Diffractive parton distribution functions considering higher twist corrections

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   - Twist-4 correction
   - Reggeon contribution

2. Diffractive PDFs extraction
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   - Experimental data
   - Our tools for calculation

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Diffractive process

A significant fraction (around 10%) of deep inelastic scattering (DIS) events observed at HERA at small x are diffractive events

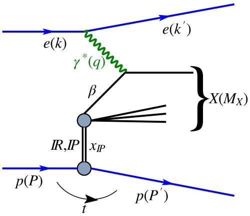


Figure: Diagram for diffractive DIS $ep \to epX$

$$\beta = \frac{Q^2}{2(P-P')\cdot q}, \quad x_{IP} = \frac{x}{\beta}, \tag{1}$$

Diffractive DIS variables

The reduced cross section is given in term of diffractive structure function

$$\sigma_r^{D(3)}(\beta, Q^2; x_{IP}) = F_2^{D(3)}(\beta, Q^2; x_{IP}) - \frac{y^2}{1+(1-y)^2} F_L^{D(3)}(\beta, Q^2; x_{IP}). \quad (2)$$

The diffractive structure functions can be written as a convolution of the diffractive PDFs and the hard scattering coefficient functions:

$$F_{2/L}^{D(4)}(\beta, Q^2; x_{IP}, t) = \sum_i \int_\beta^1 \frac{dz}{z} C_{2/L,i}\left(\frac{\beta}{z}\right) f_i^D(z, Q^2; x_{IP}, t), \quad (3)$$

DPDFs including Twist-4 correction

Twist-4 contribution is proportional to $1/Q^2$ and for diffractive mass $M_X \to 0$ or $\beta \to 1$ dominates over twist-2.

$$F^D_{Lq\bar{q}} = \frac{3}{16\pi^4 x_{IP}} e^{-B_D|t|} \sum_f e_f^2 \frac{\beta^3}{(1-\beta)^4} \times \int_0^{[Q^2(1-\beta)]/4\beta} dk^2 \frac{k^2/Q^2}{\sqrt{1-\frac{4\beta}{1-\beta}\frac{k^2}{Q^2}}}$$
$$\times \left(k^2 \int_0^\infty dr r K_0 \left(\sqrt{\frac{\beta}{1-\beta}} kr \right) J_0(kr) \hat{\sigma}(x_{IP}, r) \right)^2 . \qquad (4)$$

Here $\hat{\sigma}(x_{IP}, r)$ is considered to have the simple form

$$\hat{\sigma}(x_{IP}, r) = \sigma_0 \{1 - \exp(-r^2 Q_s^2/4)\}, \qquad (5)$$

where $Q_s^2 = (x_{IP}/x_0)^{-\lambda}$ and $\sigma_0 = 29$ mb, $x_0 = 4 \times 10^{-5}$, $\lambda = 0.28$.

Reggeon contribution

The diffractive data frome H1 collaboration for higher valuse of x_{IP} hints towards a contribution wich decrases with energy. The Reggeon structure function contribution can be written as bellow

$$\frac{dF_2^R}{dx_{IP}dt}(x,Q^2,x_{IP},t) = \sum_{R_i} f^{R_i}(x_{IP},t)\,F_2^R(\beta,Q^2)\,, \tag{6}$$

and

$$F_2^R(\beta,Q_0^2) = w_1\beta^{w_2}(1-\beta)^{w_3}(1+w_4\sqrt{\beta}+w_5\beta^5) \tag{7}$$

Diffractive PDFs

The DPDFs can be written as

$$f_{i/p}^{D}(\beta,Q^2;x_{IP},t) = f_{IP/p}(x_{IP},t) f_{i/IP}(\beta,Q^2) + f_{IR/p}(x_{IP},t) f_{i/IR}^{IR}(\beta,Q^2) \quad (8)$$

