MEASUREMENT OF THE $t\bar{t}$ PRODUCTION CROSS SECTION IN THE LEPTON + JETS CHANNEL USING JET PROBABILITY AT CDF

Enrique Palencia, Instituto de Física de Cantabria
for the CDF Collaboration

APS Meeting, April 18, 2005

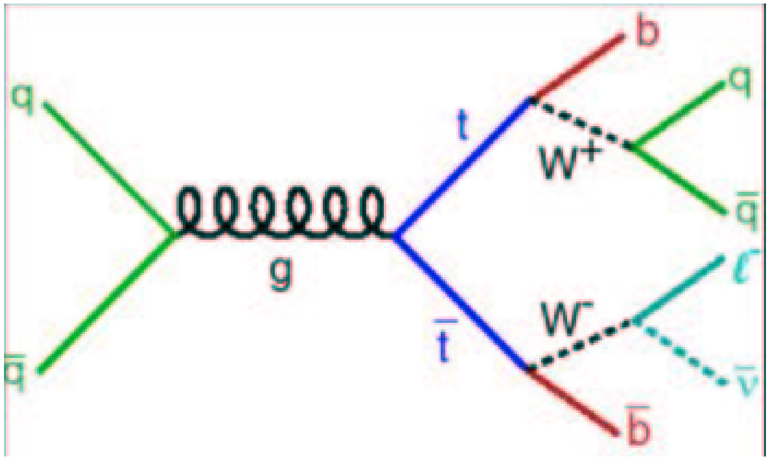
Outline

- Motivation
  - Why Top?
  - Why Lepton+Jets?
  - Why Jet Probability?
- Jet Probability tagger description
  - Algorithm
  - Efficiency
  - MisTag Rate
- $t\bar{t}$ Cross Section Measurement

Motivation

- Why Top?
  - Heaviest known fundamental particle $\Rightarrow$ special role in EWSB
  - Might be sensitive to Physics Beyond the Standard model
  - Decays before it hadronizes due to its yactosecond lifetime
  - Most recently discovered quark (1995, FNAL): detailed study with increased statistics

- Why Lepton+Jets?
  - 1 lepton (electron or muon), $\geq$ 3 jets and high $\not\!\!E_T$
  - S/B = 2/1 (Dilepton 4/1, All hadronic 1/4)
  - BR = 30% (Dilepton 5%, All hadronic 44%)



- Why HF tagging?
  - Top signal has 2 b's and only $\sim$ 1% of the main backgrounds has HF $\Rightarrow$ S/B greatly increased

- Why Jet Probability?
  - Measure $t\bar{t}$ x-section with a different tagging algorithm (SecVtx, SLT)
  - JP provides (a priori) a more flexible way to understand the composition of the tagged sample by tunning the JP cut
  - JP can be tuned/optimized differently for other kinds of analysis

Jet Probability Algorithm (I)

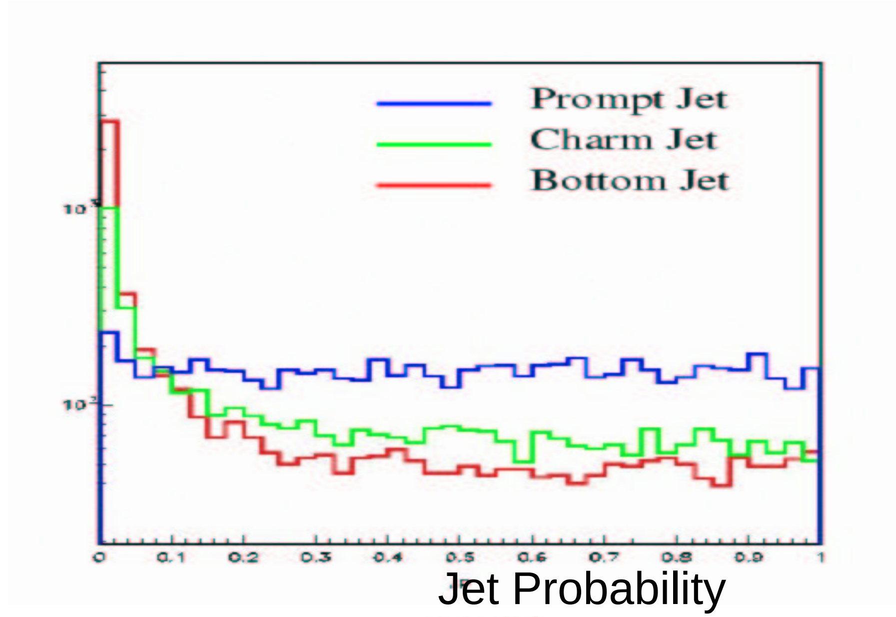
- Jet Probability is an algorithm to determine whether a jet has been produced at the primary interaction point or from the hadronization of a HF quark

