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Measurement of the Top Pair Production Cross Section in the Lepton Plus Jets Decay Channel with Loose SecVtx

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Abstract

We present here a measurement of the top quark pair production cross section using the loose SecVtx secondary vertex tagger on 318 pb^{-1} of data. We calculate the detector acceptance for top quark events in the lepton+jets decay mode, and we use the Method II approach to calculate expected backgrounds to both single- and double-tagged top signal events. For the standard event selection, we measure cross sections of $8.6^{+1.0}_{-0.9}$(stat)$^{+1.3}_{-1.1}$(syst) pb for single-tags and $9.5^{+1.5}_{-1.4}$(stat)$^{+2.1}_{-1.5}$(syst) pb for double-tags. After applying additional requirements on the H_T and W transverse mass, we measure $8.7^{+0.9}_{-0.9}$(stat)$^{+1.2}_{-0.9}$(syst) pb for single-tags and $10.1^{+1.6}_{-1.4}$(stat)$^{+2.1}_{-1.4}$(syst) pb for double-tags.

Contents

1 Introduction

The top quark cross section and mass are still among the most relevant measurements that can be made at the TeVatron. As Run II has already gathered and processed almost three times as much data as Run I, these analyses are also no longer statistically limited. One way to take full advantage of this new statistical power is to move to fully reconstructed $t\bar{t}$ events, where we require tags on both b's in each event. The cross section has already been measured in Gen4 with the default tagger using doubly-tagged events, and the mass measurement is pulled strongly by these events as well.

The background to top in the double-tagged sample is sufficiently small that we would be willing to suffer an increase in background for even a modest increase in efficiency. The SecVtx b-tagger was re-engineered in Gen4 for exactly this purpose. In CDF6983 [9], an increase of 40% in the top signal was observed by using the loosened tagger for a double-tagged analysis. The loose tagger has been optimized again in Gen5, and the cross section analysis has been repeated. Here, we present results for both the inclusive and double-tagged top production cross section.

The cross section is calculated using the following formula:

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{(\Phi_e \epsilon_{tag})\, \epsilon_{pretag} \int \mathcal{L}dt}$$

- N_{obs}: Number of events in data passing event selection
- N_{bkg}: Number of non-$t\bar{t}$ events expected to pass event selection
- ϵ_{tag}: Efficiency to tag ≥ 1 or ≥ 2 jets in Monte Carlo
- Φ_e: Ratio of event tagging efficiencies in the data and Monte Carlo
- ϵ_{pretag}: $t\bar{t}$ acceptance (geometric acceptance and event selection efficiency)
- $\int \mathcal{L}dt$: Integrated luminosity

In some cases, the background estimate will depend on the assumed top cross section. We therefore assume an initial cross section of 6.1 pb (which corresponds to the 178 GeV top mass in the Pythia simulation), and iterate until the resulting cross section is stable. In this note, we discuss the loose SecVtx tagger in Section 2, the signal expectation (denominator) in Section 4, and the data and backgrounds (numerator) in Sections 3 and 5. Final results are presented in Section 7. Summary tables will be presented with the text, but more information on most calculations can be found in Appendix E.

2 Loose SecVtx

The SecVtx tagger is used to explicitly reconstruct heavy flavor decay vertices inside jets. After selecting a subset of tracks (based on track momentum, silicon information, and displacement from the interaction point), the tagger uses CTVMFT to fit pairs of tracks together, then cuts on the two-dimensional distance from the vertex to the origin (in the jet direction) and the quality of the fit. The strategy for loosening the tagger was to slacken the track requirements (since the vertexing efficiency is roughly combinatoric in the number of tracks) and tighten the vertex quality (χ^2 and L_{2d} significance). The expense of this strategy is a rapidly increasing negative tag rate, which constitutes a lack of heavy-flavor purity in the tagged sample. In this analysis, however, the background remains small enough not to compromise the quality of the measurement. The High-p_T b-Tag group has now characterized the performance of the loosened SecVtx tagger alongside the default (*tight*) configuration, and most results are presented in parallel. The parameters used in the Gen5 tagger are shown in Table 1 for comparison, and we briefly summarize the important tagger properties in Sections 2.1 and 2.2.

		Loose				Tight	
		Gen4		Gen5		Gen5	
		pass 1	pass 2	pass 1	pass 2	pass 1	pass 2
Use L00	$>$	no		yes		yes	
Use IO tracks	$>$	no		yes		yes	
COT cuts	$>$	defTracks		defTracks		defTracks	
SVX layers	$>$	3		2	3	3	
Track-χ^2	$>$	10.		8.0		8.0	
Δ track-z_0 (cm)	$<$	5.0		2.0		2.0	
Track-d_0 (cm)	$<$	0.15		0.15		0.15	
Track-p_T (GeV)	$>$	0.5	1.0	0.5	1.0	0.5	1.0
Track-d_0 Sign.	$>$	2.5	3.0	2.0	3.0	2.0	3.5
Attachment cut d_0 Sig.	$<$	4.0	–	6.0	–	3.0	–
Seed Vertex χ^2	$>$	50					
At lest one Track-p_T (GeV)	$>$	1.0	1.5	1.0	1.5	1.0	1.5
Track prune χ^2	$>$	1000	1000	90	1000	45	30
Vertex fit χ^2	$<$	2000	2000	120	2000	50	
Lifetime track χ^2	$<$	50					
L_{xy} Significance	$>$	3.0		6.0		7.5	
TryHarderPass1		no		yes		yes	
Material Removal		no		no		yes	

Table 1: Comparison of parameters for the Gen4 and Gen5 loose SecVtx taggers and the Gen5 tight tagger.

2.1 Scale Factor

A Method II top analysis requires a Monte Carlo simulation to determine the expected top contribution to the pretag and tagged data samples. While we trust the simulation to get many of the low-level properties of top events correct, such as the missing E_T and lepton energy, we apply various *scale factors* to correct the acceptance and tagging efficiency observed in Monte Carlo (see Section 4). We assume a single *b-tagging scale factor* (SF) adequately corrects the MC efficiency to tag a bottom-quark jet; that is, we assume the dependence of the efficiency on jet energy, η, ϕ, Z, etc., are well-modeled in simulation, but the overall value is overestimated. The discrepancy most likely arises from a tracking inefficiency in data that is not reproduced in simulation, or in omissions to the simulation like underlying event tracks.

This scale factor is measured in both the 8-GeV electron and 8-GeV muon samples. The first method uses electrons with and without conversion as corresponding light and heavy flavor samples and measures the tag rate differences to determine the efficiency. The second determines the b content of the sample by performing p_T^{rel} fits (μ relative to the jet axis) and extracts the absolute tag rate in those events. For Gen5, these measurements were merged for the first time, yielding an average value of 0.927 ± 0.066 for the loose tagger [1]. The separate measurements and a comparison with Gen4 are shown in Table 2. We use the same SF with double uncertainty for charm jets, since it is difficult to get a charm-enriched sample in data (without enriching the b content as well). The scale factor is the largest systematic in the double-tag analysis (where the error is applied twice), though its effect on the single-tag cross section is mitigated by the presence of multiple heavy-flavor jets. This will be discussed at more length in Section 4.2.

	Electron Method		Muon Method
	Gen4	Gen5	Gen5
Data ϵ	0.285 ± 0.007	0.317 ± 0.007	0.460 ± 0.011
MC ϵ	0.340 ± 0.010	0.354 ± 0.011	0.492 ± 0.002
SF	0.838 ± 0.024	0.895 ± 0.028	0.934 ± 0.022

Table 2: Summary of data and MC efficiencies in the scale factor samples.

2.2 Mistag Rates

An important figure of merit for tagger performance is the mistag rate, the rate at which light-flavor jets are falsely identified as b's. These tags can come from imperfect detector resolution (mismeasured prompt tracks), material interactions (conversion electrons or nuclear stars), or real displaced decays of light particles (K_s's and Λ's). Since the first of these sources is symmetric, a first-order estimate of the mistag contamination is simply the number of negative tags (vertices constructed *behind* the interaction point). The Gen5 SecVtx re-optimization tuned the tagger performance based on the b-jet efficiency in top MC and this negative tag rate in generic jets; for the loose tagger, the objective was to get as high an efficiency as possible while keeping the mistags at roughly 1%. These rates for the tight and loose taggers are shown in Table 3. The expense of increased efficiency over the tight tagger is a factor of nearly three in the negative tag rate.

Mistags also contribute an important background to the cross section measurement. To determine the contribution from mistagged events, we use a *mistag matrix*, which parametrizes the generic jet tag rate in terms of the jet energy, η, ϕ, N_{tracks}, and the sum of the transverse energy in the event. The tag matrices for both the tight and loose taggers are described in depth in CDF7326 [10], and the background measurement is described in Section 5.4. Plots of the predicted and observed tag rates versus jet energy and η in the ΣE_T sample are shown in Figures 1 and 2.

Negative tag in Jet50 data (%)			
	Tight	Loose	Increase
Gen4	0.362 ± 0.003	1.193 ± 0.005	3.3x
Gen5	0.478 ± 0.003	1.195 ± 0.004	2.5x
Increase	32 %	0 %	

Table 3: Overall negative tag rate in generic jet data. The Gen5 loose tagger configuration was selected to maximize the efficiency without increasing the mistag rate.

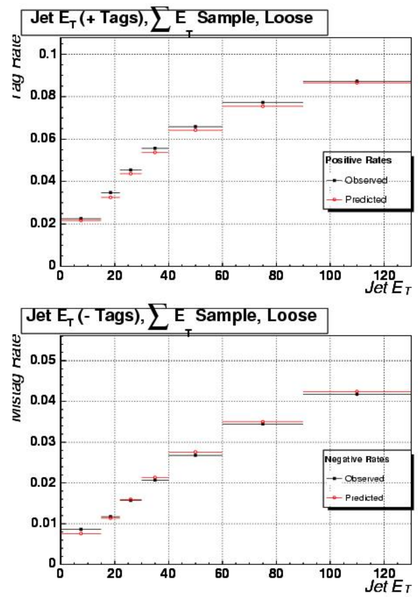

Figure 1: Predicted and observed tag rates in the ΣE_T sample versus jet E_T.

3 Event Selection

We use the full dataset up to the September 2004 shutdown, which includes roughly 318.5 pb^{-1} of data. This dataset excludes runs 179057-186598 (compromised COT) altogether and runs prior to 150145 for the CMX (305.2 pb^{-1}). We use good run list version 7.0, requiring good silicon for tagging, applied to datasets `bhel0d` and `bhmu0d` for tight electrons and muons, respectively. The event selection is identical to the official Lepton + Jets selection, outlined in CDF7372 [5].

In short, we require jets to have corrected energy (Level 4, `JetClu` 0.4) above 15 GeV and η<2.0, leptons to have E_T (electrons) or p_T (muons) above 15 GeV and isolation energy less than 10% of their own energy, and missing E_T to be over 20 GeV (also at Level 4). Additional vetoes are applied for cosmic rays, conversions, dileptons, and Z decays. The signal region consists of events with exactly one tight lepton and three or more jets; the one- and two-jet bins are considered a control region. The inclusive analysis also requires that *at least one* jet be tagged, and the double-tag analysis requires *at least two* tags. The tagged samples are therefore not statistically independent, so combination is not straightforward. An attempt at handling this is in Section 8.

Additional cuts on the event H_T (scalar sum of all transverse energy, muon momenta, and missing energy) for 3 or more jets and m_T^W (invariant mass of the lepton and missing energy) have been shown to improve the fractional error on the cross section measurement [6]; the H_T cut appears optimal at close to

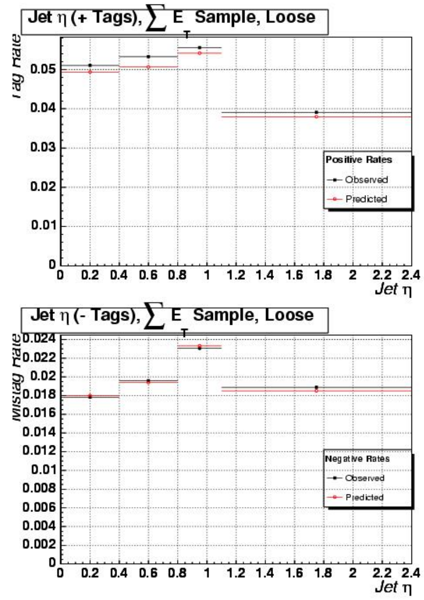

Figure 2: Predicted and observed tag rates in the ΣE_T sample versus jet η.

200 GeV for this analysis as well (Figure 3), and the m_T^W cut is near 20 GeV/c^2 (Figure 4). More effort was devoted to investigating these cuts for the tight tagger, and we have no clear indication that we can gain substantially by adjusting them; in fact, it is vital that these analyses be as similar as possible for purposes of comparison. We will therefore present separate results for this alternate selection (H_T/m_T^W together) in parallel, referred to as the *optimized* selection. Unless otherwise noted, however, numbers correspond to the *unoptimized* analysis. More optimization studies for the loose tagger are presented in Appendix D.2.

Our tagged dataset is not a strict superset of the tight tagger dataset. Three jets were tagged with standard SecVtx and not with the loose tagger. None of these three was part of a double-tagged event. A full summary of the unoptimized data counts is shown in Table 4. Run and event numbers for tight and loose tags are listed in Appendix B.

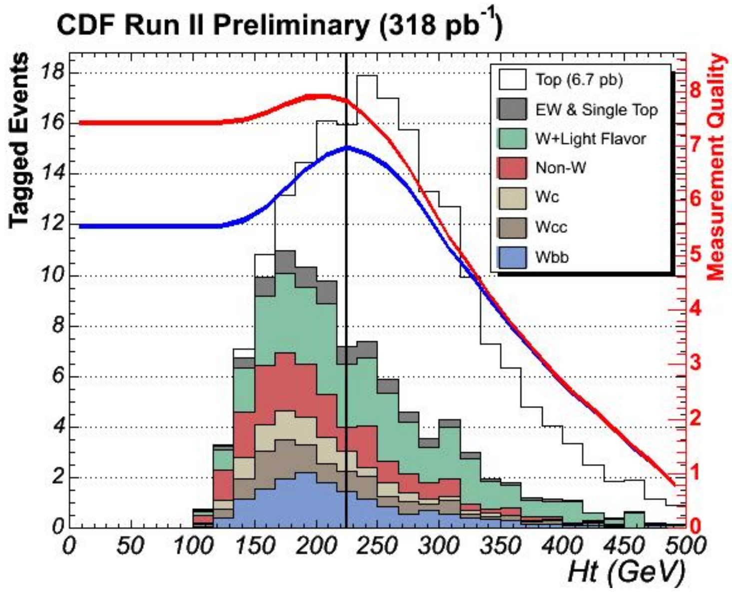

Figure 3: Optimization of the H_T cut for the single-tag analysis.

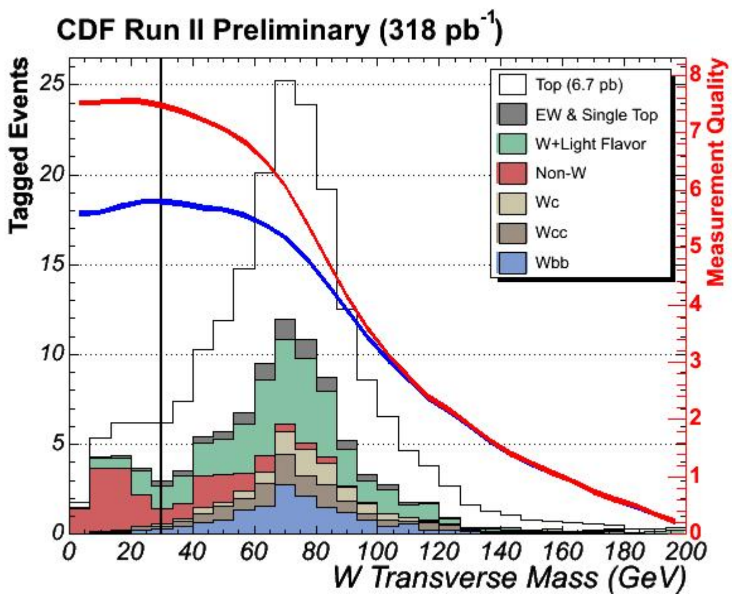

Figure 4: Optimization of the m_T^W cut for the single-tag analysis.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
CEM					
Pretag	17648	2846	469	115	19
≥1 Tag	447	212	78	47	12
≥2 Tags	0	20	18	12	2
CMUP					
Pretag	8514	1263	202	46	11
≥1 Tag	177	98	35	23	8
≥2 Tags	0	11	7	10	2
CMX					
Pretag	4466	682	98	18	6
≥1 Tag	106	52	14	8	4
≥2 Tags	0	0	2	4	2
Total					
Pretag	30628	4791	769	179	36
≥1 Tag	730	362	127	78	24
≥2 Tags	0	31	27	26	6

Table 4: Data counts in the pretag and tagged samples with no H_T or m_T cut.

3.1 Overlap with Tight Tagger

Since the track selection and vertex cuts were both changed to loosen the SecVtx tagger, the loose-tagged sample need not be a strict superset of the tight-tagged sample. In Gen5, there are 15 events that have one tight tag and no loose tags, three of which are in the signal region. Every tight double-tag is a loose double-tag as well. Tables 5 and 6 show the exact counts for all combinations of tight and loose tags. These results are summed over all lepton types and ≥3 jets.

	Tight		
	Untagged	1 Tag	≥2 Tags
≥2 Loose Tags	4	19	36
1 Loose Tag	51	119	0
Loose Untagged	752	3	0

Table 5: Correlations in number of tight and loose tags in data for the unoptimized selection.

	Tight		
	Untagged	1 Tag	≥2 Tags
≥2 Loose Tags	727	7021	17177
1 Loose Tag	7502	36093	388
Loose Untagged	26339	476	2

Table 6: Correlations in number of tight and loose tags in top Monte Carlo for the unoptimized selection.

4 Signal Expectation

As discussed in the Introduction, we quantify the top expectation (as a function of the cross section) in two distinct parts: the acceptance (including the geometric acceptance and pretag efficiency) and the tagging efficiency. The former determines the top content of the pretag sample, and the latter is the rate at which these events become tagged. The next two subsections are devoted to the calculation of these two quantities.

4.1 Acceptance

All signal estimates (acceptance and efficiency) are based on a Pythia $t\bar{t}$ sample generated with a top mass of 178 GeV/c^2 (`ttopel`). We apply our event selection directly to the simulation as a first-order estimate of the acceptance, which is calculated separately in each jet bin (merging ≥5 jets) and sorted by tight lepton; we accept only events where the lepton is a muon in the CMUP or CMX or an electron in the CEM. Plug electrons and BMU muons are rejected.

The Monte Carlo sample is generic $t\bar{t}$, so no additional restriction is placed on the top decay channel at simulation. A nominal *lepton+jets* event will have exactly one lepton and four jets, but other decays may enter the pretag sample (such as a dilepton event where one jet is lost). As long as these events are modelled reasonably in the Monte Carlo, the top branching ratio is explicitly taken into account here.

In principle, then, the acceptance is simply the fraction of simulated events that reach the pretag stage in our event selection. Depending on the lepton detector, though, this rate is corrected for some known limitations in the Monte Carlo; the efficiency to identify a lepton and the Z vertex-finding efficiency, for example, are adjusted by applying additional *scale factors*, as presented to the Joint Physics Group [15]. A summary of these scale factors is in Table 7.

Scale Factors	
CEM	0.959
CMUP	0.794
CMX	0.954
Common	0.951

Table 7: A summary of scale factors applied to the pretag acceptances. The *Common Scale Factor* is an extra correction for all detectors.

The total number of events in each detector (before event selection) is scaled to $\sigma_{t\bar{t}} \int \mathcal{L}dt$, initially assuming a cross section of 6.1 pb; multiplying by the corrected acceptance gives an estimate of the number of events in the pretag sample. We put no uncertainty on the cross section at this stage. The total luminosity-weighted acceptance in the signal region (in units of events per pb), is 23.5 ± 3.1 for the unoptimized selection and 21.0 ± 3.0 for the optimized. A summary of acceptances and pretag estimates is given in Tables 8 and 9.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
CEM					
Raw Acceptance (%)	0.2	1.1	2.1	1.9	0.6
Pretag Expectation (6.1pb)	3.7 ± 0.3	19.5 ± 1.7	38.0 ± 3.4	34.4 ± 3.1	10.6 ± 0.9
CMUP					
Raw Acceptance (%)	0.1	0.7	1.4	1.2	0.4
Pretag Expectation (6.1pb)	2.0 ± 0.2	10.3 ± 1.2	20.3 ± 2.4	17.9 ± 2.2	5.5 ± 0.7
CMX					
Raw Acceptance (%)	0.0	0.2	0.5	0.4	0.1
Pretag Expectation (6.1pb)	0.7 ± 0.1	4.0 ± 0.5	7.8 ± 1.0	6.8 ± 0.9	2.1 ± 0.3

Table 8: Raw acceptances from Monte Carlo and pretag estimates for the unoptimized analysis.

4.2 Efficiency

For reasons outlined in Section 2.1, we can not assume the tagging efficiencies in Monte Carlo accurately reproduce the efficiencies in data. The b-tagging scale factor (SF) is the measured ratio of *single-jet, single b* tagging efficiencies in a low-E_T sample, but applying it to four-jet, two-b events is not straightforward. A summary of the matched MC efficiencies is shown in Table 10, which can be compared to the efficiencies in the scale factor sample in Table 2. We have implemented the *event scale factor* method first used in CDF6983 and more recently for the tight tagger in CDF7486 [9] [7].

This strategy divides the sample by number of jets, lepton type, and the heavy flavor content of the event (b, c, and light), matching jets to heavy flavor hadrons in a cone of 0.4. If we know the per-jet efficiency for each jet type, which we extract from MC truth information, it is straightforward to calculate the probability to tag *exactly* zero ($\epsilon^0_{MC}(b, c, light)$) or *exactly* one jet ($\epsilon^1_{MC}(b, c, light)$) in the event. After applying the requisite scale factors to the per-jet efficiencies, we can repeat the calculation to determine the data efficiencies ($\epsilon^0_{data}(b, c, light)$ and $\epsilon^0_{data}(b, c, light)$). The relevant event scale factors are then:

	1-jet	2-jet	3-jet	4-jet	≥5-jet
CEM					
Raw Acceptance (%)	0.2	1.1	1.8	1.8	0.6
Pretag Expectation (6.1pb)	3.6 ± 0.3	19.0 ± 1.7	31.7 ± 2.8	32.3 ± 2.9	10.2 ± 0.9
CMUP					
Raw Acceptance (%)	0.1	0.7	1.1	1.1	0.4
Pretag Expectation (6.1pb)	1.9 ± 0.2	9.9 ± 1.2	16.8 ± 2.0	16.6 ± 2.0	5.2 ± 0.6
CMX					
Raw Acceptance (%)	0.0	0.2	0.4	0.4	0.1
Pretag Expectation (6.1pb)	0.7 ± 0.1	3.9 ± 0.5	6.5 ± 0.8	6.5 ± 0.8	2.1 ± 0.3

Table 9: Raw acceptances from Monte Carlo and pretag estimates for the optimized analysis.

Quark	Tight SecVtx	Loose SecVtx	Jet Prob (1%)
Raw MC Tagger Efficiency (%)			
b	44.3 ± 0.3	52.3 ± 0.3	44.9 ± 0.3
c	9.6 ± 0.2	13.8 ± 0.3	10.6 ± 0.2
Data Efficiency (%)			
b	40.3 ± 2.7	48.5 ± 3.5	36.7 ± 3.1
c	8.7 ± 1.2	12.8 ± 1.8	8.7 ± 1.5

Table 10: A summary of tagging efficiencies for matched jets in Gen5 top Monte Carlo (178 GeV). The data efficiency simply includes the relevant tagging scale factor.

$$\Phi_{\geq 1} = \frac{1 - \epsilon^0_{data}(b, c, light)}{1 - \epsilon^0_{MC}(b, c, light)}$$

$$\Phi_{\geq 2} = \frac{1 - \epsilon^0_{data}(b, c, light) - \epsilon^1_{data}(b, c, light)}{1 - \epsilon^0_{MC}(b, c, light) - \epsilon^1_{MC}(b, c, light)}$$

A detailed binomial expansion of these terms is shown in CDF7486.

There are two sources of inaccuracy within this method: it does not account for correlations in tagging between jets in the same event, and it requires the light-flavor tag rate in data, which has not been measured. The former is a second-order effect, which is mitigated by the use of the event tag rate multiplied by a scale factor, rather than directly applying the measured efficiency. Correlations are therefore covered everywhere but in Φ, where there is only a subtle dependence on the per-jet efficiencies. In our signal Monte Carlo, the b and c efficiencies used are the same as those in Table 10, which are averaged over all heavy flavor jets in the sample.

The resolution for the second issue is a little trickier, and requires the measurement of a K-factor. The light-flavor tag rate is easily measured in Monte Carlo (although it does have some dependence on the matching efficiency), but a comparison with data is impossible. Rather than attempting to scale the MC tag rate directly, we run the negative mistag matrix (see Section 2.2) on the light jets in MC to approximate the equivalent data tag rate. The mistag rate is corrected for the heavy flavor in the matrix (using the α and β from Section 5.4), and the K-factor, which determines the ratio of mistag matrix predictions in data and MC, is applied.

The method for measuring the K-factor is identical to that in CDF6983 and CDF7486. For the central value, we compare the expected tag rates in Jet50 data and Monte Carlo, only looking at jets above the trigger threshold. This type of measurement is subject to several assumptions about the validity of the comparison; we choose to assign an inflated systematic based on an alternate, low-statistics method. We run the mistag matrix on the untagged jets in the double-tagged sample in data and top Monte Carlo, assuming the heavy-flavor content is more likely to agree between data and simulation. The deviation from unity is taken as an estimate of the uncertainty. For the loose tagger in Gen5, we measure a K factor of 0.88 $\pm$ 0.23. The per-jet mistag rate from top Monte Carlo is shown in Table 11 before K has been applied. The total event efficiency for the unoptimized and optimized cross sections is shown in Table 12, and a lepton comparison of efficiencies and acceptances is shown in Table 13.

	1-jet	2-jet	3-jet	4-jet	$\geq$5-jet
Per-jet mistag rate	0.012	0.014	0.016	0.017	0.017
Corrected light flavor tag rate	0.014	0.017	0.019	0.020	0.020

Table 11: Average light jet mistag matrix prediction in top MC before and after K, α, and β corrections. The actual tag rate for light jets in the simulation is 1.1%.

Loose SecVtx Event Efficiency (%)		
	$H_T > 0$, $M_T^W > 0$	$H_T > 200$, $M_T^W > 20$
$\geq$ 1-Tag efficiency	68 $\pm$ 5	69 $\pm$ 5
$\geq$ 2-Tag efficiency	23 $\pm$ 3	24 $\pm$ 3
Tight SecVtx Event Efficiency (%)		
$\geq$ 1-Tag efficiency	59 $\pm$ 3	60 $\pm$ 3
$\geq$ 2-Tag efficiency	15 $\pm$ 2	16 $\pm$ 2
Approximate Event Efficiency Gain		
$\geq$ 1-Tag efficiency	15 %	
$\geq$ 2-Tag efficiency	50 %	

Table 12: The final event tagging efficiencies for the single-tag and double-tag cross section measurements. All relevant scale factors have been applied.

5 Backgrounds

In addition to real $t\bar{t}$ production, other physics processes have a signature consistent with our event selection. We consider four main categories of background for this analysis: generic QCD with a faked W, real W's with light flavor tags (mistags), W's produced in association with real heavy flavor, and diboson and single top production. These backgrounds and the methods for their evaluation are described in detail in the following subsections.

5.1 Non-W

The pretag requirements of an identified lepton and large missing energy enhance the W content of the pretag sample, but some events can pass these requirements without a real W. Fake W's can come from conversions (electrons) or mis-identified pions (muons), and additional real leptons from off-shell W's can

	Electrons	Muons
Trigger Efficiency	0.959 $\pm$ 0.015	0.877 $\pm$ 0.015
Unoptimized		
Pretag Acceptance (/pb)	13.6 $\pm$ 1.2	10.1 $\pm$ 0.9
Single-Tag Efficiency (%)	68 $\pm$ 5	68 $\pm$ 5
Total Efficiency (/pb)	9.3 $\pm$ 1.0	6.9 $\pm$ 0.8
Double-Tag Efficiency (%)	22 $\pm$ 3	23 $\pm$ 3
Total Efficiency (/pb)	3.1 $\pm$ 0.5	2.3 $\pm$ 0.4
Optimized		
Pretag Acceptance (/pb)	12.2 $\pm$ 1.1	9.0 $\pm$ 0.8
Single-Tag Efficiency (%)	69 $\pm$ 5	69 $\pm$ 5
Total Efficiency (/pb)	8.4 $\pm$ 0.9	6.2 $\pm$ 0.7
Double-Tag Efficiency (%)	23 $\pm$ 3	23 $\pm$ 3
Total Efficiency (/pb)	2.8 $\pm$ 0.5	2.1 $\pm$ 0.4

Table 13: Acceptances and efficiencies for the single/double optimized/unoptimized analyses.

come from semi-leptonic heavy flavor decays, for instance; Missing energy results from mismeasured jets, detector effects, and some energy at very high η that misses the detector altogether.

To evaluate the contribution from these events, we employ the canonical four-region "Missing E_T-Isolation" method. The primary assumptions of this method are that the lepton's (or fake's) direction and the missing energy are roughly independent of the jets' directions. Under these conditions, the missing E_T and the lepton isolation (*i.e.*, the amount of *additional* energy – as a fraction of the lepton energy – surrounding it in a cone of 0.4 in ΔR) are uncorrelated. We divide the missing E_T-isolation plane into four separate regions and establish a similarity relationship between their contents. The region definitions are as follows:

- **A:** Missing $E_T < 15$ GeV, Isolation > 0.2
- **B:** Missing $E_T < 15$ GeV, Isolation < 0.1
- **C:** Missing $E_T > 20$ GeV, Isolation > 0.2
- **D:** Missing $E_T > 20$ GeV, Isolation < 0.1 (Signal Region)

We estimate the background contribution to the pretag sample (Region D) by assuming the ratio of non-W events in regions B and A is equal to that between regions D and C. Since the signal region is dominated by real W's, we extract F_{non-W}, the fraction of the pretag sample from such events. The pretag distributions in the missing energy-isolation place are shown in Figure 5. Electrons and muons are treated separately, and we assign a 25% systematic to this method by varying the borders for the four regions.

The non-W contribution to the tagged samples is calculated in two ways: the *tag* and *pretag* methods. The former assumes the same similarity relationship holds for tagged events, or, equivalently, that the ratio of tag rates in regions B and A is the same as the ratio of non-W tag rates in regions D and C. To conserve statistics, we merge counts in the $\geq$3 jet bins, and an additional systematic of 33% is assigned. The *pretag* method simply assumes that the non-W tag rate in regions D and B are the same, and the region B rate is applied to F_{non-W}. An additional systematic of 20% is placed on this assumption, combined in quadrature with the initial uncertainty on F_{non-W} itself. In both cases, jets within a ΔR cone of 0.4 of the lepton are not counted. This effect is only relevant in Regions C and A.

The weighted average of these two methods is used for the single-tag estimate, but only the *pretag* method is used in the double-tag measurement; statistics are far too low even after merging jet bins. The double-tag estimate is then saddled with a 60% systematic. In all cases, the counts in each region (per jet bin) are corrected for the expected contribution of top events, since real W events can fail the event selection and end up elsewhere. Such W's can introduce a correlation between missing energy and isolation, which we attempt to account for here. This correction is only substantial in the signal region, where top can account for as much as 50% of the pretag sample.[1]

For the optimized analysis, the H_T cut is only applied in regions C and D; the transverse mass cut is applied universally. A summary of the results is shown in Table 14.

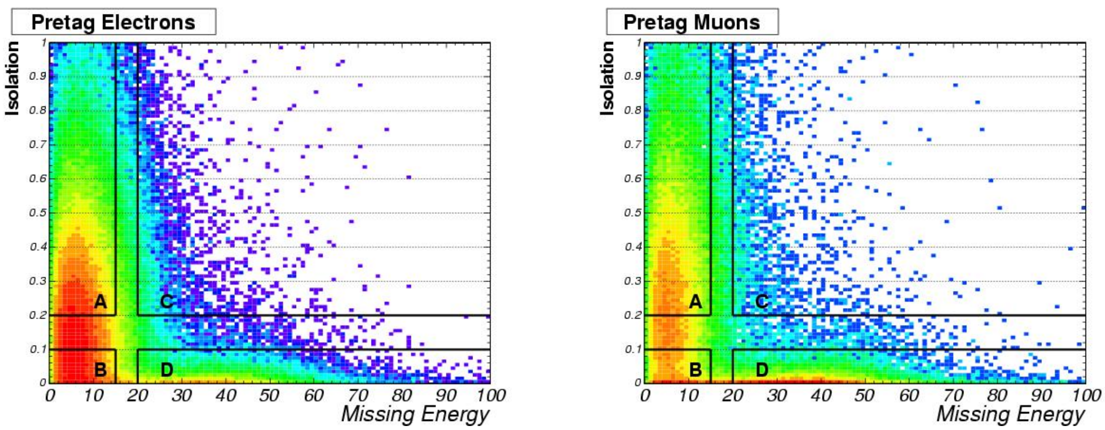

Figure 5: Missing energy vs. Isolation distribution in electron (left) and muon (right) pretag events (in log scale).

	1-jet	2-jet	3-jet	4-jet	≥5-jet
			Electrons		
F_{non-W}	0.101 ± 0.025	0.129 ± 0.033	0.131 ± 0.034		
$N^{+}_{non-W;tag}$	74.2 ± 25.4	31.8 ± 11.2	10.8 ± 4.3	4.6 ± 2.0	1.0 ± 0.7
$N^{+}_{non-W;pretag}$	43.7 ± 14.0	19.4 ± 6.3	6.7 ± 2.3	3.1 ± 1.3	0.5 ± 0.4
$N^{+}_{non-W;average}$	50.9 ± 12.3	22.3 ± 5.5	7.6 ± 2.0	3.5 ± 1.1	0.6 ± 0.3
$N^{++}_{non-W;pretag}$	-	0.6 ± 0.3	0.5 ± 0.3	0.7 ± 0.3	0.2 ± 0.1
			Muons		
F_{non-W}	0.038 ± 0.009	0.045 ± 0.011	0.076 ± 0.021		
$N^{+}_{non-W;tag}$	12.8 ± 4.5	6.4 ± 2.2	5.1 ± 2.2	2.6 ± 1.2	0.3 ± 0.3
$N^{+}_{non-W;pretag}$	14.0 ± 4.5	6.3 ± 2.4	3.0 ± 1.3	2.1 ± 1.1	0.6 ± 0.8
$N^{+}_{non-W;average}$	13.4 ± 3.2	6.4 ± 1.6	3.5 ± 1.1	2.3 ± 0.8	0.3 ± 0.2
$N^{++}_{non-W;pretag}$	-	0.1 ± 0.0	0.4 ± 0.0	0.3 ± 0.1	0.6 ± 0.3

Table 14: A summary of non-W single- and double-tagged events for the unoptimized analysis. No correction for top has been performed.