The parametrization for the quarks and gloun DPDFs are as follow:

$$\beta f_q(\beta,Q_0^2) = \alpha_q \beta^{\beta_q}(1-\beta)^{\gamma_q}(1+\eta_q\sqrt{\beta})$$
$$\beta f_g(\beta,Q_0^2) = \alpha_g \beta^{\beta_g}(1-\beta)^{\gamma_g}(1+\eta_g\sqrt{\beta}) \quad (9)$$

The Pomeron and Reggeon flux can be written as bellow

$$f_{IP,IR}(x_{IP},t) = A_{IP,IR}\frac{e^{B_{IP,IR}t}}{x_{IP}^{2\alpha_{IP,IR}(t)-1}}, \quad (10)$$

where $\alpha_{IP,IR}(t) = \alpha_{IP,IR}(0) + \alpha'_{IP,IR}t$.

Experimental data

In this work we ues all availble and up-to-date data sets

Experiment	Observable	$[\beta^{\min}, \beta^{\max}]$	$[x_{I\!P}{}^{\min}, x_{I\!P}{}^{\max}]$	Q^2 [GeV^2]	# of points
H1-LRG-11 $\sqrt{s} = 225$ GeV	$\sigma_r^{D(3)}$	[0.033–0.88]	$[5\times10^{-4} - 3\times10^{-3}]$	4–44	**22**
H1-LRG-11 $\sqrt{s} = 252$ GeV	$\sigma_r^{D(3)}$	[0.033–0.88]	$[5\times10^{-4} - 3\times10^{-3}]$	4–44	**21**
H1-LRG-11 $\sqrt{s} = 319$ GeV	$\sigma_r^{D(3)}$	[0.089–0.88]	$[5\times10^{-4} - 3\times10^{-3}]$	11.5–44	**14**
H1-LRG-12	$\sigma_r^{D(3)}$	[0.0017–0.80]	$[3\times10^{-4} - 3\times10^{-2}]$	3.5–1600	**277**
H1/ZEUS combined	$\sigma_r^{D(3)}$	[0.0018–0.816]	$[3\times10^{-4} - 9\times10^{-2}]$	2.5–200	**192**
Total data					**526**

In this analysis we have used xFitter which is a standard packege for performing the global analysis.

