Beam instability study for FCC-hh

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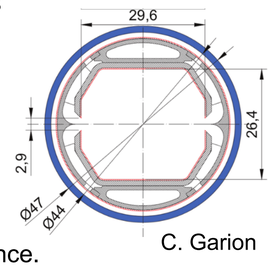
Introduction

Previous studies already showed that the FCC-hh beam intensities are limited by the resistive wall and the collimator impedances. In addition, electron clouds also contribute to the total impedance and could be the cause of instabilities. Numerical model of beam instabilities taking into account the impedance model is being developed. This should also be extended and include electron clouds.

Resistive wall impedance

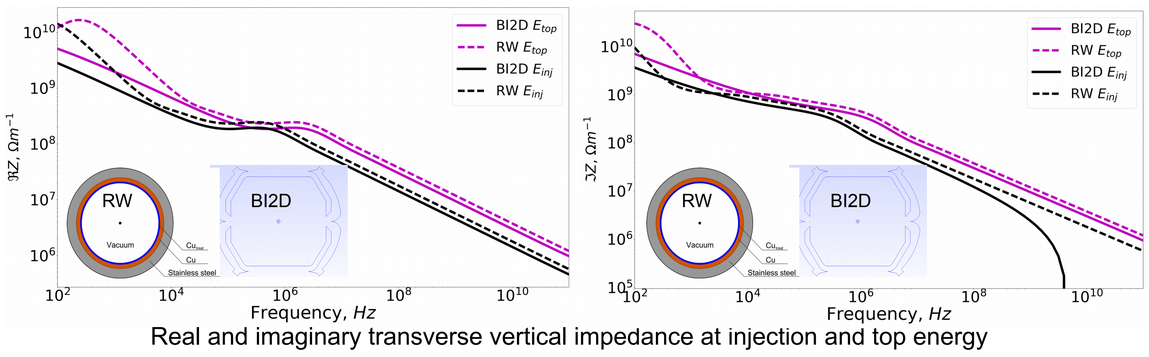
Due to the 100 km of beam pipe length, at injection the most critical issues will be the resistive wall impedance.

Material	Thickness, [mm]
Stainless steel	1.25
Cu	0.3
Laser treated Cu	$10^{-3}...10^{-1}$



C. Garion

Additional laser treated copper-coating on a beam screen can affect the impedance.
$\rho_{layer} / \rho_{bulk} \approx 18$ at T = 50K (S. Arsenyev)



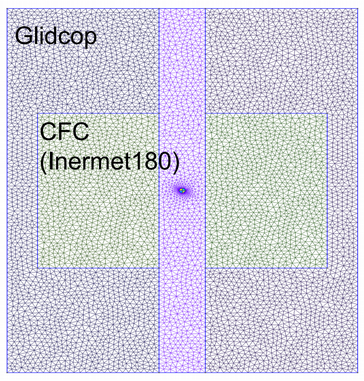
Real and imaginary transverse vertical impedance at injection and top energy

Collimator impedance

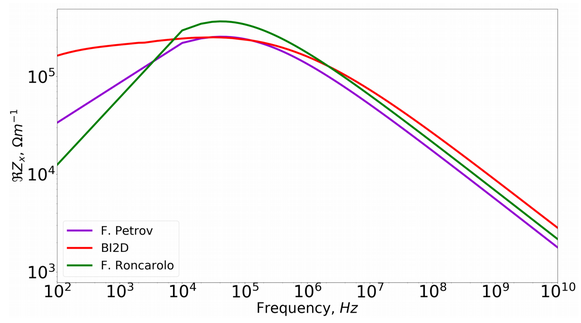
At collision energy the most important is the collimators' impedance.

2 main types of collimators:
1) TCP (primary) and TCS (secondary): CFC + Glidcop
2) TCT (tertiary) Inermet180 W + Glidcop

Material	σ, [MS/m]
Inermet180 W	10.42
Glidcop (Cu alloy)	53.3
CFC	0.3



Collimator with half-gap = 5.2 mm at E_{inj} and 2.6 mm at E_{top}

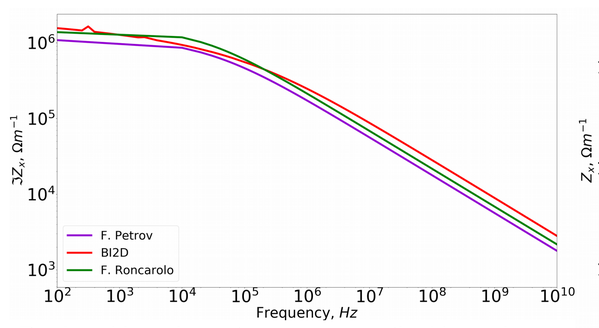


BeamImpedance2D (U. Niedermeyer)

