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Combined Measurement of the Top Pair Production Cross Section and SecVtx Scale Factor in 695 pb^{-1}

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Abstract

We present a measurement of the $t\bar{t}$ production cross section in the lepton+jets decay channel with 695 pb^{-1} of CDF data. By requiring that the singly and multiply SecVtx-tagged samples correspond to the same cross section, we fit simultaneously for the cross section and the b-tagging scale factor. The results for $\sigma_{t\bar{t}}$ are consistent with those presented in CDF8120 and CDF8037, and the corresponding scale factors agree with the measurements in the low-p_T lepton samples discussed in CDF8025. The best measurement using loose SecVtx and requiring $H_T > 200$ GeV for three or more jets is 8.6 $\pm$ 0.9 (stat+SF) $\pm$ 0.9 (syst) pb, with a scale factor of 0.93 $\pm$ 0.06. For tight SecVtx, the best result is 8.1 $\pm$ 0.9 (stat+SF) $\pm$ 0.8 (syst), with a scale factor of 0.92 $\pm$ 0.06. The resulting scale factors show a 15% improvement in precision and are generally applicable to other high-p_T analyses.

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1 Introduction and Motivation

As of the Winter 2006 conferences, the precision of the flagship measurements in the CDF top program (e.g. the mass and cross section) is limited by systematic uncertainties. Looking forward to the next round of analyses, it is critical to exploit better our large dataset to reduce these errors. Central to this charge are a better understanding of the composition of signal samples and a more thorough evaluation of the tools, both of which can be achieved with a proper tuning of the SecVtx cross section analysis.

As the cross section is measured now [5][1], the event selection requires *at least one* tag in the event; an alternate selection requires *two or more* tags, and the result with those events is presented as a cross check. The cross section in each case is (still) 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

While the double-tagged selection has a very high purity (roughly 90%) and fair statistics (10% relative error), the systematic uncertainty is dominated by the error on Φ_e, nearly 20%. The size of the uncertainty is driven entirely by the error on the b-jet tagging scale factor (SF), almost 8% in CDF8025. However, if we statistically separate the single- and double-tagged samples and constrain the measured cross section to be the same in the two subsamples, we get an additional handle on SF which may improve the overall quality of the cross section measurement (or any other high-p_T b-tagging analysis). It is worth stating that this does blind you from observing new physics in the double-tagged sample, although some aspects of the analysis are already biased against finding non-top. (Additionally, the general agreement between the inclusive and double-tagged measurements suggests that any additional signal in this sample is not large.)

Using the signal sample to constrain the scale factor has been discussed before, but it has not been implemented before due to limited double-tag statistics; in the current large dataset, this is not a restriction. However, this note is intended more as a feasibility study for the Summer than a true analysis. In the text, we will first briefly review the most recent scale factor and cross section measurements in Sections 2 and 3, then describe the necessary changes to the efficiency and background calculations in Section 3.1. Details of the fit procedure can be found in 4, and initial results are in Section 5.

1.1 Glossary

Most of the text assumes some familiarity with the SecVtx scale factor and cross section measurements. We list here (for the uninitiated) some of the vocabulary and background relevant to those analyses which is repeated in this note.

- **Tight/Loose**: The two main configurations of the SecVtx tagger. The former is the default tagger, which has a roughly 40% b-tagging efficiency in $t\bar{t}$ events and a 0.4% mistag rate. The latter is a higher-efficiency, lower-purity version of the tagger that is 48% efficienct for b's but has a mistag rate of 1.2%; this tagger was developed to improve the quality of the double-tag measurement. The tight tagger analysis is described in CDF8037, the loose in CDF8120.

- **Optimized/Unoptimized**: Two different event selections used in the cross section analyses. The optimized version is identical to the unoptimized, except for an additional requirement that the H_T (sum of all jet E_T, lepton p_T, and missing E_T) exceed 200 GeV for events with 3 or more jets. This cut dramatically reduces the background with only a small effect on the signal. Results with and without the H_T cut are historically presented in parallel, and we keep that convention here.

- **Single-Tag, Double-Tag, Inclusive-Tag**: The three possible tag requirements in a cross section analysis. The vast majority of cross section analyses simply require *one or more* tags to get the best possible measurement, then use the subsample with *two or more* tags as a cross check measurement. Here, we will distinguish between the single-tag (exactly one tag) and inclusive-tag (one or more) samples, but will use *double-tag* to represent events with two or more tags.

2 Scale Factor

Nearly all high-p_T tagging analyses use Monte Carlo simulations to determine the expected yield of signal and background events in data. Where discrepancies between data and simulation are known, they are typically accounted for with it ad hoc scale factors applied to the acceptance or efficiency. For SecVtx, we assume the existence of a single *b-tagging scale factor* (SF) which is sufficient to correct (on a per-jet basis) the tagging efficiency observed in Monte Carlo.[1] We are implicitly assuming that the simulation models the efficiency's dependence on various jet properties (E_T, η, φ) correctly, and additional systematic uncertainties are assigned accordingly. The suspected causes of such a discrepancy are a tracking inefficiency in data that is not reproduced in simulation and omissions to the simulation (such as multiple interactions).

This scale factor is measured in both the 8-GeV electron and 8-GeV muon samples. The first method uses non-isolated electrons with and without conversion partners as corresponding light and heavy flavor samples and measures the tag rate differences to determine the efficiency. [3]. The second determines the b content of the sample by performing p_T^{rel} fits (μ p_T relative to the jet axis) and extracts the absolute tag rate in those events. [2]. The results are combined to a single unified value to be applied in all tagging analyses. [6]. Averaging over all 700 pb^{-1}, the total scale factor is estimated to be 0.89 ± 0.07 for tight SecVtx and 0.91 ± 0.07 for loose SecVtx.

The systematic uncertainty is dominated by the observed E_T dependence of the scale factor. Since we measure the efficiency in a sample of relatively low jet energies, it is difficult to extrapolate with any precision to $t\bar{t}$ events, where b-jets can have energies as large as 100 GeV. The error of 6% is currently estimated by evaluating the efficiency in several bins of jet energy, then re-weighting according to the E_T distribution in b-jets from top Monte Carlo. The efficiency and scale factor dependence on the jet E_T for the electron method are shown in Figure 1.

The apparent size of the E_T dependence (and how poorly we can actually measure it) is the real motivation for the cross section-SF fit. Even if the scale factor determined here has a larger uncertainty than the measured value, we at least have some additional evidence to support or oppose the observed slope.

3 Cross Section

The most recent SecVtx cross sections in the lepton+jets channel were measured in the full samples of high-p_T leptons, comprised of 695 pb^{-1} of good Silicon data acquired up to September 2005. The event selection requires a 20-GeV lepton, three or more 15-GeV (corrected) jets, and 20 GeV of missing E_T. An additional optimization cut requires the scalar sum of transverse energies in these objects (H_T) to be greater than 200

[1] The scale factor for charm and bottom are assumed to be identical, although the systematic is historically doubled for charm to account for the lack of a concrete measurement.

