Superconducting fluctuations in a thin NbN film probed by the Hall effect

Daniel Destraz,[1*] Konstantin Ilin,[2] Michael Siegel,[2] Andreas Schilling,[1] and Johan Chang[1]

[1]Department of Physics, University of Zurich, Switzerland
[2]Institute of Micro- and Nanoelectronic Systems (IMS), Karlsruhe Institute of Technology, Germany
[*]destraz@physik.uzh.ch

University of Zurich[UZH]

Introduction

The observation of a pseudogap phase in thin films of NbN has led to the proposal of normal state preformed Cooper pairs. This phase fluctuating scenario should be confirmed experimentally. As a first step in that, we have studied the superconducting fluctuations outside the pseudogap phase. More precisely, we performed Hall effect measurements on a thin film of NbN with a thickness of 11.9 nm [1].

Resistance measurements

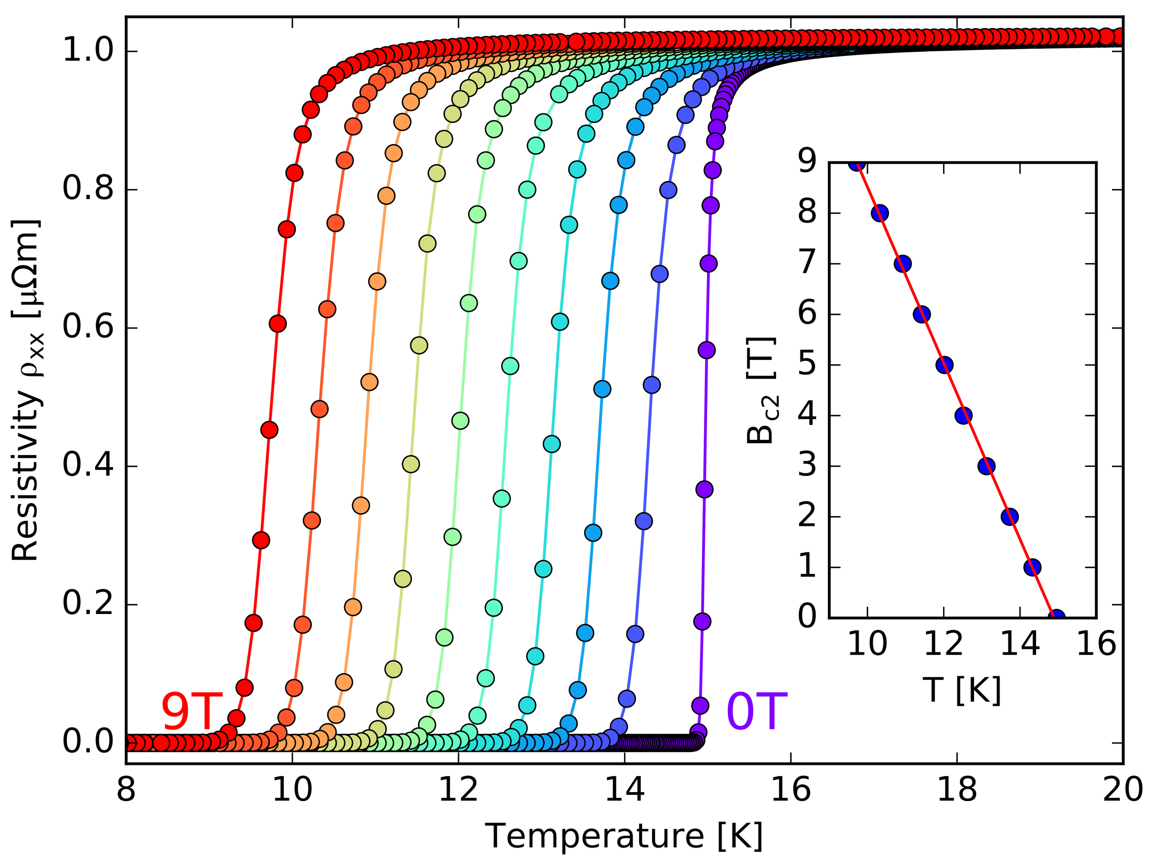

FIG 1. Resistance versus temperature for different magnetic fields applied perpendicular to the NbN film. In zero magnetic field, the superconducting transition temperature is T_c = 14.96 K. For the critical field at zero temperature we find $H_c(0)$ = 18 T and for the coherence length we find ξ = 4.3 nm. Essentially no magnetoresistance is observed.

