BESSY II

HZB Helmholtz Zentrum Berlin

HOM Damping of 3rd Harmonic Copper Cavities for Active Operation in the BESSY II Storage Ring

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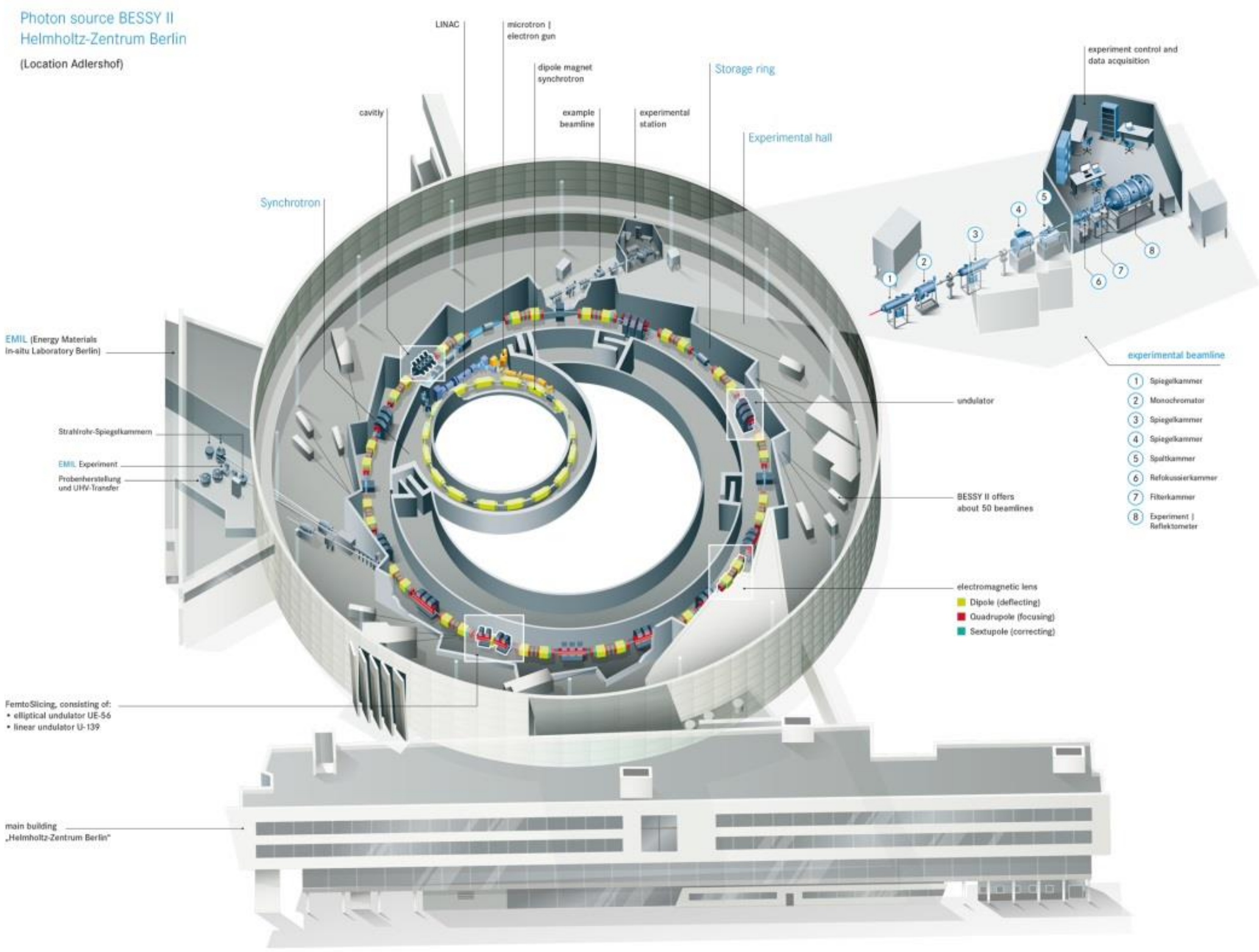
MAX IV, Lund, Sweden

BESSY II Storage Ring

- BESSY II is a 1.7 GeV synchrotron radiation source operating for 20 years in Berlin
- Core wavelength in the range from Terahertz region to hard X rays



BESSY II Parameters	
Lattice	DBA
Circumference	240 m
Energy	1.7 GeV
Current	300 mA
RF Frequency	500 MHz
RF Voltage	1.5 MV
Bunch Length	15 ps
Emmitance	6 nm rad

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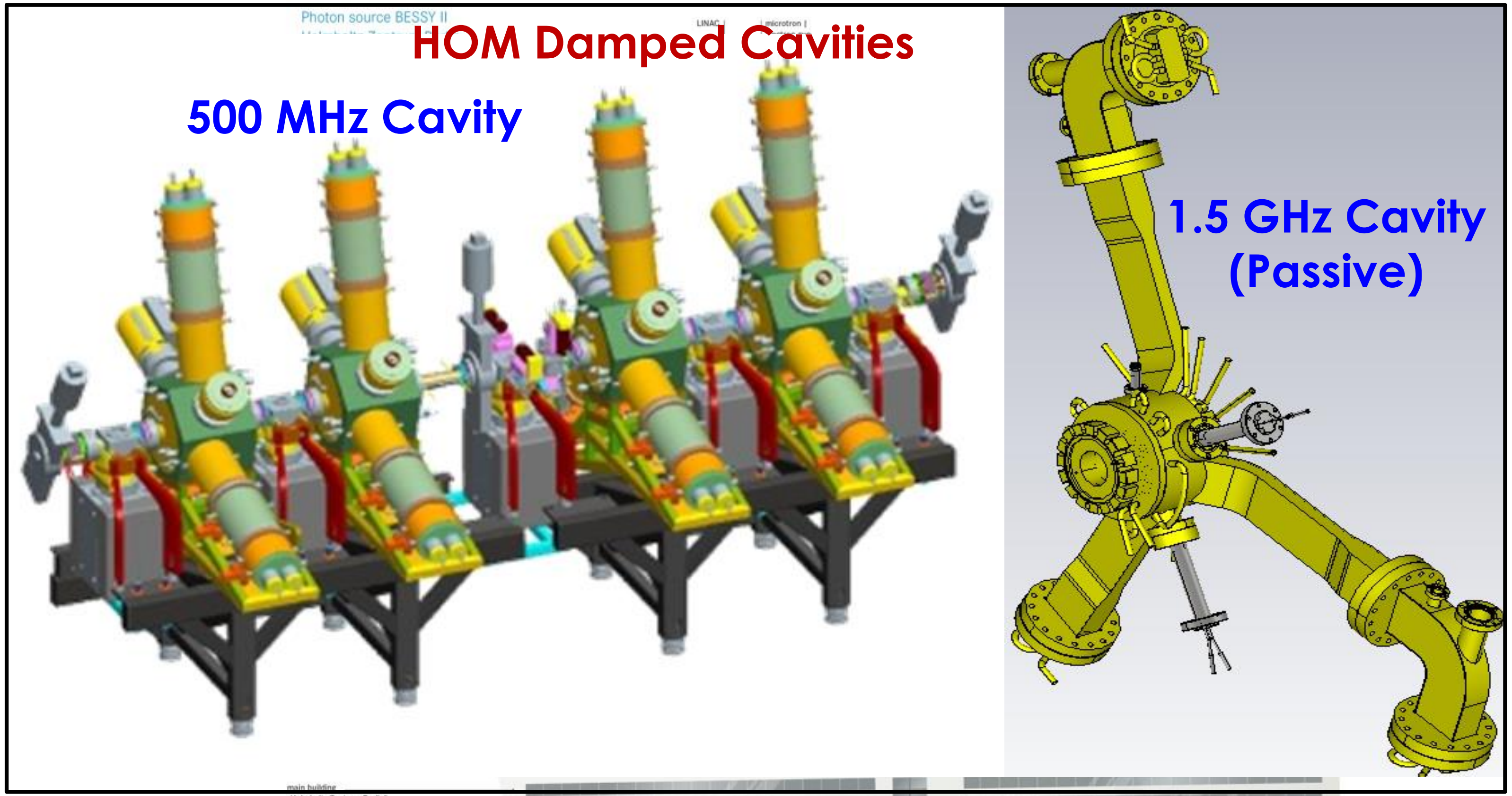

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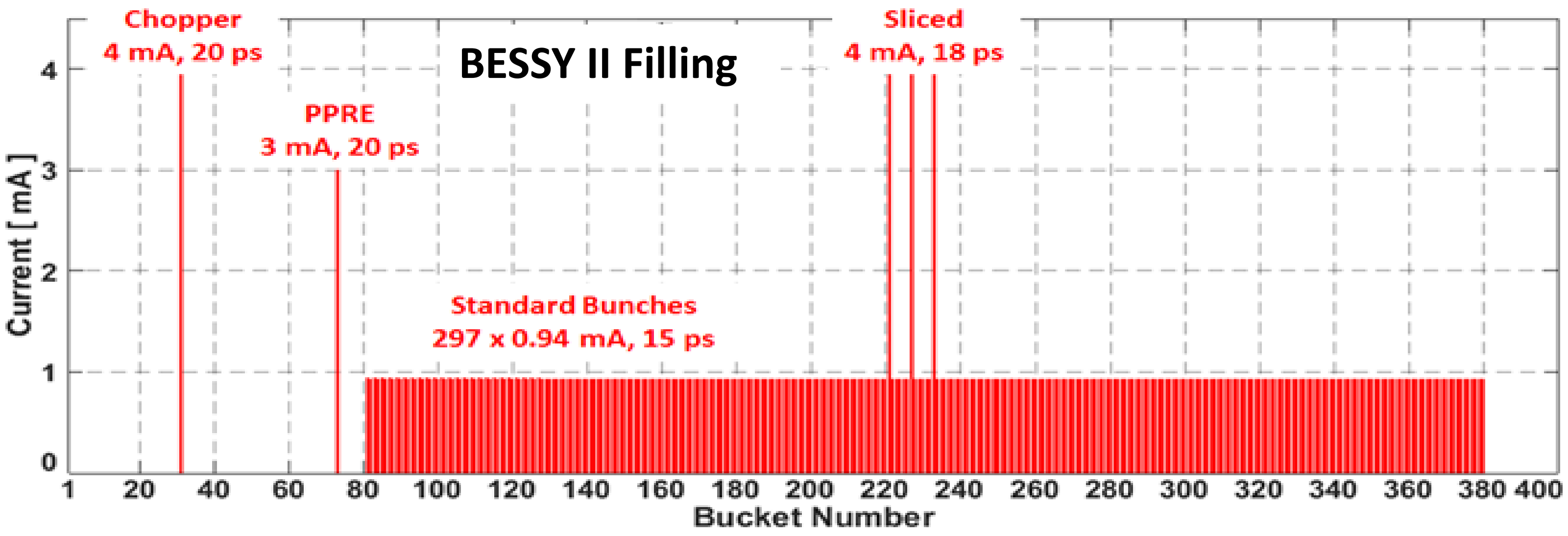
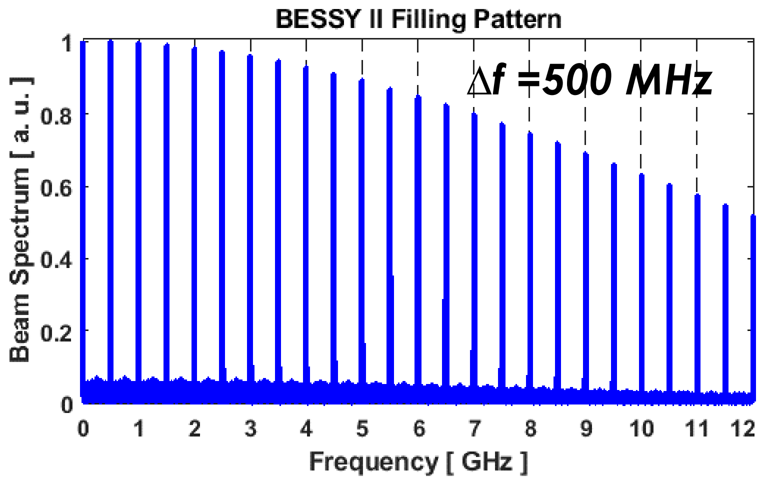
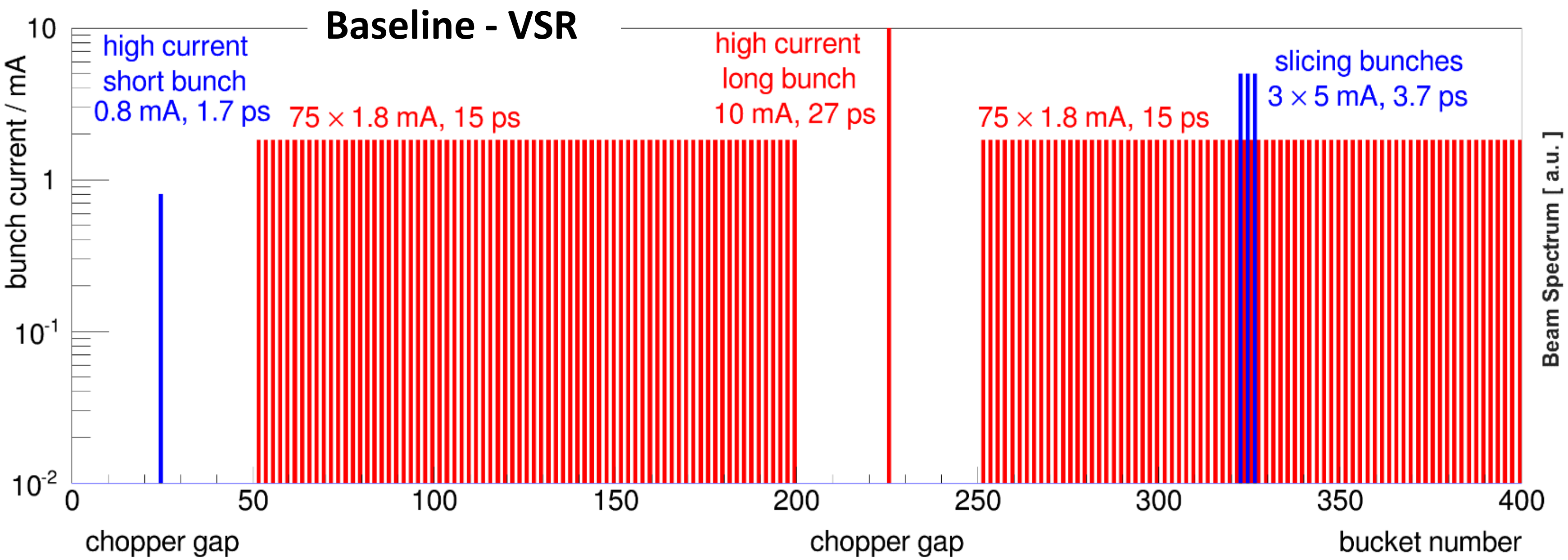
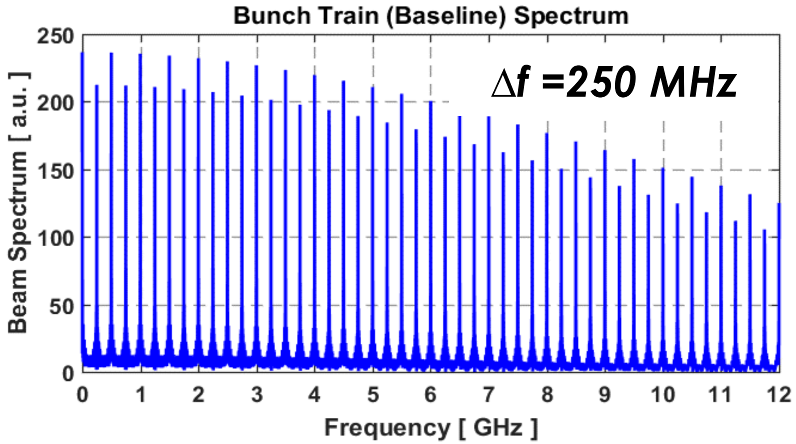
BESSY II Filling Patterns

