Experimental report

24/01/2024

Proposal: **CRG-2809** **Council:** 10/2020

Title: Investigation of structural and magnetic excitation spectra in the frustrated antiferromagnet TbB4

Research area:

This proposal is a new proposal

Main proposer: **Fabienne DUC**

Experimental team: Frederic BOURDAROT

Local contacts: Frederic BOURDAROT

Samples: TbB4

Instrument	Requested days	Allocated days	From	To
IN22	8	15	01/03/2021	09/03/2021
			05/06/2023	07/06/2023

Abstract:

Experimental report for CRG-1374: Investigation of structural and magnetic excitation spectra in the frustrated antiferromagnet TbB_4

IN22, 1-9 March 2021

Experimental team: Frédéric Bourdarot and Fabienne Duc

Scientific background:

Over the last decade, the rare-earth tetraborides (RB_4), which has a tetragonal structure of space group P4/mbm, have garnered attention due to their complex phase diagrams, displaying a variety of magnetic phases resulting from the geometrical frustrated lattice of the R^{3+} ions. The latter form a network of squares and equilateral triangles in the ab- plane, leading to orthogonal dimers which are topologically equivalent to the frustrated Shastry-Sutherland lattice (SSL). Depending on the R atoms, various mechanisms coupling the lattice, orbital and charge degrees of freedom are proposed to explain their unusual magnetic properties (RKKY interaction, crystal field effect or quadrupolar order). Plateaus with fractional values of the saturation magnetization are a common feature to many of RB_4 family members but are often observed in quite moderate magnetic fields applied along the easy magnetic axis.

In TbB_4 (Tb^{3+}, g_J = 3/2, J = 6), two successive antiferromagnetic (AF) transitions have been reported in zero field at $T_{N1} \approx 44$ K and $T_{N2} \approx 24$ K. The magnetic structures of both the low and intermediate temperature phases, established by powder neutron diffraction, lead to a quasi-planar non-collinear AF structure described by the propagation vector **k** = (000). In contrast to other RB_4, TbB_4 shows a strong magnetic anisotropy, exhibiting a large magnetization jump at H_C = 15.9 T for **H** // [100] and at 12 T for **H** // [110] and a devil-staircase-like magnetization process, stabilizing a series of plateau states upon the application of high magnetic fields ($16 \le \mu_0 H \le 28$ T) along the c-axis, i.e. perpendicular to its magnetic easy plane.

Aim of the proposal:

To probe the magnetic structure associated with the various magnetization plateau phases in TbB_4, we already performed single crystal neutron diffraction experiments in high pulsed magnetic fields up to 35 T on the CRG spectrometer IN22 operated in double-axis mode. At low temperatures, the field dependence of the diffracted intensity of the antiferromagnetic reflection (100) shows step-like variations which reveal subtle changes in the magnetic structures of the different phases. In spite of these new results, it is difficult to go further on the determination of the structure of the plateau states since only the field dependence of the intensity of three reflections could be followed during those experiments.

Experimental setup:

IN22 was set up in W-configuration. We used a double focusing PG monochromator, a PG analyzer and a PG filter in the neutron scattered beam. The data have been collected with a fixed k_f = 2.662 $Å^{-1}$. The single crystal (with a mass of about 153 mg) was mounted with the [100]– [001] directions in the scattering plane. An orange cryostat was used to cool the sample.

Results:

Inelastic neutron scattering measurements on IN22 were mainly performed at T = 1.7 K. We found 5 different excitations (Fig.1): three not dispersive around 6, 10.5 and 14.5 meV respectively, and two dispersive magnetic excitations with gaps of 3.3 and 4.4 meV respectively at the AF point and the Γ point. The gaps of 3.3 and 4.4 meV at Q = (1,0,1) was confirmed with a high-resolution configuration with $k_f = 1.54$ Å^{-1} (Fig.2). These measurements deserved further investigations.

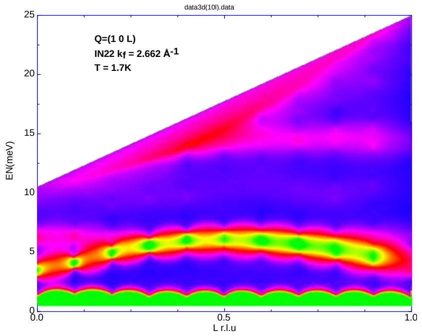

Figure 1: Magnetic dispersion along [1 0 L]

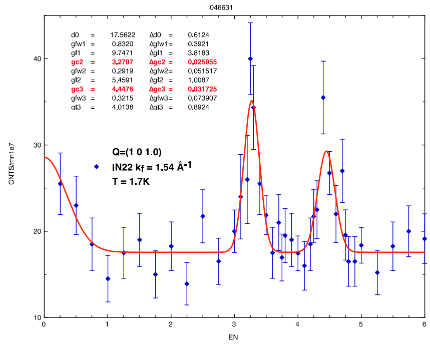

Figure 2: Magnetic excitation measured at Q = (1 0 1) in high resolution configuration.