IR6 squeeze for layout HLLHCV1.2

M. Fitterer, R. De Maria

Acknowledgments: R. Bruce, S. Fartoukh, J. Uythoven, M. Fraser
Outline

1. IR6 optics – aperture optimization at injection
2. IR6 constraints from ABT and collimation
3. IR6 squeeze (round, flat, flathv)
IR6 constraints from ABT + collimation

Constraints derived from V1.0 squeeze analysis and RunII optics (M.A. Fraser, J. Uythoven, R. Bruce):

1. maximize $\beta$-functions at dump in order to ensure a sufficient distribution of the beam energy
   - Beam 1: $\beta_x > 5012$ m, $\beta_y > 3955$ m
   - Beam 2: $\beta_x > 5052$ m, $\beta_y > 3698$ m
   Limits taken not to decrease nominal LHC ones.
   -> Can they be relaxed to minimum over both beams ?
   -> What is the true minimum on the $\beta$ in one plane, what is the minimum on $\sqrt{\beta_x \beta_y}$ ? -> FLUKA simulations needed (Jan)

2. MQY.4L6.B1 and MQY.4R6.B2 constant in order to ensure enhancement of the MKD kick (1% gradient error acceptable)

3. dispersion smaller than 0.5 m in straight section (educated guess)
IR6 constraints from ABT + collimation

Constraints derived from V1.0 squeeze analysis and RunII optics (M.A. Fraser, J. Uythoven, R. Bruce):

2. asynchronous dump:
   • phase advance of $\pi/2$ between MKD and TCDQ to ensure protection by TCDQ in case of asynchronous dumps -> 10% relative error tolerable
     \[ \Delta \mu_x (\text{MKD->TCDQ}) = 0.5*\pi \pm 0.025*\pi \]
   • maximize $\beta$-functions at TCDQ in order to ensure a sufficient distribution of the beam energy (hor. less critical as already diluted by horizontal kick)
     \[ \beta_{x/y} (\text{TCDQ}) > 160 \text{ m} (= \text{nominal LHC}) \]

in addition: aperture limit at 7 TeV = $\beta_{\text{IR6}} < \beta_{\text{arc}} + 20 \text{ m}$, e.g. flat $\beta_{\text{arc}} = 1150 \text{ m}$
Injection $\beta^*=6m$ - optics

IR6 Beam 1

IR6 Beam 2

- **TCDQ (black/red)**
- **MKD**
### Injection $\beta^* = 6$ m - aperture

<table>
<thead>
<tr>
<th>layout</th>
<th>$\beta_{x/y}^* ; [\text{m}]$</th>
<th>minimum n1, Beam 1</th>
<th>minimum n1, Beam 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>element</td>
<td>value</td>
</tr>
</tbody>
</table>

*injection with MQT for adjustment of WP (beta-betating), strength unchanged

**aperture for b1 worse in order to fulfill $\beta_{x/y} (TCDQ) > 160$ m, for beam 2 dump constrained is not fulfilled $\beta_{x/y} (dump, V1.1) = 3538$ m < 3955 m

$\Rightarrow$ aperture degraded in order to meet ABT+collimation constraints  
+ n1>9.4 in straight section

$\Rightarrow$ relaxation of $\beta_{x/y} (TCDQ)$ or $\beta_{x/y} (dump)$ would improve aperture at injection (see V1.1 optics)
Injection $\beta^* = 6m$ - aperture

9.4 (real target to be defined)
Squeeze round: 0.48 m -> 0.15 m

- not possible to remove (origin kq10.l6b1)
- no change of slope

WP2 Task Leader meeting, Squeeze IR6 for HL-LHC layout V1.2, 09.09.2015
very difficult to remove
- small change results
  in large impact on
  other quadrupoles

no change of slope

results in change of slope in kq4.r6b1

flat 0.40/0.10 m

round
induces strong changes of slope in \( k_{q5,l6b1}, k_{q9,r6b1}, k_{q10,r6b1}, k_{q10,l6b1}, \ldots \)

induces strong change of slope in \( k_{q4,l6b2} \)

Squeeze flathv: 0.48 m \( \rightarrow \) 0.30/0.075 m

round

flat 0.10/0.40 m
Summary

1. injection aperture could be improved if $\beta_{x/y}$ (TCDQ) or $\beta_{x/y}$ (dump) are relaxed

2. round, flat and flathv meet ABT/collimation constraints (MQY4 strength for kick enhancement, maximum beta at dump and TCDQ for dump and asynchronous dump protection, dispersion)

3. smoothness of flat and flathv could be improved by squeezing both planes equally fast. Each change in the squeeze causes “steps”. Ideal squeeze x/y-ratio for $\beta^*$-leveling to be defined.
The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.
## beta @ MKD and TCDQ

<table>
<thead>
<tr>
<th>layout</th>
<th>$\beta_{x/y}$ * [m]</th>
<th>MKD.H5[LR]6.B[12], $\beta$ [m]</th>
<th>TCDQA.A4[LR]6.B[12], $\beta$ [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$x$, $b1$</td>
<td>$y$, $b1$</td>
</tr>
<tr>
<td>LHC, RunI</td>
<td>0.6/0.6</td>
<td>382</td>
<td>356</td>
</tr>
<tr>
<td>LHC, RunII*</td>
<td>0.8/0.8</td>
<td>382</td>
<td>356</td>
</tr>
<tr>
<td>HLLHCV1.0</td>
<td>0.15/0.15</td>
<td>195</td>
<td>460</td>
</tr>
<tr>
<td>HLLHCV1.1</td>
<td>0.15/0.15</td>
<td>232</td>
<td>438</td>
</tr>
<tr>
<td>HLLHCV1.2</td>
<td>0.15/0.15</td>
<td>258</td>
<td>363</td>
</tr>
<tr>
<td>HLLHCV1.2</td>
<td>0.075/0.3</td>
<td>380</td>
<td>327</td>
</tr>
<tr>
<td>HLLHCV1.2</td>
<td>0.3/0.075</td>
<td>270</td>
<td>320</td>
</tr>
</tbody>
</table>

*injection with MQT for adjustment of WP (beta-betating), strength unchanged*
Injection $\beta^* = 6m$ - aperture

9.4 (real target to be defined)
Squeeze round with V1.1 injection endpoint

WP2 Task Leader meeting, Squeeze IR6 for HL-LHC layout V1.2, 09.09.2015