DQW HOM Update and Recent Developments

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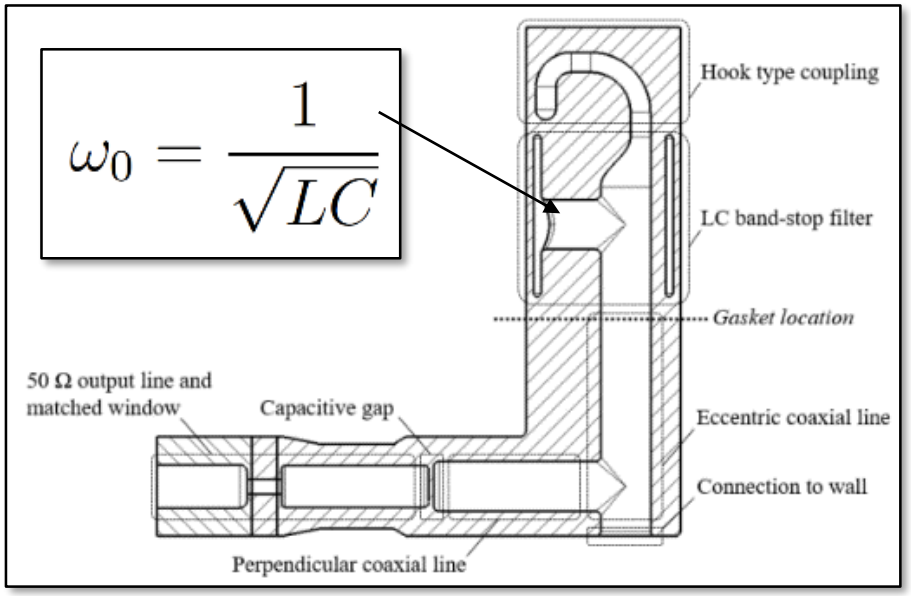
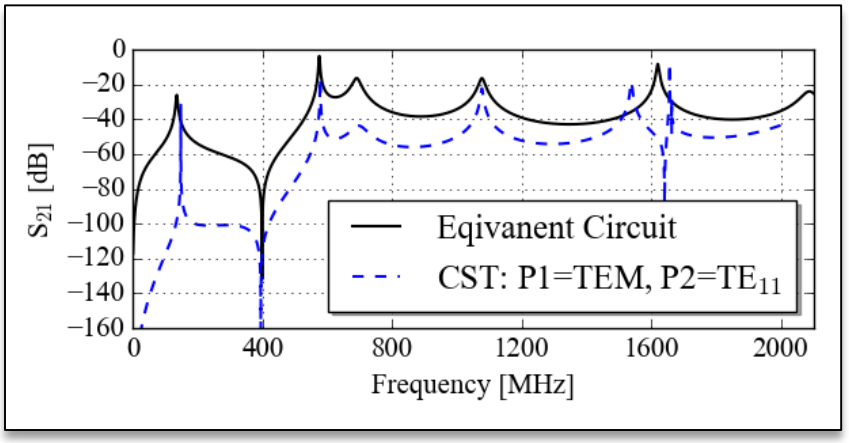
DQW HOM Coupler

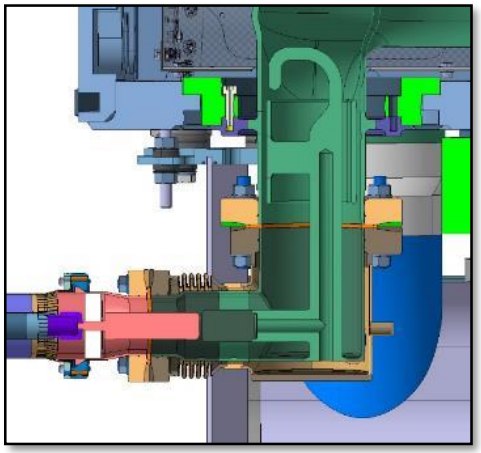
Vacuum model





Niobium

Conductively cooled by superfluid L-He (2 K)

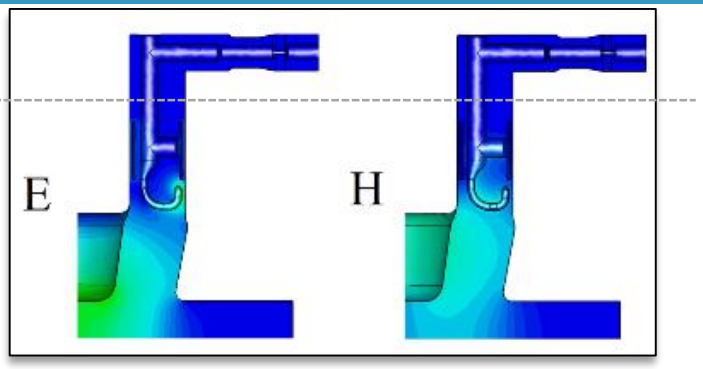


Operation:

- Hook-type coupling (electric and magnetic).
  - *Demountable.*
- High-pass filter response.
- LC band-stop filter.
- Capacitively coupled output.
  - *Broadens notch.*
  - *No moment on window.*

