W and Z Production at the Tevatron

ICHEP2006, Moscow

27th July 2006

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For the DØ and CDF Collaborations

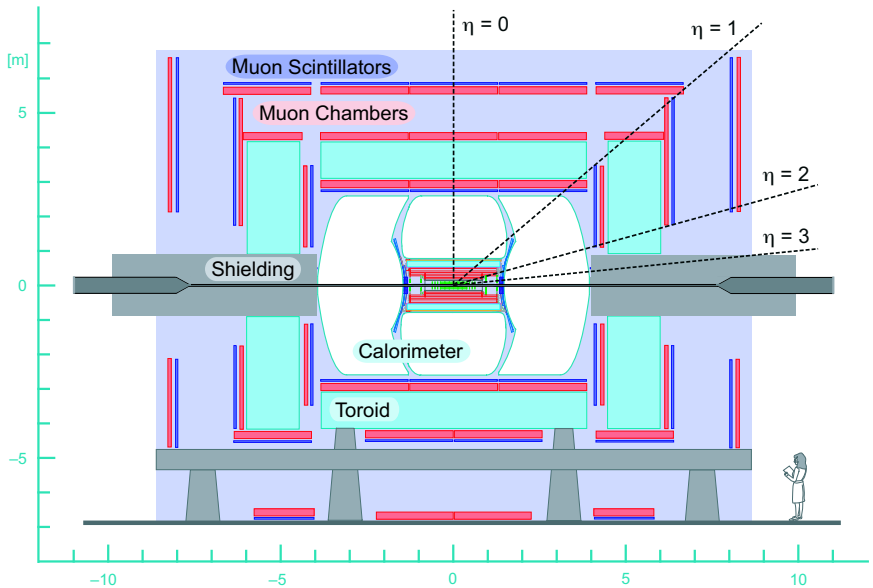
Outline

- Tevatron
- Inclusive W & Z production cross sections
- W charge asymmetries
- Z rapidity
- Conclusion & Outlook

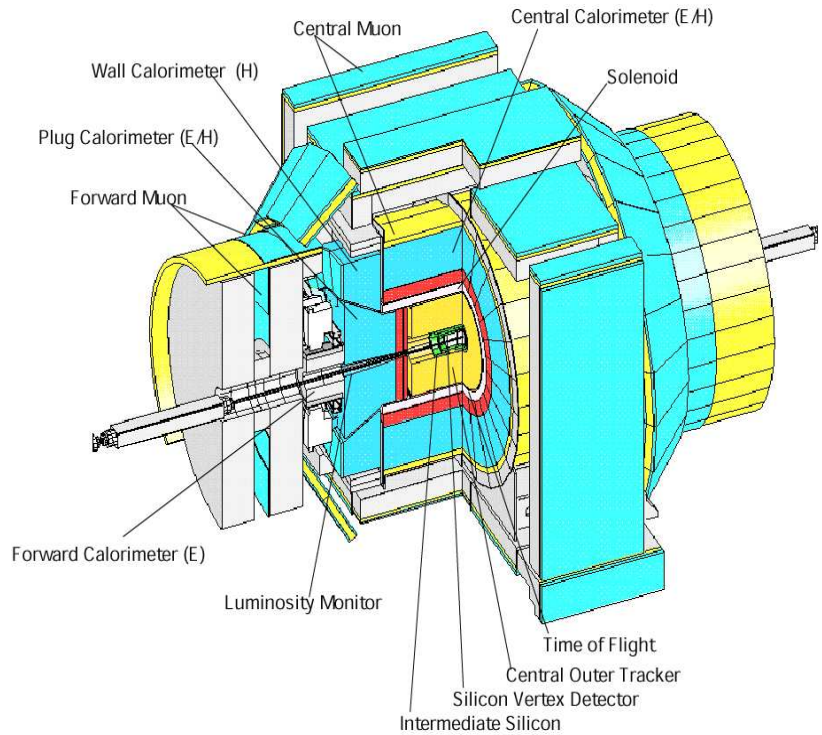
Tevatron

- $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
- Up to now: $\int \mathcal{L} dt \simeq 1.5$ fb^{-1} delivered / experiment
- Results shown in this talk: up to 350 pb^{-1}

