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Testing charge conjugation invariance: From pions to positronium

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Bound systems composed of matter-antimatter are known to provide substantial testing ground for fundamental symmetries and decay dynamics. For example the lightest quark-antiquark system, the neutral pion π_0, which decays predominantly into two photons ($\sim 98.82\%$). Due to Charge conjugation (C) symmetry π_0 cannot decay into three photons. However, if calculated the branching ratio (BR) of $\pi_0 \to 3\gamma$ with respect to $\pi_0 \to 2\gamma$, with amplitude consistent with gauge invariance and Bose symmetry intact, the BR is extremely suppressed ($\sim 10^{-31}$). Such decays are a straightforward test for the invariance of C-symmetry. The present experimental upper limit on this decay channel is 3×10^{-8} at 90 % C.L.

Since the π_0 production typically requires high energy proton beams or photons of GeV scale, a low-energy alternative is the electron-positron bound state called Positronium (Ps). Ps is produced in the interaction of positron with electron in a porous material medium into two states - singlet, para-Positronium (p-Ps) and triplet ortho-Positronium (o-Ps). Due to C-symmetry, o-Ps (p-Ps) decays into even (odd) number of photons. The decay dynamics of p-Ps is additionally constrained by the bosonic nature of the photons, which forbids its decay into a configuration of 4 photons flying off in the direction of a regular tetrahedron vertices. Hence, observation of o-Ps decaying into this particular configuration could be used to test the violation of C-symmetry while mitigating the major background from p-Ps. Utilizing the triggerless data acquisition in the modular J-PET detector, we obtain a non-zero detection efficiency for such rare events. In this presentation, the ongoing study of this forbidden decay with the J-PET detector shall be discussed.

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Collaboration

J-PET

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