Preliminary Design of an FFAG to 25 GeV for the IDS

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Linear Non-Scaling FFAG

- Larger number of passes through RF
- Arc accepts factor of 2 or more in energy
- Reasonable magnet aperture
- Accelerates using high-frequency RF
- Simple (FODO, doublet), identical cells
- Linear combined-function magnets
- Sufficient drift for RF cavity
Design Goals

- Accelerate from 12.6 GeV to 25 GeV
- 30 mm normalized transverse acceptance
- Two 201 MHz SCRF cells per lattice cell
  - Time variation with transverse amplitude
- Four empty drifts for injection/extraction
- Drift lengths: 2 m (FODO)/3 m (doublet)
- Optimize for cost including decays
<table>
<thead>
<tr>
<th>Parameters</th>
<th>FODO</th>
<th>Doublet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cells</td>
<td>62</td>
<td>61</td>
</tr>
<tr>
<td>D radius (cm)</td>
<td>9.5</td>
<td>10.3</td>
</tr>
<tr>
<td>D peak field (T)</td>
<td>7.6</td>
<td>8.4</td>
</tr>
<tr>
<td>F radius (cm)</td>
<td>20.7</td>
<td>20.6</td>
</tr>
<tr>
<td>F peak field (T)</td>
<td>3.4</td>
<td>3.1</td>
</tr>
<tr>
<td>Circumference (m)</td>
<td>462 m</td>
<td>463 m</td>
</tr>
<tr>
<td>RF Voltage (MV)</td>
<td>1526</td>
<td>1450</td>
</tr>
<tr>
<td>Decay loss (%)</td>
<td>3.5</td>
<td>3.7</td>
</tr>
</tbody>
</table>
Lattice Design Discussion

- FODO and doublet lattices very similar
  - Costs, size comparable
  - Both have somewhat over 8 turns
  - Doublet needs slightly less voltage
  - Doublet has higher field, larger D magnet
- Biggest difference: longer (3 m vs. 2 m) drift in doublet
Injection

- Septum followed by kicker in subsequent drift
- 2 cm separation between circulating beam and injected beam at septum
- Ideal tune septum to kicker: 0.25
- Horizontal injection
- Prefer septum just before defocusing magnet
  - Defocusing magnet pushes beam out
  - Beam smaller near defocusing magnet
Lattice Tune

![Graph showing Lattice Tune with varying Total Energy (GeV) and Cell Tune. The graph includes curves for FODO Horizontal, FODO Vertical, Doublet Horizontal, and Doublet Vertical, each represented by a different color.]
## Injection Parameters

<table>
<thead>
<tr>
<th></th>
<th>Doublet D First</th>
<th>Doublet F First</th>
<th>FODO First</th>
<th>FODO Second</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kicker Field (T)</strong></td>
<td>0.62</td>
<td>0.62</td>
<td>0.88</td>
<td>1.19</td>
</tr>
<tr>
<td><strong>D Radius (cm)</strong></td>
<td>11.0</td>
<td>16.1</td>
<td>9.2</td>
<td>9.9</td>
</tr>
<tr>
<td><strong>F Radius (cm)</strong></td>
<td>20.9</td>
<td>33.5</td>
<td>13.2</td>
<td>18.7</td>
</tr>
</tbody>
</table>
Injection: Commentary

- Kicker fields too high (0.5 T goal)
  - Better in doublet: longer drift
  - Use second kicker

- Magnet aperture needed close to design
  - Except when F near septum
  - Outside “good field region,” but not for long
  - FODO slightly better than doublet
Injection Doublet Commentary

- F near septum requires too much aperture
  - Want to avoid special magnets
  - Symmetry breaking bad for FFAGs
- Doublet must either inject or extract wrong way
  - Could inject vertically, extract horizontally
    - Tunes near 0.25 for both these
Injection
Doublet, F Near Septum

Horizontal Coordinate (cm)

Lonigitudinal Coordinate (m)
Lattice Tune

Cell Tune vs Total Energy (GeV)

- FODO Horizontal
- FODO Vertical
- Doublet Horizontal
- Doublet Vertical
Injection and extraction with D near septum

- Kicker in first drift more effective
  - Horizontal tune high
  - Most phase advance in D
    - First drift about 0.25 away
- Kickers half of length for doublet
Injection
FODO, Kicker in First Drift
Injection
FODO, Kicker in Second Drift
Tasks

◉ Design simplistic at this point
  ◐ Compute longitudinal parameters more carefully
  ◐ Study performance under tracking
  ◐ Study less expensive option (fewer cavities)

◉ Injection
  ◐ Study 2-kicker solutions
  ◐ Consider vertical injection with doublet