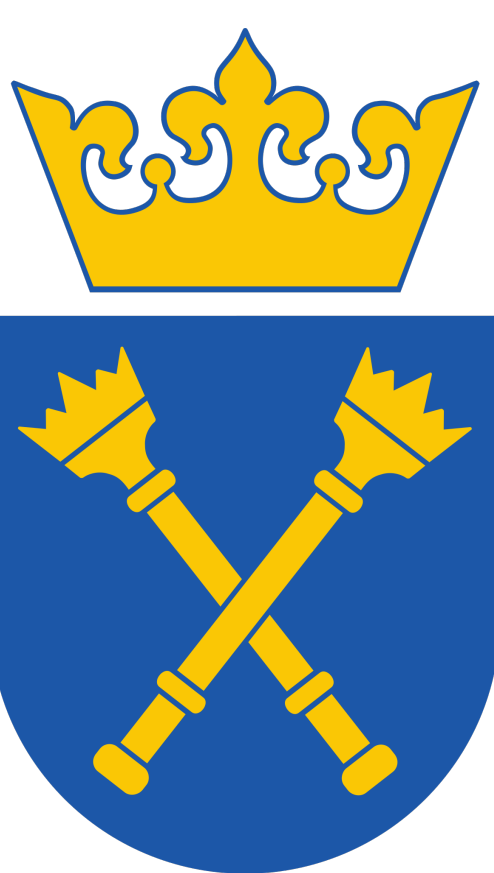




Mirror Matter in Positronium Decay Searches with the J-PET Detector

Justyna Mędrala-Sowa^{1, 2}, Elena Perez del Rio^{1, 2}, Paweł Moskal^{1, 2}
on behalf of the J-PET Collaboration

¹Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, 30-348 Kraków, Poland,
²Centre for Theranostics, Jagiellonian University, 31-501 Kraków, Poland



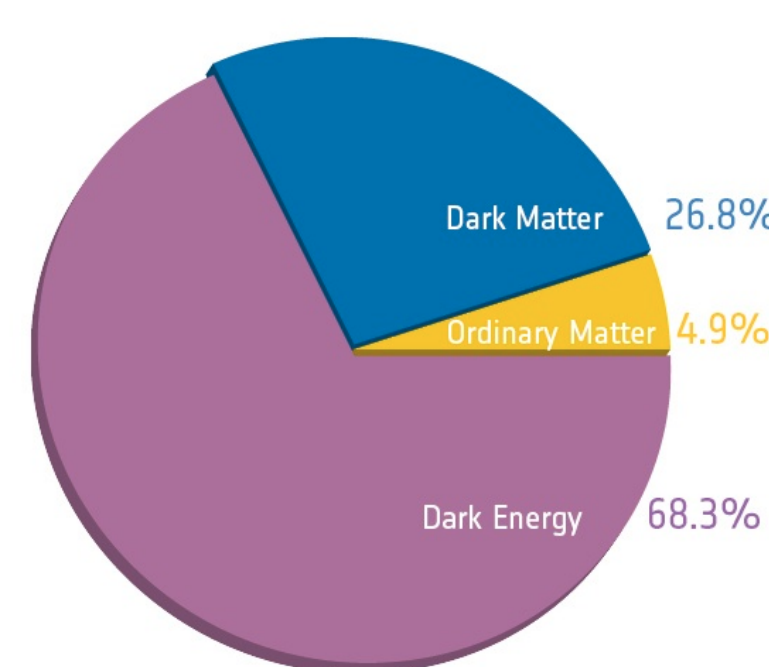
Objectives

The positronium (Ps) atom, a bound state of an electron and a positron, is a fascinating system for fundamental physics research. Its properties, well-described by Quantum Electrodynamics (QED) within the Standard Model (SM), make it an ideal candidate for precise tests. The J-PET setup [1, 2] at Jagiellonian University, based on plastic scintillator detectors with high angular and timing resolutions, enables multidisciplinary studies including tests of symmetries, quantum entanglement [3, 4], and the search for Dark Matter through positronium decays.

This work focuses on current searches for Dark Matter (DM) involving ortho-Positronium (o-Ps) decays using the J-PET detector. The primary goal is to investigate Mirror Matter [5], a proposed type of matter that could restore parity invariance and serve as a potential DM candidate. This study aims to achieve unprecedented precision in measuring the o-Ps decay to three gamma quanta, comparing results to QED predictions in the search for elusive DM [6].

