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Using Track Impact Parameter To Distinguish Hadronically-Decaying τ's in Top Quark Decays from Light Quark Jets

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Abstract

We examine the possibility of using the distributions of impact parameter d_0 as an additional means of distinguishing hadronically decaying τ's from light quark jets. There is a distinct statistical differentiation between signal and background. We suggest that the impact parameter be used as a probability in τ identification in the dilepton modes of top decay to reject W+jet background.

1 Introduction

The tau lepton lifetime ($c\tau$) is 87 μm, comparable if not large compared to the expected resolution in impact parameter of $\sigma = 10$ μm projected for the L00/SVX detectors in Run II. In Run I, two of the four candidates for taus in top dilepton decay were measured to have significant lifetimes [1]. We propose following up on the Run I results by using the impact parameter as part of tau identification *ab initio*.

The inclusion of the dilepton channel with one of the leptons being the tau would double, from 4/81 to 8/81, the branching ratio of $t\bar{t}$ events into dileptons. The tau, as another third-generation particle, could well have enhanced couplings to new physics, particularly any particles that couple to mass. For example, the decay of a top quark into a charged Higgs boson could well produce an excess of tau leptons in the dilepton final state.

In this note we propose using the impact parameter of the track(s) in the tau candidate as a probability to separate tau's from light quark jets. Section 2 describes the monte carlo generation and sample. Section 3 describes the geometric and kinematic acceptances. The tau identification selection is described briefly in Section 4; more details are given in tables and plots in Appendix A. The discrimination between tau's, light jets, and b-jets using the impact parameter is described in Section 5. Fake rates for the selection cuts used here (which are probably far from what will eventually be used) are given for light quark jets and b-quark jets in Appendices B and C, respectively. A discussion of the measured prong distribution is given in Appendix D.

2 Monte Carlo Generation and Sample

We have generated a Monte Carlo sample of top quark pairs with one top decaying into a τ lepton using Pythia and the Tauola module in Cdfsoft2 release 4.7.1, with default inputs. We simulate $t\bar{t}$ production and force the decays $W^+ \rightarrow u\bar{d}$ and $W^- \rightarrow \tau\bar{\nu_\tau}$, so that each event includes one tau lepton, two b jets, and two light quark jets from the W^+ decay. We ignore other flavors in the W^+ decay for now. The Monte Carlo sample consists of 70,000 events.

The sample was then run through the CdfSim detector simulation and event reconstruction (Production), also using Version 4.7.1. All settings were defaults, using the TCL files in the Cdfsoft Production directory.

3 Geometric and Kinematic Acceptance: Reconstructable Taus

3.1 Using HEPG Information Only

The HEPG block contains information on the particles generated by Pythia. We define those entries in the HEPG block with PDG code 15 as 'HEPG taus'; we find 142,500 HEPG taus in the 70,000 events, of which 70,000 come from W^- decay, as expected [2]. Of these we find 45,325 HEPG taus (64.8%) that decay hadronically, in good agreement with the expectation[3] of 64.7%.

The 45,325 events with hadronically-decaying HEPG taus form the sample for the study of the impact parameter [4]. For the present study we restrict ourselves to events with central taus that pass conservative geometric and kinematic cuts [1]. We require central taus ($|\eta_{HEPG}| < 1.1$); 33,045 events (73%) survive this cut. Kinematic cuts consist of requiring $E_T > 15$ GeV and $p_T^{seed\ track} > 4.5$ Gev/c; 26,811 (59% of the events with hadronically-decaying taus) survive these cuts. Table 1 summarizes the number of τ's from the W^- in top decay surviving the geometric and kinematic cuts at the HEPG level. We note that the $\mathrm{E_T}$ cut itself is quite efficient; it is the η and $\mathrm{p_T}$ cuts that create large losses, and both of these may be aided by inclusion of the impact parameter in the overall tau identification using the extended silicon coverage of the SVX/L00 and ISL[5].

3.2 Matching Reconstructed Taus to HEPG Taus

Each of the 70,000 reconstructed events includes a CdfTauCollection created by TauFinderModule. There are 117,194 CdfTau objects ("CdfTau's' ") that form the sample of candidate taus, an average of 1.67 CdfTau objects per event. We need to 'match' a CdfTau object to the parent HEPG tau to establish that the HEPG tau was found by TauFinderModule, as there is no backward linkage from the output of the event reconstruction to the HEPG bank.

The 26,811 HEPG τ's with a W parent that decayed hadronically and satisfied the geometric and kinematic selection criteria of Table 1 may be taken as an estimate of the number of 'reconstructable taus'. We limit the matching of CdfTaus and HEPG taus to events in which the HEPG τ from W^- decay is reconstructable by this definition.

Cut	HEPG Taus	Cumulative %	% Of Previous
Total τ's in HEPG	142,500	N/A	N/A
τ's from W^-	70,000	N/A	N/A
Hadronically decaying	45,325	100%	64.7%
$\lvert\eta_{HEPG}\rvert < 1.1$	33,045	72.9% $(= A_{geom})$	72.9%
$E_T > 15$ GeV	31,817	70.2%	96.3%
$p_T^{seed\ track} > 4.5$ GeV/c	26,811	59.2% $(=A_{geom\cdot kinematic})$	84.3%

Table 1: The number of HEPG τ's from the W^- in top decay surviving conservative geometric and kinematic cuts. Percentages are relative to the number of hadronically-decaying τ's from W^- decay. We begin with all τ's found in the HEPG block; this number reflects the double entry for most taus created by Pythia. Approximately 3/5 of all hadronically-decaying taus from the W in top decay are 'reconstructable' with these cuts, with the biggest loss being due to the rapidity cut.

For each reconstructed CdfTau object, we loop over the HEPG taus in the event, considering only those which come from a W and which decay hadronically (as reported in the HEPG block). We compute $(\Delta R)^2 = (\eta_{CdfTau} - \eta_{HEPG})^2 + (\phi_{CdfTau} - \phi_{HEPG})^2$ between the CdfTau object and each HEPG tau. The nearest HEPG tau with $\Delta R < 0.1$, should one exist, is chosen as a matching HEPG tau for the CdfTau object. Figure 1 shows the distributions in ΔR and ΔE_T between matched and HEPG taus. The ΔR spectrum contains a large number of matches at small ΔR and an extended tail proportional to $(\Delta R)^2$. We infer from this plot that requiring $\Delta R < 0.1$ for a match is a reasonable cutoff for the study of the impact parameter. Figure 2 shows the distributions of ΔR *vs.* ΔE_T and $\Delta E_T/E_T$ between matched and HEPG taus.

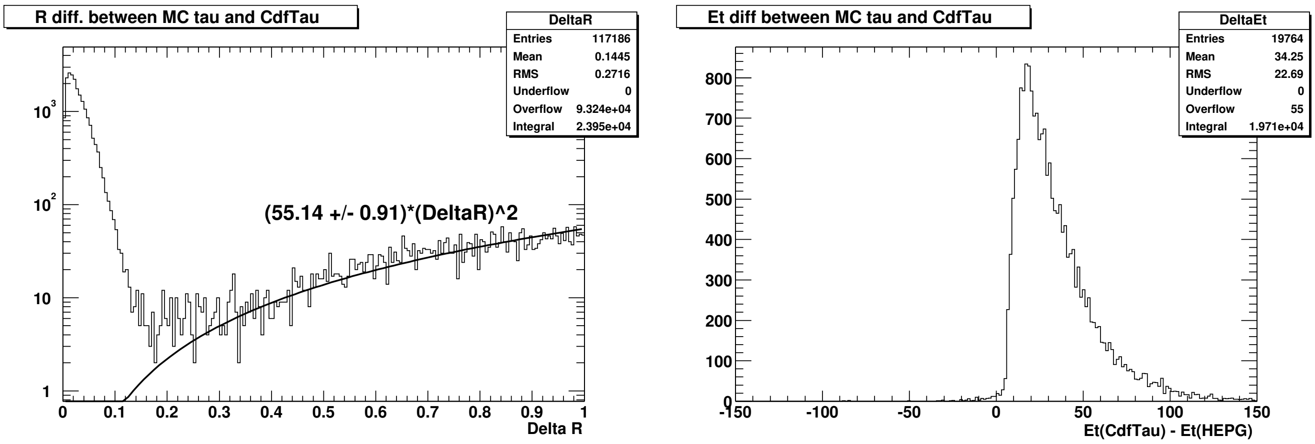

Figure 1: Left: ΔR between HEPG taus and CdfTaus matched to them. For $\Delta R > 0.2$, we have fit to $const \cdot \Delta R^2$. The fit is good, suggesting that we have an evenly distributed background. Right: $\Delta E_T = E_{T_{CdfTau}} - E_{T_{HEPG}}$ between HEPG taus and CdfTaus matched to them.

