CDF note 9321

Measurement of the b Jet Production Cross Section in Events with a $W^{\pm}$ Boson

The CDF Collaboration
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The b jet production cross section is measured for events with a $W^{\pm}$ boson in $p\bar{p}$ collisions at 1.96 TeV. The data were collected using the Collider Detector at Fermilab (CDF) experiment during Run II of the Fermilab Tevatron collider. $W^{\pm} + b$ jet events are selected by requiring a high p_T central electron or muon, large $\not\!\!E_T$ and one or two high E_T central jets; vertex information are used from the jets to select the subset that are consistent with originating from b quark production. For this analysis a new operating point for the widely used CDF vertex tagger was implemented that has significantly increased b purity over standard methods. Assuming standard model cross sections for top and diboson processes, the b jet production cross section for events with a leptonically decaying $W^{\pm}$ boson is measured to be 2.74 $\pm$ 0.27 (stat) $\pm$ 0.42(syst) pb. The measurement is compared to several available theoretical predictions. This measured cross section provides a data-driven measurement of a difficult-to-predict background for single top and Higgs searches.

I. INTRODUCTION

Signatures containing $W^\pm$ bosons and b quarks are particularly interesting at hadron colliders. The final state containing a $W^\pm$ boson and one or more b-jets is a promising Higgs search channel at the Tevatron. The $W^\pm$ + b jet signature could be a window to new physics such as technicolor both at the Tevatron and LHC. The top quark decays to a $W^\pm$ and a b nearly 100% of the time; studies of top production, both production of top pairs and single top production, benefit from understanding the $W^\pm$ + b signature in detail. These $W^\pm$ and b quark production mechanisms share this signature with a more mundane process: simple electroweak production of a $W^\pm$ in events with QCD production of b's, the process we refer to as $W^\pm$ + b jet production.

The importance of understanding $W^\pm$ + b jets is amplified by the large predicted rate of such events. From the theory side, tree-level predictions are available for $W^\pm$ + up to 2 b jet production from $\mathcal{O}(\alpha_s^2)$ to $\mathcal{O}(\alpha_s^5)$ [1]. An example of one of these LO diagrams is shown in Figure 1. These predictions, which include effects from the nonzero b mass, indicate that the inclusive event cross section for $W^\pm$ + b jets production, with $W \to \ell\nu$, is in the range 2-3pb. Calculations at NLO have demonstrated a factor of $\sim$2 enhancement over LO results [2], [3]. These predictions can be compared to the standard model (SM) predictions for single top production ($\sim$1pb for s- and t-channel inclusive [4] with a leptonically decaying $W^\pm$) and WH ($\sim$0.01-0.03pb for the mass range 100 GeV/c^2 < M_H < 140 GeV/c^2 [5] with a leptonically decaying $W^\pm$). Hence $W^\pm$ + b jets is a significant source of background events for these two searches.

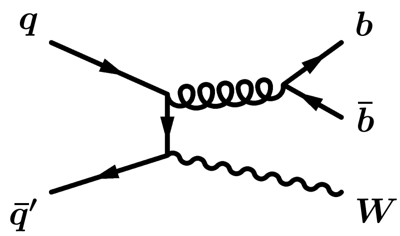

FIG. 1: An $\mathcal{O}(\alpha_s^2)$ diagram for $W^\pm$ + b jets production.

Theory predictions for the rate of $W^\pm$ + b jet production in $p\bar{p}$ collisions are imprecise. At CDF, a hybrid data + simulation technique was developed in Run I [6] to derive the $W^\pm$ + light flavor (LF, meaning jets from $u/d/s$ production) and $W^\pm$ + heavy flavor (HF, b/c production) backgrounds in the $W^\pm$ + jets sample in the context of the top search. However this method is frought with systematic error, most of which comes from an imprecise calibration of the heavy flavor content of the simulated event samples. The technique, which continues to be used in current Run II analyses, is only able to predict the $W^\pm$ + b jets contribution to within 30-40%. While this level of accuracy was sufficient for extracting a relatively large signal like $t\bar{t}$ production, small statistics searches such as single top and Higgs would benefit from a more precise knowledge of the rate of these events.

