# New Developments in LHAPDF/LHAGLUE

# and

# PDF use from the Tevatron to the LHC


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## Outline

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  - Recent developments in LHAPDF/LHAGLUE
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  - Brute force v/s PDF weights
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- Example studies
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  - Gluon fusion to Higgs at LHC
  - High $P_T$ inclusive jet at TeV and LHC
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# Motivation

- Use MC to compare theoretical predictions with experimental results.
- TeV and LHC collide hadrons so every event generated uses PDFs

$$\frac{\mathrm{d}\,\sigma}{\mathrm{d\ variable}}[\mathrm{pp} \to \mathrm{X}] \sim \sum_{\mathrm{ij}} \left(\mathrm{f}_{\mathrm{i/p}}(\mathrm{x}_1)\mathrm{f}_{\mathrm{j/p}}(\mathrm{x}_2) + (\mathrm{i} \leftrightarrow \mathrm{j})\right) \hat{\sigma} \qquad (1)$$

$\hat{\sigma}$ - cross section for the partonic subprocess $ij \to X$

$\mathrm{x}_1, \mathrm{x}_2$ - parton momentum fractions,

$\mathrm{f}_{\mathrm{i/p}}(\mathrm{x}_\mathrm{i})$ - probability to find a parton $i$ with $x_i$ in the proton.

- Standard PDF access is important $\longrightarrow$ LHAPDF
- $\delta\sigma_{th} = \delta\sigma_{PDF} +$....

## TeV/LHC physics affected by PDFs

- UE tunes

  $\longrightarrow$ See talk by R. Field on Pythia tune with CTEQ61

- Luminosity to few percent at LHC using Z/W production

- Heavy flavor PDFs

  $\longrightarrow$ See nice talk by C. Jackson (Brookhaven meeting)

- W+/W- constrain flavor decomposition

- High $P_T$ jet cross section

$\longrightarrow$ See talk "Issues in PDFs" by Wu-Ki Tung from first meeting for nice summary.

## LHAPDF/LHAGLUE

- The Les Houches Accord PDF library is replacement for PDFLIB.
- LHAGLUE is a “PDFLIB-like” interface for HERWIG and PYTHIA

$\longrightarrow$ See talk by J. Huston (Dec.1 2005 QCD working group) for summary of LHAPDF and LHAGLUE.

# Recent developments in LHAPDF

- v4 March 2005
  - Photon and pion PDFs from PDFLIB
  - New proton PDFs: MRST2004 and Alekhin's a02m
  - Simplified file structure (All 'source' files in src)
  - Access to $\Lambda^{QCD}_{4/5}$
- v4.1 August 2005
  - New installation method (configure;make;make install)

$\longrightarrow$ See hep-ph/0508110 for more detail and complete history of LHAPDF/LHAGLUE

# LHAPDF V5 coming soon!

- Will be possible to keep PDFs from multiple sets stored in memory.
- Feedback from Tevatron experiments implemented
  - pftopdg.f added from PDFLIB.
    - Some CDF and D0 programs use this.
    - pftopdg converts flavor convention of PDFLIB to PDG convention
  - Various generic names changed to be unique to LHAPDF

    These are only internal names which do NOT affect the average user.
- NEW: LHAPDF v5 available ups/upd at FNAL...
  - ”lhapdf” ”v5_0_0_beta” ”Linux+2.4-2.3.2” ”GCC3_4_3” ”development”
  - ”lhapdf_source” ”v5_0_0_beta” ”NULL” ”” ”development”

  → Thanks to Lynn Garren!
- Please check v5! Your suggestions/problems can still be dealt with in v5.

→ CDF and D0 use will help validate and develop tools and ideas that will also be useful to the LHC. This is important!