DQW HOMC: Design Advantages

1. Gasket heating

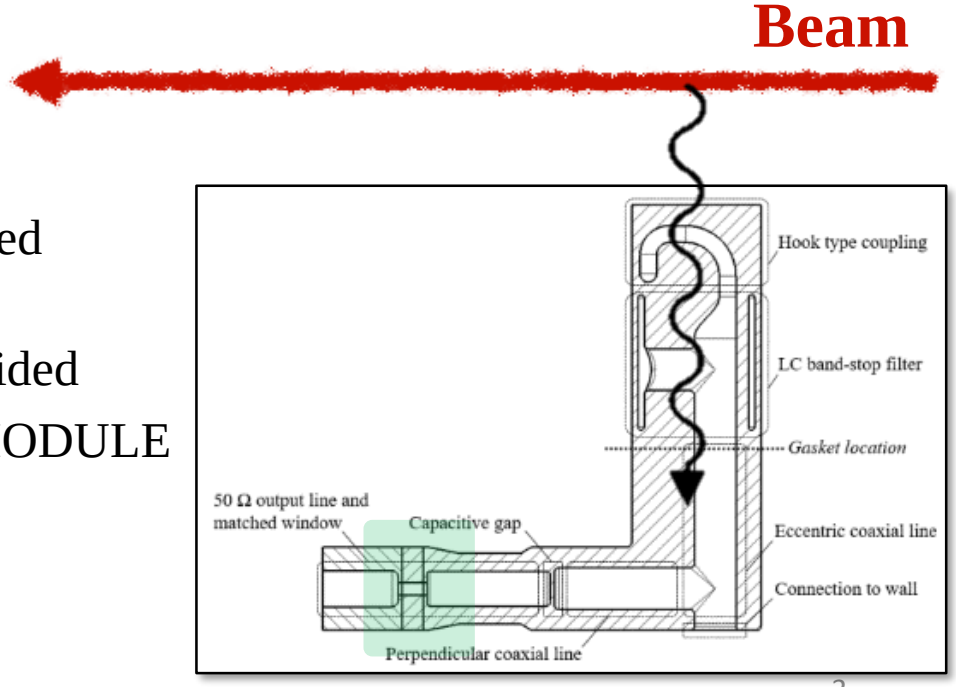


- The **LC band-stop** is <u>before</u> the **gasket**.
- This acts like an **electrical short**.

- Very little dynamic heat load on the copper gasket (~ mW)!
- CRYOMODULE HAS DYNAMIC HEAT LOAD LIMIT (~ 20 W).

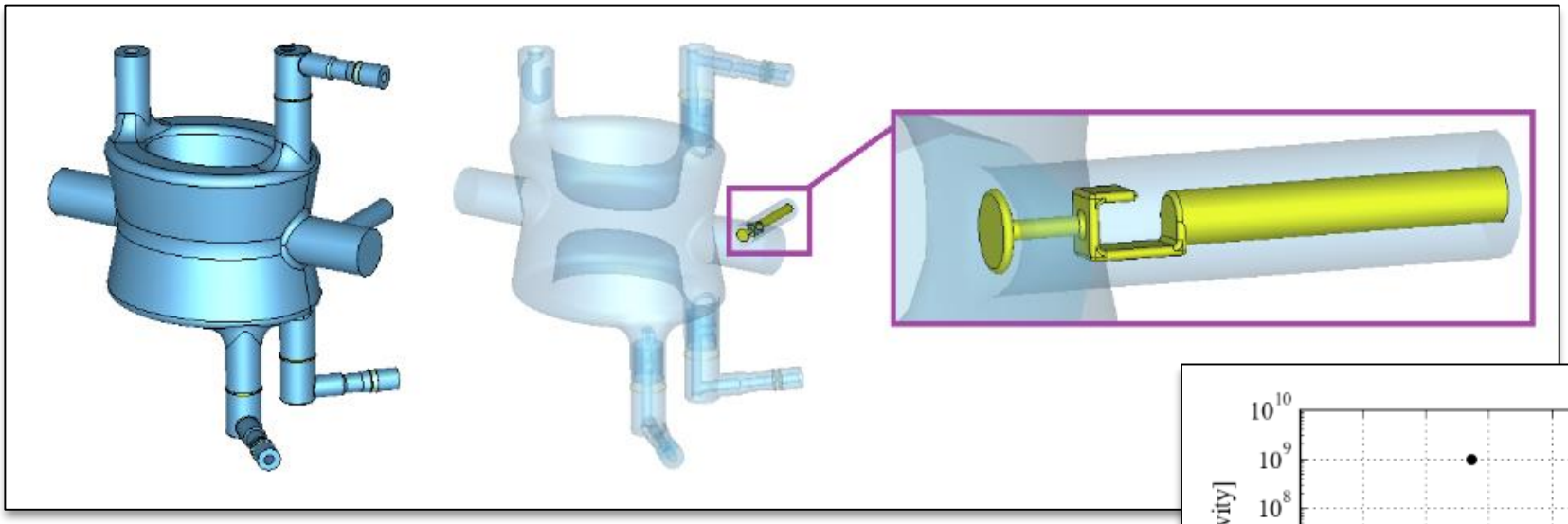
2. Window location

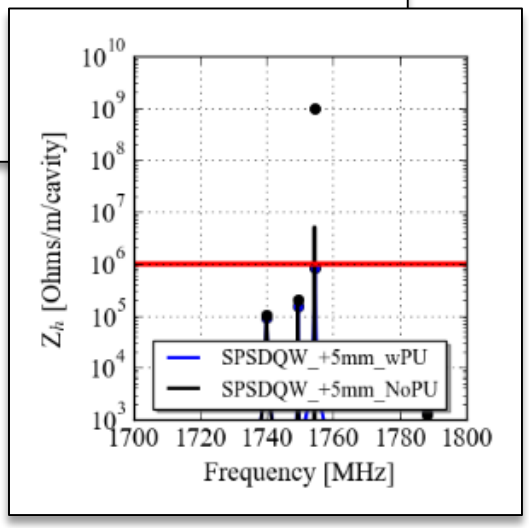
- Window is perpendicular to charged particles ejected from beam.
- Screening current on window avoided
- WINDOW BREAKS → CRYOMODULE DOWN!



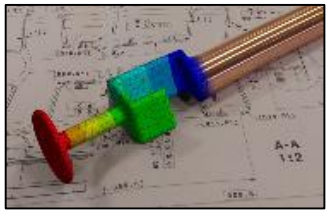
Field Probe as Fourth HOM coupler

- The pick-up is designed extract 1 W at the fundamental mode frequency → $\mathbf{Q_e = 1.6 \times 10^{10}}$.
- It is also a HOM coupler for the 1.75 GHz mode → cannot couple to this mode with HOM couplers.



