



J-PET



European
Funds
Smart Growth



Republic
of Poland



Foundation for
Polish Science

European Union
European Regional
Development Fund



Studies of the polarization of gamma photons originating from the decay of positronium atom

Sushil K. Sharma on behalf of the J-PET collaboration

Jagiellonian PET

Outline



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⌘ Jagiellonian - **P**ositron **E**mission **T**omograph



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- ⌘ Time Over Threshold (Energy deposition)
(Identification of the photons from diff. origins)



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- ⌘ Studies on the measurement of photon's polarization in frame of J-PET



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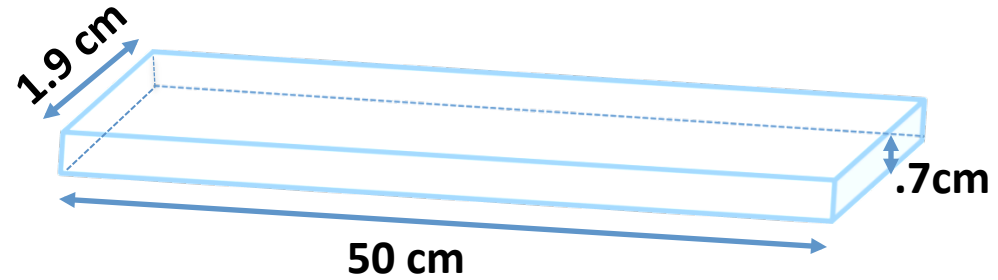
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(Identification of the photons from diff. origins)
- ⌘ Studies on the measurement of photon's polarization in frame of J-PET
- ⌘ Summary & outlook



Jagiellonian - **P**ositron **E**mission **T**omograph



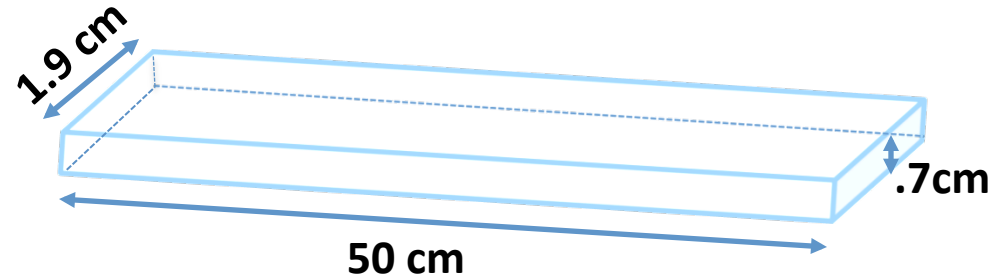
Jagiellonian - **P**ositron **E**mission **T**omograph



192 plastic Scintillators



Jagiellonian - Positron Emission Tomograph



192 plastic Scintillators

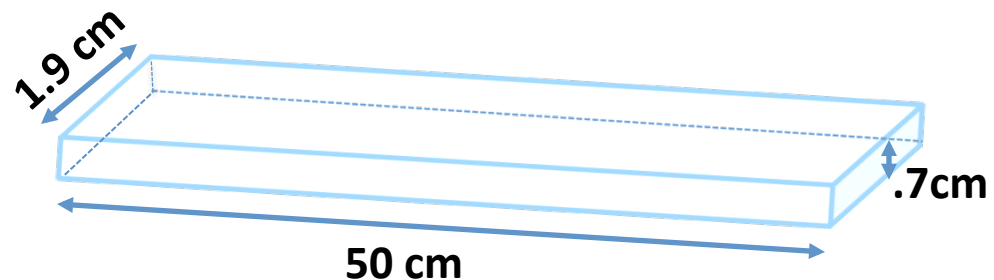
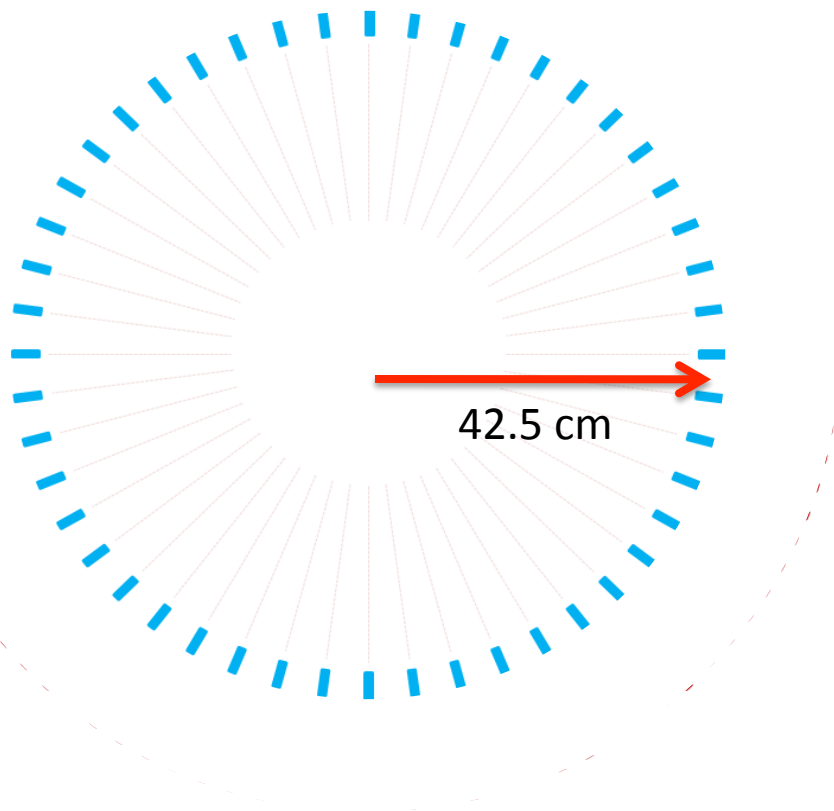
Arranged axially in **3 layers**



