t-tbar cross-section at Tevatron

Lepton + jets channel

Anton Kapliy

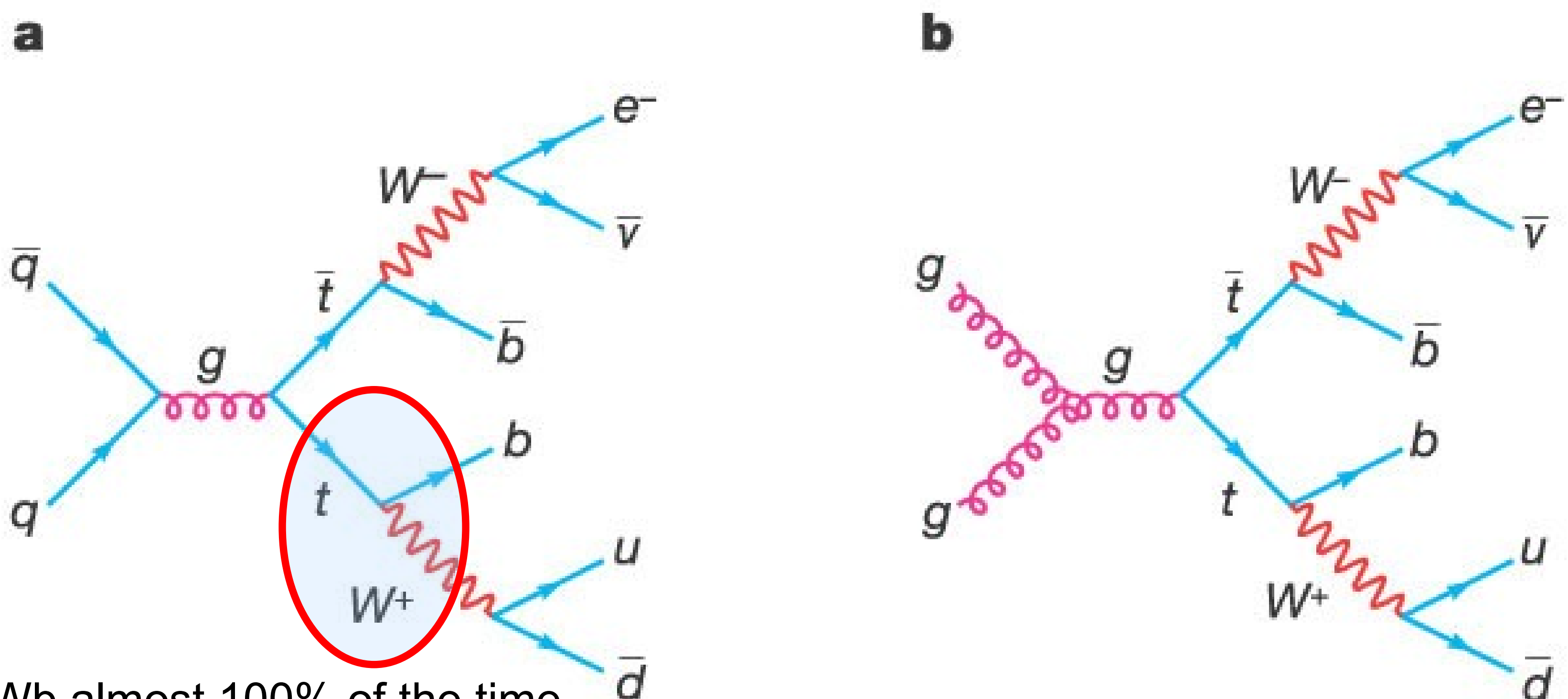
2009

DAY 1

Top quark: production and decay

Quark-antiquark annihilation

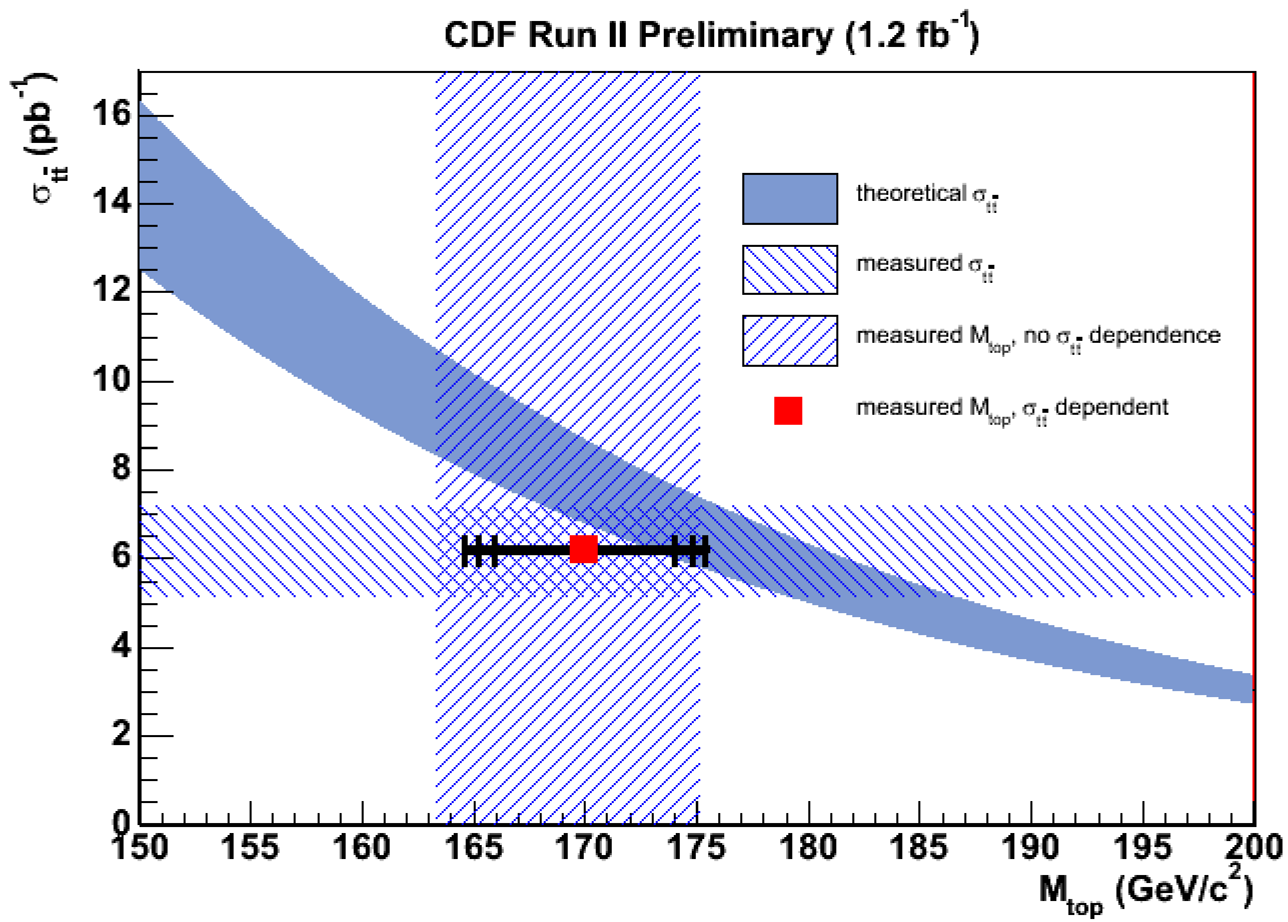
Gluon fusion (~10%)



t->Wb almost 100% of the time

High-Pt lepton, missing Et, three or more jets, at least one of which is b-tagged

Theoretical prediction



Computed to NLO + soft gluon emission corrections
Leading theoretical uncertainty: PDF's (gluons at large x)
For every 1 GeV increase in Mtop, xsection decreases by 0.2 pb

II-a. Charged particle tracking

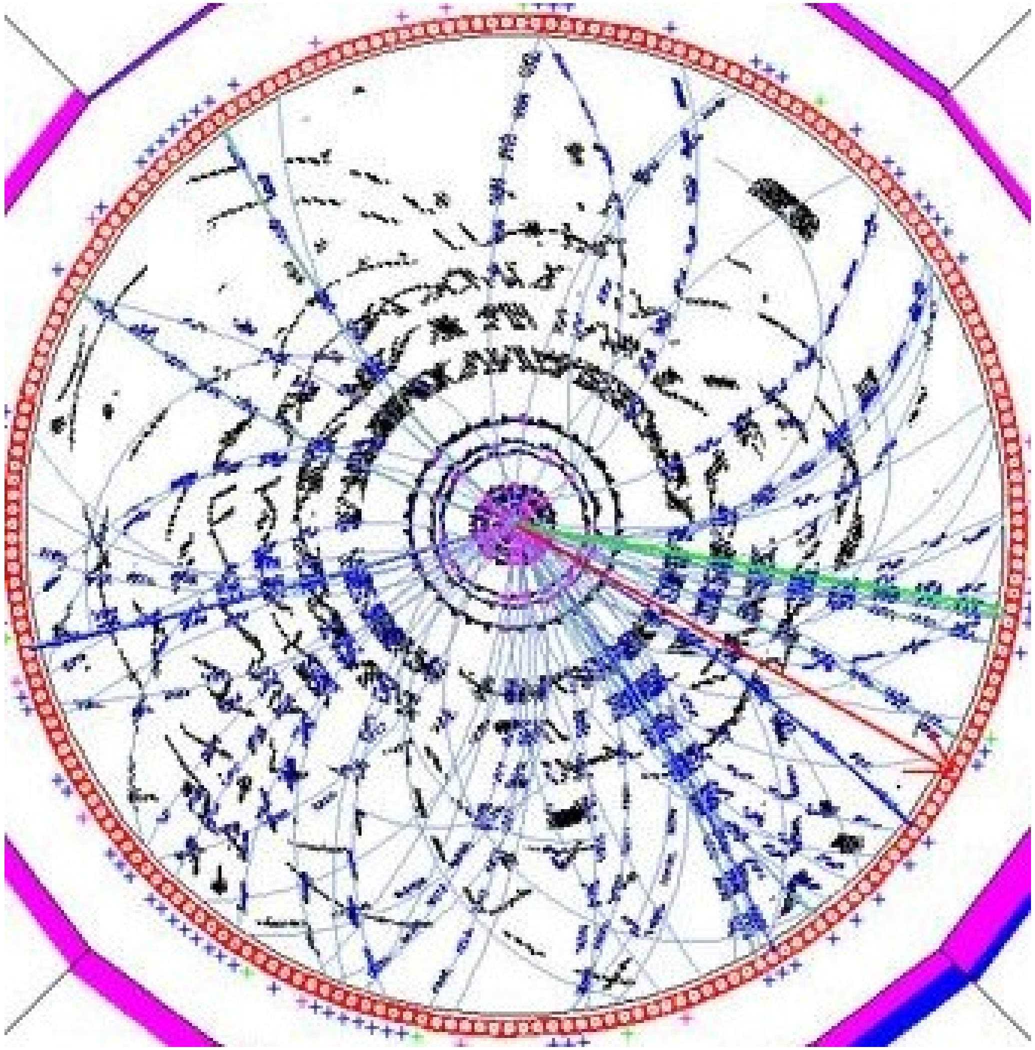
<u>SVX</u> (silicon microstrips):
5 double-sided layers; +stereo
R = 2.5 – 11 cm
Eta < 2.0
Hit resolution: 11 microns
+ ISL (intermediate silicon layers)

