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B-tagging efficiency and background estimate for the Top Hadronic analysis in the Run II multijet dataset

The all-hadronic team
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Abstract

We measure the b-tagging efficiency to be used in the cross section measurement of the $t\bar{t}$ production in the all hadronic channel. We discuss also the estimate of the expected background based on a jet-based tag rate parametrization.

1 Introduction

The measurement of the $t\bar{t}$ production cross section in the all-hadronic channel requires the determination of three parameters:

- the tagging efficiency;
- the background form QCD and mistags after tagging.
- the systematics uncertainties associated to the background estimate

This note describes the procedure used to derive these numbers.

2 The Multijet Dataset

This dataset is derived from the *TOP_MULTI_JET* trigger which, essentially, requires at least 4 clusters of calorimetric towers with a minimum amount of total energy. In particular, the most recent (since February 2002) instantiation of the *multijet* trigger requires[1]:

- at **Level 1**: at least 1 tower with $E_T \geq 10$ GeV
- at **Level 2** : at least 4 clusters with $E_T^{cluster} \geq 15$ GeV and total energy $\sum E_T \geq 125$ GeV
- at **Level 3**: $N_{jet} \geq 4$ (JetClu), with $R_{cone} = 0.4$ and $E_T^{jet} \geq 10$ GeV ($z_{vertex} = 0$)

Such a trigger has a cross section of about 10 nb. From a TrgSim emulation of the trigger on MC data we have measured an efficiency of 66% on inclusive $t\bar{t}$ events and 88% efficient on all-hadronic events. The sample we currently have amounts to an integrated luminosity of 165 ± 10 pb^{-1} (good runs[2] from 140829 to 167751).

This dataset has been processed through the 4.8.4 production plus the "remake" procedure described in [1]. The analysis of this dataset (and of all Monte Carlo samples[2], production 4.9.1) has been made using *TopEventModule/TopNtuple* [3, 4] version 4.11.1

2.1 Prerequisites

We define some prerequisites[5] in order to have a sample of events as well defined and as clean as possible. These are the requests we make (jets are *JetClu* jets with fixed cone radius 0.4):

1. cut on the vertex: $|z_{vert}| < 60$ cm where z_{vert} is the "highest-SumPt" class-12 vertex, to restrict the analysis to events with a well centered beam-crossing. We ask also that the distance between this vertex and the one from PrimVtx be $|z_{vert} - z_{primvtx}| < 5$ cm, to insure that the vertex used for tagging is indeed close to the one used for jet clustering;
2. at least 4 jets with raw-$E_T > 15$ GeV and a loose cut on $|\eta| < 3.0$ (in *TopEventModule* to replicate the trigger;
3. MET significance: $\not{E}_T/\sqrt{\sum E_T} < 6$ as clean-up;
4. $\sum E_T$ of all jets ≥ 125 GeV, to replicate the trigger;
5. removal of events with a *good, high-P_T electron or muon* as in the single-lepton top definition[3] to avoid overlap with other leptonic analyses.

[1] Before February 2002, i.e. before run 143938, the Level 2 trigger required only $\sum E_T \geq 140$ GeV.
[2] Good runs according to the DQM group: version 4.0, QCD list with silicon.
[3] Default run II lepton-id *TopEventModule* parameters: *leptonIdCuts set 2*. Phoenix electrons are not considered.

2.2 Kinematical selection

The kinematical selection requires[5]:

- $6 \leq N_{jet} \leq 8$ (raw-$E_T \geq 10$, corrected-$E_T \geq 20$ GeV, $|\eta_{detector}| \leq 2.0$)
- $A + 0.0037 \sum_3 E_T \geq 0.85$
- $C \geq 0.77$
- $\sum E_T \geq 320$ GeV

where A is the Aplanarity and C is the Centrality of events.
This selection reaches a good value $S/B \approx 1/24$ with a reasonable efficiency ($\epsilon \approx 6.2\%$). The systematic uncertainty on the efficiency amounts to 30%.

3 b-tagging efficiency

3.1 Counting method

The SECVTX[4] tagging efficiency is evaluated on a $t\bar{t}$ sample generated with Herwig (ttopli).
In the counting method we degrade the tagged jets with a scale factor[5] (SF = 0.81 ± 0.07)[7], that is we randomly discard (100-81)% of positively tagged jets.
To understand the variation in efficiency between the single lepton analysis and the all-hadronic one, we study the dependence of the efficiency on the number of jets and we calculate the efficiency in 6 particular cases:

1. 3 jets + lepton[6]
2. 4 jets ($E_{Tcorr} \geq 20$ GeV, $|\eta_{detector}| \leq 2.0$)
3. 5 jets
4. 6 jets
5. ≥ 6 jets
6. ≥ 6 jets + kinematical selection

[4]The version of the tagger used is the one described in the High p_T B-Tagging group web page for Summer 2003.
[5]The scale factor accounts for the difference in efficiency between MonteCarlo events and real heavy floavor data.
[6]In this case the efficiency from[8] amounts to 52.3 ± 0.3 ± 7.0%.