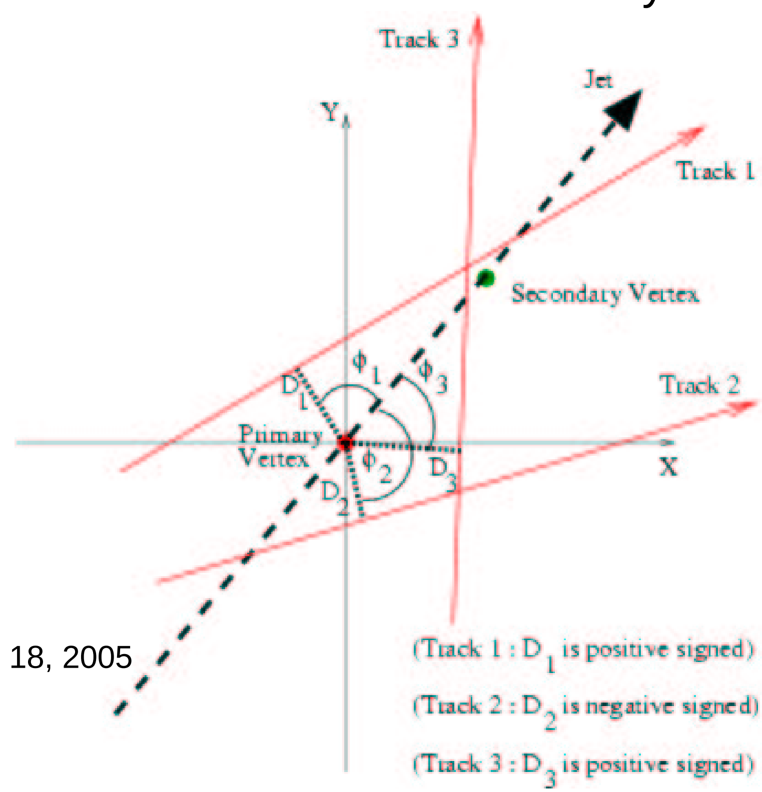
- Physically, it represents the probability for a jet to come from the primary interaction vertex

- Uniform probability for light quark or gluon jets and peaks at 0 for jets containing displaced tracks from HF decays

- We use a signed impact parameter: D$>$0 if point of closest approach to the primary vertex lies in the same direction as the jet direction ($\cos\phi > 0$)

- + (-) Jet Probability: only tracks with positive (negative) impact parameter

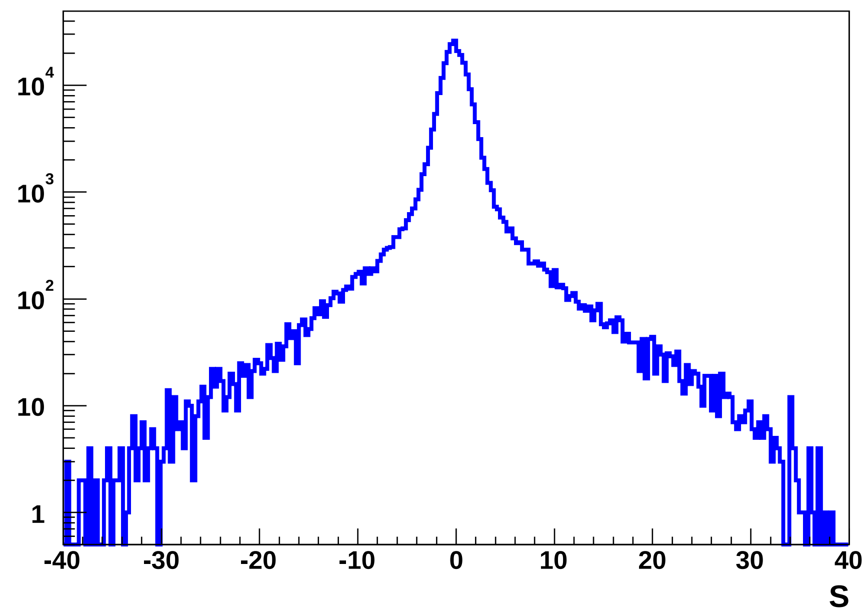




Jet Probability Algorithm (II)

