CDF/PHYS/PUB/CDF6352
Version 1.0
March 7, 2003

Revisiting the '2-Jet Excess' in W + b-tags: Are We Calculating $Wb\bar{b}$ and $Wc\bar{c}$ Production Correctly?

Henry Frisch
Enrico Fermi Institute, University of Chicago

DRAFT

Abstract

The W+2 Jet bin with at least one tagged jet was the source of much discussion in Run I. It is still possible that we are underestimating the amount of Wbbar and Wccbar background in the bin. We present generator-level numbers calculated using the MadGraph generator, which allows separate choice of the renormalization and factorization scales. In addition we have calculated the crossections when one b-quark or c-quark in gluon splitting can be missed entirely, and also when the two quarks are within $\Delta R = 0.4$ of each other. We find the cross sections are very sensitive to these several effects. For Run II we have better tools to estimate the background and its systematic uncertainties; this small study is a first step in my trying to better understand the subtleties and the separation of contributions from individual effects which were by-and-large too hard for me in Run I (e.g. the 'SuperJet' analysis). The samples exist in standard HEPG format. Lastly, some implications for the Run2 top crossection measurement are briefly discussed.

1 Introduction

Understanding the production of W's and Z's with heavy flavor is key to measuring the top cross section, single top production, looking for the Higgs, and also searching for new particles such as a heavy b' quark. In Run I the W+ 2jets bin persistently showed more detected events than the background estimates [1, 2, 3]; the 3 and 4 jet bins were the signal bins for the top quark. In addition, the W+2 jet bins had more soft lepton tags in SVX-tagged jets than expected. This issue took lots of time.

Figure 1 (left) shows the distribution in Njets in W+jets events with SVX tags from the 1996 analysis of Run I data [4]. Figure 1 (right) shows the same distribution from the final analysis and publication [5]. This 'excess' was expected to have at most a one-sigma effect on the top crossection at the Run I level of statistics measured in the 3 and 4 jet bins [6], but has led to much speculation about the 2 jet bin [7].

The preliminary Wnjet plot for Run II is shown in Figure 2. While not statistically very significant, the 2jet bin measurement is again prominently (as presented in the plot) above the prediction.

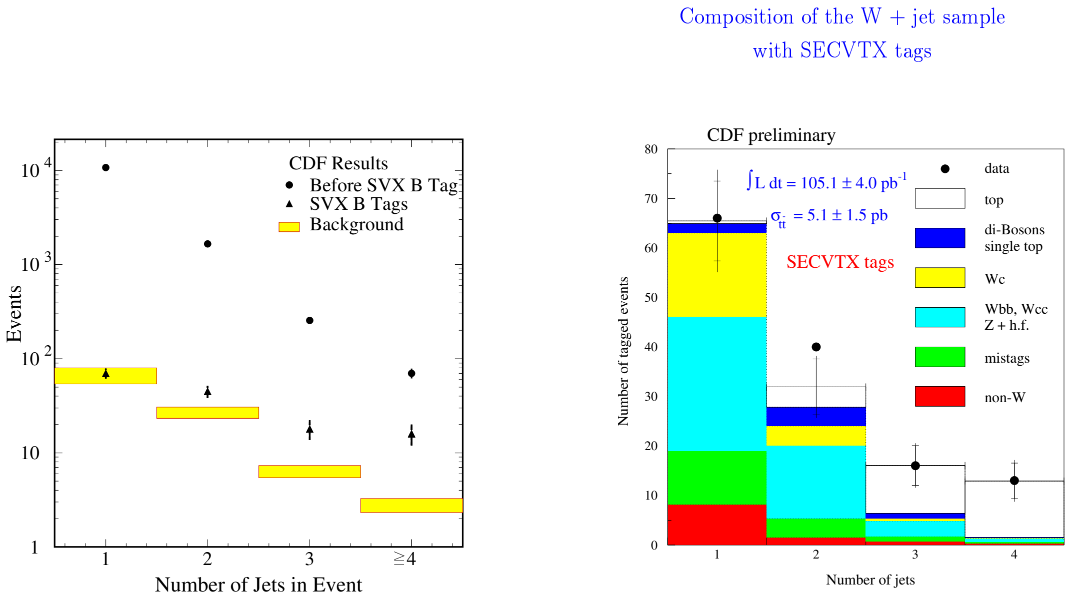


Figure 1: The numbers of events in W+N jets versus the number of jets, N, for the original Run I analysis (left) and the final Run I analysis (right). Note that the data in the 2jet bin tend to be above the predictions. The sample in the right-hand plot is where CDF found an 'excess' of soft-lepton tags over the SM estimate.

