Transverse momentum resummation at small x

... or ...

W/Z/Higgs Production & Uncertainties

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2005 DIS Workshop
28 April 2005

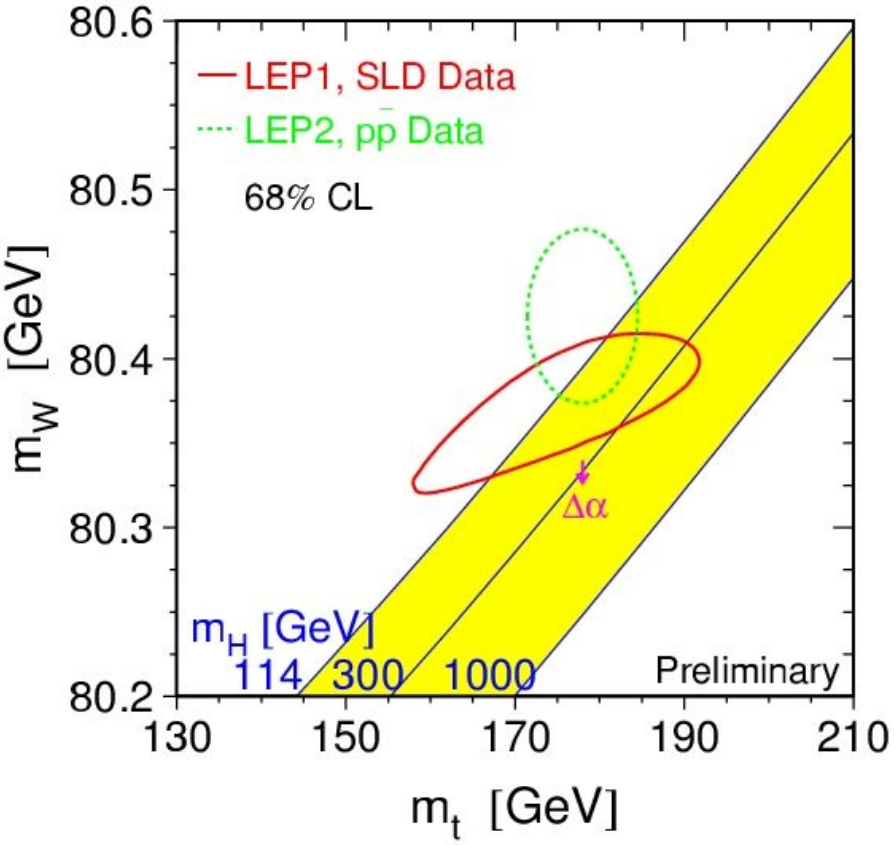
Motivation: W, Z, Higgs Production

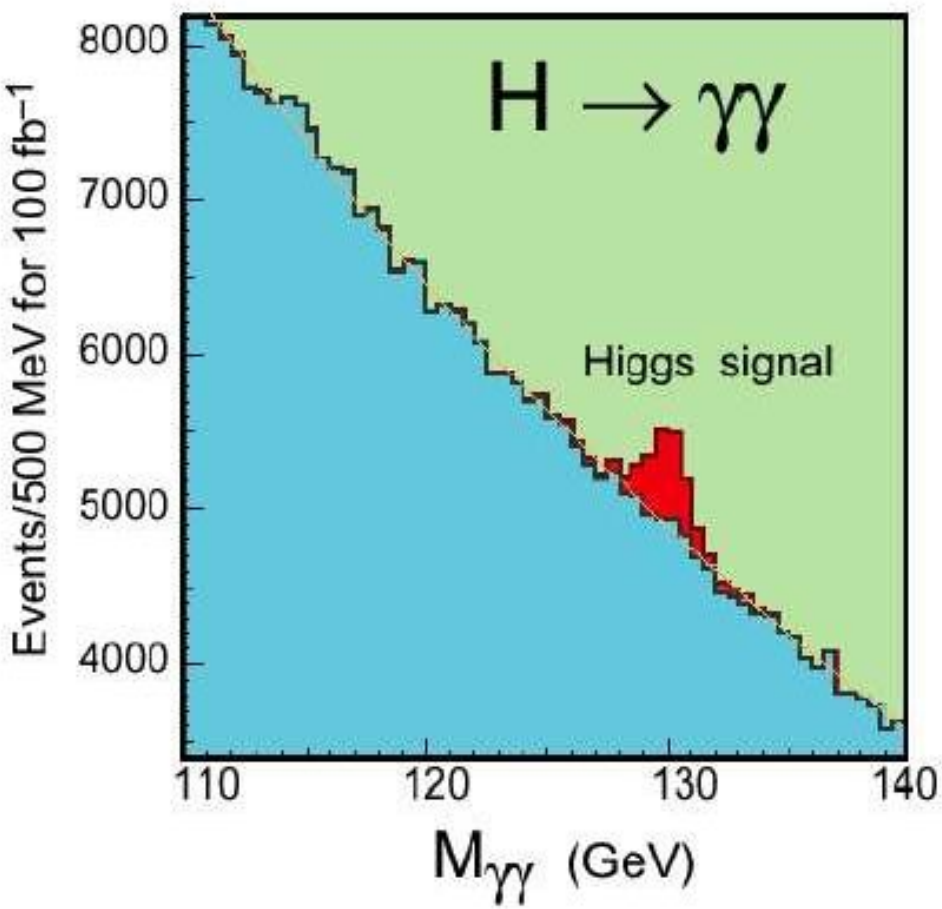
Fundamental SM Parameter

Precision M_W provides clues of Higgs

Higgs discovers relies on accurate predictions

details depend on channel





NLO QCD Corrections to Boson Production

Vector boson production at hadron–hadron colliders

Incoming particles

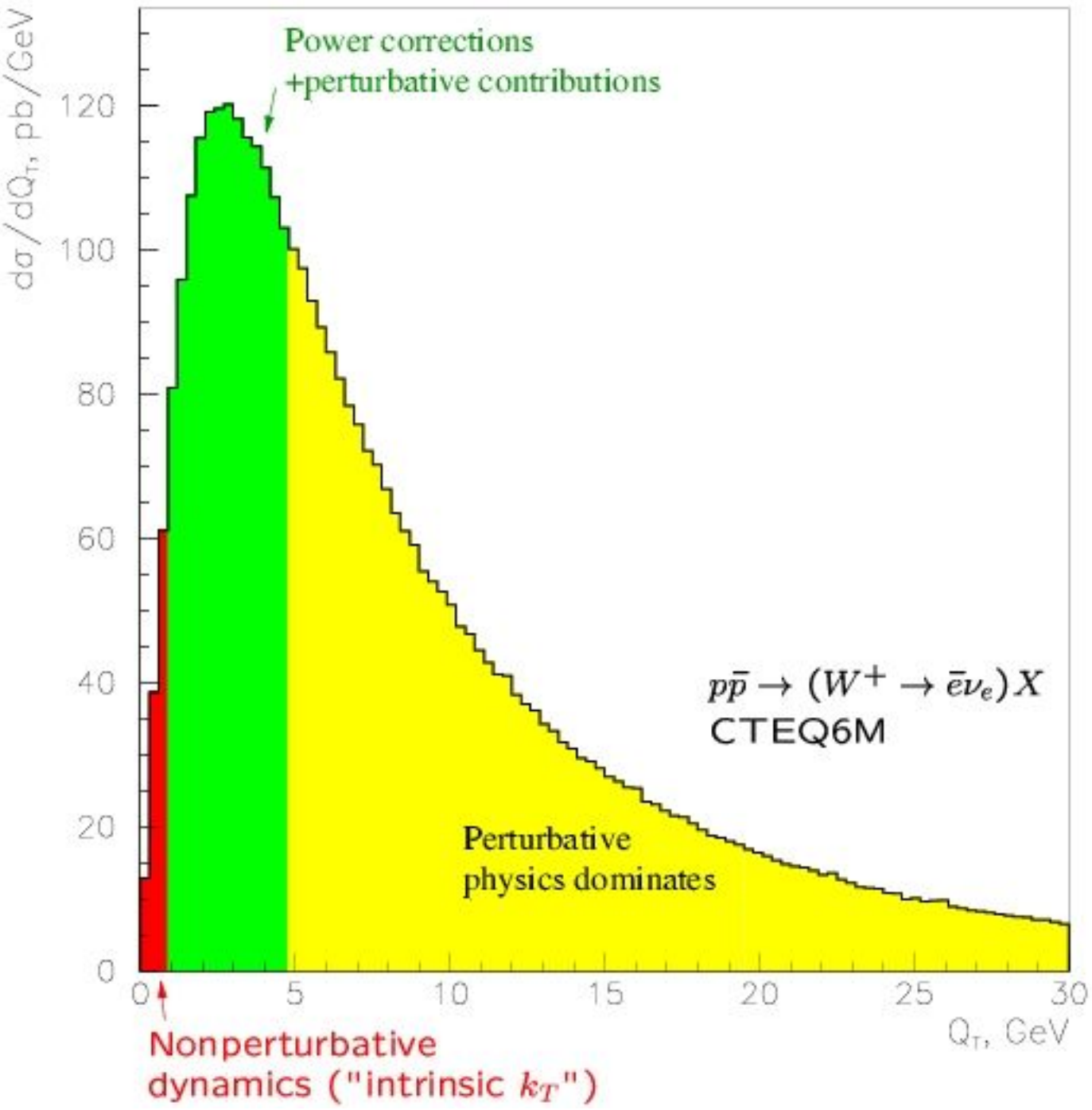
Outgoing particles

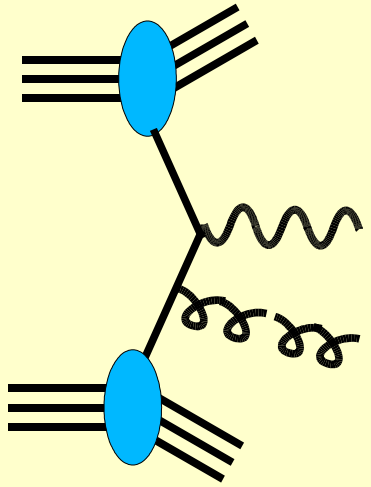
No QCD radiation q → $\bar{q}$, W

QCD radiation → $\theta \neq 0$, $q_T \neq 0$

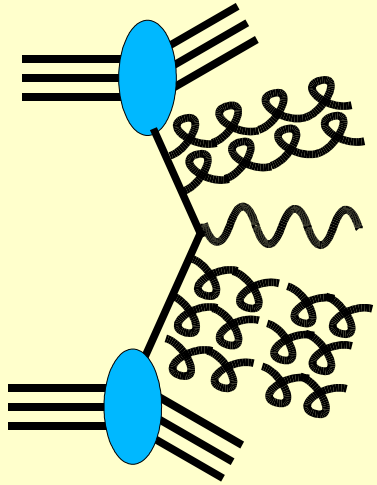
z

Ingredients for full q_T distribution





Single hard
perturbative emission



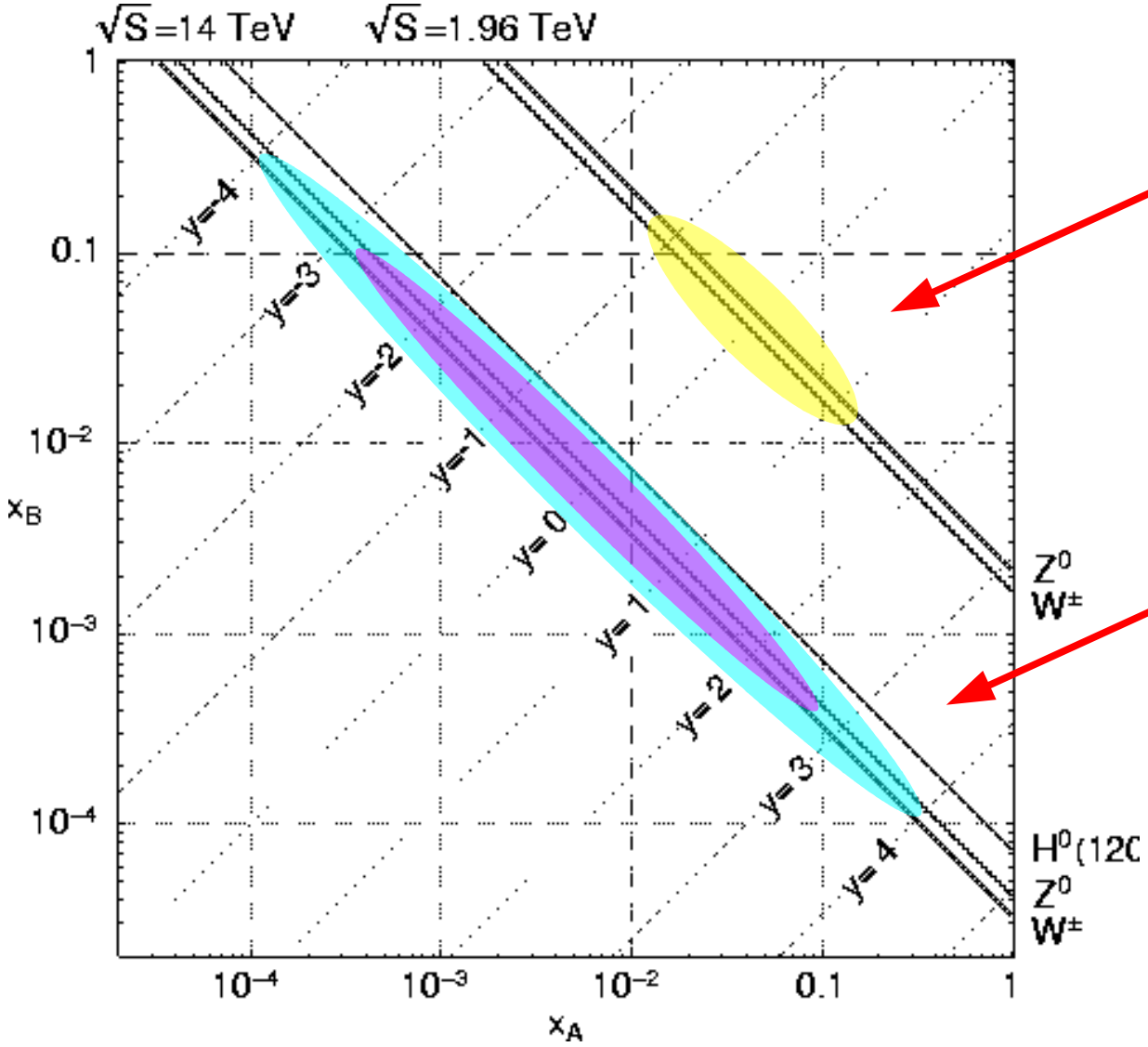
multiple soft gluon
emissions

W / Z / HIGGS Kinematics

What is relevant x region for W / Z / Higgs Production

Kinematics of boson production

$$\sigma = f(x_A) f(x_B) \hat{\sigma}$$



This is the region of present measurement

