HOM studies for DQWCCs and HOM filter design

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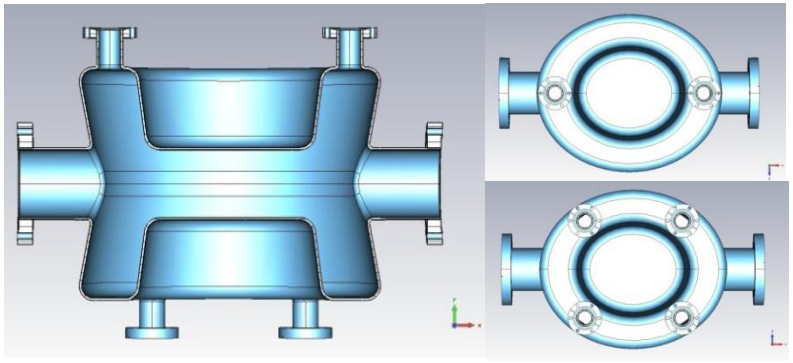
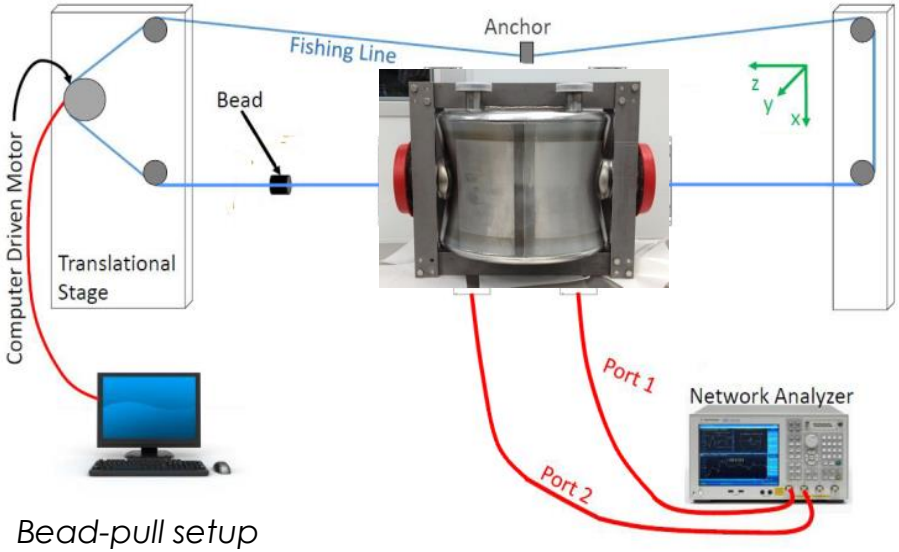
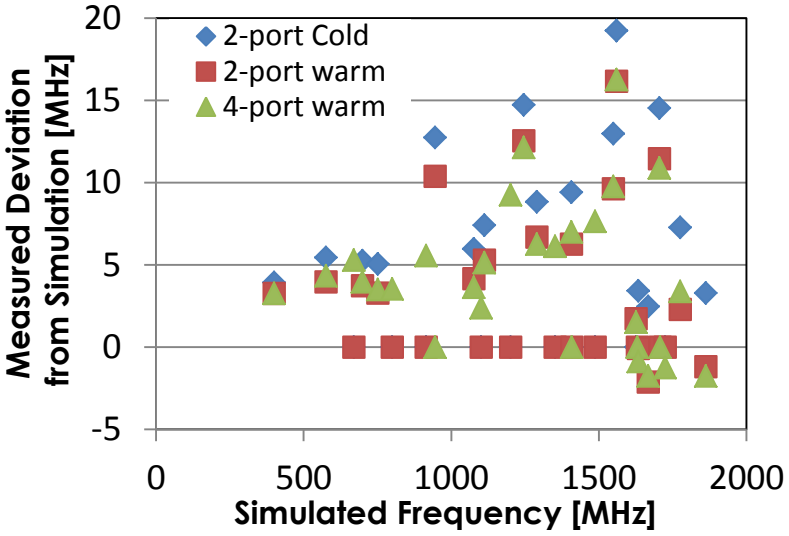
PoP DQW: Bead Pulling



Proof-of-Principle (PoP)
Double-Quarter Wave Crab Cavity (DQWCC)

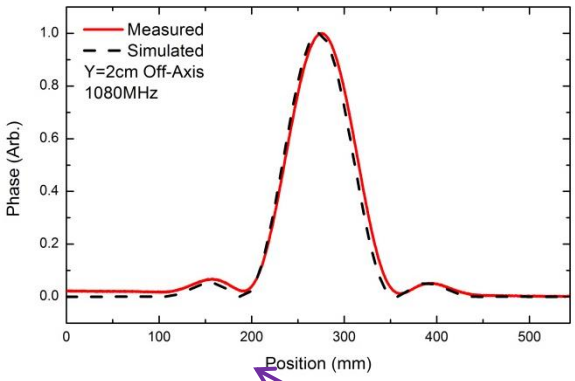


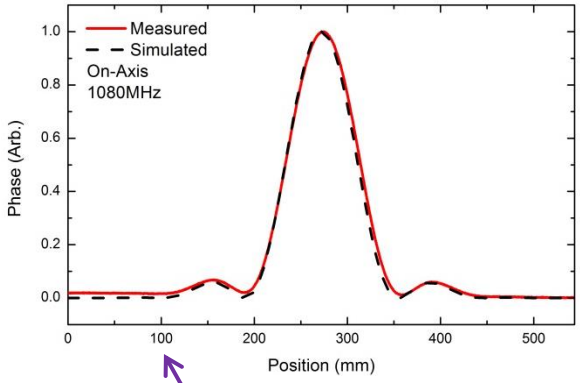
Bead-pull setup

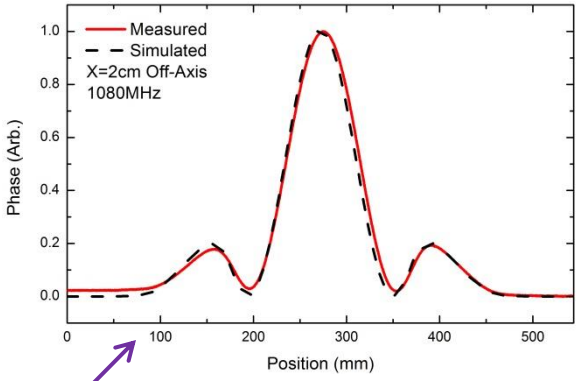


- Cavity prototype smaller than RF model cause frequencies shifting up.
- HOM frequencies deviated from designed values due to unspecified tolerances for PoP cavity.

