Experimental Report

25/02/2014

Proposal: **4-01-1296** **Council:** 10/2012

Title: Effect of a high magnetic field onthe resonance mode in the Kondo insulator Yb[11B]12

This proposal is continuation of: 4-03-1649

Researh Area: Physics

Main proposer: **MIGNOT Jean-Michel**

Experimental Team: MIGNOT Jean-Michel
ALEKSEEV Pavel A
NEMKOVSKIY Kirill

Local Contact: IVANOV Alexandre

Samples: Yb[11B]12

Instrument	Req. Days	All. Days	From	To
IN8	7	5	20/03/2013	25/03/2013

Abstract:

Neutron studies of the archetype Kondo-insulator compound YbB12 have revealed several intriguing features in its magnetic excitation spectrum. Below 10 K, the magnetic response exhibits a spin gap and several low-lying excitations, one of which, at E = 15 meV, bears interesting similarities with the "resonance mode" (RM) intensively studied in HTC superconductors and other materials. In previous experiments on IN22 and IN8, we have investigated the effect of an applied magnetic field and observed a decrease in the intensity of the RM peak at 10 T, together with a more pronounced localization of the mode in Q space near the AF L-point, q = (1/2, 1/2, 1/2). However, the run on IN8 was hampered by a number of sample-environment problems, resulting in substantial loss of beam-time, and serious unreliability in background corrections. We therefore apply for continuation beam time in order to confirm, complement, and precise the experimental data. Specifically we need to ascertain the effects of the field on the intensity, energy width, and Q dependence of the RM in YbB12.

Report 4-01-1296

Effect of a high magnetic field on the resonance mode in the Kondo insulator $Yb^{11}B_{12}$

The magnetic excitation spectrum of YbB_{12} at low temperature exhibits a spin gap, with an exciton-like peak occurring within this spin gap. This intriguing feature has been consistently observed in a number of inelastic neutron scattering experiments [1-5], and is now considered to be a distinctive feature of this material in its Kondo-insulator state. The peak is located at about 14 meV, and bears strong similarity to the so-called “resonance modes” (RM), which have been extensively studied in a variety of superconducting (HTC cuprates, Fe-based superconductors, heavy-fermion superconductor UPd_2Al_3) or nonsuperconducting (CeB_6) materials. It disappears with increasing temperature, together with, or even prior to, the closing of the spin- and charge gaps. The origin of the RM in those various systems is an important question for understanding the formation of their many-body ground states. In the itinerant approach, it has been ascribed to residual AFM correlations between renormalized quasiparticles, which can stabilize a spin-exciton mode when low-energy electron-hole excitations become suppressed by the gap opening. In this approach, some dependence on an applied magnetic field could be anticipated.

The aim of the present measurements was to confirm, complement, and precise the experimental data from the previous run (experimental report 4-03-1649) by focusing on the main parameters (energy, intensity, width, position in $\boldsymbol{Q}$ space) of the RM. The experiment was carried out on IN8 using the same sample, consisting of two co-aligned single crystals, as previously, with a PG(002) analyzer set to the fixed k_f of 2.662 $Å^{-1}$. Preliminary scans using the PG(002) monochromator showed that the increase in the intensity of the signal, as compared to the Si (111) monochromator, was not substantial, and Si was thus preferred in order to remove the contamination at 18 meV energy transfer (originating from $2k_i = 3\ k_f$ elastic scattering), which was sizable in the case of PG. In this configuration, conditions were appropriate for the foreseen measurements, in spite of a significant sloping background scattering from the magnet in the energy transfer range of interest (~ 14 meV) and up.

Spectra were recorded as a function of the magnetic field up to H = 10–12 T in a limited temperature range, 1.5 K–50 K (the upper limit corresponding to the full suppression of the peak). We set out to trace the change in the integrated intensity of the RM with increasing field to see, in particular, how it relates to the energy width and the temperature evolution for particular $\boldsymbol{Q}$ vectors.

The performance of IN8 and of the superconducting magnet during the time scheduled for the experiment was excellent and allowed us to confirm most of the observations done in the previous run with improved experimental accuracy due to a better reproducibility of the background.