This is the region we need at LHC

LHC probes new {x,Q} range.

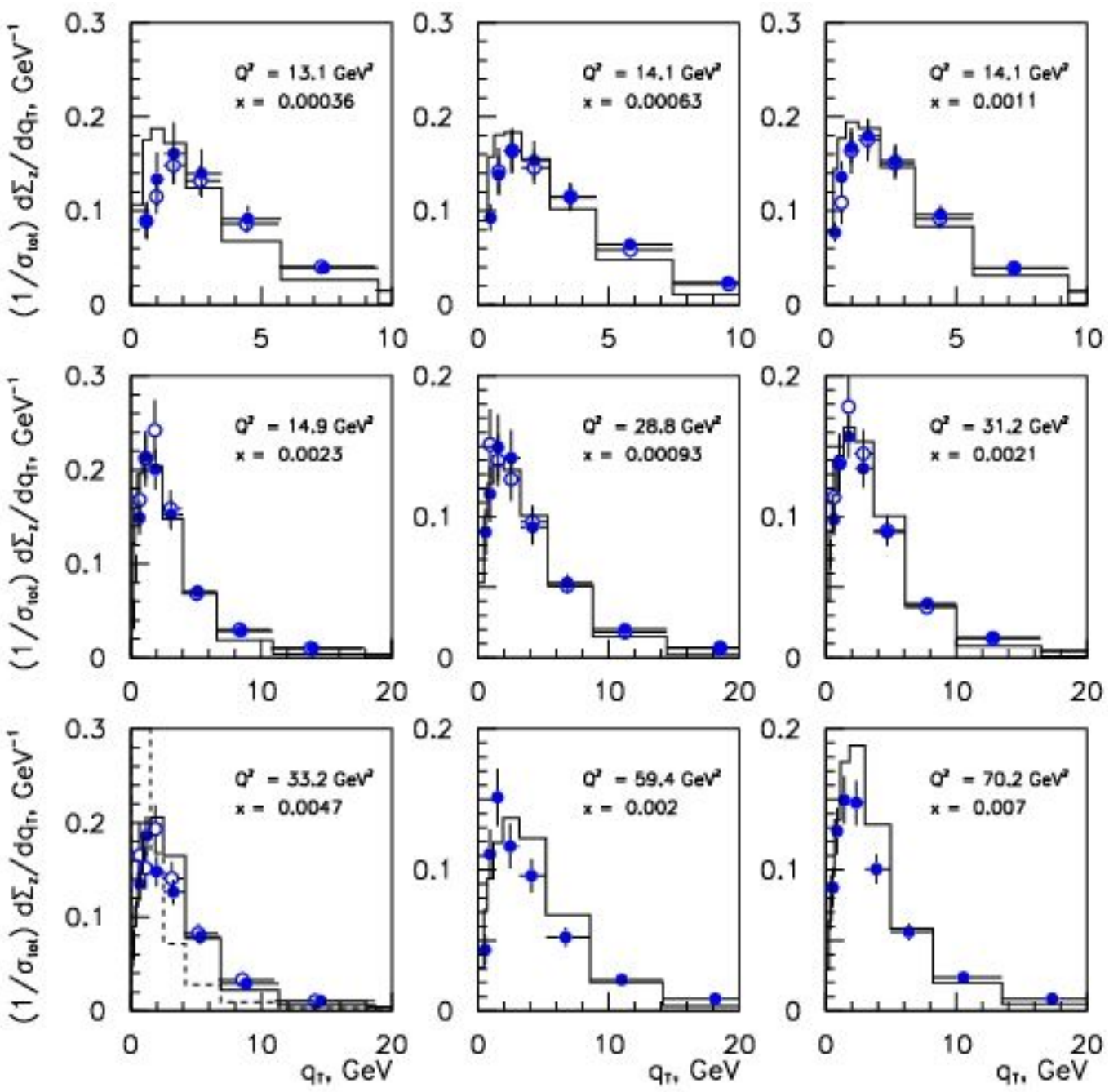
Requires extrapolation

x range for Tevatron

x range for LHC

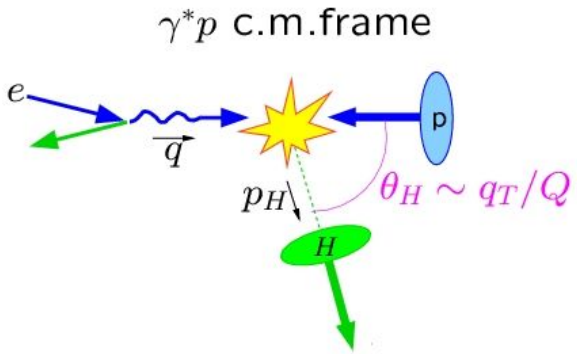
HERA has measured the crossed process (DIS) for this region and found ...

Differential energy flow at small-x???



$$\frac{d\Sigma_z}{dx\,dQ^2\,dq_T}$$

$$d\Sigma_z = \int z\,\frac{d\sigma}{dz}$$



Extra q_T broadening
for $x<10^{-2}$

H1 Collaboration,
PL B356, 118 (1995)
EPJ C12,595 (2000)

What new effects appear at small-x???

HERA measured DIS eq→eq

Observed additional q_T broadening at small-x (x<0.01)

This effect is <u>beyond</u> the usual Sudakov soft gluon resummation

Source: Log(1/x) terms??? BFLK???

We'll parameterize our ignorance

$$e^{-S(q_T,Q)} \rightarrow e^{-S(q_t,Q)-\rho(x)q_T^2}$$

Only turns on at small-x

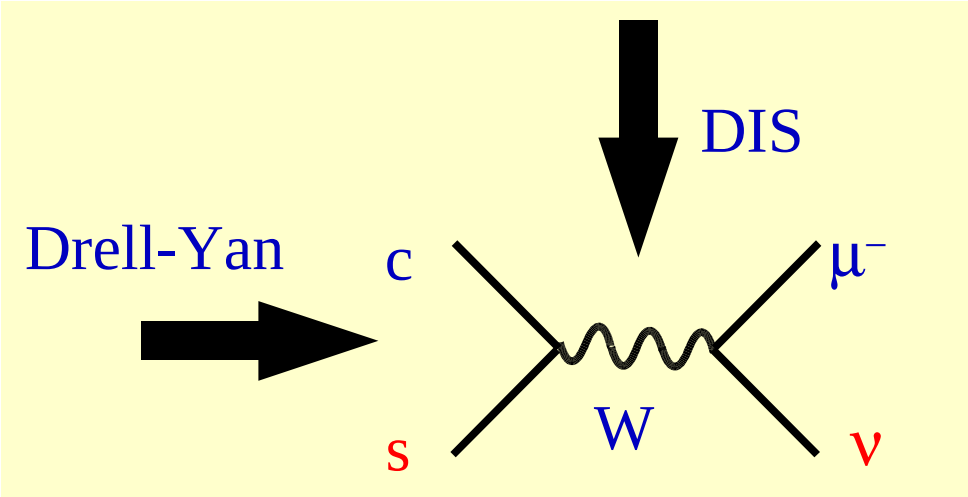
Additional small-x broadening term
Form taken from HERA data

J. C. Collins, D. E. Soper and G. Sterman, Nuc.Phys. B250, 199 (1985)
J. C. Collins and A. Metz, hep-ph/0408249..

What are the implications for LHC???

