Using CDF and D0 to Understand the Tevatron

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DOE Review

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Three Ways to Use CDF and D0 Data

- Computed versus measured luminosity
  - Cross check on instrumentation, β^*

- Size of the luminous region versus z
  - Information on lattice at interaction points, emittances
  - Use silicon vertex detectors for very accurate determination
  - Stan Lai, William Trischuk, U. of Toronto, et al
  - Juan Estrada, Avdhesh Chandra, D0, et al

- σ_z of proton and anti-proton bunches
  - Time of flight and Central Tracking Chamber in CDF
  - Mathew Jones, U. of Penn.

Calculated Luminosity

$$L = \frac{10^{-5} fBN_p N_{\bar{p}} \left(6\beta_r \gamma_r\right)}{2\pi\beta^* \sqrt{\left(\varepsilon_p + \varepsilon_{\bar{p}}\right)_x \left(\varepsilon_p + \varepsilon_{\bar{p}}\right)_y}} H\left(\sigma_l / \beta^*\right)$$

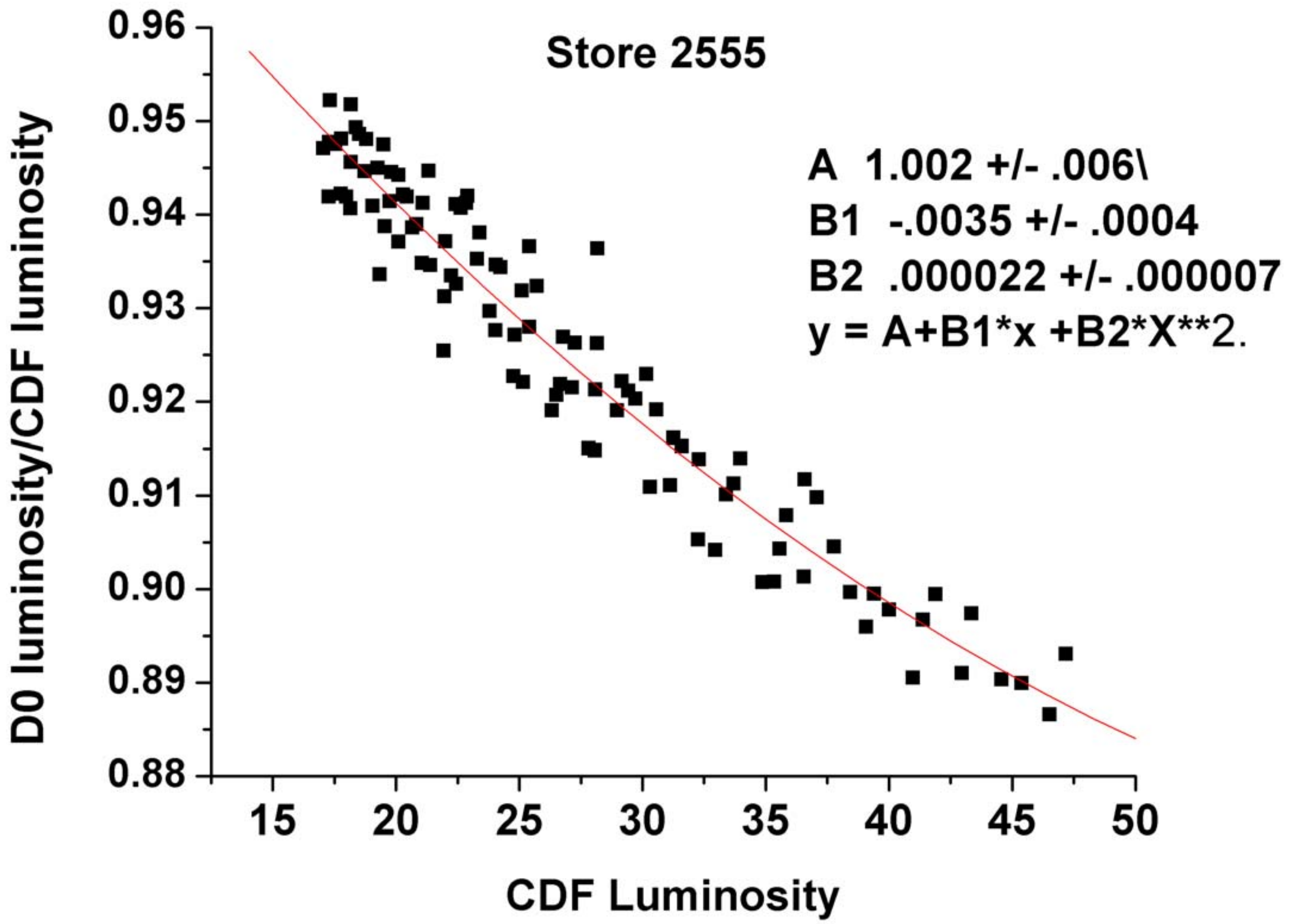
. (1)

N = numbers of protons, anti-protons per bunch (10^9)
B = number of bunches (36)
f = revolution frequency (47.7 KHz)
$B_r\gamma_r$ = relativistic factor, 1045
β^* = interaction point (cm, assumed equal in x and y).
H = hourglass factor, function of $\sigma_{l,}$ bunch length, β^*
ε = transverse emittances

Measured Luminosity

- CDF – CLC (Cherenkov Luminosity Counter)
- D0 – system of scintillation counters
- Accurate measurement crucial to experiments for cross section determination
  - Goal is 5% systematic error, < 1% statistical error
- Systematic difference between D0 and CDF
  - Ratio is linear with luminosity
  - 10% difference at 4.0 10^{31}

