Experimental report

05/09/2022

Proposal: **CRG-2609**

Council: 4/2019

Title: Spin-space anisotropy of magnetic excitations in CaK[Fe(1-x)Ni(x)]4As4with hedgehod spin-vortex crystal order

Research area:

This proposal is a new proposal

Main proposer: **Yuan LI**

Experimental team: Chang LIU
Huiqian LUO
Guanhong HE
Xingyu WANG
Yvan SIDIS

Local contacts: Frederic BOURDAROT

Samples: CaK[Fe(1-x)Ni(x)]4As4

Instrument	Requested days	Allocated days	From	To
IN22	8	8	26/08/2020	03/09/2020

Abstract:

Experimental Report CRG-2609: Spin-space anisotropy of magnetic excitations in $CaK(Fe_{1-x}Ni_x)_4As_4$ with hedgehog spin-vortex crystal order

C. Liu[1], P. Bourges[2], Y. Sidis[2], T. Xie[3], G. He[4], F. Bourdarot[5], Y. Li[4], and H. Luo[1]

[1]Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

[2]Laboratoire Leon Brillouin, CEA-CNRS, Universite Paris-Saclay, CEA Saclay, 91191 Gif-sur-Yvette, France

[3]Neutron Scattering Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

[4]International Center for Quantum Materials, School of Physics, Peking University, Beijing 100871, China

[5]Universite Grenoble Alpes, CEA, INAC, MEM MDN, F-38000 Grenoble, France

Spin-orbit coupling (SOC) is a key to understand the magnetically driven superconductivity in iron-based superconductors, where both local and itinerant electrons are present, and the orbital angular momentum is not completely quenched [1-4]. Here, we used spin-polarized neutron scattering to address the issue of spin anisotropies of magnetic excitations in the bilayer iron-based superconductor $CaK(Fe_{1-x}Ni_x)_4As_4$ with coexisting superconductivity and spin-vortex crystal (SVC) magnetic order [5-6](T_c = 20.1 K, T_N = 48.1 K).

About 4.426 grams of crystals were co-aligned on the scattering plane [H, 0, 0] x [0, 0, L]. Polarized neutron scattering experiments were performed at the CEA-CRG IN22 spectrometer in ILL, Grenoble, France, using the CryoPAD system and Heusler monochromator and analyzed [7]. We focused on the spin-flip (SF) channels both before and after the sample given by three cross sections: σ_x^{SF}, σ_y^{SF}, and σ_z^{SF} (Fig. 1(a)). After considering the geometries of lattice and polarization at two unparallel but equivalent wave vectors, we can separate all three magnetic excitation components: M_a, M_b, and M_c along the lattice axes a_M, a_M, and c, respectively.

We performed polarized elastic neutron scattering measurements to confirm the SVC order. Fig. 1(b) shows the dependence of magnetic peak intensity at Q = (1, 0, 3) and (1, 0, 2), and the all the three components of the static moments M_a, M_b, and M_c are shown in Fig. 1(c). Only the in-plane component M_a has nonzero value, consistent with the geometry of coplanar SVC order.

We then performed polarization analysis on the anisotropy of low-energy excitations in spin space. The raw data of energy and temperature dependence of σ_x^{SF}, σ_y^{SF}, and σ_z^{SF} are presented in Fig. 2. The deduced dynamic spin components M_a, M_b, and M_c are shown in Fig. 3. For the odd spin resonance mode in the superconducting state (T = 5 K), there is a c-axis polarized component that peaked around E = 4 meV, and the in-plane excitations are also weakly anisotropic below E = 10 meV (Fig. 3(a)) At T = 25 K (T_c < T < T_N), the spin resonance disappears, but the spin anisotropy persists (Fig. 3(b)). When further warming up into the paramagnetic state (T = 55 K), where the spin gap closes thus the low-energy spin excitations increase, the spin anisotropy only exists below 5 meV (Fig. 3(c)). Fig. 3(d) shows that the c-axis component M_c is always stronger than the in-plane components M_a and M_b, and the spin anisotropy can persist up to a very high temperature of about 100 K, about twice of T_N. Such behavior is reminiscent of the results in $BaFe_{2-x}Ni_xAs_2$, $Ba_{1-x}K_xFe_2As_2$, and $NaFe_{1-x}Co_xAs$, where the low-energy spin anisotropy can survive well above T_N in the paramagnetic state.

