W Charge Asymmetry at CDF

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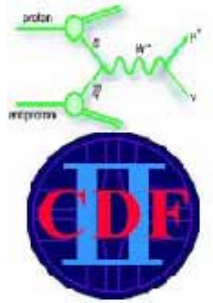
on behalf of CDF collaboration

Ph.D. thesis of Bo-Young Han

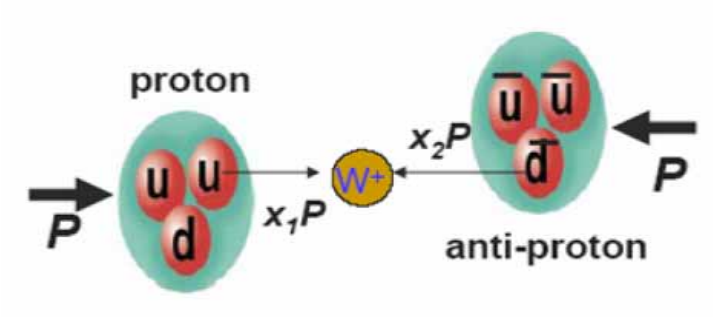
DIS 2008, UC-London, 8 April 2008

Outline



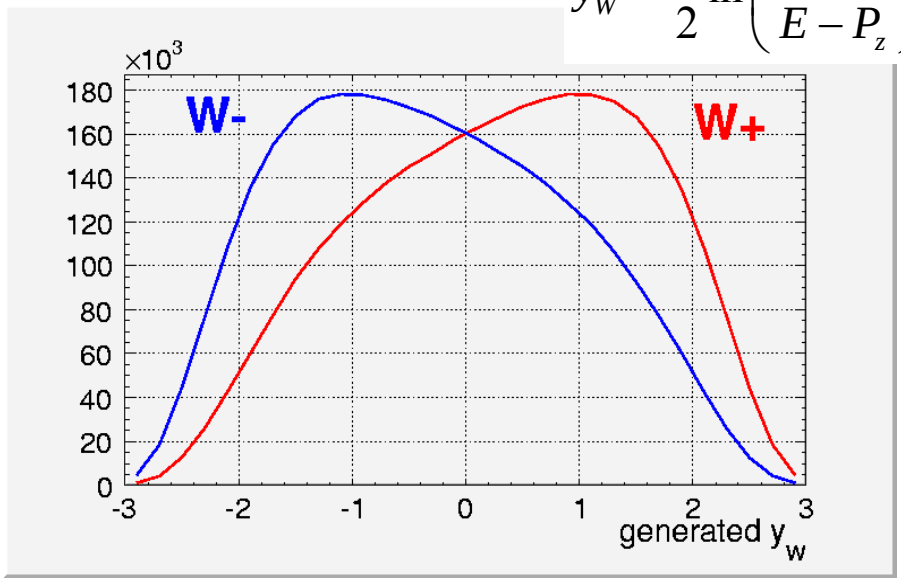
- Introduction and Analysis Technique
- Signal, Backgrounds and Corrections
- Uncertainties
- Preliminary results

W Charge Asymmetry and PDFs



- At Tevatron, $W^{\pm}$ are produced primarily by u_{proton} $(\bar{d}_{anti\text{-}proton})$ and $\bar{u}_{anti\text{-}proton}$ (d_{proton})

$$y_W = \frac{1}{2}\ln\left(\frac{E+P_z}{E-P_z}\right)$$



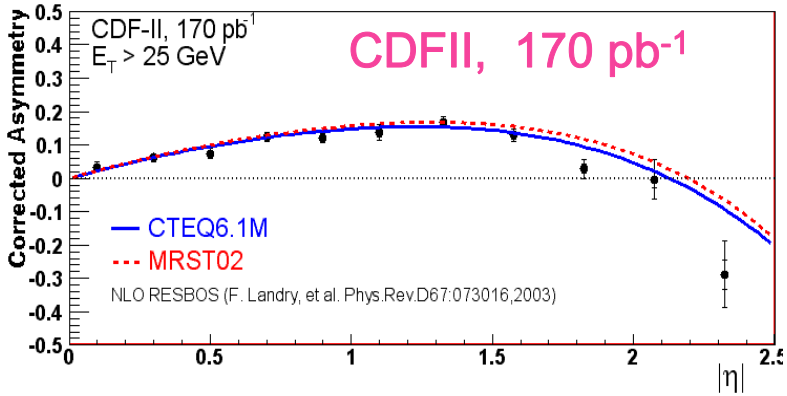
W charge Asymmetry

$$A(y_W) = \frac{d\sigma_+/dy_W - d\sigma_-/dy_W}{d\sigma_+/dy_W + d\sigma_-/dy_W} \approx \frac{u(x_+)d(x_-) - d(x_+)u(x_-)}{u(x_+)d(x_-) + d(x_+)u(x_-)}$$

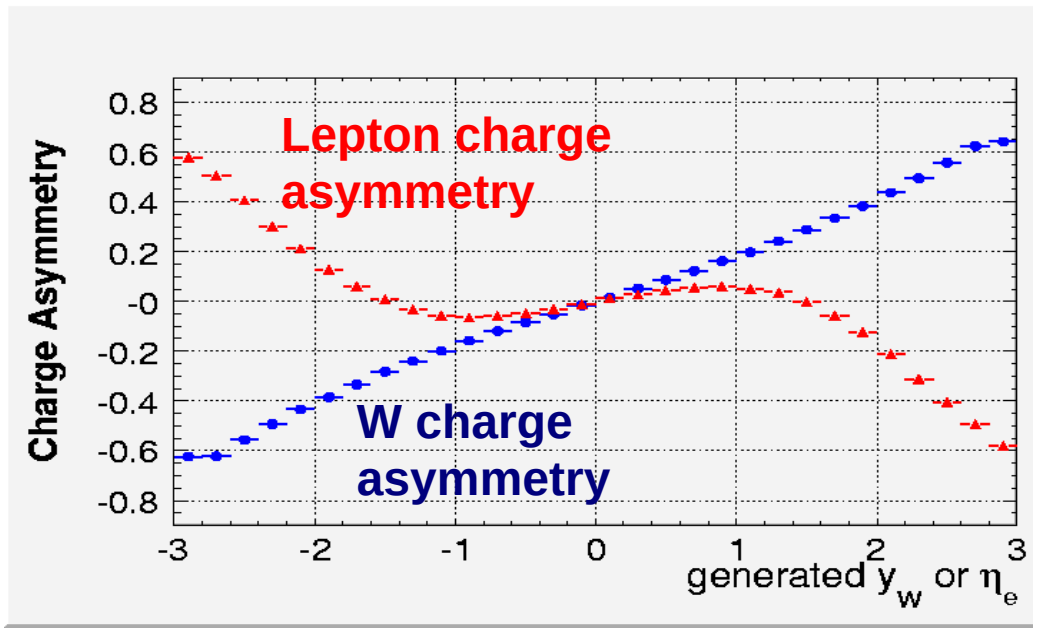
$$\text{where } x_\pm = \frac{M_W}{\sqrt{s}} e^{\pm y_W}$$