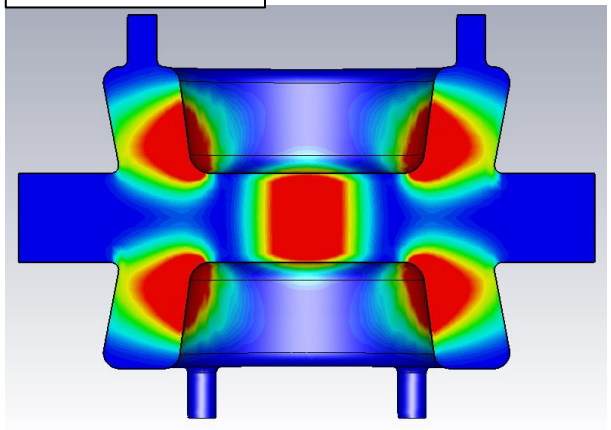
PoP DQW: Bead Pulling

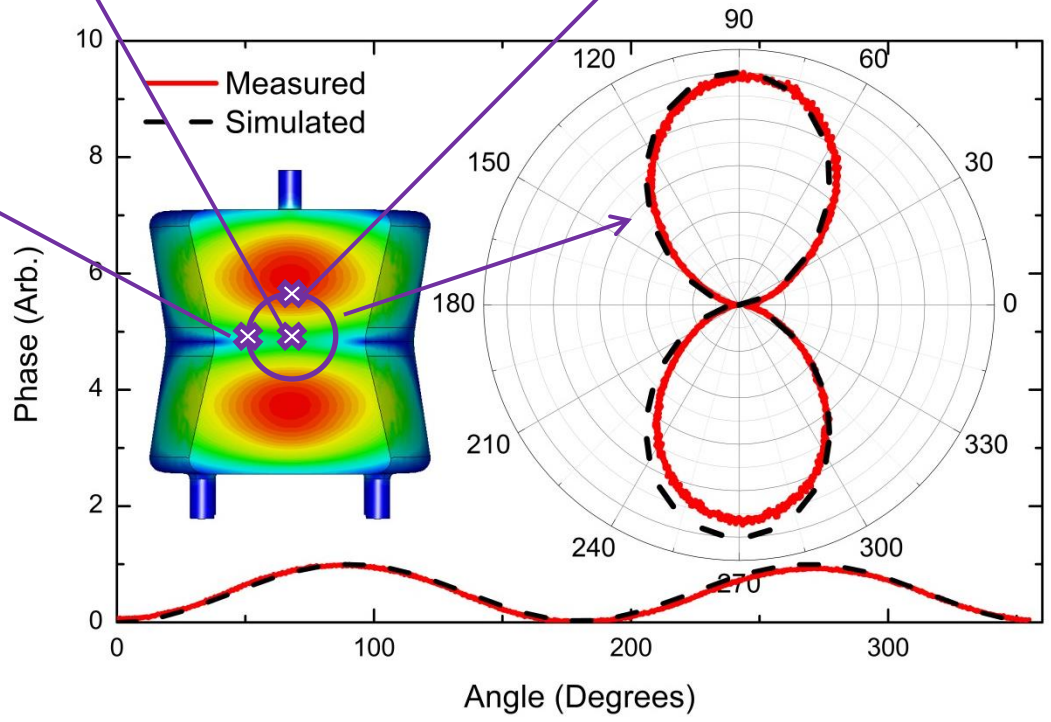






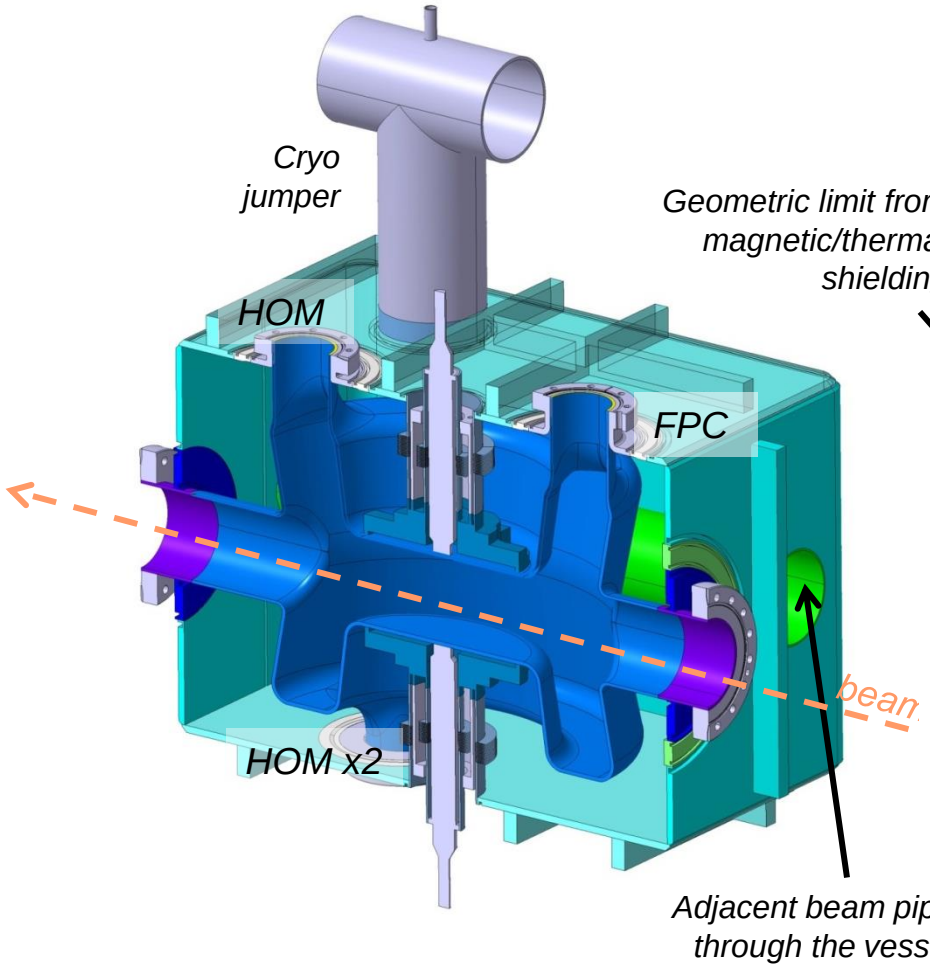
1080 MHz



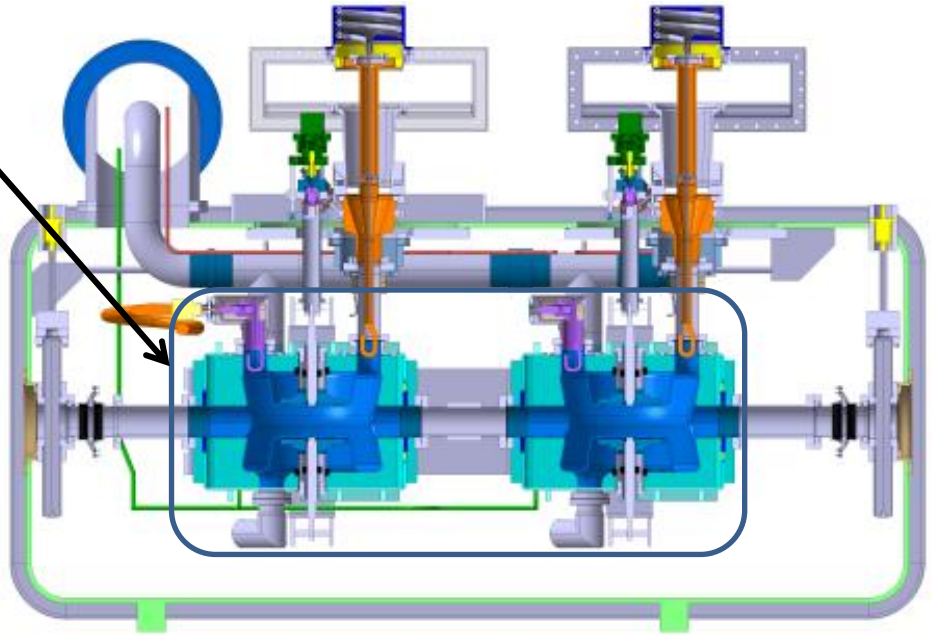


© Carlos Marques (Master thesis)

SPS double quarter wave

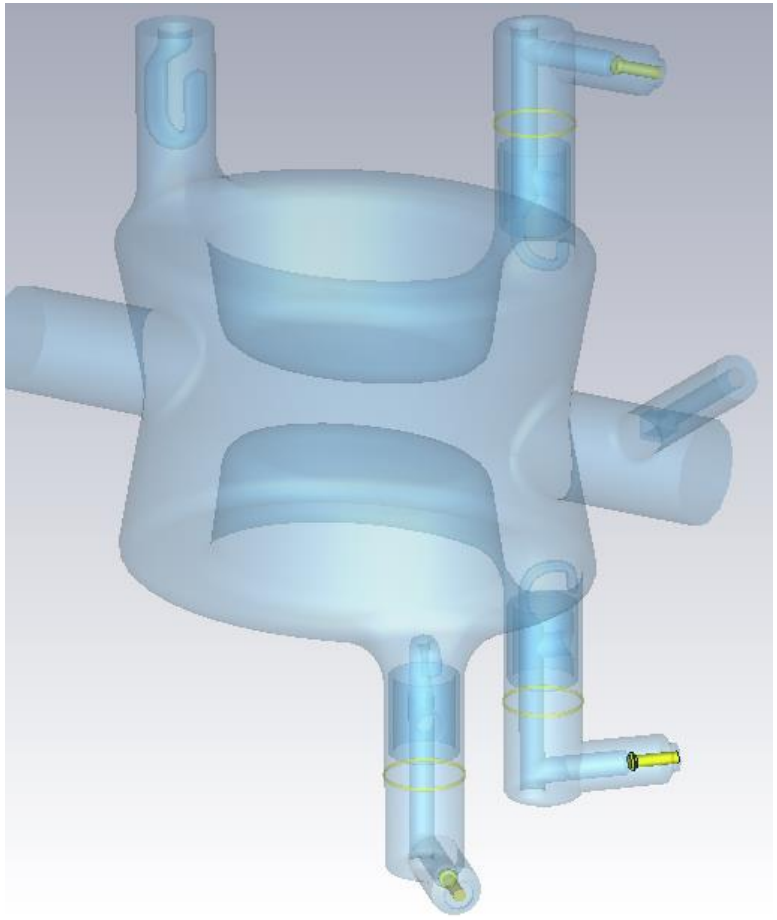


Geometric limit from magnetic/thermal shielding



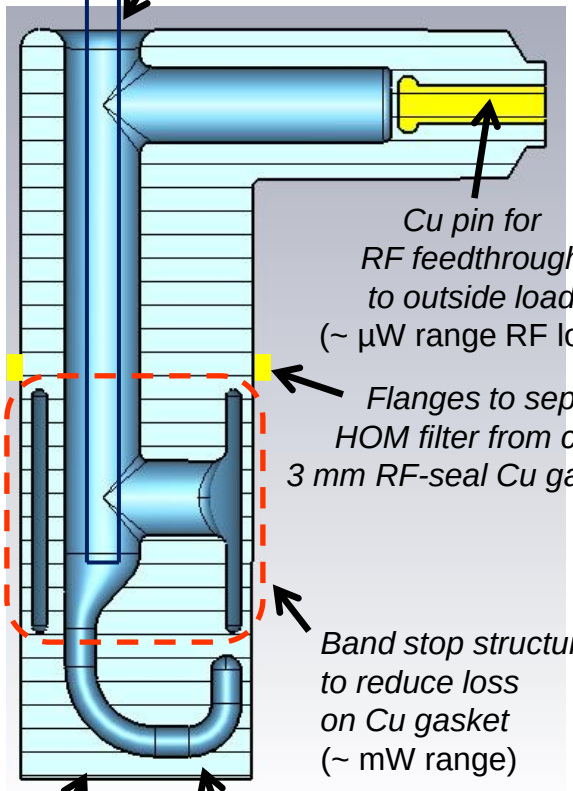
Adjacent beam pipe through the vessel