Jagiellonian - Positron Emission Tomograph



2-D front view J-PET



192 plastic Scintillators

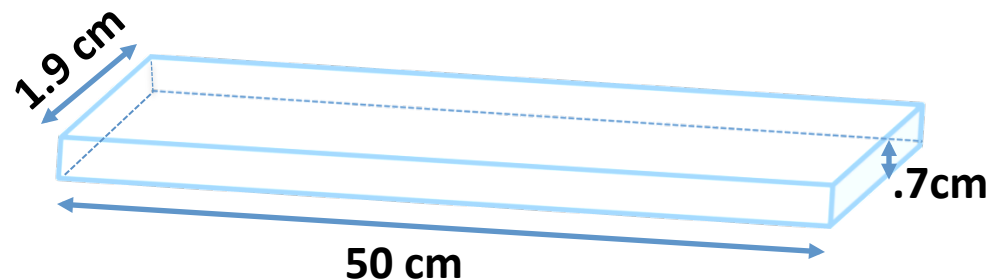
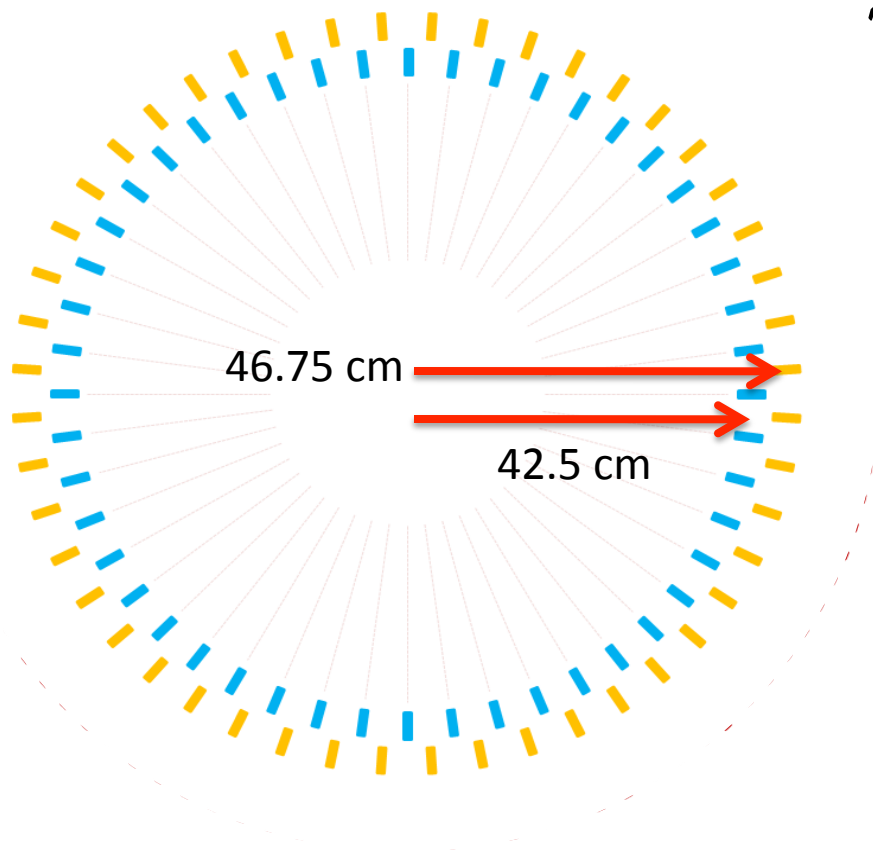
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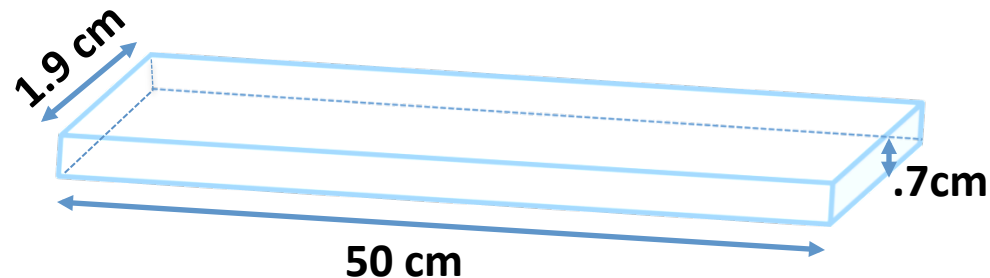
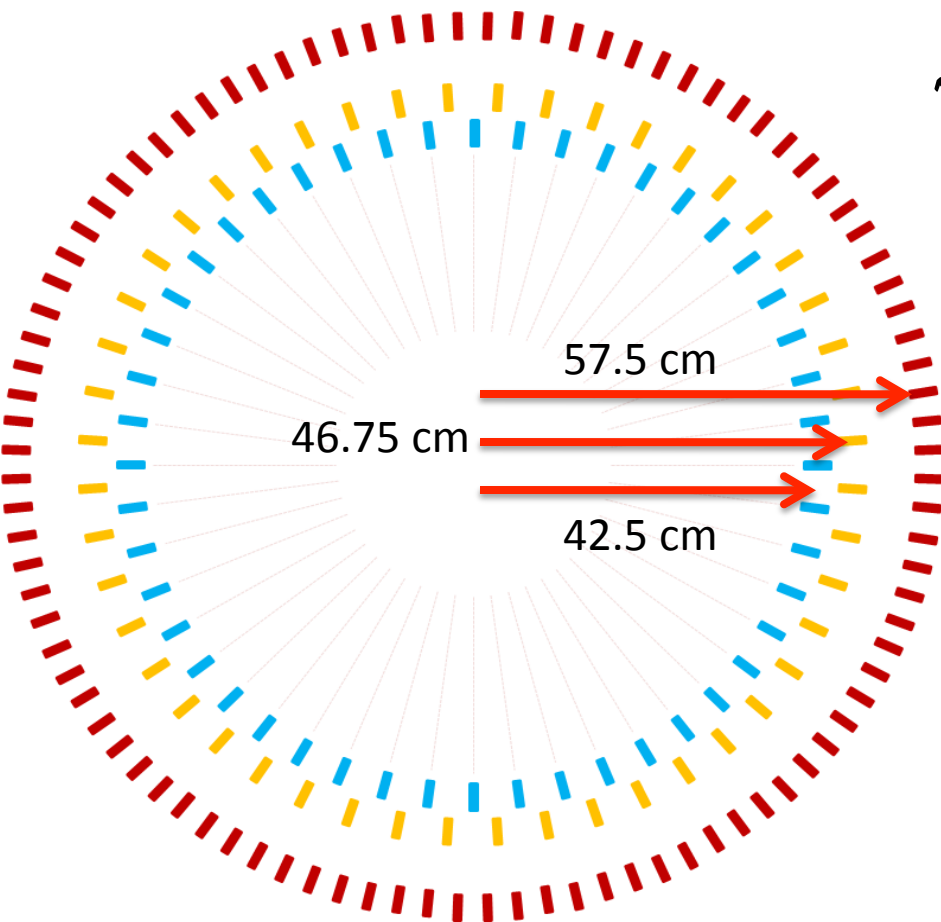
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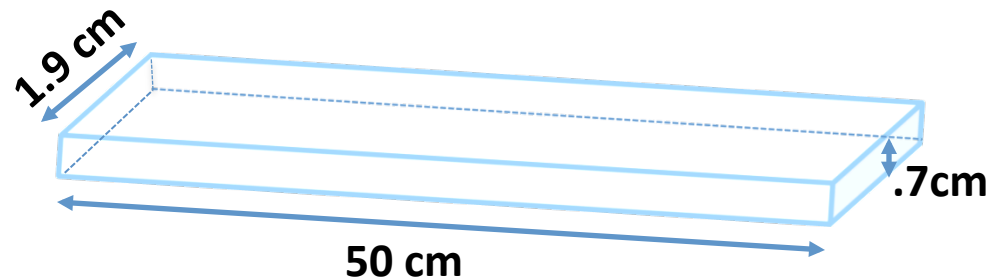
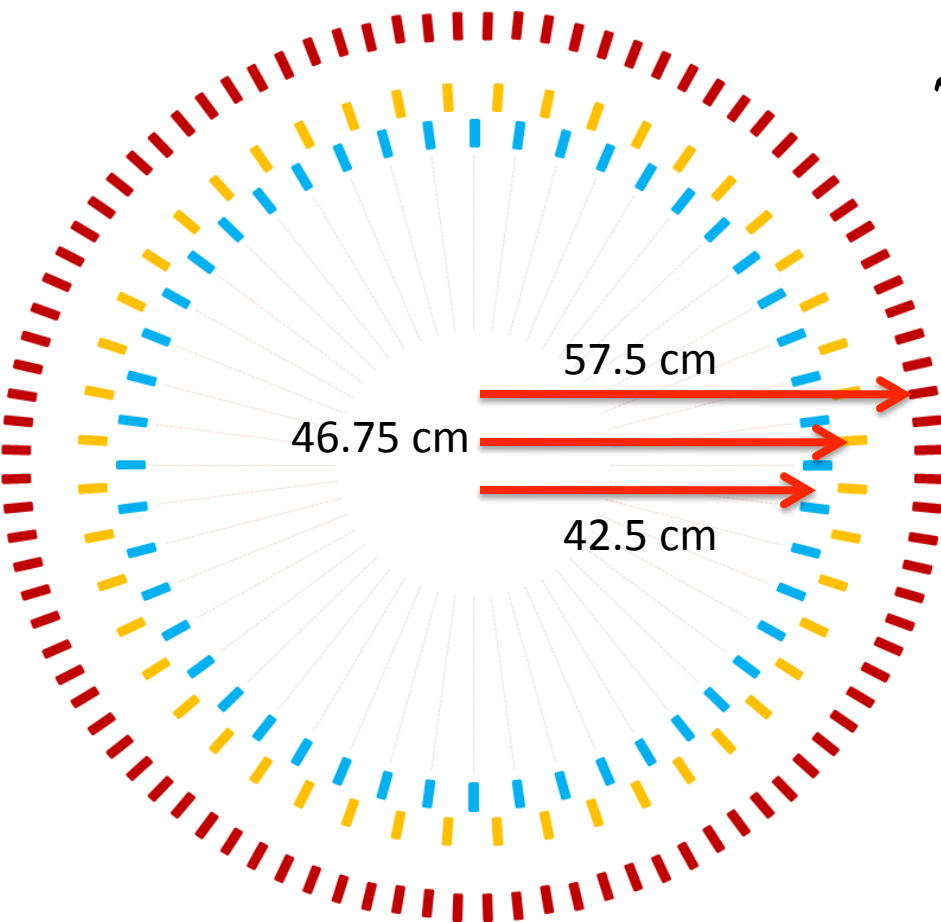
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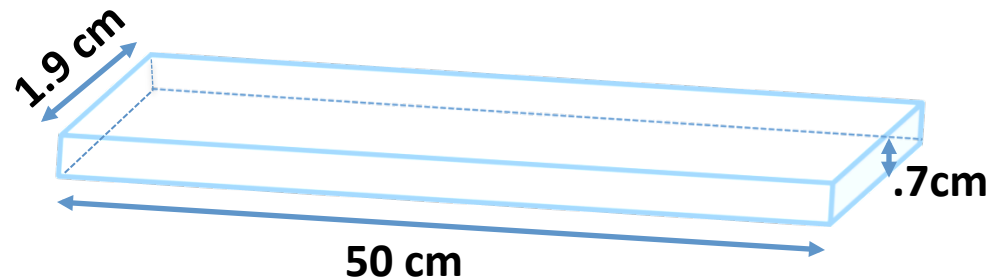
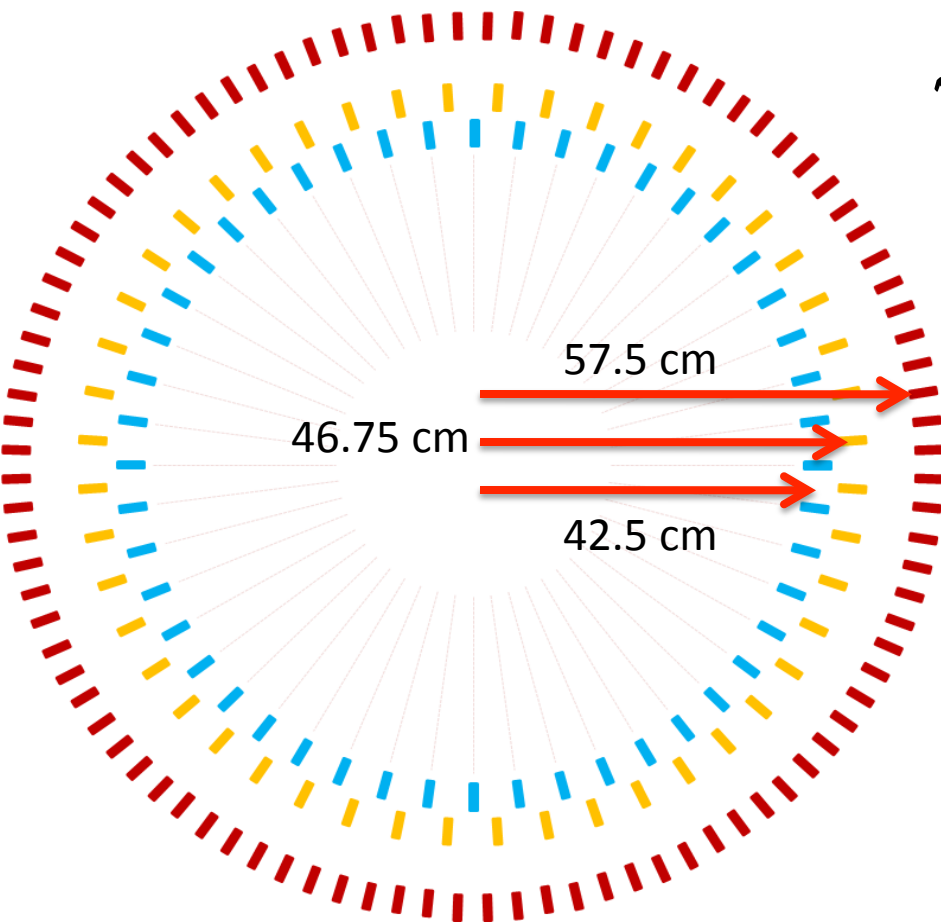
Key features :



