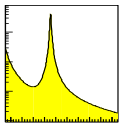

Interface for using LHAPDF in PYTHIA and HERWIG

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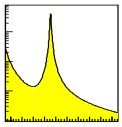
CERN, HERA-LHC Workshop

- **P.D.F. uncertainties and the LHAPDF library version 2**
- **The LHAGLUE interface**
- **Checks with Drell-Yan pairs and Higgs production at LHC and TEVATRON**
- **Outlook**

e-Print Archive: hep-ph/0305126
http://cern.ch/bourilkov/heralhc1.{ps.gz,pdf}



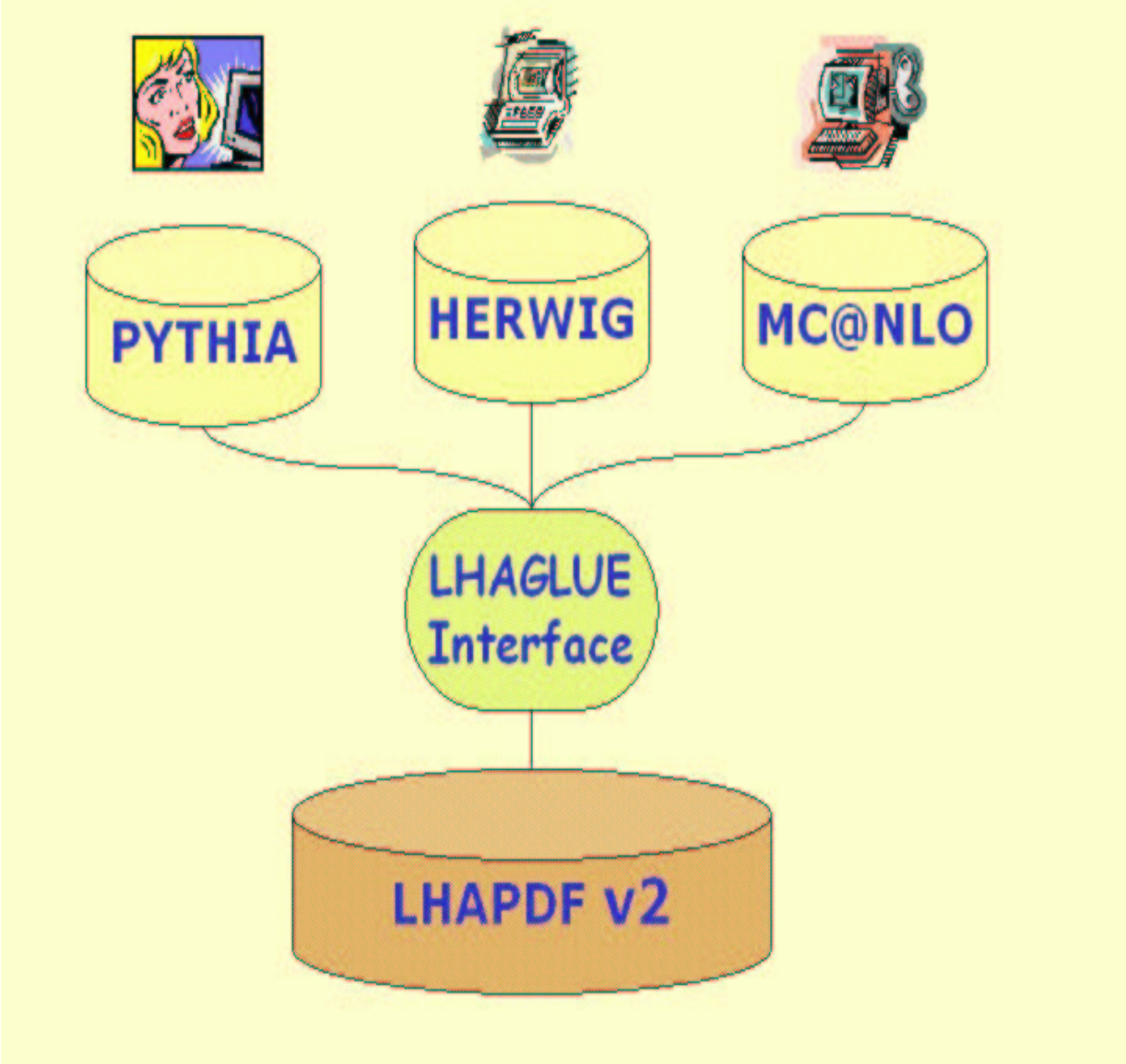
Les Houches Accord P.D.F. work with P.D.F. sets
Rich set of PDF "families" available: CTEQ, MRST, Fermi, Alekhin, Botje

