COMBINED PDF AND STRONG COUPLING UNCERTAINTIES AT THE LHC WITH NNPDF2.0

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We present predictions for relevant LHC observables obtained with the NNPDF2.0 set. We compute the combined PDF+α_s uncertainties on these observables, and show that combining errors in quadrature yields an excellent approximation to exact error propagation. We then compare the NNPDF2.0 results to the other global PDF fits using a common value of α_s. At LHC 7 TeV, reasonable agreement, both in central values and in uncertainties, is found for NNPDF2.0, CTEQ6.6 and MSTW08.

1 Combined PDF+α_s uncertainties for LHC observables

The determination of the theoretical accuracy in the predictions for LHC observables is one of the most important tasks now that the LHC is producing collisions at $\sqrt{s}$ =7 TeV. QCD uncertainties coming from Parton Distribution Functions (PDFs) and from the strong coupling constant $\alpha_s\,(M_Z)$ are among the dominant sources of theoretical uncertainties for most relevant LHC cross sections.

In this contribution we present predictions for important LHC observables based on the NNPDF2.0 global PDF analysis [1]. First we will discuss the results for the combined PDF+α_s uncertainty on several LHC observables, and then we compare the NNPDF2.0 predictions with those of the other two global analyses, MSTW2008 and CTEQ6.6. For the latter comparison we use the sets with varying α_s recently presented by these two groups [2,3] in order to use consistently a common value of α_s. The observables have been computed with the MCFM program [4]. We point out that predictions from previous NNPDF sets [5,6,7,8] are consistent with the NNPDF2.0 results, albeit with larger PDF uncertainties due to the reduced dataset used there.

First of all we present results for several LHC observables at 7 TeV computed with the NNPDF2.0 PDF set: W^+ and Z^0 production, $t\bar{t}$ production and Higgs production in gluon–fusion for $m_H = 120$ GeV. We compute predictions for various values of α_s in order to determine the combined PDF+α_s uncertainties for these observables. Our choice for the reference value of α_s and its uncertainty is $\alpha_s\,(M_Z) = 0.119 \pm 0.002$, where the uncertainty is to be interpreted as a 68% C.L. The combined PDF+α_s uncertainty is computed both adding in quadrature the two uncertainties and using exact error propagation, following the methods presented in Refs. [9,10].

Results are shown in Fig. 1. It is clear that the two methods, quadrature and exact propagation, yield essentially identical results. Indeed, they ought to give exactly the same result [3] if the combined uncertainty can be obtained as a one–sigma ellipse from a quadratic χ^2. We also note from Fig. 1 that PDF uncertainties are independent of α_s for any reasonable range of α_s.

For processes which depend on α_s at leading order like Higgs or $t\bar{t}$ production, the combined PDF+α_s uncertainty is as expected sizably larger than the PDF uncertainty alone: for such processes, comparing predictions from different PDF sets using a common value of α_s is mandatory to obtain a meaningful comparison.

