Experimental report

18/09/2017

Proposal: 4-02-478 **Council:** 4/2016

Title: Spin-space anisotropy in over-doped Ba(Fe1-xCox)2As2

Research area: Physics

This proposal is a new proposal

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Samples: Ba(Fe1-xCox)sAs2

Instrument	Requested days	Allocated days	From	To
IN20 CPA	7	6	26/09/2016	03/10/2016

Abstract:

Several polarised inelastic neutron scattering experiments on doped BaFe2As2 revealed that the so-called resonance mode actually consists of two components: a low-energy peak that is anisotropic in spin-space and a broader isotropic feature at higher energy. Therefore, the resonance enhanced scattering in the superconducting state bears astonishing similarity with the anisotropy of the antiferromagnetic gaps in the parent compound. For hole-doping far beyond the suppression of static AFM order, the anisotropic feature clearly persists. However, for Co and thus electron doping a comparable study still lacks.
(Continuation of CRG2180 proposal)

Experimental Report: 4-02-478
Spin-space anisotropy in over-doped $Ba(Fe_{1-x}Co_x)_2As_2$

In this experiment we aimed to investigate the polarisation of the spin resonance mode in Co-overdoped $BaFe_2As_2$. Co-under and Co optimum doped compounds display two anisotropic resonance modes, and the corresponding character changes from two anisotropic resonance modes at 4.5% Co-doping to one anisotropic and one isotropic mode at 6% doping [1]. Additionally, on the related Ni-overdoped compound an essentially isotropic spin-resonance mode is reported [2], although close inspection of this data yields some evidence for anisotropy at low energy. Therefore, we prepared ~1g of 11% Co-doped $BaFe_2As_2$ within the [110]/[001] scattering geometry. In order to conduct the polarisation analysis the CryoPAD option on IN20 was employed and we define the frame of reference as the following: x is parallel to the scatting vector Q, y is perpendicular to Q and within the scattering plane and z is perpendicular to the scattering plane.

The Tc of our crystal amounts to ~11K and due to the universal scaling ratio, $E_{res}/k_BT_c \sim 4.6$, the spin resonance mode is expected to peak at ~4.4meV. Matan et al. conducted an unpolarised inelastic neutron scattering (INS) experiment for 14% Co-doping, thus similar to our Co concentration [3]. In their data the signal is most intense at ~10meV, but they did not report on the resonance mode. However, from their data we could estimate that the magnetic signal is roughly five times weaker than that in the 6% and thus optimal doped compound. Taking this into account we counted at least 25min per point at Q = (0.5,0.5,1), where the magnetic signal should be strongest, in order to extract the magnetic response, c.f. Fig (a). However, the data does not show any sizeable signal. Additionally we probed two energies in the next Brillouin zone at (0.5,0.5,3) yielding the same unsatisfying result.

In order to estimate the magnetic signal in our sample, we abandoned the setup for polarisation analysis: Heusler monochromator – Heusler analyser, and switched to the unpolarised setup: Silicon monochromator – PG analyser, which provided an eleven times higher neutron flux. This ratio of incident neutron flux was estimated by comparing phonon signals. Figure (b-c) shows the energy scans with the corresponding background for Q = (0.5,0.5,1) and Q = (0.5,0.5,3), respectively. Even with this higher neutron flux the signal at (0.5,0.5,1) is almost identical to the estimated background at (0.3,0.3,1.94). In the next Brillouin zone at (0.5,0.5,3) there seems to be a significant signal above the background level, which was taken at BG1 = (0.3,0.3,3.52) and BG2 = (0.66,0.66,2.24). Note that the absolute values of Q for the background and for the Q-position, where the signal is taken, are the same. In order to confirm this signal we performed rocking scans at various energies around the central position at (0.5,0.5,3), c.f. Fig (d). When we normalise the resulting intensity, e.g. at 8meV, on phonon scattering and compare this ratio with the one we obtain for our Co-optimum and –underdoped sample, it is at least a factor of ten weaker. In our case this reduces the intensity by an additional factor of two in comparison to the data in the report by Matan et al. [3]. Nonetheless, this assures us that there is some weak magnetic signal and we went back to the setup for polarisation analysis. Subsequently, we spent the rest of the remaining beamtime to collect data with sufficient statistics at Q = (0.5,0.5,3) at selected energies. However, the magnetic signal is too small for any statement on a potential isotropy/ anisotropy.

