

Les Houches Accord PDF - status report

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Outline of presentation

- Introduction
- Recap (V1,V2,V3)
- New features since last meeting (V4)
- Summary/Future Developments

Introduction

- LHAPDF is being developed as a replacement for PDFLIB to do the following:
 - ***give access to the latest PDF sets,***
 - ***be able to handle the multiple set error PDFs,***
 - ***be more flexible than PDFLIB in updating.***

- Developed (in FORTRAN) by Walter Giele of FNAL following the 2001 Les Houches meeting (LH accord#2)

- I became involved in 2003 as it needed a permanent home – and I already ran PDF server as part of HEPDATA.

Recap – Version 1

- V1 appeared in 2002 (Walter Giele).
 - PDFs were produced 'on-the-fly' starting from the fitted parton distributions at Q_0 and evolved (normally) to higher Q values using an evolution code program.
 - QCDNUM(16.12) was/is the default evolution program used for the MRST, Alekhin, Botje and Fermi sets. EVLCTEQ was/is used for CTEQ.
 - Input files are small (<100 lines with typically 20-40 parameters) and separate from the program code (cf. PDFLIB where the authors – often large – interpolation grid files are part of the program code).

Recap – Version 1

- Standard FORTRAN calling routines were developed.

```
call InitPDFset(name)
```

```
call InitPDF(member)
```

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

```
call numberPDF(number)
```

```
call alphasPDF(Q)
```

```
etc.....
```

*Concept of a PDFset containing many members
– eg an error set*

← $f(6,5,\dots,0,\dots,-5,-6)$

- A Web site was produced by Walter from which all the program and example code and input datasets could be downloaded, and which contained an on-line manual.

Wonderful but

- ❑ Many PDFs were missing.
- ❑ Problems incorporating the older sets. } Parameters not available

- ❑ MRST evolution code – was not QCDNUM
(slight $\sim 0.5\%$ differences between the LHAPDF numbers and those of the authors is now believed to be due to mismatches in the grid structure around the parton thresholds)

- ❑ Can be slow in some circumstances
(eg repeatedly calling `InitPDF(member)` for a given PDFset)

Recap – Version 2

- V2 appeared ~March 2004.
 - Gave access to the original interpolation grids of the PDF authors, as well as to the parameter/evolution method of V1.
 - .LHgrid files ← interpolation grid method
 - .LHpdf files ← parameter/evolution method
 - Advantage(s) → can include older PDF sets
→ faster in some cases
 - Disadvantage → much larger files – but still separate from the code. 😊

Recap – Version 3

- V3 appeared ~September 2004
 - More new and legacy PDF sets.
ZEUS,H1,CTEQ4/5,GRV98,MRSTc2003
 - LHAGlue interface introduced
a PDFLIB type interface to LHAPDF developed
with Dimitri Bourilkov (U. of Florida)

