Study of time reversal symmetry in the decay of ortho-Positronium atoms using J-PET

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Contents:

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- Introduction of the J-PET detector
- Brief description of the discrete symmetry odd operator
- Methodology used to study the expectation values of the symmetry odd-operator
- Preliminary Experimental Results from the Collected Data
- Summary and future plans of the research

Jagiellonian Positron Emission Tomography

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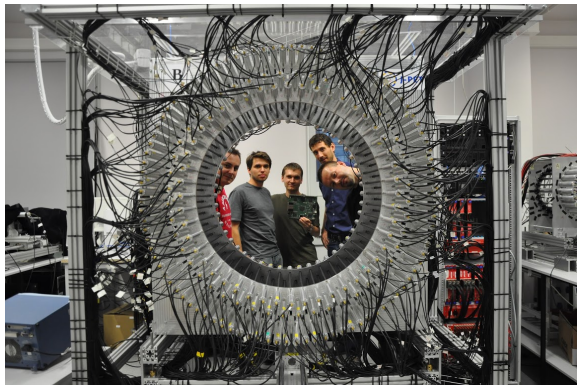

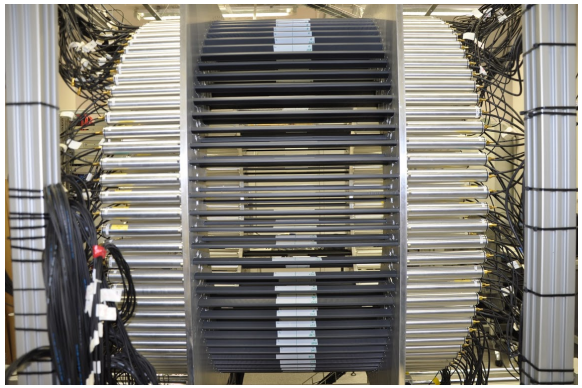

Figure 1: 3-Layers with 192 modules in total (500mmx17mmx9mm)

J-PET	**Standard PET**
Polymers	Crystals
High acceptance	Low acceptance
Compton scattering	Photoelectric effect
Time domain	Energy domain
Digital electronics	Analog electronics

Talk by P.Moskal on "Tests of discrete symmetries in positronium decays with the J-PET detector"

Discrete Symmetry Odd-Operators for o-Ps

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Table 1: Symmetry Odd-Operators

Operator	**C**	**P**	**T**	**CP**	**CPT**
$\vec{S}.\vec{k_1}$	+	-	+	-	-
$S.(k_1 x k_2)$	+	+	-	+	-
$(\vec{S}.\vec{k_1})(\vec{S}.(\vec{k_1} x \vec{k_2}))$	+	-	-	-	+
$\vec{\epsilon_1}.\vec{k_2}$	+	-	-	-	+
$\vec{S}.\vec{\epsilon_1}$	+	+	-	+	-
$\vec{S}.(\vec{k_2} x \vec{\epsilon_2})$	+	-	+	-	-

