Measurements from Tevatron on production of W, Z, Drell-Yan, and constraints on PDFs

DIS 2009
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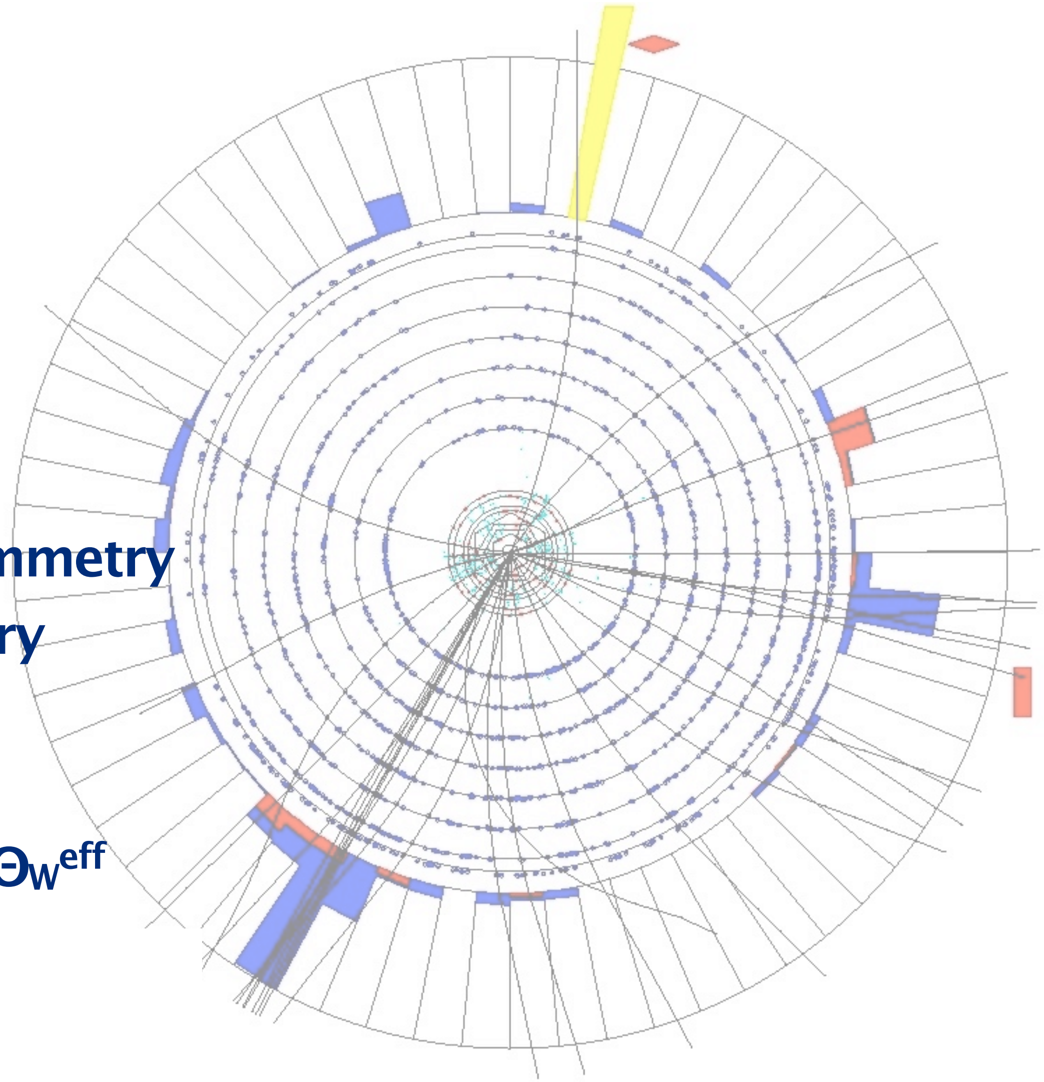
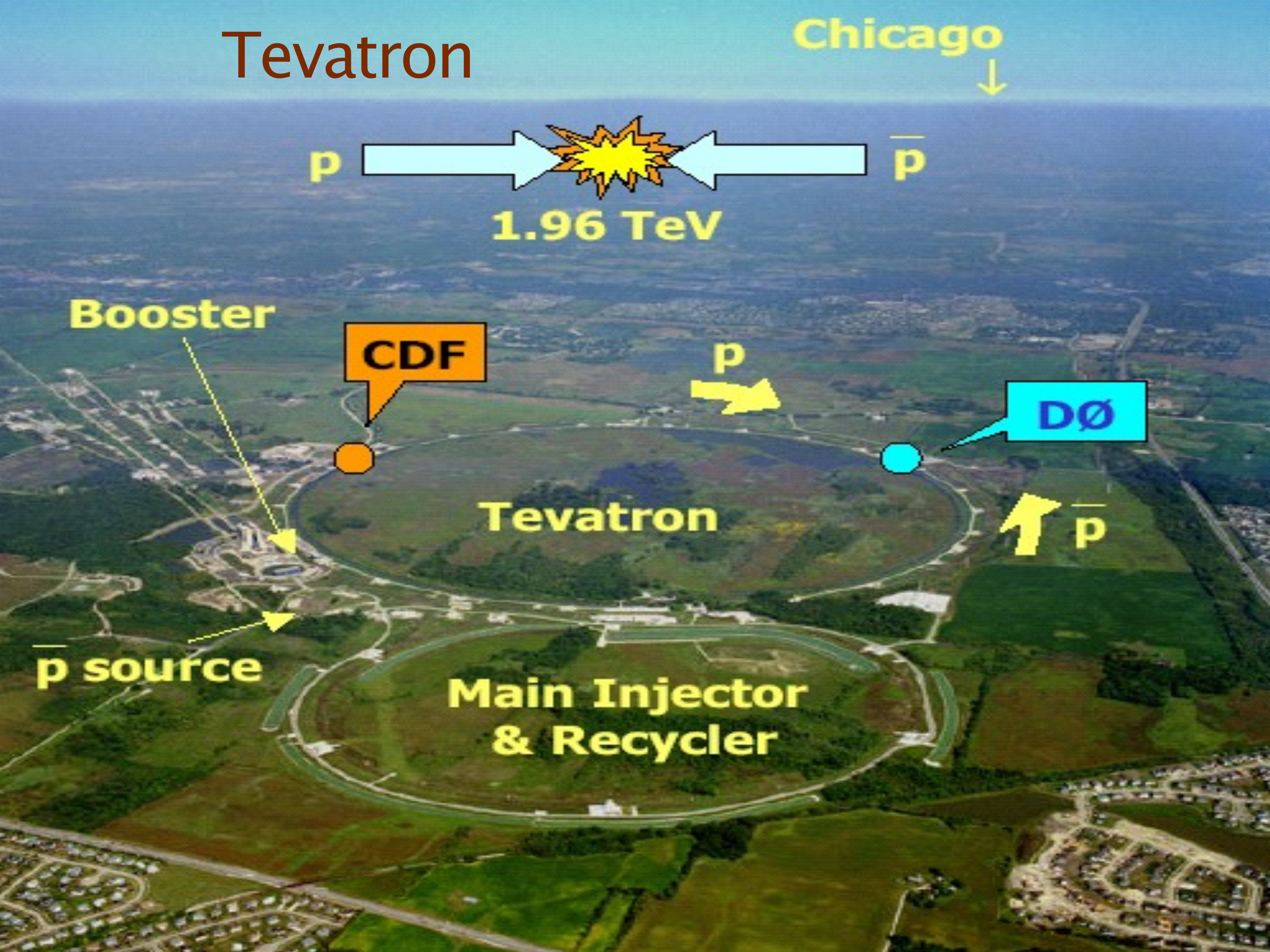
for the Tevatron Experiments

Contents

- **Tevatron, DØ and CDF**
- **Z^0 Boson & Drell-Yan**
  - **p_T Measurements**
  - **Rapidity**
- **W Boson**
  - **Lepton Charge Asymmetry**
  - **W Charge Asymmetry**
- **Z^0 Boson & Drell-Yan**
  - **σ in $Z/\gamma \rightarrow \tau\tau$**
  - **Asymmetry and $\sin\Theta_W^{eff}$**

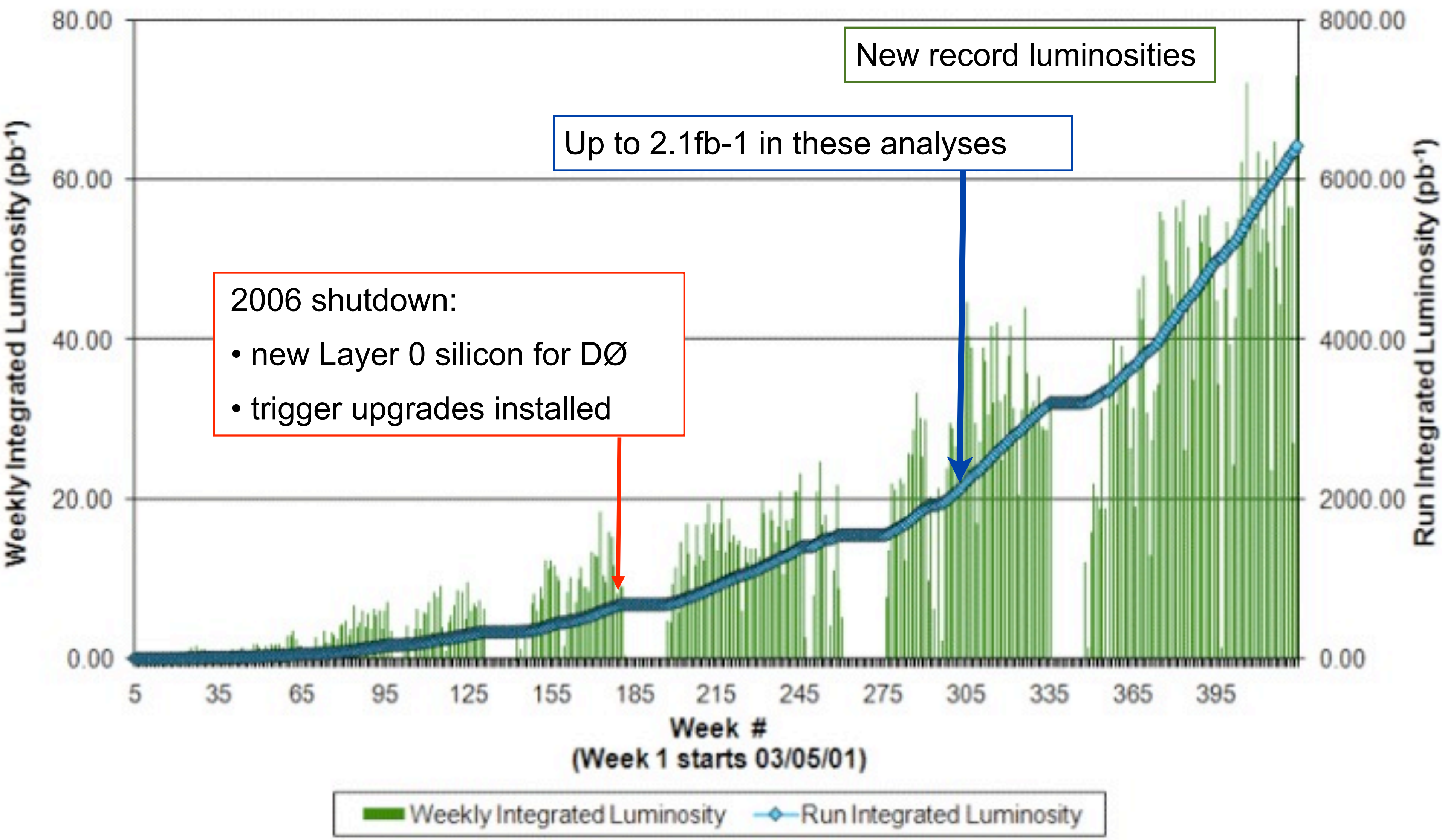


Tevatron



Chicago
p
$\bar{p}$
1.96 TeV
Booster
CDF
p
DØ
Tevatron
$\bar{p}$
$\bar{p}$ source
Main Injector
& Recycler

