Spin susceptibility of charge ordered YBa$_2$Cu$_3$O$_y$ across the upper critical field


Introduction

The upper critical field $H_{c2}$ is a fundamental, and technologically important, property that measures the ability of a superconductor to withstand magnetic fields. Recently, there has been a controversy regarding $H_{c2}$ values in high-$T_c$ copper-oxides. The dispute has become particularly acute in the context of the competition between superconductivity and charge density wave (CDW) order in underdoped YBa$_2$Cu$_3$O$_y$. Since the issue has been tackled almost exclusively by macroscopic techniques so far, there is a clear need for local-probe measurements.

Experimental

We have used NMR to measure the field dependence (up to 45 T on the NHMFL hybrid magnet) of the spin susceptibility $\chi_{\text{spin}}$ at low temperature ($T$) in charge ordered YBa$_2$Cu$_3$O$_y$. More specifically, we have measured the total $^{17}$O Knight shift in four different crystals and have determined its spin part $K_{\text{spin}}$, proportional to $\chi_{\text{spin}}$ of the CuO$_2$ planes, by subtracting the orbital contribution, while the contribution from diamagnetic shielding was found to be negligible at the fields used. Even though in the cuprates, $\chi_{\text{spin}}$ is in general not related to $N(E_F)$ in a simple way, we expect the field dependence of $\chi_{\text{spin}}$ at low $T$ to reflect the field-dependence of $N(E_F)$.

Results and Discussion

The central result of this study is the observation of an essentially linear increase in $\chi_{\text{spin}}$ up to a point in the range of 20 to 40 T, followed by a constant value. This saturation point agrees quantitatively with $H_{c2}$ values claimed in [G. Grissonnanche et al., Nat. Commun. 5, 3280 (2014)], showing a very large depression around $p = 0.12$ doping (Fig.1). Our data further show that a large pseudogap persist above $H_{c2}$ in the zero-temperature limit and that $\chi_{\text{spin}}$ is insensitive to the onset of three-dimensional long-range charge-density-wave (CDW) order.

Conclusions

Our results [1] show that short-range CDW order (already present in zero field) reconstructs the Fermi surface and reduces $H_{c2}$ in underdoped YBa$_2$Cu$_3$O$_y$. They also show that the pseudogap is a ground-state property, independent of the superconducting gap.

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References