LHAPDF – status report

Version 3

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11th October 2004 – HERA and the LHC - CERN

"LHAPDF is a replacement for PDFLIB as the source of up-to-date PDFs"

- **PDFLIB no longer maintained and does not have the latest PDF sets**
- **The "error PDF sets" would not easily be included in PDFLIB**

LHAPDF Version 1 - Developed by Walter Giele (FNAL) after the Les Houches meeting in 2001 to provide easy access to the new "error PDF sets".

The new concept was to have "on-the-fly" evolution of PDFs starting from the fitted f(x) distributions at Q0, as produced by the PDF authors (MRST, CTEQ, ..)

Featured:

→ small parameter files (xxxx.LHpdf) defining the fitted f(x) distributions at the momentum transfer value Q0.

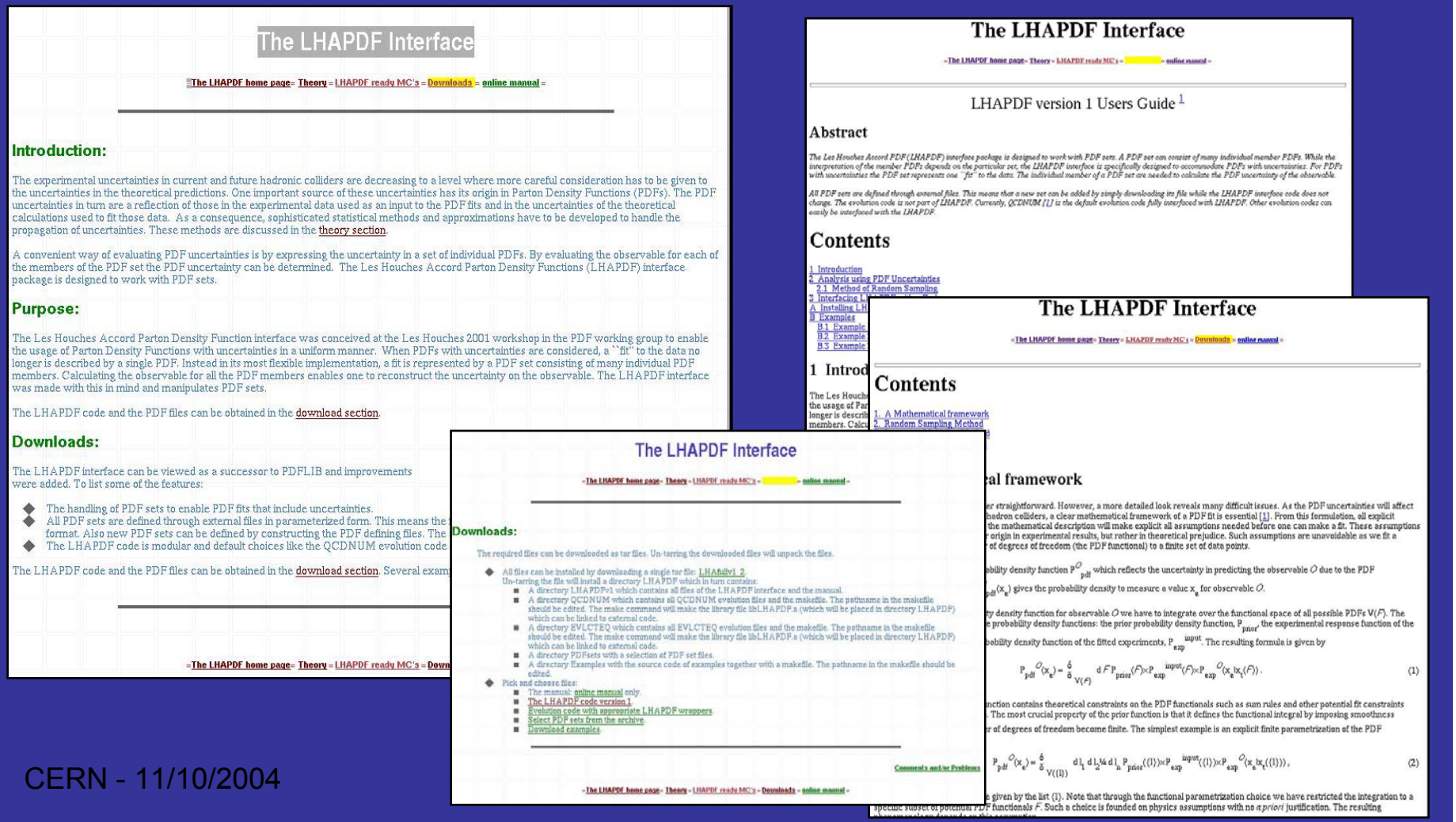
→ QCDNUM and EVLCTEQ codes to evolve to higher Q values

