Les Houches heavy flavor pdf benchmark studies

J. Huston in collaboration with S. Forte, P. Nadolsky, J. Rojo…

Benchmarks

- Previous Les Houches workshops have produced benchmarks for PDF evolution, that have served as a standard for understanding use of DGLAP evolution
  - see for example, hep-ph/0204316,0511119
- Heavy flavor pdf's are a crucial aspect of much of precision physics at the LHC, so it would be useful to extend this benchmarking to include this aspect
  - and produce benchmarks/standard candles that will be useful for LHC predictions
  - that will be included in the Les Houches 2009 proceedings, but are certainly relevant for PDF4LHC as well
  - …and we're happy to start/continue the discussion at this meeting

2001 study

- Previous Les Houches study used 'toy pdfs', determined using the CTEQ5M1 parameterization
- We propose to do the same here, but first we will produce grids that can be downloaded to LHAPDF for easier distribution/use of these benchmark pdf's
  - maybe allow more freedom for strange quark

1.3 Reference results for the evolution of parton distributions[7]

In this section we provide a new set of benchmark tables for the evolution of unpolarized parton distributions of hadrons in perturbative QCD. Unlike the only comparable previous study [16], we include results for unequal factorization and renormalization scales, $\mu_{\rm f} \neq \mu_{\rm r}$, and for the evolution with a variable number of partonic flavours $N_{\rm f}$. Besides the standard LO and NLO approximations, we also present the evolution including the (still approximate) NNLO splitting functions and the corresponding non-trivial second-order matching conditions at the heavy-quark thresholds. Our reference results are computed using two entirely independent and conceptually different evolution programs which, however, agree to better than 1 part in 10^5 for momentum fractions $10^{-8} < x < 0.9$.

1.32 Initial conditions and heavy-quark treatment

The following initial conditions for the reference results have been set up at the Les Houches meeting: The evolution is started at

$$\mu_{\rm f,0}^2 \;=\; 2\,{\rm GeV}^2 \; . \qquad (30)$$

Roughly along the lines of the CTEQ5M parametrization [38], the input distributions are chosen as

$$\begin{aligned}
xu_v(x,\mu_{\rm f,0}^2) &= 5.107200\, x^{0.8}\,(1-x)^3 \\
xd_v(x,\mu_{\rm f,0}^2) &= 3.064320\, x^{0.8}\,(1-x)^4 \\
xg\,(x,\mu_{\rm f,0}^2) &= 1.700000\, x^{-0.1}(1-x)^5 \\
x\bar{d}\,(x,\mu_{\rm f,0}^2) &= .1939875\, x^{-0.1}(1-x)^6 \\
x\bar{u}\,(x,\mu_{\rm f,0}^2) &= (1-x)\; x\bar{d}\,(x,\mu_{\rm f,0}^2) \\
xs\,(x,\mu_{\rm f,0}^2) &= x\bar{s}\,(x,\mu_{\rm f,0}^2) \;=\; 0.2\,x(\bar{u}+\bar{d})(x,\mu_{\rm f,0}^2)
\end{aligned} \qquad (31)$$

where, as usual, $q_{i,v} \equiv q_i - \bar{q}_i$. The running couplings are specified via

$$\alpha_{\rm s}(\mu_{\rm r}^2\!=\!2\,{\rm GeV}^2) \;=\; 0.35 \; . \qquad (32)$$

For simplicity these initial conditions are employed regardless of the order of the evolution and the ratio of the renormalization and factorization scales. At LO this ratio is fixed to unity, beyond LO we use

$$\mu_{\rm r}^2 \;=\; k_{\rm r}\mu_{\rm f}^2 \; , \qquad k_{\rm r} \;=\; 0.5\,,\; 1\,,\; 2 \; . \qquad (33)$$

For the evolution with a fixed number $N_{\rm f} > 3$ of quark flavours the quark distributions not specified in Eq. (31) are assumed to vanish at $\mu_{\rm f,0}^2$, and Eq. (32) is understood to refer to the chosen value of $N_{\rm f}$. For the evolution with a variable $N_{\rm f} = 3 \ldots 6$, Eqs. (31) and (32) always refer to three flavours. $N_{\rm f}$ is then increased by one unit at the heavy-quark pole masses taken as

$$m_{\rm c} \;=\; \mu_{\rm f,0}\,, \quad m_{\rm b} \;=\; 4.5\,{\rm GeV}^2\,, \quad m_{\rm t} \;=\; 175\,{\rm GeV}^2\;, \qquad (34)$$

Some reference tables from 2001

Table 2: Reference results for the $N_f = 4$ (FFN) and the variable-N_f (VFN) leading-order evolution for the initial conditions (30) – (32), shown together with the input parton distributions (31). The respective values for $\alpha_s(\mu_r^2 = \mu_f^2 = 10^4\ \text{GeV}^2)$ read 0.117374 (FFN) and 0.122306 (VFN). For the notation see the first two paragraphs of Section 1.33.

