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Preliminary Method 2 Backgrounds For Top Pair Production in Lepton Plus Jets Events with `SecVtx` using 318.5 pb^{-1} of $\mathrm{p\bar{p}}$ Data

Andy Foland [1], Melissa Franklin [2], João Guimarães da Costa [3],
Salvatore Rappoccio [4] Daniel Sherman [5],

Harvard University

Abstract

We present an estimate of the backgrounds to $\mathrm{t\bar{t}}$ production in the lepton plus jets channel with ≥ 1 and ≥ 2 `SecVtx` tags. We use the "Method 2" technique where a combination of data and Monte Carlo is used to estimate the backgrounds from electroweak processes, single top, fake leptons, fake tags, and real $W+$ Heavy Flavor production. This note includes support work for cdfnote 7562 which is the preliminary cdfnote from the Lepton+Jets group, with the background estimate in the Gen 5 SECVTX-tagged lepton + jets sample.

[1] adf@fnal.gov
[2] franklin@fnal.gov
[3] guima@fnal.gov
[4] rappocc@fnal.gov
[5] dsherman@fnal.gov

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0 Changes since Blessing

We have updated our mistag estimate. Previously, we were double counting our light flavor tags from top and other backgrounds. We now correct the mistag estimate for light flavor tags counted elsewhere. Now, the mistag estimate is an estimate of the $W+$ light flavor component. To do this, we updated the equation for the double mistag calculation. We have also included a factor to correct α_{LF} to reflect the true light-flavor asymmetry. We now also use a $\sum E_T$ dependent α_{LF}.

There was also a small change in the weighting of the Non-W backgrounds. Instead of assuming the errors on R_B and F_{Non-W} are correlated, we assume they are uncorrelated because the former is a tag rate, and the latter is a fraction of events in the signal region. A statistical fluctuation in Region B will show up in F_{Non-W}, but not in R_B. In addition, we previously (incorrectly) took the weighted average of the pretag and tag methods using the errors to the first power, when it should be squared.

1 Data Sample and Event Selection

The data sample is the 318 pb^{-1} collected until the September 2004 shutdown, covering runs 138425 (Feb 4, 2002) - 186598 (Aug 22, 2004), excluding the COT compromised data (runs 179057-182842). We use DQM Good Run List v7.0, including requirements on good silicon data, and ignoring CMX bits for runs before 150145. The integrated luminosity for this period is 318.5 $\pm$ 19.1 for CEM and CMUP, and 305.2 $\pm$ 18.3 for CMX, where a 1.9% correction has been applied.

We use datasets `bhel0d` and `bhmu0d` for the signal data for electrons and muons, respectively. We use the standard Lepton Plus Jets group data selection outlined in Ref [1]. That is, we require

- Jets clustered with `JetClu` with a cone of 0.4, corrected to Level 4 with jet corrections version `jetCorr04`
- One tight, isolated trigger lepton.
- $\not\!\!E_T > 20.0$ GeV (corrected to Level 4)
- Dilepton, Z boson, conversion, cosmic veto
- $|\Delta z_{lepton-zvtx}| < 5.0$ cm
- z_{vtx} found with `ZVertexModule` using the beamline as seed.
- ≥ 1 or ≥ 2 positive tight SecVtx tags.
- Signal region defined as: ≥ 3 jets with $E_T > 15$ GeV (at Level 4) and $|\eta_{detector}| < 2.0$

Event yields are shown in Table 1.

2 Event Tagging Efficiency

We calculate the event tagging efficiency for our backgrounds by counting the number of events with ≥ 1 or ≥ 2 tags in the Monte Carlo, and then dividing by the number of pretag events.

$$\epsilon_{MC}^{tag} = \frac{N_{MC}^{tag}}{N_{MC}^{pre}} \tag{1}$$

In order to take the scale factor into account, we take the ratio of the event tag rates derived from the binomial expression for tagging N jets, given inputs from the b and c quark tagging efficiencies, and the mistag rate. The full expression for the

Data					
	1 jet	2 jets	3 jets	4 jets	≥ 5 jets
CEM					
Pretag	17648	2846	469	115	19
$\geq 1+$ Tag	249	142	59	39	8
$\geq 2+$ Tag	0	10	11	7	1
$\geq 1-$ Tag	62	24	8	3	1
$\geq 1+-$ Tag	0	1	2	1	1
$\geq 2-$ Tag	0	0	0	0	0
CMUP					
Pretag	8514	1263	202	46	11
$\geq 1+$ Tag	110	66	25	18	7
$\geq 2+$ Tag	0	5	5	6	2
$\geq 1-$ Tag	27	12	2	1	0
$\geq 1+-$ Tag	0	0	0	0	0
$\geq 2-$ Tag	0	0	0	0	0
CMX					
Pretag	4466	682	98	18	6
$\geq 1+$ Tag	73	34	11	6	4
$\geq 2+$ Tag	0	0	1	3	0
$\geq 1-$ Tag	11	7	1	0	0
$\geq 1+-$ Tag	0	0	0	0	0
$\geq 2-$ Tag	0	0	0	0	0
Total					
Pretag	30628	4791	769	179	36
≥ 1 Tag	432	242	95	63	19
≥ 2 Tag	0	15	17	16	3
$\geq 1-$ Tag	100	43	11	4	1
$\geq 1+-$ Tag	0	1	2	1	1
$\geq 2-$ Tag	0	0	0	0	0

Table 1: Events Yields for $318.5pb^{-1}$.

combinatoric combination of tagging exactly N_{jet} jets N_{tag} times is

$$\begin{aligned}\epsilon_{ev} = \sum_{n_b=0}^{N_{jet}} \sum_{n_c=0}^{N_{jet}} \sum_{n_p=0}^{N_{jet}} \Big\{ F_{n_b n_c n_p} \times \sum_{n_b^+=0}^{n_b} \sum_{n_c^+=0}^{n_c} \sum_{n_c^+=0}^{n_c} & \Big[\binom{n_b}{n_b^+} \quad (\epsilon_b SF_b)^{n_b^+} \, (1-\epsilon_b SF_b)^{(n_b - n_b^+)} \\ \times & \binom{n_c}{n_c^+} \quad (\epsilon_c SF_c)^{n_c^+} \, (1-\epsilon_c SF_c)^{(n_c - n_c^+)} \\ \times & \binom{n_p}{n_p^+} \quad (M_p SF_p)^{n_p^+} \, (1-M_p SF_p)^{(n_p - n_p^+)} \Big] \Big\}\end{aligned} \tag{2}$$

$$n_b + n_c + n_p = N_{jet} \tag{3}$$

$$n_b^+ + n_c^+ + n_p^+ = N_{tag} \tag{4}$$

$$\binom{r}{k} = \frac{r!}{(r-k)!k!} \tag{5}$$

where F_{bcp} is the fraction of events with b b-jet, c c-jets, and p p-jets, ϵ_b and ϵ_c are the Monte Carlo efficiencies for jets matched to B- and C-hadrons at HEPG level, M_p is the per-jet prediction of the mistag matrix applied to light quark jets in $t\bar{t}$ Monte Carlo, SF_b and SF_c are the scale factors for b and c-jets, and SF_p is the ratio of predicted tag rates in data and Monte Carlo in JET50 events, multiplied by the light flavor asymmetry (1.37 ± 0.23) as described in Ref [2]. A further discussion of SF_p will be given below.

We then calculate the ratio of the event tagging efficiency with and without the b-tagging scale factors, which we denote by Φ_E:

$$\Phi_E = \frac{\epsilon_{ev}(\epsilon_b SF_b, \epsilon_c SF_c, M_p SF_p)}{\epsilon_{ev}(\epsilon_b, \epsilon_c, \epsilon_p)} \tag{6}$$

Subsequently, we multiply the event tag rate by Φ_E to obtain the event tag rate including the scale factor.

$$\epsilon_{DATA} = \epsilon_{MC} \times \Phi_E \tag{7}$$

Henceforth, all per-jet and event tagging efficiencies will be denoted in terms of ϵ (for the MC efficiency) multiplied by SF or Φ_E.

2.1 SF_p (aka K-Factor)

When applying the mistag matrix to the Monte Carlo, we need to worry about discrepancies in the distributions that parameterize the matrix. The Monte Carlo has known differences from the data, and we must be careful not to introduce a bias when using the matrix in the Monte Carlo. It is thus necessary to introduce a K-factor, which we call the primary-jet scale factor SF_p.

Figure 1 shows the distributions of jets in JET50 data (points) and PYTHIA Monte Carlo (green), using the matrix binning. Here, we have only examined the tag rates for jets with $E_T > 50$ GeV. We allow all jets with $E_T > 10$ GeV and $\eta < 2.4$ to enter into the $\sum E_T$ calculation, as is done in the analysis. All jets use uncorrected jet E_T.

It is clear that the E_T, ϕ, and $\sum E_T$ distributions are all modelled quite well by the Monte Carlo. The number of good tracks is not modelled well, and the ratio of average number of tracks is

$$\kappa = \frac{5.626 \pm 0.002}{5.897 \pm 0.005} = 0.954 \pm 0.001 \tag{8}$$

The ratio of average tag rates is given by

$$SF_p = \frac{0.01093 \pm 0.000044}{0.01245 \pm 0.000054} = 0.878 \pm 0.006. \tag{9}$$

We also check if the $\sum E_T$ is well-modelled, and only count jets with $E_T > 50$ GeV in the $\sum E_T$ calculation. We see from Figures 2 that the $\sum E_T$ peaks at 50 GeV, which means that on average, only one jet is being counted. Thus, this is a place in the matrix that is not populated very much since the matrix is constructed from mostly dijet data. It is a good cross-check, however, since this is what happens in the 1-jet bin in this analysis. The SF_p is determined to be

$$SF_p = \frac{0.0100 \pm 0.0003}{0.0114 \pm 0.0004} = 0.88 \pm 0.05 \tag{10}$$

We can examine the predicted tag rates in both the data and the Monte Carlo to see what the major effect is. Figure 4 shows the predicted tag rates in the data (black) and Monte Carlo (red) for the various matrix variables. It is clear that the tag rates versus number of tracks matches very well, but the other distributions have an offset. This is attributed to the fact that the means of the number of good tracks are different in the data and the Monte Carlo, and hence the tag rates are different. Examining 5 shows the ratios of the predictions (data/MC) for the various matrix variables. It is clear that the ratio is fairly flat for everything except the E_T and number of good tracks. However, the jet E_T is highly correlated with the number of good tracks, and hence that correlation is showing up in the SF_p.

The η distribution is also not modelled perfectly, but this is a secondary effect. If we additionally restrict ourselves to only $\eta < 1.0$, as is shown in Figure 3, we see that now the η distributions match well, and SF_p now becomes

$$SF_p = \frac{0.0101 \pm 0.0006}{0.0115 \pm 0.0007} = 0.88 \pm 0.01 \tag{11}$$

We see that the SF_p is robust under these modifications. Thus, we feel the only difference that is impacting SF_p is the number of good tracks distribution. It only remains to show that the number of good tracks is similarly modelled in the signal data and Monte Carlo.

Figure 6 shows the number of tracks distribution in taggable jets in the pretag data and $\mathrm{t\bar{t}}$ Monte Carlo, for ≥ 3 jets. The distributions are similar. The ratio of average number of good tracks is

$$\kappa_{\mathrm{t\bar{t}}} = \frac{5.8 \pm 0.1}{6.0 \pm 0.0} = 0.97 \pm 0.02 \tag{12}$$

which agrees with Equation 8, which is the result for JET50.

It is also possible that the distributions do not agree because of the fact that the Monte Carlo does not have minimum bias events overlayed, whereas the data does. Figure 7 shows a comparison of the number of good tracks in taggable jets in all jet bins for the default $\mathrm{t\bar{t}}$ Monte Carlo, and Monte Carlo with 1 and 2 mb of minbias events overlayed. There only a very small change in the number of tracks because of the fact that we require good tracks to lie within 1.0 cm of the primary vertex.

Therefore, we feel that the primary difference between the application of the mistag matrices on the data and the Monte Carlo is due to the misestimation of the tracking efficiency in the Monte Carlo, which also gives rise to the b-tagging scale factor.

In order to estimate the spread of SF_p values for the observed ratios of average number of tracks in data and Monte Carlo, we fit the negative tag rate versus N_{good} in the data and Monte Carlo. We then input the average number of good tracks in the data and Monte Carlo, and obtain the average prediction. We then take the ratio of those predictions to obtain an effective SF_p for each type of distribution.

Table 2 shows the spread of possible SF_p values given the input average number of good tracks for the data and the Monte Carlo. The ratio of the average number of tracks (κ) is given, along with the average number of tracks in data and Monte Carlo, plus the fit results of the input average number of tracks, and the effective SF_p. It is clear that 0.88 ± 0.25 covers the possible spread of values in this sample.

Evaluation of Effective L.F. Scale Factors						
Description	N_{trk}^{data}	N_{trk}^{MC}	κ	$< R_- >^{data}$	$< R_- >^{MC}$	Effective SF_p
JET50	5.6	5.9	0.95	0.0067	0.0074	0.88
$t\bar{t}$ Fiducial	4.9	5.3	0.94	0.0048	0.0056	0.85
$t\bar{t}$ Taggable	5.8	6.0	0.97	0.0071	0.0077	0.93
$t\bar{t} \geq 1$ Tag	7.0	7.1	0.98	0.011	0.012	0.95
$t\bar{t} \geq 2$ Tag	6.7	7.1	0.94	0.010	0.012	0.86

Table 2: Effective SF_p factors given the average number of good tracks in the data and the Monte Carlo. Here, $\kappa = N_{trk}^{data}/N_{trk}^{MC}$, and $< R_- >$ is the average negative tag rate taken from the fit in Figure 8. SF_p is then the ratio $< R_- >^{data} / < R_- >^{MC}$

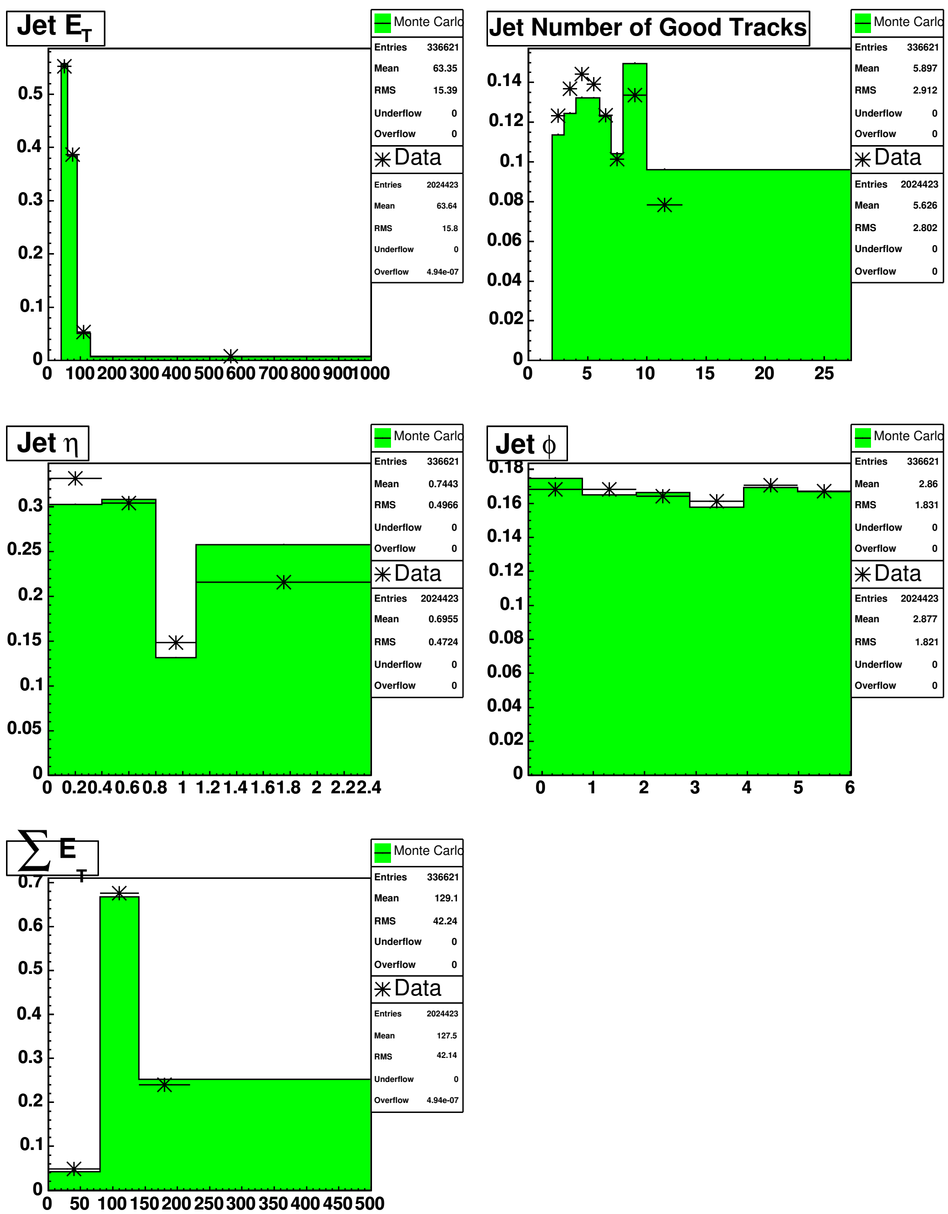

Figure 1: Comparison of matrix variables for JET50 data and Pythia Monte Carlo. Here, we examine only jets with $E_T > 50$. The primary difference arises in the number of good tracks distribution, which is higher in the Monte Carlo. Here, the binning is that used for the matrix.

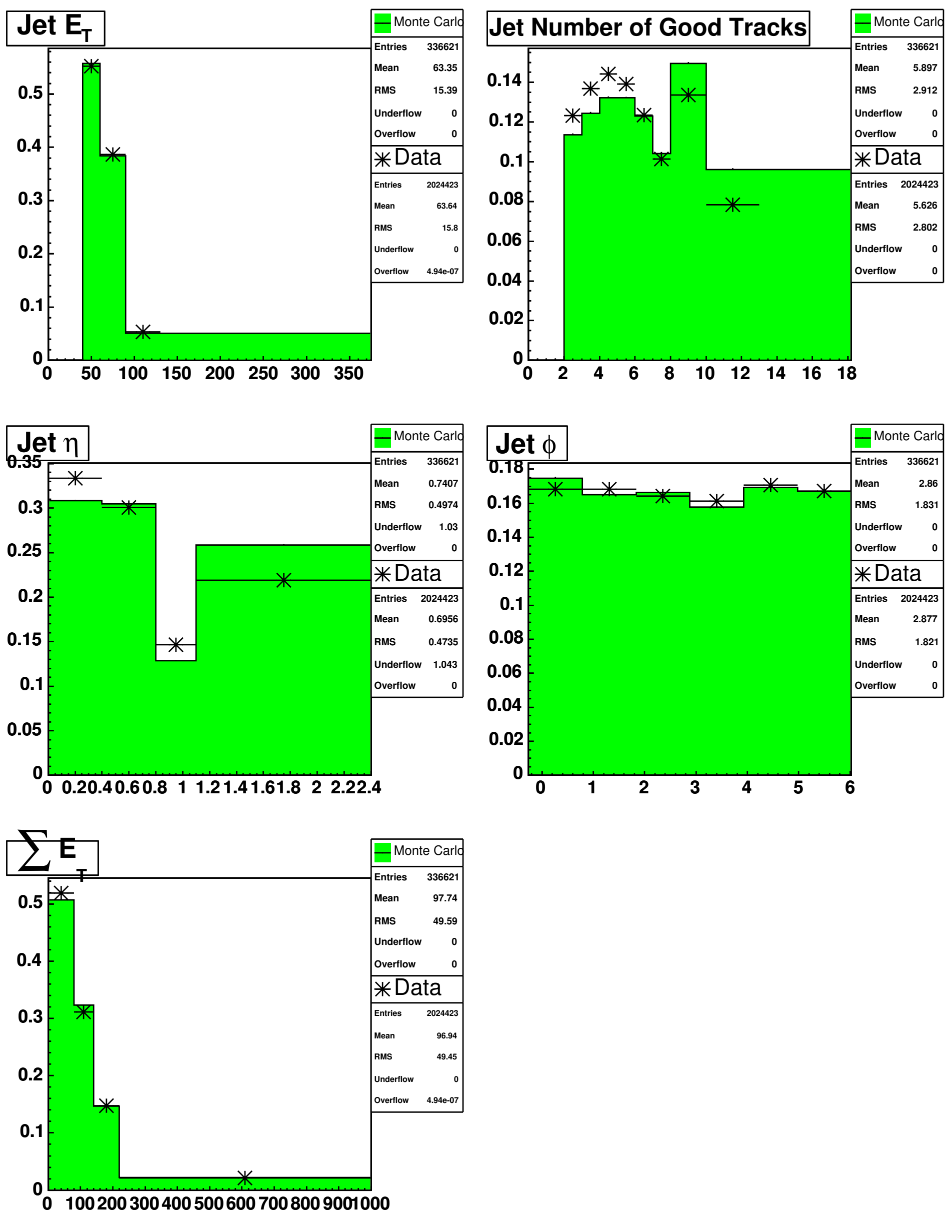

Figure 2: Comparison of matrix variables for JET50 data and Pythia Monte Carlo. Here, we examine only jets with $E_T > 50$, and make an additional requirement that the $\sum E_T$ variable only be calculated for jets with $E_T > 50$. This is a cross check to be sure the $\sum E_T$ dependence of the SF_p is correctly modelled. The primary difference is still in the number of good tracks distribution, which is higher in the Monte Carlo. Here, the binning is that used for the matrix.

