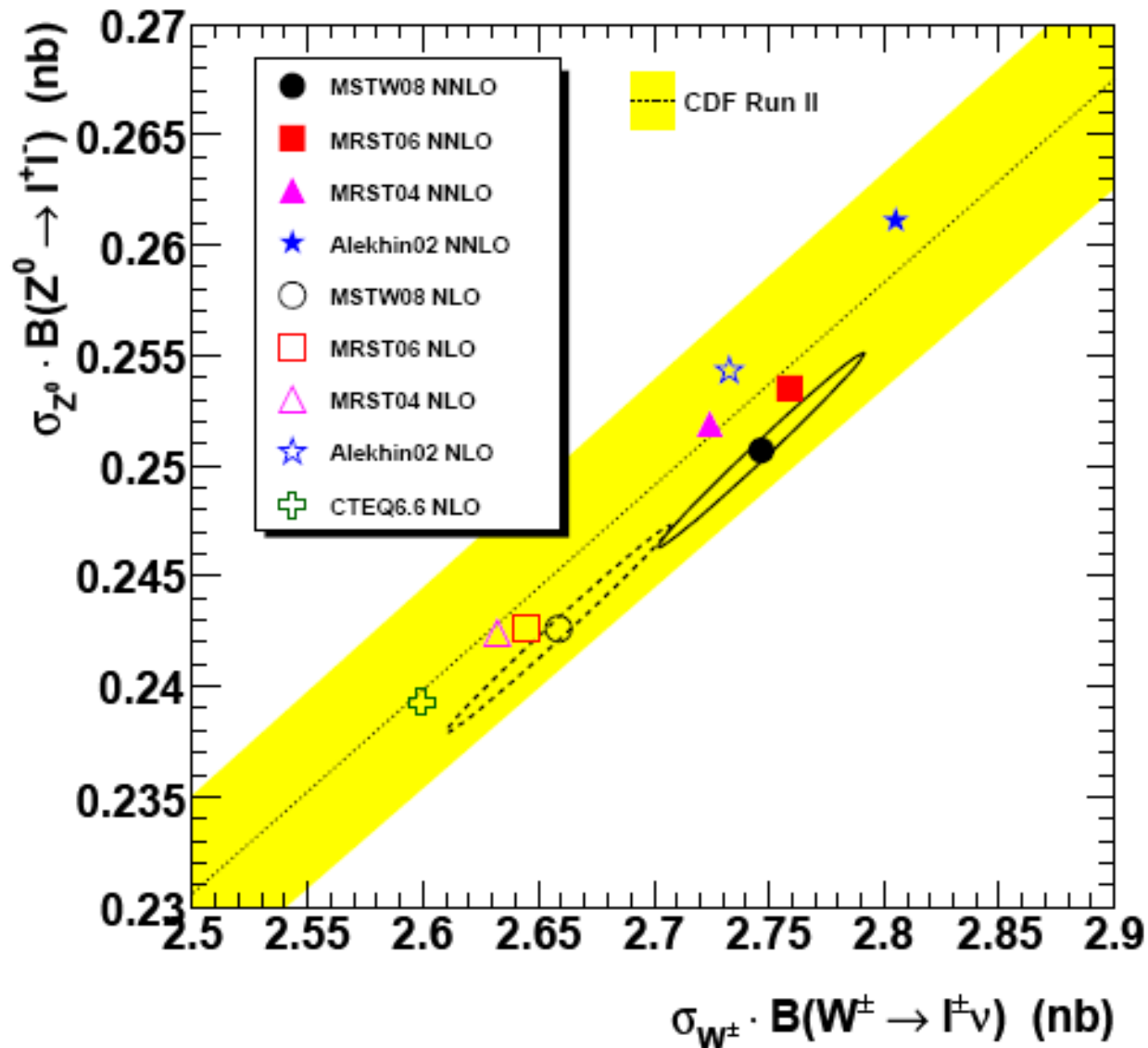
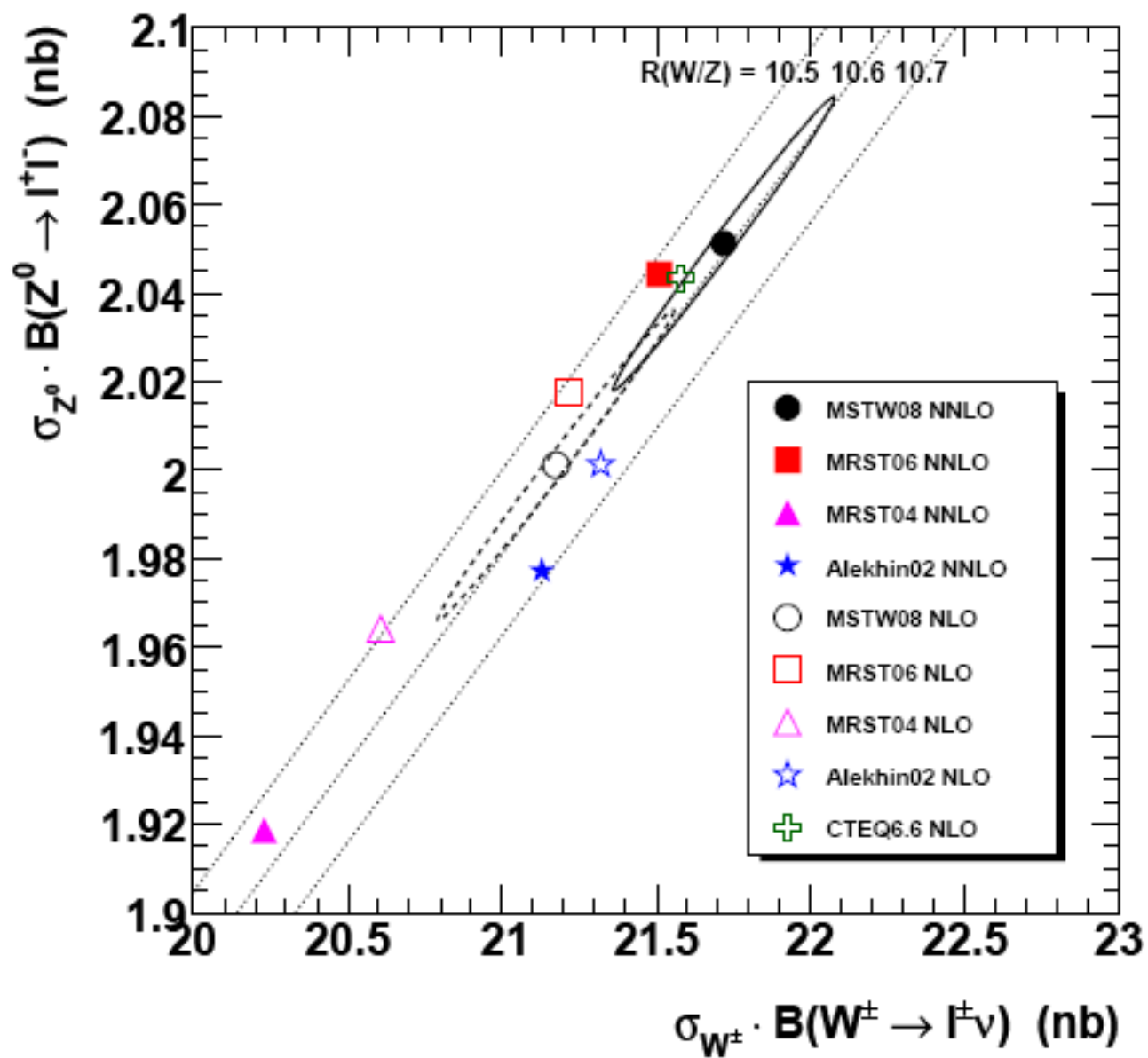


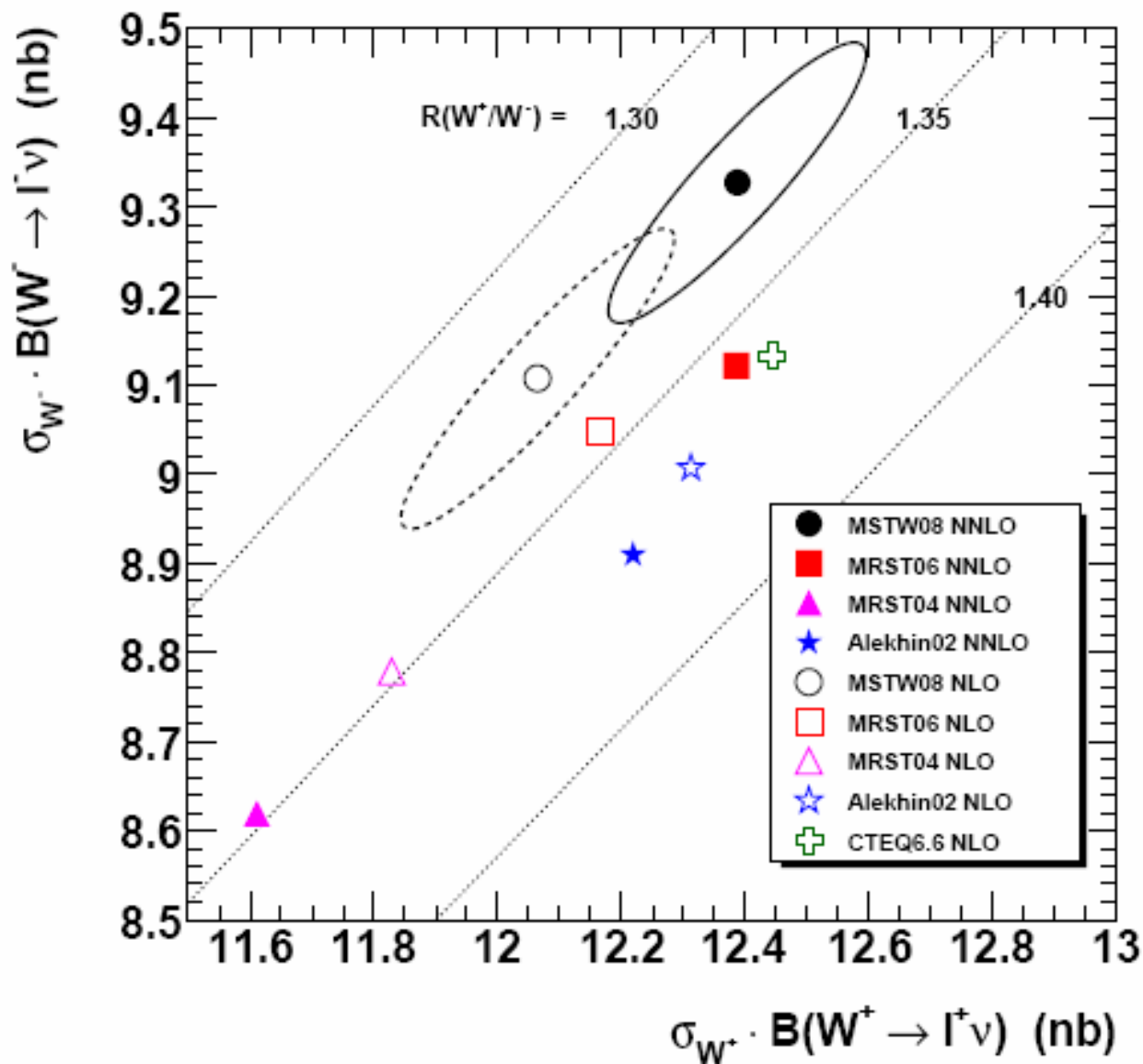
## W and Z total cross sections at the Tevatron



