W/Z Results from CDF

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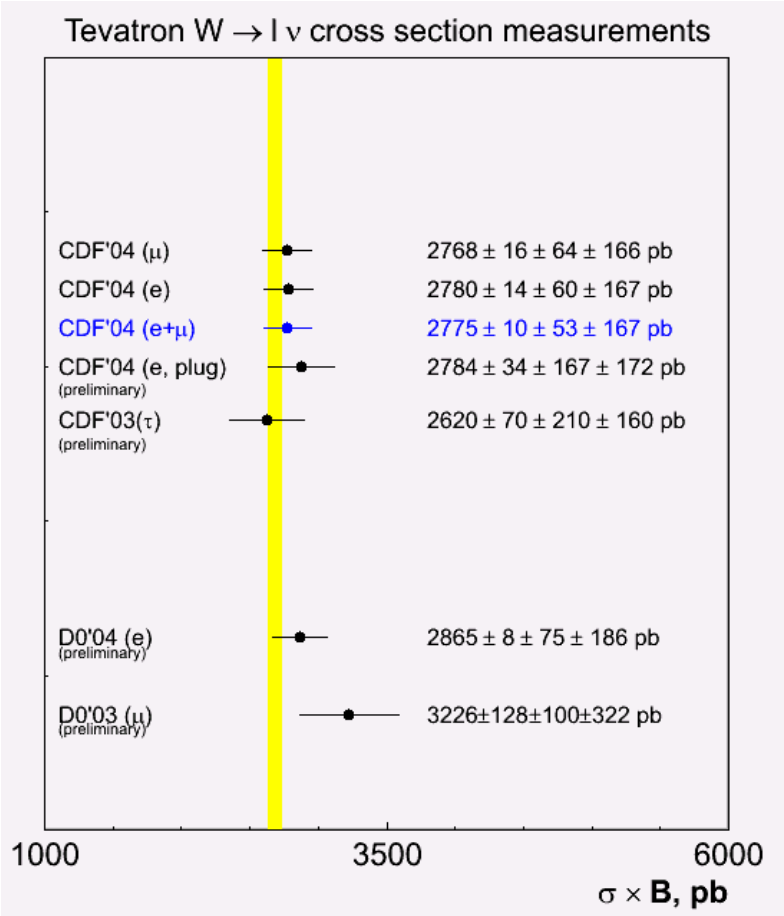
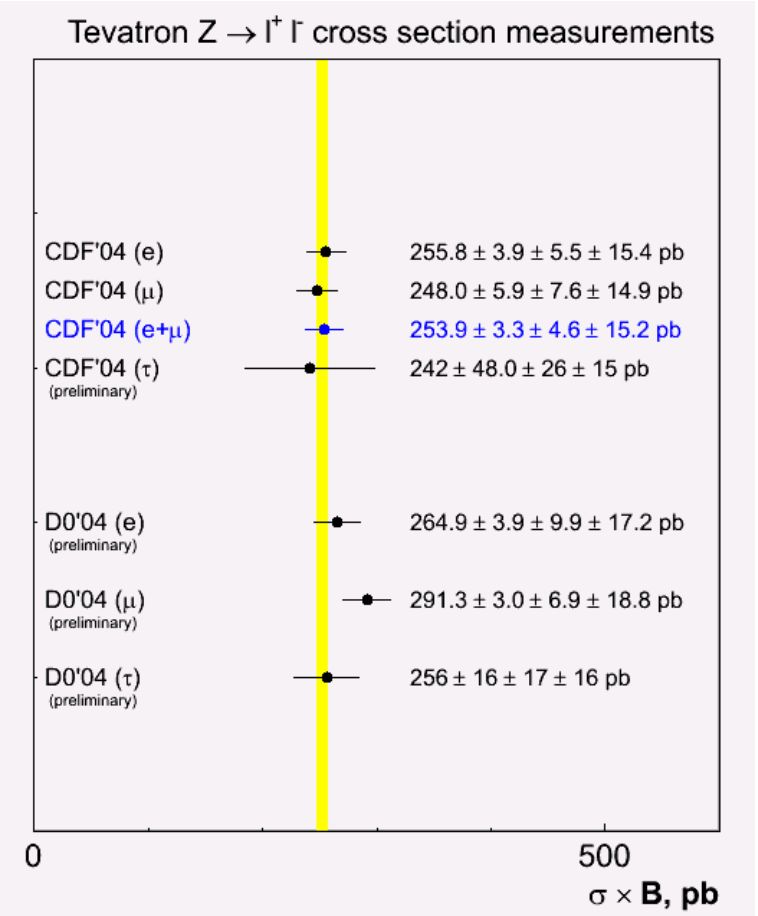
CTEQ/CDF/D0 W/Z Workshop

- Inclusive Cross-Section Measurements
- R(W/Z)
- R(W/Z) : New Ideas
- W Charge Asymmetry
- W Charge Asymmetry : New Ideas
- Other W/Z Measurements
- [W Mass → Ashutosh]

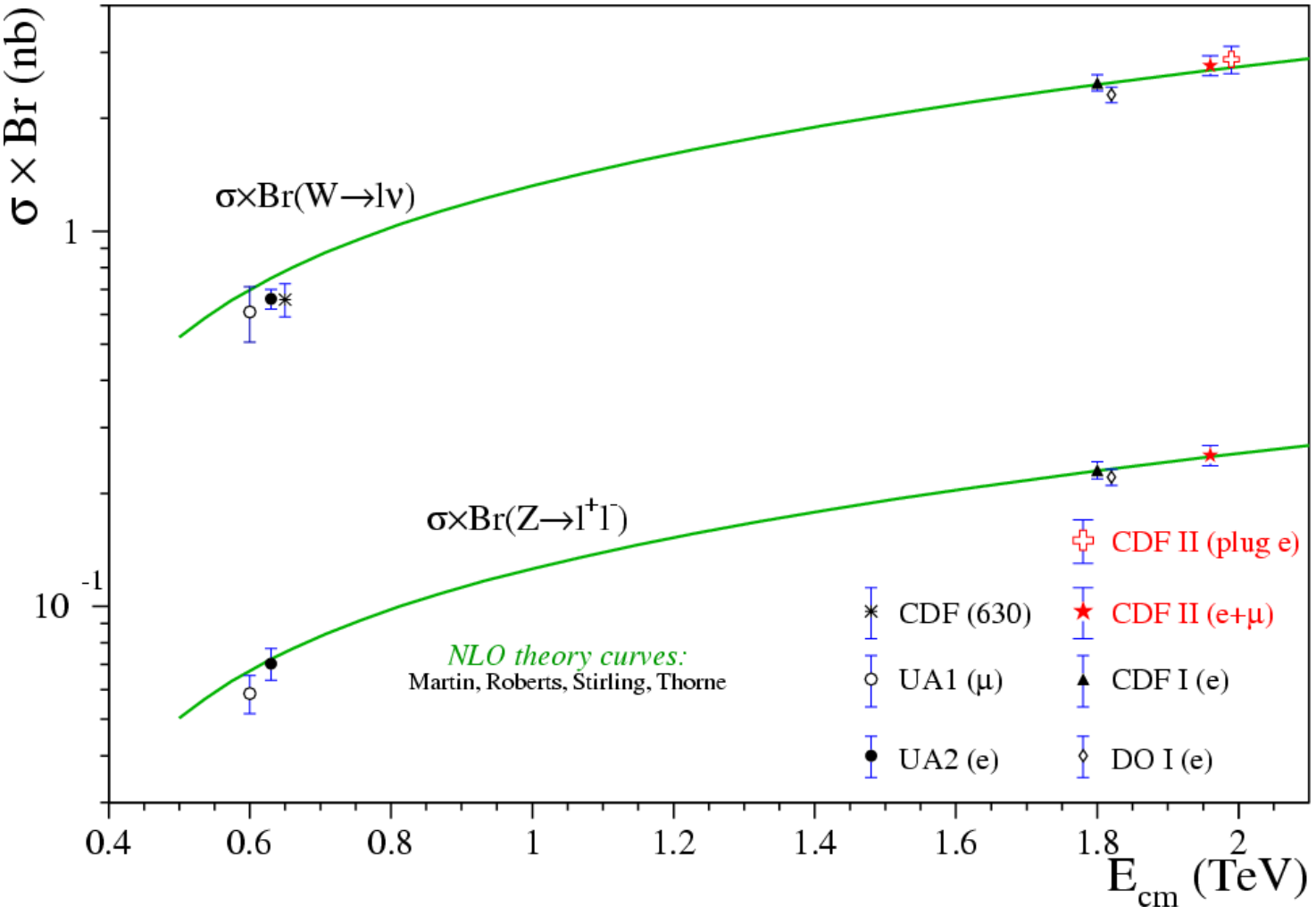
Inclusive W/Z Cross-Section Measurements





- e/μ : 2% systematics limited cross-section measurements (w/o correlated *L* uncertainty)
- Dominant systematics : acceptance (PDF's); efficiency.
- Benchmark measurements for all high P_T lepton analyses.

