Can Neutron Scattering measure Quantum Entanglement in Quantum Magnets and in Hydrogen?

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Many magnetic systems have entangled ground states, such as weakly interacting dimers, antiferromagnetic chains and liquid helium. A characteristic of the neutron scattering from all of these systems is that there is an absence of Bragg scattering and that all the scattering is inelastic. The scattering does however satisfy the well known first moment or f-sum rule. In contrast the scattering has been measured from hydrogen using very high energy neutrons with the inverse time-of-flight VESUVIO spectrometer. It was expected that at these energies, several eV, the scattering would arise from independent hydrogen atoms and largely obey the impulse approximation. The experimental results [1] showed, however, that the scattering was weaker than expected by about 50% and this result was interpreted as evidence for entanglement of the hydrogen atoms. The experiment has been repeated using hydrogens in water, in plastics and in metals with essentially the same results. Analysis of the theory suggests that the zeroeth and first moment sum rules are both obeyed even if the hydrogens are entangled, because the energy resolution in the experiments is much larger than the possible difference in the energies of the entangled states. It will be shown that some of the loss of the intensity arises because the transformation of the inverse time-of-flight data at constant angle, to energy scans at constant Q is not usually performed correctly. This is because the intensity from the time-of-flight data integrated over all energy transfers is infinite. Nevertheless this cannot explain all of the discrepancy and the remainder arises possibly from the uncertainties in the monitor efficiencies at these high energies.

1. C. A. Chatzidimitriou-Dreismann et al., Phys. Rev. Lett. 78, 2839 (1997)