MD#3205 Beam screen shielding of Quench Heater discharge with warmer beam screen

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Re-cap motivation and plan

- Very **fast effect** on the circulating beam has been observed during dipole quenches due to quench heater firing. Effect was confirmed in MD at injection.
- Rise time of current in quench heater ~30 µs.
- The rise time of observed kick (~200 µs) is **faster than expected** from beam screen shielding effects ($\tau \propto 1/\rho$).
- For the **HL-LHC triplets**, kicks from single quench heater firing are expected to **reach critical levels**.

- QH firing with beam screen at ~70 K and two different currents with three circulating bunches.
- Dedicated measurements with MQXFS4b in SM18 → not part of this talk.

### HL-LHC: QH parameters and expected kick

<table>
<thead>
<tr>
<th>Magnet</th>
<th>L (m)</th>
<th>$I_{\text{QH}}$ (A)</th>
<th>B (μT)</th>
<th>Kick ($\sigma$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MB</td>
<td>14.3</td>
<td>80</td>
<td>450</td>
<td>0.4</td>
</tr>
<tr>
<td>MQXF</td>
<td>7.15</td>
<td>200</td>
<td>472</td>
<td>1.28</td>
</tr>
</tbody>
</table>

Quench of MB.C28L5 on July 12th 2016

~15 µm RMS orbit change

3.5 ms until dump
MD#3205

- MB.C28L5
- Beam screen temperature \( \sim 70 \text{ K} \)
- Three nominal bunches circulating
- Quench heaters fired at 5822 A (3.5 TeV) and 10792 A (6.5 TeV)
- Kick & magnetic field from quench heaters reconstructed from ADTObsBOX

Measured beam excursion at ADT pick-up (Q7R5)

- 3.5 TeV
- 6.5 TeV
Magnetic field 1 ms after QH firing
Rise time of magnetic field (10 % → 65 % at 1 ms)
Summary of Observations

- **Effect of beam screen** temperature increase from 20 K → 70 K:
  - Faster rise time and higher magnetic field reached **as expected**
  - Quantitative **changes not reproduced** by models
- **Effect of increased main field** with beam screen at 70 K:
  - Faster rise time and higher magnetic field reached **as expected**
  - **Quantitative order** of change correct, details to be understood
- **Effect of increased main field** with beam screen at 20 K:
  - Much faster rise time and significantly higher magnetic field reached
  - **Relative change in good agreement** with models

<table>
<thead>
<tr>
<th>Energy (TeV)</th>
<th>I (A)</th>
<th>T (K)</th>
<th>$\rho$ (10^{-10}\Omega.m)</th>
<th>QH field rise time (10% → 65% at 1ms) (µs)</th>
<th>fraction of magnetostatic field after 1 ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.45</td>
<td>850</td>
<td>20</td>
<td>2.5</td>
<td>500</td>
<td>0.22</td>
</tr>
<tr>
<td>6.5</td>
<td>10792</td>
<td>20</td>
<td>5.22</td>
<td>175</td>
<td>0.47</td>
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<tr>
<td>3.5</td>
<td>5822</td>
<td>70</td>
<td>17.4</td>
<td>140</td>
<td>0.57</td>
</tr>
<tr>
<td>6.5</td>
<td>10792</td>
<td>70</td>
<td>18.52</td>
<td>110</td>
<td>0.69</td>
</tr>
</tbody>
</table>
Conclusion and Outlook

- Measurements agree qualitatively with expectations
- Nevertheless, discrepancies between simulation models and beam observations in respect to effect of beam screen resistance remain
  - Measurements with changed beam screen temperature are an essential input to adapt the transient field effect simulations in STEAM, especially focusing on the effect of the main coil on the quench heater field seen by the beam
- SM18 measurements with MQXFS4b and beam screen are currently being analysed and will be compared to STEAM simulations
- Further experiments in SM18 with final beam screen design are under preparation