The btagging efficiency per event, $\epsilon_{tag}^{overall-event}$, in the case of ≥ 1 (or ≥ 2) SecVtx tag in the various cases is summarized in Table 1. These efficiencies represent the fraction of $t\bar{t}$ events which have at least one (two) tagged jet, disregarding its origin. We evaluate also the efficiency $\epsilon_{ave-tag}^{jet}$ for finding tags.

Table 1: *b-tag efficiency summary (statistical uncertainty only)*

Efficiency (%)	3j+l	4j	5j	6j	$\geq$ 6j	$\geq$ 6j + kin.sel.
$\epsilon_{tag}^{overall}(\geq 1\,tag)$	51.3 $\pm$ 0.3	50.6 $\pm$ 0.3	52.2 $\pm$ 0.3	54.1 $\pm$ 0.3	54.4 $\pm$ 0.3	59.1 $\pm$ 0.5
$\epsilon_{tag}^{overall}(\geq 2\,tag)$	10.7 $\pm$ 0.1	10.4 $\pm$ 0.1	11.5 $\pm$ 0.1	12.7 $\pm$ 0.1	13.0 $\pm$ 0.1	16.1 $\pm$ 0.2
$\epsilon_{ave-tag}^{jet}$	62.2 $\pm$ 0.3	61.4 $\pm$ 0.3	64.2 $\pm$ 0.3	67.6 $\pm$ 0.3	68.3 $\pm$ 0.3	76.3 $\pm$ 0.5

For the cross section we need to know the efficiency for tagging any jet, disregarding its association to a b or a c quark. Such an efficiency amounts to $\epsilon_{ave-tag}$ = 76.3 $\pm$ 0.5(stat.) $\pm$ 6.5(syst.)% for $t\bar{t}$ events after the kinematical selection. The dominating systematic uncertainty is derived by comparing the efficiency obtained with SF = 0.81 + 0.07 and SF = 0.81 - 0.07.

3.2 Factorization Method

An alternative way to evaluate the efficiency is to factorize it to account for different components. The total efficiency can be defined as[6]:

$$\epsilon_{tag}^{overall-event} = \epsilon_{btag}^{event} + (1 - \epsilon_{btag}^{event}) \times \epsilon_{non-b}^{event} \tag{1}$$

with :

- ϵ_{non-b}^{event} being the fraction of starting events with at least 1 tagged non B-jet (a charm or a n on-heavy flavor jet)
- ϵ_{btag}^{event} being the fraction of starting events with at least 1 tagged B-jet[7]

This fraction is equal to:

$$\epsilon_{btag}^{event} = F_{2b} \times \epsilon_{btag} \times SF \times (2 - \epsilon_{btag} \times SF) + F_{1b} \times \epsilon_{btag} \times SF \tag{2}$$

where:

- F_{2b} = fraction of starting events that contain 2 taggable B-jets

[7] A tagged jet is associated to a b if ΔR < 0.4 between jet and b.

- F_{1b} = fraction of starting events that contain 1 taggable B-jets[8]

- SF = 0.81 ± 0.07

- ϵ_{btag}= efficiency, as measured in the $t\bar{t}$ Monte Carlo, for tagging a jet in acceptance (*taggable jet*).

Table 2: *Factorization Method tagging efficiency on events with ≥ 6j + kin.sel.*

Efficiency (%)	factor. method
F_{1b}	28.5 ± 1.7 (sta.+syst.)
F_{2b}	63.3 ± 2.0 (sta.+syst.)
ϵ_{btag}	53.3 ± 0.5 (stat.)
ϵ_{non-b}^{event}	2.9 ± 0.1 (stat.)
ϵ_{btag}^{event}	55.2 ± 4.5 (stat.+syst.)
$\epsilon_{tag}^{overall-event}$	56.6 ± 4.5 (stat.+syst.)

The efficiency found with this method, $\epsilon_{tag}^{overall-event} = (56.6 \pm 4.5)\%$, is smaller than what found with the tagging method because with the factorization we do not consider fully the correlations amongs tags. In addition, about 0.6% of the events would have 3 taggable B jets (i.e. 3 jets with ΔR < 0.4 respect to the b quarks) and these cases are not accounted for in the formula.

We summarize all efficiencies in figure 1.