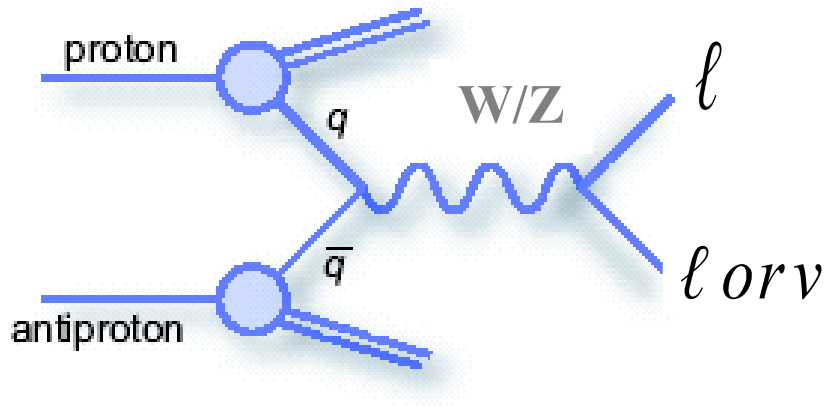
DØ



CDF

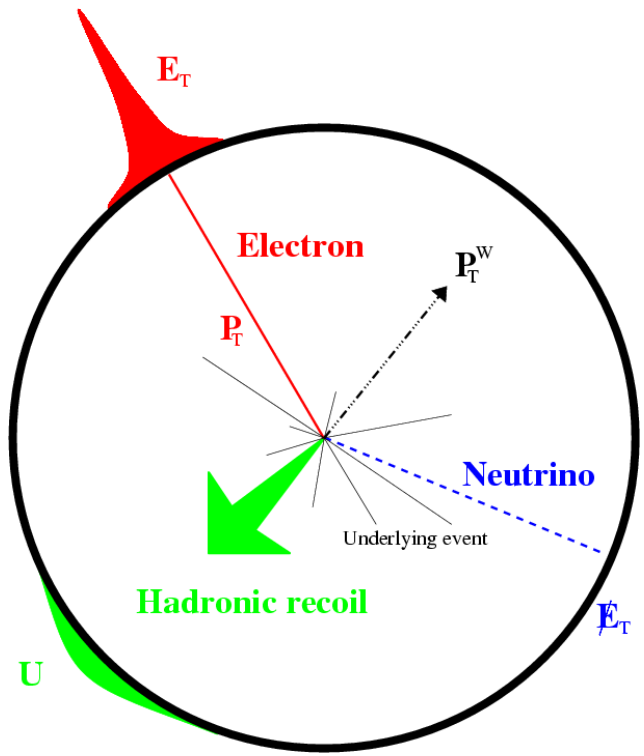


W & Z Production



- Test QCD at NNLO
- Probe PDF's
- W & Z production properties ($\rightarrow m_{\mathrm{W}}$ measurement)
- Benchmark for other measurements
- Luminosity measurement ($\rightarrow$ LHC)

W Experimental Signature

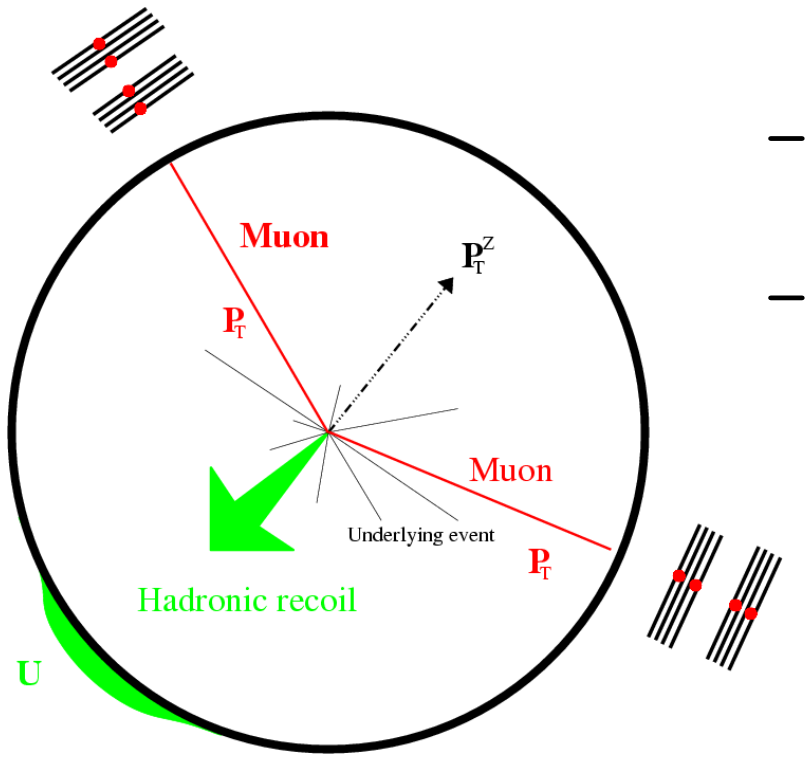


- Single lepton, $p_T > 20 - 25$ GeV
- $\not{E}_T > 20 - 25$ GeV
- Background from:
  - c-, b-quark decays (μ: 1%)
  - Electron-like jets (e: 1%)
  - $Z \to ll$ (μ: 5%; e: 0.5%)
  - $W \to \tau\nu$ (2%)

