Experimental Report

09/09/2013

Proposal: **4-01-1241** **Council:** 10/2012

Title: Magnetic excitations in A-type $CeCu_2Si_2$

This proposal is continuation of: 4-01-713

Researh Area: Physics

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Experimental Team: HUESGES Zita

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Samples: $CeCu_2Si_2$

Instrument	Req. Days	All. Days	From	To
IN12	7	7	31/07/2013	07/08/2013

Abstract:

$CeCu_2Si_2$ continues to be a model system for the study of the relationship of magnetism and unconventional superconductivity. Recently, we have measured the magnetic excitations in the superconducting and the normal phase of $CeCu_2Si_2$. For comparison, we would now like to measure the excitations in the antiferromagnetic phase with our new A-type $CeCu_2Si_2$ crystal.

Magnetic excitations in A-type and A/S-type $CeCu_2Si_2$

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$CeCu_2Si_2$, a model system for the study of magnetic quantum critical points (QCPs), has attracted much interest due to the occurence of unconventional superconductivity close to the QCP. Recent developments in the single crystal synthesis have opened new possibilities for inelastic neutron measurements, which allow to study the interplay of magnetism and superconductivity on a microscopic level. In $CeCu_2Si_2$, the ground state can be tuned by slight variations of the 1:2:2 stoichiometry: silicon excess stabilises magnetic order while silicon deficiency suppresses magnetism and leads to a superconducting gound state. Samples very close to the 1:2:2 composition have been found to show both a magnetic and a superconducting phase, with $T_{\mathrm{N}} > T_{\mathrm{C}}$. Samples of respective ground states are called A-type, S-type and A/S-type.

On the triple axis spectrometer IN12, we have investigated an A-type $CeCu_2Si_2$ crystal (3g) and an A/S-type $CeCu_2Si_2$ crystal (4g). Both samples are doped with 2 % of germanium on the silicon site to stabilise magnetic order. A dilution cryostat allowed cooling to a base temperature of about 100 mK. Measurements were taken with fixed final neutron wave vector $k_f = 1.15$ Å^{-1} (for a few scans also 1.07 Å^{-1}).

For the A-type crystal, the first step was the measurement of the temperature dependence of the magnetic Bragg peak. The Néel temperature was found to be 900 mK, in agreement with heat capacity measurements. The maximum intensity is reached at 400 mK, while around 10 % of the intensity are lost when the sample is further cooled to 100 mK. This effect was observed earlier and was explained by parasitic superconductivity [1]. Therefore, the antiferromagnetic phase should be studied at 400 mK rather than base temperature.

Then, we have taken spectra at $Q_{\mathrm{AFM}} = (0.215\ 0.215\ 1.475)$. The magnetic response is quasi-elastic, both in the antiferromagentic and in the paramagnetic phase, and broadens towards higher temperatures. At $T = 400$ mK and $T = 1$ K, we also studied the dispersion of the magnetic response by taking Q-scans at constant energy transfer along [110] and [001]. Data are shown in figure 1.

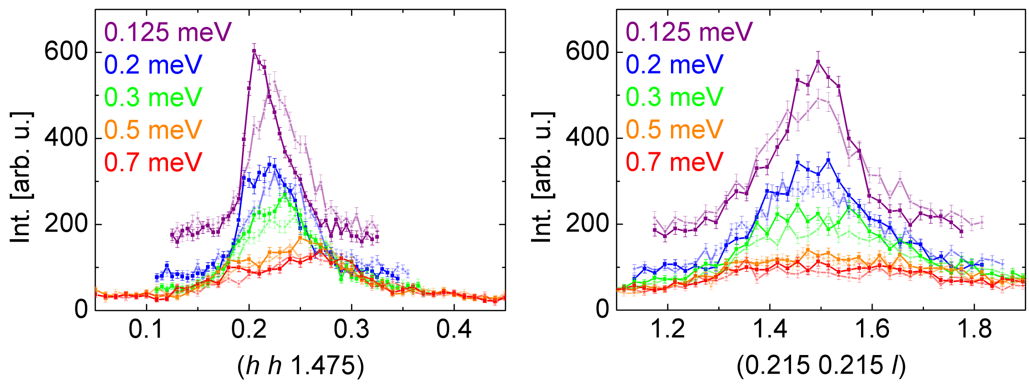

Figure 1: A-type $CeCu_2Si_2$: Dispersion in [110] (left) and [001] (right) direction. Opaque print belongs to data taken at 400 mK, transparent print to data at 1 K.

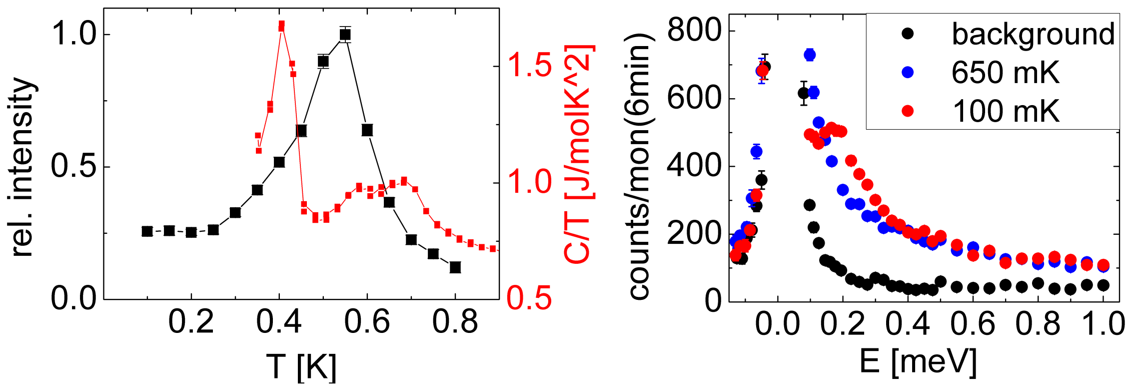

Figure 2: A/S-type $CeCu_2Si_2$: *(Left)* Temperature dependence of the magnetic Bragg peak, plotted with the heat capacity C/T. *(Right)* Spectra taken with $k_f = 1.07$ Å^{-1}. Note that the elastic peak intensity is approximately the same at 650 mK and 100 mK. The background was measured at the arbitrary Q position (0.1 0.1 1.6).

Also for the A/S-type sample, we have measured the temperature dependence of the magnetic Bragg peak (see left part of figure 2). Here, magnetic intensity is strongly suppressed by the appearence of superconductivity: At 100 mK, only one fourth of the maximum intensity, measured at 550 mK, remains. The leftover magnetic intensity—just as the parasitic superconductivity in A-type $CeCu_2Si_2$—might be explained by inhomogeneities in the sample, which lead to locally different ground states. We note that the volume fraction which stays magnetically ordered is probably smaller than 25 %, since the ordered moment has most likely not yet reached its saturation value at 550 mK.

Spectra taken at Q_{AFM} =(0.215 0.215 1.475) are shown in the right part of figure 2. With $k_f = 1.15$ Å^{-1}, a superconducting gap could not be clearly observed so we changed to $k_f = 1.07$ Å^{-1}. In clear contrast to the quasi-elastic response of the magentic phase, we observe a minimum between the elastic and inelastic signal at $T = 100$ mK. However, the drop is less sharp than in purely superconducting samples [2]. This might hint to a finite density of states in the gap.

[1] O. Stockert *et al.*, J. Phys.: Conf. Ser. 51 (2006), 211

[2] O. Stockert *et al.*, Nature Physics 7 (2011), 119