Possible layout for arc cells of HE-LHC
- With updates

Demin Zhou and Yuri Nosochkov

Acknowledgements:

2nd HE-LHC optics meeting, CERN, Aug. 08, 2017
1. Possible layouts for the arcs of HE-LHC

➤ Arcs designed by Y. Nosochkov
- 18x 60-deg (helhc_v102)
- 20x 90-deg (helhc_v201) [Almost given up because of poor geometry fit to LHC layout]
- 18x 80-deg (helhc_v300) [Preserve resonance cancelation condition: 4x2\pi ]

➤ Possible modifications using the same layout of helhc_v102
- 18x 90-deg [Preserve resonance cancelation condition if considering DS as a 90-deg cell: 4x2\pi => Add sextuples to DSs, similar as LHC]
1. Possible layouts for the arcs of HE-LHC

➤ 18x 60-deg (helhc_v102 by Y.N.)

- LB=14.18m, LQ=3.1m, LS=0.369m
- LBQ=2.358m, LSB=1.829m, LQS=0.16m, LBB=1.36m
1. Possible layouts for the arcs of HE-LHC

- 18x 80-deg (helhc_v300 by Y.N., same geometry of helhc_v102)
  - LB=14.18m, LQ=3.1m, LS=0.369m
  - LBQ=2.358m, LSB=1.829m, LQS=0.16m, LBB=1.36m
1. Possible layouts for the arcs of HE-LHC

➢ 18x 90-deg (Same geometry of helhc_v102 by Y.N.)

- $LB = 14.18\text{m}$, $LQ = 3.1\text{m}$, $LS = 0.369\text{m}$
- $LBQ = 2.358\text{m}$, $LSB = 1.829\text{m}$, $LQS = 0.16\text{m}$, $LBB = 1.36\text{m}$
1. Possible layouts for the arcs of HE-LHC

- **20x 90-deg**
  - LB = 12.625 m, LQ = 3.1 m, LS = 0.369 m
  - LBQ = 2.36 m, LSB = 1.831 m, LQS = 0.16 m, LBB = 1.36 m
1. Possible layouts for the arcs of HE-LHC

**FCC tech:** 16 T@B, 400 T/m@Q, 7800 T/m²@S

<table>
<thead>
<tr>
<th></th>
<th>LHC-like</th>
<th>18x60°</th>
<th>18x80°</th>
<th>18x90°</th>
<th>20x90°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc cell phase advance [deg]</td>
<td>90/90</td>
<td>60/60</td>
<td>80/80</td>
<td>90/90</td>
<td>90/90</td>
</tr>
<tr>
<td>Arc cell length [m]</td>
<td>106.958</td>
<td>137.233</td>
<td></td>
<td></td>
<td>124.8</td>
</tr>
<tr>
<td>K1 [m⁻¹]</td>
<td>0.027</td>
<td>0.0148</td>
<td>0.019</td>
<td>0.021</td>
<td>0.023</td>
</tr>
<tr>
<td>βmax/min [m]</td>
<td>181.3/31.5</td>
<td>236.7/79.5</td>
<td>227.7/50.0</td>
<td>233.0/40.4</td>
<td>211.7/36.8</td>
</tr>
<tr>
<td>ηmax/min [m]</td>
<td>2.2/1.1</td>
<td>6.7/4.1</td>
<td>4.3/2.2</td>
<td>3.6/1.8</td>
<td>3.0/1.5</td>
</tr>
<tr>
<td>Dipole length [m]</td>
<td>14.3 [x6]</td>
<td>14.18 [x8]</td>
<td></td>
<td></td>
<td>12.625 [x8]</td>
</tr>
<tr>
<td>Dipole field [T] @13.5TeV</td>
<td>16.06</td>
<td></td>
<td>15.59</td>
<td></td>
<td>15.92</td>
</tr>
<tr>
<td>Quad. gradient [T/m] @13.5TeV</td>
<td>391.7</td>
<td>214.8</td>
<td>276.2</td>
<td>303.9</td>
<td>334.7</td>
</tr>
<tr>
<td>Sext. gradient [T/m²] @13.5TeV</td>
<td>4883</td>
<td>866</td>
<td>1824</td>
<td>?</td>
<td>2940</td>
</tr>
<tr>
<td>Filling factor</td>
<td>0.802</td>
<td></td>
<td>0.827</td>
<td></td>
<td>0.809</td>
</tr>
</tbody>
</table>
1. Possible layouts for the arcs of HE-LHC

