Effect of collimator coating thickness on HL-LHC octupole thresholds

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Motivation and previous work

Operation at the HL-LHC intensity (2.3×10^{11} ppb) is not compatible with the present LHC transverse impedance

In order to reduce the impedance, an upgrade of the collimator system is planned

- Lower the total impedance and the octupole threshold by ~ 50%

Secondary collimators in IR-7 are coated with 5 µm Mo

- The coating thickness should provide sufficient margins for stable operation

References:

N. Biancacci, 'Update on the HL-LHC impedance budget', 4th HL-LHC Meeting, KEK, Japan, 2014

E. Metral, *et al.*, 'Beam intensity limitations', 4th HL-LHC Meeting, KEK, Japan, 2014

N. Biancacci, 'HL-LHC impedance and beam stability', 5th HL-LHC Meeting, CERN, 2015

S. Antipov, *et al.*, 'Machine impedance and HOM power update', 7th HL-LHC Meeting, Madrid, 2017

A. Mereghetti, *et al.*, 'Impedance measurement of TCSPM collimator', LHC MD2193 Note, CERN, in preparation

Goal: Update the estimate on how the thickness of the coating affects the octupole threshold

Most challenging, Ultimate, OP scenario

Three coating scenarios:

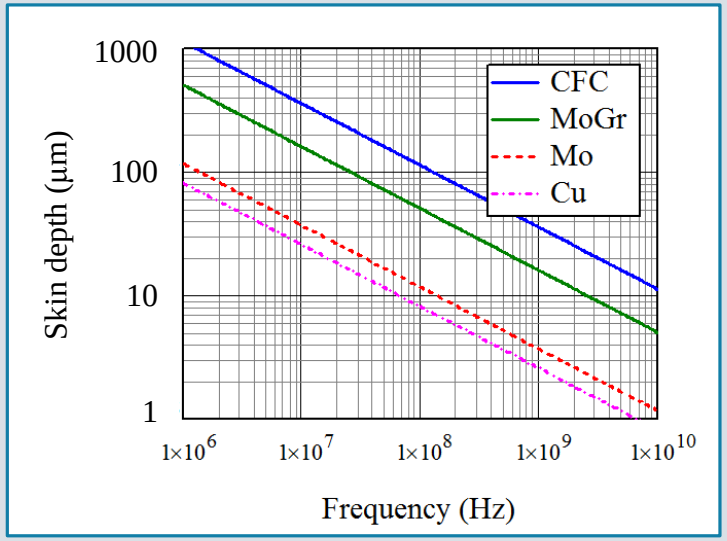
- **Mo+MoGr**
- Cu+MoGr
- Cu+CFC

Various coating thickness:

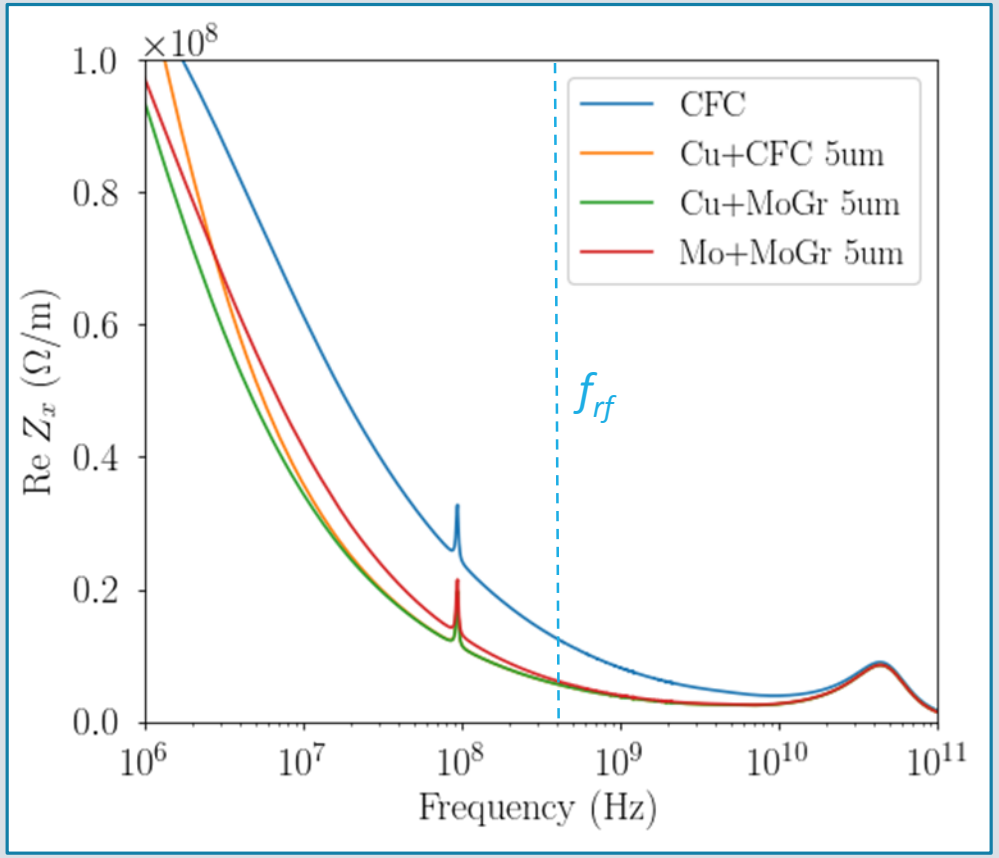
- 1, 3, **5** μm

Energy, β^*	E = 7 TeV, β^* = 41 cm
Beam intensity	M = 2760, $N_b = 2.3 \times 10^{11}$ p
Beam emittance Bunch length	ε_n = 2.1 μm (injection) σ_z = 9.0 cm, rms, Gaussian
Damper	d = 100 turns^{-1}
Octupole SD	Negative polarity, no ATS Tails cut at 3 rms beam size
Collimator settings	Nominal (2.5 μm ref. ε): TCP – 6.7σ TCSG – 9.1σ

