Top quark production cross-section measurements at DØ

Flera Rizatdinova (KSU)
for the DØ collaboration

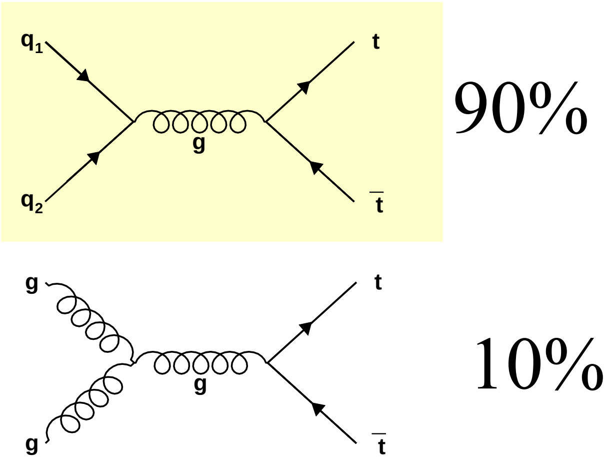
- *Introduction*
- *Lepton+jets topological analysis (see W&C talk by B.Abbott)*
- *Lepton+jets analysis based on b-tagging*
- *Conclusions*
- *Outlook*

Motivation for the top quark studies

- Top quark has been discovered by CDF and DØ collaborations in 1995 with data of ~50 pb^{-1};
- Top quark is the only known fermion with a mass on the electroweak scale:
  - *Study of the top quark provides an excellent probe of the electroweak symmetry breaking mechanism;*
  - *New physics may be discovered in either its production or decays;*
- Tevatron is the only place to study top quark properties before LHC operation.

Top quark production and decay

➢ in proton-antiproton collisions at Tevatron energies ($\sqrt{s}$ = 1.96 TeV), top quarks are mostly produced in pairs



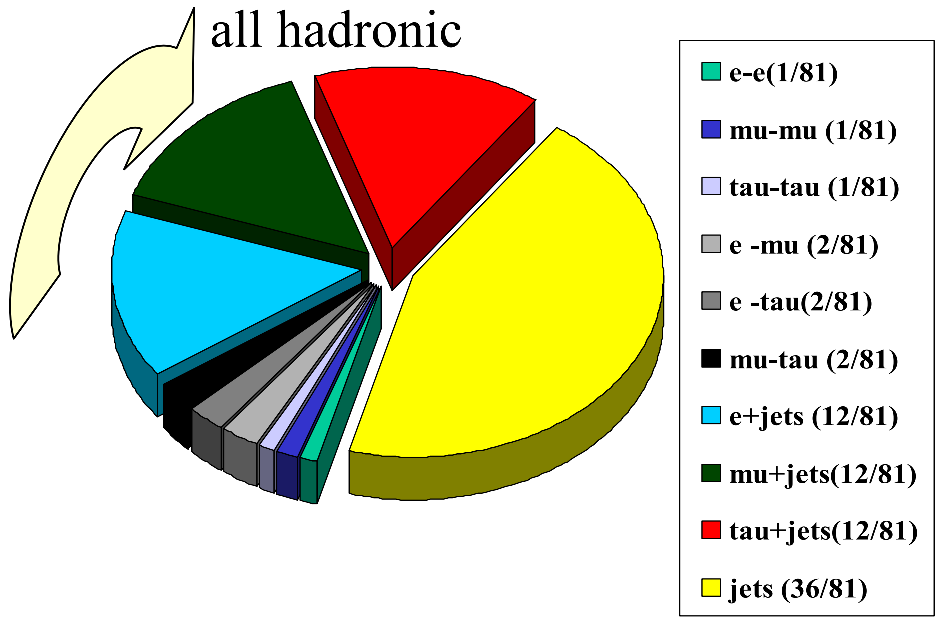
EW single top production: not yet observed

➢ $Br(t \to Wb) \cong 100\%$ in the SM

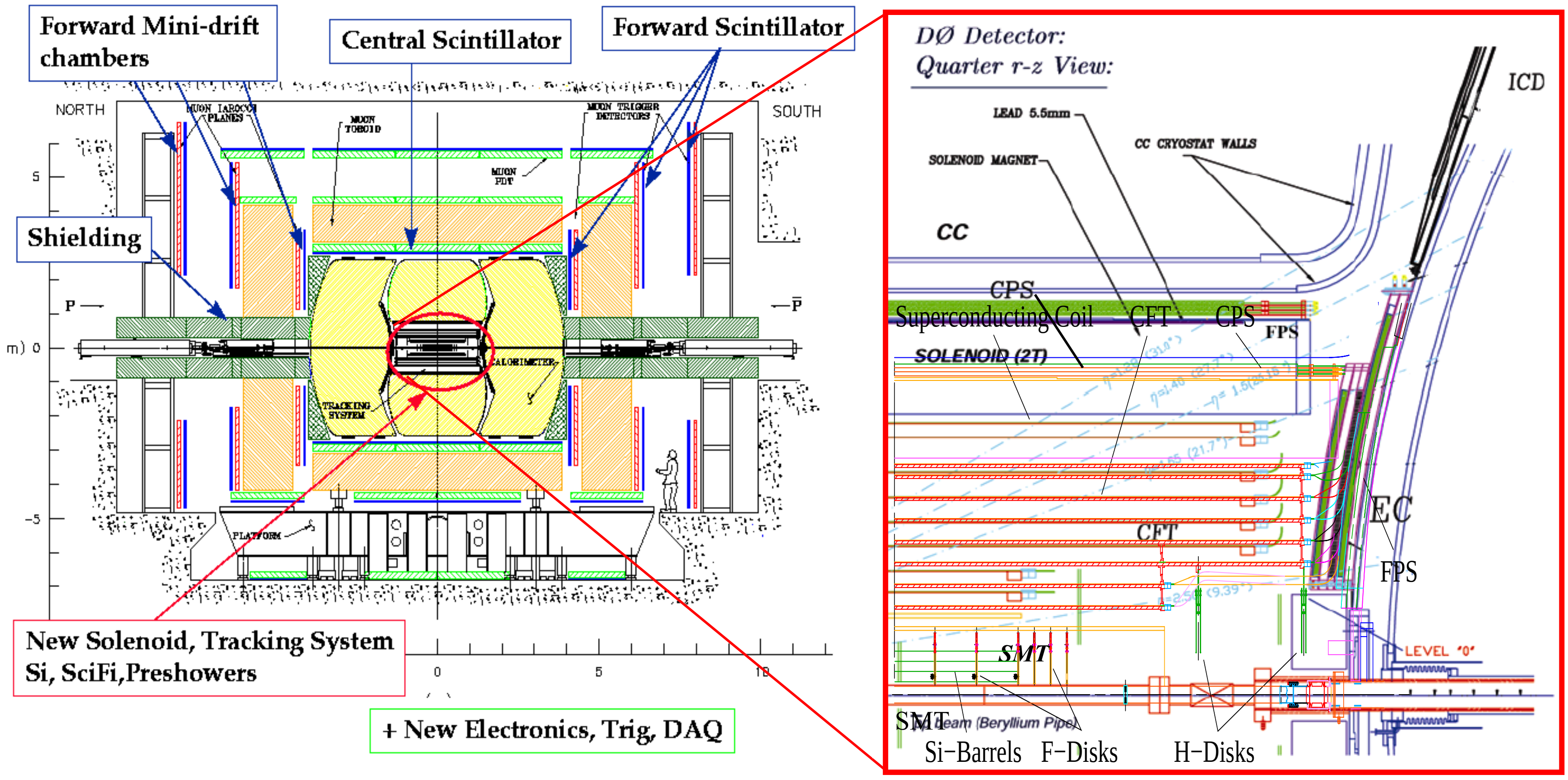
Both W's decay via W→lν (l=e or μ; 5%)
dilepton

One W decays via W→lν (l=e or μ; 30%)
lepton+jets

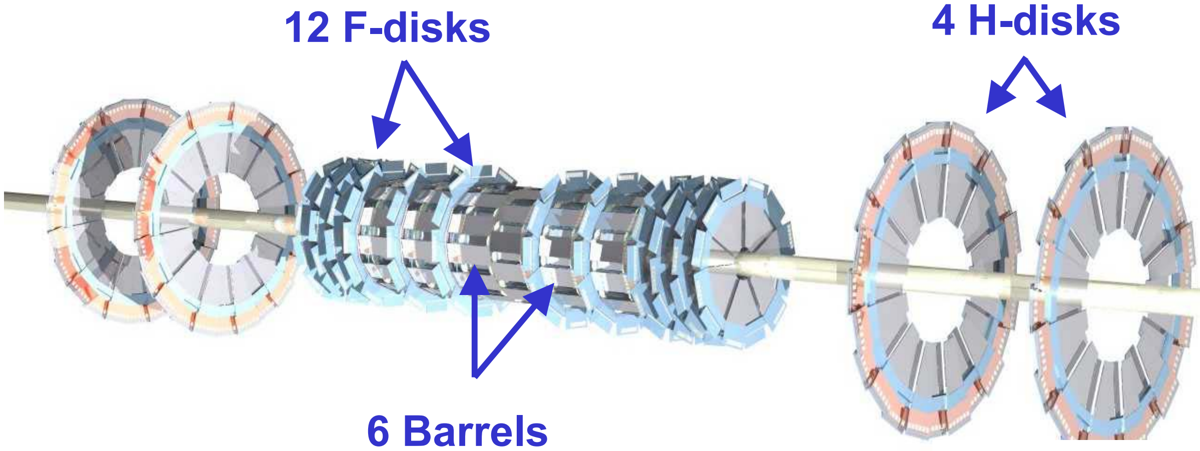
Both W's decay via W→qq (44%)
all hadronic

