PDFLIB : Nucleon, Pion and Photon Parton Density Functions and α_s Calculations

Users's Manual

Version 7.09

ABSTRACT

This article describes an integrated package of Parton Density Functions called PDFLIB which has been added to the CERN Program Library Pool W999 and is labelled as W5051. In this package all the different sets of parton density functions of the **nucleon**, the **pion** and the **photon** which are available today have been put together. All these sets have been combined in a consistent way such that they all have similar calling sequences and no external data files have to be read in anymore. A default set has been prepared, although those preferring their own set or wanting to test a new one may do so within the package. The package also offers a program to calculate the strong coupling constant α_s to first or second order. The correct Λ_{QCD} associated to the selected set of structure functions and the number of allowed flavours with respect to the given Q^2 is automatically used in the calculation. The selection of sets, the program parameters as well as the possibilities to modify the defaults and to control errors occurred during execution are described.

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Language: FORTRAN 77
Library: PDFLIB

PDFLIB - User's Manual

CERN Computer Program Library entry W5051

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PROGRAM SUMMARY

Title of program: PDFLIB, version 7.09

Catalogue number: W5051 in the CERN Computer Program Library

Program obtainable from: CERN Computer Program Library Office

Computer for which the program is designed and others on which it has been tested:
Computer: IBM 3090, VAX, IBM-RISC, DECS, SUN, APOLLO, HP-UX, Silicon Graphics, NEXT, CDC, CRAY, IBM-PC

Operating system: VM/CMS, VAX/VMS, Unix, Windows NT

Programming language used:
FORTRAN 77, program is available in the CVS format

Number of lines in distributed program, including test data, etc: 192 000

Memory storage required including testprograms and some documentation: 25 Mbytes (*Source code:* 10 Mbytes, *Library:* 10 Mbytes)

No. of bits in a word: 64

Peripherals used: Line printer (optional)

Libraries needed: the CERNLIB packlib, mathlib, kernlib

Keywords:
parton density functions, structure functions, W5051, nucleon -, proton -, pion -, photon density parametrisations, Altarelli-Parisi equation, strong coupling constant α_s

Nature of physical problem:
All theoretical calculations of cross sections involving the hadronic structure of the incoming particles, i.e. protons, pions or photons, use the parton density at a given longitudinal momentum X of the parton and at a given momentum transfer Q^2. There is a variety of parametrisations available, but each of them has its own structure for input and/or output.

Method of solution:
Collection of all available parton density parametrisations and application in an identical format for all of them, regardless of the author's convention or of the particle type.

References:
[1] H. Plothow-Besch, *'PDFLIB: Structure Functions and α_s Calculations'*, Users's Manual - Version 1.00, W5051 PDFLIB, 1991.03.21, CERN-PPE.
[2] H. Plothow-Besch, *'PDFLIB: a library of all available parton density functions of the nucleon, the pion and the photon and the corresponding α_s calculations'*, Comp. Phys. Comm. 75 (1993) 396-416.
[3] H. Plothow-Besch, *'The Parton Distribution Function Library'*, Int. J. Mod. Phys. A10 (1995) 2901-2910.

PDFLIB : new version 7.09

0 Major Differences compared to earlier Versions

0.1. The actual Version 7.09 wrt Version 6.00:

The following major changes compared to version 6.00 of PDFLIB have been implemented:

- Several **nucleon** structure function sets have been added:
  - the NLL sets A of Martin Roberts and Stirling (MRS-A lQ) for *low* Q^2 of May 1995 in the DIS and the $\overline{MS}$ renormalisation schemes, as well as the NLL sets A' for 6 different values of α_s (MRS-Ap-150, MRS-Ap-201, MRS-Ap-266, MRS-Ap-344, MRS-Ap-435, MRS-Ap-542), the J and J' sets (MRS-J and MRS-Jp) of May 1996 which include the high p_T-jet data of the TEVATRON, and the latest MRS sets R1 to R4 (MRS-R1, MRS-R2, MRS-R3, MRS-R4) of May 1996 with grid data as well as in its parametrized form (MRS-R1-F) and (MRS-R2-F);
  - version 4 of the CTEQ group of June 1996 as NLL parametrisation in the $\overline{MS}$ as well as in the DIS renormalisation scheme and as LO (CTEQ4M, CTEQ4D, CTEQ4L), the CTEQ4M set for 5 different values of α_s (CTEQ4A1, CTEQ4A2, CTEQ4A3, CTEQ4A4, CTEQ4A5), a set which includes the high p_T-jet data of the TEVATRON (CTEQ4HJ), and a set for *low* Q^2 (CTEQ4lQ);
  - the new sets of Glück, Reya, Stratmann and Vogelsang as LO and of August 1995 as NLL in the $\overline{MS}$ renormalisation scheme of polarized parton distributions in a 'standard' and a 'valence' fit version (GRSVpolS, GRSVpolV). A special COMMON block (COMMON /GRSVA1/ A1P, A1N, A1D) transmits directly the spin asymmetries of the proton, the neutron and the deuteron.

- A **new group** of authors of **photon** structure function sets has been added:
  - the 4 old LO sets of Schuler and Sjostrand of March 1995, as well as the 4 LO sets of their revised version of May 1996 (SaS-G-1D, SaS-G-1M, SaS-G-2D, SaS-G-2MD).

- Several new **photon** structure function sets have been added:
  - the recent LO set of Glück, Reya and Stratmann of February 1996 (GRS-G);
  - the recent LO sets of Gordon and Storrow of August 1996 (GS-G, GS-G).

- To take into account the need for more input parameters for parton densities of the photon a **new subroutine** STRUCTP has been added which should be called instead of STRUCTM in case of applications of the photon.

- Several **corrections** to existing structure function sets have been performed:
  - to account for heavy quark contributions (c and b) in the nucleon parton densities of Glück, Reya and Vogt (GRV94), now automatically the old GRV parton densities of 1992 are called for c and b quarks as advised in their paper;

- corrections for LINNUX-systems suggested by V. Balashov have been taken into account.

- A **bug** in the data tables for the parton densities of the photon of the set of Aurenche, Fontannaz and Guillet (AFG-G) has been fixed.

More details can be found on the next pages of this updated User's Manual.

The response from the Physics community has been very satisfactory, which is encouraging us to keep up-to-date with the latest developments in this area. The author will be pleased to learn about new parton density functions, as well as to receive suggestions to improve both, the usage and the documentation. Please send your comments to plothow@mail.cern.ch.

0.2. Version 6.00 wrt Version 5.00:

The following major changes compared to version 5.00 of PDFLIB have been implemented:

- Several **nucleon** structure function sets have been added:
  - the NLL sets A' and G of Martin Roberts and Stirling (MRS-Ap) and (MRS-G) of February 1995 with grid data as well as in its parametrized version (MRS-Ap-F) and (MRS-G-F),
  - version 3 of the CTEQ group of October 1994 as NLL parametrisation in the $\overline{MS}$ as well as in the DIS renormalisation scheme and as LO (CTEQ3M, CTEQ3D, CTEQ3L),
  - the new sets of GRV of November 1994 as NLL in the $\overline{MS}$ as well as in the DIS renormalisation scheme and as LO (GRV94-MS, GRV94-DI, GRV94-LO).

- a **new** group of **photon** structure function sets have been added:
  - the six LO sets of the WHIT group (WHIT1-G to WHIT6-G).

Please note that the **default set** has been changed to the new MRS set (G) (NPTYPE = 1, NGROUP = 3, NSET = 41).

0.3. Version 5.00 wrt Version 4.00:

The following major changes compared to version 4.00 of PDFLIB had been implemented:

- **Nucleon** structure functions sets have been updated or added:
  - the recent NLL set of Martin, Roberts and Stirling (MRS) set (A) of May 1994 with grid data as well as in its parametrized form.
- **Photon** structure function sets have been added:
  - the new NLL sets of Aurenche, Fontannaz and Guillet (AFG-G) of December 1993.
- Some improvements in the usage of the package have been made:
  - more protections have been implemented and inconsistancies have been corrected. For the correct application of PDFLIB please consult the example in the Appendix,

  and finally,

  - an inconsistancy in the documentation concerning the calling sequence in the PDG format (contents of DXPDF(1) and DXPDF(2)) has been removed.

0.4. Version 4.00 wrt Version 3.00:

The following major changes compared to version 3.00 of PDFLIB have been implemented:

- **Nucleon** structure functions sets have been updated or added:
  - the updated NLL set of Martin, Roberts and Stirling (MRS) of November 1992, the sets S0', D0' and D-' in the $\overline{MS}$ as well as the sets S0', D0' and D-' in the DIS renormalisation scheme. Please note that the previous S0, D0 and D- sets have been retracted by the authors. The new MRS(H) set in both schemes has been added as well,
  - the NLL and LO sets of the CTEQ collaboration (CTEQ) in its parametrized form of January 1993. These are the sets 1M, 1MS and 1ML in the $\overline{MS}$, the set 1D in the DIS renormalisation scheme and the LO set 1L,
  - the new NLL sets A and B of Berger and Meng (BM) of February 1993 with special gluon distributions,

  and finally

  - the new NLL and LO sets of the CTEQ collaboration (CTEQ) in its parametrized form of August 1993. These are the sets 2M, 2MS, 2MF and 2ML in the $\overline{MS}$, the set 2D in the DIS renormalisation scheme and the LO set 2L. The revised CTEQ2 version, CTEQ2p, of November 1993 is recommended by the authors.

Please note that the default set has been put to the GRV set HO (NPTYPE = 1, NGROUP = 5, NSET = 3 / formerly MODE = 72).

- The **most drastic** change to the package has been, however, the **new format** of **parameter settings**. Instead of using only **one** parameter (MODE) to select a set of parton density functions (PDF), each PDF set is now identified by **three** parameters. The change of format had been necessary to take into account the inflationarily growing number of PDFs until now, and to foresee already the possibility of adding new PDFs in a more flexible way. The **three new** parameters are, **NPTYPE**, **NGROUP** and **NSET**, for **particle type** (Nucleons, Pions or Photons), **author group** (f.ex. MRS, CTEQ, GRV, etc) and the **parametrisation set** within the group. The user should therefore provide **three** parameters (NPTYPE, NGROUP, NSET) to the subroutine PDFSET, each time a PDF set shall be selected. But to make life nice and easy, it is also possible to select a PDF set by transferring only **one** parameter to PDFSET as before: this parameter should then identify the **name** of the author group in an **unequivocal** way; the selection of the PDF set within the author group is made by the corresponding VALUE value (f.ex. PARM(1) = 'MRS' with VALUE(1) = 29.0D0 would select the 29thset of the nucleon PDFs of MRS, while PARM(1) = 'GRVph' with VALUE(1) = 1.0D0 would select the first set of the photon PDFs of GRV). As a suggestion, the **name** for each PDF set can be found in the new COMMON block /W505110/SFNAME, where SFNAME is a CHARACTER*8 array with dimension SFNAME(NPTYMX,NGRMAX,NSETMX), and NPTYMX, NGRMAX, NSETMX are defined by the parameter sequence, +SEQ,W5051P2. In case the user wants to select the **default**, it is sufficient to transfer as the **only** parameter PARM(1) = 'Nset' with VALUE(1) = 0.0D0. Please note that in case of any **inconsistancy** of parameter settings, the **default** setting is always chosen.

