IP displacement and IC misalignment effects on the triplet radiation load

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WP10
Energy deposition & R2E
OUTLINE

Effects on the triplet radiation load derived from:

• Displacement of the Interaction Point (IP) for horizontal crossing:
  • Horizontal: in the crossing plane
  • Vertical: in the perpendicular plane

• Misalignment of the interconnect (IC) between Q2A and Q2B for horizontal crossing:
  • Transverse shift of the IC with respect to the quadrupole and displacement of the BPM tungsten shielding

Effect of the orbit correctors orientation on their exposure
THE MODEL

• Point 5
• Triplet - D1
• Horizontal crossing of 250 \( \mu \text{rad} \)
• Optics: HL-LHC v1.3
Effects of the IP displacement for horizontal crossing

essential input from R. De Maria
BE-ABP
**IP DISPLACEMENT**

*in the crossing plane*

vertical axis

(+225 urad half crossing angle)

+50% for peaks
+10% for totals

when the debris cone is moved to a higher field region at the triplet entrance

SLHC-IRP1, TDG Meeting, June 4th 2009

F. Cerutti

Effect to be evaluated for realistic conditions

Jan 30th, 2018
IP displacement at IR5

- Crossing angle: 250 $\mu$rad on the horizontal plane
- Three cases:
  - Reference position (noOff)
  - Displacement of 2 mm on the horizontal plane (+2mmH)
  - Displacement of 2 mm on the vertical plane (+2mmV)
Peak dose distribution in the triplet-D1

Peak dose profile in the inner coils ($L_{\text{int}} = 3000 \text{ fb}^{-1}$)
HL-LHCv1.3 Round 250urad

31 – 38 MGy for 4000 fb$^{-1}$

IR5 no offset

Q1  Q2A  Q2B  Q3  CP  D1

Distance from IP [m]

Peak dose [MGy / 3000 fb$^{-1}$]
Peak dose distribution in the triplet-D1

Peak dose profile in the inner coils ($L_{\text{int}} = 3000 \text{ fb}^{-1}$)
HL-LHCv1.3 Round 250urad

- **31 – 38 MGy for 4000 fb$^{-1}$**
- **43 – 50 MGy for 4000 fb$^{-1}$**

- IR5 no offset
- IR5 with an IP displacement of +2mmH

**Legend:**
- Q1
- Q2A
- Q2B
- Q3
- CP
- D1

**peak dose distribution graph:**
- Y-axis: Peak dose [MGy / 3000 fb$^{-1}$]
- X-axis: Distance from IP [m]
- Graph shows peak dose distribution for different regions (Q1, Q2A, Q2B, Q3, CP, D1) with data points and error bars.
Peak dose distribution in the triplet-D1

Peak dose profile in the inner coils ($L_{\text{int}} = 3000 \text{ fb}^{-1}$)
HL-LHCV1.3 Round 250urad

- 31 – 38 MGy for 4000 fb$^{-1}$
- 43 – 50 MGy for 4000 fb$^{-1}$
- 31 – 36 MGy for 4000 fb$^{-1}$

IR5 no offset
IR5 with an IP displacement of +2mmH
IR5 with an IP displacement of +2mmV

Distance from IP [m]

Peak dose [MGy/3000 fb$^{-1}$]
Peak dose distribution in the triplet-D1

Dose profile in the inner coils ($l_{int} = 3000 \text{ fb}^{-1}$)

HL-LHCv1.3 Round 250urad

IR5 no offset
IR5 with an IP displacement of +2mmH
IR5 with an IP displacement of +2mmV

M. Sabate-Gilarte
Oct 18th, 2018
8th HL-LHC Collaboration Meeting
Peak dose distribution in the triplet-D1
Peak power distribution in the triplet-D1

Peak power density profile in the inner coils (L = 5.0 x 10^{34} \text{ cm}^{-2} \text{s}^{-1})

Distance from IP [m]

Q1 Q2A Q2B Q3 CP D1

Peak power density [mW/\text{cm}^3]

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

IR5 no offset
Peak power distribution in the triplet-D1

Peak power density profile in the inner coils (L = 5.0x10^{34} \text{ cm}^{-2} \text{ s}^{-1})

Distance from IP [m]

Distance from IP [m]

