High Field Magneto-Transport Near a Quantum Critical Point in High Temperature Superconductors

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Introduction

The subject of this study, $BaFe_2(As_{1-x}P_x)_2$, is an unconventional superconductor with anomalous normal-state transport properties, including T-linear resistivity [1,2]. Prior to this year we have identified a scaling relationship between magnetic field and temperature in the optimally doped member of this series (*x = 0.31*). Here we have extended this study to other compositions (*x* values) in this doping series.

Experimental

We measured the in-plane magnetoresistance of $BaFe_2(As_{1-x}P_x)_2$ with field parallel to the c-axis. Ohmic contacts were obtained with a combination of gold sputtering and Epotek h20e conductive epoxy. To suppress superconductivity at low temperatures and maximize the parameter space for the scaling analysis we used the NHMFL's pulsed field facility at Los Alamos National Laboratory to access magnetic fields up to 65 Tesla.

Results and Conclusions

In our last two experimental sessions we where able to identify that Magnetic field-temperature scaling holds not only at optimal composition but also at high temperatures for samples near optimal composition up to some cutoff in doping phase diagram (see Fig. 1). This means that the scaling applies to the region of parameter space expected for quantum critical phenomena and therefore strongly supports the hypothesis that the anomalous transport properties of $BaFe_2(As_{1-x}P_x)_2$ are the result of quantum critical physics. The particular scaling relationship we have found, in which the scattering rate is just given by a quadrature sum of T and B, is highly unusual in that field and temperature seem to have identical roles in determining the transport properties. This limits severely the theories that could explain T-linear resistivity in this material because magnetic field only couples very selectively to electronic degrees of freedom.

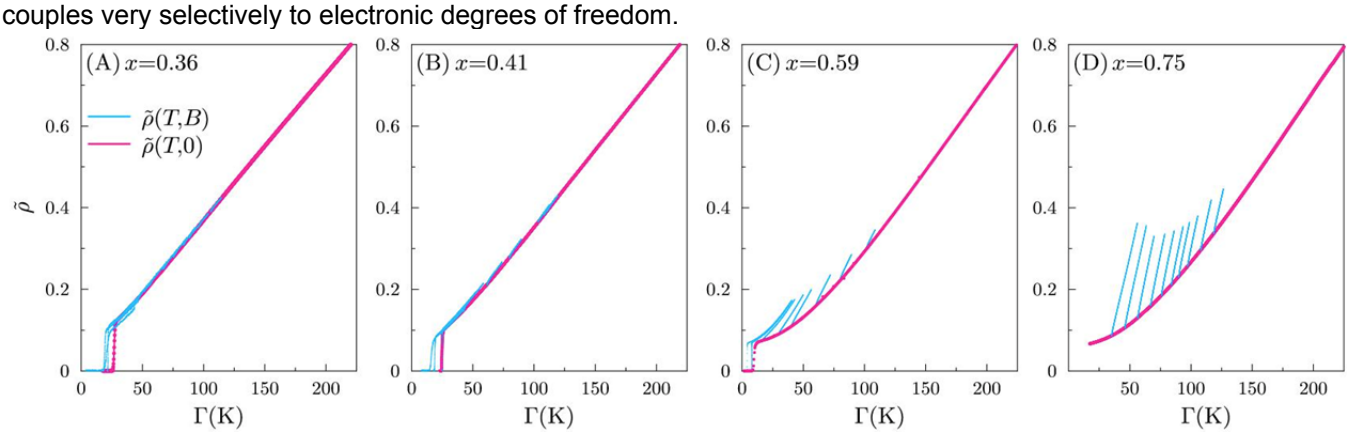

Figure 1. Normalized resistivity (ρ/ρ(273K)) plotted against the quadrature sum of Magnetic Field and Temperature (Gamma, measure in Kelvin); near optimal doping the zero field resistivity (pink) and the resistivity in the presence of a magnetic field (blue) is a single linear function of this quantity for high temperatures (above T_c), but no scaling obtains for *x > 0.5*.

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References

[1] Kasahara, S. *et al.,* Physical Review B, **81**, 184519 (2010)
[2] Analytis, J. G., *et al.*, Nature Physics, **10**, 194-197 (2014)