- a "fit" to the data is represented by a P.D.F. set with many members; member ZERO is the best fit, the others are used for uncertainties
- uncertainties on observables are estimated by calculating the observable for ALL members of the set (lots of CPU time!)

- CTEQ6 and CTEQ61 with 40 members or MRST2001E with 30 members:
  use eigenvectors for the P.D.F. parameters $(2 \cdot N_P)$ and estimate uncertainty e.g. ~ 90 % CL for CTEQ:

$$\Delta X = \frac{1}{2}\sqrt{\Sigma[X(S_+) - X(S_-)]^2}$$

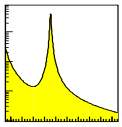
- Fermi2002, Alekhin2000, Botje with 100(1000) members:
  estimate the standard deviation from the set
- additional newest e.g. Alekhin2003, MRST2002 and legacy sets available
- two Q^2 evolution codes: EVLCTEQ v1 and QCDNUM v 16.12



Three-tier Architecture

Developed for LHAPDF v1, now upgraded for v2

Provide seamless, automatic access without changing the MC generator code



Isolate MC generators from details of LHAPDF library, features, names and locations of PDF sets etc.

Use existing hooks to PDFLIB, but link LHAPDF + LHAGLUE as one library instead

Routines:

- PDFSET: initialization
- STRUCTM: structure functions of (anti)protons

Interfaced to PYTHIA 6.2, HERWIG 6.5 and MC @ NLO 2.3

y	0	2	4
M = 91.2 GeV			
x_1	0.0065	0.0481	0.3557
x_2	0.0065	0.0009	0.0001
M = 200 GeV			
x_1	0.0143	0.1056	0.7800
x_2	0.0143	0.0019	0.0003
M = 1000 GeV			
x_1	0.0714	0.5278	-
x_2	0.0714	0.0097	-

Drell-Yan at LHC

Tests with

- Drell-Yan $70 < M < 120$ GeV: valence and sea (anti)quarks

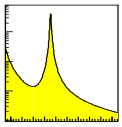
  PYTHIA - MSUB(1) = 1; $Z \rightarrow \mu^+\mu^-$

  HERWIG - IPROC = 1353

- Higgs M = 120 GeV: mostly gluons

  PYTHIA - MSUB(102) = 1

  HERWIG - IPROC = 1699

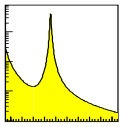


Cross sections with PYTHIA 6.221, Herwig 6.504; samples of 10000 events for each PDF member, no unfolding of MC errors (~ 0.5 %)
No special care to make sure that all input (default) parameters are exactly the same - this is a technical check, NOT a detailed physics study

