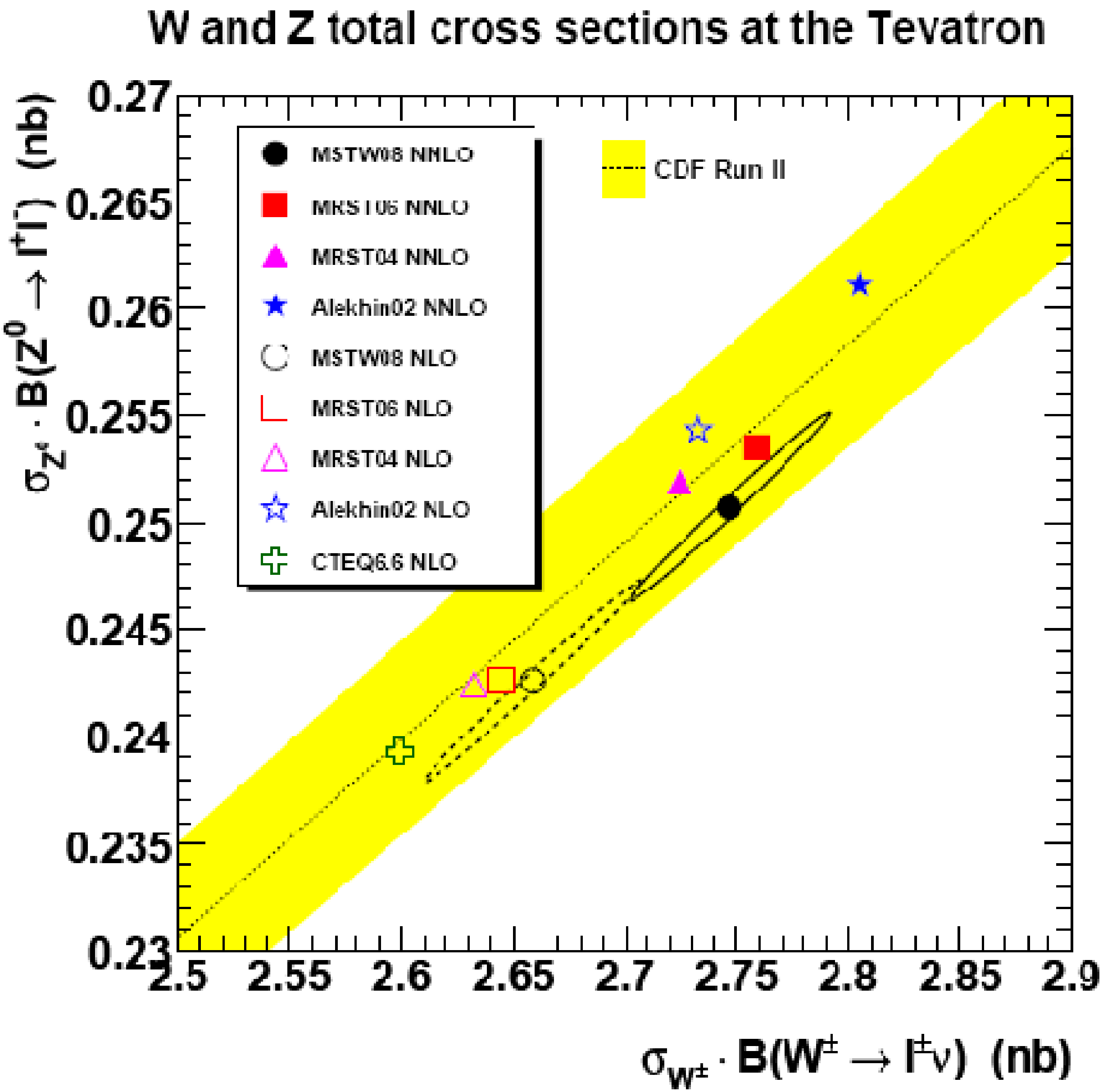
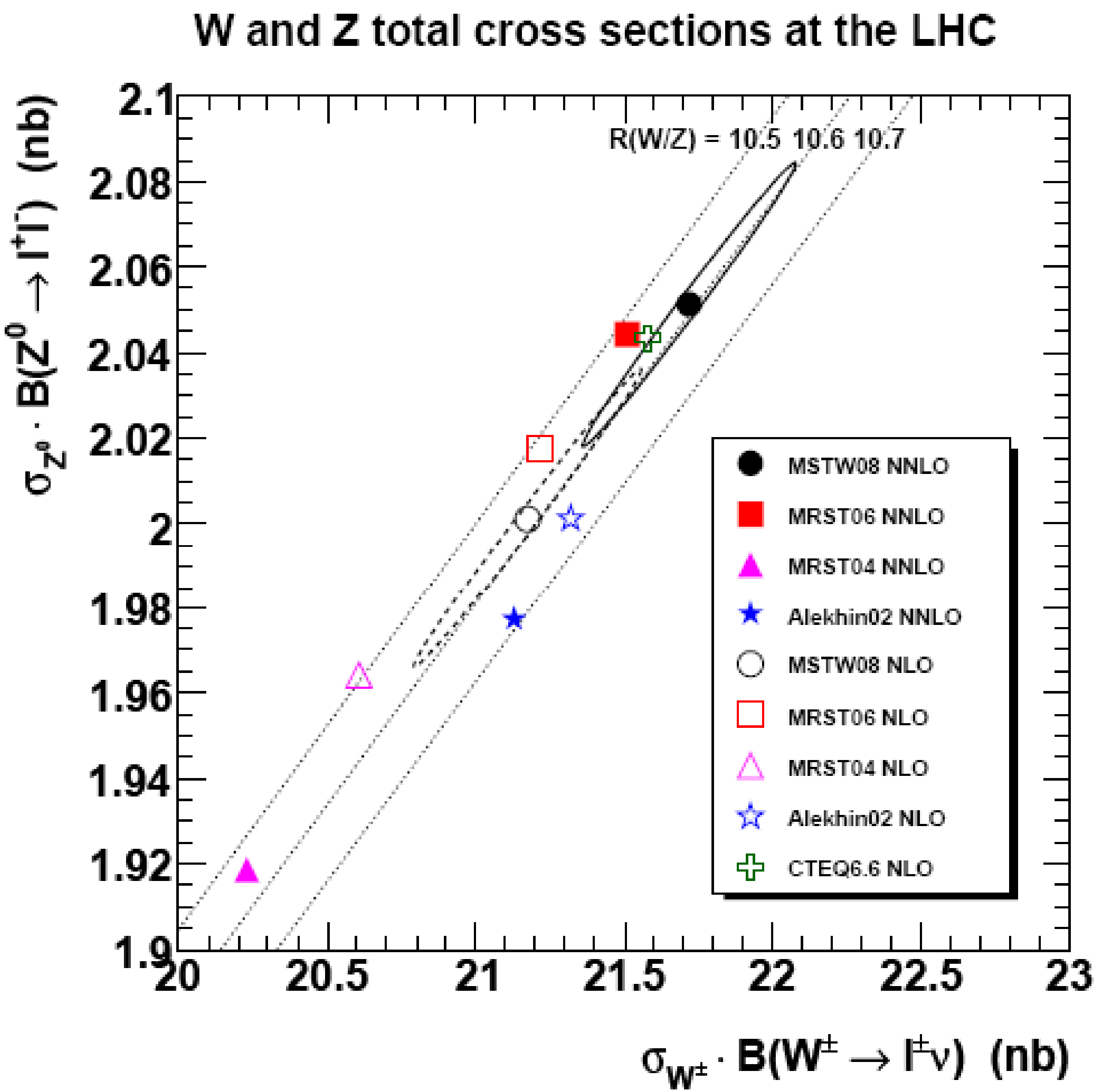
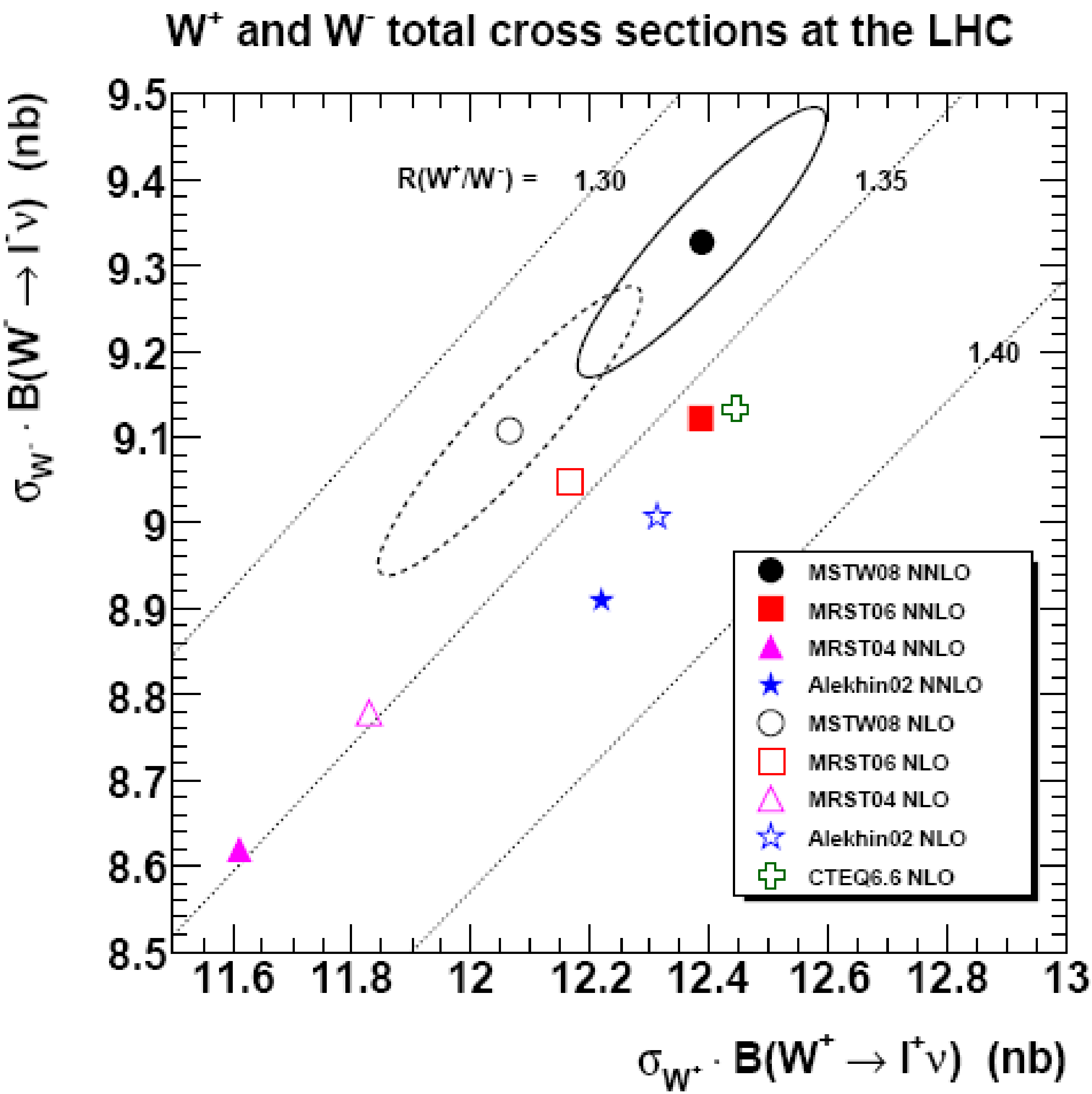