Hall effect measurements

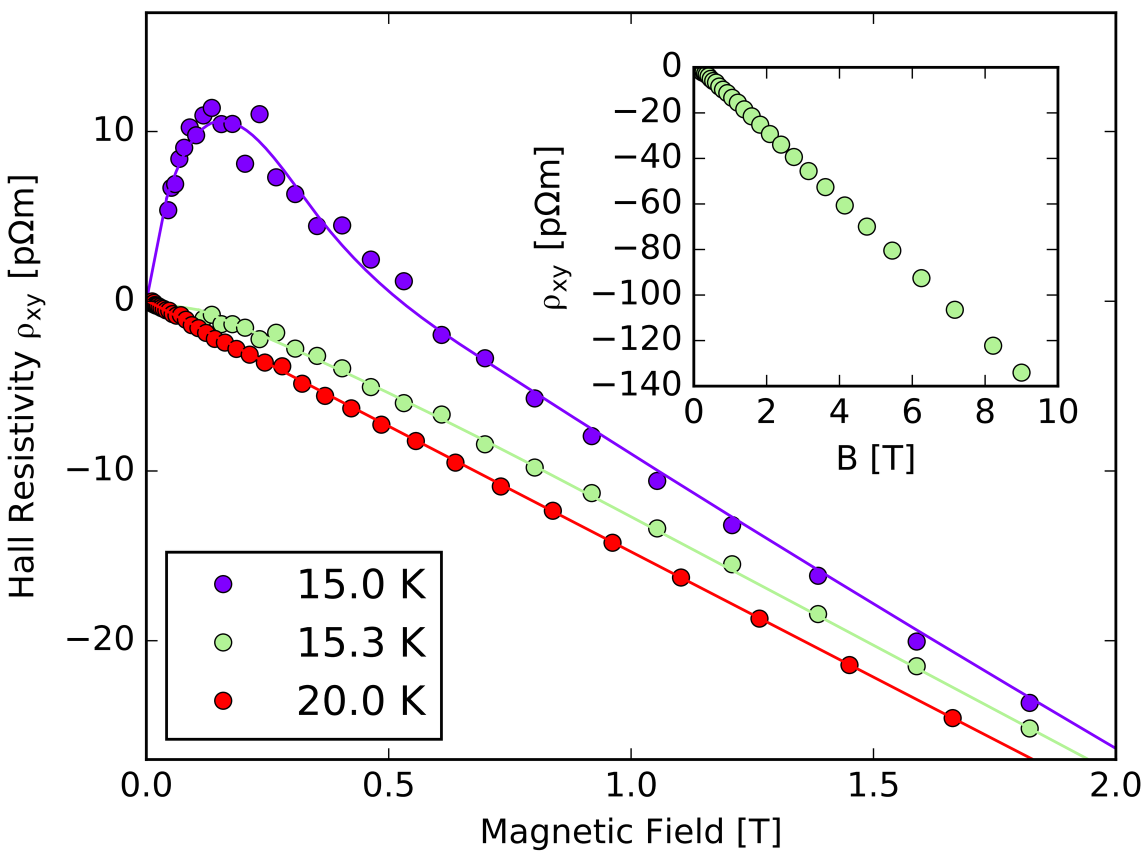

FIG 2. Hall resistance isotherms for T ≈ T_c, 15.3 K, and 20.0 K respectively. The high-field linear field dependence yields a carrier density of n = 4.2 × 10^{29} m^{-3}. In the low field limit, a deviation from a negative linear dependence to a positive response is found in a narrow temperature range around T_c. This striking sign change is due to superconducting fluctuations.

