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$t\bar{t}$ Acceptance Calculation for the Run 1B SVX B-Tag Analysis

Cross Section and Branching Ratios Working Group

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Abstract

We report on the calculation of the $t\bar{t}$ acceptance for the run 1B SVX B-tag analysis. For a top mass of 175 GeV/c^2 we calculate a total efficiency, including tagging, of 0.040 ± 0.006. We measure the scale factor using ≈ 60 pb^{-1} of run 1B inclusive electron data. We find $SF = 0.98 \pm 0.04 \pm 0.14$, where the first error is statistical and the second error is the quadrature sum of all systematic errors.

1 Introduction

This note is almost wholly taken from Reference [1]. The Monte Carlo samples used were generated by Rob Roser *et al.* with the PYTHIA generator. The $t\bar{t}$ samples were simulated using QFL, while the $b\bar{b}$ samples were simulated using CDFSIM. All samples use the SVX$'$ MC, described in Reference [2], to simulate the SVX$'$ detector. We use the CDFSIM $b\bar{b}$ sample to determine the scale factor. As reported in Reference [3], the ratio of tagging efficiencies between the QFL and CDFSIM simulations is consistent with one. Thus, we do not correct the CDFSIM determined scale factor when applying it to the QFL determined tagging efficiencies of the $t\bar{t}$ sample.

2 Acceptance for a Standard Model Top Quark

We use a combination of data and Monte Carlo to determine our efficiency for identifying a $t\bar{t}$ event. The Monte Carlo generator is Pythia, and Standard Model couplings are assumed. We consider the top quark masses $M_t = 150, 170$, and 190 GeV/c^2. We consider the event selection criteria as described in Reference [4], which details the standard lepton plus jets selection. We calculate the total event detection efficiency as follows

$$\epsilon_{t\bar{t}} = A_{t\bar{t}} \cdot \epsilon_{|z_{pvtx}|} \cdot \epsilon_{trig} \cdot \epsilon_{lepton\ id} \cdot \epsilon_{tag} \tag{1}$$

where

$A_{t\bar{t}} \equiv$ the fraction of $t\bar{t}$ events within the geometric acceptance of the CDF detector and passing the kinematic requirements of the event selection

$\epsilon_{|z_{pvtx}|} \equiv$ the efficiency of the cut $|z_{pvtx}| < 60$ cm

$\epsilon_{trig} \equiv$ the trigger efficiency for identifying high P_T leptons

$\epsilon_{lepton\ id} \equiv$ the efficiency of the lepton identification cuts

$\epsilon_{tag} \equiv$ the efficiency for tagging at least one jet in the event.

We discuss each piece separately below.

2.1 Determination of $A_{t\bar{t}}$

The geometric and kinematic acceptance is calculated as follows.

$$A_{t\bar{t}} = \epsilon_{geom} \cdot \epsilon_{kin} \cdot \epsilon_{\not{E}_T} \cdot \epsilon_{iso} \tag{2}$$

where

$\epsilon_{geom} \equiv$ the fraction of fiducial $t\bar{t}$ events, defined as the fraction of all generated $t\bar{t}$ events with ≥ 1 lepton with $P_T > 15$ GeV/c and $|\eta| < 3.0$

$\epsilon_{kin} \equiv$ the fraction of fiducial $t\bar{t}$ events with ≥ 1 one good electron or muon, defined as an electron (muon) with E_T (P_T) > 20 GeV/c and $|\eta| < 2.0$ and ≥ 3 jets ($E_T > 15$ GeV, $|\eta| < 2.0$).

$\epsilon_{\not{E}_T} \equiv$ the fraction of $t\bar{t}$ events with ≥ 1 good electron or muon, ≥ 3 jets and with $\not{E}_T > 20$ GeV

$\epsilon_{iso} \equiv$ the fraction of $t\bar{t}$ events having ≥ 1 good lepton, ≥ 3 jets and passing the $\not{E}_T$ requirements in which the high P_T lepton additionally passes the isolation requirement, $I_{cal} < 0.1$.

Each of these efficiencies is conditional upon the previous one.

We assign a $\pm 5\%$ and $\pm 2\%$ (relative) systematic error due to uncertainties in the modelling of initial state (ISR) and final state (FSR) radiation, respectively. These errors are estimated by taking half the difference in $A_{t\bar{t}}$ between Monte Carlo samples with the ISR and FSR turned off separately and that obtained using the default Monte Carlo parameters. We additionally assign a $\pm 2\%$ (relative) error due to detector resolution effects and a $\pm 7\%$ (relative) error due to uncertainties in the jet energy scale. Finally, we assign a $\pm 1\%$ (relative) error due to the dependence

$A_{t\bar{t}} = \epsilon_{geom}\cdot\epsilon_{lepton}\cdot\epsilon_{\not{E}_T}\cdot\epsilon_{iso}$

M_t :	150 GeV/c^2	170 GeV/c^2	190 GeV/c^2
$A_{t\bar{t}}$:	$0.105 \pm 0.003 \pm 0.010$	$0.116 \pm 0.002 \pm 0.011$	$0.122 \pm 0.003 \pm 0.012$

Table 1: Combined geometric and kinematic acceptances for $t\bar{t}$ events at various assumed top quark masses, M_t. The first error is statistical, the second is the quadrature sum of all systematic errors.

of ϵ_{iso} on the number of multiple interactions in an event. This last uncertainty is estimated by measuring the efficiency of the $I_{cal} < 0.1$ cut on a sample of $W \to \mu\nu$ events as a function of the instantaneous luminosity. This is shown in Figure 1. We assume the distribution is flat and estimate a systematic by taking half the difference assuming the $\pm 1\sigma$ slope variations convoluted with the instantaneous luminosity distribution of events in our signal region. Table 1 shows $A_{t\bar{t}}$ for several masses of the top quark. The first error is statistical and the second is the quadrature sum of all systematic errors.

3 Determination of ϵ_{trig} and $\epsilon_{lepton\ id}$

We measure the trigger and lepton identification efficiencies using $Z \to \ell\ell$ ($\ell = e$ or μ) events [5] [6]. The results are given in Table 2. For $\epsilon_{lepton\ id}$ we *exclude* the explicit isolation cut, I_{cal}, which is included as part of the $A_{t\bar{t}}$ calculation discussed in Section 2.1. Taking the average efficiency over all detector components weighted by their relative acceptances yields $\epsilon_{trig} = 0.854 \pm 0.014$ and $\epsilon_{lepton\ id} = 0.903 \pm 0.008$ for leptons with $P_T > 20$ GeV/c. The lepton samples used to measure the above efficiencies have isolation environments different from leptons in $t\bar{t}$ events. We measure the dependence of $\epsilon_{trig}\cdot\epsilon_{id}$ as a function of the isolation variable, I_{cal}, and the number of jets in the event, N_{jet}, using a sample of $W \to \mu\nu$ events required to pass the standard lepton plus jets event selection criteria [4]. We fit the resulting

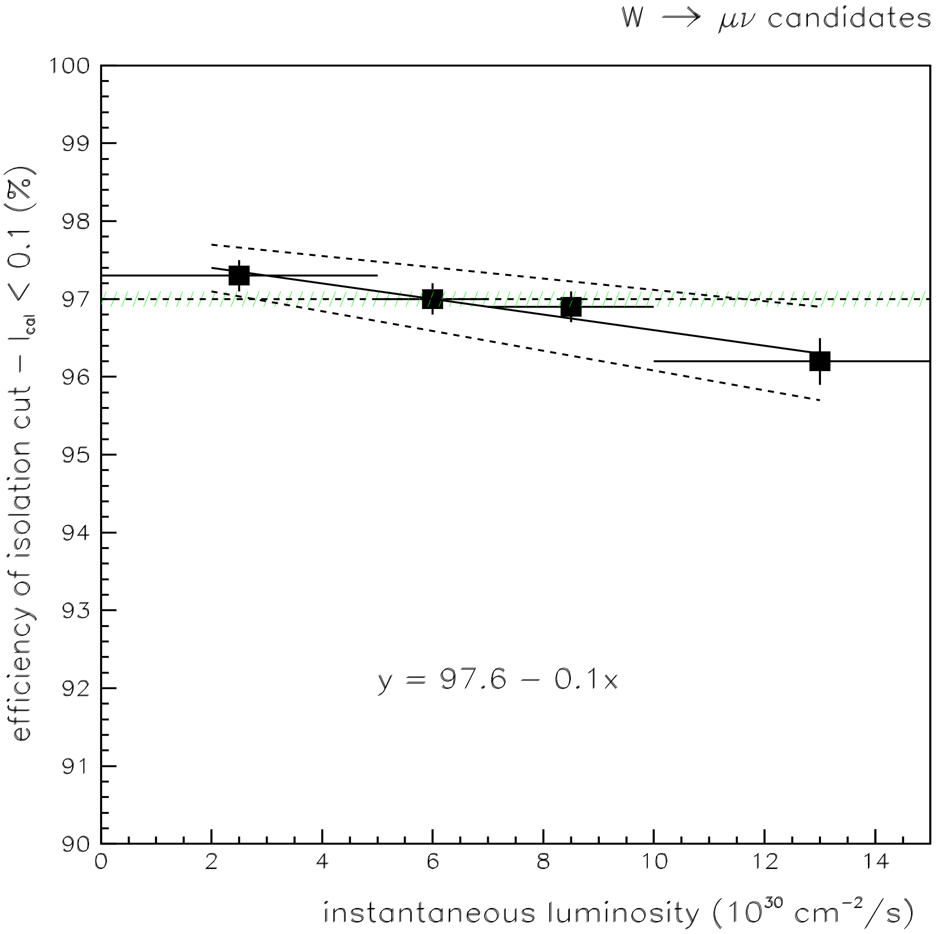

Figure 1: The efficiency of the isolation cut, $I_{cal} < 0.1$, as a function of the instantaneous luminosity in the event. We use $W \to \mu\nu$ events and assume the distribution is the same for electron events. The result of a fit to a sloped line is given and displayed (solid line). The $\pm 1\sigma$ variation on the slope is also displayed as the dashed lines. The $\pm 1\sigma$ bounds assuming no dependence are given by the hatched region.