# Cross sections and uncertainty checks

| Cross sections in [pb] - TEVATRON 2 TeV | | | | |
|---|---|---|---|---|
| | Drell-Yan | | Higgs | |
| PDF set | PYTHIA | HERWIG | PYTHIA | HERWIG |
| CTEQ6 | 198 $\pm$ 6.9 | 195 $\pm$ 6.6 | 0.30 $\pm$0.02 | 0.31 $\pm$ 0.02 |
| CTEQ6l | 178 | 176 | 0.26 | 0.26 |
| CTEQ6ll | 180 | 178 | 0.25 | 0.26 |
| CTEQ6mE | 198 $\pm$ 6.9 | 195 $\pm$ 6.6 | 0.30 $\pm$0.02 | 0.31 $\pm$ 0.02 |
| CTEQ61(one) | 198 $\pm$ 6.8 | 195 $\pm$ 6.6 | 0.31 $\pm$0.02 | 0.31 $\pm$ 0.02 |
| CTEQ5m | 207 | 205 | 0.32 | 0.33 |
| CTEQ5m1 | 203 | 200 | 0.30 | 0.30 |
| CTEQ5d | 193 | 190 | 0.36 | 0.36 |
| CTEQ5l | 185 | 183 | 0.25 | 0.25 |
| CTEQ4m | 207 | 204 | 0.33 | 0.33 |
| CTEQ4d | 194 | 191 | 0.36 | 0.36 |
| CTEQ4l | 184 | 182 | 0.27 | 0.27 |
| MRST2001 | 202 | 199 | 0.32 | 0.33 |
| MRST2001lo | 179 | 177 | 0.28 | 0.28 |
| MRST2001nlo(Standard) | 202 | 200 | 0.32 | 0.32 |
| MRST2001nlo(low $\alpha_s$) | 202 | 200 | 0.31 | 0.32 |
| MRST2001nlo(low $\alpha_s$) | 209 | 206 | 0.33 | 0.34 |
| MRST2001nlo(Jet Fit) | 201 | 198 | 0.33 | 0.33 |
| MRST2001nnlo | 206 | 203 | 0.34 | 0.33 |
| MRST2001E | 202 $\pm$ 2.2 | 199 $\pm$ 2.2 | 0.32 $\pm$0.01 | 0.33 $\pm$ 0.01 |
| MRST2002nlo | 202 | 199 | 0.32 | 0.33 |
| MRST2002nnlo | 205 | 203 | 0.34 | 0.34 |
| MRST98(central) | 203 | 200 | 0.31 | 0.28 |
| MRST98(low g) | 204 | 202 | 0.30 | 0.27 |
| MRST98(high g) | 200 | 298 | 0.32 | 0.28 |
| MRST98(low $\alpha$) | | | | |
| MRST98(high $\alpha$) | | | | |
| MRSTCNLO | 206 | 204 | 0.35 | 0.35 |
| MRSTCNNLO | 205 | 203 | 0.32 | 0.32 |
| Fermi2002_100 | 207 $\pm$ 5.1 | 204 $\pm$ 4.9 | 0.27 $\pm$0.02 | 0.27 $\pm$ 0.02 |
| Fermi2002_1000 | 209 $\pm$ 5.0 | 206 $\pm$ 4.9 | 0.29 $\pm$ ... | 0.29 $\pm$ ... |
| Alekhin_100 | 216 $\pm$ 4.0 | 214 $\pm$ 4.0 | 0.32 $\pm$0.02 | 0.32 $\pm$ 0.02 |
| Alekhin_1000 | 218 $\pm$ 5.1 | 216 $\pm$ 5.2 | 0.34 $\pm$ ... | 0.34 $\pm$ 0.02 |