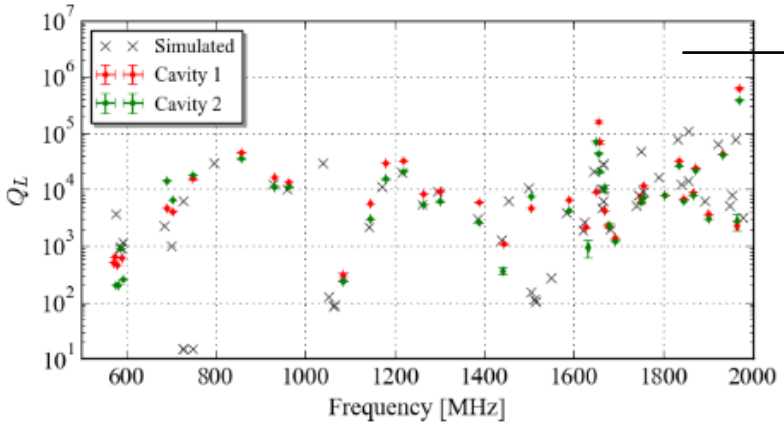


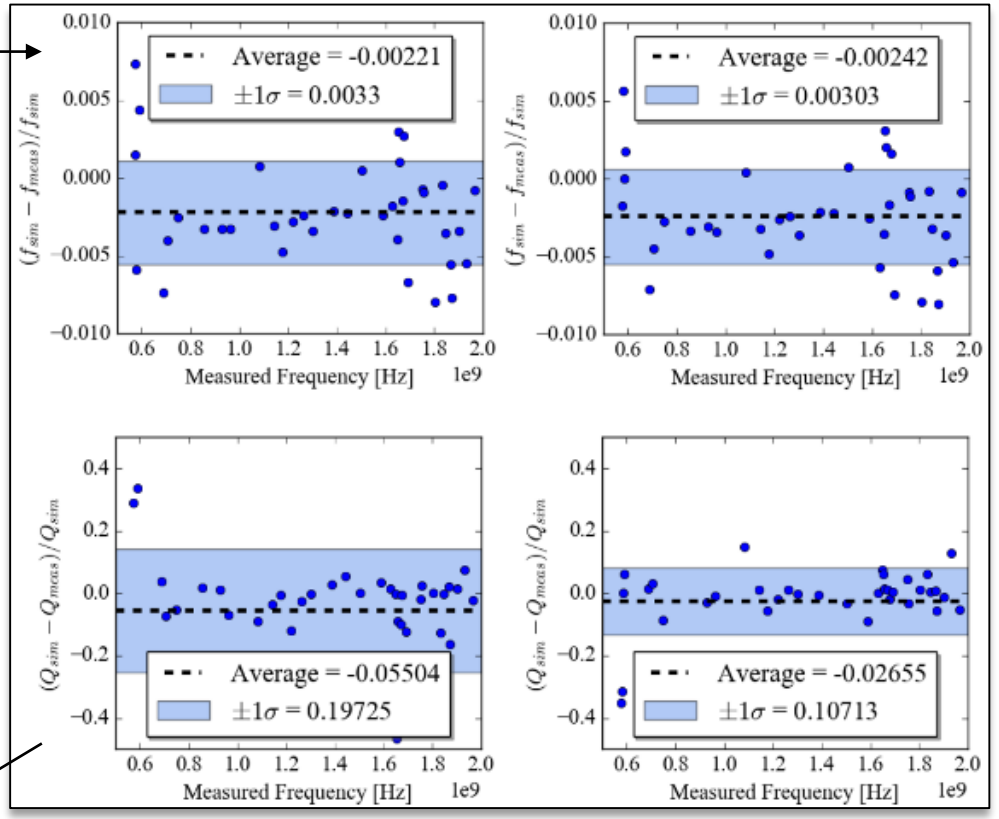
- The PU is made from Nb and Cu to avoid heating.



Mode Measurements

- Transmission measurements using VNA in cryomodule cold test in M7 buncker.





Deviations are hence:

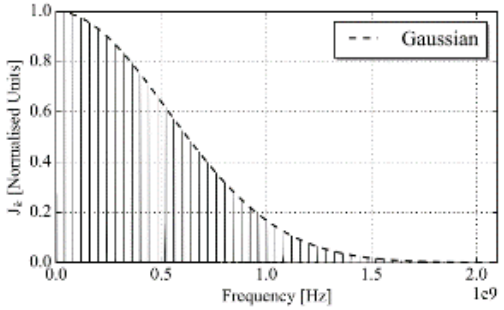
$$\frac{\Delta f}{f} = 0.003$$

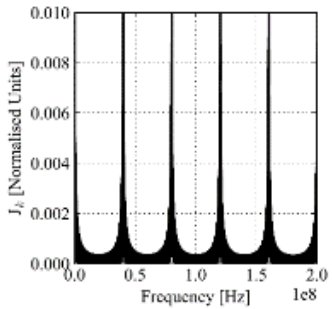
$$\frac{\Delta Q_e}{Q_e} = 0.2$$

HOM Power

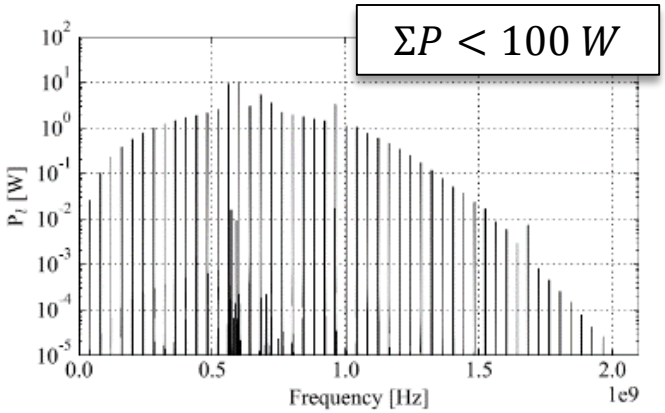
Parameter	Value
Machine	HL-LHC
Bunch profile	Gaussian
Number of bunches, M	2748
Particles per bunch, N_p	2.2E11
Harmonic number, h	35640
RF frequency, f_{RF}	400.8 MHz
Bunch length, σ_t	1.2 ns
Bunch spacing, t_{bb}	24.95 ns