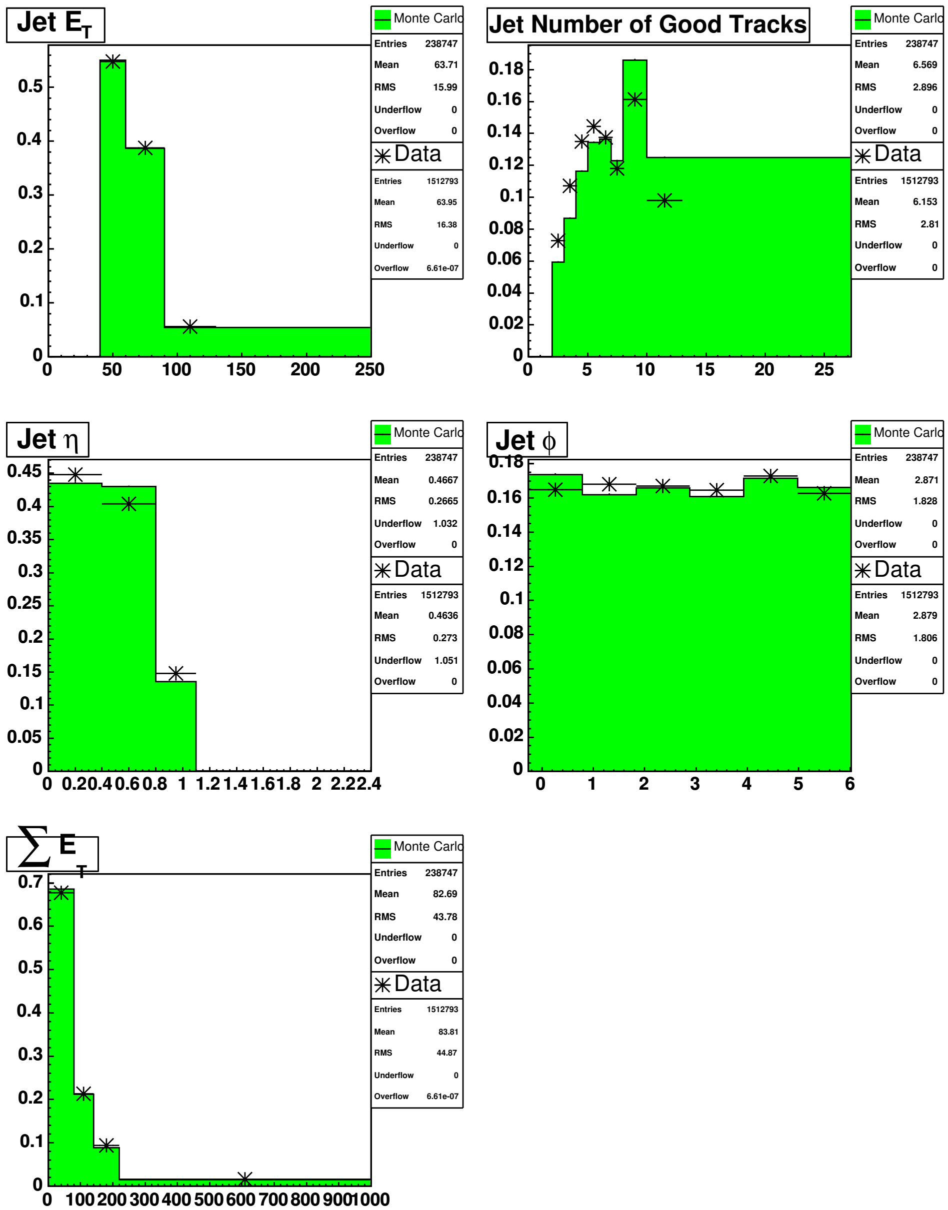

Figure 3: Comparison of matrix variables for JET50 data and Pythia Monte Carlo. Here, we examine only jets with $E_T > 50$ and $\eta < 1.0$. This is a cross check to be sure the η dependence of the SF_p is correctly modelled. The primary difference is still in the number of good tracks distribution, which is higher in the Monte Carlo. Here, the binning is that used for the matrix.

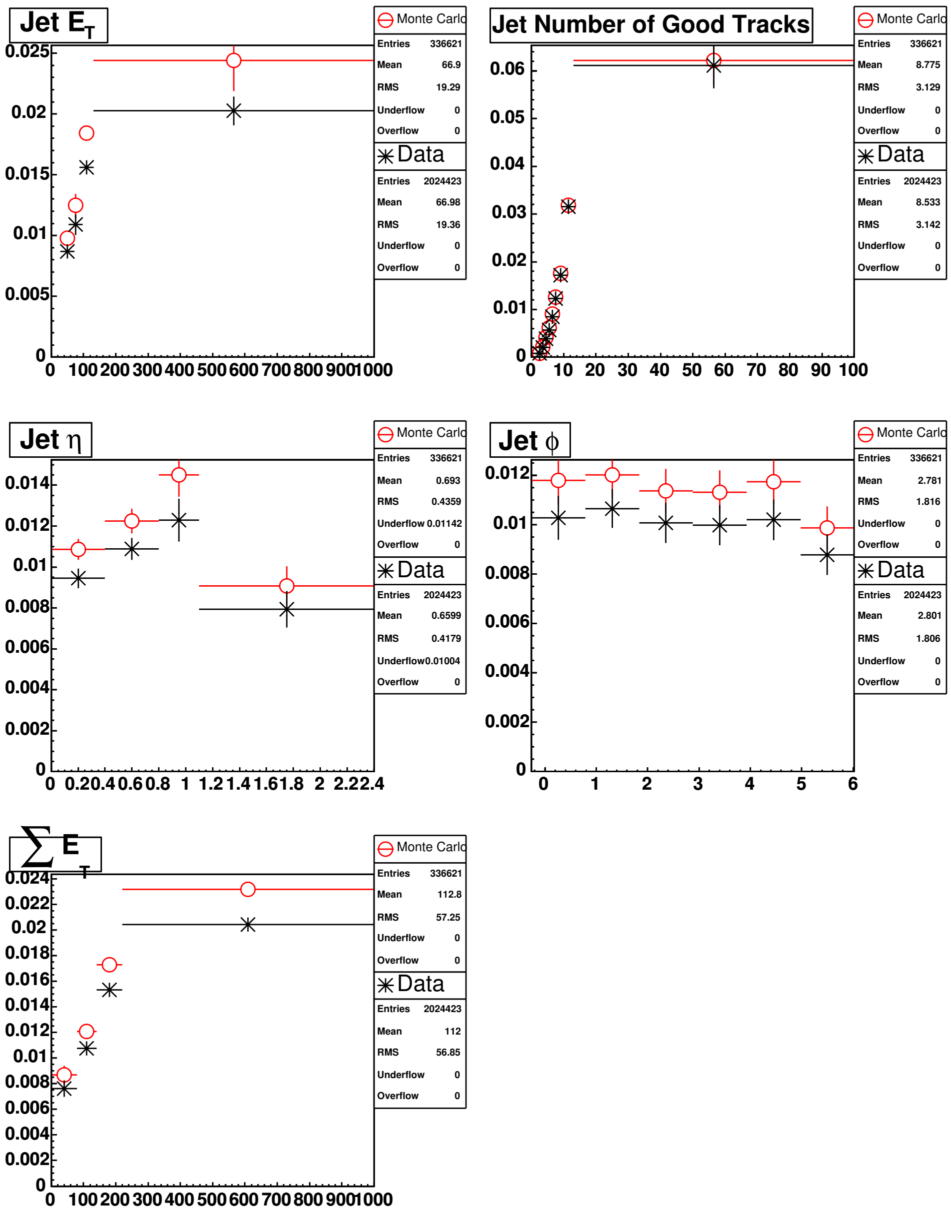

Figure 4: Predicted negative tag rates for JET50 data and Monte Carlo. It is clear that the tag rates versus the number of good tracks is very close in the data and Monte Carlo, but the fact that there are different means in the two distributions results in a higher overall tag rate in the Monte Carlo.

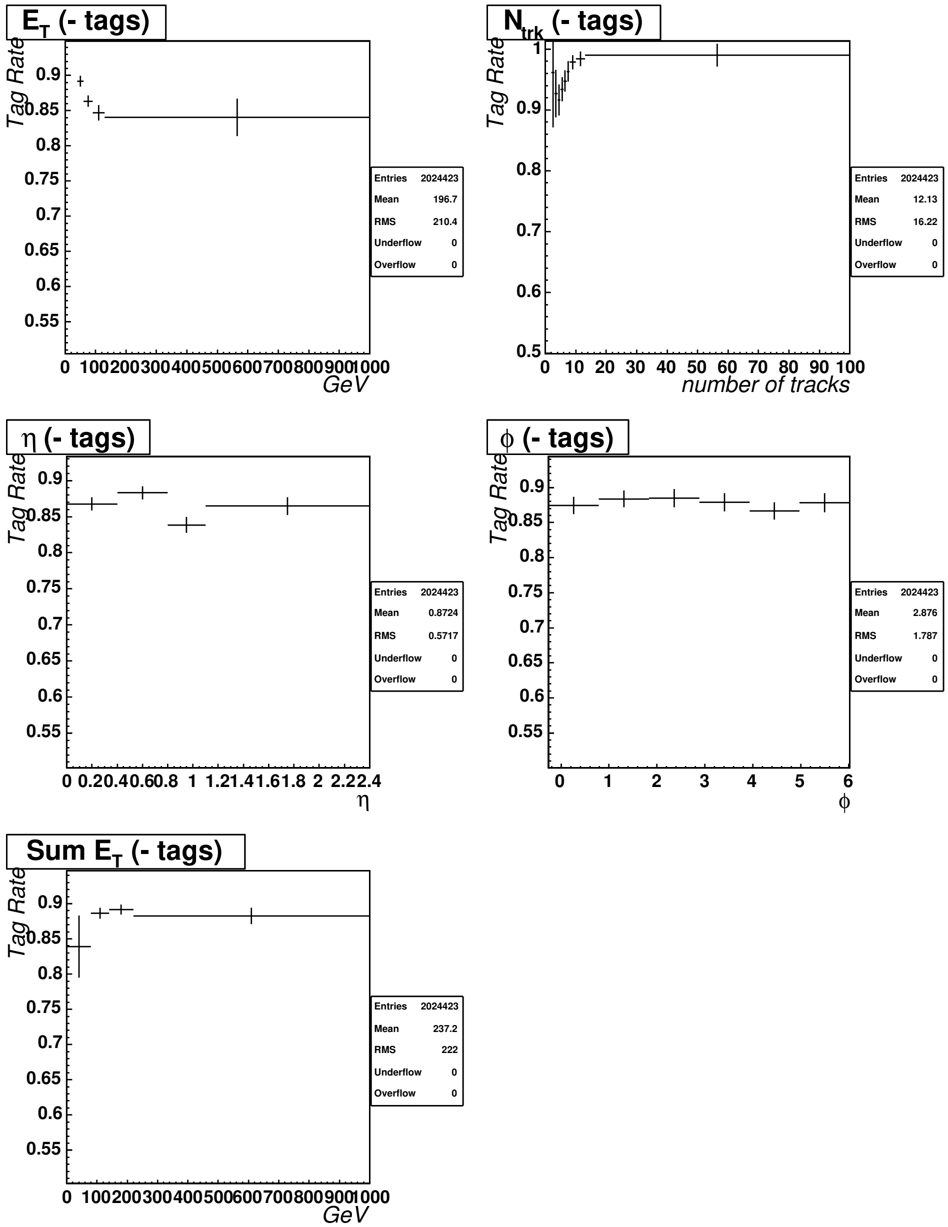

Figure 5: Ratio of predicted negative tag rates for JET50 data and Monte Carlo (data/MC). The ratio is roughly flat for η and ϕ, as well as $\sum E_T$ (within statistics). The jet E_T and number of good tracks are very correlated for fake jets, and so we see that the primary difference arises from the number of good tracks distribution.

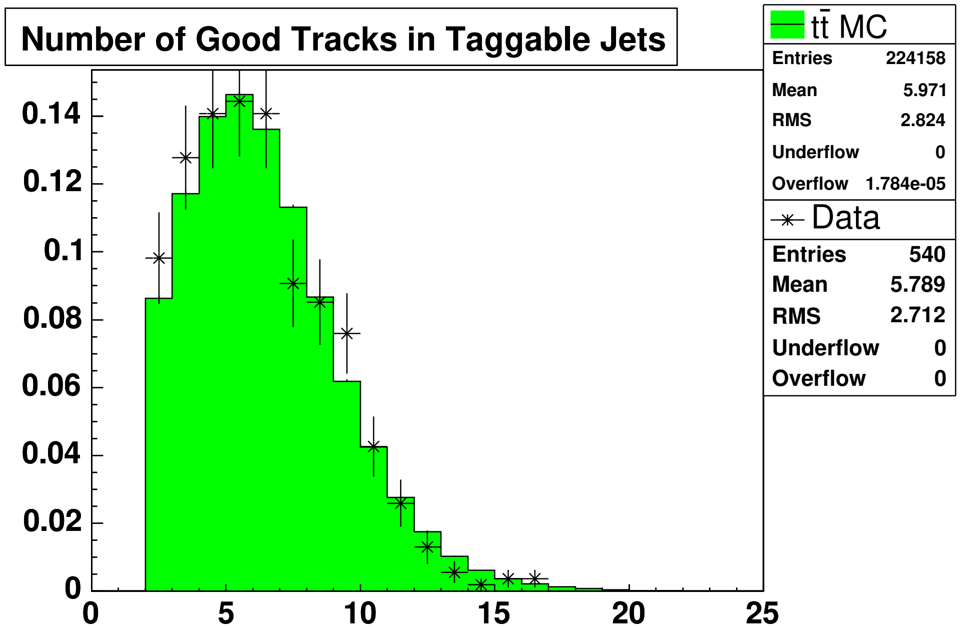

Figure 6: Number of good tracks in taggable jets for the $t\bar{t}$ sample and `ttopel` Monte Carlo. The ratio of mean number of tracks is consistent with that obtained from the jet samples.

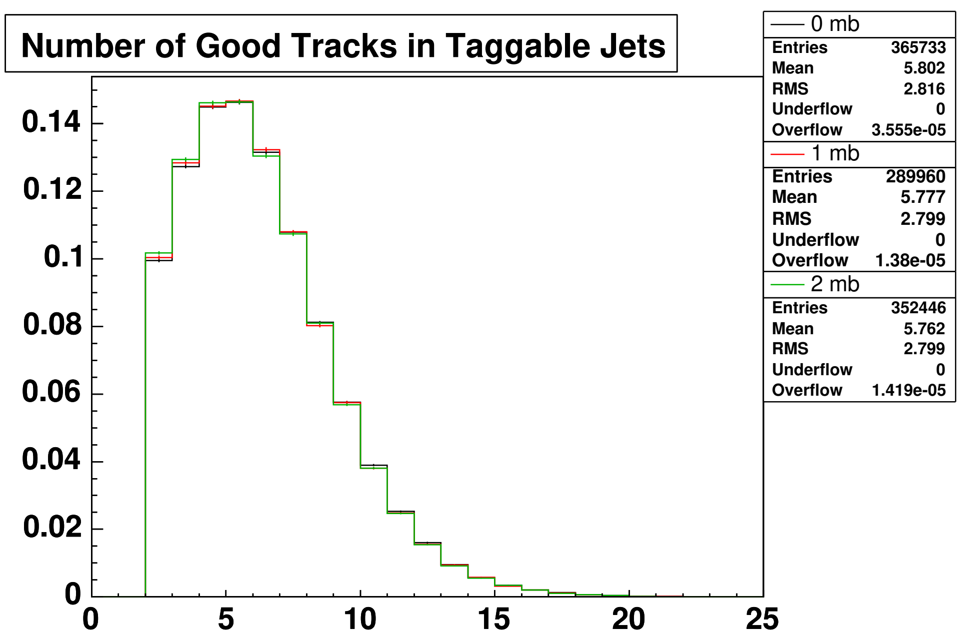

Figure 7: Number of good tracks in taggable jets for the $t\bar{t}$ samples with 0, 1 and 2 mb of minbias events overlayed. The effect of this on the SF_p will be small.

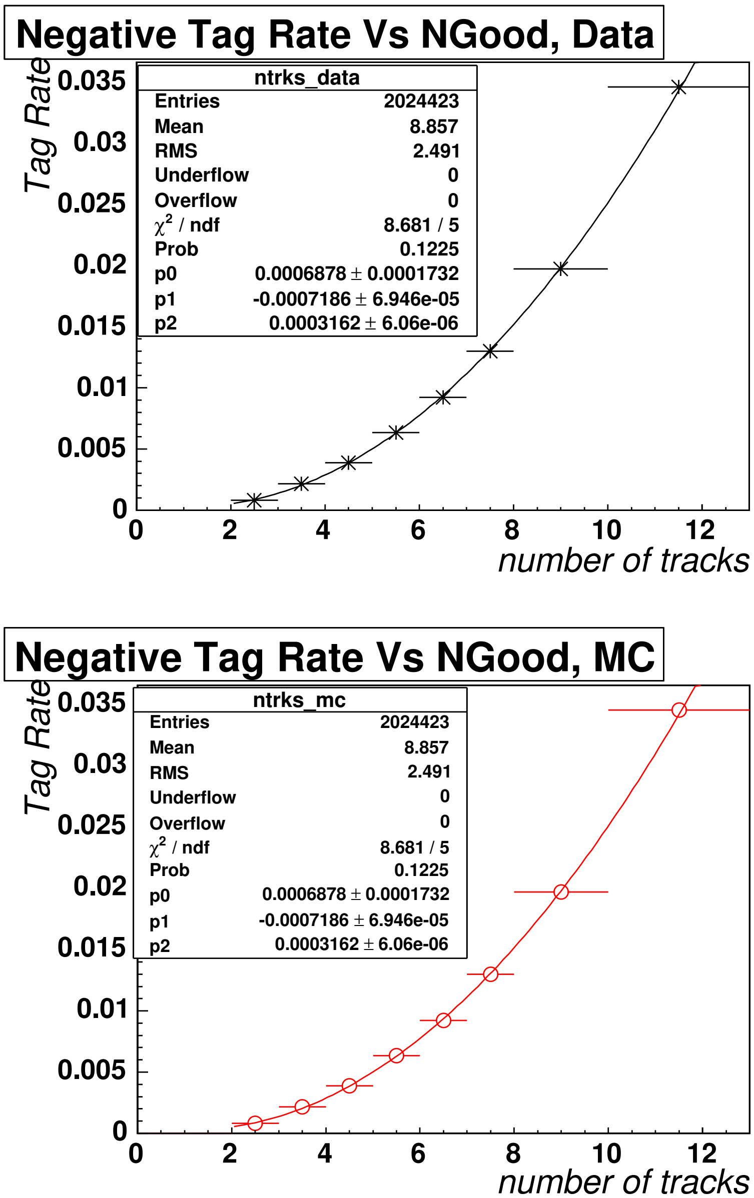

Figure 8: Fit to number of good tracks in taggable jets for the JET50 data and Monte Carlo. From this distribution we can extract an effective K factor given the average number of good tracks in data and Monte Carlo.

3 Method 2 Backgrounds

There are four categories of backgrounds for the lepton plus jets channel.

- **Electroweak and Single Top**. These backgrounds are taken from Monte Carlo, scaled to theoretical cross sections.
- **Non-W Backgrounds**. This background is estimated from the $\not\!\!E_T$ vs lepton isolation sidebands in the data sample.
- **W+Heavy Flavor**. These backgrounds are estimated using the efficiency derived from Monte Carlo and the scale factor outlined in [3], plus the heavy flavor fractions in W plus jets events measured for the first round of publications, scaled to the pretag data.
- **W+Light Flavor Mistags**. This background is estimated using the negative tag matrix outlined in [4] applied to the pretag sample (corrected for other backgrounds), with the appropriate scaling for the asymmetry of the light flavor L_{2D} distribution.

3.1 Electroweak and Single Top

The electroweak and single top backgrounds are determined from the theoretical cross section and luminosity with the equation:

$$N^{p\bar{p}\rightarrow X} = \sigma^{p\bar{p}\rightarrow X}\epsilon_{pretag}\epsilon_{tag}\int\mathcal{L}dt \tag{13}$$

where $\sigma^{p\bar{p}\rightarrow X}$ is the theoretical cross section, $\int\mathcal{L}dt$ is the integrated luminosity, ϵ_{pretag} is the pretag efficiency, and ϵ_{tag} is the event tagging efficiency. The event tagging efficiency is determined in the same way as the $t\bar{t}$ expection, using

$$\epsilon_{tag} = \epsilon_{tag}^{MC} \times \Phi_E \tag{14}$$

where ϵ_{tag}^{MC} is the event tag rate in Monte Carlo, and Φ_E is the "effective event scale factor" analogous to Equation 6.

The theoretical cross sections along with their errors for the backgrounds considered are shown in Table 3, along with the theoretical prediction for the top quark.

3.2 Non-W Backgrounds

The non-W backgrounds are estimated using the "standard" $\not\!\!E_T$ versus isolation method. The regions are:

- Region A: isolation > 0.2 and $\not\!\!E_T < 15$ GeV
- Region B: isolation < 0.1 and $\not\!\!E_T < 15$ GeV

Theoretical Cross Sections	
WW	13.25 ± 0.25 *pb*
WZ	3.96 ± 0.06 *pb*
ZZ	1.58 ± 0.02 *pb*
Single Top, s-channel	0.88 ± 0.05 *pb*
Single Top, t-channel	1.98 ± 0.08 *pb*
$t\bar{t}$	6.1 ± 0.07 *pb*
$Z \to \tau\tau$	13.0 ± 1.5 *pb*

Table 3: Theoretical cross sections and errors for the electroweak and single top backgrounds, along with the theoretical cross section for $t\bar{t}$.

- Region C: isolation > 0.2 and $\not{E}_T > 20$ GeV
- Region D: isolation < 0.1 and $\not{E}_T > 20$ GeV (signal region)

The number of events in each region is given in Figure 9. We use the following formulas for the estimation of the number of Non-W events in Region D (the signal region).

$$
\begin{aligned}
F_{Non-W} &= \frac{N_B^{pre}}{N_A^{pre}} \frac{N_C^{pre}}{N_D^{pre}} && (15) \\
N_{Non-W}^{pretags} &= F_{Non-W} N_{pretags} && (16) \\
N_{Non-W}^{\geq 1} : A &= \frac{N_B^{+}}{N_A^{+}} N_C^{+} && (17) \\
N_{Non-W}^{\geq 1} : B &= N_{pretags} F_{Non-W} \frac{N_B^{+}}{N_B^{pre}} && (18) \\
N_{Non-W}^{\geq 2} &= N_{pretags} F_{Non-W} \frac{N_B^{++}}{N_B^{pre}} && (19)
\end{aligned}
$$

where $N_{(A,B,C,D)}^{pre}$ is the number of pretagged events in regions (A,B,C,D), F_{Non-W} is the fraction of events in the pretag sample that we expect to come from non-W backgrounds, $N_{(A,B,C)}^{+}$ is the number of single-tagged events in regions (A,B,C), and $N_{(A,B,C)}^{++}$ is the number of double-tagged events in regions (A,B,C).

For the ≥ 1 tag tag estimates, we take a weighted average of $N_{Non-W} : A$ (the "tag method") and $N_{Non-W} : B$ (the "pretag method"). We take F_{Non-W}, $\frac{N_B^+}{N_A^+}$, and $\frac{N_B^{++}}{N_A^{++}}$ to be the same in ≥ 3 jets to conserve statistics. We also combine the CMUP and CMX muons into one estimate for F_{Non-W}, $\frac{N_B^+}{N_A^+}$, and $\frac{N_B^+}{N_A^+}$. For the double tagged estimate, we use only the "pretag method" since the "tag method" suffers from very low statistics.

We remove $t\bar{t}$ from the various $\not{E}_T$ versus isolation regions, as shown in Table 28. We use the theoretical prediction for the number of events in each region, and then include the cross section in our "iteration" procedure to calculate the final result.

Because of the very small statistics in the various regions for the QCD double tags, we compute a Feldman-Cousins interval [5] for the number of QCD events. That is, we compute

$$N_{++}^{QCD} = N_{++}^{obs} - N_{++}^{t\bar{t}} \tag{20}$$

In this case, $t\bar{t}$ is the "background", and we wish to compute N_{++}^{QCD}. We take the 68% C.L. interval for the Feldman-Cousins construction, and then take

$$N_{++}^{QCD} = \left(\frac{N_{up} + N_{lo}}{2}\right) \pm \left(\frac{N_{up} - N_{lo}}{2}\right) \tag{21}$$

where N_{up} is the upper 68% limit, and N_{lo} is the lower 68% limit. That is, we take the center of the interval as our central value, plus half the interval as the error. We then compute the backgrounds using Equations 15, substituting N_{++}^{QCD} for N_{++}.

