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SITUATION IN STUDY OF ELECTRIC POLARIZABILITY AND MEAN SQUARE CHARGE RADIUS OF THE NEUTRON

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DISCUSSION

The definition of neutron electric polarizability (NEP) was advanced and its manifestation noted by Alexandrov and Bondarenko (1956) in connection with studies of neutron scattering by the Coulomb fields of a nucleus.[1] Polarizability is a fundamental characteristic of a particle introduced for the purpose of fully describing elementary particles interaction. It carries information not only about the ground but also excited nucleon states. Although the neutron was the first hadron for which attempts were made to measure the NEP (see, for ex.[2]) up to now only the polarizabilities of the proton and pion have been successfully measured with reasonable accuracy.

The best result for the NEP coefficient $(0.0\pm0.5)\times10^{-3}$ fm^3 was obtained by the Dubna-Germany-Latvia cooperation using neutron resonance technique on ^{208}Pb [3]. Concerning the measurement performed by Schmiedmayer et al.[4](Vienna-Oak Ridge cooperation) it was shown in [2,5] that this result should have given rise to doubt (mainly due to the influence of small angle neutron scattering [2]). The discussion of Schmiedmayer's experiment led to the assumption that the data reduction in [4] only allowed the determination of an upper limit of about 2×10^{-3}fm^3 for the NEP. It was also shown [2,3] that the NEP determined by neutron transmition depends on the neutron mean square charge radius (NMSCR).

In the limit case of low energy the "dimension" of a neutron may be defined with the help of NMSCR:

$$\langle r_E^2\rangle = 6(dG_E/dq^2)_{q^2=0} \qquad (1)$$

where G_E is the neutron electric form factor and q^2 is the four-moment transfer squared.

On the other side:

$$\langle r_E^2\rangle = 6(dF_1/dq^2)_{q^2=0} + \tfrac{3}{2}\mu_n\hbar^2/(M^2c^2) \qquad (2)$$

where F_1 is the Dirac form factor. The second term in (2) is of a magnetic nature associated with the Zitterbewegung of the neutron, satisfying the Dirac equation and having an anomalous magnetic moment μ_n. As for the first term , it arises from the neutron's internal structure, known as intrinsic NMSCR, related to the spatial distribution of charge density $\rho(\vec{r})$ inside the neutron[6] :

$$\langle r_{E,in}^2\rangle = \int \rho(\vec{r})r^2d^3\vec{r} = 6(dF_1/dq^2)_{q^2=0} = (3\hbar^2/Mc^2)(a_{ne} - a_F) \qquad (3)$$

where a_{ne} is the scattering of a neutron on an electron (ne-interaction), and $a_F = \mu_n(e^2/2Mc^2) = -1.468\times10^{-3}$fm is the Foldy scattering length. Experimental results can be devided into two groups: from Refs.[7,8]

$$\langle a_{ne}\rangle = (-1.309 \pm 0.024) \times 10^{-3}\mathrm{fm}$$

which lead to $\langle r^2_{E,in}\rangle > 0$ in contradiction with modern theory, and from Refs. [9–11]

$$\langle a_{ne}\rangle = (-1.577 \pm 0.034) \times 10^{-3}\mathrm{fm}$$

which leads to $\langle r^2_{E,in}\rangle < 0$, in confirmation of modern theory (see, for ex. [2]).

Recently it was shown [12] that the most probable reason for the discrepancy between the results of the Garching, Germany [8] and Dubna[11] determinations of the a_{ne} for bismuth is the difference in the methods of accounting for the influence of negative energy resonances on the measurable a_{ne}.Calculations of the σ_{tot} based on S matrices that do account for the phenomenon of inter-resonance interference has also shown that the additional inter-resonance term does not depend in any practical way on energy. Therefore, introduction of this term cannot affect the result of the a_{ne} determination in Dubna's experiment. This conclusion disagrees with the opinion made in [13], but as shown in [14] the result of [13] cannot be considered correct. In [12] it was also shown that for ^{208}Pb the resonance scattering can be neglected in the electronvolt range of neutron energy.

CONCLUSIONS

In my opinion , the a_{ne} values obtained in [7,8] are not well founded, and the actual $\langle r^2_{E,in}\rangle < 0$ is, (if eq.(3) is correct). This conclusion is in agreement with the results of [9–11] and with modern theoretical ideas[2,15,16] but it desagrees with the result of the analysis of experimental data made in [17]. Nevertheless, no interpretation of the results [7,8] can be achieved within the framework of known models of the neutron. If the [7,8] results are correct, then a serious fault resists our understanding of the structure of the neutron. To conclude, let it be noted that sometimes a question arises of whether theoretical results should be compared with $\langle r^2_{E,in}\rangle$ or with $\langle r^2_{E,in}\rangle + \frac{3}{2}\mu_n\hbar^2/(M^2c^2)$. As all calculations of nucleon radii are usually performed under the assumption of a motionless (not recoiling) heavy nucleon ($M \to \infty$) for which $(dG_E/dq^2)_{q^2=0} = \frac{1}{6}\langle r^2_{E,in}\rangle$, (see (1),(2) and (3)) it seems correct to compare the calculated result with $\langle r^2_{E,in}\rangle$ (see, Ref.[2])

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