For each fb^{-1}, about 1M candidates

Hadronic decays very hard to select

Z Experimental Signature



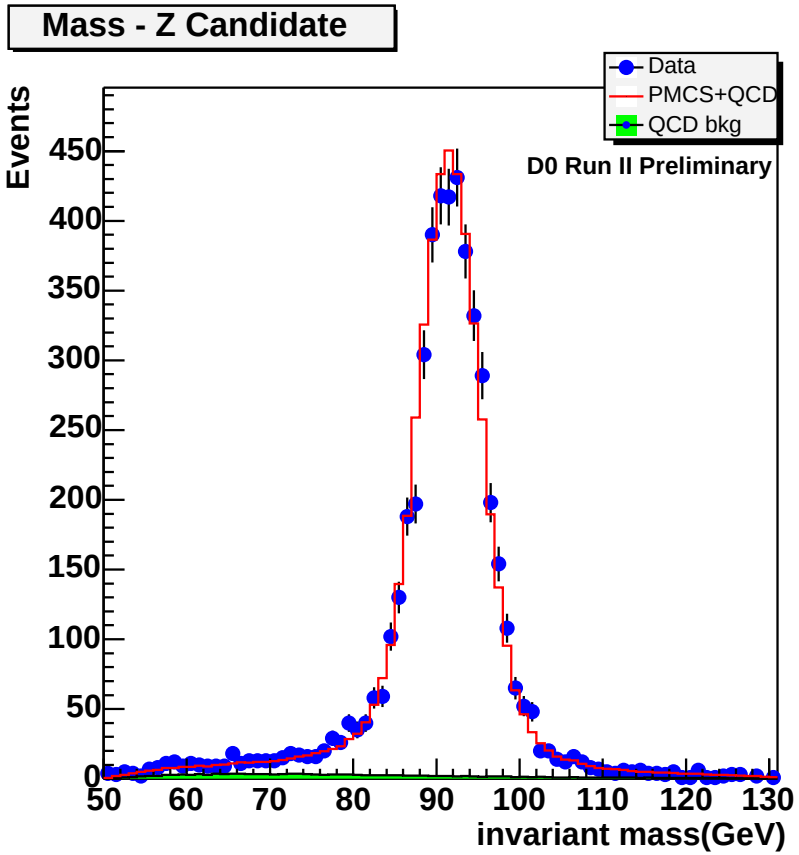
- Two leptons, $p_{\mathrm{T}} > 15 - 25$ GeV
- Background from:
  - c-, b-quark decays (μ: 0.5%)
  - Electron-like jets (e: 1%)
  - $Z \to \tau\tau$ ($< 0.5\%$)

For each fb^{-1}, about 100k candidates

Hadronic decays very hard to select

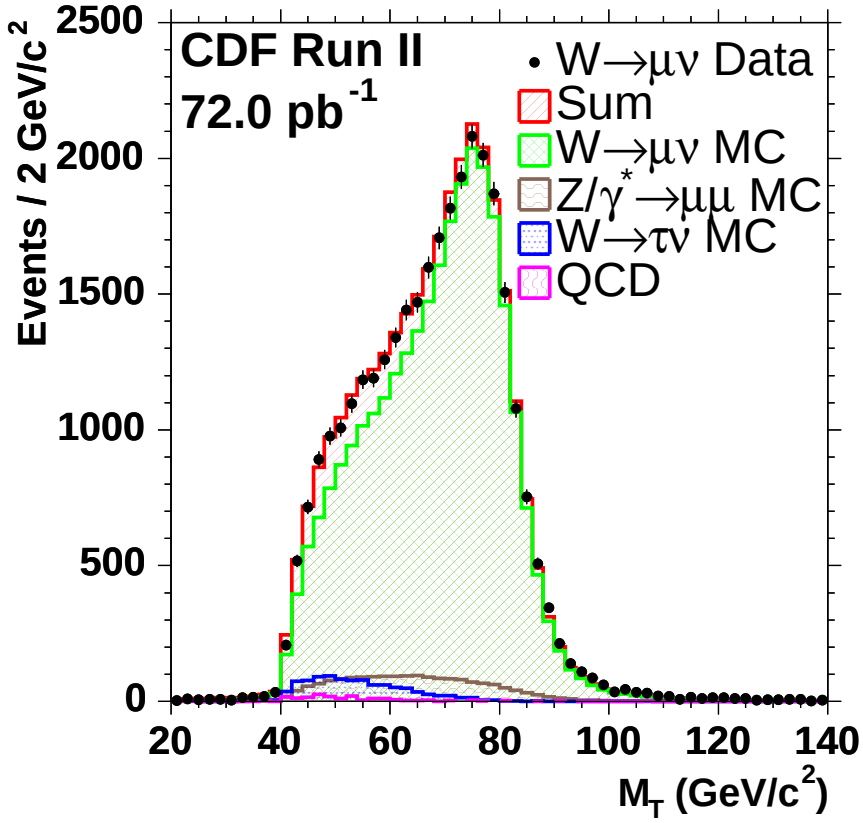
W & Z Selection Results (DØ/CDF)