Drell-Yan ($qq \rightarrow W/Z/\ /H \rightarrow ee$) at

LHC is simply crossed DIS process



Apply to LHC:

Use ResBos (*Resummed Boson Production Code*):

Implements Sudakov soft gluon resummation via CSS

Collins, Soper Sterman

Include small-x broadening in Sudakov exponent

actually implemented in b-space

$$e^{-S(q_T,Q)} \rightarrow e^{-S(q_t,Q)-\rho(x)q_T^2}$$

Additional small-x broadening term Form taken from HERA data

Only turns on at small-x

$$\rho(x) = c_0\left(\sqrt{\frac{1}{x^2}+\frac{1}{x_0^2}}-\frac{1}{x_0}\right)$$

$x_0 = 0.005$

$c_0 = 0.013$

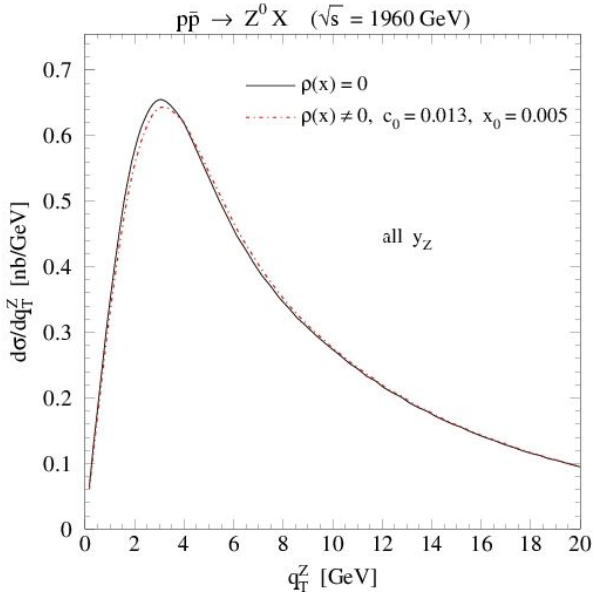
Crossing is valid. See Collins & Metz

J. C. Collins and A. Metz, hep-ph/0408249.

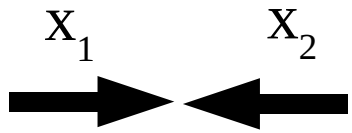
J. C. Collins, D. E. Soper and G. Sterman, Nuc.Phys. B250, 199 (1985).