| Cross sections in [pb] - LHC 14 TeV | | | | |
|---|---|---|---|---|
| | Drell-Yan | | Higgs | |
| PDF set | PYTHIA | HERWIG | PYTHIA | HERWIG |
| CTEQ6 | 1673 $\pm$ 64 | 1636 $\pm$ 63 | 16.2 $\pm$ 0.7 | 16.0 $\pm$ 0.7 |
| CTEQ6m | 1673 | 1636 | 16.2 | 16.0 |
| CTEQ6l | 1538 | 1500 | 18.3 | 17.6 |
| CTEQ6ll | 1647 | 1608 | 17.8 | 17.4 |
| CTEQ6mE | 1673 $\pm$ 64 | 1636 $\pm$ 62 | 16.2 $\pm$ 0.7 | 16.0 $\pm$ 0.7 |
| CTEQ61(one) | 1659 $\pm$ 76 | 1624 $\pm$ 78 | 16.0 $\pm$ 0.8 | 15.8 $\pm$ 0.8 |
| CTEQ5m | 1802 | 1756 | 15.8 | 15.9 |
| CTEQ5m1 | 1711 | 1667 | 15.7 | 15.5 |
| CTEQ5d | 1684 | 1647 | 15.7 | 15.7 |
| CTEQ5l | 1642 | 1611 | 17.1 | 16.8 |
| CTEQ4m | 1752 | 1707 | 15.4 | 15.3 |
| CTEQ4d | 1653 | 1615 | 15.8 | 15.6 |
| CTEQ4l | 1640 | 1609 | 16.9 | 16.5 |
| MRST2001lo | 1595 | 1556 | 17.0 | 15.5 |
| MRST2001nlo(Standard) | 1699 | 1657 | 15.5 | 15.4 |
| MRST2001nlo(low $\alpha_s$) | 1692 | 1658 | 15.8 | 15.6 |
| MRST2001nlo(high $\alpha_s$) | 1740 | 1700 | 15.5 | 15.6 |
| MRST2001nlo(Jet Fit) | 1686 | 1647 | 15.1 | 15.1 |
| MRST2001nnlo | 1656 | 1617 | 14.6 | 14.5 |
| MRST2001E | 1682 $\pm$ 26 | 1645 $\pm$ 28 | 15.4 $\pm$ 0.3 | 15.3 $\pm$ 0.3 |
| MRST2002nlo | 1693 | 1652 | 15.4 | 15.3 |
| MRST2002nnlo | 1656 | 1617 | 14.7 | 15.2 |
| MRST98(central) | 1684 | 1639 | 15.4 | 15.2 |
| MRST98(low g) | 1695 | 1656 | 15.6 | 15.4 |
| MRST98(high g) | 1665 | 1618 | 15.1 | 14.9 |
| MRST98(low $\alpha$) | | | | |
| MRST98(high $\alpha$) | | | | |
| MRSTCNLO | 1374 | 1353 | 15.8 | 15.5 |
| MRSTCNNLO | 1399 | 1373 | 14.0 | 13.8 |
| Fermi2002_100 | 1391 $\pm$ 28 | 1364 $\pm$ 27 | 14.2 $\pm$ 0.5 | 13.7 $\pm$ 0.5 |
| Fermi2002_1000 | 1418 $\pm$ 27 | 1391 $\pm$ 27 | 14.9 $\pm$ ... | 14.4 $\pm$ 0.5 |
| Alekhin_100 | 1763 $\pm$ 65 | 1722 $\pm$ 64 | 15.6 $\pm$ 0.6 | 15.4 $\pm$ 0.6 |
| Alekhin_1000 | 1793 $\pm$ 64 | 1744 $\pm$ 64 | 16.2 $\pm$ ... | 16.1 $\pm$ 0.6 |

## Cross sections and uncertainty checks cont..

| Cross sections in [pb] - TEVATRON 2 TeV | | | | |
|---|---|---|---|---|
| | Drell-Yan | | Higgs | |
| PDF set | PYTHIA | HERWIG | PYTHIA | HERWIG |
| a02_lo_v | 216 | 212 | 0.28 | 0.27 |
| a02_nlo_v | 229 | 226 | 0.32 | 0.31 |
| a02_nnlo_v | 233 | 230 | 0.32 | 0.31 |
| Botje_100 | 198 ± 1.0 | 196 ± 1.0 | 0.27 ±0.01 | 0.27 ± 0.01 |
| Botje_1000 | 201 ± 2.1 | 198 ± 2.0 | 0.29 ± ... | 0.29 ± 0.01 |
| Zeus2002_TR | 204 | 202 | 0.31 | 0.32 |
| Zeus2002_ZM | 203 | 200 | 0.30 | 0.31 |
| Zeus2002_FF | 205 | 203 | 0.36 | 0.34 |
| H12000_ms | 205 | 203 | 0.32 | 0.33 |
| H12000_mse | 206±4.2 | 203±3.6 | 0.32±0.01 | 0.33 ±0.02 |
| H12000_lo2 | 198 | 196 | 0.37 | 0.37 |
| H12000_lo2e | 197±3.2 | 195±3.4 | 0.37±0.01 | 0.37 ±0.01 |
| H12000_lo | 199 | 196 | 0.17 | 0.18 |
| H12000_loE | 198±4.5 | 196±4.6 | 0.17±0.01 | 0.18 ±0.01 |
| H12000_dis | 196 | 193 | 0.34 | 0.34 |
| H12000_disE | 196±3.8 | 194±3.8 | 0.34±0.01 | 0.34 ±0.01 |
| GRV98_lo | 190 | 188 | | 0.31 |
| GRV98_nlo | 199 | 196 | | 0.39 |

