Feasibility studies of Dark Photon searches with the J-PET detector

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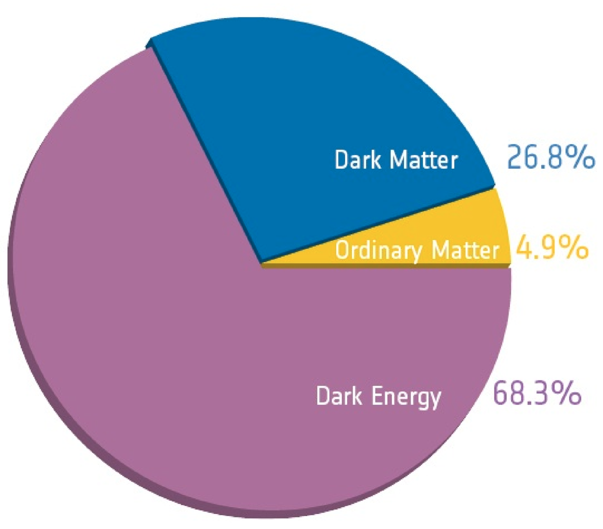
Objectives

The positronium, a bound state of electron and positron is a unique system to perform highly precise tests, due to no hadronic background and precise QED predictions. Being a system of lepton and antilepton, its properties are precisely described by Quantum Electrodynamics (QED) in the SM [1]. The final events topology can be simulated using Monte Carlo techniques. The J-PET detector is a multi-purpose, large acceptance system which is very well-suitable to the studies of positronium decay due to its excellent angular (1^o) and timing resolution [2, 3].
We present results on the feasibility of searching for Dark Matter (DM) candidates in the decay o-Ps → invisible[4] with the J-PET, which is well suited for the detection of positronium decay products. Toy Monte Carlo simulations have been prepared to incorporate DM decay models to the o-Ps decay expectations in order to assess the detector capabilities to search for such an elusive component of our Universe.

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.

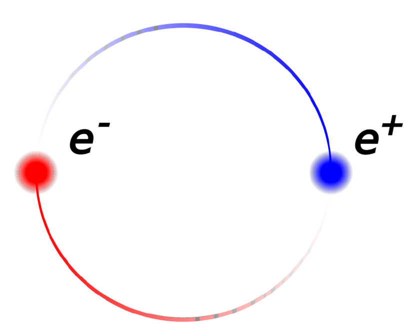


Several DM hypotheses and theoretical models have been proposed:

- WIMPs
- Axions
- MACHOs
- Fuzzy Dark Matter
- Self-Interacting Dark Matter
- Dark Photon, U boson
- Others

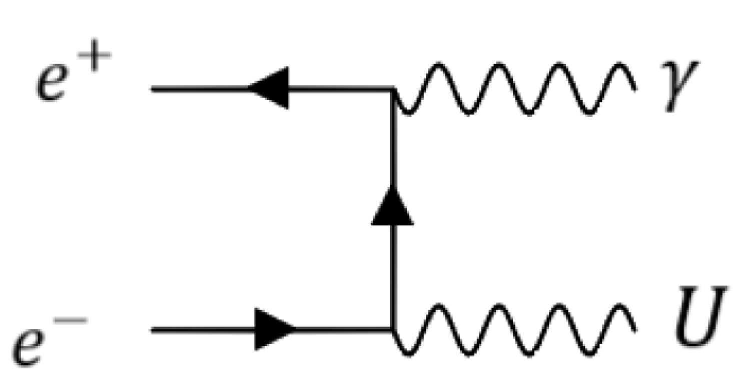
Positronium

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



An excellent candidate for testing quantum electrodynamics (QED)

DM model by P. Fayet and M. Mezard [4]:

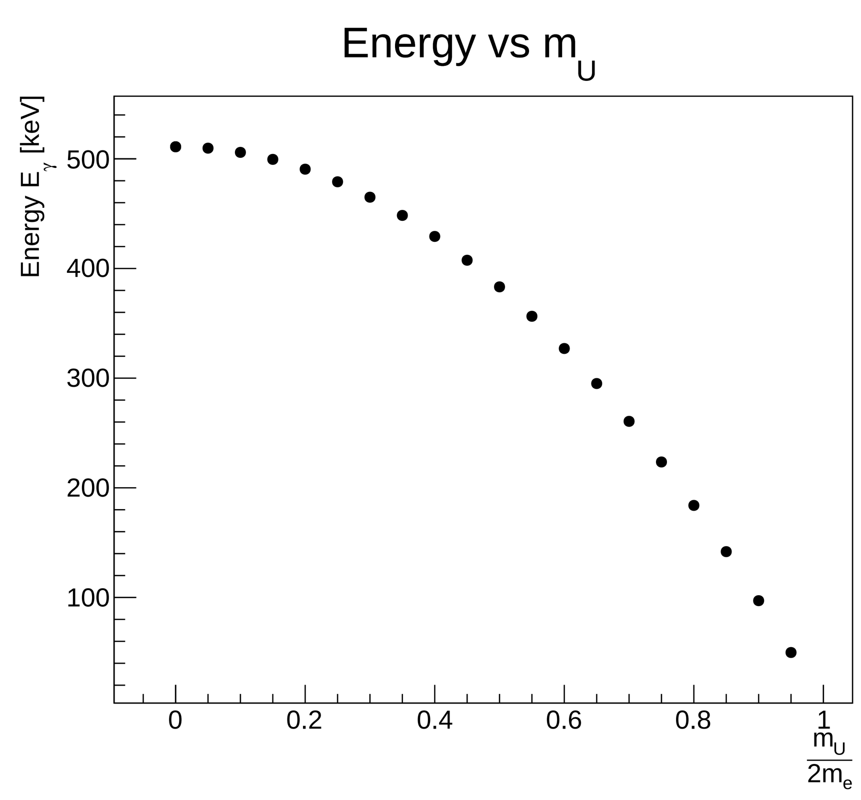


Branching ratio [4]:

$$\frac{\tau(1^3S_1 \to \gamma\gamma\gamma)}{\tau(1^3S_1 \to \gamma U)} \simeq 3.5 \cdot 10^{-8} \cdot \left|1 - \left(\frac{m_e}{2m_U}\right)^4\right|$$

Photon energy

$$E_\gamma = m_e - \frac{m_U^2}{4m_e}$$



Background

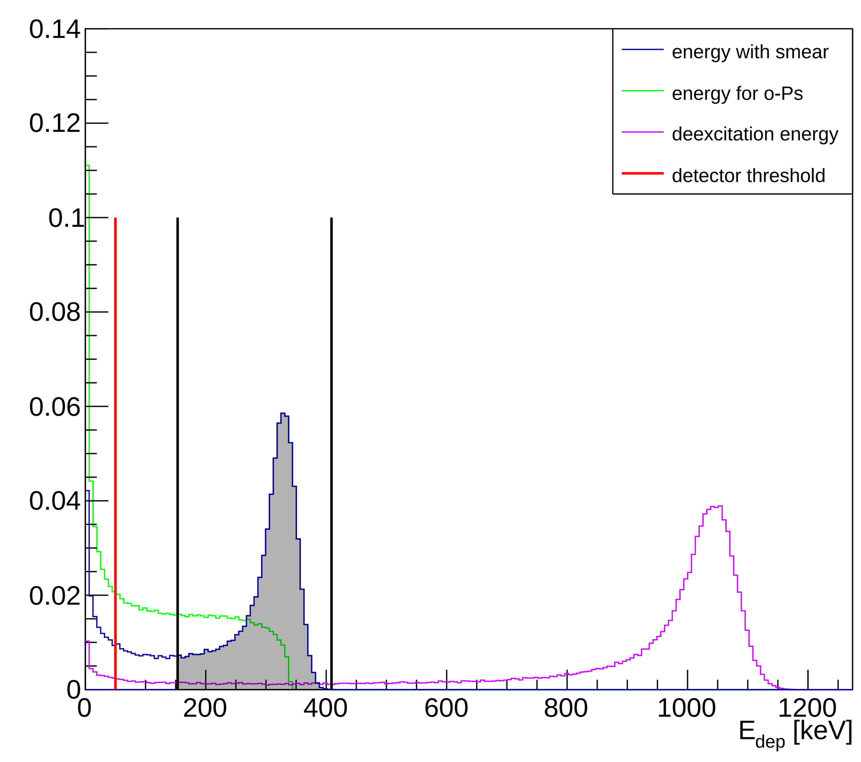
- o-Ps→ $\gamma\gamma\gamma$ with one photon registered,
- p-Ps→ $\gamma\gamma$ with one photon registered,
- Accidental events,
- Cosmic rays,
- Electronic noise.