[1]The top correction obviously depends on the measured cross section. We therefore take this correction as part of the iteration procedure described in section 7.

5.2 Electroweak & Single Top (MC Backgrounds)

Several distinct physics processes involving real W's can fake the signature of top pair production. In this analysis, we account for contributions from di-boson production (WW, WZ, and ZZ), single top production, and $Z \to \tau\tau$. These are all processes which have well-defined theoretical cross sections and a high probability of producing a tagged jet. WW and WZ events can result in a leptonic W and a heavy flavor decay of the other boson; single top yields at least one b-jet and a real W; ZZ requires one Z to decay leptonically with one missed (or misidentified) lepton, with other going to $b\bar{b}$ or $c\bar{c}$; and $Z \to \tau\tau$ events may have one τ decay leptonically with a tag on the opposite-side three-prong hadronic decay. In principle, these last two are at least partially covered by the non-W estimate, but as they are insignificant in the signal region (all these backgrounds "peak" in the one- or two-jet bin), we evaluate them for historical reasons.

The di-boson and single top background calculations are analogous to the signal acceptance and efficiency calculations. Again, the average b, c, and light jet tag rates are extracted from simulation and used in an *event scale factor*, which corrects the event tag rate (in each heavy flavor bin). The exceptional background is $Z \to \tau\tau$, since we have no model for a tag on a three-prong τ decay. We assume the efficiency is the same as for a charm decay and apply the relevant scale factor to this τ, and we figure the branching ratio into the cross section. This is not precisely correct, but the contribution is tiny nonetheless.

The assumed cross sections are the latest theoretical results, listed in Table 15. More specifics on how these processes contribute to the background is available in CDF6893 [14]. We present a short summary here of the single- and double-tag estimates from each background for the unoptimized analysis (Tables 16 and 17). More detailed tables are available in Appendix E.

Process	Cross Section (pb)	Number of Events
WW	13.25 ± 0.05	396337
WZ	3.96 ± 0.06	400943
ZZ	1.58 ± 0.02	396973
Single Top (s-channel)	0.29 ± 0.02	187559
Single Top (t-channel)	0.66 ± 0.27	193181
$Z \to \tau\tau$	13.0 ± 1.5	890892

Table 15: Cross sections used to scale backgrounds. The $Z \to \tau\tau$ estimate has already been scaled by the relevant branching ratio.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
WW	4.1 ± 0.6	7.9 ± 1.2	2.4 ± 0.4	0.5 ± 0.1	0.1 ± 0.0
WZ	2.3 ± 0.3	3.9 ± 0.5	0.9 ± 0.1	0.2 ± 0.0	0.0 ± 0.0
ZZ	0.0 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Single Top (s-channel)	2.0 ± 0.3	5.9 ± 0.8	1.2 ± 0.2	0.2 ± 0.0	0.0 ± 0.0
Single Top (t-channel)	6.1 ± 2.6	7.5 ± 3.2	1.7 ± 0.7	0.3 ± 0.1	0.0 ± 0.0
Z→ $\tau\tau$	0.8 ± 0.2	0.2 ± 0.1	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Total	15.3 ± 4.0	25.5 ± 5.8	6.2 ± 1.4	1.1 ± 0.3	0.24 ± 0.07

Table 16: Expected contribution of single-tagged events from diboson and single top backgrounds for the unoptimized analysis.

	2-jet	3-jet	4-jet	≥5-jet
WW	0.1 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
WZ	0.5 ± 0.1	0.2 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
ZZ	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Single Top (s-channel)	1.8 ± 0.4	0.4 ± 0.1	0.1 ± 0.0	0.0 ± 0.0
Single Top (t-channel)	0.4 ± 0.2	0.4 ± 0.2	0.0 ± 0.0	0.0 ± 0.0
Total	2.9 ± 0.6	1.0 ± 0.3	0.2 ± 0.1	0.04 ± 0.02

Table 17: Expected contribution of double-tagged events from diboson and single top backgrounds for the unoptimized analysis.

5.3 W + Heavy Flavor

The linchpin of the Method 2 cross section measurement is the assumption that after subtracting off the non-W, electroweak, and signal contributions to the pretag and tagged samples, what remains can be modelled as generic W+jets. This assumption alleviates the necessity of calculating cross sections for all W processes, which is especially cumbersome at high order. Instead, we measure the *heavy flavor fractions*, which determine how much of the remaining pretag sample, presumable just W+jets, contains b and c jets. The method is at least partially Monte Carlo driven, but the final measurements are checked against generic jet data [2]. We consider contributions from $Wc\bar{c}$, $Wb\bar{b}$, and Wc, and allow for the possibility of missing a heavy flavor jet. The heavy flavor fractions depend on whether the H_T cut is applied; we show both results from CDF7007 in Table 18. An assumption of our analysis is that the transverse mass cut does not affect these numbers. Based on the evidence presented in CDF7536, sufficiently few real W's (<5%) are cut out that this is a fair approximation. Note that the fractions merge the ≥ 4 jet bin, so here we assume the fraction is the same in the 4 and 5-jet bin separately.

	1-jet	2-jet	3-jet	≥4-jet
No H_T cut				
$Wb\bar{b}$, 1 b	1.0 ± 0.3	1.4 ± 0.4	2.0 ± 0.5	2.2 ± 0.6
$Wb\bar{b}$, 2 b		1.4 ± 0.4	2.0 ± 0.5	2.6 ± 0.7
$Wc\bar{c}$, 1 c	1.6 ± 0.4	2.4 ± 0.6	3.4 ± 0.9	3.6 ± 1.0
$Wc\bar{c}$, 2 c		1.8 ± 0.5	2.7 ± 0.7	3.7 ± 1.0
Wc, 1 c	4.3 ± 0.9	6.0 ± 1.3	6.3 ± 1.3	6.1 ± 1.3
H_T> 200 GeV for ≥3 jets				
$Wb\bar{b}$, 1 b	1.0 ± 0.3	1.4 ± 0.4	2.4 ± 0.6	2.2 ± 0.6
$Wb\bar{b}$, 2 b		1.4 ± 0.4	2.3 ± 0.6	2.6 ± 0.7
$Wc\bar{c}$, 1 c	1.6 ± 0.4	2.4 ± 0.6	3.8 ± 1.0	3.5 ± 1.0
$Wc\bar{c}$, 2 c		1.8 ± 0.5	2.9 ± 0.8	3.7 ± 1.0
Wc, 1 c	4.3 ± 0.9	6.0 ± 1.3	6.0 ± 1.3	5.9 ± 1.3

Table 18: The heavy flavor fractions for the unoptimized and optimized W+Heavy Flavor background, from CDF7007.

The tagging efficiency for each class of event is measured in Monte Carlo, then scaled in analogy to the signal estimate (with a few simplifications). We allow tags on light flavor jets as well, including the relevant term in the event scale factor expansions. This is a different approach to measuring this background, but it does eliminate the ambiguous definition of such events as both *mistags* and $W + HF$. We further simplify our classification into only four categories: 1b, 2b, 1c, and 2c. Alpgen Monte Carlo samples for $Wb\bar{b}$+0,1,2p, $Wc\bar{c}$+0,1,2p, and Wc+0,1,2,3p were generated, and we use the exclusive MLM matching scheme introduced by Ferretti *et. al.* to reduce double-counting. Inclusive matching was used when necessary in the ≥4 jet bin. The results after event selection are weighted according to the generated cross sections (Table 19) and merged. The product of the heavy flavor fractions and the expected data efficiency gives a total tag rate for W+Heavy Flavor, which determines the fraction of the corrected pretag sample that is tagged. Since the correction to the pretag sample is dependent on the $t\bar{t}$ cross section, this background will also change during the iteration procedure.

A summary of the unoptimized efficiencies is shown in Table 20.

Sample	Cross Section (pb)
$Wb\bar{b}$+0p	2.914 ± 0.003
$Wb\bar{b}$+1p	1.557 ± 0.002
$Wb\bar{b}$+2p	0.744 ± 0.001
$Wc\bar{c}$+0p	4.755 ± 0.006
$Wc\bar{c}$+1p	2.737 ± 0.005
$Wc\bar{c}$+2p	1.394 ± 0.002
Wc+0p	21.67 ± 0.02
Wc+1p	12.96 ± 0.02
Wc+2p	5.397 ± 0.006
Wc+3p	1.959 ± 0.002

Table 19: Generated cross section used to weight the W+Heavy Flavor samples (from C. Ferretti). [16]

	1-jet	2-jet	3-jet	≥4-jet
No H_T cut				
$Wb\bar{b}$, 1 b	41 ± 3	46 ± 3	50 ± 4	48 ± 6
$Wb\bar{b}$, 1 b (double)	-	1 ± 0	2 ± 1	3 ± 2
$Wb\bar{b}$, 2 b	-	66 ± 4	68 ± 4	70 ± 5
$Wb\bar{b}$, 2 b (double)	-	23 ± 3	24 ± 3	29 ± 5
$Wc\bar{c}$, 1 c	10 ± 1	16 ± 2	21 ± 3	29 ± 5
$Wc\bar{c}$, 1 c (double)	-	0 ± 0	0 ± 0	1 ± 1
$Wc\bar{c}$, 2 c	-	20 ± 3	28 ± 4	28 ± 4
$Wc\bar{c}$, 2 c (double)	-	1 ± 0	3 ± 1	4 ± 1
Wc, 1 c	11 ± 2	14 ± 2	19 ± 2	26 ± 4
Wc, 1 c (double)	-	0 ± 0	0 ± 0	1 ± 0

Table 20: The efficiencies for tagging W+Heavy Flavor events corrected for tagging scale factors in the unoptimized analysis.

5.4 Mistags

After accounting for all non-W events, heavy and light tags in top and other electroweak processes, and heavy flavor tags in generic W+jets, the only remaining contribution is from tags in W+Light Flavor, or *mistags*. This background is expected to dominate with the loosened tagger, as outlined in Section 2.2. A zeroth order estimate is to run the *negative mistag matrix* on the pretag sample, then to scale down by the fraction of events which are not W+Light Flavor. The matrix applies the generic jet tag rate (parametrized in jet energy, η, φ, N_{tracks}, and ΣE_T) to jets in the pretag sample and determines a probability for each jet to be tagged; the sum of these probabilities is the expected number of mistagged jets.

This estimate is corrected by the *mistag asymmetry*, α, measured in CDF7585 for the Gen5 taggers. This accounts for two features of the mistag matrix approach: the heavy flavor content of the sample in which the matrix was made and the positive bias in light flavor tags. b and c jets, which comprise nearly 10% of the generic jet samples, have a higher negative tag rate than light jets due to the higher track multiplicity, and so pull the mistag prediction up. On the other hand, using the *negative* tag matrix prediction for the *positive* mistag estimate is an underestimate of the background; long-lived light flavor decays (Λ's and K_s's) and interactions in the material add a long positive tail to a symmetric vertex decay length distribution from resolution tags. Repeating the method of $c\tau$ fitting put forth in CDF6739, the α

measured in Gen5 for the loose tagger is 1.26 ± 0.11 in `Jet50`. [11]

The α correction is insufficient to correct the tag rates in generic jets, however. This factor corrects the *numerator* of the tag rate (*i.e.*, the number of tags), but the denominator (the total number of jets) still contains the heavy flavor jets in the sample. For this reason, we further scale the mistag prediction by the inverse of the *light flavor* fraction of the `Jet50` sample. Monte Carlo matching estimates this correction to be 1.077; using the fit heavy flavor content of the tagged sample from CDF7585 and dividing by the data efficiency for b's and c's to estimate the heavy flavor in the pretag sample yields an estimate of 1.087. We measure 1.08 ± 0.04 as our final correction for pretag heavy flavor in this sample.

Both α and the second correction, which has been given the unfortunate nickname β, are sample-dependent. Since the matrix is a patchwork of all generic jet datasets with different heavy flavor content and tag rates, we have repeated the measurement in `Jet20`, `Jet70`, and `Jet100`, and we have determined a ΣE_T-dependent correction to the negative matrix prediction which includes both α and β. A single fit is performed in each sample, and the results are weighted according to the matrix composition in bins of ΣE_T. A plot of the correction and the relative contribution from each sample is shown in Figure 6. Since the result is only substantially different below 50 GeV, this has a minimal effect on the signal region mistag estimate. A slightly more quantitative discussion can be found in CDF7585.

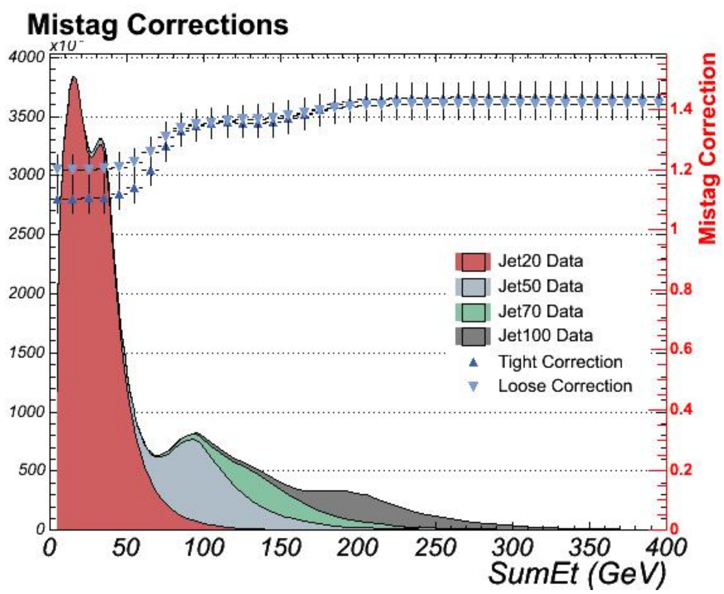

Figure 6: Mistag correction vs. ΣE_T for the tight and loose taggers.

Finally, we need to scale the mistag prediction to account for those events which are not W+Light Flavor. We have attempted to explicitly account for tags on light jets in other backgrounds, but the mistag matrix is run on the entire sample. For the single mistags, we threfore scale the matrix prediction down by the fraction of the pretag sample devoted to top, diboson and single top, non-W, and W+Heavy Flavor. Once again, this background will depend on the cross section and will therefore change during the iteration procedure.

The mistag background in the double-tag measurement is slightly more subtle. To get a matrix prediction, we run over all "away" jets in events with at least one tagged jet. If an event is double-tagged, we run over the jets opposite to each tag once and scale the prediction down by a factor of two. This double-mistag prediction is then scaled in analogy to the single tags: α and β are applied, then the estimate is scaled down by the number of *single tags* (rather than pretags) attributed to other physics processes.

The remaining term should explicitly equal the number of double-tags expected from W+Light Flavor events. We assign a 50% systematic to this estimate. Note that the iterative step corrects the mistags for top using the double-tag cross section; the single- and double-tag measurements are kept as independent as possible.

To be explicit:

$$N_{mistag} = N^{-}_{pred}\alpha\beta\frac{N^{pre} - N^{pre}_{t\bar{t}} - N^{pre}_{non-W} - N^{pre}_{MC} - N^{pre}_{W+HF}}{N^{pre}} \tag{1}$$

$$N^{double}_{mistag} = (N^{+})^{-}_{pred}\alpha\beta\frac{N^{+} - N^{+}_{t\bar{t}} - N^{+}_{non-W} - N^{+}_{MC} - N^{+}_{W+HF}}{N^{+}} \tag{2}$$

$$\alpha = \frac{N^{+}_{light}}{N^{-}_{light} + N^{-}_{heavy}} \tag{3}$$

$$\beta = \frac{N^{pre}_{light} + N^{pre}_{heavy}}{N^{pre}_{light}} \tag{4}$$

The last two quantities are measured in generic jets, where the average mistag rate estimated in the same jet samples is:

$$R^{-}_{mistag} = \frac{N^{-}_{light} + N^{-}_{heavy}}{N^{pre}_{light} + N^{pre}_{heavy}} \tag{5}$$

A summary of the mistag background is in Table 21.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Electrons					
N^{-} Predicted	148.2	65.6	21.7	8.0	1.6
Actual Negative Tags	140	74	22	11	2
N^{+} Predicted	181.4	85.3	29.6	11.2	2.3
Corrected Mistags	151 ± 33	61.4 ± 13.5	18.2 ± 4.0	4.7 ± 1.0	0.4 ± 0.1
$(N^{+})^{-}$ Predicted	-	3.2	2.9	2.1	0.8
Actual Pos-Neg Tags	-	3	4	3	2
$(N^{+})^{+}$ Predicted	-	4.3	4.0	3.0	1.2
Corrected Double Mistags	-	1.8 ± 0.9	1.1 ± 0.6	0.8 ± 0.4	0.3 ± 0.3
Muons					
N^{-} Predicted	103.8	41.5	11.9	4.7	1.7
Actual Negative Tags	93	48	8	2	0
N^{+} Predicted	126.6	53.9	16.2	6.5	2.4
Corrected Mistags	113 ± 25	42.6 ± 9.4	10.4 ± 2.3	2.4 ± 0.5	0.8 ± 0.2
$(N^{+})^{-}$ Predicted	-	2.0	1.5	2.0	1.0
Actual Pos-Neg Tags	-	3	0	0	0
$(N^{+})^{+}$ Predicted	-	2.6	2.0	2.8	1.4
Corrected Double Mistags	-	1.2 ± 0.6	0.5 ± 0.3	0.6 ± 0.4	0.6 ± 0.4

Table 21: A summary of the mistag predictions and corrected background for the unoptimized analysis, assuming a cross section of 6.7 pb.

6 Systematics

The equation used to calculate the cross section is shown in Section 1; we must now consider all sources of systematic uncertainty that affect each term in this equation separately. A summary of the canonical errors follows.

- **Luminosity**: A 5.9% systematic is assigned to the integrated luminosity figure (318 pb^{-1}). This includes the uncertainty in the $p\bar{p}$ inelastic cross section and the precision of the `CLC`. It affects the pretag expectation for signal, and also is included in the expectations for the MC backgrounds.

- ***b*-Tagging**: The actual tagging efficiency in data is calculated by scaling the efficiency in Monte Carlo by SF, which comes with a 7.1% relative error. The full sysytematic does not affect the signal due to the presence of multiple heavy flavor jets, but this is still a large contribution to the error; it is the dominant error for the double-tag analysis. This systematic is also included in the calculations of the MC and W+HF backgrounds.

- **Jet Energy Scale**: The raw calorimeter energy of the jets is corrected to better represent the relevant physics quantity, and this rescaling carries a systematic uncertainty. By calculating the effect on signal yield after moving the correction $\pm 1\sigma$, we derive a source of error on the signal expectation.

- **Lepton ID**: A detector-specific correction adjusts the lepton identification efficiency in the simulation to better represent the data. These are part of the scale factors discussed in Section 4.1. Like the luminosity error above, this affects the top signal and the MC backgrounds.

- **ISR/FSR**: We measure the effect on the acceptance of using simulations with more or less initial and final state radiation. We determine the top yield (before and after tagging) using Monte Carlo samples (Pythia, m_t=178 GeV/c^2) with the ISR and FSR settings adjusted. We see an RMS fluctuation of 0.7% in the acceptance and 0.9% in the optimized, single-tag cross section, so we take a 1% overall systematic.

- **Pythia vs. Herwig**: We check the difference in acceptance when using an alternate Monte Carlo generator for our $t\bar{t}$ signal. This number is corrected for the different W branching ratios in the two MC generators. We see an overall shift of 2% in the acceptance, and we take this as a systematic uncertainty.

- **PDF**: Uncertainties in the proton parton distribution function can also propagate into the acceptance. We use the Monte Carlo reweighting scheme introduced in CDF6907 to estimate this error (also same as CDF7536).

- **Multiple Interactions**: In the most recent data, a non-negligible number of events have more than one interaction, a feature not present in the simulation. We check the signal acceptance in Pythia samples with one and two minimum bias events superimposed. We find a negligible (¡0.2% for 1 min bias event, ¡1% for 2 min bias events) change in the acceptance; since this systematic should only apply to a fraction of the data, we assign no additional uncertainty. (It is surprising here that the acceptance goes down in both cases. The tight lepton and isolation cuts are harsher for the minbias samples; the former is likely due to having the wrong Z vertex or additional tracking inefficiency, and the latter effect arises from the excess energy in the detector from the other vertices.)

- **Lepton Isolation**: This is an additional 5% systematic hung on the lepton identification efficiency; its purpose is to cover a difference between the efficiency in clean Z decays (where the *lepton ID* *scale factors* are measured) and in busier multi-jet environments, as we have in top events. This is included in the signal acceptance and the Monte Carlo backgrounds.

- **Background Errors**: There are several background specific errors that affect the precision of the cross section, most of which are discussed in their respective subsection. Chief among these is the **heavy flavor fraction** uncertainties, which dominate the W+Heavy Flavor background but also sneak into the mistag calculation. The various **non-W methods** have large errors, as do the **mistag matrix** and α **and** β **corrections**. The ratio of the total background error to the signal expectation is referred to below as the *background* systematic.

A summary of the pretag acceptances and cross sections for the systematic samples is in Table 22, Table 23 breaks down the systematics used in background calculations, and final systematics for all four measurements are in Table 24.

	Pretag Acceptance (events/pb)	Cross Section (pb)
Default (Pythia 178)	21.15	8.74
Less ISR	21.17	8.74
More ISR	21.23	8.72
Less FSR	21.15	8.77
More FSR	21.37	8.71
Herwig 178	22.16	8.30
Pythia 178 + 1 MinBias	21.12	8.71
Pythia 178 + 2 MinBias	20.95	8.94
Herwig 167.5	20.33	9.16
Herwig 170	20.90	8.84
Herwig 172.5	21.10	8.73
Herwig 175	21.61	8.54
Herwig 177.5	22.42	8.27
Herwig 180	22.36	8.22
Herwig 182.5	22.74	7.99

Table 22: Summary of pretag acceptances and cross sections for the systematic samples with the optimized selection. Herwig cross sections have not been rescaled to account for the $+W$ branching fraction.

7 Results

Since many of the backgrounds (non-W, mistags, and W+Heavy Flavor) depend on the top contribution to the tagged and pretag samples, we initally assume a cross section of 6.1 pb, which corresponds to the top mass of 178 GeV/c^2 used in the Monte Carlo. We evaluate the ratio of the tag *excess* (data minus background) and the top expectation summed over the 3, 4, and 5-jet bins, and we repeat the background calculations after scaling the assumed cross section until it is stable to <1%. Since the backgrounds are not linear in the cross section, this is the only straightforward way of achieving a consistent measurement of the backgrounds and signal. With statistical errors only, the resulting cross sections for the unoptimized analyses are **8.6 ± 0.9 pb** for single tags and **9.5 ± 1.4 pb** for double tags. The optimized measurement yields consistent results; we measure **8.7 ± 0.9 pb** for single tags and **10.1 ± 1.5 pb** for double tags. All these numbers are higher than the theoretical cross section (roughly 7pb for the latest world average top mass), but not entirely inconsistent given their errors; they are in good agreement with some of

	Relative Error (%)	Impact on Cross Section (pb)
Non-W		
F_{non-W}	25%	<0.1
Tag Method	33%	0.1
ϵ_B	20%	<0.1
MC Backgrounds		
Lepton ID/Isolation	7%	<0.1
b-Tagging Scale Factor	7%	<0.1
Luminosity	5.9%	<0.1
Theoretical Cross Sections	5-40%	<0.1
W+Heavy Flavor		
Heavy Flavor Fractions	20-30%	0.3
b-Tagging Scale Factor	7%	<0.1
Mistags		
Matrix Method	12%	0.2
α, β correction	10%	0.2
Pretag Correction	5%	<0.1

Table 23: Summary of background systematics and their *approximate* effect on the single-tag, optimized cross section.

the most current measurements in this data sample, including those using the tight tagger [6] and the `JetProbability` tagger [8].

Background summaries for all four measurements are presented here both as Tables (25-28) and Figures (7-10). Figures 11 and 12 show likelihood functions for the cross sections with $\pm 1\sigma$ statistical bands.

After systematic errors have been included, we measure $\mathbf{8.6^{+1.0}_{-0.9}(stat)^{+1.3}_{-1.1}(syst)\ pb}$ for single-tags and $\mathbf{9.5^{+1.5}_{-1.4}(stat)^{+2.1}_{-1.5}(syst)\ pb}$ for double-tags in the unoptimized analysis and $\mathbf{8.7^{+0.9}_{-0.9}(stat)^{+1.2}_{-0.9}(syst)\ pb}$ for single-tags and $\mathbf{10.1^{+1.6}_{-1.4}(stat)^{+2.1}_{-1.4}(syst)\ pb}$ for double-tags in the optimized analysis.

	Unoptimized		Optimized	
Systematic	≥ 1 Tag	≥ 2 Tags	≥ 1 Tag	≥ 2 Tags
Lepton ID (CEM)	1.6			
Lepton ID (CMUP)	1.9			
Lepton ID (CMX)	1.7			
ISR/FSR	1.0			
PDF (CEM)	2.0			
Pythia vs. Herwig	2.0			
Lepton Isolation	5.0			
Luminosity	5.9			
JES	2.8		4.8	3.8
b-Tagging	6.0	13.4	6.0	13.4
Backgrounds	9.7	7.6	6.9	5.0
Total	14	18	13	17

Table 24: Summary of systematic uncertainties on the cross section measurements.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Pretag	30628	4791	769	179	36
WW	4.1 ± 0.6	8.0 ± 1.2	2.4 ± 0.4	0.46 ± 0.069	0.13 ± 0.03
WZ	2.3 ± 0.3	3.9 ± 0.5	0.86 ± 0.11	0.18 ± 0.028	0.033 ± 0.008
ZZ	0.04 ± 0.01	0.10 ± 0.02	0.06 ± 0.01	0.02 ± 0.003	0.006 ± 0.002
Single Top (s-ch)	2 ± 0.3	5.9 ± 0.8	1.2 ± 0.16	0.19 ± 0.03	0.027 ± 0.006
Single Top (t-ch)	6.1 ± 2.6	7.5 ± 3.2	1.7 ± 0.71	0.28 ± 0.12	0.05 ± 0.02
$Z \rightarrow \tau\tau$	0.8 ± 0.2	0.2 ± 0.05	0.05 ± 0.01	0.005 ± 0.001	0.0009 ± 0.0003
MC Backgrounds	15 ± 4	26 ± 6	6.3 ± 1.4	1.1 ± 0.3	0.24 ± 0.07
Wbb	115 ± 36	64.3 ± 19	13.1 ± 3.4	2.0 ± 0.6	0.16 ± 0.05
Wcc	47 ± 13	30 ± 9	8.0 ± 2.4	1.4 ± 0.5	0.11 ± 0.035
Wc	129 ± 33	34.6 ± 8.7	6.8 ± 1.6	1.08 ± 0.27	0.08 ± 0.02
W+Heavy Flavor	291 ± 82	129 ± 37	27.9 ± 7.4	4.5 ± 1.3	0.35 ± 0.11
W+Light Flavor	264 ± 58	104 ± 23	27.7 ± 6.1	5.6 ± 1.2	0.58 ± 0.13
QCD	64 ± 13	29 ± 6	10 ± 2	5.2 ± 1.2	0.61 ± 0.33
Background	634 ± 101	288 ± 44	72.3 ± 10.8	16.4 ± 2.8	1.79 ± 0.65
Top (8.6 pb)	3.57 ± 0.44	28.3 ± 3.2	61.3 ± 6.8	59.3 ± 6.4	18.6 ± 2.0
Total	638 ± 101	316 ± 44.5	134.1 ± 12.8	75.7 ± 7.0	20.4 ± 2.1
Tags	730	362	127	78	24

Table 25: Summary of backgrounds for the single-tag, unoptimized analysis.

	2-jet	3-jet	4-jet	≥5-jet
Pretag	4791	769	179	36
WW	0.12 ± 0.01	0.09 ± 0.02	0.016 ± 0.004	0.010 ± 0.003
WZ	0.55 ± 0.10	0.16 ± 0.03	0.03 ± 0.01	0.007 ± 0.002
ZZ	0.03 ± 0.01	0.010 ± 0.002	0.002 ± 0.001	0.0010 ± 0.0004
Single Top (s-ch)	1.90 ± 0.35	0.42 ± 0.08	0.06 ± 0.01	0.010 ± 0.002
Single Top (t-ch)	0.37 ± 0.16	0.36 ± 0.16	0.08 ± 0.04	0.016 ± 0.008
MC Backgrounds	2.9 ± 0.6	1.0 ± 0.3	0.2 ± 0.06	0.044 ± 0.016
Wbb	11.5 ± 3.7	2.48 ± 0.75	0.42 ± 0.15	0.0192 ± 0.0069
Wcc	1.0 ± 0.4	0.46 ± 0.21	0.09 ± 0.05	0.0042 ± 0.0022
Wc	0.5 ± 0.2	0.07 ± 0.03	0.03 ± 0.02	0.0012 ± 0.0007
W+Heavy Flavor	13.1 ± 3.9	3.0 ± 0.9	0.54 ± 0.17	0.02 ± 0.01
W+Light Flavor	2.8 ± 1.4	0.72 ± 0.37	0.17 ± 0.14	0.27 ± 0.25
QCD	0.61 ± 0.61	0.68 ± 0.68	0.63 ± 0.63	1.0 ± 1.0
Background	19.4 ± 4.44	5.44 ± 1.83	1.53 ± 0.96	1.35 ± 1.06
Top (9.5 pb)	7.3 ± 1.3	19.7 ± 3.4	23.4 ± 4.0	7.62 ± 1.32
Total	26.7 ± 4.6	25.1 ± 3.9	24.9 ± 4.2	9.0 ± 1.7
Tags	31	27	26	6

Table 26: Summary of backgrounds for the double-tag, unoptimized analysis.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Pretag	30283	4676	324	142	34
WW	4.0 ± 0.6	7.9 ± 1.2	1.3 ± 0.2	0.32 ± 0.05	0.11 ± 0.03
WZ	2.3 ± 0.3	3.8 ± 0.5	0.41 ± 0.06	0.13 ± 0.02	0.033 ± 0.008
ZZ	0.04 ± 0.01	0.10 ± 0.02	0.03 ± 0.01	0.009 ± 0.003	0.005 ± 0.002
Single Top (s-ch)	2.0 ± 0.28	5.8 ± 0.8	0.8 ± 0.11	0.16 ± 0.02	0.03 ± 0.01
Single Top (t-ch)	6.0 ± 2.6	7.4 ± 3.2	0.99 ± 0.42	0.23 ± 0.10	0.05 ± 0.02
$Z \to \tau\tau$	0.5 ± 0.1	0.11 ± 0.03	0.010 ± 0.002	0.0010 ± 0.0002	0.0005 ± 0.0001
MC Backgrounds	15 ± 4	25.1 ± 5.6	3.5 ± 0.8	0.9 ± 0.2	0.22 ± 0.07
Wbb	115 ± 35	63 ± 19	6.1 ± 1.7	1.4 ± 0.8	0.17 ± 0.09
Wcc	46 ± 13	30 ± 9	3.8 ± 1.2	1.1 ± 0.4	0.14 ± 0.04
Wc	129 ± 33	34 ± 9	3.0 ± 0.8	0.82 ± 0.22	0.10 ± 0.03
W+Heavy Flavor	289 ± 81	127 ± 36	13.0 ± 3.6	3.4 ± 1.3	0.40 ± 0.16
W+Light Flavor	261 ± 57	101 ± 22	14.5 ± 3.2	4.4 ± 1.0	0.62 ± 0.14
QCD	58 ± 12	24 ± 5	2.8 ± 0.7	2.5 ± 0.8	0.20 ± 0.18
Background	624 ± 100	277 ± 43	33.7 ± 5.8	11.2 ± 2.4	1.45 ± 0.58
Top (8.7 pb)	3.5 ± 0.4	27.9 ± 3.2	52.7 ± 5.8	56.6 ± 6.1	18.1 ± 2.0
Total	628 ± 100	304.9 ± 43.5	86.4 ± 8.2	67.8 ± 6.6	19.6 ± 2.1
Tags	722	346	80	71	23

Table 27: Summary of backgrounds for the single-tag, optimized analysis.

	2-jet	3-jet	4-jet	≥5-jet
Pretag	4676	324	142	34
WW	0.12 ± 0.01	0.037 ± 0.005	0.016 ± 0.004	0.010 ± 0.003
WZ	0.53 ± 0.10	0.066 ± 0.012	0.023 ± 0.005	0.007 ± 0.002
ZZ	0.03 ± 0.01	0.006 ± 0.001	0.002 ± 0.001	0.00 ± 0.00
Single Top (s-ch)	1.8 ± 0.3	0.29 ± 0.05	0.05 ± 0.01	0.010 ± 0.002
Single Top (t-ch)	0.36 ± 0.16	0.24 ± 0.10	0.07 ± 0.03	0.016 ± 0.008
MC Backgrounds	2.8 ± 0.6	0.63 ± 0.18	0.16 ± 0.05	0.043 ± 0.015
Wbb	11.4 ± 3.7	1.29 ± 0.43	0.208 ± 0.082	0.010 ± 0.004
Wcc	0.93 ± 0.41	0.22 ± 0.11	0.069 ± 0.036	0.004 ± 0.002
Wc	0.51 ± 0.15	0.05 ± 0.03	0.021 ± 0.012	0.001 ± 0.001
W+Heavy Flavor	12.8 ± 3.9	1.56 ± 0.43	0.30 ± 0.11	0.015 ± 0.007
W+Light Flavor	2.6 ± 1.3	0.03 ± 0.11	0.0 ± 0.12	0.16 ± 0.23
QCD	0.59 ± 0.59	0.28 ± 0.28	0.5 ± 0.5	0.35 ± 0.35
Background	18.8 ± 4.3	2.5 ± 1.2	0.96 ± 0.83	0.57 ± 0.47
Top (10.1 pb)	7.5 ± 1.3	18.4 ± 3.2	23.6 ± 4.1	7.8 ± 1.4
Total	26.4 ± 4.5	21.0 ± 3.4	24.6 ± 4.2	8.4 ± 1.4
Tags	30	23	25	6

Table 28: Summary of backgrounds for the double-tag, optimized analysis.

