Measurement of the Top Quark Pair Production Cross Section in Lepton+Jets Final States at D∅ using Lifetime b-Tagging

Flera Rizatdinova (KSU)
for the D∅ Collaboration

- *Introduction*
- *Analysis overview*
- *b-tagging performance*
- *Background calculation*
- *Results*
- *Conclusions*

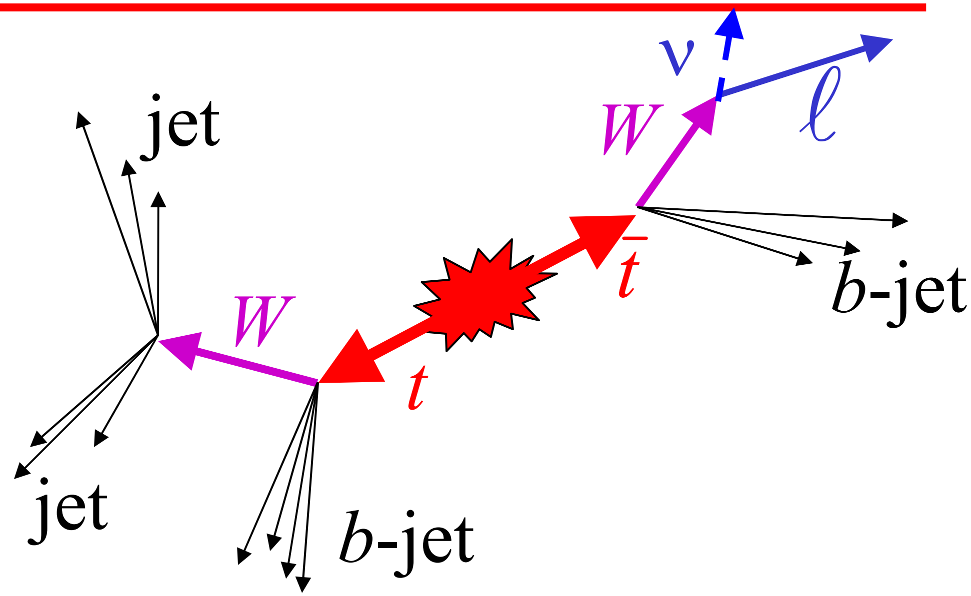
Introduction

- 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 (like top decays to a charged Higgs boson and *b* quark).
- Good test of perturbative QCD which predicts $t\bar{t}$ cross section.
- Tevatron is the only place to study top quark properties before LHC operation (where it will be a major background to many searches of new physics).
- ***Top quark studies are the primary goal of the Run II at the Tevatron.***

Lepton+jets channel

Golden mode:

- Large statistics (compared to dilepton channel);
- Clear signature (compared to all-jets channel);
- *b*-tagging - effective tool to improve signal-to-background ratio



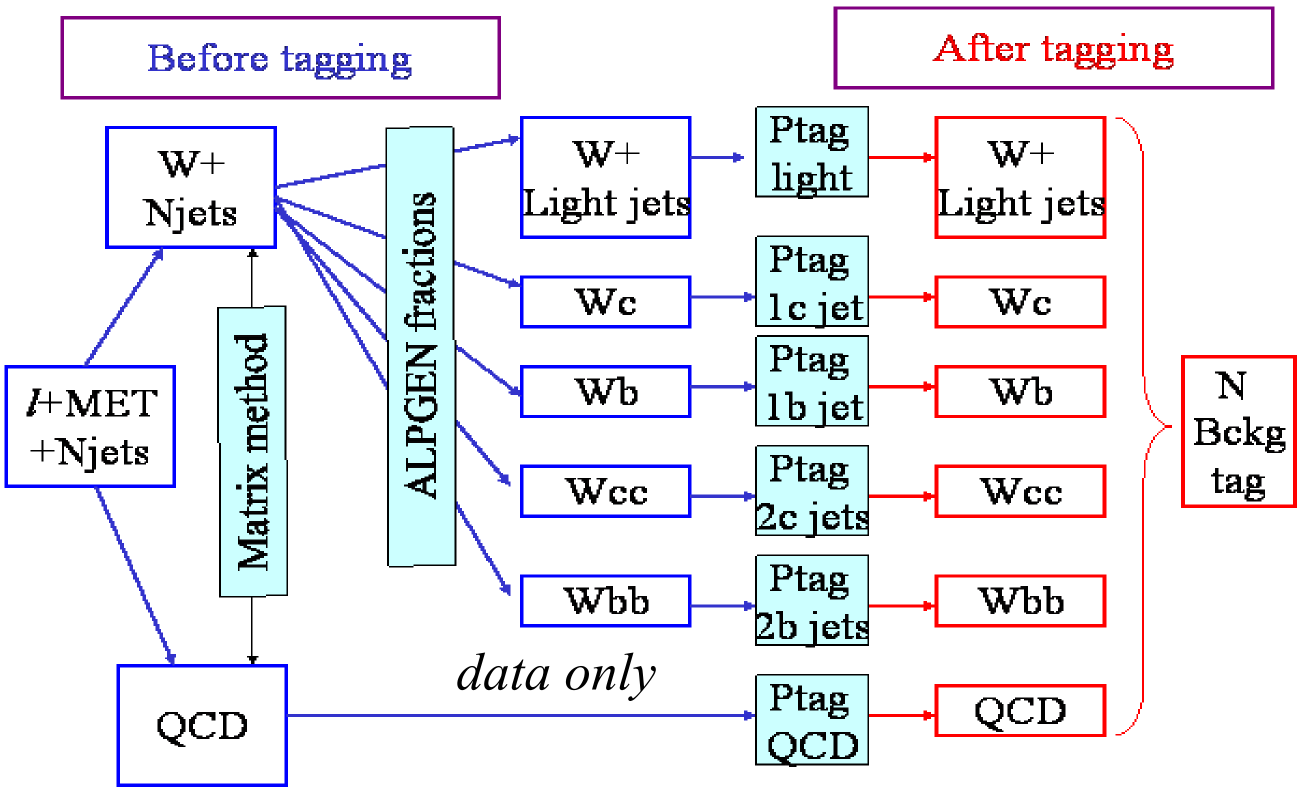
Event selection:

