

Experimental report

06/02/2026

Proposal: CRG-3010

Council: 4/2023

Title: Investigation of the Polarization-Dependence of Field-Induced Roton Minima in the 2D van der Waals Honeycomb Antiferromagnet YbBr₃

Research area: Physics

This proposal is a new proposal

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Samples: YbBr₃

Instrument	Requested days	Allocated days	From	To
IN12	7	7	14/09/2023	25/09/2023

Abstract:

Enhanced quantum fluctuations are believed to give rise to novel magnetic ground states and excitations. The presence of strong quantum fluctuations causes excitations to deviate from what is expected from semi-classical theories, where the effect of the fluctuations is taken into account perturbatively. In the van der Waals antiferromagnet YbBr₃, strong quantum fluctuations are present due to the low coordination of the honeycomb planes of the material.

Previous unpolarized inelastic neutron scattering (INS) experiments with a magnetic field applied perpendicular to the honeycomb planes of YbBr₃ revealed 1) a broad continuum of excitations in the Brillouin zone boundary in zero-field, and 2) large damping and energy renormalization of the magnetic excitations in the field-canted phase. Matrix product states (MPS) and exact diagonalization (ED) treatments of the nearest-neighbor Heisenberg model on the 2D honeycomb lattice capture all the features of the observed dynamics at all fields.

Interestingly, in the field-canted phase, MPS predicts roton-like minima in the longitudinal and transversal components of $S(Q, E)$. This prediction is directly measurable with polarized INS.

Investigation of the Polarization-Dependence of Field-Induced Roton Minima in the 2D van der Waals Honeycomb Antiferromagnet YbBr₃

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The inelastic spectrum of YbBr₃ in a magnetic field was measured at the IN12 spectrometer using linear polarization analysis. Because of the cryomagnet at the sample position, the neutron spin polarization was manipulated by a Mezei-type spin flipper upstream in the guide before the monochromator. The polarization was maintained by the use of guide fields. The energy and polarization of the scattered beam was analyzed by the Heusler(111) analyzer of IN12. A representative flipping ratio for our experiment is $R = 20.06$ at 4 Tesla.

In this geometry, the spin excitations with a polarization along the magnetic field (z-direction) are contained only in the non-spin-flip (NSF) channel with the polarization along z. Conversely the excitations transversal to the applied field are contained in the spin-flip (SF) channel. This polarization analysis setup allowed us to separate the two different excitation branches (longitudinal and transverse) of YbBr₃ in an applied field.

A calculation of the spin excitation spectrum of YbBr₃ by the MPS method indicated that the dispersion of the magnetic excitations in a field of 4 Tesla possessed a non monotonic shape very similar to the roton-phonon dispersion in superfluid 4He. This dispersion is contained exclusively in the S_{zz} excitation channel, which coincides with the non-spin-flip channel of our IN12 experiment.

We determined the magnetic excitations in the SF and NSF channels along the $(1k0)$ direction in the reciprocal lattice at 5 T, and in the NSF channel at 4 T. The measured NSF spectra alongside a calculation by MPS is shown in Fig. 1(b, c, e, f). The data is in spectacular agreement with the MPS calculation, which itself is in stark contrast to the expected dispersion from linear spin-wave theory [shown as the red lines of Fig. 1], establishing that the interactions between the single magnons and the nearby continua are key in order to describe the measured spectra.

The data collected during this experiment has been published in *Phys. Rev. Lett.* **135**, 146701 (2025).

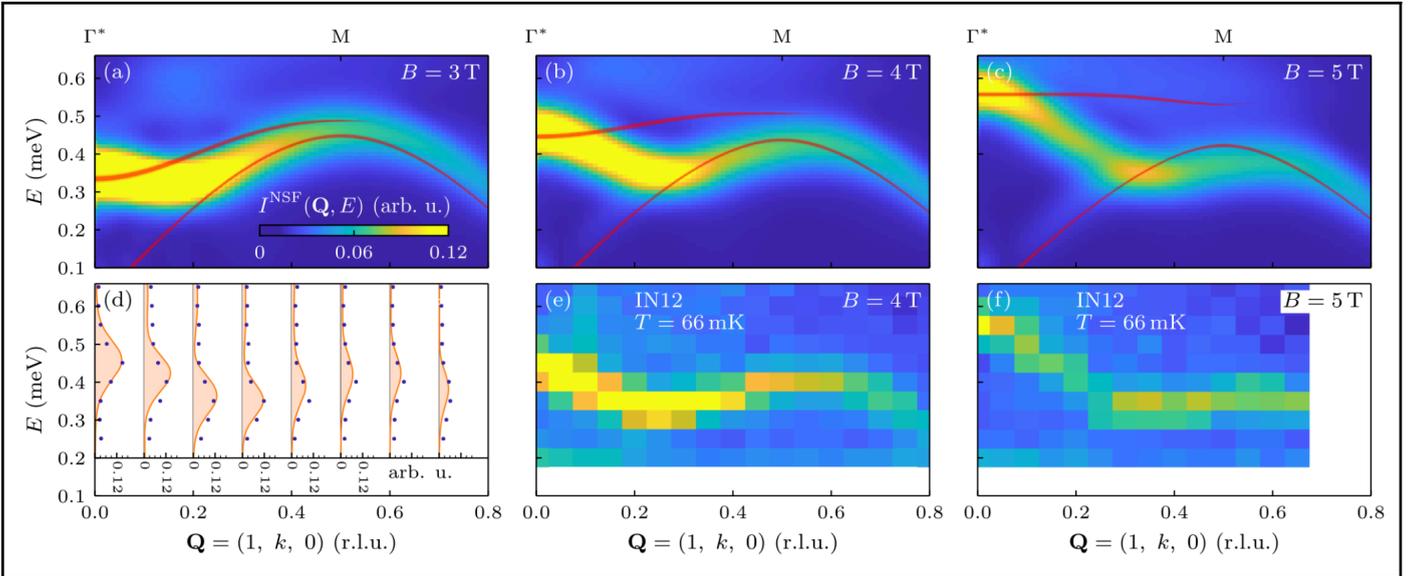


Fig. 1. Longitudinal spin excitations in YbBr3 at 4 Tesla. (a-c) MPS calculations of the S_{zz} spin excitation channel at 3 (a), 4 (b) and 5 (c) Tesla. The red line shows the prediction of linear spin-wave theory with a linewidth proportional to the intensity. The non-spin-flip spectra measured at IN12 at $T = 66$ mK are shown in panels (d, e) and (f) for a field of 4 and 5 Tesla respectively. A resolution-limited roton-like mode as well as weak continuum scattering above the background is clearly visible in our 4 T data in full agreement with the MPS simulation. Figure taken from *Phys. Rev. Lett.* **135**, 146701 (2025) with permission.