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Valentin Peschansky and puzzles of magnetotransport

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Starting from the 1950s, the Kharkov school of theoretical physics was one of the world leaders in the theory of metals. In particular, the research by V.G. Peschansky for many years was focused on studying the relationship between magnetic field dependence of resistivity components and the electron energy spectrum. V.G. Peschansky elaborated an elegant theory of magnetoresistance that took into account surface scattering of electrons. The physics of bulk 3D metals was almost exhausted by the end of 1970s and Peschansky extended his research to the low-dimensional electron systems. Through all his scientific life, V.G. Peschansky advocated the idea that magnetoresistance is a powerful tool that can be used to explore rich physics of electron systems. By now, numerous experimental and theoretical studies of magnetoresistance behavior in various systems, from simple to the most complex ones, confirm the fruitfulness of this idea.

PACS: **71.30.+h** Metal-insulator transitions and other electronic transitions;
72.15.Rn Localization effects (Anderson or weak localization);
73.40.Qv Metal-insulator-semiconductor structures (including semiconductor-to-insulator).

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1. Introduction

With age, I started feeling obligated to write occasional memoirs in order to reward distinguished scientists whom I met in my life. I appreciate them for sharing with students the overview of the architecture of science, for the object lessons in creativity and, quite important, for the lessons in regardful attitude towards the students. The latter ingredient makes a specific favorable friendly atmosphere in physical research. Particularly, I greatly appreciate Professor Valentin Peschansky not only for his remarkable contribution to the theory of metals, but also for his perpetual benevolence. Physics is made by people, and without knowing personalities the physics would be colorless, like boring black-and-white textbooks. Young scientists must know the biographies of outstanding personalities, because major scientific achievements often appear to be linked with events in their life.

I met Valentin Peschansky for the first time at the Kapitza Institute for Physical Problems (named after Kapitza after his death), in Moscow, where I was a graduate student of Professor M.S. Khaikin. The period from the 1950s to 1970s was triumphal for metal physics. Experimentalists succeeded in purifying materials and growing state-of-the-art single crystals of almost all metals. There was certainly a sort of competition among them in achieving record values of the resistance ratio, $R_{300}/R_{4.2}$, or the electron mean free path. The high quality of the studied samples inspired respect to the published data.

The research in experimental laboratories at the Kapitza Institute was in a full swing: Yu.V. Sharvin did beautiful experiments on electron focusing with point contacts. M.S. Khaikin with his young co-workers discovered numerous phenomena in microwave resonant electron transport in Bi, Sn, In, Pb, W, including the size effects in cyclotron motion of electrons. N.E. Alexeevskii and collaborators studied magnetoresistance anisotropy in Be, V, Nb. N.V. Zavaritskii studied phonon drag and acousto-magnetic effects in Sn and Al. The next generation of experimentalists, V.F. Gantmakher, V.S. Edelman, Yu.P. Gaidukov and others, grew up in these parent laboratories and started their own research also from metal physics.

The period from the 50s to the 70s was also a golden age for the Kharkov school of theoretical physics. One has to recall that Mark Ya. Azbel, Moissei I. Kaganov, Arnold M. Kosevich, Ilya M. Lifshitz, and Valentin G. Peschansky were highly creative, working at the same time and the same place. This short list of distinguished theorists could do an honor for any University all over the world. The Kharkov theorists were welcome at the Kapitza Institute; they often came to give talks at the famous Kapitza seminars and visited experimental laboratories. Their activity in the 50s and the 60s was focused on studying the relationship between observable features in electron properties in magnetic field and electron energy spectrum [1,2]. The nearly-free-electron approach has just emerged and the Fermi surfaces for the majority of metals yet remained to be explored.

