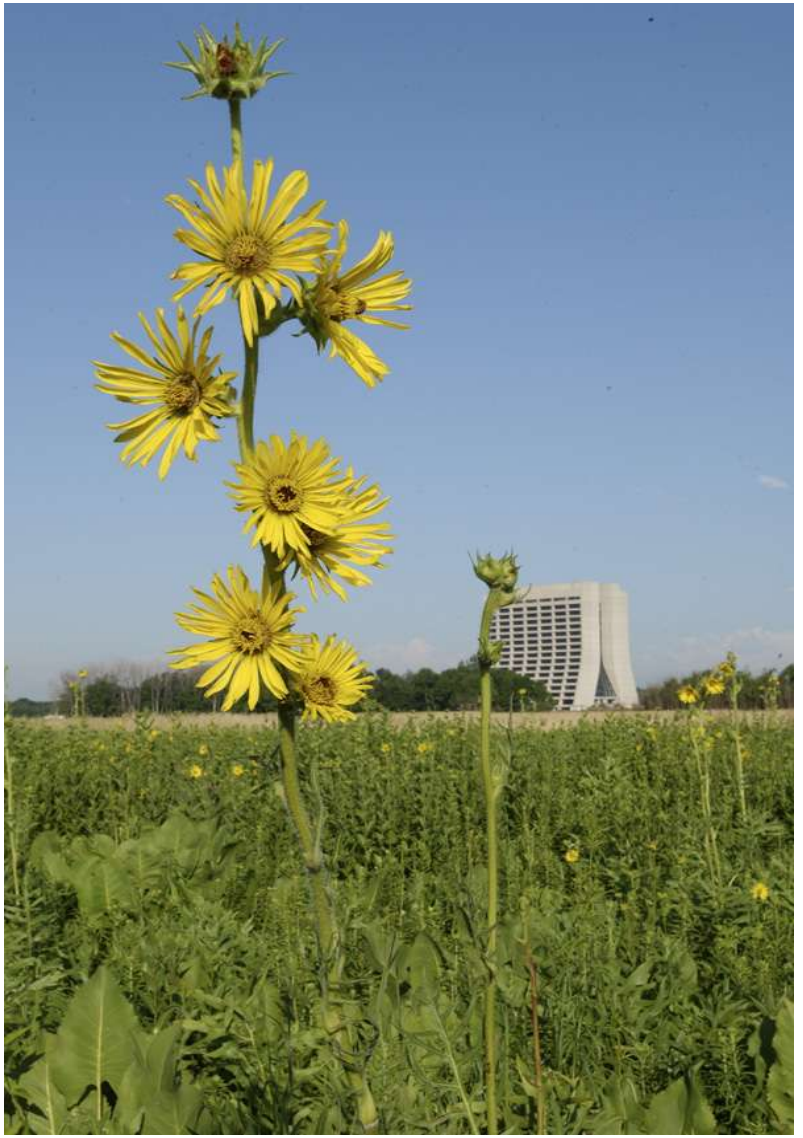
W/Z (+ Jets) Cross Sections at 1.96 TeV

Gavin Hesketh
Northeastern University
On behalf of the DØ and CDF collaborations.

39th Recontres de Moriond
QCD and Hadronic Interactions

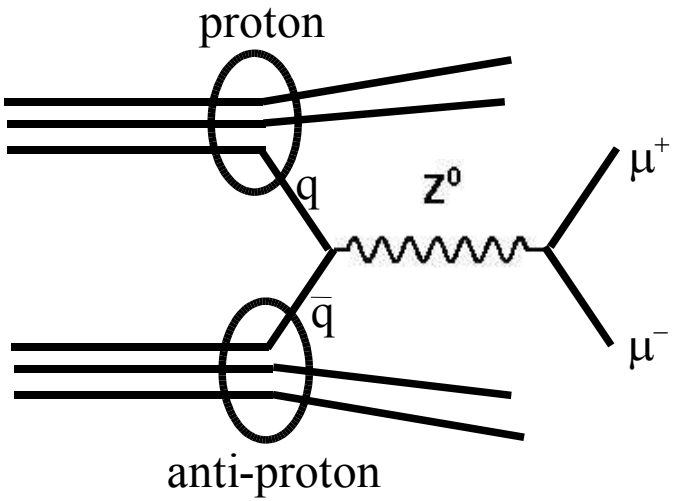
- W and Z Physics at the Tevatron
- Measuring the W and Z
- Inclusive Cross Sections
- Cross Section Ratio
- W/Z + Jets
- Asymmetries

All results preliminary.



W and Z Physics at the Tevatron

Study e and μ W/Z decay modes:
- clean signal
- no ambiguity with hadronic initial state

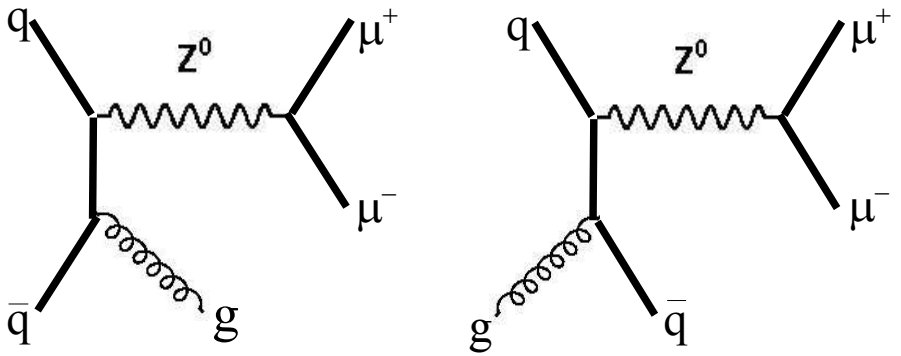


$\sigma(W\to l\nu) \sim 10 \times \sigma(Z\to ll)$

~ millions of W's, ~100k Z's with 2 fb^{-1} in Run II.

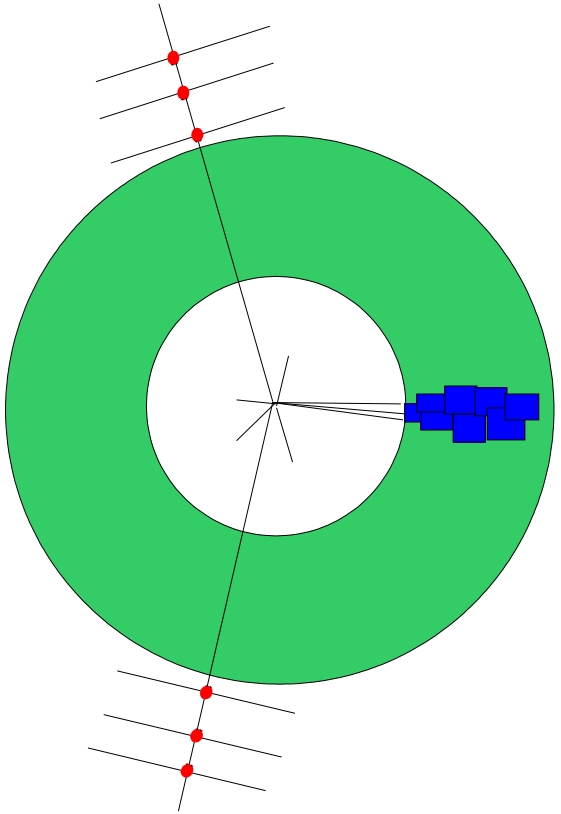
W/Z Physics and QCD

- inclusive production cross section
- indirect W width measurement
- cross section + jets
- boson pT
- boson rapidity
- asymmetry measurements



Detecting the W and Z (+ Jets)

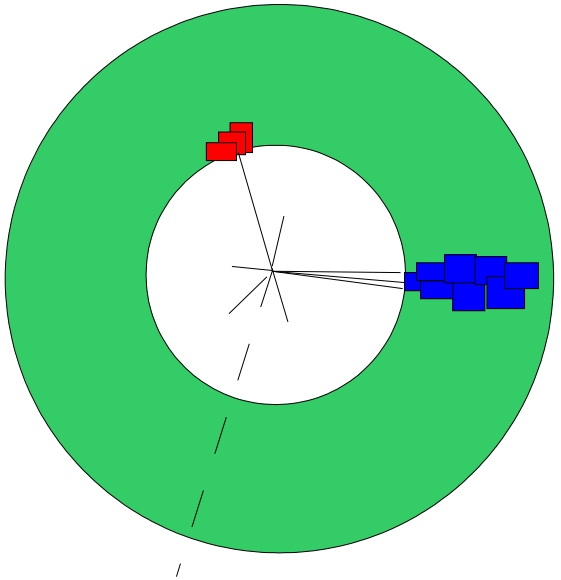
$Z \rightarrow \mu\mu$



Two leptons:
- fully reconstruct Z

Low background.