The bulk has little effect on impedance for a sufficiently thick coating



Material	Bulk resistivity (nΩ-m)
CFC	5000
MoGr	1000
Cu	26
Mo	53.5

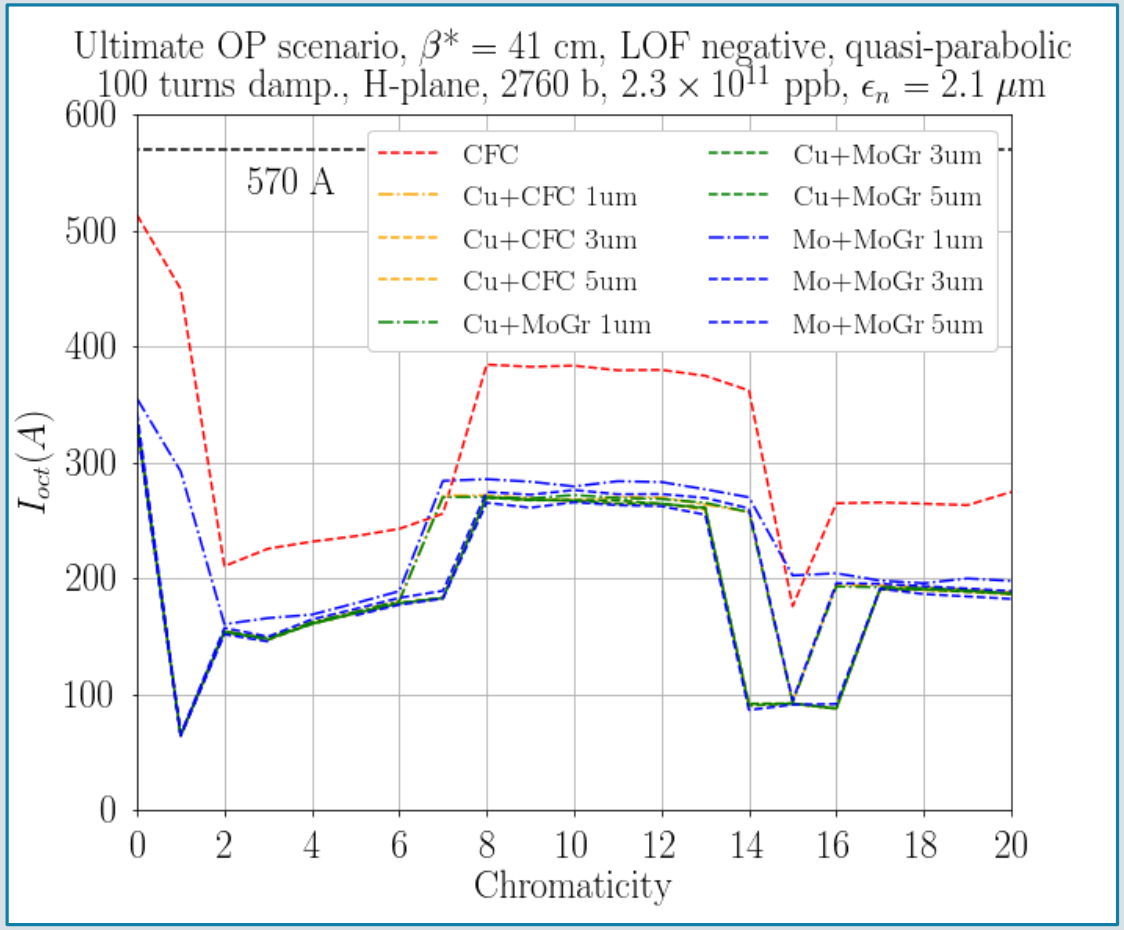


Octupole threshold increases for thinner coatings

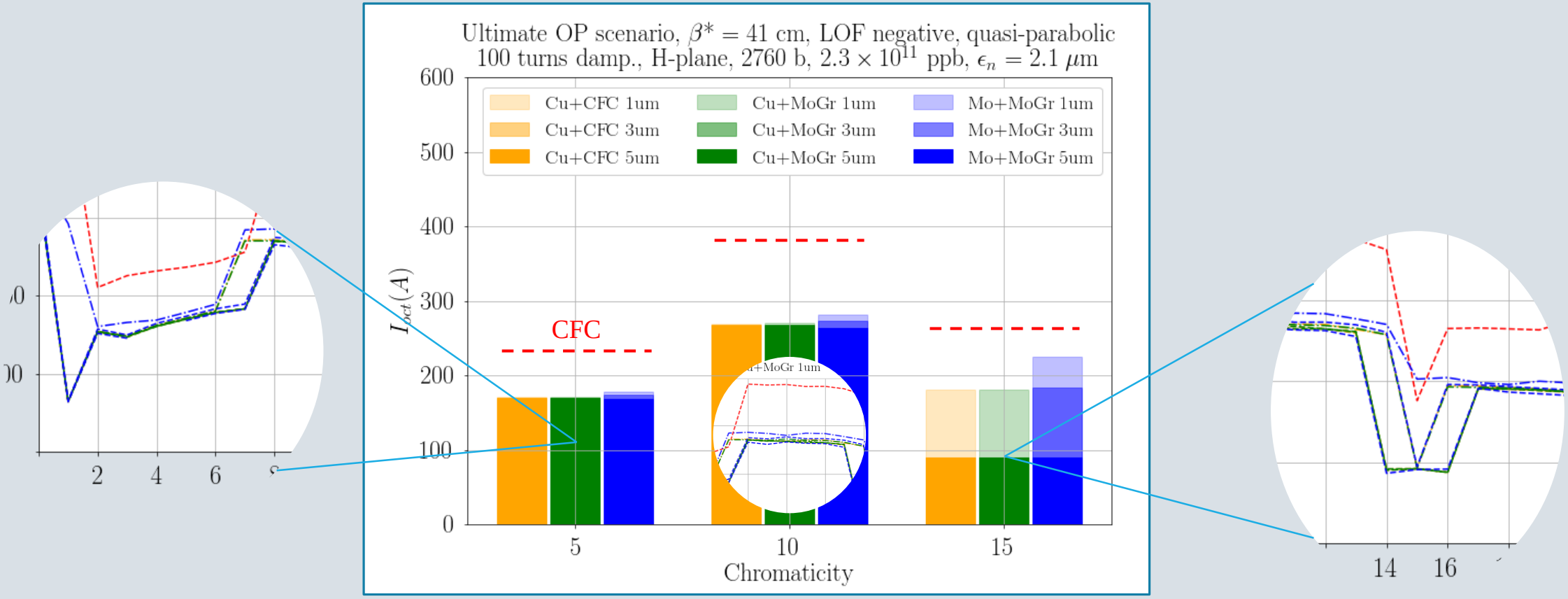
Mo: +20 A for Q' ~ 8-12

Cu: no significant difference for Cu around Q' ~ 10