- Track impact parameter significance: $S = D/\sigma_D$
- Fit the distribution of the track impact parameter significance to obtain a resolution function $R(S)$ (different for data and MC)
- Negative side of $R(S)$ used to determine the probability ($P_{tr}(S_0)$) that the impact parameter significance (S_0) of a given track is due to the detector resolution

$$P_{tr}(S_0) = \frac{\int_{-\infty}^{-|S_0|} R(S)dS}{\int_{-\infty}^{0} R(S)dS}$$



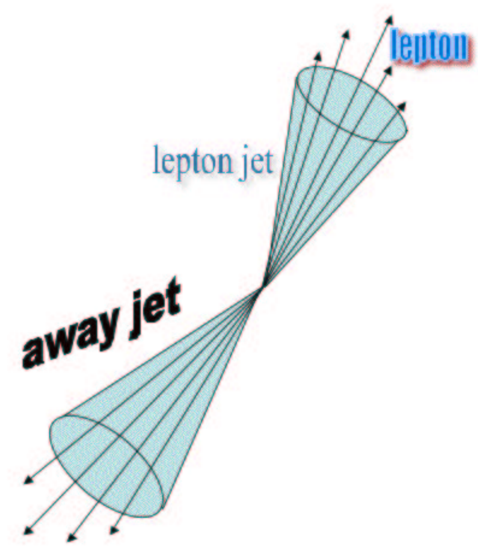
- The probability that a jet is consistent with a zero lifetime hypothesis is defined as

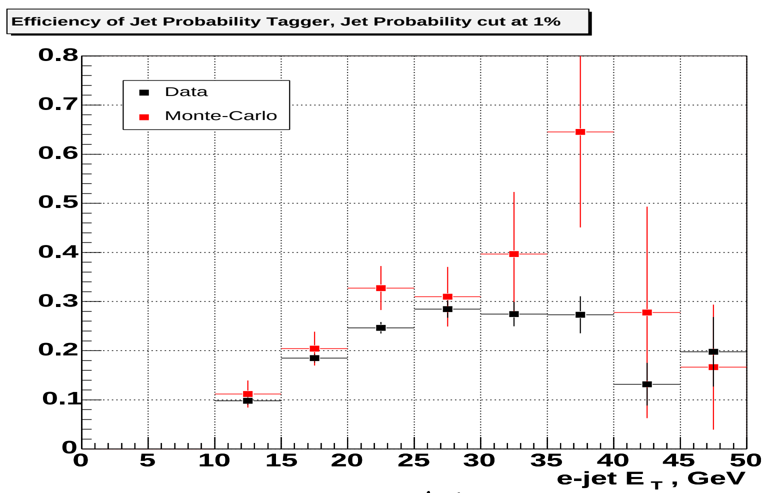
$$\prod_{l=1}^{N_{tr}} P_{tr} \times \sum_{k=0}^{N_{tr}-1} \frac{(-ln \prod_{l=1}^{N_{tr}} P_{tr})^k}{k!}$$

Jet Probability Efficiency

- Measured using an 8 GeV inclusive electron data sample since it is enriched with HF due to the semiloptenic B decays
- Single tag method: $\epsilon = \frac{N^{+}_{ej} - N^{-}_{ej}}{N_{ej}} \cdot \frac{1}{F_B}$
  - Disadvantage: relays on the correct determination of the heavy flavor fraction in the sample
- Double tag method: as HF quarks are mostly produced in pairs, HF content in one jet is enhanced requiring that the "other" jet (away jet) is tagged
- Since we use MC in the analysis, we also need to measure the efficiency in MC and then calculate the Scale Factor ($\epsilon^{data}/\epsilon^{MC}$)
- Efficiencies to tag a heavy flavor jet with $E_T > 10$ GeV and 162 pb^{-1}