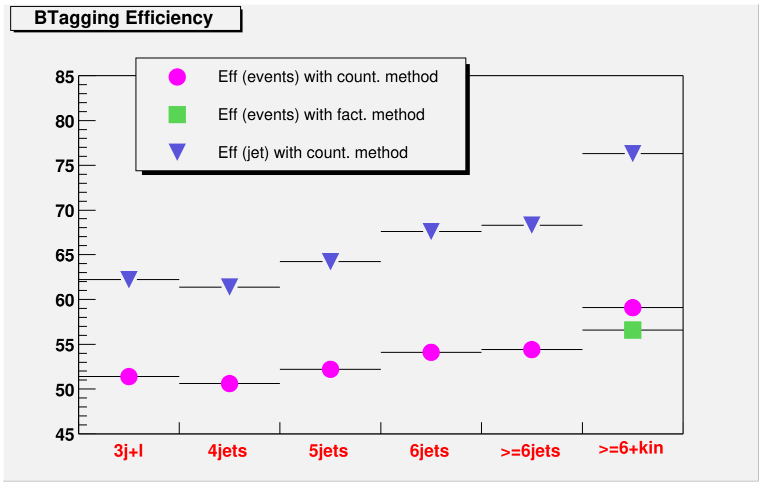

Figure 1: *Efficiencies per event and per jet with two methods. The uncertainties shown are statistical only. A systematic uncertainty of about 9% (=$\frac{0.07}{0.81}$) should be considered.*

[8] To evaluate the systematic uncertainty on F_{2b} and F_{1b} we repeat the matching with ΔR < 0.2 and quote half the difference.

4 Background estimate

In the multijet sample we expect the presence of tags coming from processes different from $t\bar{t}$ production. These processes are:

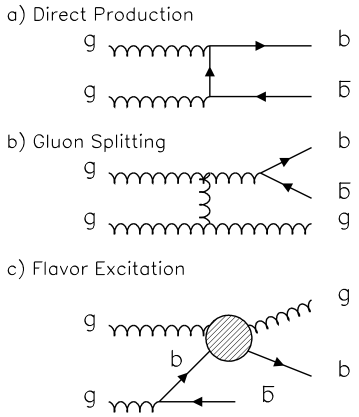

Figure 2: *Three sources of heavy flavour in inclusive jets: a) direct production; b) gluon splitting; c) flavour excitation.*

- QCD production of $b\bar{b}$ ($c\bar{c}$) by: direct production, gluon splitting or flavour excitation (fig.2);
- W and Z bosons production with radiation which produces $b\bar{b}$ by gluon splitting;
- W and Z bosons production with W/Z decaying into heavy flavors;
- mis-tag of light quark jets;

where the most important background contribution comes from the first one.

The method to estimate the total background is based on the assumption that even if the relative contribution from these processes changes as a function of jet multiplicity, the probability for a taggable jet to be tagged remains flat increasing the jet multiplicity (see fig.3). This allows to use the positive tag rate extracted on a $N(jet) = 4$ sample on jets in events with higher jet multiplicity or even other samples in order to estimate the number of expected tags. Such a probability (*tag rate*) is defined as:

$$\mathcal{P} = \frac{\#\ of\ tagged\ jets}{\#\ of\ taggable\ jets}$$

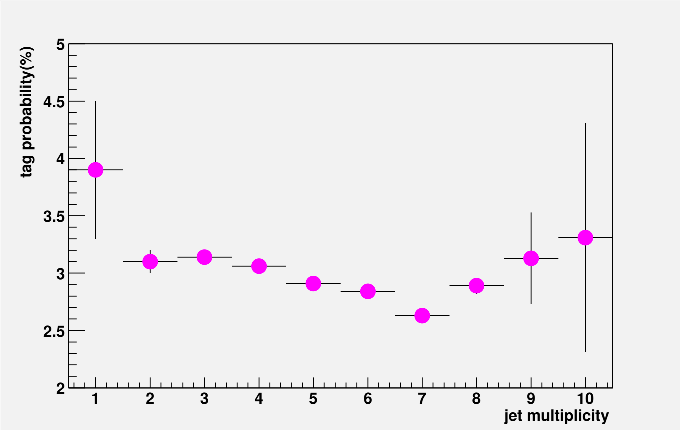

Figure 3: *Tagging probability for a taggable jet vs jet multiplicity.*

This is a pure "Method 1" background. There are a couple of drawbacks to this approach that represent the limitation of this measurement:

- the overall background estimate includes contribution from the $t\bar{t}$ signal, that needs to be iteratively subtracted for the cross section calculation
- it is important to measure the contribution to observed tags from the different processes and the change in the heavy flavor fractions as a function of jet multiplicites. Such "Method 2" approach relies on the use of large statistic MC datasets with the appropriate jet multiplicities. This work is currently in progress.

The negative tag rate parametrization will not be used directly for any final background estimate but only as a cross check of the matrix parametrization technique (see Appendix B).

4.1 Tag rate parametrization

To determine which variables are more suitable for the parametrization of the tag probability, we have studied its dependence on specific jet variables as E_T, η, the number of taggable tracks (N_{trk}) into the jet cone and the event Aplanarity (see figs.4, 5, 6, 7).