→ Recipes for extracting the individual parton distributions from the evolved f(x)s

→ The grouping of PDFs into sets – collections of related PDFs with individual PDF members (eg an error set or a specific distribution set)

The LHAPDF V1 web site (authored by Walter Giele)

http://vircol.fnal.gov/index.html

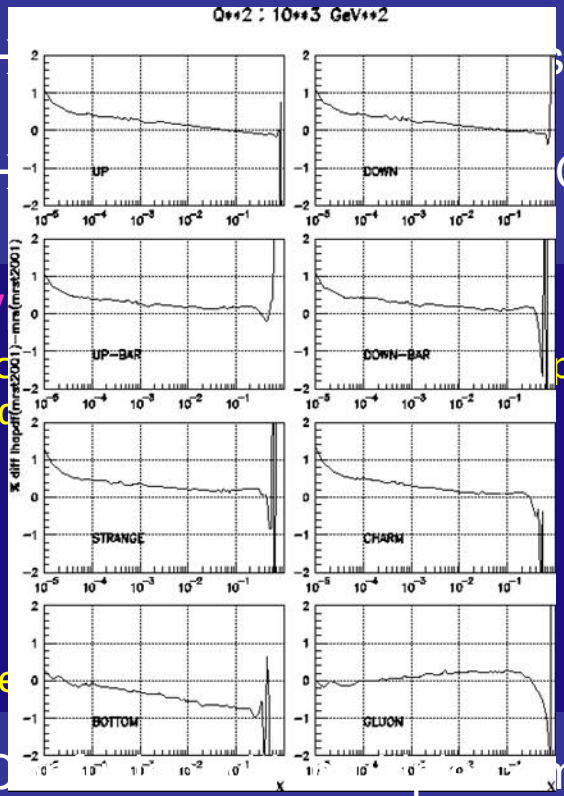


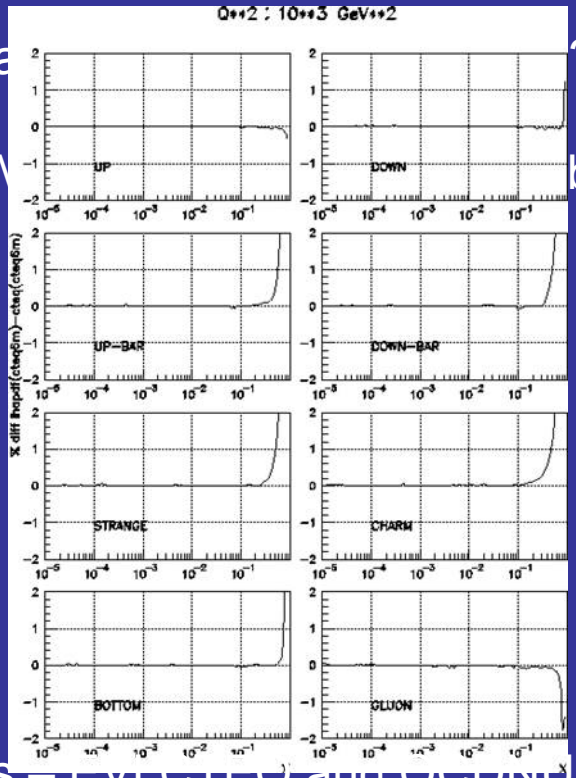
CERN - 11/10/2004

Introduction (continued):-

Version 1 works fine, in principle – but some practical problems:

→ possible small disagreements with values given by the original author codes, if a different evolution code had been used in the fit. (eg MRST ~0.2%).





→ C… …mpilations – EVLCTEQ and QCDNUM

Introduction (continued):-

Version 2 – appeared in March 2003 - after the Durham group became involved in the project.

In collaboration with Walter, "solved" the Version 1 problems by including the option to use the original interpolation code methods of the authors – xxxx.LHgrid files.

→ no evolution code progams needed
→ can include older legacy PDF sets
→ much faster

→ also single compilation for all.

LHAPDF V2	CTEQ6	MRST	CTEQ6	MRST
	LHpdf		LHgrid	
Time (sec) per InitPDFset	0.3	2.6	2.8	5.4
Time (sec) per 100,000 calls to EvolvePDF	1.6	3.5	1.8	0.6
Time (sec) per InitPDF	0.32	2.2	5*10^-7	5*10^-7

The downside is that the xxxx.LHgrid files are much larger than the xxxx.LHpdf files - we are effectively doing the same as PDFLIB, but with external files!