xFitter
PDF Fitting package

Initial inputs

$Q_0^2 = 1.8$ GeV^2
$m_c = 1.4$ GeV
$m_b = 4.75$ GeV

Fit Results

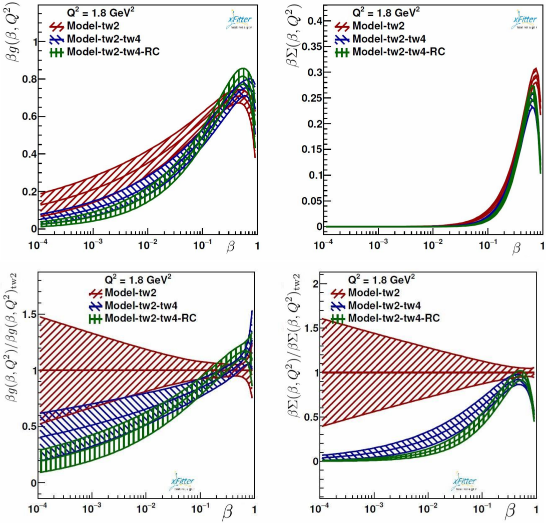
Best Fit Parameters For Three Scenarios

Parameters	SKMHS22-tw2	SKMHS22-tw2-tw4	SKMHS22-tw2-tw4-RC
α_g	1.00 ± 0.16	1.07 ± 0.17	1.43 ± 0.23
β_g	0.226 ± 0.066	0.332 ± 0.070	0.447 ± 0.070
γ_g	0.27 ± 0.15	0.19 ± 0.14	0.37 ± 0.14
η_g	0.0^*	0.0^*	0.0^*
α_q	0.305 ± 0.022	0.517 ± 0.041	0.727 ± 0.059
β_q	1.474 ± 0.069	1.887 ± 0.081	2.149 ± 0.0584
γ_q	0.509 ± 0.034	0.980 ± 0.0948	1.137 ± 0.050
η_q	0.0^*	0.0^*	0.0^*
$\alpha_{I\!P}(0)$	1.0934 ± 0.0032	1.1021 ± 0.0037	1.0965 ± 0.0037
$\alpha_{I\!R}(0)$	0.316 ± 0.053	0.400 ± 0.053	0.418 ± 0.054
$A_{I\!R}$	21.7 ± 5.7	15.0 ± 3.9	13.2 ± 3.5
w_1	0.0^*	0.0^*	0.23^*
w_2	0.0^*	0.0^*	3.79^*
w_3	0.0^*	0.0^*	14.9^*
w_4	0.0^*	0.0^*	0.0^*
w_5	0.0^*	0.0^*	0.0^*
$\alpha_s(M_Z^2)$	0.1185^*	0.1185^*	0.1185^*
m_c	1.40^*	1.40^*	1.40^*
m_b	4.75^*	4.75^*	4.75^*

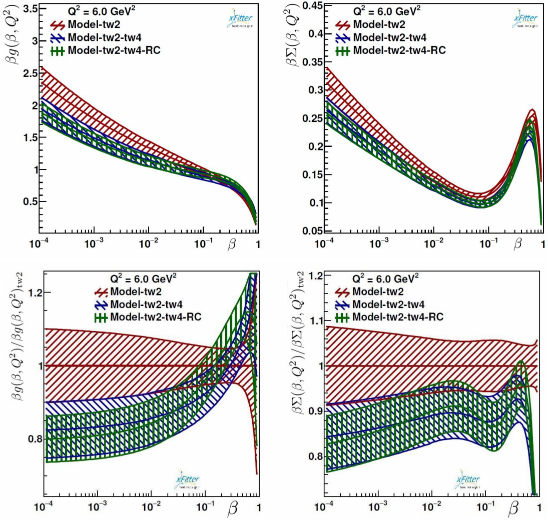
χ^2/dof for three scenarios

	SKMHS22-tw2	SKMHS22-tw2-tw4	SKMHS22-tw2-tw4-RC
Experiment	χ^2/N_{pts}	χ^2/N_{pts}	χ^2/N_{pts}
H1-LRG-11 $\sqrt{s} = 225$ GeV	11/13	11/13	12/13
H1-LRG-11 $\sqrt{s} = 252$ GeV	20/12	21/12	19/12
H1-LRG-11 $\sqrt{s} = 319$ GeV	6.6/12	3.7/12	4.6/12
H1-LRG-12	136/165	143/165	124/165
H1/ZEUS combined	129/100	124/100	125/100
Correlated χ^2	11	16	19
Log penalty χ^2	+11	+22	+15
$\chi^2/\mathbf{dof}$	$324/293 = 1.10$	$319/293 = 1.16$	$319/293 = 1.08$

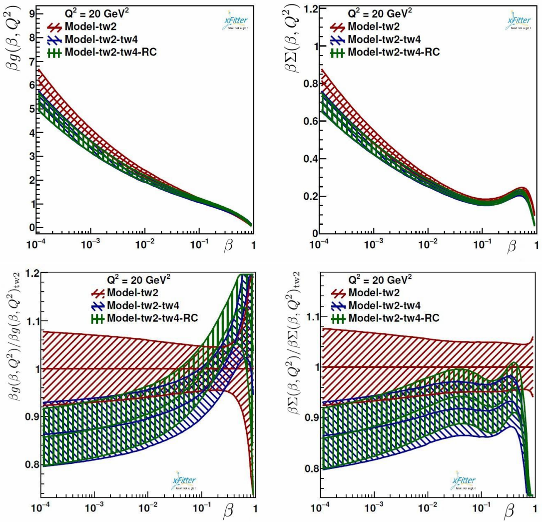
SKMHS22 Diffractive PDFs at $Q^2 = 1.8\mathrm{GeV}^2$