The jet tagging rate is parameterized in terms of corrected jet-E_T, jet-η and number of SVX tracks, N_{trk} and Aplanarity (A)). The tag rate is then:

$$\mathcal{P} = \mathcal{P}(E_T, \eta, N_{trk}, A)$$

With this choice we evaluate a 4-dimensional matrix[9] of positive tag rates in the control sample of

[9] 8 bins in E_T (20-25, 25-30, 30-40, 40-55, 55-75, 75-100 , 100-130, $\geq$ 130), 3 bins in η (0-1, 1-1.2, $\geq$ 1.2), 11 bins in N_{trk} and 3 bins in Aplanarity (0-0.1,0.1-0.25,0.25-0.5)

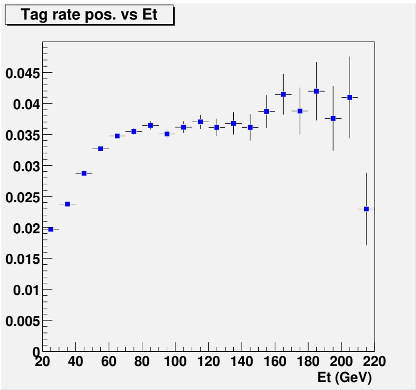

Figure 4: *Positive tag rate as a function of jet* E_T*.*

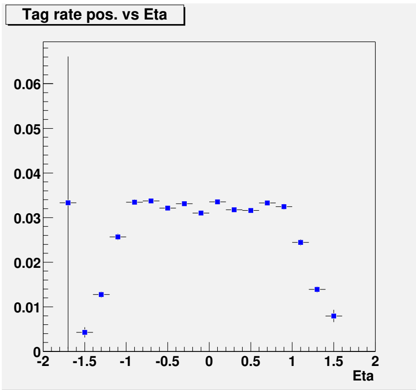

Figure 5: *Positive tag rate as a function of jet* η*.*

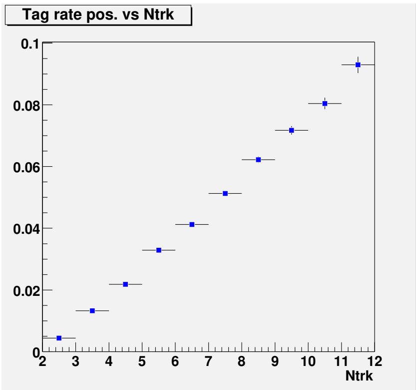

Figure 6: *Positive tag rate as a function of Ntrk.*

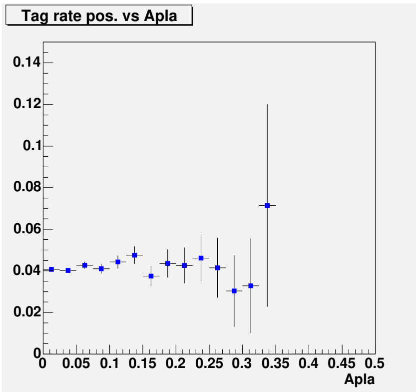

Figure 7: *Positive tag rate as a function of the Aplanarity.*

events with exactly 4 jets.

We use then this parametrization to estimate the expected tags in different samples or subsamples. The contribution to the total number of expected tags from the i-th event with n taggable jets is calculated as:

$$N^i_{exp} = \sum_{j=1}^{n} \mathcal{P}(E^j_T, \eta^j, N^j_{trk}, A)$$

while the expected background over all N events amounts simply to:

$$N_{exp} = \sum_{i=1}^{N} N^i_{exp}$$

We consider the numbers of *observed* and *expected* tags for events with respectively 4, 5, 6 and ≥ 7 jets:

Table 3: *Observed and Expected Positive Tags in our sample. Errors are statistical only*

N(jet)	4	5	6	7 or 8
Events	532634	249573	66807	15599
Taggable jets	1274233	742349	238532	67039
Obs Tags	38421	21313	6680	1708
Exp Tags	38421 ± 191	21150 ± 116	6524 ± 46	1734 ± 18
$\frac{N_{obs}-N_{exp}}{N_{exp}}$ (%)	0 ± 0.8	0.3 ± 0.9	2.3 ± 1.4	-1.4 ± 2.6

We see that the expectation agrees with the observed number of tags within a few % (see fig.8).

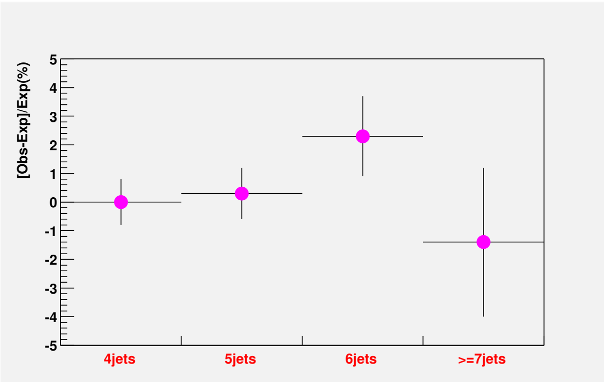

Figure 8: $N_{obs} - N_{exp}/N_{exp}$ *vs jet multiplicity.*

The agreement can be seen also in terms of average number of tags per event, see fig.9. In Appendix A we compare these numbers to those obtained for the jet50 mistag matrix.

