

Progress in the Neural Network Determination of Polarized Parton Distributions

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We review recent progress towards a determination of a set of polarized parton distributions from a global set of deep-inelastic scattering data based on the NNPDF methodology, in analogy with the unpolarized case. This method is designed to provide a faithful and statistically sound representation of parton distributions and their uncertainties. We show how the FastKernel method provides a fast and accurate method for solving the polarized DGLAP equations. We discuss the polarized PDF parametrizations and the physical constraints which can be imposed. Preliminary results suggest that the uncertainty on polarized PDFs, most notably the gluon, has been underestimated in previous studies.

DIS 2010

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Polarized PDFs with the NNPDF approach The interest in polarized deep inelastic scattering was revived in 1988 by the results of the EMC experiment that led to the so-called “spin crisis”. Since then a lot of progress has been made [1–3]. Several experiments have been completed at CERN, SLAC, DESY and JLAB, with several more are ongoing including RHIC, the first polarized hadronic collider, and on the theory side, it was understood that the “spin crisis” is a sign of the non-trivial spin structure of the nucleon, which should be understood in terms of QCD. While on a first stage interest was focused on the determination of the first moments of the polarized parton densities and the associated polarized sum rules, in the recent years attention is now shifting to the full reconstruction of polarized parton densities, particularly the gluon density. The current bottleneck is the accurate determination of the uncertainties on polarized parton distributions, a problem which in the unpolarized case is starting to be solved only in recent times.

On the other hand, one of the most important advances in unpolarized global PDF analysis in the recent years has been the development of the NNPDF methodology [4–8]. NNPDF provides a determination of unpolarized PDFs and their uncertainty which is independent of the choice of data set, and which has been shown in benchmark studies [9] to behave in a statistically consistent way when data are added or removed to the fit. The use of artificial neural networks as unbiased interpolants is crucial to obtain unbiased results which are independent of the choice of input functional form for the PDFs, which is specially relevant for those PDF combinations which are loosely constrained by data. Also, because of the use of a Monte Carlo approach, the NNPDF methodology is easily amenable to the use of standard statistical tools, and does not rely on any of the usual gaussian approximations used for the PDF uncertainty estimation and determination in many analysis.

In this contribution we review progress towards the applications of the NNPDF approach to the determination of a polarized structure functions based on inclusive polarized DIS data: NNPDFpol1.0.¹ We show that once the bias from the choice of fixed functional forms are removed, the uncertainty on some polarized PDFs, most notably the gluon, are rather larger than previously estimated.

The NNPDFpol1.0 analysis The first NNPDF polarized analysis will be NNPDFpol1.0. Fig. 1 shows the inclusive polarized DIS experiments and their kinematical coverage included in the NNPDFpol1.0 analysis. The number of data points after kinematical cuts is $N_{\text{dat}} \sim 250$, about an order of magnitude smaller than in the unpolarized case. The kinematical cuts applied $Q^2 \geq 1 \text{ GeV}^2$ and $W^2 \geq 6.25 \text{ GeV}^2$ find a compromise between keeping the maximum number of data where remaining in the perturbative region and removing dynamical higher twist effects [11].

As in the unpolarized case, the polarized PDF evolution as implemented in the FastKernel framework has been benchmarked with the Les Houches benchmark tables of Ref. [12], obtained from the HOPPET [13] and PEGASUS [14] evolution packages. Results of this benchmark comparison are shown in Table 1, where it can be seen that the accuracy is excellent for all data points and all polarized PDFs.

