DPDF: A Library for Diffractive Parton Distributions

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Abstract
A code library is presented which provides a common interface to available parameterizations of diffractive parton distribution functions determined from QCD fits to HERA diffractive structure function data.

1 Introduction

In recent years, various precise measurements of the diffractive reduced cross section[1] $\sigma_r^{D(3)}(x_{I\!P}, \beta, Q^2)$ have been made by the HERA experiments H1 and ZEUS. Within the framework of QCD factorization in diffractive DIS [1], several sets of *diffractive parton distributions* (dpdf's) have been obtained from leading or next-to-leading order DGLAP QCD fits to these data[2]. The extracted dpdf's are a crucial input for the calculations of the cross sections of less inclusive diffractive processes such as diffractive jet, heavy quark or even Higgs production.

Since these diffractive pdf's are used in many different Monte-Carlo generators as well as in fixed order QCD calculations, it is desirable to provide them through a common software interface, similar in spirit to the common PDFLIB [2] and LHAPDF [3] packages for non-diffractive pdf's. To achieve this, the DPDF library has been developed. When a new dpdf set becomes available, it then needs to be implemented only in one place. Furthermore, additional features such as custom QCD evolution, structure function calculation and error information are available. Thus, the DPDF library provides a useful way to make the knowledge from HERA available to the TEVATRON, LHC and theory communities.

2 Theoretical Framework

The concept of QCD factorization in diffractive DIS implies that the diffractive $\gamma^* p$ cross section can be expressed as a convolution of universal diffractive parton distributions f_i^D with process-dependent coefficient functions:

$$\frac{\mathrm{d}^2\sigma(x, Q^2, x_{I\!P}, t)^{\gamma^* p \to p' X}}{\mathrm{d}x_{I\!P}\,\mathrm{d}t} \;=\; \sum_i \int_x^{x_{I\!P}} \mathrm{d}\xi\; \hat{\sigma}^{\gamma^* i}(x, Q^2, \xi)\; f_i^D(x_{I\!P}, t, \xi, Q^2)\;. \tag{1}$$

The diffractive pdf's $f_i^D(x_{I\!P}, t, \beta, Q^2)$ can be extracted from a DGLAP QCD analysis of the diffractive reduced cross section σ_r^D.

For many (but not all) of the included parameterizations the $(x_{I\!P}, t)$ dependence factorizes ("Regge factorization") so that a *flux factor* $f_{I\!P/p}(x_{I\!P}, t)$ and dpdf's $f_i^{I\!P}(\beta, Q^2)$ are defined separately:

$$f_i^D(x_{I\!P}, t, \beta, Q^2) = f_{I\!P/p}(x_{I\!P}, t) \cdot f_i^{I\!P}(\beta, Q^2)\;. \tag{2}$$

For those parameterizations which include a secondary Reggeon exchange contribution (often using a pion structure function) in order to describe the data at high $x_{I\!P}$, such a possibility is also included. The dpdf's are typically parameterized in terms of a light quark flavor singlet and a gluon distribution, which are evolved using the (N)LO DGLAP equations[3].

[1] The reduced cross section σ_r^D corresponds to the structure function F_2^D if contributions from F_L^D and xF_3^D are neglected.
[2] In some cases, final state data were used in addition in order to better constrain the diffractive gluon density.
[3] For details of the parameterizations, see the original publications.

Table 1: Overview of the diffractive pdf sets implemented in the DPDF package. The Q^2, β and $x_{I\!P}$ ranges correspond to the approximate kinematic range of the data used in the fit.