W and Z total cross sections at the Tevatron
MSTW08 NNLO
MRST06 NNLO
MRST04 NNLO
Alekhin02 NNLO
MSTW08 NLO
MRST06 NLO
MRST04 NLO
Alekhin02 NLO
CTEQ6.6 NLO
CDF Run II
0.27
0.265
0.26
0.255
0.25
0.245
0.24
0.235
0.23
2.5
2.55
2.6
2.65
2.7
2.75
2.8
2.85
2.9
$\sigma_{Z^0} \cdot B(Z^0 \to l^+l^-)$ (nb)
$\sigma_{W^\pm} \cdot B(W^\pm \to l^\pm\nu)$ (nb)

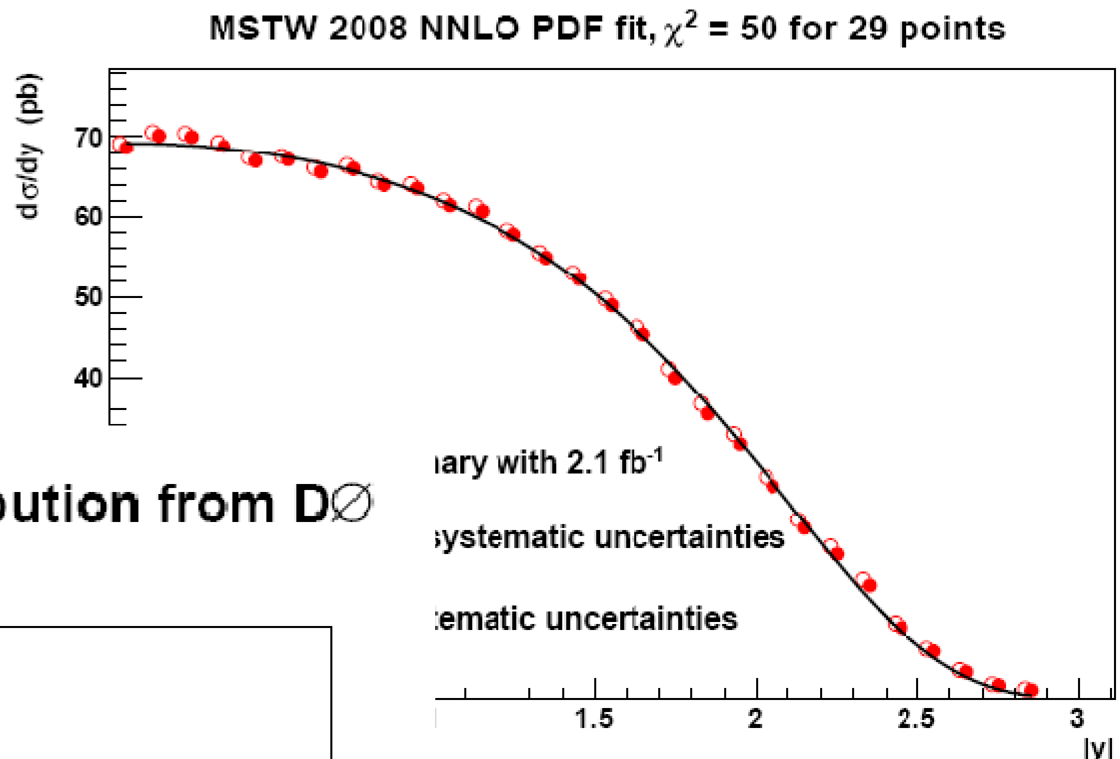


W and Z total cross sections at the LHC
R(W/Z) = 10.5 10.6 10.7
MSTW08 NNLO
MRST06 NNLO
MRST04 NNLO
Alekhin02 NNLO
MSTW08 NLO
MRST06 NLO
MRST04 NLO
Alekhin02 NLO
CTEQ6.6 NLO
$\sigma_{Z^0} \cdot B(Z^0 \rightarrow l^+l^-)$ (nb)
$\sigma_{W^\pm} \cdot B(W^\pm \rightarrow l^\pm\nu)$ (nb)
2.1
2.08
2.06
2.04
2.02
2
1.98
1.96
1.94
1.92
1.9
20
20.5
21
21.5
22
22.5
23

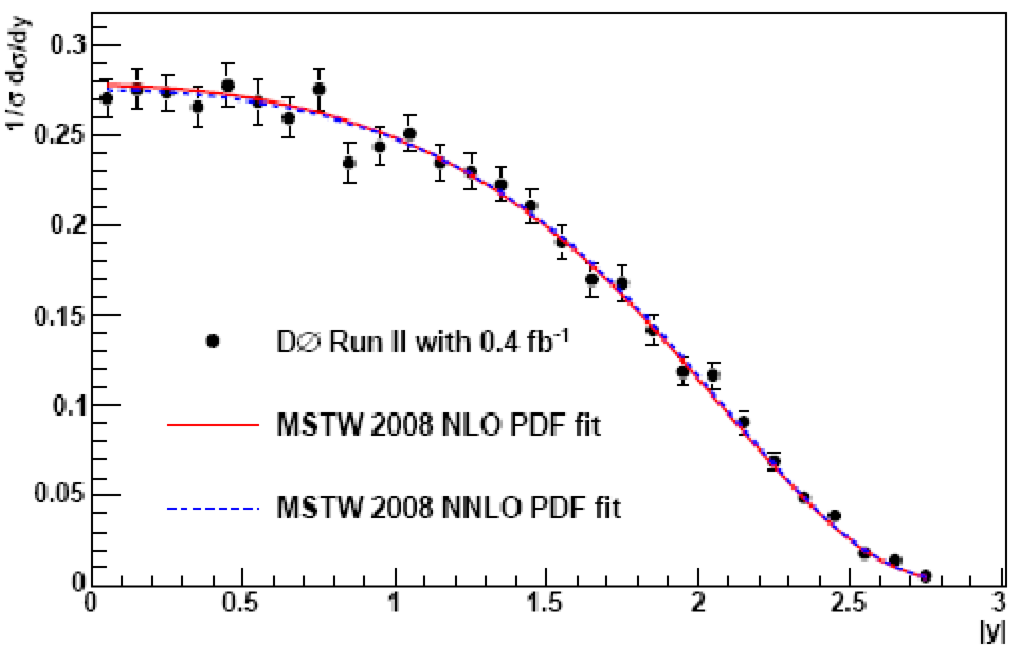


W+ and W- total cross sections at the LHC
R(W+/W-) =
1.30
1.35
1.40
MSTW08 NNLO
MRST06 NNLO
MRST04 NNLO
Alekhin02 NNLO
MSTW08 NLO
MRST06 NLO
MRST04 NLO
Alekhin02 NLO
CTEQ6.6 NLO
9.5
9.4
9.3
9.2
9.1
9
8.9
8.8
8.7
8.6
8.5
11.6
11.8
12
12.2
12.4
12.6
12.8
13
$\sigma_{W^-} \cdot B(W^- \rightarrow l^-\nu)$ (nb)
$\sigma_{W^+} \cdot B(W^+ \rightarrow l^+\nu)$ (nb)

Z/γ* rapidity distribution from CDF

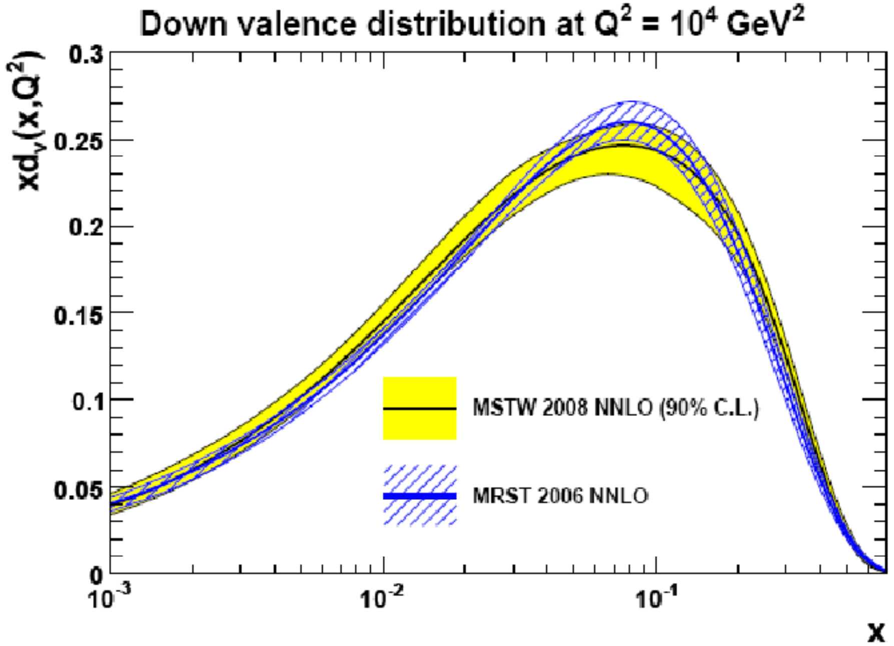


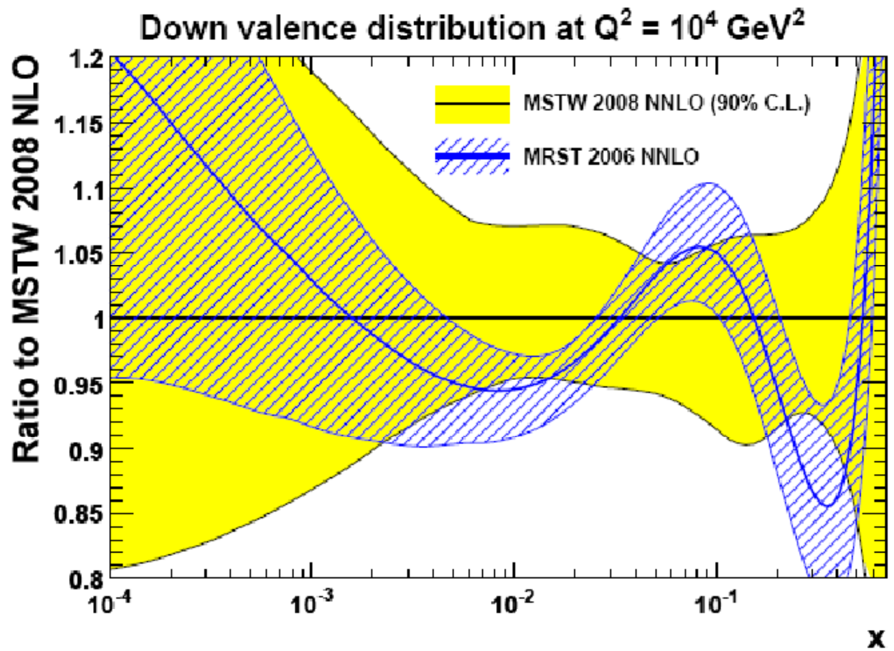
Z/γ* rapidity shape distribution from DØ