- Using SPS HOM coupler and HL-LHC parameters:

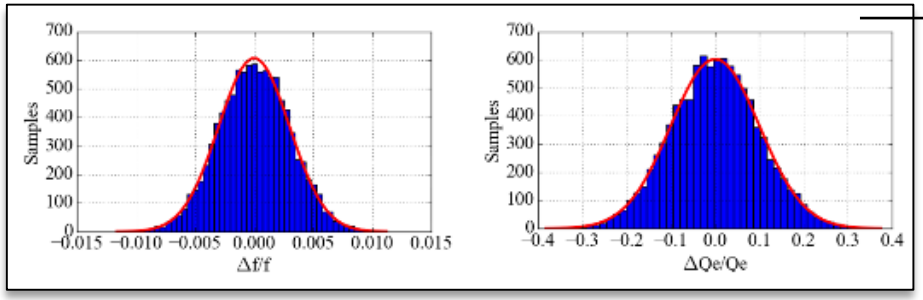


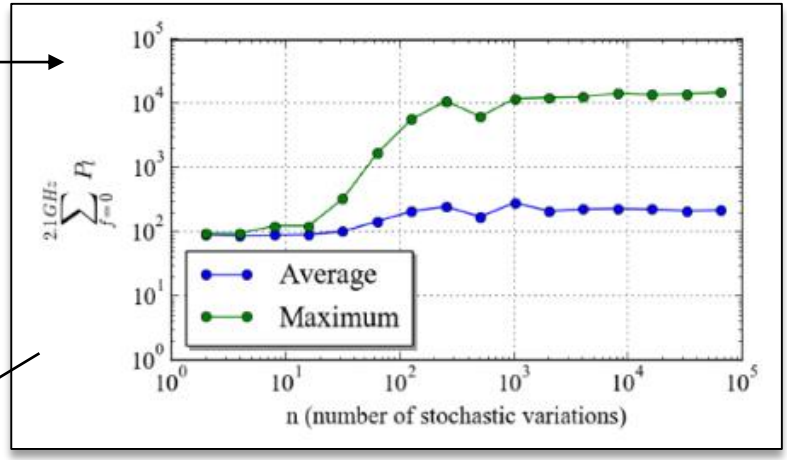


$$P_{\parallel} = J_A^2 \sum_{-\infty}^{\infty} Re\left\{Z_{\parallel}(k\omega_0)\right\} |J_k|^2$$



- However, the frequency and Q_e of the modes can change.
- Stochastically varying these two parameters, a worst-case power can be calculated.