Set	Fit	Var	Name	Ref.	Order	Q^2 (GeV^2)	β	$x_{I\!P}$
1	4	–	H1-1997-LO-Fit-1	H1 Coll. [5]	LO	4.5..75	0.04..0.9	< 0.05
1	5	–	H1-1997-LO-Fit-2		LO			
1	6	–	H1-1997-LO-Fit-3		LO			
2	1	–	H1-2002-NLO	H1 Coll. (prel.) [6]	NLO	6.5..800	0.01..0.9	< 0.05
2	2	–	H1-2002-LO		LO			
3	1	1..3	ACTW-NLO-A	Alvero et al. [7]	NLO	6.0..75	0.20..0.7	< 0.01
3	2	1..3	ACTW-NLO-B		NLO			
3	3	1..3	ACTW-NLO-C		NLO			
3	4	1..3	ACTW-NLO-D		NLO			
3	5	1..3	ACTW-NLO-SG		NLO			
4	–	–	BGH-LO	Buchmueller et al. [8]	LO	4.5..75	0.04..0.9	< 0.01
5	–	–	HS-NLO	Hautmann and Soper [9]	NLO			
6	–	–	ZEUS-LPS	ZEUS Coll. [11, 12]	NLO	2.4..39	0.01..0.5	< 0.01
7	1	–	MRW-NLO-Lambda	Martin et al. [10]	NLO	2.4..90	0.01..0.9	< 0.05
7	2	–	MRW-NLO-MRST		NLO			
8	–	–	ZEUS-MX	Groys et al. [13]	NLO	4.0..55	0.01..0.9	< 0.01

3 Implementation

DPDF is a FORTRAN 77 package. A C++ wrapper will be provided. There is an external dependency on the QCDNUM [4] package, which can be disabled.

3.1 Available Parameterizations

Currently the following dpdf sets are implemented: the fits performed by the H1 collaboration in [5], the preliminary H1 fits presented in [6], the fits by Alvero et al. [7], a parameterization of the semi-classical model by Buchmueller et al. [8], the fits by Hautmann and Soper [9] and by Martin et al. [10], the ZEUS fit from [11, 12] and a fit to recent ZEUS data presented at this workshop [12, 13].

Details of the available dpdf sets are presented in table 1, including the kinematic ranges of the data which were included in the fits. This information can be used as a guideline for the range of validity of the fits. Note in particular that typically only data for $x_{I\!P} < 0.05$ or < 0.01 are included in the fits, which introduces an additional uncertainty when these fits are used for comparisons with experimental data at higher $x_{I\!P}$.

3.2 Interface to QCDNUM

DPDF provides an interface to the NLO DGLAP QCD evolution package QCDNUM [4]. It is possible to perform a QCD evolution of the given pdf set from its starting scale Q_0^2 using either the original evolution scheme and parameters, or by providing modified parameters. The benefits are:

- QCDNUM calculates the full (N)LO structure functions F_2 and F_L for light and heavy quarks, which can be used for consistent comparisons with experimental data;
- The QCD evolution parameters such as α_s can be varied for systematic studies;

– The dpdf's can be evolved to Q^2 or β values beyond the grid on which the original parameterization is provided, which is particularly interesting for LHC applications.

3.3 Usage

The DPDF package can be obtained from [14]. In the following the principal user subroutines of the library are listed.

– The package is initialized for a given dpdf by calling `dpdf_init(iset,ifit,ivar)` where `iset`, `ifit` and `ivar` are the parameters as given in table 1.
– The diffractive proton pdf's for either Pomeron or sub-leading Reggeon exchange or their sum (if provided) are returned at given values of $(x_{I\!P}, t, \beta, Q^2)$ in an array `xpq(-6:6)` using `dpdf_ppdf`. The result may also be integrated over t.
– If provided, the flux factors $f_{I\!P}(x_{I\!P}, t)$ and the parton densities $f_i(\beta, Q^2)$ can be obtained separately from `dpdf_flux` and `dpdf_pdf`.
– The diffractive structure function can be obtained from `dpdf_f2d`.
– QCD evolution using QCDNUM can be performed using default parameters for the given set with `dpdf_evolve_std` and using modified evolution parameters with `dpdf_evolve`.

Note that the details of the user interface may change in the future. For details refer to the user manual available from [14].

4 Outlook

It is planned to update DPDF if new dpdf sets become available. Additional features such as the possibility of error dpdf's (as for LHAPDF) are foreseen. The code and manual are available from [14].

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