GKG18 diffractive parton distribution functions and their uncertainties in the xFitter framework

Hamzeh Khanpour
University of Science and Technology of Mazandaran and IPM

In collaboration with
Muhammad Goharipour (IPM) and Vadim Guzey (PNPI)

Diffraction and LOw-x 2018, Reggio Calabria, Italy

Ref: Eur. Phys. J. C 78 (2018) 309 [arXiv:1802.01363]

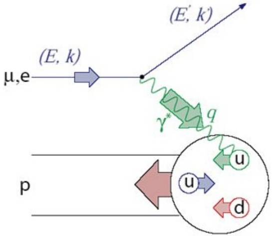
Outline

Outline ...

- Introduction
- Diffractive DIS
- QCD Global Analysis Framework
- Diffractive DIS Data Sets
- Results
- Outlook

Introduction

Deep Inelastic Scattering (DIS)



$$Q^2 = -(k-k')^2 \overset{lab}{=} 4EE'\sin^2\frac{\vartheta}{2}$$
$$P\cdot q \overset{lab}{=} M\nu = M(E-E')$$
$$P\cdot k \overset{lab}{=} ME$$

$$x \overset{lab}{=} \frac{Q^2}{2M\nu} = \frac{-q^2}{2P\cdot q}$$

$$y \overset{lab}{=} \frac{\nu}{E} = \frac{P\cdot q}{P\cdot k}$$

$$0 \leq x, y \leq 1$$

QCD Factorization Theorem

When pQCD can be applied, the factorization theorem states that the cross section of DIS process can be written as the convolution of Parton Distribution Functions (PDFs) and the hard subprocesses.

DIS Cross Section

$$\frac{d\sigma^{ep\to eX}}{dP} = \sum_f \int dx f(x,\mu^2) \times \frac{d\hat{\sigma}^{ef\to eX'}}{dP}. \quad (1)$$

Diffractive DIS

Diffractive Process

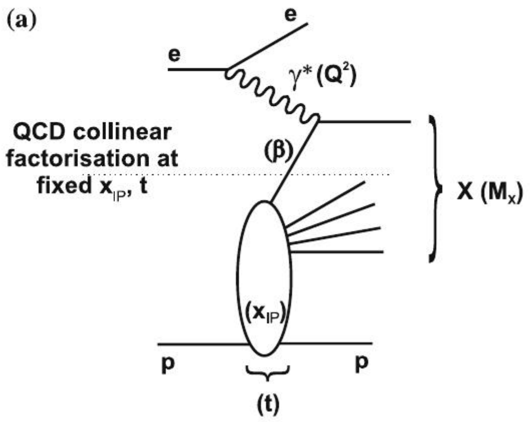


Figure: Schematic illustration of the neutral current diffractive DIS process $ep \to epX$.

Proton Vertex Factorisation

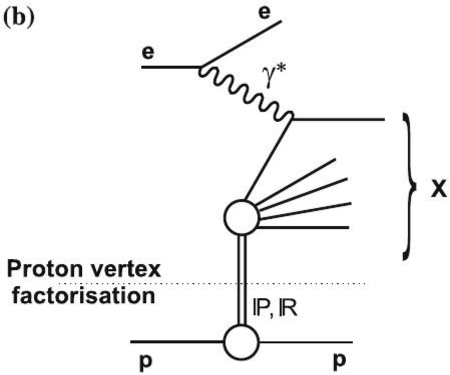


Figure: Schematic illustration of diffractive DIS process $ep \to epX$ considering proton vertex factorisation.

Diffractive DIS Kinematic Variables

In addition to the common DIS variables Q^2 (photon virtuality), x (longitudinal momentum fraction) and y (inelasticity), there are some additional variables in the case of diffractive DIS.

Diffractive Variables

- $t = (P - P')^2$, the squared four-momentum transferred at the proton vertex where P and P' are the four-momenta of the incoming and outgoing protons, respectively.
- M_X, the mass of hadronic final state X.
- $\beta = \frac{Q^2}{2(P-P').q}$, the Bjorken variable defined for the diffractive exchange.
- $x_{I\!P} = \frac{(P-P').q}{P.q}$,the fraction of the momentum of the proton carried by the diffractive exchange.