Jagiellonian - Positron Emission Tomograph



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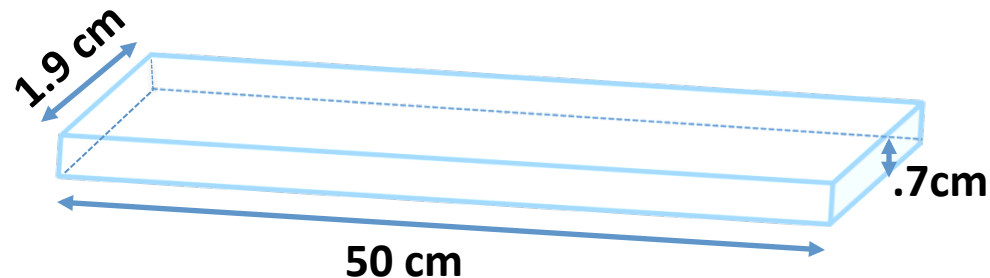
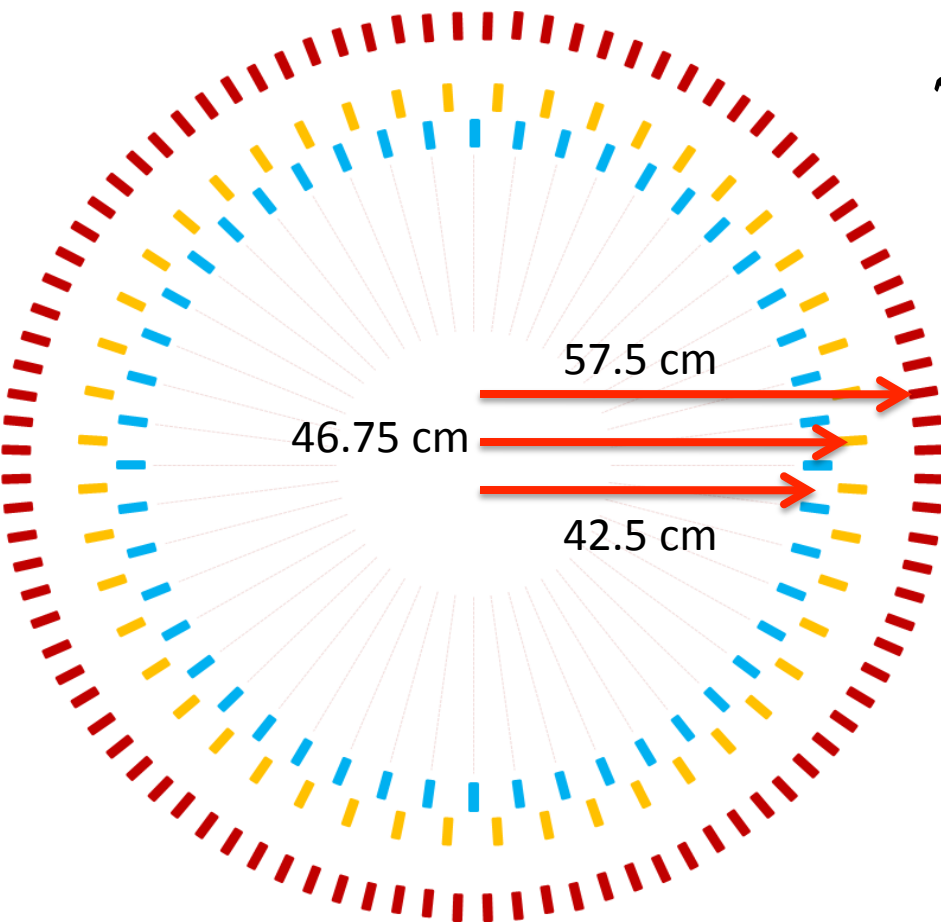
- ☑ Trigger less **DAQ**



