WEAK VECTOR COUPLING CONSTANT FROM NEUTRON β-DECAY

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The precise measurements of neutron β-decay give an opportunity for determination of vector (G_V) and axial-vector (G_A) constants of weak interaction. This needs experimental data from neutron lifetime (τ_n) and asymmetry of neutron β-decay (A_n). This way for determination of G_V for a long time could not compete with a well known way of finding G_V from superallowed $0^+ - 0^+$ nuclear transitions because of low accuracy in a neutron experiment. However the progress in the accuracy of the neutron lifetime determination as well as it's β-decay asymmetry has formed recently [1—6]. The great contribution in neutron data accuracy increasing was made by LNPI experiments, which were performed on the liquid-hydrogen source of polarized cold and ultracold neutrons from WWR-M reactor /7/ (fig.1). The experiment on neutron lifetime measuring

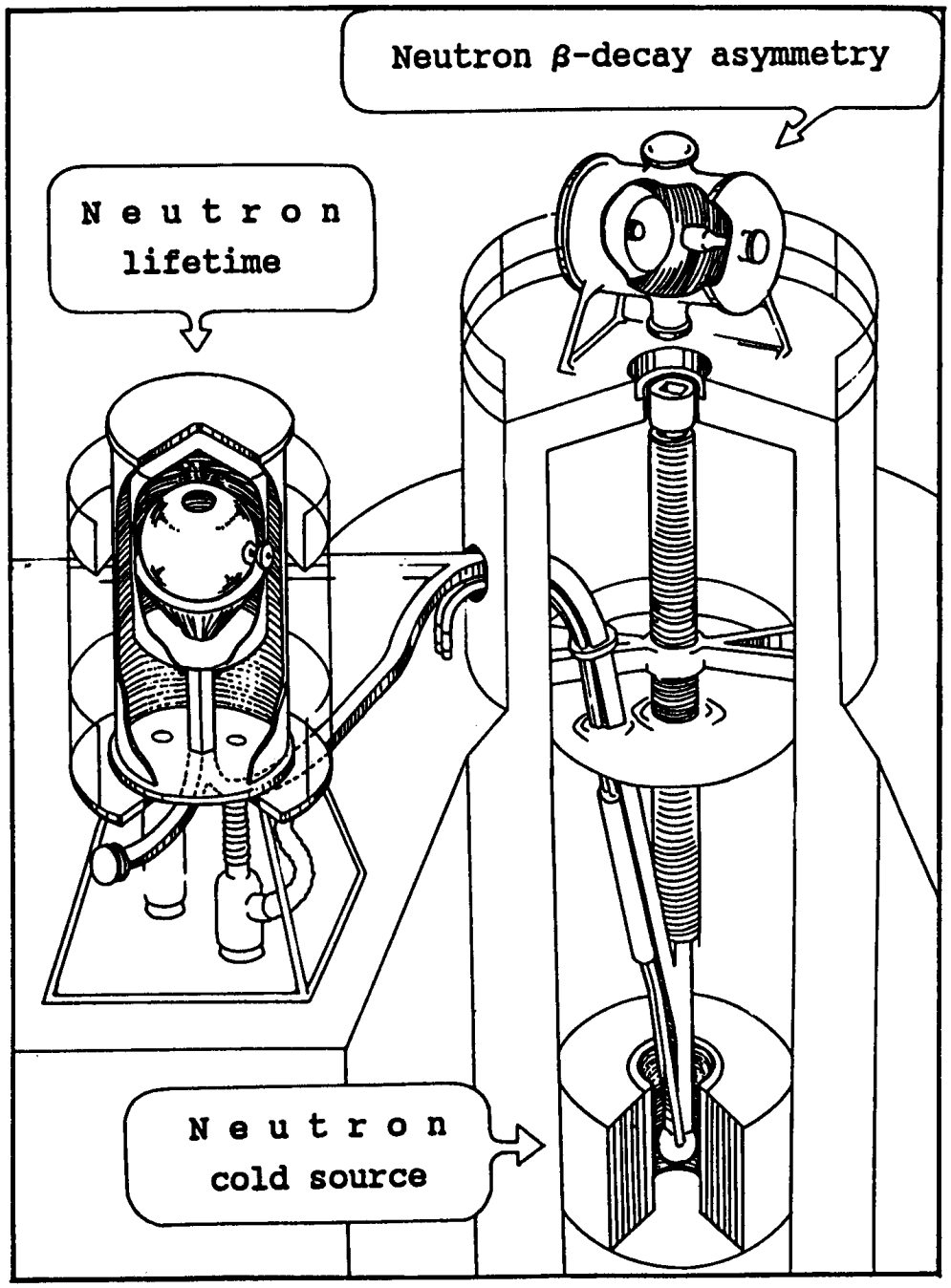

Fig.1. Liquid hydrogen source of polarized cold and ultracold neutrons in WWR-M reactor and experimental setups for neutron lifetime and β-decay asymmetry measurements

is performed in collaboration with JINR /1/, the experiment on measuring β-decay asymmetry — in collaboration with IAE [2]. The description of these experiments is presented in this collection.