Note: β can be also expressed as $\beta = x/x_{I\!P}$.

Diffractive DIS Cross Section

The t-integrated differential cross section for the diffractive process, $ep \to epX$, is presented in the form of a diffractive reduced cross section $\sigma_r^{D(3)}(\beta, Q^2; x_{I\!P})$ as

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

Reduced Cross Section

The diffractive reduced cross section is given by

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

where $F_2^{D(3)}$ and $F_L^{D(3)}$ are the diffractive structure functions.

QCD Factorization Theorem

In the QCD factorization approach, the diffractive structure functions can be written as a convolution of hard scattering coefficient functions with the diffractive PDFs,

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

where the sum runs over quarks and gluons.

The Wilson coefficient functions C_2 and C_L are the same as in inclusive DIS and calculable in perturbative QCD.

Diffractive PDFs

If the proton vertex factorization is assumed, the $x_{I\!P}$ and t dependencies of the diffractive PDFs factorize from the dependencies on β and Q^2.

Diffractive PDFs

In this framework, the diffractive PDFs can be written as

$$f_{i/p}^{D}(\beta, Q^2; x_{I\!P}, t) = f_{I\!P/p}(x_{I\!P}, t) f_{i/I\!P}(\beta, Q^2) + f_{I\!R/p}(x_{I\!P}, t) f_{i/I\!R}^{I\!R}(\beta, Q^2)\,, \qquad (5)$$

where $f_{i/I\!P}(\beta, Q^2)$ and $f_{i/I\!R}^{I\!R}(\beta, Q^2)$ are the partonic structures of Pomeron and Reggeon, respectively.

Flux Factors

The emission of Pomeron and Reggeon from the proton can be described by the flux-factors of $f_{I\!P/p}(x_{I\!P}, t)$ and $f_{I\!R/p}(x_{I\!P}, t)$.

QCD Global Analysis Framework

Parametrizations of the diffractive PDFs

The diffractive PDFs are modeled at the starting scale $Q_0^2 = 1.8\,\text{GeV}^2$ in terms of quark $zf_q(z, Q_0^2)$, and gluon $zf_g(z, Q_0^2)$ distributions.
For the quark distributions we assume that all light-quarks and their antiquarks distributions are equal, $f_u = f_d = f_s = f_{\bar{u}} = f_{\bar{d}} = f_{\bar{s}}$.

DPDF Parametrizations

Our standard parametrizations for the quarks and gluon diffractive PDFs are as follows:

$$zf_q(z, Q_0^2) = \alpha_q\, z^{\beta_q}\, (1 - z)^{\gamma_q}\,, \tag{6}$$

$$zf_g(z, Q_0^2) = \alpha_g\, z^{\beta_g}\, (1 - z)^{\gamma_g}\,. \tag{7}$$

Note: An additional factor of $e^{-\frac{0.001}{1-z}}$ is included to ensure that the distributions vanish for $z \to 1$.

Flux Factors

Flux Parametrizations

The $x_{I\!P}$ dependence of diffractive PDFs $f_{i/p}^{D}(z, Q^2; x_{I\!P}, t)$ is parametrized by the Pomeron and Reggeon flux factors.

$$f_{I\!P,I\!R}(x_{I\!P}, t) = A_{I\!P,I\!R} \frac{e^{B_{I\!P,I\!R}\, t}}{x_{I\!P}^{2\alpha_{I\!P,I\!R}(t)-1}}, \qquad (8)$$

where the trajectories are assumed to be linear,
$\alpha_{I\!P,I\!R}(t) = \alpha_{I\!P,I\!R}(0) + \alpha'_{I\!P,I\!R} t$.

Note: The Pomeron and Reggeon intercepts, $\alpha_{I\!P}(0)$ and $\alpha_{I\!R}(0)$, and the normalization of the Reggeon term, $A_{I\!R}$, are free parameters and should be extracted from the fit to data. The value of the normalization parameter $A_{I\!P}$ is absorbed in α_q and α_g.