ϵ_{trig} and $\epsilon_{lepton\ id}$

	muons	electrons
ϵ_{trig}	$0.871^{+0.061}_{-0.091}$ (CMNP) $0.834^{+0.021}_{-0.023}$ (CMUP) $0.696^{+0.045}_{-0.049}$ (CMX)	0.928 ± 0.002 (CEM)
$\epsilon_{lepton\ id}$	$0.953^{+0.026}_{-0.044}$ (CMNP) $0.971^{+0.008}_{-0.011}$ (CMUP) $0.943^{+0.016}_{-0.021}$ (CMX)	0.837 ± 0.012 (CEM)

Table 2: The trigger and lepton identification efficiencies as measured using $Z \to \ell\ell$ ($\ell = e$ or μ) events. The errors are statistical only.

distributions, shown in Figure 2, to a sloped line and recalculate the trigger efficiency using the resulting $\pm 1\sigma$ slope variations convoluted with the appropriate distribution for leptons in fiducial $t\bar{t}$ events. We set the systematic error equal to half the difference between these variations and the value obtained assuming no dependence on isolation or jet multiplicity. The resulting systematic error is 5%.

4 Determination of $\epsilon_{|z_{pvtx}|}$

An additional fiducial requirement is that the z co-ordinate of the primary event vertex be within 60 cm of the nominal interaction point, $|z_{pvtx}| < 60$ cm. We use $W \to \mu\nu$ events passing the lepton identification criteria discussed in Reference [4] to measure the efficiency of this cut. We measure $\epsilon_{|z_{pvtx}|} = 0.949 \pm 0.001$, where the error is statistical only. The z_{pvtx} distribution for all of run 1B is shown in Figure 3. Since the TeVatron parameters are changing during the course of the run, we investigate for a possible time dependence by plotting $\epsilon_{|z_{pvtx}|}$ as a function of the total integrated luminosity as shown in Figure 4. It is observed to be flat to within

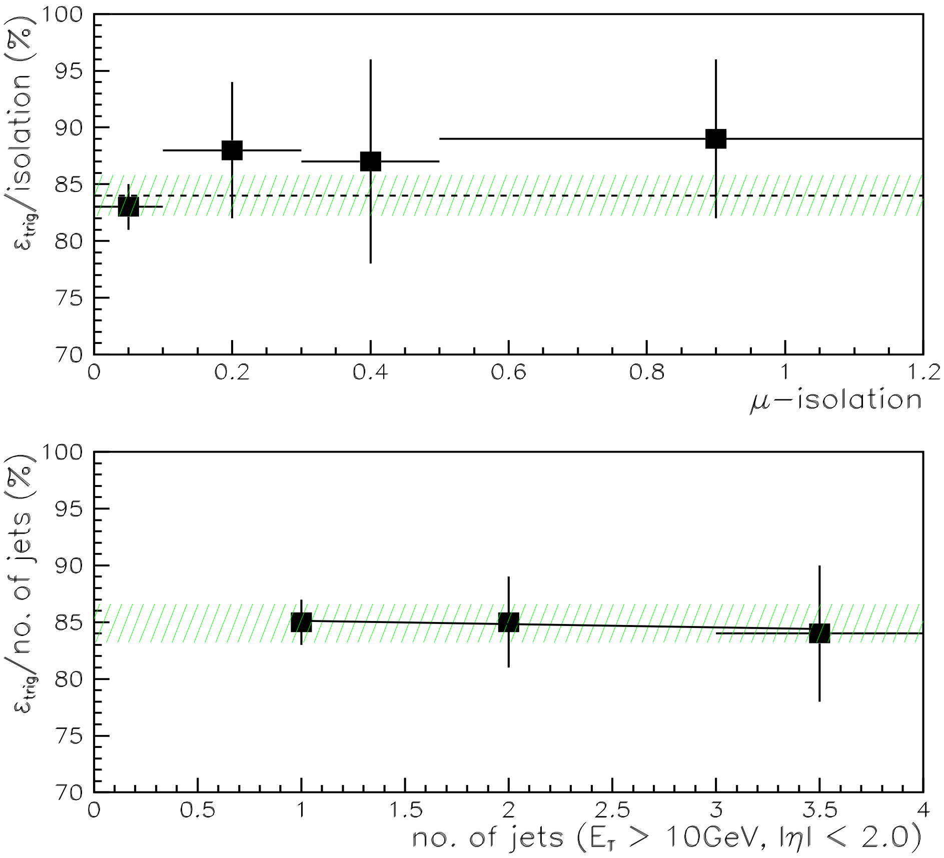

Figure 2: The CMUP trigger efficiency as a function of the muon isolation, I_{cal} (top), and the number of jets ($E_T > 10$ GeV and $|\eta| < 2.0$) in the event, N_{jet} (bottom). We assume the shapes of these distributions are the same for all triggers used in analysis.

1%. To determine whether or not the distribution is biased by requiring ≥ 3 jets ($E_T > 15$ GeV/c, $|\eta| < 2.0$) we measure $\epsilon_{|z_{pvtx}|}$ as a function of the number of jets in the event, N_{jet}. This is also shown in Figure 4 and is flat to within 2%.

We assign a systematic error of $\pm 0.8\%$ and $\pm 2.3\%$ to our assumptions that $\epsilon_{|z_{pvtx}|}$ is flat as a function of total integrated luminosity and the number of jets in the event, respectively. These are estimated by fitting the appropriate curve in Figure 4 to a sloped line and taking half the maximum difference assuming the $\pm 1\sigma$ variations of the fit parameters.

5 Determination of ϵ_{tag}

We define our efficiency for tagging at least one jet in $t\bar{t}$ events passing all other event selection criteria as

$$\epsilon_{tag} = \epsilon^{event}_{B-tag} + \epsilon^{event}_{mistag} - \epsilon^{event}_{B-tag} \cdot \epsilon^{event}_{mistag} \tag{3}$$

where

$\epsilon^{event}_{B-tag} \equiv$ the fraction of $t\bar{t}$ events passing all event selection criteria with ≥ 1 tagged B-jet

$\epsilon^{event}_{mistag} \equiv$ the fraction of $t\bar{t}$ events passing all event selection criteria with ≥ 1 tagged nonB-jet.

We discuss each separately below.

5.1 Determination of $\epsilon^{event}_{mistag}$

We estimate the fraction of $t\bar{t}$ events in which at least one non-B-jet is tagged using Monte Carlo. We find $\epsilon^{event}_{mistag} = 1 \pm 1\%$, where the error is dominated by the systematic uncertainty derived by comparing various Monte Carlo simulations.

