Experimental report

09/02/2016

Proposal: **4-01-1468** **Council:** 4/2015

Title: Spinon deconfinement and re-confinement in the 2D Heisenberg antiferromagnet Ba2Cu3O4Cl2

Research area: Physics

This proposal is a new proposal

Main proposer: **Peter BABKEVICH**

Experimental team: Peter BABKEVICH

Local contacts: Alexandre IVANOV
Mechthild ENDERLE
Louis Pierre REGNAULT

Samples: Ba2Cu3O4Cl2

Instrument	Requested days	Allocated days	From	To
IN20	9	7	08/09/2015	16/09/2015
IN22	9	0		
IN8	9	0		

Abstract:

The Heisenberg antiferromagnet is a well-known model used to describe the magnetic properties of layered and metal-organic Mott insulators which have been explored both experimentally and theoretically. Recent interest has focused on the static and dynamic studies of CFTD – an almost ideal realisation of a 2D Heisenberg antiferromagnet (AFM) on a square lattice. The excitation spectrum of this system was understood in terms of unbinding of spin-waves into spinon pairs at Q = (pi, 0) position. In this proposal we aim to investigate the inelastic spectrum of a closely related Ba2342 spin-1/2 square-lattice framework which consists of coupled AFM spin-systems as a testing ground of the new theoretical model.

4-01-1468 Experimental report:
Spinon deconfinement and re-confinement in the 2D Heisenberg antiferromagnet $Ba_2Cu_3O_4Cl_2$

P. Babkevich[1], H.M. Ronnow[1], M. Mourigal[2], N.B. Christensen[3] and M. Enderle[4]

[1] Laboratory for Quantum Magnetism, École Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland
[2] School of Physics, Georgia Institute of Technology, Atlanta, Georgia 30332, USA
[3] Technical University of Denmark, Fysikvej, 311 DK-2800, Kgs. Lyngby, Denmark
[4] Institut Laue{Langevin, BP 156, 38042 Grenoble Cedex 9, France

We have performed inelastic neutron scattering measurements on $Ba_2Cu_3O_4Cl_2$ layered antiferromagnet to investigate the zone-boundary excitations and the effect of an applied magnetic field on the spinons. We find a small sharpening at the (π/2, π/2) position.

From our detailed neutron scattering investigation of the zone boundary effect in $Cu(DCOO)_2.4D_2O$ and our theoretical approach based on the staggered flux description, we were able to successfully reproduce the zone boundary anomaly in CFTD [1-4]. This led us to the conclusion that spin-waves unbind into deconfined spinon pairs around the (π,0) point [6]. Experiments on $Cu(pyz)_2(ClO_4)_2$ [5] have shown that moderate magnetic fields compared to the saturation field lead to sharp spin-wave modes at the magnetic zone boundary, which we interpret as the confinement of spinons into magnons. The goal of this experiment was to investigate in much more detail the field-induced confinement of zone-boundary spinons into magnons. To do so, we have focused on the square-lattice material $Ba_2Cu_3O_4Cl_2$ (Ba2342). With a much cleaner phonon background at the ZB energies compared to CFTD, this material should give good quality data without the need for polarised neutrons. The Ba2342 compound contains two coupled AFM square-lattice spin-systems which makes this an intriguing material to study.

To perform the measurements, we have employed the IN20 spectrometer. Five co-aligned single-crystal samples with a total mass of 4.1 g aligned to give access to the (*h*,*k*,0) scattering plane were mounted inside a 10 T vertical field magnet. The field was applied along the *c*-axis. High-quality data was collected at 0 and 10 T.

Figure 1 shows the observed zone-boundary dispersion measured in the ordered state where the peak at 20 meV corresponds to the ZB of the Cu_B site excitations. On applying a field there is a shift of the excitations to lower energies while at the same time, a very small sharpening of the mode is observed. In Fig. 2 we show that the magnetic order on the Cu_B sublattice is coupled to the much more strongly coupled Cu_A sublattice with the spin-gap which softens at Cu_B become disordered.

We wish to thank the technical staff for their assistance during the experiment.

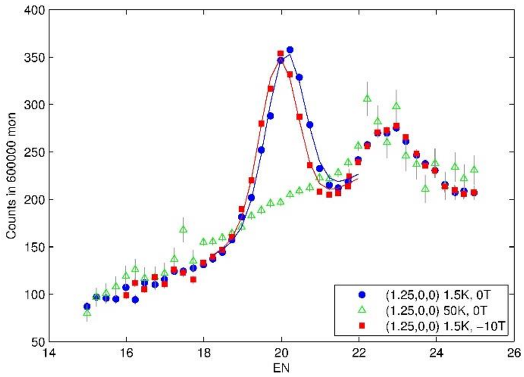

Figure 1. Effect of the applied magnetic field on the zone-boundary dispersion in Ba2342 at the (π/2, π/2) position. The green points show the spectrum above the sublattice ordering temperature.

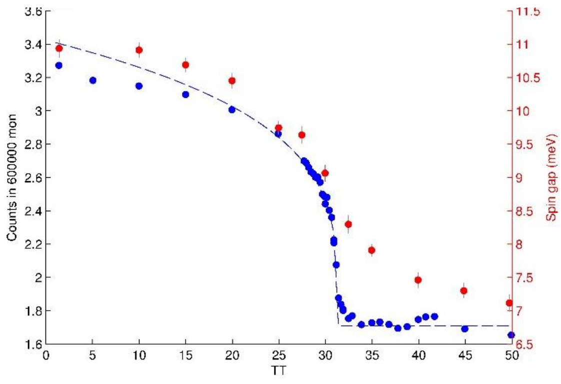

Figure 2. (blue) Amplitude of the magnetic Bragg peak as a function of temperature; (red) spin gap of the Cu_A sublattice as a function of temperature.

[1] Ronnow *et al.*, Phys. Rev. Lett. **82**, 3152 (1999);
[2] Ronnow *et al.*, Phys. Rev. Lett. **87**, 037202 (2001) ;
[3] Syljuaasen and Ronnow, J. Phys. Condens. Matter **12**, L405 (2000) ;
[4] Christensen *et al.*, Proc. Nat. Acad. Sci. **104**, 15264 (2007) ;
[5] Tsyrulin *et al.*, Phys. Rev. B **81**, 134409, (2010) ;
[6] Dalla Piazza *et al.*, Nature Physics **11**, 62–68 (2015) ;