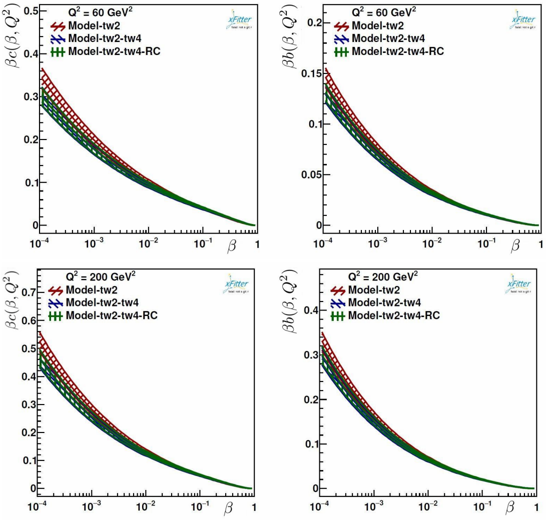
SKMHS22 Diffractive PDFs at $Q^2 = 6.0\text{GeV}^2$



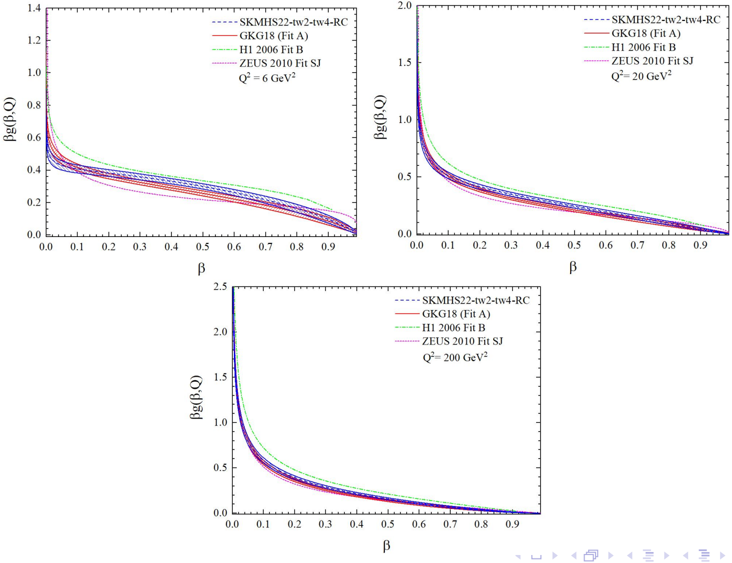
SKMHS22 Diffractive PDFs at $Q^2 = 20\text{GeV}^2$



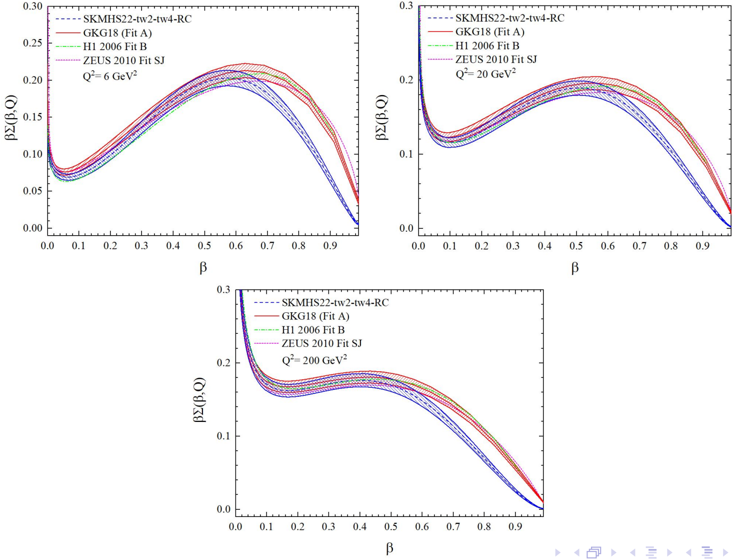
SKMHS22 Diffractive PDFs at $Q^2 = 60\text{GeV}^2$



