Experimental report

14/02/2017

Proposal: **5-53-256**

Council: 4/2015

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

Research area: Physics

This proposal is a continuation of 5-53-237

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Samples: HgBa2CuO4+d

Instrument	Requested days	Allocated days	From	To
IN3	1	1	03/11/2016	04/11/2016
D7	10	10	04/11/2016	14/11/2016

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 YBa2CuO6.85 with the polarized diffractometer D7 has indeed detected indications of this scattering at the pseudogap temperature. Our preliminary measurement in single layer HgBa2CuO4+d (Hg1201) last November with D7 gives unclear result because of signal-to-noise problems. With improvement of sample quality and mass, and better understanding of using the instrument, we propose to measure this new observation again in Hg1201 to test its universality.

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

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 $HgBa_2CuO_{4+\delta}$ (Hg1201). The q=0 magnetism has now also been detected in Bi2212 and LSCO, and is therefore universally observed in the cuprates. One possible explanation of this unusual magnetism is the current-loop-order proposal by Varma. Recent measurements of nearly-optimally-doped YBCO single crystals 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 natural motivation for using D7 to explore the q=0 magnetism in Hg1201, which is a structurally much simpler compound and hence most suitable for testing theoretical proposals.

The goal of our experiment was to explore the capability of measuring q=0 magnetism in Hg1201 on D7, and to check the existence of a c-axis component in Hg1201. 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 carbon single crystal of similar mass, as well as Vanadium for detector calibration. Measurements were performed on our moderately underdoped ($T_c \approx$ 71 K, UD71) and nearly optimal-doped Hg1201 ($T_c \approx$ 95 K, OP95) sample.

During the first half of the beam time, we performed measurements at the Bragg positions (0 0 3), (2 0 0), and (1 0 0) for all three polarization directions; at temperatures from slightly above T_c to well above the pseudogap temperature (~ 450 K), with 20 K steps. Figure 1 shows the temperature dependence of the reverse flipping ratio (1/FR) in UD71 at (2 0 0) in red, and (1 0 0) in black. The (0 0 3) data were very unstable upon temperature changes, so they are not used. We can see a clear enhancement of 1/FR at (1 0 0), consistent with the onset of q=0 magnetism. To confirm this result, we explored the temperature dependence of 1/FR in the OP95 sample at (1 0 0) during the remainder of the beamtime, where we had previously confirmed the absence of q=0 Bragg scattering (Exp. No. 5-53-237). These data, shown in Figure 1 in green, agree quite well with the UD71 (2 0 0) data, where no significant magnetic signal is expected; therefore, they are a good "background" reference. After subtracting the estimated background from the UD71 (1 0 0) data, we found significant spectral weight along polarization direction P || X and P || Y (parallel to the Cu-O planes), consistent with a significant c-axis component.

The above observations show that D7 allows a quantitative measurement of the q=0 magnetism in Hg1201 single crystals. We have learnt how to best perform the experiment, including the selection of the detector. We plan to write to submit a continuation proposal and wish to study full doping dependence of the q=0 magnetism in Hg1201. This in turn will enable us to best test theoretical models for the pseudogap phenomenon.

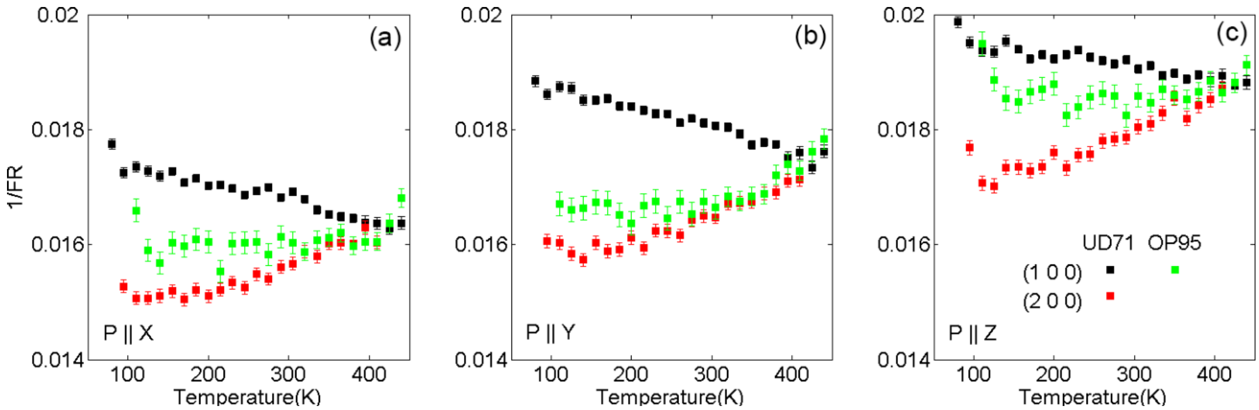

Figure 1 | Temperature dependence of the q=0 magnetic scattering. (a)-(c) The inverse flipping ratio (1/FR) with neutron polarization direction parallel to X, Y and Z, respectively. Data obtained on D7 for two Hg1201 samples (UD71, T_c = 71K; OP91, T_c = 95K). The colors of the symbols are explained in the legend in (c). The values of 1/FR for UD71 (2 0 0) and OP95 (1 0 0) are shifted to match the average of the data at the five highest temperatures for UD71 (1 0 0).

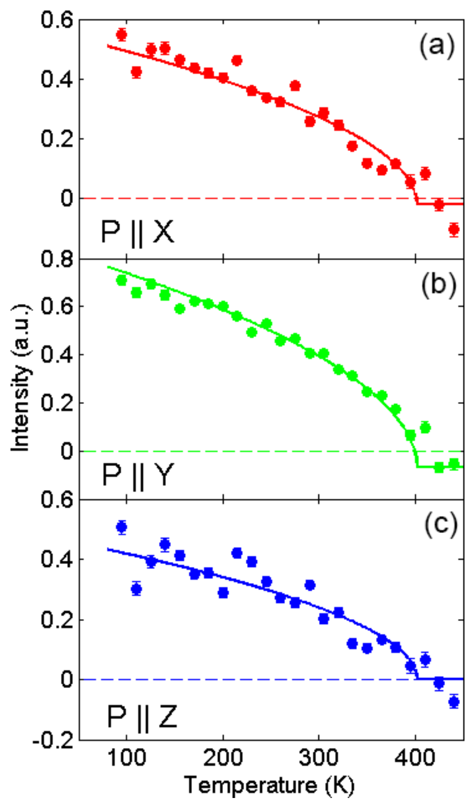

Figure 2 (a)-(c) q=0 magnetic scattering along the three polarization directions. Data are extracted by subtracting the average of the non-magnetic signal for UD71 at (2 0 0) and OP95 at (1 0 0) from the UD71 (1 0 0) data. Lines are fit results assuming that the signal in all three principal polarization directions comes from a decomposition of independent magnetic scattering in the ab plane (M_{ab}) and along c axis (M_c). Strong evidence of existence of M_c comes from the large signal in the || X and P || Y channels.