B–JETS AND Z + B–JETS AT CDF

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We present CDF cross–section measurements for the inclusive production of b jets and the production of b jets in association with a Z^0 boson. Both measurements are in reasonable agreement with NLO QCD predictions.

In hadronic collisions, heavy flavour quarks can be produced by several mechanisms: "flavour creation" where pairs of heavy flavour quarks are directly produced in the final state; "flavour excitation" where a heavy quark is picked up from the sea of the initial state proton or anti–proton; and "gluon splitting" where a final state gluon decays into a heavy quark anti–quark pair. We study the production of b jets both inclusively and in conjunction with the production of a Z boson. These processes are sensitive to different combinations of these heavy flavour production mechanisms, so their measurement provides a test of these mechanisms. QCD heavy flavour production is also an important background to the identification of rare phenomena, such as top quark and Higgs boson production, which are often identified by their preferential decay to b quark jets. A good understanding of these QCD processes is therefore an essential input to such measurements and searches.

The Tevatron produces $p\overline{p}$ collisions at a centre–of–mass energy of 1.96 TeV. The data used to produce the results presented in this paper correspond to an integrated luminosity of around 300 pb^{-1}.

CDF[1] is a general purpose detector consisting of a high precision charged particle tracking system inside a uniform solenoidal magnetic field of 1.4 Tesla, electromagnetic and hadronic calorimeters, and muon detectors. The Central Outer Tracker (COT) is a large wire chamber, which covers the region with pseudorapidity $|\eta| < 1$, and measures up to 96 points per track; half the wires are parallel to the beam direction, and the other half at a small stereo angle to the beam direction, allowing full three dimensional track reconstruction. Inside the COT are the various components of the silicon tracker, which covers the region $|\eta| < 2$. Layer00 is mounted directly on the beam pipe, and is a radiation hard single sided silicon detector. Outside Layer00 lie the five double sided silicon layers of the SVXII, followed by 1 or 2 layers of the Intermediate Silicon Layers (ISL). These layers contain strips parallel, perpendicular and at a small stereo angle to the beam axis, giving full three dimensional tracking information. The tracking detectors are surrounded by electromagnetic and hadronic calorimeter detectors; these are sampling calorimeters with alternating layers of lead (electromagnetic) or steel (hadronic) and scintillator. Outside the calorimeters are wire chambers used for the identification of muons.

Hadronic jets are identified as clusters of energy in the calorimeters using a cone algorithm in $\eta - \phi$ space; the results presented here use a cone of radius 0.7. Once the jets are identified, their measured energy is corrected to account for the detector response and non-uniformities, and for the effect of multiple $p\overline{p}$ interactions in the same bunch crossing.

Tracks are first identified in the COT and extrapolated into the silicon detector, where silicon hits are attached to tracks. Unattached silicon hits are used to search for additional tracks, which recovers efficiency in the forward region. These silicon only tracks are then extrapolated out into the COT, where additional hits may be attached.

b jets are identified by making use of B hadrons' relatively long lifetime ($c\tau \sim 500\mu m$), which leads to the formation of B decay vertices well separated from the primary event vertex. We consider well reconstructed tracks lying inside a $\eta - \phi$ cone of 0.4 around the jet axis. Tracks displaced from the primary vertex are used to search for displaced secondary vertices. In a first pass vertices with at least three tracks are considered; if no such vertex is found, two–track vertices are also considered. The reconstructed vertex is required to be well separated from the primary vertex, with a significance of separation in the $x - y$ plane of at least 7.5. Jets containing such a displaced vertex are deemed "tagged".

To measure the fraction of b jets in a sample, the sample of "tagged" jets is considered. This sample contains not only b jets, but also fake tags from light quark jets, and true vertices found in charmed jets. To estimate the fraction of true b jets in this sample, we consider the invariant mass of the tracks associated to the vertex. The invariant mass of b jet vertices is on average higher than that of c and light jets due to the high b quark mass of around $5GeV/c^2$. By fitting the distribution of vertex mass to the sum of templates from b and non–b jets, the number of true b jets in the tagged jet sample can be estimated. An example of such an invariant mass fit is shown in fig. 1.

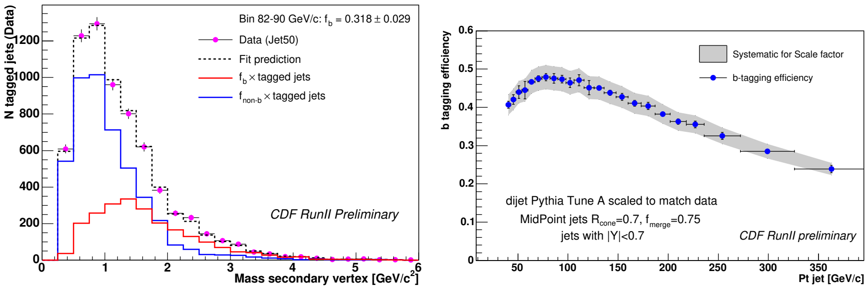

Figure 1. Left: example of a template fit to the vertex invariant mass. Right: the b tagging efficiency for b jets as a function of jet p_T.

