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Inhomogeneous condensate and phase structure in the $(1+1)d$ Gross–Neveu Model based on an Extended k-Shape Method

We present an extended version of the k-Shape method, originally developed for time-series clustering, and apply it to lattice simulations of the finite-temperature and finite-density $(1+1)$ -dimensional Gross–Neveu model. The method has been generalized from real to complex scalar fields and from one-dimensional to multidimensional configurations, allowing a detailed analysis of spatially varying condensates.

By employing the extended k-Shape method, we can extract detailed information about phase structure that is not easily accessible through conventional techniques. In the uniform, chiral-symmetry-broken phase, the phase structure can be characterized sufficiently by the expectation value of the configuration. Near the phase boundary, however, the k-Shape method reveals smooth variations in the configuration pattern, providing a sensitive probe of the transition region. The extended k-Shape method can analyze spatial dependencies that do not resemble simple sinusoidal waves. This makes it particularly suitable for identifying nontrivial spatial patterns that emerge in inhomogeneous condensate. In kink-like configurations, for example, the minimum of the correlation function is not necessarily negative, indicating a richer structure than can be captured by traditional correlation analysis.

These results demonstrate that the k-Shape approach offers a powerful and versatile framework for extracting detailed features of phase transitions and for exploring the interplay between uniform and inhomogeneous condensate in lattice field theories.

Parallel Session (for talks only)

QCD at nonzero temperature and density

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