Needless to say, there was a plethora of novel experimental data at the Kapitza Institute for theorists to explain; in their turn, theorists were eager to have their predictions tested experimentally. The mutual attraction of Moscow experimentalists and Kharkov theorists has made the Kapitza Institute the center of meetings and discussions, particularly in the field of electronic properties of normal metals. After Landau death, Kapitza wanted to strengthen the theory department of his Institute, and, soon after, Ilya Lifshitz (in 1969) and Moissei Kaganov (in 1970) joined the Kapitza Institute. Even earlier, in 1966, Emmanuil Rashba, also an originally Ukranian theorist, joined the Landau Institute for Theoretical Physics. Peschansky, Azbel and Kaner remained working and lecturing in Kharkov, however I saw them very often in Moscow at IPP.

Valentin Peschansky stood out among other Ukranian theorists by his friendly attitude and benevolence toward surrounding people. He spoke with a soft voice and never put the opponent in an awkward situation. My own graduate research was also related to the electron energy spectrum of metals, therefore, when the time came to defend the PhD thesis, my scientific supervisor M.S. Khaikin suggested Peschansky as an opponent. As usual, he kindly agreed. This was indeed a good choice that left the best reminiscence.

As the result of experimental efforts in crystal growth, the quality of the metal samples reached such the state-of-the-art, where the electron mean free path at low temperatures became comparable with a sample size. It appeared unexpectedly that the electron scattering at the sample surface is an elastic and almost mirror-reflection process. As an example, M.S. Khaikin observed quantum transport of electrons skipping at the surface; Yu.V. Sharvin and V.S. Tsoi studied focusing of the electrons which experienced mirror reflection at the surface; V.S. Edel'man, V.F. Gantmakher, and Yu.P. Gaidukov also observed various size effects caused by mirror reflection of electrons at the sample surfaces.

Yet at the Institute for Physical Problems, Yu.P. Gaidukov studied magnetoresistance anisotropy and, using the theory by Peschansky *et al.*, reconstructed the Fermi surface topology [3]. When Gaidukov moved to the Low-Temperature Department of the Moscow State University, he extended his research from bulk to whisker crystals of metals. These tiny specimens a typical size of $1\times10\times100$ μm behaved wonderfully. They could be easily charged electrostatically and bent into a spiral with no loss of quality and with no residual defects. Gaidukov and collaborators succeeded in growing whisker crystals of Bi, Sb, Zn, and Cd from vapor phase (he even found whisker crystals of tin which grew on his old tin-lined skates).

Besides their extreme mechanical properties, whisker crystals were the ideal object for size effect studies owing to their small thickness and mirror-flat natural surfaces. Experimental studies of magnetoresistance in Gaidulkov's laboratory were very fruitful. To handle the tiny objects under microscope one had to have perfect vision and strong nerves, because moving the crystals, fixing them, and making tiny contacts took many hours of delicate work using eye-surgery tools. In Gaidukov's laboratory this research was performed by young female PhD and graduate students. One of the Gaidukov's PhD student, Elena Goliamina, became my wife, and for this reason I also became indirectly involved in the “whisker business”, have read Peschansky's papers, and even have done some research on tiny whisker crystals grown by Gaidukov [4].

Semimetals such as Bi and Sb were good test objects for experimentalists because of the low melting point, high purity, and extremely small and almost cylindric electronic pockets at the Fermi surface. The latter lead to huge amplitude of quantum oscillatory effects, resonant effects, etc.

On the theoretical side, Valentin Peschansky with collaborators also intensively studied kinetic properties of semimetals [5,6]. The most elegant effect, elaborated theoretically by Peschansky and collaborators was the “static skin effect” [5,7,8]. It appeared that the contribution of ordinary “bulk” electrons (which don't scatter by the surface) to conductivity could become much less than the contribution of electrons mirror-reflected by the sample surface. In other words, for a given sample thickness d and a given mean free path l, $d > l$, one can set such a strong magnetic field, where the current will be concentrated within a thin layer near the surface; the thickness of this layer is an order of the cyclotron radius, r. This concept radically changed the preceding viewpoint on conduction in thin samples and lead to such interesting observable effects as novel type of magnetoresistance, magnetoresistance anisotropy, and oscillatory dependent nonuniform conduction in the bulk. However, the “static skin effect” was expected to be very sensitive to the presence of a minor diffusivity in the electron scattering at the surface, the drawback that made the experimental verification of the theoretical prediction rather difficult.