The goal then is to precisely measure the $W^\pm$ + b jets cross section in the CDF data. Such a result could contribute to more precise background predictions for the searches. Also desirable and more ambitious would be to use the direct measurement of $W^\pm$ + b jets production as a feedback loop into the improvement of event production models, to improve the rate predictions and verify the kinematic distributions from simulations for such events.

II. EVENT SELECTION

Identification of the $W^\pm$ + b jet signature relies on selecting events with leptonic $W^\pm$ decays, $W \to \ell\nu$ where $\ell = e$ or μ. This choice serves two purposes: electronic or muonic

$W^{\pm}$ decays offer a relatively clean event trigger and provide a sample with less complicated backgrounds than the case of $W^{\pm}$'s decaying hadronically or via $W \rightarrow \tau\nu$.

The triggers utilized in this analysis require a transverse energy E_T(transverse momentum p_T) > 18 GeV, $\mid \eta \mid < 1.1$ (1.0) electron (muon). The events actually come on three separate trigger paths. A single trigger path for the electronic $W^{\pm}$ decays is considered in this analysis and herein this path is referred to as "CEM"; two trigger paths are used to isolate the muonic $W^{\pm}$ decays, the "CMUP" path for muons with $\mid \eta \mid$<0.6, and "CMX" for 0.6 <$\mid \eta \mid$1.0. The nominal 1.7 MHz Tevatron crossing rate is reduced to 2-3 Hz on these trigger paths, which provide a manageable sample from which to construct the $W^{\pm}$ + b jets measurement. This sample constitutes about 2-3% of the bandwidth out of the final layer of the 3 level CDF trigger. When considering just data taking periods in which the relevant subsystems of CDF were powered and operational, the total integrated luminosity for these trigger paths is 1.9 fb^{-1}.

To ensure efficient and well-understood object identification for all observable products in each interaction, the first criteria imposed on selected events is that they be within the luminous portion of the CDF interaction region with $|z_0| < 60$cm. For comparison CDF's main silicon tracker SVX-II extends to $|z_0| = 50$cm.

Leptonically decaying $W^{\pm}$ bosons, characterized by a high energy charged lepton and neutrino, are selected offline from the triggered sample of events. Standard electron and muon identification criteria from the CDF Joint Physics recommendations are used universally [7]. The selected tight lepton is required to be isolated; the ratio, I, of the E_T in the R=0.4 cone around the candidate to the candidate track p_T is required to be small, $I < 0.1$. This requirement preferentially selects leptons from $W^{\pm}$ decay instead of those from semileptonic hadron decay or sources of fake leptons. Electrons are required to not be consistent with photon conversion. Muons are subject to a cut on the track χ^2 to avoid background from decays-in-flight. Finally, muons consistent with cosmic rays traversing the CDF detector are vetoed.

Events are required to have large missing transverse energy, $\not\!\!E_T$. The neutrino from leptonic $W^{\pm}$ decay escapes CDF without interacting with any of the particle detecting apparatus; hence its energy is not deposited anywhere, and the presence of the neutrino in the event is inferred as an imbalance in the energy measured among the event's observable final state particles. Raw $\not\!\!E_T$ is corrected to take into account the primary interaction point of the event, the presence of high p_T muons, and for corrected jet energies. The cut used in this analysis ($\not\!\!E_T > 25$ GeV) is larger than the standard one used in other analyses looking for top and Higgs signals in this final state. The higher $\not\!\!E_T$ cut is motivated by the desire to reduce fake $W^{\pm}$ background as much as possible, and a specific fake $W^{\pm}$ veto is implemented as well, see below. In a measurement of $W^{\pm}$ + b jet production, signal statistics are not a problem so such a cut is reasonable. The high p_T lepton and $\not\!\!E_T$ requirements constitute the $W^{\pm}$ selection.