Z

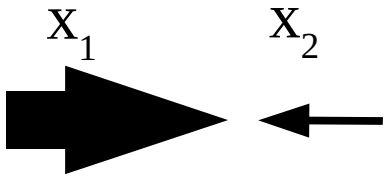
Z Production at the Tevatron



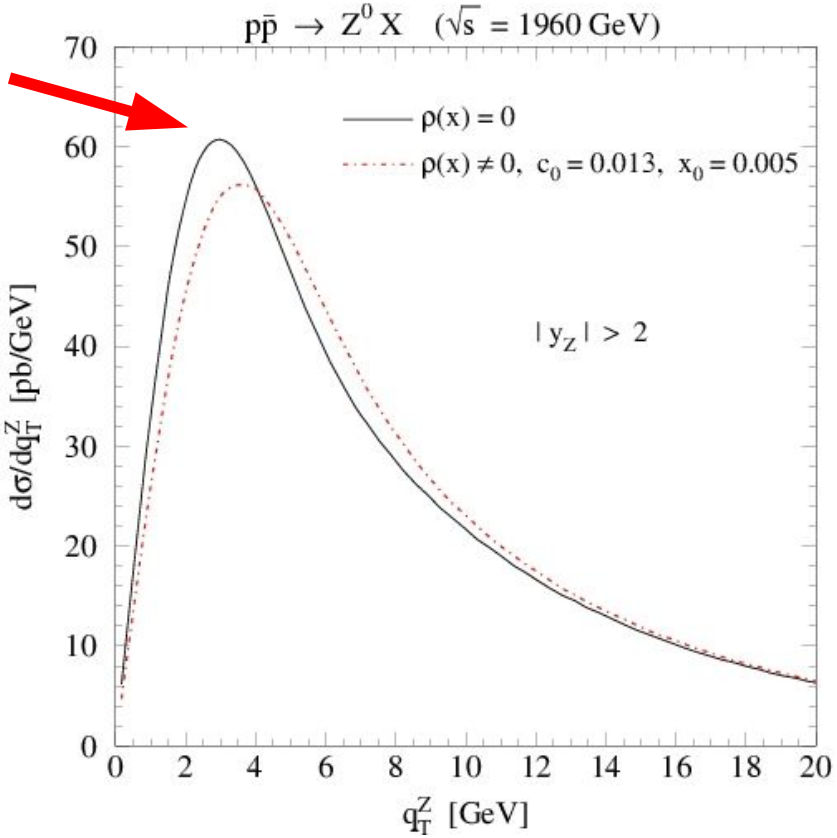
Central Rapidity

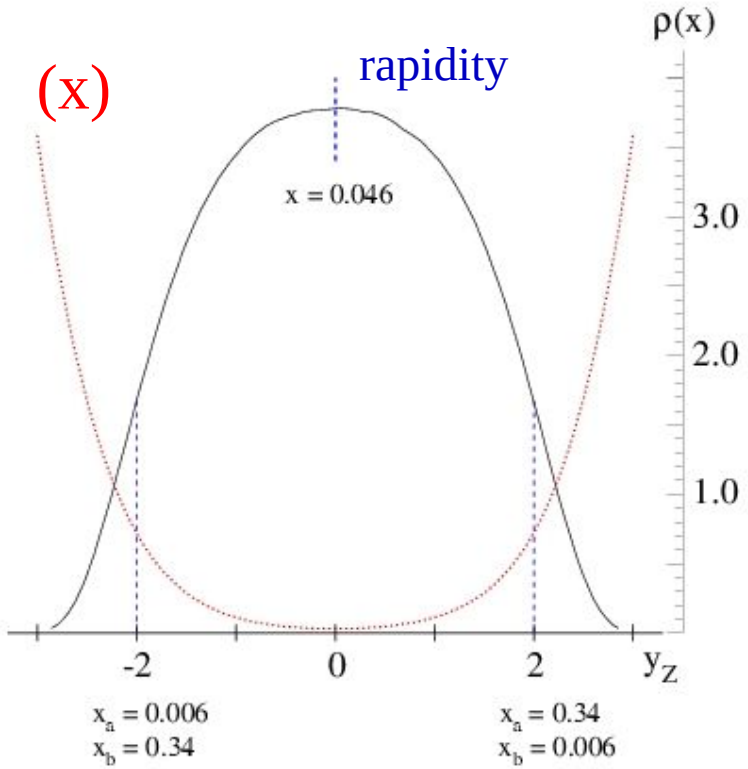


Forward Rapidity



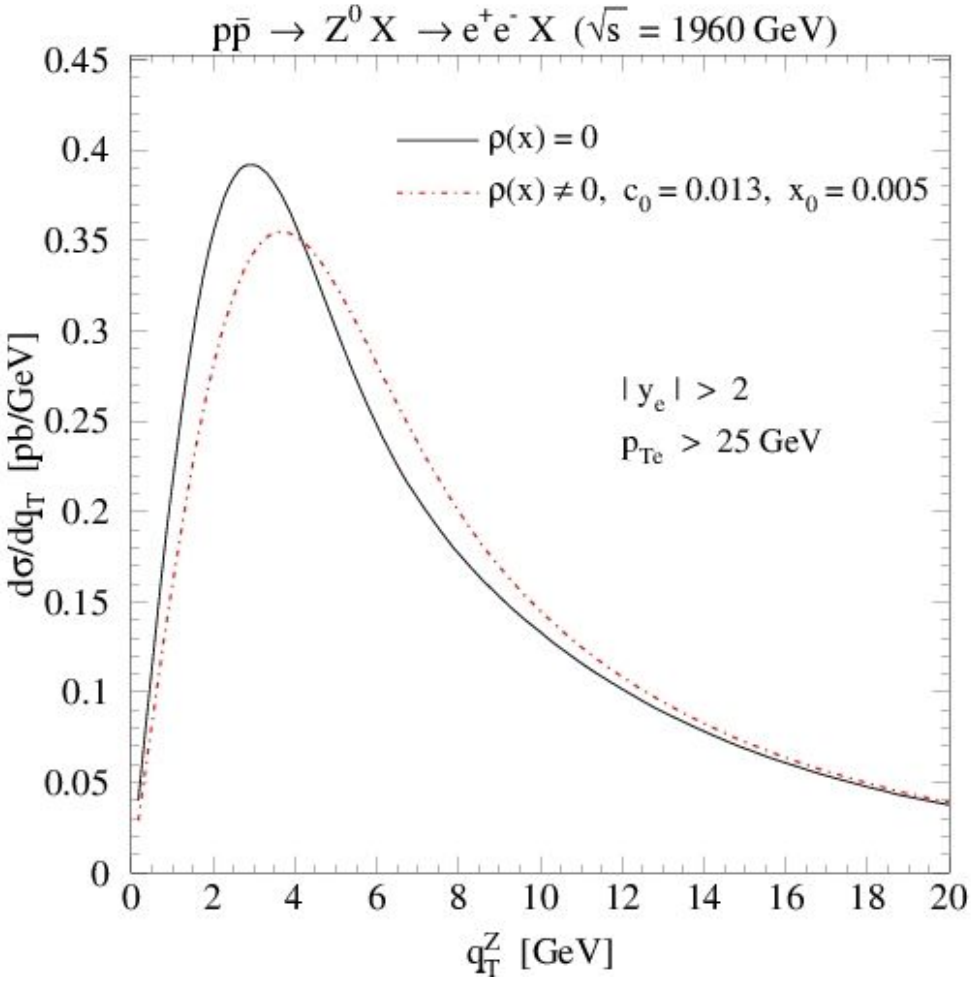
Position of q_T peak shifts by 25%



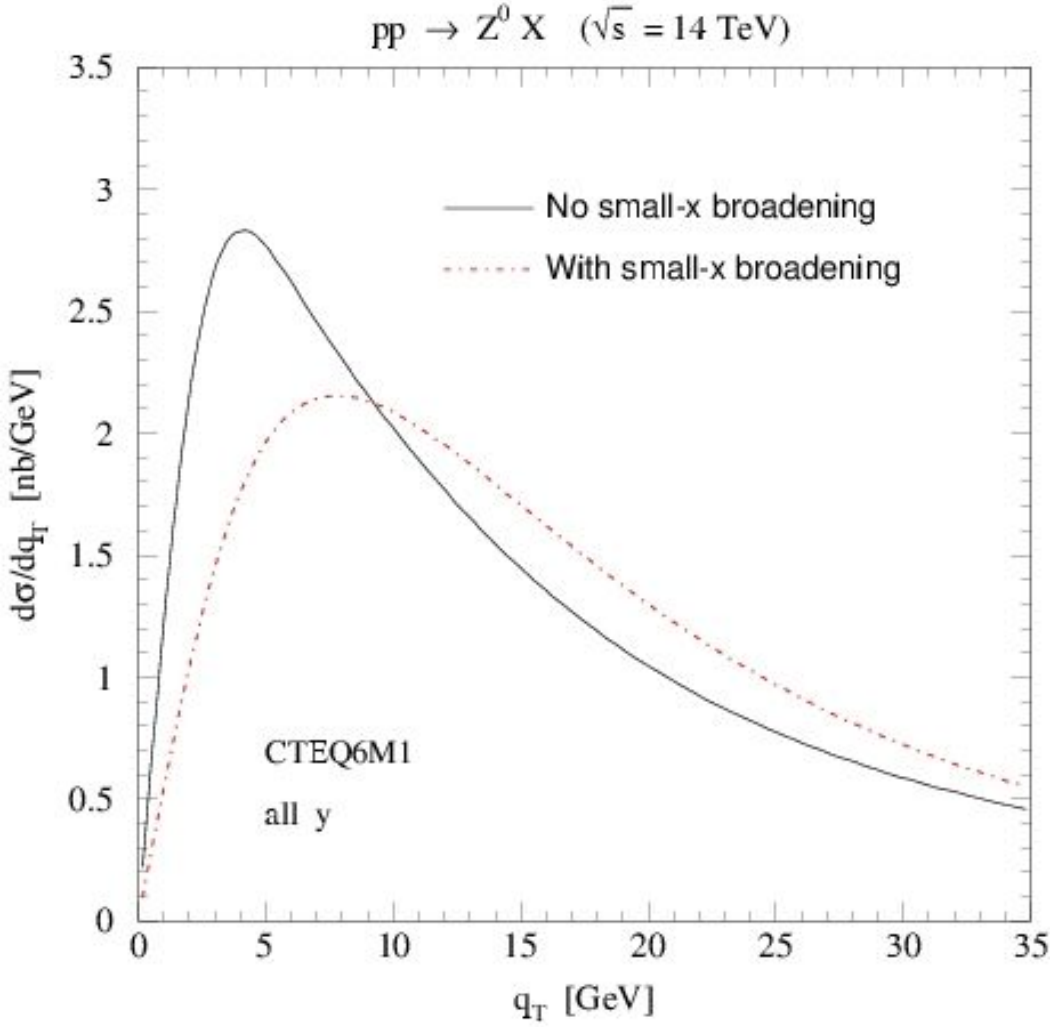


Z Production: Tevatron & LHC

Tevatron



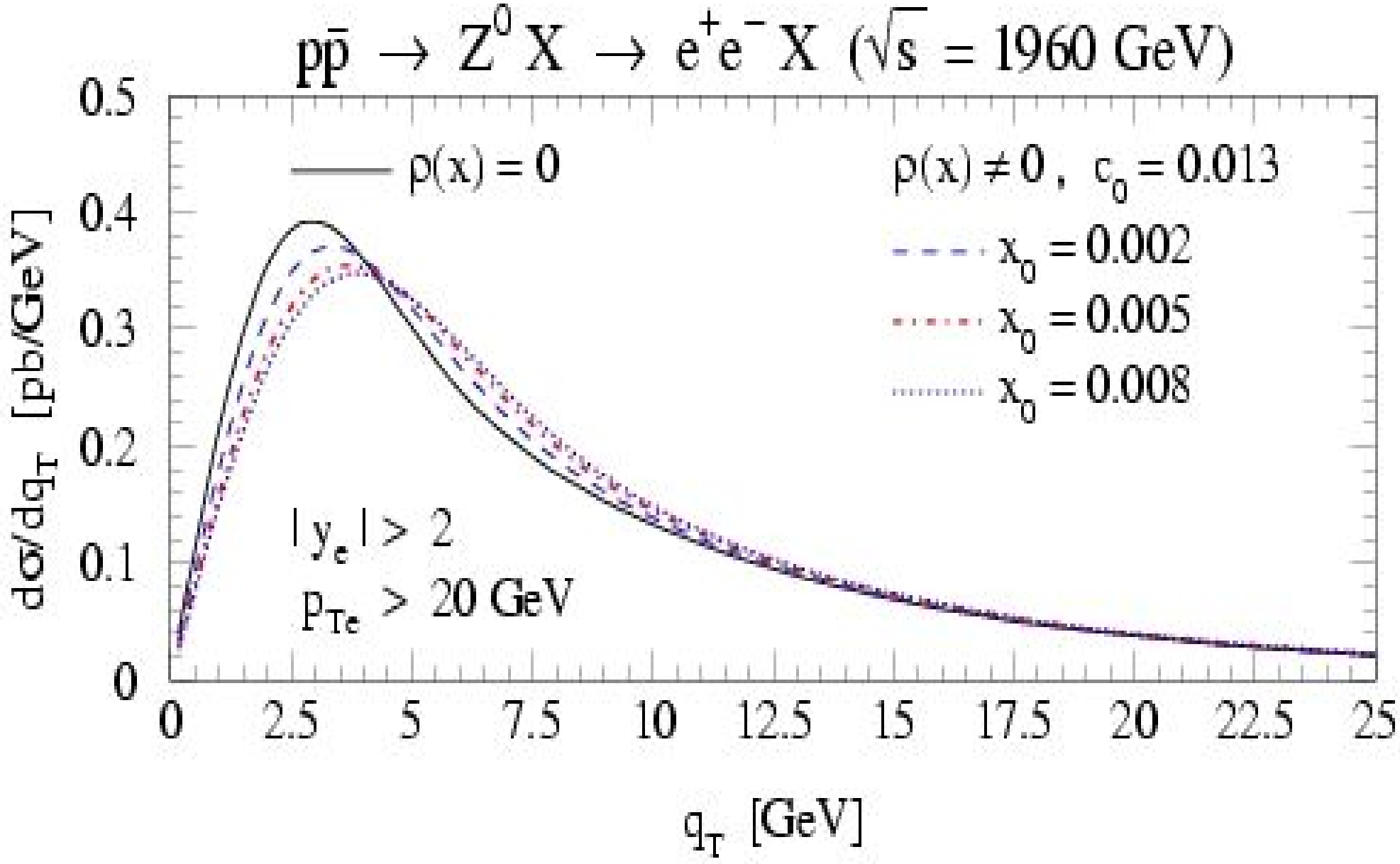
LHC



With cuts on y_e and p_{Te}

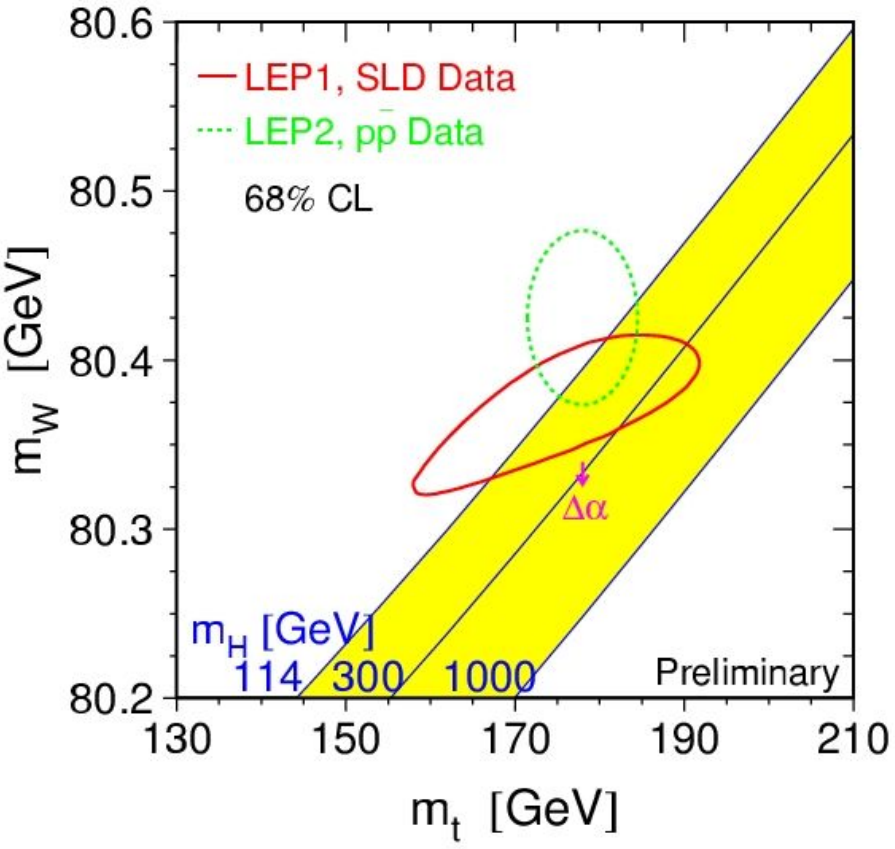
No y cut necessary !!!

What is the uncertainty???