Warning : please also note that the internal COMMON block /W50511/ has been modified to /W50511/NPTYPE,NGROUP,NSET,MODE,NFL,LO,TMAS.

- A new feature, PDFLIB in quiet mode, has been implemented. If the user does not want to see any output from PDFLIB, not even the version number, he/she must set the parameter PARM(1)='first' with value VAL(1)=0.D0. Under this condition any output is suppressed.

- Full **backward compatibility** with previous versions is ensured !! This means that old programs using PDF sets up to version 3.00 of PDFLIB should run without **any** change. To ensure this, four new COMMON blocks have been added:

  a) COMMON /W50519/ NEWVER : flags the new/old version with the **logical** variable NEWVER,
  b) COMMON /W505120/ NPGSMX(NPTYMX,NGRMAX), NSETFL(NPTYMX,NGRMAX,NSETMX) : provides the maximum number of parametrisation sets per particle type and author group, and flags the retracted PDF sets (NSETFL(I,J,K) = 0),
  c) COMMON /W505121/ NPTYCR(MODEMX),NGROMX(MODEMX), NSETCR(MODEMAX) : provides the cross reference to the NPTYPE, NGROUP and NSET value (**new** format) for a given MODE value (**old** format),

  and

d) COMMON /W505122/ MODECR(NPTYMX,NGRMAX,NSETMX) : provides the cross reference to the MODE value (**old** format) for a given NPTYPE, NGROUP and NSET value (**new** format). In case of the above added PDF sets **no** MODE value is available; in that case MODECR(I,J,K) = -1 is returned.

0.5. Version 3.00 wrt Version 2.00:

The following major changes compared to version 2.00 of PDFLIB had been implemented:

- **Nucleon** structure functions sets had been updated or added:
  - the updated NLL set of Aurenche et al. (ABFOW) of March 1992.
  - the updated NLL set of Kwiecinski, Martin Roberts and Stirling (KMRS) set B0 with $\overline{up} \neq \overline{down}$ of April 1992.
  - the new NLL sets of Martin, Roberts and Stirling (MRS) set S0, D0 and D- with $\overline{up} \neq \overline{down}$ of April 1992.

Please note that the default set had been put to the MRS set S0 (MODE = 45).

- **Pion** structure function sets had been added:
  - the new LO and NLL sets of Glück, Reya and Vogt (GRV-P) of August 1991.
  - the new sets 2 and 3 of Aurenche et al. (ABFKW-P).

Please also note that the ABFKW set had changed MODE number from 110 $\rightarrow$ 180, as well as the SMRS sets from 120ff $\rightarrow$ 130ff, and that earlier inconsistencies in the parton density definitions had been corrected.

- For the first time also **photon** structure function sets had been added to the package. These sets were the following:
  - the old Duke and Owens (DO-G) LO and NLL sets.
  - the old LO sets 1 to 4 of Drees and Grassie (DG-G).
  - the new LO sets 1 to 3 of Abramowicz, Charchula and Levy (LAC-G).
  - the new LO sets 1 and 2 and the NLL set of Gordon and Storrow (GS-G) of July 1991.
  - the new LO and NLL sets, as well as the leading term of the NLL calculation of Glück, Reya and Vogt (GRV-G) of December 1991.
  - the new NLL sets of Aurenche et al. (ACFGP-G) of April 1992.

- Some improvements in the usage of the package had been made:
  - more protections had been implemented and inconsistencies had been corrected to make the package more robust and available on **all** system areas,

  and finally

- a subroutine STRUCTM had been added. STRUCTM is basically the same routine as the old steering subroutine STRUCTF apart from **one** additional parameter in the argument list which had been added to transfer separately the parton densities for $\overline{up}$ and $\overline{down}$. The argument list of the subroutine STRUCTF was as before; in case of STRUCTF sea = $(\overline{up} + \overline{down})/2$ is transferred. The subroutine PFTOPDG, which is the steering routine in PDG format, was unchanged; this routine always transferred $\overline{up}$ and $\overline{down}$ separately.

0.6. Version 2.00 wrt Version 1.00:

The following major changes compared to version 1.00 of PDFLIB had been implemented:

- New parton density functions of the **nucleon** had been added:
  - the old LO set of Buras and Gaemers of 1978 (BEBC) for completeness,
  - all the LO sets of Diemoz, Ferroni, Longo and Martinelli (DFLM) including their parametrisation for the NLL average fit,
  - the new LO set 1.1 of Owens (DO 1.1) of June 1991,

  and finally
  - the new LO and NLL sets of Glück, Reya and Vogt (GRV) of August 1991.
- **Pion** structure function sets had been added to the package:
  - the old Owens (OW) sets 1 and 2,
  - the Aurenche et al. set (ABFKW)

  and
  - the Sutton, Martin, Roberts and Stirling (SMRS) sets 1, 2 and 3.
- Some improvements in the usage of the package had been made:
  - COMMON block names had been changed to avoid interference to those defined by the user (/IMODE/ → /W50511/, /ALAMB/ → /W50512/),
  - three new COMMON blocks had been added:
    - a) COMMON /W50513/ XMIN,XMAX,Q2MIN,Q2MAX : to provide the minimal and maximal values of x and Q^2 for each set of structure functions,
    - b) COMMON /W50510/ IFLPRT : to provide a print flag at different levels to print
      - b.1) the variables of the three COMMON blocks /W50511/, /W50512/ and /W50513/ at job initialisation,
      - b.2) error messages during job execution,
    - c) COMMON /W50514W/ PDFWGT : to take into account the event weight for error counting,
  - a subroutine PDFSTA had been added to allow at job termination for a summary how often x and Q^2 limits have been exceeded,

– the MODE number of some structure functions had been changed to keep consistency,
– the number of parameters which can be set through the subroutine PDFSET had been extended to 20,
– more protections had been implemented and inconsistencies had been corrected to make the package more robust,

and finally

– a subroutine PFTOPDG has been provided as an interface for those users who prefer the flavour code convention of the PDG instead of the PDFLIB format.

1. The Library of Parton Densities: PDFLIB

1.1. Introduction

Perturbative QCD describes the Q^2 dependence of the parton densities through the solution of the Altarelli-Parisi equations. Its predictive power is given by the universality of these densities. Usually these densities are extracted from precision measurements in fixed-target experiments of a given process at some scale - recently they have also been extracted from the HERA ep-collision experiments -, and then used to perform calculations for different reactions in an extrapolated range of Q^2 provided that the elementary cross sections at the parton level are known. To be able to predict cross sections for a wide range of hard scattering processes, it is of fundamental importance to have a reliable and precise set of parton density distributions, together with a precise value of the strong coupling constant α_s. Therefore the momentum distributions of quarks and gluons are key ingredients for the lepton-lepton, lepton-hadron and hadron-hadron collider phenomenology, whenever the hadronic structure of nucleons, pions or photons is involved. Apart from the obvious applications mentioned above, the study of parton distributions provides also information about flavour dependence, isospin symmetry, partons in nuclei, sum rules, polarized parton distibutions, etc.. For any application the parton densities should therefore be sufficiently well known, and the different sets should be easily accessible.

1.2. Structure Functions of the Nucleon

The number of sets of parton density functions of the **nucleon** available today is about 70 and is still growing. The older sets are leading order (LO) evolutions of the Altarelli-Parisi equations only, like

- Buras and Gaemers (BEBC)[1] ,
- Owens and Reya (O-R)[2] ,
- Baier, Engels and Petersson (BEP)[3] ,
- Glück, Hoffmann and Reya (GHR)[4] ,
- Duke and Owens (DO)[5] sets 1 and 2,
- Eichten, Hinchliffe, Lane and Quigg (EHLQ)[6] sets 1 and 2,
- Diemoz, Ferroni, Longo and Martinelli (DFLM)[7] with $\Lambda^{[4]}_{QCD} = 200$ MeV for soft and hard valence quark and soft and hard gluon distributions,

and

- the set 1.1 of Owens (DO 1.1)[8] , replacing the DO[5] sets 1 and 2.

Most of the sets, essentially the more recent ones, are next-to-leading order (NLL) evolutions of the Altarelli-Parisi equations, like

- the different sets of Diemoz, Ferroni, Longo and Martinelli (DFLM)[7]

- Martin, Roberts and Stirling (MRS)[9] sets 1 to 3, E, B, E' and B',
- Harriman, Martin, Roberts and Stirling (HMRS)[10] sets E, E+, E- and B,
- Kwiecinski, Martin, Roberts and Stirling (KMRS)[11] sets B0 and B-, and for the B-set with different radii for shadowing,
- Martin, Roberts and Stirling (MRS-BΛ)[11] for the B0 set also with different values of $\Lambda^{[4]}_{QCD}$ = 135, 160, 200 and 235 MeV,
- Martin, Roberts and Stirling (MRS)[12] sets S0, D0 and D- as well as the upgraded KMRS set B0, all having $\overline{up} \neq \overline{down}$,
- Morfin and Tung (M-T)[13] sets 1 to 6,
- Glück, Reya and Vogt (GRV)[14] ,
- the set of Aurenche et al. (ABFOW)[15] ,
- the upgraded Martin, Roberts and Stirling (MRS)[16] sets S0', D0' and D-' as well as the more recent MRS(H) set all in both, the $\overline{MS}$ and the DIS renormalisation schemes,
- the Berger and Meng (BM)[17] sets 1 and 2 with special gluon distributions,
- the two first versions of the CTEQ collaboration (CTEQ1 and CTEQ2)[18] ,
- the set of Martin, Roberts and Stirling (MRS-A)[19] in form of a grid and in form of a parametrisation,
- the two sets of Martin, Roberts and Stirling (MRS-A' and MRS-G)[20] in form of a grid and in form of a parametrisation,
- the third versions of the CTEQ collaboration (CTEQ3)[21] ,
- the 1994 set of Glück, Reya and Vogt (GRV)[22] ,
- the recent sets of Martin, Roberts and Stirling for low Q^2 (MRS-A lQ)[23] and the MRS-A' sets for 6 different values of α_s (MRS-Ap-150 to MRS-Ap-542)[24] ,
- the more recent sets of Martin, Roberts and Stirling (MRS-J and MRS-Jp)[25] and the latest sets R1 to R4 (MRS-R1 to MRS-R4)[26] in form of a grid and in form of a parametrisation,
- the fourth versions of the CTEQ collaboration (CTEQ4)[27] ,

and finally

- the LO and NLL sets of Glück, Reya, Stratmann and Vogelsang (GRSV)[28] of polarized parton densities,

The different NLL sets use either the DIS[44] or the $\overline{MS}$ renormalisation scheme. Some of the sets are available in both renormalisation schemes. Most of the sets are made using four flavours in the initial state (NF = 4). The value of the QCD scale factor, $\Lambda^{[4]}_{QCD}$, ranges from 45 to 500 MeV.