Dark matter

- Hypothesized as an elusive substance that constitutes a large part of the universe's total mass,



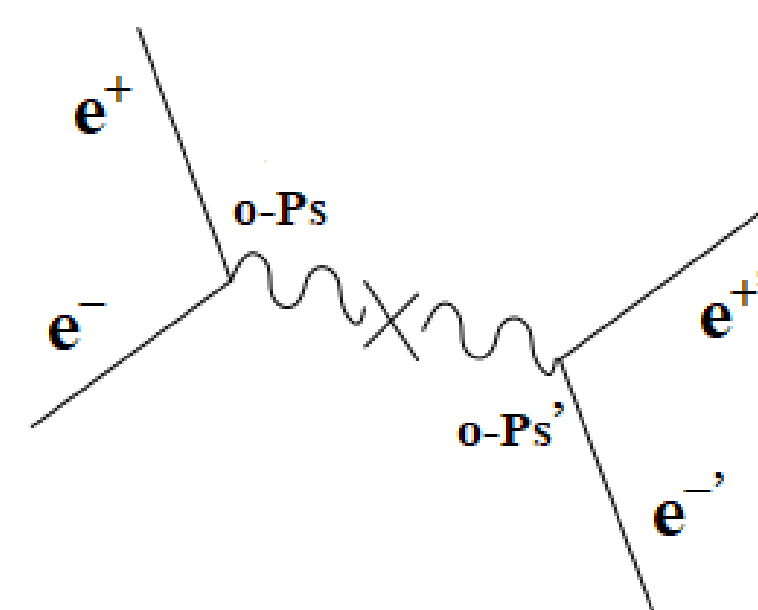
- Does not emit, absorb, or reflect electromagnetic radiation.

Mirror matter

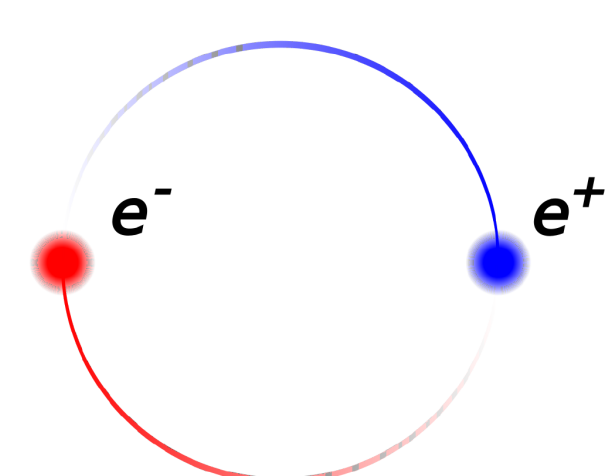
- predicted to exist parallel to the familiar matter we observe,
- interacts very weakly with ordinary matter,
- consists of particles, which are reflections of the observed particles,
- an excellent candidate for Dark matter**

Mirror matter in o-Ps

γ' is not visible in the detector $\rightarrow$ observed lifetime will deviate from predicted one [7]