# W and Z total cross sections at the LHC

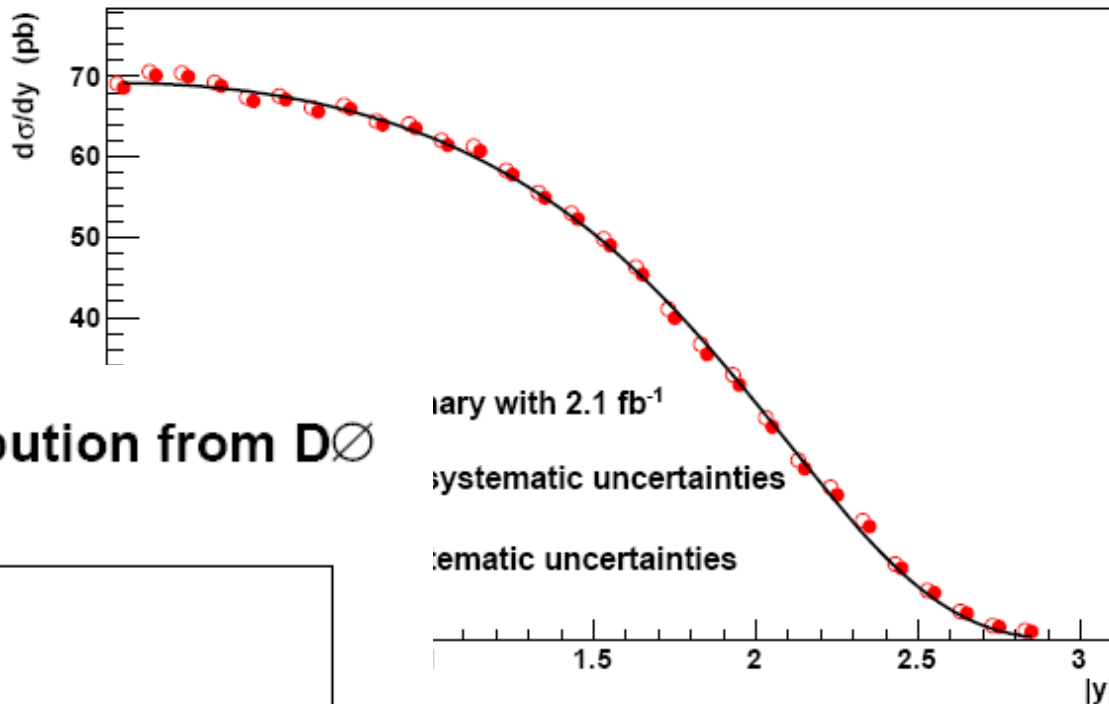


# $W^+$ and $W^-$ total cross sections at the LHC

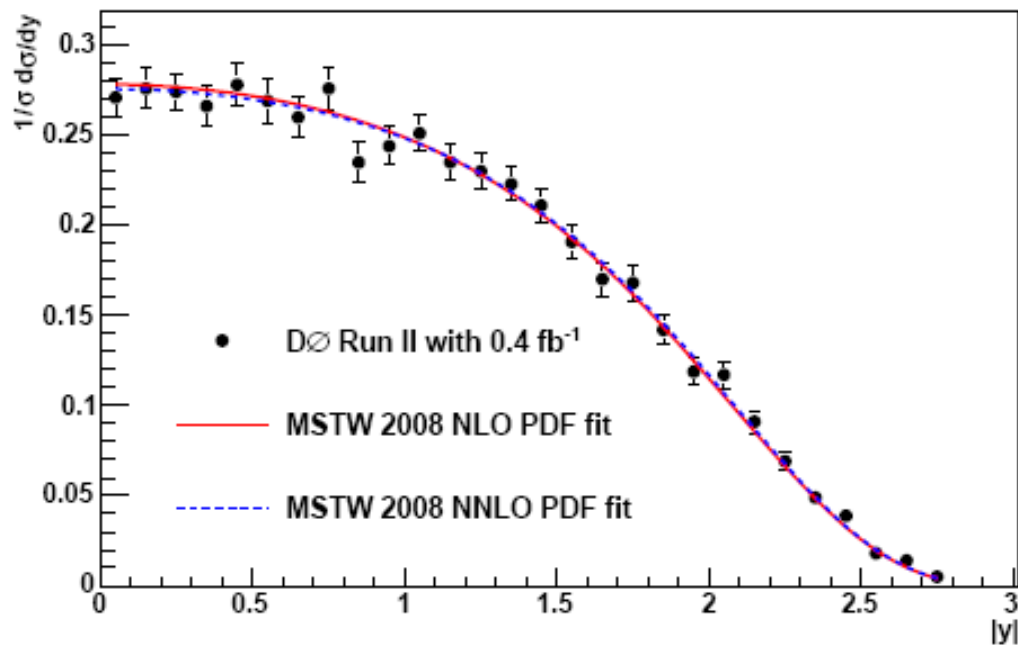


# $Z/\gamma^*$ rapidity distribution from CDF

MSTW 2008 NNLO PDF fit,  $\chi^2 = 50$  for 29 points

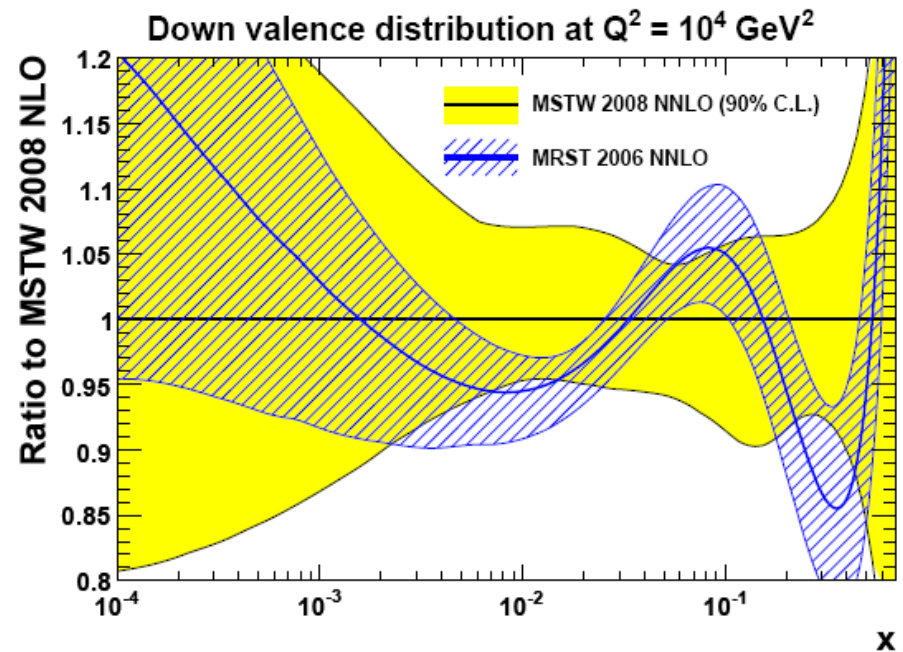
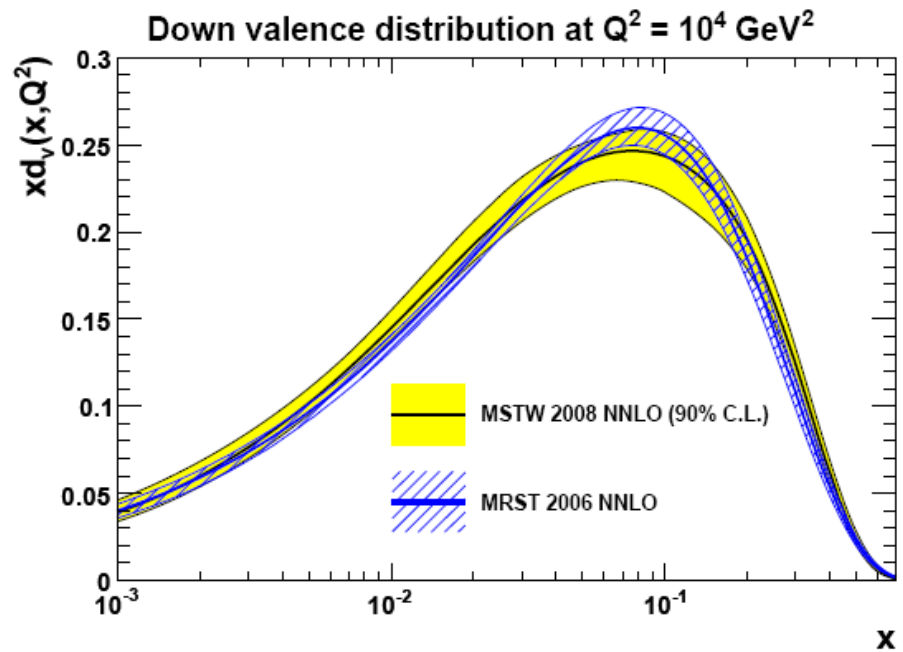