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| Cross sections in [pb] - LHC 14 TeV | | | | |
|---|---|---|---|---|
| | Drell-Yan | | Higgs | |
| PDF set | PYTHIA | HERWIG | PYTHIA | HERWIG |
| a02_lo_v | 1706 | 1668 | 17.4 | 16.4 |
| a02_nlo_v | 1841 | 1792 | 16.4 | 15.7 |
| a02_nnlo_v | 1864 | 1813 | 16.3 | 15.6 |
| Botje_100 | 1850 ± 47 | 1802 ± 46 | 16.0 ± 0.4 | 15.6 ± 0.4 |
| Botje_1000 | 1891 ± 46 | 1843 ± 45 | 16.9 ± ... | 16.4 ± 0.4 |
| Zeus2002_TR | 1732 | 1696 | 16.3 | 16.1 |
| Zeus2002_ZM | 1748 | 1713 | 16.7 | 16.6 |
| Zeus2002_FF | 1742 | 1706 | 16.9 | 19.1 |
| H12000_ms | 1730 | 1700 | 17.6 | 17.2 |
| H12000_mse | 1735± 27 | 1705 ±25 | 17.5±0.3 | 17.2 ±0.3 |
| H12000_lo2 | 1565 | 1539 | 15.4 | 15.3 |
| H12000_lo2e | 1561± 19 | 1534 ±19 | 15.4±0.2 | 15.3 ±0.2 |
| H12000_lo | 1646 | 1606 | 15.4 | 14.9 |
| H12000_loE | 1640± 44 | 1601 ±39 | 15.4±0.6 | 15.0 ±0.6 |
| H12000_dis | 1629 | 1599 | 18.4 | 17.7 |
| H12000_disE | 1635± 25 | 1604 ±24 | 18.4±0.3 | 17.7 ±0.3 |
| GRV98_lo | 1569 | 1535 | | 17.9 |
| GRV98_nlo | 1563 | 1530 | | 16.9 |

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# PDF Uncertainty:Example CTEQ6

- "The Hessian Method"
  - PDF parameterization
    $F(x,Q) = a_0 x^{a_1}(1-x)^{a_2} P(x; a_3, ..., a_i) i = 1, ...N$
  - Fit to data using N=20 free parameters $\longrightarrow$ central value $S_0$
  - Increase the global $\chi^2$ by $\Delta\ \chi^2$=100 to form error matrix
    $\rightarrow \Delta\ \chi^2 = \chi^2 - \chi_0^2 = \sum_{i=1}^{N} \sum_{j=1}^{N} H_{ij}(a_i - a_i^0)(a_j - a_j^0)$
  - Diagonalize the error matrix $\longrightarrow$ N eigenvectors
  - Vary Up/Down in tolerance along each of the N eigenvector directions to obtain 2N=40 new members of the PDF set $\longrightarrow S_i^{\pm}(i = 1, .., N)$

$$LHAPDF \rightarrow F_i^{\pm} = F(x, Q; S_l^{\pm})$$

$\longrightarrow$ See hep-ph/0101032 for details

# 4 “Master” equations for uncertainties on observables?

1) $\Delta X_1 = \frac{1}{2}\sqrt{\sum_{i=1}^{N}(X_i^+ - X_i^-)^2}$

What if $X_i^+$ and $X_i^-$ lie on the same side of $X_0$?

2) $\Delta X_2 = \frac{1}{2}\sqrt{\sum_{i=1}^{2N} R_i^2}$ ($R_1 = X_1^+ - X_0$,$R_2 = X_1^- - X_0$, $R_3 = X_2^+ - X_0$ ...)