	JP < 1%	JP < 5%
ϵ^{data}	0.197 ± 0.012	0.262 ± 0.013
ϵ^{MC}	0.250 ± 0.020	0.319 ± 0.023
Scale Factor	0.787 ± 0.105	0.820 ± 0.095

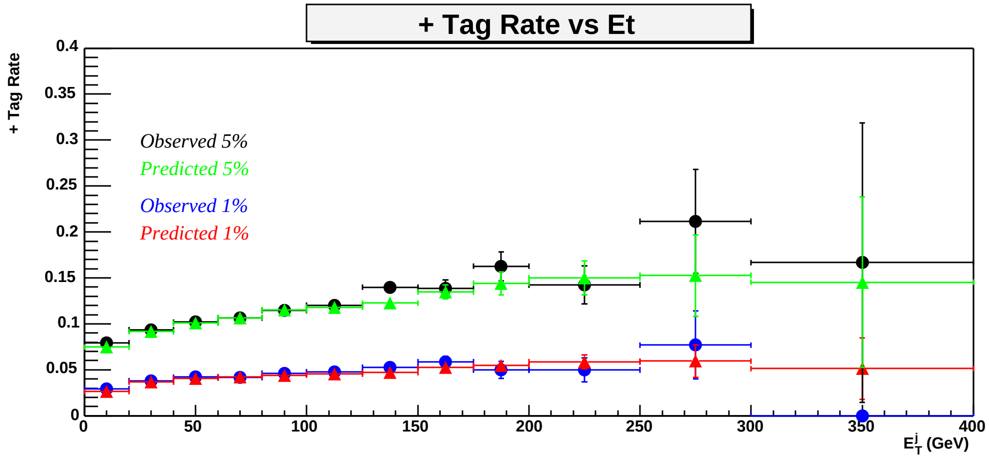


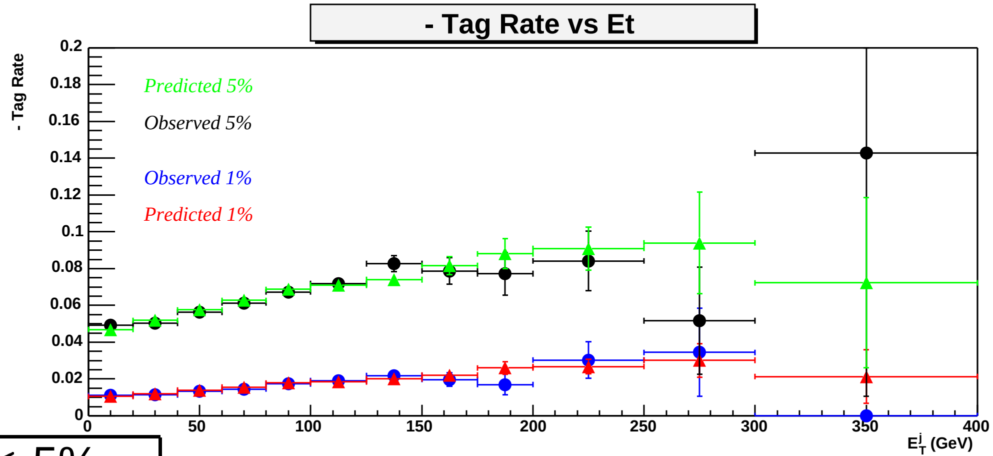


JP Efficiency vs E_T^{jet} (JP<1%) in inclusive electron sample

Jet Probability: MisTag Rate

- Determined using inclusive jet data samples with triggers thresholds of 20, 50, 70 and 100 GeV
- Parameterized as a 6 dimensional matrix of the following variables: $(E_T, N_{trk}, \sum E_T^j, \eta, Z_{vtx}, \phi)$
- Cross check: observed from the multijet trigger sample vs prediction from the inclusive jet data
- Results with 162 pb^{-1}





	JP $<$ 1%	JP $<$ 5%
Overall - tag rate (%)	1.11 $\pm$ 0.08	4.89 $\pm$ 0.19
Overall + tag rate (%)	3.22 $\pm$ 0.21	8.53 $\pm$ 0.34

$t\bar{t}$ Cross Section Measurement: Data Selection

- Counting experiment: $\sigma_{t\bar{t}} = \frac{N_{obs} - B_{bkg}}{\epsilon_{t\bar{t}} \times \int Ldt}$
- Data sample based on Run II data (with Si) taken untill September 03

