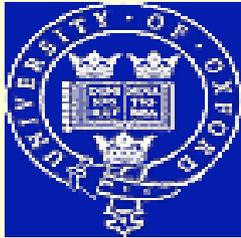


Recent Electroweak Results from CDF



Chris Hays

University of Oxford

for the CDF Collaboration



Fermilab Wine & Cheese

June 16, 2006

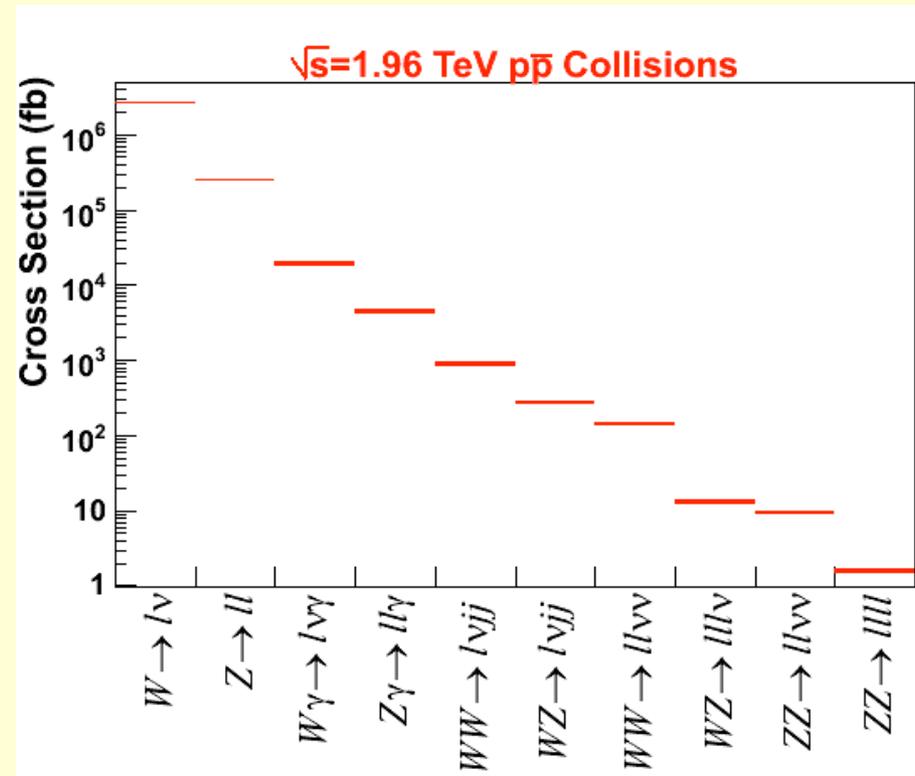


Electroweak Physics at the Tevatron

Mono-boson measurements:

- * High cross sections \rightarrow high statistics
- * Precision measurements of electroweak parameters (e.g., W mass)
- * Constraints on QCD

Precision



Di-boson measurements:

- * Low cross sections \rightarrow some processes still not observed
- * Probe $SU(2) \times U(1)$ gauge boson self-interactions
- * Search for new couplings, resonances (e.g., Higgs)

Searches

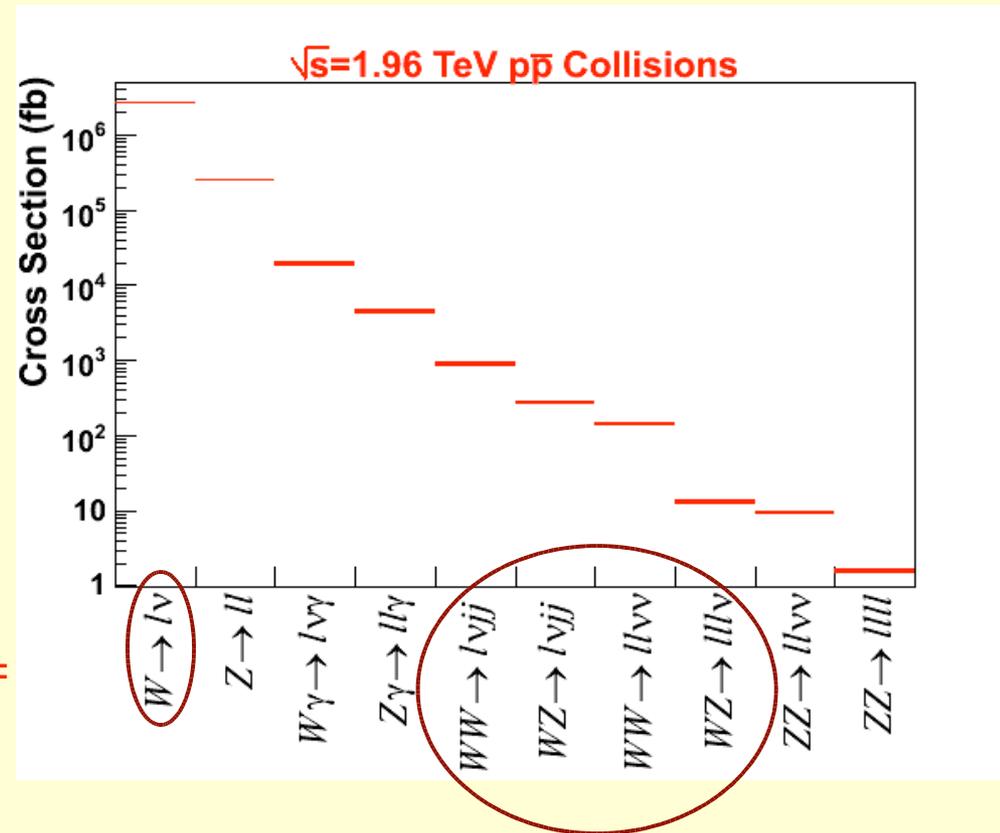
Electroweak Physics at the Tevatron

Mono-boson measurements:

- * High cross sections \rightarrow high statistics
- * Precision measurements of electroweak parameters (e.g., W mass)
- * Constraints on QCD

Precision

σ_W Measurement with Forward e^\pm



Di-boson measurements:

- * Low cross sections \rightarrow some processes still not observed
- * Probe $SU(2) \times U(1)$ gauge boson self-interactions
- * Search for new couplings, resonances (e.g., Higgs)

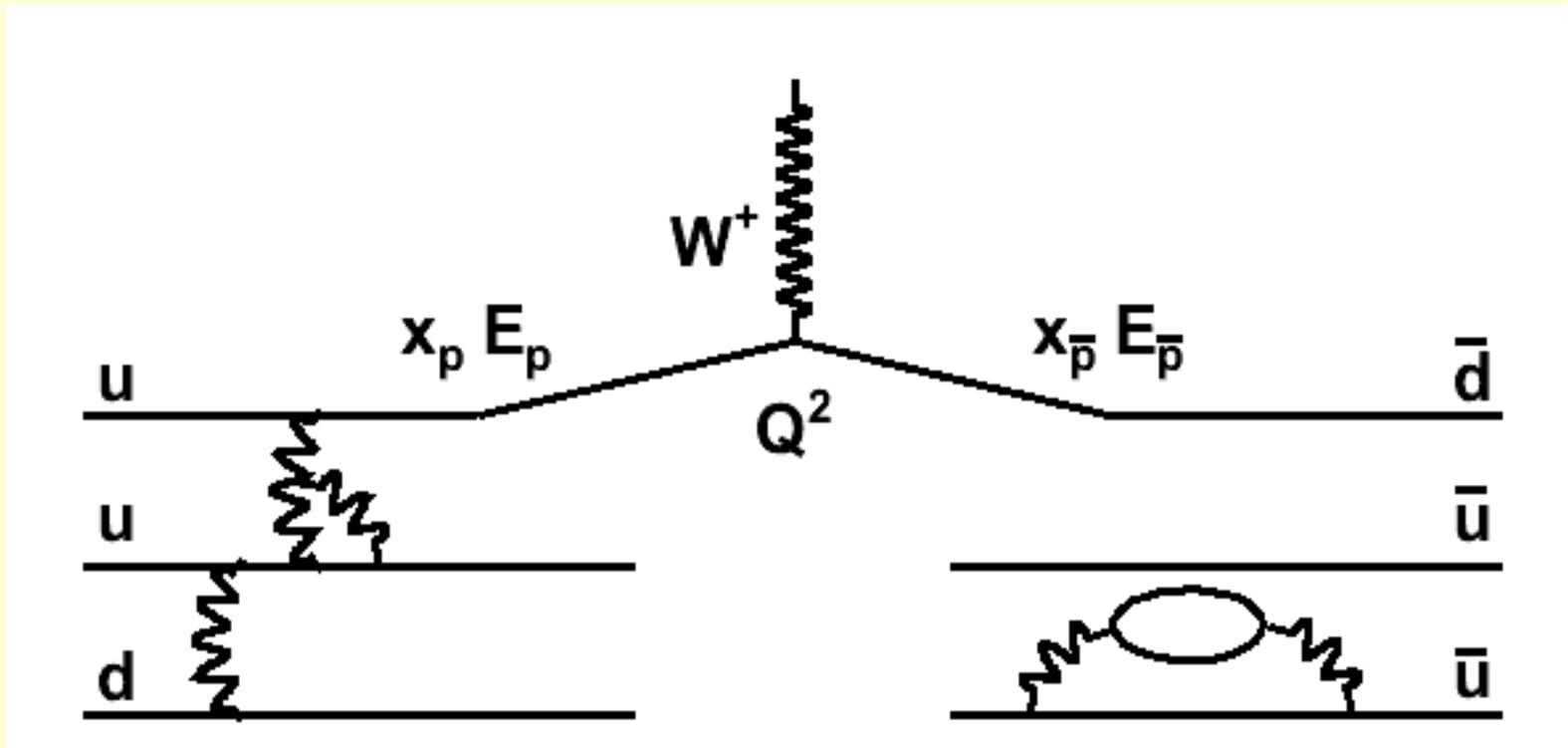
Searches

σ_{WW} Measurement and Searches for WW & WZ Production

W Cross Section Measurement with Forward Electrons

W Production

Hard scattering of q, \bar{q}' inside p, \bar{p} produces W



$$\sigma = \sum_{ab} \int dQ \delta(Q - 2E_p \sqrt{x_p x_{\bar{p}}}) \int dx_p f_a(x_p, Q) \int dx_{\bar{p}} f_b(x_{\bar{p}}, Q) \hat{\sigma}(Q)$$

Sum over quarks, gluons

Kinematic
constraint

Parton distribution
functions

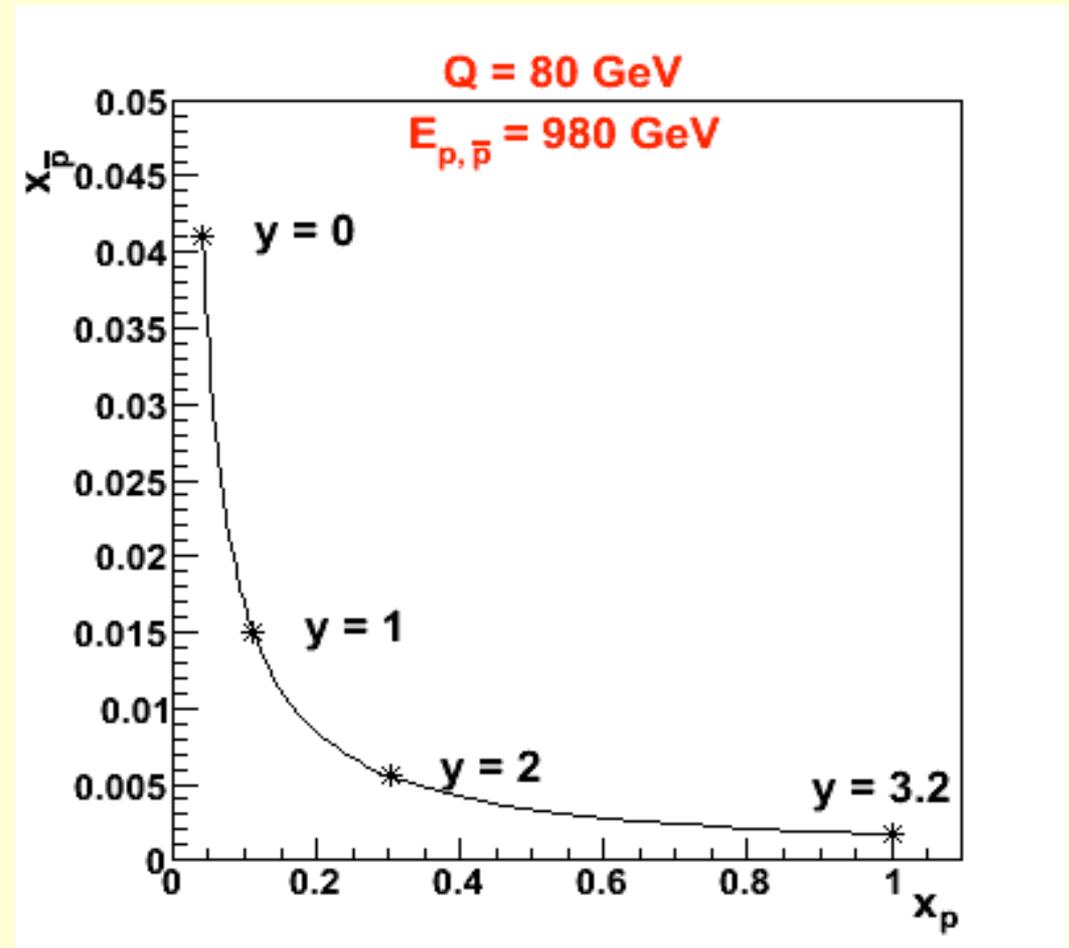
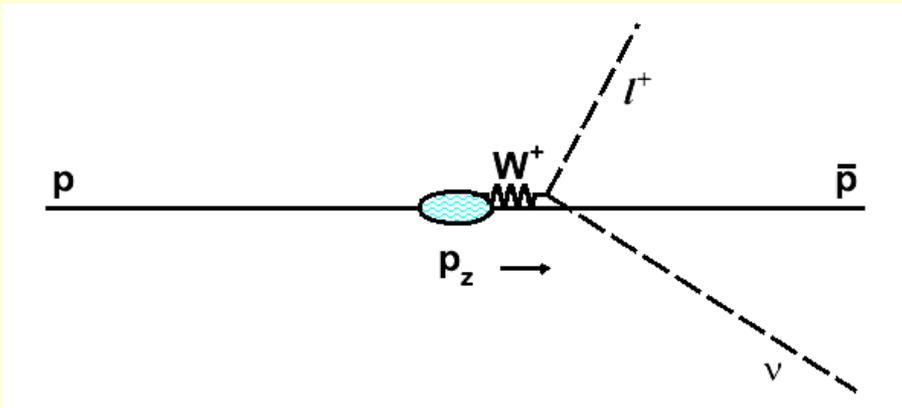
Calculable hard
scattering cross section

W Rapidity

Relative size of x_p , $x_{\bar{p}}$ determines the longitudinal momentum of W

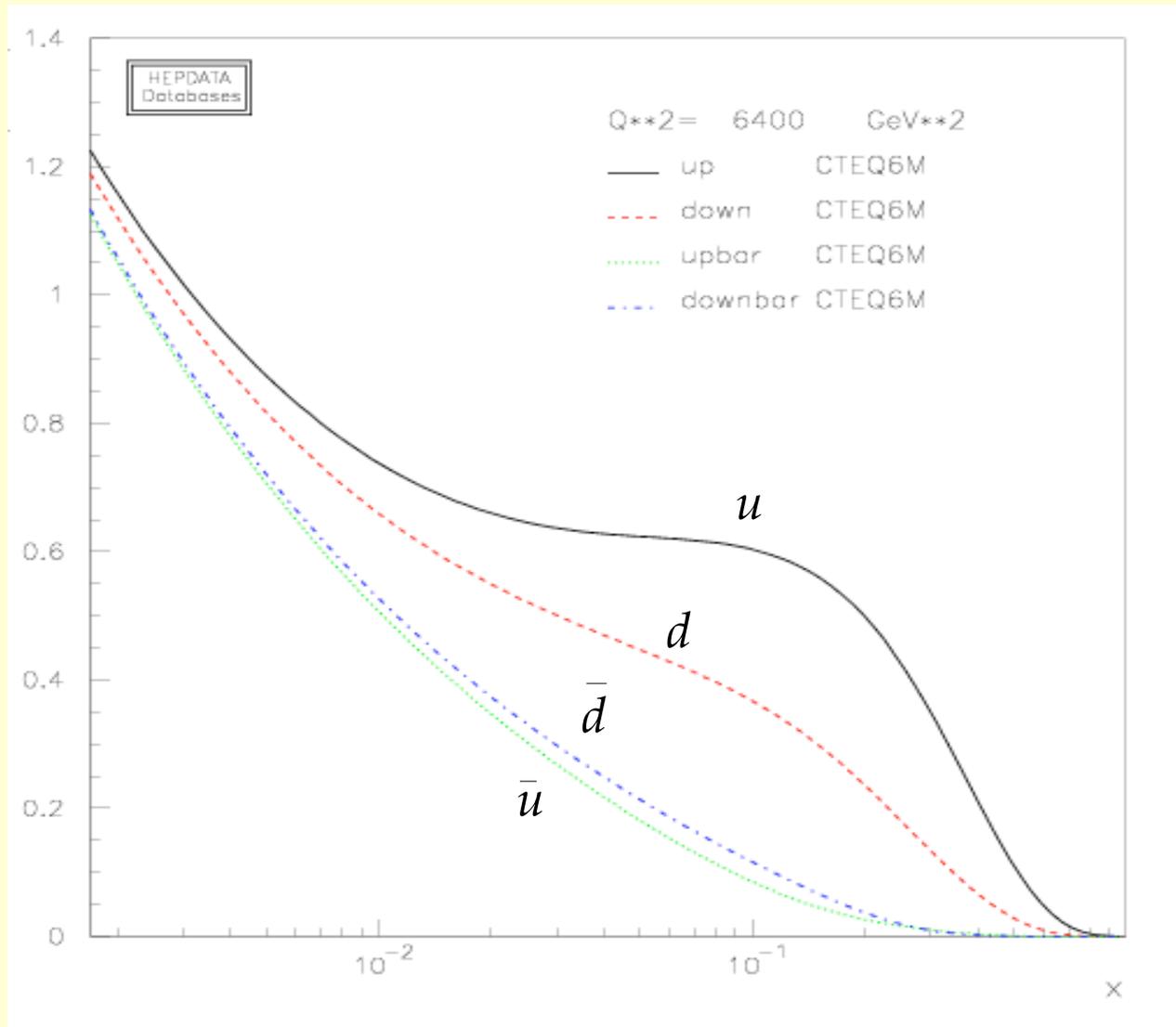
$$y = \frac{1}{2} \ln[(E + p_z) / (E - p_z)]$$

$$= \frac{1}{2} \ln(x_p / x_{\bar{p}})$$



Parton Distribution Functions

Parton momentum fraction depends on quark type & valence vs sea



<http://durpdg.dur.ac.uk/hepdata/pdf3.html>

PDF Parametrization

Two competing groups (CTEQ & MRST) fit existing data to PDF functions

CTEQ parametrization: $xf_a(x, Q_0) = A_0 x^{A1} (1-x)^{A2} e^{(A3)x} (1 + A_4 x)^{A5}$

Separate functions for $u, d, g, \bar{u}, \bar{d}$: 30 parameters (10 are fixed)

