Analysis of higher twists in DIS and diffractive DIS at HERA and its implications for the saturation model

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Plan: synthetic conclusions from Higher Twist analyses

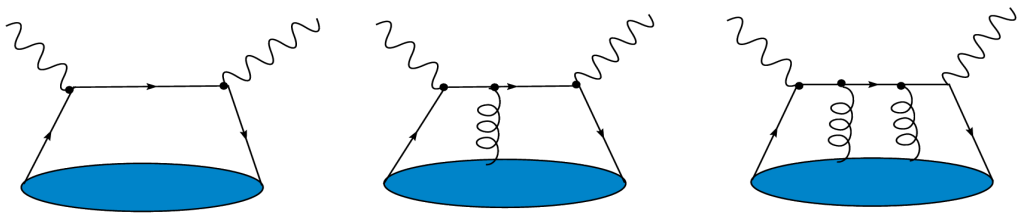
- Higher Twists - why?
- Multiple scattering: saturation models
- What data tell
- Theoretical analysis
- Conclusions for HTs and saturation models

Main results obtained with Jochen Bartels, Krzysztof Golec-Biernat (2009), Mariusz Sadzikowski and Wojtek Słomiński (2012)

OPE, twists and DGLAP in high energy scattering

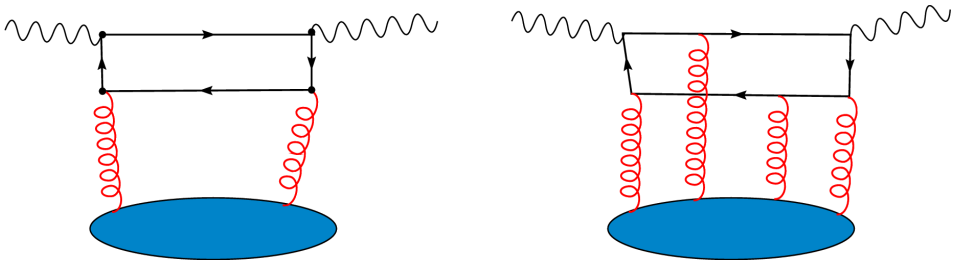
- The basis of QCD description of hard scattering: short distance expansion (OPE)

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



- Leading contribution: twist 2 – single scattering and universal parton densities

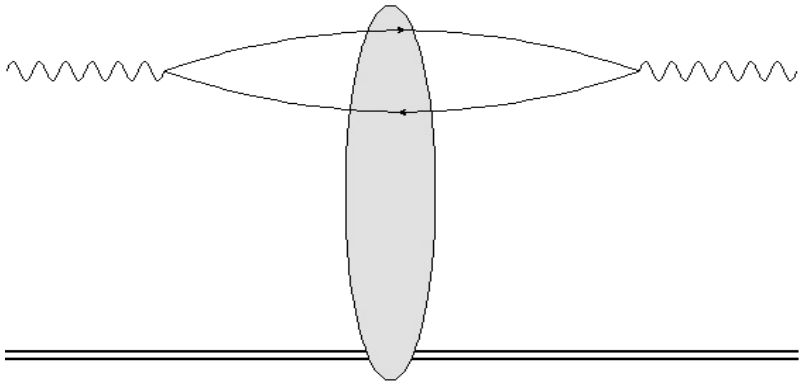
- Leading higher twist operators – multiple parton densities – enhanced at large energies (small x)



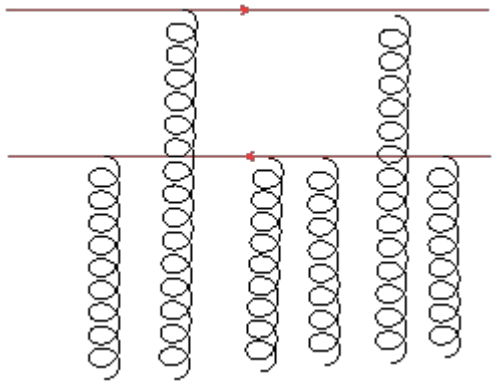
Gluons: $$\frac{\text{Twist 4}}{\text{Twist 2}} \sim \frac{1}{Q^2 R^2} \exp\left(\sqrt{b \log(Q^2) \log(1/x)}\right)$$

Beyond DGLAP: eikonal GBW saturation model

Inclusive scattering: large energy factorisation + eikonal colour dipole scattering