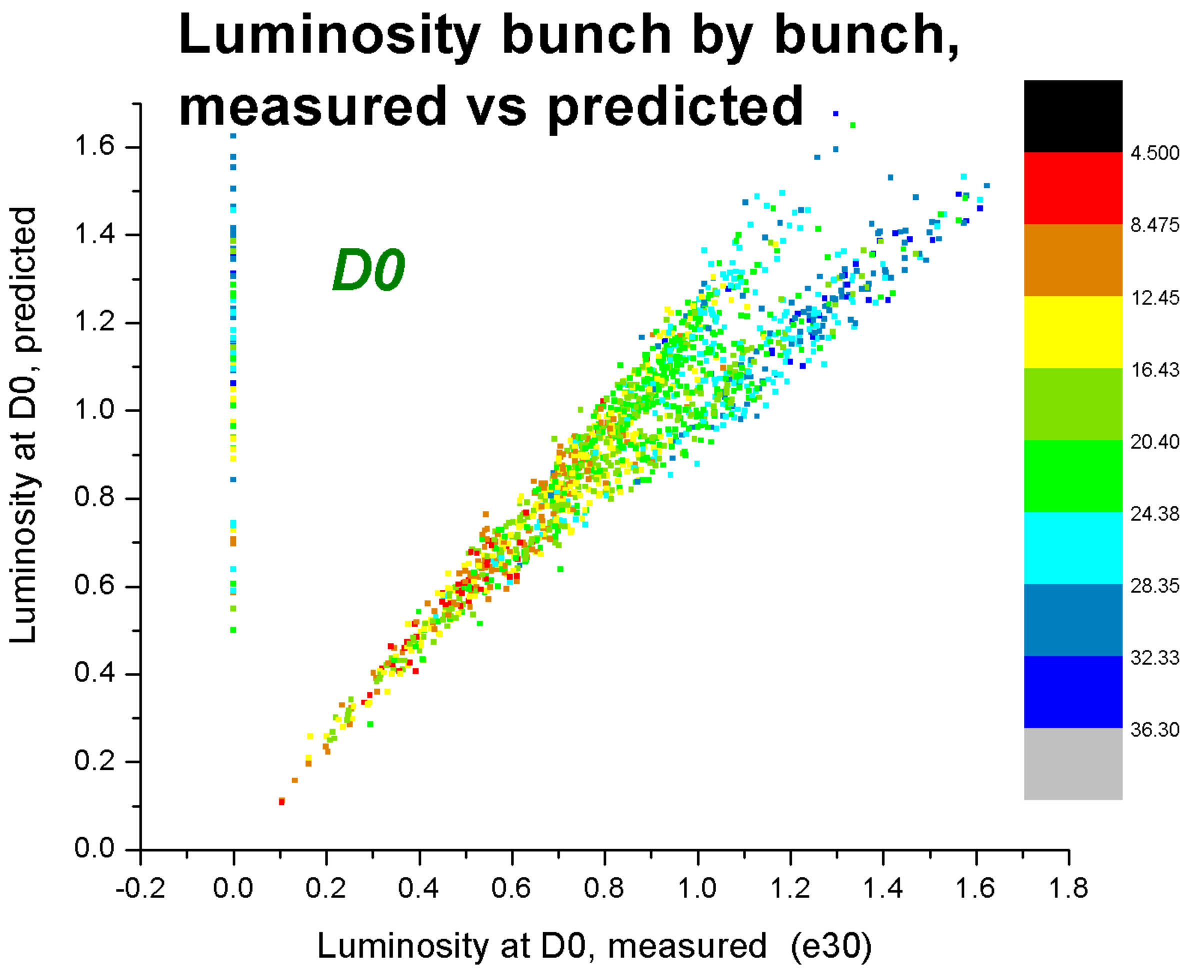
Ratio of D0 to CDF Luminosity



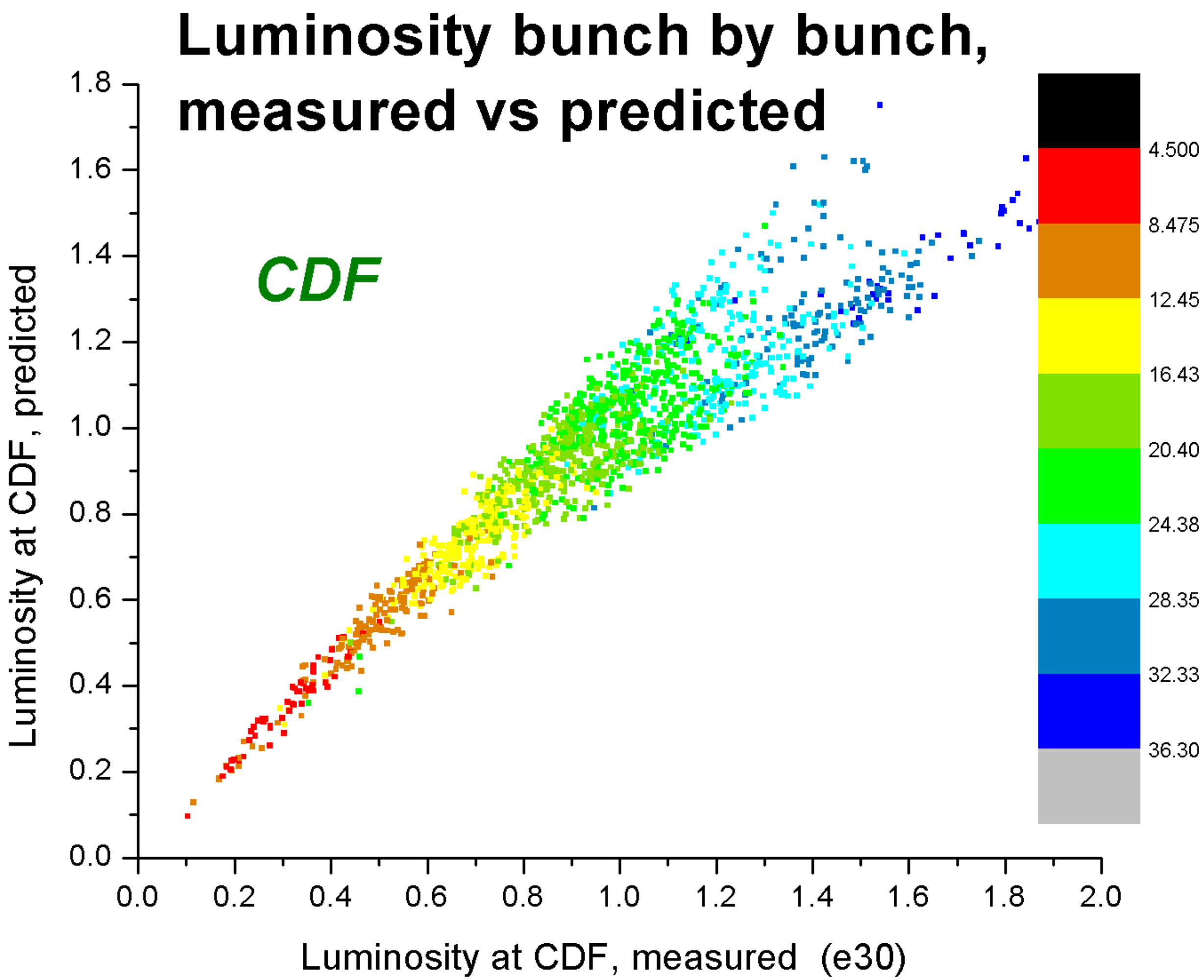
Components to Calculated Luminosity

- Number of protons, anti-protons
  - FBI (Fast Bunch Integrator) or SBD (Sampled Bunch Display)
- Transverse emittances
  - SyncLite
- Bunch lengths
  - SBD

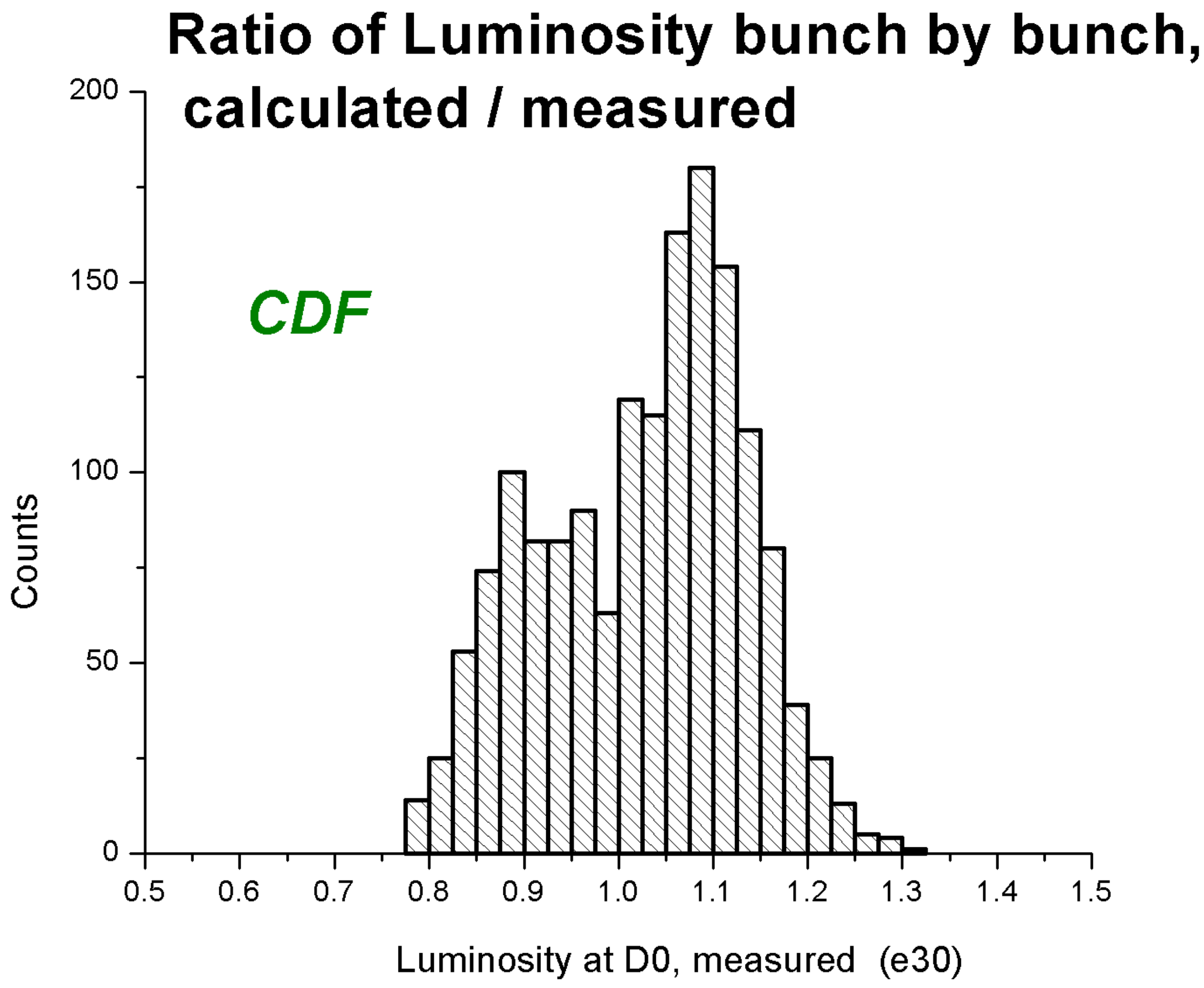
D0 Measured Luminosity versus Calculated Luminosity



