Experimental report

12/02/2018

Proposal: **4-01-1502**

Council: 4/2016

Title: Nature of the Spin Dynamics and 1/3 Magnetization Plateau in frustrated spin-2 chain system Ca3Co2O6

Research area: Physics

This proposal is a continuation of 4-01-1346

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Samples: Ca3Co2O6

Instrument	Requested days	Allocated days	From	To
IN8	5	0		
IN20	0	7	06/12/2016	13/12/2016

Abstract:

Ising-like spin-chain compound Ca3Co2O6 has recently attracted a lot of attention because of its interesting magnetic properties, such as field-induced magnetization steps, time-dependent magnetic order, and nanoscale magnetic fluctuations. In our recent inelastic neutron scattering study, a gapped band of magnetic excitation, dispersing between ~27 and 30.5 meV (along the chain direction), with a bandwidth of ~3.5 meV, was observed. The gap was minimum at zone center and maximum at zone boundary. The observed large ratio of the gap to bandwidth (~7.7) and no dispersion perpendicular to the chain direction confirmed that this material is highly 1D. In the proposed work, we plan to investigate the magnetic excitation under an applied magnetic (along the chain axis) to understand the origin of 1/3 magnetization plateau and spin dynamics in Ca3Co2O6.

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Introduction. Ising-like spin-chain compound $Ca_3Co_2O_6$ has interesting magnetic properties: field-induced magnetization steps, time-dependent magnetic order, and nanoscale magnetic fluctuations. It crystallizes in the space group $R3c$ and the crystal structure contains spin-chains, made up of alternating face-sharing CoO_6 octahedra and CoO_6 trigonal prisms. Ferromagnetic intra-chain and antiferromagnetic interchain interactions combined with a triangular lattice arrangement of the spin chains give rise to a geometrical frustration.

Previous results. We performed the experiment to investigate magnetic excitations in single crystals of $Ca_3Co_2O_6$ by means of inelastic neutron scattering (INS). At 1.5 K, a gapped band of magnetic excitation, dispersing between $\sim$ 27 and 30.5 meV, with a bandwidth of $\sim$ 3.5 meV, was observed. The gap was minimum at zone center and maximum at zone boundary. The observed large ratio of the gap to bandwidth ($\sim$ 7.7) and no dispersion perpendicular to the chain direction confirmed that this material is highly 1D.
Further study of the magnetic excitations of the sample has been done under an applied magnetic field of 13.5 T. The spin wave gap is found to increase (by 1.3 meV) corresponding to Zeeman shift. Surprisingly, the magnetic signal shifts towards higher energies upon warming (above $T_N = 25$ K). With further increasing of temperature signal become significantly contaminated, presumably due to the cryomagnet. We expect that with changing the multi-analyzer to a normal one will allow us to continue temperature study up to at least 100K.

Aim of experiment. In the previous experiment we observed that above T_N, the energy mode of the paramagnons in the magnetic field go up with heating. In order to confirm or refute this unexpected behavior, we proposed to map out the temperature dependance of the magnetic mode in $Ca_3Co_2O_6$ in the field applied along the crystallographic c-axis (same configuration). This time we asked a single channel detector to increase the resolution.

Experimental details.

Results and discussion. In fig. 1 one can see the field dependence of the energy spectrum done at fixed q-position. There are two peaks, which are partially intersected. It is seen, that they have different field dependence: the one which appears at lower energy and has lower intensity (left one) doesn't respond on the field staying at the same energy; the other one, however, moves up in energy with increasing the field, which indicates its magnetic nature. The shift corresponds to the Zeeman shift, and was already observed in our previous studies. The non-magnetic peak we associate with the aluminum powder line.

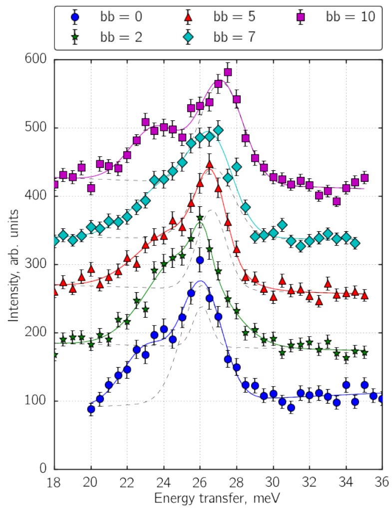

Figure 1: Field dependence of the energy spectrum at fixed q-position. The shift in intensity is added to each of the datasets to separate the datapoints. In legend 'bb' denotes field.