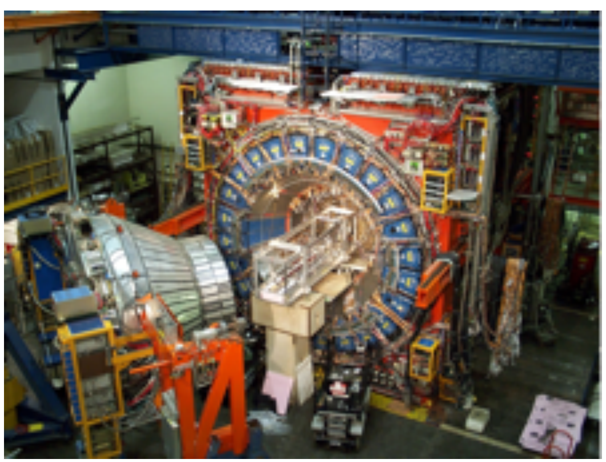
Tevatron Luminosity

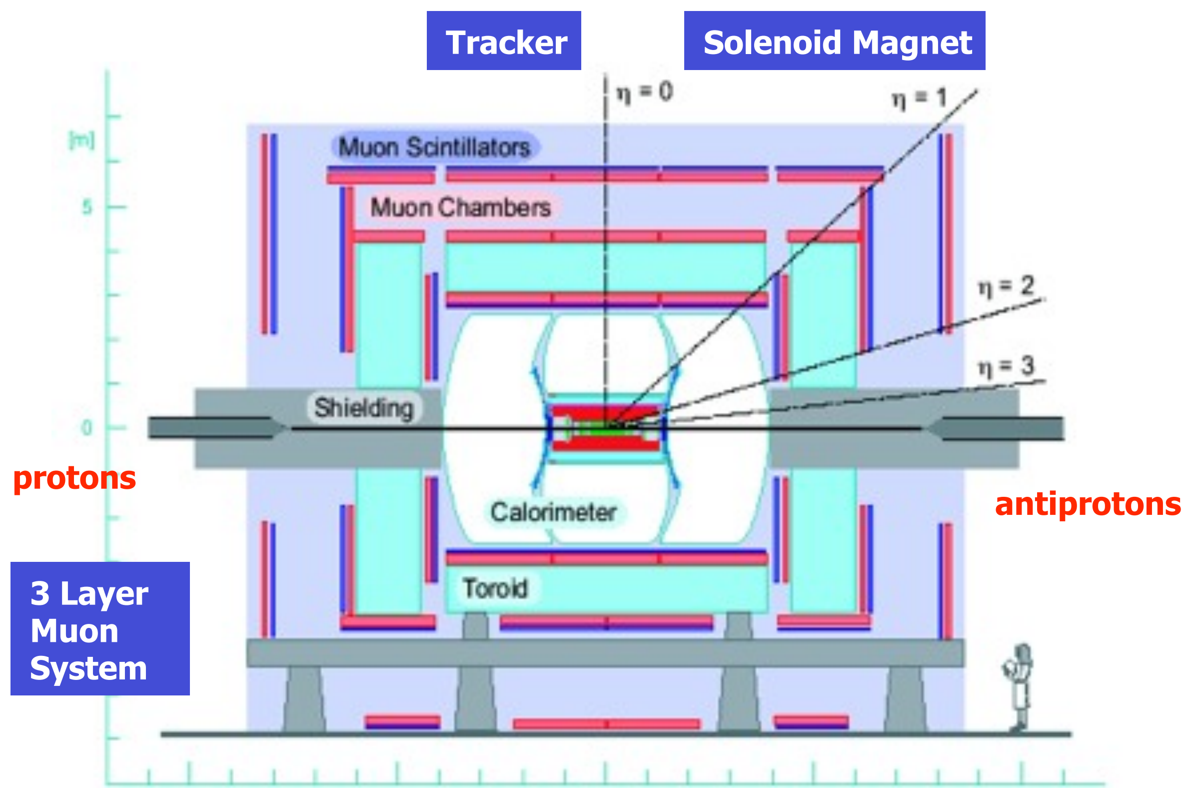


Two General Purpose Detectors:	CDF	DØ
Electron acceptance	$\|\eta\|<2.0$	$\|\eta\|<3.0$
Muon acceptance	$\|\eta\|<1.5$	$\|\eta\|<2.0$
Silicon Precision tracking	$\|\eta\|<2.0$	$\|\eta\|<3.0$
Hermetic Calorimeter	$\|\eta\|<3.6$	$\|\eta\|<4.2$

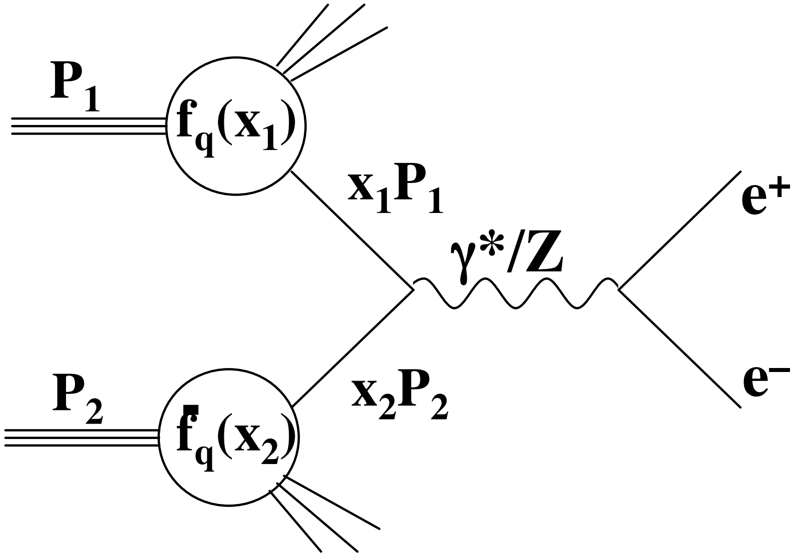
Powerful trigger systems (2.5MHz → 50Hz)

Dilepton triggers with $p_T > 4$GeV





Q and x at the Tevatron



The quarks carry a momentum fraction $x_{1,2}$ of the (anti–) proton which is described by the structure functions f(x).

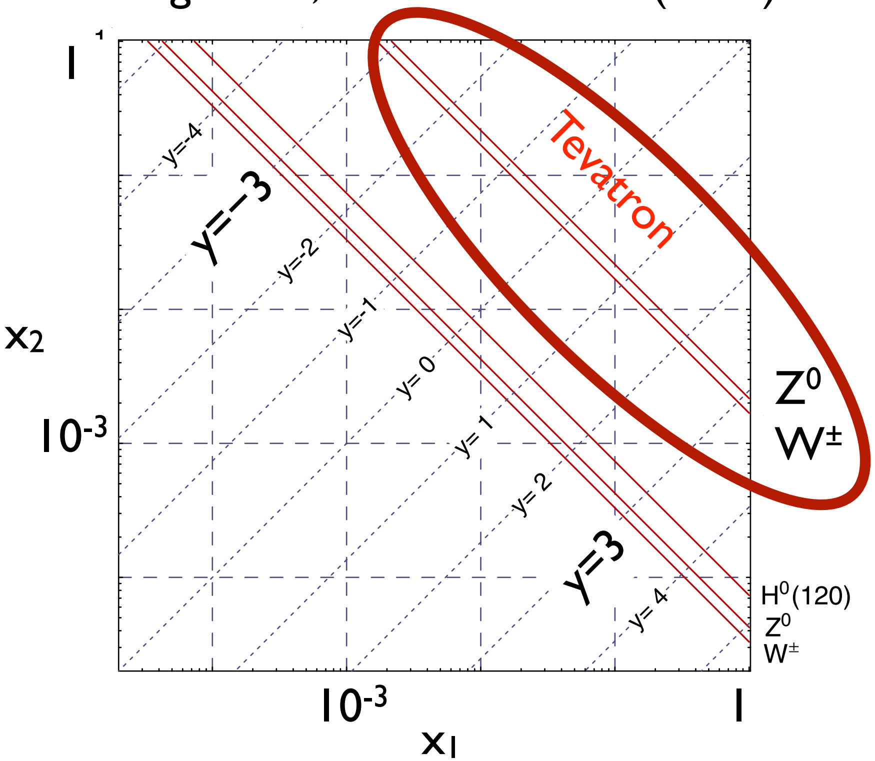
Rapidity

$$y = \frac{1}{2} \ln \frac{E + p_z}{E - p_z}$$

and $x_{1,2}$ are related by $x_{1,2} = \frac{Q}{\sqrt{s}} e^{\pm y}$

Q and x at the Tevatron

Berge et al, PRD 72 033015 (2005)