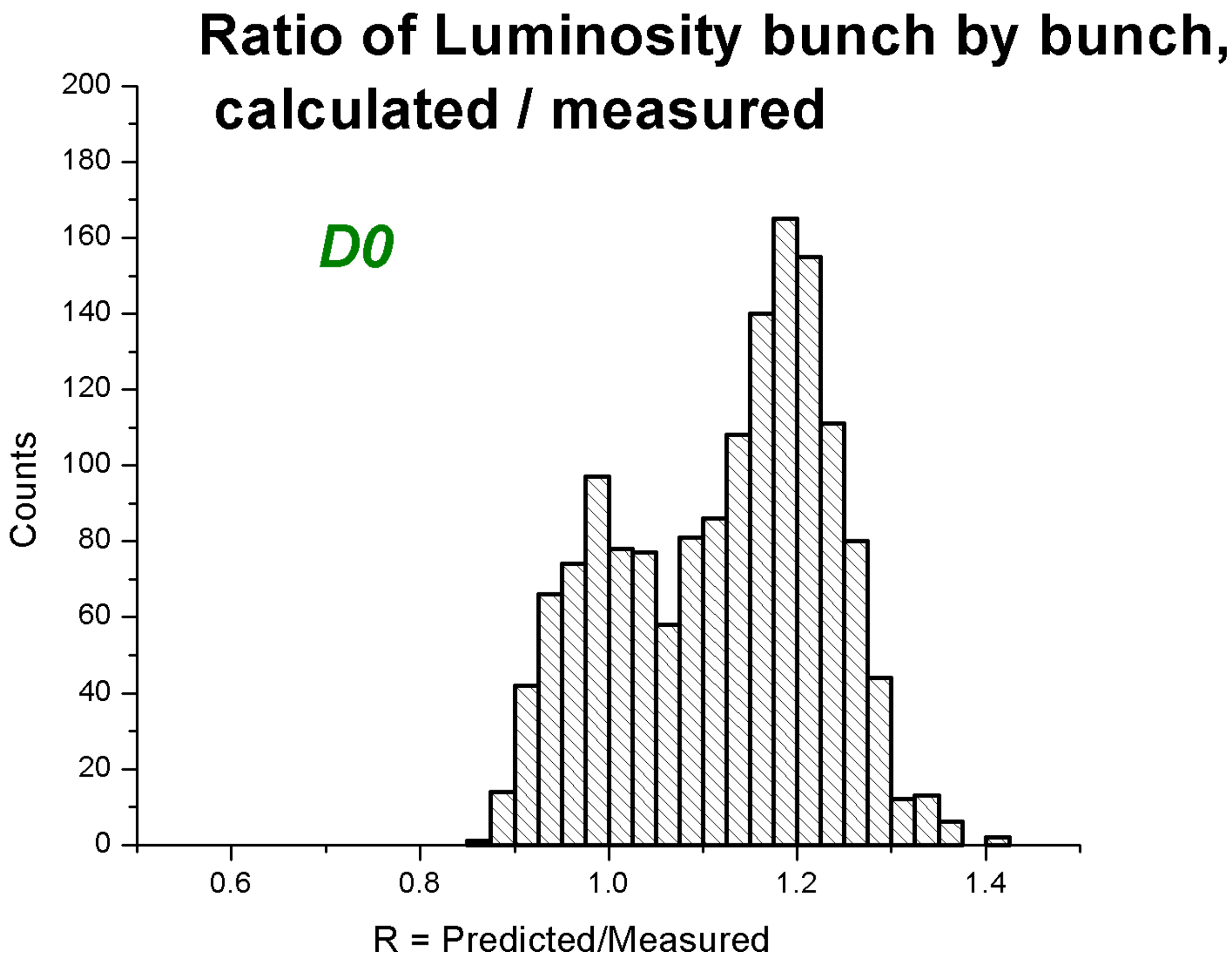
CDF measured Luminosity versus Calculated Luminosity



CDF Ratio


Ratio of Luminosity bunch by bunch,
calculated / measured
CDF
Counts
200
150
100
50
0
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
Luminosity at D0, measured (e30)

D0 Ratio


Ratio of Luminosity bunch by bunch,
calculated / measured
D0
Counts
200
180
160
140
120
100
80
60
40
20
0
0.6
0.8
1.0
1.2
1.4
R = Predicted/Measured

