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A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held at the P. N. Lebedev Physics Institute of the USSR Academy of Sciences on May 25 and 26, 1983. The following reports were heard at the session:

May 25

1. *E. R. Aleksandrov, A. A. Ansel'm, Yu. V. Pavlov, and R. M. Umarkhodzhaev,* Limitations on the magnitude of the hypothetical fundamental long-range interaction between spins in an experiment with mercury nuclei.

2. *D. A. Kirzhnits and F. M. Pen'kov,* Coulomb interaction of composite particles.

May 26

3. *M. M. Makarov, G. Z. Obrant, and V. V. Sarantsev,* Splitting of the deuteron by π-mesons with intermediate energies.

4. *Yu. R. Gismatullin and V. I. Ostroumov,* Mechanism of proton emission accompanying inelastic scattering of π and K mesons with intermediate energies.

A brief summary of the reports is published below.

E. B. Aleksandrov, A. A. Ansel'm, Yu. V. Pavlov, and R. M. Umarkhodzhaev. *Limitations on the magnitude of the hypothetical fundamental long-range interaction between spins in an experiment with mercury nuclei.* Different variants of the extension of the "standard model" of the electroweak interaction (supersymmetry, grand unification, inclusion of horizontal symmetry) can lead to a complex Higgs structure of the theory. In this case, the existence of physical massless Goldstone bosons, related to spontaneous breakdown of possible additional global symmetries of the theory[1] (such symmetries could be present if, for example, Higgs bosons are actually composite particles, similar to the manner in which this occurs in technicolor models) becomes important. Exchange of a massless pseudoscalar Goldstone particle (arion) between fermions (quarks and leptons) leads to the appearance of spin-dependent forces between them, similar to the dipole magnetic interaction of spins:

$$V(r)=x_1x_2\left(\frac{G_F}{8\pi\sqrt{2}}\right)\frac{1}{r^3}\left[\sigma_1\sigma_2-3(\sigma_1\mathbf{n})(\sigma_2\mathbf{n})\right];$$

where r is the distance between the particles σ_1 and σ_2 are their spins, $\mathbf{n}=\mathbf{r}/|\mathbf{r}|$, G_F is the Fermi weak interaction constant, and x_1 and x_2 are dimensionless parameters that depend on the details of the model being examined (of the order of unity in the simplest variants).

Any methods for observing the weak magnetic field in an experiment, in which oriented spins are present, if the true magnetic forces created by them are reliably screened (for example, with the help of superconducting shielding[2]), or are monitored with high accuracy, can be used to detect the arionic interaction. The first attempt at observing the arionic interaction experimentally is briefly discussed below.

To distinguish the arionic spin interaction against the background of the much stronger magnetic interaction, an attempt was made to measure the ratio of the precession frequencies of two types of nuclei with different gyromagnetic ratios γ_1 and γ_2 in an external magnetic field. As long as only a magnetic field acts on the nuclei, the ratio of the precession frequencies by definition equals γ_1/γ_2 independently of the magnitude of the field. If the nuclei are placed in the field of a polarized ferromagnet, then, in addition to the magnetic field of the oriented electron spins, the arionic field of the same spins will act on the nuclei. The increase in the precession frequencies of nuclei 1 and 2 in an arionic field in general is by no means proportional to γ_1 and γ_2, and for this reason in the constant field of a permanent magnet, the ratio of the precession frequencies of the nuclei will no longer equal γ_1/γ_2. For the experiment, we used an atomic vapor consisting of a mixture of mercury 199 and 201 isotopes. The effective technique of optical orientation,[3] with the help of which the ratio γ_1/γ_2 can be measured with an accuracy up to 8–9 significant figures, is known for these isotopes.[4]

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A permalloy screen served as the source of the arionic field. A volume with mercury vapor and a coil for creating an auxiliary magnetic field of $H_0 \sim 0.1$ Oe, in which the initial measurement of the ratio γ_1/γ_2 of the precession frequencies of the nuclei was performed, were placed inside the screen. Then the screen was magnetized with an external field $H_\alpha \| H_0 (H_\alpha \sim 100$ Oe). In this case, the arionic field of polarized electron spins in the screen acted on the mercury nuclei, while the magnetic field of these spins and of the external inductor compensated one another with an accuracy up to the small quantity H_α/k, where $k \gg 1$ is the screening factor. Thus, the precession frequencies of the nuclei varied insignificantly due to the penetration of the magnetic field H_α/k through the screen, and this facilitated the precision measurement of their ratio.

The arionic interaction was not observed in the experiment. The accuracy achieved permits asserting that the magnetic interaction of mercury 199 nuclei with electron spins is at least a factor of $10^{11}\lambda$ times stronger than the hypothetical arionic interaction. Here, λ is the parameter calculated with the known wave function of the nuclei:

$$\lambda = \frac{\gamma_2}{\gamma_1} \frac{\langle {}^{201}\mathrm{Hg} | \hat{\Sigma} | {}^{201}\mathrm{Hg} \rangle}{\langle {}^{199}\mathrm{Hg} | \hat{\Sigma} | {}^{199}\mathrm{Hg} \rangle}, \quad \hat{\Sigma} = \sum_p \sigma_p - \sum_n \sigma_n.$$

The summation in the operator $\hat{\Sigma}$ extends over the protons and neutrons of the corresponding nucleus. The use of a rough model for the mercury nucleus gives $\lambda = 0.1$. In terms of the parameters x_i introduced above, the upper limit obtained on the product $x_e x_q$ has the following form for electrons and quarks:

$$x_e x_q < 2{,}5 \cdot 10^{-8}.$$

In the future, we propose to repeat the experiment with a different pair of fermions, which would permit a more reliable calculation of the parameter λ.

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[3]B. Cagnac, Ann. Phys. **6**, 467 (1961).
[4]J. C. Lehmann and R. Barbe, C. R. Ac. Sci. **257**, 3152 (1963).