Susceptibility measurements on single crystals of the magnetically ordered superconductor $RbEuFe_4As_4$ in fields up to 65 T

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Introduction

The superconducting phase diagram of single crystal $RbEuFe_4As_4$ (T_c ~ 36.5 K), which has long-range Eu magnetic order [1,2] at T_m ~ 15 K, has been measured in pulsed magnetic fields up to 65 T. Small superconducting anisotropy which decreases with temperature is observed, trending towards inversion. Significant Pauli paramagnetic limiting effects are observed, suggesting a possible low temperature FFLO state [3,4] above the 65 T limit of the magnet.

Experimental

The proximity detector oscillator (PDO) technique was used to measure superconducting transitions on single crystals of $RbEuFe_4As_4$ with H // (110) and H // (001) at various temperatures in pulsed magnetic fields up to 65 T using the NHFML 65 T Pulse Field Facility at Los Alamos National Laboratory.

Results and Discussion

In **Fig. 1** we show magnetic susceptibility vs temperature of $RbEuFe_4As_4$ with H // (110). In both zero field- and field-cooled measurements, the magnetic transition at ~15 K is clear; multiple techniques agree this is due to long-range Eu order [1,2]. In **Fig. 2**, we show the pulse field measurement-derived magnetic phase diagram. The data rapidly falls away from the high-temperature low-field Ginzburg-Landau slopes obtained via calorimetry [5], indicating the importance of paramagnetic and/or multi-band effects. A model incorporating a Fermi surface of warped cylinders captures the curvature well, yielding a Maki parameter $\alpha = \sqrt{2}*H_{orb}(0)/H_{Pauli}(0) > 1.8$, suggesting the possibility of a Fulde-Ferrel-Larkin-Ovchinnikov (FFLO) superconducting state [3,4] at high field / low temperature. The temperature dependence of the anisotropy can be interpreted as being an effect of both Pauli limiting and an anisotropic spin susceptibility.

Conclusions

The low Pauli limiting fields observed in-plane suggest the presence of an FFLO state at low temperature, but the critical fields at low temperature likely exceed the measurement limit on the 65 T magnet by 10 to 20 T. The small, temperature dependent superconducting anisotropy is consistent with observation at low fields of weak coupling between the superconductivity and magnetic order.

Acknowledgements

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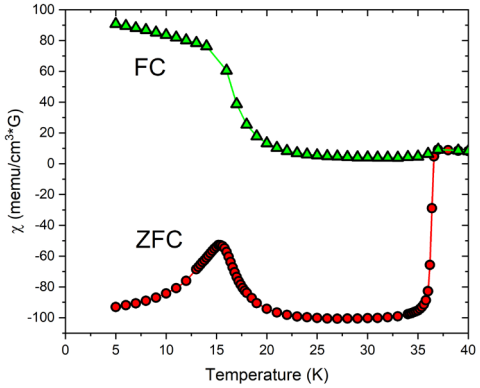

Fig.1 Magnetic susceptibility vs T of $RbEuFe_4As_4$ with H // (110) in 10 G. The cusp deep in the superconducting state is due to bulk Eu magnetic order.

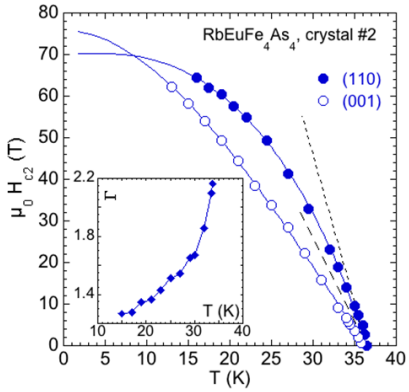

Fig.2 Magnetic phase diagram of $RbEuFe_4As_4$. A low Pauli limiting field causes the strong curvature and suggests a low-T FFLO state at H > 65 T.