Nptype	Ngroup	Nset	$\Lambda_{QCD}^{[4]}$	Q^2_{min}	Name of set			Reference
		0	**255**	**5**	**MRS (G)**	$\overline{\mathbf{MS}}$	**NLL**	**Default**
1	1	1			PRIVATE to user			
1	1	2	45	0.5	BEBC		LO	[Nucl.Phys. B132 (1978) 249]
1	1	3	500	1.8	OR		LO	[Phys.Rev. D17 (1978) 3003]
1	1	4	470	5	BEP		LO	[Z. Phys. C2 (1979) 265]
1	1	5	400	4	GHR		LO	[Z. Phys. C13 (1982) 119]
1	1	6	200	4	DO Set 1		LO	[Phys.Rev. D30 (1984) 49]
1	1	7	400	4	DO Set 2		LO	
1	1	8	200	5	EHLQ Set 1		LO	[Rev.Mod. Phys. 56 (1984) 579;
1	1	9	290	5	EHLQ Set 2		LO	Rev.Mod. Phys. 58 (1985) 1065]
1	1	10	177	4	DO Set 1.1		LO	[Phys.Lett. 266B (1991) 126]
1	2	1	200	10	DFLM soft valence		LO	[Z. Phys. C39 (1988) 21]
1	2	2	200	10	DFLM hard valence		LO	
1	2	3	200	10	DFLM soft gluon		LO	
1	2	4	200	10	DFLM hard gluon		LO	
1	2	5	200	10	DFLM centr. average		LO	
1	2	6	300	10	DFLM centr. average	DIS	NLL	
1	2	7	160	10	DFLM 160	DIS	NLL	[unpublished]
1	**2**	**8**	**260**	**10**	**DFLM 260**	**DIS**	**NLL**	
1	2	9	360	10	DFLM 360	DIS	NLL	
1	3	1	107	5	MRS 1	$\overline{MS}$	NLL	[Phys.Rev. D37 (1988) 1161]
1	3	2	250	5	MRS 2	$\overline{MS}$	NLL	
1	3	3	178	5	MRS 3	$\overline{MS}$	NLL	
1	3	4	91	5	MRS E	$\overline{MS}$	NLL	[Phys.Lett. 206B (1988) 327]
1	3	5	228	5	MRS B	$\overline{MS}$	NLL	
1	3	6	91	5	MRS E'	$\overline{MS}$	NLL	[Mod.Phys.Lett. A4 (1989) 1135]
1	3	7	228	5	MRS B'	$\overline{MS}$	NLL	
1	3	8	100	5	HMRS E (1.1990)	$\overline{MS}$	NLL	[retracted]
1	3	9	190	5	HMRS B (1.1990)	$\overline{MS}$	NLL	
1	3	10	100	5	HMRS E (3.1990)	$\overline{MS}$	NLL	
1	3	11	190	5	HMRS B (3.1990)	$\overline{MS}$	NLL	
1	3	12	100	5	HMRS E+ (4.1990)	$\overline{MS}$	NLL	[Phys.Lett. 243B (1990) 421]
1	3	13	100	5	HMRS E- (4.1990)	$\overline{MS}$	NLL	
1	3	14	100	5	HMRS E (4.1990)	$\overline{MS}$	NLL	[Phys.Rev. D42 (1990) 798]
1	3	15	190	5	HMRS B (4.1990)	$\overline{MS}$	NLL	
1	3	16	100	5	HMRS B (8.1990)	$\overline{MS}$	NLL	[unpublished]
1	3	17	300	5	HMRS B (8.1990)	$\overline{MS}$	NLL	
1	3	18	190	5	KMRS B- (7.1990)	$\overline{MS}$	NLL	[Phys.Rev. D42 (1990) 3645]
1	3	19	190	5	KMRS B-R2 Sha. (7.90)	$\overline{MS}$	NLL	
1	3	20	190	5	KMRS B-R5 Sha. (7.90)	$\overline{MS}$	NLL	
1	3	21	190	5	KMRS B0-190 (7.1990)	$\overline{MS}$	NLL	
1	3	22	135	5	MRS B0-135 (10.1990)	$\overline{MS}$	NLL	[Phys.Rev. D43 (1991) 3648]
1	3	23	160	5	MRS B0-160 (10.1990)	$\overline{MS}$	NLL	
1	3	24	200	5	MRS B0-200 (10.1990)	$\overline{MS}$	NLL	
1	3	25	235	5	MRS B0-235 (10.1990)	$\overline{MS}$	NLL	
1	3	26	215	5	MRS S0 (4.1992)	$\overline{MS}$	NLL	[retract.-Phys.Rev.D47 (1993) 867]
1	3	27	215	5	MRS D0 (4.1992)	$\overline{MS}$	NLL	
1	3	28	215	5	MRS D- (4.1992)	$\overline{MS}$	NLL	
1	3	29	230	5	MRS S0' (11.1992)	$\overline{MS}$	NLL	[Phys.Lett. 306B (1993) 145]
1	3	30	230	5	MRS D0' (11.1992)	$\overline{MS}$	NLL	
1	3	31	230	5	MRS D-' (11.1992)	$\overline{MS}$	NLL	
1	3	32	230	5	MRS S0' (11.1992)	DIS	NLL	
1	3	33	230	5	MRS D0' (11.1992)	DIS	NLL	
1	3	34	230	5	MRS D-' (11.1992)	DIS	NLL	
1	3	35	230	5	MRS (H) (11.1993)	$\overline{MS}$	NLL	[RAL-93-077 (1993)]
1	3	36	230	5	MRS (H) (11.1993)	DIS	NLL	
1	3	37	230	5	MRS (A) (05.1994)	$\overline{MS}$	NLL	[Phys.Rev. D50 (1994) 6734]
1	3	38	230	5	MRS (A) (05.1994)	$\overline{MS}$	NLL	(Parametrisation of MRS (A))
1	3	39	230	5	MRS (Ap) (02.1995)	$\overline{MS}$	NLL	[Phys.Lett. 354B (1995) 155]
1	3	40	231	5	MRS (Ap) (02.1995)	$\overline{MS}$	NLL	(Parametrisation of MRS (Ap))

Table 1: List of available sets of NUCLEON structure functions in PDFLIB version 7.09

Nptype	Ngroup	Nset	$\Lambda^{[4]}_{QCD}$	Q^2_{min}	Name of set			Reference
1	**3**	**41**	**255**	**5**	**MRS (G) (02.1995)**	$\overline{\mathbf{MS}}$	**NLL**	[RAL-95-021 (1995)]
1	3	42	255	5	MRS (G) (02.1995)	$\overline{MS}$	NLL	(Parametrisation of MRS (G))
1	3	43	230	0.625	MRS (A) low Q^2 (05.1995)	$\overline{MS}$	NLL	[Phys.Rev. D51 (1995) 4756]
1	3	44	230	0.625	MRS (A) low Q^2 (05.1995)	DIS	NLL	
1	3	45	150	5	MRS (Ap-150) (02.1995)	$\overline{MS}$	NLL	[Phys.Lett. 356B (1995) 89]
1	3	46	201	5	MRS (Ap-201) (02.1995)	$\overline{MS}$	NLL	
1	3	47	266	5	MRS (Ap-266) (02.1995)	$\overline{MS}$	NLL	
1	3	48	344	5	MRS (Ap-344) (02.1995)	$\overline{MS}$	NLL	
1	3	49	435	5	MRS (Ap-435) (02.1995)	$\overline{MS}$	NLL	
1	3	50	542	5	MRS (Ap-542) (02.1995)	$\overline{MS}$	NLL	
1	3	51	344	5	MRS (J) (05.1996)	$\overline{MS}$	NLL	[Phys.Lett. 381B (1996) 89]
1	3	52	507	5	MRS (Jp) (05.1996)	$\overline{MS}$	NLL	
1	3	53	241	1.25	MRS (R1) (05.1996)	$\overline{MS}$	NLL	[DTP/96/44 (1996)]
1	3	54	344	1.25	MRS (R2) (05.1996)	$\overline{MS}$	NLL	
1	3	55	241	1.25	MRS (R3) (05.1996)	$\overline{MS}$	NLL	
1	3	56	344	1.25	MRS (R4) (05.1996)	$\overline{MS}$	NLL	
1	3	57	241	2	MRS (R1) (05.1996)	$\overline{MS}$	NLL	(Parametrisation of MRS (R1))
1	3	58	344	2	MRS (R2) (05.1996)	$\overline{MS}$	NLL	(Parametrisation of MRS (R2))
1	4	1	212	4	MT S1	DIS	NLL	[retract. - Z. Phys. C52 (1991) 13]
1	4	2	194	4	MT B1	DIS	NLL	
1	4	3	191	4	MT B2	DIS	NLL	
1	4	4	155	4	MT E1	DIS	NLL	
1	4	5	237	4	MT 6 (1/2s)	DIS	NLL	
1	4	6	212	4	MT S1	$\overline{MS}$	NLL	
1	4	7	194	4	MT B1	$\overline{MS}$	NLL	
1	4	8	191	4	MT B2	$\overline{MS}$	NLL	
1	4	9	155	4	MT E1	$\overline{MS}$	NLL	
1	4	10	237	4	MT 6 (1/2s)	$\overline{MS}$	NLL	
1	4	11	144	4	MT LO		LO	
1	4	12	168	4	CTEQ 1L		LO	[retracted]
1	4	13	231	4	CTEQ 1M	$\overline{MS}$	NLL	
1	4	14	231	4	CTEQ 1MS	$\overline{MS}$	NLL	
1	4	15	322	4	CTEQ 1ML	$\overline{MS}$	NLL	
1	4	16	247	4	CTEQ 1D	DIS	NLL	
1	4	17	190	4	CTEQ 2L		LO	[retracted]
1	4	18	213	4	CTEQ 2M	$\overline{MS}$	NLL	
1	4	19	208	4	CTEQ 2MS	$\overline{MS}$	NLL	
1	4	20	208	4	CTEQ 2MF	$\overline{MS}$	NLL	
1	4	21	322	4	CTEQ 2ML	$\overline{MS}$	NLL	
1	4	22	235	4	CTEQ 2D	DIS	NLL	
1	4	23	190	4	CTEQ 2pL		LO	[to be published]
1	**4**	**24**	**213**	**4**	**CTEQ 2pM**	$\overline{\mathbf{MS}}$	**NLL**	
1	4	25	208	4	CTEQ 2pMS	$\overline{MS}$	NLL	
1	4	26	208	4	CTEQ 2pMF	$\overline{MS}$	NLL	
1	4	27	322	4	CTEQ 2pML	$\overline{MS}$	NLL	
1	4	28	235	4	CTEQ 2pD	DIS	NLL	
1	4	29	177	4	CTEQ 3L		LO	[MSUHEP-41024]
1	4	30	239	4	CTEQ 3M	$\overline{MS}$	NLL	
1	4	31	247	4	CTEQ 3D	DIS	NLL	
1	4	32	235	2.56	CTEQ 4L		LO	[MSUHEP-60426, CTEQ-604]
1	4	33	296	2.56	CTEQ 4D	DIS	NLL	
1	**4**	**34**	**296**	**2.56**	**CTEQ 4M**	$\overline{\mathbf{MS}}$	**NLL**	
1	4	35	213	2.56	CTEQ 4A1	$\overline{MS}$	NLL	
1	4	36	253	2.56	CTEQ 4A2	$\overline{MS}$	NLL	
1	4	37	296	2.56	CTEQ 4A3	$\overline{MS}$	NLL	
1	4	38	344	2.56	CTEQ 4A4	$\overline{MS}$	NLL	
1	4	39	399	2.56	CTEQ 4A5	$\overline{MS}$	NLL	
1	4	40	302	2.56	CTEQ 4HJ	$\overline{MS}$	NLL	
1	4	41	259	0.49	CTEQ 4lQ	$\overline{MS}$	NLL	

