Nano-criticality in small CoO particles

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Abstract

Through a neutron scattering study of CoO bulk and nano-powders, we have measured the critical magnetic scattering at temperatures below and above the phase transition, T_N. From the size and shape of the magnetic diffraction peak, we extract the magnetic order parameter, M (where = T/T_C-1 is the reduced temperature), and the magnetic coherence length (-)$^{-}$.

We have found a of 0.31 and 0.35 for bulk and nano respectivly, which is close to that of a 3-D Ising model of 5/16 = 0.3125 0.3258 [2]. The critical scattering is strongly enhanced in nano sized particles, corresponding to larger values of .
The measuremens have been conducted running in 2-axis mode, using a PSD.

What is criticality?

- The behaviour of order parameters close to (on both sides of) a phase transition.
- Local / localized order/disorder with a charateristic correlation length.

Why CoO?

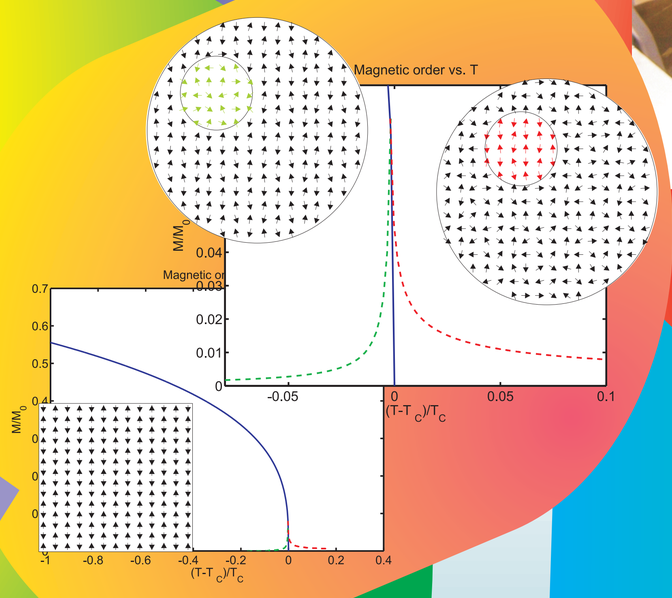
- Simple antiferromagnetic structure.
- Good neutron scattering intensity.

Why Nano?

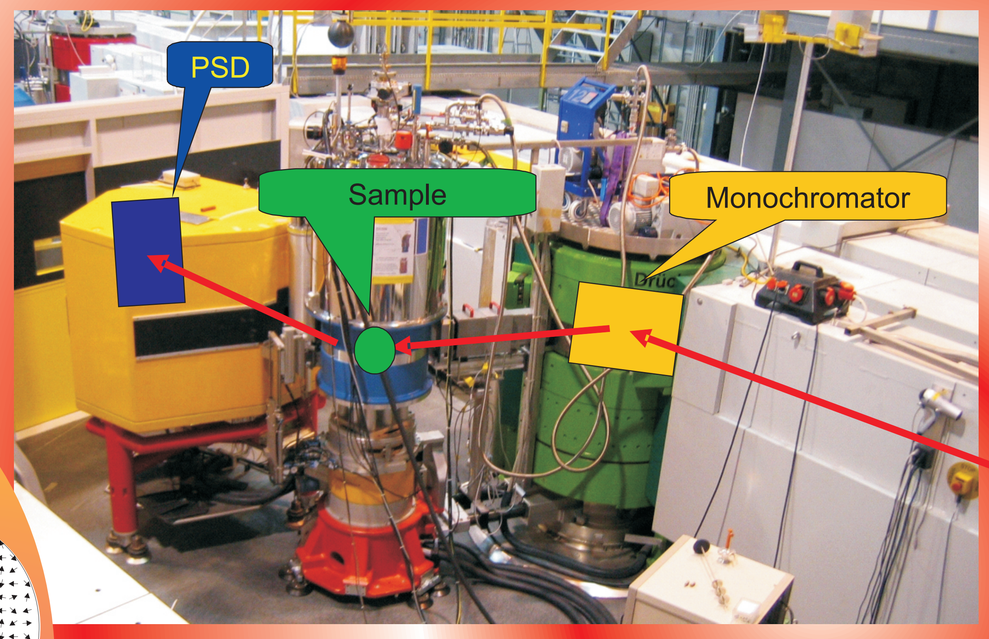
- Little is known about the behaviour of criticality in nano-materials.

Why Neutrons?

- Probe of magnetic order.
- Well suited instrument available (the Danish RITA-2 at PSI).



The RITA-2@PSI.CH



The RITA-2 spectrometer in 2-axis configuration, which was used for measurements.