NOTE: For symmetric and asymmetric deviations, $\Delta X_1$ varies from $0 \rightarrow \frac{2}{\sqrt{2}}\Delta X_2$

3) CMS positive and negative variations

$\Delta X_{CMS}^+ = \sqrt{\sum_{i=1}^{N}(X_i^+ - X_0)^2}$, $\Delta X_{CMS}^- = \sqrt{\sum_{i=1}^{N}(X_i^- - X_0)^2}$

4) Consider maximal positive and negative variations separately.*

- $\Delta X_{max}^+ = \sqrt{\sum_{i=1}^{N}[max(X_i^+ - X_0, X_i^- - X_0, 0)]^2}$
- $\Delta X_{max}^- = \sqrt{\sum_{i=1}^{N}[max(X_0 - X_i^+, X_0 - X_i^-, 0)]^2}$

$\longrightarrow$See hep-ph/0110378 (P.M. Nadolsky and Z. Sullivan)*

## Techniques for using the "Master" equations

- Brute force
  - Generate MC sample 41 times (once for each PDF in the set)
  - Requires large CPU time! (especially with detector simulation)
  - Need many events to isolate PDF uncertainty over statistical variation.
- PDF weight technique
  - Only one MC sample is generated but 40 PDF weights are stored for each event $\rightarrow W_n^0 = 1, W_n^i = \frac{F(x_1,Q;S_i)F(x_2,Q;S_i)}{F(x_1,Q;S_0)F(x_2,Q;S_0)}$ $n = 1...N_{events}, i = 1..N_{PDF}$
  - Only one run, so kinematics do not change and no residual statistical variation in uncertainty.
  - Must weight the observable (weighted histograms)
- With the above 2 methods use a master equation after you get a result for each PDF.
- One final option is to study which PDFs in the set you are most sensitive to and then just run this subset. Since the contributions add in quadrature this is often good enough.

# Implementing the weighting technique for PYTHIA

- Two options for using the weight technique
  - Store 40 weights for each event (we do it this way).
  - Store $X_1, X_2, F_1, F_2$, and $Q^2$ and calculate the weights "offline".
- Momentum fractions for the 2 initial partons from the hard scattering.

$$X_1 = PARI(33) \text{ and } X_2 = PARI(34)$$

- Flavor type of 2 initial partons

$$F_1 = MSTI(15) \text{ and } F_2 = MSTI(16)$$

- $Q^2$ for the hard scattering

$$Q^2 = PARI(24)$$

This is everything you need to calculate PDF weights using LHAPDF, but we are in the process of writing a general robust code for all users, so you won't have to.

$\longrightarrow$ Thanks to Torbjörn Sjöstrand for the PYTHIA help!

## get_weights SUBROUTINE

- The user passes in the Pythia information.

  W_F1=MSTI(15)

  W_F2=MSTI(16)

  W_X1=PARI(33)

  W_X2=PARI(34)

  W_q2=PARI(24)

- Two arrays are returned; one for the PDF value of each parton.

  LHA_PDFS1(-PDF_ LENGTH:PDF_ LENGTH)

  LHA_PDFS2(-PDF_ LENGTH:PDF_ LENGTH)

  - central value: LHA_PDFS1(0) (member 0)
  - First '+' variation: LHA_PDFS1(1) (member 1)
  - First '-' variation: LHA_PDFS1(-1) (member 2)
  - ...

