W/Z + Jets Measurements in Run II

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W/Z with Jet production

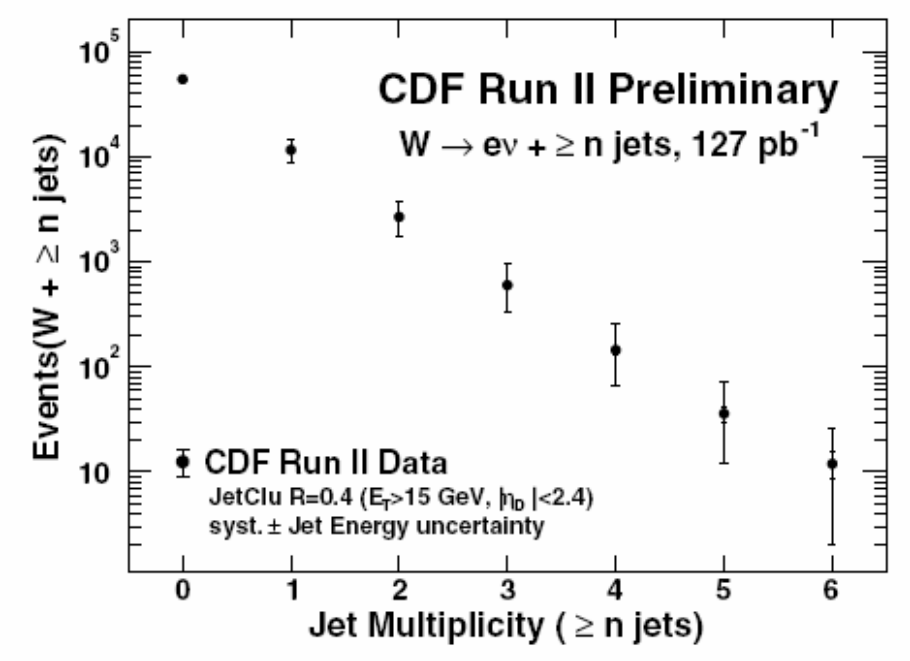
- Laboratory for QCD
  - well-defined scale
  - major backgrounds to many physics of interest
- Items to study
  - Rates
  - Differential distributions
  - Flavor composition
- Compare with theory
  - LO ME generators matched to PS
  - NLO calculations

W + Jets

- Cross Section
- Kinematics
- Flavor Composition

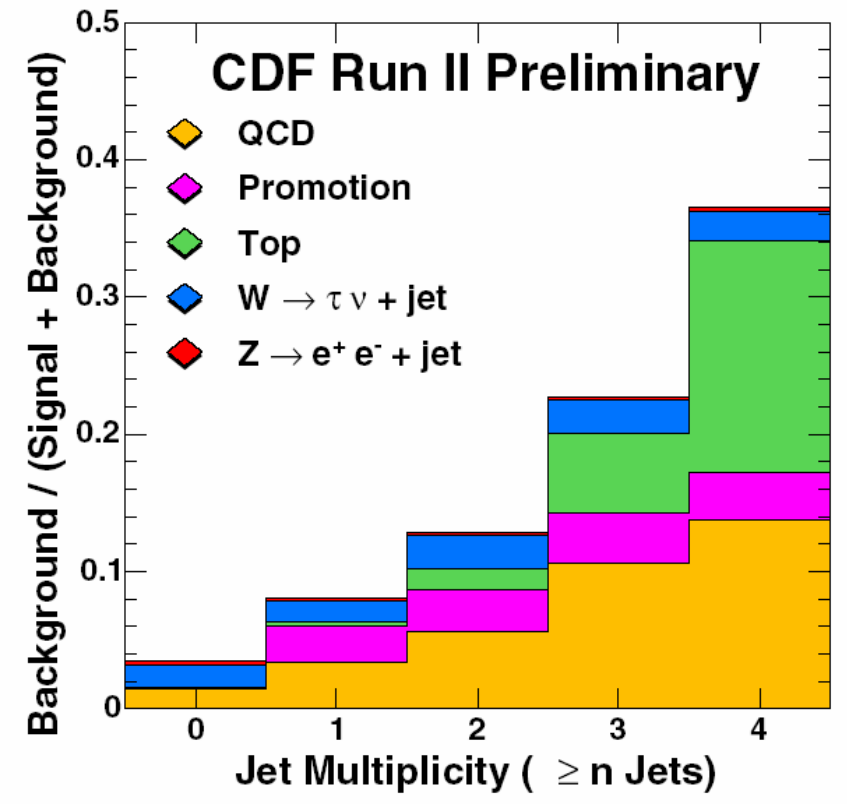
W + jets at CDF

- Cross section measurement
  - 127 pb^{-1}
  - Same technique as Run I publ.
  - Electron channel
  - Correct back to parton-level
- Selection
  - PV |z|<60 cm
  - Electron
    - E_T>20 GeV, |η|<1.1
    - E/P, dE/dx
    - Electron track - PV distance
    - EM energy fraction, shower shape
    - isolation
  - Jet
    - R=0.4, E_T>15 GeV, |η|<2.4
    - After energy correction to the parton level
  - MET>30 GeV
  - Z→ee veto



Jet multiplicity	≥ 0	≥ 1	≥ 2	≥ 3	≥ 4	≥ 5	≥ 6
Central	54799± 234	11615± 96	2680± 50	602± 24	145± 12	36± 6	12± 3
syst. Up	—	+1818	+708	+236	+71	+23	+7
syst. Down	—	-1552	-519	-145	-43	-12	-5

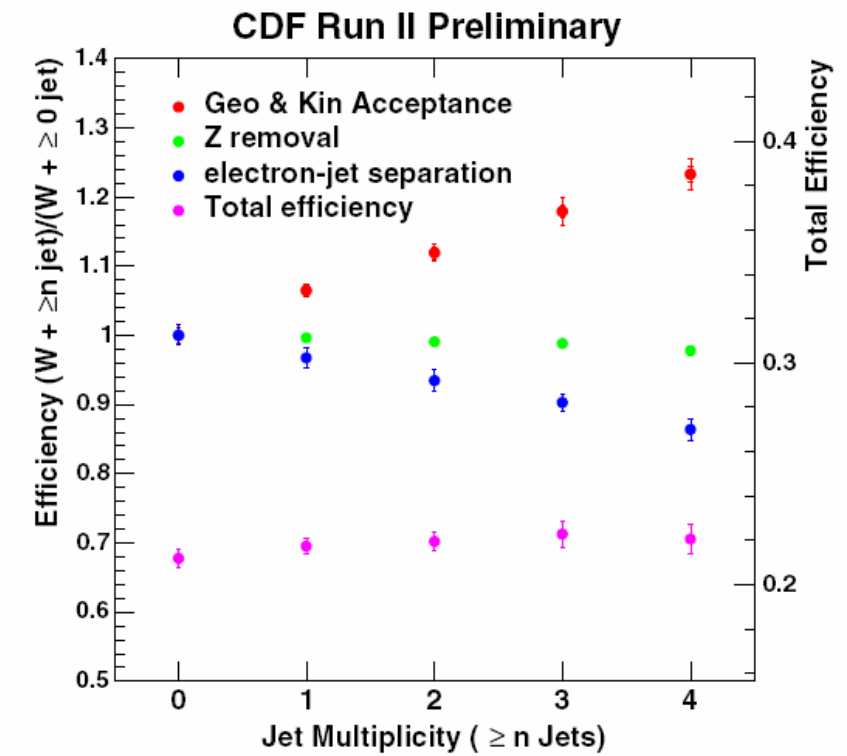
Backgrounds to W+Jets

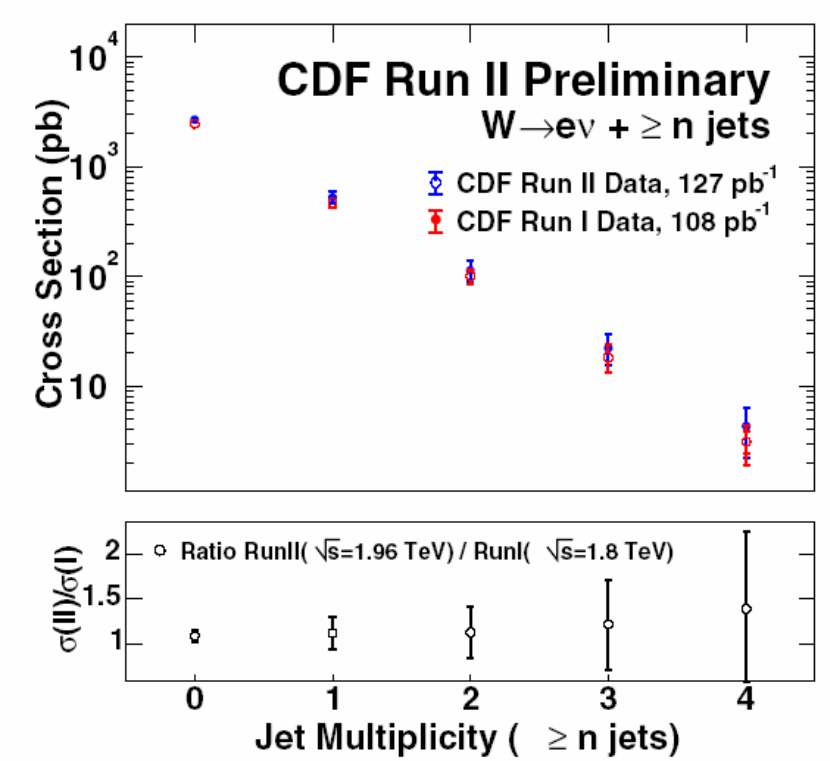


- QCD – estimated from data using “Matrix” method.
- Top dominates for higher jet multiplicities
- Promotion – n-1 jet event can become n jet due to multiple interactions
- Cancellation does not occur in ratios

