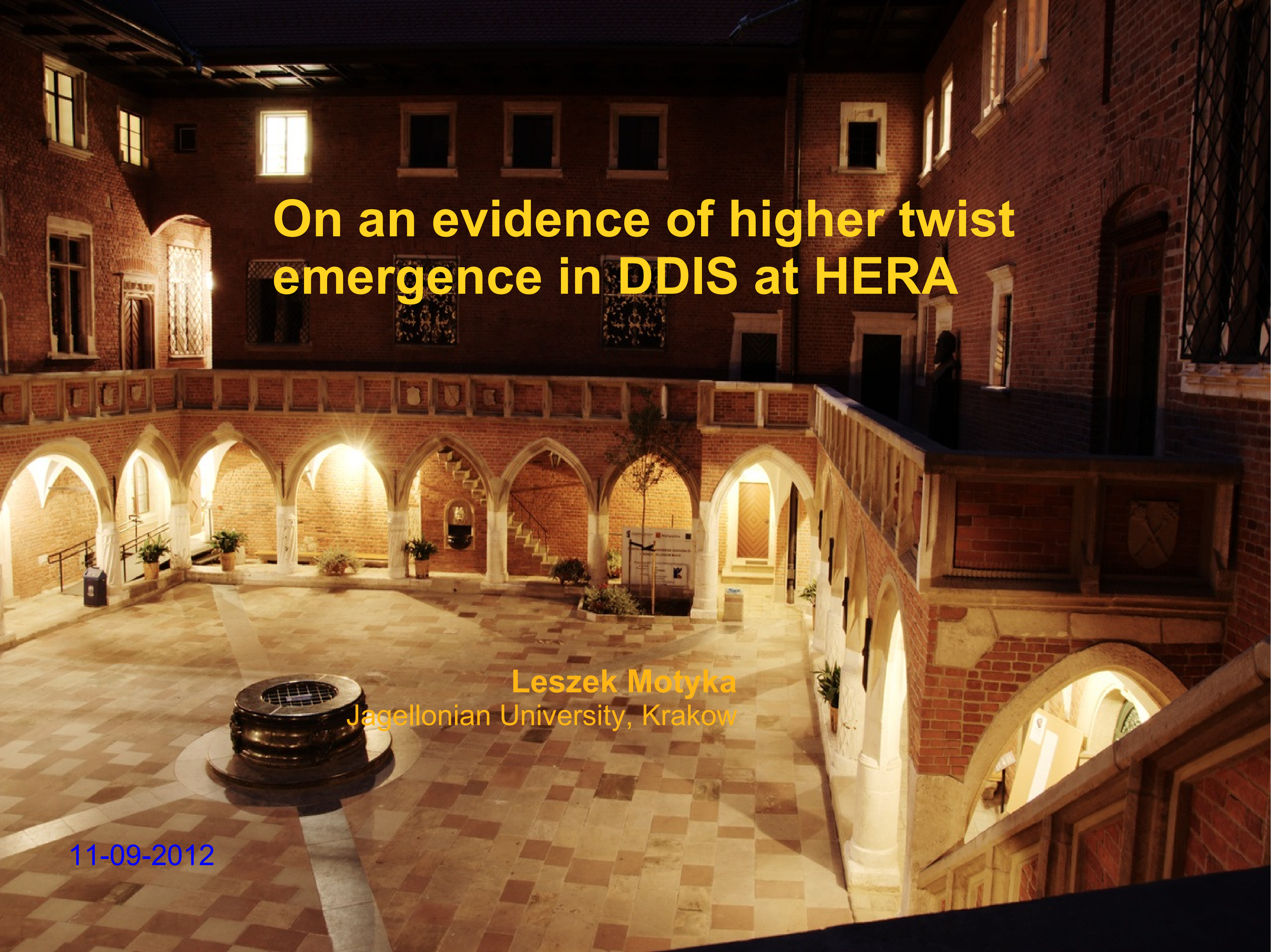

# On an evidence of higher twist emergence in DDIS at HERA

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# Plan: to prove observation of higher twists at HERA

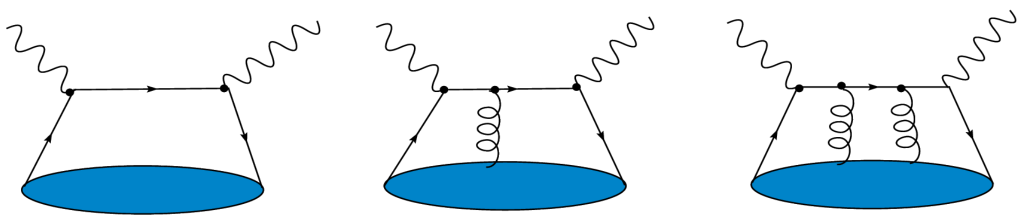
- DGLAP description of DDIS (at HERA)
- DGLAP breakdown
- Inclusion of multiple scattering: saturation models
- Emergence and representation of higher twist
- Higher twists and the data
- Conclusions

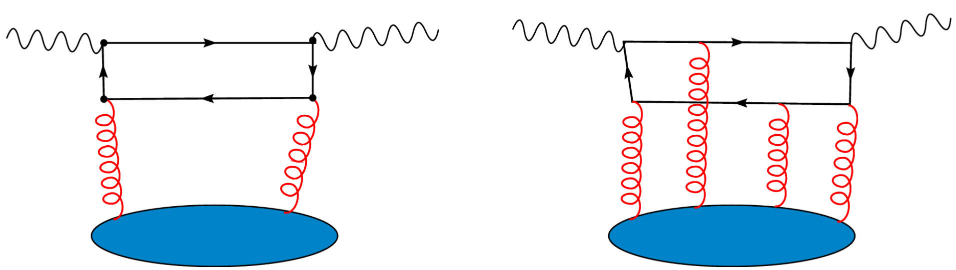
Work in progress with
Mariusz Sadzikowski and Wojtek Słomiński

# OPE, twists and DGLAP

- The basis of QCD description of hard scattering: short distance expansion (OPE)
- Leading contribution: twist 2 – single scattering and universal parton densities
- Leading higher twist operators – multiple parton densities – enhanced at large energies (small x)