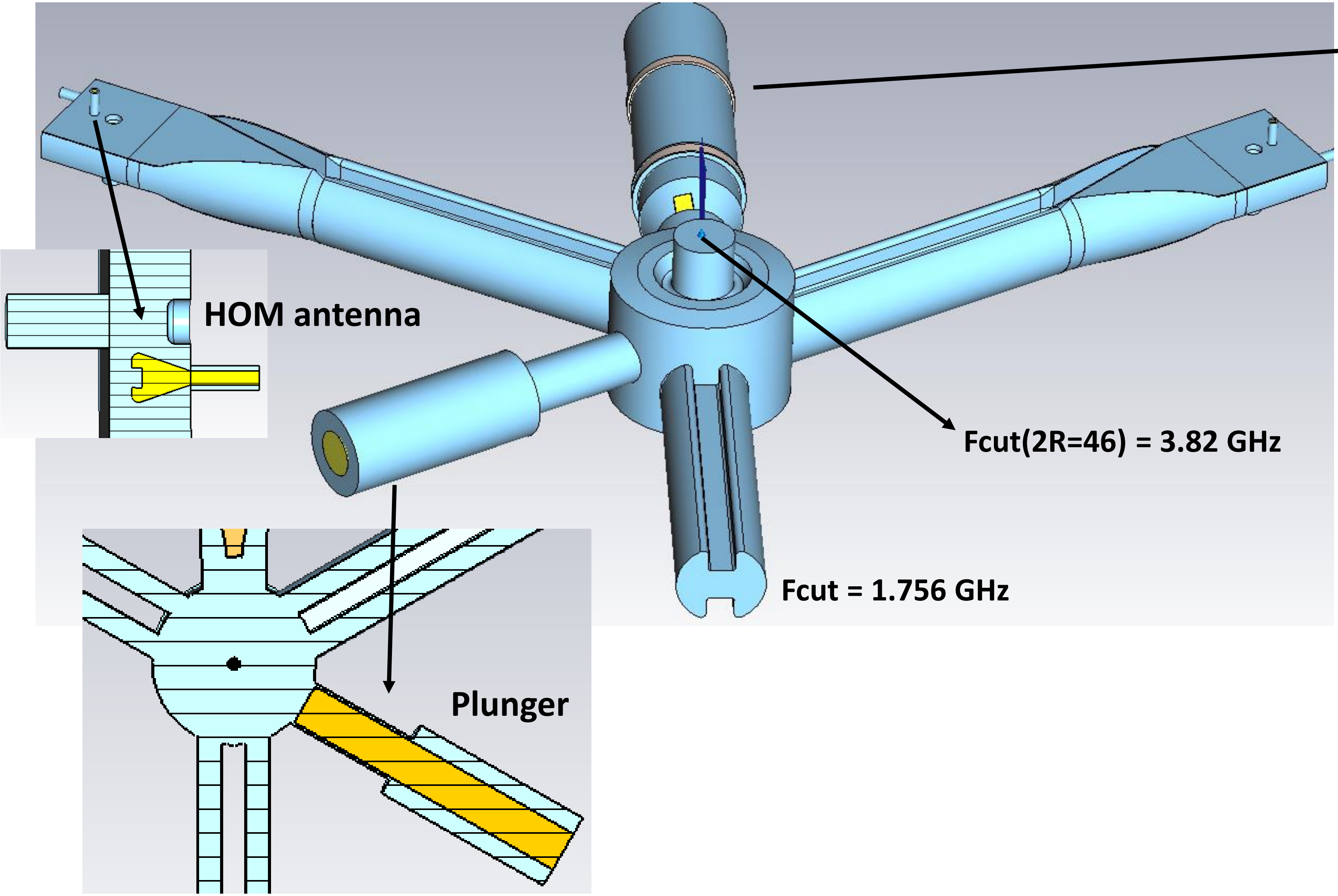




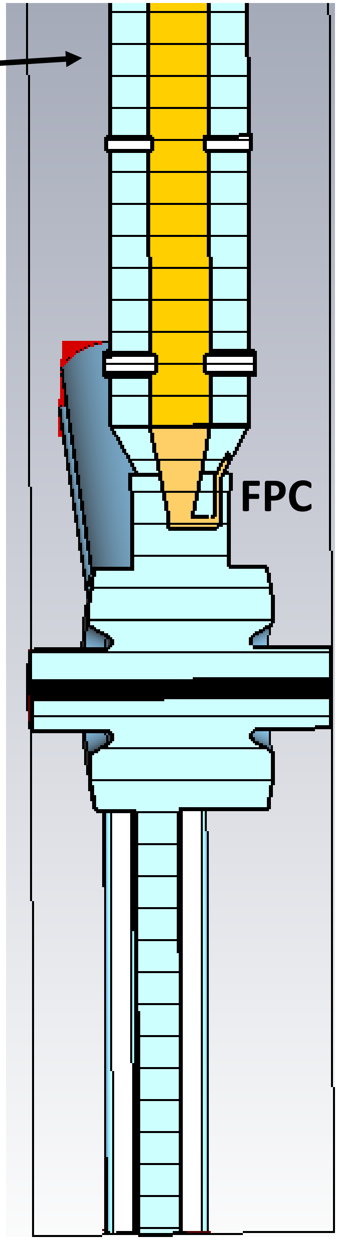




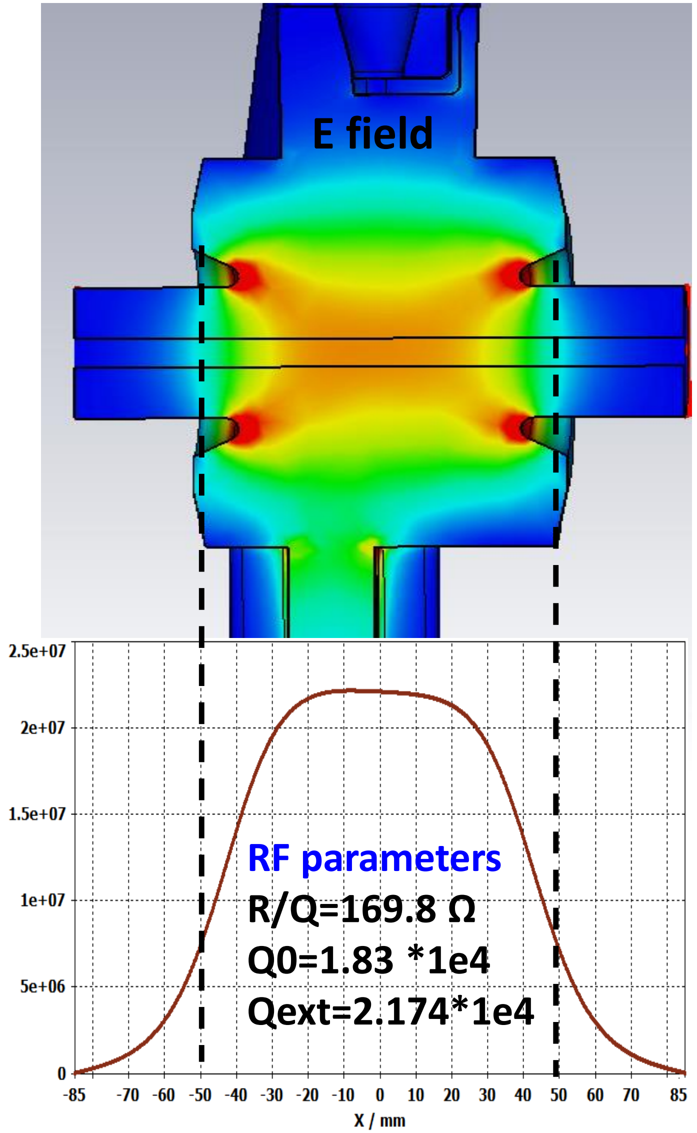
1.5GHz Cu Cavity – ALBA Design

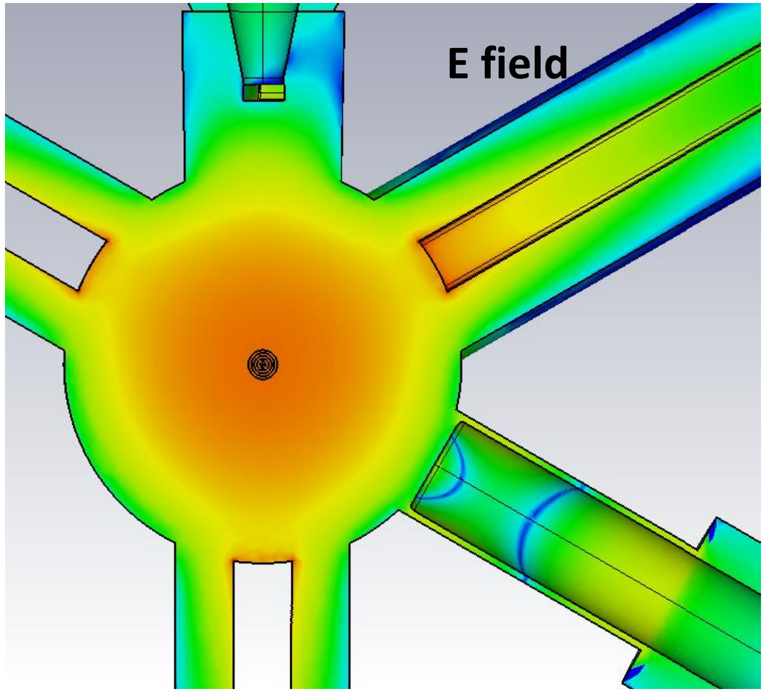


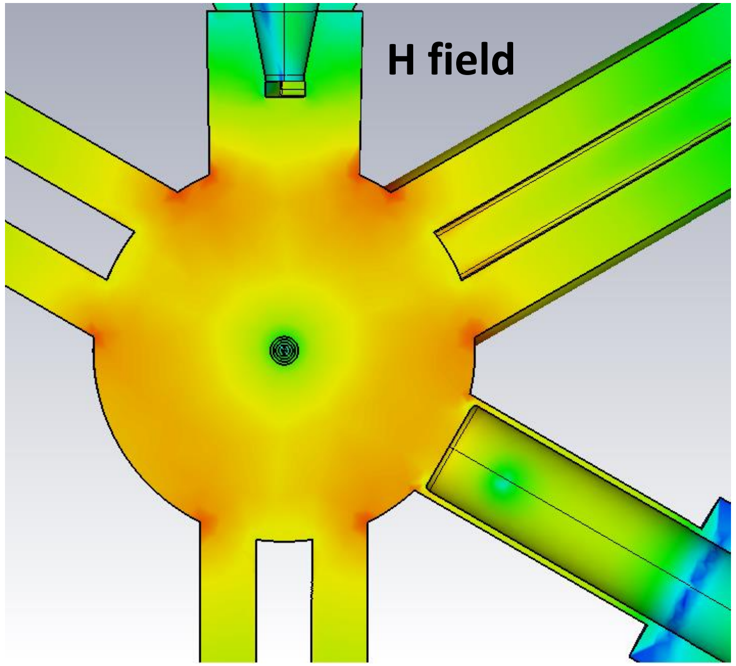
Fcut (FPC-TE)= 1.74 GHz



Fundamental mode

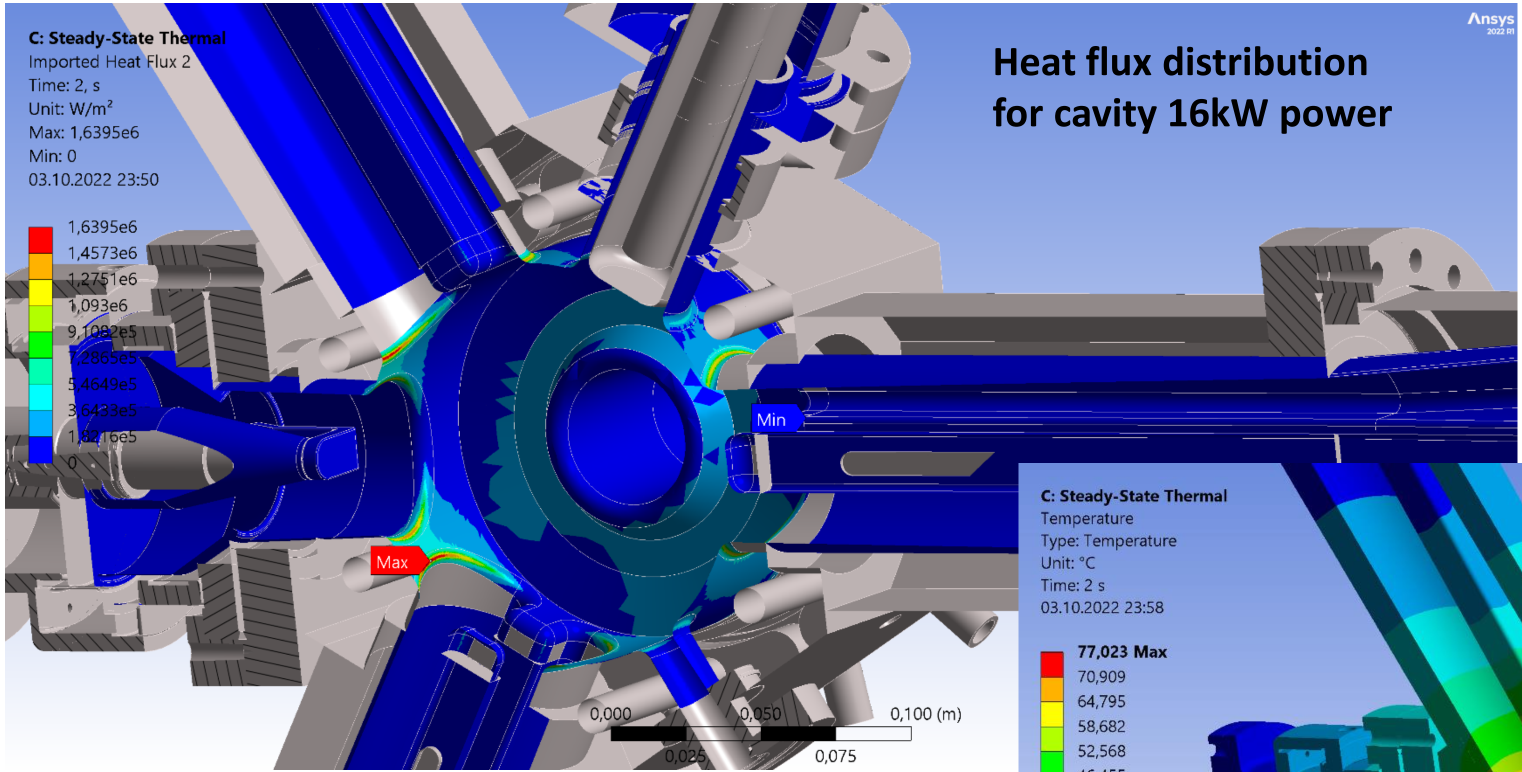


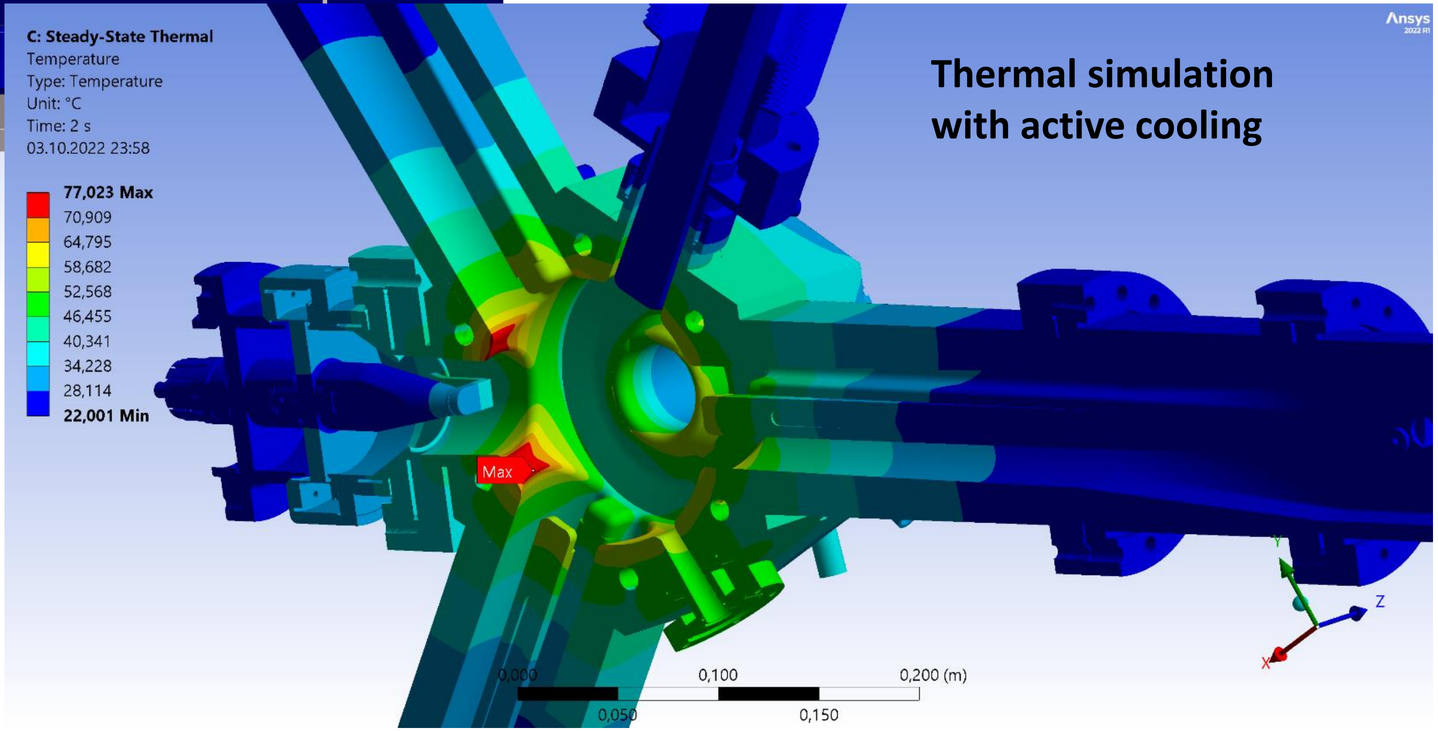




- ➢ High E-field around the in inner gap corners could be limitation for gradient – discharge issue.
- ➢ High B-field at connection of cavity body & attached elements – heat issue.
- ➢ Field has asymmetry due to the FPC etc. – field map tracking is required (Beam dynamic)

Thermal Simulations

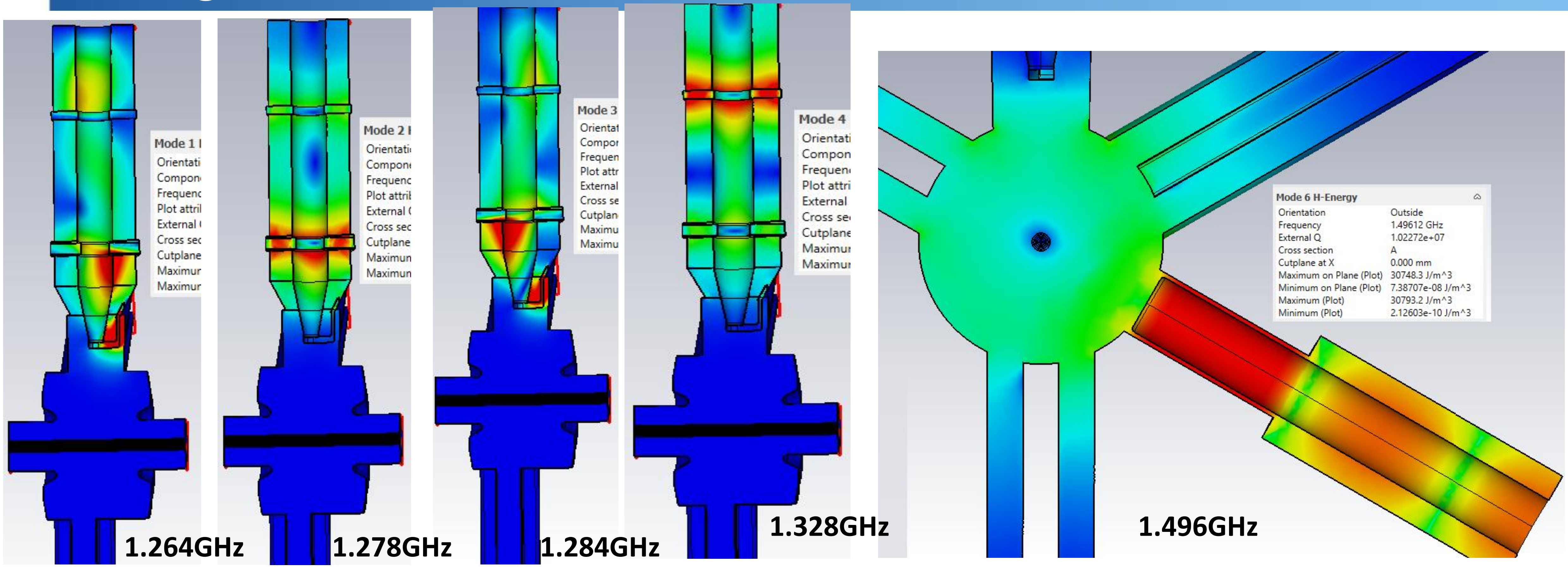




- First thermal simulation with active cooling shows that at HOM waveguide–cavity body connection points the temperature can rise up to 70°C while the average cavity temperature remains below 45°C.
- More simulations are foreseen with different cooling rates implying changes in water pipe dimensions.
- Based on practical experience keeping, the local heat flax <1.2 W/mm^2 can improve the life time of the cavity.

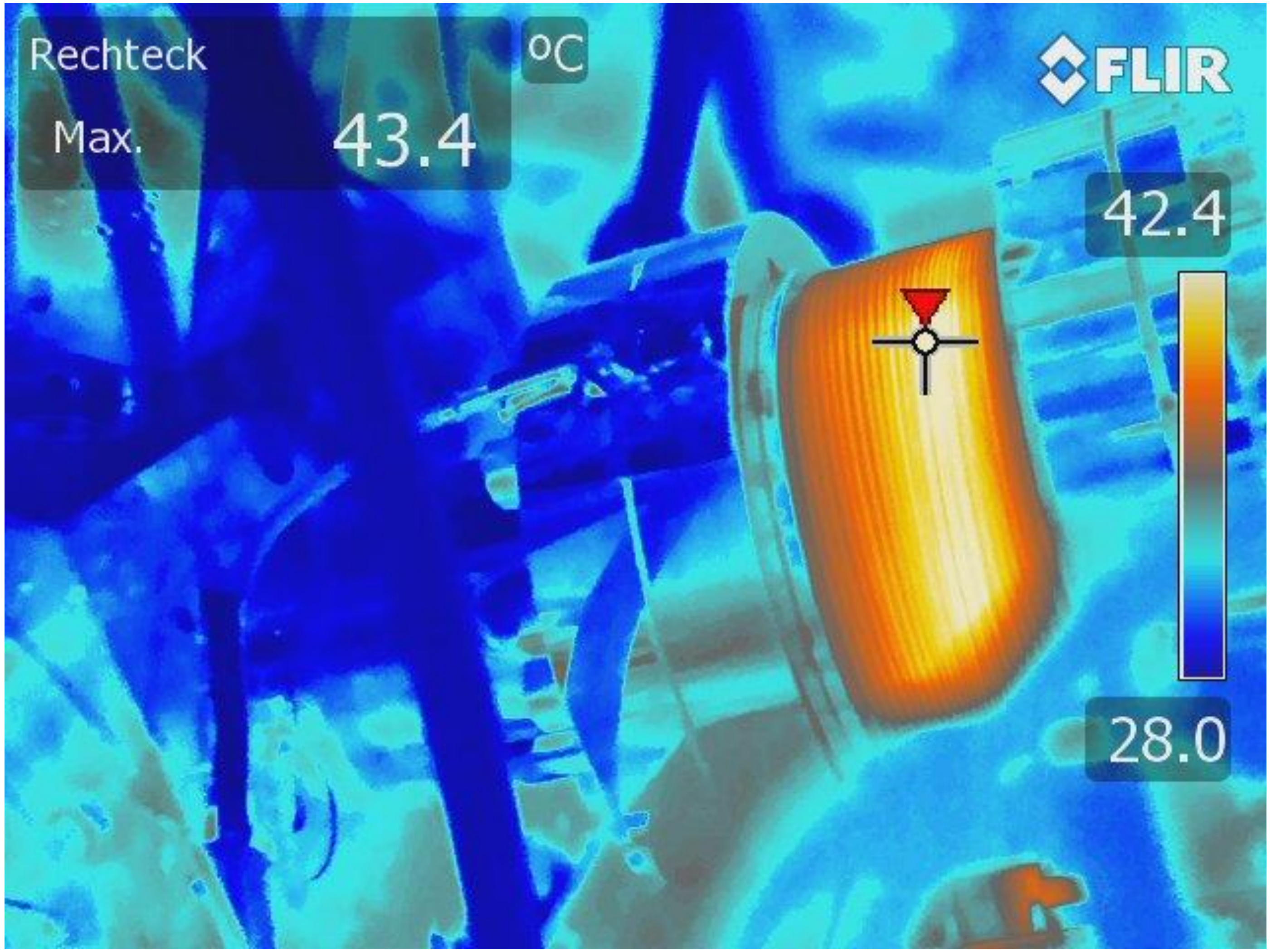
Courtasy of M. Dirsat, HZB

Eigenmodes



- All those modes have very low R/Q & Qext except the mode localised in plunger.
- The mode localized in the plunger is not damped & can lead to heating issues, i.e. some frequency ranges to be avoided… more detailed simulation are required for different plunger positions.
- In case FPC antenna is fixed, what are the scenarios for operation – master clock shifts ?

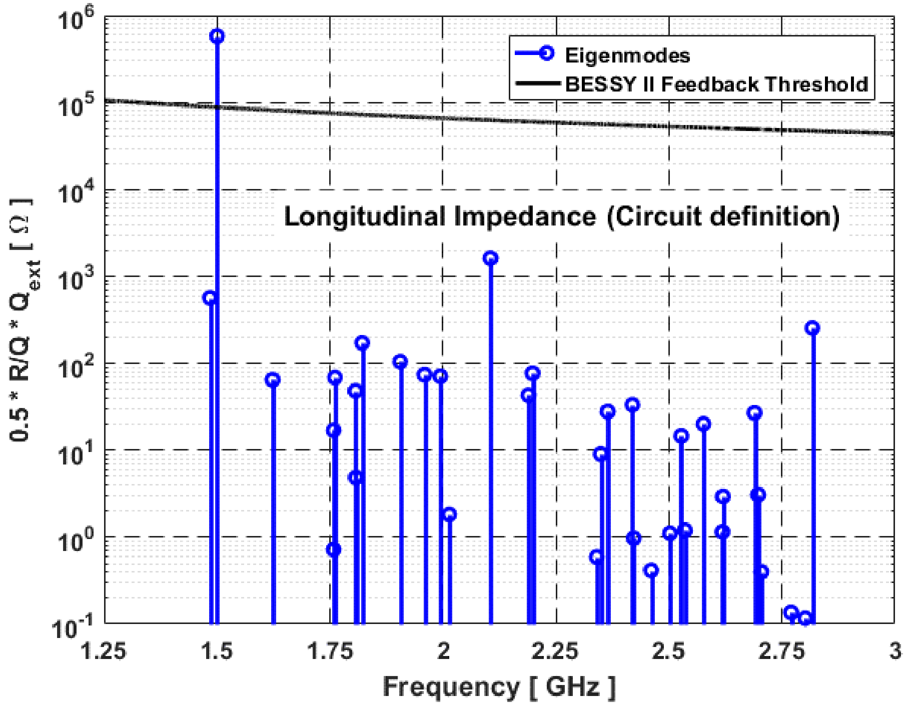
Plunger Bellow



- During cavity commissioning the highest heat load is observed in plunger bellow.
- The plunger bellow is made of stainless still & has no shielding. The highest temperature of bellow was ~43°C while the entire cavity outside surface <30°C.
