Experimental Report

13/11/2013

Proposal:	**4-01-1199**	**Council:**	4/2012

Title: Polarized neutron investigation ofnon-bulk superconductor FeTe0.78Se0.22

This proposal is a new proposal

Researh Area: Physics

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Samples: FeTe0.78Se0.22

Instrument	Req. Days	All. Days	From	To
IN20 CPA	7	7	30/10/2012	06/11/2012

Abstract:

We wish to continue our measurement of the anisotropy of the inelastic responses since this is key to understanding the pairing mechanism. We propose to measure the x=0.22 sample with polarized neutrons. Prior to the experiment, we will orient our x=0.22 sample with the c axis vertical to be able easily reach both, (0.5, 0, 0) and (0.5, 0.5, 0) position which are the magnetic ordering Q and the spin resonance Q, respectively. Using CRYOPAD, we will determine the diagonal elements of the polarization cross sections (6 channels) at two different temperatures (at 2 K and above TC at 20 K). This will enable us to calculate the responses along and perpendicular to the c axis. In addition, we wish to determine the energy dependencies and q profiles at these positions and follow their evolution with temperature. Based on experience from our last experiment on IN20 with polarized beam we estimate that we shall require 7 days of beam time.

Polarized neutron investigation of non-bulk superconductor $FeTe_{1-x}Se_x$

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INTRODUCTION

Magnetism is a key ingredient in the formation of Cooper pairs in unconventional high temperature superconductors[1]. A consequence of magnetism and the symmetry of the superconducting order parameter is a magnetic resonance that has been detected through inelastic neutron scattering for a wide range of magnetic superconductors[2]. The iron based superconductors consist from several group of compounds, all containing the same structural ingredient FeAs or FeSe planes. The iron chalcogenide $Fe_{1+y}(Te_{1-x}Se_x)$ is structurally the simplest of the Fe-based superconductors[1]. Although the Fermi surface is similar to iron pnictides the parent compound exhibits antiferromagnetic order with an in-plane magnetic wave vector (π,0) (ref. [3]) what is in contrast to the pnictide parent compounds where the magnetic order has an in-plane magnetic wave vector (π,π)[4]. Despite these differences, both the pnictide and chalcogenide Fe superconductors exhibit a superconducting spin resonance around (π,π). The role of magnetic fluctuations, possible involvement of orbital degrees of freedom and their relevance to the superconductivity is highly debated.

EXPERIMENTS

We measured the samples $FeTe_{0.78}Se_{0.22}$ and $FeTe_{0.6}Se_{0.4}$ with polarized neutrons on CRYOPAD. We oriented our samples with the c axis vertical to be able to reach both (0.5, 0, 0) and (0.5, 0.5, 0) positions which are the magnetic ordering Q and the spin resonance Q, respectively. We measured both samples with a wavelength of k_f=2.662 $Å^{-1}$. We collected data at 65 K and 1.6 K for both samples and additionally at 20 K for $FeTe_{0.78}Se_{0.22}$. We did q-scans at several positions in the *ab* plane and energy scans on selected positions with non-polarized neutrons and

TABLE I: A table of the measurements performed at IN20. A cross marks that the respective sample was measured at the marked position (row) and temperature (column). Q represents a q-scan while E represents an energy scan. Every measurement was done with non-polarized neutrons and with polarized neutrons along the x, y and z axis.

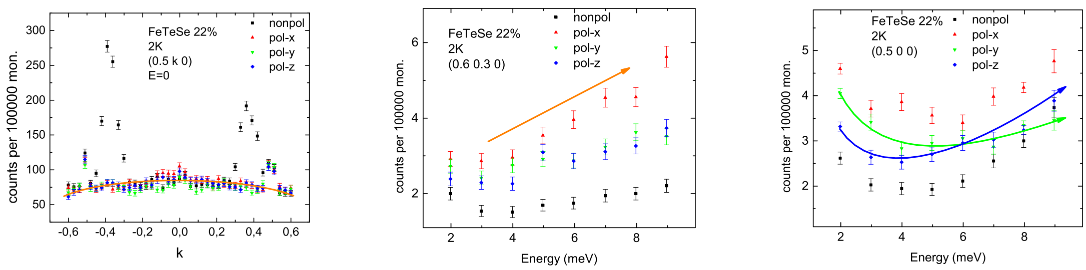
$FeTe_{0.78}Se_{0.22}$				$FeTe_{0.6}Se_{0.4}$	
	1.6 K	20 K	65 K	1.6 K	65 K
Q ($\frac{1}{2}$ k 0) elastic	X	X	X		
Q (h -k 0) elastic	X	X	X	X	
E ($\frac{2}{3}$ $\frac{1}{3}$ 0)	X		X	X	X
E ($\frac{1}{2}$ 0 0)	X	X	X	X	X
E ($\frac{1}{2}$ $\frac{1}{4}$ 0)	X				
E ($\frac{1}{2}$ $\frac{1}{2}$ 0)	X			X	X
E (0.8 0.2 0)	X				

with polarized neutrons along the x, y and z axis. Table I displays the measurements that were done.