We find that the HEPG taus arise either from W^- decay or from B meson decay, dividing the matched CdfTaus into two classes. We find 19,764 CdfTaus that match a HEPG tau, of which

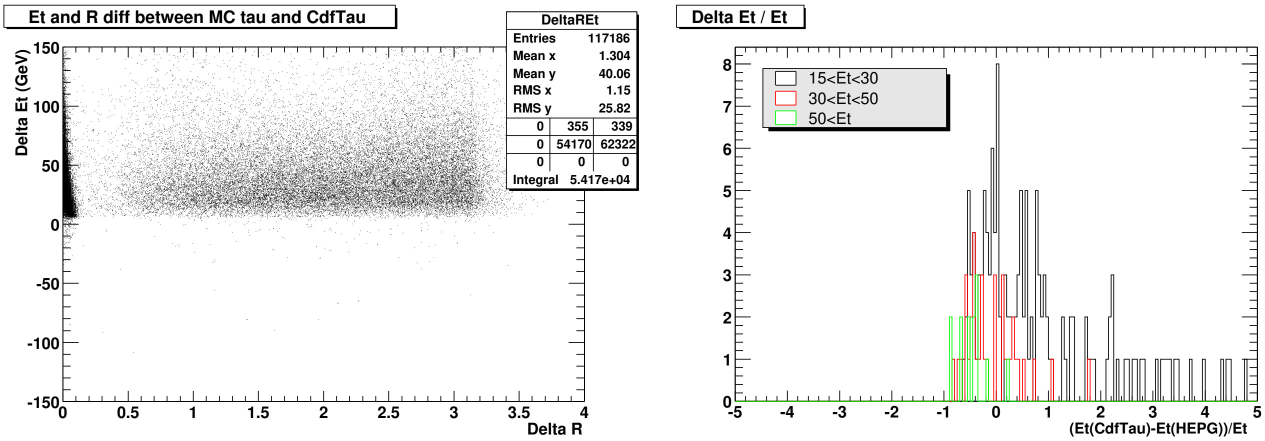

Figure 2: Left: ΔR vs. ΔE_T between HEPG taus and CdfTaus matched to them. Note the heavy concentration at small ΔR (< 0.2). Right: $\Delta E_T/E_T$ for E_T in ranges $15 < E_T < 30$ GeV (black), $30 < E_T < 50$ GeV (red), and $E_T > 50$ GeV (green).

19,624 are from W^- decay and 140 are from B meson decay.

To summarize, of an estimated 26,811 reconstructable HEPG taus, TauFinderModule reconstructs 19,624 as matched CdfTau objects, giving a TauFinder reconstruction efficiency of $\epsilon_{reconstruct} = 73.2\%$ [6], for an overall efficiency for creating a CdfTau object for a tau from the W in top decay of 43.3%.

4 Tau Identification Cuts

The τ identification cuts used here to search for hadronically decaying τ leptons are essentially those in Marcus Hohlmann's thesis [1]. This is a well-documented (published!), but overly tight, set of cuts that we use as a baseline; these are being improved. We require $E_T > 15$ GeV, seed track $p_T > 4.5$ GeV$/c$, 1 or 3 tracks in a cone of $10°$, and 0 tracks between $10°$ and $30°$. We further reject electrons and muons, require a fiducial z extrapolated at the CES, cut on the rms cluster width, impose tracking and calorimeter isolation cuts, and impose a track quality cut for the seed track by requiring more than 25 COT axial and stereo hits. Because the use of the impact parameter in tau identification is not expected to be strongly dependent on the specifics of tau identification, and because the Tau Working Group is working on improved tau identification, we have relegated the details of the cuts to Appendix A. A summary of the cut efficiencies is given in Table 2. Figure 3 compares η for CdfTaus matched to HEPG taus, and for those that are matched to HEPG taus and pass all ID cuts.

5 Impact Parameter for Taus and Jets

To study the impact parameter in tau decays, we further require that the τ seed track have 2 or more silicon hits. This additional requirement reduces the number of events considered to 4524.

	# Events	Cumulative %
HEPG τ's from W decay	70,000	N/A
HEPG: Hadronically decaying	45,325	100%
HEPG: Reconstructable	26,811	59.2%
CdfTau: Matched to HEPG	19,624	43.3%
CdfTau: Geometric acceptance	15,687	34.6%
CdfTau: $E_T > 15$ GeV	13,377	29.5%
CdfTau: τ ID cuts	4,881	10.8%
CdfTau: 2 SVX hits on seed track	4,524	10.0%

Table 2: Summary of τ acceptance and efficiency for the "Run 1" cuts. We expect that the low final efficiency should not affect the conclusions on the usefulness of the impact parameter.

The impact parameter distribution for the seed track from the CdfTau objects that pass all ID cuts and the silicon 2-hit requirement is shown in the left-hand plot of Fig. 4.

In the 70,000 events there are 155 light quark jets that pass the geometric, kinematic, tau ID and SVX 2-hit cuts. The right-hand plot of Fig. 4 displays the corresponding impact parameter distribution for jets faking taus.

A direct comparison of the shapes of the impact parameter distributions from taus and light jets can be see in Fig. 5, which shows both distributions superposed.

The eventually-achievable impact parameter resolution remains to be seen as L00 and the SVX are still being understood. The design values, however, are very good, and we have every reason to expect that values in the ball-park of the design will eventually be achieved. The design goals using L00 are to have a constant term of $A \leq 7\ \mu m$ with a multiple-scattering term $B \leq 21\ \mu m$, where the resolution has been parameterized as $\sigma = A \oplus B/\mathrm{p_T}(GeV)$. The SVXII alone is designed to have $A \leq 10\ \mu m$ and $B \leq 38\ \mu m$ [7]. Thus for a seed track of 4.5 GeV (the minimum in the present selection criteria) the design resolutions are 8.4 μm and 13 μm for L00 and SVXII-alone, respectively.

Fig 6 shows the impact parameter distribution for four samples before τ ID cuts. The upper left plot is for CdfTaus matched to a HEPG τ coming from W^- decay. The upper right plot shows the impact parameter for CdfTaus matched to a HEPG τ coming from B meson decay. The lower left plot is for CdfTaus that do not match HEPG τ's but do match a u or $\bar{d}$ quark jet. The lower right plot is for CdfTaus that do not match a HEPG τ but do match a b quark jet. One can see the long tail on the light-quark jet distribution and the naturally-long distribution from b-quark jets before the τ identification cuts have been applied.

Fig 7 shows the same four plots as Fig 6, but for only those CdfTaus which pass the τ ID cuts of Table 4. It is these plots, rather than those of Fig 6, which give the approximate fake rates for jets faking taus in this energy range.

