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QED in the Clothed-Particle Representation (CPR): a fresh look at positronium bound states description

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We have extended our previous applications of the method of unitary clothing transformations (UCTs) in mesodynamics [1] to quantum electrodynamics (QED) [2,3]. Starting from the primary canonical interaction between electromagnetic and electron-positron fields, the QED Hamiltonian has been expressed through a new family of the Hermitean and energy independent interaction operators built up in the e^2-order for the clothed electrons and positrons. The problem of describing the bound states in QED in case of the positronium has been considered by using the new interaction. At the beginning, we have evaluated the first correction to positronium ground state energy by using the perturbation theory recipe. It is proved that its value surprisingly coincides with those estimations given in [4] (see formula (1.1) therein). In order to verify such a coincidence beyond the perturbation theory, we are addressing to the partial wave decomposition of the positronium eigenvectors that has been successful when finding the u and w components of the deuteron wave function (WF) [5]. In this context, we derive the partial eigenvalue equation for the para-positronium WFs that belong to the total angular momentum J, viz.,

$$2\mathrm{p}_0\Psi^J(p) + \int_0^\infty \frac{p'^2 dp'}{p_0 p'_0}\Psi^J(p')\bar{V}^J(p,p') = m_{\text{p-Ps}}\Psi^J(p).$$

Here $\bar{V}^J(p,p')$ is the partial electron-positron quasipotential derived in the momentum representation from the new e^-e^+-interaction operator, $m_{\text{p-Ps}} = m_{e^-} + m_{e^+} + \varepsilon_{\text{p-Ps}}$ the para-positronium mass and $\varepsilon_{\text{p-Ps}}$ its binding energy. In turn, we have

$$^J(p,p') = \bar{v}^J(\text{Feynman-like}) + \bar{v}^J(\text{off-energy-shell}).$$

Such a separation implies that only the Feynman-like part survives on the energy shell, where $p'_0 = \sqrt{p'^2 + m^2} = p_0 = \sqrt{p^2 + m^2}$. Our next step will be to solve the eigenvalue equation to obtain the corresponding positronium states in the CPR (see Appendix C in [6]). Finally, our aim is to evaluate the positronium decay rates.

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