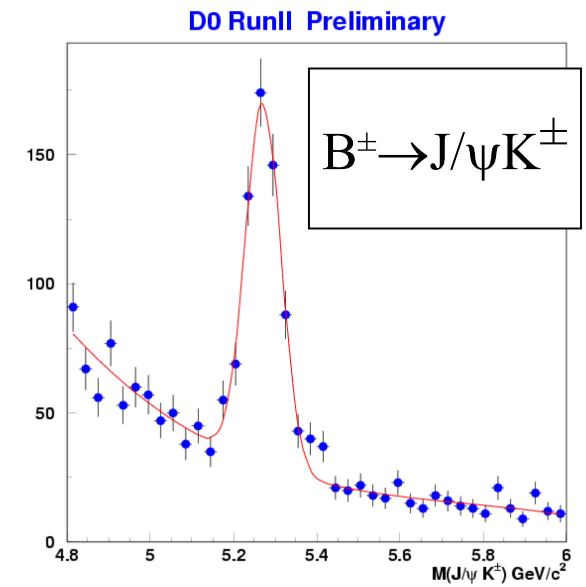


DØ detector


Forward Mini-drift chambers
Central Scintillator
Forward Scintillator
Shielding
New Solenoid, Tracking System Si, SciFi,Preshowers
+ New Electronics, Trig, DAQ
NORTH
SOUTH
MUON TOROID
CALORIMETER
TRACKING SYSTEM
PLATFORM
DØ Detector: Quarter r-z View:
ICD
LEAD 5.5mm
CC CRYOSTAT WALLS
SOLENOID MAGNET
CC
CPS
Superconducting Coil
CFT
FPS
SOLENOID (2T)
EC
SMT
LEVEL "0"
Beam (Beryllium Pipe)
Si-Barrels
F-Disks
H-Disks

Silicon Microstrip Detector (SMT)





SMT combines vertex and tracking capabilities and provides good primary and secondary vertex resolutions.

Lepton +jets channels

➢ ***"Golden" mode for top studies:*** ~30% yield and relatively clean

Event preselection:

- 1 high p_T isolated charged lepton (e,μ).
- Neutrinos: large missing E_T
- Large jet multiplicity
- dilepton veto

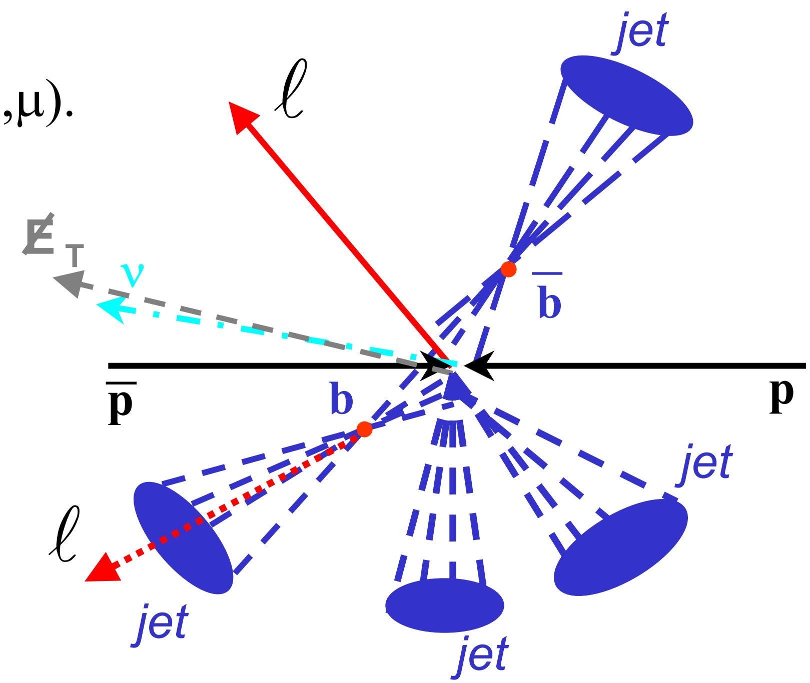
Backgrounds:

Further selection & techniques:

- W+jets and fake leptons in QCD
- topological analysis: $n \geq 4$ jets
- tag b jets with Soft Lepton Tag (SLT)

  ≥ 3 jets, ≥ 1 SLT
- **tag b jets with displaced VTX or IP:**

  ≥ 3 jets, ≥ 1 b tag



$t(\rightarrow W^{\pm}b)\ t(\rightarrow W^{\pm}b)$

└→ $e^{\pm},\mu^{\pm}$ └→ qq

Lepton+jets: topological analysis

- ***Event selection:***
  - Preselect a sample enriched in W events (leptons with $p_T>20$ GeV, $\not{E}_T>20$ GeV)
- ***QCD background estimation (from the data)***
  - Separate $W+t\bar{t}$ and QCD events with loose (L) and tight (T) lepton characteristics.
  - Difference between loose and tight samples for e+jets is in the track match to EM object; for μ+jets is in the muon isolation.
  - Matrix method is a way to calculate fractions of signal and BG based on different probabilities for a high p_T lepton from signal ε_{W+tt} and from QCD BG ε_{QCD} to pass selection criteria:

$$\begin{cases} N_L = \tilde{N}_{W+t\bar{t}} + \tilde{N}_{QCD} \\ N_T = \varepsilon_{W+t\bar{t}} \tilde{N}_{W+t\bar{t}} + \varepsilon_{QCD} \tilde{N}_{QCD} \end{cases} \Rightarrow \begin{cases} \tilde{N}_{W+tt} = \varepsilon_{W+tt} \dfrac{N_T - \varepsilon_{QCD} N_L}{\varepsilon_{W+tt} - \varepsilon_{QCD}} \\ \tilde{N}_{QCD} = \varepsilon_{QCD} \dfrac{\varepsilon_{QCD} N_L - N_T}{\varepsilon_{W+t\bar{t}} - \varepsilon_{QCD}} \end{cases}$$

- ***W+4 jet BG estimated from the data with Berends scaling.***

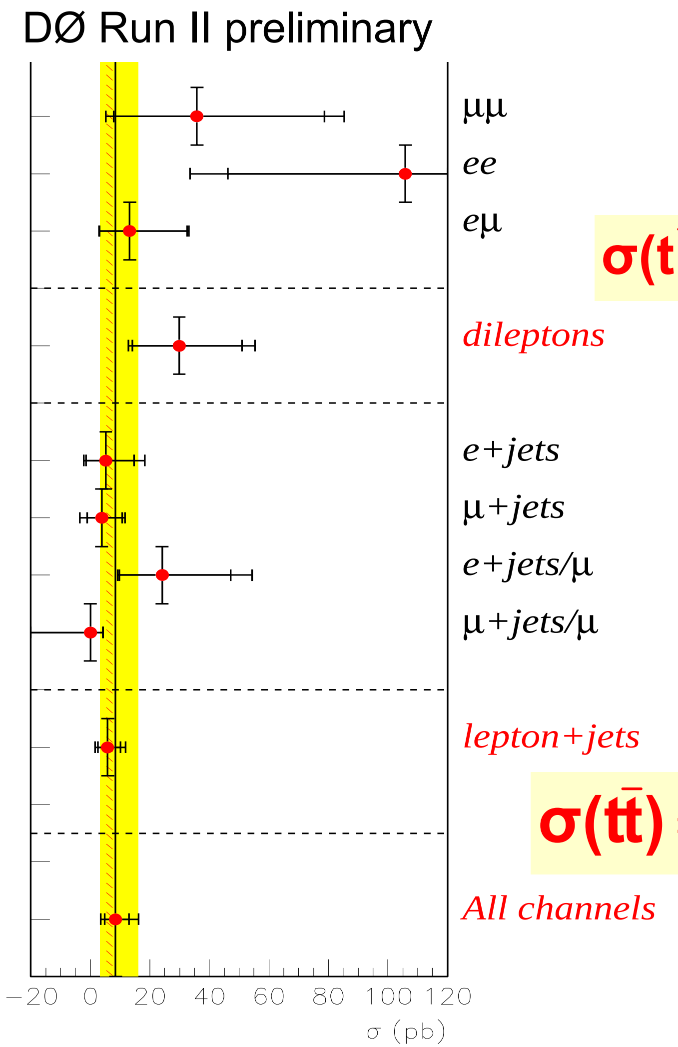
Lepton+jets: topological cuts and SLT

e+jets (49.5 pb^{-1})	*μ+jets* (40 pb^{-1})	l+jets with SLT
$E_T(W) > 60$ GeV	MET(Cal) > 15 GeV	$E_T(W)$/ MET(Cal)
$\lvert\eta_W\rvert < 2$	P_T(leading jet) >55GeV	$\lvert\eta_W\rvert$ or P_T(leading jet)
$H_T > 180$ GeV	$H_T^{all} > 220$ GeV	H_T>110 GeV
Aplanarity > 0.065	Aplanarity > 0.065	Aplanarity > 0.04

