Experimental report

31/03/2017

Proposal: **4-05-637** **Council:** 4/2016

Title: Magnetic moment fragmentation in the quantum spin ice $Nd_2Zr_2O_7$

Research area: Physics

This proposal is a new proposal

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Samples: $Nd_2Zr_2O_7$

Instrument	Requested days	Allocated days	From	To
IN5	7	7	05/10/2016	12/10/2016

Abstract:

Recent combined magnetization, inelastic and elastic neutron experiments demonstrate that the spin ice pyrochlore $Nd_2Zr_2O_7$ allows to study a new mechanism called fragmentation. In this material, the emergent electromagnetic field characteristic of spin ice is found to fragment into a charged part, giving rise to a crystal of monopoles, and a divergence free part, which remains fluctuating, giving rise to a quasi-elastic pinch points pattern. Applying a magnetic field is expected to destabilize the fragmentation and recombine the two fragments. The present experiment is aimed at studying this recombination. To this end, we wish to measure the spin dynamics under an applied magnetic with H // [110]. A related proposal has been submitted on D23 to measure the associated field induced structure.

Experimental report on 4-05-637
Magnetic moment fragmentation in the quantum spin ice $Nd_2Zr_2O_7$

In this proposal we asked for beam time on the IN5 time-of-flight spectrometer to study, in $Nd_2Zr_2O_7$, the influence of a magnetic field applied along [110] on the fractionalization mechanism called "magnetic fragmentation" [1] that we had recently discovered in this compound [2]. The objective was to study the way the two fragments that we had evidenced in zero field (an ordered all-in all-out antiferromagnetic fragment, and a dynamic Coulomb like fragment) would recombine in the presence of a magnetic field. Meanwhile, we realized that the [111] direction should open the way to more exotic excitations, so that we finally made the measurements on IN5 with the field applied along the [111] direction of the sample.

Our INS experiment has been carried out on IN5 in a complex set-up involving a cryomagnet and a dilution insert. The measurements were performed with a wavelength of 6 Å to be able to resolve the small energy gap (about 70 μeV). Note that the scattering plane in our experimental conditions ((1 1 -2) – (-1 1 0)) is not favorable with respect to the dynamical structure factor, so that long counting times were needed to reach enough statistics.

In zero field, we were able to measure the flat mode, characteristic of the dynamic Coulomb fragment (see Figure 1). Its Q-dependence, as well as the dispersion we observed, is consistent with our previous calculations which allowed to determine the key parameters of the Hamiltonian. When applying a magnetic field, the excitations persist up to 0.75 T, thus well above the field (about 0.1 T) where the other fragment loses its all-in all-out character [3]. This points out the fact that the two fragments seem to behave almost independently as a function of the magnetic field.
In addition, we observed that the dispersion is strongly affected by the magnetic field, while a new mode appears at 0.3 meV in a field of 1 T.

The analyses are on-going to understand these results, and to check whether they are consistent with the quantum fragmentation mechanism recently described in ref [4].

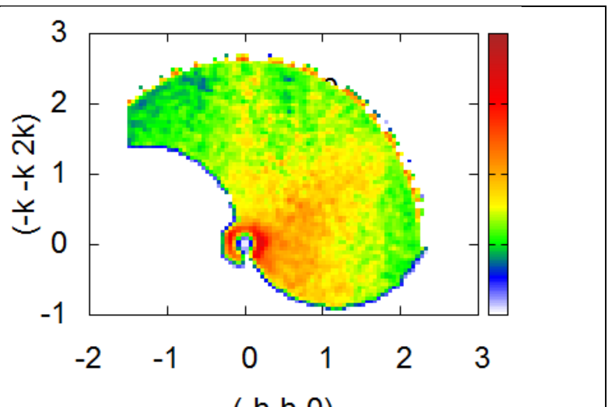

Fig. 1: Inelastic neutron scattering intensity at E =70 μeV measured at T = 60 mK and H=0 with an incident wavelength λ = 6 Å.