Figure 10 shows the ratio of events in Regions B to A for single and double tags, for both electrons and muons. This ratio is constant for ≥ 3 jets, so we combine the ≥ 3 jet bins for one estimate of this quantity. Figure 11 shows the event tag rates versus $\not\!\!E_T$ for single and double tags, for the regions with $iso > 0.2$ and $iso < 0.1$. It is clear that although the tag rates versus $\not\!\!E_T$ are not constant for the $iso > 0.2$ regions because of biases from heavy flavor, the tag rates versus $\not\!\!E_T$ are constant for the $iso < 0.1$ region. Thus, we feel the tag rate in Region B (low $\not\!\!E_T$, $iso < 0.1$) is indicative of the tag rates in Region D for Non-W events.

The results of the QCD background calculation are shown in Table 4. The derivation is shown in Table 29.

3.3 W+Heavy Flavor

The W+HF backgrounds are estimated in the "standard" Method 2 formulation (see Ref [6]), where the pretag sample (corrected for the Non-W, electroweak, and single top backgrounds, as well as the expectation from $t\bar{t}$ in the pretag sample) is scaled by the heavy flavor fraction. This number is then multiplied by the tagging efficiencies measured in the ALPGEN $W + Q\overline{Q} + Np$ samples described in Ref [7]. We use the heavy flavor fractions determined by Ref [8], outlined in Table 5.

$$N_{W+HF} = (N_{pretag}(1 - F_{non-W}) - N_{EW,singletop} - N_{t\bar{t}})\,(f_{HF})(\epsilon_{tag})(\Phi_E) \tag{22}$$

where N_{pretag} is the number of pretag events, F_{non-W} is the non-W fraction outlined in Section 3.2, $N_{(EW,SingleTop,t\bar{t})}$ is the number of electroweak, single top, and top pair events as outlined in Section 3.1, and f_{HF} is the heavy flavor fraction outlined in Ref [8].

We remove the contribution of Non-W pretag events, as well as the contributions from electroweak, single top, and $t\bar{t}$ to the pretag sample. This is the origin of the first term in Table 22. Table 6 shows the various components of this correction.

ϵ_{tag} is the *event tagging efficiency* in W+HF ALPGEN + HERWIG Monte Carlo ($\frac{N^{\geq 1+}}{N_{pre}}$ and $\frac{N^{\geq 2+}}{N_{pre}}$). We require tags to be within $\Delta R < 0.4$ of hadrons at the HEPG

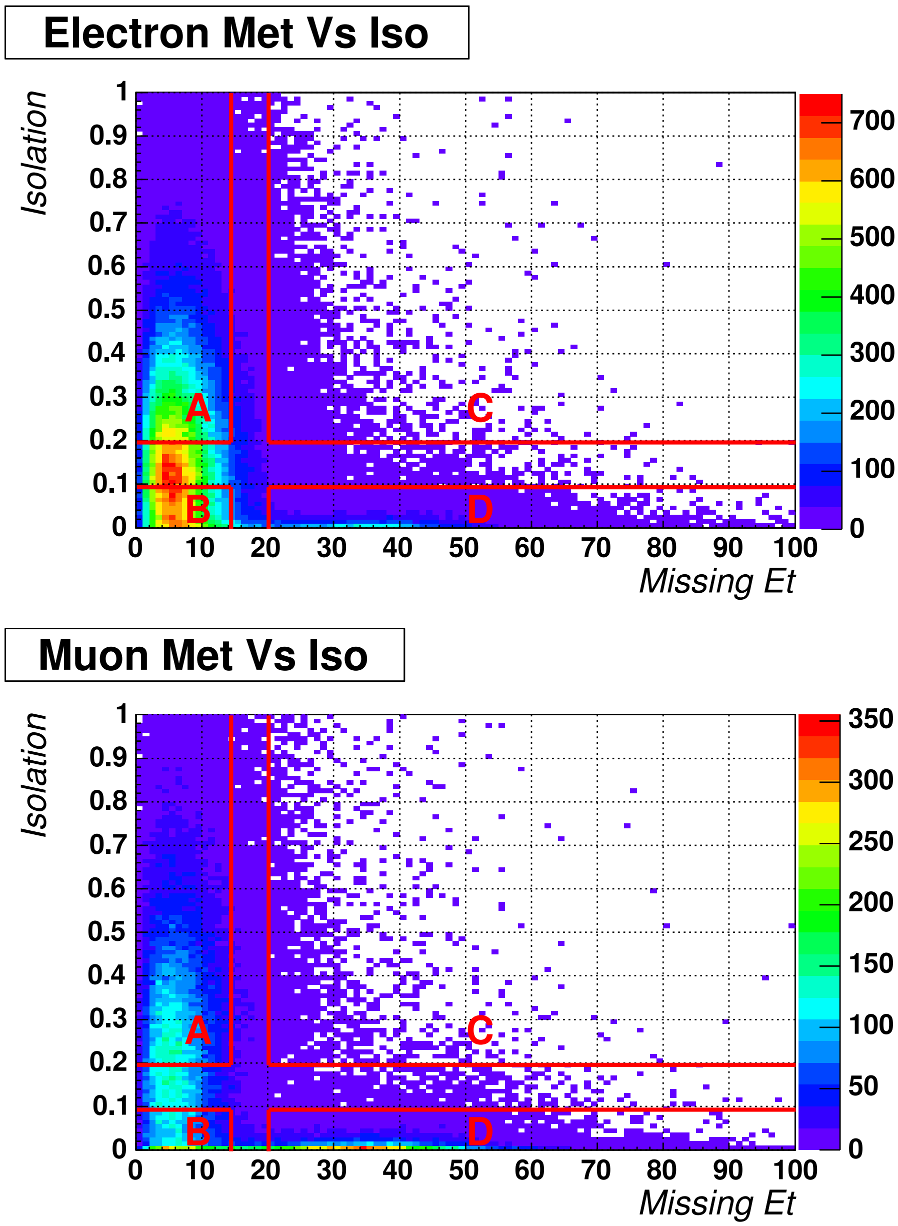

Figure 9: Pretag events in Regions A,B,C,D for electrons and muons.

level. The scale factor is taken into account by using the *per-jet* tagging efficiency, and calculating the event Φ_E factor analagously to Section 2.

We have used *exclusive matching* for combining the different $W + Q\overline{Q} + Np$ backgrounds for the 1-3 jet bins. However, since we do not have samples for $W+BB+3p$ and $W+CC+3p$, we take *inclusive matching*, where extra jets are allowed in the matching scheme, to cover the 4- and $\geq$ 5- jet bins. We require tags to be in reconstructed jets

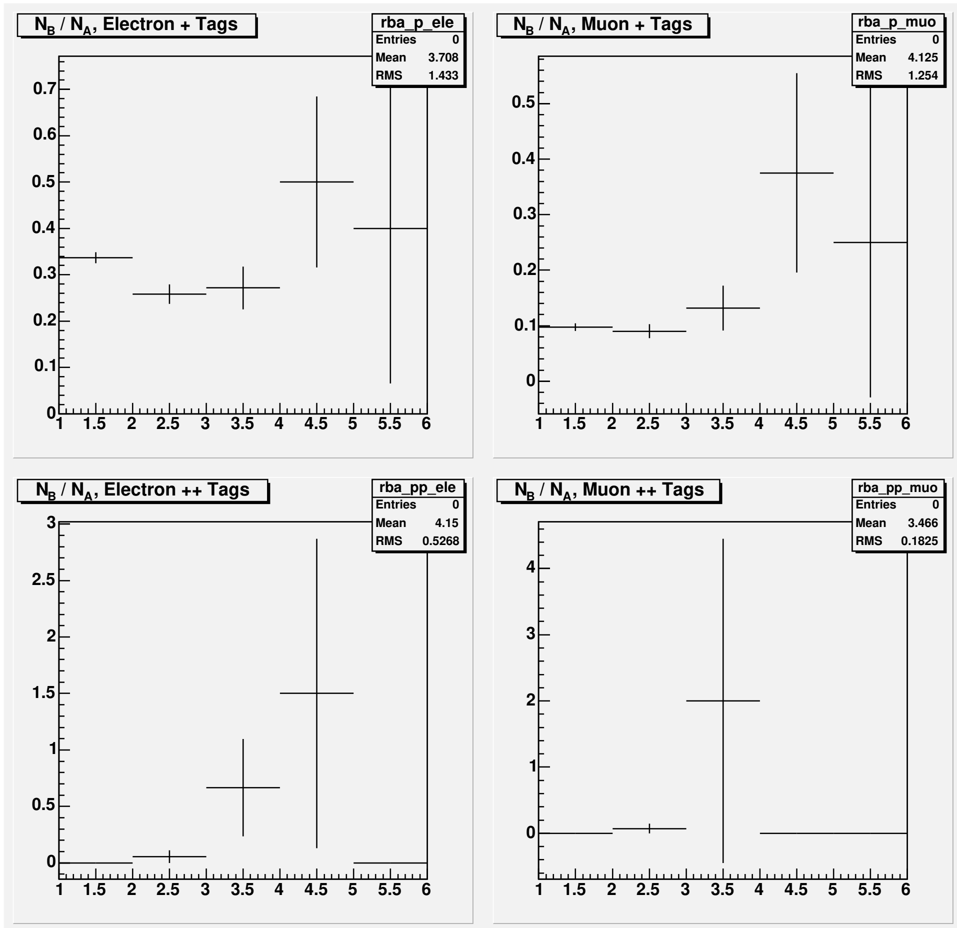

Figure 10: Ratio of events in regions B and A for electrons (left) and muons (right), for single (top) and double (bottom) tags.

within $\Delta R < 0.4$ of a B or C meson at the `HEPG` level.

The tagging rates for the different samples are shown in Table 7. Figures 12-16 show the contributions to the N_{jet} spectrum from the various contributions of the $W + HF + Np$ samples, for pretags, ≥ 1 tags, and ≥ 2 tags. The lower left shows the ≥ 1 and ≥ 2 event tag rates.

3.4 W+Light Flavor Mistags

The W+Light Flavor single tag mistag background is estimated by applying the negative tag matrix outlined in [4] to the pretag sample (N^{-}_{pred}). We correct for the number of tagged light flavor events already counted in the Non-W, W+HF, and Monte Carlo derived backgrounds, as well as for the $t\bar{t}$ expectation, and apply a factor to account for the fact that the light flavor L_{2D} distribution of `SecVtx` is not symmetric, outlined in [2]. This has been recently re-measured in `5.3.3_nt`, and has a value of $\sim 1.37 \pm 0.23$.

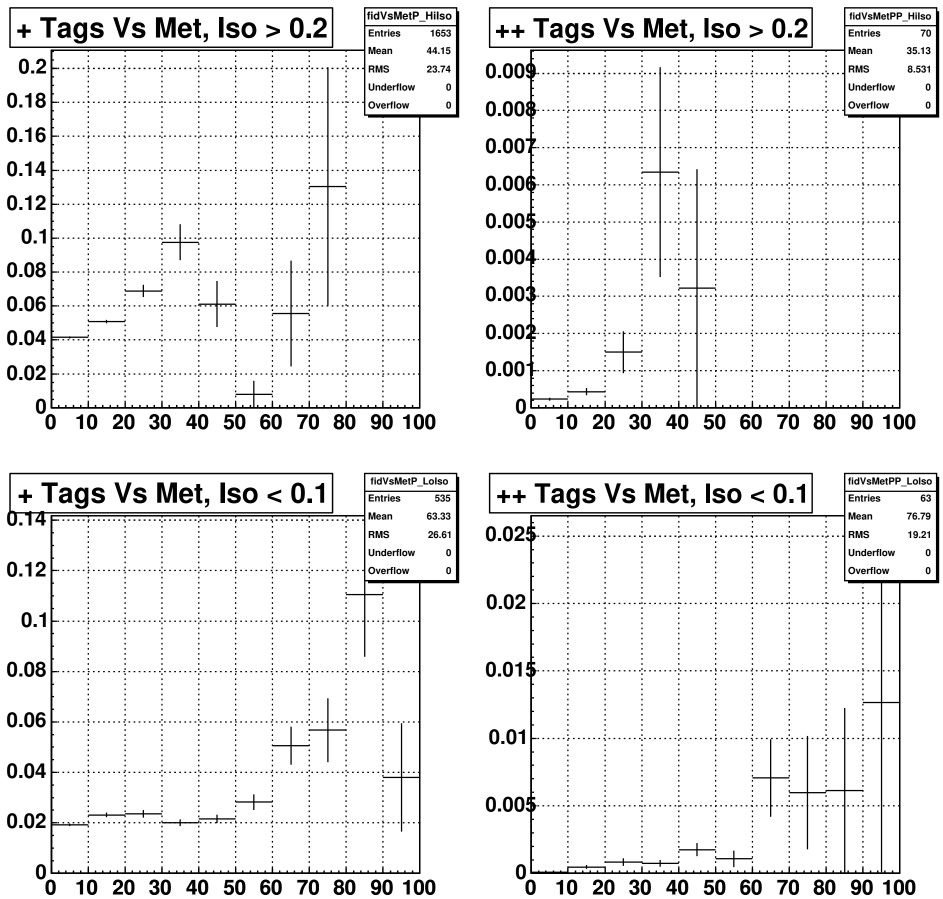

Figure 11: Event tag rates versus $\not\!\!E_T$ for single tags (left) and double tags (right), for $iso > 0.2$ (top) and $iso < 0.1$ (bottom). Although the tag rates versus $\not\!\!E_T$ are not constant for $iso > 0.2$ due to the presence of heavy flavor in the non-isolated lepton sample, the event tag rates versus $\not\!\!E_T$ are constant for the $iso < 0.1$ region.

It is taken to be $\sum E_T$ dependent, as described in Ref [2]. Figure 21 shows the light flavor asymmetry correction versus $\sum E_T$.

The double mistags are calculated by running the mistag matrix over away jets in the ≥ 1 tag sample ($N^{pred}_{+,-}$). It is designed to represent the fake + fake background arising from $W + LF$. The Monte-Carlo derived backgrounds, Non-W background, $W + HF$ backgrounds, and the $t\bar{t}$ signal all have real + fake contributions in their respective ≥ 2 tag rate.

The double mistag calculation has changed since the previous version. Instead of adding contributions from the observed negative tags, Non-W single tags, and $W + C$ single tags, we correct the ≥ 1 tag sample for $t\bar{t}$, the MC derived backgrounds, Non-W single tags, and $W + HF$ single tags. Mistags due to those processes are counted within

Non-W					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
Electrons					
F_{Non-W} (%)	10.08 $\pm$ 2.53	12.89 $\pm$ 3.27	12.43 $\pm$ 3.37		
N_+^B/N_+^A (%)	34.20 $\pm$ 1.23	26.08 $\pm$ 2.15	27.73 $\pm$ 4.50		
$N_+^{tagmethod}$	47.45 $\pm$ 16.27	22.31 $\pm$ 8.01	6.23 $\pm$ 2.78	2.07 $\pm$ 1.17	0.61 $\pm$ 0.54
R_+^B (%)	1.63 $\pm$ 0.33	3.50 $\pm$ 0.75	6.90 $\pm$ 1.80	10.68 $\pm$ 4.76	13.02 $\pm$ 15.34
$N_+^{pretagmethod}$	28.91 $\pm$ 9.32	12.82 $\pm$ 4.26	4.02 $\pm$ 1.52	1.53 $\pm$ 0.80	0.31 $\pm$ 0.37
R_{++}^B (%)	0.00 $\pm$ 0.00	0.03 $\pm$ 0.02	0.67 $\pm$ 0.39	3.28 $\pm$ 2.49	5.40 $\pm$ 5.81
$N_{++}^{pretagmethod}$	0.00 $\pm$ 0.00	0.10 $\pm$ 0.09	0.39 $\pm$ 0.25	0.47 $\pm$ 0.38	0.13 $\pm$ 0.14
Pretag	1778.22 $\pm$ 446.14	366.89 $\pm$ 93.13	58.31 $\pm$ 15.80	14.30 $\pm$ 3.87	2.36 $\pm$ 0.64
$\geq$ 1+ Tag	33.49 $\pm$ 8.04	14.91 $\pm$ 3.74	4.53 $\pm$ 1.33	1.70 $\pm$ 0.66	0.41 $\pm$ 0.31
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.10 $\pm$ 0.09	0.39 $\pm$ 0.25	0.47 $\pm$ 0.38	0.13 $\pm$ 0.14
Muons					
F_{Non-W} (%)	3.75 $\pm$ 0.94	4.44 $\pm$ 1.15	6.90 $\pm$ 2.01		
N_+^B/N_+^A (%)	9.76 $\pm$ 0.68	8.82 $\pm$ 1.29	14.17 $\pm$ 4.30		
$N_+^{tagmethod}$	8.28 $\pm$ 2.93	4.30 $\pm$ 1.69	3.21 $\pm$ 1.68	1.48 $\pm$ 0.86	0.19 $\pm$ 0.22
R_+^B (%)	1.91 $\pm$ 0.40	5.27 $\pm$ 1.30	8.92 $\pm$ 3.64	28.26 $\pm$ 19.00	42.85 $\pm$ 96.97
$N_+^{pretagmethod}$	9.29 $\pm$ 3.05	4.55 $\pm$ 1.63	1.85 $\pm$ 0.93	1.25 $\pm$ 0.92	0.50 $\pm$ 1.15
R_{++}^B (%)	0.00 $\pm$ 0.00	0.22 $\pm$ 0.14	2.43 $\pm$ 1.63	6.71 $\pm$ 5.33	174.42 $\pm$ 235.07
$N_{++}^{pretagmethod}$	0.00 $\pm$ 0.00	0.19 $\pm$ 0.13	0.50 $\pm$ 0.37	0.30 $\pm$ 0.25	2.04 $\pm$ 2.83
Pretag	487.24 $\pm$ 122.62	86.33 $\pm$ 22.28	20.69 $\pm$ 6.04	4.41 $\pm$ 1.29	1.17 $\pm$ 0.34
$\geq$ 1+ Tag	8.76 $\pm$ 2.09	4.43 $\pm$ 1.17	2.17 $\pm$ 0.82	1.37 $\pm$ 0.62	0.20 $\pm$ 0.22
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.19 $\pm$ 0.13	0.50 $\pm$ 0.37	0.30 $\pm$ 0.25	0.20 $\pm$ 2.83

Table 4: Results of QCD background calculation. Derivation can be seen in Table 29. The contribution from $t\bar{t}$ to Regions A,B,C has been removed to make the calculation. The theoretical prediction using 6.1 pb is used, and then iterated to 8.9 to construct this table.

W + HF Fractions				
Jet Multiplicity	1 jet	2 jets	3 jets	$\geq$ 4 jets
$W + b\bar{b}, 1B$	1.0 $\pm$ 0.3	1.4 $\pm$ 0.4	2.0 $\pm$ 0.5	2.2 $\pm$ 0.6
$W + b\bar{b}, 2B$	-	1.4 $\pm$ 0.4	2.0 $\pm$ 0.5	2.6 $\pm$ 0.7
$W + c\bar{c}, 1C$	1.6 $\pm$ 0.4	2.4 $\pm$ 0.6	3.4 $\pm$ 0.9	3.6 $\pm$ 1.0
$W + c\bar{c}, 2C$	-	1.8 $\pm$ 0.5	2.7 $\pm$ 0.7	3.7 $\pm$ 1.0
$W + c, 1C$	4.3 $\pm$ 0.9	6.0 $\pm$ 1.3	6.3 $\pm$ 1.3	6.1 $\pm$ 1.3

Table 5: Heavy flavor fractions taken from Ref [8]. These are measured using template fits derived from ALPGEN $W + Q\overline{Q} + Np$ samples applied to the lepton+jets data.

each process seperately.

Corrections to Pretag data					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
Data	30628.00 ± 0.00	4791.00 ± 0.00	769.00 ± 0.00	179.00 ± 0.00	36.00 ± 0.00
Non-W	2265.47 ± 567.81	453.22 ± 114.65	79.00 ± 21.10	18.71 ± 5.00	3.53 ± 0.94
$t\bar{t}$ (8.9 pb)	9.20 ± 0.82	49.55 ± 4.40	96.66 ± 8.58	86.37 ± 7.67	26.63 ± 2.38
EW	157.32 ± 14.33	151.44 ± 13.67	31.54 ± 2.92	5.26 ± 0.47	0.82 ± 0.07
Single Top	18.71 ± 4.51	23.37 ± 5.04	4.54 ± 0.97	0.72 ± 0.16	0.09 ± 0.02
Data, Corrected	28177.30 ± 584.08	4113.43 ± 134.29	557.27 ± 32.49	67.94 ± 13.03	4.92 ± 3.37

Table 6: Corrections to pretag data. The corrected pretag data is used in the W+HF estimate. Here the $t\bar{t}$ cross section is taken at the measured value of 8.9 pb. The level of $t\bar{t}$ is iterated to obtain the final result of the cross section.

W+Heavy Flavor Tagging Efficiencies					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
WBB, 1B, 1 Tag	35.04 ± 2.35	37.93 ± 2.38	39.38 ± 4.08	42.76 ± 3.46	
WBB, 2B, 1 Tag	0.00 ± 0.00	57.86 ± 3.52	59.01 ± 4.28	60.50 ± 3.92	
WBB, 2B, 2 Tag	0.00 ± 0.00	14.10 ± 1.93	16.06 ± 2.42	17.45 ± 2.83	
WCC, 1C, 1 Tag	7.44 ± 1.04	8.78 ± 1.37	12.57 ± 2.33	10.53 ± 4.26	
WCC, 2C, 1 Tag	0.00 ± 0.00	15.48 ± 2.40	16.59 ± 3.48	23.32 ± 5.14	
WCC, 2C, 2 Tag	0.00 ± 0.00	0.36 ± 0.19	0.18 ± 0.12	0.00 ± 0.00	
WC, 1C, 1 Tag	8.19 ± 1.10	8.84 ± 1.23	9.53 ± 1.56	13.16 ± 2.56	

Table 7: Efficiencies of W+HF samples, derived from exclusive matching of ALPGEN + HERWIG Monte Carlo samples. The scale factor has been applied.

ALPGEN + HERWIG Generated Cross Sections	
Sample	Cross Section (pb)
$W \rightarrow l\nu + BB + 0p$	2.914 ± 0.003
$W \rightarrow l\nu + BB + 1p$	1.557 ± 0.002
$W \rightarrow l\nu + BB + 2p$	0.744 ± 0.001
$W \rightarrow l\nu + CC + 0p$	4.755 ± 0.006
$W \rightarrow l\nu + CC + 1p$	2.737 ± 0.005
$W \rightarrow l\nu + CC + 2p$	1.392 ± 0.002
$W \rightarrow l\nu + C + 0p$	21.67 ± 0.02
$W \rightarrow l\nu + C + 1p$	12.96 ± 0.02
$W \rightarrow l\nu + C + 2p$	5.397 ± 0.006
$W \rightarrow l\nu + C + 3p$	1.959 ± 0.002

Table 8: Generated cross sections used to combine the various $W + HF + Np$ samples. Taken from Ref [9].