- Dedicated test is planned to understand the origin of the heat load in bellow, i.e. is it due to the fundamental mode, plunger localized mode or some HOMs.

Courtasy of V. Dürr, HZB

Mode Atlas – Eigenmode Solver

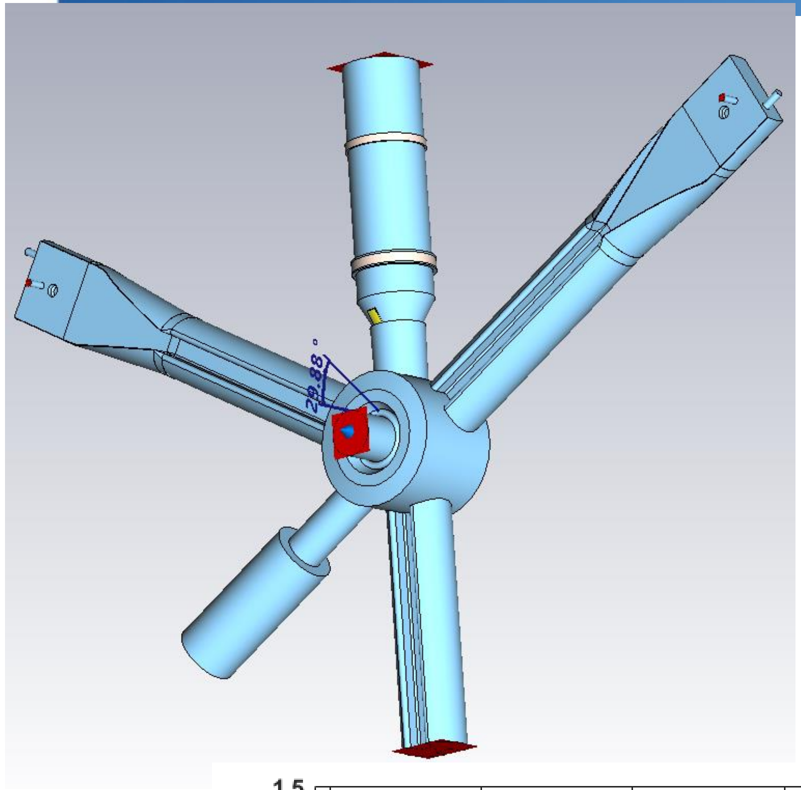


Nr.	f (GHz)	Q external	R/Q	R/Q with TT	
1	1.484	6060.0	0.46520	0.18652	Input Coupler
2	1.486	Inf	0.00705	0.00282	Input Coupler
3	1.495	Inf	0.05498	0.05321	Tuner
4	1.500	7017.0	419.18275	164.59412	Fundamental Mode
5	1.623	76.2	4.73829	1.69462	Input Coupler
6	1.758	243.2	0.00004	0.14009	HOM Coupler
7	1.758	239.8	0.00170	0.00602	HOM Coupler
8	1.761	191.0	2.77207	0.71835	HOM Coupler
9	1.806	117.1	0.00115	0.82379	HOM Coupler
10	1.807	116.7	0.01390	0.08317	HOM Coupler
11	1.821	101.3	14.47335	3.37674	HOM Coupler
12	1.894	Inf	0.19130	0.34047	HOM Coupler
13	1.896	Inf	0.00256	1.00400	HOM Coupler
14	1.905	97.9	9.83414	2.13453	HOM Coupler
15	1.913	25.9	0.00000	0.00000	Input Coupler
16	1.913	34.4	0.00002	0.00001	Input Coupler
17	1.942	12.4	0.02038	0.00689	
18	1.959	556.2	0.13958	0.26542	(Tuner)
19	1.968	11.5	0.02513	0.01531	(Tuner)
20	1.994	23.5	0.28876	6.01877	
21	2.006	Inf	0.00005	0.00001	Input Coupler
22	2.006	Inf	0.00046	0.00012	Input Coupler
23	2.014	64.7	0.16314	0.05644	
24	2.024	Inf	7.77731	1.23831	HOM Coupler
25	2.059	Inf	0.00000	0.00000	Input Coupler
26	2.059	Inf	0.00000	0.00026	Input Coupler
27	2.105	68.0	0.05942	47.61088	TM_{011}
28	2.124	Inf	0.00019	0.00031	Tuner

- Eigenmodes are computed for fixed plunger position.
- The eigenmode solver gives accurate results up to 3GHz. At higher >3GHz frequencies the resonant modes spectrum becomes very dense & sensitive on port boundaries.
- For broader frequency range up to 10GHz long-range wakefield simulation are required.