	N_W	N_{QCD}	All BG	Exp tt*	N_{obs}
e+jets	1.3±0.5	1.4±0.4	**2.7±0.6**	**1.8**	**4**
μ+jets	2.1±0.9	0.6±0.4	**2.7±1.1**	**2.4**	**4**
e+jets(SLT)	0.0±0.1	0.2±0.1	**0.2±0.1**	**0.5**	**2**
μ+jets(SLT)	0.2±0.1	0.4±0.1	**0.6±0.1**	**0.4**	**0**

$\sigma(t\bar{t})$= 7pb

Cross-section from topological analyses



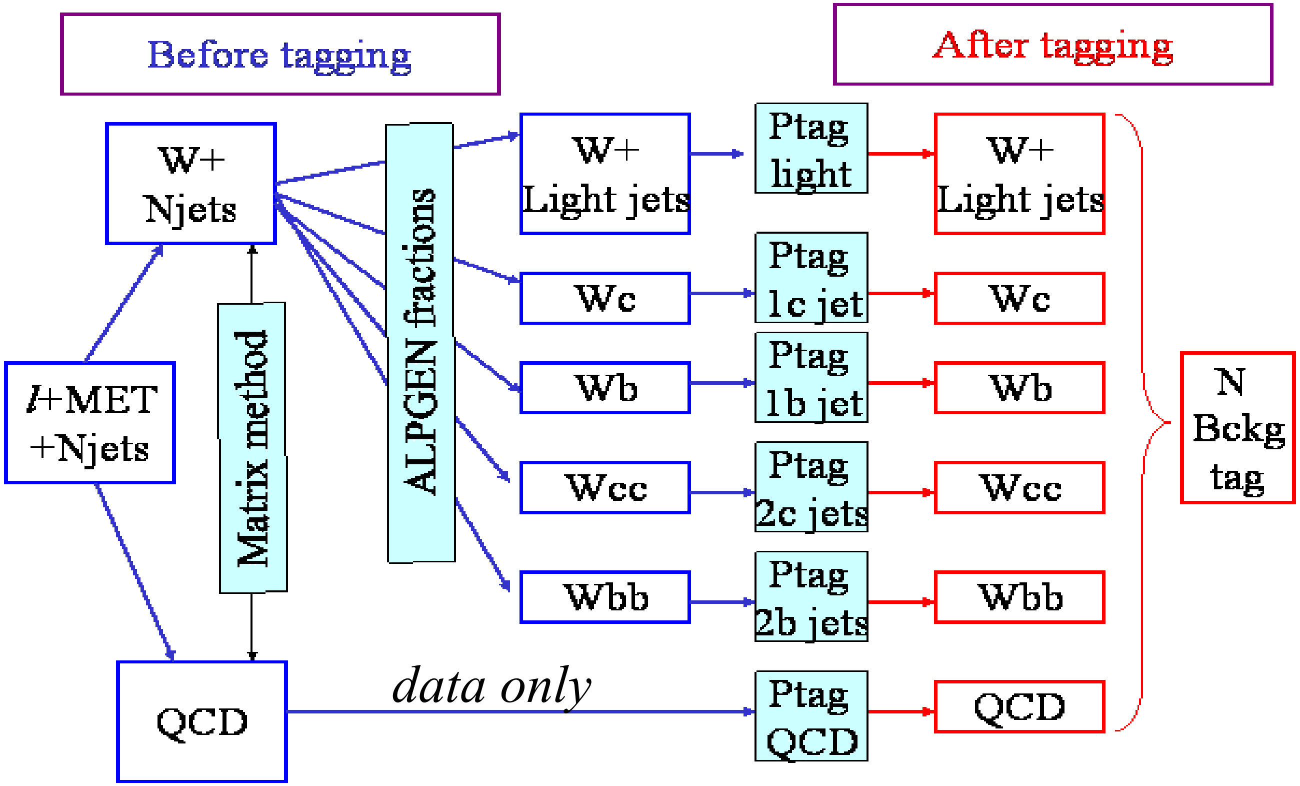
lepton+jets channels only

$$\sigma(t\bar{t}) = 5.8^{+4.3}_{-3.4}(\text{stat})^{+4.1}_{-2.6}(\text{sys}) \pm 0.6(\text{lumi})\ \text{pb}$$

all combined

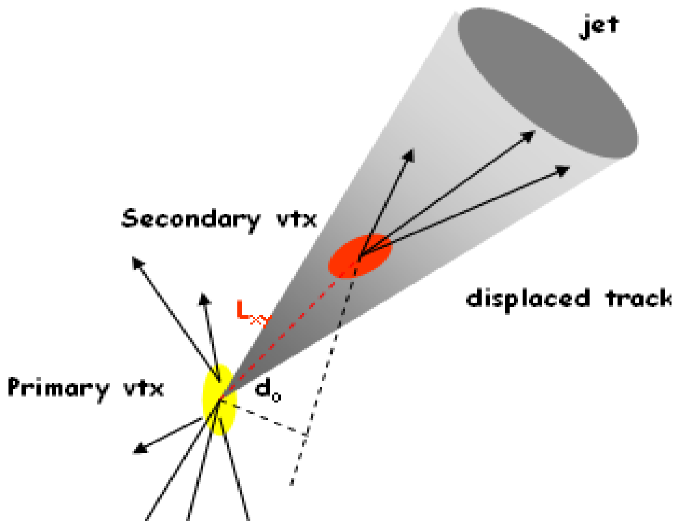
$$\sigma(t\bar{t}) = 8.5^{+4.5}_{-3.6}(\text{stat})^{+6.3}_{-3.5}(\text{sys}) \pm 0.8(\text{lumi})\ \text{pb}$$

Lepton+jets with b-tagging: Method overview



Estimate production cross-section from the excess observed in the number of tagged events w.r.t. BG expectation in 3 and 4jet multiplicity bins.

Two b-tagging methods

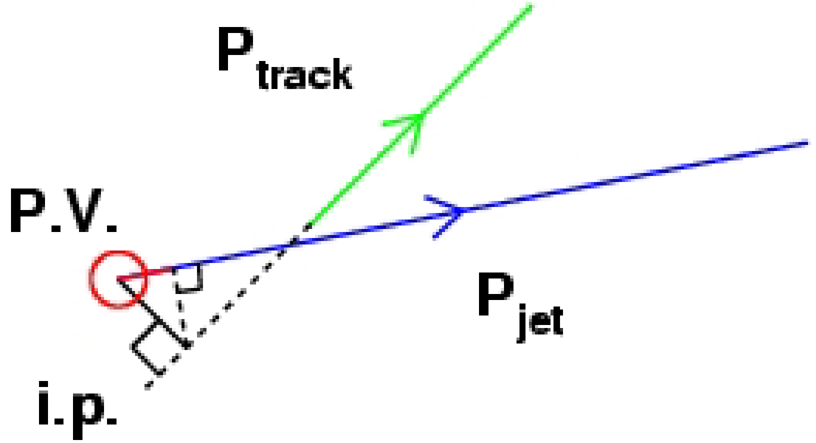


Secondary Vertex Tag (SVT)

- Look for displaced vertices (≥ 2 tracks),
- jet is tagged as b jet
  - If signed decay length significance >5

Counting Signed Impact Parameter tag (CSIP)

- $S = IP/\sigma(IP)$
- Jet is positively tagged if it has
  - at least two tracks with S>3 or
  - at least three tracks with S>2



Signal data

- The *e*+jets channel: L = 49.5 pb^{-1}

N	*W*+1j	*W*+2j	*W*+3j	*W*+4j
preselected data	2599	741	146	25
$W \to e$+j	2004±54	462±30	71±15	12±4
$QCD \to e$+j	595±9	279±8	75±6	13±3

