Experimental report

22/10/2018

Proposal: 4-02-532 **Council:** 4/2018

Title: Spin anisotropy in the stoichiometric iron-based superconductor CaKFe4As4

Research area: Physics

This proposal is a new proposal

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Samples: CaKFe4As4

Instrument	Requested days	Allocated days	From	To
IN20	0	0		
IN22 CPA	9	7	18/09/2018	25/09/2018

Abstract:

We propose to study the low energy spin excitations, especially the anisotropy of spin resonance, in the newly discovered stoichiometric superconductor CaKFe4As4 by polarized neutron scattering. In our previous unpolarized inelastic neutron scattering experiments, triple spin resonance modes with odd and even L-symmetries are found to appear around 9.5 meV, 13 meV and 18.3 meV. This is the first clear discovery of an even mode of spin resonance in iron-based superconductors. Since the disorder from the dopants no longer exists and the electron structure is nearly two-dimensional, the orbital order in this ultraclean compound may behave differently in each resonance mode, or be absent at all pairing channels. Such rich physics will certainly give a nice opportunity to study the multi-band superconductivity in iron-based superconductors. The experiment will yield very first hand results of spin anisotropy about the this new 1144 compound. The coming results of this new 1144 type iron pnictides will be fully compared with the well studied 122 system, and help us to understand the magnetism, orbital physics and their relations with superconductivity in iron-based superconductors.

Spin anisotropy in the stoichiometric iron-based superconductor $CaKFe_4As_4$

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The superconductivity in iron pnictide superconductors always emerges beneath the antiferromagnetic order and evolves to optimal near the boundary of antiferromagnetism. The co-existence and competition between antiferromagnetism and superconductivity results in very complex fate of the magnetic order upon electron or hole dopings. Such behavior may be driven by the orbital interactions under Hund's coupling, which is in coupled with the spin freedom, leading to an anisotropic nature of electronic state, such as nematic phase, orbital ordering or spin anisotropy. Polarized neutrons, with full analysis of the spatial anisotropy of spin orientation and fluctuation, is a unique and powerful tool to explore the spin-orbit interactions in crystalline samples. We have performed unpolarized inelastic neutron scattering experiments in the stoichiometric iron pnictide superconductor $CaKFe_4As_4$ with T_c = 35 K [1]. Triple modes of spin resonance are found with strong L-modulation, where two odd modes appear around 9.5 meV and 13 meV, and one even mode locates around 18.3 meV(Fig. 1).

To examine the spin anisotropy of the spin resonance modes, we performed polarized inelastic neutron scattering experiment on the same $CaKFe_4As_4$ sample. We carried out energy scans up to 22 meV in spin flip channels with X-X, Y-Y, Z-Z polarizations at Q = (1, 0, 3.3) and (1, 0, 2.2) at the base temperature (1.5 K below T_c) and high temperature (40 K above T_c). While the spin excitations for two odd modes of resonance are anisotropic, the spin excitations for the even resonance mode (L = 2.2) are demonstrated to be isotropic (Fig. 2(a,c)). Above T_c in the normal state, the spin excitations are nearly isotropic at most energies but slightly anisotropic below 5 meV (Fig. 2(b)). After combining the polarization analysis at Q = (1, 0, 1.1) for the odd modes, we found that the 9.5 meV mode is nearly c-axis polarized (M_c>>M_a, M_b) and 13 meV mode is nearly in-plane polarized with weak difference between M_a and M_b (Fig. 2(d)). By tracking the temperature dependence of the spin resonance at 10 meV and spin gap at 2 meV induced by superconductivity, we reveal that the spin anisotropy is transferred from the low energy to higher energy due to the opening of superconducting gap (Fig. 2(e, f)).

These results give better understanding on the spin-orbit coupling in iron-based superconductors, which can also enlighten us about the nature of magnetism and its relation with unconventional superconductivity.