DØ



$Z \to ee$, 177 pb^{-1}

CDF



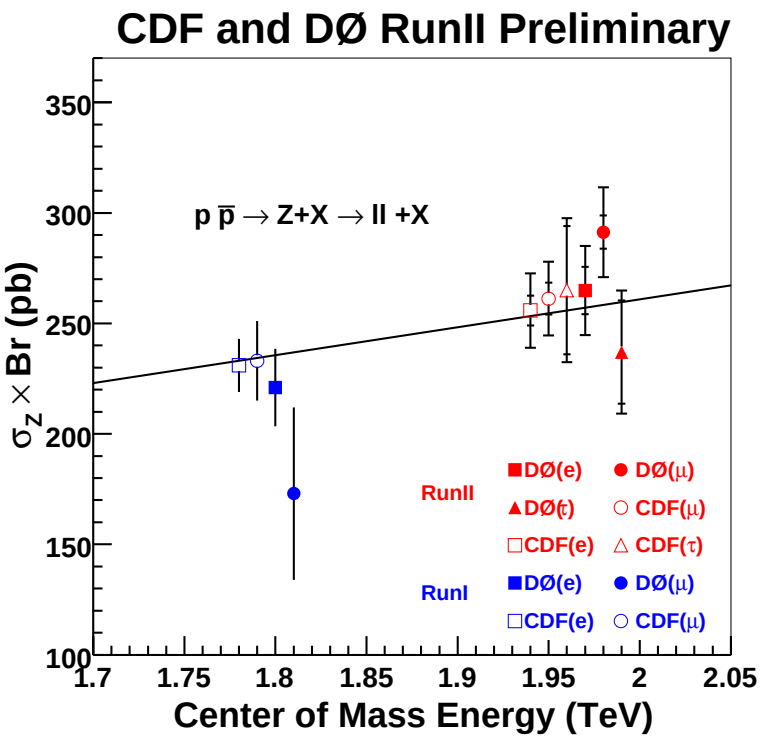
$W \to \mu\nu$, 72 pb^{-1}

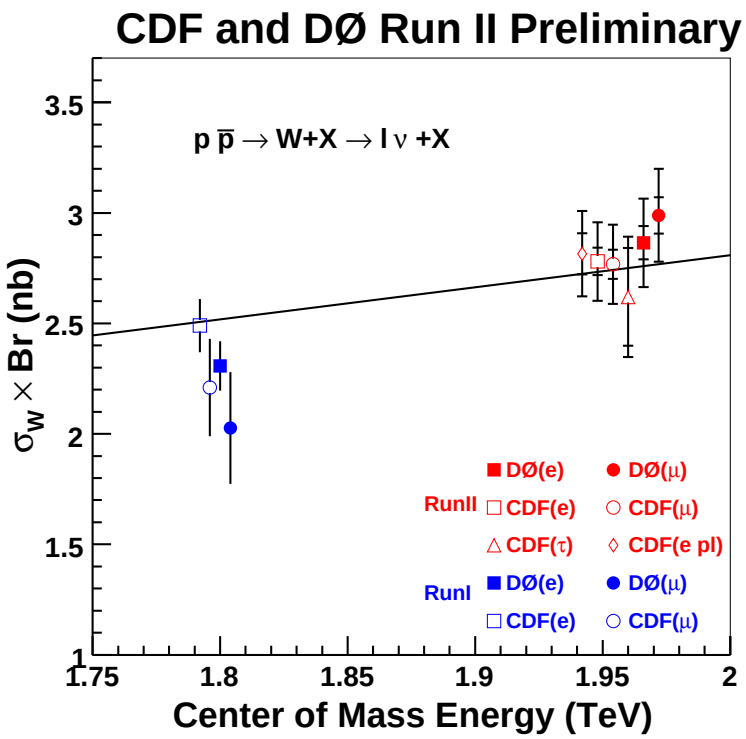
W & Z Cross Section Measurement

$$\sigma \cdot B = \frac{N_{\text{candidates}} - N_{\text{background}}}{\epsilon A \int \mathcal{L} \mathrm{d}t}$$

- $N_{\text{background}}$: from data (QCD) or Monte Carlo (EW)
- Efficiency ϵ : from data, precision $< 2\%$
- Acceptance A : from Monte Carlo, precision 1.5% (PDF's)

W & Z Cross Section Results (DØ/CDF)

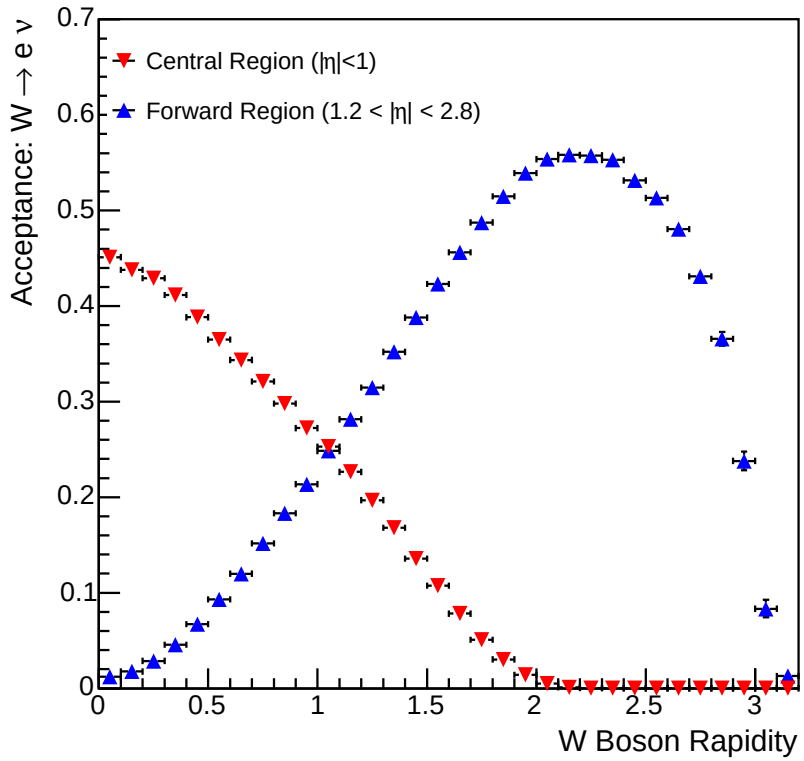




- Good agreement with theory (NNLO)
- Largest uncertainty ($\sim 6\%$) from $\int \mathcal{L} dt$ (72 – 350 pb^{-1})
- Note: also results in τ channel
  - ∗ Important benchmark for Higgs and new-physics searches

W Cross Section with Forward Electrons (CDF)