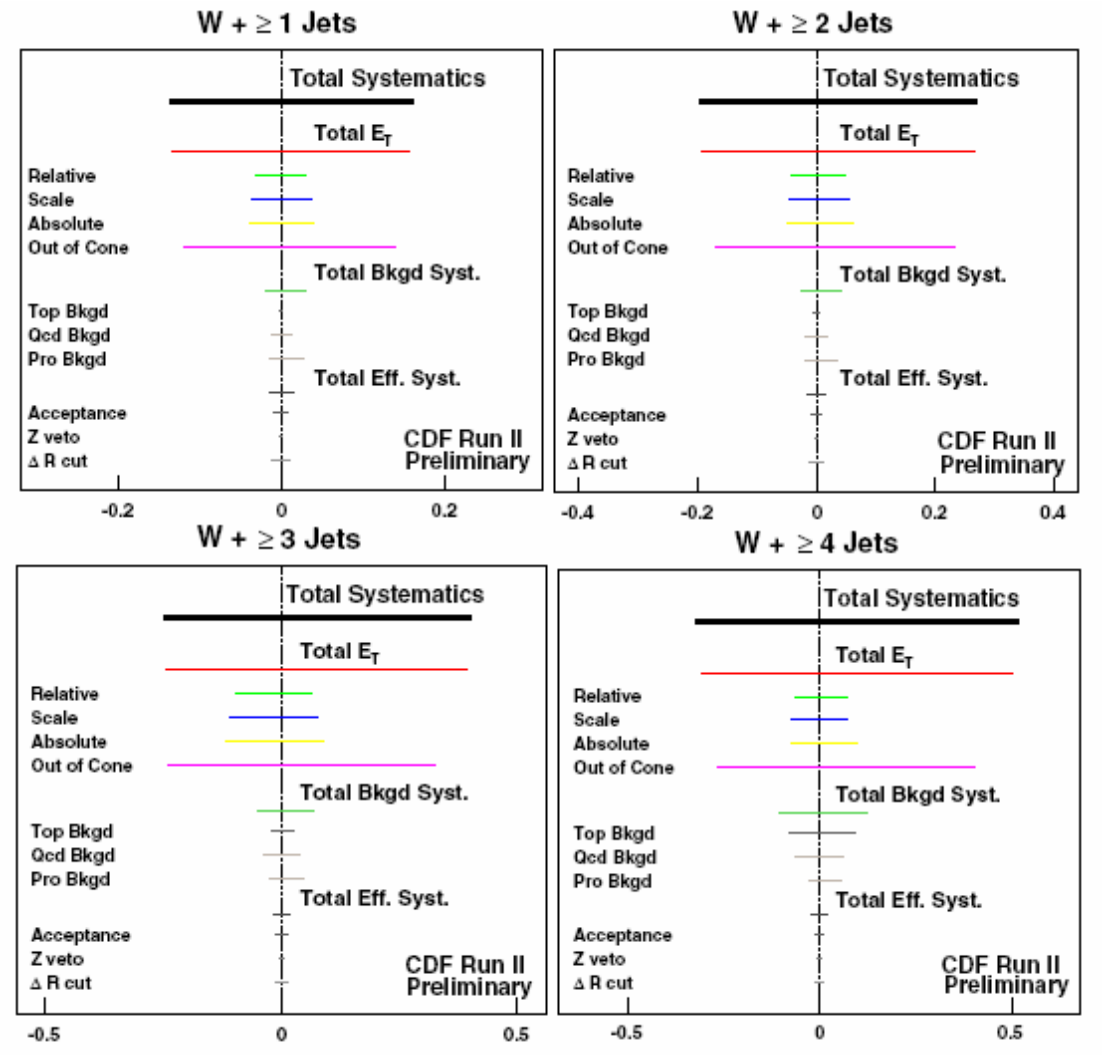
W+Jets Production Cross Sections

- Acceptance corrected



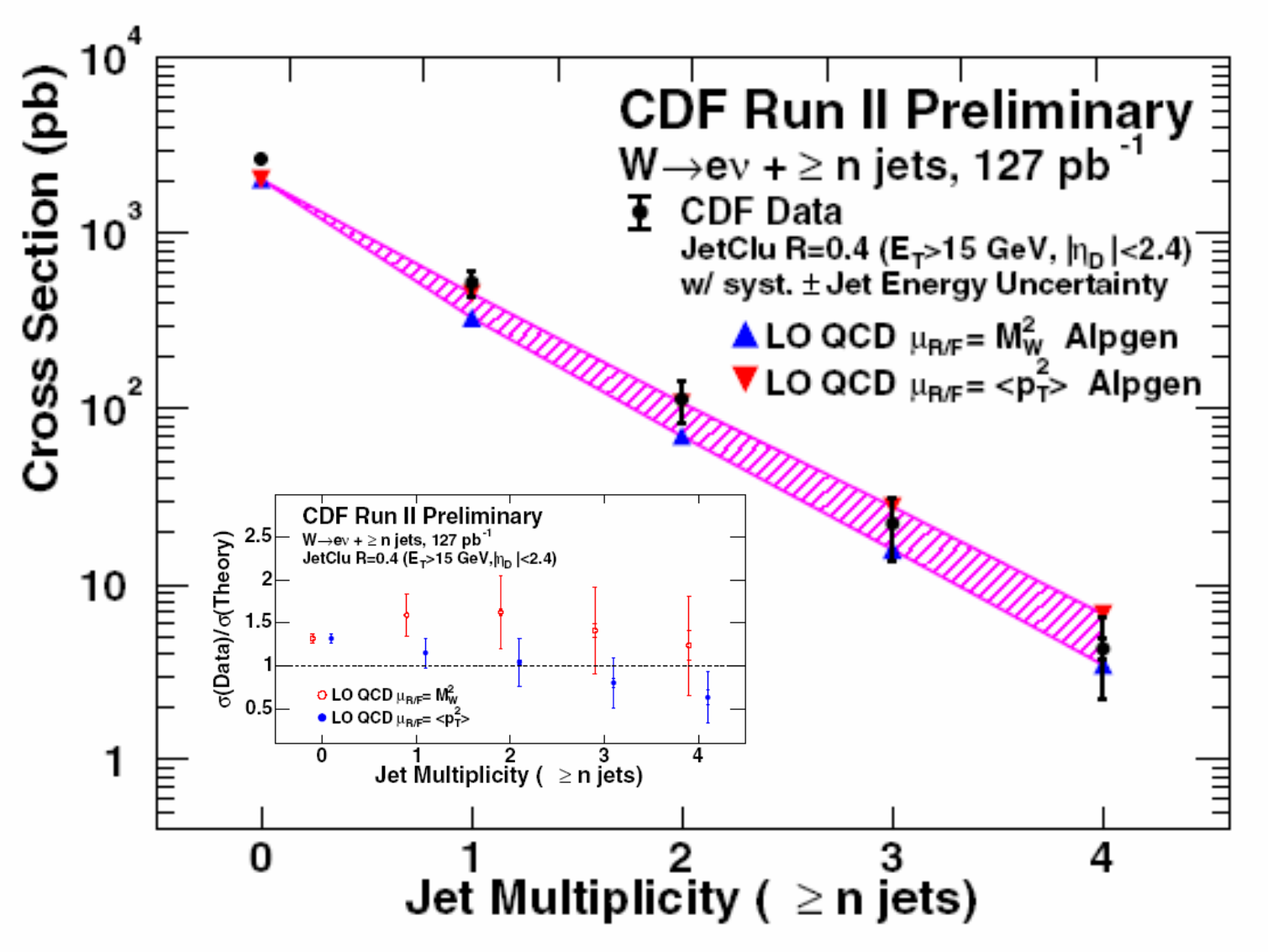


Systematic Uncertainties



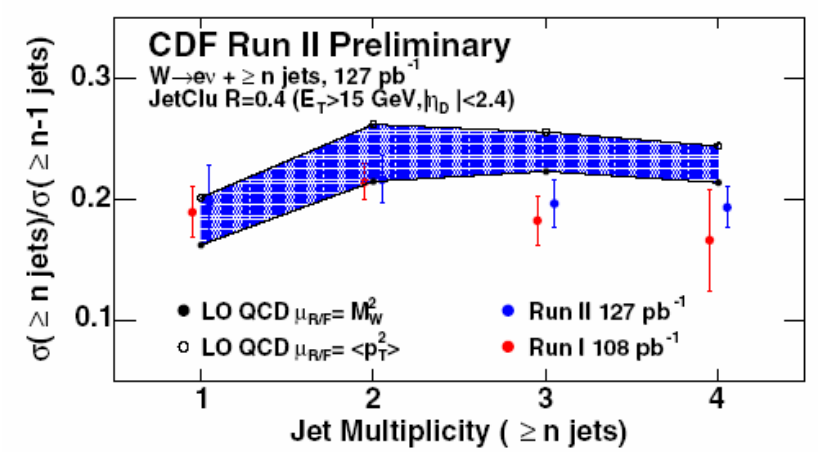
- Grows like njets

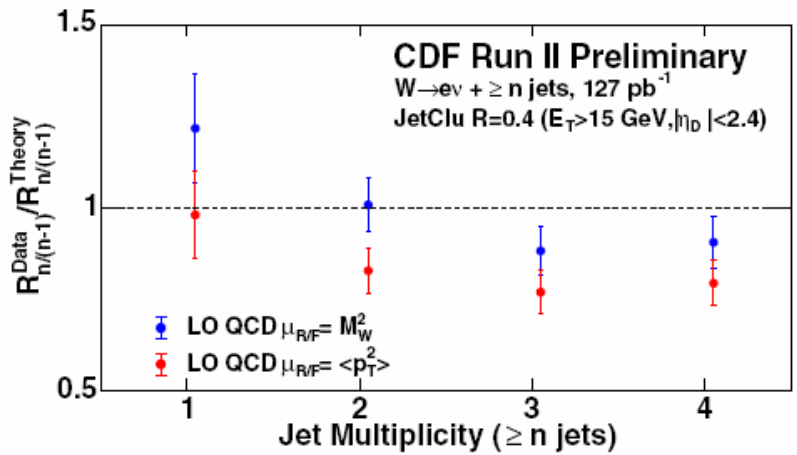
Comparison with LO Theory



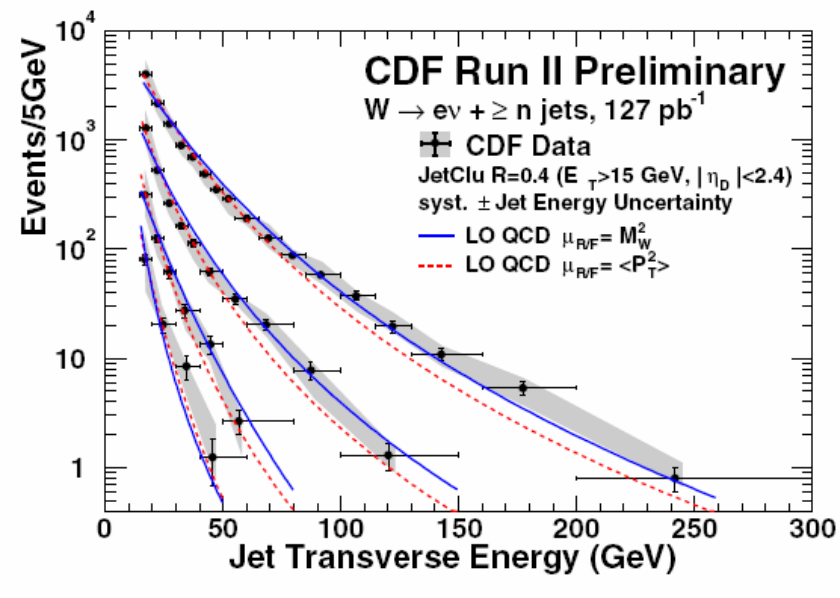
Ratio of Cross Sections

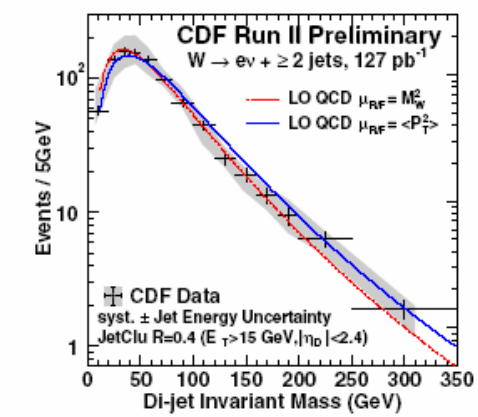
- Reduce the effect of jet uncertainty

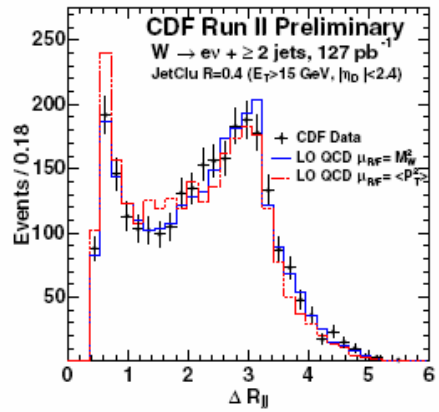


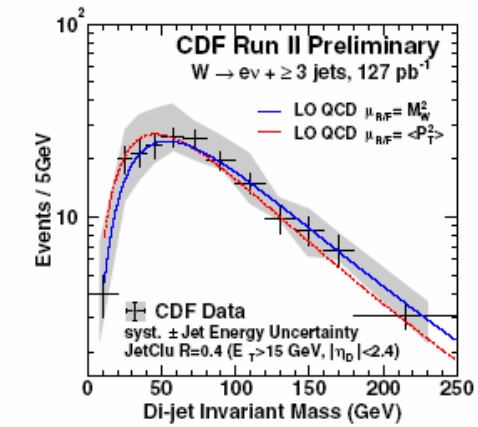