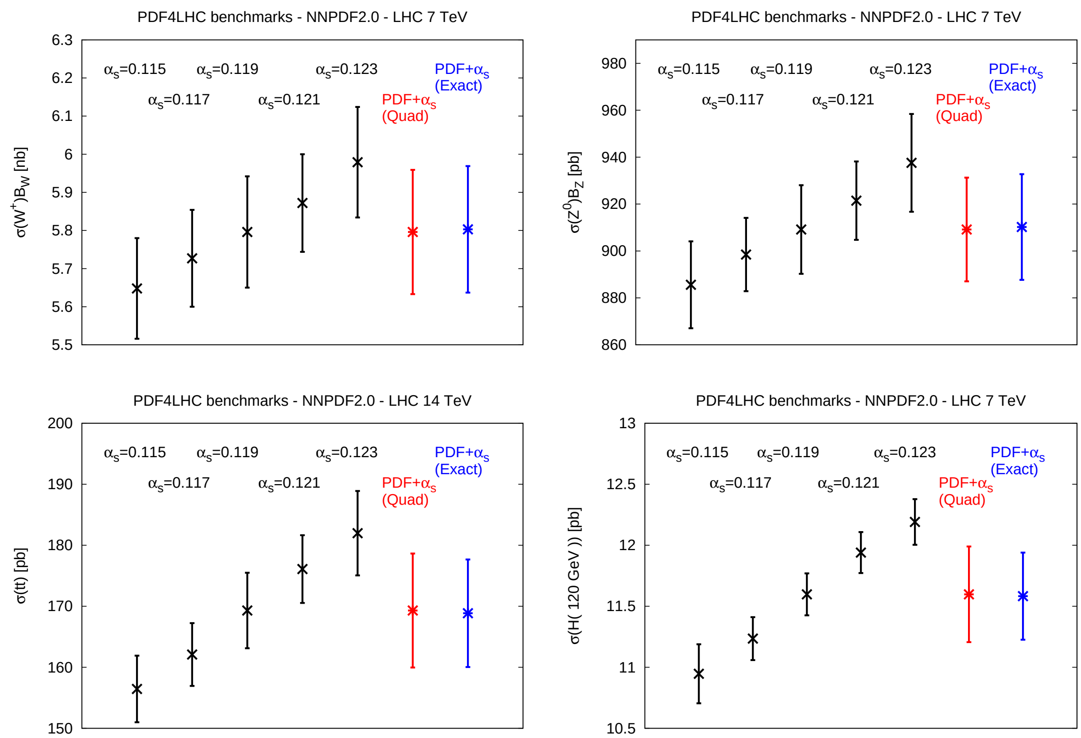

Figure 1: Predictions for some important LHC observables computed at 7 TeV. From top to bottom and from left to right: W^+ and Z production, $t\bar{t}$ production, and Higgs production in gluon-gluon fusion for $m_H = 120$ GeV. Results are shown for different values of $\alpha_s\,(M_Z)$ as well as for the combined PDF+α_s uncertainties.

2 Comparison between global PDF sets

Now we compare predictions for important LHC observables from the three global PDF fits: NNPDF2.0, MSTW08 [11] and CTEQ6.6 [12] for the LHC 7 TeV run. The comparison is shown in Fig. 2 and in Table 1. For CTEQ and MSTW we show results both at the default value of α_s and for a common value $\alpha_s\,(M_Z) = 0.119$. For the CTEQ6.6 and MSTW08 predictions with $\alpha_s = 0.119$ the specific sets from Refs. [2,3] have been used. We also assume that the PDF uncertainty for these two PDF sets does not depend in a statistically significant way on the value of α_s when switching from the default to the common value of α_s (which in both cases differ by $\delta\alpha_s = 0.001$). Note that NNPDF2.0 uses as default the value $\alpha_s\,(M_Z) = 0.119$.

It is clear from Fig. 2 that using a common value of the strong coupling improves the agreement between global PDF sets. If predictions with $\alpha_s = 0.119$ are compared, we observe that the three global PDF sets are in reasonable agreement. From Table 1 is clear that PDF uncertainties extracted from the NNPDF2.0, CTEQ6.6 and MSTW08 global fits are quite similar. We note that a conservative PDF+α_s uncertainty which accounts for the remaining small discrepancies between PDF sets could be obtained using the envelope method discussed in Ref. [10].