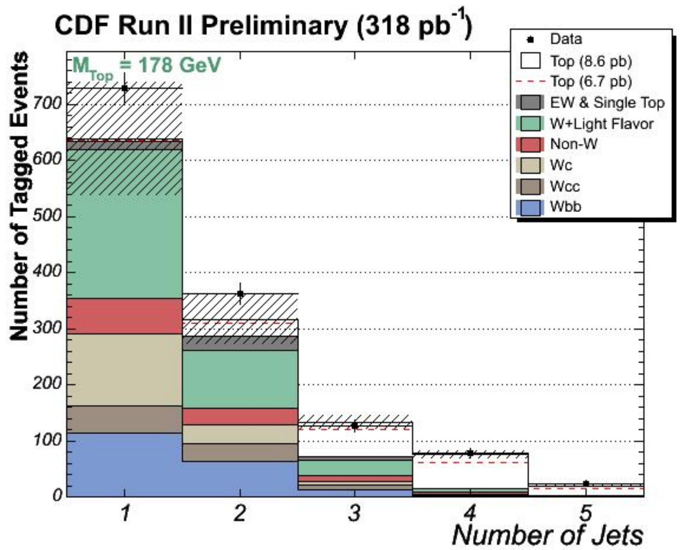

Figure 7: Background summary for the unoptimized, single-tag analysis.

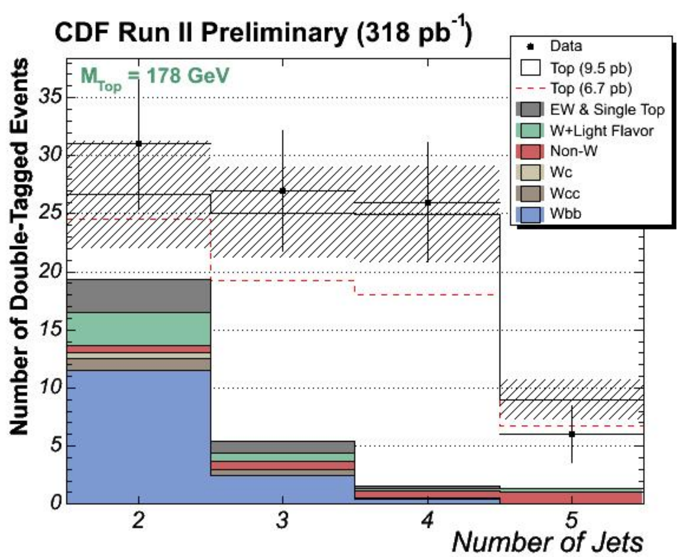

Figure 8: Background summary for the unoptimized, double-tag analysis.

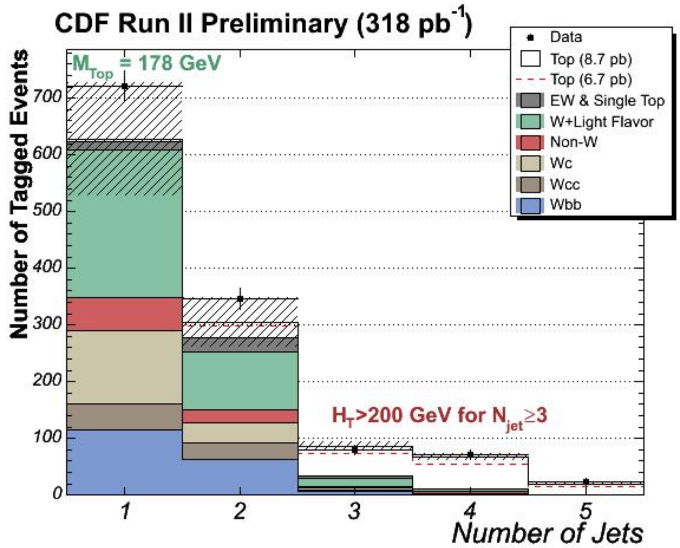

Figure 9: Background summary for the optimized, single-tag analysis.

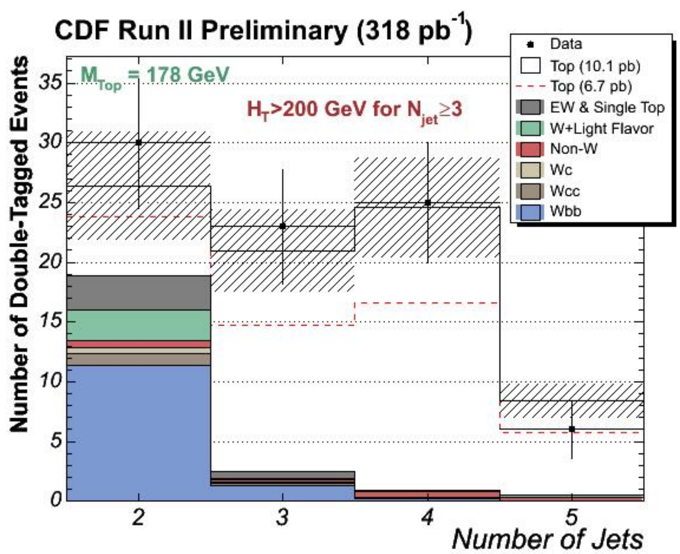

Figure 10: Background summary for the optimized, double-tag analysis.

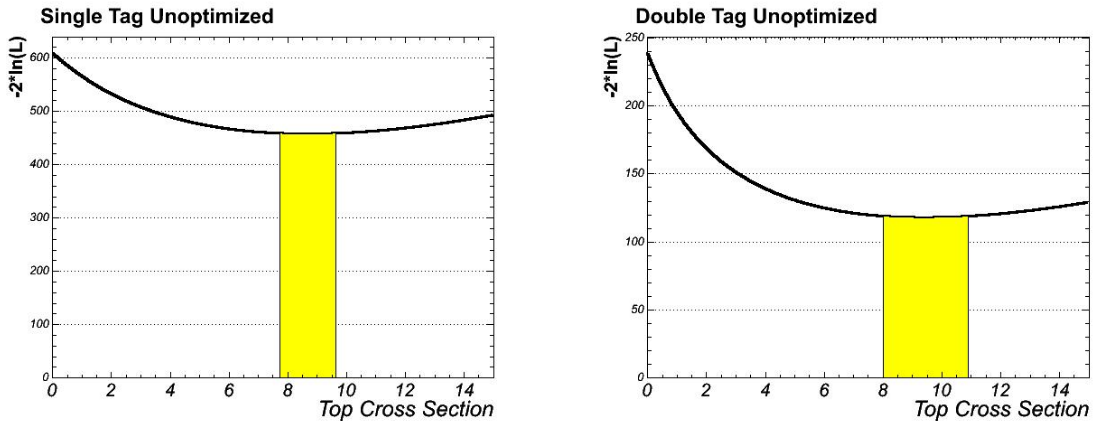

Figure 11: Likelihood and 1σ statistical region for the unoptimized analyses.

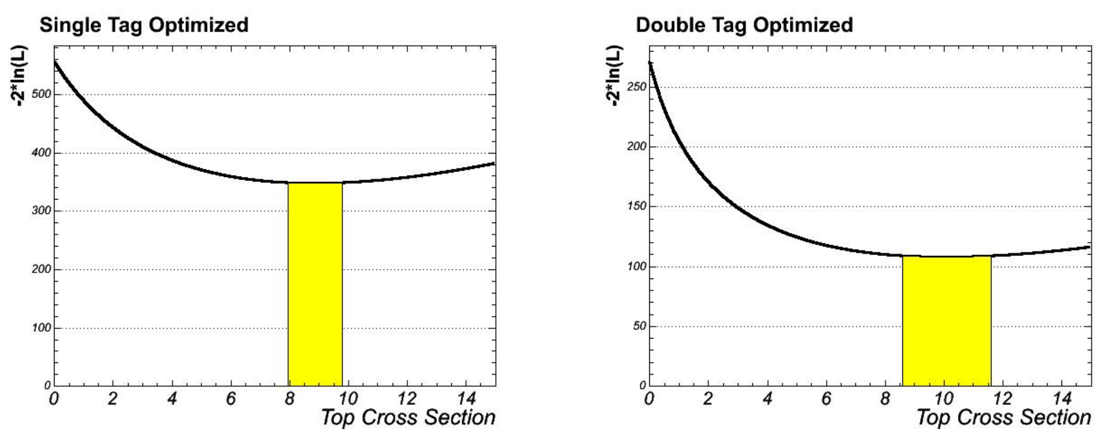

Figure 12: Likelihood and 1σ statistical region for the optimized analyses.

8 Combining Cross Sections

Since the single-tag analysis includes all events with *at least one* tag, the single- and double-tagged samples are not statistically independent. It is therefore not totally straightforward to combine the cross sections from the two analyses. We present here two attempts to account for the overlapping events and unify the single- and double-tag measurements: a simple statistical separation (the *exactly one* method) and the N_{jets} fit first discussed in CDF7536 for the tight tagger.

8.1 Statistical Independence

To eliminate the overlapping events between the single- and double-tagged samples, we would like to evaluate the expectations for signal and background for events with *exactly* one tag, rather than one or more. Direct calculation of these quantities is prohibitively complicated, since the efficiency is currently treated as the complement to the zero-tag rate. We instead adopt the simple approach of subtracting the double-tag expectations from the inclusive tags, and we attempt to properly account for the common uncertainties (dominated by the b-tagging scale factor). In most cases, the inclusive backgrounds will dwarf the double-tags.

A summary of the backgrounds and signal expectation for the unoptimized and optimized one-tag cross section are in Tables 29 and 30. Accompanying plots are in Figures 13 and 14. If we then reweight the single and double cross sections by their uncorrelated errors (taking out the b-tagging and acceptance systematics) and merge them, we can measure one overall combined cross section. The two one-tag measurements are 8.1 ± 1.2 ± 1.2 pb (unoptimized) and 8.0 ± 1.1 ± 1.1 (optimized). The weighted averages with total errors are 8.8 ± 1.5 pb and 8.9 ± 1.4 pb, slightly better than the inclusive cross sections.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Pretag	30628	4791	769	179	36
Pretag Top (8.1 pb)	8.49 ± 0.852	45.3 ± 4.42	88.4 ± 8.59	79.1 ± 7.69	24.4 ± 2.39
WW	4.1 ± 0.6	7.9 ± 1.2	2.3 ± 0.37	0.44 ± 0.073	0.12 ± 0.033
WZ	2.3 ± 0.3	3.3 ± 0.58	0.7 ± 0.14	0.15 ± 0.034	0.025 ± 0.0099
ZZ	0.04 ± 0.006	0.1 ± 0.02	0.05 ± 0.01	0.01 ± 0.004	0.005 ± 0.002
Single Top (s-ch)	2 ± 0.28	4.1 ± 1.1	0.82 ± 0.24	0.13 ± 0.039	0.017 ± 0.0081
Single Top (t-ch)	6.1 ± 2.6	7.2 ± 3.4	1.3 ± 0.87	0.2 ± 0.16	0.033 ± 0.031
$Z \to \tau\tau$	0.8 ± 0.2	0.2 ± 0.05	0.05 ± 0.01	0.005 ± 0.001	0.001 ± 0.0003
MC Backgrounds	15 ± 3.9	23 ± 5.1	5.3 ± 1.1	0.94 ± 0.19	0.2 ± 0.053
Wbb	115 ± 36	52.8 ± 23	10.7 ± 4.2	1.63 ± 0.8	0.153 ± 0.075
Wcc	47 ± 13	29 ± 9.5	7.6 ± 2.6	1.4 ± 0.54	0.13 ± 0.05
Wc	129 ± 33	34.6 ± 8.7	6.82 ± 1.6	1.15 ± 0.29	0.108 ± 0.027
W+Heavy Flavor	291 ± 82	116 ± 40	25.1 ± 8.3	4.15 ± 1.6	0.389 ± 0.15
W+Light Flavor	264 ± 40	101 ± 15	26.8 ± 4	5.14 ± 0.77	0.179 ± 0.027
QCD	64 ± 13	28 ± 6	9.7 ± 2.4	4.5 ± 1.5	-0.34 ± 0.69
Background	634 ± 91.8	268 ± 44.1	66.9 ± 9.98	14.8 ± 2.53	0.427 ± 0.767
Top (8.1 pb)	3.36 ± 0.415	20.5 ± 1.95	41 ± 3.46	35.9 ± 2.6	11 ± 0.772
Total	638 ± 91.8	289 ± 44.2	108 ± 10.6	50.7 ± 3.63	11.4 ± 1.09
Tags	730	331	100	52	18

Table 29: Summary of backgrounds for the *exactly one* unoptimized cross section.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Pretag	30283	4676	324	142	34
Pretag Top (8.0 pb)	8.2 ± 0.824	43.5 ± 4.24	72.8 ± 7.08	73.2 ± 7.12	23.2 ± 2.28
WW	4 ± 0.59	7.7 ± 1.2	1.2 ± 0.19	0.31 ± 0.055	0.1 ± 0.031
WZ	2.3 ± 0.29	3.3 ± 0.56	0.34 ± 0.067	0.11 ± 0.027	0.025 ± 0.01
ZZ	0.04 ± 0.006	0.1 ± 0.02	0.02 ± 0.006	0.007 ± 0.003	0.005 ± 0.002
Single Top (s-ch)	2 ± 0.28	4 ± 1.1	0.51 ± 0.16	0.11 ± 0.034	0.016 ± 0.008
Single Top (t-ch)	6 ± 2.6	7.1 ± 3.3	0.75 ± 0.53	0.16 ± 0.13	0.029 ± 0.029
$Z \to \tau\tau$	0.5 ± 0.1	0.1 ± 0.03	0.01 ± 0.002	0.001 ± 0.0002	0.0005 ± 9e-05
MC Backgrounds	15 ± 3.8	22 ± 5	2.9 ± 0.6	0.69 ± 0.15	0.18 ± 0.05
Wbb	115 ± 35	51.9 ± 22	4.9 ± 2.2	1.29 ± 0.98	0.185 ± 0.14
Wcc	46 ± 13	29 ± 9.3	3.7 ± 1.3	1.2 ± 0.46	0.17 ± 0.066
Wc	129 ± 33	34.1 ± 8.6	3.12 ± 0.78	0.922 ± 0.24	0.132 ± 0.035
W+Heavy Flavor	289 ± 81	114 ± 40	11.6 ± 4.2	3.35 ± 1.7	0.479 ± 0.24
W+Light Flavor	261 ± 39	98.7 ± 15	14.2 ± 2.1	4.12 ± 0.62	0.252 ± 0.038
QCD	58 ± 12	23 ± 5.2	2.5 ± 0.85	2.1 ± 1	-0.11 ± 0.34
Background	624 ± 91.1	259 ± 43.3	31.2 ± 5.12	10.3 ± 2.23	0.798 ± 0.501
Top (8.0 pb)	3.23 ± 0.399	19.7 ± 1.87	33.9 ± 2.8	33.3 ± 2.39	10.5 ± 0.729
Total	627 ± 91.1	278 ± 43.3	65.1 ± 5.83	43.6 ± 3.26	11.3 ± 0.885
Tags	722	316	57	46	17

Table 30: Summary of backgrounds for the *exactly one* optimized cross section.

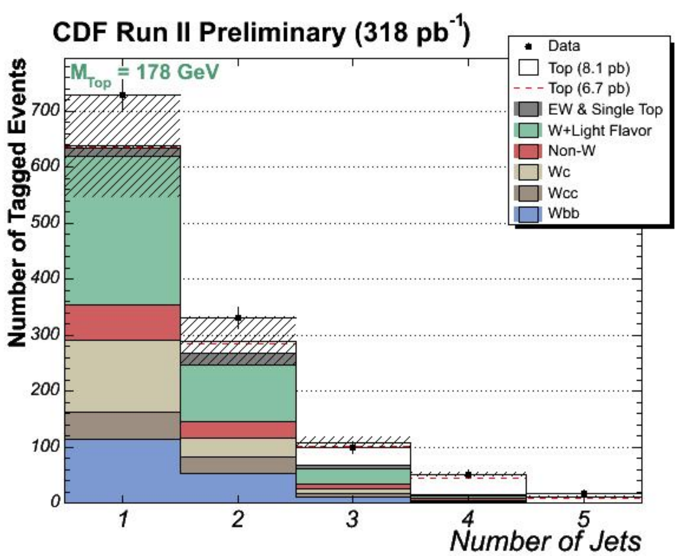

Figure 13: Background summary for the unoptimized one-tag analysis.

8.2 Likelihood Fitting

A second approach discussed at length in CDF7536 is to do a simultaneous likelihood fit for the single- and double-tagged cross sections. The fit allows fluctuations in the background due to misestimates of the mistags, tagging scale factors, heavy flavor fractions, and QCD backgrounds, and does therefore

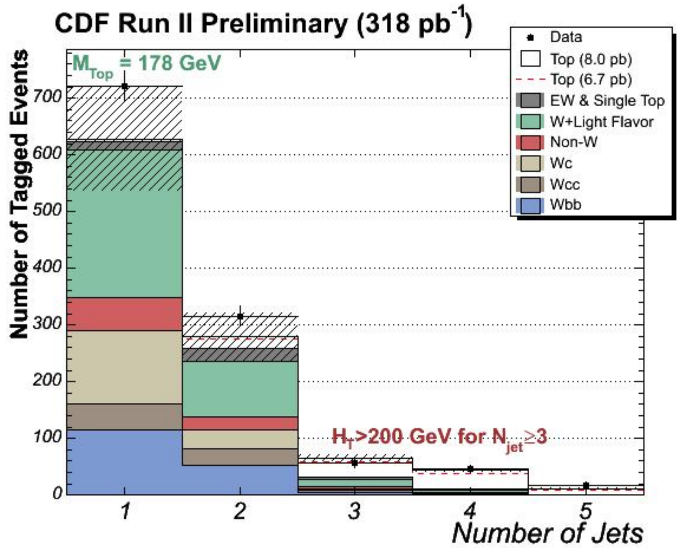

Figure 14: Background summary for the unoptimized one-tag analysis.

approximate the correlations between the two measurements. We perform the fit here only for the optimized analysis. It determines the total cross section to be **8.7 ± 0.9 ± 1.2 pb**, consistent with the merged cross section in Section 8.1. A short summary of the fit results is in Table 31. The W+Heavy Flavor scaling is the only deviation from unity, repeating the result for the tight tagger. [6] Many more details on the method can be found in the documentation for that analysis.

Scale Factor	Fit Value
MC Backgrounds	1.00 ± 0.24
Non-W (single)	1.02 ± 0.20
Non-W (double)	0.97 ± 0.90
Mistags (single)	1.03 ± 0.12
Mistags (double)	1.00 ± 0.50
Heavy Flavor Fractions	1.26 ± 0.13
b-Tagging Efficiency	1.01 ± 0.06

Table 31: Results from likelihood fitting to the signal and background. Only the heavy flavor fractions deviate from unity.

9 Cross Checks

As an additional cross check, we measured the cross section using the same method with two alternate event selections. First, we try applying the H_T cut ($>$ 200 GeV for $\geq$3 jets) without the W transverse mass cut. This should be a better parallel with what was done in the last round of analyses, and is not subject to any assumptions about the accuracy of the heavy flavor fractions, which were measured without selecting on m_T^W. Second, we try cutting harder on the event missing E_T, at 30 GeV rather than 20 GeV. This is clearly not an optimal cut (statistically or systematically, see Figure 46, but it does dramatically reduce the non-W background, which was the motivation for the transverse mass cut as well; if the non-

W contribution is measured reasonably well, the cross section should be consistent after tightening this cut (from the unoptimized analysis). We also measure the cross section separately for events with tight electrons and muons to verify that the two are close. A summary of all measurements with statistical errors is shown in Table 32. We find no inconsistencies in these measurements. Summary tables and plots for the lepton comparison in the unoptimized single-tag analysis are in Tables 33 and 34 and Figures 15 and 16. Figures 17 to 20 show background levels for the two new event selections.

We further attempt to measure the cross section using a sample identical to that in Gen4. We use the Version 4 good run list (162 pb^{-1}) and recalculate the mistag and QCD backgrounds. In principle, this good run list should be applied to the Monte Carlo as well, but we assume this is a small effect, particularly since we do not recalculate the mistag matrix or scale factor using the truncated data set. We measure a cross section of **8.3 ± 1.3 ± 1.2 pb** for the unoptimized selection, consistent with the result for the entire sample. The single-tag analysis for the loose tagger last yielded a result of 6.4 pb [9] in Gen4, though that number did not account properly for mistags; we estimate a cross section of roughly 7 pb in that analysis when the backgrounds are properly adjusted. Additionally, under these conditions, we do not reproduce the large excesses seen in the 1- and 2-jet bins, which were present in the previous analysis and persist here. A summary plot is shown in Figure 21.

Since the loose tagger no longer attempts to veto interactions in the material, we have measured the cross section using a simple cut at 1 cm in R_{xy}, the two-dimensional vertex position. Plots of the tag radius for the unoptimized selection can be found in Figure 37; there are clear bumps near the beampipe and innermost silicon layers that are not completely reproduced in the simulation. Though the structure would be smeared out (the CDF origin is not the center of the beampipe in MC) and are not expected to show up in the MC templates, the data excesses there are, in principle, accounted for statistically through the use of the α and β corrections to the light jet tag rate. Additionally, this material veto does have an effect on the b-tagging scale factor and the mistag predictions, which we do not explicitly recalculate. We scale the mistag prediciton down by 30% (roughly the fraction of light Jet50 jets with tag radius outside 1cm), and leave the scale factor as is. We measure a single-tag cross section of **8.3 pb** for the unoptimized analysis, consistent with our central value. The double-tag cross section comes out low, at **7.1 pb**, though any discrepancy in the scale factor will have a much larger effect for this number. Based on top Monte Carlo, the change in the double-tags is roughly a 2σ effect. If we instead assume that the scale factor is lower by 4Figures 22 and 23 show background summaries after the R_{xy} cut.

A final check if to measure the cross section for the unoptimized event selection but requiring at least 4 jets, rather than 3. It is demonstrated in Appendix D.2 that this is preferred for a cross section of 6.7 pb under some simple assumptions about the backgrounds. We find a cross section of **9.5 ± 1.1 ± 1.1 pb**, comparable in relative error to the H_T-optimized analysis.

	Total	Electrons	Muons
Unoptimized			
Single	8.6 ± 0.9	8.7 ± 1.3	8.4 ± 1.4
Double	9.5 ± 1.4	8.9 ± 1.9	10.3 ± 2.3
H_T> 200 GeV for ≥3 jets			
Single	8.7 ± 0.9	9.0 ± 1.2	8.3 ± 1.3
Double	10.0 ± 1.5	9.5 ± 1.9	10.8 ± 2.3
H_T> 200 GeV for ≥3 jets and m_T^W> 20 GeV			
Single	8.7 ± 0.9	8.9 ± 1.2	8.4 ± 1.3
Double	10.1 ± 1.5	9.3 ± 1.9	11.2 ± 2.4
Missing E_T>30 GeV			
Single	8.3 ± 1.0	8.5 ± 1.3	8.1 ± 1.4
Double	9.2 ± 1.5	8.8 ± 2.0	9.7 ± 2.4

Table 32: Summary of cross sections with statistical errors for all event selections and primary lepton types. All measurements are in pb.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Pretag	17648	2846	469	115	19
Pretag Top (8.7 pb)	5.24 ± 0.519	27.9 ± 2.71	54.1 ± 5.25	49 ± 4.76	15.1 ± 1.47
WW	2.2 ± 0.32	4.7 ± 0.72	1.4 ± 0.2	0.26 ± 0.036	0.062 ± 0.013
WZ	1.4 ± 0.18	2.3 ± 0.28	0.49 ± 0.062	0.11 ± 0.015	0.023 ± 0.0052
ZZ	0.01 ± 0.002	0.05 ± 0.006	0.03 ± 0.005	0.007 ± 0.001	0.006 ± 0.002
Single Top (s-ch)	1.2 ± 0.17	3.5 ± 0.46	0.73 ± 0.096	0.11 ± 0.016	0.015 ± 0.0028
Single Top (t-ch)	3.6 ± 1.6	4.5 ± 1.9	1 ± 0.43	0.14 ± 0.061	0.033 ± 0.015
$Z \rightarrow \tau\tau$	0.4 ± 0.09	0.1 ± 0.03	0.03 ± 0.005	0.004 ± 0.0008	0.0009 ± 0.0002
MC Backgrounds	9 ± 2.3	15 ± 3.4	3.7 ± 0.79	0.63 ± 0.13	0.14 ± 0.038
Wbb	64.4 ± 20	36.7 ± 11	7.87 ± 2	1.38 ± 0.4	0.0259 ± 0.0074
Wcc	26 ± 7.5	17 ± 5.2	4.8 ± 1.4	0.97 ± 0.31	0.018 ± 0.0058
Wc	72.2 ± 18	19.7 ± 4.9	4.05 ± 0.96	0.743 ± 0.19	0.0139 ± 0.0035
W+Heavy Flavor	163 ± 46	73.9 ± 21	16.7 ± 4.5	3.1 ± 0.93	0.058 ± 0.045
W+Light Flavor	151 ± 33	61.2 ± 13	17.6 ± 3.9	3.77 ± 0.83	0.088 ± 0.019
QCD	51 ± 12	22 ± 5.5	7.2 ± 1.9	3.1 ± 0.98	0.4 ± 0.26
Background	373 ± 58	173 ± 26	45.2 ± 6.75	10.6 ± 1.87	0.682 ± 0.401
Top (8.7 pb)	2.08 ± 0.255	16.4 ± 1.85	35.3 ± 3.89	34.6 ± 3.73	10.8 ± 1.16
Total	376 ± 58	189 ± 26.1	80.6 ± 7.79	45.2 ± 4.18	11.5 ± 1.23
Tags	447	212	78	47	12

Table 33: Summary table for the unoptimized, single-tag analysis with primary electrons only. The top cross section is scaled to 8.7 pb.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Pretag	12980	1945	300	64	17
Pretag Top (8.4 pb)	3.74 ± 0.383	20.1 ± 1.96	39.4 ± 3.84	34.7 ± 3.38	10.7 ± 1.06
WW	1.9 ± 0.27	3.3 ± 0.51	1 ± 0.16	0.2 ± 0.033	0.064 ± 0.017
WZ	0.92 ± 0.12	1.6 ± 0.2	0.37 ± 0.048	0.072 ± 0.012	0.0093 ± 0.0027
ZZ	0.03 ± 0.004	0.09 ± 0.01	0.02 ± 0.004	0.009 ± 0.002	0 ± 0
Single Top (s-ch)	0.81 ± 0.11	2.4 ± 0.31	0.5 ± 0.066	0.075 ± 0.012	0.011 ± 0.0028
Single Top (t-ch)	2.5 ± 1.1	3.1 ± 1.3	0.66 ± 0.28	0.14 ± 0.061	0.016 ± 0.008
$Z \to \tau\tau$	0.3 ± 0.06	0.1 ± 0.02	0.02 ± 0.004	0.002 ± 0.0003	0.0004 ± 8e-05
MC Backgrounds	6.4 ± 1.6	11 ± 2.4	2.6 ± 0.56	0.5 ± 0.12	0.1 ± 0.031
Wbb	50.7 ± 16	27.6 ± 8.1	5.26 ± 1.4	0.631 ± 0.18	0.134 ± 0.039
Wcc	21 ± 5.9	13 ± 3.9	3.2 ± 0.95	0.45 ± 0.14	0.095 ± 0.03
Wc	56.9 ± 14	14.8 ± 3.7	2.7 ± 0.64	0.34 ± 0.086	0.0722 ± 0.018
W+Heavy Flavor	128 ± 36	55.5 ± 16	11.2 ± 3	1.42 ± 0.42	0.301 ± 0.09
W+Light Flavor	113 ± 25	42.5 ± 9.4	10.1 ± 2.2	1.81 ± 0.4	0.534 ± 0.12
QCD	13 ± 3.2	6.4 ± 1.6	3.2 ± 0.99	2 ± 0.75	0.22 ± 0.19
Background	261 ± 43.9	115 ± 18.6	27 ± 4.27	5.76 ± 1.24	1.16 ± 0.334
Top (8.4 pb)	1.47 ± 0.184	11.9 ± 1.35	25.8 ± 2.85	24.5 ± 2.65	7.74 ± 0.842
Total	262 ± 43.9	127 ± 18.7	52.8 ± 5.13	30.3 ± 2.93	8.9 ± 0.906
Tags	283	150	49	31	12

Table 34: Summary table for the unoptimized, single-tag analysis with primary muons only. The top cross section is scaled to 8.5 pb.

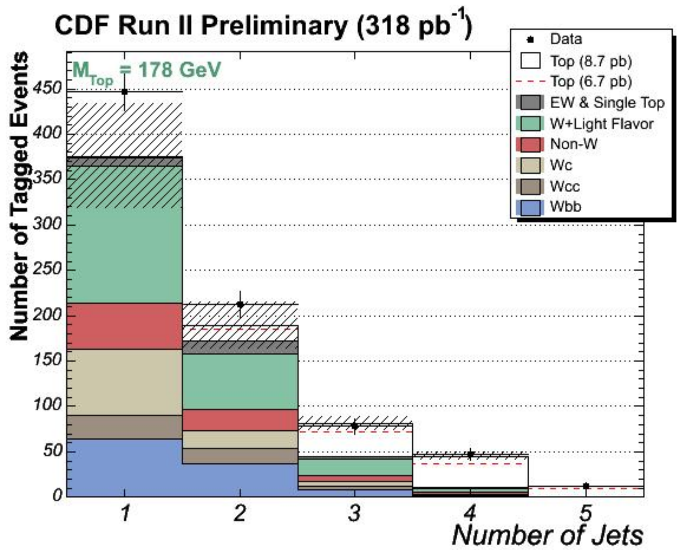

Figure 15: Background summary for the unoptimized single-tag analysis with electrons only.

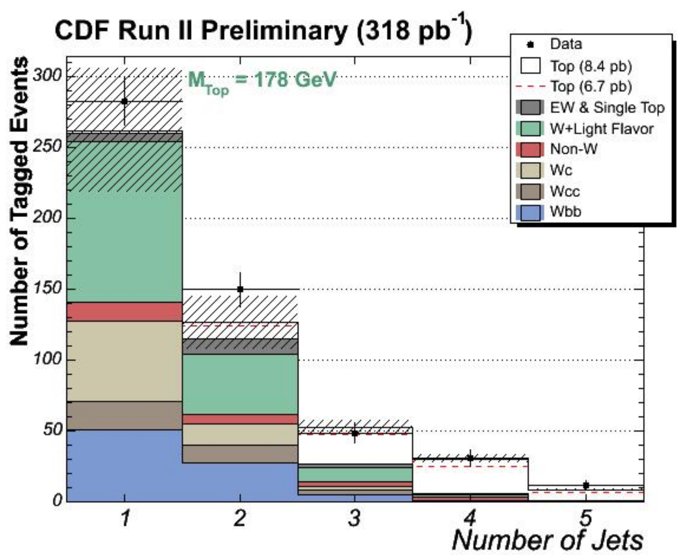

Figure 16: Background summary for the unoptimized single-tag analysis with muons only.

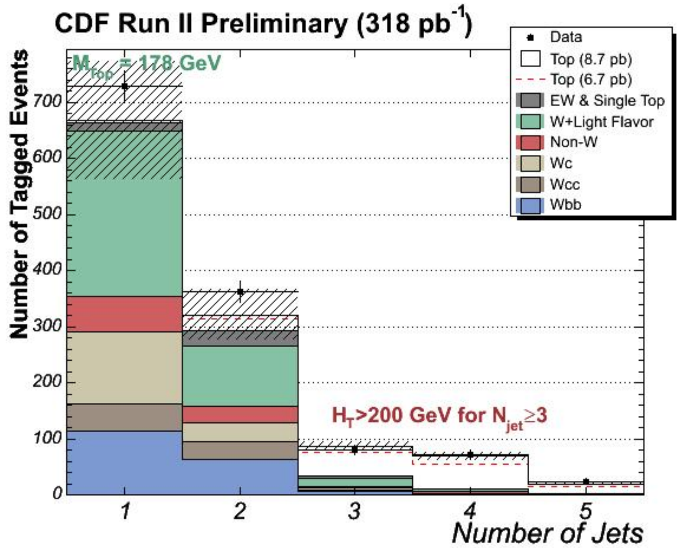

Figure 17: Background summary for the H_T cut single-tag analysis.

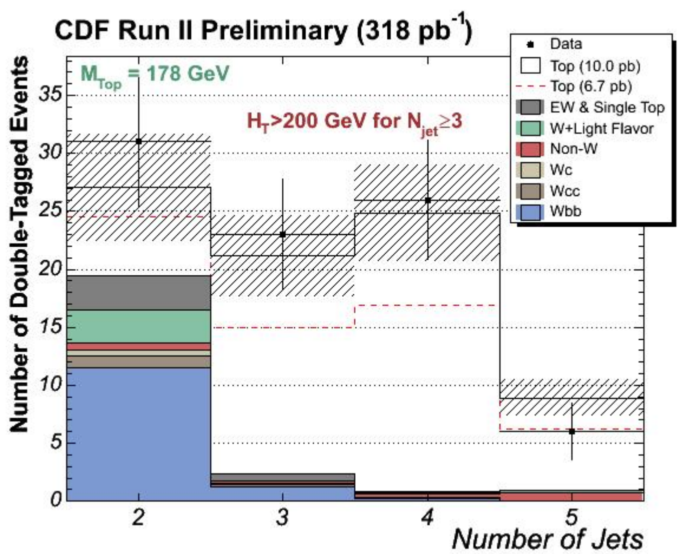

Figure 18: Background summary for the H_T cut double-tag analysis.

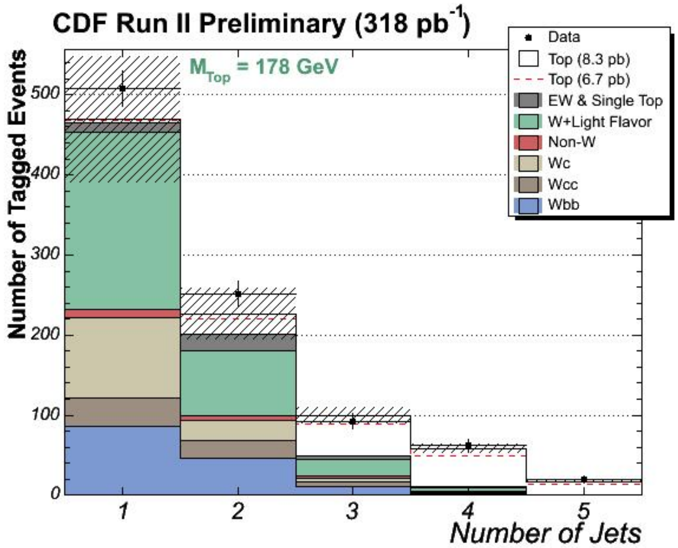

Figure 19: Background summary for the higher missing E_T cut single-tag analysis.