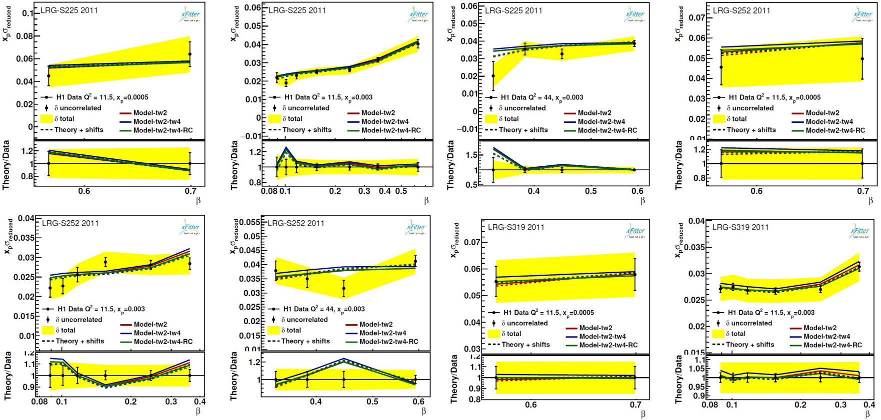
Comparison with the other groups



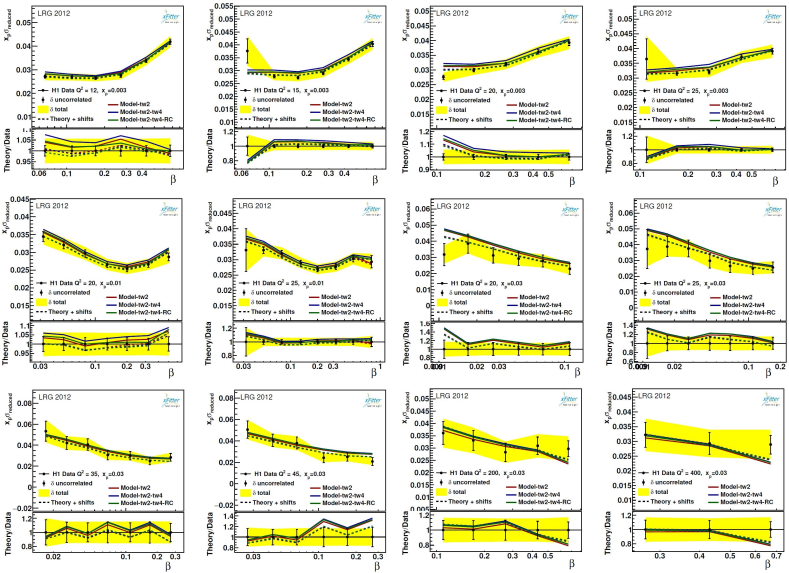
Comparison with the other groups



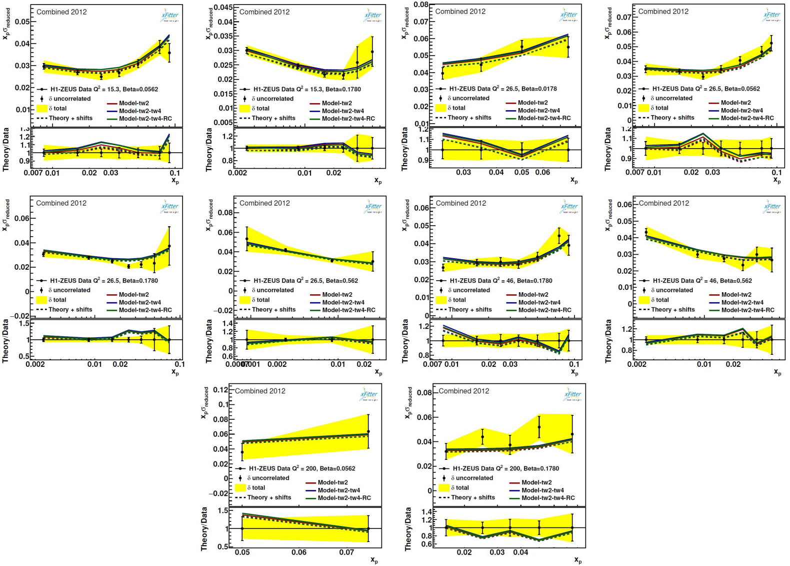
Comparison with the experimental data



Comparison with the experimental data



Comparison with the experimental data



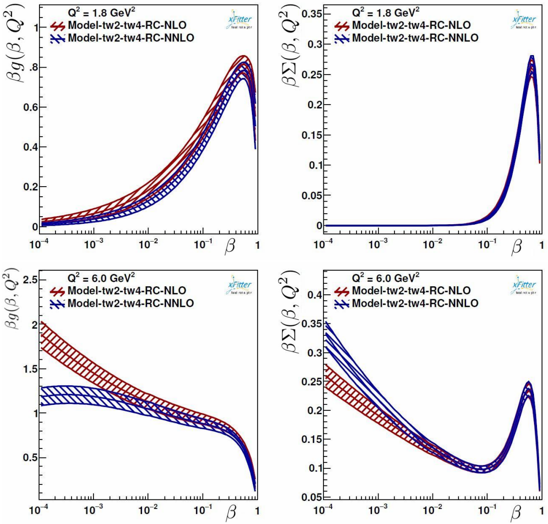
NNLO approach

Parameters	SKMHS22-tw2-tw4-RC (NLO)	SKMHS22-tw2-tw4-RC (NNLO)
α_g	1.43 ± 0.23	1.53 ± 0.24
β_g	0.447 ± 0.070	0.535 ± 0.071
γ_g	0.37 ± 0.14	0.43 ± 0.15
η_g	0.0^*	0.0^*
α_q	0.727 ± 0.059	0.785 ± 0.066
β_q	2.149 ± 0.084	2.248 ± 0.090
γ_q	1.137 ± 0.050	1.144 ± 0.051
η_q	0.0^*	0.0^*
$\alpha_{I\!P}(0)$	1.0965 ± 0.0037	1.0961 ± 0.0037