The effect may be large at some chromaticities



Increase in octupole threshold assuming ΔQ' = ±1 uncertainty in Q'



Conclusion

The choice of bulk collimator material has little effect on the machine impedance and hence beam stability if the coating is sufficiently thick

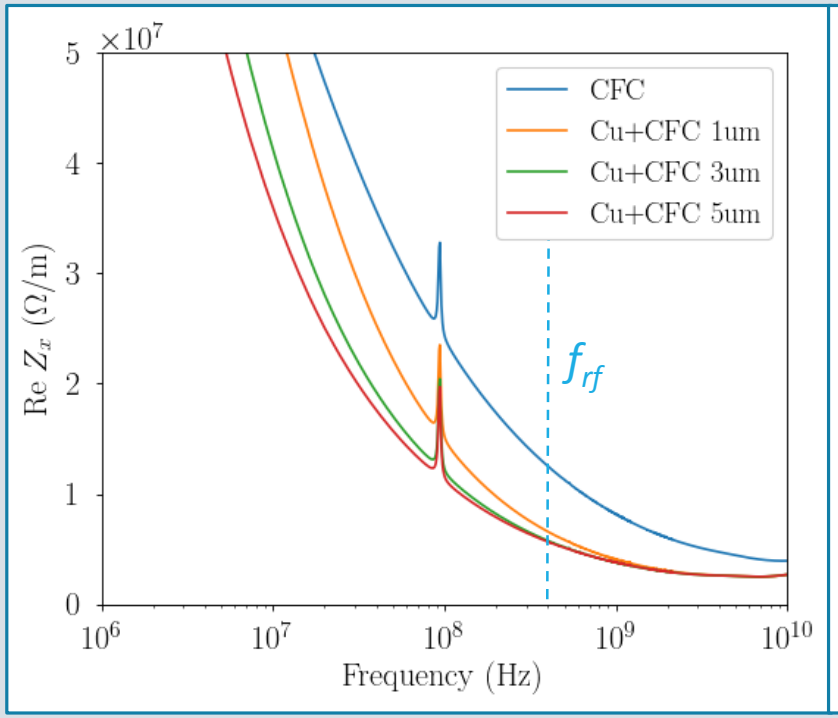
5 µm coating provides a significant safety margin in terms of the octupole threshold

