Interaction region of $c\tau$ project

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Parameters for interaction region

<table>
<thead>
<tr>
<th>Energy, GeV</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam current, A</td>
<td>1.36</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>295</td>
</tr>
<tr>
<td>$\beta_x$, mm</td>
<td>20</td>
</tr>
<tr>
<td>$\beta_y$, mm</td>
<td>0.76</td>
</tr>
<tr>
<td>$\varepsilon_x$, nm rad</td>
<td>10</td>
</tr>
<tr>
<td>Coupling $\varepsilon_y/\varepsilon_x$, %</td>
<td>1</td>
</tr>
<tr>
<td>Beam length $\sigma_z$, cm</td>
<td>1</td>
</tr>
<tr>
<td>Crossing angle, mrad</td>
<td>34</td>
</tr>
<tr>
<td>Tune shift $\xi_y$</td>
<td>0.13</td>
</tr>
<tr>
<td>Particles per bunch</td>
<td>$7 \cdot 10^{10}$</td>
</tr>
<tr>
<td>Luminosity, cm$^{-2}$sec$^{-1}$</td>
<td>$1 \cdot 10^{35}$</td>
</tr>
<tr>
<td>Hour glass $\frac{\sigma_x}{\theta \beta_y}$</td>
<td>1.095</td>
</tr>
<tr>
<td>Piwinski angle $\varphi = \frac{\sigma_z \theta}{\sigma_x}$</td>
<td>12</td>
</tr>
</tbody>
</table>

✦ No bend for incoming beam.
✦ No longitudinal field integral over each final focus lens.
✦ Longitudinal field is compensated before each final focus lens.
✦ Interaction region length less than 100 m.
✦ Place for CRAB sextupole.
Blocks of interaction region

FFT — YCCS — XCCS — CRAB — ET

SIR experimental region
Crab sextupole and beta chromaticity correction
Unix version 8.5/15 15/09/08 15.01.34

\[ \delta_{v/p_0c} = 0.000000E+00 \]

Table name = TWISS

CRAB:
\[ \mu_x = 2\pi \]
\[ \mu_y = 2.75\pi \]
Map: \[ R = \begin{pmatrix} R_{11} & 0 \\ 0 & R_{22} \end{pmatrix} \]

Twiss transformation:

\[ \beta = R_{11}^2 \beta_0 \]
\[ \alpha = \alpha_0 = 0 \]
\[ \gamma = R_{22}^2 \gamma_0 \]

Simple formulae for chromaticities and \( d\beta/d\delta = 0 \):

\[ R_{11}(\delta) = R_{11} + T_{116} \delta + U_{1166} \delta^2 \]

\[ \frac{d\mu_x}{d\delta} = \frac{T_{126}}{\beta_0 R_{11}} \]
\[ \frac{d^2 \mu_x}{d\delta^2} = \frac{2U_{1266}}{\beta_0 R_{11}} - 2 \frac{T_{126} T_{116}}{\beta_0 R_{11}^2} \]

\[ \beta = R_{11} \beta_0 + \delta \left[ 2 R_{11} T_{116} \beta_0 \right] + \delta^2 \left[ (T_{116}^2 + 2 R_{11} U_{1166}) \beta_0 + \frac{T_{126}^2}{\beta_0} \right] \]

\[ \alpha = \delta \left[ -R_{11} T_{216} \beta_0 - \frac{T_{126} R_{22}}{\beta_0} \right] + \delta^2 \left[ -\beta_0 \left( R_{11} U_{2166} + T_{116} T_{216} \right) - \gamma_0 \left( R_{12} U_{2266} + T_{126} T_{226} + U_{1266} R_{22} \right) \right] \]
General chromaticity formulae

\[ \frac{d\mu}{d\delta} = \frac{1}{2} \int_0^\Pi \beta_0(s) \left[ S(s)D_0(s) - K(s) \right] ds \]

\[ \frac{d^2\mu}{d\delta^2} = \frac{1}{2} \int_0^\Pi \beta_1(s) \left[ S(s)D_0(s) - K(s) \right] ds + \int_0^\Pi \beta_0(s)S(s)D_1(s)ds - 2 \frac{d\mu}{d\delta} \]

\[ \frac{\beta_1(s)}{\beta_0(s)} = \frac{1}{\beta_0(s)} \frac{d\beta}{d\delta}(s) = \frac{1}{2 \sin(\mu_0)} \int_s^{s+\Pi} \left[ S(s')D_0(s') - K(s') \right] \beta_0(s') \times \cos \left( \mu_0 - 2 |\mu(s') - \mu(s)| \right) ds' \]

\[ D_1(s) = \frac{dD}{d\delta}(s) = -\frac{\sqrt{\beta_0(s)}}{\sin(\mu_0/2)} \int_s^{s+\Pi} \sqrt{\beta_0(s')} \left[ S(s')D_0(s') - K(s') \right] \times D_0(s') \cos \left( \frac{\mu_0}{2} - |\mu(s') - \mu(s)| \right) ds' \]

T. Sen and M. Syphers "Second Order Chromaticity of the Interaction Regions in the Collider"
Telescope because of easy tuning and simplicity of chromatic analysis.

Two pairs of sextupoles at \( n\pi \) phase advance from two FF lenses respectfully and \(-I\) map inside the pair.

CRAB sextupole at \( \mu_x = \pi m \) and \( \mu_y = \pi(2n + 1)/2 \) from IP and zero dispersion.

Additional sextupoles: low beta functions but high beta chromaticity, high second order dispersion, weaker than main sextupoles.

Octupoles: high beta and dispersion.
Final lens trajectories

Trajectories at 15°

G1 = -2.9 kGs/cm  G2 = 1.5 kGs/cm  θ = 34 mrad

Trajectories at 50°
\[ \frac{\delta_E}{p_0 c} = 0.0000000 \times 10^0 \]

Table name = TWISS
Nonlinear elements SIR
Chromatic functions

RINGIP2

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\[ \frac{\delta E}{p_0 c} = 0.000000E+00 \]

Table name = TWISS
$\mu$ dependence on $\delta$

**RINGIP2**

$Q_x$  $Q_y$

**Table name = TUNES**
$\beta_{IP}$ dependence on $\delta$

**RINGIP2**

\[ dBX/BX \quad dBY/BY \]

**Table name = SPECIAL**
Survey plot of IR

\[ X, m \]

\[ S, m \]
Conclusion

- Designed interaction region provides luminosity of $10^{35}$ cm$^{-2}$sec$^{-1}$ with not extreme parameters.
- There is freedom in beam-beam tune shift, which allows to decrease coupling coefficient and increase luminosity.
- The presented interaction region satisfies all geometrical constraints.
- Sufficient energy aperture ($\pm 1\%$) is obtained.
- Dynamic aperture is small and requires further optimization.