Two-dimensional Quantum Critical Point in Underdoped $Bi_2Sr_2CaCu_2O_{8+x}$ Revealed by Superfluid Density Measurements

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With the goal of comparing quantum critical scaling in a highly anisotropic cuprate with the three-dimensional (3D) scaling seen in moderately-anisotropic $YBa_2Cu_3O_{7-\delta}$ (YBCO), a series of both sputtered and pulsed laser deposited $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi-2212) films have been fabricated with a wide range of hole underdoping, such that T_c extends as low as 5 K. For films near optimal doping, superfluid density is linear at low-T, and displays a sharp downturn near T_c. However, with underdoping the sharp downturn gradually fades, and superfluid density becomes roughly linear all the way to T_c. The disappearance of critical thermal fluctuations may be explained, at least in part, by strong quantum critical fluctuations. The superfluid density at $T = 0$ scales linearly with T_c, which indicates that superconductivity disappears at a 2D quantum critical point (QCP) in Bi-2212, unlike the 3D QCP seen in YBCO. The difference likely traces back to the much higher $ab-$ *vs.* $c-$axis anisotropy in Bi-2212.