

Photoemission on the Kondo lattice system CeNi_2Ge_2

D. Ehm¹, R. Claessen², Th. Finteis¹, S. A. Kellar³, P. A. Bogdanov³,
X. J. Zhou³, V. Eyert², F. Reinert¹, Z. X. Shen³, S. Hüfner¹

¹Fachrichtung Experimentalphysik, Universität des Saarlandes, D-66041 Saarbrücken,
Germany

²Experimentalphysik II, Universität Augsburg, D-86135 Augsburg, Germany

³Department of Physics, Applied Physics and Stanford Synchrotron Radiation Laboratory,
Stanford University, Stanford, CA 94305, USA

A number of intermetallic rare earth compounds appear to be phenomenologically related to the concept of the Kondo lattice [1]. An example is the non-magnetic heavy-fermion (HF) compound CeNi_2Ge_2 whose thermodynamic properties indicate non-Fermi-liquid behaviour (NFL) induced by a proximity to an antiferromagnetic quantum critical point (QCP) [2]. The strong electronic correlations responsible for these low energy properties should also be reflected in the experimental electronic bandstructure. Whereas thermodynamic investigations have a more integral character, angle-resolved photoelectron spectroscopy (ARPES) is an ideal tool for probing the momentum dependence of the electronic bandstructure. Due the small relevant energy scales typically encountered in 4f systems, very high instrumental resolution, both in energy and angle, are required for meaningful ARPES experiments.

The experiments were performed on beamline 10.0.1.1 with its high energy resolution spectrometer (HERS). The very small focus of the monochromator and the 2 rotational and 3 translational degrees of freedom of the low temperature (down to 10 K) manipulator were essential for these measurements. In addition, the high brightness of the light source is very important for photoemission studies on rare earth compounds due to short surface lifetime of these materials, which is caused by their high chemical reactivity.

Up to now, only ARPES results on monocrystalline thin films of this material on a single crystalline surface were published which did not allow to resolve the most interesting spectral structures near the Fermi energy [3–5]. Therefore, here we present very high resolution measurements ($\Delta E \approx 11$ meV, $\Delta \vartheta \approx 0.3^\circ$) at low temperature ($T \approx 15$ K) on surfaces which are prepared by *in situ* cleaving of a single crystal.

Fig. 1 shows the energy distribution curves measured along the (100) (i.e. Γ -N-Z) azimuth using an excitation energy of $h\nu = 35$ eV. This photon energy was chosen due to previous $h\nu$ -dependent experiments which show spectral weight near E_F at defined emission angles most pronounced at this photon energy. The dispersion of different spectral features is clearly observable. Special attention

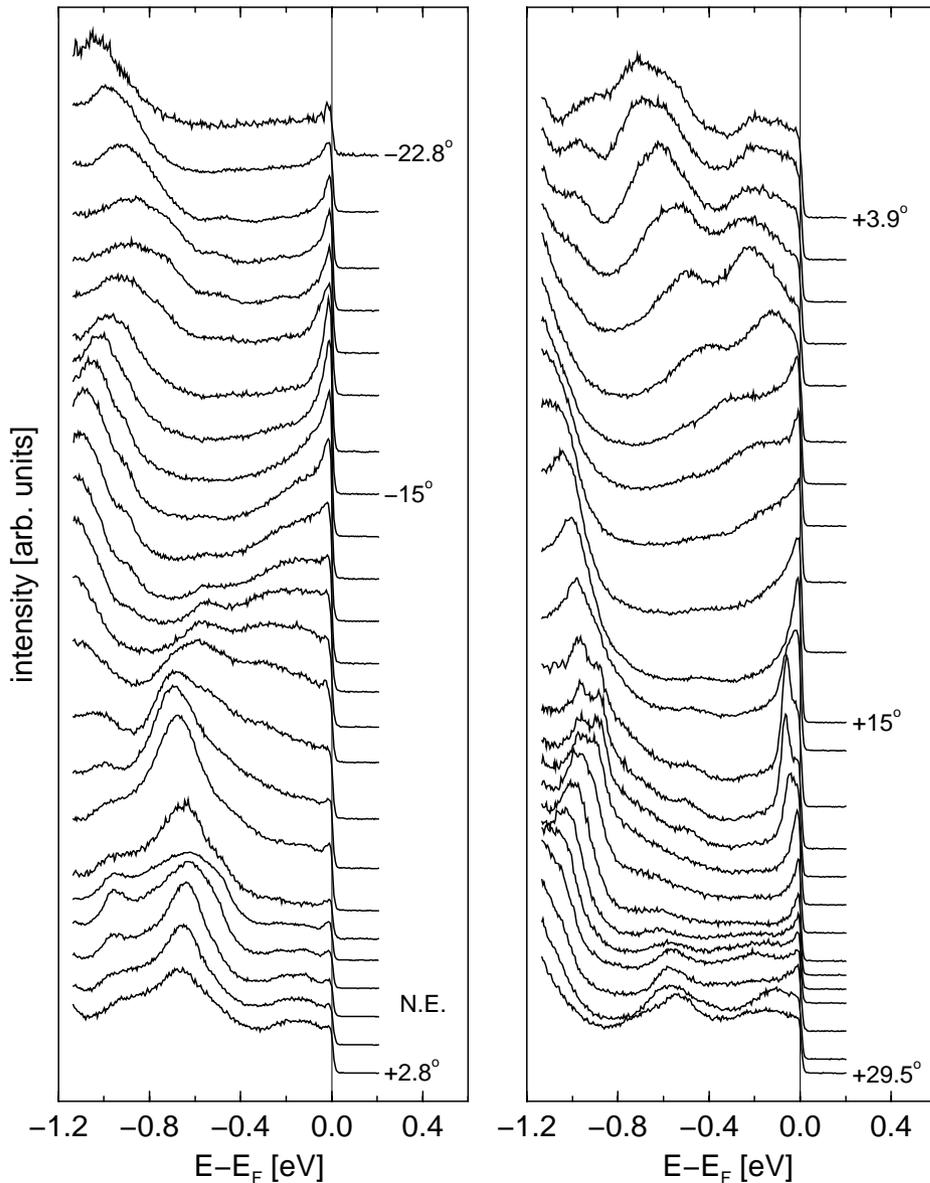


Figure 1: Angle-resolved photoemission spectra taken at 35 eV photon energy and temperatures down to 15 K showing the near Fermi-edge region along the (100) azimuth, i.e. the momentum \mathbf{k} is probed along the Γ -Z-N-plane. The spectra were taken at angular steps of about 0.3° ; here we show only every third one.