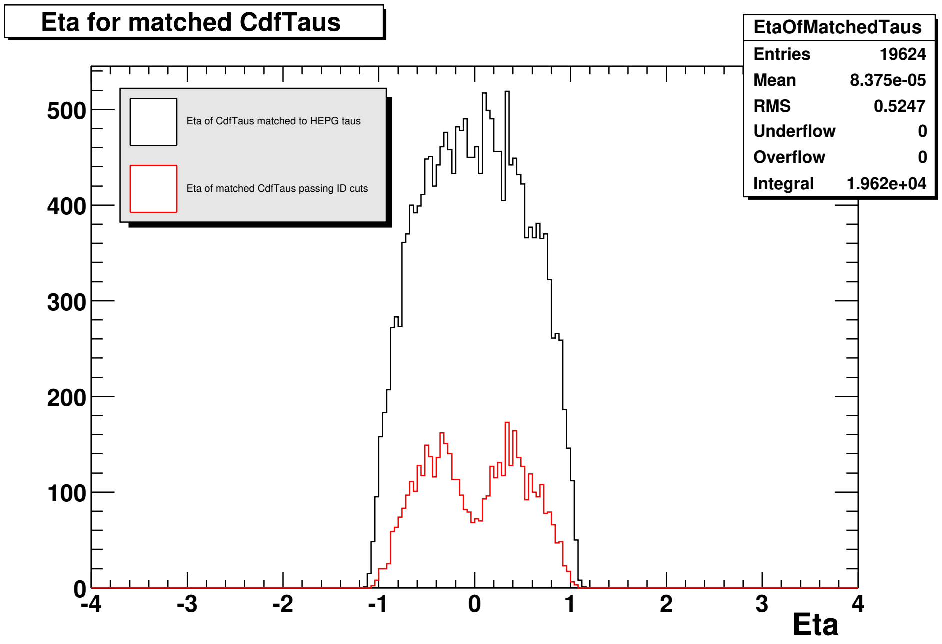

Figure 3: Black: η for CdfTaus matched (within ΔR of 0.1) to HEPG taus. Red: η for those matched CdfTaus that also pass all ID cuts. The loss at low η is due to the requirement on fiducial z_{ces}.

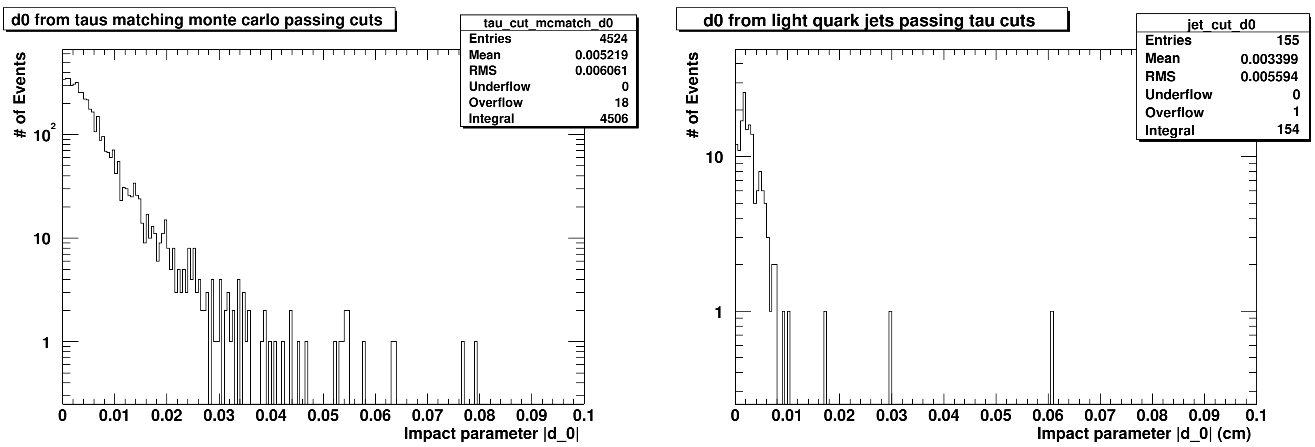

Figure 4: Left: Impact parameter distribution for τ leptons passing all τ ID cuts, and matched to HEPG taus from W^- decay. Right: Impact parameter distribution for light quark jets passing all τ ID cuts, in events where another τ is matched to a HEPG tau. These require the SVX 2-hit cut as well.

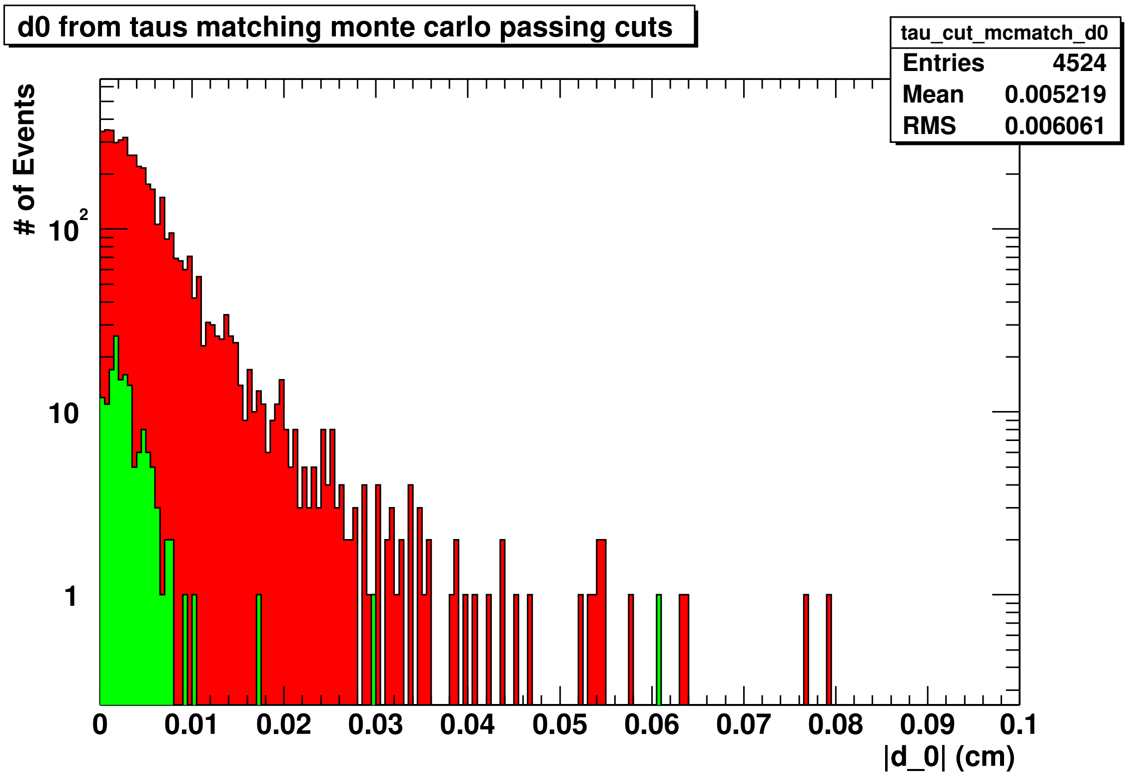

Figure 5: Impact parameter distribution for reconstructed light quark jets (green) and τ's (red).

