Measurement of Bottom Quark–Antiquark Azimuthal Production Correlations Using the J/ψ+lepton Sample in Run Ib CDF Data

Text for the blessed web page – CDF note 6263

The CDF Collaboration

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Abstract

We present a measurement of $b\bar{b}$ azimuthal angular correlations in CDF Run Ib data. This analysis uses events from the J/ψ trigger in which a SLT electron or SLT CMUP muon is also found. The $b\bar{b}$ purity as a function of $\Delta\phi^{J/\psi\ell}$ is determined by fitting the decay length of the J/ψ,and the impact parameter of the soft lepton simultaneously. The fraction of $b\bar{b}$ pairs in the same azimuthal hemisphere ($\Delta\phi^{J/\psi\ell} < \pi/2$) is found to be:

$$18.6^{+6.3}_{-5.7} \text{ (fit error)}^{+0.5}_{-0.6} \text{ (fit syst. error)} \pm 1.7 \text{ (B} \rightarrow \text{b error)\%}$$
$$33.4^{+8.9}_{-7.9} \text{ (fit error)}^{+7.7}_{-3.0} \text{ (fit syst. error)} \pm 2.3 \text{ (B} \rightarrow \text{b error)\%}$$

for the electron and muon samples, respectively. The measurements are consistent with both leading-log (Pythia) and next-to-leading order (MNR) QCD predictions.

This measurement of $b\bar{b}$ azimuthal angular correlations is interesting, because it is optimized to measure the low $\Delta\phi$ region which is least understood in experimental measurements and theoretical predictions. The measurement shows that high-order corrections are important to describe the angular corrections accurately. The chosen data sample has similar bottom momenta and rapidity distributions as the Run II samples used in mixing and CP violation measurements. Therefore, this result aids in the understanding of bottom flavor taggers used in such measurements

1 Description

For this measurement, the 90 pb^{-1} data sample taken during the 1994-1995 run (Run Ib) is used. In order to start with a low p_T sample with enhanced bottm content, the J/ψ trigger is used. The samples' bottom content is further enhanced by requiring an additional SLT electron or CMUP muon. The $b\bar{b}$ content of the sample as a function of $\Delta\phi$ is extracted by fitting the pseudo-$c\tau$ of the J/ψ and the impact parameter of the SLT candidate, simulataneously, using a constrained unbinned maximum log-likelihood technique. The fit uses the estimated numbers of various background sources as constraints. Our result is statistical dominated. The larger Run II data set would produce a much more precise result, both statistically and systematically. With such a measurement, much more information on bottom production can be obtained, including the $\langle k_T \rangle$ of the $b\bar{b}$ system and the relative normalizations of the three production mechanism (flavor creation, flavor excitation, and gluon splitting) used in lead-log Monte Carlos (Herwig,Pythia).

2 Blessed Numbers

This section summarizes the numbers which have been blessed for this analysis.

2.1 Fit results

Fit parameter	Electron	Electron Constraints	Muon	Muon Constraints
$n^t_{b\bar{b}}$	$29.6^{+11.7}_{-10.4}$		$23.0^{+7.6}_{-6.9}$	
n^t_{bd}	$1.5^{+8.5}_{-8.1}$		$1.6^{+4.6}_{-2.9}$	
n^t_{bconv}	0.6(fixed)		N/A	
n^t_{db}	0 (fixed)		0 (fixed)	
n^t_{dd}	$37.0^{+8.0}_{-7.3}$		$11.3^{+5.1}_{-4.5}$	
n^t_{dconv}	$2.8^{+2.1}_{-1.7}$		N/A	
n^t_{side}	$45.4^{+6.9}_{-6.2}$	45	$32.9^{+5.7}_{-5.1}$	34
$n^t_{B_{fake}}$	$2.8^{+0.7}_{-0.7}$	2.85 ± 0.75	$10.7^{+2.5}_{-2.5}$	11.7 ± 2.6
$n^t_{B_c}$	$10.0^{+3.2}_{-3.3}$	$10.0^{+3.5}_{-3.3}$	$5.1^{+2.5}_{-2.5}$	$7.2^{+2.6}_{-2.4}$
n^t_{signal}	107.1	107	68.2	64
n^t_{conv}	5.6	6	N/A	
$n^a_{b\bar{b}}$	$124.7^{+17.9}_{-16.7}$		$43.6^{+10.2}_{-9.0}$	
n^a_{bd}	$-1.4^{+12.5}_{-12.2}$		$8.1^{+8.0}_{-7.5}$	
n^a_{bconv}	1.2(fixed)		N/A	
n^a_{db}	0 (fixed)		0 (fixed)	
n^a_{dd}	$49.5^{+9.2}_{-8.5}$		$16.0^{+5.5}_{-5.2}$	
n^a_{dconv}	$6.0^{+2.6}_{-2.2}$		N/A	
n^a_{side}	$47.6^{+7.1}_{-6.5}$	47	$18.2^{+4.5}_{-3.9}$	17
n^a_{signal}	204.9	205	76.8	78
n^a_{conv}	9.5	9	N/A	
r_{side}	$0.505^{+0.043}_{-0.043}$	0.501 ± 0.044	$0.501^{+0.043}_{-0.043}$	0.501 ± 0.044
r_{conv}	$0.99^{+0.31}_{-0.28}$	1.00 ± 0.37	N/A	

See CDF 7253 for fit variable and likelihood description.

2.2 Systematic errors

Fit systematic errors not already included in the likelihood function.