<u>COT</u> (drift chamber) & XFT (LUTs):
8 superlayers w/ 12 wires; +stereo
R<1.4 meters
Eta < 1.0
Hit resolution: 140 microns
Electron eff: 99.93% (via W->ev)

Axial B-field = 1.4T
=> Pt measurement

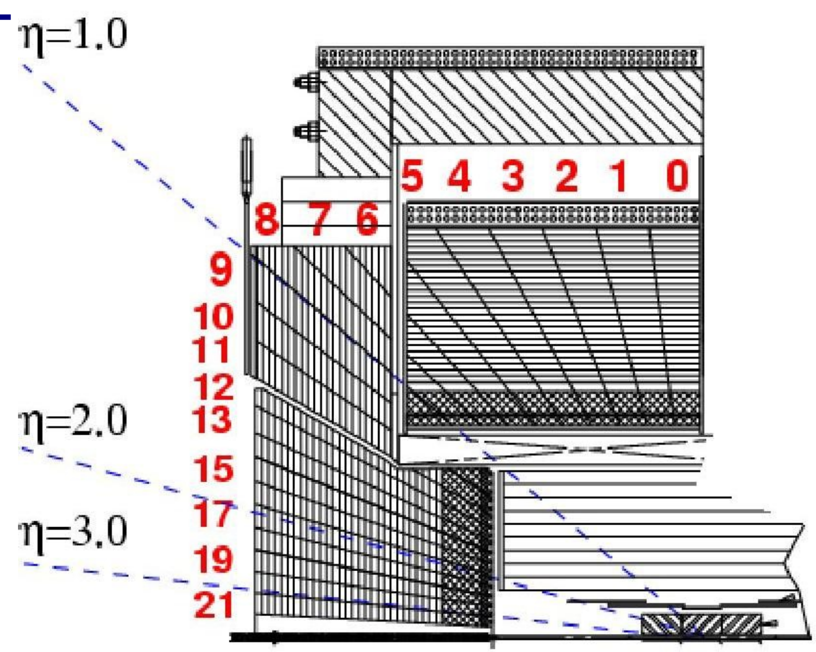
SVX+COT combined *outside-in*:
[Extrapolate and refit]

Final IP resolution: 30 microns



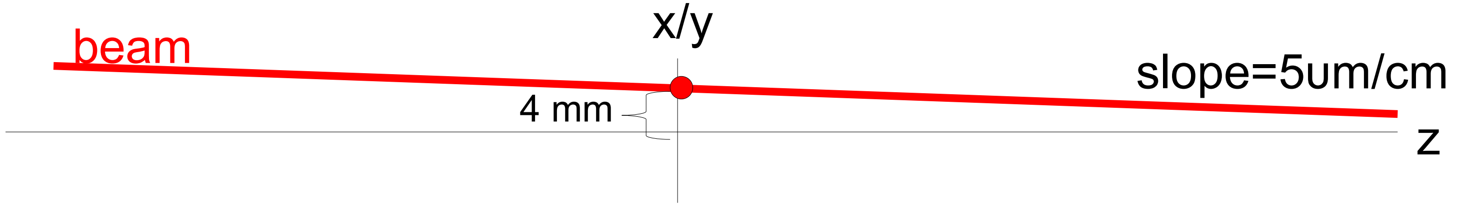
II-b/c. Calorimetry and muons

- Outside of the tracker and solenoid
- Eta < 3.6
- Electrons: isolated EM clusters in CEM matching XFT track
  - $\frac{\sigma(E_T)}{E_T} = 13.5\%/\sqrt{(E_T/GeV)} + 2\%$
- Jets use cone: 0.4
- Standard jet energy corrections
- Jet energy resolution:
  - $(0.1(E_T/GeV + 1.0))GeV$
- Muons are of two types:
  - *CMX* – eta = 0.6..1.0
  - *CMUP* – eta<0.6



Beam profile and primary vertex

- B-hadrons have longer lifetime
  - B-jets are displaced from primary vertex
- Primary vertex: source of all prompt tracks
  - Must be reconstructed in |z|<60 cm region
  - With pileup, avg of 1.4 / evt (separated in z)
- Luminous region:
  - σ_z=29 cm; σ_R=30-60 microns (depends on z)
  - Beamline neither parallel nor centered:

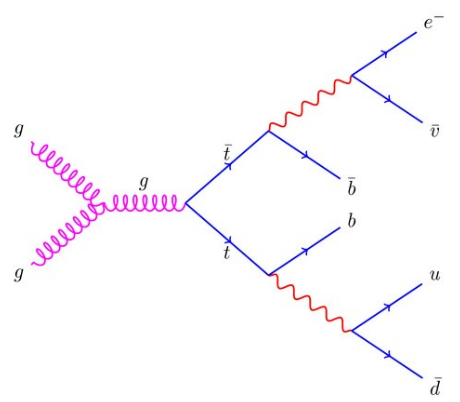


III-a. Beam data

- March 2002 – August 2003
- Instantaneous Lumi = 0.4 – 4.0 x 10^{31}
  - As usual, measured by Cherenkov at large eta
- Total lumi: 150 (CMX) – 162 (CMUP) pb^{-1}
- Trigger: high-P_T electrons or muons
  - XFT (COT) track matched to EM or muons
  - P_T>8GeV, E_T>16GeV, had/ev<0.125 (for e^-)
- Q: why not require E_T-miss or jet triggers?

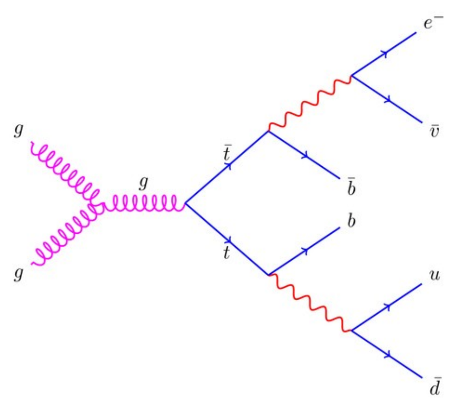
III-b. MC samples

- Pythia and Herwig with CTEQ5L PDF's
  - LO hard scatter + parton showering
- For b-tagging (Wbbar): Alpgen
  - High-multiplicity final states using exact ME
- GEANT+GFLASH, as usual



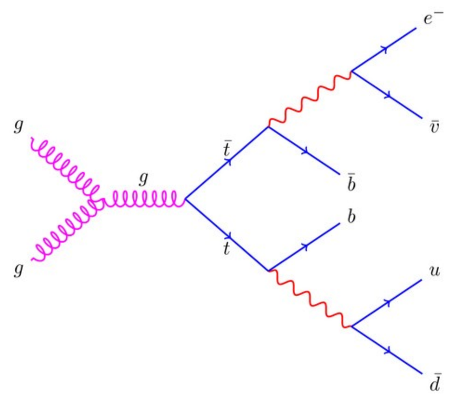
III-c. W+Jets selection (1)

- Electrons:
  - E_T>20GeV matched to track with P_T>10GeV
  - EM cluster shower shape cuts
  - Isolation requirement in cone of 0.4: <0.1
- Photon conversion: electron background
  - Reject e^+ + e^- tracks consistent w/ conversion
- Muons:
  - COT track > 20GeV matching CMUP/CMX
  - Extrapolate from outside to inside; veto cosmics



III-c. W+Jets selection (2)

- Neutrino:
  - Missing E_T from calo towers > 20 GeV
  - If muon is found, subtract its E_T and add its P_T
- Dilepton top decay and Z decay supression:
  - Require only one lepton
  - Invariant mass of leptop+"object" != 76..106 GeV
  - "object" is isolated track, EM cluster, jet
- Require at least one jet – see next page



III-c. W+Jets selection (3)

$$\sigma_{t\bar{t}} = (N_{\rm obs} - N_{\rm bkg})/(\epsilon_{t\bar{t}} \times \mathcal{L})$$

- Jets: E_T>15 GeV, |eta|<2.0
- If >=3 jets:
  - Electron acceptance*efficiency = 4%
  - Muon acceptance*efficiency = 1%(CMX)/2%(CMUP)

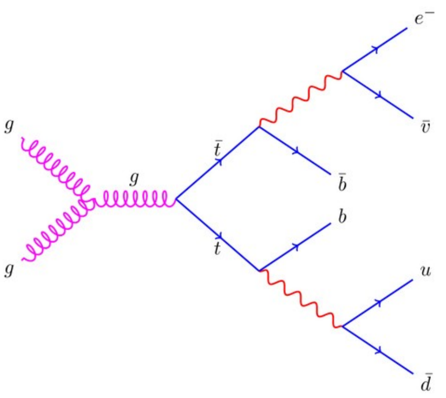
TABLE I: Number of events selected, before b-tagging, for each jet multiplicity.

