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The renormalization scale-setting problem in QCD

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A vital issue in making accurate predictions in QCD is establishing the renormalization scale μ_r to determine the correct running coupling in the perturbative expansion. In conventional scaling, the renormalization scale is set to the typical process scale Q, and errors are estimated by scaling over a range of two $[Q/2, 2Q]$. This procedure introduces a considerable ambiguity in the scheme and renormalization scale in the final results to a fixed order. Therefore, this dependency directly impacts the predictions of several high-energy processes.

Currently, some strategies for scale setting optimization have been proposed in the literature, such as the Fastest Apparent Convergence (FAC), the Principle Minimal Sensitivity (PMS), the BLM method and the Principle of Maximum Conformity (PMC). Because the renormalization group imposes self-incidence properties such as singularity, reflexivity, symmetry, and transitivity, we see that FAC and PMS can lead to incorrect results in particular kinematic regions. Furthermore, they do not solve the problem presented by the ambiguity generated by the adjustment. Of conventional scale since they were designed to find an optimal renormalization. While BLM and PMC satisfies the theoretical requirements for the scale setting procedure based on the standard invariance of the renormalization group, it eliminates a systematic error in the pQCD predictions.

The principle of maximum conformality is used to remove uncertainties from the renormalization scale and scheme through a systematic way to absorb the non-conformal terms in the running coupling, obtaining an effective coupling $\alpha_s\,(Q_{\mathrm{PMC}})$, and determine an optimal effective scale as a result of the setting, PMC gives us a completely conformal perturbative observable. This method is based on the standard renormalization group invariance, and it succeeds in removing unnecessary systematic errors for high-precision pQCD predictions. It can be applied to virtually all high-energy hadronic processes, including multiscale problems.

The purpose of this paper is to present the main ideas of the Principle of Maximum Conformality and to show some applications under a single-scale and multi-scale PMC setting.

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