# Experimental Report

17/02/2015

**Proposal:** **5-53-237** **Council:** 4/2014

**Title:** Magnetic critical scattering of the pseudogap order parameter in the high-Tc superconductor HgBa2CuO4+delta

**This proposal is a new proposal**

**Researh Area:** Physics


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**Experimental Team:** TANG Yang

**Local Contact:** WILDES Andrew


**Samples:** HgBa2CuO4

| Instrument | Req. Days | All. Days | From | To |
|---|---|---|---|---|
| D7 | 10 | 8 | 17/11/2014 | 25/11/2014 |


**Abstract:**

It is often argued that the superconductivity in the cuprates is mediated by fluctuations of a distinct order parameter. One of the most interesting is the circulating current (CC) order proposed to explain the pseudogap state. Elastic polarized neutron experiments have indeed detected signatures of magnetic scattering on top of select nuclear Bragg peaks as expected for a model involving two-cirulating current/CuO2 plaquette. This so called q=0 order was found to appear in the pseudogap state universally in the cuprates. If this detected order is truly due to the novel CC order, critical magnetic scattering is expected to be observed upon approaching the ordering temperature. Recent work on double layer YBa2CuO6+δ with the polarized diffractometer D7 has indeed detected indications of this scattering at the pseudogap temperature. We here propose to test the universality of this new observation on the model single layer cuprate close to optimal doping.

**Magnetic critical scattering of the pseudogap order parameter in the high-$T_c$ superconductor $HgBa_2CuO_{4+d}$**

Recent polarized neutron diffraction experiments have revealed an unusual q=0 (lattice translational symmetry preserving) magnetic order below a characteristic temperature $T_{mag} \approx T^*$ in both double-layer $YBa_2CuO_{6+\delta}$ (YBCO) and single-layer Hg1201. The q=0 magnetism has now also been detected in Bi2212 and LSCO, and is therefore universally observed in the cuprates. A possible explanation of this unusual magnetism is the current-loop-order proposal by Varma. If the pseudogap temperature T* indeed marks a phase transition, we would expect to observe low-energy critical magnetic scattering, i.e., a cusp in the temperature-dependent quasi-elastic magnetic intensity, upon approaching T*. This observation of further evidence of a phase transition would be a big step forward, as it would severely constrain theoretical proposals for the pseudogap state. Indeed, a recent measurement on nearly-optimally-doped YBCO on D7 at ILL (Exp. No. 5-53-234) revealed a peak in the magnetic intensity at a wave-vector slightly displaced from the Bragg positions, and at approximately the same temperature below which the q=0 order is observed ($T_{mag} \approx 190$ K). This result therefore constitutes initial evidence for the sought-after critical scattering.

The goal of our experiment was to explore the existence of the same critical scattering in $HgBa_2CuO_{4+\delta}$ (Hg1201), in order to establish its universality. The experiment was performed during eight days of beam time. Approximately half a day was used to set up the spectrometer, and another half a day was used to measure the empty sample can, as well as Vanadium for detector calibration. Measurements were performed on our nearly optimal-doped Hg1201 (Tc ≈ 95 K) sample.

During the first half of the beam time, we performed measurements at different off-Bragg positions (1 0 L), with L = 0.2, 0.4 and 0.5, for all three polarization directions, at temperatures both below and above the pseudogap temperature. Figure 1 shows the pure magnetic signal extracted by the longitudinal polarization analysis (LPA). No critical scattering peak was observed. During the remainder of the beamtime, we explored the temperature dependence of the q=0 order magnetic signal at the (1 0 0) Bragg peak, which is a well-established feature at lower doping. However, as shown in Figure 2, the intensities in all three channels were found to decrease linearly, with no noticeable change across $T^* \approx 190$ K ($T^*$ determined from resistivity measurements). .

The absence of critical scattering suggest that either our measurements was not optimally performed (a considerable amount of time was spent to search for a good Q-position for our scan), or that the doping level of our sample was too large for there to remain significant two-deimensional correlations. Although we did not obtain useful data, we learnt a lot through this experiment and through the discussion with our local contact, such as how to better calibrate the instrument, how to select a good Q position, and how to best analyze the data. There are several ways in which we can improve the experiment in the future: (i) use a somewhat larger sample; (ii) work with smaller ki to minimize Hg absorption; (iii) measure a sample with a slightly lower doping level, similar to the successful study of YBCO.

