Diffractive structure function F_L from the analysis with higher twist

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Cracow Epiphany Conference, January 4-6, 2007

Motivation

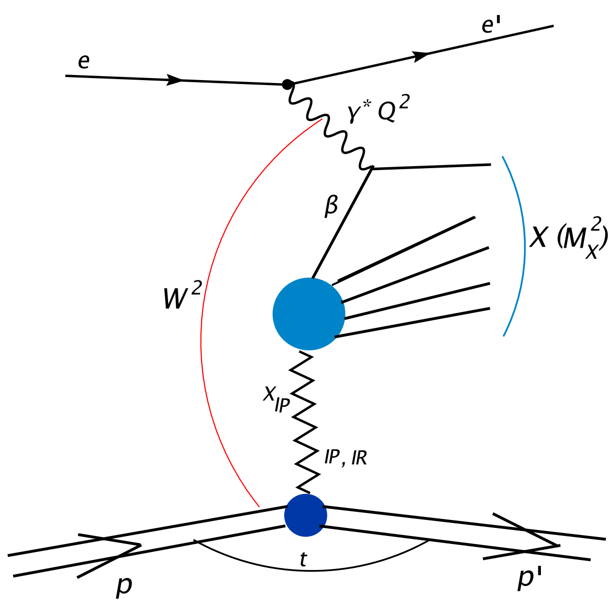
- Consistent description of diffractive structure function F_2^D measured at HERA in the analysis with higher twist-4.
- Predictions for diffractive structure function F_L^D - supposed to be measured at HERA.

OUTLINE

- Diffractive structure functions.
- Detailes of the description.
- Results of the analysis.
- Summary and outlook.

Diffractive DIS

- DIS diffractive process: $e\,p \to e\,p'X$.
- Several dimensional scales involved:
  - Q^2 photon virtuality
  - $t = (p - p')^2$ squared four momentum transfer
  - M^2 squared invariant mass of diffractive system
  - W^2 squared invariant energy of $\gamma^* p$



- Exchange of the pomeron $I\!P$ with partonic structure.
- $x_{I\!P}$: fraction of the proton momentum carried by the pomeron.
- β: fraction of the pomeron momentum carried by the struck quark.

Diffractive cross section

- The four-fold diffractive cross section is given in terms of the diffractive structure functions F_2^D and F_L^D:

$$\frac{d^4\sigma^D}{d\beta\, dQ^2\, dx_{I\!P}\, dt} = \frac{2\pi\alpha_{em}^2}{\beta\, Q^4}\left(1+(1-y)^2\right)\left\{F_2^D - \frac{y^2}{1+(1-y)^2}F_L^D\right\}.$$

- Both structure functions depend on four kinematic variables $(\beta, Q^2, x_{I\!P}, t)$ defined as follows:

$$x_{I\!P} = \frac{Q^2+M^2-t}{Q^2+W^2}\,, \qquad \beta = \frac{Q^2}{Q^2+M^2-t}\,,$$

- The diffractive structure functions are measured in a certain range of t, thus the integrated structure functions are defined:

$$F_{2,L}^{D(3)}(\beta, Q^2, x_{I\!P}) = \int_{-|t_{max}|}^{-|t_{min}|} dt\, F_{2,L}^D(\beta, Q^2, x_{I\!P}, t)\,.$$

Main idea of the analysis

- Comprehensive analysis of diffractive structure function data from HERA.
- We analyse H1 and ZEUS data sets separately (no global fit).
- Analysis with the following elements:
  - twist-2 contribution with diffractive parton distributions
  - twist-4 contribution
  - reggeon contribution
- Predictions on longitudinal structure function from this analysis.