In this analysis we seek only events that have a single identified lepton; events with additional leptons (or additional objects satisfying a less stringent or non-isolated lepton definition) are rejected to protect against dilepton $t\bar{t}$ background. Events consistent with $Z \rightarrow \ell\ell$ production are vetoed by rejecting events that have a tight lepton and an additional isolated track that have a reconstructed mass near the Z. Events are finally subject to a veto that targets fake $W^{\pm}$ events. These events arise mostly form QCD multijet production in which a jet fakes a lepton signature and the event contains spurious missing transverse energy. A stringent fake $W^{\pm}$ veto was developed in the context of the single top search [8] and was employed here as well.

Jets are identified using a cone algorithm with cone size, $R = 0.4$. The towers from the leptons qualifying for the dilepton $t\bar{t}$ veto above are removed before clustering of the jets. The jets considered in this analysis are corrected such that the ultimate energy used for object definition corresponds on average to the constituent hadrons from the which the jet originated [9] and are required to have E_T>20 GeV and $\mid \eta \mid$<2.0. Events are required to have exactly 1 or 2 such reconstructed jets; most $W^{\pm}$ + b jet signal has 1 or 2 jets, and considering higher jet multiplicities would introduce $t\bar{t}$ background at a significant rate.

This analysis seeks jets originating from b quark production. One characteristic of the b is its long lifetime; at CDF an algorithm has been designed that exploits this long lifetime for the purpose of selecting jets consistent with b production. This so-called b-tagger examines the charged particle tracks inside each jet and attempts to reconstruct a common origination point well-displaced from the primary $p\bar{p}$ interaction location. This secondary vertex is indicative of the decay position of the B hadron formed by the b quark, and the distance between the primary and secondary vertices corresponds to the trajectory through which the relativistically boosted B traveled during its lifetime.

For the purpose of this analysis, a new operating point for the CDF vertex tagger was developed. This new operating point makes more stringent selection on the tracks considered for secondary vertex construction and increases the minimum number of tracks for qualifying vertices. These changes to the default algorithm have the cumulative effect of significantly increasing the b purity of the selected sample: the rate of tagging light flavor jets is reduced by x10 and the rate of tagging charm jets is reduced by x4 at the expense of a reduction by 50% of the tags of real b jets [10]. This operating point of the tagger was designed specifically for this $W^{\pm}$ + b jet analysis in which one can afford such a loss in signal efficiency for the sake of significantly reducing the tags from non-$b$jets. This allows for a better understanding of the tagged sample.

Among the events satisfying the selection criteria, 943 tagged jets are ultimately selected in the three trigger paths used, as outlined in Table I.

Trigger Sample	Events before tagging	Jets before tagging	Tagged jets
CEM	98004	111226	504
CMUP	47243	54030	294
CMX	30465	34414	145
Total	175712	199670	943

TABLE I: Yields of tagged jets in data events passing the complete event selection on each trigger path.

III. MEASUREMENT STRATEGY

The b jet cross section for $W^{\pm}$ + b jets production, $\sigma_{b-\text{jets}}(W + b-\text{jets})$ is defined as

$$\sigma_{b-\text{jets}}(W + b-\text{jets}) \times BR(W \to \ell\nu) = \frac{n_{\text{tag}} \cdot f^{b\text{ jets}} - n_{\text{bkgd}}^{b\text{ jets}}}{\epsilon_{z_0} \cdot \sum_t [\mathcal{L} \cdot \mathcal{A}_{W+Nb}^{b\text{ jets}} \cdot \epsilon^b{}_{\text{tag}} \cdot \epsilon_{\text{trig}} \cdot \epsilon_{\ell\text{ID}}]_t} \quad (1)$$