Where,

$$|\vec{k_1}| > |\vec{k_2}| > |\vec{k_3}| \tag{1}$$

P.Moskal et. al., Acta Phys. Polon. B47 (2016) 509

Time Reversal Symmetry Odd-Operator for o-Ps

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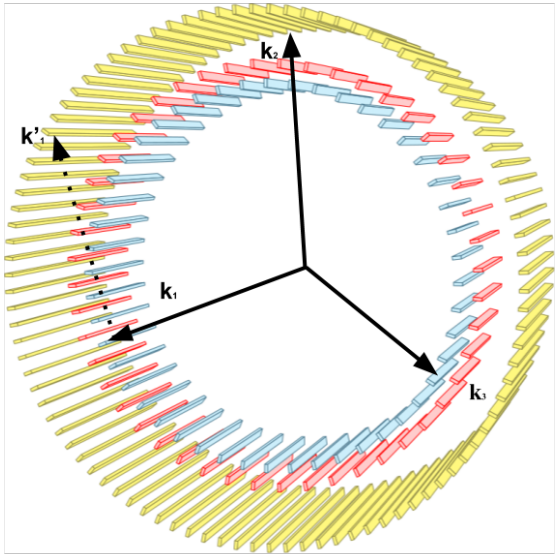
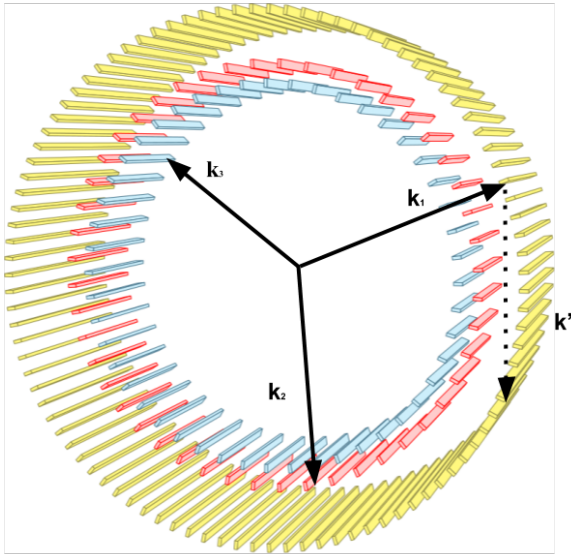
Table 2: Time Reversal Symmetry Odd-Operator

Operator	C	P	T	CP	CPT
$\vec{\epsilon_1}.\vec{k_2}$	+	-	-	-	+

$$\vec{\epsilon_1} = (\vec{k_1} x \vec{k_1'}) \tag{2}$$





Time Reversal

Polarization of para-Positronium

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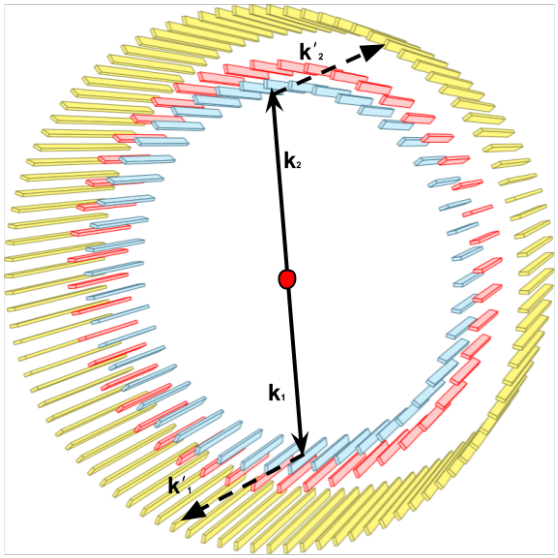
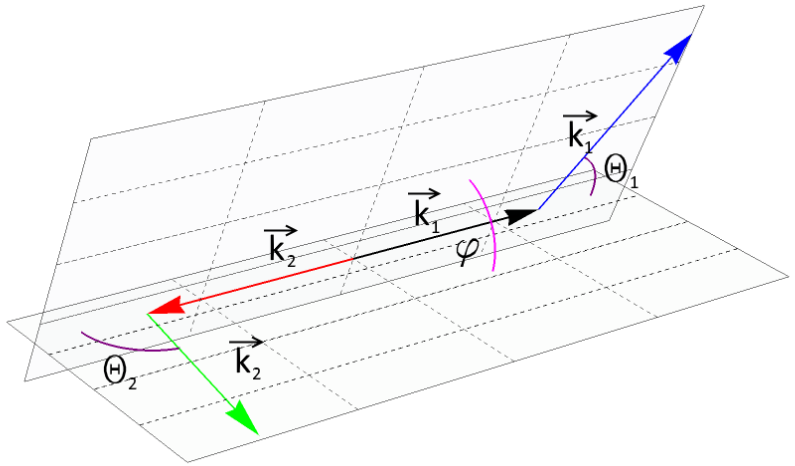
- p-Ps decay into even number of gamma
- Scatter Angle (θ)
- Angle between the scatter planes (φ)





Poster by N.Krawczyk on "Feasibility study of the measurement of annihilation photons polarization with the J-PET detector