	$W+1$ jet	$W+2$ jets	$W+3$ jets	$W+4$ jets	$W+3$ jets	$W+4$ jets
			$H_T>0$		$H_T>200$ GeV	
Electrons	8828	1446	241	70	117	63
Muons	6486	1002	146	37	63	28

Sum E_T

Top contribution negligible; BG cross-check

Expect excess due to top decay

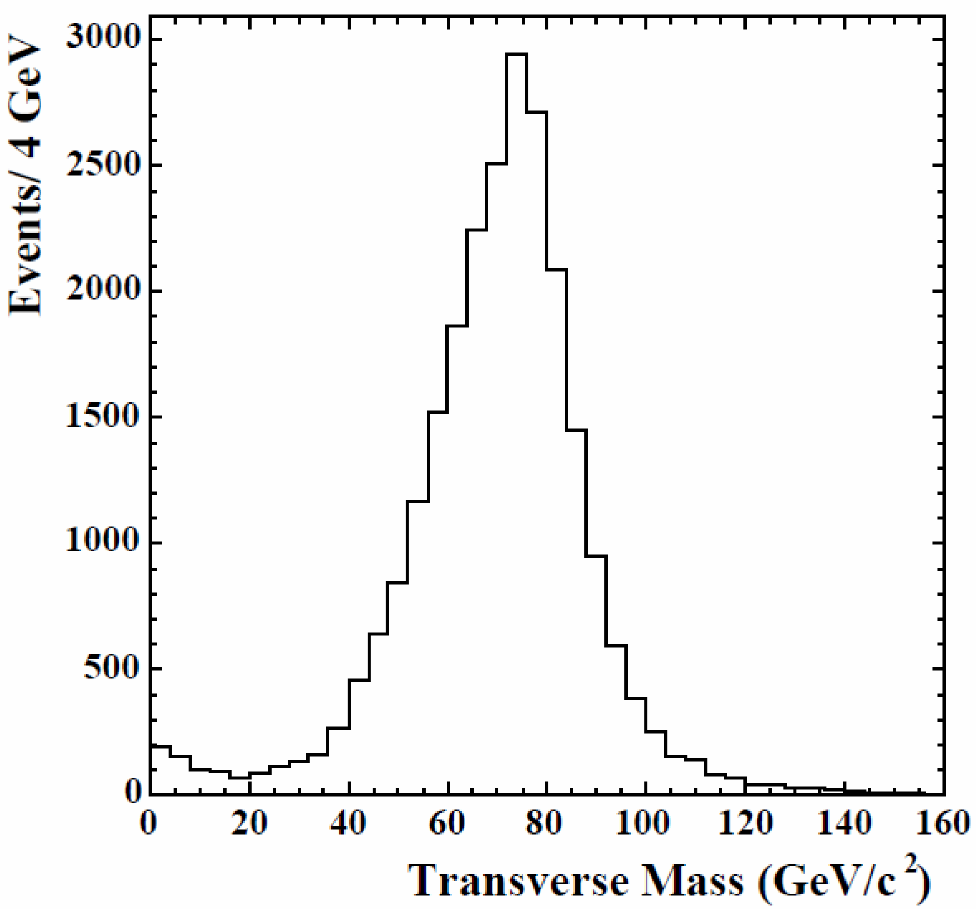


III-c. W+Jets selection (4)

- W mass: leptop mass + E_T miss

Require M_T to be consistent with W.

But is there an actual cut?



IV. B-tagging

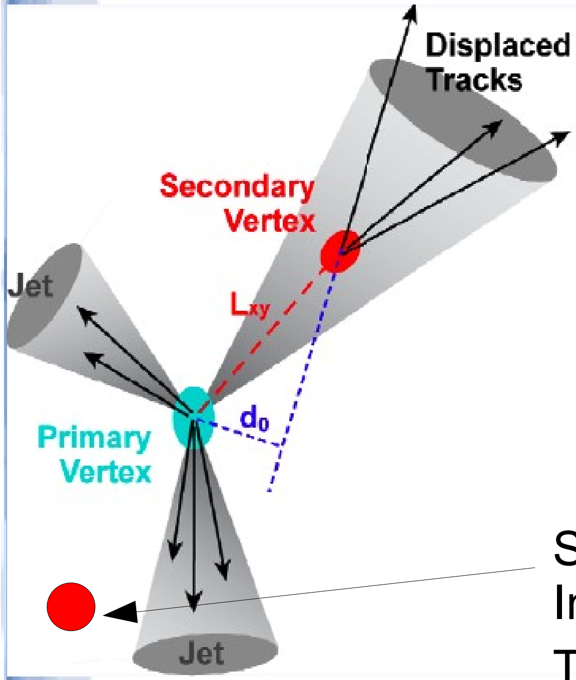
- Most non-signal events in W+jets don't have b/c
- SecVtx algorithm allows to tag heavy jets
  - Basic idea: presence of displaced vertex with respect to the primary vertex
- Requiring >=1 b-tagged jet:
  - Kills ~50% of t-tbar signal
  - But: kills 95% of BG!
- They seem to only describe offline b-tagging

IV-a. SexVtx algorithm: primary vtx

- Construct a list of vertices from tracks [*how?*]
- Choose a seed vertex: closest to identified lepton, or (without a lepton) highest scalar p_T
- Fit tracks within z=±1cm around seed:
  - With IP significance < 3
  - Remove tracks that contribute chi2>10
  - Repeat with only remaining tracks
- Fitted transverse position uncertainty:
  - 10-32 microns

IV-a. SexVtx algorithm: secondaries

- Operated on per-jet basis
- Takes into account p_T, hits and their quality
- Only considers jets with >=2 “good” tracks
- These tracks are input into SecVtx:



- 1st pass: >=**3** tracks with Pt>0.5 GeV; d/σ>2.5
- 2nd pass:>=**2** tracks with Pt>1 GeV; d/σ>3
- Apply a cut on L_{xy}==L_{2D} being large
- A jet is defined “tagged” if it has a good secondary vertex.

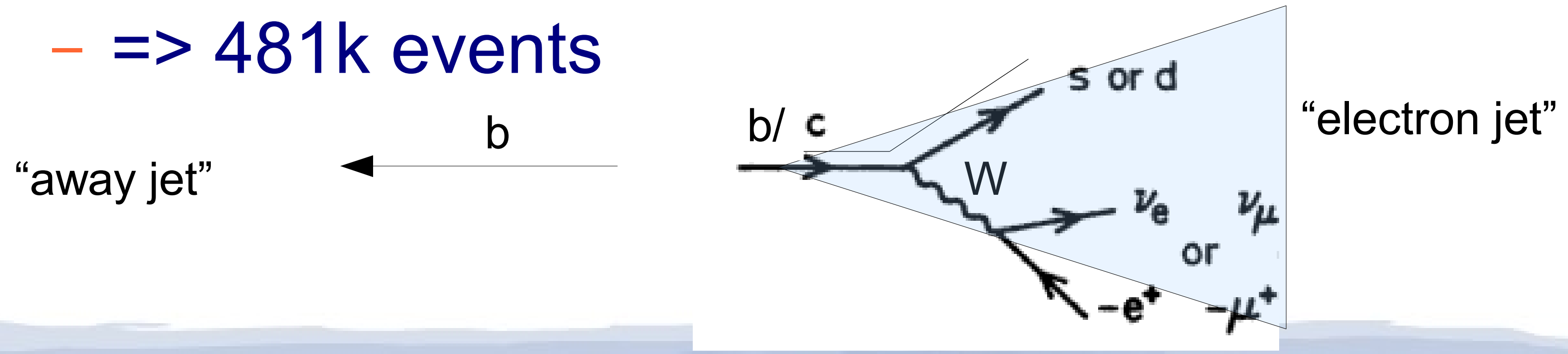
Sometimes secondary vertex is reconstructed here.
In this case, L_{xy} is defined as negative.
These “negative” b-tags are used to study false positives tag rate

IV-b. Tagging efficiencies (1)

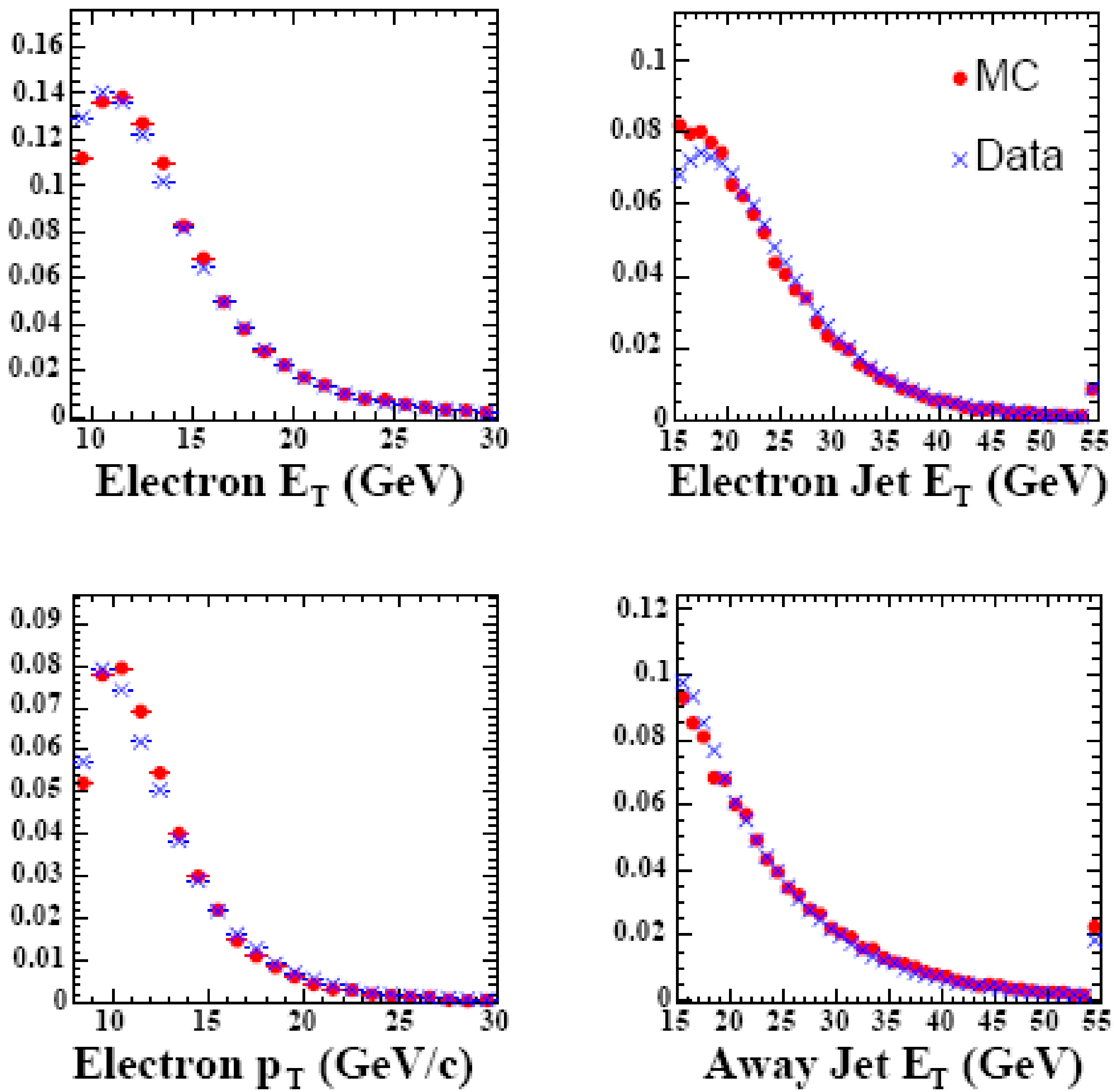
- Need to know how often a b-jet is tagged
- Tagging efficiency depends on eta, jet energy, track multiplicity etc – many parameters
- **Plan**: Use detailed MC to derive geometrical and energy dependence of the tagger
- Use special data sample to derive tagging efficiency in calibration region. Its ratio to MC gives the absolute scale factor to be applied to MC rates in the previous bullet.