The Nobel Prize in Physics 1982

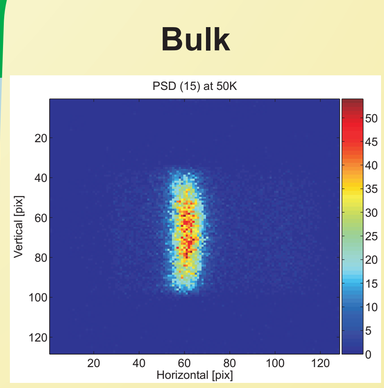
To Kenneth Wilson, Cornell, USA

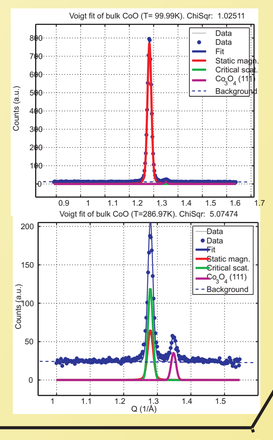
"for his theory for critical phenomena in connection with phase transitions"

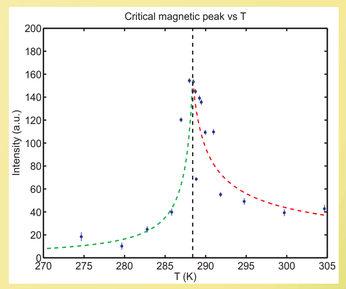
from [1].

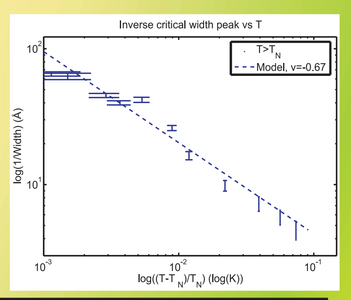
Data analysis

Bulk

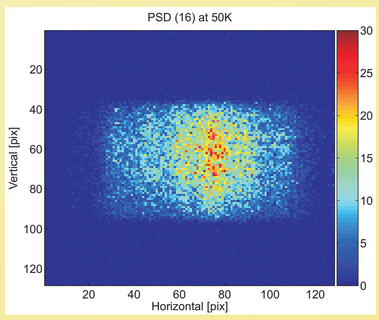


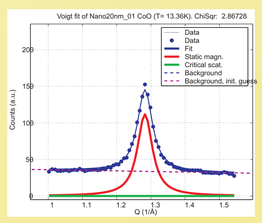


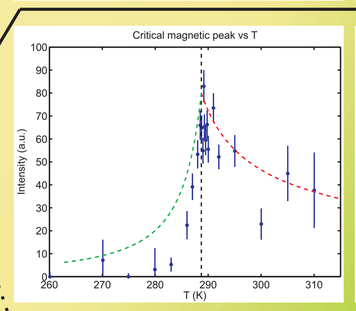


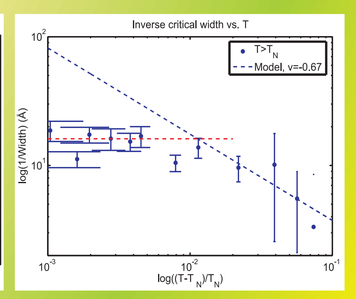


Nano 20nm

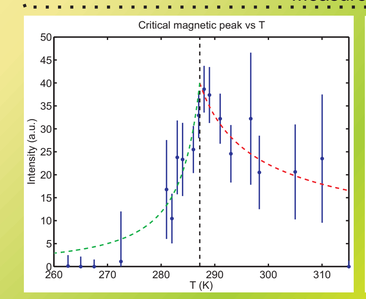


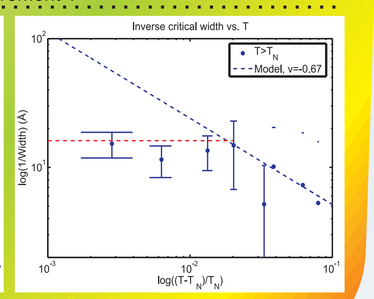






Measurement 1





Measurement 2

Results summary

Our results

Bulk:

T_N = 290.25 ± 2.69
= 0.319 ± 0.048
^{2} = 0.47880

Nano 20nm (1):

T_N = 288.7 ± 0.0
= 0.370 ± 0.019
^{2} = 1.26024

Nano 20nm (2):

T_N = 288.7 ± 0.0
= 0.381 ± 0.072
^{2} = 0.18179

Litterature

Renormalization group calculations [2]:

= 0.3258 ± 0.0014
= 0.6304 ± 0.0013

Measured bulk values [3]:

T_N 289K
= 0.290 ± 0.25

Conclusion

We have investigated the critical scattering of CoO bulk powder and of 20nm nano-powder, and determined the intensity and width of the critical component. The found values for the bulk sample are in good accordance with predicted values, [2] whereas nano values differ somewhat.

The finte size is very evident in the nano-particles, limiting the critical correlation length by a cut-off.

Recent measurements indicate that in smaller nano-particles the critical exponents differ more, as well as there are indications that the cut-off of the correlation length is lowered.

Contact

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Do not hesitate to contact me if you have suggestions, comments etc.

[1] www.nobel.se
[2] J. Zinn-Justin, ArXiv, 9810193
[3] M. D. Rechtin, Phys. Rev. L26 (24) (1971) 1480-1483