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Event $|Z_{\rm vtx}| \leq 60$ cm Cut Acceptance for Run II

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ABSTRACT

The typical analysis event selection requires that the event vertex fall within ± 60 cm of the center of CDF: $|Z_{\rm vtx}| \leq 60$ cm. This limits the event acceptance to a portion of the full luminous region of $p\bar{p}$ collisions while the luminosity reported by the CLC is over the full luminous region in z. Minimum bias data are used to measure the longitudinal profile of the $p\bar{p}$ luminous region, and the Tevatron $p\bar{p}$ longitudinal beam profile function is used to estimate the fraction of the luminous region at large z. For high P_T Top, EWK, and Exotic analyses that use data up to 04 Sep 2005, $\epsilon_{\rm vtx} = 0.955 \pm 0.003$.

1 The Beam Luminosity Function

The luminosity correction for the $|Z_{\rm vtx}| \leq 60$ cm cut is derived from the $p\bar{p}$ beam luminosity function [1]:

$$\frac{d\mathcal{L}(z)}{dz} = N_p N_{\bar{p}} \frac{1}{\sqrt{2\pi}\sigma_z} \, \frac{\exp\left(-z^2/2\sigma_z^2\right)}{4\pi\sigma_x(z)\,\sigma_y(z)}, \tag{1}$$

where z is $Z_{\rm vtx}$, $N_{p,\bar{p}}$ are the p, $\bar{p}$ fluxes, and

$$\sigma_x^2(z) \simeq \frac{1}{6\pi\gamma}\,\beta_x(z)\,\epsilon_x \tag{2}$$

$$\sigma_y^2(z) = \frac{1}{6\pi\gamma}\,\beta_y(z)\,\epsilon_y \tag{3}$$

$$\beta(z) = \beta^*[1 + (\frac{z - z_0}{\beta^*})^2] \tag{4}$$

are the transverse beam widths. This form is motivated by a Run II measurement of σ_x and σ_y versus z [2] that finds that for a portion of the 2003 data, $\beta_x^* \simeq \beta_y^*$, but $z_{0x} \simeq 12$ cm and $z_{0y} \simeq -9$ cm. The $p\bar{p}$ beam luminosity function is simplified by assuming $\beta_x^* = \beta_y^*$, but allowing two independent z_0's:

$$\frac{d\mathcal{L}(z)}{dz} = N_0 \, \frac{\exp\left(-z^2/2\sigma_z^2\right)}{\sqrt{[1 + (\frac{z-z_{01}}{\beta^*})^2][1 + (\frac{z-z_{02}}{\beta^*})^2]}} \tag{5}$$

A Run II study on the luminous interaction region [3] finds $\sigma_{\bar{p}} \simeq 50$ cm and $\sigma_p \simeq 70$ cm. From these, σ_z can be calculated [1]: $\sigma_z = \sigma_p \cdot \sigma_{\bar{p}} / \sqrt{\sigma_p^2 + \sigma_{\bar{p}}^2} \simeq 41$ cm.

2 Z Vertex Distribution

The Run II $Z_{\rm vtx}$ distribution is obtained from Stream G min-bias events via the Beamline Group's production pre-processing executable, BeamExe [4]. The COT track only $Z_{\rm vtx}$ is used (FitBeamModule's *cotz* histogram). All primary vertices found are included in the histogram. The min-bias trigger path is `MINBIAS_1HZ`, with the L2 rate limited to 1 Hz. Min-bias events are selected with the L3 Prereq module.

All *cotz* histograms for all runs in the DQM [5] good run list for e/μ's with no silicon are weighted and summed up to give a luminosity weighted $Z_{\rm vtx}$ distribution. The *cotz* histogram for each run is weighted with the following luminosity factor, $f_{\rm run}$,

$$f_{\rm run} = \frac{\mathcal{L}_{\rm run}}{\mathcal{L}_{\rm total}} \cdot \frac{N_{\rm total}}{N_{\rm run}}, \tag{6}$$

where $\mathcal{L}_{\rm run}$ is the integrated luminosity for the run, $N_{\rm run}$ is the number of vertices in the histogram for the run, $\mathcal{L}_{\rm total}$ is the total integrated luminosity for all the good runs, and $N_{\rm total}$ is the total number of vertices in all the good runs.