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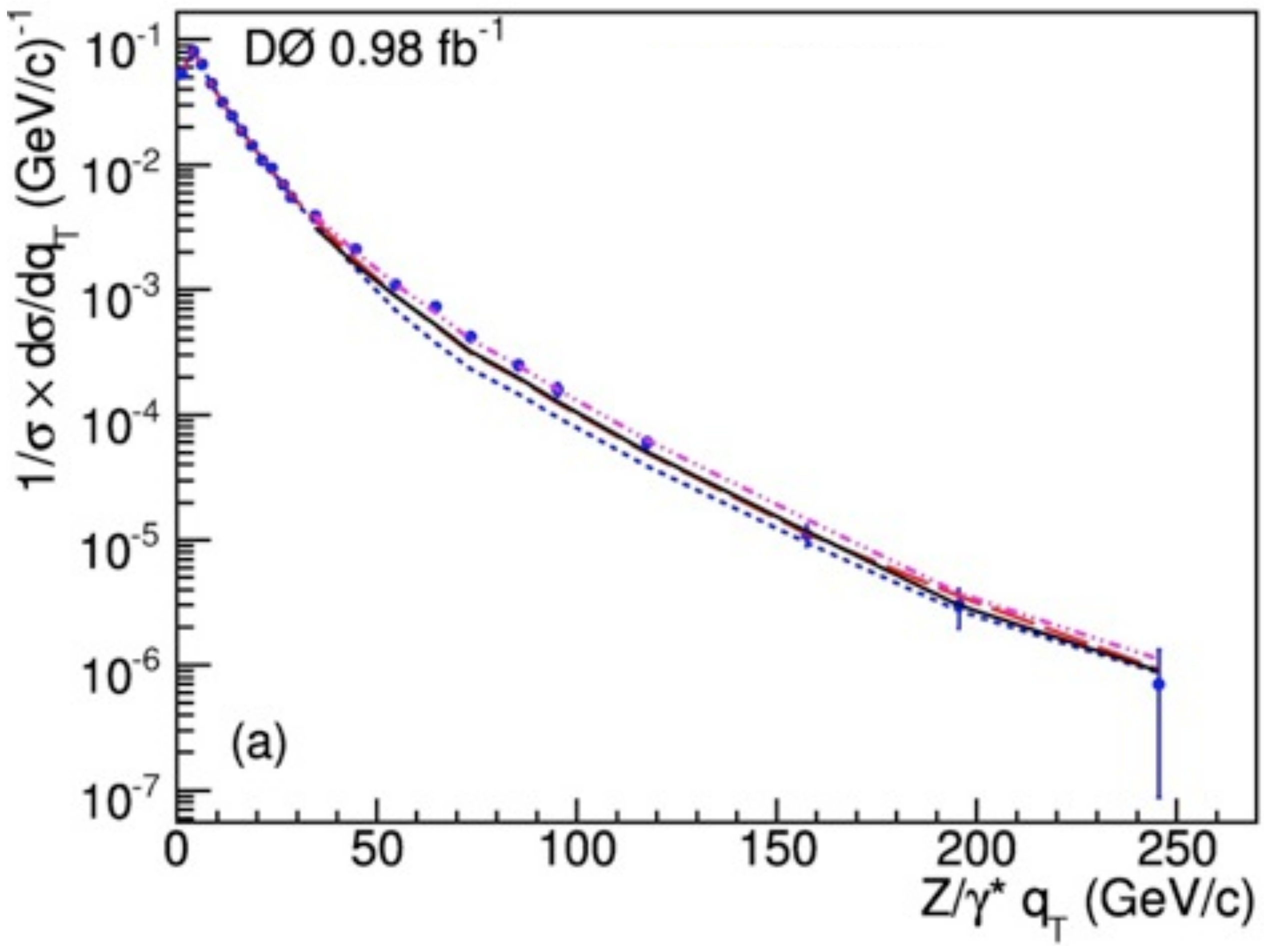
For W production at the Tevatron $\mathbf{Q^2 \approx M_W^2}$ and |y|< 3 (3.2) for electrons measured at CDF (DØ) this results in probing an x region of **0.002 < x < 0.8 (1)**

Z p_T Measurement



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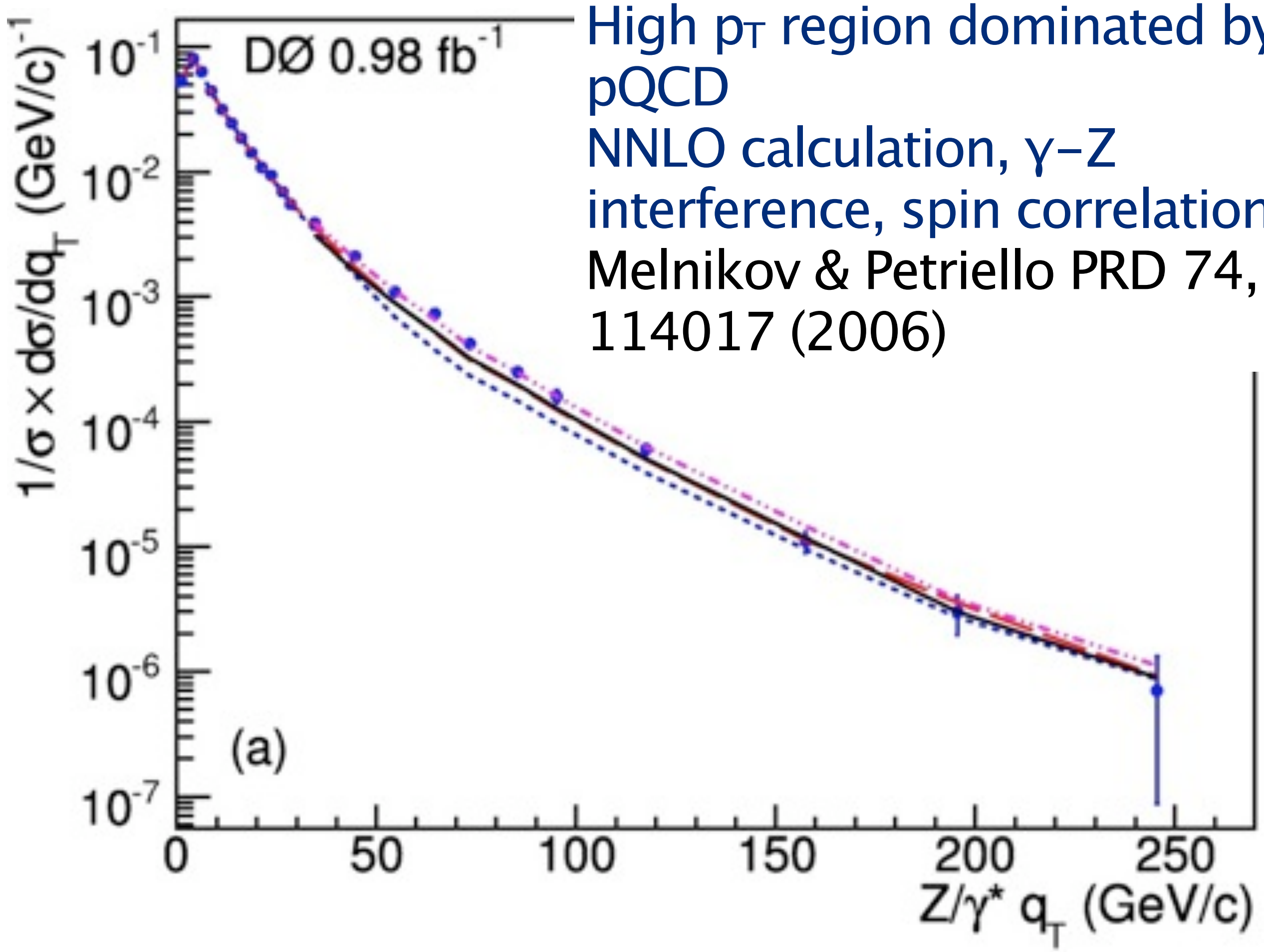

High p_T region dominated by pQCD
NNLO calculation, γ–Z interference, spin correlation
Melnikov & Petriello PRD 74, 114017 (2006)

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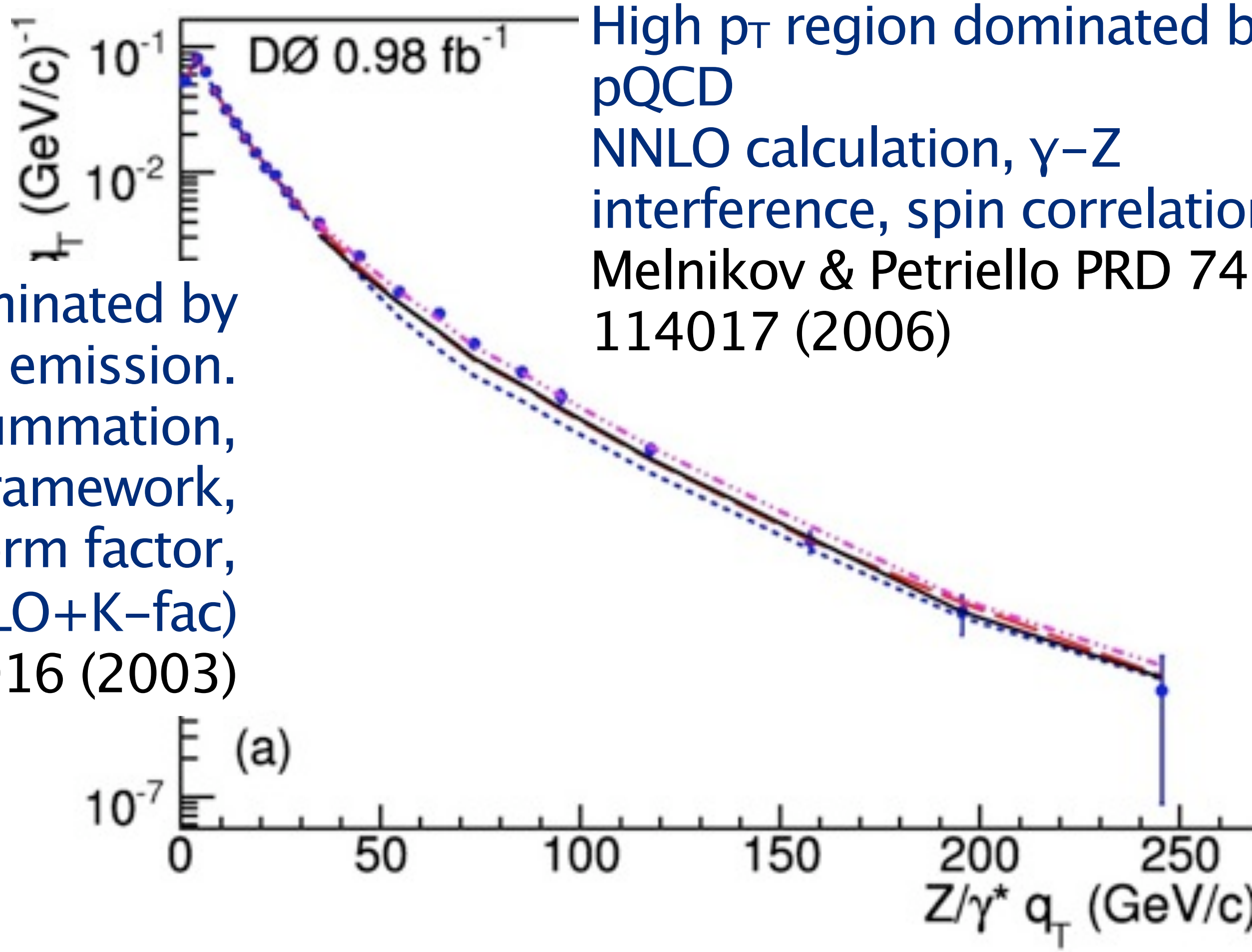