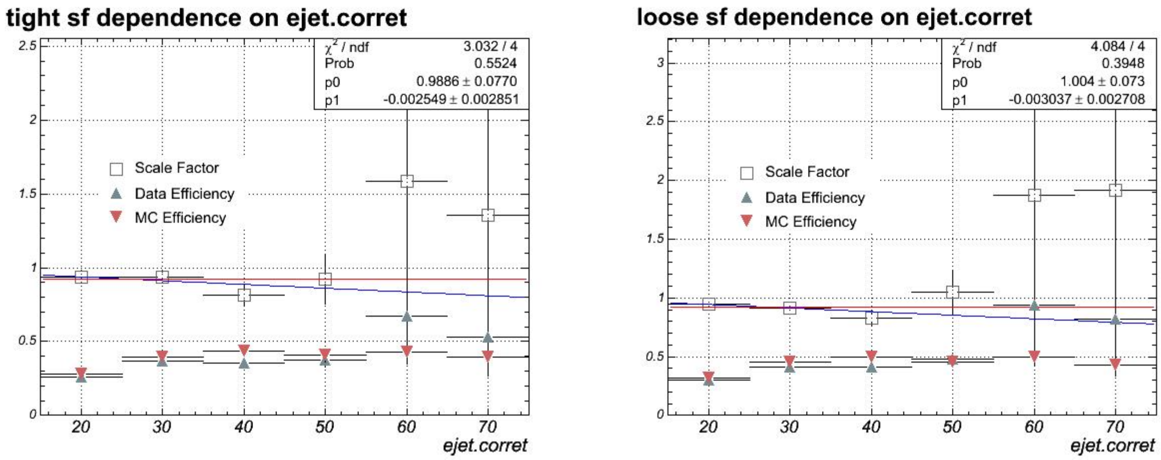


Figure 1: Dependence of the tight (left) and loose (right) scale factors and efficiencies on the electron jet corrected E_T. Errors are statistical (data and MC) only, and linear and constant fits are shown.

GeV in the signal region (see Section 1.1). **We will treat the *optimized loose* analysis as the main result in this note.** Equivalent results for the tight tagger and unoptimized selection will be presented in Section 6.

Schematically, the cross section measurement (detailed in CDF8120) proceeds as follows: assuming an initial cross section of 6.7 pb, we evaluate the expected number of events before and after tagging from various background processes (dibosons, single top, generic W production with light and heavy-quark jets, and non-W) and $t\bar{t}$ signal. If the number of tagged events in data differs from the expectation, we scale the assumed cross section to cover the discrepancy. Since nearly all backgrounds depend on the assumed $t\bar{t}$ contribution to the sample, the entire procedure is repeated until the cross section is stable to 0.01 pb. While it may be possible to write out the explicit dependence of the backgrounds on the cross section and solve exactly, the iterative approach can be done to arbitrary precision. [2]

The scale factor enters the equation in both the signal efficiency term and in the W+heavy flavor and diboson/single top backgrounds. In these cases, the tag expectation is derived from simulation, so the per-jet efficiency must be scaled down for heavy flavor tags. Since the measured scale factor is less than unity, the approach in CDF8120 is to randomly ignore (1-SF) of b and c-jet tags. This should account for the tagging correlations between the jets at leading order, and therefore gives the right distribution of single and multiple-tag events. Using this technique in the $\geq$1 tag sample, a final cross section of 8.8 ± 0.6 (stat) ± 1.1 (syst) pb is measured. For events with two or more tags, the cross section is measured to be 9.2 ± 0.9 (stat) ± 1.7 (syst) pb. The discrepancy is not significant, but a larger SF would improve the agreement.

Summaries of the backgrounds in these samples for a scale factor of 0.91 are shown in Tables 1 and 2, as well as in Figure 2. The cross section has been scaled to its measured value, and the systematic from the scale factor has not been included.

3.1 Efficiency Calculation

The efficiency calculation implemented for the cross section measurement is perfectly adequate for describing the expected efficiency in data for a given scale factor, but it suffers from some unfortunate deficiencies in this analysis. First, it is not well-defined for a scale factor greater than 1, which we should be including in our measurement. (*Increasing* the b-tag efficiency by a constant rate requires knowledge of the initial tag rate.)

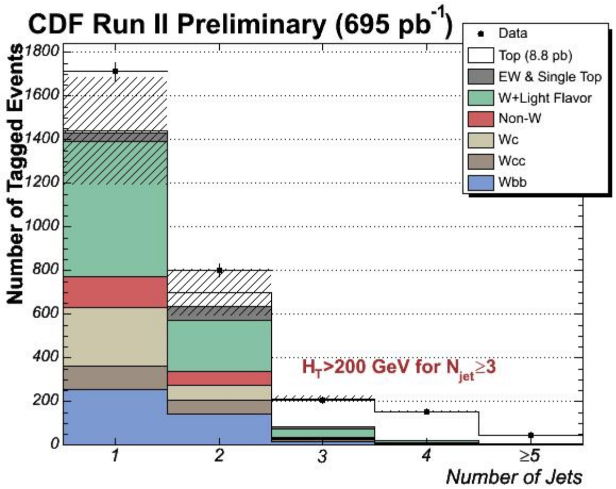
[2] In fact, most backgrounds are trivial to write out as a function of $\sigma_{t\bar{t}}$. The non-W background, however, as a weighted average of two quotients, would still prohibit a simple and exact solution.

Process	1 jet	2 jets	3 jets	4 jets	≥5 jets
Pretag	68174	10645	845	318	83
Pretag Top (8.8 pb)	21.45 ± 0.32	110.79 ± 1.66	190.45 ± 2.86	181.13 ± 2.72	56.58 ± 0.85
WW	7.98 ± 0.20	17.48 ± 0.44	3.18 ± 0.08	1.01 ± 0.03	0.29 ± 0.01
WZ	3.66 ± 0.08	6.78 ± 0.14	0.93 ± 0.02	0.25 ± 0.01	0.08 ± 0.00
ZZ	0.13 ± 0.01	0.32 ± 0.02	0.07 ± 0.00	0.02 ± 0.00	0.01 ± 0.00
Single Top (s-ch)	4.56 ± 0.78	13.07 ± 2.24	1.78 ± 0.30	0.36 ± 0.06	0.05 ± 0.01
Single Top (t-ch)	13.55 ± 1.66	15.96 ± 1.95	2.29 ± 0.28	0.48 ± 0.06	0.06 ± 0.01
$Z \to \tau\tau$	9.54 ± 0.30	7.05 ± 0.22	0.86 ± 0.03	0.12 ± 0.00	0.00 ± 0.00
$Wb\bar{b}$	255.66 ± 92.18	140.93 ± 49.15	15.54 ± 5.05	3.05 ± 1.03	0.54 ± 0.18
$Wc\bar{c}$	107.60 ± 34.45	63.72 ± 21.15	8.50 ± 2.85	1.90 ± 0.65	0.34 ± 0.12
Wc	266.87 ± 77.26	70.16 ± 20.69	6.34 ± 1.87	1.33 ± 0.39	0.24 ± 0.07
W+Light Flavor	621.08 ± 136.64	236.55 ± 52.04	35.41 ± 7.79	7.38 ± 1.62	1.58 ± 0.35
Non-W	139.93 ± 27.24	61.26 ± 12.13	7.54 ± 1.57	5.38 ± 1.28	1.41 ± 0.33
Background	1430.56 ± 247.15	633.29 ± 105.84	82.44 ± 12.75	21.28 ± 3.05	4.60 ± 0.64
Top (8.8 pb)	8.86 ± 0.13	65.19 ± 0.98	128.16 ± 1.92	130.37 ± 1.96	41.17 ± 0.62
Tags	1713	803	206	155	47

Table 1: Expected signal and background composition of the inclusive-tagged sample with the H_T cut. The $t\bar{t}$ expectation is scaled to the measured cross section.