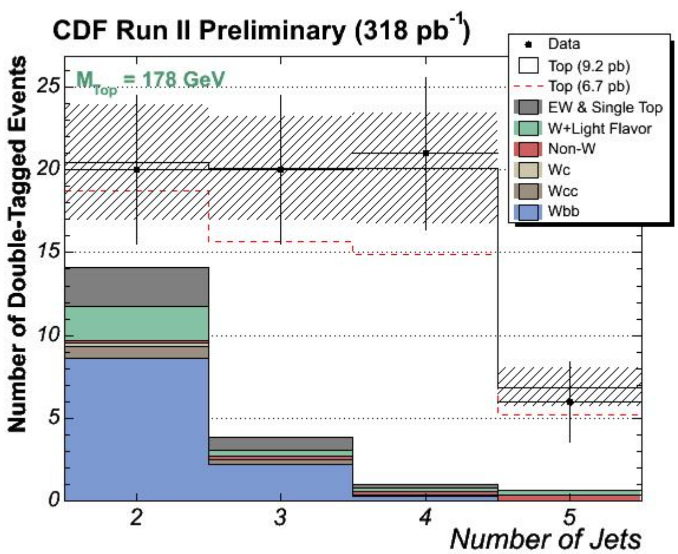

Figure 20: Background summary for the higher missing E_T cut double-tag analysis.

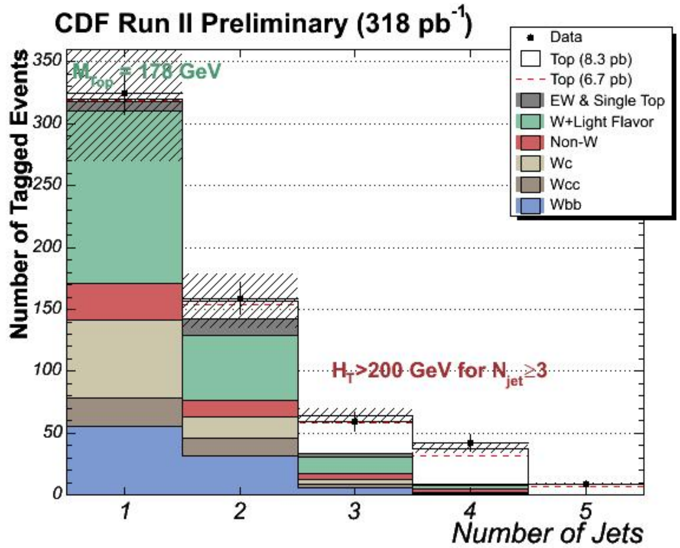

Figure 21: Background summary for the unoptimized single-tag analysis using only the first 162 pb^{-1}.

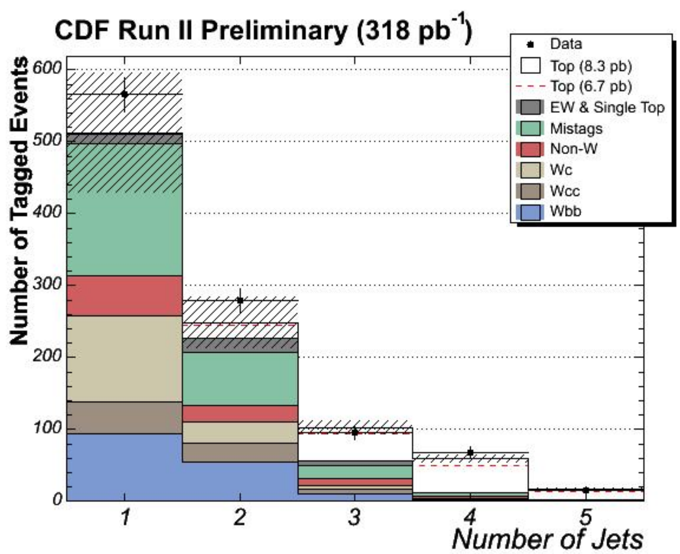

Figure 22: Background summary for the unoptimized single-tag analysis requiring tags to have R_{xy}<1 cm.

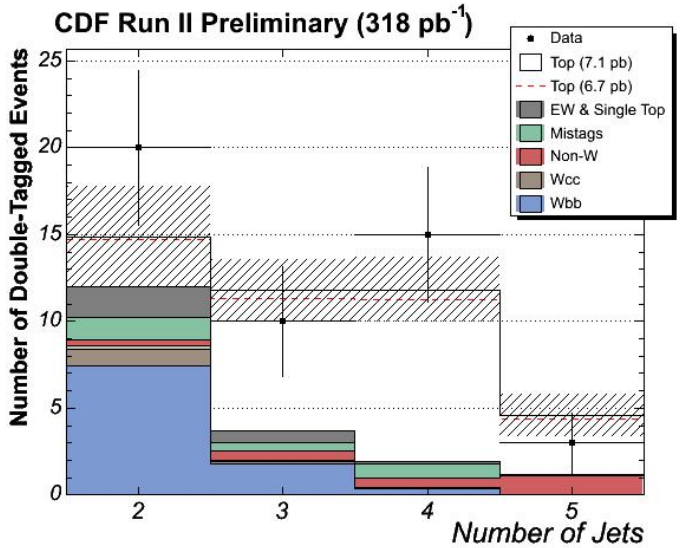

Figure 23: Background summary for the unoptimized double-tag analysis requiring tags to have R_{xy}<1 cm.

9.1 Mass Dependence

The acceptance and efficiency were based on a Pythia Monte Carlo simulation assuming a top mass of 178 GeV/c^2, the best mass measurement from Run II using the first half of the data. More recently, superior CDF results indicate that the actual top mass is slightly lower, at 173 GeV/c^2. A top simulation using a smaller top mass may have a different acceptance and tagging efficiency due to the different jet and lepton energies. We therefore recalculate the cross section using `Herwig` samples generated at 2.5 GeV/c^2 intervals in the vicinity of the central top mass. We take the slope of a linear fit to these data and apply this as a correction to our measured cross section value. Since our presented measurement involved a Pythia sample, there is no strict requirement that our central value fall on this line; important factors like the W branching ratio and the tagging scale factor will be different in these samples, and we have not explicitly recalculated the backgrounds for each top sample (this is only substantial for the non-W $t\bar{t}$ correction).

Results of the fits are shown in Figure 24 for the optimized analysis only. The intercept ($p0$) is the fit value at 175 GeV/c^2. For the single-tag cross section, we measure a slope of -0.077 $\pm$ 0.008 pb per GeV/c^2, and we measure -0.101 $\pm$ 0.008 pb per GeV/c^2 for the double-tag analysis. A shift to the world average top mass of 175 GeV/c^2, then, corresponds to a shift of 0.2 pb and 0.3 pb for the single- and double-tag cross sections.

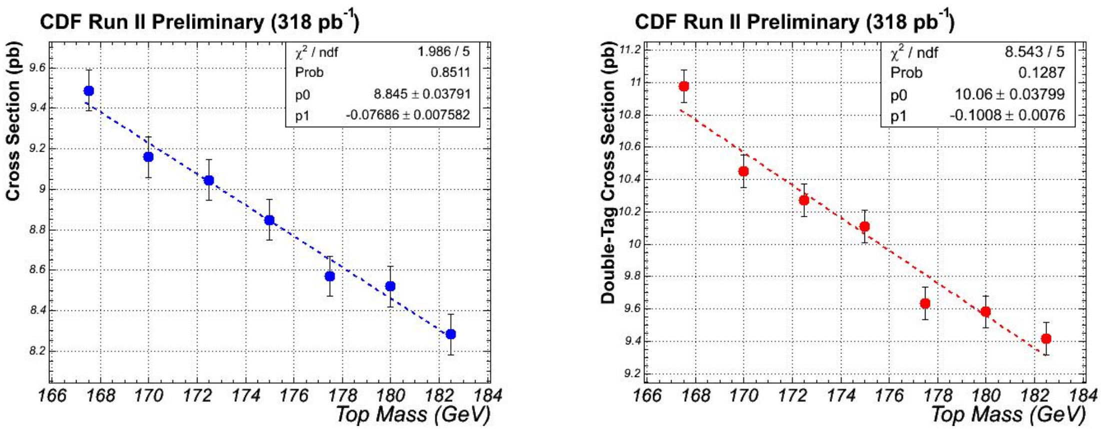

Figure 24: Mass dependence of the top cross section for the single-tag (left) and double-tag (right), optimized analysis.

10 Conclusions

We have measured the top pair production cross section using a loose version of the SecVtx b-tagger. We find results consistent with those using the default tagger, as well as in other decay modes. For the default, unoptimized analysis, we measure $\mathbf{8.6^{+1.0}_{-0.9}(stat)^{+1.3}_{-1.1}(syst)}$ **pb** for single-tags and $\mathbf{9.5^{+1.5}_{-1.4}(stat)^{+2.1}_{-1.5}(syst)}$ **pb** for double-tags. For the alternate event selection optimized for the tight analysis, which includes additional H_T and W transverse mass requirements, we measure $\mathbf{8.7^{+0.9}_{-0.9}(stat)^{+1.2}_{-0.9}(syst)}$ **pb** for single-tags and $\mathbf{10.1^{+1.6}_{-1.4}(stat)^{+2.1}_{-1.4}(syst)}$ **pb** for double-tags.

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A Backgrounds for Mass Analysis

The loose SecVtx tagger may be used as a higher-statistics cross check to the default analysis. Since that measurement is in large part driven by the double-tag sample, where the backgrounds are minimal, the expected 50% increase in statistics may even yield a better result.

The backgrounds were therefore re-calculated for the top mass analysis using similar procedures to the cross section measurement. The only significant changes were to separate out the 3.5-jet bin from the 3-jet bin, which contains events with exactly three tight jets and *at least* one loose jet (corrected $E_T > 8$ GeV), and to allow tags only on the first four tight jets. This second requirement is a small effect restricted to the 5-jet bin estimate, but explains the discrepancy in the total tag estimate in the signal region. We assume a cross section of 6.1pb, expected for a mass of 178 GeV/c^2 (as in the Monte Carlo). The single (inclusive) tag backgrounds are in Table 35 and the double tag backgrounds are in Table 36. The 3-jet bin, as shown below, includes the contribution from the 3.5-jet bin.

	1-jet	2-jet	3-jet	4-jet	≥5-jet	3.5-jet
Pretag	30628	4791	769	179	36	280
WW	4.05 ± 0.612	7.87 ± 1.24	2.38 ± 0.357	0.449 ± 0.0696	0.11 ± 0.03	0.72 ± 0.08
WZ	2.32 ± 0.304	3.85 ± 0.494	0.851 ± 0.113	0.177 ± 0.0279	0.03 ± 0.01	0.23 ± 0.03
ZZ	0.04 ± 0.006	0.1 ± 0.02	0.06 ± 0.009	0.02 ± 0.004	0.006 ± 0.002	0.02 ± 0.01
Single Top (s-ch)	2.0 ± 0.3	5.89 ± 0.79	1.23 ± 0.166	0.18 ± 0.03	0.03 ± 0.01	0.38 ± 0.04
Single Top (t-ch)	6.08 ± 2.6	7.5 ± 3.21	1.66 ± 0.709	0.279 ± 0.121	0.05 ± 0.02	0.49 ± 0.06
$Z \to \tau\tau$	0.8 ± 0.2	0.2 ± 0.05	0.05 ± 0.01	0.005 ± 0.001	0.0009 ± 0.0003	0.02 ± 0.01
MC Backgrounds	15.3 ± 3.97	25.5 ± 5.8	6.22 ± 1.36	1.11 ± 0.251	0.23 ± 0.07	1.87 ± 0.21
Wbb	115 ± 35.5	64.6 ± 18.9	13.8 ± 3.57	2.72 ± 0.783	0.36 ± 0.11	4.87 ± 1.65
Wcc	46.7 ± 13.5	30.7 ± 9.11	8.51 ± 2.51	1.96 ± 0.615	0.26 ± 0.08	3.00 ± 1.25
Wc	129 ± 32.7	34.8 ± 8.72	7.14 ± 1.69	1.48 ± 0.375	0.20 ± 0.05	2.57 ± 1.12
WHF	291 ± 81.8	130 ± 36.8	29.4 ± 7.81	6.16 ± 1.79	0.82 ± 0.24	10.44 ± 4.02
Mistag	294 ± 35.2	109 ± 13.1	29 ± 3.48	7.38 ± 0.89	1.24 ± 0.25	11.65 ± 1.28
QCD	64.2 ± 12.7	28.7 ± 5.71	10.6 ± 2.21	5.4 ± 1.28	0.72 ± 0.35	3.82 ± 0.98
Background	664 ± 90.1	293 ± 40.3	75.3 ± 9.68	20.1 ± 2.84	3.1 ± 0.7	27.78 ± 4.37
Top	2.51 ± 0.322	19.9 ± 2.37	43.2 ± 5.03	41.8 ± 4.77	13.1 ± 1.5	21.3 ± 2.5

Table 35: Backgrounds for the top mass analysis with ≥1 tagged jet.

	1-jet	2-jet	3-jet	4-jet	≥5-jet	3.5-jet
Pretag	30628	4791	769	179	36	280
WW	0 ± 0	0.115 ± 0.0144	0.0884 ± 0.0152	0.016 ± 0.004	0.009 ± 0.003	0.04 ± 0.01
WZ	0 ± 0	0.542 ± 0.1	0.154 ± 0.0284	0.0296 ± 0.00599	0.006 ± 0.002	0.05 ± 0.01
ZZ	0 ± 0	0.03 ± 0.005	0.01 ± 0.002	0.002 ± 0.0005	0.0008 ± 0.0004	0.003 ± 0.001
Single Top (s-ch)	0 ± 0	1.85 ± 0.35	0.414 ± 0.0783	0.0598 ± 0.0117	0.009 ± 0.002	0.14 ± 0.03
Single Top (t-ch)	0 ± 0	0.363 ± 0.161	0.355 ± 0.158	0.0824 ± 0.0372	0.015 ± 0.007	0.14 ± 0.04
MC Backgrounds	0 ± 0	2.9 ± 0.63	1.02 ± 0.28	0.19 ± 0.06	0.04 ± 0.01	0.38 ± 0.09
Wbb	0 ± 0	13.5 ± 4.21	3.08 ± 0.903	0.762 ± 0.267	0.10 ± 0.04	0.97 ± 0.34
Wcc	0 ± 0	1.16 ± 0.482	0.571 ± 0.245	0.169 ± 0.0848	0.02 ± 0.01	0.20 ± 0.09
Wc	0 ± 0	0.609 ± 0.148	0.0868 ± 0.037	0.0462 ± 0.0263	0.008 ± 0.003	0.02 ± 0.01
WHF	0 ± 0	15.3 ± 4.46	3.73 ± 1.03	0.977 ± 0.288	0.13 ± 0.04	1.20 ± 0.44
Mistag	0 ± 0	3.08 ± 1.54	1.74 ± 0.869	1.7 ± 0.849	0.88 ± 0.44	0.89 ± 0.45
QCD	0 ± 0	0.622 ± 0.622	0.756 ± 0.756	0.757 ± 0.757	0.93 ± 0.93	0.39 ± 0.39
Background	0 ± 0	21.9 ± 4.91	7.25 ± 1.93	3.62 ± 1.3	1.98 ± 1.03	2.86 ± 0.75
Top	0 ± 0	4.62 ± 0.818	12.6 ± 2.23	15 ± 2.64	4.86 ± 0.82	6.03 ± 1.07

Table 36: Backgrounds for the top mass analysis with ≥2 tagged jets.

B Run and Event Numbers

3-Jet CEM										
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	e^- E_T	Jet E_T	Jet φ	3.5 Jets
141618	1968597	yes	yes	232.6	58.5	10.5	30.0	91.6	2.6	no
144674	1782954	yes	yes	252.7	31.8	104.0	94.5	37.8	2.3	yes
150395	98852	yes	yes	140.7	25.2	39.2	20.8	25.5	3.7	no
150418	1033033	yes	yes	112.9	23.7	49.8	31.8	18.7	5.3	no
150803	2939258	no	yes	513.9	131.5	105.6	131.8	193.6	0.9	yes
151688	1312087	no	yes	292.5	38.6	118.8	111.1	22.2	3.6	no
151869	690782	yes	yes	178.0	38.4	54.7	31.5	25.6	3.2	no
152598	542476	no	yes	241.4	30.9	61.7	63.9	23.9	1.9	yes
155145	132579	yes	yes	270.9	43.6	69.1	52.6	32.1	4.5	yes
155145	132579	yes	yes	270.9	43.6	69.1	52.6	62.5	0.5	yes
155345	3194866	yes	yes	190.7	64.1	60.7	24.9	43.4	4.7	yes
155747	770313	no	yes	167.9	45.5	72.7	37.7	20.4	2.9	yes
155770	1158754	no	yes	207.7	22.4	91.5	96.2	18.5	2.4	no
155770	1158754	no	yes	207.7	22.4	91.5	96.2	55.4	3.7	no
155793	4312618	yes	yes	260.8	40.7	87.1	62.7	34.7	4.5	no
156116	6116596	no	yes	249.9	30.6	49.3	25.2	54.9	5.7	no
156116	6116596	yes	yes	249.9	30.6	49.3	25.2	65.9	3.7	no
156116	6116596	yes	yes	249.9	30.6	49.3	25.2	73.2	1.2	no
160303	181578	no	yes	147.4	54.7	54.8	24.0	27.2	4.9	no
160599	129700	yes	no	187.1	23.7	24.3	43.4	55.3	1.3	yes
161409	1820111	no	yes	206.6	39.5	66.4	55.3	36.4	4.9	no
161678	1080224	yes	yes	197.9	70.5	67.2	29.5	17.2	5.7	yes
161678	1080224	yes	yes	197.9	70.5	67.2	29.5	21.6	0.2	yes
162178	2690653	yes	yes	208.4	49.0	86.0	44.0	62.0	6.0	no
162396	1484932	no	yes	281.5	98.6	52.9	22.8	74.9	0.5	no
162462	1484328	no	yes	213.2	60.0	74.4	29.7	84.0	2.4	no
162663	80178	yes	yes	218.3	42.3	77.7	35.8	45.1	4.8	no
162663	80178	yes	yes	218.3	42.3	77.7	35.8	51.3	0.2	no
162837	433408	yes	yes	392.4	28.8	125.2	139.3	59.9	2.3	yes
162837	433408	yes	yes	392.4	28.8	125.2	139.3	61.6	4.3	yes
162856	2522552	no	yes	300.2	27.6	102.9	103.8	100.1	2.8	no
162857	4107280	yes	yes	258.5	31.7	74.6	57.8	48.2	3.2	yes
164451	7530950	yes	yes	201.4	51.2	41.4	24.1	20.6	1.4	yes
164989	1594353	yes	yes	318.3	28.8	120.8	139.9	94.0	2.6	yes
165121	428911	no	yes	382.6	51.0	58.0	55.0	40.4	2.7	no
165121	428911	yes	yes	382.6	51.0	58.0	55.0	58.2	3.7	no
165271	1508874	no	yes	183.5	28.9	67.8	63.6	51.5	4.8	no
165271	6116896	yes	yes	345.2	146.1	73.4	31.9	90.4	5.9	no

Table 37: Event information for all tags in 3-jet CEM events.

3-Jet CEM										
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	e^- E_T	Jet E_T	Jet φ	3.5 Jets
165836	566421	yes	no	241.0	34.8	55.3	26.3	79.2	5.8	no
165902	1487424	yes	yes	260.0	66.7	44.1	37.4	38.4	4.6	no
166007	498553	no	yes	275.4	56.6	64.9	46.0	52.3	3.6	yes
166007	498553	yes	yes	275.4	56.6	64.9	46.0	63.8	4.0	yes
166037	1912411	yes	yes	144.1	26.4	67.8	52.4	26.1	1.0	no
166038	3453993	no	yes	224.0	30.7	92.9	84.6	59.1	6.0	no
166479	4910255	yes	yes	192.2	58.1	84.7	40.1	50.5	3.0	no
166567	6377008	yes	yes	164.3	43.9	77.5	40.8	36.8	1.4	no
166615	6805282	no	yes	178.1	23.5	61.4	55.2	62.5	0.4	no
166615	6805282	yes	yes	178.1	23.5	61.4	55.2	20.5	2.1	no
166927	8307431	yes	yes	283.2	21.3	90.9	112.5	53.3	2.6	no
167053	5091995	yes	yes	301.4	22.0	101.1	129.7	30.9	5.5	no
167053	7442159	yes	yes	231.5	39.6	95.7	74.8	61.1	6.1	yes
167977	703804	yes	yes	252.0	50.3	34.6	46.3	53.3	4.5	no
167977	785542	yes	yes	418.2	44.9	57.1	52.9	125.0	2.6	no
167977	785542	yes	yes	418.2	44.9	57.1	52.9	174.7	6.1	no
168599	2754645	no	yes	193.9	24.8	87.6	92.7	17.9	3.8	yes
168599	3427662	yes	yes	252.4	34.9	67.5	44.7	68.4	2.9	no
168599	3427662	yes	yes	252.4	34.9	67.5	44.7	77.5	6.2	no
168889	12039476	yes	yes	318.8	34.8	35.8	76.2	55.1	0.7	no
168889	12039476	yes	yes	318.8	34.8	35.8	76.2	85.1	3.0	no
176651	297931	yes	yes	164.6	40.8	75.8	40.7	27.1	4.9	no
177314	4056160	yes	yes	252.2	99.8	46.1	28.3	56.1	1.5	no
177927	3216152	yes	yes	362.1	83.0	168.7	131.5	18.1	3.1	no
178389	322702	yes	yes	308.7	43.7	27.2	52.1	140.8	4.9	yes
178440	595503	no	yes	254.3	64.5	70.5	54.8	44.2	4.4	yes
178738	10453838	yes	yes	325.0	38.0	89.9	59.9	90.2	4.3	no
178759	1601160	yes	yes	200.2	58.3	72.0	23.7	26.5	1.4	no
178759	1601160	yes	yes	200.2	58.3	72.0	23.7	38.3	3.7	no
178882	1300078	yes	yes	317.2	54.6	88.0	57.5	123.4	5.4	no
178882	1300078	yes	yes	317.2	54.6	88.0	57.5	50.0	2.6	no
183209	281684	yes	yes	206.4	21.0	35.3	37.9	74.6	4.9	no
183557	1258104	yes	yes	170.6	25.9	57.3	42.6	43.5	2.2	no
183785	3862531	no	yes	229.9	56.5	67.8	38.5	60.4	5.0	no
183785	3862531	yes	yes	229.9	56.5	67.8	38.5	45.1	4.1	no
184068	2338573	no	yes	233.6	40.0	93.2	59.5	30.5	3.5	yes
184068	2338573	yes	yes	233.6	40.0	93.2	59.5	24.1	3.3	yes
184377	11014941	yes	yes	258.2	25.8	83.1	71.4	51.5	5.5	no
184377	819252	no	yes	184.8	23.7	79.7	71.2	43.7	5.9	no
184495	1152315	yes	yes	619.1	35.0	134.4	131.9	181.2	0.2	yes
184495	4025111	yes	yes	402.3	79.1	32.2	42.1	103.9	6.2	yes
184832	3000449	no	yes	122.8	21.7	60.6	50.5	17.6	4.6	no
184832	7457593	yes	yes	221.3	30.6	39.0	52.4	20.2	6.0	yes
185037	3988707	yes	yes	179.6	32.4	100.9	85.4	22.5	1.9	no

Table 38: Event information for all tags in 3-jet CEM events (continued).

3-Jet CEM										
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	e^- E_T	Jet E_T	Jet φ	3.5 Jets
185249	1839747	yes	yes	163.5	42.9	12.5	27.6	31.2	3.3	no
185249	5691924	no	yes	307.6	118.1	227.3	116.2	32.6	2.7	no
185249	5691924	yes	yes	307.6	118.1	227.3	116.2	25.4	5.4	no
185260	4464842	yes	yes	537.1	37.9	115.7	94.3	168.9	3.0	yes
185260	4464842	yes	yes	537.1	37.9	115.7	94.3	84.9	0.1	yes
185281	18790239	yes	yes	254.4	61.4	92.0	40.1	94.2	0.3	yes
185332	11657514	yes	yes	184.0	47.6	82.8	51.8	35.1	5.6	no
185332	12612503	yes	yes	154.3	29.8	48.9	20.5	35.5	1.9	no
185332	14950478	yes	yes	250.5	26.8	62.7	42.3	81.8	5.3	yes
185332	16515484	yes	yes	204.3	38.8	82.3	52.5	51.6	5.6	yes
185542	2182962	no	yes	198.1	36.6	30.0	50.3	34.2	3.2	no
185542	2866245	no	yes	277.7	35.2	42.0	24.7	68.5	6.1	no
185594	1202801	no	yes	181.1	49.2	82.9	41.2	46.3	4.4	yes
185634	6538828	yes	yes	189.4	49.8	69.6	30.9	57.0	3.7	yes
185782	2406585	no	yes	218.1	28.5	71.8	55.6	20.9	0.1	no
186084	3182017	yes	yes	158.2	35.8	63.0	52.4	24.0	0.2	yes
186302	2168909	no	yes	226.3	56.9	69.1	30.0	35.8	0.0	no

Table 39: Event information for all tags in 3-jet CEM events (continued).

3-Jet CMUP										
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	$\mu\ p_T$	Jet E_T	Jet φ	3.5 Jets
141597	1353293	yes	yes	204.8	28.1	75.0	50.3	34.2	2.7	yes
141597	1353293	yes	yes	204.8	28.1	75.0	50.3	41.3	1.8	yes
151869	647873	no	yes	251.2	54.9	22.0	38.2	99.8	2.8	yes
152615	1274128	yes	yes	163.7	50.5	27.2	24.1	33.3	5.4	no
154021	1352107	yes	yes	316.9	24.8	60.3	46.3	30.5	2.6	yes
154021	1352107	yes	yes	316.9	24.8	60.3	46.3	91.3	3.4	yes
155743	280777	no	yes	169.4	29.4	60.8	34.2	35.7	1.6	yes
160591	501642	no	yes	181.9	65.2	61.7	21.1	16.2	2.7	no
160988	228339	no	yes	181.8	31.5	60.7	31.9	46.2	4.3	no
164274	2932602	yes	yes	208.2	34.0	103.5	85.7	32.7	4.0	yes
165121	7186180	yes	yes	140.5	44.4	76.5	33.8	18.1	5.9	no
166614	2146736	no	yes	285.3	35.7	61.8	88.8	112.8	2.1	yes
166653	1554047	no	yes	195.6	41.2	80.5	41.5	15.4	2.2	no
166771	846042	yes	yes	135.0	33.2	54.9	37.2	25.5	1.7	yes
166779	3800533	yes	yes	245.8	82.3	86.5	42.2	56.1	2.0	no
167259	1142209	yes	yes	175.0	34.1	81.5	49.0	39.9	2.9	yes
167297	535675	yes	yes	187.2	34.4	90.9	64.5	44.1	5.6	no
167824	8234433	no	yes	196.4	46.6	67.0	31.4	43.7	2.4	yes
167849	1739510	no	yes	313.2	100.9	82.1	24.1	55.1	1.4	yes
167954	4519267	no	yes	204.7	21.8	58.3	44.9	59.6	0.2	yes
167954	4519267	yes	yes	204.7	21.8	58.3	44.9	33.1	2.6	yes
177628	1517364	yes	yes	159.3	45.9	52.2	33.8	47.7	4.2	no
178390	3929243	yes	yes	294.2	66.9	103.1	55.0	45.6	5.0	yes
178738	2055079	no	yes	128.7	28.4	66.8	41.7	22.0	5.2	no
178738	5844388	yes	yes	224.5	46.6	67.9	39.3	27.5	2.5	yes
178852	2167379	yes	yes	326.9	47.1	80.6	98.6	145.7	0.3	no
178881	10612822	yes	yes	153.5	23.9	32.5	46.9	40.1	3.1	yes
178881	4573859	no	yes	210.7	20.7	64.5	59.2	81.6	3.6	yes
182874	78353	yes	yes	168.9	34.0	77.8	46.7	25.0	4.7	no
183530	4037862	yes	yes	221.1	75.9	128.4	65.6	27.6	5.1	yes
183557	1288983	yes	yes	337.6	44.1	68.5	28.2	142.4	2.9	no
183557	1288983	yes	yes	337.6	44.1	68.5	28.2	16.9	5.5	no
183965	7773800	yes	yes	183.1	25.1	45.7	22.8	36.5	1.3	no
184015	737953	no	yes	199.0	33.5	63.5	40.5	29.5	1.3	yes
184015	737953	yes	yes	199.0	33.5	63.5	40.5	55.1	2.6	yes
184377	11678359	yes	yes	243.3	37.2	51.2	23.8	22.4	1.0	no
184445	609320	yes	yes	220.8	71.6	21.3	28.4	48.1	5.7	yes
184762	2561196	yes	yes	344.0	63.2	72.2	75.4	128.6	2.1	no
184762	2561196	yes	yes	344.0	63.2	72.2	75.4	61.2	4.1	no
184802	3421801	yes	yes	199.3	24.8	67.7	50.0	21.0	5.0	no
184802	3421801	yes	yes	199.3	24.8	67.7	50.0	58.1	0.0	no
186145	6729198	yes	yes	365.1	36.7	78.1	52.3	114.9	4.6	yes

Table 40: Event information for all tags in 3-jet CMUP events.

3-Jet CMX										
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	$\mu\ p_T$	Jet E_T	Jet φ	3.5 Jets
160406	154621	yes	yes	207.4	25.4	70.5	56.6	37.8	1.2	no
160796	2445318	no	yes	145.9	27.5	76.5	59.3	15.3	5.9	no
161171	1163361	yes	yes	352.7	26.1	69.8	56.8	110.3	5.6	no
162631	7109631	yes	yes	221.8	24.7	47.5	74.6	16.5	1.2	yes
166325	1249548	yes	yes	151.3	25.7	42.0	22.4	61.9	1.8	yes
166567	490760	yes	yes	256.1	95.5	147.4	72.8	30.0	2.2	no
166567	490760	yes	yes	256.1	95.5	147.4	72.8	40.6	1.6	no
166927	5822870	yes	yes	266.6	33.9	47.4	35.0	88.4	0.3	no
168889	4979781	no	yes	592.0	215.6	421.4	253.6	27.0	5.7	yes
178071	282015	yes	yes	199.5	23.6	80.9	78.0	50.8	5.6	yes
183965	4462113	yes	yes	311.7	82.0	66.3	40.2	81.6	1.8	no
184765	405764	yes	yes	325.2	88.1	65.7	28.5	145.1	4.2	no
185037	4098975	yes	yes	247.5	66.1	70.6	29.4	42.6	4.1	yes
185377	1984427	no	yes	317.6	53.5	67.1	45.6	133.0	4.1	yes
185377	1984427	no	yes	317.6	53.5	67.1	45.6	63.9	0.9	yes
185848	10192934	yes	yes	175.6	61.9	58.7	29.7	42.4	0.5	no

Table 41: Event information for all tags in 3-jet CMX events.

4-Jet CEM									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	e^- E_T	Jet E_T	Jet φ
144574	1407330	no	yes	185.8	55.7	76.3	32.4	18.9	2.9
150432	2581346	no	yes	264.1	117.1	117.3	37.9	23.9	1.6
152504	482659	no	yes	294.8	31.0	75.3	45.9	50.3	6.1
153694	1694029	yes	yes	301.3	31.5	56.3	31.8	118.1	3.5
153694	1694029	yes	yes	301.3	31.5	56.3	31.8	60.1	0.6
153738	205803	yes	yes	302.7	83.7	38.7	31.7	100.0	6.3
153738	205803	yes	yes	302.7	83.7	38.7	31.7	46.3	1.5
153738	2083102	yes	yes	333.1	64.2	74.3	22.1	102.9	3.4
154175	1630925	yes	yes	336.1	122.5	77.6	29.9	18.2	3.1
155320	480816	yes	yes	243.6	29.3	77.9	93.2	51.5	3.8
155919	2689969	no	yes	269.3	47.4	65.7	51.1	24.0	3.1
155919	2689969	yes	yes	269.3	47.4	65.7	51.1	84.0	2.9
156457	13182	yes	yes	236.7	66.0	72.0	33.1	33.6	2.6
160153	1270879	yes	yes	333.6	55.8	70.5	92.0	50.4	6.0
160230	805211	yes	yes	342.6	84.4	11.5	64.6	20.6	1.9
160230	805211	yes	yes	342.6	84.4	11.5	64.6	57.4	0.8
160441	3910866	no	yes	422.1	53.9	73.2	110.7	46.9	1.8
160441	3910866	yes	yes	422.1	53.9	73.2	110.7	84.3	4.6
160594	290458	yes	yes	275.3	42.2	113.8	91.6	50.1	0.5
161633	1571961	yes	yes	269.4	32.8	62.2	48.2	54.9	4.2
161792	391660	yes	yes	235.4	55.9	67.1	45.1	28.0	0.8
162423	261933	yes	yes	218.6	33.5	93.1	73.6	38.4	2.3
164110	954852	yes	yes	224.0	41.3	56.2	28.6	30.7	5.9
164110	954852	yes	yes	224.0	41.3	56.2	28.6	45.9	6.3
164274	1449940	yes	yes	215.9	24.0	70.6	59.6	46.7	4.4
164819	1242550	yes	yes	404.2	42.8	68.9	146.1	23.6	1.7
165314	236898	no	yes	295.4	32.4	56.9	71.4	73.3	5.2
165314	236898	yes	yes	295.4	32.4	56.9	71.4	26.1	5.3
166614	804529	yes	yes	357.0	28.6	60.2	113.6	22.5	1.3
166614	804529	yes	yes	357.0	28.6	60.2	113.6	50.3	4.2
166653	1499964	yes	yes	325.6	37.6	53.8	91.9	18.2	4.0
166653	1499964	yes	yes	325.6	37.6	53.8	91.9	73.4	1.2
166715	357810	yes	yes	190.1	41.6	84.4	45.7	22.9	2.7
166717	3530653	yes	yes	217.5	44.1	81.6	38.0	16.4	2.2
167053	12401969	yes	yes	275.3	24.1	91.7	93.5	46.8	0.4
167715	557934	no	yes	224.2	28.5	62.8	46.9	22.3	0.4
167715	557934	no	yes	224.2	28.5	62.8	46.9	46.3	1.5
168563	2395692	yes	yes	253.7	49.8	57.6	31.3	25.2	4.8
177314	2950396	no	yes	256.8	68.6	79.0	24.3	29.6	1.0
177314	2950396	yes	yes	256.8	68.6	79.0	24.3	50.7	2.9
177345	3135596	yes	no	296.5	55.1	94.2	57.0	15.0	6.1
178258	782935	yes	yes	265.0	65.8	36.7	26.2	56.7	2.3
178677	4378990	yes	yes	338.9	65.1	32.1	34.4	64.5	2.2

Table 42: Event information for all tags in 4-jet CEM events.