High p_T region dominated by pQCD
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Low p_T region dominated by soft gluon emission.
Resummation,
CSS framework,
$S_{NP}^{BLNY}(b,Q^2)$ form factor,
RESBOS (NLO+K–fac)
BLNY PRD67, 073016 (2003)

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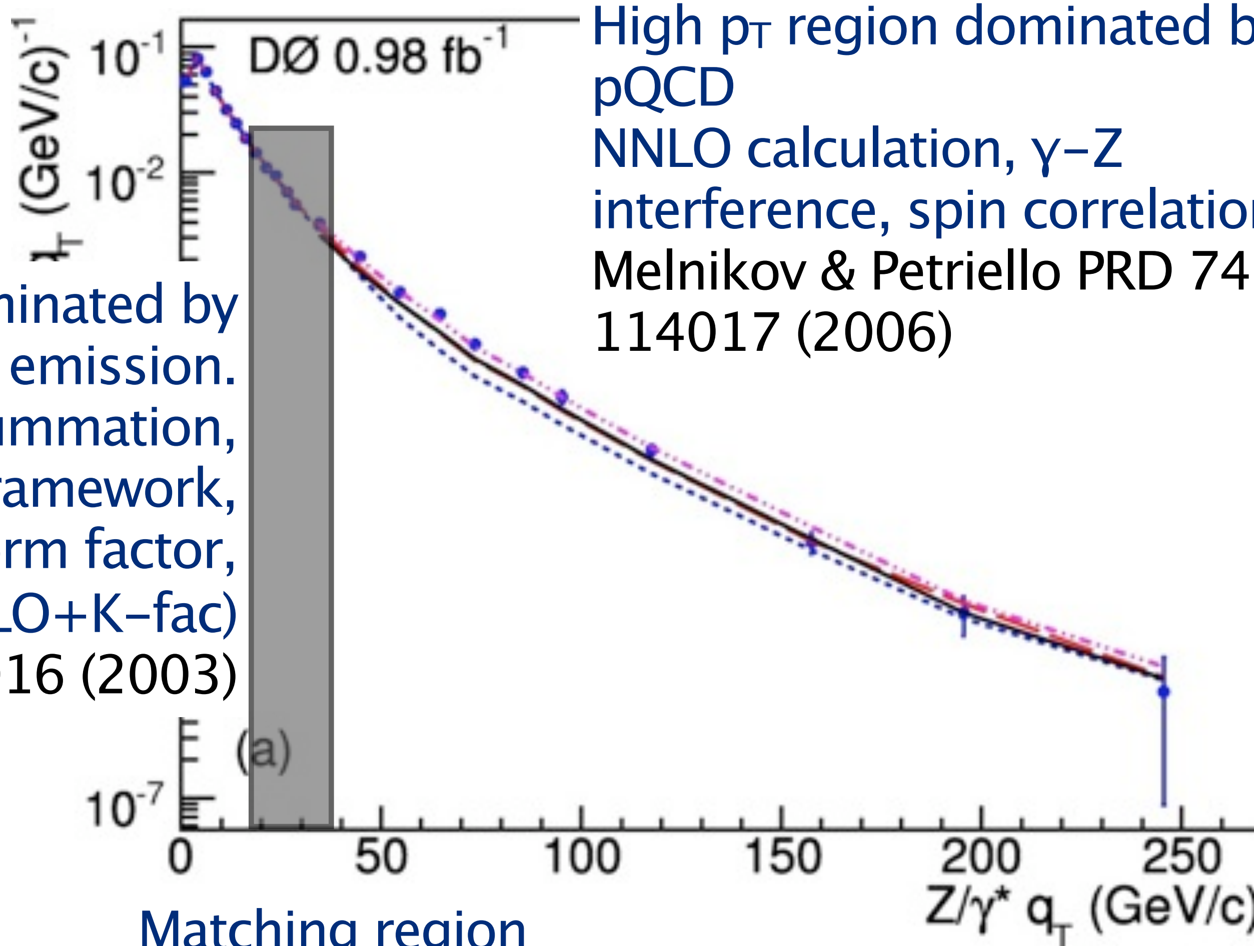

Matching region
RESBOS
NuclPhys B250
199 (1985)

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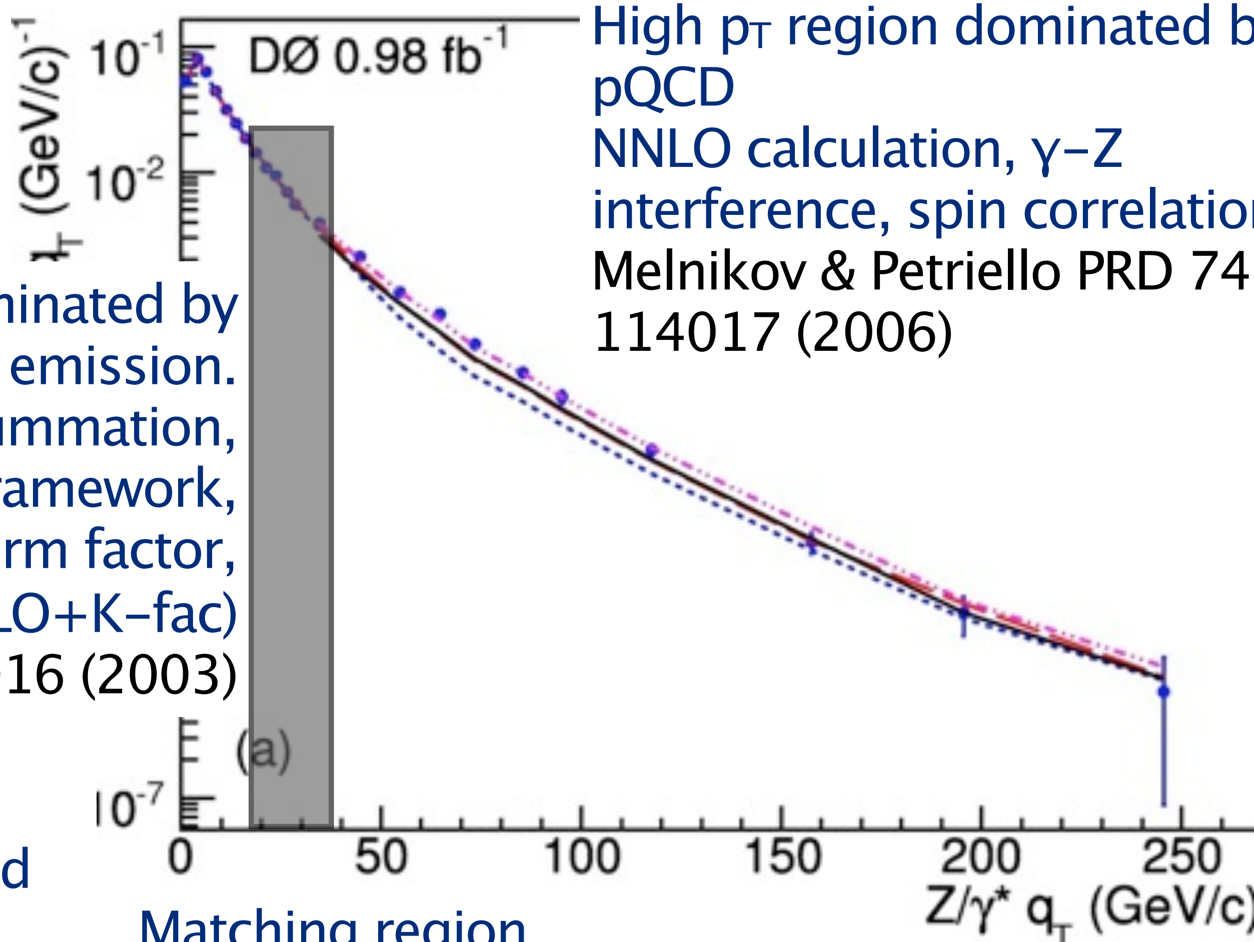

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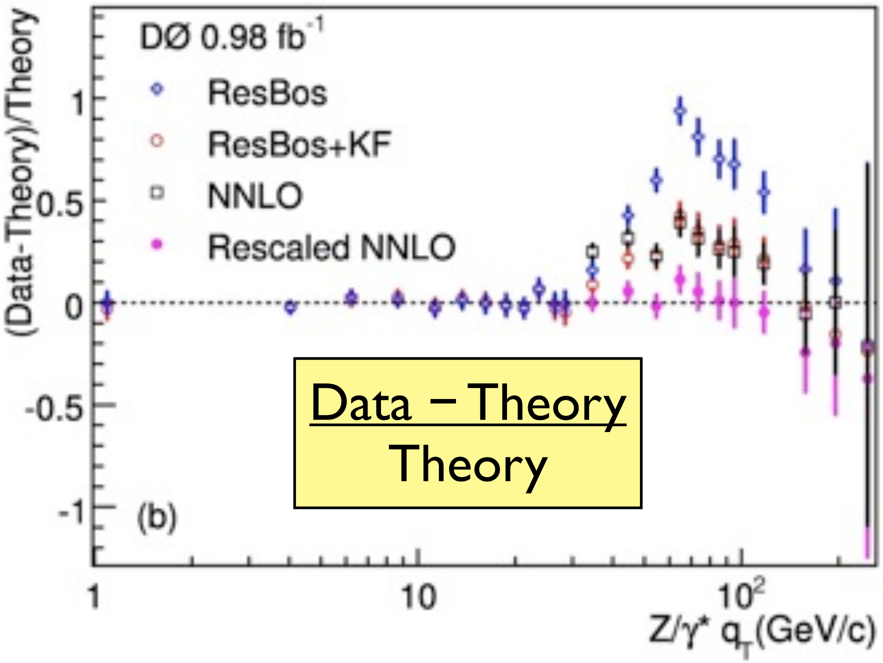
Small–x (high y): q_T broadening predicted from SIDIS data
PRD 72, 033015 (2005)

Matching region
RESBOS
NuclPhys B250 199 (1985)

Z p_T Measurement

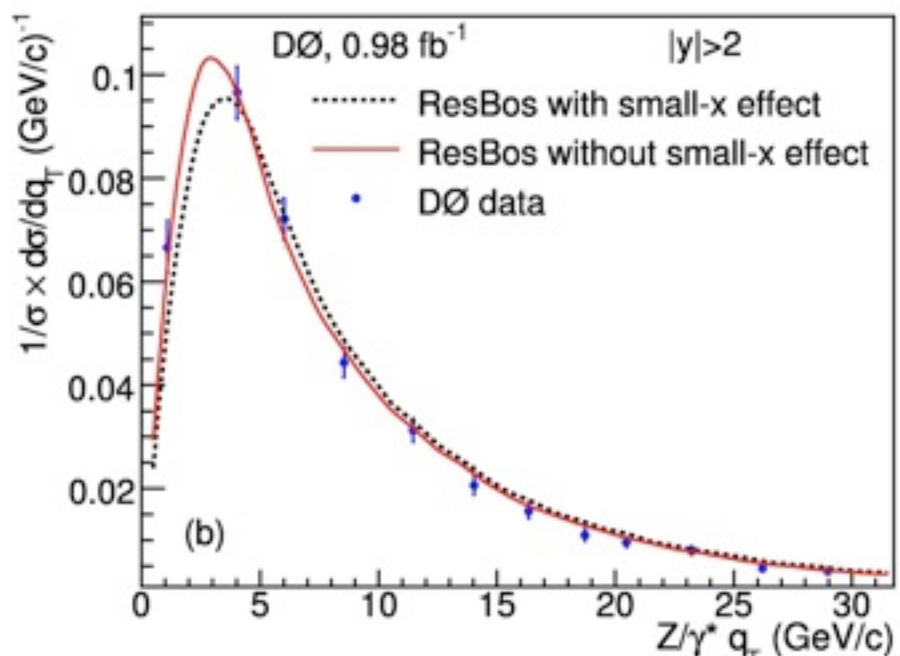


Resbos with the non-perturbative Sudakov form factor describes the data well for qT<30 GeV.