In summary, the magnetic signal in this 11% Co-overdoped $BaFe_2As_2$ sample could be quantified by unpolarised experiments but it turned out too weak for performing a reliable polarisation analysis.

[1] Waßer et al., Sci. Rep., 7, 10307 (2017)
[2] Liu et al., PRB, 85, 214516 (2012)
[3] Matan et al., PRB, 82, 054515 (2010)

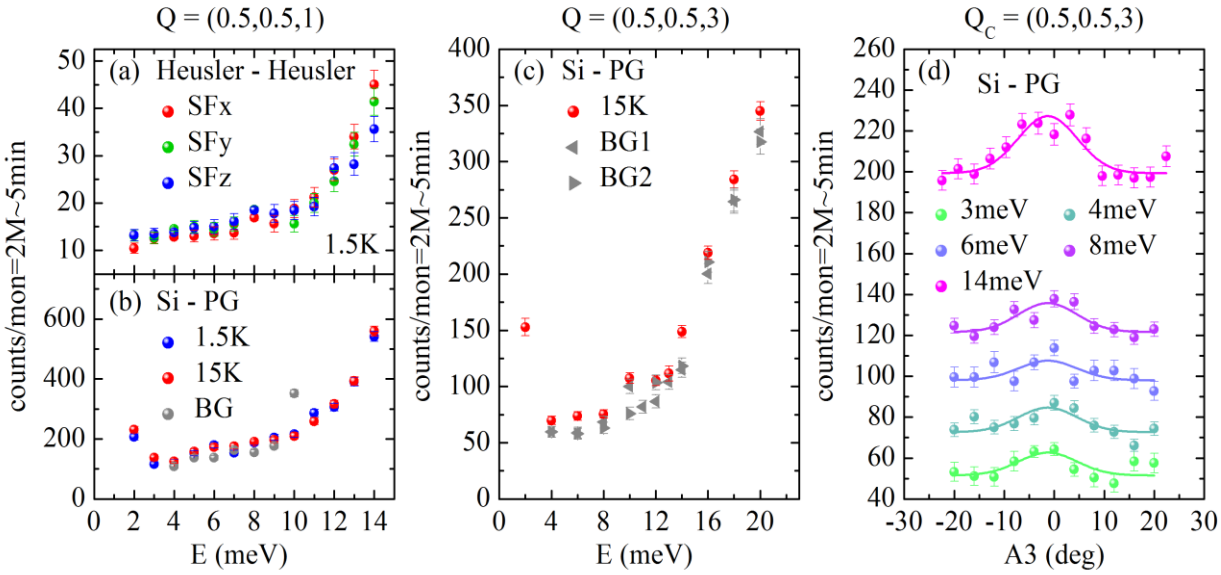

Figure: (a) Energy scan at Q = (0.5,0.5,1) at 1.5K with Heusler monochromator and Heusler analyser in order to perform the polarisation analysis. Although each data point includes at least 25min of beamtime no statistically significant magnetic signal can be extracted. **(b)** The same scan as in (a) at 1.5K and 15K but with the unpolarised setup, Si monochromator and PG analyser, which generate roughly an eleven times higher neutron signal. However, the signal remains almost undetectable, as it is nearly identical to the background taken at Q = (0.3,0.3,1.94). **(c)** Energy dependence in the next Brillouin zone at (0.5,0.5,3) and at 15K with the identical setup as in (b). The corresponding background was measured at BG1 = (0.3,0.3,3.52) and BG2 = (0.66,0.66,2.24) revealing clearly lower intensity than at the signal. **(d)** By performing rocking scans over some selected points in the scan-path of (c) a very weak magnetic signal can be identified.