- *u* quarks carry more momentum than *d* quarks

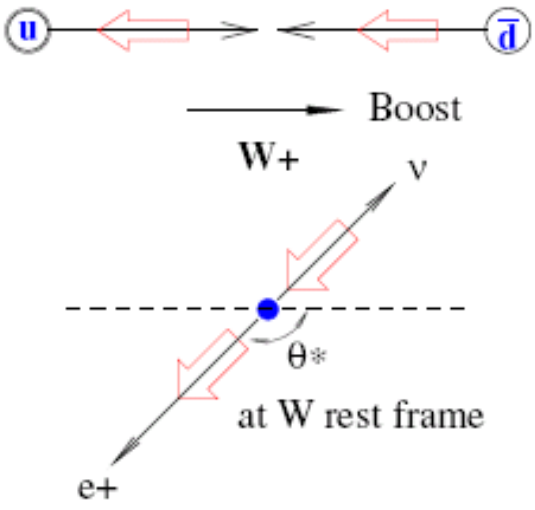
Lepton Charge Asymmetry

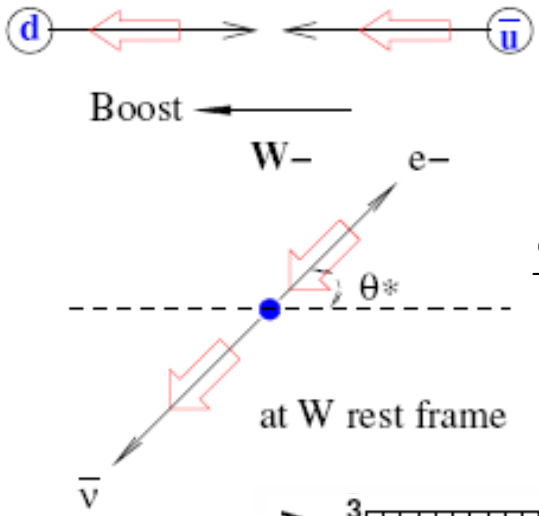


- Previous work from TeVatron has measured the charge asymmetry vs. lepton pseudorapidity (η) in $W \to \ell\nu$
- This observable is a convolution of the ***W*** charge asymmetry and V-A ***W*** decay angular distribution



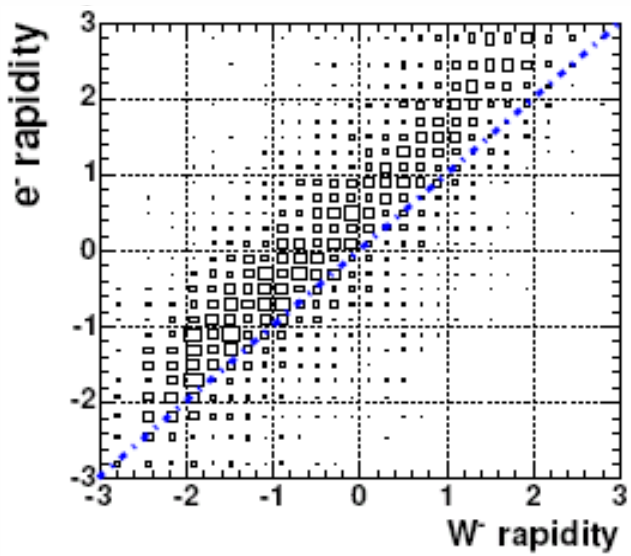
Lepton and W Rapidity





$$\frac{d\Gamma(W \to e^{\pm}\nu)}{d\theta^*} \propto \left(1 \mp \cos\theta^*\right)^2$$

- Lepton prefers to decay against boost



Analysis Technique

- Measure $W^{\pm}$ rapidity ⇒ $y_W = \frac{1}{2}\ln\left(\frac{E+P_z}{E-P_z}\right)$ $\quad \overrightarrow{P_z^W} = \overrightarrow{P_z^l} + \overrightarrow{P_z^\nu}$

  can't measure !!!

- Use W mass constraint
  solve eqn. $M_W^2 = (E_l + E_\nu)^2 - (\overrightarrow{P_l} + \overrightarrow{P_\nu})^2$ answer : $P_{z1}^\nu,\ P_{z2}^\nu$