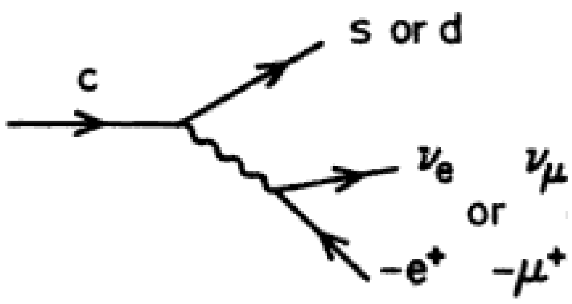
IV-b. Tagging efficiencies (2)

- Tagging efficiency from data (calibration region):
  - Low-PT inclusive electrons enriched in semileptonic b- and c-hadron decays
  - E_T, P_T cut on electrons (9 & 8 GeV) + etc
  - Require two more jets:
    - "Electron" jet >15 GeV, within cone 0.4 of e^-
    - "Away" jet ~ back-to-back with electron jet
  - => 481k events



IV-b. Tagging efficiencies (3)

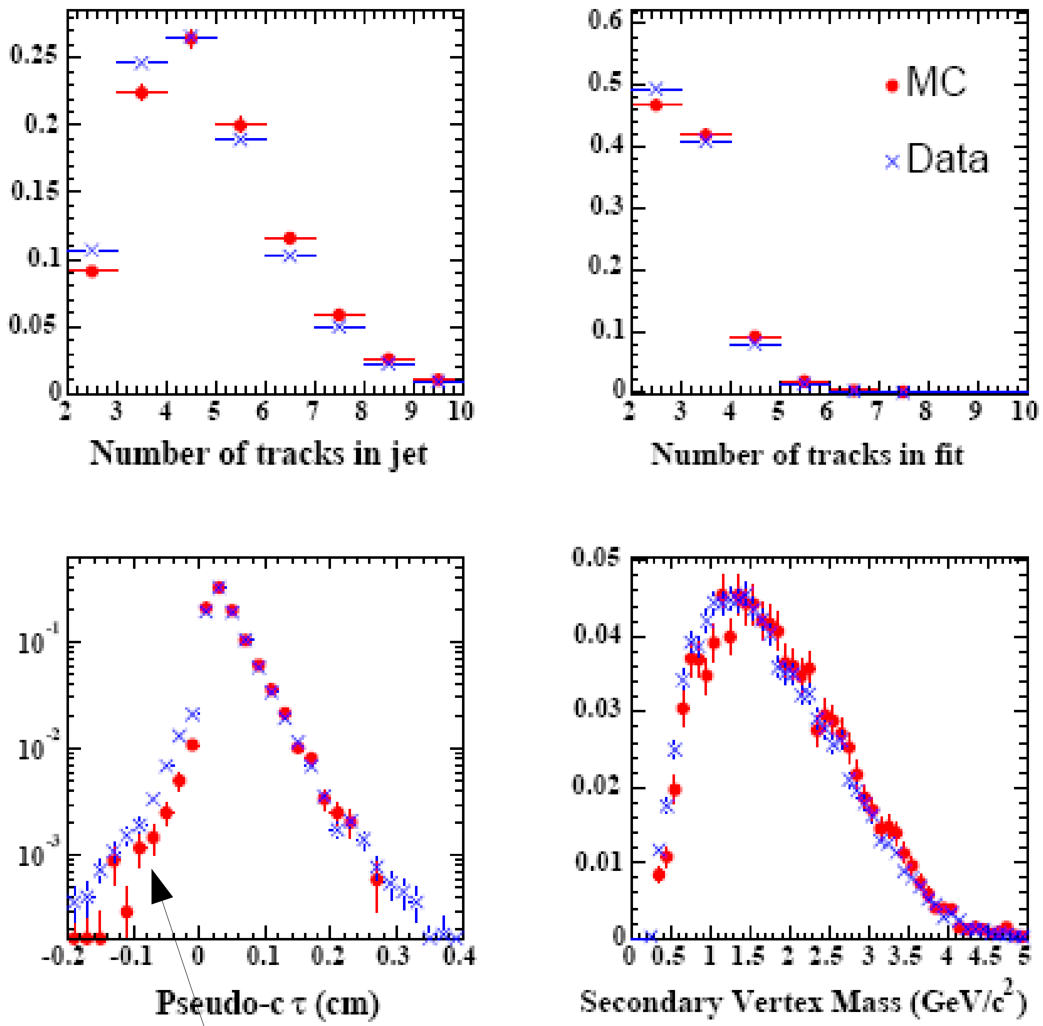


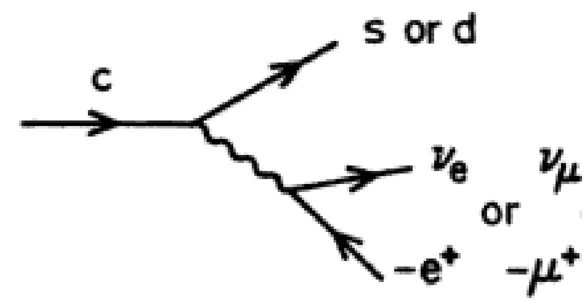


Data -vs- MC

Differences are due to presence of fake e^- in data (but not in MC)

IV-b. Tagging efficiencies (4)





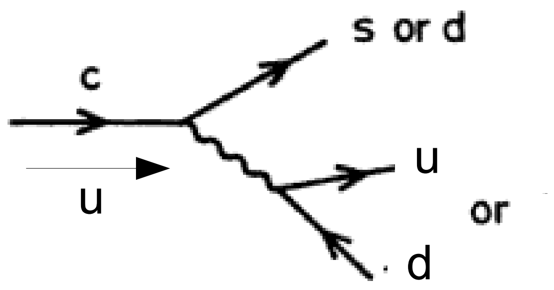
Data -vs- MC (electron jets)

- # good tracks in jet
- # tracks in tagged vertex
- Vertex mass of tagged jets
- Pseudo-ct pos/neg tagged

Differences are due to presence of fake e^- in data (but not in MC)

MC underestimates mistags!

IV-b. Bottom-quark content of e^--jets



- Estimate fraction of b hadrons F_b: $D^0 \to K^- \pi^+$
  - Reconstruct D^0 resonance within e^--jet
  - Use invariant mass sidebands to remove BG-?
- Or: look for secondary muons in e-jet resulting from cascading charm decay (?)
- **F_b=0.161±0.038**

IV-b. Heavy-quark content of e⁻-jets

- $F_{HF}=F_b+F_c=$**0.259±0.064**
- Fit mass spectrum of tracks in pos-tagged jets
- Fit parameter: F_c/F_b

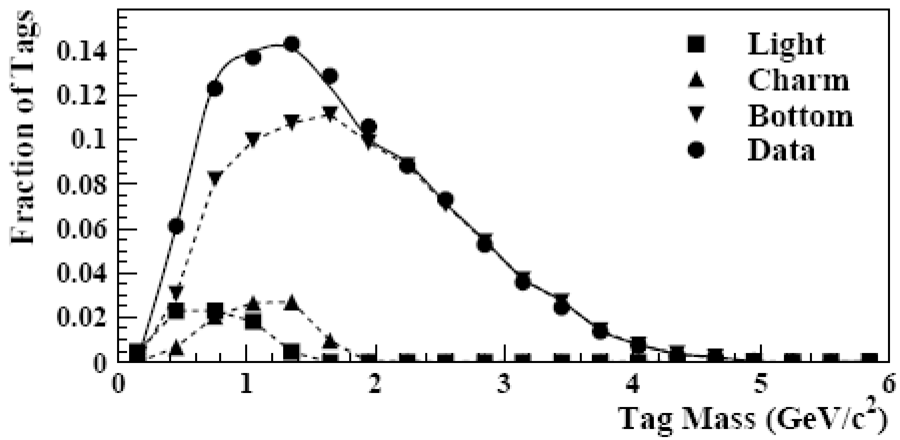


FIG. 4: Fit (solid line) of the relative b and c contributions to the vertex tag mass distribution. Templates for the different flavors are derived from simulation (and the data in the case of light flavor). The error bars for the data are contained within the markers.

IV-b. Tagging efficiencies (5)

- Double-tag technique:
  - Require that away jet is tagged by SecVtx
  - Enhances F_{HF} in electron-jets (see note below)
  - Reduces charm component to 10% of bottom

events with positively tagged electron and away jets

HF due to gluon splitting, or "away" is mistagged

$$\varepsilon = \frac{(N_{a+}^{e+} - N_{a+}^{e-}) - (N_{a-}^{e+} - N_{a-}^{e-})}{(N_{a+} - N_{a-})} \cdot \frac{1}{F_{HF}^{a}}$$

$=0.861$

Fraction of e-jets containing heavy-flavor, given that away jet is tagged.
This is close to one, since having an away b-jet says the event is likely tt
Charm component is also reduced.

IV-b. Tagging efficiency results (1)

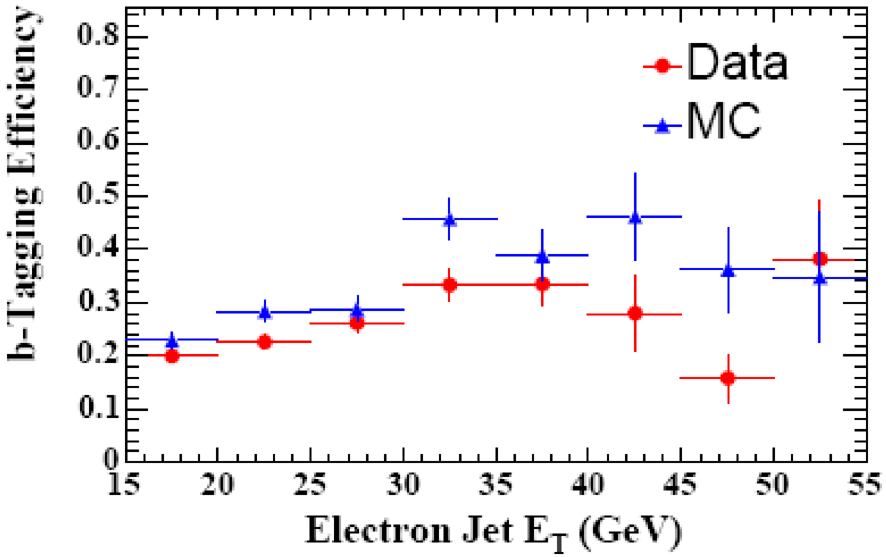
TABLE II: Efficiency to tag a heavy flavor electron jet in data and Monte Carlo, and the data/MC ratio (scale factor). Uncertainties on the efficiencies are statistical only; systematic uncertainties on the scale factor are summarized in Table III.