$W \rightarrow e\nu$



Reconstruct electron
Infer neutrino from
missing transverse energy.

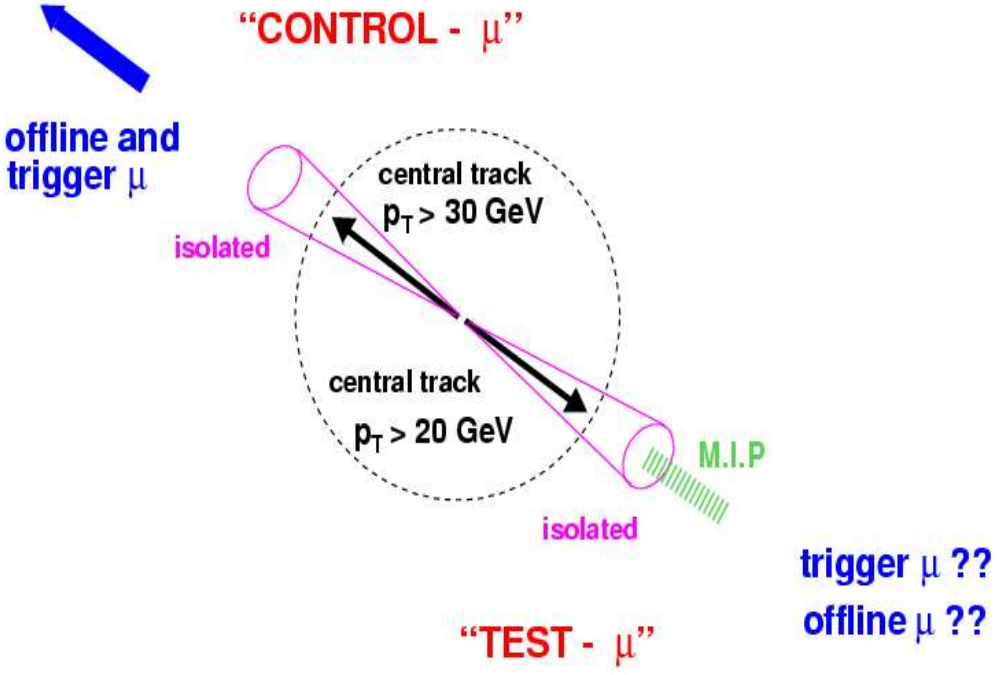
Higher statistics than Z,
higher backgrounds as well.

Important background for
top, higgs search.

Inclusive Z Cross Section (Muon Channel), DØ

$$\sigma \cdot B = \frac{N_{obs} - N_{bkg}}{A\varepsilon \int Ldt}$$

A = acceptance
ε = efficiency

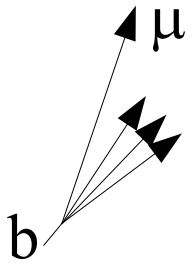


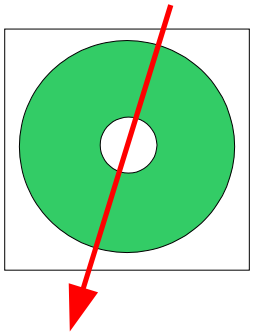
Measurement strategy:

- measure all efficiencies in data
- tune 'fast' detector simulation (DØ)
- use full detector simulation (CDF)
- use Pythia MC for acceptance

Backgrounds:

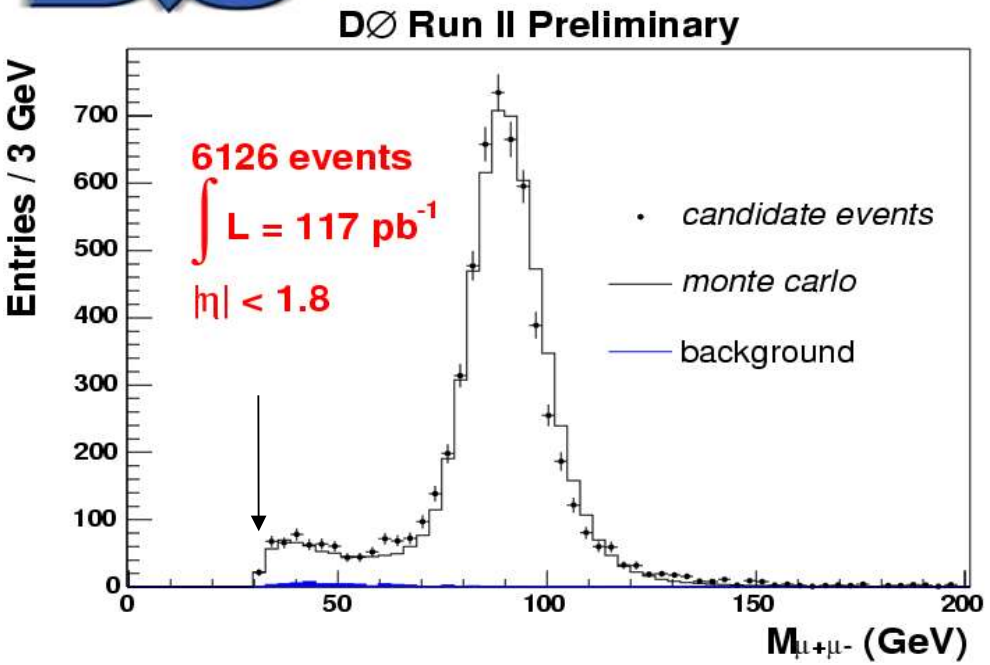
- semi-leptonic quark decays: 0.6 %
- cosmic rays: negligible
- $Z \rightarrow \tau\tau$: 0.5 %





cosmic ray

Z Cross Section, DØ



Z→μμ

Apply correction for Z/γ*

Dominant Systematics:

- luminosity: 10 %
- efficiencies: 3.3 % (stats limited)
- PDF's: 1.6 %

$\sigma.B = 262 \pm 5 \pm 9 \pm 26.2$ pb

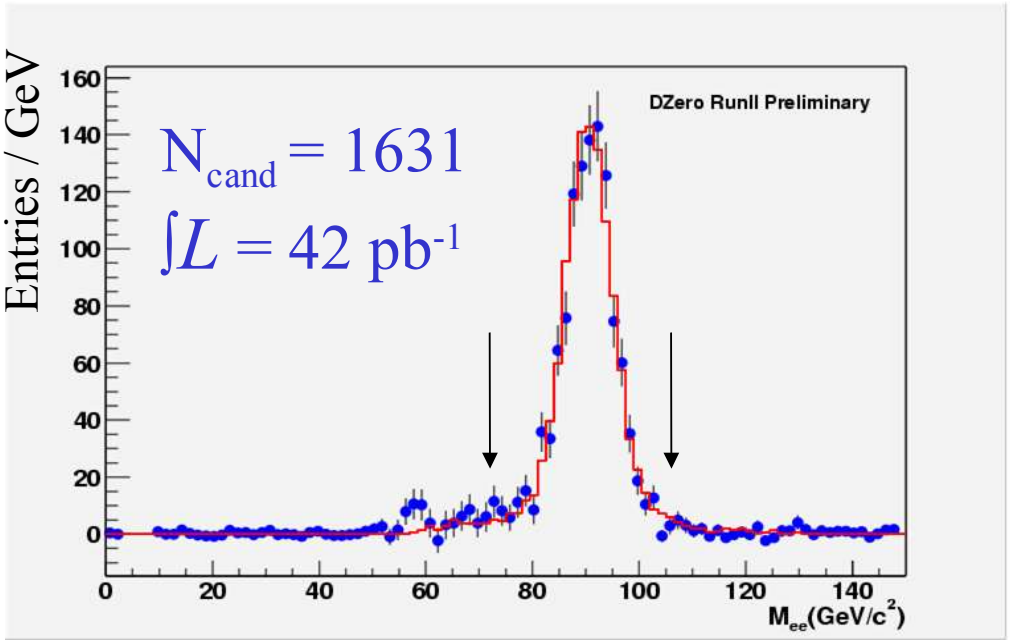
NNLO: 252 ± 9 Van Neerven *et al*

Z→ee

Similar methods for efficiencies and backgrounds.

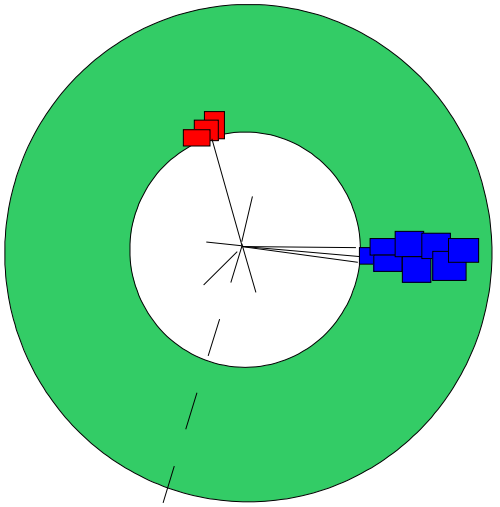
Comparable systematics.