- The μ+jets channel:L = 40.0 pb^{-1}

N	*W*+1j	*W*+2j	*W*+3j	*W*+4j
preselected data	2796	973	217	40
$W \to \mu$+j	2188±100	650±54	126±23	25±9
$QCD \to \mu$+j	608±85	323±44	91±20	13±6

Primary vertex selection

- $|z_{PV}| \leq 60$ cm;
- N of tracks in the PV ≥ 3;

Efficiency measured on:

- EMqcd sample requiring signal trigger for *e*+jets channel;
- μ+jets loose sample for μ+jets channel

Efficiencies for PV cuts:

	1j	2j	3j	4j
e+jets	92.27±0.06	93.8±0.1	95.0±0.3	95.2±0.4
μ+jets	89.0±0.3	90.8±0.3	91.7±0.4	91.8±0.7

Jet tagging probability

The probability to tag a jet was split into two components:

- the probability for a jet to be taggable (at least 2 tracks with p_T>0.5 GeV and χ^2<3 in the jet cone ΔR<0.5 with at least 3 hits in silicon detector (SMT) or 2 SMT hits in the innermost SMT layers) - *TAGGABILITY*:

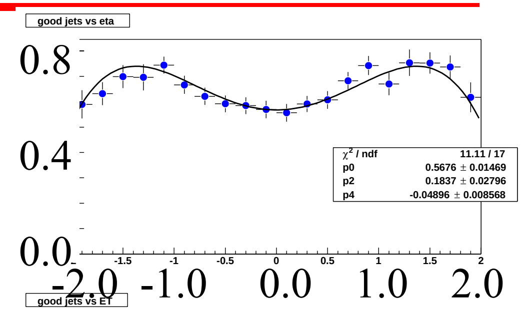
$$P^{taggable}(E_T,\eta) = \frac{N^{taggable}(E_T,\eta)}{N^{total}(E_T,\eta)}$$

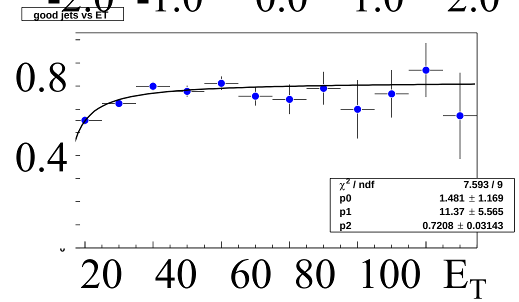
- the probability for a taggable jet to be tagged - *TAGGING EFFICIENCY:*

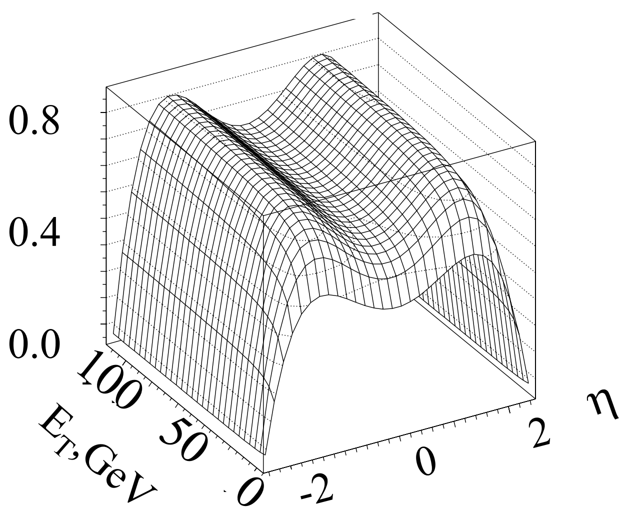
$$\varepsilon_{tag}(E_T,\eta) = \frac{N_{jet}^{tagged}(E_T,\eta)}{N_{jet}^{taggable}(E_T,\eta)}$$

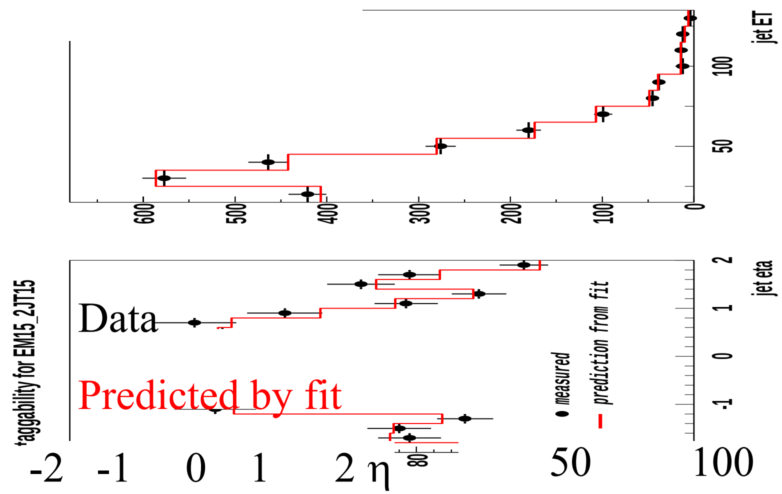
Taggability

- Taggability was measured on the signal sample;
- The fit to the data distributions vs E_T and η was performed;
- Two-dimensional parameterization was obtained;
- Cross-checked the 2-d parameterization applying it back to the data.









B-tagging efficiency

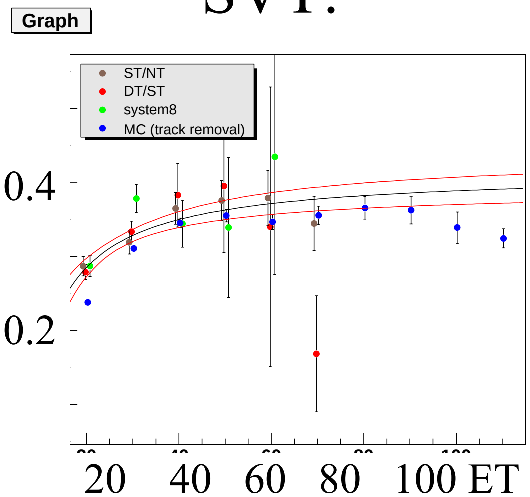
B-tagging efficiency was measured by three different methods and compared to the MC prediction.

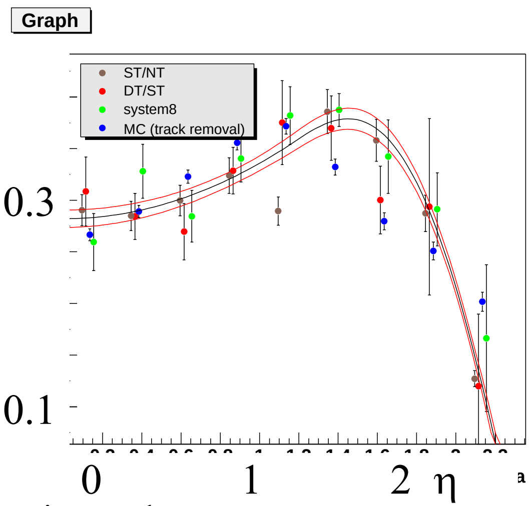
All measurements are in a good agreement with each other.

Average b-tagging efficiency for basic method:

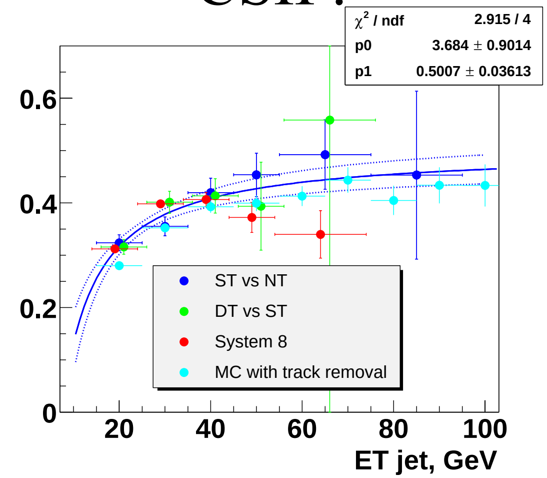
	SVT	CSIP
ε_{btag}	(31.9±1.6)%	(36.3±1.9)%

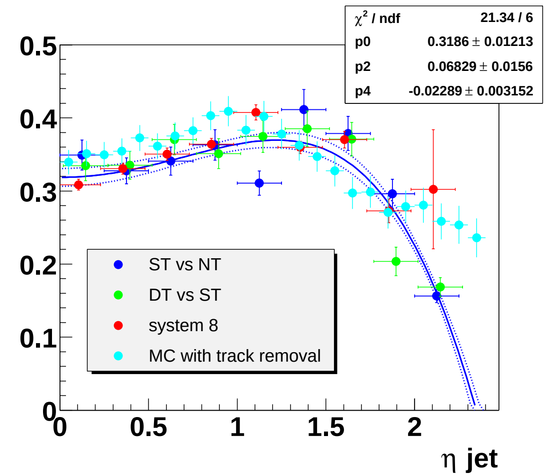
SVT:





CSIP:





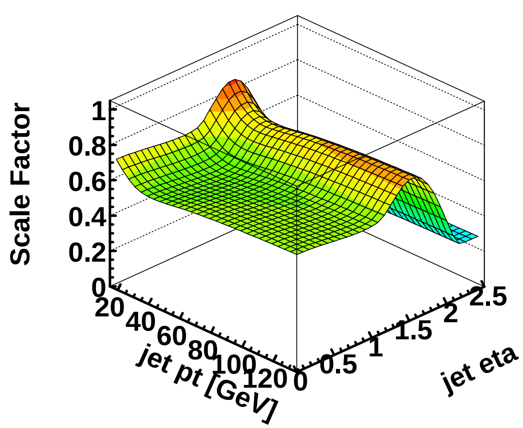
B-tagging efficiency calibration

We use MC to calculate W+jets BG and top expectation ⇒ have to use b-tagging efficiency calibrated to the data. The way to calibrate - introduce $SF_{b\to\mu}(E_T, \eta)$:

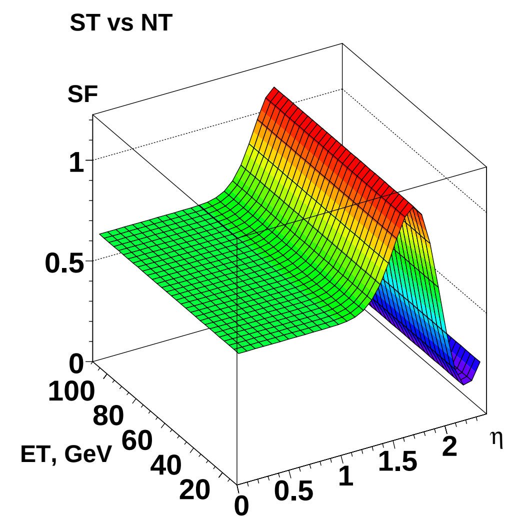
$$SF_{b\to\mu}(E_T,\eta) = \frac{\varepsilon^{data}_{b\to\mu}}{\varepsilon^{MC}_{b\to\mu}}$$

Shown two-dimensional scale factor SF are obtained as a products of one-dimensional scale factors assuming that they are not correlated.

SVT:



CSIP:



c-tagging efficiency

c-tagging efficiency was not measured directly on the data.

Instead, we use b-tagging efficiency measured on the data and apply to it the correction factor $CF_{b\to c}$.

$$CF_{b\to c} = \frac{\varepsilon^{MC}_{ctag}(E_T, \eta)}{\varepsilon^{MC}_{btag}(E_T, \eta)}$$

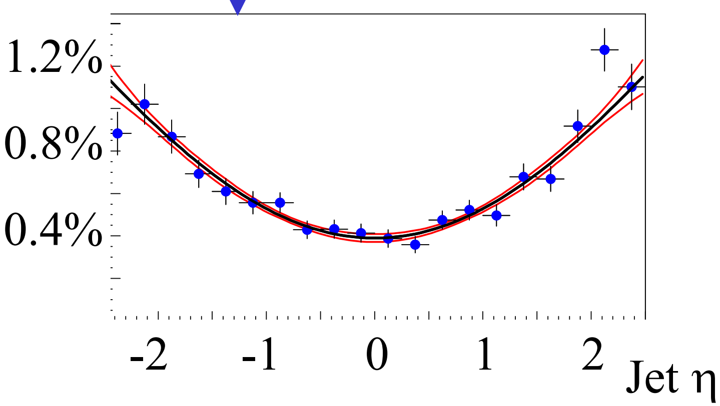
Correction factor $CF_{b\to c}$ is calculated using Monte Carlo.

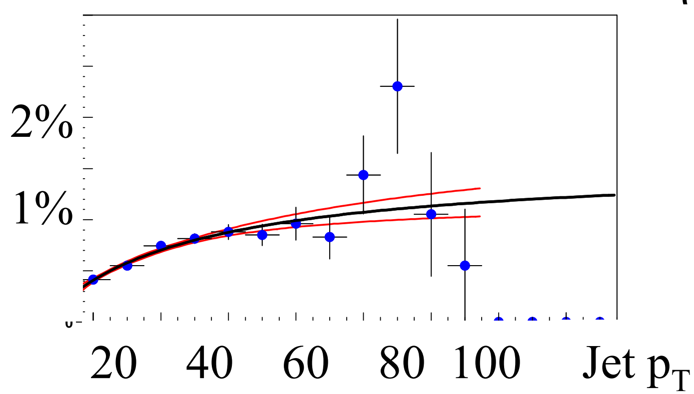
Resulting c-tagging efficiency is $\varepsilon^{data}_{ctag} = \varepsilon^{data}_{btag} \times CF_{b\to c}$

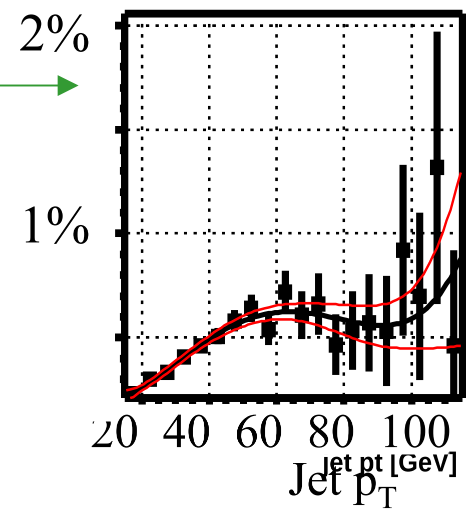
Negative tagging rate

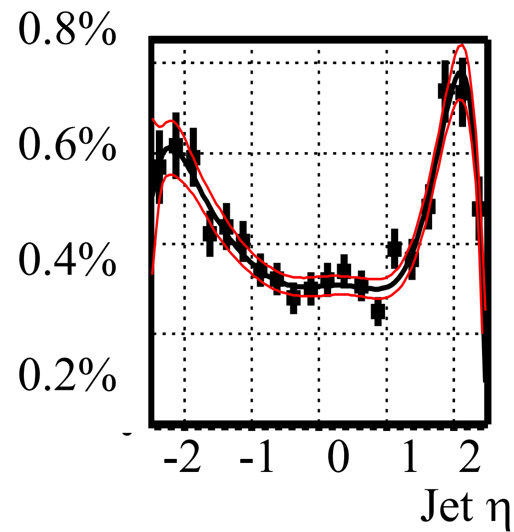
Measured on data

CSIP SVT









Negative tagging means:

SVT: signed decay length of SV <-5

CSIP: signed IP of tracks is <-3 for two tracks or <-2 for three tracks in jet

Estimation of the mistagging rate

Need to calculate the contribution from W+light jets events to the total BG. Measured negative tagging rate on data, but want to know the probability to tag a light jet (jet originated from u,d,s quarks).

Need to correct negative tagging rate:

- for the presence of heavy flavor in data in negative tags (correction factor SF_{hf});
- for the missing contribution from long-lived particles (correction factor SF_{ll})

$$\varepsilon_{light} = \varepsilon_{data}^{negative}(E_T, \eta) SF_{hf} SF_{ll}$$

From MC studies

SVT	CSIP
1.11±0.11	1.09±0.09

MC samples for W+jets BG estimation

- ***W+jets with ALPGEN 1.1***

We generated 14 processes with W and various numbers of partons of different flavors. From these samples we determine fractions of the different W+jets flavor processes contributing to each exclusive jet multiplicity bin.

