Experimental report

16/09/2018

Proposal: **4-01-1583**

Council: 4/2018

Title: Probing g-factor anisotropy in CeB6 by neutron scattering

Research area: Physics

This proposal is a new proposal

Main proposer: **Pavlo PORTNICHENKO**

Experimental team: Pavlo PORTNICHENKO

Local contacts: Alexandre IVANOV

Samples: CeB6

Instrument	Requested days	Allocated days	From	To
THALES	8	6	19/06/2018	25/06/2018

Abstract:

CeB6 is a heavy-fermion metal with a simple cubic crystal structure, characterized by the rich magnetic-field-temperature phase diagram. An external magnetic field B enhances TQ and rapidly suppresses TN. The AFQ state in CeB6 has been extensively studied as it represents an example of a magnetically hidden order, associated with the ordering of magnetic quadrupolar moments. Very recently, ESR measurements revealed a significant anisotropy of the g-factor as a function of the applied field direction. Our neutron results show significant difference of the resonance energy upon change of the field direction. Qualitatively similar behavior can be reproduced using the theory, and corresponding calculations were done by A. Akbari. Branches have a very clear anisotropy with respect to the field direction. We already managed to observe the onset of the second branch for fields parallel to [110] above ~12T. In accordance with the calculations, we expect to find a similar second branch with a magnetic field applied along [111], but at lower field values, therefore we will be able to follow its field dependence and to check how good is consistency with theory.

Proposer: P. Portnichenko
Experimental team: P. Portnichenko (TU Dresden).

Introduction

CeB_6 is a heavy-fermion metal characterized by the rich magnetic-field – temperature phase diagram. In zero field, it exhibits a high-temperature paramagnetic phase I; an AFQ phase II at intermediate temperatures between T_N=2.3 K and T_Q=3.2 K [1]; and an AFM ground-state phase III below T_N. The AFQ state in CeB_6 has been extensively studied as it represents an example of a magnetically hidden order [1–3]. Sharp resonant mode was initially revealed below T_N at the propagation wave vector of the AFQ phase [4], and a strong FM mode in the magnetic excitation spectrum of CeB_6 at the zone center Γ was discovered later [5]. We have measured magnetic field dependence of the FM resonance at different instruments with the field applied parallel to [1$\bar{1}$0] and [001]. Our neutron results show significant difference of the resonance energy upon change of the field direction. Qualitatively similar behavior can be reproduced using the theory discussed in Ref. 6, and corresponding calculations done by *A. Akbari* are shown in Fig. 2(b). For the field direction applied alon [111], above 10 T we expected to measure strongly enhanced Mode II. As we already know, the signal from the second mode is very weak, and the required fields above 10 T are achievable only with the 15 T magnet. Therefore we carried out proposed experiment at Thales.

Experimental configuration

Measurements were performed on a single-crystalline sample of CeB_6 with a mass of 4 grams, prepared from 99.6 % isotopically enriched ^{11}B to minimize neutron absorption. The sample was mounted in the cryomagnet with its crystallographic [111] axis aligned vertically. The wave vector of the scattered neutrons $k_f = 1.3\,\text{Å}^{-1}$ was fixed and the measurements were performed with a Be-filter.

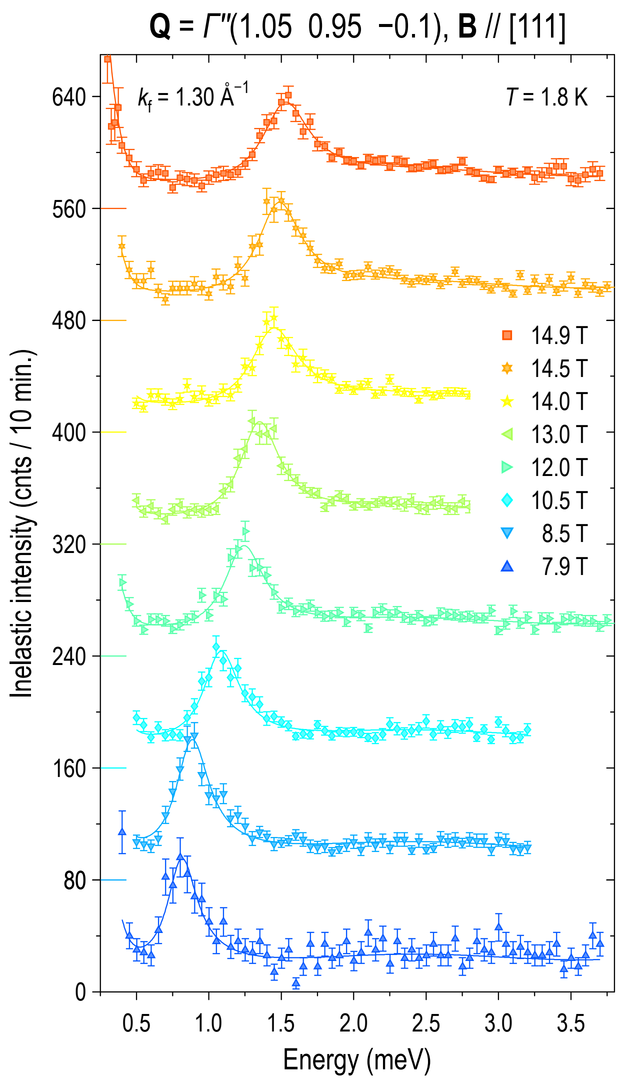

Fig. 1: INS spectra measured near the zone center at a slightly incommensurate wave vector. The spectra are shifted vertically for clarity with horizontal lines indicating the background baseline for each spectrum. Solid lines represent Lorentzian fits.

