Impedance considerations on the aC coating of the LHC beamscreen

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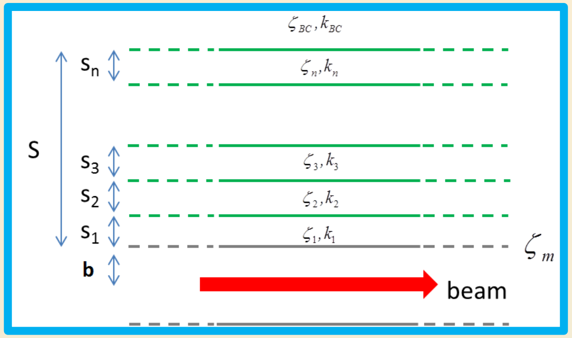
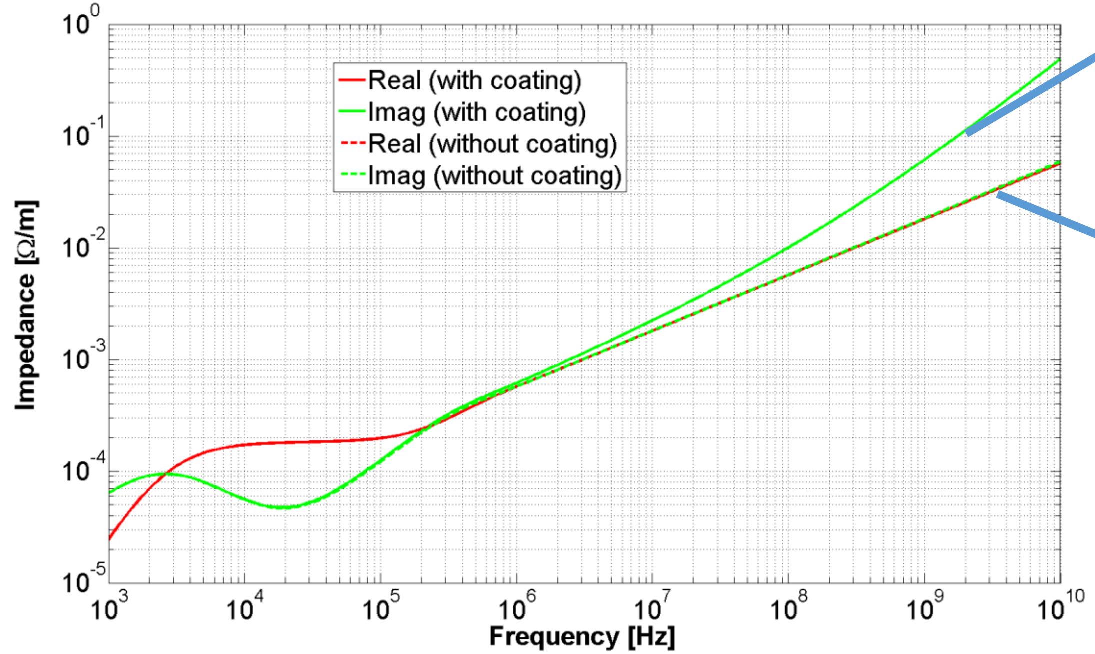
Impedance model for analytical calculation

- Case with aC coating
  - 5 layer structure
    - 1st layer (aC)
    - 2nd layer (Ti)
    - 3rd layer (Cu)
    - 4th layer (StSt)
    - 5th layer (Vacuum)
- Case without aC coating
  - 3 layer structure
    - 1st layer (Cu)
    - 2nd layer (StSt)
    - 3rd layer (Vacuum)



Material	σ_{el} [S/m]	ε_r	Thickness [μm]
aC coating	400	5.4	0.5
Titanium coating	10^6	1	0.1
Copper	10^9	1	50
Stainless steel	$1.35\ 10^6$	1	1000
Vacuum	0	1	Infinity

Longitudinal impedance: effect of aC coating



Significant effect on the imaginary part

$$\Delta\left(\frac{Z}{n}\right)_{eff}^{triplets} \approx 5\times10^{-5}\,\Omega \approx 5\times10^{-4}\left(\frac{Z}{n}\right)_{eff}^{LHC}$$