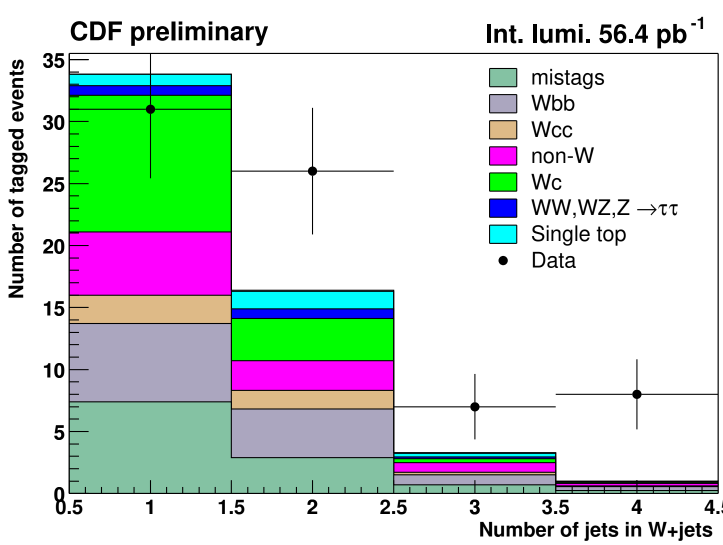


Figure 2: The numbers of events in W+N jets versus the number of jets, N, for the preliminary Run II analysis.

2 Two Effects: Q^2 Dependence; And the 'WB Effect'

We have used MadGraph [8, 9] to look at two effects that can change both the rate and the b-content (one b or 2 b's per jet) in $Wb\bar{b}$ production. The same studies have been also done for the $Wc\bar{c}$ case. We note that a higher rate of 2 b's (c's) per jet can change the prediction for SVX-SLT tagged jets. The two effects are discussed in turn below, although they are not completely independent.

2.1 The different Q^2 Dependence in the Numerator and in the Denominator in the Method 2 $Wb\bar{b}$ and $Wc\bar{c}$ Calculation

Method 2 is the CDF jargon for calculating the $Wb\bar{b}$ and $Wc\bar{c}$ background contributions in the top search by using the Monte Carlos to predict the ratio $(Wb\bar{b}/Wjj)_{MC}$, and then multiplying the measured number of Wjj events by this ratio. For example, in the $Wb\bar{b}$ case:

$$(Wb\bar{b})_{Method2} = (Wb\bar{b}/Wjj)_{MC} \times (Wjj)_{data} \tag{1}$$

It is generally assumed that the Q^2 dependences will cancel in the ratio. This is probably true for the factorization scale, but not obviously so (being polite) for the renormalization scale. The diagrams for producing a heavy-flavor quark pair in the kinematic region of interest (the 'numerator' in $Wb\bar{b}/Wjj)_{MC}$) are dominated by gluon splitting, while the production of two jets (the 'denominator') are dominated by independent gluon emission. The renormalization scales (and hence the value of α_s at the vertices) may be quite different.

2.2 When the 2nd B is lost, and the Crossection is Higher Due to More Phase Space and Because the Pair has lower Q^2 (the 'WB Effect'

Willenbrock and collaborators have pointed out that discrepancy in the estimates of Wbbbar production through flavor excitation and through gluon splitting can be resolved by lowering the Q^2 and also allowing one b to go 'elsewhere'- i.e. not satisfy the high Pt cuts [10]. This process can contribute directly to the 1-jet bin, and with an ISR/FSR jet can contribute a single tagged jet to the 2-jet bin. In either case the raw cross sections can be substantially enhanced (see the generator-level numbers below).

We've dubbed this the 'WB Effect' to give it a name (as there is a W and only one b-quark, among reasons).

3 Some Generator-Level Crossections With MadGraph

We used MadGraph to make Wbbbar events with a central electron ($|\eta| < 1$), $E_T > 1$ GeV (essentially the total W production crossection with a central lepton), neutrino anywhere with $E_T > 1$, and at least one bjet $|\eta| < 2$, $E_T > 10$ GeV. The other b jet is allowed either to be anywhere ($|\eta| < 10$, $E_T > 0$- called the 1b case) or is required to be the same as the