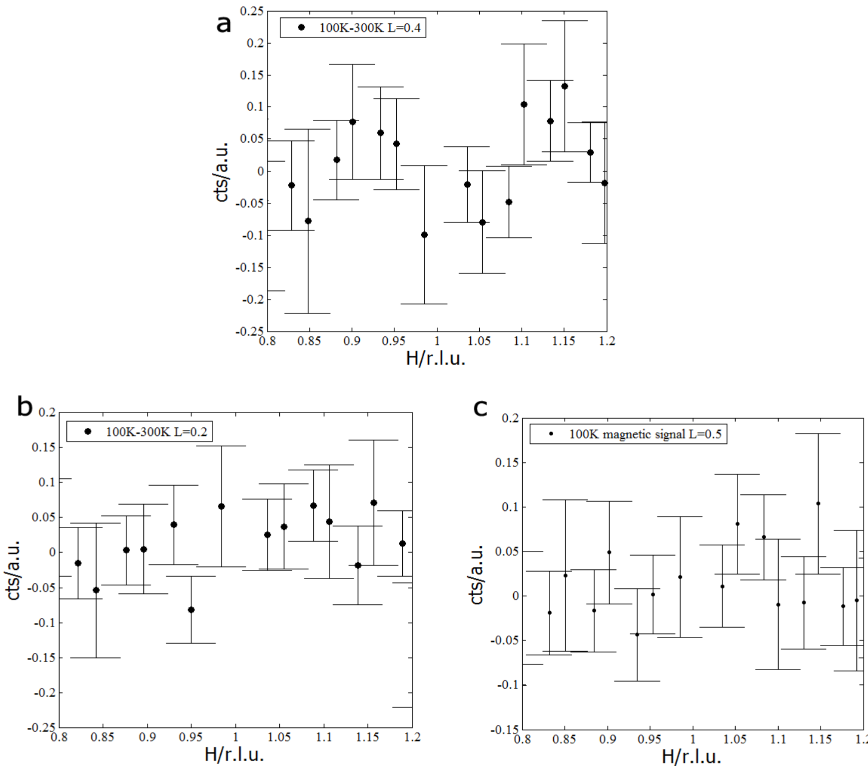


Figure 1: Magnetic signals at off-Bragg positions. (a) Temperature difference between 100K (below T*) and 300K (above T*) of the magnetic signals calculated by LPA, at Q=(1 0 0.2). (b) Similar data for Q=(1 0 0.4) (c) Similar data at T=100K for Q=(1 0 0.5).

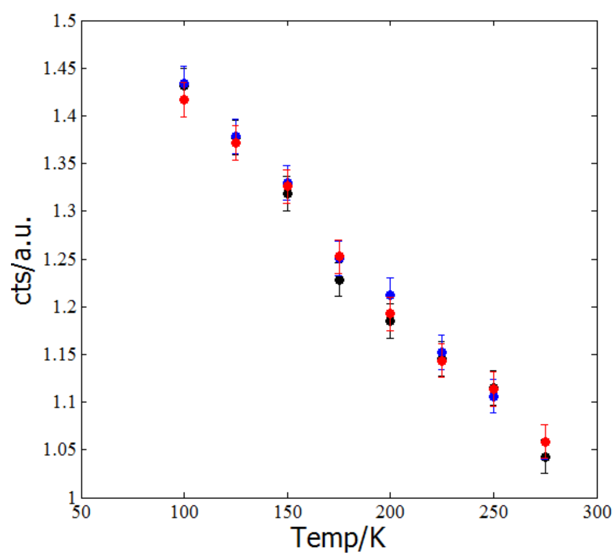


Figure 2: Temperature dependence of the Bragg peak intensity. The peak intensities are determined by subtract intensity averaged by the center 4 points near Bragg peak from the average of rest points as background. Data are shown in all three polarization channels Y(blue, parallel to scattering vector Q) and Z(red, out of scattering plane), X (black, perpendicular to Y and Z).