Experiments at the Moscow State University were motivated in part by the predictions of the “static skin effect” theory. Correspondingly, the paper by Peschansky *et al.* [5] was one of the “hand-books” at the Yurii Gaidukov's laboratory. Within the period from 1973 to 1978, Gaidukov and collaborators studied the size effect in magnetoresistance of Cd, Sb, and Zn whisker crystals [9–11]. Some features of the observed magnetoresistance agreed qualitatively with Peschansky theory. Particularly, the magnetoresistance data scaled for samples with different thicknesses, and in weak magnetic field the "parallel" magnetoresistance $(B \parallel I)$ exhibited a maximum. However, quantitatively, the maximum didn't agree with the theory, for it was observed at fields $r(B) \propto d$, while in the theory it should be located at $r(B) \propto \sqrt{d}$. The disagreement with the theory was sample dependent: it was minor for Sb, and more essential for Zn and Cd. The experimental results thus pointed to the insufficiently smooth surface and lack of ideal mirror reflection at the Zn and Cd surfaces.

Despite lacking of quantitative agreement with theory, the experimental data have manifested unambiguously the striking difference in magnetoresistance for thin samples ($d \sim r$) and that for thick 3D samples ($d \gg r$). The most direct confirmation of the theory was achieved in experiments with Sb. Whereas the bulk Sb samples showed almost isotropic magnetoresistance, the thin plate-like whiskers of Sb demonstrated a factor of 10 larger and anisotropic magnetoresistance. This fact clearly demonstrated the contribution of surface scattering to electron transport for thin 3D samples, which was the central point of the Peschansky theory.

As often occurs in experiments, besides the sought for monotonic magnetoresistance, Gaidukov and Goliamina unexpectedly observed a novel oscillatory size effect, the Shubnikov–de Haas oscillations cut-off in such weak magnetic fields [11,12], where the cyclotron orbit became larger than the whisker thickness. Remarkably, even earlier, Peschansky also wrote a theoretical paper [13] on Shubnikov–de Haas effect in thin conductors, where he predicted the oscillation cut off, but didn't consider the mirror reflection case. The experiments were made with Sb, the material in which electron scattering at the surface was of the mirror type, and in which monotonic magnetoresistance demonstrated the best agreement with the "static skin effect" theory. The experiments, however, revealed more rich physics, than the theory predicted: in magnetic fields lower than the cyclotron orbit cut-off, new series of oscillations emerged, due to quantization in magnetic fields of the truncated electron orbits with mirror reflected trajectories.

Soon after, Elena Goliamina had her PhD thesis ready and Peschansky, as the major expert in the field, was invited to act as the opponent. After the official defence he was very surprised to learn that he played the same role for the second time for the same family.

2. Magnetoresistance in low dimensional systems

The golden age of electronic properties of three-dimensional metals was over by the end of the 70s. In 1979, Peschansky published comprehensive reviews on kinetic size effects in metals [6,7]. Five years later, he and several other Russian "metal physicists", including the author, wrote a book [8,14] to overview their preceding research in the physics of 3D metals. These and many other reviews summarize the results of the 20-years long intensive investigations in physics of metals. The bulk metals appeared to be rather simple and their physics was quickly exhausted. Besides knowledge of the Fermi surfaces for the majority of metals [15], the net result of these studies was the development of a number of milestone concepts, including the approaches of nearly-free-electrons, strong and weak coupling, Fermi liquid paradigm, and Fermi surface. Another key result was the development of a number of powerful experimental and theoretical tools for studying electronic systems.