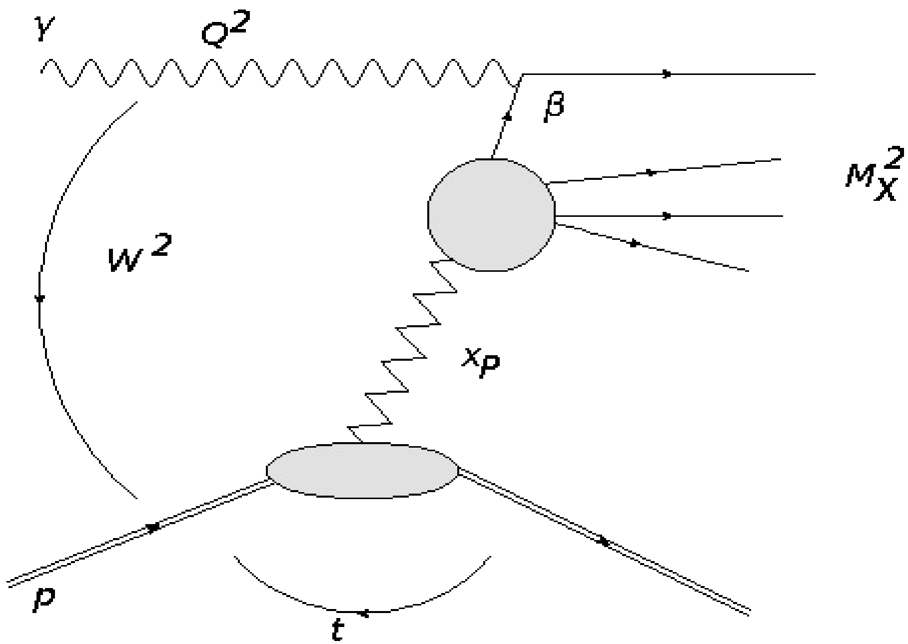
$$W^{\mu\nu} = \sum_\tau \left(\frac{\Lambda}{Q}\right)^{\tau-2} \sum_i C^{\mu\nu}_{\tau,i} \otimes f_{\tau,i}(Q^2/\Lambda^2)$$





Gluons: $\frac{\text{Twist 4}}{\text{Twist 2}} \sim \frac{1}{Q^2 R^2} \exp\left(\sqrt{b \log(Q^2) \log(1/x)}\right)$

# Diffractive DIS: process and variables

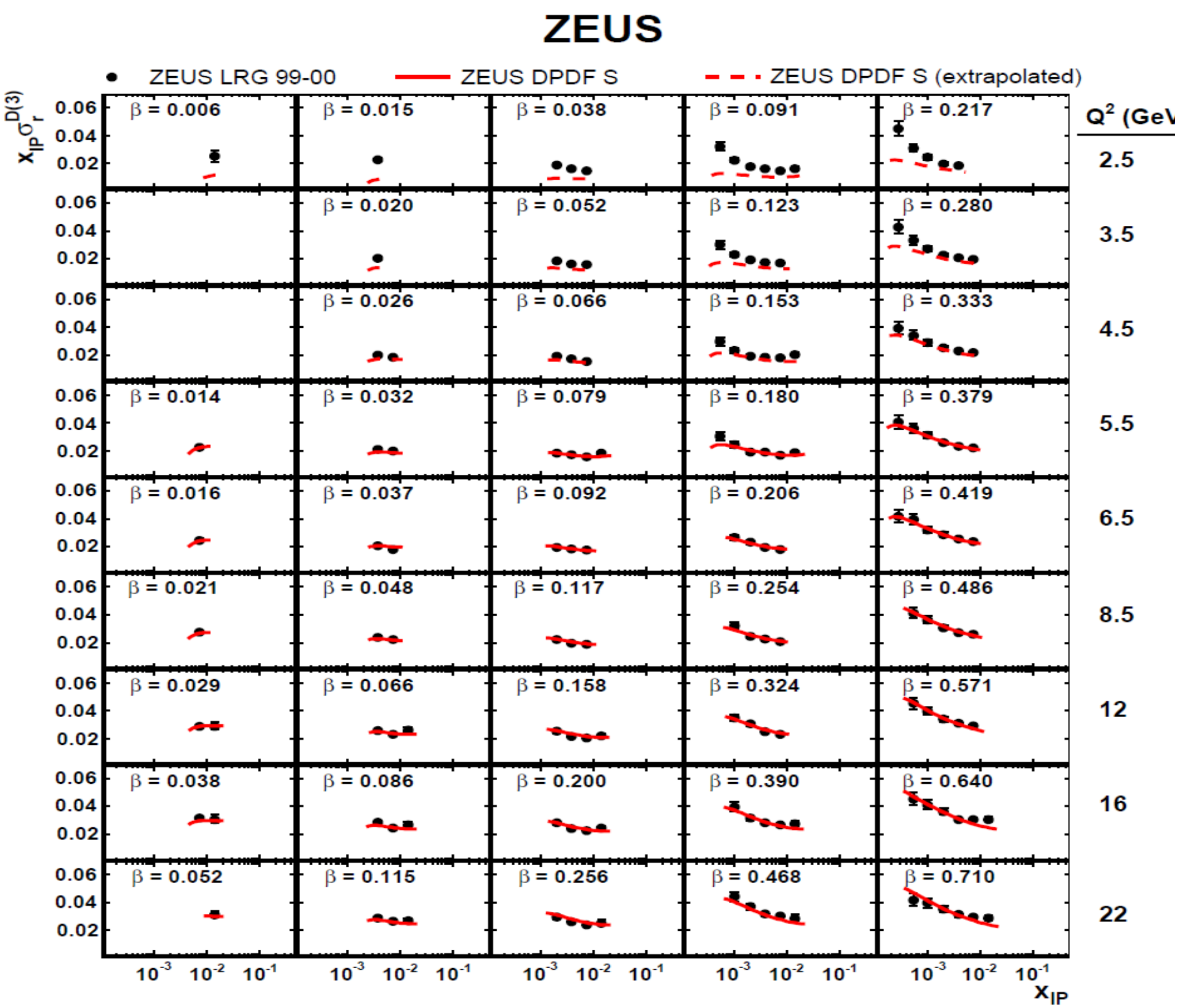



- collinear factorisation theorem → universal diffractive pdfs
- At twist-2: DGLAP evolution of pdfs
- Input: multi-component Regge ansatz

$$\frac{d\sigma^{ep\to eXp}}{d\beta dQ^2 dx_{I\!P}} = \frac{2\pi\alpha^2}{\beta Q^4}\left[1+(1-y)^2\right]\sigma_r^{D(3)}(\beta, Q^2, x_{I\!P})$$

$$\sigma_r^{D(3)}(\beta, Q^2, x_{I\!P}) = F_2^{D(3)}(\beta, Q^2, x_{I\!P}) - \frac{y^2}{1+(1-y)^2}\, F_L^{D(3)}(\beta, Q^2, x_{I\!P})$$