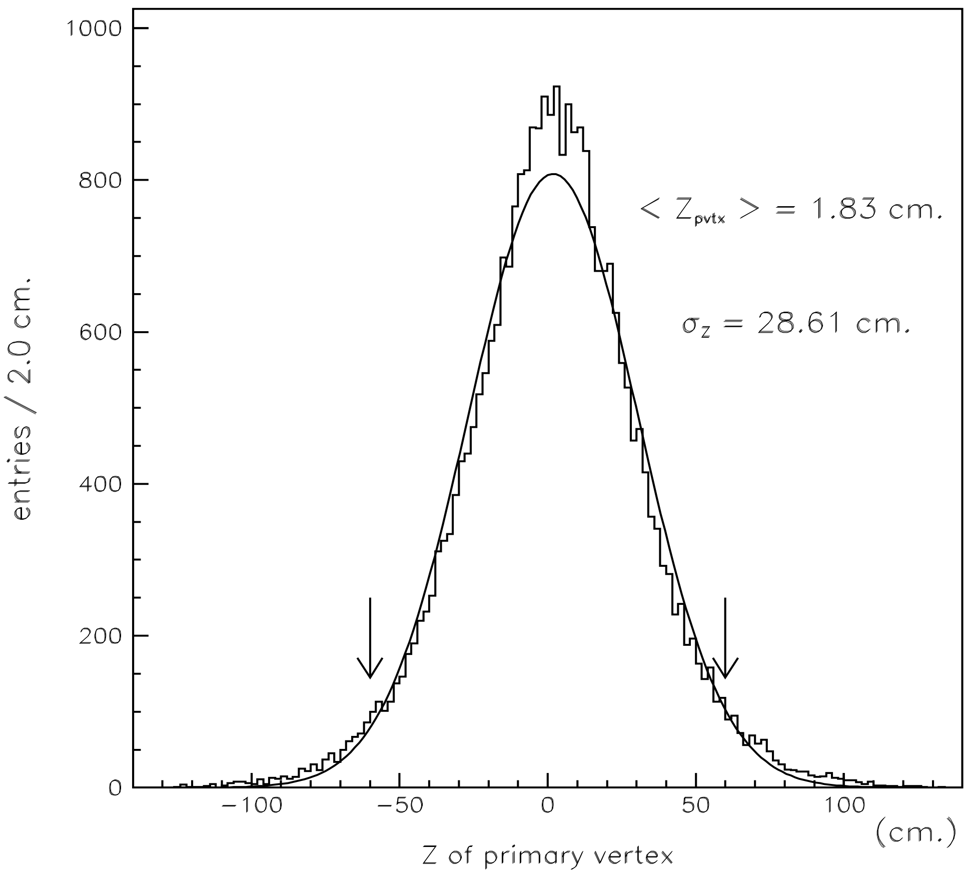

Figure 3: The z_{pvtx} distribution for all run 1B data. The results of a fit to a Gaussian are also displayed. The arrows indicate the cut value of ± 60 cm.

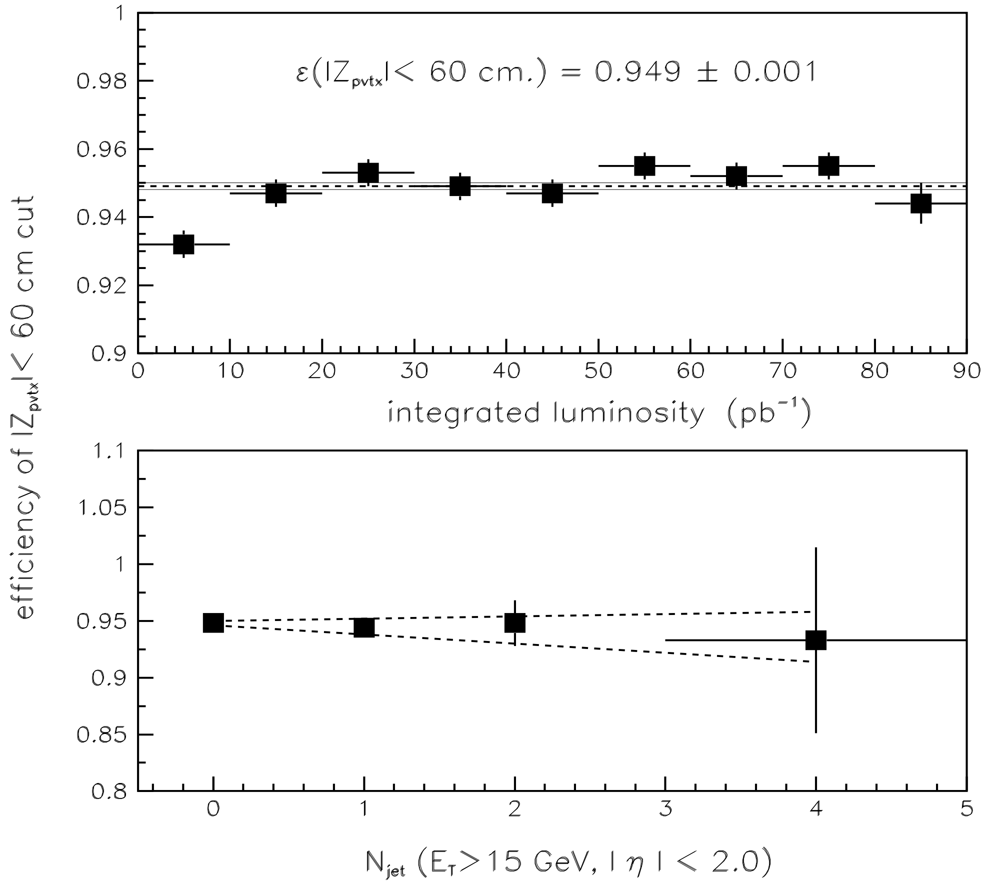

Figure 4: The $\epsilon_{|z_{pvtx}|}$ as a function of the total integrated luminosity (top) is flat to within 1% and yields an average efficiency of $\epsilon_{|z_{pvtx}|} = 0.949 \pm 0.001$ (shaded region). The $\epsilon_{|z_{pvtx}|}$ as a function of the number of jets in the event, N_{jet}, is fit to a sloped line (bottom). The $\pm 1\sigma$ variations of the slope are shown as dashed lines.

5.2 Determination of ϵ^{event}_{B-tag}

The efficiency for tagging ≥ 1 B-jet in a $t\bar{t}$ event passing all event selection criteria is calculated using a mixture of data and Monte Carlo. From the data we measure the efficiency for tagging *semileptonic* B-decays. We then rely on a Monte Carlo simulation to extrapolate the measured B-tagging efficiency for semileptonic B-decays to that expected for the generic B-decays in $t\bar{t}$ events. This extrapolation requires that we scale the measured Monte Carlo tagging efficiency by the efficiency observed in data. We call this the B-tagging scale factor, SF. The determination of the semileptonic B-decay tagging efficiency and of the data to Monte Carlo scale factor is described below. The measurements discussed all use run 1B data unless otherwise specified. We consider differences between run 1A and run 1B data at the end of this Section.

We use the B-enriched, low P_T, inclusive electron data set described in Reference [7] to help determine the efficiency *per jet* of the SECVTX B-tagging algorithm. Two different methods are employed, and each yields the B-tagging efficiency for *semileptonic* B-decays.

For each event we define the "electron jet" (or "ejet") as that jet closest to the electron in $\eta - \phi$ space and require

$$E_T^{ejet} > 10 \text{ GeV}$$
$$|\eta^{ejet}| < 2.0$$
$$\Delta R_{ele-jet} = \sqrt{\Delta\eta^2_{ele-jet} + \Delta\phi^2_{ele-jet}} < 0.4.$$

We define the "away jet" (or "ajet") as that jet opposite the electron jet and require

$$\Delta R_{ejet-ajet} > 2.5$$
$$E_T^{ajet} > 15 \text{ GeV}$$
$$|\eta^{ajet}| < 2.4.$$

We also require that the away jet be "taggable". A taggable jet has associated with it ≥ 2 good tracks within the SVX fiducial volume. A good track is defined as any track passing all "pass 1" cuts, *excluding the S_{d_0} cut*, described in Reference [7].

The first method employed to measure the B-tagging efficiency uses the expression

$$\epsilon_{B-tag}^{method\ 1} = \left(\frac{P_{ejet} - N_{ejet}}{T_{ejet}}\right) \cdot \left(\frac{1}{F_B}\right) \tag{4}$$

$$= (XS_{ejet}) \cdot \left(\frac{1}{F_B}\right) \tag{5}$$

where

$P_{ejet} \equiv$ the number of positively tagged electron jets (there is *no away tag requirement*)

$N_{ejet} \equiv$ the number of negatively tagged electron jets (there is *no away tag requirement*)

$T_{ejet} \equiv$ the number of taggable electron jets (there is *no away tag requirement*)

$F_B \equiv$ the fraction of electron jets associated with a real semileptonic B-decay

$XS_{ejet} = (P_{ejet} - N_{ejet}) / T_{ejet} \equiv$ the positive excess tagging rate in the electron jets.

Since we only consider tags in the electron jets — that is, we require no away jet tag — we call this the "single tag" method.

In determining the electron jet tagging efficiency, we subtract the negative tagged electron jets. This is a small background subtraction of order 5% . The positive excess tagging rate for all electrons jets with $E_T^{ejet} > 10$ GeV is $XS_{ejet} = 12.0 \pm 0.1$ %. The correction factor, F_B, is required to account for the B-purity of the pre-tagged electron jets. We measure F_B by looking for a nearby, low P_T muon ($\Delta R_{\mu-ejet} < 0.4$, and $P_T^{\mu} > 2$ GeV$/c$) associated with the semileptonic sequential decay of a charmed hadron, $B \to eDX \to e^{\pm}\mu^{\mp}X$. We use the following expression to calculate F_B

$$F_B = \left(\frac{OS_{e-\mu} - SS_{e-\mu}}{\epsilon_{\text{soft }\mu}}\right) \cdot \left(\frac{1}{T_{ejet}}\right) \tag{6}$$

where

$OS(SS)_{e-mu} \equiv$ the number of opposite (same) sign $e - \mu$ pairs

$\epsilon_{\textbf{soft }\mu} \equiv$ the efficiency for finding the muon associated with the sequential charm decay.

