Experimental report

18/08/2026

Proposal: 4-04-547 **Council:** 4/2025

Title: Directly observing anisotropy in the crystal electric field of CeBr3

Research area: Physics

This proposal is a new proposal

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Samples: CeBr3

Instrument	Requested days	Allocated days	From	To
IN20 He3 Spin Filter	6	6	27/08/2025	03/09/2025

Abstract:

Interacting magnetic moments with competing interactions or geometrical frustration has the potential to display exotic ground states revealing new physics in quantum matter [1]. In this field, rare earth trihalides have emerged as a rediscovered garden of interesting compounds with their localized magnetism. Among the most recent examples are the layered 2D honeycomb rare earth tribromides with plaquette fluctuations in the spin-½ honeycomb lattice YbBr3 and tunable band gap at the Dirac points in ErBr3 [2,3]. These compounds are in the 2D limit, and the magnetic anisotropy of these systems can be tuned by changing the rare-earth ion at every site in the honeycomb lattice, which allows the study of 2D magnetism in the XY, Ising or Heisenberg limit. Here we aim to study the Q-dependence of the crystal fields in CeBr3, with the goal of establishing the crystal field models, explaining the broadness of the levels, searching for possible coupling to e.g. phonons, and understanding how CeBr3 develops spin waves with extreme anisotropy over the entire magnetic bandwidth.

Polarisation dependence of the crystal-field excitations in $CeBr_3$

Experimental report

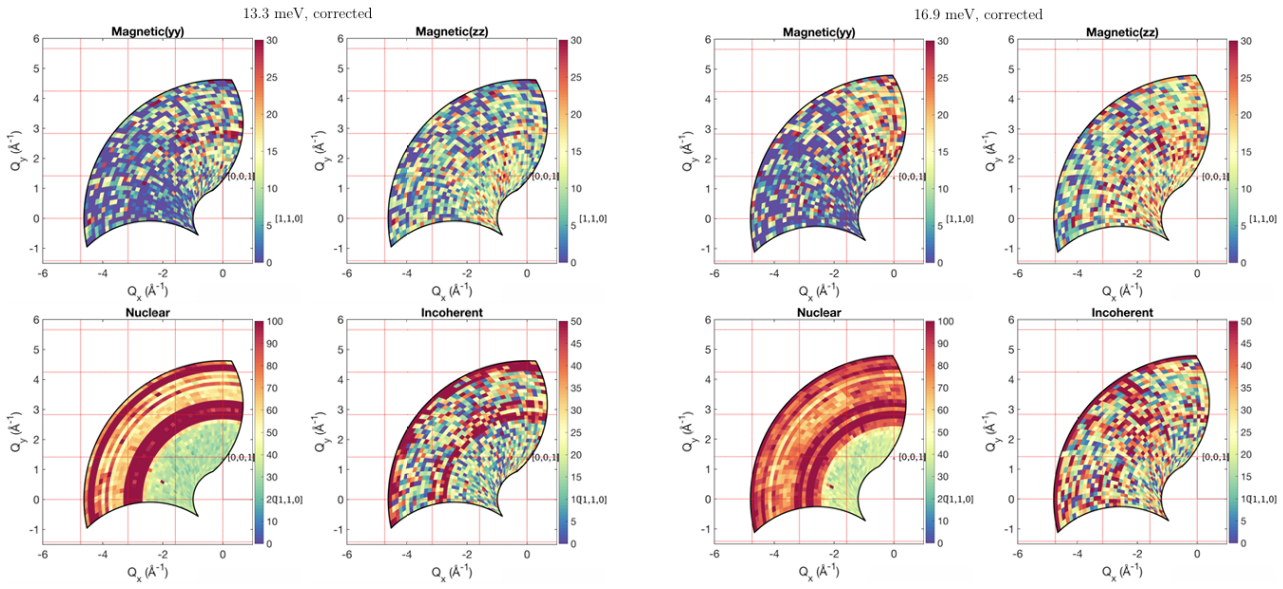
$CeBr_3$ ($P6_3/m$, Ce^{3+}, $4f^1$) places the Ce ion on a site of C_{3h} point symmetry, so the $J = 5/2$ multiplet splits into three Kramers doublets of pure m_J character: $|\pm 5/2\rangle$ (ground state), $|\pm 1/2\rangle$ and $|\pm 3/2\rangle$. Time-of-flight data (MERLIN) show two inelastic features near 13.3 and 16.9 meV of comparable intensity. Within a pure crystal-field (CEF) picture only one of the two excited doublets is dipole-allowed from the $|\pm 5/2\rangle$ ground state ($|\pm 5/2\rangle \rightarrow |\pm 3/2\rangle$, $|\Delta m_J| = 1$), the other being forbidden ($|\Delta m_J| = 2$). This experiment addresses this feature.