x	xu_v	xd_v	xL_-	xL_+	xs_+	xc_+	xb_+	xg
Input, $\mu_f^2 = 2\ \text{GeV}^2$								
10^{-7}	1.2829^{-5}	7.6972^{-6}	9.7224^{-8}	3.8890^{+0}	7.7779^{-1}	0.0^{+0}	0.0^{+0}	8.5202^{+0}
10^{-6}	8.0943^{-5}	4.8566^{-5}	7.7227^{-7}	3.0891^{+0}	6.1782^{-1}	0.0^{+0}	0.0^{+0}	6.7678^{+0}
10^{-5}	5.1070^{-4}	3.0642^{-4}	6.1341^{-6}	2.4536^{+0}	4.9072^{-1}	0.0^{+0}	0.0^{+0}	5.3756^{+0}
10^{-4}	3.2215^{-3}	1.9327^{-3}	4.8698^{-5}	1.9478^{+0}	3.8957^{-1}	0.0^{+0}	0.0^{+0}	4.2681^{+0}
10^{-3}	2.0271^{-2}	1.2151^{-2}	3.8474^{-4}	1.5382^{+0}	3.0764^{-1}	0.0^{+0}	0.0^{+0}	3.3750^{+0}
10^{-2}	1.2448^{-1}	7.3939^{-2}	2.8946^{-3}	1.1520^{+0}	2.3041^{-1}	0.0^{+0}	0.0^{+0}	2.5623^{+0}
0.1	5.9008^{-1}	3.1864^{-1}	1.2979^{-2}	4.9319^{-1}	9.8638^{-2}	0.0^{+0}	0.0^{+0}	1.2638^{+0}
0.3	6.6861^{-1}	2.8082^{-1}	7.7227^{-3}	8.7524^{-2}	1.7505^{-2}	0.0^{+0}	0.0^{+0}	3.2228^{-1}
0.5	3.6666^{-1}	1.1000^{-1}	1.6243^{-3}	9.7458^{-3}	1.9492^{-3}	0.0^{+0}	0.0^{+0}	5.6938^{-2}
0.7	1.0366^{-1}	1.8659^{-2}	1.0259^{-4}	3.8103^{-4}	7.6207^{-5}	0.0^{+0}	0.0^{+0}	4.2810^{-3}
0.9	4.6944^{-3}	2.8166^{-4}	1.7644^{-7}	4.3129^{-7}	8.6259^{-8}	0.0^{+0}	0.0^{+0}	1.7180^{-5}
LO, $N_f = 4$, $\mu_f^2 = 10^4\ \text{GeV}^2$								
10^{-7}	5.7722^{-5}	3.4343^{-5}	7.6527^{-7}	9.9465^{+1}	4.8642^{+1}	4.7914^{+1}	0.0^{+0}	1.3162^{+3}
10^{-6}	3.3373^{-4}	1.9800^{-4}	5.0137^{-6}	5.0259^{+1}	2.4263^{+1}	2.3685^{+1}	0.0^{+0}	6.0008^{+2}
10^{-5}	1.8724^{-3}	1.1065^{-3}	3.1696^{-5}	2.4378^{+1}	1.1501^{+1}	1.1042^{+1}	0.0^{+0}	2.5419^{+2}
10^{-4}	1.0057^{-2}	5.9076^{-3}	1.9071^{-4}	1.1323^{+1}	5.1164^{+0}	4.7530^{+0}	0.0^{+0}	9.7371^{+1}
10^{-3}	5.0392^{-2}	2.9296^{-2}	1.0618^{-3}	5.0324^{+0}	2.0918^{+0}	1.8089^{+0}	0.0^{+0}	3.2078^{+1}
10^{-2}	2.1955^{-1}	1.2433^{-1}	4.9731^{-3}	2.0433^{+0}	7.2814^{-1}	5.3247^{-1}	0.0^{+0}	8.0546^{+0}
0.1	5.7267^{-1}	2.8413^{-1}	1.0470^{-2}	4.0832^{-1}	1.1698^{-1}	5.8864^{-2}	0.0^{+0}	8.8766^{-1}
0.3	3.7925^{-1}	1.4186^{-1}	3.3029^{-3}	4.0165^{-2}	1.0516^{-2}	4.1379^{-3}_{*}	0.0^{+0}	8.2676^{-2}
0.5	1.3476^{-1}	3.5364^{-2}	4.2815^{-4}	2.8624^{-3}	7.3138^{-4}	2.6481^{-4}	0.0^{+0}	7.9240^{-3}
0.7	2.3123^{-2}	3.5943^{-3}	1.5868^{-5}	6.8961^{-5}	1.7725^{-5}	6.5549^{-6}	0.0^{+0}	3.7311^{-4}
0.9	4.3443^{-4}	2.2287^{-5}	1.1042^{-8}	3.6293^{-8}	1.0192^{-8}	4.8893^{-9}_{*}	0.0^{+0}	1.0918^{-6}
LO, $N_f = 3\ldots5$, $\mu_f^2 = 10^4\ \text{GeV}^2$								
10^{-7}	5.8771^{-5}	3.4963^{-5}	7.8233^{-7}	1.0181^{+2}	4.9815^{+1}	4.9088^{+1}	4.6070^{+1}	1.3272^{+3}
10^{-6}	3.3933^{-4}	2.0129^{-4}	5.1142^{-6}	5.1182^{+1}	2.4725^{+1}	2.4148^{+1}	2.2239^{+1}	6.0117^{+2}
10^{-5}	1.9006^{-3}	1.1229^{-3}	3.2249^{-5}	2.4693^{+1}	1.1659^{+1}	1.1201^{+1}	1.0037^{+1}	2.5282^{+2}
10^{-4}	1.0186^{-2}	5.9819^{-3}	1.9345^{-4}	1.1406^{+1}	5.1583^{+0}	4.7953^{+0}	4.1222^{+0}	9.6048^{+1}
10^{-3}	5.0893^{-2}	2.9576^{-2}	1.0730^{-3}	5.0424^{+0}	2.0973^{+0}	1.8147^{+0}	1.4582^{+0}	3.1333^{+1}
10^{-2}	2.2080^{-1}	1.2497^{-1}	4.9985^{-3}	2.0381^{+0}	7.2625^{-1}	5.3107^{-1}	3.8106^{-1}	7.7728^{+0}
0.1	5.7166^{-1}	2.8334^{-1}	1.0428^{-2}	4.0496^{-1}	1.1596^{-1}	5.8288^{-2}	3.5056^{-2}	8.4358^{-1}
0.3	3.7597^{-1}	1.4044^{-1}	3.2629^{-3}	3.9592^{-2}	1.0363^{-2}	4.0740^{-3}	2.2039^{-3}	7.8026^{-2}
0.5	1.3284^{-1}	3.4802^{-2}	4.2031^{-4}	2.8066^{-3}	7.1707^{-4}	2.5958^{-4}	1.3522^{-4}	7.4719^{-3}
0.7	2.2643^{-2}	3.5134^{-3}	1.5468^{-5}	6.7201^{-5}	1.7278^{-5}	6.3958^{-6}	3.3996^{-6}	3.5241^{-4}
0.9	4.2047^{-4}	2.1529^{-5}	1.0635^{-8}	3.4998^{-8}	9.8394^{-9}	4.7330^{-9}	2.8903^{-9}	1.0307^{-6}