Parameters are determined at $Q_0 = 1.3 \text{ GeV}$, valid for all Q
Q dependence of PDFs given by renormalization equation (DGLAP):

$$df_a(x, Q)/d\ln Q = \sum_b \int_x^1 dy/y P_{ab}(x/y, \alpha_s(Q)) f_b(y, Q)$$

parton type

kernel perturbatively calculable

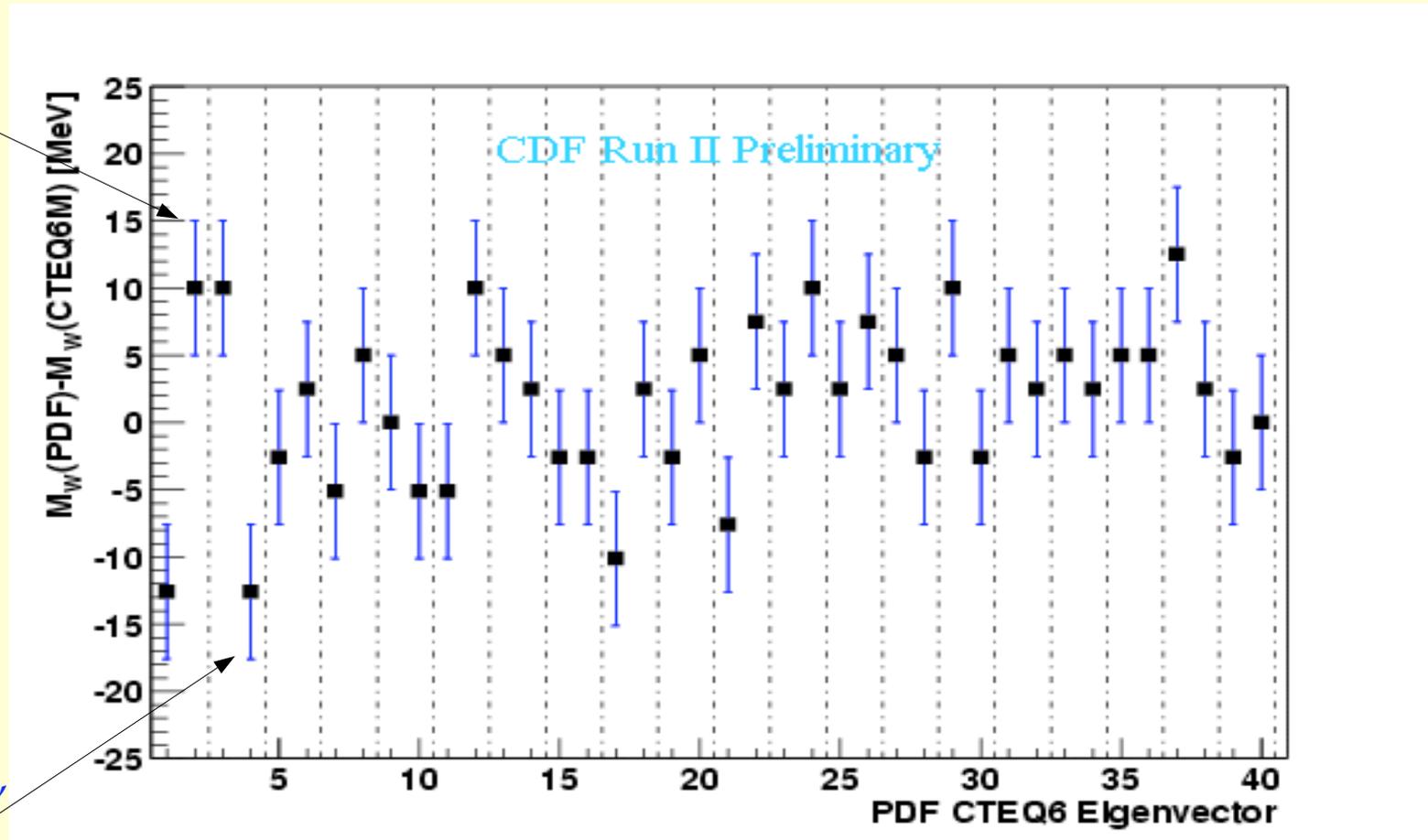
A parameters correlated: determine eigenvectors to facilitate uncertainty calculations

An Example: W mass PDF Uncertainty

W mass PDF uncertainty by eigenvector:

valence up quark

A1: low x



valence down quark,

sea quarks

A1: low x

W Mass Measurement

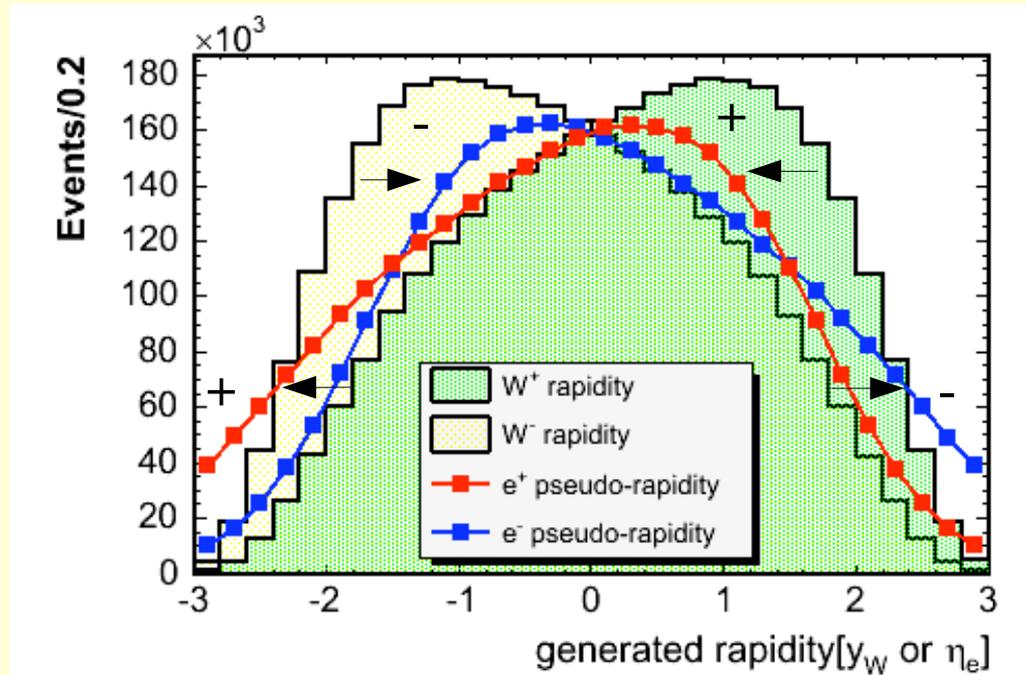
CDF systematic uncertainties determined with 200 pb⁻¹ of Run 2 data:

Systematic Uncertainty	Electrons	Muons	
 Energy Scale & Resolution	70	30	} <i>Constrain with data -- Roughly scale with \mathcal{L}</i>
 Recoil Scale & Resolution	50	"	
 W pT model	15	"	} <i>Theoretical inputs -- do not directly scale with \mathcal{L}</i>
 PDFs	15	"	
QED	15	20	
Backgrounds	20	20	

Constraining individual systematic uncertainties to better than **10 MeV**
will produce total m_W uncertainty below **25 MeV**

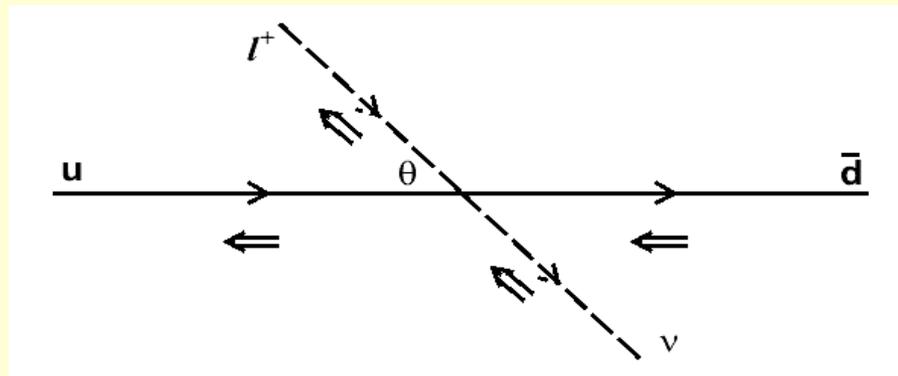
W Production Charge Asymmetry

Asymmetric u, d PDFs \longrightarrow Asymmetric W^+, W^- rapidity distributions



W decay:

$$d\sigma/d\theta \propto (1 + \cos\theta)^2$$

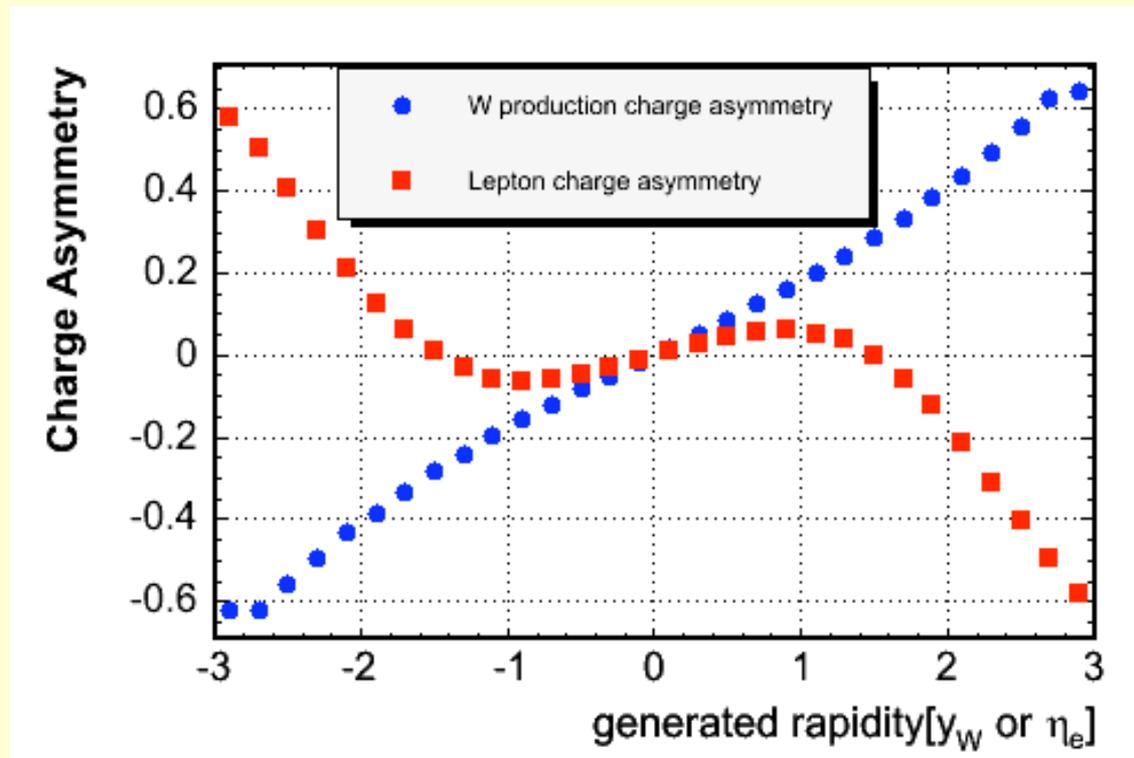


$$(x_p = x_{\bar{p}})$$

W Charge Asymmetry

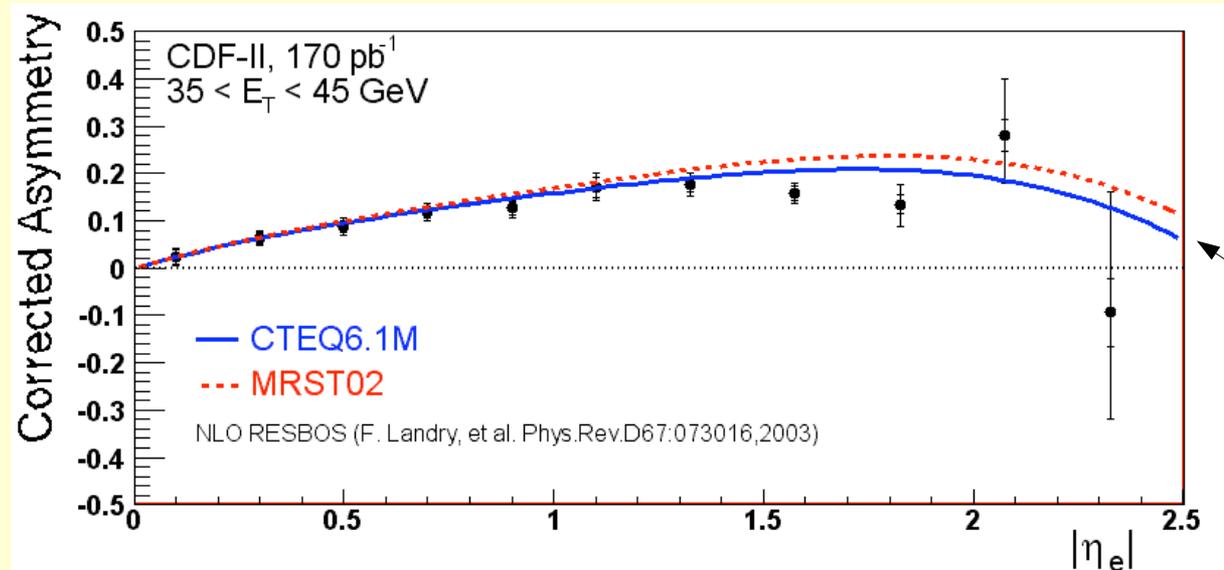
Define the asymmetry as:

$$A_{W,l}^{\pm}(y_{W,l}) = \frac{\sigma_{W,l+}(y) - \sigma_{W,l-}(y)}{\sigma_{W,l+}(y) + \sigma_{W,l-}(y)}$$

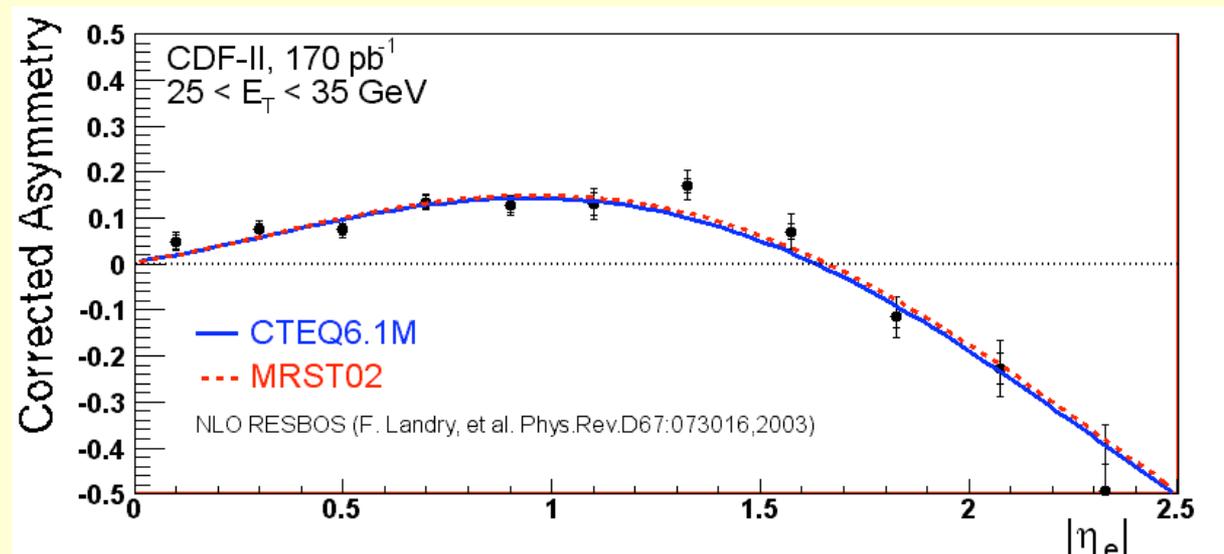


CDF Run II W Asymmetry Measurement

Probe production asymmetry with high E_T leptons:



More sensitive
to PDFs



PRD 71, 051104
(2005)

Future CDF W Asymmetry Measurement

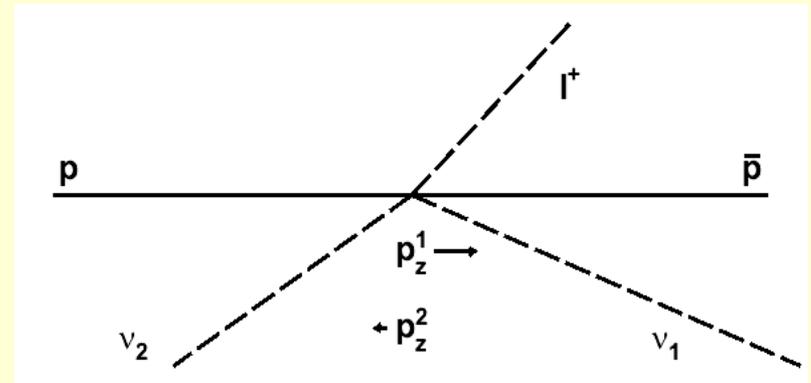
Goal: Directly measure W production charge asymmetry

Method: Use known W mass to solve for p_z^{ν} and reconstruct y_W

$$m_W = \sqrt{2(E^l E^\nu - p_x^l p_x^\nu - p_y^l p_y^\nu - p_z^l p_z^\nu)}$$

Measured

Two solutions



Address p_z^{ν} ambiguity by weighting each solution by theoretical $\sigma(y_W)$ production distribution

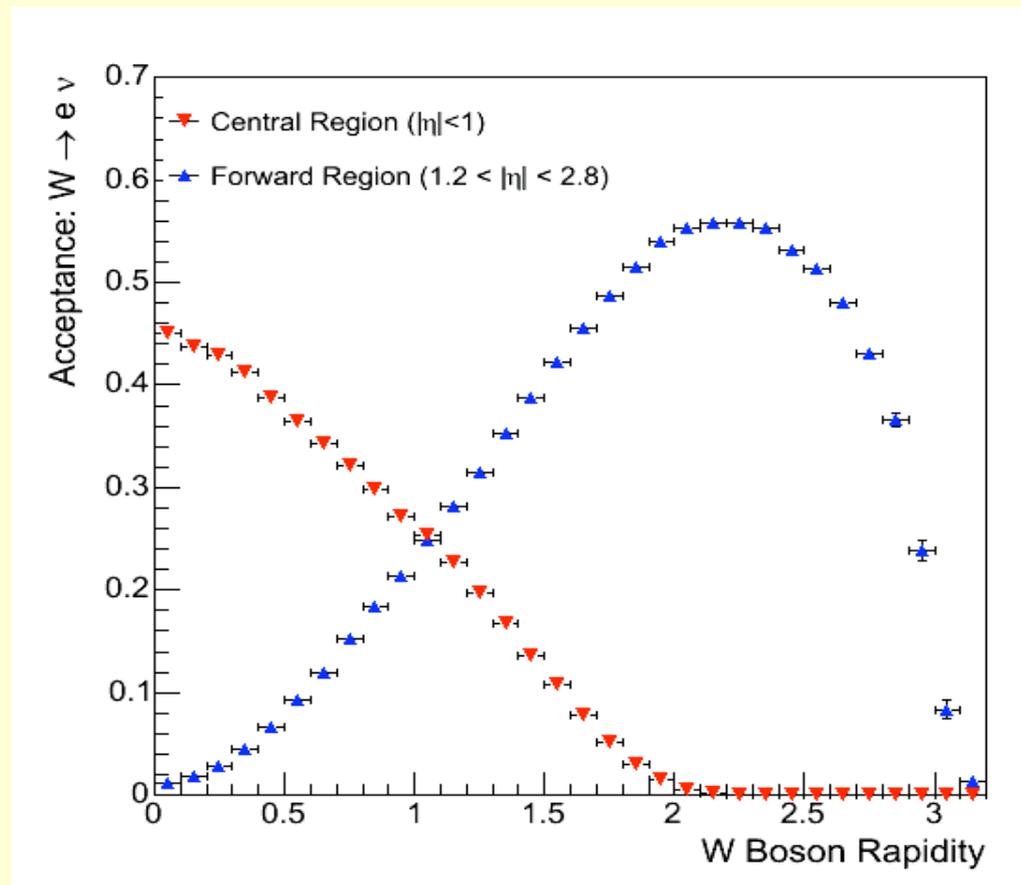
Remove theoretical bias by iterating procedure:
after measurement, reweight by measured distribution