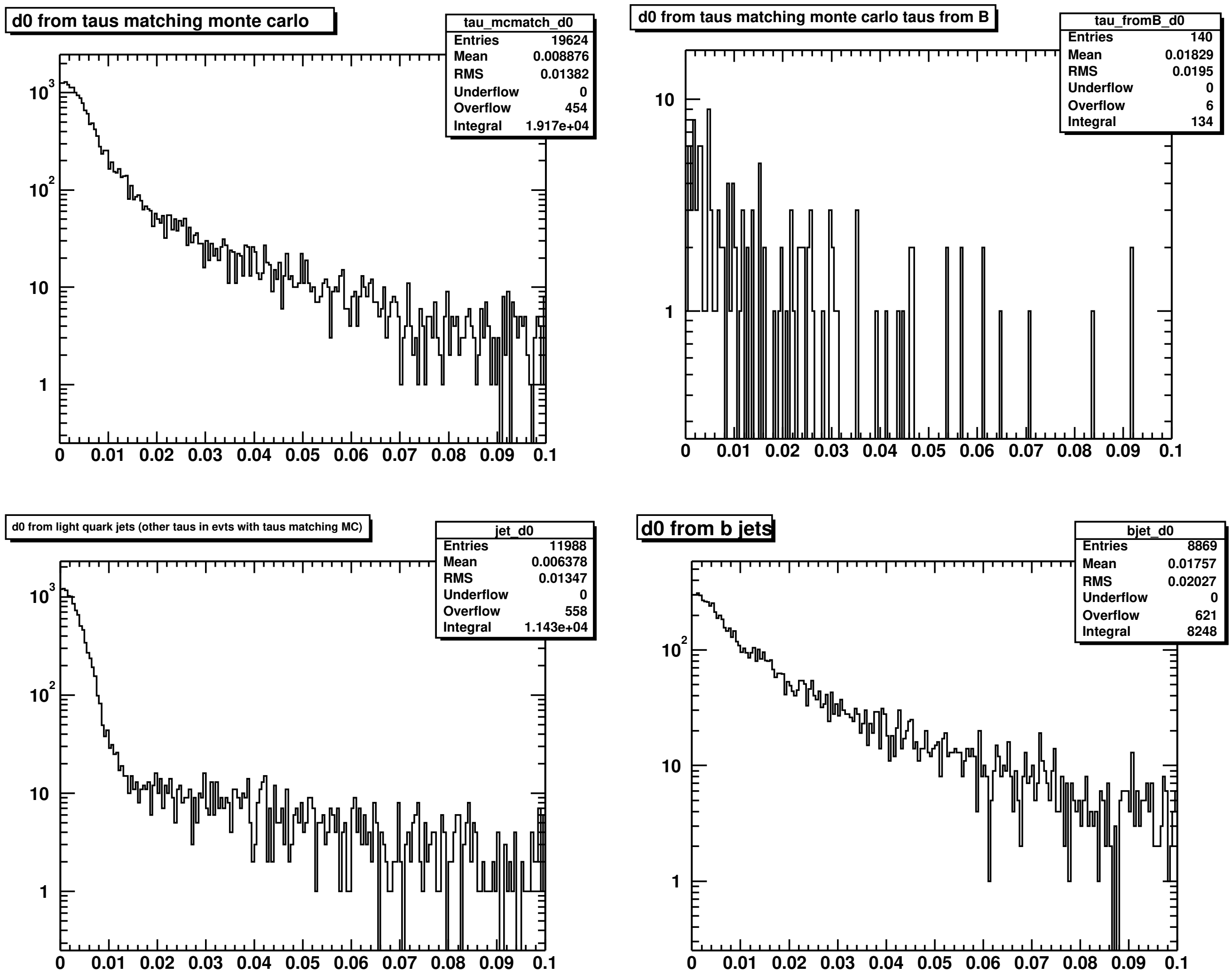

Figure 6: Impact parameter distribution for four samples before τ ID cuts. First, we have CdfTaus matched to a HEPG τ coming from W^- decay. Second, we have CdfTaus matched to a HEPG τ coming from B meson decay. Next, we have CdfTaus that do not match a HEPG τ but do match a u or $\bar{d}$ quark jet, and finally CdfTaus that do not match a HEPG τ but do match a b quark jet.

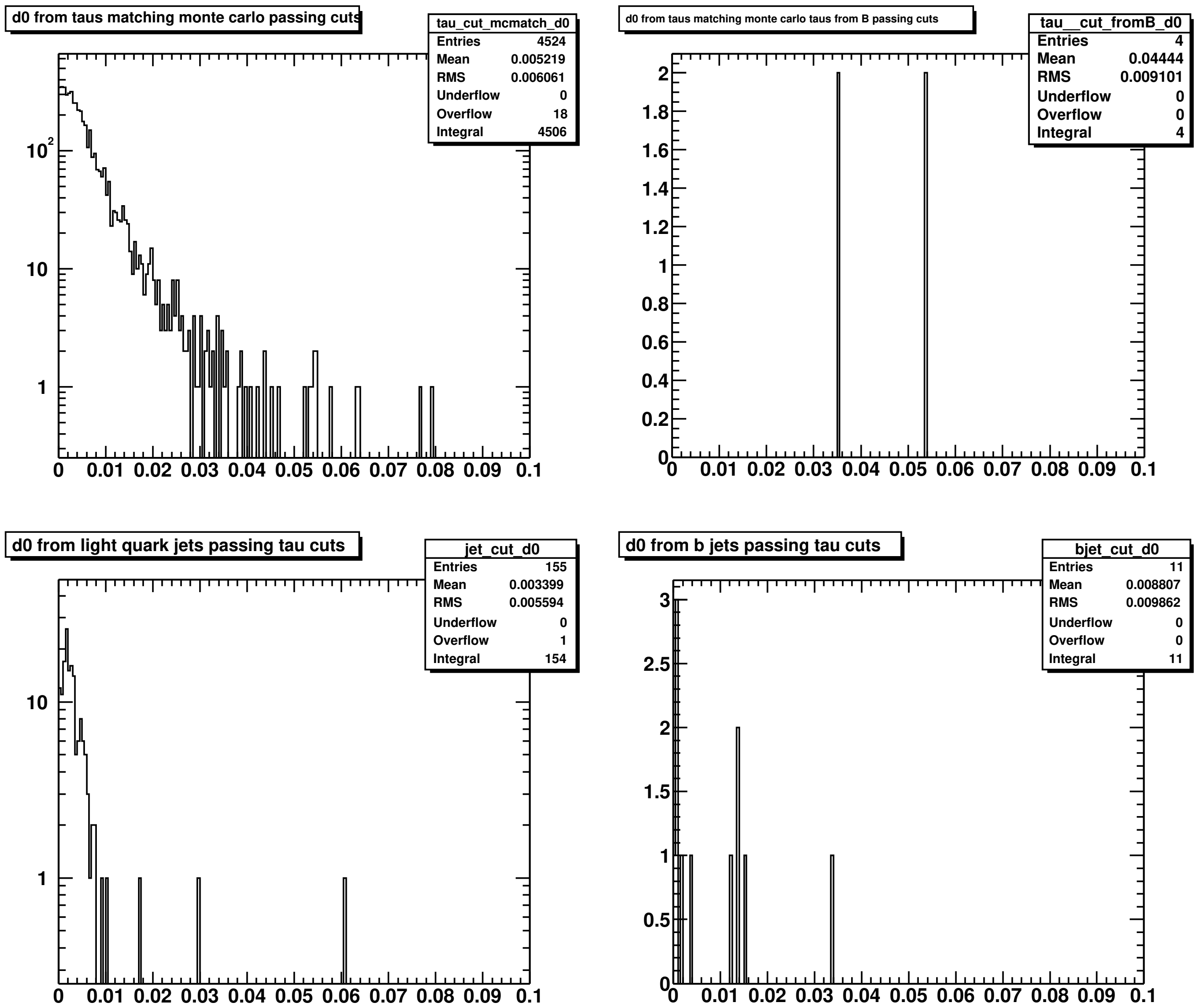

Figure 7: Impact parameter distribution for the same four samples as in Fig. 6, but keeping only those CdfTaus which pass all of the τ ID cuts as presented in Table 4. First, we have CdfTaus matched to a HEPG τ coming from W^- decay. Second, we have CdfTaus matched to a HEPG τ coming from B meson decay. Next, we have CdfTaus that do not match a HEPG τ but do match a u or $\bar{d}$ quark jet, and finally CdfTaus that do not match a HEPG τ but do match a b quark jet.

5.1 Comparison of Impact Parameter Distributions for τ's and Jets

Fig. 8 shows the fraction of taus and jets passing a cut on d_0 as a function of the cut. Fig. 9 displays a plot of jet rejection efficiency and tau efficiency as a function of location of a cut on the maximum allowed $|d_0|$. We (re)emphasize that the impact parameter should not be cut on, but included as a 'tagging' probability in the separation of taus from background jets.

