

Self-Energy Pole Optimization of Superconductivity in the Bilayer Hubbard Model

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In strongly correlated superconductors, the nontrivial real-frequency dependence of the self-energy is believed to hold a key to elucidating the pairing mechanism. Indeed, a cluster dynamical mean-field study of the single-layer Hubbard model showed that self-energy poles originating from the Mott insulator enhance superconductivity [1]. In the single-layer system, however, the pole structure is poorly controllable, and so is superconductivity through it.

Motivated in part by the discovery of high-temperature superconductivity in the bilayer nickelate $\text{La}_3\text{Ni}_2\text{O}_7$ [2], we focus on the bilayer Hubbard model with the interlayer hopping $t_\perp$ as a control parameter. Superconductivity in this model has been discussed mainly from the weak-coupling viewpoint [3]. We instead analyze it with the dynamical cluster approximation, a nonperturbative method, and reveal self-energy poles produced by Mott physics and their role in enhancing superconductivity [4].

At half filling, the crossover from a Mott insulator (MI) to a band insulator (BI) appears as a reorganization of the self-energy poles controlled by $t_\perp$. This pole structure is inherited by the superconducting state upon doping and yields an $s^\pm$ -wave superconducting solution enhanced by the poles of the anomalous self-energy. The superconducting order parameter is then maximized in the strongly correlated regime at the point of the crossover where the self-energy poles cross (Fig. 1), because the anomalous self-energy poles of the two bands simultaneously lie at low energies and cooperatively enhance the pairing. These poles can further be understood in terms of the same pairing-enhancement mechanism as in the single-layer system, namely hybridization with emergent fermions. The bilayer system thus offers a platform that materializes a new guiding principle for optimizing strongly correlated superconductivity: the control of self-energy poles through $t_\perp$.

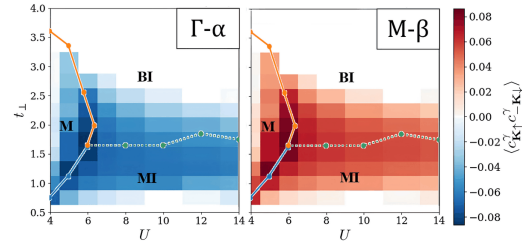


Fig. 1: $(U, t_\perp)$ dependence of the superconducting order parameter at $\delta = 0.02$ (left: $\mathbf{K} = (0,0)$ antibonding; right: $\mathbf{K} = (\pi,\pi)$ bonding). The sign reversal indicates the $s^\pm$ -wave symmetry. The half-filling phase diagram (M: metal, MI, BI) is overlaid.

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