- Missing E_T (neutrino) (>20 GeV in *e*+jets and > 17 GeV in μ+jets channel);
- One high-p_T isolated lepton (p_T>20 GeV);
- Number of jets ≥ 3 (E_T>15 GeV)

Backgrounds:

- W+jets production – dominant ;
- QCD multijet production;
- Single top, VV production, $Z \to \tau^+\tau^-$
- Z+jets production;

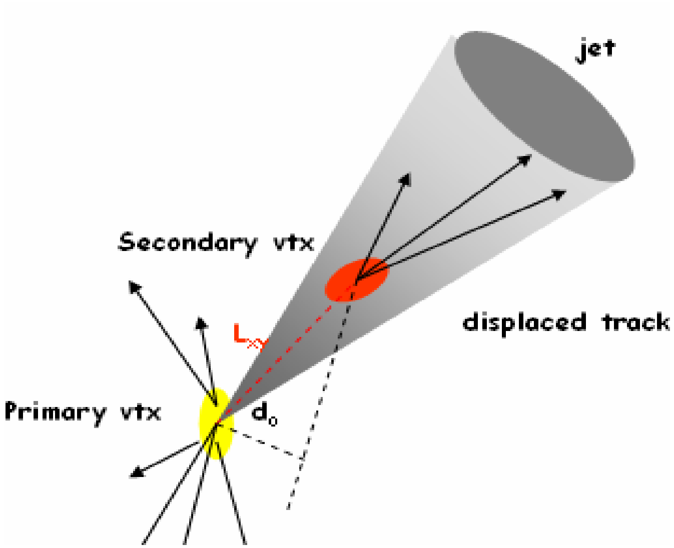
Lepton+jets with b-tagging: Method overview



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

Other small backgrounds are estimated using SM cross sections; will discuss in more details further

Two b-tagging methods

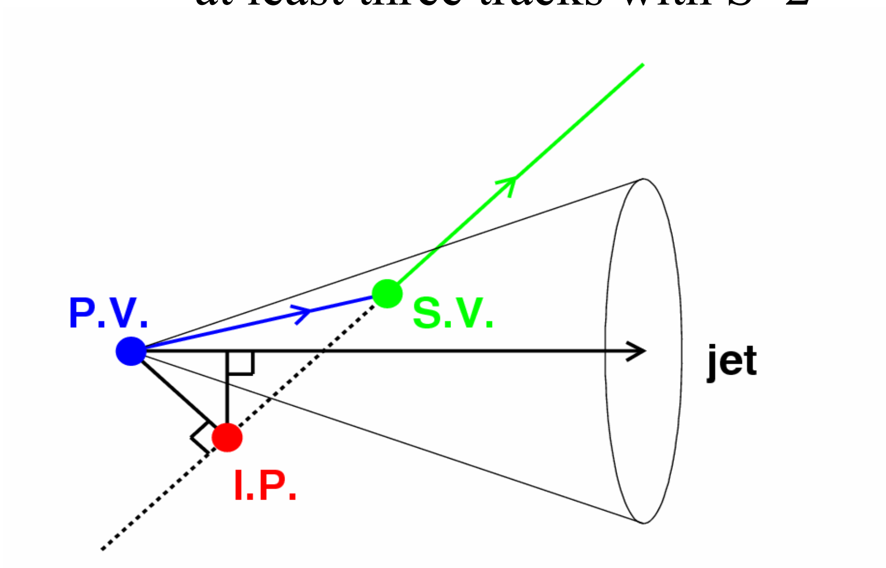


Secondary Vertex Tag (SVT)

- Look for displaced vertices (≥ 2 tracks),
- jet is tagged as a *b* jet
  - If signed decay length significance >7

Counting Signed Impact Parameter tag (CSIP)

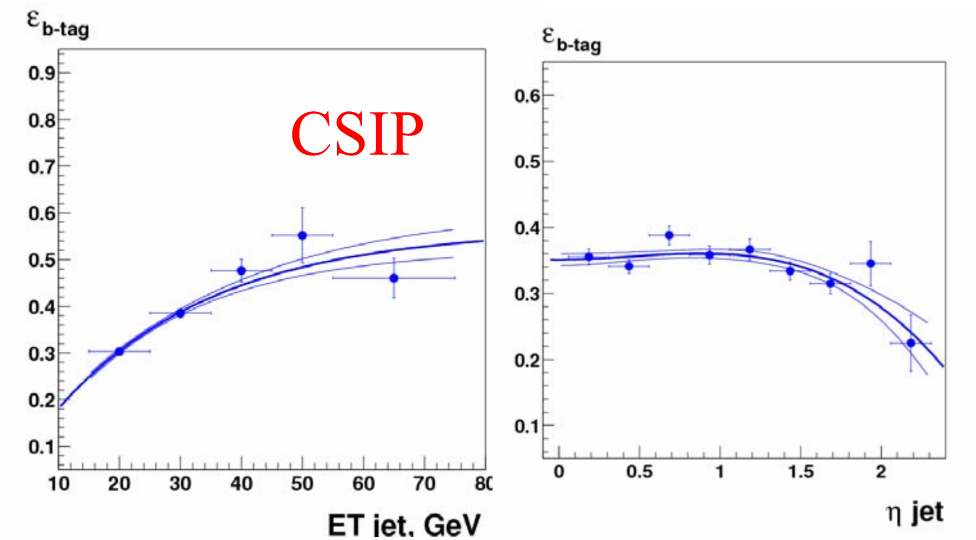
- S = IP/σ(IP)
- Jet is positively tagged if it has
  - at least two tracks with S>3 or
  - at least three tracks with S>2