Inclusive W/Z Cross-Section Measurements



$$R = \frac{\sigma_W \times BR(W \to l\nu)}{\sigma_Z \times BR(Z \to l^+ l^-)} = 10.92 \pm 0.15(\text{stat.}) \pm 0.14(\text{syst.})$$

- e, μ combined
- correlated systematics fully taken into account

R(W/Z)

$$R = \frac{\sigma_W \times BR(W \to l\nu)}{\sigma_Z \times BR(Z \to l^+ l^-)}$$

$$= \frac{\sigma_W}{\sigma_Z} \frac{\Gamma_Z}{\Gamma(Z \to l^+ l^-)} \frac{\Gamma(W \to l\nu)}{\Gamma_W}$$

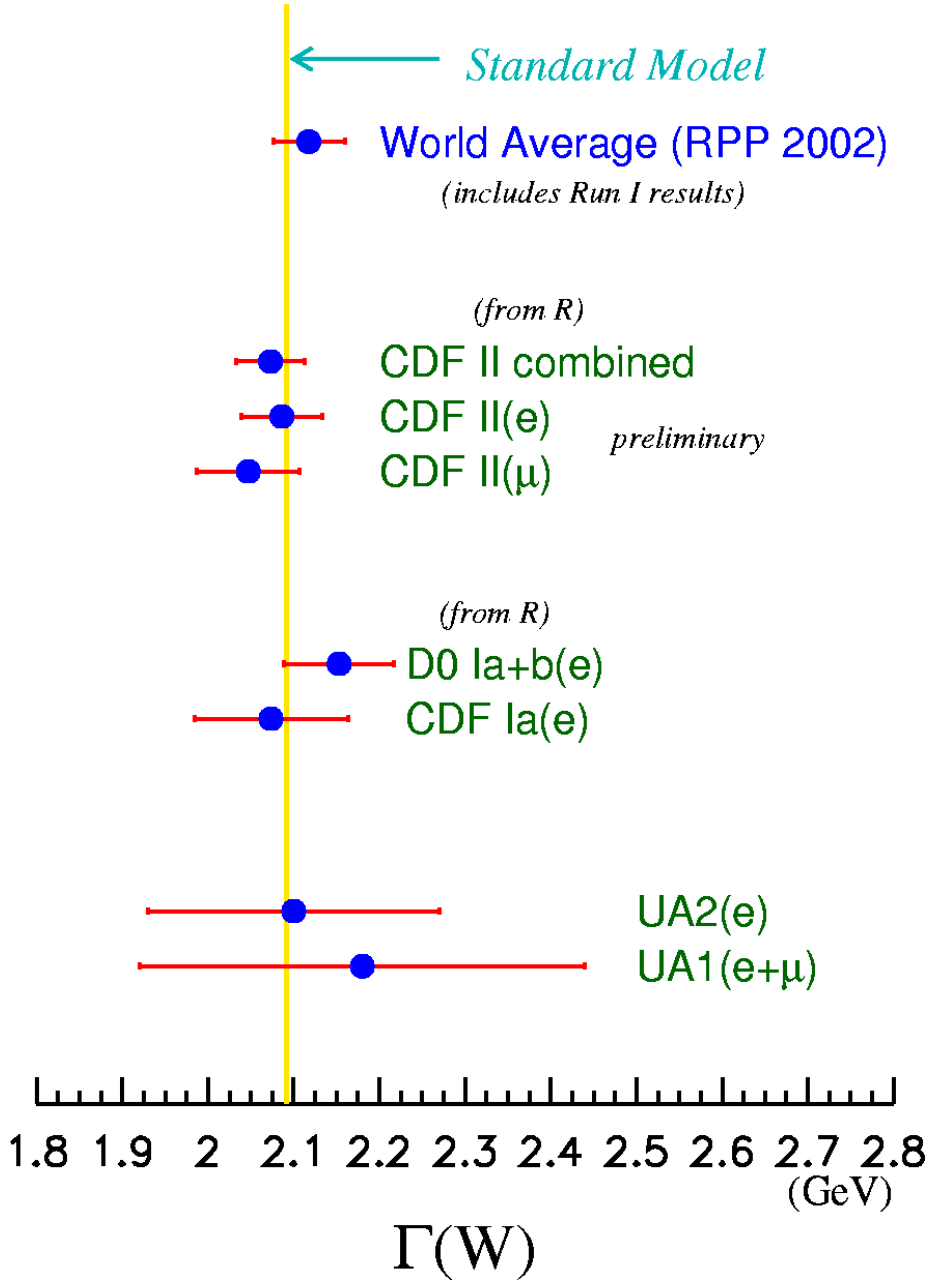
SM : 3.361 ± 0.024

LEP

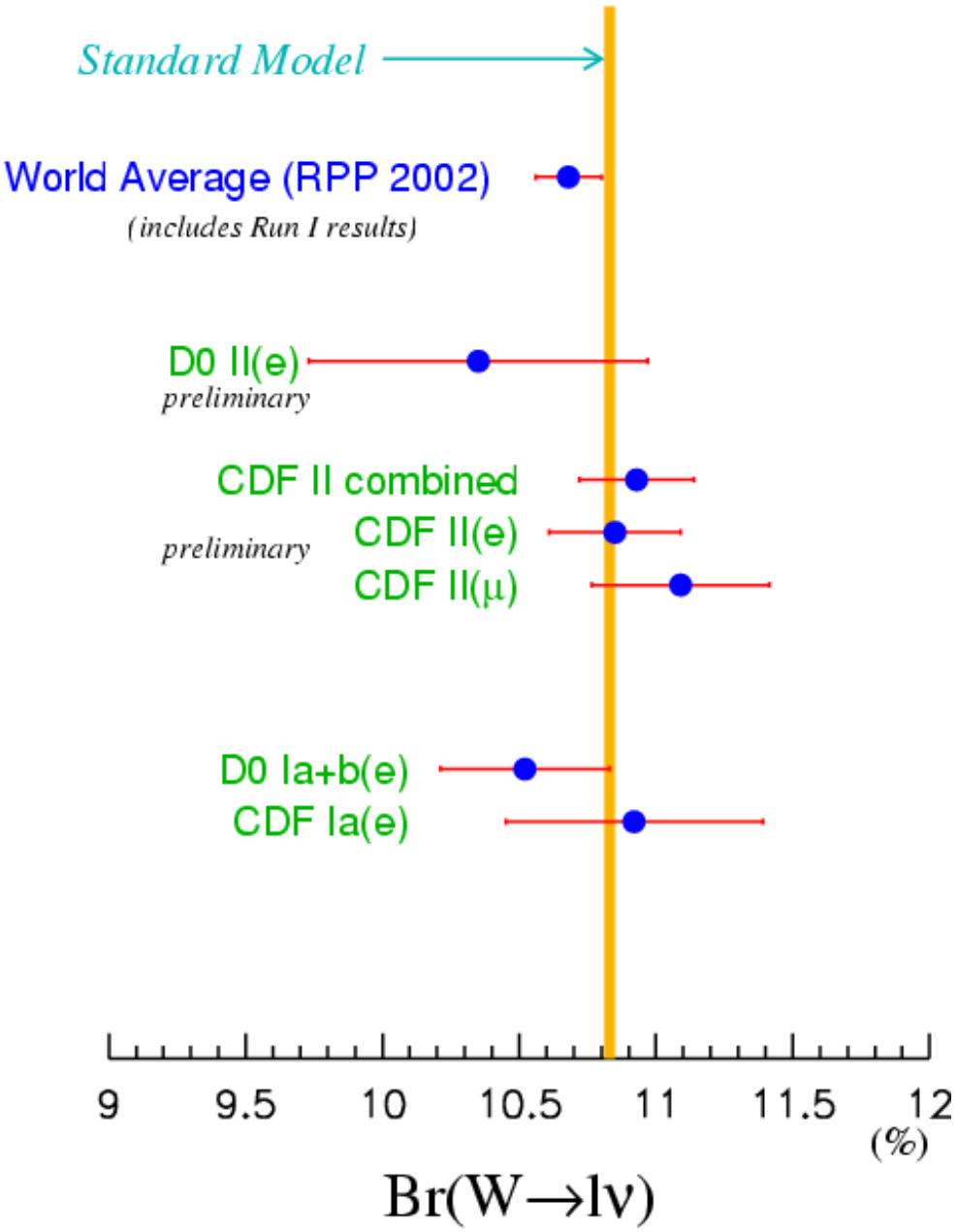
SM : 226.4 ± 0.3 MeV

$$\Gamma_W(\text{indirect}) = 2.079 \pm 0.041 \text{ GeV}$$

$$\Gamma_W(\text{WA}) = 2.118 \pm 0.042 \text{ GeV}$$



Branching Ratios



BUT :

