Experimental report

17/02/2020

Proposal: 4-02-561 **Council:** 4/2019

Title: Spin fluctuations near the quantumcritical point in La2-xSrxCuO4

Research area: Physics

This proposal is a resubmission of 4-02-550

Main proposer: Stephen M. HAYDEN

Experimental team: Mengze ZHU
Alexander PETSCH
Stephen M. HAYDEN

Local contacts: Martin BOEHM
Paul STEFFENS

Samples: La2-xSrxCuO4 (x=0.24)

Instrument	Requested days	Allocated days	From	To
THALES	8	5	11/01/2020	16/01/2020

Abstract:

Quantum critical points (QCP) can be detected through measurement of the specific heat and entropy. It has been proposed that there may be such a QCP at critical doping p* in cuprate superconductors. Below p*, we enter the enigmatic pseudogap phase which corresponds to the onset of new anisotropy in the electronic properties and a loss of low-energy electronic quasiparticles [1,2]. The critical doping, p*, is special not only because it is where the pseudogap phase ends, but because the superconducting phase forms a dome around this point and, the resistivity exhibits an anomalous linear dependence on temperature. Here, we propose to make wavevector-dependent (at T~Tc) measurements of the low-energy magnetic excitations close to p* in La2-xSrxCuO4 to determine whether the magnetic excitations have the anomalous character (i.e. low energy scale) expected at a quantum critical point.

Experimental Report

Abstract

The nature of the pseudogap phase in high temperature superconductors remains an outstanding issue. Recent specific heat measurements have revealed a peak in the electronic specific heat coefficient $\gamma = C_{el}/T$ at the pseudogap critical point p*, suggesting a quantum critical point (QCP) [1,2]. Here, we performed inelastic neutron scattering experiments on the low-energy spin fluctuations in $La_{2-x}Sr_xCuO_4$ (x = 0.24) close to p*, and revealed that the magnetic excitations indeed have a low energy scale (~5 meV) compared with other compositions, as expected at a QCP.

Experimental details

We have 8.5 g of LSCO single crystals (x = 0.24, T_c = 18 K) co-aligned in the (HHL) scattering plane. PG monochromators and analysers were used. We have made constant-E scans over the incommensurate wave vectors **Q** = (0.5-δ 0.5 L) and (0.5 0.5+δ L) from 2 to 10 meV at T = 20 K above T_c.

Results

Figure 1 shows the constant-E scans at representative energy transfers E = 2, 4, 6, 8 and 10 meV across **Q** = (0.5-δ 0.5 L) and (0.5 0.5+δ L), δ ≈ 0.13, respectively. Magnetic excitations are clearly observed at these incommensurate wave vectors, similar to underdoped and optimally doped LSCO. For E = 8 and 10 meV, a phonon mode (green peak at 8 meV) is also seen.