The main results can be summarized as follows:

The magnetic field, up to 10 T, has no significant effect on the temperature dependence of the energy position and integrated intensity of the resonance mode at 14 meV but, as already suggested from the previous round of measurements, it enhances the localization of the excitation in $\boldsymbol{Q}$ space, especially for the (1.2, 1.2, q_l) direction along which the mode intensity remained almost constant in zero field [6].

The intensity of the RM is totally suppressed just above 30 K, a temperature at which the suppression of spin gap through the appearance of a quasielastic magnetic signal (spin fluctuations with a characteristic energy of ~ 10 meV) is incipient. The latter signal becomes well distinct from the background, within experimental statistics, only between 30 K and 40 K.

An interesting observation, besides the studied effects of temperature and magnetic field on the RM, was made from the constant-E scans measured at different wavevectors. One set of measurements performed at $T = 1.5$ K for $\boldsymbol{Q} = (q, q, 0.5)$, with q in the range 1.9 –1.1, is shown in Fig. 1. A pronounced energy dispersion, together with a decrease in the peak intensity of the RM, is seen to occur as one departs from the antiferromagnetic point (1.5, 1.5, 0.5). Here the direction of the scans is perpendicular to [0.5 0.5 q], a direction along which the intensity and energy of the RM was previously found to have little variation in zero field.

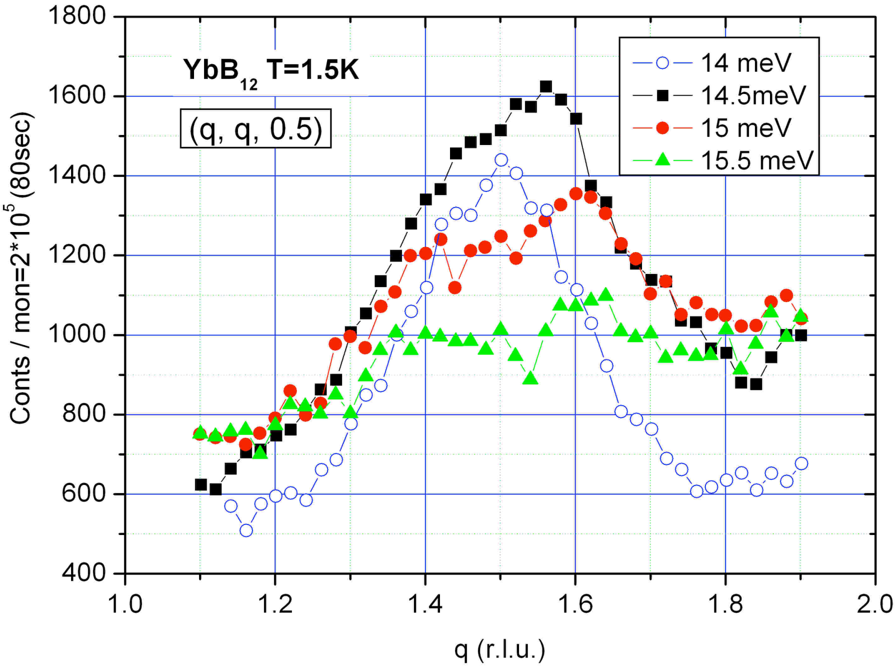

Fig. 1 Experimental constant-energy scans measured on a YbB_{12} single crystal at 1.5 K for $\boldsymbol{Q}$ = (q, q, 0.5) across the L-point in the Brillouin zone.

1. E.V. Nefeodova, P.A. Alekseev, J.-M. Mignot *et al.*, Phys. Rev. B **60** (1999) 13507.
2. A. Bouvet, T. Kasuya, M. Bonnet *et al.*, J. Phys.: Condens. Matter **10** (1998) 5667.
3. F. Iga, A. Bouvet, L.-P. Regnault *et al.*, J. Phys. Chem. Solids **60** (1999) 1193.
4. J.-M. Mignot, P.A. Alekseev, K.S. Nemkovski *et al.*, Phys. Rev. Lett. **94** (2005) 247204.
5. K.S. Nemkovski, J.-M. Mignot, P.A. Alekseev, A.S. Ivanov *et al.*, Phys. Rev. Lett. **99**, 137204(2007).
6. K.S. Nemkovski, P.A. Alekseev, J.-M. Mignot, and A.S. Ivanov, Physics Procedia **42**, 18 (2013).