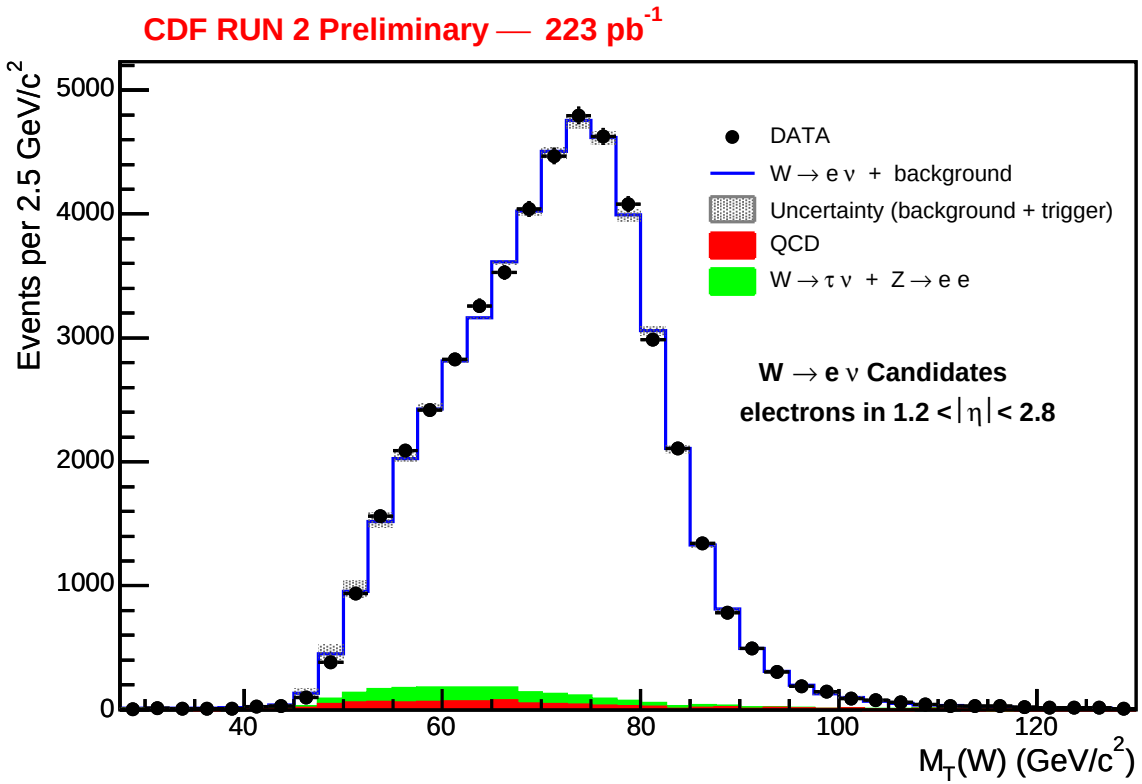
Electrons in forward detectors $\Leftrightarrow$ W bosons at large y_{W}



$\Rightarrow$ Sensitive to PDF's at small/large x $(= \frac{m_{\mathrm{W}}}{\sqrt{s}} e^{(\pm) y_{\mathrm{W}}})$

– Requires forward tracking and calorimetry

W Cross Section with Forward Electrons (CDF)



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

– In agreement with theory and $\sigma \cdot B$ from central electrons

W Cross Section with Forward Electrons (CDF)

- Visible cross section: $\sigma_{\text{vis}} = \sigma_{\text{W}} \cdot A$
- On σ_{vis} ratio: no PDF uncertainty, reduced $\int \mathcal{L} \mathrm{d}t$ uncertainty
- Measured:

$$\sigma_{\text{vis}}^{\text{central}} / \sigma_{\text{vis}}^{\text{forward}} = 0.925 \pm 0.033$$

- Predicted:

$$A^{\text{central}} / A^{\text{forward}} = 0.924^{+0.023}_{-0.030} \text{ (CTEQ)}$$
$$A^{\text{central}} / A^{\text{forward}} = 0.941^{+0.011}_{-0.015} \text{ (MRST)}$$

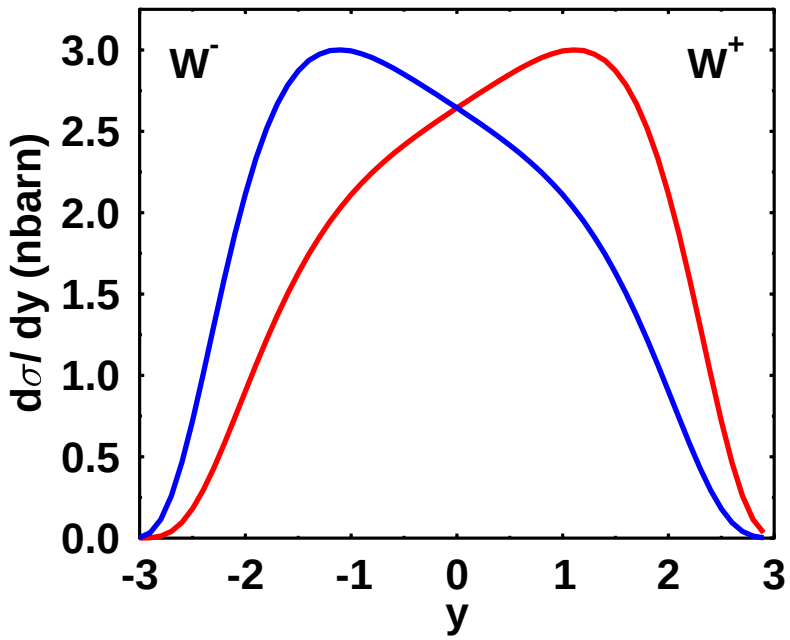
$\Rightarrow$ First measurement using $\sigma_{\text{W}}(\eta_l)$ to probe PDF's