LHAPDF Version 3

released Sept 2004

http://durpdg.dur.ac.uk/lhapdf/ -> http://durpdg.dur.ac.uk/lhapdf3/
http://durpdg.dur.ac.uk/lhapdf2/
http://durpdg.dur.ac.uk/lhapdf1/

older versions are "frozen" and kept available

(1) More PDFs available:

New : ZEUS – LHpdf file using QCDNUM (thanks to Mandy Cooper-Sarkar)
H1 – LHgrid file (thanks to Christian Pascaud)
MRST2003c (nlo and nnlo) – LHpdf and LHgrid files

Legacy: CTEQ4, CTEQ5, GRV98 – all using the original interpolation codes – ie LHgrid files

PDF sets added in Version1, Version2, Version 3

Alekhin – Alekhin_100,_1000, Alekhin2002

Botje – Botje_100,_1000

Fermilab – Fermilab2002_100,_1000,

CTEQ – CTEQ61(E),CTEQ6(E),CTEQ5,CTEQ4

MRST – MRST2003c, MRST2002, MRST2001(E),MRS98

GRV – GRV98

ZEUS – ZEUS2002 (VFN(TR), FF, ZM – error sets)

H1 – H12000 (nlo msbar&dis + lo – error sets
extended to higher Q^2 – 10^6)

LHAPDF Version 3

released Sept 2004

http://durpdg.dur.ac.uk/lhapdf/

(2) New Feature:

LHAGLUE – a PDFLIB like interface to LHAPDF

→ developed by/with Dimitri Bourilkov and Craig Group of U. of Florida

→ available in addition to the standard LHAPDF calling routines

→ initial development has been with PYTHIA and HERWIG

LHAGLUE

"The LHAGLUE package, plus a unique PDF numbering scheme, enables LHAPDF to be used in the same way as PDFLIB, without requiring *any* changes in the PYTHIA or HERWIG codes"

"LHAGLUE fortran calls:-

```
      CHARACTER*20 parm(20)
      DOUBLE PRECISION value(20)
      …
→     Call PDFSET(parm,value)
      …
      …
→     Call STRUCTM(X,Q,UPV,DNV,USEA,DSEA,STR,CHM,BOT,TOP,GLU)
      …
```

Control of which PDFs sets to use and other settings is through the paired parm() and value() arrays – similar to PDFLIB.

Using LHAGLUE

Where to find the input files:

PARM(20).ne.'LHAPATH' (default) – looks in the current working directory to find the input files (LHpdf or LHgrid)

PARM(20).eq.'LHAPATH' – user defined path in the common block COMMON/LHAPDFC/LHAPATH – a CHARACTER*132 variable

Which mode to use (PYTHIA, HERWIG or Stand-Alone)

PYTHIA: PARM(1).eq.'NPTYPE' (set automatically in PYTHIA)

HERWIG: PARM(1).eq.'HWLHAPDF' (set by the user in HERWIG)

Stand-Alone: PARM(1).eq.'DEFAULT'

Using LHAGLUE

Using the interface from PYTHIA:

MSTP(52) = 2 (to use an external PDF library)
MSTP(51) = PDF number

(COMMON/PYPARS/MSTP(200),PARP(200),……)

PDF set number is ABS(MSTP(51))

Using the interface from HERWIG:

AUTPDF(1) = 'HWLHAPDF'
AUTPDF(2) = 'HWLHAPDF'

MODPDF(1) = PDF number
MODPDF(2) = PDF number

PDF set number is ABS(INT(value(1)))

Stand-Alone:
PARM(1)='DEFAULT'
VALUE(1)=PDF number

Using LHAGLUE

Other settings:

PARM(18) – allows extrapolation of the PDFs beyond the defined limits of xmin,xmax and Q2min,Q2max.

- default is to “freeze” the PDFs at the boundaries

- ‘EXTRAPOLATE’ extrapolates (at own risk)

PARM(19) - defines the amount of printout.