d_v

more flexible parametrization for extra W,Z Tevatron data

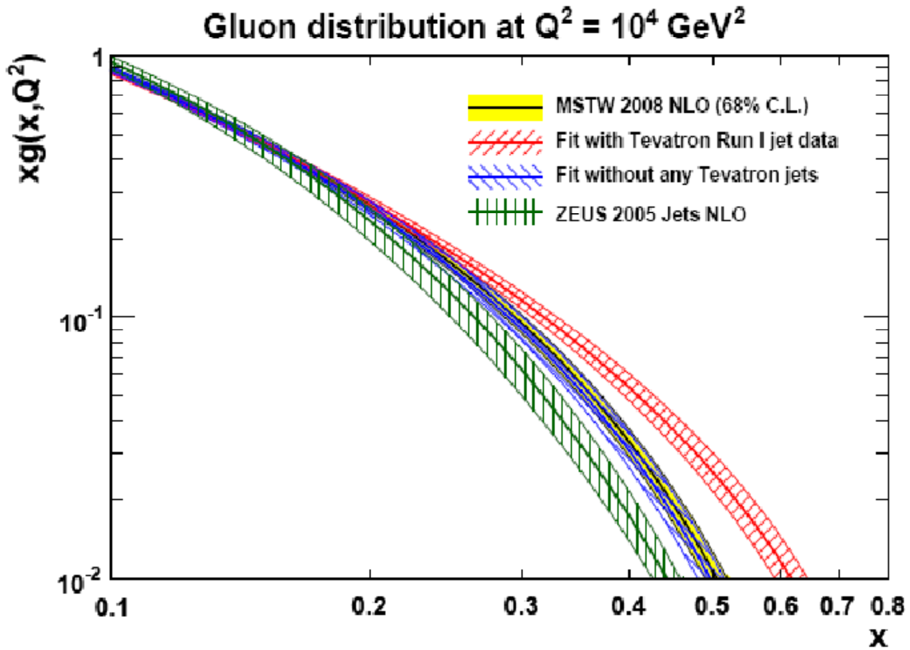


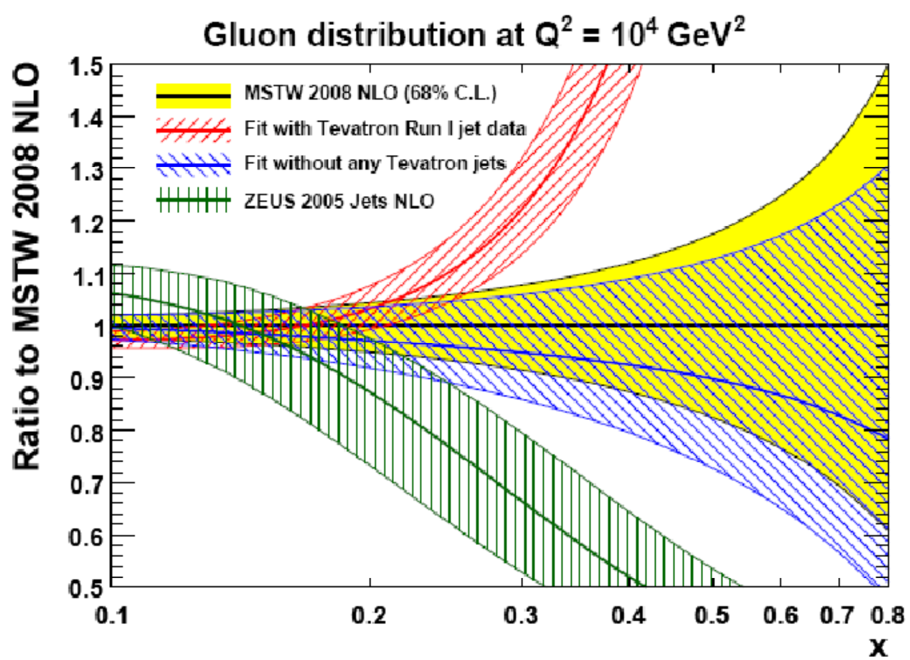


g

Run II Tevatron jet data require softer gluon

ZEUS fit has no fixed target data

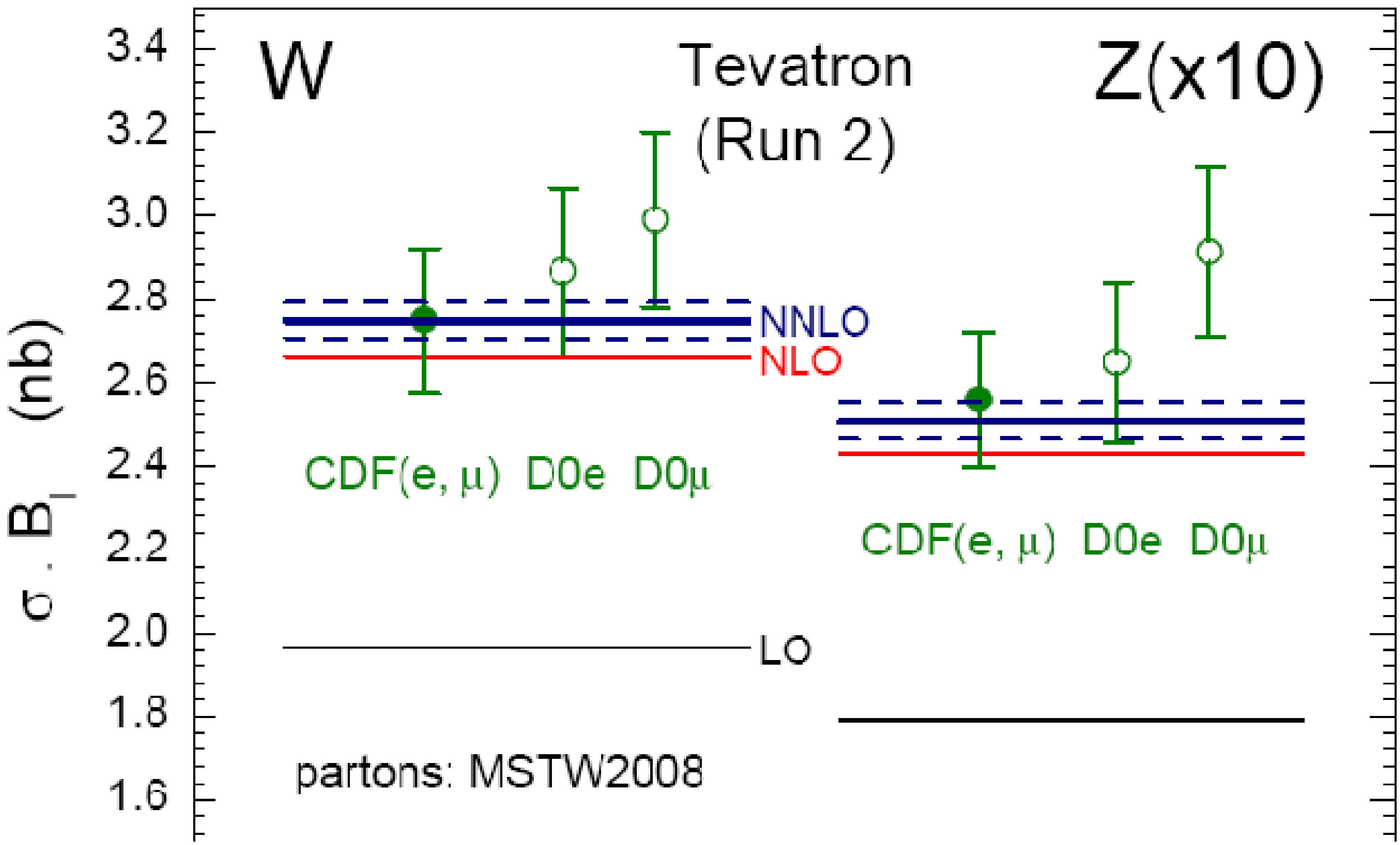


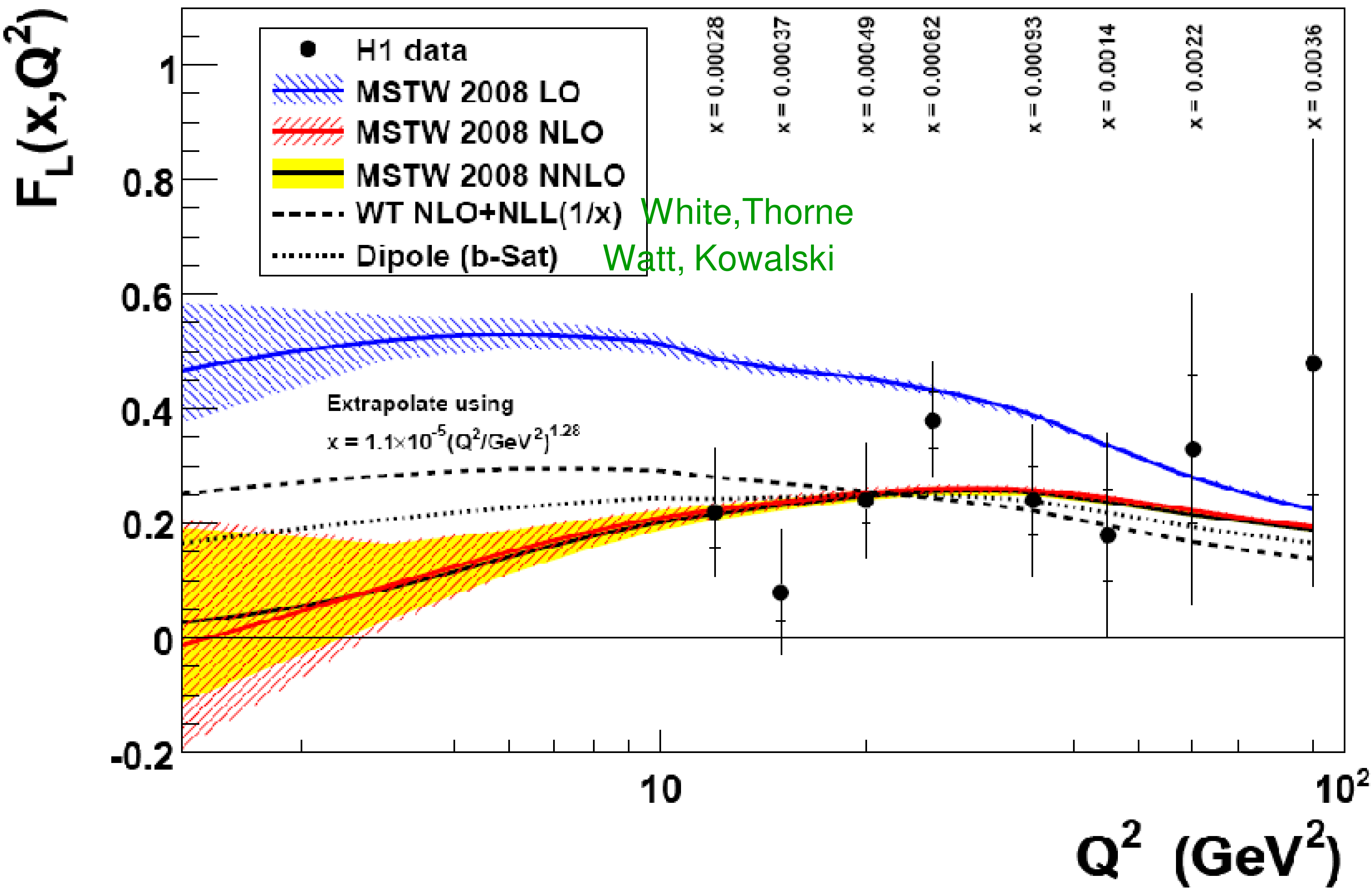


Tevatron, $\sqrt{s} = 1.96$ TeV	$B_{l\nu} \cdot \sigma_W$ (nb)	$B_{l^+l^-} \cdot \sigma_Z$ (nb)	R_{WZ}
MSTW 2008 LO	$1.963^{+0.025}_{-0.028}$ $\binom{+1.2\%}{-1.4\%}$	$0.1788^{+0.0023}_{-0.0025}$ $\binom{+1.3\%}{-1.4\%}$	$10.98^{+0.02}_{-0.03}$ $\binom{+0.2\%}{-0.3\%}$
MSTW 2008 NLO	$2.659^{+0.057}_{-0.045}$ $\binom{+2.1\%}{-1.7\%}$	$0.2426^{+0.0054}_{-0.0043}$ $\binom{+2.2\%}{-1.8\%}$	$10.96^{+0.03}_{-0.02}$ $\binom{+0.3\%}{-0.2\%}$
MSTW 2008 NNLO	$2.747^{+0.049}_{-0.042}$ $\binom{+1.8\%}{-1.5\%}$	$0.2507^{+0.0048}_{-0.0041}$ $\binom{+1.9\%}{-1.6\%}$	$10.96^{+0.03}_{-0.03}$ $\binom{+0.2\%}{-0.2\%}$

LHC, $\sqrt{s} = 10$ TeV	$B_{l\nu} \cdot \sigma_W$ (nb)	$B_{l^+l^-} \cdot \sigma_Z$ (nb)	R_{WZ}
MSTW 2008 LO	$12.57^{+0.13}_{-0.19}$ $\binom{+1.1\%}{-1.5\%}$	$1.163^{+0.011}_{-0.017}$ $\binom{+1.0\%}{-1.5\%}$	$10.81^{+0.02}_{-0.02}$ $\binom{+0.2\%}{-0.2\%}$
MSTW 2008 NLO	$14.92^{+0.31}_{-0.24}$ $\binom{+2.1\%}{-1.6\%}$	$1.390^{+0.029}_{-0.022}$ $\binom{+2.1\%}{-1.5\%}$	$10.73^{+0.02}_{-0.02}$ $\binom{+0.2\%}{-0.2\%}$
MSTW 2008 NNLO	$15.35^{+0.26}_{-0.25}$ $\binom{+1.7\%}{-1.6\%}$	$1.429^{+0.024}_{-0.022}$ $\binom{+1.7\%}{-1.6\%}$	$10.74^{+0.02}_{-0.02}$ $\binom{+0.2\%}{-0.2\%}$

LHC, $\sqrt{s} = 14$ TeV	$B_{l\nu} \cdot \sigma_W$ (nb)	$B_{l^+l^-} \cdot \sigma_Z$ (nb)	R_{WZ}
MSTW 2008 LO	$18.51^{+0.22}_{-0.32}$ $\binom{+1.2\%}{-1.7\%}$	$1.736^{+0.019}_{-0.028}$ $\binom{+1.1\%}{-1.6\%}$	$10.66^{+0.02}_{-0.02}$ $\binom{+0.2\%}{-0.2\%}$
