Coupling impedance of the FCC-hh cold beamscreen

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What is cold beamscreen and what is coupling impedance?

Deflecting voltage

Transverse coupling impedance

\[ Z = \frac{V}{I} \]

Beam current

Higher coupling impedance = lower maximum beam current before the beam goes unstable
Sources of beamscreen impedance

1. Resistive wall
2. E-cloud surface treatment
3. Pumping holes
4. Interconnects
Role of beamscreen in the impedance model (1/2)

Beamscreen-related impedance:
• Resistive wall
• E-cloud surface treatment
• Pumping holes
• Interconnects

Effective impedance for the coupled bunch instability (y-plane)

Max allowed impedance:
−1350 MΩ/m

Max allowed impedance:
−4100 MΩ/m

Effective impedance for the coupled bunch instability (y-plane)

Beamscreen-related impedance dominates coupled-bunch instability
Role of beamscreen in the impedance model (2/2)

Beamscreen-related impedance:

- Resistive wall
- E-cloud surface treatment
- Pumping holes
- Interconnects

Max allowed impedance: $12\,\text{M}\Omega/m$

Beamscreen-related impedance is important for single-bunch instability at injection.

Effective impedances for the single bunch instabilities (y-plane)
Resistive wall impedance of beamscreen

25% increase in impedance
Detrimental effect on head-tail instability – see C. Tambasco’s talk

Vertical dipolar impedance weighted by the $\beta$-function
E-cloud surface treatment (1/2)

Amorphous carbon or TiN coating

~30% impedance increase at 1 GHz

Laser treatment

Unknown impedance increase
E-cloud surface treatment (2/2)

Interpretation of a rough surface

Conductivity vs depth into the wall

For this sample Im(Z) increased by a factor of 3.5-7 after the treatment

Measurements by Sarah Aull, June 2017
Pumping holes (1/3)

**LHC**
- Holes take up 4% of surface

**FCC**
- Holes take up 22% of surface

- Cooling channel 40 - 57 K
- Sawtooth surface finishing
- Perforated baffle
- LASE
An estimate based on the traveling wave method for the slit size 7.5 mm:

\[ \text{Im}(Z_x)_{total} \leq 0.1 \text{ MΩ/m} \]

All 10.5 million holes together
Pumping holes (3/3)

- Find dispersion of N bands in one period
- For each band find intersection with the synchronous line
- For each intersection find \(R/Q\)\(\parallel\), \(R/Q\)\(\perp\)
- Use the resonator model to obtain impedances

\[
Z_{\parallel}(f) \approx i \sum_{n=1}^{N} \alpha_n \left(\frac{R}{Q}\right)_{\parallel}^w
\]

\[
Z_{\perp}(f) \approx i \sum_{n=1}^{N} \alpha_n \left(\frac{R}{Q}\right)_{\perp}^w
\]

Correction due to non-zero group velocity \(\alpha_n = \frac{1}{1-v_g/c}\)
Interconnects

Imaginary part of dipolar impedance for all 5516 interconnects

\[ \text{Im} \left( Z_{\text{total}} \right) = 1.5 \, \text{M} \Omega / \text{m} \]

\[ \text{Im} \left( Z_{\text{total}} \right) = 1.9 \, \text{M} \Omega / \text{m} \]

Taper-down + taper-up to block SR

Abrupt change in cross-section

CST model
Conclusions

Transverse impedance of the

- resistive wall
  - OK, if aperture=13.2 mm
  - Maybe not OK, if aperture=12.22 mm due to the head-tail instability

- e-cloud surface treatment
  - OK, if AC or TiN coating is used
  - Unknown, if laser treatment is used (waiting for measurements at FRESCA)

- pumping holes
  - OK

- interconnects
  - OK, but can be better

Open questions:
- Power dissipation through the pumping holes (long. impedance)
- Impedance of a laser-treated surface
- Resistive impedance of interconnects (higher temperature)