$\sigma.B = 275 \pm 9 \pm 9 \pm 28$ pb



W Cross Section (Electron Channel), CDF

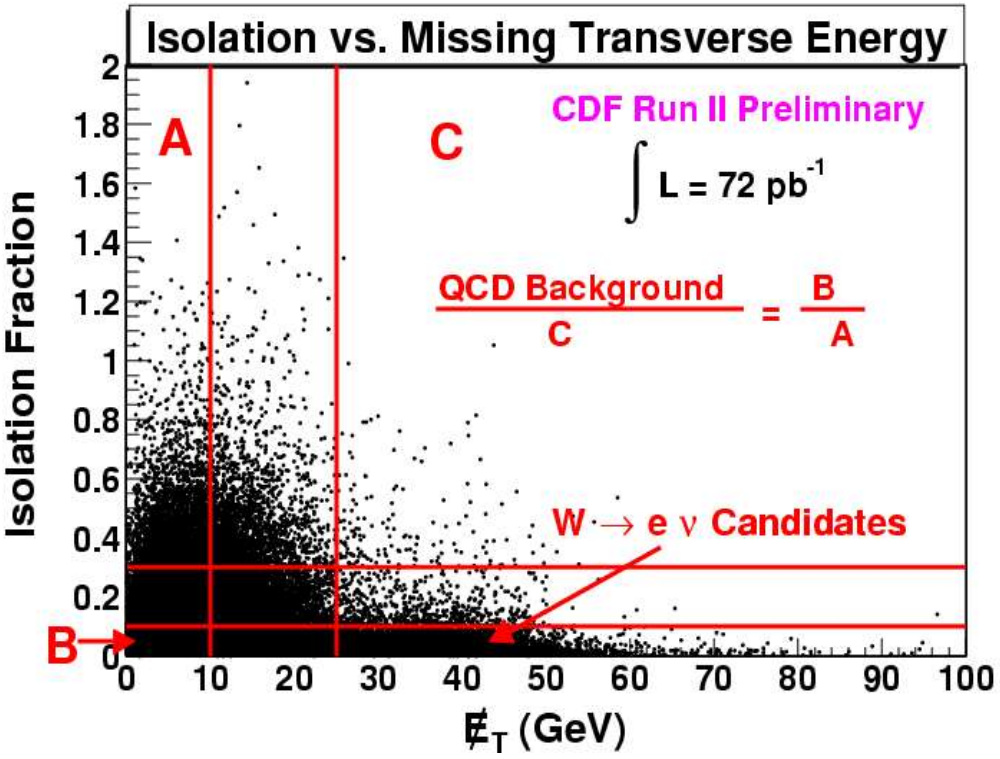
One electron > 25 GeV
Missing Transverse Energy > 25 GeV



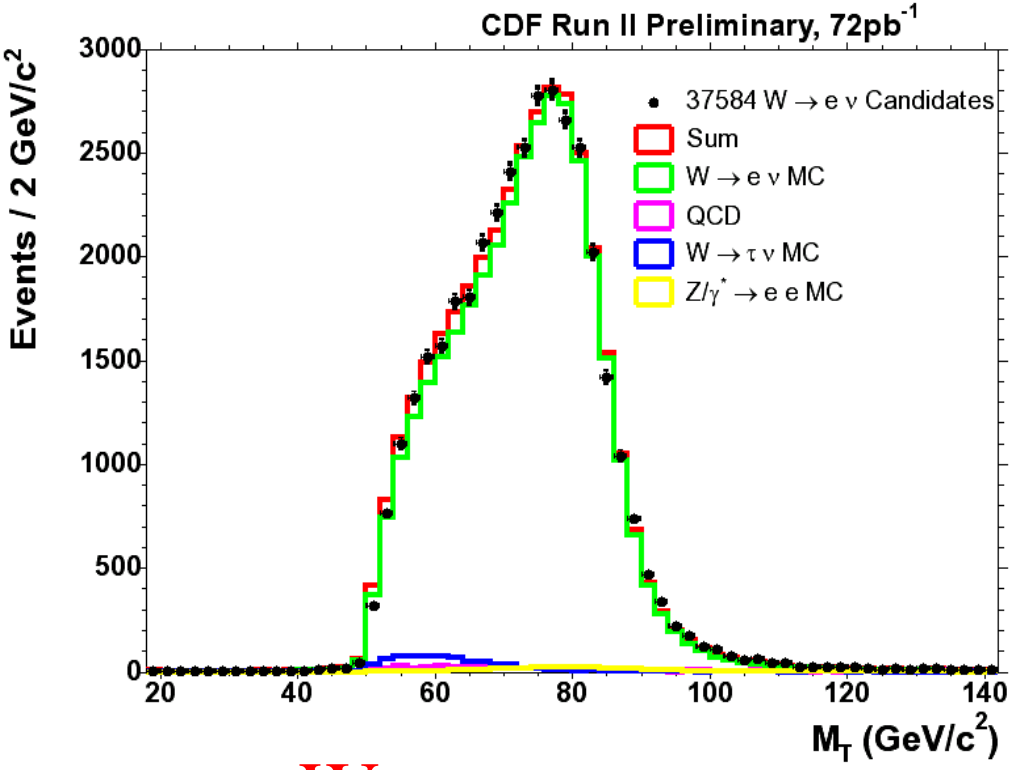
Main backgrounds:

Measured in Monte Carlo:
$W \rightarrow \tau\nu$: 2 %
$Z \rightarrow ee$, one electron not reconstructed: 0.8 %

Measured in data:
QCD: semi leptonic decays, fakes
- Estimate using isolation and $\not\!\!E_T$
- 1.5 % of final sample



W Cross Section, CDF



W→eν

Dominant Systematics:

- luminosity: 6 %
- PDF's: 1 - 1.4 %
- material model in simulation: 0.7 %

$\sigma.B = 2782 \pm 14 \,^{+61}_{-56} \pm 167$ pb

NNLO: 2690 ± 100 Van Neerven *et al*

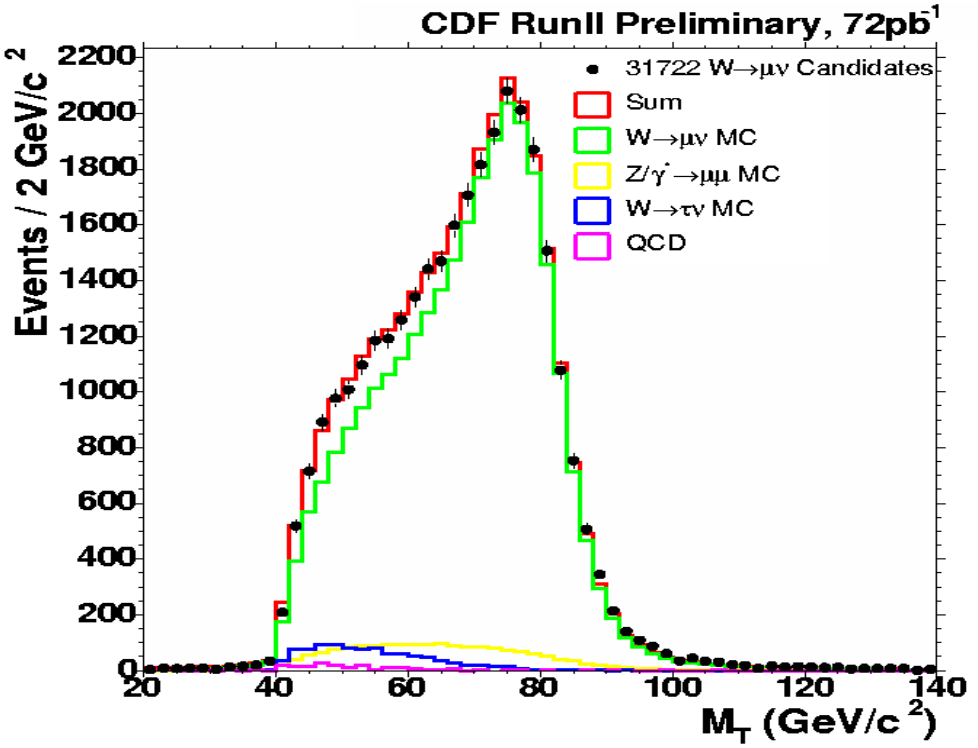
W→μν

Backgrounds ~ 10 %

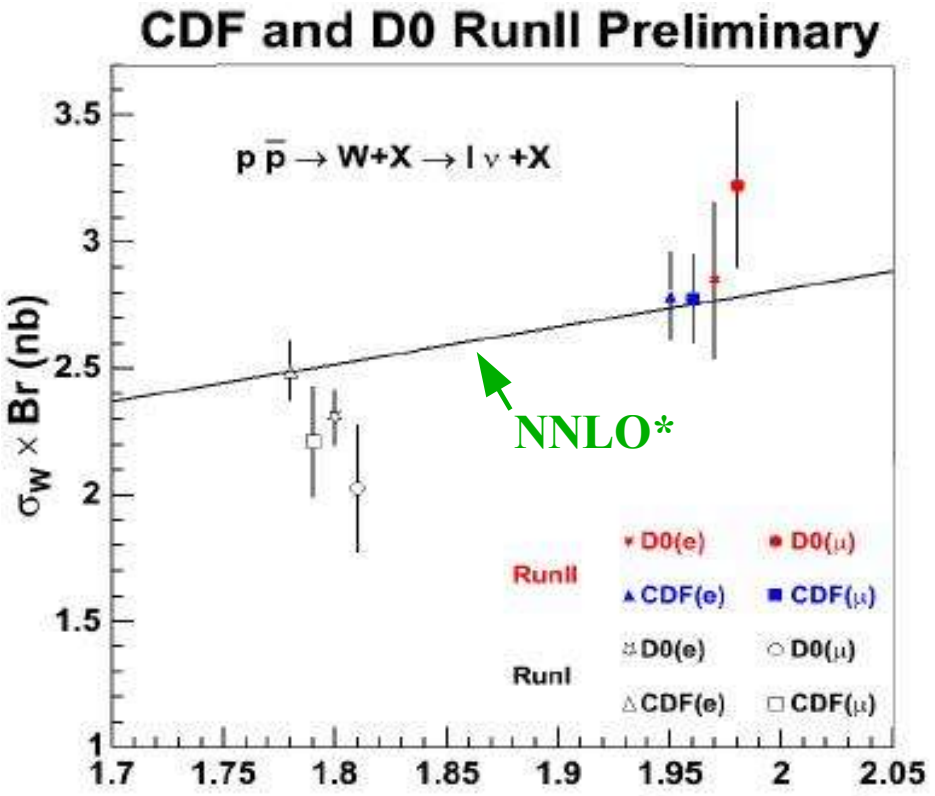
- Z→μμ ~ 5 %
- W→τν ~ 3 %
- QCD ~ 0.6 %

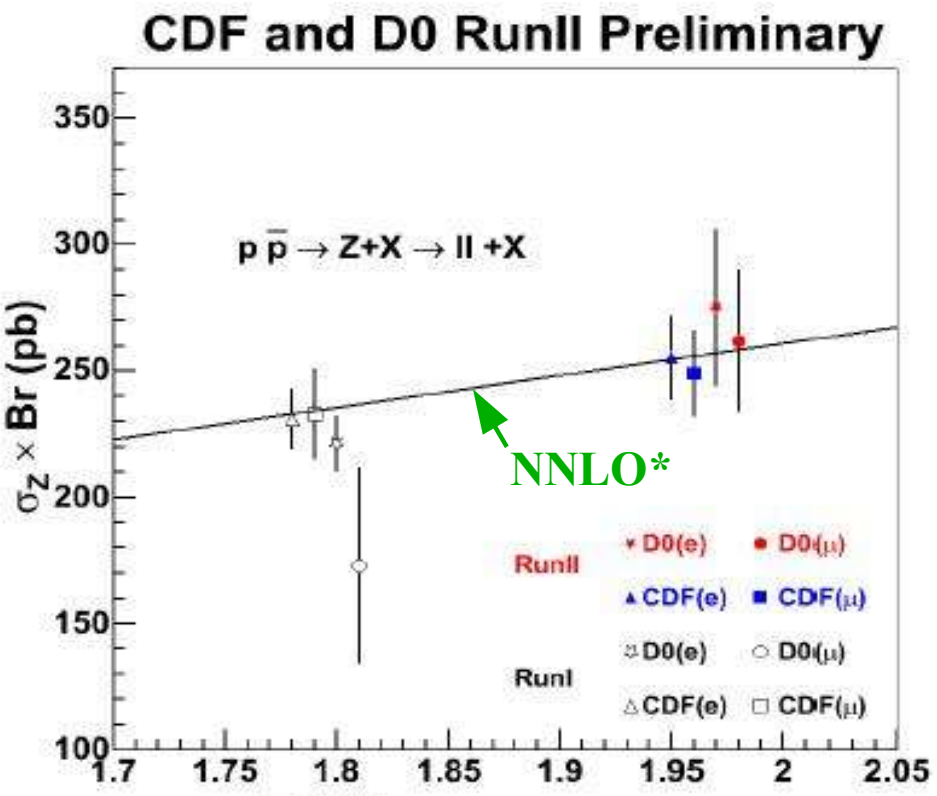
Comparable systematics to e channel

$\sigma.B = 2772 \pm 16 \,^{+64}_{-60} \pm 166$ pb



Inclusive Cross Sections





Center of mass energy (TeV)

*Van Neerven *et al*
(nucl phys. B359, 343, 1991)

DØ and CDF have agreed on a common luminosity normalisation.
Next round of plots will use this common scheme.

W/Z Cross Section Ratio

Many systematics cancel:
- luminosity, PDF's, efficiencies

$$R = \frac{\sigma \times Br(W \to l\nu)}{\sigma \times Br(Z \to ll)} = \frac{\sigma_W}{\sigma_Z} \frac{\Gamma(Z)}{\Gamma(Z \to ll)} \frac{\Gamma(W \to l\nu)}{\Gamma(W)}$$

NNLO

LEP

SM

Latest result from CDF:

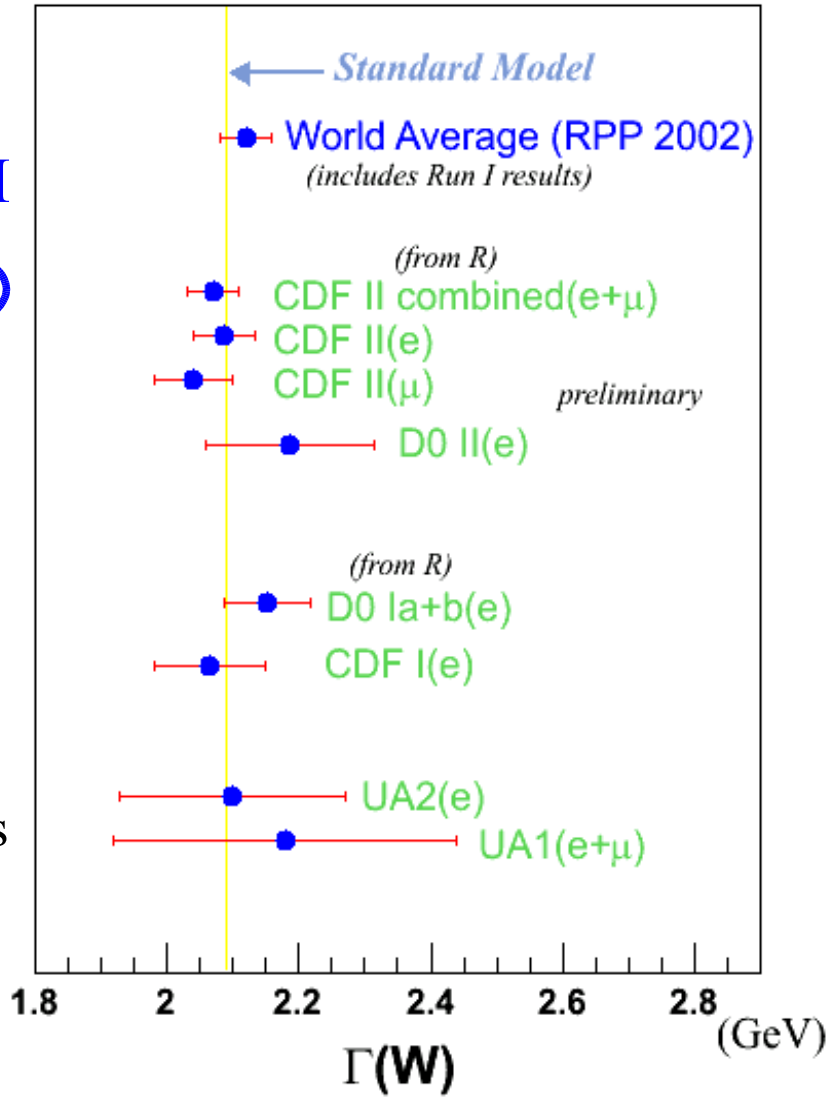
$R = 10.94 \pm 0.15\ (stat) \pm 0.13\ (syst)$ e and μ channels