W Rapidity Measurement

Can also use W mass constraint to directly measure $y_{W_{\pm}}$ distributions

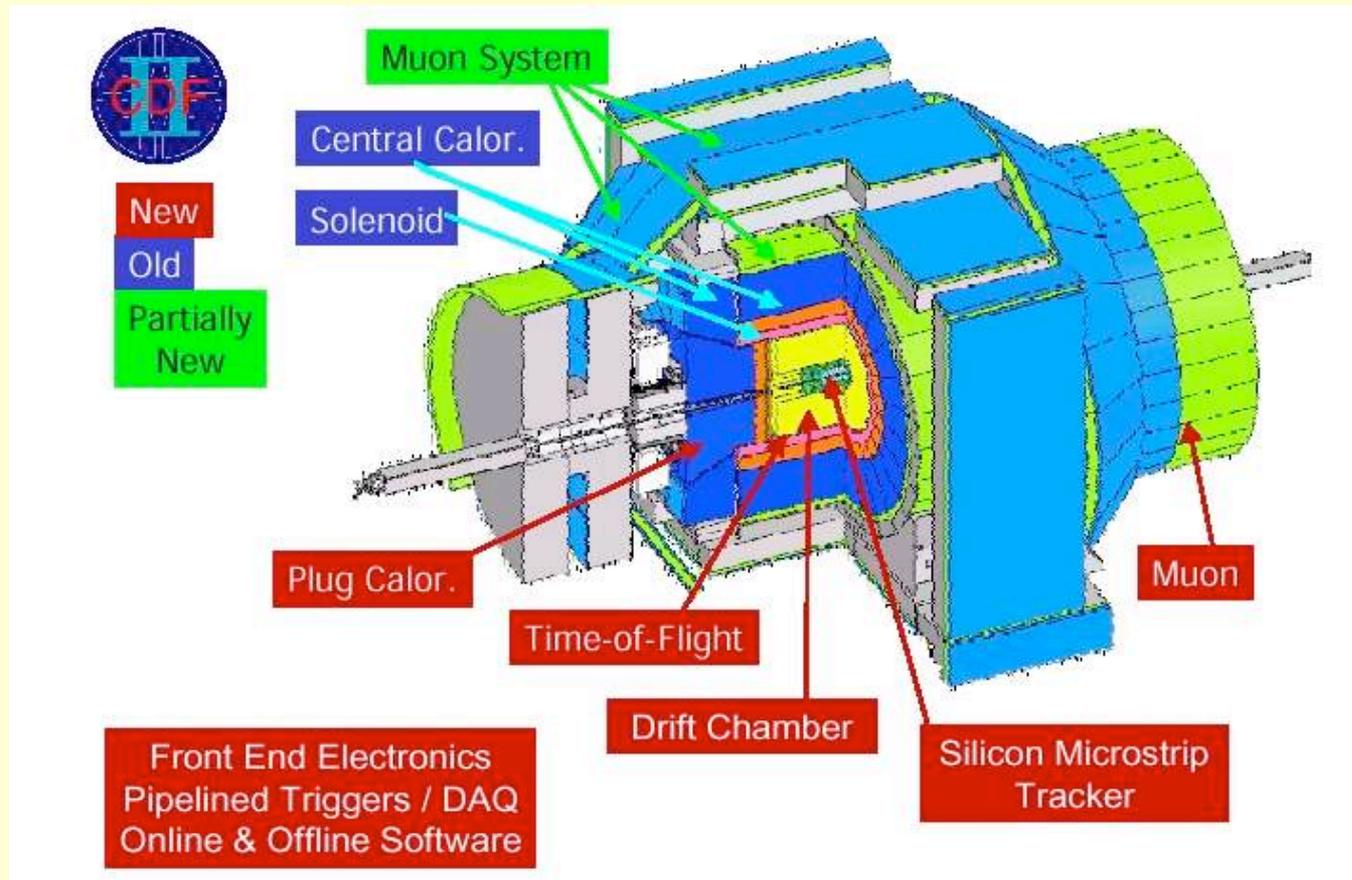
First step: Understand W selection in forward calorimeter

- * Measure W cross section using forward electrons
- * Ratio of cross sections (forward/central electrons) gives first-order sensitivity to $|y_W|$:



CDF Detector

Forward calorimeter ('Plug') coverage: $1.2 < |\eta_l| < 2.8$



Central triggers: One electron or muon

Forward W trigger: One electron and transverse energy imbalance (E_T)

W Cross Section Measurement with Central Electrons

Cross section measured with 72 pb^{-1} of data (**37584 candidates**)

Measured cross section: $\sigma_W = 2780 \pm 14 \text{ (stat)}^{+63}_{-57} \text{ (sys)} \pm 166 \text{ (lum)} \text{ pb}$

NNLO cross section: $\sigma_W = 2684 \pm 54 \text{ pb}$

Dominant uncertainties:

Luminosity	$\pm 6\%$
PDF	$+1.2\%, -1.5\%$
Electron Identification	$\pm 0.9\%$
Backgrounds	$\pm 0.8\%$
Tracker Material	$\pm 0.7\%$
Statistics	$\pm 0.5\%$

Phys. Rev. Lett. 94, 091803 (2005);

hep-ex/0508029, submitted to Phys. Rev. D

W Cross Section Measurement with Forward Electrons

Requires precise understanding of forward calorimeter and tracker

* Aim to achieve ~1% precision in each experimental component

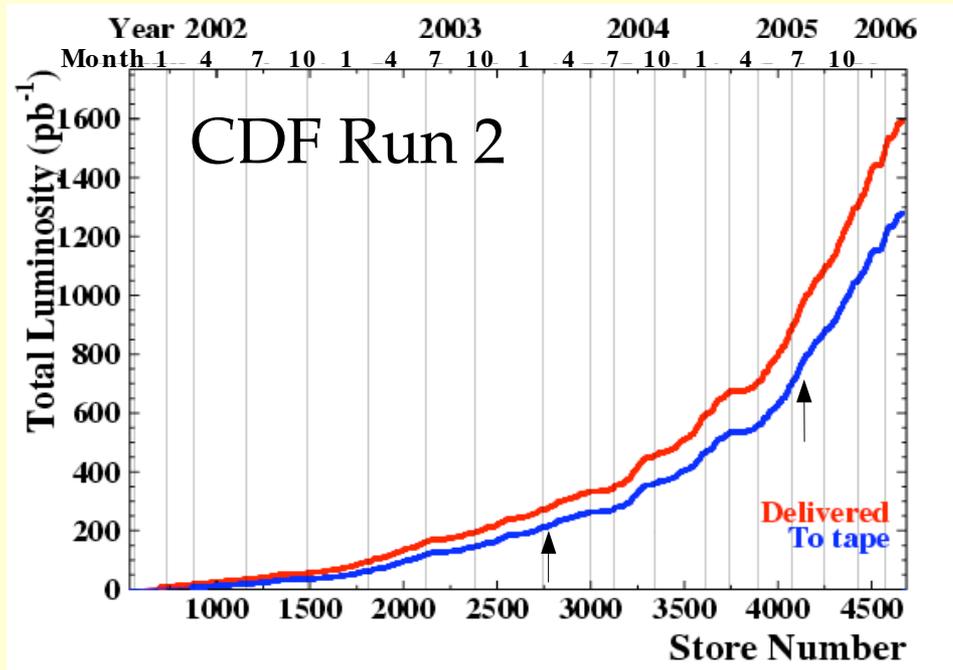
Cross section determination:

$$\sigma = (N_{data} - N_{bd}) / (A \times \epsilon \times L)$$

The diagram shows the formula $\sigma = (N_{data} - N_{bd}) / (A \times \epsilon \times L)$ with arrows pointing from descriptive text to the variables:

- N_{data} : Observed candidates
- N_{bd} : Estimated background
- A : Geometric and kinematic acceptance
- ϵ : Electron identification and trigger efficiencies
- L : Luminosity

Luminosity



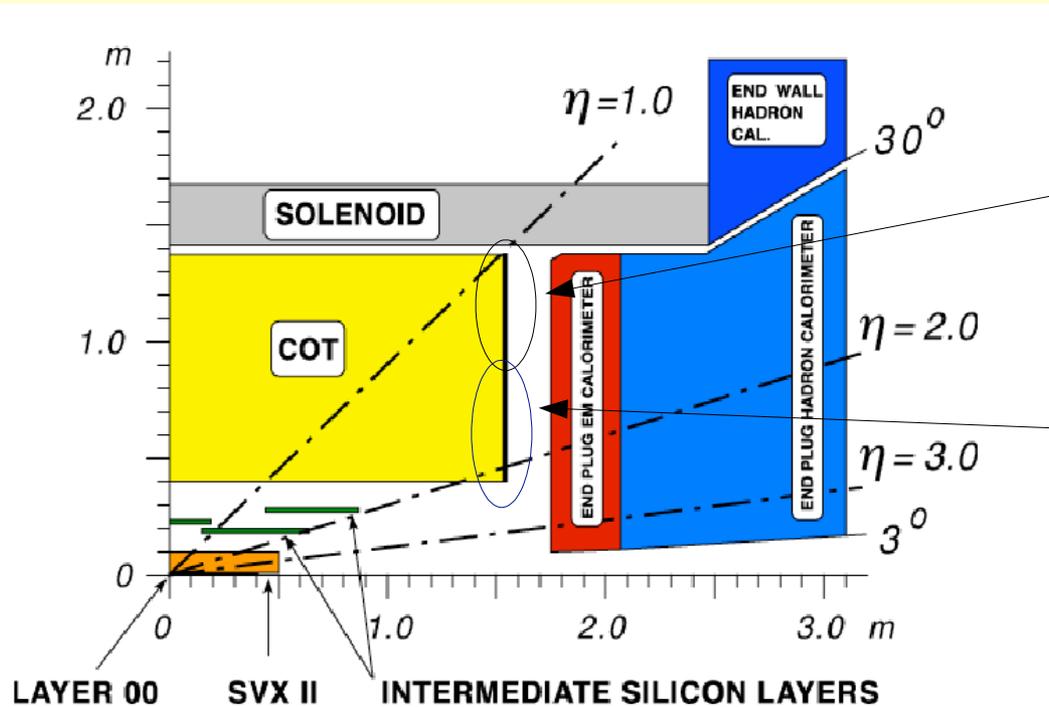
Tevatron has produced 1.6 fb^{-1} of
 $1.96 \text{ TeV } \sqrt{s} \text{ pp} \bar{\text{p}}$ collisions

W cross section measurement uses 223 pb^{-1} of integrated luminosity

Diboson results use up to 825 pb^{-1} of integrated luminosity

Forward Track Reconstruction

Outer tracker acceptance varies significantly for $1.2 < |\eta| < 2$



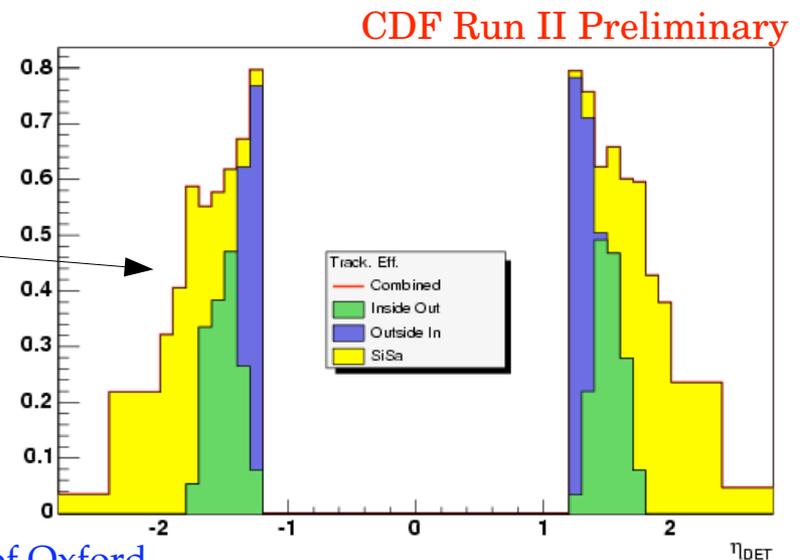
COT-seeded tracking
(Outside-in algorithm):

$$|\eta| < 1.5$$

Silicon-seeded tracking
(Inside-out algorithm)

$$1 < |\eta| < 2.8$$

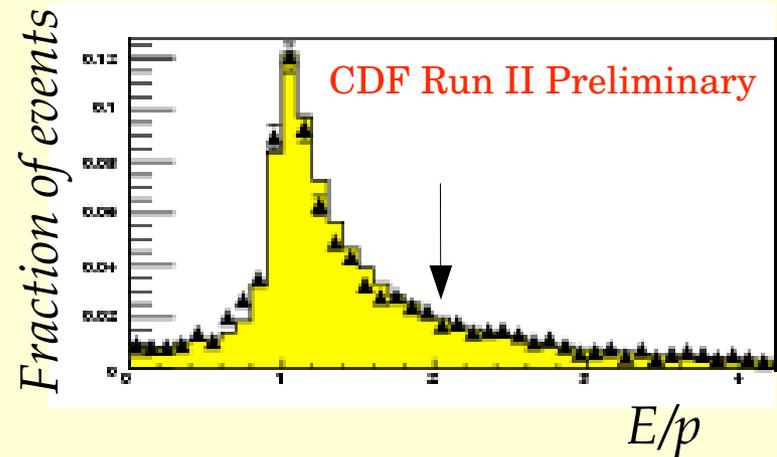
Tracking efficiency
reduces as $|\eta|$ increases



Forward Electron Identification

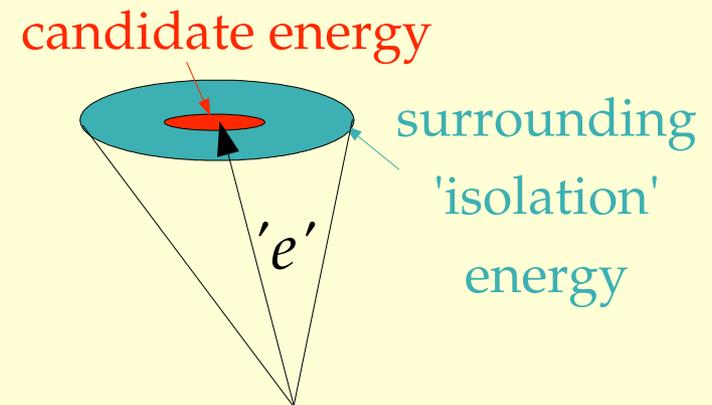
Calorimeter-track matching:

- * Energy-to-momentum ratio ($E/p < 2$)
- * Calorimeter to extrapolated track positions ($\Delta x, \Delta y < 3$ cm)



Calorimeter identification:

- * Hadronic-to-Electromagnetic energy ratio ($\text{Had}/\text{EM} < 0.05$)
- * Fractional energy surrounding electron candidate (isolation < 0.1)



W Boson Selection

Single high-transverse-energy electron

$$(E_T > 20 \text{ GeV})$$

Large transverse energy imbalance

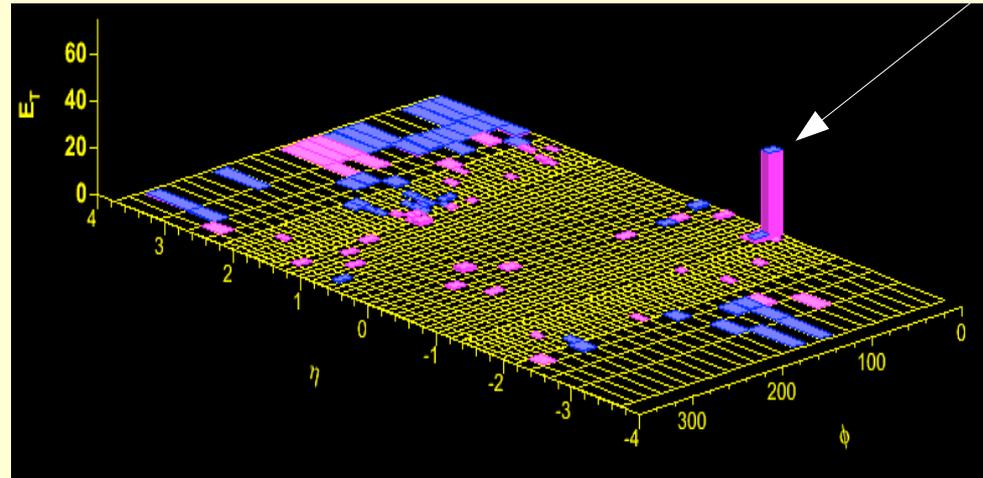
$$(\cancel{E}_T > 25 \text{ GeV})$$

Trigger requires $E_T > 20 \text{ GeV}$, $\cancel{E}_T > 20 \text{ GeV}$

No other high-EM-fraction calorimeter cluster (remove $Z \rightarrow ee$ events)

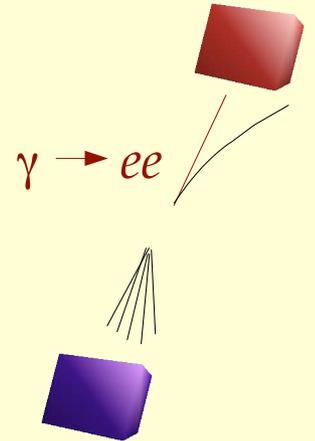
48165 candidates

(0.5% statistical uncertainty)



Sample Composition

$W \rightarrow e\nu$:	95.2% (45832 events)
$W \rightarrow \tau\nu$:	2.2% (1070 events)
Jet production:	1.8% (846 events)
$Z \rightarrow ee$:	0.9% (417 events)



Jet production includes:

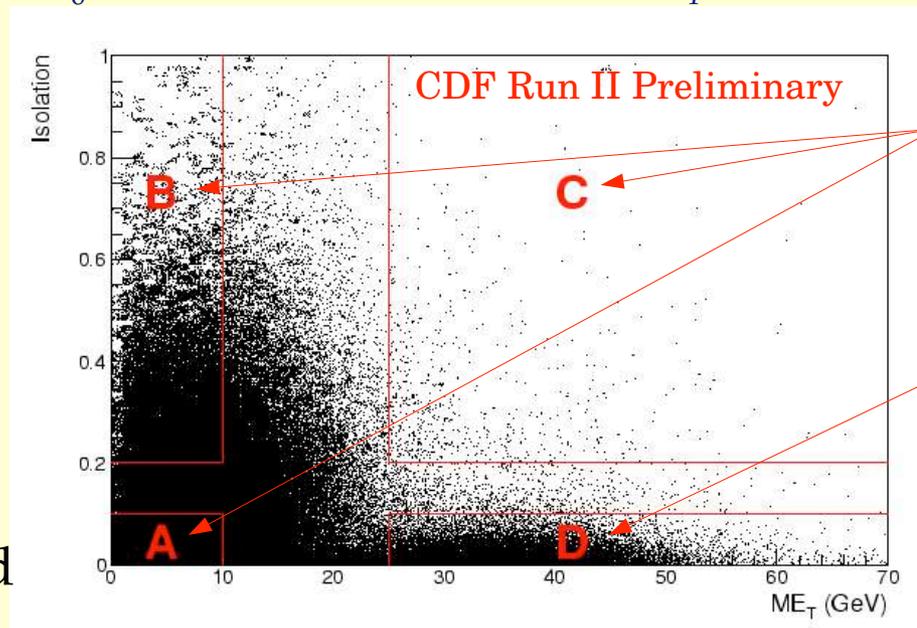
- (1) γ + jet production (jet E_T mismeasurement to produce \cancel{E}_T)
- (2) Heavy flavor production with semileptonic decays
- (3) Dijet production with $\pi_0 \rightarrow \gamma\gamma$ inside a jet, and jet E_T mismeasurement