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

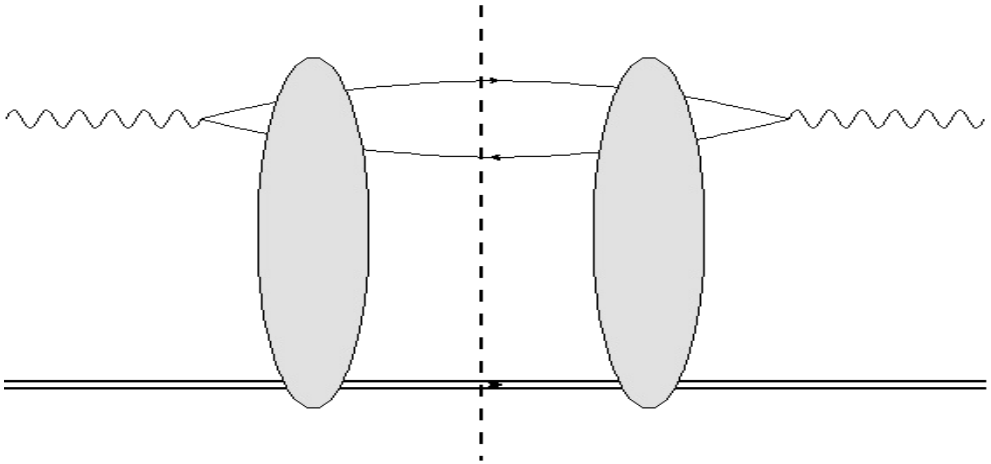


$$\sigma(x, r^2) = \sigma_0 \left[1 - \exp(-Q_0^2 r^2 x^{-\lambda})\right]$$

Diffraction: quark-dipole contribution

Quark-box: 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

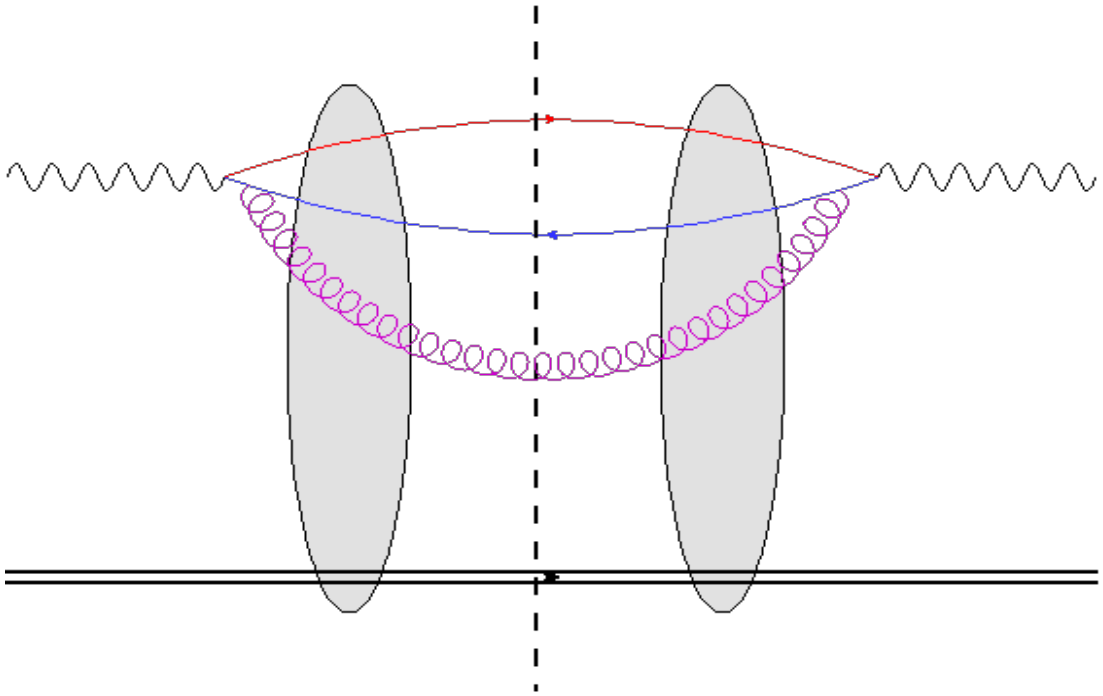


$$\sigma^{diff} \sim \int d^2r\, dz\, |\Psi(z, Q^2 r^2)|^2\, \sigma_d^2(x, r^2)$$