where t runs over the three trigger paths. In the jet cross section expression above, n_{tag} is the number of tagged jets in the selected sample ($n_{\text{tag}} = 943$) and $f^{b\text{ jets}}$ is the fraction found to be from b jets, discussed below. From this yield of total b jets, the contribution from background b jets, $n_{\text{bkgd}}^{b\text{ jets}}$, is subtracted. This difference is then the yield of b jets due to the $W^{\pm}$ + b-jets signal. $\mathcal{A}_{W+Nb}^{b\text{ jets}}$ is the signal jet acceptance and $\epsilon^b{}_{\text{tag}}$ is the signal b-jet tag efficiency. The efficiencies ϵ_{trig}, $\epsilon_{\ell\text{ID}}$ and ϵ_{z_0} are for trigger, lepton identification and the efficiency for the event to be in the luminous region of the detector. Dividing the yield of signal b jets by the product of the jet acceptance, various efficiencies and the integrated luminosity $\mathcal{L}$ completes the calculation of the b jet cross section. The branching ratio of the $W^{\pm}$, $BR(W \to \ell\nu)$ is not removed from the cross section calculation for convenience in calculating acceptance.

It should be noted that a jet production cross section is measured here instead of an event production cross section [14]. This is done to avoid strong dependence in the measured result on the details of the signal model we employ during acceptance studies (here we use ALPGEN [11] as discussed below).

We further insulate the result from model dependency by restricting the phase space of events we consider. Simulated events are required to possess:

- a truth level electron or muon with $p_T > 20$ GeV/c, $\mid \eta \mid < 1.1$
- a truth level neutrino with $p_T > 25$ GeV/c
- 1 or 2 total truth level jets with $E_T > 20$ GeV/c^2, $\mid \eta \mid < 2.0$

These restrictions are chosen in such a way as to match the corresponding analysis level requirements placed on reconstructed objects. This is done because we seek only to rely on the signal model in regions of the final state particles' phase space where we have experimental sensitivity.

A. Species of Tagged Jets

Despite employing a high purity operating point for the CDF vertex tagging algorithm, the 943 tagged jets are not solely from b quarks; some fraction are also from charm and LF. The b content of the tagged sample is extracted through a maximum likelihood fit of the mass of the found secondary vertices. This quantity, defined as the invariant mass of the charged particle tracks participating in each found vertex, discriminates between LF, b and c jets. Vertex mass shapes for the b and c jet species are constructed from simulated events; the LF jets are taken from CDF inclusive jet data. Studies of the fit procedure in pseudoexperiments with varying amounts of signal and background jets indicated that the fit results were accurate, unbiased and would provide a relative statistical precision in the range of 5-10% .

Figure 2 shows the result of the fit for the tagged jets in the selected sample. The tagged jets are found to be dominated by b's: $f^{b \text{ jets}} = 71.3 \pm 4.7(stat) \pm 6.4(syst)\%$. The statistical error is driven by the fit, and the systematic error is driven by uncertainty in the vertex mass shape for b. This systematic is determined through the construction of a independent calibration sample of b jets in the data and the examination of differences between this calibration sample and the model we use for b's built from simulated jets.

The fit values for the three species can be checked for consistency in kinematic and tagging variables. Figures 3- 5 demonstrate that the species fractions found from the vertex mass fit do a good job of representing the data in these other variables.

B. Standard Model Backgrounds

Not all tagged b jets in the selected sample after tagging are from $W^{\pm}+$ b jet production. Background sources of b jets need to be subtracted from the overall yield of tagged b jets to get the contribution from signal. Standard model background sources are considered here.

Simulated events are used for many of the background sources. The largest background contribution comes from top production processes; the Pythia event generator [12] is used to simulate $t\bar{t}$ production and MadEvent [13] is used for single top production. For these purposes, SM next-to-leading-order cross sections and $m_t = 175$ GeV/c^2 are universally assumed. Simulated Pythia events are also used for diboson production. Other small background contributions come from Z + b jets and $W^{\pm}$ + b-jets with $W \rightarrow \tau\nu$. Tag rates in the simulated events are multiplied by the data-to-simulation efficiency scale factor. An integrated luminosity of 1.9/fb is assumed for the total background yields.