Assume jet production is uncorrelated in \cancel{E}_T , isolation

$$N_{jet}^D = N_{jet}^C (N_{jet}^A / N_{jet}^B)$$

Uncertainty estimate:

Vary B & C regions by increasing isolation threshold



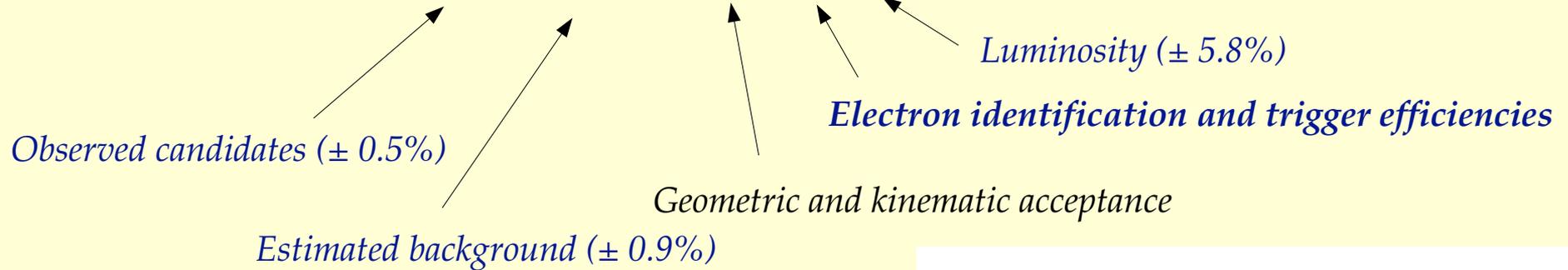
jet-dominated regions

Measurement region

$$\Delta N_{jet}^D / N_{jet}^D = 50\%$$

Forward Electron Efficiencies

$$\sigma = (N_{data} - N_{bd}) / (A \times \epsilon \times L)$$



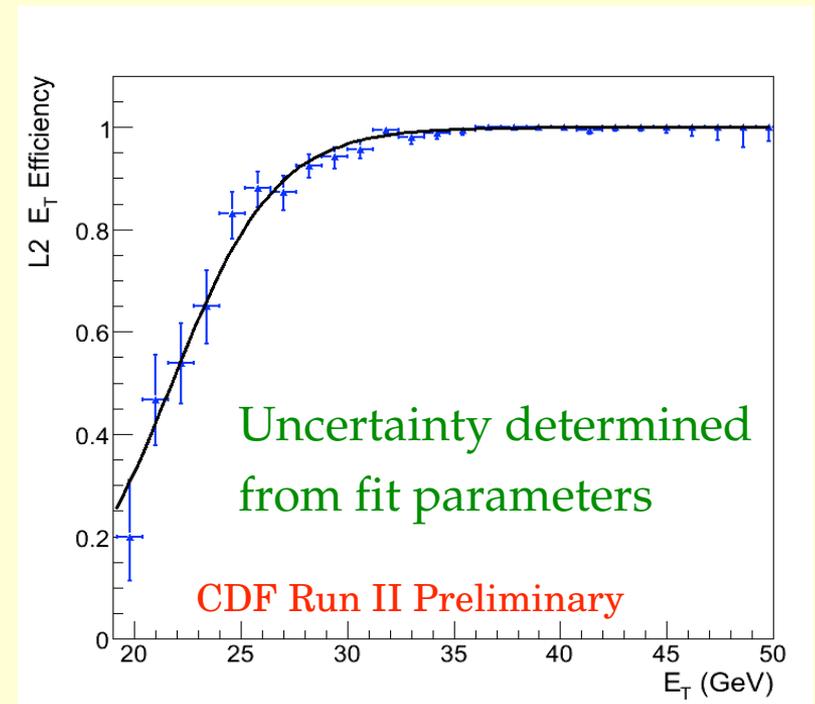
Key efficiencies

- * Trigger: $\epsilon_{trig}(E_T, \cancel{E}_T)$
- * Track reconstruction: ϵ_{trk}
- * Electron identification: $\epsilon_{id}(E_T)$

$\epsilon_{trig}(\cancel{E}_T)$ measured using W candidates

Other efficiencies measured using centrally triggered $Z \rightarrow ee$ events

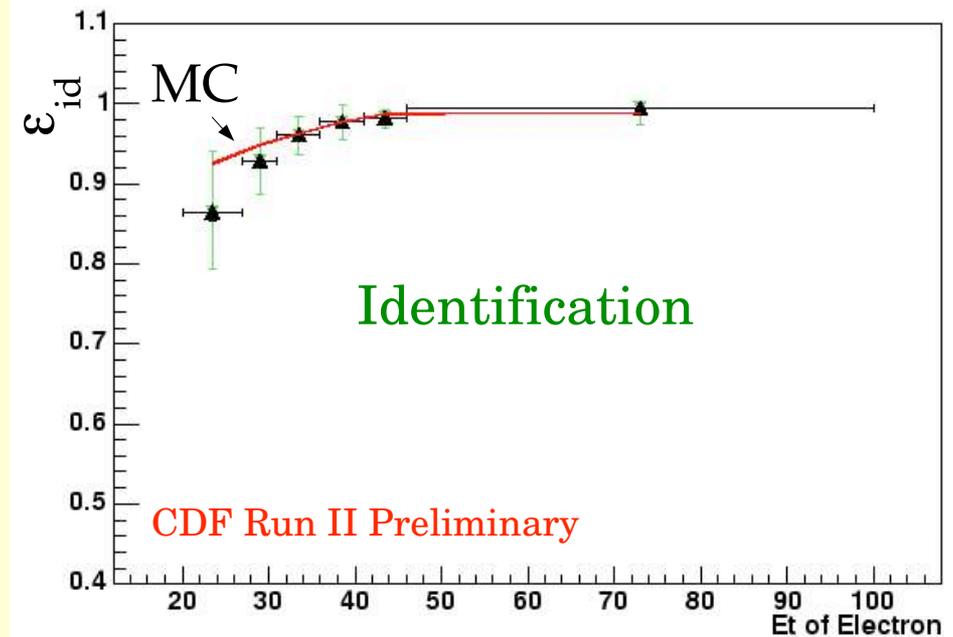
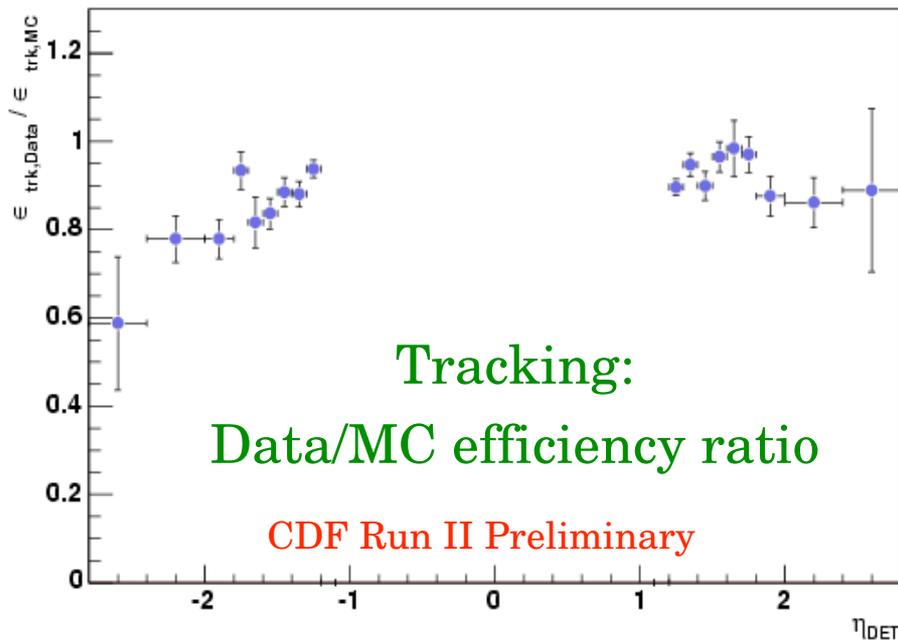
Integrated trigger efficiency: $\epsilon_{trig} = 96.1^{+0.3}_{-0.4} \%$



Forward Electron Identification Efficiency

Separately measure tracking, E/p , and identification efficiencies

- * Correct MC as a function of η for tracking efficiency
- * Identification efficiency well modelled by MC
 - o Measurement has large uncertainty from background correction



Track-matching efficiency:

$$\epsilon_{\text{track}} = (46.2 \pm 0.5)\%$$

E/p efficiency:

$$\epsilon_{E/p} = (71.3 \pm 0.7)\%$$

Identification efficiency:

$$\epsilon_{\text{id}} = (95.5 \pm 1.9)\%$$

Acceptance Determination

$$\sigma = (N_{data} - N_{bd}) / (A \times \epsilon \times L)$$

Observed candidates ($\pm 0.5\%$)

Estimated background ($\pm 0.9\%$)

Geometric and kinematic acceptance

Electron identification and trigger efficiencies ($\pm 2.5\%$)

Luminosity ($\pm 5.8\%$)

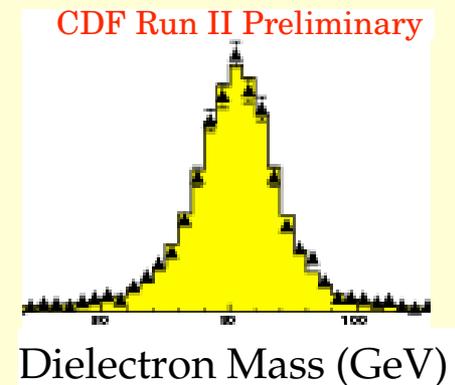
Acceptances determined from MC

Experimental uncertainties:

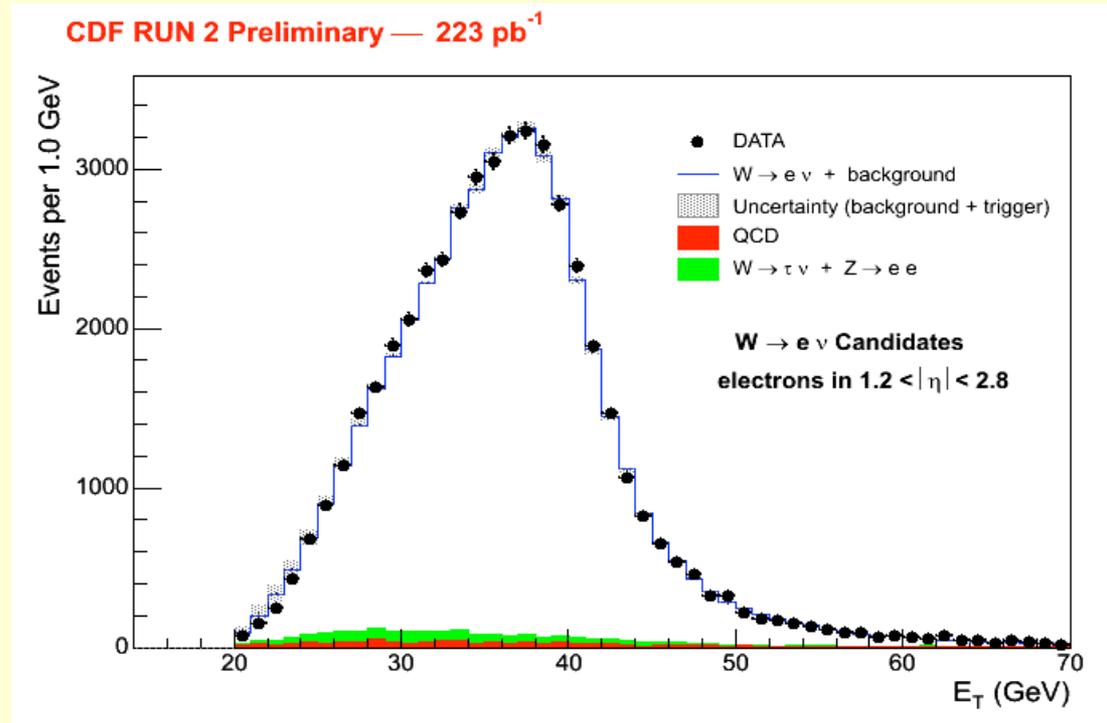
- * **Electrons:** calorimeter material modelling, energy scale calibration, non-linearity of calorimeter response
- * **Neutrinos:** hadronic response and resolution modelling

Theoretical uncertainties:

- * PDFs, $W p_T$ model, higher-order QCD corrections



Forward Electron Acceptance



Calibrate energy scale and resolution with $Z \rightarrow ee$ reconstructed mass

* Cross-check with E/p peak ($\Delta A/A = 0.24\%$)

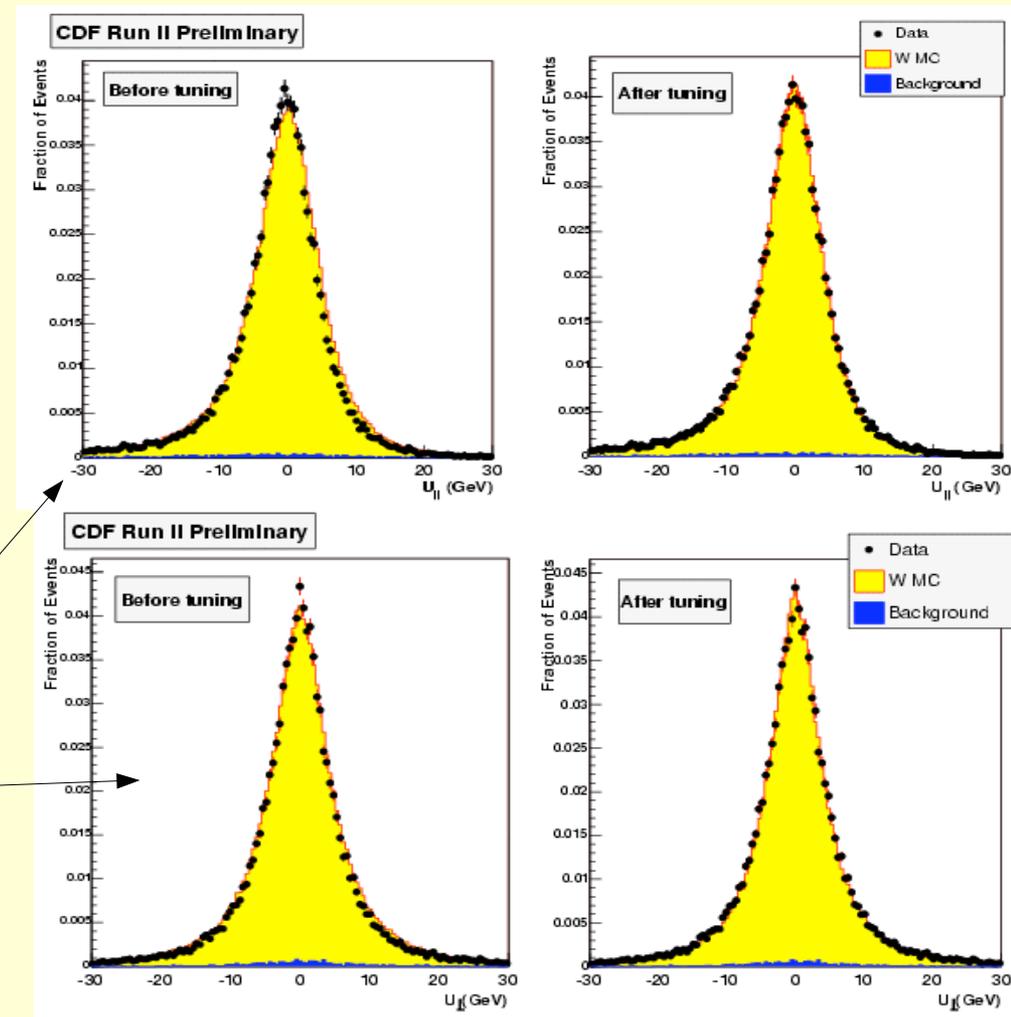
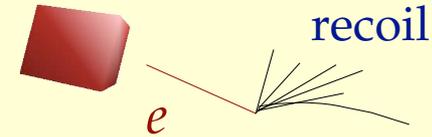
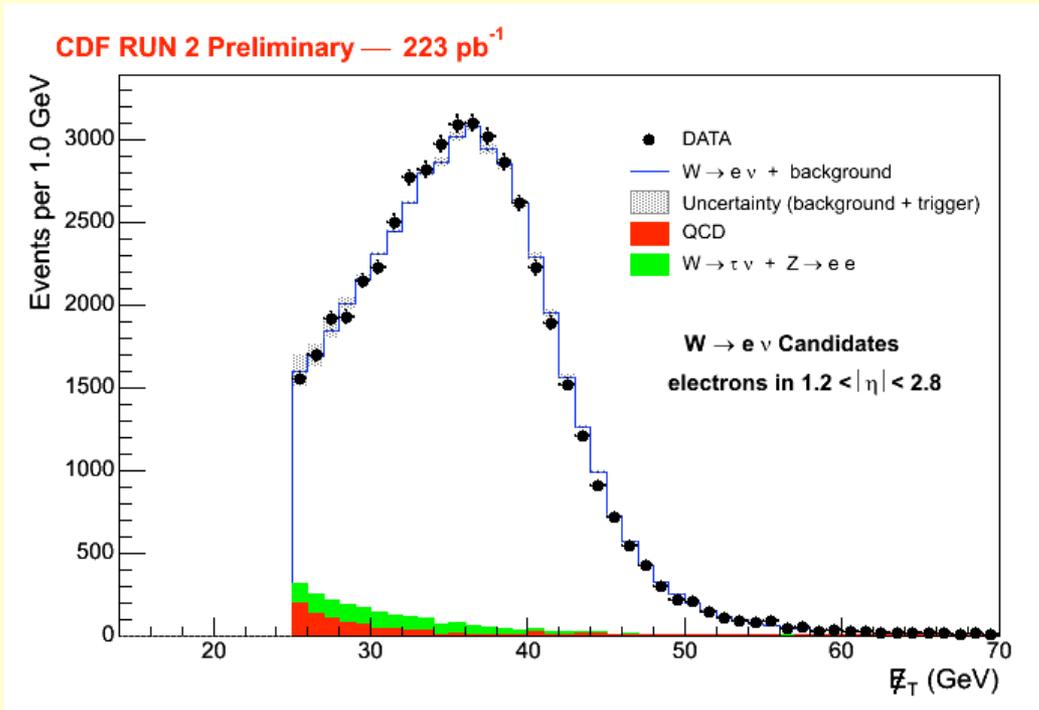
Check scale non-linearity using $\langle E/p \rangle$ as a function of E_T

* Uncertainty in data fit results in $\Delta A/A = 0.26\%$

Material upstream of calorimeter affects electromagnetic shower

* Material uncertainty results in $\Delta A/A = 0.71\%$

Neutrino Acceptance



Tune simulation of hadronic recoil energy using net energy parallel and perpendicular to lepton

