# Antiferromagnetism Experiment on the ARGUS Instrument

ISIS Muon Training Course
February 2005

**Outline:**

In this experiment an antiferromagnetic transition will be observed using μSR. The internal field at the muon site will be determined and muon spin relaxation will be used to study the magnetic fluctuations above and below the transition temperature.

**Sample:**

The sample for this experiment is a member of the Lanthanum Barium Cuprate family of high temperature superconductors known as LBCO. The family of materials has the general composition $La_{2-x}Ba_xCuO_4$ and samples are generally superconductors for x>0.05. However around the particular composition x~0.125 (corresponding to a hole concentration of 1/8 per Cu) the superconducting transition is strongly suppressed and the material becomes an antiferromagnetic insulator with ordered Cu spins and a transition temperature in the region of 25-30 K (see phase diagram Fig.1). This is the antiferromagnetic sample studied here.

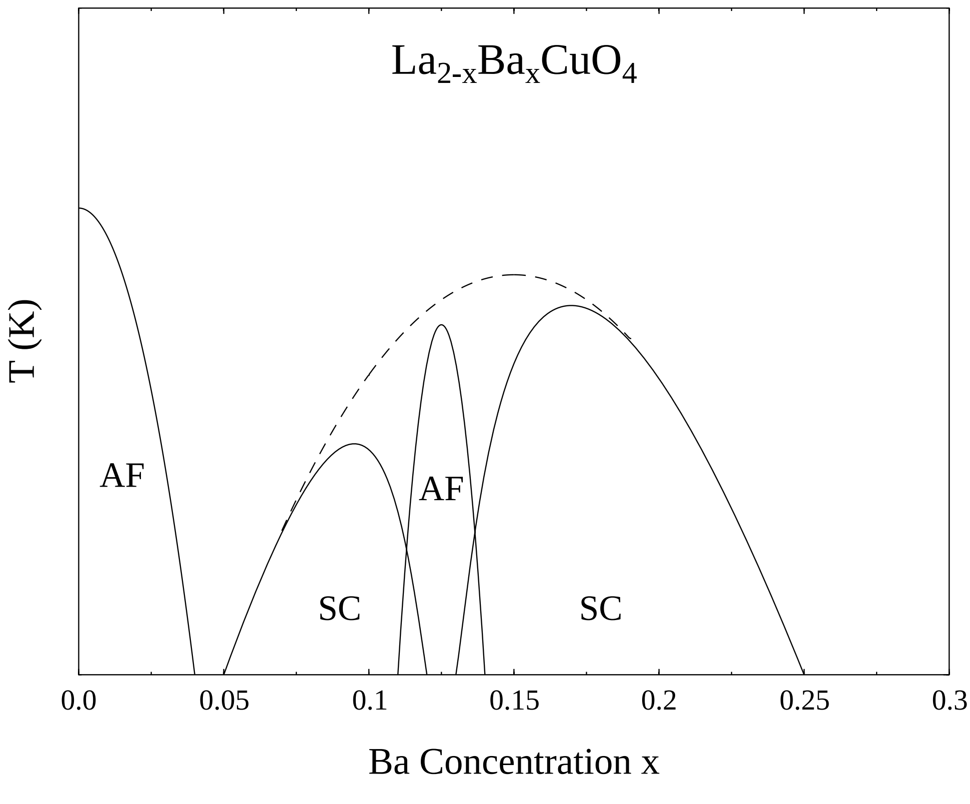


Fig.1 Schematic phase diagram for the LBCO high temperature superconductor system showing the antiferromagnetic phase that appears within the broad superconducting phase for a narrow region centred around x=0.125.

**Measurement Sequence:**

Load the sample into the cryostat and cool to 50 K, which is well above the transition, so the sample will still be in the paramagnetic state. Perform a transverse field calibration. Study the relaxation function at zero field and for several low longitudinal fields up to 20 G. Analyse this data as the product of a Kubo-Toyabe term, representing nuclear dipolar relaxation, and a Lorentzian term representing the relaxation from the Cu spins. Cool the sample to 1.7 K in zero field and look for a zero field precession signal at 1.7 K. Study the precession frequency spectrum and fit the precession signal in the time domain to determine the internal field at the muon site. Set up a script to take zero field data overnight, warming in steps from 3 K to 50 K. Finally go back to 1.7 K and measure the decoupling field by taking a series of short runs in longitudinal field, varying the field from 10 G to 3950 G.

**Detailed Analysis of Temperature Dependent Data:**

Relaxation Signal

Firstly, ignore the precession signal (use a large binning factor) and fit the data to single Lorentzian relaxation component. Plot the amplitude and relaxation rate of this component against temperature. Observe the peak in the relaxation rate that occurs around the magnetic transition and measure the shift in the amplitude of the relaxing component on passing through the transition. Estimate the transition temperature $T_N$ from the temperature dependent relaxation behaviour.

Precession Signal

Now restore the fine binning so that the oscillations are visible again and add back the precessing component to the fitted relaxation function. Fit the data sequence to give precession frequency or internal field against temperature. Determine the transition temperature from this analysis. Critical parameters for the transition can be derived from the temperature dependence of the internal field by fitting the precession frequency to the functional form $B(T) = B(0)\,(1-(T/T_N)^{\alpha})^{\beta}$.

Decoupling Data

Go back to the coarse binning and fit the asymmetry as a function of longitudinal field. Determine the decoupling field at which 50% of the full asymmetry is recovered. This provides another estimate of the internal field seen by the muon to compare with that obtained from the precession.

Further Analysis (optional, if time allows)

The antiferromagnetic phase in this sample is believed to be a spatially modulated stripe-ordered phase rather than a uniform antiferromagnetic phase. Explore whether any evidence of this can be seen from the measured data.

**General Reference:** P. Dalmas de Reotier and A. Yaouanc 'Muon Spin Rotation and Relaxation in Magnetic Materials' J. Phys.:Condens. Matter 9 (1997) 9113.