The summed $Z_{\rm vtx}$ distribution has some biases at large values of z because of increased contamintion from non-$p\bar{p}$ interactions such as beam-gas interactions and the falloff of the COT track acceptance. The relative drop in the COT track acceptance is estimated from the $Z0$ distribution of cosmic ray COT tracks [6]. The cosmic ray $Z0$ distribution is shown in Fig. 1. Linear fits indicate that the $|z| < 70$ cm region is flat. Therefore, the cosmic ray $Z0$ distribution is fit with the following function:

$$N(z) = \begin{cases} c_1 & \text{if } |z| < z_0 \\ c_1 + c_2 \cdot (|z| - z_0)^2 & \text{otherwise} \end{cases} \tag{7}$$

where c_1, c_2, and z_0 are fit parameters. The fit to $N(z)$ has $\chi^2 = 154$ and $c_1 = 236.44 \pm 1.69$, $c_2 = (-3.645 \pm 0.138) \cdot 10^{-2}$, and $z_0 = 72.65 \pm 1.64$ cm. The effects of the falloff in the COT track acceptance has also been studied with the HERWIG $W \to e\nu$ simulation. The "COT Standalone" FastZVertexColl vertex collection provides the reconstructed $p\bar{p}$ interaction vertices at $z = Z_{\rm vtx}$. This is the numerator piece in the efficiency, and the denominator is the number of events generated at at the same z, where this z location is the location of the event's $p\bar{p}$ collision. The $Z_{\rm vtx}$ finding efficiency from the simulation is shown in Fig. 2.

The cosmic ray track $Z0$ and simulation $Z_{\rm vtx}$ finding efficiency both indicate that the $Z_{\rm vtx}$ finding efficiency within $|z| < 60$ cm is flat. Because of this, the acceptance within the $p\bar{p}$ beam luminous region of $|Z_{\rm vtx}| < 60$ cm is determined from the fit to $d\mathcal{L}(z)/dz$ within $|z| < 60$ cm. The acceptance is calculated from the fit to the beam's z profile as follows:

$$\epsilon(|z| < z_{\rm cut}) = \frac{\int_{-z_{\rm cut}}^{+z_{\rm cut}} [d\mathcal{L}(z)/dz]\, dz}{\int_{-\infty}^{+\infty} [d\mathcal{L}(z)/dz]\, dz}\,. \tag{8}$$

Measurements of $\epsilon_{\rm vtx}$ using these analysis techniques on previous datasets are here [7]. There are small differences because of changes in the beam z profile. See Section 3 for a summary.

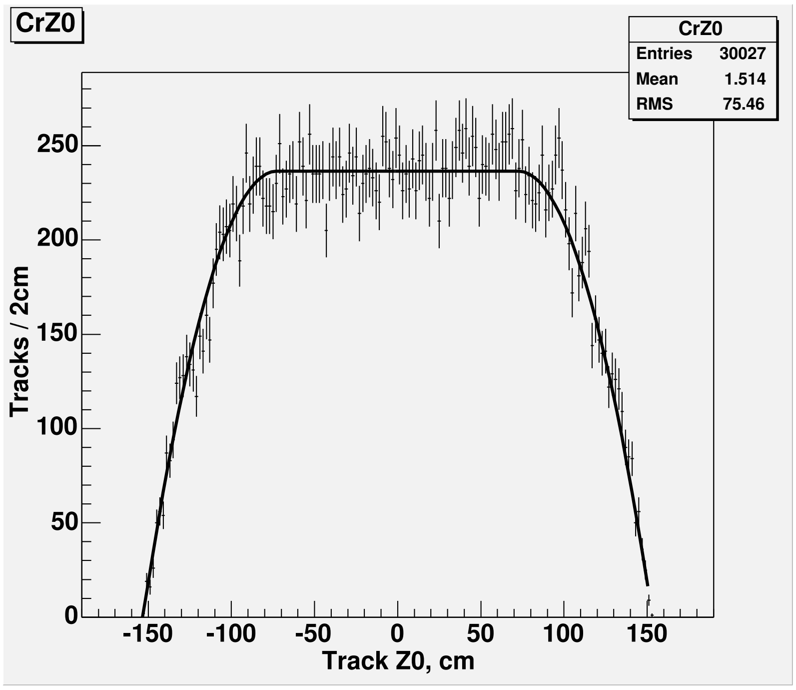

Figure 1: The cosmic ray track $Z0$ distribution. The curve is the fit described in the text.