The equations used to calculate the mistags are

$$N_{\geq 1\ mistag} = N_{-}^{pred} \times \alpha_{LF}\beta \times \left(\frac{N_{pre} - N_{pre}^{t\bar{t}} - N_{pre}^{NonW} - N_{pre}^{W+HF} - N_{pre}^{MC}}{N_{pre}} \right) \quad (23)$$

$$N_{\geq 2\ mistag} = N_{+,-}^{pred} \times \alpha_{LF}\beta \times \left(\frac{N_{+} - N_{+}^{t\bar{t}} - N_{+}^{NonW} - N_{+}^{W+HF} - N_{+}^{MC}}{N_{+}} \right) \quad (24)$$

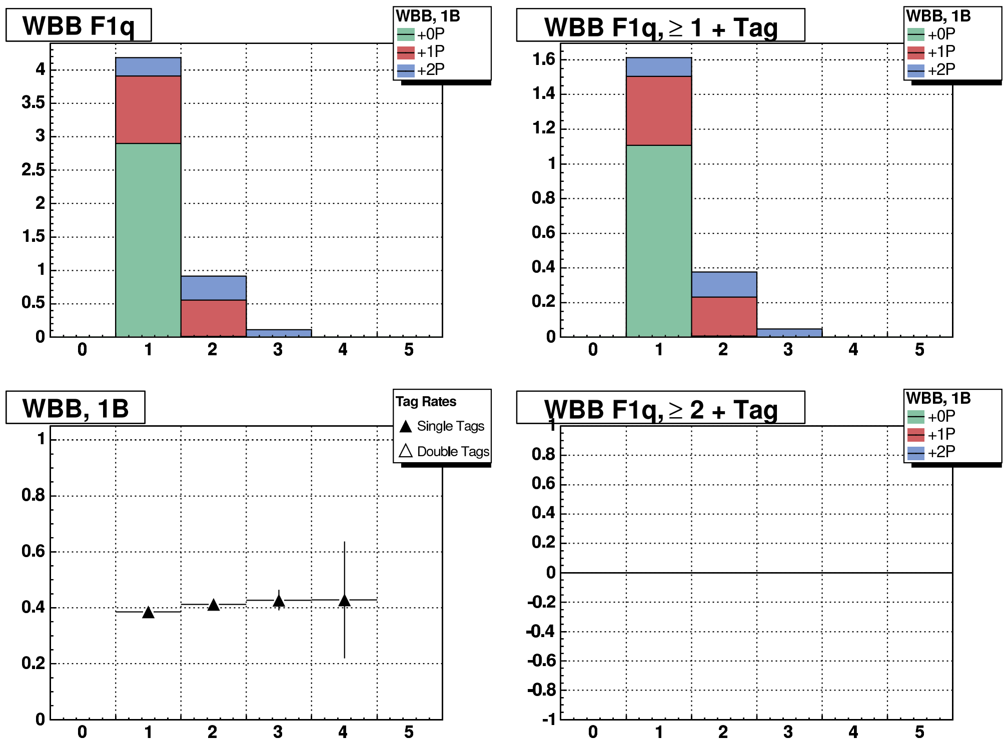

Figure 12: Contributions to the N_{jet} spectrum from the various $W+BB+Np$ samples, when there is 1 matched b-jet in the event. The upper left shows the pretags, the upper right shows the ≥ 1 tags, and the lower right shows the ≥ 2 tags. The lower left shows the event tag rates after combination of the samples. The cross sections used to put the samples together are given in Table 8.

where N_{-}^{pred} is the predicted number of negatives tags using the matrix outlined in [4], $N_{+,-}^{pred}$ is the predicted number of negative tags in positively tagged events, $\alpha_{LF}\beta$ is the light flavor asymmetry, N_{pre}^{X} is the number of pretags expected from background type X, N_{+}^{X} is the number of tags expected from background type X, N_{pre} is the observed pretags, and N_{+} is the observed tagged events. We add light-flavor tags on the various backgrounds to their respective contributions. Here, "mistags" are really $W+$ light flavor.

Figures 17-20 show the observed and predicted negative tags in the data sample versus number of jets, jet E_T, and number of good tracks in the jet. We see good predictions across all variables using this matrix.

4 Systematics

The systematics on the various backgrounds come from several sources. The following errors are derived elsewhere and we use the determined systematics:

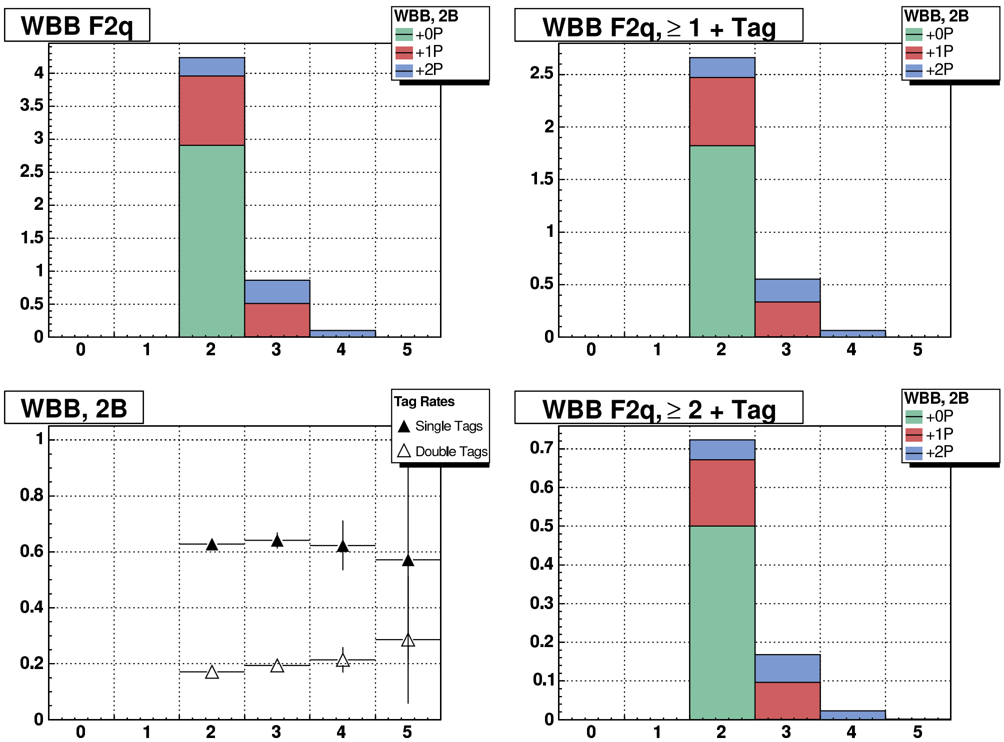

Figure 13: Contributions to the N_{jet} spectrum from the various $W+BB+Np$ samples, when there are 2 matched b-jets in the event. The upper left shows the pretags, the upper right shows the ≥ 1 tags, and the lower right shows the ≥ 2 tags. The lower left shows the event tag rates after combination of the samples. The cross sections used to put the samples together are given in Table 8.

Mistags					
	1 jet	2 jets	3 jets	4 jets	≥ 5 jets
Mistag Matrix Prediction, Including $\alpha_{LF} \times \beta$					
(+) Pred	447.03 $\pm$ 5.18	169.45 $\pm$ 1.04	49.27 $\pm$ 0.65	18.45 $\pm$ 0.11	4.75 $\pm$ 0.08
(-) Pred	109.96 $\pm$ 4.98	52.51 $\pm$ 0.96	18.27 $\pm$ 0.63	7.35 $\pm$ 0.08	1.99 $\pm$ 0.05
(+,-) Pred	0.00 $\pm$ 0.00	1.62 $\pm$ 0.15	1.94 $\pm$ 0.05	2.19 $\pm$ 0.08	0.77 $\pm$ 0.05
(-,-) Pred	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
Number of Mistags (corrected for $\sigma_{t\bar{t}} = 8.9\ pb$)					
≥ 1 Tag	94.05 $\pm$ 19.28	39.12 $\pm$ 7.86	11.05 $\pm$ 2.24	2.27 $\pm$ 0.45	0.22 $\pm$ 0.05
≥ 2 Tag	0.00 $\pm$ 0.00	0.54 $\pm$ 0.12	0.22 $\pm$ 0.05	0.06 $\pm$ 0.03	0.03 $\pm$ 0.05

- **Heavy flavor fractions**: This affects the W+HF backgrounds. The systematics on the heavy flavor fractions are taken to be the same as calculated in Ref [8]. There is an overall relative error of 26% on the heavy flavor fractions.

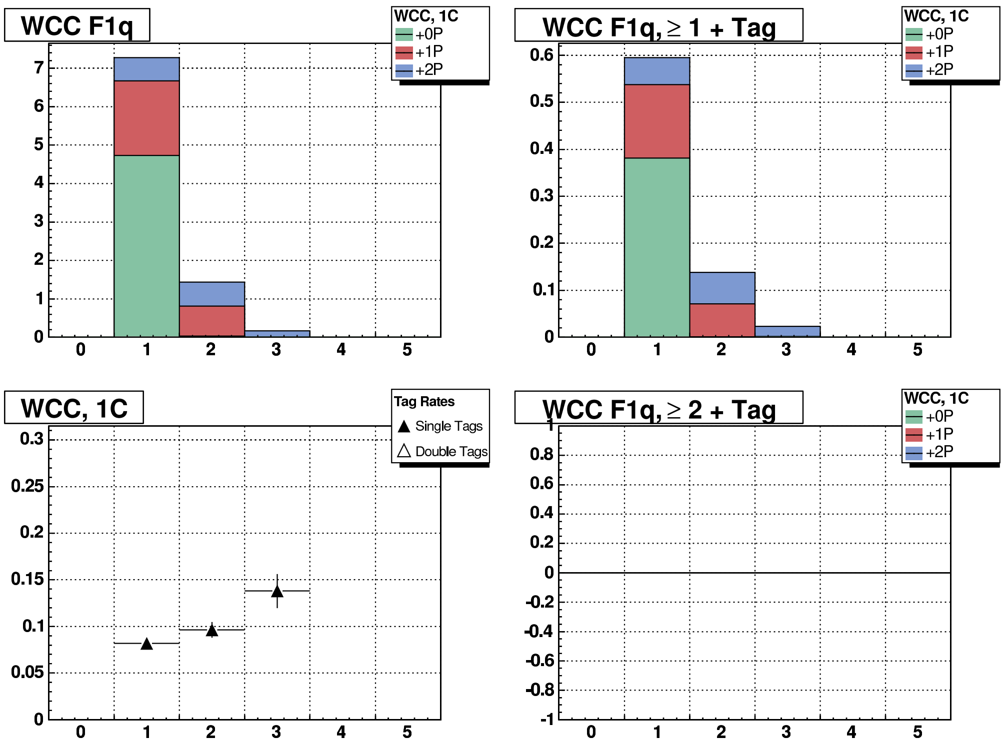

Figure 14: Contributions to the N_{jet} spectrum from the various $W + CC + Np$ samples, when there is 1 matched c-jet in the event. The upper left shows the pretags, the upper right shows the ≥ 1 tags, and the lower right shows the ≥ 2 tags. The lower left shows the event tag rates after combination of the samples. The cross sections used to put the samples together are given in Table 8.

- **B-Tagging Scale Factor**: This affects the W+HF, electroweak, and single top backgrounds, as well as the signal prediction. We take the systematic from Ref [10]. There is an overall relative error of 6.6% on the scale factor.

- **B-Tagging Tag Matrices**: This affects the mistag background. We take the systematic from Ref [4]. There is an overall relative error of 8% from the matrix itself and 22% due to the light flavor asymmetry, for a total of 23% relative error on the mistag prediction.

- **Lepton ID Scale Factors**: This affects the electroweak and single top backgrounds, and the signal prediction. We take the systematic from Ref [1]. There is an overall relative error of 8% on the lepton ID scale factors.

The following errors are specific to this analysis and are estimated here:

- **Jet energy scale**: This affects the $t\bar{t}$ efficiency, the electroweak and single top backgrounds, and the W+HF background. We use the procedure outlined in [11]

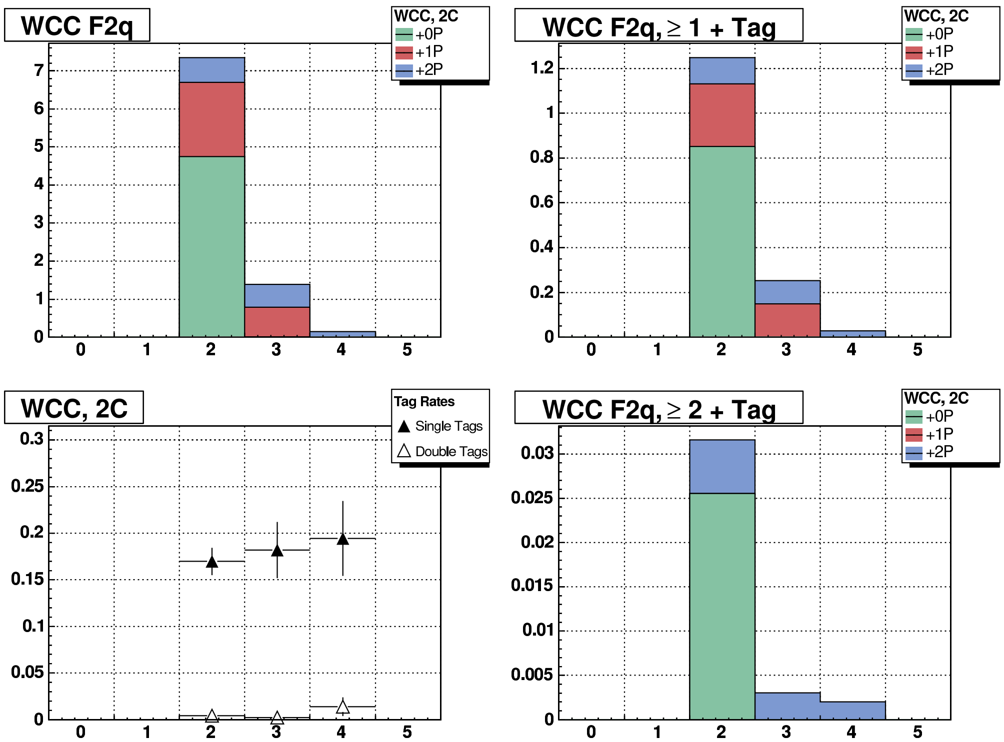

Figure 15: Contributions to the N_{jet} spectrum from the various $W+CC+Np$ samples, when there are 2 matched c-jets in the event. The upper left shows the pretags, the upper right shows the ≥ 1 tags, and the lower right shows the ≥ 2 tags. The lower left shows the event tag rates after combination of the samples. The cross sections used to put the samples together are given in Table 8.

to estimate the effect of the JES on these backgrounds.

- **Non-W Background Specific**: This background has an additional error due to the definition of the sideband regions. We vary the definition of the sideband regions, and take the average of the deviations as an additional systematic.

4.1 Non-W Background Systematics

The $\not\!\!E_T$ versus isolation method of determining the Non-W background carries a systematic due to the definition of the background regions. To determine the effect of this on the Non-W background estimate, we add the sideband regions into the main regions and re-calculate F_{Non-W}. The results of this variation can be found in Table 9.

We see that the results of varying the isolation region up and down results in an average deviation of 23.5%, and that varying the $\not\!\!E_T$ region up and down results in an average deviation of 21.3%. We take 25% as our systematic for this effect. We take this to be the same for electrons and muons.

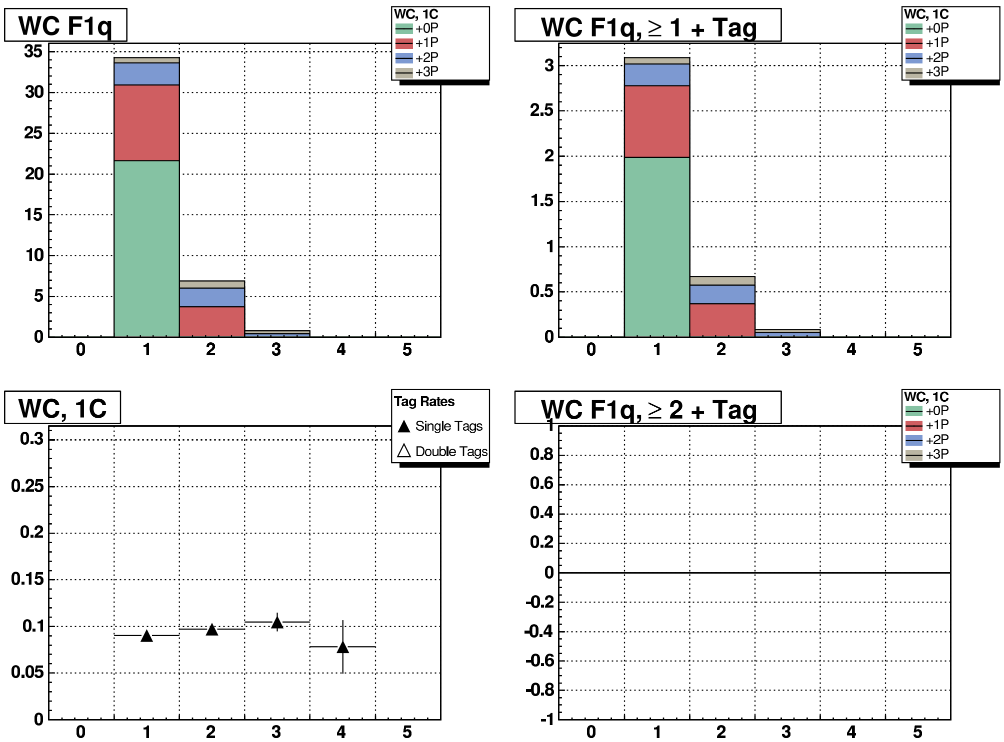

Figure 16: Contributions to the N_{jet} spectrum from the various $W + C + Np$ samples, when there is 1 matched c-jet in the event. The upper left shows the pretags, the upper right shows the ≥ 1 tags, and the lower right shows the ≥ 2 tags. The lower left shows the event tag rates after combination of the samples. The cross sections used to put the samples together are given in Table 8.

We also assign an additional 50% systematic on the QCD double-tag estimate because of the use of the Feldman-Cousins prescription described in Section 3.2. Thus, the overall systematic on the QCD double tags is 60%.

Variation	ΔF_{Non-W}, Ele (%)	ΔF_{Non-W}, Muo (%)	Average
Isolation Down	52%	16%	
Isolation Up	3%	23%	23.5%
$\not\!\!E_T$ Down	4%	19%	
$\not\!\!E_T$ Up	32%	30%	21.3%

Table 9: Effect of varying the $\not\!\!E_T$ versus isolation sidebands on the Non-W background. We take 25% as our overall systematic.

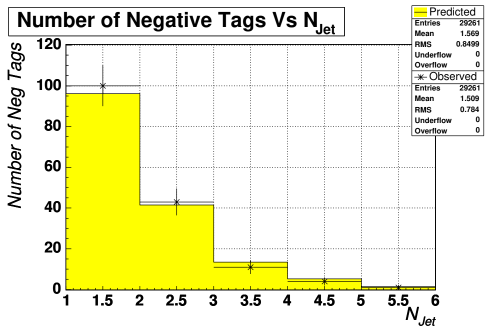

Figure 17: Observed (points) and predicted (yellow histogram) negative tags in the signal region versus number of jets.

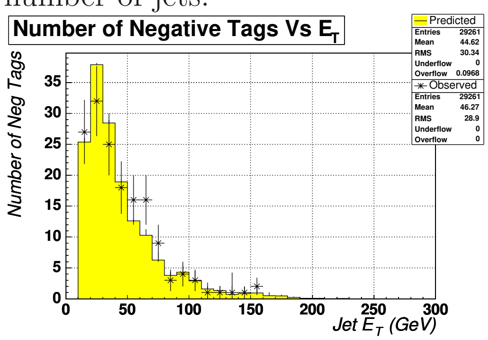

Figure 18: Observed (points) and predicted (yellow histogram) negative tags in the signal region versus jet E_T.

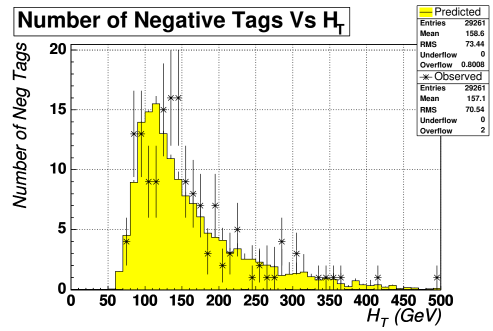

Figure 19: Observed (points) and predicted (yellow histogram) negative tags in the signal region versus the scalar sum of transverse energies in the event (H_T).

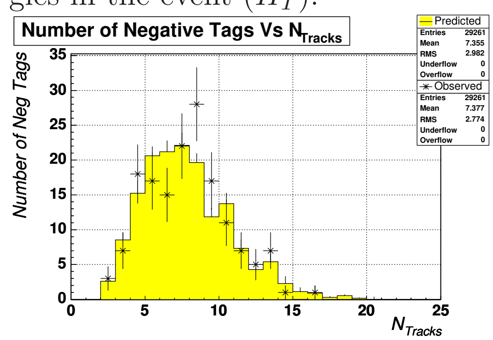

Figure 20: Observed (points) and predicted (yellow histogram) negative tags in the signal region versus the number of good tracks in the jet.

4.2 Jet Energy Scale

We use the procedure outlined in [11] to estimate the systematic due to the jet energy scale. We estimate the background levels varying the jet energy scale by $\pm 1\sigma$, and take the average deviation as a systematic on the result. The results are summarized below for each background. We have updated the jet energy scale corrections to use `jetCorr04b`, which results in a decrease in the systematic due to a bug in the the combination of errors.

4.2.1 $t\bar{t}$ Acceptance

We have calculated the jet energy scale systematic on the $t\bar{t}$ acceptance at different stages of the analysis. We use the total systematic function provided by the jet energy group. The effect of the jet energy scale on the $t\bar{t}$ expectation is 2.9%.

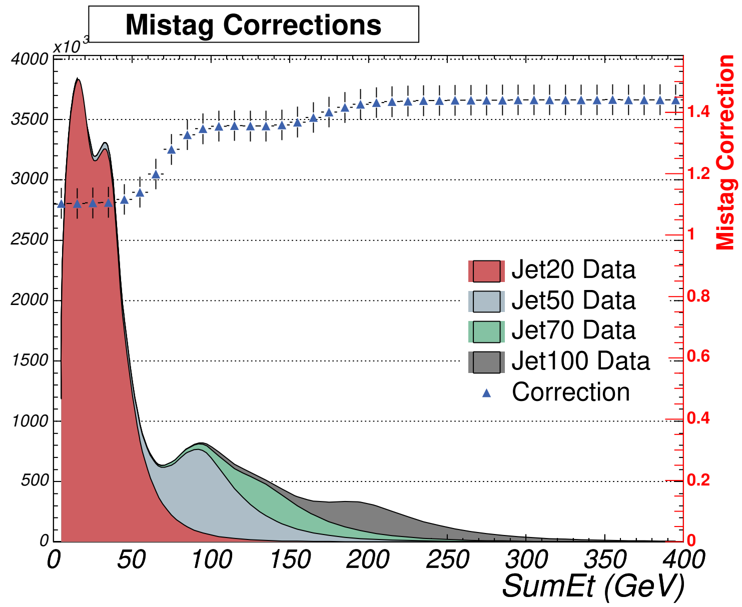

Figure 21: Light flavor asymmetry correction versus $\sum E_T$, taken from Ref [2].