4-Jet CEM									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	e^- E_T	Jet E_T	Jet φ
182874	765090	no	yes	411.3	30.6	116.7	175.6	25.6	1.9
183209	1059754	yes	yes	204.0	21.3	25.5	21.3	52.7	4.6
183553	2239398	no	yes	284.9	30.4	65.4	41.1	33.6	6.1
183631	31445	yes	yes	168.8	26.8	61.4	36.6	25.8	2.7
183752	3562502	yes	yes	281.6	75.2	89.9	45.9	50.3	6.2
184012	278184	no	yes	306.7	45.3	67.0	35.5	73.7	0.4
184419	291129	yes	yes	335.6	52.7	142.1	97.2	62.6	0.3
184453	19917	yes	yes	396.5	104.1	31.3	24.5	169.1	3.4
184782	2170277	yes	yes	297.8	75.8	44.6	47.7	49.2	6.1
185075	4388549	yes	yes	331.4	36.8	110.3	99.0	31.4	1.4
185249	4078300	no	yes	241.4	31.4	94.9	105.7	27.1	3.3
185332	1622825	yes	yes	354.6	35.0	17.8	32.0	21.2	4.0
185349	57399	yes	yes	326.7	22.4	84.1	88.4	66.5	1.4
185349	57399	yes	yes	326.7	22.4	84.1	88.4	68.2	4.6
185777	5392044	yes	yes	191.2	20.9	22.6	35.2	33.1	0.4
186145	11985698	no	yes	226.4	24.7	63.7	58.8	78.2	3.6
186145	9795252	yes	yes	263.6	21.1	56.1	68.5	34.9	4.6

Table 43: Event information for all tags in 4-jet CEM events (continued).

4-Jet CMUP									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	$\mu\ p_T$	Jet E_T	Jet φ
145036	245760	yes	yes	288.9	64.5	59.3	28.1	95.3	4.9
152266	3554	yes	yes	214.0	41.5	72.0	31.9	43.8	4.5
153693	799494	yes	yes	345.1	41.0	75.2	51.3	100.1	2.5
153693	799494	yes	yes	345.1	41.0	75.2	51.3	52.6	4.0
160437	280173	yes	yes	262.5	33.2	71.7	40.2	56.8	4.6
160591	894406	no	yes	518.5	105.4	50.4	119.7	70.8	2.4
161788	361577	yes	yes	439.6	71.5	63.2	37.6	120.7	2.6
161788	361577	yes	yes	439.6	71.5	63.2	37.6	63.3	5.9
162310	350026	no	yes	294.7	78.0	141.2	63.8	22.7	2.3
162837	921871	yes	yes	255.1	37.1	90.3	57.1	38.4	2.7
163012	2249546	no	yes	300.1	26.2	80.7	74.7	87.8	4.1
163012	2249546	yes	yes	300.1	26.2	80.7	74.7	25.5	5.9
166529	4938	yes	yes	216.1	42.6	83.0	41.4	56.8	4.7
166567	11615607	no	yes	323.6	58.8	70.8	40.1	76.1	4.4
166567	11615607	yes	yes	323.6	58.8	70.8	40.1	77.7	6.0
166717	2288892	yes	yes	350.4	60.5	94.8	82.7	32.9	0.0
166717	2288892	yes	yes	350.4	60.5	94.8	82.7	51.0	4.8
166805	2534588	yes	yes	308.5	48.9	91.4	54.9	126.2	3.3
168000	1041510	no	yes	255.9	48.9	93.0	57.5	48.8	0.1
168889	1456443	no	yes	247.7	33.0	82.8	53.1	46.3	4.8
168889	1456443	yes	yes	247.7	33.0	82.8	53.1	39.2	0.3
178064	309288	no	yes	214.4	42.2	68.4	36.3	59.1	4.1
178120	86683	yes	yes	244.7	21.2	50.2	31.8	52.7	5.6
178855	5504617	no	yes	326.5	45.7	81.6	37.5	46.6	3.7
178855	5504617	yes	yes	326.5	45.7	81.6	37.5	102.3	1.4
178855	5504617	yes	yes	326.5	45.7	81.6	37.5	33.2	6.2
185248	8569330	yes	yes	280.8	23.9	67.3	71.8	40.7	1.6
185248	8569330	yes	yes	280.8	23.9	67.3	71.8	71.4	2.1
185332	4430084	no	yes	357.7	54.0	56.1	86.3	41.9	3.1
185332	4430084	yes	yes	357.7	54.0	56.1	86.3	96.5	0.6
185518	330101	yes	yes	355.4	21.0	46.2	143.4	20.1	3.5
186087	17361	yes	yes	249.6	51.8	60.6	44.6	29.9	1.3
186087	17361	yes	yes	249.6	51.8	60.6	44.6	55.5	3.5
186092	8910	no	yes	275.0	32.8	84.3	72.4	65.8	2.7

Table 44: Event information for all tags in 4-jet CMUP events.

4-Jet CMX									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	$\mu\ p_T$	Jet E_T	Jet φ
154654	6534372	yes	yes	317.8	44.3	71.4	39.4	110.9	4.3
155313	268020	no	yes	143.4	21.0	41.1	23.8	23.4	0.9
166367	516271	yes	yes	213.2	36.9	37.7	50.9	21.3	2.4
166367	516271	yes	yes	213.2	36.9	37.7	50.9	26.8	2.6
167139	1191211	yes	yes	254.8	63.8	66.5	32.3	39.8	5.1
167139	1191211	yes	yes	254.8	63.8	66.5	32.3	58.9	1.9
178785	1428968	yes	yes	291.8	63.0	68.8	57.1	68.1	0.8
178862	204149	no	yes	254.7	53.4	66.5	49.1	26.3	1.8
178862	204149	no	yes	254.7	53.4	66.5	49.1	53.9	4.1
179039	2128943	no	yes	318.6	69.5	78.6	39.2	56.0	5.6
179039	2128943	yes	yes	318.6	69.5	78.6	39.2	56.5	2.2
179039	2128943	yes	yes	318.6	69.5	78.6	39.2	57.9	3.3
184832	12978334	yes	yes	249.4	59.4	54.6	33.9	34.1	2.3

Table 45: Event information for all tags in 4-jet CMX events.

5-Jet CEM									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	e^- E_T	Jet E_T	Jet φ
161013	111162	yes	yes	416.5	82.8	32.5	75.5	110.2	2.4
161414	68227	yes	yes	352.6	65.3	65.6	51.4	25.0	3.4
162631	163651	no	yes	262.8	52.1	98.2	52.0	15.3	3.0
162986	1538897	yes	yes	389.0	57.0	55.3	55.8	30.6	0.5
162986	1538897	yes	yes	389.0	57.0	55.3	55.8	41.9	3.6
163519	1262057	yes	yes	256.8	68.1	70.2	20.1	72.8	5.3
167551	7969376	no	yes	311.5	63.3	82.0	57.8	71.4	2.5
167551	7969376	yes	yes	311.5	63.3	82.0	57.8	28.8	3.5
168599	6653973	no	yes	343.2	53.8	69.2	29.4	57.5	2.7
178761	1716435	yes	yes	402.2	62.9	71.9	56.2	58.0	5.0
183631	495685	no	yes	262.3	25.8	33.1	33.6	24.8	3.4
184519	377410	yes	yes	303.9	36.3	78.6	93.9	41.4	3.5
185201	2535873	no	yes	250.7	20.3	56.6	44.0	43.8	3.3

Table 46: Event information for all tags in 5-jet CEM events.

5-Jet CMUP									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	μ p_T	Jet E_T	Jet φ
166779	3652540	yes	yes	463.5	135.9	58.3	29.9	42.3	3.1
167551	3626393	yes	yes	256.7	48.1	69.3	27.1	15.0	4.6
167551	3626393	yes	yes	256.7	48.1	69.3	27.1	23.6	6.3
167551	3626393	yes	yes	256.7	48.1	69.3	27.1	73.8	2.6
183126	45329	yes	yes	530.3	149.3	33.0	69.3	32.8	3.4
184802	6650412	no	yes	355.7	45.0	29.0	74.8	34.5	4.0
185377	5133539	yes	yes	310.4	40.7	97.9	62.4	33.4	5.7
185377	5133539	yes	yes	310.4	40.7	97.9	62.4	77.6	0.4
185379	300012	yes	yes	300.0	21.5	16.7	29.0	82.3	2.3
185848	7195410	yes	yes	337.4	52.6	67.3	35.8	91.2	5.5

Table 47: Event information for all tags in 5-jet CMUP events.

5-Jet CMX									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	μ p_T	Jet E_T	Jet φ
162837	1447297	no	yes	322.6	44.3	101.0	81.8	50.1	5.8
162837	1447297	yes	yes	322.6	44.3	101.0	81.8	68.0	2.1
186145	4971965	no	yes	263.2	36.7	113.9	103.1	21.3	0.2
186145	4971965	yes	yes	263.2	36.7	113.9	103.1	24.7	2.9

Table 48: Event information for all tags in 5-jet CMX events.

6-Jet CMX									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	μ p_T	Jet E_T	Jet φ
185172	2492855	yes	yes	359.1	29.6	74.9	81.1	43.0	1.0
185594	10091587	yes	yes	249.9	42.8	28.2	21.4	17.3	4.8

Table 49: Event information for all tags in 6-jet CMX events.

7-Jet CEM									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	e^- E_T	Jet E_T	Jet φ
178761	2861250	yes	yes	342.8	33.4	86.4	59.8	52.8	5.0

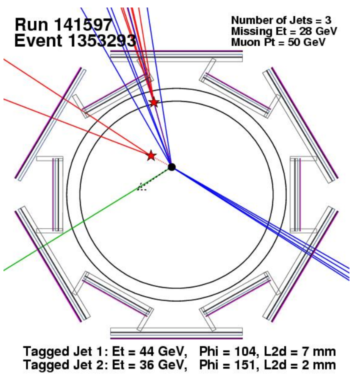
Table 50: Event information for all tags in 7-jet CEM events.

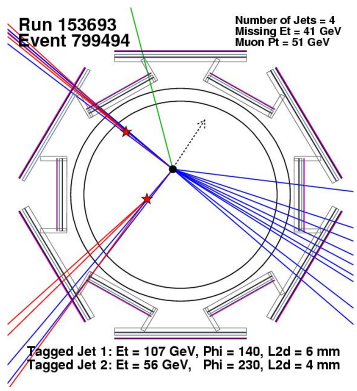
7-Jet CMUP									
Run	Event	Tight	Loose	H_T	Missing E_T	m_T^W	μ p_T	Jet E_T	Jet φ
155409	1291806	yes	yes	544.2	64.0	80.5	40.4	130.0	1.4

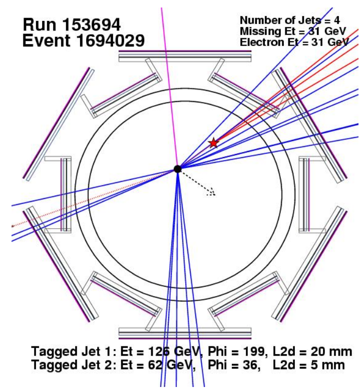
Table 51: Event information for all tags in 7-jet CMUP events.

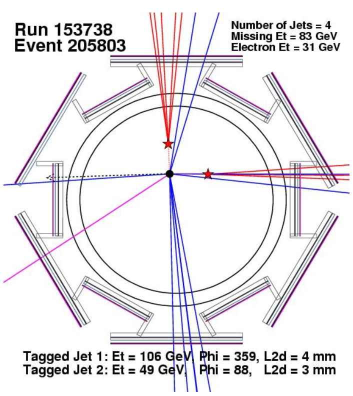
C Double-Tag Vertex Displays

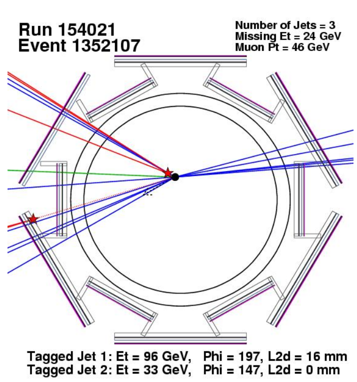
The following pages contain simplified event displays for the 59 double-tagged signal region events used in unoptimized the cross section measurement. The scale is fixed to show the beampipe (inner radius 1.1 cm) and Layer00 (courtesy of Stephen Levy). In all plots, the black point shows the primary vertex, and the red stars show the location of the tags. The tags are also shown with gray error ellipses, but these are typically much smaller than the marker. Blue lines show all good silicon tracks, and are traced back to the IP; red lines are tracks used in the SecVtx fit, and are shown originating from that vertex. The dotted red lines show the reconstructed path of the b. The missing E_T, corrected for muons and jet corrections, is shown as a dashed black arrow. The lepton track is also illustrated, colored green for muons and magenta for electrons.

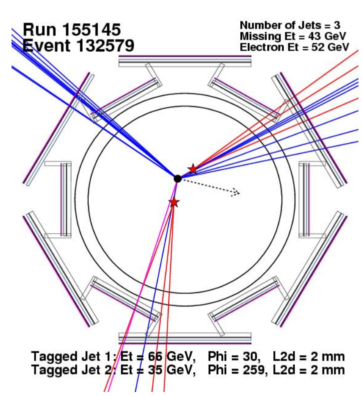


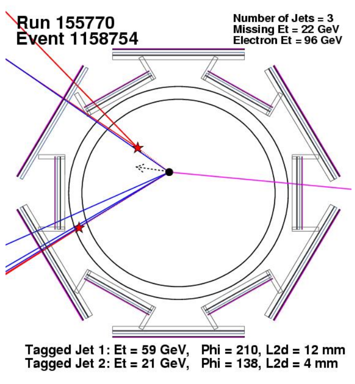


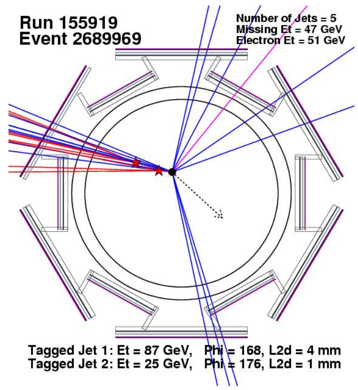


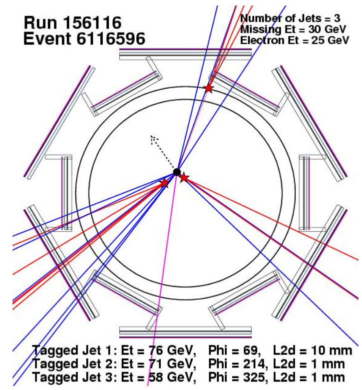


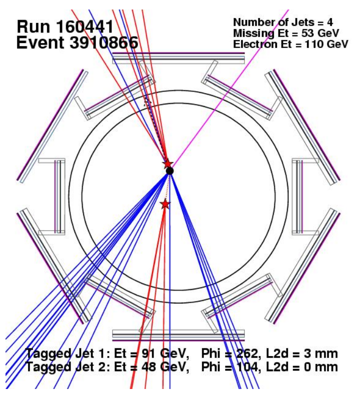


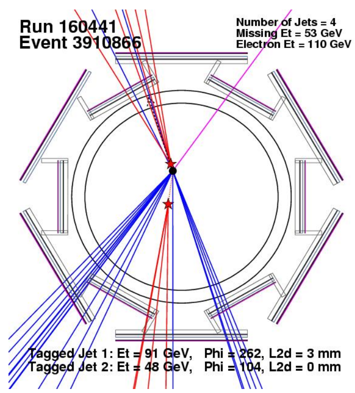


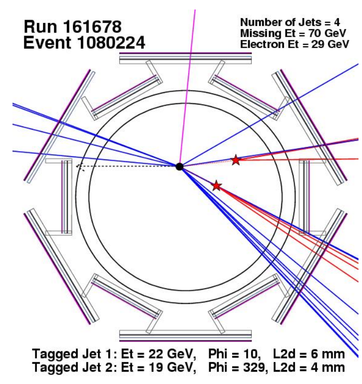

Run 155770
Event 1158754
Number of Jets = 3
Missing Et = 22 GeV
Electron Et = 96 GeV
Tagged Jet 1: Et = 59 GeV, Phi = 210, L2d = 12 mm
Tagged Jet 2: Et = 21 GeV, Phi = 138, L2d = 4 mm

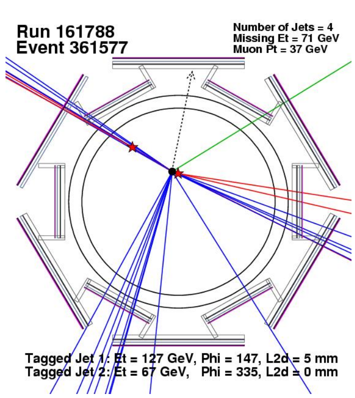

Run 155919
Event 2689969
Number of Jets = 5
Missing Et = 47 GeV
Electron Et = 51 GeV
Tagged Jet 1: Et = 87 GeV, Phi = 168, L2d = 4 mm
Tagged Jet 2: Et = 25 GeV, Phi = 176, L2d = 1 mm

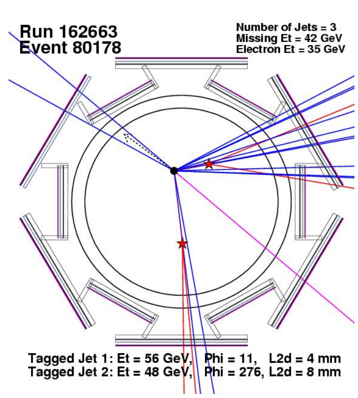

Run 156116
Event 6116596
Number of Jets = 3
Missing Et = 30 GeV
Electron Et = 25 GeV
Tagged Jet 1: Et = 76 GeV, Phi = 69, L2d = 10 mm
Tagged Jet 2: Et = 71 GeV, Phi = 214, L2d = 1 mm
Tagged Jet 3: Et = 58 GeV, Phi = 325, L2d = 1 mm

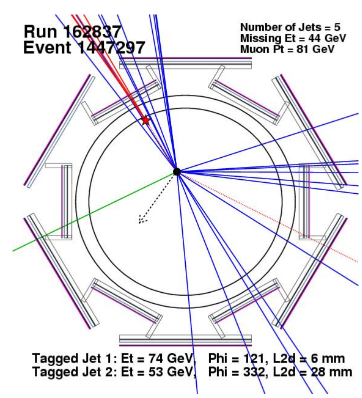

Run 160441
Event 3910866
Number of Jets = 4
Missing Et = 53 GeV
Electron Et = 110 GeV
Tagged Jet 1: Et = 91 GeV, Phi = 262, L2d = 3 mm
Tagged Jet 2: Et = 48 GeV, Phi = 104, L2d = 0 mm

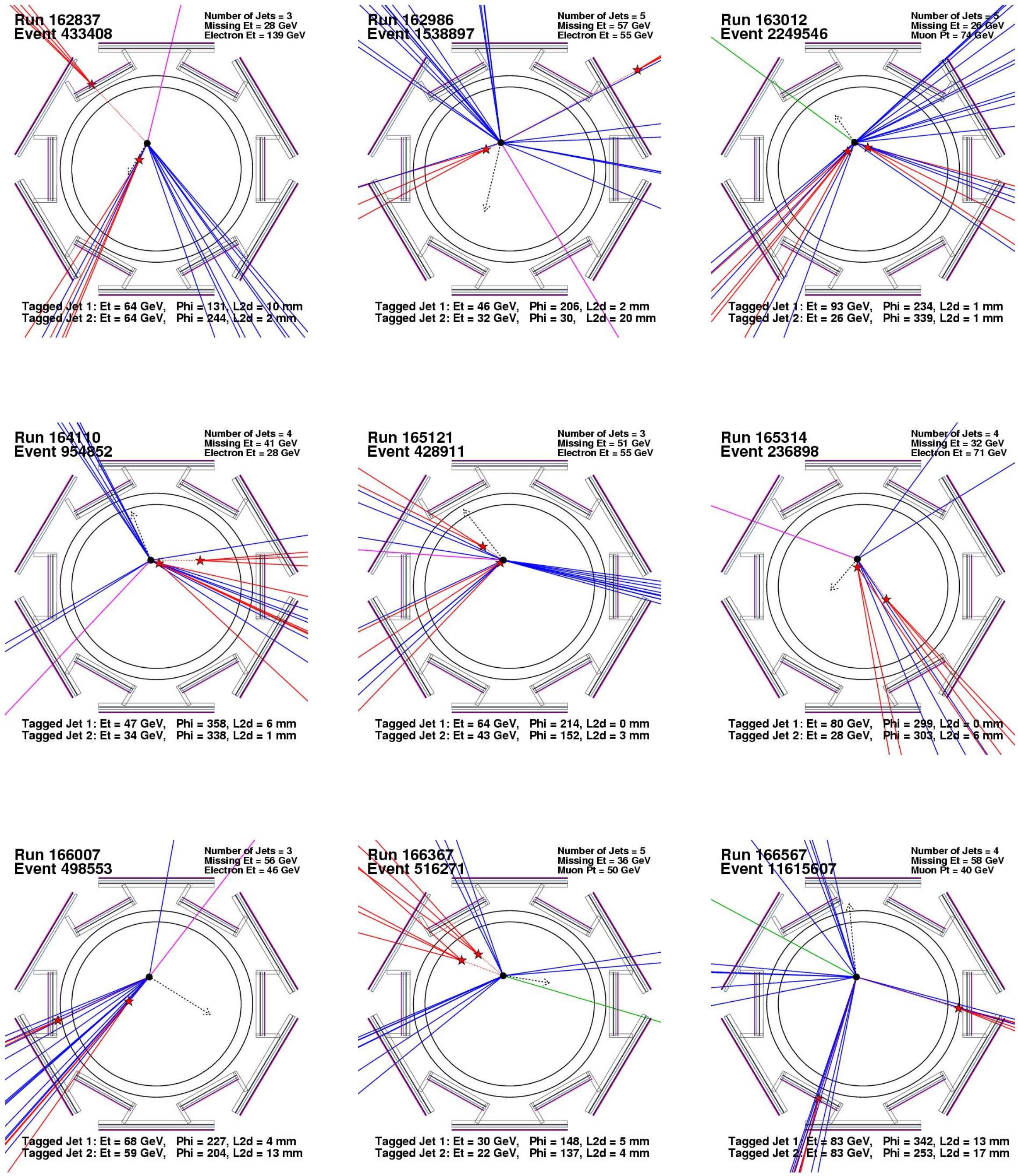

Run 160441
Event 3910866
Number of Jets = 4
Missing Et = 53 GeV
Electron Et = 110 GeV
Tagged Jet 1: Et = 91 GeV, Phi = 262, L2d = 3 mm
Tagged Jet 2: Et = 48 GeV, Phi = 104, L2d = 0 mm

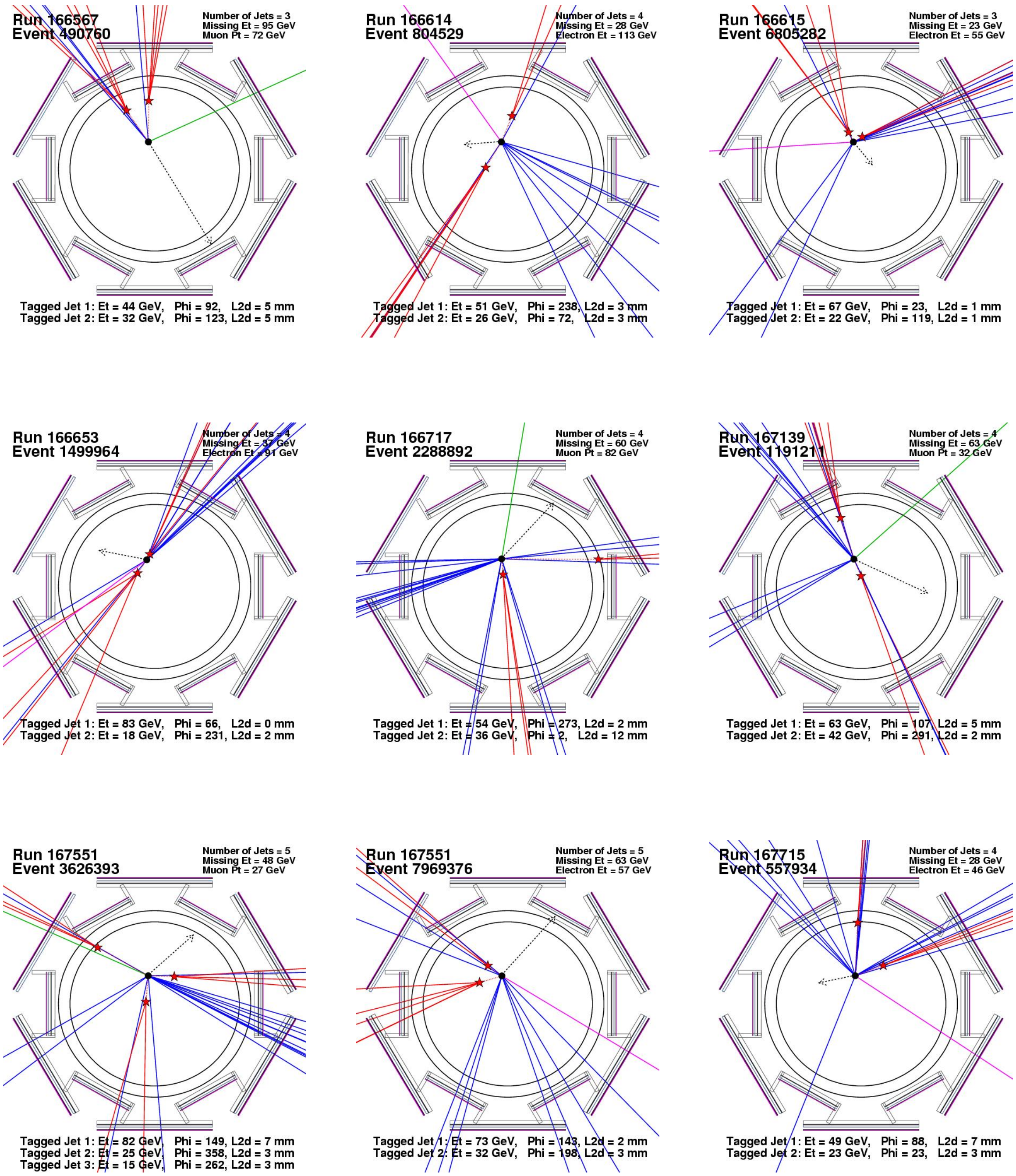

Run 161678
Event 1080224
Number of Jets = 4
Missing Et = 70 GeV
Electron Et = 29 GeV
Tagged Jet 1: Et = 22 GeV, Phi = 10, L2d = 6 mm
Tagged Jet 2: Et = 19 GeV, Phi = 329, L2d = 4 mm


Run 161788
Event 361577
Number of Jets = 4
Missing Et = 71 GeV
Muon Pt = 37 GeV
Tagged Jet 1: Et = 127 GeV, Phi = 147, L2d = 5 mm
Tagged Jet 2: Et = 67 GeV, Phi = 335, L2d = 0 mm

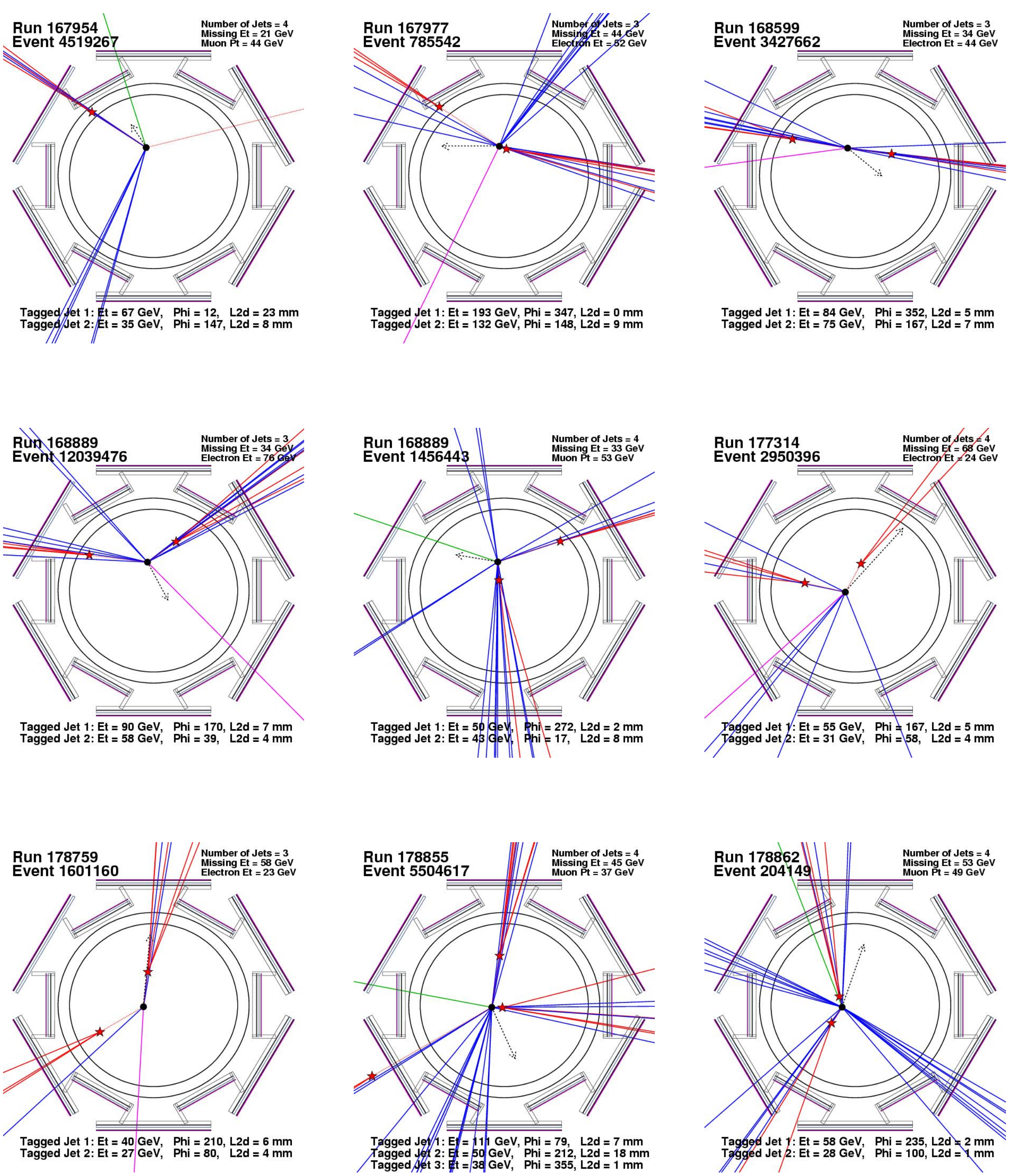

Run 162663
Event 80178
Number of Jets = 3
Missing Et = 42 GeV
Electron Et = 35 GeV
Tagged Jet 1: Et = 56 GeV, Phi = 11, L2d = 4 mm
Tagged Jet 2: Et = 48 GeV, Phi = 276, L2d = 8 mm

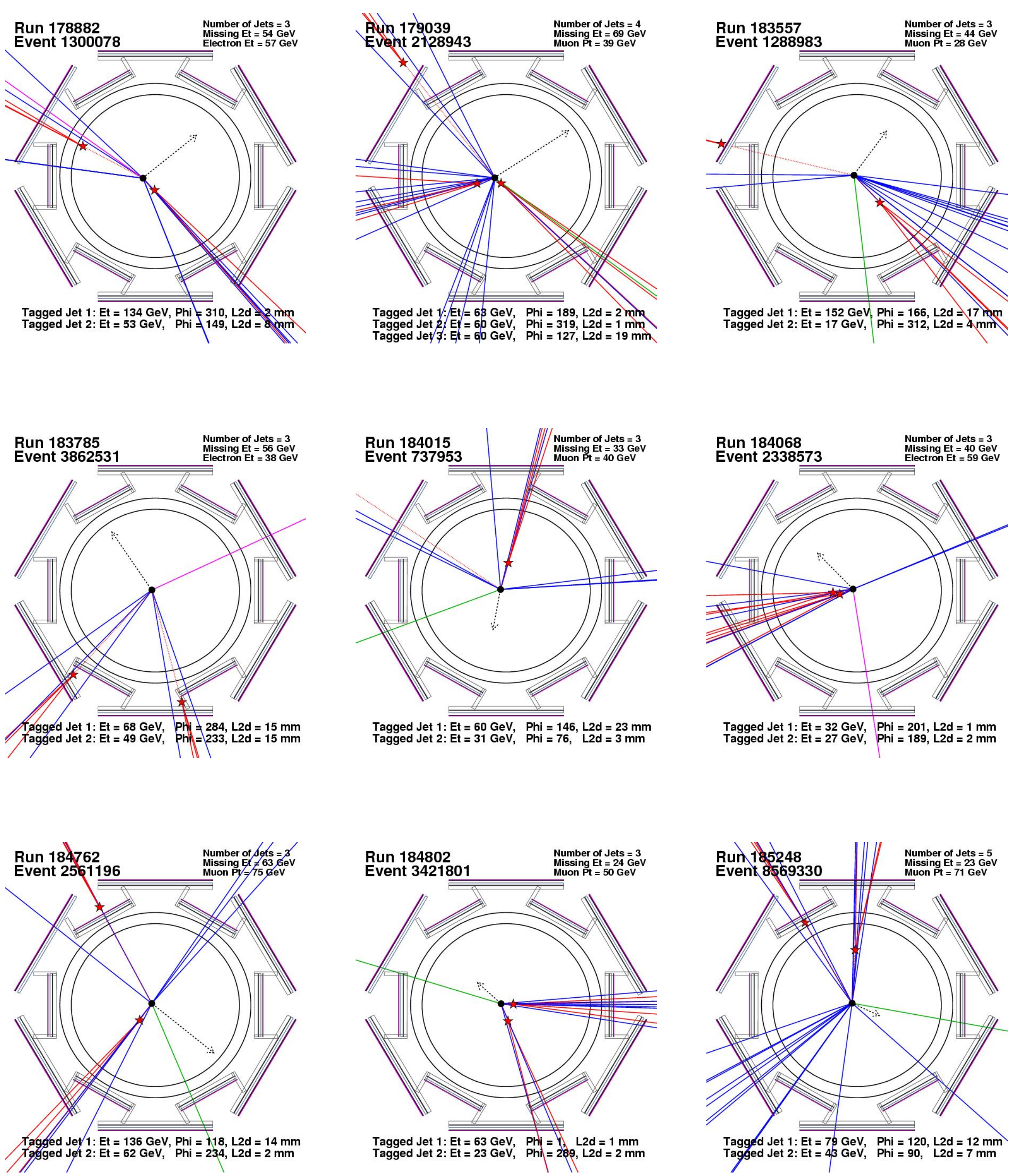

Run 162837
Event 1447297
Number of Jets = 5
Missing Et = 44 GeV
Muon Pt = 81 GeV
Tagged Jet 1: Et = 74 GeV, Phi = 121, L2d = 6 mm
Tagged Jet 2: Et = 53 GeV, Phi = 332, L2d = 28 mm