Indirect measurement of the W width:

$$\Gamma(W) = 2071 \pm 40\ \text{MeV}$$

Current World Average: 2118 ± 42 MeV

SM Prediction: 2092 ± 2.5 MeV

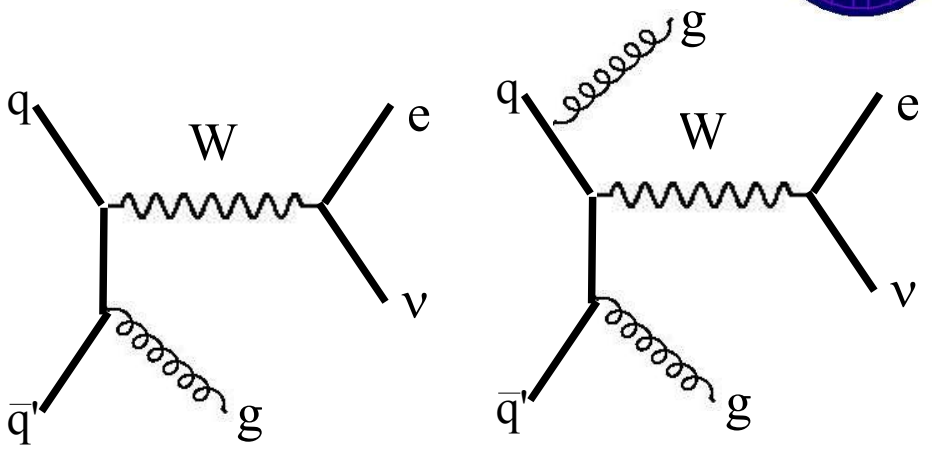


TeV EWWG will combine DØ and CDF results.

W + Jets

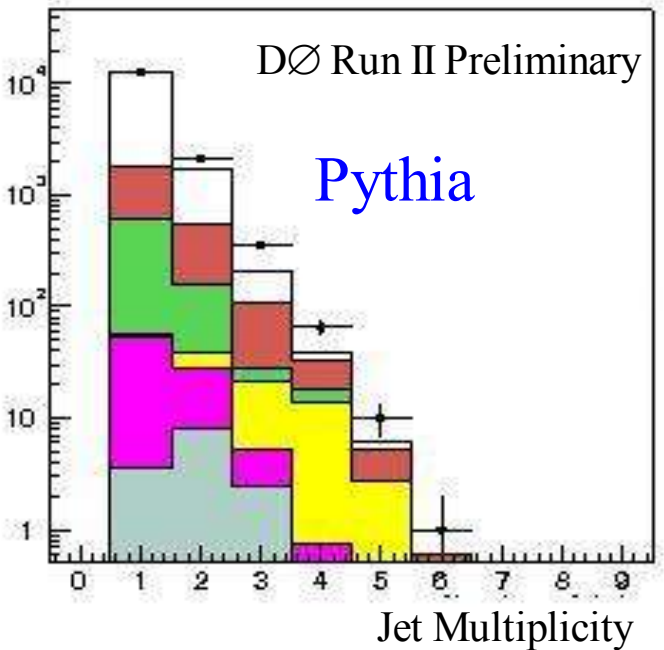
Production of W + jets:

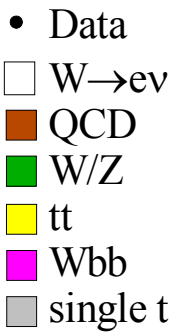
- test of perturbative QCD.
- important background for top, higgs

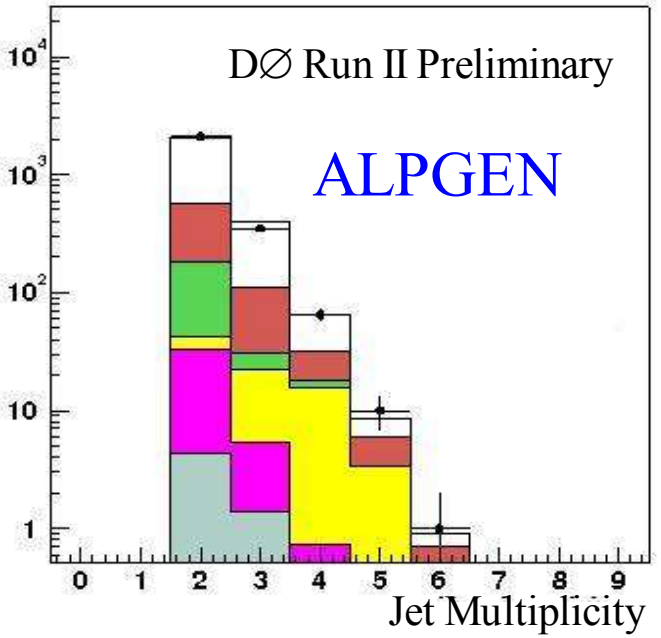


Monte Carlo:

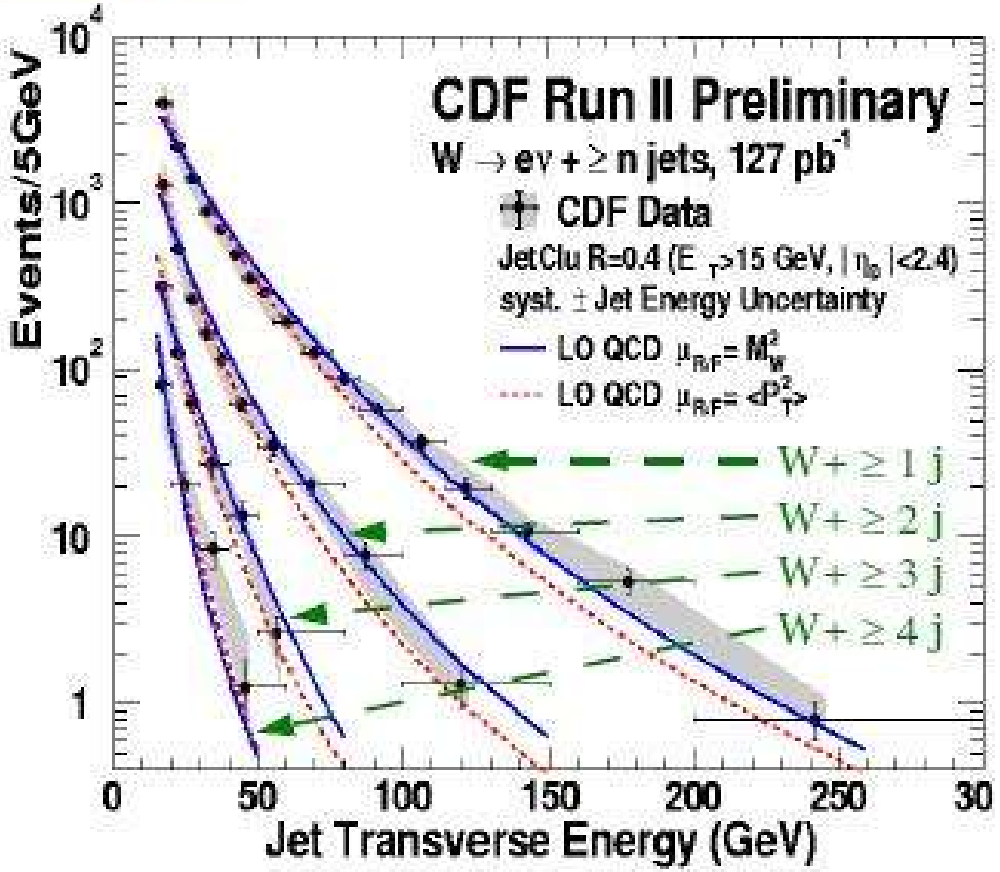
- Not well described by Pythia
- ALPGEN: W/Z + *n* parton MC (LO)
- Showering handled by Herwig / Pythia







Kinematics in W→eν + Jets

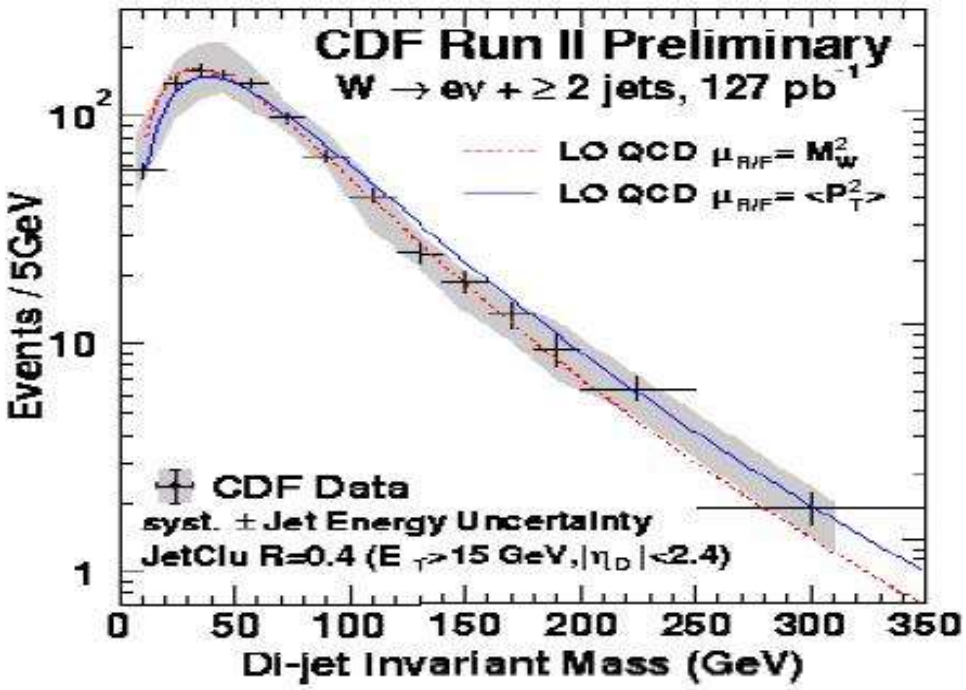


Differential cross section vs. E_T for *n*th highest E_T jet in W + ≥*n* jets.