The effect on the real part is negligible

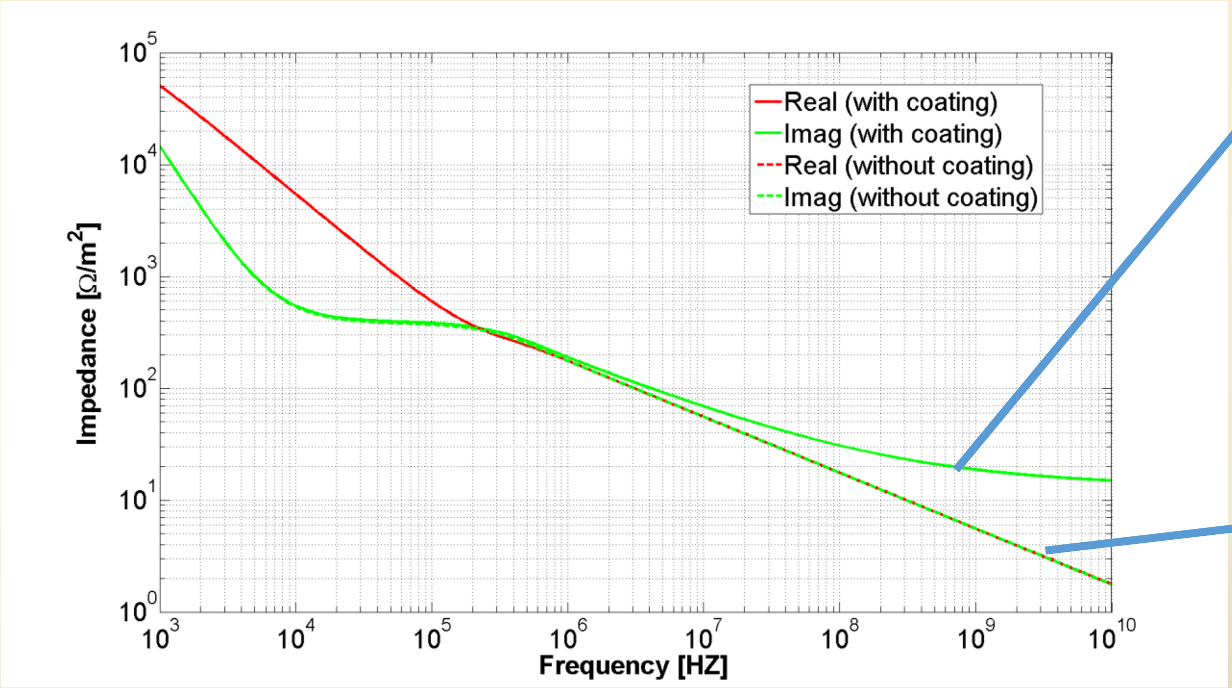
No effect on beam induced heating (single beam)

Two beams heating

$$\Delta W(s) = \left(\frac{\omega_0}{\pi}\right)^2 \sum_{p=0}^{\infty} |\Lambda(p\omega_0)|^2 \left\{\mathrm{Re}\left[Z_{||}^0(p\omega_0)\right] + [\Delta y_1(s) + \Delta y_2(s)]\,\mathrm{Re}\left[Z_{||}^1(p\omega_0)\right]\right\}(1-\cos p\omega_0\tau_s)$$

First order longitudinal impedance due to the weld
No impact of aC coating (3D CST simulations)

Transverse impedance: effect of aC coating



Significant effect on the imaginary part

Coherent tune shift, TMCI thresholds

$$E = 6500 \ GeV$$

$$\Delta\left(Z_y\right)_{eff}^{triplets} \approx 40\frac{k\Omega}{m} \approx 2\times 10^{-3}\left(Z_y\right)_{eff}^{LHC}$$

The effect on the real part is negligible

Why the imaginary part depends on the aC coating?

- Case without aC coating
  - 1 layer structure
    - 1st layer (Cu)

- Case with aC coating
  - 2 layer structure
    - 1st layer (aC)
    - 2st layer (Cu)

From transmission line theory one can derive the surface impedance seen by the beam

$$\zeta_m = \zeta_{Cu}$$

$$\zeta_{Cu} < \zeta_{aC}$$
$$\delta_{aC} >> s_{ac}$$
$$\omega\varepsilon_0\varepsilon_r^{'} << \sigma_{el(aC)}$$

$$\Rightarrow \zeta_m = \zeta_{Cu} + j\omega\mu s_{ac}$$

Coating thickness

The aC coating introduces an additional contribution to the imaginary impedance

Summary

- The aC coating, where applied, is expected to increase significantly the imaginary part of the resistive wall beam coupling effective impedance per unit length (about a factor 2)
    - The effect on the full LHC longitudinal impedance is expected to be below 0.1 % (about 0.05%)
    - The effect on the full LHC transverse impedance is expected to be well below 1% (about 0.2% in the worst case scenario)
- No impact is expected on the beam induced heating

Thank you very much for your attention