Table 2: List of available sets of NUCLEON structure functions, cont'd

Nptype	Ngroup	Nset	$\Lambda^{[4]}_{QCD}$	Q^2_{min}	Name of set			Reference
1	5	1	160	0.2	old GRV HO	$\overline{MS}$	NLL	[retracted]
1	5	2	220	0.2	old GRV LO		LO	
1	5	3	200	0.3	GRV HO	$\overline{MS}$	NLL	[Z. Phys. C53 (1992) 127]
1	5	4	200	0.25	GRV LO		LO	
1	5	5	200	0.4	GRV 94 LO		LO	
1	**5**	**6**	**200**	**0.4**	**GRV 94 HO**	$\overline{\mathbf{MS}}$	**NLL**	[Z. Phys. C67 (1995) 433]
1	5	7	200	0.4	GRV 94 HO	DIS	NLL	
1	5	8	200	0.4	GRSV pol. LO standard		LO	[Phys.Lett. 359B (1995) 201]
1	5	9	200	0.4	GRSV pol. LO valence		LO	
1	5	10	200	0.4	GRSV pol. HO standard	$\overline{MS}$	NLL	[Phys.Rev. D53 (1996) 4775]
1	5	11	200	0.4	GRSV pol. HO valence	$\overline{MS}$	NLL	
1	6	1	230	2	ABFOW	$\overline{MS}$	NLL	[Phys.Rev. D39 (1989) 3275]
1	7	1	254	5	BM set A	$\overline{MS}$	NLL	[Phys.Lett. 304B (1993) 318;
1	7	2	254	5	BM set B	$\overline{MS}$	NLL	CERN-TH 6739/92 (1992)]

Table 3: List of available sets of NUCLEON structure functions, cont'd

A summary of all parton density functions of the **nucleon** available in the package can be found in Tables 1, 2 and 3.

1.3. Structure Functions of the Pion

There is also a limited number of parton density functions of the **pion** available. These are the set to leading order evolutions of

- Owens (OW)[29] , sets 1 and 2,

and the next-to-leading order evolutions of

- Aurenche et al. (ABFKW-P)[30] , sets 1, 2 and 3,
- Sutton, Martin, Roberts and Stirling (SMRS-P)[31] sets 1, 2 and 3, and
- Glück, Reya and Vogt (GRV-P)[32] , the LO and NLL sets.

A summary of all parton density functions of the **pion** available in the package can be found in Table 4.

Nptype	Ngroup	Nset	$\Lambda^{[4]}_{QCD}$	Q^2_{min}	Name of set			Reference
2	1	1	200	4	OW-P Set 1		LO	[Phys.Rev. D30 (1984) 943]
2	1	2	400	4	OW-P Set 2		LO	
2	3	1	190	5	SMRS-P 1	$\overline{MS}$	NLL	[Phys.Rev. D45 (1992) 2349]
2	**3**	**2**	**190**	**5**	**SMRS-P 2**	$\overline{\mathbf{MS}}$	**NLL**	
2	3	3	190	5	SMRS-P 3	$\overline{MS}$	NLL	
2	**5**	**1**	**200**	**0.3**	**GRV-P HO**	$\overline{\mathbf{MS}}$	**NLL**	[Z. Phys. C53 (1992) 651]
2	5	2	200	0.25	GRV-P LO		LO	
2	**6**	**1**	**231**	**2**	**ABFKW-P Set 1**	$\overline{\mathbf{MS}}$	**NLL**	[Phys.Lett. 233B (1989) 517]
2	6	2	181	2	ABFKW-P Set 2	$\overline{MS}$	NLL	
2	6	3	281	2	ABFKW-P Set 3	$\overline{MS}$	NLL	

Table 4: List of available sets of PION structure functions in PDFLIB version 7.09

1.4. Structure Functions of the Photon

In addition there are also a few parton density functions of the **photon** available. These are the leading order evolutions of

- Duke and Owens (DO-G) (and the NLL)[33] using an asymptotic solution of the Altarelli-Parisi equation,
- Drees and Grassie (DG-G)[34] sets 1 to 4 using a full solution of the Altarelli-Parisi equation,
- Abramowicz, Charchula and Levy (LAC-G)[35] sets 1 to 3 using a full solution of the Altarelli-Parisi equation,

and of

- Watanabe, Hagiwara, Izubuchi and Tanaka (WHIT1 to WHIT6)[36] ,

and the next-to-leading order evolutions of

- Gordon and Storrow (GS-G)[37] , the LO sets 1 and 2 and the NLL set,
- Glück, Reya and Vogt (GRV-G)[38] , the LO, NLL and the leading term of the NLL sets,
- Aurenche et al. (ACFGP-G)[39] , sets 1 and 2, without and with massive charm,

and finally

- the LO and NLL sets of Aurenche, Fontannaz and Guillet, (AFG-G).[40]

Recently new sets of of the parton densities of the photon have been come out:

- Schuler and Sjostrand (SaS-G)[41] ,
- the new sets of Glück, Reya and Stratmann (GRG-G)[42] ,

and

- the new sets of Gordon and Storrow (GS-G).[43]

A summary of all parton density functions of the **photon** available in the package can be found in Table 5.

1.5. The Library PDFLIB

We have put together all these different sets of parton density functions in **one single package** called PDFLIB.[45] This library PDFLIB can be found in and obtained from the CERN Computer Program Library under the registration number W5051.

Please notice that the use of the PDFLIB library does not prevent to consult the publications of the different authers, which can be found in the bibliography of this manual, for

Nptype	Ngroup	Nset	$\Lambda^{[4]}_{QCD}$	Q^2_{min}	Name of set			Reference
3	1	1	380	10	DO-G Set 1		LO	[Phys.Rev. D26 (1982) 1600]
3	**1**	**2**	**440**	**10**	**DO-G Set 2**	$\overline{\mathbf{MS}}$	**NLL**	
3	**2**	**1**	**400**	**1**	**DG-G Set 1**		**LO**	[Z.Phys. C28 (1985) 451]
3	2	2	400	1	DG-G Set 2		LO	
3	2	3	400	10	DG-G Set 3		LO	
3	2	4	400	200	DG-G Set 4		LO	
3	**3**	**1**	**200**	**5**	**LAC-G Set 1**		**LO**	[Phys.Lett. 269B (1991) 458]
3	3	2	200	5	LAC-G Set 2		LO	
3	3	3	200	5	LAC-G Set 3		LO	
3	4	1	200	5.3	GS-G HO	$\overline{MS}$	NLL	[Z.Phys. C56 (1992) 307]
3	4	2	200	5.3	GS-G LO set 1		LO	
3	4	3	200	5.3	GS-G LO set 2		LO	
3	**4**	**4**	**200**	**5.3**	**GS-G-96 HO**	$\overline{\mathbf{MS}}$	**NLL**	[ANL-HEP-PR-96-33]
3	4	5	200	5.3	GS-G-96 LO		LO	
3	5	1	200	0.3	GRV-G lHO	DIS*)	NLL	[Phys.Rev. D46 (1992) 1973;
3	5	2	200	0.3	GRV-G HO	DIS*)	NLL	Phys.Rev. D45 (1992) 3986]
3	5	3	200	0.25	GRV-G LO		LO	
3	**5**	**4**	**200**	**0.6**	**GRS-G LO**		**LO**	[Phys.Rev. D51 (1995) 3220]
3	6	1	200	2	ACFGP Set HO	$\overline{MS}$	NLL	[Z.Phys. C56 (1992) 589]
3	6	2	200	2	ACFGP Set HO-mc	$\overline{MS}$	NLL	
3	**6**	**3**	**200**	**2**	**AFG-G Set HO**	$\overline{\mathbf{MS}}$	**NLL**	[Z. Phys. C64 (1994) 621]
3	8	1	400	4	WHIT-G 1		LO	[Phys.Rev. D51 (1995) 3197]
3	8	2	400	4	WHIT-G 2		LO	
3	8	3	400	4	WHIT-G 3		LO	
3	8	4	400	4	WHIT-G 4		LO	
3	8	5	400	4	WHIT-G 5		LO	
3	8	6	400	4	WHIT-G 6		LO	
3	9	1	200	0.36	SaS-G 1D (Version 1)		LO	[Z.Phys. C68 (1995) 607]
3	9	2	200	0.36	SaS-G 1M (Version 1)		LO	
3	9	3	200	4	SaS-G 2D (Version 1)		LO	
3	9	4	200	4	SaS-G 2M (Version 1)		LO	
3	9	5	200	0.36	SaS-G 1D (Version 2)		LO	[Phys.Lett. 376B (1996) 193]
3	9	6	200	0.36	SaS-G 1M (Version 2)		LO	
3	9	7	200	4	SaS-G 2D (Version 2)		LO	
3	9	8	200	4	SaS-G 2M (Version 2)		LO	

*) not standard, please consult references.

Table 5: List of available sets of PHOTON structure functions in PDFLIB version 7.09

details about each parton density function.

We have modified the sets such that **no** external data files for the grids have to be read in anymore. All these structure function sets have been combined in a consistent way such that they all appear in an **identical structure** to the user. The selection is made via **three** parameters, NPTYPE, NGROUP and NSET, which identify a PDF set by its **particle type** (Nucleon: NPTYPE = 1, Pion: NPTYPE = 2, Photon: NPTYPE = 3), its **author group** (f.ex. MRS: NGROUP = 3) and its **PDF set within the group** (NSET = 1, 2, 3, etc.). These parameters should be set with a call to subroutine PDFSET at the initialization phase. A simple SUBROUTINE call, which is **identical** for all applications (nucleons, pions and photons), returns the parton densities for all partons (u, d, s, c, b, t, gluon and their antiquarks) at a given X value (where X is the fraction of the longitudinal momentum carried by the parton) and the Q-scale SCALE (in GeV). A **default** set has been prepared, although those preferring their **own private** set or wanting to test a **new** one may do so within the package. Error control can be obtained by setting a print flag to obtain output either during execution and/or as a summary at job termination via a call to the subroutine PDFSTA.

