Study of Loss Distribution with detailed Aperture Model

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- Beam loss distribution is important input for the BLM-system
- Dilution length of losses: important information for LHC collimation system
Aperture Model + Particle Tracking Environment

- Aperture Information for Dispersion Suppressor and Arc downstream (beam1) of IR7
  - First marker at: ~235 m from IP7
  - Last marker at: ~2845 m from IP7

- Every change of aperture is included (transition pieces, BPMs, beamscreens outside the magnets, locations of bellows, …)
  - At some locations in the order of 5m without aperture element: more markers will be included

- MBs and MQs are sliced
Aperture Model + Particle Tracking Environment

- MAD-X: Aperture Information → LHC sequence.
- MAD-X: Particle Tracking
- Post-processing:
  - longitudinal loss distribution \( N_{\text{lost}}(s) \)
  - list of hit elements
  - coordinates of lost particles at each hit element
  - dilution length for losses
Definition of Dilution Length

- **Dilution Length and collimation:**
  The cleaning inefficiency is determined via tracking programs producing secondary and tertiary halo particles.

  Cleaning inefficiency for N lost particles:
  \[
  \eta_c(a_c) = \frac{1}{N} \sum_{i=1}^{N} H(A_r - a_c)
  \]

- **Local cleaning inefficiency:** required local cleaning inefficiency defined via quench limit and maximum loss rate
  \[
  \tilde{\eta}_c = \eta_c / L_{dil} = \frac{R_q}{\dot{N}_{\text{max}}}
  \]

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Definition of Dilution Length

- Assumption on dilution length so far: 50m
- To determine the dilution length from our data:
  - output of simulation: number of lost particles per m: \( N_{\text{lost}}(s) \)
  - dilution length:

\[
L_{\text{dil}}^{-1} = \frac{\max_{s} N_{\text{lost}}(s)}{\sum_{s} N_{\text{lost}}(s)}
\]
Testing the Environment …

- Loss distributions for test particle configurations (uniform distributions in x and y)
- 7 TeV protons, $10^4$ particles
- single pass through the section with detailed aperture
- No errors
Uniform distribution in $y, x = 0$
Comparison: cuts in phase space:
whole arc (46 halfcells) – 29 halfcells
Uniform distribution in y, x=0: normalized phase-space: cut at ~55σ
Lost Distribution: uniform distribution $y, x=0$. Losses occur only at quads.
Comparison: loss locations - horizontal aperture limits …
Comparison: loss locations - vertical aperture limits …
Comparison: uniform distribution in x (y=0) and uniform distribution in y (x=0)
Uniform distribution in $x$ (80$\sigma$), $y=0$; Energy offset: $\sigma_\delta=0.001$
Uniform distribution in x and y (80σ);
Energy offset: $\sigma_0 = 0.001$
### Some numbers …

<table>
<thead>
<tr>
<th>Uniform distribut.</th>
<th>$L_{dil}$</th>
<th>cut</th>
<th>loss@ quads</th>
<th>loss@ bends</th>
<th>else</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>[m]</td>
<td>[σ]</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>$x, y=0$</td>
<td>3.4</td>
<td>~75</td>
<td>83</td>
<td>4</td>
<td>13</td>
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<tr>
<td>$x, \delta \neq 0$</td>
<td>7</td>
<td>~60</td>
<td>38</td>
<td>39</td>
<td>23</td>
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<tr>
<td>$\sigma_\delta=0.001$</td>
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<td></td>
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<tr>
<td>$y, x=0$</td>
<td>6.3</td>
<td>~55</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$x, y$</td>
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<td>63.3</td>
<td>29.3</td>
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<td>$x, y, \delta \neq 0$</td>
<td>17.6</td>
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<td>52</td>
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<td>8</td>
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<tr>
<td>$\sigma_\delta=0.001$</td>
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</tbody>
</table>
Conclusion

- We now have a tool to study longitudinal beam loss distributions.
- As it is based on MAD, errors in the machine (orbit, misalignments,…) can be easily included.

- For the next step (dilution length for collimation system) we need realistic initial particle coordinates: Halo data from Ralph.