Measurement of the $t\bar{t}$ Production Cross Section in SecVtx Tagged Lepton + Jet Events

T. Kubo[a], Y. Kusakabe[b], **T. Masubuchi[a]**, M. McFarlane[d], J. Naganoma[b], J. Nielsen[d], A. Taffard[c], W. Yao[d],

a) University of Tsukuba, b) Waseda University, c) University of Illinois at Urbana-Champaign, d) LBNL

1. Introduction & Motivation

• At Tevatron, with cm energy = 1.96 TeV, top quark pair are produced via $q\bar{q}$ annihilations (85%) or guluon fusion(15%).
Within the SM, BR(t→Wb)~100%

• Branching ratio of Lepton + jets channel is larger than dilepton channel

• Background is smaller than all hadronic channel's

→ The so-called lepton+jets channel is **the golden channel** to measure top properties due to its large statistic and manageable background

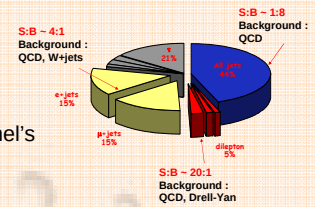

Figure 1: BR of top and S/B after b-tagging

Motivation for Cross Section Measurement

• Provides a test of QCD calculations

• Provides a test of SM decay t→Wb

• Significant deviation from SM indicates non-SM production decaying to $t\bar{t}$ pairs or non-SM decay like charged Higgs

• Indirect measurement of top quark mass

2. CDF Detector

• Central tracker : measure momentum (p) → detect e, μ

• Calorimeter : measure energy (E) → detect e, jet

• Muon chamber → detect μ

• Silicon detector → detect displaced vertex

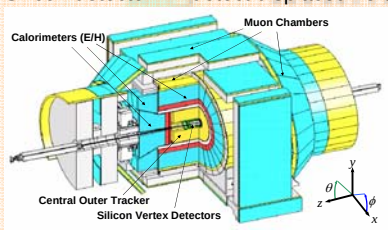

Figure 2: Isometric view of CDF detector

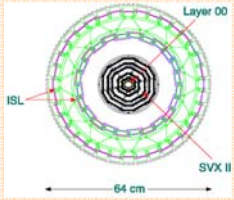

Figure 3: Silicon detector in r-Φ view

3. Event Selection

• Require isolated high p_T (>20GeV/c) lepton (e or μ)

• Large Missing E_T (>20 GeV) from W neutrino

• At least 3 jets with high E_T (>15 GeV, |η| < 2.0)

• At least 1 jet with secondary vertex b-tagging to reduce QCD background

• Apply Ht cut (>200 GeV)

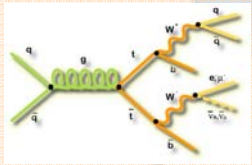

Figure 4: lepton+jets diagram

The definitions

$$\eta = -\ln(\tan(\frac{\theta}{2}))$$

$$E_T = E\sin\theta, \quad p_T = p\sin\theta$$

$$H_T = \sum E_T(\text{jet}) + \not{E}_T + p_T(\text{lepton})$$

Data Sample

Use 695±42pb^{-1} data collected from March 2002 to September 2005

4. Identifying b jets

SecVtx b-tagging Algorithm

• B hadrons are massive and long-lived

→ The signature of b decay has displaced vertex

Efficiency

• Measure efficiency (~50%) data and MC using heavy flavor enriched sample. Determine data/MC scale factor

Mistag rate

• Derive probability of misidentifying jet not from B quarks using generic jet sample

• Average mistag rate is ~0.5%

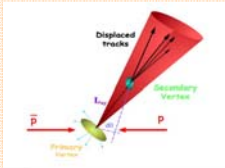

Figure 5: schematic view of displaced vertex

Neural Network b-tagging Algorithm

• Get a better separation between b jets from c jets or mistag and improvement of the purity of b-tagging

• The tagger employs two neural networks and apply them on SecVtx tagged jets
- Train one network to separate b jets and light quark jets (nnbl)
- Train another network to separate b jets and charm jets (nnbc)

→ **Keeps 90% of b jets** while **rejecting 50% of charm jets** and **65% of mistags**

(by requiring nnbl > 0.182 & nnbc > 0.242)