Quark-anti quark – gluon contribution

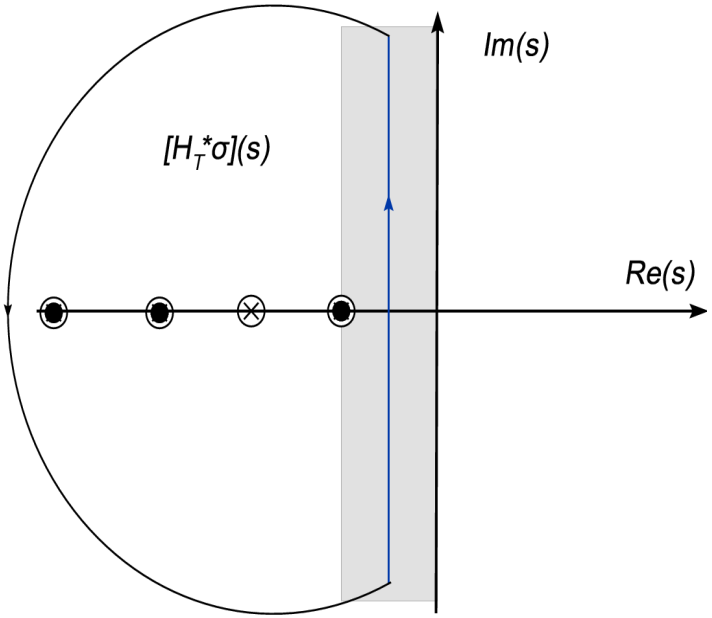
Effectively (large N limit) – two dipoles

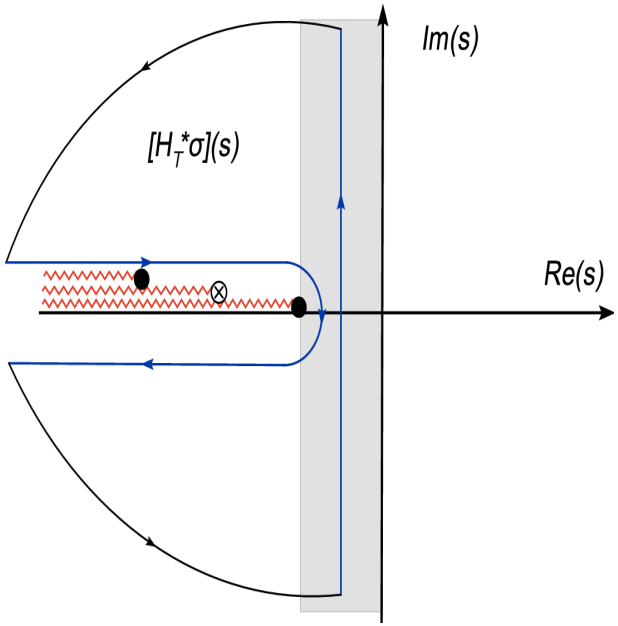
Subleading in the strong coupling constant, but enhanced due to the dipole size – important at smaller ß – carries dominant higher twist contributions



Higher twist extraction from saturation model

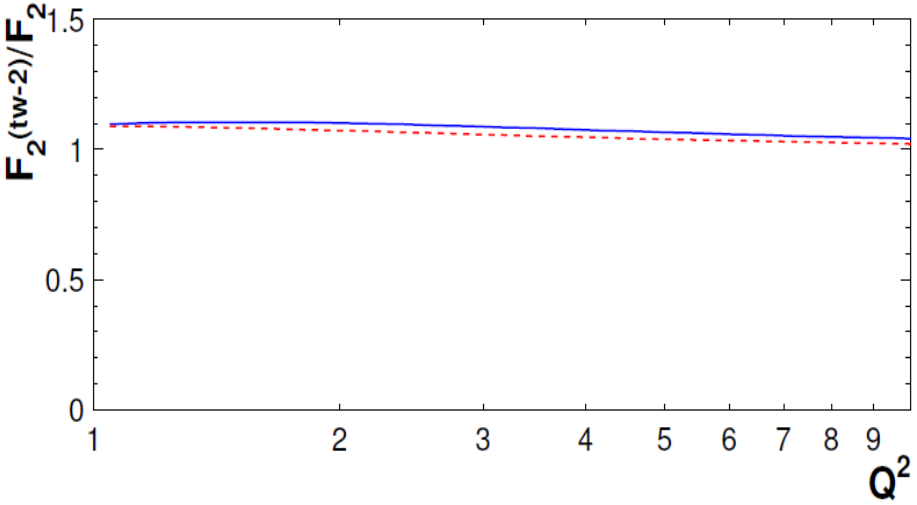
Method: Mellin space and extraction of singularities (poles, cuts). Contributions from photon splitting and exchanged ladders – in accordance with QCD



