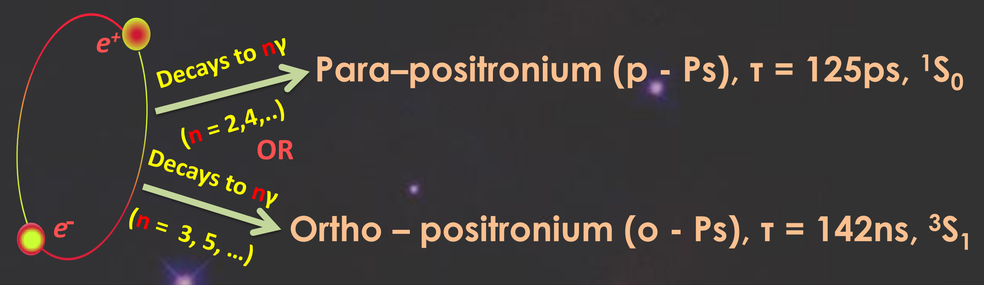
Search for the Charge symmetry forbidden decays of electron positron pair using the J-PET detector

J. Chhokar on behalf of the J-PET collaboration
Faculty of Physics, Astronomy and Applied Computer Science,
Jagiellonian University in Krakow, Lojasiewicza 11, 30-348 Krakow, Poland

Introduction

- ✓ Positronium atom which is a bound state of electron and its anti-particle (positron) is proved an excellent tool for studying the various phenomena e.g., discrete symmetries [1-3] , entangled states of photons [4,5] etc.
- ✓ The best limit Mills and Berko obtained for measuring the C-forbidden decays of singlet state ($^1S_0$) by estimating the ratio of decay to 3γ to 2γ for various angular correlation between the photons [6] was $R<<2.8x10^{-6}$ at 68% confidence level.
- ✓ With the better time and high angular resolution of the J-PET detector, We are aiming to perform the test to estimate the rate ratio (R) for three to two photon decay of positronium atom.

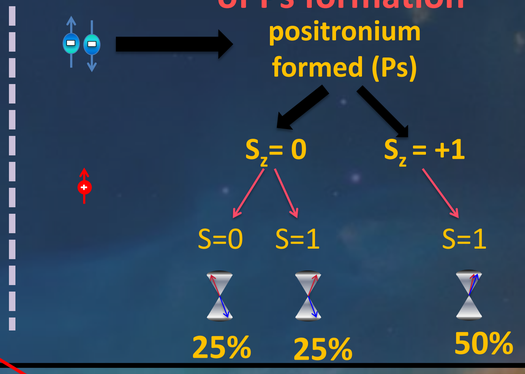
Positronium atom



J-PET detector to study the decay of positronium atom

- ⊙ J-PET is constructed of 192 polymer scintillators where each scintillator is attached with photomultiplier at each end.
- ⊙ Plastic scintillators offer high time and angular resolution.

Schematic diagram of combined spin states probabilities of Ps formation



Charge Conjugation symmetry

- ✓ With the C-violating weak interaction, Ps gains access to new photonic decay modes. The simplest one: p-Ps ->3γ.
- ✓ According to Bose Statistics, the rate of $^1S_0$ decaying into 3 Photons must vanish in the symmetric configuration.

Motivation:
- Charge symmetry test
- Bose statistics test

Lifetime Spectroscopy

Fig. 1 : Pictorial representation for the idea to measure the life time of Positronium atom.