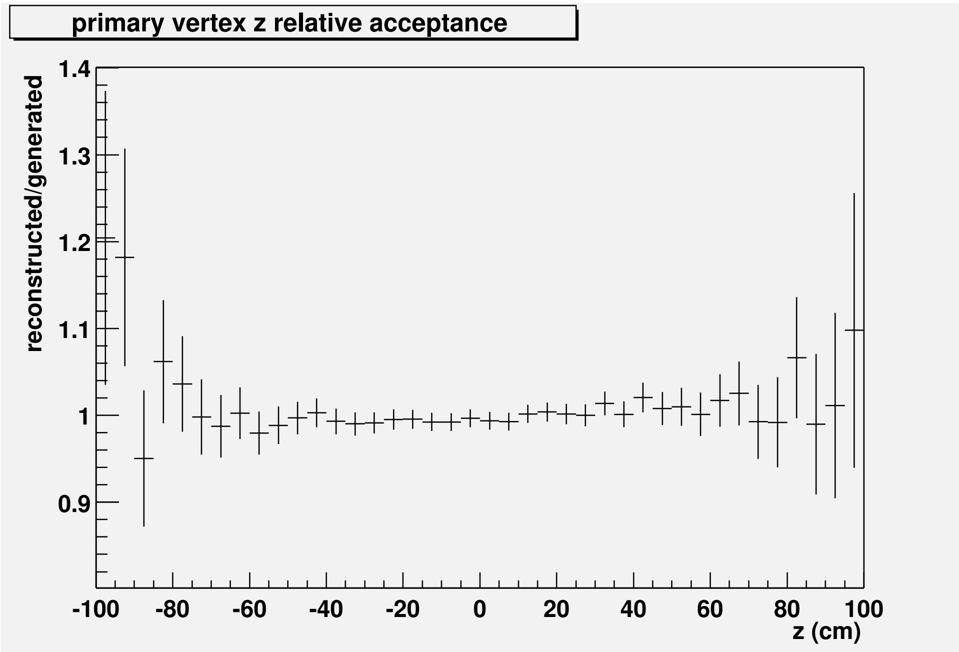

Figure 2: The Z_{vtx} reconstruction efficency from the HERWIG $W \to e\nu$ simulation. This is the Z_{vtx} from the "COT Standalone" FastZVertexColl collection.

	Set A Fit value (cm)	Set B Fit value (cm)	Set C Fit value (cm)	Set D Fit value (cm)
Parameter	$\chi^2 = 106$	$\chi^2 = 317$	$\chi^2 = 532$	$\chi^2 = 488$
σ_z	40.47 ± 0.21	40.51 ± 0.42	40.91 ± 0.20	41.92 ± 0.13
z_{01}	3.06 ± 2.45	20.16 ± 0.60	0.07 ± 1.53	2.19 ± 0.72
z_{02}	3.22 ± 2.45	-8.87 ± 0.76	0.07 ± 1.53	2.17 ± 0.72
β^*	42.59 ± 0.28	41.95 ± 1.11	37.28 ± 0.20	31.62 ± 0.09

Table 1: Beam profile fits over $|z| < 60$ cm for Sets A, B, C , and D.

	Set A Fit value (cm)	Set B Fit value (cm)	Set C Fit value (cm)	Set D Fit value (cm)
Parameter	$\chi^2 = 162$	$\chi^2 = 805$	$\chi^2 = 1300$	$\chi^2 = 1380$
σ_z	40.08 ± 0.08	39.55 ± 0.13	40.51 ± 0.08	41.58 ± 0.05
z_{01}	3.18 ± 1.77	20.90 ± 0.58	-0.15 ± 1.44	2.09 ± 0.66
z_{02}	3.21 ± 1.77	-8.47 ± 0.64	-0.15 ± 1.44	2.09 ± 0.66
β^*	43.12 ± 0.16	43.68 ± 0.66	37.64 ± 0.12	31.80 ± 0.06

Table 2: Beam profile fits over $|z| < 100$ cm for Sets A, B, C, and D.