# DGLAP fit to DDIS data (ZEUS,2009)

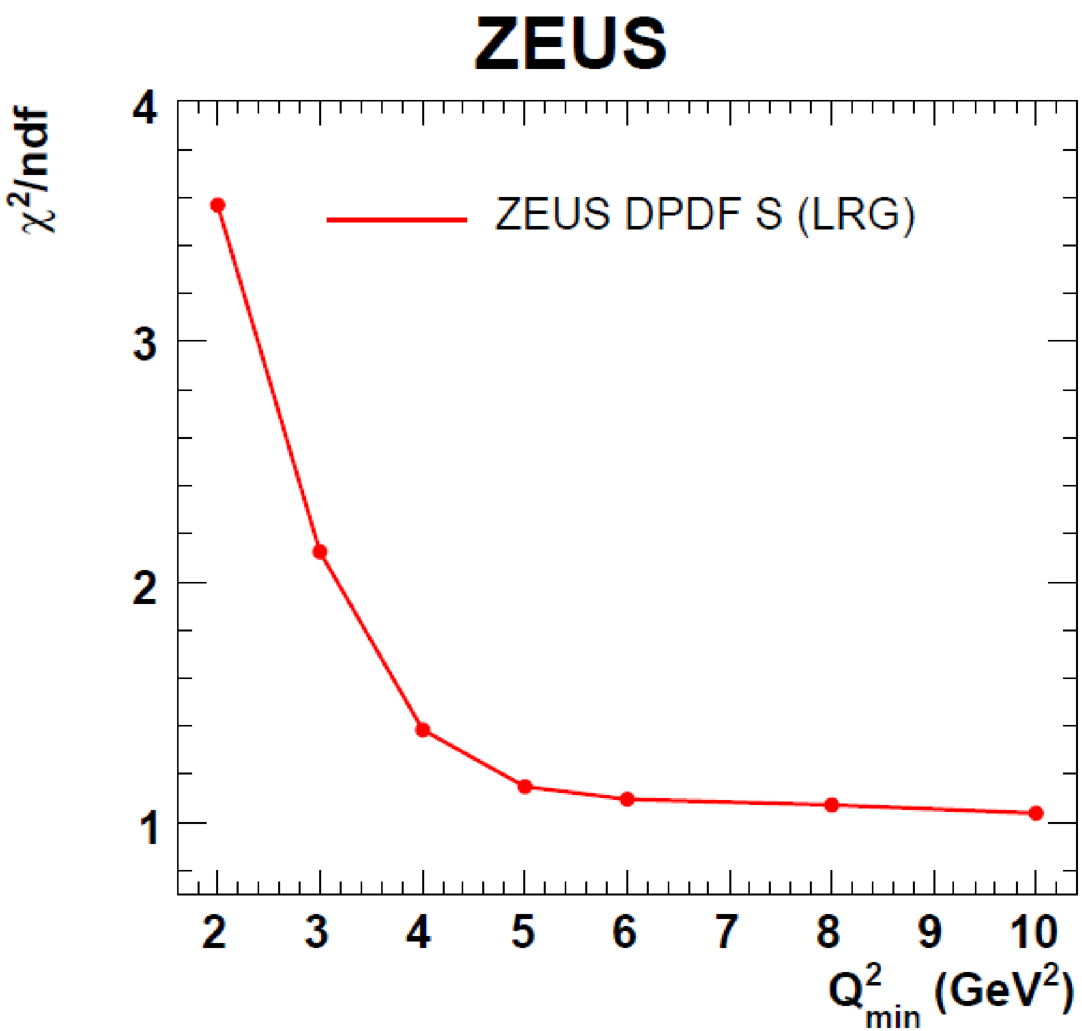



- DGLAP, twist-2 fit
- LRG + LPS ZEUS data

- $2.5<Q^2<255$ $GeV^2$ (LRG)
- 265 d.o.f

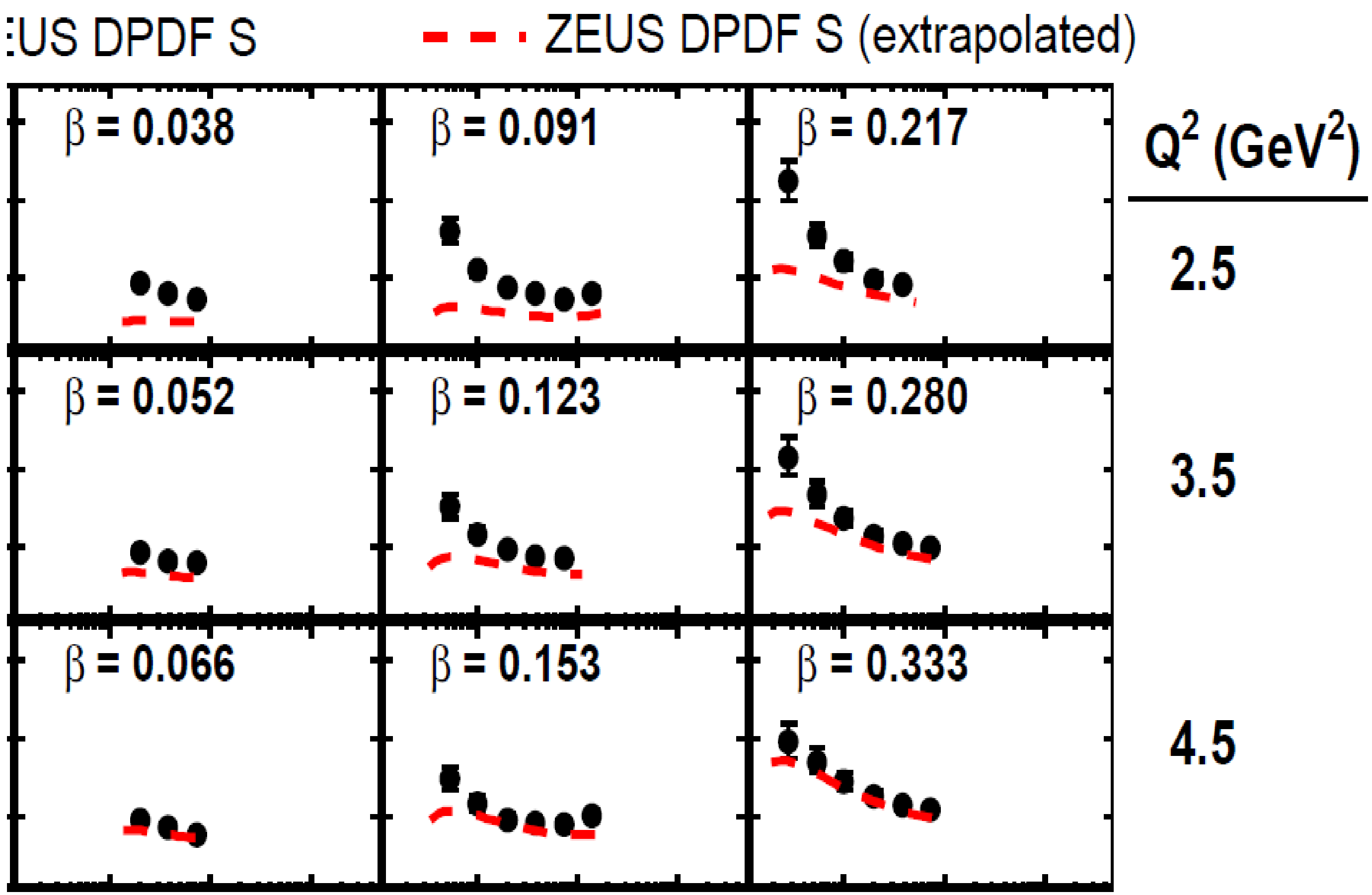
- In general, the fit looks well except of...

