Quantum mechanical effects in superconductors visualized and quantified with polarized neutrons

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The most prominent macroscopic quantum mechanical effects in superconductivity are the well known zero electrical resistance and the Meissner effect (magnetic field expulsion), less known is the effect of magnetic flux trapping (pinning) in materials in their superconducting intermediate state. The investigations of flux trapping are still subject of many publications since L. Landau proposed in 1938 a solution that a body in the intermediate state consists of alternating layers of superconducting and normal phase [1]. The intermediate state reveals phenomena that were not predicted by the first theories, and experiments are still necessary to understand better flux trapping/pinning in type-I superconductors [2]-[4].

Recent investigations with the new instrument for polarized neutron tomography (PONTO) with large (>cm^3) and virtually zero demagnetization samples (lead, superconductor type-I and niobium, type-II) yielded very surprising results [5], [6]. It could be shown that both the Meissner effect and flux trapping in high purity lead samples (type-I superconductor) occur different for the crystalline (mosaic spread 1.7°) and extreme homogeneous and pure (99.999wt-%) polycrystalline samples, respectively. The trapped flux of an uniform external magnetic field applied to the lead polycrystalline samples is for $T < T_c$ not uniform distributed but centered and squeezed around the rod axis of the samples (see Fig.1). Calculations concerning the partial Meissner effect and flux trapping agree perfectly with experimental resulting images if a "squeezed" Gaussian shaped B-field is assumed.

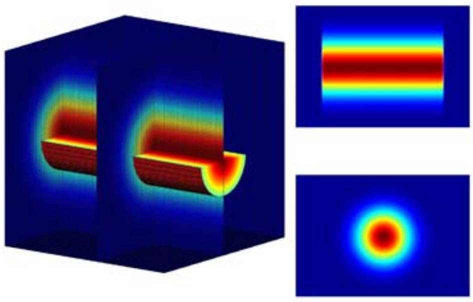

Fig.1 Shape of the calculated trapped magnetic field

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