Process	2 jets	3 jets	4 jets	≥5 jets
Pretag	10645	845	318	83
Pretag Top (9.2 pb)	116.87 ± 1.75	200.90 ± 3.01	191.07 ± 2.87	59.69 ± 0.90
WW	0.32 ± 0.01	0.11 ± 0.00	0.07 ± 0.00	0.05 ± 0.00
WZ	1.26 ± 0.03	0.16 ± 0.00	0.04 ± 0.00	0.02 ± 0.00
ZZ	0.05 ± 0.00	0.02 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Single Top (s-ch)	4.05 ± 0.69	0.63 ± 0.11	0.14 ± 0.02	0.02 ± 0.00
Single Top (t-ch)	0.86 ± 0.10	0.54 ± 0.07	0.14 ± 0.02	0.02 ± 0.00
$Z \to \tau\tau$	0.24 ± 0.01	0.12 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$Wb\bar{b}$	26.05 ± 9.08	3.44 ± 1.13	0.71 ± 0.24	0.12 ± 0.04
$Wc\bar{c}$	2.38 ± 0.80	0.65 ± 0.22	0.23 ± 0.08	0.04 ± 0.01
Wc	1.43 ± 0.42	0.41 ± 0.12	0.10 ± 0.03	0.02 ± 0.00
W+Light Flavor	2.47 ± 0.54	1.07 ± 0.24	0.26 ± 0.06	0.06 ± 0.01
Non-W	1.26 ± 0.82	0.25 ± 0.19	0.57 ± 0.46	0.15 ± 0.12
Background	40.36 ± 9.46	7.38 ± 1.27	2.26 ± 0.59	0.49 ± 0.14
Top (9.2 pb)	15.16 ± 0.23	40.73 ± 0.61	50.82 ± 0.76	17.30 ± 0.26
Tags	58	47	55	17

Table 2: Expected signal and background composition of the double-tagged sample with the H_T cut. The $t\bar{t}$ expectation is scaled to the measured cross section.



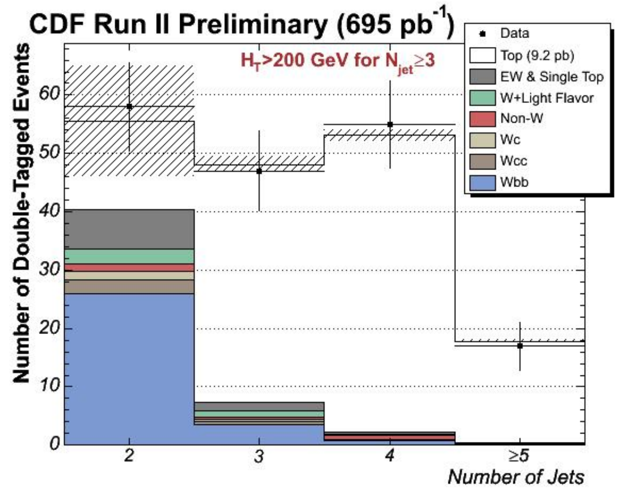


Figure 2: Stacked plot showing the breakdown signal and background events in each jet bin for the optimized measurements. The left plot is for the inclusive-tag case, and the right is for ≥2 tags. In both cases, the $t\bar{t}$ contribution is scaled to its measured value.

Secondly, one can not explicitly evaluate the dependence on the scale factor without sampling several points and fitting, which is slow and computationally expensive. We suggest here a straightforward (but cumbersome) adjustment to the method that yields a simple polynomial expression for the efficiency as a function of the scale factor.

Rather than ignoring heavy flavor tags with some probability based on SF, we simply weight the event in bins of the number of expected data tags; the weights correspond to the probabilities of removing different numbers of tags by the previous method. For instance, a singly b-tagged event in Monte Carlo gets a weight of SF in the one-tag bin, and a weight of $(1 - SF)$ in the 0-tag bin. Since these are probabilties, the weights necessarily sum to unity. Additionally, each weight is a polynomial in SF, with the order of the polynomial equal to the number of Monte Carlo tags. Getting the total efficiency expectation only requires adding the coefficients in the polynomial. A summary of the weights is shown in Table 3. We consider events up to 4 tags, which is roughly the maximum number of tags observed in Monte Carlo. Even though the individual weights in some events may become negative for a SF greater than one, the sum over all events is still be well-defined. (There is a problem when the corrected efficiency is greater than one, which happens for b-jets with the loose tagger when the scale factor approaches 2. Having a b-tag efficiency that high is, sadly, not going to be a problem.)

Data/MC	0-tag	1-tag	2-tag	3-tag	4-tag
0-tag	1	$1 - SF$	$(1 - SF)^2$	$(1 - SF)^3$	$(1 - SF)^4$
1-tag	0	SF	$2SF(1 - SF)$	$3SF(1 - SF)^2$	$4SF(1 - SF)^3$
2-tag	0	0	SF^2	$3SF^2(1 - SF)$	$6SF^2(1 - SF)^2$
3-tag	0	0	0	SF^3	$4SF^3(1 - SF)$
4-tag	0	0	0	0	SF^4

Table 3: The tagging weights corresponding to the number of observed heavy flavor tags in Monte Carlo (horizontal) for each possible number of tags in data (vertical). Taking the sum of the coefficients of each power of SF ultimately yields a fourth-order polynomial expression for the expected data efficiency as a function of the scale factor.

This prescription is only valid for heavy-flavor tags. The light-flavor tagging probabilities are computed in analogy to CDF8120. There, the mistag matrix prediction for each light jet in Monte Carlo (scaled by the ΣE_T-dependent α and β corrections [4]) is used to compute the total probability for having 0, 1 and 2 light-flavor tags. The proper heavy-flavor weight is then promoted with these additional corrections. In this way, for instance, the single-tag probability per-event in data includes the possibility of having one heavy-flavor tag and zero light-flavor tags **plus** the possibility of the only tag being a light-flavor.

Some examples of the resulting efficiency curves follow. Figure 3 shows the expected tag rate for 4-jet $Wc\bar{c}$ events where one (left) or two (right) charm jets are found. When there is only one heavy flavor jet, the single-tag efficiency is a linear function of the scale factor, where the intercept is the light-flavor tag rate. The double-tag rate also increases with SF, but stays small due to necessity for at least one light-flavor tag. When both charm jets are found, the double-tag rate increases as SF^2. The downward concavity of the single-tag rate is due to the promotion of single-tags to double-tags. The equivalent plots for $Wb\bar{b}$ are shown in Figure 4. Both cases exhibit qualitatively similar behavior, although the correlations between the single- and double-tag efficiencies are more obvious. Above a scale factor of roughly one, two-b events are *more likely to be double-tagged than single-tagged*, so the efficiency turns over.

The same phenomenon happens in $t\bar{t}$ signal, shown in Figure 5. With two b's (and frequently an extra charm jet), the double-tag rate dominates the single-tag rate above a scale factor of about 1.2. (Amusingly, if our objective was only to minimize the scale factor systematic in the cross section, we would throw out events with more than one tag. Of course, the signal-to-background in the single-tag sample is not so good.) At SF=0.91, we recover the inclusive-tag efficiency of 70% and double-tag rate of 24% derived in CDF8120.

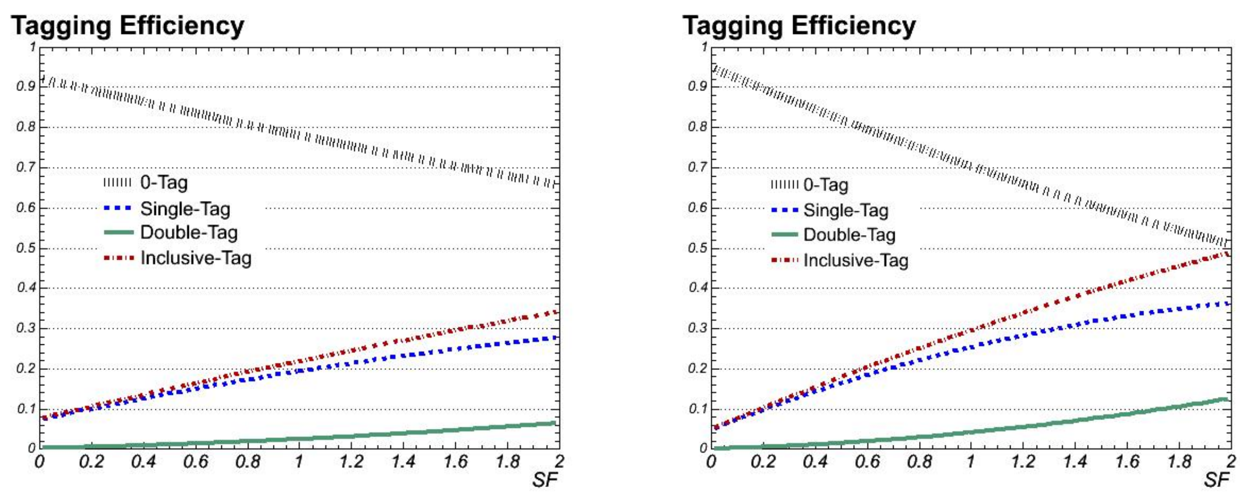


Figure 3: Expected SF-dependence of the tag rate for 4-jet $Wc\bar{c}$ events where one (left) or two (right) charm jets are found. All curves are parametrized as fourth-order polynomials.