Table 3: Reference results for the $N_f = 4$ next-to-leading-order evolution for the initial conditions (30) – (32). The correspon ing value of the strong coupling is $\alpha_s(\mu_r^2 = 10^4\ \text{GeV}^2) = 0.110902$. As in the leading-order case, the valence distributions s and c_v vanish for the input (31). The notation is explained in the first two paragraphs of Section 1.33.

NLO, $N_f = 4$, $\mu_f^2 = 10^4\ \text{GeV}^2$							
x	xu_v	xd_v	xL_-	xL_+	xs_+	xc_+	xg
$\mu_r^2 = \mu_f^2$							
10^{-7}	1.0616^{-4}	6.2328^{-5}	4.2440^{-6}	1.3598^{+2}	6.6913^{+1}_{*}	6.6195^{+1}	1.1483^{+3}_{*}
10^{-6}	5.4177^{-4}	3.1719^{-4}	1.9241^{-5}	6.8396^{+1}	3.3342^{+1}	3.2771^{+1}	5.3911^{+2}
10^{-5}	2.6870^{-3}	1.5677^{-3}	8.3575^{-5}	3.2728^{+1}	1.5685^{+1}	1.5231^{+1}	2.3528^{+2}
10^{-4}	1.2841^{-2}	7.4558^{-3}	3.4911^{-4}	1.4746^{+1}	6.8355^{+0}	6.4769^{+0}	9.2872^{+1}_{*}
10^{-3}	5.7926^{-2}	3.3337^{-2}	1.4162^{-3}	6.1648^{+0}_{*}	2.6659^{+0}	2.3878^{+0}	3.1502^{+1}
10^{-2}	2.3026^{-1}	1.2928^{-1}	5.3251^{-3}	2.2527^{+0}	8.4220^{-1}_{*}	6.5246^{-1}	8.1066^{+0}
0.1	5.5452^{-1}	2.7336^{-1}	1.0011^{-2}	3.9336^{-1}	1.1489^{-1}	6.0351^{-2}	8.9867^{-1}
0.3	3.5393^{-1}	1.3158^{-1}	3.0362^{-3}	3.5848^{-2}	9.2030^{-3}	3.3890^{-3}	8.3451^{-2}
0.5	1.2271^{-1}	3.1967^{-2}	3.8265^{-4}	2.4126^{-3}	5.8424^{-4}	1.6955^{-4}	8.0473^{-3}
0.7	2.0429^{-2}	3.1473^{-3}_{*}	1.3701^{-5}	5.3622^{-5}	1.2393^{-5}	2.7807^{-6}	3.8721^{-4}
0.9	3.6096^{-4}	1.8317^{-5}	8.923^{-9}	2.092^{-8}	4.039^{-9}	-2.405^{-10}	1.2127^{-6}
$\mu_r^2 = 2\,\mu_f^2$							
10^{-7}	9.2960^{-5}	5.4699^{-5}	3.3861^{-6}	1.2214^{+2}	5.9987^{+1}	5.9265^{+1}	1.0911^{+3}
10^{-6}	4.8463^{-4}	2.8440^{-4}	1.5820^{-5}	6.1831^{+1}	3.0056^{+1}	2.9483^{+1}	5.1456^{+2}
10^{-5}	2.4578^{-3}	1.4374^{-3}	7.1265^{-5}	2.9845^{+1}	1.4240^{+1}	1.3785^{+1}	2.2580^{+2}
10^{-4}	1.2018^{-2}	6.9946^{-3}	3.1111^{-4}	1.3618^{+1}	6.2690^{+0}	5.9088^{+0}	8.9753^{+1}
10^{-3}	5.5483^{-2}	3.2009^{-2}	1.3254^{-3}	5.8076^{+0}	2.4848^{+0}	2.2050^{+0}	3.0729^{+1}
10^{-2}	2.2595^{-1}	1.2720^{-1}	5.2141^{-3}	2.1896^{+0}	8.0746^{-1}	6.1564^{-1}	8.0188^{+0}