The source code of the different parton density sets has been modified in such a way that the library can be used on all the different computer systems known today. Full backward compatibility will always be assured. PDFLIB has been run under different operating systems like *VM/CMS, VAX/VMS and ULTRIX* without problems. The library has been tested on the different system areas to ensure identical results within the given machine precision. The program has been run and tested on the following computers: *IBM 3090, VAX, IBM-RISC, DECS, SUN, APOLLO, HP-UX, Silicon Graphics, CDC, CRAY, IBM-PC.* The programming language is FORTRAN 77. The actual source code manager system used is CVS. The required memory storage including testprograms and some documentation is about 25 Mbytes. The latest edition (July 1997) is version 7.09 and can be requested from the CERN Computer Program Library. To run PDFLIB a link to the CERN library (PACKLIB, MATHLIB and KERNLIB) is required.

1.6. Calculations of the Strong Coupling Constant α_s

Within the **same package** a program is also provided to calculate the **strong coupling constant** α_s to second order (default) or to first order (by user's choice). The **correct $\mathbf{\Lambda_{QCD}}$** associated to the selected set of structure functions and the number of allowed flavours with respect to the give Q^2 is automatically used in the calculation. For those structure functions where the evolution has been performed to leading order only, the α_s value to first order is returned.

2. Application of the Parton Densities Package PDFLIB

In the following the use of and the access to the PDFLIB package is described.

2.1. Parameter Setting and Selection of Sets

To access his/her preferred set of structure functions the user must define the **three** parameters, NPTYPE, NGROUP and NSET, which identify each set of parton density functions, via a call to the subroutine

CALL PDFSET(PARM,VALUE)

at the initialisation phase of his/her MAIN program, or may use the package as a 'black box' with the default values (see below). An example of the application of PDFLIB is given in the appendix. The arguments PARM and VALUE are **vectors** of **dimension 20** and have the following meaning

PARM(I)	=	character*20 variable, which defines in any order the variables 'NPTYPE', 'NGROUP', 'NSET', 'MODE', 'INIT0', 'NFL', 'LO', 'TMAS', 'QCDL4', 'QCDL5' and 'XMIN', 'XMAX', 'Q2MIN', 'Q2MAX'
VALUE(I)	=	the corresponding numerical value of the variable PARM(I) (TMAS, QCDL4, QCDL5, XMIN, XMAX, Q2MIN and Q2MAX are DOUBLE PRECISION variables),

where

NPTYPE	=	number of particle type ranging from 1 to 3 (Nucleons: NPTYPE = 1, Pions: NPTYPE = 2, Photons: NPTYPE = 3) (Default: NPTYPE = 1)
NGROUP	=	number of author group ranging from 1 to 9 (Default: NGROUP = 3)
NSET	=	number of a selected structure function set within the author group ranging from 1 to 58 (Default: NSET = 41)
(MODE	=	number of a selected structure function set ranging from 0 to 281 - **old** format !! -) (Default: MODE = 45)
INIT0	=	in case of PARM(1) = 'INIT0' PDFSET fills as the only action the COMMON blocks /W505110/, /W505120/, /W505121/ and /W505122/
NFL	=	desired number of flavours in the α_s calculation ranging from 3 to 6 (Default: NFL = 5)
LO	=	order of α_s calculation; if LO = 1, α_s is calculated to first order only (Default: LO = 2)
TMAS	=	the user defined value of the top-quark mass in GeV/c^2 (optional) (Default: TMAS = 180.0D0)
QCDL4	=	QCD scale, $\Lambda^{[4]}_{QCD}$, in GeV for four flavours
QCDL5	=	QCD scale, $\Lambda^{[5]}_{QCD}$, in GeV for five flavours corresponding to QCDL4

and

XMIN	=	minimal allowed x value
XMAX	=	maximal allowed x value
Q2MIN	=	minimal allowed Q^2 value (in $(GeV/c)^2$)
Q2MAX	=	maximal allowed Q^2 value (in $(GeV/c)^2$)

for each set of structure functions.

Please note that PDFSET can be called as often as the user likes. In order to redefine the parameters to select other sets of structure functions which the user wants to investigate it might be necessary to call PDFSET in an alternating way, but it is always mandatory to transfer either the **three** parameters, NPTYPE, NGROUP, NSET, or the 'NAME' of the author group with their corresponding VALUE values. The subroutine PDFSET fills the **internal** COMMON blocks

COMMON/W50511/ NPTYPE,NGROUP,NSET,MODE,NFL,LO,TMAS
COMMON/W50512/ QCDL4,QCDL5
COMMON/W50513/ XMIN,XMAX,Q2MIN,Q2MAX

at the time the routine is called. Please note that in case of a multiple call to PDFSET with fewer parameters redefined than in a preceeding call, always the last parameters are kept in memory. All variables of the three COMMON blocks can be automatically printed at job initialisation by setting the print flag IFLPRT in the COMMON block COMMON/W50510/ IFLPRT to IFLPRT = 2.

The program is protected against calculations of Q^2 values below Q2MIN (in this case Q^2 = Q2MIN) and of X values in unphysical regions ($X < 0$ or $X > 1$). The execution of the program is stopped in the later case. To control how often the X or Q^2 ranges have been exceeded during execution of the user's program a call to the subroutine

CALL PDFSTA

at the termination phase of his/her MAIN program allows to print a summary of these errors. The print flag in the COMMON/W50510/IFLPRT may be set to IFLPRT = 3 to print an error message **each time** a limit has been exceeded during job execution. Please note that this may produce an **enormous amount of output!**

2.2. The Calling Sequence: PDFLIB Format

The main steering routine for a set of structure functions is accessed as follows:

CALL STRUCTM(X,SCALE,UPV,DNV,USEA,DSEA,STR,CHM,BOT,TOP,GL)

Please note that all variables are defined as **DOUBLE PRECISION**. The user has to provide the following INPUTs:

X	=	x value of parton
SCALE	=	QCD scale in GeV

The subroutine STRUCTM returns the following OUTPUT:

UPV	=	up valence quark
DNV	=	down valence quark
USEA	=	sea ($\overline{up}$)
DSEA	=	sea ($\overline{down}$)
STR	=	strange quark
CHM	=	charm quark
BOT	=	bottom quark
TOP	=	top quark
GL	=	gluon

In case $\overline{up}$ is not given separately from $\overline{down}$ it is set USEA = DSEA.

The recommended set of structure functions from the different authors is put in bold characters. If NSET is set to zero (or if any of the parameters, NPTYPE, NGROUP or NSET, is undefined) **one default set** is selected which is always the Nucleon parton densities, the set of MRS set G (NPTYPE = 1, NGROUP = 3, NSET = 41), also in case of NPTYPE = Pion or Photon.

Please note that in any of the calling sequences for the nucleon, the pion and the photon it is always returned **X × parton distribution function !**

2.3. The Calling Sequence: PDG Format

To allow the use of the package with the flavour code convention of the Particle Data Group (PDG) an interface has been written which translates the PDFLIB format (see Section 2.2) into the PDG format. Instead of calling the subroutine STRUCTM the user preferring the flavour code convention of the PDG accesses the package via a call to the subroutine

CALL PFTOPDG(X,SCALE,DXPDF).

All variables are defined as **DOUBLE PRECISION** as before, and X and SCALE are INPUTs provided by the user with the same meaning as before.

The subroutine PFTOPDG outputs a vector DXPDF(-6:6) of which its variables have the following meaning:

DXPDF(0)	=	gluon
DXPDF(1)	=	down valence quark + $\overline{down}$ sea
DXPDF(2)	=	up valence quark + $\overline{up}$ sea
DXPDF(3)	=	strange quark
DXPDF(4)	=	charm quark
DXPDF(5)	=	bottom quark
DXPDF(6)	=	top quark
and DXPDF(-1)	to	DXPDF(-6) are the corresponding antiquarks.

DXPDF(-1) = DXPDF(-2) stands for $\overline{down} = \overline{up}$ or $(\overline{down} + \overline{up})/2$ in allmost all parametrisations. In case where $\overline{down} \neq \overline{up}$ DXPDF(-1) = $\overline{down}$ and DXPDF(-2) = $\overline{up}$. In all sets is DXPDF(3) = DXPDF(-3), DXPDF(4) = DXPDF(-4), DXPDF(5) = DXPDF(-5) and DXPDF(6) = DXPDF(-6) so far.

2.4. Error Handling

A note of caution should be addressed here. All structure functions are limited in X and Q^2 which range for most of the sets from

$$4 - 10 < Q^2 < 10^6 - 10^8\ (GeV/c)^2$$
$$10^{-5} - 10^{-4} < \mathrm{X} < 1.$$

If the user wants to extend the X or Q^2 ranges, it is possible for some of the structure function sets, but the result should be looked at with great caution. If in doubt, please check with the authors of the structure function set. The program is protected against calculations of Q^2 values below Q2MIN (in this case Q^2 = Q2MIN) and of X values in unphysical regions ($X < 0$ or $X > 1$). The execution of the program is stopped in the later case.

A COMMON block can be accessed

COMMON/W50513/ XMIN,XMAX,Q2MIN,Q2MAX

where

XMIN	=	minimal allowed x value
XMAX	=	maximal allowed x value
Q2MIN	=	minimal allowed Q^2 value (in $(GeV/c)^2$)
Q2MAX	=	maximal allowed Q^2 value (in $(GeV/c)^2$)

is given for each set of structure functions. To control how often the x or Q^2 ranges have been exceeded during execution of the user's program a call to the subroutine

CALL PDFSTA

at the termination phase of his/her MAIN program allows to print a summary of these errors. If the COMMON block

COMMON/W50514W/ PDFWGT

where

PDFWGT = weight

is filled by the user on an event-to-event basis the statistics in the error summary takes into account this weight.

The print flag in the COMMON/W50510/IFLPRT may be set to IFLPRT = 3 to print an error message **each time** a limit has been exceeded during job execution. Please note that this may produce an **enormous amount of output!**

2.5. Features

If NPTYPE = 1, NGROUP = 1 and NSET = 1, the user has the possibility to use his/her own **private set** of structure functions (i.e. the CDHS effective structure functions could be inserted here, or the user could implement a new set of structure functions for testing purposes). To insert the private set the DUMMY subroutine

SUBROUTINE STRPRIV(X,SCALE,UPV,DNV,USEA,DSEA,STR,CHM,BOT,TOP,GL)

should be activated by the user. All variables have to be defined as DOUBLE PRECISION. The variables have the same meaning as described for the subroutine STRUCTM in Section 2.2 (for explanations see there).