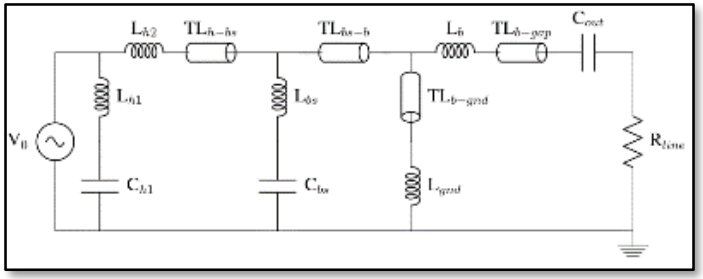


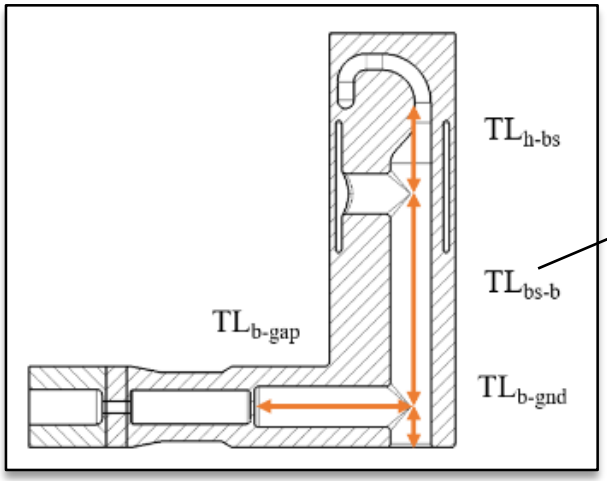


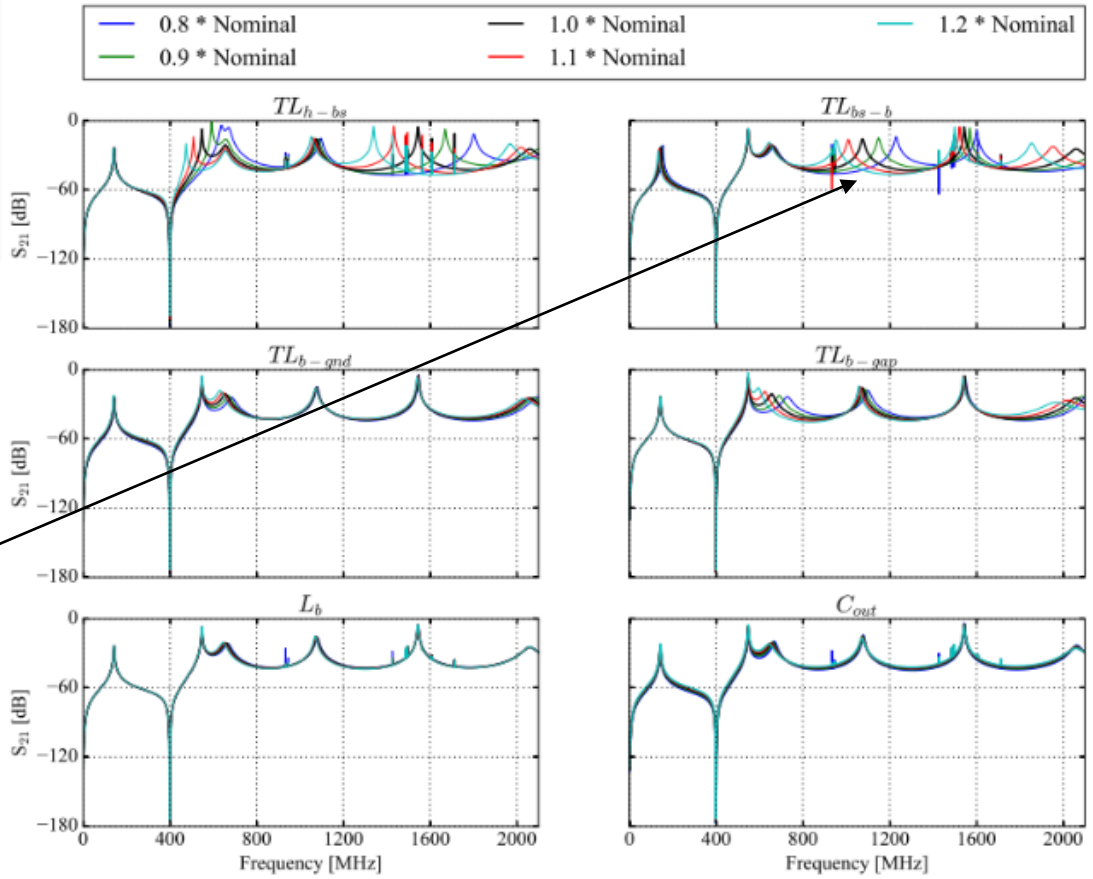
13 times larger than 1 kW limit.
Due to mode at 960 MHz – coupler needs to be altered.

SPS HOM Coupler Development

- The coupler should be altered to:
  1. **Reduce transverse impedance below threshold.**
  2. **Reduce maximum foreseeable HOM power to below 1 kW.**
  3. Improve ease of manufacture.







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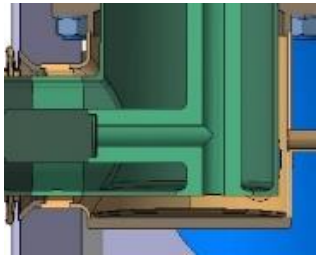
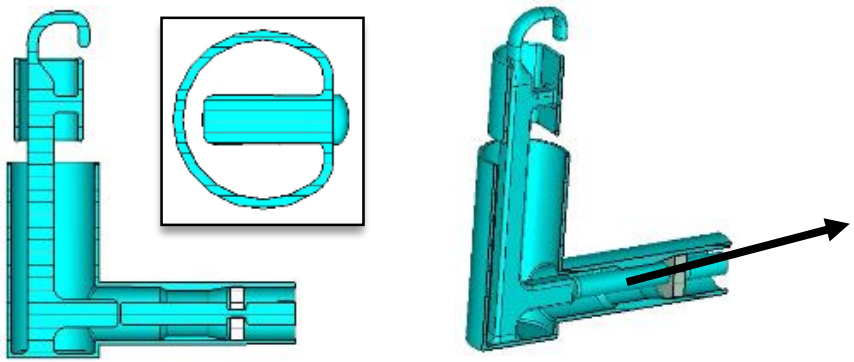
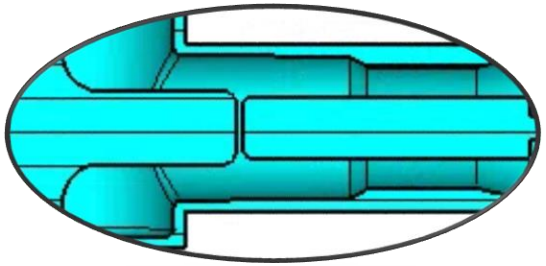
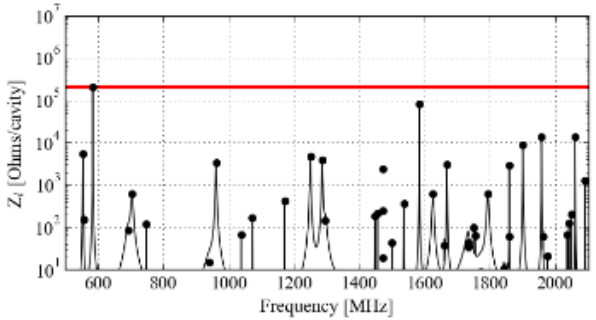
Issue		Solution
Machining time for circular cross-section.	 	Rectangular cross-section.
Difficult to EB-Weld on curved surface.	 	Flat section on capacitive jacket.
Wasted Material: Perpendicular coax line is 'flush' with coupler base.	  	Lift output line.

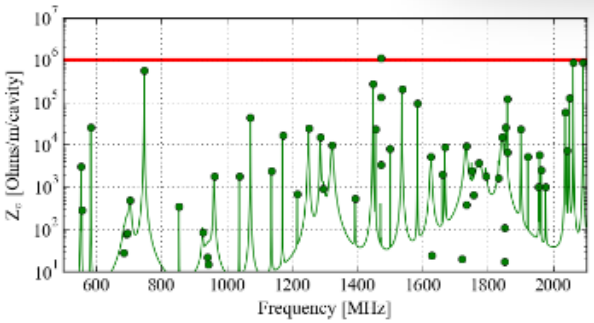
DQW HOMC V2

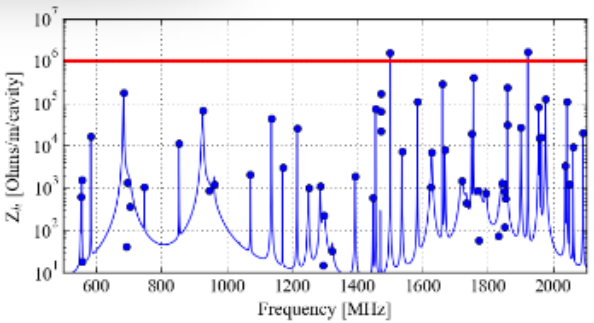
1. Flat section on capacitive jacket.
2. Square profile throughout.
3. Lifted output line for extruded ‘can’.