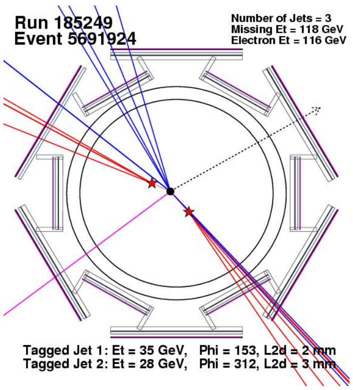

Run 162837
Event 433408
Number of Jets = 3
Missing Et = 28 GeV
Electron Et = 139 GeV
Tagged Jet 1: Et = 64 GeV, Phi = 131, L2d = 10 mm
Tagged Jet 2: Et = 64 GeV, Phi = 244, L2d = 2 mm
Run 162986
Event 1538897
Number of Jets = 5
Missing Et = 57 GeV
Electron Et = 55 GeV
Tagged Jet 1: Et = 46 GeV, Phi = 206, L2d = 2 mm
Tagged Jet 2: Et = 32 GeV, Phi = 30, L2d = 20 mm
Run 163012
Event 2249546
Number of Jets = 5
Missing Et = 26 GeV
Muon Pt = 74 GeV
Tagged Jet 1: Et = 93 GeV, Phi = 234, L2d = 1 mm
Tagged Jet 2: Et = 26 GeV, Phi = 339, L2d = 1 mm
Run 164110
Event 954852
Number of Jets = 4
Missing Et = 41 GeV
Electron Et = 28 GeV
Tagged Jet 1: Et = 47 GeV, Phi = 358, L2d = 6 mm
Tagged Jet 2: Et = 34 GeV, Phi = 338, L2d = 1 mm
Run 165121
Event 428911
Number of Jets = 3
Missing Et = 51 GeV
Electron Et = 55 GeV
Tagged Jet 1: Et = 64 GeV, Phi = 214, L2d = 0 mm
Tagged Jet 2: Et = 43 GeV, Phi = 152, L2d = 3 mm
Run 165314
Event 236898
Number of Jets = 4
Missing Et = 32 GeV
Electron Et = 71 GeV
Tagged Jet 1: Et = 80 GeV, Phi = 299, L2d = 0 mm
Tagged Jet 2: Et = 28 GeV, Phi = 303, L2d = 6 mm
Run 166007
Event 498553
Number of Jets = 3
Missing Et = 56 GeV
Electron Et = 46 GeV
Tagged Jet 1: Et = 68 GeV, Phi = 227, L2d = 4 mm
Tagged Jet 2: Et = 59 GeV, Phi = 204, L2d = 13 mm
Run 166367
Event 516271
Number of Jets = 5
Missing Et = 36 GeV
Muon Pt = 50 GeV
Tagged Jet 1: Et = 30 GeV, Phi = 148, L2d = 5 mm
Tagged Jet 2: Et = 22 GeV, Phi = 137, L2d = 4 mm
Run 166567
Event 11615607
Number of Jets = 4
Missing Et = 58 GeV
Muon Pt = 40 GeV
Tagged Jet 1: Et = 83 GeV, Phi = 342, L2d = 13 mm
Tagged Jet 2: Et = 83 GeV, Phi = 253, L2d = 17 mm

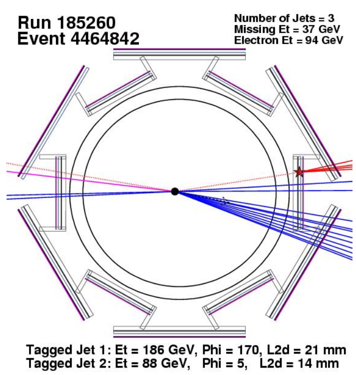


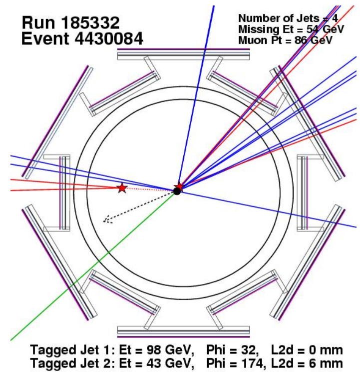
Run 166567
Event 490760
Number of Jets = 3
Missing Et = 95 GeV
Muon Pt = 72 GeV
Tagged Jet 1: Et = 44 GeV, Phi = 92, L2d = 5 mm
Tagged Jet 2: Et = 32 GeV, Phi = 123, L2d = 5 mm
Run 166614
Event 804529
Number of Jets = 4
Missing Et = 28 GeV
Electron Et = 113 GeV
Tagged Jet 1: Et = 51 GeV, Phi = 238, L2d = 3 mm
Tagged Jet 2: Et = 26 GeV, Phi = 72, L2d = 3 mm
Run 166615
Event 6805282
Number of Jets = 3
Missing Et = 23 GeV
Electron Et = 55 GeV
Tagged Jet 1: Et = 67 GeV, Phi = 23, L2d = 1 mm
Tagged Jet 2: Et = 22 GeV, Phi = 119, L2d = 1 mm
Run 166653
Event 1499964
Number of Jets = 4
Missing Et = 37 GeV
Electron Et = 91 GeV
Tagged Jet 1: Et = 83 GeV, Phi = 66, L2d = 0 mm
Tagged Jet 2: Et = 18 GeV, Phi = 231, L2d = 2 mm
Run 166717
Event 2288892
Number of Jets = 4
Missing Et = 60 GeV
Muon Pt = 82 GeV
Tagged Jet 1: Et = 54 GeV, Phi = 273, L2d = 2 mm
Tagged Jet 2: Et = 36 GeV, Phi = 2, L2d = 12 mm
Run 167139
Event 1191211
Number of Jets = 4
Missing Et = 63 GeV
Muon Pt = 32 GeV
Tagged Jet 1: Et = 63 GeV, Phi = 107, L2d = 5 mm
Tagged Jet 2: Et = 42 GeV, Phi = 291, L2d = 2 mm
Run 167551
Event 3626393
Number of Jets = 5
Missing Et = 48 GeV
Muon Pt = 27 GeV
Tagged Jet 1: Et = 82 GeV, Phi = 149, L2d = 7 mm
Tagged Jet 2: Et = 25 GeV, Phi = 358, L2d = 3 mm
Tagged Jet 3: Et = 15 GeV, Phi = 262, L2d = 3 mm
Run 167551
Event 7969376
Number of Jets = 5
Missing Et = 63 GeV
Electron Et = 57 GeV
Tagged Jet 1: Et = 73 GeV, Phi = 143, L2d = 2 mm
Tagged Jet 2: Et = 32 GeV, Phi = 198, L2d = 3 mm
Run 167715
Event 557934
Number of Jets = 4
Missing Et = 28 GeV
Electron Et = 46 GeV
Tagged Jet 1: Et = 49 GeV, Phi = 88, L2d = 7 mm
Tagged Jet 2: Et = 23 GeV, Phi = 23, L2d = 3 mm

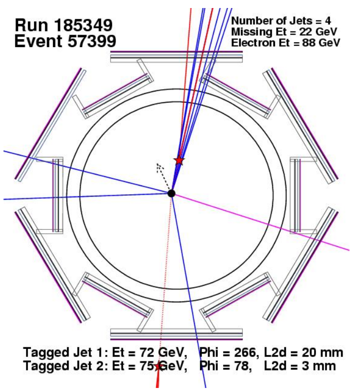

Run 167954
Event 4519267
Number of Jets = 4
Missing Et = 21 GeV
Muon Pt = 44 GeV
Tagged Jet 1: Et = 67 GeV, Phi = 12, L2d = 23 mm
Tagged Jet 2: Et = 35 GeV, Phi = 147, L2d = 8 mm
Run 167977
Event 785542
Number of Jets = 3
Missing Et = 44 GeV
Electron Et = 52 GeV
Tagged Jet 1: Et = 193 GeV, Phi = 347, L2d = 0 mm
Tagged Jet 2: Et = 132 GeV, Phi = 148, L2d = 9 mm
Run 168599
Event 3427662
Number of Jets = 3
Missing Et = 34 GeV
Electron Et = 44 GeV
Tagged Jet 1: Et = 84 GeV, Phi = 352, L2d = 5 mm
Tagged Jet 2: Et = 75 GeV, Phi = 167, L2d = 7 mm
Run 168889
Event 12039476
Number of Jets = 3
Missing Et = 34 GeV
Electron Et = 76 GeV
Tagged Jet 1: Et = 90 GeV, Phi = 170, L2d = 7 mm
Tagged Jet 2: Et = 58 GeV, Phi = 39, L2d = 4 mm
Run 168889
Event 1456443
Number of Jets = 4
Missing Et = 33 GeV
Muon Pt = 53 GeV
Tagged Jet 1: Et = 50 GeV, Phi = 272, L2d = 2 mm
Tagged Jet 2: Et = 43 GeV, Phi = 17, L2d = 8 mm
Run 177314
Event 2950396
Number of Jets = 4
Missing Et = 68 GeV
Electron Et = 24 GeV
Tagged Jet 1: Et = 55 GeV, Phi = 167, L2d = 5 mm
Tagged Jet 2: Et = 31 GeV, Phi = 58, L2d = 4 mm
Run 178759
Event 1601160
Number of Jets = 3
Missing Et = 58 GeV
Electron Et = 23 GeV
Tagged Jet 1: Et = 40 GeV, Phi = 210, L2d = 6 mm
Tagged Jet 2: Et = 27 GeV, Phi = 80, L2d = 4 mm
Run 178855
Event 5504617
Number of Jets = 4
Missing Et = 45 GeV
Muon Pt = 37 GeV
Tagged Jet 1: Et = 111 GeV, Phi = 79, L2d = 7 mm
Tagged Jet 2: Et = 50 GeV, Phi = 212, L2d = 18 mm
Tagged Jet 3: Et = 38 GeV, Phi = 355, L2d = 1 mm
Run 178862
Event 204149
Number of Jets = 4
Missing Et = 53 GeV
Muon Pt = 49 GeV
Tagged Jet 1: Et = 58 GeV, Phi = 235, L2d = 2 mm
Tagged Jet 2: Et = 28 GeV, Phi = 100, L2d = 1 mm

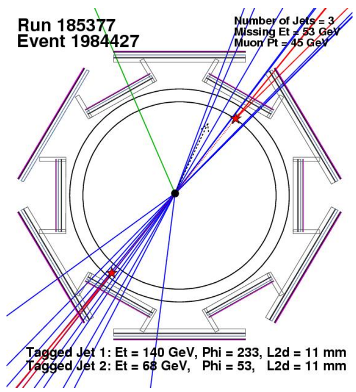

Run 178882
Event 1300078
Number of Jets = 3
Missing Et = 54 GeV
Electron Et = 57 GeV
Tagged Jet 1: Et = 134 GeV, Phi = 310, L2d = 2 mm
Tagged Jet 2: Et = 53 GeV, Phi = 149, L2d = 8 mm
Run 179039
Event 2128943
Number of Jets = 4
Missing Et = 69 GeV
Muon Pt = 39 GeV
Tagged Jet 1: Et = 63 GeV, Phi = 189, L2d = 2 mm
Tagged Jet 2: Et = 60 GeV, Phi = 319, L2d = 1 mm
Tagged Jet 3: Et = 60 GeV, Phi = 127, L2d = 19 mm
Run 183557
Event 1288983
Number of Jets = 3
Missing Et = 44 GeV
Muon Pt = 28 GeV
Tagged Jet 1: Et = 152 GeV, Phi = 166, L2d = 17 mm
Tagged Jet 2: Et = 17 GeV, Phi = 312, L2d = 4 mm
Run 183785
Event 3862531
Number of Jets = 3
Missing Et = 56 GeV
Electron Et = 38 GeV
Tagged Jet 1: Et = 68 GeV, Phi = 284, L2d = 15 mm
Tagged Jet 2: Et = 49 GeV, Phi = 233, L2d = 15 mm
Run 184015
Event 737953
Number of Jets = 3
Missing Et = 33 GeV
Muon Pt = 40 GeV
Tagged Jet 1: Et = 60 GeV, Phi = 146, L2d = 23 mm
Tagged Jet 2: Et = 31 GeV, Phi = 76, L2d = 3 mm
Run 184068
Event 2338573
Number of Jets = 3
Missing Et = 40 GeV
Electron Et = 59 GeV
Tagged Jet 1: Et = 32 GeV, Phi = 201, L2d = 1 mm
Tagged Jet 2: Et = 27 GeV, Phi = 189, L2d = 2 mm
Run 184762
Event 2561196
Number of Jets = 3
Missing Et = 63 GeV
Muon Pt = 75 GeV
Tagged Jet 1: Et = 136 GeV, Phi = 118, L2d = 14 mm
Tagged Jet 2: Et = 62 GeV, Phi = 234, L2d = 2 mm
Run 184802
Event 3421801
Number of Jets = 3
Missing Et = 24 GeV
Muon Pt = 50 GeV
Tagged Jet 1: Et = 63 GeV, Phi = 1, L2d = 1 mm
Tagged Jet 2: Et = 23 GeV, Phi = 289, L2d = 2 mm
Run 185248
Event 8569330
Number of Jets = 5
Missing Et = 23 GeV
Muon Pt = 71 GeV
Tagged Jet 1: Et = 79 GeV, Phi = 120, L2d = 12 mm
Tagged Jet 2: Et = 43 GeV, Phi = 90, L2d = 7 mm

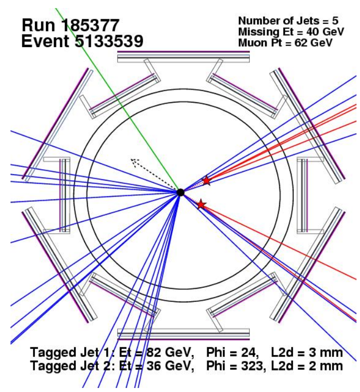

Run 185249
Event 5691924
Number of Jets = 3
Missing Et = 118 GeV
Electron Et = 116 GeV
Tagged Jet 1: Et = 35 GeV, Phi = 153, L2d = 2 mm
Tagged Jet 2: Et = 28 GeV, Phi = 312, L2d = 3 mm

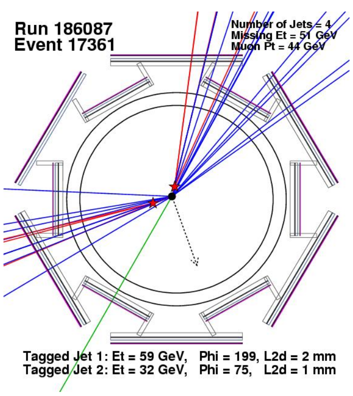

Run 185260
Event 4464842
Number of Jets = 3
Missing Et = 37 GeV
Electron Et = 94 GeV
Tagged Jet 1: Et = 186 GeV, Phi = 170, L2d = 21 mm
Tagged Jet 2: Et = 88 GeV, Phi = 5, L2d = 14 mm

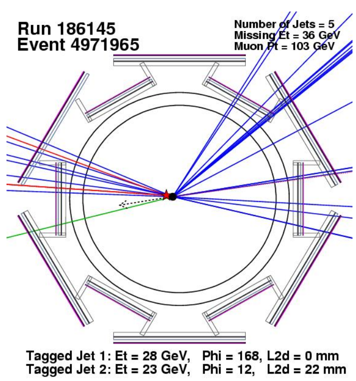

Run 185332
Event 4430084
Number of Jets = 4
Missing Et = 54 GeV
Muon Pt = 86 GeV
Tagged Jet 1: Et = 98 GeV, Phi = 32, L2d = 0 mm
Tagged Jet 2: Et = 43 GeV, Phi = 174, L2d = 6 mm


Run 185349
Event 57399
Number of Jets = 4
Missing Et = 22 GeV
Electron Et = 88 GeV
Tagged Jet 1: Et = 72 GeV, Phi = 266, L2d = 20 mm
Tagged Jet 2: Et = 75 GeV, Phi = 78, L2d = 3 mm


Run 185377
Event 1984427
Number of Jets = 3
Missing Et = 53 GeV
Muon Pt = 45 GeV
Tagged Jet 1: Et = 140 GeV, Phi = 233, L2d = 11 mm
Tagged Jet 2: Et = 68 GeV, Phi = 53, L2d = 11 mm


Run 185377
Event 5133539
Number of Jets = 5
Missing Et = 40 GeV
Muon Pt = 62 GeV
Tagged Jet 1: Et = 82 GeV, Phi = 24, L2d = 3 mm
Tagged Jet 2: Et = 36 GeV, Phi = 323, L2d = 2 mm


Run 186087
Event 17361
Number of Jets = 4
Missing Et = 51 GeV
Muon Pt = 44 GeV
Tagged Jet 1: Et = 59 GeV, Phi = 199, L2d = 2 mm
Tagged Jet 2: Et = 32 GeV, Phi = 75, L2d = 1 mm


Run 186145
Event 4971965
Number of Jets = 5
Missing Et = 36 GeV
Muon Pt = 103 GeV
Tagged Jet 1: Et = 28 GeV, Phi = 168, L2d = 0 mm
Tagged Jet 2: Et = 23 GeV, Phi = 12, L2d = 22 mm

D Kinematic Distributions

In the following subsections, we attempt to compare kinematic distributions in data and Monte Carlo, which requires a model for each of the backgrounds. Unless noted, the MC and $W + HF$ backgrounds have their shapes taken directly from the simulation. The mistag template is usually taken from the data, weighted by the event mistag probability; for vertex properties, the negative tag distributions are used (events with both a positive and negative tag are used for double mistags). The Non-W background shape is taken from data that fails only the lepton isolation cut. All plots sum the expectations from the 3, 4, and 5-jet bins, and none of the *optimization* cuts ($H_T > 200$ GeV, $m_T^W > 20$ GeV/c^2, Missing $E_T > 30$ GeV) have been applied.

D.1 Signal Region

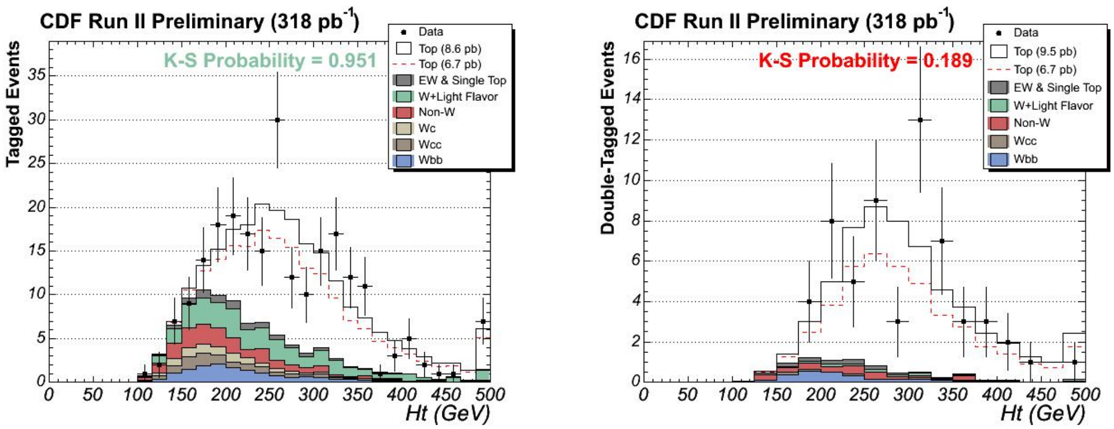


Figure 25: Expected signal and background H_T distributions in single-tagged (left) and double-tagged (right) events.

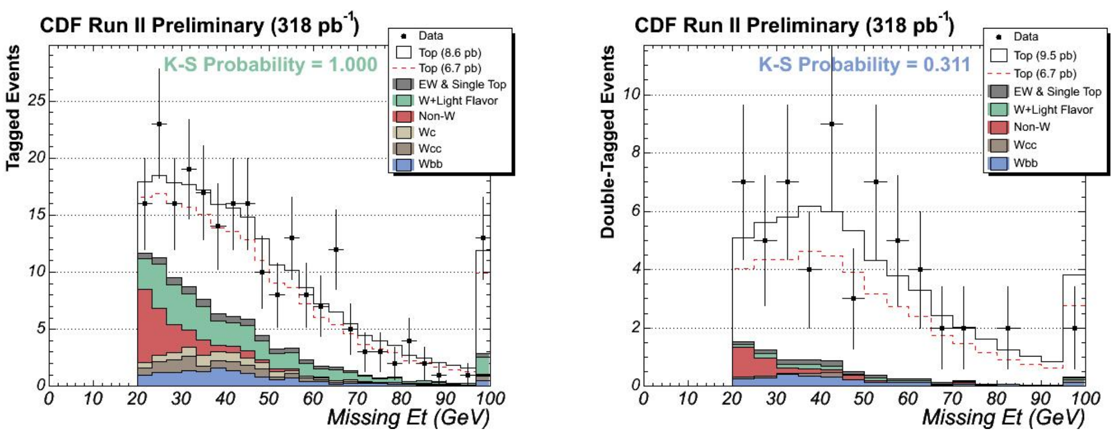


Figure 26: Expected signal and background missing E_T distributions in single-tagged (left) and double-tagged (right) events.

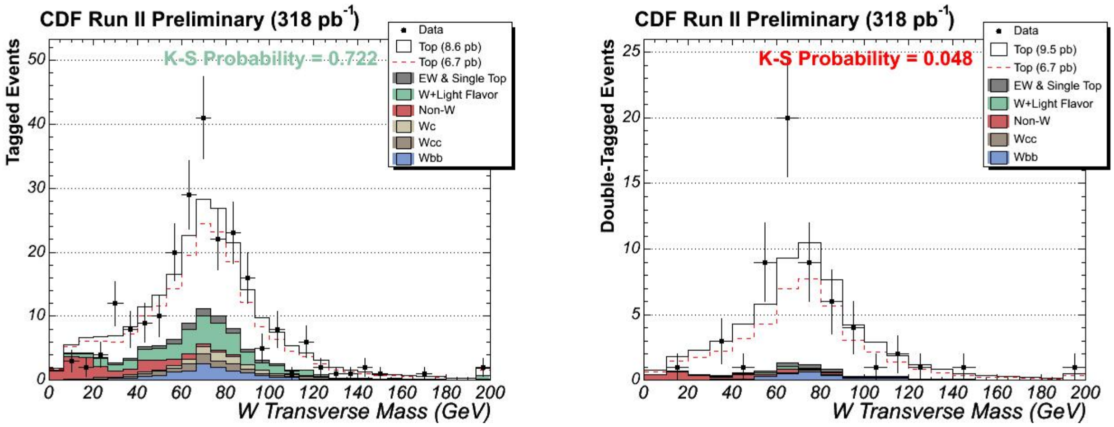


Figure 27: Expected signal and background W transverse mass distributions in single-tagged (left) and double-tagged (right) events.

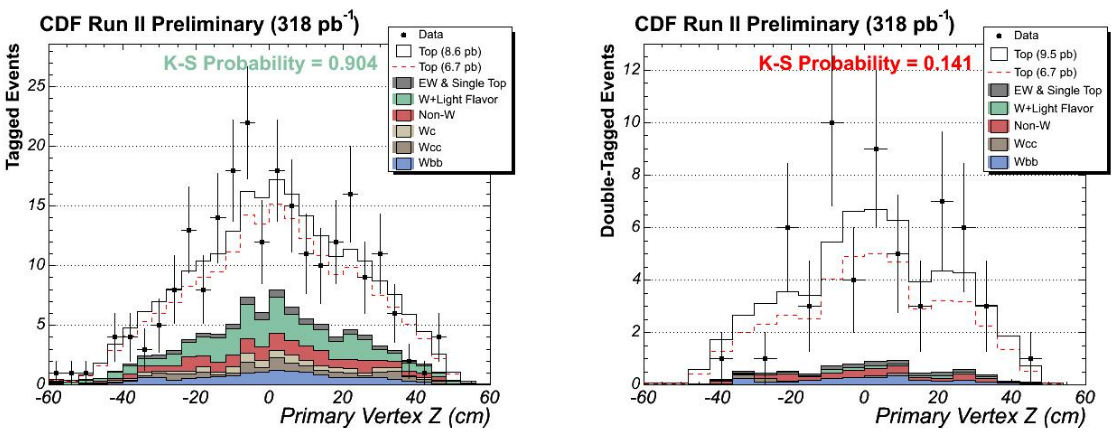


Figure 28: Expected signal and background Z distributions in single-tagged (left) and double-tagged (right) events.

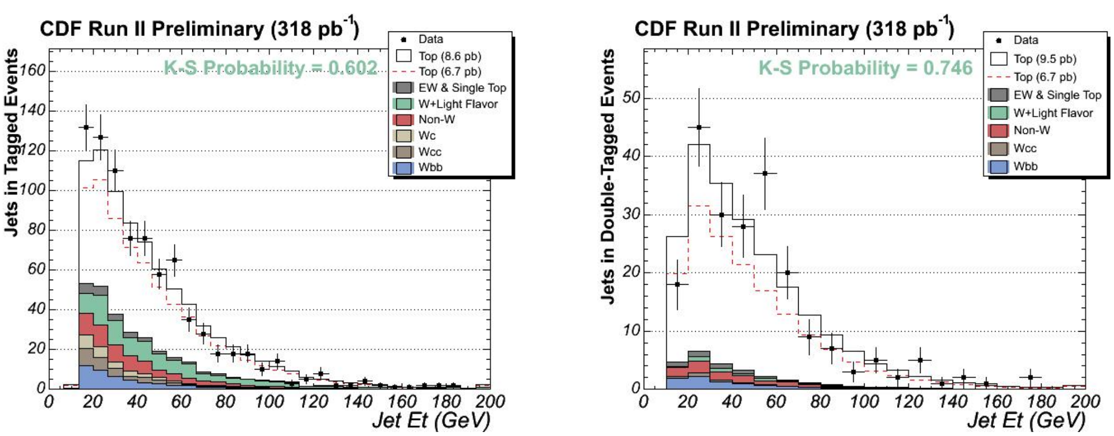


Figure 29: Expected signal and background jet E_T distributions in single-tagged (left) and double-tagged (right) events.

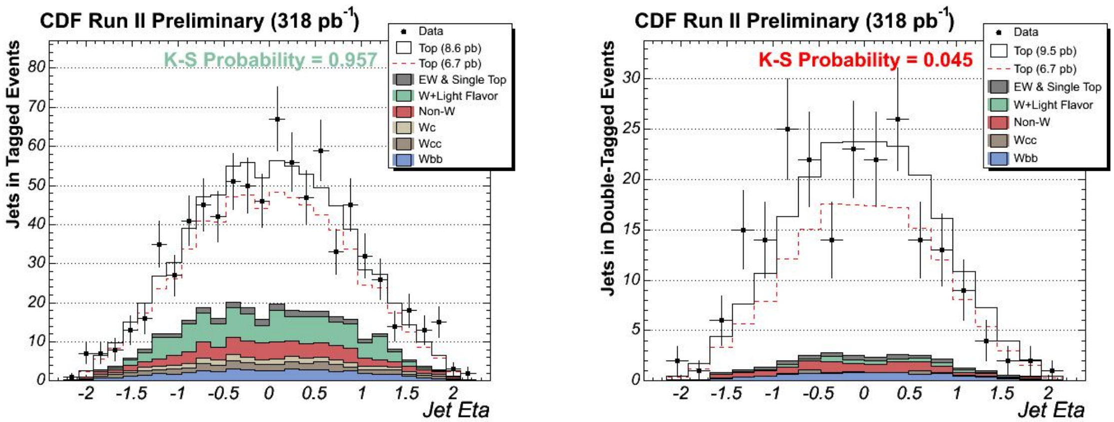


Figure 30: Expected signal and background jet η distributions in single-tagged (left) and double-tagged (right) events.

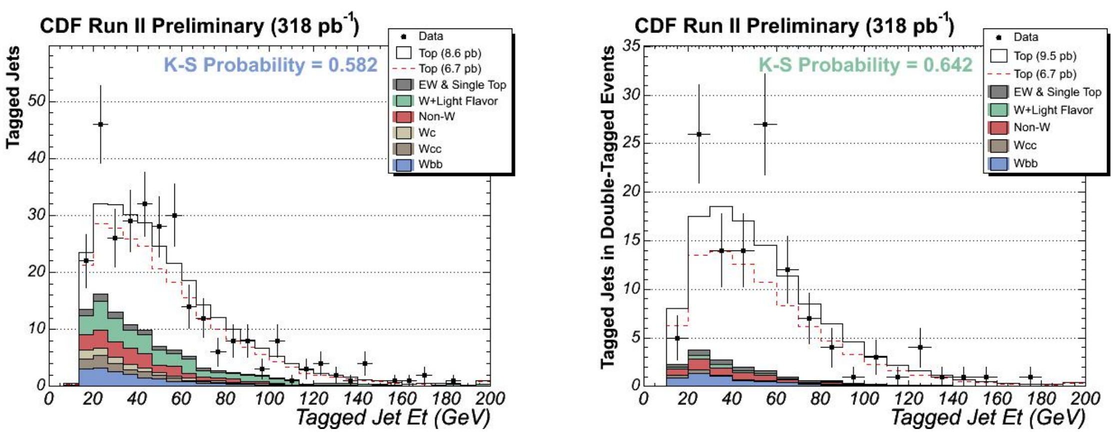


Figure 31: Expected signal and background tag E_T distributions in single-tagged (left) and double-tagged (right) events.

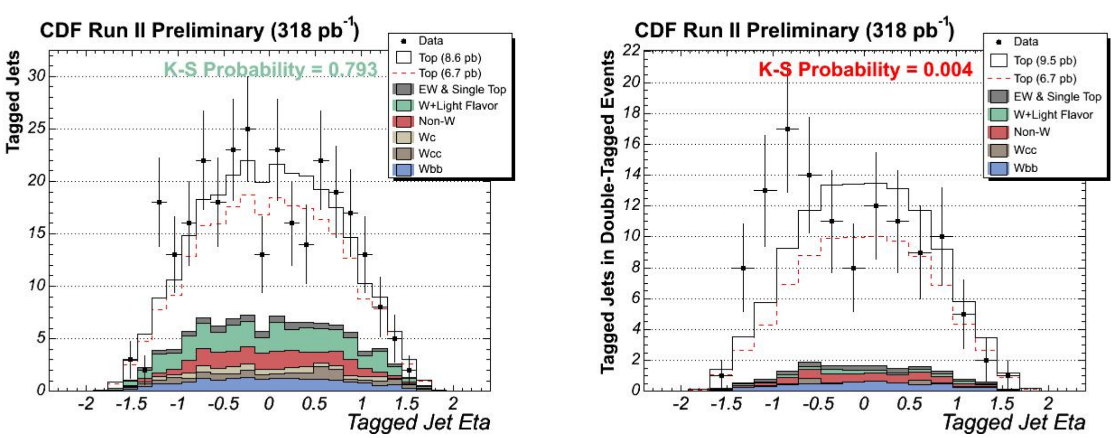


Figure 32: Expected signal and background tag η distributions in single-tagged (left) and double-tagged (right) events.

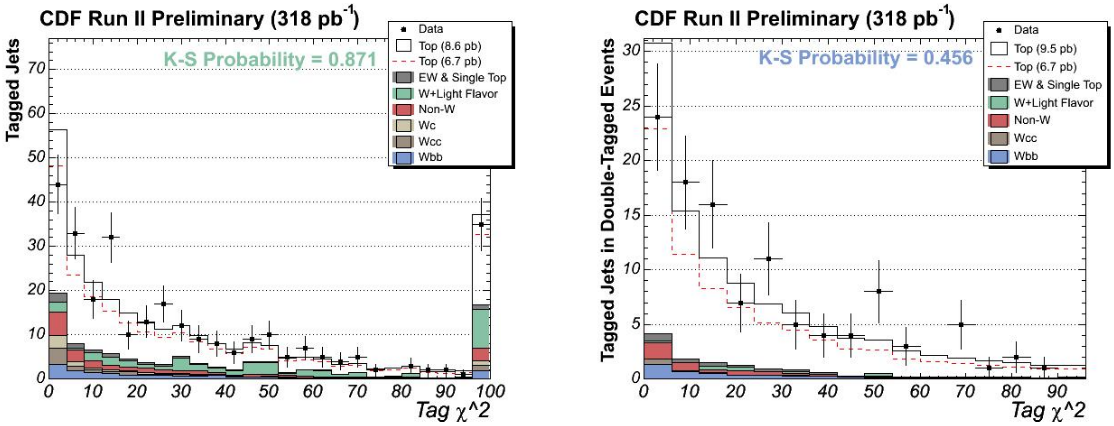


Figure 33: Expected signal and background vertex χ^2 distributions in single-tagged (left) and double-tagged (right) events.

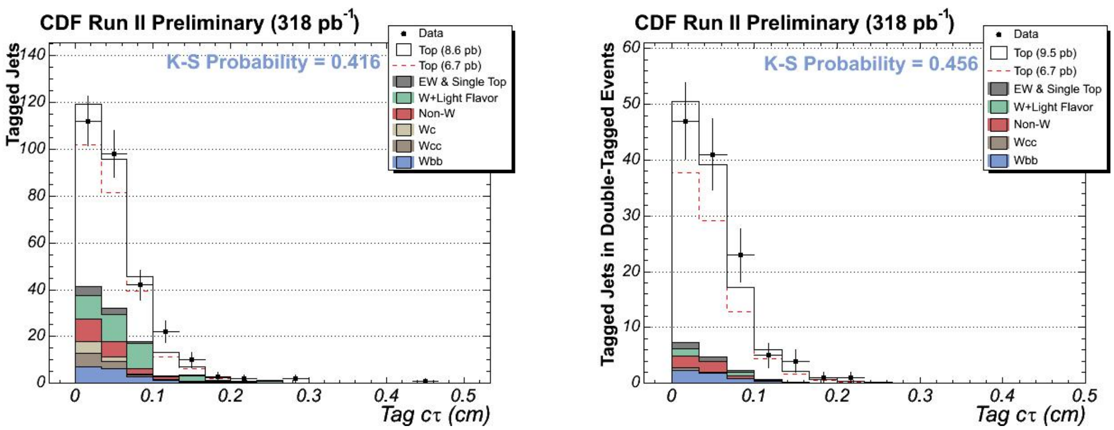


Figure 34: Expected signal and background vertex $c\tau$ distributions in single-tagged (left) and double-tagged (right) events.