# DGLAP breakdown: "critical scale"




- Extensions of DGLAP fits below 5 GeV$^2$ fail
- Strong DGLAP breaking effects below 3 GeV$^2$
- Rapid growth with decreasing $Q^2$

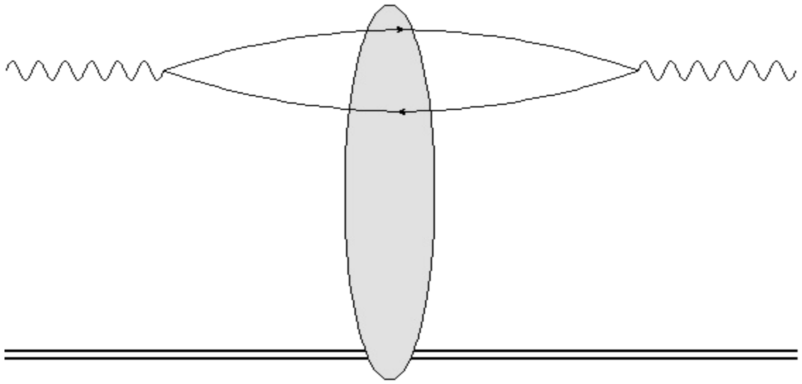
# DGLAP breakdown: closer look



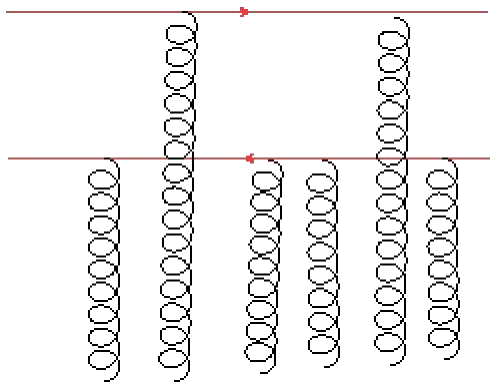

**Problematic region: low $x_P$ and low $Q^2$ – indications of multiple exchanges? Perhaps higher twists?**

# Beyond DGLAP: GBW saturation model

Inclusive scattering: large energy factorisation + eikonal colour dipole scattering



$$\sigma \sim \int d^2r\, dz\, |\Psi(z, Q^2r^2)|^2\, \sigma_d(x, r^2)$$

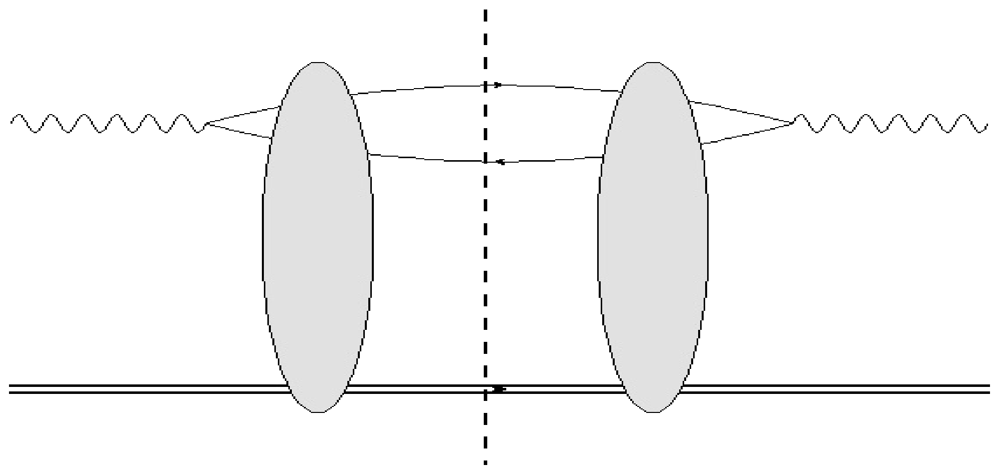


$$\sigma(x, r^2) = \sigma_0 \left[1 - \exp(-Q_0^2 r^2 x^{-\lambda})\right]$$

# Diffraction: quark-dipole contribution

Differences w.r.t. the inclusive case

- full colour singlet exchange on the amplitude level
- A t-dependence of the amplitude ~ exp(-B|t|/2)
- Strongly suppressed at small ß

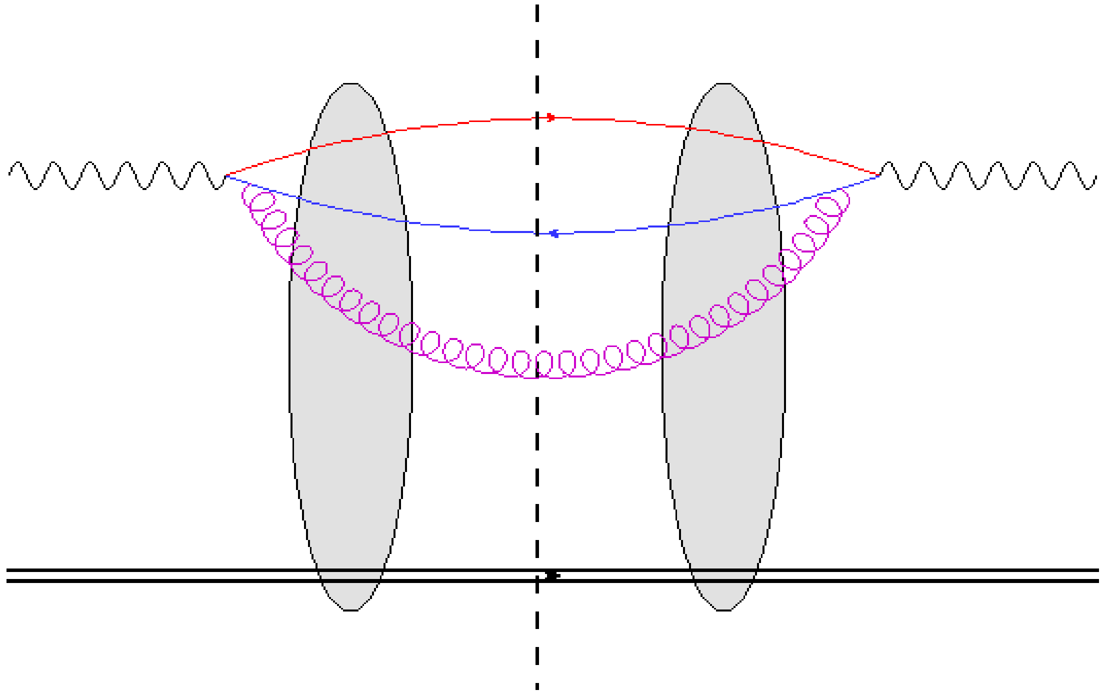


$$\sigma^{diff} \sim \int d^2r\, dz\, |\Psi(z, Q^2r^2)|^2\, \sigma_d^2(x, r^2)$$

# Quark-anti quark – gluon contribution

Effectively (large N limit) – two dipoles

Subleading in the strong coupling constant, but enhanced due to the dipole size – important at smaller ß



