

Gradient-Flow Renormalization of Nonlocal Quasi Operators in Lattice QCD

Sunday, 11 October 2026 15:25 (15)

Large-momentum effective theory (LaMET) enables first-principles studies of hadron structure from spatially nonlocal quasi observables, for which renormalization is essential to connect lattice calculations to continuum perturbative schemes. While the renormalization of local operators has been extensively studied using methods such as RI/MOM and gradient flow, nonlocal quasi operators containing space-like Wilson lines involve additional linear divergences and require dedicated renormalization strategies. Conventional self-renormalization can properly remove these divergences, but in practice the extraction of lattice-spacing-dependent renormalization factors is entangled with discretization effects and typically relies on simultaneous analyses at multiple lattice spacings. In this work, we develop a gradient-flow-based renormalization strategy for nonlocal quasi operators. The flow-dependent Wilson-line self energy is extracted from gauge-fixed Wilson lines and then applied as a common long-distance renormalization factor for different quasi matrix elements. After subtracting the linear divergence, the flowed operators are perturbatively matched to the $\overline{\text{MS}}$ scheme, thereby separating the Wilson-line self-energy subtraction from the remaining lattice-spacing dependence. Gradient flow also improves the long-distance signal of Wilson-line observables while retaining a controlled field-theoretic interpretation. We implement the procedure on two CLQCD ensembles with different lattice spacings. The extracted self-energy correction shows mild lattice-spacing dependence and yields well-behaved renormalized quasi matrix elements at large separations.

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Session Classification : Section 13