Current status of the impedance budget for FCC-ee IR

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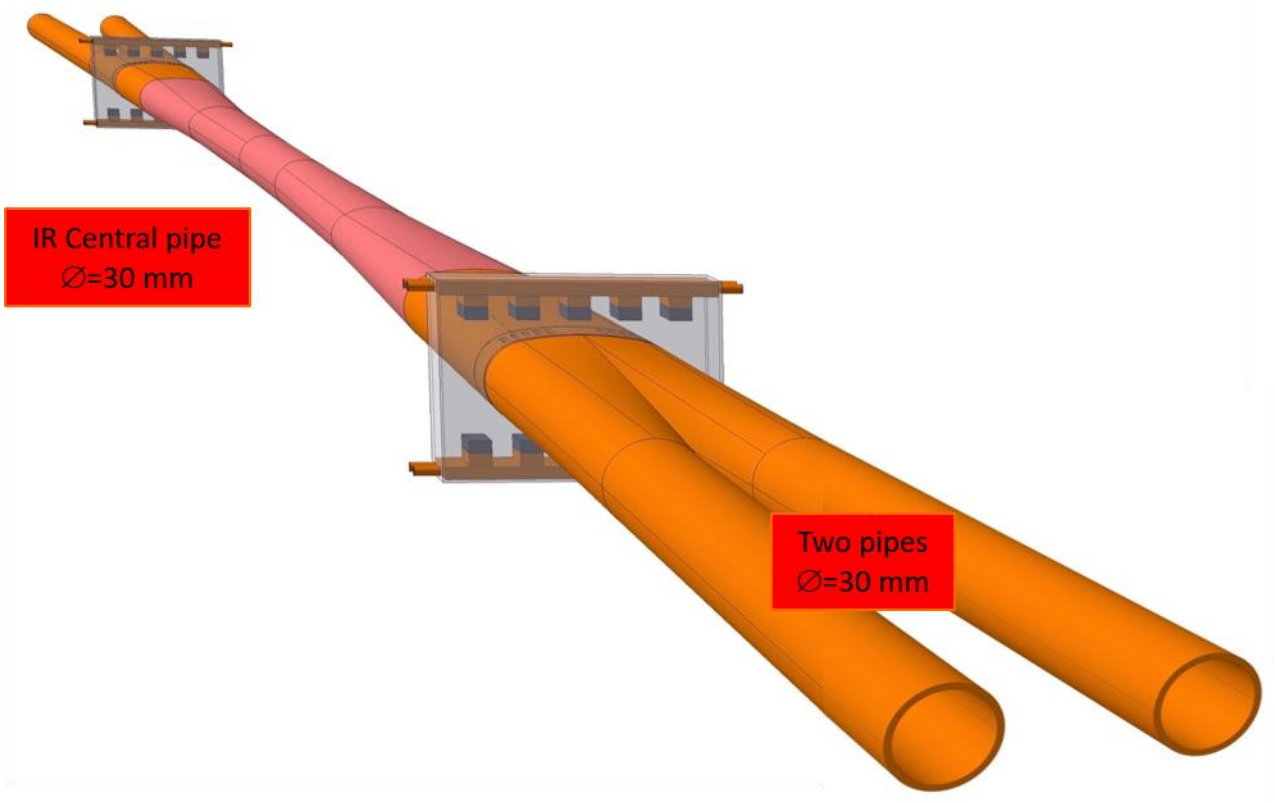
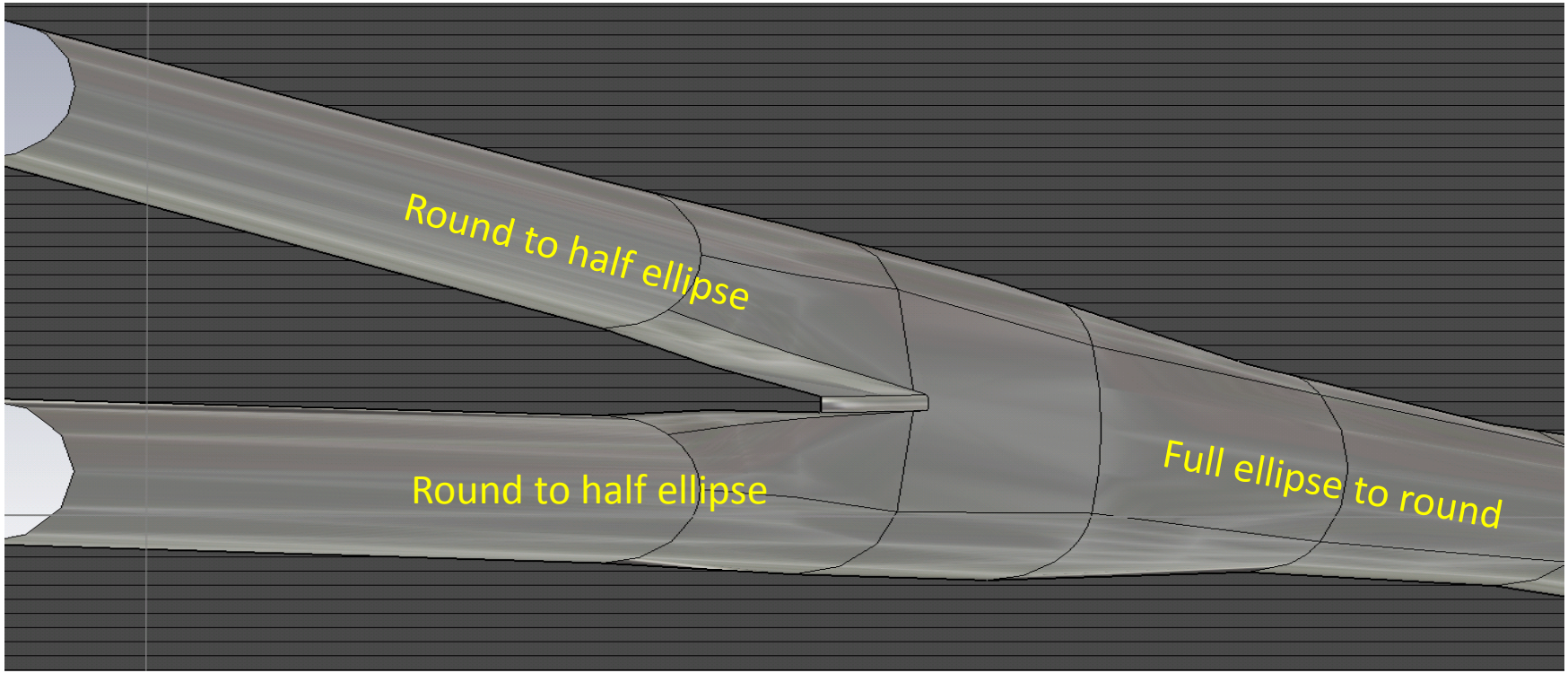
Outline