# Tunning the model

- The dipole cross section fixed by the GBW fit to inclusive data (massless quarks, no charm)
- The term with a gluon: Good-Walker → Białas-Peschanski → Munier-Shoshi approach:

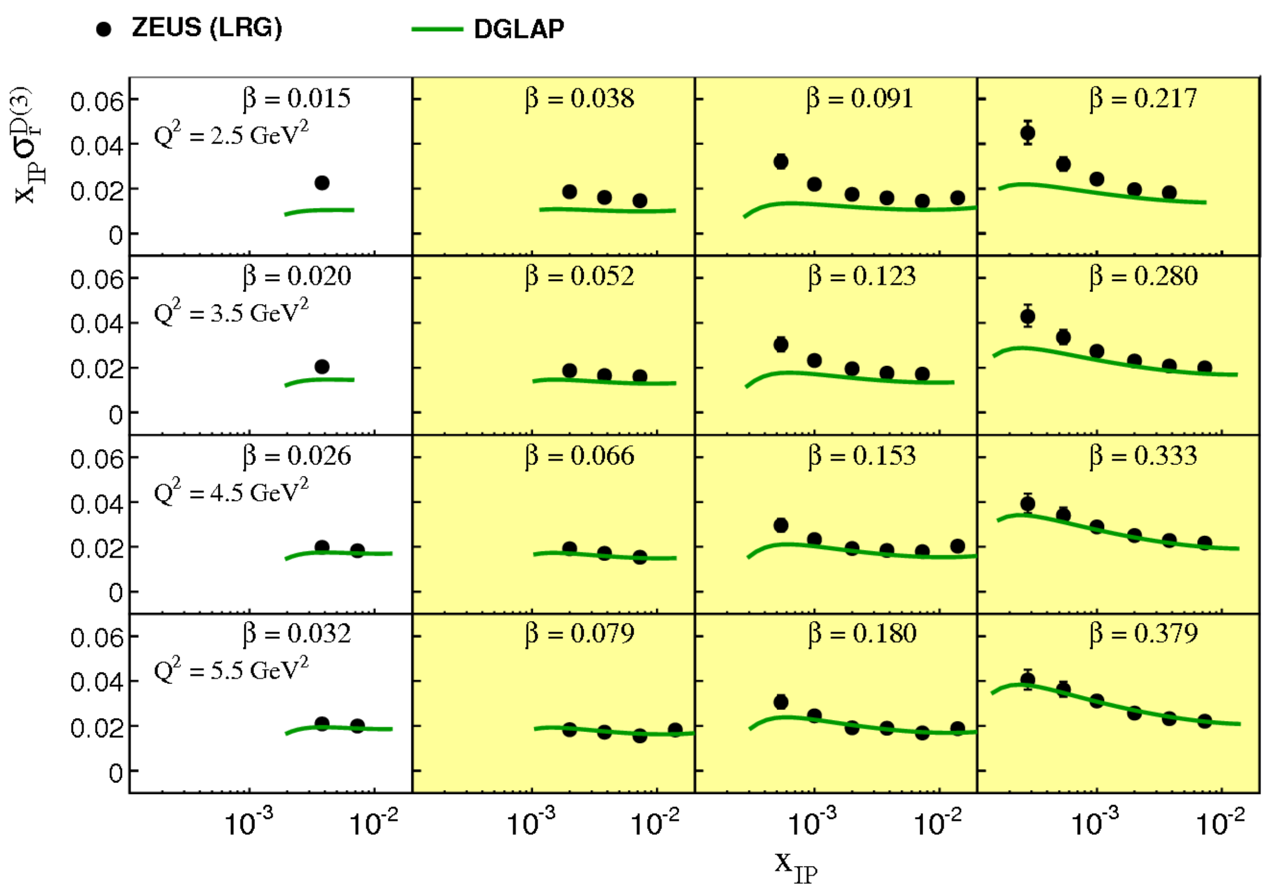
$$\sigma_{2d} \sim \alpha_s \int d^2 r_{02}\, K(r_{01}, r_{02})\, [\, N_{02} + N_{12} - N_{01} - N_{02} N_{12}\, ]^2$$

- Beta-improvement by Marquet, following G-BW calculation

$$F_2^{D(3)}(x, Q^2, \beta) = F_2^{D(3),LL(1/\beta)}(x, Q^2)\, \frac{F_2^{GBW}(x, Q^2, \beta)}{F_2^{GBW}(x, Q^2, \beta = 0)}$$

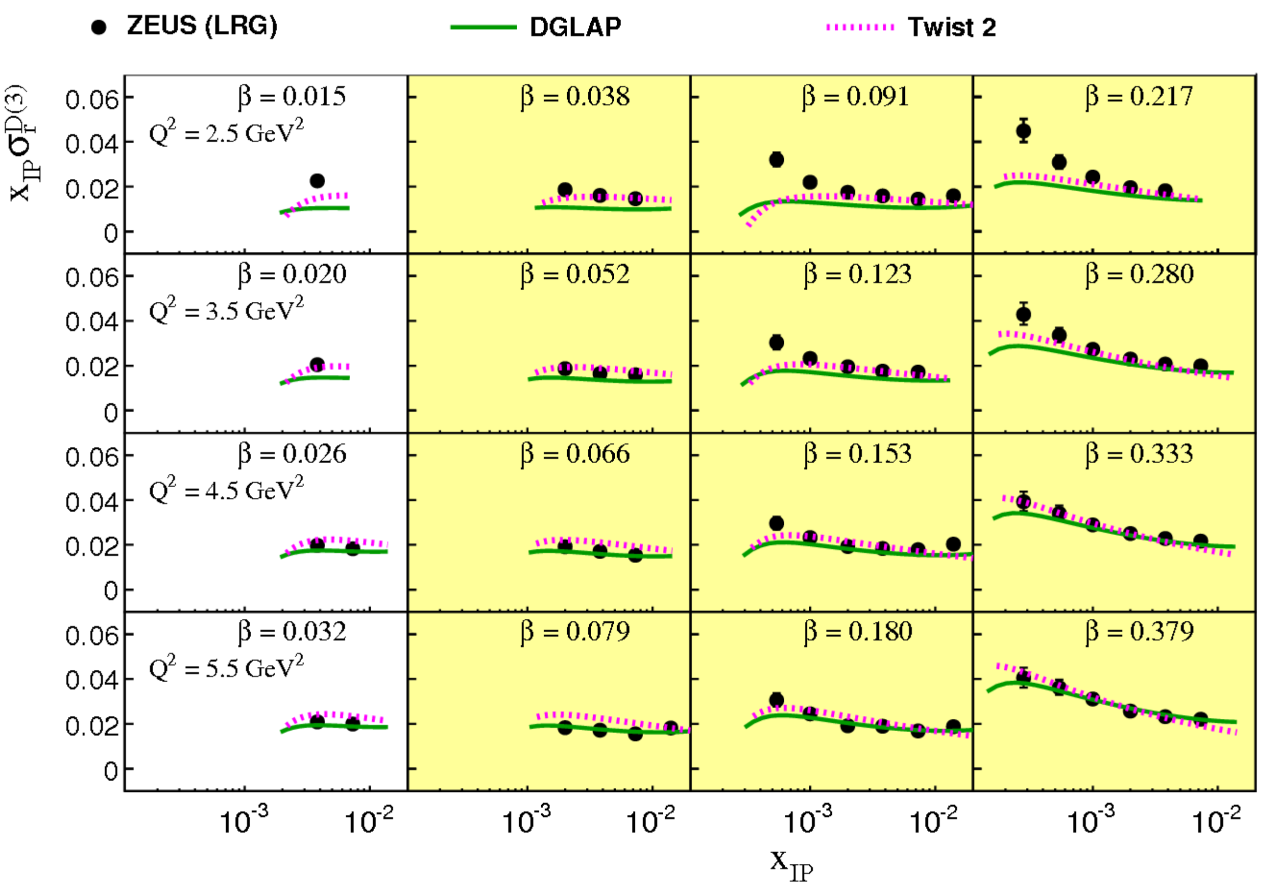
- In the gluonic term, “x” gluon is rescaled by a factor of 2 – in inclusive case “x” gluon is given the threshold value