SPS DQW: filter integration

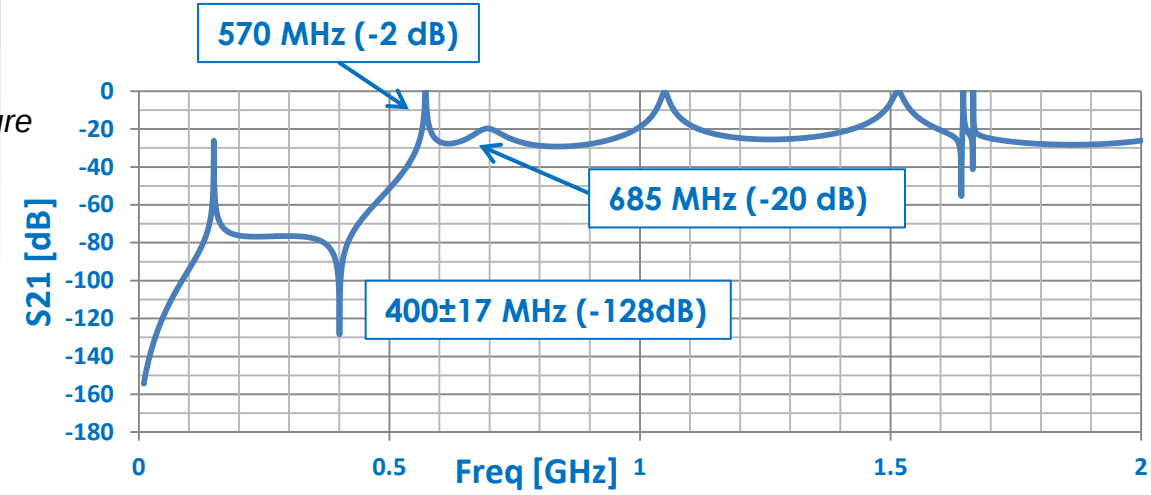


- 3 HOM filters per cavity, with two 60-degree away from the center to give ***clearance to the other beam pipe*** in horizontal kick scheme
- ***Symmetrical*** design to minimize multipolar components.
- 60 degree is chosen to provide more coupling to HOMs.
- ***Compact*** to fit into cryomodule.
- Longer RF cables can be easily attached to the L shape filter to ***reduce static heating***.