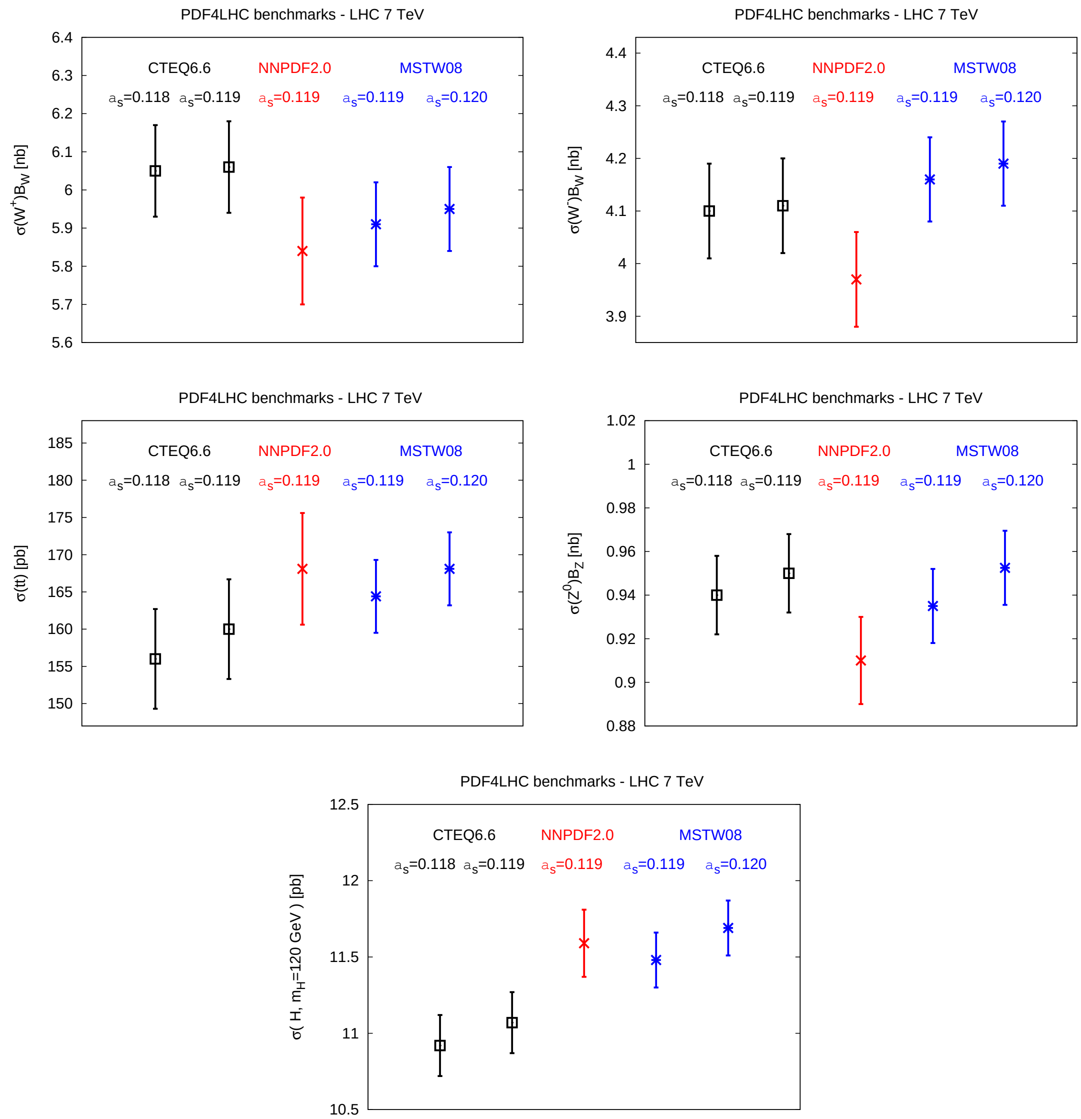

Figure 2: Comparison of predictions for LHC observables for NNPDF2.0, MSTW08 and CTEQ6.6 sets for the LHC at center of mass energy of 7 TeV.

3 Summary

We have presented predictions for important LHC observables obtained with the NNPDF2.0 set. We have computed the combined PDF+α_s uncertainties on these observables, and shown that combining errors in quadrature yields an excellent approximation to exact error propagation. The comparison of the NNPDF2.0 results at the LHC for $\sqrt{s}$ =7 TeV with the other global PDF analyses, CTEQ6.6 and MSTW08, performed using a common value of α_s shows a reasonable agreement both in central values and in uncertainties. To understand the remaining moderate differences between PDF sets a detailed benchmarking on the lines of the HERA-LHC benchmarks [13] would be required.

The NNPDF2.0 PDFs, including sets determined using all values of $0.114 \leq \alpha_s(M_Z) \leq 0.124$ in steps of $\Delta\alpha_s(M_Z) = 0.001$, are available from the NNPDF web site,

`http://sophia.ecm.ub.es/nnpdf .`

They are also available through the LHAPDF interface [14].

	$\sigma(W^+)\mathrm{Br}\left(W^+ \to l^+\nu_l\right)$ [nb]	$\sigma(W^-)\mathrm{Br}\left(W^- \to l^+\nu_l\right)$ [nb]	$\sigma(Z^0)\mathrm{Br}\left(Z^0 \to l^+l^-\right)$ [nb]
NNPDF2.0	5.84 ± 0.14	3.97 ± 0.09	0.91 ± 0.02
CTEQ6.6 - $\alpha_s = 0.118$	6.05 ± 0.12	4.10 ± 0.09	0.94 ± 0.02
CTEQ6.6 - $\alpha_s = 0.119$	6.06 ± 0.12	4.11 ± 0.09	0.95 ± 0.02
MSTW08 - $\alpha_s = 0.119$	5.91 ± 0.11	4.16 ± 0.08	0.94 ± 0.02
MSTW08 - $\alpha_s = 0.120$	5.95 ± 0.11	4.19 ± 0.08	0.95 ± 0.02

	$\sigma(t\bar{t})$ [pb]	$\sigma(H, m_H = 120\,\mathrm{GeV})$ [pb]
NNPDF2.0	168.1 ± 7.5	11.59 ± 0.22
CTEQ6.6 - $\alpha_s = 0.118$	156.0 ± 6.7	10.92 ± 0.20
CTEQ6.6 - $\alpha_s = 0.119$	160.1 ± 6.7	11.07 ± 0.20
MSTW08 - $\alpha_s = 0.119$	164.4 ± 4.9	11.48 ± 0.18
MSTW08 - $\alpha_s = 0.120$	168.1 ± 4.9	11.69 ± 0.18

Table 1: Cross sections for W, Z, $t\bar{t}$ and Higgs production at the LHC at $\sqrt{s} = 7$ TeV and the associated PDF uncertainties. All quantities have been computed at NLO using MCFM for the NNPDF2.0, CTEQ6.6 and MSTW08 PDF sets. All uncertainties shown are one–sigma level. See Fig. 2 for the graphical representation of the results of this table.

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