Mirror Matter in Ortho-Positronium Decay Searches using the J-PET Detector

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on behalf of the J-PET Collaboration

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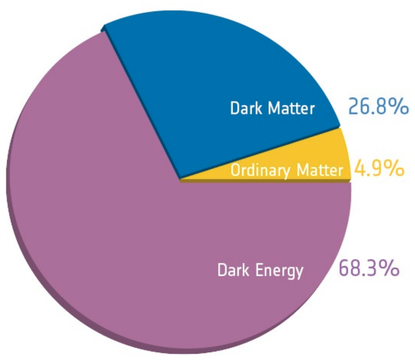
Objectives

Positronium (Ps), governed by Quantum Electrodynamics (QED), offers a fascinating realm for exploring fundamental physics. Monte Carlo simulations of its decay shed light on diverse particle physics aspects. The development of the J-PET setup [1], a novel tomography system at Jagiellonian University utilizing scintillator detectors with high angular and timing resolutions, not only facilitates multi-disciplinary studies encompassing fundamental physics tests, medical research, and quantum entanglement measurements [2, 3] but also enhances our capacity to investigate positronium decays in pursuit of potential dark matter (DM) candidates, a lingering enigma within the current SM framework.
In our research, we are utilizing the J-PET detector to investigate ortho-positronium (o-Ps) decays as part of our ongoing quest for dark matter. The primary objective is to explore mirror matter, a proposed form of matter aimed at reinstating parity invariance and considered a potential candidate for the Universe's DM component. Our study aims to stretch the current boundaries of precision measurement regarding the decay width of o-Ps decay to three gamma quanta, to compare these findings to the precise description in our pursuit of understanding the elusive nature of dark matter [4].

Dark matter

- Postulated mysterious and invisible substance that makes up a significant portion of the total mass in the universe,
- Does not emit, absorb, or reflect electromagnetic radiation.

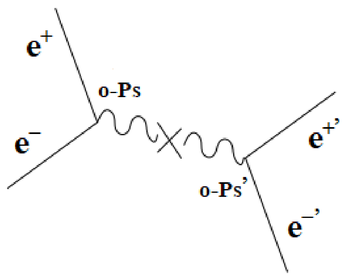


Mirror matter

- 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**

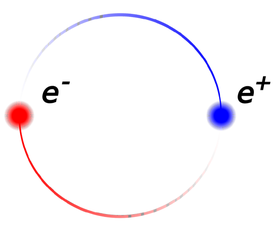
Mirror matter in o-Ps

γ' is not visible in the detector $\rightarrow$ observed lifetime will be enlarged [5]



Positronium

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

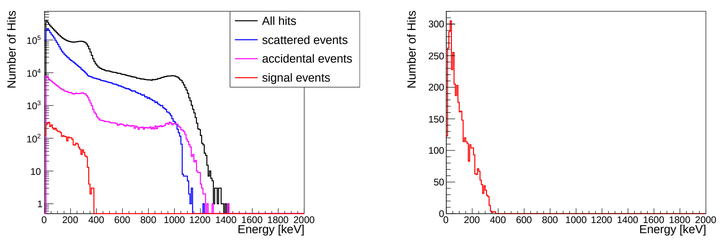


An excellent candidate for testing quantum electrodynamics (QED)

Main background sources

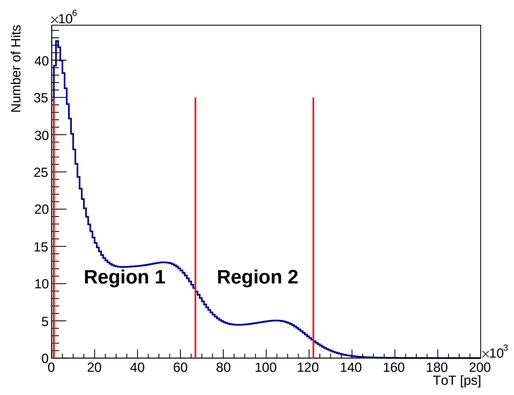
- random coincident events,
- cosmic rays and particles,
- scattered photons,
- pick-off - events where positron from a positronium annihilate with different electron from detector volume.

Energy for MC samples

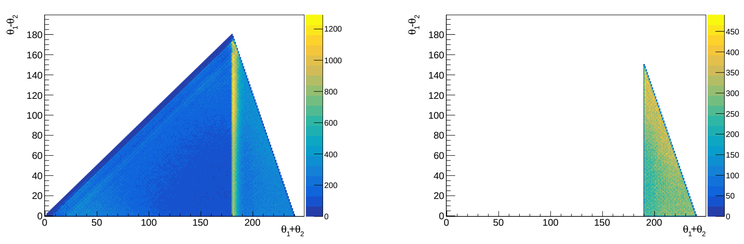


Data selection

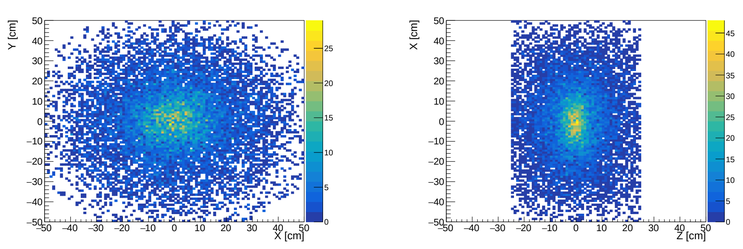
1. number of the hits equals 4
2. 3 annihilation hit: exactly 3 hits in Region 1
3. prompt: exactly one hit in Region 2



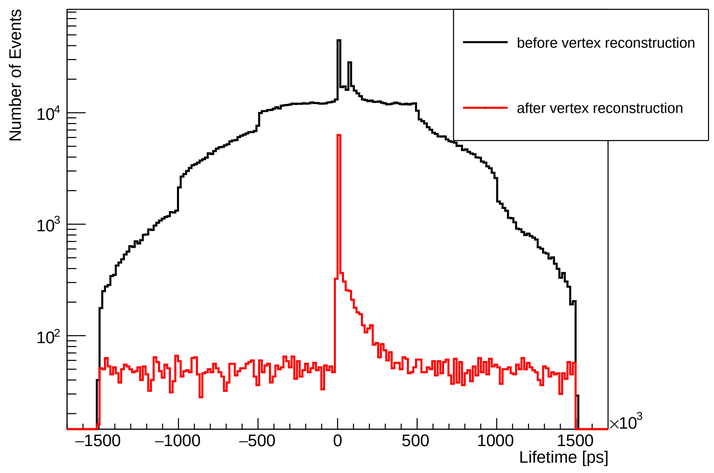
4. sum of two smallest angles $\geq 190^o$



5. decay point inside the detector



Lifetime



Summary

- The main focus of research 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 final goal is to determine the lifetime of positronium using the J-PET detector, specifically engineered for the precise measurement of annihilation processes.

References

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Acknowledgements

We acknowledge support from the National Science Centre of Poland through Grants No. 2019/35/B/ST2/03562, 2020/38/E/ST2/00112, the Ministry of Education and Science through grant no. SPUB/SP/490528/2021, and the SciMat and qLife Priority Research Area budget under the auspices of the program Excellence Initiative-Research University at Jagiellonian University.