The temperature dependence of the energy spectrum under 10T external magnetic field is shown in fig. 3. The high temperature (@250K) was subtracted from the data. Due to the small temperature dependence of the position and intensity of non-magnetic peak, the small background slope appears at low temperatures after the subtraction. This effect was taking into account during the fit. From the data, one can see that the paramagnons follow the conventional scenario: going down and becoming smeared in energy with increasing the temperature. This effect is explained by the magnon-phonon scattering.

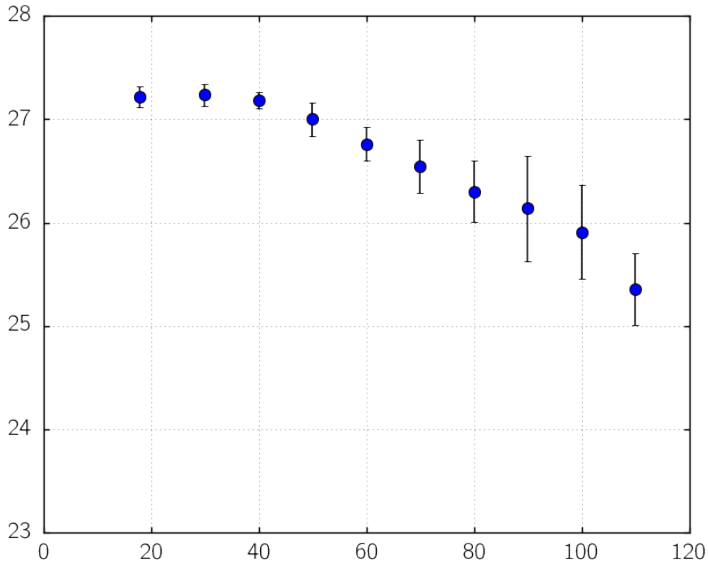

Figure 3: Temperature dependence of the peak position extracted from the fit of the data shown in fig. 3. The background was fitted with linear function.

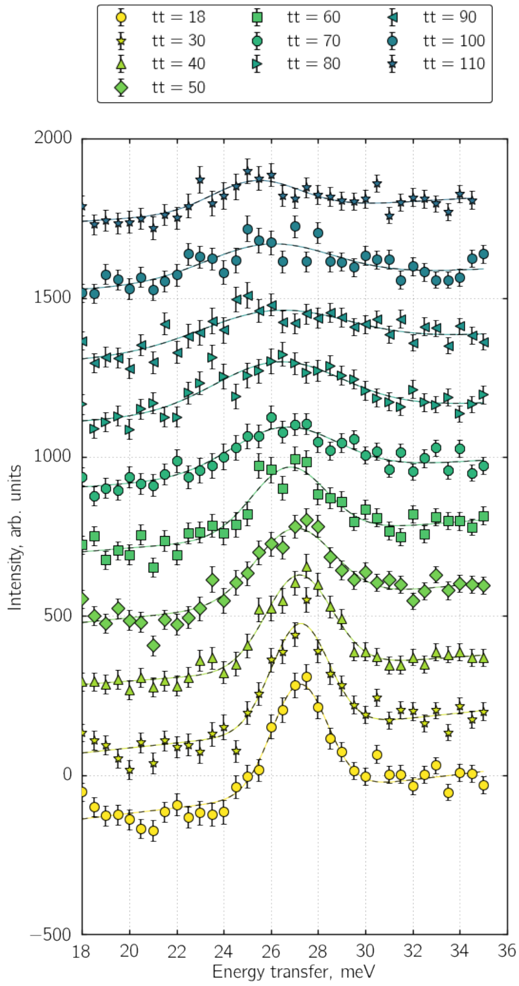

Figure 2: Temperature dependence of the energy spectrum done at fixed q-position. The magnetic field of 10T is applied along c-axis of the crystal (along FM chains). The background was measured at 250K and subtracted from the data. The shift in intensity is added to each of the datasets to separate the datapoints. In legend 'tt' denotes temperature.