0.1	5.6007^{-1}	2.7697^{-1}	1.0180^{-2}	3.9945^{-1}	1.1570^{-1}	5.9661^{-2}	9.1201^{-1}
0.3	3.6474^{-1}	1.3612^{-1}	3.1588^{-3}	3.7501^{-2}	9.6302^{-3}	3.5499^{-3}	8.6368^{-2}
0.5	1.2843^{-1}	3.3610^{-2}	4.0510^{-4}	2.5822^{-3}	6.3044^{-4}	1.8999^{-4}	8.4178^{-3}
0.7	2.1779^{-2}	3.3725^{-3}	1.4798^{-5}	5.9125^{-5}	1.3961^{-5}	3.5593^{-6}	4.0836^{-4}
0.9	3.9817^{-4}	2.0321^{-5}	9.987^{-9}	2.555^{-8}	5.586^{-9}	7.930^{-10}	1.3008^{-6}
$\mu_r^2 = 1/2\,\mu_f^2$							
10^{-7}	1.2438^{-4}	7.2817^{-5}	5.5568^{-6}	1.4556^{+2}	7.1706^{+1}	7.0990^{+1}	1.1468^{+3}
10^{-6}	6.1759^{-4}	3.6051^{-4}	2.4322^{-5}	7.3406^{+1}	3.5851^{+1}	3.5282^{+1}_{*}	5.4041^{+2}
10^{-5}	2.9770^{-3}	1.7316^{-3}	1.0121^{-5}_{*}	3.5158^{+1}_{*}	1.6903^{+1}	1.6452^{+1}	2.3663^{+2}
10^{-4}	1.3820^{-2}	7.9998^{-3}	4.0093^{-4}	1.5795^{+1}	7.3626^{+0}	7.0057^{+0}	9.3640^{+1}
10^{-3}	6.0585^{-2}	3.4766^{-2}	1.5300^{-3}	6.5284^{+0}	2.8504^{+0}	2.5740^{+0}	3.1795^{+1}
10^{-2}	2.3422^{-1}_{*}	1.3114^{-1}	5.4411^{-3}	2.3221^{+0}	8.8022^{-1}	6.9260^{-1}	8.1613^{+0}
0.1	5.4824^{-1}	2.6954^{-1}	9.8435^{-2}	3.8787^{-1}	1.1419^{-1}	6.0997^{-2}	8.9361^{-1}
0.3	3.4425^{-1}	1.2760^{-1}	2.9317^{-3}	3.4294^{-2}	8.7599^{-3}	3.1681^{-3}	8.2031^{-2}
0.5	1.1794^{-1}	3.0618^{-2}	3.6454^{-4}	2.2530^{-3}	5.3541^{-4}	1.4134^{-4}	7.8595^{-3}
0.7	1.9356^{-2}	2.9698^{-3}	1.2847^{-5}	4.8328^{-5}	1.0666^{-5}	1.6668^{-6}	3.7624^{-4}_{*}
0.9	3.3264^{-4}	1.6800^{-5}	8.124^{-9}	1.573^{-8}	2.024^{-9}	-1.870^{-9}	1.1647^{-6}

Proposal

- Start with (x,Q^2) grids of LO, NLO and NNLO benchmark pdf's
- Evolve at different orders using your favorite evolution program (provided it agrees with the Les Houches benchmark)
- Compute observables
  - F_2
  - F_L
  - F_2^c
- Use standards
  - m_c=1.4 GeV
  - m_b=4.75 GeV
  - but examine sensitivities
- In
  - ZM-VFN
  - GM-schemes
    - ACOT
    - TR
    - improved ZM
    - FONLL
    - …
  - isolating first the HQ contributions and second the differences between the HQ schemes
  - PDF groups use same HQ code as used in their pdf analysis
- Use (x,Q^2) bins similar to latest HERA publications