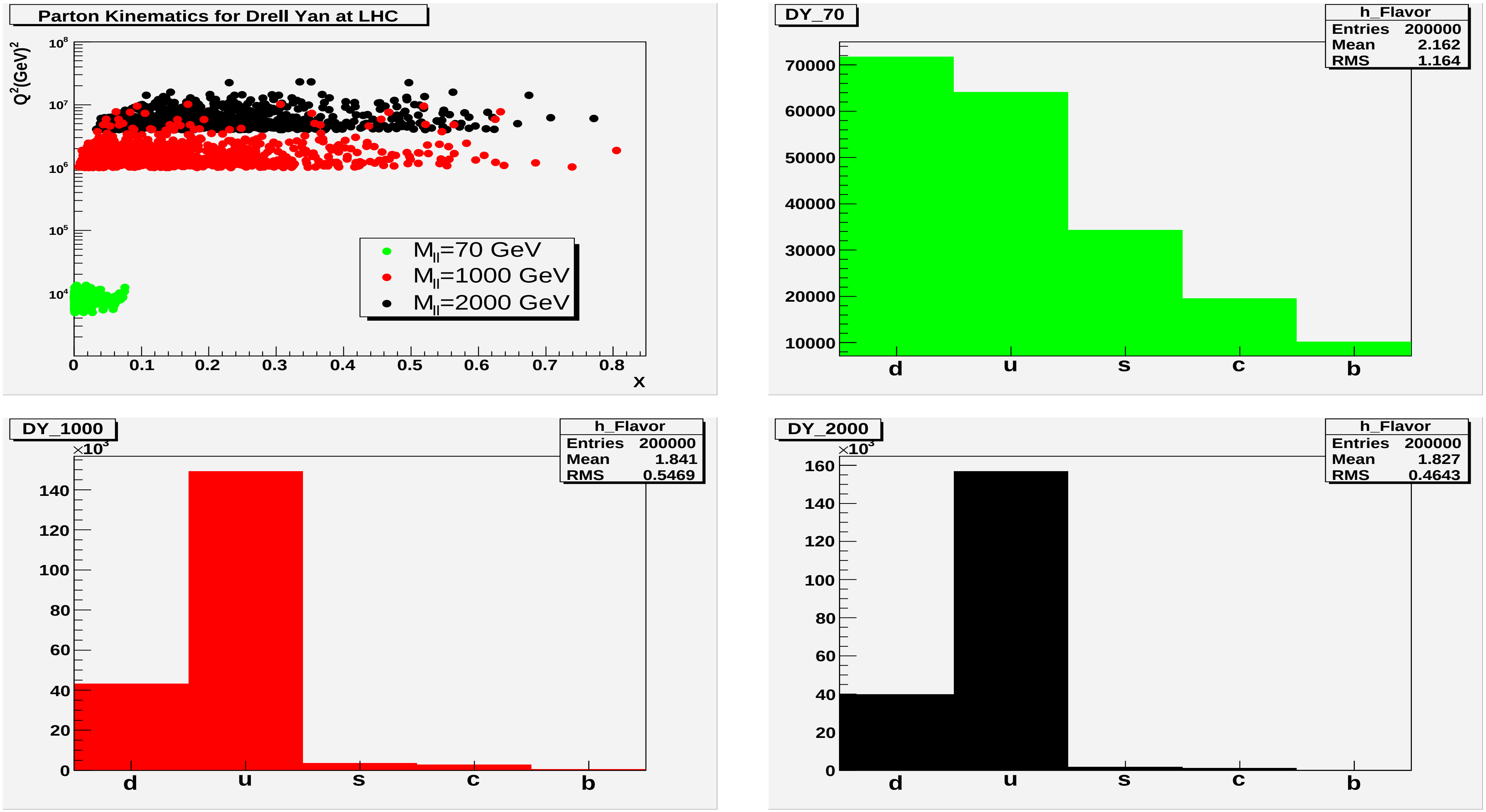
# 3 example studies

- Drell Yan at the LHC: M=70,1000,2000 ($|\eta| < 2.4$)
- Gluon fusion to Higgs at the LHC
- Dijet500 at TeV and LHC

For all studies PYTHIA v6.324 was used with LHAPDF v4.1.1.

The point of these studies is only to compare the predictions of the weight and "brute force" method as well as the various master equations, not to make predictions for YOUR analysis.

# DY Parton kinematics and flavor contributions



## TeV2LHC: Drell Yan error results (in pb)

| Process (method) | $X_0$ (best fit) | $\Delta X_1$ | $\Delta X_2$ | $+\Delta X^+_{CMS}$ | $-\Delta X^-_{CMS}$ | $+\Delta X^+_{max}$ | $-\Delta X^+_{max}$ |
|---|---|---|---|---|---|---|---|
| 70<M<110 (B.F.) | 1086 | 48 | 42 | +55 | -63 | +51 | -62 |
| 70<M<110 (W) | 1086 | 48 | 42 | +55 | -64 | +51 | -63 |
| M>1000 (B.F.) | 6.7e-3 | 3.5e-4 | 2.6e-4 | + 3.5e-4 | -3.8e-4 | +3.4e-4 | -3.9e-4 |
| M>1000 (W) | 6.7e-3 | 5.3e-4. | 4.7e-4 | +4.5e-4 | -8.3e-4 | +8.1e-4 | -4.6.1e-4 |
| M>2000 (B.F.) | 2.2e-4 | 1.8e-5 | 1.3e-5 | +1.9e-5 | -1.9e-5 | +2.0e-5 | -1.7e-5 |
| M>2000 (W) | 2.2e-4 | 3.1e-5 | 2.9e-5 | +2.3e-5 | -5.3e-5 | +5.3e-5 | -2.2e-5 |