Diffractive structure functions

- In the QCD approach DSF decomposed into twist-2 and twist-4 contributions:

$$F^D_{2,L}(x_{I\!P}, t, \beta, Q^2) \;=\; F^{D(tw2)}_{2,L} \;+\; F^{D(tw4)}_{2,L} \;+\; \ldots$$

- Twist-2 part given in terms of diffractive parton distributions (DPD):

$$F^{D(tw2)}_2 \;=\; \sum_f e_f^2\, \beta\, \{q^D_f \;+\; \overline{q}^D_f\} \;+\; \alpha_s \cdot NLL(q^D_f, g^D)$$

$$F^{D(tw2)}_L \;=\; 0 \;+\; \alpha_s \cdot NLL(q^D_f, g^D)$$

- Regge form of DPD with pomeron flux $f_{I\!P}$ and pomeron parton distributions $(I\!PPD)$

$$q^D(\beta, Q^2, x_{I\!P}, t) \;=\; f_{I\!P}(x_{I\!P}, t)\, q^{I\!P}(\beta, Q^2)\,.$$

DGLAP based fits

- $I\!\!PPD$ evolve with Q^2 through DGLAP evolution equations.
- $I\!\!PPD$ at initial scale Q_0^2 contain 6 fitted parameters

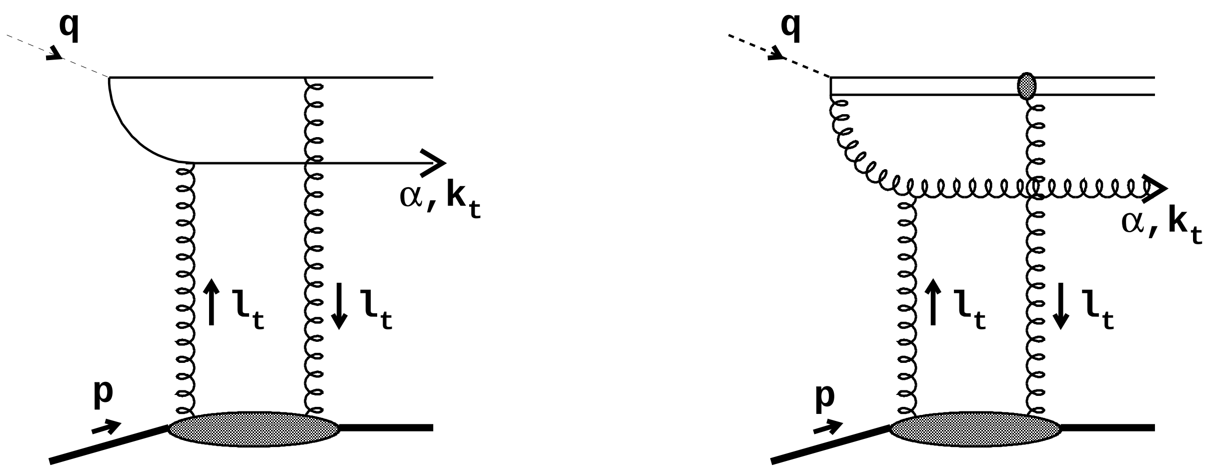
$$\Sigma^{I\!\!P}(\beta, Q_0^2) = A_S\, \beta^{B_S}\, (1-\beta)^{C_S}$$

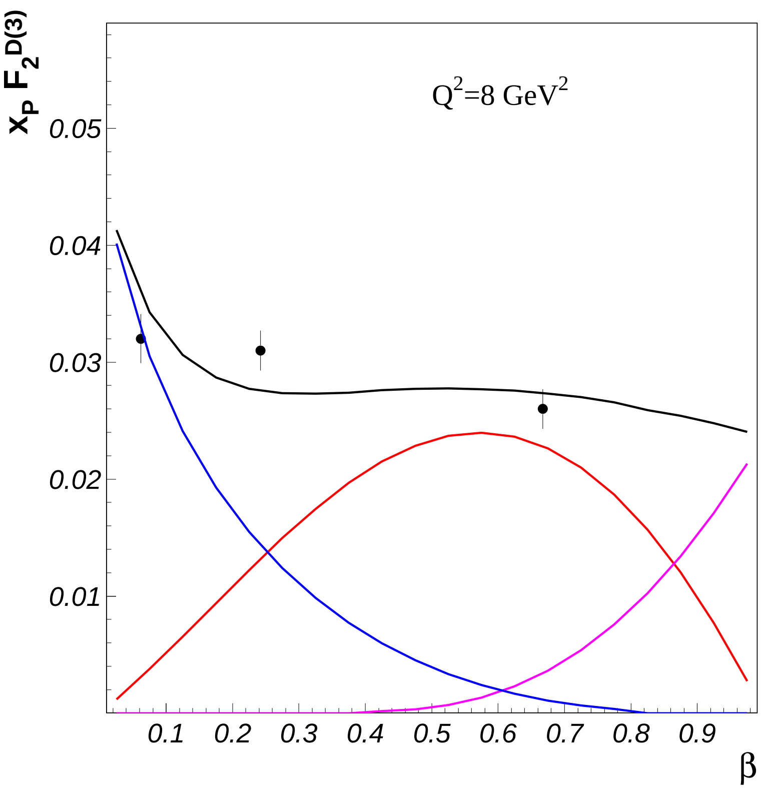
$$G^{I\!\!P}(\beta, Q_0^2) = A_G\, \beta^{B_G}\, (1-\beta)^{C_G}$$

