Quantum critical point inside the superconducting dome and electronic nematic transition above the dome in $BaFe_2(As_{1-x}P_x)_2$

Takasada Shibauchi

Department of Physics, Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan

An enduring question in condensed matter physics is whether high transition temperature (T_c) superconductivity is driven by an underlying quantum critical point (QCP) separating different electronic phases at absolute zero-temperature. In particular, whether a QCP lies beneath the superconducting dome or the criticality is avoided by the transition to the superconducting state has been a central issue. We report a sharp depression of the superfluid density in very clean samples [1,2] of the iron-based superconductor, $BaFe_2(As_{1-x}P_x)_2$ that gives the first convincing signature of a second-order quantum phase transition deep inside the dome. We find that the x-dependence of London penetration depth exhibits a sharp peak at the optimum composition $x = 0.30$ ($T_c = 30$ K). This likely results from pronounced quantum fluctuations associated with the QCP which separates two distinct superconducting phases [3]. Moreover, from the magnetic torque measurements we find evidence for the electronic nematic transition well above the structural transition temperature extending to the overdoped side of the superconducting dome [4]. These results indicate that the nematic instability precedes the superconductivity in pnictides whilst the QCP inside the dome has an antiferromagnetic nature.

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