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Three-loop jet function for boosted heavy quarks

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Event shapes for massless quarks in e^+e^- colliders have been widely used to investigate the gauge structure of the strong interactions, tune Monte Carlo simulations, learn about hadronization, and to determine the strong coupling with high precision. For the production of primary top quarks, it has been shown that a class of event shapes related to the invariant mass of the hemisphere can be used to measure the top quark mass with a precision smaller than Λ_{QCD} . The maximal sensitivity to the top mass — which plays a central role in testing the validity of the Standard Model— is attained in the peak of the distribution, where both Boosted Heavy Quark Effective Theory (bHQET), and Soft Collinear Effective Theory (SCET) are applicable.

The use of Effective Field Theories (EFTs) allows for the factorization of expressions for various observables, effectively separating contributions from different physical scales. In these factorized expressions, the jet function —previously known at two loops— emerges as a universal ingredient, common to many observables. Thus, computing the jet function at higher perturbative orders is warranted. However, studying processes at more than one loop requires dedicated techniques to handle the large number of Feynman diagrams that contribute. In this talk we will present our analytic computation of the three-loop jet function for boosted heavy quarks.

We will briefly discuss the main properties and renormalization of the jet function and outline the workflow for a fixed-order calculation, including the strategies used for evaluating the master integrals. The three-loop piece of the jet function in dimensional regularization will be presented, and several important tests of our results will be discussed. Our computation provides the last missing piece to obtain the N^3LL' resummed (self-normalized) thrust distribution used for the calibration of the top quark mass parameter in parton-shower Monte Carlo generators. Additionally, it contributes to the N^3LL'-accurate invariant mass distribution of reconstructed top quarks, which can be employed for a precise top mass determination at future lepton colliders.

Abstract

The jet function is a universal ingredient appearing in factorized expressions for many observables in the production of jets initiated by top quarks in e+e- collisions. These observables can be used to determine the top quark mass in a renormalon-free scheme, which plays a key role in testing the consistency of the Standard Model. Thus, computing the jet function at higher perturbative orders is warranted.

In this talk we will present our analytic computation of the three-loop jet function for boosted heavy quarks. We will briefly discuss the main properties and renormalization of the jet function and outline the workflow for a fixed-order calculation, including the strategies used for evaluating the master integrals. The three-loop piece of the jet function in dimensional regularization will be presented, and several important tests of our results will be discussed.

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