Additional Constraints

Reggeon Density

The Reggeon parton densities $f_{i/\mathbb{R}}^{\mathbb{R}}(z,Q^2)$ are obtained from the GRV parametrization derived from a fit to pion structure function data.

Fixed Parameters

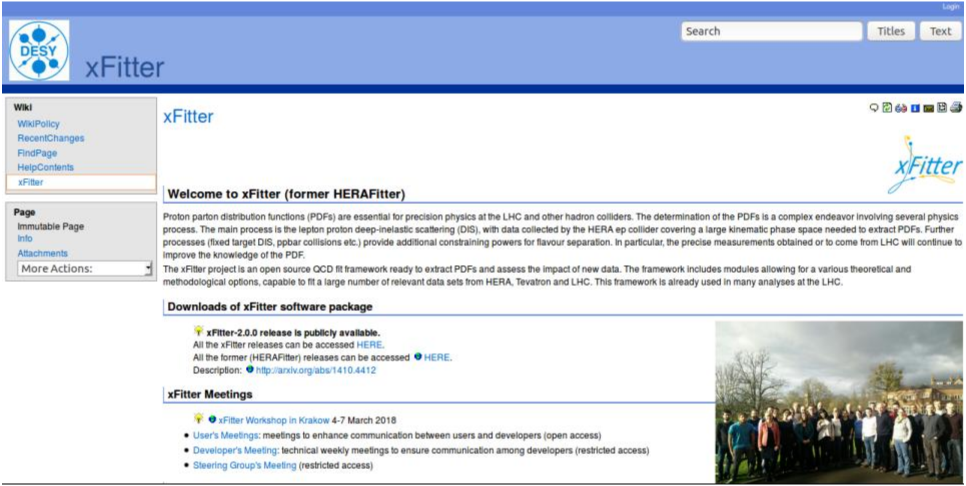
One can extract the normalisation parameter $A_{\mathbb{P}}$ from the condition

$$\int x_{\mathbb{P}} f_{\mathbb{P}}(x_{\mathbb{P}},t)dt = 1 \text{ at } x_{\mathbb{P}} = 0.003. \tag{9}$$

The values of the parameters which are fixed in `GKG18-DPDFs` fit, are the following:

$$\begin{aligned} \alpha'_{\mathbb{P}} &= 0.0\,, & B_{\mathbb{P}} &= 7.0\,\mathrm{GeV}^{-2}\,, \\ \alpha'_{\mathbb{R}} &= 0.90\,, & B_{\mathbb{R}} &= 2.0\,\mathrm{GeV}^{-2}\,. \end{aligned} \tag{10}$$

Computational Tools



Login

Search | Titles | Text

DESY xFitter

Wiki
- WikiPolicy
- RecentChanges
- FindPage
- HelpContents
- xFitter

Page
- Immutable Page
- Info
- Attachments
- More Actions:

xFitter

xFitter

Welcome to xFitter (former HERAFitter)

Proton parton distribution functions (PDFs) are essential for precision physics at the LHC and other hadron colliders. The determination of the PDFs is a complex endeavor involving several physics process. The main process is the lepton proton deep-inelastic scattering (DIS), with data collected by the HERA ep collider covering a large kinematic phase space needed to extract PDFs. Further processes (fixed target DIS, ppbar collisions etc.) provide additional constraining powers for flavour separation. In particular, the precise measurements obtained or to come from LHC will continue to improve the knowledge of the PDF.

The xFitter project is an open source QCD fit framework ready to extract PDFs and assess the impact of new data. The framework includes modules allowing for a various theoretical and methodological options, capable to fit a large number of relevant data sets from HERA, Tevatron and LHC. This framework is already used in many analyses at the LHC.

