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Transverse-Momentum Resummation in DY Production from Effective Field Theory

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Using Soft-Collinear Effective Theory, a closed-form, all-order expression for the Drell-Yan cross section at small transverse momentum is derived, which is free of large perturbative logarithms. The anomalous dimensions and matching coefficients necessary for resummation at next-to-next-to-leading logarithmic order are given explicitly. The precise relation between the effective-theory result and the Collins-Soper-Sterman formula is discussed, and as a by-product the three-loop coefficient $A^{(3)}$ is obtained. Contrary to what is assumed in the literature, this coefficient differs from the three-loop cusp anomalous dimension. A nontrivial feature of the resummation is that the naive factorization of the cross section at small transverse momentum is broken by a collinear anomaly, which prevents a process-independent definition of $x_\perp$-dependent parton distribution functions. Studying the all-order form of this anomaly, a factorization theorem is derived for the product of two such functions, in which the dependence on the hard momentum transfer is separated out. The remainder factors into a product of two universal functions of longitudinal momentum variables and $x_\perp^2$. Their renormalization-group evolution is obtained and solved in closed form. The necessary anomalous dimensions are known to three-loop order. The matching of these functions at small $x_\perp$ onto standard parton distributions is calculated at one-loop order.

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