Update on Interaction Region description at 10 TeV

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04-March-2022
In the following slides a first version of a FF scheme for the 10TeV Muon collider with only combined function magnets is presented.

This new FF scheme is an update of an earlier version presented here.

**TABLE I. 10 TeV center of mass energy muon collider.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Unit</th>
<th>10TeV com mc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle energy</td>
<td>$E$</td>
<td>GeV</td>
<td>5000</td>
</tr>
<tr>
<td>Particle momentum</td>
<td>$P_0$</td>
<td>GeV c$^{-1}$</td>
<td>5000</td>
</tr>
<tr>
<td>Luminosity</td>
<td>$\mathcal{L}$</td>
<td>$10^{34}$ cm$^{-2}$ s$^{-1}$</td>
<td>20</td>
</tr>
<tr>
<td>Bunch population</td>
<td>$N_p$</td>
<td>$10^{12}$ ppb</td>
<td>1.8</td>
</tr>
<tr>
<td>Transverse normalized rms emittance</td>
<td>$\varepsilon_{nx} = \varepsilon_{ny}$</td>
<td>$\mu$m</td>
<td>25</td>
</tr>
<tr>
<td>Longitudinal emittance ($4\pi \sigma_E \sigma_T$)</td>
<td>$\varepsilon_l$</td>
<td>eVs</td>
<td>0.314</td>
</tr>
<tr>
<td>Rms bunch length</td>
<td>$\sigma_z$</td>
<td>mm</td>
<td>1.5</td>
</tr>
<tr>
<td>Relative rms energy spread</td>
<td>$\delta$</td>
<td>%</td>
<td>0.1</td>
</tr>
<tr>
<td>Beta function at IP</td>
<td>$\beta_x^* = \beta_y^*$</td>
<td>mm</td>
<td>1.5</td>
</tr>
<tr>
<td>Beam power with 10 Hz repetition rate</td>
<td>$P_{\text{beam}}$</td>
<td>MW</td>
<td>14.4</td>
</tr>
</tbody>
</table>
Interaction Region - Final Focusing scheme

• $L^* = 6\text{m}$.

• The maximum allowed magnetic field at the FF scheme is assumed to be the 20T.

• In this version of the FF scheme only combined function dipole-quadrupole magnets are used where the dipolar component is 2T for all magnets.

• With the addition of a 2T dipolar component and the use of circular magnet aperture, the available gradient is reduced and therefore, the length of the FF scheme is increased by $\sim 4.5\text{m} (\sim 6.9\%)$ over the case with only quads.

• Due to the abrupt increase of the $\beta$ functions right after the IP, the first magnet is splitted in three shorter ones with different gradient, reducing that way the length of the FF scheme (this treatment is not needed for the last two magnets).

• The last two elements of the FF triplet are used for the point to parallel matching ($\alpha_{x,y} = 0$ at the FF triplet end).
Interaction region - FF scheme

Blue hashed boxes are the dipole-quadrupole magnets

- $\beta_x$
- $\beta_y$
- $D_x$
- $5\sigma + 2[\text{cm}]$

Chromatic functions ($W_{x,y}$ and $D_{D_x}$) developed in FF scheme

$L = 35.15 \, [\text{m}]$

$L^* = 6 \, \text{m}$
Interaction region - FF scheme

Blue hashed boxes are the dipole-quadrupole magnets

<table>
<thead>
<tr>
<th>Name</th>
<th>$B_{tot}$ [T]</th>
<th>$B_d$ [T]</th>
<th>Aperture [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>iqf1</td>
<td>20</td>
<td>2</td>
<td>8.67</td>
</tr>
<tr>
<td>iqf1a</td>
<td>20</td>
<td>2</td>
<td>10.88</td>
</tr>
<tr>
<td>iqf1b</td>
<td>20</td>
<td>2</td>
<td>13.81</td>
</tr>
<tr>
<td>iqd1</td>
<td>20</td>
<td>2</td>
<td>22.09</td>
</tr>
<tr>
<td>iqf2</td>
<td>20</td>
<td>2</td>
<td>19.36</td>
</tr>
</tbody>
</table>

Total deflection angle from the FF scheme is ~6.7 mrad (1/$\gamma_r$~2.1E-5)
Interaction region - FF scheme

• If the 20T are not realistic and drop to 16T that is the FCC target, the same IR scheme (with similar quadrupole gradients) can be used with one or a combination of the following modifications:

  ▪ reduction of the com energy to 8TeV, this configuration reaches the design luminosity for an 8TeV com muon collider (as $\beta^*$ is inversely proportional to the energy)

  ▪ reduction of the apertures without significantly changing the gradients:

    • by reducing the beam envelope to $4\sigma+1.5$cm, the luminosity degradation is negligible (less than 1%)

    • by increasing the $\beta^*$ by a factor $\sim 2.04$ (a bit larger than $(5/4)^2$)
A first design of the FF triplet with combined function magnets is shown.

The addition of a 2T dipolar component at every magnet of the FF scheme and the use of circular magnet aperture increase the length of the FF scheme.

Need to clarify if the:
- 2T at the FF triplet improve the BIB or if a stronger dipolar component is needed
- 20T of the FF magnets is feasible
- ...
Thank you for your time.
Interaction region - FF scheme

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  - reduction of the com energy to 8TeV, this configuration reaches the design luminosity for an 8TeV com muon collider (as $\beta^*$ is inversely proportional to the energy)
  - reduction of the beam envelope to $4\sigma + 1.5$cm, the luminosity degradation is negligible (less than 1%)
  - increase of the $\beta^*$ by a factor $(10/7)^2 \sim 2.04$ (a bit larger than $(5/4)^2$)

- These modifications are associated with the free parameters ($E$, $\lambda$, $\beta^*$) in the following approximated equation for the magnetic field in a quadrupole:

\[
B_k \approx \frac{k_1 \beta_r E}{e c} \sqrt{\frac{e_n \nu m_0 c^2}{\beta_r E}} \frac{s}{\sqrt{\beta^*_\nu}} \sim \lambda \sqrt{\frac{E}{\beta^*_\nu}}
\]

$\lambda$ is a real positive number (define particle distance from reference orbit in terms of rms beam size) and $\nu=x$ if $k=y$ or $\nu=y$ if $k=x$. 