- Weight the two solutions

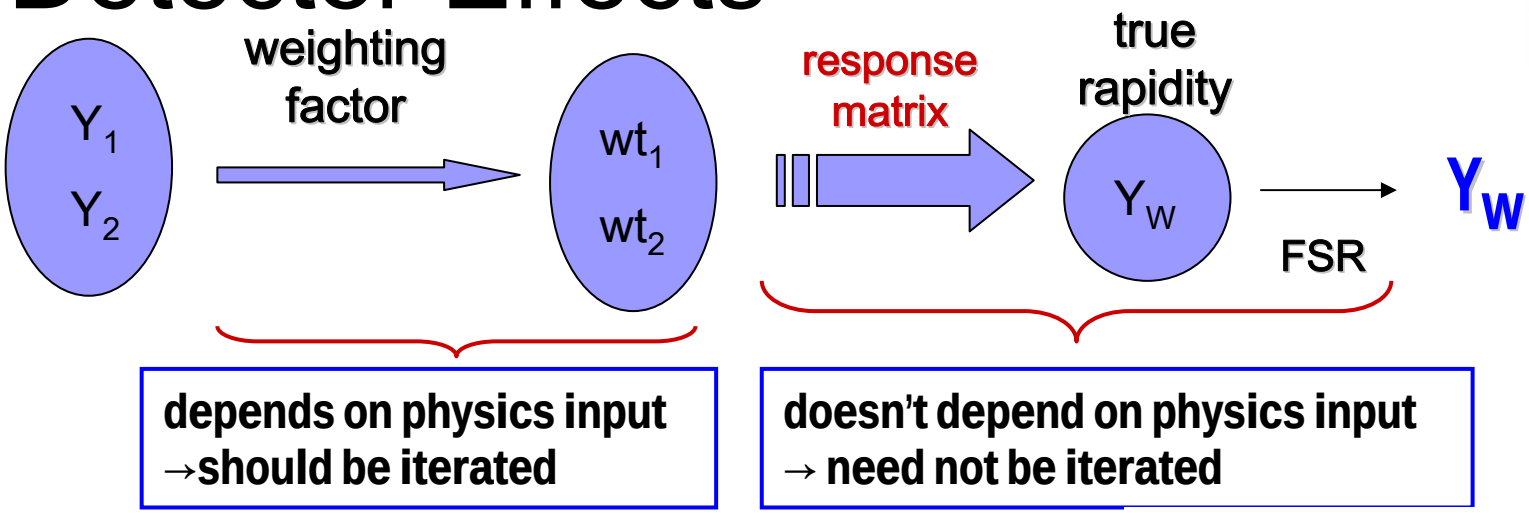
  Probability of angular distribution

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

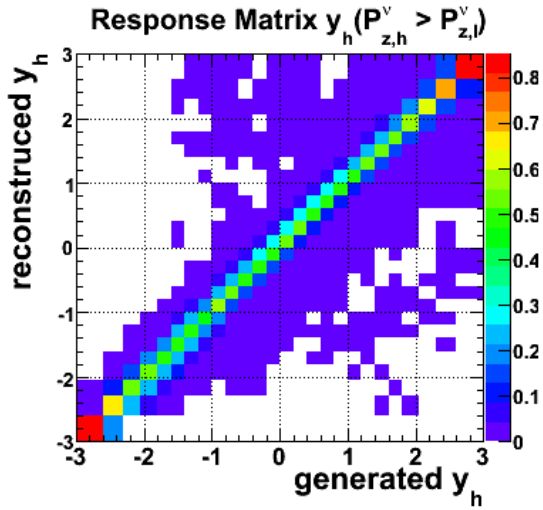
Differential W cross section

- This method must be iterated to remove input bias
  - *shown it does not depend on assumed charge asymmetry*

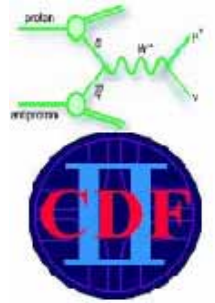
Complications: Detector Effects



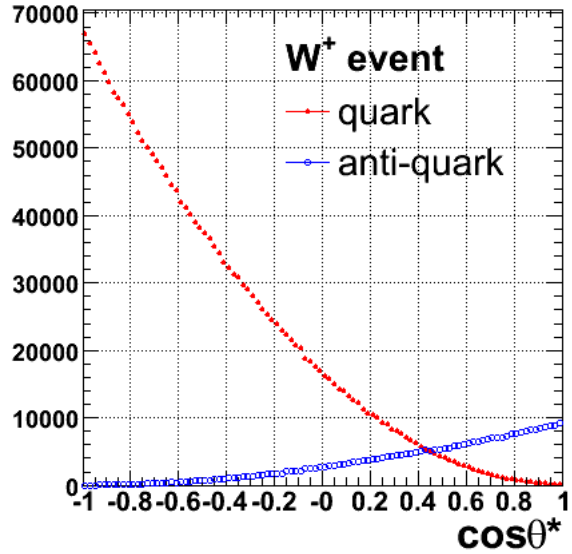
- Response matrix showing the acceptance, smearing and final state effects
  - QED, $W \rightarrow \tau\nu \rightarrow e\nu\nu\nu$



Complications: W Production from the sea

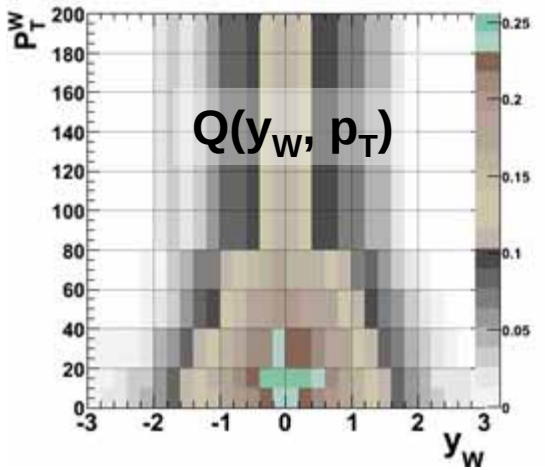


- Sign of V-A angular bias flips when $W^{\pm}$ is produced from anti-quarks
  - take this fraction as an input

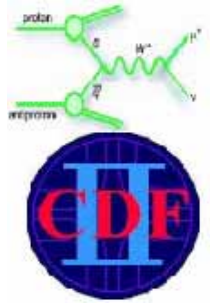


$$P_{\pm}(\cos\theta^*, y_W, p_t^W) = \underbrace{(1 \mp \cos\theta^*)^2}_{q<P>+\bar{q}<\bar{P}>} + Q(y_W, p_t^W)\underbrace{(1 \pm \cos\theta^*)^2}_{\bar{q}<P>+q<\bar{P}>}$$

ratio of two angular distributions at each rapidity



What is input, and what is measured?



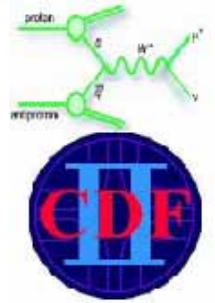
- Inputs from theory:
  - $\frac{\bar{u}+\bar{d}}{u+d}$ and $\frac{d\sigma(p\bar{p}\to W^+X)}{dy_W}+\frac{d\sigma(p\bar{p}\to W^-X)}{dy_W}$

- Output from iteration:

$$A\left(y_W\right)=\frac{\frac{d\sigma(p\bar{p}\to W^+X)}{dy_W}-\frac{d\sigma(p\bar{p}\to W^-X)}{dy_W}}{\frac{d\sigma(p\bar{p}\to W^+X)}{dy_W}+\frac{d\sigma(p\bar{p}\to W^-X)}{dy_W}}$$

method documented in B.Y.Han *et al.*, arXiv:hep-ph/0711.2859

Outline



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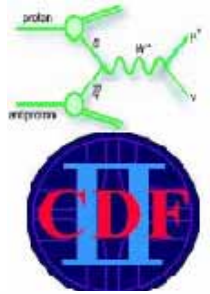
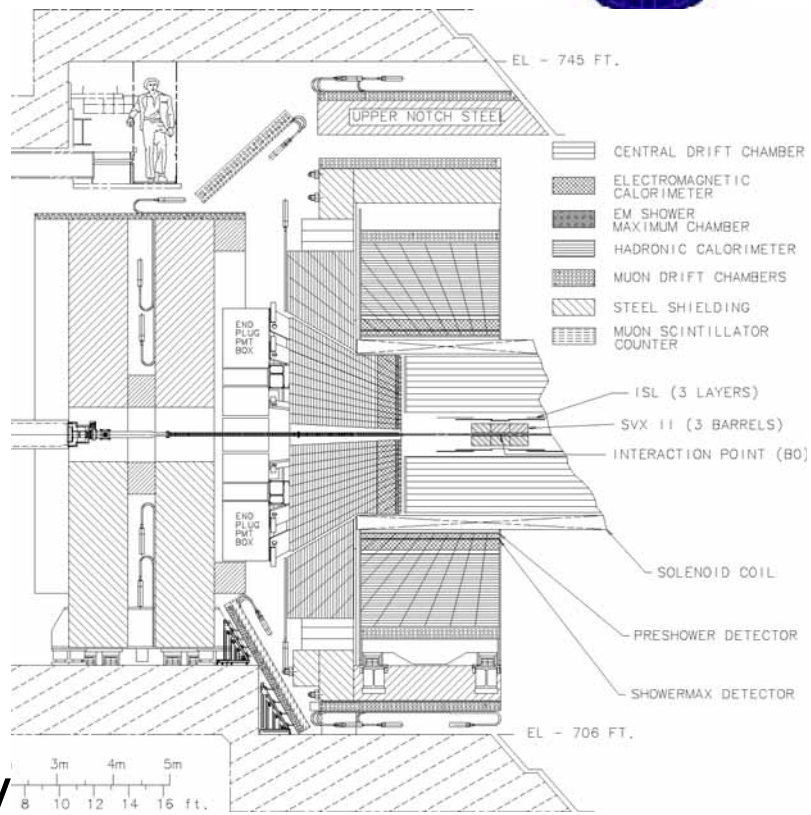
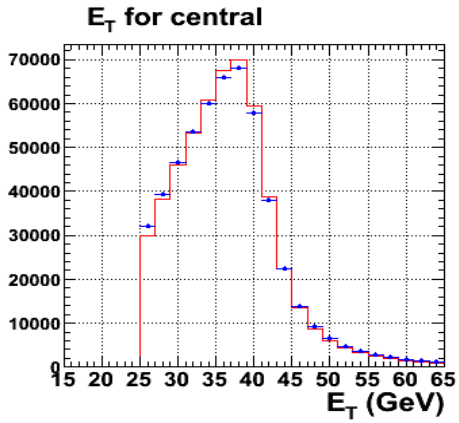
Summary of Data Issues