* Response and resolution

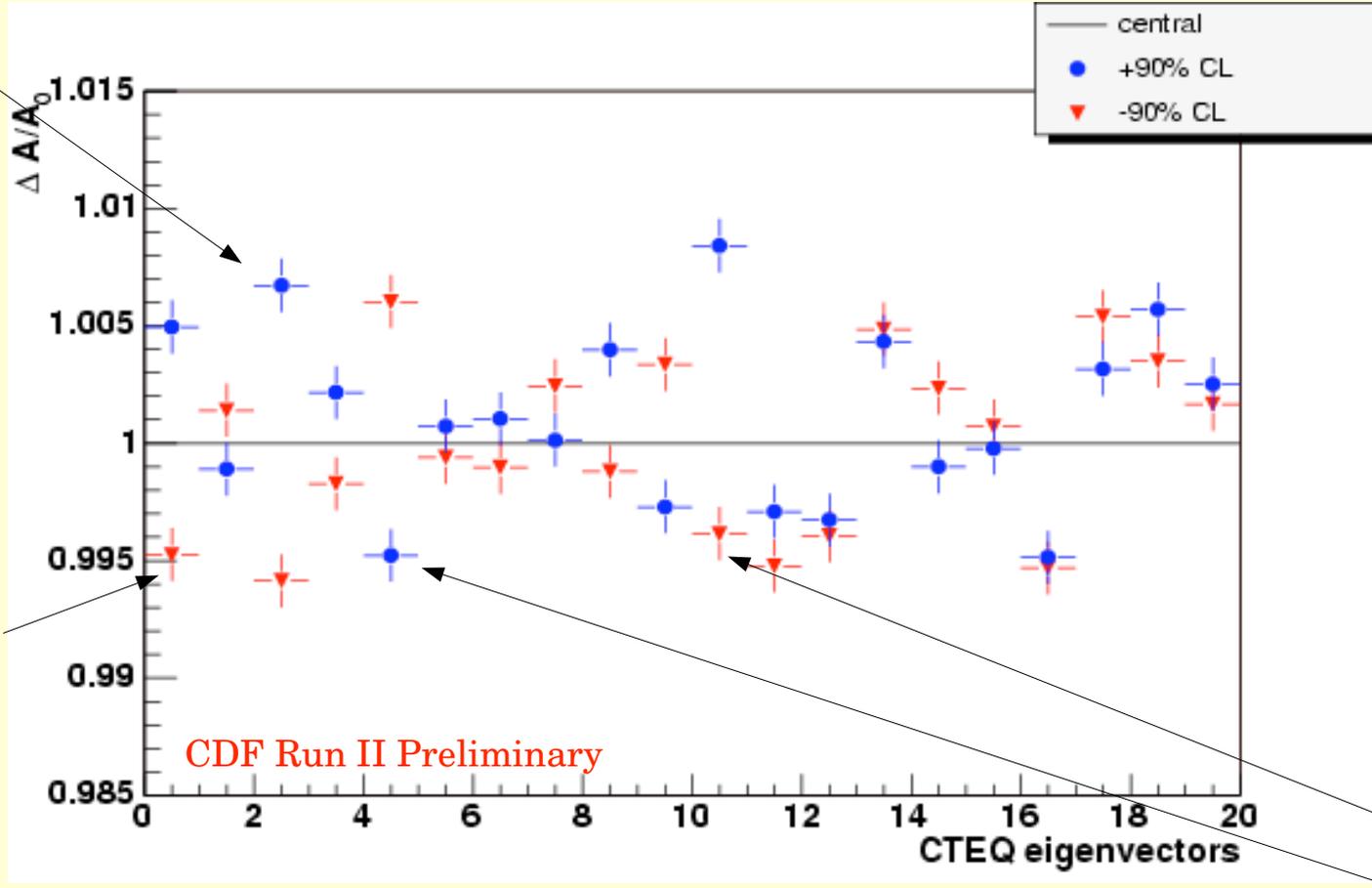
$$\frac{\Delta A}{A} = 0.35\%$$

PDF Acceptance Uncertainty

PDF uncertainty by eigenvector:

*valence down quark
+ sea quarks
A1: low x*

*valence up quark
A1: low x*



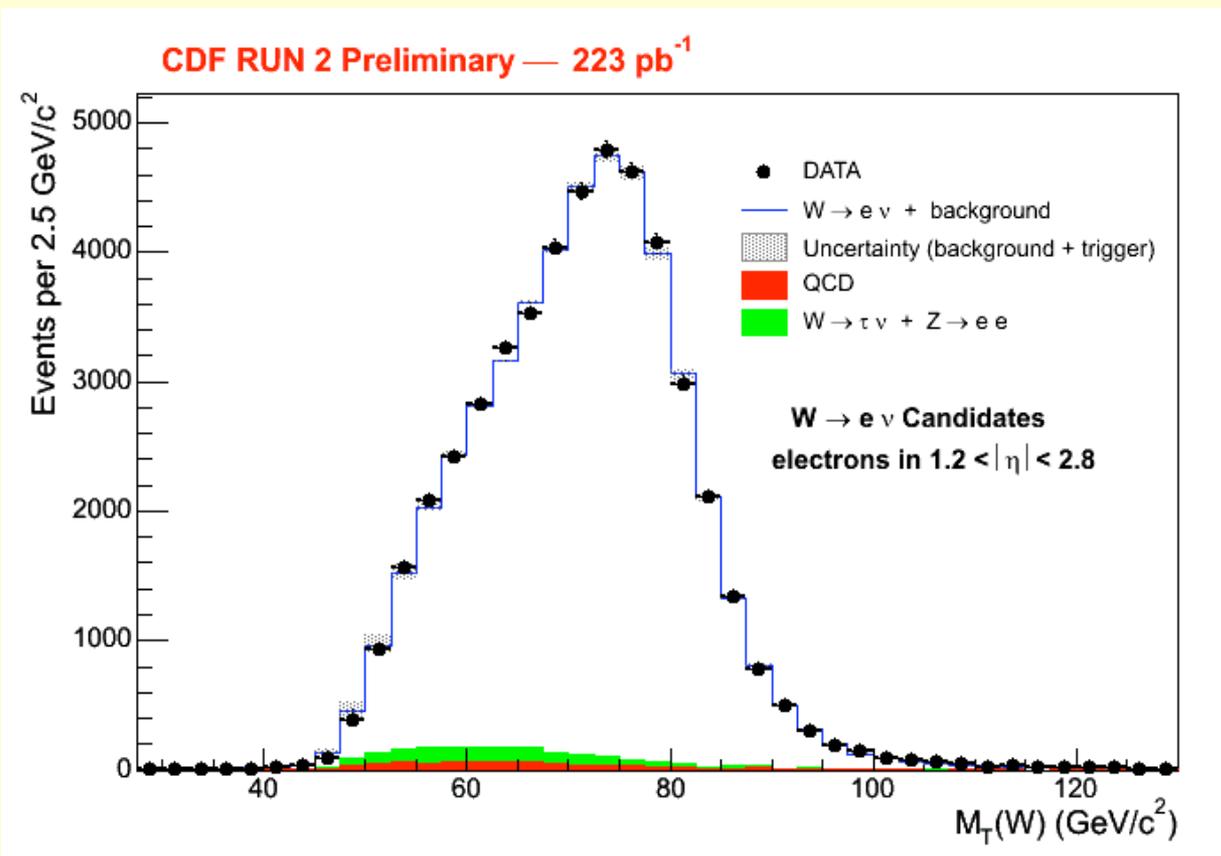
*gluon
A1, A4
A1: low x*

$$\Delta A/A = +1.7\%, -1.3\%$$

Measured W Cross Section

$$\sigma_W = 2796 \pm 13 \text{ (stat)}^{+95}_{-90} \text{ (sys)} \pm 162 \text{ (lum)} \text{ pb}$$

NNLO cross section: $\sigma_W = 2684 \pm 54 \text{ pb}$



Dominant uncertainties:

Luminosity	$\pm 5.8\%$
Electron Identification	$\pm 2\%$
PDF	+1.7%, -1.3%
Track Reconstruction	$\pm 1.1\%$
E/p Efficiency	$\pm 1.0\%$
Backgrounds	$\pm 0.9\%$
Calorimeter Material	$\pm 0.7\%$

Test of W Boson Production Theory

Take forward/central σ_W ratio to reduce luminosity uncertainty

Separate theoretical and experimental uncertainties

Define the 'visible' cross section: $\sigma_{\text{vis}} = \sigma_W \times A$

Taking the ratio:

$$\sigma_{\text{vis}}^{\text{cen}} / \sigma_{\text{vis}}^{\text{for}} = 0.925 \pm 0.033$$

measurement:

*no PDF uncertainties,
luminosity uncertainty 1%*

$$A^{\text{cen}} / A^{\text{for}} = 0.924^{+0.023}_{-0.030} \quad (\text{CTEQ})$$

$$A^{\text{cen}} / A^{\text{for}} = 0.941^{+0.011}_{-0.015} \quad (\text{MRST})$$

*predicted acceptance ratio:
theoretical uncertainties only*

First measurement to use $\sigma_W(\eta_l)$ to probe PDFs

Cross Section Ratio PDF Uncertainties

PDF uncertainty by eigenvector:

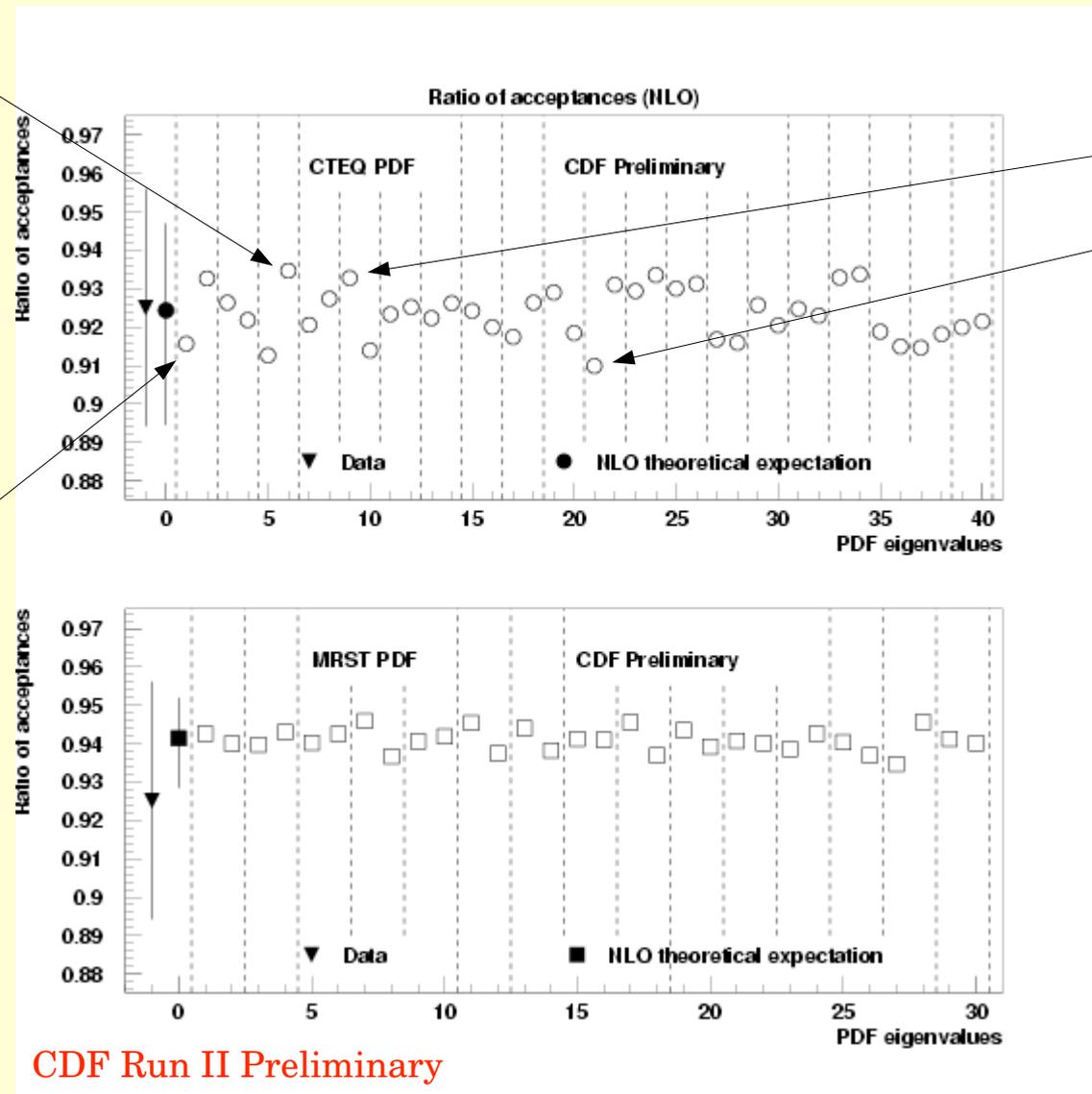
*valence down quark
+ sea quarks
A1: low x*

gluon

A1: low x

A1, A4

*valence up quark
A1: low x*



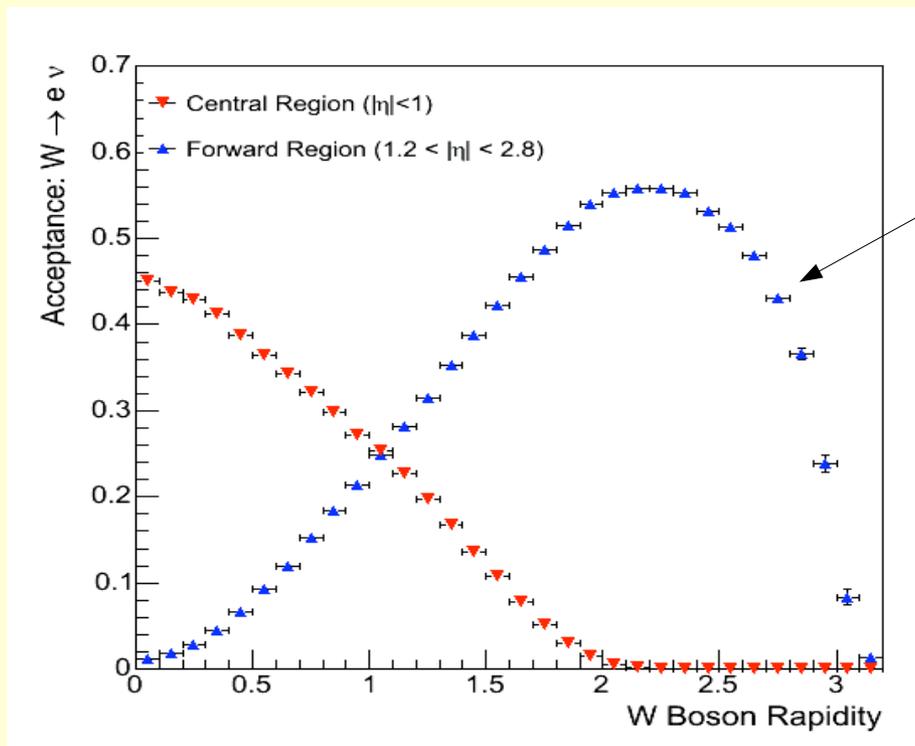
CDF Run II Preliminary

W Cross Section Summary

First measurement to use $\sigma_W(\eta_l)$ to probe PDFs

First CDF measurement of σ_W with forward electrons

- * Full understanding of forward calorimeter and tracking system
- * Can perform precision measurements with forward W events



Additional window to precision physics at CDF

Next step:

- * Precision 1 fb^{-1} PDF measurements
 - o W charge asymmetry
 - o Z rapidity
 - o W^\pm rapidity?

Goal: Constrain W mass PDF uncertainty with CDF data

WW & WZ Measurements and Searches

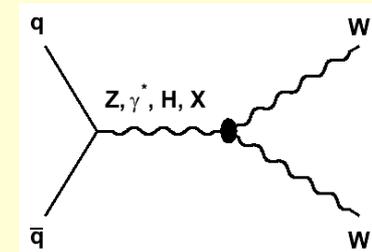
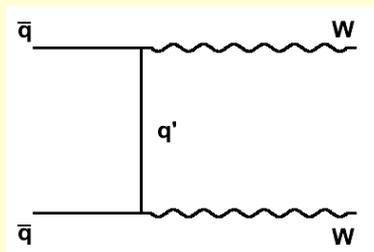
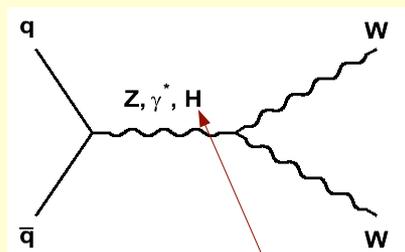
Dibosons: Triple-Gauge-Coupling Probes

Process

Standard Model

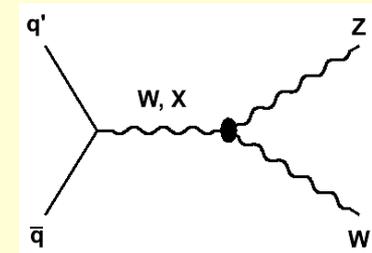
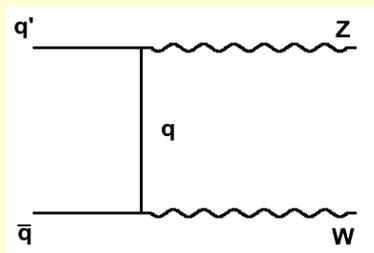
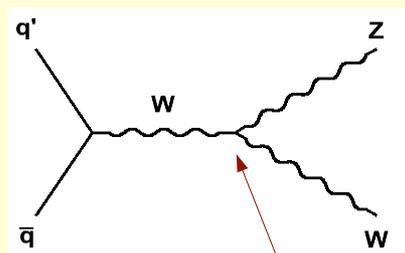
Beyond the SM