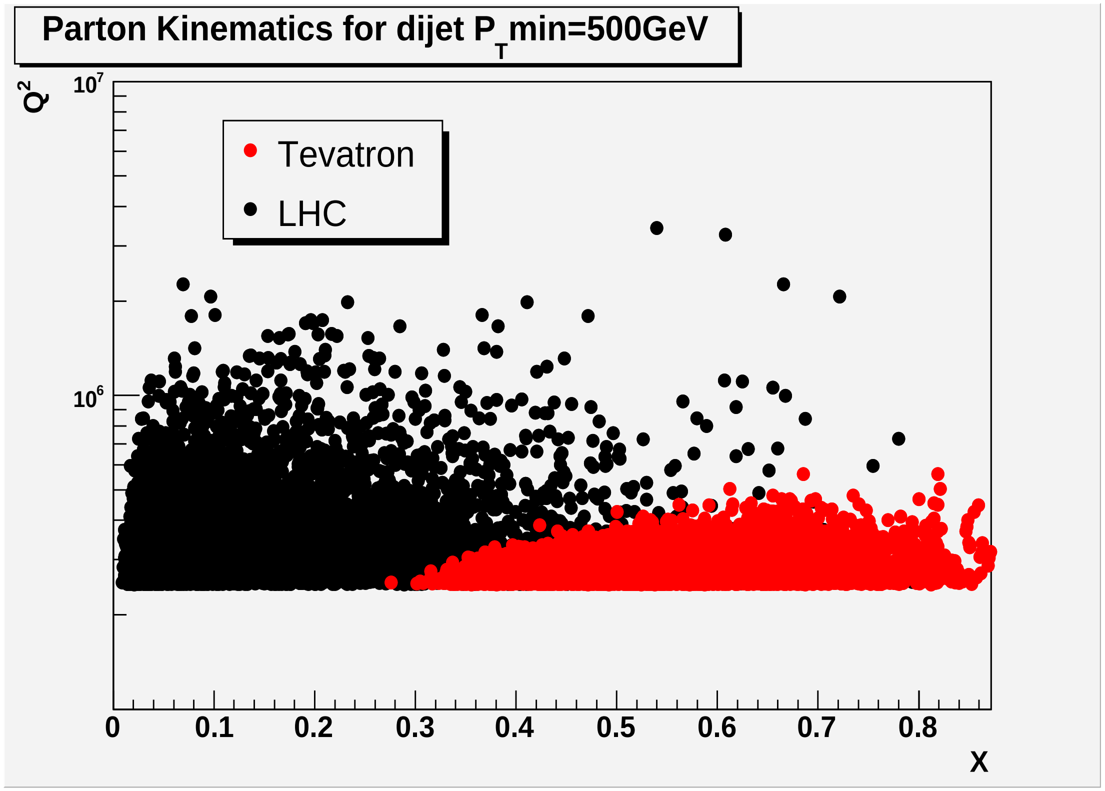
## Gluon Fusion to Higgs ($M_H = 120$ GeV)

- No need for kinematics plot here.
  - $Q^2 \sim M_H^2$
  - $x < \frac{M_H}{7000}$
- Results (in pb)

| Process (method) | $X_0$(best fit) | $\Delta X_1$ | $\Delta X_2$ | $+\Delta X^+_{CMS}$ | $-\Delta X^-_{CMS}$ | $+\Delta X^+_{max}$ | $-\Delta X^+_{max}$ |
|---|---|---|---|---|---|---|---|
| $gg \rightarrow H$ (B.F.) | 17 | .94 | .68 | +.82 | -1.1 | +.8 | -1.1 |
| $gg \rightarrow H$ (W) | 17 | .94 | .68 | +.82 | -1.1 | +.8 | -1.1 |