Taking the functional forms of the efficiency for $t\bar{t}$, W+Heavy Flavor, and the diboson/single top backgrounds, it is trivial to compute the cross section for any value of SF. The iterative step (necessary for the non-W background) prevents an explicit function for σ, but the precision can be made arbitrarily small. Figure 6 shows the shape of the loose optimized single-tag and double-tag cross sections as the scale factor varies, including statistical errors and the independent SF measurement in the low-p_T samples. The resulting SF is 4% higher than the central value, but perfectly consistent within those uncertainties. As expected, with an increasing SF, the cross section is somewhat below the previously measured values, although well-covered by the original scale factor systematic.

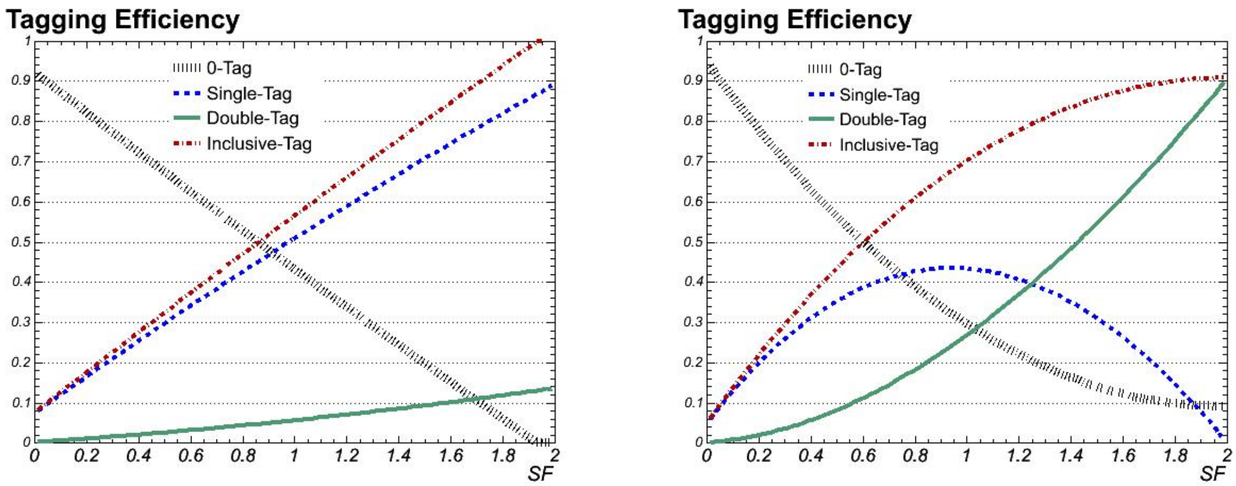


Figure 4: Expected SF-dependence of the tag rate for 4-jet $Wb\bar{b}$ events where one (left) or two (right) bottom jets are found. All curves are parametrized as fourth-order polynomials.

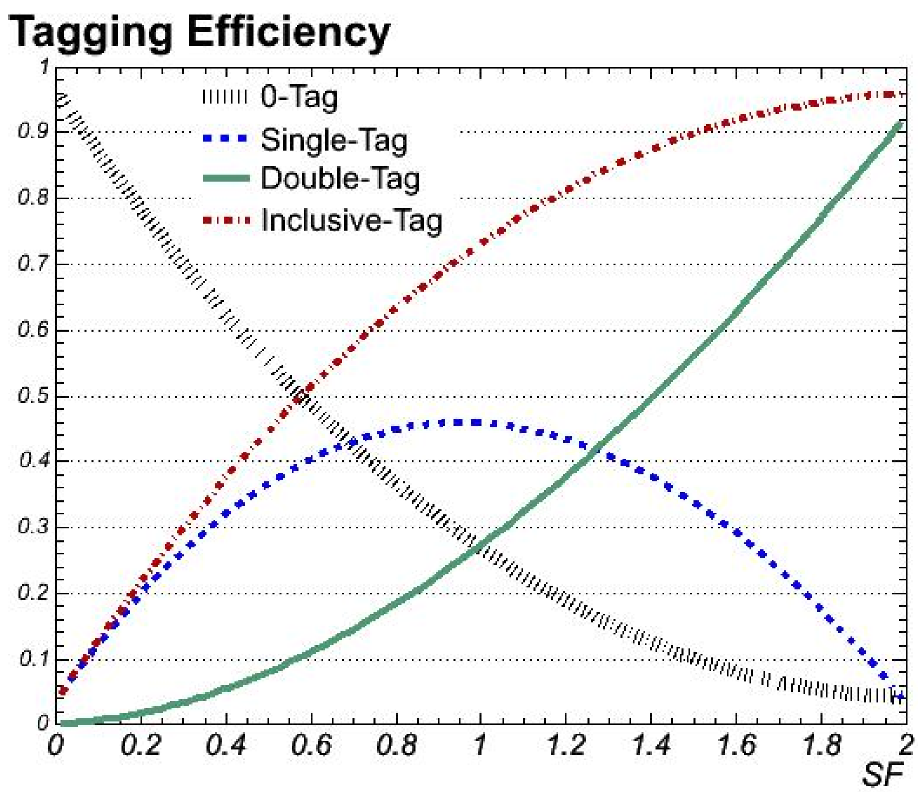


Figure 5: Expected SF-dependence of the tag rate for 4-jet $t\bar{t}$ events. All curves are parametrized as fourth-order polynomials.

4 Likelihood

As mentioned above, the efficiency calculation allows us trivially to get two statistically distinct samples, single-tags (with exactly one tagged jet) and double-tags (with two or more tags). Since the dependence on the scale

