EXPERIMENTAL LIMIT ON EXISTENCE OF ELECTRON QUASIMAGNETIC (ARION) INTERACTION

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A number of theoretical models (supersymmetric, technicolor and grand unification models) suggests the possible existence of physical massless or very light particles. The standard model permits the existence of such particles. They are very interesting from the experimental point of view, since they can be detected in experiments at the laboratory scale. Various theoretical models predict the existence of a stable, massless,

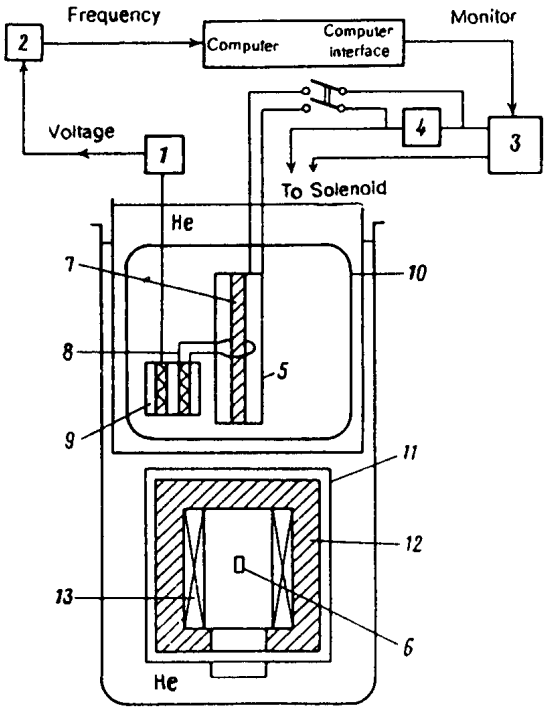

Fig.1. Experiment scheme: 1 — magnetometer, 2 — voltmeter, 3 — power amplifier, 4 — shunt, 5— calibration coil, 6 — Hall probe, 7 — ferromagnetic rod, 8 — flux transformer, 9 — Zimmerman SQUID, 10 - lead screen, 11 — niobiun screen, 12 — ferromagnetuc screen, 13 — superconducting solenoid

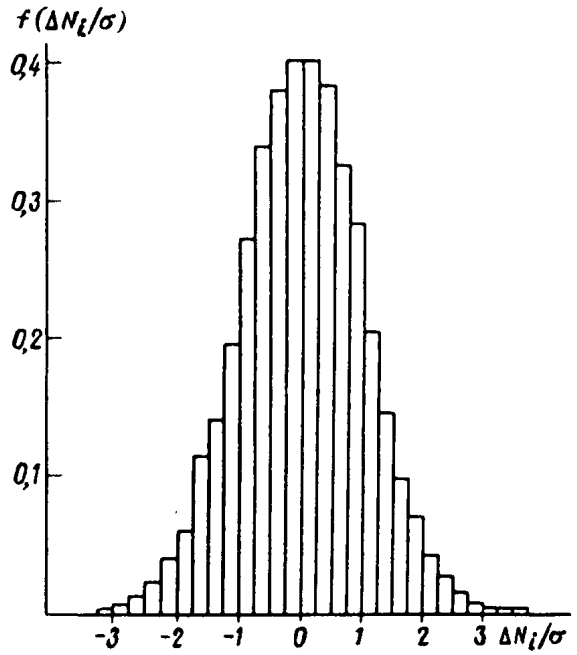

Fig.2. Histogram of dictribution of deviation from mean value ΔN_i normalized to its rms deviation

pseudoscalar particle - the arion [1,2]. The method of the arion detection is based on the arion field property to create the long-range arion force. There is an analogy between the arion and magnetic fields. Arion exchange between two fermions f_1 and f_2 leads to the potential:

$$V(r) = -x_{f_1} \cdot x_{f2} \cdot \frac{G_F}{8\pi\sqrt{2}} \cdot \frac{1}{r^3} [\vec{\sigma}1 \cdot \vec{\sigma}_2 - (\vec{\sigma}_1 \cdot \vec{n}) \cdot (\vec{\sigma}_2 \cdot \vec{n})],$$

where $\vec{\sigma}_1$ and $\vec{\sigma}_2$ are the Pauli spin matrices, $\vec{m} = (\vec{r}/r)$, G_F is the Fermi constant and x_f is a parameter which depends on the vacuum expectation values of the fields. This interaction is equivalent, up to the sign, to the interaction of spin magnetic moments with the magneton $x_f(G_F/8\pi\sqrt{2})^{1/2}$. The arion field is, like the

magnetic field. generated by oriented spins. The main difference is that the arion field is not related to moving electric charges.

