Experimental report

18/09/2019

Proposal: 4-05-734 **Council:** 10/2018

Title: Non-monotonic behavior of the spingap in ZnCr2Se4 in magnetic field

Research area: Physics

This proposal is a new proposal

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Samples: ZnCr2Se4

Instrument	Requested days	Allocated days	From	To
IN12	6	0		
THALES	6	6	22/07/2019	29/07/2019

Abstract:

The three-dimensional magnetic material ZnCr2Se4 has a cubic spinel (Fd¯3m) structure, in which magnetic Cr3+ ions (S = 3/2) are arranged in the pyrochlore sublattice consisting of geometrically frustrated corner-sharing tetrahedra. At low temperatures and low magnetic field, it displays a helical structure propagating along the (100) direction. With an increasing magnetic field, it gives way to a fully polarised regime through the yet unidentified phase at intermediate fields. Our recent experiment at LET revealed that the field dependence of the pseudo-Goldstone gap at the positions of magnetic Bragg peaks, suppressed by the domain selection, is not monotonic and the gap closes at 6 T, which corresponds to the recently proposed quantum critical point (QCP). The goal of the proposed experiment is to investigate the field dependence of the pseudo-Goldstone mode in the vicinity of the quantum criticality.

The experimental report for the beamtime 4-05-734.

The magnetic ground stat of $ZnCr_2Se_4$ is a proper helix with the propagation vector $(00q_h)$. Due to the cubic degeneracy, the three equivalent domains are possible. The field-cooling, however, allows to suppress the domains with the propagation vectors perpendicular to the field. It was shown previously, that the low-energy magnetic spectrum of the $ZnCr_2Se_4$ consists of the Goldstone modes, magnetic excitations stemmed from the selected pair of Bragg-peaks, and the pseudo-Goldstone modes, which are the gapped excitations with pronounced minimum in their dispersion (the soft mode) at the position of the suppressed Bragg-peaks. Both types of modes have comparable spectral weight in the inelastic neutron scattering signal.

In the earlier study we mapped out the energy-momentum space for 0 T, 3 T, 6 T, and 8 T fields using TOF spectrometer. The field was applied along 00L direction. The data display complex behavior of the magnon dispersion. Thus, upon application of the 3 T field, the pseudo-Goldstone modes splits, forming two local minima, which shift symmetrically one form the other along the field direction. The 6 T field merge the minima together again, and narrow the gap, so it is almost unresolvable. Further increasing the field up to 8 T, the gap become significantly larger compared even with 0 T case. In both 6 T and 8 T data the spectrum is symmetric in H0L plane, preventing the discrimination between true- and pseudo-Goldstone modes.