x_0 is a measure of where small x effects turn on

W

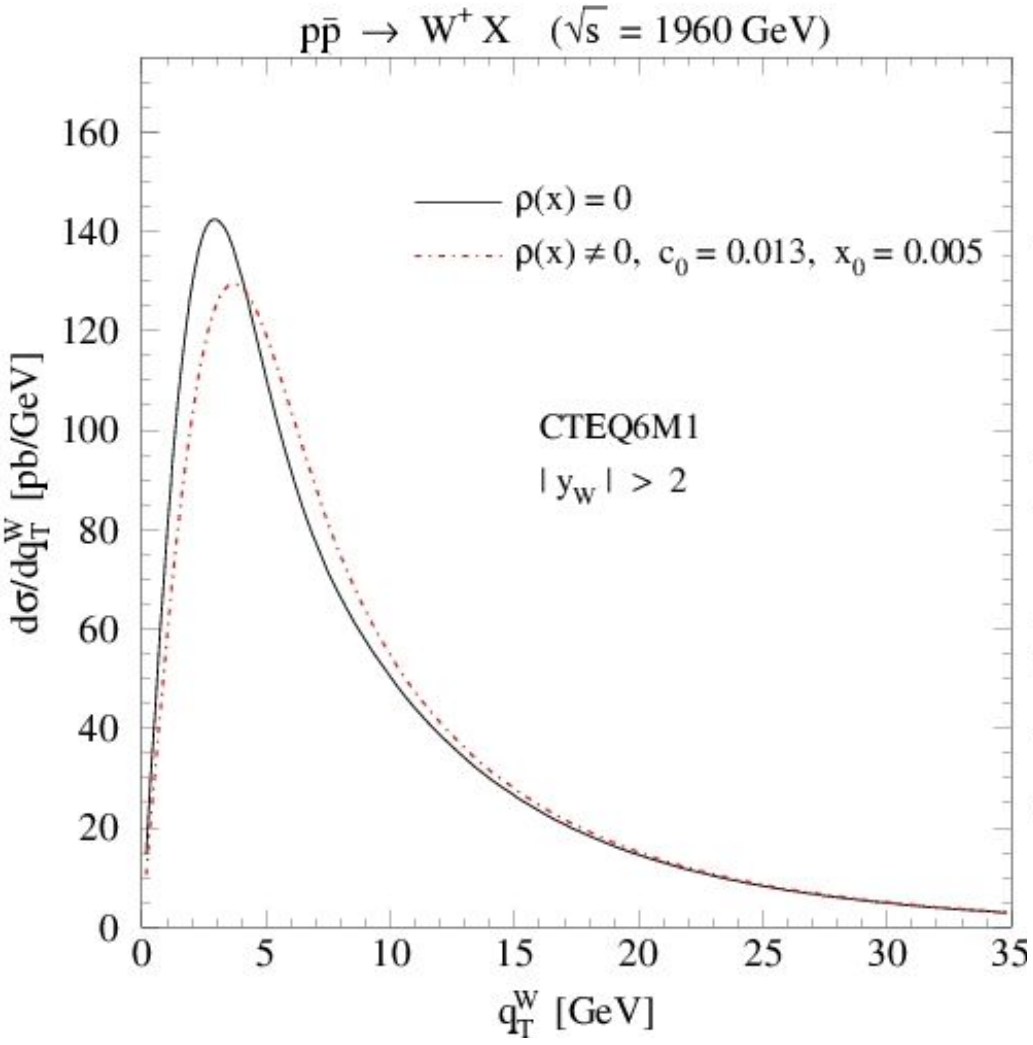


Fundamental SM Parameter

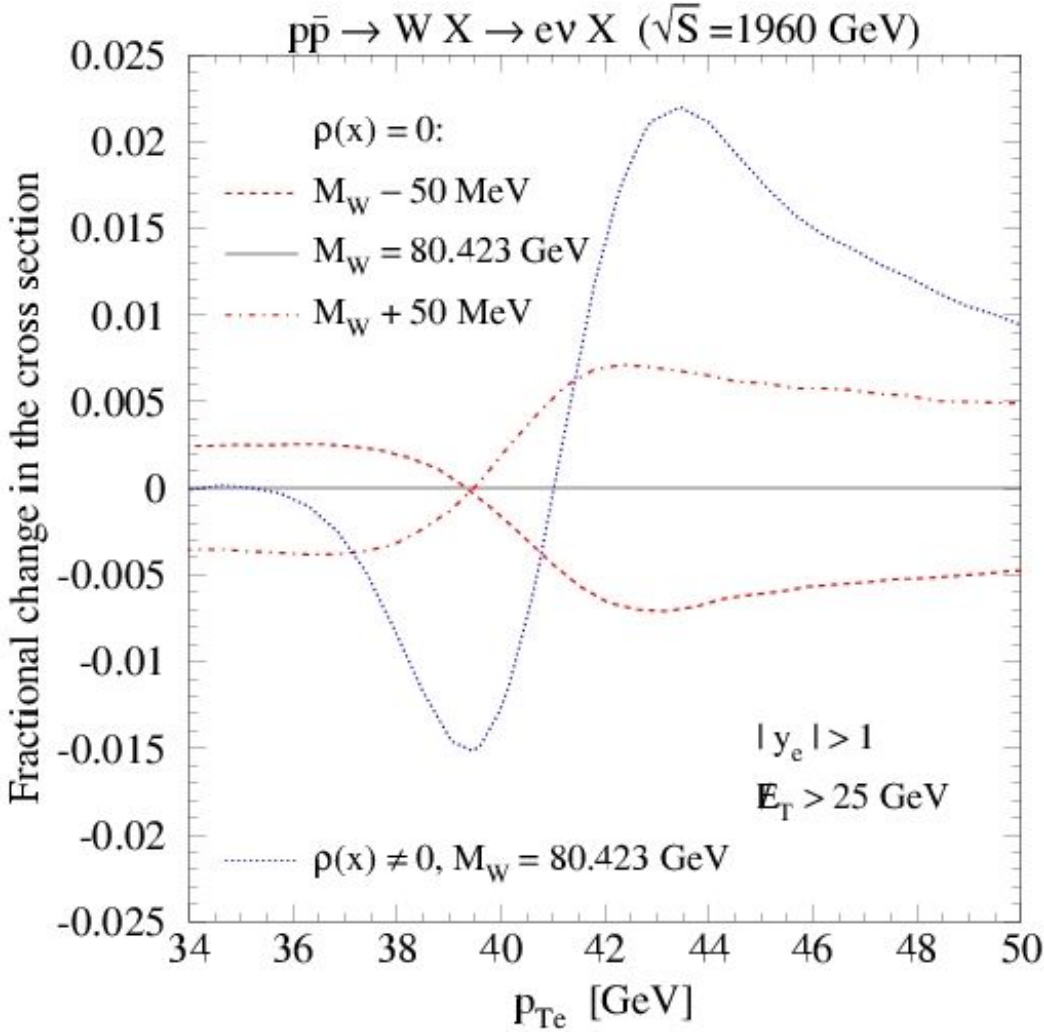
Precision M_W provides clues of Higgs

W Production at the Tevatron

Shift of W q_T distribution

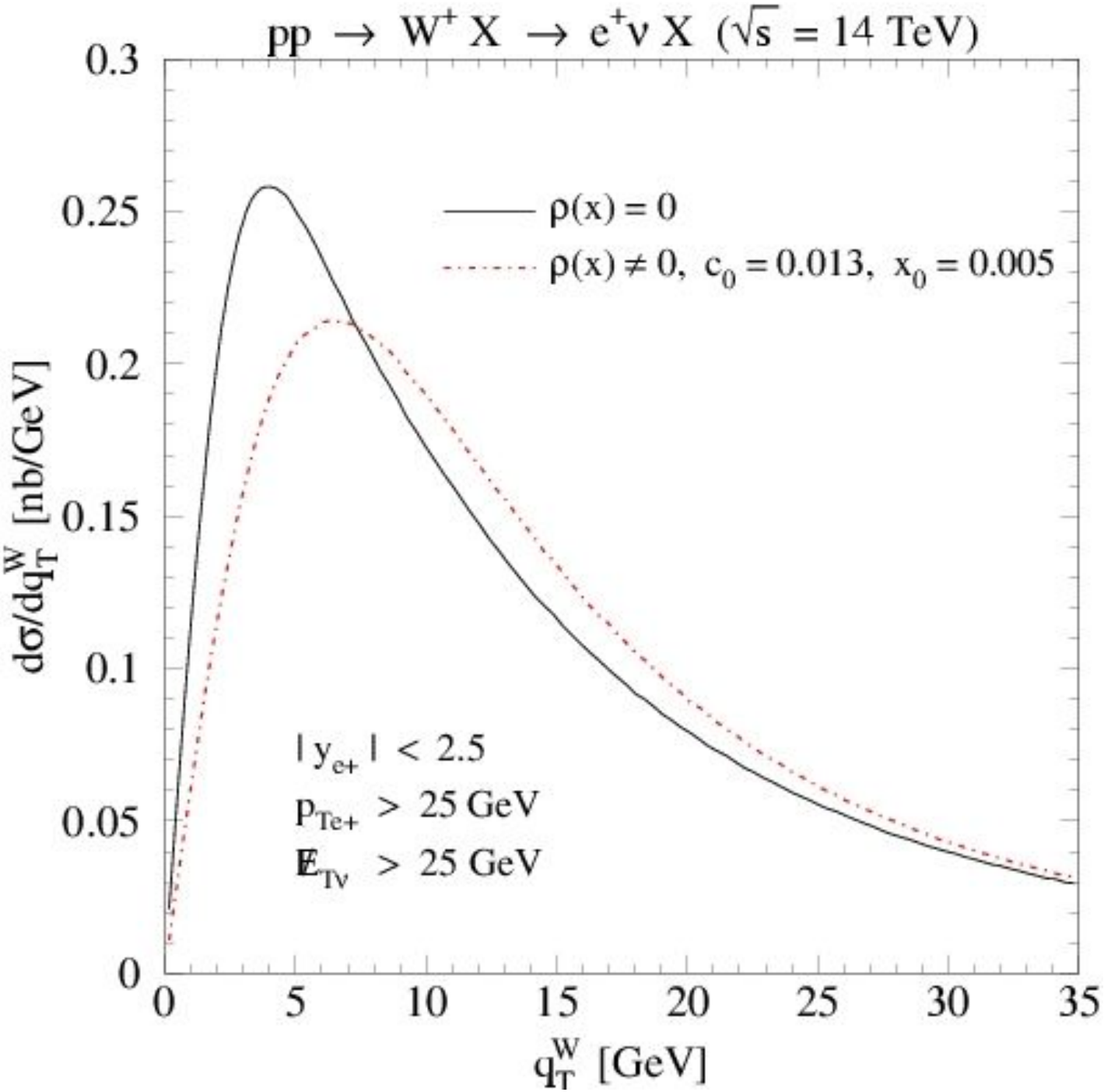


Effect on Jacobian Peak



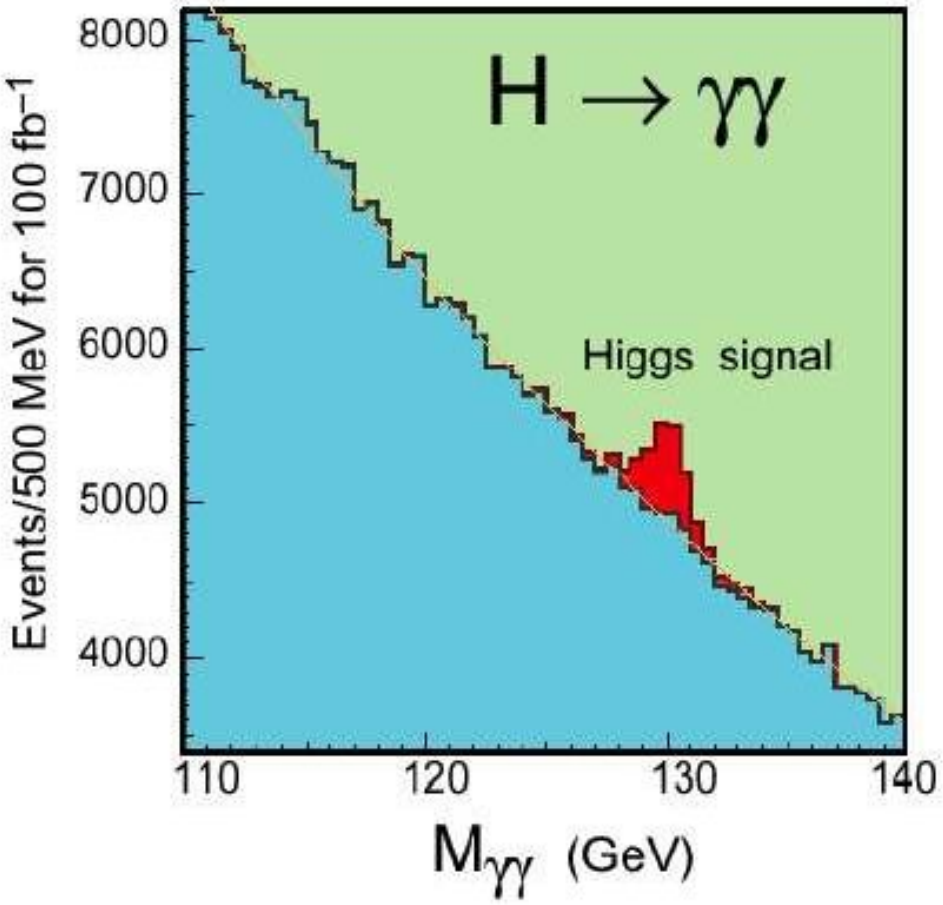
Potentially, this effect can limit precision of M_W determination