Source	Electron	Muon
Sequential Rate	$\pm0.1\%$	$\pm0.3\%$
B Lifetime	$\pm0.3\%$	$\pm2.2\%$
Fragmentation Fractions	$\pm0.1\%$	$\pm0.2\%$
n_{bconv}/n_{dconv} ratio	$\pm0.1\%$	
Residual Conversion Shape	$\pm0.2\%$	
Direct Impact Parameter Shape	$^{+0.3}_{-0.4}\%$	$^{+7.4}_{-1.0}\%$
f_{back} (for $F^{c\tau}_{Direct}$ and $F^{c\tau}_{b}$)	$\pm0.02\%$	$\pm0.01\%$
N_{db}	$\pm0.1\%$	$\pm1.9\%$
Total	$^{+0.5}_{-0.6}\%$	$^{+8.0}_{-3.1}\%$

2.3 Final result

2.3.1 Electron Toward Fraction

For the electrion, with the following b quark cuts:

- J/ψ b quark: $p_T > 6.8$ GeV and $|y| < 0.67$
- SLT b quark: $p_T > 4.3$ GeV and $|y| < 0.99$

NLO MRST99	
$\langle k_T\rangle = 0.0$ GeV	$16.9\% \pm 0.2\%$ (stat.)$^{+3.6\%}_{-3.8\%}$ (sys.)
$\langle k_T\rangle = 1.0$ GeV	$19.4\% \pm 0.3\%$ (stat.)$^{+4.8\%}_{-4.1\%}$ (sys.)
$\langle k_T\rangle = 2.0$ GeV	$23.2\% \pm 0.4\%$ (stat.)$^{+5.8\%}_{-5.0\%}$ (sys.)
$\langle k_T\rangle = 3.0$ GeV	$31.9\% \pm 0.6\%$ (stat.)$^{+5.3\%}_{-5.7\%}$ (sys.)
$\langle k_T\rangle = 4.0$ GeV	$44.9\% \pm 0.7\%$ (stat.)$^{+5.4\%}_{-4.8\%}$ (sys.)
NLO CTEQ5M	
$\langle k_T\rangle = 0.0$ GeV	$16.5\% \pm 0.2\%$ (stat.)$^{+3.7\%}_{-3.3\%}$ (sys.)
$\langle k_T\rangle = 1.0$ GeV	$19.1\% \pm 0.3\%$ (stat.)$^{+4.9\%}_{-3.9\%}$ (sys.)
$\langle k_T\rangle = 2.0$ GeV	$23.1\% \pm 0.4\%$ (stat.)$^{+5.2\%}_{-5.0\%}$ (sys.)
$\langle k_T\rangle = 3.0$ GeV	$31.7\% \pm 0.6\%$ (stat.)$^{+6.0\%}_{-5.4\%}$ (sys.)
$\langle k_T\rangle = 4.0$ GeV	$45.1\% \pm 0.7\%$ (stat.)$^{+5.5\%}_{-4.6\%}$ (sys.)
PYTHIA	$26.4\% \pm 0.2\%$ (stat.)
Data	$18.6^{+6.3}_{-5.7}$ (fit error)$^{+0.5}_{-0.6}$ (fit syst. error) $\pm$ 1.7 (B $\rightarrow$ b error)%

2.3.2 Muon Toward Fraction

For the muon, with the following b quark cuts:

- J/ψ b quark: $p_T > 7.0$ GeV and $|y| < 0.67$
- SLT b quark: $p_T > 6.0$ GeV and $|y| < 0.61$

NLO MRST99	
$\langle k_T \rangle = 0.0$ GeV	$16.7\% \pm 0.3\%$ (stat.)$^{+5.2\%}_{-3.6\%}$ (sys.)
$\langle k_T \rangle = 1.0$ GeV	$22.7\% \pm 0.6\%$ (stat.)$^{+6.1\%}_{-7.0\%}$ (sys.)
$\langle k_T \rangle = 2.0$ GeV	$24.7\% \pm 0.6\%$ (stat.)$^{+6.7\%}_{-6.5\%}$ (sys.)
$\langle k_T \rangle = 3.0$ GeV	$32.1\% \pm 0.6\%$ (stat.)$^{+6.4\%}_{-6.9\%}$ (sys.)
$\langle k_T \rangle = 4.0$ GeV	$44.9\% \pm 0.9\%$ (stat.)$^{+5.1\%}_{-6.6\%}$ (sys.)
NLO CTEQ5M	
$\langle k_T \rangle = 0.0$ GeV	$16.8\% \pm 0.3\%$ (stat.)$^{+4.1\%}_{-3.8\%}$ (sys.)
$\langle k_T \rangle = 1.0$ GeV	$22.1\% \pm 0.5\%$ (stat.)$^{+5.6\%}_{-5.9\%}$ (sys.)
$\langle k_T \rangle = 2.0$ GeV	$23.8\% \pm 0.9\%$ (stat.)$^{+7.4\%}_{-5.0\%}$ (sys.)
$\langle k_T \rangle = 3.0$ GeV	$31.9\% \pm 0.9\%$ (stat.)$^{+5.7\%}_{-6.5\%}$ (sys.)
$\langle k_T \rangle = 4.0$ GeV	$44.4\% \pm 1.2\%$ (stat.)$^{+7.1\%}_{-5.0\%}$ (sys.)
PYTHIA	$25.5\% \pm 0.4\%$ (stat.)
Data	$33.4^{+8.9}_{-7.9}$ (fit error)$^{+7.7}_{-3.0}$ (fit syst. error) $\pm$ 2.3 (B $\rightarrow$ b error)%

3 Blessed Figures

The following figures have been blessed for this analysis. More text can be found in CDF note 6263.