To estimate the number of b jets in the original jet sample, this number of tagged b jets is then corrected by the efficiency for tagging b jets. Fig. 1 also shows the efficiency of the b tagging algorithm, which varies between $\sim$ 25 and $\sim 50\%$, depending on the jet p_T. After correcting for the kinematic acceptance, and accounting for the integrated luminosity of the sample being considered, cross–sections can be calculated.

In the measurement of the inclusive b jet cross–section, around $300 \pm 17\,pb^{-1}$ of data were analysed. The data were collected by jet–based triggers with various jet E_T thresholds between 5 and 100 GeV. Jets in a restricted kinematic range, $38 < p_T^{jet} < 400 GeV/c$ and rapidity $|y| < 0.7$, were considered, restricting the cross–section measurement to a region where the jet energy corrections and the b tagging performance are both well understood. The jets are split into sub–ranges of jet p_T, and the number of true b jets and the b jet tagging efficiency are estimated in each range. The inclusive b jet cross–section is measured in each jet p_T range. These cross–sections are shown in fig. 2.

This measured cross–section is compared to the NLO prediction[2], which is corrected for the effect of the underlying event and hadronisation. The ratio of the measured to the predicted cross–sections is shown in fig. 2. The prediction is in fairly good agreement with the measurement considering the significant uncertainties on both the experimental measurement and the theoretical prediction.

Data with an integrated luminosity of around $330 \pm 19\,pb^{-1}$ were analysed for the measurement of the cross–section of heavy flavour jets in con-

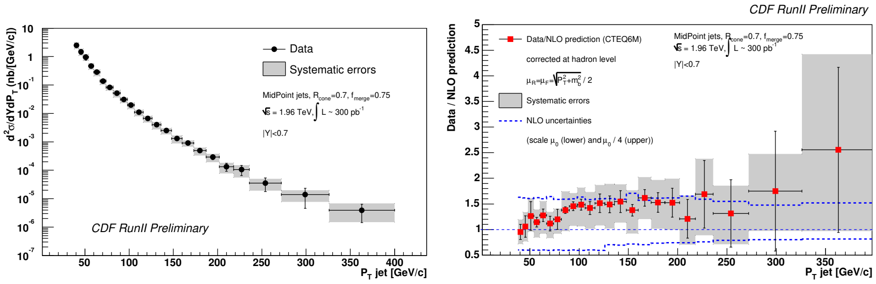

Figure 2. Left: the inclusive b jet cross–section as a function of jet p_T. Right: comparison of measured cross–section with the predictions from NLO QCD.

junction with a Z^0 boson[3]. The data were collected by triggers requiring a high p_T muon or electron. Z^0 bosons were identified by their decay into e^+e^- and $\mu^+\mu^-$ pairs. Events were required two same–flavour opposite–sign leptons with an invariant mass between 66 and 116 GeV/c^2. In addition to a reconstructed Z^0 boson, at least one additional jet, with $E_T > 20GeV$ and pseudorapidity $|\eta| < 1.5$, was required. The jets were then tagged, and backgrounds from non-Z^0 events, estimated to be of the order of a few percent, were subtracted from the data. The fractions of true b and c jets in the sample were then estimated using a fit to the vertex mass distribution.

Cross–section ratios $\sigma(Z^0+b-jet)/\sigma(Z^0+jet)$ and $\sigma(Z^0+b-jet)/\sigma(Z^0)$ are measured and combined with the CDF measurement of inclusive Z^0 production to extract $\sigma(Z^0 + b - jet)$. These measurements are compared the NLO QCD prediction[4] , and are shown in table 1. The measured values agree with the NLO QCD prediction within the experimental and theoretical uncertainties.

Table 1. Measured $Z^0 + b$ jet cross–section and cross–section ratios.

Cone0.7, $E_T^{jet} > 20$ GeV, $\lvert\eta^{jet}\rvert < 1.5$	CDF RunII: $\sqrt{s} = 1.96$ TeV, $\mathcal{L} \sim 330pb^{-1}$	NLO (MCFM)
$\sigma(Z^0 + b - jet)/\sigma(Z^0 + jet)$	$0.0236 \pm 0.0074 \pm 0.0053$	0.0181 ± 0.0027
$\sigma(Z^0 + b - jet)/\sigma(Z^0)$	$0.0037 \pm 0.0011 \pm 0.0008$	0.0019 ± 0.0003
$\sigma(Z^0 + b - jet) \times \mathcal{B}(Z \to l^+l^-)$	$0.93 \pm 0.29 \pm 0.21$	0.45 ± 0.07

References

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