$$\mathrm{BR}(W \to l\nu)_{\mathrm{CDF}} = 10.89 \pm 0.22\ \%$$

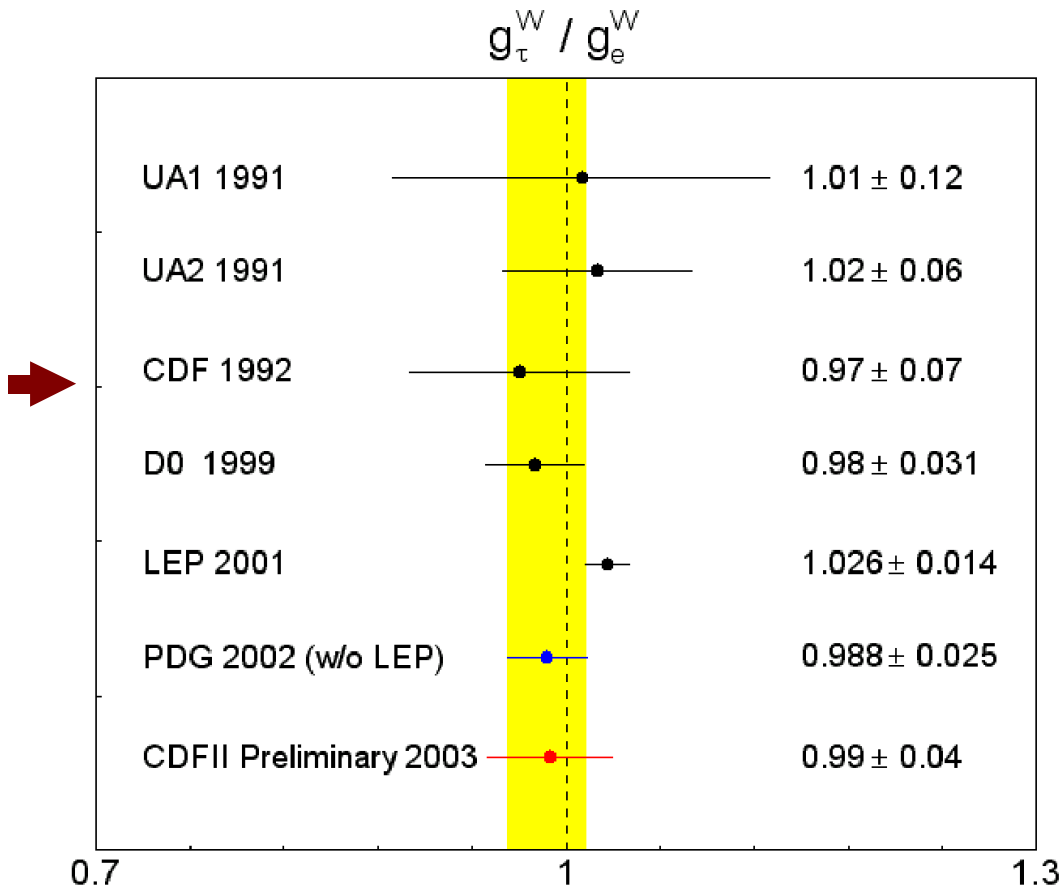
$$\mathrm{BR}(W \to l\nu)_{\mathrm{WA}} = 10.68 \pm 0.12\ \%$$

Universality Tests

$$\sqrt{\frac{\mathrm{BR}(W\to\mu\nu)}{\mathrm{BR}(W\to e\nu)}} = \frac{g_\mu^W}{g_e^W}(\mathrm{CDF}) = 0.998 \pm 0.012$$

[similar to LEP]

$$\sqrt{\frac{\mathrm{BR}(W\to\tau\nu)}{\mathrm{BR}(W\to e\nu)}} = \frac{g_\tau^W}{g_e^W}(\mathrm{CDF}) = 0.99 \pm 0.04$$



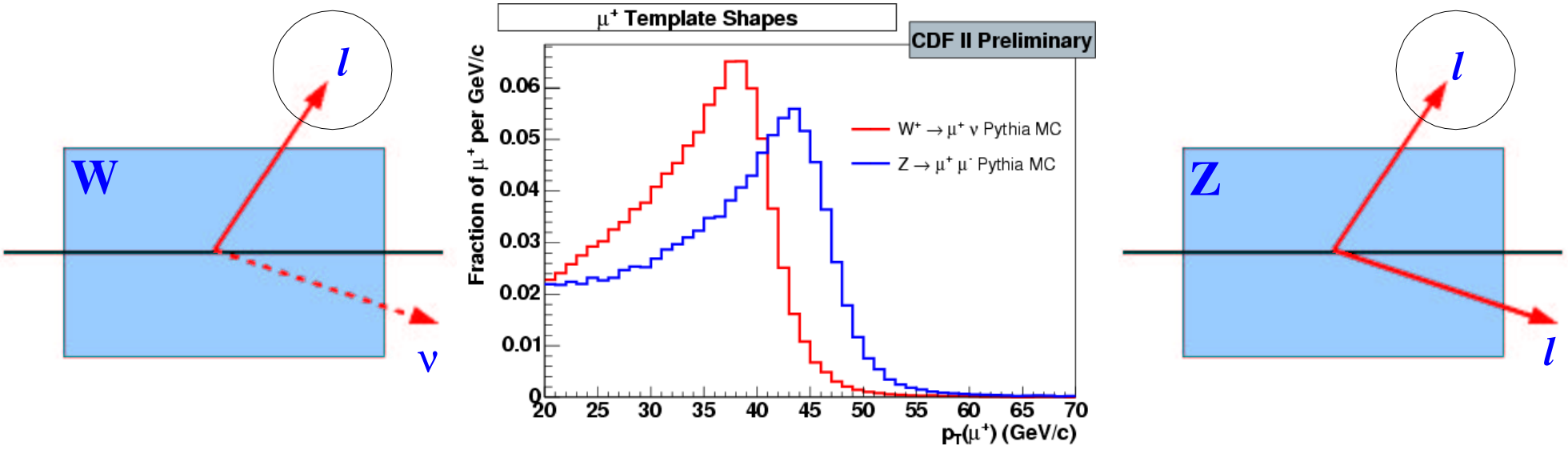
R(W/Z) 72pb^{-1} : Closer Look at Major Systematics

	category	electron	muon
	central value ± syst	10.82 ± 0.16	11.12 ± 0.18
acceptance	PDF	0.07	0.09
acceptance	material	0.03	0.00
acceptance	recoil	0.03	0.04
	efficiency	0.12	0.11
	background	0.04	0.09

R(W/Z) : New Approach

K. Copic (U Mich.); V. Martin, M. Schmitt (NWU)

- Select W's & Z's with identical cuts.
- Single lepton only must pass trigger and full lepton ID requirements.
- Fit the lepton $p_T(\mu)$, $E_T(e)$ spectra to obtain the relative W & Z fractions.



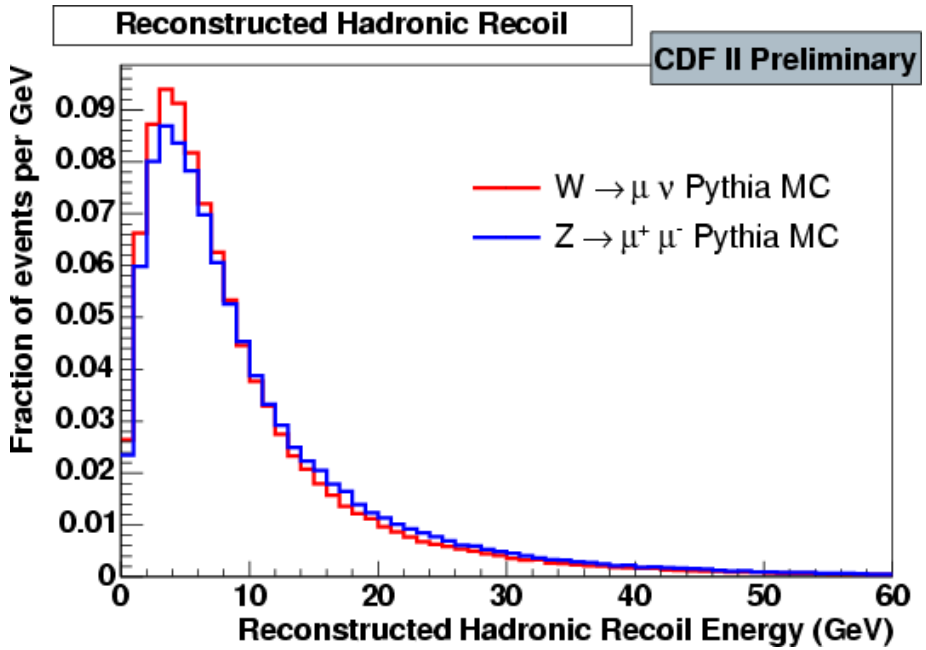
R(W/Z) : New Approach

Efficiencies :

- Single lepton requirement virtually eliminates efficiency differences between W's and Z's.

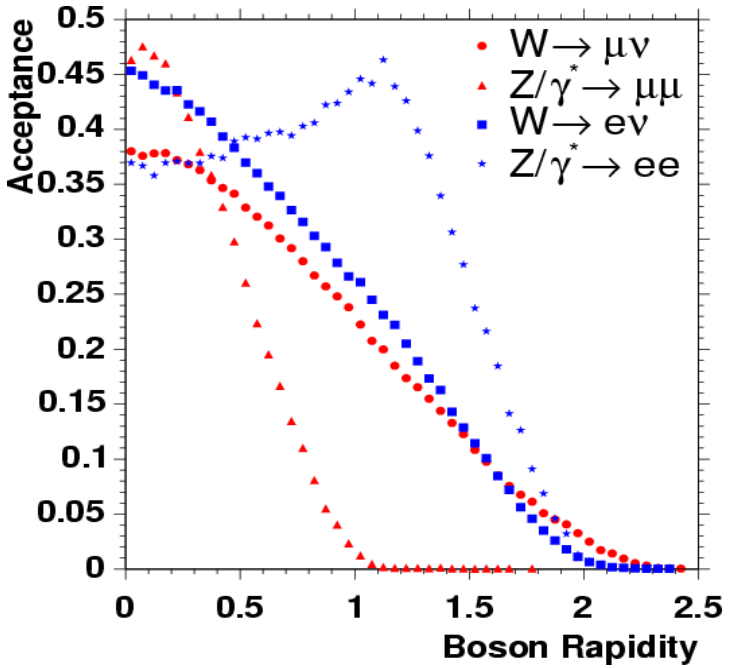
Backgrounds :

