Experimental report

02/11/2023

Proposal:	**4-01-1795**	**Council:**	4/2023

Title: Investigating the spin excitationsin the two dimensional antiferromagnet Na2BaMn(PO4)2

Research area: Physics

This proposal is a new proposal

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Samples: Na2BaMn(PO4)2

Instrument	Requested days	Allocated days	From	To
THALES	8	0		
IN12	8	7	06/09/2023	13/09/2023
ORIENTEXPRESS	1	1	05/09/2023	06/09/2023

Abstract:

Our goal is to investigate the spin excitations in the recently discovered triangular lattice system Na2BaMn(PO4)2. This compound exhibits a nearly classical magnetic phase diagram predicted for frustrated triangular lattice systems, with an additional unknown phase in the readily accessible field region around 3T. Recent macroscopic measurements suggest that this may be the exotic "super-solid" phase. We plan to study the effect of the applied field on the spin excitation spectrum to reveal the possible nature of the observed states.

Scientific background:

Super-solid phases have been the subject of scientific investigation since the late 1960s with periods of increased interest, especially following the discovery of unusual behaviors in Helium-4 and, more recently, the identification of similar phenomena in magnetic lattices. The super-solid phases require the coexistence of diagonal and off-diagonal long-range order, embodying both particle crystallization and quantum-driven superfluidity. These systems show vacancy-induced disorder, which condenses into a single, phase-coherent state at low temperatures, leading to super-solid formation. This is observed in both bosonic and spin systems, with the latter resulting in a "spin super-solid" state. The study of geometrically frustrated systems with antiferromagnetically (AFM) ordered spins on a two-dimensional lattice has recently gained considerable attention for their exotic quantum magnetic properties. A compound ripe for investigation is $Na_2BaMn(PO_4)_2$, featuring Mn^{2+} ions with a spin-5/2, for which no neutron measurements are reported. The material crystallizes in the space group P3m1 (No. 164) with lattice parameters a = b= 5.37 Å, and c = 7.1 Å and orders AFM below T=1.3K.

Aim of the proposal:

In this experiment we investigated the spin excitation spectrum of $Na_2BaMn(PO_4)_2$ under a magnetic field. For this aim we have prepared and extensively characterized single crystals with an overall mass of about 2.1 g which we co-aligned. The crystals were placed in six circular shaped Cu foils.

Experimental setup and preliminary results:

IN12 was set up in W-configuration. We used unpolarized neutron beam, a double focusing PG monochromator and a PG analyzer. Data have been collected with a fixed k_f. The co-aligned single crystals were oriented in the [*hh0*]/[*00l*] scattering plane, and as a sample environment, we had a dilution fridge and a vertical 10 T magnet. First, we have identified a strong magnetic signal originating at **Q** = (1/3, 1/3, 0.18) which disappears for temperatures T > 1.2 K. Following the intensity of the magnetic Bragg peak at 55 mK with a magnetic field applied parallel to the *ab*-plane we managed to track several magnetic phase transitions which are roughly in agreement with the published H-T phase diagram constructed from magnetisation and heat capacity measurements.

Since the magnetic structure of the field-induced phases is still not yet established, we tried to obtain the spin excitation spectrum of the ground state (at T = 55 mK and H = 0 T). We collected data with different fixed k_f (e.g. 1.05, 1.1, 1.4, and 1.8 $Å^{-1}$) to obtain a wide range in (**Q**, E) - space with the desired resolution. Despite our efforts, we could not obtain any spin waves scattering at H = 0 T along the (*h*, *h*, 0.18) and (1/3, 1/3, *l*) directions in the energy range of 0 < E < 5 meV. Therefore, we focused on the "spin-polarised" state at 10 T where we obtained magnon dispersion relations (see Figs 1(a,b)). Similarly to the $Na_2BaCo(PO_4)_2$ and $Na_2BaNi(PO_4)_2$ systems, we observed dispersing magnons along the (0, 0, 0)-(1/3, 1/3, 0)-(1/2, 1/2, 0) path (see Fig.1a) and flat bands along the *c*-direction for (1/3, 1/3, l) and (1/2, 1/2, l) (see Fig.1b). We point out that also for the Ni and Co analogues no magnons are reported for the ground state.

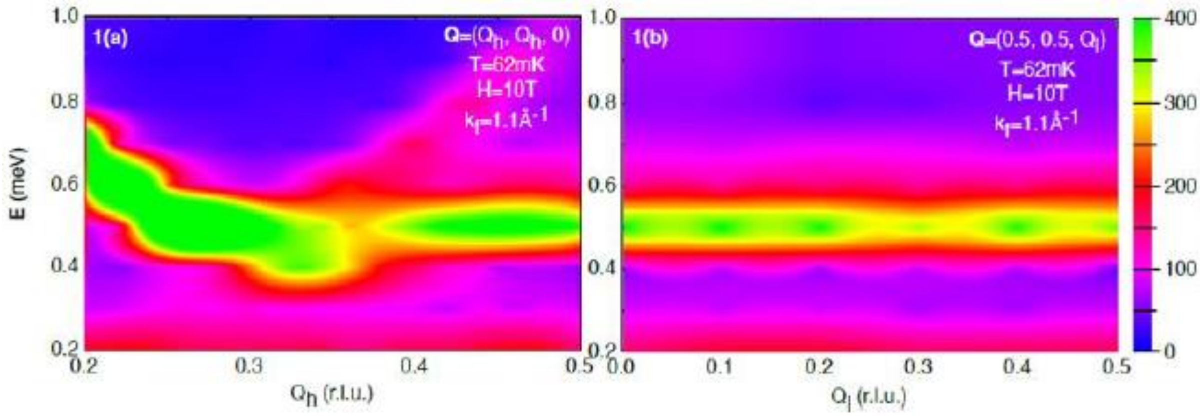

Fig. 1: Magnetic excitations in the field polarized state (T=62mK, H=10T, for H//*ab*-plane) of $Na_2BaMn(PO_4)_2$ along **(a)** the (0, 0, 0)-(1/3, 1/3, 0)-(1/2, 1/2, 0) and **(b)** (1/2, 1/2, *l*) paths.