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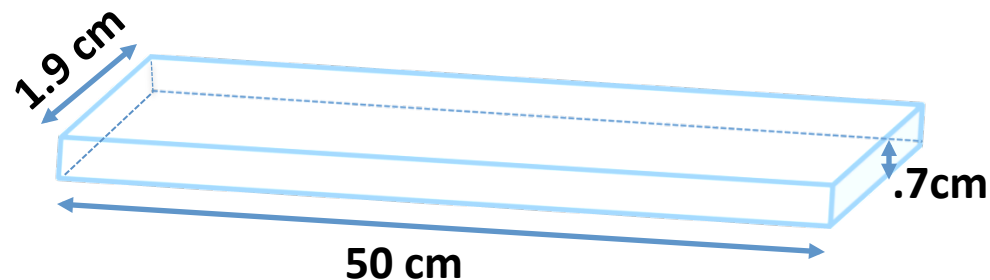
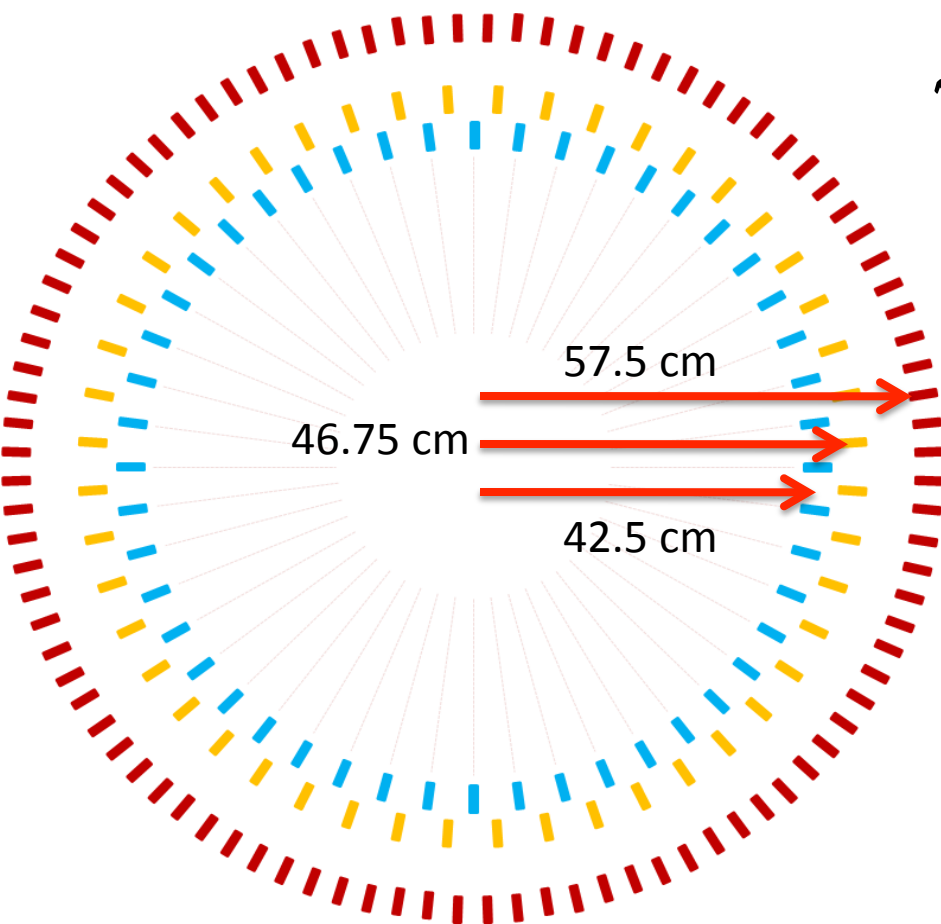
- ✓ Trigger less **DAQ**
- ✓ **TOT** as measure of energy deposition



Jagiellonian - Positron Emission Tomograph



2-D front view J-PET



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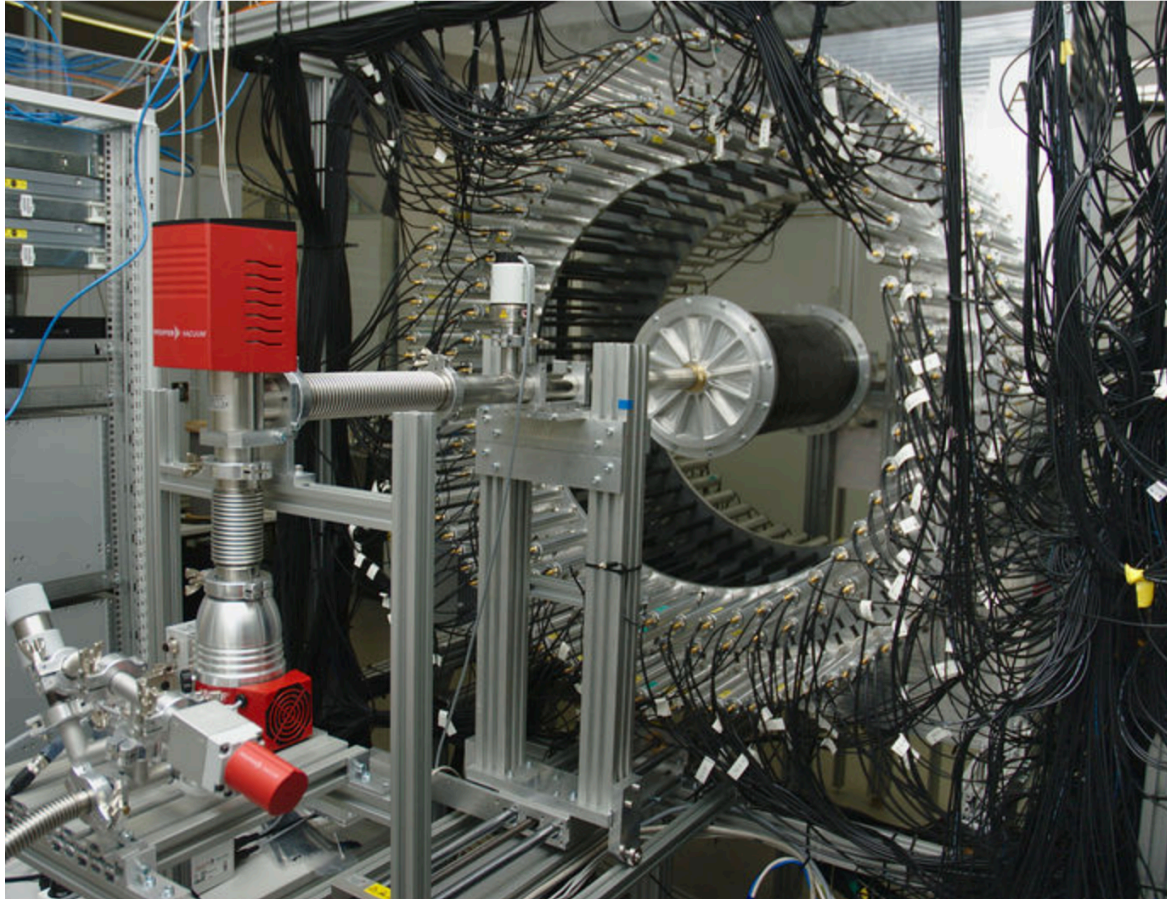
- ✓ Trigger less **DAQ**
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Advantages in favour to perform such studies:

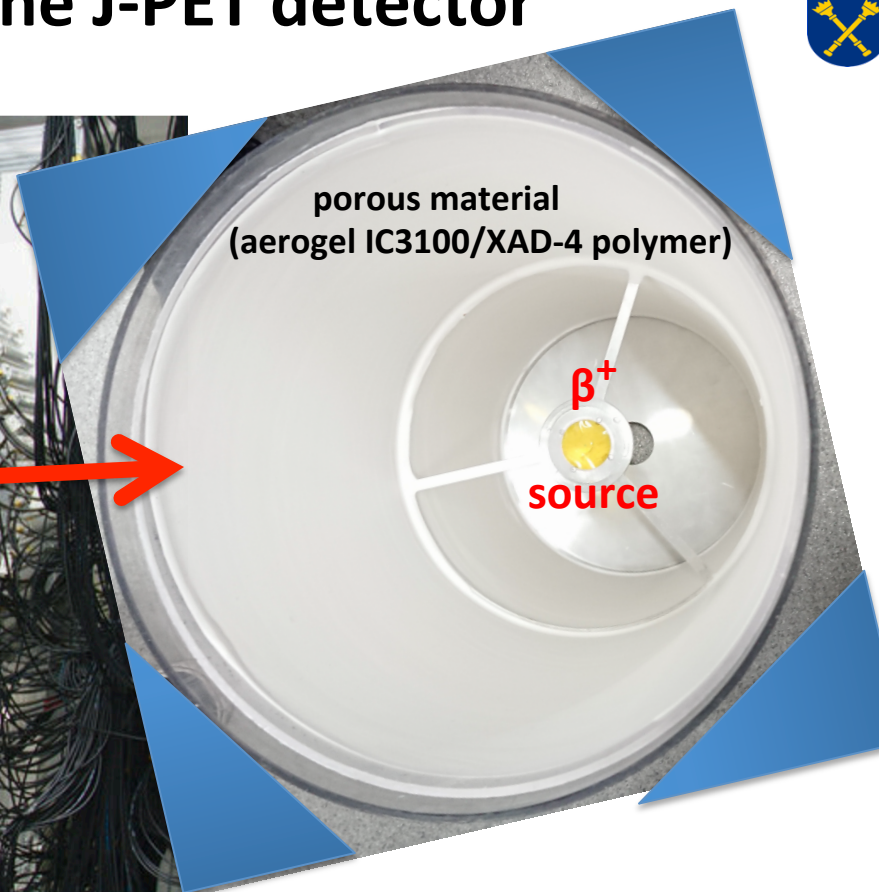
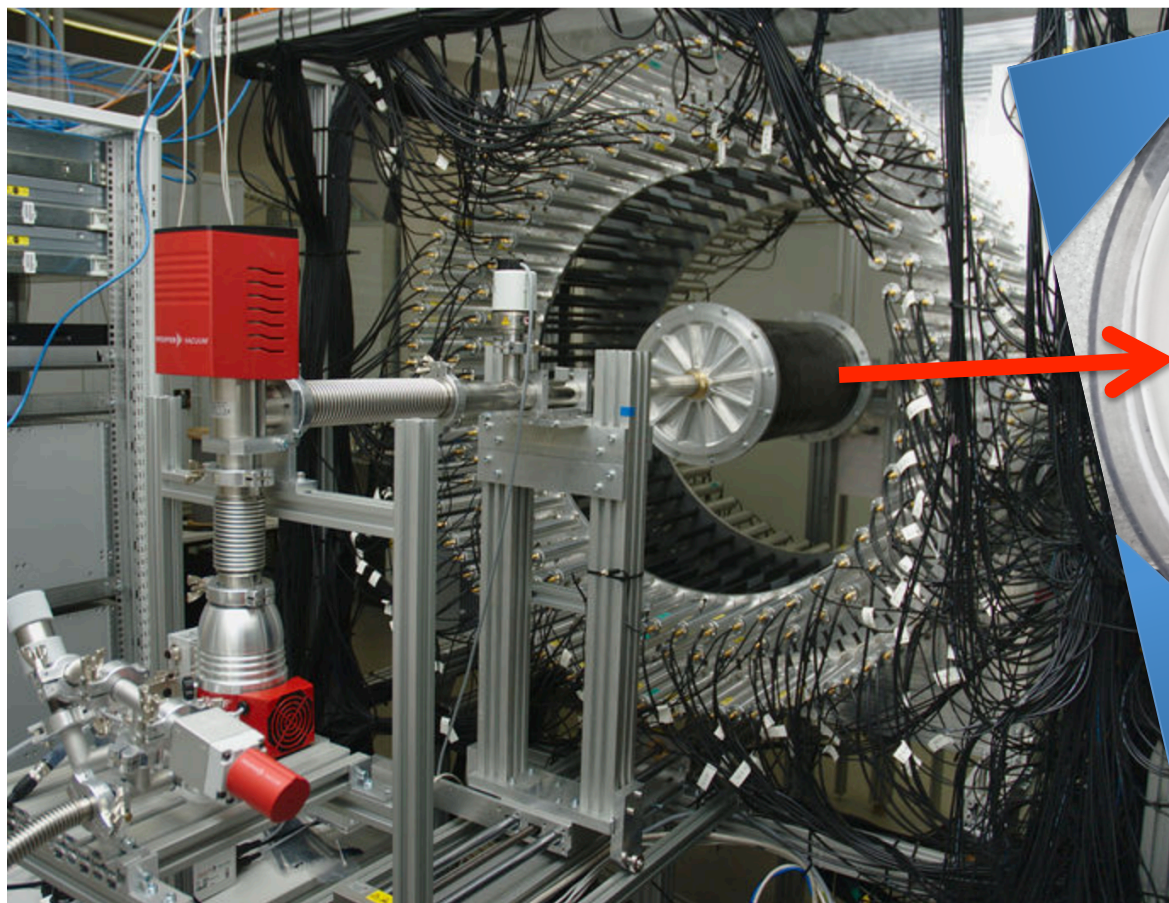
- ✓ Good angular resolution and small light attenuation
- ✓ Superior time properties and lower pile-ups



Commissioning of the J-PET detector



Commissioning of the J-PET detector



Annihilation chamber

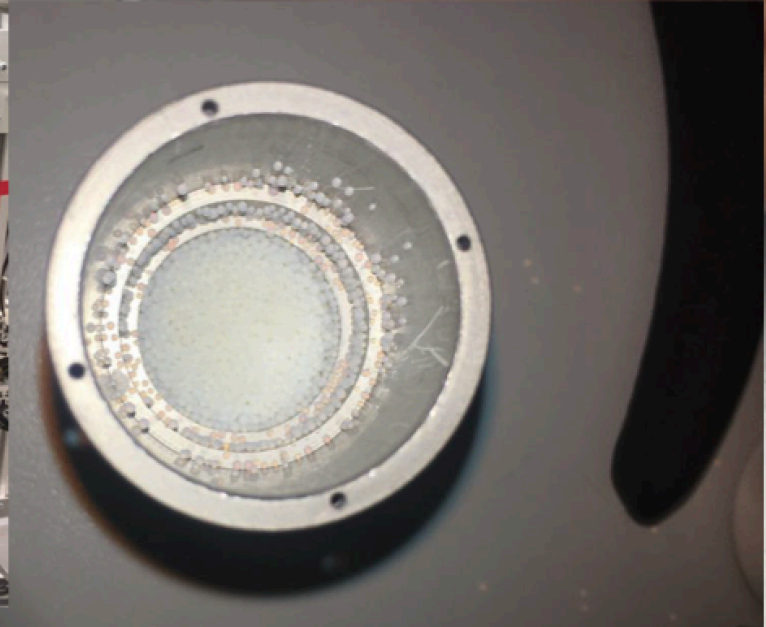
Recent selected results :

- P. Kowalski et al., *Phys. in Med. & Bio.* **63** (2018)
- L. Raczyński et al., *Phys. Med. Bio.* **62** (2017) 5076
- P. Moskal et al., *Phys. in Med. & Bio.* **61** (2016) 2025
- D. Kaminska et al., *Eup. Phys. J. C* **76** (2016)

- G. Korcyl et al., *IEEE Trans. on Med. Imag.* (2018)
- A. Wieczorek et al., *PLoS ONE* **12** (11): E0186728 (2017)
- A. Gajos et al., *Nucl. Inst. & Meth. In Phys. Res. A* **819**(2016) 54