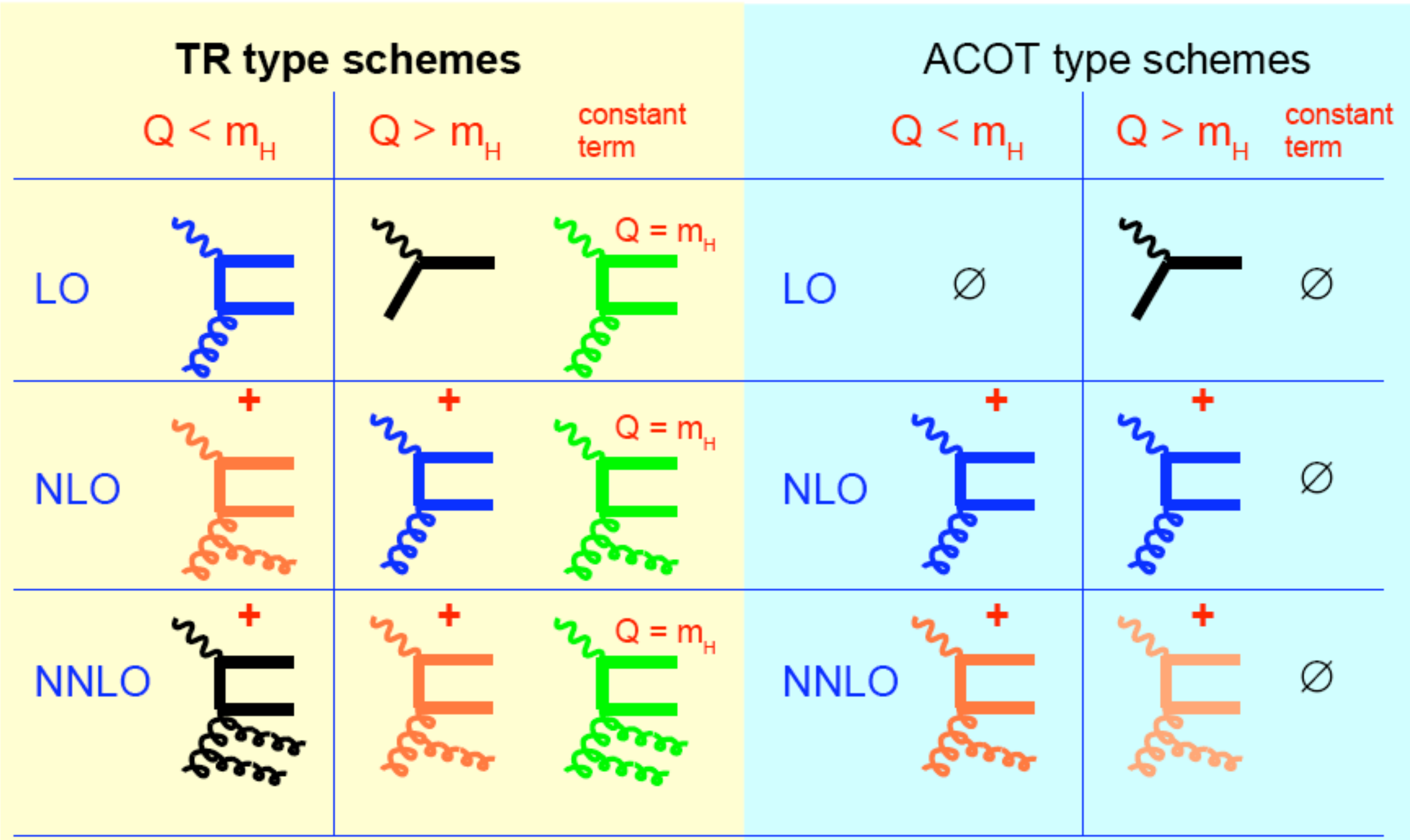
Proposal…

- Important that exactly the same PDF analysis should be repeated with and without heavy quark mass effects, with everything else kept exactly the same

- Benchmark fits can then be used to compute standard candles at the LHC
  - W, Z
  - W/Z
  - tT
  - Higgs
    - both SM and BSM
- In ZM and GM schemes
- Using perhaps MCFM with given reference scales/parameters

Pictorial summary of HF schemes

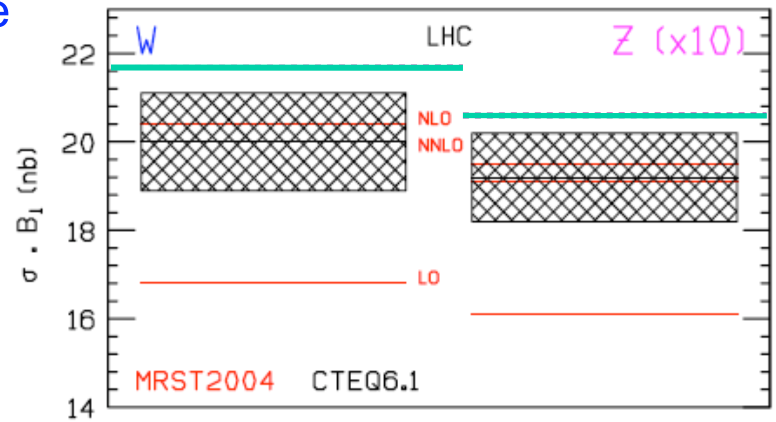
…see also Paolo's talk



Olness &Schienbein, arXiv:0812.3371 [hep-ph]