A single crystal of $CeBr_3$ was mounted with the $[(HHL)]$ plane horizontal and cooled to $T = 2$ K. Q-maps at 13.3 and 16.9 meV were collected in the spin-flip (SF) and non-spin-flip (NSF) channels. Both excitations are unambiguously magnetic (Fig. 1a and 1b). This is clear from the signal in the yy and zz channels. Thus, both peaks are CEF levels. The magnetic bandwidth is much lower than 1 meV and does not interfere with this analysis.

On more careful inspection, it is also clear that the yy channels at 13.3 and 16.9 meV both show a Q-dependence; most of the magnetic intensity is along [001], while along [110] there is no magnetic intensity. In contrast, the zz channels show a flat intensity at all Q. Thus, the Q-dependence of the two CEF levels is identical.

This is precisely what two independent CEF transitions would not produce: in C_{3h} the allowed $|\pm 5/2\rangle \rightarrow |\pm 3/2\rangle$ transition carries a purely in-plane (transverse) spectral weight, $M_{xx} = M_{yy} = 0.94\,\mu_B^2$ and $M_{zz} = 0$, whereas the $|\pm 5/2\rangle \rightarrow |\pm 1/2\rangle$ transition is dipole-forbidden ($|M| < 10^{-7}\,\mu_B^2$). Two independent CEF levels would therefore have to differ drastically in polarisation dependence – one of them being invisible altogether. Our calculations for $|\pm 5/2\rangle \rightarrow |\pm 3/2\rangle$ is shown in Figure 2, and match the experimental data excellently. The observation of two peaks with equal polarisation dependence rules out that assignment and establishes that both observed modes derive from a single CEF transition. Modeling including phonon mixing is currently ongoing.

In summary, PASTIS polarisation analysis on IN20 shows that (i) both inelastic features in $CeBr_3$ near 13.3 and 16.9 meV are purely magnetic, and (ii) they share the same polarisation dependence. Together, these observations exclude an assignment as two separate crystal-field transitions.



(a) **(b)**

caption Polarisation analysis of the two CEF levels in $CeBr_3$ measured on IN20 with PASTIS. Both levels show a Q-dependence in the yy channel and no Q-dependence in the zz channel.

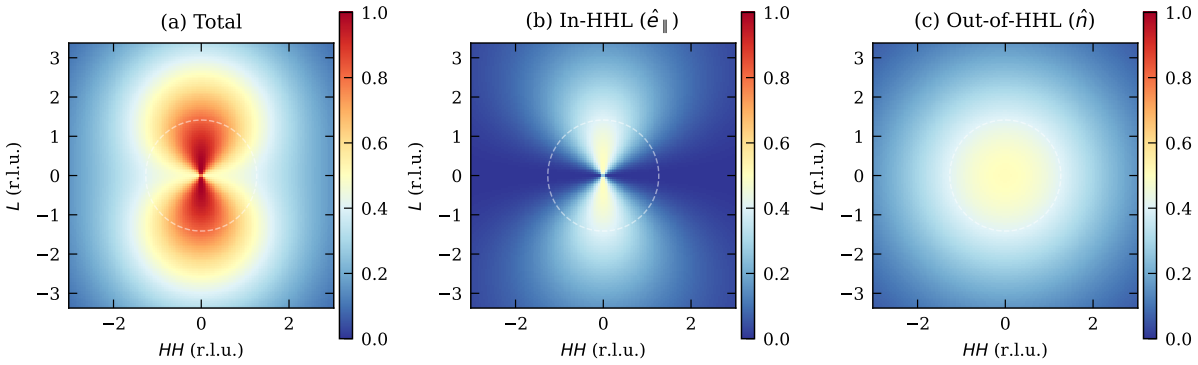


Figure 2: Calculations of the Q-dependence for the transition $|\pm 5/2\rangle \rightarrow |\pm 3/2\rangle$.