Desired number of Hits for p-Ps events

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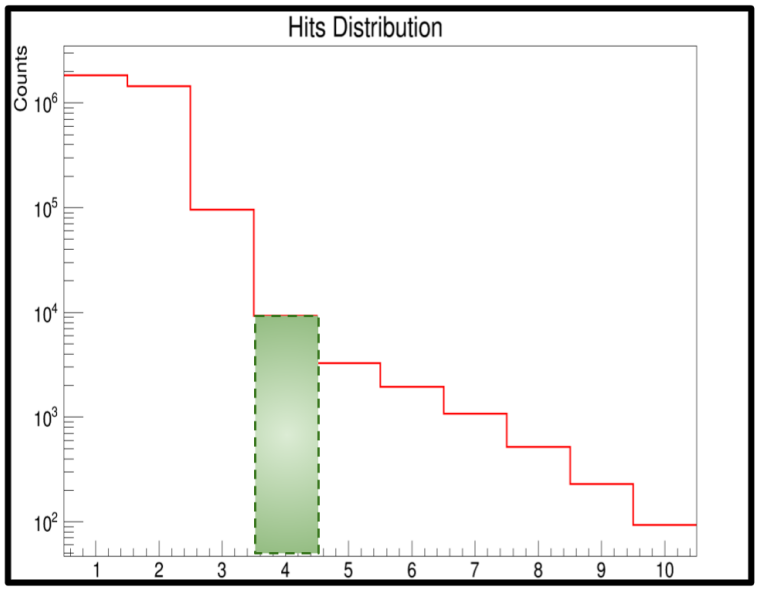
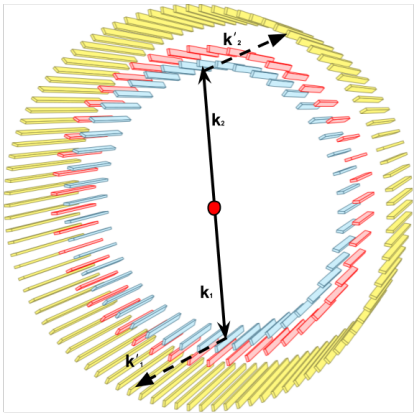
- 1.0% of the total data collected.
- Selection of 4-hit events only.





G.Korcyl et. al., Bio-Algorithms and Med-Systems 2014; 10(1): 37–40

Energy Loss used to differentiate the De-excitation gamma from Annihilation gamma

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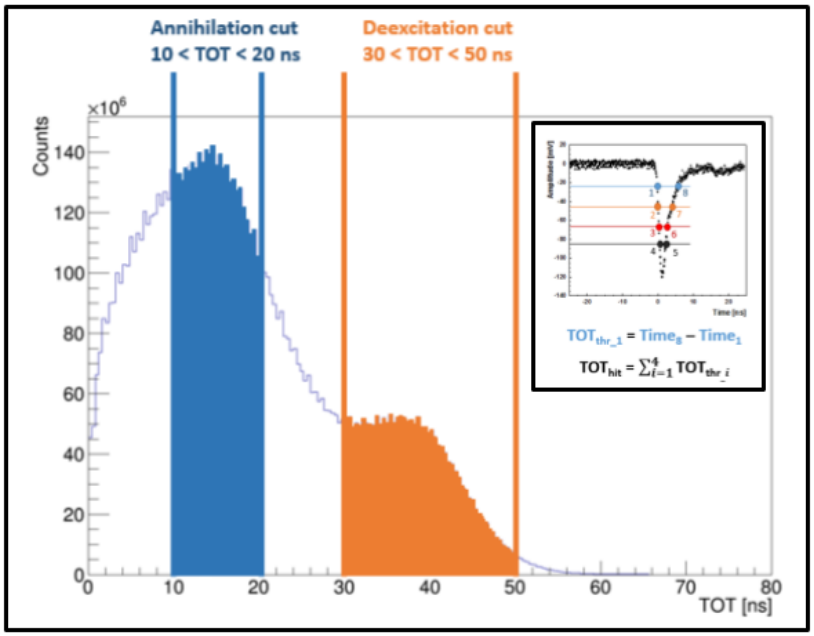
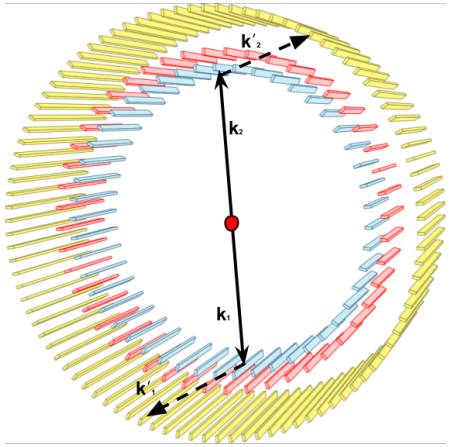
TOT - Time Over Threshold