LHAglue

**LHAglue is a PDFLIB look-alike front-end package to LHAPDF
(written mainly by Dimitri Bourilkov)**

```
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.

LHAglue

Where to find the input files:

PARM(20).ne.'LHAPATH' (default) – looks in the current working directory

PARM(20).eq.'LHAPATH' – user defined path in the common block

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'

Extrapolate (or freeze) beyond x and Q2 limits

PARM(18) – default is to freeze. '**EXTRAPOLATE**' extrapolates (at own risk)

Limit printed output

PARM(19) – default is print info. – '**SILENT**' supresses printout

page taken
from the
online manual

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 availability 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

10000-19999 CTEQ
20000-29999 MRST
30000-39999 Fermi
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

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
MRST2001nlo (NNLO fit)	-	20070	MRST2001nlo	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

Version 4 – what's new!

□ New proton PDFs – MRST2004, a02m

improved interpolation
routine from a02

□ Photon and Pion PDFs.

New gluon parametrisation
at large x

□ New (simpler) file structure.

□ Alphas(Q) routine improvements.

□ Lambda4/Lambda5 routines.

V4 Photon and Pion PDFs

All the **photon** and **pion** routines that were in PDFLIB are now directly available (as .LHgrid) files in LHAPDF.

photons

NpType	Ngroup	Nset	Λ_{QCD}	Q^2_{min}	Name of set		Reference
3	1	1	300	10	DO-G Set 1	LO	[Phys.Rev. D36 (1982) 1000]
3	1	2	440	10	DO-G Set 2	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	3	4	200	5	GAL-G	LO	[hep-ph/9711355]
3	4	1	200	5.3	GS-G HO	M/S	[Z.Phys. C56 (1992) 307]
3	4	2	200	5.3	GS-G LO set 1	NLL	
3	4	3	200	5.3	GS-G LO set 2	LO	
3	4	4	200	5.3	GS-G-96 HO	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 HO	DIS ⁺	[Phys.Rev. D46 (1992) 1973, Phys.Rev. D45 (1992) 3986]
3	5	2	200	0.3	GRV-G HO	DIS ⁻	
3	5	3	200	0.25	GRV-G LO	LO	
3	5	4	200	0.6	GRV-G LO	LO	[Phys.Rev. D51 (1995) 3220]
3	6	1	200	2	ACFGP Set HO	M/S	[Z.Phys. C56 (1992) 589]
3	6	2	200	2	ACFGP Set HO-mc	M/S	
