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Study of angular correlations in the ortho-positronium annihilation with the J-PET detector for the search of CPT symmetry violation

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The test of the three discrete symmetries of quantum mechanics under the chargeconjugation (C), parity transformation (P), and time reversal (T) is one of the most important issues in nuclear and elementary particle physics. All of three discrete symmetries are violated, singly or in pairs with different orders. The CPT combination of these three symmetries seems to be conserved in nature so far.

Studies of the observables violating the combined CPT symmetry constitute precise tests of the Standard Model. However, The CP-symmetry violation was observed to date only for systems involving quarks, raising the importance of searches its manifestations e.g. in purely leptonic systems. The 3 decay of spin-aligned ortho-positronium atoms (o-Ps) can be used to test CPT invariance in such a purely leptonic system. We search for CPT violating decay processes in positronium, using the angular correlation of $\vec{S}.\ (\vec{k}_1 \times \vec{k}_2)$ where $\vec{S}$ is the positronium spin and $\vec{k}_1$, $\vec{k}_2$ are the directions of the most energetic positronium decay photons.

The Jagiellonian Positron Emission Tomograph (J-PET) detection system enables experimental tests of both CP and CPT symmetries through measurement of the expectation values of angular correlation operators odd under these transformations and constructed from the spin vector of the ortho-positronium atom, the co-planar momentum vectors of 3 gamma photons originating from the decay of the positronium atom, and the linear polarization direction of annihilation photons.

Precise experimental symmetry tests with J-PET are possible using the trilateration based reconstruction technique of 3 ortho-positronium decays and a positronium production chamber including a highly porous material target, whose setup allows for determining the ortho-positronium spin liner polarization without the use of an external magnetic field.

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