

Winning the student presentation award at the 2025 JPS March meeting

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At the Physical Society of Japan (JPS) conference held in March 2025, I gave an oral presentation in Division 8. I am deeply honored to report that I was selected for the Student Excellence Presentation Award based on the evaluation of the JPS committee members.

My presentation, entitled “Extremely large superconducting gap opening and evidence of BCS-BEC crossover in small Fermi pocket of cuprate superconductors,” addressed one of the most persistent puzzles in condensed matter physics. Despite four decades of research into high- T_c cuprates, a consensus on the superconducting mechanism remains elusive.

To address this, our research focused on the BCS-BEC crossover theory—a framework describing the smooth transition between Bardeen–Cooper–Schrieffer (BCS) pairing and Bose-Einstein condensation (BEC). While this crossover has been observed in other solid systems, it remains controversial in cuprates, largely due to the mismatch between theory and experimental data. One main reason for this mismatch is that the ‘conventional’ cuprate compounds that have been extensively studied so far, are intrinsically vulnerable to the disorder effect, stemming from the proximity of the dopant layer and CuO_2 planes

We overcame this limitation by investigating a multilayer cuprate, which contains three or more CuO_2 planes per unit cell. Unlike conventional, the inner CuO_2 planes in the multilayer system are protected from dopant-induced disorder, preserving a “clean” electronic state. Among multilayer systems, we focused on the 4-layer compound, which is expected to have a larger carrier concentrations yet maintaining clean inner CuO_2 planes. Using angle-resolved photoemission spectroscopy (ARPES) and quantum oscillation measurements, we

successfully observed a small Fermi pocket in the 4-layer cuprates. Indeed, we confirmed that the effective doping level is higher than previously reported in 5- and 6-layer systems.

Furthermore, with the increased carrier concentration, we found that an extremely large superconducting gap coexists with this small Fermi pocket. This suggests that superconductivity and antiferromagnetic order are not merely competing phases but share an intimate relationship. Furthermore, the combination of a small Fermi energy and a large gap points to a high pairing strength, providing strong evidence for the BCS-BEC crossover—a regime previously inaccessible in conventional cuprates.

I would like to express my sincere gratitude to my supervisor, Prof. Takeshi Kondo, and to Prof. Yoshimitsu Kohama for their guidance with the ARPES and quantum oscillation measurements. I also thank Prof. Kazuyasu Tokiwa (Tokyo University of Science) and his laboratory members for providing the high-quality single crystals that made this research possible.