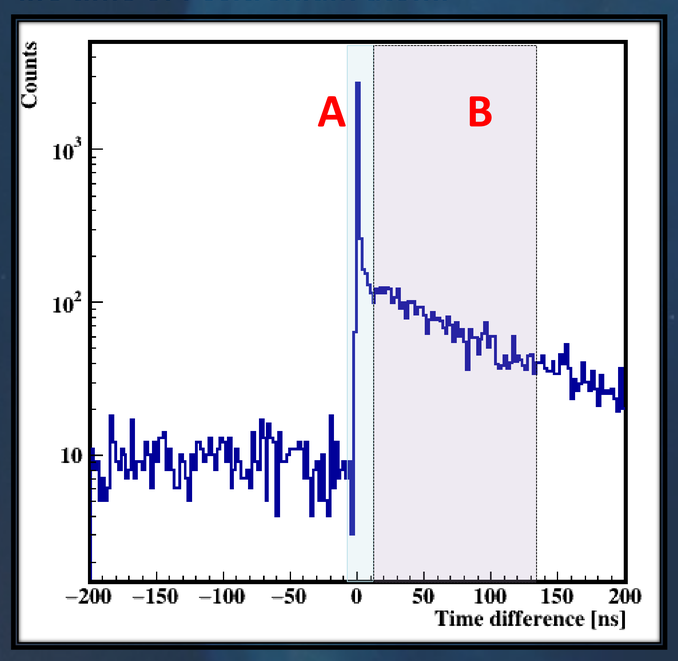
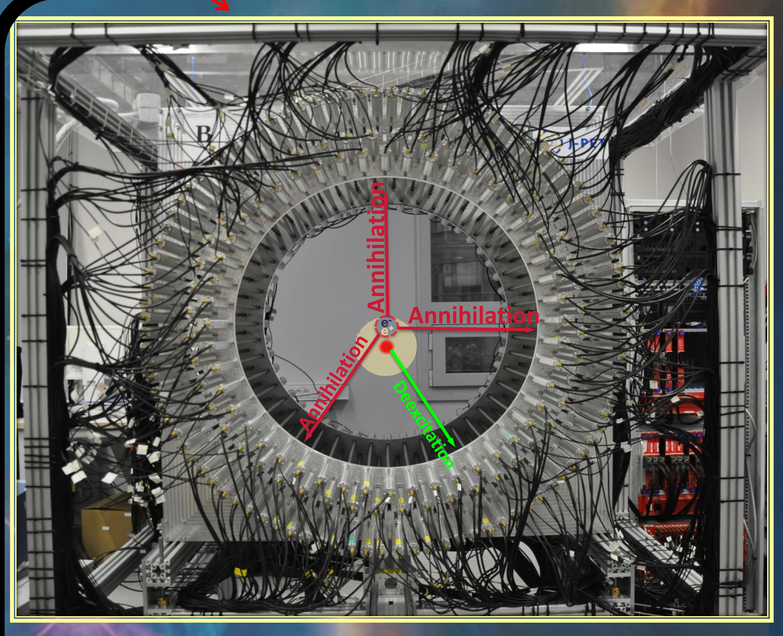


Fig. 2 : Experimentally measured Life time spectra of Positronium atom [7].



Experimental results

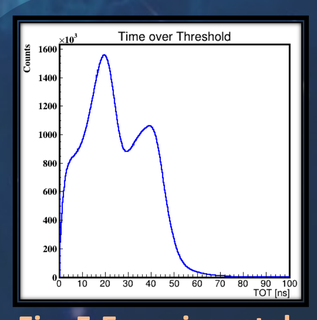
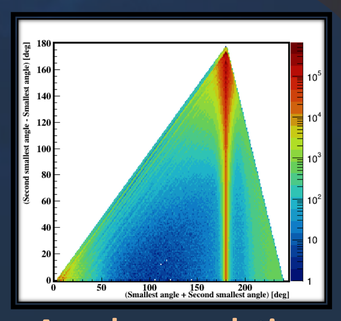


Fig. 5 Experimental measured TOT [ns].



Angular correlation

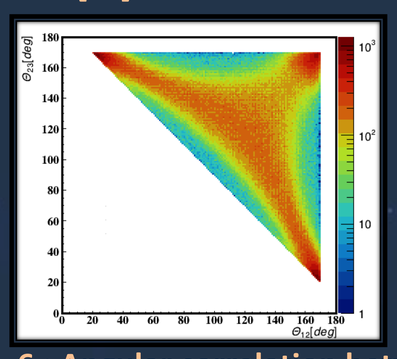


Fig. 6 : Angular correlation between annihilation photons.