Species	JES systematic
$t\bar{t}$	2.9%
EW + Single Top	2.9%
W+HF	5.0%

Table 10: Effect of varying the jet energy scale on $t\bar{t}$, electroweak and single top, and W+HF backgrounds. We apply the same systematic to the electroweak and single top as the $t\bar{t}$ acceptance. The effect of the jet energy scale on the W+HF background is taken from Ref [8].

4.2.2 Backgrounds

- **W+HF**: The jet energy scale systematic is already included in the overall systematic for the heavy flavor fractions. Ref [8] estimates 5% systematic on $W + b\bar{b}$ and $W + c\bar{c}$, and a 10% systematic on $W + c$.

- **Electroweak and Single Top**: The electroweak and single top backgrounds were assumed to have the same jet energy scale systematic as the $t\bar{t}$ signal expectation. We take the same 2.9% systematic on these backgrounds due to the jet energy scale.

4.3 Overall Background Uncertainties

Table 11 describes the errors on the various backgrounds and the $t\bar{t}$ signal, and how they are estimated.

Background Level Uncertainties			
	≥ 1 Tag	≥ 2 Tags	Estimated From
EW + Single Top	11%	16%	Lepton ID + modeling (6.7%), b-tag SF (6.6%), JES(3.9%), lum (6.0%)
W+HF	26%	28%	Matching (15%), ISR/FSR (10%), m_Q (6%) JES (5%), PDF (5%), Q^2 scale (4%), b-tag SF (6.6%)
Mistags	22%	22%	Mistag matrix (8%), light-flavor asymmetry (22%)
Non-W Tag Method	25%	n/a	Vary sidebands (25%)
Non-W Pretag Method	33%	60%	F_{Non-W} (25%), R_B (20%) small stats (double tags:50%)

Table 11: Background level uncertainties summary.

5 Results

The results of the Method 2 background calculation are shown in Table 12, along with the prediction from $t\bar{t}$. The $t\bar{t}$ contribution is shown at the measured cross sections of 8.9 pb for the ≥ 1 tags and 8.2 pb for the ≥ 2 tags. See [12] for a derivation of these results.

Summary					
Jet Multiplicity	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
Pretags					
Data	30628	4791	769	179	36
$t\bar{t}$ (8.9 pb)	9.20 $\pm$ 0.82	49.55 $\pm$ 4.40	96.66 $\pm$ 8.58	86.37 $\pm$ 7.67	26.63 $\pm$ 2.38
$\geq$ 1 Tags					
EW	4.47 $\pm$ 0.69	8.47 $\pm$ 1.25	2.10 $\pm$ 0.34	0.39 $\pm$ 0.08	0.10 $\pm$ 0.03
Single Top	6.86 $\pm$ 1.71	11.55 $\pm$ 2.42	2.50 $\pm$ 0.53	0.41 $\pm$ 0.09	0.06 $\pm$ 0.01
Non-W	42.25 $\pm$ 10.05	19.34 $\pm$ 4.77	6.70 $\pm$ 1.92	3.07 $\pm$ 1.06	0.61 $\pm$ 0.39
W + LF Mistags	94.05 $\pm$ 19.28	39.12 $\pm$ 7.86	11.05 $\pm$ 2.24	2.27 $\pm$ 0.45	0.22 $\pm$ 0.05
$W + c$	99.23 $\pm$ 26.61	21.06 $\pm$ 6.03	3.22 $\pm$ 0.98	0.51 $\pm$ 0.23	0.02 $\pm$ 0.02
$W + c\bar{c}$	33.52 $\pm$ 10.17	20.13 $\pm$ 6.60	4.88 $\pm$ 1.70	0.81 $\pm$ 0.40	0.02 $\pm$ 0.02
$W + b\bar{b}$	98.74 $\pm$ 32.37	55.13 $\pm$ 17.85	10.94 $\pm$ 3.44	1.70 $\pm$ 0.79	0.12 $\pm$ 0.12
$t\bar{t}$ (8.9 pb)	3.08 $\pm$ 0.35	25.19 $\pm$ 2.66	55.28 $\pm$ 5.74	53.78 $\pm$ 5.50	16.80 $\pm$ 1.73
Bkg	379.12 $\pm$ 72.53	174.80 $\pm$ 32.04	41.39 $\pm$ 6.84	9.16 $\pm$ 1.83	1.15 $\pm$ 0.43
Bkg + $t\bar{t}$ (8.9 pb)	382.20 $\pm$ 72.53	199.99 $\pm$ 32.15	96.67 $\pm$ 8.93	62.94 $\pm$ 5.80	17.95 $\pm$ 1.78
Data	432	242	95	63	19
$\geq$ 2 Tags					
EW	-	0.42 $\pm$ 0.09	0.14 $\pm$ 0.04	0.02 $\pm$ 0.01	0.01 $\pm$ 0.01
Single Top	-	1.52 $\pm$ 0.29	0.53 $\pm$ 0.13	0.09 $\pm$ 0.03	0.02 $\pm$ 0.01
Non-W	-	0.29 $\pm$ 0.17	0.90 $\pm$ 0.50	0.78 $\pm$ 0.49	0.34 $\pm$ 2.64
W + LF Mistags	-	0.55 $\pm$ 0.12	0.30 $\pm$ 0.06	0.20 $\pm$ 0.04	0.08 $\pm$ 0.05
$W + HF$	-	8.39 $\pm$ 2.93	1.81 $\pm$ 0.61	0.34 $\pm$ 0.16	0.03 $\pm$ 0.02
$t\bar{t}$ (8.2 pb)	-	4.28 $\pm$ 0.70	11.68 $\pm$ 1.91	14.06 $\pm$ 2.27	4.63 $\pm$ 0.74
Bkg	-	11.17 $\pm$ 2.96	3.71 $\pm$ 0.82	1.42 $\pm$ 0.52	0.48 $\pm$ 2.64
Bkg + $t\bar{t}$ (8.2 pb)	-	15.46 $\pm$ 3.04	15.39 $\pm$ 2.08	15.48 $\pm$ 2.33	5.11 $\pm$ 2.74
Data	-	15	17	16	3

Table 12: Method 2 background calculation summary for 318.5 pb^{-1}. Here the $t\bar{t}$ prediction is show for the measured cross sections of 8.9 pb and 8.2 pb for ≥ 1 and ≥ 2 tags, respectively.

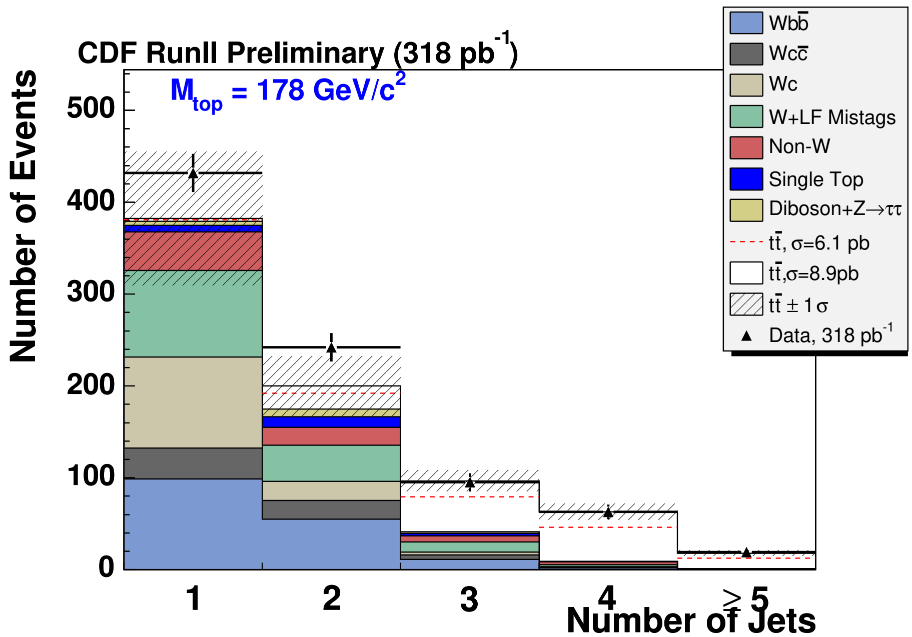

Figure 22: Number of jets for ≥ 1 tags. $t\bar{t}$ cross section is shown at the measured value of 8.9 pb in the white solid histogram.

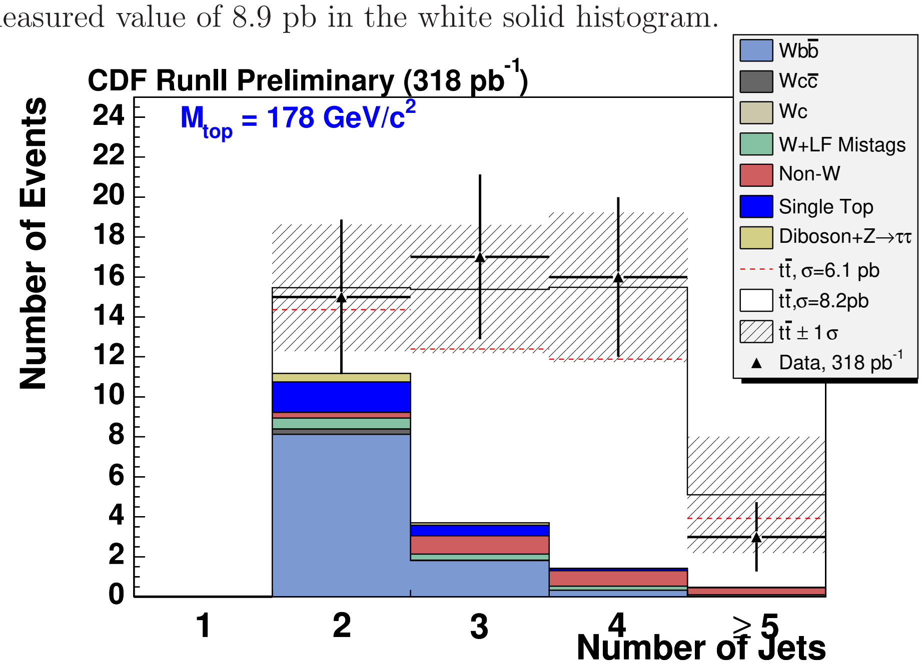

Figure 23: Number of jets for ≥ 2 tags. $t\bar{t}$ cross section is shown at the measured value of 8.2 pb in the white solid histogram.

Summary	
Jet Multiplicity	3.5 jets
Pretags	
Data	280
$t\bar{t}$ (6.1 pb)	33.29 ± 2.98
≥ 1 Tags	
EW	0.67 ± 0.11
Single Top	0.59 ± 0.13
Non-W	2.24 ± 0.78
Mistags	4.60 ± 0.91
$W + c$	1.22 ± 0.36
$W + c\bar{c}$	1.84 ± 0.63
$W + b\bar{b}$	4.12 ± 1.27
$t\bar{t}$ (6.1 pb)	18.97 ± 1.98
Bkg	15.28 ± 2.56
Bkg + $t\bar{t}$	34.25 ± 3.24
Data	39
≥ 2 Tags	
EW	0.04 ± 0.01
Single Top	0.12 ± 0.03
Non-W	0.52 ± 0.32
Mistags	0.17 ± 0.03
$W + HF$	0.68 ± 0.23
$t\bar{t}$ (6.1 pb)	4.30 ± 0.70
Bkg	1.54 ± 0.40
Bkg + $t\bar{t}$	5.84 ± 0.81
Data	6

Table 13: Method 2 background calculation summary for 318.5 pb^{-1} in the 3.5 jet bin. Here, the $t\bar{t}$ subtraction from the backgrounds is taken for $\sigma = 6.1$ pb.

Summary	
Jet Multiplicity	3.5 jets
Pretags	
Data	280
$t\bar{t}$ (8.9 pb)	48.57 ± 4.35
≥ 1 Tags	
EW	0.67 ± 0.11
Single Top	0.59 ± 0.13
Non-W	1.99 ± 0.72
Mistags	4.30 ± 0.85
$W + c$	1.13 ± 0.35
$W + c\bar{c}$	1.72 ± 0.60
$W + b\bar{b}$	3.85 ± 1.22
$t\bar{t}$ (8.9 pb)	27.68 ± 2.89
Bkg	14.25 ± 2.45
Bkg + $t\bar{t}$	41.93 ± 3.79
Data	39
≥ 2 Tags	
EW	0.04 ± 0.01
Single Top	0.12 ± 0.03
Non-W	0.39 ± 0.30
Mistags	0.02 ± 0.01
$W + HF$	0.64 ± 0.22
$t\bar{t}$ (8.9 pb)	6.28 ± 1.02
Bkg	1.22 ± 0.38
Bkg + $t\bar{t}$	7.50 ± 1.09
Data	6

Table 14: Method 2 background calculation summary for 318.5 pb^{-1} in the 3.5 jet bin. Here, the $t\bar{t}$ subtraction from the backgrounds is taken for $\sigma = 8.9$ pb.

Corrections to Pretag data					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
Data	30628.00 ± 0.00	4791.00 ± 0.00	769.00 ± 0.00	179.00 ± 0.00	36.00 ± 0.00
Non-W	2265.47 ± 567.81	453.22 ± 114.65	79.00 ± 21.10	18.71 ± 5.00	3.53 ± 0.94
$t\bar{t}$ (8.9 pb)	9.20 ± 0.82	49.55 ± 4.40	96.66 ± 8.58	86.37 ± 7.67	26.63 ± 2.38
EW	157.32 ± 14.33	151.44 ± 13.67	31.54 ± 2.92	5.26 ± 0.47	0.82 ± 0.07
Single Top	18.71 ± 4.51	23.37 ± 5.04	4.54 ± 0.97	0.72 ± 0.16	0.09 ± 0.02
Data, Corrected	28177.30 ± 584.08	4113.43 ± 134.29	557.27 ± 32.49	67.94 ± 13.03	4.92 ± 3.37

Table 15: Corrections to pretag data for the W+HF background estimate. After an initial measurement, the $t\bar{t}$ cross section is input back into this calculation, and the process is iterated until the result is stable to 1%.

$t\bar{t}$ (8.9 pb)					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	44.43 ± 0.79	44.80 ± 0.26	44.80 ± 0.17	44.77 ± 0.17	43.83 ± 0.31
$\epsilon_{c-jet}(\%)$	10.97 ± 2.51	10.40 ± 0.57	10.07 ± 0.25	9.36 ± 0.21	9.80 ± 0.35
$\epsilon_{b-jet} * SF(\%)$	40.39 ± 2.76	40.72 ± 2.70	40.72 ± 2.69	40.70 ± 2.69	39.84 ± 2.64
$\epsilon_{c-jet} * SF(\%)$	9.97 ± 2.63	9.45 ± 1.35	9.15 ± 1.23	8.51 ± 1.14	8.91 ± 1.22
$\Phi_e^{\geq 1}(\%)$	91.04 ± 6.13	92.65 ± 5.23	93.23 ± 5.03	93.76 ± 4.77	94.13 ± 4.78
$\Phi_e^{\geq 2}(\%)$	0.00 ± 0.00	83.20 ± 11.40	84.35 ± 11.56	85.13 ± 11.44	86.36 ± 11.45
$\epsilon_{\geq 1}(\%)$	36.81 ± 0.70	54.88 ± 0.31	61.34 ± 0.22	66.41 ± 0.22	67.00 ± 0.40
$\epsilon_{\geq 2}$ (%)	0.00 ± 0.00	11.28 ± 0.20	15.55 ± 0.16	20.75 ± 0.19	21.83 ± 0.35
$\epsilon_{\geq 1} * \Phi_e$ (%)	33.51 ± 2.34	50.85 ± 2.88	57.19 ± 3.09	62.27 ± 3.17	63.07 ± 3.22
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 ± 0.00	9.38 ± 1.30	13.12 ± 1.80	17.66 ± 2.38	18.85 ± 2.52
$\epsilon_{bjet}(\%)$				44.65 ± 0.11	
$\epsilon_{cjet}(\%)$				9.68 ± 0.15	
$\epsilon_{bjet} * SF(\%)$				40.59 ± 2.68	
$\epsilon_{cjet} * SF(\%)$				8.80 ± 1.17	
$\epsilon_{\geq 1}(\%)$				64.15 ± 0.15	
$\epsilon_{\geq 2}(\%)$				18.49 ± 0.12	
$\Phi_E^1(\%)$				93.62 ± 4.87	
$\Phi_E^2(\%)$				85.10 ± 11.48	
$\epsilon_{\geq 1}(\%) * \Phi_E^1$				60.06 ± 3.13	
$\epsilon_{\geq 2}(\%) * \Phi_E^2$				15.73 ± 2.13	
CEM					
ϵ_{Pretag}	0.21 ± 0.00	1.10 ± 0.01	2.14 ± 0.01	1.94 ± 0.01	0.60 ± 0.01
$\epsilon_{Pretag} * SF$	0.19 ± 0.01	1.00 ± 0.07	1.95 ± 0.13	1.77 ± 0.12	0.55 ± 0.04
ϵ_{pretag}				4.68 ± 0.02	
$\epsilon_{pretag} * SF$				4.27 ± 0.29	
Pretag	5.43 ± 0.48	28.44 ± 2.55	55.32 ± 4.95	50.15 ± 4.49	15.51 ± 1.41
$\geq$ 1+ Tag	1.82 ± 0.21	14.46 ± 1.54	31.64 ± 3.31	31.23 ± 3.22	9.78 ± 1.02
$\geq$ 2+ Tag	0.00 ± 0.00	2.67 ± 0.44	7.26 ± 1.19	8.86 ± 1.43	2.92 ± 0.47
CMUP					
ϵ_{Pretag}	0.13 ± 0.00	0.71 ± 0.01	1.39 ± 0.01	1.22 ± 0.01	0.37 ± 0.01
$\epsilon_{Pretag} * SF$	0.10 ± 0.01	0.54 ± 0.04	1.05 ± 0.07	0.92 ± 0.06	0.28 ± 0.02
ϵ_{pretag}				2.98 ± 0.02	
$\epsilon_{pretag} * SF$				2.25 ± 0.15	
Pretag	2.78 ± 0.25	15.20 ± 1.38	29.75 ± 2.68	26.11 ± 2.36	7.92 ± 0.74
$\geq$ 1+ Tag	0.93 ± 0.11	7.73 ± 0.83	17.01 ± 1.79	16.26 ± 1.69	4.99 ± 0.53
$\geq$ 2+ Tag	0.00 ± 0.00	1.43 ± 0.24	3.90 ± 0.64	4.61 ± 0.75	1.49 ± 0.24
CMX					
ϵ_{Pretag}	0.04 ± 0.00	0.24 ± 0.00	0.47 ± 0.01	0.41 ± 0.01	0.13 ± 0.00
$\epsilon_{Pretag} * SF$	0.04 ± 0.00	0.22 ± 0.01	0.43 ± 0.03	0.37 ± 0.03	0.12 ± 0.01
ϵ_{pretag}				1.00 ± 0.01	
$\epsilon_{pretag} * SF$				0.91 ± 0.06	
Pretag	0.99 ± 0.09	5.91 ± 0.53	11.58 ± 1.07	10.10 ± 0.94	3.20 ± 0.29
$\geq$ 1+ Tag	0.33 ± 0.04	3.01 ± 0.32	6.62 ± 0.71	6.29 ± 0.67	2.02 ± 0.21
$\geq$ 2+ Tag	0.00 ± 0.00	0.56 ± 0.09	1.52 ± 0.25	1.78 ± 0.29	0.60 ± 0.10
Total					
Pretag	9.20 ± 0.82	49.55 ± 4.40	96.66 ± 8.58	86.37 ± 7.67	26.63 ± 2.38
$\geq$ 1 Tag	3.08 ± 0.35	25.19 ± 2.66	55.28 ± 5.74	53.78 ± 5.50	16.80 ± 1.73
$\geq$ 2 Tag	0.00 ± 0.00	4.65 ± 0.76	12.68 ± 2.07	15.26 ± 2.46	5.02 ± 0.81

Table 16: Summary table for $t\bar{t}$ at the measured cross section of 8.6 pb. ϵ_{q-jet} is the MC per-jet efficiency to tag a jet with flavor q, $\epsilon_{q-jet}SF$ is the efficiency times b-tag scale factor (0.909 ± 0.060), Φ_E is the "effective event scale factor", $\epsilon_{\geq 1}$ is the ≥ 1 event efficiency in the data, and similarly for ≥ 2. ϵ_{pretag} is the lepton ID efficiency in the Monte Carlo, and $\epsilon_{pretag} * SF$ is the pretag efficiency times the product of the pretag data-to-Monte Carlo scale factors.