For the calculation of the strong coupling constant α_s (see Section 4) with the user's private set of structure functions the user should provide a value for the variables QCDL4 and QCDL5 via the subroutine PDFSET at the initialisation phase. In fact, because only the parameter QCDL5 is used in the α_s calculation, only this definition is mandatory.

2.6. How to find PDFLIB

At CERN the PDFLIB library and corresponding documentation are available on all systems in the standard areas.

System	**Library**
VXCERN	CERN:[NEW.LIB]PDFLIB.OLB
Unix systems	/cern/new/lib/libpdflib.a

At CERN on Unix systems the package may be accessed via the 'cernlib' command:

\ *'cernlib pdflib packlib mathlib kernlib'* \

All necessary information about PDFLIB can also be found on the World Wide Web via the path 'CERN.Computing.CERNLIB.documentation' or directly as

for the flat version :	http://wwwcn.cern.ch/asdoc/pdflib/pdflib.html
or for the PostScript version :	http://wwwcn.cern.ch/asdoc/psdir/pdflib.ps.gz .

The source code of PDFLIB may be obtained from asisftp.cern.ch via anonymous ftp with:

get	/cernlib/share/new/src/mclibs/pdf	or
get	/cernlib/share/new/src/mclibs/pdf.tar	or
get	/cernlib/share/new/src/mclibs/pdf.tar.gz	

even, if the last two files are not visible via the command 'ls'.

Whenever you use this program, please give reference to the following papers:

H. Plothow-Besch, *'The Parton Distribution Function Library'*,
Int. J. Mod. Phys. A10 (1995) 2901-2920.

and/or

H. Plothow-Besch, *'PDFLIB: A Library of all available Parton Density Functions of the Nucleon, the Pion and the Photon and the corresponding α_s Calculations'*,
Comp. Phys. Comm. 75 (1993) 396-416.

and/or

H. Plothow-Besch, *'PDFLIB: Structure Functions and α_s Calculations'*,
User's Manual - Version 1.00, W5051 PDFLIB, 1991.03.21, CERN-PPE.

and/or

H. Plothow-Besch, *'PDFLIB: Nucleon, Pion and Photon Parton Density Functions and α_s Calculations'*, Users's Manual - Version 7.09, W5051 PDFLIB, 1997.07.02, CERN-PPE.

3. PION and PHOTON Parton Densities

The calling sequences to the **pion** and the **photon** sets of parton densities is kept identical to those described in Sections 2.2 and 2.3 for the nucleon structure functions.

In case of the **pion** structure functions it is set and returned UPV = DNV, SEA = STR (USEA = DSEA = STR) and TOP = 0 (DXPDF(1) = DXPDF(2), DXPDF(3) = DXPDF(-1) = DXPDF(-2) and DXPDF(6) = 0).

In case of the **photon** structure functions it is set and returned UPV = USEA, DNV = DSEA and TOP = 0 (DXPDF(1) = 2 * DXPDF(-1), DXPDF(2) = 2 * DXPDF(-2), as a result of the definitions - see Section 2.3 -, and DXPDF(6) = 0), while all the other quarks are set identical to their antiquark densities. Note that the α_{QED} has to be taken care of by the user !

To take into account the need for more input parameters for parton densities of the photon a **new subroutine** STRUCTP has been added which should be called instead of STRUCTM in case of applications of the photon. Therefore, the main steering routine for a set of structure functions of the photon should now be accessed as follows:

CALL STRUCTP(X,Q2,P2,IP2,UPV,DNV,USEA,DSEA,STR,CHM,BOT,TOP,GL)

Please note that all variables (INPUT and OUTPUT) are defined as **DOUBLE PRECISION**. The user has now to provide the following INPUTs:

X	=	x value of parton
Q2	=	QCD scale in GeV^2
P2	=	virtuality of the photon in GeV^2, should be = 0 for an on-shell photon
IP2	=	parameter to evaluate off-shell anomalous component

The OUTPUT parameters are defined as for STRUCTM (see Section 2.2).

4. α_s Calculation

Within the same package a program is provided to calculate the strong coupling constant α_s to second order as a function of Λ_{QCD} of five flavours and the desired number of flavours (NFL) for the selected set of structure functions, which fixes Λ_{QCD}. The formula on which the calculations are based upon can be found in Ref. [46]. The same three parameters, NTYPE, NGROUP and NSET, which select a structure function set, is used to steer the calculation of the α_s value at a given scale from the Λ_{QCD} defined in the selected structure function.

The value of α_s is matched at the thresholds q = m_q. When invoked with NFL < 0, it chooses NFL as the number of flavours for which the masses are less then q. For the quark masses where thresholds are changed the following values have been used:

$m_{charm} = 1.5\ GeV/c^2$, $m_{bottom} = 4.75\ GeV/c^2$, $m_{top} = 100\ GeV/c^2$.

A call to the function:

FUNCTION ALPHAS2(SCALE),

where the user has to provide as INPUT only the QCD scale in GeV, provides as OUTPUT the value of alpha strong to second order, if LO not equal to one. For those structure functions, for which the evolution is done to leading order only, α_s to first order is returned.

The *internal* COMMON block COMMON/W50512/ QCDL4,QCDL5 with

QCDL4	=	QCD scale, $\Lambda^{[4]}_{QCD}$, in GeV for four flavours
QCDL5	=	QCD scale, $\Lambda^{[5]}_{QCD}$, in GeV for five flavours corresponding to QCDL4

provides the actual value of $\Lambda^{[4]}_{QCD}$ and $\Lambda^{[5]}_{QCD}$ used in the α_s calculation for four and five flavours, respectively, for each set of structure functions.

5. Conclusions

As an example, the **nucleon** structure function distributions at the scale $Q^2 = m_W^2$ for the **up** valence quark is shown in Fig. 1 as a function of the parton X. The average X values for CERN and FNAL as well as for LHC and SSC energies are indicated. It can be seen from that figure that there is a large spread in shape for the different sets leading to different results in a cross section calculation. It should be pointed out that the spread of different parametrisations in the **same** renormalisation scheme is **much larger** than the spread of parametrisations in **different** renormalisation schemes. This is valid for **all** parton densities, and in particular at small X values !

A comparison to recent data is shown in Fig. 2, where the ratio F_2^n/F_2^p at the Q^2 of the experimental points is displayed. Note that the older sets of structure functions, namely the set of Owens and Reya[2] and the set of Baier et al.[3] have only been implemented for completeness. These sets should not be used for cross section calculations of any hard process at high energies anymore. From Fig. 2 we conclude that also the other older sets of structure functions, namely the two sets of Duke and Owens[5] and the two sets of Eichten et al.[6] , should be used with care, because they do not fit the recent low energy deep-inelastic lepton-nucleon data from NMC and BCDMS.[47] This is not surprising because these data were not available when the sets have been made. The new set of DO 1.1[8] superseeds the old DO sets 1 and 2, but still gives very limited results in the low X region, even though data are available there. We conclude that the recent sets of parton densities could be preferred for all theoretical predictions involving structure functions, because they fit the present nucleon data best.

In Fig. 3 the F_2^p distribution of Ref. [48] ($Q^2 = 5\ GeV^2$) together with recent data ($Q^2 = 15\ GeV^2$) from the H1 and the ZEUS experiments[49] at the ep-collider HERA is shown as a function of X. Overlayed on the same Figure are theoretical predictions of more recent parton parametrisations[12–16] at $Q^2 = 15\ GeV^2$. Please note that most of these parametrisations are **not true** predictions because the data are fully or partially used in the fits. From Figs. 2 and 3 we conclude that the recent sets of parton densities, namely the GRV set HO[14] , but also the old MT set B2[13] - both sets are true predictions - , and the updated MRS set H[16] , could be preferred for all theoretical predictions involving nucleon structure functions, because they fit the present data best which, at the moment, are still suffering from large uncertainties.

Figure 4 shows a comparison of F_2^γ/α_{QED} at $Q^2 = 100\ GeV^2$ of the different **photon** structure function sets as a function of X. The charm quark density has been taken into account. The theoretical predictions are compared with experimental data from the JADE experiment[50] at the same Q^2 value. Because of large experimental uncertainties no distinction between the different parton density sets can be made yet.

The response from the Physics community has been very satisfactory, which is encouraging us to keep up-to-date with the latest developments in this area. Therefore, please **continue sending your feedback on the usage and possible improvements to us.** Coming new sets of structure functions should be easily implemented in the package. Authors of **new sets** are kindly asked to **provide us** with the **relevant information. Please return any problems, questions, suggestions for improvements to the author of the package** (e-mail address: plothow@mail.cern.ch).

6. Acknowledgements

The author of the package would like to thank M.A. Marquina/CERN-CN for help and support, making this package available to the Physics community as part of the CERN Program Library. In addition, we would like to give many thanks to G. Folger/CERN-CN and to I. McLaren/CERN-CN for thoroughly testing out the package on the different system areas.

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And finally, we acknowledge K. Charchula/DESY who provided the source code of some of the photon structure functions which had previously been implemented in the package.

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see also to References therein.

