Experimental report

29/09/2015

Proposal: **4-01-1374**

Council: 4/2014

Title: Spin excitations in KxFe2-ySe2-zSz

Research area: Physics

This proposal is a new proposal

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Samples: K0.89Fe1.65SeS
K0.78Fe1.66Se0.7S1.3

Instrument	Requested days	Allocated days	From	To
IN8 Flatcone	7	7	22/09/2014	29/09/2014

Abstract:

The recently discovered AxFe2-ySe2 high Tc superconductor has caused heated debate regarding its pairing symmetry. Theoretically, it has been proposed that its pairing state could be d wave, s+- or even s++. One way to distinguish the aforementioned pairing states is to investigate the impurity effects on the superconductivity and the spin fluctuations in these materials, since the sign reversal pairing state is very fragile against non-magnetic impurities while the s++ wave pairing states is less sensitive to the impurity scattering. Here, we propose to use inelastic neutron scattering technique to study the evolution of the resonance modes under S doping in the superconducting KxFe2-ySe2. The success of this experiment will shed some new light on our understanding of the pairing symmetry of the AxFe2-ySe2 superconductors.

Experimental Report of Proposal 4-01-1374

Spin resonant mode in sulfur doped $K_xFe_{2-y}Se2\text{-}_zS_z$

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The distinctive features of newly discovered superconductivity in $A_xFe_{2-y}Se_2$ (A= K, Rb, Cs) has attracted great research interests. While the iron-pnictides are mostly recognized to have s ± pairing symmetry, the paring state of iron-chalcogenides remains controversial. The absence of electron Fermi surfaces revealed by ARPES studies and resonant mode observed by inelastic neutron scattering measurements suggest a d-wave rather than s ± pairing [1, 2]. Besides, the s++ pairing mediated by the orbital fluctuations has also been proposed [3], which is consistent with the experimental fact that the superconducting gap is nodeless [1]. Chemical doping can serve as an effective way to distinguish the pairing state. According to Abrikosov-Gorkov theory, the sign reversal pairing state is very fragile against non-magnetic impurities while the s++ wave pairing states is robust against them. Our proposed experiment is to use inelastic neutron scattering technique to study the evolution of the spectral weight redistribution below and above T_c under S doping in superconducting $K_xFe_{2-y}Se_2$.

The $K_xFe_{2-y}Se_{2-z}S_z$ (z=0.5) single crystalline sample were aligned in the (H, K, 0) scattering plane within ~ 1.5 degrees mosaicity for the measurements. We define the wave vector Q at (q_x, q_y, q_z) as (h, k, l) = ($q_xa/2\pi$, $q_yb/2\pi$, $q_zc/2\pi$) reciprocal lattice units (r.l.u.) in the 1-Fe unit cell. Both the monochromator and analyzer were double focused and no collimations were used.

We first did Q-scans to determine the momentum structure of the spin excitations. Figure 1 shows that the magnetic excitations are centered at Q = (0.5, 0.77, 0), which is close to the wave vector Q = (π, 0.5 π, 0) reported in $A_xFe_{2-y}Se_2$ [4, 5]. Upon entering the superconducting state, the spin fluctuations around 13 meV increases drastically. We carefully measured the temperature dependence of the spin fluctuations at Q = (0.5, 0.77, 0) and E = 13 meV. The intensity shows an order parameter-like behavior with a kink at T_c, which suggests that the intensity change is strongly induced by superconductivity.

Energy dependence of the spin fluctuations was measured from 5 meV to 31 meV in normal state and superconducting state. Figure 2 shows the background subtracted data (1.5K-35K). It is interesting that in addition to a resonant peak at around 13 meV, the spectra exhibit a small shoulder at higher energy transfer which exceeds the 2 delta value (delta is the superconducting gap value determined by ARPES measurement). The shoulder above 2 delta is not consistent with the criteria of a resonant mode which is regarded as an evidence of a sign-changing pairing state. Therefore the superconductivity induced change of spectral weight above 2 delta may be associated with the elusive pairing state in A_xFe_{2-}

$_y$Se$_2$. To shed more light on the pairing mechanism in in $A_xFe_{2-y}Se_2$, more experiments on different amount of sulfur doped $K_xFe_{2-y}Se_{2-z}S_z$ need to be performed.

Reference

[1] Y. Zhang et al., Nat. Materials, 709. (2012)

[2] T.A. Maier et al., Phys. Rev. B 83, 100515(R) (2011)

[3] H.Kontani and S. Onari: Phys. Rev. Lett. 104, 157001 (2010)

[4] J. T. Park et al., Phys. Rev. Lett. 107, 177005 (2011)

[5] Friemel et al., Europhys. Lett. 99, 67004 (2012).