MSTW 2008 NLO	$21.17^{+0.42}_{-0.36}$ $\binom{+2.0\%}{-1.7\%}$	$2.001^{+0.040}_{-0.032}$ $\binom{+2.0\%}{-1.6\%}$	$10.58^{+0.02}_{-0.02}$ $\binom{+0.2\%}{-0.2\%}$
MSTW 2008 NNLO	$21.72^{+0.36}_{-0.36}$ $\binom{+1.7\%}{-1.7\%}$	$2.051^{+0.035}_{-0.033}$ $\binom{+1.7\%}{-1.6\%}$	$10.59^{+0.02}_{-0.03}$ $\binom{+0.2\%}{-0.3\%}$

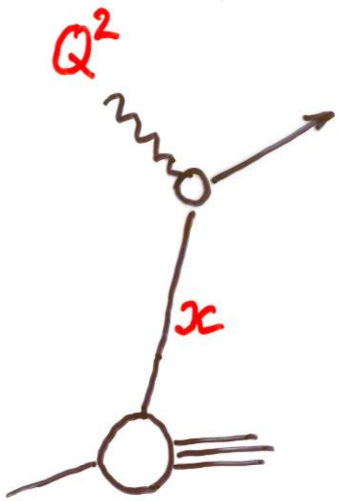

W
Tevatron
(Run 2)
Z(x10)
NNLO
NLO
LO
CDF(e, μ) D0e D0μ
CDF(e, μ) D0e D0μ
partons: MSTW2008
σ . B_l (nb)
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6



$F_L(x,Q^2)$
H1 data
MSTW 2008 LO
MSTW 2008 NLO
MSTW 2008 NNLO
WT NLO+NLL(1/x)
Dipole (b-Sat)
White,Thorne
Watt, Kowalski
x = 0.00028
x = 0.00037
x = 0.00049
x = 0.00062
x = 0.00093
x = 0.0014
x = 0.0022
x = 0.0036
Extrapolate using
$x = 1.1\times10^{-5}(Q^2/GeV^2)^{1.28}$
Q^2 (GeV^2)

Diffractive deep inelastic scattering (DDIS)

DIS

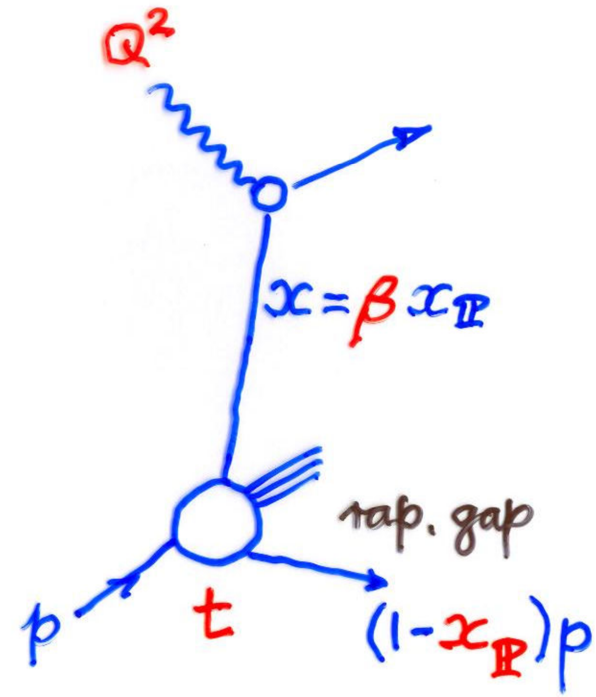


↓

parton densities a

Diffractive DIS

(10-20%)

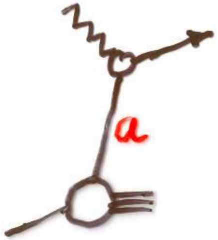


↓

diffractive parton densites a^D

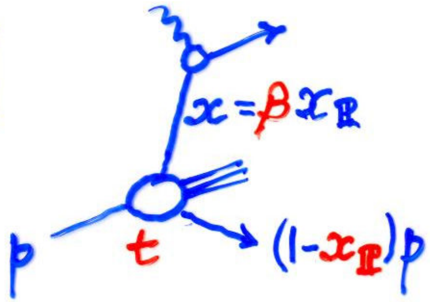
Conventionally DDIS analyses use two levels of factorisation
- collinear factorization and Regge factorization

DIS



$$F_2(x,Q^2) = \sum_a C_{2,a} \otimes a$$

DDIS



$$F_2(x_{\mathbb{P}},\beta,Q^2) = \sum_a C_{2,a} \otimes a^D$$

collinear fact^n proved for DDIS (Collins), but important modifications in the HERA regime

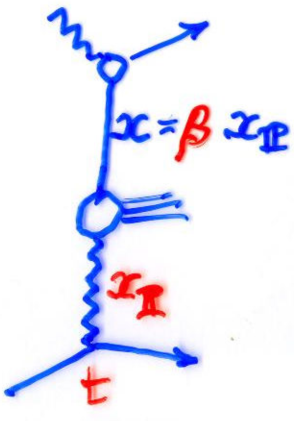
---

conventional to also assume

Regge fact^n

Ingelman-Schlein

$\mathbb{P} \sim$ particle



$$a^D(x_{\mathbb{P}},\beta,Q^2) = f_{\mathbb{P}}(x_{\mathbb{P}})\; a^{\mathbb{P}}(\beta,Q^2)$$

⇓

$$\mathbb{P}\text{ flux} \quad f_{\mathbb{P}} = \int dt \, \frac{e^{Bt}}{x_{\mathbb{P}}^{\,2\alpha_{\mathbb{P}}(t)-1}}$$