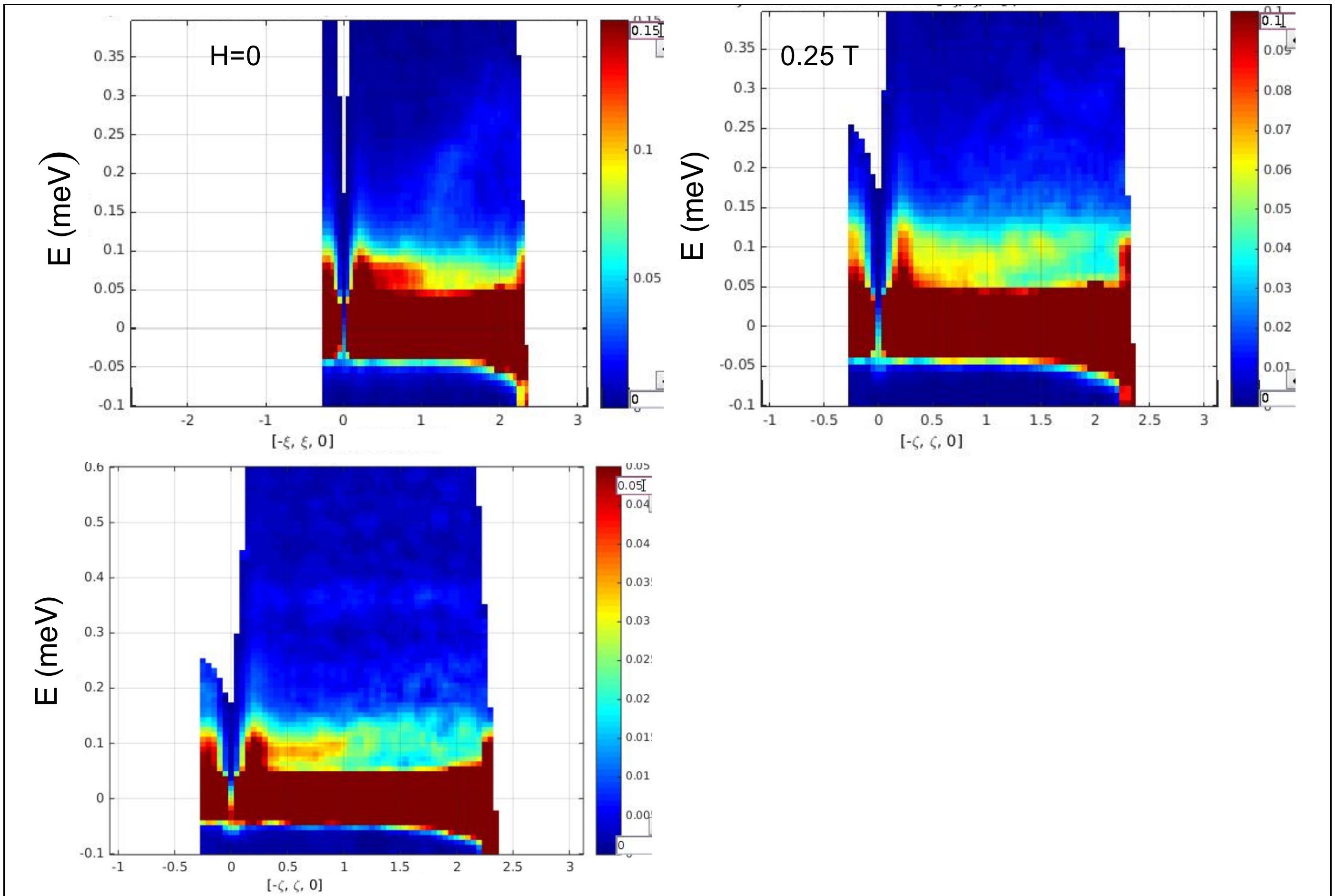

Fig. 1: Inelastic neutron scattering intensity at E=70 μeV measured at T = 60 mK with an incident wavelength λ = 6 Å for several magnetic fields: H=0, 0.25 T and 1 T.

[1] Brooks-Bartlett et al., Phys. Rev. X 4, 011007 (2014).
[2] Petit et al., Nature Phys. 12, 746 (2016).
[3] Lhotel et al, Phys. Rev. Lett. 115, 197202 (2015).
[4] Benton, Phys. Rev. B 94, 104430 (2016).