Poster by K.Dulski titled "Positronium decay study with the J-PET detector"

Angle Estimation

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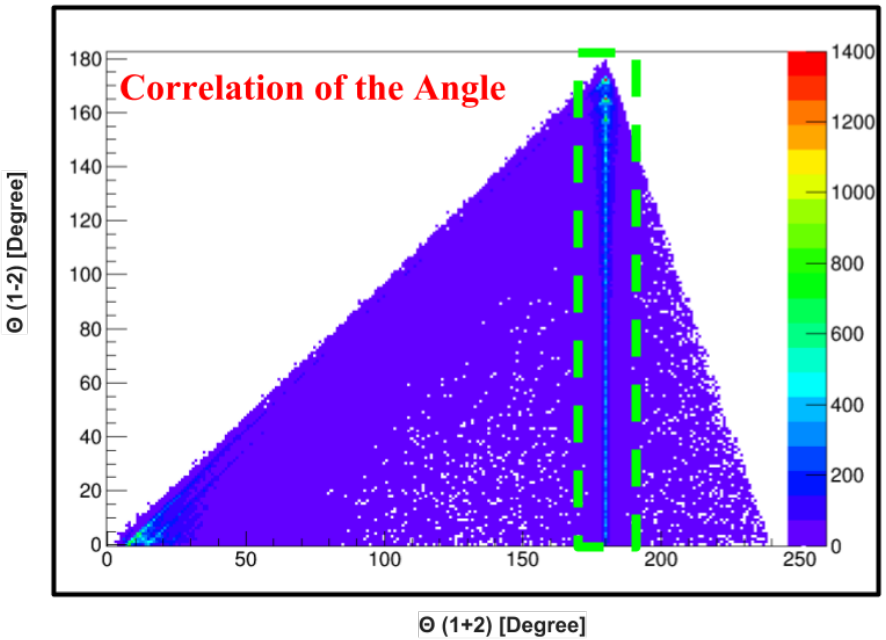