B, $\alpha'_{\mathbb{P}}$ from soft data, but

$\alpha_{\mathbb{P}}(0)$ = parameter

Hint of problem with Regge factorisation assumption

assumes Pomeron ~ hadron of size R
Regge fact^n occurs in non-pert region $\mu<\mu_0$, where $\mu\sim1/R$

but $\alpha_P(0)\sim1.2$ from DDIS > $\alpha_P(0)\sim1.08$ from soft data

→ small-size component from pQCD domain with larger $\alpha_P(0)$

New DDIS analysis---Watt, Martin, Ryskin

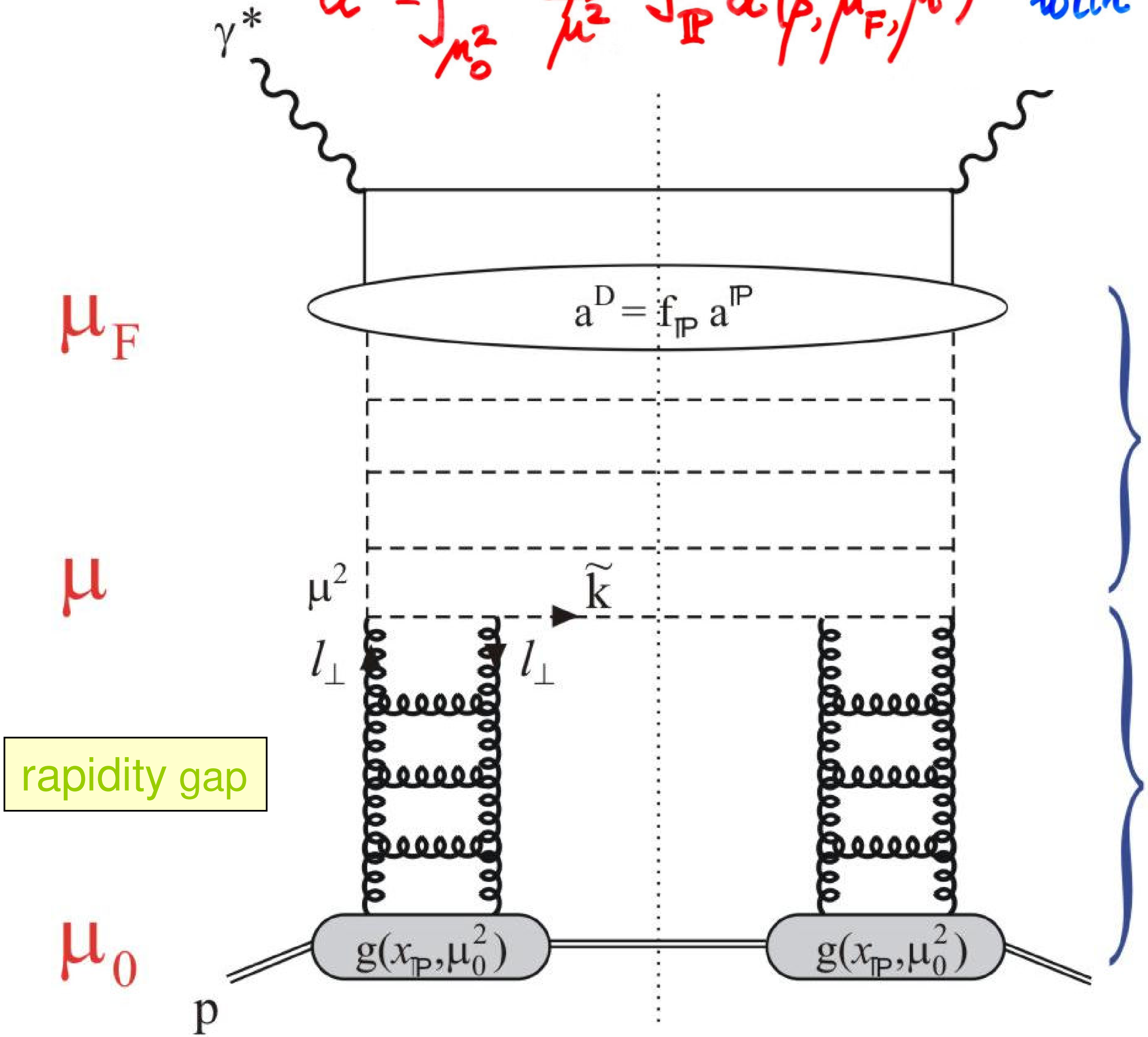
Replaces Regge factorization by pQCD

Collinear factorization, which holds asymptotically, must be modified in the HERA regime:

-- inhomogeneous term in DGLAP evolution
-- direct charm contribution
-- twist-4 F_L^D component

pert. contrib.

$$a^D = \int_{\mu_0^2}^{\mu_F^2} \frac{d\mu^2}{\mu^2} f_{I\!P}\, a^{I\!P}(\beta, \mu_F^2, \mu^2) \quad \text{with } f_{I\!P} \sim [g(x_{I\!P}, \mu^2)]^2$$



DGLAP($\mu \to \mu_F$) for $a^{I\!P}$ from $P_{aI\!P}$ (β) input

$f_{I\!P}(x_{I\!P}; \mu^2)$ given in terms of the gluon $g(x_{I\!P}, \mu^2)$ determined in global DIS analysis

$$a^D = \int_{Q_0^2}^{Q^2} \frac{d\mu^2}{\mu^2} f_{I\!P}(x_{I\!P},\mu^2)\, a^{I\!P}(\beta, Q^2, \mu^2)$$

given by pQCD

$a^{I\!P}(\beta,\mu^2,\mu^2)$

$$\frac{\partial a^D}{\partial \ln Q^2} = \sum_{a'} P_{aa'} \otimes a'^D + f_{I\!P}(x_{I\!P},Q^2)\, P_{aI\!P}(\beta)$$

DGLAP with inhomogeneous term

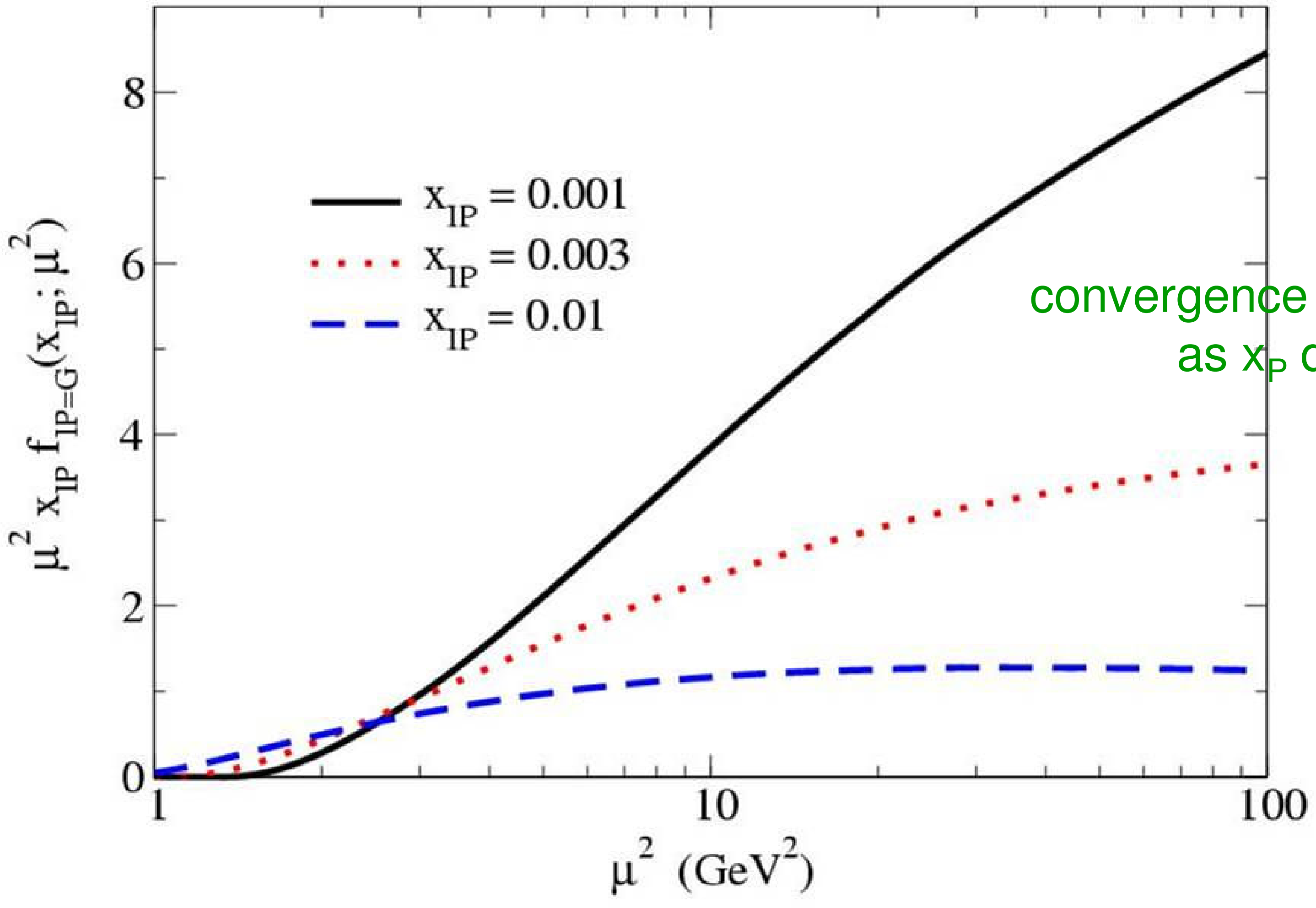
cf DGLAP for γ

Recall flux $f_{I\!P}(x_{I\!P},Q^2) = \frac{1}{x_{I\!P}}\left[\frac{\alpha_s}{Q} x_{I\!P}\, g(x_{I\!P},Q^2)\right]^2$