3	6	3	200	2	AFG-G Set HO	M/S	[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 1M (Version 1)	LO	[Z.Phys. C68 (1996) 607]
3	9	2	200	0.36	SaS-G 1M (Version 2)	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	

pions

NpType	Ngroup	Nset	Λ_{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	M/S	[Phys.Rev. D45 (1992) 3349]
2	3	2	190	5	SMRS-P 2	M/S	
2	3	3	190	5	SMRS-P 3	M/S	
2	5	1	200	0.3	GRV-P HO	M/S	[Z.Phys. C53 (1992) 651]
2	5	2	200	0.25	GRV-P LO	LO	
2	6	1	231	2	ABFKW-P Set 1	M/S	[Phys.Lett. 333B (1989) 517]
2	6	2	181	2	ABFKW-P Set 2	M/S	
2	6	3	281	2	ABFKW-P Set 3	M/S	

LHAgIue uses 3 digits for the set number

call evolvePDFp(x, Q, P2, IP2, f)

New calling routine for photons

Photon PDF Set Summary			
PDF set	Members	.LHpdf File	.LHgrid File
DO-G LO	1	-	DOG0.LHgrid
DO-G NLO	1	-	DOG1.LHgrid
DG-G LO	4	-	DGG.LHgrid
LAC-G/GAL-G LO	4	-	LACG.LHgrid
GS-G LO	2	-	GSG0.LHgrid
GS-G NLO	1	-	GSG1.LHgrid
GS-G-96 LO	1	-	GSG960.LHgrid
GS-G-96 NLO	1	-	GSG961.LHgrid
GRV-G/GRS-G LO	2	-	GRVG0.LHgrid
GRV-G NLO	2	-	GRVG1.LHgrid
ACFGP/AFG-G NLO	3	-	ACFGP.LHgrid
WHIT-G LO	6	-	WHITG.LHgrid
SAS-G(v1/v2) LO	8	-	SASG.LHgrid
Pion PDF Set Summary			
PDF set	Members	.LHpdf File	.LHgrid File
OW-P LO	2	-	OWPI.LHgrid
SMRS-P NLO	3	-	SMRSP.LHgrid
GRV-P LO	1	-	GRVPI.LHgrid
GRV-P NLO	1	-	GRVPI1.LHgrid
ABFKW-P/NLO	3	-	ABFKWPI.LHgrid

V4 – simpler file structure

Previous

New – from V4

LHAPDFv3

LHAPDFv4

LHAPDF
CUSTOM
QCDNUM
EVLCTEQ



src

PDFsets
Makefile
libLHAPDF.a

PDFsets
Makefile
libLHAPDF.a

Why:

- Files are not large in number/no name duplication
- More typically expected file structure
- Will fit more readily into GENSER

V4 – alpha_s(Q)

The function `GetAlphas(Q)` gives the value of ALPHA_s at the scale Q (GeV) for the selected PDF set as given by the PDF authors.

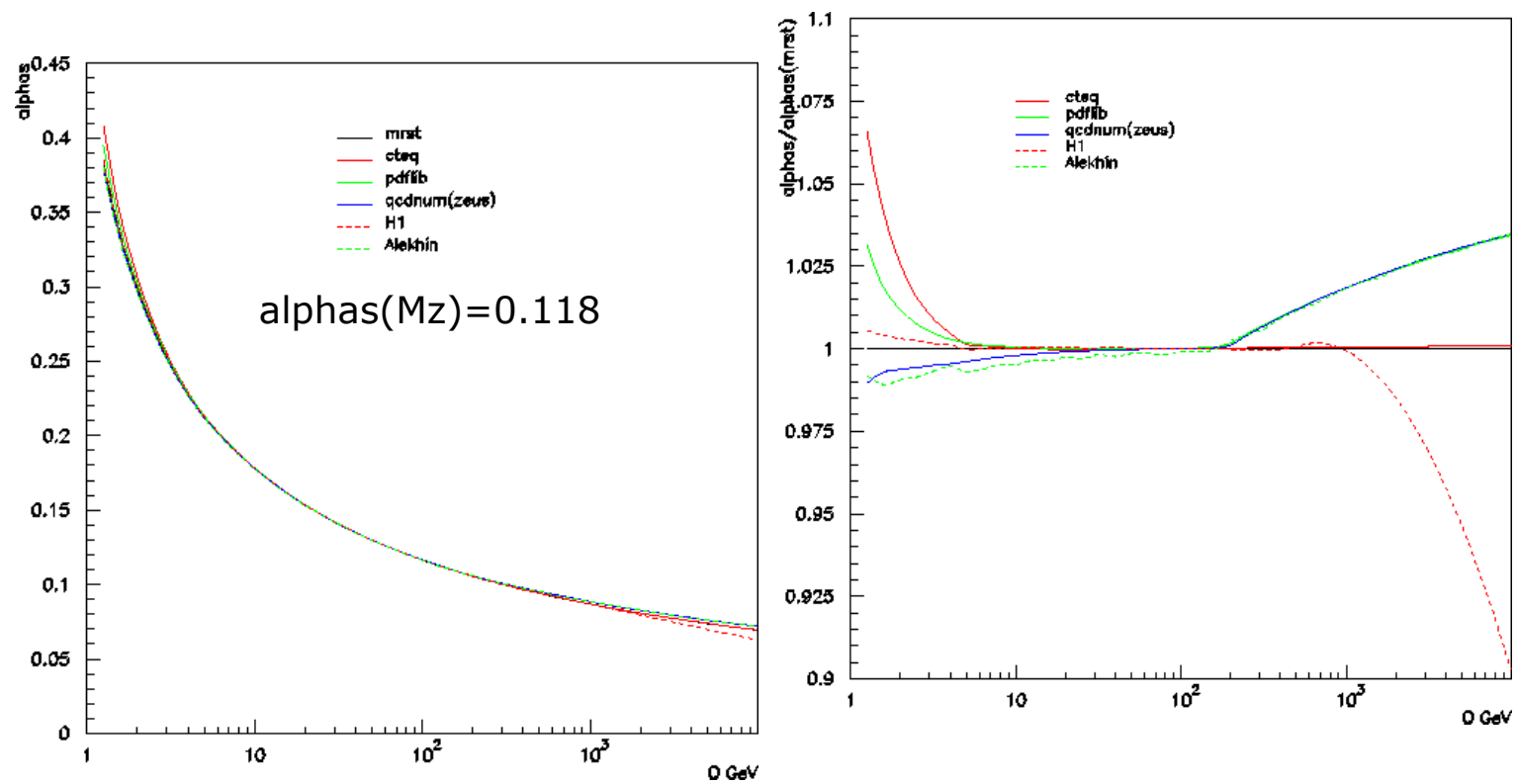
Several sources of code used in LHAPDF:

MRST
CTEQ
QCDNUM
H1
Alekhin
PDFLIB

↑
Photon and Pion PDFs

In LHAPDF version 4 these are more strictly adhered to than in previous versions, to ensure that the ALPHA_s output corresponds with that used by the individual PDF fitters.

V4 – $\alpha_s(Q)$



V4 – LAMBDA4/5

At the request of users the values of Lambda4/5 applicable to the various PDF sets has been made available (read-only) in V4 –