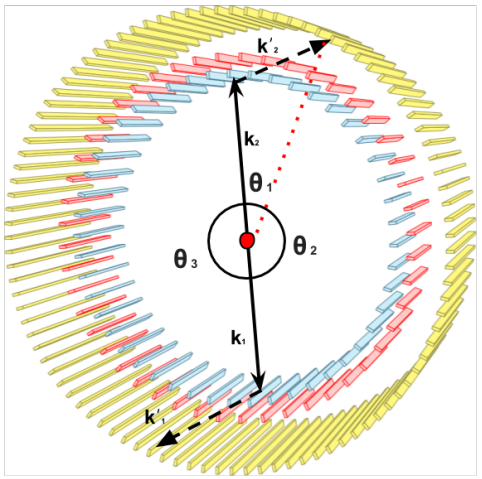

Where ,

$$\Theta(1+2) = \theta_1 + \theta_2 \tag{3}$$

and

$$\Theta(1-2) = \theta_1 - \theta_2 \tag{4}$$

D. Kaminska et al. (J-PET) Eur.Phys.J. C76 (2016), 445

Primary and Secondary Gamma Correlation

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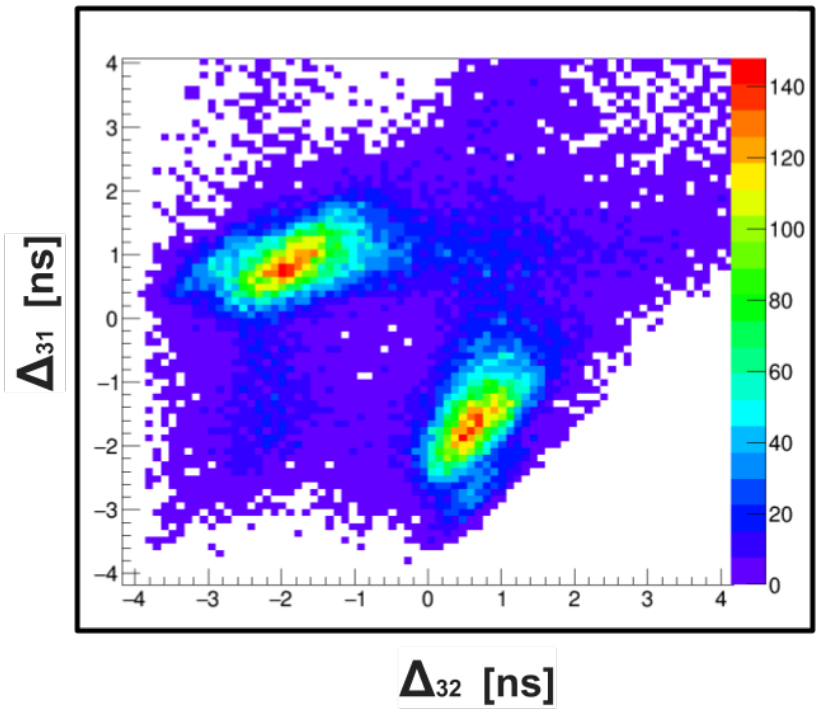

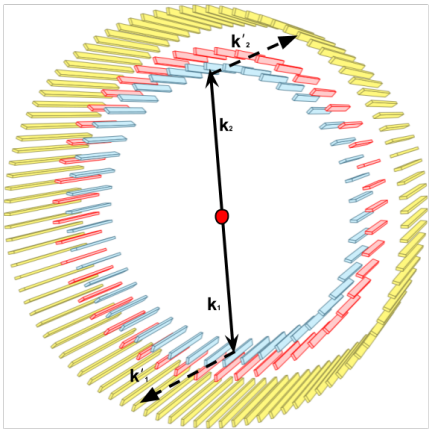

$$\Delta_{32} = (HitTimeDifference_{32}) - (CalculatedTimeDifference_{32}) \quad (5)$$

$$\Delta_{31} = (HitTimeDifference_{31}) - (CalculatedTimeDifference_{31}) \quad (6)$$

Compton Angles

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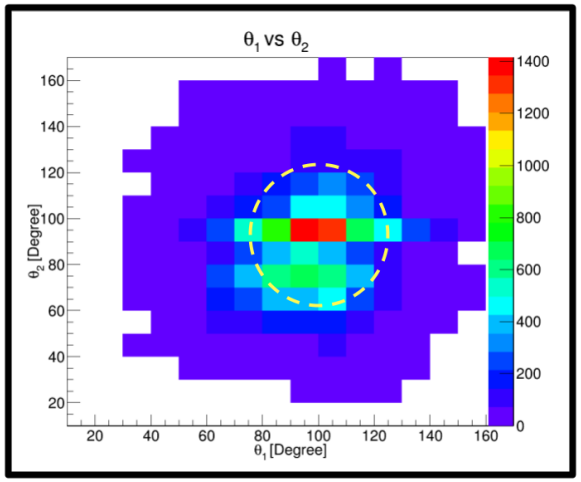