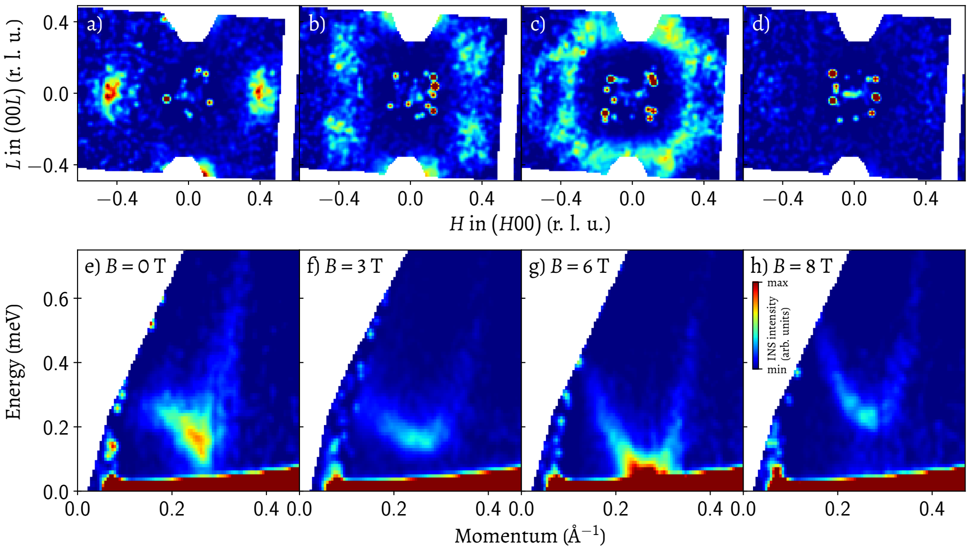

Figure 1: The neutron TOF spectrum of $ZnCr_2Se_4$ measured in magnetic field applied along 00L direction. The panels a, b, c, and d show the constant energy cuts of the H0L plane at 0.17 meV for 0, 3, 6, and 8 T respectively. Correspondingly, the panels e, f, g, and h shows the energy-momentum cuts taken along the direction which connect the Γ-point with the local minimum of the dispersion.

Foreseeing the gap closing around 6 T near the suppressed Bragg position, we proposed to map out the field dependence of the low-energy magnetic modes along H00 direction. Our obvious requirements were the cold neutron instrument with decent intensity and the availability of the magnet with maximum field up to 8 T. We were offered the beam-time on ThALES with the 10T vertical magnet.

The crystal was oriented so to apply the field along 00L direction, similarly to the previous TOF experiment, with the HK0 scattering plane. Due to the heavy magnet, the goniometers were demounted completely, so even small tilts of the scattering plane were not possible. At the beginning of the experiment, the data were collected in the double focusing mode without collimation, although, later on we decided to insert the collimation, staying with only the horizontal focusing, aiming to increase the spatial and therefore also the energy resolution.

The most indicative feature in the accessible part of the spectrum is the dispersion along the H00 direction. From the previous measurements we know that in $B = 0T$ and $B \leq 6T$ the magnetic dispersion has a local minimum at (q_h00). Somewhere between 0 and 3 T and up to 6 T the minimum splits and shifts deep into H0L plane, so in the H00 cut we would expect to see how the minima join each other.

In fig.2 we summarize the results of the experiment. Below 4 T the excited mode gradually moves up in energy, accompanied with significant loss of intensity. After 4 T, the mode reaches the maximum in energy, and starts to decrease. We associate this with the doubling and subsequent shift apart of the pseudo-Goldstone modes, that after 4 T, are getting closer again.

Approaching 6 T, the mode become sharper and gains the intensity, touching the zero-energy level at 6.25 T. Further amplification of the field immediately opens the gap, that from this time on grows linearly.

The experiment confirmed our expectation, and extended the picture of the field evolution of the low-energy spectrum.

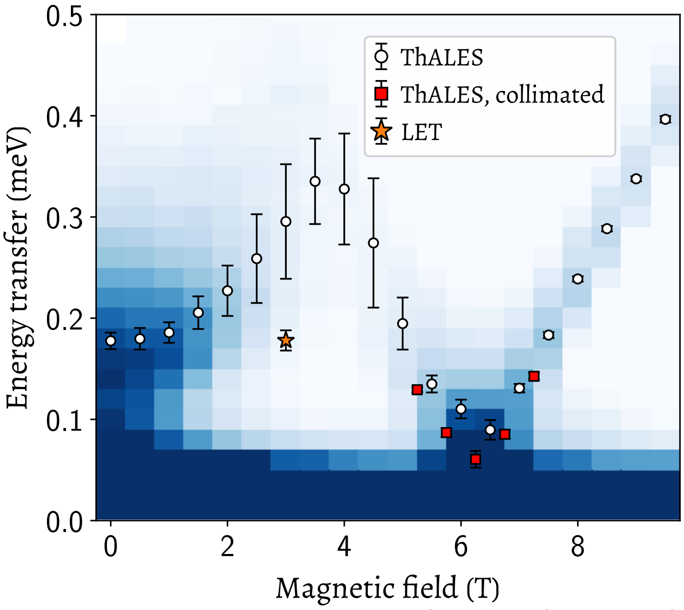

Figure 2: Inelastic neutron spectrum taken at (q_h00) measured as a function of magnetic field applied along 00L direction. The white circles denote the position of the gaussian fit of the raw data shown underneath with a color plot. The red triangles denote the gaussian fit of the data taken with improved collimation. The raw data are not shown. The yellow stars show the value of the gap at the local minimum of the dispersion, taken from the TOF data.