$T_{ejet} \equiv$ the number of taggable electron jets (there is *no away tag requirement*)

The largest background in the determination of F_B is due to fake leptons. The number of same-sign $e - \mu$ pairs provides a calibration of this background. Gluon splitting is not expected to contribute significantly to the opposite-sign sample. The fraction of all $b\bar{b}$ events which come from gluon splitting is predicted to be $\sim 25\%$. The cone cut of $\Delta R_{ele-jet} < 0.4$ and the isolation cuts implicit in the electron identification reduce this to $< 10\%$. Therefore, the excess of opposite-sign over same-sign events, $OS_{e-\mu} - SS_{e-\mu}$, is a clean signature for sequential semileptonic B-decays. The distribution of the $e - \mu$ invariant mass, $M_{e-\mu}$, after background subtraction, is shown in Figure 5 for all electron jets with an away jet tag and is consistent with the $M_{e-\mu}$ distribution derived from a $B \to eDX \to e^{\pm}\mu^{\mp}X$ Monte Carlo.

The efficiency for finding the sequential μ in the electron jet is calculated as

$$\epsilon_{\text{soft }\mu} = F(B \to eDX \to e\mu X; P_T^{\mu} > 2 \text{ GeV}/c) \cdot \epsilon_{\mu \text{ find}} \tag{7}$$

where

$F \equiv$ the fraction of $B \to eDX$ decays that also have a μ from the sequential charm decay with $P_T > 2.0$ GeV/c; the μ is required to be within a cone of 0.4 from the electron jet axis in $\eta - \phi$ space, $\Delta R_{\mu-ejet} < 0.4$

$\epsilon_{\mu \textbf{ find}} \equiv$ the efficiency for finding a muon with $P_T > 2.0$ GeV/c.

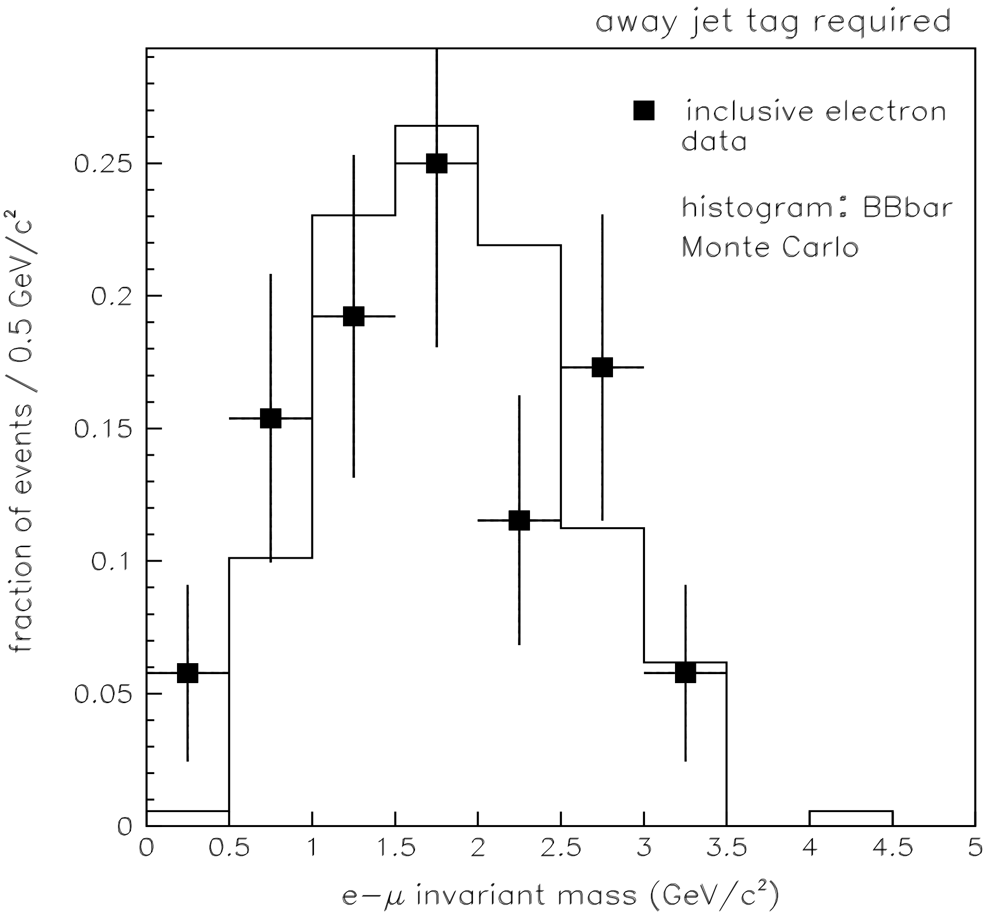

Figure 5: The $e - \mu$ invariant mass distribution for all electron jets with an away side tag required. The data points include a background subtraction.

Using a Monte Carlo of $b\bar{b}$ events, passing all the same event selection criteria used in the data, we measure $F = 0.028 \pm 0.002$, where the error is statistical only. The muon finding efficiency, $\epsilon_{\mu\ \mathrm{find}}$, is measured separately for each central muon detector component (CMU, CMP, and CMX) as a function of P_T^{μ} using $Z \rightarrow \mu\mu$ and $J/\psi \rightarrow \mu\mu$ data events [8]. We then calculate $\epsilon_{\mu\ \mathrm{find}}$ as the average over all central muon detector components weighted by their relative acceptance and by the P_T spectrum of the sequentially decaying muons as determined in the Monte Carlo. We find, within the limited statistics available, $\epsilon_{\mu\ \mathrm{find}}$ is independent of E_T^{ejet} and is given as $\epsilon_{\mu\ \mathrm{find}} = 0.866 \pm 0.087$. This yields a soft muon finding efficiency of $\epsilon_{\mathrm{soft}\ \mu} = 0.024 \pm 0.003$, which is also independent of E_T^{ejet}. We measure for all electron jets with $E_T^{ejet} > 10$ GeV that $F_B = 39 \pm 5$ % and $\epsilon_{B-tag}^{method\ 1} = 31 \pm 4$ %, where the error is dominated by the uncertainty in $\epsilon_{\mu\ \mathrm{find}}$.

The second method employed to measure the B-tagging efficiency uses the expression

$$\epsilon_{B-tag}^{method\ 2} = \left(\frac{P_{ejet}^{atag}}{T_{ejet}^{atag}}\right) \cdot \left(\frac{P_{ajet}}{P_{ajet} - N_{ajet} \cdot (1 - F_B)}\right) \tag{8}$$

$$= R \cdot \left(\frac{1}{1 - F_{non-B}}\right) \tag{9}$$

where

$P_{ejet}^{atag} \equiv$ the number of positively tagged electron jets with a *positively tagged away jet required* on the opposite side (this increases the B-purity by a factor of ~ 2 on the electron jet side)

$T_{ejet}^{atag} \equiv$ the number of taggable electron jets with a *positively tagged away jet required* on the opposite side

$P_{ajet} \equiv$ the number of positively tagged away jets

$N_{ajet} \equiv$ the number of positively tagged away jets as predicted using the tag rate parameterization discussed in References [7] and [9]

$F_B \equiv$ the fraction of electron jets from B decay as determined above

$R \equiv$ the electron jet tagging rate

$F_{non-B} \equiv$ an estimate of the non-B fraction of electron jets with an away jet tag required

For all electron jets with $E_T^{ejet} > 10$ GeV we measure $R = 29 \pm 1$ %. The factor F_{non-B} is required as a small background subtraction and is of order 15%. Since an away jet tag is required in both the numerator and denominator of the electron jet tagging rate, R, we call this the "double tag" method. For all electron jets with $E_T^{ejet} > 10$ GeV we find $\epsilon_{B-tag}^{method\ 2} = 34 \pm 2$ %, where the error is statistical only.

In Figure 6(top) we plot $\epsilon_{B-tag}^{method\ 1}$ and $\epsilon_{B-tag}^{method\ 2}$ as a function of E_T^{ejet}. They are consistent to within 1.5σ of each other in all but the first bin ($10 < E_T^{ejet} <$ 15 GeV), where they differ by 2σ. This difference could be due to simultaneous statistical fluctuations in the number of both double and single tagged events or due to an undiscovered dependence on E_T^{ejet} of some element used in determining the efficiencies. In particular, in the single tag method one might expect $\epsilon_{\mu\ \mathrm{find}}$, since it depends on the P_T^{μ}, to likewise depend on the E_T^{ejet}. As previously mentioned, this dependence might be masked by the limited statistics of the available Monte Carlo sample. We should note that in $t\bar{t}$ events we only consider jets with $E_T > 15$ GeV for tagging. Our reason for including this lower E_T bin in this study becomes more obvious when we discuss the determination of the scale factor in the next section.

We also note in Figure 6(top) that the efficiency as determined using the single tag method is systematically lower than the efficiency as determined using the double tag method. We discuss this in the next Section.