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5 Systematics uncertainties on the background estimate

The systematic uncertainties on the background prediction are evaluated with the help of suitable control samples which are essentially composed of background events with the smallest possible presence of $t\bar{t}$ events. At the same time we need to keep these samples highly populated. To define these samples, we try to exclude $t\bar{t}$ events by "negating,, the all-hadronic kinematical selection[5]. Namely, we do it in this way:

- for the systematic on N_{jet} we consider all events with $N_{jet} \geq 6$, $\sum E_T \leq 320$ GeV, Centrality ≤ 0.77 and $(A + 0.0037 \sum_3 E_T) \leq 0.85$ (control sample #1);
- for the systematic on $\sum E_T$ we consider 5-jets which have Centrality ≤ 0.77 and $(A + 0.0037 \sum_3 E_T) \leq 0.85$ (control sample #2);

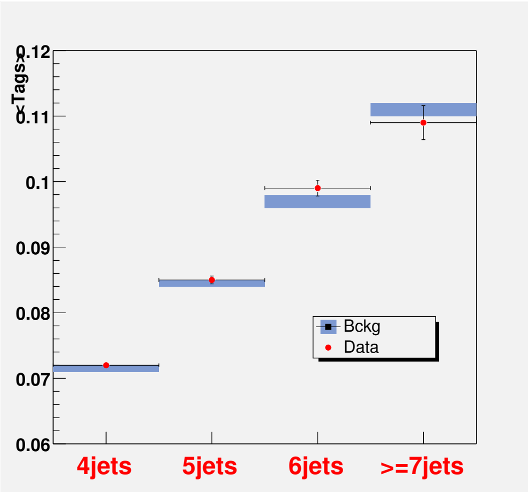

Figure 9: *Average number of tags per event before kinematical selection as a function of the jet multiplicity.*

- for the systematic on Centrality, we consider 5-jets events which have $\sum E_T \leq 320$ GeV and $(A + 0.0037 \sum_3 E_T) \leq 0.85$ (control sample #3);
- for the systematic on $(A + 0.0037 \sum_3 E_T)$ we consider 5-jets events which have Centrality ≤ 0.77 and $\sum E_T \leq 320$ GeV (control sample #4);
- for the systematic on the instantaneous luminosity, run number and jet-ϕ we consider events with 4 jets (control sample #5).

5.1 Procedure for the N_{jet} systematic

In this case to derive the systematic uncertainty we perform a direct comparison between the number of OBServed and EXPected tags in the control sample #1 and we obtain:

$$N_{obs} = 3542 \tag{3}$$

$$N_{exp} = 3550 \pm 47 \tag{4}$$

$$(N_{obs} - N_{exp})/N_{exp} = 0.2\% \tag{5}$$

5.2 Procedure for the Luminosity, Run number and the jet-ϕ systematics

To calculate the systematic uncertainties on these variables we proceed in this way:

- in the corresponding control sample (control sample #5) we fit the distributions of the N_{obs}/N_{exp} ratio with a first degree polynomial;
- convolute the polynomial function with the corresponding distribution of the events passing our kinematical selection;
- the integral of the convolution, compared to the tags present in the events passing the kinematical selection, gives the total systematic uncertainty.

We use the procedure described above with control sample #5 and make the convolution. The systematics on jet-ϕ , luminosity and run number are $\ll 1\%$ (fig.11, 12, 10).

5.3 Procedure for the $\sum E_T$, Centrality and $(A+0.0037\sum_3 E_T)$ systematics

To calculate the systematic uncertainties on these variables we need to use a particular procedure. We proceed in this way:

- in the corresponding control sample we fit the distributions of the N_{obs}/N_{exp} ratio with a first degree polynomial;
- for events passing the kinematical selection, we drop the 6^{th} (and additional) jet and reconstruct new $\sum E_T$, Centrality and $(A+0.0037\sum_3 E_T)$ distributions (“6-to-5 jet,, distributions);
- convolute the polynomial function with the corrisponding “6-to-5,, distribution;
- the integral of the convolution , compared to the tags present in the events passing the kinematical selection, gives the total systematic uncertainty.