Right at this time the physics of low-dimensional systems started emerging worldwide and the seeds of the 3D metal physics fell on the good ground. With the development of semiconductor technology and the advent of high-quality low-dimensional systems many "metal physicists" in the 70s and 80s switched to the physics of "low-dimensions". Some of them started studying two-dimensional (2D) electron systems at semiconductor interfaces, some other - to layered (1D and 2D) crystals.

As mentioned above, the twenty-years-long studies of electronic properties of 3D metals resulted in a number of elaborated powerful concepts and tools. Their list includes, first of all, Shubnikov–de Haas and de Haas–van Alfven effects, cyclotron resonance, and magnetoresistance. In bulk metals, and even in thin conductors, the magnetoresistance was used as a probe to test electron orbital motion. The spin degree of electron freedom considered almost irrelevant. Much later, the researchers encountered the effects of electron–electron (exchange) interactions, governed by physics of spin. Now, it is well recognized that the magnetoresistance can also be used to probe the electron–electron interaction, i.e., the physics of spins. In this interesting swing, the physicists came back to the original Peschansky idea that the magnetoresistance can be a key tool for probing the unknown electron system and understanding its microscopic architecture.

2.1. Magnetoresistance and cyclotron resonance in organic low-dimensional systems

Searching for a new field of research, the author also started studying low-dimensional systems: in 1980 — the 2D electron systems in semiconductors, and in 1998 — quasi-one-dimensional organic conductors. The latter objects, in particular, compounds of the $(TMTSF)_2X$ family, are very interesting: at low temperatures, they exhibit physics related with spin density wave state [16] in low or zero magnetic fields, whereas at elevated pressure the spin-density wave state is suppressed and $(TMTSF)_2PF_6$ at finite temperatures behaves as a quasi-1D layered metal.

The $(TMTSF)_2PF_6$ has a quasi-one-dimensional electron system confined in a three dimensional host lattice. The electron system is therefore highly sensitive to external parameters and, depending on pressure, magnetic field, temperature etc., exhibits properties inherent of 1D, 2D, and 3D systems [16]. The unique property of $(TMTSF)_2PF_6$ is that its P–B–T phase diagram contains numerous phases such as the spin density wave (SDW) state, field induced spin density wave (FISDW) state, quantum Hall effect, and superconducting state (at temperatures below ≈ 1 K). This is because the paramagnetic metallic state of the quasi-1D electronic system is unstable and due to electron–electron interaction, at lowering temperatures, undergoes a transition to the SDW state, which is an antiferromagnetic (AF) spin-ordered state (an insulator). Increasing pressure destroys the SDW order and makes the paramagnetic metallic state more favorable [16]. Again, as in bulk 3D metals, the magnetoresistance appears to be the most powerful experimental tool for studying the origin of various phases and phase transitions in this quasi-1D material.

It is a coincidence that Valentin Peschnasky in his theoretical studies also switched from 3D metals to quasi-two dimensional conductors [17–19]. In particular, in Ref. 19, he studied theoretically cyclotron resonance in layered materials. Almost at the same time, we sought for the cyclotron resonance, but in quasi-one-dimensional $(TMTSF)_2PF_6$. At first sight, the idea of cyclotron motion in 1-dimensional systems sounds odd. However, due to finite transfer integrals, the system under study is quasi-one-dimensional. In the metallic state it has an open Fermi surface; the magnetic field (below the onset of the field-induced spin-density wave state, FISDW [16]) applied perpendicular to the conducting plane causes one-dimensionalization of the electron motion. Nevertheless, the finite transfer integrals (perpendicular to the most conducting direction) lead to the periodic motion of the electrons in magnetic field. This motion was detected in our experiments by observing the cyclotron resonance in the mm-wave range [20]. The measured cyclotron mass was found larger than the theory expected; the discrepancy motivated theorists to revise the existing "standard" models of the field-induced spin density wave state [16].