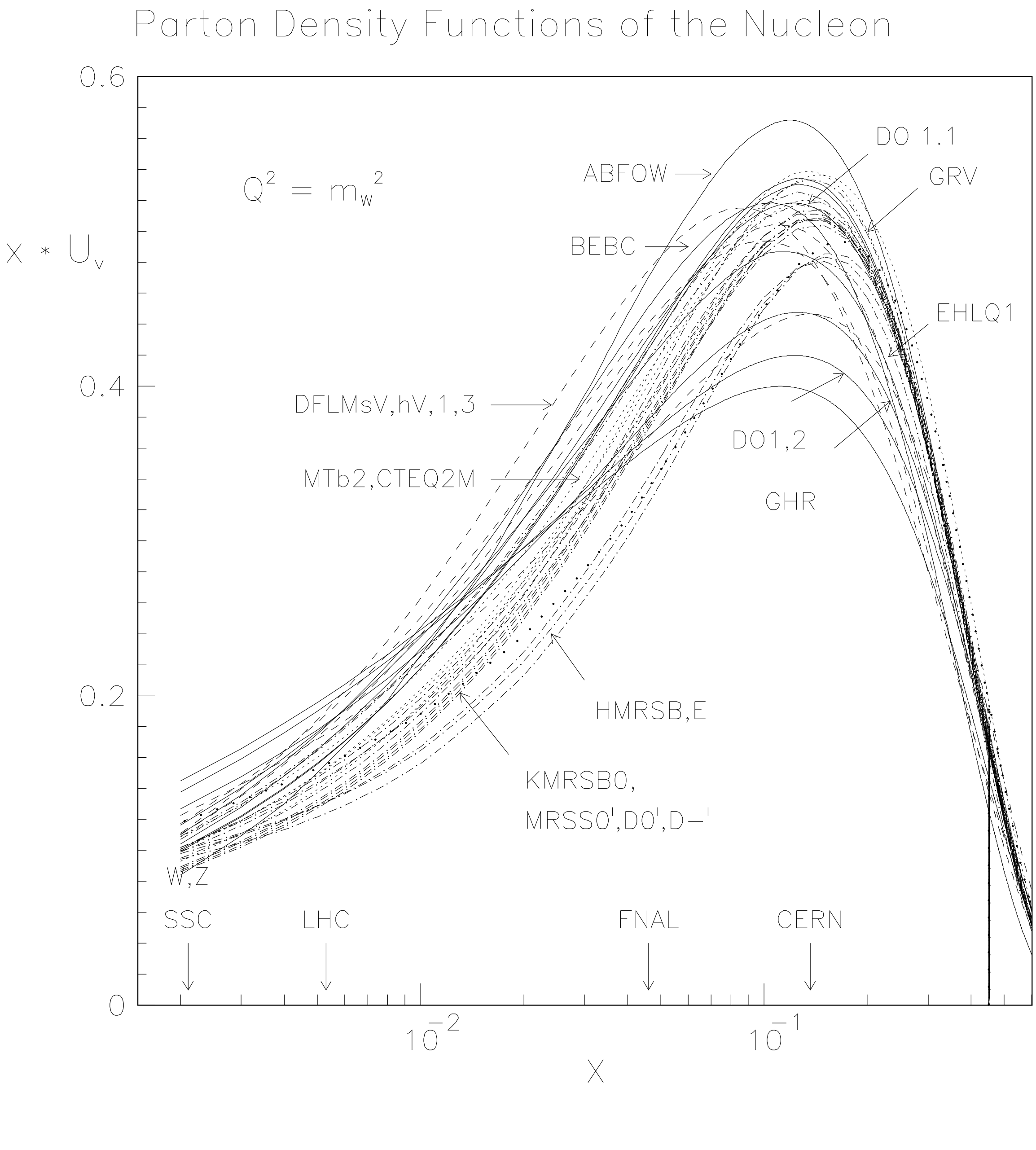

Figure 1: u valence quark distribution as a function of X

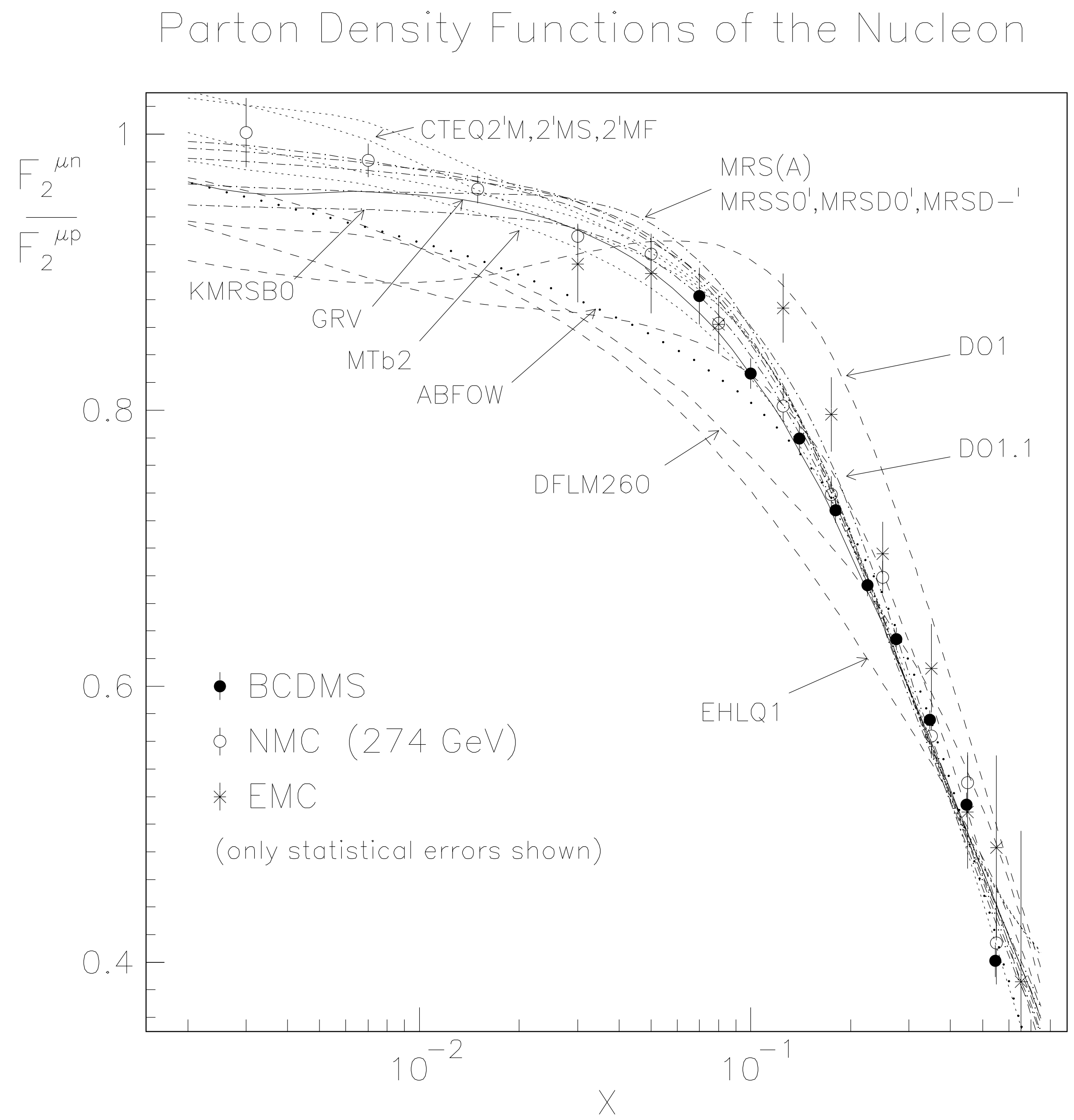

Figure 2: F_2^n/F_2^p ratio as a function of X

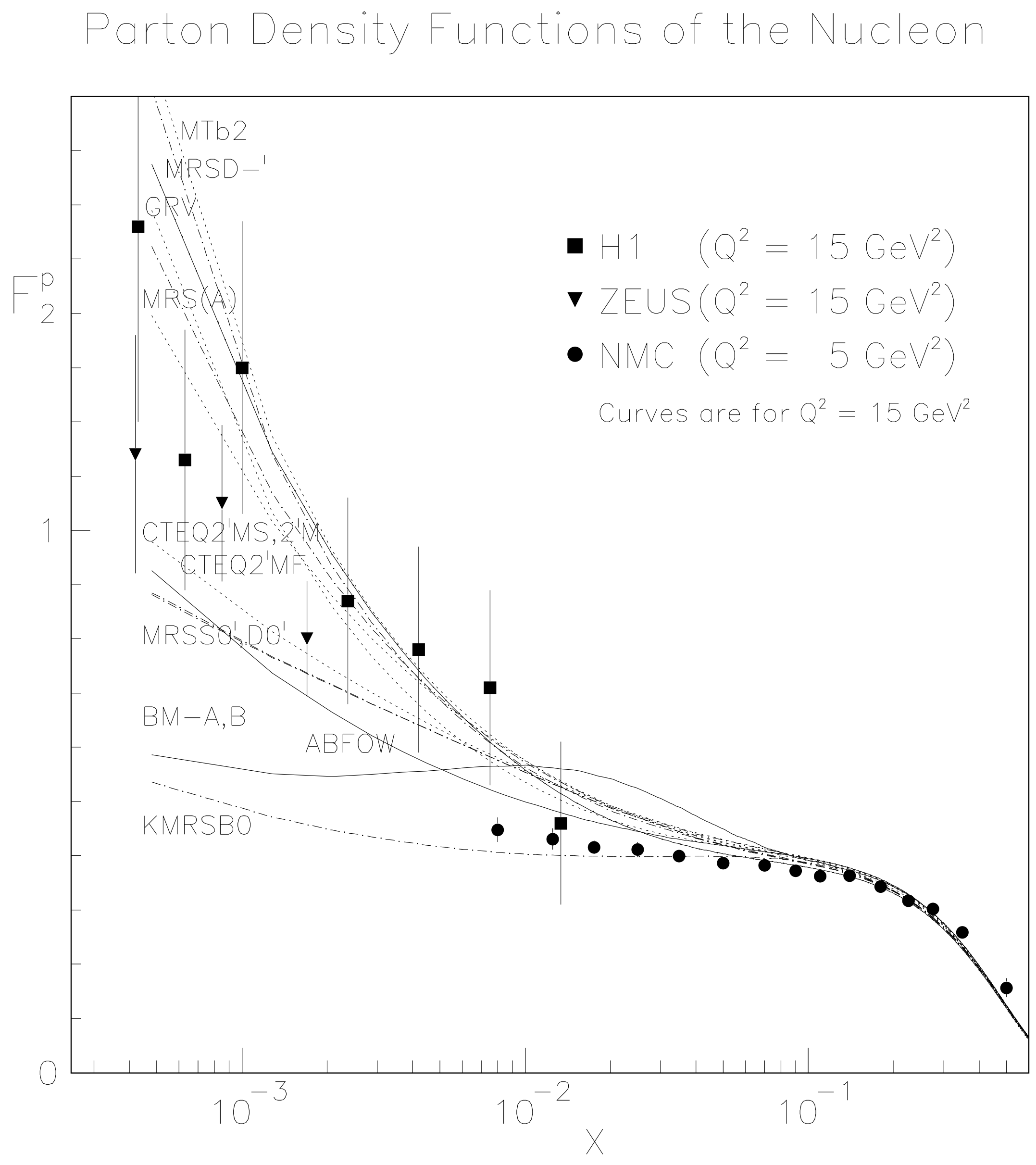

Figure 3: F_2^p as a function of X

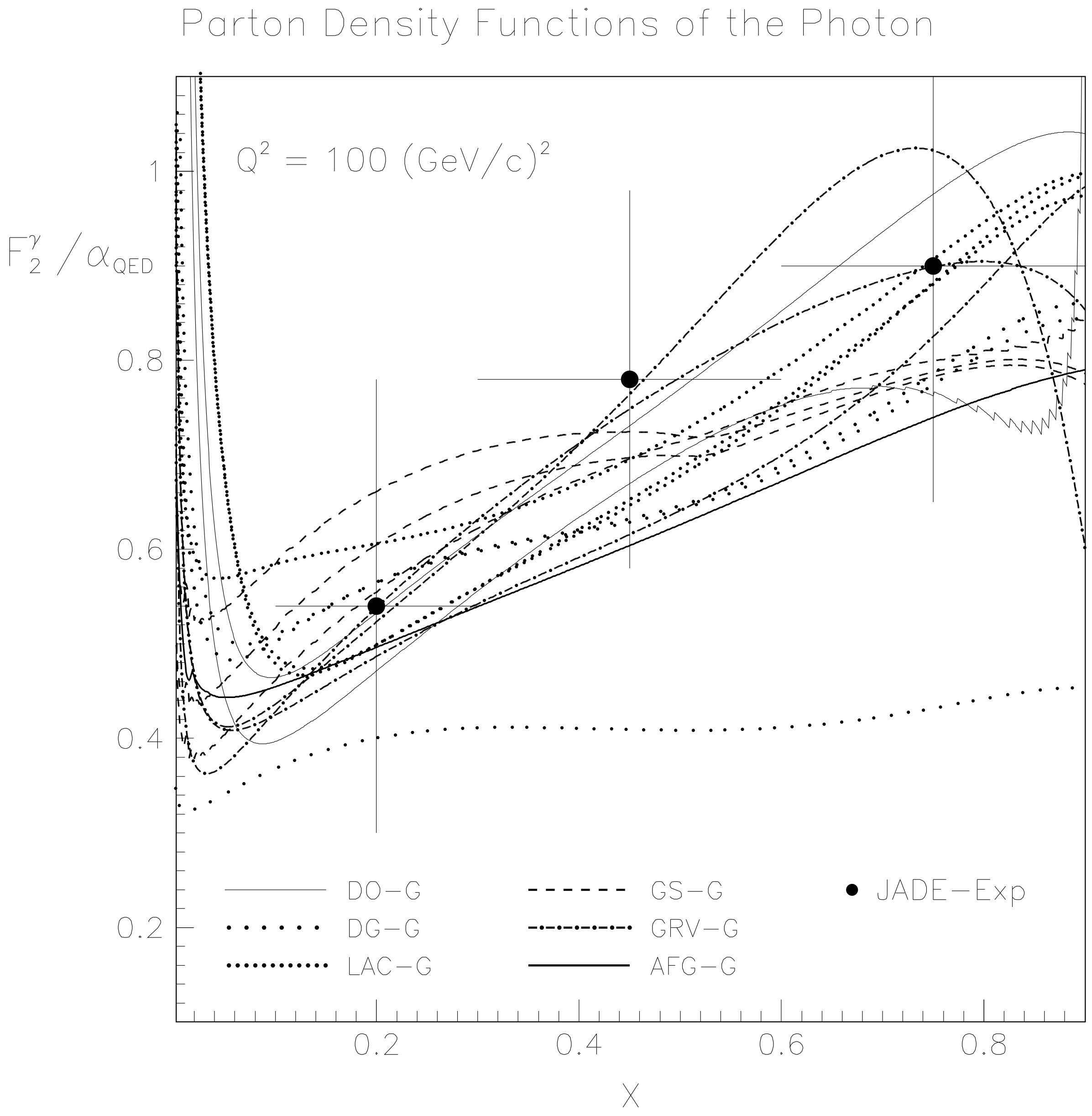

Figure 4: F_2^γ/α_{QED} distribution as a function of X

Appendix A

As an example how to use the package, the FORTRAN code to obtain Fig. 1 is given below:

Example for Fig. 1 :

```
      PROGRAM PDFUPV
C     define maximum number of PDF sets, the NAME and the cross reference
      PARAMETER (NPTYMX = 3, NGRMAX = 9, NSETMX = 58)
      COMMON /W505120/ NPGSMX(NPTYMX,NGRMAX),NSETFL(NPTYMX,NGRMAX,NSETMX)
      CHARACTER*8 SFNAME(NPTYMX,NGRMAX,NSETMX)
      COMMON /W505110/ SFNAME
      COMMON /W505122/ MODECR(NPTYMX,NGRMAX,NSETMX)
C     define HBOOK settings
      PARAMETER (NHBMEM = 500000)
      COMMON /PAWC/ HMEM(NHBMEM)
      PARAMETER (NB=900, ID=100)
C     define DOUBLE PRECISION variables for calling sequence to STRUCTM
      DOUBLE PRECISION DX,DSCALE
      DOUBLE PRECISION DUPV,DDNV,DUSEA,DDSEA,DSTR,DCHM,DBOT,DTOP,DGL
      DOUBLE PRECISION ALF,ALPHAS2
      REAL X, SCALE, UPV, DNV, USEA, DSEA, STR, CHM, BOT, TOP, GL
      COMMON/W50516/ FIRST
      LOGICAL FIRST
      CHARACTER*20 PARM(20)
      DOUBLE PRECISION VAL(20)
      DATA SCALE/80.140/, X00/0.002/,DX0/0.001/,XLOW/0.0015/,XUP/0.9015/
      CALL HLIMIT(NHBMEM)
      DSCALE = SCALE
C     first call to PDFSET to initialize COMMON /W505110/, /W505120/ and /W505122/
      PARM(1) = 'Init0'
      VAL(1) = 0.D0
      CALL PDFSET(PARM,VAL)
C     loop over all existing sets of NUCLEON structure functions (SF)
      NPTYPE = 1
      NHB = 0
      DO 20 IGR = 1,NGRMAX
        IF(NPGSMX(NPTYPE,IGR).EQ.0) GOTO 20
        DO ISET = 1,NPGSMX(NPTYPE,IGR)
C     book histograms for each set of SF separately
          NHB = NHB + 1
          CALL HBOOK1(ID+NHB,' U Valence quark ',NB,XLOW,XUP,0.)
C     force label printing for each set of SF (not only the 1st)
          FIRST = .TRUE.
C     define and set parameters
          PARM(1) = 'Nptype'
          VAL(1) = NPTYPE
          PARM(2) = 'Ngroup'
          VAL(2) = IGR
          PARM(3) = 'Nset'
          VAL(3) = ISET
          CALL PDFSET(PARM,VAL)
          DO 10 I = 1,NB
            X = X00 + (I-1)*DX0
            IF(X.LT.XLOW .OR. X.GT.XUP) GOTO 10
            DX = X
            CALL STRUCTM(DX,DSCALE,
     +           DUPV,DDNV,DUSEA,DDSEA,DSTR,DCHM,DBOT,DTOP,DGL)
            UPV = DUPV
            IF(X.GT.0.499 .AND. X.LE.0.500) WRITE(6,1000) X,SCALE,UPV
1000        FORMAT(/,' X= ',F6.4,' Q= ',F6.3,' UPV= ',8.4)
            CALL HF1(ID+NHB,X,UPV)
10        CONTINUE
```

Example for Fig. 1 : (cont'd)

```
C         get alpha(s) for selected set of SF at Q = SCALE
            ALF = ALPHAS2(DSCALE)
            WRITE(6,4000) NPTYPE,IGR,ISET,SFNAME(NPTYPE,IGR,ISET),
     +            MODECR(NPTYPE,IGR,ISET),NHB
            WRITE(6,4001) DSCALE,ALF
4000        FORMAT(/,' Nptype = ',I1,' Ngroup = ',I1, ' Nset = ',I2,' Name = "',A8,
     +            '" CrMode = ',I3,' HBId = ',I3)
4001        FORMAT(1H ,' Scale = ',F8.4,' alpha(s) = ',F6.4)
C         get error summary for each set of SF
            CALL PDFSTA
          ENDDO
20        CONTINUE
C
          STOP
          END
```