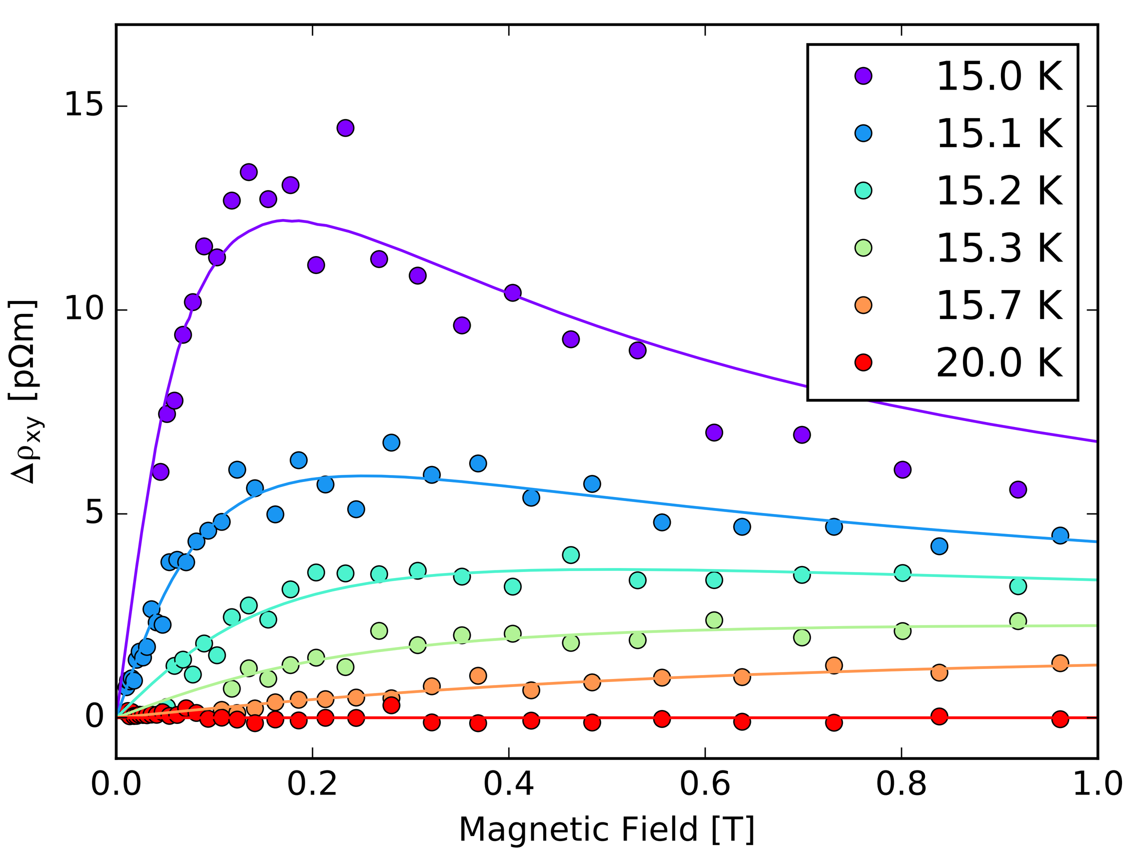

FIG 3. Hall resistance due to superconducting fluctuations obtained by subtracting the quasiparticle contribution by fitting a straight line through 0 to the high field part of FIG 2.