Consider W/Z benchmark

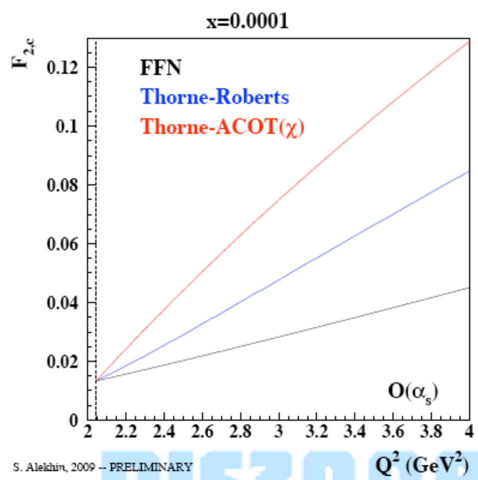
- Inclusion of heavy quark mass effects affects DIS data in x range appropriate for W/Z production at the LHC
- Sizeable increase in W/Z cross sections at the LHC in going from CTEQ6.1 to CTEQ6.5/6.6
- …but MSTW2008 also has increased W/Z cross sections at the LHC
  - now CTEQ6.6 and MSTW2008 in good agreement



CTEQ6.5(6)

MSTW08

Figure 80. Predicted cross sections for *W* and *Z* production at the LHC using MRST2004 and CTEQ6.1 pdfs. The overall pdf uncertainty of the NLO CTEQ6.1 prediction is approximately 5%, consistent with figure 77.

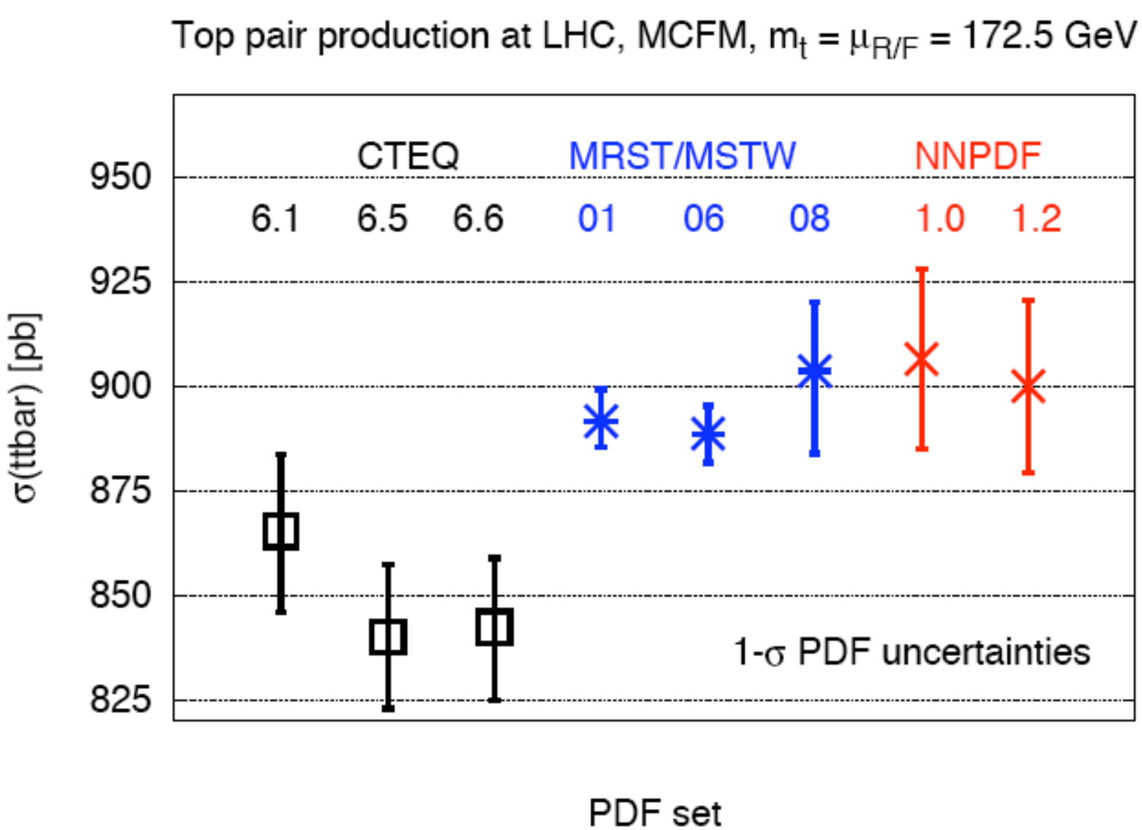


Alekhin and Blumlein

…but consider top

$\sigma^{\mathrm{tot}}(t\bar{t})$ at the LHC

Compare results from different PDF sets (errors: 68% confidence levels)



