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Heavy quark contributions in Bjorken sum rule with analytic coupling

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We consider heavy quark contributions to the polarized Bjorken sum rule. We found good agreement between the experimental data and the predictions of analytic QCD. To satisfy the limit of photoproduction, we use new representation of the perturbative part of the polarized Bjorken sum rule, recently proposed.

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Experimental data for the polarized Bjorken sum rule (BSR) $\Gamma_1^{p-n}(Q^2)$ [1, 2] are now available for a fairly wide range of spacelike momentum squared Q^2: $0.021\,\mathrm{GeV}^2 \leq Q^2 < 5\,\mathrm{GeV}^2$ (see [3, 4]) and references therein), making the BSR an important observable for QCD studies at low Q^2 [5, 6].

In the last thirty years, an extension of the QCD coupling constant without the Landau singularity for low Q^2, known as analytic perturbation theory (APT) [7–10], has been developed. APT has already been applied to compare theoretical expressions with experimental data for BSR [4, 11–19] (see also other recent studies on the BSR in [20–23]).

In this paper we apply the results for the heavy quark contributions to the BSR calculated at the two-loop level in Ref. [24]. Our study is conducted within the APT framework, and we also explore the possibility of applying the heavy quark contributions to the photoproduction limit.

By investigating the low Q^2 behavior, we find a discrepancy between the results obtained in the fits and the photoproduction. Specifically, the results of the fits extended to low Q^2 lead to negative values for the BSR $\Gamma_{\mathrm{MA},1}^{p-n}(Q^2)$: $\Gamma_{\mathrm{MA},1}^{p-n}(Q^2 \to 0) < 0$, which contradicts the finiteness of the cross section in the real photon limit, leading to $\Gamma_{\mathrm{MA},1}^{p-n}(Q^2 \to 0) = 0$.

To solve the problem, we use a low Q^2 modification of the OPE formula for $\Gamma_{\mathrm{MA},1}^{p-n}(Q^2)$ introduced in [4]. With this modification, we find good agreement with full sets of experimental data for the BSR $\Gamma_{\mathrm{MA},1}^{p-n}(Q^2)$, as well as with its limit $Q^2 \to 0$, i.e. with photoproduction. Moreover, the results are very close to those obtained in [4, 19], as well as to the predictions of phenomenological models [25–30].

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