Anomalous superconducting properties coupled with antiferromagentic quantum criticality

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The heavy-fermion superconductor $CeCoIn_5$ (a HoCoGa5-type tetragonal structure, T_c=2.3 K) shows clear signatures of quantum criticality in the paramagnetic state above the superconducting upper critical field H_{c2} [1], but its role in the superconducting (SC) state is unresolved. Recent muon spin relaxation experiments for the mixed alloys $CeCo(In_{1-x}Zn_x)_5$ revealed that the AFM order develops above x_c=0.03, characterized by a continuous increase in the AFM transition temperature T_N with x, and the SC magnetic penetration depth exhibits the diverging behavior toward x_c [2]. These findings suggest that the AFM quantum critical point (QCP), corresponding to the Zn concentration of x_c, exists deep inside the SC phase, and the AFM fluctuations enhanced around the QCP play a significant role in the various unconventional nature of the superconductivity in $CeCoIn_5$. We have thus performed elastic neutron-scattering experiments for $CeCo(In_{1-x}Zn_x)_5$ with $x > 0.03$ using the triple-axis spectrometers GPTAS and HQR located at the JRR3 research reactor of JAEA.

Displayed in Fig. 1 is the neutron-scattering profile at the (1/2,1/2,1/2) position for x=0.045 (T_c=1.85 K), obtained by the scan at the momentum transfer of q=(ζ, ζ, 1/2). A Bragg peak originating for the AFM spin alignment appears at 0.67 K, and the peak intensity is reduced with increasing temperature. The AFM transition temperature is estimated to be T_N=1.25 K from the disappearance of the peak, which is smaller than T_c. The AFM Bragg peaks are also observed at the equivalent q positions in the reciprocal space investigated. A similar trend is also found in the other Zn concentrations above x=0.035, and the obtained x-T phase diagram is consistent with that suggested by the muon spin relaxation experiments [2]. These experimental results indicate that the AFM order with the propagation vector of (1/2,1/2,1/2) coexists with the SC state above x~0.03.

[1] C. Petrovic et al., JPCM 13, L337 (2001).

[2] W. Higemoto et al., PNAS 119, e2209549119 (2022).

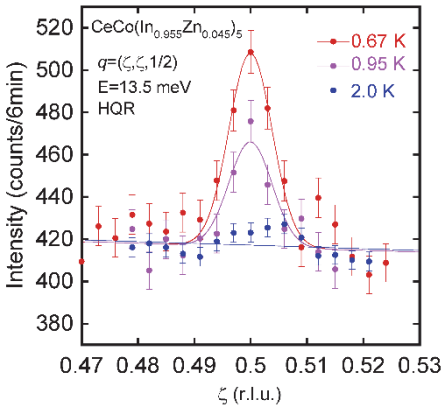

Fig. 1. Neutron-scattering profile at the (1/2,1/2,1/2) position for x=0.045 (T_c=1.85 K).