I. Geometry of the FCC ee IR beam pipe.
II. Trapped modes and propagating waves.
III. HOM absorber.
IV. Discussion on the resistive-wall wake field losses

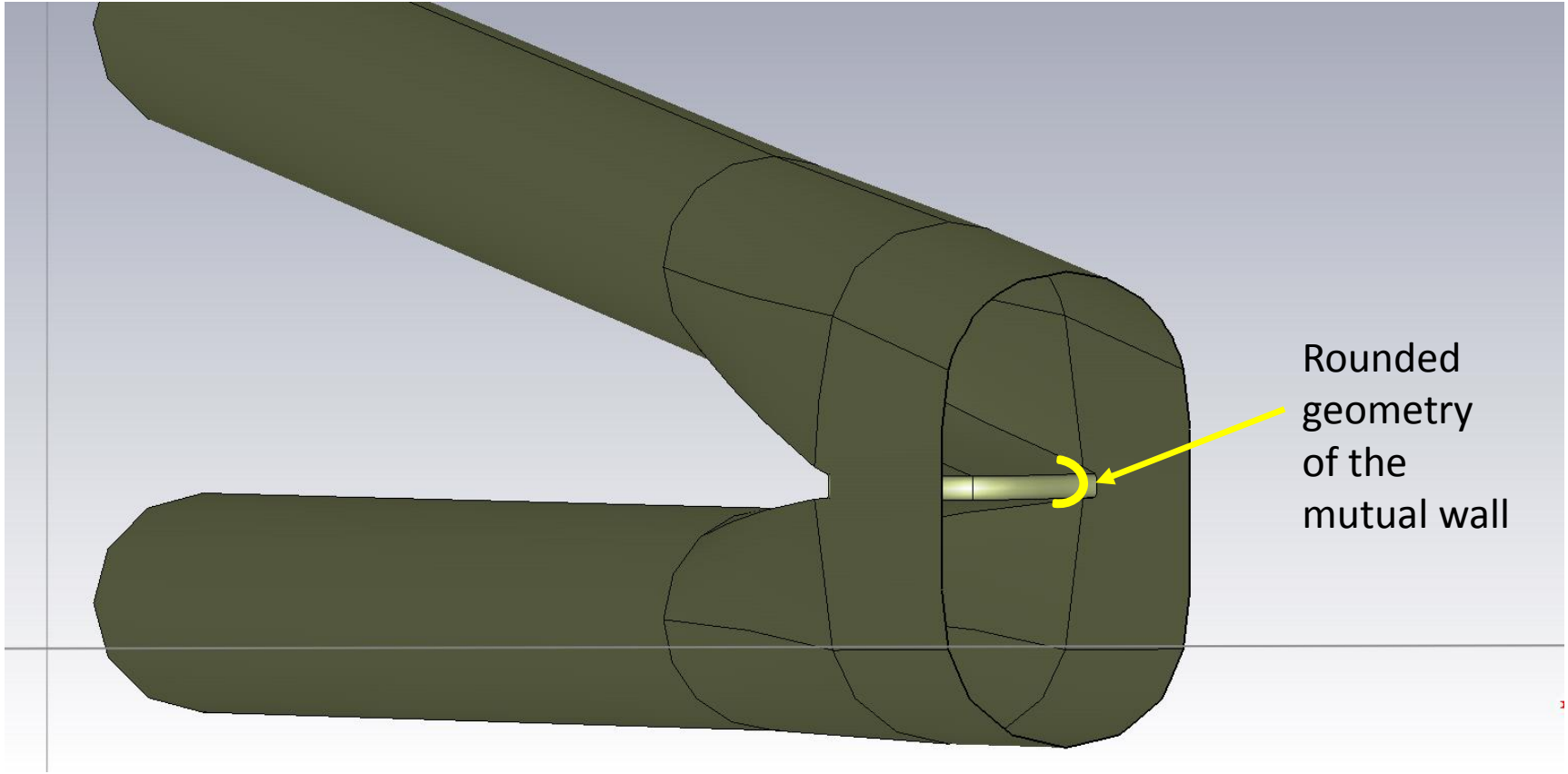
FCC IR beam pipe geometry



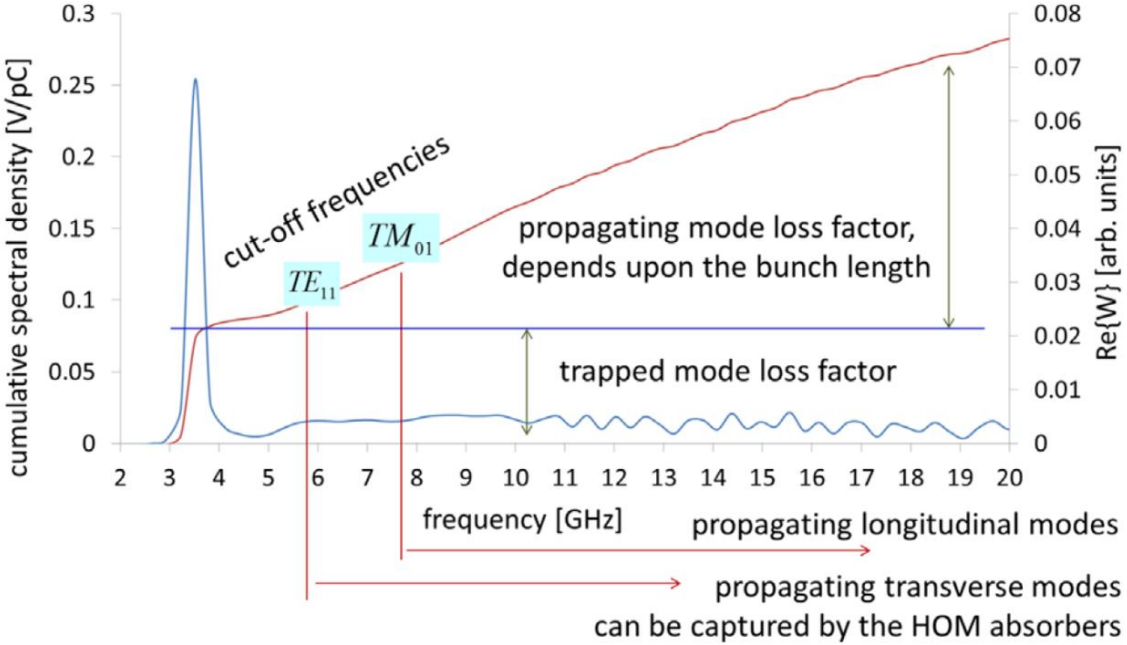
All smooth geometrical transitions.