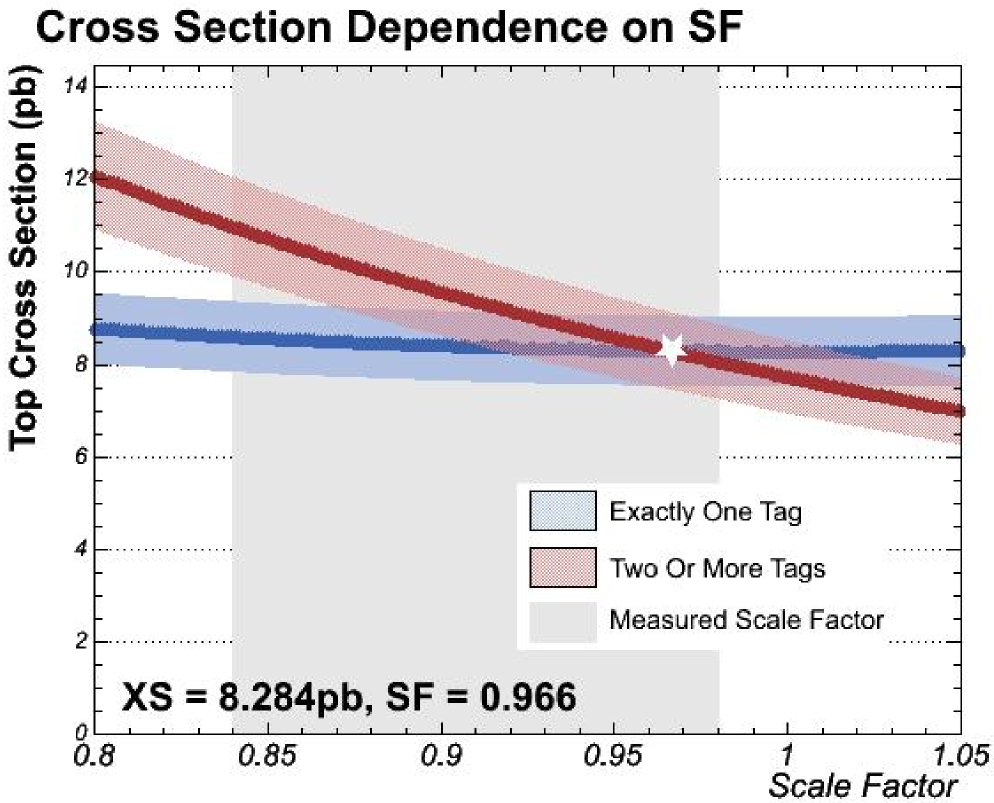


Figure 6: Expected SF-dependence of the loose, optimized single-tag and double-tag cross sections. The point where the two measurements agree is taken as the central value, in good agreement with the original SF measurement. The colored bands show the statistical error at each point.

factor is different in the two subsamples, constraining the two cross sections to be equal is effectively a constraint on SF. The remaining question is how to handle properly the uncertainties, systematic and statistical. Based on the cross section formula in Section 1, the only necessary inputs are the observed tags, the background, and the denominator. Since the central values are determined by matching the single-tag and double-tag cross sections, we can quote these values at that measured cross section, and only treat statistical fluctuations to fix the b-tag and statistical uncertainty. The likelihood function including statistical errors only is straightforward:

$$N_{exp} = \sigma_{t\bar{t}} \left(\Phi_e \epsilon_{tag}\right) \epsilon_{pretag} \int \mathcal{L} dt + N_{bkg} \quad (1)$$

$$-2ln(L) = -2N_{obs} ln(N_{exp}) + 2ln(N_{obs}!) + 2N_{exp} \quad (2)$$

The total likelihood is the product of the single-tag and double-tag values (or the sum of the log-likelihoods).

An additional subtlety arises from the dependence of N_{bkg} on the cross section. As described in CDF8120, the background determination requires $\sigma)t\bar{t}$ as an input. Since we don't have an explicit expression for this dependence, we approximate the background as a linear function of the cross section. As seen in Figure 7, this is a good local approximation near the minimum. (Only the non-W background has a non-linear dependence.) We further assume the background *slope* vs. σ at the nominal scale factor is a constant. We determine that a 5% change in SF adjusts the slope by less than 2%. The treatment of the backgrounds may be improved in the future, but the approximation seems valid for our purposes. This correction increases the uncertainty, since the effects of varying the cross section on the background and signal estimates partially cancel.

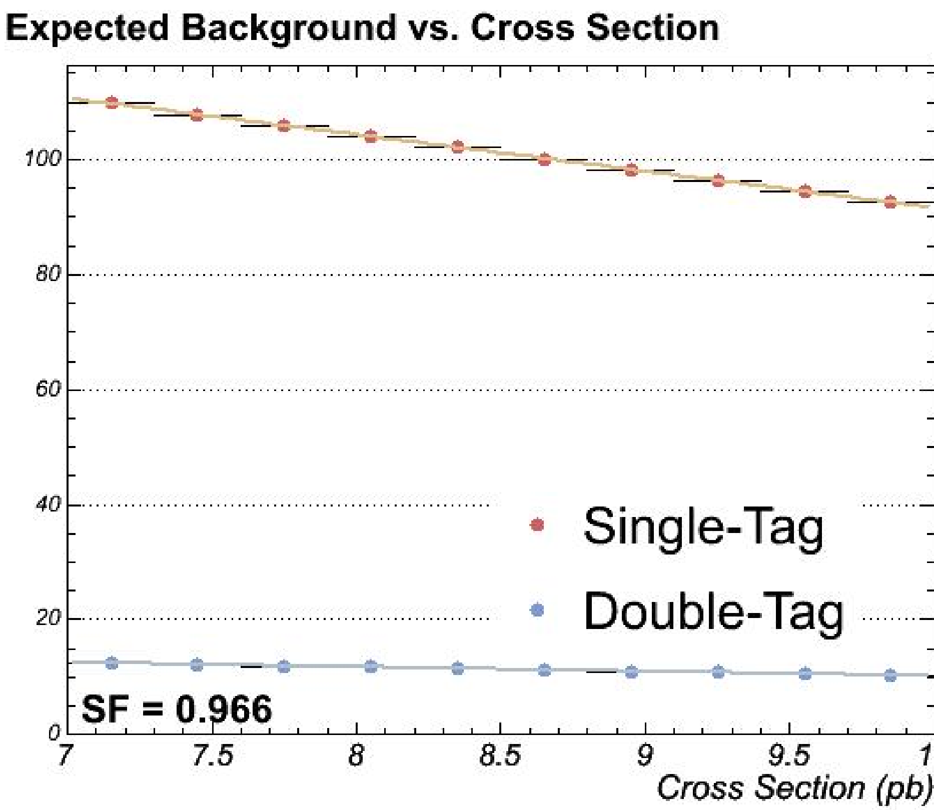


Figure 7: Background dependence on the assumed cross section for the loose, optimized analysis. The slopes of the linear fits at the "best" scale factor are assumed to be constant for all nearby scale factors.

Finally, a simple modification explored here is to allow the SF to float, but to penalize the likelihood for deviations from the independent measurement in the low-p_T lepton samples (see Section 2). Since the measurements are 100% uncorrelated, this only requires one additional likelihood term:

$$-2ln(L) = -2N_{obs}ln(N_{exp}) + 2ln(N_{obs}!) + 2N_{exp} + \left(\frac{SF - SF_{measured}}{\delta_{SF}}\right)^2 \quad (3)$$

$SF_{measured}$ and δ_{SF} are the previously-measured scale factor and its uncertainty, respectively. When this term is included in the likelihood, we will refer to the result as the "constrained SF" measurement.

5 Results

The likelihood function including statistical errors only is shown in Figure 8. The resulting measurements are $\sigma_{t\bar{t}} = 8.28^{+1.18}_{-1.05}$ pb and $SF = 0.966^{+0.084}_{-0.083}$, where the error on the cross section combines the statistical and scale factor errors. The inclusion of systematic uncertainties will also affect the likelihood, mostly in the cross section (the pretag systematics, such as luminosity and jet energy scale, should not have an impact on the scale factor, since they affect the single-tag and double-tag cross sections in the same way). The background systematics, however, affect the single-tag and double-tag cross section differently, so do alter the scale factor uncertainty. Since the double-tag background uncertainty is dominated by the heavy flavor fractions, we make the approximation that the W+heavy flavor single-tag and double-tag backgrounds are 100%

correlated, and the remaining backgrounds are also 100% correlated. (The "other background" uncertainties are a combination of theoretical cross section, mistag matrix predictions, and non-W method systematics, common to both measurements, but in different proportions.) This will be a slight overestimate of the error, but a reasonable first-order attempt. We ultimately derive a cross section of 8.3 ± 1.1 (stat) ± 1.1 (syst) pb and a scale factor of 0.966 ± 0.084 (stat) ± 0.042 (syst).