Contribution	W+1jet	W+2jets	W+3jets	W+≥4jets
$F_{Wb\bar{b}}$		$(0.88 \pm 0.04)\%$	$(1.57 \pm 0.09)\%$	$(3.17 \pm 0.88)\%$
$F_{Wc\bar{c}}$		$(1.25 \pm 0.13)\%$	$(2.33 \pm 0.26)\%$	$(3.34 \pm 0.88)\%$
$F_{W(b\bar{b})}$	$(0.50 \pm 0.11)\%$	$(1.70 \pm 0.48)\%$	$(1.40 \pm 0.44)\%$	$(0.92 \pm 0.83)\%$
$F_{W(c\bar{c})}$	$(1.21 \pm 0.16)\%$	$(2.16 \pm 0.55)\%$	$(5.52 \pm 0.88)\%$	$(9.28 \pm 2.66)\%$
F_{Wc}	$(2.96 \pm 0.07)\%$	$(6.51 \pm 0.69)\%$	$(3.84 \pm 0.83)\%$	$(3.86 \pm 1.69)\%$
$F_{W+jets(mistags)}$	$(95.33 \pm 0.20)\%$	$(87.51 \pm 0.99)\%$	$(85.35 \pm 1.26)\%$	$(79.43 \pm 3.32)\%$

W+jets background estimation

- Estimated number of tagged W+jets events:
- *Particular case:* Expected contribution of *W+nj* events after SVT tagging in μ+jets channel is shown in the table:

$$\tilde{N}_{W+nj} = N_{W+nj}\,\varepsilon_{PV}\,\tilde{P}^{tag}_{W+nj}$$

N of preselected W+nj events before tagging (N_{W+nj})

Average event tagging probability ($\tilde{P}^{tag}_{W+nj}$)

$$\tilde{P}^{tag}_{W+nj} = \sum_{flavor} F_{flavor} P^{tag}_{W+nj(flavor)}$$

Source	W+1j	W+2j	W+3j	W+≥4j
W+light	4.71±1.22	2.81±0.71	0.77±0.26	0.23±0.10
Wbb	0.00±0.00	1.52±0.29	0.52±0.15	0.26±0.13
Wcc	0.00±0.00	0.77±0.23	0.29±0.11	0.11±0.06
W(bb)	1.49±0.75	1.90±1.15	0.27±0.18	0.04±0.05
W(cc)	0.98±0.47	0.68±0.41	0.35±0.16	0.13±0.10
Wc	2.85±0.86	2.31±0.80	0.26±0.14	0.09±0.07

Expect ~3.34 events from W+nj BG after tagging in W+3j and W+≥4j event topologies

QCD background in e+jets channel

Sources of QCD BG - fake Compton QCD and fake electrons (jets)

Reminder: N_{QCD} events before tagging is estimated using Matrix Method;
Measured probability to tag a QCD event P_{QCD} on data directly for the different jet multiplicity bins;
N'_{QCD} after tagging is product of N_{QCD} and P_{QCD}

P_{QCD}	*W*+1j	*W*+2j	*W*+3j	*W*+4j
SVT	(1.02±0.03)%	(1.81±0.08)%	(2.71±0.26)%	(3.30±0.73)%
CSIP	(1.26±0.03)%	(2.19±0.09)%	(3.33±0.28)%	(3.80±0.77)%

Numbers of predicted QCD events after tagging:

N'_{QCD}	*W*+1j	*W*+2j	*W*+3j	*W*+4j
SVT	2.98±0.15	3.45±0.23	1.62±0.23	0.39±0.14
CSIP	3.69±0.17	4.19±0.28	1.98±0.27	0.45±0.16

QCD background in μ+jets channel

Sources of QCD BG - semileptonic heavy flavor decays.

Could not use the same method as for e+jets since the anti-W cuts used to select pure μQCD sample affect the flavor composition.

Final method:

apply the Matrix Method to the tagged signal sample and obtain N'_{QCD} in the tagged sample directly.

Numbers of predicted QCD events after tagging:

N'_{QCD}	W+1j	W+2j	W+3j	W+≥4j
SVT	3.90±1.50	3.00±1.10	1.90±0.70	0.70±0.30
CSIP	4.59±1.40	3.44±1.22	1.94±0.83	0.61±0.41

Expected $t\bar{t}$ yield in *e*+jets channel

N of expected tt events after tagging: $N'_{t\bar{t}} = BR \times \sigma \times L \times \varepsilon_{PV} \times \varepsilon_{trig} \times \varepsilon_{sel} \times P^{tag}_{t\bar{t}}$

P^{tag}_{tt} is a probability to tag a top event - calculated in the same way as probability to tag a *W*+*nj* event;

ε_{sel} and ε_{trig} – selection and trigger efficiencies for tt events;

ε_{PV} -measured on data for both *e*+jets and μ+jets channels

P_{tt}	*W*+1j	*W*+2j	*W*+3j	*W*+4j
SVT	(16.69±3.30)%	(27.88±3.41)%	(36.83±4.14)%	(42.35±4.66)%
CSIP	(18.42±2.94)%	(30.26±3.56)%	(39.60±4.34)%	(45.75±4.86)%

Numbers of expected tt events after tagging (assuming σ(tt) = 7 pb):

N'_{tt}	*W*+1j	*W*+2j	*W*+3j	*W*+4j
SVT	0.02±0.01	0.40±0.06	1.35±0.18	1.68±0.26
CSIP	0.02±0.01	0.43±0.07	1.45±0.19	1.81±0.28

Expected $t\bar{t}$ yield in μ+jets channel

P_{tt}	*W*+1j	*W*+2j	*W*+3j	*W*+4j
SVT	(12.50±2.91)%	(27.37±3.45)%	(36.15±4.13)%	(41.33±4.61)%
CSIP	(15.73±2.39)%	(30.27±3.59)%	(39.61±4.36)%	(45.56±4.84)%

Numbers of expected tt events after tagging (assuming σ(tt) = 7 pb):

N'_{tt}	*W*+1j	*W*+2j	*W*+3j	*W*+4j
SVT	**0.01±0.01**	**0.24±0.04**	**1.20±0.17**	**2.00±0.31**
CSIP	**0.01±0.01**	**0.26±0.04**	**1.31±0.18**	**2.20±0.34**

Systematic uncertainties

- Took into account 26 different sources of systematic errors
- Largest uncertainties:
- Jet Energy Scale (~1.25 pb);
- N_W and N_{QCD} in data (~0.8 pb);
- Tagging probability (~0.8 pb);
- Semileptonic b-tagging efficiency in MC (~0.5-0.8 pb);
- Semileptonic b-tagging efficiency in data (~0.5 pb);
- W fractions from gluon splitting in HERWIG (~0.5 pb)

Selections

- Preselection efficiency;
- Trigger efficiency;
- PV selection efficiency;
- N_W and N_{QCD} in data;
- Tagging probability;
- W fractions from ALPGEN;

Object ID

- Track matching with EM cluster;
- Electron identification efficiency;
- Muon identification efficiency;
- Jet identification efficiency;
- Jet resolution;
- Jet Energy Scale;

Tagging probability

- Taggability in data;
- Flavor dependence of taggability;
- Inclusive b-tagging efficiency in MC;
- Inclusive c-tagging efficiency in MC;
- Semileptonic b-tagging efficiency in MC;
- Semileptonic b-tagging efficiency in data;
- Negative tagging rate in data
- Light flavor SF in MC;
- Fragmentation model;
- Assumption $SF_c = SF_b$;

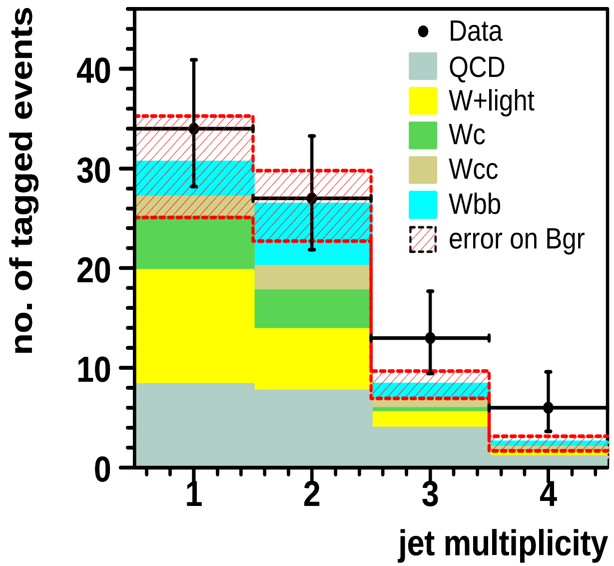
MC

- W fractions from g splitting in HERWIG;
- W fractions from PDF

Observed numbers of events vs predicted

Combined lepton + jets channels:

D0 Run II preliminary



CSIP

D0 Run II preliminary

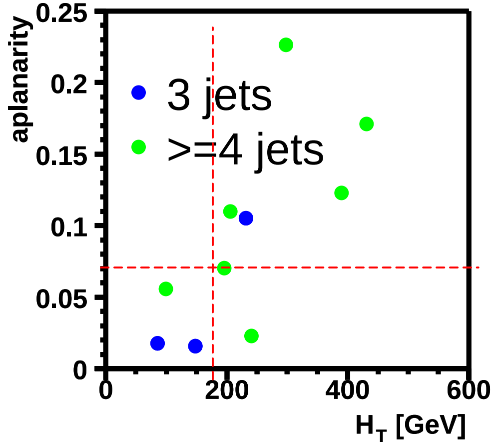
lepton + jets	1 jet	2 jet	3 jet	≥ 4 jet
Before tag	3681	1351	298	65
W + jets	22.3 ± 4.7	18.7 ± 3.4	4.4 ± 0.9	1.4 ± 0.4
QCD	8.2 ± 1.4	7.6 ± 1.2	3.9 ± 0.9	1.1 ± 0.4
Total BG	30.6 ± 5.0	26.4 ± 3.5	8.3 ± 1.3	2.5 ± 0.7
Expected $t\bar{t}$		0.7±0.1	2.8 ± 0.2	4.0 ± 0.6
BG + $t\bar{t}$	**30.6 ± 5.0**	**27.1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

Good agreement with BG expectation in the first two bins (no top contribution is expected there), clear excess observed in the number of tagged events over predicted BG in third and fourth jet multiplicity bins.