This code will produce the following output:

1. HBOOK Output :

one histogram for each set of structure functions. The histogram output has then been accessed, and each histogram has been superimposed on one single frame using the PAW package[51] to obtain Fig. 1.

2. Print Output (Example is given for NPTYPE = 1, NGROUP = 3, NSET = 41 only) :

```
1***** PDFLIB Version: 7.09 Released on 970702 at 16.05 in the CERN Computer Program Library W5051 *****
 ***** Library compiled on 970702 at 16.05 *****

Nucleon PDFs : Ngroup = 3, Nset = 41, for MRS Set (G) Structure Functions
----------------------------------------------------------------------------

X= 0.5000 Q= 80.140 UPV= 0.1176

Nptype = 1 Ngroup = 3 Nset = 41 Name = "MRS-G " CrMode = -1 HBId = 60
Scale = 80.1400 alpha(s) = 0.1154

PDFLIB : Summary from PDFSTA
Nptype = 1 Ngroup = 3 Nset = 41 Name = "MRS-G " CrMode = -1
Nfl = -5, LO = 2, Tmas = 100.00 GeV/c**2
QCDL4 = 0.2550 GeV, QCDL5 = 0.1708 GeV
Xmin = 0.10E-04, Xmax = 0.99999E+00, Q2min = 5.000 (GeV/c)**2, Q2max = 0.27E+10 (GeV/c)**2

PDFSTA: NO errors occured
```

Appendix B

A list of subroutines, functions, COMMON blocks and parameters of relevance to the user which are used in PDFLIB is given below:

List of relevant subprograms and COMMON blocks in PDFLIB :

(S = Subroutine, F = Function, C = COMMON, P = Parameter)

S	PDFSET	: to set all parameters for PDFLIB
S	STRUCTF	: to access PDFLIB with output in PDFLIB format
S	STRUCTM	: to access PDFLIB with output in PDFLIB format (with $\overline{down} \neq \overline{up}$)
S	STRUCTP	: to access PDFLIB with output in PDFLIB format for PHOTON structure functions
S	PFTOPDG	: to access PDFLIB with output in PDG format
S	PDFSTA	: to print summary of parameters and error statistics
F	ALPHAS2	: to calculate alpha(s) to second order QCD
C	W50510	: IFLPRT - to set print flag
C	W50511	: NPTYPE,NGROUP,NSET,MODE,NFL,LO,TMAS - to select structure function set, to define number of flavours, flag for leading order and value for the mass of the top quark
C	W50512	: QCDL4,QCDL5 - contains $\Lambda^{[4]}_{QCD}$, $\Lambda^{[5]}_{QCD}$ (in GeV)
C	W50513	: XMIN,XMAX,Q2MIN,Q2MAX - contains minimal and maximal values of x and Q^2
C	W50516	: FIRST - to force printing of name of structure function set in case of multiple choices
C	W50519	: NEWVER - defines **new** or **old** version of PDFLIB format
C	W505110	: SFNAME - contains NAME (CHARACTER*8 array with dimension SFNAME(NPTYMX,NGRMAX,NSETMX)) for each set of PDFs
C	W505120	: NPGSMX(NPTYMX,NGRMAX), NSELFL(NPTYMX,NGRMAX,NSETMX) - contains maximum number of structure functions per particle type and author group, and FLAG for retracted PDF sets (NSETFL(I,J,K) = 0)
C	W505121	: NPTYCR(MODEMX),NGROCR(MODEMX),NSETCR(MODEMX) - cross reference to the NPTYPE, NGROUP and NSET value (**new** format) for a given MODE value (**old** format)
C	W505122	: MODECR(NPTYMX,NGRMAX,NSETMX) - cross reference to the MODE value (**old** format) for a given NPTYPE, NGROUP, NSET value (**new** format)
P	W5051P2	: MODEMX - maximum number of structure function sets in the **old** PDFLIB format
		: NPTYMX,NGRMAX,NSETMX - maximum number of structure function sets in the **new** PDFLIB format for particle typ, author group number and number of sets within an author group
P	W5051P7	: L6 - to define logical print unit number

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