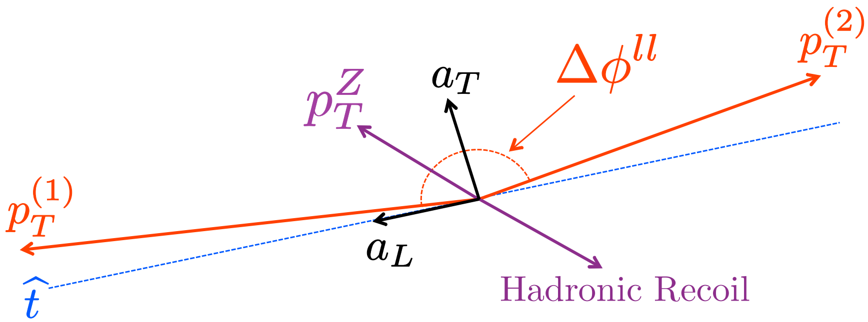
NNLO describes the q_T>30GeV data best but underestimates the cross section by 25%

q_T broadening at low-x as inferred from SIDIS is disfavoured.

At low q_T the uncertainty is dominated by PDF, energy scale and resolution (unfolding) and selection efficiency as a function of q_T.



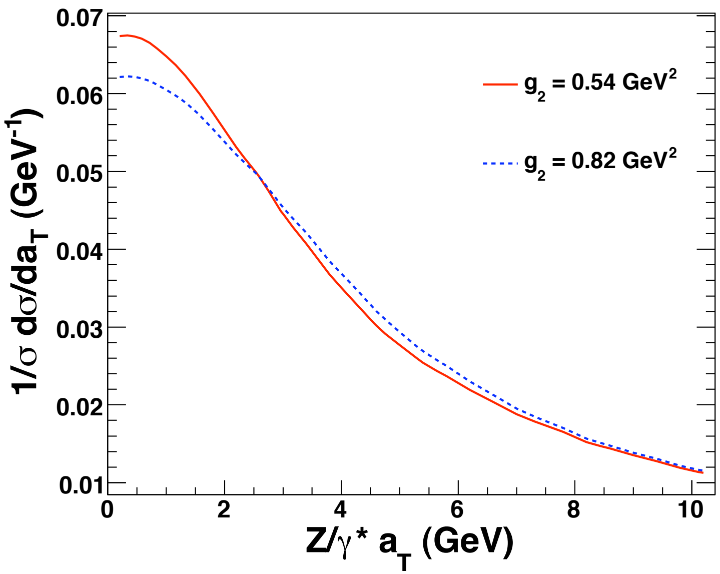
"Z p_T" Novel Technique



New technique: project p_T^Z perpendicular to thrust axis of the l^+l^- system

Reduce sensitivity to p_T^l and detector systematics

$$S_{NP}^{BLNY} = \exp\left[-g_1 - g_2 \ln\left(\frac{Q}{2Q_0}\right) - g_1 g_3 \ln(100 x_1 x_2)\right] b^2$$



At the Tevatron the measurement of p_T^Z or a_T are only sensitive to g_2.

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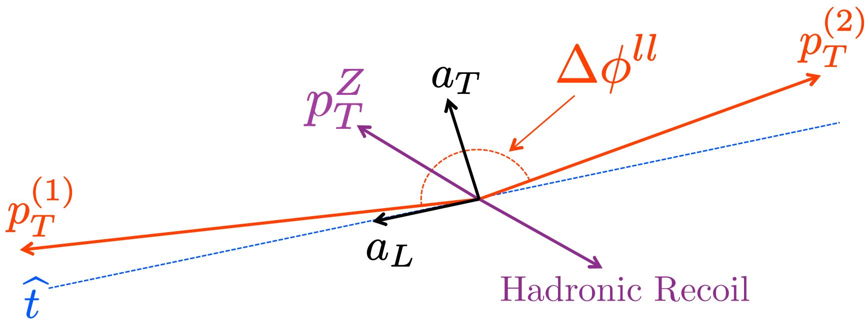

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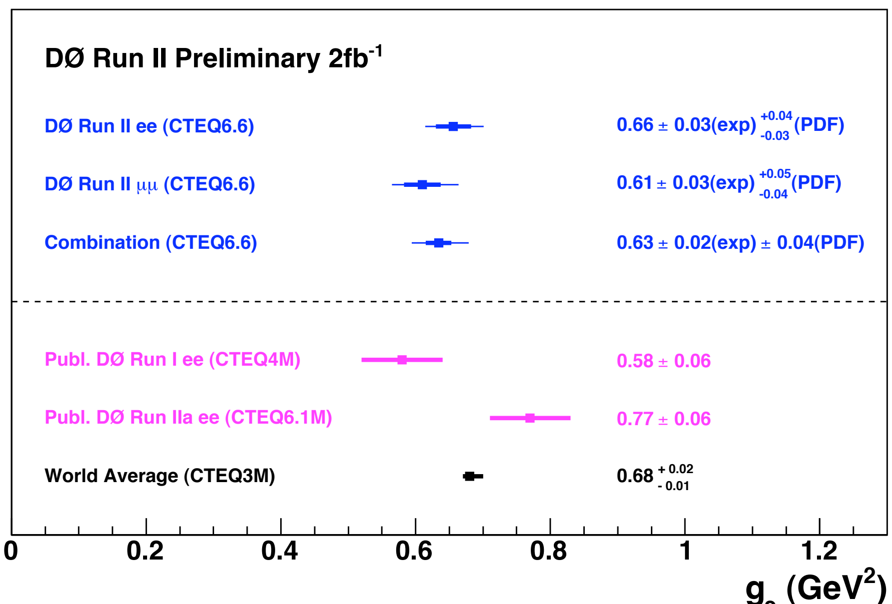


DØ result:

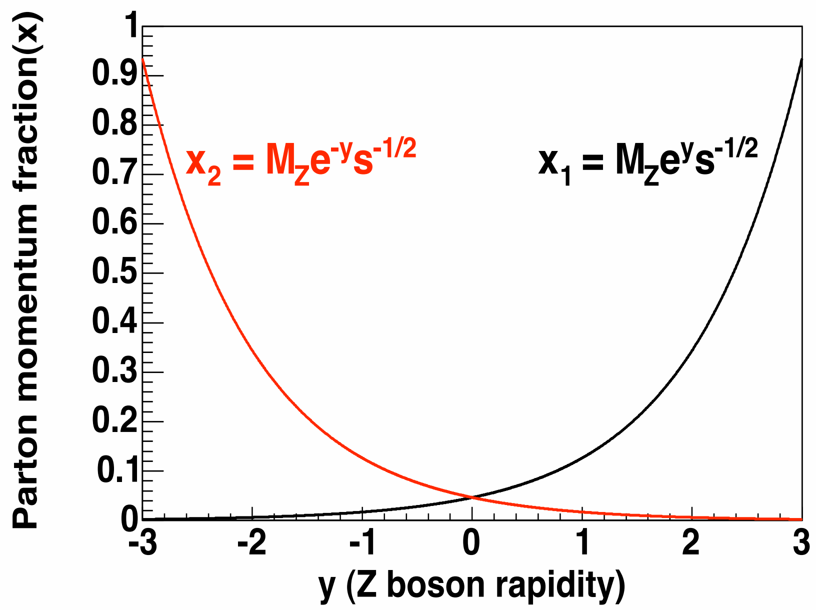
g_2=0.63±0.02(exp)±0.04(PDF)

World average:

g_2=0.68+0.02−0.01 (CTEQ 3M; does not include the PDF uncertainty)

New global fit!

Z Rapidity



Probe PDFs at low x and at very large x.

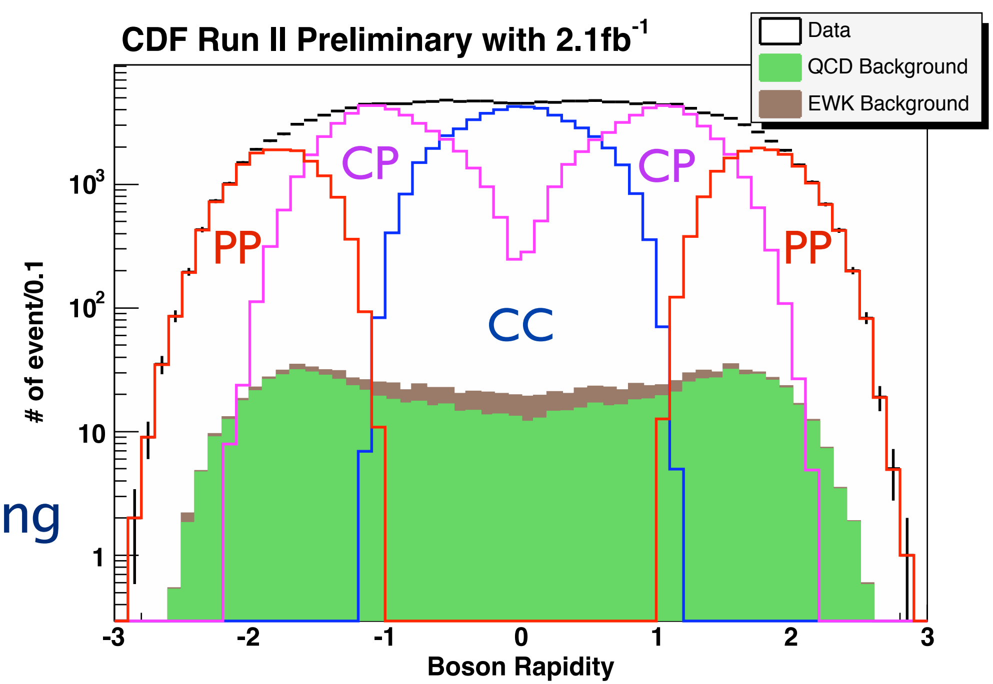
Measure electrons in the very forward direction is essential.