Use Silicon Detectors for Size of the Luminous Region

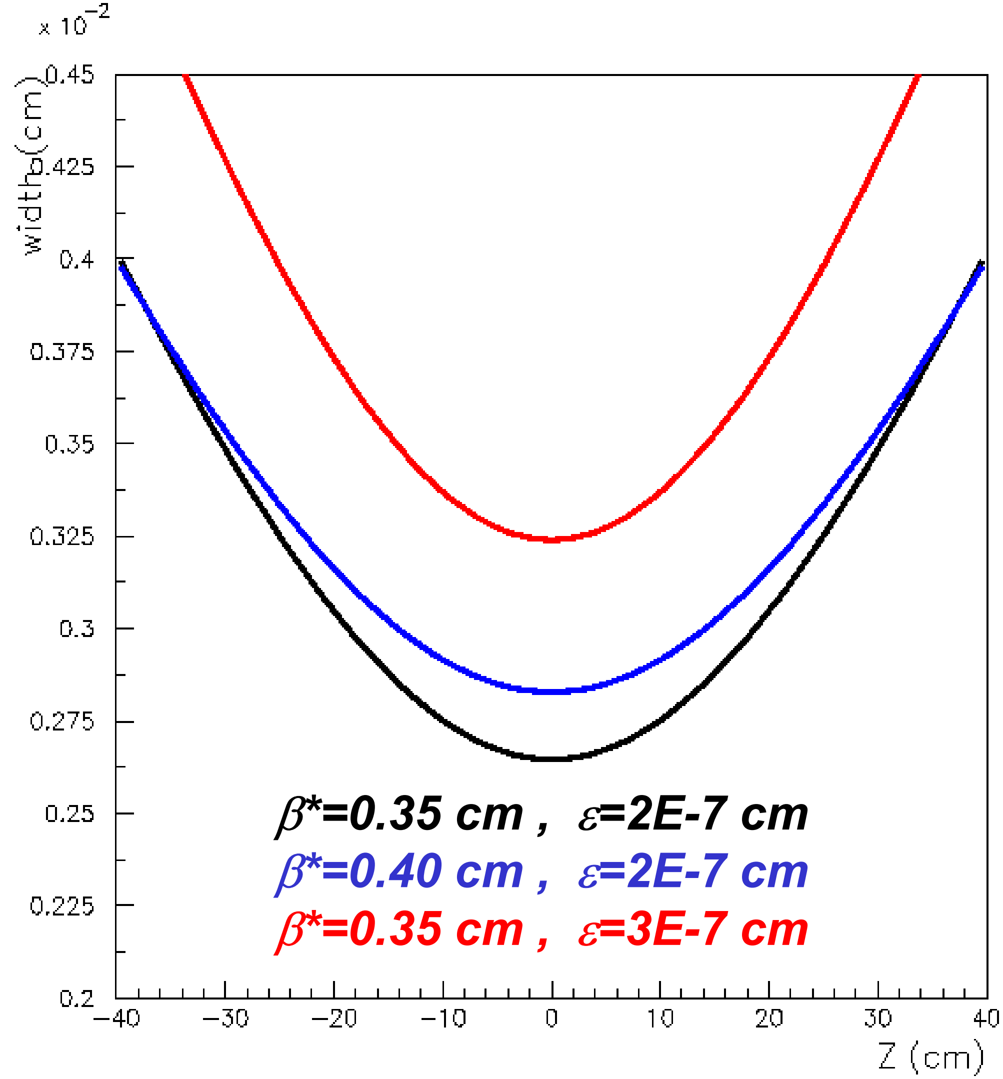
.

$$\sigma^2 = \varepsilon_{eff}\left[\beta^* + \frac{(z - z_0)^2}{\beta^*}\right]$$

$$\varepsilon_{eff} = \frac{\varepsilon_p \varepsilon_{pbar}}{\varepsilon_p + \varepsilon_{pbar}}$$

Nominal value has ***β* = 0.35 cm.***

Two methods
1. vertices
2. distance of closest approach for 2 track pairs



Method 1 - Use Vertexes

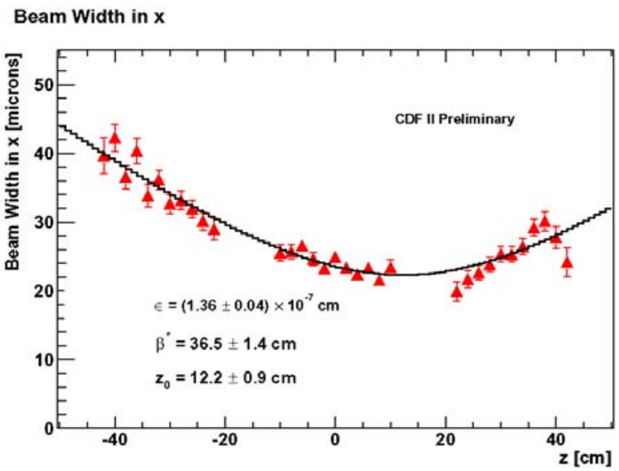
- Given a distribution of vertexes (x_i, y_i, z_i) then observed width is:

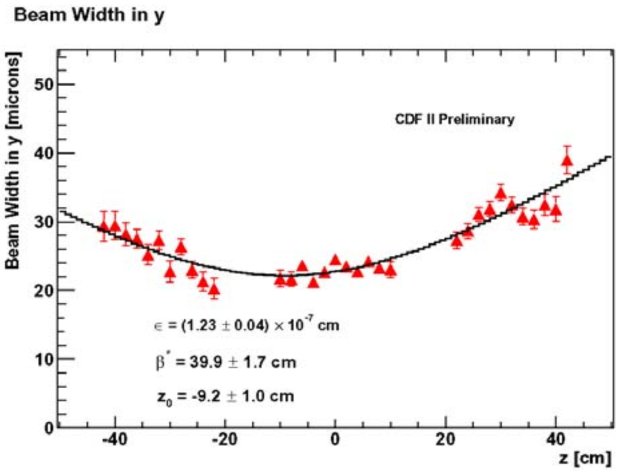
$$\sigma_{obs}^2 = \sigma_{beam}^2 + \sigma_{vertex}^2$$

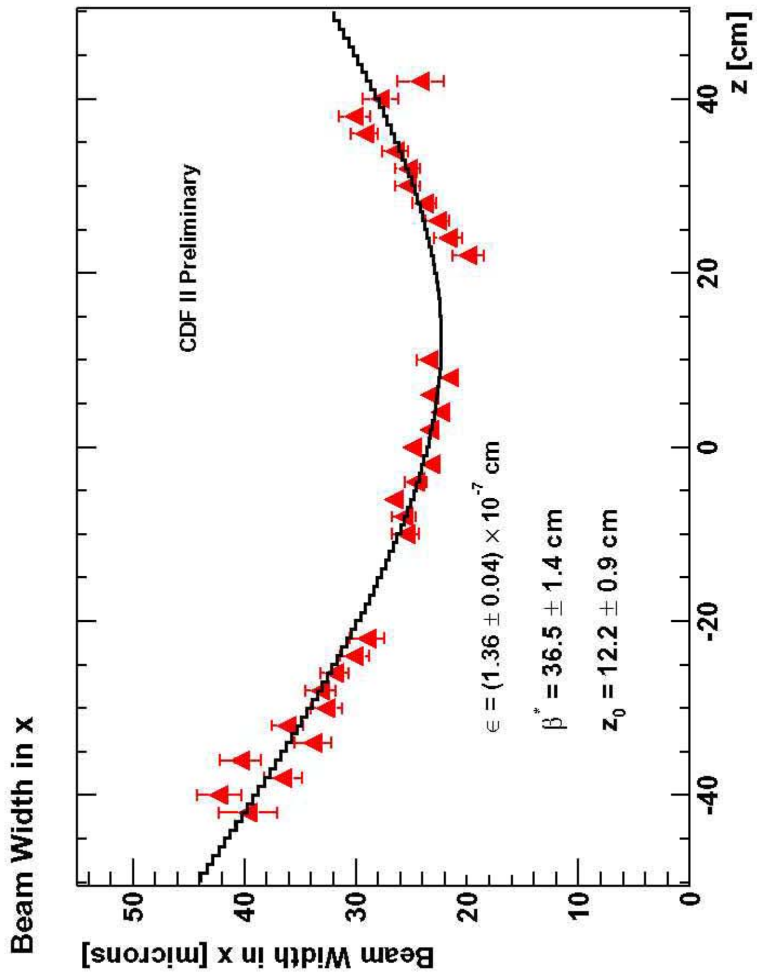
- σ_{beam} = width of the luminous region
- σ_{vertex} = error in the vertex position
- Problem - estimate for σ_{vertex} is smaller than the real error in the vertex, so find k from the data doing a linear fit

$$\sigma_{obs}^2 = \sigma_{beam}^2 + k \times \sigma_{vertex}^2$$

CDF results


Beam Width in x
Beam Width in x [microns]
CDF II Preliminary
$\epsilon = (1.36 \pm 0.04) \times 10^{-7}$ cm
$\beta^* = 36.5 \pm 1.4$ cm
$z_0 = 12.2 \pm 0.9$ cm
z [cm]