…but consider top

…going from ZM to GM increases the W/Z cross sections, but also decreases the tT cross section for CTEQ
Why? Because of the anti-correlation between the W/Z and tT cross sections

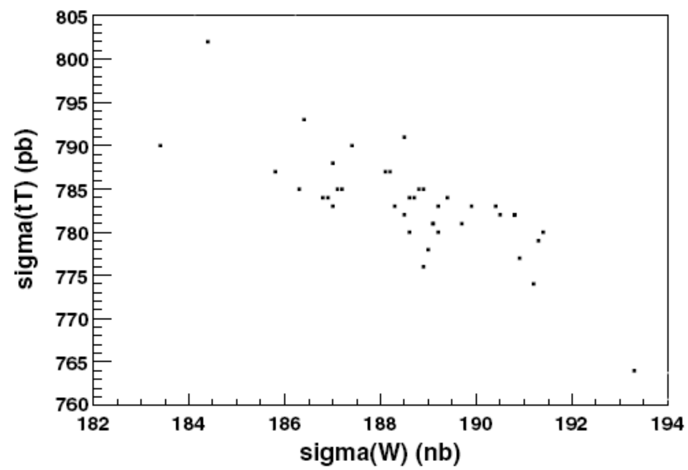
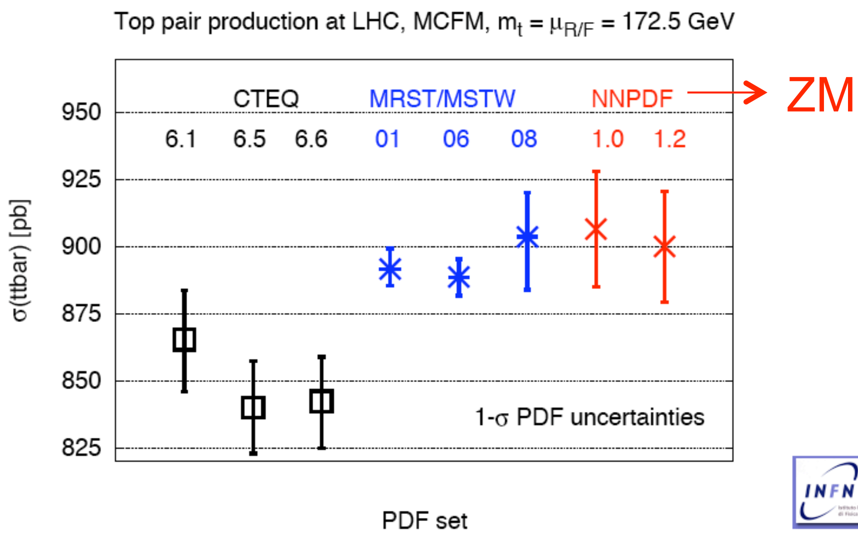


Figure 93. The cross section predictions for $t\bar{t}$ production versus the cross section predictions for W production at the LHC plotted using the 41 CTEQ6.1 pdfs.

Introduction The NNPDF approach

$\sigma^{tot}(t\bar{t})$ at the LHC

Compare results from different PDF sets (errors: 68% confidence levels)



MRST->MSTW (partially) compensated by increase of α_s

For completeness: LH09 NLM worklist

1. Expand wish-list to include more 2->4 processes; NEW, indicate precision needed for all processes on wishlist (this would indicate if EW corrections needed, for example)
   a. all (existing and future)_ NLO codes should add decays, including spin correlations, if possible; for example, tTH->tTH(->bB)
   b. collect scale-dependent terms in such a way that scale variations can be more easily calculated (and potentially stored); use Nagy proposal for calculating factorization scale uncertainties
2. Development of Les Houches Accord to allow for merging of real and virtual corrections from different groups; see web page for draft
3. General study of NLO multi-leg calculations (in particular W/Z + n jets)
   a. detailed comparison of Rocket and Blackhat results for W + 3 jets
   b. how well does the leading color approximation work? Can we generalize to W + 4 jets for example?
   c. can we understand/generalize an appropriate scale choice to use at LO to approximate the NLO calculation? For example, the BlackHat people find that HT works best for W + 3 jets. A scale choice of mW leads to a K-factor significantly below 1.
   d. can we understand the impact of jet vetos on K-factors, especially for signal and background processes (e.g. tTbB vs tTH)?
   e. impact of jet algorithms on multi-leg final states; connections between parton level and hadron level.
   f. NLO vs LO with mod LO pdf's