WW					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	41.94 $\pm$ 8.86	37.86 $\pm$ 4.78	43.33 $\pm$ 5.22	25.93 $\pm$ 8.43	25.00 $\pm$ 12.50
$\epsilon_{c-jet}(\%)$	7.71 $\pm$ 0.47	8.46 $\pm$ 0.33	8.09 $\pm$ 0.67	7.36 $\pm$ 1.51	9.09 $\pm$ 3.88
$\epsilon_{b-jet} * SF(\%)$	38.12 $\pm$ 8.44	34.41 $\pm$ 4.90	39.39 $\pm$ 5.41	23.57 $\pm$ 7.82	22.73 $\pm$ 11.46
$\epsilon_{c-jet} * SF(\%)$	7.01 $\pm$ 1.02	7.69 $\pm$ 1.06	7.35 $\pm$ 1.15	6.69 $\pm$ 1.63	8.26 $\pm$ 3.69
$\Phi_e^{\geq 1}(\%)$	90.90 $\pm$ 12.18	90.92 $\pm$ 12.09	91.07 $\pm$ 11.53	91.41 $\pm$ 10.99	92.16 $\pm$ 9.48
$\Phi_e^{\geq 2}(\%)$	0.00 $\pm$ 0.00	82.63 $\pm$ 18.39	82.64 $\pm$ 17.97	82.75 $\pm$ 17.58	83.16 $\pm$ 16.70
$\epsilon_{\geq 1}(\%)$	2.06 $\pm$ 0.11	4.42 $\pm$ 0.16	5.68 $\pm$ 0.39	5.75 $\pm$ 0.96	11.83 $\pm$ 3.35
$\epsilon_{\geq 2}$ (%)	0.00 $\pm$ 0.00	0.04 $\pm$ 0.01	0.12 $\pm$ 0.06	0.00 $\pm$ 0.00	1.08 $\pm$ 1.07
$\epsilon_{\geq 1} * \Phi_e$ (%)	1.87 $\pm$ 0.27	4.02 $\pm$ 0.55	5.17 $\pm$ 0.75	5.26 $\pm$ 1.08	10.90 $\pm$ 3.28
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 $\pm$ 0.00	0.03 $\pm$ 0.01	0.10 $\pm$ 0.05	0.00 $\pm$ 0.00	0.90 $\pm$ 0.91
$\epsilon_{bjet}(\%)$				37.98 $\pm$ 4.27	
$\epsilon_{cjet}(\%)$				8.01 $\pm$ 0.61	
$\epsilon_{bjet} * SF(\%)$				34.52 $\pm$ 4.50	
$\epsilon_{cjet} * SF(\%)$				7.28 $\pm$ 1.11	
$\epsilon_{\geq 1}(\%)$				5.83 $\pm$ 0.36	
$\epsilon_{\geq 2}(\%)$				0.12 $\pm$ 0.05	
$\Phi_E^1(\%)$				91.19 $\pm$ 11.31	
$\Phi_E^2(\%)$				82.80 $\pm$ 17.54	
$\epsilon_{\geq 1}(\%) * \Phi_E^1$				5.32 $\pm$ 0.74	
$\epsilon_{\geq 2}(\%) * \Phi_E^2$				0.10 $\pm$ 0.05	
CEM					
ϵ_{Pretag}	1.93 $\pm$ 0.02	1.92 $\pm$ 0.02	0.39 $\pm$ 0.01	0.06 $\pm$ 0.00	0.01 $\pm$ 0.00
$\epsilon_{Pretag} * SF$	1.76 $\pm$ 0.12	1.75 $\pm$ 0.12	0.36 $\pm$ 0.03	0.05 $\pm$ 0.00	0.01 $\pm$ 0.00
ϵ_{pretag}				0.47 $\pm$ 0.01	
$\epsilon_{pretag} * SF$				0.43 $\pm$ 0.03	
Pretag	74.28 $\pm$ 6.83	73.90 $\pm$ 6.79	15.01 $\pm$ 1.42	2.31 $\pm$ 0.21	0.38 $\pm$ 0.04
$\geq$ 1+ Tag	1.39 $\pm$ 0.24	2.97 $\pm$ 0.49	0.78 $\pm$ 0.13	0.12 $\pm$ 0.03	0.04 $\pm$ 0.01
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.02 $\pm$ 0.01	0.01 $\pm$ 0.01	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
CMUP					
ϵ_{Pretag}	1.20 $\pm$ 0.02	1.14 $\pm$ 0.02	0.25 $\pm$ 0.01	0.04 $\pm$ 0.00	0.01 $\pm$ 0.00
$\epsilon_{Pretag} * SF$	0.91 $\pm$ 0.06	0.86 $\pm$ 0.06	0.19 $\pm$ 0.01	0.03 $\pm$ 0.00	0.01 $\pm$ 0.00
ϵ_{pretag}				0.29 $\pm$ 0.01	
$\epsilon_{pretag} * SF$				0.22 $\pm$ 0.02	
Pretag	38.24 $\pm$ 3.57	36.33 $\pm$ 3.40	7.97 $\pm$ 0.80	1.27 $\pm$ 0.12	0.32 $\pm$ 0.03
$\geq$ 1+ Tag	0.72 $\pm$ 0.12	1.46 $\pm$ 0.24	0.41 $\pm$ 0.07	0.07 $\pm$ 0.02	0.03 $\pm$ 0.01
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.01 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
CMX					
ϵ_{Pretag}	0.49 $\pm$ 0.01	0.46 $\pm$ 0.01	0.09 $\pm$ 0.00	0.02 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{Pretag} * SF$	0.44 $\pm$ 0.03	0.42 $\pm$ 0.03	0.08 $\pm$ 0.01	0.02 $\pm$ 0.00	0.00 $\pm$ 0.00
ϵ_{pretag}				0.12 $\pm$ 0.01	
$\epsilon_{pretag} * SF$				0.11 $\pm$ 0.01	
Pretag	17.98 $\pm$ 1.69	16.88 $\pm$ 1.59	3.30 $\pm$ 0.30	0.73 $\pm$ 0.07	0.00 $\pm$ 0.00
$\geq$ 1+ Tag	0.34 $\pm$ 0.06	0.68 $\pm$ 0.11	0.17 $\pm$ 0.03	0.04 $\pm$ 0.01	0.00 $\pm$ 0.00
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
Total					
Pretag	130.50 $\pm$ 11.72	127.10 $\pm$ 11.42	26.28 $\pm$ 2.40	4.32 $\pm$ 0.39	0.70 $\pm$ 0.06
$\geq$ 1 Tag	2.44 $\pm$ 0.42	5.11 $\pm$ 0.84	1.36 $\pm$ 0.23	0.23 $\pm$ 0.05	0.08 $\pm$ 0.02
$\geq$ 2 Tag	0.00 $\pm$ 0.00	0.04 $\pm$ 0.01	0.03 $\pm$ 0.01	0.00 $\pm$ 0.00	0.01 $\pm$ 0.01

Table 17: Summary table for WW. See Table 16 for a description of the variables.

WZ					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	41.08 $\pm$ 1.09	40.68 $\pm$ 0.81	38.97 $\pm$ 1.75	37.42 $\pm$ 3.89	47.83 $\pm$ 10.42
$\epsilon_{c-jet}(\%)$	7.41 $\pm$ 0.77	9.24 $\pm$ 0.56	9.05 $\pm$ 1.07	9.22 $\pm$ 2.44	11.76 $\pm$ 5.53
$\epsilon_{b-jet} * SF(\%)$	37.34 $\pm$ 2.66	36.98 $\pm$ 2.55	35.42 $\pm$ 2.83	34.01 $\pm$ 4.19	43.48 $\pm$ 9.90
$\epsilon_{c-jet} * SF(\%)$	6.74 $\pm$ 1.13	8.40 $\pm$ 1.22	8.23 $\pm$ 1.46	8.38 $\pm$ 2.48	10.69 $\pm$ 5.22
$\Phi_e^{\geq 1}(\%)$	90.90 $\pm$ 6.86	92.08 $\pm$ 6.38	92.29 $\pm$ 6.51	92.37 $\pm$ 6.40	92.38 $\pm$ 7.33
$\Phi_e^{\geq 2}(\%)$	0.00 $\pm$ 0.00	82.63 $\pm$ 11.68	82.83 $\pm$ 11.61	83.00 $\pm$ 11.71	82.79 $\pm$ 12.13
$\epsilon_{\geq 1}(\%)$	10.77 $\pm$ 0.33	16.02 $\pm$ 0.37	15.81 $\pm$ 0.79	18.47 $\pm$ 1.99	19.12 $\pm$ 4.77
$\epsilon_{\geq 2}$ (%)	0.00 $\pm$ 0.00	2.03 $\pm$ 0.14	2.69 $\pm$ 0.35	2.37 $\pm$ 0.78	4.41 $\pm$ 2.49
$\epsilon_{\geq 1} * \Phi_e$ (%)	9.79 $\pm$ 0.80	14.75 $\pm$ 1.08	14.59 $\pm$ 1.26	17.06 $\pm$ 2.19	17.66 $\pm$ 4.62
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 $\pm$ 0.00	1.68 $\pm$ 0.26	2.23 $\pm$ 0.43	1.97 $\pm$ 0.70	3.65 $\pm$ 2.13
$\epsilon_{bjet}(\%)$				38.94 $\pm$ 1.58	
$\epsilon_{cjet}(\%)$				9.18 $\pm$ 0.97	
$\epsilon_{bjet} * SF(\%)$				35.40 $\pm$ 2.74	
$\epsilon_{cjet} * SF(\%)$				8.34 $\pm$ 1.41	
$\epsilon_{\geq 1}(\%)$				16.29 $\pm$ 0.73	
$\epsilon_{\geq 2}(\%)$				2.69 $\pm$ 0.32	
$\Phi_E^1(\%)$				92.31 $\pm$ 6.51	
$\Phi_E^2(\%)$				82.87 $\pm$ 11.65	
$\epsilon_{\geq 1}(\%) * \Phi_E^1$				15.04 $\pm$ 1.26	
$\epsilon_{\geq 2}(\%) * \Phi_E^2$				2.23 $\pm$ 0.41	
CEM					
ϵ_{Pretag}	0.95 $\pm$ 0.02	1.08 $\pm$ 0.02	0.23 $\pm$ 0.01	0.04 $\pm$ 0.00	0.01 $\pm$ 0.00
$\epsilon_{Pretag} * SF$	0.87 $\pm$ 0.06	0.98 $\pm$ 0.07	0.21 $\pm$ 0.02	0.04 $\pm$ 0.00	0.01 $\pm$ 0.00
ϵ_{pretag}				0.27 $\pm$ 0.01	
$\epsilon_{pretag} * SF$				0.25 $\pm$ 0.02	
Pretag	10.93 $\pm$ 1.02	12.42 $\pm$ 1.15	2.65 $\pm$ 0.27	0.46 $\pm$ 0.04	0.12 $\pm$ 0.01
$\geq$ 1+ Tag	1.07 $\pm$ 0.13	1.83 $\pm$ 0.22	0.39 $\pm$ 0.05	0.08 $\pm$ 0.01	0.02 $\pm$ 0.01
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.21 $\pm$ 0.04	0.06 $\pm$ 0.01	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
CMUP					
ϵ_{Pretag}	0.59 $\pm$ 0.01	0.65 $\pm$ 0.01	0.13 $\pm$ 0.01	0.03 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{Pretag} * SF$	0.45 $\pm$ 0.03	0.49 $\pm$ 0.03	0.10 $\pm$ 0.01	0.02 $\pm$ 0.00	0.00 $\pm$ 0.00
ϵ_{pretag}				0.17 $\pm$ 0.01	
$\epsilon_{pretag} * SF$				0.13 $\pm$ 0.01	
Pretag	5.62 $\pm$ 0.52	6.19 $\pm$ 0.57	1.24 $\pm$ 0.15	0.29 $\pm$ 0.03	0.00 $\pm$ 0.00
$\geq$ 1+ Tag	0.55 $\pm$ 0.07	0.91 $\pm$ 0.11	0.18 $\pm$ 0.03	0.05 $\pm$ 0.01	0.00 $\pm$ 0.00
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.10 $\pm$ 0.02	0.03 $\pm$ 0.01	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
CMX					
ϵ_{Pretag}	0.22 $\pm$ 0.01	0.26 $\pm$ 0.01	0.06 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{Pretag} * SF$	0.20 $\pm$ 0.02	0.24 $\pm$ 0.02	0.05 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
ϵ_{pretag}				0.07 $\pm$ 0.00	
$\epsilon_{pretag} * SF$				0.06 $\pm$ 0.00	
Pretag	2.41 $\pm$ 0.24	2.85 $\pm$ 0.28	0.66 $\pm$ 0.06	0.11 $\pm$ 0.01	0.00 $\pm$ 0.00
$\geq$ 1+ Tag	0.24 $\pm$ 0.03	0.42 $\pm$ 0.05	0.10 $\pm$ 0.01	0.02 $\pm$ 0.00	0.00 $\pm$ 0.00
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.05 $\pm$ 0.01	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
Total					
Pretag	18.96 $\pm$ 1.71	21.46 $\pm$ 1.93	4.54 $\pm$ 0.43	0.86 $\pm$ 0.08	0.12 $\pm$ 0.01
$\geq$ 1 Tag	1.86 $\pm$ 0.23	3.17 $\pm$ 0.37	0.66 $\pm$ 0.09	0.15 $\pm$ 0.02	0.02 $\pm$ 0.01
$\geq$ 2 Tag	0.00 $\pm$ 0.00	0.36 $\pm$ 0.07	0.10 $\pm$ 0.02	0.02 $\pm$ 0.01	0.00 $\pm$ 0.00

Table 18: Summary table for WZ. See Table 16 for a description of the variables.

ZZ					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	29.76 $\pm$ 4.99	46.10 $\pm$ 2.90	42.19 $\pm$ 4.37	33.33 $\pm$ 8.61	44.44 $\pm$ 16.56
$\epsilon_{c-jet}(\%)$	8.70 $\pm$ 2.94	8.15 $\pm$ 1.79	8.49 $\pm$ 2.71	5.88 $\pm$ 4.04	0.00 $\pm$ 0.00
$\epsilon_{b-jet} * SF(\%)$	27.05 $\pm$ 4.87	41.90 $\pm$ 3.82	38.35 $\pm$ 4.71	30.30 $\pm$ 8.08	40.40 $\pm$ 15.29
$\epsilon_{c-jet} * SF(\%)$	7.91 $\pm$ 2.87	7.41 $\pm$ 1.90	7.72 $\pm$ 2.67	5.34 $\pm$ 3.74	0.00 $\pm$ 0.00
$\Phi_e^{\geq 1}(\%)$	90.90 $\pm$ 9.46	92.37 $\pm$ 8.05	92.52 $\pm$ 8.10	92.68 $\pm$ 8.26	92.81 $\pm$ 6.50
$\Phi_e^{\geq 2}(\%)$	0.00 $\pm$ 0.00	82.63 $\pm$ 14.28	82.96 $\pm$ 14.15	82.96 $\pm$ 14.38	82.63 $\pm$ 14.06
$\epsilon_{\geq 1}(\%)$	4.78 $\pm$ 0.75	15.78 $\pm$ 1.25	16.01 $\pm$ 1.94	15.73 $\pm$ 3.86	15.79 $\pm$ 8.37
$\epsilon_{\geq 2}$ $(\%)$	0.00 $\pm$ 0.00	3.53 $\pm$ 0.63	3.09 $\pm$ 0.92	1.12 $\pm$ 1.12	5.26 $\pm$ 5.12
$\epsilon_{\geq 1} * \Phi_e$ $(\%)$	4.35 $\pm$ 0.82	14.58 $\pm$ 1.72	14.81 $\pm$ 2.21	14.58 $\pm$ 3.81	14.65 $\pm$ 7.84
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 $\pm$ 0.00	2.92 $\pm$ 0.72	2.56 $\pm$ 0.88	0.93 $\pm$ 0.94	4.35 $\pm$ 4.29
$\epsilon_{bjet}(\%)$				40.72 $\pm$ 3.80	
$\epsilon_{cjet}(\%)$				7.53 $\pm$ 2.18	
$\epsilon_{bjet} * SF(\%)$				37.01 $\pm$ 4.23	
$\epsilon_{cjet} * SF(\%)$				6.84 $\pm$ 2.18	
$\epsilon_{\geq 1}(\%)$				15.95 $\pm$ 1.70	
$\epsilon_{\geq 2}(\%)$				2.80 $\pm$ 0.77	
$\Phi_E^1(\%)$				92.58 $\pm$ 8.02	
$\Phi_E^2(\%)$				82.93 $\pm$ 14.20	
$\epsilon_{\geq 1}(\%) * \Phi_E^1$				14.77 $\pm$ 2.03	
$\epsilon_{\geq 2}(\%) * \Phi_E^2$				2.32 $\pm$ 0.75	
CEM					
ϵ_{Pretag}	0.07 $\pm$ 0.00	0.07 $\pm$ 0.00	0.04 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{Pretag} * SF$	0.06 $\pm$ 0.00	0.06 $\pm$ 0.00	0.04 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
ϵ_{pretag}				0.05 $\pm$ 0.00	
$\epsilon_{pretag} * SF$				0.05 $\pm$ 0.00	
Pretag	0.32 $\pm$ 0.03	0.32 $\pm$ 0.03	0.18 $\pm$ 0.02	0.05 $\pm$ 0.00	0.00 $\pm$ 0.00
$\geq$ 1+ Tag	0.01 $\pm$ 0.00	0.05 $\pm$ 0.01	0.03 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
CMUP					
ϵ_{Pretag}	0.08 $\pm$ 0.00	0.08 $\pm$ 0.00	0.03 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{Pretag} * SF$	0.06 $\pm$ 0.00	0.06 $\pm$ 0.00	0.02 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
ϵ_{pretag}				0.04 $\pm$ 0.00	
$\epsilon_{pretag} * SF$				0.03 $\pm$ 0.00	
Pretag	0.30 $\pm$ 0.03	0.30 $\pm$ 0.03	0.11 $\pm$ 0.01	0.04 $\pm$ 0.00	0.00 $\pm$ 0.00
$\geq$ 1+ Tag	0.01 $\pm$ 0.00	0.04 $\pm$ 0.01	0.02 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
CMX					
ϵ_{Pretag}	0.03 $\pm$ 0.00	0.03 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{Pretag} * SF$	0.03 $\pm$ 0.00	0.03 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
ϵ_{pretag}				0.01 $\pm$ 0.00	
$\epsilon_{pretag} * SF$				0.01 $\pm$ 0.00	
Pretag	0.13 $\pm$ 0.01	0.13 $\pm$ 0.01	0.04 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$\geq$ 1+ Tag	0.01 $\pm$ 0.00	0.02 $\pm$ 0.00	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
Total					
Pretag	0.76 $\pm$ 0.07	0.76 $\pm$ 0.07	0.34 $\pm$ 0.03	0.08 $\pm$ 0.01	0.00 $\pm$ 0.00
$\geq$ 1 Tag	0.03 $\pm$ 0.01	0.11 $\pm$ 0.02	0.05 $\pm$ 0.01	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00
$\geq$ 2 Tag	0.00 $\pm$ 0.00	0.02 $\pm$ 0.01	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00

Table 19: Summary table for ZZ. See Table 16 for a description of the variables.

$Z \to \tau\tau$					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	52.00 ± 9.99	41.67 ± 10.06	33.33 ± 15.71	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{c-jet}(\%)$	6.12 ± 3.42	8.70 ± 4.15	5.88 ± 5.71	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{b-jet} * SF(\%)$	47.27 ± 9.60	37.88 ± 9.48	30.30 ± 14.42	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{c-jet} * SF(\%)$	5.56 ± 3.19	7.91 ± 3.91	5.34 ± 5.24	0.00 ± 0.00	0.00 ± 0.00
$\Phi_e^{\geq 1}(\%)$	90.90 ± 18.90	91.42 ± 18.28	92.44 ± 17.24	90.90 ± 33.24	0.00 ± 0.00
$\Phi_e^{\geq 2}(\%)$	0.00 ± 0.00	82.63 ± 27.42	82.63 ± 27.03	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{\geq 1}(\%)$	2.06 ± 0.30	4.53 ± 0.78	7.75 ± 2.35	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{\geq 2}$ (%)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{\geq 1} * \Phi_e$ (%)	1.87 ± 0.48	4.14 ± 1.09	7.16 ± 2.55	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{bjet}(\%)$			33.33 ± 15.71		
$\epsilon_{cjet}(\%)$			5.00 ± 4.87		
$\epsilon_{bjet} * SF(\%)$			30.30 ± 14.42		
$\epsilon_{cjet} * SF(\%)$			4.55 ± 4.47		
$\epsilon_{\geq 1}(\%)$			6.80 ± 2.08		
$\epsilon_{\geq 2}(\%)$			0.00 ± 0.00		
$\Phi_E^1(\%)$			92.35 ± 18.19		
$\Phi_E^2(\%)$			82.63 ± 27.03		
$\epsilon_{\geq 1}(\%) * \Phi_E^1$			6.28 ± 2.28		
$\epsilon_{\geq 2}(\%) * \Phi_E^2$			0.00 ± 0.00		
CEM					
ϵ_{Pretag}	0.11 ± 0.00	0.03 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{Pretag} * SF$	0.10 ± 0.01	0.03 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
ϵ_{pretag}			0.01 ± 0.00		
$\epsilon_{pretag} * SF$			0.01 ± 0.00		
Pretag	4.15 ± 0.61	1.13 ± 0.17	0.38 ± 0.06	0.00 ± 0.00	0.00 ± 0.00
$\geq$ 1+ Tag	0.08 ± 0.02	0.05 ± 0.01	0.03 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
$\geq$ 2+ Tag	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
CMUP					
ϵ_{Pretag}	0.06 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{Pretag} * SF$	0.05 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
ϵ_{pretag}			0.00 ± 0.00		
$\epsilon_{pretag} * SF$			0.00 ± 0.00		
Pretag	1.88 ± 0.27	0.63 ± 0.09	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\geq$ 1+ Tag	0.04 ± 0.01	0.03 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\geq$ 2+ Tag	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
CMX					
ϵ_{Pretag}	0.03 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{Pretag} * SF$	0.03 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
ϵ_{pretag}			0.00 ± 0.00		
$\epsilon_{pretag} * SF$			0.00 ± 0.00		
Pretag	1.08 ± 0.16	0.36 ± 0.05	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\geq$ 1+ Tag	0.02 ± 0.01	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\geq$ 2+ Tag	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Total					
Pretag	7.11 ± 0.83	2.12 ± 0.24	0.38 ± 0.06	0.00 ± 0.00	0.00 ± 0.00
$\geq$ 1 Tag	0.13 ± 0.04	0.09 ± 0.03	0.03 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
$\geq$ 2 Tag	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Table 20: Summary table for $Z \to \tau\tau$. See Table 16 for a description of the variables.