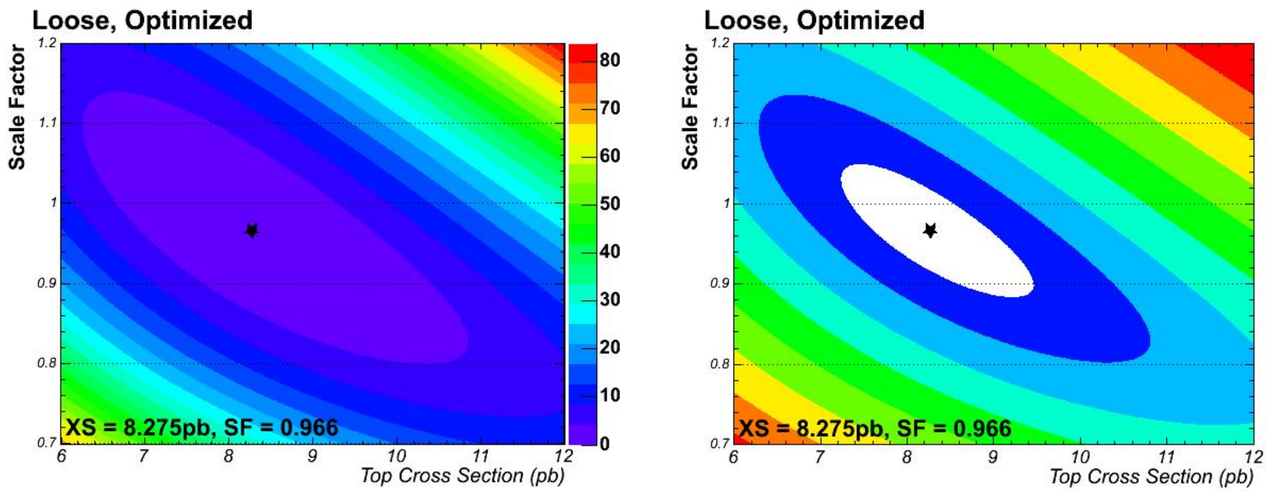


Figure 8: The likelihood function (left) and confidence bands (right) for the loose, optimized analysis. The central values are consistent with the results from the standard measurement.

Since the single- and double-tag samples have very different signal purities, the floating scale factor inflates the background systematic on the cross section. If we further constrain SF to be in agreement with the measured value, we can mitigate this effect. The measured value of the cross section with this additional requirement is 8.6 ± 0.9 pb, and the scale factor is 0.933 ± 0.053. With systematic uncertainties, the final result is 8.6 ± 0.9 (stat+SF) ± 1.0 (syst) pb, with a corresponding scale factor of 0.933 ± 0.053 (stat) ± 0.016 (syst). The relative cross section uncertainty is equivalent to the result in CDF8120, but the scale factor uncertainty is redcued by nearly 20%. Plots of the total likelihood and significance bands (statistical only) are shown in Figure 9.

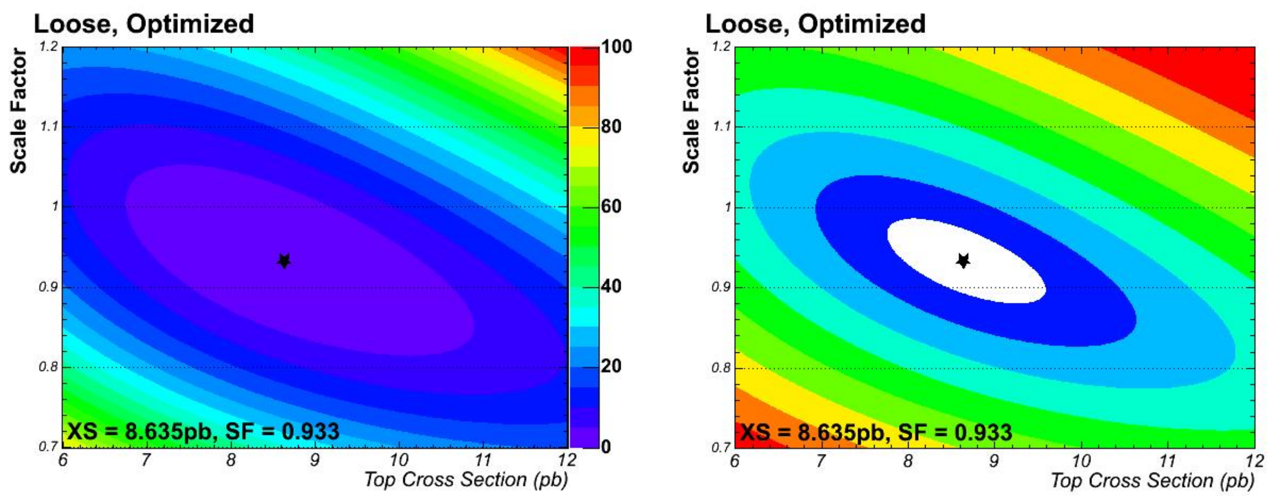


Figure 9: The likelihood function (left) and confidence bands (right) for the loose, optimized analysis, including an additional constraint that the scale factor determined in this sample be consistent with the measured value of 0.91 ± 0.07. The central values here are (by construction) consistent with the results from the standard measurement, but the uncertainty is reduced.

6 Alternate Selections

The loose SecVtx analysis with the H_T cut is expected to have the best constraint on the scale factor, since the statistical power of the double-tags limits the precision. However, there is a tradeoff with background systematics, so we present here cross checks for the other three selections: loose unoptimized and both tight tagger analyses. The cross section dependencies on the scale factor are displayed with statistical errors in Figures 10 to 12. Note that the cross section measurements were carried out using the method of the loose SecVtx measurement, so differ slightly from the results of CDF8037.

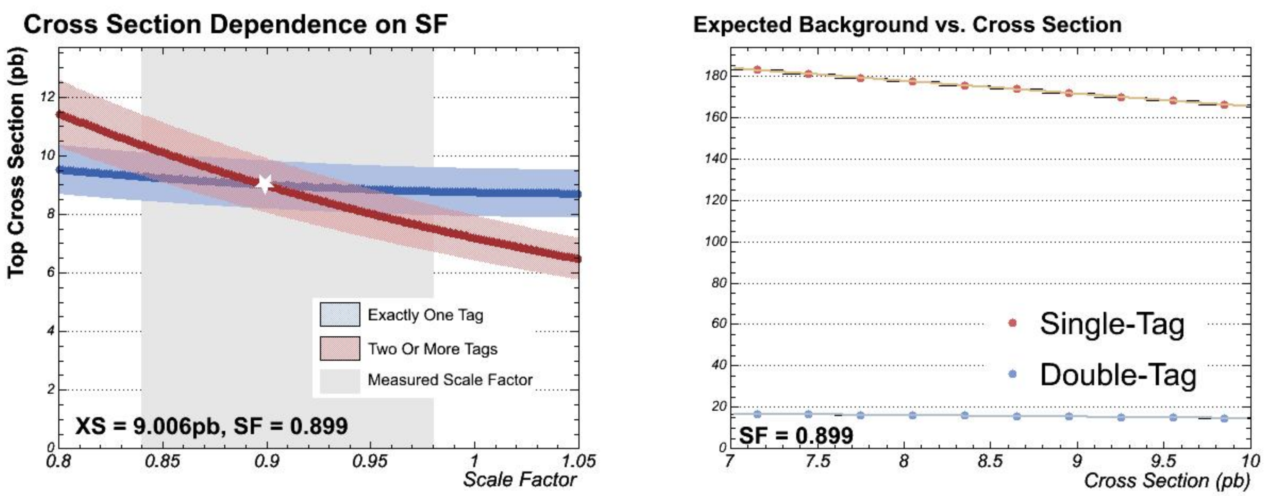


Figure 10: (left) Expected SF-dependence of the loose, unoptimized single-tag and double-tag cross sections. The point where the two cross section measurements agree is taken as the central value, consistent with the original SF measurement. The colored bands show the statistical error at each point. (right) Dependence of the background on the cross section near the “best” scale factor.