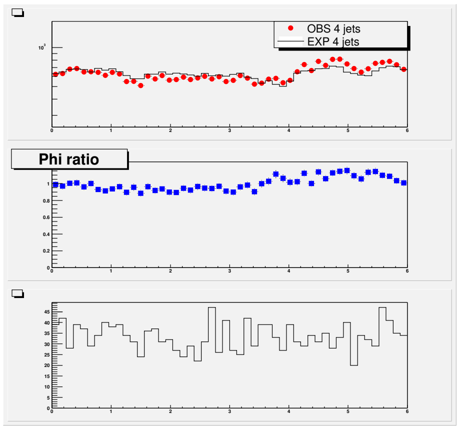

Figure 10: *Top: jet-ϕ distribution for OBServed and EXPected tags in the control sample. Middle: ratio N_{obs}/N_{exp} vs jet-ϕ in the control sample. Bottom: jet-ϕ distribution after kinematical selection.*

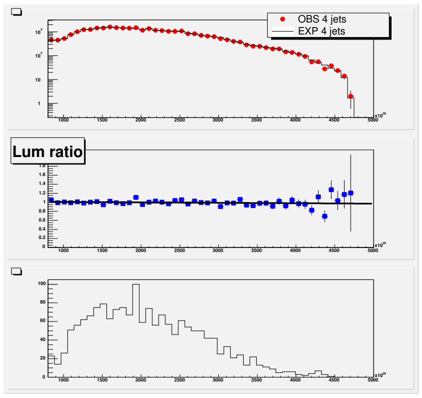

Figure 11: *Top: Luminosity distribution for OBServed and EXPected tags in the control sample. Middle: ratio N_{obs}/N_{exp} vs Luminosity in the control sample. Bottom: Luminosity distribution after kinematical selection.*

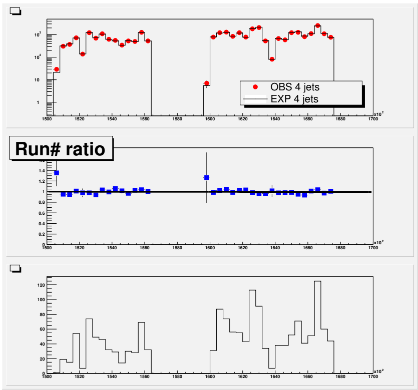

Figure 12: *Top: Run number distribution for OBServed and EXPected tags in the control sample. Middle: ratio N_{obs}/N_{exp} vs Run number in the control sample. Bottom: Run number distribution after kinematical selection.*

5.3.1 Systematics on $\sum E_T$

We use the procedure described above with control sample #2 and make the convolution (fig.13). The systematic on $\sum E_T$ is 1.4%.

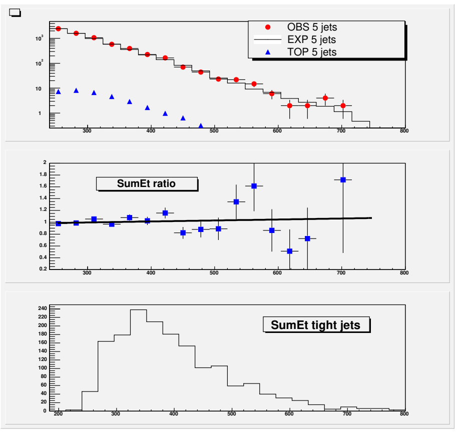

Figure 13: *Top: $\sum E_T$ distribution for OBServed and EXPected tags in the control sample also shown in the expectation from $t\bar{t}$. Middle: ratio N_{obs}/N_{exp} vs $\sum E_T$ in the control sample. Bottom: "6-to-5" $\sum E_T$ distribution for events passing the kinematical selection.*

5.3.2 Systematics on Centrality

We use the procedure described above with control sample #3 and make the convolution (fig.14). The systematic on Centrality is 0.3%.

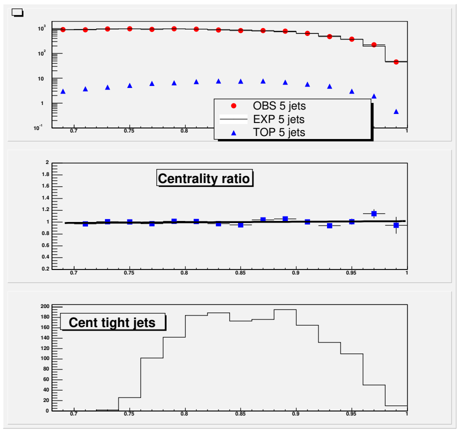

Figure 14: *Top: Centrality distribution for OBServed and EXPected tags in the control sample also shown in the expectation from $t\bar{t}$. Middle: ratio N_{obs}/N_{exp} vs Centrality in the control sample. Bottom: "6-to-5" Centrality distribution for events passing the kinematical selection.*

5.3.3 Systematics on $(A + 0.0037 \sum_3 E_T)$

We use the procedure described above with control sample #4 and make the convolution (fig.15). The systematic on $(A + 0.0037 \sum_3 E_T)$ is 4.7%.