Single top, t-channel					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	46.35 ± 0.40	45.89 ± 0.36	43.80 ± 0.71	41.43 ± 1.61	44.16 ± 4.00
$\epsilon_{c-jet}(\%)$	7.69 ± 1.91	6.85 ± 0.85	9.05 ± 1.98	11.11 ± 4.28	0.00 ± 0.00
$\epsilon_{b-jet} * SF(\%)$	42.13 ± 2.80	41.71 ± 2.77	39.81 ± 2.71	37.66 ± 2.88	40.14 ± 4.50
$\epsilon_{c-jet} * SF(\%)$	6.99 ± 1.97	6.23 ± 1.13	8.23 ± 2.10	10.10 ± 4.11	0.00 ± 0.00
$\Phi_e^{\geq 1}(\%)$	90.90 ± 6.04	91.22 ± 5.86	92.41 ± 5.16	93.00 ± 4.85	93.28 ± 4.77
$\Phi_e^{\geq 2}(\%)$	0.00 ± 0.00	82.63 ± 11.55	82.69 ± 11.05	82.83 ± 10.99	83.03 ± 10.84
$\epsilon_{\geq 1}(\%)$	39.59 ± 0.37	47.05 ± 0.37	55.19 ± 0.86	59.47 ± 2.13	64.20 ± 5.33
$\epsilon_{\geq 2}$ (%)	0.00 ± 0.00	1.80 ± 0.10	10.68 ± 0.53	14.82 ± 1.54	19.75 ± 4.42
$\epsilon_{\geq 1} * \Phi_e$ (%)	35.99 ± 2.41	42.92 ± 2.78	51.00 ± 2.96	55.31 ± 3.50	59.89 ± 5.84
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 ± 0.00	1.49 ± 0.22	8.83 ± 1.26	12.28 ± 2.07	16.40 ± 4.25
$\epsilon_{bjet}(\%)$				43.44 ± 0.64	
$\epsilon_{cjet}(\%)$				9.12 ± 1.74	
$\epsilon_{bjet} * SF(\%)$				39.49 ± 2.67	
$\epsilon_{cjet} * SF(\%)$				8.29 ± 1.92	
$\epsilon_{\geq 1}(\%)$				55.95 ± 0.79	
$\epsilon_{\geq 2}(\%)$				11.42 ± 0.51	
$\Phi_E^1(\%)$				92.55 ± 5.09	
$\Phi_E^2(\%)$				82.74 ± 11.03	
$\epsilon_{\geq 1}(\%) * \Phi_E^1$				51.78 ± 2.94	
$\epsilon_{\geq 2}(\%) * \Phi_E^2$				9.45 ± 1.33	
CEM					
ϵ_{Pretag}	4.43 ± 0.05	4.55 ± 0.05	0.86 ± 0.02	0.13 ± 0.01	0.02 ± 0.00
$\epsilon_{Pretag} * SF$	4.04 ± 0.27	4.15 ± 0.28	0.78 ± 0.06	0.12 ± 0.01	0.02 ± 0.00
ϵ_{pretag}				1.01 ± 0.02	
$\epsilon_{pretag} * SF$				0.92 ± 0.06	
Pretag	8.49 ± 3.52	8.72 ± 3.61	1.65 ± 0.68	0.25 ± 0.10	0.04 ± 0.02
$\geq$ 1+ Tag	3.06 ± 1.28	3.74 ± 1.57	0.84 ± 0.35	0.14 ± 0.06	0.02 ± 0.01
$\geq$ 2+ Tag	0.00 ± 0.00	0.13 ± 0.06	0.15 ± 0.06	0.03 ± 0.01	0.01 ± 0.00
CMUP					
ϵ_{Pretag}	2.59 ± 0.04	2.72 ± 0.04	0.50 ± 0.02	0.09 ± 0.01	0.01 ± 0.00
$\epsilon_{Pretag} * SF$	1.96 ± 0.14	2.05 ± 0.14	0.38 ± 0.03	0.07 ± 0.01	0.01 ± 0.00
ϵ_{pretag}				0.59 ± 0.02	
$\epsilon_{pretag} * SF$				0.45 ± 0.03	
Pretag	4.11 ± 1.70	4.32 ± 1.79	0.79 ± 0.33	0.14 ± 0.06	0.02 ± 0.01
$\geq$ 1+ Tag	1.48 ± 0.62	1.85 ± 0.78	0.40 ± 0.17	0.08 ± 0.03	0.01 ± 0.00
$\geq$ 2+ Tag	0.00 ± 0.00	0.06 ± 0.03	0.07 ± 0.03	0.02 ± 0.01	0.00 ± 0.00
CMX					
ϵ_{Pretag}	0.95 ± 0.02	0.91 ± 0.02	0.18 ± 0.01	0.03 ± 0.00	0.00 ± 0.00
$\epsilon_{Pretag} * SF$	0.86 ± 0.06	0.83 ± 0.06	0.16 ± 0.01	0.03 ± 0.00	0.00 ± 0.00
ϵ_{pretag}				0.21 ± 0.01	
$\epsilon_{pretag} * SF$				0.19 ± 0.02	
Pretag	1.74 ± 0.72	1.66 ± 0.69	0.33 ± 0.14	0.05 ± 0.02	0.00 ± 0.00
$\geq$ 1+ Tag	0.62 ± 0.26	0.71 ± 0.30	0.17 ± 0.07	0.03 ± 0.01	0.00 ± 0.00
$\geq$ 2+ Tag	0.00 ± 0.00	0.02 ± 0.01	0.03 ± 0.01	0.01 ± 0.00	0.00 ± 0.00
Total					
Pretag	14.34 ± 4.08	14.70 ± 4.20	2.77 ± 0.79	0.45 ± 0.13	0.05 ± 0.02
$\geq$ 1 Tag	5.16 ± 1.51	6.31 ± 1.85	1.41 ± 0.41	0.25 ± 0.07	0.03 ± 0.01
$\geq$ 2 Tag	0.00 ± 0.00	0.22 ± 0.07	0.24 ± 0.08	0.05 ± 0.02	0.01 ± 0.00

Table 21: Summary table for single top (t-channel). See Table 16 for a description of the variables.

Single top, s-channel					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	44.87 ± 0.47	44.40 ± 0.24	44.04 ± 0.53	41.35 ± 1.34	38.76 ± 3.37
$\epsilon_{c-jet}(\%)$	0.00 ± 0.00	5.95 ± 1.83	10.81 ± 2.08	3.64 ± 2.52	0.00 ± 0.00
$\epsilon_{b-jet} * SF(\%)$	40.79 ± 2.73	40.36 ± 2.67	40.03 ± 2.69	37.59 ± 2.76	35.23 ± 3.85
$\epsilon_{c-jet} * SF(\%)$	0.00 ± 0.00	5.41 ± 1.81	9.83 ± 2.29	3.31 ± 2.33	0.00 ± 0.00
$\Phi_e^{\geq 1}(\%)$	90.90 ± 6.02	93.06 ± 4.73	93.17 ± 4.73	93.20 ± 4.74	93.39 ± 4.85
$\Phi_e^{\geq 2}(\%)$	0.00 ± 0.00	82.63 ± 10.95	82.78 ± 10.93	82.89 ± 10.92	83.38 ± 10.70
$\epsilon_{\geq 1}(\%)$	42.81 ± 0.45	64.91 ± 0.31	65.77 ± 0.70	64.09 ± 1.81	62.14 ± 4.78
$\epsilon_{\geq 2}$ (%)	0.00 ± 0.00	18.18 ± 0.25	19.38 ± 0.58	16.45 ± 1.40	18.45 ± 3.82
$\epsilon_{\geq 1} * \Phi_e$ (%)	38.91 ± 2.61	60.41 ± 3.08	61.28 ± 3.18	59.73 ± 3.47	58.03 ± 5.39
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 ± 0.00	15.02 ± 2.00	16.04 ± 2.17	13.64 ± 2.14	15.38 ± 3.75
$\epsilon_{bjet}(\%)$				43.58 ± 0.49	
$\epsilon_{cjet}(\%)$				8.78 ± 1.65	
$\epsilon_{bjet} * SF(\%)$				39.61 ± 2.65	
$\epsilon_{cjet} * SF(\%)$				7.98 ± 1.83	
$\epsilon_{\geq 1}(\%)$				65.48 ± 0.64	
$\epsilon_{\geq 2}(\%)$				18.99 ± 0.53	
$\Phi_E^1(\%)$				93.18 ± 4.73	
$\Phi_E^2(\%)$				82.81 ± 10.92	
$\epsilon_{\geq 1}(\%) * \Phi_E^1$				61.01 ± 3.15	
$\epsilon_{\geq 2}(\%) * \Phi_E^2$				15.73 ± 2.12	
CEM					
ϵ_{Pretag}	3.08 ± 0.04	6.08 ± 0.06	1.25 ± 0.03	0.19 ± 0.01	0.03 ± 0.00
$\epsilon_{Pretag} * SF$	2.81 ± 0.19	5.55 ± 0.38	1.14 ± 0.08	0.17 ± 0.01	0.03 ± 0.00
ϵ_{pretag}				1.47 ± 0.03	
$\epsilon_{pretag} * SF$				1.34 ± 0.09	
Pretag	2.62 ± 0.28	5.18 ± 0.55	1.06 ± 0.12	0.16 ± 0.02	0.03 ± 0.00
$\geq$ 1+ Tag	1.02 ± 0.13	3.13 ± 0.37	0.65 ± 0.08	0.10 ± 0.01	0.01 ± 0.00
$\geq$ 2+ Tag	0.00 ± 0.00	0.78 ± 0.13	0.17 ± 0.03	0.02 ± 0.00	0.00 ± 0.00
CMUP					
ϵ_{Pretag}	1.74 ± 0.03	3.55 ± 0.04	0.73 ± 0.02	0.11 ± 0.01	0.01 ± 0.00
$\epsilon_{Pretag} * SF$	1.31 ± 0.09	2.68 ± 0.18	0.55 ± 0.04	0.08 ± 0.01	0.01 ± 0.00
ϵ_{pretag}				0.86 ± 0.02	
$\epsilon_{pretag} * SF$				0.65 ± 0.05	
Pretag	1.23 ± 0.13	2.50 ± 0.27	0.51 ± 0.06	0.08 ± 0.01	0.01 ± 0.00
$\geq$ 1+ Tag	0.48 ± 0.06	1.51 ± 0.18	0.32 ± 0.04	0.05 ± 0.01	0.00 ± 0.00
$\geq$ 2+ Tag	0.00 ± 0.00	0.38 ± 0.06	0.08 ± 0.01	0.01 ± 0.00	0.00 ± 0.00
CMX					
ϵ_{Pretag}	0.64 ± 0.02	1.21 ± 0.03	0.23 ± 0.01	0.04 ± 0.00	0.01 ± 0.00
$\epsilon_{Pretag} * SF$	0.58 ± 0.04	1.10 ± 0.08	0.21 ± 0.02	0.04 ± 0.00	0.01 ± 0.00
ϵ_{pretag}				0.28 ± 0.01	
$\epsilon_{pretag} * SF$				0.25 ± 0.02	
Pretag	0.52 ± 0.06	0.98 ± 0.11	0.19 ± 0.02	0.03 ± 0.00	0.01 ± 0.00
$\geq$ 1+ Tag	0.20 ± 0.03	0.59 ± 0.07	0.11 ± 0.01	0.02 ± 0.00	0.00 ± 0.00
$\geq$ 2+ Tag	0.00 ± 0.00	0.15 ± 0.03	0.03 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
Total					
Pretag	4.37 ± 0.42	8.67 ± 0.84	1.77 ± 0.17	0.27 ± 0.03	0.04 ± 0.00
$\geq$ 1 Tag	1.70 ± 0.20	5.24 ± 0.57	1.08 ± 0.12	0.16 ± 0.02	0.02 ± 0.00
$\geq$ 2 Tag	0.00 ± 0.00	1.30 ± 0.21	0.28 ± 0.05	0.04 ± 0.01	0.01 ± 0.00

Table 22: Summary table for single top (s-channel). See Table 16 for a description of the variables.

W + LF Mistags					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
CEM					
(+) Pred	260.91 $\pm$ 4.43	101.76 $\pm$ 0.79	31.50 $\pm$ 0.64	11.61 $\pm$ 0.09	2.42 $\pm$ 0.06
(-) Pred	65.25 $\pm$ 4.27	32.28 $\pm$ 0.73	12.00 $\pm$ 0.63	4.70 $\pm$ 0.06	0.99 $\pm$ 0.04
(+,-) Pred	0.00 $\pm$ 0.00	1.07 $\pm$ 0.13	1.37 $\pm$ 0.05	1.16 $\pm$ 0.05	0.35 $\pm$ 0.03
(-,-) Pred	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
CMUP					
(+) Pred	121.45 $\pm$ 2.19	44.41 $\pm$ 0.61	11.99 $\pm$ 0.09	4.92 $\pm$ 0.06	1.57 $\pm$ 0.04
(-) Pred	29.74 $\pm$ 2.10	13.38 $\pm$ 0.56	4.21 $\pm$ 0.06	2.03 $\pm$ 0.04	0.68 $\pm$ 0.03
(+,-) Pred	0.00 $\pm$ 0.00	0.38 $\pm$ 0.07	0.36 $\pm$ 0.02	0.87 $\pm$ 0.06	0.29 $\pm$ 0.03
(-,-) Pred	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
CMX					
(+) Pred	64.66 $\pm$ 1.53	23.28 $\pm$ 0.28	5.78 $\pm$ 0.10	1.92 $\pm$ 0.02	0.76 $\pm$ 0.03
(-) Pred	14.97 $\pm$ 1.47	6.84 $\pm$ 0.26	2.06 $\pm$ 0.09	0.62 $\pm$ 0.01	0.32 $\pm$ 0.02
(+,-) Pred	0.00 $\pm$ 0.00	0.17 $\pm$ 0.02	0.21 $\pm$ 0.02	0.16 $\pm$ 0.02	0.13 $\pm$ 0.02
(-,-) Pred	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
Total					
(+) Pred	447.03 $\pm$ 5.18	169.45 $\pm$ 1.04	49.27 $\pm$ 0.65	18.45 $\pm$ 0.11	4.75 $\pm$ 0.08
(-) Pred	109.96 $\pm$ 4.98	52.51 $\pm$ 0.96	18.27 $\pm$ 0.63	7.35 $\pm$ 0.08	1.99 $\pm$ 0.05
(+,-) Pred	0.00 $\pm$ 0.00	1.62 $\pm$ 0.15	1.94 $\pm$ 0.05	2.19 $\pm$ 0.08	0.77 $\pm$ 0.05
(-,-) Pred	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
CEM					
Pretag	17648.00 $\pm$ 0.00	2846.00 $\pm$ 0.00	469.00 $\pm$ 0.00	115.00 $\pm$ 0.00	19.00 $\pm$ 0.00
$\geq$ 1+ Tag	54.27 $\pm$ 11.42	23.18 $\pm$ 4.67	7.16 $\pm$ 1.48	1.58 $\pm$ 0.32	0.02 $\pm$ 0.00
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.35 $\pm$ 0.08	0.20 $\pm$ 0.04	0.11 $\pm$ 0.02	-0.10 $\pm$ 0.02
CMUP					
Pretag	8514.00 $\pm$ 0.00	1263.00 $\pm$ 0.00	202.00 $\pm$ 0.00	46.00 $\pm$ 0.00	11.00 $\pm$ 0.00
$\geq$ 1+ Tag	25.92 $\pm$ 5.50	10.24 $\pm$ 2.09	2.45 $\pm$ 0.49	0.49 $\pm$ 0.10	0.08 $\pm$ 0.02
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.13 $\pm$ 0.03	-0.00 $\pm$ 0.00	-0.02 $\pm$ 0.00	0.07 $\pm$ 0.02
CMX					
Pretag	4466.00 $\pm$ 0.00	682.00 $\pm$ 0.00	98.00 $\pm$ 0.00	18.00 $\pm$ 0.00	6.00 $\pm$ 0.00
$\geq$ 1+ Tag	13.86 $\pm$ 3.09	5.70 $\pm$ 1.16	1.44 $\pm$ 0.29	0.20 $\pm$ 0.04	0.12 $\pm$ 0.03
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.07 $\pm$ 0.02	0.02 $\pm$ 0.00	-0.02 $\pm$ 0.00	0.06 $\pm$ 0.02
Total					
Pretag	30628.00 $\pm$ 0.00	4791.00 $\pm$ 0.00	769.00 $\pm$ 0.00	179.00 $\pm$ 0.00	36.00 $\pm$ 0.00
$\geq$ 1 Tag	94.05 $\pm$ 19.28	39.12 $\pm$ 7.86	11.05 $\pm$ 2.24	2.27 $\pm$ 0.45	0.22 $\pm$ 0.05
$\geq$ 2 Tag	0.00 $\pm$ 0.00	0.54 $\pm$ 0.12	0.22 $\pm$ 0.05	0.06 $\pm$ 0.03	0.03 $\pm$ 0.05

Table 23: Summary table for mistag background. N_{+}^{pred} is the positive tag matrix prediction over the pretag data, N_{-}^{pred} is the negative tag matrix prediction over the pretag data, $N_{+,-}^{pred}$ is the positive tag matrix prediction over the ≥ 1 tag data, $N_{-,-}^{pred}$ is the negative tag matrix prediction over the ≥ 1 negative data, and the results are given corrected for the other backgrounds and the light flavor asymmetry (α_{LF}).

$W+c$					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	28.57 $\pm$ 12.07	20.00 $\pm$ 6.32	30.43 $\pm$ 9.59	40.00 $\pm$ 21.91	0.00 $\pm$ 0.00
$\epsilon_{c-jet}(\%)$	9.56 $\pm$ 0.33	9.50 $\pm$ 0.50	8.84 $\pm$ 0.83	12.14 $\pm$ 1.68	9.59 $\pm$ 3.45
$\epsilon_{b-jet} * SF(\%)$	25.97 $\pm$ 11.10	18.18 $\pm$ 5.87	27.66 $\pm$ 8.91	36.36 $\pm$ 20.06	0.00 $\pm$ 0.00
$\epsilon_{c-jet} * SF(\%)$	8.69 $\pm$ 1.19	8.64 $\pm$ 1.23	8.04 $\pm$ 1.30	11.04 $\pm$ 2.11	8.72 $\pm$ 3.34
F_{1c} (%)	4.30 $\pm$ 0.90	6.00 $\pm$ 1.30	6.30 $\pm$ 1.30	6.10 $\pm$ 1.30	6.10 $\pm$ 1.30
F_{2c} (%)	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
WCC, 1C, 1 Tag (%)	8.19 $\pm$ 1.10	8.84 $\pm$ 1.23	9.53 $\pm$ 1.56	13.16 $\pm$ 2.56	7.42 $\pm$ 3.69
WCC, 2C, 1 Tag (%)	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	19.48 $\pm$ 6.30	33.05 $\pm$ 13.88
WCC, 2C, 2 Tag (%)	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$\Phi_e^{\geq 1}(\%)$	90.90 $\pm$ 12.00	90.90 $\pm$ 12.00	90.90 $\pm$ 12.00	90.90 $\pm$ 12.00	90.90 $\pm$ 12.00
$\Phi_e^{\geq 2}(\%)$	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{\geq 1}(\%)$	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{\geq 2}$ (%)	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{\geq 1} * \Phi_e$ (%)	0.35 $\pm$ 0.09	0.51 $\pm$ 0.13	0.58 $\pm$ 0.14	0.75 $\pm$ 0.19	0.40 $\pm$ 0.10
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
$\epsilon_{bjet}(\%)$			0.00 $\pm$ 0.00		
$\epsilon_{cjet}(\%)$			0.00 $\pm$ 0.00		
$\epsilon_{bjet} * SF(\%)$			0.00 $\pm$ 0.00		
$\epsilon_{cjet} * SF(\%)$			0.00 $\pm$ 0.00		
$\epsilon_{\geq 1}(\%)$			0.00 $\pm$ 0.00		
$\epsilon_{\geq 2}(\%)$			0.00 $\pm$ 0.00		
$\Phi_E^1(\%)$			100.00 $\pm$ 0.00		
$\Phi_E^2(\%)$			100.00 $\pm$ 0.00		
$\epsilon_{\geq 1}(\%) * \Phi_E^1$			100.00 $\pm$ 0.00		
$\epsilon_{\geq 2}(\%) * \Phi_E^2$			100.00 $\pm$ 0.00		
CEM					
Pretag	677.83 $\pm$ 161.40	140.94 $\pm$ 36.75	21.07 $\pm$ 5.72	2.89 $\pm$ 1.13	0.03 $\pm$ 0.13
$\geq$ 1+ Tag	55.52 $\pm$ 15.34	12.02 $\pm$ 3.58	1.94 $\pm$ 0.60	0.36 $\pm$ 0.15	0.00 $\pm$ 0.01
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
CMUP					
Pretag	342.82 $\pm$ 77.20	66.67 $\pm$ 16.09	8.88 $\pm$ 2.40	0.83 $\pm$ 0.40	0.10 $\pm$ 0.09
$\geq$ 1+ Tag	28.08 $\pm$ 7.39	5.69 $\pm$ 1.58	0.82 $\pm$ 0.25	0.10 $\pm$ 0.05	0.01 $\pm$ 0.01
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
CMX					
Pretag	190.97 $\pm$ 40.06	39.19 $\pm$ 8.64	5.16 $\pm$ 1.15	0.42 $\pm$ 0.15	0.17 $\pm$ 0.05
$\geq$ 1+ Tag	15.64 $\pm$ 3.88	3.34 $\pm$ 0.86	0.47 $\pm$ 0.12	0.05 $\pm$ 0.02	0.01 $\pm$ 0.00
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
Total					
Pretag	1211.62 $\pm$ 278.66	246.81 $\pm$ 61.48	35.11 $\pm$ 9.26	4.14 $\pm$ 1.67	0.30 $\pm$ 0.27
$\geq$ 1 Tag	99.23 $\pm$ 26.61	21.06 $\pm$ 6.03	3.22 $\pm$ 0.98	0.51 $\pm$ 0.23	0.02 $\pm$ 0.02
$\geq$ 2 Tag	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00

Table 24: Summary table for the W+C background. F_{ic} is the heavy flavor fraction measured from [8], and the efficiencies given are the event tag rates in Monte Carlo. Φ_E is the ratio of event efficiencies with and without the b-tagging scale factor using the full binomial expression.

$W+c\bar{c}$					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	50.00 ± 35.36	0.00 ± 0.00	33.33 ± 15.71	25.00 ± 21.65	0.00 ± 0.00
$\epsilon_{c-jet}(\%)$	8.89 ± 0.76	10.14 ± 1.02	10.32 ± 1.92	10.80 ± 1.96	5.36 ± 3.01
$\epsilon_{b-jet} * SF(\%)$	45.45 ± 32.28	0.00 ± 0.00	30.30 ± 14.42	22.73 ± 19.74	0.00 ± 0.00
$\epsilon_{c-jet} * SF(\%)$	8.08 ± 1.27	9.22 ± 1.53	9.38 ± 2.14	9.82 ± 2.20	4.87 ± 2.81
F_{1c} (%)	1.60 ± 0.40	2.40 ± 0.60	3.40 ± 0.90	3.60 ± 1.00	3.60 ± 1.00
F_{2c} (%)	0.00 ± 0.00	1.80 ± 0.50	2.70 ± 0.70	3.70 ± 1.00	3.70 ± 1.00
WCC, 1C, 1 Tag (%)	7.44 ± 1.04	8.78 ± 1.37	12.57 ± 2.33	10.53 ± 4.26	0.00 ± 0.00
WCC, 2C, 1 Tag (%)	0.00 ± 0.00	15.48 ± 2.40	16.59 ± 3.48	23.32 ± 5.14	11.88 ± 6.58
WCC, 2C, 2 Tag (%)	0.00 ± 0.00	0.36 ± 0.19	0.18 ± 0.12	0.00 ± 0.00	0.00 ± 0.00
$\Phi_e^{\geq 1}(\%)$	90.90 ± 12.00	91.15 ± 11.70	91.13 ± 11.73	91.23 ± 11.61	91.13 ± 11.73
$\Phi_e^{\geq 2}(\%)$	0.00 ± 0.00	82.63 ± 21.82	82.63 ± 21.82	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{\geq 1}(\%)$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{\geq 2}$ (%)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{\geq 1} * \Phi_e$ (%)	0.12 ± 0.03	0.49 ± 0.14	0.88 ± 0.26	1.20 ± 0.36	0.44 ± 0.13
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{bjet}(\%)$				0.00 ± 0.00	
$\epsilon_{cjet}(\%)$				0.00 ± 0.00	
$\epsilon_{bjet} * SF(\%)$				0.00 ± 0.00	
$\epsilon_{cjet} * SF(\%)$				0.00 ± 0.00	
$\epsilon_{\geq 1}(\%)$				0.00 ± 0.00	
$\epsilon_{\geq 2}(\%)$				0.00 ± 0.00	
$\Phi_E^1(\%)$				100.00 ± 0.00	
$\Phi_E^2(\%)$				100.00 ± 0.00	
$\epsilon_{\geq 1}(\%) * \Phi_E^1$				100.00 ± 0.00	
$\epsilon_{\geq 2}(\%) * \Phi_E^2$				100.00 ± 0.00	
CEM					
Pretag	252.22 ± 70.32	98.66 ± 30.18	20.40 ± 6.67	3.45 ± 1.56	0.04 ± 0.16
$\geq$ 1+ Tag	18.75 ± 5.84	11.49 ± 3.90	2.93 ± 1.04	0.57 ± 0.27	0.00 ± 0.01
$\geq$ 2+ Tag	0.00 ± 0.00	0.15 ± 0.06	0.02 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
CMUP					
Pretag	127.56 ± 33.92	46.67 ± 13.38	8.60 ± 2.80	1.00 ± 0.54	0.11 ± 0.11
$\geq$ 1+ Tag	9.48 ± 2.83	5.44 ± 1.74	1.23 ± 0.44	0.16 ± 0.09	0.01 ± 0.01
$\geq$ 2+ Tag	0.00 ± 0.00	0.07 ± 0.03	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
CMX					
Pretag	71.06 ± 17.80	27.44 ± 7.29	5.00 ± 1.40	0.51 ± 0.21	0.20 ± 0.08
$\geq$ 1+ Tag	5.28 ± 1.50	3.20 ± 0.96	0.72 ± 0.22	0.08 ± 0.04	0.01 ± 0.00
$\geq$ 2+ Tag	0.00 ± 0.00	0.04 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Total					
Pretag	450.84 ± 122.03	172.76 ± 50.85	33.99 ± 10.87	4.96 ± 2.30	0.36 ± 0.34
$\geq$ 1 Tag	33.52 ± 10.17	20.13 ± 6.60	4.88 ± 1.70	0.81 ± 0.40	0.02 ± 0.02
$\geq$ 2 Tag	0.00 ± 0.00	0.26 ± 0.11	0.03 ± 0.01	0.00 ± 0.00	0.00 ± 0.00

Table 25: Summary table for the W+CC background. F_{ic} is the heavy flavor fraction measured from [8], and the efficiencies given are the event tag rates in Monte Carlo. Φ_E is the ratio of event efficiencies with and without the b-tagging scale factor using the full binomial expression.