For the present study – small annihilation chamber was used





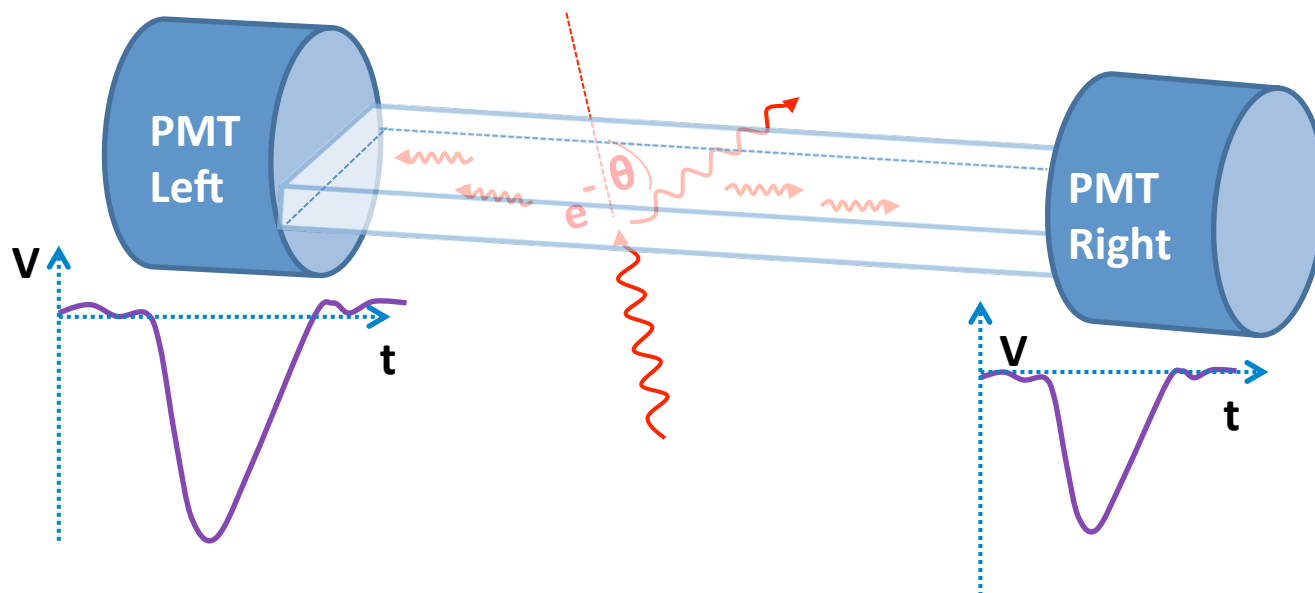
Time Over Threshold as a measure of Energy deposition

Time **O**ver **T**hreshold as measure of Energy Deposition



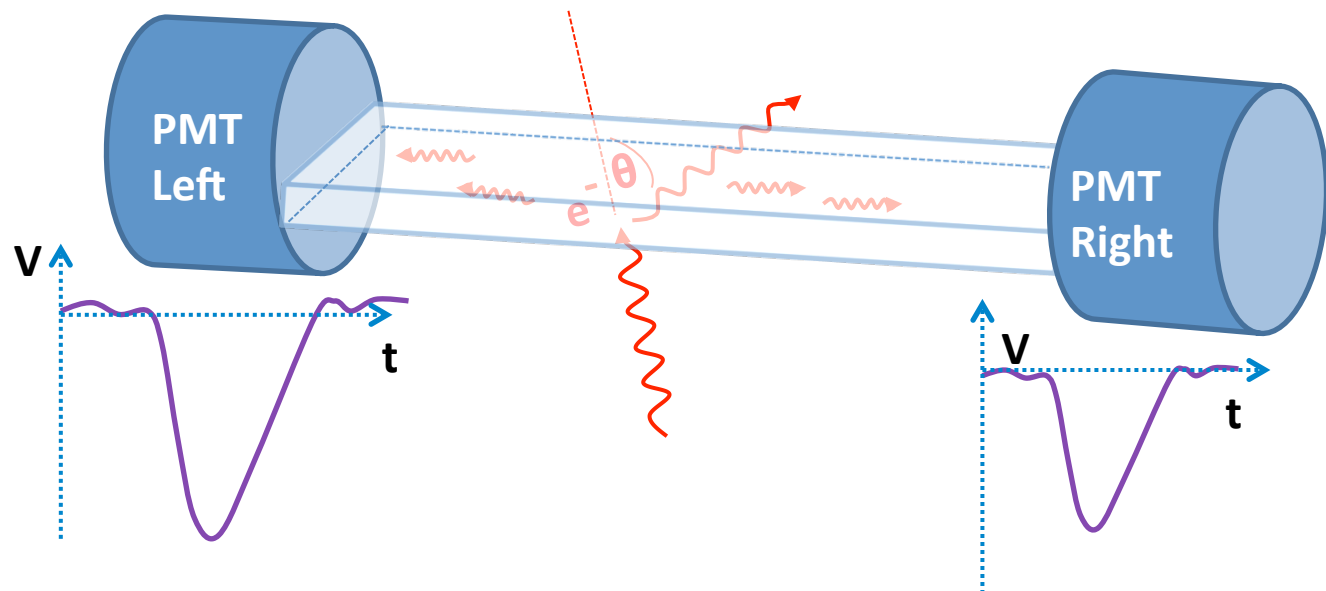


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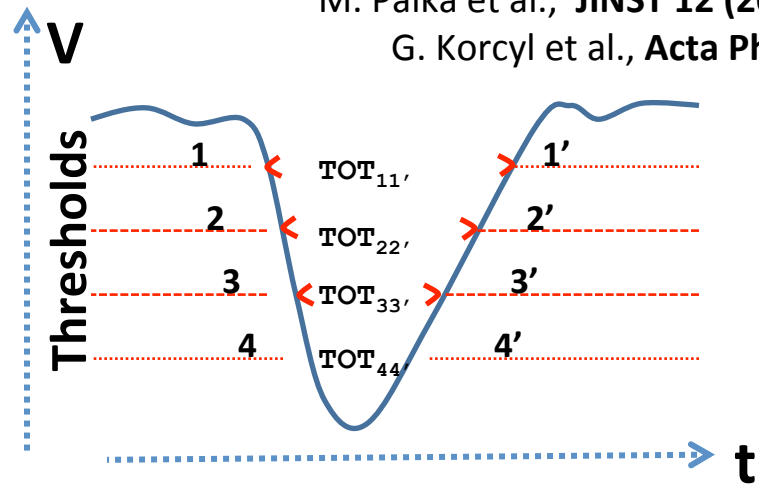




Time **O**ver **T**hreshold as measure of Energy Deposition



M. Palka et al., *JINST* **12** (2017) P08001
G. Korcyl et al., *Acta Phys. Polon. B* **47**, 491 (2016)



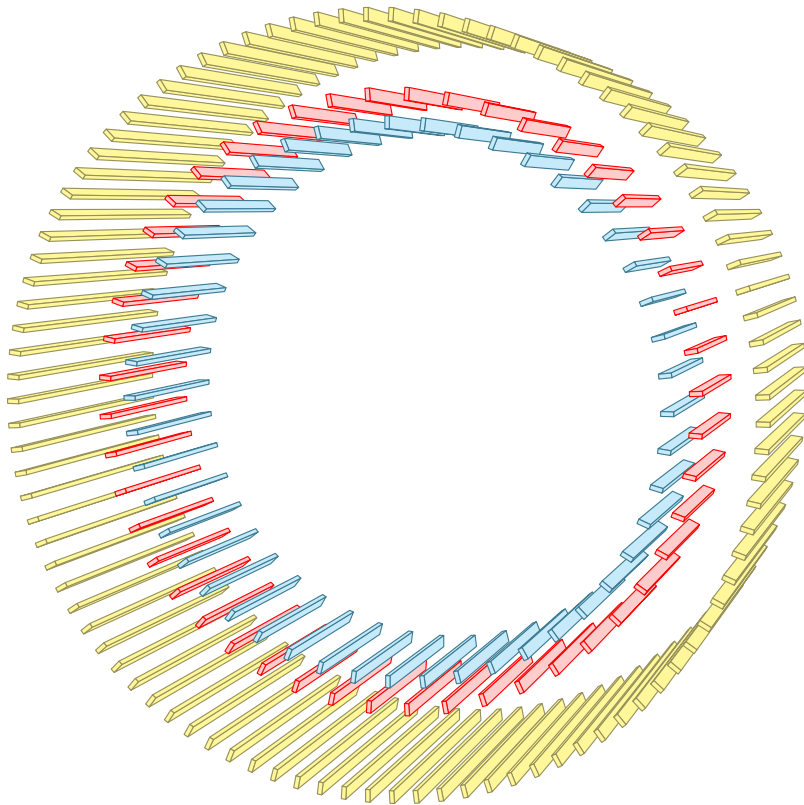
Signals are probed at **four thresholds**.