# $Z/\gamma^*$ rapidity shape distribution from $D\bar{D}$



$$d_v$$

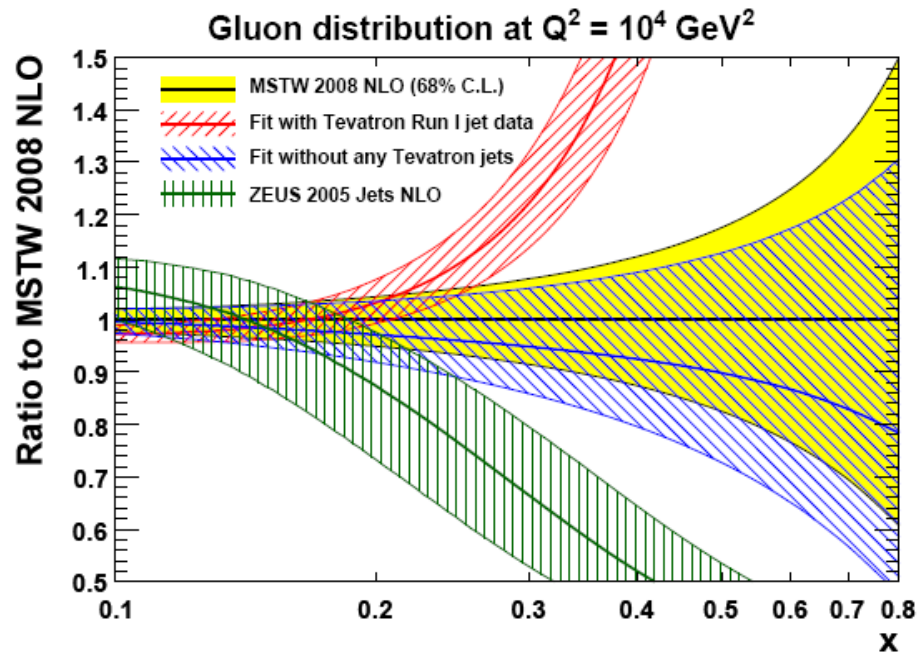
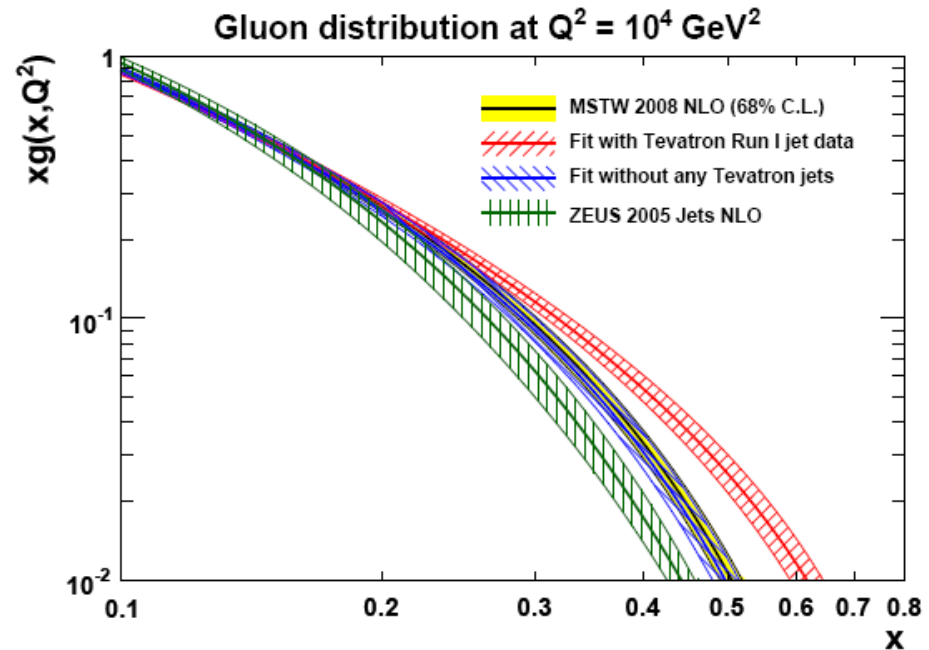
more flexible  
parametrization  
for extra W,Z  
Tevatron data



g

Run II Tevatron  
jet data require  
softer gluon

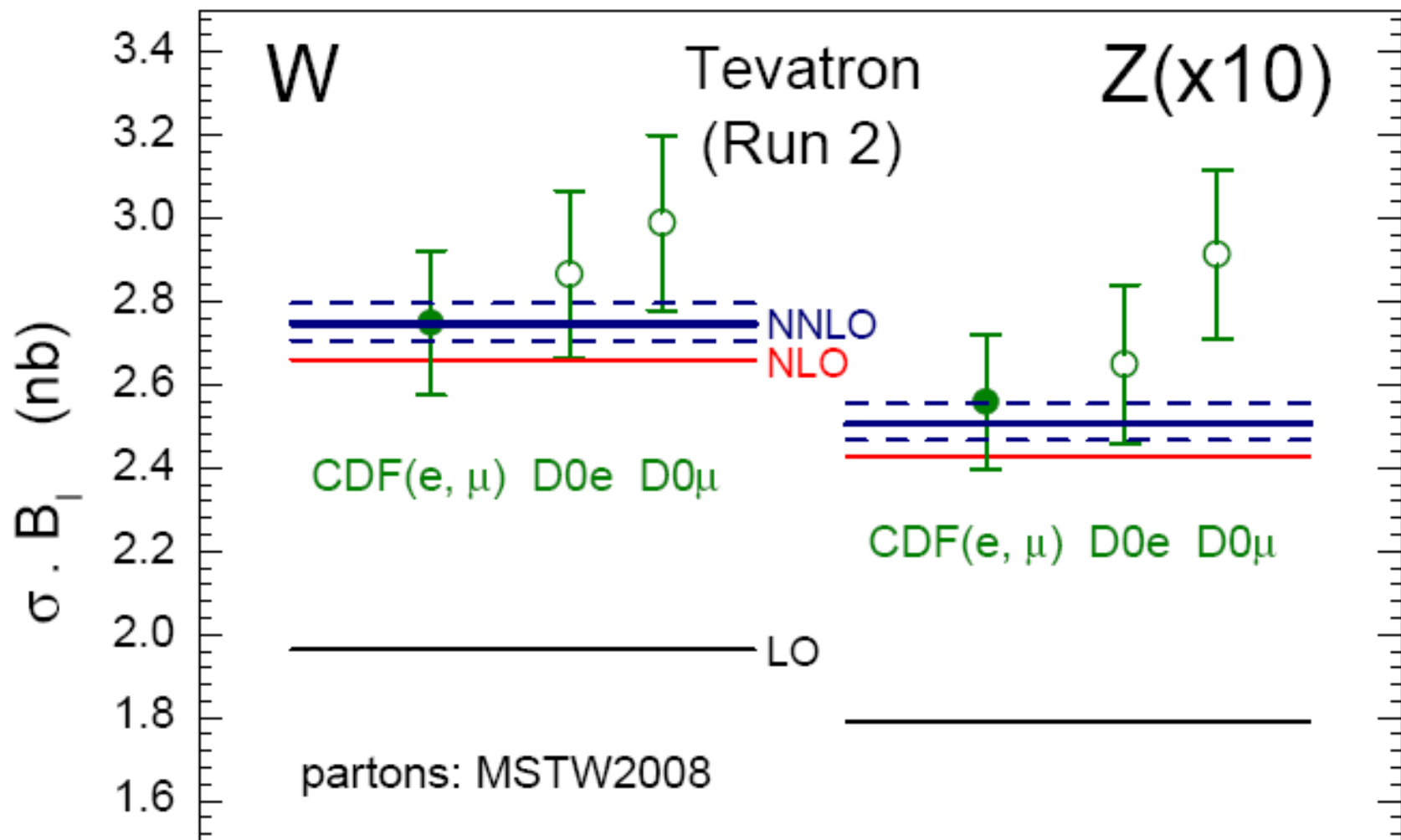
ZEUS fit has no  
fixed target data



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	$1.963^{+0.025}_{-0.028}$ (+1.2%) (-1.4%)	$0.1788^{+0.0023}_{-0.0025}$ (+1.3%) (-1.4%)	$10.98^{+0.02}_{-0.03}$ (+0.2%) (-0.3%)
MSTW 2008 NLO	$2.659^{+0.057}_{-0.045}$ (+2.1%) (-1.7%)	$0.2426^{+0.0054}_{-0.0043}$ (+2.2%) (-1.8%)	$10.96^{+0.03}_{-0.02}$ (+0.3%) (-0.2%)
MSTW 2008 NNLO	$2.747^{+0.049}_{-0.042}$ (+1.8%) (-1.5%)	$0.2507^{+0.0048}_{-0.0041}$ (+1.9%) (-1.6%)	$10.96^{+0.03}_{-0.03}$ (+0.2%) (-0.2%)