$\alpha_{I\!R}(0)$	0.418 ± 0.054	0.416 ± 0.053
$A_{I\!R}$	13.2 ± 3.5	13.4 ± 3.5
w_1	0.23^*	3.368^*
w_2	3.790^*	5.087^*
w_3	14.90^*	18.27^*
w_4	0.0^*	0.0^*
w_5	0.0^*	0.0^*
$\alpha_s(M_Z^2)$	0.1185^*	0.1185^*
m_c	1.40^*	1.40^*
m_b	4.75^*	4.75^*

NNLO approach

	SKMHS22-tw2-tw4 (NLO)	SKMHS22-tw2-tw4-RC (NNLO)
Experiment	χ^2/N_{pts}	χ^2/N_{pts}
H1-LRG-11 $\sqrt{s} = 225$ GeV	$12/13$	$12/13$
H1-LRG-11 $\sqrt{s} = 252$ GeV	$19/12$	$19/12$
H1-LRG-11 $\sqrt{s} = 319$ GeV	$4.6/12$	$5.5/12$
H1-LRG-12	$124/165$	$121/165$
H1/ZEUS combined	$125/100$	$128/100$
Correlated χ^2	19	18
Log penalty χ^2	$+15$	$+14$
$\chi^2/$**dof**	$319/293 = 1.088$	$317/293 = 1.081$

NNLO approach




Thank you