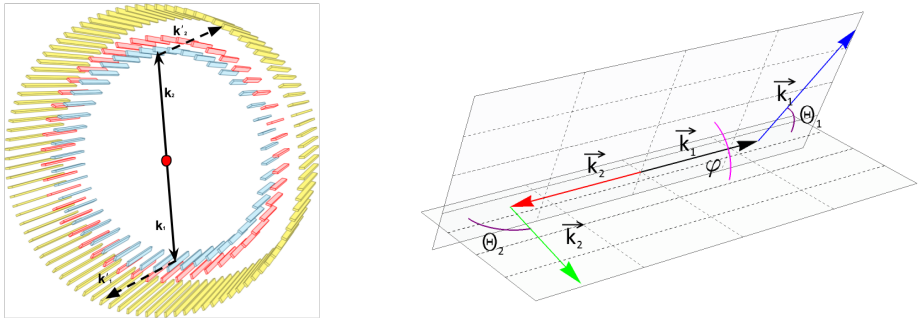

Figure 2: Angle between the Primary and Secondary Annihilation Photons

Angle between the Scattering Planes

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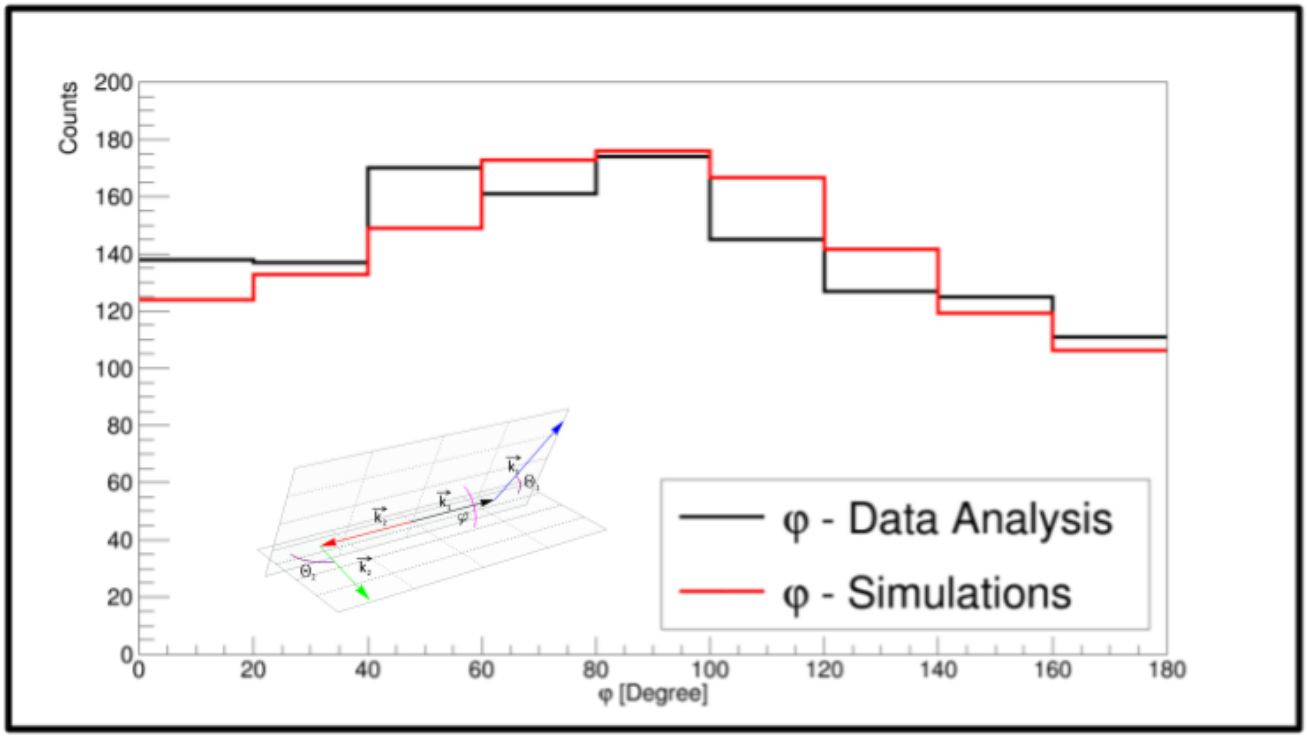

Figure 3: Angle between the two Scattering Planes

Summary:

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- Discrete symmetries play a fundamental role in particle and nuclear physics.
- There is still a substantial lack of experimental data on fundamental symmetries tests in the leptonic sector.
- The J-PET detector has a potential to contribute in Time Reversal Symmetry and improve the limits by atleast one order of magnitude.
- The detector is under the commissioning and first test measurements were done.

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