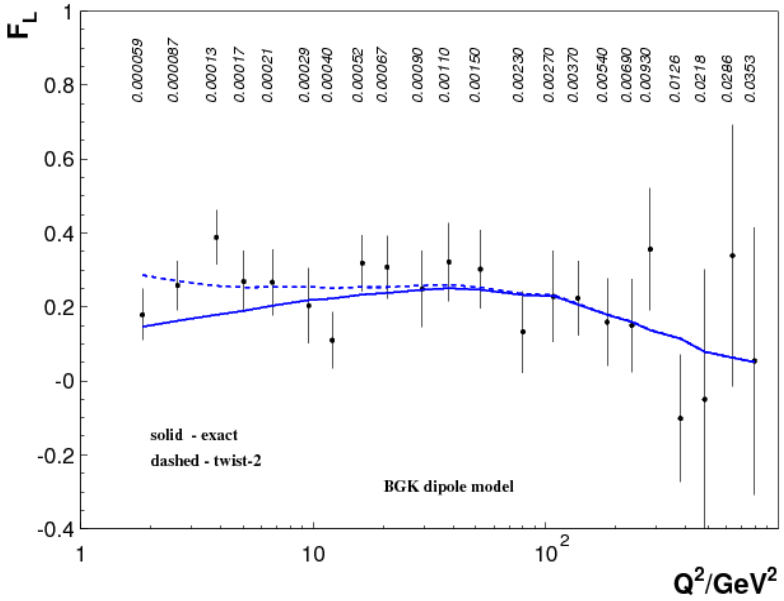


Higher twists in GBW model – inclusive DIS

F2 - strong cancellations: a striking result! 1% effect of higher twists

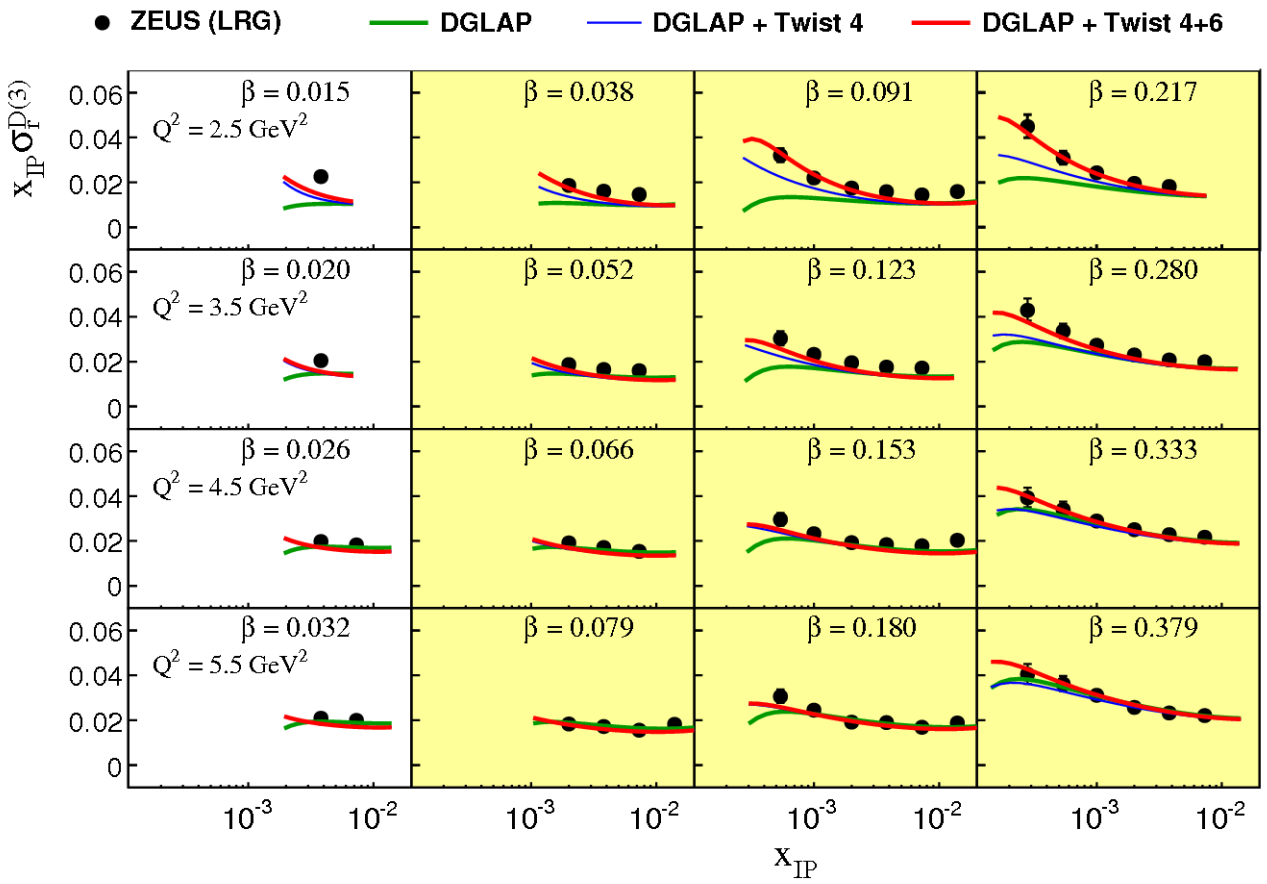


FL – up to O(40%) effects of higher twists – still not sufficient to provide good constraints



Inclusive data leave a lot of freedom for higher twists

DDIS with DGLAP + twist 4 and 6 from saturation model



Inclusion of twist 4 and 6 – essential to describe the data!

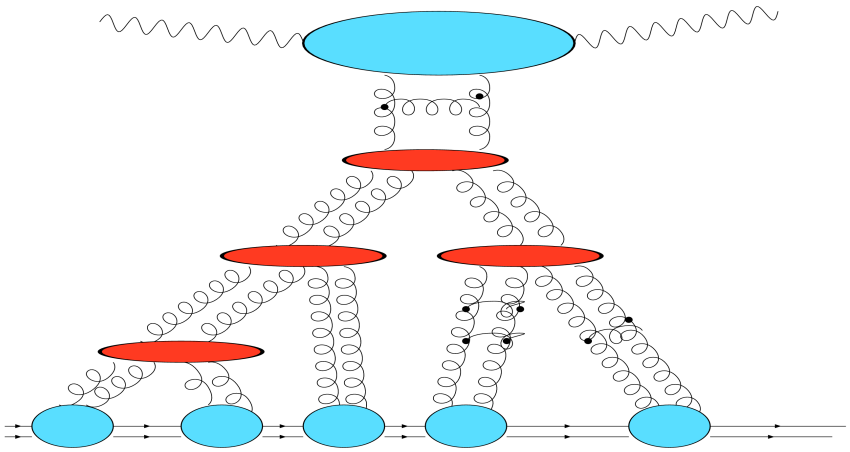
Problem: inclusion of all twists: below DGLAP + twist 4! - need for truncation of twists from the saturation model