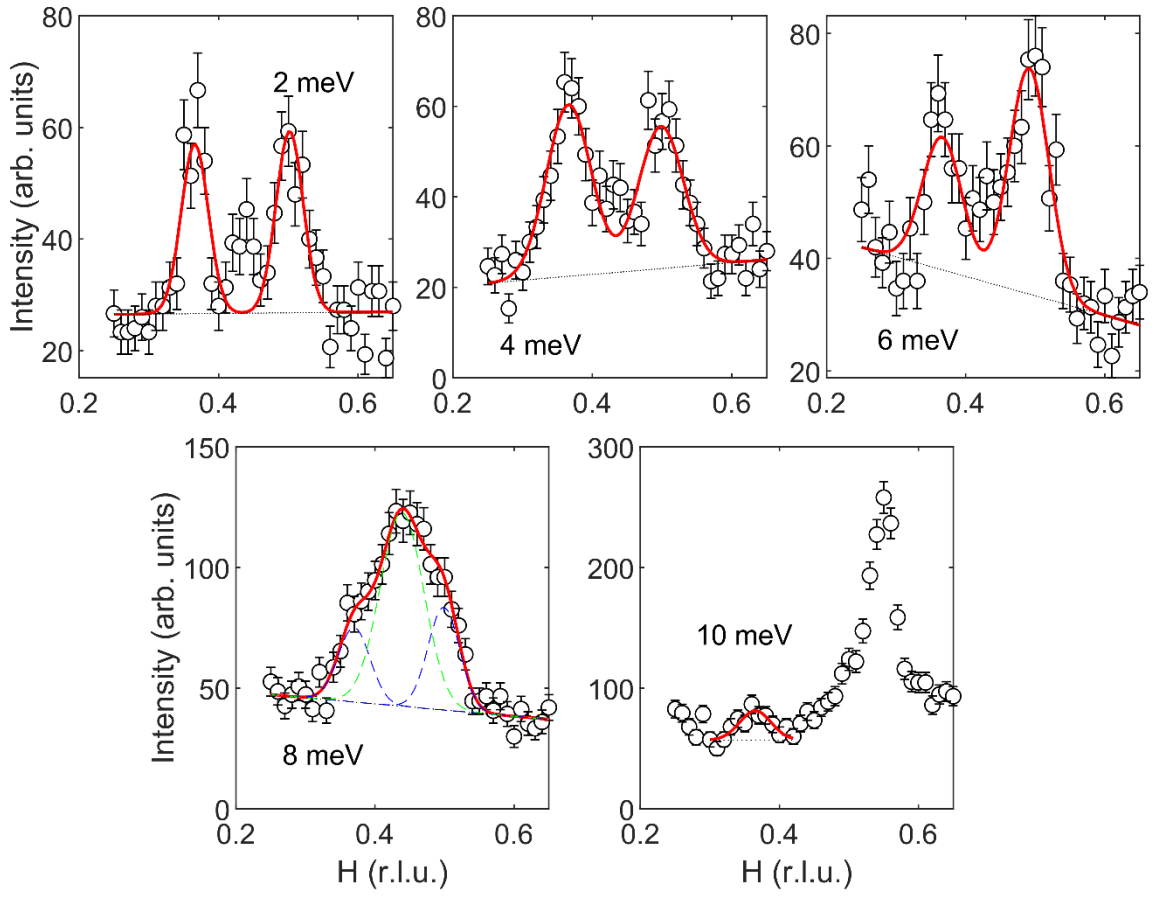

Fig. 1. Constant-E scans on LSCO (x = 0.24) at T = 20 K.

Figure 2 shows the imaginary part of generalized magnetic susceptibility χ'' (Q,ω) as a function of energy transfer at T = 20 K. The solid red line is a fit by the response function of an overdamped harmonic oscillator, with a typical energy scale of E ≈ 5 meV.

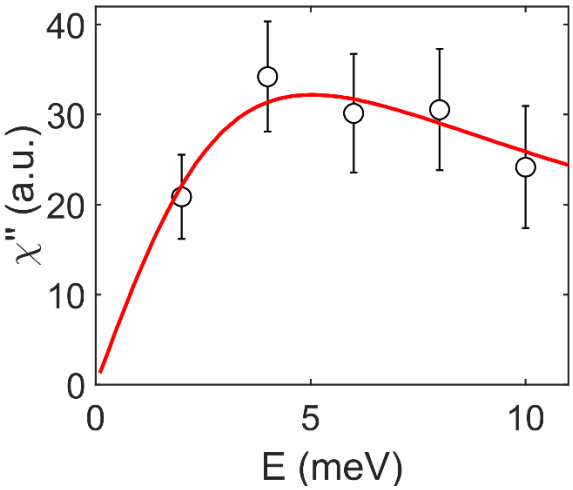

Fig. 2. Magnetic response at **Q** = (0.37 0.5 L) at T = 20 K.

Figure 3 shows the constant-E scans at E = 4 meV at T = 20 and 80 K. The intensity is nearly unchanged indicating a possible QCP.

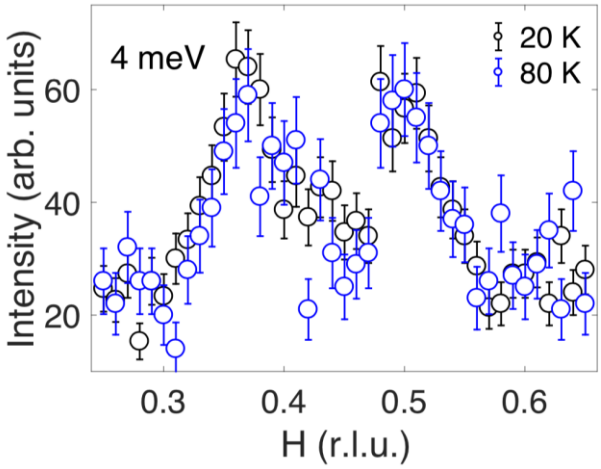

Fig. 3. Incommensurate magnetic excitations at E = 4 meV at T = 20 and 80 K.

Conclusion and future work

We have carried out inelastic neutron scattering measurements on the low energy magnetic excitations of LSCO (x = 0.24) close to the pseudogap endpoint p*. We found that the magnetic excitations in the normal state have a characteristic energy scale of 5 meV, lower than the underdoped (x = 0.14) [3], optimally doped [4] and less overdoped LSCO (x = 0.22) [5], as expected from the presence of a QCP.

At a QCP, the critical fluctuations are expected to exhibit quantum critical scaling. We plan to make temperature dependent measurements on these low energy magnetic excitations in LSCO (x = 0.24) and determine whether $\chi''(Q,\omega)$ shows the similar scaling behaviour as in LSCO (x = 0.14) [3].

References

[1] J. W. Loram, J. Phys. Chem. Sol **62**, 59 (2001).

[2] N. Momono et al, Physica C 233, 395 (1994); Horio et al, Phys. Rev. Lett. **121**, 077004 (2018); B. Michon et al, Nature **567**, 218 (2019).

[3] G. Aeppli et al, Science **278**, 1432 (1997).

[4] B. Vignolle et al, Nature Phys. **3**, 163(2007).

[5] O. J. Lipscombe et al, Phys. Rev. Lett. **99**, 067002 (2007).