ABOUT QUADRUPOLE TOROIDAL MOMENT OF POSITRONIUM

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It is known that positronium (Ps) is the only accessible leptonic system that has eigenstates of C (charge conjugation) and CP (charge conjugation and parity) as well as of P [1]. For this reason it offers a unique opportunity to search for violations of these discrete symmetries [2–4]. In [3] the authors presented a general analysis for one-photon optical and microwave transitions of the form $Ps \to Ps' + \gamma$ (stimulated emission) or $Ps + \gamma \to Ps'$ (absorption), as tests of discrete symmetries C and/or P and/or T. Their conclusion is that the most promising experiments in positronium are those which search for T-violation without P-violation. Namely T-odd, P-even (TOPE) interaction between electron and positron is discussed in this paper.

One of the consequences of the presence of the mentioned TOPE interaction is the appearance of quadrupole toroidal moment (QTM) of positronium. It is known, that existence of static toroidal moments is caused by the violation of discrete symmetries. Odd rank static toroidal moments appear under parity violation and time-reversal conservation. On the contrary, the toroidal moments of even ranks arise under time-reversal violation and conservation of the parity. The toroidal moment of rank 1 (anapole moment) has been calculated for positronium by Sandars et al. in [5]. Here we discuss the next multipole moment, i. e. quadrupole toroidal moment of positronium. We showed that positronium QTM is different from zero if we assume that TOPE electron–positron interaction is mediated by light axial boson with mass μ ($\mu \leq \alpha m$, m is electron mass). In the opposite case of a heavy mediating boson the quadrupole toroidal moment of positronium is shown to vanish.

Unfortunately quadrupole toroidal moment can not be mesuared directly. In the analogy with anapole moment, QTM can manifest itself in the interaction with external electromagnetic field. For instance, one can consider the interaction of certain particle current with quadrupole toroidal moment of positronium or to study positronium QTM in the reaction

$e^+ + e^- \to Ps + \gamma$. Extracting T-odd, P-even correlations, such as $(\mathbf{p_i} \times \mathbf{p_f})\mathbf{S}$ (where $\mathbf{p_i}(\mathbf{p_f})$ and $\mathbf{S}$ are the initial (final) momenta and spin of the external particle), from the amplitudes of these processes we will be able to obtain the restriction on the TOPE interaction constant.

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