Studies of Machine protection for a Crab Cavity in the LHC

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Scheme

- Introduction
- Results
- Summary
A device called “crab cavity” (CC) applies a tiny sideways kick to each particle bunch, in order to change its dynamics to achieve a head-on collision at the IP. For the HL-LHC the luminosity will increase by a factor of 5 (with respect to the nominal).

Figure 1: The CC’s effect in the beam at collision point in the LCC scheme.
Layout of the CC

Figure 2 : The scheme layout at right part of the IP for the LHC.
Transverse distribution

Figure 3: The Transverse beam profile obtained by using the CMS measurements. The sigma of the tails is 1.9 times than the core.
Figure 4: In the Normal operation (NO) represent the ideal performance of the CC.
Figure 5: The phase space in $X$ (left) with a cut at $3\,\sigma$ and $Y$ (right) without cut.
Absorbed particles on Collimators

Figure 6. The numbers of particles absorbed on collimators when the CCs work in the normal operation case. Most of the particles are absorbed on TCP.C6L7.B1.
Figure 7. The Percentage of particle lost in the aperture for the failures case of phase. The numbers of particles more than $6 \times 10^6$. 

Absorbed particles
Figure 8. The Percentage of particle lost in the aperture for the failures case of phase. The numbers of particles more than $6 \times 10^6$.
Figure 9 The Local loss Map, obtained by tracking the double Gaussian beam distribution beyond of 3 sigma cut in the Normal operation and failure in phase in one turn.
### Tracking results

Table 1: The Summary of the beam lost for the studies using a double Gaussian. The initial FP Failure in phase for the last 18 turns.

<table>
<thead>
<tr>
<th>CASE</th>
<th>Absorbed particles</th>
<th>Lost particles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[%]*</td>
<td>Energy (kJ)**</td>
</tr>
<tr>
<td>Normal Operation</td>
<td>0.17</td>
<td>9.14</td>
</tr>
<tr>
<td>PF in 1 turn</td>
<td>0.81</td>
<td>41.93</td>
</tr>
<tr>
<td>PF in 3 turns</td>
<td>0.40</td>
<td>20.87</td>
</tr>
<tr>
<td>PF in 5 turns</td>
<td>0.37</td>
<td>19.45</td>
</tr>
</tbody>
</table>

*Percentage with respect the total survival particles (around the 99.35% remains) before start the failure.

**Assuming the total store energy at 7 TeV is 692.84 MJ, thus, the fraction of the equivalent deposited energy is 5.12 MJ=(0.0074)692.84 MJ.
Summary

• The percentage of absorbed particles and lost particles after the failures are 0.65 and $1.7 \times 10^{-4}$ for the distribution beyond 3 $\sigma$.

• The phase failure in one turn represents the most dangerous cases, i.e. the FP1 case.

• The different in the amount of losses produced for the failures in 3 and 5 turns are similar.
Backup
Figure 10. The transverse beam distribution used for these simulations. The numbers of particles more than $6 \times 10^6$. 

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Figure 11. The longitudinal beam distribution used for these simulations. The numbers of particles more than $6 \times 10^6$. 
Percentage of the population

Table 2: The percentage of particles of the double Gaussian distribution beyond the numbers of $\sigma$.

<table>
<thead>
<tr>
<th>Cut ($\sigma$)</th>
<th>Percentage of the population [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.04</td>
</tr>
<tr>
<td>2</td>
<td>5.66</td>
</tr>
<tr>
<td>3</td>
<td>0.74</td>
</tr>
<tr>
<td>4</td>
<td>0.13</td>
</tr>
<tr>
<td>5</td>
<td>0.02</td>
</tr>
</tbody>
</table>