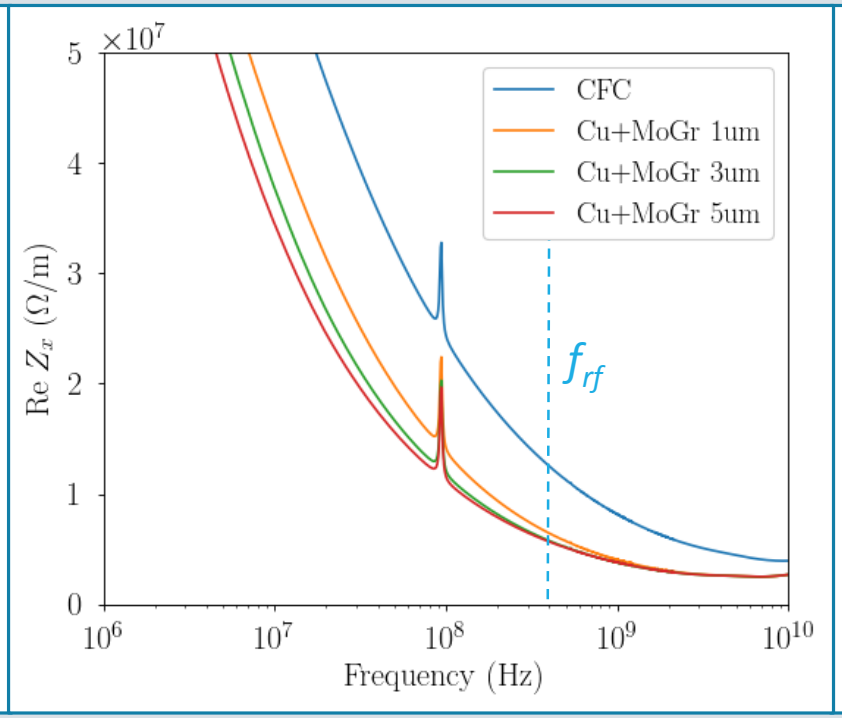
The increase of octupole current for thinner coatings is relatively small for most positive Q', even when its thickness is reduced to 1 µm

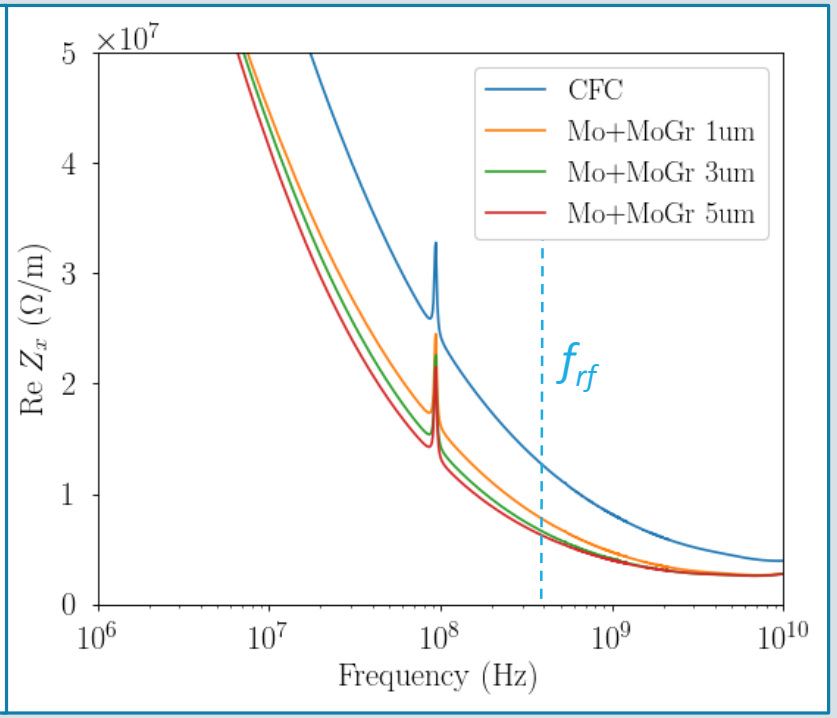
- Up to 20 A (~10% of the total) for Mo coating on MoGr and Q' ~ 10
- Nearly no effect for better coatings with lower resistivity, such as Cu
- The octupole threshold may double for certain values of Q'
  - Still, it shall **not exceed 300 A** at any chromaticity in the range **Q' = 5-20**