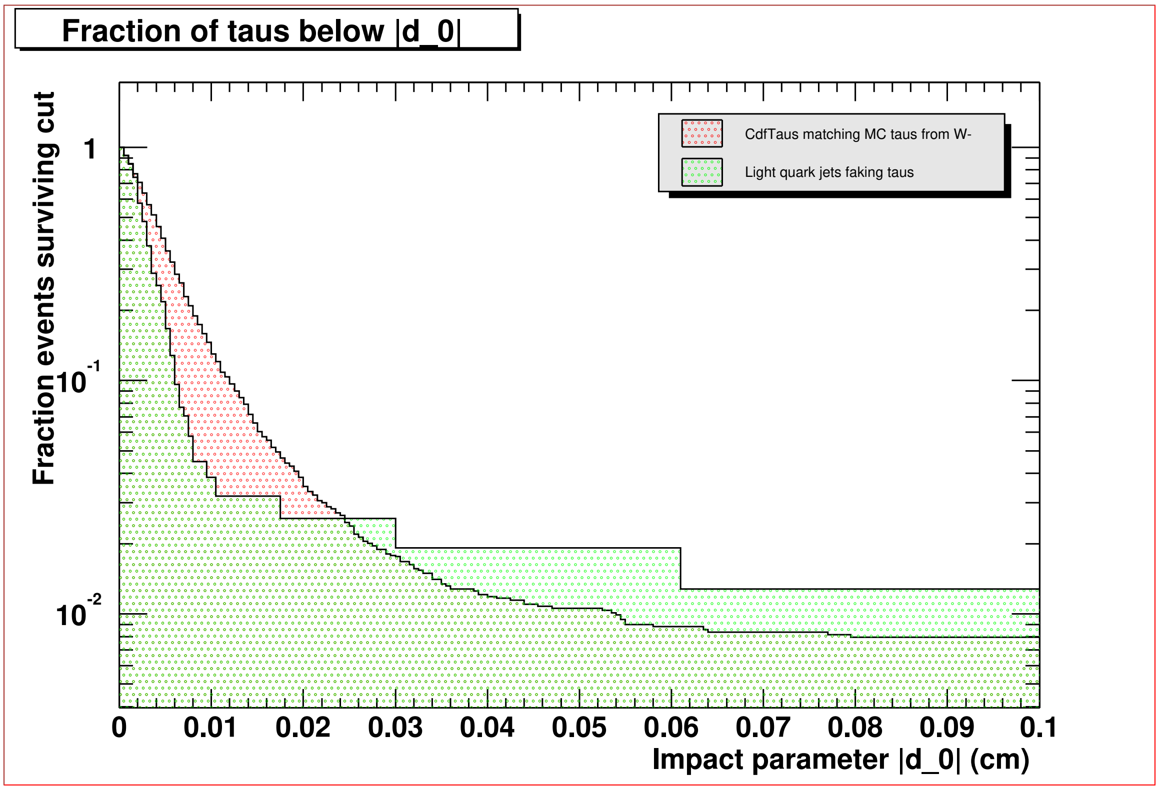

Figure 8: Fraction of taus and jets, passing all other τ ID cuts, which survive a cut on $|d_0|$ as a function of $\min|d_0|$.

Table 3 gives the shape of the two integral distributions in impact parameter. One can see that there is a strong discrimination against light quark jets, as one would expect from the inherent resolutions. We do not know how well the detector simulation represents the real situation, and so the final shape of these curves will have to be determined by data, but this is a good starting point for comparison with the data.

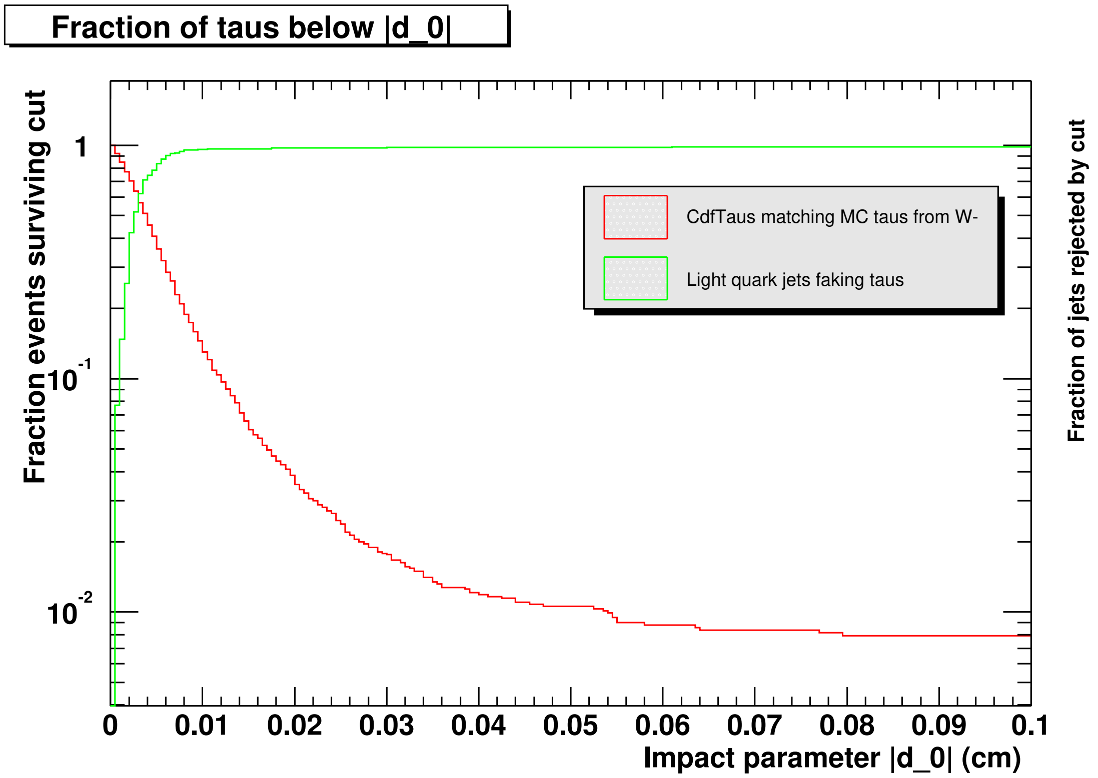

Figure 9: Fraction of taus passing all other τ ID cuts that survive a cut on $|d_0|$ as a function of min$|d_0|$, and jets rejected by the cut.

$\lvert d_0\rvert_{max}(\mu m)$	% τ's accepted	% jets rejected
10	92.4	7.69%
20	77.1	25.6%
30	63.8	51.9%
40	51.2	71.2%
50	40.8	78.2%
60	32.2	87.2%
70	26.2	92.3%
80	21.0	94.2%
90	17.4	95.5%
100	14.6	96.2%

Table 3: Fraction of taus passing, and the fraction of light-quark jets rejected, by a cut $|d_0| < |d_0|_{max}$ versus $|d_0|_{max}$. We note that the expected resolution for a track of 4.5 GeV (the present minimum for the seed) is 10μm using L00.

6 Conclusions

Our preliminary simulation studies show that the impact parameter is a good discriminant between τ's and light quark jets, as would be expected from simple considerations of the tau lifetime and the SVX/L00 impact parameter resolutions. Table 3 summarizes the acceptance for τ's and rejection of light quark jets for various values of $|d_0|_{max}$ as calculated in the simulation. We will not cut on this variable, but it will be useful when folded into a likelihood estimate based on data. It should also be noted that very few b quark jets survive τ ID cuts (less than 0.2%).

The τ ID cuts used in this study are quite strict, and can be substantially improved for higher efficiencies. This should not affect the conclusions on the impact parameter, we believe. Also, the resolution for impact parameter in 4.7.1 Monte Carlo will improve significantly in release 4.9.0, with the use of Layer 00. The addition of information on π^0's (beyond the number found) will also improve the tau ID efficiency, as $p_T^{trk+\pi^0} > p_T^{trk}$.

7 Acknowledgements

We would like to thank Fedor Ratnikov, Pasha Murat, and Peter Onyisi for much help.

References

[1] Hohlmann, M. *Observation of Top Quark Pairs in the Dilepton Decay Channel Using Electrons, Muons, and Taus* University of Chicago Dissertation, August 1997.

[2] Pythia creates two entries for most tau's in the HEPG bank. Only one of them has the correct parent, and so there is no double counting in the final numbers.