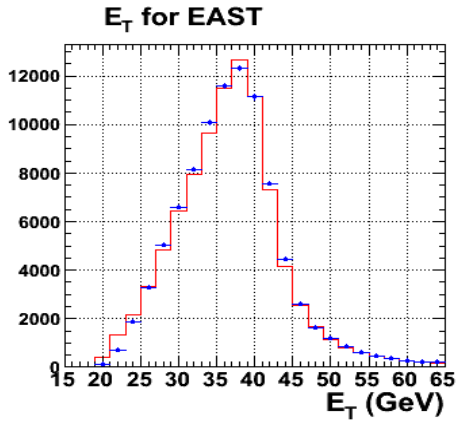


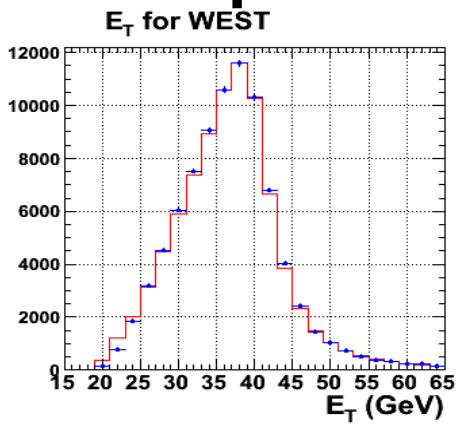
- Require one high E_T electron and missing E_T to tag the neutrino
  - E_T^e>25(20) GeV in central (plug) detector
  - missing E_T>25 GeV
- Detector response, including missing E_T, tuned on $Z \rightarrow e^+e^-$ sample
- Highlight backgrounds (primarily jets faking electrons) and charge mis-measurement
  - also, trigger and detector acceptance and smearing

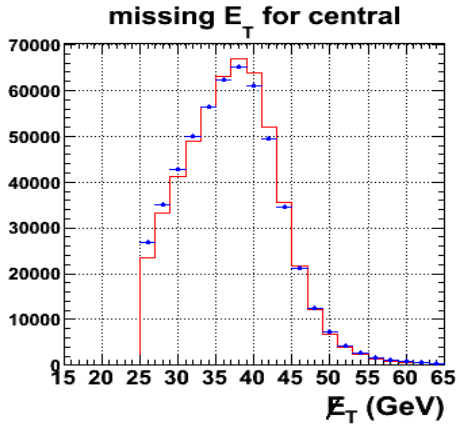


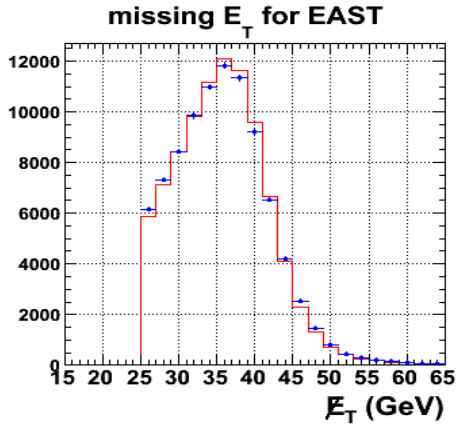
Data and Simulation Kinematic Distributions, W→ev Sample

