

BCS-BEC crossover driven by small Fermi pockets of cuprate high- T_c superconductor

J. Jeong^A, K. Kurokawa^A, Y. Enomoto^B, Y. Kohama^A, T. Nakayama^B, K. Ando^B, S. Huh^A, Z. Yang^A, T. Nomura^A, C. Lin^C, M. Hashimoto^C, D. Lu^C, M. D. Watson^D, T. K. Kim^D, C. Cacho^D, S. Sakai^E, T. Tohyama^F, K. Tokiwa^A and T. Kondo^A

^A*Institute for Solid State Physics, the Univ. of Tokyo, Japan*

^B*Dept. of Applied Electronics, Tokyo Univ. of Science, Japan*

^C*Stanford Synchrotron Radiation Lightsource, SLAC national laboratory, U.S.A.*

^D*Diamond Light Source, Harwell campus, U.K.*

^E*Faculty of Science and Technology, Sophia Univ., Japan*

^F*Dept. of Applied Physics, Tokyo Univ. of Science, Japan*

The pairing mechanism of cuprate high- T_c superconductors remains elusive, despite the numerous detailed and systematic studies since its discovery. The single- and bilayer cuprates are especially the most studied cuprate family. However, these compounds, the CuO_2 planes where superconductivity arises from, have been pointed out that they are vulnerable to electronic disorders caused by adjacent dopant layers [1]. On the other hand, fewer studies have been performed on the multilayer cuprates. The multilayer cuprates contain three or more CuO_2 planes in a unit cell, and therefore host clean inner planes (IPs) which are well protected from electronic disorder by outer planes (OPs). The perspective of clean IPs of multilayer cuprates has been empirically motivated by the recent observation of a small Fermi pocket centered at the antiferromagnetic (AF) zone boundary, unveiling exotic phenomena that couldn't be accessible in single- or bilayer counterparts [2,3]

However, the doping-dependent evolution of superconductivity on this small Fermi pocket remains elusive to date. How do superconducting pairs evolve under the Mott state with AF order? To address this question, we focus on 4-layer cuprate $\text{Ba}_2\text{Ca}_3\text{Cu}_4\text{O}_8(\text{F}, \text{O})_2$ with two inner CuO_2 planes per unit cell, which are protected from disorder yet can be effectively controlled with doping. Our study employs angle-resolved photoemission spectroscopy (ARPES) and quantum oscillation measurements to investigate the detailed electronic band structures of the 4-layer cuprate. By studying 4-layer samples with various doping levels, we aim to characterize the exotic behavior of superconducting pairs, pseudogap, and chemical potential, thereby expanding our understanding of the high- T_c superconductivity of cuprates [4].

[1] K. McElroy *et al.*, *Science* **309**.5737 (2005).

[2] S. Kunisada *et al.*, *Science* **369**, 6505 (2020).

[3] K. Kurokawa *et al.*, *Nat. Commun.* **14**, 4064 (2023).

[4] J. Jeong *et al.*, *Nat. Commun.* (2026, Article in press).