# Improving DGLAP: DGLAP vs the data



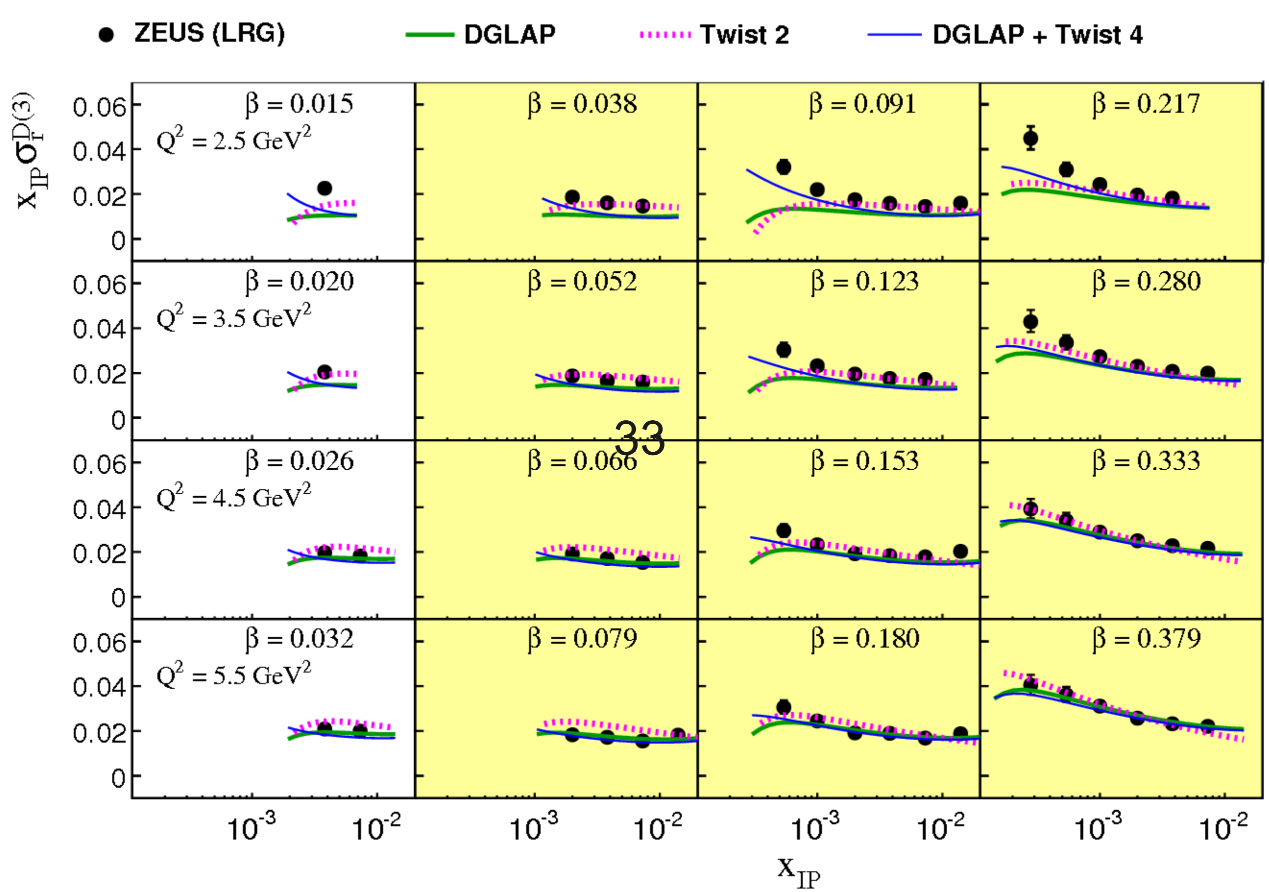

- **Crucial bins of low $Q^2$**
- **Low ß region – expected contributions from 2 gluon emissions from the dipole**