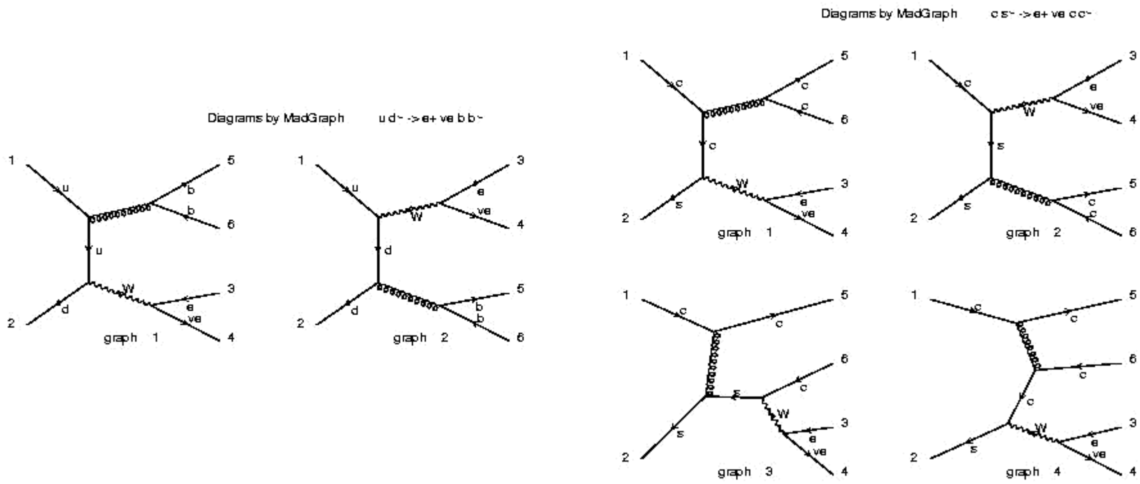


Figure 3: Left: the largest diagrams (of many) for $Wb\bar{b}$ production; Right: some of the many diagrams for $Wc\bar{c}$ production. Note that the $Wc\bar{c}$ has diagrams that include the charm content of the PDF, while in the scheme we are using the $Wb\bar{b}$ process has only gluon splitting. (See Ref [10] for a discussion of the impact of this.) Further on in the text we calculate these using a renormalization scale and (separately) a factorization scale calculated using the values of the momenta at the vertices event-by-event.

first bjet ($|\eta| < 2$, $E_T > 10$ GeV– the 2b case). The b quark mass is taken to be 4.75 GeV; the c quark is massless by default, but a cutoff of $s_min = (2 * m_c)^2$ where $m_c = 1.7$ GeV is used (in all cases except where specified).

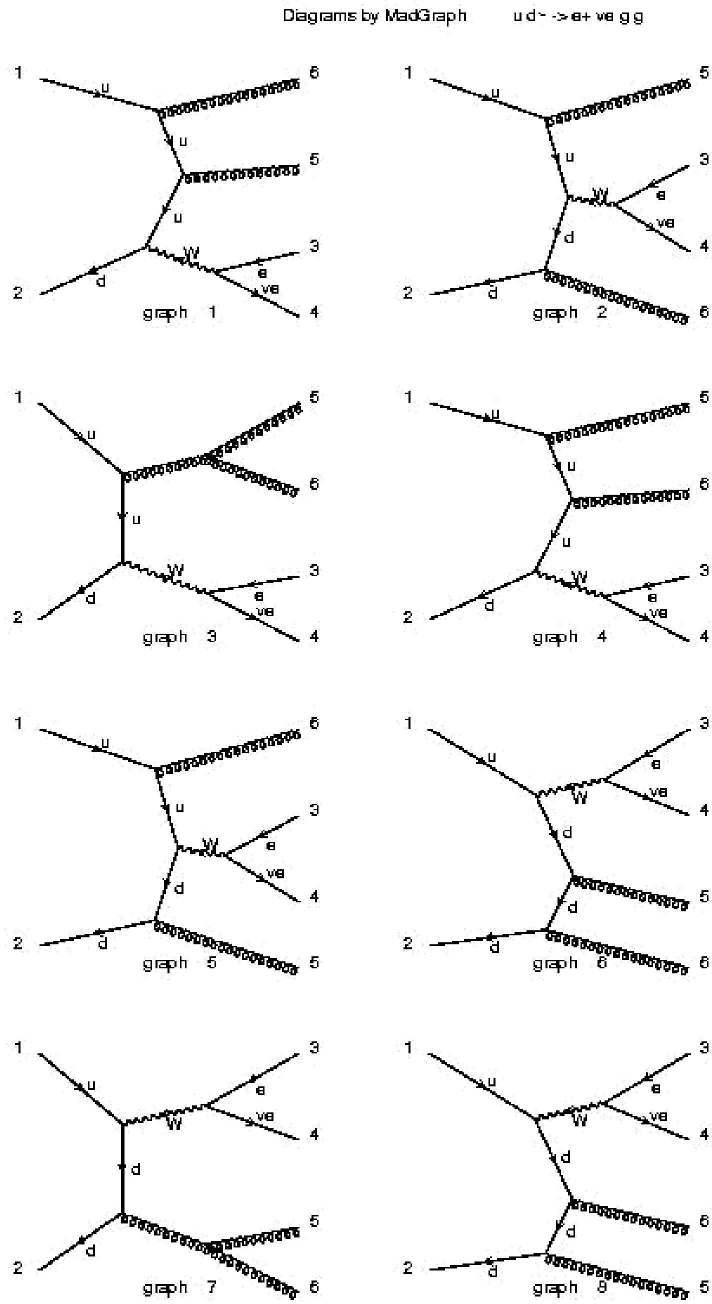
3.1 $Wb\bar{b}$: Factorization Scale= Renormalization Scale