[1] T. Xie et al., Phys. Rev. Lett. 120, 267003(2018)

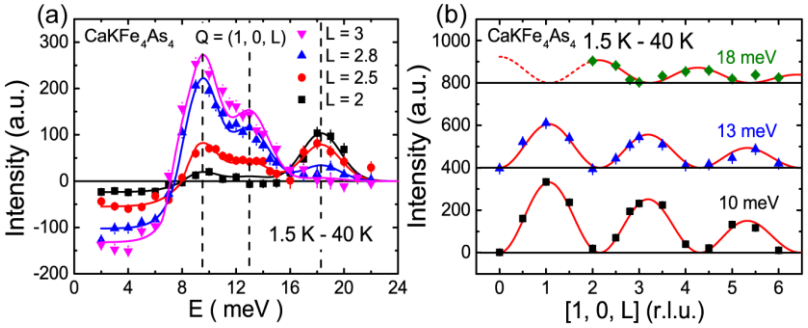

Fig. 1 Unpolarized results of $CaKFe_4As_4$: (a) Energy dependence of the spin resonances of $CaKFe_4As_4$ at Q = (1, 0, L); (b) L dependence of three resonance modes of $CaKFe_4As_4$ at E_R = 10, 13, 18 meV.

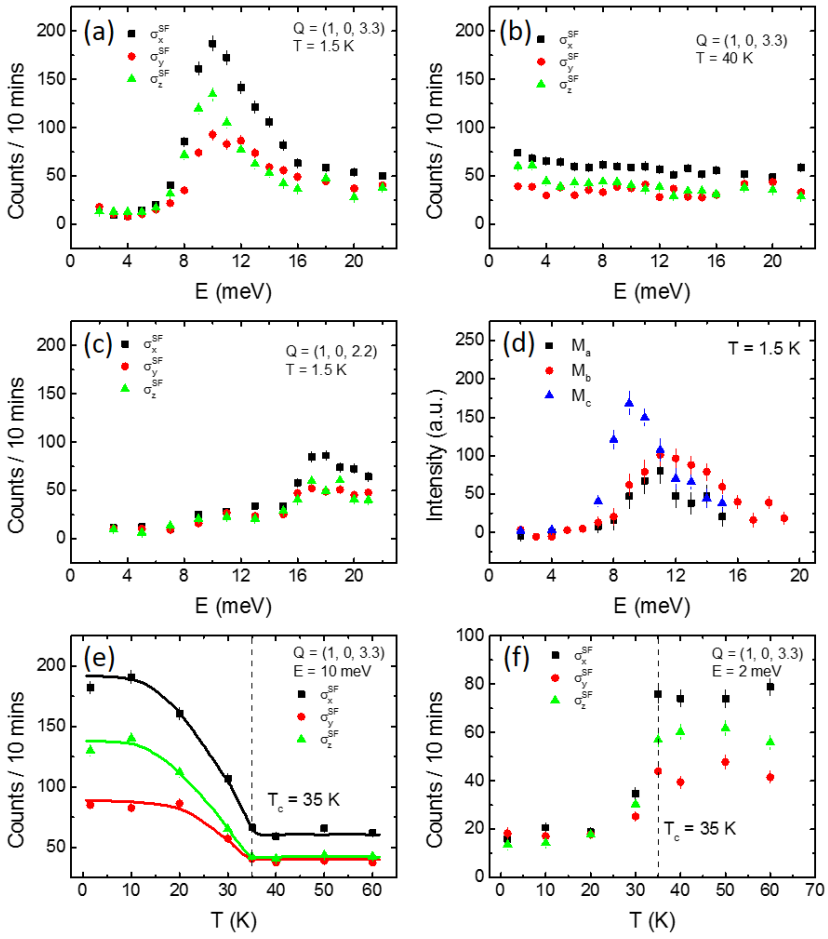

Fig. 2 Polarized results of $CaKFe_4As_4$ in spin flip channels with X-X, Y-Y, Z-Z polarizations: (a, b) Energy dependence of spin excitations at Q = (1, 0, 3.3) at 1.5 K and 40 K; (c) Energy dependence of spin excitations at Q = (1, 0, 2.2) at 1.5 K; (d) Energy dependence of the calculated M_a, M_b, and M_c; (e, f) Temperature dependence of spin excitations at Q = (1, 0, 3.3) at 10 meV and 2 meV.