Analysis

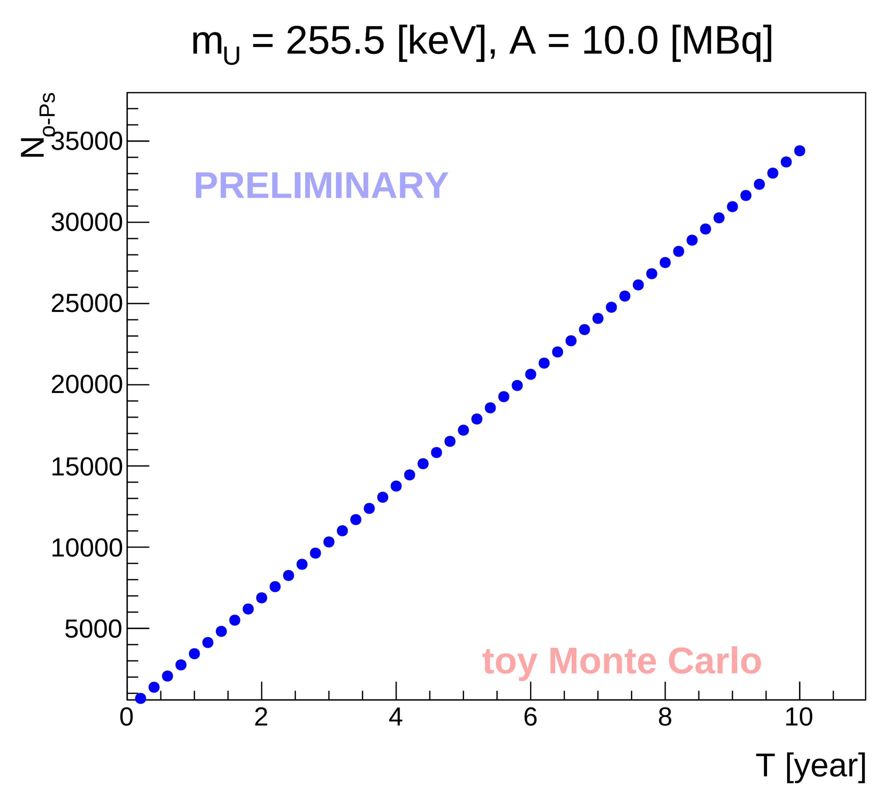
We measure prompt gamma and look for associated one-hit events in the extremely long delayed time window.

$$N_{o-Ps\to\gamma U}(m_U) = \frac{dN}{dt} \cdot BR(m_U) \cdot T \cdot \varepsilon(m_U)$$

- $\frac{dN}{dt}$ - the number of o-Ps produced per second,
- $BR(m_U)$ - the branching ratio,
- T - the observation time,
- $\varepsilon(m_U)$ - the detection efficiency.



Results



PRELIMINARY

	m_U [keV]	0.0	255.5	511.0	715.4
efficiency %	geometric	70.71			
	detection	17.47	17.90	19.41	22.12
	contribution from deposited energy	74.52	72.00	61.18	0.75
	contribution from the time window ($t_{shitf} = 200$ ns, $t_{acc} = 50$ ms)	1.24			
	total efficiency %	0.114	0.113	0.104	0.001

Summary

- It is possible to register 5000 candidates assuming activity 10 MBq events after 2 years,
- The background can be highly suppressed,
- More work is needed to analyse eg. the influence of cosmic rays.

References

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Acknowledgements

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