## Dijet 500 parton kinematics

- MSEL=1
- CKIN(3)=500



## Dijet 500 error results (in pb)

| Process (method) | $X_0$ (best fit) | $\Delta X_1$ | $\Delta X_2$ | $+\Delta X^{+}_{CMS}$ | $-\Delta X^{-}_{CMS}$ | $+\Delta X^{+}_{max}$ | $-\Delta X^{+}_{max}$ |
|---|---|---|---|---|---|---|---|
| TeV (B.F.) | 2.2e-11 | 6.8e-12 | 5.74e-12 | 4.8e-12 | 1.0e-11 | 1.1e-11 | 4.2e-12 |
| TeV (W) | 2.2e-11 | 6.8e-12 | 5.75e-12 | 4.8e-12 | 1.0e-11 | 1.1e-11 | 4.2e-12 |
| LHC (B.F.) | 8.8e-7 | 6.3e-8 | 4.7e-8 | 5.6e-8 | 7.4e-8 | 7.6e-8 | 5.3e-8 |
| LHC (W) | 8.8e-7 | 6.3e-8 | 4.7e-8 | 5.7e-8 | 7.5e-8 | 7.7e-8 | 5.3e-8 |

No $\eta$ or $P_T$ cuts applied.

## SUMMARY

- Recent developments in LHAPDF/LHAGLUE were discussed as well as changes that will be included in the new v5 code.
- PDF uncertainty techniques were discussed including the “Brute Force” v/s the PDF weights method.
- New code written for the physics community to use the PDF weights techniques was described.
- Results from studies done for this workshop were shown for...
  - There is good agreement between the ’weighting’ and ’brute force’ technique for all processes EXCEPT high mass Drell Yan pairs.
  - The $\Delta X_1$ prediction is consistently larger than $\Delta X_2$. It will underestimate however if the variations have a more “asymmetric” affect on the observable.
  - The two non-symmetric equations have consistent results although it seems that the ’CMS’ version is expecting the ’+’, ’-’ variations to be non-arbitrary

- Thanks to J. Huston, T. Sjstrand, K. Matchev, and R. Field for useful correspondence.

## Full error table

| Process (method) | $X_0$(best fit) | $\Delta X_1$ | $\Delta X_2$ | $+\Delta X^{+}_{CMS}$ | $-\Delta X^{-}_{CMS}$ | $+\Delta X^{+}_{max}$ | $-\Delta X^{+}_{max}$ |
|---|---|---|---|---|---|---|---|
| $70<M<110$ (B.F.) | 1086 | 48 | 42 | +55 | -63 | +51 | -62 |
| $70<M<110$ (W) | 1086 | 48 | 42 | +55 | -64 | +51 | -63 |
| $M>1000$ (B.F.) | 6.7e-3 | 3.5e-4 | 2.6e-4 | + 3.5e-4 | -3.8e-4 | +3.4e-4 | -3.9e-4 |
| $M>1000$ (W) | 6.7e-3 | 5.3e-4. | 4.7e-4 | +4.5e-4 | -8.3e-4 | +8.1e-4 | -4.6.1e-4 |
| $M>2000$ (B.F.) | 2.2e-4 | 1.8e-5 | 1.3e-5 | +1.9e-5 | -1.9e-5 | +2.0e-5 | -1.7e-5 |
| $M>2000$ (W) | 2.2e-4 | 3.1e-5 | 2.9e-5 | +2.3e-5 | -5.3e-5 | +5.3e-5 | -2.2e-5 |
| $gg \rightarrow H$ (B.F.) | 17 | .94 | .68 | +.82 | -1.1 | +.8 | -1.1 |
| $gg \rightarrow H$ (W) | 17 | .94 | .68 | +.82 | -1.1 | +.8 | -1.1 |
| DJ500 TeV (B.F.) | 2.2e-11 | 6.8e-12 | 5.74e-12 | 4.8e-12 | 1.0e-11 | 1.1e-11 | 4.2e-12 |
| DJ500 TeV (W) | 2.2e-11 | 6.8e-12 | 5.75e-12 | 4.8e-12 | 1.0e-11 | 1.1e-11 | 4.2e-12 |
| DJ500 LHC (B.F.) | 8.8e-7 | 6.3e-8 | 4.7e-8 | 5.6e-8 | 7.4e-8 | 7.6e-8 | 5.3e-8 |
| DJ500 LHC (W) | 8.8e-7 | 6.3e-8 | 4.7e-8 | 5.7e-8 | 7.5e-8 | 7.7e-8 | 5.3e-8 |