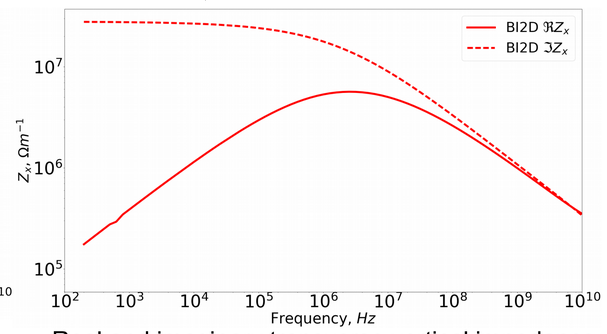
active material thickness [mm]	20
L [m]	1
β_c [m]	745

$$Z_{col} = Y(1+sign(\omega)i)\frac{c\mu_0 L_c}{2\pi b^2}\frac{1}{sign(\omega)(1+b\sqrt{\frac{\mu_0\omega\sigma_{DC}}{2}})-i}$$

Koschik et al., EPAC 2004



Real and imaginary transverse vertical impedance at injection energy



Real and imaginary transverse vertical impedance at top energy

Transverse coupled-bunch growth rate

One important effect of the resistive wall on the single bunch dynamics is related to the transverse coupled-bunch instability.

Growth rate

$$\tau_0^{-1} = \frac{j}{2Q\omega_0}\frac{e\beta I_0}{\gamma m_0 L}\Re\left(Z_{tr,0}\right)$$

Effective impedance

$$Z_{tr,k} = \frac{\sum Z(\omega_p)H(\omega_p,k)}{\sum H(\omega_p,k)}$$

E_{inj} [TeV]	3.3
$E_{c.o.m.}$ [TeV]	50
Circumference [km]	100
Arc dipole field [T]	1...16
Beam current [mA]	500
No. of bunches [p/b]	10600
Bunch length [ns]	1.07(8cm)
Q_x/ Q_y	108.28/107.31
Q_s	2.43×10^{-3}
Revolution frequency, f_0 [Hz]	2942

Beam screen (vertical plane)

E [TeV]	Growth rate [Turns] $Q_f = 0.72$, $f_{sb} = 840$ Hz	Growth rate [Turns] $Q_f = 0.32$, $f_{sb} = 2$ kHz
1.5	30	48
3.3	67	108
50	1011	1582

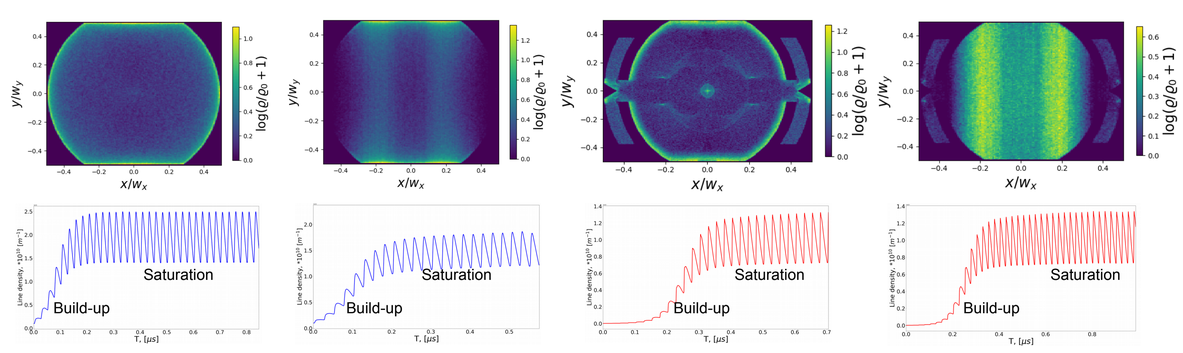
F. Petrov → 91 turns and X. Buffat → 100 turns at 3.3 TeV

Collimator with half-gap = 5.2 mm at E_{inj} and 2.6 mm at E_{top}

E [TeV]	Growth rate [Turns]
1.5	1729
3.3	3805
50	8018

F. Petrov → ~3500 turns at 3.3 TeV

Ecloud build-up



openecloud (O. Haas)

Comparison for electron cloud build-up between LHC-like (left) and FCC (right) geometry of beam screen for the case B = 0T and B = 1T.

Intensity = 1.1e11
25 ns spacing
40 bunches

sey = 1.5
fully Cu-coated beam screen

Conclusion and Outlook

Resistive wall impedance:
- comparison between formula, ReWall & BI2D
- growth rate is about 100 turns at injection and 1500 turns at top energy

Collimator impedance:
- comparison between formulas & BI2D
- growth rate is about 3800 turns at injection and 8000 turns at top energy

Conclusion:
the impedance and coupled-bunch growth rate study confirms previous results

Future plans:
- electron cloud study with openecloud (O. Haas)
- creating the numerical model for studying the electron cloud build-up and instabilities

References

[1] O. Boine-Frankenheim et al., "FCC-hh impedances and instabilities", EuroCirCol meeting, ALBA, Barcelona, Spain, 7-9 November, 2016
[2] Uwe Niedermayer, Oliver Boine-Frankenheim, and Herbert De Gersem, PRSTAB 18, 032001, 2015
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[5] F. B. Petrov et al. Interaction of relativistic short proton bunches with space charge limited electron clouds, Phys.Rev. ST Accel. Beams 17 no.12, 121001, 2014
[6] N. Mounet and E. Metral, "Impedances of an Infinitely Long and Axisymmetric Multilayer Beam Pipe: Matrix Formalism and Multimode Analysis," IPAC10, Kyoto, Japan, June 2010.

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