5.3 Determination of the Scale Factor

We compare the Btag efficiency measured in data with the same efficiency determined using Monte Carlo. A $b\bar{b}$ Monte Carlo is used and is required, after a full detector simulation, to pass all the same event selection criteria as the data. We calculate the ratio of data to Monte Carlo tagging efficiency for the electron jet as

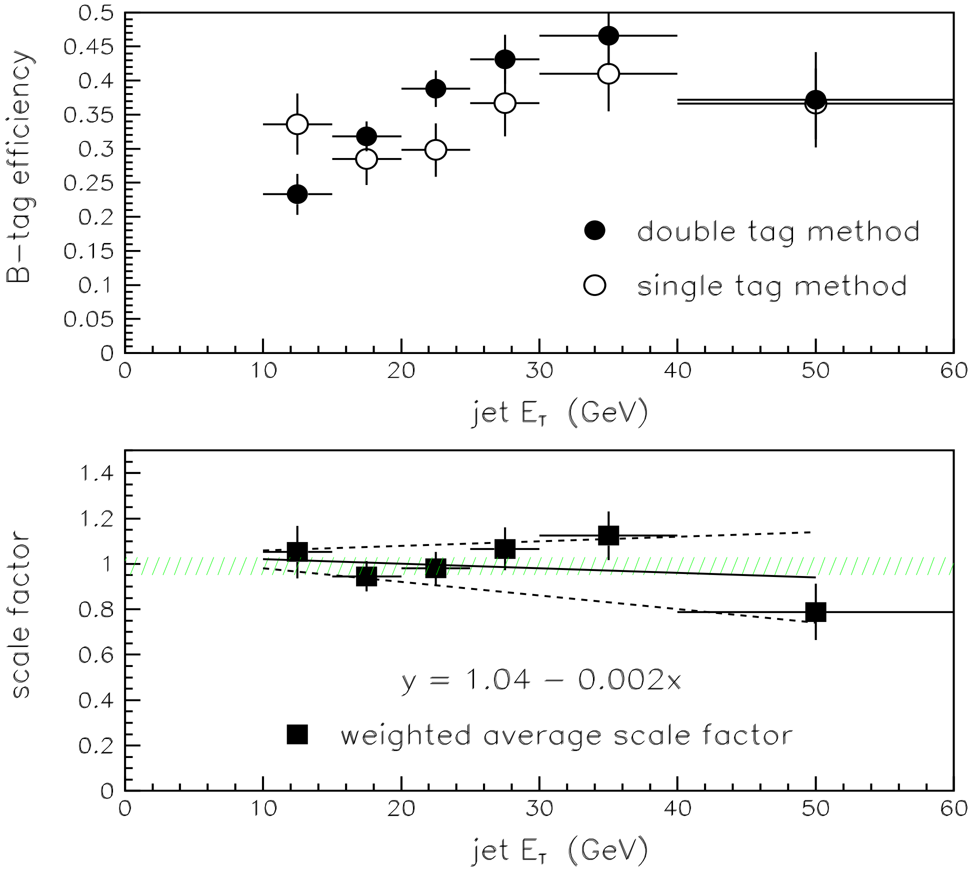

Figure 6: The B-tag efficiency, as determined using the two methods described in Section 5.2, is plotted versus the E_T^{ejet} (top). The weighted average scale factor as a function of E_T^{ejet} is also plotted (bottom). The result of a fit to a sloped line is given and is displayed as the solid line. The $\pm 1\sigma$ variations of the slope are given as dashed lines. The shaded region is the $\pm 1\sigma$ bounds of a fit assuming no dependence on E_T^{ejet}.

a function of the electron jet E_T,

$$SF = \left(\frac{\epsilon^{data}_{B-tag}}{\epsilon^{MC}_{B-tag}}\right) \cdot R_{taggable} \tag{10}$$

where

$\epsilon^{data}_{B-tag} \equiv$ the efficiency for tagging a B-jet as measured in the data; we take the weighted average of single and double tag methods

$\epsilon^{MC}_{B-tag} \equiv$ the efficiency for tagging a B-jet as measured in a $b\bar{b}$ Monte Carlo

$R_{taggable} \equiv$ the data to Monte Carlo ratio of the fraction of jets which are taggable

The correction $R_{taggable}$ is required since we normalize our tagging efficiencies to the number of taggable jets (cf. equations 9 and 5). It is measured to be 0.990 ± 0.002 independent of jet E_T. We assume this to be flat during the course of the run and assign a 1.2% (relative) systematic derived by fitting the distribution in Figure 9 to a sloped line and taking half the difference assuming the $\pm 1\sigma$ slope variations. Figure 6(bottom) shows SF as a function of jet E_T. The distribution is consistent with being flat to within $\sim 5\%$. In each E_T bin we determine ϵ^{data}_{B-tag} by taking the weighted average of ϵ_{B-tag} as determined using the single and double tag methods. Averaging over all jet $E_T > 10$ GeV yields $SF = 0.98 \pm 0.04$. We also find good agreement between the kinematic features of the tags in the data and $b\bar{b}$ Monte Carlo as shown in Figures 7 and 8. We compare the number of tracks included in the secondary vertex tag, N_{trk}, the summed P_T and invariant mass of those tracks (P_T^{vtx} and M_{vtx} respectively), and the "psuedo-cτ" $= \frac{L_{xy} \cdot M_{vtx}}{P_T^{vtx}}$ of the vertex for both the semileptonic B-decay tags in electron jets (with an away tag) and for the generic B-decay tags in away jets. The discrepancy in the 2 track bin of the N_{trk} distribution for away jets is consistent with an expected $\sim 7-10\%$ contribution from mistags. These comparisons give us confidence that the scale factor is appropriate for arbitrary B-decays.

To determine the appropriate scale factor for $t\bar{t}$ events, we assume that SF is independent of E_T^{jet} and measure for all $E_T^{jet} > 10$ GeV that $SF = 0.98 \pm 0.04$,

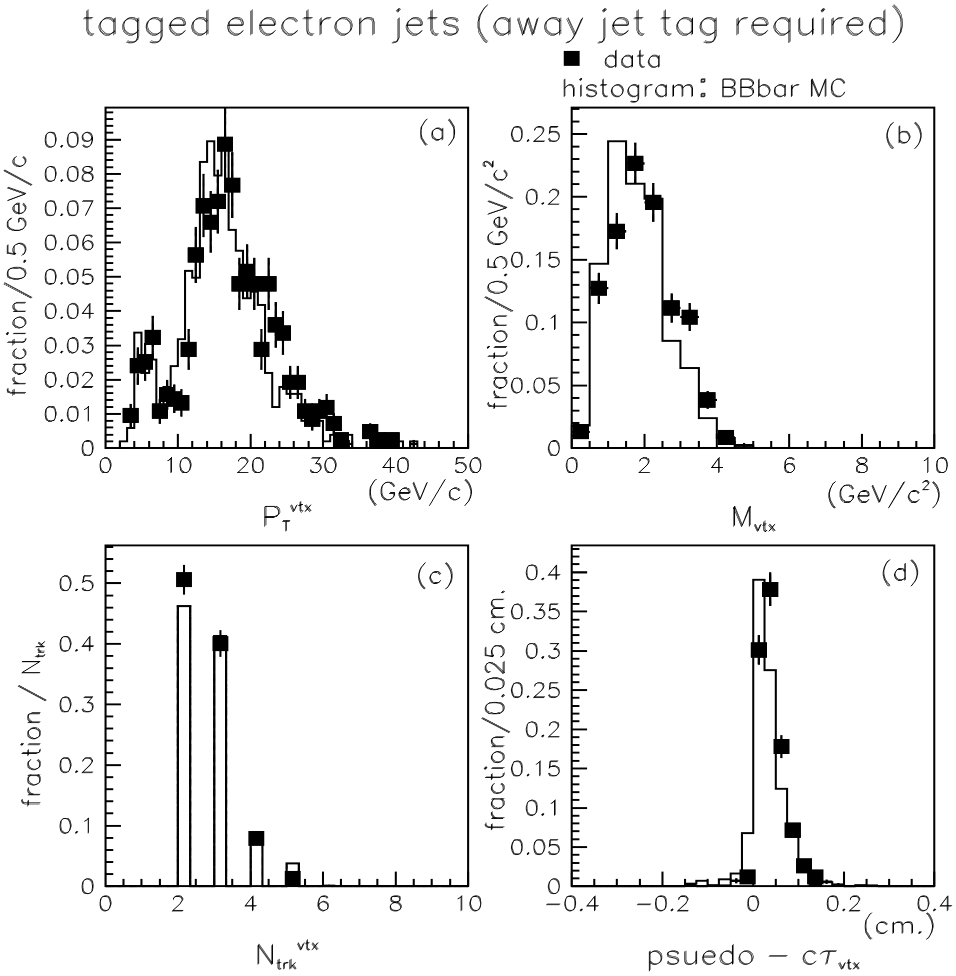

Figure 7: A comparison between tags in electron jets with an away tag required (points) and $b\bar{b}$ Monte Carlo (histogram) for various kinematic properties of the tracks included in the secondary vertex tag.