The beam profile fits to the summed $Z_{\rm vtx}$ distribution for the current data are done over a set of run ranges: "Set A": 141544–156487, "Set B": 159603–176567, "Set C": 176568–186598, and "Set D": 190697–203799. Between runs 156487 and 176567, the beam y_0 position shifts from 4mm to 6mm. After run 176567, the Tevatron beam line at B0 is lower by about 4–5mm. The "corrected" 35 cm β^* Tevatron optics was implemented on 12May04 (Runs > 182580), and for this optics, $z_{01} \simeq z_{02}$. The beam profile fits are restricted to have $|z_{01}| < 30$ cm and $|z_{02}| < 30$ cm, and are done over two z regions: $|z| < 60$ cm and $|z| < 100$ cm. Table 1 shows the results of the fits over the $|z| < 60$ cm region. Table 2 shows the results of the fits over the $|z| < 100$ cm region. The Set A, B, C, and D $Z_{\rm vtx}$ distributions with the $|z| < 60$ cm fits are shown in Figures 3, 4, 5, and 6, respectively. The acceptances of the $|Z_{\rm vtx}| < 60$ cm luminous region cut from the fits to $d\mathcal{L}(z)/dz$ over $|z| < 60$ cm are:

$$\begin{aligned}
\epsilon(|Z_{\rm vtx}| < 60, \text{ Set A}) &= 0.9498 \pm 0.00087 \\
\epsilon(|Z_{\rm vtx}| < 60, \text{ Set B}) &= 0.9462 \pm 0.00199 \\
\epsilon(|Z_{\rm vtx}| < 60, \text{ Set C}) &= 0.9551 \pm 0.00066 \\
\epsilon(|Z_{\rm vtx}| < 60, \text{ Set D}) &= 0.9597 \pm 0.00030\,,
\end{aligned}$$

where the errors are statistical only. The fits over $|z| < 100$ cm for Sets A, B, C, and D give the following acceptances: 0.951 ± 0.001, 0.948 ± 0.001, 0.956 ± 0.001, and 0.9604 ± 0.0006, respectively. The fits over $|z| < 100$ cm include the $Z_{\rm vtx}$ efficiency correction of Eqn. 7. This correction reduces the χ^2 of the fit.

The $Z_{\rm vtx}$ distribution for the full data set is also fit to a Gaussian for the purposes of providing the beam z-profile for use in simple Monte Carlo simulations. A single