2.2. Magnetoresistance in two-dimensional systems

Historically, the physics of 2D systems emerged in 1966 when Allan Fowler, Frank Fang, *et al.* observed Shubnikov–de Haas oscillations in silicon MOSFET (metal–oxide–semiconductor field effect transistor) [21]. By tilting the sample in magnetic field they found the period of quantum oscillations to be governed by perpendicular field component solely, and thus, had proven the two-dimensionality of the studied electron systems. Initially, the same theoretical ideas that were developed earlier for 3D metals were now applied for 2D systems and it appeared they worked, at least to the first approximation. For about twenty years the 2D physical community used conventional Lifshitz–Kosevich formulae for 3D systems with minor transparent modifications for the 2D density of states; V.G. Peschansky also contributed to this research and published in 2002 a paper on magnetotransport effects in organic layered conductors [17].

In the 1980s, the experimental studies in high perpendicular magnetic fields revealed huge effects of the electron–electron interactions, which were negligibly small in 3D metals and ignored therefore previously. To parametrize the electron–electron interaction, a dimensionless ratio r_s of the potential Coulomb interaction energy to the kinetic Fermi energy is commonly used. In 2D systems, the r_s values as high as ~ 10 can be easily achieved by decreasing the electron density in high quality samples. The presence of electron–electron interaction makes the 2D system much more complex, and its physics much more deep. During only 30 years of research, we evidenced three Nobel prizes for discovery of unexpecting phenomena in 2D electron systems: integer and fractional quantum Hall effects, and physics of graphene. Surely, more discoveries are still waiting to be awarded.

The most familiar interaction effect is the negative compressibility, κ, of the electron system, where κ changes sign at $r_s \approx 1.4$. The effect was predicted theoretically by A.L. Efros [22] and observed in Ref. 23 in 2D system of Si-MOSFET, and later on, by J. Eisenstein on double-layer GaAs/AlGaAs heterostructure [24]. The physics of this effect is straightforward: as one adds new electrons to the 2D interacting system, the gain in potential electron (exchange interaction) energy overpowers the growth in kinetic (Fermi) energy. The total system (2D electrons+lattice+gate) remains neutral due to the presence of the metallic gate, or due to the installed dopants near the interface. Therefore, the classical electrostatic energy maintains the stability of the system, in contrast to the black holes in cosmology which also have negative compressibility.

It turns out that the interaction effects are strongly enhanced in perpendicular field; this effect was initially described in terms of interaction between resolved Landau levels. The effects such as quantum oscillations of the Landau level splitting, enhanced and oscillatory spin-splitting, and Landau level broadening are the most known consequence of the interaction effects in perpendicular field.

3. Magnetoresistance in the in-plane field

More delicate physics of inter-electron interaction can be revealed in magnetic fields parallel to the 2D plane. In such geometry, the field does not couple to the electrons motion and couples only to their spins. For a noninteracting ideal 2D system, the in-plane field doesn't cause a magnetoresistance. When the thickness of the 2D layer becomes comparable to the magnetic length l_H, one has to take into account a diamagnetic shift of the energy levels. We ignore these strong field and finite thickness effects and focus only on the electron–electron interaction induced magnetoresistance.

