ST. FRANCIS XAVIER UNIVERSITY

Physics Colloquium

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Evolution of the spin susceptibility near the superconducting critical doping in YBCO

The parent materials (undoped) of high temperature superconductors (HTSC) are Mott insulators with static long-range 3D antiferromagnetic (AF) order below TN. Doping of holes into the CuO2 planes fundamentally changes the nature of the ground state from a long-range AF insulator to a superconductor (SC) for doping larger than SC critical doping. The interplay between magnetism and superconductivity and how one phase is transformed to the other by doping continues to be one of the most prominent questions in the physics of HTSC. Neutron scattering has proven to be a vital experimental probe in unveiling the intrinsic magnetic properties of HTSC. I will briefly review the properties of the YBa2Cu3O6+x (YBCO6+x) HTSC family determined by neutron scattering experiments so far. I will then present the results of our comprehensive polarized and unpolarized neutron scattering study of the evolution of dynamical spin susceptibility in high quality YBCO6+x crystals near the superconducting critical doping with x=0.35 (Tc=18 K), x=0.33 (Tc=8.5 K), x=0.31 (non-SC) and x=0.28 (non-SC). Our experiments on both superconducting and non-SC crystals have allowed an accurate determination of the magnetic phase diagram of YBCO6+x near the superconducting critical doping. We find there is a region of doping just below the superconducting critical doping where only short-range quasielastic AF correlations exist. Although the short-range AF correlations persist into the superconducting dome, the correlations become shorter and appear at lower temperatures with increasing doping before disappearing at higher doping. The correlations gradually grow on cooling with no indication of a transition to a Neel state. At low temperatures, we find a reentrant behavior where a decrease in the intensity of the AF peaks and a simultaneous decrease in correlation lengths primarily along the c-direction are observed upon cooling. We associate this behaviour with appearance of a quasi-static disorder at low temperatures as a disruption mainly in the stacking of the AF CuO2 bilayers. Surprisingly the reentrant behaviour is less noticeable in samples with higher doping. The presence of a more pronounced disorder both within and between CuO2 planes in samples with higher doping may account for this behaviour. Inelastic neutron scattering shows no resonance peak for low doped crystals, instead we find a dramatic shift to low energies in the electronic spectrum of CuO2 planes. Nonetheless these materials, without a resonance and without incommensurate order, do indeed condense into a paired SC state.