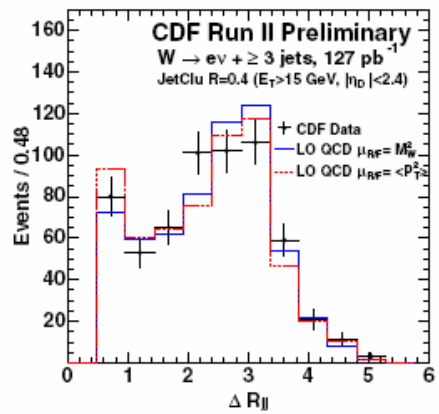
Jet Kinematics in W+jets









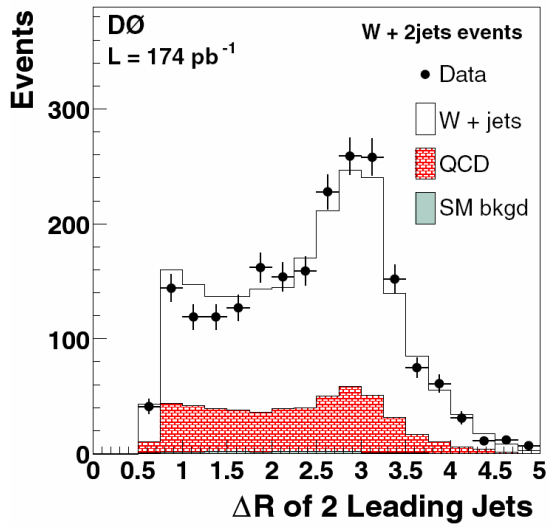


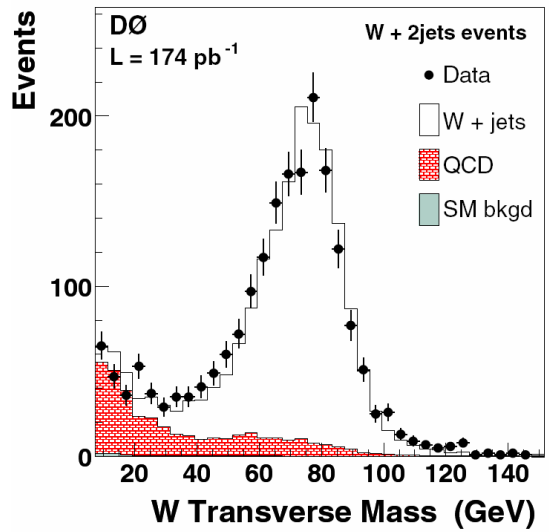
Hadron level measurement
In progress

W+bb at D0

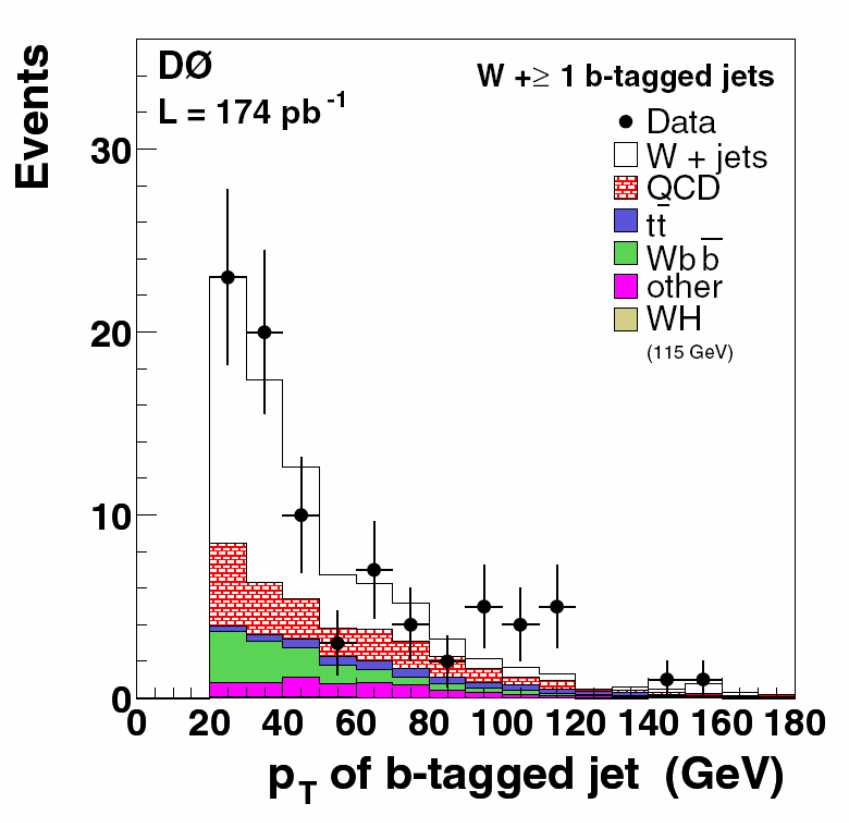
- Select W + 2 jets from 174 pb^{-1}
  - Electron: p_T>20 GeV, $|\eta|$<1.1
  - Missing E_T: E_T>25 GeV
  - 2 Jets: p_T>20 GeV, $|\eta|$<2.5
  - Veto dileton events
  - 2567 evts (2670 ± 838 expected)
- QCD background estimated from data
  - EM p_T dependent estimation
