Experimental report

16/08/2026

Proposal: EASY-1515 **Council:** 4/2025

Title: Investigating the crystal-electric-field structure of triangular lattices Ba6Nd2Ti4O17, HoTa7O19 and PrTa7O19

Research area: Physics

This proposal is a new proposal

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Samples: PrTa7O19

Instrument	Requested days	Allocated days	From	To
PANTHER	8	8	16/09/2025	17/09/2025

Abstract:

Rare-earth (RE)-based frustrated lattices are prominent candidates for realizing quantum spin liquid (QSL) behaviour, owing to strong spin–orbit coupling and the localized nature of 4f electrons. Recently, the RETa7O19 family has emerged as a promising platform for QSL physics. Additionally, Ba6Nd2Ti4O17 (BNTO), a related layered triangular compound, has been identified as a potential QSL candidate, exhibiting persistent spin dynamics at millikelvin temperatures. For HoTa7O19 and PrTa7O19, magnetic susceptibility, specific heat, and muon spin relaxation measurements have been conducted. No magnetic ordering is detected down to 30 mK, indicating a magnetic disordered ground state. For BNTO, we have done a comprehensive study, and claimed it as a quantum spin liquid candidate. To further understand the underlying magnetic ground states of these compounds, especially their low-energy excitations and apparent energy scales, we propose detailed crystal electric field (CEF) measurements, which are essential to distinguish between low-energy spin dynamics of magnetic origin and relaxation processes driven by CEF excitations.

Investigating the crystal-electric-field structure of triangular lattice $PrTa_7O_{19}$

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1. Introduction

Quantum spin liquids (QSLs) are magnetically disordered ground states characterized by long-range quantum entanglement, with potential relevance to quantum computation and high-temperature superconductivity. Rare-earth frustrated magnets are promising QSL candidates because of their strong spin–orbit coupling and localized 4f electrons . Recently, the $RETa_7O_{19}$ (RE = rare earth) family has emerged as a promising platform for exploring QSL physics. Within this family, we have performed a detailed muon spin relaxation study of $PrTa_7O_{19}$. However, inelastic neutron scattering (INS) measurements are required to determine its crystal electric field (CEF) level scheme and thereby clarify the microscopic origin of its magnetic ground state.

2. Experiment

The INS spectra were collected by using the thermal neutron time-of-flight spectrometer PANTHER at the Institute Laue-Langevin (ILL), Grenoble, France. The powdered sample of 2.4 g was wrapped by Al foil and mounted inside a cylindrical Al can. The measurements were performed at 1.5 and 30 K with incident energies E_i =7.5, 8.75, 10, 76 and 171 meV. The collected data was reduced and analyzed using the software MANTID.

3. Results

The color-coded plot of INS intensity at 1.5 K as a function of energy-momentum transfers with E_i = 76 meV is shown in **Fig. 1(a)**. Two flat modes indicating CEF magnetic excitations are observed. The Q integrated data over Q =1-2.5 Å^{-1} is shown in **Fig. 1(b)**. The CEF signals are characterized by two Gaussian functions. The CEF energy levels yielded from the fitting are 21.9 meV and 31.1 meV.

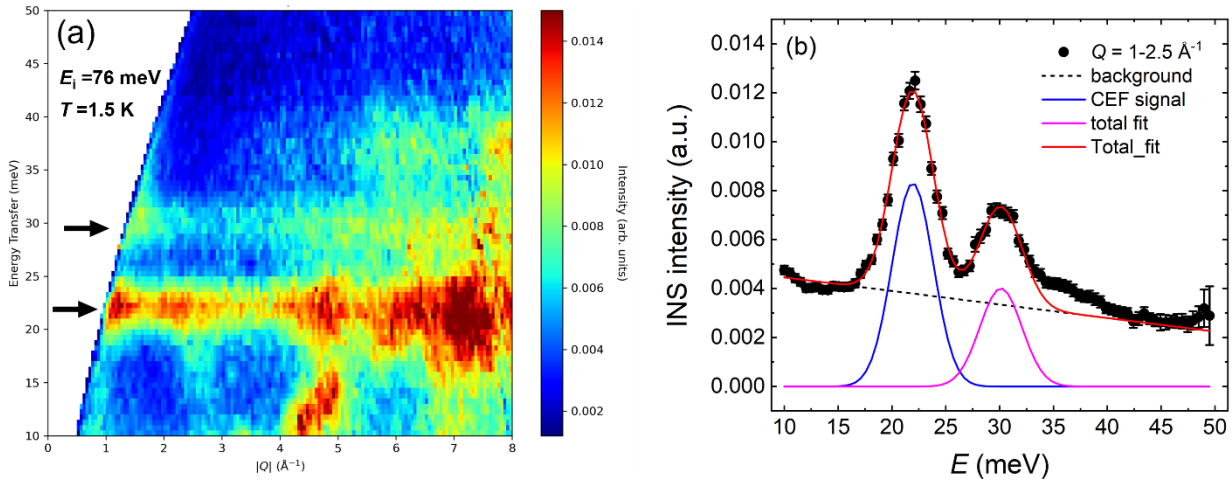


Fig. 1. (a) Color-coded plots of the INS intensity of PTO at 1.5 K as a function of energy transfer and momentum transfer with an incident energy E_i = 76 meV. The black arrows mark the CEF excitations. (b) INS intensity as a function of energy transfer obtained by integrating the data over Q =1-2.5 Å^{-1}. The fitting model (red solid line) includes the background (dashed line) and CEF signals (blue and pink solid lines). The broad feature around 35 meV originates from the Al sample can and is therefore excluded from the fitting.

Table 1 shows the CEF energy levels calculate by point-charge model using PycrystalField. The experimentally observed two CEF energy levels are possibly the first and second excited energy level. No more CEF energy levels are observed even with E_i = 171 meV.

Table 1. Calculated CEF energy levels using point-charge model.

Ground state	1st excited	2nd excited	3rd excited	4th excited	5th excited
doublet	singlet	singlet	doublet	singlet	doublet
0	22.7 meV	42.6 meV	96.1 meV	119.0 meV	121.1 meV

4. Conclusion

In conclusion, we investigated the CEF excitations of PTO by INS. Two CEF excitations were observed at 21.9 and 31.1 meV, which is transition from the ground state to the first and second excited CEF level, respectively. The Pr^{3+} ions in PTO have D_3 point-group symmetry, for which the CEF Hamiltonian contains six independent B_{lm} parameters. Consequently, the two observed CEF levels are insufficient to determine the CEF Hamiltonian. Nevertheless, the well-separated excited levels support an effective spin-1/2 physics at low temperatures.