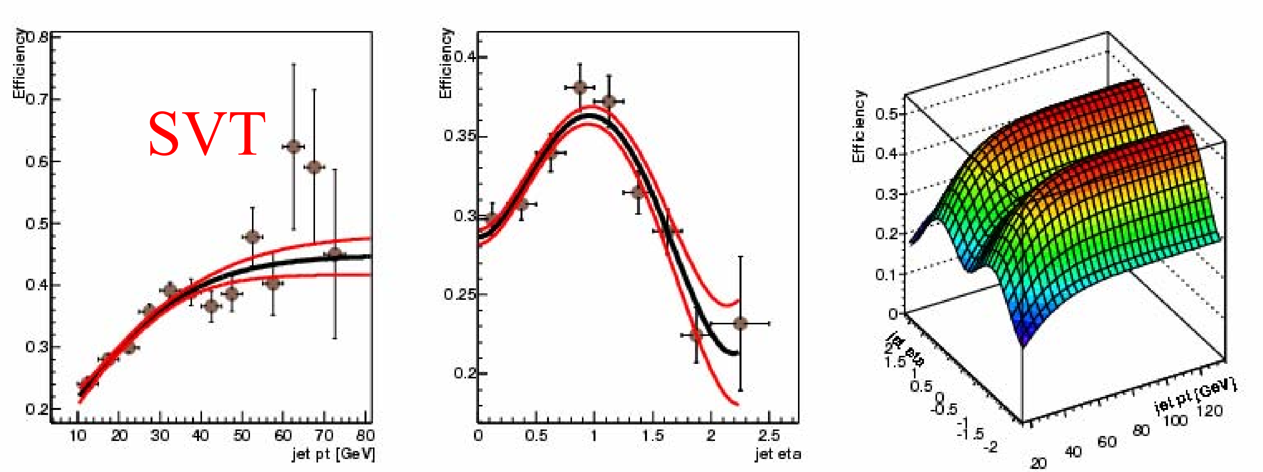


b-tagging efficiency in data

b-tagging efficiency measured in data:

Used data set of jets that have a muon inside them – this data is enhanced with heavy flavor content





Probability to tag a tt event P($n_{tag} \geq 1$):

CSIP: ~61%

SVT : ~58%

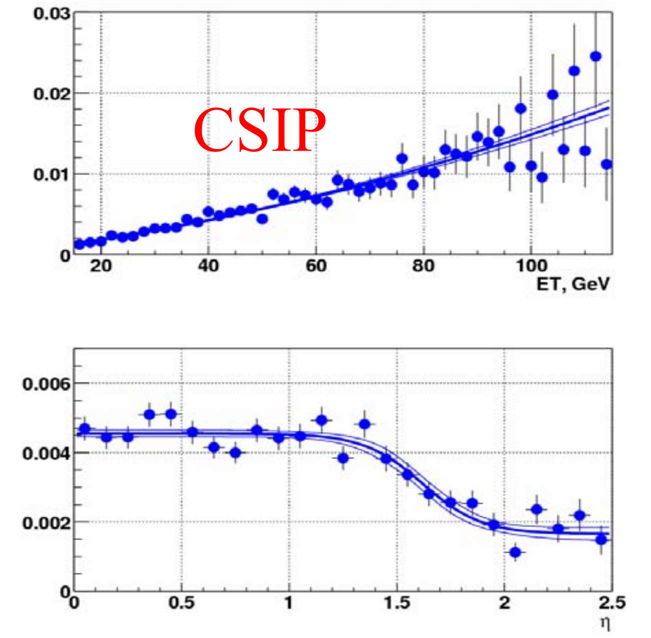
Mistagging rate in data

Measured negative tagging rate ε^- (NTR) on data;

Need to correct NTR for presence of heavy flavor component and for absence of fragments from long-lived particles:

$$\varepsilon_{light}(p_T,\eta) = \varepsilon^-(p_T,\eta) \cdot SF_{hf} \cdot SF_{ll}$$

These coefficients were derived from Monte Carlo, their product is ~1

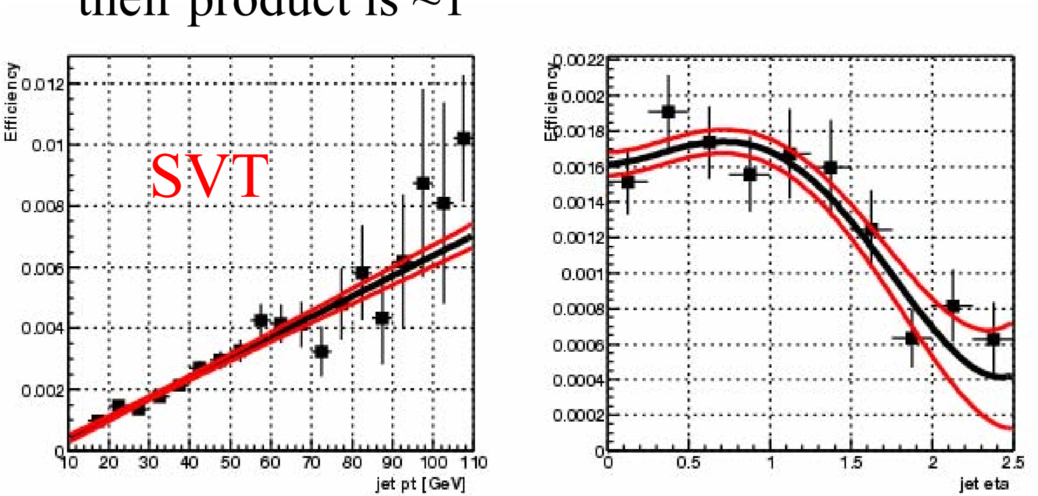


W+4 light jets events

$P(n_{tag} \geq 1)$:

CSIP: ~2.6%

SVT: ~1.1%



Background estimation: W+jets

- Use *W+jets* sample generated with ALPGEN interfaced to PYTHIA;
- Rely on ratios of the cross sections;
- Apply matching procedure to eliminate double counting and reduce sensitivity to parton generation cuts.

