# Tevatron jets results

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- Motivation

- Measurements of the differential cross sections of W+ c-jets and W+ b-jets production at D0

- Measurement of the ratio of inclusive cross sections $\sigma(Z+2b) / \sigma(Z+2jets)$ at D0

- Measurement of $W(l\nu)$ + jets production cross sections at CDF

- Conclusions

<u>Precise measurements of associated production of a vector boson and jets are important because:</u>

● It is stringent test of quantum chromodynamics

● these processes are potentially large backgrounds for various SM processes studies (such as $t\bar{t}$, single top, $h$) and BSM searches

  • evaluation of process cross sections

  • are higher order corrections needed?

  • quark and gluon PDF test (in particular for s, c, b-quarks)

  • hadronization mechanism test
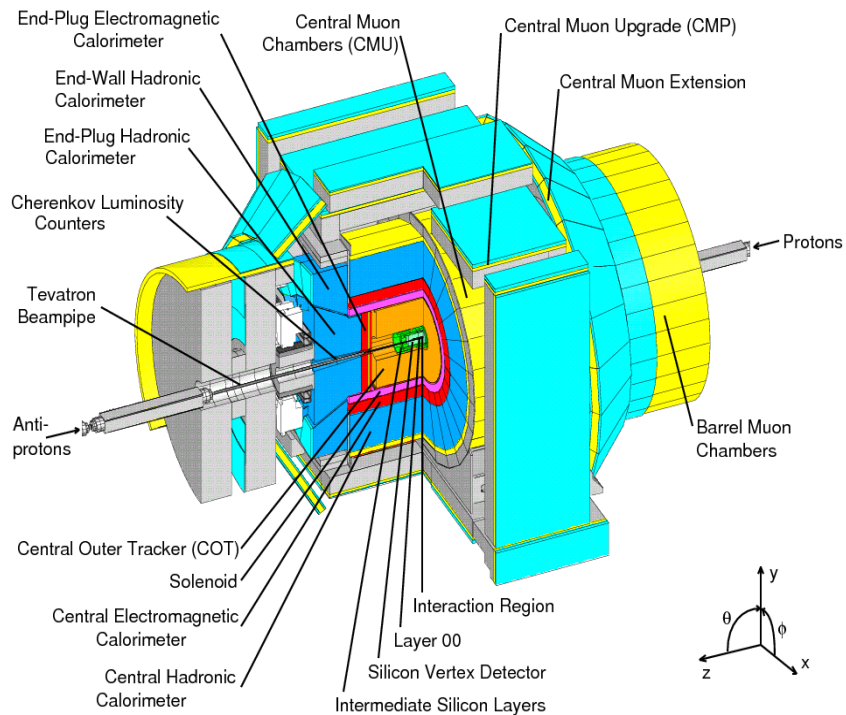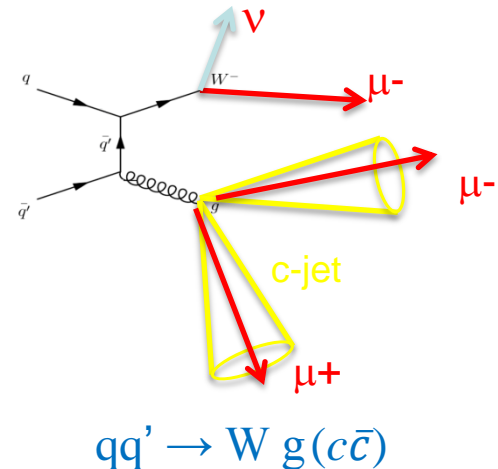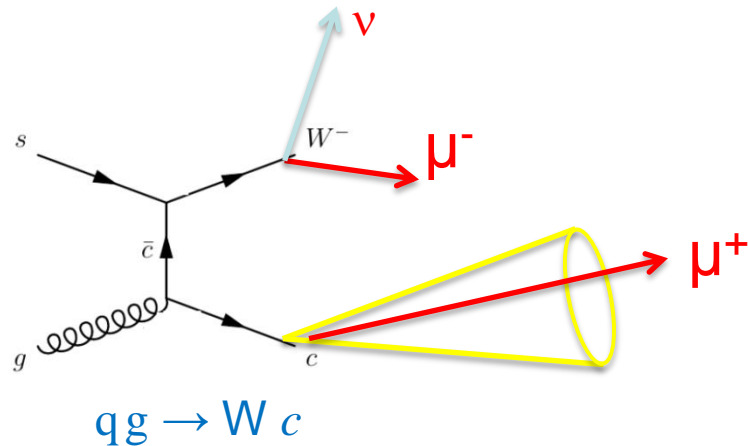
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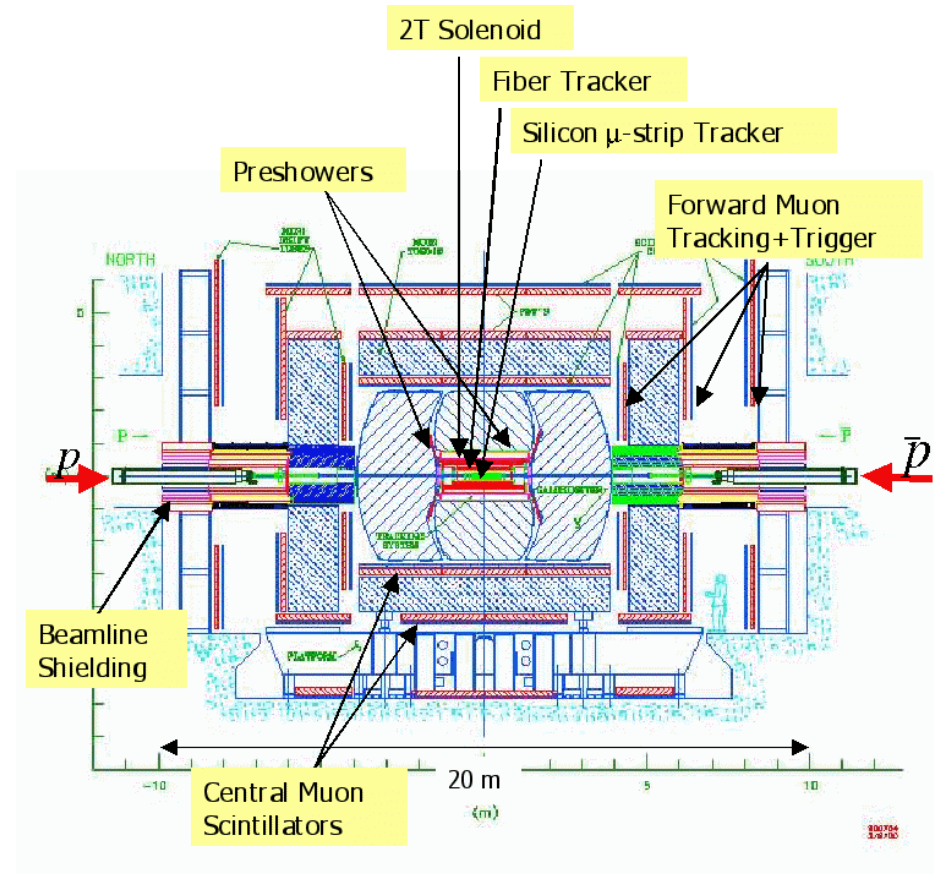
Detector CDF

Detector D0

$$q\,g \to W\,c$$



c-jet

$$qq' \to W\,g(c\bar{c})$$

Two dominant processes contributing to W+c-jet:

$q\,g \to W\,c$        dominates

$qq' \to W\,g(c\bar{c})$     $P_t$ (jet): 20 GeV $\to$ 100 GeV : 25%  $\to$ 45%



For  $q\,g \to W\,c$ :  $q = d\,/\,s$ ⇨ 15% ⁄ 85%  at Tevatron

⇨ W+ c-jet process is sensitive to s-quark PDF
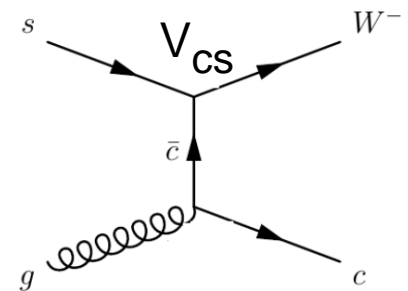
For the first time soft lepton was not required inside jet

In case of  W+ b-jet   contributing processes  are:

$q\,g \rightarrow W\,b$        $\lesssim 5\%$

$q\,q' \rightarrow W\,g(b\bar{b})$    $\sim 85\%$

$b\,\bar{q} \rightarrow W\,b\,\bar{q}'$        $\sim 15\%$



$$q\,q' \rightarrow W\,g(b\bar{b})$$

Selected kinematic region:

Pt ($\mu$) > 20 GeV/c      |$\eta$ ($\mu$)| <1.7

Pt($\nu$) > 25GeV

20 < Pt(jet) < 150 GeV     |$\eta$ (jet)| <1.5
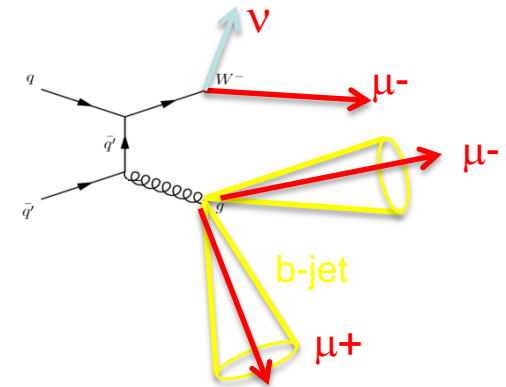
Backgrounds to W+ c-jet and W+ b-jet :

W + light parton jets

Z / $\gamma$* + jets

$t\,\bar{t}$

single top quark

VV (V=W,Z)

QCD multijets with misID  muon

PLB 743 , 6 (2015)
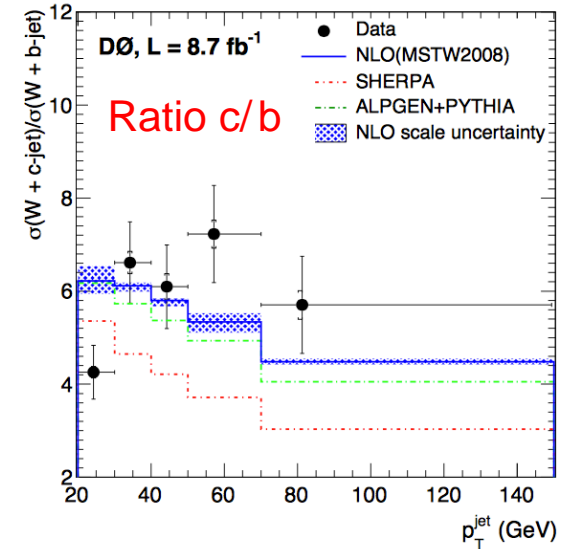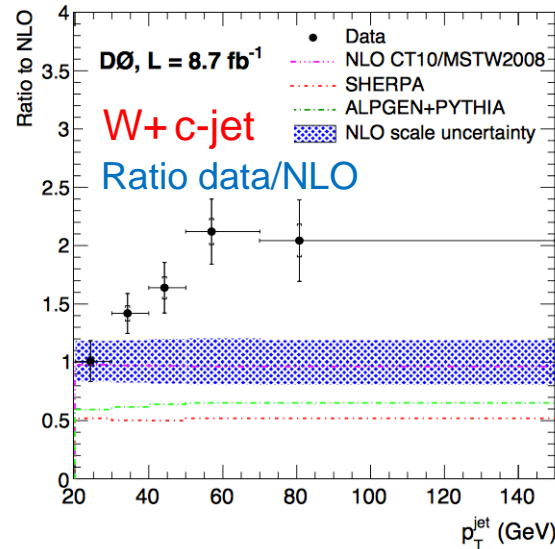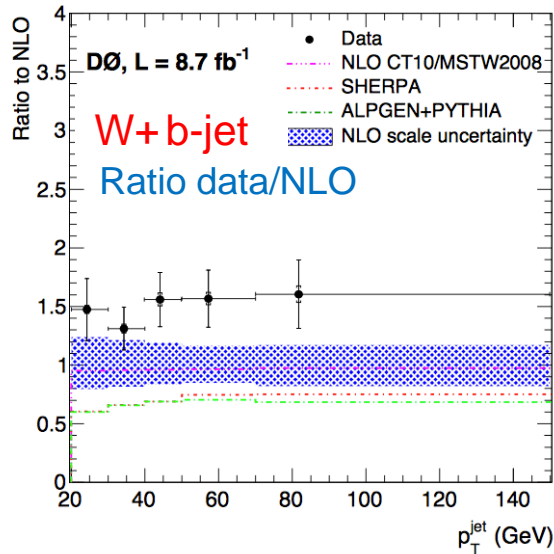