¹Note that the NNPDF approach was applied to the determination of polarized asymmetries from inclusive polarized data in Ref. [10]

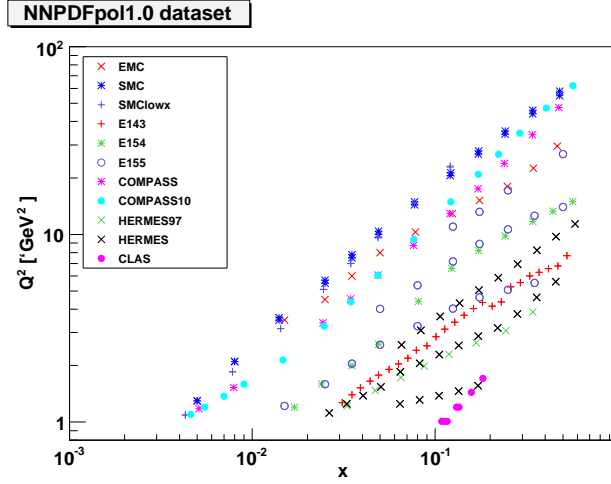


Figure 1: The kinematical coverage of the inclusive polarized DIS experiments included in the NNPDF-pol1.0 analysis.

x	$\epsilon_{\text{rel}}(\Delta u_V)$	$\epsilon_{\text{rel}}(\Delta d_V)$	$\epsilon_{\text{rel}}(\Delta \Sigma)$	$\epsilon_{\text{rel}}(\Delta g)$
10^{-3}	$1.1 \cdot 10^{-4}$	$9.2 \cdot 10^{-5}$	$9.9 \cdot 10^{-5}$	$1.1 \cdot 10^{-4}$
10^{-2}	$1.4 \cdot 10^{-4}$	$1.9 \cdot 10^{-4}$	$3.5 \cdot 10^{-4}$	$9.3 \cdot 10^{-5}$
0.1	$1.2 \cdot 10^{-4}$	$1.6 \cdot 10^{-4}$	$5.4 \cdot 10^{-6}$	$1.7 \cdot 10^{-4}$
0.3	$2.3 \cdot 10^{-6}$	$1.1 \cdot 10^{-5}$	$7.5 \cdot 10^{-6}$	$1.7 \cdot 10^{-5}$
0.5	$5.6 \cdot 10^{-6}$	$9.6 \cdot 10^{-6}$	$1.6 \cdot 10^{-5}$	$2.5 \cdot 10^{-5}$
0.7	$1.2 \cdot 10^{-4}$	$9.2 \cdot 10^{-7}$	$1.6 \cdot 10^{-4}$	$7.8 \cdot 10^{-5}$
0.9	$3.5 \cdot 10^{-3}$	$1.1 \cdot 10^{-2}$	$4.1 \cdot 10^{-3}$	$7.8 \cdot 10^{-3}$

Table 1: Comparison of the accuracy of our polarized PDF evolution with respect to the Les Houches benchmark tables for different polarized PDF combinations at NLO in the ZM-VFNS.

In this analysis four polarized PDFs are parametrized with artificial neural networks. The specific basis which we choose at the initial evolution scale $Q_0^2 = 1 \text{ GeV}^2$ is given by the following linear combinations:

- the singlet distribution, $\Delta \Sigma(x) \equiv \sum_{i=1}^{n_f} (\Delta q_i(x) + \Delta \bar{q}_i(x))$,
- the non-singlet triplet, $\Delta T_3(x) \equiv (\Delta u(x) + \Delta \bar{u}(x)) - (\Delta d(x) + \Delta \bar{d}(x))$,
- the non-singlet octet, $\Delta T_8(x) \equiv (\Delta u(x) + \Delta \bar{u}(x)) + (\Delta d(x) + \Delta \bar{d}(x)) - 2(\Delta s(x) + \Delta \bar{s}(x))$,
- the gluon, $\Delta g(x)$.

Each of these polarized PDFs has 37 free parameters (2-5-3-1 architecture) to be determined from experimental data using the minimization strategy discussed in Ref [5]. Heavy quark PDFs are generated dynamically, and heavy quark mass effects can be taken into account using the FONLL general-mass scheme [15].

An important constraint on the normalization of the polarized triplet and octet can be provided by the axial sum rules [2],

$$[\Delta T_3(Q_0^2)] \equiv \int_0^1 dx \Delta T_3(x, Q_0^2) = a_3, \quad (0.1)$$

$$[\Delta T_8(Q_0^2)] \equiv \int_0^1 dx \Delta T_8(x, Q_0^2) = a_8, \quad (0.2)$$

where a_3 and a_8 are respectively the triplet and octet axial charges, which can be determined from weak baryon decays,

$$a_3 = g_A = 1.2670 \pm 0.0035 \quad a_8 = 0.585 \pm 0.025, \quad (0.3)$$

The value of a_8 assumes exact SU(3) symmetry, the effects of potential SU(3) violations can be accounted for by adding a suitable theoretical uncertainty.