$W + b\bar{b}$					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
$\epsilon_{b-jet}(\%)$	37.29 ± 0.56	40.71 ± 0.64	39.15 ± 0.84	41.91 ± 1.33	39.87 ± 2.76
$\epsilon_{c-jet}(\%)$	5.61 ± 3.16	0.00 ± 0.00	7.52 ± 2.29	9.42 ± 3.00	11.89 ± 5.62
$\epsilon_{b-jet} * SF(\%)$	33.90 ± 2.29	37.00 ± 2.51	35.59 ± 2.47	38.10 ± 2.79	36.24 ± 3.47
$\epsilon_{c-jet} * SF(\%)$	5.10 ± 2.95	0.00 ± 0.00	6.83 ± 2.27	8.57 ± 2.96	10.81 ± 5.31
$F_{1b}(\%)$	1.00 ± 0.30	1.40 ± 0.40	2.00 ± 0.50	2.20 ± 0.60	2.20 ± 0.60
$F_{2b}(\%)$	0.00 ± 0.00	1.40 ± 0.40	2.00 ± 0.50	2.60 ± 0.70	2.60 ± 0.70
WBB, 1B, 1 Tag (%)	35.04 ± 2.35	37.93 ± 2.38	39.38 ± 4.08	42.76 ± 3.46	39.59 ± 7.30
WBB, 2B, 1 Tag (%)	0.00 ± 0.00	57.86 ± 3.52	59.01 ± 4.28	60.50 ± 3.92	61.82 ± 5.10
WBB, 2B, 2 Tag (%)	0.00 ± 0.00	14.10 ± 1.93	16.06 ± 2.42	17.45 ± 2.83	14.53 ± 3.41
$\Phi_e^{\geq 1}(\%)$	90.90 ± 6.00	92.18 ± 5.24	92.11 ± 5.28	92.27 ± 5.18	92.24 ± 5.21
$\Phi_e^{\geq 2}(\%)$	0.00 ± 0.00	82.63 ± 10.91	82.78 ± 11.06	83.08 ± 11.37	83.46 ± 11.77
$\epsilon_{\geq 1}(\%)$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{\geq 2}$ (%)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\epsilon_{\geq 1} * \Phi_e$ (%)	0.35 ± 0.11	1.34 ± 0.39	1.96 ± 0.50	2.50 ± 0.69	2.46 ± 0.68
$\epsilon_{\geq 2} * \Phi_e(\%)$	0.00 ± 0.00	0.20 ± 0.06	0.32 ± 0.09	0.45 ± 0.14	0.38 ± 0.11
$\epsilon_{bjet}(\%)$				0.00 ± 0.00	
$\epsilon_{cjet}(\%)$				0.00 ± 0.00	
$\epsilon_{bjet} * SF(\%)$				0.00 ± 0.00	
$\epsilon_{cjet} * SF(\%)$				0.00 ± 0.00	
$\epsilon_{\geq 1}(\%)$				0.00 ± 0.00	
$\epsilon_{\geq 2}(\%)$				0.00 ± 0.00	
$\Phi_E^1(\%)$				100.00 ± 0.00	
$\Phi_E^2(\%)$				100.00 ± 0.00	
$\epsilon_{\geq 1}(\%) * \Phi_E^1$				100.00 ± 0.00	
$\epsilon_{\geq 2}(\%) * \Phi_E^2$				100.00 ± 0.00	
CEM					
Pretag	157.64 ± 51.83	65.77 ± 21.69	13.38 ± 4.21	2.27 ± 1.02	0.03 ± 0.11
$\geq$ 1+ Tag	55.24 ± 18.56	31.48 ± 10.56	6.57 ± 2.11	1.18 ± 0.54	0.01 ± 0.05
$\geq$ 2+ Tag	0.00 ± 0.00	4.64 ± 1.66	1.07 ± 0.37	0.21 ± 0.10	0.00 ± 0.01
CMUP					
Pretag	79.73 ± 25.18	31.11 ± 9.66	5.64 ± 1.77	0.66 ± 0.35	0.08 ± 0.07
$\geq$ 1+ Tag	27.94 ± 9.03	14.89 ± 4.71	2.77 ± 0.89	0.34 ± 0.19	0.04 ± 0.04
$\geq$ 2+ Tag	0.00 ± 0.00	2.19 ± 0.74	0.45 ± 0.16	0.06 ± 0.04	0.01 ± 0.01
CMX					
Pretag	44.41 ± 13.35	18.29 ± 5.30	3.28 ± 0.88	0.33 ± 0.14	0.13 ± 0.05
$\geq$ 1+ Tag	15.56 ± 4.79	8.75 ± 2.59	1.61 ± 0.44	0.17 ± 0.07	0.07 ± 0.03
$\geq$ 2+ Tag	0.00 ± 0.00	1.29 ± 0.41	0.26 ± 0.08	0.03 ± 0.01	0.01 ± 0.00
Total					
Pretag	281.77 ± 90.36	115.18 ± 36.64	22.29 ± 6.85	3.26 ± 1.51	0.24 ± 0.23
$\geq$ 1 Tag	98.74 ± 32.37	55.13 ± 17.85	10.94 ± 3.44	1.70 ± 0.79	0.12 ± 0.12
$\geq$ 2 Tag	0.00 ± 0.00	8.12 ± 2.82	1.79 ± 0.61	0.31 ± 0.15	0.02 ± 0.02

Table 26: Summary table for the W+BB background. F_{ib} is the heavy flavor fraction measured from [8], and the efficiencies given are the event tag rates in Monte Carlo. Φ_E is the ratio of event efficiencies with and without the b-tagging scale factor using the full binomial expression.

Non-W : Raw Counts					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
Electrons					
N_A^{pre}	101832	12862	1773	189	30
N_B^{pre}	63472	5328	612	87	11
N_C^{pre}	2853	889	175	37	9
N_D^{pre}	17643	2845	468	114	19
N_A^{+}	3017	714	161	23	5
N_B^{+}	1032	187	44	11	2
N_C^{+}	139	87	25	9	3
N_D^{+}	249	141	58	39	8
N_A^{++}	0	18	6	2	1
N_B^{++}	0	1	4	3	0
N_C^{++}	0	3	3	1	0
N_D^{++}	0	9	11	7	1
F_{Non-W} (%)	10.08 $\pm$ 2.53	12.94 $\pm$ 3.28	13.11 $\pm$ 3.48		
N_+^B/N_+^A (%)	34.21 $\pm$ 1.23	26.19 $\pm$ 2.15	30.16 $\pm$ 4.56		
$N_+^{tagmethod}$	47.55 $\pm$ 16.29	22.79 $\pm$ 8.12	7.54 $\pm$ 3.12	2.71 $\pm$ 1.34	0.90 $\pm$ 0.62
R_+^B (%)	1.63 $\pm$ 0.33	3.51 $\pm$ 0.75	7.19 $\pm$ 1.82	12.64 $\pm$ 4.77	18.18 $\pm$ 14.44
$N_+^{pretagmethod}$	28.92 $\pm$ 9.32	12.93 $\pm$ 4.28	4.42 $\pm$ 1.62	1.91 $\pm$ 0.88	0.45 $\pm$ 0.38
R_{++}^B (%)	0.00 $\pm$ 0.00	0.02 $\pm$ 0.02	0.65 $\pm$ 0.35	3.45 $\pm$ 2.14	0.00 $\pm$ 0.00
$N_{++}^{pretagmethod}$	0.00 $\pm$ 0.00	0.07 $\pm$ 0.07	0.40 $\pm$ 0.24	0.52 $\pm$ 0.35	0.00 $\pm$ 0.00
Muons					
N_A^{pre}	39078	5565	709	90	19
N_B^{pre}	12008	976	119	18	2
N_C^{pre}	1586	489	128	32	8
N_D^{pre}	12977	1919	297	63	16
N_A^{+}	2345	583	89	15	4
N_B^{+}	229	52	12	6	1
N_C^{+}	85	50	25	12	2
N_D^{+}	182	100	36	24	11
N_A^{++}	0	13	1	0	0
N_B^{++}	0	1	2	0	1
N_C^{++}	0	3	2	1	1
N_D^{++}	0	5	6	9	2
F_{Non-W} (%)	3.76 $\pm$ 0.94	4.47 $\pm$ 1.15	7.59 $\pm$ 2.14		
N_+^B/N_+^A (%)	9.77 $\pm$ 0.68	8.92 $\pm$ 1.29	17.59 $\pm$ 4.38		
$N_+^{tagmethod}$	8.30 $\pm$ 2.94	4.46 $\pm$ 1.73	4.40 $\pm$ 2.02	2.11 $\pm$ 1.06	0.35 $\pm$ 0.29
R_+^B (%)	1.91 $\pm$ 0.40	5.33 $\pm$ 1.31	10.08 $\pm$ 3.66	33.33 $\pm$ 17.07	50.00 $\pm$ 62.05
$N_+^{pretagmethod}$	9.30 $\pm$ 3.05	4.63 $\pm$ 1.65	2.30 $\pm$ 1.06	1.62 $\pm$ 0.95	0.65 $\pm$ 0.82
R_{++}^B (%)	0.00 $\pm$ 0.00	0.10 $\pm$ 0.10	1.68 $\pm$ 1.24	0.00 $\pm$ 0.00	50.00 $\pm$ 62.05
$N_{++}^{pretagmethod}$	0.00 $\pm$ 0.00	0.09 $\pm$ 0.09	0.38 $\pm$ 0.30	0.00 $\pm$ 0.00	0.65 $\pm$ 0.82
Electrons					
Pretag	1778.78 $\pm$ 446.23	368.39 $\pm$ 93.37	61.47 $\pm$ 16.33	15.07 $\pm$ 4.00	2.49 $\pm$ 0.66
$\geq$ 1+ Tag	33.52 $\pm$ 8.04	15.07 $\pm$ 3.77	5.08 $\pm$ 1.43	2.15 $\pm$ 0.73	0.58 $\pm$ 0.32
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.07 $\pm$ 0.07	0.40 $\pm$ 0.24	0.52 $\pm$ 0.35	0.00 $\pm$ 0.00
Muons					
Pretag	487.46 $\pm$ 122.66	86.92 $\pm$ 22.38	22.78 $\pm$ 6.42	4.86 $\pm$ 1.37	1.29 $\pm$ 0.36
$\geq$ 1+ Tag	8.78 $\pm$ 2.09	4.55 $\pm$ 1.19	2.75 $\pm$ 0.94	1.84 $\pm$ 0.70	0.38 $\pm$ 0.27
$\geq$ 2+ Tag	0.00 $\pm$ 0.00	0.09 $\pm$ 0.09	0.38 $\pm$ 0.30	0.00 $\pm$ 0.00	0.38 $\pm$ 0.82

Table 27: Raw event counts for Non-W backgrounds.

$t\bar{t}$ (8.9 pb)					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
Electrons					
N_A^{pre}	0.03 ± 0.00	0.18 ± 0.02	0.51 ± 0.05	0.69 ± 0.06	0.64 ± 0.06
N_B^{pre}	0.28 ± 0.02	1.52 ± 0.14	3.55 ± 0.32	3.30 ± 0.30	1.14 ± 0.10
N_C^{pre}	0.88 ± 0.08	3.40 ± 0.30	4.96 ± 0.44	2.83 ± 0.25	1.38 ± 0.13
N_D^{pre}	5.43 ± 0.48	28.44 ± 2.55	55.32 ± 4.95	50.15 ± 4.49	15.51 ± 1.41
N_A^{+}	0.01 ± 0.00	0.08 ± 0.01	0.22 ± 0.02	0.27 ± 0.03	0.26 ± 0.03
N_B^{+}	0.09 ± 0.01	0.81 ± 0.09	2.03 ± 0.21	2.06 ± 0.21	0.72 ± 0.07
N_C^{+}	0.28 ± 0.03	1.47 ± 0.16	2.55 ± 0.27	1.54 ± 0.16	0.79 ± 0.08
N_D^{+}	1.82 ± 0.21	14.46 ± 1.54	31.64 ± 3.31	31.23 ± 3.22	9.78 ± 1.02
N_A^{++}	0.00 ± 0.00	0.01 ± 0.00	0.03 ± 0.01	0.03 ± 0.00	0.03 ± 0.01
N_B^{++}	0.00 ± 0.00	0.17 ± 0.03	0.50 ± 0.08	0.57 ± 0.09	0.22 ± 0.03
N_C^{++}	0.00 ± 0.00	0.13 ± 0.02	0.51 ± 0.08	0.35 ± 0.06	0.15 ± 0.02
N_D^{++}	0.00 ± 0.00	2.67 ± 0.44	7.26 ± 1.19	8.86 ± 1.43	2.92 ± 0.47
Muons					
N_A^{pre}	0.02 ± 0.00	0.17 ± 0.02	0.46 ± 0.04	0.64 ± 0.06	0.49 ± 0.04
N_B^{pre}	0.17 ± 0.01	1.22 ± 0.11	2.76 ± 0.25	2.77 ± 0.25	0.79 ± 0.07
N_C^{pre}	0.70 ± 0.06	2.75 ± 0.25	4.49 ± 0.40	2.83 ± 0.25	1.13 ± 0.10
N_D^{pre}	3.77 ± 0.34	21.11 ± 1.89	41.33 ± 3.70	36.22 ± 3.24	11.12 ± 1.01
N_A^{+}	0.01 ± 0.00	0.08 ± 0.01	0.21 ± 0.02	0.30 ± 0.03	0.23 ± 0.02
N_B^{+}	0.05 ± 0.01	0.60 ± 0.06	1.63 ± 0.17	1.70 ± 0.17	0.48 ± 0.05
N_C^{+}	0.23 ± 0.03	1.23 ± 0.13	2.37 ± 0.25	1.58 ± 0.16	0.64 ± 0.07
N_D^{+}	1.26 ± 0.14	10.73 ± 1.14	23.64 ± 2.47	22.55 ± 2.32	7.02 ± 0.73
N_A^{++}	0.00 ± 0.00	0.01 ± 0.00	0.04 ± 0.01	0.04 ± 0.01	0.02 ± 0.00
N_B^{++}	0.00 ± 0.00	0.11 ± 0.02	0.43 ± 0.07	0.51 ± 0.08	0.15 ± 0.02
N_C^{++}	0.00 ± 0.00	0.17 ± 0.03	0.49 ± 0.08	0.33 ± 0.05	0.16 ± 0.03
N_D^{++}	0.00 ± 0.00	1.98 ± 0.33	5.42 ± 0.89	6.40 ± 1.03	2.10 ± 0.34

Table 28: Expectation of $t\bar{t}$ in Non-W sideband regions.

Non-W					
	1 jet	2 jets	3 jets	4 jets	$\geq$ 5 jets
Electrons					
N_A^{pre}	101831.97 ± 319.11	12861.82 ± 113.41	1772.49 ± 42.11	188.31 ± 13.75	29.36 ± 5.48
N_B^{pre}	63471.72 ± 251.94	5326.48 ± 72.99	608.45 ± 24.74	83.70 ± 9.33	9.86 ± 3.32
N_C^{pre}	2852.12 ± 53.41	885.60 ± 29.82	170.04 ± 13.24	34.17 ± 6.09	7.62 ± 3.00
N_D^{pre}	17643.00 ± 132.83	2845.00 ± 53.34	468.00 ± 21.63	114.00 ± 10.68	19.00 ± 4.36
N_A^+	3016.99 ± 54.93	713.92 ± 26.72	160.78 ± 12.69	22.73 ± 4.80	4.74 ± 2.24
N_B^+	1031.91 ± 32.12	186.19 ± 13.68	41.97 ± 6.64	8.94 ± 3.32	1.28 ± 1.42
N_C^+	138.72 ± 11.79	85.53 ± 9.33	22.45 ± 5.01	7.46 ± 3.00	2.21 ± 1.73
N_D^+	247.18 ± 15.78	126.54 ± 11.97	26.36 ± 8.30	7.77 ± 7.02	-1.78 ± 3.01
N_A^{++}	0.00 ± 0.00	18.30 ± 4.50	6.52 ± 2.73	2.47 ± 1.75	1.54 ± 1.19
N_B^{++}	0.00 ± 0.00	1.40 ± 1.18	4.06 ± 2.22	2.75 ± 1.98	0.53 ± 0.53
N_C^{++}	0.00 ± 0.00	3.10 ± 2.08	2.80 ± 2.00	1.22 ± 1.18	0.56 ± 0.56
N_D^{++}	0.00 ± 0.00	6.90 ± 3.23	4.32 ± 3.24	0.88 ± 0.88	0.24 ± 0.24
F_{Non-W} (%)	10.08 ± 2.53	12.89 ± 3.27	12.43 ± 3.37		
N_+^B/N_+^A (%)	34.20 ± 1.23	26.08 ± 2.15	27.73 ± 4.50		
$N_+^{tagmethod}$	47.45 ± 16.27	22.31 ± 8.01	6.23 ± 2.78	2.07 ± 1.17	0.61 ± 0.54
R_+^B (%)	1.63 ± 0.33	3.50 ± 0.75	6.90 ± 1.80	10.68 ± 4.76	13.02 ± 15.34
$N_+^{pretagmethod}$	28.91 ± 9.32	12.82 ± 4.26	4.02 ± 1.52	1.53 ± 0.80	0.31 ± 0.37
R_{++}^B (%)	0.00 ± 0.00	0.03 ± 0.02	0.67 ± 0.39	3.28 ± 2.49	5.40 ± 5.81
$N_{++}^{pretagmethod}$	0.00 ± 0.00	0.10 ± 0.09	0.39 ± 0.25	0.47 ± 0.38	0.13 ± 0.14
Muons					
N_A^{pre}	39077.98 ± 197.68	5564.83 ± 74.60	708.54 ± 26.63	89.36 ± 9.49	18.51 ± 4.36
N_B^{pre}	12007.83 ± 109.58	974.78 ± 31.24	116.24 ± 10.91	15.23 ± 4.25	1.21 ± 1.42
N_C^{pre}	1585.30 ± 39.82	486.25 ± 22.11	123.51 ± 11.32	29.17 ± 5.66	6.87 ± 2.83
N_D^{pre}	12977.00 ± 113.92	1919.00 ± 43.81	297.00 ± 17.23	63.00 ± 7.94	16.00 ± 4.00
N_A^+	2344.99 ± 48.43	582.92 ± 24.15	88.79 ± 9.43	14.70 ± 3.87	3.77 ± 2.00
N_B^+	228.95 ± 15.13	51.40 ± 7.21	10.37 ± 3.47	4.30 ± 2.46	0.52 ± 1.00
N_C^+	84.77 ± 9.22	48.77 ± 7.07	22.63 ± 5.01	10.42 ± 3.47	1.36 ± 1.42
N_D^+	180.74 ± 13.49	89.27 ± 10.06	12.36 ± 6.49	1.45 ± 5.42	3.98 ± 3.40
N_A^{++}	0.00 ± 0.00	13.49 ± 4.09	2.17 ± 1.34	1.26 ± 0.89	1.27 ± 0.90
N_B^{++}	0.00 ± 0.00	2.12 ± 1.33	2.83 ± 1.79	1.02 ± 0.73	2.12 ± 1.32
N_C^{++}	0.00 ± 0.00	3.91 ± 2.11	2.66 ± 1.67	1.92 ± 1.33	2.07 ± 1.33
N_D^{++}	0.00 ± 0.00	4.27 ± 2.53	2.60 ± 2.06	4.21 ± 2.85	1.76 ± 1.43
F_{Non-W} (%)	3.75 ± 0.94	4.44 ± 1.15	6.90 ± 2.01		
N_+^B/N_+^A (%)	9.76 ± 0.68	8.82 ± 1.29	14.17 ± 4.30		
$N_+^{tagmethod}$	8.28 ± 2.93	4.30 ± 1.69	3.21 ± 1.68	1.48 ± 0.86	0.19 ± 0.22
R_+^B (%)	1.91 ± 0.40	5.27 ± 1.30	8.92 ± 3.64	28.26 ± 19.00	42.85 ± 96.97
$N_+^{pretagmethod}$	9.29 ± 3.05	4.55 ± 1.63	1.85 ± 0.93	1.25 ± 0.92	0.50 ± 1.15
R_{++}^B (%)	0.00 ± 0.00	0.22 ± 0.14	2.43 ± 1.63	6.71 ± 5.33	174.42 ± 235.07
$N_{++}^{pretagmethod}$	0.00 ± 0.00	0.19 ± 0.13	0.50 ± 0.37	0.30 ± 0.25	2.04 ± 2.83
Electrons					
Pretag	1778.22 ± 446.14	366.89 ± 93.13	58.31 ± 15.80	14.30 ± 3.87	2.36 ± 0.64
$\geq$ 1+ Tag	33.49 ± 8.04	14.91 ± 3.74	4.53 ± 1.33	1.70 ± 0.66	0.41 ± 0.31
$\geq$ 2+ Tag	0.00 ± 0.00	0.10 ± 0.09	0.39 ± 0.25	0.47 ± 0.38	0.13 ± 0.14
Muons					
Pretag	487.24 ± 122.62	86.33 ± 22.28	20.69 ± 6.04	4.41 ± 1.29	1.17 ± 0.34
$\geq$ 1+ Tag	8.76 ± 2.09	4.43 ± 1.17	2.17 ± 0.82	1.37 ± 0.62	0.20 ± 0.22
$\geq$ 2+ Tag	0.00 ± 0.00	0.19 ± 0.13	0.50 ± 0.37	0.30 ± 0.25	0.20 ± 2.83

Table 29: Non-W expectation, removing $t\bar{t}$.

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