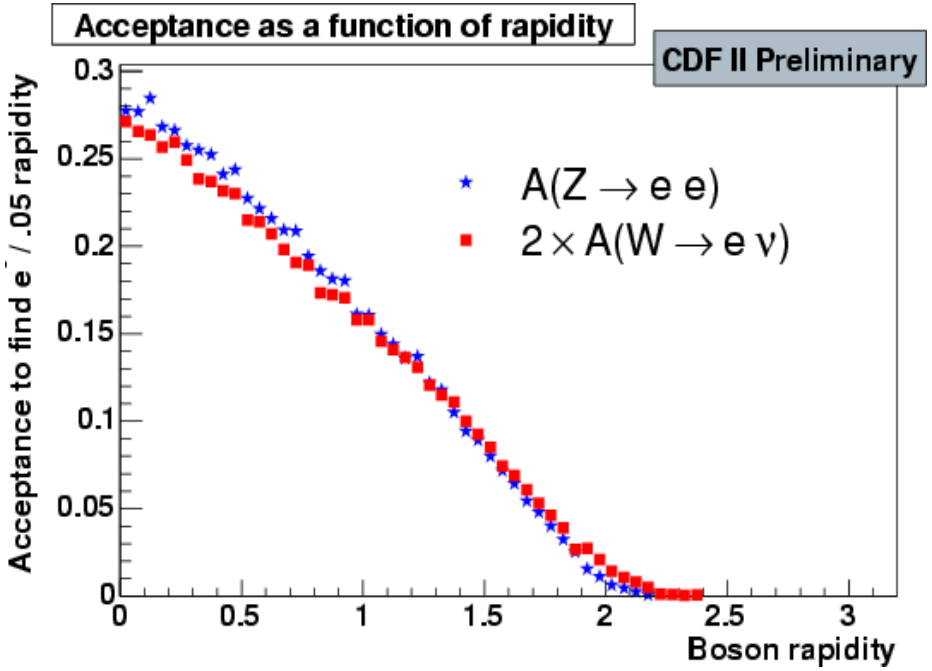
- QCD background reduced with a hadronic recoil cut (made similar for W's & Z's by looking for “loose” second leptons)
- Background shapes important.



R(W/Z) : New Approach

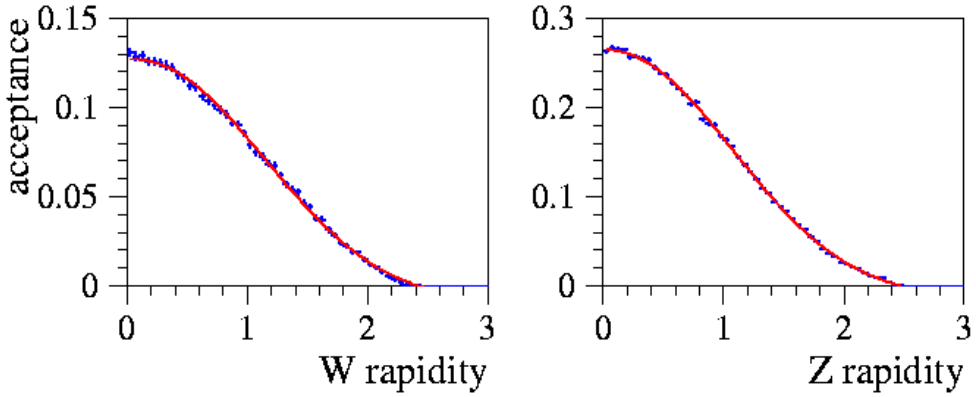
- Acceptance : made similar for W's & Z's :





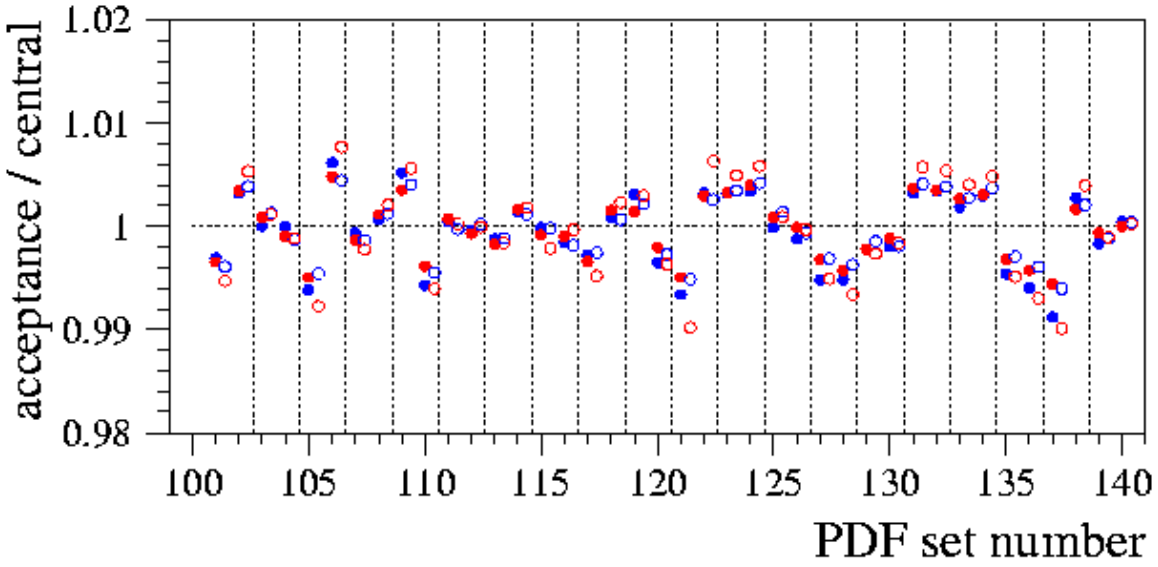
PDF Uncertainty :

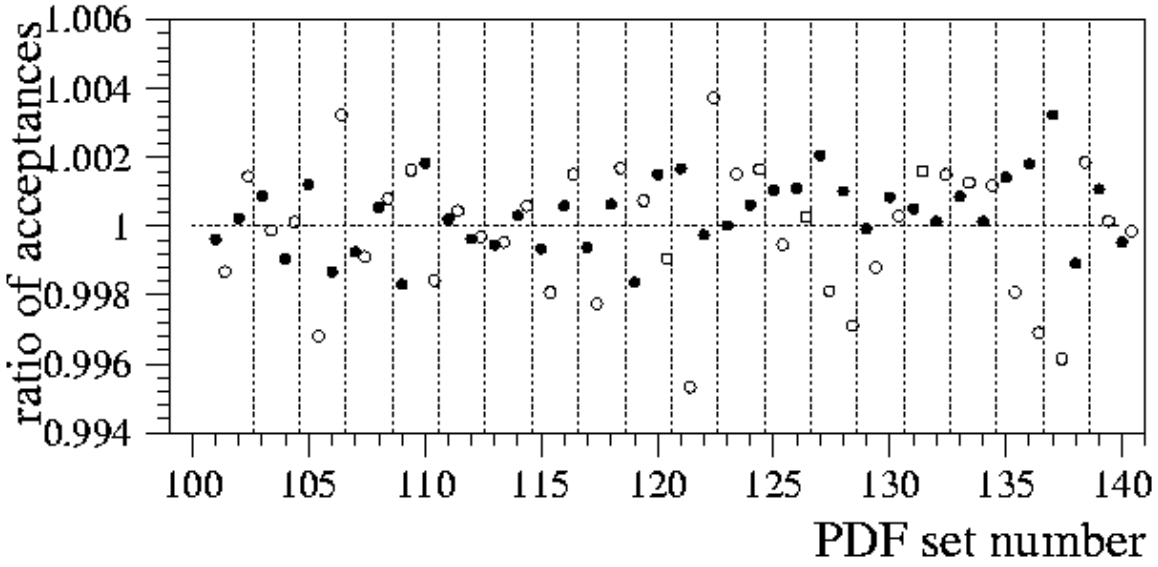
- Parameterize above acceptance functions :
- Reweight large event ensembles to correspond to error PDF sets.