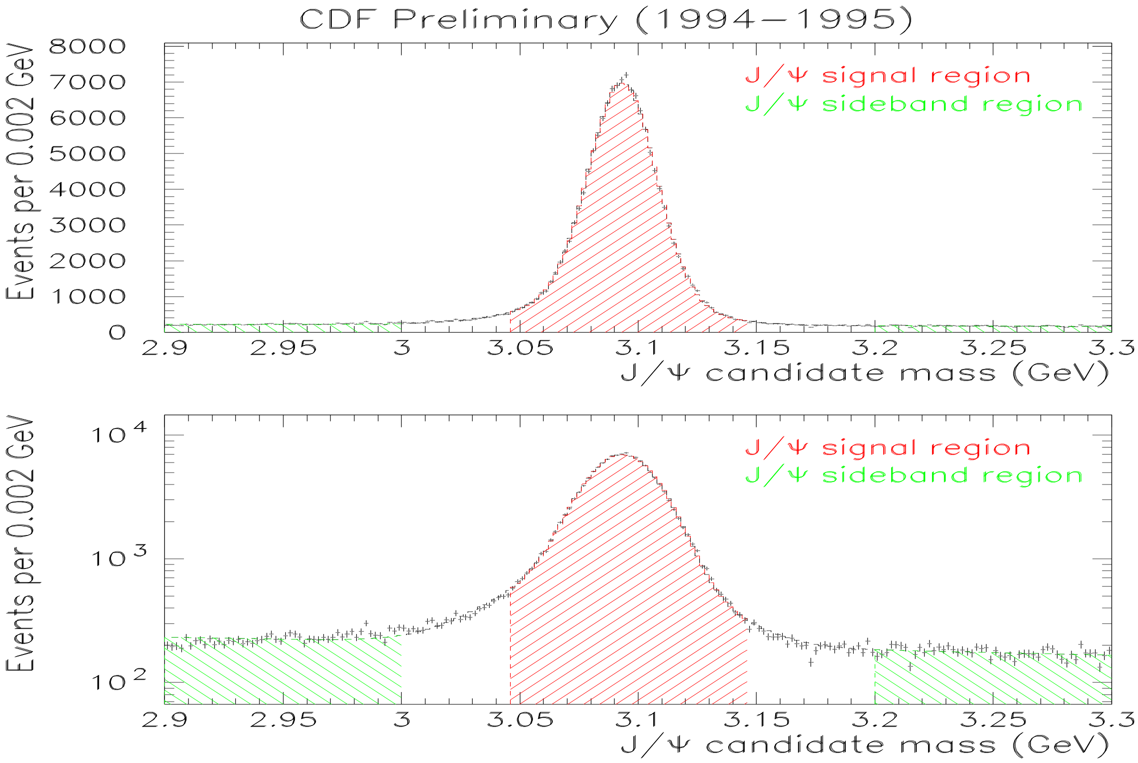

Figure 1: Di-muon invariant mass distribution from events passing selection criteria. Top: Linear scale. Bottom: Logarithmic scale.

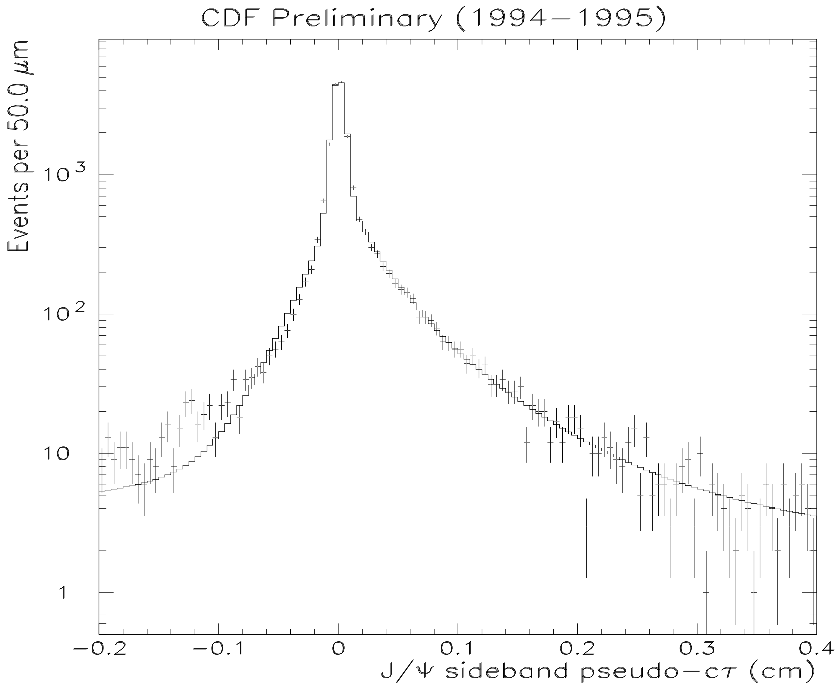

Figure 2: pseudo-$c\tau$ fit of J/ψ candidates in the mass sideband region.

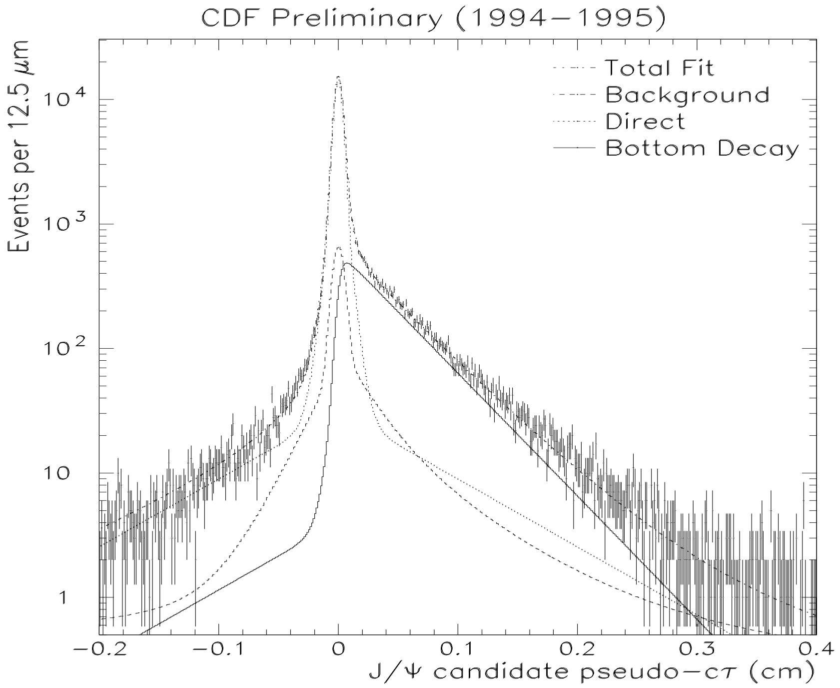

Figure 3: pseudo-$c\tau$ fit of J/ψ candidates in the mass signal region.