Back-up slides

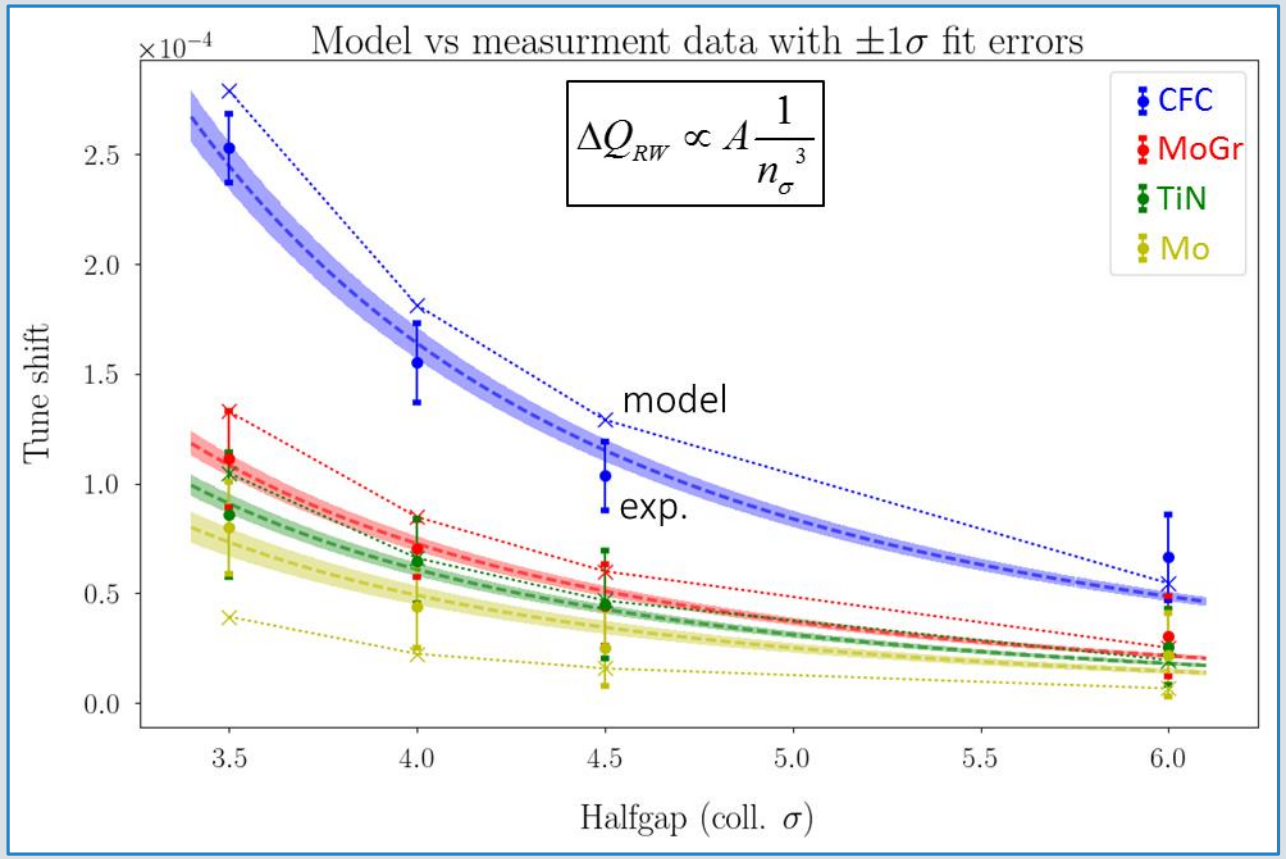
Impedance of different coating thickness options







Mo resistivity might be not as good as expected



Material resistivities (in nΩ-m): measured vs expected

Material	Beam Meas.	Lab Meas. (AC)	IW2D Model
CFC	4030 ± 380	–	5000
MoGr	760 ± 60	800 – 1200	1000
TiN	340 ± 40	Not measurable	400
Mo	250 ± 50	20 – 100	50