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# Precision tests of discrete symmetries in the decays of positronium atoms using the J-PET detector

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Positronium is a purely leptonic object self annihilating into photons. It is an atom bound by a central potential and thus the states of positronium are parity eigenstates. Furthermore, as an atom composed of a particle (e-) and its antiparticle (e+), 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, only by the effects due to the weak interactions expected at the level of 10-14 [1] and photon-photon interactions expected at the level of 10-9 [2]. Violation of T or CP invariance in purely leptonic systems has not been observed yet[3]. The experimental limits on CP and CPT symmetry violation in the decays of positronium atom are set at the level of 10-3 [4,5] and limits on charge conjugation violation are set at the level of 10-7 [6-8]. Thus, there is still a margin of six orders of magnitude as regards T and CP, and two orders of magnitude as regards the C symmetry, where the phenomena beyond the Standard Model can be sought for by improving the experimental precision in investigations of decays of positronium atoms.
The Jagiellonian Positron Emission Tomograph (J-PET) is constructed of 192 polymer scintillators placed in three consecutive cylindrical layers of diameter 85, 93.5 and 115 cm respectively [9-15 ]. J-PET is optimized for the registration of photons from the electron- positron annihilation and provides a superior time resolution, higher granularity and lower pile-ups in comparison to crystal based detectors. With higher angular resolution of plastic scintillators, the geometrical acceptance of J-PET allows us to estimate the angle between the planes of gamma photons before and after the scattering. Thus, the J-PET is one of the unique facilities, which allows studying the polarization direction of photons [16-17]. The capability of registering multi-photons originating from the decays of positronium atoms enables to perform tests on discrete symmetries via the determination of the expectation values of the discrete-symmetries-odd operators, which might be constructed from the spin of ortho-positronium atom and the momenta and polarization vectors of photons originating from its annihilation [16-20].
In the proposed talk, the proof of capabilities of the J-PET in performing the precision tests on the discrete symmetries will be presented and the first experimental results (with precision higher than in the previous experiments) obtained in the recent data taking campaigns with the J-PET detector will be discussed.

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