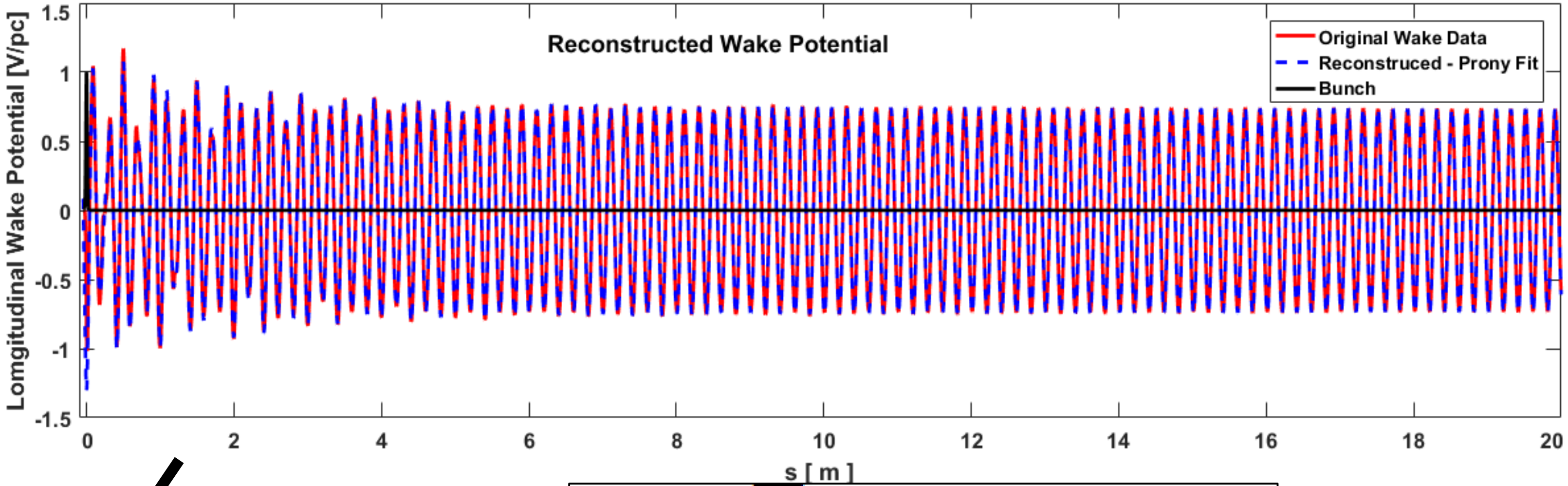
Courtasy of TEMF/TU-Darmstadt

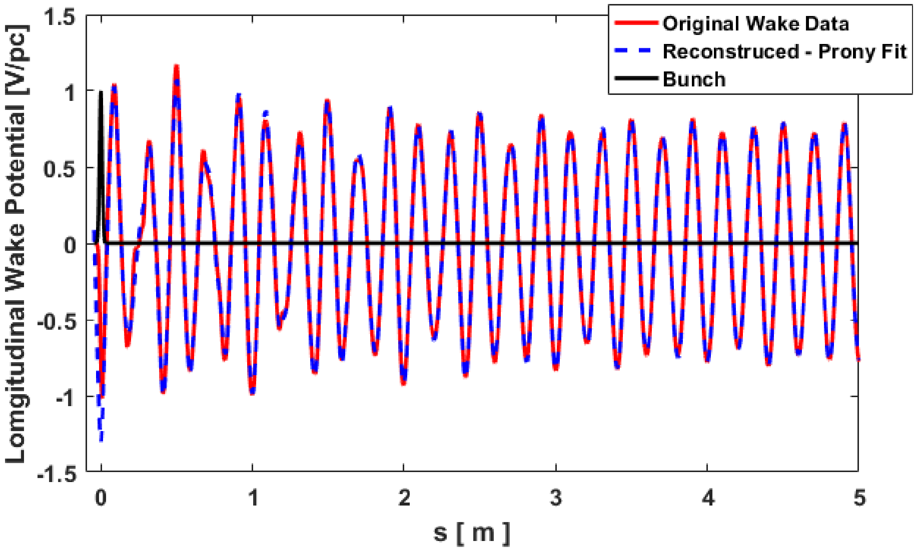
Wakefield Simulations



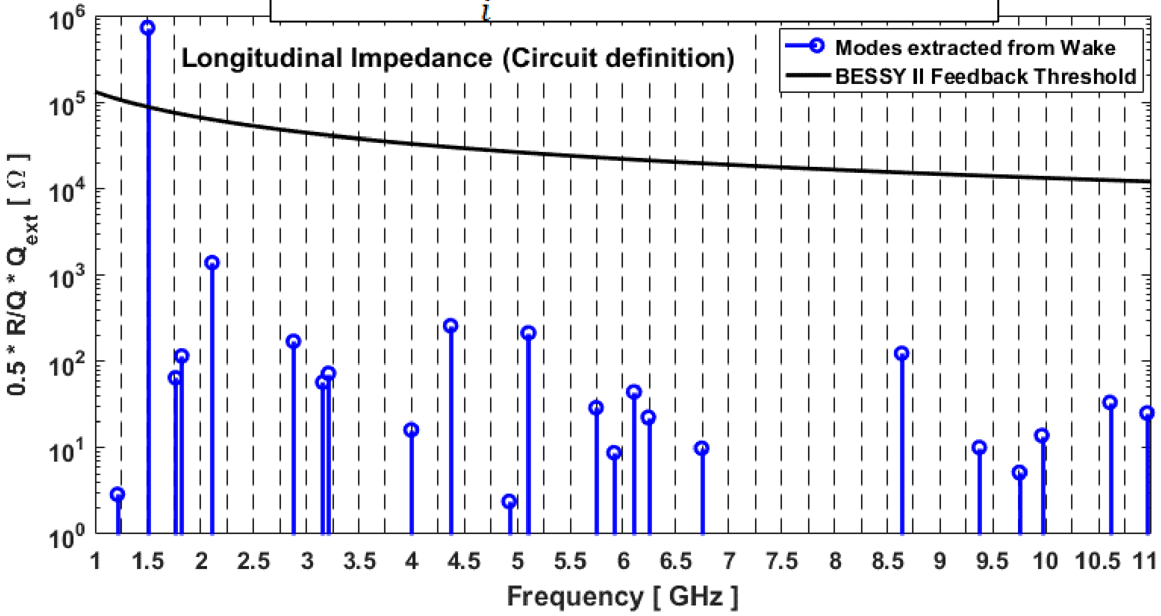
Long Range Wakefield Simulation

(Off-axis XY=2.1mm, 9mm bunch, 20m wake length)

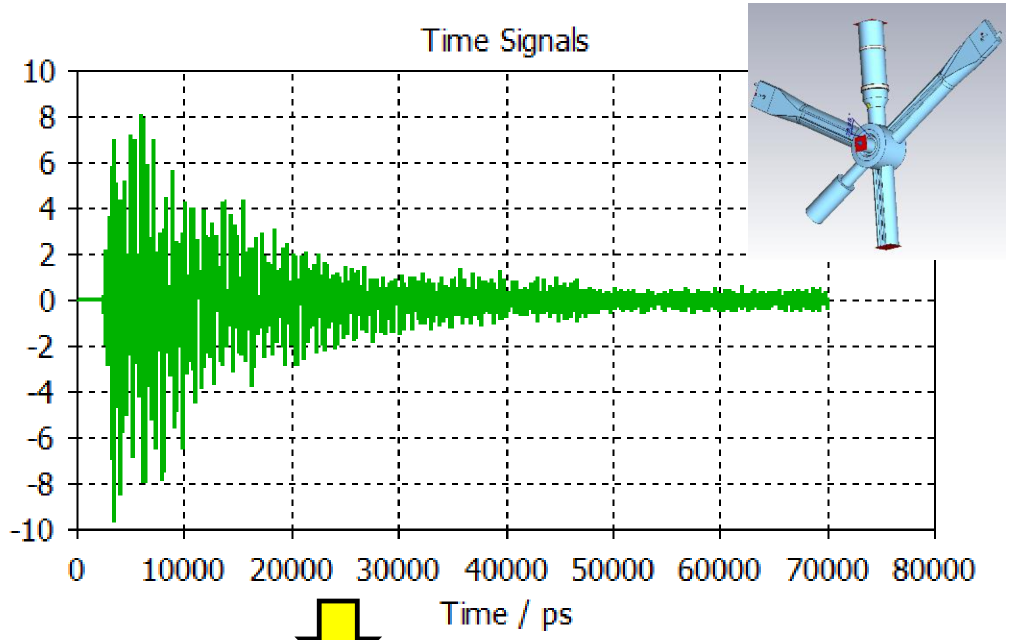


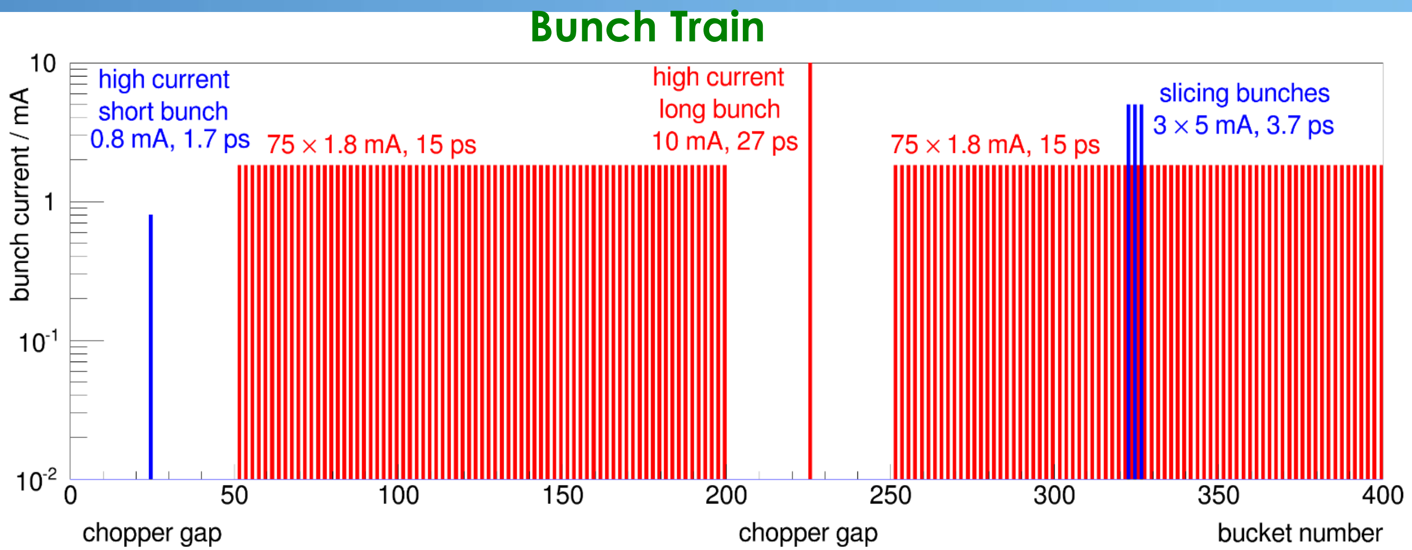


$$W(t) = 2 \sum_i K_{loss,i} \cdot \cos[\omega_i \cdot t] \cdot e^{-\alpha_i t}$$

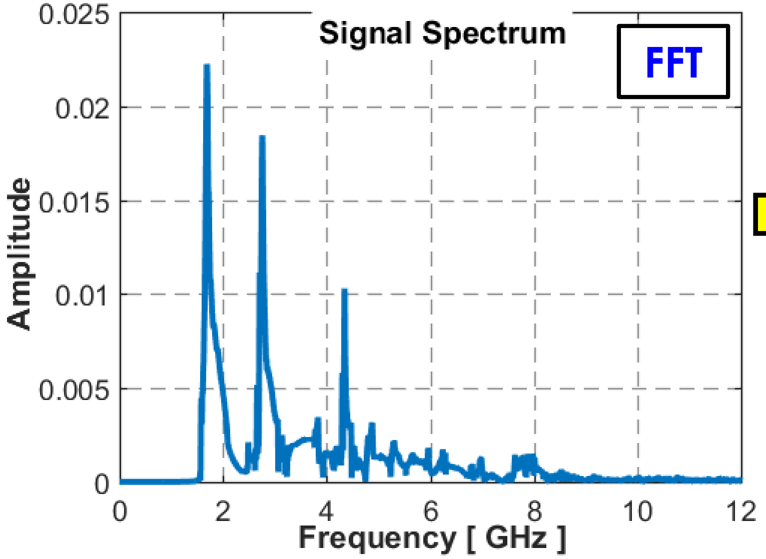


Signal Spectral Weighting Technique





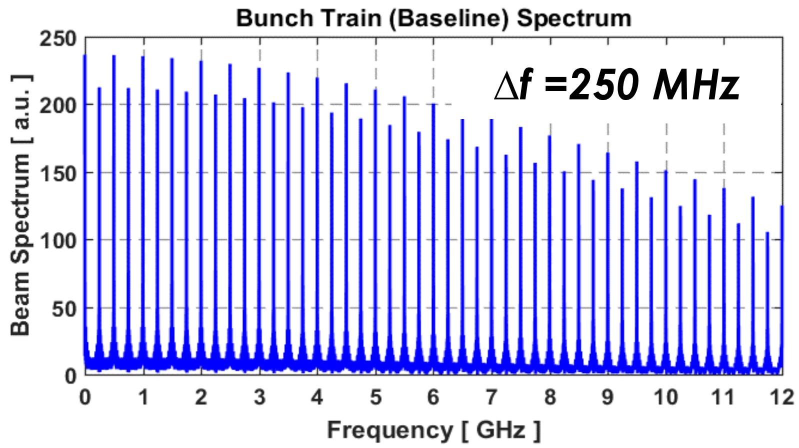
$$\tilde{I}_b(\omega) = f_{rev} \sum_n q_n \cdot e^{-0.5\cdot\omega^2\sigma_n^2} \cdot e^{j\,\omega\,t_{0,n}}$$



