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## Metal State with Spontaneously Broken Time-Reversal Symmetry above the Superconducting Phase Transition

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Fundamentally, what distinguishes a superconducting state from a normal state is a spontaneously broken symmetry corresponding to the long-range coherence of Cooper pairs, leading to zero resistivity and diamagnetism.

Here we report a set of thermodynamic, transport and muon spectroscopy observations on a series of hole-doped  $\text{Ba}_{1-x}\text{K}_x\text{Fe}_2\text{As}_2$ . Our specific-heat measurements indicate the formation of fermionic bound states when the temperature is lowered from the normal state. However, at the doping level  $x \approx 0.8$ , instead of the characteristic onset of diamagnetic screening and zero resistance expected below a superconducting phase transition ( $T_c$ ), we observe the opposite effect: the generation of self-induced magnetic fields in the resistive state, measured by spontaneous Nernst effect [1] and muon spin rotation experiments [2,3] (see Fig.1). This combined evidence indicates the existence of a bosonic metal state in the temperature range  $T_c \leq T \leq T_{Z2}$  in which Cooper pairs of electrons lack coherence, but the system spontaneously breaks time-reversal symmetry ( $Z_2$ ). The observations are consistent with the theory of a state with fermionic quadrupling, in which long-range order exists not between Cooper pairs but only between *pairs of pairs*.

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[1] V. Grinenko et al., Nat. Phys. 17, 1254–1259 (2021).

[2] V. Grinenko et al., Phys. Rev. B 95, 214511 (2017).

[3] V. Grinenko et al., Nat. Phys. 16, 789–794 (2020).

**Primary authors:** Dr GRINENKO, Vadim (Institute for Solid State and Materials Physics, Technische Universität Dresden, Dresden, Germany); Dr WESTON, Daniel (Department of Physics, KTH Royal Institute of Technology, Stockholm, Sweden); Dr CAGLIERIS, Federico (National Research Council, SPIN, Genova, Italy); Dr WUTTKE, Christoph (Leibniz-Institute for Solid State and Materials Research, Dresden, Germany); Dr STEGANI, Nadia (National Research Council, SPIN, Genova, Italy); Prof. HESS, Christian (Bergische Universität Wuppertal, Germany); Dr GOTTSCHALL, Tino (Dresden High Magnetic Field Laboratory (HLD-EMFL), Germany); Dr MACCARI, Ilaria (Department of Physics, KTH Royal Institute of Technology, Stockholm, Sweden); Dr GORBUNOV, Denis (Dresden High Magnetic Field Laboratory (HLD-EMFL), Germany); Dr ZHERLITSYN, Sergei (Dresden High Magnetic Field Laboratory (HLD-EMFL), Germany); Prof. WOSNITZA, Jochen (Dresden High Magnetic Field Laboratory (HLD-EMFL), Germany); Mr SHIPULIN, Ilya (Leibniz-Institute for Solid State and Materials Research, Dresden, Germany); Prof. RYDH, Andreas (Department of Physics, Stockholm University, Stockholm, Sweden); Dr KIHOU, Kunihiro (National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan); Dr LEE, Chul-Ho (National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan); SARKAR, Rajib (TU Dresden); Dr GARAUD, Julien (Institut Denis Poisson CNRS-UMR, Université de Tours, France); Prof.

BÜCHNER, Bernd (Leibniz-Institute for Solid State and Materials Research, Dresden, Germany); KLAUSS, Hans-Henning (TU Dresden); Prof. BABAEV, Egor (Department of Physics, KTH Royal Institute of Technology, Stockholm, Sweden)

**Presenter:** KLAUSS, Hans-Henning (TU Dresden)

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