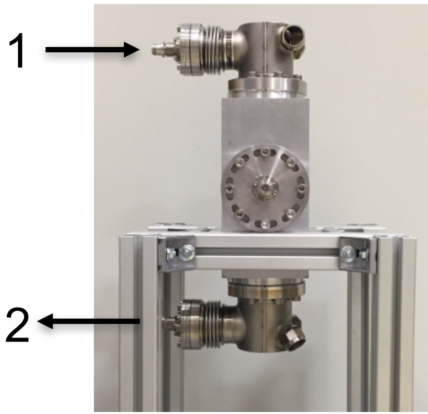
Side A　　Side B – two couplers　　Side B

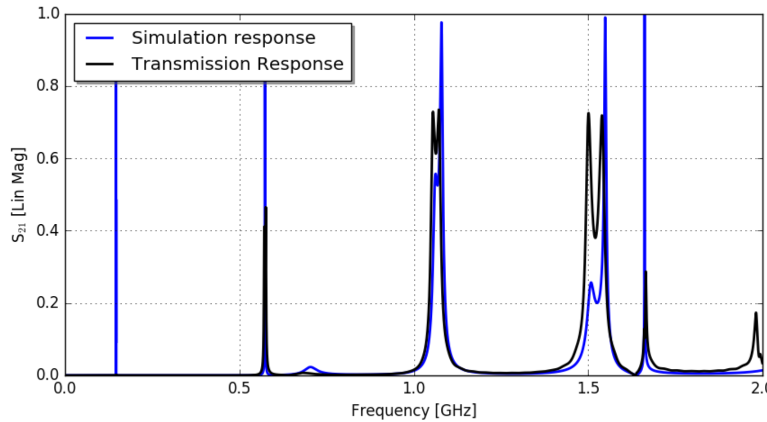
- As shown on the last slide, the frequency of the stop band was ~ 5 MHz higher for Coupler_5 when placed on side B of the test box.
- Coupler_2 was taken off side A and the stop-band frequency was again measured.
- Again this was ~ 5 MHz off the expected.

- There appears to be a problem with the set-up on side B but statistically it is not possible to say this.
- For this reason, one of the couplers should be re-tested on port B to see if it was an assemble error.
- Testing on the coaxial chamber should also validate this.

Transmission characteristics

- In addition to the spectral response of the HOM couplers the transmission between the two HOM couplers was measured.
- This allowed the feasibility of **HOM coupler conditioning** to be evaluated.



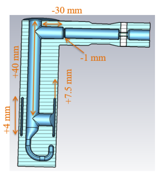


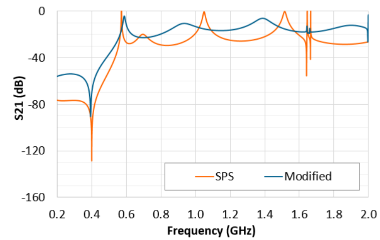
- Clear discrete frequency bands where transmission between HOM couplers is high.
- These frequency bands correlate to the frequencies of the HOM coupler's filter interaction regions.

HOM Coupler – LHC considerations

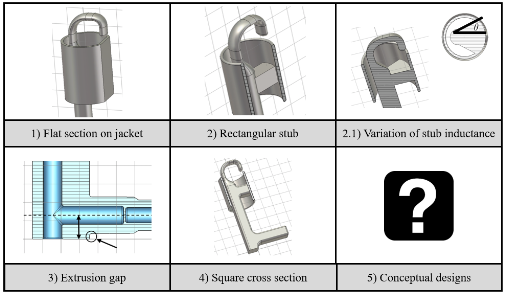
- For LHC it was decided that the HOM coupler design should be re-visited.
- Two main aims:
  - **<u>Increase damping of HOMs.</u>**
  - **<u>Improve ease of manufacture in terms of machining time, tolerances and cost.</u>**

- Initial RF improvements investigated by B. Xiao et al, see talk by Q. Wu.