- ‘SILENT’ suppresses the printout of initialization information from PDFSET

Using LHAPDF routines with LHAGLUE

Except for the initialization routines “InitPDFset” an “InitPDF” all the other LHAPDF subroutines can be used with LHAGLUE

```
call evolvePDF(x,Q2,f)
```

Returns the pdfs f(-6:6) at x and Q2

```
call alphasPDF(Q)
```

Returns the value of alpha_s at the scale *Q*

```
call numberPDF(Nmem)
```

The integer *Nmem* will contain the number of PDF members, excluding the best fit member (0)

```
call getDesc()
```

Prints out the PDF description given at the beginning of the PDF file

+ others (see the user guide)

page taken from the online manual

10000-19999 CTEQ
20000-29999 MRST
30000-39999 Fermilab
40000-49999 Alekhin
50000-59999 Botje
60000-69999 ZEUS
70000-79999 H1
80000-89999 GRV

Notes:

When both LHpdf and LHgrid exist then: LHgrid = LHpdf + 50

Legacy sets occupy the very high numbers

New sets will be added numerically increasing from the lower end

B PDF set numbers and names

PDF numbering scheme in LHAGLUE/LHAPDF

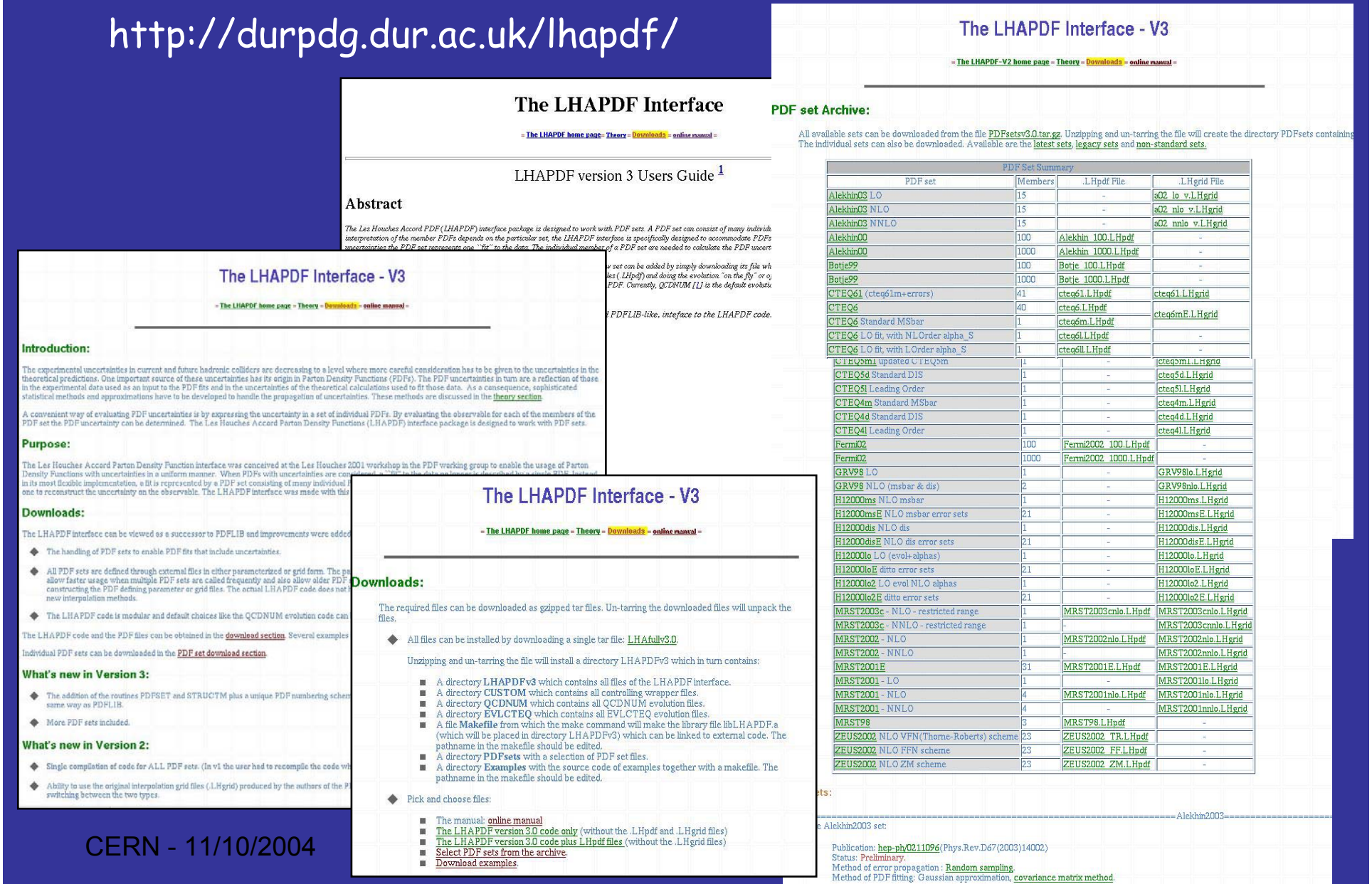
Notes:

- **When using the LHAGLUE initialization method:**
  - The columns headed .LHpdf and .LHgrid give the set numbers to use with LHAGLUE
- **When Using the direct LHAPDF initialization routines:**
  - The .LHpdf and .LHgrid columns show the availablity of the respective files
  - The File Name and Member columns give the names to use in the direct LHAPDF initialization routines.
  - .LHpdf or .LHgrid has to be appended to the File Name depending the availability of that file (as indicated in the table) and wishes of the user

PDF set	.LHpdf	.LHgrid	File Name	Member	Xmin	Xmax	Q2min GeV^2	Q2max GeV^2
CTEQ6m (central value)	10000	10050	CTEQ6m	0	10^{-6}	1	1.69	10^8
CTEQ6 (40 error sets)	10001-10040	10051-10090	CTEQ6	1-40	10^{-6}	1	1.69	10^8
CTEQ6l (LO fit/NLO alphas)	10041	-	CTEQ6l	0/1	10^{-6}	1	1.69	10^8
CTEQ6ll (LO fit/LO alphas)	10042	-	CTEQ6ll	0/1	10^{-6}	1	1.69	10^8
CTEQ61 (central value)	10100	10150	CTEQ61	0	10^{-6}	1	1.69	10^8
CTEQ61 (40 error sets)	10101-10140	10151-10190	CTEQ61	1-40	10^{-6}	1	1.69	10^8
CTEQ5m (Standard MSbar)	-	19050	CTEQ5m	0/1	10^{-5}	1	1.00	10^8
CTEQ5m1 (updated CTEQ5m)	-	19051	CTEQ5m1	0/1	10^{-5}	1	1.00	10^8
CTEQ5d (Standard DIS)	-	19060	CTEQ5d	0/1	10^{-5}	1	1.00	10^8
CTEQ5l (LO fit)	-	19070	CTEQ5l	0/1	10^{-5}	1	1.00	10^8
CTEQ4m (Standard MSbar)	-	19150	CTEQ4m	0/1	10^{-5}	1	2.56	10^8
CTEQ4d (Standard DIS)	-	19160	CTEQ4d	0/1	10^{-5}	1	2.56	10^8
CTEQ4l (LO fit)	-	19170	CTEQ4l	0/1	10^{-5}	1	2.56	10^8
MRST2001nlo (Standard MSbar)	20000	20050	MRST2001nlo	0/1	10^{-5}	1	1.25	10^7
MRST2001nlo (lower α_S)	20002	20052	MRST2001nlo	2	10^{-5}	1	1.25	10^7
MRST2001nlo (higher α_S)	20003	20053	MRST2001nlo	3	10^{-5}	1	1.25	10^7
MRST2001nlo (Jet Fit)	20004	20054	MRST2001nlo	4	10^{-5}	1	1.25	10^7
MRST2001lo (LO fit)	-	20060	MRST2001lo	0/1	10^{-5}	1	1.25	10^7
MRST2001nnlo (NNLO fit)	-	20070	MRST2001nnlo	0/1	10^{-5}	1	1.25	10^7
MRST2001E (central value)	20100	20150	MRST2001E	0	10^{-5}	1	1.25	10^7
MRST2001E (30 error sets)	20101-20130	20151-20180	MRST2001E	1-30	10^{-5}	1	1.25	10^7

The LHAPDF V3 web site

http://durpdg.dur.ac.uk/lhapdf/



The LHAPDF Interface

= The LHAPDF home page = Theory = Downloads = online manual =

LHAPDF version 3 Users Guide [1]

Abstract

The Les Houches Accord PDF (LHAPDF) interface package is designed to work with PDF sets. A PDF set can consist of many individu
interpretation of the member PDFs depends on the particular set, the LHAPDF interface is specifically designed to accommodate PDFs
uncertainties the PDF set represents one "fit" to the data. The individual member of a PDF set are needed to calculate the PDF uncert
w set can be added by simply downloading its file wh
les (.LHpdf) and doing the evolution "on the fly" or o
FDF. Currently, QCDNUM [1] is the default evolutio
PDFLIB-like, inteface to the LHAPDF code.

The LHAPDF Interface - V3

= The LHAPDF home page = Theory = Downloads = online manual =

Introduction:

The experimental uncertainties in current and future hadronic colliders are decreasing to a level where more careful consideration has to be given to the uncertainties in the theoretical predictions. One important source of these uncertainties has its origin in Parton Density Functions (PDFs). The PDF uncertainties in turn are a reflection of those in the experimental data used as an input to the PDF fits and in the uncertainties of the theoretical calculations used to fit those data. As a consequence, sophisticated statistical methods and approximations have to be developed to handle the propagation of uncertainties. These methods are discussed in the theory section.

