A New Approach For Single Transverse-Spin Asymmetries From Twist-3 Soft-Gluon Mechanism

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Single transverse-spin asymmetry (SSA) is a naively time-reversal-odd observable, and it only occurs from the interference between the amplitudes which have different phases. For hard processes at large transverse-momentum of produced particle, SSA is described on the basis of the collinear factorization as a twist-3 observable, which represents quark-gluon correlations inside hadron. In this framework, SSA is derived by the collinear expansion of the cut diagrams for the cross section in terms of the parton's transverse momenta, and by identifying the pole contribution of an internal propagator in the partonic subprocess, to obtain the interfering amplitude with relative imaginary phases. In standard Feynman gauge calculation, however, expressing SSA in terms of gauge invariant correlation functions through such procedure is quite involved, in particular for so-called soft-gluon pole contributions. In this work, we propose a new systematic approach employing Feynman gauge, which allows us to derive the SSA originating from the soft gluonic poles with great ease using diagrammatic manipulation. Utilizing constraints from Ward identities, we reorganize the relevant terms from the collinear expansion of the diagrams, so that the identificaiton of the soft-gluon poles in the partonic subprocess, and of cancellation between some of those contributions, is made explicit at the diagrammatic level. We demonstrate that the remaining contributions can be united into a single diagrammatic expression, which allows us to immediately write down a compact analytic formula of the corresponding SSA, and is applicable to a range of processes like Drell-Yan and direct-photon production, and semi-inclusive deep inelastic scattering.