W Production at the LHC



effect present in central rapidity region

HIGGS



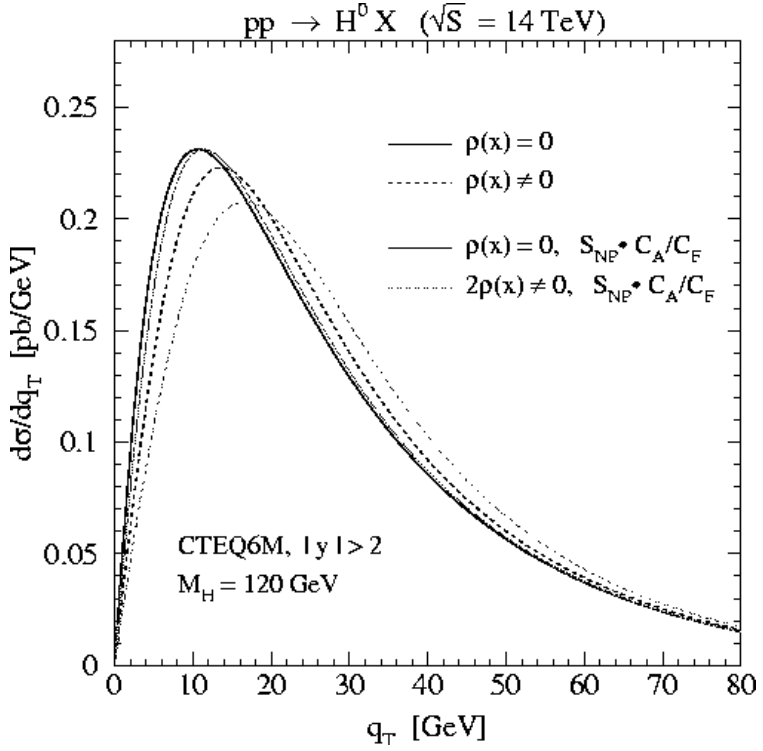
Higgs discovers relies
on accurate predictions

Effect on Higgs

Broadening not important for discovery

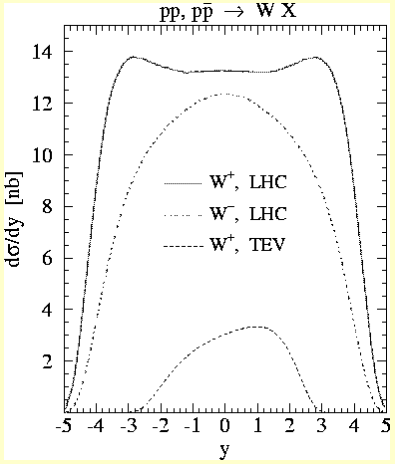
Important for precise M_H measurement

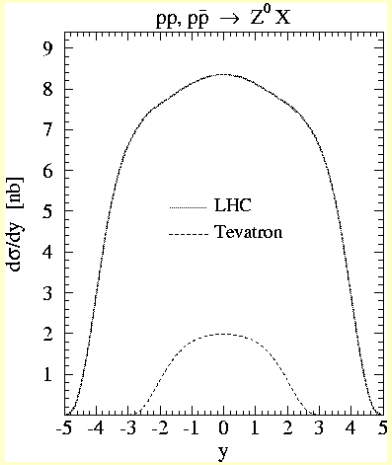
i.e., to characterize SUSY model

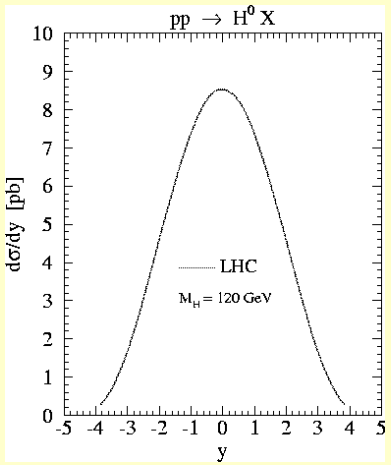


Reduced effect on Higgs

Consequence of y distribution







Berge, Nadolsky, Olness, Yuan, hep-ph/0410375.

Summary

* Small-x DIS data provide important constraints on the PDF's
  - PDF's are essential ingredient for exploration of
  - Higgs, SUSY, and other "New Physics" signals

* LHC probes smaller x values:
  - Resummation & Log(1/x) effects can alter W/Z/Higgs production
  - Significant impact for LHC
  - Tevatron can observe such effects in forward (y~2) region

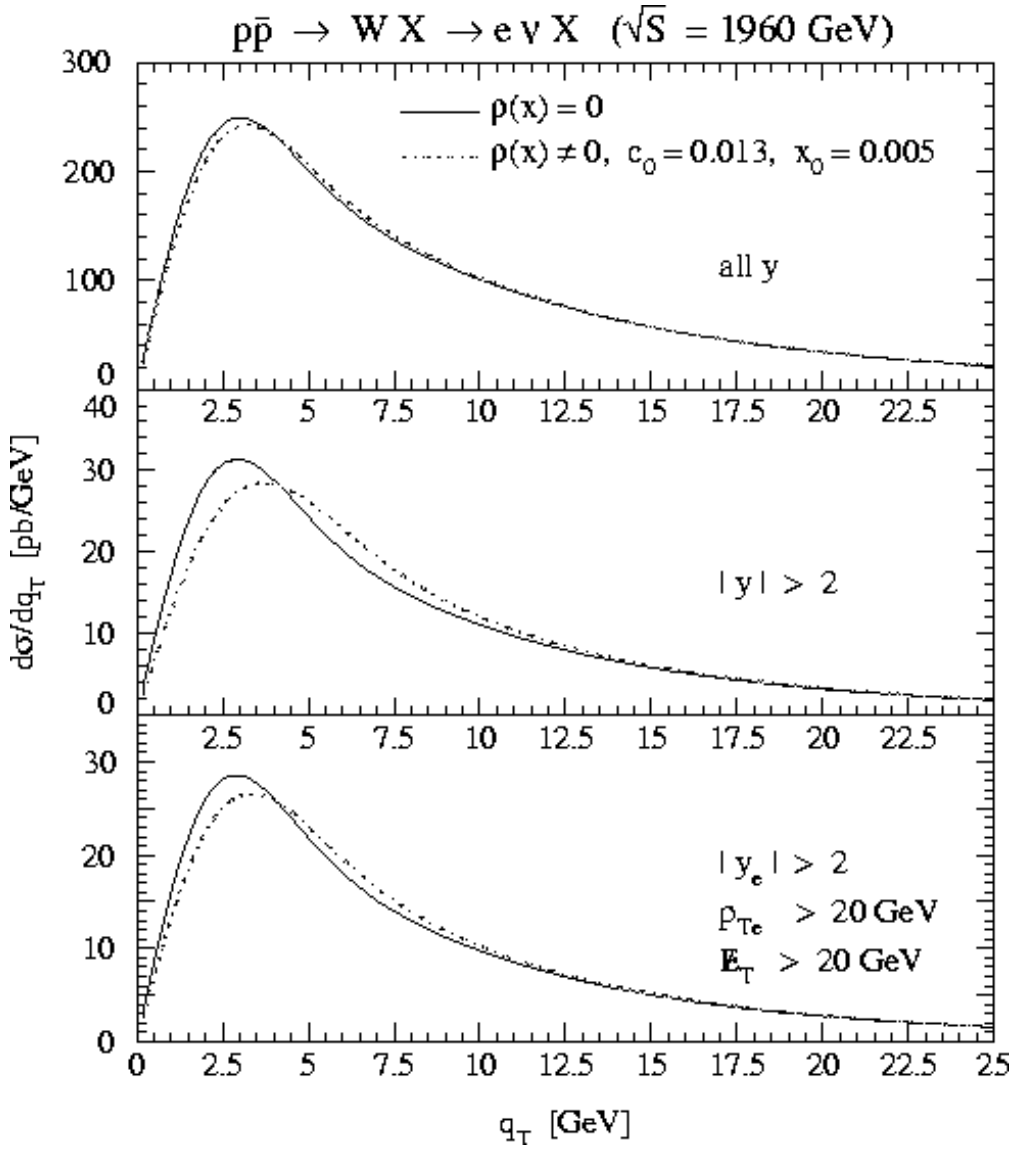
* Need to accommodate these effects and uncertainties
  - Make best use of HERA & Tevatron data
  - Be prepared to cross-check using early LHC data