$p\bar{p} \rightarrow WW$



Promising Higgs decay mode

$p\bar{p} \rightarrow WZ$

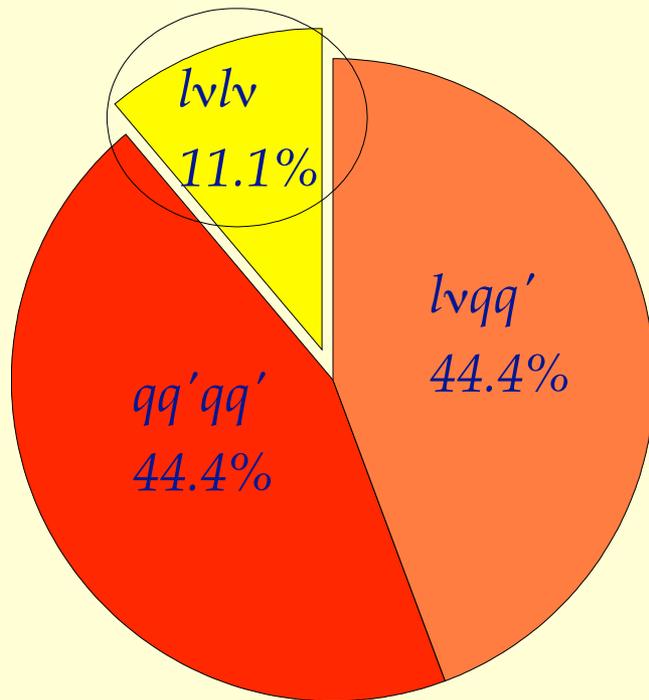


Not directly accessible at LEP

WW Production Cross Section

NLO cross section: $\sigma(pp \rightarrow WW) = (12.4 \pm 0.8) \text{ pb}$

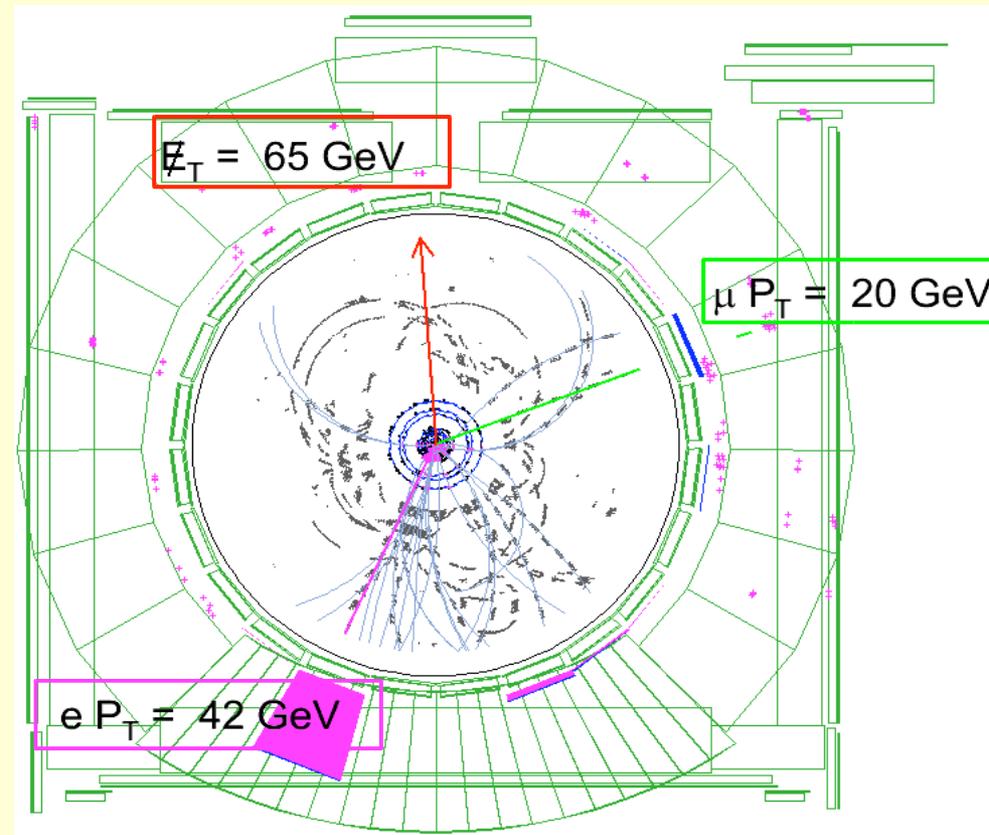
WW decay modes



'Dilepton' channel:

- * Low hadronic-jet background
 - * First observed in $\sim 200 \text{ pb}^{-1}$ in Run 2
(CDF evidence in Run 1)
 - o CDF: 17 events, 5.2 background
 - o DØ : 25 events, 8.0 background
- 5.2 σ significance

WW Candidate Selection



Two leptons ($E_T > 20$ GeV)

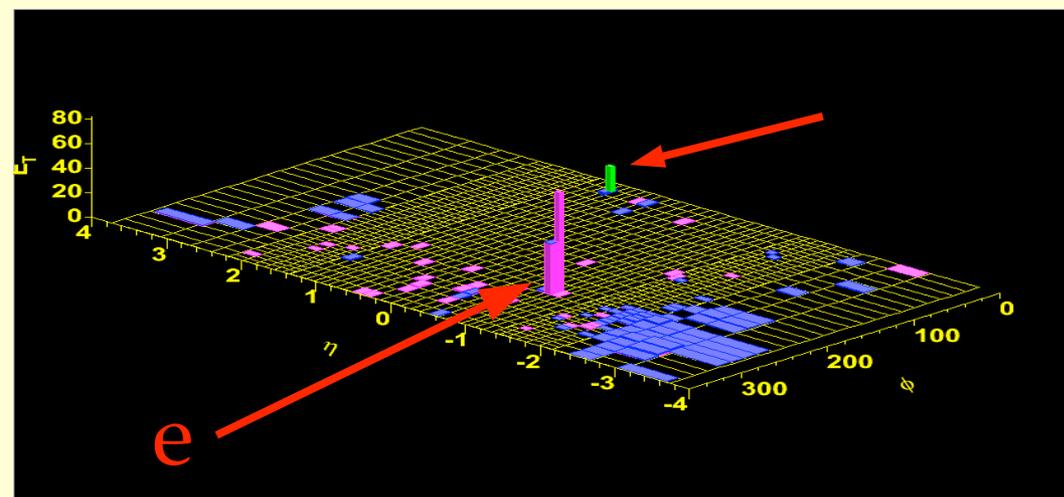
Large transverse energy imbalance
($E_T > 25$ GeV)

Remove Z events:

* If $76 < m_{ll} < 106$ GeV, $E_T / \sqrt{\Sigma E_T} > 3$

* If $E_T < 50$ GeV,

minimum $\Delta\phi(E_T, l, \text{jet}) > 20^\circ$



Remove $t\bar{t}$ events:

* **No jets** ($E_T > 15$ GeV in $|\eta| < 2.5$)

WW Backgrounds and Acceptance

Z:

- * Use MC to model high \cancel{E}_T tail
- * Cross-check ($\cancel{E}_T^{sig} < 3$): data [18](#), bd [15.4](#)

W + jet:

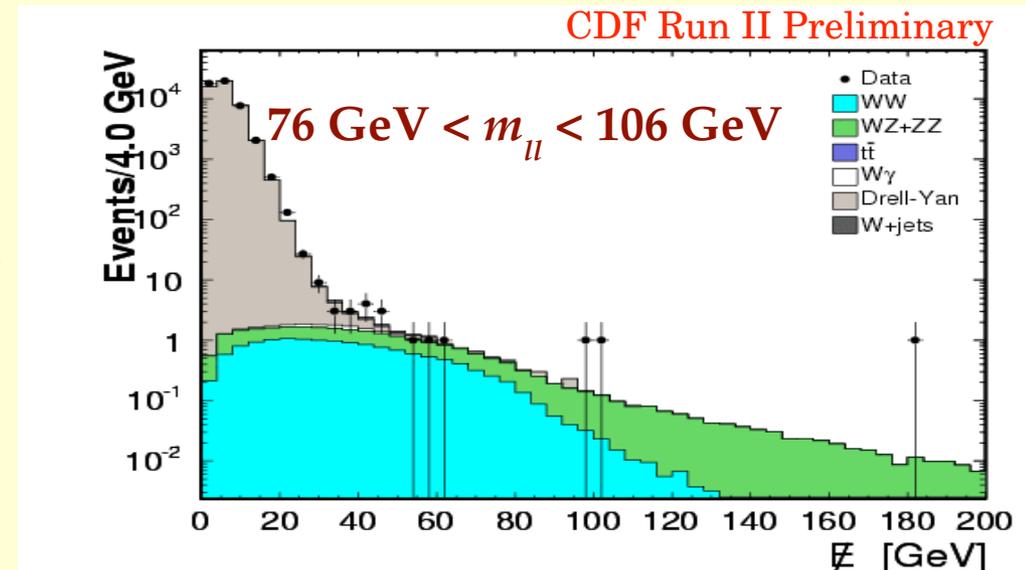
- * Measure jet \rightarrow lepton rate
- * Apply rate to jet in W + jet events
- * Cross-check with like-charge dileptons: data [24](#), background [21](#)

W + γ :

- * Photon conversion in detector mimics dilepton + \cancel{E}_T final state

Dominant acceptance uncertainties:

Jet Rejection	$\pm 7.8\%$
Trigger Efficiency	$\pm 2\%$
PDF	$\pm 1.7\%$
Electron Identification	$\pm 1\%$



WW Cross Section Results

Expected signal and backgrounds:

CDF Run II Preliminary

Mode	ee	$e\mu$	$\mu\mu$	ll
WW	$12.8 \pm 0.1 \pm 1.1$	$28.8 \pm 0.1 \pm 2.4$	$10.7 \pm 0.1 \pm 0.9$	$52.4 \pm 0.1 \pm 4.3$
Drell-Yan	$5.0 \pm 0.5 \pm 1.3$	$3.8 \pm 0.4 \pm 1.0$	$3.0 \pm 0.4 \pm 0.8$	$11.8 \pm 0.8 \pm 3.1$
W +jets	$3.0 \pm 0.2 \pm 0.7$	$6.7 \pm 0.4 \pm 2.0$	$1.3 \pm 0.2 \pm 0.5$	$11.0 \pm 0.5 \pm 3.2$
$WZ + ZZ$	$3.6 \pm 0.0 \pm 0.4$	$0.9 \pm 0.0 \pm 0.1$	$3.4 \pm 0.0 \pm 0.3$	$7.9 \pm 0.0 \pm 0.8$
$W\gamma$	$3.6 \pm 0.1 \pm 0.7$	$3.2 \pm 0.1 \pm 0.7$	$0.0 \pm 0.0 \pm 0.0$	$6.8 \pm 0.2 \pm 1.4$
$t\bar{t}$	$0.1 \pm 0.0 \pm 0.0$	$0.1 \pm 0.0 \pm 0.0$	$0.0 \pm 0.0 \pm 0.0$	$0.2 \pm 0.0 \pm 0.0$
Sum Bkg	$15.2 \pm 0.6 \pm 1.7$	$14.8 \pm 0.6 \pm 2.3$	$7.8 \pm 0.4 \pm 1.0$	$37.8 \pm 0.9 \pm 4.7$
Expected	$28.0 \pm 0.6 \pm 2.0$	$43.7 \pm 0.6 \pm 3.3$	$18.5 \pm 0.4 \pm 1.3$	$90.2 \pm 0.9 \pm 6.4$
Data	29	47	19	95

$$\sigma_{WW} = 13.6 \pm 2.3 \text{ (stat)} \pm 1.6 \text{ (sys)} \pm 1.2 \text{ (lum)} \text{ pb}$$

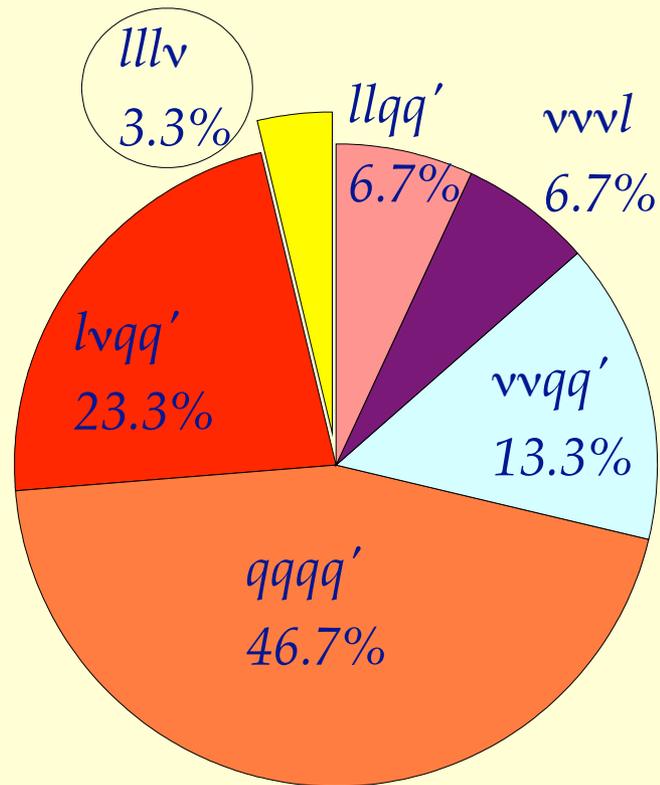
Measurement accuracy now $\sim 20\%$ (from $\sim 40\%$ in 200 pb^{-1})

* 10σ significance

WZ Search

NLO cross section: $\sigma(p\bar{p} \rightarrow WZ) = (3.7 \pm 0.3) \text{ pb}$

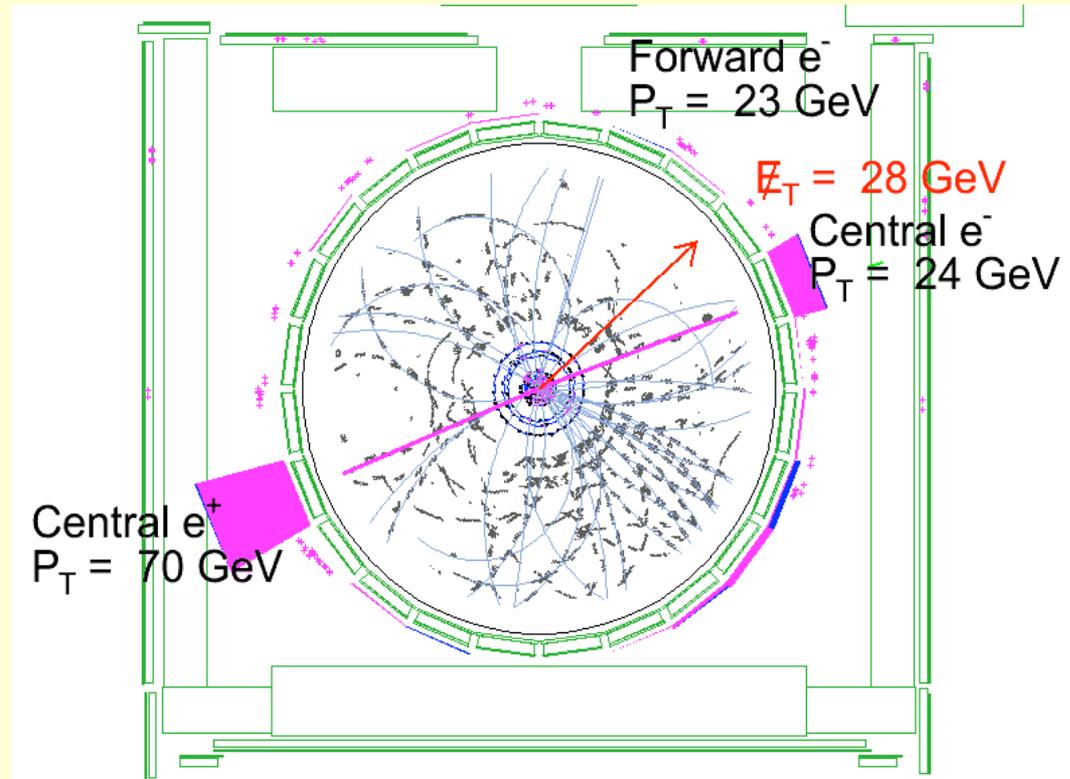
WZ decay modes



'Trilepton' channel:

- * Very low hadronic-jet background
- * Not yet observed at the Tevatron
 - o DØ : 3 events, 0.7 background ($\sim 300 \text{ pb}^{-1}$)
 - 3.5% probability to observe ≥ 3 , given an expectation of 0.7

WZ Candidate Selection



Three leptons (highest $E_T > 20$ GeV,
others $E_T > 10$ GeV)

Two leptons consistent with Z decay:

$$76 \text{ GeV} < m_{ll} < 106 \text{ GeV}$$

Large transverse energy imbalance
($E_T > 25$ GeV)

Remove ZZ events:

* No additional lepton or high p_T track

$$\text{with } 76 < m_{ll} < 106 \text{ GeV}$$

WZ Backgrounds

Total background < 1 event:

Signal:

WZ: 3.72 ± 0.02 (stat.) ± 0.15 (syst.)

Backgrounds:

ZZ: 0.50 ± 0.01 (stat.) ± 0.05 (syst.)

Z γ : 0.03 ± 0.01 (stat.) ± 0.01 (syst.)

t \bar{t} : 0.05 ± 0.01 (stat.) ± 0.01 (syst.)

Z+jets: 0.34 ± 0.07 (stat.) $^{+0.15}_{-0.09}$ (syst.)

Total: 0.92 ± 0.07 (stat.) $^{+0.16}_{-0.10}$ (syst.)

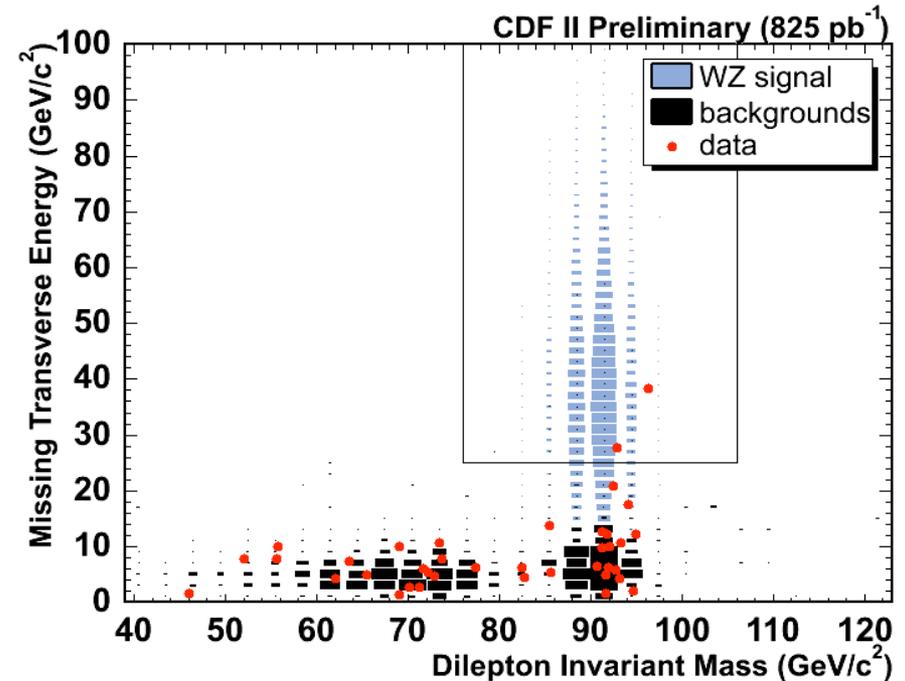
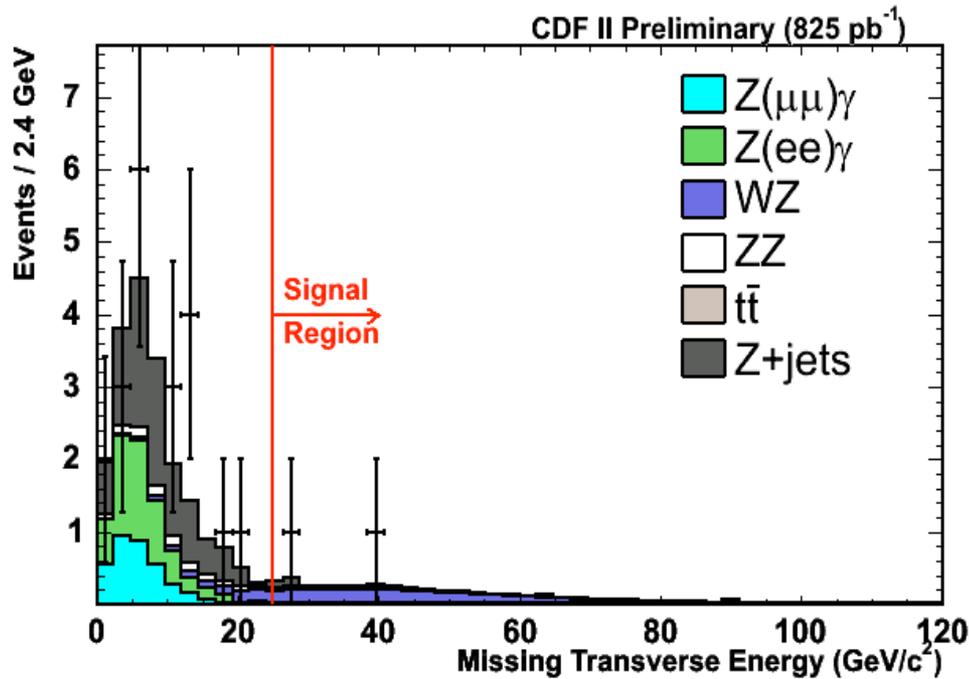
Expect $\sim 3\sigma$ significance for WZ signal observation