W+ b-jet cross section is systematically higher than QCD NLO and two MC.
W+c-jet is above QCD NLO except first bin in Pt.
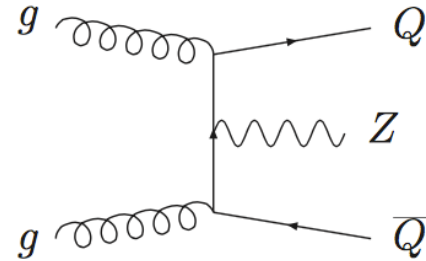Disagreement can be explained by missing higher order corrections.
Also reasons could be underestimated gluon splitting contribution or enhancement in strange quark PDF.
Ratio of W+c-jet and W+b-jet is reasonably agree with predictions  except first bin. SHERPA  MC does not agree with data.
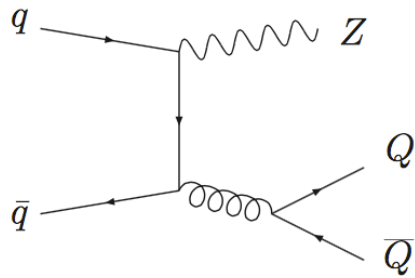
$$qq \to Z\,bb \quad (\sim 76\%)$$

$$gg \to Z\,bb \quad (\sim 24\%)$$

Z+2b is significant background for ZH(H→bb) studies and sbottom searches

Ratio measurement benefits from cancellation of many systematic uncertainties

b-jet tagging is based on relatively long lifetime of b-hadrons (N of secondary vertices, charge track multiplicity, decay length and impact parameter of SV, …)

Z→μμ and Z→ ee channels were treated separately (due to different mixture of backgrounds) and were finally combined