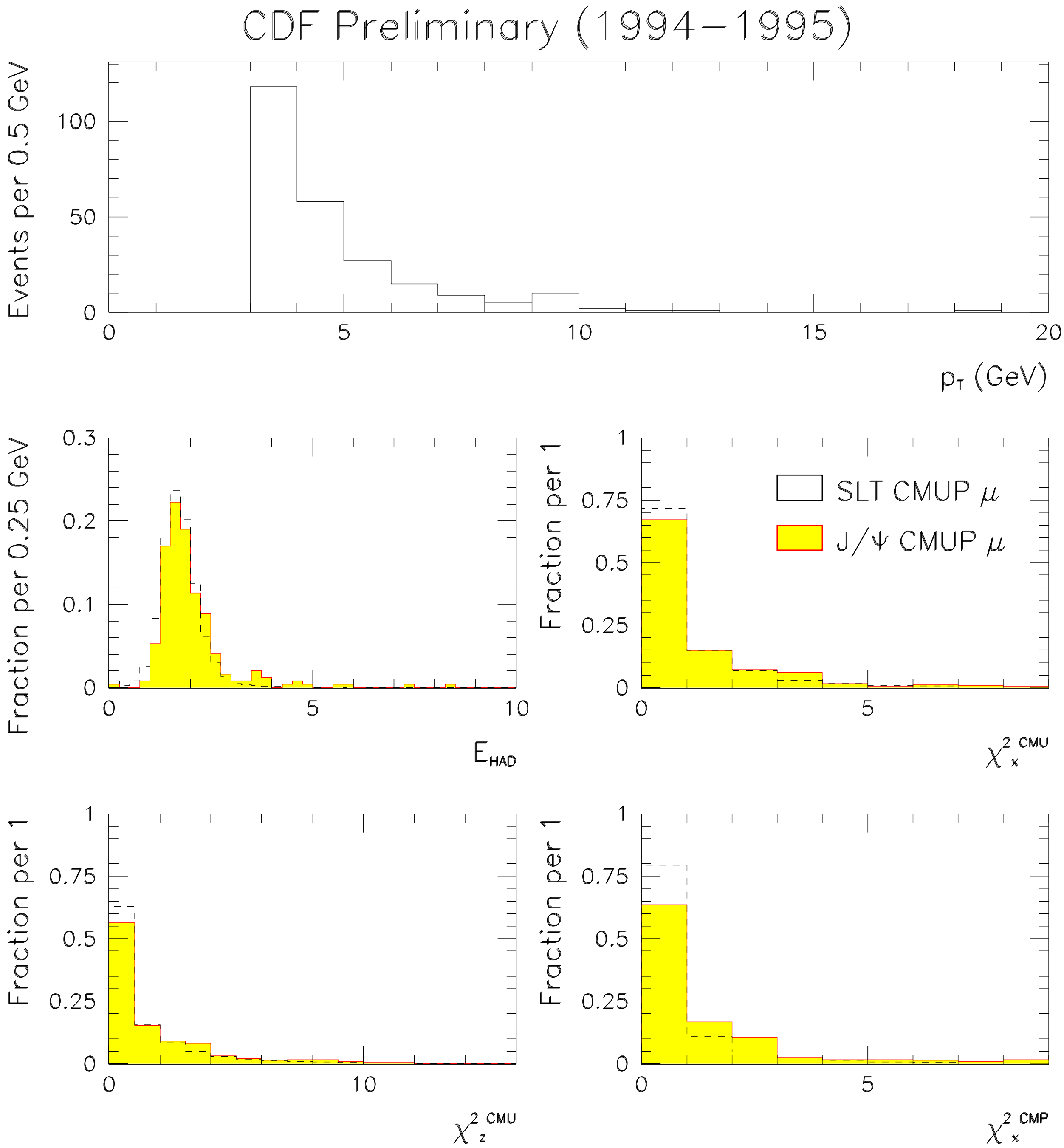

Figure 4: Top: The p_T of the CMUP muon candidates. Middle Left: Hadronic energy deposited by the SLT CMUP muon candidates (solid, filled) and by CMUP muons from J/ψ decay. Middle Right: χ^2 of r–ϕ stub matching in the CMU for the SLT CMUP muon candidates (solid, filled) and for CMUP muons from J/ψ decay. Bottom Left: χ^2 of r–z stub matching in the CMU for the SLT CMUP muon candidates (solid, filled) and for CMUP muons from J/ψ decay. Bottom Right: χ^2 of r–ϕ stub matching in the CMP for the SLT CMUP muon candidates (solid, filled) and for CMUP muons from J/ψ decay.

