Experimental Report

15/01/2014

Proposal:	**4-01-1233**	**Council:**	4/2012	
Title:	Superconductivity and critical spin fluctuations			

This proposal is continuation of: 4-01-1036

Researh Area: Physics

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Samples: La_{2-x}Sr_xCuO_4, x=0.16

Instrument	Req. Days	All. Days	From	To
IN12	0	3	18/03/2013	22/03/2013

Abstract:

In a succesful recent experiment on IN5, we were able to show that in contrast to commonly accepted wisdom, the excitation gap in nearly optimally doped La(1.855)Sr(0.145)CuO(4) does not open at the superconducting transition temperature, Tc, but at a much lower temperature T0~Tc/2. Combining this result with published data from the literature suggests a highly intriguing trend - consist with quantum criticality near optimal doping in a simple cuprate superconductor - of an energy scale T0 approaching zero at the critical doping level xc=0.13 at which spin-density wave ordering sets in. In this continuation proposal, we aim to pursue this novel discovery and suggest to determine the doping dependence of T0.

Superconductivity and critical spin fluctuations

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In the quest to understand cuprate high-temperature superconductivity, much research has focused on the evolution of the spin excitation spectrum with doping, from the Mott insulating state of the undoped parent compounds to the overdoped Fermi liquid phase. Resonant inelastic x-ray scattering (RIXS) demonstrated that the high-energy part of the spin excitation spectrum does not change much with doping [1]. This is in strong contrast to the low-energy part of the spectrum that has a rich and complex dependence on doping and temperature. In our work, we focus on $La_{2-x}Sr_xCuO_4$ (LSCO).

It has long been known that the spin excitation spectrum of optimally doped cuprate superconductors is gapped below the superconducting transition temperature T_c [2-3]. We decided to probe the temperature dependence of this spin gap in order to investigate whether and how it correlates with superconductivity. After having studied underdoped LSCO, x=0.145 (exp. report 4-01-1036), we attempted to perform a similar study in the optimally doped regime (x=0.16). While the first experiment had been carried out on the time-of-flight spectrometer IN5, we were allocated 3 days the recently upgraded IN12 three-axes-spectrometer for the second experiment. It might be worth sharing the following remarks regarding the differences between time of flight and three axes spectrometers for our specific experiment:

(1) The signals we are interested in are very weak. Therefore, the only reliable measurement mode consisted of taking q-scans at different energies and temperatures. Due to the limited beam time, we had to choose energies and temperatures wisely. Thus, we could not address the energy dependence of the magnetic fluctuations above the gap. By contrast, in time-of-flight experiments, some information about such details comes for free.

(2) We had to run the instrument in a high-flux configuration, which limited the smallest accessible energy transfers to about 1 meV (see Figure 1), At IN5 this limit was 0.2 meV.

(3) Finally, time-of-flight data can benefit from symmetrization of the four peaks to increase the signal to noise ratio. At the same time, it is easier to avoid spurious features in energy-momentum space.

Besides these more general remarks, we were very pleased with the performance of the upgraded IN12 spectrometer. It allowed us to track the opening of the spin gap below T_c and we consider the experiment successful.

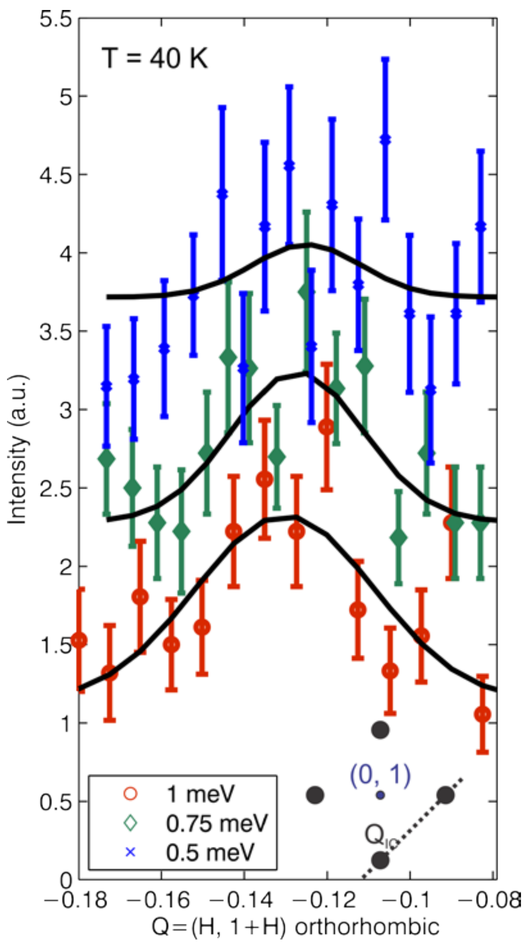

FIGURE 1: *Q-scans through the incommensurate wave vector Q_{IC} at different energy transfers (cf. inset and legend).*

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REFERENCES:

[1] M. Le Tacon *et al.*, Nature Physics 7, 725–730 (2011)	[2] M. Kofu *et al.*, Physical Review Letters **102**, 047001 (2009)
[3] J. Chang *et al.*, Physical Review Letters **102**, 177006 (2009), N.B. Christensen *et al.*, J. Phys. Soc. Jpn. **80SB**, SB030 (2011)	