SPS DQW: L-shape Filter

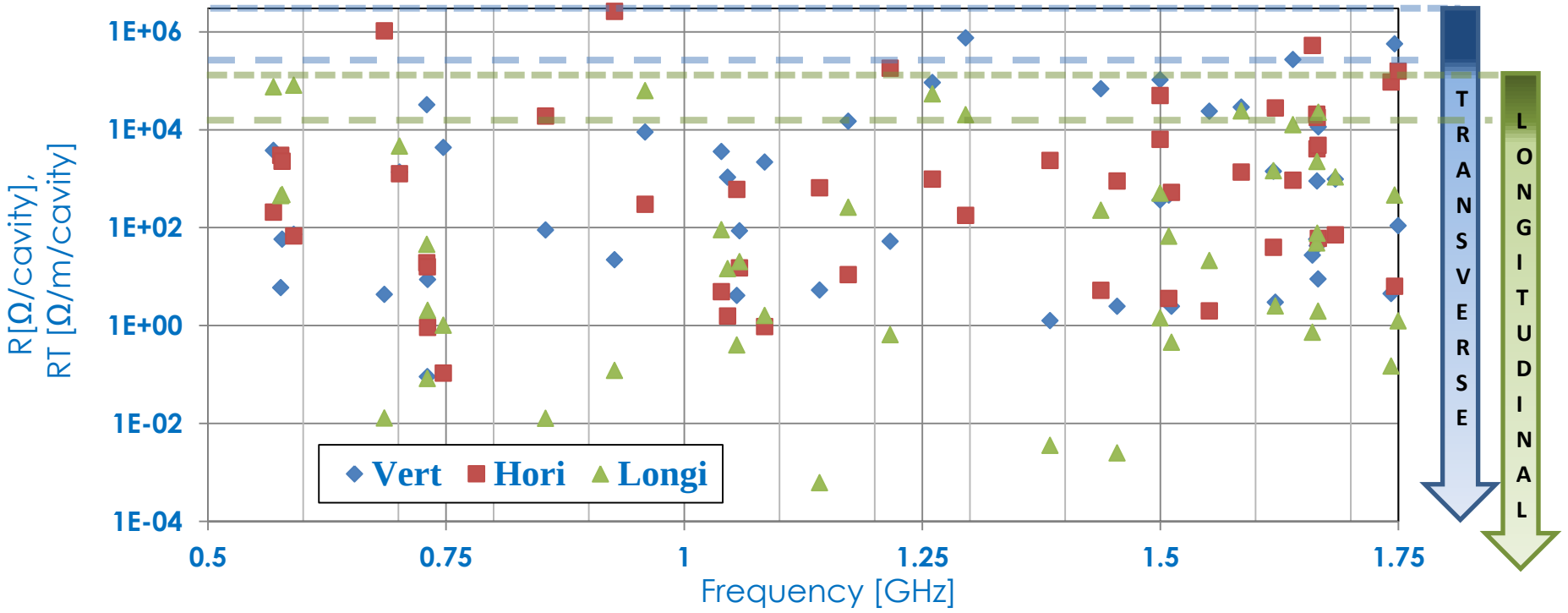


- **Designed to handle kW range HOM power per cavity**
- **Coupling to 400 MHz: 7.9×10^{9}**
  (1.1 W at each port to outside load)
- **RF losses estimated for crabbing mode with Vt = 3.34 MV**
  Estimation of RF losses from HOMs will follow.



Budget Limit

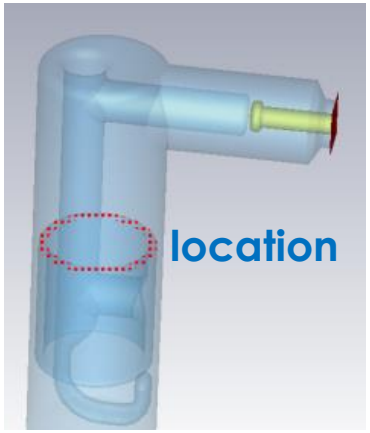
Impedance limits [Ref: Ranking Criteria, May 2014]	Lower	Upper/2	Upper
Longitudinal (kΩ/cavity)	12.5	62.5	125
Transverse (MΩ/m/cavity)	0.3	1.5625	3.125

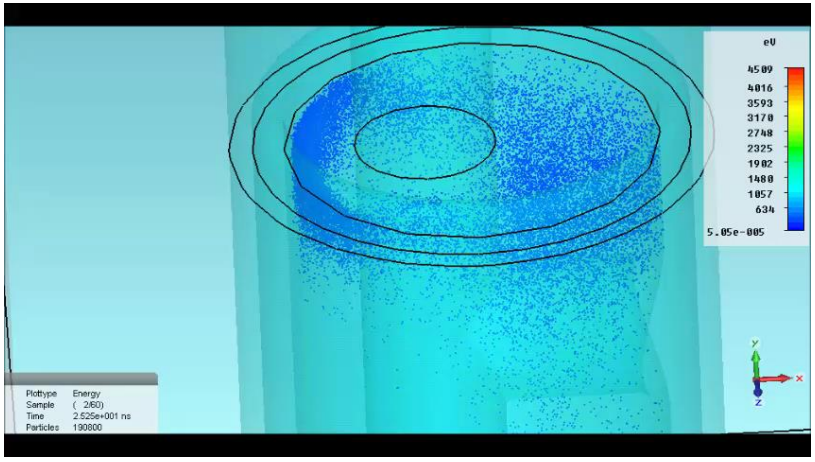


- **Below upper limit:** *all*
- **Higher than half-upper limit:** *0.569, 0.590, 0.927 GHz*
- **Higher than lower limit:** *0.685, 0.959, 1.261, 1.296, 1.585, 1.639, 1.660, 1.666, 1.746 GHz + abovementioned*

