Field-induced Transition in CeRhIn$_5$; Possible Fermi-surface Topology Change

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Introduction
Currently, two theoretical proposals are being discussed for the nature of quantum criticality. The first is the spin-density-wave (SDW) type which is supposed to favor the occurrence of heavy fermion superconductivity (as observed in some Ce-based heavy fermion compounds). The second is described in terms of the destruction of the local Kondo singlet at $T=0$. The main difference of these two theoretical descriptions is associated with the Kondo screening process at sufficiently low temperatures. In the latter case, the Kondo screening is fully developed only at the quantum critical point; the f-electrons are assumed to be localized in the antiferromagnetic state, but delocalized in the paramagnetic side, leading to a sudden change of Fermi-surface topology. However, for the SDW-type of quantum criticality, Kondo screening is already developed in the magnetic state, and hence no sharp transition of Fermi-surface is expected at the quantum critical point. Experimental investigations of Fermi-surface topology around a quantum critical point are, therefore, crucial for developing a theory of quantum criticality.

The heavy fermion family CeTIn$_5$ (T=Co, Rh, Ir) provides great opportunities to study these issues. By using magnetic fields of up to 75 T, we demonstrate what appears to be a field-induced quantum critical point in CeRhIn$_5$. At this transition, the Fermi surface appears to change its topology.

Experimental
De Haas-van Alphen (dHvA) oscillations were recorded in the differential susceptibility ($dM/dH$) of high-quality, single-crystals. The susceptibility was measured using triply compensated susceptometers in the 75 and 65 T short-pulse magnets at NHMFL-LANL [1].

Results and Discussion
It has been known in literature that the magnetic state in CeRhIn$_5$ survives up to very high magnetic field, undergoing a metamagnetic transition at a field of about 2.5 T. This was further verified in our dHvA experiments. Fig. 1 shows the dHvA signals as a function of magnetic field at $T=0.5$ K; a metamagnetic transition ($\mu_0H_M = 2.7$ T) and a high-magnetic-field transition ($\mu_0H_c = 50$ T) are clearly observed. Furthermore, quantum oscillations can be resolved in high fields; the shape of waveform and the component frequencies differ on either side of the critical field $H_c$. This suggests that there is a change in Fermi-surface topology at $H_c$. Further experiments are in progress [1].

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References