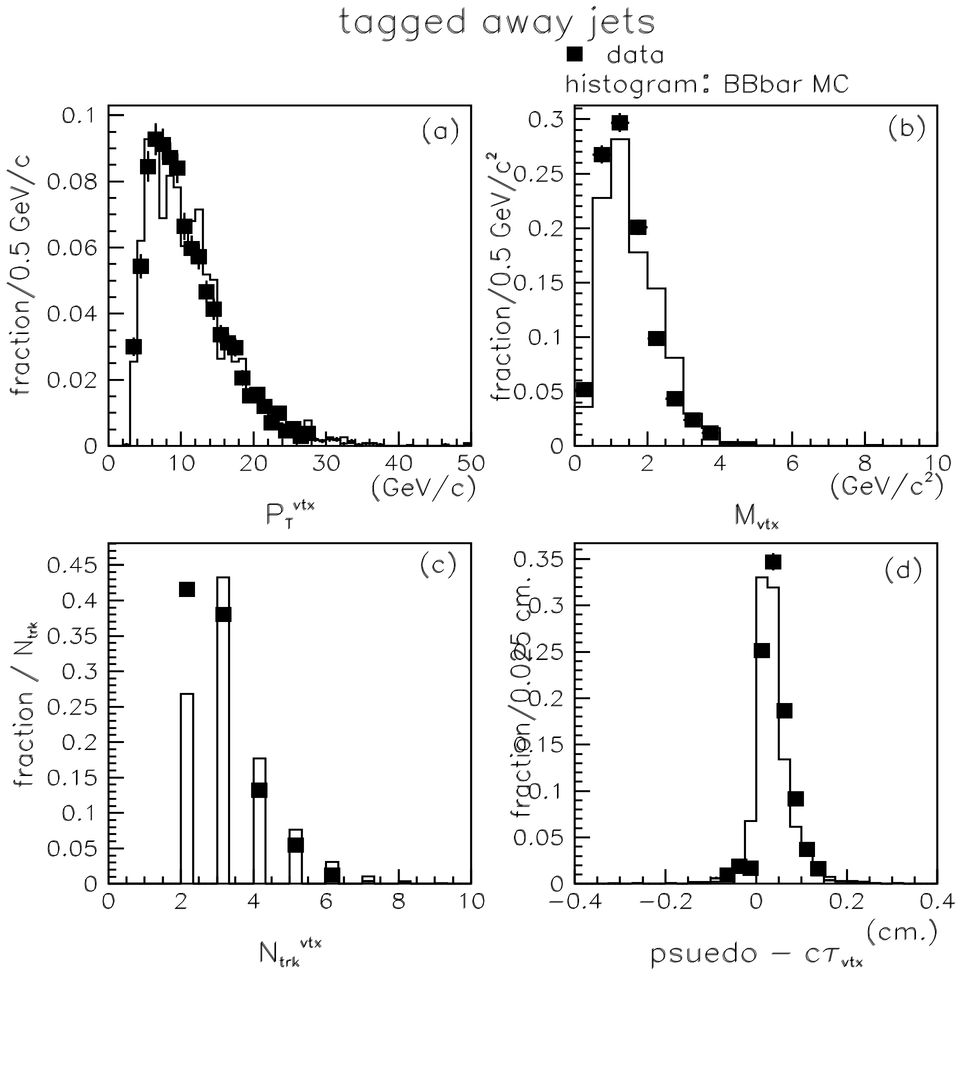

Figure 8: A comparison between tags in away jets (points) and $b\bar{b}$ Monte Carlo (histogram) for various kinematic properties of the tracks included in the secondary vertex tag.

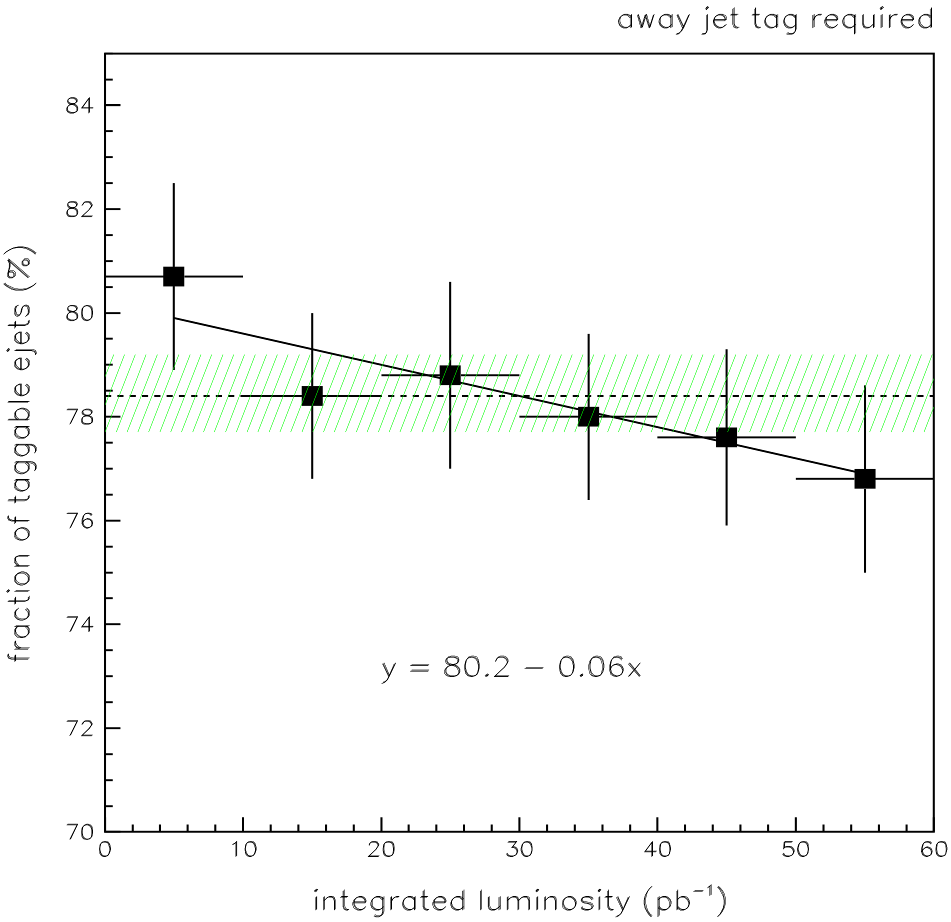

Figure 9: The fraction of taggable electron jets (with an away tag required) as a function of the total integrated luminosity. The average is given as a dotted line and the $\pm 1\sigma$ bounds are given by the shaded band. The results of a fit to a sloped line are also given and drawn as a solid line.

where the error is statistical. To obtain the systematic error we fit the SF versus E_T^{jet} distribution to a sloped line and convolute the fit result, assuming the $\pm 1\sigma$ variations on the slope, with the E_T distribution of B-jets in Monte Carlo $t\bar{t}$ events passing all event selection criteria. Half the difference between this result and the result assuming the scale factor is flat in E_T^{jet} is taken as the systematic error, which is of order 13% (relative) for all assumed top masses.

We check for other variations of the SF by measuring the B-tag efficiencies, $\epsilon_{B-tag}^{method\ 1}$ and $\epsilon_{B-tag}^{method\ 2}$, as a function of the instantaneous luminosity, L_{inst}, and total integrated luminosity, L_{total}. We worry the tagging rate might be affected by the increased track multiplicity of events with high L_{inst} — such an affect would manifest itself as a dependence of the tagging rate on the instantaneous luminosity. Additionally, we worry that radiation damage to the SVX detector might also affect the tagging rates — this would manifest itself as a dependence of the tagging rate on the total integrated luminosity. Figure 10 shows $\epsilon_{B-tag}^{method\ 2}$ as a function L_{inst} and L_{total}. Both distributions are consistent with being flat. As a second check, we take advantage of the large statistics available in the single tag sample and make no corrections for F_B, which has large errors associated with it. Since we use the same selection criteria independent of L_{inst} and L_{total}, we do not expect F_B to vary as a function of these variables. As demonstrated in Figure 11, this is indeed the case. In Figure 12 we plot XS_{ejet} as a function of L_{inst} and L_{total}. Each distribution is fit to a sloped line. Even if we conservatively assume the $\pm 1\sigma$ slope parameters, the excess tagging rate is affected by $< 1\%$ over the entire range of both L_{inst} and L_{total}. A variation of this size is wholly accounted for by the assigned systematic error.