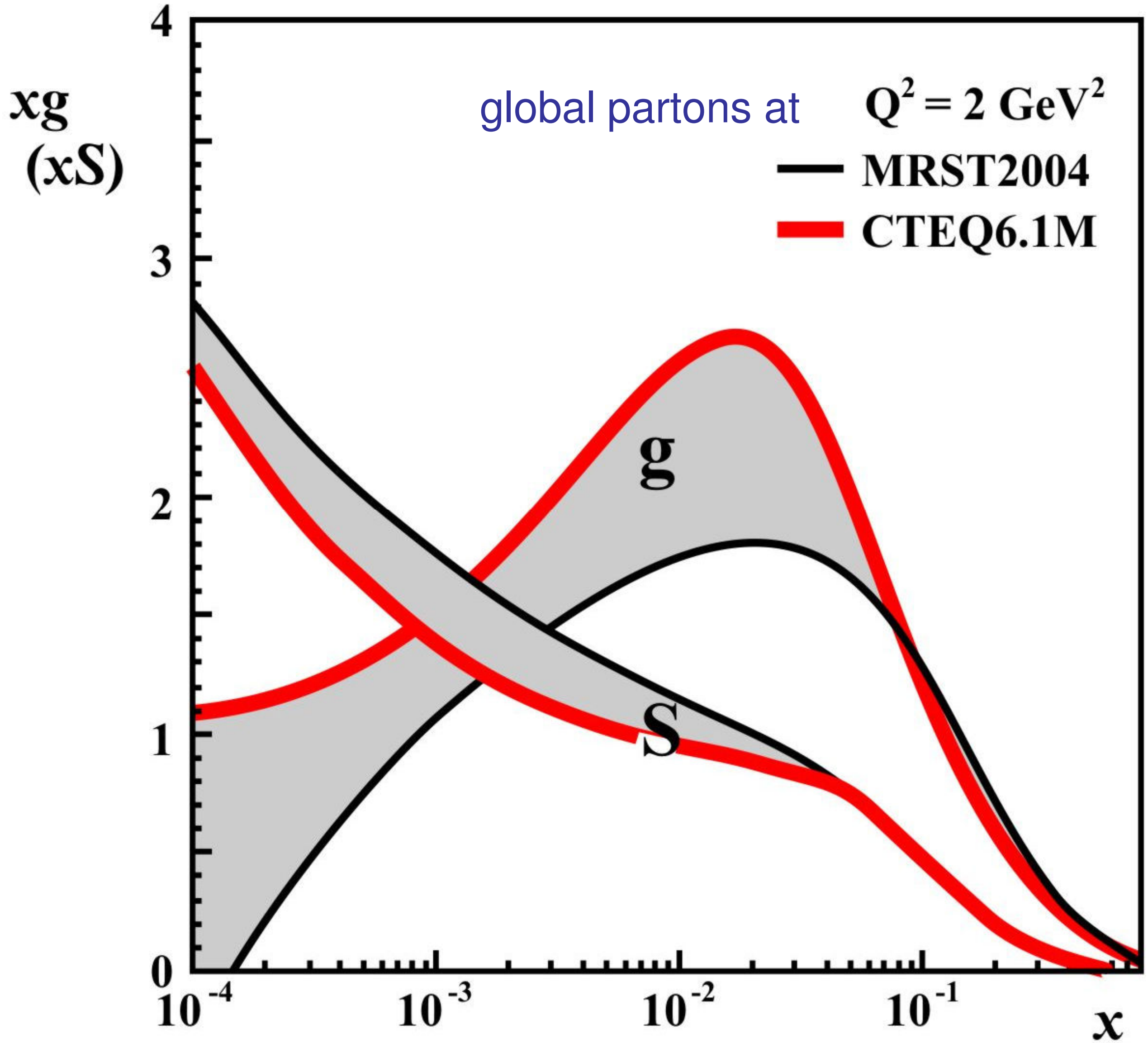
- if $f_{I\!P} \sim \frac{1}{Q^2}$ then inhomogeneous term ~ power correction
  collinear DDIS fact^n & DGLAP OK
- but at small $x_{I\!P}$, $g(x_{I\!P},Q^2)$ grows rapidly with Q^2
  so inhomogeneous term must be included

inclusion of the inhomogeneous term makes g^P smaller

$\mu^2 f_P$ → flux does not behave as $1/\mu^2$



convergence decreases as x_P decreases



but one of the HERA surprises….

g: valence-like
S: Pomeron-like

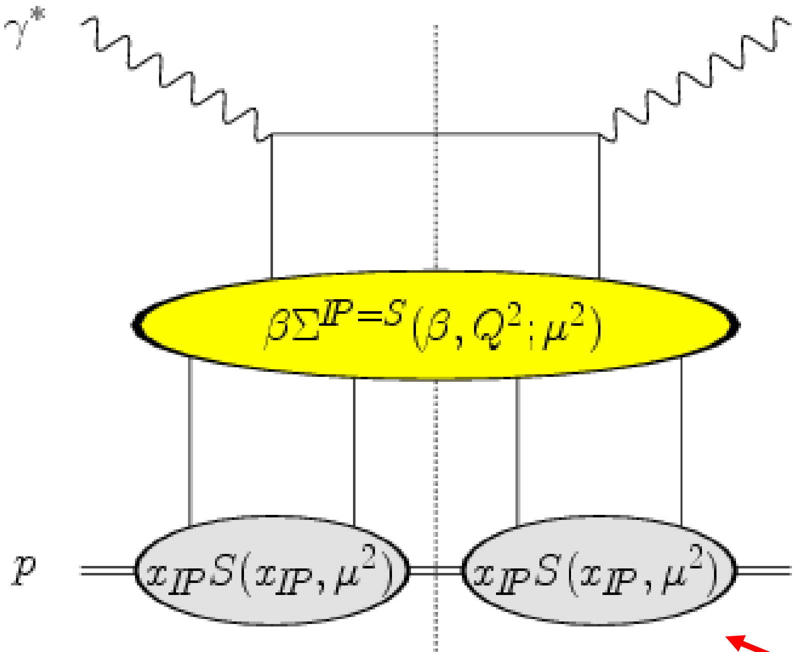
whereas expect
$\lambda_g \sim \lambda_S \sim 0.1$

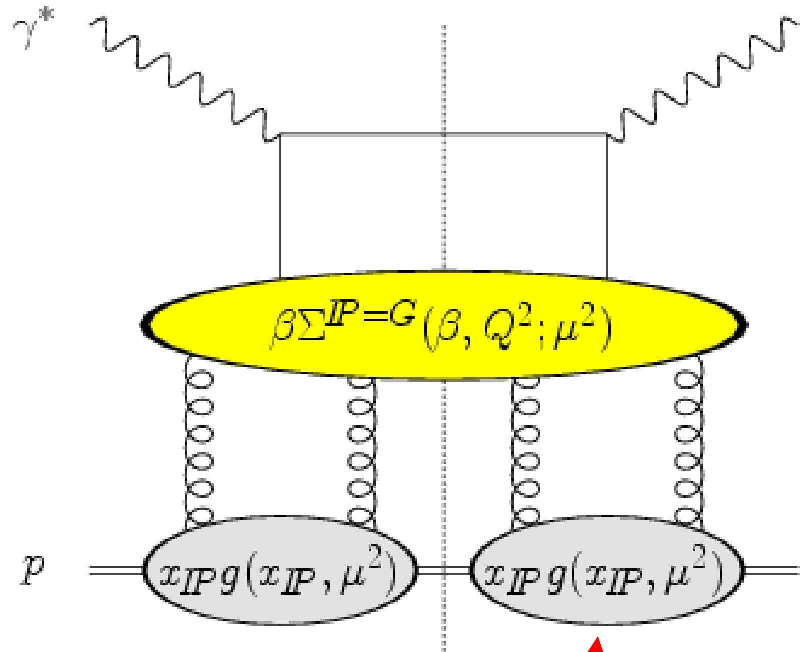
($xg \sim x^{-\lambda g}$
$xS \sim x^{-\lambda S}$)

Would have anticipated both driven by same vac. singularity need to introduce Pomeron made of col. singlet $q\bar{q}$ pair