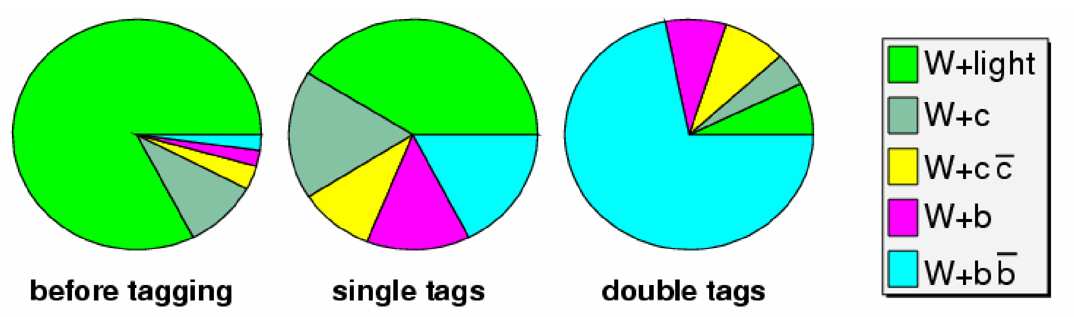
Estimated N of W+jets events after tagging:

$$\tilde{N}_{W+nj} = N_{W+nj} \times \tilde{P}^{tag}_{W+nj}$$

N of preselected W+nj events before tagging

Average event tagging probability

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



Background estimation: QCD background

e+jets ("ordinary" QCD)

- N_{QCD} in **preselected** sample is estimated from Matrix Method:
  - Different probabilities for lepton from QCD and W decays to pass certain criteria
- Measure probability P_{QCD} to tag a QCD event on data;
- Expected number of events after tagging:

$$N_{QCD}^{tag} = P_{QCD} \times N_{QCD}$$

μ*+jets* (a lot of heavy flavor)

- Apply *b*-tagging to preselected sample;
- N_{QCD} in **tagged** sample is estimated from Matrix Method;
- Checked with *e+jets* data that both methods give the same results within errors

Caveat:

- Low statistics of tagged sample leads to relatively large statistical error on N_{QCD} events

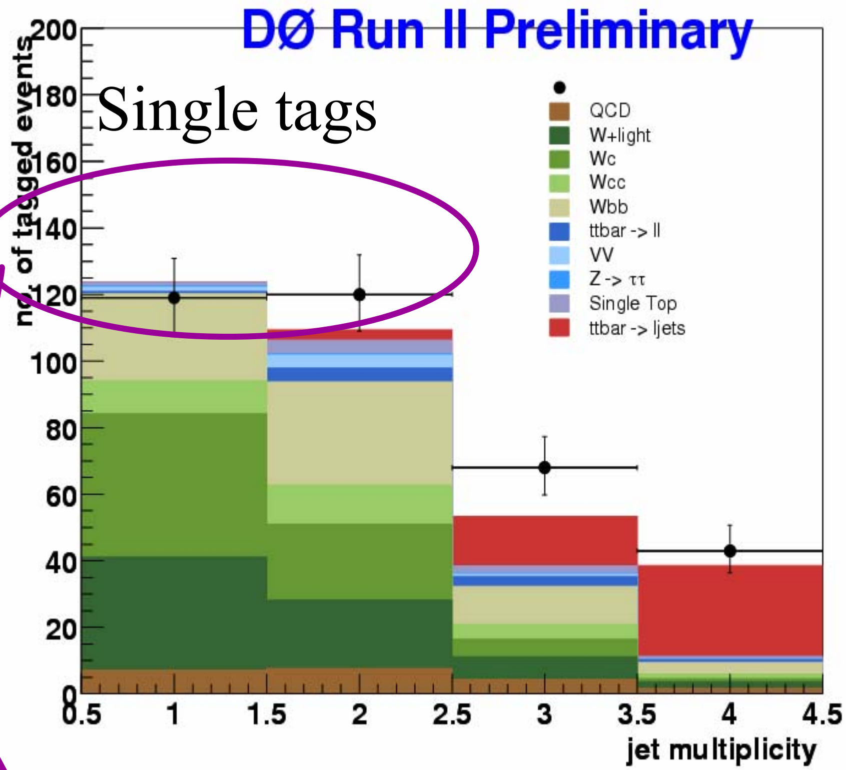
Background estimation: other small backgrounds

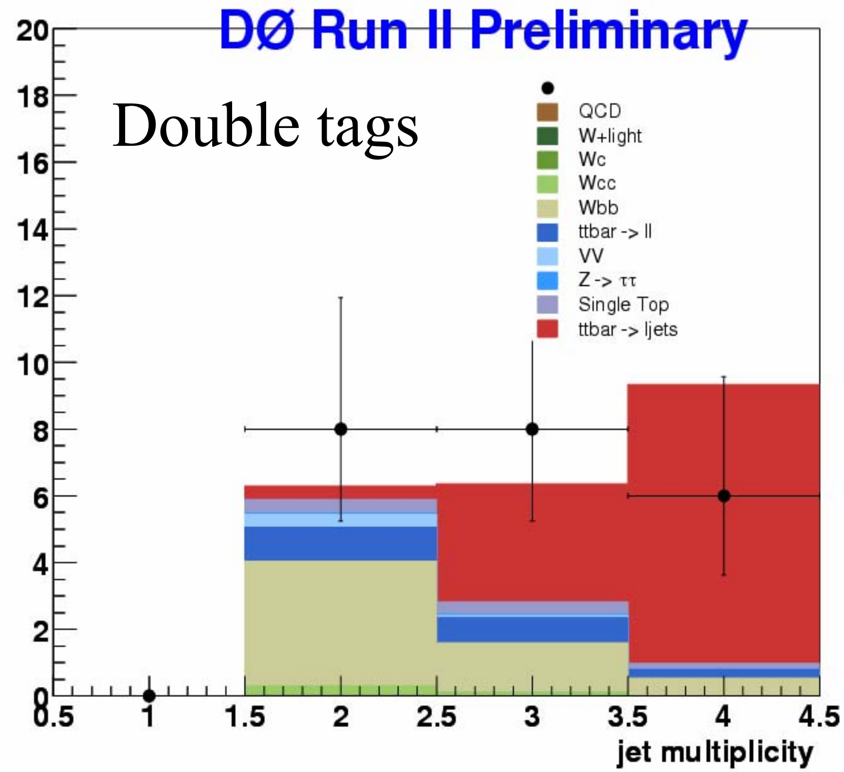
- Single top, WW, WZ, ZZ production, $Z \rightarrow \tau^+\tau^-$;
  - Subtract using theoretical cross sections;
  - Theoretical uncertainties do not have big impact since the contribution from these processes is small;
- Z+jets production;
  - Similar to W+jets (but much smaller), treat them together;
- $tt \rightarrow$dileptons
  - Treat as a signal