A convenient way of evaluating PDF uncertainties is by expressing the uncertainty in a set of individual PDFs. By evaluating the observable for each of the members of the PDF set the PDF uncertainty can be determined. The Les Houches Accord Parton Density Functions (LHAPDF) interface package is designed to work with PDF sets.

Purpose:

The Les Houches Accord Parton Density Function interface was conceived at the Les Houches 2001 workshop in the PDF working group to enable the usage of Parton Density Functions with uncertainties in a uniform manner. When PDFs with uncertainties are considered, a "fit" to the data as long as is described by a single PDF. Instead in its most flexible implementation, a fit is represented by a PDF set consisting of many individual one to reconstruct the uncertainty on the observable. The LHAPDF interface was made with this

Downloads:

The LHAPDF interface can be viewed as a successor to PDFLIB and improvements were added

- The handling of PDF sets to enable PDF fits that include uncertainties.
- All PDF sets are defined through external files in either parameterized or grid form. The pa
allow faster usage when multiple PDF sets are called frequently and also allow older PDF s
constructing the PDF defining parameter or grid files. The actual LHAPDF code does not
new interpolation methods.
- The LHAPDF code is modular and default choices like the QCDNUM evolution code can

The LHAPDF code and the PDF files can be obtained in the download section. Several examples

Individual PDF sets can be downloaded in the PDF set download section.

What's new in Version 3:

- The addition of the routines PDFSET and STRUCTM plus a unique PDF numbering scheme
same way as PDFLIB.
- More PDF sets included.

What's new in Version 2:

- Single compilation of code for ALL PDF sets. (In v1 the user had to recompile the code wh
- Ability to use the original interpolation grid files (.LHgrid) produced by the authors of the P
switching between the two types.

The LHAPDF Interface - V3

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Downloads:

The required files can be downloaded as gzipped tar files. Un-tarring the downloaded files will unpack the files.

- All files can be installed by downloading a single tar file: LHAfully3.0.

  Unzipping and un-tarring the file will install a directory LHAPDFv3 which in turn contains:

  - A directory **LHAPDFv3** which contains all files of the LHAPDF interface.
  - A directory **CUSTOM** which contains all controlling wrapper files.
  - A directory **QCDNUM** which contains all QCDNUM evolution files.
  - A directory **EVLCTEQ** which contains all EVLCTEQ evolution files.
  - A file **Makefile** from which the make command will make the library file libLHAPDF.a (which will be placed in directory LHAPDFv3) which can be linked to external code. The pathname in the makefile should be edited.
  - A directory **PDFsets** with a selection of PDF set files.
  - A directory **Examples** with the source code of examples together with a makefile. The pathname in the makefile should be edited.

- Pick and choose files:

  - The manual: online manual
  - The LHAPDF version 3.0 code only (without the .LHpdf and .LHgrid files)
  - The LHAPDF version 3.0 code plus LHpdf files (without the .LHgrid files)
  - Select PDF sets from the archive.
  - Download examples.

The LHAPDF Interface - V3

= The LHAPDF-V2 home page = Theory = Downloads = online manual =

PDF set Archive:

All available sets can be downloaded from the file PDFsetsv3.0.tar.gz. Unzipping and un-tarring the file will create the directory PDFsets containing
The individual sets can also be downloaded. Available are the latest sets, legacy sets and non-standard sets.