For comparison the figure also contains theoretical bands obtained from density functional bandstructure calculations using the augmented spherical wave (ASW) method and the local density approximation (LDA). Due to the unknown size of the surface-perpendicular momentum component k_\perp we compare to calculations for $k_\perp = 0$ (Γ -Z line; dashed curves) and $k_\perp = \frac{\pi}{c}$ (Z- Γ line; dotted curves). Good agreement between theory and experiment is observed for the band which disperses from about -0.7 eV at $k_\parallel = 0$ towards the Fermi level. For the other bands we find no clear correlation between experimental and theoretical dispersion on the small energy scale of Fig. 2. This is attributed to the unknown size of the probed k_\perp in this three-dimensional material. In

should be paid to the peak close to E_F which appears very sharp and intense at emission angles of about $\pm 15^\circ$ around normal emission. It displays a parabolic dispersion symmetric about a very shallow energy minimum at $+15^\circ$ and seems to disperse through the Fermi level on either side of it. In Fig. 2 the same data are displayed as a gray scale intensity map in the E- \mathbf{k} -plane. Here the dispersion of bands is even more obvious.

the next step we intend to perform more photon energy-dependent measurements in order to fix the momentum \mathbf{k} three-dimensionally, e.g. by determining an inner potential V_0 and an analysis of the ARPES data on the basis of free-electron-like final states. This should also help to elucidate the nature of the shallow metallic band at $k_{\parallel} = 0.9 \text{ \AA}^{-1}$.

Despite the need for further measurements, the present high resolution ARPES data on CeNi_2Ge_2 single crystals prove the existence of sharply defined and dispersive excitations on a rather small energy scale within the chemical potential.

This work was supported by the Sonderforschungsbereich (SFB) 277 and the Deutsche Forschungsgemeinschaft (DFG) CL 124/4-1.

Principal investigator: Dirk Heinrich Ehm, University of Saarbruecken. Email: d.ehm@rz.uni-sb.de. Telephone: +49-(0)681-302-2247.

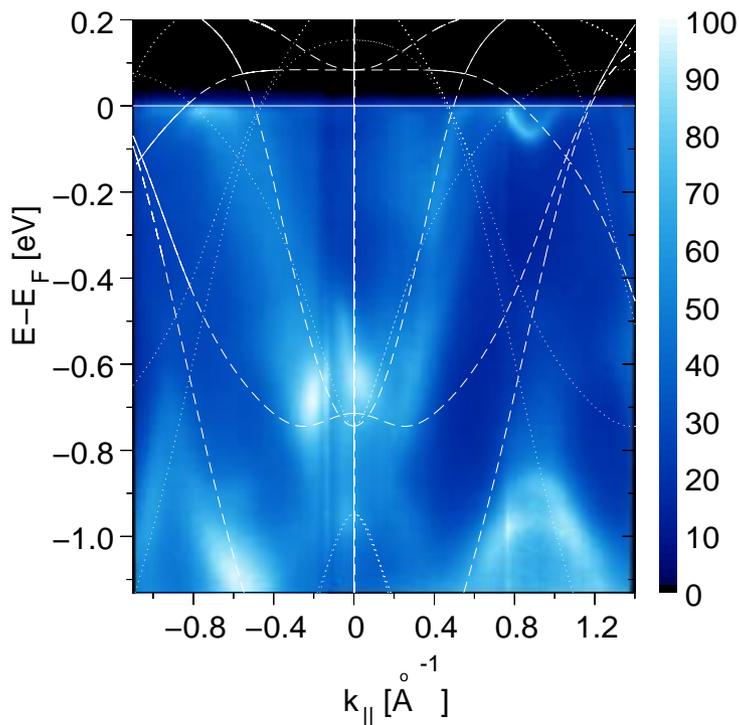


Figure 2: Gray scale intensity map of the spectra of Fig. 1. The dashed and dotted curves represent the results of LDA-bandstructure calculations. See text for details.

References

- [1] S. Doniach. *Physica B*, 91:231–234, 1977.
- [2] F. Steglich, B. Buschinger, P. Gegenwart, M. Lohmann, R. Helfrich, C. Langhammer, P. Hellmann, L. Donnevert, S. Thomas, A. Link, C. Geibel, M. Lang, G. Sparn, and W. Assmus. *J.Phys.:Condens.Matter*, 8:9909–9921, 1996.
- [3] B. Schmied, M. Wilhelm, U. Kübler, M. Getzlaff, G. H. Fecher, and G. Schönhense. *Physica B*, 230-232:290–293, 1997.
- [4] B. Schmied, M. Wilhelm, U. Kübler, M. Getzlaff, G. H. Fecher, and G. Schönhense. *Surface Science*, 377-379:251–255, 1997.
- [5] M. Getzlaff, B. Schmied, M. Wilhelm, U. Kübler, and G. H. Fecher. *Phys.Rev.B*, 58(15):9670–9673, 1998.