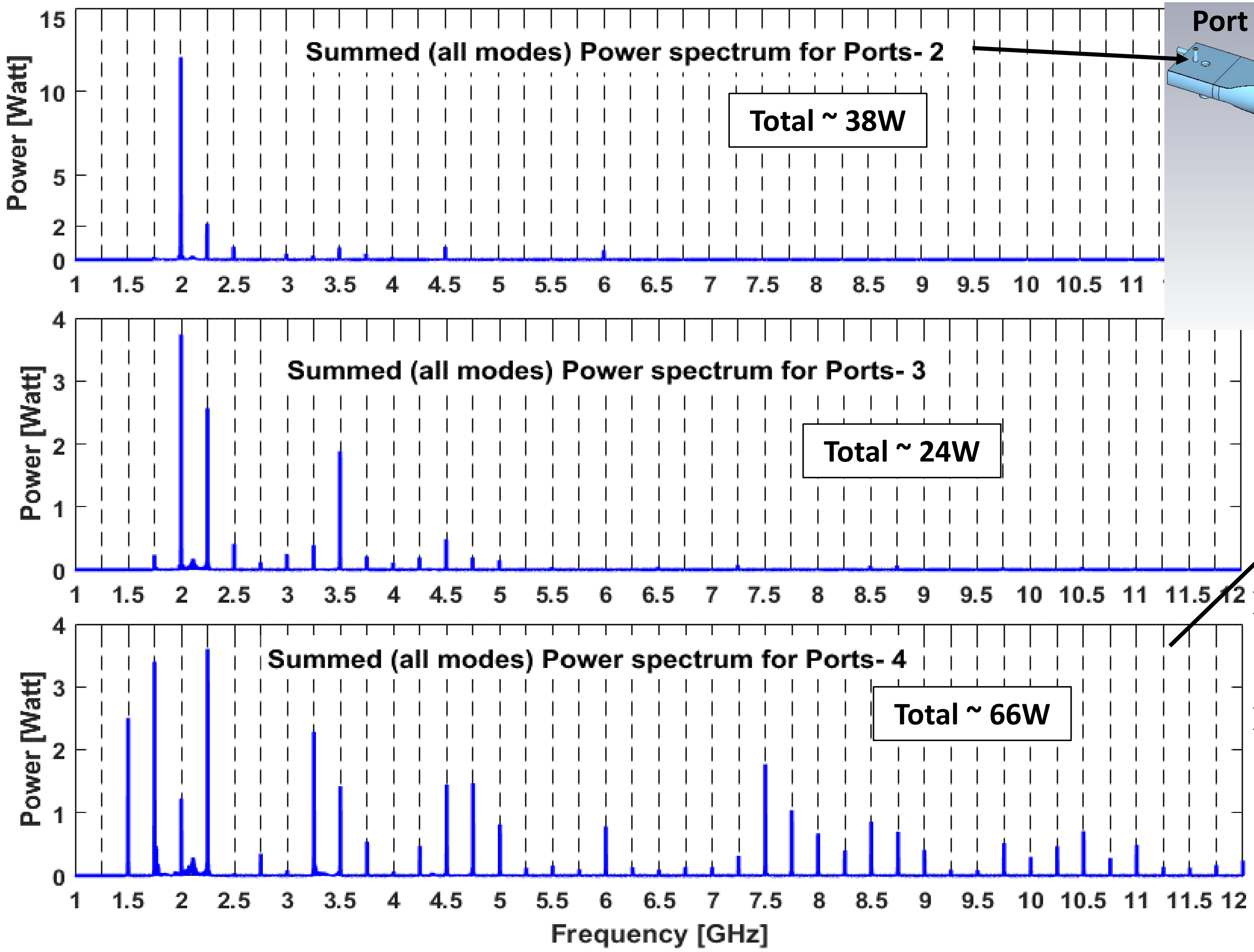
Spectral weighting of port signal & Power per freq. bins (FFT)

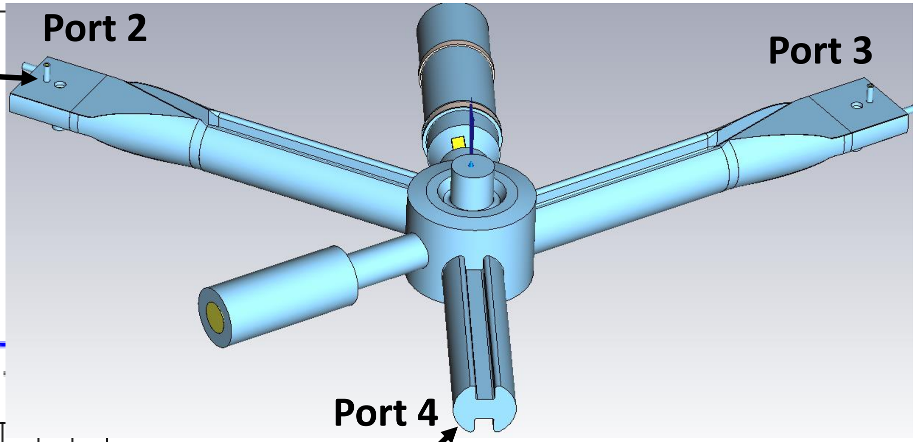
$$P(\omega) = \left| \frac{\tilde{I}_b}{\tilde{I}_0} \mathcal{F}(\omega) \right|^2$$

$\tilde{I}_0$ - Simulated single bunch



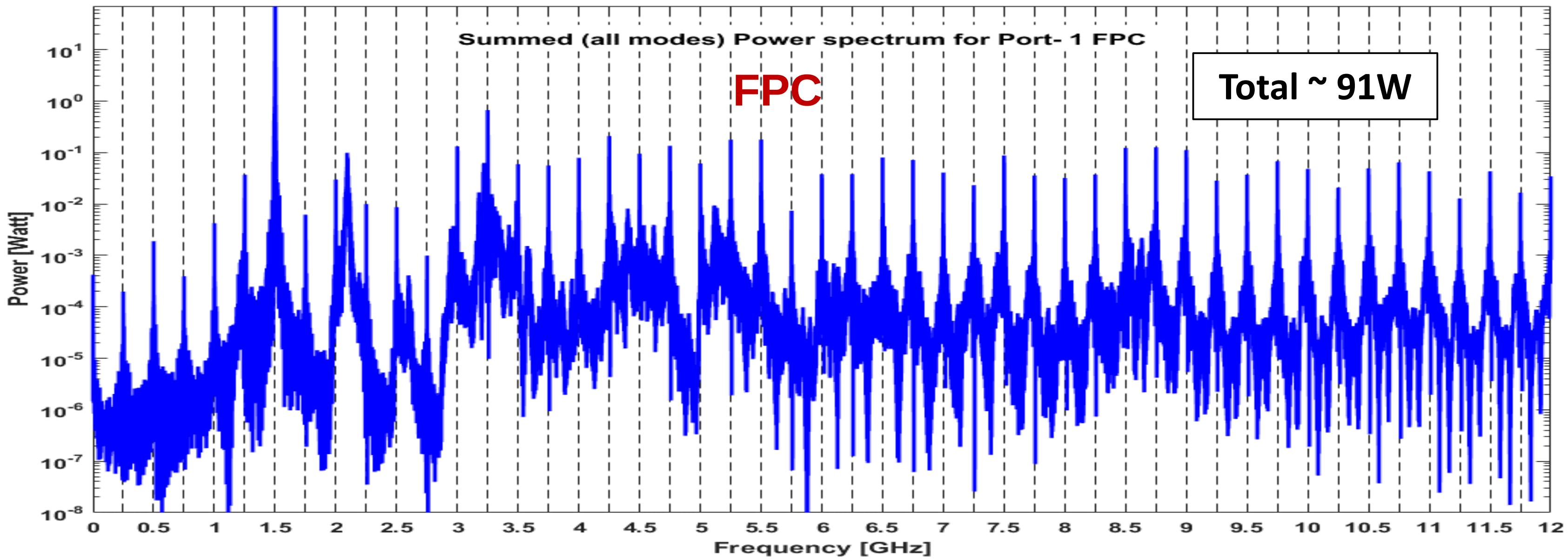
ALBA – HOM Power Distribution at Ports

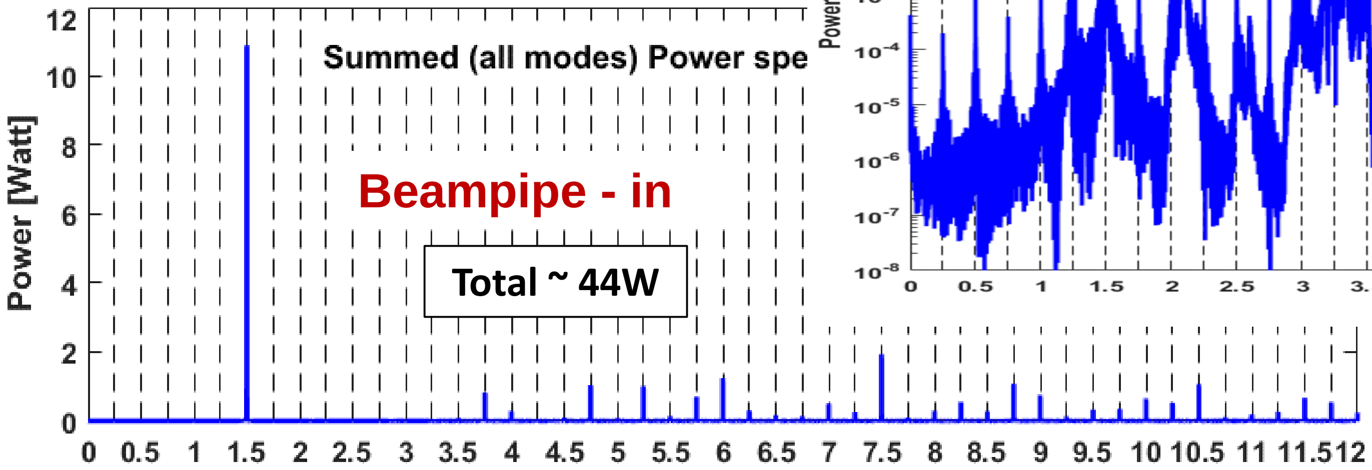


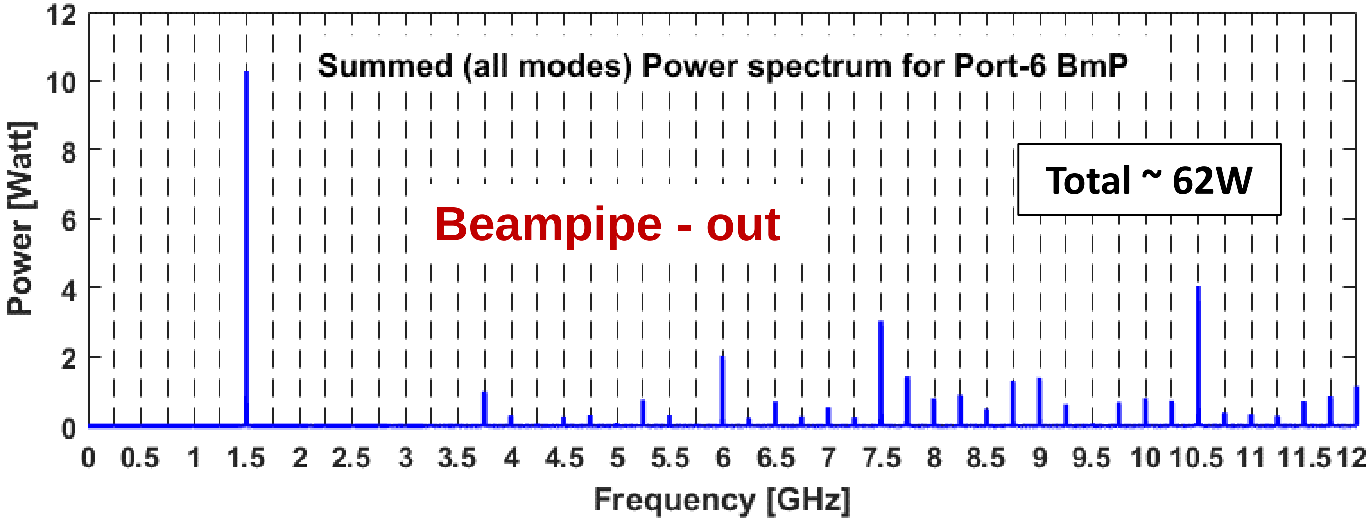


- HOM damping with antennas should be prepared at least for 50W.
- Integration of absorbers in the HOM waveguides will increase the HOM damping significantly and reduce its propagation thru beampipes into the ring.

ALBA – HOM Power Distribution at Ports

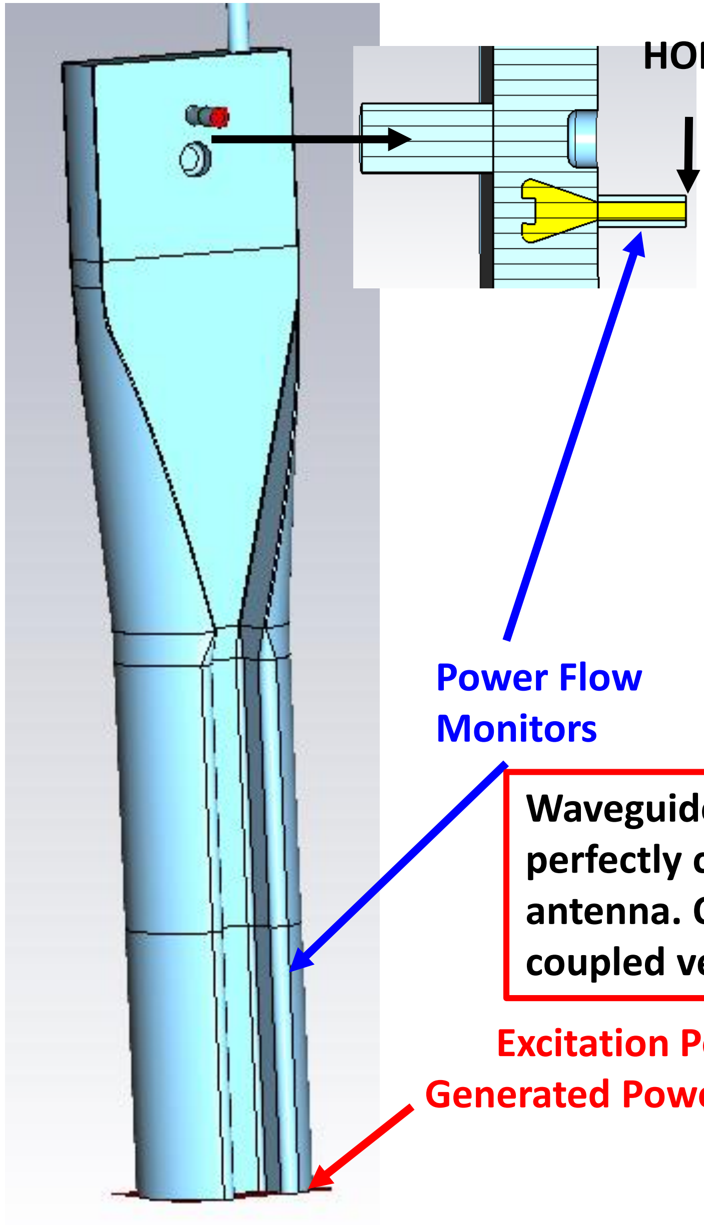






- In FPC main contribution is for fundamental mode, i.e. HOM damping is very weak in FPC <1W.
- High level HOM power is flowing out thru beampipes as the HOM dampers are acting weakly. **HOM power analyses is required including neighboring components in the ring**.