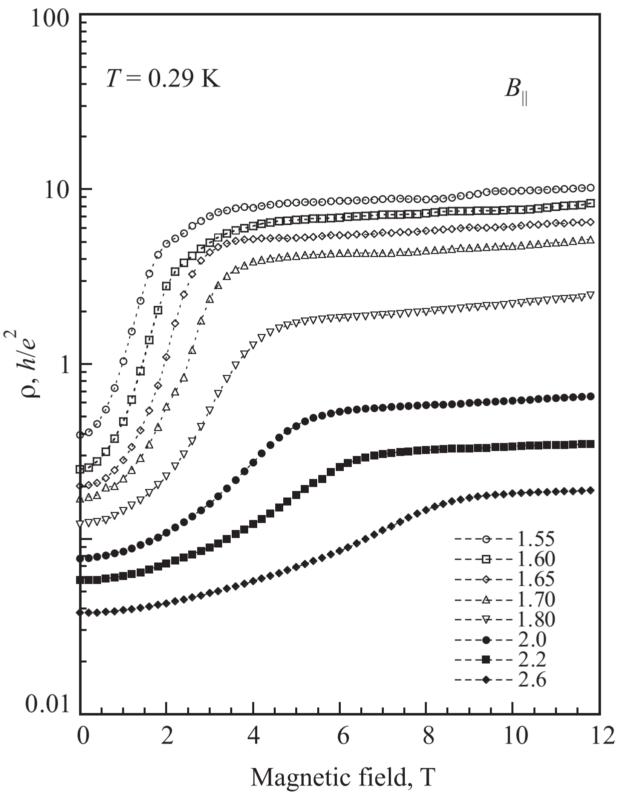

Fig. 1. Resistivity vs parallel magnetic field, measured at $T = 0.29$ K on Si-MOSFET sample. Different symbols correspond to the gate voltages from 1.55 to 2.6 V, or, equivalently, to the densities from 1.01 to $2.17 \cdot 10^{11}$ cm^{-2}. Represented from Ref. 26.

Application of the in-plane magnetic field to the strongly interacting and clean 2D electron system was found to cause a dramatic increase of the resistance, more than by two orders of magnitude, as seen in Fig. 1 [25,26]. At high fields, the resistance saturates. Such behavior was found in all high-mobility 2D samples with strongly interacting carrier system. Thus, the magnetic field simply destroys the metallic state. At fields higher than a density dependent value B^*, the magnetoresistance saturates; the saturation field approximately corresponds to full spin polarization of the 2D electron system, $g\mu_B B^* = 2E_F$.

This remarkable magnetoresistance effect was observed in 1997; it took about 5 years to understand the interaction-induced magnetoresistance in $B_\|$ field. In 2002, Zala, Narozhny, and Aleiner (ZNA) [27] developed a theory that took into account all interaction contributions to the conductivity, including the exchange ones. This theory offers a unified approach to both ballistic ($T\tau \gg 1$) and diffusive ($T\tau \ll 1$) interaction regimes by considering the quantum interference between electron waves scattered off a short-range random potential "dressed" by Friedel oscillations of the electron density. The theory was extended for the case of a long-range scattering potential by Gornyi and Mirlin (GM) [28]. The theories [27,28] naturally incorporate the Altshuler–Aronov (AA) results for the interaction corrections to the conductivity in the diffusive regime [29].

The theories [27,28] predict that the magnitude and sign of the the interaction correction to conductivity, $\Delta\sigma(T,B)$ is determined by the Fermi-liquid parameter F_0^σ, and therefore, the F_0^σ value can be found from $\Delta\sigma(T,B)$ measurements [30]. Independently, this parameter was also found by measuring the Shubnikov–de Haas (18) oscillations in weak magnetic fields tilted to the plane of a 2D structure [31,32].

3.1. Modern view on magnetoresistance in interacting 2D system

The in-plane magnetic field, being coupled mostly to electron spins, provides a useful tool for exploring the interaction effects in the low-temperature conductivity of 2D system [25,26]. When the Zeeman energy $E_Z = g_b\mu_B B$ ($g_b = 2$ is the bare g-factor, μ_B is the Bohr magneton) becomes much greater than T, the number of triplet terms that contribute to interaction correction $\Delta\sigma_{ee}(T)$ is reduced from 15 to 7. Similar reduction of triplet terms is expected for a valley splitting $\Delta_V > T$. These two effects have been accounted by the theory of interaction corrections [27,33]; in the presence of the magnetic field and/or valley splitting the interaction correction to the conductivity can be expressed as follows [33]:

$$\Delta\sigma_{ee}(T,\tau,F_0^\sigma,B_\|,\Delta_V) = \Delta\sigma_{ee}(T) + 2\Delta\sigma^Z(E_Z,T) + \\ + 2\Delta\sigma^Z(\Delta_V,T) + \Delta\sigma^Z(E_Z+\Delta_V,T) + \Delta\sigma^Z(E_Z-\Delta_V,T), \quad (1)$$