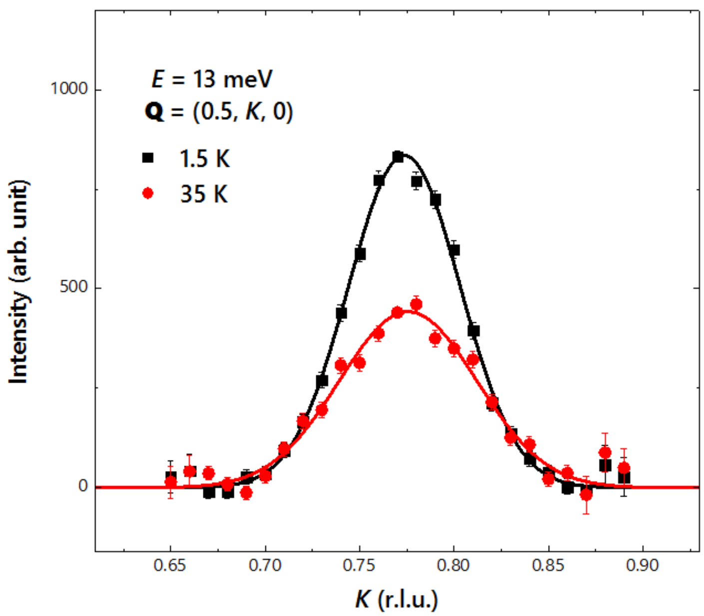

Figure 1. Momentum dependence of the magnetic excitations in $K_xFe_{2-y}Se_{1.5}S_{0.5}$ below and above T_c. The black and red dots represent date in the superconducting and normal state, respectively. A slope background is subtracted.

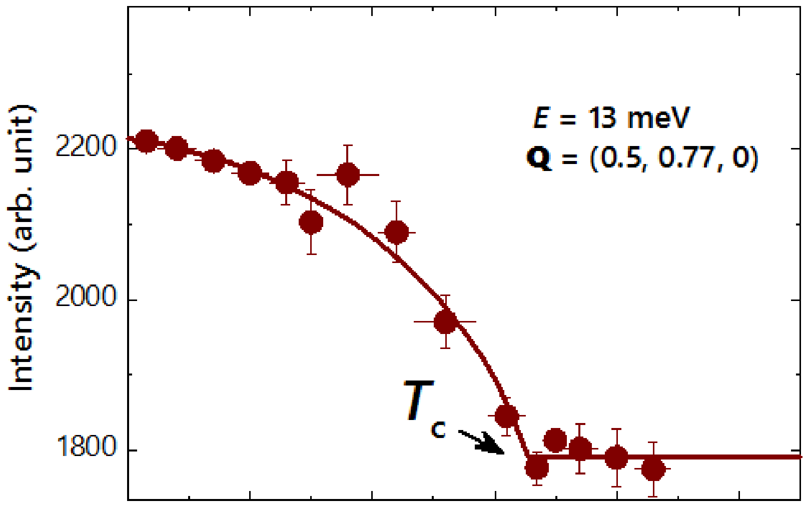

Figure 2. Temperature dependence of spin fluctuation in $K_xFe_{2-y}Se_{1.5}S_{0.5}$. indicate the temperature range within which data were combined. The vertical error bars indicate one standard deviation. The solid lines are guides to the eye.

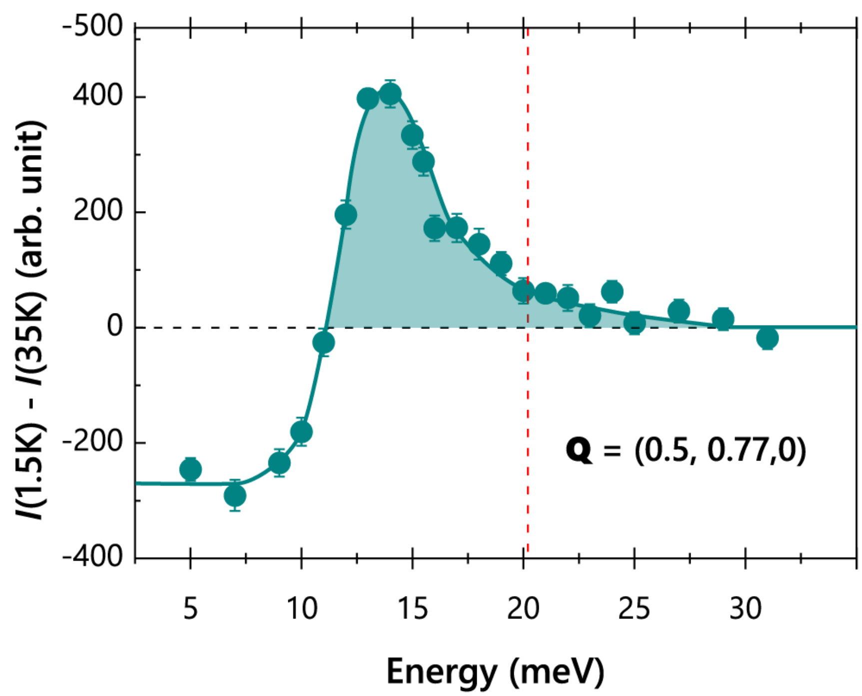

Figure 3. Energy dependence of the intensity difference between the superconducting and the normal states in the vicinity of Q = (0.5, 0.75, 0). The dashed lines represent 2delta determined by ARPES measurement. The shaded area denotes the spectral weight enhancement below T_c.