Worklist

4. Modification of LHEF2.0 to allow for general communication between NLO and PS programs (see webpage for draft)
    a. sub-set of the above framework for current ROOT ntuple output for NLO programs (a la FROOT)
5. Hard multi-jet production
    a. can we observe BFKL effects in early W + jets production at the LHC?
    b. parton shower for BFKL calculations (summarized as "Jeppe needs a shower")
6. PDF's and uncertainties
    a. MSTW vs CTEQ vs Neural Net (understanding new MSTW uncertainties using alpha_s variations)
    b. new normalization processes, e.g. Z at high pT (~200 GeV/c)
    c. more complete determination of uncertainty for b,c pdf's and implications for Higgs/BSM physics
    d. better inclusion of photon pdf's
7. Photons
    a. isolation: can Frixione-type isolation for theory be matched to strict experimental isolation, i.e. both effectively remove the fragmentation contribution, but in different ways
    b. need for codes with complete NLO QCD and EW corrections for final states with photons, e.g. W gamma

6b: high p_T Z

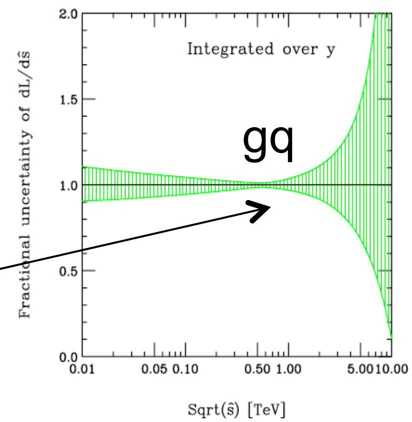
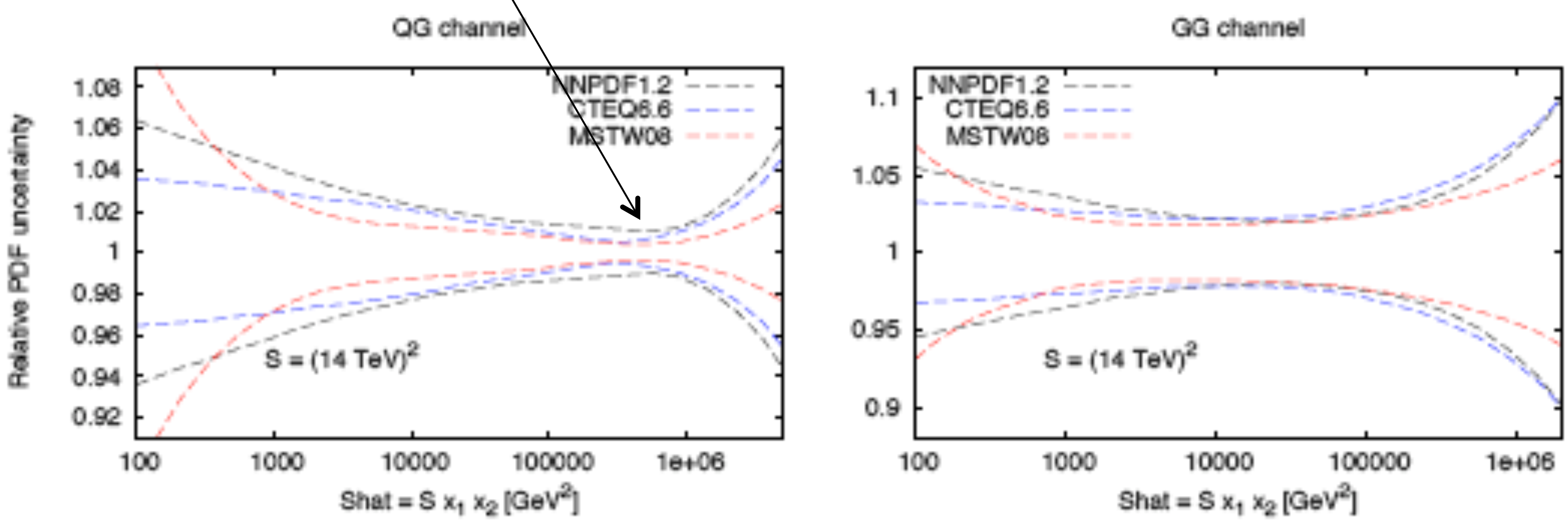


Fig. 6: Fractional uncertainty for Luminosity integrated over y for $g(d+u+s+c+b)+g(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})+(d+u+s+c+b)g+(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})g$,

RELATIVE UNCERTAINTY ON FLUX



Worklist

8. Drell-Yan
    a. detailed study of all uncertainties, both theoretical and experimental
9. Z + jets
    a. detailed studies of
        i. rapidity differences between the jets, differential 3-jet rates, event shapes, etc
10. Higgs searches
    a. Higgs in WW channel at LHC
        i. can similar normalization as worked for tT be used?
        ii. how well can tT(+jets) prediction be used to understand backgrounds to Higgs?
    b. new look at tTH at LHC
        i. new observables: delta_phi bB, mass of tTH system, invariant mass of bB
        ii. boosted Higgs; better assignment of b-jets/better mass resolution
        iii. impact of jet veto on signal/background
        iv. new mindset: coupling measurement versus discovery channel
    c. Higgs at the Tevatron
        i. are assumed QCD uncertainties too small? can CTEQ take a semi-coherent look at this issue?
        ii. impact of Prophecy4F radiative corrections on Tevatron analyses