Issues

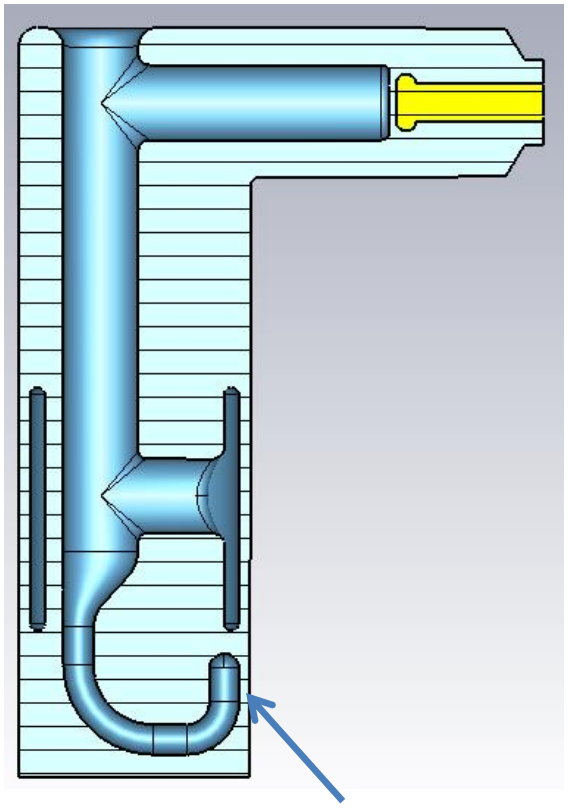
Multipacting





Preliminary multipacting analysis

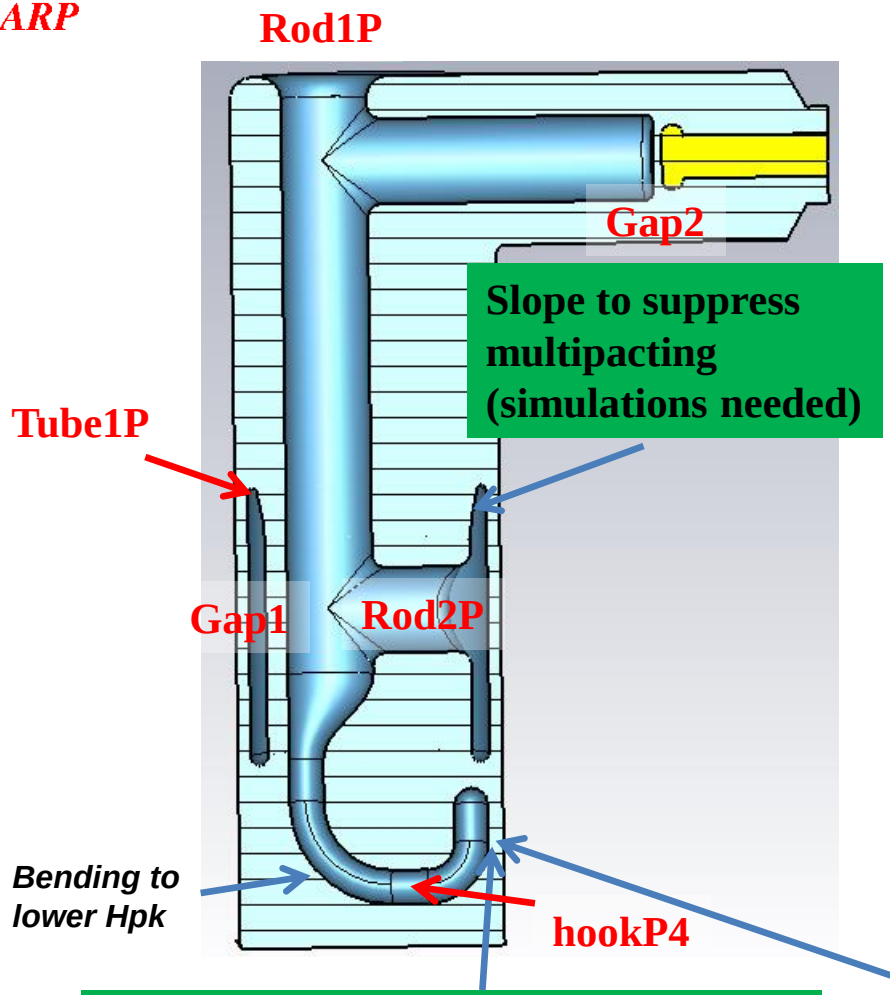
Peak E field



High Epk of 40.3MV/m.
(cavity: 36.7MV/m)

© Graeme Burt & Ben Hall using CST, confirmed by Z. Li using ACE3P

Modifications and assembly error



Evaluate the red numbers in ±0.3mm range
Tube1P and Rod2P will not affect RF performance

	S21 [dB]	ΔS21 [dB]			
Freq [GHz]	orig. model	Gap1	Gap2	hookP4	Rod1P
0.569	-22.3	-1.4	-0.8	-2.9	-0.4
0.590	-6.2	-3.15	-1.0	-8.7	-7.3
0.927	-26.5	-0.1	-0.7	-0.2	-0.5

On-going: slightly modify the filter to suppress the fabrication error induced performance degradation.

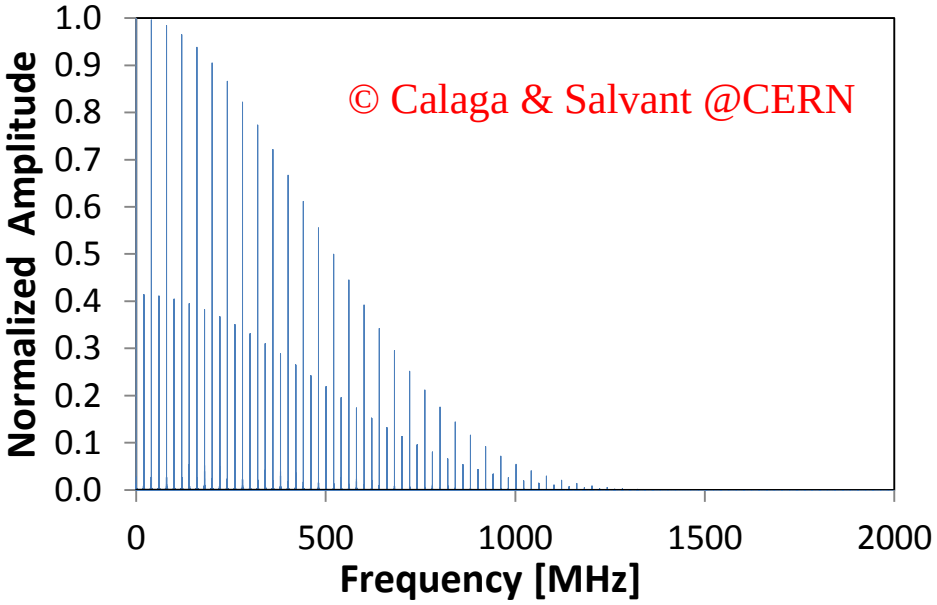
This gap will affect the damping of first several modes significantly, possible to tune?