Downloads of xFitter software package

xFitter-2.0.0 release is publicly available.
All the xFitter releases can be accessed HERE.
All the former (HERAFitter) releases can be accessed HERE.
Description: http://arxiv.org/abs/1410.4412

xFitter Meetings

xFitter Workshop in Krakow 4-7 March 2018

- User's Meetings: meetings to enhance communication between users and developers (open access)
- Developer's Meeting: technical weekly meetings to ensure communication among developers (restricted access)
- Steering Group's Meeting (restricted access)

Diffractive DIS Data Sets

Data Sets

The list of all diffractive DIS data points used in global analysis is as follows:

Experiment	Observable
H1-LRG-11 $\sqrt{s} = 225$	$\sigma_r^{D(3)}$
H1-LRG-11 $\sqrt{s} = 252$	$\sigma_r^{D(3)}$
H1-LRG-11 $\sqrt{s} = 319$	$\sigma_r^{D(3)}$
H1-LRG-12	$\sigma_r^{D(3)}$
H1/ZEUS combined	$\sigma_r^{D(3)}$

Kinematic Cuts

To ensure the validity of the DGLAP evolution equations and also avoid regions which are most likely to be influenced by higher twist (HT) corrections, we have to impose certain cuts on M_X, β and Q^2 of the data sets.

Kinematic Cuts

- We apply $\beta \leq 0.80$ over the data sets.
- The data with $M_X > 2\,\mathrm{GeV}$ are included in the fit.
- In order to finalize the cut on Q^2, the sensitivity of χ^2 to variations in $Q^2 > Q^2_{\mathrm{min}}$ should be investigated for data used in the analysis. Then the data with $Q^2 < Q^2_{\mathrm{min}}$ are excluded.

χ^2 scans

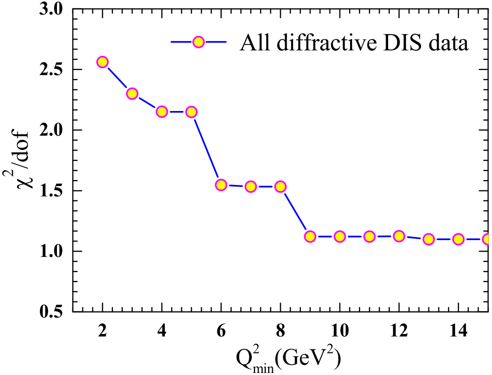


Figure: Dependence of χ^2/dof on the minimum cut value of Q^2_{min} for all data sets used in the analysis.

χ^2 scans

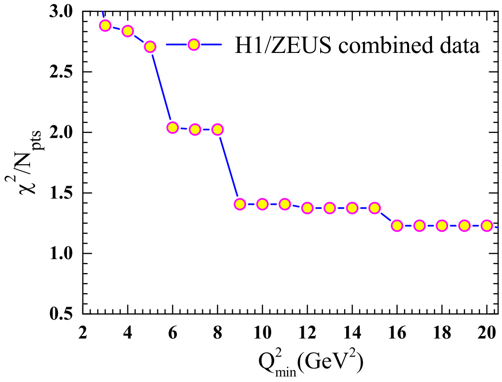


Figure: Dependence of χ^2/N_{pts} on the minimum cut value of Q^2_{min} for H1/ZEUS combined data.

χ^2 scans

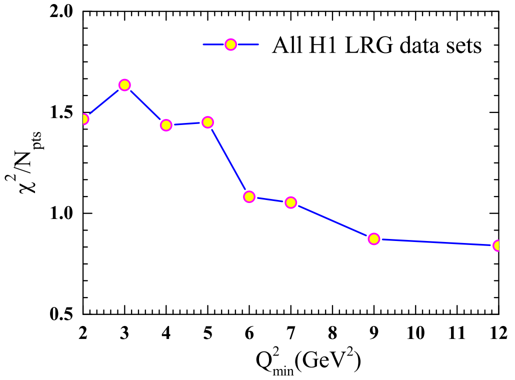


Figure: Dependence of χ^2/N_{pts} on the minimum cut value of Q^2_{min} for all H1 LRG data sets.