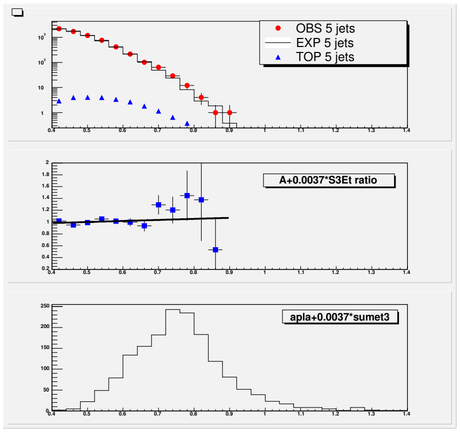

Figure 15: *Top: $(A + 0.0037 \sum_3 E_T)$ distribution for OBServed and EXPected tags in the control sample also shown in the expectation from $t\bar{t}$. Middle: ratio N_{obs}/N_{exp} vs $(A+0.0037 \sum_3 E_T)$ in the control sample. Bottom: "6-to-5,,$(A+0.0037 \sum_3 E_T)$ distribution for events passing the kinematical selection.*

5.4 Total systematic uncertainty with the 4-dim parametrization

The total systematic uncertainty, obtaining by summing all sources in quadrature, amounts to 5%.

Table 4: *Summary table of parametrization systematics*

Source	%
N(jet)	0.2
Run #	$\ll 1$
Luminosity	$\ll 1$
Phi	$\ll 1$
$\sum E_T$	1.4
Centrality	0.3
Aplanarity $+0.0037 \sum E_T^3$	4.7
Total	5

6 Background estimate after kinematical selection

We now estimate the background expected after the kinematical selection:

Table 5: *Observed and Expected Tags in our sample after kin. selection*

N(jet)	4	5	6	7 or 8
Events	60	420	773	883
Obs Tags	11	70	170	156
Exp Tags (stat.+syst. unc.)	$7.9 \pm 0.4 \pm 0.4$	$62.9 \pm 1.4 \pm 3.1$	$126 \pm 2 \pm 6$	$152 \pm 2 \pm 8$
$N_{obs} - N_{exp}$	3.1 ± 0.6	7.1 ± 3.1	44 ± 6	4 ± 8

For $N_{jet} \geq 6$ (SIGNAL REGION) we have:

$$N_{obs} = 326 \; tags \tag{6}$$

$$N_{exp}(bck) = 278.0 \pm 2.8(stat) \pm 13.9(syst.) \; tags \tag{7}$$

$$N_{obs} - N_{exp}(bck) = 48.0 \pm 14.0 \; tags \tag{8}$$

The presence of the excess is visible also in fig.16.

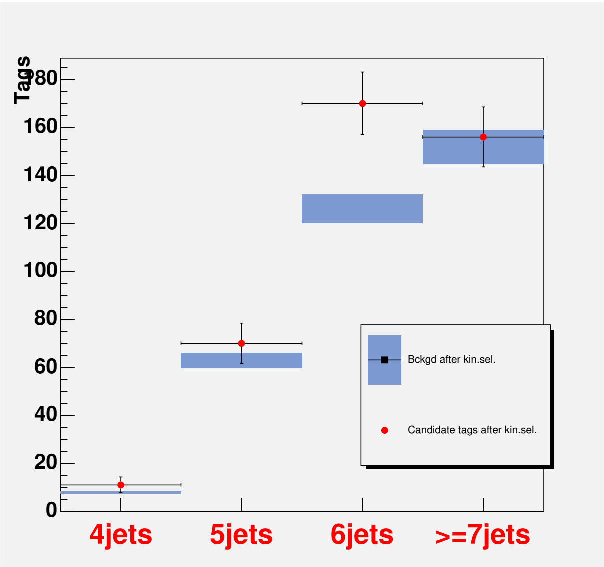

Figure 16: *Comparison between OBServed and EXPected tags in each multiplicity bin.*

To evaluate the significance of the measure excess, we first smear the expected background $N_{exp}(\text{bck}) = 278$ by the 2.8 statistical uncertainty, then we fluctuate according to Poisson statistics, finally we smear the resulting value by the 5% systematic uncertainty and calculate the likelihood that a fluctuation of the background (so obtained) alone would yield a number of tagged jets larger of equal to 326, the number observed. This probability amounts to P = 1.7×10^{-2} corresponding to 2.1 σ.

The evidence of the excess, mainly in the 6 jets bin, is apparent also when we look at the average number of tags per event as a function of the jet multiplicity (see fig.17).