- Pomeron intercept $\alpha_{I\!\!P}$ in pomeron flux is the 7^{th} parameter

$$f(x_{I\!\!P}) \sim x_{I\!\!P}^{1-2\alpha_{I\!\!P}}$$

Twist-4 contribution





- Three contributions to F_2^D
- $F_2^D = F_{q\bar{q}}^T + F_{q\bar{q}g}^T + F_{q\bar{q}}^L$
- Twist-4 $F_{q\bar{q}}^L \sim 1/Q^2$ dominates at $\beta \to 1$.

Summary of the contributions

- In our analysis diffractive structure functions are of the form:

$$F_2^D = F_2^{D(tw2)} + F_{Lq\bar{q}}^{D(tw4)} + F_2^{D(R)}$$

$$F_L^D = F_L^{D(tw2)} + F_{Lq\bar{q}}^{D(tw4)}$$

- $x_{I\!P}$-dependence of twist-4 contribution computed using saturation model of GBW.

- In addition, f_2 and ω reggeon exchange contributions – important for large $x_{I\!P} > 0.01$:

$$F_2^{D(R)} = f_R(x_{I\!P}, t)\,(A_R\,\beta^{-0.08})$$

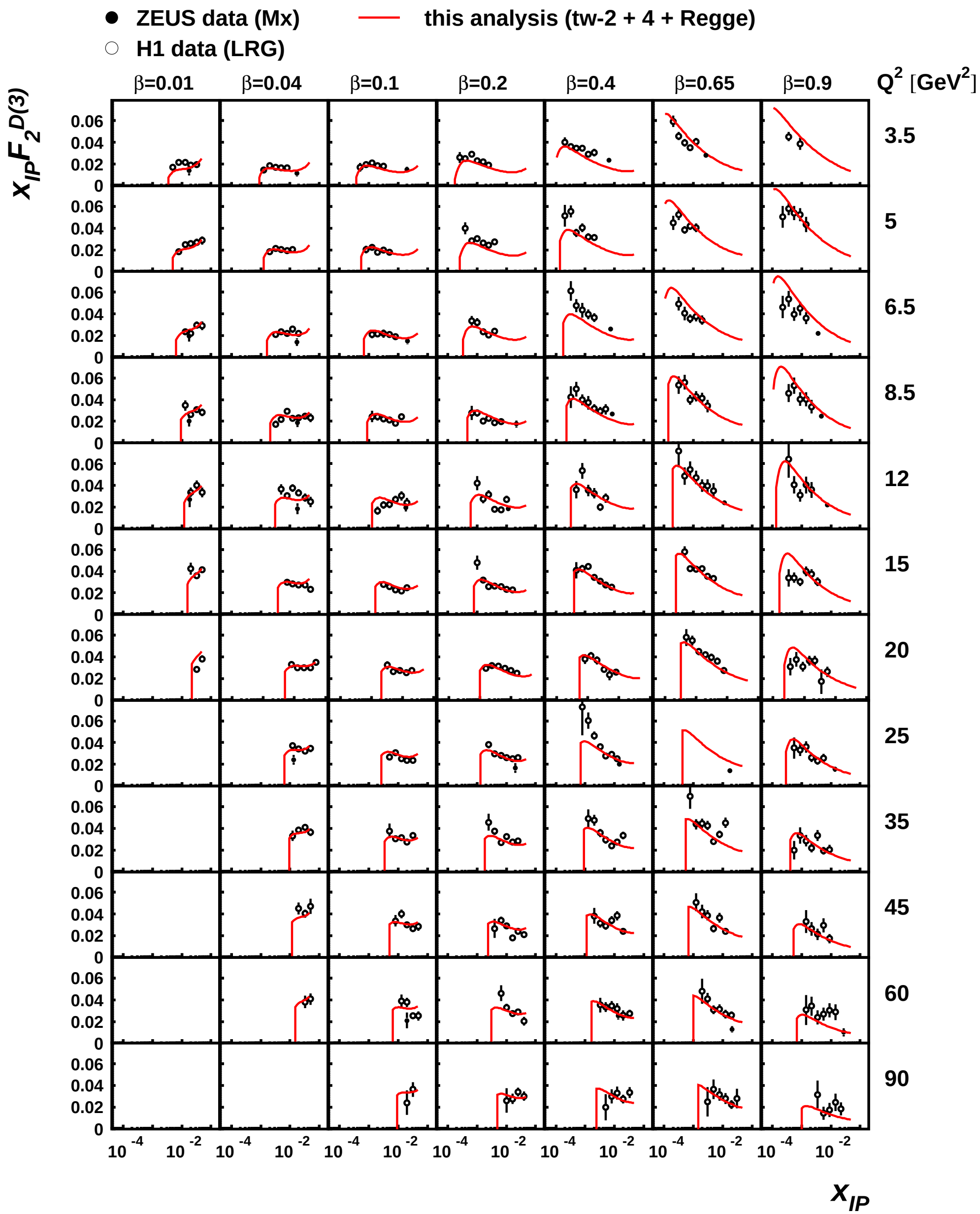
Fits to data

Collaboration	Data	t-range [GeV^2]	Q^2-range	β-range
H1 (72)	leading proton	$0.08 < \lvert t \rvert < 0.5$	$[2.0, 50]$	$[0.02, 0.7]$
H1 (276)	$M_Y < 1.6$ GeV	$\lvert t_{min} \rvert < \lvert t \rvert < 1$	$[3.5, 1600]$	$[0.0017, 0.8]$
ZEUS (80)	leading proton	$0.075 < \lvert t \rvert < 0.35$	$[2.0, 100]$	$[0.007, 0.48]$
ZEUS (198)	$M_Y < 2.3$ GeV	$\lvert t_{min} \rvert < \lvert t \rvert < \infty$	$[2.2, 80]$	$[0.003, 0.975$