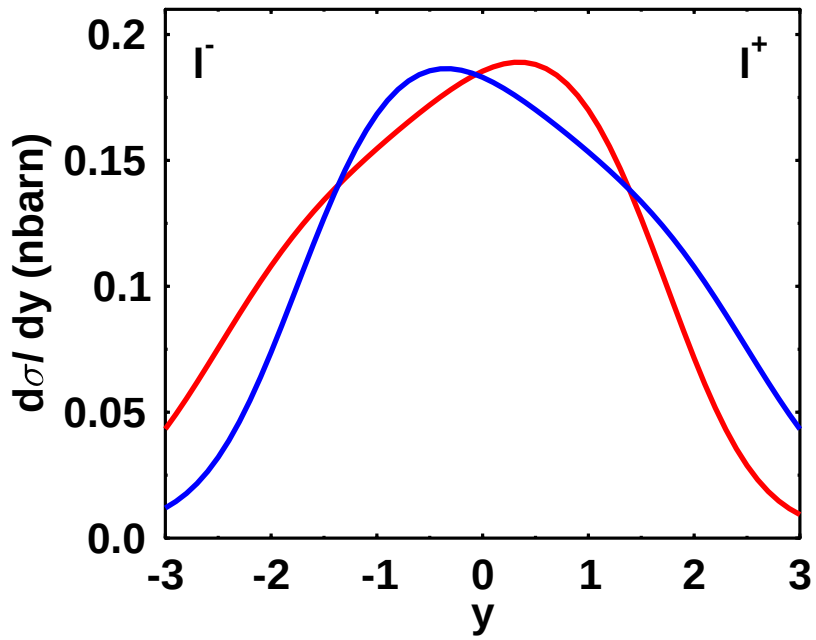
W Production Charge Asymmetry

– Proton's momentum fraction of u-quark > d-quark

$\Rightarrow$ $W^{+(-)}$ boosted in $p(\bar{p})$ direction $\Rightarrow$ charge asymmetry

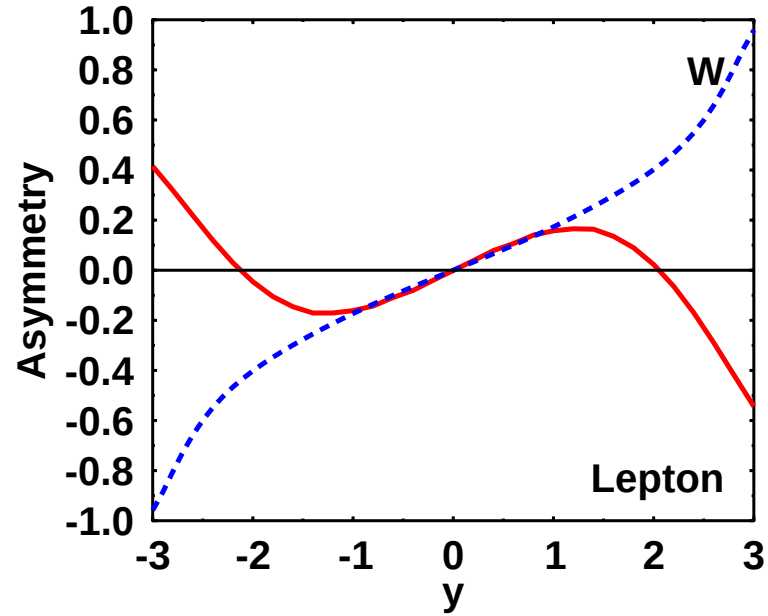
– Asymmetry partly preserved by decay-leptons





W Charge Asymmetry (DØ/CDF)

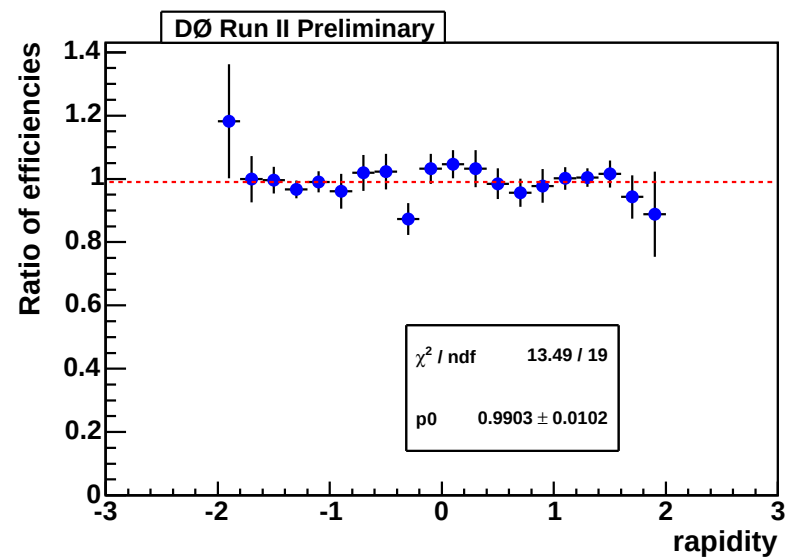
$$A = \frac{N^+(y) - N^-(y)}{N^+(y) + N^-(y)}$$