PRD 91 , 052010 (2015)
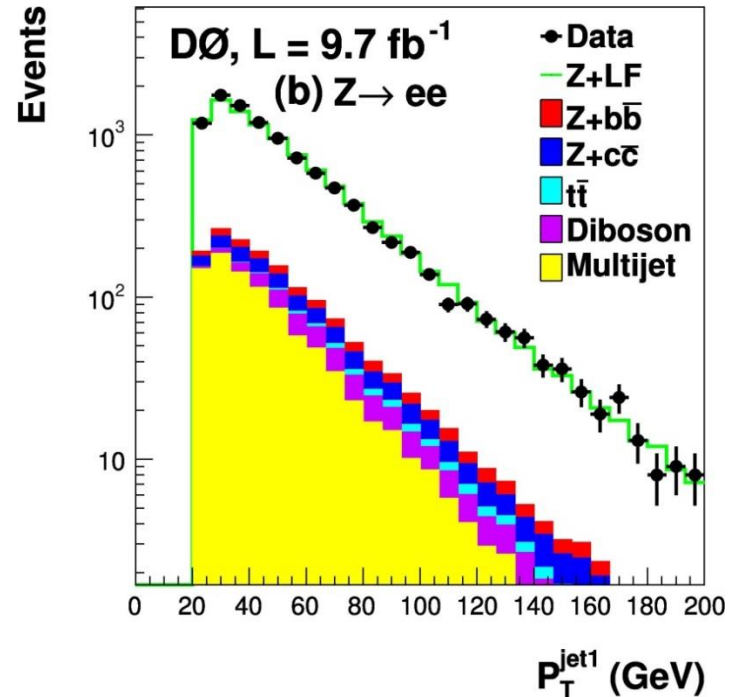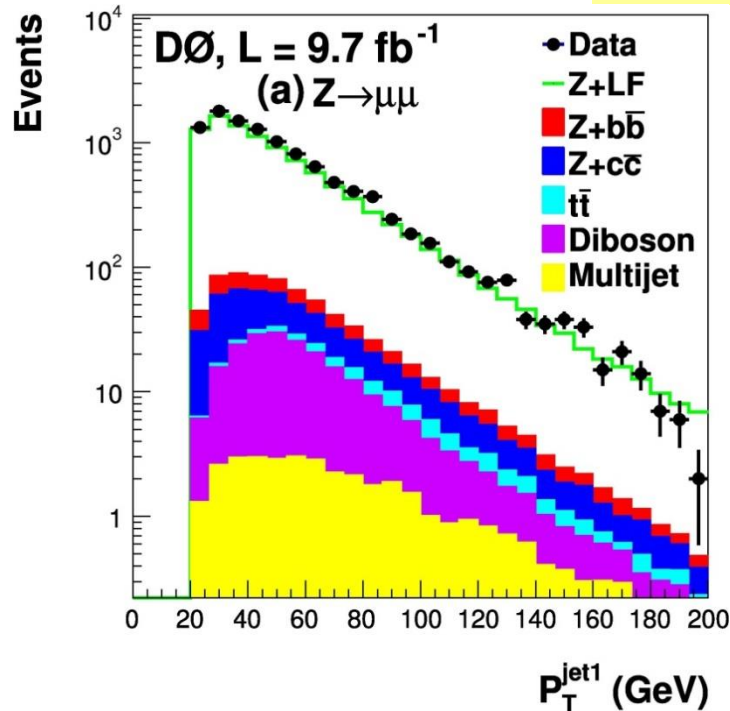


Leading jet Pt (two channels) for data and background Z+2jets before b-tagging

To discriminate between Z+2b and Z+2c after light-jet, tt and other SM background subtraction we apply 2D fit using both jets templates for variable:

$$D_{MJL}=1/2(M_{SV}/5-\ln(JLIP)/20)$$

$M_{SV}$ – mass of secondary vertex,     JLIP – Jet Lifetime Probability

PRD 91 , 052010 (2015)
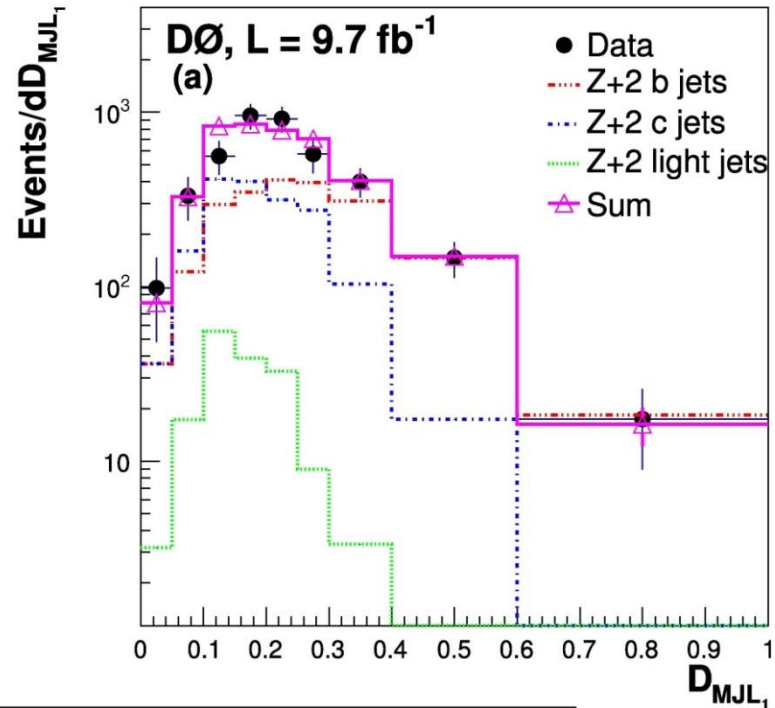
Selected kinematic region:
Pt $(\ell)$ > 15 GeV/c      $|\eta\,(\ell)|$ <2.0
Pt(jet) > 20 GeV     $|\eta\,(jet)|$ <2.5

b-jets and c-jets fractions are
obtained from fit



$$\sigma(p\bar{p} \to Z + 2\,b\ \text{jet})/\sigma(p\bar{p} \to Z + 2\ \text{jet})$$

| Data $\pm\delta_{stat} \pm \delta_{syst}$ | $\delta_{tot}$ | NLO QCD(MSTW) | PYTHIA | ALPGEN |
|---|---|---|---|---|
| $(2.36 \pm 0.32 \pm 0.35) \times 10^{-2}$ | $0.47\times 10^{-2}$ | $(1.76 \pm 0.26) \times 10^{-2}$ | $2.42\times 10^{-2}$ | $2.21\times 10^{-2}$ |

Good agreement with theoretical predictions

One lepton (electron or muon), large missing transverse energy and at least one jet are required.

Selected kinematic region:
Pt $(\ell)$ > 25 GeV/c       $|\eta (\ell)|$ <1.0
Et(jet) > 25 GeV     $|\eta (\text{jet})|$ <2.0
$m^T(W)$ > 40 GeV/$c^2$

This process is large background to $t\bar{t}$ , single top quark, Higgs, various BSM

Backgrounds to this process: W$(\tau\nu)$ +jets, Z$(\ell\ell)$  + jets, $t\bar{t}$ , single top, WW, WZ, ZZ, multijets.
 Z$(\ell\ell)$  + jets is dominant background at Njets = 1,2
 $t\bar{t}$   background is dominant at Njets = 3,4

Preliminary (2015)