Different Scenarios

Fit A

Experiment	$[\beta^{\min}, \beta^{\max}]$	$[x_{I\!P}^{\min}, x_{I\!P}^{\max}]$	Q^2 [GeV^2]	# of points
H1-LRG-11	[0.089–0.699]	[0.0005 – 0.003]	11.5–44	13
H1-LRG-11	[0.089–0.699]	[0.0005 – 0.003]	11.5–44	12
H1-LRG-11	[0.089–0.699]	[0.0005 – 0.003]	11.5–44	12
H1-LRG-12	[0.0067–0.80]	[0.0003 – 0.03]	12–1600	165
H1/ZEUS	[0.0056–0.562]	[0.0009 – 0.09]	15.3–200	96
Total data				298

Fit B

Experiment	$[\beta^{\min}, \beta^{\max}]$	$[x_{I\!P}^{\min}, x_{I\!P}^{\max}]$	Q^2 [GeV^2]	# of points
H1-LRG-11	[0.089–0.699]	[0.0005 – 0.003]	11.5–44	13
H1-LRG-11	[0.089–0.699]	[0.0005 – 0.003]	11.5–44	12
H1-LRG-11	[0.089–0.699]	[0.0005 – 0.003]	11.5–44	12
H1-LRG-12	[0.0067–0.80]	[0.0003 – 0.03]	12–1600	165
H1/ZEUS	[0.0056–0.562]	[0.0009 – 0.09]	26.5–200	70
Total data				272

Results

Fit Results

The values of χ^2/N_{pts} for the data sets included in the global fits are as follows:

χ^2 values

	Fit A	Fit B
Experiment	χ^2/N_{pts}	χ^2/N_{pts}
H1-LRG-11 $\sqrt{s} = 225$ GeV	11/13	12/13
H1-LRG-11 $\sqrt{s} = 252$ GeV	20/12	21/12
H1-LRG-11 $\sqrt{s} = 319$ GeV	6.5/12	6.2/12
H1-LRG-12	135/165	138/165
H1/ZEUS combined	128/96	86/70
χ^2/dof	$322/289 = 1.11$	$279/263 = 1.06$

Optimum Parameters

Parameters obtained with the different fits at the initial scale $Q_0^2 = 1.8\,\mathrm{GeV}^2$ and their experimental uncertainties are as follows:

Fit Parameters

Parameters	Fit A	Fit B
α_g	1.00 ± 0.15	0.79 ± 0.13
β_g	0.206 ± 0.064	0.160 ± 0.071
γ_g	0.30 ± 0.16	0.12 ± 0.15
α_q	0.304 ± 0.022	0.285 ± 0.022
β_q	1.465 ± 0.069	1.516 ± 0.076
γ_q	0.516 ± 0.035	0.516 ± 0.036
$\alpha_{I\!P}(0)$	1.0937 ± 0.0032	1.0988 ± 0.0037
$\alpha_{I\!R}(0)$	0.320 ± 0.053	0.385 ± 0.057
$A_{I\!R}$	21.3 ± 5.6	17.9 ± 5.1
$\alpha_s(M_Z^2)$	0.1176^*	0.1176^*
m_c	1.35^*	1.35^*
m_b	4.30^*	4.30^*

Diffractive PDFs

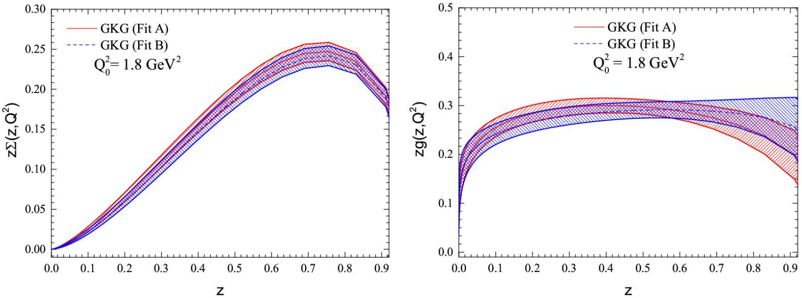
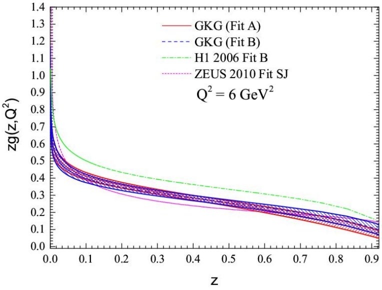


Figure: The total quark singlet $z\Sigma(z, Q_0^2)$ (left) and gluon $zg(z, Q_0^2)$ (right) distributions obtained from our NLO QCD fits, shown at the input scale $Q_0^2 = 1.8\,\mathrm{GeV}^2$.