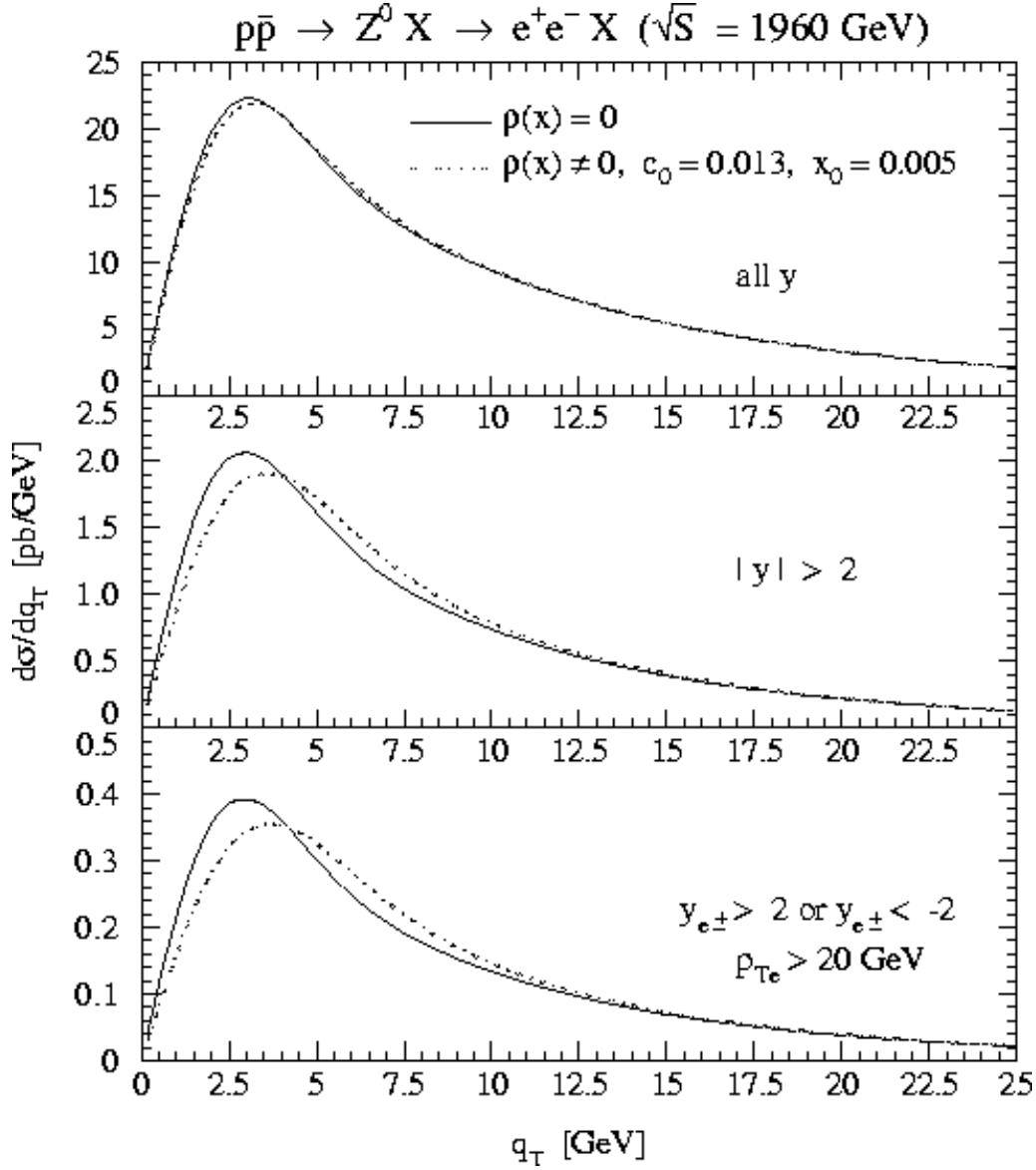
Thanks to: S. Berge, P. Nadolsky, W. Tung, S. Kretzer, J. Owens,

S. Kuhlmann, J. Pumplin, H. Lai, J. Huston, E. Berger

BACKUP

W/Z Production at Tevatron





Berge, Nadolsky, Olness, Yuan, hep-ph/0410375.

What is effect of additional q_T broadening at LHC

Result of this effect:

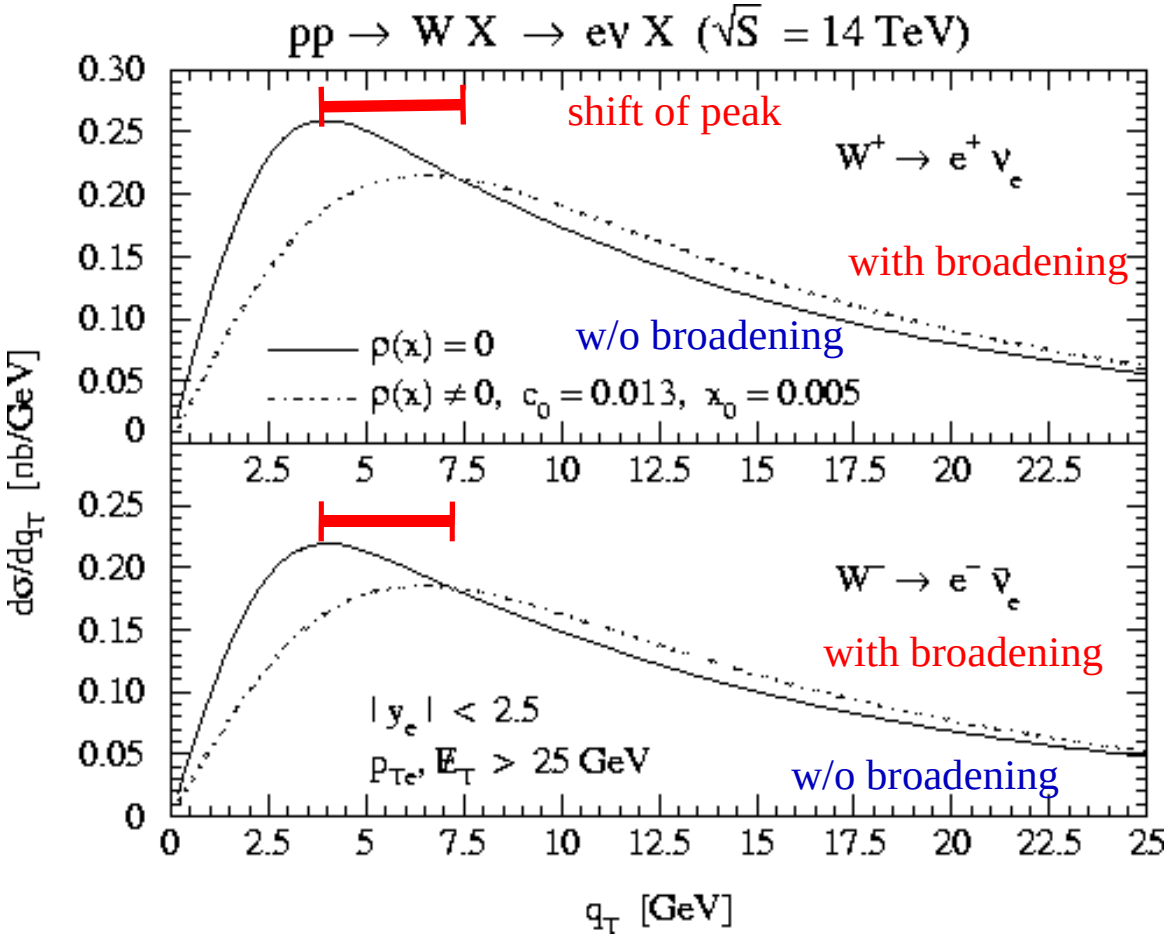
Shift of distribution

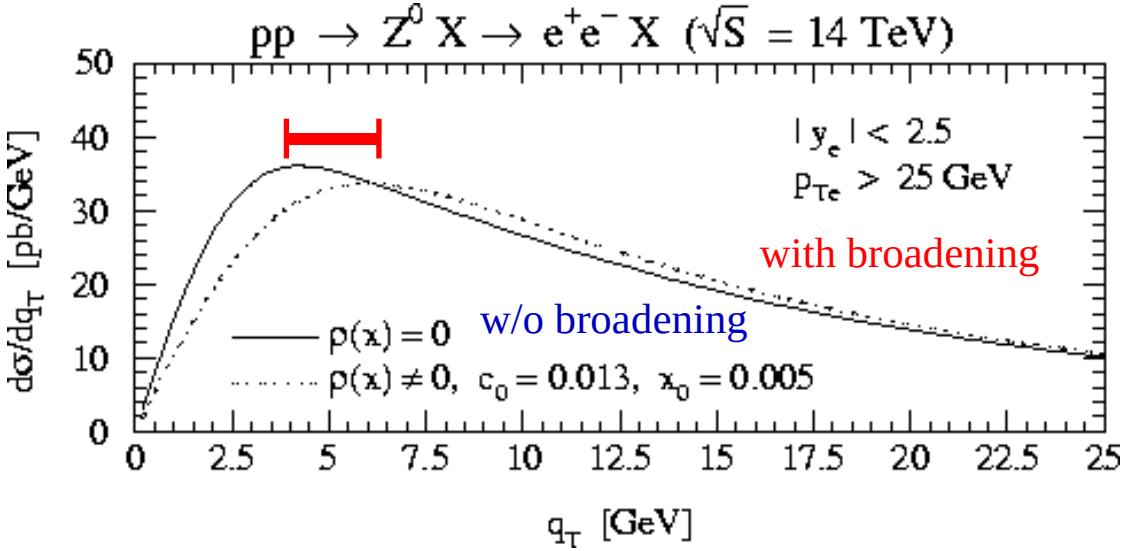
Shift of normalization

This will effect M_W measurement at both Tevatron and LHC

Tevatron can look for this effect by measuring forward W and Z production

These uncertainties are not acceptable for "benchmark" processes





Berge, Nadolsky, Olness, Yuan, hep-ph/0410375.

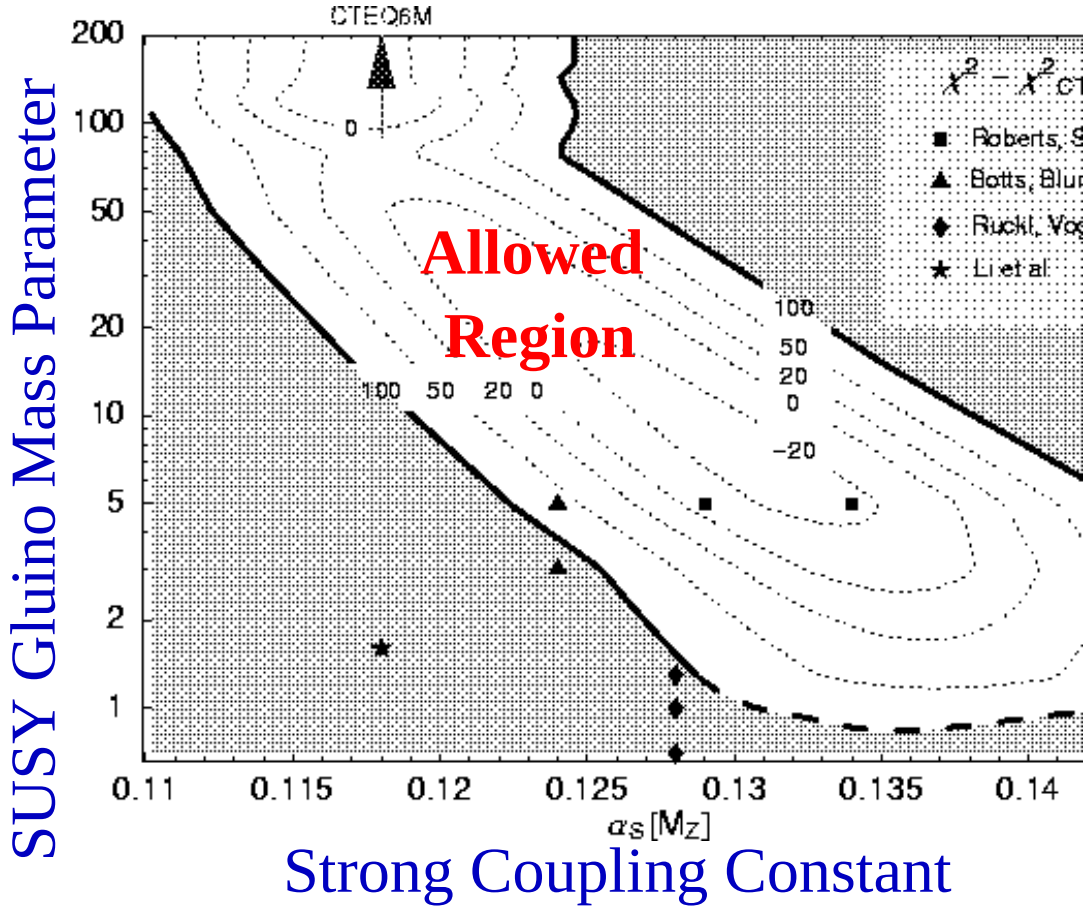
Another source of uncertainty for the PDFs

Inclusion of new strongly interacting particles *(e.g., gluino)* affect PDF's at higher scales.