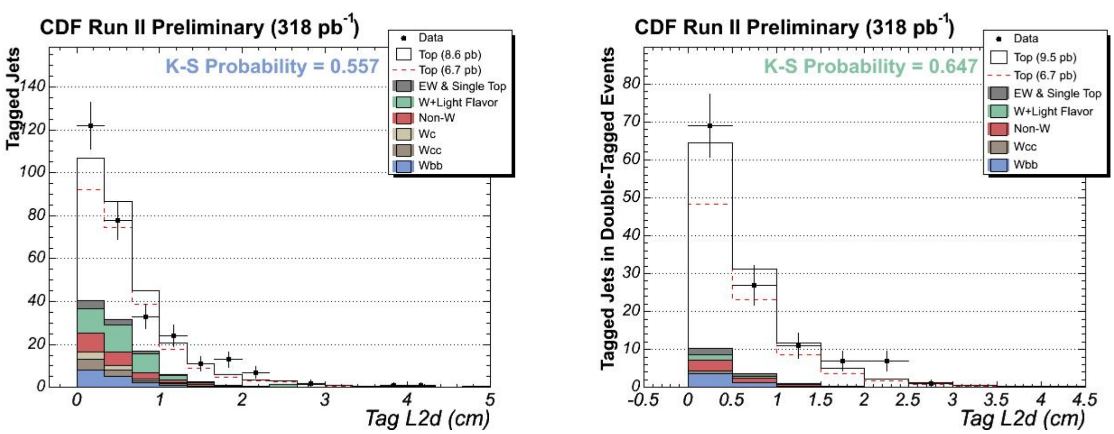


Figure 35: Expected signal and background vertex L_{2d} distributions in single-tagged (left) and double-tagged (right) events.

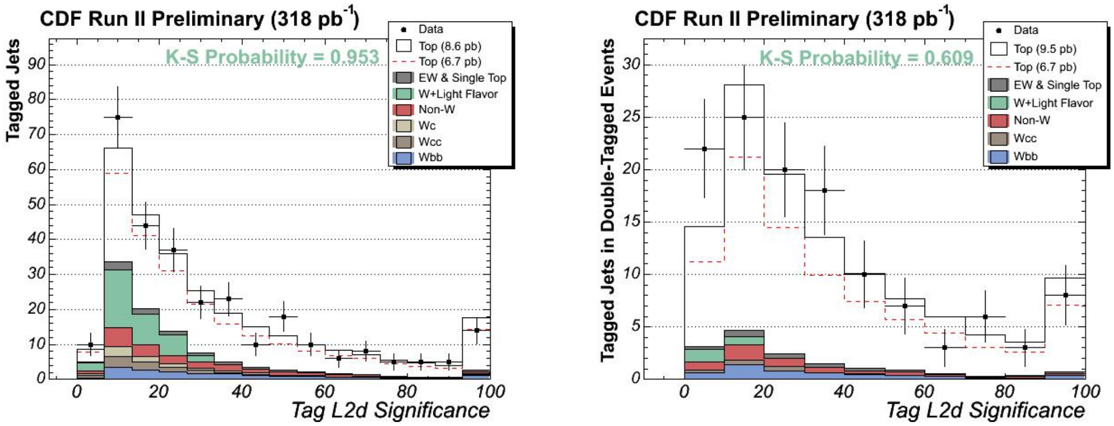


Figure 36: Expected signal and background vertex L_{2d} significance distributions in single-tagged (left) and double-tagged (right) events.

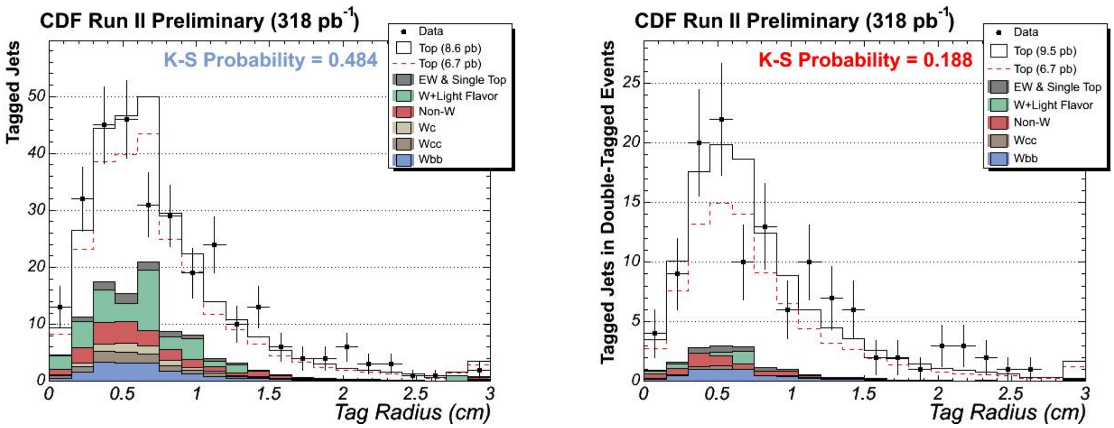


Figure 37: Expected signal and background vertex radius distributions in single-tagged (left) and double-tagged (right) events.

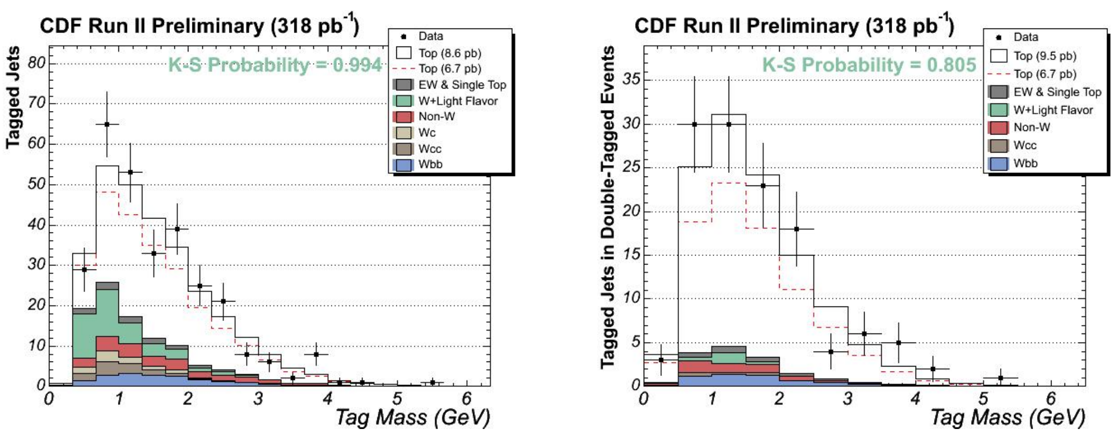


Figure 38: Expected signal and background vertex mass distributions in single-tagged (left) and double-tagged (right) events.

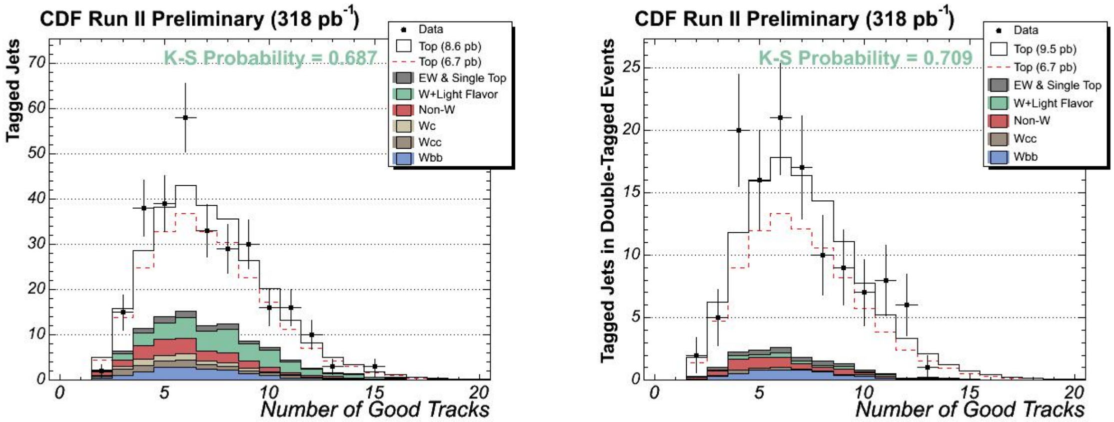


Figure 39: Expected signal and background good track multiplicity distributions in single-tagged (left) and double-tagged (right) events.

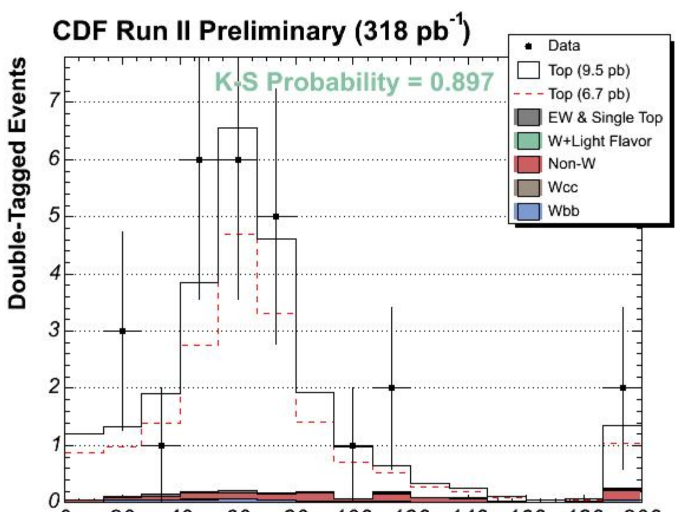


Figure 40: Mass of the untagged jets in double-tagged events with exactly four jets.

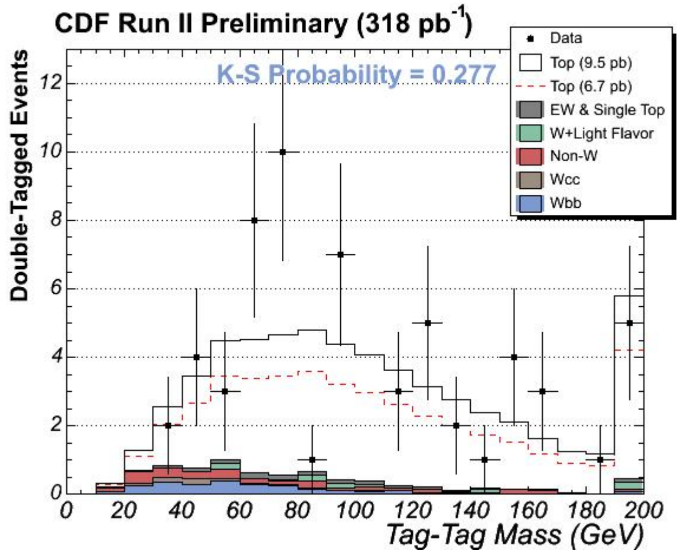


Figure 41: Mass of the tagged jets in double-tagged events.

D.2 Optimization

Here we show a simplistic check of the optimization study done in CDF7536 for the tight tagger. We assume a cross section of 6.7 pb, and calculate the expected $\frac{S}{\sqrt{S+B}}$ as a function of the cut. The statistical significance is shown in red. We further check the total error by adding a term which includes the background error, $\frac{S}{\sqrt{S+B+\Delta B^2}}$. We make the approximation that the relative background error is constant as a function of the cut, which is only true if the background composition is constant. Any further precision would be undermined by the lack of good non-W and mistag templates in these plots. The result for this figure of merit is shown in blue. Vertical lines indicate the optimal cut, if one exists. We find the preferred H_T cut to be very near the 200 GeV tight tagger selection, and we therefore choose not to alter that choice. The m_T^W and missing E_T plots suffer from a poor model of the non-W background, but we keep the 20 GeV/c^2 from the previous analysis for the former. Cutting higher on the missing energy was doe as a cross check discussed in Section s:crosschecks.

The plots shown here motivate more stringent cuts on jet E_T, tagged jet energy, and the number of jets in the signal region ($\geq$4 instead of $\geq$3). None of these is reinforced in the double-tag optimization. We do, however, check the 4-jet result in Section 9, and find a slight improvement over the unoptimized measurement. This effect is necessarily weakened by the increase in the jet energy scale systematic for this selection, which was not explicitly evaluated.

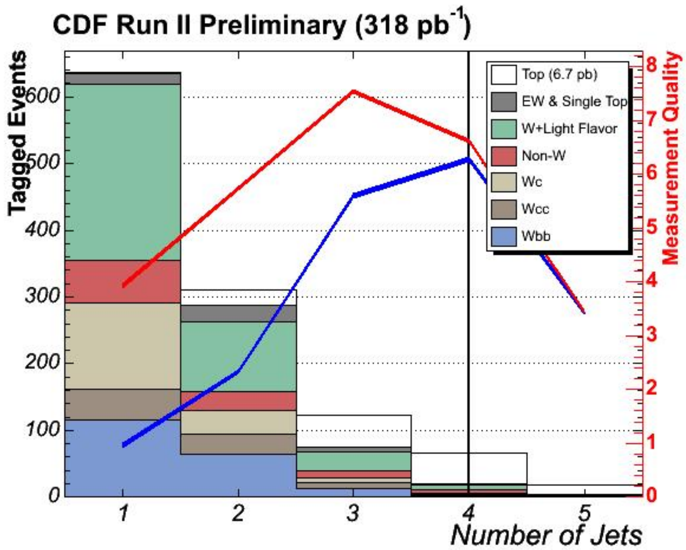


Figure 42: Optimization of the N_{jet} cut using single-tagged events.

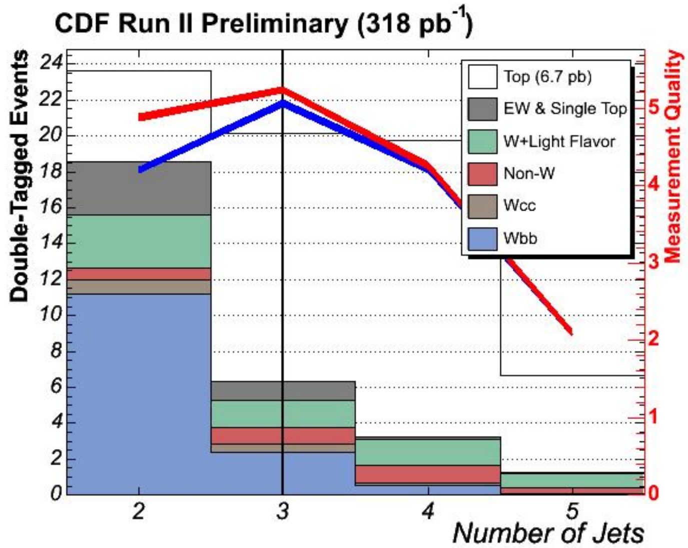


Figure 43: Optimization of the N_{jet} cut using double-tagged events.

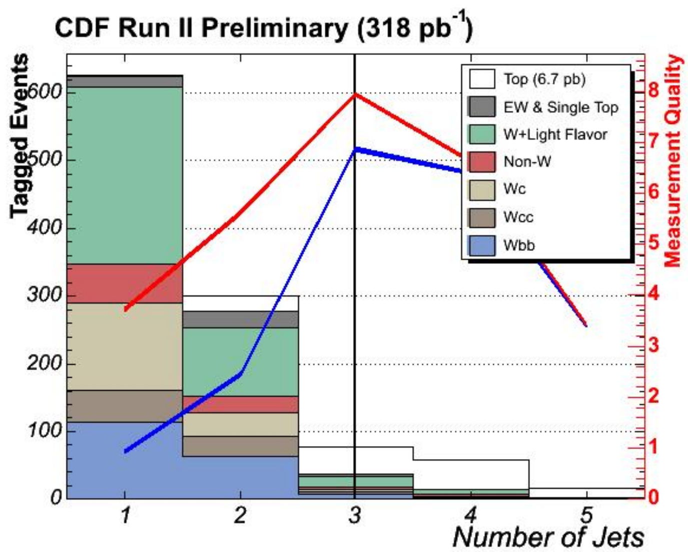


Figure 44: Optimization of the N_{jet} cut using single-tagged events after the H_T and m_T^W cuts have been applied.

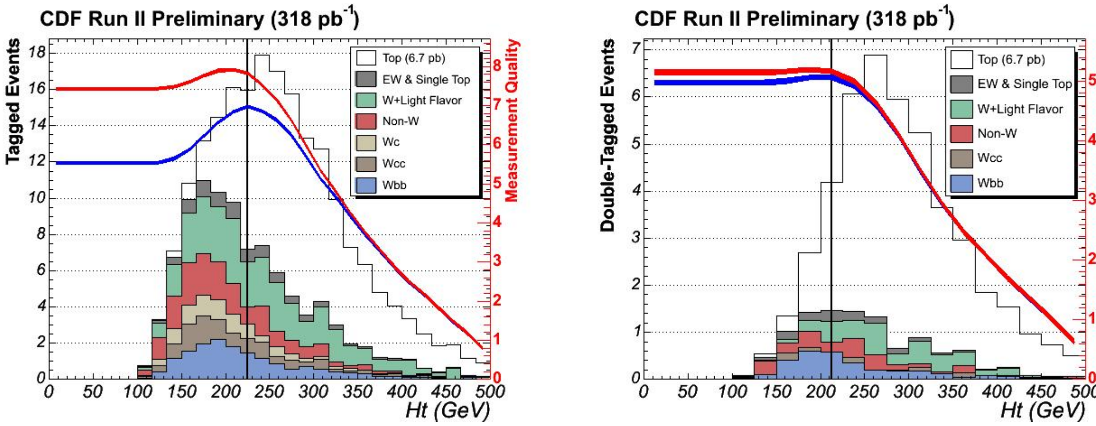


Figure 45: Optimization of an H_T cut in single-tagged (left) and double-tagged (right) events.

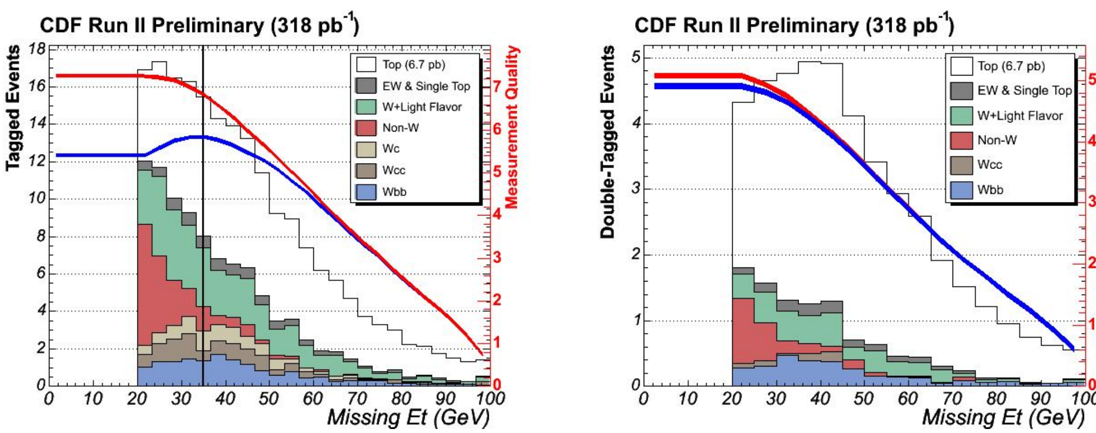


Figure 46: Optimization of a missing E_T cut in single-tagged (left) and double-tagged (right) events.

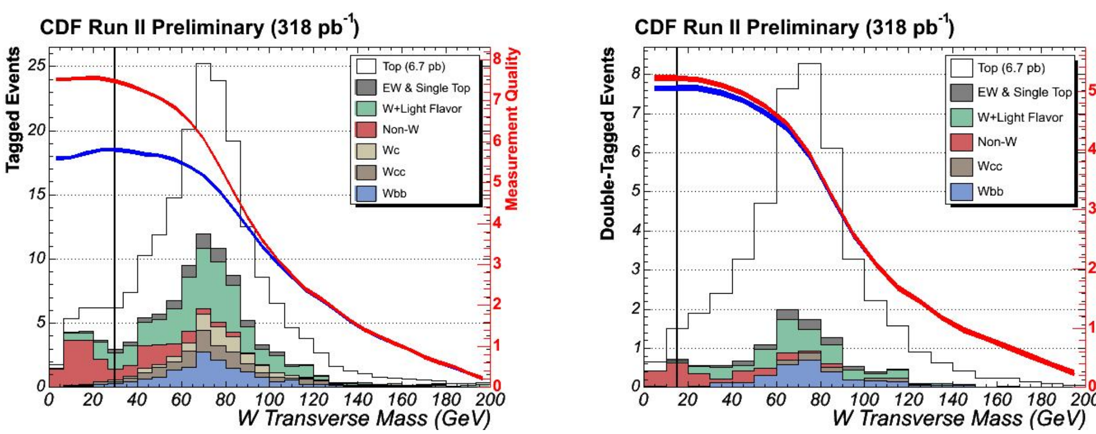


Figure 47: Optimization of an m_T^W cut in single-tagged (left) and double-tagged (right) events.

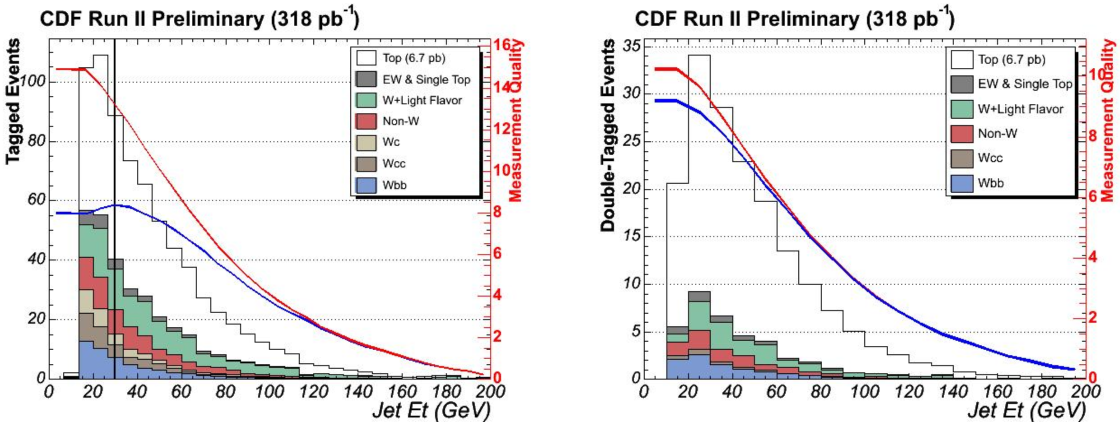


Figure 48: Optimization of a jet E_T cut in single-tagged (left) and double-tagged (right) events.

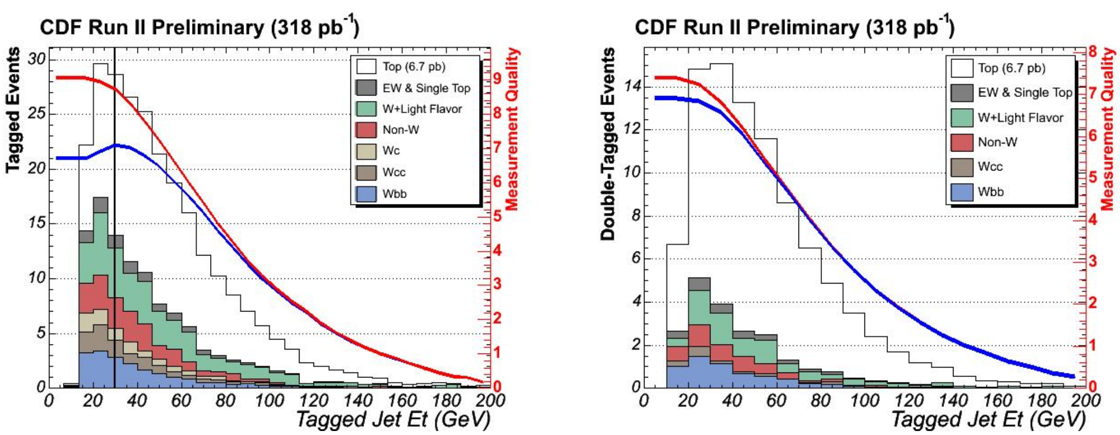


Figure 49: Optimization of a tagged jet E_T cut in single-tagged (left) and double-tagged (right) events.

E Detailed Tables

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Electrons					
Pretag	17648	2846	469	115	19
≥1 Tag	447	212	78	47	12
≥2 Tags	0	20	18	12	2
Muons					
Pretag	12980	1945	300	64	17
≥1 Tag	283	150	49	31	12
≥2 Tags	0	11	9	14	4
Total					
Pretag	30628	4791	769	179	36
≥1 Tag	730	362	127	78	24
≥2 Tags	0	31	27	26	6

Table 52: Data counts in the unoptimized pretag and tagged samples.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Electrons					
Pretag	17448	2780	197	95	18
≥1 Tag	442	204	52	41	12
≥2 Tags	0	20	16	11	2
Muons					
Pretag	12835	1896	127	47	16
≥1 Tag	280	142	28	30	11
≥2 Tags	0	10	7	14	4
Total					
Pretag	30283	4676	324	142	34
≥1 Tag	722	346	80	71	23
≥2 Tags	0	30	23	25	6

Table 53: Data counts in the optimized pretag and tagged samples.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
CEM					
Pretag A	101832	12862	1773	189	30
Pretag B	63472	5328	612	87	11
Pretag C	2853	889	175	37	9
Pretag D	17643	2845	468	114	19
Single Tag A	4312	994	223	36	6
Single Tag B	1561	280	67	18	2
Single Tag C	205	113	33	14	3
Single Tag D	447	211	77	47	12
Double Tag A	0	27	11	4	1
Double Tag B	0	8	5	4	1
Double Tag C	0	5	7	1	0
Double Tag D	0	19	18	12	2
CMUP					
Pretag A	23546	3331	424	51	8
Pretag B	7670	605	81	12	0
Pretag C	907	299	84	23	6
Pretag D	8515	1247	202	45	10
Single Tag A	1957	477	81	12	2
Single Tag B	209	47	12	7	0
Single Tag C	67	45	24	11	2
Single Tag D	176	98	35	23	8
Double Tag A	0	13	3	1	0
Double Tag B	0	1	2	0	0
Double Tag C	0	1	1	1	1
Double Tag D	0	11	7	10	2
CMX					
Pretag A	15532	2234	285	39	11
Pretag B	4338	371	38	6	2
Pretag C	679	190	44	9	2
Pretag D	4462	672	95	18	6
Single Tag A	1088	285	49	7	5
Single Tag B	135	25	4	1	1
Single Tag C	46	23	8	5	0
Single Tag D	106	52	13	8	4
Double Tag A	0	5	2	0	0
Double Tag B	0	0	0	1	1
Double Tag C	0	2	1	0	0
Double Tag D	0	0	2	4	2

Table 54: Raw non-W counts for the unoptimized analysis.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
CEM					
Pretag A	51191	5955	887	95	16
Pretag B	35939	3317	396	54	10
Pretag C	2290	605	38	17	3
Pretag D	17443	2779	198	94	18
Single Tag A	2137	464	99	19	3
Single Tag B	909	169	52	15	1
Single Tag C	164	65	11	5	2
Single Tag D	442	203	52	41	12
Double Tag A	0	17	3	3	0
Double Tag B	0	6	5	4	0
Double Tag C	0	1	3	1	0
Double Tag D	0	19	16	11	2
CMUP					
Pretag A	9162	1189	172	19	3
Pretag B	3993	321	48	6	0
Pretag C	490	136	8	3	4
Pretag D	8383	1203	86	33	9
Single Tag A	747	171	25	5	0
Single Tag B	114	21	8	5	0
Single Tag C	31	23	1	1	1
Single Tag D	173	90	18	23	7
Double Tag A	0	7	1	0	0
Double Tag B	0	0	2	0	0
Double Tag C	0	1	0	0	0
Double Tag D	0	10	5	10	2
CMX					
Pretag A	6124	788	113	22	8
Pretag B	2230	211	19	2	2
Pretag C	519	130	10	4	2
Pretag D	4448	667	38	13	6
Single Tag A	388	80	22	3	4
Single Tag B	63	14	3	0	1
Single Tag C	36	15	2	2	0
Single Tag D	106	52	9	7	4
Double Tag A	0	1	2	0	0
Double Tag B	0	0	0	0	1
Double Tag C	0	2	0	0	0
Double Tag D	0	0	2	4	2

Table 55: Raw non-W counts for the optimized analysis.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Electrons					
F_{non-W}	0.101 ± 0.025	0.129 ± 0.033	0.131 ± 0.034		
$N^{+}_{non-W;tag}$	74.2 ± 25.4	31.8 ± 11.2	10.8 ± 4.3	4.6 ± 2.0	1.0 ± 0.7
$N^{+}_{non-W;pretag}$	43.7 ± 14.0	19.4 ± 6.3	6.7 ± 2.3	3.1 ± 1.3	0.5 ± 0.4
$N^{+}_{non-W;average}$	50.9 ± 12.3	22.3 ± 5.5	7.6 ± 2.0	3.5 ± 1.1	0.6 ± 0.3
$N^{++}_{non-W;pretag}$	-	0.6 ± 0.3	0.5 ± 0.3	0.7 ± 0.3	0.2 ± 0.1
Muons					
F_{non-W}	0.038 ± 0.009	0.045 ± 0.011	0.076 ± 0.021		
$N^{+}_{non-W;tag}$	12.8 ± 4.5	6.4 ± 2.2	5.1 ± 2.2	2.6 ± 1.2	0.3 ± 0.3
$N^{+}_{non-W;pretag}$	14.0 ± 4.5	6.3 ± 2.4	3.0 ± 1.3	2.1 ± 1.1	0.6 ± 0.8
$N^{+}_{non-W;average}$	13.4 ± 3.2	6.4 ± 1.6	3.5 ± 1.1	2.3 ± 0.8	0.3 ± 0.2
$N^{++}_{non-W;pretag}$	-	0.1 ± 0.0	0.4 ± 0.0	0.3 ± 0.1	0.6 ± 0.3

Table 56: A summary of non-W single- and double-tagged events for the unoptimized analysis. No correction for top has been performed.

	1-jet	2-jet	3-jet	4-jet	≥5-jet
Electrons					
F_{non-W}	0.092 ± 0.023	0.121 ± 0.031	0.086 ± 0.025		
$N^{+}_{non-W;tag}$	69.8 ± 24.0	23.7 ± 8.7	6.2 ± 2.9	2.8 ± 1.6	1.1 ± 0.9
$N^{+}_{non-W;pretag}$	40.7 ± 13.1	17.2 ± 5.7	2.2 ± 0.8	2.3 ± 0.8	0.2 ± 0.2
$N^{+}_{non-W;average}$	47.3 ± 11.5	19.1 ± 4.7	2.5 ± 0.8	2.4 ± 0.8	0.2 ± 0.2
$N^{++}_{non-W;pretag}$	-	0.6 ± 0.3	0.2 ± 0.1	0.6 ± 0.3	0.0 ± 0.0
Muons					
F_{non-W}	0.032 ± 0.008	0.038 ± 0.010	0.038 ± 0.013		
$N^{+}_{non-W;tag}$	10.4 ± 3.8	5.3 ± 2.2	0.9 ± 0.6	0.9 ± 0.6	0.3 ± 0.3
$N^{+}_{non-W;pretag}$	11.7 ± 3.8	4.7 ± 1.7	0.8 ± 0.4	1.1 ± 0.7	0.3 ± 0.4
$N^{+}_{non-W;average}$	11.1 ± 2.7	4.9 ± 1.3	0.8 ± 0.3	1.0 ± 0.5	0.3 ± 0.2
$N^{++}_{non-W;pretag}$	-	0.0 ± 0.0	0.14 ± 0.07	0.0 ± 0.0	0.29 ± 0.14

Table 57: A summary of non-W single- and double-tagged events for the optimized analysis. No correction for top has been performed.

	1-jet	2-jet	3-jet	$\geq$4-jet
No H_T cut				
MC Tag Rates (%)				
$Wb\bar{b}$, 1 b	44.1 ± 0.3	48.0 ± 0.7	51.4 ± 2.4	48.0 ± 5.5
$Wb\bar{b}$, 1 b (double)	-	0.7 ± 0.1	2.1 ± 0.7	2.7 ± 1.8
$Wb\bar{b}$, 2 b	-	70.0 ± 0.5	70.8 ± 1.3	72.7 ± 3.5
$Wb\bar{b}$, 2 b (double)	-	22.7 ± 0.4	24.2 ± 1.2	28.8 ± 3.6
$Wc\bar{c}$, 1 c	11.2 ± 0.2	15.1 ± 0.7	17.0 ± 1.2	20.5 ± 2.7
$Wc\bar{c}$, 1 c (double)	-	0.3 ± 0.1	0.1 ± 0.1	1.1 ± 0.7
$Wc\bar{c}$, 2 c	-	21.5 ± 0.8	27.5 ± 1.6	26.0 ± 2.2
$Wc\bar{c}$, 2 c (double)	-	1.2 ± 0.2	3.4 ± 0.6	3.7 ± 1.0
Wc, 1 c	11.5 ± 0.1	13.3 ± 0.2	15.9 ± 0.7	18.5 ± 1.8
Wc, 1 c (double)	-	0.25 ± 0.03	0.24 ± 0.1	0.8 ± 0.4
Expected Data Tag Rates (%)				
$Wb\bar{b}$, 1 b	40.9 ± 2.9	45.6 ± 3.2	50.3 ± 4.1	48.3 ± 6.4
$Wb\bar{b}$, 1 b (double)	-	0.6 ± 0.1	1.8 ± 0.6	2.4 ± 1.5
$Wb\bar{b}$, 2 b	-	66.2 ± 3.6	67.7 ± 3.8	70.3 ± 5.0
$Wb\bar{b}$, 2 b (double)	-	19.5 ± 2.8	20.8 ± 3.1	24.8 ± 4.7
$Wc\bar{c}$, 1 c	10.4 ± 1.5	15.9 ± 2.1	20.6 ± 2.7	28.8 ± 4.7
$Wc\bar{c}$, 1 c (double)	-	0.2 ± 0.1	0.1 ± 0.1	1.0 ± 0.6
$Wc\bar{c}$, 2 c	-	20.0 ± 2.8	27.7 ± 3.9	28.2 ± 4.1
$Wc\bar{c}$, 2 c (double)	-	1.0 ± 0.3	3.0 ± 1.0	3.2 ± 1.2
Wc, 1 c	10.7 ± 1.5	14.1 ± 1.8	19.4 ± 2.2	25.8 ± 3.5
Wc, 1 c (double)	-	0.21 ± 0.02	0.2 ± 0.1	0.7 ± 0.4

Table 58: The efficiencies for tagging W+Heavy Flavor events in the unoptimized analysis.