The experiment which we have carried out is shown schematically in fig.1. As the arion field source we used a massive ferromagnetic screen, magnetized by the switching of a superconducting solenoid. A ferromagnetic rod in a superconducting screen placed along the source axis as close as possible to its face served as the detector. The variation of the magnetic flux inside the rod was measured by means of a SQUID with the flux transformer. The experiment measured the ratio $\Delta B/B_0$ in the screen region, where B_0 is the magnetic field of the polarized spin and ΔB is the value of the field measured by the spin detector in the screened region. It is therefore necessary to create the maximum possible B_0 and then to be able to suppress it to a level smaller than ΔB, i.e. such that the screening coefficient satisfies $K > \Delta B/B_0$. In our experiment the screening coefficient can be represented as the product of three coefficients: $K = K_f K_n K_l$, where K_f is the screening coefficient of the ferromagnetic screen, K_n is the screening coefficient of the nioblium screen, and K_1 is the screening coefficient of the lead screen. Each of these coefficients was measured: $K_f > 10^2$, $K_n \approx 10^5$, and $K_1 \approx 10^8$. Altogether, we have $K > 10^{15}$. Therefore, the search for the effect can be extended to the level $\Delta B/B_0 \approx 10^{-15}$. In addition, the screening coefficient of the lead screens imposes certain requirements on the value of the magnetic field leaking from the current lead: $\Delta B_c < K_l \Delta B$. The field leakage was monitored by the quantum magnetometer on an optical pump. For a solenoid current 15 A ($B_0 \approx 200$ *Oe*) we obtain $\Delta B_c < 10^{-6}$ *Oe*. For this lead leakage and screening coefficient $K_l \approx 10^8$ the effect can be sought down to the level $\Delta B/B_0 \approx 10^{-16}$.

The setup operated in the following mode. A computer controls the feeding of a current from an electronic module to the control winding of the power amplifier, which feeds a superconducting solenoid. The magnetic field in the solenoid circuit is controlled by a Hall probe. The current in the solenoid sircuit is controlled by the voltage on the measuring shunt. The output voltage from the SQUID magnetometer is transformed to a frequency by a digital voltmeter and then fed to the counters which continuously operate an array of N_i^+ and N_i^- counters for the corresponding polarity of a single set of measurements. The difference $\Delta N_i = N_i^+ - N_i^-$ is proportional to the desired arion field. To rescale ΔN_i to the arion interaction constant it is necessary to calibrate the measuring system. This can be done by supplying a known magnetic field to the rod. The voltage from the measurement shunt is fed to the calibration coil. The same program used to make the measurements is then used to determine the calibration constant $\Delta N_k = N^+ - N^-$. If we denote the amplitude of the gauge field by H_k, we then can write

$$\frac{\Delta B}{B_0} = \frac{\Delta N \pm \sigma}{\Delta N_k} \cdot \frac{H_k}{B_0}.$$

According to calibration results, $\Delta B/B_0 = |5.7 \cdot 10^{-15} (\Delta N \pm \sigma)|$. For the interaction constant we find

$$x_e^2 = \frac{\Delta N \pm \sigma}{\Delta N_k} \cdot \frac{H_k}{4.7 \cdot 10^{-11} B_0} \approx |1.2 \cdot 10^{-4} (\Delta N \pm \sigma)|.$$

Nearly two hundred measurements cycles were carried out. The total set of statistics was ≈ 28 hours of data acquisition time. The histogram of ΔN_i is shown in fig.2. According to the Pearson criterion, the hypothesis of a normal distribution is satisfied at a significance level

$$q = 0.1 \ (\chi_n^2 \approx 8.7, \ \chi^2 \approx 11.7, \ \chi_b^2 \approx 27.7).$$

$\Delta B/B_0 < 8.5 \cdot 10^{-15}$The combined analysis of the full set of measurements gives the result

$$\Delta N = (-0.7 \pm 7.9) \cdot 10^{-1}.$$

The measured effect lies within the error. At the 95% confidence level we obtain the limit

$$\Delta B/B_0 < 8.5 \cdot 10^{-15}.$$

Therefore, in the experiment we have attained a screening coefficient of $\approx 10^{14}$ and have shown that at this level the polarized electron interaction energy does not have any "quasymagnetic" correction. This leads to the following limit on the arion interaction parameter of electrons at the 95% confidence level:

$$x_e^2 < 2 \cdot 10^{-4}.$$

this is five times more stringent than the limit of the earlier study of ref.3. It should be noted that the method can be improved further so that the sensitivity is increased by 1—2 orders of magnitude.

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