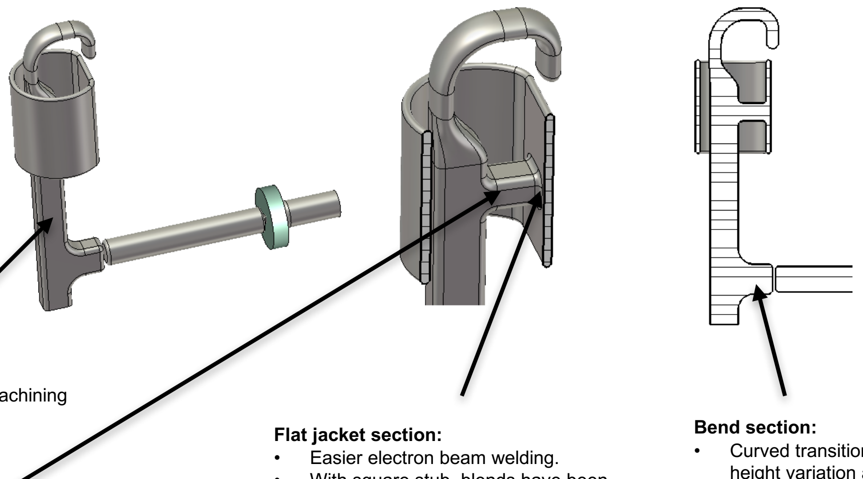
- Manufacturing improvements investigated at CERN.
  - A few examples are shown on the right.



James Mitchell – j.a.mitchell@lancaster.ac.uk – 25/04/17

HOM Coupler Manufacturing Improvements

- After analysing several mechanical improvements, a conceptual design was arrived upon.
- With each alteration, the effect on the RF characteristics were logged and thus geometric weighting factors can be associated with each parameter. This allowed a quick analytical RF optimisation (next slide).



Rectangular cross section:
- Constant width for easy machining from single Nb block.

Square stub:
- Constant height, smooth transition from shaft.
- Easier machining.
- RF: Larger stop-band tuning range (rectangular cross section allows large inductance variation).
- RF: larger available correction for other parametric alterations.

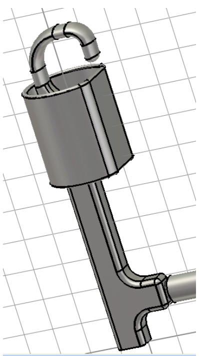
Flat jacket section:
- Easier electron beam welding.
- With square stub, blends have been designed to allow enough space at either side for simple weld.
- RF: square stub allows effect of flat jacket on stop-band frequency to be rectified by altering the height and hence inductance of the LC filter.

Bend section:
- Curved transition sections and height variation allow good control over inductance.
- Moved slightly in the direction of the hook. This allows the Nb outer wall to be rolled and extruded rather than machined from one block. This has significant cost savings associated.

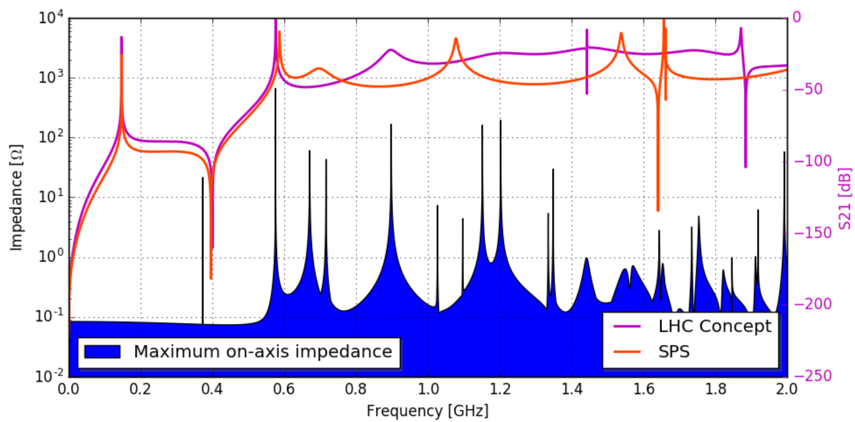
HOM Coupler Manufacturing Improvements

- The S21 transmission characteristics of the new design are shown below.
- It is plotted alongside the SPS design for comparison.
- **The RF optimisation was done by putting higher weighting factors at the places where the on axis impedance was higher.**
  - It was also done using results found from research done by B. Xiao et al.
- Therefore, for visualisation, the on-axis impedance spectrum is plotted alongside.

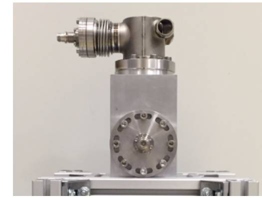
SPS

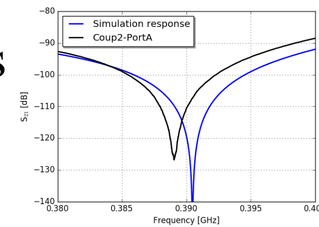


LHC concept



Overview and Questions





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HOM coupler design considerations: LHC

1. LHC considerations for HOM coupler design