PDF Set Summary

PDF set	Members	.LHpdf File	.LHgrid File
Alekhin03 LO	15	-	a02_lo_v.LHgrid
Alekhin03 NLO	15	-	a02_nlo_v.LHgrid
Alekhin03 NNLO	15	-	a02_nnlo_v.LHgrid
Alekhin00	100	Alekhin_100.LHpdf	-
Alekhin00	1000	Alekhin_1000.LHpdf	-
Botje99	100	Botje_100.LHpdf	-
Botje99	1000	Botje_1000.LHpdf	-
CTEQ61 (cteq61m+errors)	41	cteq61.LHpdf	cteq61.LHgrid
CTEQ6	40	cteq6.LHpdf	cteq6mE.LHgrid
CTEQ6 Standard MSbar	1	cteq6m.LHpdf	
CTEQ6 LO fit, with NLOrder alpha_S	1	cteq6l.LHpdf	-
CTEQ6 LO fit, with LOrder alpha_S	1	cteq6ll.LHpdf	-
CTEQ5m1 updated CTEQ5m	1	-	cteq5m1.LHgrid
CTEQ5d Standard DIS	1	-	cteq5d.LHgrid
CTEQ5l Leading Order	1	-	cteq5l.LHgrid
CTEQ4m Standard MSbar	1	-	cteq4m.LHgrid
CTEQ4d Standard DIS	1	-	cteq4d.LHgrid
CTEQ4l Leading Order	1	-	cteq4l.LHgrid
Fermi02	100	Fermi2002_100.LHpdf	-
Fermi02	1000	Fermi2002_1000.LHpdf	-
GRV98 LO	1	-	GRV98lo.LHgrid
GRV98 NLO (msbar & dis)	2	-	GRV98nlo.LHgrid
H12000ms NLO msbar	1	-	H12000ms.LHgrid
H12000msE NLO msbar error sets	21	-	H12000msE.LHgrid
H12000dis NLO dis	1	-	H12000dis.LHgrid
H12000disE NLO dis error sets	21	-	H12000disE.LHgrid
H12000lo LO (evol+alphas)	1	-	H12000lo.LHgrid
H12000loE ditto error sets	21	-	H12000loE.LHgrid
H12000lo2 LO evol NLO alphas	1	-	H12000lo2.LHgrid
H12000lo2E ditto error sets	21	-	H12000lo2E.LHgrid
MRST2003c - NLO - restricted range	1	MRST2003cnlo.LHpdf	MRST2003cnlo.LHgrid
MRST2003c - NNLO - restricted range	1	-	MRST2003cnnlo.LHgrid
MRST2002 - NLO	1	MRST2002nlo.LHpdf	MRST2002nlo.LHgrid
MRST2002 - NNLO	1	-	MRST2002nnlo.LHgrid
MRST2001E	31	MRST2001E.LHpdf	MRST2001E.LHgrid
MRST2001 - LO	1	-	MRST2001lo.LHgrid
MRST2001 - NLO	4	MRST2001nlo.LHpdf	MRST2001nlo.LHgrid
MRST2001 - NNLO	4	-	MRST2001nnlo.LHgrid
MRST98	6	MRST98.LHpdf	-
ZEUS2002 NLO VFN(Thorne-Roberts) scheme	23	ZEUS2002_TR.LHpdf	-
ZEUS2002 NLO FFN scheme	23	ZEUS2002_FF.LHpdf	-
ZEUS2002 NLO ZM scheme	23	ZEUS2002_ZM.LHpdf	-

ets:

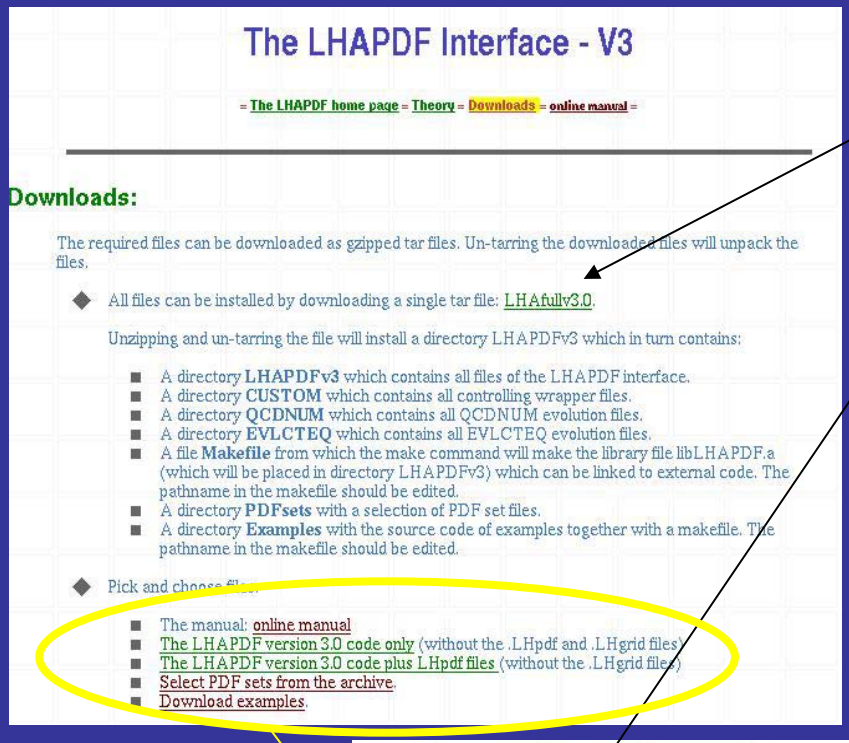
Alekhin2003

e Alekhin2003 set:

Publication: hep-ph/0211096(Phys.Rev.D67(2003)14002)
Status: Preliminary.
Method of error propagation : Random sampling.
Method of PDF fitting: Gaussian approximation, covariance matrix method.