Reasonable MC-data agreement.

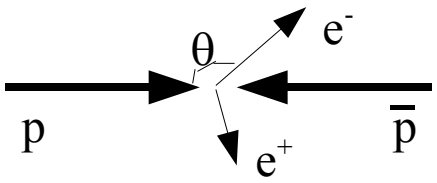
Dijet invariant mass in W + ≥2 jets.

Sensitive to soft / hard jet production and angular distributions.



Z + Jets, Asymmetry

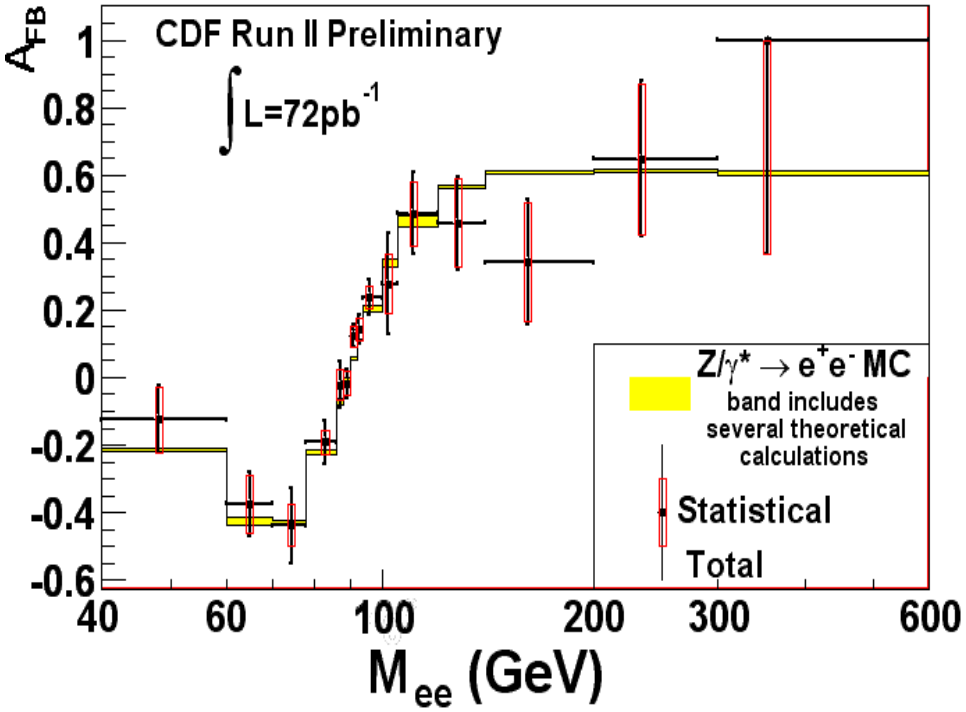
Forward-Backward Asymmetry



$$A_{fb} = \frac{\sigma(\cos\theta > 0) - \sigma(\cos\theta < 0)}{\sigma(\cos\theta > 0) + \sigma(\cos\theta < 0)}$$

Measure asymmetry for Z/γ*

- measure $\sin^2\theta_w$
- assume world average of $\sin^2\theta_w$ and probe pdf's



Z + Jets Studies

Lower backgrounds, fully reconstruct the Z:

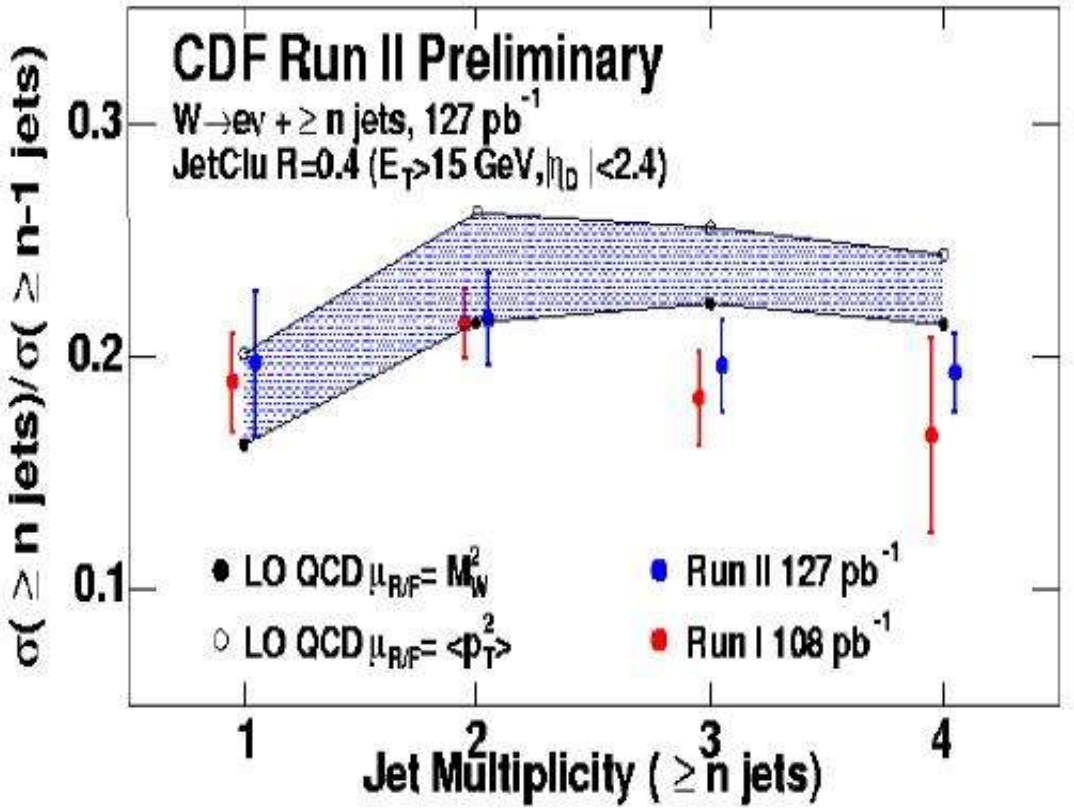
- Leptonic Z's are an excellent test of QCD!
- measure Z p_T, rapidity
- but, lower statistics
- studies ongoing

Conclusions

- W and Z physics in lepton channels:
  - precision electroweak measurements
  - excellent test of QCD.
- Inclusive cross sections:
  - good data – Monte Carlo agreement
  - systematics dominated by luminosity and PDF's
  - preliminary W width shows improvement on world average.
- W / Z + jets:
  - first detailed studies of data – Monte Carlo agreement.