Comparison to other DPDFs



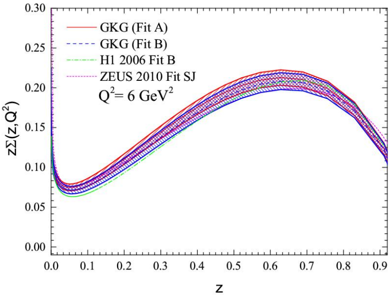


Figure: A Comparison between the total quark singlet $z\Sigma(z, Q_0^2)$ (right) and gluon $zg(z, Q_0^2)$ (left) distributions at scale $\mathrm{Q}_0^2 = 6\,\mathrm{GeV}^2$ and the H1 and ZEUS DPDFs.

Comparison to other DPDFs

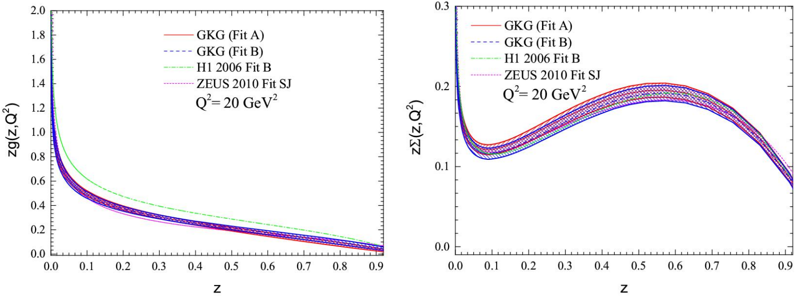
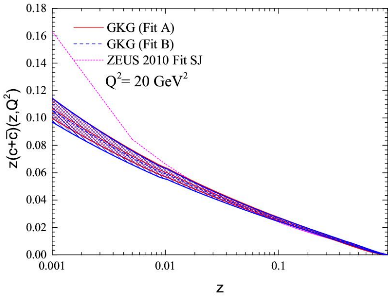


Figure: A Comparison between the total quark singlet $z\Sigma(z,Q_0^2)$ (right) and gluon $zg(z,Q_0^2)$ (left) distributions at scale $Q_0^2 = 6\,\text{GeV}^2$ and the H1 and ZEUS DPDFs.

Comparison to other DPDFs



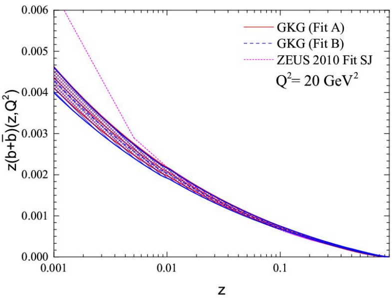
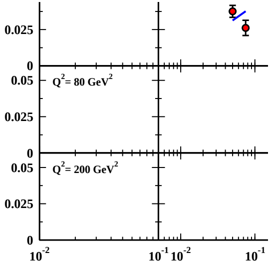
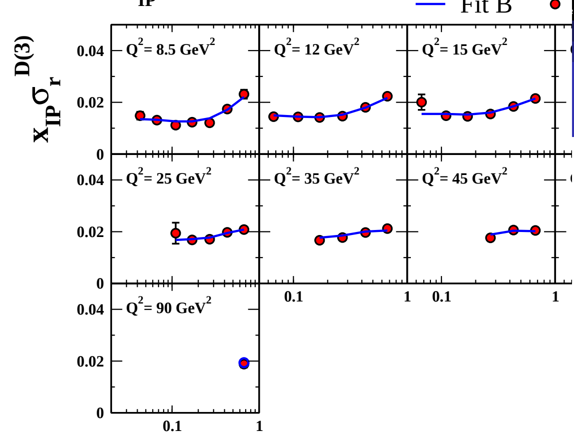


Figure: A Comparison between the charm $z(c+\bar{c})(z,Q^2)$ (left) and bottom $z(b+\bar{b})(z,Q^2)$ (right) distributions at scale $Q^2 = 20$ GeV^2 and the ZEUS results.