R(W/Z) : PDF Uncertainty

CTEQ 6.1

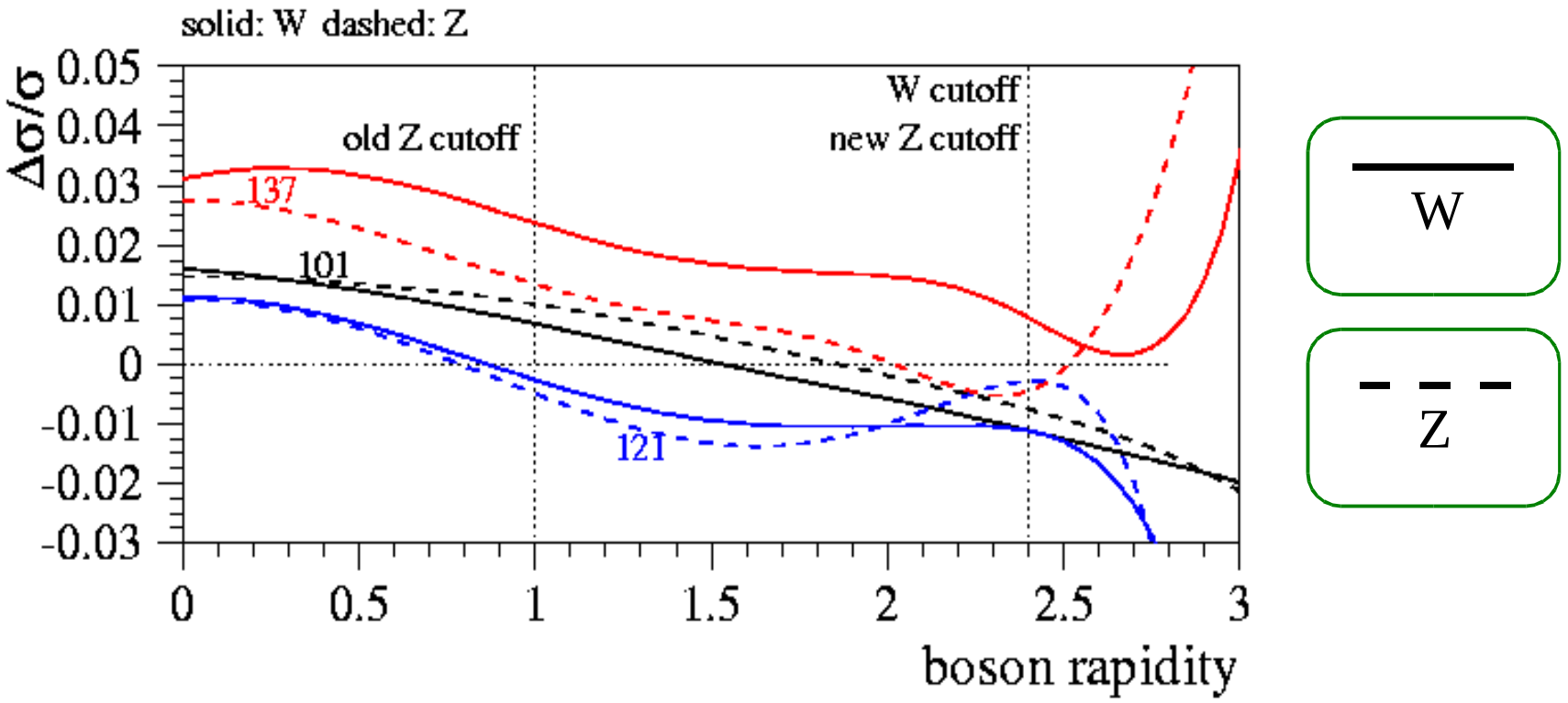




- Z→μμ (new)
- W→μν (new)
- Z→μμ (old)
- W→μν (old)

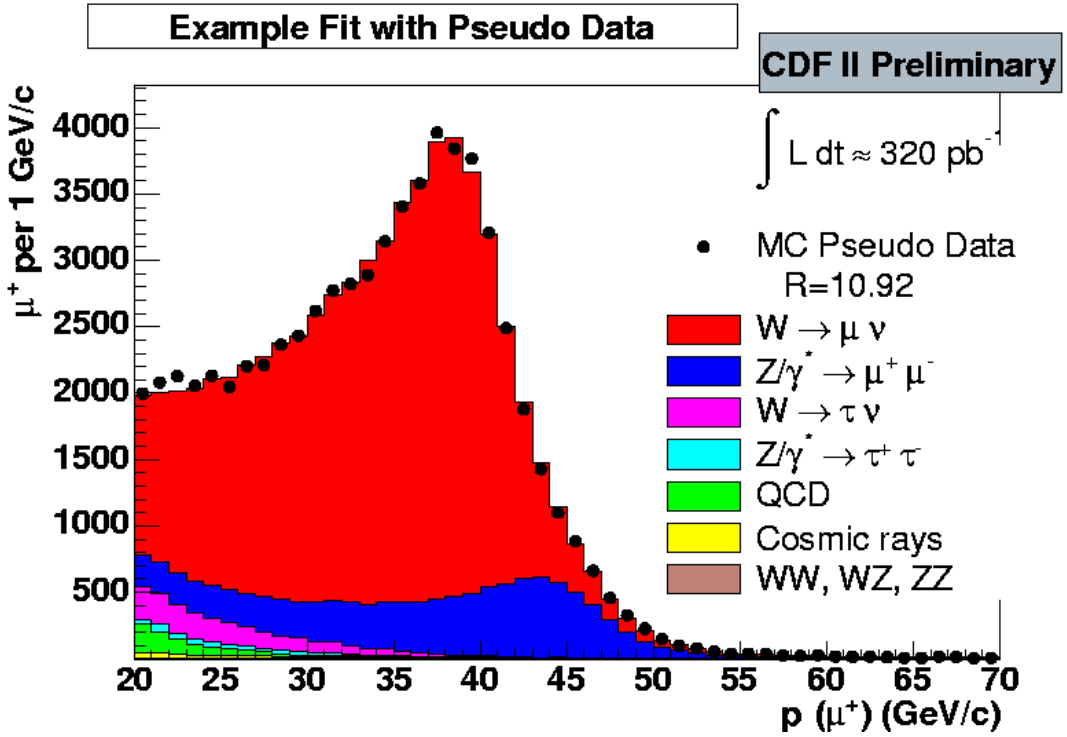
- R (new)
- R (old)

R(W/Z) : PDF Uncertainty



- Future measurements (dσ/dy ?) might constrain relevant PDF sets ?
- Even without further constraints, **PDF systematic on R ≤ 0.5%**

R(W/Z) : Prospects



- Correlations between charges/legs have been studied : minimal.
- With 400-500 pb^{-1} : new method should have a similar statistical precision to the current (72 pb^{-1}) determination of R, with considerably smaller systematics.

W Charge Asymmetry

$$A(y_W) = \frac{d\sigma(W^+)/dy_W - d\sigma(W^-)/dy_W}{d\sigma(W^+)/dy_W + d\sigma(W^-)/dy_W}$$

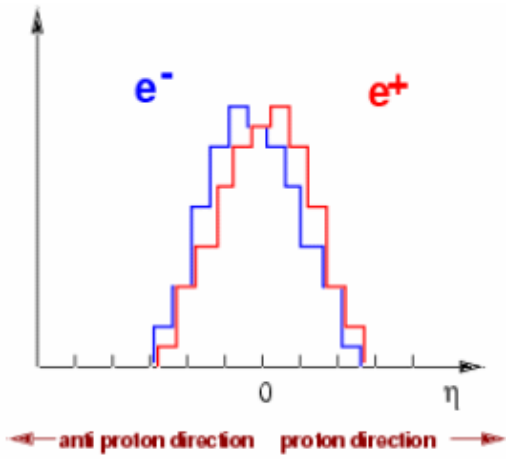
$$A(y_W) \approx \frac{u(x_1)d(x_2) - d(x_1)u(x_2)}{u(x_1)d(x_2) + d(x_1)u(x_2)}$$

Rapidity charge asymmetry is sensitive to **d(x)/u(x)** ratio at high-**x** → primary interest of PDF fitters.

- cannot reconstruct y_W directly
- measure charged lepton only

$$A(\eta_l) = \frac{d\sigma(l^+)/d\eta_l - d\sigma(l^-)/d\eta_l}{d\sigma(l^+)/d\eta_l + d\sigma(l^-)/d\eta_l}$$

$$A(\eta_l) =$$



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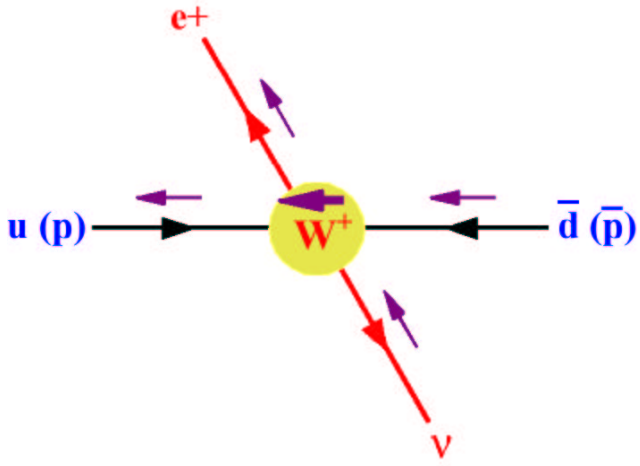


