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Soft gluon resummation and a novel asymptotic formula for double-spin asymmetries in dilepton production at small transverse momentum

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We study the double-spin asymmetries in transversly/longitudinally
polarized Drell-Yan processes at transverse momentum Q_T of the produced
lepton pair. We first consider the double transverse-spin asymmetry A_{TT}(Q_T)
in the transversely polarized Drell-Yan process in detail, in particular,
in the small Q_T region, where the bulk of dileptons are produced.
The large logarithms due to the soft gluon emission at small Q_T are
resummed in the Drell-Yan cross sections at the next-to leading
logarithmic (NLL) accuracy, employing the impact parameter b-space
formulation. The numerical calculation shows that the effects of the
soft gluon resummation to the polarized and unpolarized cross sections
largely cancel in A_{TT}(Q_T), but the significant corrections still remain.
In particular, as a result of the resummaiton, the flat behavior of A_{TT}(Q_T)
is generically observed in the small Q_T region, from Q_T =0 to the peak region
of the cross-section Q_T-spectrum, indicating that the Q_T =0 limit of A_{TT}(Q_T)
is theoretically a useful quantity. We evaluate the impact parameter b-integral
in the resummed cross sections at Q_T=0 by the saddle-point method, and derive
a novel asymptotic formula of A_{TT}(Q_T =0), which obeys a remarkably simple analytic
form and is exact when the dilepton mass Q is large. We demonstrate the accuracy of
our asymptotic formula even at the kinematics of RHIC, J-PARC, and GSI,
comparing with the corresponding results of the numerical calculation.
Because of the simple structure of our formula, it enables us to extract information
on the transversity directly from the data of A_{TT}(Q_T) measured in polarized
Drell-Yan processes in the small Q_T region.
We also extend our framework to the double-spin asymmetry A_{LL}(Q_T) in the
longitudinally polarized Drell-Yan process in the small Q_T region, and derive
the corresponding asymptotic formula for A_{LL}(Q_T =0), and discuss its usefulness for
extracting the information on the helicity distributions of quarks and gluons
inside nucleon.

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