Inner view



Spectrum and cumulative spectral density of the energy losses



PHYSICAL REVIEW ACCELERATORS AND BEAMS **20,** 111005 (2017)

Unavoidable trapped mode in the interaction region of colliding beams

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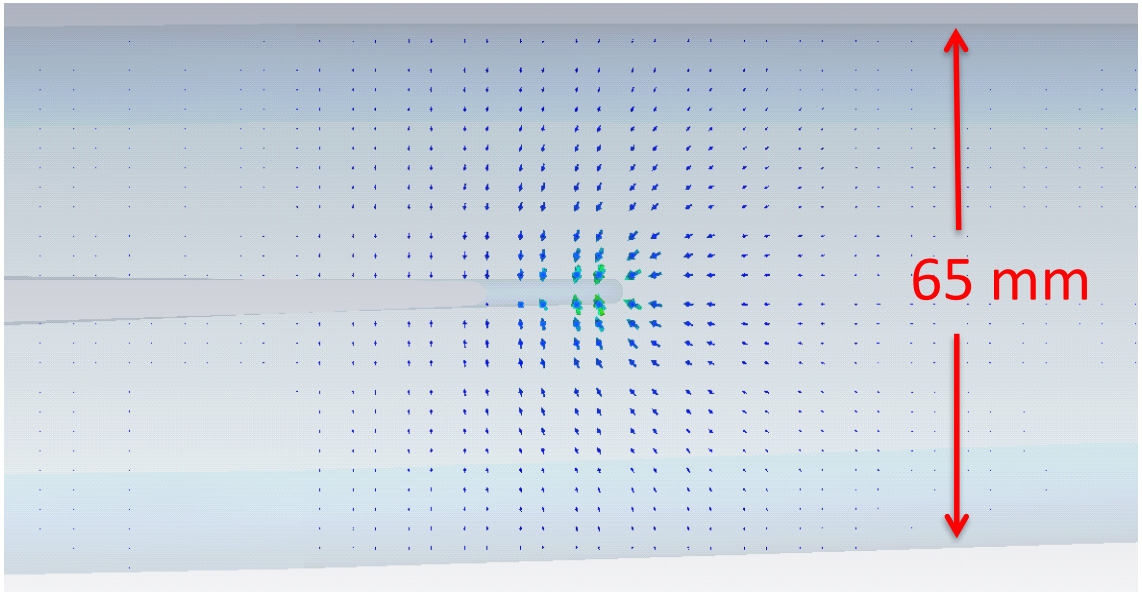
$$P_{prop} = I^2 \left(k - k_{HOM}\right) \times \tau_b$$

$$P_{HOM} = 2I^2 k_{HOM} \tau_{l,HOM}$$

Because of the very high bunch charge Q~ 30 nC and high current I~1.4 A, each beam will produce electromagnetic power of approximately 5 KW in both beam pipe connections.

A trapped HOM in IR



A trapped mode is localized in the region where two beam pipes emerge into one. This mode has a transverse electrical component near the pipe connection. If we make longitudinal cuts here in the wall then this mode will radiate out of the beam pipe.

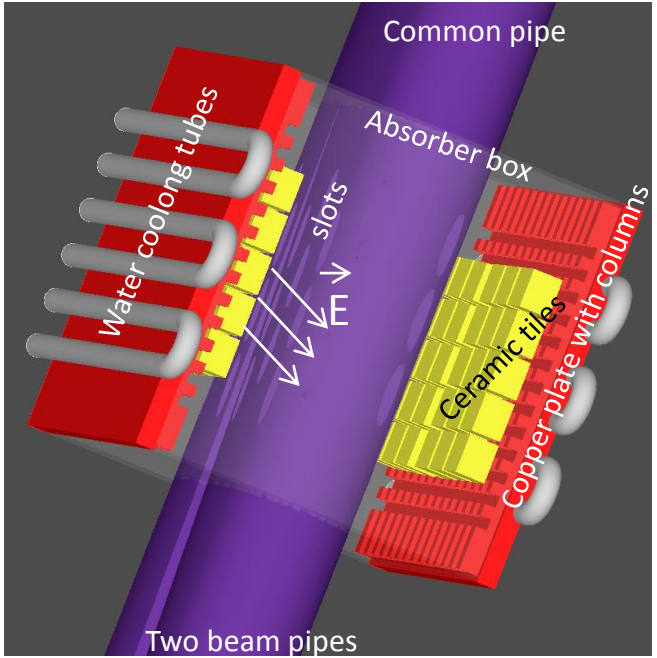
The concept of the HOM absorber

The absorber vacuum box is situated near (around) beam pipe connection. Inside the box we have ceramic absorbing tiles and copper plates (walls). The beam pipe in this place have longitudinal slots, which connect the beam pipe and the absorber box. Outside the box we have stainless steel water-cooling tubes, braised to the copper plates.