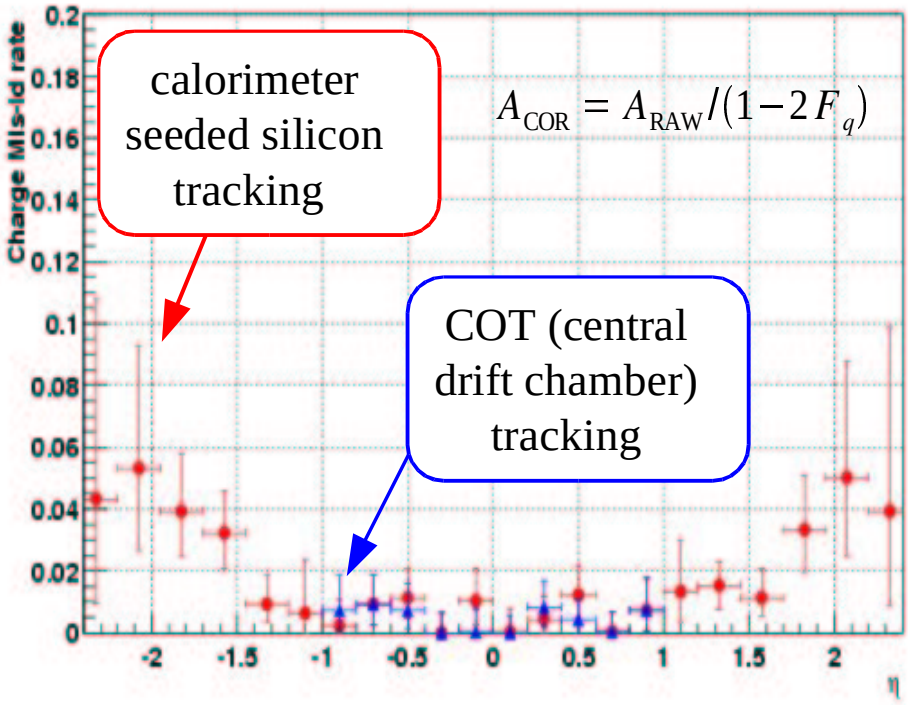
W Charge Asymmetry

C. Issever, A. Scott, D. Stuart (UCSB); T. Nelson (FNAL)

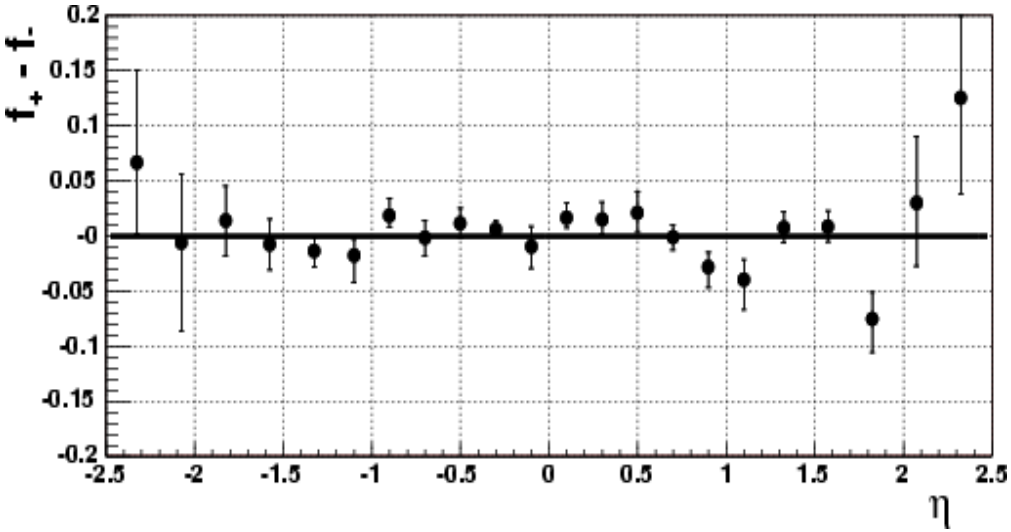
PRD71, 051104 (2005)

Systematics :

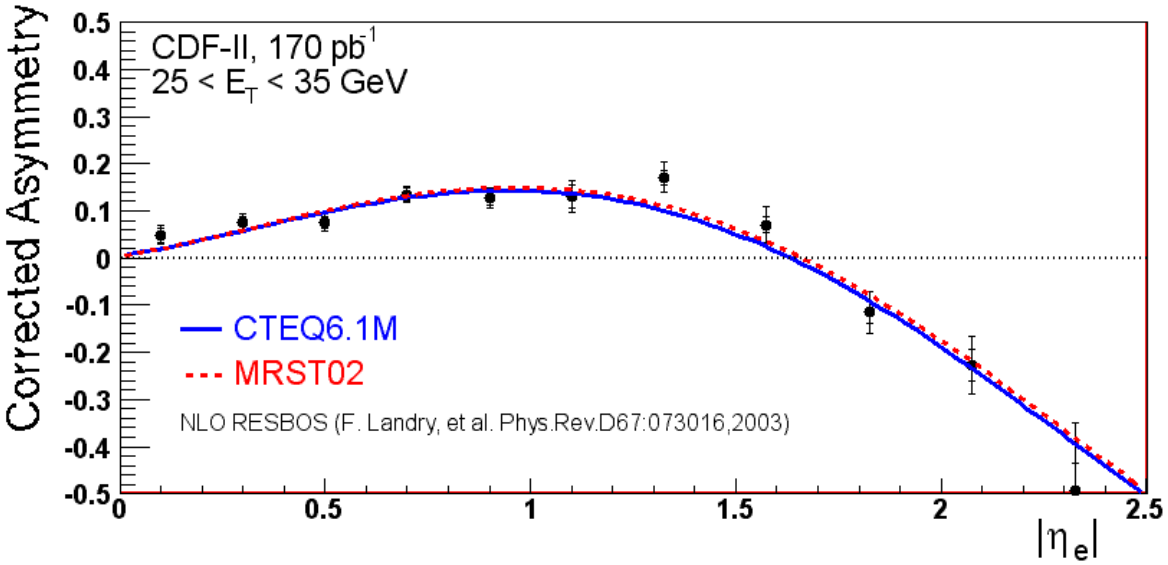
- Charge mis-identification : **dominant**
- Backgrounds.
- Calorimeter energy scales, etc.



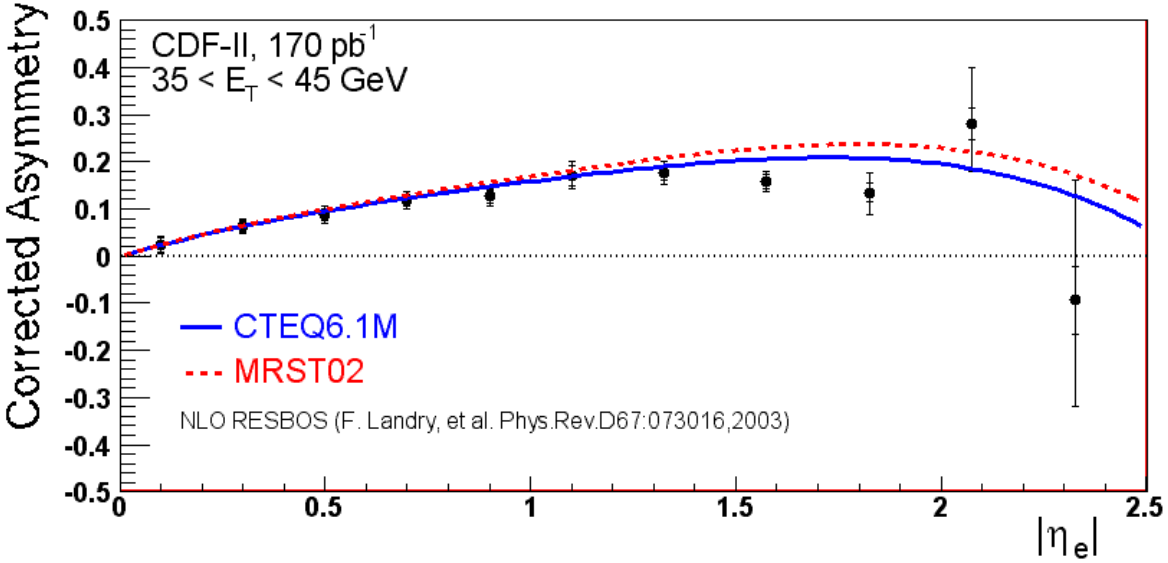
- Look for evidence of charge dependent charge mis-id rate :



