New Optics for the Tevatron

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Contents

1. Optics measurement using orbit response matrix fit
2. Basic luminosity formulae
3. Implementation of the beta*=28cm optics
4. Results of the optics correction
5. End of store studies
6. Summary and outlook
Using the differential orbit measurements and response matrix fit we find the following machine parameters:

- Quadrupole gradient errors (~2e-3)
- Quadrupole tilts
- Steering magnet calibrations
- Steering magnet tilts
- BPM gains
- BPM tilts

A computer model was built based on the measurements with beta function accuracy of ~5% (cross-checked with other methods)
Skew-Quadrupole Errors

Integrated Quad Strength (kGs)

Skew-Quads
Skew Quadrupole Errors at D16 and A38

Based on Tech data:

• At D-16, quadrupole TQ184D has the lugs set incorrectly for the roll angle. If we call the correct orientation straight up, when the lugs are set level the field is pointing 12 mr toward the aisle.

• At A-39, quadrupole TQ096D has the lugs set incorrectly for the roll angle. If we call the correct orientation straight up, when the lugs are set level the field is pointing 10 mr toward the aisle.
Present Beta Functions

![Graph of Beta Functions]

<table>
<thead>
<tr>
<th></th>
<th>$\beta_x$ (cm)</th>
<th>$\beta_y$ (cm)</th>
<th>± 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDF</td>
<td>32.0</td>
<td>37.1</td>
<td>± 5%</td>
</tr>
<tr>
<td>DO</td>
<td>35.8</td>
<td>40.0</td>
<td>± 5%</td>
</tr>
</tbody>
</table>
Lattice and Luminosity

\[
L = \frac{N_p N_a f \cdot H(\beta^*/\sigma)}{2\pi \sqrt{\sigma_{p,x}^2 + \sigma_{a,x}^2 \sqrt{\sigma_{p,y}^2 + \sigma_{a,y}^2}} = \frac{N_p N_a f \cdot H(\beta^*/\sigma)}{2\pi \sqrt{\varepsilon_{p,x} \varepsilon_{p,y} + \varepsilon_{a,x} \varepsilon_{a,y} + \varepsilon_{a,y} \varepsilon_{a,y}}}
\]

\[
\beta(z) = \beta^* + z^2 / \beta^*
\]

Beta* 35cm -> 28cm gain is 11% not 25%!
Dynamic Beta Effect

Beam-Beam parameter \( \xi = \frac{N_p r_p}{4\pi\varepsilon_p} = 0.01 \)

\[
M = \begin{pmatrix}
\cos \mu & \beta^* \sin \mu \\
-\frac{1}{\beta^*} \sin \mu & \cos \mu
\end{pmatrix}
\begin{pmatrix}
1 & 0 \\
-\frac{4\pi}{\beta^*} \xi & 1
\end{pmatrix}
\]

\[
\mu' = \mu + 2\pi \xi
\]

\[
\beta' = \beta^* \frac{\sin \mu}{\sin \mu'}
\]
The Proposed Optics Correction

- Decrease beta* from 35 to 28 cm
- Eliminate difference between B0 and D0 IPs
- Correct beta-beating in the arcs

<table>
<thead>
<tr>
<th>Element</th>
<th>Present I (A)</th>
<th>Delta I (A)</th>
<th>New I (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C: AQ0F</td>
<td>100.7</td>
<td>100</td>
<td>200.7</td>
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<tr>
<td>C: AQ9F</td>
<td>555.6</td>
<td>-50</td>
<td>505.6</td>
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<tr>
<td>C: AQ7F</td>
<td>602.6</td>
<td>100</td>
<td>702.6</td>
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<tr>
<td>C: B0Q6F</td>
<td>3647.4</td>
<td>780</td>
<td>4427.4</td>
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<tr>
<td>C: B0QT6F</td>
<td>-22.9</td>
<td>5</td>
<td>-17.9</td>
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<tr>
<td>C: B0Q5F</td>
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<td>-40</td>
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<td>681.0</td>
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<tr>
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<tr>
<td>C: DOQ5F</td>
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<tr>
<td>C: DOQT3F</td>
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<tr>
<td>C: DQ7F</td>
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<td>714.5</td>
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<td>C: DQ9F</td>
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<tr>
<td>C: DQ0F</td>
<td>46.3</td>
<td>80</td>
<td>126.3</td>
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Beta Functions After Correction

<table>
<thead>
<tr>
<th></th>
<th>$\beta_x^*$ (cm)</th>
<th>$\beta_y^*$ (cm)</th>
<th>±5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDF</td>
<td>30.3</td>
<td>29.1</td>
<td>±5%</td>
</tr>
<tr>
<td>D0</td>
<td>29.2</td>
<td>28.2</td>
<td>±5%</td>
</tr>
</tbody>
</table>
End of Store Studies 8/4 and 8/26

Fast (30 s) transition to the new optics with sequencer works. No increase of losses. Luminosity gain was ~3% in CDF, ~5% in D0.
CDF Measurement of beta* in 8/26 EOS

(Chris Neu)

With Default Lattice

\[ \epsilon = 2.094 \times 10^{-07} \pm 1.424 \times 10^{-08} \]
\[ \beta^* = 25.68 \pm 2.488 \]
\[ z_0 = 2.219 \pm 1.623 \]

Beam width in xz plane - SVT track pairs

\[ \epsilon = 2.128 \times 10^{-07} \pm 1.747 \times 10^{-08} \]
\[ \beta^* = 38.48 \pm 4.153 \]
\[ z_0 = 0.9134 \pm 2.103 \]

Beam width in yz plane - SVT track pairs
CDF Measurement of beta* in 8/26 EOS
(Chris Neu)

With $\beta^*=28\text{cm lattice}$

- Beam width in xz plane - SVT track pairs

- $\epsilon = 2.196 \times 10^{-7} \pm 1.478 \times 10^{-8}$
  - $\beta' = 25.3 \pm 2.428$
  - $z_0 = 4.089 \pm 1.637$

- Beam width in yz plane - SVT track pairs

- $\epsilon = 2.59 \times 10^{-7} \pm 1.97 \times 10^{-8}$
  - $\beta' = 32.82 \pm 3.485$
  - $z_0 = 9.398 \pm 1.823$
Summary

- Response matrix fit method with the new BPM system allows beta function measurement with the accuracy of 5%
- The optics modification has been developed in order to:
  - Correct beta-beating in the arcs
  - Eliminate the difference between the two IPs
  - Decrease the beta* from 35 to 28 cm
- Expected increase of the peak luminosity is ~7% in CDF and ~12% in D0
- The new optics has been implemented during EOS Tev studies with the positive effect immediately observed
- Beta* reduction is confirmed by CDF measurements
- The new optics is ready for use earlier in a store. Minor adjustments can be made without interference with collider operation