

Continuous Renormalization Group Beta Function in Four-Flavor QCD

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The renormalization group beta function encodes how the strength of the strong interaction changes with energy scale, connecting asymptotic freedom at high energies to the onset of nonperturbative dynamics at low energies. We study the beta function of four-flavor QCD using the continuous gradient-flow approach, which provides a nonperturbative definition of the running coupling and its scale evolution. Our calculation follows the running from the perturbative regime toward stronger coupling, with controlled continuum and infinite-volume extrapolations. This provides a first-principles view of the transition between perturbative and nonperturbative QCD dynamics in a theory with four dynamical sea-quark flavors.

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