- Fit results for 7 parameters

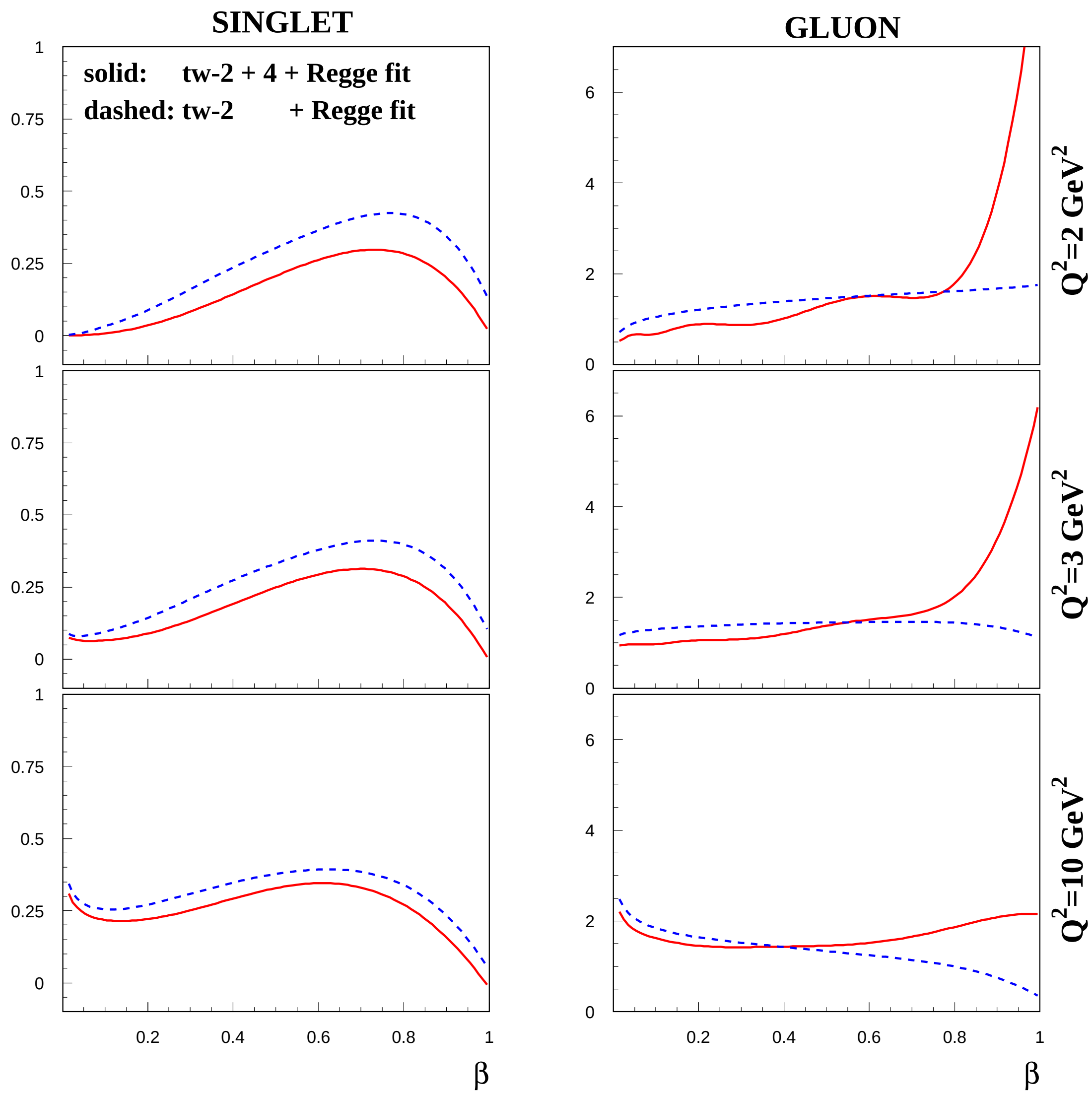
Data	Fit	$\alpha_{I\!P}$	A_S	B_S	C_S	A_G	B_G	C_G	χ^2/N
H1	tw-2	1.05	0.64	0.31	-0.43	34.6	0.62	9.23	0.60
(lp)	tw-2+4	1.04	0.64	0.23	-0.40	20.4	0.43	8.62	0.57
H1	tw-2	1.08	1.53	1.08	0.31	3.10	0.10	0.59	1.11
	tw-2+4	1.10	2.17	1.83	0.70	1.32	-0.04	-0.48	1.29
	tw-2+reg	1.13	1.31	1.60	0.49	1.66	0.20	-0.01	0.93
	2+4+reg	1.14	2.01	2.40	0.89	0.89	0.12	-0.55	1.01

