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Studies of discrete symmetries in decays of positronium atoms

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If the Nature was utterly symmetric the matter would not exist. Yet, processes driven by the gravitational, electromagnetic and strong interactions seem to be symmetric with respect to reflection in space (P), reversal in time (T) and charge conjugation (C). So far violations of these symmetries were observed only in processes governed by the weak interaction. Interestingly, though the matter which we know is made of quarks and leptons, violation of CP and T symmetries have been observed only for systems including quarks, and it has not yet been discovered in any processes involving purely leptonic matter.
Positronium is the lightest purely leptonic object decaying into photons. As an atom bound by a central potential, it is a parity eigenstate, and as an atom built out of an electron and an anti-electron, it is an eigenstate of the charge conjugation operator. Therefore, the positronium is a unique laboratory to study discrete symmetries whose precision is limited, in principle, by the effects due to the weak interactions expected at the level of 10^−14 and photon−photon interactions expected at the level of 10^−9. The newly constructed Jagiellonian Positron Emission Tomograph (J-PET) enables to perform tests of discrete symmetries in the leptonic sector via the determination of the expectation values of the discrete-symmetries-odd operators, which may be constructed from the spin of ortho-positronium atom and the momenta and polarization vectors of photons originating from its annihilation. We will present the potential of the J-PET detector to test the C, CP, T and CPT symmetries in the decays of positronium atoms and report on results from the first data-taking campaigns. J-PET built of plastic scintillators, provides superior time resolution, high granularity, low pile-ups, and opportunity of determining photon's polarization. These features allow us to expect a significant improvement in tests of discrete symmetries in decays of positronium atom (a purely leptonic system).
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