- Compared with ALPGEN LO MC
  - PYTHIA showering and full detector simulation
- SM backgrounds

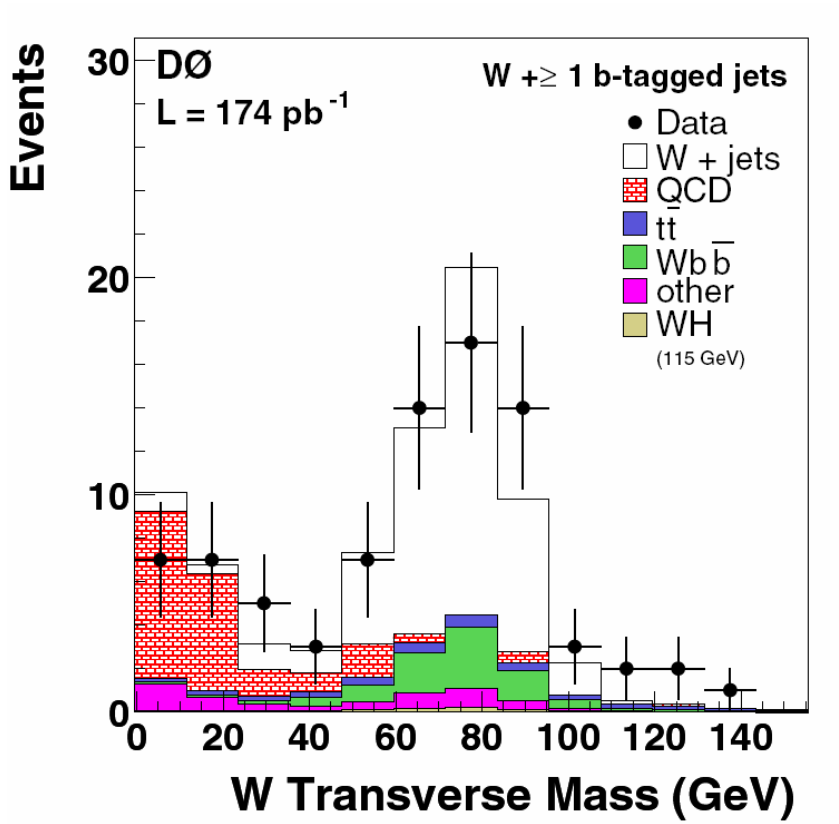
  Z + jets where Z→ee or Z→ττ,
  W→τν, tt-bar, single top





W+HF

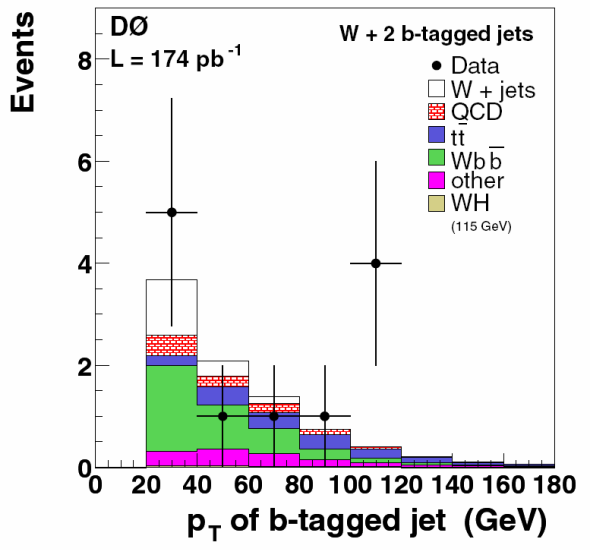

DØ
L = 174 pb^{-1}
W +≥ 1 b-tagged jets
Data
W + jets
QCD
tt̄
Wb b̄
other
WH
(115 GeV)
Events
p_T of b-tagged jet (GeV)

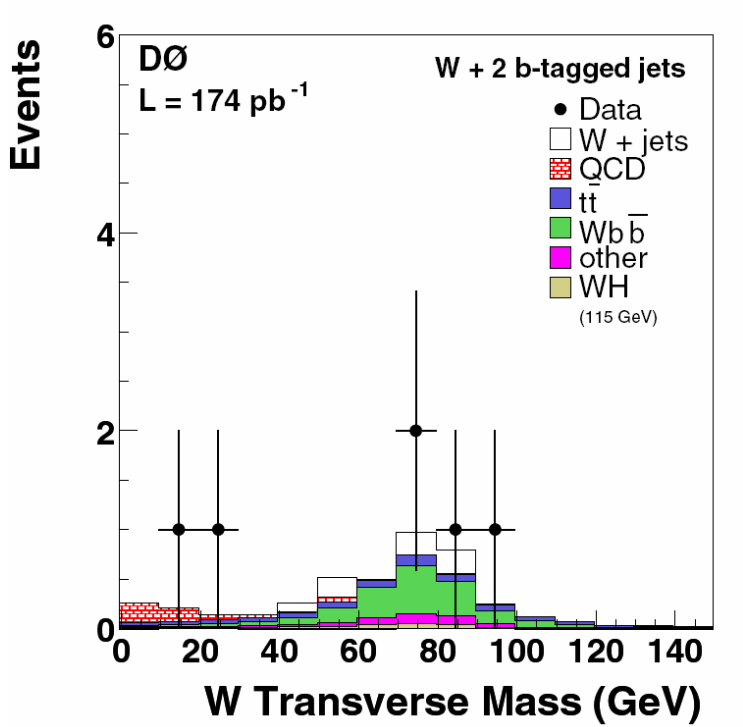

DØ
L = 174 pb^{-1}
W +≥ 1 b-tagged jets
Data
W + jets
QCD
tt̄
Wb b̄
other
WH
(115 GeV)
Events
W Transverse Mass (GeV)