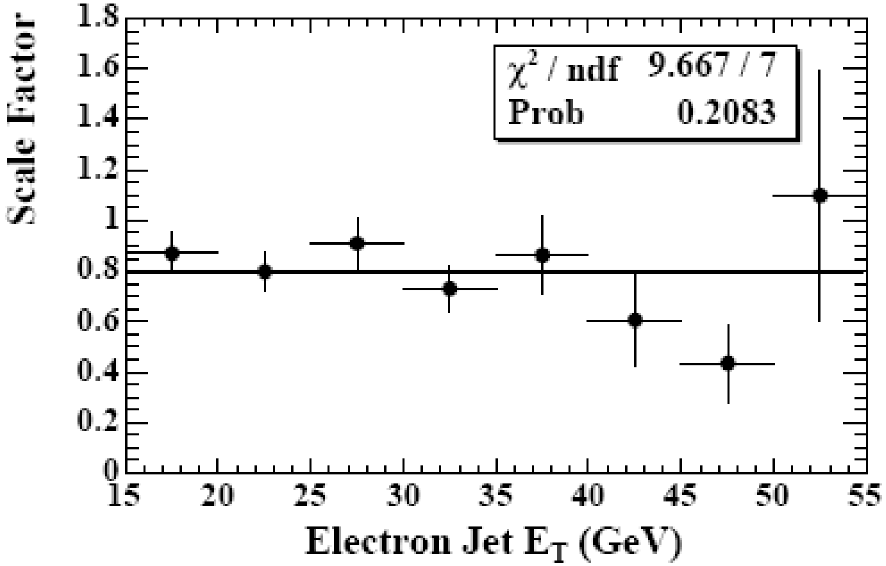
ε(Data)	0.240 ± 0.007
ε(MC)	0.292 ± 0.010
Scale Factor	0.82 ± 0.06

Total systematic uncertainty: 6.2% (mostly F_{HF} estimation)
Total statistical uncertainty: 3.2% for data and 3.6% for MC

Detailed break-down of scale factor uncertainties is in Table III.

IV-b. Tagging efficiency results (2)

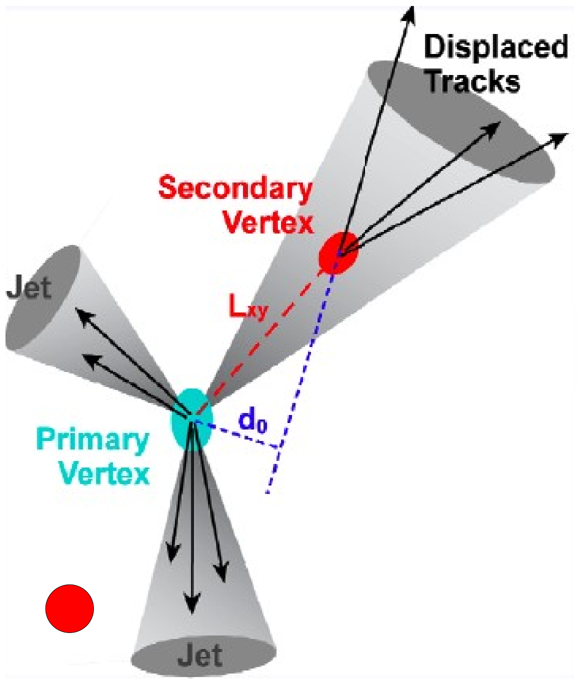




Statistically, E_T independent!

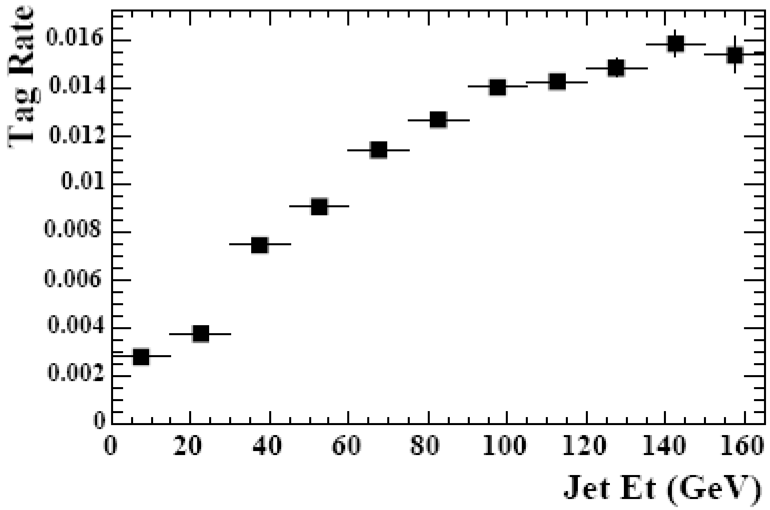
IV-c. Mistag rate

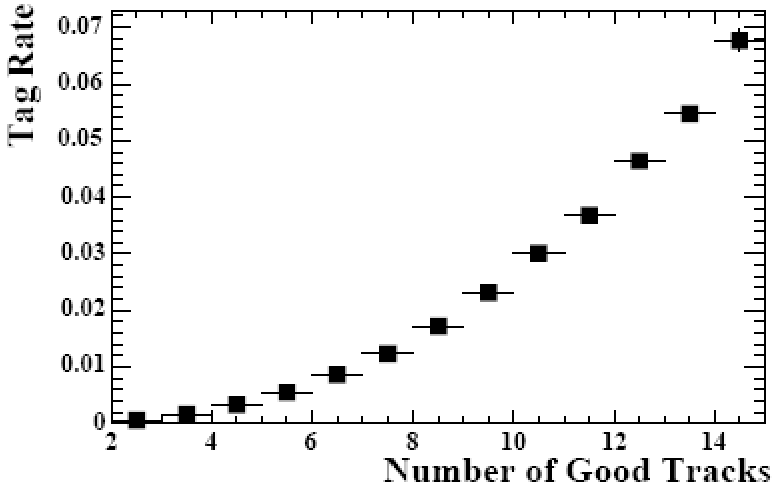
- Mostly caused by tracks that appear displaced due to tracking errors
- SecVtx tags equally well pos and neg L_{xy}
  - Use negative tag rate as an estimate of mistagging
  - But: some of neg tags do contain heavy flavor
    - Correction of ~20%
- Mistag rate parametrized in bins of E_T, track multiplicity, eta, phi, scalar Sum E_T



IV-c. Mistag results

(corrected) negative tag rate





Uncertainty on total mistag rage = 11%

DAY 2

V. W+HF production

- Wbb, Wcc, Wc etc contaminate b-tagged lepton + jets sample, even though W+light flavor dominated BG in pre-tag sample
- MC generators are LO => large absolute uncertainty on overall rate normalization
- **Plan**:
  - overall W+jets rate taken from data
  - Fraction of above with heavy flavor – from MC
- W+HF contribution = # data (pretag) * W+HF fraction * [MC tagging efficiency * scale factor]

V-a. HF MC samples

- Alpgen does matrix element
  - Good for new, separated partons
- Herwig does parton showering
  - Good for softer gluons
- Must be careful to avoid double counting:
  - Shower in W+n -vs- W+(n+1) Alpgen MC
  - Solution: match final state MC to jets
    - Reject events with extra or missing jets
- Compare MC W+jets cross-section with data

V-a. W+jets MC vs data

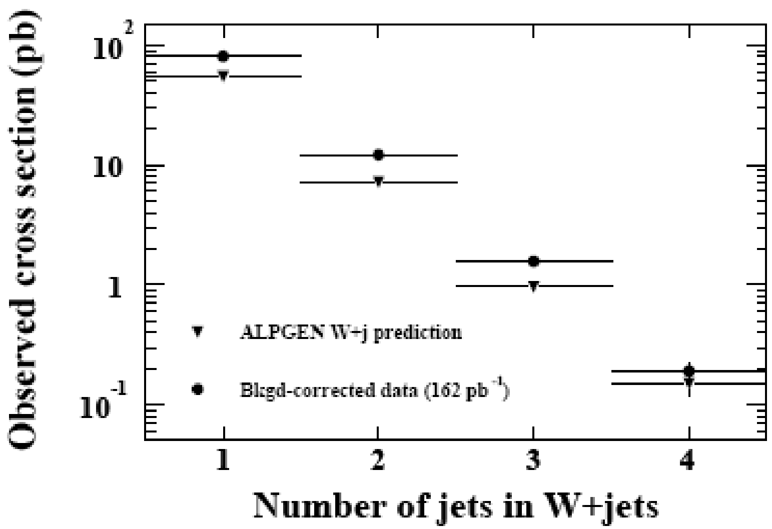


FIG. 8: Observed W + jets cross section compared with the ALPGEN W + jets prediction as a function of number of jets. (Only statistical errors are shown, and the results are not corrected for acceptance.)

Even though overall normalization is off (no correction for acceptance), the jet multiplicity dependence is modeled correctly

V-b. HF fraction in W+jets

- Fraction = W+HF / W+jets cross-sections
- Computed from Alpgen MC

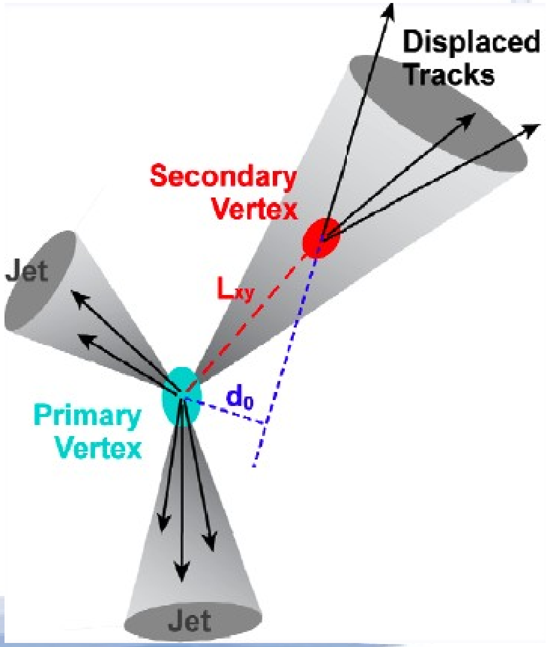
TABLE VI: Summary of systematic uncertainties in the heavy flavor fraction determination.

Source	Uncertainty		
Fractions	Wbb	Wcc	Wc
Matching criteria	15%	15%	10%
Q^2 scale ($2M_W^2$ to $0.5M_W^2$)	4%	4%	5%
PDF	5%	5%	10%
Jet energy scale	5%	5%	10%
ISR/FSR	10%	10%	10%
b, c masses ($4.75, 1.55 \pm 0.3$ GeV$/c^2$)	6%	10%	
Total	21%	22%	21%

What exactly is this scale?