Despite a specially designed veto applied in the selection of events, the $W^{\pm}$ signature can be faked. This can happen for example in QCD multijet events where one jet satisfies the lepton selection criteria and mismeasurement of the energies of additional jets produces spurious $\not{E}_T$. Tags can be found on these additional jets, some of which are from b's.

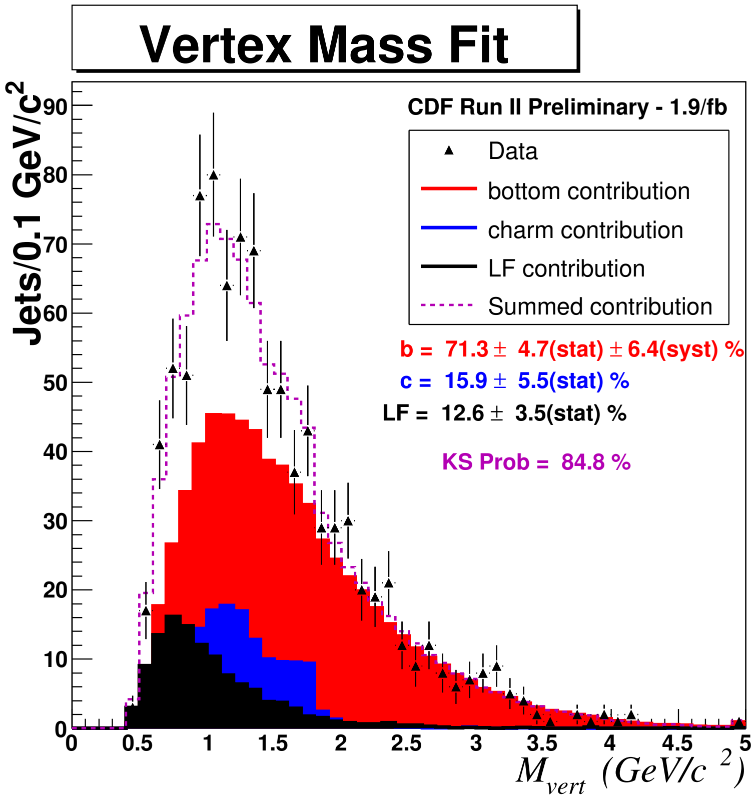

FIG. 2: Vertex mass fit for tagged jets in selected sample in 1.9/fb.

(a) **(b)**

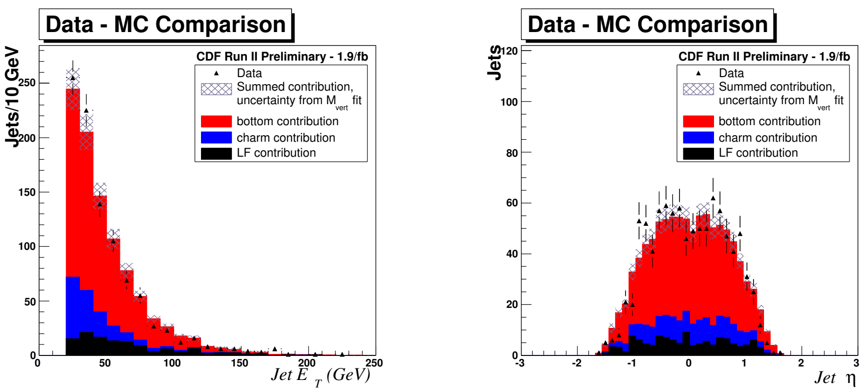

FIG. 3: Comparison of corrected jet E_T (a) and detector η (b) for data and simulated events. The species fractions are those found in the vertex mass fit. The simulation shapes are made from the same samples from which the vertex mass templates are constructed.