DataSet	Q	E_T, η of 2nd b	Sigma (fb)	Factor
Wbbbar_QMW_2b	Mw	$E_T > 10., \lvert\eta\rvert < 2.0$	341 fb	1.0
Wbbbar_QMWo2_2b	Mw/2	$E_T > 10., \lvert\eta\rvert < 2.0$	440 fb	1.29
Wbbbar_Qpt34_2b	Ptw	$E_T > 10., \lvert\eta\rvert < 2.0$	486 fb	1.41
Wbbbar_QMW_1b	Mw	$E_T > 0.1, \lvert\eta\rvert < 10.$	541 fb	1.58
Wbbbar_QMWo2_1b	Mw/2	$E_T > 0.1, \lvert\eta\rvert < 10.$	707 fb	2.07
Wbbbar_Qpt34_1b	Ptw	$E_T > 0.1, \lvert\eta\rvert < 10.$	838 fb	2.46

Table 1: Cross section for Wbbbar for different values of Q2 (top three rows) and also letting the 2nd b go elsewhere (bottom three rows).

Note that there is a big increase- up to a factor of 2.65. Even if one pays a factor of 4-5 for a second uncorrelated (e.g. ISR) jet, this could have be a noticeable contribution.

Postscript Diagrams



1

Figure 4: Left: one page of the 69 pages (!) of diagrams for Wjj production. Note how different these are from those for $Wb\bar{b}$ and also for $Wc\bar{c}$, and so will have different Q^2 dependences, particularly for the renormalization scale.

3.2 $Wc\bar{c}$: Factorization Scale= Renormalization Scale

The numbers for the $Wc\bar{c}$ case are shown in Table 2. The Qsquared dependence is the same in $Wc\bar{c}$ as in $Wb\bar{b}$; the 'WB' effect is appreciably larger, up to a factor of 3.7 in cross section. Even after paying the price of about a factor of 5 for a 2nd light jet and including the factor of 2 in tagging rate for only one charmed jet, this could be a significant contribution to the charm rate.

DataSet	Q	E_T, η of 2nd b	Sigma (fb)	Factor
Wccbar_QMW_2c	Mw	$E_T > 10., \|\eta\| < 2.0$	458 fb	1.0
Wccbar_QMWo2_2c	Mw/2	$E_T > 10., \|\eta\| < 2.0$	601 fb	1.31
Wccbar_Qpt34_2c	Ptw	$E_T > 10., \|\eta\| < 2.0$	651 fb	1.42
Wccbar_QMW_1c	Mw	$E_T > 0.1, \|\eta\| < 10.$	1070 fb	2.33
Wccbar_QMWo2_1c	Mw/2	$E_T > 0.1, \|\eta\| < 10.$	1385 fb	2.47
Wccbar_Qpt34_1c	Ptw	$E_T > 0.1, \|\eta\| < 10.$	1698 fb	3.71

Table 2: Cross section for Wccbar for different values of Q2 and also letting the 2nd c go elsewhere.

3.3 W+2 Jets: Factorization Scale= Renormalization Scale

Table 3 shows the same numbers for W+2 jets. Again, there is a Delta-R cut of 0.4 between the 2 jets (which is necessary, as there is no quark mass to cut off the singularity). The numbers for the '1-legged' case (1jet with $E_T > 10., |\eta| < 2.0$) are included only for completeness (the Et threshold for the non-observed jet is only 0.1 GeV). However the fact that they behave so differently from the heavy quark numbers is in itself an indication of how careful we have to be with the generation.

DataSet	Q	E_T, η of 2nd b	Sigma (pb)	Factor
Wjj_QMW_2j	Mw	$E_T > 10., \|\eta\| < 2.0$	30.6 pb	1.0
Wjj_QMWo2_2j	Mw/2	$E_T > 10., \|\eta\| < 2.0$	41.3 pb	1.35
Wjj_Qpt34_2j	Ptw	$E_T > 10., \|\eta\| < 2.0$	49.4 pb	1.61
Wjj_QMW_1j	Mw	$E_T > 0.1, \|\eta\| < 10.$	477 pb	15.6
Wjj_QMWo2_1j	Mw/2	$E_T > 0.1, \|\eta\| < 10.$	631 pb	20.6
Wjj_Qpt34_1j	Ptw	$E_T > 0.1, \|\eta\| < 10.$	824 pb	26.9

Table 3: Cross section for Wjj for different values of Q2 and also letting the 2nd jet go elsewhere, with an Et cutoff of 0.1 GeV. These latter numbers are probably meaningless (which is the point, because they are meaningful for the $Wb\bar{b}$ case, and thus one should not treat the two processes identically in the Method 2 ratio.)