These results suggest that the c-axis magnetic excitations are universally preferred by the presumably orbital-selective superconducting pairing regardless of the details of magnetic pattern or lattice symmetry in the iron-based superconductors.

Results from this experiment have been published in Physical Review Letters. Please see [PHYSICAL REVIEW LETTERS 128, 137003 (2022)] for details.

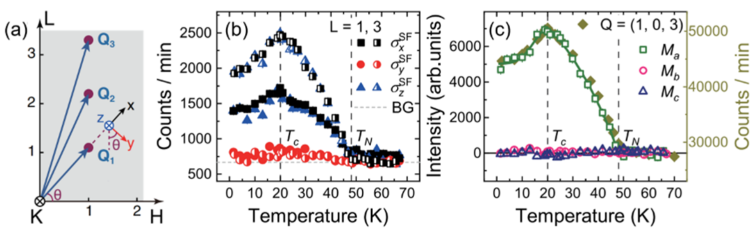

Fig. 1. (a) The scattering plane and the definition of spin-polarization directions in reciprocal space. (b) Magnetic order parameter at Q = (1, 0, 1) and (1, 0, 3). (c) Three components of static moments (open) in comparison with the previous unpolarized results (solid).

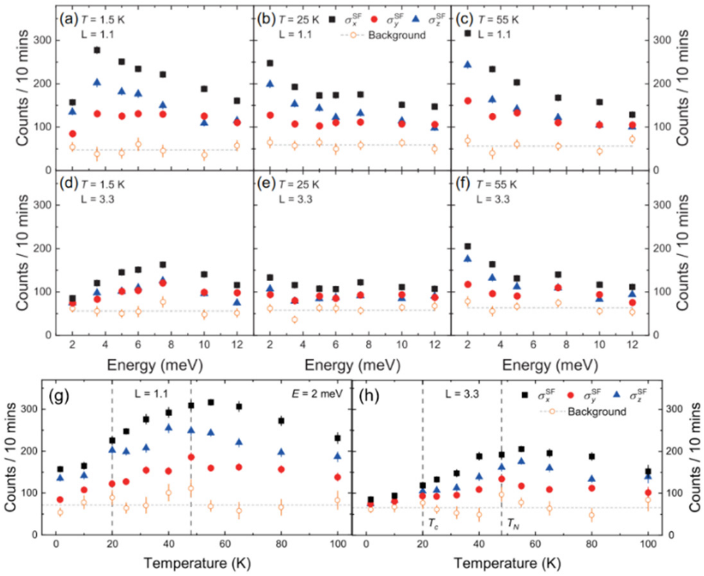

Fig. 2. (a)-(f) The energy dependence of σ_x^{SF}, σ_y^{SF}, and σ_z^{SF} for Q = (1, 0, 1.1) and (1, 0, 3.3) at T = 1.5, 25 and 55 K. (g)-(h) The temperature dependence of σ_x^{SF}, σ_y^{SF}, and σ_z^{SF} at E = 2 meV for Q = (1, 0, 1.1) and (1, 0, 3.3).

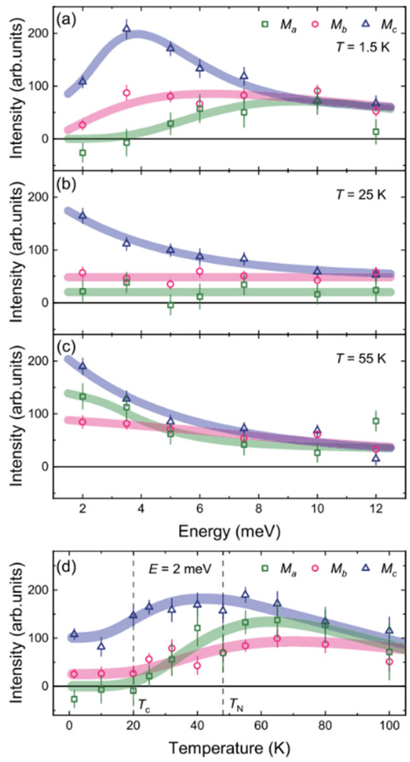

Fig. 3. Polarization analysis on the low-energy spin excitations. (a)-(c) the energy dependence of M_a, M_b, and M_c at T = 1.5, 25 and 55 K. (d) The temperature dependence of M_a, M_b, and M_c at E = 2 meV. All bold transparent lines are guide to eyes.

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