Fit quality



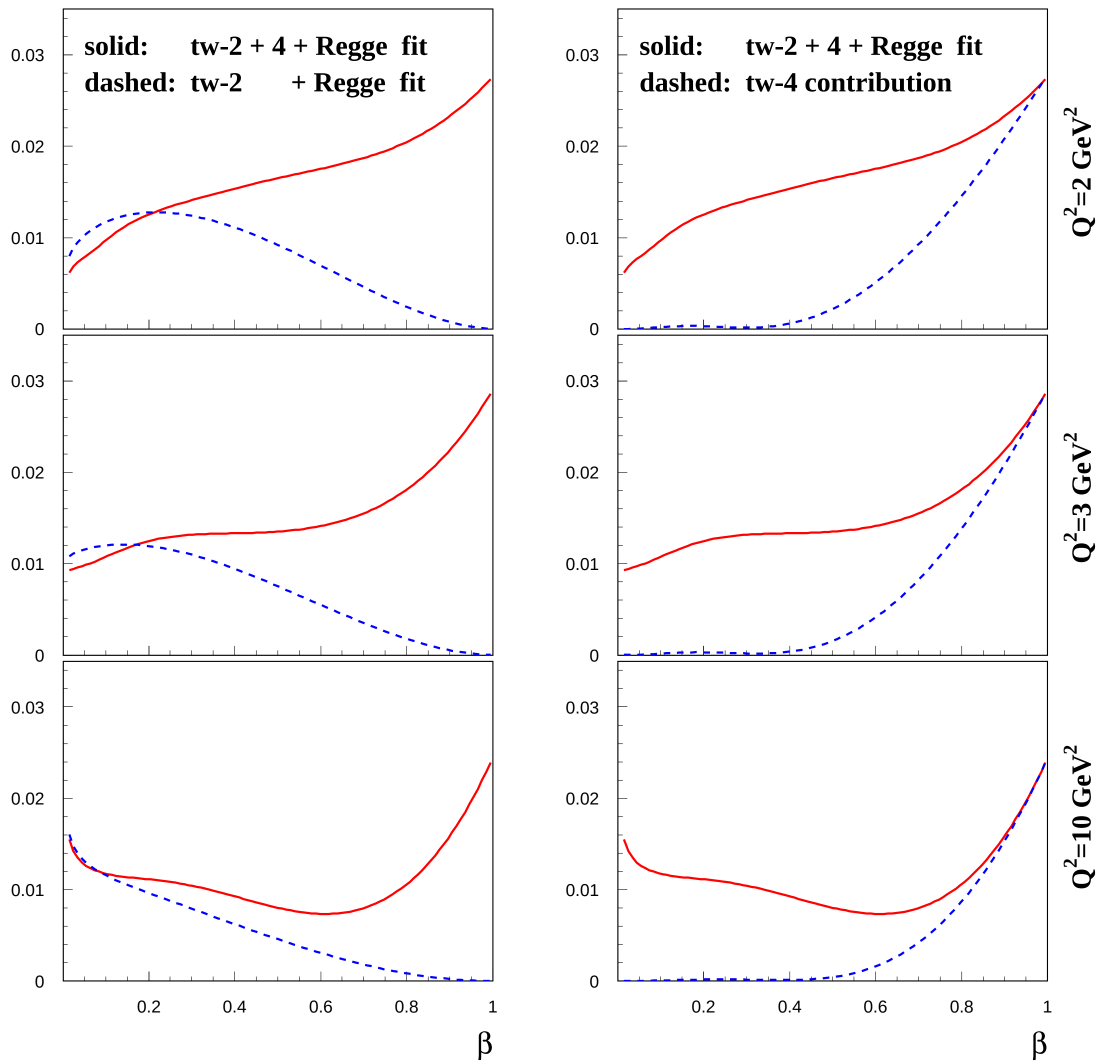
ZEUS data (Mx)
H1 data (LRG)
this analysis (tw-2 + 4 + Regge)
β=0.01
β=0.04
β=0.1
β=0.2
β=0.4
β=0.65
β=0.9
Q² [GeV²]
3.5
5
6.5
8.5
12
15
20
25
35
45
60
90
$x_{IP}F_2^{D(3)}$
0.06
0.04
0.02
0
10^{-4}
10^{-2}
x_{IP}

Diffractive PD from fits



- Large impact of twist-4 fit on gluon distribution for $\beta \rightarrow 1$.

Predictions for diffractive F_L



- Large impact of twist-4 analysis on predictions for F_L^D.

Summary and outlook

- Twist-4 is important in data description for $\beta > 0.7$.
- Twist-4 strongly influences gluon distribution at $\beta \to 1$
- F_L with twist-4 contribution is significantly different from F_L with twist-2 only in the region of $\beta > 0.4$.
- Regge contribution improves fit quality through better $x_{I\!P}$-shape.
- Outlook: ZEUS data analysis.