where $\Delta\sigma_{ee}(T)$ is given by Eq. (2):

$$\Delta\sigma_{ee}(T) = \delta\sigma_C(T) + 15\delta\sigma_T(T). \quad (2)$$

Here $\delta\sigma_C$ is the so-called "charge" contribution which combines Fock correction and the singlet part of Hartree correction, and $\delta\sigma_T$ is the "triplet" contribution due to the triplet part of the Hartree term. The valley index can be considered as a pseudo-spin in multi-valley systems, and the valley degeneracy increases the number of triplet terms due to the spin exchange processes between electrons in different valleys. For the (100) Si-MOSFET system with two degenerate valleys, the total number of interaction channels is $4\times 4 = 16$, among them 1 singlet and 15 triplet terms (for comparison, there are 1 singlet and 3 triplet terms for a single-valley system).

All the terms $\Delta\sigma^Z(Z,T)$ have a form

$$\Delta\sigma^Z(Z,T) \equiv \sigma(Z,T) - \sigma(0,T) = \delta\sigma_b(Z) + \delta\sigma_d(Z) = \\ = \frac{1}{\pi}\left\{\left[\frac{2F_0^\sigma}{1+F_0^\sigma}(T\tau)K_b\left(\frac{Z}{2T},F_0^\sigma\right)\right] + \left[K_d\left(\frac{Z}{2\pi T},F_0^\sigma\right)\right]\right\}, \quad (3)$$

if the relevant energies $Z \ll E_F$ (Z stands for E_Z, Δ_V, and combinations $E_Z \pm \Delta_V$). The explicit expressions for the functions K_b and K_d are given in Ref. 27. In particular, Eq. (3) describes the interaction-driven magnetoconductivity in the magnetic fields which are much weaker than the field of full spin polarization of a system. In Eq. (3), we neglected the crossover function which is numerically small and does not modify the value of $\Delta\sigma(Z,T)$ outside the ballistic-diffusive crossover region by more then one percent.

3.2. Magnetoconductivity. Comparison of the experiment with theory

Since the theory calculates corrections to conductivity rather than resistivity, from now, we switch to the magnetoconductivity (MC). To test the theoretical predictions on the magnetoconductivity induced by in-plane magnetic fields, in Ref. 34 $\sigma(B_{\|})$ dependences were measured at fixed temperatures. The MC for sample Si6-14 over the field range $-4.5\ \mathrm{T} < B_{\|} < 4.5\ \mathrm{T}$ is shown for different densities and temperatures in Fig. 2.

The theoretical $\Delta\sigma(B_{\|})$ dependences, see Eqs. (1), (3), plotted in Fig. 2 as solid curves, describe the observed MC very well in not-too-strong magnetic fields $g_b\mu_B B_{\|} < 0.2E_F$. The only adjustable parameter was the $F_0^\sigma(n)$ value extracted for each density from fitting the MC at high temperatures (≈ 0.7 K) where the effects of valley splitting or intervalley scattering on $\Delta\sigma_{ee}(T,B)$ can be neglected. The fitted $F_0^\sigma(n)$ values were found to agree with those independently measured earlier from Shubnikov–de Haas oscillation beats in tilted magnetic fields [32].

As $B_{\|}$ grows and/or density decreases, the data start deviating from the theoretical curves (see Fig. 2,*d*); this deviation can be attributed to the violation of the condition $g_b\mu_B B \ll E_F$ required for applicability of Eqs. (1), (3).