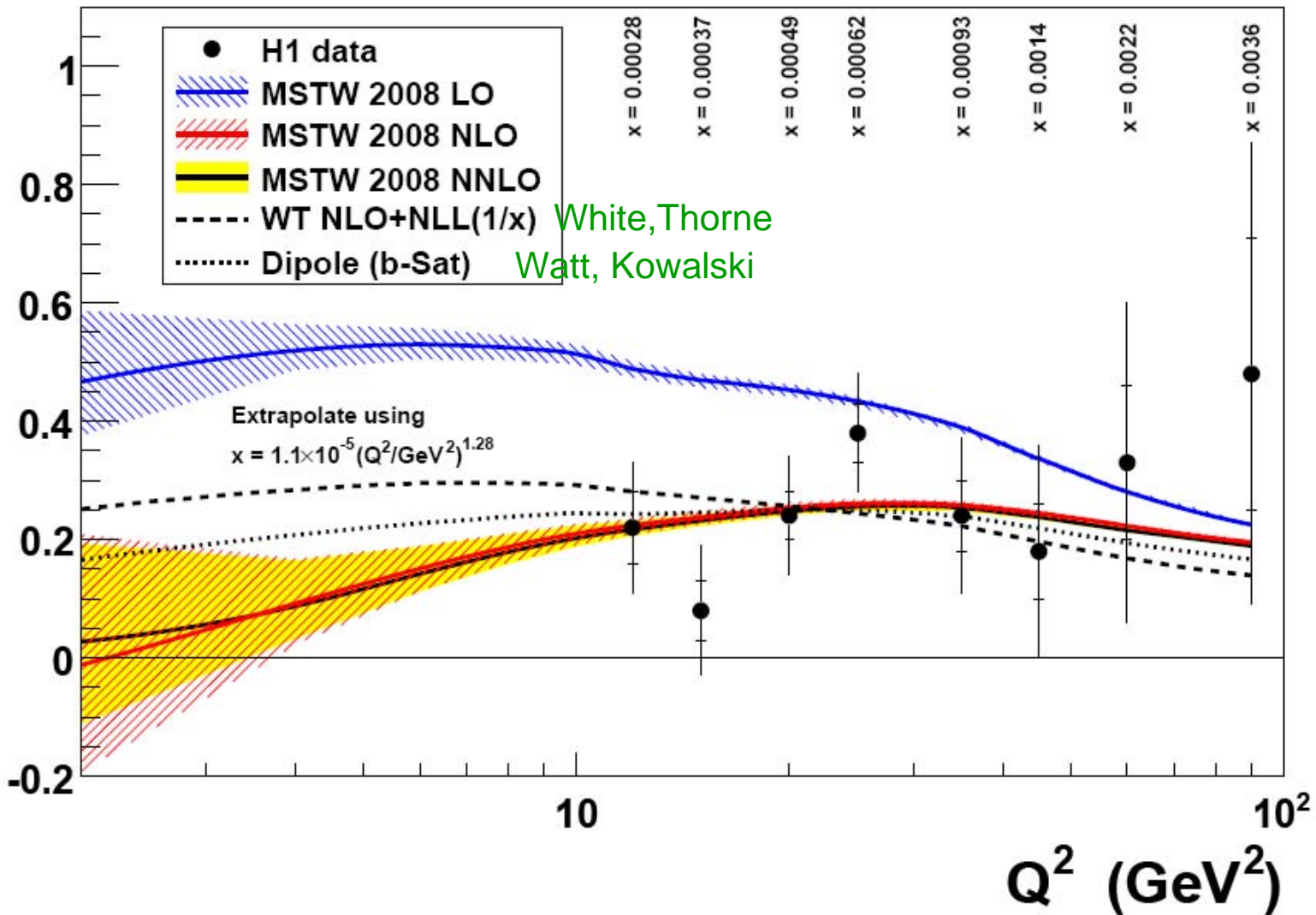
LHC, $\sqrt{s} = 10$ TeV	$B_{l\nu} \cdot \sigma_W$ (nb)	$B_{l+l-} \cdot \sigma_Z$ (nb)	$R_{WZ}$
MSTW 2008 LO	$12.57^{+0.13}_{-0.19}$ (+1.1%) (-1.5%)	$1.163^{+0.011}_{-0.017}$ (+1.0%) (-1.5%)	$10.81^{+0.02}_{-0.02}$ (+0.2%) (-0.2%)
MSTW 2008 NLO	$14.92^{+0.31}_{-0.24}$ (+2.1%) (-1.6%)	$1.390^{+0.029}_{-0.022}$ (+2.1%) (-1.5%)	$10.73^{+0.02}_{-0.02}$ (+0.2%) (-0.2%)
MSTW 2008 NNLO	$15.35^{+0.26}_{-0.25}$ (+1.7%) (-1.6%)	$1.429^{+0.024}_{-0.022}$ (+1.7%) (-1.6%)	$10.74^{+0.02}_{-0.02}$ (+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	$18.51^{+0.22}_{-0.32}$ (+1.2%) (-1.7%)	$1.736^{+0.019}_{-0.028}$ (+1.1%) (-1.6%)	$10.66^{+0.02}_{-0.02}$ (+0.2%) (-0.2%)
MSTW 2008 NLO	$21.17^{+0.42}_{-0.36}$ (+2.0%) (-1.7%)	$2.001^{+0.040}_{-0.032}$ (+2.0%) (-1.6%)	$10.58^{+0.02}_{-0.02}$ (+0.2%) (-0.2%)
MSTW 2008 NNLO	$21.72^{+0.36}_{-0.36}$ (+1.7%) (-1.7%)	$2.051^{+0.035}_{-0.033}$ (+1.7%) (-1.6%)	$10.59^{+0.02}_{-0.03}$ (+0.2%) (-0.3%)



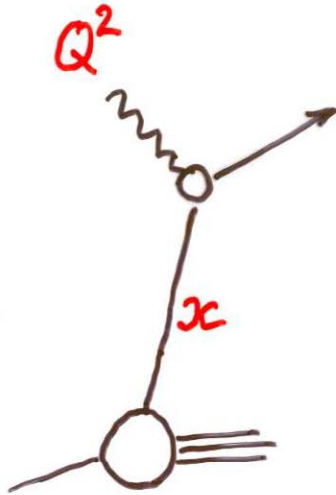


$F_L(x, Q^2)$



# Diffractive deep inelastic scattering (DDIS)

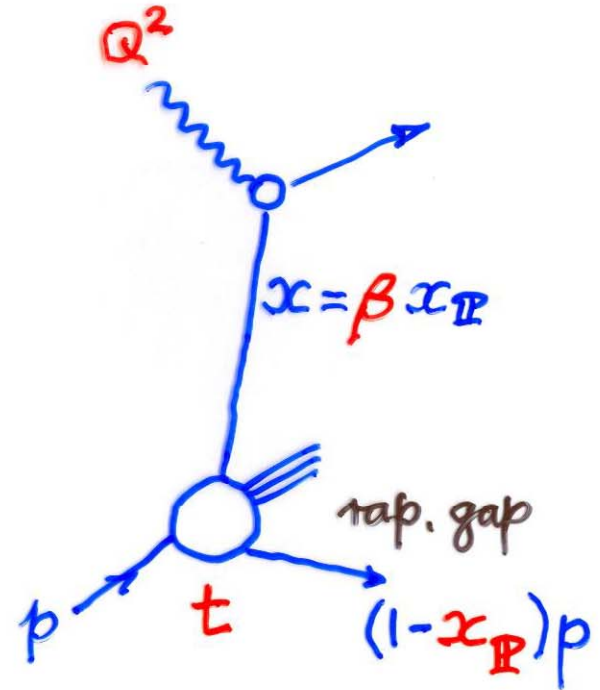
DIS



↓  
parton densities  $a$

Diffractive DIS

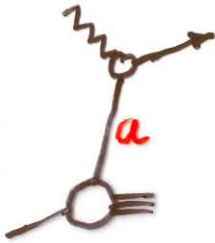
(10-20%)



↓  
diffractive parton densities  $a^D$

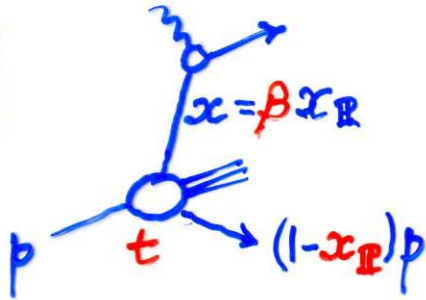
Conventionally DDIS analyses use two levels of factorisation  
 - collinear factorization and Regge factorization

DIS



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

DDIS



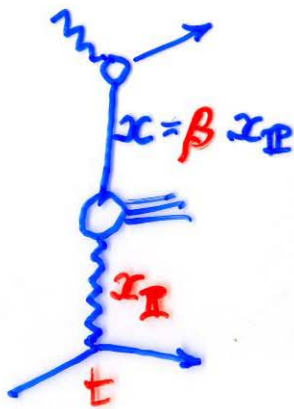
$$F_2(x_{\mathbb{R}}, \beta, Q^2) = \sum_a C_{2,a} \otimes a^{\mathbb{D}}$$

collinear fact<sup>n</sup> proved for DDIS (Collins), but important modifications in the HERA regime

conventional  
 to also assume

Regge fact<sup>n</sup>

Ingelman-Schlein  
 $\mathbb{R} \sim$  particle



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

$$\mathbb{R} \text{ flux } f_{\mathbb{R}} = \int dt \frac{e^{\mathcal{B}t}}{x_{\mathbb{R}}^{2\alpha_{\mathbb{R}}(t)-1}}$$

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

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

Hint of problem with **Regge factorisation** assumption

assumes Pomeron  $\sim$  hadron of size  $R$

Regge fact<sup>n</sup> occurs in non-pert region  $\mu < \mu_0$ , where  $\mu \sim 1/R$

but  $\alpha_P(0) \sim 1.2$  from DDIS  $>$   $\alpha_P(0) \sim 1.08$  from soft data