Cross-check with control region ($\cancel{E}_T < 20$ GeV):

* Expect 20.5 ± 0.5 , observe 19 events

WZ Results

2 candidate events observed:



15% probability for 4.6 events to fluctuate down to ≤ 2

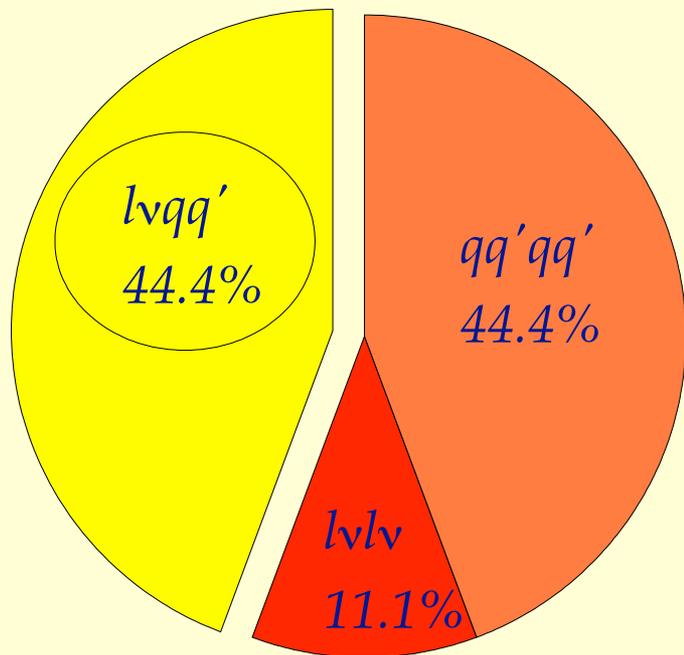
95% Confidence Level limit on WZ production: $\sigma_{WZ} < 6.3$ pb

(c.f. NLO cross section: $\sigma(p\bar{p} \rightarrow WZ) = (3.7 \pm 0.3)$ pb)

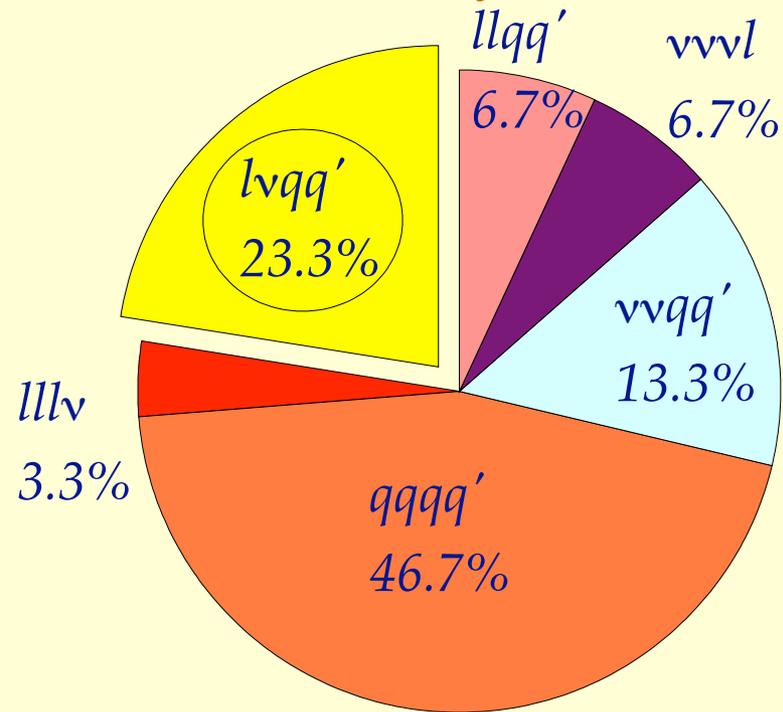
WW + WZ Search

NLO cross section: $\sigma(p\bar{p} \rightarrow WW+WZ) = (16.1 \pm 0.9) \text{ pb}$

WW decay modes



WZ decay modes



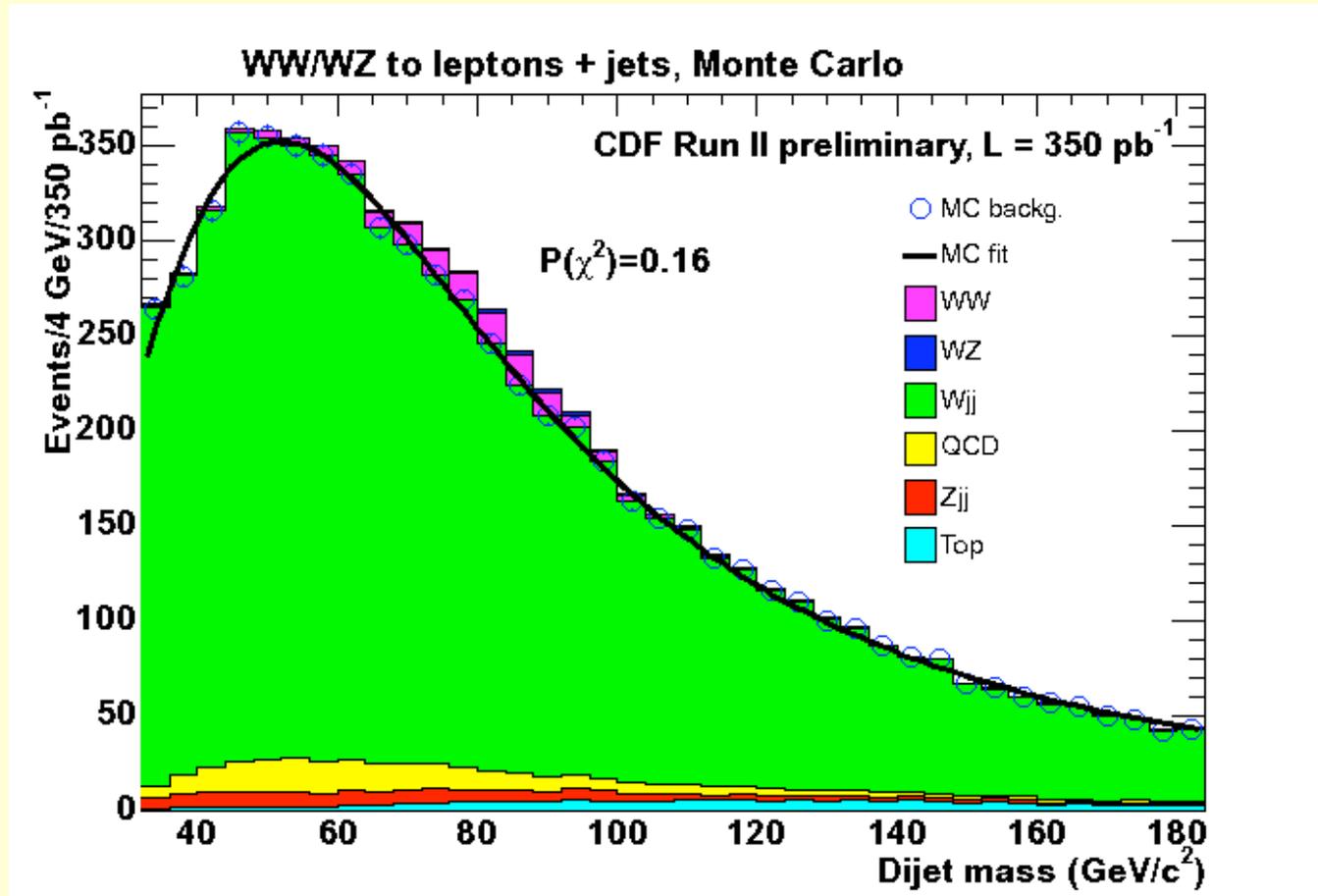
'Lepton + jets' channel:

- * Large branching ratios (4x dileptons, 7x trileptons)
- * Large W + 2 jets background
- * **Goal:** use large branching ratio to search for new physics

WW + WZ Signal Extraction

Use dijet mass distribution to fit for signal

* Cannot separate WW from WZ due to dijet resolution



Systematic uncertainties in $W + \text{jets}$ mass shape

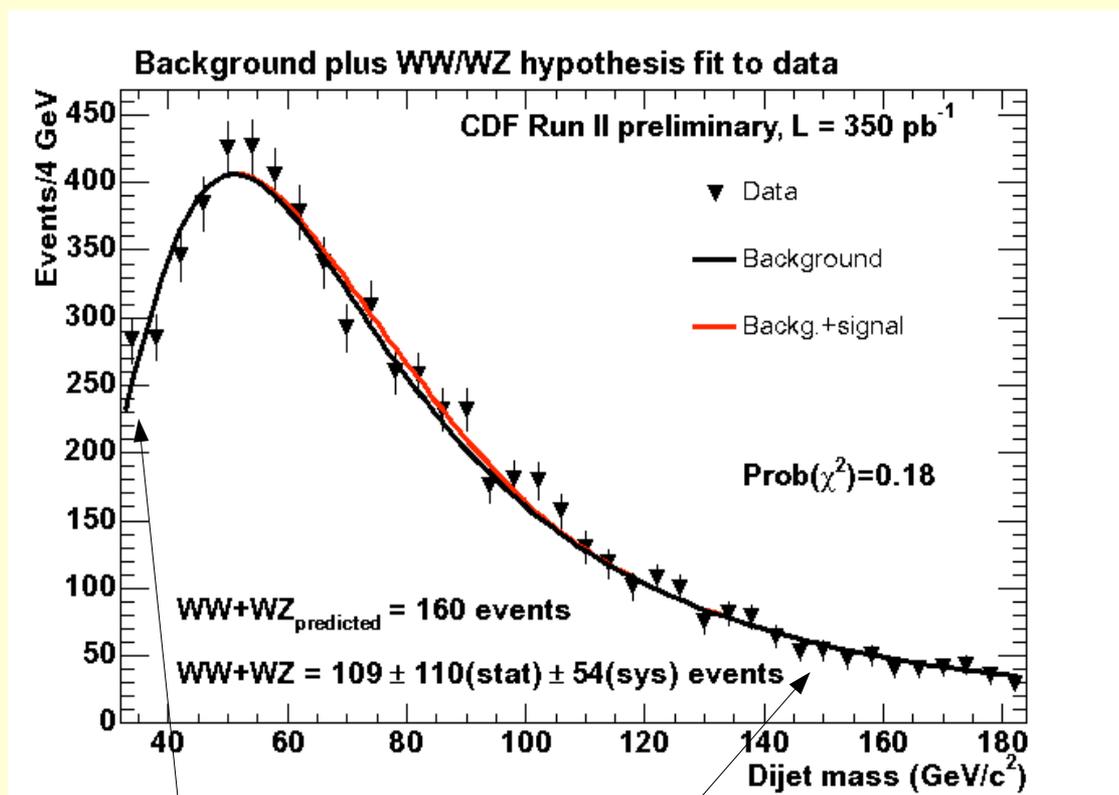
* Theoretical renormalization scale & detector jet energy scale

Dijet Mass Modelling

Use data to constrain $W + \text{jets}$ dijet mass shape

* Two methods:

- o Fit distribution to Landau (suggested from MC)
- o Rescale MC with parameters for jet energy and renormalization scales



Extend distribution to low and high mass to constrain parameters

WW + WZ Limits

No evidence for WW +WZ signal in dijet mass fit

* 0.9σ excess above background ($109 \pm 110 \pm 54$ events)

* Set 95% CL limit: $\sigma_{WW+WZ} < 36$ pb

Systematic uncertainties:

Jet Resolution	$\pm 19\%$
Jet Energy Scale	$\pm 16\%$
Multijet Background	$\pm 16\%$
Signal Shape Model	$\pm 10\%$
ISR/FSR	$\pm 10\%$
Renormalization Scale	$\pm 8\%$

Could still have evidence for anomalous couplings at high mass scale

* Focus on high E_T events where background is low

Anomalous Triple-Gauge Couplings

Parametrize new physics in effective Lagrangian:

$$L_{WWV}/g_{WWV} = \underbrace{ig_1^V}_{\text{SM: } g_1^\gamma = g_1^Z = 1} (W_{\mu\nu}^t W^\mu V^\nu - W_{\mu\nu}^t V_\nu W^{\mu\nu}) + \underbrace{i\kappa_V}_{\text{SM: } \kappa_\gamma = \kappa_Z = 1} W_{\mu\nu}^t W_\nu V^{\mu\nu} + \underbrace{i\lambda_V/M_W^2}_{\text{SM: } \lambda_\gamma = \lambda_Z = 0} W_{\lambda\mu}^t W_\nu^\mu V^{\nu\lambda}$$

SM: $g_1^\gamma = g_1^Z = 1$ SM: $\kappa_\gamma = \kappa_Z = 1$ SM: $\lambda_\gamma = \lambda_Z = 0$
 AC: $\Delta g_1^Z (= g_1^Z - 1)$ AC: $\Delta\kappa_Z, \Delta\kappa_\gamma (= \kappa_V - 1)$ AC: $\lambda_Z, \lambda_\gamma$

Impose unitarity by introducing a 'new physics' energy scale:

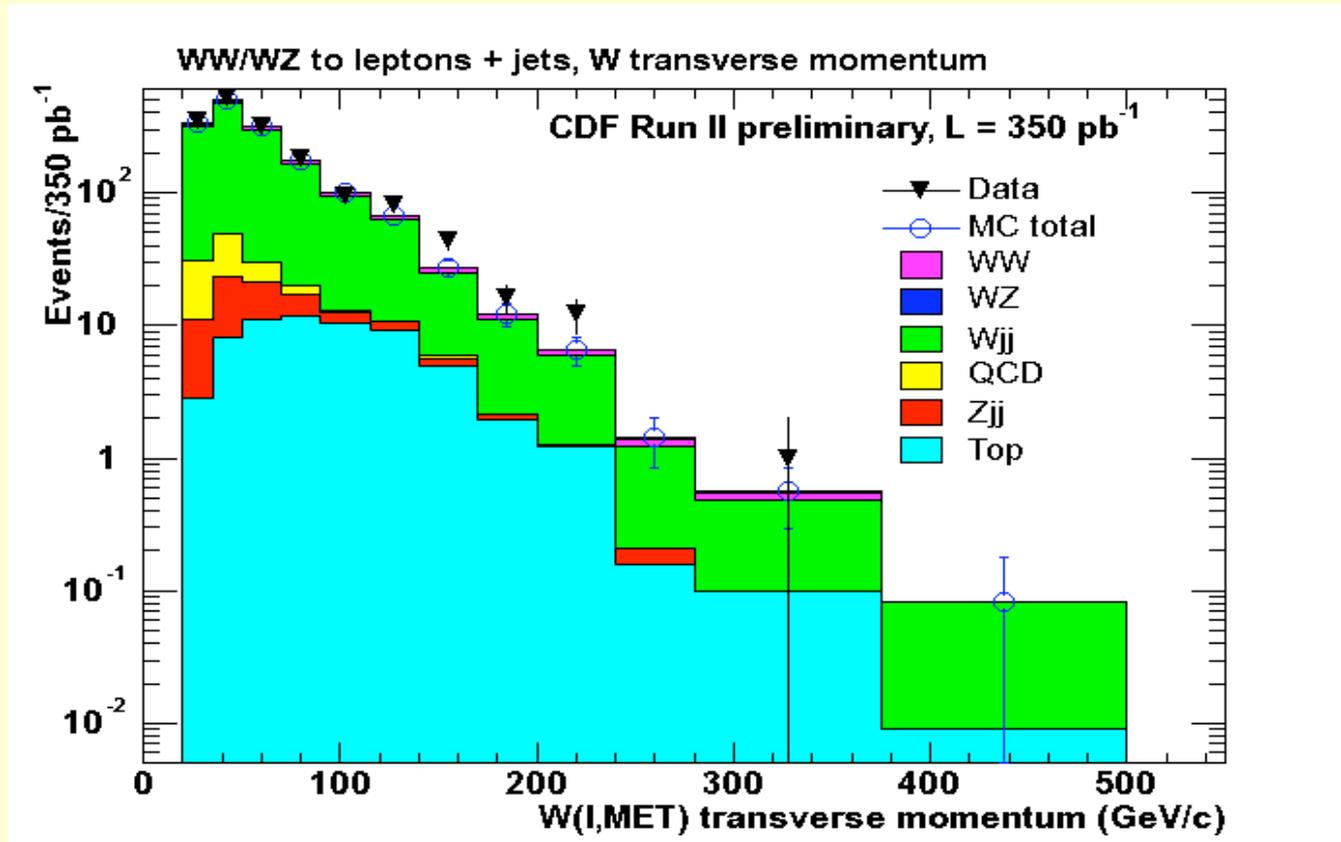
$$\alpha(s) = \alpha_0 / (1 + s/\Lambda^2)^2$$

Anomalous couplings increase as new physics scale approaches

Manifested in additional cross section at high boson p_T in WW/WZ events

Anomalous Coupling Search

No significant excess observed at high boson p_T



Limits on anomalous couplings: $|\lambda_V| < 0.28$, $-0.51 < \Delta\kappa_V < 0.44$ ($\Lambda = 1.5$ TeV)

(c.f. DØ Run 1 in this channel: $-0.36 < \lambda_V < 0.39$, $-0.47 < \Delta\kappa_V < 0.63$ ($\Lambda = 1.5$ TeV))

WW & WZ Summary

Now studying large (~ 50 -event) $WW \rightarrow l\nu l\nu$ data samples

Approaching observation of WZ production at a hadron collider

Enhancing new physics sensitivity with hadronic decay modes of bosons

Many exciting opportunities in the next year of data

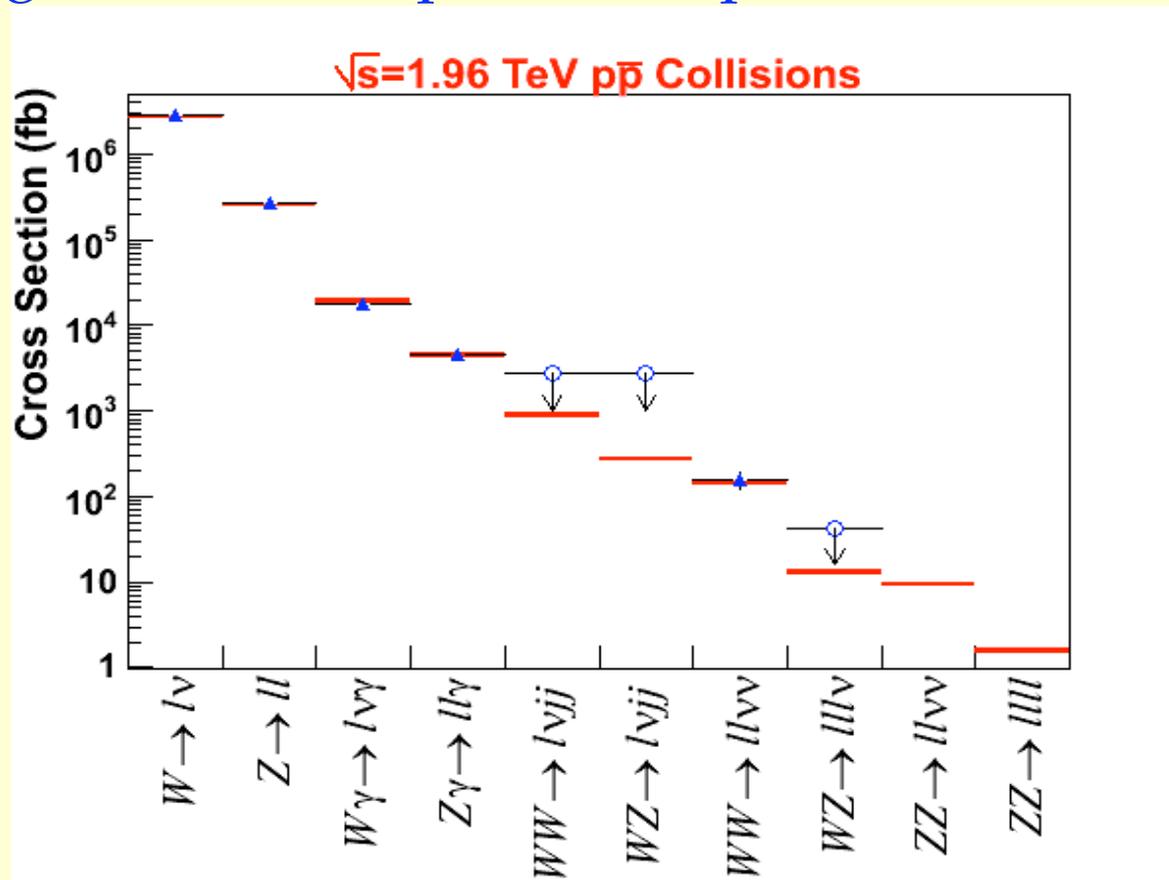
Summary

Electroweak bosons sensitive physics probes:

- * QCD constraints
- * Electroweak couplings

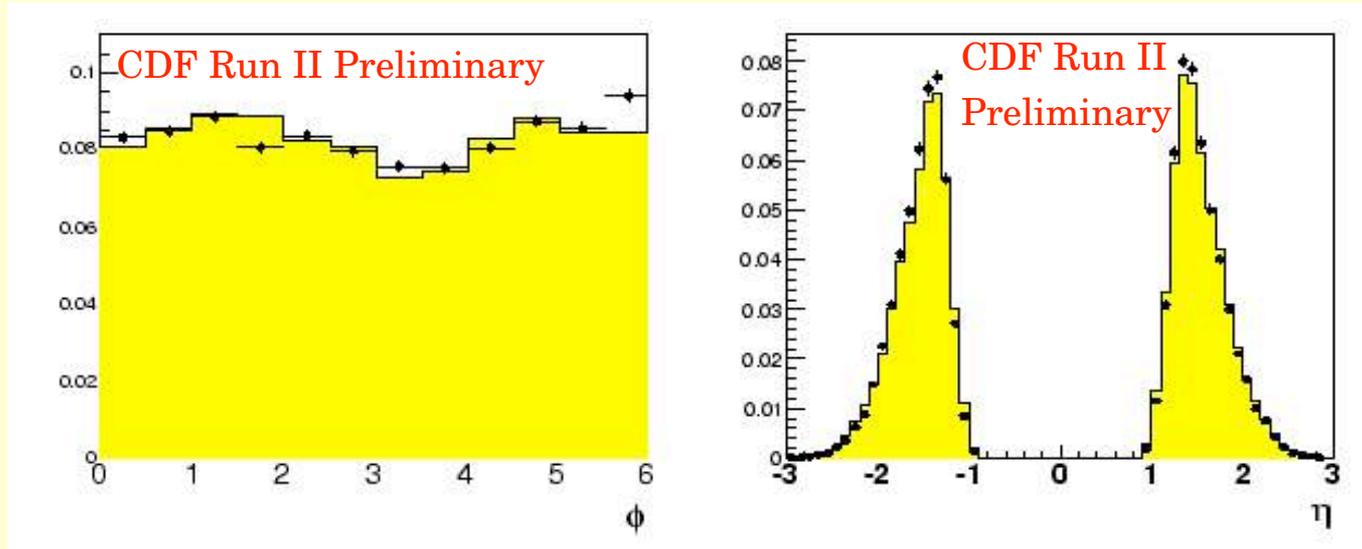
CDF using forward detector components for precision physics

- * Extends region of W acceptance for precision measurements



Forward W Geometric Distributions

Geometric acceptance determined from MRST PDFs, PYTHIA MC +GEANT simulation



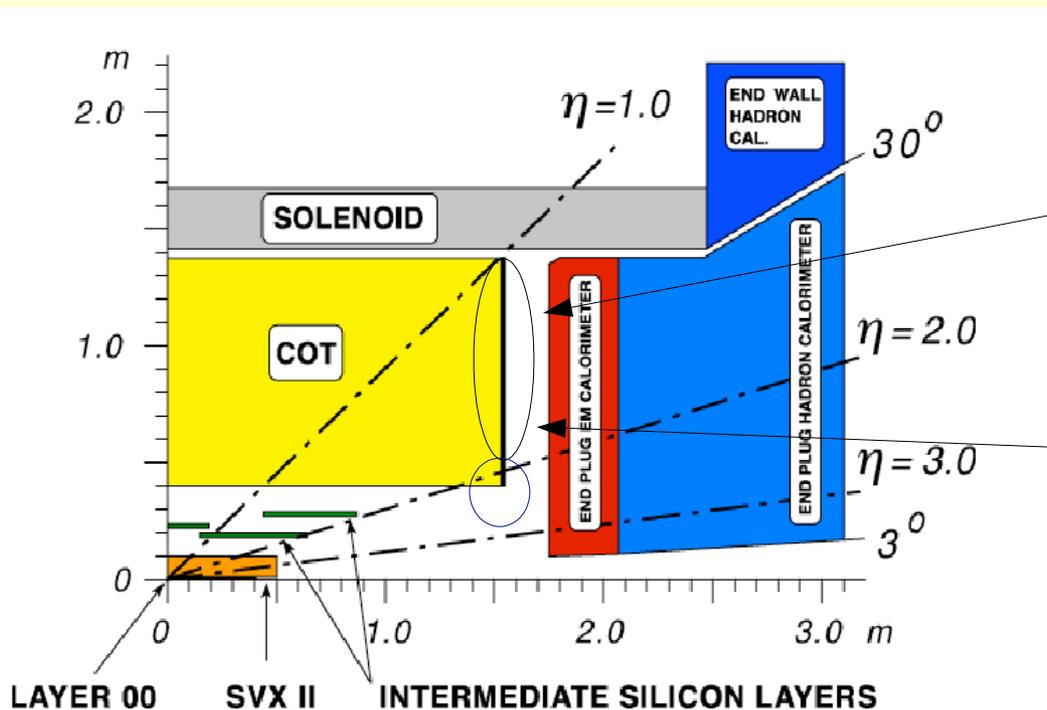
Main geometric uncertainties:

- * Parton distribution functions ($\Delta\mathcal{A}/\mathcal{A} = 1.7\%$)
- * Primary vertex reconstruction ($\Delta\mathcal{A}/\mathcal{A} = 0.05\%$)

Total acceptance:

$$\mathcal{A} = 25.7^{+0.7}_{-0.5} \%$$

New Forward Track Reconstruction



COT-seeded tracking
(Outside-in algorithm):

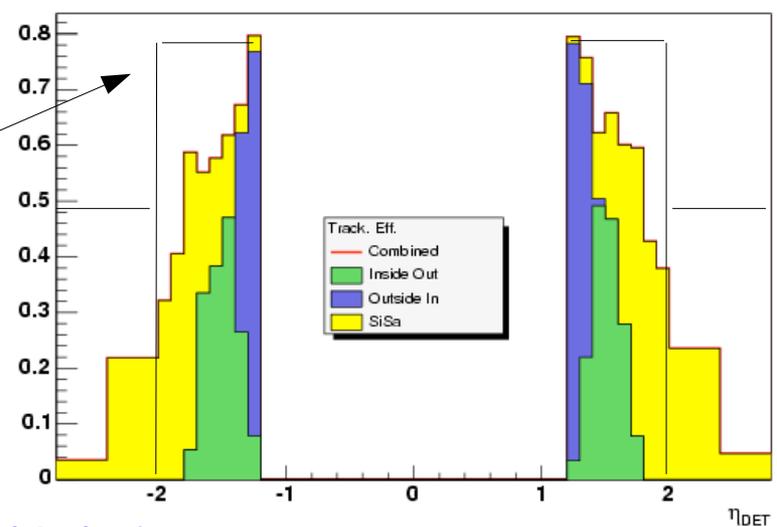
$$|\eta| < 2$$

Silicon-seeded tracking
(Inside-out algorithm)

$$1 < |\eta| < 2.8$$

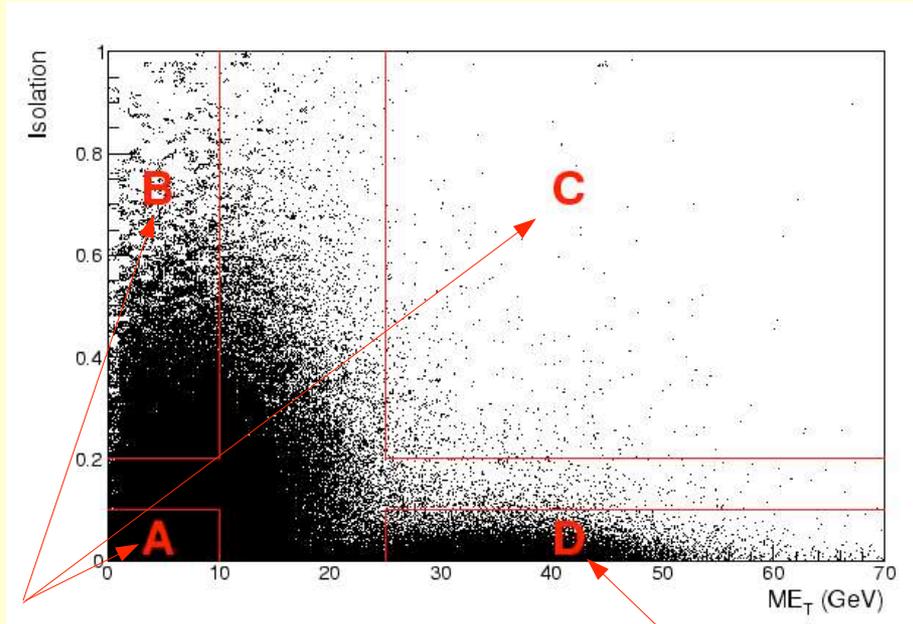
80% Tracking efficiency
to $|\eta| = 2$

Will be standard for winter
2007 physics results



Jet Background Measurement

Measure hadronic jet background by correlating E_T with isolation energy



jet-dominated regions

Measurement region

Assume jet production is uncorrelated in E_T and isolation

$$N_{jet}^D = N_{jet}^C (N_{jet}^A / N_{jet}^B)$$

* Correct for W & Z contamination in

A, B, C

* Verify with MC that γ + jet

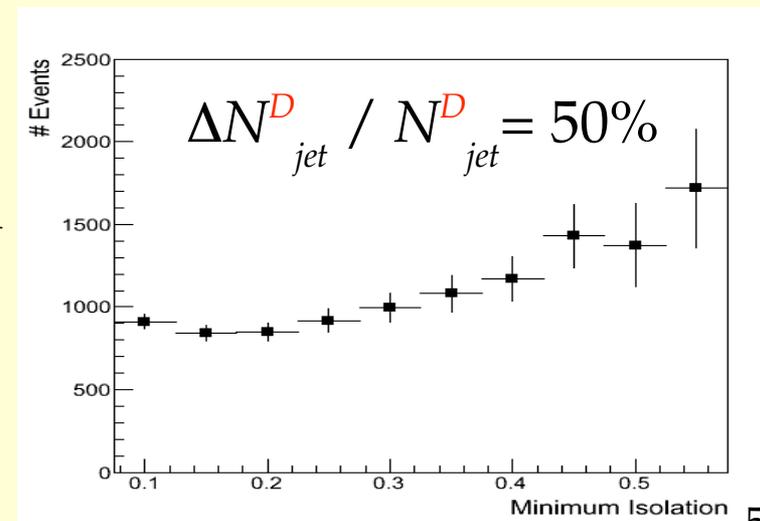
production does not bias result

Uncertainty estimate:

* Vary **B** & **C** regions by increasing isolation threshold

* Cross-check by applying a jet-to-electron rate to

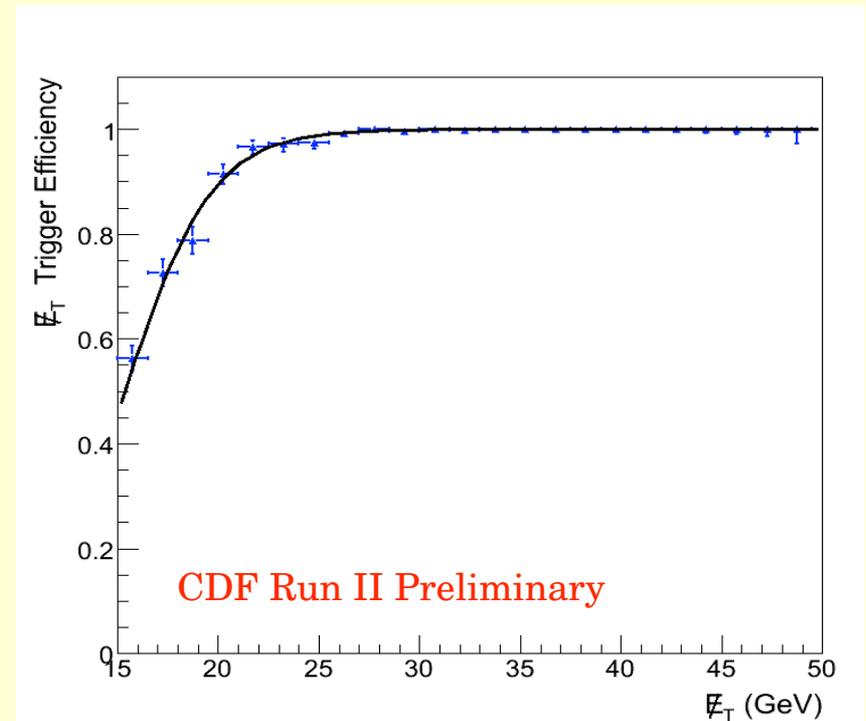
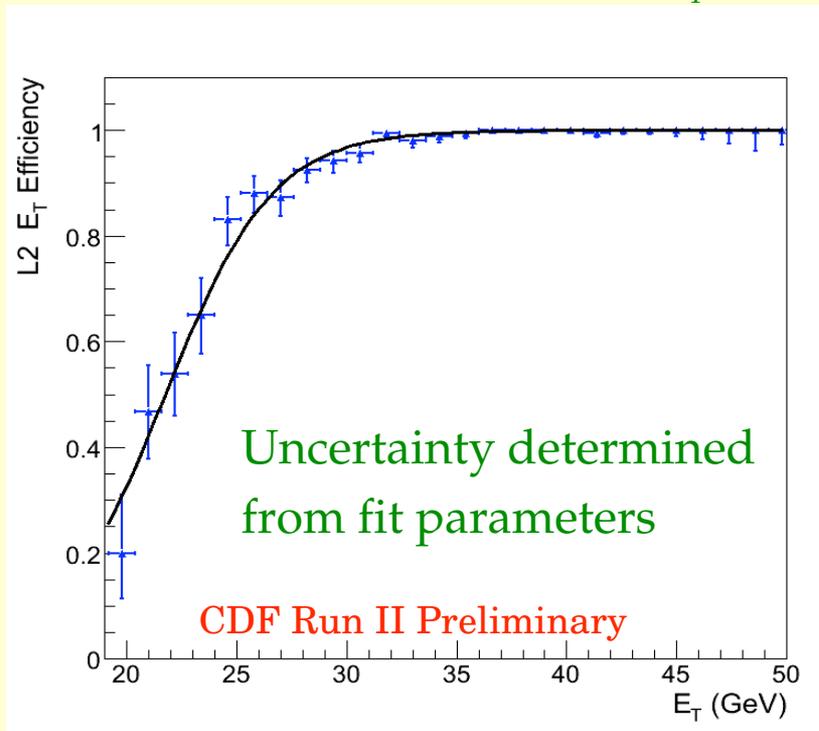
jet + E_T events (consistent to 30%)



Forward Trigger Efficiencies

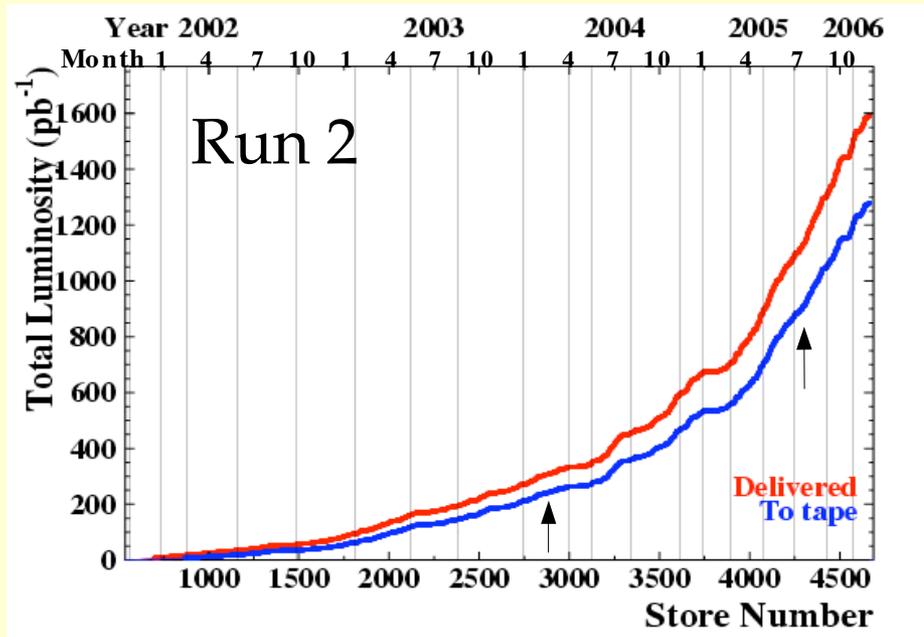
3-Level trigger system

- * Low thresholds at Level 1: 100% efficient
- * Level 2 inefficiency: increased thresholds, primitive electron identification, assumption of vertex at detector center ($z = 0$)
- * Level 3: 100% efficient for $E_T > 25$ GeV, some inefficiency in 20-25 GeV range



Integrated trigger efficiency: $\epsilon_{\text{trig}} = 96.1^{+0.3}_{-0.4} \%$

Luminosity



Tevatron has produced 1.6 fb^{-1} of
 $1.96 \text{ TeV } \sqrt{s} \text{ } p\bar{p}$ collisions

W (WW) cross section
 measurement uses $223 (825) \text{ pb}^{-1}$
 of integrated luminosity

Luminosity measurement:

$$\sigma_{p\bar{p}} = 59.3 \pm 2.4 \text{ mb}$$

- * Observe inelastic collisions in the Cherenkov Luminosity Counter (CLC)
- * Count fraction of $p\bar{p}$ crossings with no observed collision

Luminosity uncertainties:

$$\Delta L/L = 5.8\%$$

Inelastic Cross Section	$\pm 4\%$
Material Simulation	$\pm 3\%$
Inelastic Collision Generator	$\pm 2\%$
CLC Simulation	$\pm 1\%$
Gain Variation	$\pm 1\%$

Resonance Search

Can reconstruct WW/WZ transverse mass in lepton + jets channel

* Sensitive to new high-mass resonances decaying WW or WZ