W Charge Asymmetry

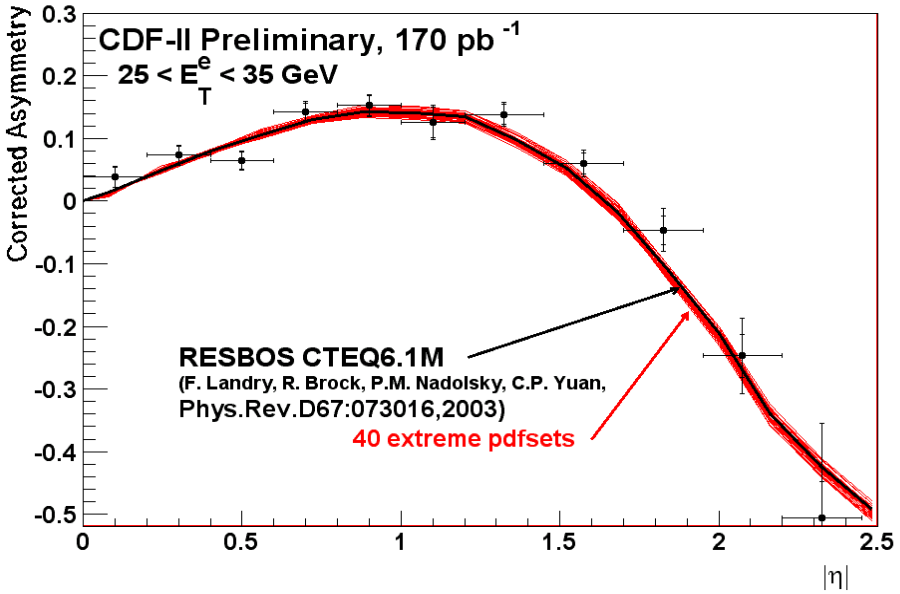


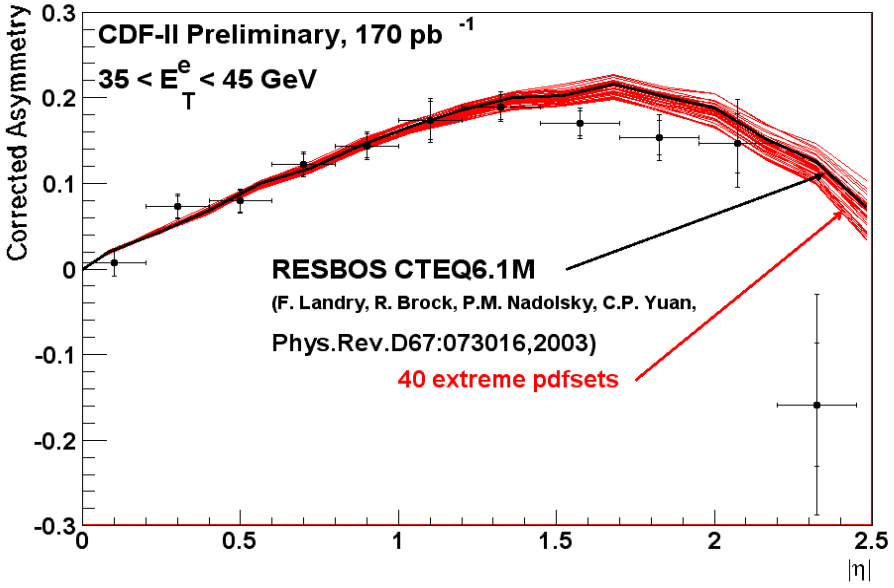
- Decay asymmetry enhanced.



- $\eta_e \rightarrow y_W$ as $E_T \uparrow$
- Production asymmetry enhanced.
- Different **x** region probed.

W Charge Asymmetry



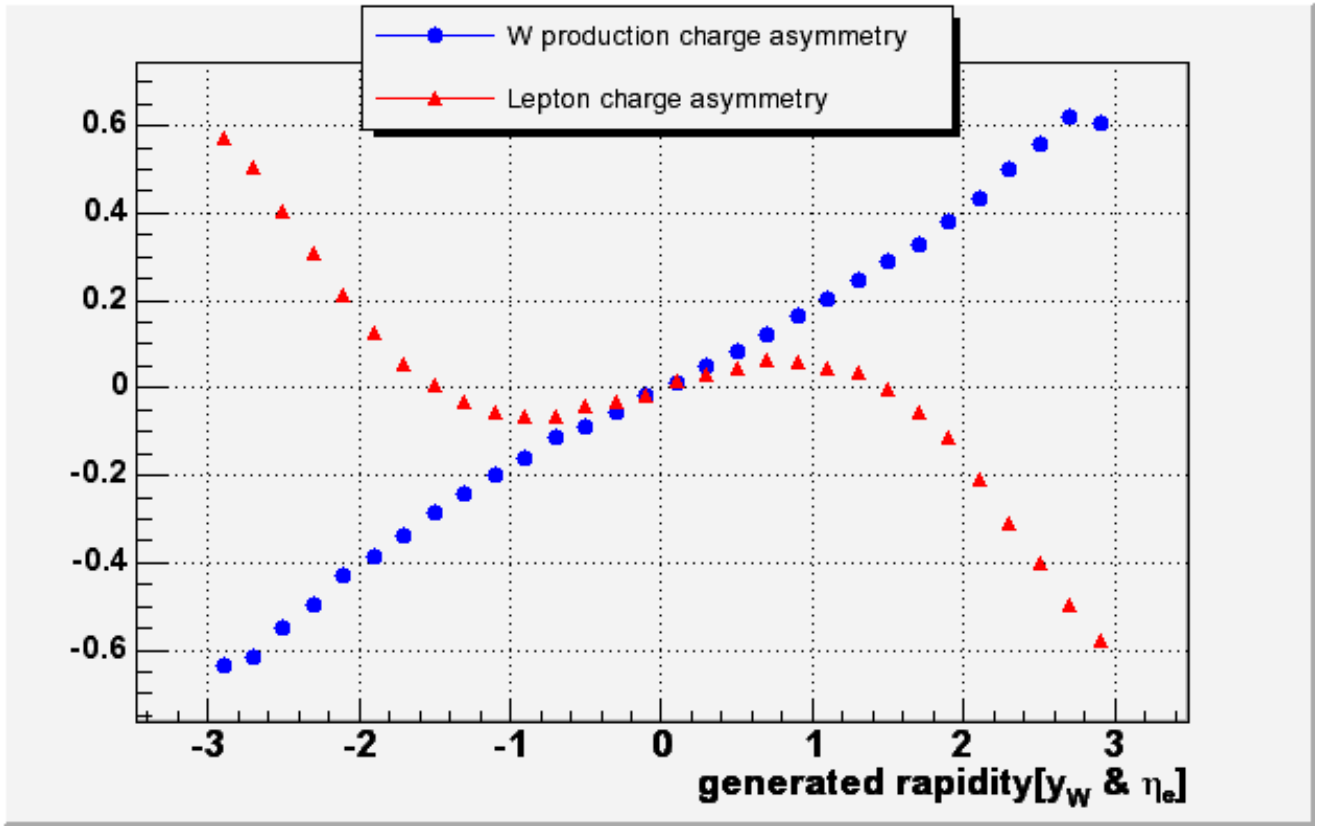


Comparison with error PDF's

W Charge Asymmetry : New Approach

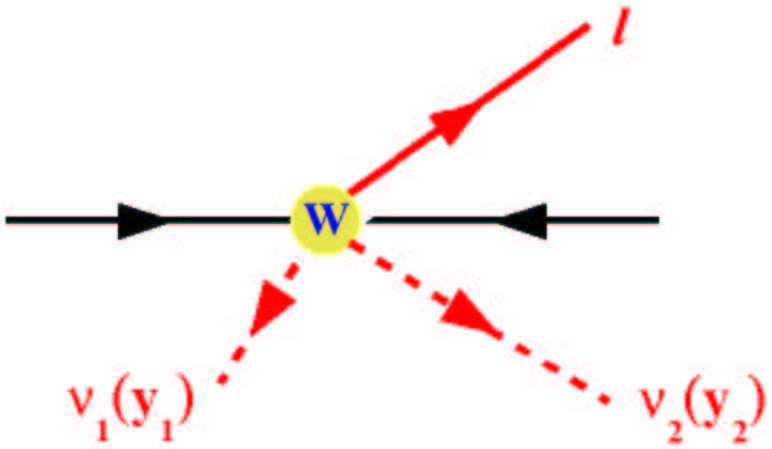
B. Han, A. Bodek, Y. Chung, E. Halkiadakis, K. McFarland (U.Rochester)

- Next logical step : exploit kinematic value of events to their full.
- Attempt to reconstruct y_W and measure production asymmetry directly.



W Charge Asymmetry : New Approach

- Unknown $p_z(\nu)$: reconstruct two solutions y_1, y_2 :



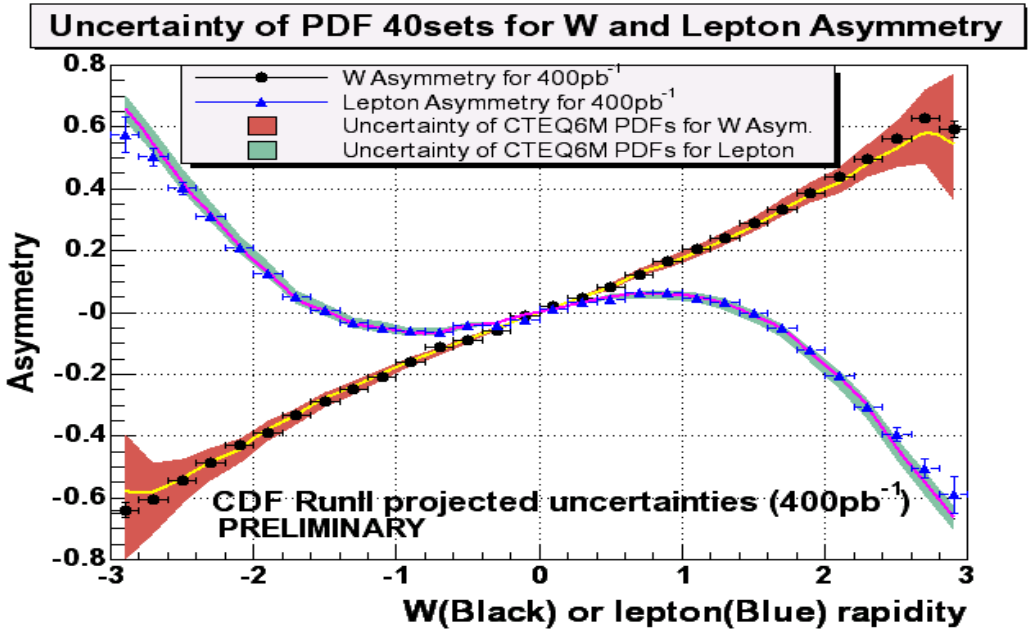
$$P_{\pm}(\cos\theta^*; y_W; p_T^W) = (1 \mp \cos\theta^*)^2 + Q(y_W, p_T^W)(1 \pm \cos\theta^*)^2$$