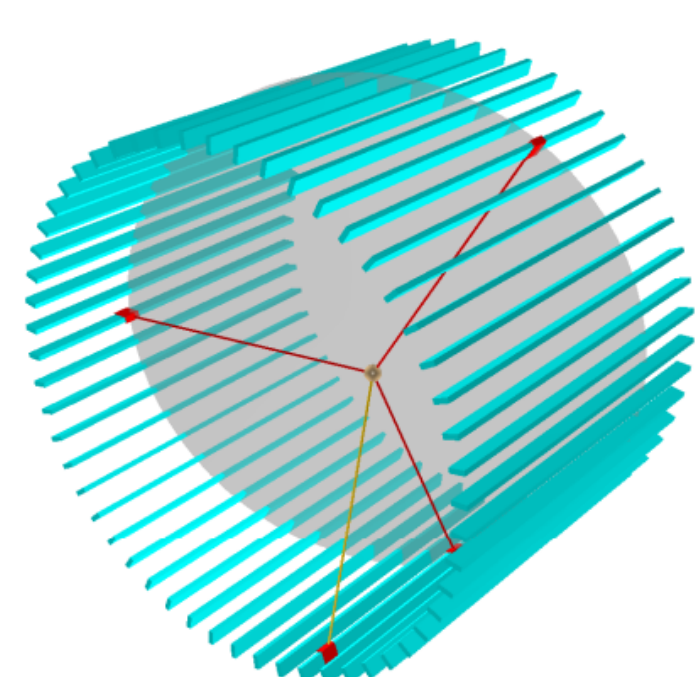
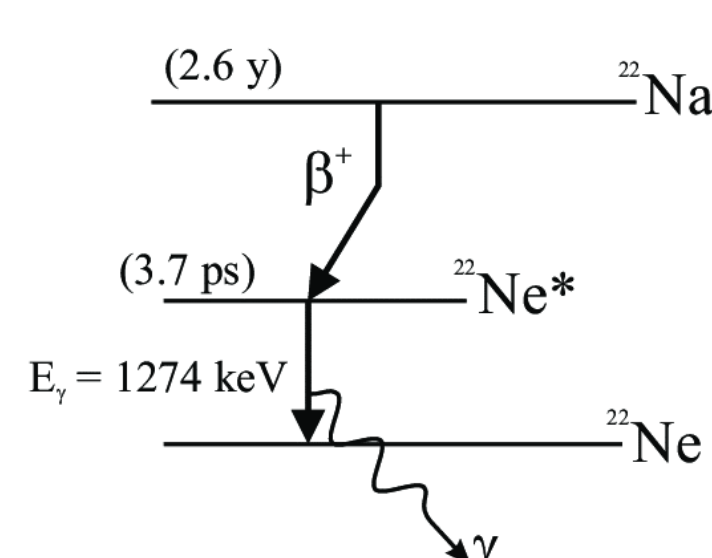
Positronium



State bound through electromagnetic interactions that consists of an electron and a positron.

It exists in two forms: a triplet state (o-Ps) and a singlet state (p-Ps). The triplet state (o-Ps) primarily decays into three photons.