4. Conclusion

The experiments show that the low-T behavior of the magnetoconductivity of interacting 2D electron system in Si MOSFETs is well described by the theory of interaction effects in systems with short-range disorder [27]. Over a wide range of intermediate temperatures ($g_b\mu_B B < T \ll E_F$), the interaction effects are strongly enhanced in Si MOSFETs due to the presence of two valleys in the electron spectrum. This factor, in combination with the interaction-driven renormalization of the Fermi-liquid parameter F_0^σ, leads to an increase of σ with decreasing T. The F_0^σ values obtained from fitting the experimental data with the theory [27] agree well with the F_0^σ data obtained from the analysis of oscillations in these samples. The considered above example demonstrates that the central idea by V.G. Peschansky that the magnetoresistance is a powerful tool to explore complex physics of the electron system, remains valid and fruitful until now.

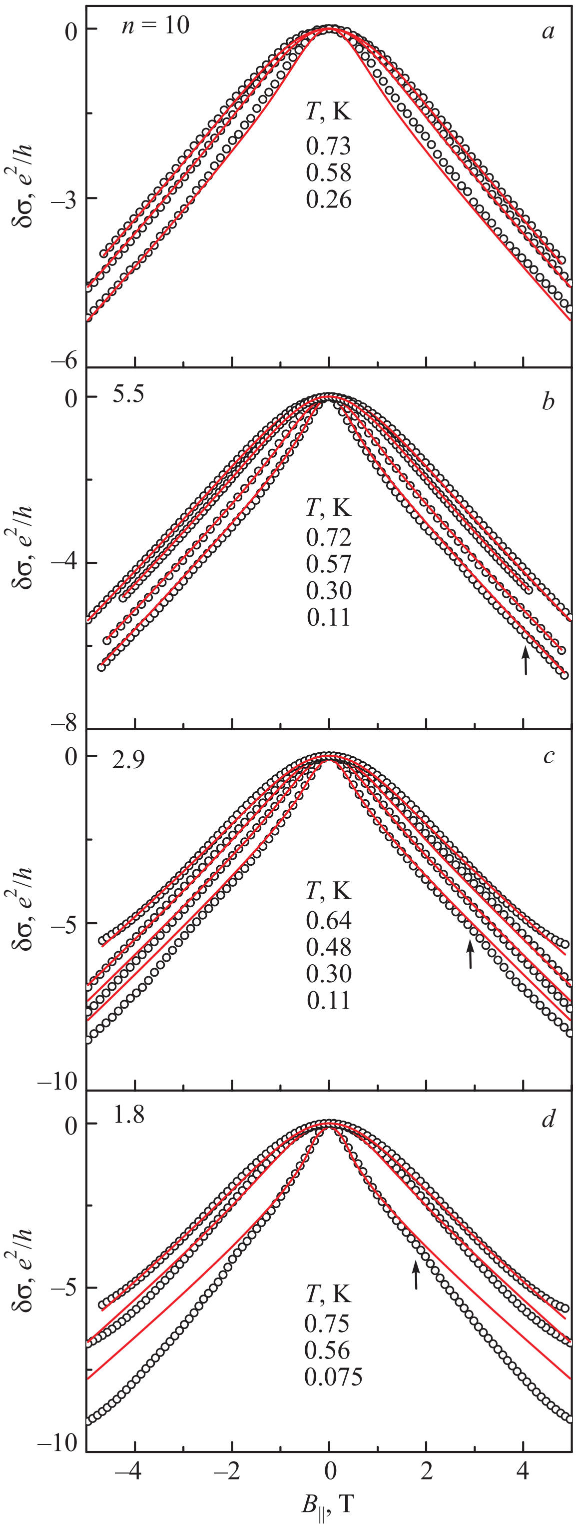

Fig. 2. (color online.) Magnetoconductance for Si-MOSFET sample at different electron densities and temperatures. Experimental data are shown by dots, the theoretical dependences calculated according to Eqs. (1)–(3) — by solid curves. The F_0^σ value is the only fitting parameter in comparison with the theory [27], the corresponding values of F_0^σ are shown in Fig. 5 of Ref. 34. Arrows indicate the fields corresponding to the condition $g\mu_B B_{\|}/2E_F = 0.1$. The values of n are shown in units of $10^{11}\ \mathrm{cm}^{-2}$. Represented from Ref. 34

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