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Exploring the ways in which superconductivity breaks down close to the upper critical field

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In Type-II superconductors, there are two critical fields, one corresponding to the end of perfect expulsion of field (Hc1), and the other to the destruction of superconductivity (Hc2). Between the two, we have the mixed state, where magnetic lines of flux enter the material, creating regions of normal state with the core of the associated magnetic vortex. As the field increases, eventually these regions of normal state overlap, and the superconducting state disappears – the orbital mechanism for the destruction of superconductivity.

The coherence length, which sets the size of the vortex core, is directly linked to Hc2. It has been known for a long time that this description cannot always explain the observed values of Hc2, which are sometimes lower than expected. This is characterized by the Maki parameter, and is usually considered to be a signature that Pauli paramagnetic effects are non-negligible, and then lead to the destruction of superconductivity, breaking up the Cooper pairs through the Zeeman splitting of the spin-up and spin-down Fermi surfaces. This effect is also a potential driver for a spatially modulated superconducting gap, with the most well-known form of this being the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) superconducting state.

Sometimes, however, some other kind of response to the field develops, such as the Q-phase in CeCoIn5. To explore this type of behaviour often requires high magnetic fields. I will present a small selection of examples where the changes in the magnetic response close to Hc2 have been identified using magnetic fields presently available at neutron scattering facilities. I will end with a case where we cannot experimentally reach the upper critical field, namely the high-Tc superconductor YBa2Cu3O7, and show what we have been able to conclude from going up to the 25 T that was available at the High Field Magnet at the Helmholtz-Zentrum Berlin.

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