[3] Particle Data Group; K. Hagiwara et al., Phys. Rev. D66,010001 (2002). The one-prong hadronic decays are listed at 36.9% and the three-prong hadronic decays at 15.2%, for a total of 52.1%, of which 71% are one-prong hadronic decays.

[4] Although it is not the focus of this present study, we note that the impact parameter should be useful in identifying the 35.2% of tau days that produce an isolated electron or muon. This may allow lowering the threshold and possibly expanding the η range in the ee, $\mu\mu$,and $e\mu$ channels.

[5] The 16% loss due to requiring the $\mathrm{p_T}$ of the seed track be greater than 4.5 GeV may be partly recoverable by lowering the threshold and using the impact parameter probability as part of an overall tau likelihood, as its efficiency shouldn't depend strongly on $\mathrm{p_T}$.

[6] This is with version 4.7.1, and presumably has been improved with the new tau identification algorithms. The 26.8% of HEPG taus for which no matching CdfTau is found beg to be studied, but while understanding this inefficiency is important, it should wait for the new code (also, the cut at $\Delta R = 0.1$ is a little tight for τ identification). The conclusions about the impact parameter should not depend on this efficiency.

[7] Proposal for Enhancement of the CDF II Detector, An Inner Silicon Layer and A Time of Flight Detector; Submitted to the Fermilab Dirctor and PAC, Sept. 22, 1998; http://www-cdf.fnal.gov/internal/upgrades/btb/

8 Appendix A: Run I Tau Identification Cuts

The tau identification cuts used here are based on those used by Marcus Hohlmann in his search for top decays into $e\tau$ and $\mu\tau$ [1]. We have started with them as a reference point and base line; it is clear that they can be improved for Run II. However they are adequate for the present study of impact parameter. We summarize some details below.

8.1 Tau Variables

- E/p: We cut on the variable $\frac{E_T}{p_T^{trk+\pi^0}}$ where E_T is obtained from the calorimeter and $p_T^{trk+\pi^0}$ is defined to be $\sum_{trk} p_T^{trk} + \sum_{\pi^0} E_T^{EM}$. The tail for one-prongs is higher than for three-prongs, so we cut at 2.0 for the former and 1.5 for the latter.

- δr: This is the RMS width of a cluster, defined as the second moment of the E_T distribution among towers,
$$(\delta r)^2 = <(\phi_i - <\phi>)^2> + <(\eta_i - <\eta>)^2> \quad (1)$$

- z_{ces}: This is the z-coordinate of the seed track extrapolated to the CES.

- $m_{trk+\pi^0}$: The invariant mass of the τ is taken from the tracks in the 10° cone together with the associated π^0's. One-prongs without identified π^0's automatically pass this cut.

- I^τ_{trk}: The tracking isolation is the sum p_T for all tracks in a cone of radius 0.4 about the tau cluster center, using only tracks for which $\Delta z = |z_{trk} - z_\tau| < 20$ cm. Tracks considered part of the tau cluster (seed and shoulder tracks) are not summed.

- I^τ_{calo}: The calorimeter isolation is the energy in a cone of radius 0.4 about the cluster center, minus the energy associated with the tau.

- Electron removal: We use E_T/p_T here, rather than $\frac{E_T}{p_T^{trk+\pi^0}}$, because the EM energy of an electron may be construed as a π^0 by the algorithm.

8.2 Tau ID Efficiencies

Starting with the 19,624 CdfTaus matching a HEPG tau from W^-, we first impose geometric acceptance cuts for central taus. There are 19,617 with $|\eta_{cluster}| < 1.1$, 16,379 of those with 20cm $< |z_{ces}| <$ 200cm, and 15,687 of those with $|z_0| < 60$ cm. Then $15,687/19,624 \sim 79.9\%$ of matched CdfTaus pass the geometric acceptance cuts. Next, we impose $E_T > 15$ GeV and seed track $p_T > 4.5$ GeV/c and find 13,377 taus remaining. Of these, 4,881 pass all tau ID cuts, giving an efficiency $4881/13377 \sim 36.25\%$. The overall efficiency of a reconstructable CdfTau to pass the ID cuts is then $4881/26811 \sim 18.2\%$.

Table 4 in Appendix A summarizes the tau ID cuts. Table 2 summarizes the tau acceptances and efficiencies. Of all the central tau objects, 5,646 pass all tau ID cuts. We find, then, that 86.8% of taus that pass the ID cuts match HEPG taus.

Tau Identification Efficiencies				
Bit	Cut	% Passing	After rest	Cumulative
0	$E_T > 15$ GeV	100%	100%	100%
1	Seed track $p_T > 4.5$ GeV/c	100%	100%	100%
2	$\frac{E_T}{p_T^{trk+\pi^0}} < 2.0$	72.8%	89.1%	72.8%
	$\frac{E_T}{p_T^{trk+\pi^0}} < 1.5$ (3-prongs)			
3	$\delta r_{ces} < 0.11 - 0.025 \times E_T/100$	94.6%	99.3%	69.2%
	$\delta r_{ces} < 0.13 - 0.034 \times E_T/100$ (3-prongs)			
4	$m_{trk+\pi^0} < 1.8$ GeV/c^2	99.6%	100%	68.8%
5	$\#\pi^0 < 3$	93.2%	99%	66.2%
6	$\lvert z_0\rvert < 60$ cm	99.9%	100%	66.2%
7	$I^{\tau}_{calo} < 3$	85.6%	97.8%	57.6%
8	$I^{\tau}_{trk} < 1$	71.7%	100%	45.4%
9	20 cm $< \lvert z_{ces}\rvert <$ 220 cm	100%	100%	45.4%
10	#COT axial hits > 25, #COT stereo hits > 25	95.9%	99.3%	43.8%
11	Electron removal: Reject 1-prongs with $E/p < 4$ & EMfrac > 0.9 or clusters with EMfrac > 0.95	90.8%	98.4%	41.9%
12	Muon removal: Reject clusters with $E_T < 8$ GeV & $0.05 < E_{EM} < 2$ GeV & $0.5 < E_{Had} < 5$ GeV or with a muon stub with $\lvert\phi_\tau - \phi_{stub}\rvert < 15^\circ$	98.9%	99.8%	41.6%
13	$n_{trks}(10^\circ) = 1$ or 3	77.8%	94.9%	36.5%
14	$n_{trks}(10^\circ - 30^\circ) = 0$	71.7%	100%	36.5%

Table 4: The efficiencies of various cuts on the CdfTaus that have matched reconstructable, hadronically-decaying HEPG τ's from W^- or B meson decay. The "Passing" column gives the number of τ's, passing all geometric and kinematic acceptance cuts, which pass the cut in question. The "After rest" column gives the number of τ's passing all other cuts, which pass the cut in question. The "cumulative" column gives the number of taus passing the cut in question and all preceding cuts. See Fig. 10 and Fig. 11 for distributions of τ variables. Note that bit 2 should improve with the addition of $p_T^{\pi^0}$, unavailable in release 4.7.1.

