POSITIVITY CONSTRAINT AND POLARIZED PARTON DISTRIBUTIONS

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The role of the positivity constraints in construction of the polarized parton distributions is focused on. Polarization of sea and gluons are considered; some similar aspects of the two are entertained. Discussion is inspired by a simple understanding of LO positivity constraint inequalities, some NLO implications, as well as existing views on the size of positive polarized gluons and negative sea in polarized DIS data.

Positivity constraints (PC) are discussed here in the context of construction of polarized parton distributions.[1] Assuming some well known definitions,[1,3] PC are inequalities of the form

$$\mid \Delta f(x) \mid \leq f(x),$$

for all x, satisfied for all partons of the naive parton model or of the QCD improved parton model in LO. In the first model, they are trivial, simply due to the probabilistic interpretation of the distributions. In the second theory, beginning with the fact that asymmetry in LO: $\mid A_1(x) \mid = \mid g_1(x) \mid / F_1(x) \leq 1$ for all possible target compositions, these inequalities can be deduced systematically for all the flavors of quark and antiquarks which make their appearance in the polarized and unpolarized structure functions at LO, but not for gluons which do not appear until the NLO level. So for gluons another process should be used to have the same relation extracted at LO.[2] At NLO the PC inequalities take a complicated scheme dependent form because of the singlet quarks mixing with gluons through the chiral anomaly and become inequalities expressed for the mixed combinations, rather than for single partons.

If PC hold for some initial scale Q_0^2, evolution seems to preserve them. If PC hold in some scheme at NLO, they are also supposed to hold for other schemes. On the questions of scale dependence and scheme changes one can consult references 2 and 5.

The LO PC inequalities were satisfied in our model for valence quarks by construction.[3,4] Taking our positive ansatz $\Delta G = xG$, which will be under focus here, PC is also satisfied, for gluons. But there was a problem with PC for the sea. Given our valence and gluon distributions, experiments gave the normalization constant: [3]

$$\eta_{av} = \langle \Delta q \rangle \,/\, \langle xq \rangle < -1$$

for most flavors, violating PC at x near 1. Note that data essentially favors negatively polarized sea here, thus negative η_{av}.

We fixed the problem with PC via replacing the normalization factor by (a weight) function $\eta(x)$. Data implies that average weight of the function to be negative, and its absolute value decreasing with x, since the problems with PC (for $| \eta_{av} | > 1$) occur at large x. We were able to satisfy PC at all x using a working form for $\eta(x)$ given farther down below.

While fixing the sea problem, we note a possible similarity of parametrization between the sea and glue so that we may write our unified ansatze for both to be of the form:

$$\Delta f(x) = \eta_f(x)\, x\, f(x).$$

It is natural to assume that what is polarized, $\Delta f(x)$, comes out of the unpolarized distribution $f(x)$. Historically, for the gluons and the sea, there was the following unified model: [6,7,8]

$$\Delta f(x) = \; x\, f(x).$$

However, the polarized structure functions $g_1(x)$ data essentially overruled it. In our first approach to the problem we chose a nonuniform treatment of the sea and the gluons, keeping the old form of $\Delta G(x)$.[1,3] This gave us a value for spin of the gluons to be approximately .5 or equivalent to the spin of proton.[3] Here, we would like to propose an extra $\eta_G(x)$ factor for a unified treatment, sign, PC, and adjustments to data. Thus, we would like to begin with a positive glue and negative sea at some beginning DIS scale (with some stability of general functional shape and sign in some reasonable Q^2 range) before possible reversals of sign within each distributions due to evolution and mixing of positive u_v and G with negative d_v and *sea* partons. As a working approximation, we suggest $\eta(x) = a + bx^n$, with parameters chosen to give a single sign for the curvature for the polarization (defined as the ratio) $\Delta f(x)/f(x)$ between $0 \leq x \leq 1$. Considering the value of the derivative of the polarization at these end points may improve the form of $\eta(x)$. We chose not to modify the $(1-x)$ dependence in order to keep the counting rule powers intact (insofar as the unpolarized distributions do this) for the large-x behavior.[9]

We may be safe in saying that gluons and sea similarly have $\Delta f(x)/f(x) = 0$ at $x = 0$. Such a parton which carries no momentum carries no spin. At $x = 1$ our model has $\Delta G(x)/G(x) = 1$ while $\Delta sea(x)/sea(x) = a + b$, $(0 \leq -(a+b) \leq 1$). So a gluon in this model which carries all the momentum carries all the spin too (the same is seen for u_v but not for other partons). Now, we suggest a similar parametrization for gluons and sea in between these end points. Considering the structure function data, some tentative limits on value of the parameter n, indicating the curvature of polarization curve, are $0 < n < 1$. We used $n = 1/2$ in reference 1. Parameters a and b are related by normalization. For the sea, the value of the parameter a is for most cases $a < \eta_{av} < -1$. For gluons, a is positive, and the curvature is so that the polarization falls above the line $\Delta G(x)/G(x) = x$ (except possibly near x=0, which is not given by the present form of $\eta(x)$) making gluon spin greater than our value of approximately .5 corresponding to that line.[3] As an interesting consequence for the sea, $\mid \eta_{av} \mid$ values become smaller than those of reference 3 approaching automatic fulfillment of PC.

One may note that positively polarized gluons through the anomaly relation, in NLO, lead to negatively polarized ($\overline{MS}$) sea distributions, supporting the signs we have here, assuming that the intrinsic (or chirally invariant) sea polarization is not dominatingly positive.

The shapes of $x\eta(x)$ which present percent polarization of sea and gluons are the key elements which we extract from data, PC, and the normalization constraints. Furthermore, QCD clarifies their behavior near the two large and small x limits. Here is some food for thought as data becomes more exact in middle x range and theory more clear at the end point limits.

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