WATRAX RF Properties

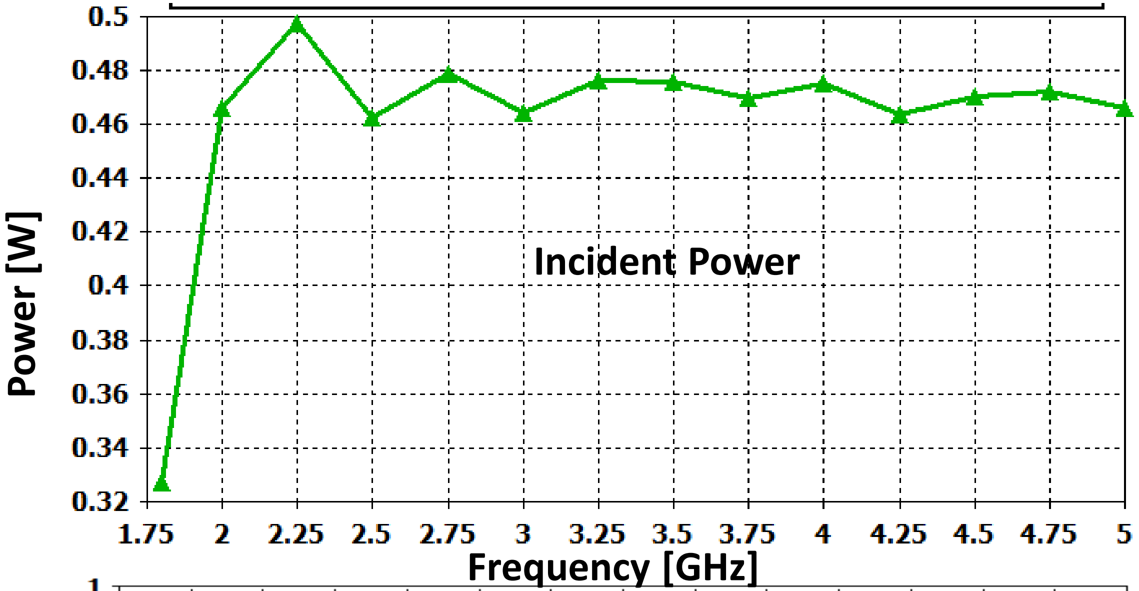


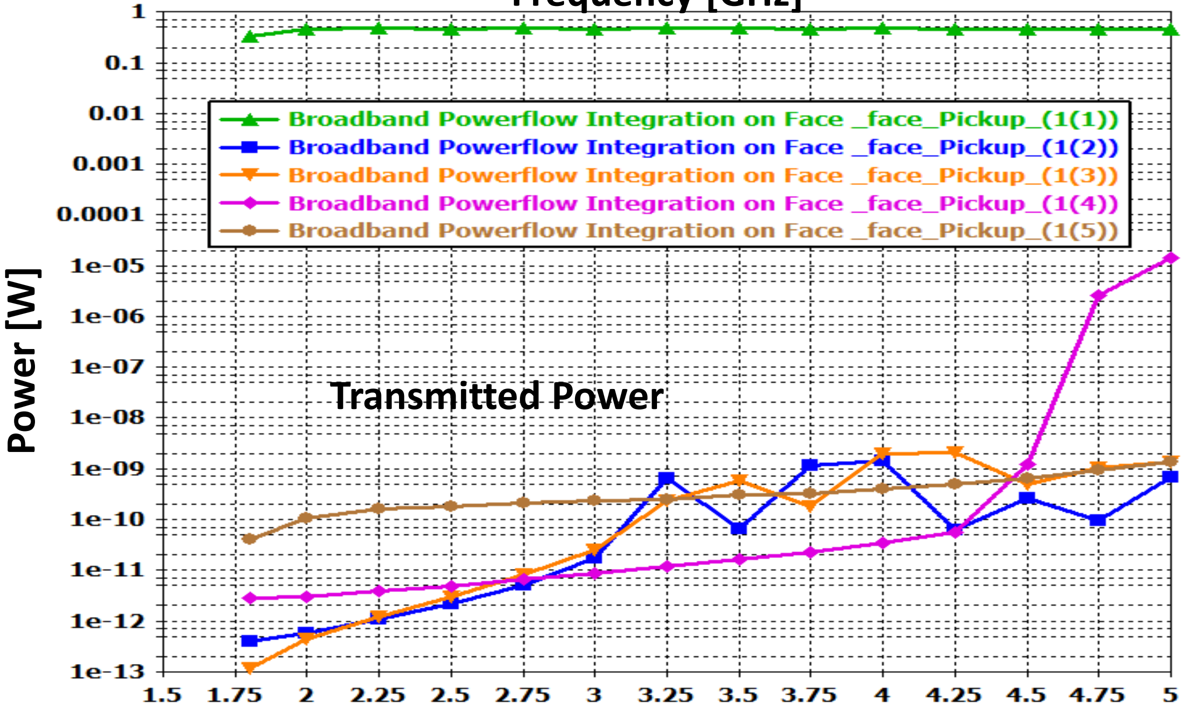
HOM Coax. Port

Power Flow Monitors

Waveguide first TE mode is perfectly coupled to HOM antenna. Other modes are coupled very weekly.

