RADIATION DOSE TO MCBC/Y

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WP10
Energy deposition & R2E

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OUTLINE

• Radiation sources
• Cold magnet areas exposed to long term damage
• Experimental Insertion Dispersion Suppressors...
• ...and Matching Sections
• Aperture imperfection impact
• HL and present triplet correctors
• Material qualification
### PAST AND FUTURE LOSS SOURCES [I]

#### RUN 1 | RUN 2 | RUN 3 | HL-LHC
--- | --- | --- | ---
beam energy [TeV] | 3.5 - 4 | 6.5 | 7 | 7

#### integrated luminosity [fb⁻¹]

<table>
<thead>
<tr>
<th></th>
<th>RUN 1</th>
<th>RUN 2</th>
<th>RUN 3</th>
<th>HL-LHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>proton-proton (ATLAS-CMS)</td>
<td>30</td>
<td>160</td>
<td>200 +</td>
<td>3000 + 33%</td>
</tr>
<tr>
<td>proton-proton (LHCB)</td>
<td>3</td>
<td>6</td>
<td></td>
<td>50 (+ 250)</td>
</tr>
<tr>
<td>ion-ion (ALICE)</td>
<td></td>
<td></td>
<td></td>
<td>10 nb⁻¹</td>
</tr>
</tbody>
</table>

7 TeV p + 7 TeV p  
[@ L₀ = 10^{34} cm^{-2} s^{-1}](https://example.com)  
yields 1 kW  
towards each (L&R) side
PAST AND FUTURE SOURCES [II]

Beam impact on collimator jaws

2808 bunches of $1.15 \times 10^{11}$ 7 TeV $p$
@ 0.2 h beam lifetime
yields 500 kW
towards the collimation system

<table>
<thead>
<tr>
<th>Year</th>
<th>Integrated Annual Beam Intensity (ps)</th>
<th>Total protons lost in IP7</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>$2.71 \times 10^{21}$</td>
<td>$4.81 \times 10^{15}$</td>
</tr>
<tr>
<td>2015</td>
<td>$7.61 \times 10^{20}$</td>
<td>$1.24 \times 10^{15}$</td>
</tr>
<tr>
<td>2016</td>
<td>$2.63 \times 10^{21}$</td>
<td>$4.29 \times 10^{15}$</td>
</tr>
<tr>
<td>HL-LHC Nominal</td>
<td>$8.60 \times 10^{21}$</td>
<td>$1.40 \times 10^{16}$</td>
</tr>
</tbody>
</table>

beam energy [TeV]

| 4          |
| 6.5        |
| 7          |
PAST AND FUTURE SOURCES [III]

Beam interaction with residual gas

<table>
<thead>
<tr>
<th></th>
<th>RUN 1</th>
<th>RUN 2</th>
<th>RUN 3</th>
<th>HL-LHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>beam energy [TeV]</td>
<td>3.5 - 4</td>
<td>6.5</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>beam current [A]</td>
<td>0.43</td>
<td>0.58</td>
<td>1.09</td>
<td></td>
</tr>
<tr>
<td>running time [days]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gas density profile [m⁻³]</td>
<td></td>
<td></td>
<td></td>
<td>5 \times 10^{12} \text{ H}_2 \text{ eq}</td>
</tr>
</tbody>
</table>

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LONG TERM THREATS ON COLD MAGNETS

cured by the TCLD collimator in the cell 11 connection cryostat

calculating with ion integrated lumi

scaling with proton integrated lumi

from triplet to DS

LSS

Point 2

Point 3.2

Point 3.3

Point 4

Point 5

Point 6

Point 7

Point 8

LHC 'B' upgrade from triplet to DS

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IR5 & 1 DISPERSION SUPPRESSORS

wrt present LHC ATS optics, HL losses from cell 9 onward scale rather well with lumi (cell 13 exception)

TCL6 has a noticeable impact only up to cell 8
BLM BENCHMARKING

Fill #5401 (October 2016)
TCLs @ 15-35-20 sigma

Experimental BLM data vs. FLUKA – TCL6 closed

6.5 TeV beams
IR5&1 DS COILS IN THE HL-LHC ERA

Maximum dose below 20 MGy for 3000 fb⁻¹ (MQ11 peak estimation is conservative due to the absence of the specific LEGR-to-MQ interconnect)
But, in 9L5 and 9L1, **15-20 MGy on MBCB (two)**
MCBC AFTER 300 + 3000 fb⁻¹ [II]

In 8L1, 8R1, 8L5 and 8R5, the MCBC (four) could take from nearly 5 MGy to roughly 15 MGy depending on the operational use of the TCL.6 collimator (lower dose as the collimator is 'closed').

Then, not so far below 5 MGy, at the level of (few) MGy, there are the six in cells 5-7 on the left and right of IP5, as well as the same ones in IR1 (a bit less exposed).

and possibly the two in cell 8 on the left and right of IP8 (in case of a further LHCb lumi upgrade to 300 fb⁻¹, not yet studied).
MCBC GETTING 5 MGy

The most impacted MCBC correctors accumulating 15-20 MGy after 3300 fb$^{-1}$, namely two magnets in $9L5$ and $9L1$ (plus four in $8L1$, $8R1$, $8L5$ and $8R5$ in the hypothetical case case of TCL6 open), would reach the $\sim$4-5 MGy threshold after about 800 fb$^{-1}$.

That is not before LS3 but before LS4.
IMPERFECTION EFFECT [II]

by C. Bahamonde and A. Lechner

35% increase in peak dose

BFPP losses on

nominal aperture

real aperture

Peak power density MB coils (mW/cm²)

Distance from IP5 (m)

Distance from IP5 (m)

BLM signal (mGy/s)

Distance from IP5 (m)
The warm masks are designed to match the beam screen aperture of the respective magnet. Assuming a 2 mm radial enlargement:

Major increase of the peak dose on the IP face of the first Q4 MCBYV. Max power density value of 2 mW/cm³ @5L₀ still acceptable, with small impact on the total heat load.
MBCY AFTER (300 +) 3000 fb⁻¹

Not so far below 10 MGy, there are **two in cells 4 on the left and right of IP5**, as well as the respective ones in IR1 (a bit less exposed).

Other **six in cells 4 on the left and right of IP5**, as well as the respective ones in IR1, get not so far below 5 MGy.
The recommended configuration is with the inner layer giving a vertical field, i.e. horizontal correction.
PRESENT TRIPLET CORRECTORS

- benefit from **regular inversion in IR1** (-30%)
- **flat optics** even better

round optics
142.5 urad half crossing angle
[$\leq 3\text{mm radial resolution}$]

V crossing in ATLAS (IR1)
H crossing in CMS (IR5)
INSULATOR LIMIT TESTING

Calculated values refers to a mixture including insulator, superconductor and copper (representing an effective coil material). Dose in the insulator is expected to be say 20% higher than the average value referring to the mixture.

Dose in plastic by LHC irradiation and dose in plastic by gamma radiation are basically the same thing.

For calibration purposes, gamma dose in plastic and gamma dose in water are very close (1-2% difference).