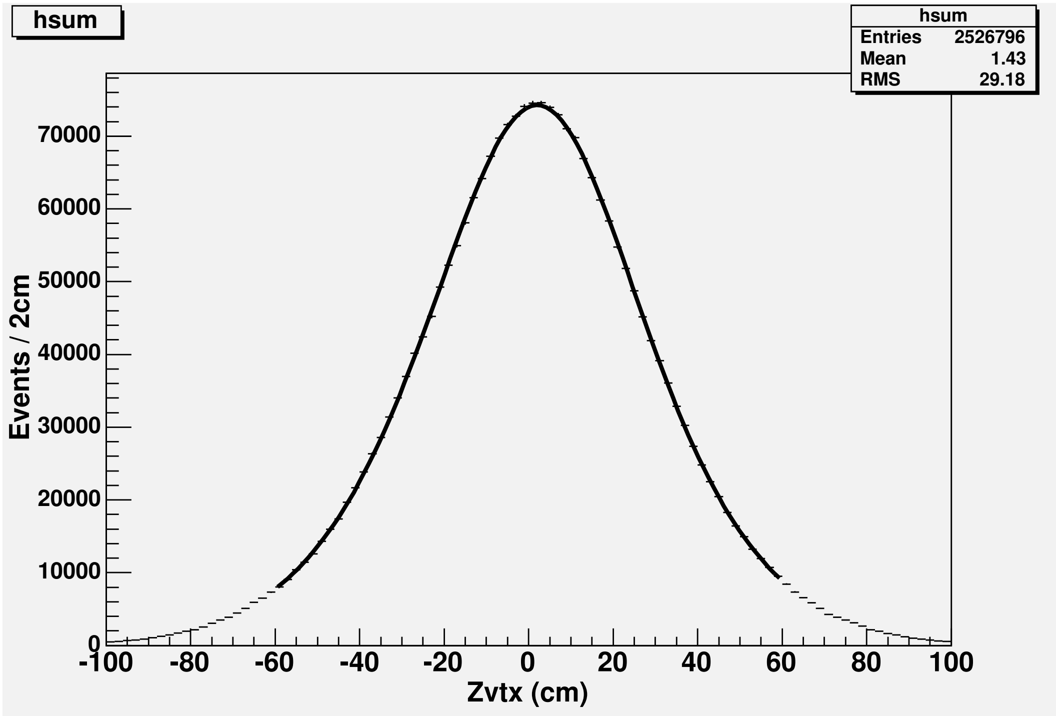

Figure 3: Set A Z_{vtx} distribution ($cotz$): Runs 141544–156487. The units are cm, there are 100 bins, and the events are weighted. The curve is the fit to $d\mathcal{L}(z)/dz$.

Gaussian fit over $|z| < 60$ cm has a $\chi^2 \sim 38823$, $\bar{z} = 1.26$ cm and $\sigma_z = 26.17$ cm. This Gaussian fit underestimates the data in the $|z| < 15$ cm and $|z| > 50$ cm regions.

3 Systematics

The beam profile fit parameters for the $|z| < 60$ cm fits as a function of run ranges are given in Table 3. The z-profile of the $p\bar{p}$ collisions has changed with time, along with changes to the Tevatron. Changes in the p and $\bar{p}$ tunes affect σ_z and changes to the low-β optics affect β^*. There is a β^* change in the next data set: the Tevatron low β lattice has been permanently changed over to $\beta^* = 28$ cm optics at store 4395. These time variations are included in good run and luminosity weighted averages, but there could be potential systematics if the efficiencies in an analysis and these changes in beam profile have time correlations.

The acceptance, $\epsilon_{|Z_{\text{vtx}}|<60}$, has a slight dependence on the z range over which the beam profile parameters are fit. Table 4 shows the dependence of $\epsilon_{|Z_{\text{vtx}}|<60}$ with the z limit ($|z| < z_{\text{lim}}$) used in the fit for Set D. This bias is taken as the systematic error of the $\epsilon_{|Z_{\text{vtx}}|<60}$ measurement. The maximum difference of the bias for Set D is 0.0020, and for Sets A, B, and C combined, it is 0.0031. The larger of the two is taken as the systematic error: 0.0031.