Additional Slides

Ratio $\sigma(\geq n \text{ jets}) / \sigma(\geq n\text{-}1 \text{ jets})$



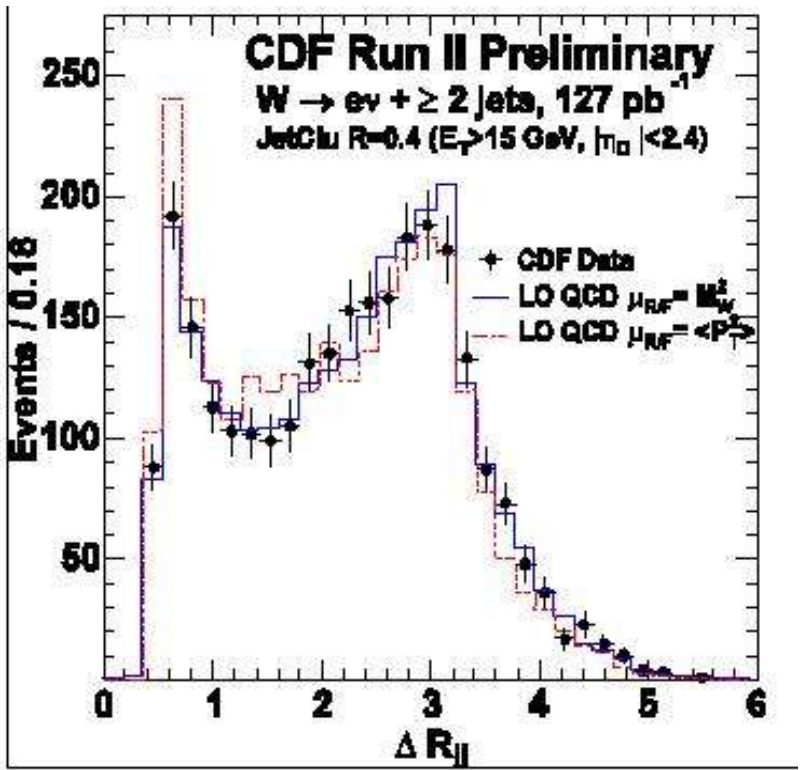
Decrease in cross section with each additional jet

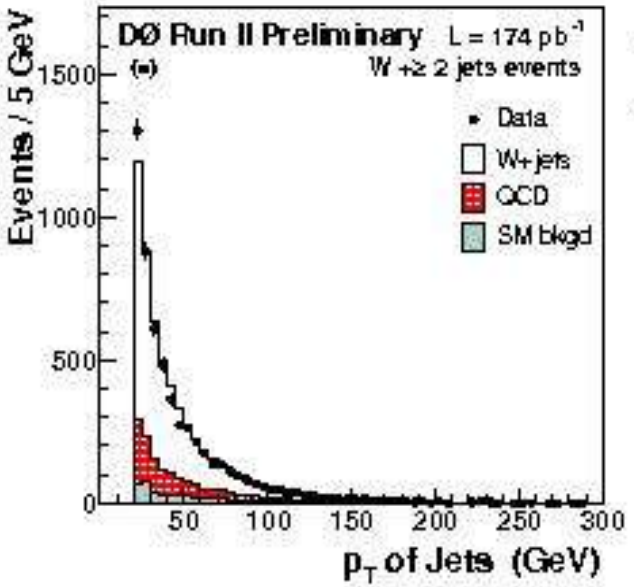
Related to α_s

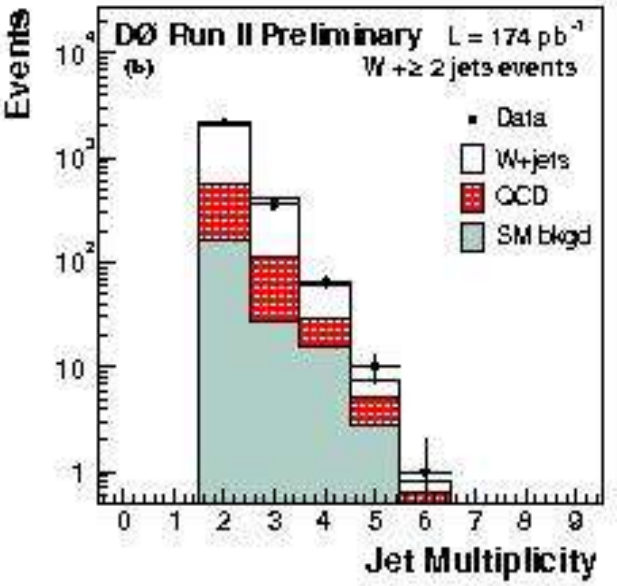
Systematics cancel in ratio

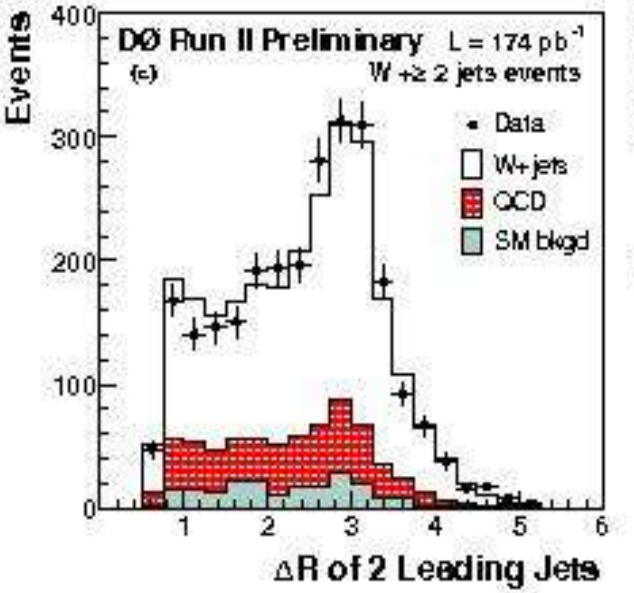
Reasonable data – Monte Carlo agreement.

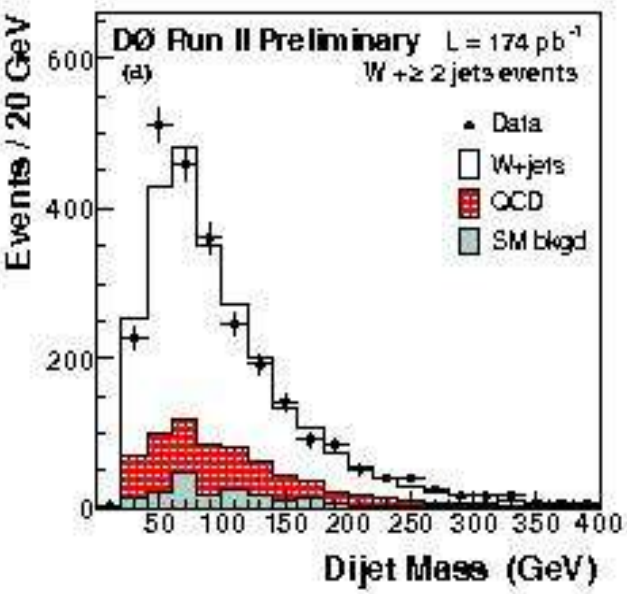
$$\Delta R = \Delta\phi \oplus \Delta\eta$$







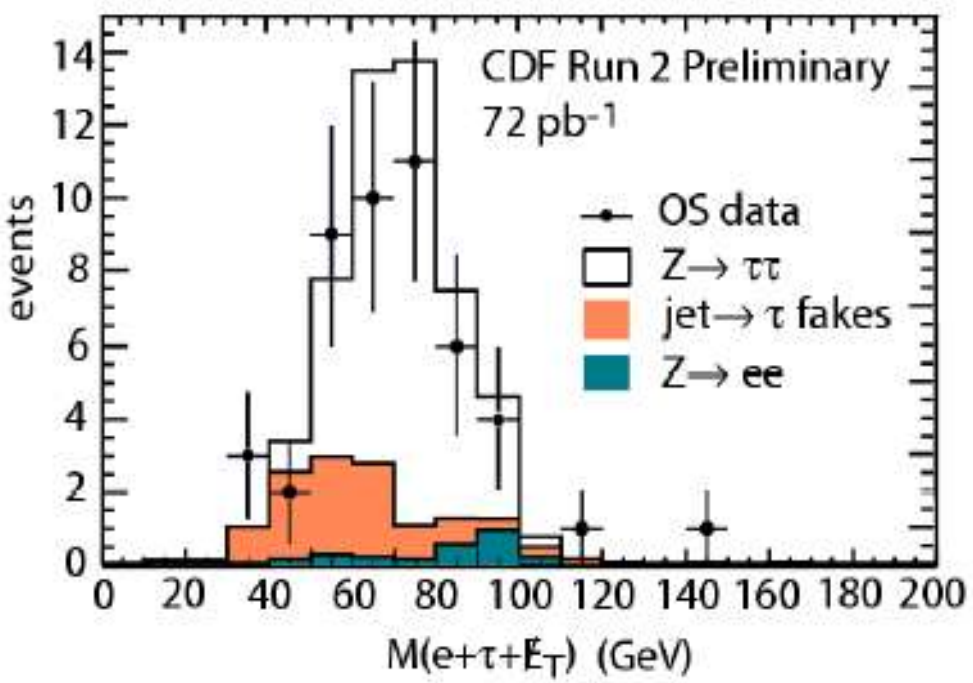




$Z \rightarrow \tau\tau$

Look for events with:

- one hadronic τ decay
- one leptonic τ decay

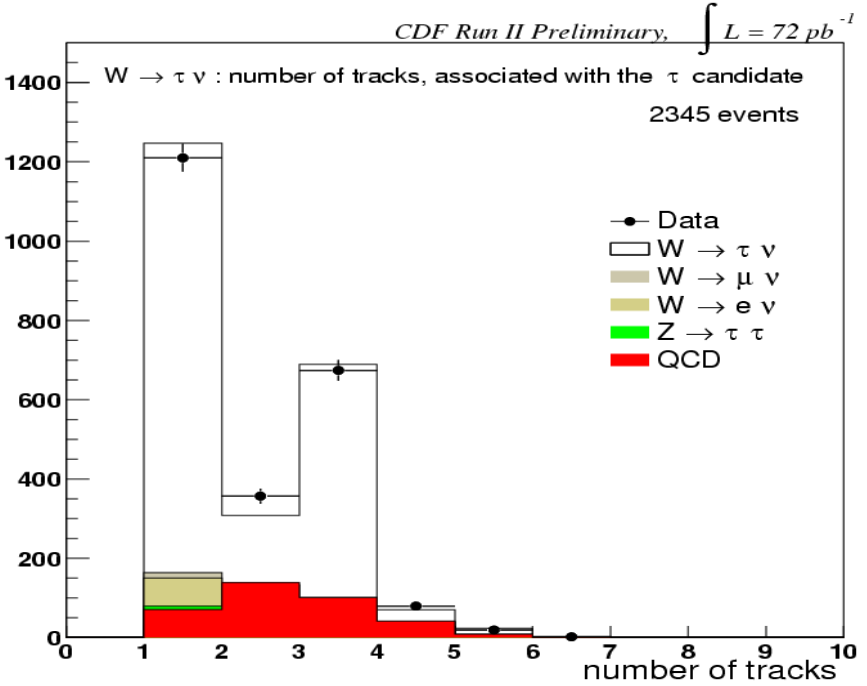


$W \rightarrow \tau\nu$

Look for hadronic τ decay.

- narrow (10^o) jet
- isolated in wider (30^o) cone
- p_T (τ) > 25 GeV
- $\not\!\!E_T$ > 25 GeV

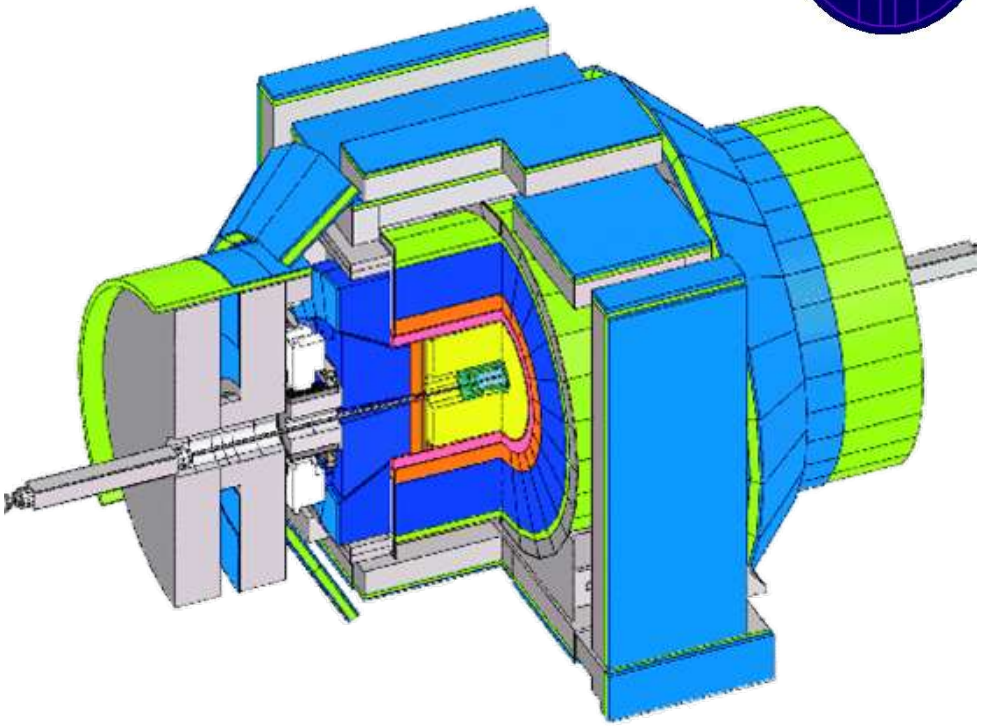
2345 candidates in 72 pb^{-1}

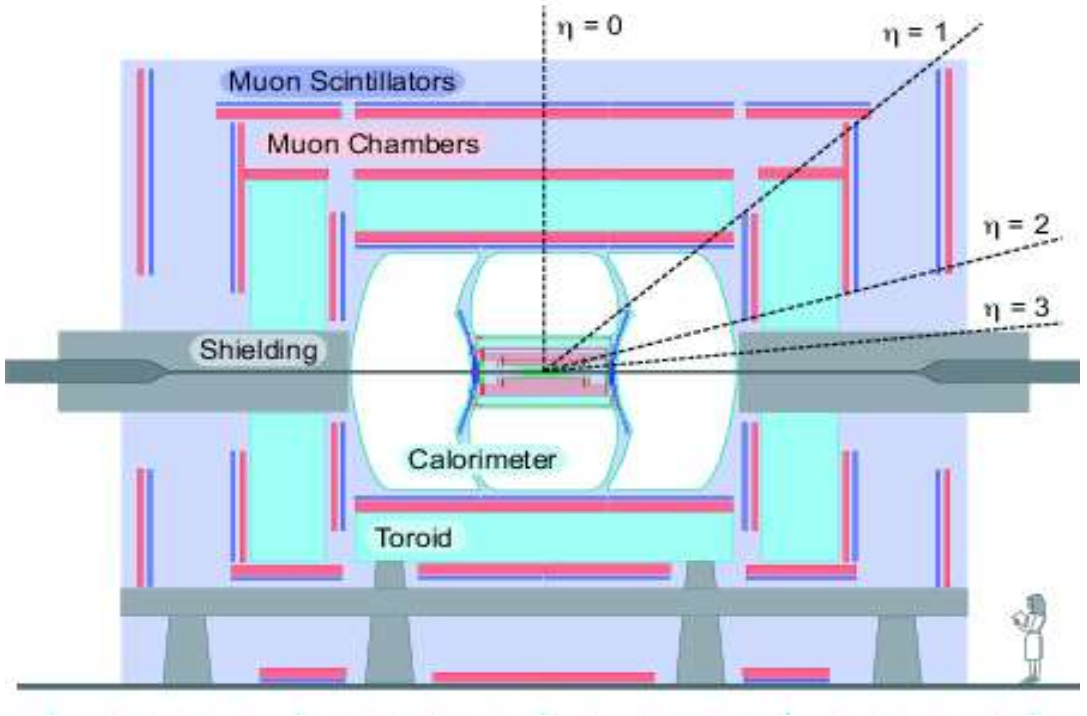


$\sigma.B = 2620 \pm 70 \pm 210 \pm 160$ pb

DØ and CDF Detectors

Run II upgrades for CDF:
- silicon detector
- time of flight detector
- forward calorimeter
- muon system
- DAQ and trigger upgrades





Run II upgrades for DØ:
- silicon detector
- central solenoid
- preshower detectors
- upgraded forward muon system
- DAQ and trigger upgrades

Cross Section Summary

CDF $W \to e\nu$: 2782 ± 15 (stat) $^{+61}_{-56}$ (syst) ± 167 (lum) pb

D∅ $W \to e\nu$: 3054 ± 100 (stat) ± 86 (syst) ± 305 (lum) pb

CDF $W \to \mu\nu$: 2772 ± 16 (stat) $^{+64}_{-60}$ (syst) ± 166 (lum) pb

D∅ $W \to \mu\nu$: 3226 ± 128 (stat) ± 100 (syst) ± 323 (lum) pb

CDF $Z \to ee$: 255.2 ± 3.9 (stat) $^{+5.5}_{-5.4}$ (syst) ± 15.3 (lum) pb

D∅ $Z \to ee$: 275 ± 9 (stat) ± 9 (syst) ± 28 (lum) pb

CDF $Z \to \mu\mu$: 248.9 ± 5.9 (stat) $^{+7.0}_{-6.2}$ (syst) ± 14.9 (lum) pb

D∅ $Z \to \mu\mu$: 261.8 ± 5.0 (stat) ± 8.9 (syst) ± 26.2 (lum) pb

Channel	Candidates & purity	Integrated luminosity (pb^{-1})	Efficiency * acceptance
CDF $W \to e\nu$	37.6K (95%)	72	14.39%
DØ $W \to e\nu$	27.4K (98%)	41	18.40%
CDF $W \to \mu\nu$	31.7K (90%)	72	17.94%
DØ $W \to \mu\nu$	8.3K (88%)	17	13.20%
CDF $Z \to ee$	4242 (1.5%)	72	22.74%
DØ $Z \to ee$	1139 (--------)	41	9.30%
CDF $Z \to \mu\mu$	1785 (1.5%)	72	10.18%
DØ $Z \to \mu\mu$	6126 (1.1%)	117	16.40%