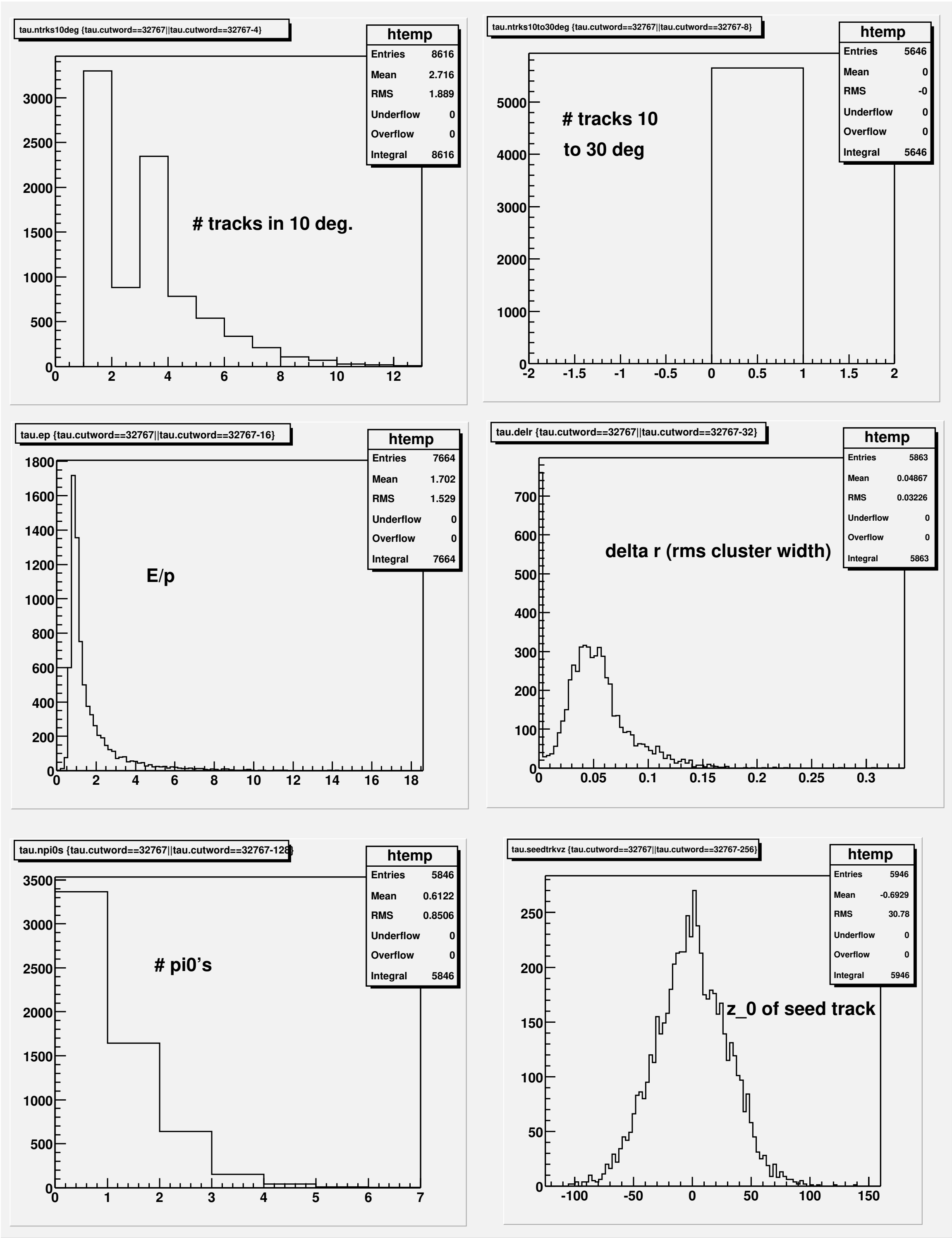

Figure 10: Distributions of τ variables, in each case plotted for CdfTaus required to pass all cuts except the cut on the variable in question.

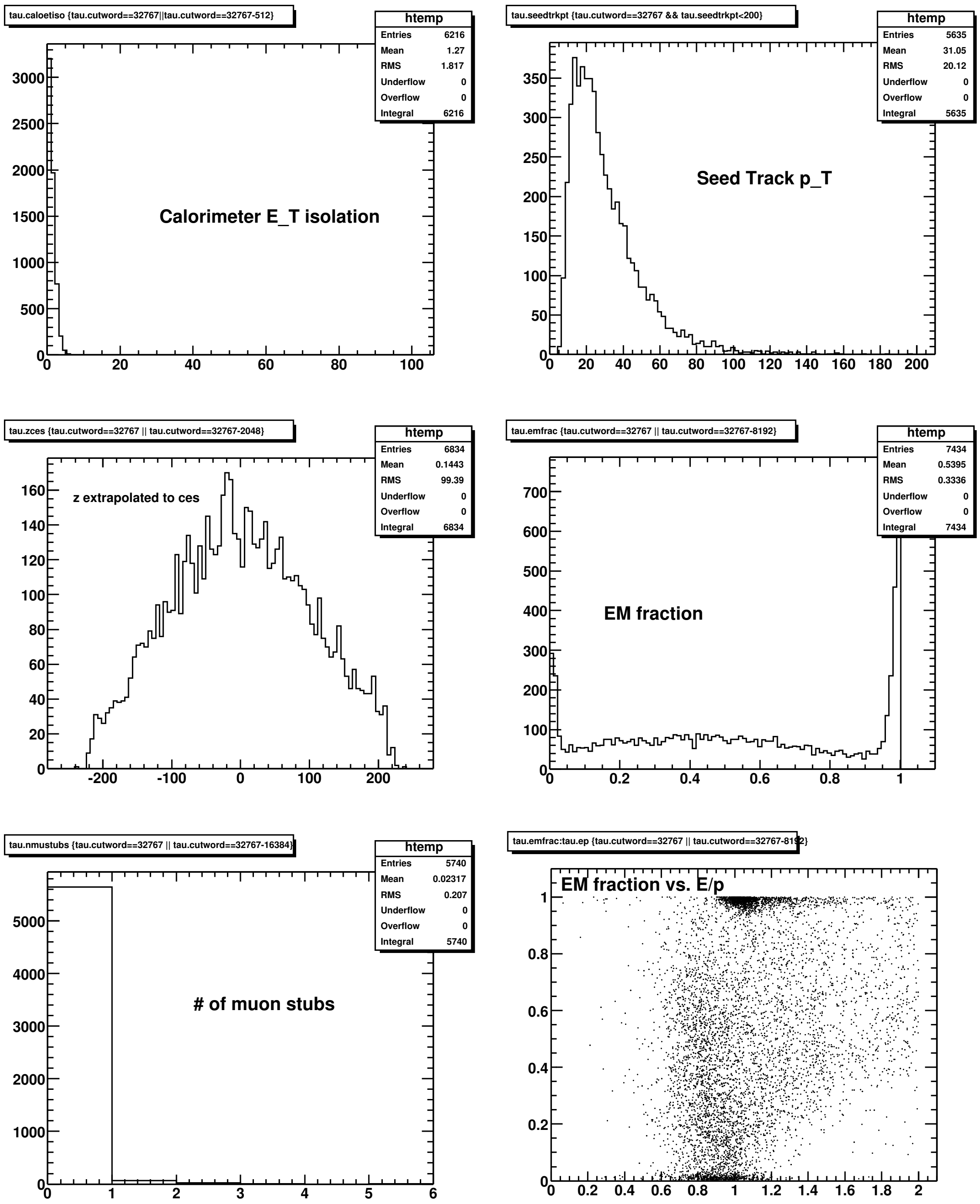

Figure 11: More distributions of τ variables, in each case plotted for CdfTaus required to pass all cuts except the cut on the variable in question.

9 Appendix B: Light Jets faking Taus

We find on average about one remaining CdfTau in events that contain a CdfTau passing the ID cuts and matched with a HEPG tau. We view these as possible candidates for jet fakes. We then attempt to match these CdfTaus to the light quarks u or $\bar{d}$ from W^+ decay. Table 4 summarizes the rejection power of the τ ID cuts for these light quark jets, working from all reconstructed taus not matching a HEPG tau in events containing a tau matching a HEPG tau. We estimate the fake rate from this. Each event should have 2 light quark jets, corresponding to the u and $\bar{d}$ quarks from W decay. Then we expect a total, in the events with matched taus, of $19,764 \times 2 = 39,528$ jets. Of these, 155 fake taus, giving a fake rate of 0.39%. This is 44% larger than the Run I value $0.27 \pm .02\%$ in Ref. [1]. However, that value was constructed from a sample of dijets in data. Tau ID cuts applied to jets are summarized in Table 5. If the jets do not match a u or $\bar{d}$ quark, we further attempt to match them to a b or $\bar{b}$ quark. The cuts applied to these jets are summarized in Table 6. Only 12 of these b jets show up as a CdfTaus passing the ID cuts, suggesting a fake rate for these of 0.06%.