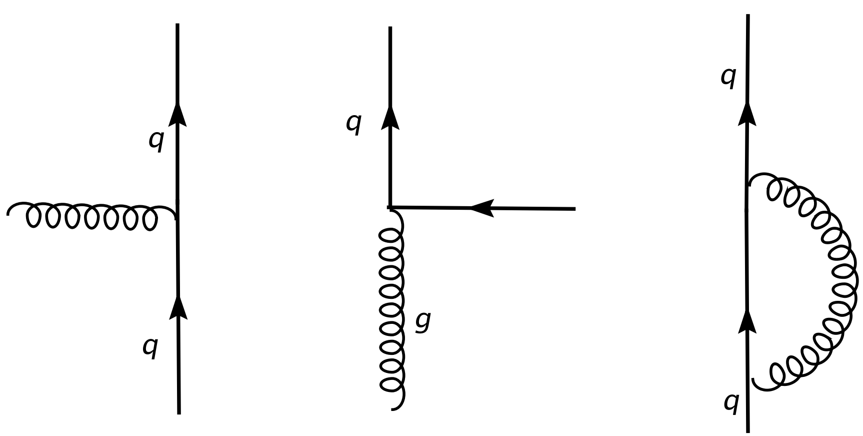
Why gluon is large ?

- Pomeron exchange carries vacuum quantum numbers

$$q_f^{I\!P}(\beta,Q^2) = \bar{q}_f^{I\!P}(\beta,Q^2) = \frac{1}{N_f}\Sigma^{I\!P}(\beta,Q^2)\,,$$

- $\Sigma^{I\!P}(\beta,Q^2)$ - is singlet quark distribution

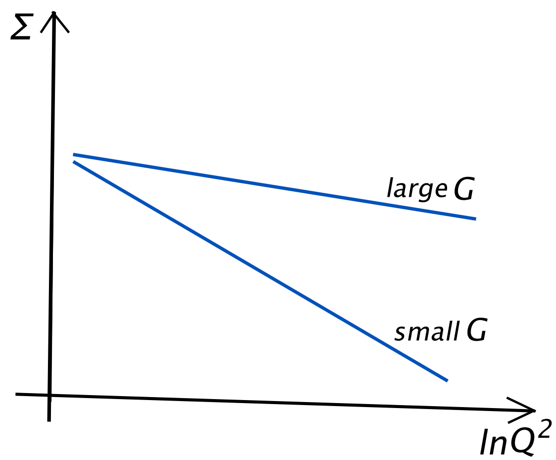
- $\frac{d\Sigma}{d ln Q^2}$ = $\int P_{qq}\,\Sigma$ + $\int P_{qg}\,G$ - $\Sigma \int P_{qq}$



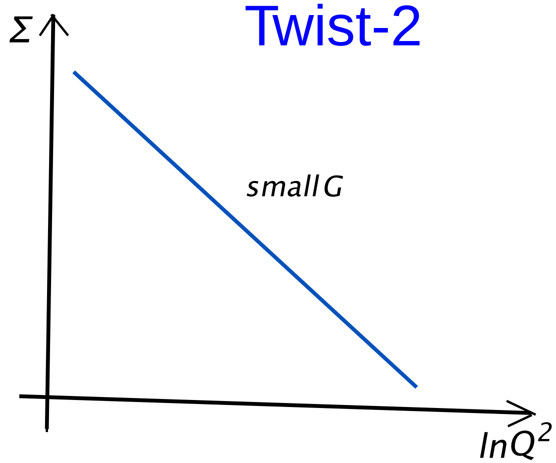
- $\Sigma \int P_{qq}$ - describes virtual contribution

Answer from our fits

- We fix β(diffractive analogue of Bjorken variable) in $\Sigma^{I\!P}(\beta, Q^2)$