Results

As the first step we tried to repeat the 7.9 T scan, in order to check the resonance energy, obtained from our previous experiments at PANDA. Obtained value was slightly different from the one measured at PANDA. As will be discussed later observed inconsistency could be due to the wrong magnetic field calibration, and this question has to be verified carefully later.

We continued to measure magnetic field dependence of the observed resonance. With every field step towards higher values, we observed that the peak energy followed previously observed linear dependence. Corresponding energy scans are shown in fig. 1. Another question, that we tried to answer during this experiment was the identification of the second branch, which we have already revealed for fields parallel to [110] above 12 T, as well as for the magnetic field along [001], where the second resonance can be clearly resolved already above 4 T. At first glance, extremely weak broad peak around ∼ 2.3 meV may look like the sought for magnetic signal. However, as can be seen it exhibits no field dependence. Moreover, it can be perfectly described with the scattering which originates from nonmagnetic scattering on free He nuclei [9]. The He gas is used for heat exchange between the sample and the cryostat. Unfortunately, we were not able to observe the second resonance up to the highest available field. In addition, we significantly expanded the energy range, but we failed in our attempts to identify the second resonance.

The data in fig. 2(a) illustrate the behavior of the zone-center excitation within the phase II. Its energy continuously increases with the applied field. Comparing with theoretical calculations, shown in fig. 2(b), we find a certain discrepancy, as it was predicted that the previously observed excitation that followed the linear dependence should deviate towards lower energies at high fields. Besides, we could not observe strong enhancement of the second resonance, predicted above 10 T. But the main issue that I would like to discuss is the observed discrepancy between the results obtained using the PANDA and Thales spectrometers, and shown in fig. 2(a).

Discrepancy between different instruments

For the purpose of our research team we are extensively using magnets at various facilities. In order to be able to adjust the model parameter of the interaction Hamiltonian we need to measure the momentum dependence of the g-factor along different field directions. TAS instruments are effective in measurements of the parametric studies, where the magnetic scattering intensity has to be measured as a function of external parameters for given positions, exactly what we did in our last experiment. Therefore, it becomes clear that for the purpose of our research it is very important to have a precise calibration of the instrument, as well as sample environment.

In our last experiments, conducted at PANDA and Thales spectrometers we have measured the energy-gap size as a function of magnetic field using two different magnets. Results, shown in fig. 2(a) clearly demonstrates that the results obtained using different instrument can be well fitted with the linear law, with two different slope values. This may suggest that the actual value of the magnetic field is different from the one than is expected. Certainly such a discrepancy can also arise from the incorrect spectrometer alignments, and as a consequence energy transfer value would be also wrong. But in my opinion this is unlikely. We did a lot of experiments where we had to plot the data from different experiments and instruments on a same plot, and we did not observe mentioned above discrepancy. We find a much better correspondence between the data obtained from other magnets and other experiments. Besides, similar type 15 T magnet was used at FLEXX. Results measured with 15 T magnets at FLEXX and Thales have a perfect agrement, however, as already stated require a linear fit with a different slope, as compared to other magnets.

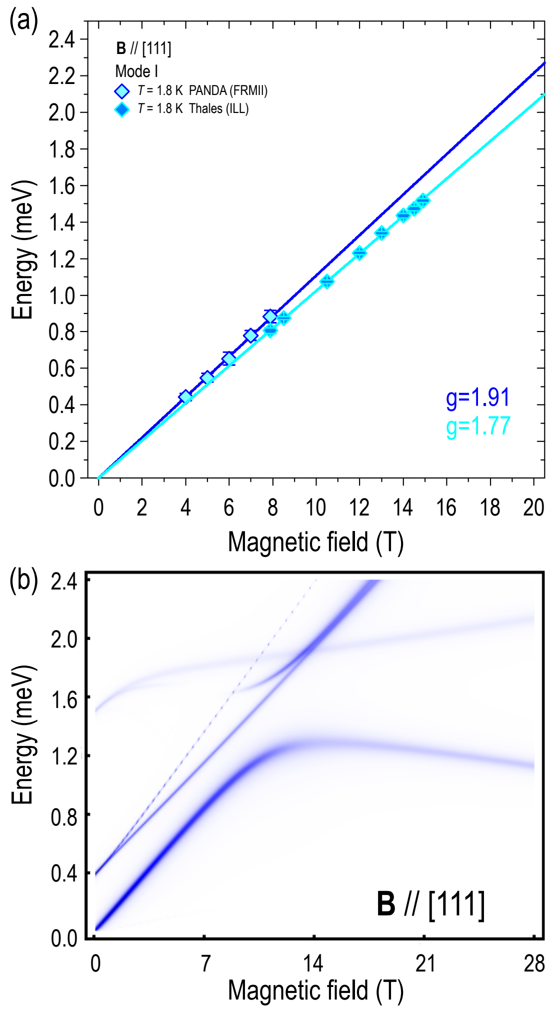

Fig. 2: (a) Summary of the magnetic field dependence of zone-center excitation, for the magnetic field applied parallel to [111]. (b) Multipolar excitation branches (see Ref. 6) at the Γ point as a function of magnetic field, for the same field direction.

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