3.4 $W + 0$ jets: Changing The Factorization Scale Only

The cross section for W+ 0 jet production depends only on the factorization scale through the GLAP evolution of the structure functions, as α_s doesn't enter into the matrix element anywhere. However the cross section is a useful number for comparison between monte carlo generators and as an overall experimental normalization. We used MadGraph to calculate the $W^+ \to e^+\nu$ cross section for the cuts listed in Section 3 as a function of the factorization scale Q. The results are listed in Table 4. The decrease (mild) in crossection as Q^2 decreases is not unreasonable, as W production at the Tevatron is at an average Feynman x of 0.05, which is below the 'tipping point' about which the PDF's rock as Q^2 changes.

Process	Q_F	Q_R	Sigma (pb)	Factor
$W^+ \to e^+\nu$ + 0 jets	Mw	Mw	1011 pb	1.0
$W^+ \to e^+\nu$ + 0 jets	10	Mw	935 pb	0.93
$W^+ \to e^+\nu$ + 0 jets	40	Mw	998 pb	0.99
$W^+ \to e^+\nu$ + 0 jets	80	Mw	1011 pb	1.0
$W^+ \to e^+\nu$ + 0 jets	120	Mw	1015 pb	1.00
$W^+ \to e^+\nu$ + 0 jets	160	Mw	1016 pb	1.00

Table 4: Cross section for $W^+ \to e^+\nu$ production with 0 jets for different values of the factorization scale Q_F. The renormalization scale doesn't enter into this process. Note that for $Q \geq M_W$ there is basically no change in the cross-section from large variations in the factorization scale.

3.5 $Wb\bar{b}$: Changing the Renormalization Scale Only

MadGraph allows one to change the factorization and renormalization Q^2 scales independently. The coupling constants at either end of the gluon line in gluon creation and subsequent splitting into $b\bar{b}$ should depend on the p_T and invariant mass of the gluon. We have explored the change in cross section due to the change in the renormalization Q^2, holding the factorization scale constant at the W mass. The cross sections[1] for $Wb\bar{b}$ production with both b-jets satisfying the $E_T > 10$ and $|\eta| < 2.0$ requirements are shown in Table 5.

Process	Q_F	Q_R	Sigma (fb)	Factor
$Wb\bar{b}$	Mw	Mw	335 fb	1.0
$Wb\bar{b}$	Mw	10	744 fb	2.22
$Wb\bar{b}$	Mw	40	423 fb	1.26
$Wb\bar{b}$	Mw	80	335 fb	1.0
$Wb\bar{b}$	Mw	120	296 fb	0.88
$Wb\bar{b}$	Mw	160	272 fb	0.81

Table 5: Cross section for $Wb\bar{b}$ production with both b-jets satisfying the $E_T > 10$ and $|\eta| < 2.0$ requirements, as the renormalization scale Q_R is varied while the factorization scale, Q_F, is held constant.

[1]The crossection of 335 fb for $Q_F = Q_R = M_W$ is within the statistical uncertainty of the value of 341 fb for the same values in Table 1

The effect of changing the renormalization scale is large when the Q^2 is small, as one would expect. The cross section for gluon production and splitting into $b\bar{b}$ is expected [11] to be governed by the smaller of the two relevant Qsquareds. When the b and bbar have an invariant mass close to threshold ($2m_b$), the cross section will be appreciably larger than that calculated using $Q = M_W$. From inspection of events this doesn't happen all the time, but is not rare. Madgraph takes the b mass to be 4.75 GeV.

3.6 $Wc\bar{c}$: Changing the Renormalization Scale Only

We do the similar scan in the renormalization scale Q_R while holding the factorization scale fixed for the case of gluon splitting into the $c\bar{c}$ pairs. The effect can be bigger in the charm case, as the invariant mass of the pair can go down lower, to $2m_c$. The results show this, as can be seen in Table 6.

For the samples in Table 6 we have not explicitly put a cut on s_{min} of $(2*(1.7)\ \mathrm{GeV})^2$, and have let MadGraph cut of the singularity. We find a big change in the crossection due to the charm mass, as is expected.