Time **O**ver **T**hreshold as measure of Energy Deposition



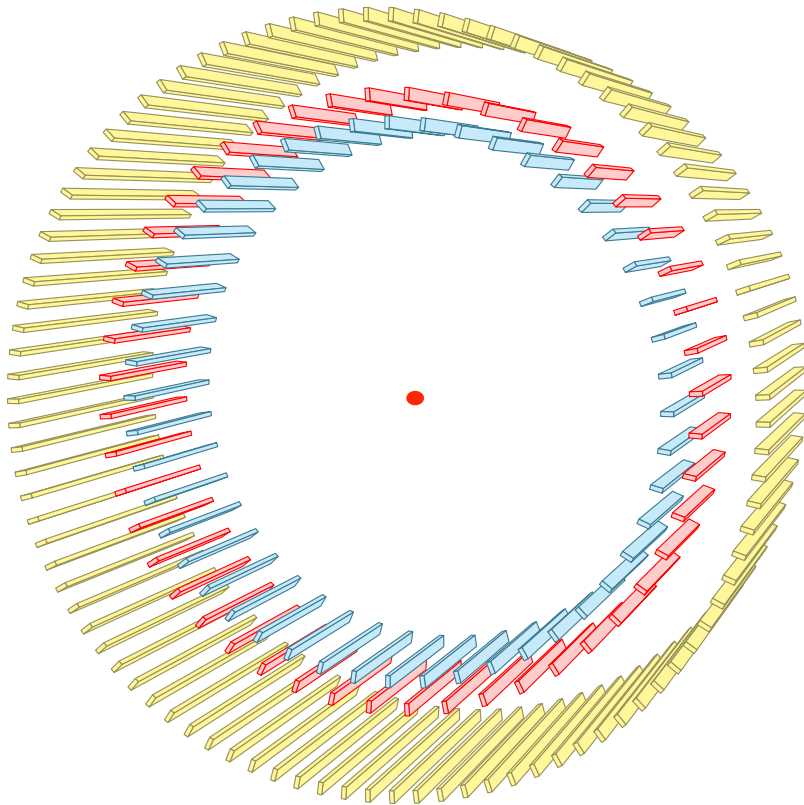
Tagging 511 keV



Time **O**ver **T**hreshold as measure of Energy Deposition



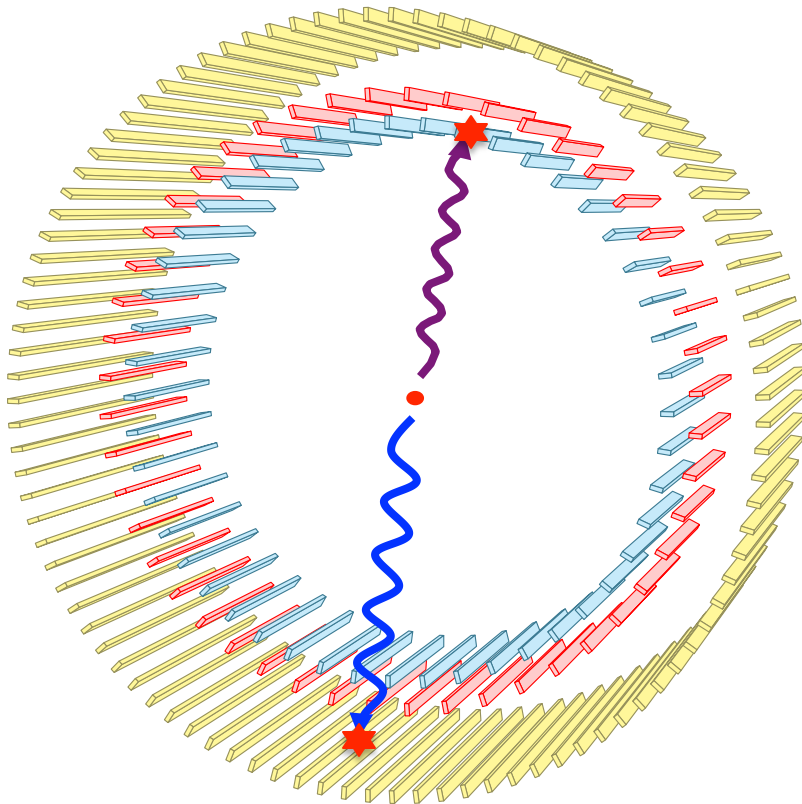
Tagging 511 keV



Time **O**ver **T**hreshold as measure of Energy Deposition



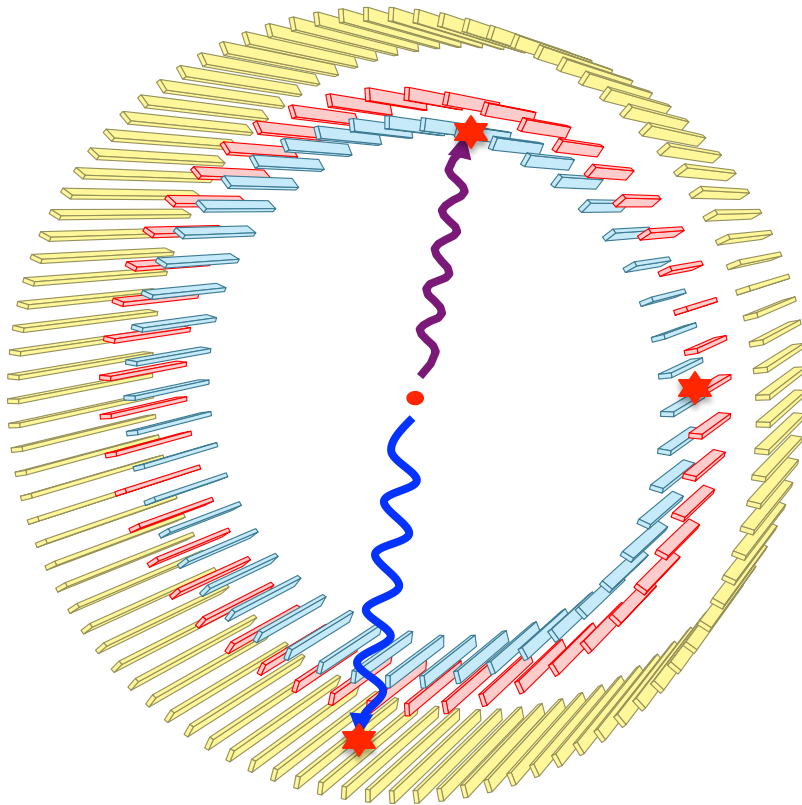
Tagging 511 keV



Time **O**ver **T**hreshold as measure of Energy Deposition



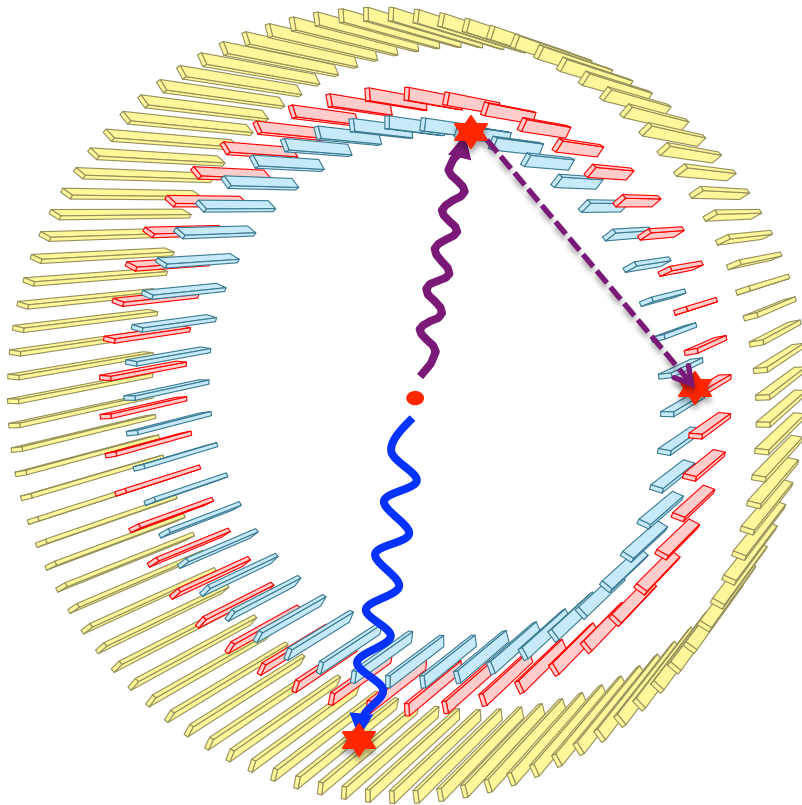