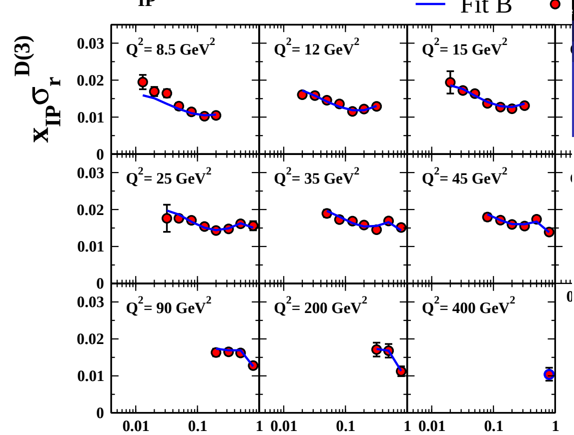
Comparison to the diffractive DIS data



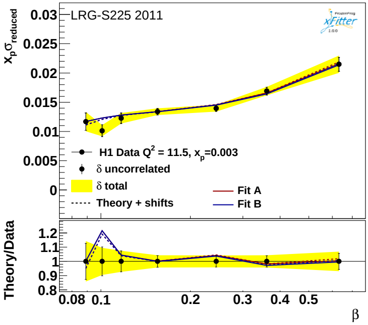
Compa


Fit B
Q^2= 8.5 GeV^2
Q^2= 12 GeV^2
Q^2= 15 GeV^2
Q^2= 25 GeV^2
Q^2= 35 GeV^2
Q^2= 45 GeV^2
Q^2= 90 GeV^2
0.04
0.02
0
0.1
1

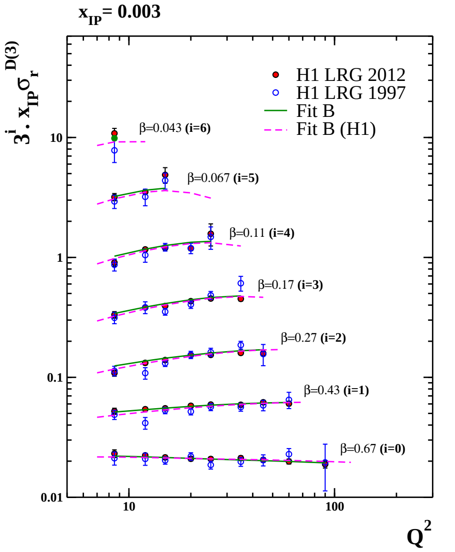
Compa…


Fit B
$x_{IP}\sigma_r^{D(3)}$
0.03
0.02
0.01
0
Q^2 = 8.5 GeV^2
Q^2 = 12 GeV^2
Q^2 = 15 GeV^2
Q^2 = 25 GeV^2
Q^2 = 35 GeV^2
Q^2 = 45 GeV^2
Q^2 = 90 GeV^2
Q^2 = 200 GeV^2
Q^2 = 400 GeV^2
0.01
0.1
1

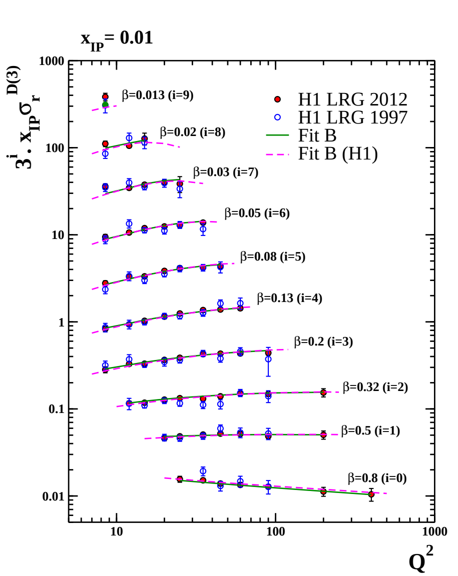
Comparison to the diffractive DIS data



Comparison to the diffractive DIS data



Comparison to the diffractive DIS data



Outlook

- Implementation of our grid files to the `LHAPDF` package.
- Implementation of our diffractive PDFs to the new version of `PYTHIA`.
- Performing a new global analysis of diffractive PDFs including the new dijet data to put further constraints on the gluon distribution.


THANK
YOU