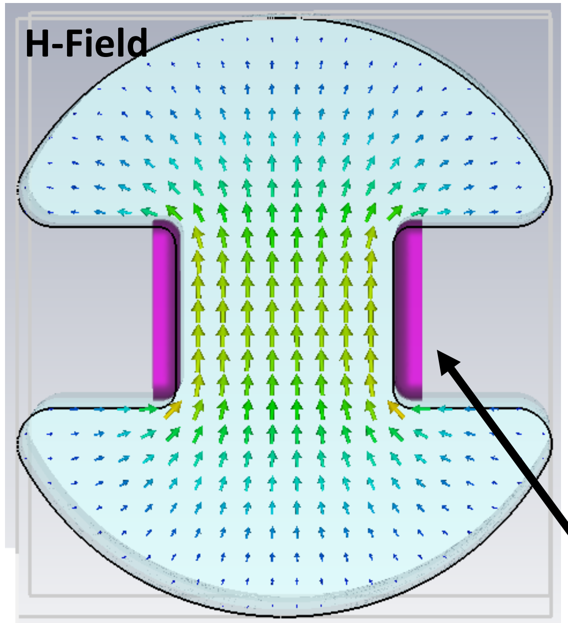
Excitation Port: Generated Power 0.5W



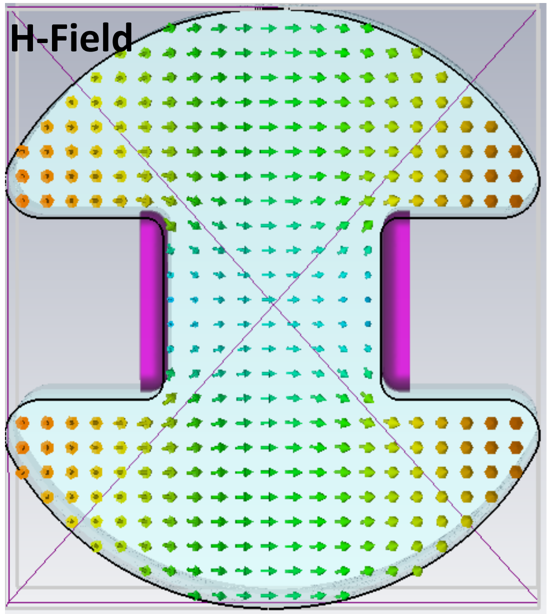


Ridged Waveguide Modes

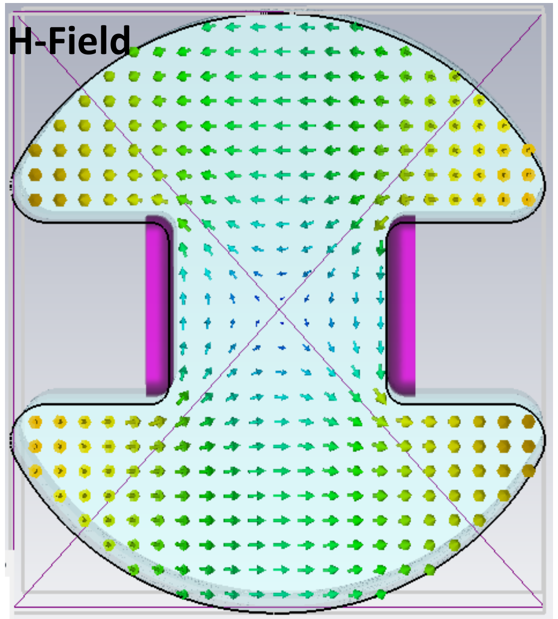
Mode 1: TE, Cut-off 1.756GHz



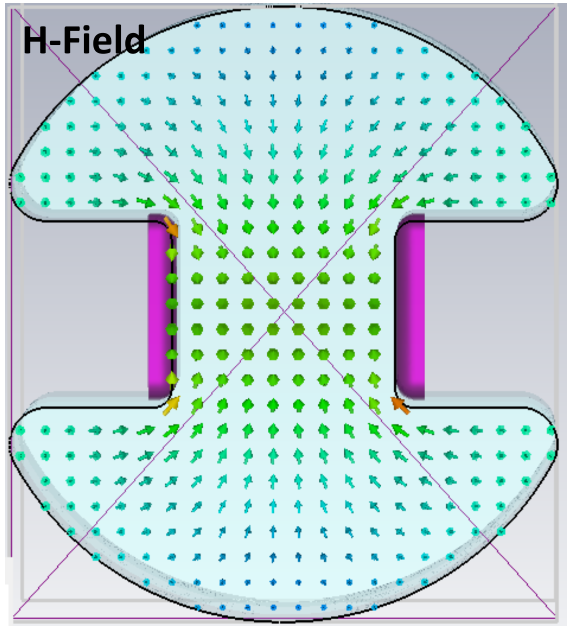
Mode 2: TE, Cut-off 3.256GHz



Mode 3: TE, Cut-off 3.32GHz



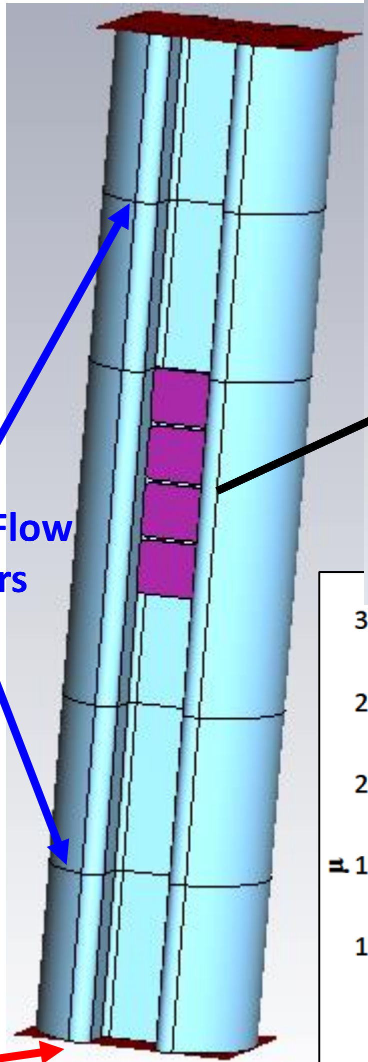
Mode 4: TE, Cut-off 4.678GHz



Introducing Ferrite Tails can efficiently absorb the HOMs

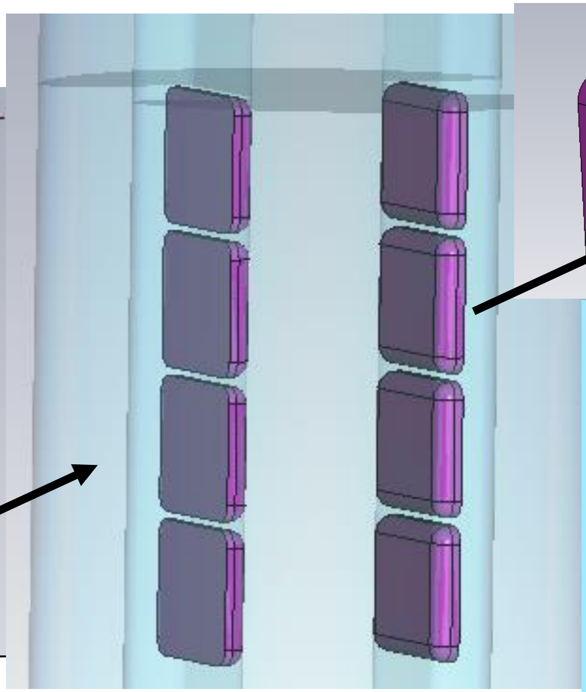
Ferrite Tiles

Extraction Port

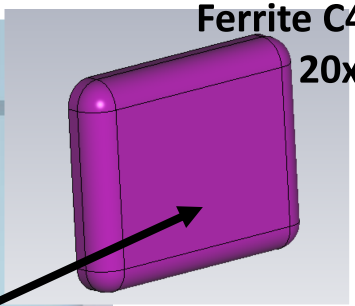


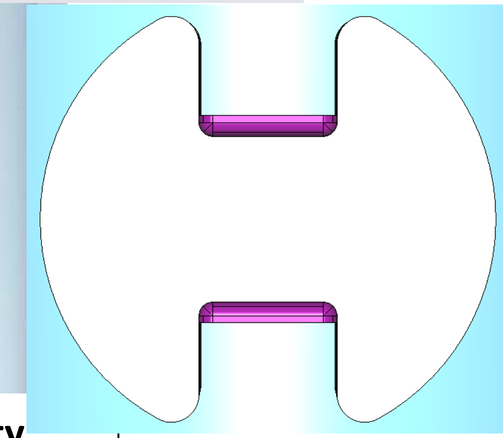
Power Flow Monitors

Excitation Port: Generated Power 0.5W

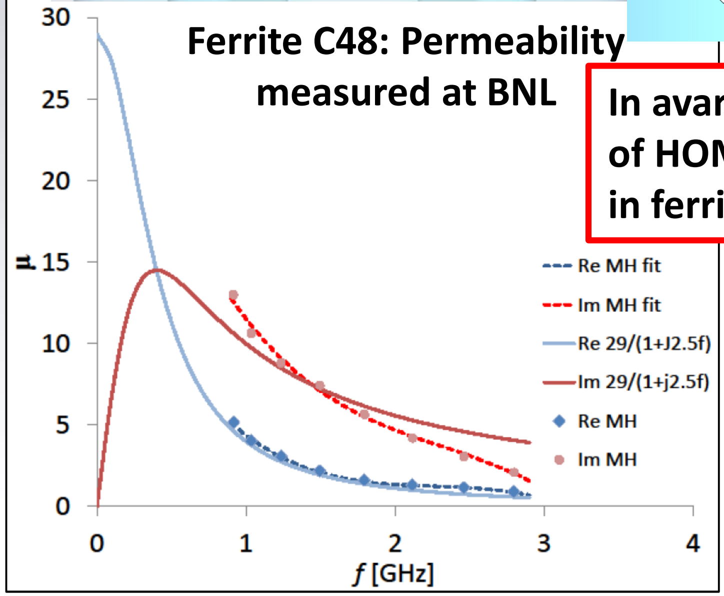


Ferrite C48: Dimensions 20x16x3mm

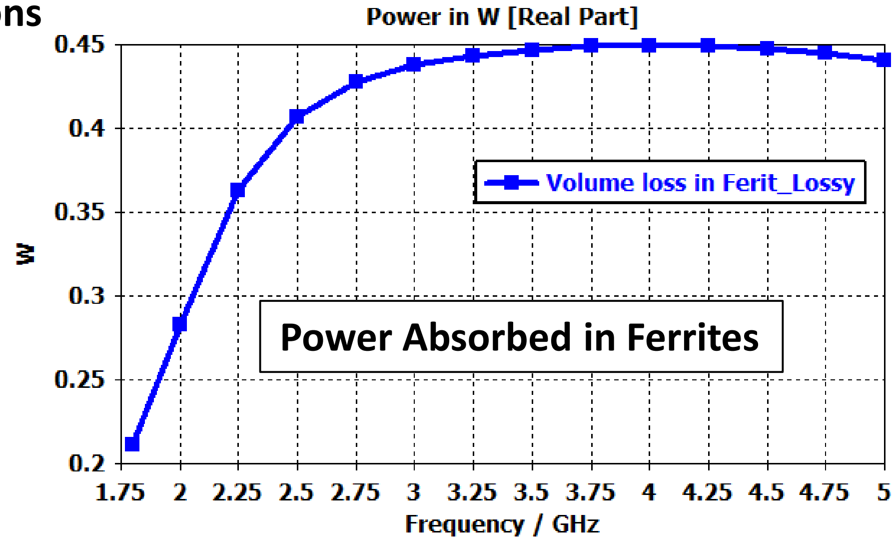


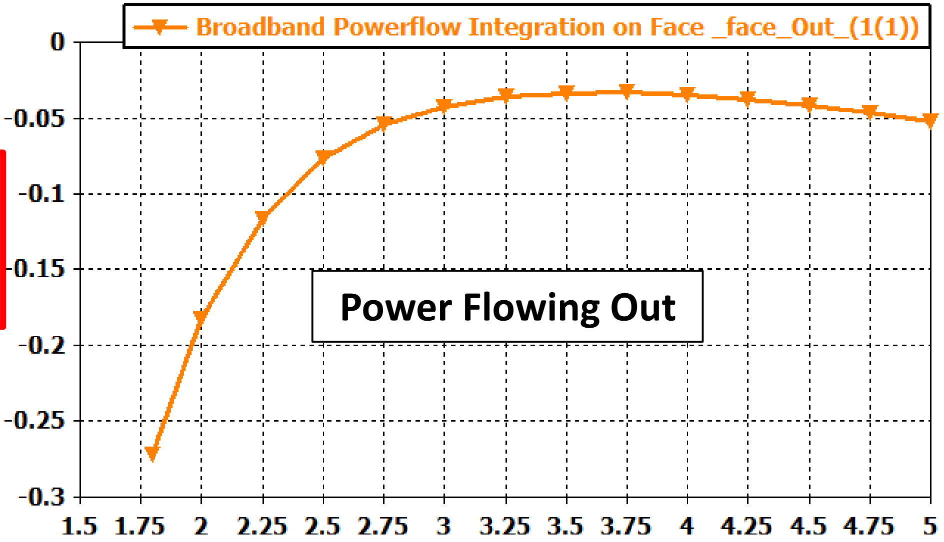


Ferrite C48: Permeability measured at BNL



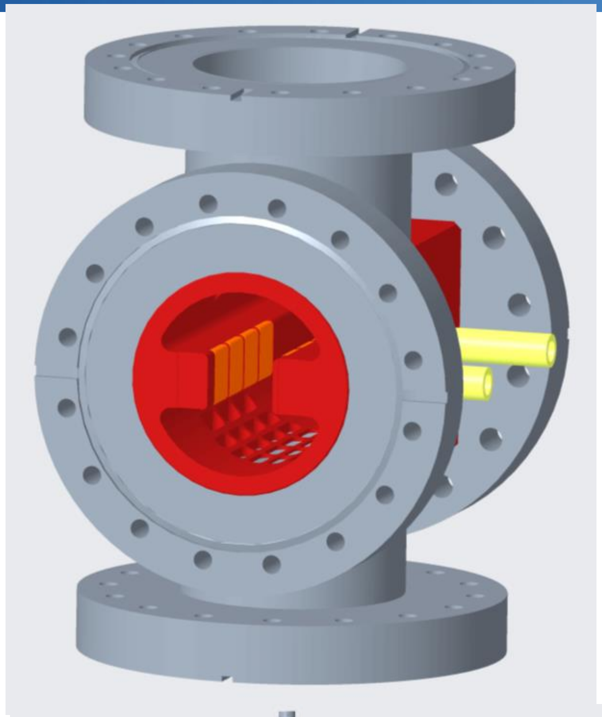
In avarage more than 70% of HOM power is absorbed in ferrite tiles.

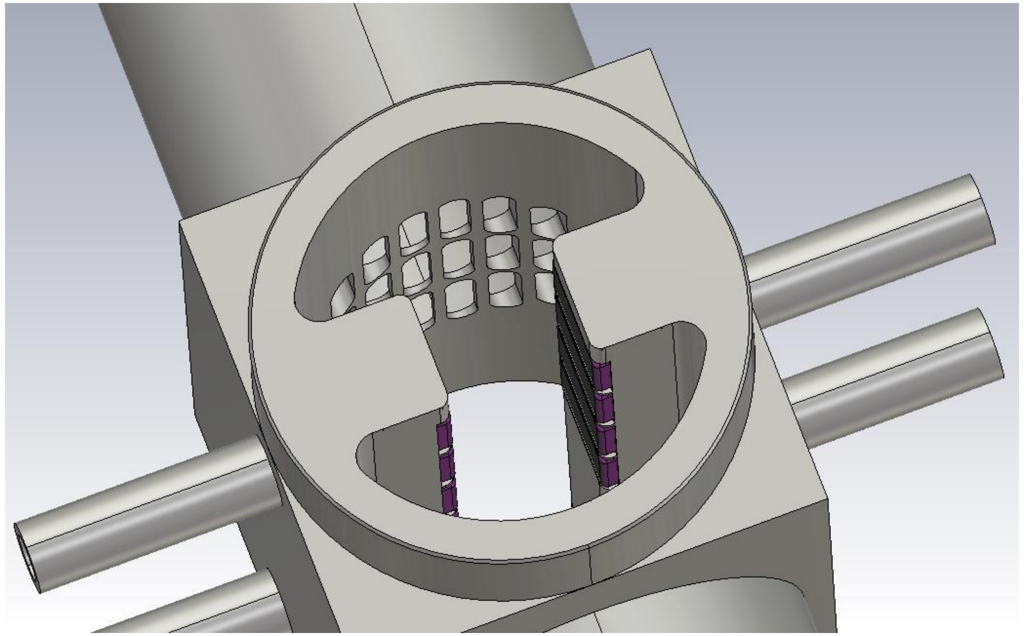


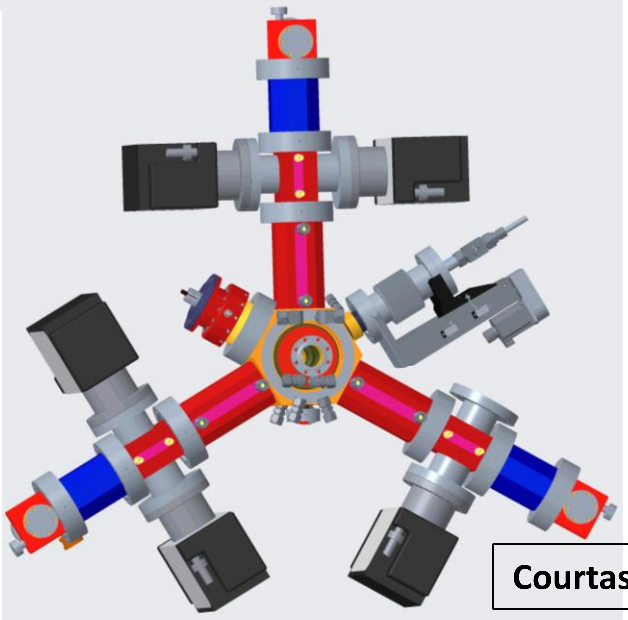


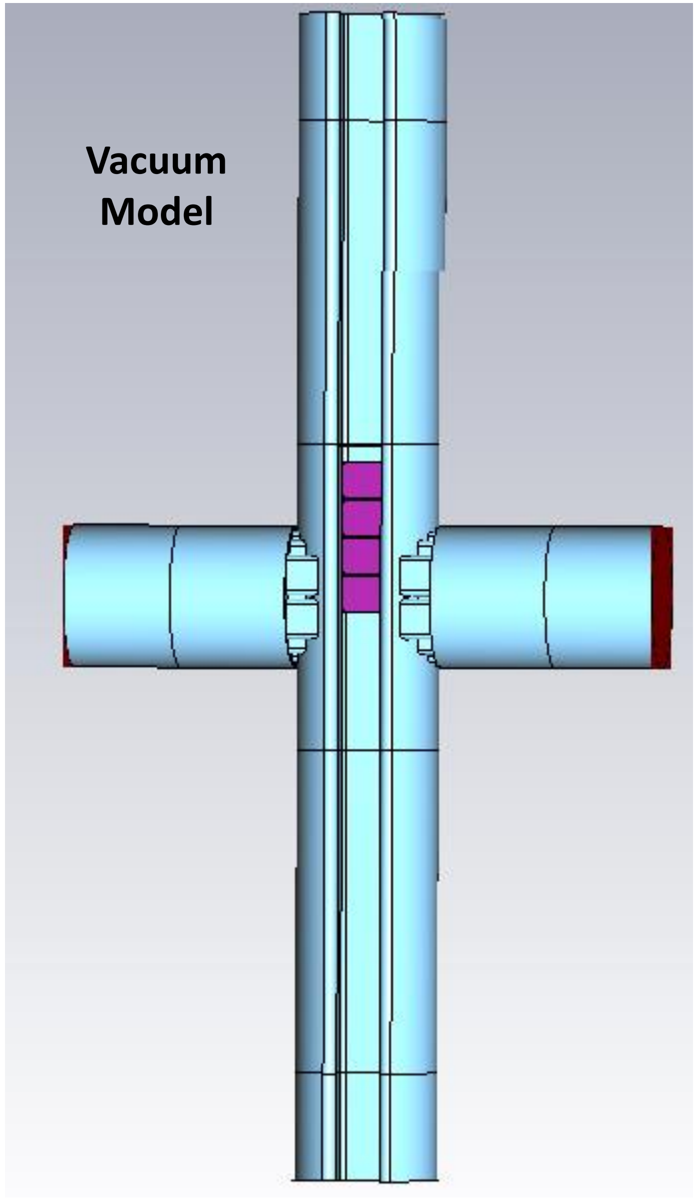
Frequency [GHz]