	CEM (Central electrons, $\|\eta\| < 1$)	CMUP (Central muons, $\|\eta\| < 0.6$)	CMX (Extension muons, $0.6 < \|\eta\| < 1$)
Lum (pb^{-1})	161.6 $\pm$ 9.5	161.6 $\pm$ 9.5	149.8 $\pm$ 8.8

- Event selection:
  - 1 high p_T isolated lepton
  - high $\not{E}_T$
  - $\geq$ 3 energetic jets
  - $\geq$ 1 tagged jet (jet with positive JP<0.01)

Jet Multiplicity	1 jet	2 jet	3 jet	$\geq$ 4 jets
Pretag events				
CEM	7819	1202	201	61
CMUP	3758	587	81	27
CMX	1971	293	36	6
Total	13548	2082	318	94
Tagged events				
CEM	78	40	21	17
CMUP	40	30	8	10
CMX	13	11	2	1
Total	131	81	31	28

$t\bar{t}$ Cross Section Measurement: Acc. and Backg.

- JP tagging efficiencies for $t\bar{t}$ events (PYTHIA Monte Carlo sample with top mass 175 GeV/c^2)

Quantity	CEM	CMUP	CMX
(SF = 0.787 $\pm$ 0.105)			
Acc. No Tag	4.09 $\pm$ 0.04 $\pm$ 0.33	2.12 $\pm$ 0.02 $\pm$ 0.21	0.95 $\pm$ 0.01 $\pm$ 0.12
Tag Eff	56.99 $\pm$ 0.28 $\pm$ 6.66	56.88 $\pm$ 0.36 $\pm$ 6.67	57.84 $\pm$ 0.60 $\pm$ 6.67
Average Tag Eff	57.24 $\pm$ 0.21 $\pm$ 3.85		
Acc. with Tag	2.33 $\pm$ 0.03 $\pm$ 0.33	1.21 $\pm$ 0.01 $\pm$ 0.19	0.55 $\pm$ 0.01 $\pm$ 0.09
$\epsilon_{t\bar{t}} \int$ L dt	3.77 $\pm$ 0.23 $\pm$ 0.58	1.95 $\pm$ 0.12 $\pm$ 0.32	0.82 $\pm$ 0.05 $\pm$ 0.15

- Background estimate:
  - Mistags: predicted by the negative tag rate matrix
  - non-W: derived from the complementary regions of $\not\!\!E_T$ vs lepton isolaton
  - W+HF: estimated using W+HF MC to

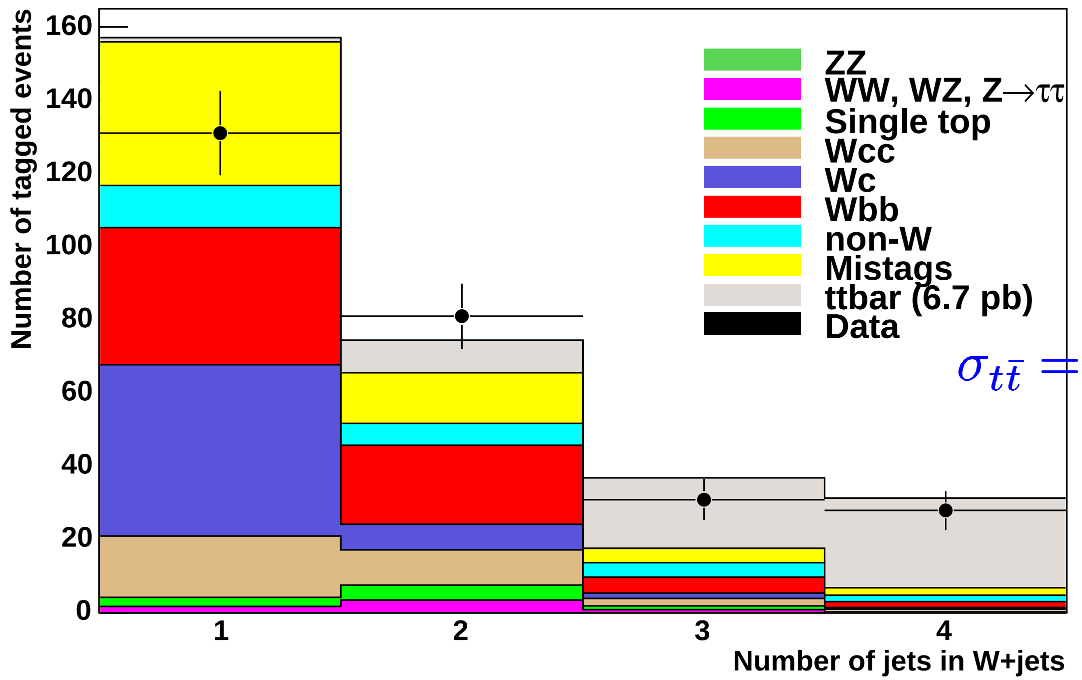
  $\rightarrow$ extract the HF fractions from $\frac{W+HF}{W+Jets}$ MC and the b-tag efficiencies

