HL-LHC triplet errors

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HL-LHC IR
How do we assign errors to the inner triplet?

- 50 units \((10^{-4})\) full range of integrated gradient error
- Random error = 2 units.
- Q1, Q3: Pairing.
- Q2: Sorting and pairing.
- 1000 machines.
Error distribution
Results: $\beta^* = 40$ cm

**Figure**: RMS $\beta$-beating

**Figure**: Max. $\beta$-beating
Results: $\beta^* = 40 \text{ cm}$
Results: $\beta^* = 30 \text{ cm}$
Results: $\beta^* = 30 \text{ cm}$
Results: $\beta^* = 20 \text{ cm}$

**Figure:** RMS $\beta$-beating

**Figure:** Max. $\beta$-beating
Results: $\beta^* = 20$ cm
Results: \( \beta^* = 15 \text{ cm} \)

**Figure:** RMS \( \beta \)-beating

**Figure:** Max. \( \beta \)-beating
Results: $\beta^* = 15 \text{ cm}$
Results: successful seeds and $\beta^*$
Results: summary

Table: Summary table for different optics. Unsuccessful seeds are not taken into account

<table>
<thead>
<tr>
<th>Optics</th>
<th>Success [%]</th>
<th>$\Delta_\beta_x/\beta_x$ [%]</th>
<th>$\Delta_\beta_y/\beta_y$ [%]</th>
<th>Max. $\Delta_\beta_x/\beta_x$ [%]</th>
<th>Max. $\Delta_\beta_y/\beta_y$ [%]</th>
<th>$\beta_x^*$ cm</th>
<th>$\beta_y^*$ cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>15cm</td>
<td>72.7</td>
<td>38</td>
<td>39</td>
<td>121</td>
<td>143</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>20cm</td>
<td>80.8</td>
<td>29</td>
<td>29</td>
<td>83</td>
<td>90</td>
<td>28</td>
<td>31</td>
</tr>
<tr>
<td>30cm</td>
<td>95.4</td>
<td>21</td>
<td>21</td>
<td>51</td>
<td>52</td>
<td>34</td>
<td>37</td>
</tr>
<tr>
<td>40cm</td>
<td>99.7</td>
<td>15</td>
<td>17</td>
<td>36</td>
<td>38</td>
<td>42</td>
<td>44</td>
</tr>
</tbody>
</table>
Conclusions

▶ Uncorrected $\beta$-beating for 15 cm is $> 100\%$.
▶ Optics commissioning should not start with $\beta^* < 30$ cm.