Runs	σ_z	β^*	z_{01}	z_{02}	$\epsilon_{\lvert Z_{\rm vtx}\rvert<60}$
141543–152945	39.3 ± 0.3	42.9 ± 0.4	3.9 ± 7.0	4.5 ± 7.0	0.954 ± 0.002
152945–156487	41.3 ± 0.3	42.6 ± 0.4	2.3 ± 3.2	2.3 ± 3.2	0.947 ± 0.001
159602–162100	39.7 ± 0.4	44.9 ± 0.6	4.4 ± 8.8	4.3 ± 8.8	0.950 ± 0.002
162100–165063	39.6 ± 0.8	40.1 ± 1.9	23.3 ± 0.7	-10.1 ± 0.9	0.950 ± 0.003
165063–166783	40.8 ± 0.9	44.6 ± 2.6	21.0 ± 1.4	-9.3 ± 1.8	0.942 ± 0.004
167783–176567	40.1 ± 1.2	44.8 ± 3.8	18.2 ± 3.2	-6.3 ± 3.7	0.945 ± 0.006
176568–178758	40.3 ± 1.1	41.8 ± 3.0	11.6 ± 2.0	-17.5 ± 1.7	0.947 ± 0.005
178759–183696	41.4 ± 0.5	40.4 ± 0.5	-1.1 ± 0.7	-1.2 ± 0.7	0.949 ± 0.002
183697–185009	40.1 ± 0.4	33.8 ± 0.4	1.1 ± 2.3	1.6 ± 2.3	0.962 ± 0.001
185010–186598	40.7 ± 0.3	33.8 ± 0.3	1.0 ± 2.0	1.5 ± 2.0	0.960 ± 0.001
190697–192400	42.7 ± 0.4	32.3 ± 0.3	2.4 ± 2.2	2.3 ± 2.2	0.956 ± 0.001
192401–194100	41.4 ± 0.4	31.1 ± 0.3	2.0 ± 2.4	2.0 ± 2.4	0.961 ± 0.001
194101–195800	41.6 ± 0.3	31.2 ± 0.2	2.1 ± 1.6	1.9 ± 1.6	0.961 ± 0.001
195801–197500	42.4 ± 0.3	31.2 ± 0.2	2.7 ± 1.6	2.3 ± 1.6	0.959 ± 0.001
197501–199200	41.7 ± 0.3	31.3 ± 0.2	2.6 ± 1.9	2.3 ± 1.9	0.961 ± 0.001
199201–202300	42.1 ± 0.3	31.8 ± 0.2	2.3 ± 1.7	2.1 ± 1.7	0.959 ± 0.001
202301–203799	41.6 ± 0.3	32.9 ± 0.3	1.5 ± 2.3	1.7 ± 2.3	0.959 ± 0.001

Table 3: Beam profile fit parameters and the corresponding $\epsilon_{|Z_{\rm vtx}|<60}$ for $|z| < 60$ cm fits in different run ranges. The errors on $\epsilon_{|Z_{\rm vtx}|<60}$ are statistical errors derived from the fits. For runs ≤ 194100, each run range has about 30 pb^{-1}. For $194101 <$ runs ≤ 203799, each run range has about 60 pb^{-1}.

$z_{\rm lim}$	$\epsilon_{\lvert Z_{\rm vtx}\rvert<60}$
050 cm	0.9584 ± 0.0006
060 cm	0.9597 ± 0.0003
070 cm	0.9604 ± 0.0001
100 cm	0.9604 ± 0.0001

Table 4: Dependence of $\epsilon_{|Z_{\rm vtx}|<60}$ with the z limit ($|z| < z_{\rm lim}$) used in the fit for Set D. The errors are statistical errors derived from the fit. The fit parameter errors are treated as uncorrelated.

