The unique properties of a two-dimensional electron gas (2DEG) in the quantum Hall (QH) regime originate from the presence of the energy gap at the Fermi level [1]. The situation is especially interesting if only one spin-split sublevel of the lowest Landau level is occupied, i.e. at bulk filling factor \( \nu = 1 \). In high magnetic fields, the ground state of the system is fully spin-polarized, while the elementary excitations are characterized by a spin flip [2]. The exchange energy of a single spin-flip excitation is supposed to be responsible for a serious enhancement of the excitation energy in comparison to the single-particle Zeeman splitting [2–5]. This enhancement is sensitive [2] to the excitation wave vector \( k \). It is widely accepted, that in transport experiments [3, 4, 6, 7] \( k = \infty \) excitations are tested, while optical investigations [5] allow to probe excitations at different \( k \). In low magnetic fields, the possibility of complicated spin textures (skyrmions) formation is still debated [6, 7].

The situation is even more intriguing at the sample edge. Any real edge profile is smooth, so the electron liquid represents a structure of compressible and incompressible strips [8]. Every incompressible strip can be characterized by a constant local filling factor \( \nu_c \). In analogy with the bulk, the electron liquid is spin polarized within the \( \nu_c = 1 \) incompressible strip, which should produce a local enhancement of the energy gap. It is not known ab initio how to extend the bulk results to the \( \nu_c = 1 \) incompressible strip, because of, e.g., higher disorder at the edge, potential drop within the incompressible strip, etc. Experimental verification is still missing, because the traditional methods (activation [3, 6], magnetocapacitance [4, 7], and optics [5]) are not suitable for local investigations.

Here, we experimentally study the energy gap within the incompressible strip at local filling factor \( \nu_c = 1 \) at the quantum Hall edge for samples of very different mobilities. The obtained results indicate strong enhancement of the energy gap in comparison to the single-particle Zeeman splitting. We identify the measured gap as a mobility gap, so a pronounced experimental in-plane magnetic field dependence can both be attributed to the spin effects as well as to the change in the energy levels broadening.

The samples are fabricated from three GaAs/AlGaAs heterostructures with different carrier concentrations and mobilities, grown by molecular beam epitaxy (MBE) in three different MBE machines. Two of them (A and B) contain a 2DEG located 200 nm below the surface. These wafers are similar in the carrier density (about \( 1.6 \times 10^{11} \text{ cm}^{-2} \)), but strongly differ in the 2DEG mobilities. The 2DEG mobility at 4 K is \( 5.5 \times 10^6 \text{ cm}^2/\text{V s} \) for the wafer A, while it is equal to \( 1.93 \times 10^6 \text{ cm}^2/\text{V s} \) for the wafer B. For the lower quality heterostructure C the relevant parameters are 70 nm, 800000 cm²/ V s and \( 3.7 \times 10^{11} \text{ cm}^{-2} \).

The samples are patterned in the quasi-Corbino sample geometry [9], see Fig. 1a. Each sample has a macroscopic (~0.5 × 0.5 mm) etched region inside, providing topologically independent inner and outer mesa edges (the so called Corbino topology). Ohmic
contacts are placed at the mesa edges. A split-gate, encircling the etched region, is used to connect inner and outer mesa edges in a controllable way. It forms a narrow gate-gap region at the outer mesa edge. The gate-gap width equals to 5 μm and outer mesa edges in a controllable way. It forms a narrow gate-gap region at the outer mesa edge. Light green (gray) area indicates uncovered 2DEG. Ohmic contacts are denoted by bars with numbers. (b) Structure of the compressible (white) and incompressible (color) regions of the electron liquid in the sample. The bulk is at the filling factor \( \nu = 2 \) (uncovered) or at the filling factor \( \nu = 1 \) (under the gate). The compressible/incompressible structure is shown at the sample edges. Arrows indicate electron transport across \( \nu = 1 \) incompressible strip in the gate-gap region.

(c) Schematic diagram of the energy levels in the gate-gap region. Filled circles represent the fully occupied electron states in the incompressible strip and in the bulk. Half-filled circles indicate the partially occupied electron states in the compressible strips. Pinning of the energy levels to the Fermi level (shot-dash) is shown in the compressible regions at electrochemical potentials \( \mu_{\text{out}} \) and \( \mu_{\text{in}} \). Open circles are for the empty states. \( \Delta_c \) is the potential jump in the \( \nu = 1 \) incompressible strip at the equilibrium (\( \mu_{\text{out}} = \mu_{\text{in}} \), no electrochemical imbalance is applied across the incompressible strip). Flat-band condition appears at the electrochemical potential imbalance \( \mu_{\text{in}} - \mu_{\text{out}} = \Delta_c \). Arrows indicate a new way for electrons along the energy level.

In a quantizing magnetic field, at bulk filling factor \( \nu = 2 \), we deplete the 2DEG under the gate to a lower filling factor \( g = 1 \). A structure of compressible and incompressible strips emerges [8] at both mesa edges and along the gate edge, see Fig. 1b. A filling factor \( g \) under the gate is chosen to coincide with the local filling factor \( \nu_c = 1 \) within the incompressible strip in the gate-gap region at the outer mesa edge. In this case, two compressible strips in the gate-gap originate from different (inner and outer) Ohmic contacts, being at their electrochemical potentials. Applying dc bias between Ohmic contacts at outer and inner edges leads to an electrochemical potential imbalance across the incompressible strip at local filling factor \( \nu_c = g = 1 \) in the gate-gap, see Figs. 1b and 1c.

In the present experiment, dc bias is applied to the outer contact with respect to the inner one. Schematic diagram of energy levels in the gate-gap region is depicted in Fig. 1c. Because of negative electron charge, the positive bias decreases the potential jump at \( \nu = 1 \), allowing the flat-band situation at \( eV = eV_{\text{th}} = \Delta_c \). If the gate-gap width \( l_{\text{int}} \) is smaller than the characteristic equilibration length \( l_{\text{eq}} = 100 \mu m \), the flat-band regime should reveal itself by a strong rising of the current, since no potential barrier exists between the compressible strips in the gate-gap. At higher biases, the excessive imbalance will be easily equilibrated until reaching the flat-band regime, which results in the equilibrium slope of the positive \( I-V \) branch above \( eV = eV_{\text{th}} \). As a result, the positive branch of the \( I-V \) curve allows the local determination of the energy gap within the \( \nu_c \) incompressible strip at the sample edge [9].

The experimental data, presented here, are obtained from samples of different quality (A1, B, C) and with different gate-gap widths (A1 and A2). They are independent from the cooling cycle. All measurements are performed in a dilution refrigerator with base temperature 30 mK, equipped with a superconducting solenoid. Standard magnetocapacitance and magneto-transport measurements were performed to characterize the electron system under the gate and in the ungated region.

Typical \( I-V \) curves for transport across the integer incompressible strip \( \nu_c = 1 \) are presented in Fig. 2 for samples with different electron concentrations and mobilities. The experimental \( I-V \) curve is strongly non-linear and asymmetric. The positive \( I-V \) branch changes its slope at the finite threshold voltage \( V_{\text{th}} \), the branch is linear above \( V_{\text{th}} \) in a wide voltage range, see Fig. 2. The negative branch is strongly non-linear. The threshold voltage \( V_{\text{th}} \) can be obtained with high accuracy from the extrapolation of the positive linear branch to zero.

The \( \nu_c = 1 \) energy gap values, obtained as a threshold voltage for the positive \( I-V \) branch are presented in Fig. 3. Accuracy of the gap determination procedure can be evaluated as 0.05 meV, which is roughly the size of the symbol in Fig. 3. Our experimental technique