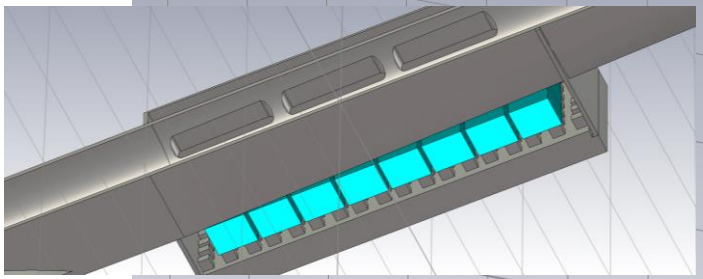
HOM fields, which are generating by the beam in the IR have a transverse electrical component and can pass through the longitudinal slots in the beam pipe.

Inside the absorber box these fields are absorbed by ceramic tiles, which have high value of the loss tangent.

Ceramic tiles are braised to copper plates with columns. The heat from ceramic tiles is transported through the copper plates to water cooling tubes.

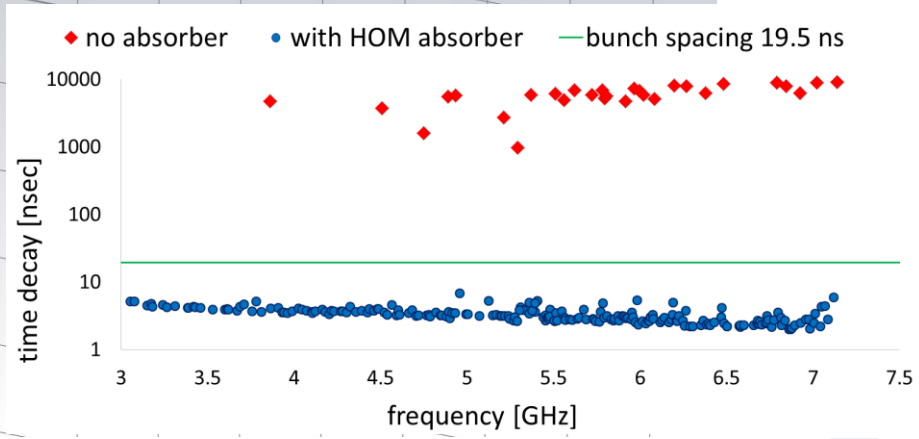


FCC ee IR beam pipe with water-cooled HOM absorbers



HOM absorber design for 10 kW power

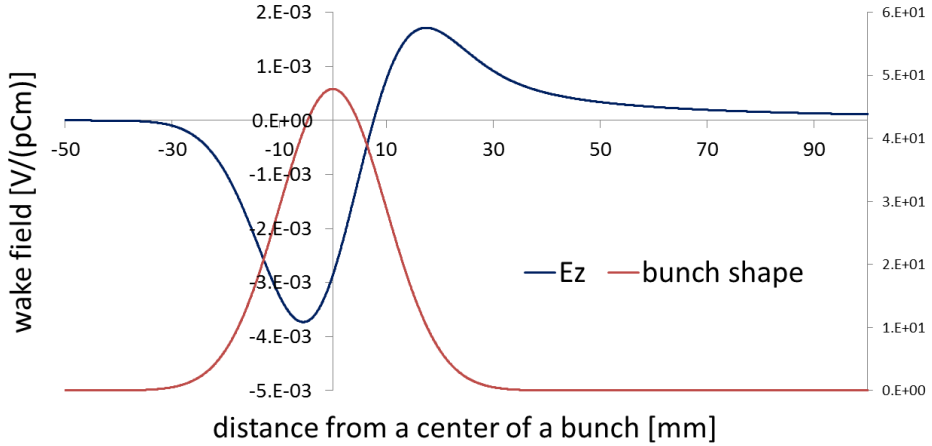
Efficiency of Damping
Trapped and Propagating Modes