V-c. HF fraction calibration to data

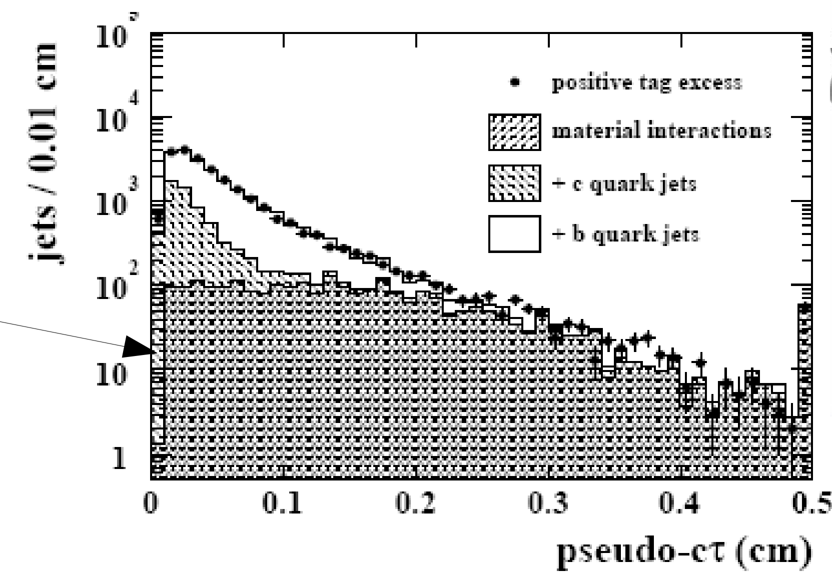
- W+jets data has limited statistics
- Inclusive jets (w/o W) have similar diagrams
  - E.g., same gluon splitting in HF pairs
- Pythia and Alpgen+Herwig MC:
  - 2 or 3 jets with E_T>15 GeV, eta<2
- Pseudo-cτ of tagged jets:
  - $L_{xy} x M_{vtx} / p^T_{vtx}$
  - Different for heavy flavor jets!

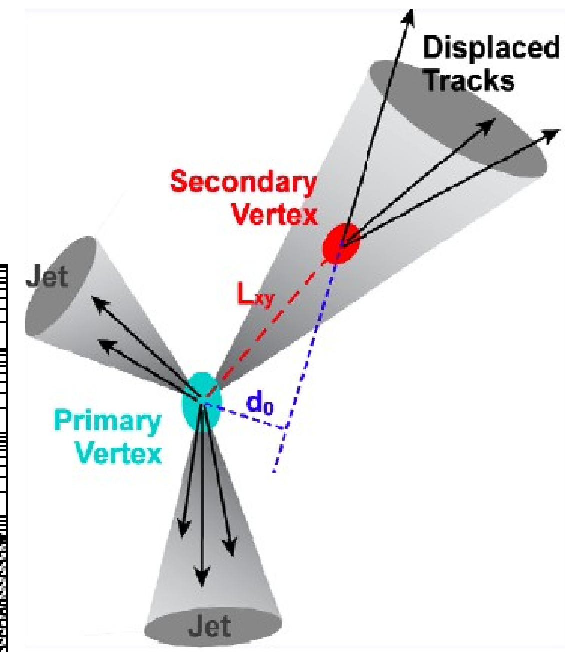


V-c. HF fraction calibration (2)

- Pseudo-cτ = $L_{xy} x M_{vtx}/p^T_{vtx}$

Templates from MC





Why is b excess visible at small ct?

FIG. 9: Pseudo-$c\tau$ distribution for jet data, including fitted contributions for the different components of heavy flavor and secondary interactions in light flavor jets.

V-c. HF fraction calibration (3)

TABLE VII: Fitted contributions from b, c jets and secondary interactions or long-lived light flavor particles in data events. The uncertainties on the b and c fractions are total uncertainties including 5% and 10% uncertainties due to the templates. The ratio $\Delta N/N$ estimates the excess of positive over negative tags in data events, due to secondary interactions and long-lived light flavor particles.

E_T (GeV)	$E_T < 25$	$25 < E_T < 35$	$35 < E_T < 45$	$E_T > 45$	All
Taggable	858,643	415,373	128,994	77,632	1,480,642
Pos. - Neg.	12,208	7131	2511	1596	23,446
Negative	3283	1999	803	697	6782
Fitted bs	7937 ± 483	4412 ± 312	1609 ± 131	843 ± 102	$15,147 \pm 507$
Fitted cs	3040 ± 427	1858 ± 276	520 ± 110	407 ± 93	5589 ± 451
Secondary	1284 ± 142	900 ± 102	379 ± 50	324 ± 39	2836 ± 171
ΔN	482 ± 224	431 ± 144	230 ± 59	227 ± 44	1336 ± 365
$\Delta N/N(\%)$	15 ± 7	22 ± 7	29 ± 7	32 ± 7	20 ± 5
bs/Jets (%)	0.92 ± 0.08	1.06 ± 0.10	1.25 ± 0.12	1.09 ± 0.14	1.02 ± 0.06
cs/Jets (%)	0.35 ± 0.06	0.45 ± 0.08	0.40 ± 0.10	0.52 ± 0.13	0.38 ± 0.05

Sec int. + long-lived u's and d's (ΔN, $\Delta N/N$)

HF fractions (bs/Jets, cs/Jets)

Stable in E_T

F_{HF} for data / F_{HF} for Alpgen = 1.5 +/- 0.4

V-c. Gluon splitting modeling

Jets with gluon splitting have a small opening angle.
=> Can compare data and MC distributions of the opening angle between two closest jets in an event to validate MC modeling of gluon splitting.

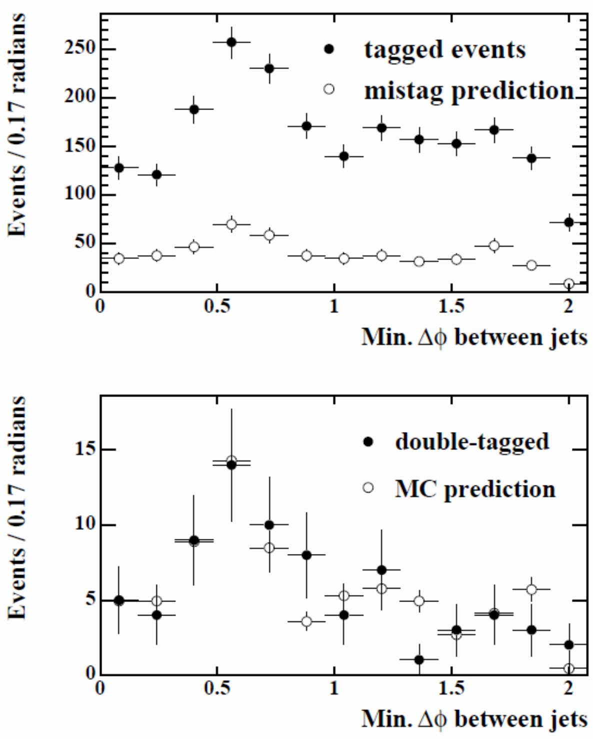


FIG. 10: Distribution of closest jets in $\Delta\phi$ for tagged 3-jet data events with fake tag prediction (top) and for double-tagged events in which the tagged jets are also the two closest jets (bottom).

V-c. HF fraction results

TABLE VIII: Ratio of W + heavy flavor production to total W + jet production, for different jet multiplicities. The heavy flavor ratios include the correction factor 1.5 ± 0.4 as measured from jet data, and the SecVtx event tagging efficiencies include the scale factor described in Section IV. These values are used in Section VI C to predict the background contribution from W + heavy flavor production.

Jet multiplicity	1 jet	2 jets	3 jets		≥4 jets	
H_T (GeV)			$H_T > 0$	$H_T > 200$	$H_T > 0$	$H_T > 200$
W + HF fractions (%)						
1B	1.0 ± 0.3	1.4 ± 0.4	2.0 ± 0.5	2.4 ± 0.6	2.2 ± 0.6	2.2 ± 0.6
2B		1.4 ± 0.4	2.0 ± 0.5	2.3 ± 0.6	2.6 ± 0.7	2.6 ± 0.7
1C	1.6 ± 0.4	2.4 ± 0.6	3.4 ± 0.9	3.8 ± 1.0	3.6 ± 1.0	3.5 ± 1.0
2C		1.8 ± 0.5	2.7 ± 0.7	2.9 ± 0.8	3.7 ± 1.0	3.7 ± 1.0
Wc	4.3 ± 0.9	6.0 ± 1.3	6.3 ± 1.3	6.0 ± 1.3	6.1 ± 1.3	5.9 ± 1.3
SecVtx tagging efficiencies (%)						
1B($\geq$ 1tag)	26.8 ± 2.0	27.8 ± 2.2	29.3 ± 2.5	30.9 ± 2.9	24.2 ± 3.3	27.4 ± 3.8
2B($\geq$ 1tag)		48.6 ± 3.2	50.0 ± 3.8	52.6 ± 4.5	50.3 ± 4.9	50.0 ± 5.1
2B($\geq$ 2tags)		9.1 ± 1.4	9.5 ± 1.5	10.4 ± 1.6	8.1 ± 1.4	8.6 ± 1.5
1C($\geq$ 1tag)	6.2 ± 0.9	6.7 ± 1.0	6.1 ± 1.1	6.6 ± 1.3	7.7 ± 1.9	7.5 ± 2.0
2C($\geq$ 1tag)		12.3 ± 1.9	11.6 ± 2.0	12.6 ± 2.5	10.1 ± 2.3	9.6 ± 2.4
2C($\geq$ 2tags)		0.5 ± 0.2	0.4 ± 0.1	0.5 ± 0.2	0.8 ± 0.4	0.9 ± 0.4
Wc ($\geq$ 1tag)	5.8 ± 0.9	6.1 ± 0.9	7.1 ± 1.2	7.6 ± 1.5	5.6 ± 1.6	5.8 ± 1.8

VI. Backgrounds

- Non t-tbar events in tagged W+jets are due to:
  - Non-W QCD background
    - Source: lepton and miss E_T fakes
    - W decay has isolated lepton + miss E_T
    - Sideband regions of lepton isolation / E_T => BG

High-p_T lepton sample

  - Mistags of light quarks in W+jets
    - Use per-jet mistag rates (described above)
  - W+HF production
    - Use HF fractions computed above
  - WW,WZ,ZZ with leptonic + b-jet decay

Non-W QCD background

TABLE IX: non-W QCD background estimate. Results from the tag rate method and the tag sample method are the number of events expected in the b-tagged lepton + jets sample.