Properties of the superconducting fluctuations

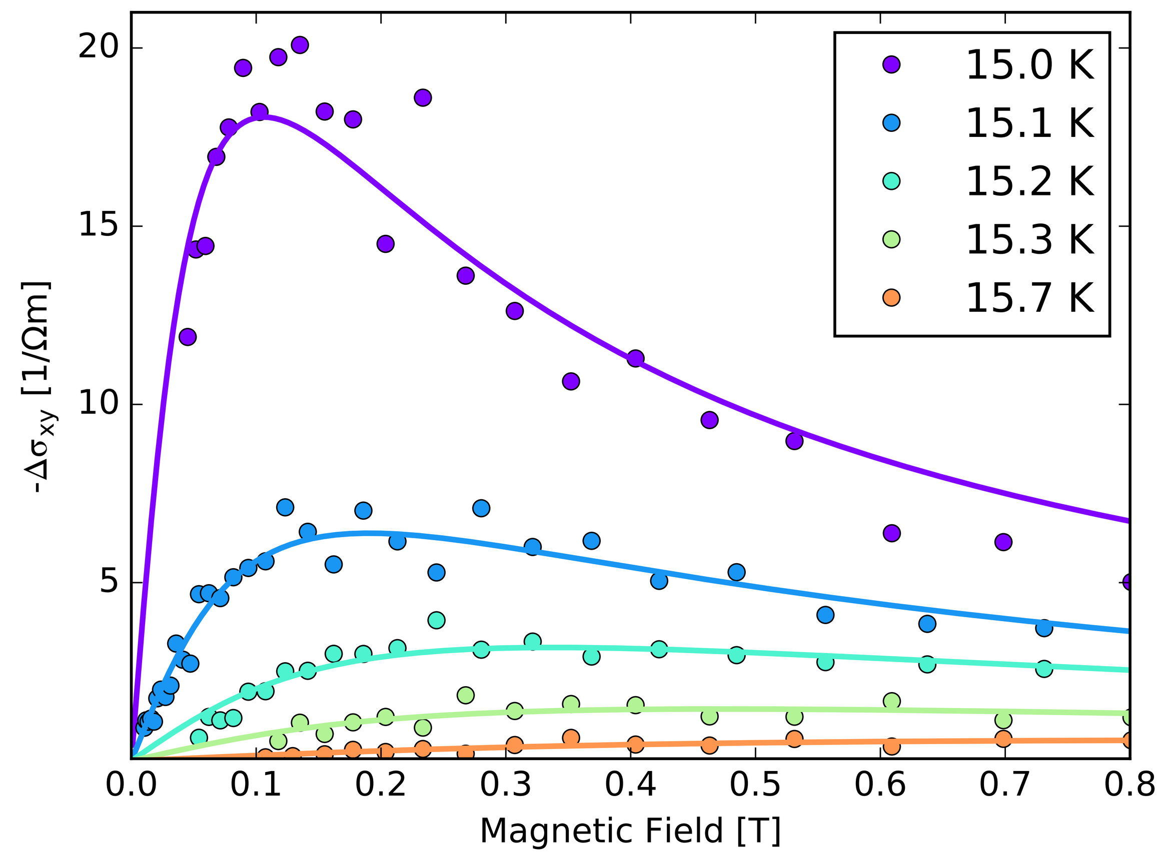

FIG 4. The contribution from superconducting fluctuations to the Hall conductivity. They decay within less than 1 K.

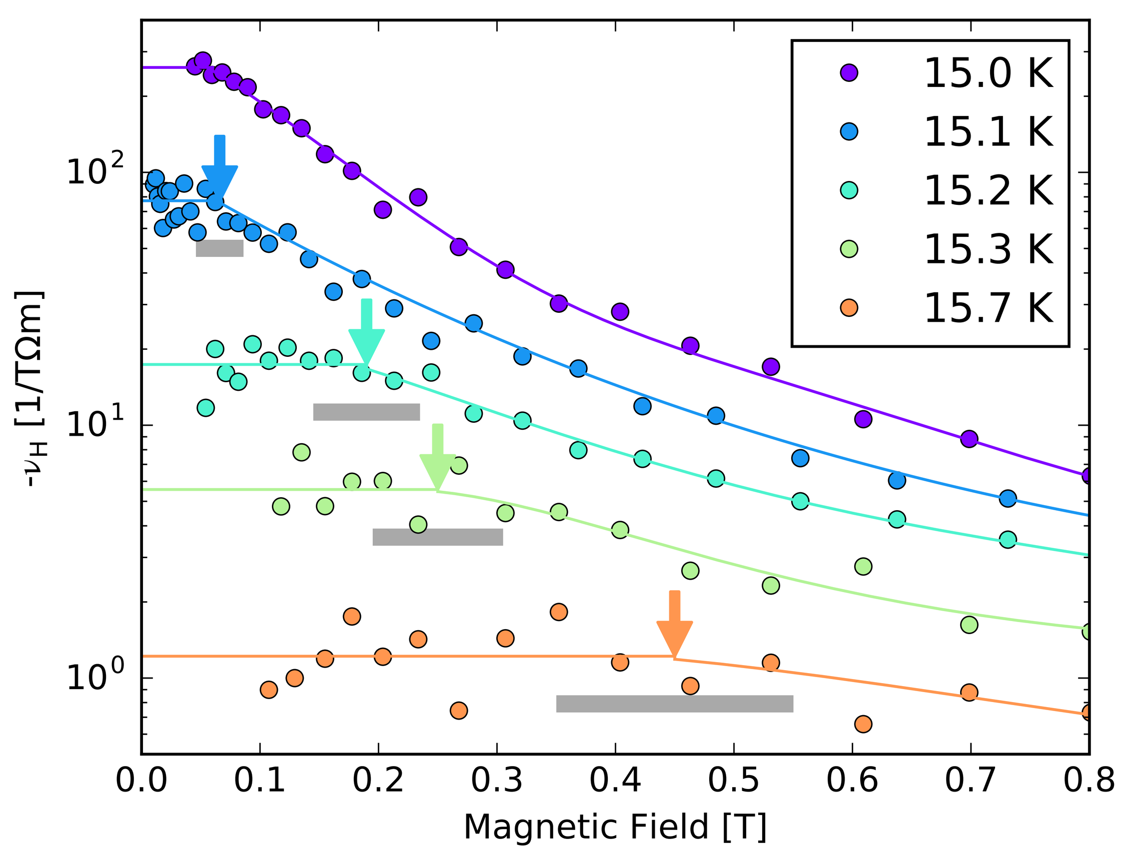

FIG 5. The conductivity of the superconducting fluctuations divided by the field ($\nu_H = \Delta\sigma_{xy}/B$). The arrows indicate deviation from an low-field constant plateau. The grey bars indicate the estimated uncertainty.