Process	Q_F	Q_R	Sigma (fb)	Factor
$Wc\bar{c}$	Mw	Mw	645 fb	1.0
$Wc\bar{c}$	Mw	5	2045 fb	3.17
$Wc\bar{c}$	Mw	10	1432 fb	2.22
$Wc\bar{c}$	Mw	40	813 fb	1.26
$Wc\bar{c}$	Mw	80	645 fb	1.0
$Wc\bar{c}$	Mw	120	569 fb	0.88
$Wc\bar{c}$	Mw	160	523 fb	0.81

Table 6: Cross section for $Wc\bar{c}$ production with both c-jets satisfying the $\mathrm{E_T} > 10$ and $|\eta| < 2.0$ requirements, as the renormalization scale Q_R is varied while the factorization scale, Q_F, is held constant. The difference in crossection from Table 2 is due to a no specific minimum $s^{c\bar{c}}_{min}$ requirement in these samples.

4 Event-By-Event Dynamic Separate Factorization and Renormalization Scales

MadGraph also allows changing both the factorization and renormalization scales on an event-by-event basis, using whatever kinematic information from the event one wants. As I'm ignorant about what the best recipe really is, I've tried a 'best guess'. The recipe I've used is, in each event, to set $Q_F^2 = M_W^2 + (\mathrm{p_T^W})^2$ (an explicit option provided in MadGraph) and $Q_R = min(\mathrm{E_T^{b\bar{b}}}, M^{b\bar{b}})$[12].

For this case, we find

$$\sigma_{b\bar{b}}\ (\mathrm{Dynamic\ Q_R, Q_F}) = 542\ \mathrm{fb} \tag{2}$$

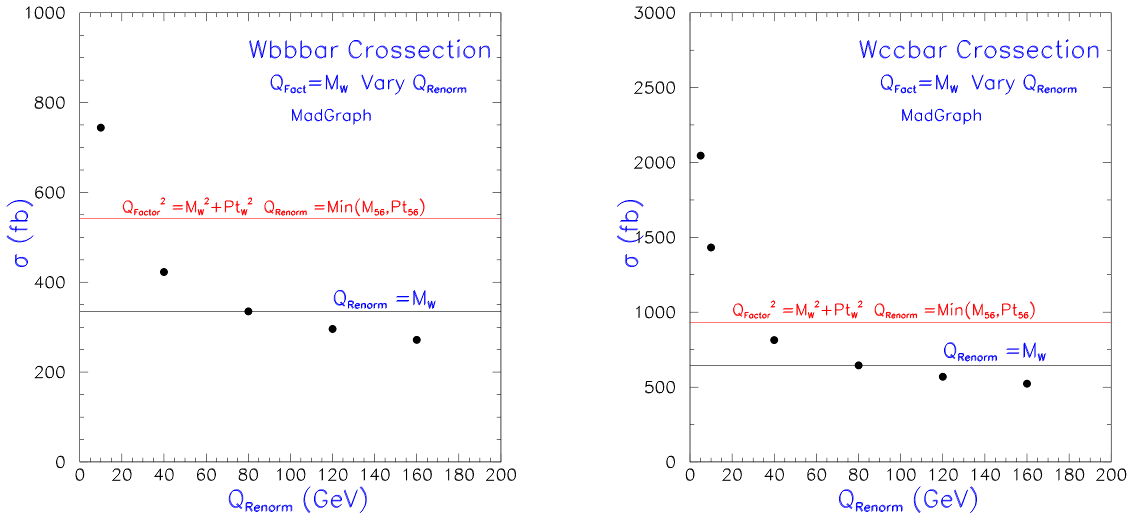


Figure 5: Left: the crossection in fb for $Wb\bar{b}$ production for fixed factorization scale $Q_F = M_W$ (black dots) versus the renormalization scale $Q_R = M_W$, and Right: the same thing for $Wc\bar{c}$ production. In each plot the black horizontal line is drawn at $Q_F = Q_R = M_W$. The 'best-guess' crossection, with $Q_F^2 = M_W^2 + \mathrm{p}_{\mathrm{T}}^2$ and $Q_R = min(\mathrm{E}_{\mathrm{T}}^{b\bar{b}}, M^{b\bar{b}})$, is shown as the red line. The enhancement factor is 1.59 for $Wb\bar{b}$ and 2.03 for $Wc\bar{c}$.

which is a factor of 1.59 higher than the crossection with $Q_R = Q_F = M_W$.

Invoking the same recipe for the charm case, we find

$$\sigma_{c\bar{c}}\ (\text{Dynamic } \mathrm{Q_R}, \mathrm{Q_F}) = 930 \text{ fb} \tag{3}$$

which is a factor of 2.03 higher than the crossection with $Q_R = Q_F = M_W$. These are shown as the red lines on Figure 5.

While this is only the numerators, and is only at generator level, the large changes from $Q_R = Q_F = M_W$ to using the event-by-event Q^2, and the difference in the diagram structures, raises the possibility that we have underestimated both the central values and the uncertainties.

