Neutron scattering under multi-extreme conditions

Pavel Naumov,[1] Marek Bartkowiak,[1] Jakub Vonka,[1] Stanislav Nikitin,[1] and Christian Rüegg[1,2,3,4]

[1] *Institute of Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland*
[2] *Paul Scherrer Institute, Villigen-PSI, Switzerland*
[3] *Institute for Quantum Electronics, ETH Zürich, Hönggerberg, Switzerland*
[4] *Department of Quantum Matter Physics, University of Geneva, Geneva, Switzerland*

Modern neutron scattering investigations require a wide range of sample environments. High-pressure techniques are particularly valuable for controlling the microscopic interactions within the system. Used in combination with magnetic fields and at low temperatures, they provide unique information about the magnetic states, transitions and excitations of materials under extreme conditions. Developing a cryomagnetic system for high-pressure research is a complex engineering challenge with multiple contradictory requirements. A strong magnetic field is achieved most easily in a small volume, but a wide bore is needed to accommodate the pressure cell and cooling system. Effective cooling requires a small sample mass, while high pressures require thick cell walls. Our new cryomagnetic system is based on a superconducting magnet providing a vertical field of 11 T over a very large sample space (100 mm). We have combined this magnet with a large ^{3}He/^{4}He dilution refrigerator (base temperature 20 mK) and two types of pressure cell, a He gas cell (up to 0.5 GPa) and a double-wall clamp cell (up to 1 GPa). For test measurements we used a high-quality single crystal of the spatially anisotropic triangular-lattice material Cs_2CuCl_4, which displays a cascade of phase transitions at $T = 0.05$ K and fields up to 11.5 T [1, 2]. Working on the triple-axis spectrometer TASP (PSI), we exploited the high cold-neutron flux to explore the novel field-induced phases. In our first trials at the target temperature, pressure and field parameters, the measured signal-to-noise ratio was sufficient to resolve only structural but not magnetic features, and thus we are changing the pressure cell to increase the sample volume. In developing this uniquely flexible facility for neutron scattering with wide-ranging coverage of the multi-extreme (P, H, T) parameter space, we aim to unveil and understand new physics in a broad spectrum of metallic and insulating quantum magnetic materials [3–5].

[1] Y. Tokiwa et al., Phys. Rev. B 73, 134414 (2006).
[2] S. A. Zvyagin et al., Nat. Commun. 10, 1064 (2019).
[3] W. Knafo et al., Nat. Commun. 7, 13075 (2016).
[4] T. Helm et al., Nat. Commun. 11, 3482 (2020).
[5] J.L. Jiménez et al., Nature 592, 370-375 (2021).