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

New DDIS analysis---**Watt, Martin, Ryskin**

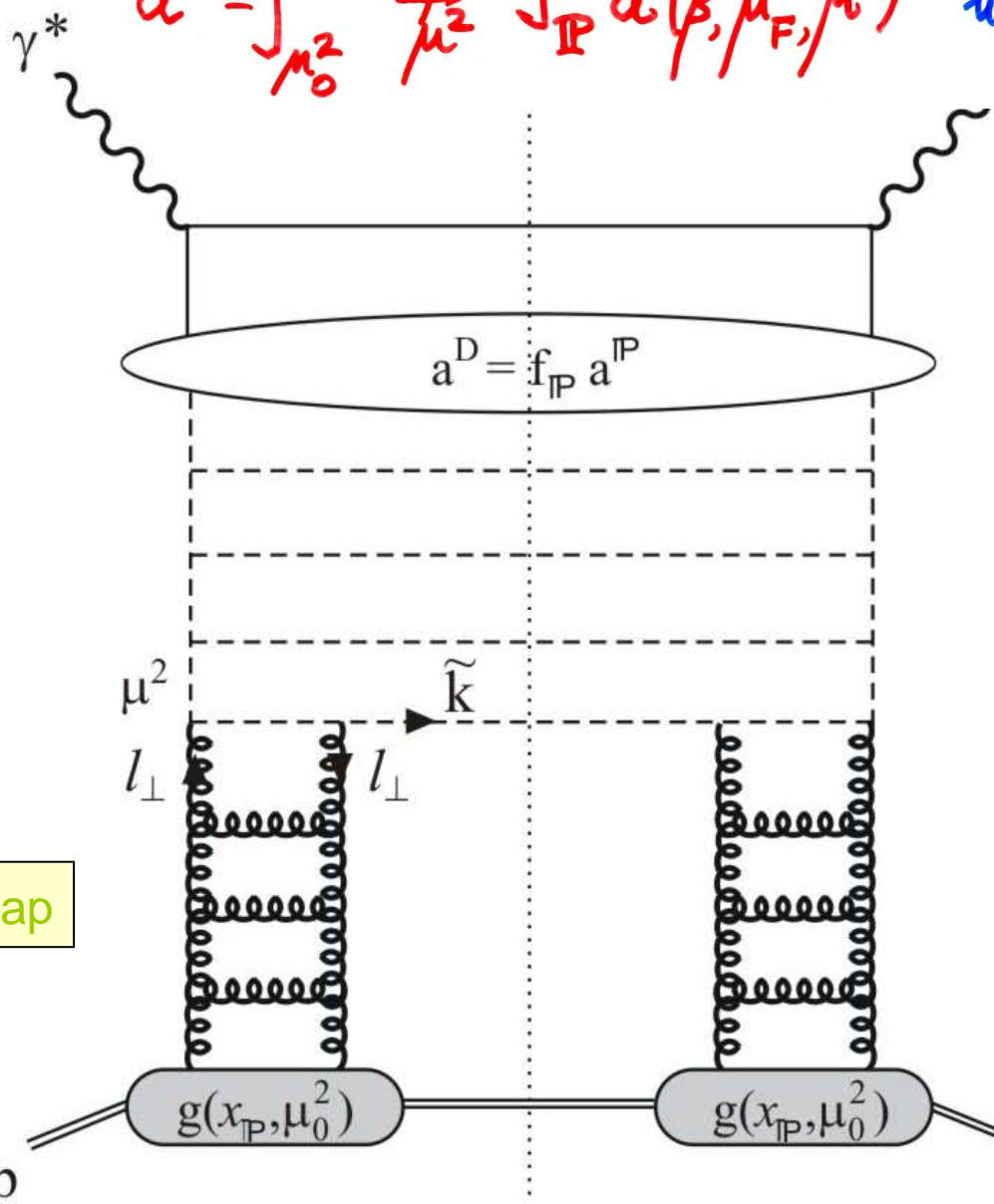
Replaces **Regge factorization** by pQCD

**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.

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



$\mu_F$

$\mu$

rapidity gap

$\mu_0$

p

DGLAP( $\mu \rightarrow \mu_F$ )  
for  $a^{\mathbb{P}}$  from  
 $P_{a\mathbb{P}}(\beta)$  input

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

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

given by pQCD

$$\underbrace{\frac{\partial a^D}{\partial \ln Q^2}}_{\text{DGLAP}} = \underbrace{\sum_a P_{aa'} \otimes a'^D}_{\text{DGLAP}} + \underbrace{f_{\mathbb{I}}(x_{\mathbb{I}}, Q^2) P_{a\mathbb{I}}(\beta)}_{\text{inhomogeneous term}}$$

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

cf DGLAP for  $\gamma$

DGLAP with inhomogeneous term

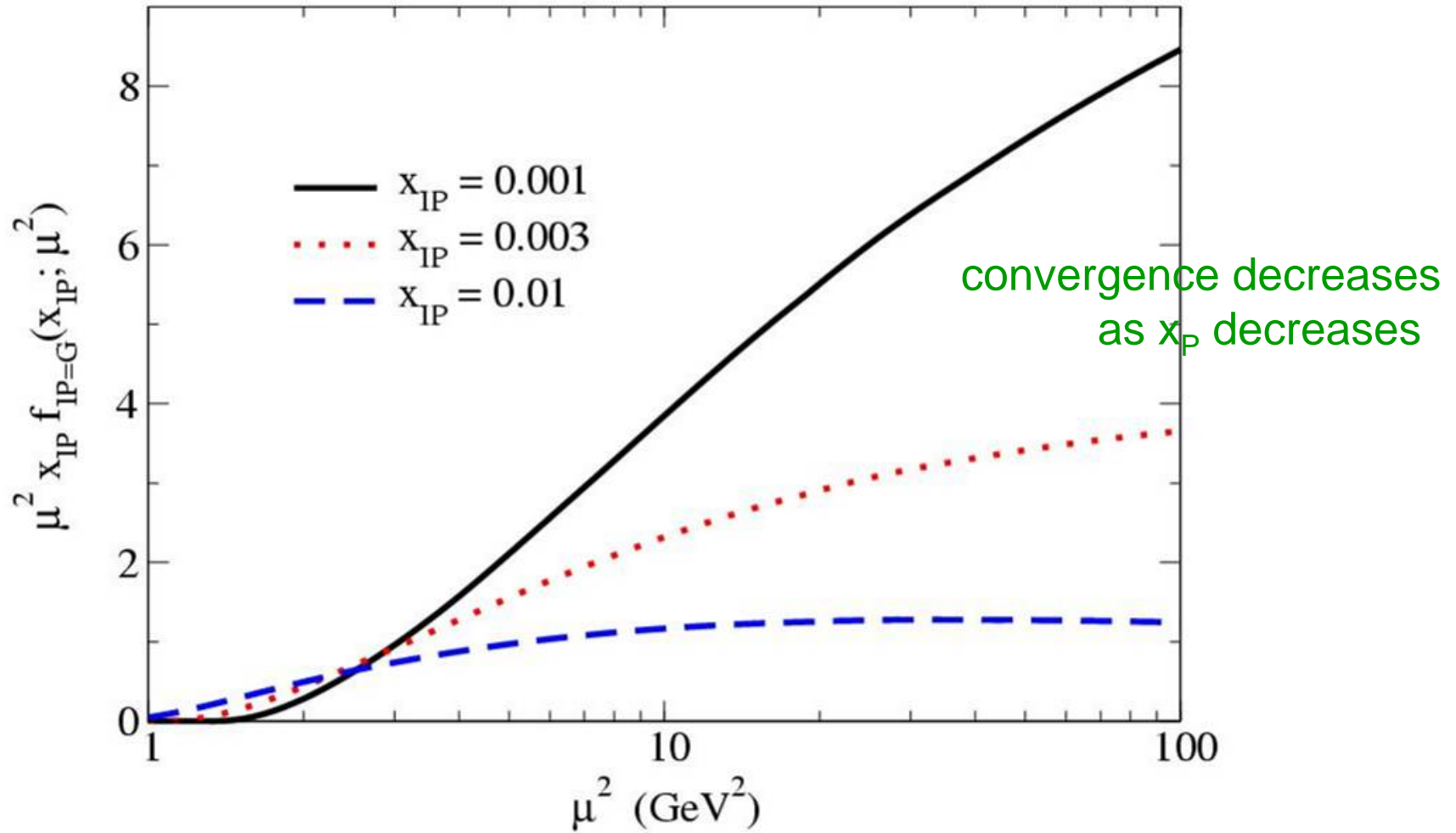
Recall flux  $f_{\mathbb{I}}(x_{\mathbb{I}}, Q^2) = \frac{1}{x_{\mathbb{I}}} \left[ \frac{\alpha_s}{Q} x_{\mathbb{I}} g(x_{\mathbb{I}}, Q^2) \right]^2$