Using the average value for neutron lifetime $\tau_n = 887.0 \pm 1.6\ s$ and the average value for the electron-spin polarization asymmetry of β-decay $A_n^0 = -0.1126 \pm 0.011$ one can obtain the results for vector and axial-vector constants of interaction ${}^nG_V'$ and ${}^nG_A'$:

$$ {}^nG_V' = G_V(1 + \Delta_\beta)^{1/2} = (1.1584 \pm 0.0024)\cdot 10^{-5}\ GeV^{-2}\ (c)^3, $$
$$ {}^nG_A' = G_A\,(1 + \Delta_\beta)^{1/2} = (-1.4561 \pm 0.0014)\cdot 10^{-5}\ GeV^{-2}\ (c)^3, $$

where Δ_β is the inner radiative correction to the process $n \to p + e^- + \tilde{\nu}_e$.

This result is shown with the right shaded ellipse in fig.2 together with the other results of the G_V-determination. The value of weak coupling constant G_V' determined from β^+-decays in superallowed $0^+ - 0^+$ transitions is presented by several results, differing from one another by nuclear structure corrections calculation. One can spot a systematic increase of ${}^{00}G_V'$. Vector coupling can be extracted from decays of strange particles using the G_μ-value, Kobayashi-Maskawa matrix unitarity and calculated value of inner radiative corrections difference for nucleon and muon decay. Finally, the asymmetry and lifetime data of ^{19}Ne, which were recently presented in the ref. [8], were also used for obtaining ${}^{Ne}G_V'$ and ${}^{Ne}G_A'$.

One can see the discrepancy between G_V'-value from β-decay and the other G_V'. The greatest contradiction occurs between G_V'-values from the neutron and ^{19}Ne (${}^nG_V' - {}^{Ne}G_V' = 3.7\,\sigma$). It survives at $2.1\,\sigma$ level if the results of asymmetry [2] having the main influence on this discrepancy are excluded (dotted-line ellipse in fig.2).

It seems possible to earmark several furtner directions for discussing of this contradiction; 1) systematical lowering of the experimentally measured absolute value of decay asymmetry and/or neutron lifetime, 2) radiative corrections, incomplete calculation of which can cause this discrepancy, 3) the presence of right-handed currents in the nucleon β-decay. The first of these options requires performing new more precise experiments. The second one seems to be rather unlike since the inner radiative correction is the correction to the elementary process $n \to p + e^- + \tilde{\nu}_e$, and the role of the strong interactions is taken into account by the structure correlations. Finally, the third option contradicts the restrictions to the right-handed currents from μ-decay. This contradiction is illustrated in fig.3, where the restrictions to the left-right model parameters from β^--decay of a neutron and β^+-decay of ^{19}Ne are presented together with the μ^+-decay data restrictions. However, if one assumes that for the Majorana masses of the right-handed neutrinos hold the relation

$$ m_{\nu_\mu^R} > m_\mu - m_e - m_{\nu_e^R},\quad m_{\nu_e^R} < m_n - m_p - m_e, $$

then the decay through the W_R is possible for a nucleon while it is forbidden for a muon and the contradiction with the muon restrictions is removed.

The choice between the three discussed above possibilities of the ${}^nG_V'$ and ${}^{00}G_V'$, ${}^{Ne}G_V'$ discrepancy can be made by the experiment, the most important for this is measurement of the ratio $\lambda_{AB} = \dfrac{A+B}{A-B}$ (simultaneous measuring the electron-spin (A) and the neutrino-spin polarization asymmetry (B)) and the independent measurement of B. For example, the most intriguing option of the right-handed currents is excluded if $B = B_{AB}$, where B is the experimental value, B_{AB} is the calculated value of neutrino-spin asymmetry from the parameter λ_{AB}, according to the classical formula of V-A theory.

References

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