Near each of these intersections, we can repeat the procedure above for extracting a cross section and scale factor. The significance bands with and without the additional SF constraint are shown in Figures 13 to 15. Final results for all four selections are shown in Table 4; all results appear to be consistent, although the correlations are very large. (The optimized selection is a strict subset of the unoptimized selection, and tight tags are *nearly* a perfect subset of loose tags.)

Selection	Default (Inclusive)		Fit (Unconstrained)		Fit (Constrained)	
	SF	$\sigma_{t\bar{t}}$ (pb)	SF	$\sigma_{t\bar{t}}$ (pb)	SF	$\sigma_{t\bar{t}}$ (pb)
Loose Opt	0.91 ± 0.07	8.8 ± 1.3	0.97 ± 0.10	8.3 ± 1.6	0.93 ± 0.06	8.6 ± 1.3
Loose Unopt	0.91 ± 0.07	8.9 ± 1.4	0.90 ± 0.11	9.0 ± 2.2	0.91 ± 0.06	8.9 ± 1.6
Tight Opt	0.89 ± 0.07	8.3 ± 1.2	0.98 ± 0.10	7.6 ± 1.4	0.92 ± 0.06	8.1 ± 1.2
Tight Unopt	0.89 ± 0.07	8.5 ± 1.3	0.90 ± 0.11	8.5 ± 1.8	0.89 ± 0.06	8.5 ± 1.5

Table 4: Summary of results using the measured cross section and the fit (with and without the SF constrained), with all systematics and background errors merged.

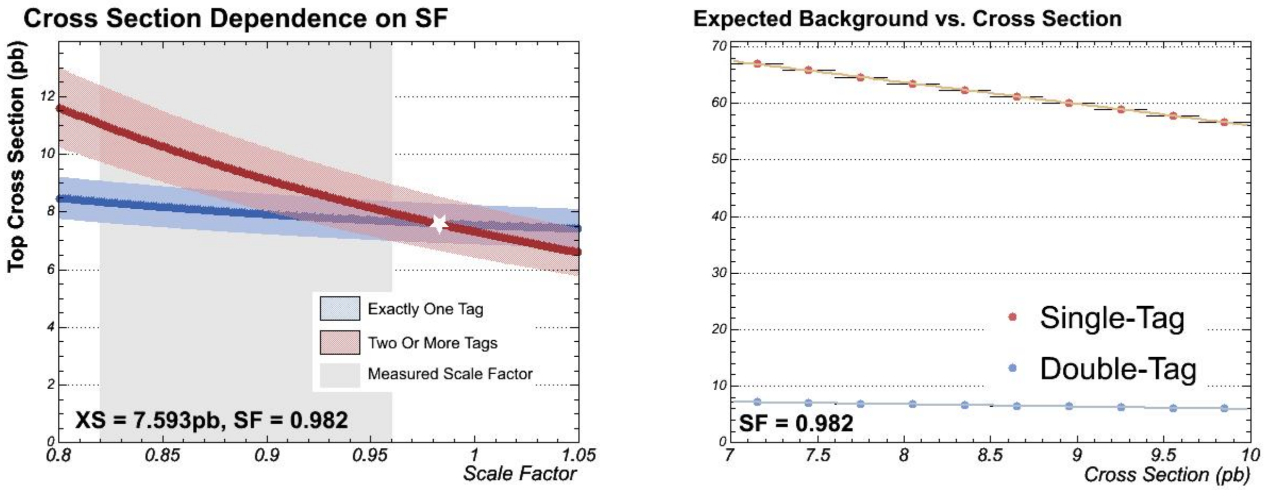


Figure 11: (left) Expected SF-dependence of the tight, optimized single-tag and double-tag cross sections. The point where the two cross section measurements agree is taken as the central value, consistent with the original SF measurement. The colored bands show the statistical error at each point. (right) Dependence of the background on the cross section near the "best" scale factor.

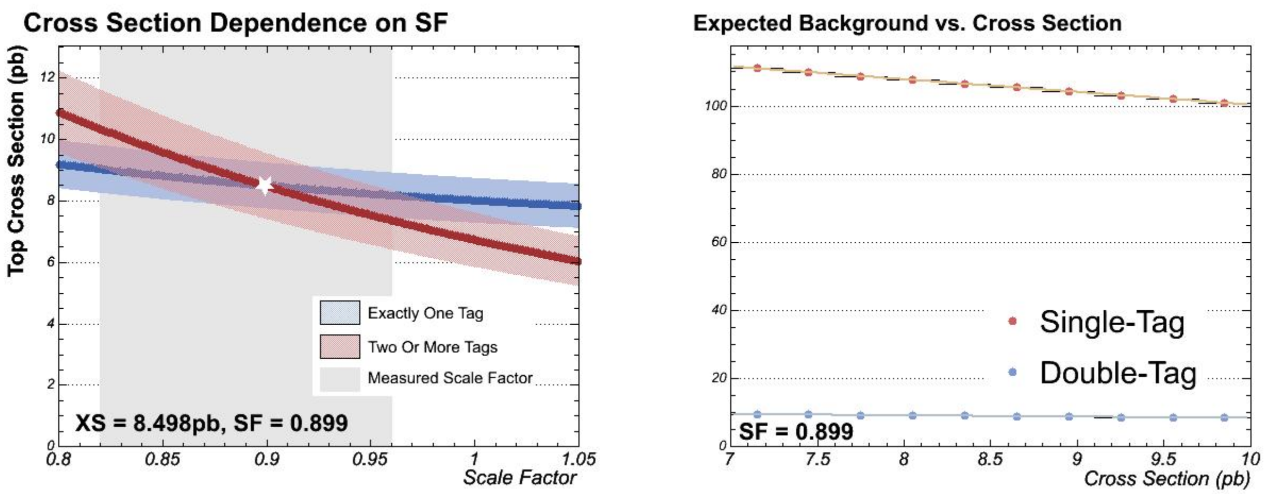


Figure 12: (left) Expected SF-dependence of the tight, unoptimized single-tag and double-tag cross sections. The point where the two cross section measurements agree is taken as the central value, consistent with the original SF measurement. The colored bands show the statistical error at each point. (right) Dependence of the background on the cross section near the "best" scale factor.

7 Conclusions

We have demonstrated the feasibility of a simultaneous fit for the scale factor and $t\bar{t}$ cross section in the 700 pb^{-1} lepton+jets dataset. The impact of such an a measurement is limited by the double-tag statistics and the signal-to-background rate, and we see no improvement if the scale factor is allowed to float. If we further impose that the scale factor be consistent with existing measurement, the relative uncertainty due to SF is significantly decreased. The best resulting cross section and scale factor measurements for the loose tagger are