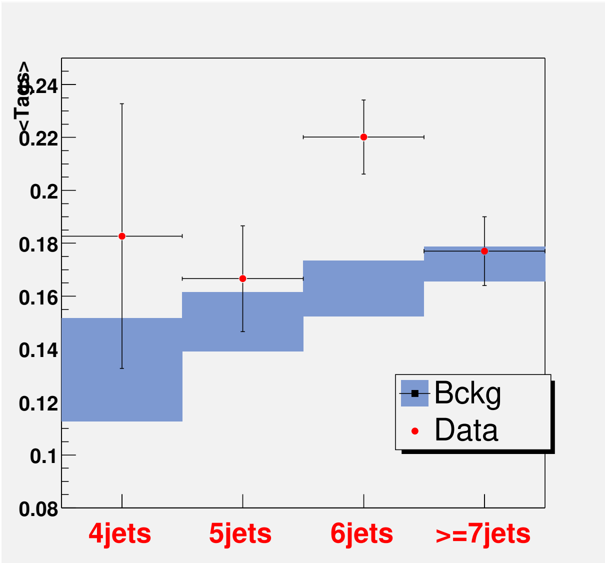

Figure 17: *Average number of tags per event as a function of the jet multiplicity.*

7 Signal after tagging

The presence of $t\bar{t}$ events in the pre-tag sample leads to an overestimate of the background. We can account for it with an iterative procedure to rescale the background in this way:

$$N'_{exp} = N_{exp} \times \left(\frac{N - N_{t\bar{t}}}{N}\right)_{pretag} \tag{9}$$

where N = 1656 is number of pre-tag events and $N_{t\bar{t}}$ is number of pre-tag $t\bar{t}$ events i.e. $(N_{obs} - N_{exp})/\epsilon_{tag}$ where $\epsilon_{tag} = (76.3 \pm 6.5)\%$. In particular:

$$N'_{exp} = 264.7 \pm 17.2 \; tags \tag{10}$$

and the corrected excess would be:

$$N_{obs} - N'_{exp} = 61.3\ tags \tag{11}$$

In this case the probability for a fluctuation of the background $N'_{exp} = 264.7 \pm 17.2$ up to the 326 observed tags is P = 3.3×10^{-3} (corresponding to 4σ).
The corrected background is shown, as a function of jet multiplicity, in the table:

Table 6: *Corrected background after the kinematical selection*

N(jet)	4	5	6	7 or 8
Events	60	420	773	883
Corrected bck	7.3 ± 0.7	61.3 ± 4.1	114 ± 7	151 ± 10

8 Conclusions

We have measured the tagging efficiency in terms of tagged jets and tagged events (i.e. events with at least 1 tagged jet). The efficiency for finding tags in events passing the kinematical selction amounts to $\epsilon_{ave-tag} = (76.3 \pm 6.5)\%$.
We have also discuss the background estimate obtained from a tag rate parametrization. Such an estimate well describes the observed tags within 5%, which assume to be our systematic uncertainty on the background prediction. In events passing the kinematical selection the expected background amounts to $N'_{exp} = 264.7 \pm 17.2$ tags.

9 Appendix A: comparison with jet50 mistag matrix.

We apply the jet50 mistag matrix on our data sample before the kinematical selection but cleary the agreement is better when we use ours. In fact the observed and the expected numbers disagree at most by 2.3% with our parametrization and as much as 6.7% with the jet50 matrix:

Table 7: *jet50 mistag matrix on our sample*

N(jet)	4	5	6	7 or 8
Events	532634	249573	66807	15599
Obs Tags	38421	21313	6680	1708
Exp Tags (stat. unc.)	37029 ± 161	20403 ± 104	6263 ± 37	1650 ± 11
$\frac{N_{obs}-N_{exp}}{N_{exp}}$(%)	3.8 ± 0.7	4.5 ± 0.9	6.7 ± 1.4	3.5 ± 2.5

The fact that the jet50 does not work well for our sample is not surprising. In fact the jet50 matrix has been derivered from a sample of inclusive jets dominated by di-jet events which have:

- different topology (i.e. smaller jet multiplicity);
- different kinematics (for istance smaller total energy);
- different trigger, hence different composition in terms of physics processes;

so its usage in the multijet sample suffers from large extrapolation and would require an additional systematic uncertainty.

10 Appendix B: negative tags.

We do not use negative tags for our background prediction, but we see however that our parametrization tends to underestimate negative tags as we increase jet multiplicity.

Table 8: *negative tags*

N(jet)	4	5	6	7 or 8
Events	532634	249573	66807	15599
Obs Tags	9774	5593	1745	515
Exp Tags (stat. unc.)	9774 ± 98	5232 ± 58	1593 ± 23	420 ± 9
$\frac{N_{obs}-N_{exp}}{N_{exp}}$(%)	0 ± 1.4	6.9 ± 1.7	9.5 ± 2.8	23 ± 5

This is 10-20% disagreement in the prediction for negative tags does not affect our measurement for positive tags because:

- the background is dominated by real heavy flavor and not fake tags: if negative tags are assumed to be essentially fake tags, then these fakes represent about 30% of positive tags;
- any inconsistency between observed and expected negative tags would appear in the positive tags decreased by such amount; in any case it would be already accounted for in our evaluation of the systematic uncertainty.

References

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[3] E. Thomson *et al.*, *CDF Note* 5947, revised October 2003; see also http://www-cdf.fnal.gov/internal/people/links/EvelynThomson/documentation2.html

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