Measurement of ttbar Production Cross Section using Lifetime Tagging at Run II

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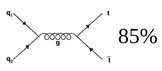
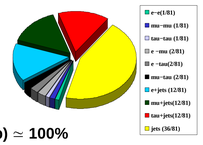
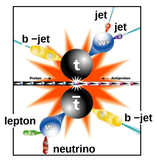
Top Quark Production and Decay



In proton−antiproton collisions at Tevatron energies of 1.96 GeV, top quarks are primarily produced in pairs



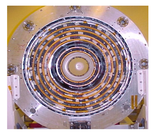


BR(t −> Wb) ≃ 100%

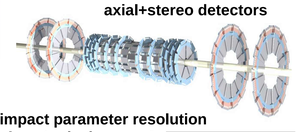
Final states are determined by the decay mode of the W

New Run II Central Tracking System

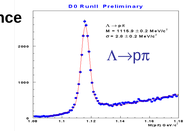
Central **F**iber **T**racker:
8 axial layers
8 stereo layers



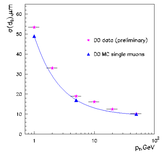
Silicon **M**icrostrip **T**racker:
4 barrel layers
12+4 disks
axial+stereo detectors



Λ resonance

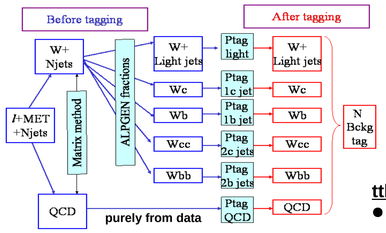


impact parameter resolution close to design



Method Overview

Predictions seperately for different W+jets topologies and QCD



W+jets Preselection

	μ+jets	e+jets
	• ν: missing E_T > 20GeV	
	μ:	electron:
	• p_T > 20GeV	• E_T > 20GeV
	• track match	• isolation
loose	• loose isolation	•
tight	• tight isolation	• track match

$\varepsilon_{sig\,/\,QCD}$

Matrix Method

single out W+ttbar and QCD

$N^{loose} = N^{W+ttbar} + N^{QCD}$

$N^{tight} = \varepsilon_{sig} N^{W+ttbar} + \varepsilon_{QCD} N^{QCD}$

Lifetime Tagging

- tagging proceeds in 2 steps
  1) taggability
  2) tagging efficiency
- the event is tagged if at least one jet is tagged
- apply 2 lifetime tagging algorithms
  - SVT (Secondary Vertex Tagger)
  - CSIP (Counting Signed Impact Parameter)

ttbar Production Cross Section Determination

- look for an excess over background in the number of observed tagged events with 3 and ≥ 4 jets

Taggability

Absorb all instrumental inefficiencies: calorimeter noise, tracking inefficiency

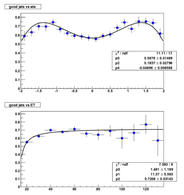
Probability for a Jet to be Taggable

at least 2 tracks matched to jet with
- p_T > 0.5 GeV
- minimum number of hits in the SMT detector
- good track χ^2

- Measure taggability in the preselected W+jets data samples
- Parametrize as a fuction of jet E_T and jet η
- Obtain 2D parametrization

$$P^{taggable}(E_T,\eta) = \frac{N^{taggable}(E_T,\eta)}{N^{total}(E_T,\eta)}$$

by folding 1D parametrizations



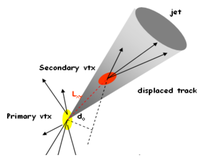
Cross check 2D parametrization by applying it back to the data

Lifetime Tagging Algorithms

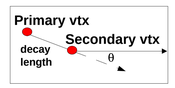
- Lifetime tagging requires a good reconstruction of the Primary Vertex (PV)
  - number of tracks associated to PV > 2
  - $|z_{PV}|$ < 60cm

