

Four Photon Decay of Positronium in GAMMASPHERE

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Positronium (Ps) is an eigenstate of the charge conjugation operator (C), and C symmetry can be tested in the decay of Ps. The physics of Ps decay is governed by Quantum Electrodynamics (QED), and QED can also be tested at high radiative orders in α .

Ps atoms from a source are formed in two states, para-Ps, or ortho-Ps, with C eigenvalues of +1 and -1. Since the photon has an intrinsic C eigenvalue of -1, para-Ps is constrained by C symmetry to decay to an even number of photons while ortho-Ps decays to an odd number.

Detecting O-Ps decaying to 4 photons would be a C violating signal. The QED allowed branching ratio for P-Ps to decay to 4 photons has been calculated to be 1.48×10^{-6} , and this has been measured with an uncertainty of 8% [1]. The best limit for a C violating decay of O-Ps to 4 γ is a branching ratio of $< 2.6 \times 10^{-6}$ [2]. These measurements required dedicated apparatus and acquisition times longer than five months.

We have performed an experiment to measure four-photon decay of Ps in Gammasphere (GS). We acquired 15 days of data using a Ps source consisting of 10 μ Ci of ^{68}Ge encapsulated in a plastic scintillator beta detector, surrounded by SiO_2 aerogel as a Ps-forming moderator. The ^{68}Ge and beta detector gave a 10-fold increase in detection efficiency for Ps decay events in GS versus the ^{22}Na source used during a test run in 2000. We collected $\sim 10^{10}$ events on tape. After an initial sort of the data, about 4×10^9 events of fully reconstructed positronium decays remain.

The beta detector was triggered by the e^+ from the ^{68}Ge decay. This acted as a start signal for a TAC, which was stopped by the decay gammas detected by GS. This allows discrimination between long-lived o-Ps and short-lived p-Ps.

To count 2, 3, and 4 γ Ps decay events, several cuts on the data reject scattered, accidental, and background events:

1. Sum energy within 8.3 keV of 1022 keV

2. γ 's must arrive within a 30 ns window of the average decay time

3. momentum sum of γ 's $< 150\text{keV}/c$

4. 2 γ events must be colinear, but 3 and 4 γ events must have no colinear photons

5. 3 γ events must be coplanar with the source, but 4 γ events must have no coplanar γ 's.

With these cuts, we observed 3.736×10^9 2 γ , 5.080×10^7 3 γ , and 43 4 γ events. The time spectrum of these events is shown in Fig. 1. C violating candidate 4 γ events occur after the initial decay of P-Ps, while allowed 4 γ events are simultaneous with this peak.

To measure branching ratios of P-Ps and O-Ps to 4 γ , simulations are necessary to determine the detection efficiency of GS for Ps decays. Using a GEANT based simulation of GS, and random event generators for decay photons based on the Ps decay kinematics, we determined the detection efficiency of GS for 2, 3, and 4 photon decays. We are now calculating expected background rates for several different event types to interpret the observed 4 γ events.

References

1. S. Adachi, et al., Phys. Rev. Lett. **65**, 2634 (1990).
2. J. Yang, et al., Phys. Rev. A **54**, 1952 (1996).

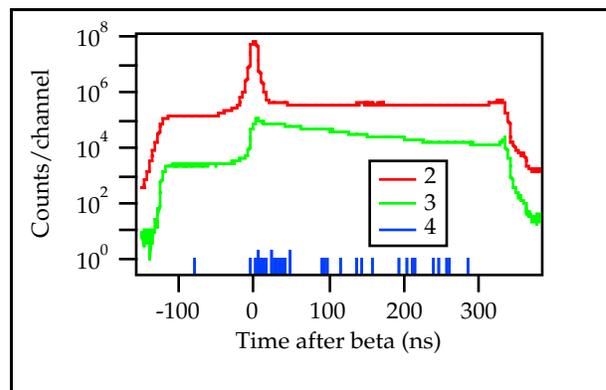


Fig. 1. Time spectrum of Ps annihilation photons in Gammasphere for April, 2001 run data.