W+bb Cross Section Limit

PRL 94, 091802 (2005)

- σ(Wbb)<6.6 pb @ 95% C.L.
  - p_T>15 GeV, $|\eta|$<2.5 and $\Delta R(bb)>0.75$
  - Measurement of Wbb cross section possible soon

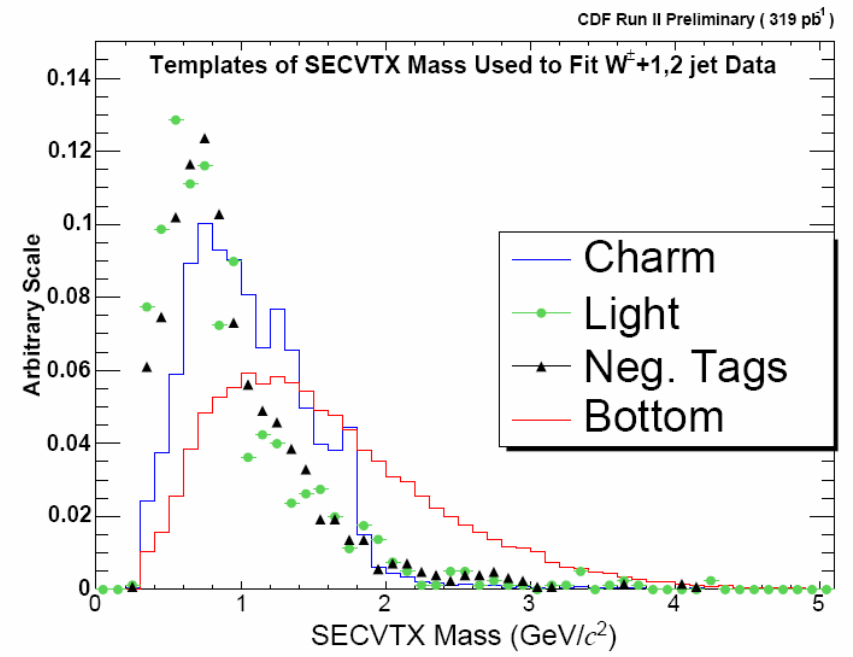


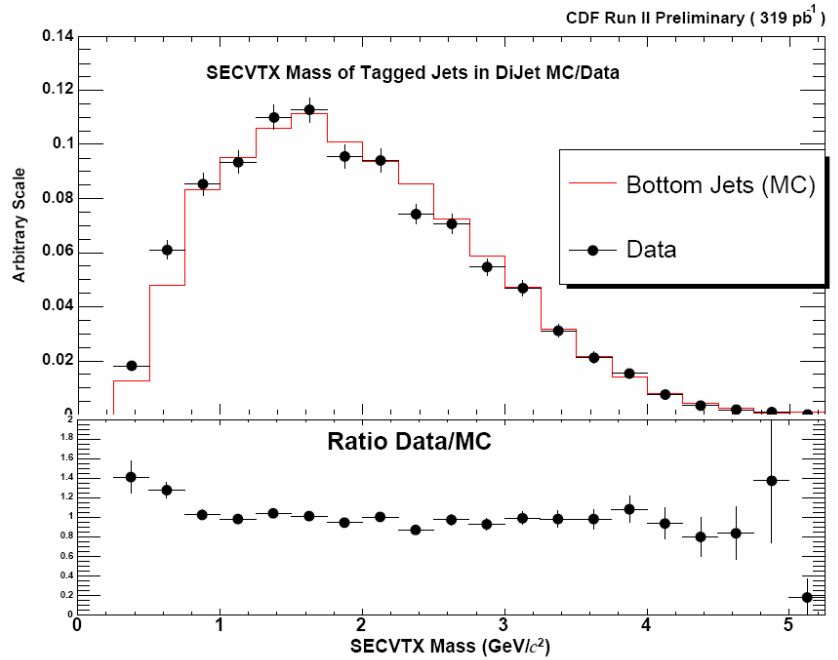


	$W+\geq 2$ jets	$W+2$ jets	$W+2$ jets (1 b-tagged jet)	$W+2$ jets (2 b-tagged jets)	$W+\geq 3$ jets (2 b-tagged jets)
WH	0.6 ± 0.1	0.4 ± 0.1	0.14 ± 0.03	0.054 ± 0.012	0.014 ± 0.004
WZ	1.4 ± 0.3	1.2 ± 0.3	0.38 ± 0.09	0.13 ± 0.03	0.02 ± 0.01
$Wb\bar{b}$	24.7 ± 6.2	21.4 ± 5.3	6.6 ± 1.5	1.72 ± 0.41	0.37 ± 0.09
$t\bar{t}$	41.4 ± 8.7	8.6 ± 1.8	2.7 ± 0.6	0.78 ± 0.19	4.63 ± 1.11
Single-top	11.6 ± 2.4	8.3 ± 1.7	2.7 ± 0.6	0.47 ± 0.11	0.30 ± 0.07
QCD multijet	492 ± 108	393 ± 86	17.1 ± 4.3	0.50 ± 0.20	0.92 ± 0.37
W or Z+jets	2008 ± 502	1672 ± 418	43.0 ± 12.9	0.78 ± 0.22	0.86 ± 0.24
Total expectation	2580 ± 626	2106 ± 513	72.6 ± 20.0	4.44 ± 1.17	7.12 ± 1.89
Observed events	2540	2116	76	6	7

W+bb/W+jj at CDF

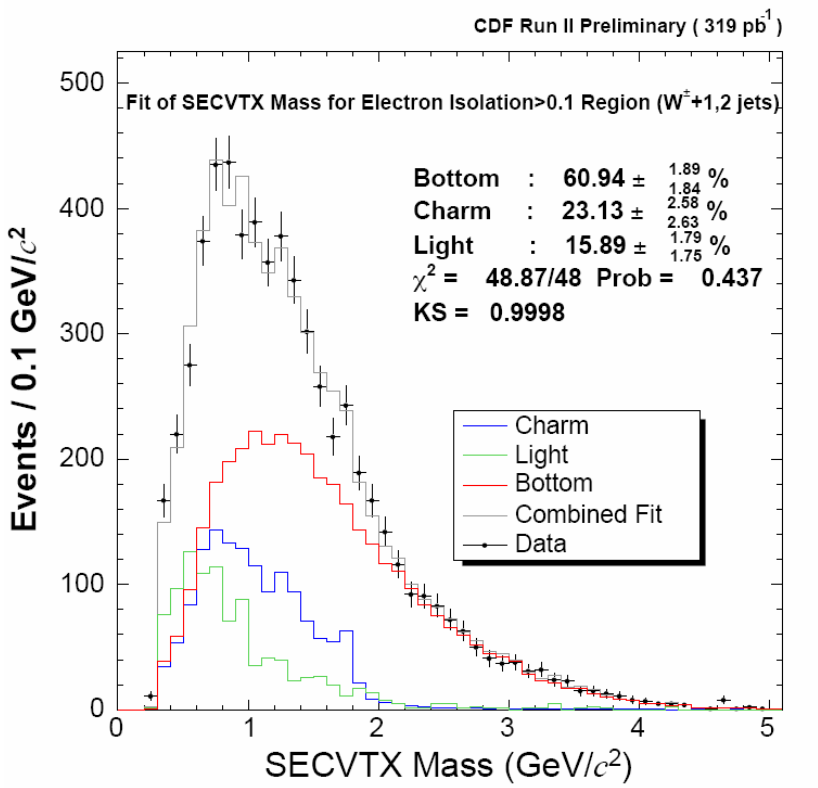
- Flavor tagging using vertex mass
- Vertex mass is a good variable