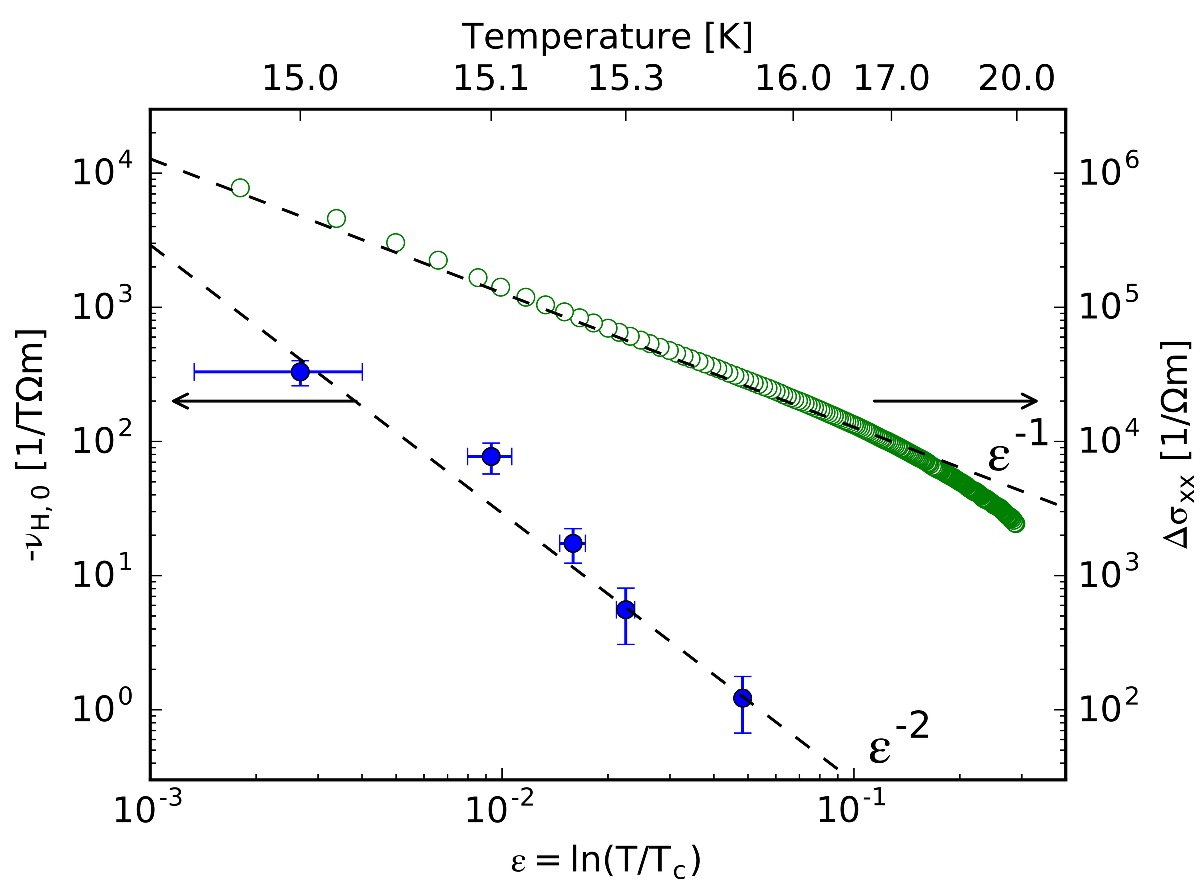

FIG 6. The values of the low field plateaus shown in FIG 5. The dashed lines are the theoretical predictions without any adjustable parameters for $\Delta\sigma_{xx}$ (Aslamazov-Larkin theory) and $\Delta\sigma_{xy}$ [2].

Conclusions

We showed that the superconducting fluctuations can be easily extracted from the Hall effect due to the difference in sign compared to the quasiparticle contribution. Both the longitudinal and Hall conductivity follow the theoretical prediction. The measurements are thus consistent with a standard Gaussian (amplitude) fluctuating scenario.

References

[1] Daniel Destraz, Konstantin Ilin, Michael Siegel, Andreas Schilling, and Johan Chang Phys. Rev. B **95**, 224501 (2017)
[2] K. Michaeli, K. S. Tikhonov, and A. M. Finkel'stein, Phys. Rev. B **86**, 014515 (2012)