5 What To Do Next

This study was largely to educate myself on the possible size of the effect of having different Q^2's in the numerator and denominator in the Method 2 estimate of $Wb\bar{b}$ and $Wc\bar{c}$, and also the increase in cross section for one b-jet if the other can go anywhere (including low pt and large rapidity). To do it correctly takes three steps:

1. To enlist our theoretical colleagues to help us integrate the cross-section predictions of NLO calculations [13] and the detailed event generation of LO calculations so that we can make correctly normalized predictions with approximately the right kinematic distributions to which we can apply analysis cuts; and

2. To simulate and produce the LO samples like those described here so that we can see what the true factors are after cuts.
3. To then tabulate the predicted rates of events with two b jets, with 1 b jet where the 2 b's are coalesced, and with 1b jet where one b is not in the kinematic/geometrical acceptance, etc.

6 Some Other Considerations

There are some other issues that are not dealt with here, but may become accessible with these datasets after simulation:

1. An increase in the number of b or c pairs in a single jet (e.g. through coalescing, with the increase due to the higher-Q^2 in the Method 2 numerator at masses near $b\bar{b}$ or $c\bar{c}$ threshold) gives rise to more soft leptons, and hence more jets with SVX-SVT tags ('SuperJets')
2. Any increase in the average charm or beauty content of jets leads to an increase in charged kaons in the jets. Via the 'Un-Ki effect' [14] these may produce more soft lepton muon tags than would be expected without the decay-in-flight momentum mis-measurement.
3. We may be able to predict and measure the track multiplicity and the two-displaced-vertex rate in jets to see if we get the coalesced rate correct.
4. The charm/bottom separation started on in Run I will play an important role in all this, and needs to be aggressively pursued.

7 Conclusions

1. The cancellation of the Q^2 scale-dependence in the Method 2 estimate of $Wb\bar{b}$ and $Wc\bar{c}$ contributions to the tagged W+2jet bin deserves careful scrutiny, as the diagrams that contribute to heavy flavor production and dijet production are quite different in structure.
2. In addition, there is a substantial part of the $Wb\bar{b}$ and $Wc\bar{c}$ crossection in which one of the two quarks does not pass the kinematic and geometrical cuts; this contribution needs to be clearly identified and estimated. It also may be enhanced by its dependence on Q^2.
3. Larger $Wb\bar{b}$ and $Wc\bar{c}$ crossections can result in more leptons, and also more kaons, which may give muon tags via mis-measurements associated with decay-in-flight. The contribution of coalesced heavy flavor pairs in a single jet needs to be clearly identified and estimated.
4. We have explored changing the renormalization and factorization scales independently, and also on an event-by-event basis, using MadGraph, which makes it easy to do so.
5. Using an event-by-event calculation for the factorization scale of $Q_F^2 = M_W^2 + \mathrm{p}_\mathrm{T}^2$, and $Q_R = min(\mathrm{E}_\mathrm{T}^{b\bar{b}}, M^{b\bar{b}})$ for the renormalization scale we find the crossections for $Wb\bar{b}$ and $Wc\bar{c}$ are larger by factors of 1.59 and 2.03, respectively.

6. The present systematic uncertainty on the W+2 jet bin needs to take account of these effects, as does the central value.
7. More theoretical work is probably required to have confidence in future CDF estimates, both for the value and its systematic uncertainty.

8 Implications for the Run 2 Cross Section Measurement

The problems of predicting the exclusive (Njet bin-by-bin in N) cross sections and the contributions from different processes are exceptionally complex. While in the long run we want to understand the details shown in Figure 2, the message I get from the sensitivity to Q^2 and the complexity of feedthrough from one bin to another in the Njet plot (e.g. the increase in crossection due to the 'WB' effect when only one b is in the acceptance) is that we will win by picking a strategy that minimizes these systematics at the expense of some statistics.

To be specific, we should explore a strategy that specifically discriminates against background processes for which the cross section has large systematics and is tricky to estimate. Specific ingredients that may help to minimize the effects studied above but still allow using the W+2jet bin as a control are:

1. Suppress the Wbbbar and Wcccbar contributions by requiring the heavy quark pair to have a large invariant mass. Requiring $M_{b\bar{b}} > 30GeV$ (say), for example, will cut the $Wb\bar{b}$ background greatly as one is cutting away from the 'pole' (regulated by the b-mass), while since the two b-quarks tend to be not close in top decay. This can be easily optimized at generator level.
2. Require 2 btags, so that one b in the acceptance and the other lost but replaced by a light quark/gluon jet is suppressed.
3. Tighten the b-tag algorithm to cut the mistag rate- the mistags enter both into 'mistag' and into the uncertainties in the 'Wbbbar' and 'Wccbar' categories. Cutting the mistag rate lowers the uncertainties due to uncertainties in the Q^2 and 'WB' rates.
4. Increase the jet threshold (this is well known as we now know the top to be heavy).
5. Implement charm-beauty separation along the lines started by David Wolinski.

