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ON THE SCALAR AND TENSOR INTERACTIONS IN ATOMIC NEUTRON DECAY: $n \rightarrow H + \bar{\nu}$

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Влияние скалярного и тензорного взаимодействий на атомный распад нейтрона: $n \to H + \bar{\nu}$

С учетом скалярной и тензорной примесей в гамильтониане слабых взаимодействий вычислены относительные вероятности различных спиновых конфигураций конечных частиц в реакции: $n \to H + \bar{\nu}$. Показано, что относительная вероятность образования атома водорода с положительной спиральностью является весьма чувствительной к величине константы скалярного и константы тензорного взаимодействия. Измерение вероятности этой конфигурации позволит на порядок улучшить существующую верхнюю границу на отношение скалярной и векторной констант слабого взаимодействия.

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On the Scalar and Tensor Interactions in Atomic Neutron Decay: $n \to H + \bar{\nu}$

The final spin configurations in the process $n \to H + \bar{\nu}$ are studied when the possible admixture of scalar and tensor interactions in a weak Hamiltonian is taken into account. It is shown that the branching ratio for the channel characterised by the positive helicity of hydrogen atoms appears to be very sensitive to the value of scalar and tensor coupling constants. Therefore the measurement of the probability of this channel is an effective method to detect the possible admixture of scalar and tensor interactions. The results of this measurement should improve the modern upper limit on the ratio of scalar and vector weak constants till one percent.

The investigation has been performed at the Laboratory of Nuclear Problem, JINR.

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The atomic neutron decay

$$n \to H + \bar{\nu} \tag{1}$$

has recently been considered by L.L.Nemenov /1/. Assuming the V-A character of the weak Hamiltonian the probability of this decay has been obtained as a function of electron and proton helicities. Nemenov also shows that spin configuration of the type I (see the Table) is strongly suppressed.

Table

Configuration	I	II	III	IV
Spin projection				
neutron	1	-1	-1	
antineutrino	-1	-1	-1	-1
proton	1	1	-1	-1
electron	1	-1	1	-1
The decay probability				
$a = 1.25$				
$g_S = 0$; $g_T = 0$	$0.55 \cdot 10^{-2}$	$54.92 \cdot 10^{-2}$	$44.5 \cdot 10^{-2}$	0
$g_S = 0.1$; $g_T = 0$	$0.19 \cdot 10^{-2}$	$52.99 \cdot 10^{-2}$	$46.82 \cdot 10^{-2}$	0
$g_S = 0$; $g_T = 0.02$	$0.41 \cdot 10^{-2}$	$54.30 \cdot 10^{-2}$	$45.29 \cdot 10^{-2}$	0

The positive spin projection coincides with the direction of outgoing atoms.

Therefore, the corresponding probability W_1 may be sensitive to the possible admixtures in the V-A Hamiltonian. Three points should be mentioned to support the possibility to determine experimentally the various partial probabilities W_i : first, the intensive enough atomic hydrogen beams, available at the modern nuclear reactors, second, the atomic quantum numbers, and third, the high efficiency of registration of the electrons, emitted in the reaction of hydrogen atoms on the metal surfaces.

In this paper we consider the scalar and tensor admixtures to the V-A interaction* and their effect on the W_i values. The results obtained enable us to determine the upper limits on the value of the constants g_S and g_T, depending on the precision of the measurements for W_i.

The additional terms due to scalar and tensor interactions in the β -decay Hamiltonian can be written as

$$\Delta H = \frac{G \cdot \cos\theta_c}{\sqrt{2}} \sum_{i=S,T} \bar{\psi}_p Q_i (g_i + g_i' \gamma_5) \psi_n \cdot \bar{\psi}_e Q_i \psi_{\bar{\nu}} , \qquad (2)$$

where G is the Fermi constant and θ_c is the Cabibbo angle. The parameters g_S' and g_T' should vanish since the weak interactions are T-invariant. The presence of tensor and scalar interactions affects the appearance of both right and left helicity antineutrinos. We shall be interested only in those amplitudes that interfere with the V-A one, in other words in those that correspond to the emission of the right helicity antineutrino. These interfering terms will give the main contribution to the corrections to partial probabilities W_i^{V-A}. Therefore, while calculating W_i', we omitted the amplitudes corresponding to the emission of the left antineutrino in the final state.

The partial probabilities which include the scalar and tensor corrections to the V-A Hamiltonian have the following form**

$$W_1 = N_1 \cdot 2[(1-a) + g_S + 2g_T]^2 \qquad (3)$$

$$W_2 = N_1 \cdot 8[a - 2g_T]^2 \qquad (4)$$

$$W_3 = N_1 \cdot 2[(1+a) + g_S - 2g_T]^2 , \qquad (5)$$

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* In our case the terms due to the pseudoscalar interaction are of an order of $v_A/c \sim 8 \cdot 10^{-4}$ (where v_A(c) is the velocity of atoms (light). Therefore, the probability of this atomic decay is not clearly sensitive to the pseudoscalar admixture.

** In our calculations we made the same approximations as in ref./1/ Hence, the accuracy of the above expressions (3)-(5) is at best one percent.

here N_1 is a proportionality coefficient, $a = g_A/g_V$; the first term in every bracket is due to the V-A interaction.

The dependence of W_i on the parameter g_S is shown in the Table and in the figure ($a = 1,25$). From these results it is easy to see that the measurement of W_1 with 10% accuracy leads to the upper limit for g_S about $2 \cdot 10^{-2}$ at the 90% confidence level.

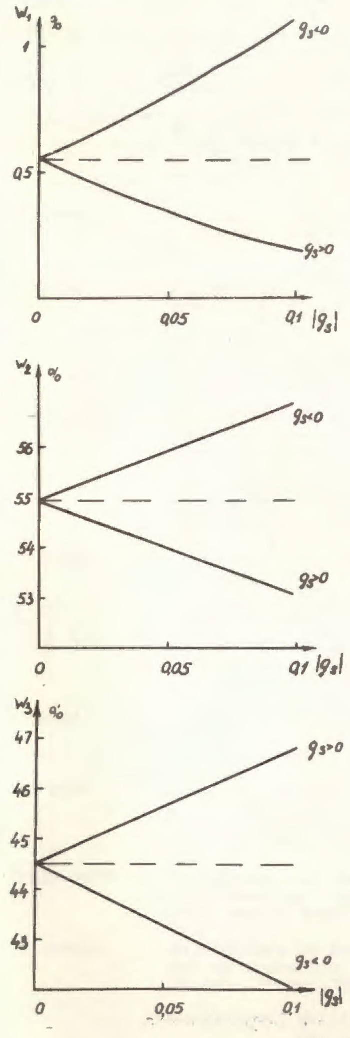

Fig. The emission probability for the hydrogen atoms in various spin configurations as a function of the parameter g_S.

The present upper levels for g_S obtained in the experiments on μ^+-decay[2] and ^{35}Ar -decay (β-ν -correlations)[3] are following

$$g_S(\mu^+) \leq 0.33 \qquad g_S(Ar) \leq 0.25 .$$

Therefore, more than one order of magnitude in accuracy may be gained if the experiment suggested in this paper was performed. If there is the scalar admixture in the weak interaction Hamiltonian, then the measurement of W_1 enables one to determine not only the value of g_S but its sign as well.

The sensitivity of W_1 to the tensor admixture is even higher. But the modern experimental ratio g_T/a obtained from the experiments on K -capture and positron emission is rather low[4]

$$g_T/a \leq 0.02.$$

The measurement of W_1 with 10% accuracy will result in no substantial improvement of this limit.

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