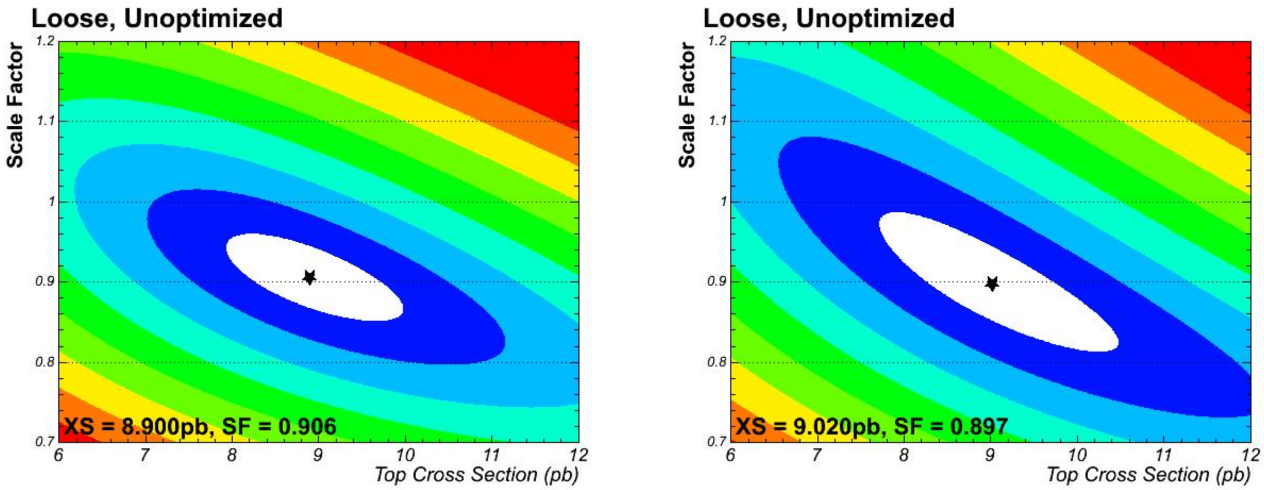


Figure 13: Significance bands for the loose, unoptimized analysis, with (left) and without (right) the SF constraint.

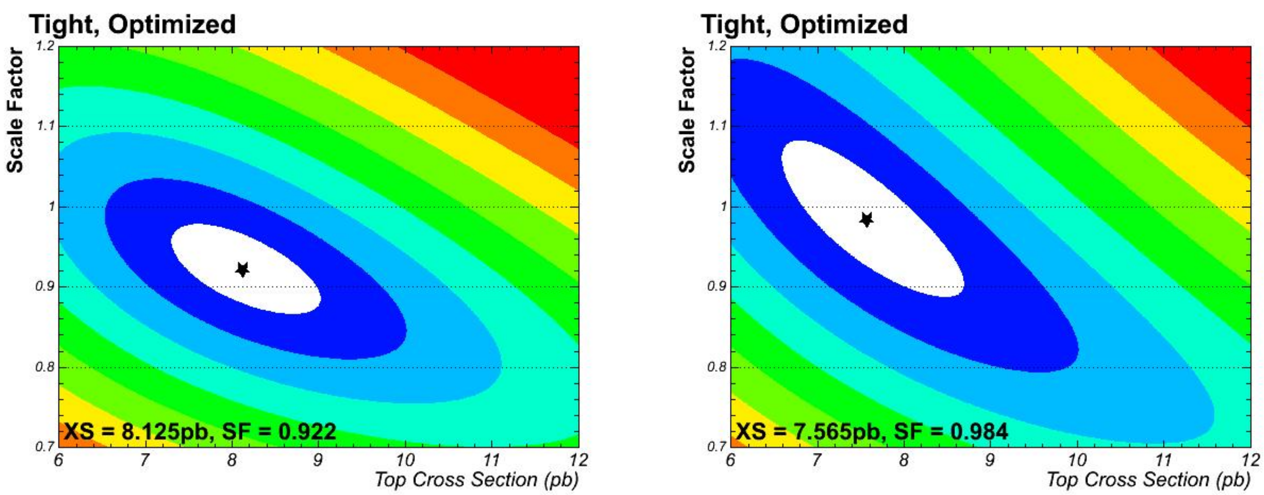


Figure 14: Significance bands for the tight, optimized analysis, with (left) and without (right) the SF constraint.

8.6 $\pm$ 0.9 (stat+SF) $\pm$ 0.9 (syst) pb and 0.93 $\pm$ 0.06, respectively. For tight SecVtx, we measure 8.1 $\pm$ 0.9 (stat+SF) $\pm$ 0.8 (syst) pb and 0.92 $\pm$ 0.06. By construction, these are the best combined measurements of the b-tagging scale factors, and are perfectly suitable for other high-p_T analyses.

If the statistical power is increased by an additional 50%, as roughly expected for the Summer 2006 analyses, we should achieve a total uncertainty on the top cross section on the order of 12-13% (assuming no progress in the background determination). The method itself has room for improvement, namely in extracting a precise expression for the background as a function of both the scale factor and cross section; here we assume that the slope of background vs. cross section is not a sharp function of the SF, which appears to be reasonable but imprecise. Further care in handling the correlations between single-tag and double-tag backgrounds may also reduce the systematic error. Obviously, any additional improvement in the determination of SF in the low-p_T samples also will improve the quality of the result.

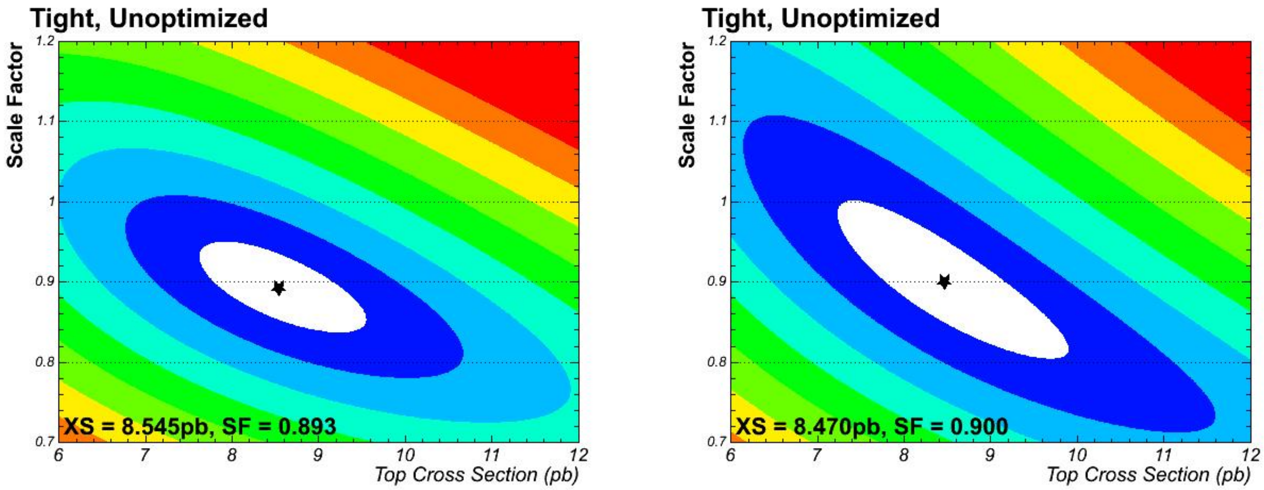


Figure 15: Significance bands for the tight, unoptimized analysis, with (left) and without (right) the SF constraint.

References

[1] Budd, S. *et al.*, 'Measurement of the t-tbar Production Cross Section in b-Tagged Lepton + Jets Events' [CDF/ANAL/TOP/CDFR/8037].

[2] Garberson, F. *et al.*, 'Determination of Gen 6 SecVtx Btag Efficiency Scale-Factor Using the Muon Relative Pt Method' [CDF//SEC_VTX//8014].

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[4] Guimarães da Costa, J., S. Rappoccio, and D. Sherman, 'Measurement of the SecVtx Mistag Asymmetry in 5.3.3' [CDF/ANAL/SEC_VTX/CDFR/7585].

[5] Guimarães da Costa, J. and D. Sherman, 'Measurement of the Top Pair Production Cross Section in 700/pb with Loose SecVtx' [CDF/ANAL/TOP/CDFR/8120].

[6] Neu *et al.*, 'Combination of the SECVTX b-Tagging Scale Factors for Winter 2006 Analyses' [CDF/DOC/SEC_VTX/CDFR/8025].