\# events:

			$H_T > 0$		$H_T > 200$ GeV	
Jet multiplicity	1 jet	2 jets	3 jets	≥ 4 jets	3 jets	≥ 4 jets
Electrons						
Pretag non-W QCD Fraction	0.14 ± 0.04	0.17 ± 0.04	0.20 ± 0.05			
Tag Rate Method	16.3 ± 4.7	7.4 ± 2.2	3.2 ± 1.0		2.1 ± 0.6	
Tag Sample Method	21.8 ± 3.8	10.0 ± 2.2	4.9 ± 1.3		2.6 ± 0.8	
Combined Tag Estimate	19.6 ± 3.0	8.7 ± 1.6	2.7 ± 0.6	1.1 ± 0.2	1.3 ± 0.3	1.0 ± 0.3
Muons						
Pretag non-W QCD Fraction	0.034 ± 0.010	0.043 ± 0.011	0.075 ± 0.023			
Tag Rate Method	4.0 ± 1.3	1.2 ± 0.6	0.7 ± 0.3		0.5 ± 0.1	
Tag Sample Method	4.8 ± 1.1	1.8 ± 0.5	1.3 ± 0.4		1.0 ± 0.3	
Combined Tag Estimate	4.5 ± 0.8	1.5 ± 0.4	0.7 ± 0.2	0.2 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
Electron+Muon	24.3 ± 3.5	10.5 ± 1.9	3.4 ± 0.7	1.3 ± 0.3	1.6 ± 0.4	1.2 ± 0.4

Light flavor mistag background

Validation of MC:

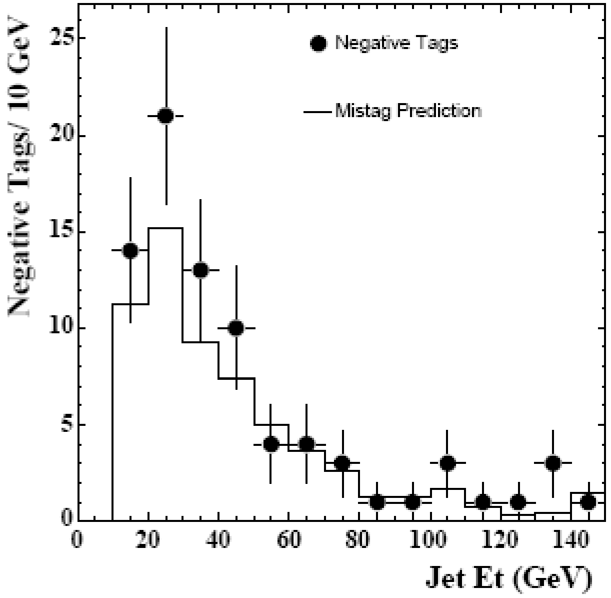


FIG. 12: Comparison of observed and predicted negative SecVtx tags *vs.* jet E_T in the lepton + jets sample.

VI. BG summary

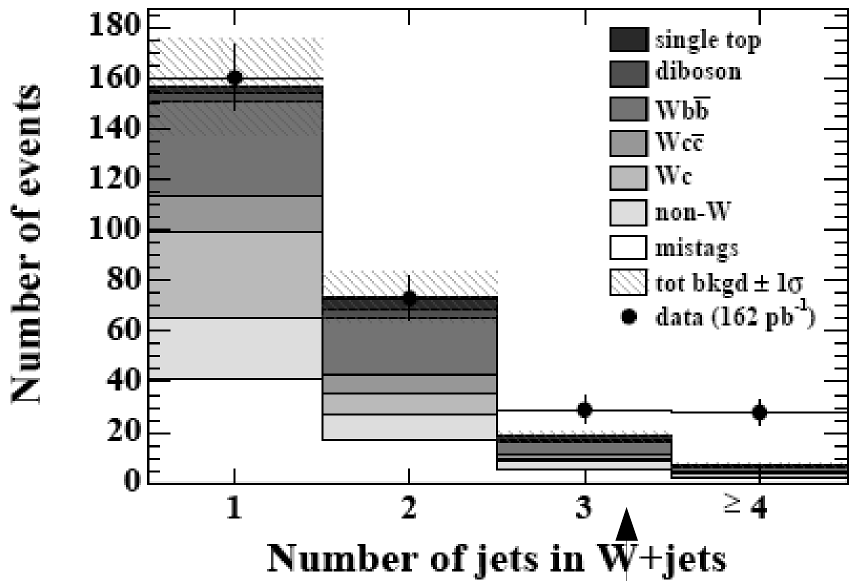


FIG. 13: Number of events passing the selection criteria with at least one tagged jet, and the background prediction for the same selection. The H_T requirement has not been applied.

Very little BG expected in #jet>=3 bins

VII. Cross-check using Z+jets (1)

- t-tbar and non-W QCD contribution is small
  - Good cross-check of BG calculations
- Heavy flavor contribution to Z+jets is similar to W+jets in terms of gluon splitting
- Event selection:
  - e^+e^- or $\mu^+\mu^-$ pairs with mass = 75..105 GeV
  - Tight leptop selection (used in W+jets study)
- What's accomplished:
  - Validate number of b-tagged Z+jets events
  - BG contribution of Z->$\mu\mu$ to W+jets

VII. Cross-check using Z+jets (2)

TABLE X: The predicted number of Z + jets events and the observed number, along with the Z + jets contribution left in the W + jets sample and the estimate of the resulting extra b tags in that sample. (The prediction of extra b-tagged events is included in the predicted background summary for the W + jets sample.)

Jet multiplicity	Z+1 jet	Z+2 jets	Z+$\geq$3 jets
$Z \to e^+e^-$	410	48	10
$Z \to \mu^+\mu^-$	402	59	15
$Z \to \ell^+\ell^-$	812	107	25
Mistags	2.4 ± 0.2	0.49 ± 0.06	0.23 ± 0.04
$Zb\bar{b}$	1.6 ± 0.4	0.8 ± 0.2	0.26 ± 0.08
$Zc\bar{c}$	4.4 ± 1.3	2.3 ± 0.7	0.8 ± 0.2
top ($\sigma_{t\bar{t}} = 5.6 \pm 1.4$)	0.08 ± 0.02	0.5 ± 0.1	0.13 ± 0.03
Pred. Total	8.5 ± 1.7	4.1 ± 0.9	1.4 ± 0.3
Observed Events	12	3	3
Pretag W+jets	289 ± 35	42 ± 7	11 ± 3
Tagged in W+jets	1.1 ± 0.3	0.6 ± 0.2	0.2 ± 0.1

VII. Cross-check using Z+jets (3)

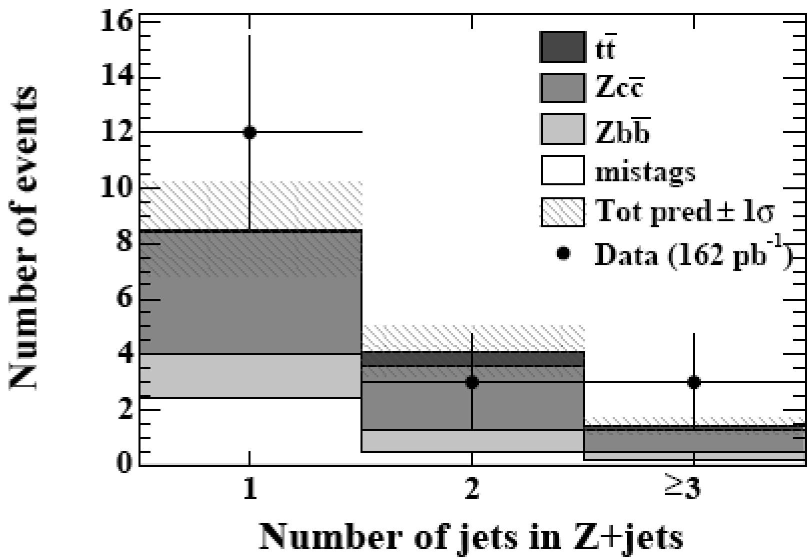


FIG. 14: Comparison of the observed and predicted number of events in the b-tagged Z + jets sample.

VIII-a. Cut optimizations

- H_T: scalar sum E_T of all objects in an event
- Since top is heavy, H_T is larger for top evts
- H_T>200GeV keeps 96% sig and 61% BG

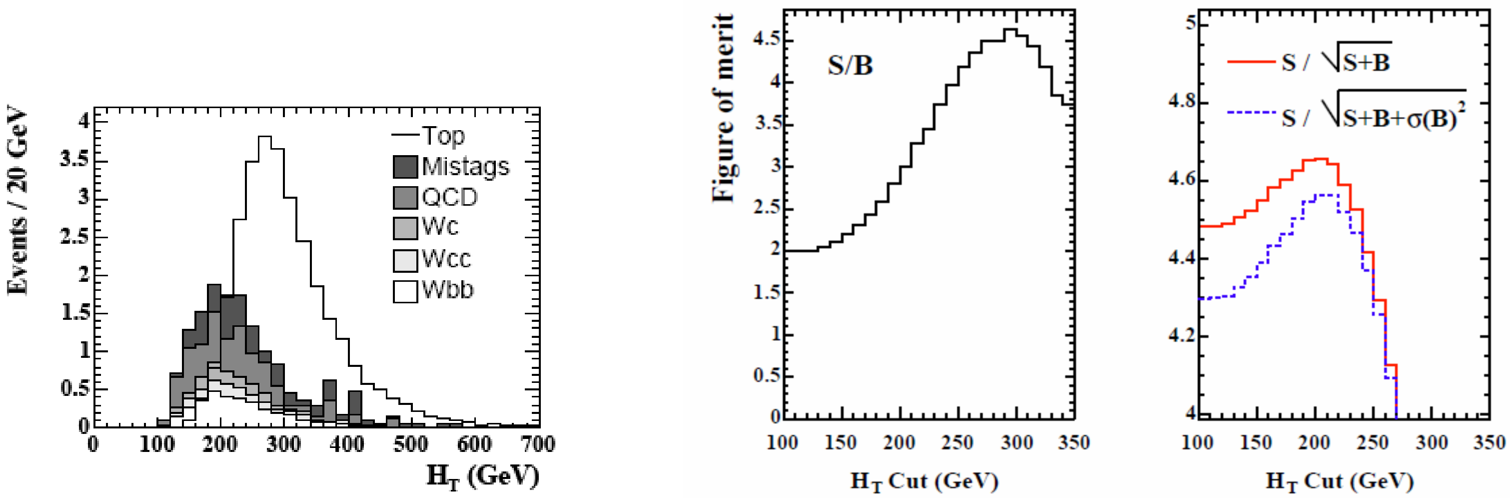


FIG. 15: Distribution of the H_T variable for $t\bar{t}$ Monte Carlo, and for various backgrounds normalized to an integrated luminosity of 107 pb^{-1}.

VIII-b. Acceptances

$$\epsilon_{t\bar{t}} = \epsilon_{\rm trig} \cdot \epsilon_{z_0} \cdot \epsilon_{\rm veto} \cdot \epsilon_{t\bar{t}}^{\rm MC} \cdot k_{\rm lep-id} \cdot \epsilon_{\rm tag-event}$$

TABLE XI: Summary table of the $t\bar{t}$ acceptance, for a top quark mass of 175 GeV/c^2.