SVT results

Lepton+jets channel:(*e+jets* : L = 169 pb^{-1} ; μ*+jets*: L = 158 pb^{-1});

tt contribution is shown for σ_{tt}= 7 pb;

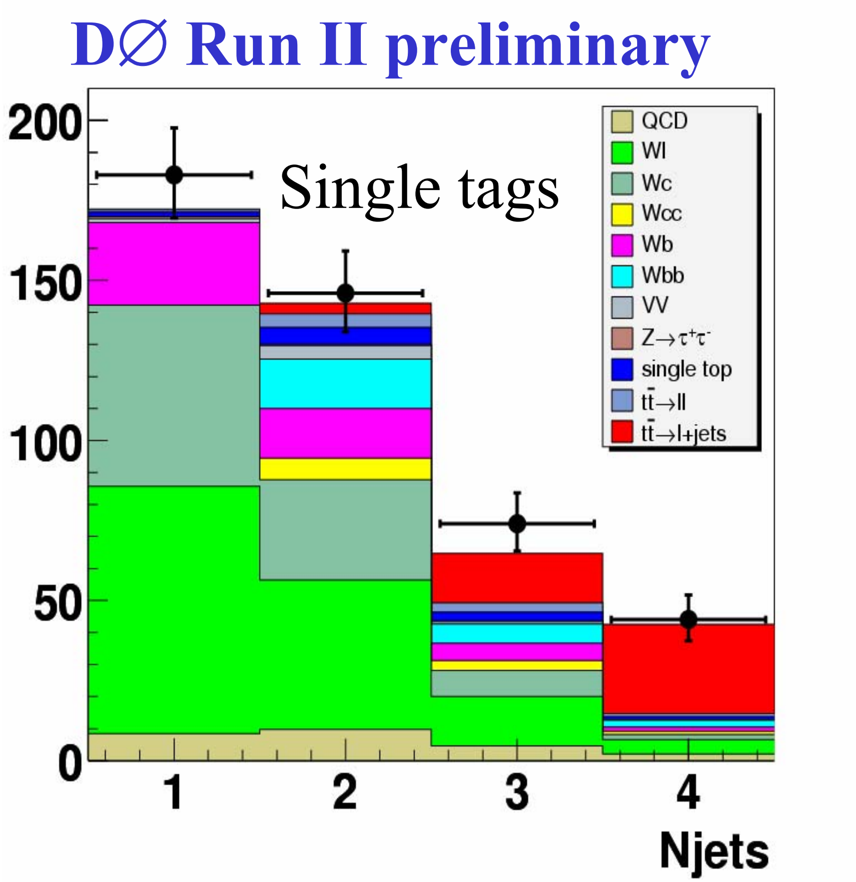


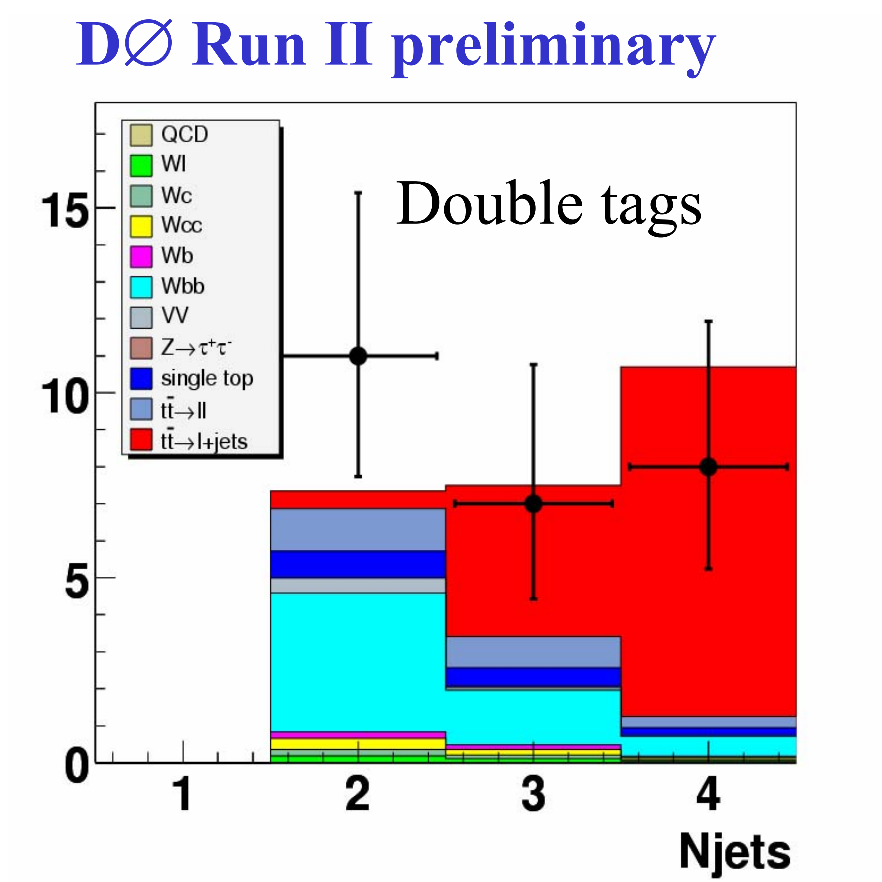


Control bins, provide control on background calculations

CSIP results

Lepton + jets channel: $t\bar{t}$ prediction is shown for $\sigma_{t\bar{t}} = 7$ pb;