SVT

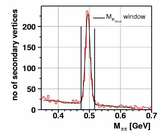
a displaced vertex is found associated to the jet with:
- a good fit (χ^2<10)
- 2 or more tracks
- signed decay length significance > 5 / < −5
- collinearity (= cos θ) > 0.9



A jet is (positively) tagged as b−jet if
A jet is negatively tagged if

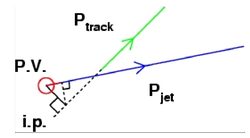


- Secondary Vertex / CSIP tracks incompatible with originating from a long lived particle: K_{short}, Λ, photon conversion (γ −> e^+e^-)



CSIP

it has at least:
- two tracks with impact parameter significance > 3 / < −3 or
- three tracks with impact parameter significance > 2 / < −2

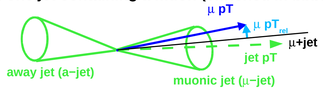


B−Tagging Efficiency in Data

Probability for a taggable jet to be tagged

$$\varepsilon_{tag}(E_T,\eta) = \frac{N_{jet}^{tagged}(E_T,\eta)}{N_{jet}^{taggable}(E_T,\eta)}$$

Use events with one jet containing a muon (enriched in bbbar)



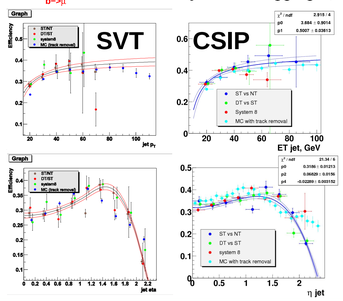
Measure semileptonic b−tagging efficiency ($\varepsilon_{b->\mu}^{data}$) for the μ−jet by measuring
- $N_{\mu-jet}$: the number of μ−jets
- $N_{\mu-jet}^{tag}$: the number of tagged μ−jets
- $F_{b->\mu}$: fraction of b−jets before tagging
- $F_{b->\mu}^{tag}$: fraction of b−jets after tagging

} performing a fit to the μ pT_{rel} distribution

$\varepsilon_{b->\mu}^{data} = (N_{\mu-jet}^{tag} F_{b->\mu}^{tag}) / (N_{\mu-jet} F_{b->\mu})$ (ST/NT)

Cross check $\varepsilon_{b->\mu}^{data}$
- in a subsample where the a−jet is tagged (further enriched in bbbar) (DT/ST)
- with a different method making use solely of data (System8)

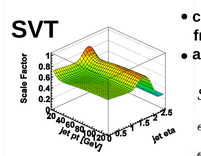
All measurements are in good agreement



Average b−tagging efficiency

CSIP	SVT
(36.3±1.9)%	(31.9±1.6)%

Monte Carlo (MC) to Data Calibration



- calibrate inclusive b− and c−tagging efficiency from MC to data introducing a scale factor (*SF*)
- assume that $SF_c = SF_b = SF_{b->\mu}$

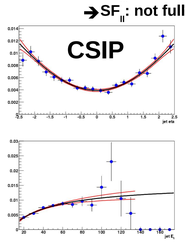
$$SF_{b->\mu}(E_T,\eta) = \frac{\varepsilon_{b->\mu}^{data}/MC}{\varepsilon_{b->\mu}}$$

$$\epsilon_c(E_T,\eta) = \epsilon_c^{MC}(E_T,\eta) SF_c(E_T,\eta)$$

$$\epsilon_b(E_T,\eta) = \epsilon_b^{MC}(E_T,\eta) SF_b(E_T,\eta)$$

Mistagging Efficiency

mistag = positive tag of a **light flavor jet** (ε_l^+)
- measure from the rate of negatively tagged jets (ε^-) (dominated by resolution) in generic QCD
- correct for
  - ➔SF_{hf}: heavy flavor (higher negative tagging rate)
  - ➔SF_{ll}: not fully removed long lived particles (K_{short}, Λ, γ −> e^+e^-)