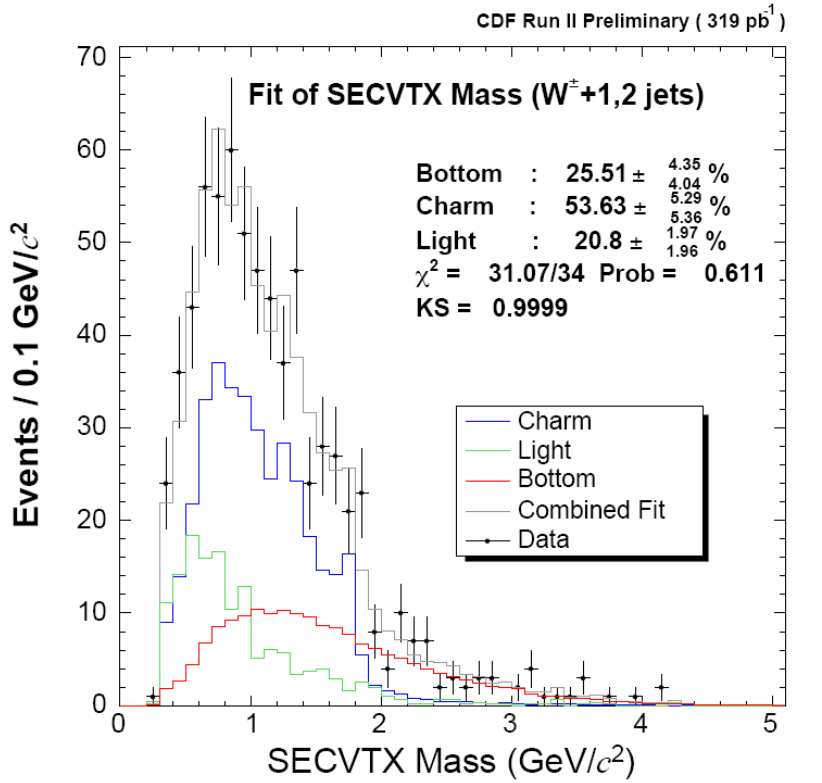


W+bb/W+j,jj

- Background region
  - Non isolated electron



- Signal region
  - Observed rate W+bb)/W+j,jj = 0.0072±0.0024(stat.)±0.0022(syst.)

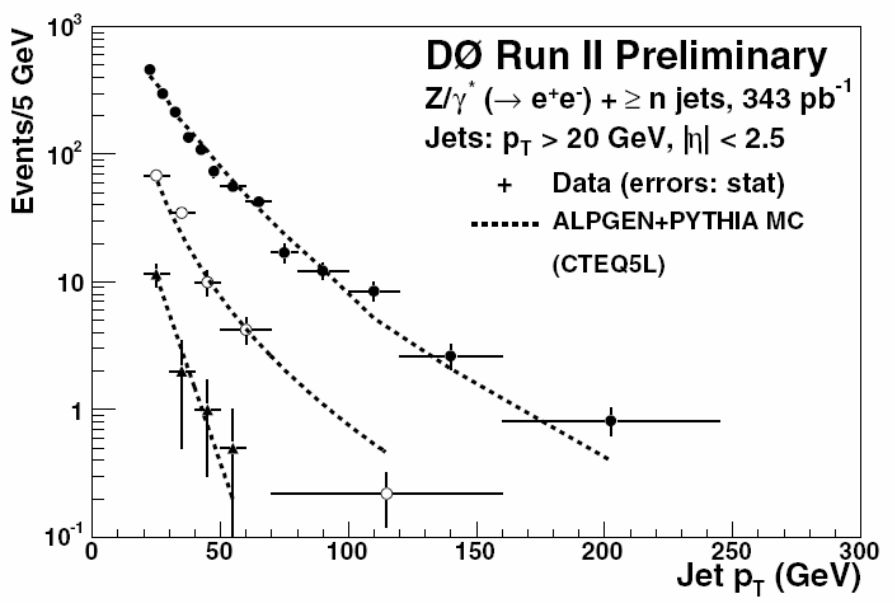


Z + Jets Measurements

- Z/γ^*+ n Jets cross section ratio
- Z+b

Z+Jets at D0

- Cross section ratio measurement at particle level
  - 343 pb^{-1}
  - electron channel
- Selection
  - Vertex |z|<60 cm
  - Electron
    - p_T>20 GeV, |η|<1.1
    - Shower development
    - Isolation
    - Two with at least one track matched
    - 75<M_{ee}<105
  - Jets
    - RunII cone R=0.5, p_T>20 GeV, |η|<2.5
    - JES corrected
  - Electron-jet separation ΔR>0.4
- 13,893 inclusive Z candidate events



- Comparison with ALPGEN LO with Pythia showering
  - Generator cuts: parton p_T>8 GeV, ΔR>0.4
  - No matching
  - Full simulation

Corrections in Z/γ*+jets

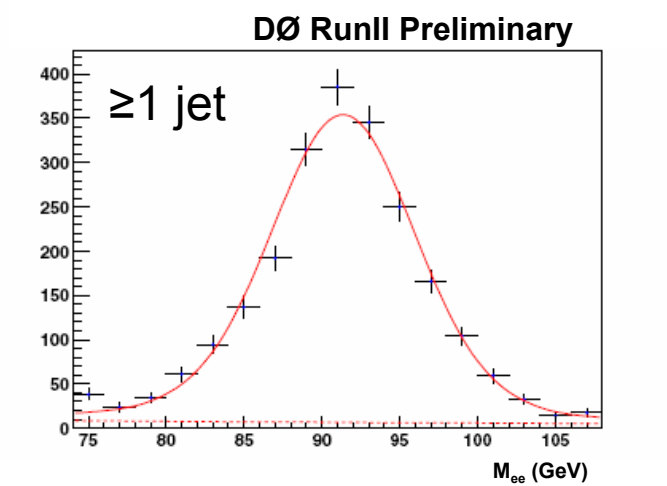
- Electron trigger, reconstruction*id efficiency
- Jet reconstruction-id efficiency
  - In data, look for jets balancing Z, measure eff as a function of Z p_T
  - Do the same in MC and scale factor derived
  - Reconstruction efficiency measured in MC * scale factor
  - Mapping to go from Z p_T to particle jet p_T
  - Closure test done
  - This will be used in unsmearing

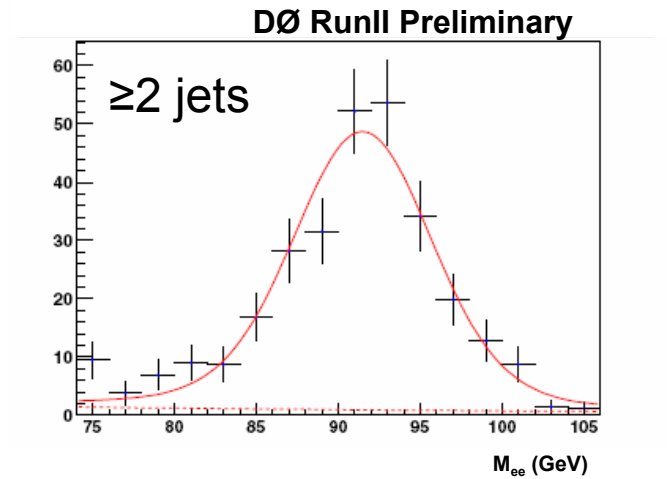
Acceptance

- Use MC
  - $Z/\gamma^* + \geq 0j$
    - Pythia reweighted to reproduce Z p_T in data
      - Den: Z/γ^* ($75<M_{ee}<105$)
      - Num: Those with two electrons $p_T>25$, $|\eta|<1.1$, |pvz|<60cm
  - $Z/\gamma^*+ \geq nj$
    - Alpgen Z+n jets sample.
      - Den: Z/γ^* ($75<M_{ee}<105$) + ≥n particle jet ($p_T>25$, $|\eta|<1.1$)
      - Num: Those with two electrons $p_T>25$, $|\eta|<1.1$, |pvz|<60cm
  - 21~30%

Background

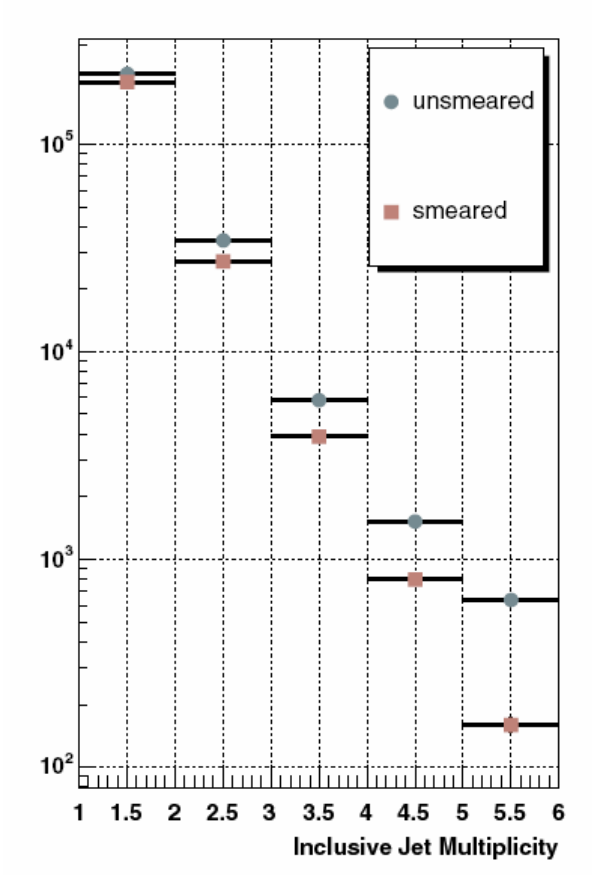
- Estimated from M_{ee} spectrum
  - Background is distributed flat
  - Relative Drell-Yan continuum contribution from simulation
  - Breit-Wigner convoluted with Gaussian + exponential function fit
  - For higher jet multiplicities, measure from side band
  - 2%~5%