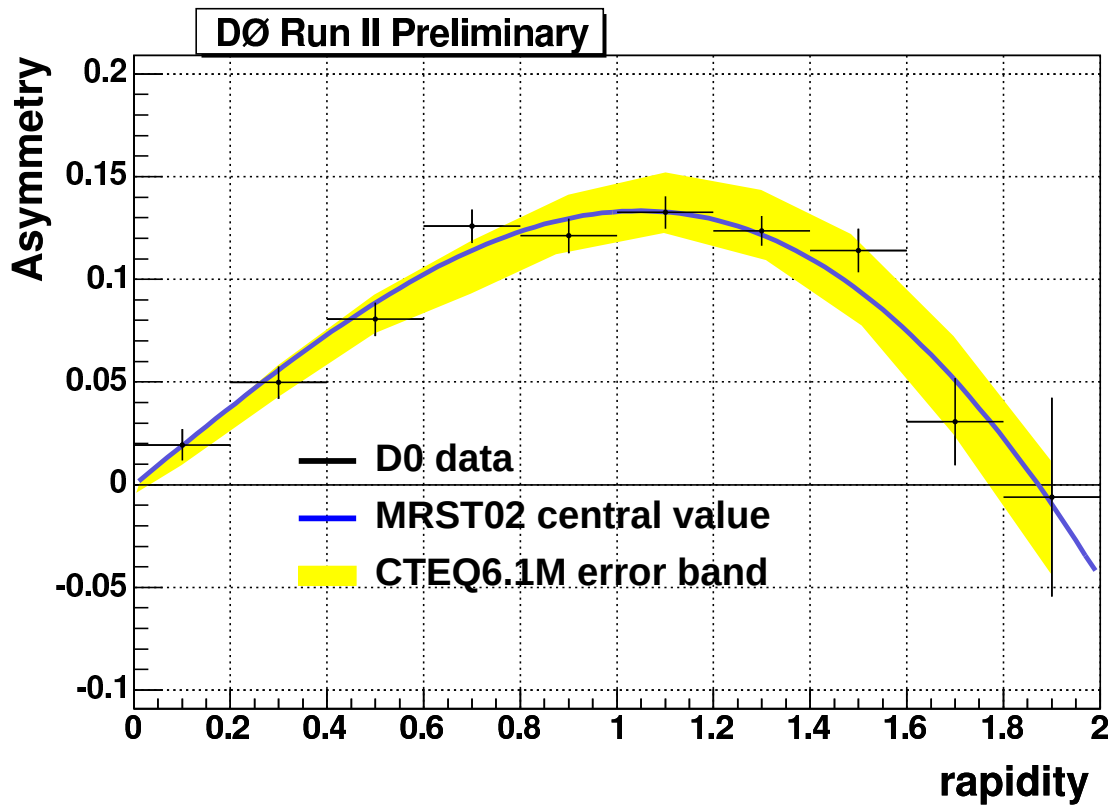
$\Rightarrow$ DØ/CDF probe (x, Q^2) not probed by, e.g., HERA

– Low charge mis-id rate:
  1% (e, CDF)
  0.01% (μ, DØ)

– Efficiencies charge independent



W ($\rightarrow \mu\nu$) Charge Asymmetry (DØ)