$\varepsilon_l^+ = SF_{hf} \times SF_{ll} \times \varepsilon^-$ from MC

SVT : 1.11 ± 0.08
CSIP: 1.09 ± 0.09

Average mistagging efficiency

CSIP	SVT
(0.69±0.06)%	(0.44±0.03)%

Observation vs. Expectation

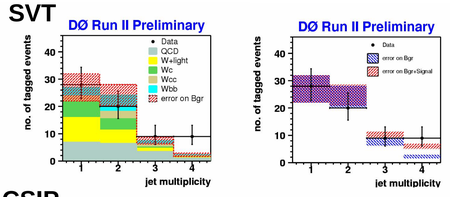
Predictions

- W+jets background and ttbar signal
  - flavor composition in W+jets from ALPGEN MC
  - event tagging probabilities from MC with calibrated tagging efficiencies and mistag rate from data
- QCD background
  - from generic QCD data sample and matrix method

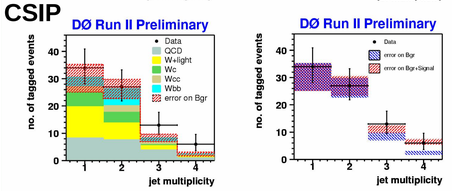
ttbar tagging probability

lepton+≥4jets	CSIP	SVT
	(45.7±4.9)%	(41.8±4.7)%

SVT



CSIP



SVT : tagged events

lepton + jets	1 jet	2 jet	3 jet	≥ 4 jet
W + jets	20.1 ± 4.8	17.8 ± 3.7	4.0 ± 1.1	1.3 ± 0.5
QCD	6.9 ± 1.5	6.4 ± 1.1	3.5 ± 0.7	1.1 ± 0.3
Total bkgr	27.0 ± 5.0	24.2 ± 3.9	7.5 ± 1.3	2.4 ± 0.6
Expected $t\bar{t}$		0.6±0.1	2.5 ± 0.2	3.7 ± 0.5
Bkgr + $t\bar{t}$	27.0 ± 5.0	24.8 ± 3.9	10.1 ± 1.3	6.1 ± 0.9
Before tag	3681	1351	298	65
tagged	28	20	9	9

CSIP : tagged events

lepton + jets	1 jet	2 jet	3 jet	≥ 4 jet
W + jets	22.3 ± 4.7	18.7 ± 3.4	4.4 ± 0.9	1.4 ± 0.4
QCD	8.2 ± 1.4	7.6 ± 1.2	3.9 ± 0.9	1.1 ± 0.4
Total bkgr	30.6 ± 5.0	26.4 ± 3.5	8.3 ± 1.3	2.5 ± 0.7
Expected $t\bar{t}$		0.7±0.1	2.8 ± 0.2	4.0 ± 0.6
Bkgr + $t\bar{t}$	30.6 ± 5.0	27.1 ± 3.6	11.1 ± 1.4	6.5 ± 1.0
Before tag	3681	1351	298	65
tagged	34	27	13	6

ttbar Cross Section

SVT : $\sigma_{t\bar{t}} = 10.8^{+4.9}_{-4.0}\,(\text{stat})\,^{+2.1}_{-2.0}\,(\text{syst}) \pm 1.1\,(\text{lumi})$ pb;

CSIP : $\sigma_{t\bar{t}} = 7.4^{+4.4}_{-3.6}\,(\text{stat})\,^{+2.1}_{-1.8}\,(\text{syst}) \pm 0.7\,(\text{lumi})$ pb.

Luminosity : 40.0 pb^{-1} (μ+jets)
49.5 pb^{-1} (e+jets)

26 different sources of systematic uncertainties taken into account associated with

Largest uncertainties

- Selections — MC statistics (0.7−0.9 pb); N_W and N_{QCD} in data (~0.8 pb)
- Object identification — Jet Energy Scale (1.3 pb)
- Tagging efficiencies — Semileptonic b−tagging efficiency in MC (0.5−0.8 pb) in data (~0.5 pb)
- MC — Gluon splitting in HERWIG (~0.5 pb)