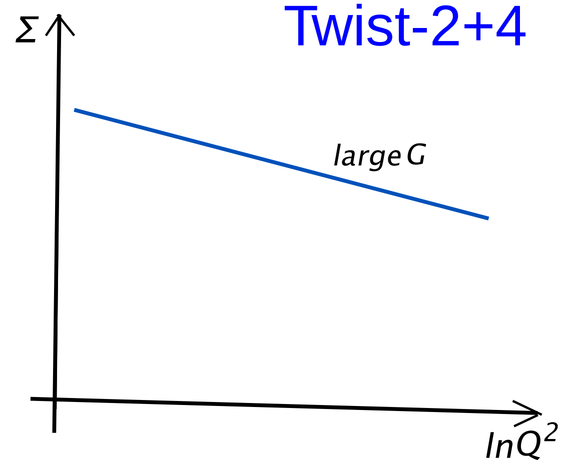


Twist-2



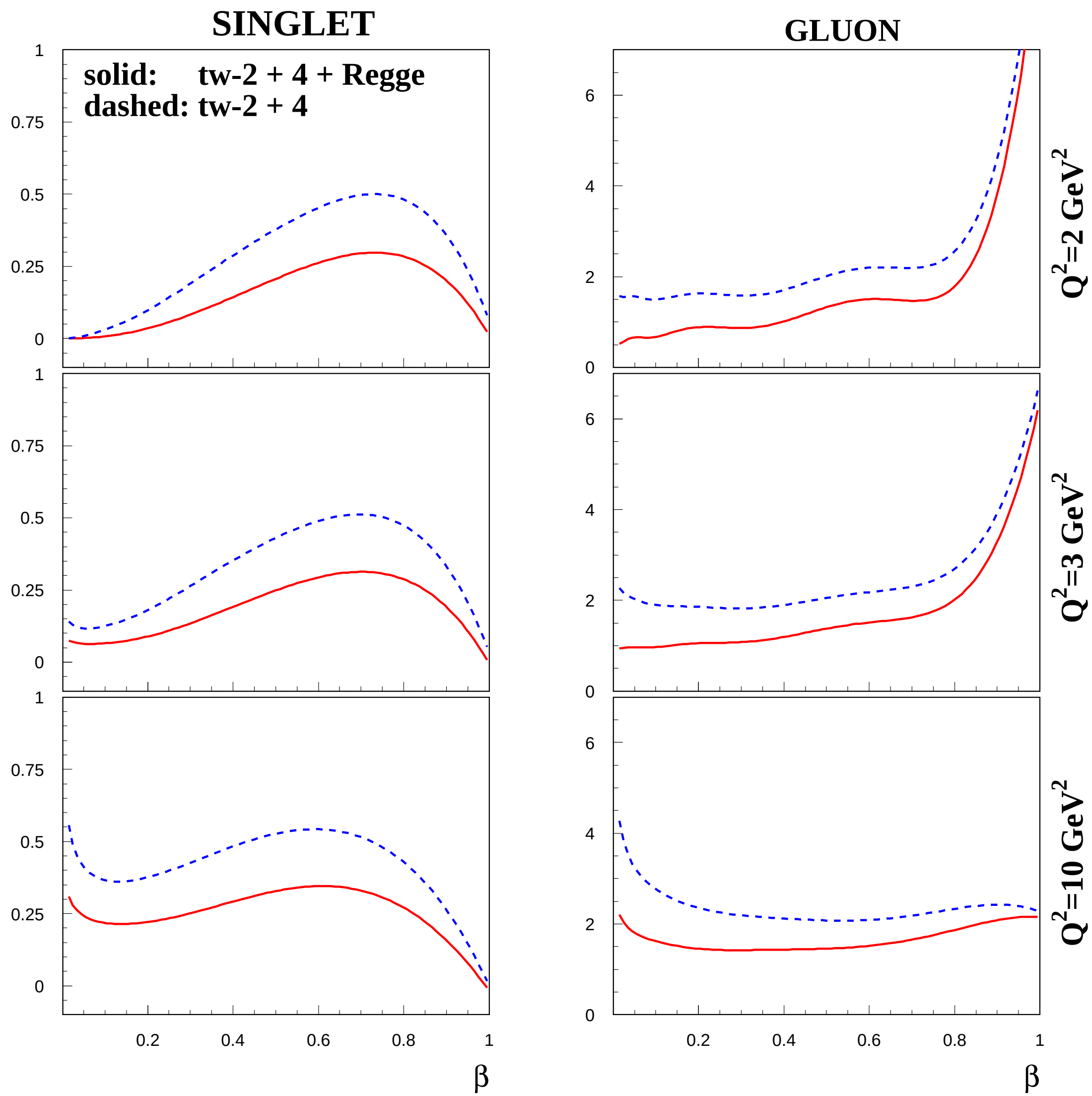
$$F_2^{exp} = F_2^{tw2} \sim \Sigma$$

Twist-2+4



$$F_2^{exp} - F_2^{tw4} \cong F_2^{tw2} \sim \Sigma$$

How important is Regge term ?



- Changes DPD up to 50%.