➤ General scaling laws

- Assume ideal FODO cell [thin-lens, 100% filling factor]

$$\sin(\Phi/2) = \frac{1}{4}K_1L_{\text{cell}}$$

$$\beta_{\pm} = \frac{2(1 \pm K_1L_{\text{cell}}/4)}{K_1 \sqrt{1 - (K_1L_{\text{cell}}/4)^2}}$$

$$\eta_{\pm} = \frac{4}{\rho K_1^2} (1 \pm K_1L_{\text{cell}}/8)$$

$$K_{2\pm} = \frac{K_1}{\eta_{\pm}}$$

Note:

Sextupole strength for chromaticity correction ONLY in arc cells.
IRs and DSs require higher $K_2$
1. Possible layouts for the arcs of HE-LHC

- General scaling laws

  - Assume ideal FODO cell [thin-lens, 100% filling factor]
  - Use 18x60 layout:

    \[ L_{\text{cell}} = 137.233 \text{ m}, \quad L_Q = 3.1 \text{ m}, \quad L_B = L_{\text{cell}}/2, \quad L_S = 0.369 \text{ m}, \quad E = 13.5 \text{ TeV} \]
1. Possible layouts for the arcs of HE-LHC

➤ General scaling laws

- Assume ideal FODO cell [thin-lens, 100% filling factor]
- Use 18x60 layout:

  \[ L_{\text{cell}} = 137.233 \text{ m}, \quad L_Q = 3.1 \text{ m}, \quad L_B = L_{\text{cell}}/2, \quad L_S = 0.369 \text{ m}, \quad E = 13.5 \text{ TeV} \]
1. Possible layouts for the arcs of HE-LHC

➢ General scaling laws

- Assume ideal FODO cell [thin-lens, 100% filling factor]
- Use 18x60 layout:

\[ L_{\text{cell}} = 137.233 \text{ m}, \quad L_Q = 3.1 \text{ m}, \quad L_B = L_{\text{cell}} / 2, \quad L_S = 0.369 \text{ m}, \quad E = 13.5 \text{ TeV} \]
1. Possible layouts for the arcs of HE-LHC

➤ General scaling laws

● Assume ideal FODO cell [thin-lens, 100% filling factor]
● Use 18x60 layout:

\[ L_{\text{cell}} = 137.233 \text{ m}, \quad L_Q = 3.1 \text{ m}, \quad L_B = \frac{L_{\text{cell}}}{2}, \quad L_S = 0.369 \text{ m}, \quad E = 13.5 \text{ TeV} \]
2. Strategy for HE-LHC design

- Task distribution
  - Arc cells and DSs
  - IR1 and IR5: Main experiment IRs
  - IR3 and IR7: collimation
  - IR4 and IR6: RF and beam dump
  - Full lattice: Global matching & optimization/chromaticity correction/toolkits
  - Beam-beam issues
  - Collective effects
  - ... ...
2. Strategy for HE-LHC design

➤ Iterative design process

● Step 1: Create arc cells, adjust DSs, matching to SLHC IRs [respect to LHC geometry]
● Step 2: IR design/update, repeat Step 1
● Step 3: Global matching&optimization/chromaticity correction
● Step 4: DA calculations with errors
● Step 5: Check challenges (technical and beam physics), if hit show-stopper, restart from Step 1
● Step 6: Collimation and other sub-system design/update (electron lens, crab cavity, etc.)