Light Jet Tau Identification Fake Rates				
Bit	Cut	% Passing	After rest	Cumulative
0	$E_T > 15$ GeV	100%	100%	100%
1	Seed track $p_T > 4.5$ GeV$/c$	100%	100%	100%
2	$\frac{E_T}{p_T^{trk+\pi^0}} < 2.0$	66.6%	98.8%	66.6%
	$\frac{E_T}{p_T^{trk+\pi^0}} < 1.5$ (3-prongs)			
3	$\delta r_{ces} < 0.11 - 0.025 \times E_T/100$	79.1%	99.7%	53.1%
	$\delta r_{ces} < 0.13 - 0.034 \times E_T/100$ (3-prongs)			
4	$m_{trk+\pi^0} < 1.8$ GeV$/c^2$	96.4%	100%	50.6%
5	$\#\pi^0 < 3$	78.2%	99.8%	42.1%
6	$\|z_0\| < 60$ cm	99.8%	100%	42%
7	$I^{\tau}_{calo} < 3$	54.4%	99.3%	23.8%
8	$I^{\tau}_{trk} < 1$	24.8%	100%	7.96%
9	20 cm $< \|z_{ces}\| <$ 220 cm	100%	100%	7.96%
10	#COT axial hits > 25, #COT stereo hits > 25	92%	99.9%	7.16%
11	Electron removal: Reject 1-prongs with $E/p < 4$ & EMfrac > 0.9 or clusters with EMfrac > 0.95	98.4%	100%	7.08%
12	Muon removal: Reject clusters with $E_T < 8$ GeV & $0.05 < E_{EM} < 2$ GeV & $0.5 < E_{Had} < 5$ GeV or with a muon stub with $\|\phi_\tau - \phi_{stub}\| < 15^\circ$	97.1%	99.9%	6.83%
13	$n_{trks}(10^\circ) = 1$ or 3	16.2%	95%	1.85%
14	$n_{trks}(10^\circ - 30^\circ) = 0$	24.8%	100%	1.85%

Table 5: The efficiencies of the τ selection cuts on the CdfTaus that do not match a HEPG tau but do match a HEPG u or $\bar{d}$ quarks in (η, ϕ). The "Passing" column gives the number of CdfTaus, passing all geometric and kinematic acceptance cuts, which pass the cut in question. The "After rest" column gives the number of CdfTaus passing all other cuts, which pass the cut in question. The "cumulative" column gives the number of CdfTaus passing the cut in question and all preceding cuts. The number passing all cuts is the fake rate for light jets in top events faking τ's; this can be compared to that measured in jet samples and other Monte Carlo samples.

10 Appendix C: B-quark Jets faking Taus

B-Quark Tau Identification Fake Rates				
Bit	Cut	% Passing	After rest	Cumulative
0	$E_T > 15$ GeV	100%	100%	100%
1	Seed track $p_T > 4.5$ GeV/c	100%	100%	100%
2	$\frac{E_T}{p_T^{trk+\pi^0}} < 2.0$ $\frac{E_T}{p_T^{trk+\pi^0}} < 1.5$ (3-prongs)	66.8%	99.8%	66.8%
3	$\delta r_{ces} < 0.11 - 0.025 \times E_T/100$ $\delta r_{ces} < 0.13 - 0.034 \times E_T/100$ (3-prongs)	75.6%	99.9%	50.4%
4	$m_{trk+\pi^0} < 1.8$ GeV/c^2	95%	100%	47.3%
5	$\#\pi^0 < 3$	62.4%	100%	32%
6	$\|z_0\| < 60$ cm	99.7%	100%	32%
7	$I^{\tau}_{calo} < 3$	47.8%	99.9%	16%
8	$I^{\tau}_{trk} < 1$	21.4%	100%	4.74%
9	20 cm $< \|z_{ces}\| <$ 220 cm	100%	100%	4.74%
10	#COT axial hits > 25, #COT stereo hits > 25	88.8%	100%	4.16%
11	Electron removal: Reject 1-prongs with $E/p < 4$ & EMfrac > 0.9 or clusters with EMfrac > 0.95	98.9%	100%	4.11%
12	Muon removal: Reject clusters with $E_T < 8$ GeV & $0.05 < E_{EM} < 2$ GeV & $0.5 < E_{Had} < 5$ GeV or with a muon stub with $\|\phi_\tau - \phi_{stub}\| < 15°$	80.2%	99.9%	2.66%
13	$n_{trks}(10°) = 1$ or 3	4.41%	97.5%	0.175%
14	$n_{trks}(10° - 30°) = 0$	21.4%	100%	0.175%

Table 6: The efficiencies of various cuts on the CdfTaus that do not match a HEPG tau but do match a HEPG b or $\bar{b}$ quarks in (η, ϕ). The "Passing" column gives the number of CdfTaus, passing all geometric and kinematic acceptance cuts, which pass the cut in question. The "After rest" column gives the number of CdfTaus passing all other cuts, which pass the cut in question. The "cumulative" column gives the number of CdfTaus passing the cut in question and all preceding cuts. The number passing all cuts gives a fake rate for b jets in top events faking τ's.

11 Appendix D: The Prong Distribution

Table 7 compares the number of prongs expected in the τ decay, determined from HEPG information, with the number of tracks found by TauFinder in a $10°$ cone of the τ cluster ('contributing tracks') to the matched CdfTau for CdfTaus passing the geometric and kinematic selection cuts of Table 4. Fig. 12 plots the number of HEPG prongs versus the number of CdfTau contributing tracks. In HEPG, 73.3% of τ's have 1 prong and 26.7% have 3 prongs, consistent with expectations [3]. Table 7 shows that after reconstruction, however, only 77% of the one-prongs and 73% of the three prongs are reconstructed with the correct number of prongs.

	Prongs Found					
# Prongs expected	1	2	3	>3	Total	% at HEPG level
1	7603	1040	882	328	9853	73.3%
3	31	364	2614	575	3584	26.7%
Total: 1+3	7634	1404	3496	903	13437	100%

Table 7: The number of expected prongs, i.e. the number of charged daughters of the τ in the HEPG bank, versus the number of prongs found, i.e. the number of tracks in a $10°$ cone of the τ cluster for CdfTaus passing the selection cuts of Table 4.

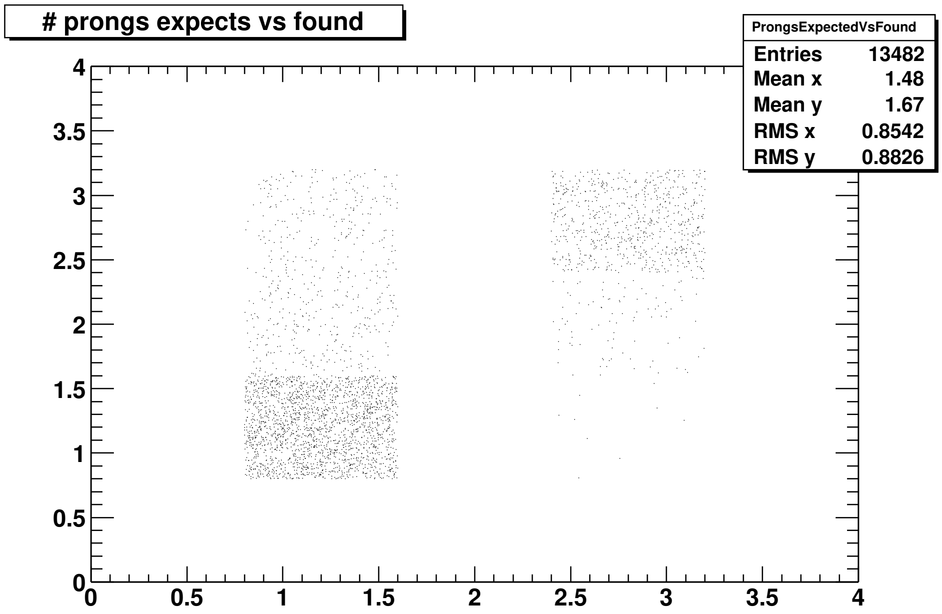

Figure 12: Number of prongs expected (from HEPG) vs. number found (contributing tracks to the CdfTau).