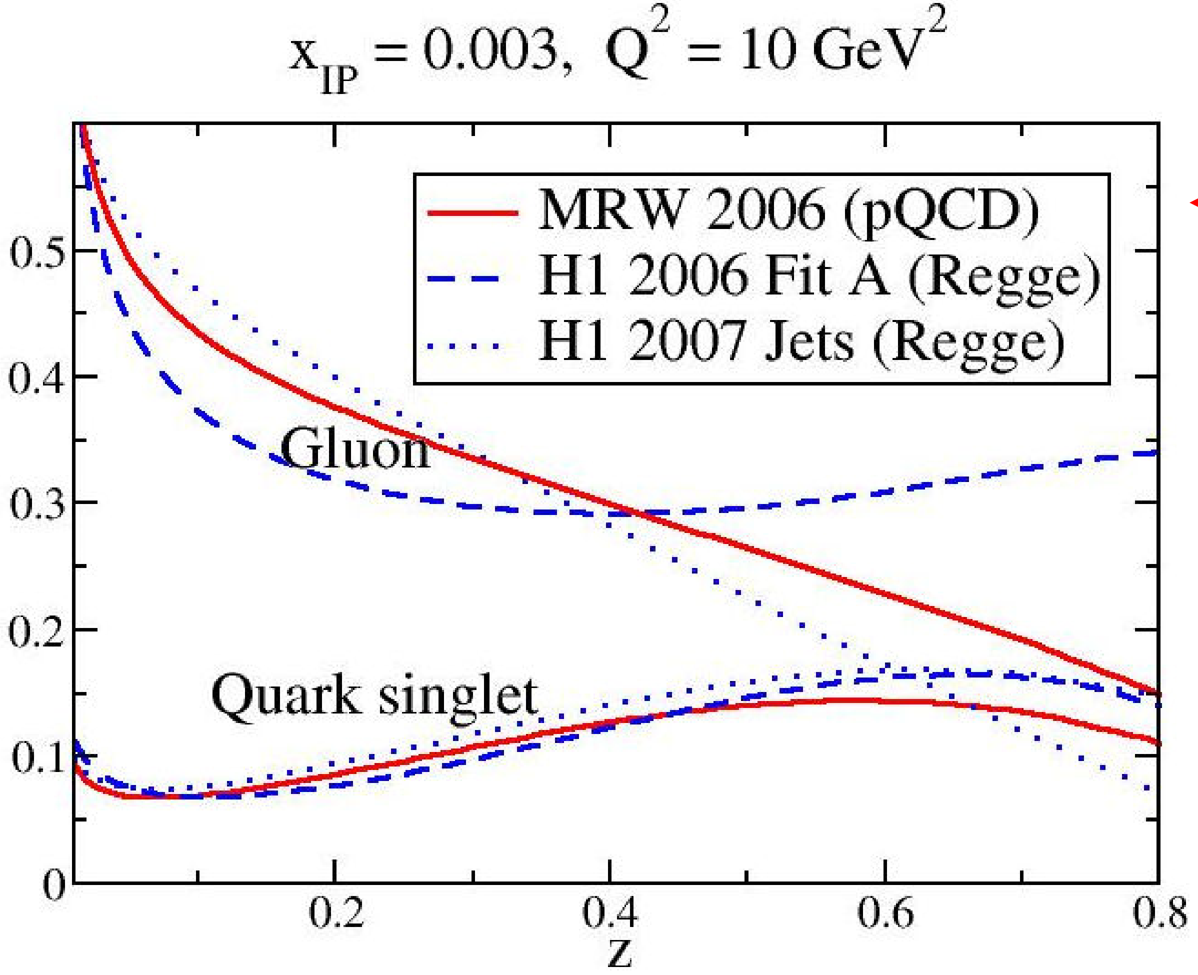
as well as

Pomeron made of two gluons



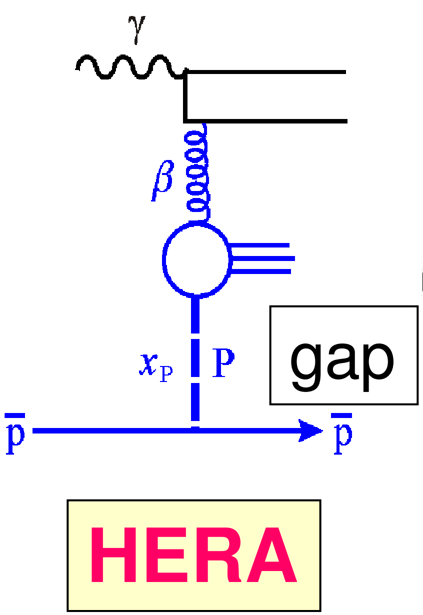


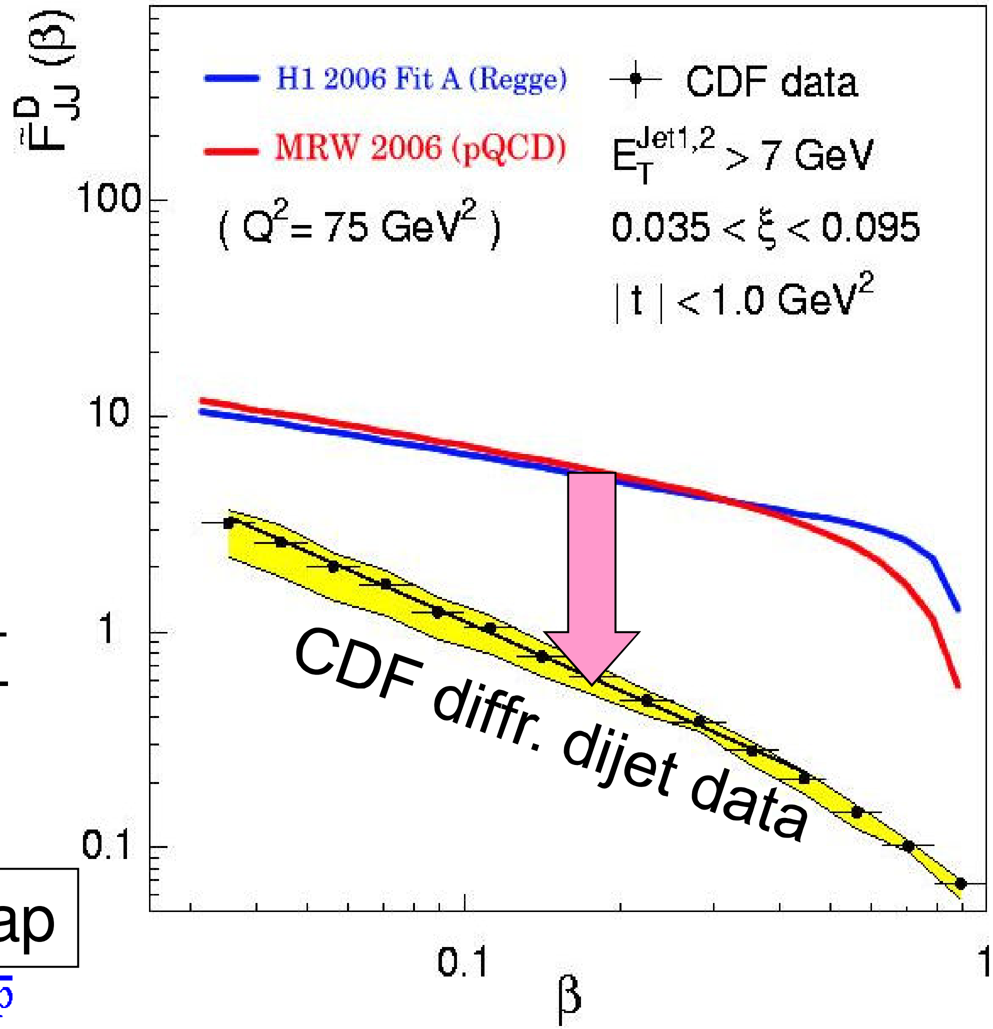
Now Pomeron flux factors depend on S^p as well as g^p



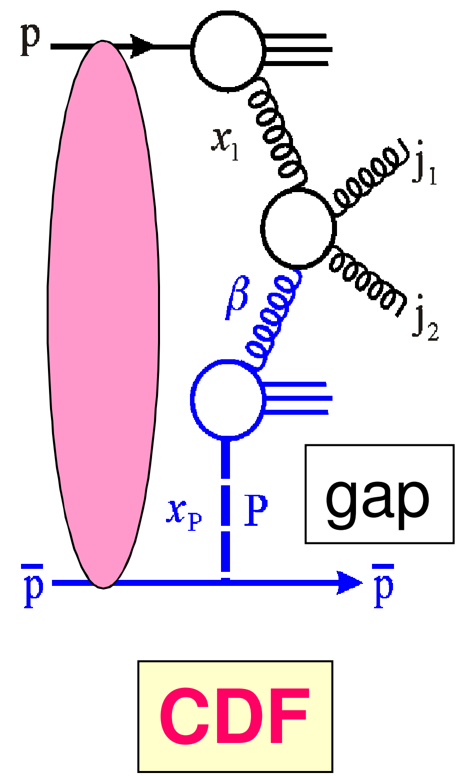
←direct+resolved Pomeron (cf. photon)

diffractive partons g^D, q^D can be used to predict diffractive processes with hard scale? Yes, but…





soft
rescatt.



Comments on GLM(2008)

GLM include some 3P effects, but get $\langle S_{enh}^2 \rangle = 0.063$

$$\langle S_{tot}^2 \rangle = 0.0235 \times 0.063 = 0.0015$$

Calculation should be extended to obtain reliable S_{enh}

1. Need to calc. b, k_t dep., S_{enh} comes mainly from periphery (after S_{eik} suppression) where parton density is small. So S_{enh} (GLM) is much too small.
2. First 3P diagram is missing, so σ_{SD} much too small.
3. Four or more multi-Pomeron vertices neglected, so σ_{tot} asymptotically decreases (but GLM have σ_{tot} asym. const.). Model should specify energy interval where it is valid.
4. Need to consider threshold suppression.
5. Should compare predictions with observed CDF data.

Comments on Strikman et al.

also predict a v.small S_{enh} !

They use LO gluon with steep 1/x behaviour.

Obtain black disc regime at LHC energy, with low x gluon so large that only on the periphery of the proton will gap have chance to survive.

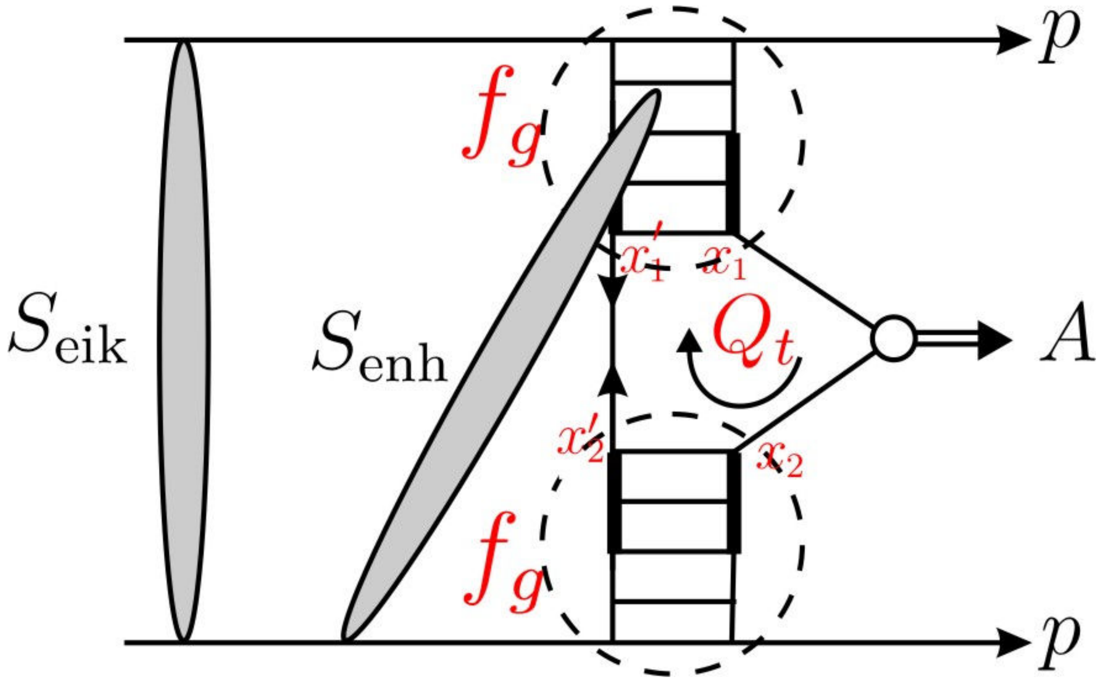
However, empricially the low x, low Q^2 gluon is flat – the steep 1/x LO behaviour is an artefact of the neglect of large NLO corrections.

Again should compare to CDF exclusive data.

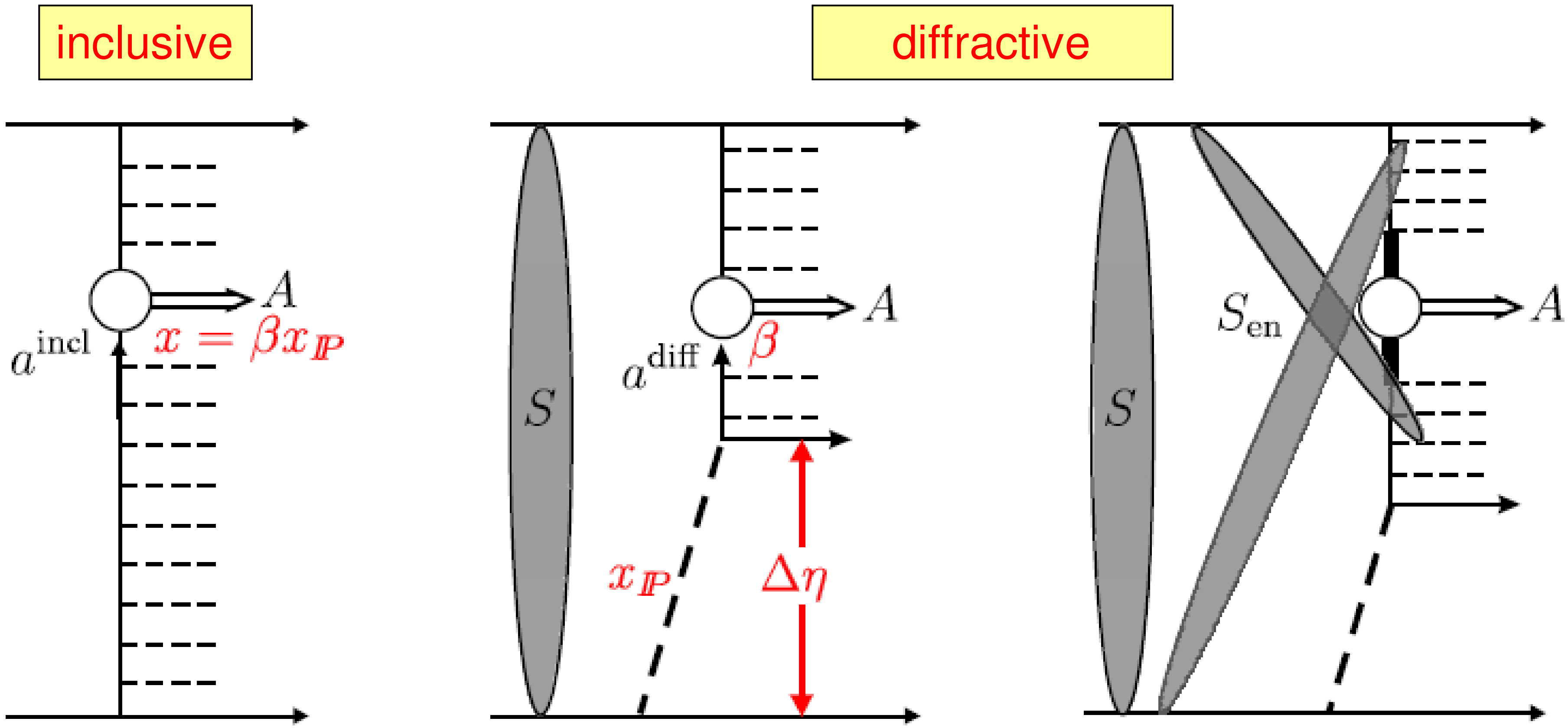
"Enhanced" absorptive effects

(break soft-hard factorization)

rescattering on an intermediate parton:



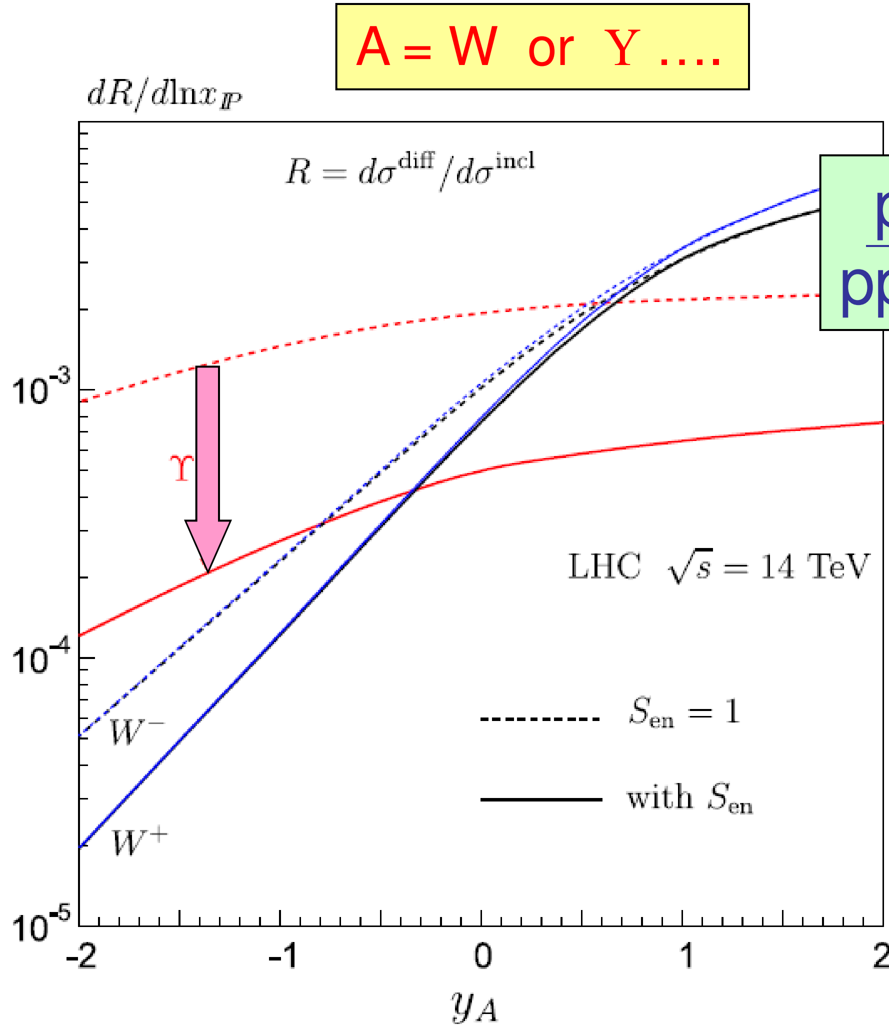
can LHC probe this effect ?



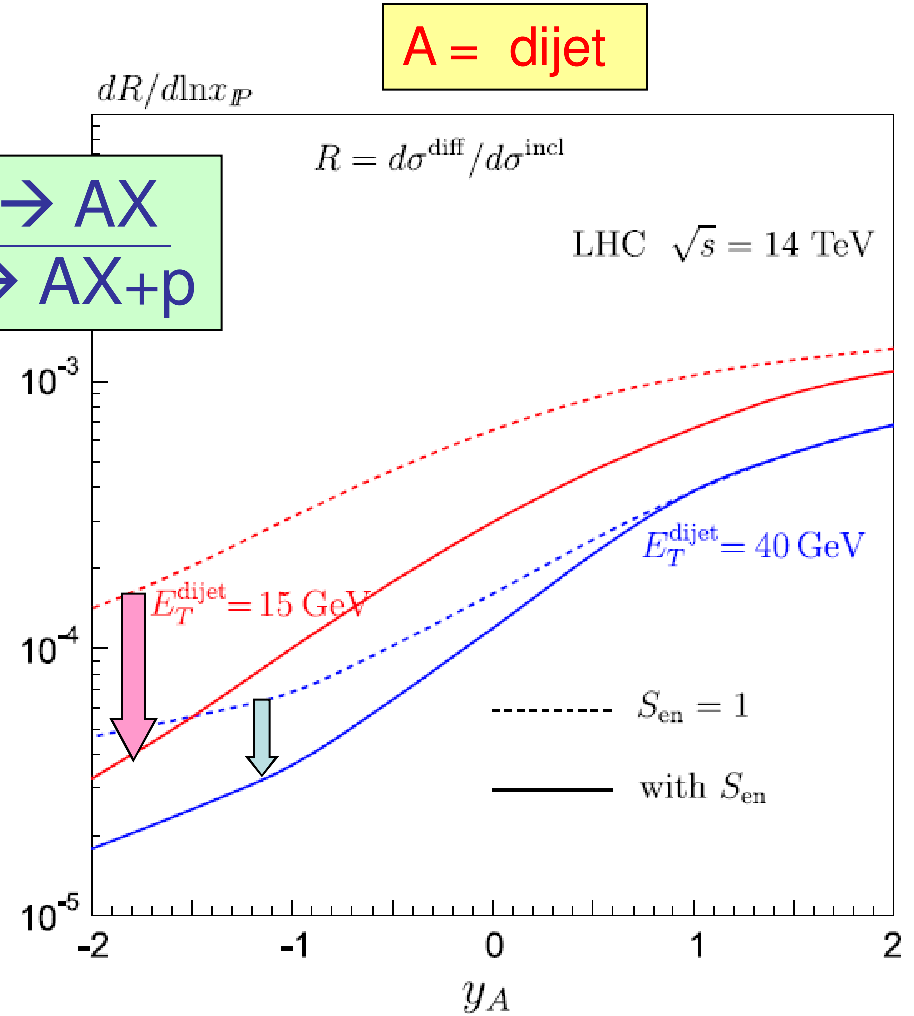
A = W or dijet or Υ ….

$$R = \frac{\text{no. of } (A + \text{gap}) \text{ events}}{\text{no. of (inclusive } A) \text{ events}} = \frac{a^{\text{diff}}(x_{I\!P}, \beta, \mu^2)}{a^{\text{incl}}(x = \beta x_{I\!P}, \mu^2)} \langle S^2 S^2_{\text{en}} \rangle_{\text{over } b_t}$$

known from HERA



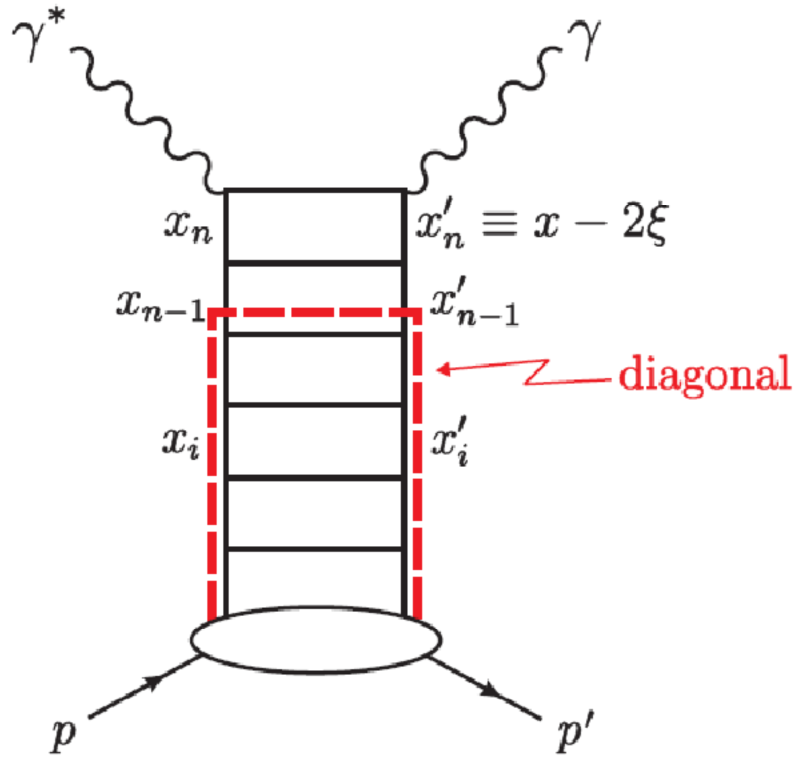
pp → AX
pp → AX+p



rough estimates of enhanced absorption S^2_{en}

MNRST – **generalized PDFs at small x** – arXiv 0812.3558

e.g. DVCS: skewing originates from uppermost cell, due the strong ordering in x in small x limit. So generalised parton distributions can be computed directly from known “global” diagonal PDFs



Evolution: (ξ unchanged)

anom.dim. of G_N = anom.dim. of M_N

GPDF(x,ξ) diag. PDF(x)

$$G_N = \sum_{n=0}^{N} c_n^N \xi^{2n} \quad \text{with} \quad c_0^N = M_N$$

Shuvaev transf. then gives GPDFs from moments with accuracy O(ξ) at small ξ at NLO.

Typical diffractive processes have $\xi \sim 10^{-2}$ (pp→p+H+p); $\xi \sim 10^{-3}$ (γp→J/ψ p)