(a) (b)

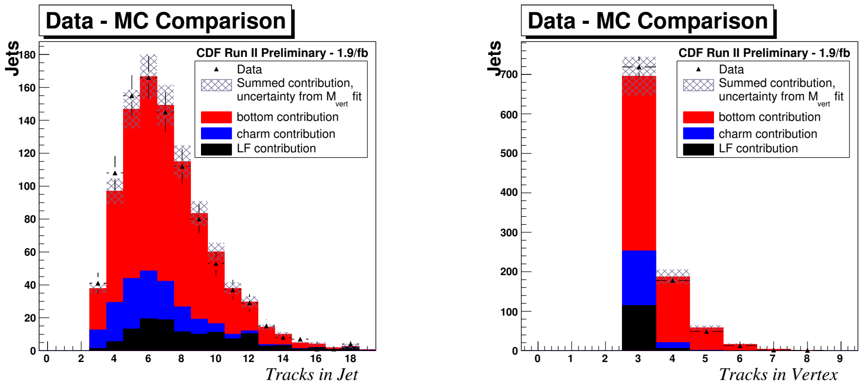

FIG. 4: Comparison of number of total tracks inside the jet (a) and number of tracks inside the tagged vertex (b) for data and simulation.

(a) (b)

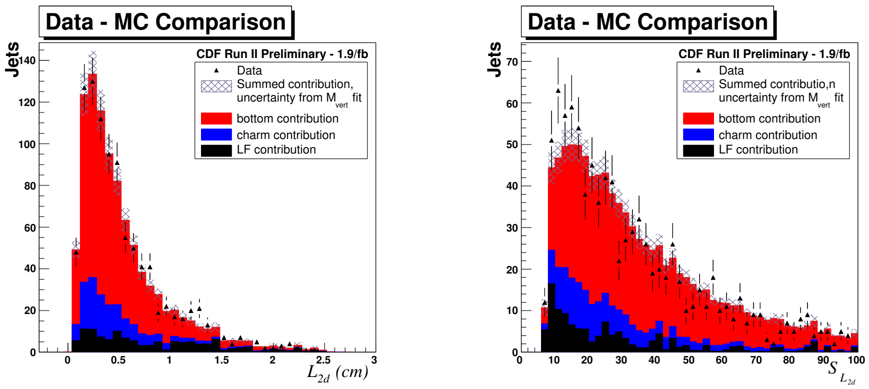

FIG. 5: Comparison of L_{2d} (a) and its significance (b) for tagged vertices in data and simulation.

These fake $W^{\pm}$ events pose an additional complication in that no accurate simulation exists for such events. Hence data must be relied upon to model these events. One such model is employed in this analysis. Data events on the CEM trigger are used; however instead of selecting events with a qualifying lepton candidate, as is done for the construction of the signal sample, for the purpose of constructing a fake $W^{\pm}$ sample, events with objects marginally failing the lepton selection are collected and are used as the fake $W^{\pm}$ model. The validity of the model relies on the fact that most fake lepton candidates only barely satisfy lepton selection criteria; these marginal leptons are then modeled using marginal failures and are considered to be a close approximation of the actual fake lepton sample.

With the fake $W^{\pm}$ model established, the task is to determine the fraction of tagged jets in fake $W^{\pm}$ events that are from b's. This is done in a two step process. First, the overall contribution from fake $W^{\pm}$ events to the tagged sample is determined. This is done by exploiting a feature of fake $W^{\pm}$'s that makes them unique: the per-event $\not{E}_T$ value for fake $W^{\pm}$ events is generally much softer than for real $W^{\pm}$ events. With shapes for real and fake $W^{\pm}$ sources, fits of $\not{E}_T$ then can give the overall contribution from fake $W^{\pm}$ to the tagged sample. The b content of the tagged fake $W^{\pm}$ sample is then determined by a fit of the vertex mass fit for the events falling into the data-driven fake $W^{\pm}$ model sample.

Table II summarizes the processes contributing to background sources of tagged b jets.

