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Theory of Nonlinear Luttinger Liquids[1]

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We developed a generalization of the Luttinger liquid theory which allowed us to consider threshold singularities in the momentum-resolved dynamic response functions at arbitrary momenta (*i.e.*, far away from the Fermi points). The main difficulty the new theory overcomes is the accounting for a generic non-linear dispersion relation of quantum particles which form the liquid. We derive an effective "quantum impurity" Hamiltonian which adequately describes the dynamics of the system at the near-threshold energies. The phenomenological theory for the constants of such Hamiltonian is built; it expresses the constants in terms of other measurable properties (energy spectra of the excitations) of the liquid. One of the most important dynamic correlation functions we consider is the momentum-resolved electron spectral function at arbitrary momenta. The spectral function is directly measurable in tunneling experiments. It is singular at the spectrum of the lowest-energy excitation branch. In the absence of spin polarization, this is the branch of spinon excitations. The derivation of the phenomenological relations for the threshold exponent uses the $SU(2)$ and Galilean invariance of the electron liquid. We also consider in detail the case of single-species fermions, which adequately describes the fully spin-polarized electron gas [1]. The theory of threshold exponents is valid at arbitrary wave vectors k, including the vicinities of Fermi points $\pm k_F$. There, the exponents approach universal values [2] which depend only on the Luttinger liquid parameter K. Remarkably, the found exponents differ from the predictions of the conventional linear Luttinger liquid theory. The deviations from that theory though are confined to the region close to the threshold; while being wide away from the Fermi points, the width of that region scales as $|k \pm k_F|^3$ at $k \to \pm k_F$ in the absence of spin polarization, and as $(k \pm k_F)^2$ for polarized electrons.

[1] A. Imambekov, L.I. Glazman, Phys. Rev. Lett., **102**, 126405 (2009)
[2] A. Imambekov, L.I. Glazman, Science, **323**, 228 (2009)

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