# Data vs DGLAP and twist-2 from GBW




**Satisfactory consistence of twist-2 SAT model and NLO DGLAP – still far from data**

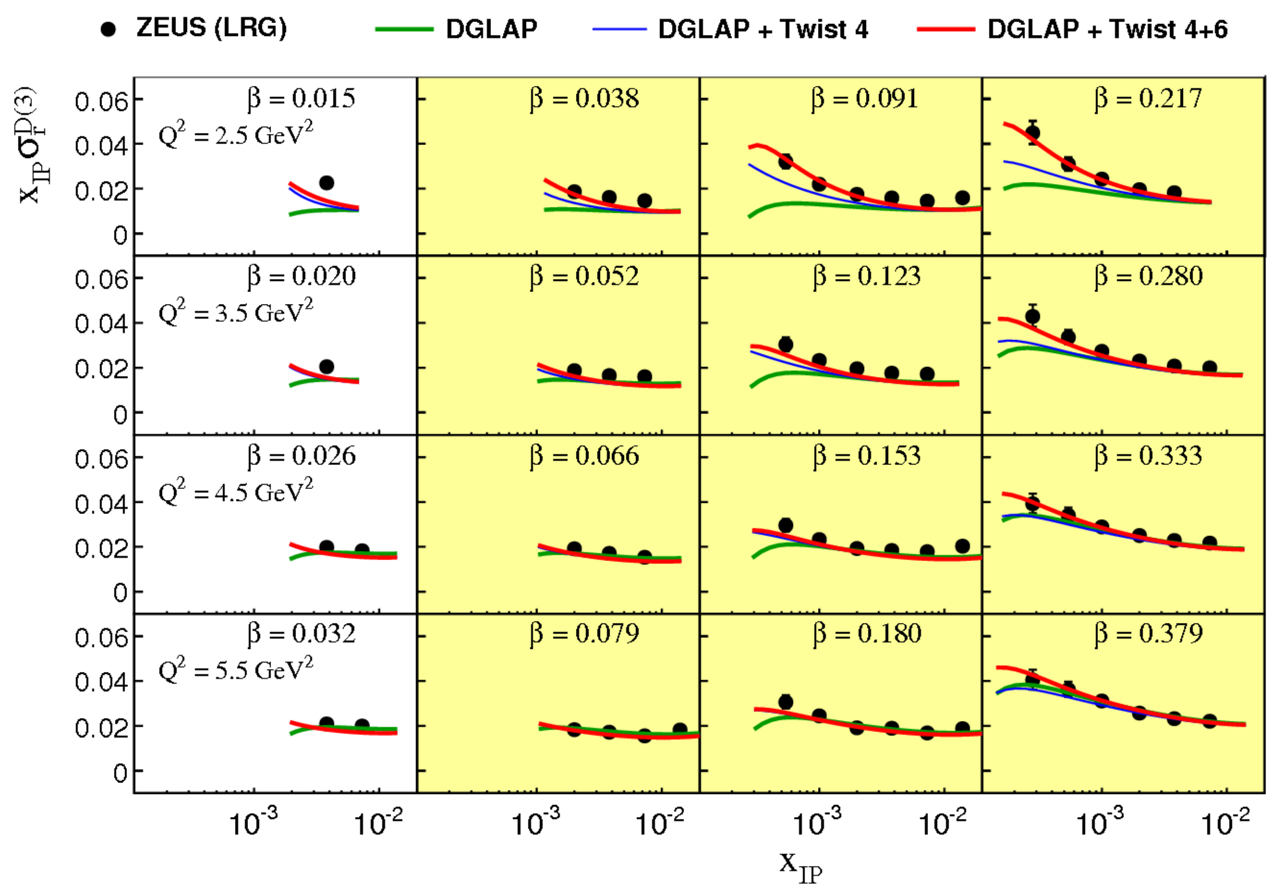
# Data vs DGLAP + twist 4




Inclusion of twist-4:correct sign of the correction but too weak effect

**Curious: emergence of twist-4 contribution correlated with data deviation from DGLAP!**

# Data vs DGLAP + twist 4 + twist 6




**Inclusion of twist 4 and 6 – accurate description of data!'**

**Notice that the steep $Q^2$ dependence of the (data – DGLAP) deviation is $1/Q^2 \sim 1/Q^4$ is very difficult to explain without higher twists**

**Warning: inclusion of all twists: below DGLAP + twist 4, but...**

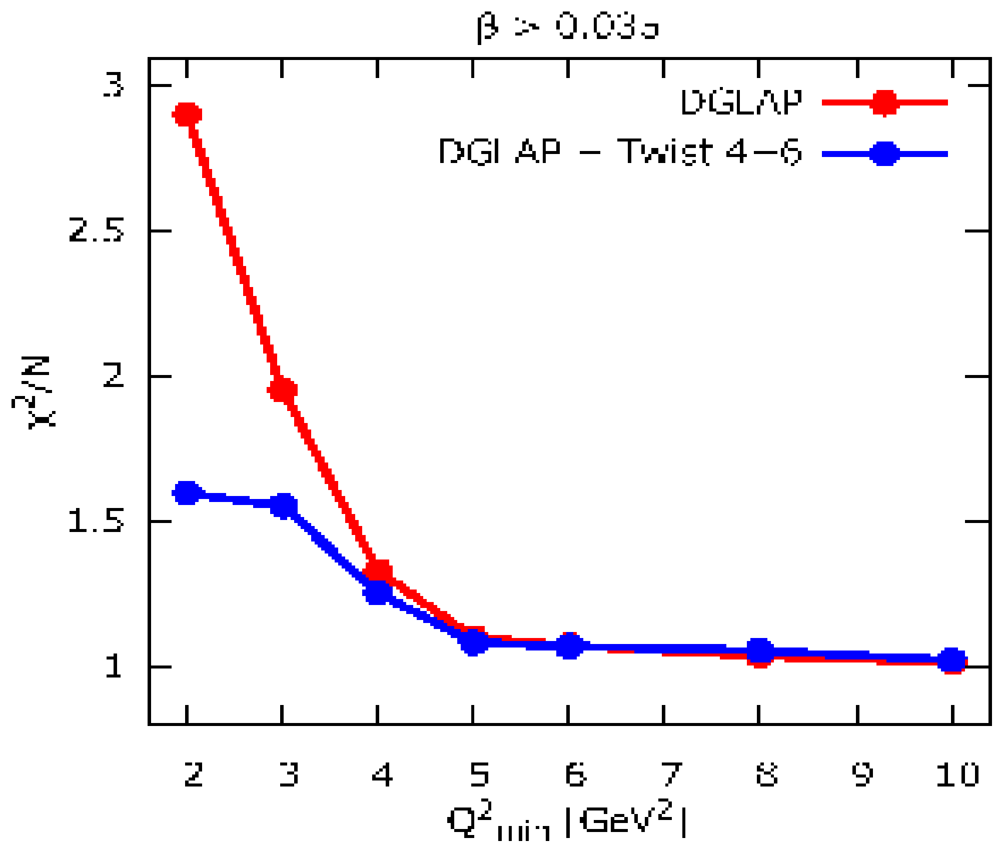
# Statistical significance

Procedure:

**1) Take data with $Q^2 > Q^2_{min}$**

2) Fit with DGLAP,
calculate chi2

3) Fith with DGLAP and
free alpha_s in higher twist
terms and calculate chi2




Fit with higher twists gives much better description but still not perfect

"+" higher twist description strongly constrained

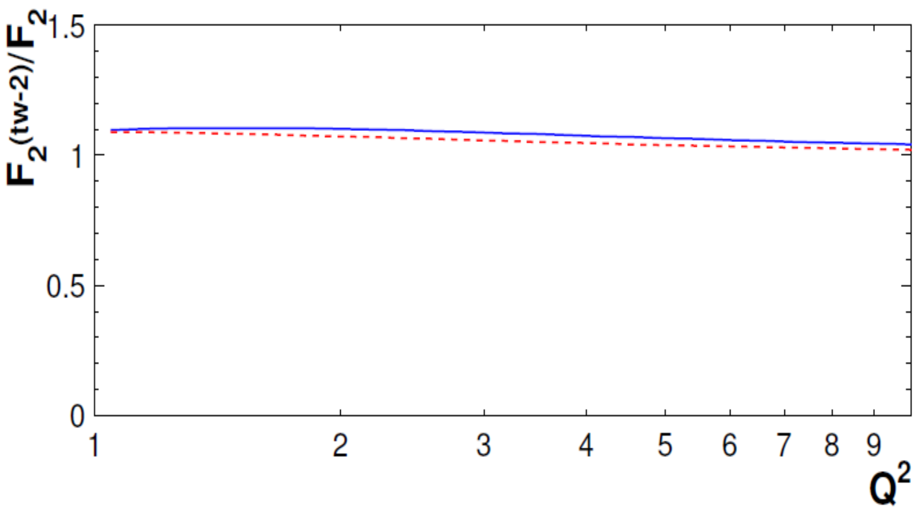
"-" arbitrary cut-off f the twist series