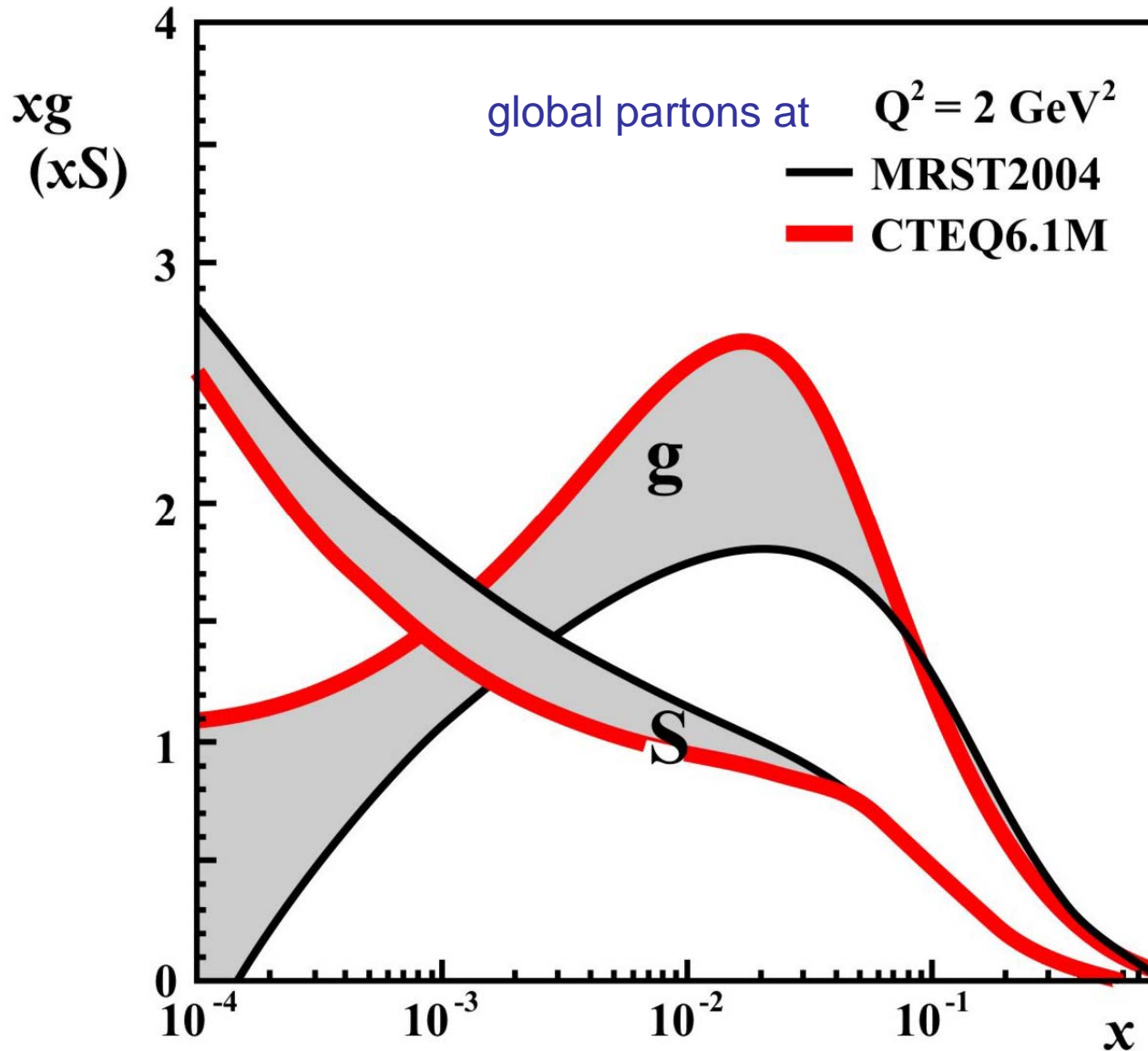
- if  $f_{\mathbb{I}} \sim \frac{1}{Q^2}$  then inhomogeneous term  $\sim$  power correction  
collinear DIS fact.<sup>n</sup> & DGLAP OK
- but at small  $x_{\mathbb{I}}$ ,  $g(x_{\mathbb{I}}, Q^2)$  grows rapidly with  $Q^2$

So inhomogeneous term must be included

inclusion of the inhomogeneous term makes  $g^P$  smaller

$\mu^2 f_p \rightarrow$  flux does not behave as  $1/\mu^2$





but one of the  
HERA surprises....

$g$ : valence-like  
 $S$ : Pomeron-like

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

( $xg \sim x^{-\lambda_g}$   
 $xS \sim x^{-\lambda_S}$ )

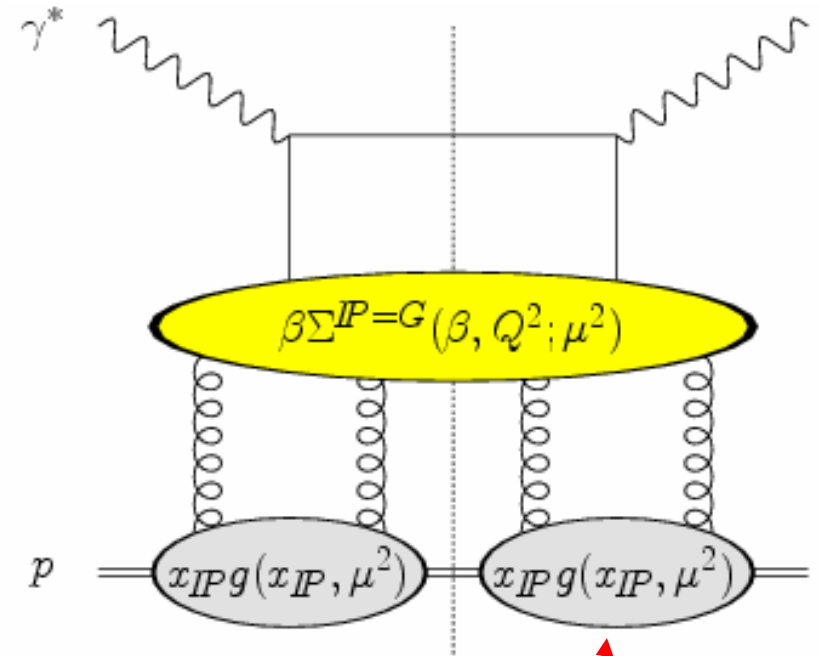
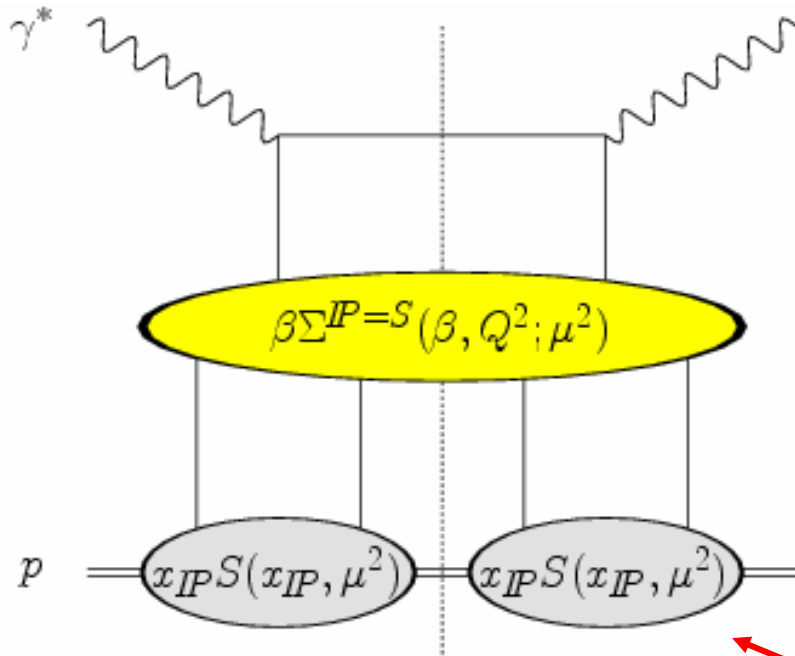
Would have  
anticipated both  
driven by same  
vac. singularity