Q1
Q2A
Q2B
Q3
CP
D1
Peak power distribution in the triplet-D1

Peak power density profile in the inner coils (L = 5.0 x 10^{34} \text{ cm}^{-2} \text{ s}^{-1})

- IR5 no offset
- IR5 with an IP displacement of +2 mmH
- IR5 with an IP displacement of +2 mmV

Distance from IP [m]
## Power by region (W)

<table>
<thead>
<tr>
<th>Region</th>
<th>No Offset</th>
<th>+2mmH</th>
<th>+2mmV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM Q1A+Q1B</td>
<td>111</td>
<td>114</td>
<td>112</td>
</tr>
<tr>
<td>BS</td>
<td>165</td>
<td>170</td>
<td>167</td>
</tr>
<tr>
<td>CM Q2A+Corr</td>
<td>95</td>
<td>101</td>
<td>98</td>
</tr>
<tr>
<td>BS</td>
<td>62</td>
<td>66</td>
<td>64</td>
</tr>
<tr>
<td>CM Q2B+Corr</td>
<td>133</td>
<td>146</td>
<td>134</td>
</tr>
<tr>
<td>BS</td>
<td>96</td>
<td>110</td>
<td>97</td>
</tr>
<tr>
<td>CM Q3A+Q3B</td>
<td>118</td>
<td>118</td>
<td>118</td>
</tr>
<tr>
<td>BS</td>
<td>69</td>
<td>69</td>
<td>67</td>
</tr>
<tr>
<td>CM CP</td>
<td>42</td>
<td>37</td>
<td>44</td>
</tr>
<tr>
<td>BS</td>
<td>49</td>
<td>38</td>
<td>47</td>
</tr>
<tr>
<td>CM D1</td>
<td>66</td>
<td>64</td>
<td>66</td>
</tr>
<tr>
<td>BS</td>
<td>46</td>
<td>44</td>
<td>46</td>
</tr>
<tr>
<td>CM Pipe</td>
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<tr>
<td>BS extension</td>
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</tr>
<tr>
<td>CM total</td>
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<td>599</td>
<td></td>
</tr>
<tr>
<td>BS</td>
<td>546</td>
<td>554</td>
<td></td>
</tr>
</tbody>
</table>

With the last interconnect configuration:

CM: cold mass  
BS: beam screen
Effects of the InterConnect misalignment for horizontal crossing

essential input from C. Garion
TE-VSC
BACKGROUND

BETTER SHIELDING

Additional shielding on non-IP side (Inermet, 11.5 cm – was 7)

BPM shielding (Inermet, 16.5 cm – was 18)

29–33 MGy after 4ab⁻¹

New IC everywhere after Q2

Effect of BPM misalignment to be contained

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Oct 18th, 2018

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Jan 30th, 2018
IC misalignment for horizontal crossing

- Interconnect between Q2A and Q2B
- Crossing angle: 250 μrad on the horizontal plane
- Two contributions:
  - BPM misalignment: -250 μm
  - IC misalignment: -250 μm
- Mechanical displacement towards the ring centre to let the hot spot more exposed
Peak dose distribution in the triplet-D1

Peak dose profile in the inner coils ($L_{int} = 3000 \text{ fb}^{-1}$)
HL–LHC V1.3 Round 250 urad

No ICQ2 misalignment

Peak dose [ MGy / 3000 fb$^{-1}$ ]

Distance from IP [m]

Q1 Q2A Q2B Q3 CP D1
Peak dose distribution in the triplet-D1

Peak dose profile in the inner coils ($L_{int} = 3000 \text{ fb}^{-1}$)
HL-LHCv1.3 Round 250urad

**total power almost unchanged**

No ICQ2 misalignment
ICQ2 misaligned by $-500\mu\text{mH}$
Effect of the orbit correctors orientation on their exposure

essential input from G. de Rijk
TE-MSC
Orbit corrector model

inner coils

outer coils

horizontal alignment

vertical alignment
Orbit corrector model

At the magnet ends, first and last 10 cm of the mechanical length, the return coils lay in the opposite plane: in the vertical plane for horizontal alignment and the other way around.
Orbit corrector model

Dose distribution transverse section at the Q2A orbit corrector:

- **Vertical crossing**
- **Horizontal crossing**

![Diagram showing dose distribution transverse sections at Q2A orbit corrector](image-url)
Peak Power density in the triplet for vertical crossing

OC: orbit corrector

Peak power density in triplet cold bore - HL-LHC IR1 (5x10^{34} cm^{-2} s^{-1})
Peak Power density in the triplet for horizontal crossing

Peak power density in triplet cold bore - HL-LHC IR5 (5x10^{34} cm^{-2} s^{-1})

OC: orbit corrector
Vertical crossing orbit corrector in the CP

Peak dose profile in the inner coils for CP-OC \( (L_{\text{int}} = 3000 \, \text{fb}^{-1}) \)

- Vertical crossing - vertical alignment
- Vertical crossing - horizontal alignment

Return coils

Deviation (%) for V-H coils

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Vertical crossing
Q2B orbit corrector

Peak dose profile in the inner coils for Q2B-OC \((L_{int} = 3000 \text{ fb}^{-1})\)

![Diagram showing peak dose profile](image)

Vertical crossing - vertical alignment
Vertical crossing - horizontal alignment

Deviation (%) for V-H coils

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Vertical crossing
Q2A orbit corrector

Peak dose profile in the inner coils for Q2A-OC ($L_{int} = 3000 \text{ fb}^{-1}$)

- Vertical crossing - vertical alignment
- Vertical crossing - horizontal alignment

Peak dose [MGy / 3000 fb$^{-1}$]

Distance from IP [m]

Deviation (%) for V-H coils

Distance from IP [m]
Horizontal crossing orbit corrector in the CP

Peak dose profile in the inner coils for CP-OC \((L_{\text{int}} = 3000 \text{ fb}^{-1})\)

- Horizontal crossing - vertical alignment
- Horizontal crossing - horizontal alignment

Deviation (%) for V-H coils

Distance from IP [m]

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Horizontal crossing
Q2B orbit corrector

Peak dose profile in the inner coils for Q2B-OC ($L_{int} = 3000 \text{ fb}^{-1}$)

- Horizontal crossing - vertical alignment
- Horizontal crossing - horizontal alignment

![Graph showing peak dose profile with horizontal and vertical alignments](graph.png)

Deviation (%) for V-H coils

![Graph showing deviation for V-H coils](deviation_graph.png)

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Horizontal crossing
Q2A orbit corrector

Peak dose profile in the inner coils for QAB-OC \((L_{int} = 3000 \text{ fb}^{-1})\)

- Horizontal crossing - vertical alignment
- Horizontal crossing - horizontal alignment

**Graphs:**
- **Upper Graph:**
  - X-axis: Distance from IP [m]
  - Y-axis: Peak dose [MGy / 3000 fb⁻¹]
  - Data points and error bars indicating peak dose values.

- **Lower Graph:**
  - X-axis: Distance from IP [m]
  - Y-axis: Deviation (%) for V-H coils
  - Data points and error bars showing deviation from baseline.

**Additional Notes:**
- Sabaté-Gilarte
- Oct 18th, 2018
- 8th HL-LHC Collaboration Meeting
Summary and Conclusions
IP displacement:

• Results for horizontal crossing with a displacement on the IP of 2mm.

• In the crossing plane:
  • The **total dose increases** by **35%** (assuming constant displacement) when the displacement is in the same plane and has the same sign as the crossing angle.
  • The **power density arises** by **40%** but the values are much below the design limit (12 mW/cm³ which is supposed to be three times lower than the quenching limit).
  • Even if locally the total power increases by 10%, in the Q2B, the global effect is around 1%.
  • Based on precious studies, a bump on the opposite side of the crossing angle could be beneficial.

• In the orthogonal plane:
  • The effect can be neglected.
IC misalignment:

- The displacement was modeled assuming two contributions:
  - Displacement of the tungsten shielding in the BPM by -250 μm.
  - Shift of the IC by -250 μm.

- Mechanical displacement towards the ring centre to let the hot spot more exposed.

- The effect is still **negligible**.
Effect of the orbit correctors orientation on their exposure:

- The orientation of the nested orbit correctors affects the maximum dose their coils are exposed to.
- The recommended configuration is with the **inner layer giving a vertical field**, i.e. horizontal correction.
Thank you for your attention