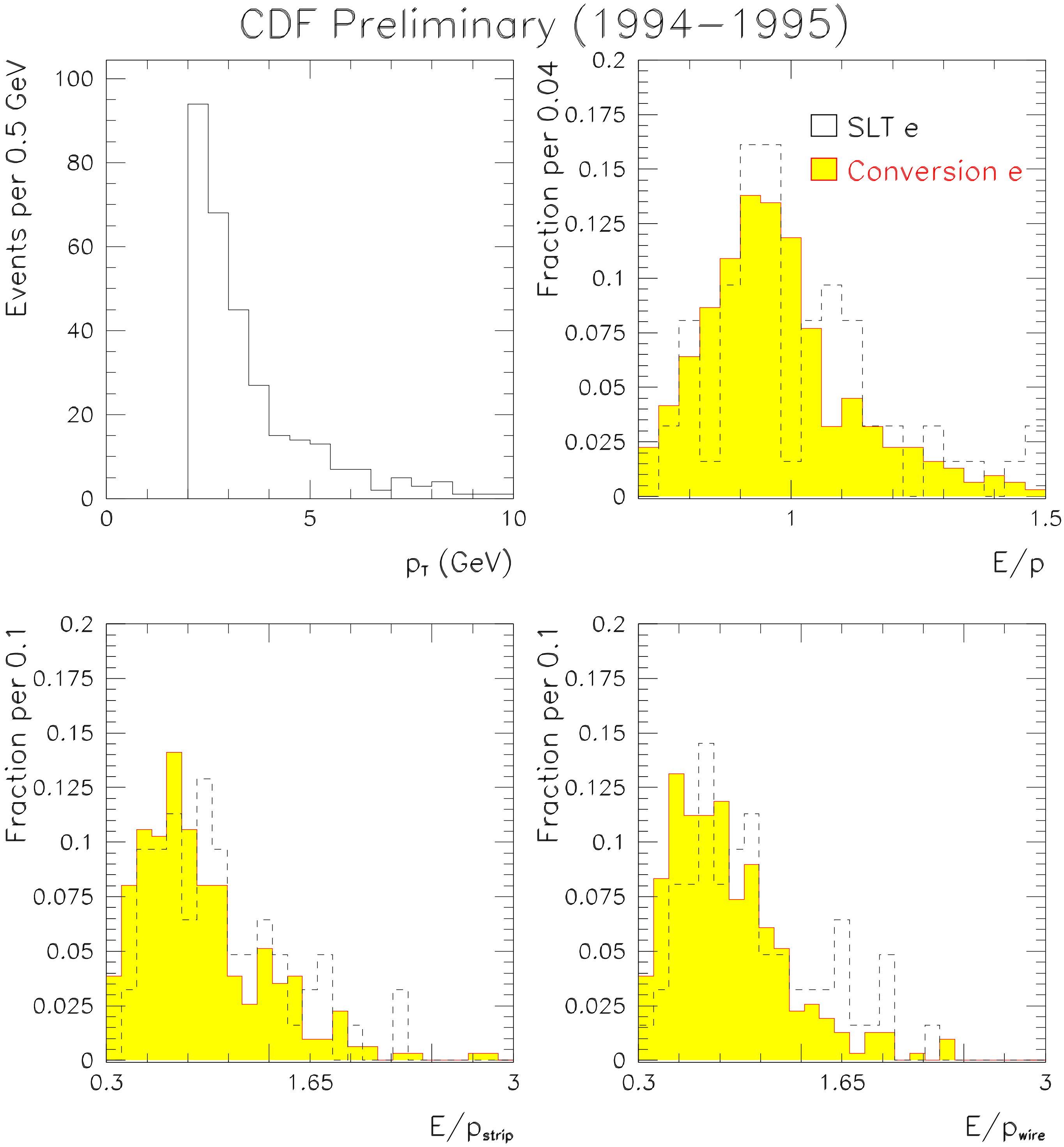

Figure 5: Top Left: p_T of the SLT electron candidates. Top Right: E/p of SLT electron candidates (filled,solid) and conversion candidates (dotted). Bottom Left: E_{strip}/p of SLT electron candidates (filled,solid) and conversion candidates (dotted). Bottom Right: E_{wire}/p of SLT electron candidates (filled,solid) and conversion candidates (dotted).