Beam Width in y
Beam Width in y [microns]
CDF II Preliminary
$\epsilon = (1.23 \pm 0.04) \times 10^{-7}$ cm
$\beta^* = 39.9 \pm 1.7$ cm
$z_0 = -9.2 \pm 1.0$ cm
z [cm]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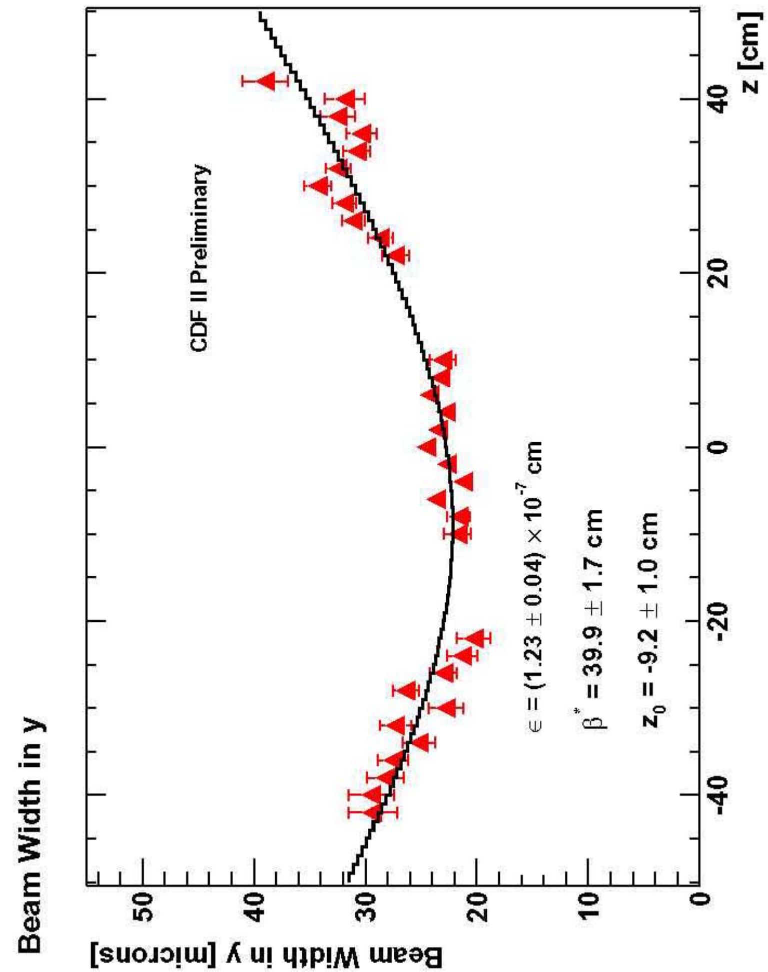
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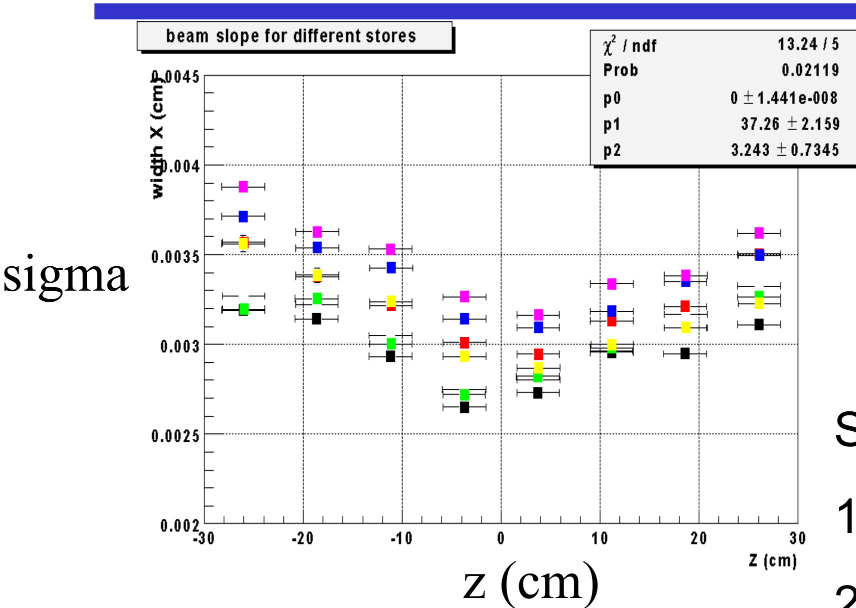
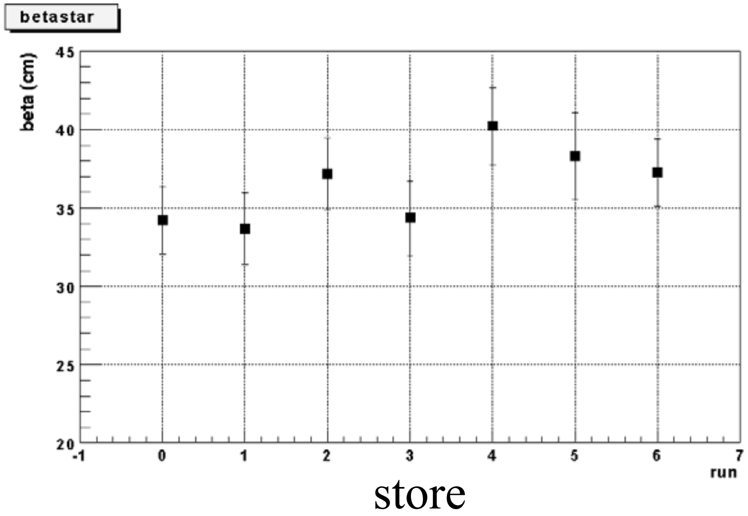
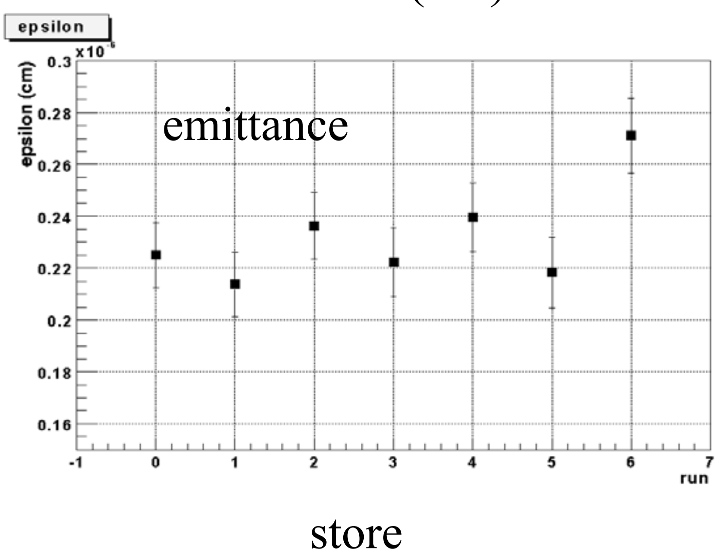
Results for X - D0