CERN - 11/10/2004

LHAPDF Version 3- Download the Code/Files



The LHAPDF Interface - V3

= The LHAPDF home page = Theory = Downloads = online manual =

Downloads:

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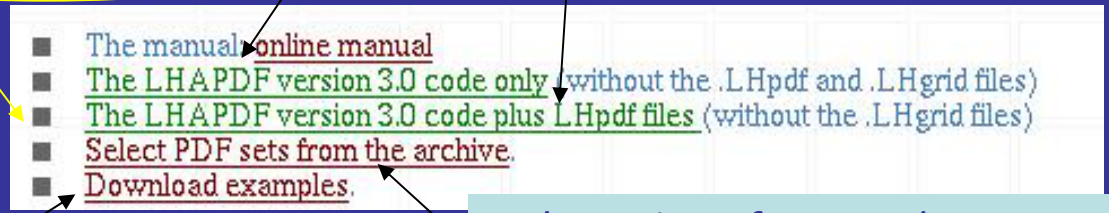
  - The manual: online manual
  - The LHAPDF version 3.0 code only (without the .LHpdf and .LHgrid files)
  - The LHAPDF version 3.0 code plus LHpdf files (without the .LHgrid files)
  - Select PDF sets from the archive.
  - Download examples.

LHAPDFfullv3.0.tar.gz
Everything – 40.5 Mbytes

LHAPDFcodev3.0.tar.gz
Code (fortran) only – 0.3 Mbytes

LHAPDFpartv3.0.tar.gz
Code+.LHpdf files – 0.8 Mbytes



- The manual: online manual
- The LHAPDF version 3.0 code only (without the .LHpdf and .LHgrid files)
- The LHAPDF version 3.0 code plus LHpdf files (without the .LHgrid files)
- Select PDF sets from the archive.
- Download examples.

Examplesv3.0.tar
Example programs – 0.2Mbyte

Select PDFs from archive –
– separate web page
PDFsetsv3.0.tar.gz – 40.3 Mbyte

Downloading the code - V3

LHAfullv3.0.tar unpacks to:-

/CUSTOM
wrap02.f
wrapcteq5.f
wrapcteq6.f
wrapevolve.f
wrapmrst.f
wrapzeus.f
wraph1.f
wrapgrv.f
lhaglue.f

/EVLCTEQ
EVLCTEQ.f
wrapEVLCTEQ.f

/QCDNUM
qcdnum.f
Sqcdnum.f
wrapQCDNUM.f

/Examples
Example1.f
Example2.f
Example3.f
Example4.f
Makefile

LHAPDFv3
CUSTOM/
EVLCTEQ/
QCDNUM/
Examples/
LHAPDFv3/
libLHAPDF.a
Makefile
PDFsets/

/LHAPDFv3
alphas.f
description.f
evolution.f
inputPDF.f
LHpdflib.f
parameter.f
parmsetup.f

/PDFsets

.LHpdf	.LHgrid
	a02_lo_v
	a02_nlo_v
	a02_nnlo_v
Alekhin_1000	
Alekhin_100	
Botje_1000	
Botje_100	
	cteq4m
	cteq4d
	cteq4l
	cteq5m1
	cteq5m
cteq61 →	cteq61
Cteq6 →	cteq6mE
cteq6m →	
cteq6l	
cteq6ll	
Fermi2002_1000	
Fermi2002_100	
MRST2001E →	MRST2001E
	MRST2001lo
MRST2001nlo →	MRST2001nlo
	MRST2001nnlo
MRST2002nlo →	MRST2002nlo
MRST2003cnlo →	MRST2003cnlo
	MRST2003cnnlo
MRST98	

.LHpdf	.LHgrid
ZEUS2002_TR	
ZEUS2002_FF	
ZEUS2002_ZM	
	H12000ms
	H12000msE
	H21000dis
	H12000disE
	H12000lo
	H12000loE
	H12000lo2
	H12000lo2E
	GRV98nlo
	GRV98lo

Summary

LHAPDF Version 3 – released - building on versions 1 and 2

- More PDFs – ZEUS, H1, mrst2003c… and legacy sets
- LHAGLUE routines included
  - Unique numbering scheme
  - PDFLIB like interface requiring no change to MCs

Future

- Add new PDFs as they are produced.
- Continue to add more legacy sets as needed.
- Set up user list to inform people of changes/new versions etc.