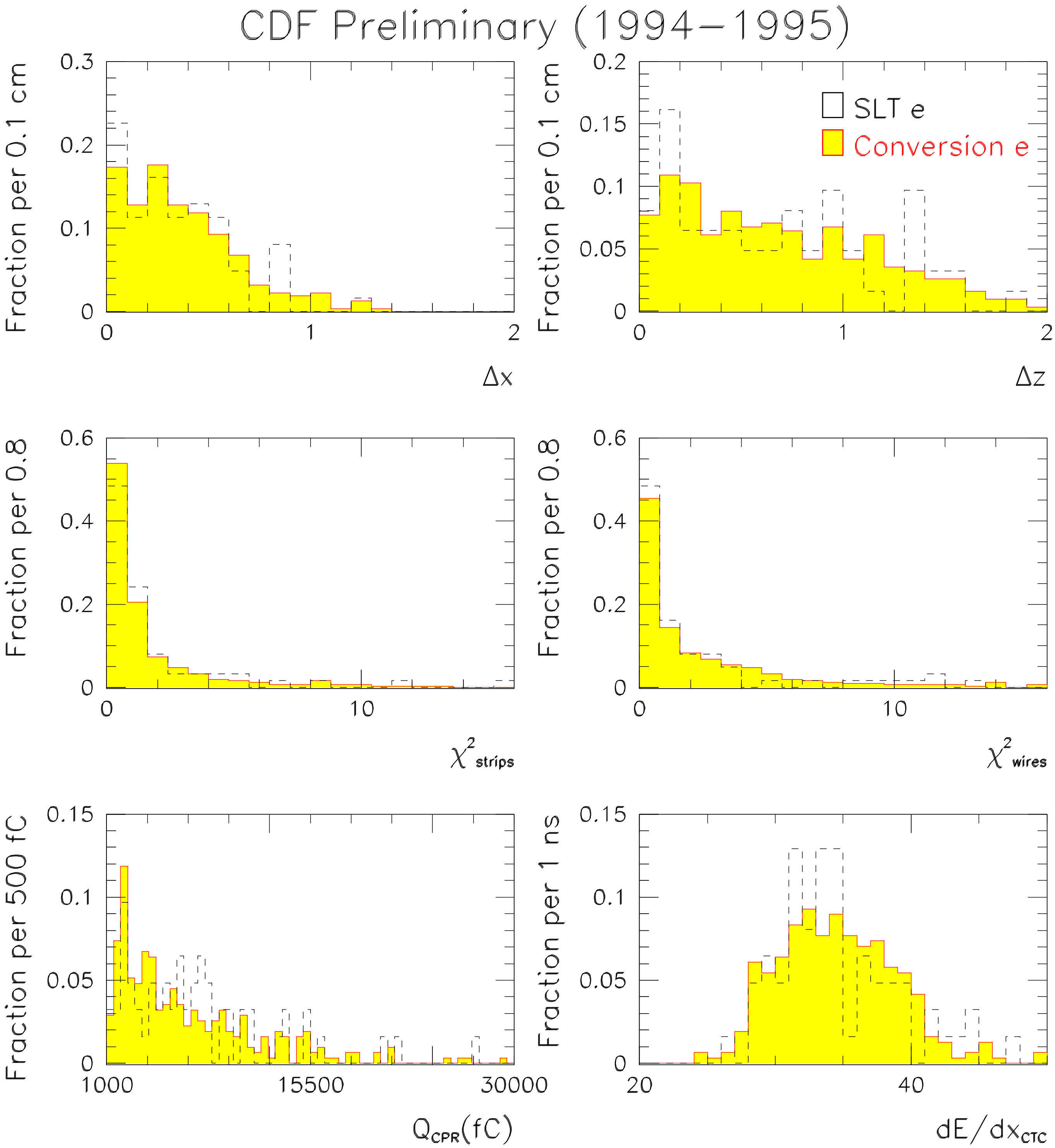

Figure 6: Distribution of electron selection variables for SLT candidates (solid,filled) and conversion candidates (dotted). Top Left: Δx. Top Right: Δz. Middle Left: χ^2_{wire}. Middle Right: χ^2_{strip}. Bottom Left: Q_{CPR}. Bottom Right: dE/dx.

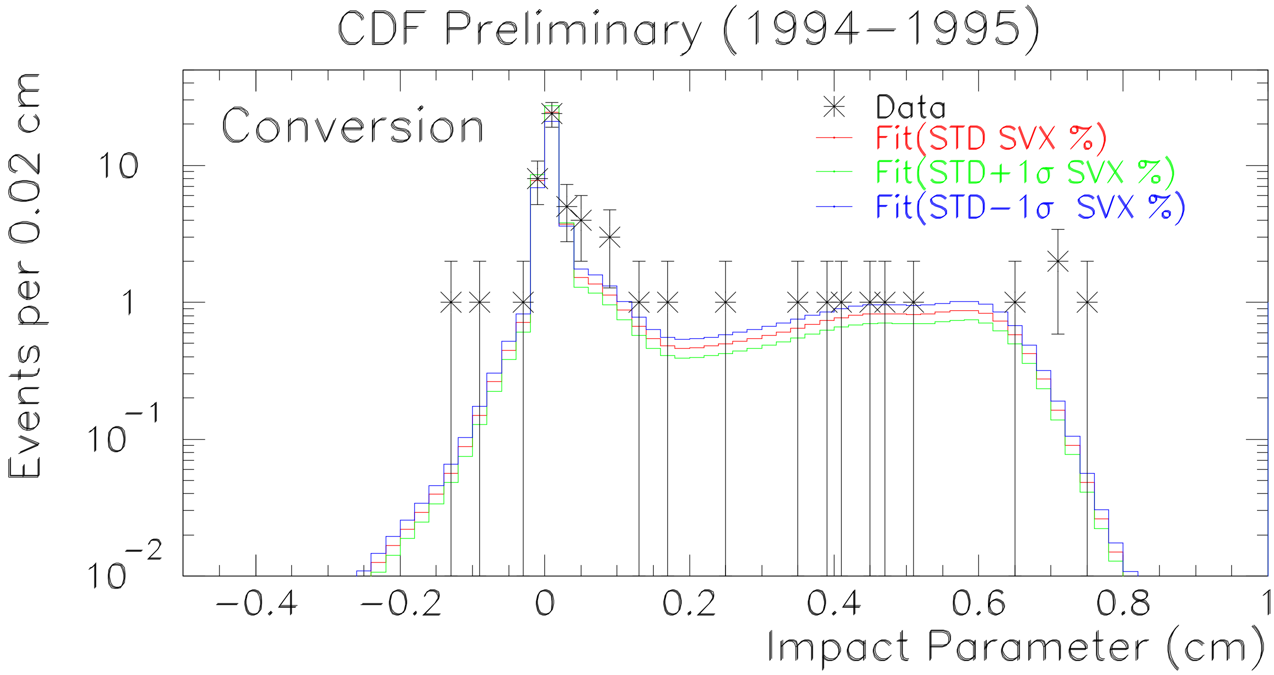

Figure 7: The signed impact parameter distribution for conversions found in data. Red: Monte carlos fit using the central value of $f_{conv}^{GoodSVX}$. Green: Monte carlos fit increasing $f_{conv}^{GoodSVX}$ by one sigma. Blue: Monte carlos fit decreasing $f_{conv}^{GoodSVX}$ by one sigma.