	1-jet	2-jet	3-jet	≥4-jet
Optimized				
MC Tag Rates (%)				
$Wb\bar{b}$, 1 b	44.0 ± 0.3	47.9 ± 0.7	55.4 ± 4.6	50.0 ± 6.4
$Wb\bar{b}$, 1 b (double)	-	0.8 ± 0.1	4.9 ± 2.0	0.0 ± 0.0
$Wb\bar{b}$, 2 b	-	70.0 ± 0.5	74.3 ± 1.8	72.7 ± 6.7
$Wb\bar{b}$, 2 b (double)	-	22.7 ± 0.4	28.1 ± 1.8	25.9 ± 6.5
$Wc\bar{c}$, 1 c	11.1 ± 0.2	15.0 ± 0.7	21.0 ± 1.9	24.3 ± 3.3
$Wc\bar{c}$, 1 c (double)	-	0.2 ± 0.1	0.3 ± 0.3	1.4 ± 0.9
$Wc\bar{c}$, 2 c	-	21.3 ± 0.8	29.6 ± 2.4	28.9 ± 2.6
$Wc\bar{c}$, 2 c (double)	-	1.2 ± 0.2	4.2 ± 1.1	4.7 ± 1.2
Wc, 1 c	11.5 ± 0.1	13.3 ± 0.2	19.9 ± 1.2	20.6 ± 2.3
Wc, 1 c (double)	-	0.25 ± 0.03	0.5 ± 0.2	1.1 ± 0.6
Expected Data Tag Rates (%)				
$Wb\bar{b}$, 1 b	40.8 ± 2.9	45.5 ± 3.2	54.1 ± 5.8	50.3 ± 7.4
$Wb\bar{b}$, 1 b (double)	-	0.7 ± 0.1	4.2 ± 1.7	0.0 ± 0.0
$Wb\bar{b}$, 2 b	-	66.2 ± 3.6	71.0 ± 4.1	70.2 ± 7.4
$Wb\bar{b}$, 2 b (double)	-	19.5 ± 2.8	24.2 ± 3.8	22.2 ± 6.4
$Wc\bar{c}$, 1 c	10.3 ± 1.5	15.9 ± 2.1	25.9 ± 3.6	34.2 ± 5.6
$Wc\bar{c}$, 1 c (double)	-	0.2 ± 0.1	0.2 ± 0.2	1.2 ± 0.8
$Wc\bar{c}$, 2 c	-	19.8 ± 2.8	29.7 ± 4.5	31.4 ± 4.6
$Wc\bar{c}$, 2 c (double)	-	1.0 ± 0.3	3.6 ± 1.4	4.1 ± 1.6
Wc, 1 c	10.6 ± 1.5	14.1 ± 1.8	24.3 ± 3.0	28.7 ± 4.2
Wc, 1 c (double)	-	0.21 ± 0.02	0.4 ± 0.2	1.0 ± 0.5

Table 59: The efficiencies for tagging W+Heavy Flavor events in the optimized analysis.

Process	Cross Section (pb)	Number of Events	ϵ_b (%)	ϵ_c (%)
WW	13.25 ± 0.05	396337	41.7 ± 10.0	11.2 ± 0.6
WZ	3.96 ± 0.06	400943	46.8 ± 1.2	11.3 ± 1.0
ZZ	1.58 ± 0.02	396973	39.7 ± 5.7	8.8 ± 3.2
Single Top (s-channel)	0.29 ± 0.02	187559	52.3 ± 0.5	18.2 ± 8.2
Single Top (t-channel)	0.66 ± 0.27	193181	53.4 ± 0.4	7.9 ± 2.1
$Z \to \tau\tau$	13.0 ± 1.5	890892	-	-
$t\bar{t}$	6.7 ± 0.0	1106645	51.4 ± 0.9	13.4 ± 2.9

Table 60: Overview of the MC backgrounds.

WZ, Unoptimized					
	1-jet	2-jet	3-jet	4-jet	geq5-jet
CEM					
N_{pre}^{MC}	37970	43340	9030	1640	310
Raw Acceptance (%)	0.95 ± 0.020	1.08 ± 0.020	0.23 ± 0.010	0.04 ± 0.000	0.01 ± 0.000
Scaled Acceptance (%)	0.86 ± 0.070	0.99 ± 0.080	0.21 ± 0.020	0.04 ± 0.000	0.01 ± 0.000
Pretag Expectation	10.89 ± 1.080	12.43 ± 1.230	2.59 ± 0.270	0.47 ± 0.060	0.09 ± 0.020
CMUP					
N_{pre}^{MC}	23740	25940	5410	1090	150
Raw Acceptance (%)	0.59 ± 0.010	0.65 ± 0.010	0.13 ± 0.010	0.03 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.45 ± 0.040	0.49 ± 0.040	0.10 ± 0.010	0.02 ± 0.000	0.00 ± 0.000
Pretag Expectation	5.64 ± 0.560	6.16 ± 0.620	1.28 ± 0.140	0.26 ± 0.040	0.04 ± 0.010
CMUP					
N_{pre}^{MC}	8740	10220	2380	280	30
Raw Acceptance (%)	0.22 ± 0.010	0.25 ± 0.010	0.06 ± 0.000	0.01 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.20 ± 0.020	0.23 ± 0.020	0.05 ± 0.010	0.01 ± 0.000	0.00 ± 0.000
Pretag Expectation	2.56 ± 0.270	2.99 ± 0.310	0.70 ± 0.080	0.08 ± 0.020	0.01 ± 0.010
Totals					
MC Efficiency (%)	13.13 ± 0.660	19.11 ± 0.960	19.78 ± 0.990	23.10 ± 1.160	25.70 ± 1.290
Data Efficiency (%)	12.22 ± 0.610	18.01 ± 0.900	18.81 ± 0.940	22.05 ± 1.100	24.43 ± 1.220
Single-Tag Expectation	2.33 ± 0.300	3.89 ± 0.480	0.86 ± 0.110	0.18 ± 0.030	0.03 ± 0.010
MC Efficiency (%)	-	2.94 ± 0.410	3.91 ± 0.550	4.22 ± 0.590	6.07 ± 0.850
Data Efficiency (%)	-	2.54 ± 0.360	3.40 ± 0.480	3.69 ± 0.520	5.31 ± 0.740
Double-Tag Expectation	-	0.55 ± 0.100	0.16 ± 0.030	0.03 ± 0.010	0.01 ± 0.000

Table 61: Information on the WZ background for the unoptimized analysis.

WZ, Optimized					
	1-jet	2-jet	3-jet	4-jet	geq5-jet
CEM					
N_{pre}^{MC}	37270	42290	3660	1080	300
Raw Acceptance (%)	0.93 ± 0.020	1.05 ± 0.020	0.09 ± 0.000	0.03 ± 0.000	0.01 ± 0.000
Scaled Acceptance (%)	0.85 ± 0.070	0.96 ± 0.070	0.08 ± 0.010	0.02 ± 0.000	0.01 ± 0.000
Pretag Expectation	10.69 ± 1.060	12.13 ± 1.200	1.05 ± 0.120	0.31 ± 0.040	0.09 ± 0.020
CMUP					
N_{pre}^{MC}	22970	25060	2160	760	120
Raw Acceptance (%)	0.57 ± 0.010	0.63 ± 0.010	0.05 ± 0.000	0.02 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.43 ± 0.030	0.47 ± 0.040	0.04 ± 0.000	0.01 ± 0.000	0.00 ± 0.000
Pretag Expectation	5.45 ± 0.550	5.95 ± 0.590	0.51 ± 0.060	0.18 ± 0.030	0.03 ± 0.010
CMUP					
N_{pre}^{MC}	8700	10140	930	180	20
Raw Acceptance (%)	0.22 ± 0.010	0.25 ± 0.010	0.02 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.20 ± 0.020	0.23 ± 0.020	0.02 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Pretag Expectation	2.54 ± 0.260	2.97 ± 0.310	0.27 ± 0.040	0.05 ± 0.010	0.01 ± 0.000
Totals					
MC Efficiency (%)	13.15 ± 0.660	19.10 ± 0.950	23.33 ± 1.170	25.29 ± 1.260	28.45 ± 1.420
Data Efficiency (%)	12.24 ± 0.610	17.99 ± 0.900	22.20 ± 1.110	24.14 ± 1.210	27.04 ± 1.350
Single-Tag Expectation	2.29 ± 0.290	3.79 ± 0.470	0.41 ± 0.060	0.13 ± 0.020	0.03 ± 0.010
MC Efficiency (%)	-	2.90 ± 0.410	4.14 ± 0.580	4.76 ± 0.670	6.72 ± 0.940
Data Efficiency (%)	-	2.51 ± 0.350	3.61 ± 0.500	4.16 ± 0.580	5.88 ± 0.820
Double-Tag Expectation	-	0.53 ± 0.100	0.07 ± 0.010	0.02 ± 0.000	0.01 ± 0.000

Table 62: Information on the WZ background for the optimized analysis.

ZZ, Unoptimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	2680	2760	1490	420	90
Raw Acceptance (%)	0.07 ± 0.000	0.07 ± 0.000	0.04 ± 0.000	0.01 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.06 ± 0.010	0.06 ± 0.010	0.03 ± 0.000	0.01 ± 0.000	0.00 ± 0.000
Pretag Expectation	0.31 ± 0.040	0.32 ± 0.040	0.17 ± 0.020	0.05 ± 0.010	0.01 ± 0.000
CMUP					
N_{pre}^{MC}	3070	3260	1110	310	10
Raw Acceptance (%)	0.08 ± 0.000	0.08 ± 0.000	0.03 ± 0.000	0.01 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.06 ± 0.010	0.06 ± 0.010	0.02 ± 0.000	0.01 ± 0.000	0.00 ± 0.000
Pretag Expectation	0.29 ± 0.030	0.31 ± 0.040	0.11 ± 0.010	0.03 ± 0.010	0.00 ± 0.000
CMUP					
N_{pre}^{MC}	1150	1320	420	70	40
Raw Acceptance (%)	0.03 ± 0.000	0.03 ± 0.000	0.01 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.03 ± 0.000	0.03 ± 0.000	0.01 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Pretag Expectation	0.14 ± 0.020	0.16 ± 0.020	0.05 ± 0.010	0.01 ± 0.000	0.00 ± 0.000
Totals					
MC Efficiency (%)	5.92 ± 0.300	18.09 ± 0.900	18.52 ± 0.930	18.83 ± 0.940	36.76 ± 1.840
Data Efficiency (%)	5.55 ± 0.280	17.16 ± 0.860	17.67 ± 0.880	17.96 ± 0.900	35.35 ± 1.770
Single-Tag Expectation	0.04 ± 0.010	0.13 ± 0.020	0.06 ± 0.010	0.02 ± 0.000	0.01 ± 0.000
MC Efficiency (%)	-	3.98 ± 0.560	3.75 ± 0.530	2.73 ± 0.380	7.48 ± 1.050
Data Efficiency (%)	-	3.42 ± 0.480	3.25 ± 0.450	2.38 ± 0.330	6.54 ± 0.920
Double-Tag Expectation	-	0.03 ± 0.000	0.01 ± 0.000	0.00 ± 0.000	0.00 ± 0.000

Table 63: Information on the ZZ background for the unoptimized analysis.

ZZ, Optimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	2560	2560	840	190	70
Raw Acceptance (%)	0.06 ± 0.000	0.06 ± 0.000	0.02 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.06 ± 0.010	0.06 ± 0.010	0.02 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Pretag Expectation	0.30 ± 0.030	0.30 ± 0.030	0.10 ± 0.010	0.02 ± 0.010	0.01 ± 0.000
CMUP					
N_{pre}^{MC}	2880	2850	400	180	10
Raw Acceptance (%)	0.07 ± 0.000	0.07 ± 0.000	0.01 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.05 ± 0.010	0.05 ± 0.010	0.01 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Pretag Expectation	0.28 ± 0.030	0.27 ± 0.030	0.04 ± 0.010	0.02 ± 0.000	0.00 ± 0.000
CMUP					
N_{pre}^{MC}	1130	1280	190	40	40
Raw Acceptance (%)	0.03 ± 0.000	0.03 ± 0.000	0.00 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.03 ± 0.000	0.03 ± 0.000	0.00 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Pretag Expectation	0.13 ± 0.020	0.15 ± 0.020	0.02 ± 0.010	0.00 ± 0.000	0.00 ± 0.000
Totals					
MC Efficiency (%)	6.04 ± 0.300	17.83 ± 0.890	17.20 ± 0.860	22.12 ± 1.110	34.56 ± 1.730
Data Efficiency (%)	5.65 ± 0.280	16.93 ± 0.850	16.39 ± 0.820	21.17 ± 1.060	33.32 ± 1.670
Single-Tag Expectation	0.04 ± 0.010	0.12 ± 0.020	0.03 ± 0.000	0.01 ± 0.000	0.00 ± 0.000
MC Efficiency (%)	-	4.08 ± 0.570	4.47 ± 0.630	5.38 ± 0.750	0.00 ± 0.000
Data Efficiency (%)	-	3.51 ± 0.490	3.86 ± 0.540	4.68 ± 0.660	0.00 ± 0.000
Double-Tag Expectation	-	0.03 ± 0.000	0.01 ± 0.000	0.00 ± 0.000	0.00 ± 0.000

Table 64: Information on the ZZ background for the optimized analysis.

WW, Unoptimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	76380	76090	15600	2530	410
Raw Acceptance (%)	1.93 ± 0.020	1.92 ± 0.020	0.39 ± 0.010	0.06 ± 0.000	0.01 ± 0.000
Scaled Acceptance (%)	1.76 ± 0.140	1.75 ± 0.130	0.36 ± 0.030	0.06 ± 0.010	0.01 ± 0.000
Pretag Expectation	74.17 ± 7.240	73.89 ± 7.210	15.15 ± 1.520	2.46 ± 0.280	0.40 ± 0.070
CMUP					
N_{pre}^{MC}	47570	45230	9720	1740	230
Raw Acceptance (%)	1.20 ± 0.020	1.14 ± 0.020	0.25 ± 0.010	0.04 ± 0.000	0.01 ± 0.000
Scaled Acceptance (%)	0.91 ± 0.070	0.86 ± 0.070	0.19 ± 0.020	0.03 ± 0.000	0.00 ± 0.000
Pretag Expectation	38.23 ± 3.740	36.35 ± 3.560	7.81 ± 0.800	1.40 ± 0.170	0.18 ± 0.040
CMUP					
N_{pre}^{MC}	18920	17990	3700	680	130
Raw Acceptance (%)	0.48 ± 0.010	0.45 ± 0.010	0.09 ± 0.000	0.02 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.44 ± 0.030	0.41 ± 0.030	0.09 ± 0.010	0.02 ± 0.000	0.00 ± 0.000
Pretag Expectation	18.73 ± 1.870	17.81 ± 1.780	3.66 ± 0.400	0.67 ± 0.100	0.13 ± 0.040
Totals					
MC Efficiency (%)	3.29 ± 0.160	6.61 ± 0.330	9.59 ± 0.480	10.49 ± 0.520	18.38 ± 0.920
Data Efficiency (%)	3.13 ± 0.160	6.26 ± 0.310	9.16 ± 0.460	10.13 ± 0.510	17.76 ± 0.890
Single-Tag Expectation	4.10 ± 0.600	8.02 ± 1.220	2.44 ± 0.350	0.46 ± 0.070	0.13 ± 0.030
MC Efficiency (%)	-	0.09 ± 0.010	0.37 ± 0.050	0.40 ± 0.060	1.39 ± 0.190
Data Efficiency (%)	-	0.09 ± 0.010	0.34 ± 0.050	0.35 ± 0.050	1.39 ± 0.190
Double-Tag Expectation	-	0.12 ± 0.010	0.09 ± 0.020	0.02 ± 0.000	0.01 ± 0.000

Table 65: Information on the WW background for the unoptimized analysis.

WW, Optimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	75730	74920	6300	1750	360
Raw Acceptance (%)	1.91 ± 0.020	1.89 ± 0.020	0.16 ± 0.010	0.04 ± 0.000	0.01 ± 0.000
Scaled Acceptance (%)	1.74 ± 0.130	1.72 ± 0.130	0.14 ± 0.010	0.04 ± 0.000	0.01 ± 0.000
Pretag Expectation	73.54 ± 7.170	72.75 ± 7.100	6.12 ± 0.640	1.70 ± 0.210	0.35 ± 0.070
CMUP					
N_{pre}^{MC}	46620	44080	3700	1220	210
Raw Acceptance (%)	1.18 ± 0.020	1.11 ± 0.020	0.09 ± 0.000	0.03 ± 0.000	0.01 ± 0.000
Scaled Acceptance (%)	0.89 ± 0.070	0.84 ± 0.070	0.07 ± 0.010	0.02 ± 0.000	0.00 ± 0.000
Pretag Expectation	37.46 ± 3.670	35.42 ± 3.470	2.97 ± 0.330	0.98 ± 0.130	0.17 ± 0.040
CMUP					
N_{pre}^{MC}	18860	17960	1420	430	130
Raw Acceptance (%)	0.48 ± 0.010	0.45 ± 0.010	0.04 ± 0.000	0.01 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.43 ± 0.030	0.41 ± 0.030	0.03 ± 0.000	0.01 ± 0.000	0.00 ± 0.000
Pretag Expectation	18.67 ± 1.860	17.78 ± 1.770	1.41 ± 0.180	0.43 ± 0.080	0.13 ± 0.040
Totals					
MC Efficiency (%)	3.28 ± 0.160	6.58 ± 0.330	12.51 ± 0.630	10.80 ± 0.540	18.34 ± 0.920
Data Efficiency (%)	3.12 ± 0.160	6.24 ± 0.310	11.98 ± 0.600	10.44 ± 0.520	17.73 ± 0.890
Single-Tag Expectation	4.05 ± 0.590	7.86 ± 1.200	1.26 ± 0.190	0.32 ± 0.050	0.11 ± 0.030
MC Efficiency (%)	-	0.10 ± 0.010	0.37 ± 0.050	0.58 ± 0.080	1.53 ± 0.210
Data Efficiency (%)	-	0.09 ± 0.010	0.35 ± 0.050	0.51 ± 0.070	1.53 ± 0.210
Double-Tag Expectation	-	0.12 ± 0.010	0.04 ± 0.010	0.02 ± 0.000	0.01 ± 0.000

Table 66: Information on the WW background for the optimized analysis.

s-Channel Single Top, Unoptimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	57750	114010	23380	3590	520
Raw Acceptance (%)	3.08 ± 0.040	6.08 ± 0.060	1.25 ± 0.030	0.19 ± 0.010	0.03 ± 0.000
Scaled Acceptance (%)	2.81 ± 0.220	5.54 ± 0.420	1.14 ± 0.090	0.17 ± 0.020	0.03 ± 0.000
Pretag Expectation	2.59 ± 0.310	5.12 ± 0.610	1.05 ± 0.130	0.16 ± 0.020	0.02 ± 0.000
CMUP					
N_{pre}^{MC}	32630	66560	13760	2050	280
Raw Acceptance (%)	1.74 ± 0.030	3.55 ± 0.040	0.73 ± 0.020	0.11 ± 0.010	0.01 ± 0.000
Scaled Acceptance (%)	1.31 ± 0.100	2.68 ± 0.210	0.55 ± 0.040	0.08 ± 0.010	0.01 ± 0.000
Pretag Expectation	1.21 ± 0.150	2.47 ± 0.300	0.51 ± 0.060	0.08 ± 0.010	0.01 ± 0.000
CMUP					
N_{pre}^{MC}	11910	22230	4300	670	150
Raw Acceptance (%)	0.64 ± 0.020	1.19 ± 0.020	0.23 ± 0.010	0.04 ± 0.000	0.01 ± 0.000
Scaled Acceptance (%)	0.58 ± 0.050	1.08 ± 0.080	0.21 ± 0.020	0.03 ± 0.000	0.01 ± 0.000
Pretag Expectation	0.55 ± 0.070	1.02 ± 0.120	0.20 ± 0.030	0.03 ± 0.010	0.01 ± 0.000
Totals					
MC Efficiency (%)	50.10 ± 2.510	72.56 ± 3.630	73.76 ± 3.690	73.98 ± 3.700	68.18 ± 3.410
Data Efficiency (%)	46.45 ± 2.320	68.87 ± 3.440	70.16 ± 3.510	70.52 ± 3.530	65.23 ± 3.260
Single-Tag Expectation	2.02 ± 0.280	5.93 ± 0.770	1.23 ± 0.160	0.19 ± 0.030	0.03 ± 0.010
MC Efficiency (%)	-	25.16 ± 3.520	27.32 ± 3.820	25.66 ± 3.590	26.68 ± 3.740
Data Efficiency (%)	-	21.63 ± 3.030	23.66 ± 3.310	22.38 ± 3.130	23.43 ± 3.280
Double-Tag Expectation	-	1.86 ± 0.350	0.42 ± 0.080	0.06 ± 0.010	0.01 ± 0.000

Table 67: Information on the s-Channel Single Top background for the unoptimized analysis.

s-Channel Single Top, Optimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	56600	111340	14750	2900	510
Raw Acceptance (%)	3.02 ± 0.040	5.94 ± 0.050	0.79 ± 0.020	0.15 ± 0.010	0.03 ± 0.000
Scaled Acceptance (%)	2.75 ± 0.210	5.41 ± 0.410	0.72 ± 0.060	0.14 ± 0.010	0.02 ± 0.000
Pretag Expectation	2.54 ± 0.300	5.00 ± 0.600	0.66 ± 0.080	0.13 ± 0.020	0.02 ± 0.000
CMUP					
N_{pre}^{MC}	31780	63890	8260	1680	270
Raw Acceptance (%)	1.69 ± 0.030	3.41 ± 0.040	0.44 ± 0.020	0.09 ± 0.010	0.01 ± 0.000
Scaled Acceptance (%)	1.28 ± 0.100	2.57 ± 0.200	0.33 ± 0.030	0.07 ± 0.010	0.01 ± 0.000
Pretag Expectation	1.18 ± 0.140	2.37 ± 0.280	0.31 ± 0.040	0.06 ± 0.010	0.01 ± 0.000
CMUP					
N_{pre}^{MC}	11830	22160	2730	580	150
Raw Acceptance (%)	0.63 ± 0.020	1.18 ± 0.020	0.15 ± 0.010	0.03 ± 0.000	0.01 ± 0.000
Scaled Acceptance (%)	0.58 ± 0.050	1.08 ± 0.080	0.13 ± 0.010	0.03 ± 0.000	0.01 ± 0.000
Pretag Expectation	0.54 ± 0.070	1.01 ± 0.120	0.13 ± 0.020	0.03 ± 0.000	0.01 ± 0.000
Totals					
MC Efficiency (%)	49.92 ± 2.500	72.46 ± 3.620	76.62 ± 3.830	76.94 ± 3.850	67.53 ± 3.380
Data Efficiency (%)	46.28 ± 2.310	68.77 ± 3.440	72.90 ± 3.640	73.35 ± 3.670	64.61 ± 3.230
Single-Tag Expectation	1.97 ± 0.280	5.77 ± 0.750	0.80 ± 0.110	0.16 ± 0.020	0.03 ± 0.010
MC Efficiency (%)	-	25.12 ± 3.520	30.58 ± 4.280	27.61 ± 3.870	27.26 ± 3.820
Data Efficiency (%)	-	21.60 ± 3.020	26.47 ± 3.710	24.09 ± 3.370	23.94 ± 3.350
Double-Tag Expectation	-	1.81 ± 0.340	0.29 ± 0.050	0.05 ± 0.010	0.01 ± 0.000

Table 68: Information on the s-Channel Single Top background for the optimized analysis.

t-Channel Single Top, Unoptimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	85530	87890	16630	2430	470
Raw Acceptance (%)	4.43 ± 0.050	4.55 ± 0.050	0.86 ± 0.020	0.13 ± 0.010	0.02 ± 0.000
Scaled Acceptance (%)	4.04 ± 0.310	4.15 ± 0.320	0.79 ± 0.060	0.11 ± 0.010	0.02 ± 0.000
Pretag Expectation	8.49 ± 3.570	8.72 ± 3.670	1.65 ± 0.690	0.24 ± 0.100	0.05 ± 0.020
CMUP					
N_{pre}^{MC}	50060	52550	9620	1650	180
Raw Acceptance (%)	2.59 ± 0.040	2.72 ± 0.040	0.50 ± 0.020	0.09 ± 0.010	0.01 ± 0.000
Scaled Acceptance (%)	1.96 ± 0.150	2.05 ± 0.160	0.38 ± 0.030	0.06 ± 0.010	0.01 ± 0.000
Pretag Expectation	4.11 ± 1.730	4.32 ± 1.820	0.79 ± 0.330	0.14 ± 0.060	0.01 ± 0.010
CMUP					
N_{pre}^{MC}	18220	17360	3360	650	80
Raw Acceptance (%)	0.94 ± 0.020	0.90 ± 0.020	0.17 ± 0.010	0.03 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.86 ± 0.070	0.82 ± 0.060	0.16 ± 0.010	0.03 ± 0.000	0.00 ± 0.000
Pretag Expectation	1.84 ± 0.780	1.76 ± 0.740	0.34 ± 0.140	0.07 ± 0.030	0.01 ± 0.000
Totals					
MC Efficiency (%)	45.80 ± 2.290	54.73 ± 2.740	63.70 ± 3.190	66.95 ± 3.350	74.54 ± 3.730
Data Efficiency (%)	42.46 ± 2.120	51.00 ± 2.550	60.14 ± 3.010	63.65 ± 3.180	71.07 ± 3.550
Single-Tag Expectation	6.13 ± 2.620	7.55 ± 3.220	1.67 ± 0.710	0.28 ± 0.120	0.05 ± 0.020
MC Efficiency (%)	-	2.80 ± 0.390	14.82 ± 2.070	21.56 ± 3.020	27.08 ± 3.790
Data Efficiency (%)	-	2.47 ± 0.350	12.87 ± 1.800	18.77 ± 2.630	23.67 ± 3.310
Double-Tag Expectation	-	0.37 ± 0.160	0.36 ± 0.160	0.08 ± 0.040	0.02 ± 0.010

Table 69: Information on the t-Channel Single Top background for the unoptimized analysis.

t-Channel Single Top, Optimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	84380	86410	9690	1890	460
Raw Acceptance (%)	4.37 ± 0.050	4.47 ± 0.050	0.50 ± 0.020	0.10 ± 0.010	0.02 ± 0.000
Scaled Acceptance (%)	3.98 ± 0.310	4.08 ± 0.310	0.46 ± 0.040	0.09 ± 0.010	0.02 ± 0.000
Pretag Expectation	8.37 ± 3.520	8.58 ± 3.610	0.96 ± 0.410	0.19 ± 0.080	0.05 ± 0.020
CMUP					
N_{pre}^{MC}	49050	51140	5090	1290	150
Raw Acceptance (%)	2.54 ± 0.040	2.65 ± 0.040	0.26 ± 0.010	0.07 ± 0.010	0.01 ± 0.000
Scaled Acceptance (%)	1.92 ± 0.150	2.00 ± 0.150	0.20 ± 0.020	0.05 ± 0.010	0.01 ± 0.000
Pretag Expectation	4.03 ± 1.690	4.20 ± 1.770	0.42 ± 0.180	0.11 ± 0.050	0.01 ± 0.010
CMUP					
N_{pre}^{MC}	18170	17330	1730	520	70
Raw Acceptance (%)	0.94 ± 0.020	0.90 ± 0.020	0.09 ± 0.010	0.03 ± 0.000	0.00 ± 0.000
Scaled Acceptance (%)	0.86 ± 0.070	0.82 ± 0.060	0.08 ± 0.010	0.02 ± 0.000	0.00 ± 0.000
Pretag Expectation	1.84 ± 0.770	1.75 ± 0.740	0.18 ± 0.070	0.05 ± 0.020	0.01 ± 0.000
Totals					
MC Efficiency (%)	45.71 ± 2.290	54.78 ± 2.740	67.22 ± 3.360	69.11 ± 3.460	73.98 ± 3.700
Data Efficiency (%)	42.38 ± 2.120	51.05 ± 2.550	63.51 ± 3.180	65.68 ± 3.280	70.52 ± 3.530
Single-Tag Expectation	6.04 ± 2.570	7.42 ± 3.160	0.99 ± 0.420	0.23 ± 0.100	0.05 ± 0.020
MC Efficiency (%)	-	2.79 ± 0.390	17.42 ± 2.440	22.08 ± 3.090	28.89 ± 4.040
Data Efficiency (%)	-	2.47 ± 0.350	15.14 ± 2.120	19.23 ± 2.690	25.25 ± 3.540
Double-Tag Expectation	-	0.36 ± 0.160	0.24 ± 0.100	0.07 ± 0.030	0.02 ± 0.010

Table 70: Information on the t-Channel Single Top background for the optimized analysis.

$t\bar{t}$, Unoptimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	22940	121980	237060	214760	66040
Raw Acceptance (%)	0.21 ± 0.000	1.10 ± 0.010	2.14 ± 0.010	1.94 ± 0.010	0.60 ± 0.010
Scaled Acceptance (%)	0.19 ± 0.010	1.01 ± 0.080	1.95 ± 0.150	1.77 ± 0.140	0.54 ± 0.040
Pretag Expectation	4.03 ± 0.400	21.45 ± 2.090	41.69 ± 4.040	37.77 ± 3.670	11.61 ± 1.130
CMUP					
N_{pre}^{MC}	14850	78090	153310	135100	41300
Raw Acceptance (%)	0.13 ± 0.000	0.71 ± 0.010	1.39 ± 0.010	1.22 ± 0.010	0.37 ± 0.010
Scaled Acceptance (%)	0.10 ± 0.010	0.53 ± 0.040	1.05 ± 0.080	0.92 ± 0.070	0.28 ± 0.020
Pretag Expectation	2.16 ± 0.220	11.36 ± 1.110	22.31 ± 2.170	19.66 ± 1.910	6.01 ± 0.590
CMUP					
N_{pre}^{MC}	4600	25880	50980	44630	14070
Raw Acceptance (%)	0.04 ± 0.000	0.23 ± 0.000	0.46 ± 0.010	0.40 ± 0.010	0.13 ± 0.000
Scaled Acceptance (%)	0.04 ± 0.000	0.21 ± 0.020	0.42 ± 0.030	0.37 ± 0.030	0.12 ± 0.010
Pretag Expectation	0.82 ± 0.090	4.64 ± 0.460	9.14 ± 0.890	8.00 ± 0.780	2.52 ± 0.250
Totals					
MC Efficiency (%)	42.68 ± 2.130	62.49 ± 3.120	68.87 ± 3.440	74.07 ± 3.700	75.16 ± 3.760
Data Efficiency (%)	39.59 ± 1.980	58.94 ± 2.950	65.31 ± 3.270	70.64 ± 3.530	71.86 ± 3.590
Single-Tag Expectation	2.78 ± 0.340	22.08 ± 2.500	47.77 ± 5.270	46.22 ± 4.990	14.48 ± 1.570
MC Efficiency (%)	-	15.82 ± 2.220	21.80 ± 3.050	28.83 ± 4.040	30.32 ± 4.240
Data Efficiency (%)	-	13.66 ± 1.910	18.95 ± 2.650	25.23 ± 3.530	26.69 ± 3.740
Double-Tag Expectation	-	5.12 ± 0.880	13.86 ± 2.410	16.51 ± 2.840	5.38 ± 0.930

Table 71: Information on the $t\bar{t}$ signal for the unoptimized analysis.

$t\bar{t}$, Optimized					
	1-jet	2-jet	3-jet	4-jet	$geq5$-jet
CEM					
N_{pre}^{MC}	22490	118820	198090	201620	63820
Raw Acceptance (%)	0.20 ± 0.000	1.07 ± 0.010	1.79 ± 0.010	1.82 ± 0.010	0.58 ± 0.010
Scaled Acceptance (%)	0.19 ± 0.010	0.98 ± 0.070	1.63 ± 0.120	1.66 ± 0.130	0.53 ± 0.040
Pretag Expectation	3.96 ± 0.390	20.90 ± 2.030	34.84 ± 3.380	35.46 ± 3.440	11.22 ± 1.100
CMUP					
N_{pre}^{MC}	14390	74930	126800	125140	39280
Raw Acceptance (%)	0.13 ± 0.000	0.68 ± 0.010	1.15 ± 0.010	1.13 ± 0.010	0.35 ± 0.010
Scaled Acceptance (%)	0.10 ± 0.010	0.51 ± 0.040	0.86 ± 0.070	0.85 ± 0.070	0.27 ± 0.020
Pretag Expectation	2.09 ± 0.210	10.90 ± 1.060	18.45 ± 1.790	18.21 ± 1.770	5.72 ± 0.560
CMUP					
N_{pre}^{MC}	4560	25790	42750	42730	13890
Raw Acceptance (%)	0.04 ± 0.000	0.23 ± 0.000	0.39 ± 0.010	0.39 ± 0.010	0.13 ± 0.000
Scaled Acceptance (%)	0.04 ± 0.000	0.21 ± 0.020	0.35 ± 0.030	0.35 ± 0.030	0.11 ± 0.010
Pretag Expectation	0.82 ± 0.090	4.62 ± 0.460	7.67 ± 0.750	7.66 ± 0.750	2.49 ± 0.250
Totals					
MC Efficiency (%)	42.51 ± 2.130	62.49 ± 3.120	70.22 ± 3.510	74.49 ± 3.720	75.14 ± 3.760
Data Efficiency (%)	39.43 ± 1.970	58.93 ± 2.950	66.61 ± 3.330	71.04 ± 3.550	71.84 ± 3.590
Single-Tag Expectation	2.71 ± 0.330	21.47 ± 2.430	40.61 ± 4.480	43.57 ± 4.710	13.96 ± 1.510
MC Efficiency (%)	-	15.86 ± 2.220	23.10 ± 3.230	29.18 ± 4.080	30.37 ± 4.250
Data Efficiency (%)	-	13.69 ± 1.920	20.08 ± 2.810	25.53 ± 3.570	26.73 ± 3.740
Double-Tag Expectation	-	4.99 ± 0.860	12.24 ± 2.130	15.66 ± 2.710	5.19 ± 0.900

Table 72: Information on the $t\bar{t}$ signal for the optimized analysis.