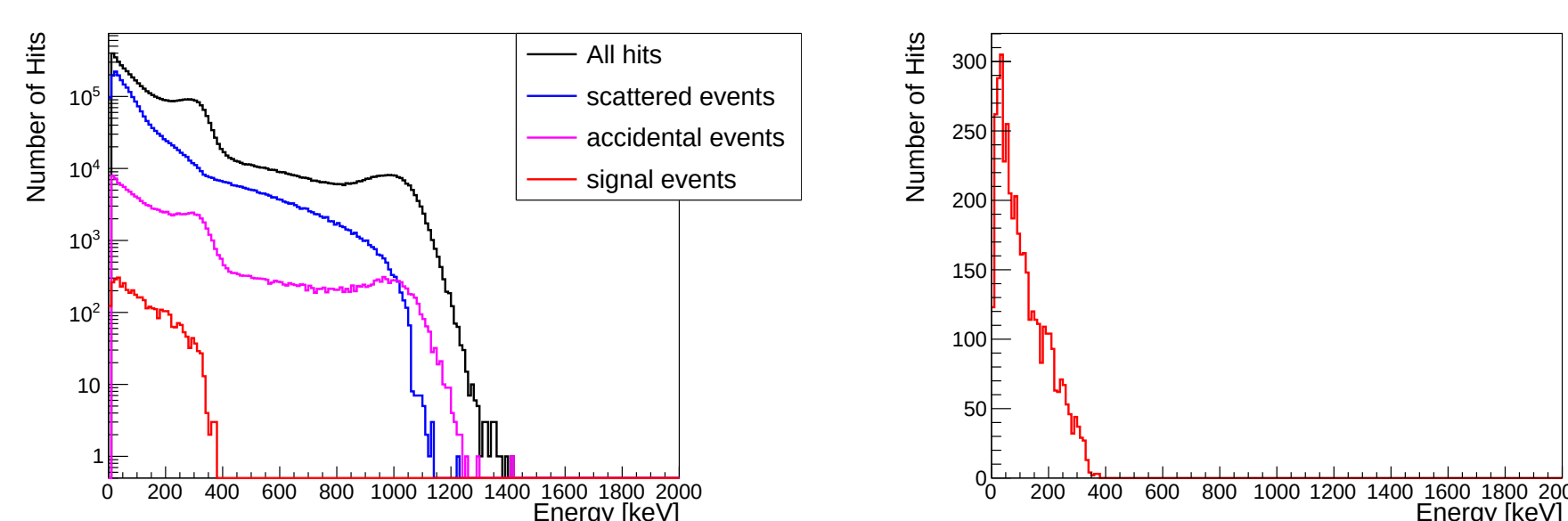
o-Ps in J-PET



Main background sources

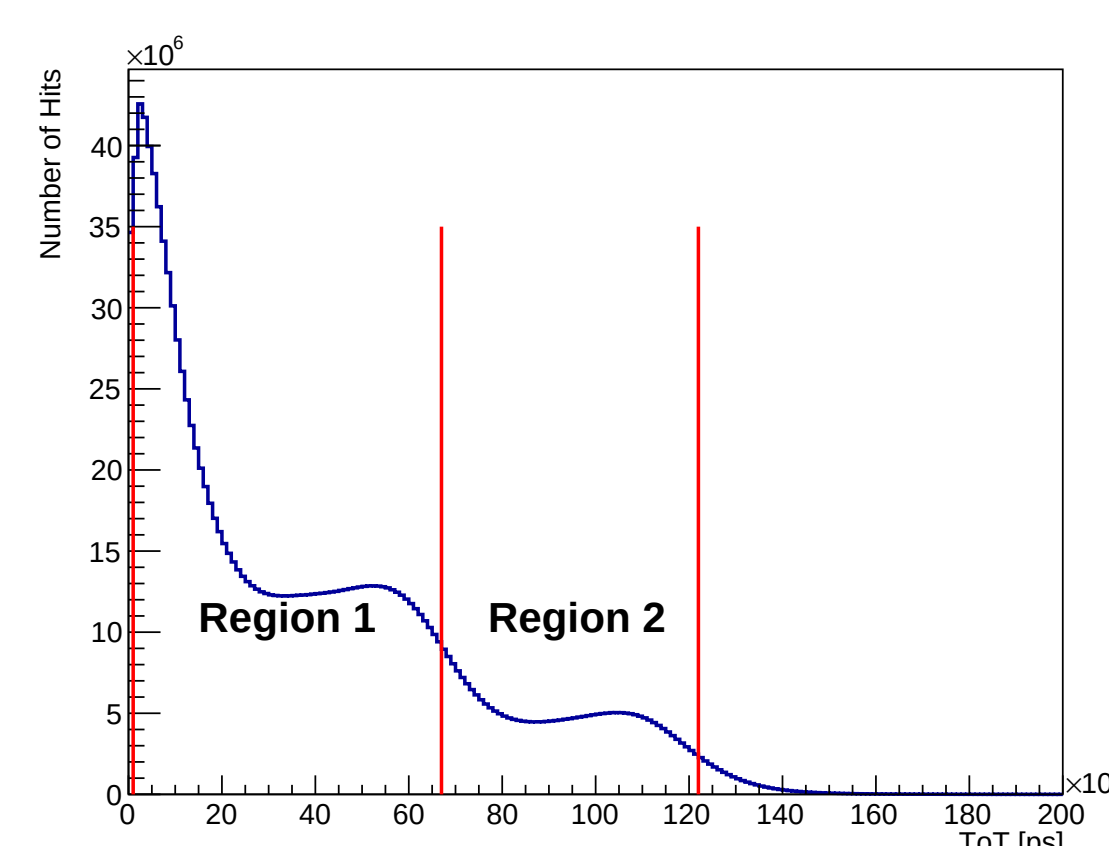
- random coincident events,
- cosmic rays and particles,
- scattered photons,
- pick-off - events where positron from a positronium annihilate with different electron from detector volume.