need to introduce  
Pomeron made of  
col. singlet  $q\bar{q}$  pair

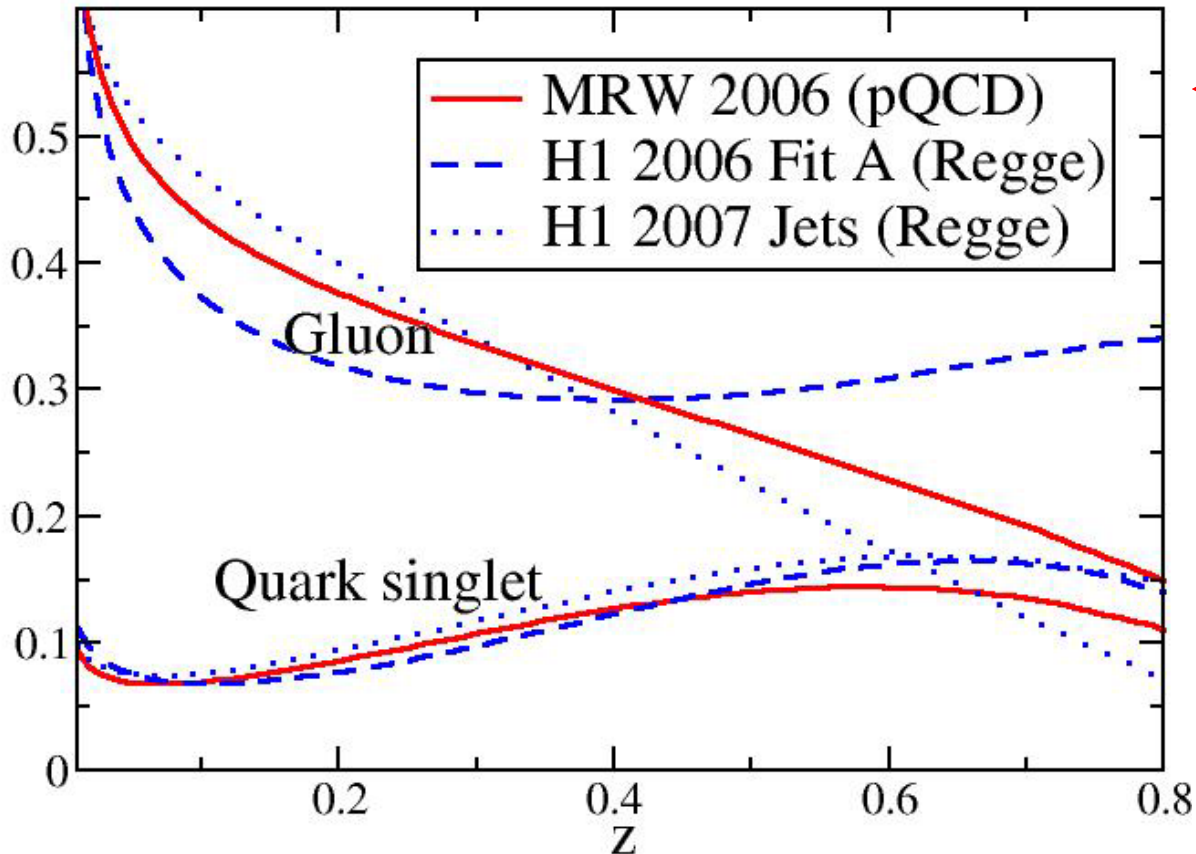
as well as

Pomeron made of  
two gluons



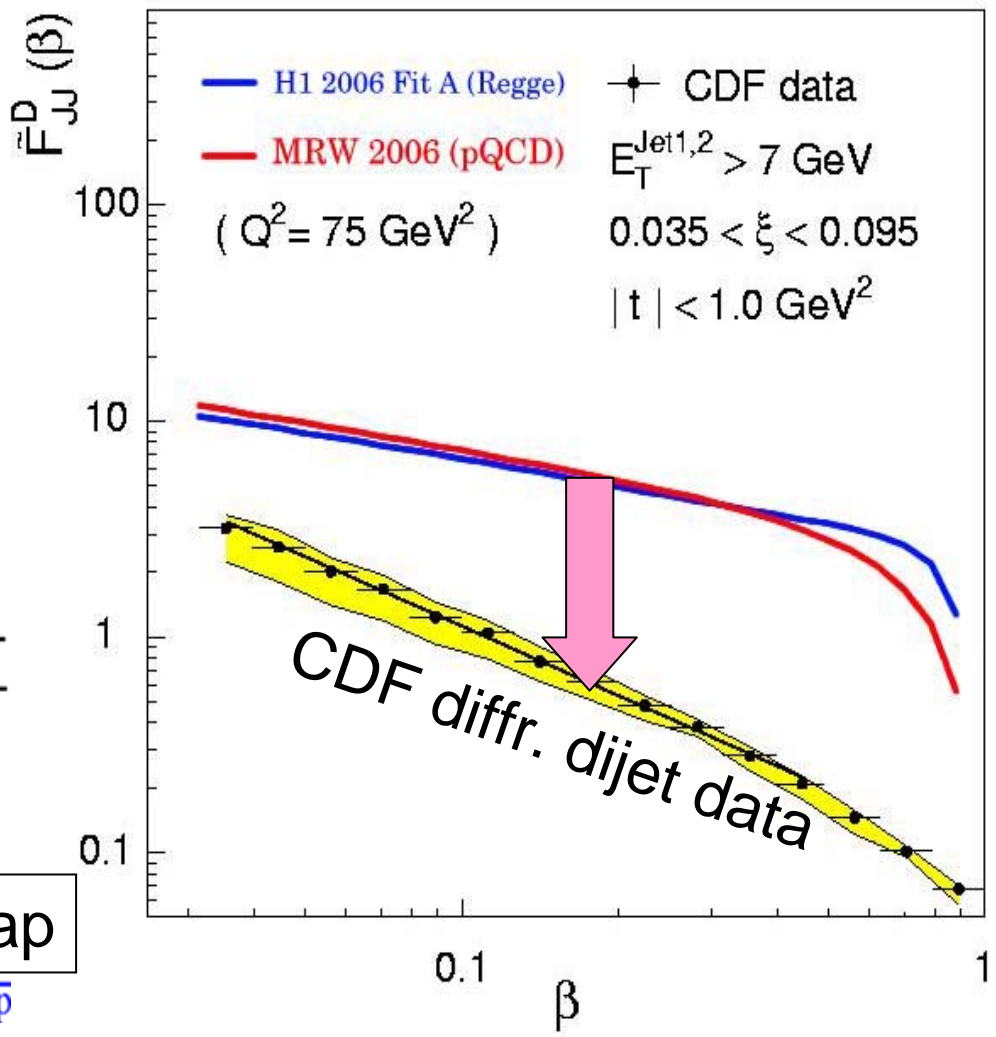
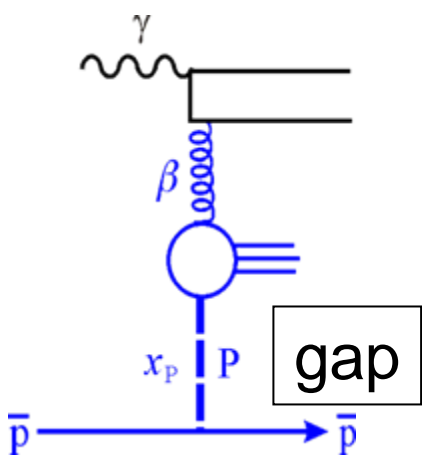
Now Pomeron flux factors depend on  $S^p$  as well as  $g^p$

$$x_{\text{IP}} = 0.003, Q^2 = 10 \text{ GeV}^2$$

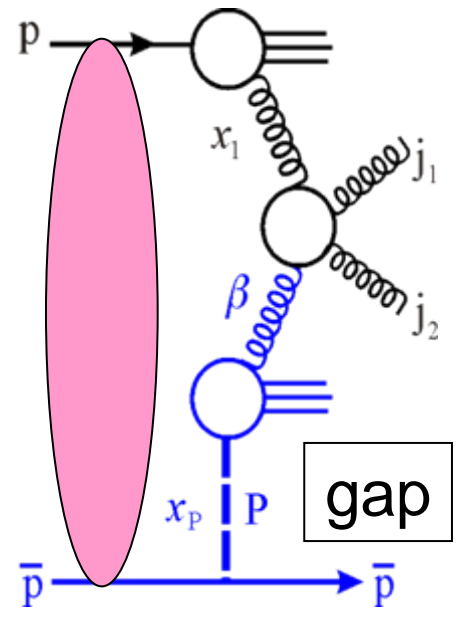


direct+resolved  
← Pomeron  
(cf. photon)

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

Calculation should be extended to obtain reliable  $S_{\text{enh}}$

1. Need to calc.  $b, k_t$  dep.,  $S_{\text{enh}}$  comes mainly from periphery (after  $S_{\text{eik}}$  suppression) where parton density is small. So  $S_{\text{enh}}$  (GLM) is much too small.
2. First 3P diagram is missing, so  $\sigma_{\text{SD}}$  much too small.
3. Four or more multi-Pomeron vertices neglected, so  $\sigma_{\text{tot}}$  asymptotically decreases (but GLM have  $\sigma_{\text{tot}}$  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  $S_{\text{enh}}$  !

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.

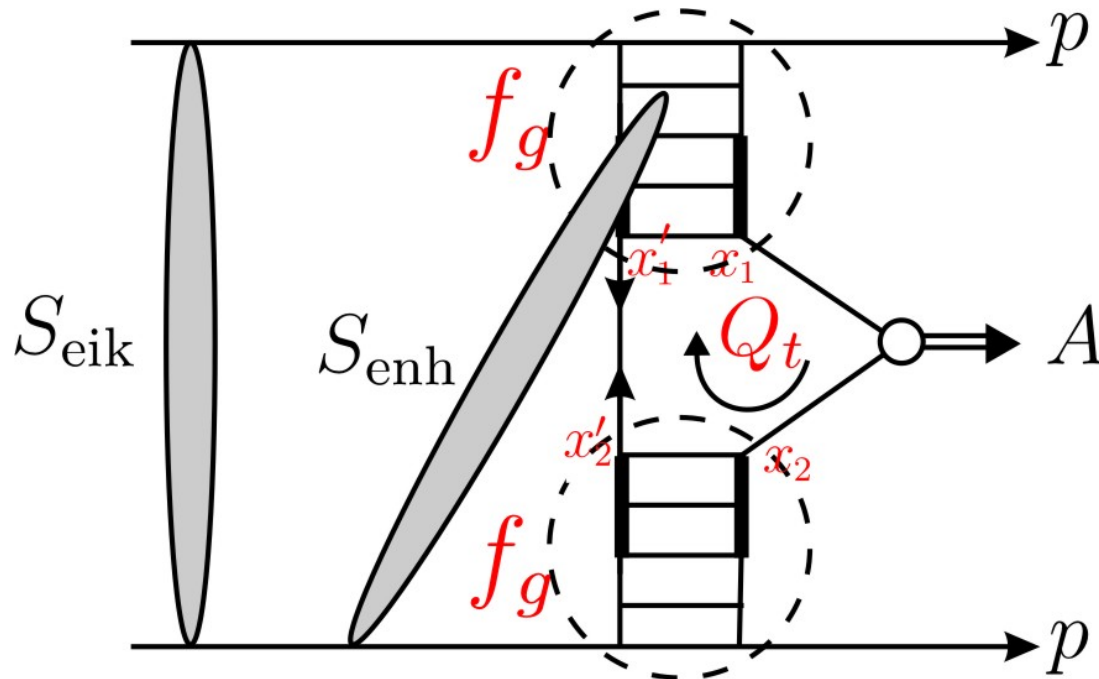
However, empirically the low  $x$ , low  $Q^2$  gluon is flat – the steep  $1/x$  LO behaviour is an artefact of the neglect of large NLO corrections.

Again should compare to CDF exclusive data.