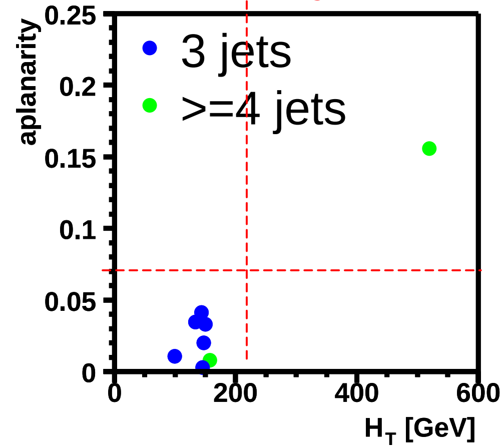
Comparison of b-tagging results with topological analysis

DØ Run II preliminary

e + jets

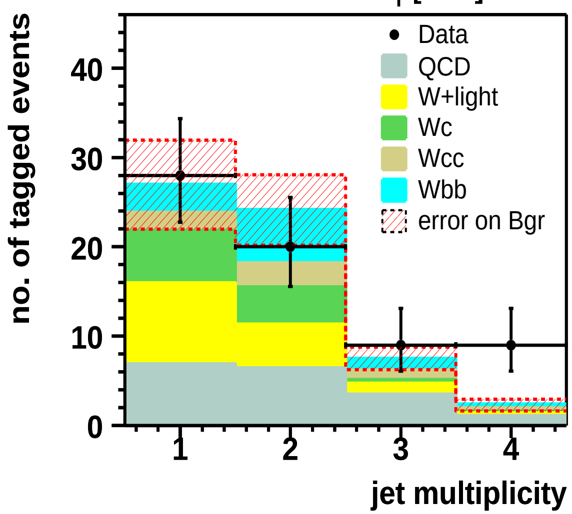


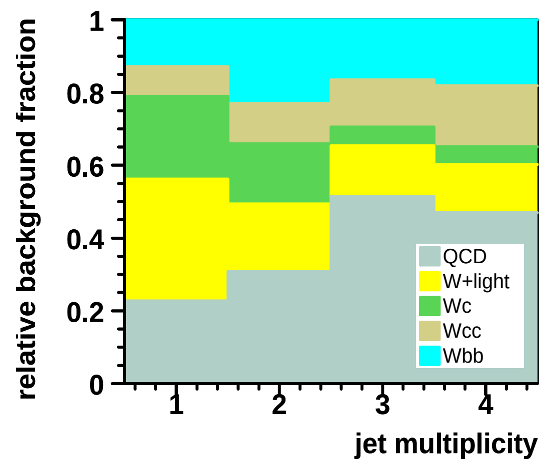
μ + jets



SVT

Many tagged events in e+jets channel pass topological cuts





Combined l+jets channels:

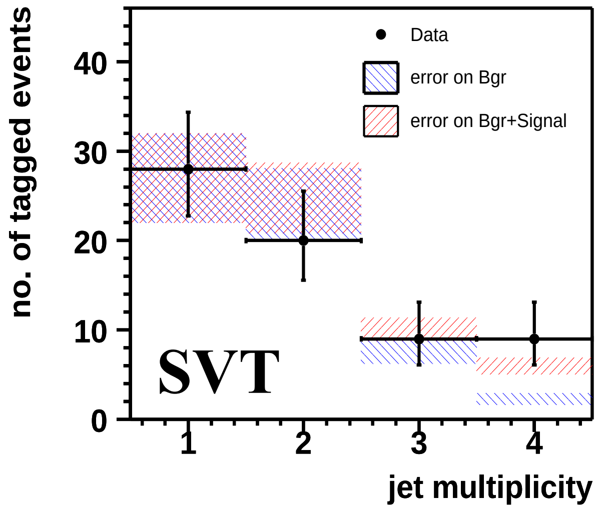
N of tagged events and BG composition

$t\bar{t}$ production cross-section

Look at the excess of tagged events over predicted ones in 3jet and ≥4jet multiplicity bins;

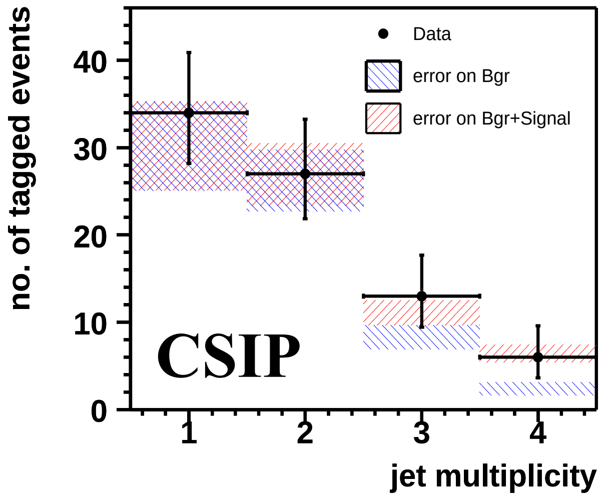
Perform a maximum likelihood fit to the observed numbers of events

# of tags	W+1 jet	W+2 jet	W+3 jet	W+≥ 4 jet
CSIP	34	27	13	6
SVT	28	20	9	9



L = 45 pb⁻¹

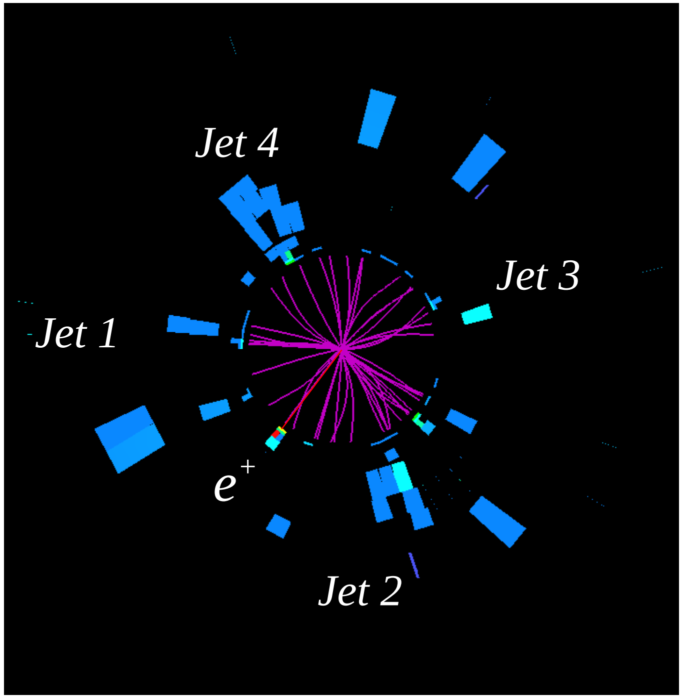
$(\sigma_{t\bar{t}} = 7\ pb)$



$$\sigma(t\bar{t}) = 10.8^{+4.9}_{-4.0}(stat)^{+2.1}_{-2.0}(syst) \pm 1.1(lumi)pb$$

$$\sigma(t\bar{t}) = 7.4^{+4.4}_{-3.6}(stat)^{+2.1}_{-1.8}(syst) \pm 0.7(lumi)pb$$

Tagged Event

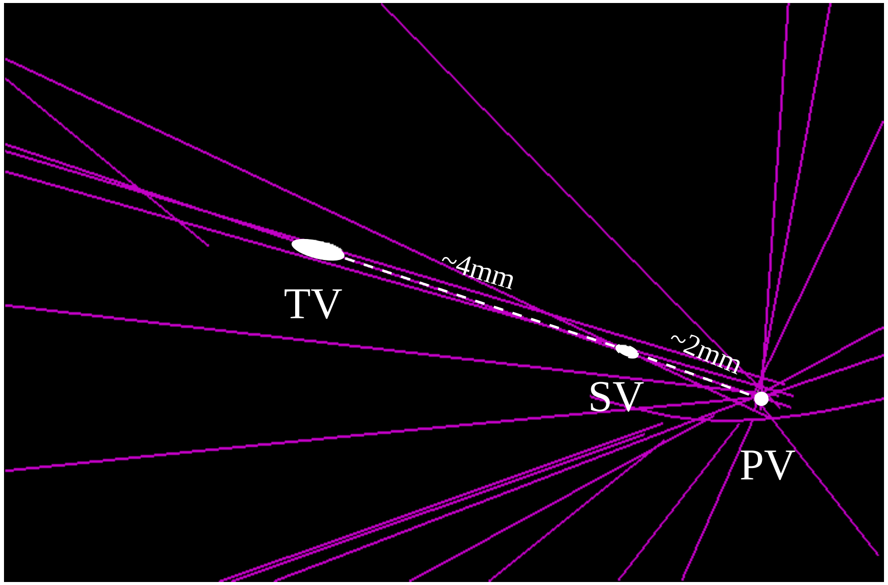


Event is tagged by both algorithms (run 169923 event 16396718)