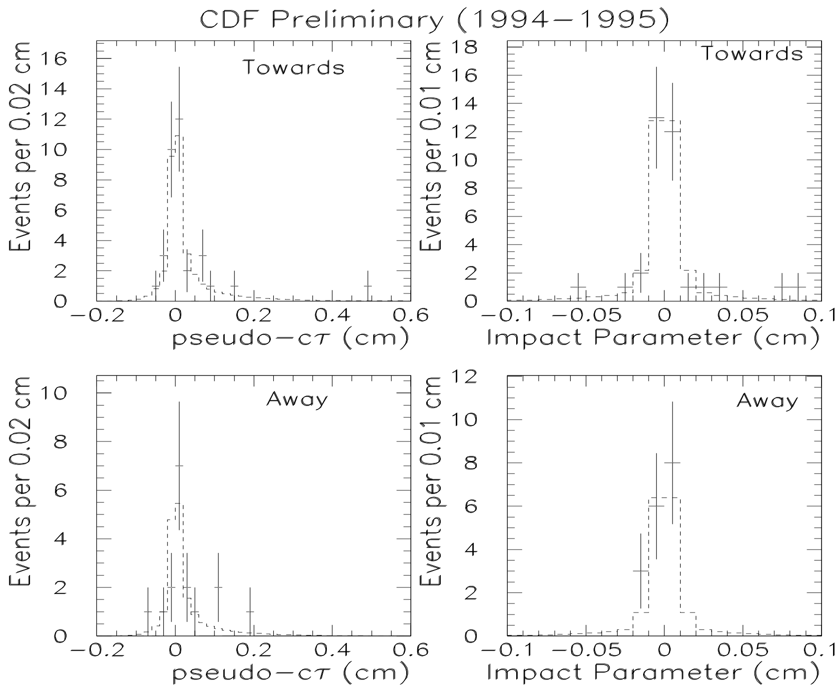

Figure 8: The fit of the muon sample's signed impact parameter and $c\tau$ distributions in the J/ψ mass sideband region.

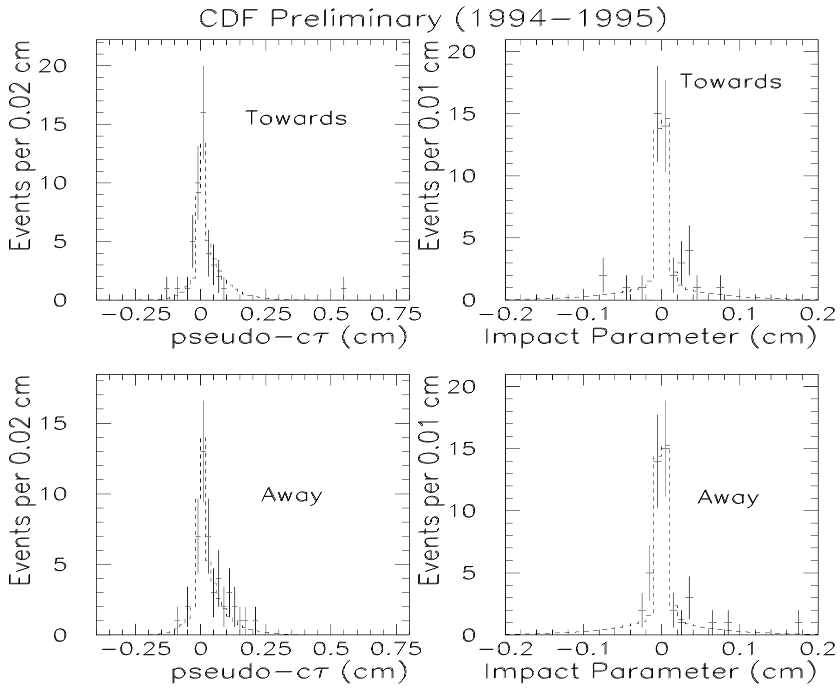

Figure 9: The fit of the electron sample's signed impact parameter and $c\tau$ distribution for the J/ψ mass sideband region.

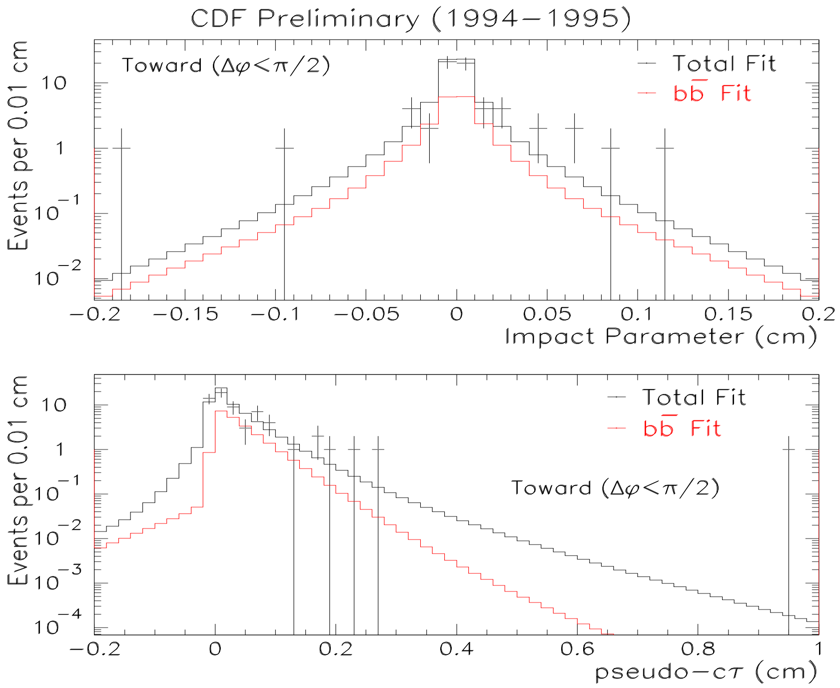

Figure 10: Result of the $c\tau$–impact parameter fit for the muon sample in the toward bin. Top: Projection onto impact parameter axis. Bottom: Projection onto $c\tau$ axis.