CC: Central–Central electrons

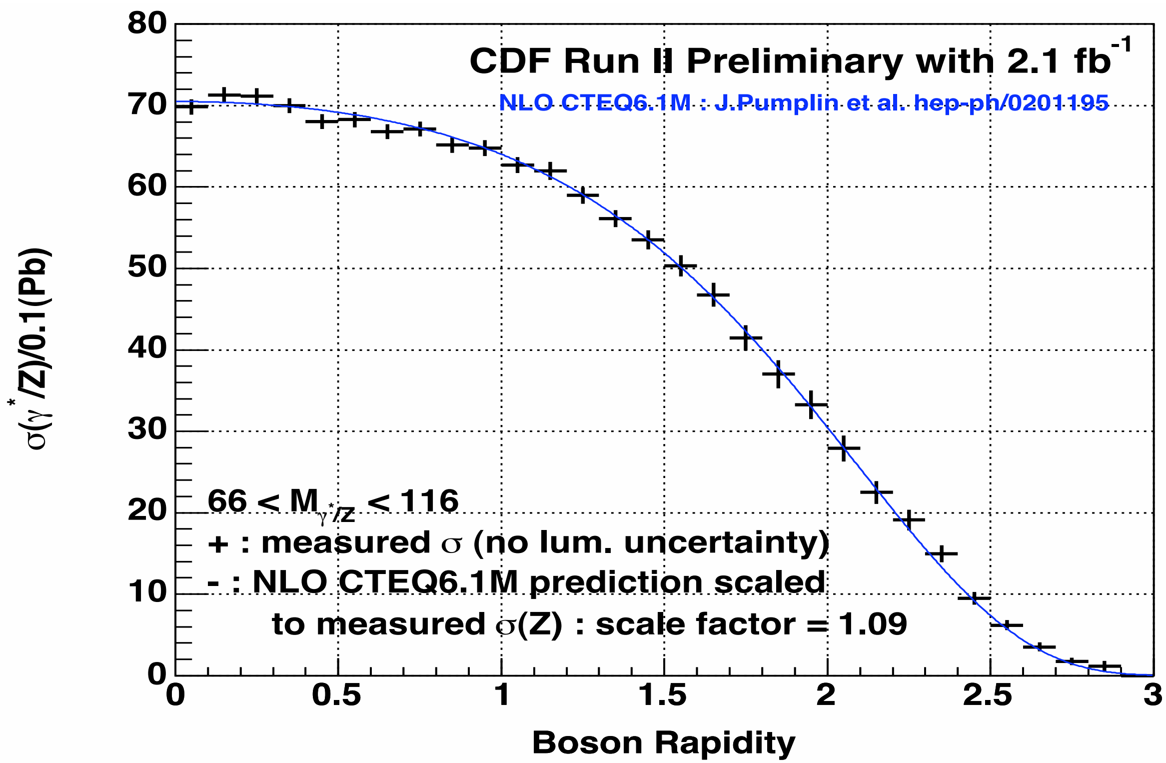
CP: Central – Plug electrons

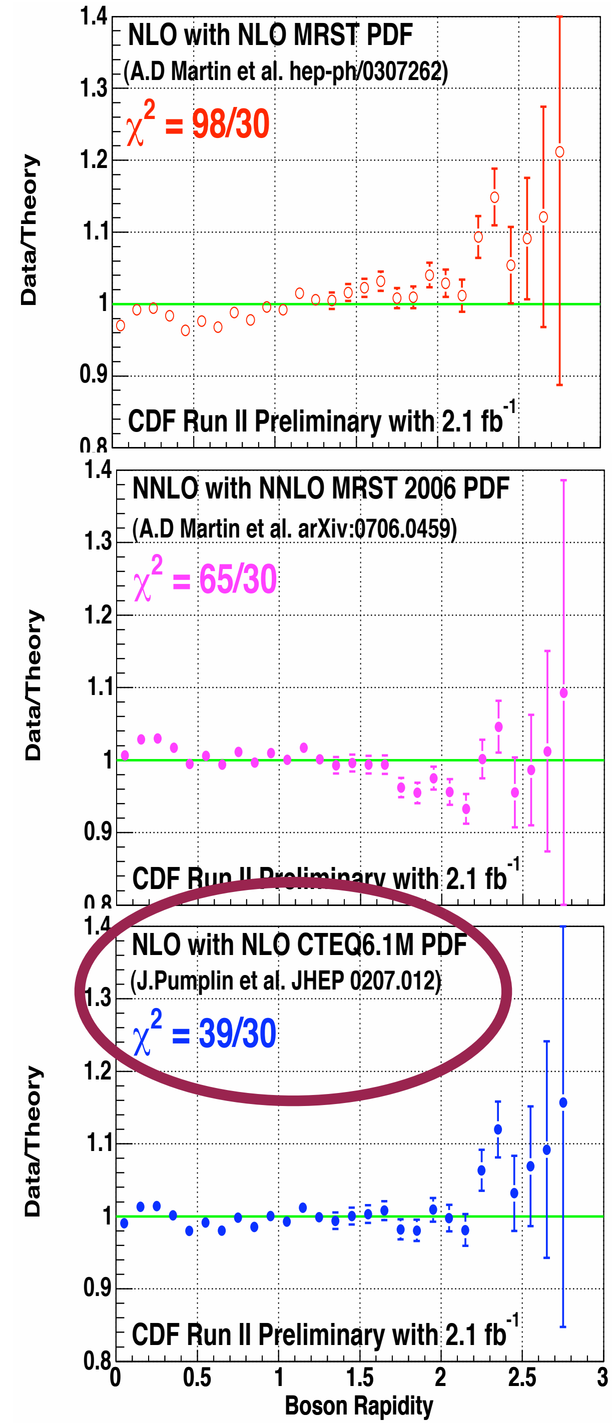
PP: Plug – Plug electrons

Systematics: Material modelling, background, electron ID, Si tracking eff, acceptance



Z Rapidity





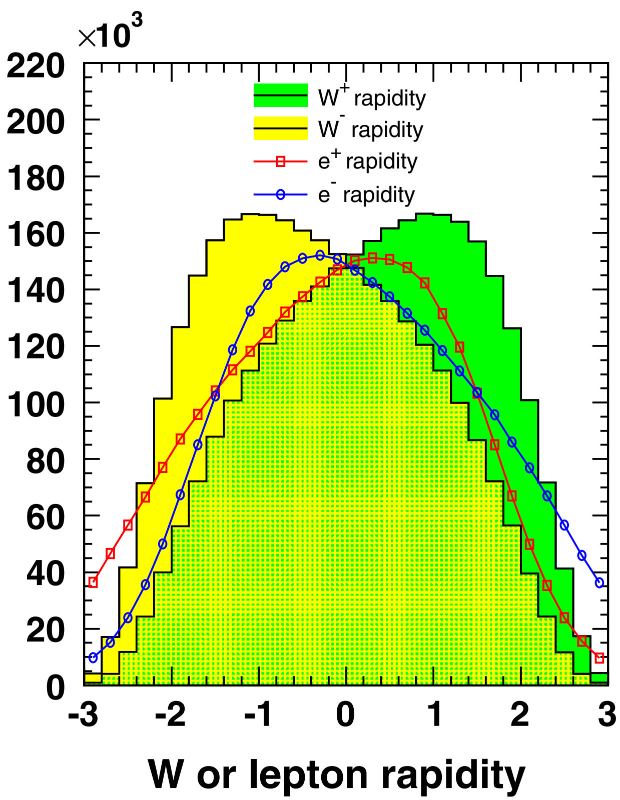
NLO with NLO CTEQ6.1M PDF show the best agreement with data.

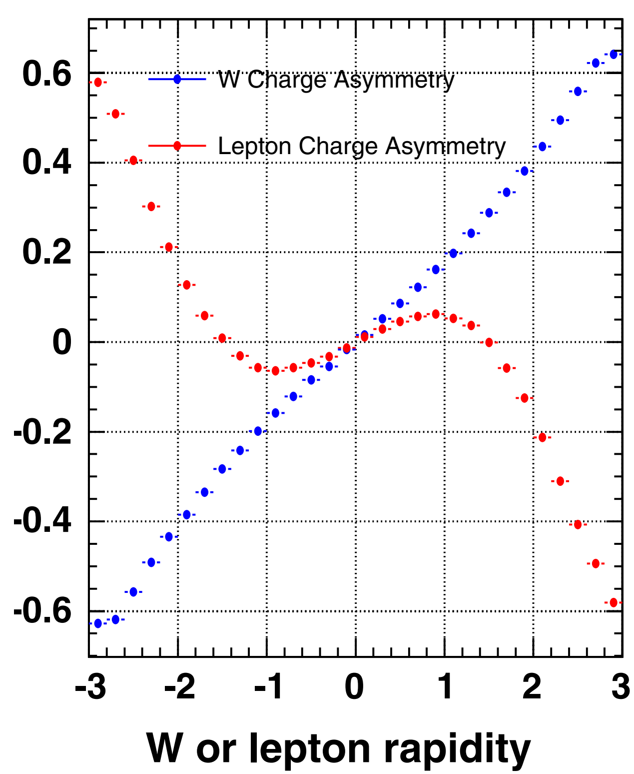
W Charge Asymmetry

$$A(y) = \frac{d\sigma^+/dy - d\sigma^-/dy}{d\sigma^+/dy + d\sigma^-/dy} \approx \frac{d/u(x_1) - d/u(x_2)}{d/u(x_1) + d/u(x_2)}$$

u quarks carry on average larger momentum than d quarks. The W^+ is preferentially boosted along proton direction.

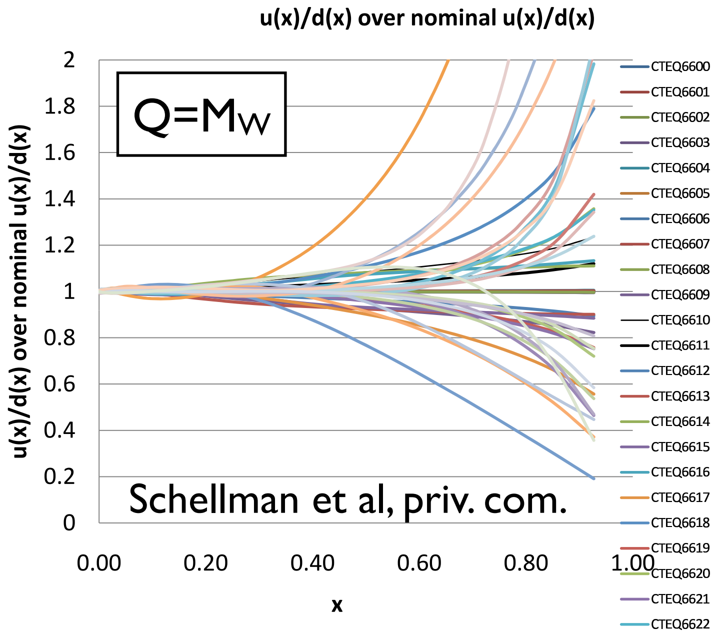
⇒ PDFs





The W charge asymmetry is translated into a lepton charge asymmetry – albeit watered down by the V−A structure of the decay.