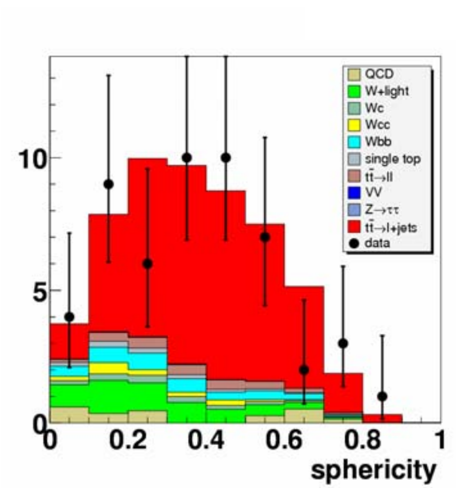


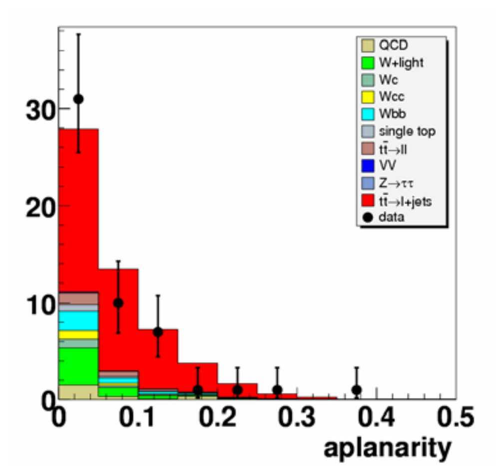


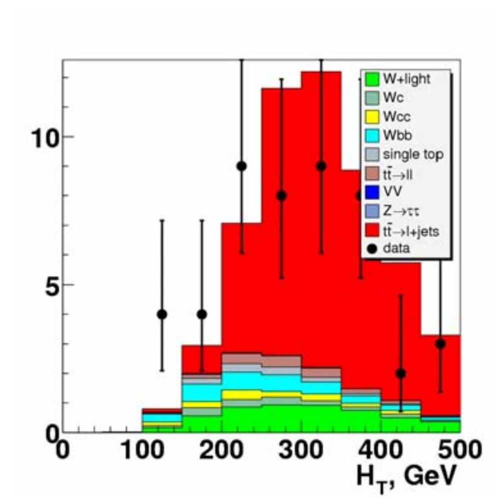
Measured $t\bar{t}$ cross section

- SVT: $\sigma_{t\bar{t}} = 8.2^{+1.3}_{-1.3}(stat)^{+1.9}_{-1.6}(syst) \pm 0.5(lumi)\,pb;$
- CSIP: $\sigma_{t\bar{t}} = 7.2^{+1.3}_{-1.2}(stat)^{+1.9}_{-1.4}(syst) \pm 0.5(lumi)\,pb;$
- Largest systematic uncertainties from jet energy scale and *b*-tagging efficiency measurement on data

Topological characteristics of observed events:

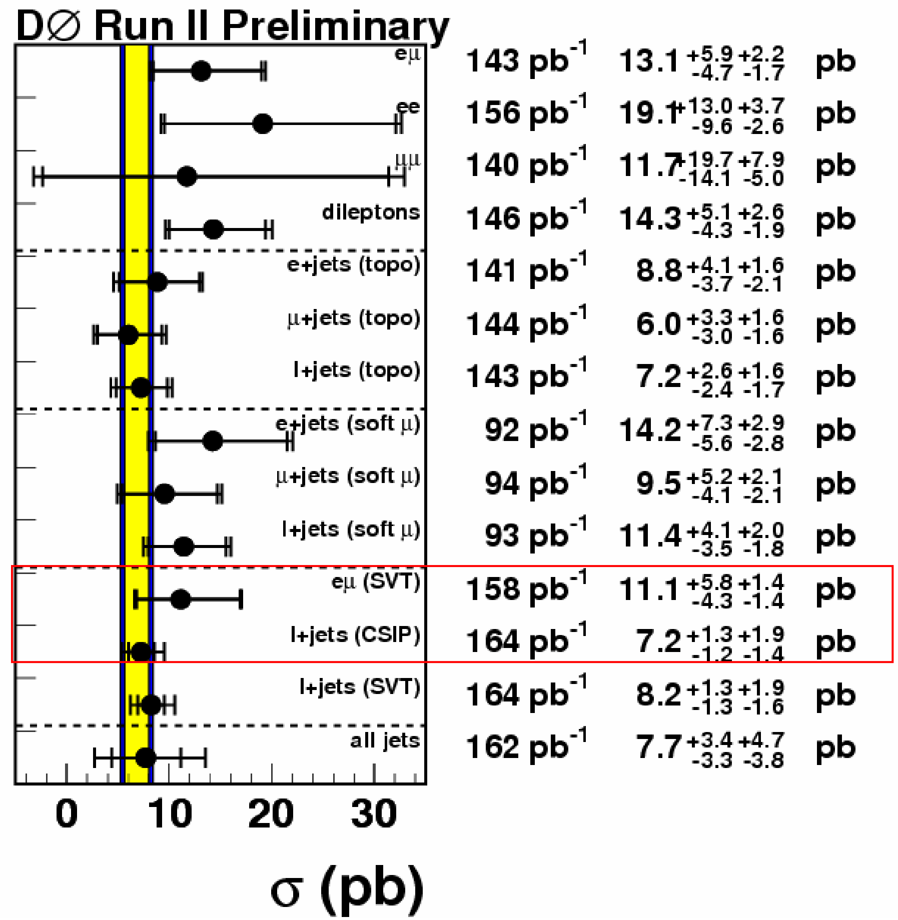






Conclusions

- DØ presented cross section measurement in lepton +jets channel performed with lifetime tagging;
- Two different methods are used to cross check results;
- This is the most precise measurement of top quark pair cross section in D∅;
- Obtained results are in a good agreement with the SM prediction



Backup slides

W+jets background estimation

process	σ (pb)	process	σ (pb)	process	σ (pb)	process	σ (pb)
Wj	424.90	Wjj	126.81	$Wjjj$	32.48	$Wjjjj$	8.89
Wc	16.01	Wcj	7.60	$Wcjj$	2.38	$Wcjjj$	0.64
		$Wb\bar{b}$	4.61	$Wb\bar{b}J$	2.00	$Wb\bar{b}Jj$	0.81
		$Wc\bar{c}$	11.43	$Wc\bar{c}J$	4.68	$Wc\bar{c}Jj$	1.93

- Use *W+jets* sample generated with ALPGEN interfaced to PYTHIA;
- Do not use absolute values of cross-sections; instead rely on their ratios;
- Apply matching procedure to eliminate double counting and reduce sensitivity to parton generation cuts.