Higher twists and multiple scattering in QCD: collinear

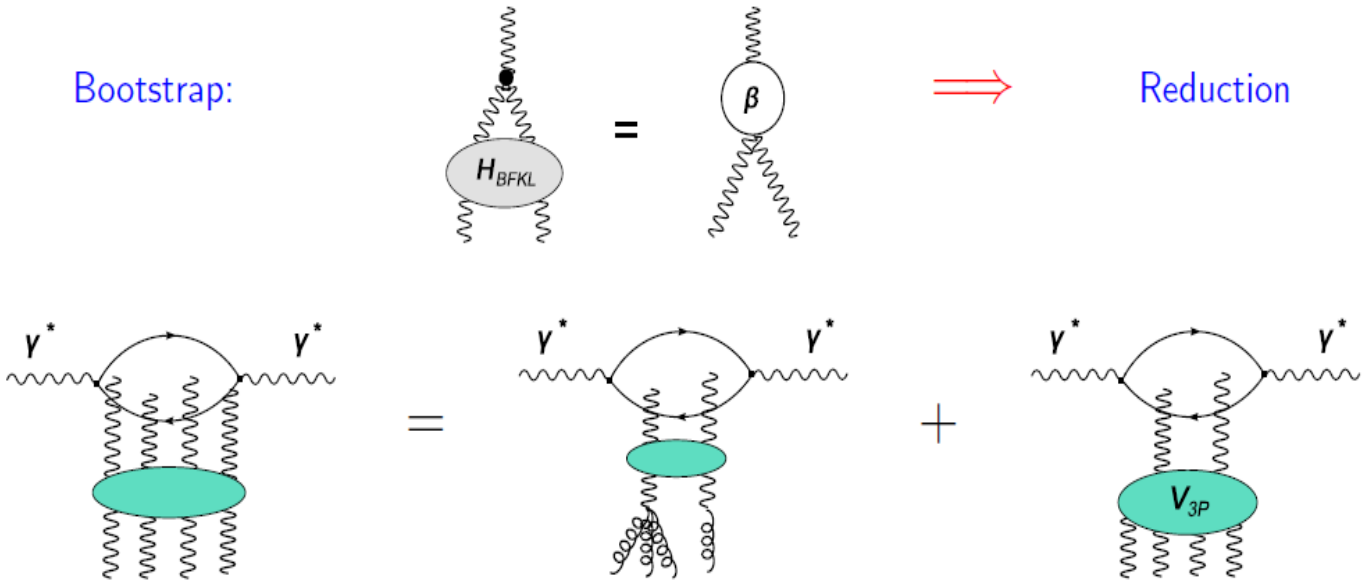
- Twist-2: DGLAP
- Twist-4 - difficult: twist-4 gluonic operators hard to treat
- Bukhvostov, Frolov, Lipatov, Kuraev (BFKL', 1985): evolution of dominant quasipartonic operators: twist = number of partons
- BFKL' evolution at LL: pair-wise interaction of t-channel partons with non-forward BFKL kernel
- Bartels, Ryskin: dominant anomalous dimension for 4 gluons in large N (1993, 2011) expansion: two singlet DGLAP ladders, with corrections from colour reconnection
- Large N limit: multiple scattering dominated by multi-DGLAP ladder exchanges