Lepton Charge Asymmetry



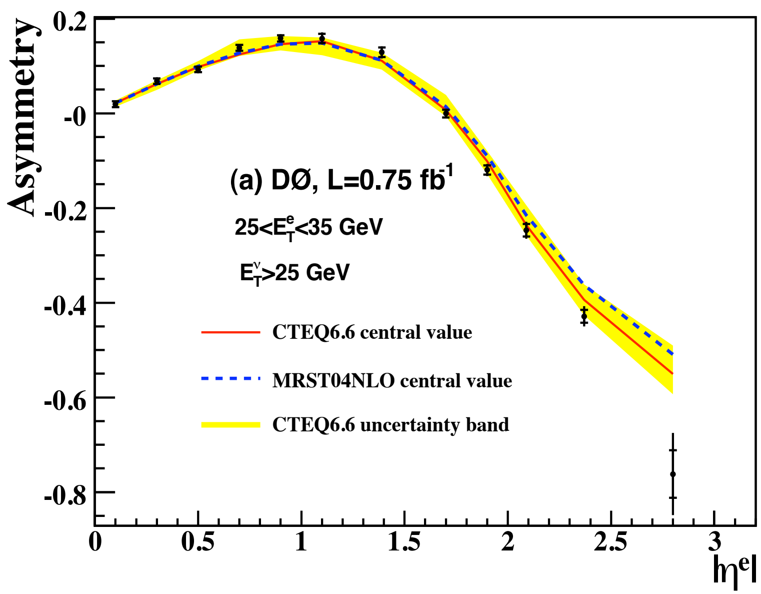
4 electron types due to detector cover

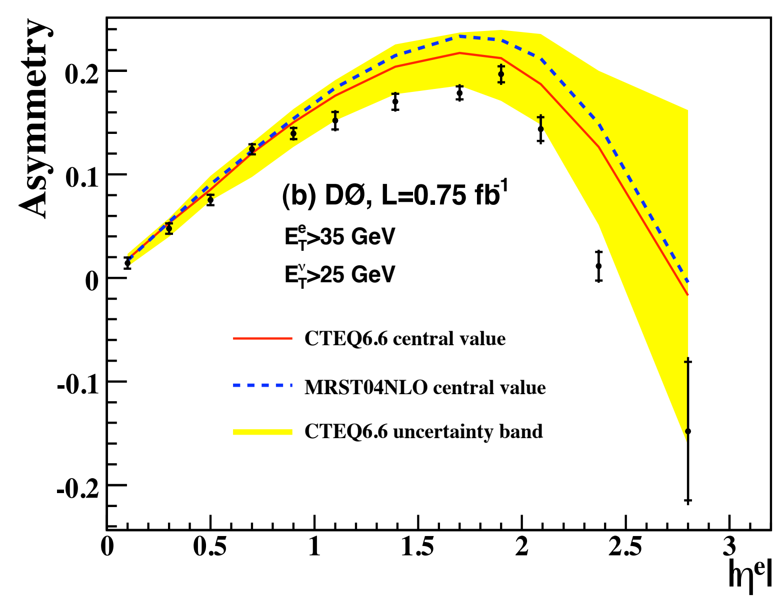
46/54 of both magnet polarities

systematics: charge mis-id, multijet bg

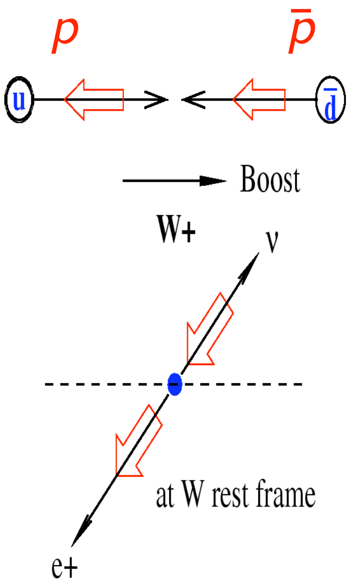
p_T bins: different W rapidities

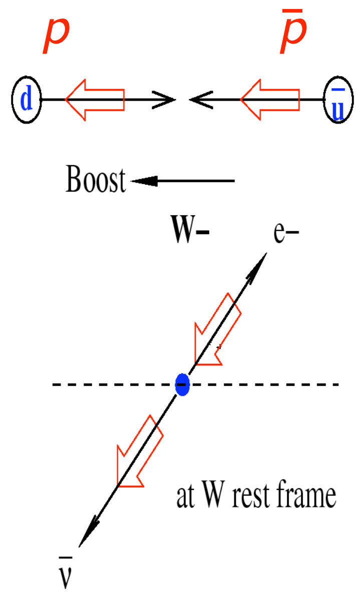
⇒ impact on new PDF fit because of small errors





W Charge Asymmetry





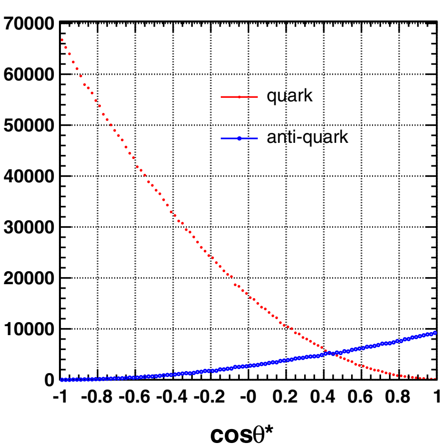
The V−A structure determines the polarity of the W boson and the decay into leptons.

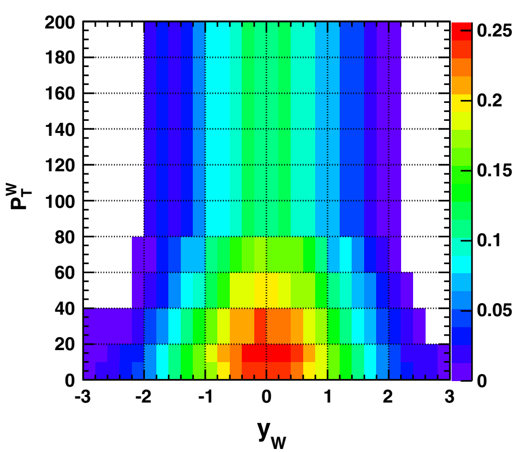
Sea-quark contributions produce the opposite W polarity!

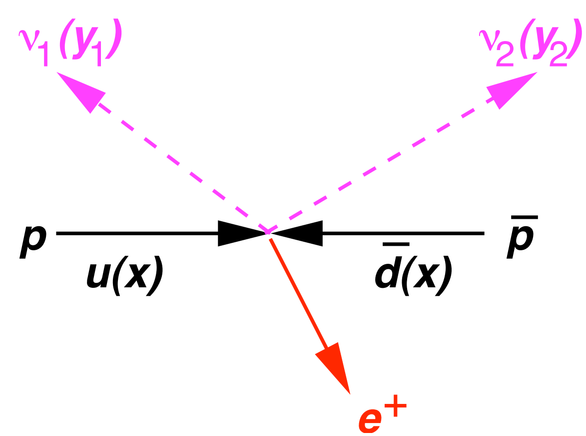
CDF new technique
(PRD 77, 111301(R) (2008)