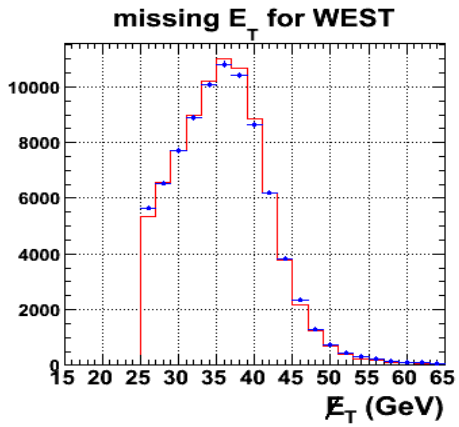












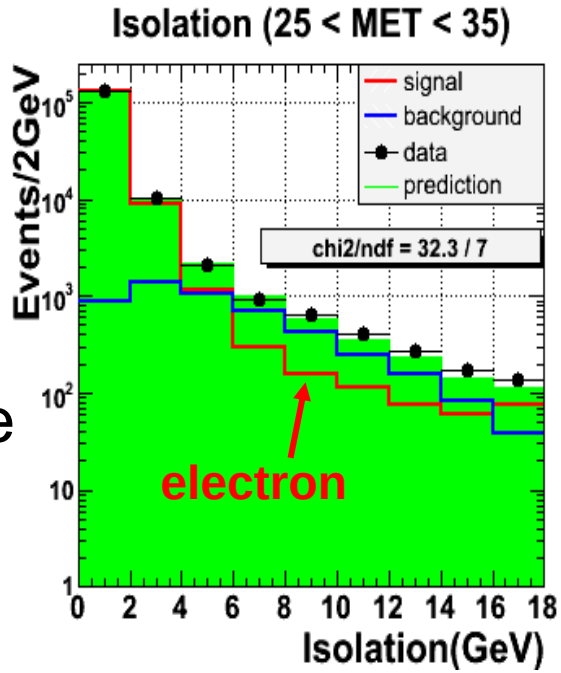
Red : MC

Blue : data

- Scale and resolution tuned on $Z \rightarrow e^+e^-$

Backgrounds

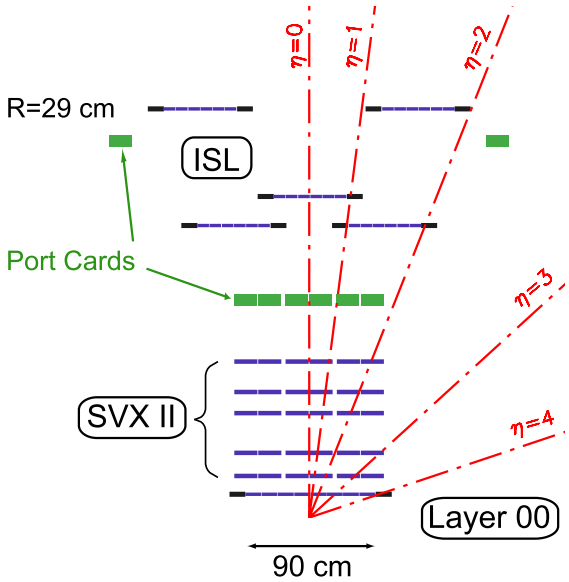
- Measure jet backgrounds directly in data
  - use extra energy “isolation” around electron to separate, and fit shape to background fraction
- Illustrative fit (one of many) shown at right
  - use jet sample to predict measured “y_W” and charge from this sample
  - uncertainty is ~0.15% of total sample
- A number of minor backgrounds (real *W*s) from simulation

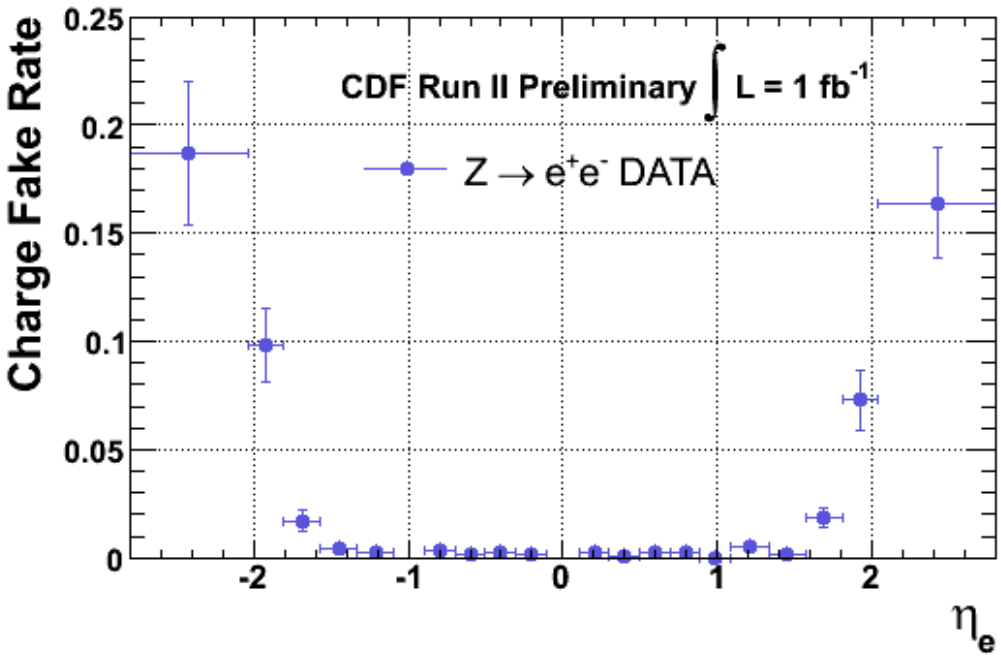


Electron Charge Identification

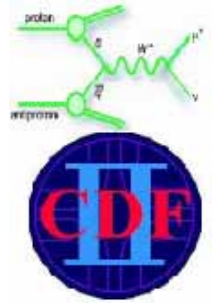
- Charge identification is crucial for this measurement
- Forward tracking has fewer points at shorter lever arm
- Determine directly from (background subtracted)

$$f_{mis} = \frac{N_{\text{same sign}}}{N_{\text{opposite sign}} + N_{\text{same sign}}}$$





Outline



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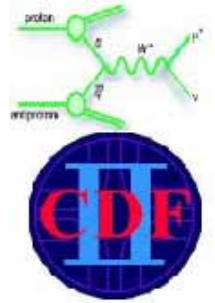
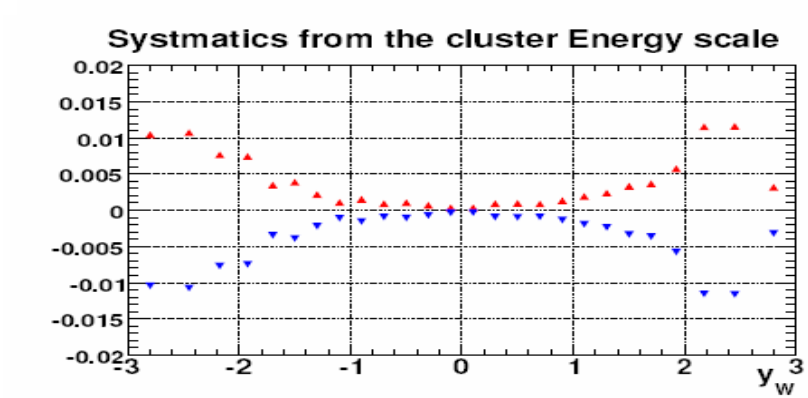
Systematic Effects



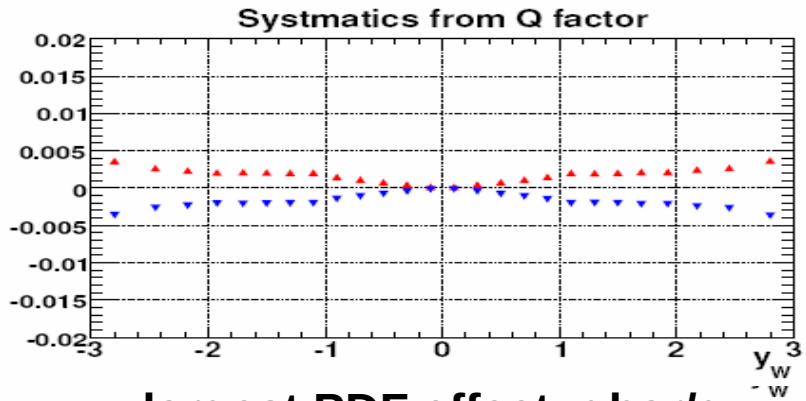
- Detector response
  - energy scale and smearing for electron and recoil
  - efficiency to find electron and pass missing E_T cut
- Inputs
  - PDF uncertainties (CTEQ6 PDF error sets) for total *W* production and quark/anti-quark fractions