Component with Ferrits & Vacuum Ports





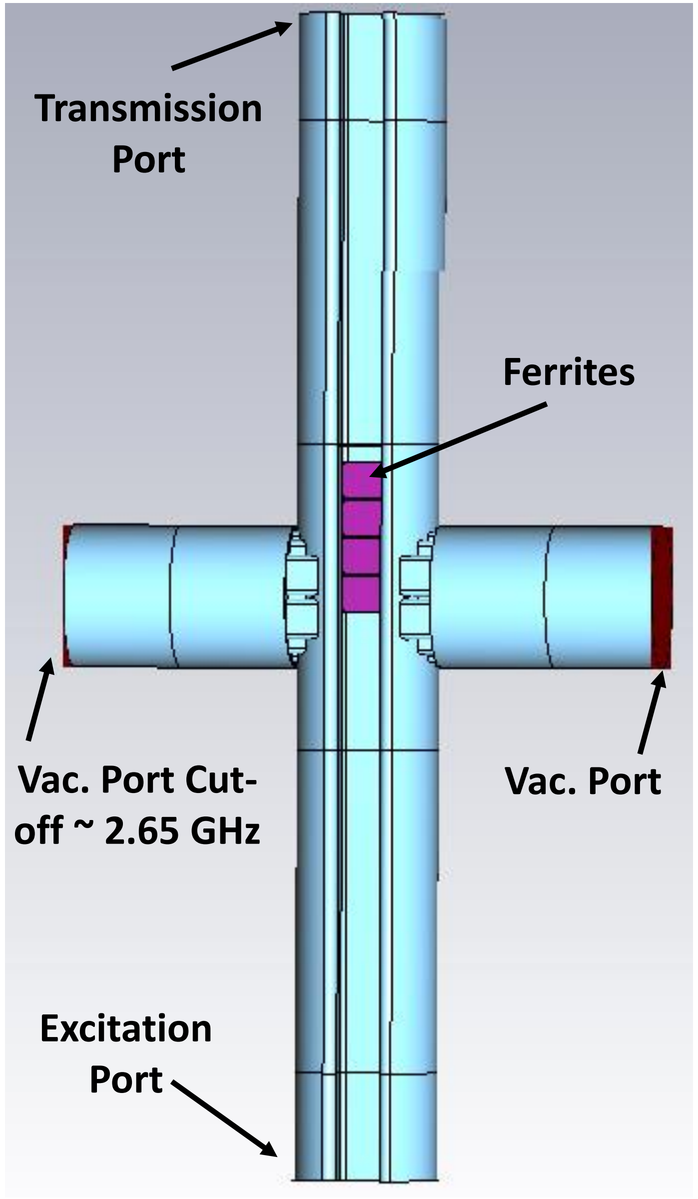


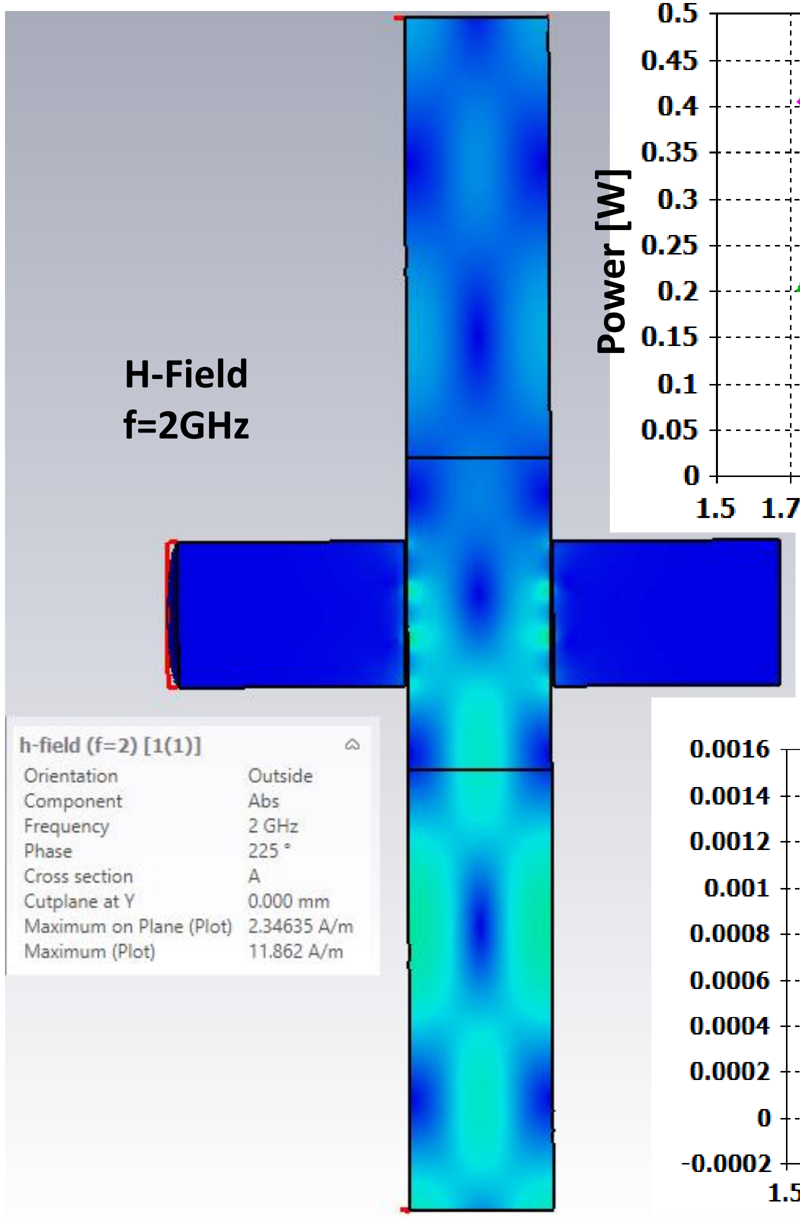


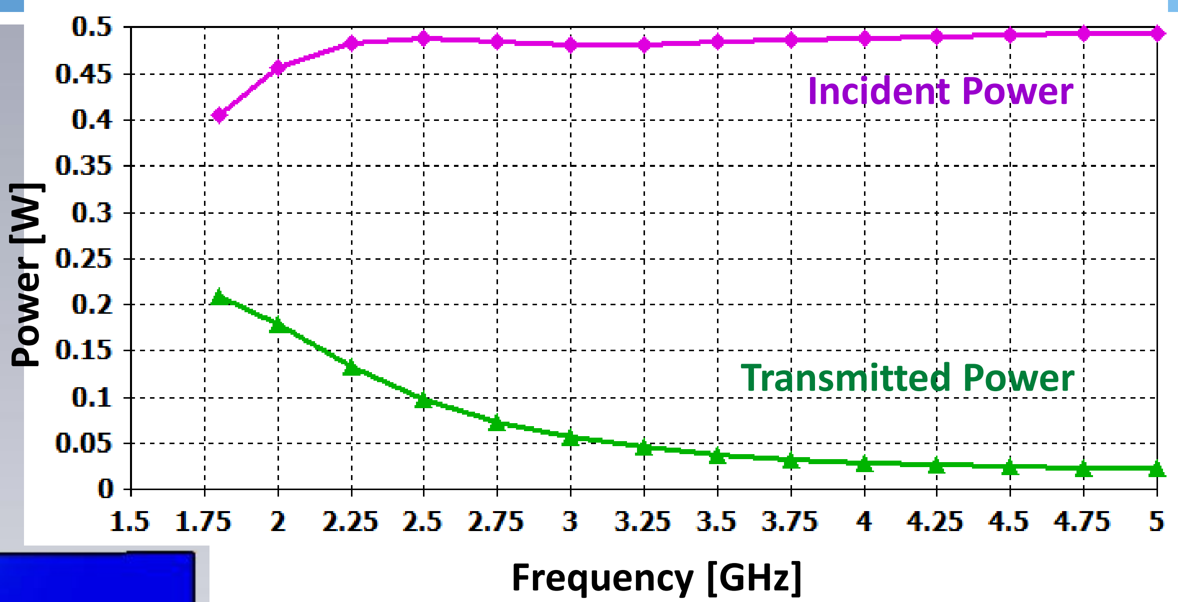
- The component with ferrit tiles & vacuum pumping ports is designed as optional part to excising ALBA cavity.

Courtasy of V. Dürr, HZB

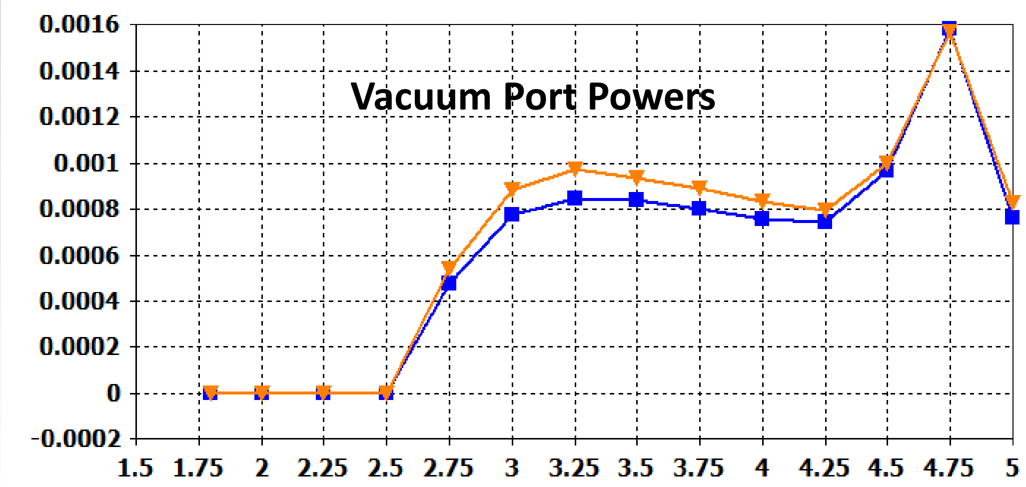
Component with Ferrits & Vacuum Ports



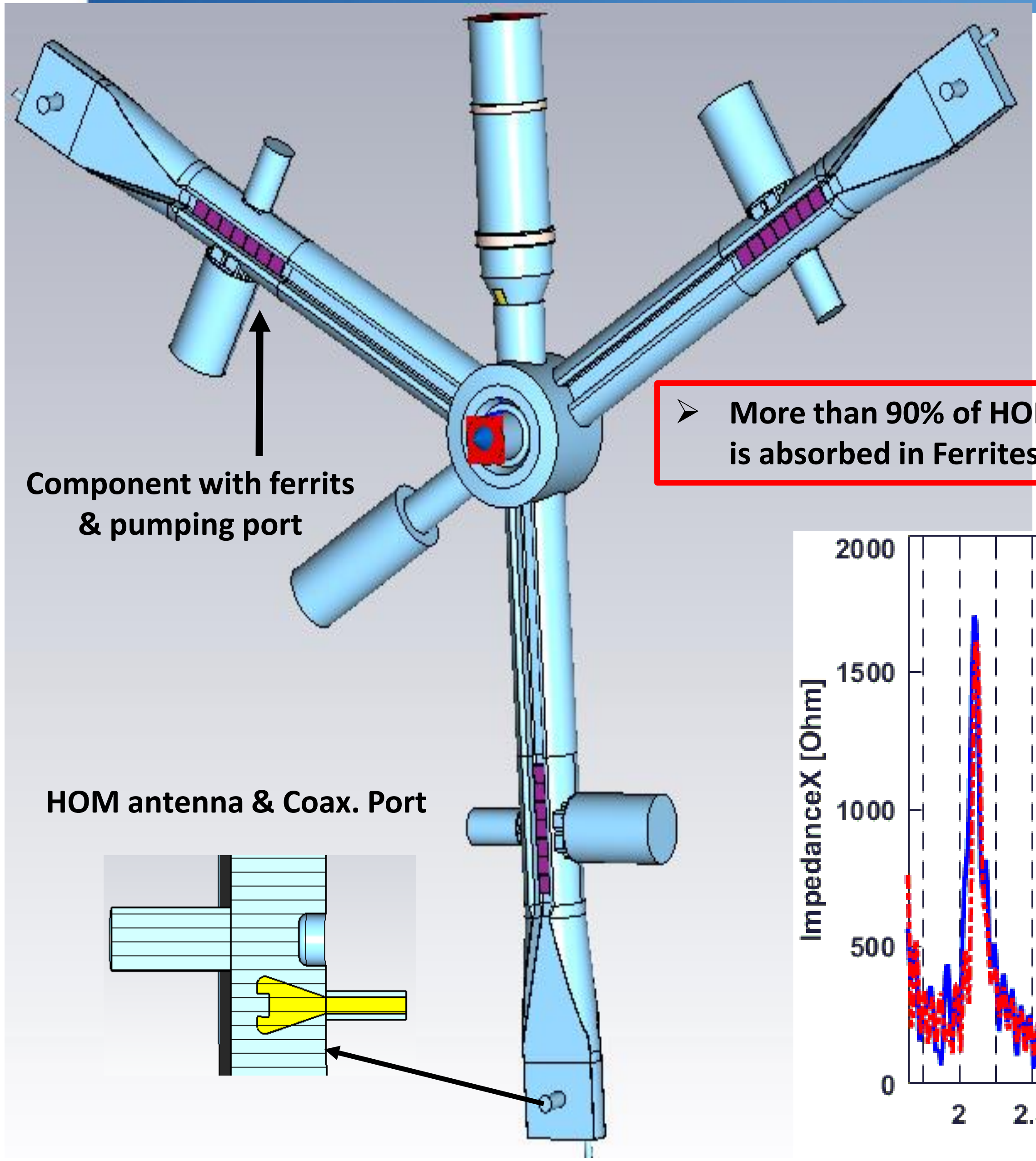




- About 70% is absorbed in Ferrites

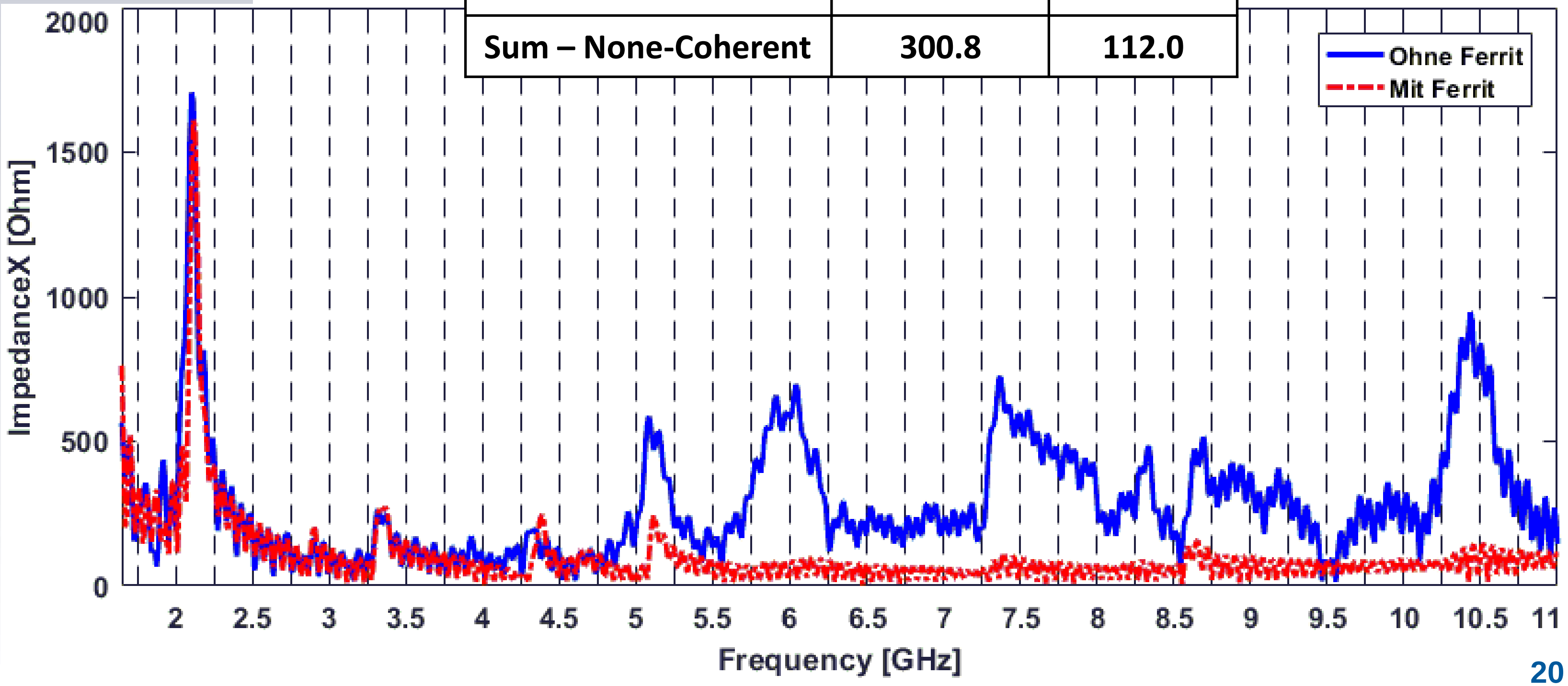


Wake Simulations with Ferrites



- More than 90% of HOM power is absorbed in Ferrites

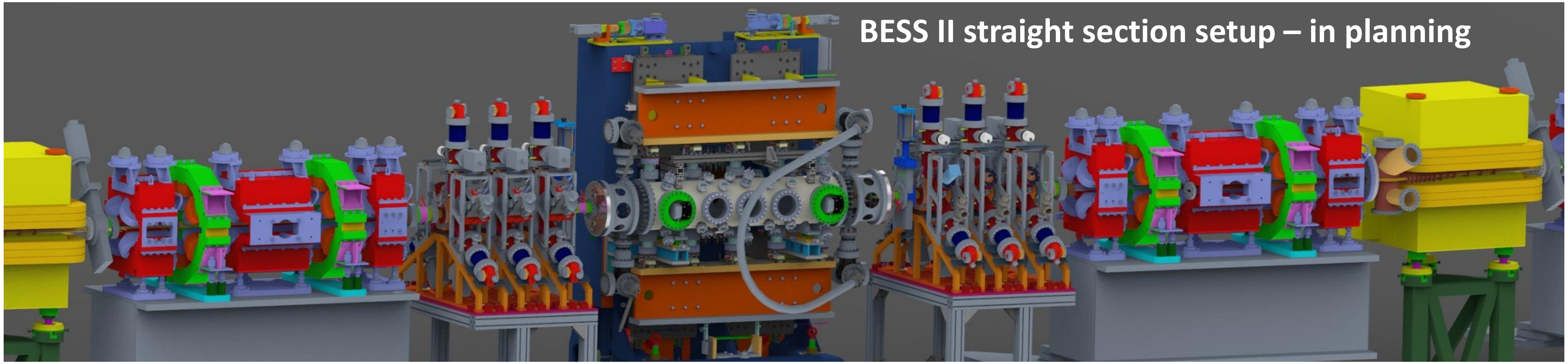
HOM Power [W] for Baseline Filling		
Port	Ohne Ferrit	Mit Ferrit
1 -FPC	12.5	11.3
2 - Antenna	40.3	1.7
3- Antenna	22.7	2.3
4 -Antenna	42..5	4.0
BmP1	29.1	27.8
BmP2	48.7	47.6
Sum - Coherent	195.8	94.8
Sum – None-Coherent	300.8	112.0



HOM Power Levels & Distribution

	HOM Power [W]					
	Baseline Filling (300mA)		BESSY II Filling (300mA)		Single Bunch 30mA	
Port	Ohne Ferrit	Mit Ferrit	Ohne Ferrit	Mit Ferrit	Ohne Ferrit	Mit Ferrit
1 -FPC	12.5	11.3	8.0	7.6	10.3	8.6
2 – HOM Antenna	40.3	1.7	27.5	0.6	67.5	5.0
3 – HOM Antenna	22.7	2.3	12.1	1.2	47.4	5.9
4 – HOM Antenna	42..5	4.0	11.0	2.4	92.9	9.6
BmP1	29.1	27.8	13.7	14.0	7.9	7.2
BmP2	48.7	47.6	25.3	24.2	10.1	9.7
Sum - Coherent	195.8	94.8	97.5	49.9	236.1	45.9
Sum – None-Coherent	300.8	112.0	150.6	54.7		

- Half of the HOM power is absorbed in HOM dampers.
- Half of the HOM power is propagating out thru beampipes into the ring. The three cavity chain should be simulated to estimate expected maximum HOM powers in the dampers.
- The sequence of different elements in the straight section should be simulated to avoid localized HOMs.
- Limited space in the straight section requires solutions for vacuum pumping.



Thank You for Your Attention !