DQW: Power Estimation

	F (MHz)	558.4	588.3	685.3	701.5	926.7	958.7
	Mode Type	M	M	h	mix	h	M
	Qext	3850	4700	1840	569	5450	4190
Impedance	Longitudinal [Ω/cavity]	49900	207000		3563		40400
	Horizontal [Ω/m/cavity]			911000	1234	1740000	
	Vertical [Ω/m/cavity]				748	287	
	HOM Power [Watt]	4.5	1.4	<0.1	57.8	<0.1	0.2
	HOM Power with freq shift in ±2MHz [Watt]	8.6	5.9	17.6	58.7	4.4	128.0

- **HOM power is about 65 Watts per cavity**
- **The power increased to 225 Watts if HOM frequencies shift in ±2 MHz range.**

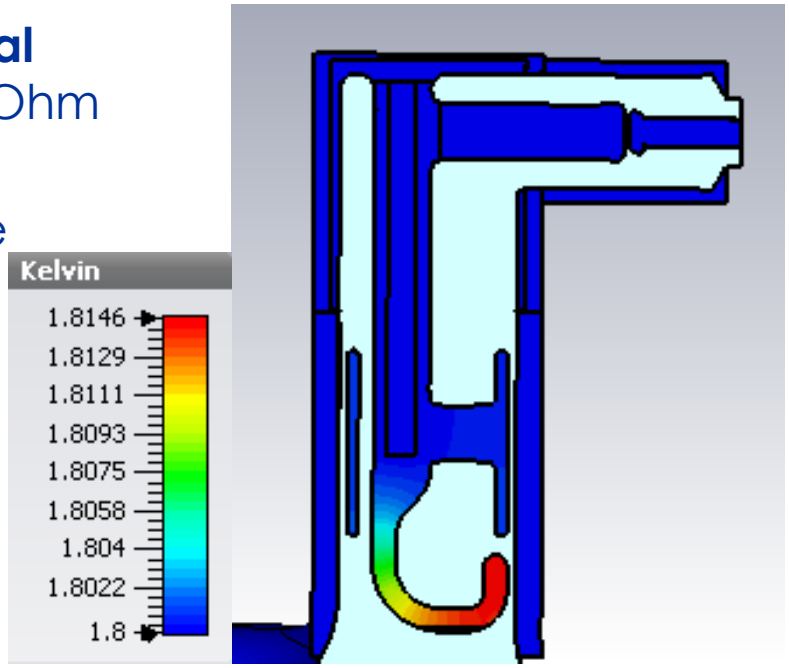
Power of transverse modes estimated based on 5mm offsets.

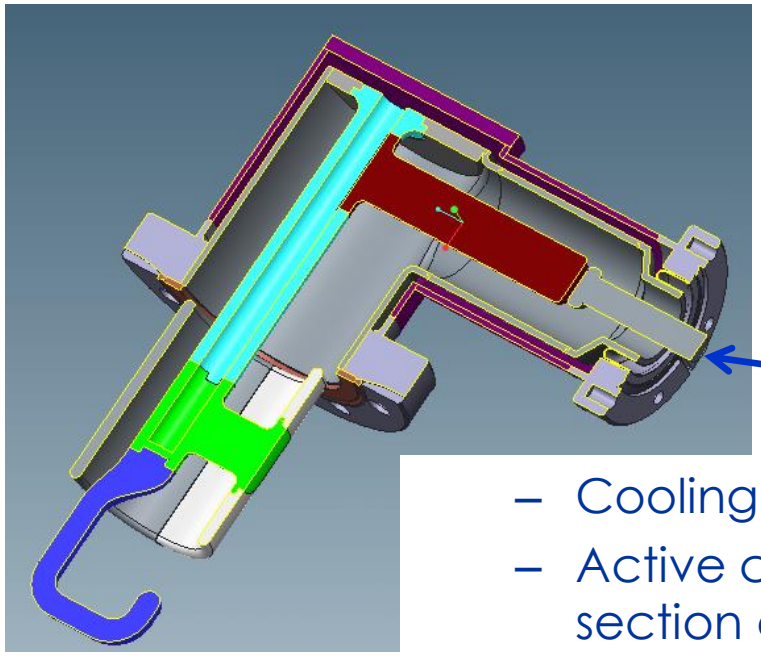


DQW: Thermal Analysis

CERN and Cockcroft

- Assumes cavity operating **at nominal deflecting voltage** of 3 MV with 5 nOhm surface resistance.
- Assumes active cooling through the center cooling channel **at 1.8 K**





Feed-through to a coax cable to an outside load

- Cooling channel larger than the previous version.
- Active cooling will be applied in the straight section of the HOM hook, and it is possible to extend it till the end of the tip.

DQW: Prototyping

- 3-D printing (BNL) + Cu coating (Epner Technology Inc.).
- Acetone etching for smoother surface.
- Evaluating different ways to deal with joint loss.
- Will figure out the ports connection based on new design.