As mentioned in the previous section, the efficiencies determined using the single tag method appear to be systematically lower than those determined using the double tag method as shown in Figure 6(top). There is evidence that the background subtraction in Equation 6 may be an underestimate, which would, in turn, lead to an underestimate in the single tag efficiency, $\epsilon_{B-jet}^{method\ 1}$ [10]. In particular, the ratio

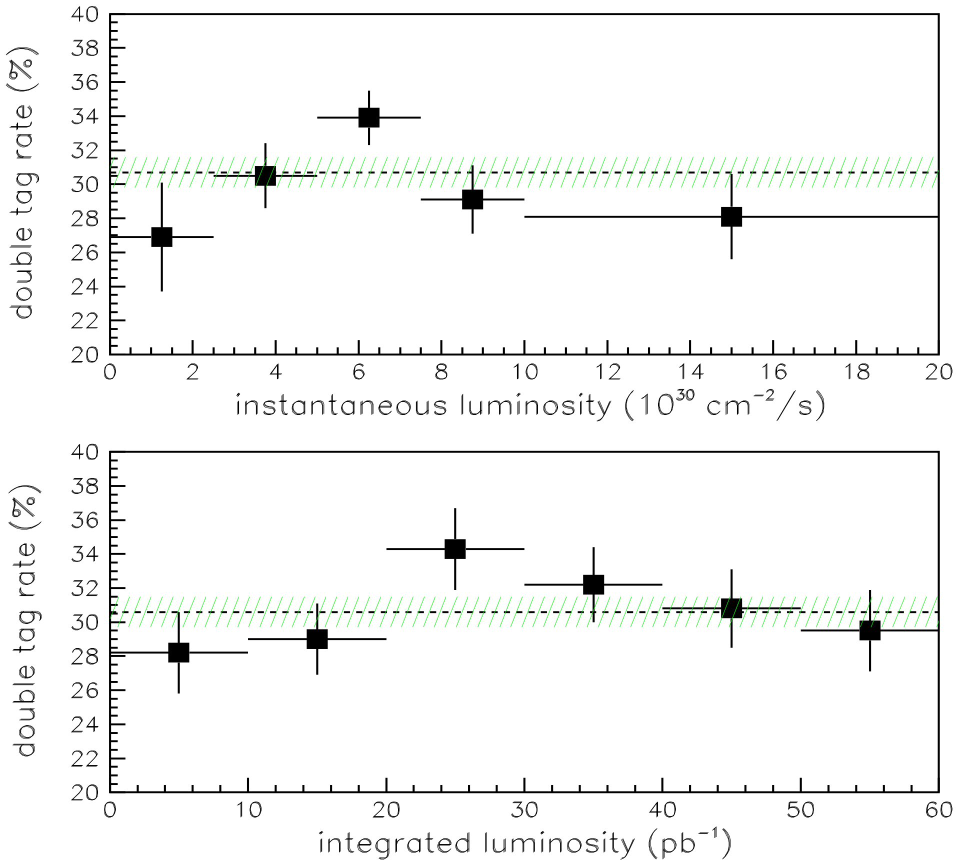

Figure 10: The double tag rate, $\epsilon_{B-tag}^{method\ 2}$, is plotted as a function of the instantaneous luminosity (top) and the total integrated luminosity (bottom). Both distributions are consistent with being flat. The weighted average is displayed as a dashed line. The shaded region indicates the $\pm 1\sigma$ bounds.

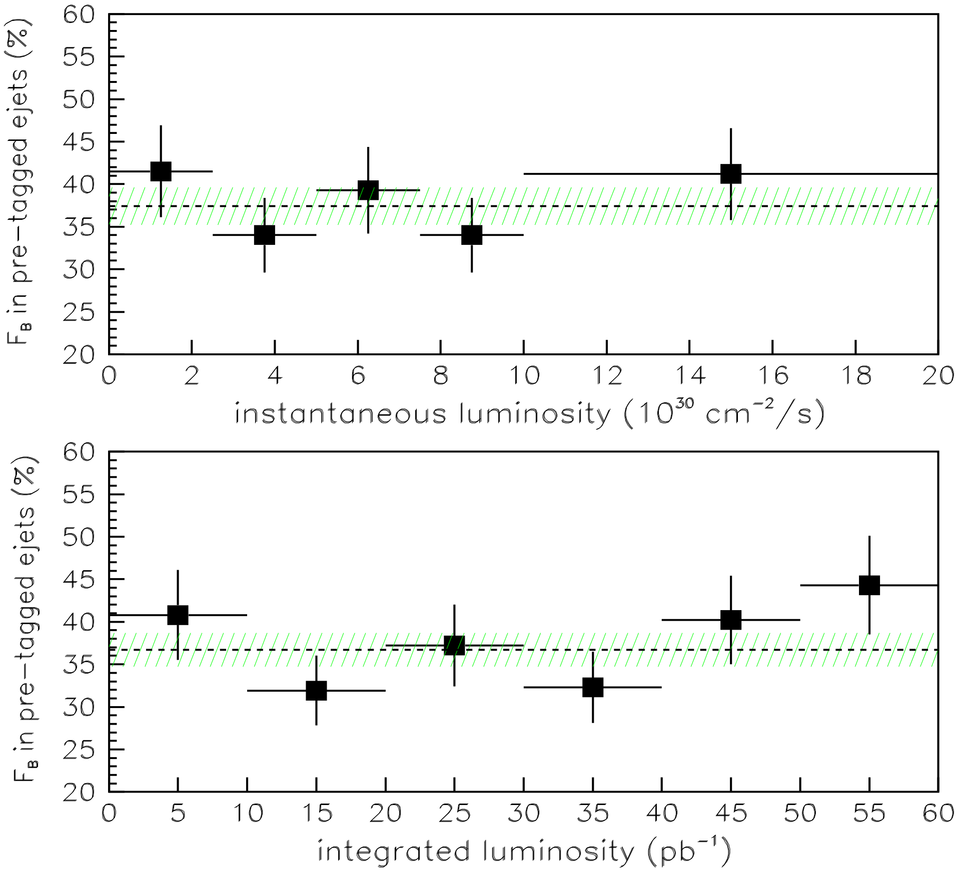

Figure 11: The estimated fraction of pre-tagged electron jets that are B-jets, F_B, as a function of the instantaneous luminosity (top) and the total integrated luminosity (bottom). The hatched bands represent the $\pm 1\sigma$ bounds of the weighted average F_B in each plot.

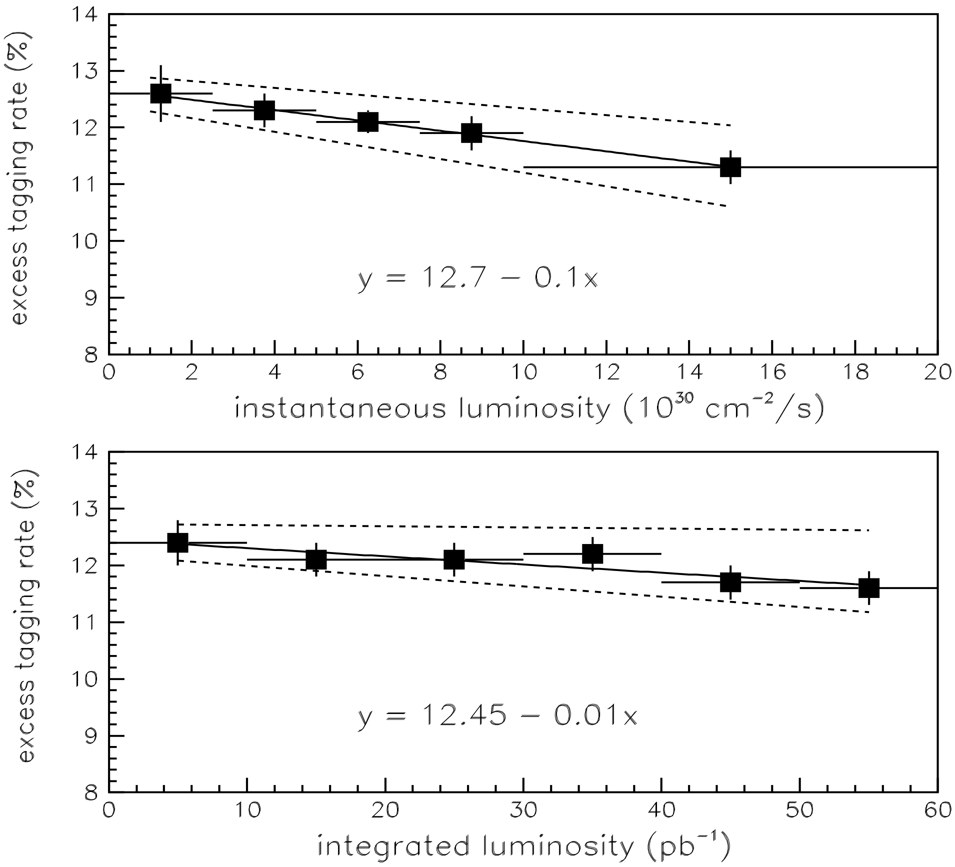

Figure 12: The excess tagging rate, XS_{ejet}, is plotted as a function of the instantaneous luminosity (top) and the total integrated luminosity (bottom). Each distribution is fit to a sloped line. The fit results are displayed and drawn as a solid line. The $\pm1\sigma$ variations of the fit parameters are drawn as dashed lines.

of opposite-sign to like-sign tracks (relative to the electron in the ejet) is measured to be 1.40 ± 0.01 when no requirement is made on an away side tag. Since the SLT fake rate approximately scales with the number of tracks, the implication is that we ought scale the SS subtraction in Equation 6 by a factor of 1.4. If we incorporate this background subtraction, the method 1 B-tag efficiency on average changes by +8%. The resulting scale factor is 1.05 ± 0.04. We take half the difference between this result and the result discussed above as an additional systematic of 3%.