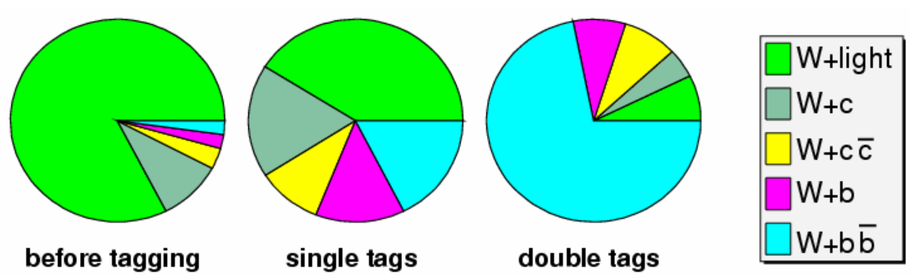
Estimated N of W+jets events after tagging:

$$\widetilde{N}_{W+nj} = N_{W+nj} \times \widetilde{P}^{tag}_{W+nj}$$

N of preselected W+nj events before tagging

Average event tagging probability

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



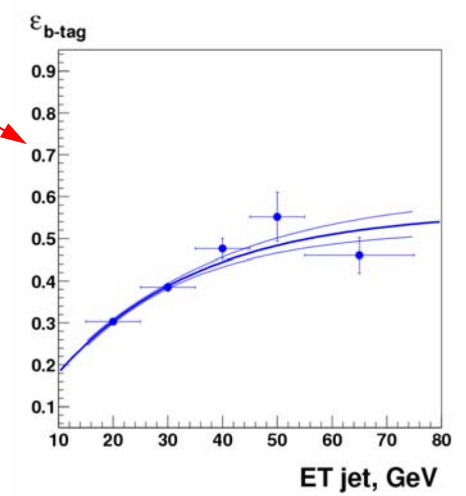
QCD background in ℓ+jets channel

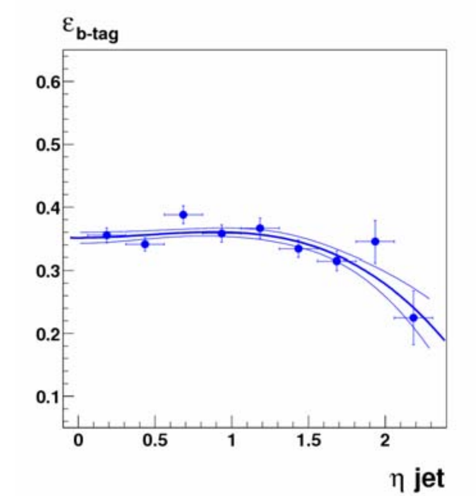
- Electron+jets channel: *fake electrons (jets) and fake Compton QCD;*
- Muon+jets channel: *heavy flavor QCD production;*
- N_{QCD} in the preselected sample is estimated by Matrix Method (MM):
- Measure probability P_{QCD} to tag a QCD event as a function of number of jets;
- Number of QCD events in the tagged sample is:

$$N_{QCD}^{tag} = P_{QCD} \times N_{QCD}$$

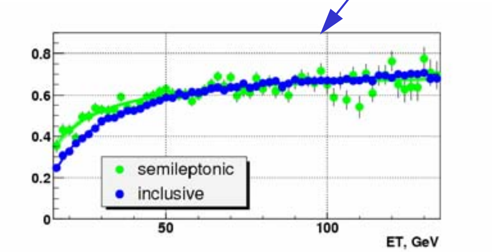
b,*c*-tagging efficiencies in data and MC

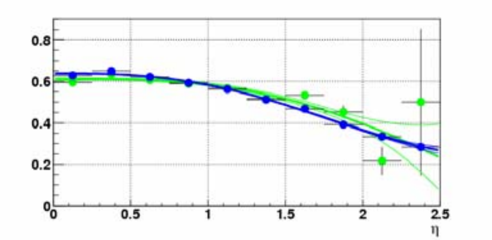
b-tagging efficiency in data was measured by three different methods. Here the basic method is shown.



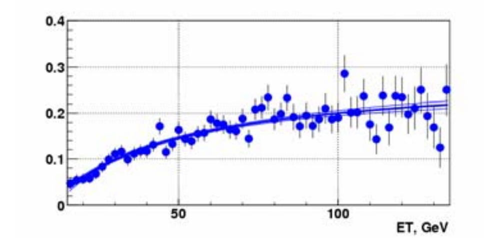


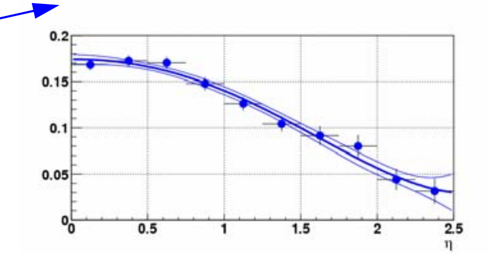
b-tagging efficiency in MC:



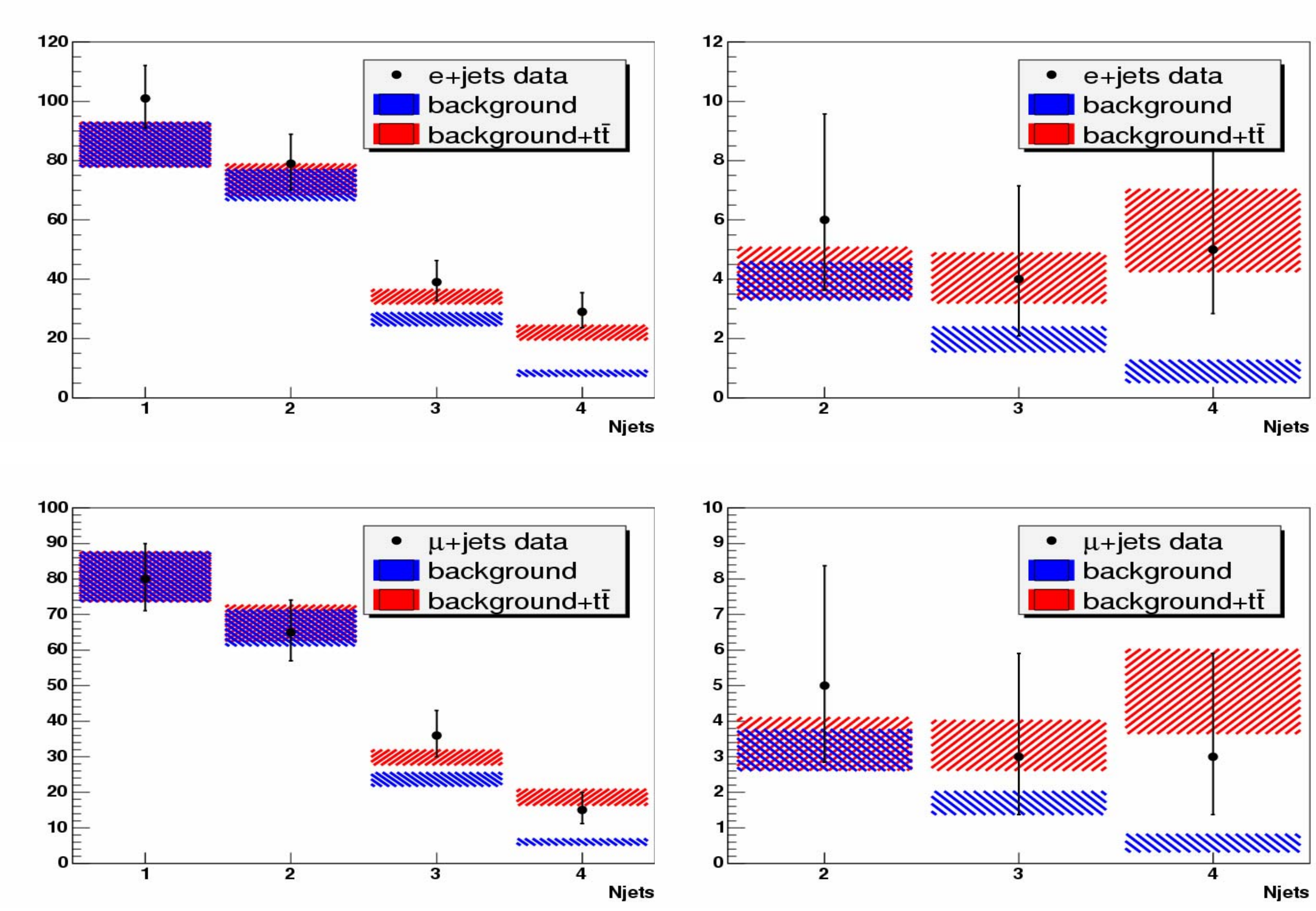


Cannot measure c-tagging efficiency on data – instead, use MC *c*-tagging efficiency corrected by ratio of b-tagging efficiencies in data to MC.





Uncertainty on predictions



Estimation of the mistagging rate

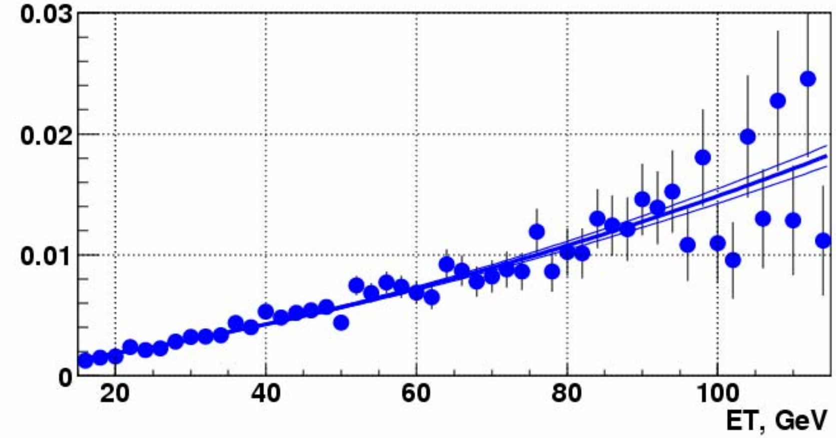
Measured negative tagging rate on data, but want to know the probability to tag a light jet (jet originated from *u,d,s* quarks).

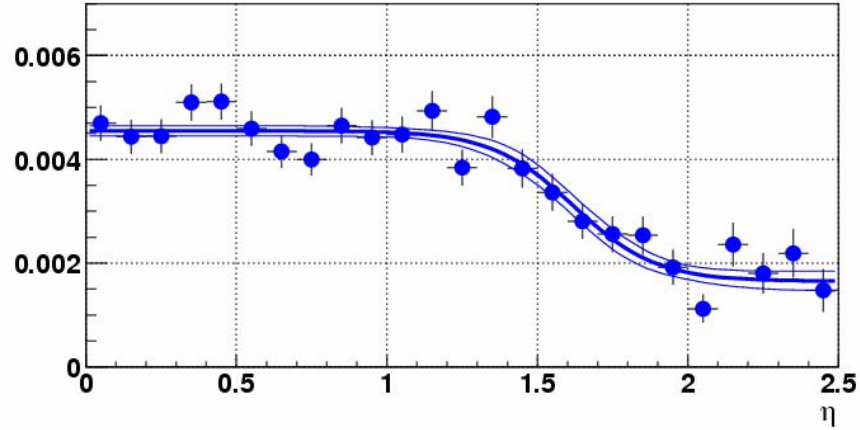
Need to correct negative tagging rate:

- 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, 0.96





Systematic uncertainties

- Took into account 26 different sources of systematic errors
- Largest uncertainties:
  - jet energy scale;
  - b-tagging efficiency in data;

- Tagability in data;
- Flavor dependence of tagability;
- 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 $SF_c = SF_{b;}$
- W fractions from g splitting in HERWIG;
- W fractions from PDF

- Pre-selection efficiency;
- Trigger efficiency;
- PV selection efficiency;
- N_W and N_{QCD} in data;
- Tagging probability;
- W fractions from ALPGEN;
- Track matching with EM cluster;
- Electron identification efficiency;
- Muon identification efficiency;
- Jet identification efficiency;
- Jet resolution;
- Jet Energy Scale;