Multiple scattering with small x resummation

- The basis: Balitsky-Fadin-Kuraev-Lipatov equation: resummation of leading and next-to-leading log(1/x)
- Multi-gluon exchanges: Bartels-Kwieciński-Praszałowicz equation (pair wise BFKL interaction)
- Change of the number of t-channel gluons – possible: Bartels, Ewerz (EGLLA), Kovchegov

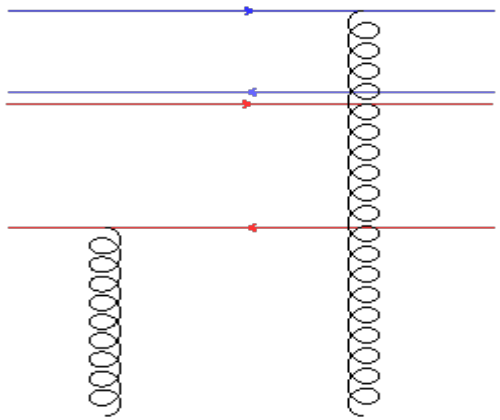


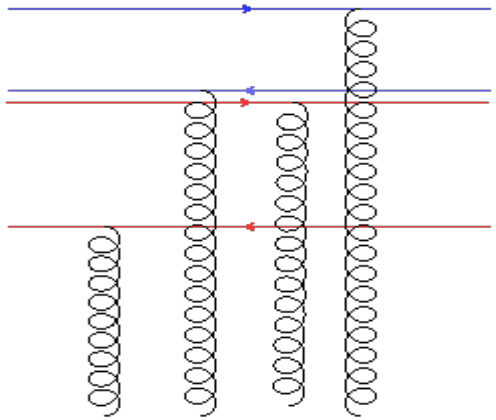
Reggeized gluons and BFKL bootstrap



- 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 in DDIS





Wusthoff (1997) coupling with gluon emission on the amplitude level: up to two gluons → twist 2 + twist 4 in diffractive cross section (twist-4 consistent with our approach)

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

Interpretation

Picture that data show:

- Extremely small higher twist effects in F2 down to low scales
- No evidence for HTs in FL
- DDIS: small effects of HTs in quark-antiquark part, large in quark-antiquark gluon component at lower scales; but: truncation of twists larger than 6 -necessary

Theory: BFKL bootstrap + common double logarithmic limit of BFKL and DGLAP – eikonal scattering not realized, one t-channel gluon per fundamental gluon line coupling: dominant (confirmed by Wusthoff calculation)

- Consistent indications of theory and data

Conclusions

- Twist decompositions of DIS and DDIS structure functions from GBW models were completed in a consistent manner
- Found: suppression of higher twists in inclusive DIS and large higher twist effect in DDIS
- FL does not tell much about higher twists
- DDIS data require truncation of eikonal series in GBW saturation model beyond twist 6
- Eikonal saturation model – not supported by theory, that suggest coupling of one t-channel gluon per one s-channel quark line
- Eikonal saturation model may and should be modified to represent better higher twist coefficient functions