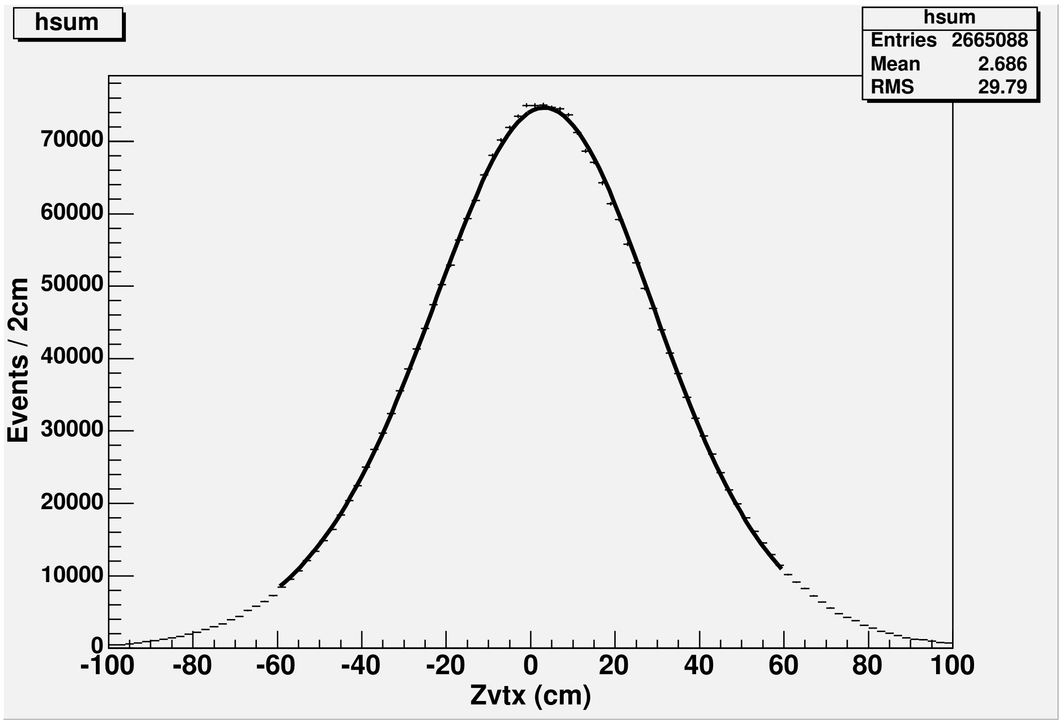

Figure 4: Set B Z_{vtx} distribution ($cotz$): Runs 159603–176567. The units are cm, there are 100 bins and the events are weighted. The curve is the fit to $d\mathcal{L}(z)/dz$.

4 Summary

The luminosity acceptance of the $|Z_{\mathrm{vtx}}| < 60$ cm cut for the current data set is the luminosity weighted average of the Set A, B, C, and D $\epsilon_{|Z_{\mathrm{vtx}}|<60}$:

$$\epsilon_{\mathrm{vtx}} = 0.9555 \pm 0.0004\,(\mathrm{stat}) \pm 0.0031\,(\mathrm{syst})\ ,$$

or 0.955 ± 0.003 if the statitical and systematic errors are combined. The Set A, B, C, and D integrated luminosities used in the average are, 81.0, 121.3, 139.5, and 385.6 pb^{-1}, repectively. These integrated luminosities are offline luminosities but do no include the 1.019 factor. They also vary somewhat with the good run list version.

References

[1] W. Badgett, P. Derwent, CDF2703: *Event z Vertex Efficiency as a Luminosity Correction for Run Ia*

[2] S. Lai et al., CDF6492: *An Updated Measurement of the Beam Width at CDF*

[3] M. Jones, R. Kephart, R. Vidal, CDF5951: *Tevatron Bunch Length Studies at CDF*