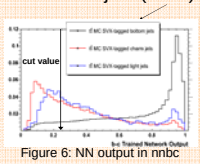

Figure 6: NN output in nnbc

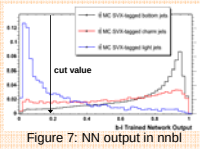

Figure 7: NN output in nnbl

5. Background and Systematic Uncertainties

◆ The challenge of the analysis is determining background composition

◆ This background composition is an input to many other analysis (Higgs and Single Top). → Higgs analysis is presented by Yoshiaki's poster

Background Estimation

•W+Heavy flavor (W+$b\bar{b}$,W+$c\bar{c}$,W+c)
– The contribution from true heavy flavor production in W+jet events is calculated from heavy flavor fraction in W+jet events and the tagging efficiency with Monte Carlo
– Their overall rates are normalized to data

• Fake b-tagged events
– Use fake (mistag) rate probability matrix

• QCD(non-W)
– Extrapolate MET and lepton isolation sidebands using data

• Single Top, Diboson, other
– Estimate with Monte Carlo sample

Table 1: Background summary in events with at least one tag

Njets	1	2	3	≥ 4
Pretag	68183	10647	816	102
Mistag	286.0 ± 42.3	119.2 ± 17.7	21.0 ± 3.2	0.6 ± 1.0
$Wb\bar{b}$	201.1 ± 62.3	109.0 ± 32.3	13.0 ± 3.5	3.3 ± 0.9
$Wc\bar{c}$	61.5 ± 18.6	40.9 ± 12.8	5.2 ± 1.6	1.5 ± 0.5
Wc	242.1 ± 62.9	50.4 ± 13.3	3.3 ± 0.9	0.4 ± 0.1
Single Top	17.2 ± 1.7	24.1 ± 2.4	2.1 ± 0.2	0.1 ± 0.1
Diboson	13.3 ± 2.1	19.2 ± 3.0	2.6 ± 0.5	1.0 ± 0.2
non-W QCD	99.9 ± 16.4	45.0 ± 7.5	5.8 ± 1.1	4.1 ± 0.8
Total	921.1 ± 113.3	407.8 ± 52.5	53.0 ± 6.1	17.2 ± 1.9
Data	1029	514	156	158

Control region — Signal region : determine cross section from >=3 jet bin

Systematic Uncertainty

Source	Systematic (%)
b-tagging	6.5
Luminosity	6.0
PDF	5.8
Jet Energy Scale	3.0
ISR/FSR	2.6
Lepton Identification	2.0
Total	11.5

Table2 : each systematic uncertainty and total systematic uncertainty

$\epsilon_{t\bar{t}}$: acceptance of ttbar events
$\mathcal{L}$: Integrated luminosity

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{\epsilon_{t\bar{t}} \times \mathcal{L}}$$

6. Results

• Jet multiplicity distributions for each tag method

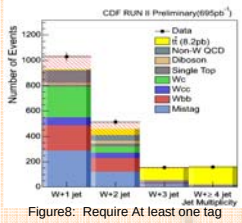

Figure8: Require At least one tag

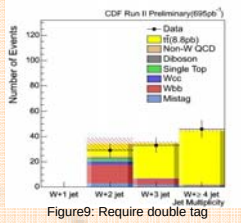

Figure9: Require double tag

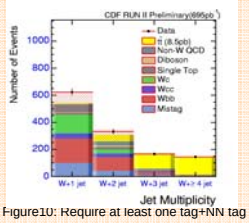

Figure10: Require at least one tag+NN tag

Best measurement of top cross section!!

Measured cross section results

8.2±0.6(stat)±1.0(sys) pb : at least one tag with Ht cut ← Main results

$8.8^{+1.2}_{-1.1}$(stat)$^{+2.0}_{-1.3}$(sys) pb : double tag

8.5±0.6(stat)±1.0(sys) pb : at least one tag with NN b-tagging ← Cross check

• σ_{tt} (Theory) = 6.7±0.8pb for M_{top}=175 GeV/c^2

• That measurement is limited by systematic and the error are comparable to the theoretical error.

Future

• Reduce systematic uncertainty (b-tagging)

• Improvement background modeling

public page
http://www-cdf.fnal.gov/physics/new/top/2006/xs_ljetsvx/public.html
http://www-cdf.fnal.gov/physics/new/top/2006/xs_ljetsvxnnb/NNxsec.html