Options for FF quads with head-on collisions

The incoming beam parameters at IP used for disruption calculation:
beam energy $E = 250$ GeV, normalized emittance $\gamma \varepsilon_x / \gamma \varepsilon_y = 10^{-6} / 3 \times 10^{-8}$ m, rms beam size $\sigma_x / \sigma_y / \sigma_z = 553$ nm / 5 nm / 300 µm, rms beam divergence $\sigma_{xp} / \sigma_{yp} = 36.9 / 12.4$ µrad, rms energy spread $\sigma_E / E = 0.001$, beta function $\beta_x / \beta_y = 15 / 0.4$ mm, particles per bunch $N = 2 \times 10^{10}$.

IP parameters for the disrupted beam (by Guinea-Pig):
$\gamma \varepsilon_x / \gamma \varepsilon_y = 32.7 \times 10^{-6} / 9.7 \times 10^{-8}$ m, $\sigma_x / \sigma_y = 549$ nm / 8.3 nm, $\sigma_{xp} / \sigma_{yp} = 246 / 29$ µrad, $\sigma_E / E = 0.055$, $(\Delta E / E)_{ave} = -0.033$, $(\Delta E / E)_{max} = -0.55$, $\beta_x / \beta_y = 4.5 / 0.345$ mm, $\alpha_x / \alpha_y = 1.76 / 0.663$.

Energy distribution for disrupted beam at IP
500 GeV cms, 34906 total particles
11–05–04
Summary of studied options for FF quads

The table below compares rms size of disrupted beam at s = 50 and 80 m after IP for various options of the FF quads. No other magnets were used. The free space at IP is 4.2 m. The FF quads have the same gradient of 250 T/m, and the quad lengths are adjusted to provide an image focal point at 300 m from IP for the nominal energy beam and to minimize beam size for low energy particles after IP. More optimization may be needed.

<table>
<thead>
<tr>
<th>FF quads (from IP)</th>
<th>$\sigma_x / \sigma_y$ (mm) at s = 50 m</th>
<th>$\sigma_x / \sigma_y$ (mm) at s = 80 m</th>
<th>Space between quads (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-F</td>
<td>2.75 / 0.26</td>
<td>3.75 / 0.46</td>
<td>2.0</td>
</tr>
<tr>
<td>D-F-D-F</td>
<td>(1) 2.33 / 0.18</td>
<td>2.62 / 0.31</td>
<td>1.0 - 2.0 - 2.0</td>
</tr>
<tr>
<td></td>
<td>(2) 2.38 / 0.21</td>
<td>2.52 / 0.37</td>
<td>1.0 - 1.0 - 3.0</td>
</tr>
<tr>
<td>F-D</td>
<td>2.10 / 0.32</td>
<td>3.66 / 0.46</td>
<td>2.0</td>
</tr>
<tr>
<td>F-D-F</td>
<td>(1) 1.55 / 0.43</td>
<td>1.54 / 0.77</td>
<td>1.0 - 3.7</td>
</tr>
<tr>
<td></td>
<td>(2) 1.62 / 0.41</td>
<td>1.66 / 0.74</td>
<td>1.0 - 3.0</td>
</tr>
<tr>
<td></td>
<td>(3) 1.33 / 0.43</td>
<td>1.45 / 0.77</td>
<td>1.0 - 3.0</td>
</tr>
<tr>
<td>F-D-F-D</td>
<td>(1) 1.31 / 0.28</td>
<td>1.39 / 0.44</td>
<td>1.0 - 8.0 - 1.0</td>
</tr>
<tr>
<td></td>
<td>(2) 1.45 / 0.31</td>
<td>1.42 / 0.55</td>
<td>1.0 - 8.0 - 1.0</td>
</tr>
<tr>
<td></td>
<td>(3) 1.56 / 0.29</td>
<td>1.45 / 0.49</td>
<td>1.0 - 10.0 - 1.0</td>
</tr>
<tr>
<td>F-D-F-D-F</td>
<td>(1) 1.26 / 0.30</td>
<td>1.49 / 0.53</td>
<td>1.0 - 1.0 - 1.0 - 1.0</td>
</tr>
<tr>
<td></td>
<td>(2) 1.39 / 0.31</td>
<td>1.49 / 0.55</td>
<td>1.0 - 1.0 - 1.0 - 1.0</td>
</tr>
<tr>
<td></td>
<td>(3) 1.44 / 0.29</td>
<td>1.43 / 0.51</td>
<td>1.0 - 3.0 - 1.0 - 1.0</td>
</tr>
<tr>
<td></td>
<td>(4) 1.49 / 0.31</td>
<td>1.45 / 0.54</td>
<td>1.0 - 2.0 - 1.0 - 2.0</td>
</tr>
</tbody>
</table>

Additional FF quadrupoles reduce overfocusing of the low energy particles in the extracted beam, but increase the total quad length and nominal beta functions in the FF.

The next slides show the following plots for the selected options (blue and red above):
- Beta functions in the FF quads for nominal energy beam (starting at IP),
- x-y distribution for disrupted beam at s = 50 m after IP.
Doublet D-F

Undisrupted beta.

Table name = TWISS

Doublet DF: disrupted x-y at 50 m after IP

"track2d.out" u 2:4
Quadruplet D-F-D-F (option 2)

Undisrupted beta.

Table name = TWISS

Quadruplet DFDF (option 2): disrupted x-y at 50 m after IP
Doublet F-D

Undisrupted beta.

Table name = TWISS

Doublet FD: disrupted x-y at 50 m after IP

"track2f.out" u 2:4
Triplet F-D-F (option 3)

Undisrupted beta.

Table name = TWISS

Triplet FDF (option 3): disrupted x-y at 50 m after IP

"track3f-3.out" u 2:4
Quadruplet F-D-F-D (option 1)

Undisrupted beta.

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Table name = TWISS

Quadruplet FDFD (option 1): disrupted x-y at 50 m after IP
5 quads F-D-F-D-F (option 3)

Undisrupted beta.

5-quads FDFDF (option 3): disrupted x-y at 50 m after IP
Comments

* Schemes with the first x-focusing quad F (nearest to IP) have an advantage of a smaller horizontal beam size in the extraction line.

* Schemes with the first x-defocusing quad D provide a lower vertical beta for the incoming nominal energy beam.

* The quadrupole FDFD scheme tends to converge to the FDF triplet when quad spacing is reduced.

* The desired spacing between the quads needs to be specified for placement of local sextupole, octupole and dipole correctors and possibly for the separators.

* Dispersive effects of the separators and bends on the extracted beam were not included.