One can see that the contribution from processes containing top quarks dominates. Fake $W^{\pm}$ events contribute a non-negligible amount as well.

Process	n^{b}_{W+1j}	n^{b}_{W+2j}	n^{b}_{W+12j}
$t\bar{t}$	7.1 ± 1.0	66.0 ± 9.2	73.1 ± 10.1
s-channel	4.0 ± 1.7	18.2 ± 7.9	22.2 ± 9.6
t-channel	13.4 ± 6.1	19.9 ± 9.0	33.4 ± 15.0
WZ	2.6 ± 0.2	6.5 ± 0.6	9.1 ± 0.9
ZZ	0.07 ± 0.008	0.21 ± 0.02	0.28 ± 0.03
WW	0.19 ± 0.04	0.64 ± 0.10	0.83 ± 0.12
$W + bb$+Np, $W \to \tau\nu$	3.6 ± 0.4	3.7 ± 0.3	7.3 ± 0.8
$Z + bb$+Np, $Z \to e^{+}e^{-}$	0.21 ± 0.03	0.46 ± 0.05	0.67 ± 0.08
$Z + bb$+Np, $Z \to \mu^{+}\mu^{-}$	2.3 ± 0.3	1.8 ± 0.2	4.1 ± 0.4
$Z + bb+ \geq$Np, $Z \to \tau^{+}\tau^{-}$	0.57 ± 0.08	0.91 ± 0.13	1.48 ± 0.20
Non-W	9.4 ± 3.7	15.1 ± 6.3	24.5 ± 8.4
Total	43.4 ± 7.5	133.4 ± 21.0	176.8 ± 22.3

TABLE II: Summary of b jet backgrounds for tagged jets for 1.9/fb.

C. Signal Acceptance and Efficiency

In order to determine the cross section for b jets in $W^{\pm}$ + b jet production, one must determine the jet acceptance and efficiency. These values are determined in simulated signal events. The ALPGEN generator is used as the signal model here. ALPGEN is a fixed order matrix element event generator. $W^{\pm}$ + b jet events are generated up to $\mathcal{O}(\alpha_s^4)$ in the hard process, corresponding to $W + b\bar{b}$ events with 0, 1 or 2 additional outgoing partons; events with even more jets are produced through ALPGEN's interface to the Pythia generator, which is used for parton showering in these signal samples. These samples are generated in a CDF run-dependent fashion, taking into account realistic detector conditions and adding in additional interactions according to the instantaneous luminosity profile. The simulated events emulate the first 1.2/fb of Run II but have been shown to be a reasonable representation of data up through 1.9/fb.

The denominator of the acceptance is defined as the pool of b jets in events passing the truth level requirements on the charged lepton, neutrino and jets as described above. Truth level jets are constructed by applying the same jet cone algorithm that is used to reconstruct analysis level jets; here the algorithm is run on the final state observable particles instead of calorimeter towers. A truth level jet is defined to be a b jet if it is matched (ΔR<0.4) to a parent B hadron. All final state particles in the event are subject to truth level jet construction except those from the leptonic $W^{\pm}$ decay. It follows then that minimum-interacting and non-interacting particles are being clustered together into the truth level jets; this creates a natural mismatch between reconstructed jet energies and truth jet energies. This mismatch is important for b-jets (5-10%) since they very often contain semi-leptonic hadron decays. No further correction is applied to the reconstructed jet energies and this effect is left to manifest itself in the acceptance.

In addition to the acceptance, the simulated signal samples are used to separately estimate the tag efficiency. The performance of the tagging algorithm in the simulation samples is overly optimistic. A study of the tag efficiency for b jets was performed in the data, and a comparison to the tag efficiency for simulated b jets allows one to scale the efficiency here in the relevant $W^{\pm}$ + b jet signal samples to achieve an accurate measurement of the tag efficiency for these signal jets in data.

b-jet acceptance and tag efficiency measurements are summarized in Table III. The acceptance values for each path incorporate the systematic error incurred through imprecise knowledge of the jet energy scale and from the choice of factorization+renormalization scale and parton distribution function in the simulated signal samples. A summary of the impact of systematic errors for all portions of the analysis can be found in Table IV.