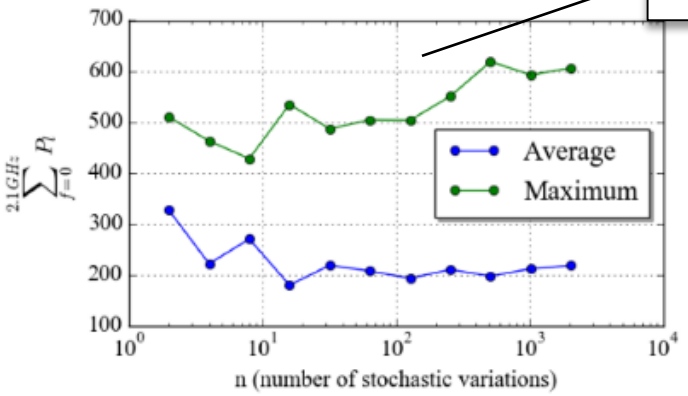


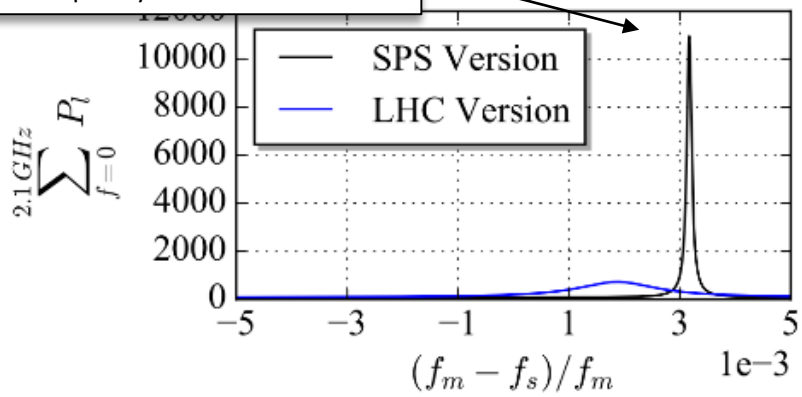




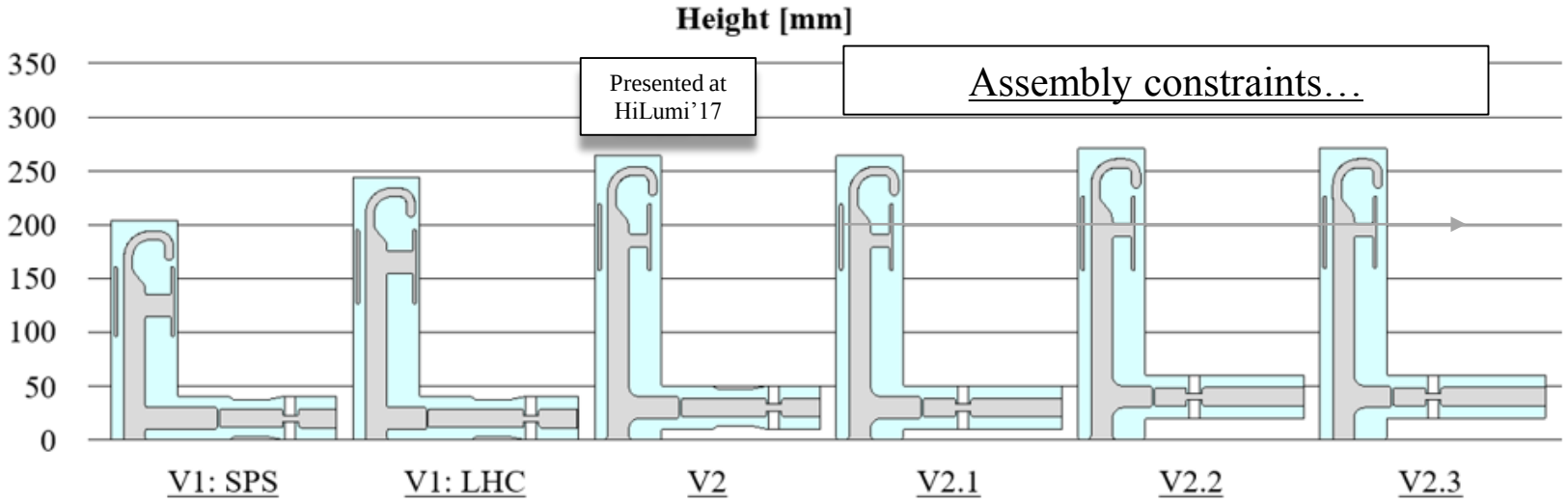


- Highest power still a result of the 960 MHz mode.
- If we vary this mode in frequency:

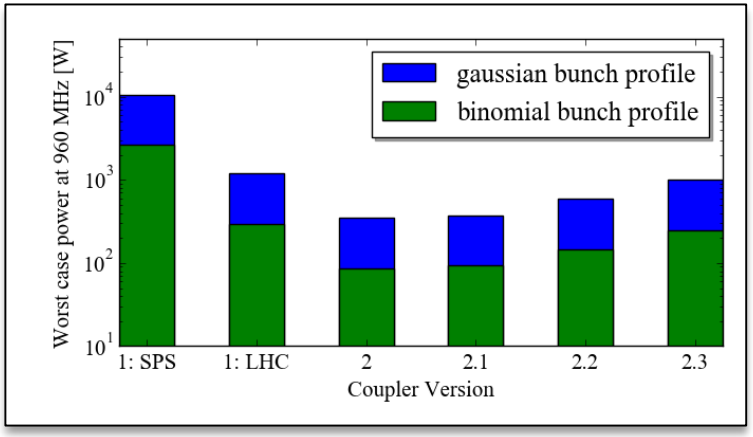




Evolution: Where we are today

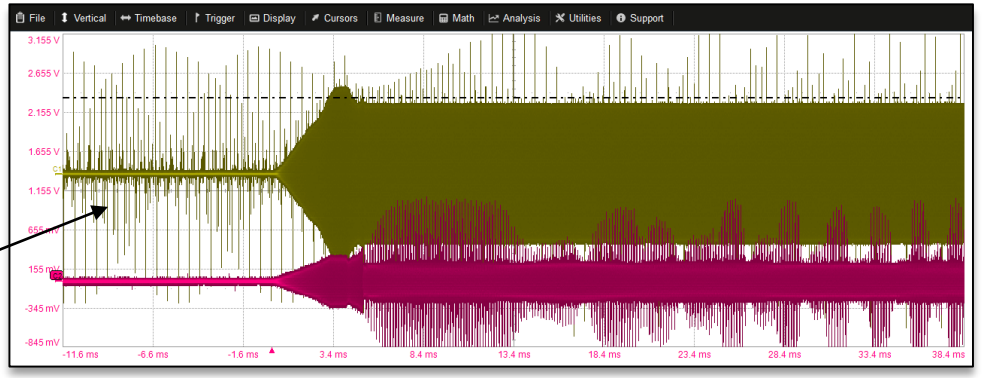


- Following the coupler presented at HiLumi'17 some alterations for easier assembly.
- However V2.2 and 2.3 started to increase the power of the 960 MHz mode.
- As the SPS tests showed up that all of this power goes through one HOM coupler, **VERSION 2.1** was selected.



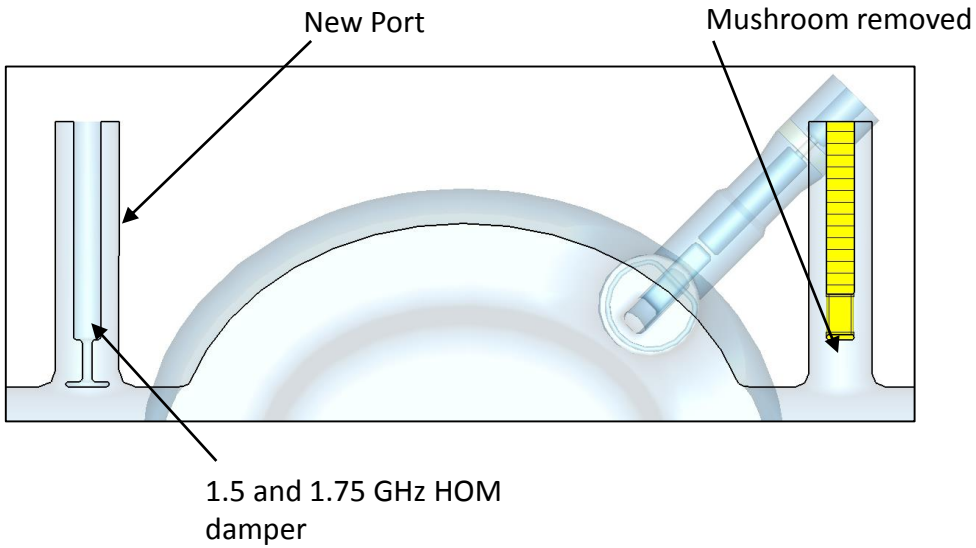
New beam pipe damper

- Antenna is also HOM coupler.
- SPS tests showed that ‘mushroom’ was coupling to the beam and creating difficulties for LLRF feedback.

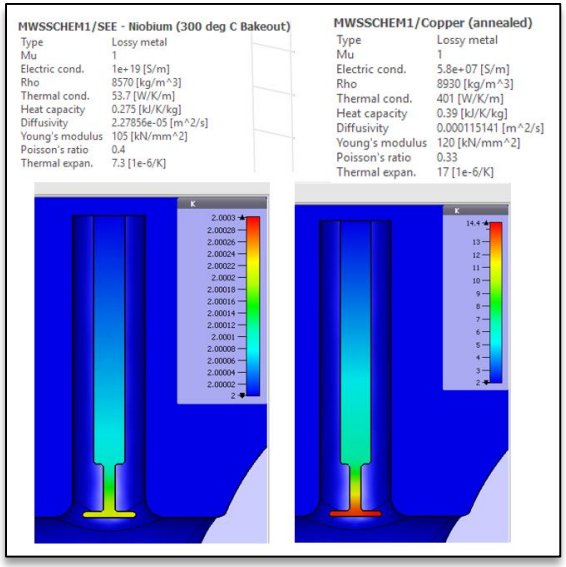


P. Baudrenghien

- Hence separated into HOM damper and antenna.