Energy for MC samples

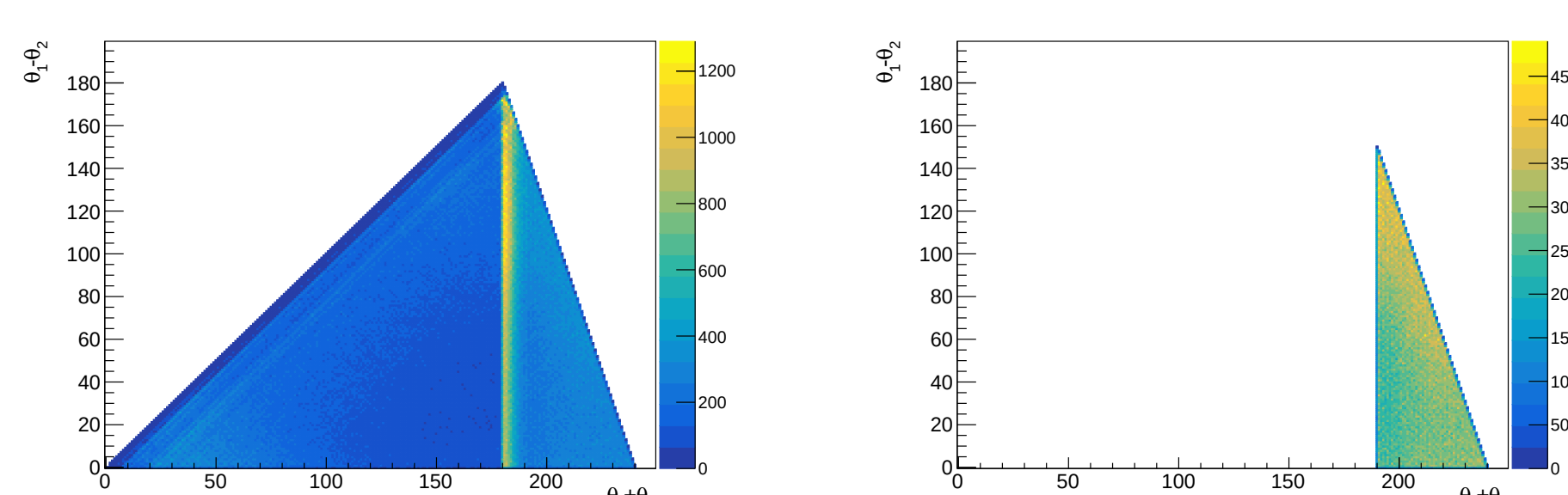


Data selection

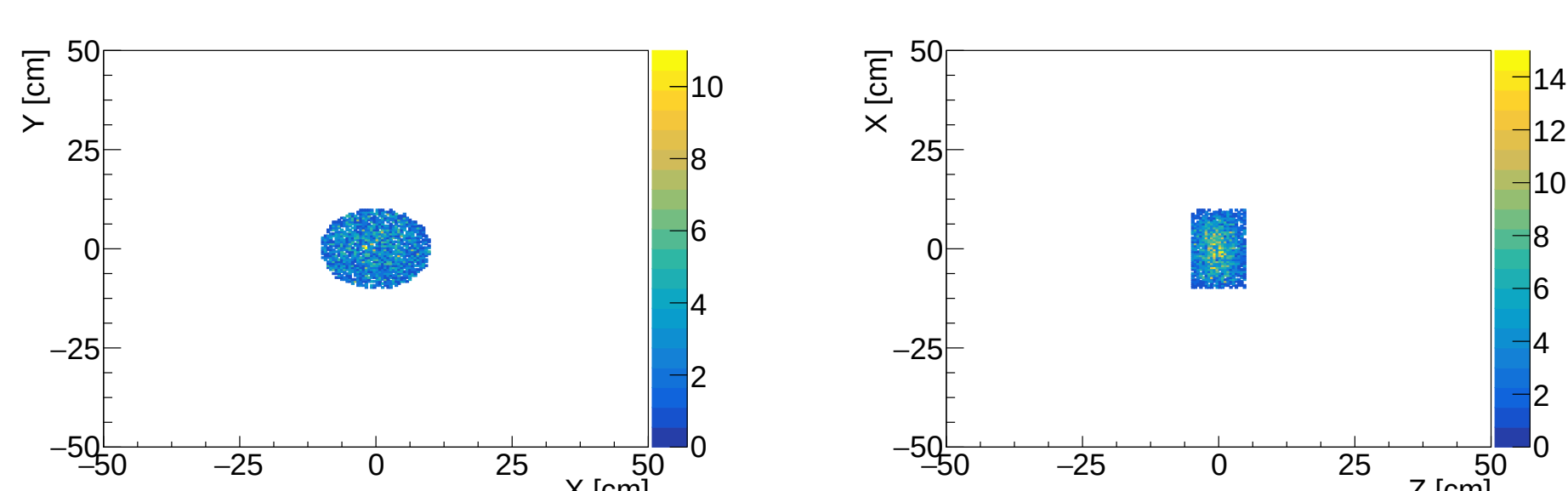
- number of the hits equals 4: $o - Ps \rightarrow 3\gamma + \gamma_{prompt}$
- 3 annihilation hit: exactly 3 hits in Region 1
- prompt: exactly one hit in Region 2