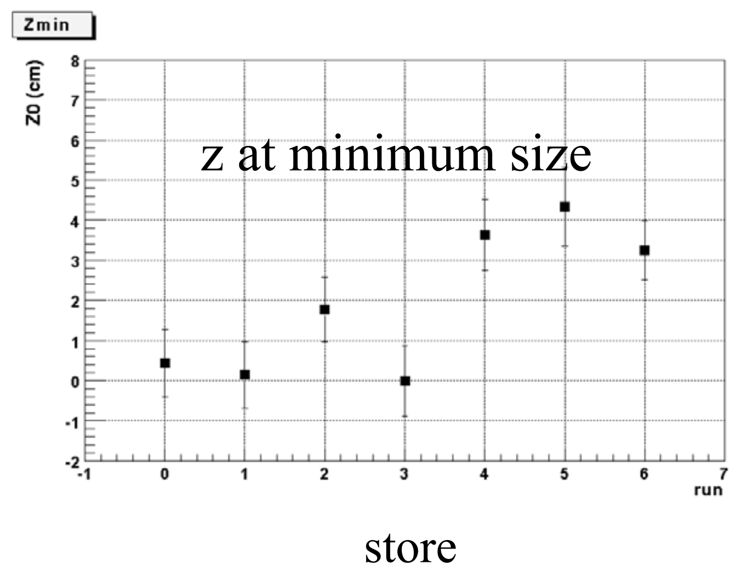




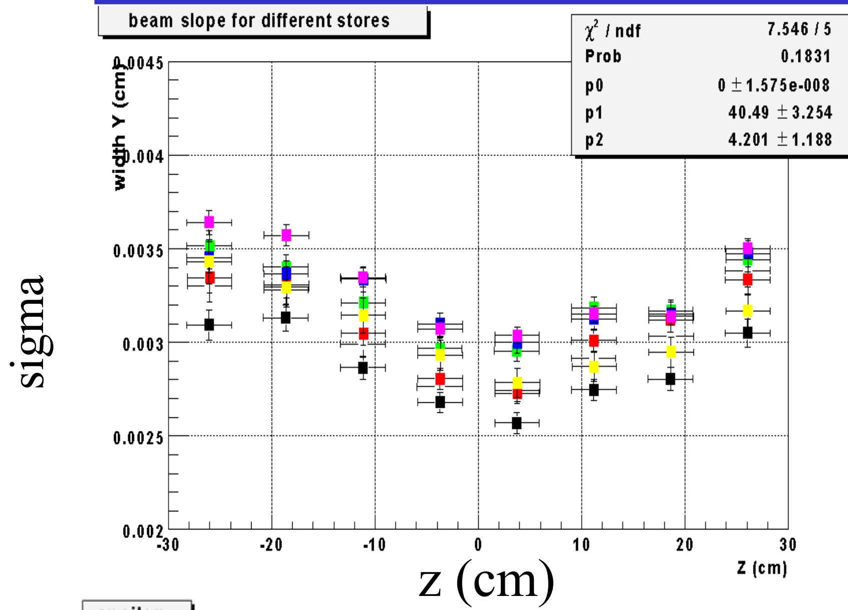
Stores:

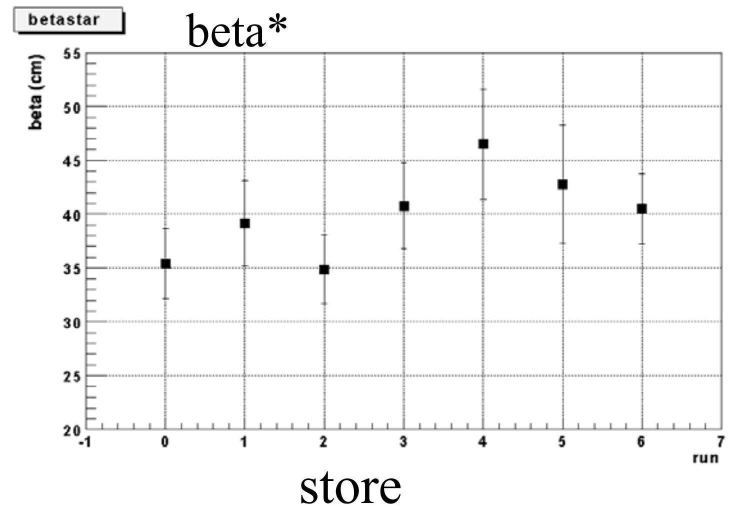
1. 2312
2. 2315
3. 2341
4. 2420
5. 2507
6. 2523
7. 2540





Results for Y - D0





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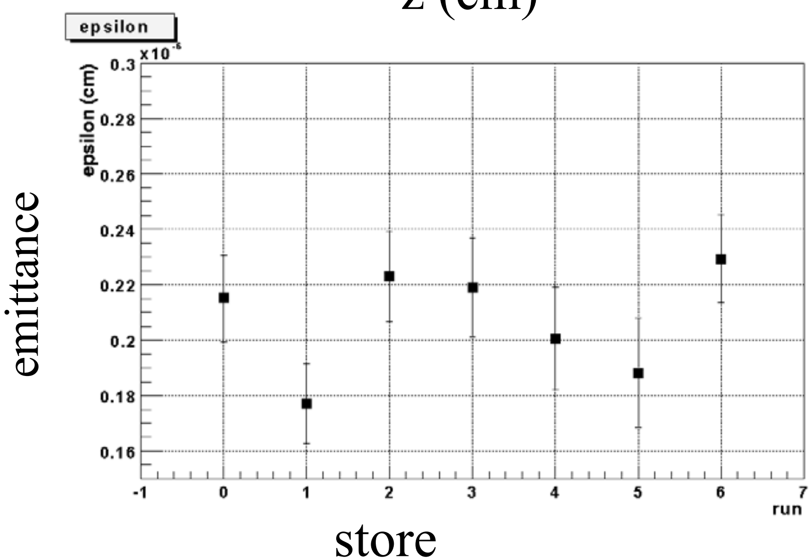
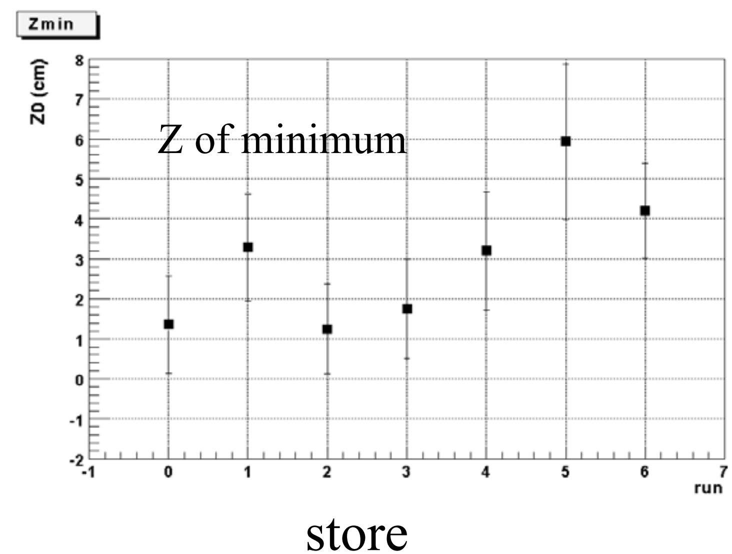
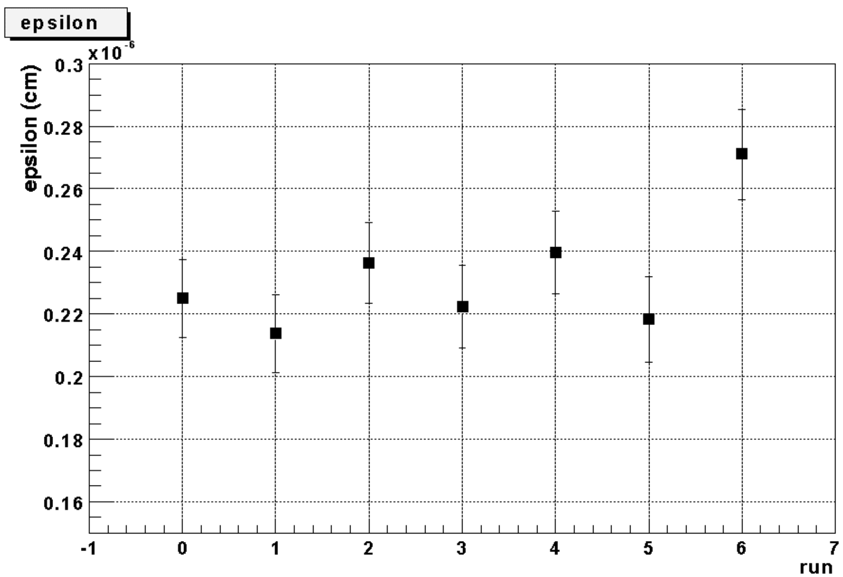