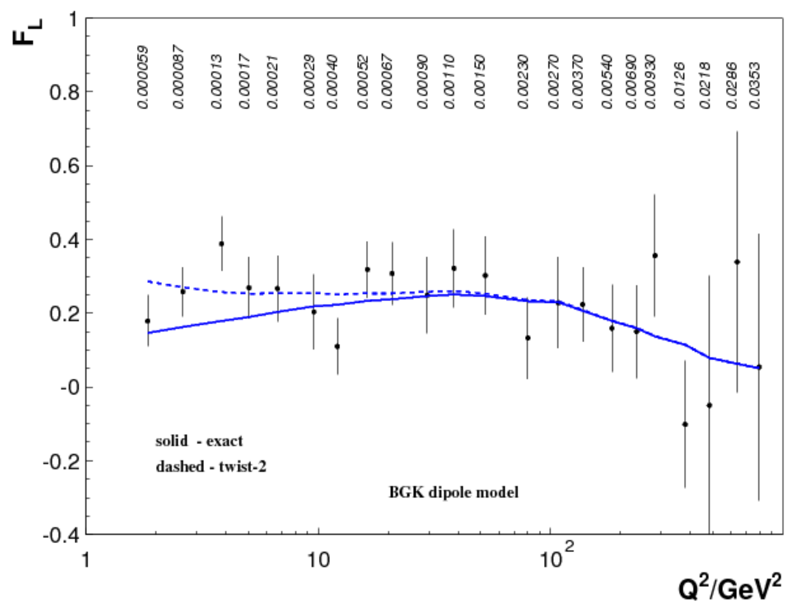
# What do we know about higher twists in SAT model?

## Inclusive DIS

**F2** - strong cancellations,
1% effect of higher twists

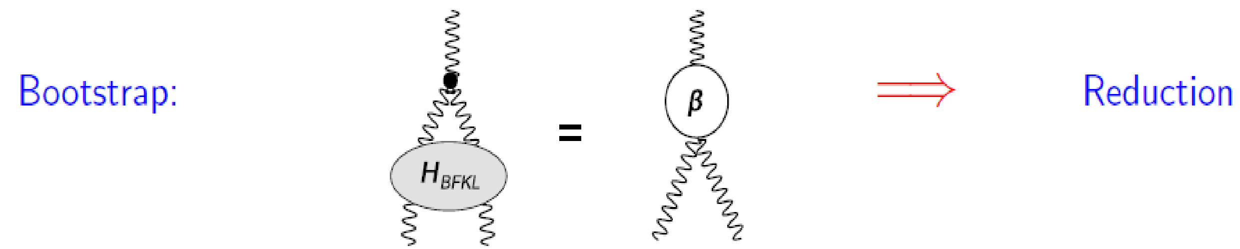
**FL –** up to O(40%) effects of higher twists – still not sufficient to provide good constraints

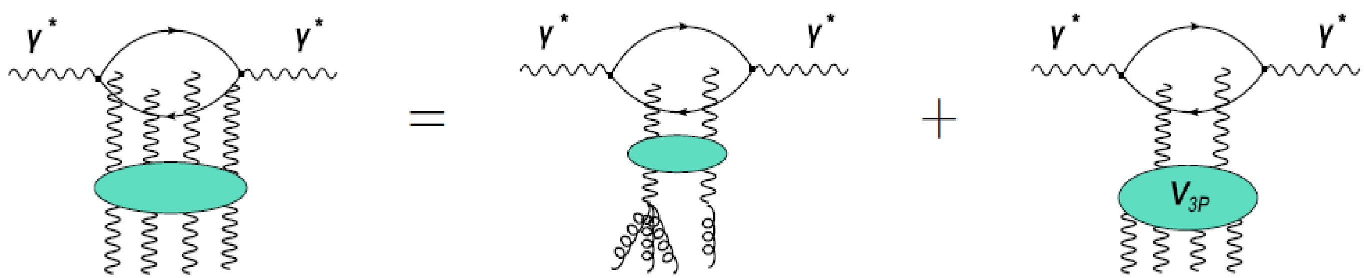



**Inclusive data leave a lot of freedom for higher twists**

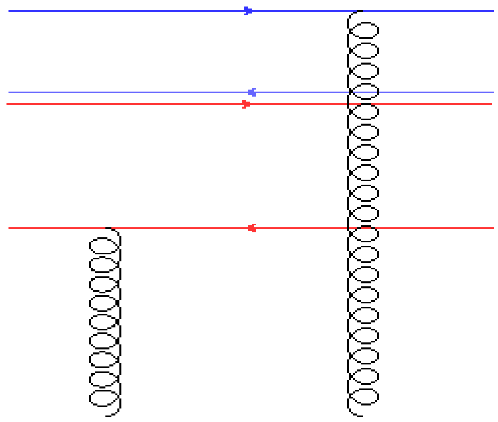
# Theoretical constraints on higher twists

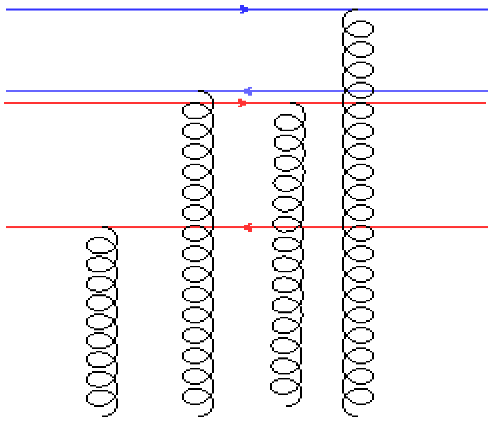



- BFKL bootstrap (LL) → only one (reggeized) gluon couples to one fundamental (quark) line
- Common double logarithmic limit of BFKL nad DGLAP evolutions → eikonal multi-gluon coupling is unrealistic → cut off of some higher twists

# Example of limitations on (much) higher twists





GBW coupling with gluon emission on the amplitude level: up to two gluons → twist 2 + twist 4 in diffractive cross section (consistent with our approach)

Possible gluon configuration in the amplitude consistent with the boostrap constraint on leading contributions. Sizable coupling pp to twist 8?

# Conclusions

- We claim that HERA data are consistent with discovery of strong (up to about 100%) positive higher twist effects in diffractive DIS at, and below 5 $GeV^2$
- The main evidence: a strong, significant, systematic deviation of DDIS data from DGLAP fits at small x and $Q^2$ with a distinct $Q^2$ and x dependence
- The saturation model predicts correctly the $(x,Q^2)$ DGLAP breakdown line due to emergence of higher twists
- The sat uration model provides good description of data when the twist series is cut-off at twist-6 that is theoretically reasonable
- There may be several important implications: experimental and theoretical exploration of higher twists may be now possible


Thank You!