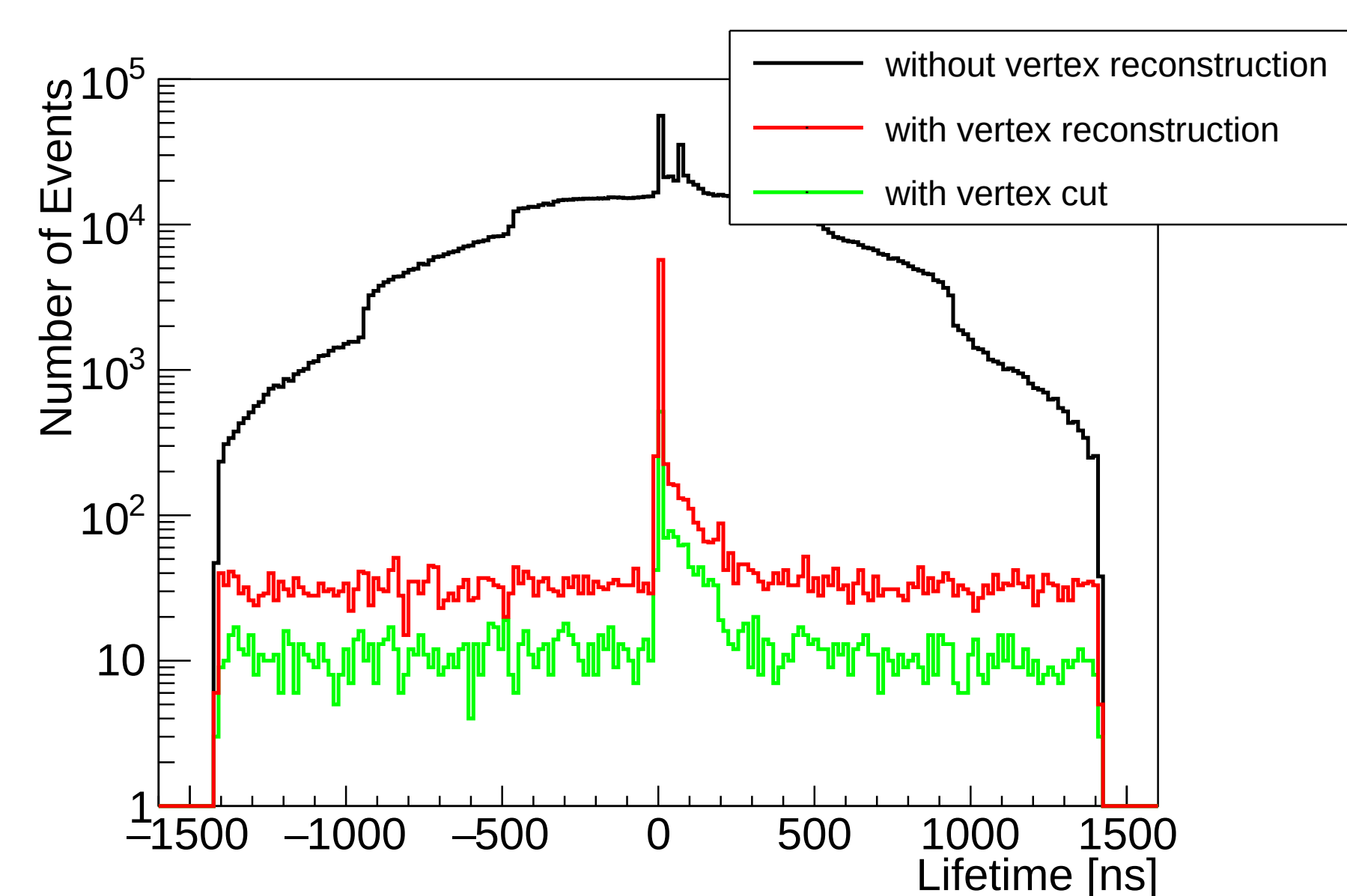
- sum of two smallest angles $\geq 190^\circ$



- decay point inside the detector



Lifetime



Summary

- The main research focus is to investigate mirror matter, a new type of matter and possible dark matter candidate.
- Positronium, with its distinct characteristics, stands out as an excellent candidate for probing new realms of physics.
- The ultimate objective is to measure the lifetime of positronium using the J-PET detector, which is specifically designed for accurate measurement of annihilation processes.

References

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