5.4 Differences in Run 1A Data

Since the SVX detector used in run 1A is radiation soft, we might expect the tagging rates in run 1A to be more affected by radiation damage. We investigate this by looking for a run dependence of the excess tagging rate in electron jets, XS_{ejet}, in a B-enriched sample selected using the same criteria as for the run 1B sample. We measure the B-fraction of the run 1A sample, $F_B^{run\ 1A} = 37 \pm 8\%$, to be consistent with the run 1B fraction, $F_B^{run\ 1B} = 39 \pm 5\%$. This facilitates a direct comparison of the run 1A and run 1B excess tagging rates. Figure 13 shows $XS_{ejet}^{run\ 1A}$ as a function of run number. The points are normalized to the first bin. There is a clear run dependence. We determine the average run 1A B-tagging efficiency by taking the luminosity weighted average over all points. We measure

$$\epsilon_{B-tag}^{run\ 1A} = (0.855 \pm 0.044) \cdot \epsilon_{B-tag}^{run\ 1B}. \tag{11}$$

We determine the average run 1A plus run 1B B-tagging efficiency by taking the luminosity weighted average of $\epsilon_{B-tag}^{run\ 1A}$ and $\epsilon_{B-tag}^{run\ 1B}$. The resulting run averaged B-tagging efficiency is a factor of 0.971 ± 0.009 smaller that the run 1B-only rates determined above. In calculating the $t\bar{t}$ detection efficiency, we diminish all tagging efficiencies by this factor*.

*We do *not* use a separate scale factor for run 1A and 1B. This is a reasonable thing to do because we now understand the run 1A scale factor to have been a manifestation of SVX radiation damage, so that a correction to the B-tag efficiency is more precisely correct. See Reference [11] for more details.

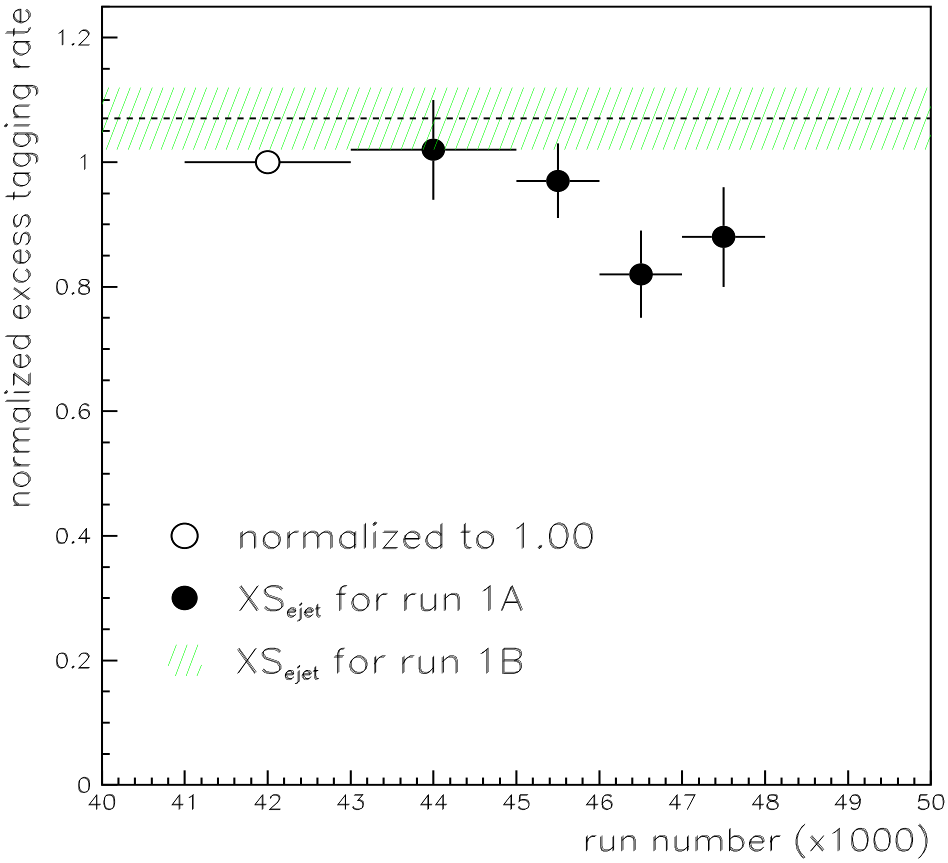

Figure 13: The excess tagging rate for a run 1A B-enriched sample as a function of run number. A clear run dependence is observed. The dotted line is the average run 1B excess tagging rate. The hatched band indicates the $\pm 1\sigma$ bounds on the run 1B rate.

5.5 Determination of ϵ_{B-tag}^{event} for $t\bar{t}$ Events

We use the following expression to determine ϵ_{B-tag}^{event} for $t\bar{t}$ events passing all the event selection criteria.

$$\epsilon_{B-tag}^{event} = F_{2B}\cdot\epsilon_{B-tag}\cdot SF\cdot(2 - \epsilon_{B-tag}\cdot SF) + F_{1B}\cdot\epsilon_{B-tag}\cdot SF \tag{12}$$

where

$F_{2B} \equiv$ the fraction of $t\bar{t}$ events passing all event selection criteria that contain 2 taggable B-jets

$F_{1B} \equiv$ the fraction of $t\bar{t}$ events passing all event selection criteria that contain only 1 taggable B-jet

$\epsilon_{B-tag} \equiv$ the *per jet* B-tagging efficiency as determined from the Monte Carlo

$SF \equiv$ the data to Monte Carlo scale factor.

Table 3 gives the resulting ϵ_{B-tag}^{event} for the assumed top masses 150, 170, and 190 GeV$/c^2$. Our total $t\bar{t}$ event detection efficiency is given in Table 4. We've measured the top mass to be $M_t = 176 \pm 8 \pm 10$ GeV$/c^2$ [12]. Assuming this mass and using a Pythia $t\bar{t}$ Monte Carlo with $M_t = 175$GeV$/c^2$ we calculate the total $t\bar{t}$ detection efficiency to be $\epsilon_{t\bar{t}} = 0.040 \pm 0.001$ (stat) ± 0.006 (sys). The numbers used for this calculation are given in Table 5.

	$M_t = 150$ GeV$/c^2$	$M_t = 170$ GeV$/c^2$	$M_t = 190$ GeV$/c^2$
F_{1B} :	0.327 ± 0.017	0.302 ± 0.007	0.279 ± 0.015
F_{2B} :	0.320 ± 0.017	0.341 ± 0.007	0.378 ± 0.018
ϵ_{B-tag} :	0.561 ± 0.004	0.561 ± 0.004	0.561 ± 0.004
SF :	0.98 ± 0.15	0.98 ± 0.15	0.98 ± 0.15
ϵ_{B-tag}^{event} :	0.42 ± 0.05	0.43 ± 0.04	0.44 ± 0.040
$\epsilon_{mistag}^{event}$:	0.010 ± 0.010	0.010 ± 0.010	0.010 ± 0.010
ϵ_{tag} :	0.43 ± 0.05	0.44 ± 0.04	0.45 ± 0.040

Table 3: The fraction of $t\bar{t}$ events passing all event selection criteria with at least one tagged B-jet. All uncertainties include statistical and systematic errors added in quadrature.

	$M_t = 150$ GeV$/c^2$	$M_t = 170$ GeV$/c^2$	$M_t = 190$ GeV$/c^2$
$A_{t\bar{t}}$:	0.105 ± 0.010	0.116 ± 0.011	0.122 ± 0.012
$\epsilon_{\lvert z_{pvtx}\rvert}$:	0.949 ± 0.023	0.949 ± 0.023	0.949 ± 0.023
ϵ_{trig} :	0.854 ± 0.045	0.854 ± 0.045	0.854 ± 0.045
$\epsilon_{lepton\ id}$:	0.903 ± 0.008	0.903 ± 0.008	0.903 ± 0.008
ϵ_{tag} :	0.43 ± 0.05	0.44 ± 0.04	0.45 ± 0.040
$\epsilon_{t\bar{t}}$:	0.033 ± 0.006	0.037 ± 0.006	0.040 ± 0.006

Table 4: The total $t\bar{t}$ event detection efficiency. All uncertainties include statistical and systematic errors added in quadrature.

for $M_t = 175$ GeV$/c^2$
$F_{1B} = 0.300 \pm 0.007$
$F_{2B} = 0.367 \pm 0.007$
$\epsilon_{B-tag} = 0.561 \pm 0.004$
$SF = 0.99 \pm 0.14$
$\epsilon_{mistag}^{event} = 0.01 \pm 0.01$
$\epsilon_{tag} = 0.45 \pm 0.04$
$A_{t\bar{t}} = 0.121 \pm 0.012$
$\epsilon_{trig} = 0.854 \pm 0.045$
$\epsilon_{lepton\ id} = 0.903 \pm 0.008$
$\epsilon_{\lvert z_{pvtx} \rvert} = 0.949 \pm 0.023$
$\epsilon_{t\bar{t}} = 0.040 \pm 0.006$

Table 5: The numbers used to calculate the total $t\bar{t}$ event detection efficiency, $\epsilon_{t\bar{t}}$, for a top mass of $M_t = 175$ GeV$/c^2$.

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