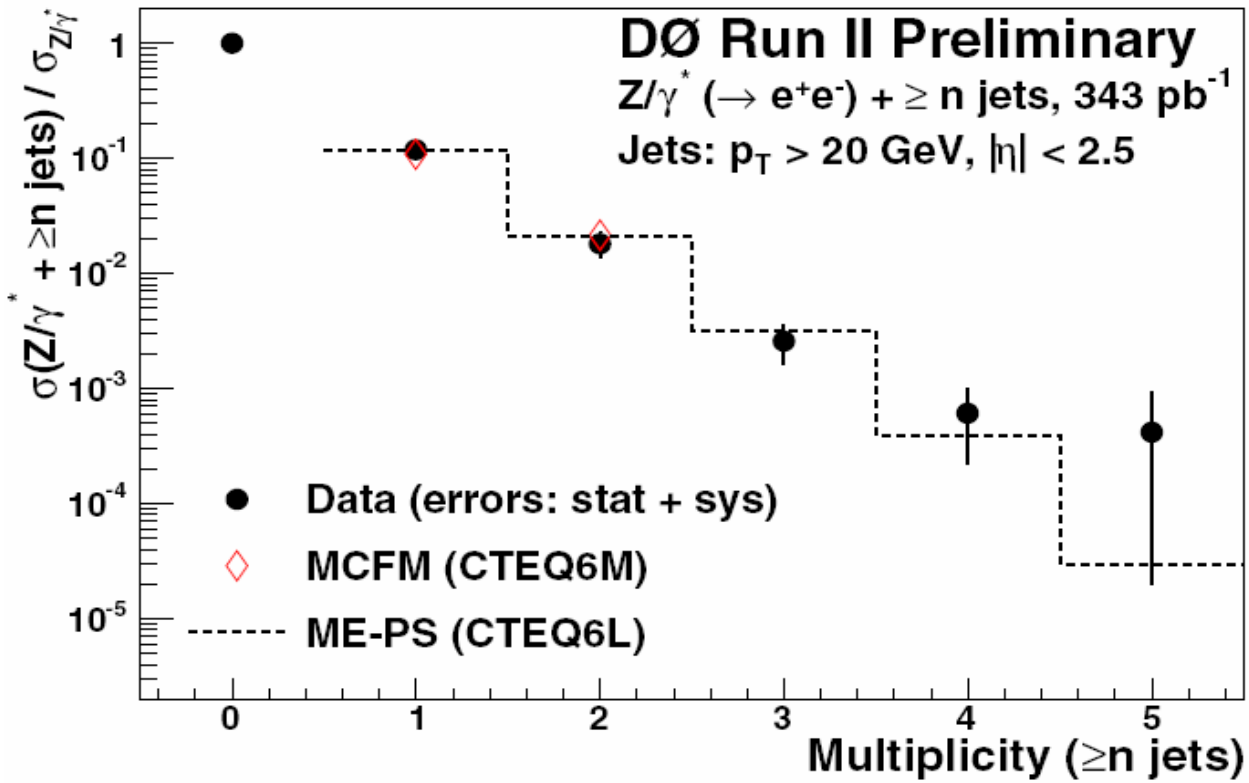


Corrections

- Unsmearing to correct for bin migration to due to
  - Jet energy resolution
  - Jet reconstruction efficiency
- Unsmearing correction factor derived using particle level PYTHIA MC
  - First reweight pythia events such that smeared MC distribution agrees with the data
- Electron-Jet overlap correction
  - Accidental overlap between Jet and electron must be accounted for
  - See how many partons fall within cone of 0.4~0.7
  - (6±3)% correction at ≥1 jet, (10±8)% at >4 jet



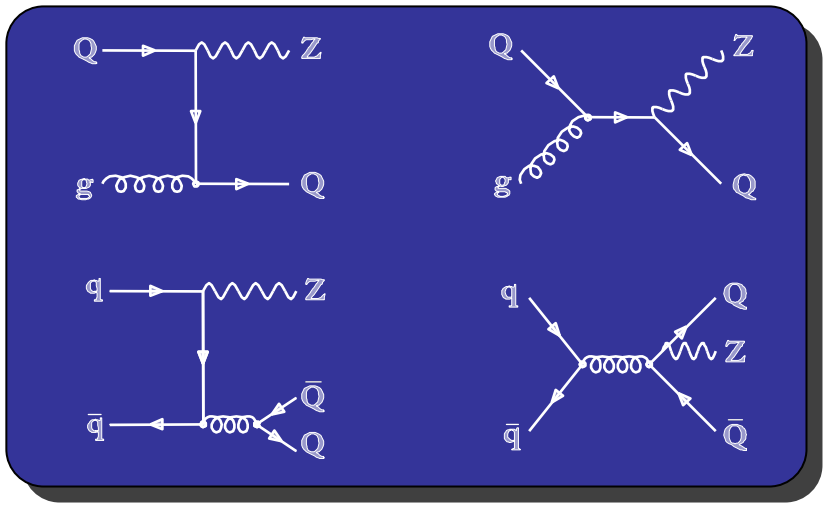
σ(Z/γ*+≥n jets)/σ(Z/γ*)



JES and jet reco efficiency uncertainty dominates

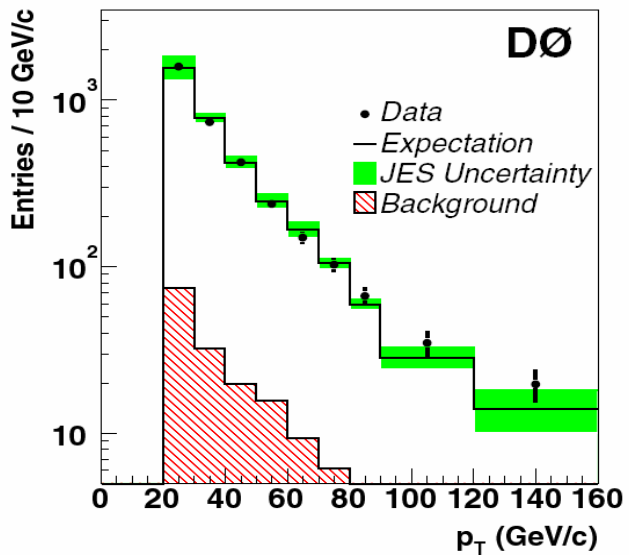
Multiplicity (≥n jets)	$R_n = \frac{\sigma_n}{\sigma_0}$ [$\times 10^{-3}$]	Statistical Uncertainty [$\times 10^{-3}$]	Systematic Uncertainty [$\times 10^{-3}$]
1	119.1	±3.3	+17.2 / -16.2
2	18.1	±1.3	+4.5 / -4.3
3	2.6	±0.52	+0.90 / -0.89
4	0.61	±0.28	+0.29 / -0.27
5	0.42	±0.30	+0.42 / -0.24

Z+Heavy Flavor



- Z + single b-tag
  - Probe of b-quark PDF
  - b PDF is important for *hb* and *single-top* production
- Measure inclusive $\sigma(Z+b)/\sigma(Z+j)$
  - Many systematics cancel