# “Enhanced” absorptive effects

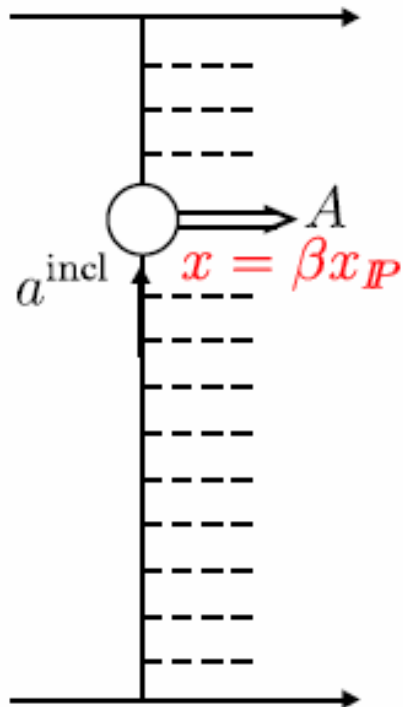
(break soft-hard factorization)

rescattering on an intermediate parton:

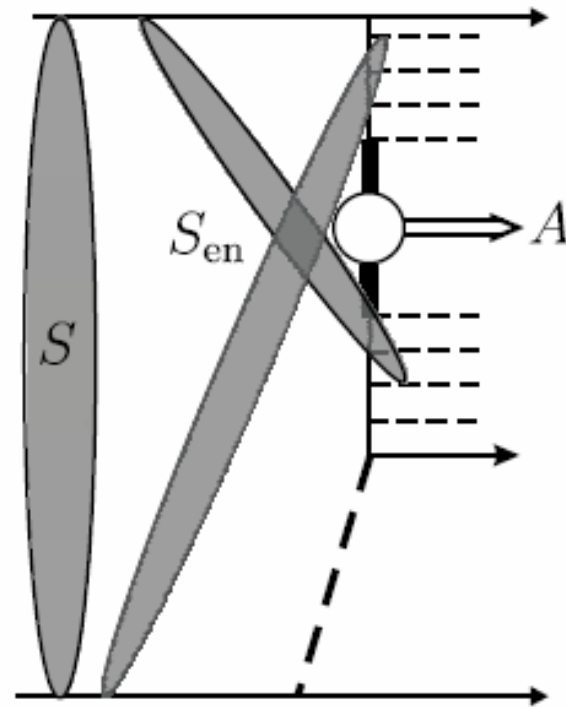
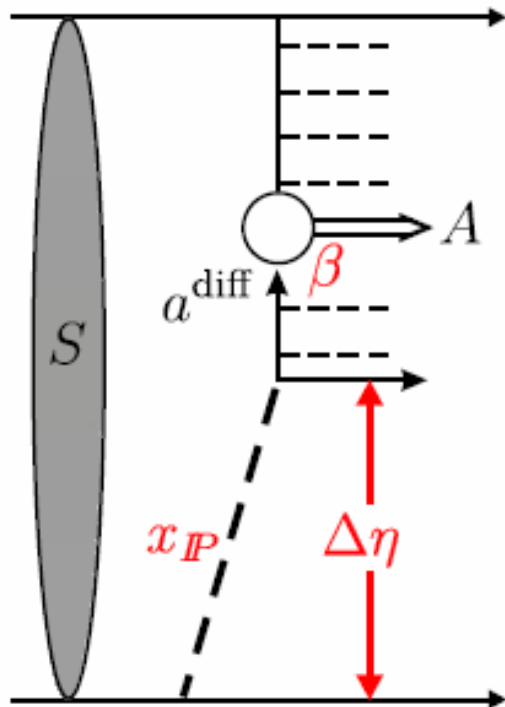


can LHC probe this effect ?

inclusive



diffractive

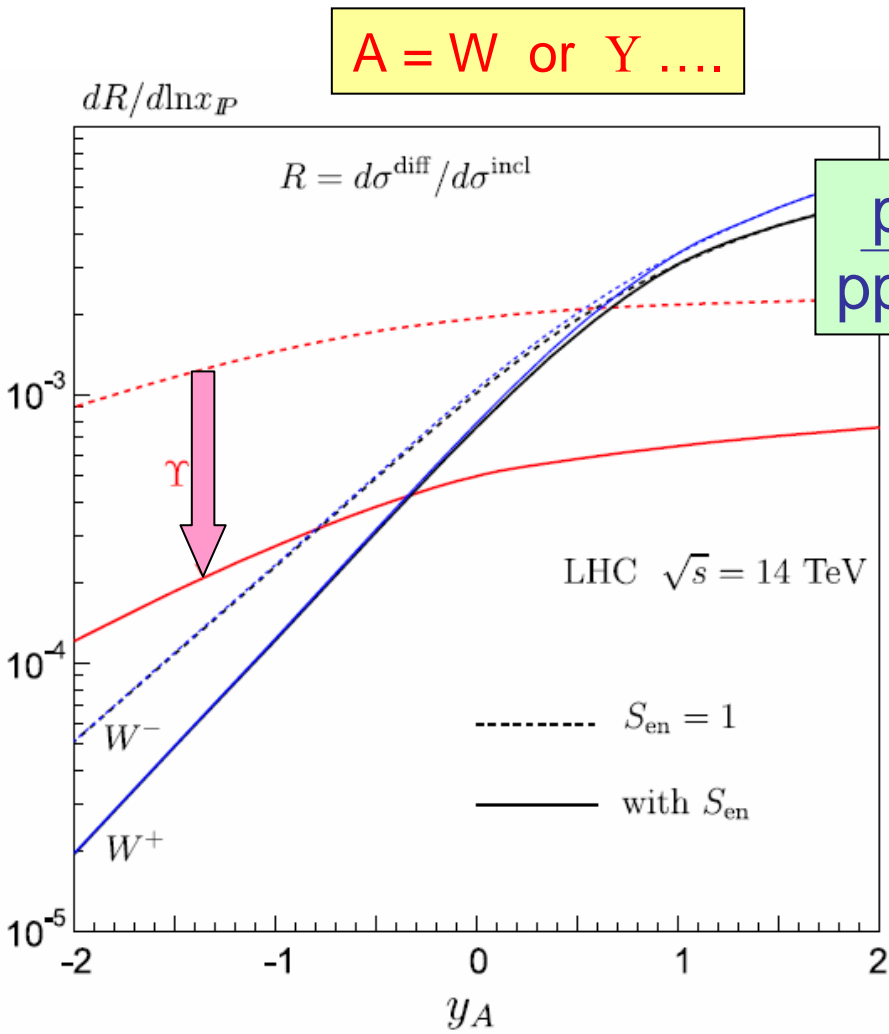


A = W or dijet or Y ....

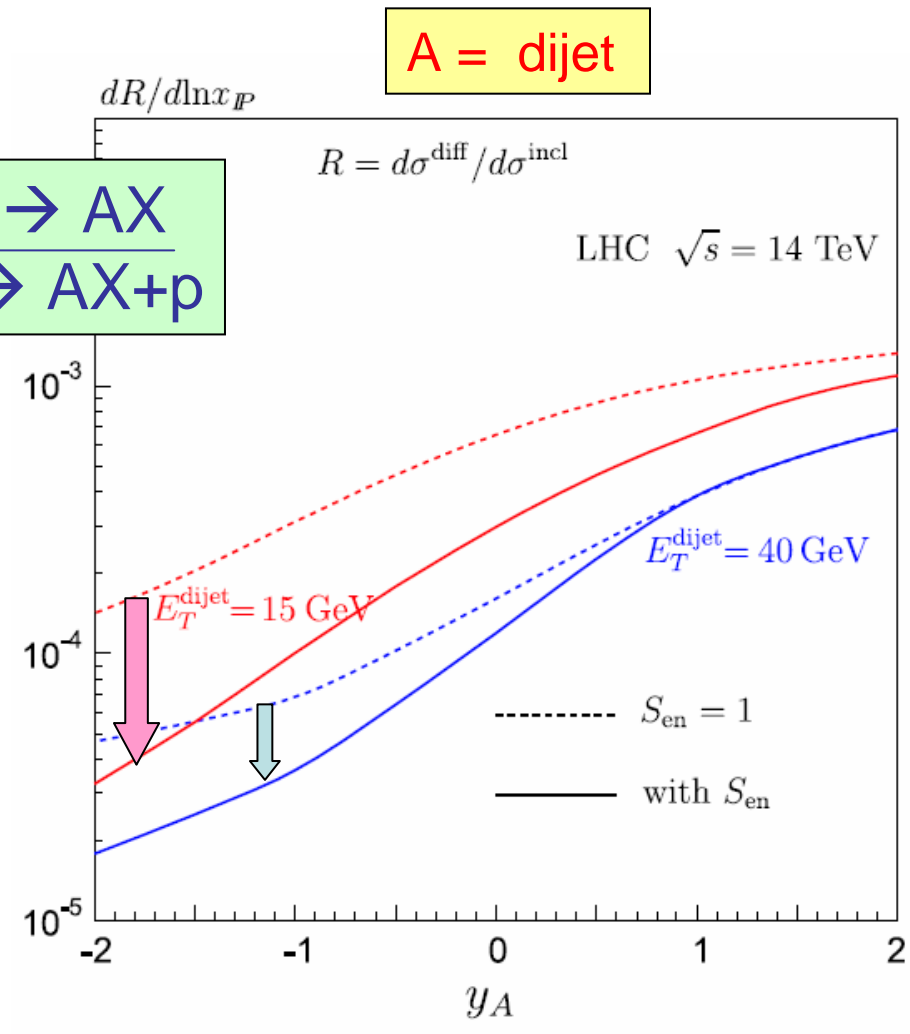
$$R = \frac{\text{no. of } (A + \text{gap}) \text{ events}}{\text{no. of (inclusive } A) \text{ events}}$$

$$= \frac{a^{\text{diff}}(x_{\text{IP}}, \beta, \mu^2)}{a^{\text{incl}}(x = \beta x_{\text{IP}}, \mu^2)} \langle S^2 S_{\text{en}}^2 \rangle_{\text{over } b_t}$$

known from HERA



$pp \rightarrow AX$   
 $pp \rightarrow AX+p$



rough estimates of enhanced absorption  $S_{\text{en}}^2$



# 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: ( $\xi$  unchanged)  
 anom.dim. of  $G_N =$  anom.dim. of  $M_N$

<b>GPDF(<math>x, \xi</math>)</b>	<b>diag. PDF(<math>x</math>)</b>
----------------------------------	----------------------------------

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

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

Typical diffractive processes have

$\xi \sim 10^{-2}$  ( $pp \rightarrow p+H+p$ );  $\xi \sim 10^{-3}$  ( $\gamma p \rightarrow J/\psi p$ )