Evaluation

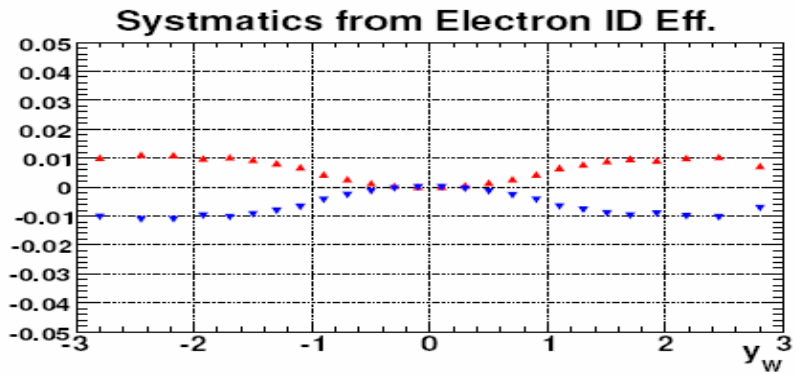
- Derive result with shifted parameters
- Systematics dominate only if y_W<0.2 or >2.6



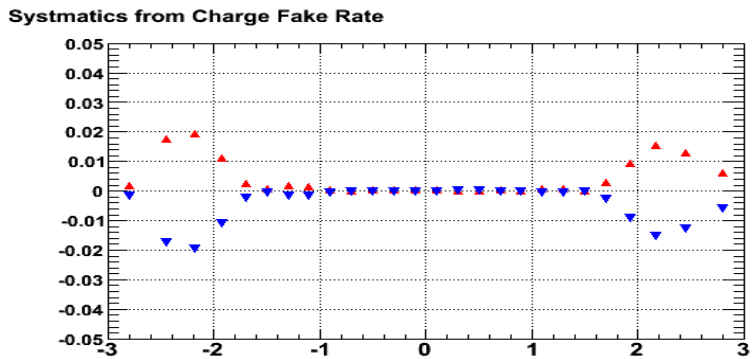
largest detector effect: energy scale



largest PDF effect: qbar/q

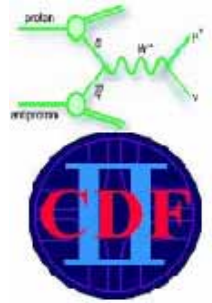


largest selection effect: elec. cuts



charge fake rate uncertainty

Outline



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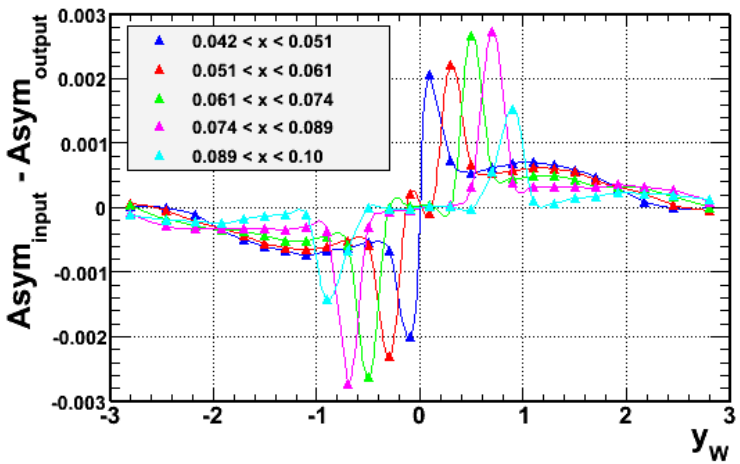
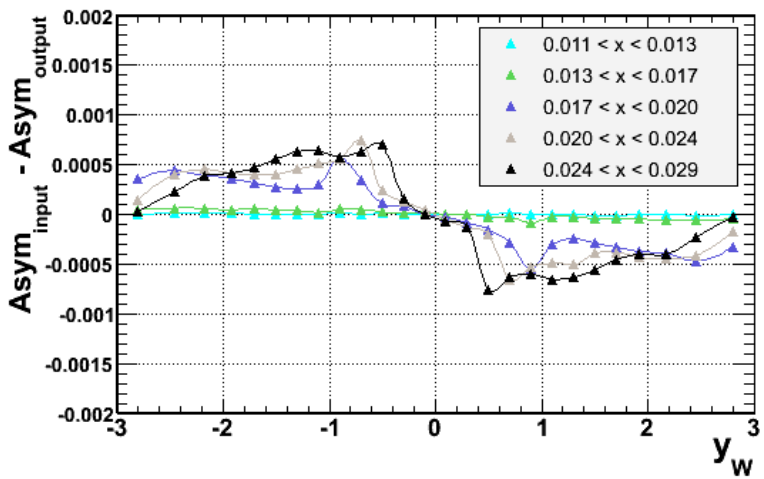
Input PDFs

- We are in the process of documenting how result depends on input PDFs
  - PDF fitters can explicitly put this in (or ignore if small)

