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Precision studies of ortho-positronium decay rate with J-PET

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Positronium atom (Ps), a fascinating purely leptonic system, serves as an excellent testbed for probing quantum electrodynamics (QED) in the bound state [1, 2]. Ps can manifest in one of two states, depending on the total spin number (S): a short-lived state with spin zero (para-Ps) and long-lived meta stable state with spin one (ortho-Ps). Prior to 1995, a significant discrepancy existed between experimentally measured and QED-predicted lifetimes values, termed as the ortho-Ps lifetime puzzle, which was later attributed to pickoff annihilations occurring during the thermalization process [3, 4]. Several groups have experimentally estimated the ortho-Ps decay rate in vacuum, yielding the most precise value of $\lambda_3 = 7.0401 \pm 0.0007\ \mu s^{-1}$ [5]. However, this remains two orders of magnitude less precise than the theoretical prediction [6, 7].
This study proposes a novel methodology for estimating the ortho-Ps decay constant by measuring the 3γ and 2γ decay rates as a function of time utilizing J-PET, a multimodule detector capable of simultaneous multiphoton registration [8-10]. The primary aim of this investigation is to significantly improve the accuracy of determining the decay rate of ortho-Ps compared to previous measurements. The forthcoming presentation will emphasize the adapted analysis algorithm and highlight the results, which have already shown a precision that is an order of magnitude better than the best value measured so far.

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