$N_{jets} = 4$; $p_T(e) = 27$ GeV , MET = 58 GeV
$p_T(jet) = 51, 36, 30, 53$ GeV ;
$H_T = 207$ GeV
Aplanarity = 0.11

Primary vertex:

$N_{track} = 17$
$z = -4.6$ cm



Conclusions

- DØ has re-established top quark signal in the majority of top quark decay modes

  Topological $\sigma(t\bar{t}) = 8.5^{+4.5}_{-3.6}(stat)^{+6.3}_{-3.5}(syst) \pm 0.8(lumi)pb$

- DØ presents its first results on measurement of the top quark cross-section with lifetime b-tagging

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

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

- Results are obtained on Moriond data samples with limited statistics and controlled systematics errors
- Expect to have much better results by Winter Conferences

Outlook

- The DØ Run II measurements of the top pair production cross section demonstrate significant progress in the optimization and understanding of the detector performance
- There is a big potential to improve crucial aspects of physics analyses (tracking in jets, physics object identification, b-tagging optimization and many others)
- With larger statistics and better understanding of the data by the end of this year we expect to perform top quark measurements with greatly improved precision

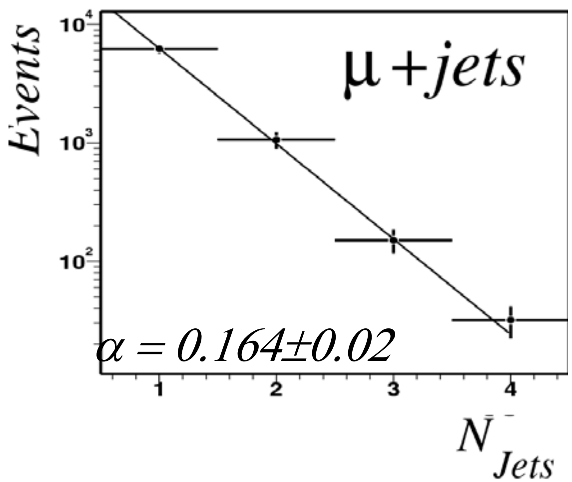
Background slides

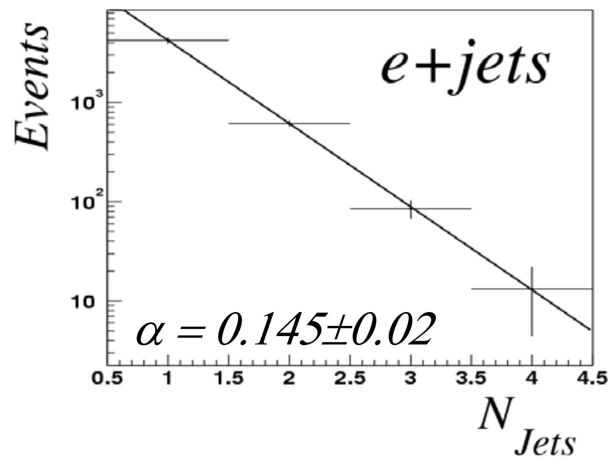
Lepton+jets: topological analysis

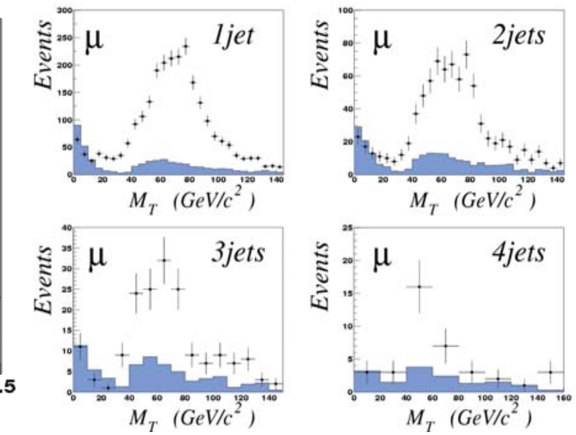
Berends scaling:

$$\alpha \equiv \frac{\sigma(W + (n+1)_{jets})}{\sigma(W + n_{jets})}$$

DØ Run II Preliminary







Estimation of the background for $N_{jets} \geq 4$ (from data, using matrix method):

$$\tilde{N}_W^4 = \begin{cases} 24.2 \\ 11.9 \end{cases} \qquad \tilde{N}_{QCD}^4 = \begin{cases} 11.9 \\ 12.5 \end{cases} \qquad N_{obs}^4 = \begin{cases} 22 \ \ (e\text{+}jets) \\ 38 \ \ (\mu\text{+}jets) \end{cases}$$

Lepton+jets: Analysis with soft lepton tagging

Selection before Soft Muon Tag

- *Use the same preselection as l+jets*
- *Require at least 3 jets*
- *Apply mild topological cuts*

(H_T>110 GeV, Aplanarity> 0.04)

(Loose/Tight sample)

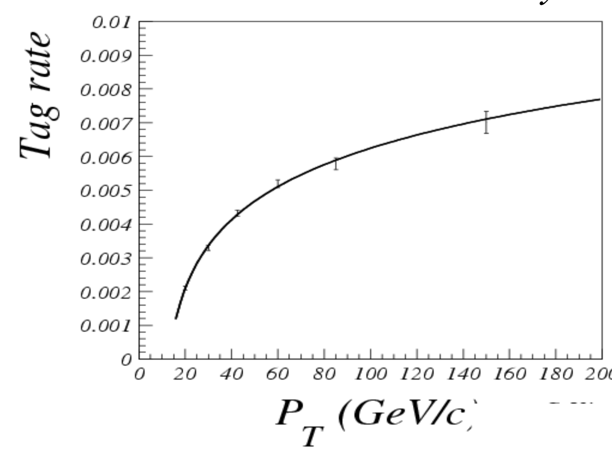
$$\Rightarrow \begin{cases} 75/23 \ (\mu\text{+jets}) \\ 459/27 \ (e\text{+jets}) \end{cases}$$

QCD background from matrix method

W bkg. from Tag rate functions:

$$\tilde{N}_W^{SLT} = \begin{cases} 0.4 \pm 0.1 \ (\mu) \\ 0.0 \pm 0.1 \ (e) \end{cases}$$

DØ Run II Preliminary



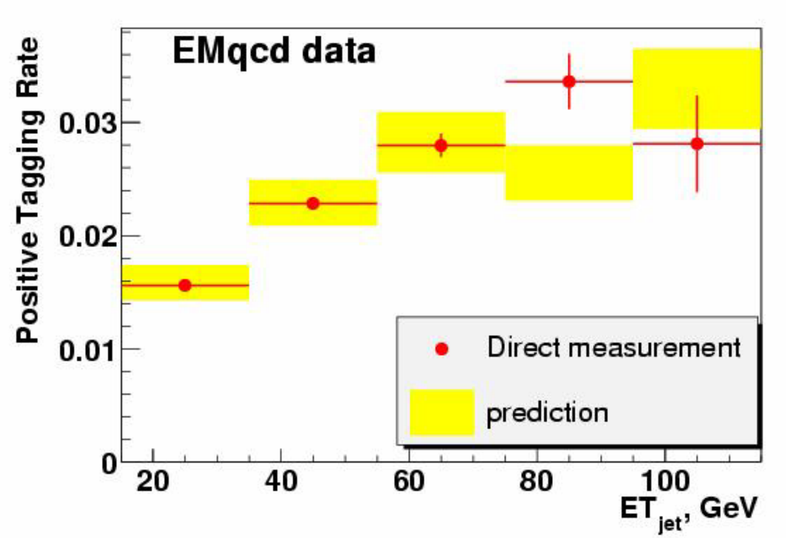
Analysis	Bkg. Tot.	Sig.*	N_{obs}
e+jets	**0.2±0.1**	**0.5**	**2**
μ+jets	**0.6±0.3**	**0.4**	**0**

* *For σ = 7pb*

Cross-check of the mistagging rate

Know light jet tagging efficiency, b and c-tagging efficiencies in data – can predict positive tagging rate in data which includes light and heavy flavor jets:

$$\varepsilon^{+} = \varepsilon_{light} \times F_{light} + \varepsilon_{btag} \times F_{b} + \varepsilon_{ctag} \times F_{c}$$



here all efficiencies and fractions are functions of (E_T,η); and

$$F_{light} = 1 - F_{b} - F_{c}$$

(F_b and F_c were obtained from QCD MC)

Good agreement between observed and predicted tagging rates!

Scale Factor (CSIP)