Update on Cu coating thickness and HL-LHC octupole thresholds

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116th WP2 Meeting: 
At least 5 μm for Mo, 2(?)-3 μm for Cu

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

It may be technologically challenging to produce Cu coating thicker than 2 μm
- Need to check also the 2 μm option

S. Antipov et al., ‘Effect of collimator coating thickness on HL-LHC octupole thresholds’, WP2 Meeting, 13.03.18
The bulk has little effect on impedance for a sufficiently thick coating.

<table>
<thead>
<tr>
<th>Material</th>
<th>Bulk resistivity (nΩ-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFC</td>
<td>5000</td>
</tr>
<tr>
<td>MoGr</td>
<td>1000</td>
</tr>
<tr>
<td>Cu</td>
<td>26</td>
</tr>
<tr>
<td>Mo</td>
<td>53.5</td>
</tr>
</tbody>
</table>

Skin depth (μm)

Re Z (Ω/m)

09/04/2018

S. ANTIPOV, UPDATE ON CU COATING THICKNESS
Octupole threshold for thinner coatings, Cu on CFC: No significant increase for 2 µm, most Q’
Octupole threshold for thinner coatings, Cu on MoGr: No significant increase for 2 μm, most Q'}
Conclusion

2 μm Cu coating seems acceptable, both on CFC and MoGr
- Effectively screens the bulk, since its thickness is larger than the skin depth at the relevant freqs.

There are certain chromaticities that require up to 100% more octupole current compared respect to a thicker coating
- Only in a small range of Q’
- The amount of Landau octupole is smaller than at Q’ ~ 10

Benoit: We start seeing detrimental effects below 3 μm.
- A sound safety margin is required
- Need to understand the implications of thicker coatings. What is the extra cost?
Back-up slides
Impedance of different coating thickness options

\[ f_{rf} \]

- CFC
- Cu+CFC 1μm
- Cu+CFC 3μm
- Cu+CFC 5μm

- CFC
- Cu+MoGr 1μm
- Cu+MoGr 3μm
- Cu+MoGr 5μm

- CFC
- Mo+MoGr 1μm
- Mo+MoGr 3μm
- Mo+MoGr 5μm
Material resistivities (in nΩ-m): measured vs expected

<table>
<thead>
<tr>
<th>Material</th>
<th>Beam Meas.</th>
<th>Lab Meas. (AC)</th>
<th>IW2D Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFC</td>
<td>4030 ± 380</td>
<td>–</td>
<td>5000</td>
</tr>
<tr>
<td>MoGr</td>
<td>760 ± 60</td>
<td>800 – 1200</td>
<td>1000</td>
</tr>
<tr>
<td>TiN</td>
<td>340 ± 40</td>
<td>Not measurable</td>
<td>400</td>
</tr>
<tr>
<td>Mo</td>
<td>250 ± 50</td>
<td>20 – 100</td>
<td>50</td>
</tr>
</tbody>
</table>

Mo resistivity might be not as good as expected