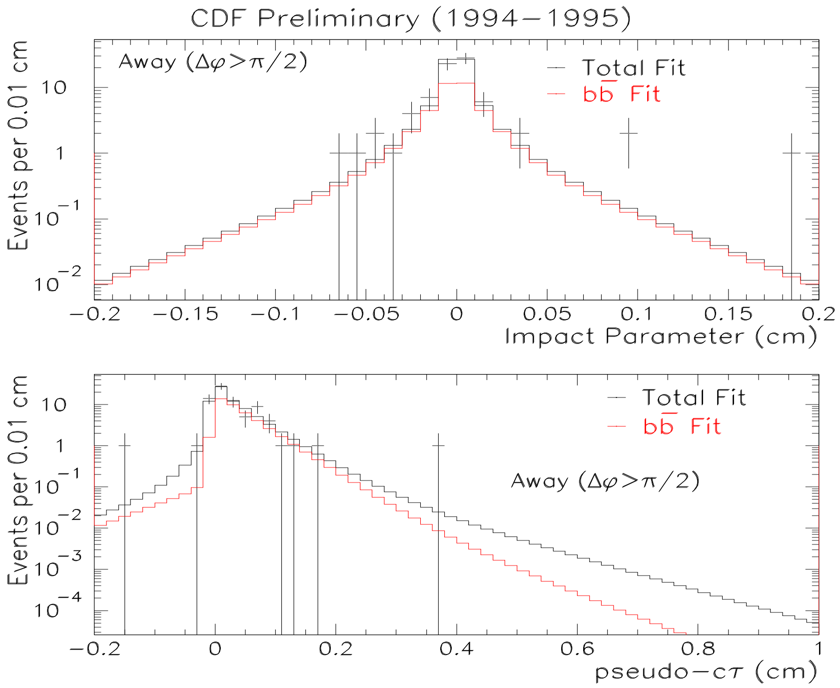

Figure 11: Result of the $c\tau$–impact parameter fit for the muon sample in the away bin. Top: Projection onto impact parameter axis. Bottom: Projection onto $c\tau$ axis.

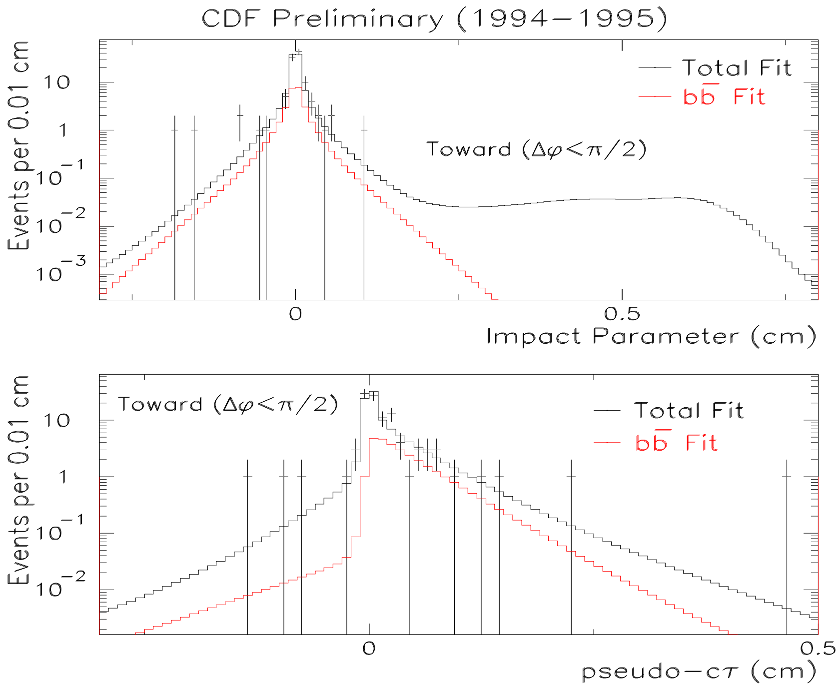

Figure 12: Result of the $c\tau$–impact parameter fit for the electron sample in the toward bin. Top: Projection onto impact parameter axis. Bottom: Projection onto $c\tau$ axis.

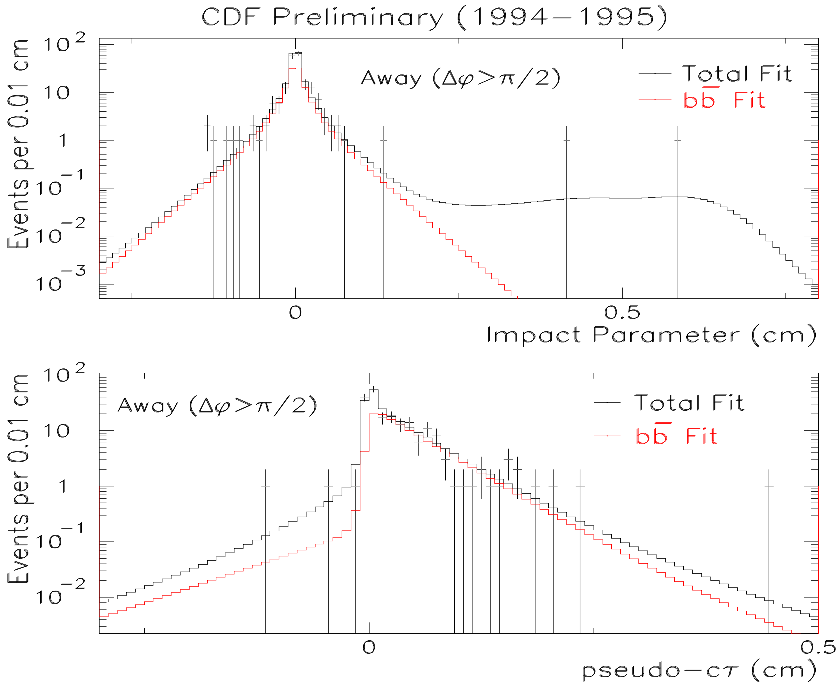

Figure 13: Result of the $c\tau$–impact parameter fit for the electron sample in the away bin. Top: Data. Bottom: Fit.