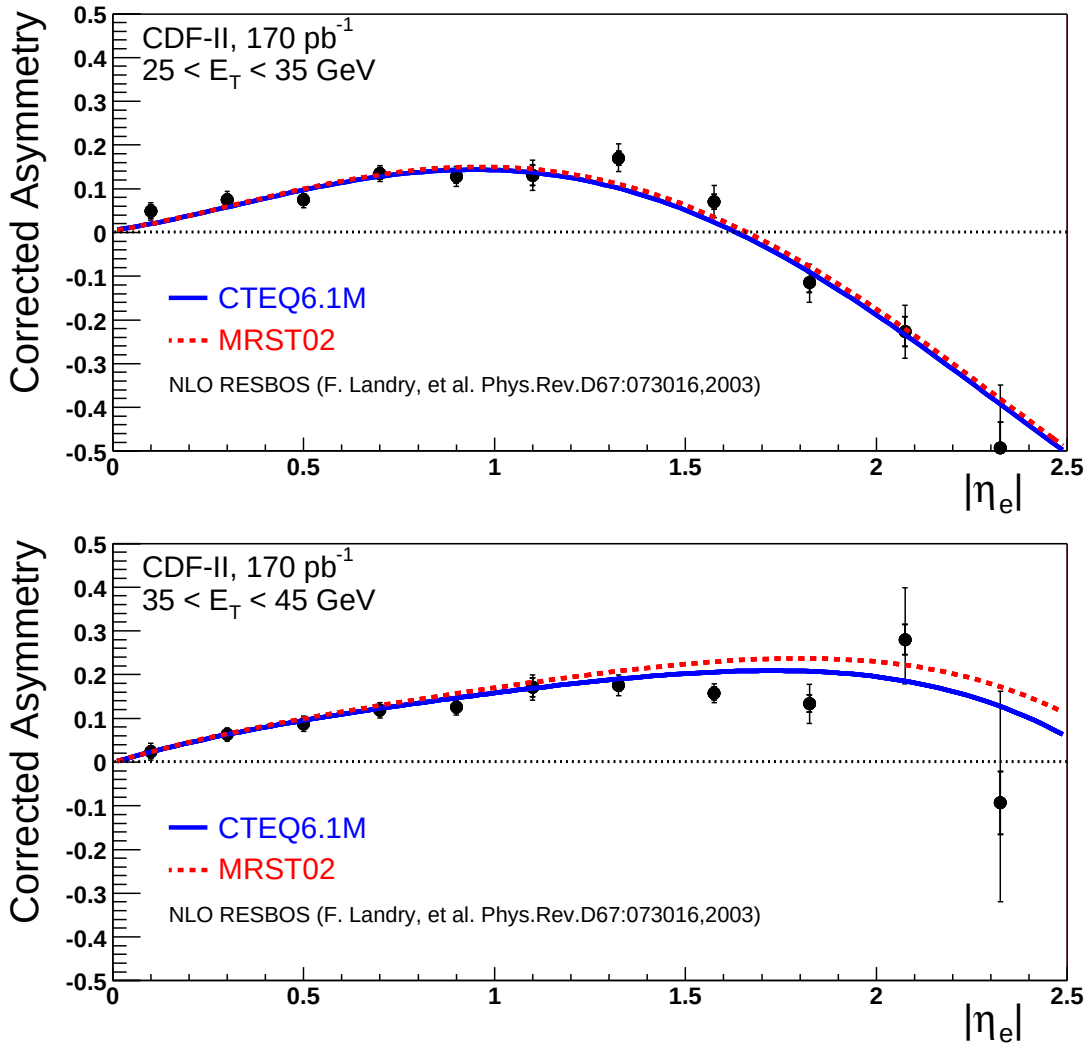


– Statistics dominated (230 pb^{-1})

– Already sensitive to PDF's

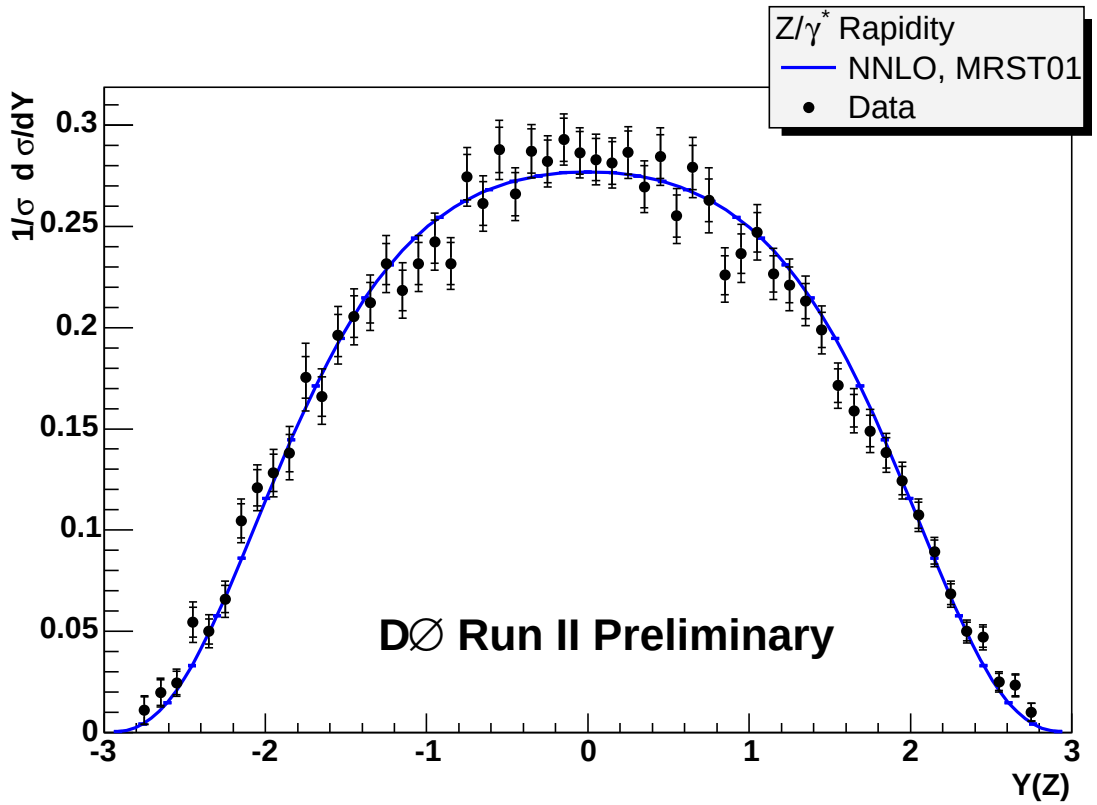
W ($\rightarrow e\nu$) Charge Asymmetry (CDF)

Charge asymmetry in bins of $E_{\mathrm{T}}(e) \Rightarrow$ extra PDF sensitivity



Z Rapidity (DØ)

Z rapidity ⇔ u/d-quark momentum fraction in proton



⇒ Good agreement with theory (NNLO) (340 pb^{-1})

– Not yet very sensitive to PDF's

Conclusion & Outlook

- Precision cross section measurements, in agreement with theory (NNLO)
- Charge asymmetries becoming sensitive to PDF's
- Order-of-magnitude more data expected
- Reduce uncertainties on PDF's, m_{W}, . . .