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Lattice QCD Determination of the TMDPDFs

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The transverse-momentum-dependent parton distribution function (TMDPDF) encodes essential information on the three-dimensional momentum structure of hadrons and plays a central role in QCD factorization for semi-inclusive processes. A first-principles determination of TMDPDFs remains highly challenging because of their intrinsically nonperturbative nature and the presence of both ultraviolet and rapidity divergences. In this work, we present a lattice QCD study of the TMDPDF within the large-momentum effective theory framework. Starting from suitably constructed nonlocal equal-time matrix elements, we extract the quasi-TMDPDF and investigate its dependence on the hadron momentum, Wilson-line geometry, and transverse separation b_{\perp} . Special attention is paid to the treatment of the intrinsic soft function, which captures the long-distance nonperturbative structure associated with TMD factorization on the lattice.

Our calculation employs gauge ensembles with multiple lattice spacings, volumes, and pion masses, enabling systematic control over discretization and chiral effects. We implement nonperturbative renormalization and matching procedures to connect the lattice observables to the physical TMDPDF. This study demonstrates the feasibility of accessing TMDPDFs directly from lattice QCD and provides new first-principles insight into the transverse momentum structure of hadrons. It also lays the foundation for a quantitative connection between lattice calculations and experimental measurements of semi-inclusive processes, advancing our understanding of hadron structure in QCD.

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