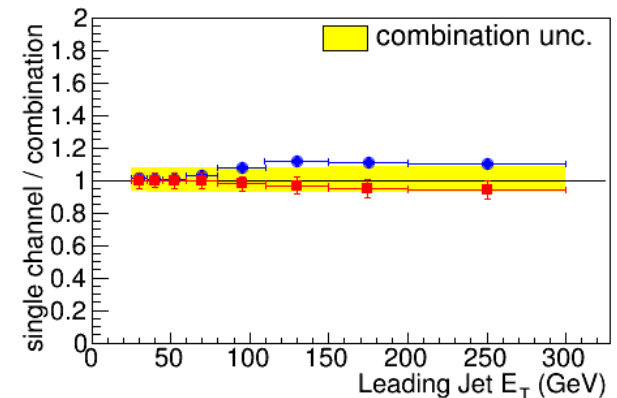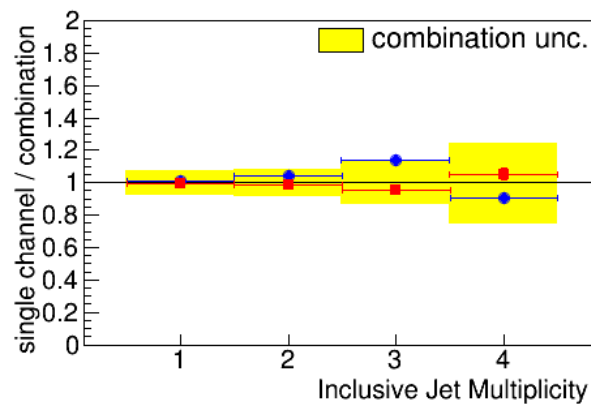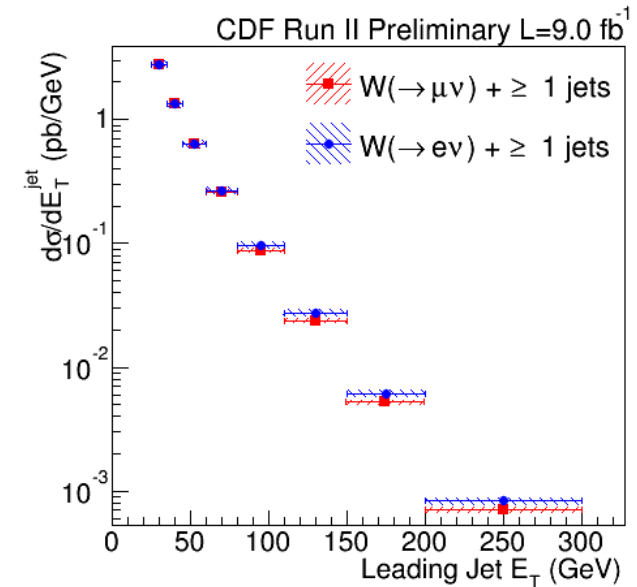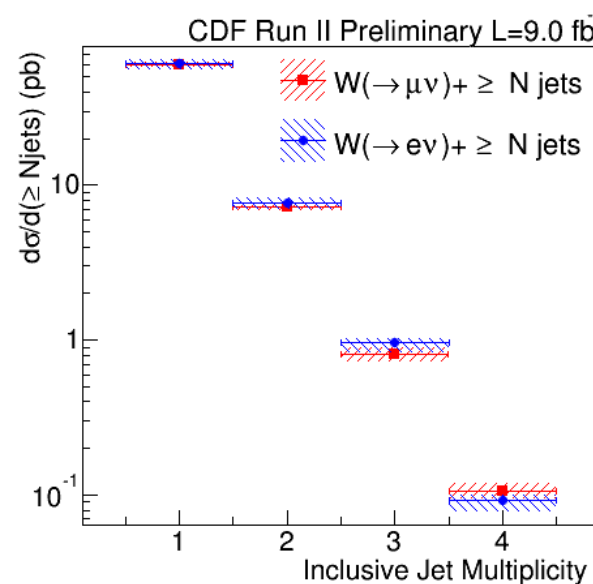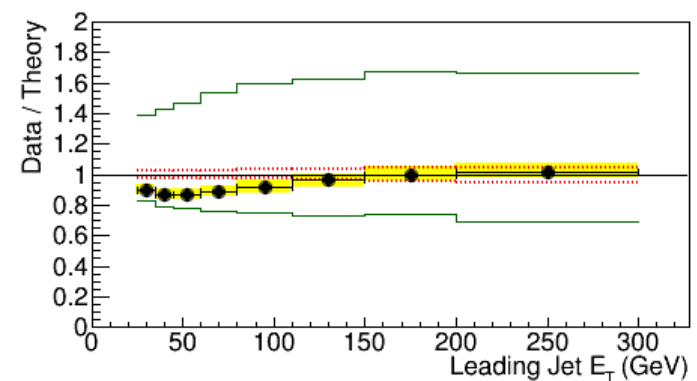Particle level cross sections are obtained

Muon and electron channels were studied separately.