Trigger Path	$\mathcal{A}$	ϵ_{tag}	$(\epsilon_{\text{trig}} \times \epsilon_{z_0} \times \epsilon_{\ell\text{ID}})$	$(\mathcal{A} \times \prod \epsilon_i)$
CEM	0.356 ± 0.023	0.16 ± 0.01	(0.915 ± 0.005)	0.052 ± 0.005
CMUP	0.207 ± 0.014	0.16 ± 0.01	(0.815 ± 0.001)	0.027 ± 0.002
CMX	0.110 ± 0.011	0.16 ± 0.01	(0.915 ± 0.007)	0.016 ± 0.002

TABLE III: Summary of the signal b jet acceptance and efficiencies.

Source	$\frac{\delta_{\sigma_{b-\text{jets}} \times BR}}{\sigma_{b-\text{jets}} \times BR}$ (%)
b shape modeling	8
c shape modeling	1
LF shape modeling	3
UT tag efficiency	6
Luminosity	6
Top Cross Sections	2
Fake $W^{\pm}$ $\not{E}_T$ fits	1
Tagged Fake $W^{\pm}$ b fraction	1
Jet Energy Scale	3
Q^2	3
PDF	2
$\lvert z_0 \rvert$ efficiency	<1
Trigger efficiency	<1
Lepton ID efficiency	<1

TABLE IV: Summary of the sources of systematic error and their impacts on the measurement.

IV. RESULTS

Given 943 tagged jets in the selected sample and a found b fraction $f^{b\text{ jets}} = 71.3 \pm 4.7(stat) \pm 6.4(syst)\%$, it follows that ∼672 tagged jets in the data are from b. Assigning ∼177 of these to background sources implies that ∼ 496 of these tagged b jets are from $W^{\pm}$ + b-jet production, our signal. Given the acceptance, efficiency and luminosity values from each trigger path and plugging into Equation 1, yields:

$$\sigma_{b-\text{jets}}(W + b-\text{jets}) \times BR(W \to \ell\nu) = 2.74 \pm 0.27(stat) \pm 0.42(syst)\text{pb} \tag{2}$$

This jet cross section result can be compared to the predictions from available leading order and next-to-leading order simulations, see Table V. One can see that for the ALPGEN generator, widely used at CDF, the prediction undershoots the data by a factor of ∼3.5. That there is a mismatch between theory and data is not surprising; that the mismatch is so large is somewhat unexpected. Investigations as to how this mismatch could come about are underway. More valuable information on the differential cross section for b jets in $W^{\pm}$ + b jet production is being extracted currently. And comparisons to more models are coming as well.

Prediction	$\sigma_{b-\text{jets}}(W + b-\text{jets}) \times BR(W \to \ell\nu)$(pb)
ALPGEN	0.78
Pythia	–
Sherpa	–
MCFM (NLO)	–
Data	2.78 ± 0.27 (stat) ± 0.42 (syst)

TABLE V: Comparisons of integrated cross section result to some available theory predictions.

V. CONCLUSIONS

We have measured the production cross section for b jets in events with a $W^{\pm}$ boson in 1.9/fb of CDF Run 2 data. Care was taken to insulate the result for influence of the model used for the signal events. The measured jet cross section is 2.74 $\pm$ 0.27 (stat) $\pm$ 0.42 (syst) pb; this jet cross section applies specifically to events that possess a high p_T central charged lepton, a high p_T neutrino and exactly 1 or 2 high E_T central jets. This result is 3-4 times higher than the prediction from ALPGEN. This result is an improvement over the previous $W^{\pm}+b$ jet analysis, which had precision only to within ~30%. This more precise measurement will be incorporated into $W^{\pm}$ + b-jet predictions for Higgs and single top searches.

Acknowledgments

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