```
call GetLam4(mem, qcd14) }  
call GetLam5(mem, qcd15) } in LHAPDF
```

COMMON/w50512/QCDL4, QCDL5 → **in LHAg1ue**

Health warning: beware of the differing definitions of Lambda which exist when using these.

Summary - v4 – LHAPDF/LHAGlue routines

LHAPDF

```
call InitPDFset(name) }  
call InitPdf(member) }  
  
call evolvePDF(x,q,f)  
call evolvePDFp(x,q,p2,ip2,f)  
  
call GetLam4(mem,qcd14)  
call GetLam5(mem,qcd15)  
  
function alphasPDF(Q) }  
call numberPDF(Nmem) }  
call GetOrderPDF(iord) }  
call GetOrderAs(iord) }  
call GetDesc() }  
call GetQmass(nf,qmass) }  
call GetThreshold(nf,Q) }  
  
call lhasilent(iprint)
```

LHAGlue

```
call pdfset(parm,value)  
  
call structm(x,q,upv,dnv,usea,dsea,str,chm,bot,top,glu)  
call structp(x,q2,p2,ip2,upv,dnv,usea,dsea,str,chm,bot,top,glu)  
  
common/w50512/qcd14,qcd15  
  
No equivalent LHAGlue routines  
  
common/lhasilent/iprint, parm(19) = 'silent'
```

iprint=1 → no printout

Summary - V4 – PDFsets available

CTEQ

cteq61, cteq6, cteq5, cteq4

MRST

mrst2004, mrst2003c, mrst2002, mrst2001, mrst98

ZEUS

zeus2002 (+soon zeus2005)

H1

H12000 (to higher Q²)

Alekhin

Alekhin_100/1000, Alekhin2002 (with improved interpolation)

GRV

GRV98

Botje

Botje_100/1000

Fermi

Fermi_100/1000

Plus photon and
pion pdfs as in
PDFLIB

Summary - V4 – Downloading Code+PDFsets

The screenshot shows the 'Downloads' section of the Lhapdf V4 website. At the top, there are navigation links: 'The Lhapdf home page', 'Theory', 'Downloads', and 'online manual'. Below this, the 'Downloads:' section explains that files can be downloaded as gzipped tar files. A diamond icon points to a list of options:

- ◆ All files can be installed by downloading a single tar file: [LHAfullv4.tar.gz](#).

Below this, it states that unzipping and un-tarring the file will install a directory 'LHAPDFv4' which contains:

- A directory **src** which contains all the fortran source files.
- A file **Makefile** from which the make command will make the library file libLHAPDF.a (which will be placed in directory LHAPDFv4) 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 4 code only](#) (without the .LHpdf and .LHgrid files)
- [The Lhapdf version 4 code plus LHpdf files](#) (without the .LHgrid files)
- [Select PDF sets from the archive.](#)
- [Download examples.](#)

At the bottom, there are more navigation links: 'The Lhapdf home page', 'Theory', 'Lhapdf ready MC's', 'Downloads', and 'online manual'. A link for 'Comments and/or Problems' is also present.

or

Download only
FORTRAN code
+ Makefile
(0.9mb)
lhacodev4.tar.gz

and

select individual
PDF sets

You have the
choice of:

either

Download everything
(42mb)

lhafullv4.tar.gz

Makefile produces
libLHAPDF.a
(1.2mb)

Summary - V4 – Downloading Individual PDFsets

The LHAPDF Interface - V4

PDF set Archive:

All available sets can be downloaded from the file [PDFsetsV4.tar.gz](http://durpdg.dur.ac.uk/PDFsetsV4.tar.gz). Unzipping and un-tarring the file will create the d. The individual sets can also be downloaded. Available are the **latest sets**, **legacy sets** and **non-standard sets**.

Nucleon PDF Set Summary			
PDF set	Members	.LHpdf File	LHgrid File
Alekhin02 LO	15	-	ale02m_lo.LHgrid
Alekhin02 NNLO	15	-	ale02m_nlo.LHgrid
Alekhin02 NNLO	15	-	ale02m_nnlo.LHgrid
Alekhin00	100	Alekhin_100.LHpdf	-
Alekhin00	1000	Alekhin_1000.LHpdf	-
Botje99	100	Botje_100.LHpdf	-
Botje99	1000	Botje_1000.LHpdf	-
CTEQ6.1 (cteq6.1m+errors)	41	cteq6.1.LHpdf	cteq6.1.LHgrid
CTEQ6	40	cteq6.LHpdf	-
CTEQ6 Standard MSbar	1	cteq6m.LHpdf	cteq6mE.LHgrid
CTEQ6 LO fit, with NLO order alpha_s	1	cteq6l.LHpdf	-
CTEQ6 LO fit, with LO order alpha_s	1	cteq6ll.LHpdf	-
CTEQ6m Standard MSbar	1	-	cteq6m.LHgrid
CTEQ6m1 updated CTEQ6m	1	-	cteq6m1.LHgrid
CTEQ6d Standard DIS	1	-	cteq6d.LHgrid
CTEQ6i Leading Order	1	-	cteq6i.LHgrid
CTEQ6m Standard MSbar	1	-	cteq6m.LHgrid
CTEQ6d Standard DIS	1	-	cteq6d.LHgrid

<http://durpdg.dur.ac.uk/lhapdf4/>

when released

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

CTEQ6i Leading Order	1	-	cteq6i.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
MRST2004nlo - NLO -	1	MRST2004nlo.LHpdf	MRST2004nlo.LHgrid
MRST2004nlo - NNLO -	1	-	MRST2004nlo.LHgrid
MRST2003c - NLO - restricted range	1	MRST2003cnlo.LHpdf	MRST2003cnlo.LHgrid
MRST2003c - NNLO - restricted range	1	-	MRST2003cnlo.LHgrid
MRST2002 - NLO	1	MRST2002nlo.LHpdf	MRST2002nlo.LHgrid
MRST2002 - NNLO	1	-	MRST2002nlo.LHgrid
MRST2001E	31	MRST2001E.LHpdf	MRST2001E.LHgrid
MRST2001 - LO	1	-	MRST2001lo.LHgrid
MRST2001 - NLO	4	MRST2001nlo.LHpdf	MRST2001nlo.LHgrid
MRST2001 - NNLO	4	-	MRST2001nlo.LHgrid
MRST98	3	MRST98.LHpdf	-
MRST98lo	5	-	MRST98lo.LHgrid
MRST98nlo	5	-	MRST98nlo.LHgrid
MRST98dis	5	-	MRST98dis.LHgrid

MRST98ht	1	-	MRST98ht.LHgrid
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	-
Photon PDF Set Summary			
PDF set	Members	.LHpdf File	LHgrid File
DOG LO	1	-	DOG0.LHgrid
DOG NLO	1	-	DOG1.LHgrid
DG-G LO	4	-	DGG.LHgrid
LAC-GGAL-G LO	4	-	LACG.LHgrid
GS-G LO	2	-	GSG0.LHgrid
GS-G NLO	1	-	GSG1.LHgrid
GS-G-96 LO	1	-	GSG960.LHgrid
GS-G-96 NLO	1	-	GSG961.LHgrid
GRV-G/GRS-G LO	2	-	GRVG0.LHgrid
GRV-G NLO	2	-	GRVG1.LHgrid
ACFGP/AFG-G NLO	3	-	ACFGPG.LHgrid
WHIT-G LO	6	-	WHITG.LHgrid
SAS-G(1N2) LO	8	-	SASG.LHgrid
Pion PDF Set Summary			
PDF set	Members	.LHpdf File	LHgrid File
OW-P LO	2	-	OWP.LHgrid
SMRS-P NLO	3	-	SMRSP.LHgrid
GRV-P LO	1	-	GRVP0.LHgrid
GRV-P NLO	1	-	GRVP1.LHgrid
ABFKW-P NLO	3	-	ABFKWP.LHgrid

Summary - V4 – Future

Some thoughts/suggestions (by no means a definitive list):

- Add new PDF sets as and when they become available.
- Add equivalent PDFSTA routine to give 'statistics' on exceeding limits etc. - [LHAGlue](#)
- Develop C++ wrapper (already have basis, courtesy of Stefan Gieseke).
- Understand alpha_s code at $Q^2 > 100$ GeV.
- Incorporate new QCDNUM when it is ready.
- More than one PDF set in memory at same time?
-