Comparing D0 pseudo-emittance with Tevatron measurements

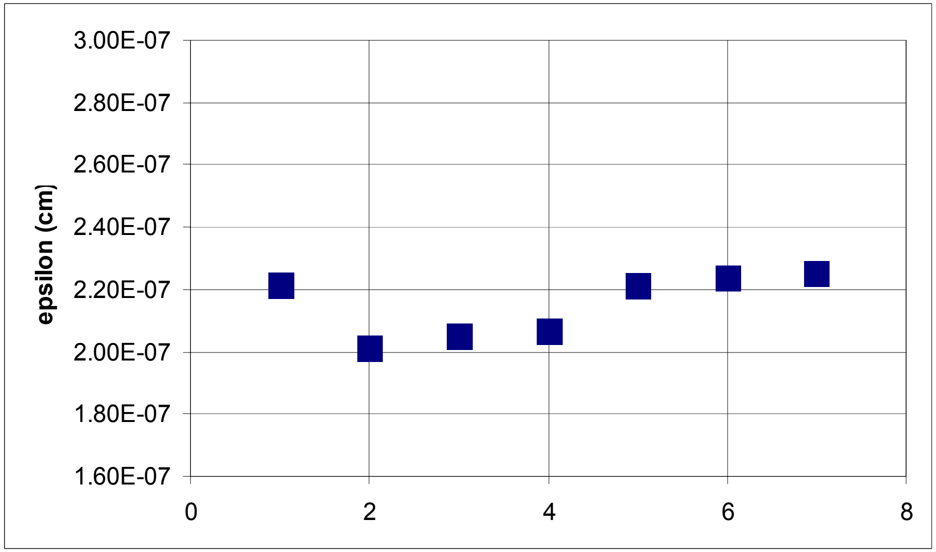
Using vertexes at DØ

Measured at Tevatron



$\varepsilon_{\bar{p}}$

store



store

$$\varepsilon = (\varepsilon_p \, \varepsilon_{pbar})/(\varepsilon_p + \varepsilon_{pbar}),$$

$\varepsilon_p \; \varepsilon_{pbar}$ are average over h and v for p and pbar

Method 2 - Track Pairs

- Use distance of closest approach (dca) parameter for pairs of tracks

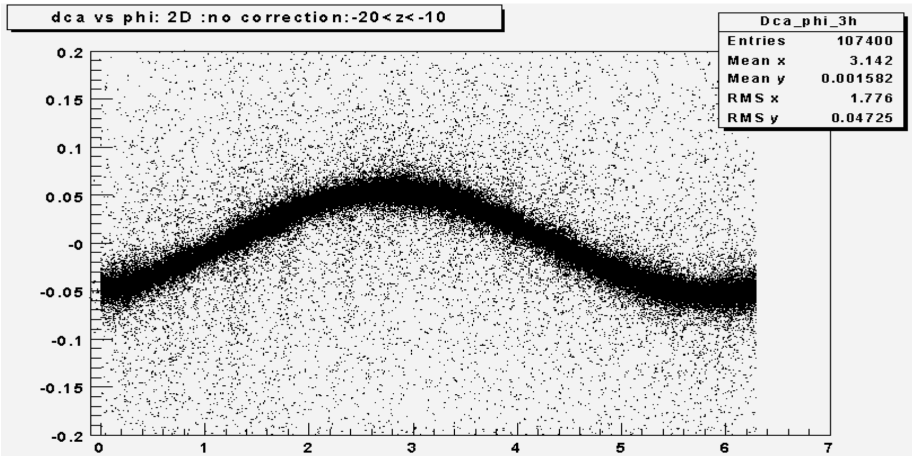
$$d_i = y\cos(\varphi_i) - x\sin(\varphi_i)$$

$$\langle d_1 d_2 \rangle = \sigma_F^2 \cos(\varphi_1 - \varphi_2)$$

This assumes a circular beam. If the beam is not circular the relation is a little more complicated. Do has done it both ways.

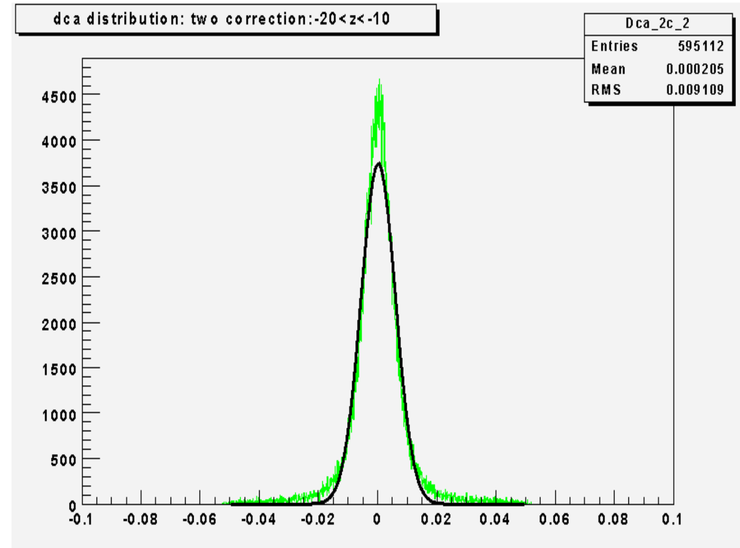
If you **include uncorrelated measurement** errors for this tracks, the equation does not change. The error terms cancel in the formula above.