Prototyping of updated version will start soon

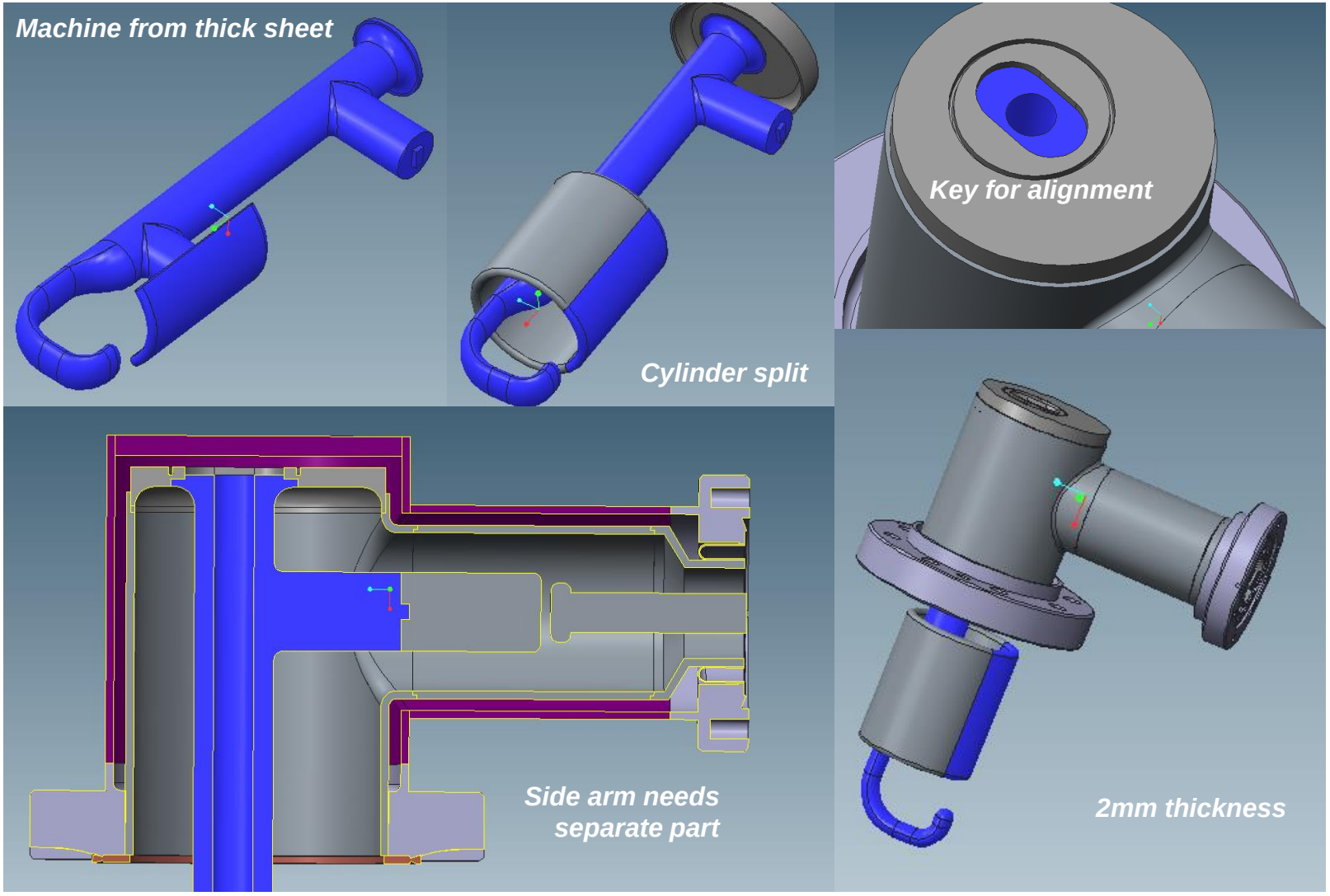
SPL HOM filter
(K. Papke, CERN)

Assembly ideas (UK, CERN)

LARP

High Luminosity LHC

In evolution…



Summary

- **Peak electric/magnetic fields** on filter smaller than on cavity. Calculations are cross-checked between CST MWS and ACE3P.
- Tolerance calculation is on-going, current results suggest that tuning at room temperature (before or after mounting onto cavity) might be necessary.

- Methodology for **R/Q calculation** has been established (UK). Values cross checked by UK and BNL using CST MWS. Additional check by SLAC with ACE3P is on going.
- Qext calculations of HOMs using two methods: eigenmode Q and S parameter Q.
- HOM filter is designed to meet the current "upper limit" and to try to achieve the current "lower limit" of impedance budget with HOM frequency up to 1.75 GHz.
- Impedance evaluation up to 2 GHz is on going.

- **Multipacting** simulations are cross-checked between CST MWS (UK) and ACE3P/TRACK3P (SLAC).

- HOM filter **assembly** is under discussion. Ideas proposed by UK and CERN.

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- I. Ben-Zvi. 4th LHC Crab Cavity Workshop; CERN, Geneva, Switzerland (2010)

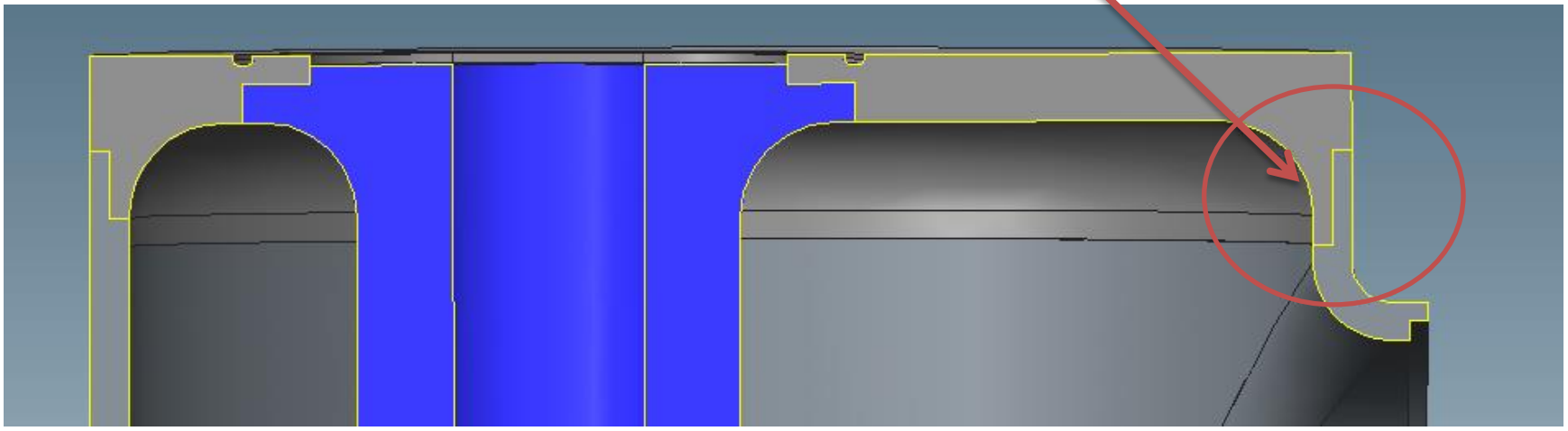
LARP

High Luminosity LHC

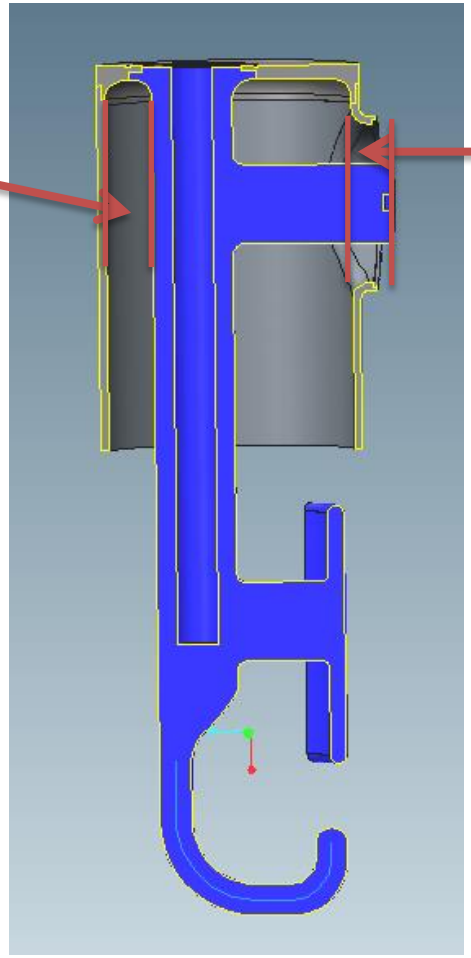
Thank you!