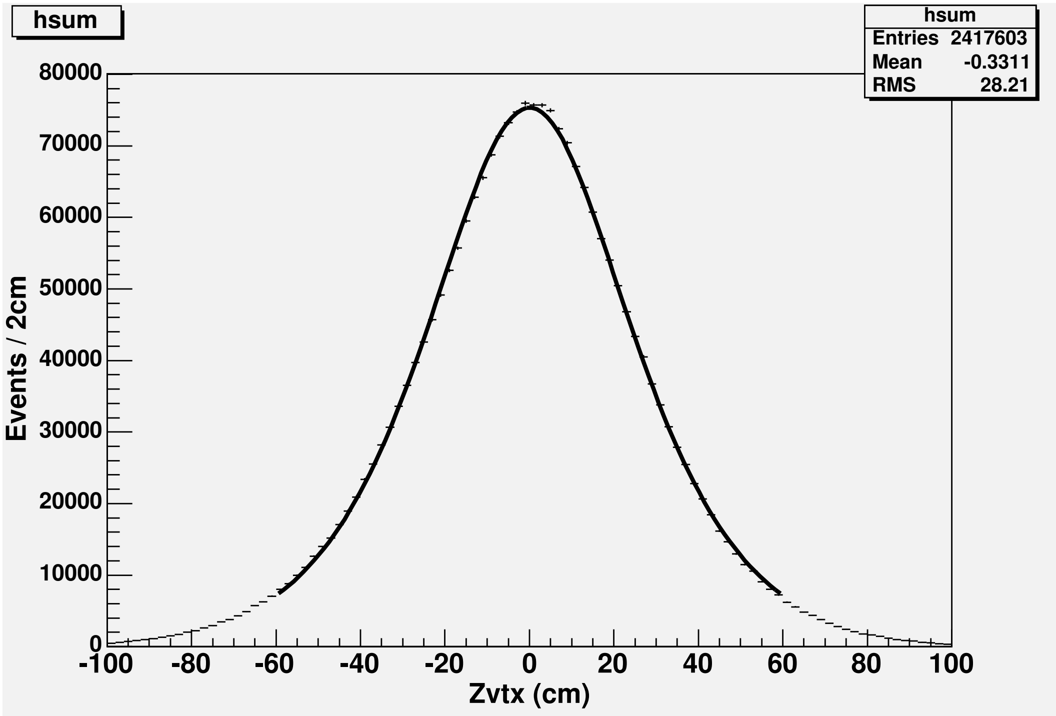

Figure 5: Set C $Z_{\rm vtx}$ distribution ($cotz$): Runs 176568–186598. The units are cm, there are 100 bins, and the events are weighted. The curve is the fit to $d\mathcal{L}(z)/dz$.

[4] The *cotz* histogram path is FitBeamModule-Willis/cotz (fcdflnx3: /cdf/opr/cdfopr/cdfprd).

[5] DQM Version 10.0 good run list with flag configuration (1,0,4,1). In addition the following runs in the good run list, 144712, 175090, 175092, 175095, 175096, and 191635–191639, are not in the BeamExe histogram set and are not included.

[6] H.K. Gerberich, A.V. Kotwal and C. Hays, CDF6089: *Cosmic Ray Tagging using COT Hit Timing*

[7] W.K. Sakumoto, A. Hocker, CDF notes 6331, 6660, 6917, and 7324: *Event* $|Z_{\rm vtx}| < 60$ *cm Cut Efficiency for Run II*

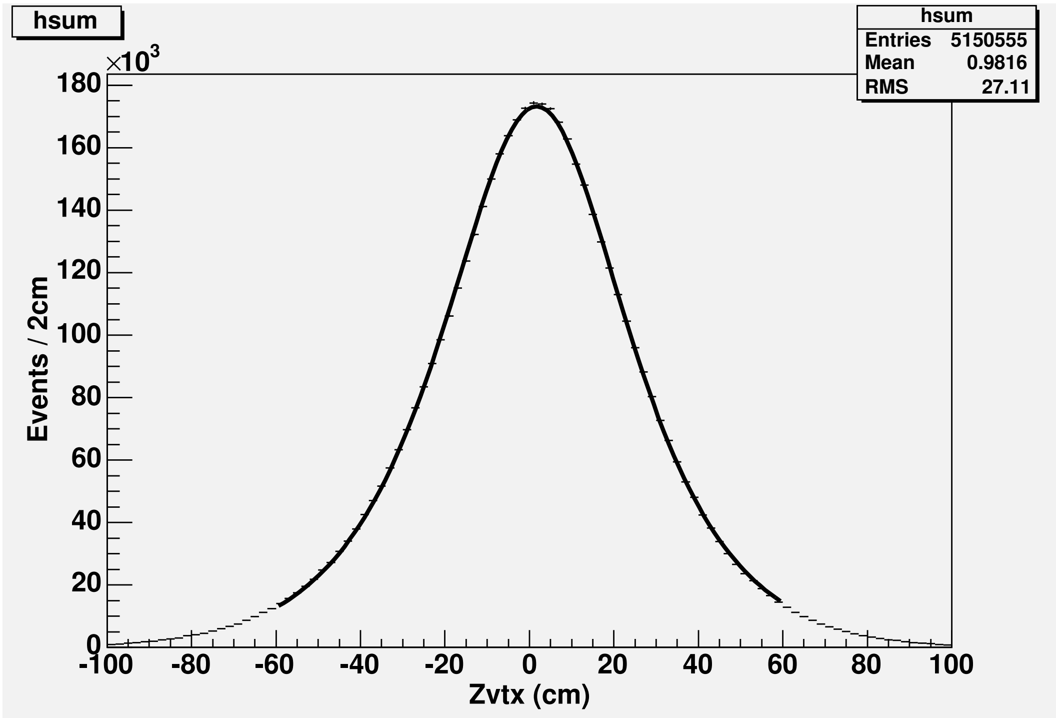

Figure 6: Set D Z_{vtx} distribution ($cotz$): Runs 190697–203799. The units are cm, there are 100 bins, and the events are weighted. The curve is the fit to $d\mathcal{L}(z)/dz$.