Distance of Closest Approach Plots

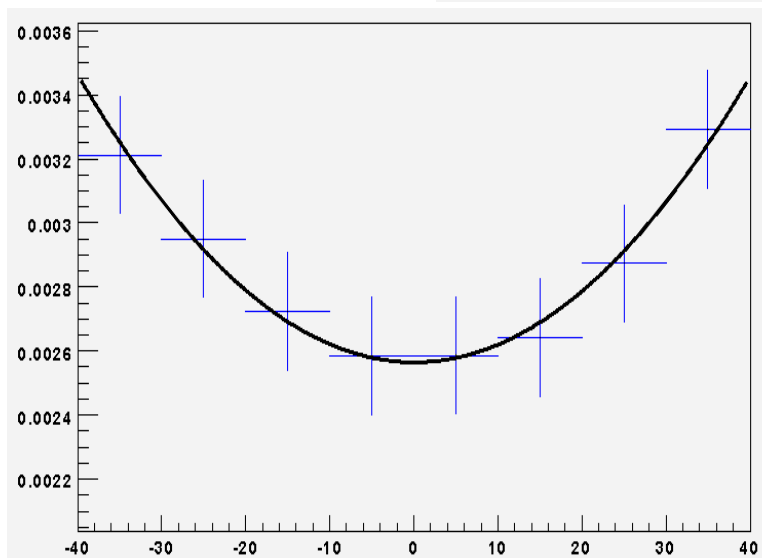


dca

phi



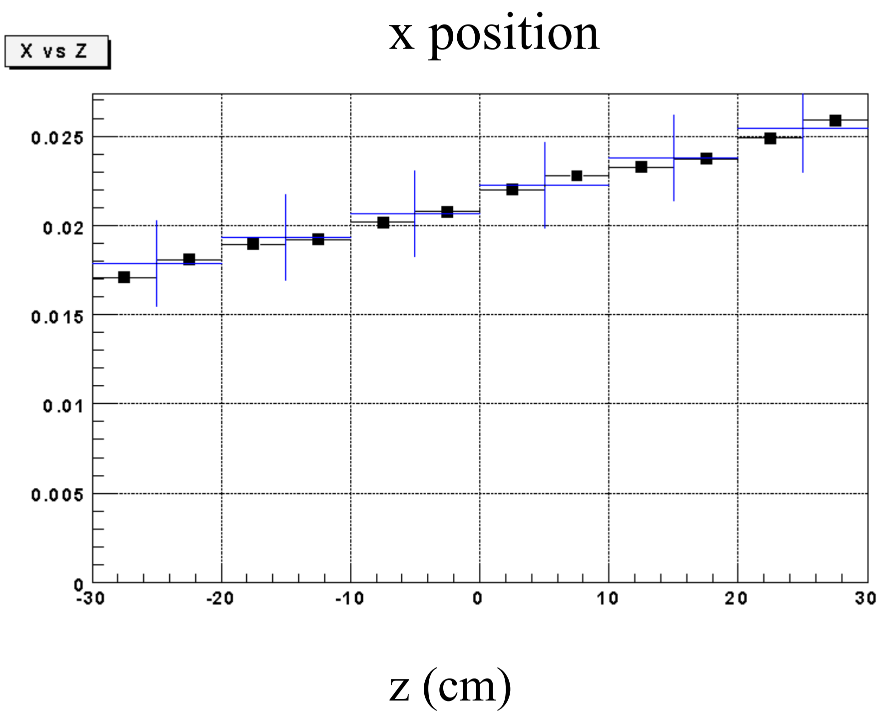
dca

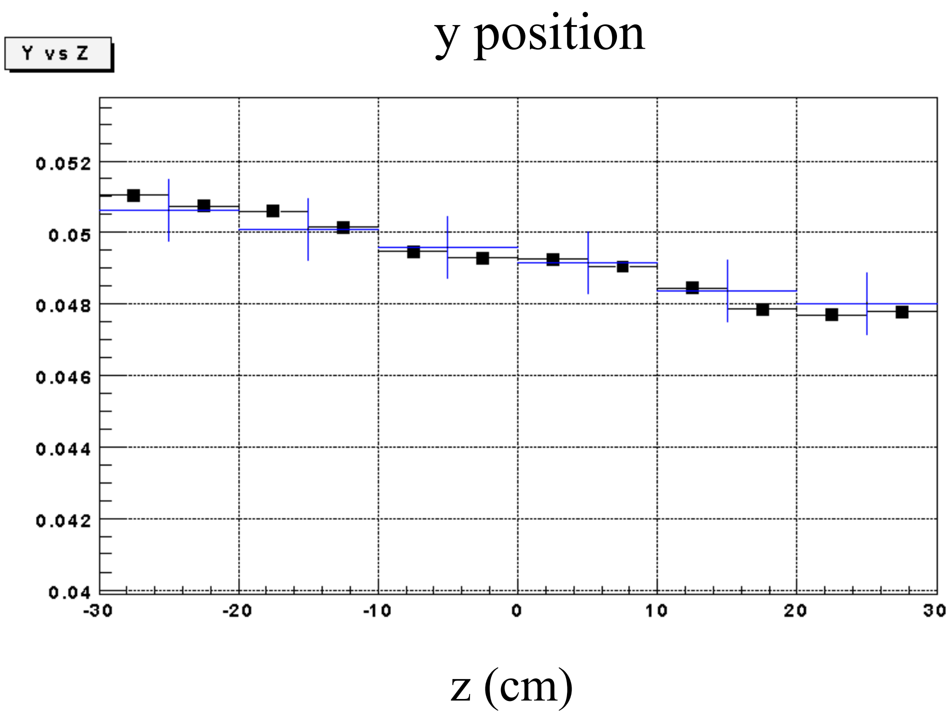


beam size (cm)

Z (cm)

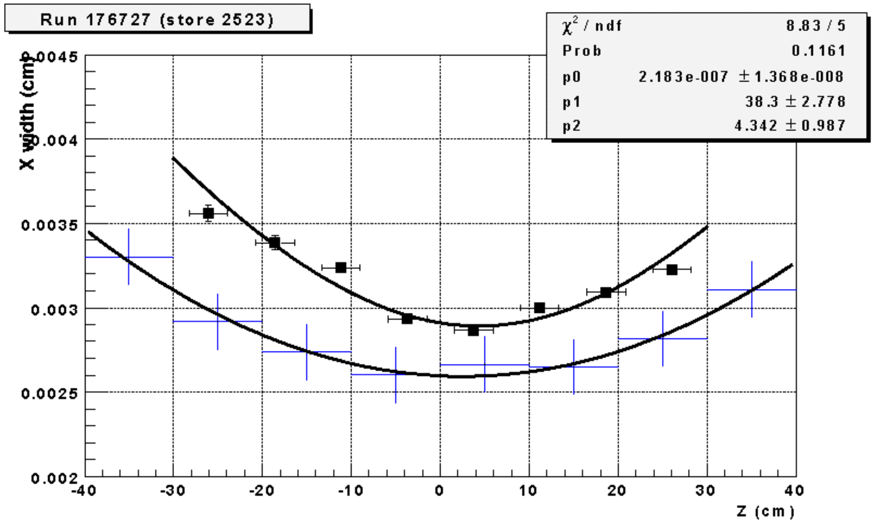
Comparing Results - Beam Positions

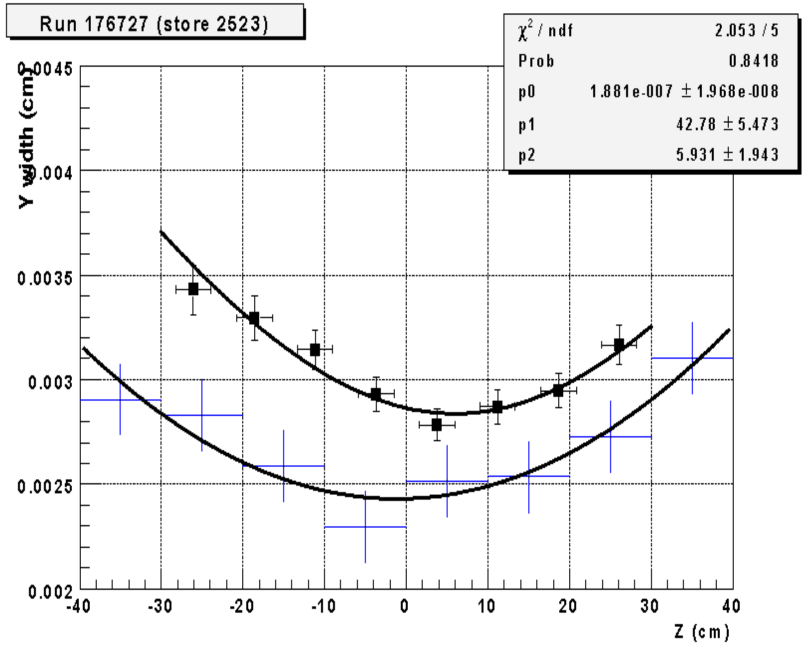




The beam position is the same, when measured with the two methods (vertexes in black and tracks in blue). All scales in cm.

Comparing Results- Sigma versus Z





Vertex method gives consistently a beam that is 3-5 um larger in width and with less curvature (larger β*). Great cross check on systematics. Under investigation.

(vertexes in black and tracks in blue) All scales in cm.

Summary

- Comparison of measured and calculated luminosities agree within the erros
  - Work to reduce the errors on each element in calculated luminosity
- Size of luminous regions
  - Interplay between understanding experiment tracking and understanding the Tevatron lattice and emittances
  - Current formula is simplistic
  - Adding dN/dz, (the number of vertices as a function of z) will help
  - Need to revive the work on the length of p and pbar bunches using the CDF time-of-flight and COT tracking