  $\rightarrow$ normalized to W+jets pretag data
  - Diboson, Z $\rightarrow \tau\tau$ and single top derived from MC

$t\bar{t}$ Cross Section Measurement: Backg. Summary

Jet Multiplicity	1 jet	2 jet	3 jet	$\geq$ 4 jets
MC Derived Backgrounds				
WW	0.753 $\pm$ 0.127	1.553 $\pm$ 0.259	0.437 $\pm$ 0.075	0.088 $\pm$ 0.017
WZ	0.539 $\pm$ 0.095	1.051 $\pm$ 0.180	0.319 $\pm$ 0.059	0.057 $\pm$ 0.015
ZZ	0.036 $\pm$ 0.008	0.078 $\pm$ 0.015	0.043 $\pm$ 0.009	0.009 $\pm$ 0.003
Z$\tau^+\tau^-$	0.473 $\pm$ 0.185	0.814 $\pm$ 0.256	0.172 $\pm$ 0.104	0.052 $\pm$ 0.053
Single Top (W^*)	0.538 $\pm$ 0.094	1.783 $\pm$ 0.312	0.558 $\pm$ 0.098	0.131 $\pm$ 0.024
Single Top (W-g)	1.907 $\pm$ 0.326	2.429 $\pm$ 0.414	0.498 $\pm$ 0.087	0.075 $\pm$ 0.015
Total	4.245 $\pm$ 0.774	7.708 $\pm$ 1.388	2.027 $\pm$ 0.382	0.412 $\pm$ 0.090
W + HF				
Wbb	37.52 $\pm$ 12.32	21.53 $\pm$ 6.80	4.43 $\pm$ 1.27	1.56 $\pm$ 0.50
Wc$\bar{c}$	16.77 $\pm$ 5.91	9.57 $\pm$ 1.96	1.96 $\pm$ 0.64	0.71 $\pm$ 0.25
Wc	46.74 $\pm$ 13.50	7.00 $\pm$ 2.06	1.48 $\pm$ 0.43	0.41 $\pm$ 0.13
Total	101.0 $\pm$ 29.5	38.10 $\pm$ 10.03	7.87 $\pm$ 1.99	2.69 $\pm$ 0.76
Others				
Mistag	$39.2^{+8.6}_{-2.6}$	$13.78^{+3.38}_{-1.65}$	$4.00^{+0.91}_{-0.24}$	$1.99^{+0.47}_{-0.15}$
Non W	11.41 $\pm$ 6.17	5.95 $\pm$ 3.29	3.86 $\pm$ 2.24	1.80 $\pm$ 1.17
Total Background	$155.85^{+31.70}_{-30.62}$	$65.53^{+11.83}_{-11.46}$	$17.76^{+3.28}_{-3.16}$	$6.89^{+1.50}_{-1.43}$
$t\bar{t}$ (6.7 pb^{-1})	1.18 $\pm$ 0.20	8.99 $\pm$ 1.53	19.10 $\pm$ 3.25	24.51 $\pm$ 4.17
DATA	131	81	31	28

$t\bar{t}$ Cross Section Measurement: Results



$$\sigma_{t\bar{t}} = 5.8^{+1.3}_{-1.2}(stat) \pm 1.3(syst)\ pb$$

(Top mass $175\ GeV/c^2$)

- Correlations in acceptance, tagging scale factor and luminosity uncertainties
- Wbb and Wcc correlated across all the bins
- Rest of the errors treated as uncorrelated