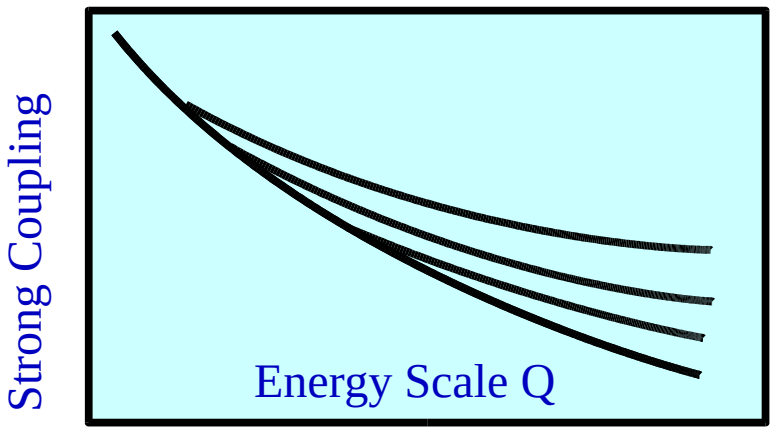
Bulk of PDF constraints are at low Q scales

Strong correlation between $_s$, gluino (and gluon)

Will affect gluon production of Higgs



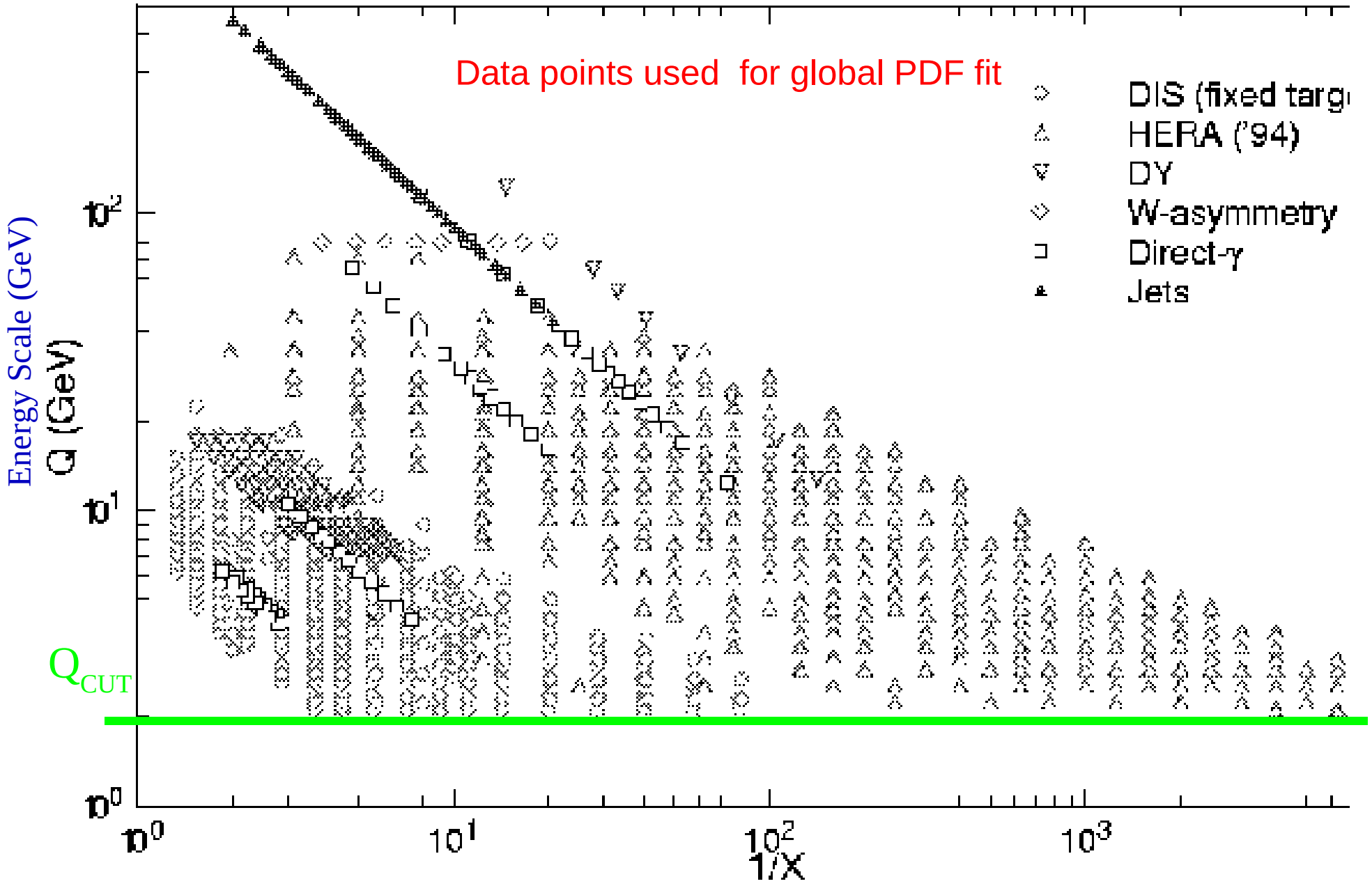
Running of $_s$(Q) with thresholds



New thresholds can significantly alter PDF's at large Q

E. L. Berger, P. M. Nadolsky, F. I. Olness and J. Pumplin. hep-ph/0406143.

Global fit to many different experiments provides proton structure

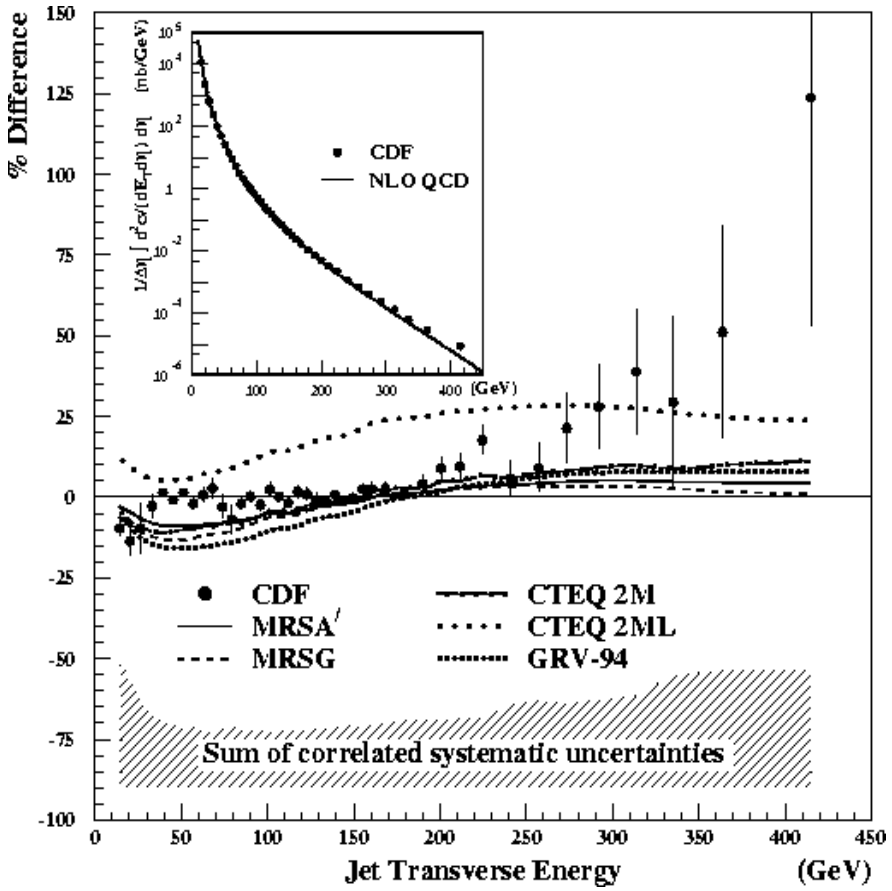


1 / (Momentum Fraction)

Would we know new physics if it bit us???

1996: Excess High E_T Jets at Tevatron

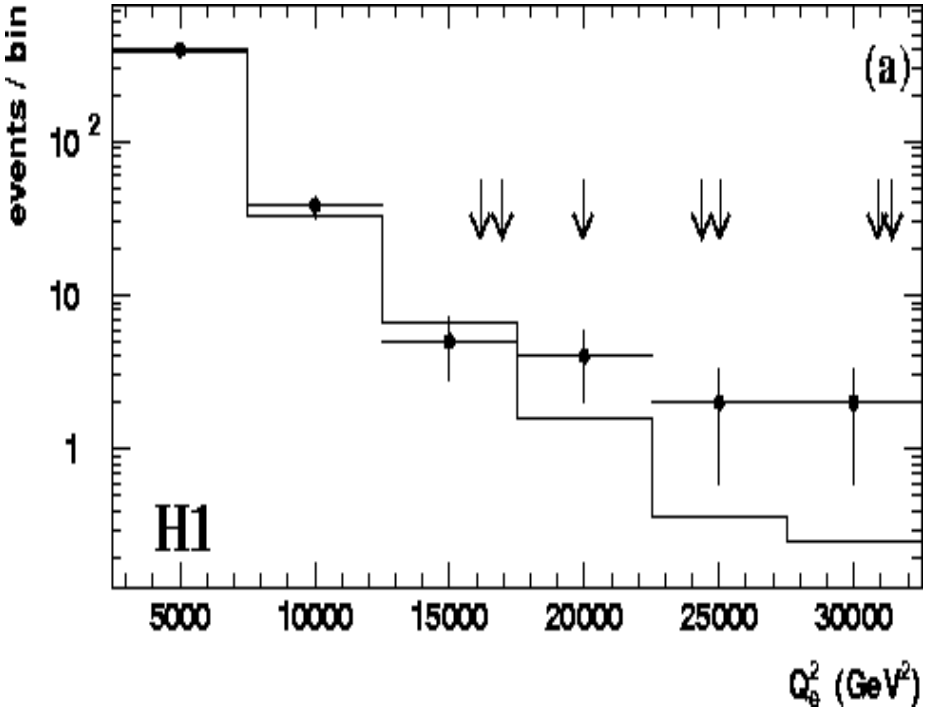
Is this a sign of compositeness?



CDF Collaboration
PRL 77, 438 (1996)

1997: Excess DIS events at large $\{x,Q^2\}$

Is this a sign of lepto-quarks?



H1 Collaboration, ZPC74, 191 (1997)
ZEUS Collaboration, ZPC74, 207 (1997)

Precision PDF's are an essential ingredient for the Search For New Physics