Good agreement between electron and muon data
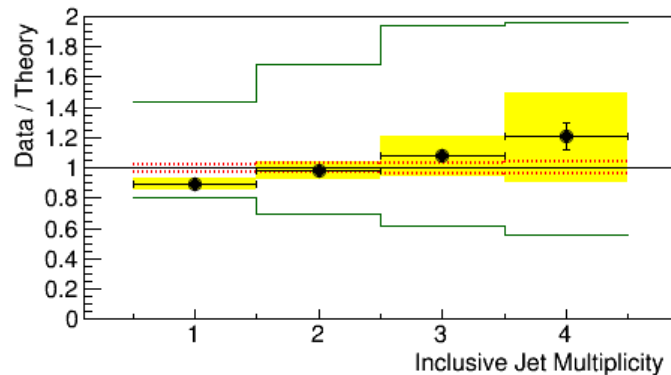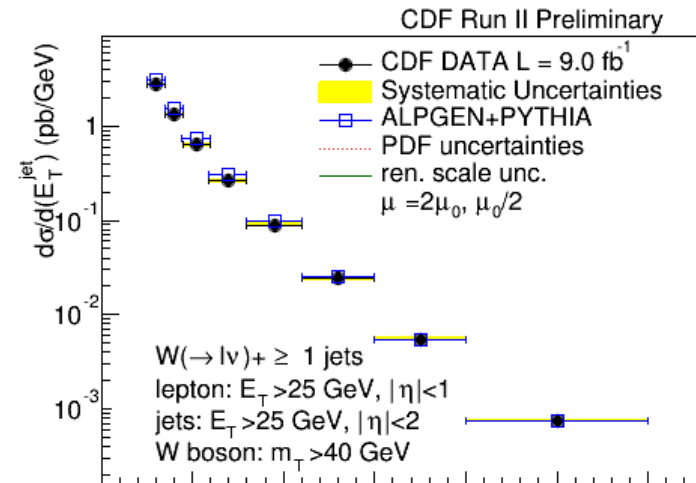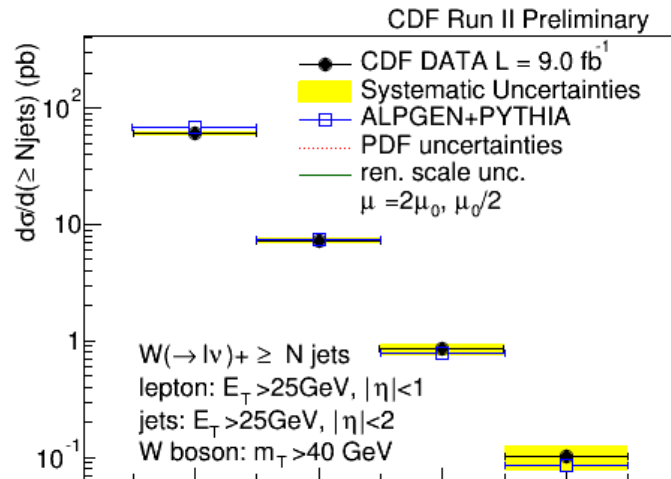
Reasonable agreement with theoretical predictions within uncertainties

For the accuracy achieved comparison with higher order calculations is desirable

# Conclusion

- Differential cross sections of W+c and W+b were measured at D0

- Ratio of inclusive cross sections $\sigma(Z+2b) / \sigma(Z+2jets)$ was measured at D0

- $W(l\nu)$ + jets production cross sections were measured at CDF

- Obtained results are in reasonable agreement with theoretical predictions. Some small discrepancies can be explained by higher order corrections. These measurements are important to provide precise background estimates for different SM processes measurements and BSM searches at LHC.