In the context of polarized structure functions, positivity implies bounds on the size of the polarized structure functions g_1^p and g_1^d determined by the size of the corresponding unpolarized structure functions F_1^p and F_1^d . We impose these bounds on g_1^p and g_1^d using consistently the unpolarized structure functions as determined in Ref. [16].

We show preliminary results for the NNPDFpol1.0 polarized PDF set in Fig. 2, where they are compared to other recent polarized PDF determinations [17, 18]. Although these results are too preliminary to draw quantitative conclusions, they seem to indicate that the uncertainty on the polarized gluon from inclusive data is rather larger than previously assumed, and in particular its sign cannot be determined.

Outlook In this contribution we have outlined recent progress towards the generalization of the NNPDF methodology to the polarized sector. We have presented preliminary results for NNPDFpol1.0, a set of polarized PDFs obtained from a global analysis of inclusive polarized DIS data using the NNPDF approach. NNPDFpol1.0 will be the first polarized PDF set which is determined consistently together with its unpolarized counterpart. Eventually we hope to also include exclusive DIS data and polarized hadronic data without any K-factor approximations using the FastKernel method, as was done recently in our global fits to unpolarized data [8].

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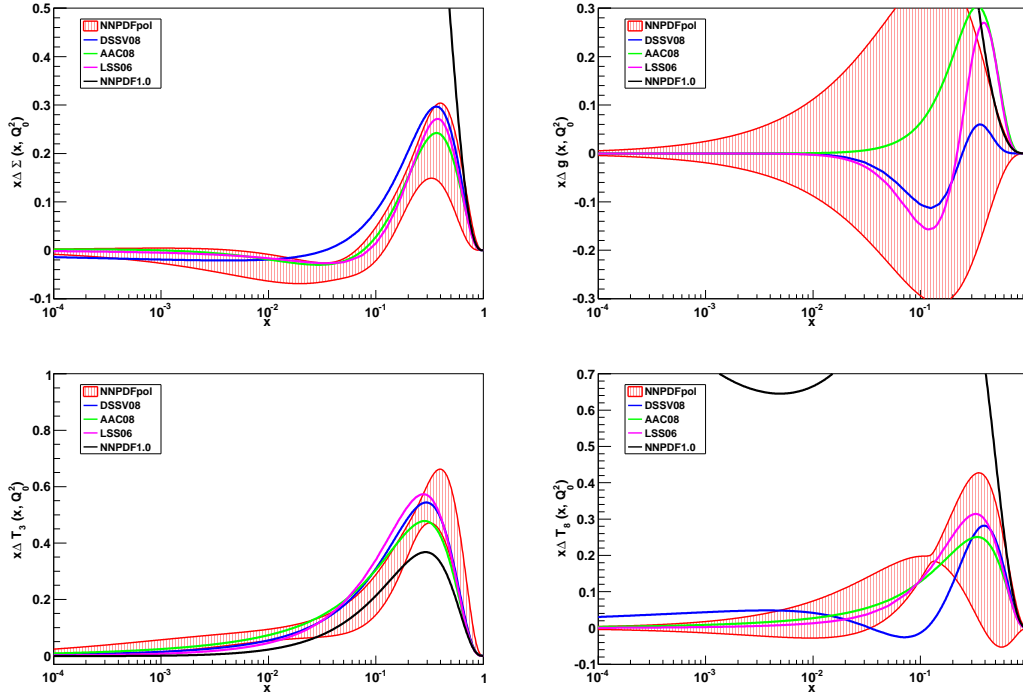


Figure 2: Comparison of the NNPDFpol1.0 polarized parton distributions at the initial evolution scale $Q_0^2 = 1 \text{ GeV}^2$, compared to other recent determinations. For illustration, we also show the corresponding unpolarized PDF set NNPDF1.0.

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