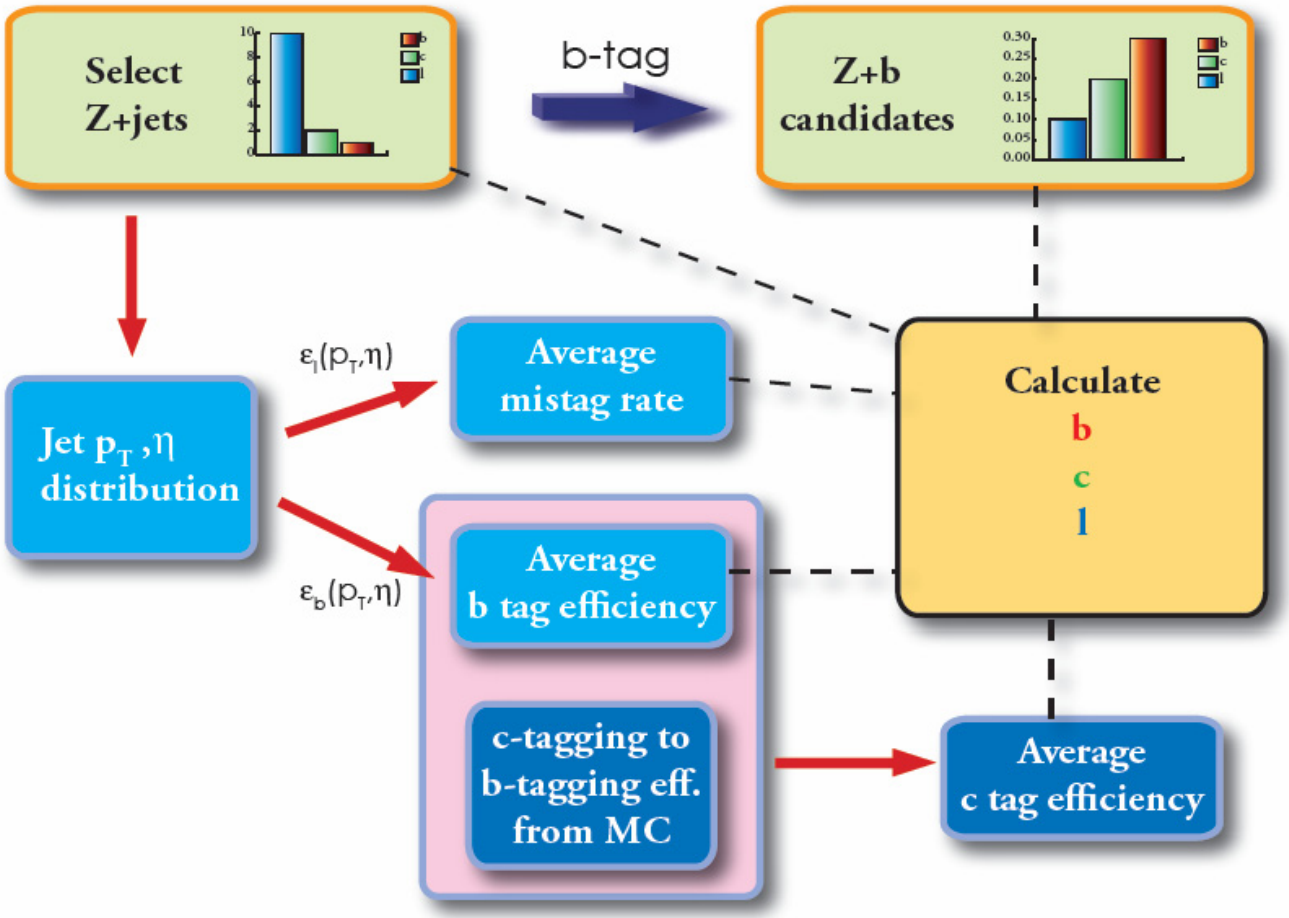
- Selection
  - Z in ee and $\mu\mu$ channels (cut on mass window)
  - $\geq$1 Jet p_T>20 GeV, $|\eta|$<2.5
  - 3458 Z+jet events



Method

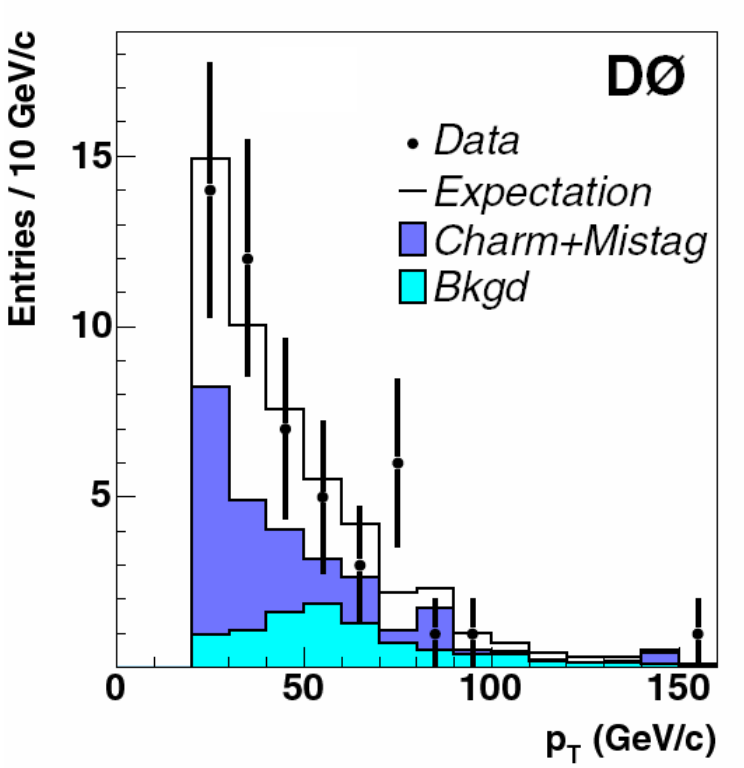
$$N_{\text{before b-tag}} = t'_b N_b + t'_c N_c + t'_\ell N_\ell$$

$$N_{\text{b-tagged}} = \bar{\epsilon}_b t'_b N_b + \bar{\epsilon}_c t'_c N_c + \bar{\epsilon}_\ell t'_\ell N_\ell$$



σ(Z+b)/σ(Z+j)

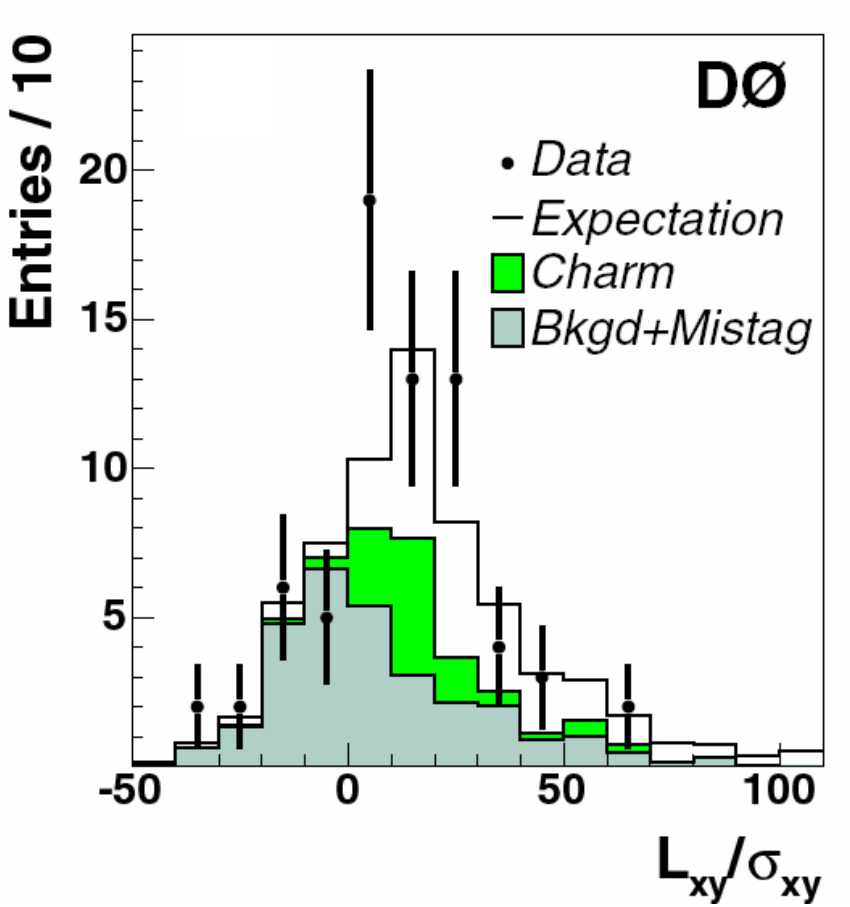
- Apply sec. vertex b-tag
  42 events with ≥1 tag
  8.3 from QCD background (sideband)



- Disentangle light, c, b contributions
  - Use light and b-tagging efficiency from data
  - c-tagging efficiency from MC and scaled for data/MC difference in b-tagging
  - N_c=1.69N_b from theory
- Cross checks with
  - Soft lepton tagging
  - Impact parameter tagging

$\sigma(Z+b)/\sigma(Z+j)$ hep-ex/0410078

- 0.021±0.004(stat)±0.002(syst)
  - Theory predicts 0.018
  - Large part of systematic error from tagging efficiency and background estimation
- Disentangling scale from b-PDF needs more measurements
  - W+(bb), W+bb
  - Z+c



Summary and Outlook

- Inclusive W/Z+jets measurement – going to hadron level
- W/Z+HF – turning into a real measurement
- Comparison with
  - ME-PS – modified CKKW, Sherpa