As the baseball maxim says, 'Hit Em Where They Ain't. We should go where the backgrounds are small and the top signal not. Optimally one wants the systematic uncertainty to be much smaller than the statistical uncertainty (I generally like 1/3, to be safe), as the quoted systematic only includes those systematics one has thought of, and so, like some of the W+2jet analyses, may underestimate the true systematics. Moving away from the singularity (although it's cut off by the mass) in the heavy-quark pair mass will cut these backgrounds which are so hard to estimate precisely.

9 Acknowledgments

I would like to thank Tim Stelzer for providing and supporting MadGraph, which allows one to change the factorization and renormalization scales independently, and which is also

user-friendly enough so that somebody like me can use it and learn from it. I also would like to thank Tim, John Campbell, and Steve Mrenna for useful discussions.

References

[1] G. APOLLINARI,M. BARONE,S. BELFORTE,P. GIROMINI,F. HAPPACHER, E. MESCHI,S. MISCETTI,A. PARRI,G. PUNZI, *EVIDENCE FOR A BB-BAR STATE OF MASS 109 GEV PRODUCED IN ASSOCIATION...*; CDF/ANAL/TOP/CDFR/3485, 1/17/96.

[2] Alexis Amadon, Jeff Berryhill, Ray Culbertson, Henry Frisch, David Toback, Peter Wilson, *More (less?) about the tagging excess in the W + 2 jet data*; CDF/ANAL/TOP/CDFR/3674, 5/10/96.

[3] G.Apollinari, M.Barone, S.Belforte, L.Breccia, P.Giromini, F.Happacher, E.Meschi, S.Miscetti, A.Parri, F.Ptohos, W.Yao; *Method II measurement of the top cross section with W+3,4 jet events with SECVTX, JPB and SLT tags*; CDF/ANAL/TOP/CDFR/4303, 8/18/97; Revision date: 3/26/99

[4] CHYI-CHANG MIAO AND WEIMING YAO, *UPDATE OF SECVTX TAGGING FOR THE TOP SVX ANALYSIS*; CDF/ANAL/TOP/CDFR/3596, 3/3/96

[5] D. Acosta et al. (CDF Collaboration), *STUDY OF THE HEAVY FLAVOR CONTENT OF JETS PRODUCED IN ASSOCIATION WITH W BOSONS IN P ANTI-P COLLISIONS AT S**(1/2) = 1.8-TEV.* ; Phys.Rev.D65:052007,2002; hep-ex/0109012 (Sept 2001).

[6] Tony Liss and Robert Roser, *Impact of the Excess of Tags in the W+2 jet Sample on the t-tbar Cross Section Calculation*; CDF/ANAL/TOP/CDFR/3967, 11/16/96.

[7] G.Apollinari, I.Fiori, P.Giromini, F.Happacher, S.Miscetti, F.Ptohos; *Superjets*; CDF/ANAL/EXOTIC/CDFR/4795; 10/28/98; Revision date: 3/6/99;

G.Apollinari, M.Barone, I.Fiori, P.Giromini, F.Happacher, S.Miscetti, A.Parri, F.Ptohos, *Additional properties of the l +MET+ b + sq events*; CDF//EXOTIC/CDFR/4348, 9/28/97; 6/15/99;

G.Apollinari, M.Barone, P.Giromini, F.Happacher, S.Miscetti, A.Parri, F.Ptohos, *Evidence for non Standard Model phusics* sic *(in w+ $\geq$ 2 jet events with a tag* CDF/ANAL/EXOTIC/CDFR/4322; 9/16/97; Revision date: 4/24/98.

P. Giromini, F. Ptohos and W. Yao *Search for new particles $X \to b\bar{b}$ Produced in W+2jet Sample* CDF/ANAL/TOP/CDFR/4112,3/19/97

[8] T. Stelzer and W.F. Long, *Comput. Phys. Commun.,*81, 357-371 (1994).

[9] F. Maltoni and T. Stelzer, *MadEvent: Automatic Event Generation with MadGraph*, hep-ph/0208156, (2002).

[10] F. Maltoni, Z. Sullivan, S. Willenbrock *Higgs-Boson Production via Bottom-Quark Fusion*, hep-ph/0301033. See also the talk by Scott at the Dec. 19, 2002 meeting of the CDF Higgs Working group.

[11] Stephen Mrenna, private communication

[12] This is my rought approximation of what I thought Stephen Mrenna told me how it all works.

[13] J. M. Campbell and R. K. Ellis, Phys. Rev. D62, 114012, (2000).

[14] UnKi Yang, presentations to the muon group; note and filter code in progress.