Experimental report

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Proposal: **4-03-1767** **Council:** 4/2023

Title: Uncovering the signature of dipolar interactions from critical scattering in Ni

Research area: Physics

This proposal is a resubmission of 4-03-1762

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Samples: Ni

Instrument	Requested days	Allocated days	From	To
IN15	6	4	24/11/2023	28/11/2023

Abstract:

The dynamical scaling behavior of dipolar ferromagnets close to T_C is well understood in terms of mode coupling and renormalization group theory calculations based on a Heisenberg model. In addition to the exchange coupling, localized spins interact via long range dipolar interaction, which drastically changes the linewidth of the critical fluctuations in the long wavelength regime. This has been verified in archetypical systems such as Fe, EuO and EuS, but conversely no clear cut evidence has been found in Ni.

That fact is conceivable due to the small dipolar wavevector q_D = 0.013 1/A, a measure of the strength of the dipolar interaction, which defines an upper bound in momentum space. For q < q_D the dynamic behavior of Ni is expected to show the signature of dipolar interactions. We aim to elucidate the existence of this dipolar coupling by measuring the dynamical scaling function just above T_C = 631 K. To accurately extract the linewidth of critical fluctuations at such small q, exceptional energy resolution, on the order of 1 mueV, is required. That is why we apply for beam time at IN15, which is uniquely capable to conduct this experiment.

Experimental Report for Proposal 4-03-1767

Uncovering the signature of dipolar interactions from critical scattering in Ni

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Basics and instrumental setup

To perform the experiment IN15 was set up in the paramagnetic spin-echo mode, which requires the removal of the π-flipper at the symmetry point. Thus, only spin flip scattering contributes to the echo signal produced by the precession zones.

Observation of critical magnetic scattering is only possible in the vicinity of the Curie temperature of T_C = 631 K. That is why, an spin-echo compatible furnace was installed at the sample position. Heating is performed by direct contact between the sample and a electrically heated plate. Thermocouples were contacted at the top and bottom of the sample by mechanically clamping them between Ni sample and surface. Temperature readout and PID control could only be performed manually without digital connection to the measurement PC.

A collimation section with circular apertures around the primary spectrometer arm and a beam stop (d_{BS} = 5.5 cm) in front of the detector were installed.

Preliminary results

T_C was determined in two ways:

1. Depolarization of the direct neutron beam due to emergence of ferromagnetic domains below the Curie temperature.
2. Increase of scattered neutron intensity due to divergence of magnetic susceptibility at T_C around the screened part of the detector.

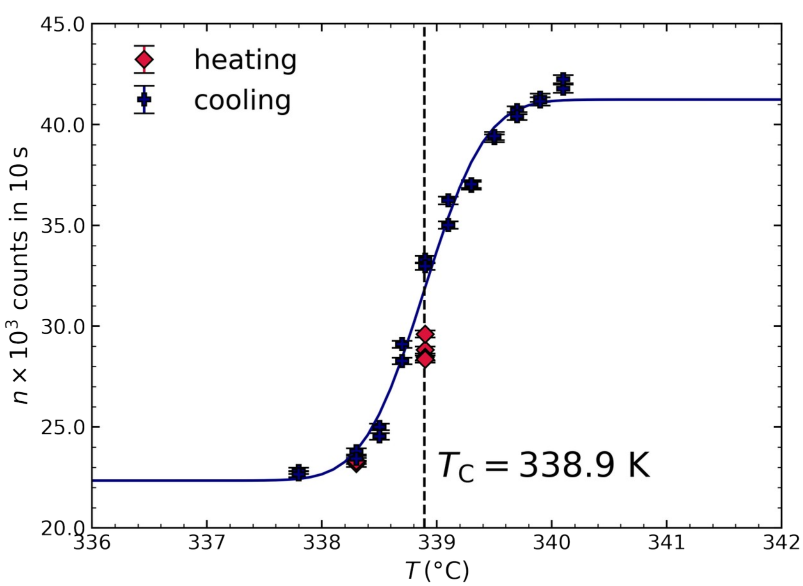

Figure 1: Determination of T_C using depolarization of the direct beam.

Subsequently, spin-echo data was taken at T - T_C = [+0.1 K, +0.4 K,

+0.6 K] over the entire available time range and a wavelength band centered around λ = 10 Å. A putative spin-echo signal could be detected for the smallest momentum transfer at unexpectedly large time scales (τ > 200 ns) going far beyond the expected dynamics of the magnetic fluctuations. Furthermore, the observed spin-echo amplitude could not be reconciled with the instrument performance during tuning.

Explanatory approaches are numerous e.g. remnant ferromagnetic regions with slow dynamics, polarization reduction in low field regions, competition of incoherent and coherent scattering or unaccounted spin flip scattering from nuclear spin-incoherent contribution.

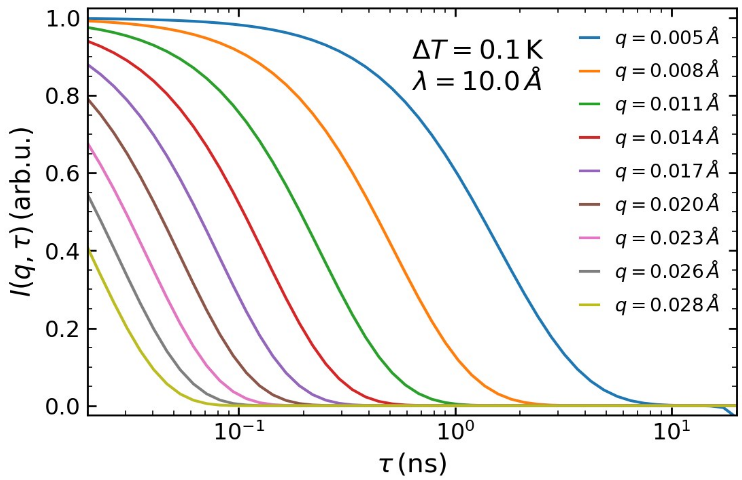

Figure 2: Simulated intermediate scattering function of the critical fluctuations in Ni. Even at the smallest q value, the polarization is expected to decay below τ = 10 ns.

Improvements and outlook

At this point, despite significant effort in data reduction, the sought after signature of the dipolar interactions in the magnetic dynamics remained oblivious.

An interplay of several factors might have lead to insufficient results. However, they can be addressed from an instrumental setup and experiment planing point of view.

- Automated temperature control needs to be implemented in conjunction with higher performance hardware, which will enable less labor intensive as well as more reliable and accurate temperature control.
- Putting effort into high temperature resolution standard compatible with furnace sample environment, to improve correction of instrument resolution.
- Introduction of a compensation coil for the low field strength region at the nominal position of the π-flipper, which might have disturb polarization transport through the instrument.
- Improved modeling and simulation of the different scattering contribution resulting in spin flip scattering.

With the implementation of hardware changes and disentanglement of expected scattering channel prior to the experiment, a second attempt on measuring the critical dynamics in nickel ought to be more successful.