	CEM	CMUP	CMX	Total
Sample (total)	344,264	344,264	344,264	344,264
# Events w/o b-tag	15,893	9791	3617	29301
Acc. w/o b-tag (%)	4.09±0.03±0.36	2.13±0.02±0.19	0.959±0.016±0.085	7.18±0.04±0.61
# Tagged Events	8490	5202	1965	15657
Tag Efficiency (%)	53.4±0.4±3.2	53.1±0.5±3.2	54.3±0.8±3.3	53.4±0.3±3.2
Acc. with b-tag (%)	2.19±0.02±0.23	1.14±0.01±0.12	0.512±0.009±0.054	3.84±0.03±0.40
Integ. Lumi. (pb^{-1})	162±10	162±10	150±9	

Largest uncertainties:

- b-tagging
- Lepton ID
- Energy scale

Overall acceptance = 3.84±0.03(stat.)±0.40(syst.)%

IX. Properties of 57 selected evts (in 3 + 4 jet bins)

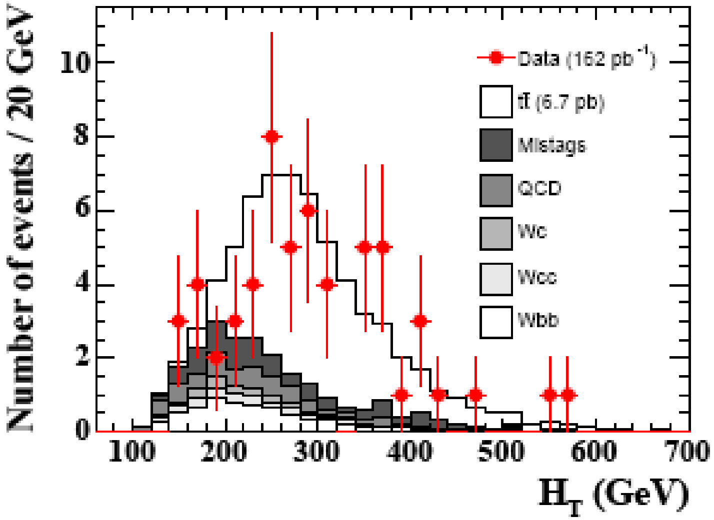


FIG. 18: H_T distribution of the 57 tagged events with three or more jets, compared to the expected background and $t\bar{t}$ signal (normalized to the theoretical cross-section of 6.7 pb).

IX. Properties of 57 selected evts

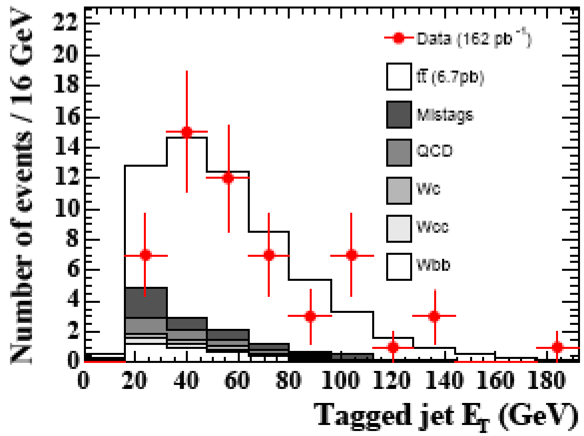


FIG. 19: E_T distribution of the tagged jets in the 57 candidate events, compared to the expected background and $t\bar{t}$ signal (normalized to the theoretical cross-section of 6.7 pb).

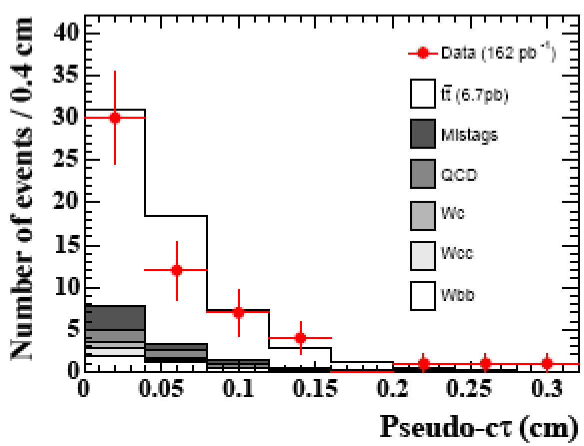
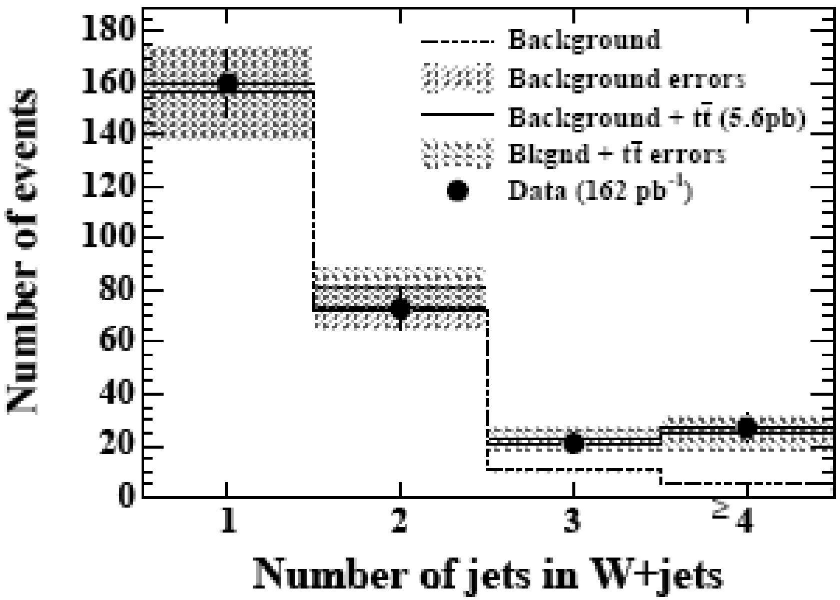


FIG. 20: Pseudo-$c\tau$ distribution of the tagged jets in the 57 candidate events, compared to the expected background and $t\bar{t}$ signal (normalized to the theoretical cross-section of 6.7 pb).

IX. Cross-section w/ >=1 B-tags

- Production cross-section: $\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{\epsilon_{t\bar{t}} \times \mathcal{L}}$
  - where we consider events in >=3 jet bins
- Most BG are normalized to #pretag events
  - After first iteration, ttbar is subtracted
- For 175 GeV top: $\sigma_{t\bar{t}} = 5.6^{+1.2}_{-1.1}(\text{stat.})^{+0.9}_{-0.6}(\text{syst.})\text{pb.}$



Major uncertainties:

- 10% signal acceptance
- 6% luminosity measurement
- 5% background estimate

IX. Background contributions

TABLE XIII: Background summary for the single-tag selection. The total backgrounds are given before and after the correction for $t\bar{t}$ events in the pretag W+jets sample.

			$H_T > 0$ GeV		$H_T > 200$ GeV	
Jet multiplicity	$W + 1$ jet	$W + 2$ jets	$W + 3$ jets	$W + \geq 4$ jets	$W + 3$ jets	$W + \geq 4$ jets
Pretag	15314	2448	387	107	179	91
Mistags	40.9 ± 6.1	17.0 ± 2.4	5.2 ± 0.7	2.6 ± 0.4	3.3 ± 0.4	2.3 ± 0.3
$Wb\bar{b}$	37.0 ± 11.2	22.5 ± 6.5	5.0 ± 1.3	1.6 ± 0.5	2.8 ± 0.8	1.4 ± 0.4
$Wc\bar{c}$	13.7 ± 3.4	8.0 ± 2.2	1.6 ± 0.5	0.6 ± 0.2	0.9 ± 0.3	0.5 ± 0.2
Wc	34.5 ± 9.0	7.7 ± 2.0	1.4 ± 0.4	0.3 ± 0.1	0.7 ± 0.2	0.3 ± 0.1
$WW/WZ/ZZ, Z \rightarrow \tau\tau$	2.2 ± 0.4	2.5 ± 0.4	0.6 ± 0.1	0.1 ± 0.0	0.3 ± 0.1	0.1 ± 0.0
non-W QCD	24.3 ± 3.5	10.5 ± 1.9	3.4 ± 0.7	1.4 ± 0.4	1.7 ± 0.4	1.2 ± 0.3
single top	2.6 ± 0.3	4.6 ± 0.5	1.1 ± 0.1	0.2 ± 0.0	0.8 ± 0.1	0.2 ± 0.0
Z+HF	1.1 ± 0.3	0.6 ± 0.2	0.2 ± 0.1		0.10 ± 0.05	
Total	156.3 ± 19.1	73.4 ± 9.8	18.5 ± 2.2	6.9 ± 0.9	10.5 ± 1.3	6.0 ± 0.8
Corrected Total	156.3 ± 19.1	73.4 ± 9.8	23.1 ± 3.0		13.5 ± 1.8	
Data	160	73	29	28	21	27

X. Cross-check with double-tags

- 57 events selected in 3 or 4 -jet bins
- 8 of those are double-tagged
- Provides extra clean sample
  - Lower systematic uncertainty
  - But much higher statistical uncertainty!
- Mistag BG dominated by 1 real + 1 fake tag
  - Mostly W-b-bbar
- Total efficiency is 0.11 +/- 0.02

X. Double-tag data and prediction

TABLE XV: Prediction for the number of double-tagged events. Corrected total comes from the $t\bar{t}$ cross section measurement where the pretag sample is corrected for the $t\bar{t}$ contribution. The expected number of $t\bar{t}$ events is calculated using the measured cross section of 5.0 pb.

Jet multiplicity	2 jets	3 jets	$\geq$ 4 jets
Single top	0.40$\pm$ 0.08	0.15$\pm$ 0.03	0.04$\pm$ 0.01
WZ	0.15$\pm$ 0.04	0.02$\pm$ 0.01	0.01$\pm$ 0.01
Wbb	2.76$\pm$ 0.86	0.64$\pm$ 0.18	0.21$\pm$ 0.06
Wcc	0.20$\pm$ 0.08	0.05$\pm$ 0.02	0.03$\pm$ 0.01
Mistag/QCD	0.14 $\pm$ 0.04	0.16 $\pm$ 0.04	0.11 $\pm$ 0.03
Total	3.65 $\pm$ 0.97	1.02 $\pm$ 0.23	0.40 $\pm$ 0.09
Corrected Total	3.6$\pm$ 1.0	1.3 $\pm$ 0.3	
$t\bar{t}$ (5.0 pb)	1.0	2.6	4.1
Data	8	3	5

$$\sigma_{t\bar{t}} = 5.0^{+2.4}_{-1.9}(\text{stat})^{+1.1}_{-0.8}(\text{syst})\text{pb}. \quad (7)$$

The systematic error is due to the following contributions: tagging efficiency (15%), acceptance (7%), luminosity (6%) and backgrounds (5%).

Consistent with 5.6 pb prediction in single-tag sample