Awaiting further RF design update

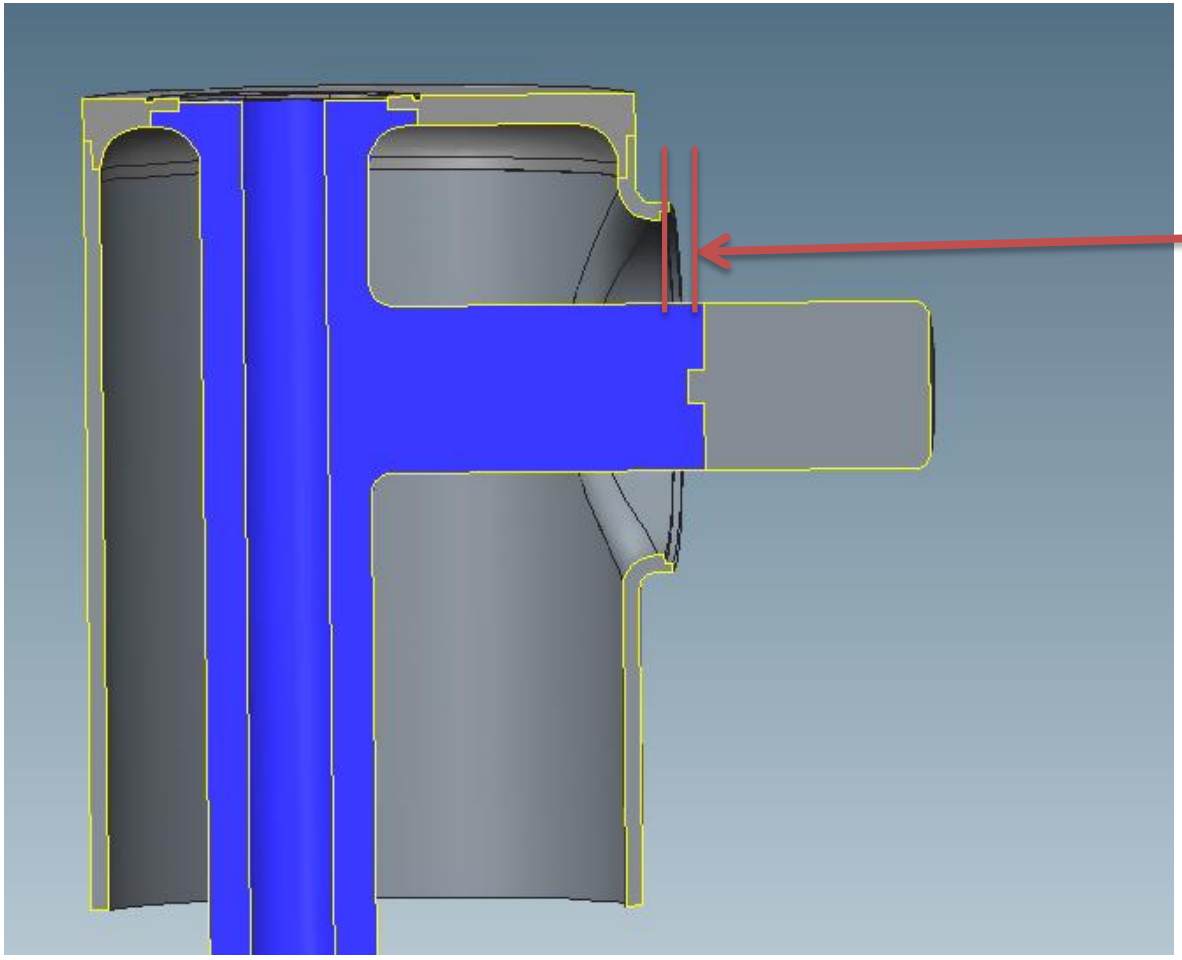
Exact height of step to be determined by RF simulations

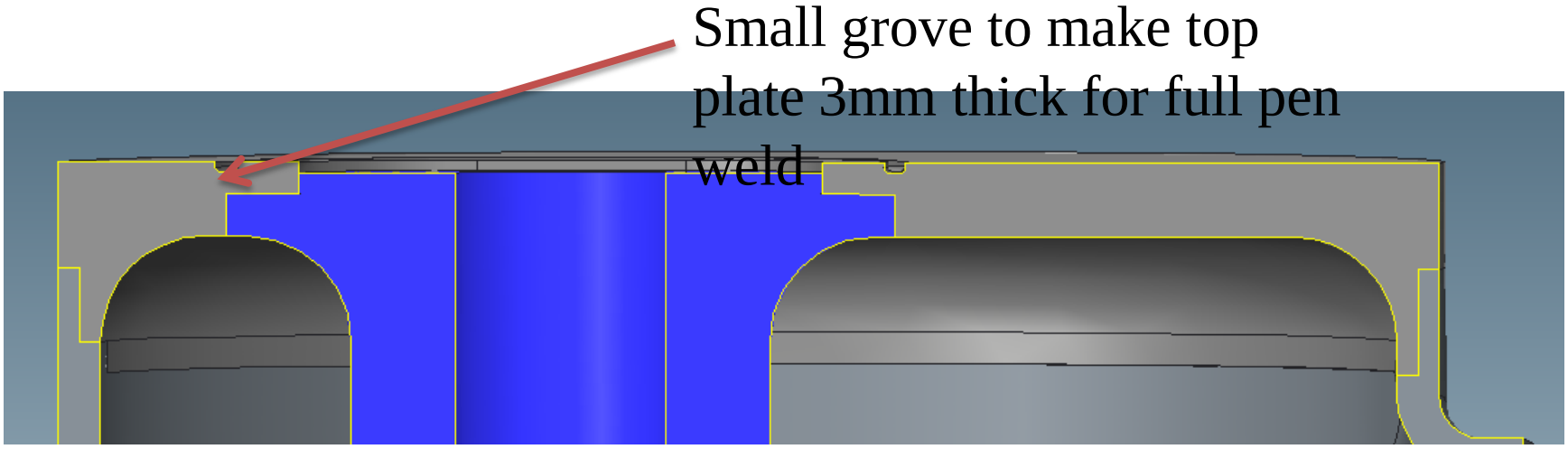


Assembled first



Then rest of stub attached,




Small grove to make top plate 3mm thick for full pen weld

Locating point.