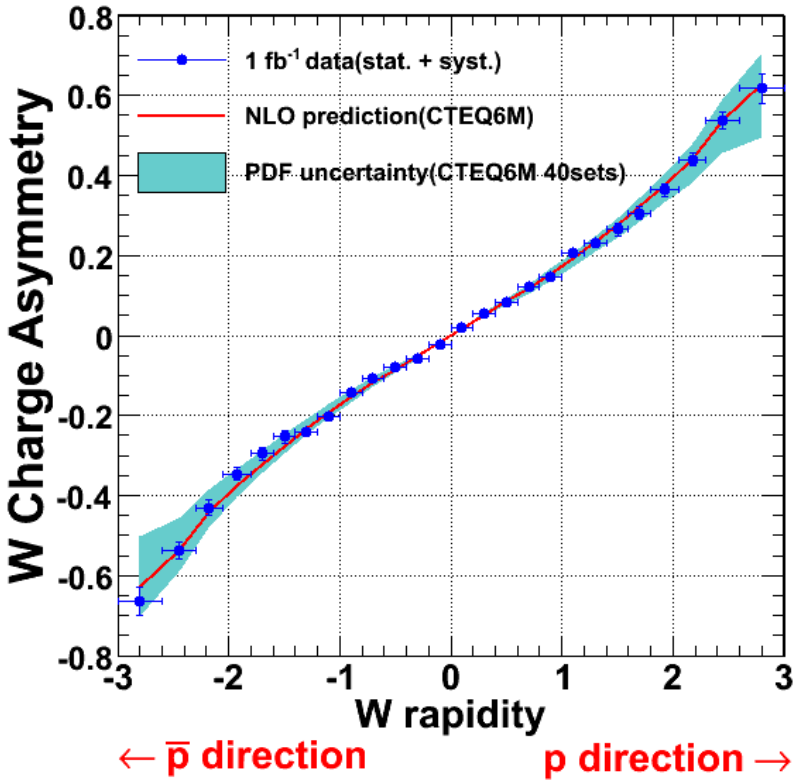


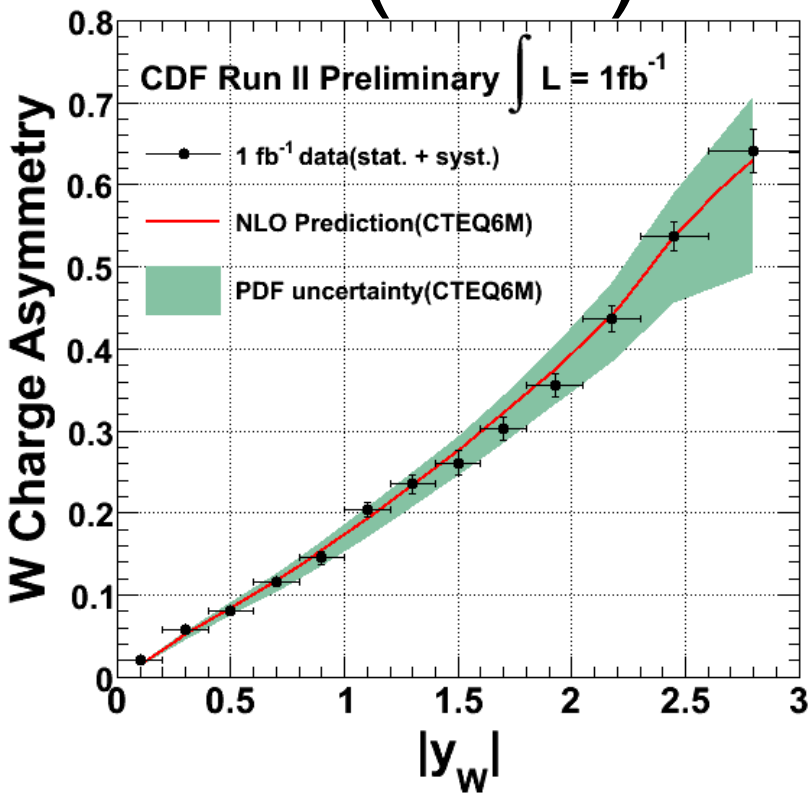
effect of increasing valence u+d by +5%



effect of increasing sea u+d by +5%

CDF Preliminary Result (1fb^{-1})

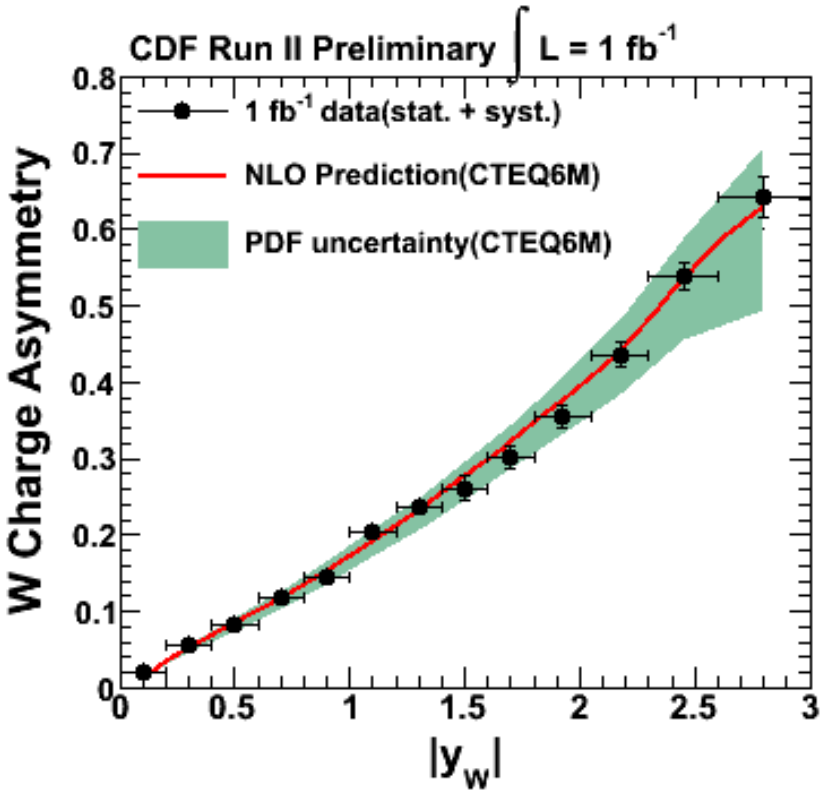


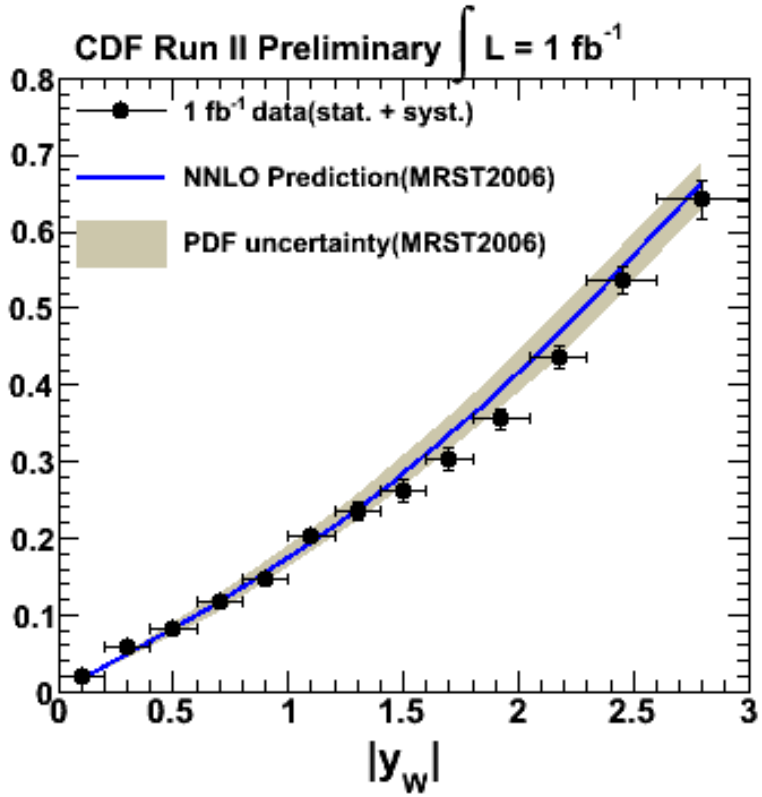


- Systematics correlated bin-to-bin.. show as a band
- Positive and negative y_W agree, so fold
  - Compared to NNLO (MRST) w/ NLO error PDF band (CTEQ)

CDF Preliminary Result (1fb^{-1})