RESULTS

$FeTe_{0.78}Se_{0.22}$

On our measurements on $FeTe_{0.78}Se_{0.22}$ we are able to see a broad magnetic signal at 2 K in the elastic scattering that points to local magnetic correlations in this sample as it is displayed in Figure 1(a). This is comparable to what is known in FeTe.



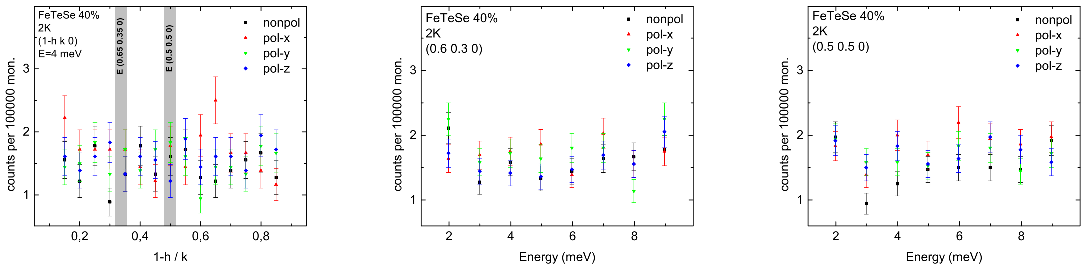
(a) (b) (c)

FIG. 1: Display of selected results at 2 K on the $FeTe_{0.78}Se_{0.22}$ sample. (a) shows a q-scan at (0.5 k 0) from k= -0.6 to 0.6 at 0 meV. (b) and (c) are energy scans from 2 to 9 meV at (0.6 0.3 0) (b) and (0.5 0 0) (c).

The most interesting results of the energy scan are on the one hand that on the position ($\frac{2}{3}$ $\frac{1}{3}$ 0) the magnetic peak is increasing with energy (see Figure 1(b)) and does not show any temperature dependence. On the other hand the energy scan at ($\frac{1}{2}$ 0 0) shows a signal to higher energies as previously claimed. This can be due to an increasing background that hides the magnetic signal when collecting data with unpolarised neutrons. Further the magnetic signal changes polarisation between low (2meV) and high (8meV) energies (see Figure 1(c)).

$\mathbf{FeTe_{0.6}Se_{0.4}}$

The superconducting sample $FeTe_{0.6}Se_{0.4}$ only gave a very weak signal and no temperature dependence is visible in resonance mode, as it is demonstrated for a selected data set in Figures 2(a)-(c). Unfortunately this leaves the question about the responsibility of the magnetism for the superconductivity open. However it may be possible that the (FeSe) superconductivity changes the magnetic response in the (FeTe) magnetic matrix in $FeTe_{1-x}Se_x$ when x is decreasing.



(a) (b) (c)

FIG. 2: Display of selected results at 2 K on the $FeTe_{0.6}Se_{0.4}$ sample. (a) shows a q-scan from (0.1 0.9 0) to (0.9 0.1 0) at 4 meV. (b) and (c) are energy scans from 2 to 9 meV at (0.6 0.3 0) (b) and (0.5 0.5 0) (c).

Further investigations are necessary to identify the homogeneity of the superconducting sample and to exclude the implication that superconducting $FeTe_{0.6}Se_{0.4}$ sample is a mixture of a magnetic matrix with a lower x and a superconducting matrix with a higher x and if the sample hosts two matrices how they are arranged.

[1] Hsu, F. C. *et al. Proc. Nat Acad. Sci. USA* **105**, 14262-14264 (2008)

[2] A. D. Christianson *et al.*, *Nature* **456**, 930 (2008)

[3] D.N. Argyriou *et al.*, *Phys. Rev. B* **81**, 220503 (R) (2010)

[4] de la Cruz, C. *et al. Nature* **453**, 899-902 (2008)