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Superconductivity magnetically enhanced by spin domains: The FFLO state

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We report angular dependent heat capacity, penetration depth, and magnetization measurements on $CeCoIn_5$, a clean and anisotropic strongly correlated superconductor. $CeCoIn_5$ has a number of unusual properties that vastly enhance the coupling of an external magnetic field to the electron spins (paramagnetic limit) over the traditional orbital coupling. We will show that the angle between an external magnetic field and the conducting planes determines the high-field superconducting ground state. Our results point to the existence of the Fulde-Ferrell-Larkin-Ovchinnikov state at fields above 10 tesla and temperatures below 300 mK with the field applied parallel to the conducting planes. The FFLO state, first predicted in 1964, consists of a periodic array of ferromagnetic walls of depaired electrons coexisting with superconducting regions. For small tilt angles, where there is an admixture of paramagnetic and orbital effects, the superconducting order parameter assumes higher Landau levels within the FFLO state. This is experimentally realized as a cascade of phase transitions in the magnetization. Finally, for an applied field at angles greater than approximately 15 degrees out of the planes, no FFLO signature is observed and a BCS-type superconducting state emerges.

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