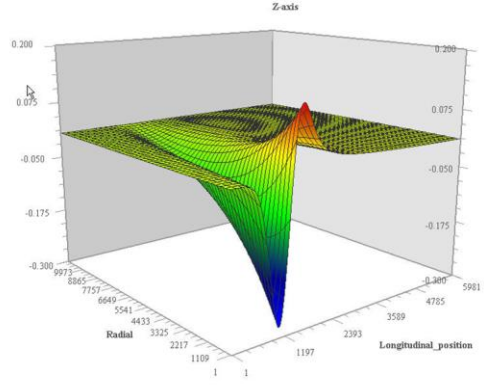


Other main source for the IR heat load

- Other electromagnetic fields exciting by the beams in the Interaction Region are due to the finite conductivity of the metal walls of the IR beam pipe

10 mm bunch
in the Be
30 mm pipe





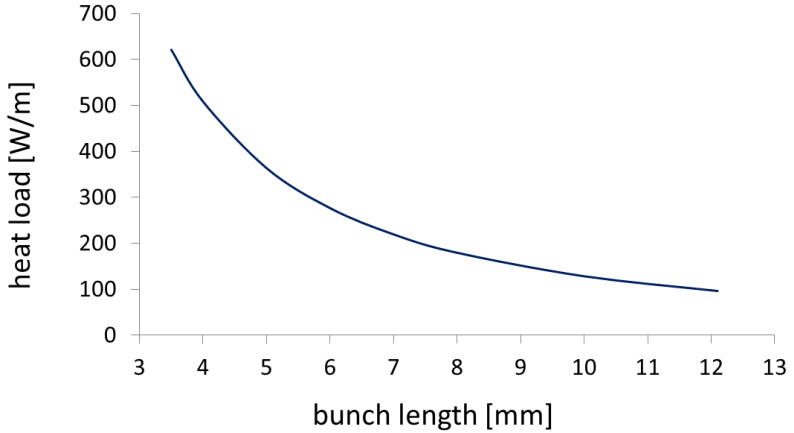
- Electrical conductivity of different materials, which can be used in IR:

Material	Cu	Au	Al	Be	Ni	SS	NEG
conductivity [Ohm/mm]	58000	48800	35000	25000	14600	1400	50 -->1000

Heat load.

bunch length [mm]	HEAT LOAD Two beams [W/m]				current [A]	Bunch spacing [ns]	
					2 x 1.39	19.50	
12.10	63.45	69.18	81.68	96.57	125.23	349.64	1473.91
Material	Cu	Au	Al	Be	Ni	SS	NEG

- Beryllium pipe takes 100 W/m for a 12 mm bunch but strongly increasing with shortening the bunch length.



Properties of Pure Beryllium

- The principal properties of beryllium are its low density, high strength, high rigidity, reflectivity, structural stability at high temperatures and conductivity of heat. Beryllium is notable among metals in terms of specific rigidity; i.e. the ratio of modulus to density.

	Beryllium	Aluminium 7075-T6	Titanium 6A1-4v	Steel 4340	Magnesium AZ80A	Metal-Matrix Composite
Density g/cm3 lb/in3	1.85 0.067	2.80 0.101	4.43 0.16	7.83 0.28	1.80 0.065	2.91 0.105
Tensile Modulus GPa 10spsi	303 44	72 10.4	113 16.5	203 29.5	44 6.4	131 19
Thermal Expansion Coefficient ppm/K ppm/F	11 6.3	23 13	10 5.5	15 8.3	26 14	14 7.6
Specific Heat J/kg.K BTU/lb.F	1925 0.46	920 0.22	540 0.13	500 0.12	1000 0.24	800 0.19
Thermal Conductivity W/m.K BTU/ft.hr.F	182 1056	215 125	4	47 27	52 0.30	12 72

No cooling Be pipe. Rough estimate.

$$\Delta T_{[K^\circ]} = \frac{P_{[W]} * L_{[m]}}{k_{[W/(K^\circ m)]} * 2\pi R_{[m]} \Delta r_{[m]}}$$

power [W/m]	length [m]	conductivity [W/(m k)]	Radius [m]	thickness [m]	dT [K]
100.000	0.125	182.000	0.015	0.001	91.091
200.000	0.125	182.000	0.015	0.001	182.183

Summary

- HOM absorber is needed
- Water cooling or other cooling is needed for IP beam pipe.
- Waiting for a new cad file with more details of IP chamber.