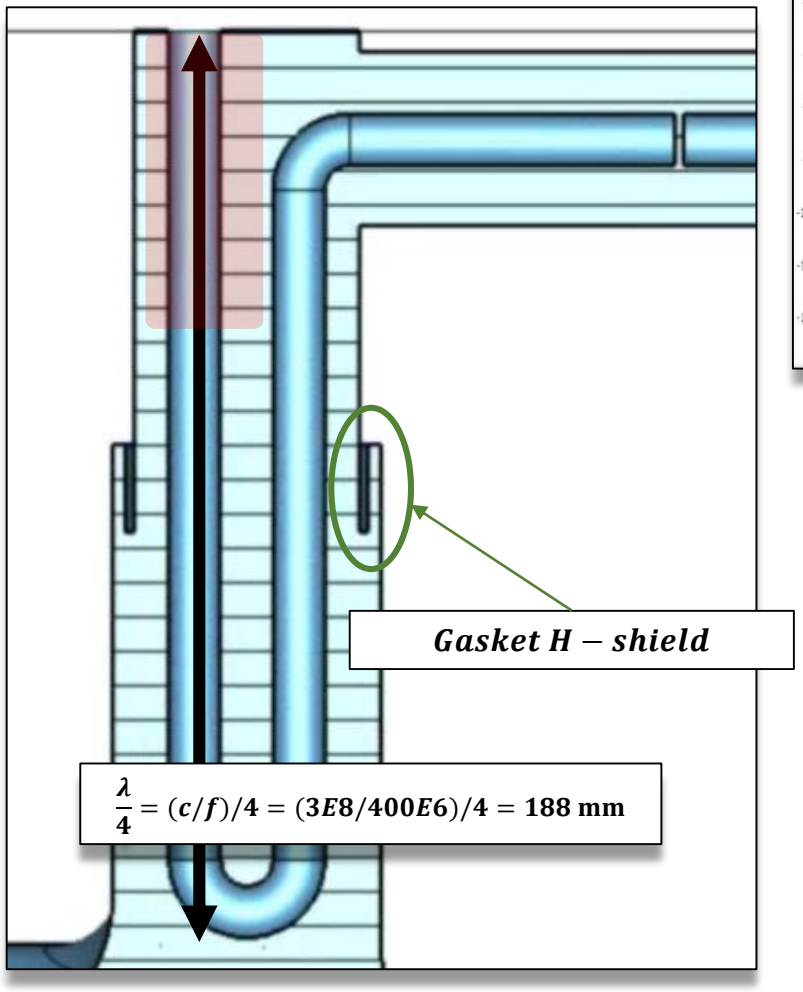
- Currently deciding between copper and niobium.
- Preliminary simulations show copper is okay.
- Feedthrough and boundary conditions under current analysis!

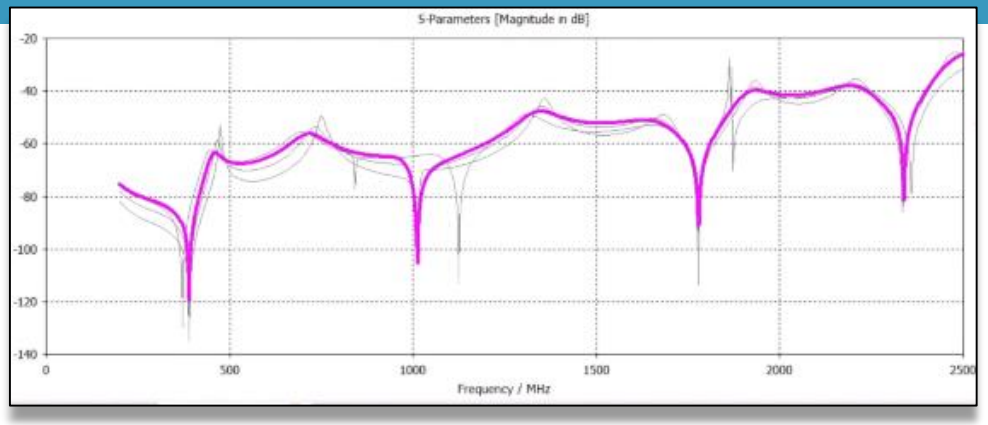


… could also be used as second antenna if primary fails, although ~10 x lower coupling.

… antenna will also be modified – see S. Verdu-Andres’ Talk (Thursday: DQW and RFD PUs)

DQW HOMC: Alternative





Operation

- **Quarter wave rejection filter – centered at fundamental mode.**
- **Harmonics reject also.**

Advantages

- Loop type coupling – magnetic coupling to HOMs – good broad-band damping.
- High H-Field on cooled section – no ΔT to He.
- Very easy to manufacture - mass produce.

Disadvantages

- Gasket heat-load – 1000 x higher than LC stopband (~0.5)
- Harmonics can be moved slightly but will always be present.

- Design still work in progress
- Could be a valid alternative if gasket dynamic heat-load is further reduced or if indium gaskets are used.

Conclusions

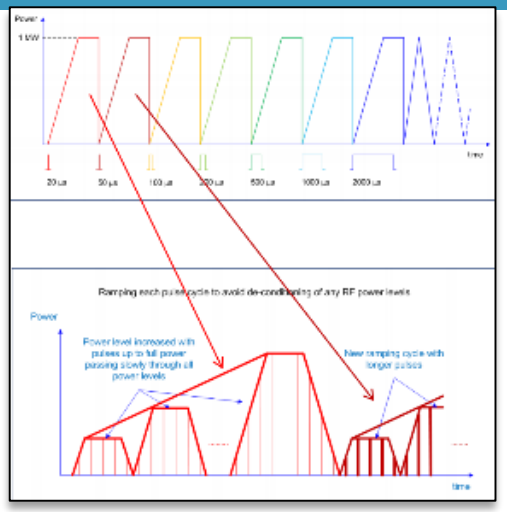
1) **Pre-installation** measurements of HOMs
   - Deviation from simulations.
   - Shows worst case power is too high due to 960 MHz mode.

2) Coupler re-designed with **RF** and **manufacture** criterion
   - Longitudinal and transverse impedances within threshold.
   - Maximum power foreseeable < 1kW.
   - Easier to manufacture.

3) New **Beam Pipe HOM damper**
   - To separate the HOM damping and antenna functions of the current antenna.
   - Design reached, multi-physics analysis on going.

4) Alternative HOM coupler under development
   - Quarter wave rejection filter being designed.
   - Simple to manufacture and less risk of thermal quench.
   - Higher heat-load on gasket.

Future Ideas – HOMC Conditioning



FPC's are conditioned before installation:

- Acceptance test, desorption of absorbed gasses, ensuring required power level (without RF breakdown), training ceramic…

Technique

- Power, pulse length, duty cycle: Low → High (with FM and AM)
- Using 'test-box' in travelling wave mode.

HOM couplers are becoming higher and higher in power

- **Do not see high power at high frequency until beam!**