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Method of the unitary clothing transformations in quantum field theory: calculation of the deuteron magnetic and quadrupole moments

We continue our explorations [1] of the electromagnetic properties of the deuteron with help of the method of unitary clothed transformations (UCTs) [2,3]. It is the case, where one has to deal with the matrix elements $\langle \mathbf{P}', M' | J^{\mu}(0) | \mathbf{P} = \mathbf{0}, M \rangle$. Here the operator $J^{\mu}(0)$ is the Nöther current density $J^{\mu}(x)$ at the point x = 0, sandwiched between the eigenstates of a "strong" field Hamiltonian H, viz., the deuteron states $|\mathbf{P} = \mathbf{0}, M \rangle$. These states meet the eigenstate equation $P^{\mu} | \mathbf{P}, M \rangle = P_d^{\mu} | \mathbf{P}, M \rangle$ with $P_d^{\mu} = (E_d, \mathbf{P}), E_d = \sqrt{\mathbf{P}^2 + m_d^2}$, $m_d = m_p + m_n - \varepsilon_d$, the deuteron binding energy $\varepsilon_d > 0$ and eigenvalues $M = (\pm 1, 0)$ of the third component of the total (field) angular-momentum operator in the deuteron center-of-mass (details in [3]). In the subspace of the two-clothed-nucleon states with the Hamiltonian $H = P^0 = K_F + K_I$ and the boost operator $\mathbf{B} = \mathbf{B}_F + \mathbf{B}_I$, where free parts K_F and \mathbf{B}_F are $\sim b_c^{\dagger}b_c$ and interactions K_I and \mathbf{B}_I are $\sim b_c^{\dagger}b_c^{\dagger}b_cb_c$, the deuteron eigenstate gets the form $|\mathbf{P}, M \rangle = \int d\mathbf{p}_1 \int d\mathbf{p}_2 C_M([\mathbf{P}]; \mathbf{p}_1\mu_1; \mathbf{p}_2\mu_2)b_c^{\dagger}(\mathbf{p}_1\mu_1)b_c^{\dagger}(\mathbf{p}_2\mu_2)|\Omega\rangle$ and we will show how one can find the C-coefficients within the clothed particle representation (CPR). Further, we use the expansion in the R-commutators

 $J^{\mu}(0) = W J^{\mu}_{c}(0) W^{\dagger} = J^{\mu}_{c}(0) + [R, J^{\mu}_{c}(0)] + \frac{1}{2} [R, [R, J^{\mu}_{c}(0)]] + \dots, (*)$

where $J_c^{\mu}(0)$ is the primary current in which the bare operators $\{\alpha\}$ are replaced by the clothed ones $\{\alpha_c\}$ and $W = \exp R$ the corresponding UCT. In its turn, the operator being between the two-clothed-nucleon states contributes as $J^{\mu}(0) = J_{one-body}^{\mu} + J_{two-body}^{\mu}$, where the operator

$$J^{\mu}_{one-body} = \int d\mathbf{p}' d\mathbf{p} F^{\mu}_{p,n}(\mathbf{p}',\mathbf{p}) b^{\dagger}_{c}(\mathbf{p}') b_{c}(\mathbf{p})$$

with $F_{p,n}^{\mu}(\mathbf{p}',\mathbf{p}) = e\bar{u}(\mathbf{p}')F_1^{p,n}[(p'-p)^2]\gamma^{\mu} + i\sigma^{\mu\nu}(p'-p)_{\nu}F_2^{p,n}[(p'-p)^2]u(\mathbf{p})$ that describes the virtual photon interaction with the clothed proton (neutron). By keeping only the one-body contribution we arrive to certain off-energy-shell extrapolation of the so-called relativistic impulse approximation (RIA) in the theory of e.m. interactions with nuclei (bound systems). Of course, the RIA results [1] should be corrected including more complex mechanisms of e-d scattering (see other our contribution). Since, as before in [1], we start with the following formula

$$\mu_d = \frac{1}{m_d} \langle \mathbf{0}; M' = 1 | \frac{1}{2} [\mathbf{B} \times \mathbf{J}(0)]^z | \mathbf{0}; M = 1 \rangle$$

for the magnetic moment of the deuteron, special attention has been paid to finding a relativistic correction due to the interaction part \mathbf{B}_{I} of the RIA results obtained in [1].

References

[1] A. Shebeko and I. Dubovyk, Few Body Syst. 54 1513 (2013).

[2] A. Shebeko, Chapter 1 in: Advances in Quantum Field Theory, ed. S. Ketov, 2012 InTech, pp. 3-30.

[3] I. Dubovyk and A. Shebeko, Few Body Syst. 48 109 (2010).

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