- in general good agreement between PDF sets

Cross sections in [pb] - LHC 14 TeV				
	Drell-Yan		Higgs	
PDF set	PYTHIA	HERWIG	PYTHIA	HERWIG
CTEQ6	1673 ± 64	1636 ± 63	16.2 ± 0.7	14.9 ± 0.6
CTEQ6m	1673	1636	16.2	14.9
CTEQ6l	1538	1500	18.3	16.3
CTEQ6ll	1647	1608	17.8	16.1
CTEQ6mE	1673 ± 64	1636 ± 62	16.2 ± 0.7	14.9 ± 0.6
CTEQ61(one)	1659 ± 76	1624 ± 78	16.0 ± 0.8	14.7 ± 0.7
CTEQ5m	1802	1756	15.8	14.7
CTEQ5m1	1711	1667	15.7	14.5
MRST2001	1699	1657	15.5	14.4
MRST2001lo	1595	1556	17.0	15.5
MRST2001nlo	1692	1650	15.5	14.3
MRST2001nnlo	1656	1617	14.6	13.6
MRST2001E	1682 ± 26	1645 ± 28	15.4 ± 0.3	14.3 ± 0.3
MRST2002nlo	1693	1652	15.4	14.2
MRST98	1684	1639	15.4	14.2
Fermi2002_100	1391 ± 28	1364 ± 27	14.2 ± 0.5	12.8 ± 0.4
Fermi2002_1000	1418 ± 27	1391 ± 27	.... ± ...	13.4 ± 0.5
Alekhin_100	1763 ± 65	1722 ± 64	15.6 ± 0.6	14.3 ± 0.5
Alekhin_1000	1793 ± 64	1744 ± 64	.... ± ...	15.0 ± 0.5
a02_lo_v	1706	1668	17.4	15.8
a02_nlo_v	1841	1792	16.4	15.0
a02_nnlo_v	1864	1813	16.3	15.0
Botje_100	1850 ± 47	1802 ± 46	16.0 ± 0.4	14.5 ± 0.3
Botje_1000	1891 ± 46	1843 ± 45	.... ± ...	15.2 ± 0.4

Cross sections in [pb] - TEVATRON 2 TeV				
	Drell-Yan		Higgs	
PDF set	PYTHIA	HERWIG	PYTHIA	HERWIG
CTEQ6	198 ± 6.9	195 ± 6.6	0.30 ±0.02	0.27 ± 0.02
CTEQ6m	198	195	0.30	0.27
CTEQ6l	178	176	0.26	0.23
CTEQ6ll	180	178	0.25	0.22
CTEQ6mE	198 ± 6.9	195 ± 6.6	0.30 ±0.02	0.28 ± 0.02
CTEQ61(one)	198 ± 6.8	195 ± 6.6	0.31 ±0.02	0.28 ± 0.02
CTEQ5m	207	205	0.32	0.29
CTEQ5m1	203	200	0.30	0.27
MRST2001	202	199	0.32	0.28
MRST2001lo	179	177	0.28	0.25
MRST2001nlo	202	199	0.32	0.28
MRST2001nnlo	206	203	0.34	0.30
MRST2001E	202 ± 2.2	199 ± 2.2	0.32 ±0.01	0.29 ± 0.01
MRST2002nlo	202	199	0.32	0.29
MRST98	203	200	0.31	0.28
Fermi2002_100	207 ± 5.1	204 ± 4.9	0.27 ±0.02	0.23 ± 0.02
Fermi2002_1000	209 ± 5.0	206 ± 4.9	.... ± ...	.... ± ...
Alekhin_100	216 ± 4.0	214 ± 4.0	0.32 ±0.02	0.28 ± 0.02
Alekhin_1000	218 ± 5.1	216 ± 5.2	.... ± ...	0.30 ± 0.02
a02_lo_v	216	212	0.28	0.25
a02_nlo_v	229	226	0.32	0.28
a02_nnlo_v	233	230	0.32	0.28
Botje_100	198 ± 1.0	196 ± 1.0	0.27 ±0.01	0.23 ± 0.01
Botje_1000	201 ± 2.1	198 ± 2.0	.... ± ...	0.25 ± 0.01



Outlook

- PYTHIA 6.2, HERWIG 6.5 and MC @ NLO 2.3 interfaced to LHAPDF
- all PDF sets/members tested successfully
- consistency checks with Drell-Yan, Higgs production for LHC and TEVATRON OK
- exceptions: some Alekhin and Botje PDFs from the 100(1000) sets are too far from the average and sometimes produce unphysical cross sections
- quite consistent picture at the TEVATRON, due to the large extrapolations variations between PDF sets sometimes more important than within sets at LHC
- different sets give different estimates of the PDF uncertainties; one sigma, 90 % CL ?! ; need unification!
- the effect of P.D.F. uncertainties on SM predictions for the investigated channels is below 5 % for LHC and TEVATRON