Geant4 Simulations of J-PET detector for o-Ps decay

Generated events

Reconstructed Simulated events

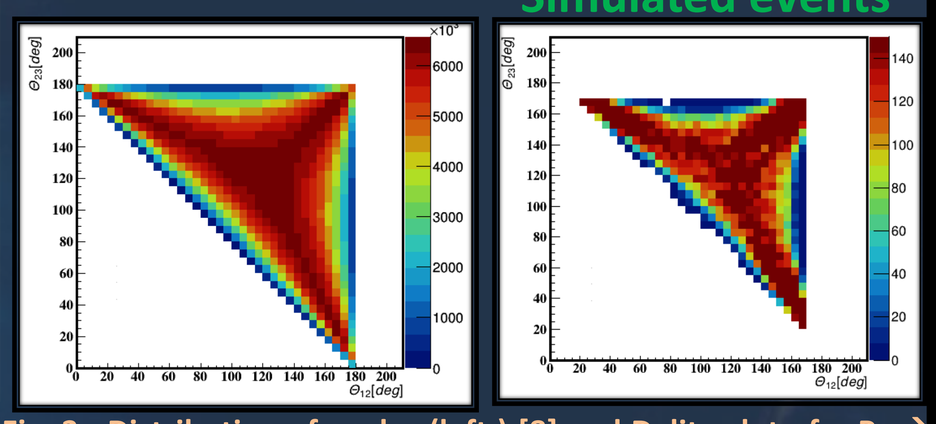


Fig. 3 : Distribution of angles (left) [8] and Dalitz plot of o-Ps → 3γ Monte Carlo based generation of o-Ps decays and angular correlations b/w the photons .

Experimentally Result corrected for efficiency map

Corrected Experimental Result

Efficiency Map

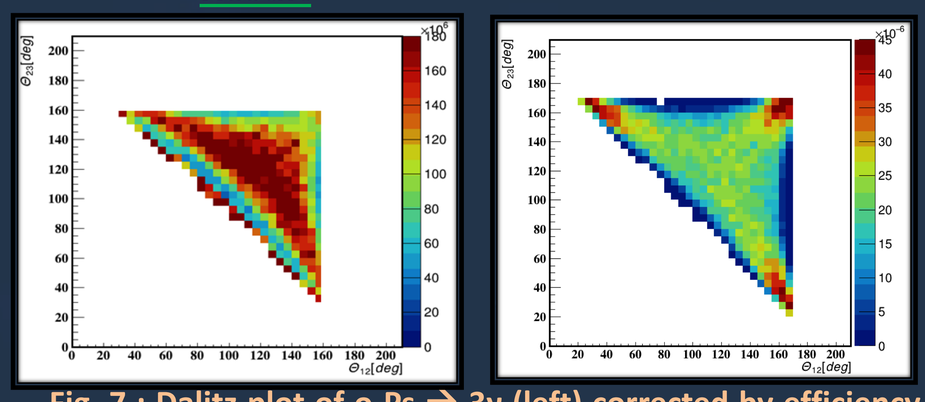


Fig. 7 : Dalitz plot of o-Ps → 3γ (left) corrected by efficiency map and Efficency map (right) obtained by dividing generated and reconstructed Dalitz's spectra from simulation (voxel by voxel).

Discussion and summary

1. The life time of the positronium is estimated based on the measured time difference (**Δt**) between detection of deexcitation gamma and the annihilation photons from the decay of Ps atom.
2. First experimental angular correlation between the annihilation photons originating from the decay of o-Ps atom are presented in Fig. 6.
3. Experimental Dalitz's spectra is corrected by efficiency map in Fig. 7.
4. In case of 3γ from the decay of p-Ps, for the symmetrical configuration one should not expect any contribution from the p-Ps -> 3**γ** [6]. The J-PET detector is unique for such studies due to the availability of many possible symmetrical configuration and investigate the influence on 3γ/2γ .
5. It is planned to compare the angular distributions for the two selected regions (A,B) divided based on the lifetime of positronium atom (Fig. 2). The voxelized based counts will be compared in order to quantify the difference between two measured distributions.

References

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