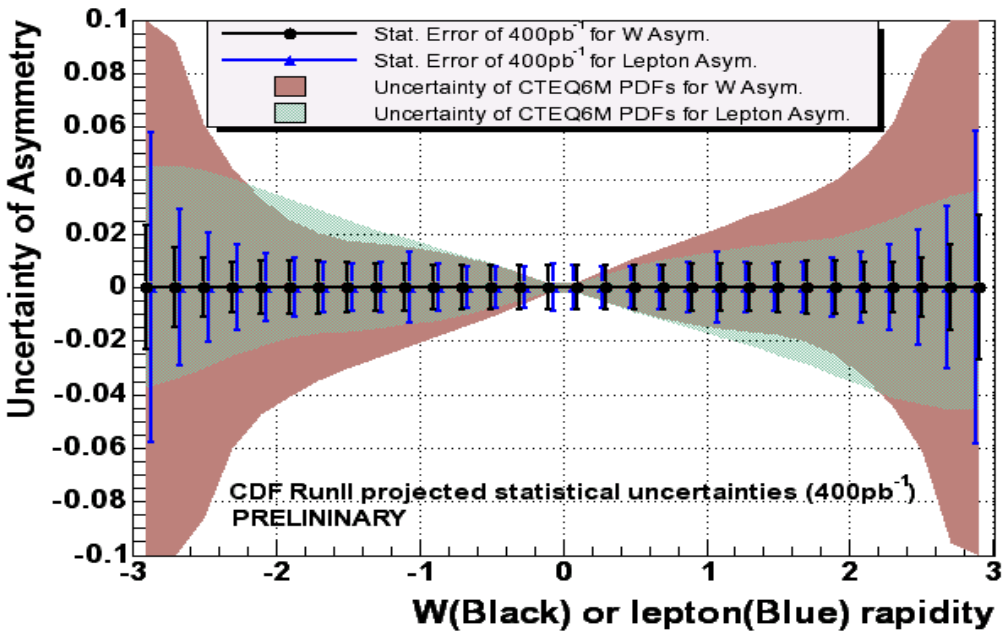
$\bar{q}(p) / q(p)$ production ratio (from MC)

- Weight each solution by $\sigma(y)$ and iterate for the asymmetry :

$$F^{\pm}_{1.,2} = \frac{P_{\pm}(\cos\theta^*_{1,2}; y_{1,2}; p_T^W)\sigma_{\pm}(y_{1,2})}{P_{\pm}(\cos\theta^*_1; y_1; p_T^W)\sigma_{\pm}(y_1) + P_{\pm}(\cos\theta^*_2; y_2; p_T^W)\sigma_{\pm}(y_2)}$$

W Charge Asymmetry : New Approach



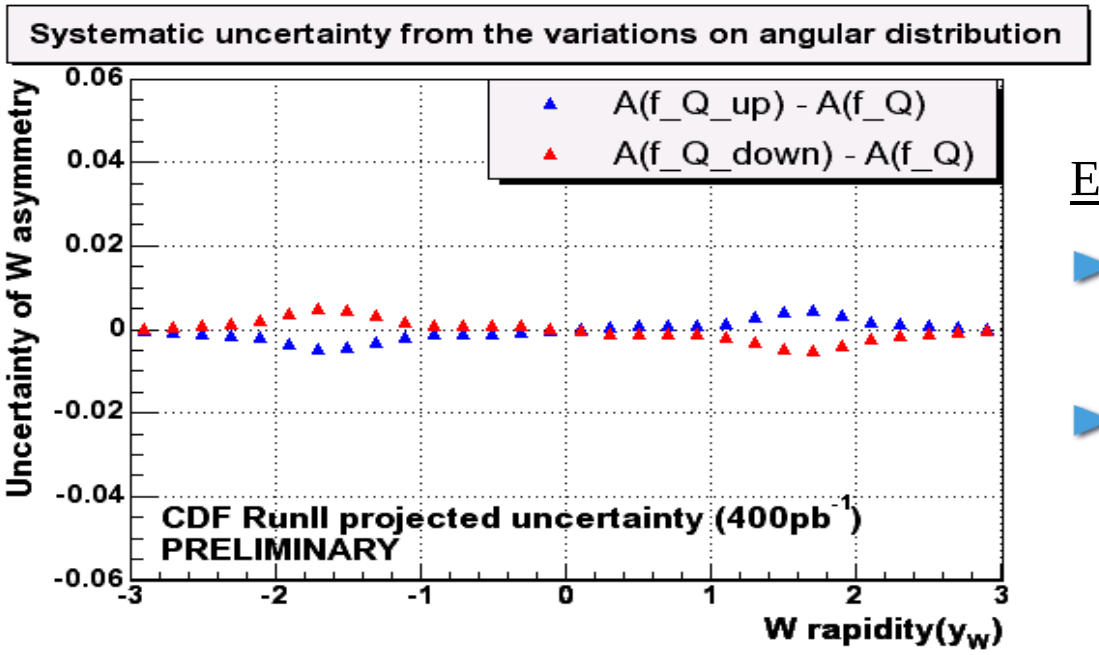


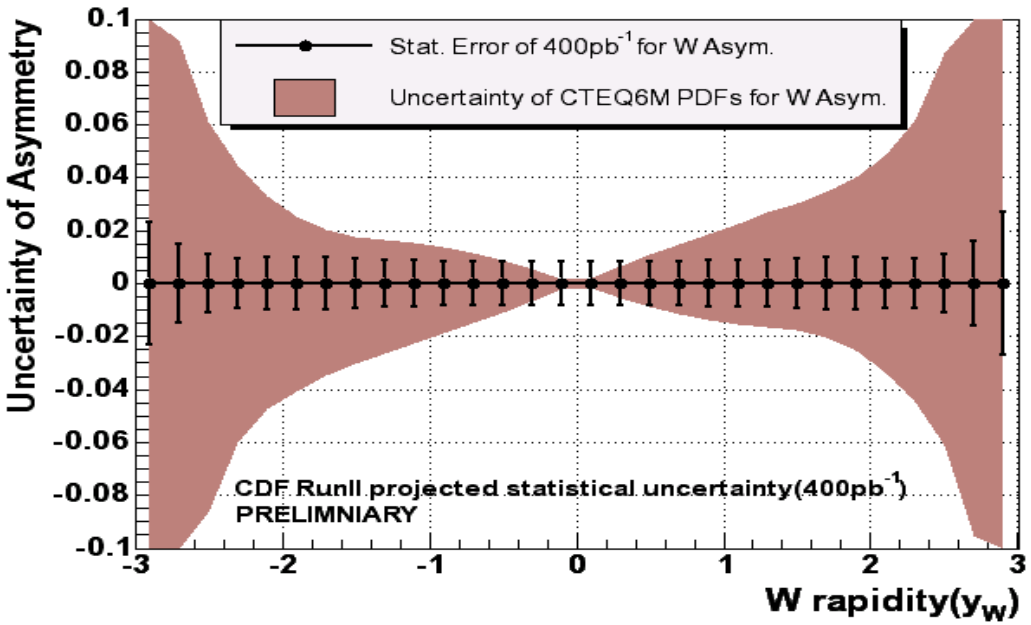
[$E_T(e) > 25$ GeV; missing-$E_T > 25$ GeV; standard ID cuts; $400pb^{-1}$]

Preliminary sensitivity study :

- Production charge asymmetry can be directly measured.
- Statistical precision improved over lepton asymmetry measurement.
- No known large additional systematics due to the method (charge mis-id will likely dominate).
- [Correlations present in new method : quantitative analysis of PDF sensitivity in progress]

W Charge Asymmetry : New Approach





Example :

- Dependence of $\bar{q}/q$ ratio on PDF's.
- $\leq 0.5\%$ (compared to few % charge mis-id)
- 400 pb^{-1} measurement should significantly constrain PDF's.

Other W/Z Measurements

- Cross sections :
  - $\sigma(W\rightarrow e\nu)$ using forward electrons.
- Tau's :
  - $\sigma(W\rightarrow\tau\nu)$ and $\sigma(W\rightarrow\tau\nu)/\sigma(W\rightarrow e\nu)$
  - $\sigma(Z/\gamma^*\rightarrow\tau(l)\tau(h))$
- Differential cross-section measurements :
  - $d\sigma(Z/\gamma^*\rightarrow l^+l^-)/dp_T$
  - $d\sigma(Z/\gamma^*\rightarrow l^+l^-)/dy$
  - $d^2\sigma(Z/\gamma^*\rightarrow l^+l^-)/dp_T dy$ (?)
- $A_{FB}(Z)$: neutral current couplings; Z' searches. Second generation analyses under way (new methods).
- Diboson measurements :
  - Complete set of cross-section measurements ($W\gamma$, $Z\gamma$, WW) or limits (WZ,ZZ) using leptonic decay channels.
  - Anomalous coupling limits from $W\gamma$, $Z\gamma$, $WW\rightarrow l\nu l\nu$, $WW/WZ\rightarrow l\nu jj$
  - Starting work on more challenging channels : $WZ\rightarrow l\nu bb$, $ZZ/ZW\rightarrow l^+l^-jj$

Conclusions

- First round of inclusive cross-section measurements mostly complete.
- Now focusing on optimising analysis methods for the most interesting physics :
  - R $\rightarrow$ width
  - Asymmetry $\rightarrow$ PDF's
  - τ/e $\rightarrow$ universality
- Some smart ideas !
- PDF and other production uncertainties can eventually limit precision measurements such as M_W. Still need to understand quantitatively how Tevatron measurements themselves (asymmetries, $d\sigma/dp_T$, etc.) can reduce such uncertainties.