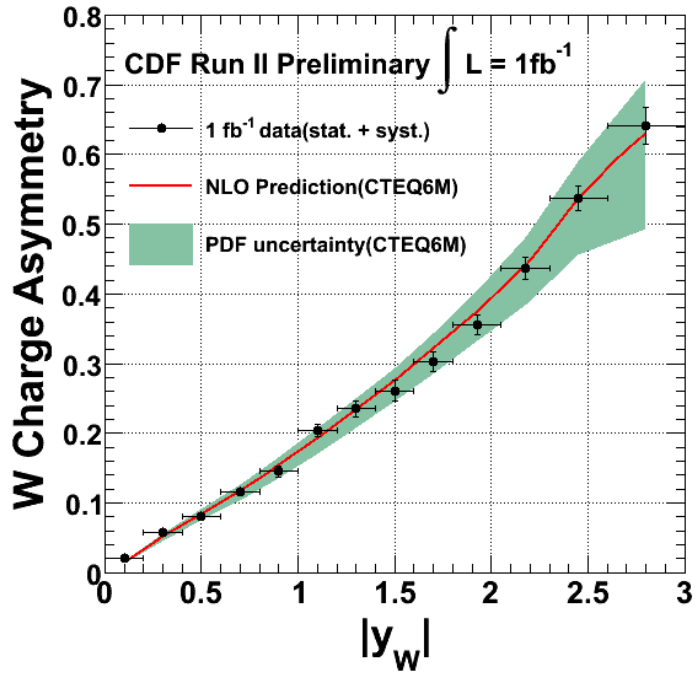
- Compare CTEQ6M and MRST2006 with PDFs and their uncertainties





Conclusions

- First direct measurement of *W* charge asymmetry
  - despite additional complication of multiple solutions, it works!
  - appears that it will have impact on *d/u* of proton
- Looking forward to working with PDF fitting groups to incorporate



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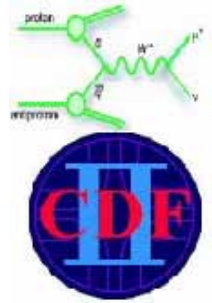

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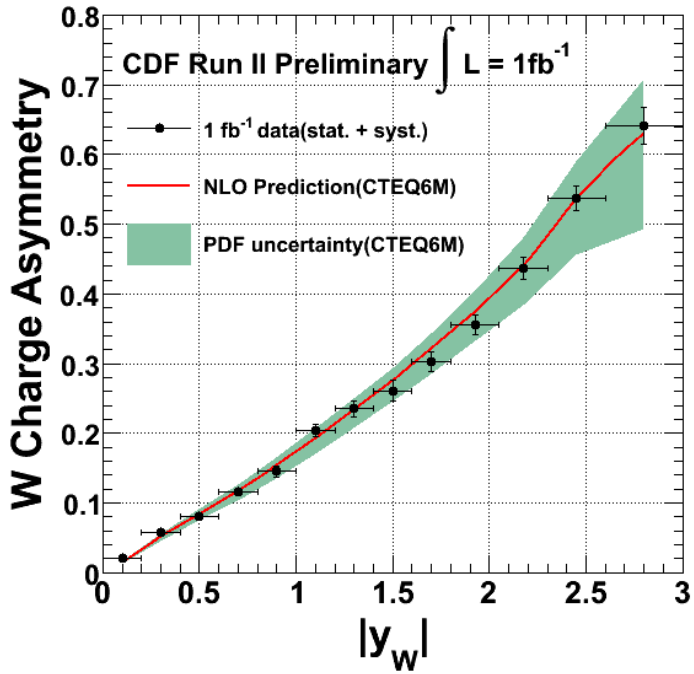
Results

$\lvert y_W \rvert$	$A(y_W)$	σ_{sys}	$\sigma_{sys+stat}$
0.0 - 0.2	0.0199	$\pm$0.0013	$\pm$0.0034
0.2 - 0.4	0.0571	$\pm$0.0027	$\pm$0.0042
0.4 - 0.6	0.0813	$\pm$0.0037	$\pm$0.0049
0.6 - 0.8	0.1168	$\pm$0.0055	$\pm$0.0063
0.8 - 1.0	0.1456	$\pm$0.0072	$\pm$0.0079
1.0 - 1.2	0.2040	$\pm$0.0084	$\pm$0.0092
1.2 - 1.4	0.2354	$\pm$0.0109	$\pm$0.0118
1.4 - 1.6	0.2613	$\pm$0.0143	$\pm$0.0151
1.6 - 1.8	0.3027	$\pm$0.0135	$\pm$0.0144
1.8 - 2.05	0.3553	$\pm$0.0126	$\pm$0.0141
2.05 - 2.3	0.4363	$\pm$0.0134	$\pm$0.0158
2.3 - 2.6	0.5374	$\pm$0.0136	$\pm$0.0178
2.6 - 3.0	0.6415	$\pm$0.0116	$\pm$0.0260



Systematics

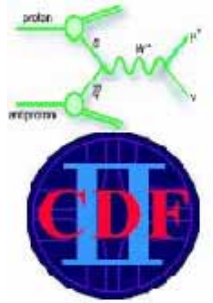
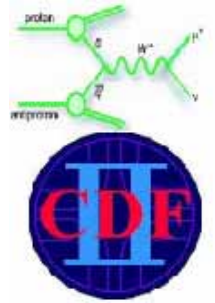


Table 1: Systematic uncertainties for the W production charge asymmetry. The values shows the correlated uncertainties for both positive and negative rapidities.

$\lvert y_W \rvert$	$\Delta A(\lvert y_W \rvert)$ ($\times 10^{-2}$)							Stat.
	CFR	BKG	EM	Recoil	Trig	ID	PDF	(1fb^{-1})
0.0 - 0.2	0.02	0.04	0.01	0.11	0.03	0.02	0.03	0.31
0.2 - 0.4	0.01	0.09	0.04	0.22	0.08	0.07	0.08	0.32
0.4 - 0.6	0.02	0.11	0.06	0.22	0.13	0.17	0.15	0.33
0.6 - 0.8	0.03	0.15	0.07	0.34	0.14	0.30	0.22	0.32
0.8 - 1.0	0.03	0.20	0.07	0.42	0.11	0.47	0.24	0.34
1.0 - 1.2	0.04	0.18	0.08	0.33	0.09	0.69	0.27	0.38
1.2 - 1.4	0.05	0.18	0.15	0.67	0.06	0.78	0.28	0.43
1.4 - 1.6	0.04	0.14	0.14	1.10	0.04	0.85	0.28	0.50
1.6 - 1.8	0.08	0.12	0.26	0.92	0.03	0.89	0.29	0.55
1.8 - 2.05	0.22	0.13	0.31	0.82	0.06	0.80	0.34	0.62
2.05 - 2.3	0.44	0.21	0.53	0.59	0.17	0.85	0.42	0.83
2.3 - 2.6	0.45	0.19	0.62	0.40	0.27	0.86	0.50	1.10
2.6 - 3.0	0.14	0.10	0.60	0.43	0.28	0.65	0.53	2.30

NNLO K-factor: $(d\sigma^{NNLO}/dy_W)/(d\sigma^{LO}/dy_W)$



- NNLO $d\sigma^{\pm}/dy_W$ (mrst2002 PDFs) from theoretical prediction.