2 possible solutions for p_L^{ν} from M_W constraint: apply weights iteratively

$w^{\pm}(\cos\Theta^*, y, p_T^W, \sigma)$

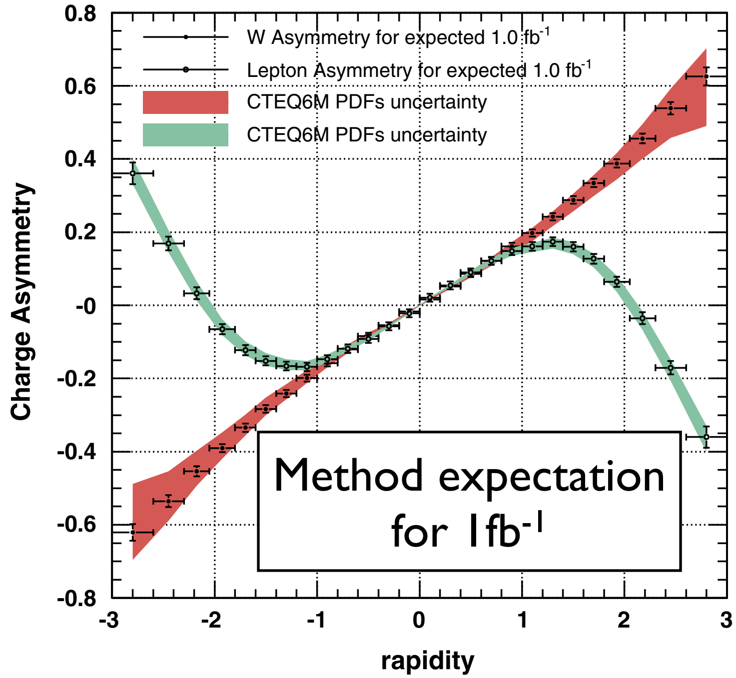


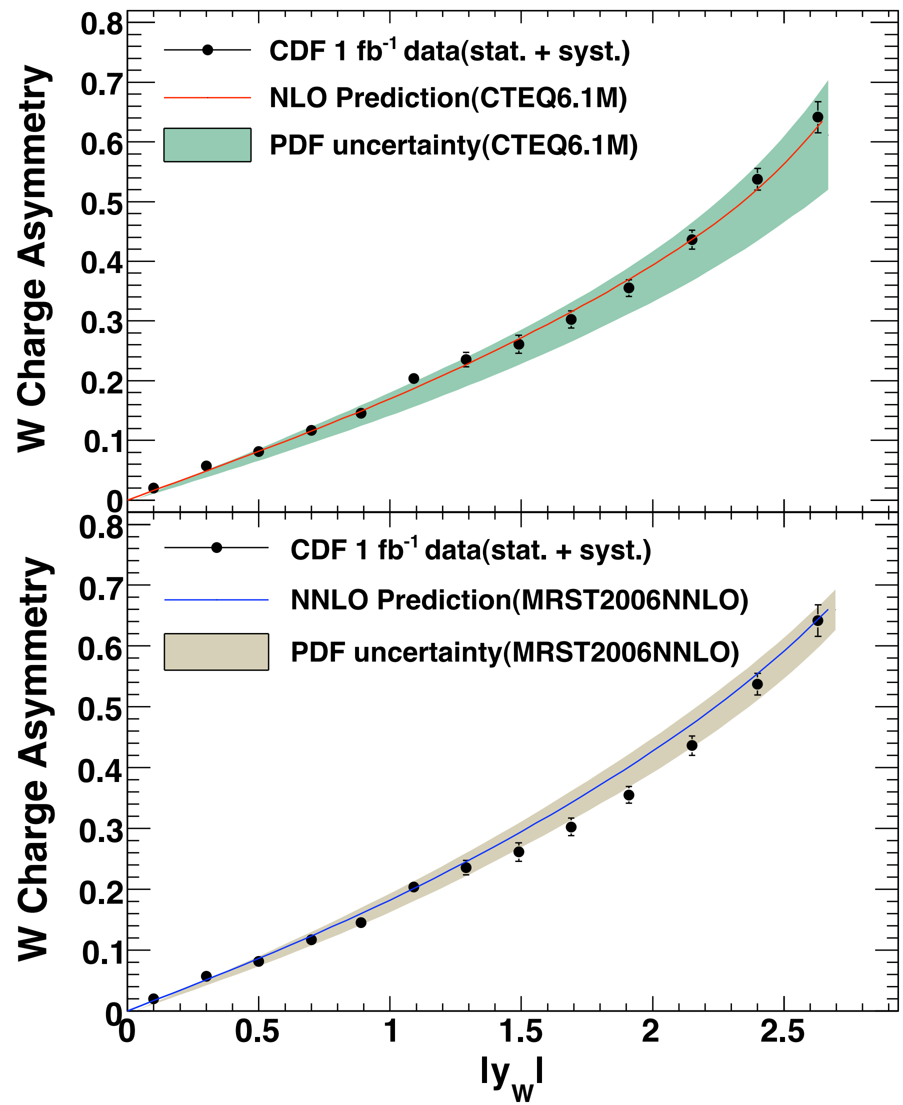




W Charge Asymmetry

Increased sensitivity to PDFs



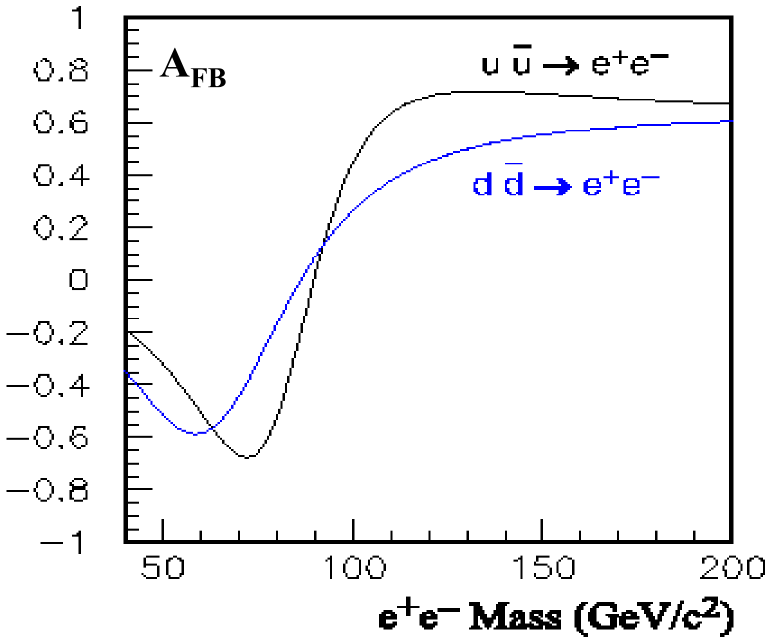


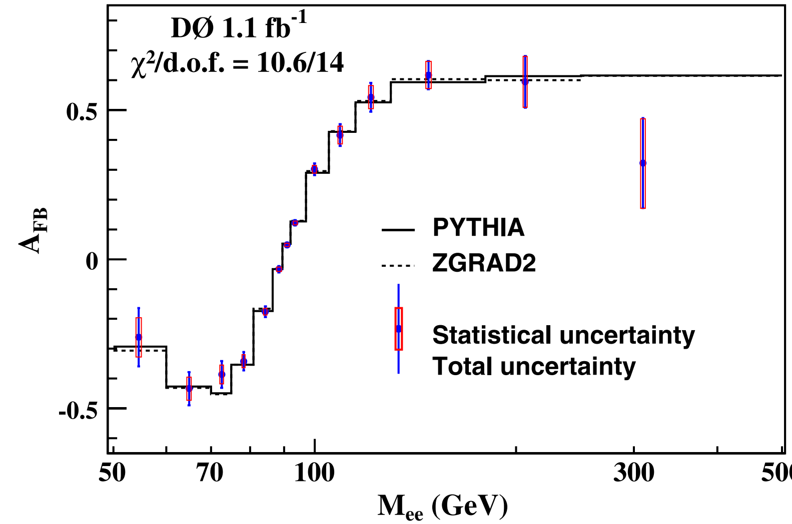
Results:

compare with CTEQ 6.1 (NLO)

and MRST2006 (NNLO)

Z AFB



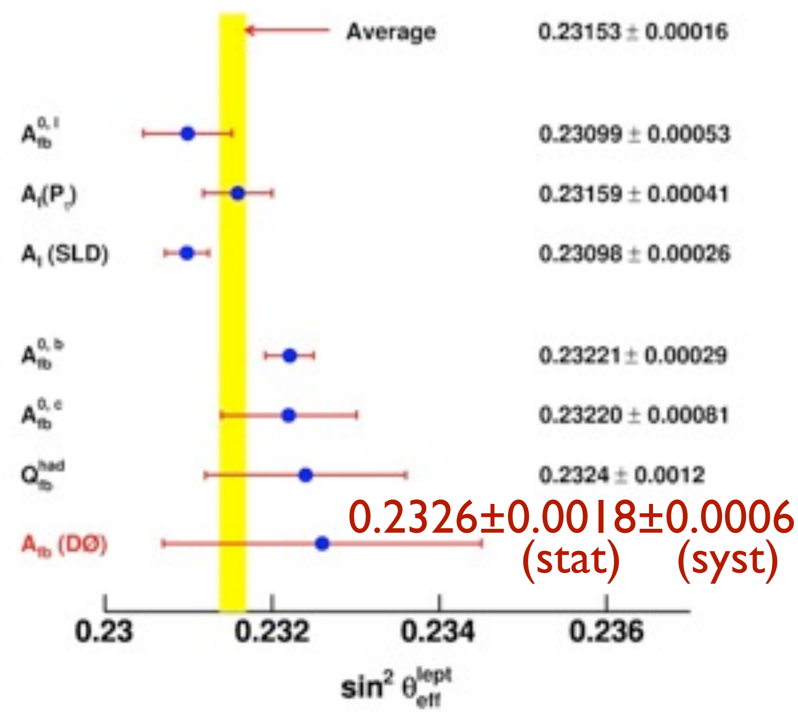


AFB: interference between γ and Z^0 (m_{ee})
Different coupling strengths to u and d quarks (compared to leptons) or new gauge bosons change AFB.

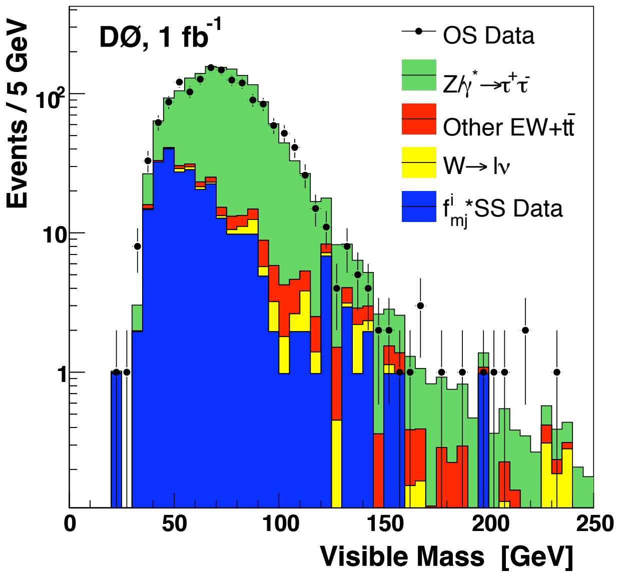
Use Collins-Soper frame to reduce sensitivity to QCD effects

Main uncertainties: **Dominated by statistics**; PDFs, detector resolution

Theory becomes relevant for large luminosities (8fb^{-1})



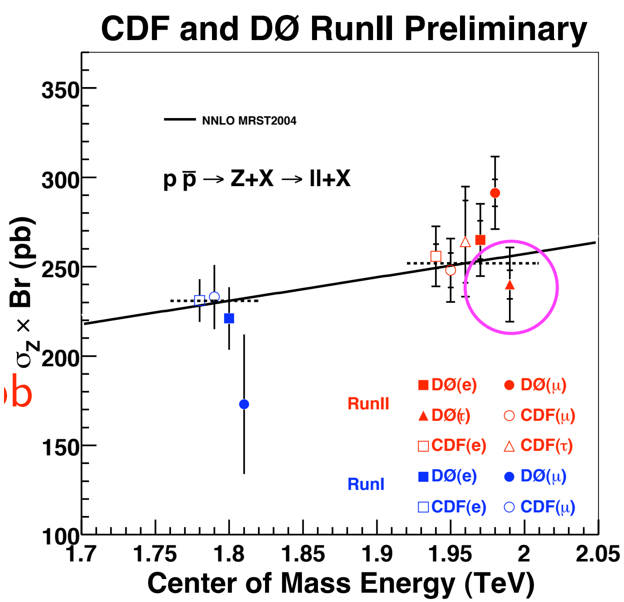
Z Production in Z→ττ



New measurement with 1fb^{-1} of the Z production cross section × branching ratio in Z→$\tau_\mu\tau_{h/e}$

Hadronic τ decays distinguish 3 types:

- 1 track, no EM sub-cluster
- 1 track, at least 1 EM sub-cluster
- 2 or more tracks, any EM sub-cluster



σ·BR=240±8(stat)±12(sys)±15(lumi) pb

Standard Model: 252pb

Benchmark for H→ττ

Summary & Conclusions

Hadron colliders have by definition three important ingredients to all of their physics:

- pQCD (at higher orders)
- npQCD
- Structure Functions

We depend on **results of global fits** as input to understand our data.

W and Z production at the Tevatron is having enough sensitivity to constrain PDFs and be used as **input to global fits**.

Many thanks to S. Blessing, T. Bolton, L. Nodulman, T. Nunnemann, A. Robson, H. Schellman, M. Verzocchi, J. Zhu