Source	Fract. Sys. Uncert.	Contrib. to $\sigma_{t\bar{t}}$
MC Acceptance Modelling	8.7%	8.9%
Tagging Scale Factor (b's/c's)	13/20%	16.6%
Mistag Matrix Prediction	+20%	-3.1%
Non W Fraction	50%	0.8%
Non W Prediction	50%	7.4%
W+HF Prediction	30%	6.1%
MC derived (σ's)	1.8%	0.1%
Luminosity	5.9%	6%
Total Syst. Uncert.		$\pm$22%

Summary

- We have described a tagging algorithm (JP) which is based on the information of the track impact parameter and that provides a continous variable to discriminate HF jets

- We characterize the algorithm by measuring, from data, its efficiency and mistag rates. We obtain an efficiency of 57.24 $\pm$ 3.86 % for $t\bar{t}$ events (JP $<$ 1%)

- We use this algorithm in the Lepton+Jets sample to calculate the $t\bar{t}$ production cross section

$$\sigma = 5.8^{+1.3}_{-1.2}(stat) \pm 1.3(syst) \text{ (Top mass } 175 GeV/c^2\text{)}$$

- The tagger algorithm is in place for the new sample of 318 pb^{-1} and the analysis is underway

BACK-UP SLIDES

Jet Probability Efficiency: Method

- Measured using an 8 GeV inclusive electron data sample and a generic 2→2 Herwig MonteCarlo sample
- Single tag method: $\epsilon = \frac{N_{ej}^{+} - N_{ej}^{-}}{N_{ej}} \cdot \frac{1}{F_B}$

  - Disadvantage: relays on the correct determination of the heavy flavor fraction in the sample
- Double tag method: sample of events with two jets

$$\epsilon = \frac{(N_{a+}^{e+} - N_{a+}^{e-}) - (N_{a-}^{e+} - N_{a-}^{e-})}{N_{a+} - N_{a-}} \cdot \frac{1}{F_B^a}$$

- Calculation of the heavy flavor content in the jet (F_B) has to be corrected for the contribution from charm (determined from MC): $F_B = F_b(1 + \lambda_{c/b})$

  - F_b from $D^0 \to K\pi$ decays: $F_b = \frac{N_{D^0}}{N_{ej}} \cdot \frac{1}{\epsilon_{D^0}}$

  - F_b from cascade muons: select b-hadrons with 2 semiletonic decays (b $\to$ c $\to$ X) emitting a pair e-μ with opposite charge:

$$F_b = \frac{1}{\epsilon_\mu} \frac{N_{ej}^{\mu}(OS) - N_{ej}^{\mu}(SS)}{N_{ej}}$$

Tag Rate Matrix Definition

Bin	E_T (GeV)	Trk. Mult.	$\sum E_T^{\text{jets}}$ (GeV)	$\lvert\eta\rvert$	$\lvert Z_{\text{vtx}}\rvert$ (cm)	ϕ
1	[0,20)	2	[0,80)	[0,1.0)	[0,10)	$[\frac{-\pi}{12},\frac{\pi}{12})$
2	[20,35)	3	[80,140)	≥ 1.0	[10,20)	$[\frac{\pi}{12},\frac{3\pi}{12})$
3	[35,50)	4,5	[140,220)		[20,40)	$[\frac{3\pi}{12},\frac{5\pi}{12})$
4	[50,65)	6,7	≥ 220		[40,50)	$[\frac{5\pi}{12},\frac{7\pi}{12})$
5	[65,80)	8,9			[50,60)	$[\frac{7\pi}{12},\frac{9\pi}{12})$
6	[80,100)	10-13			≥ 60	$[\frac{9\pi}{12},\frac{11\pi}{12})$
7	[100,120)	≥ 14				$[\frac{11\pi}{12},\frac{13\pi}{12})$
8	[120,150)					$[\frac{13\pi}{12},\frac{15\pi}{12})$
9	[150,180)					$[\frac{15\pi}{12},\frac{17\pi}{12})$
10	≥ 180					$[\frac{17\pi}{12},\frac{19\pi}{12})$
11						$[\frac{19\pi}{12},\frac{21\pi}{12})$
12						$[\frac{21\pi}{12},\frac{23\pi}{12})$