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Time **O**ver **T**hreshold as measure of Energy Deposition



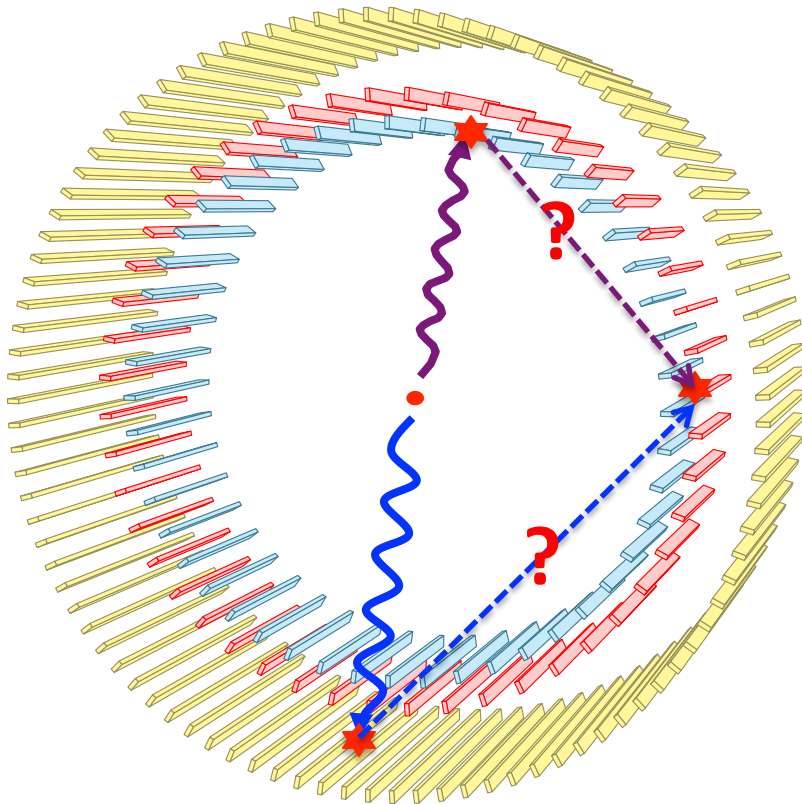
Tagging 511 keV



Time **O**ver **T**hreshold as measure of Energy Deposition



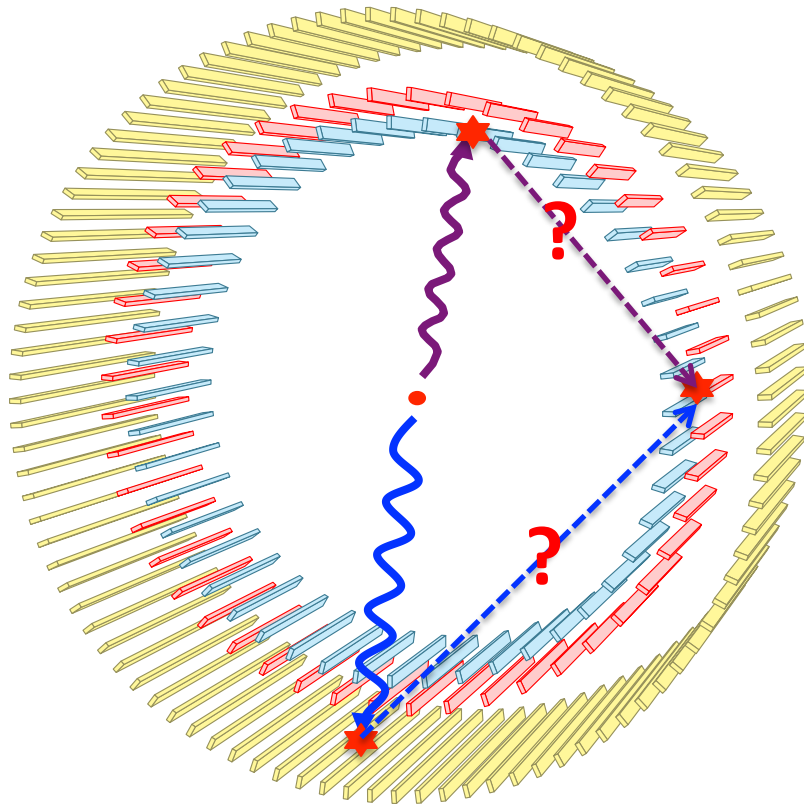
Tagging 511 keV



Time **O**ver **T**hreshold as measure of Energy Deposition



Tagging 511 keV



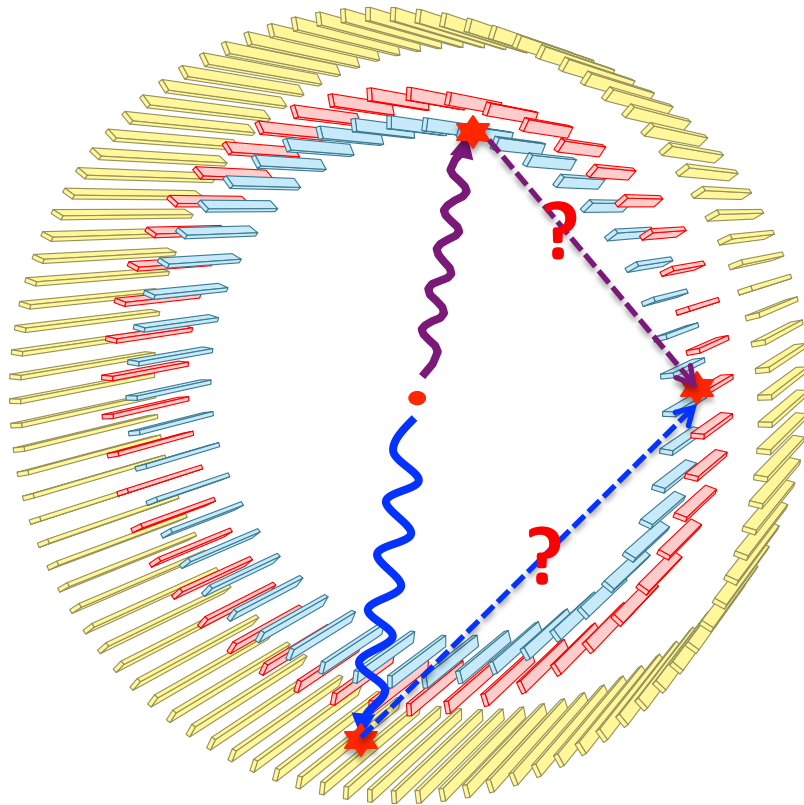
$$\text{Scatter test} = \text{time}_{\text{measured}} - \text{time}_{\text{calculated}}$$



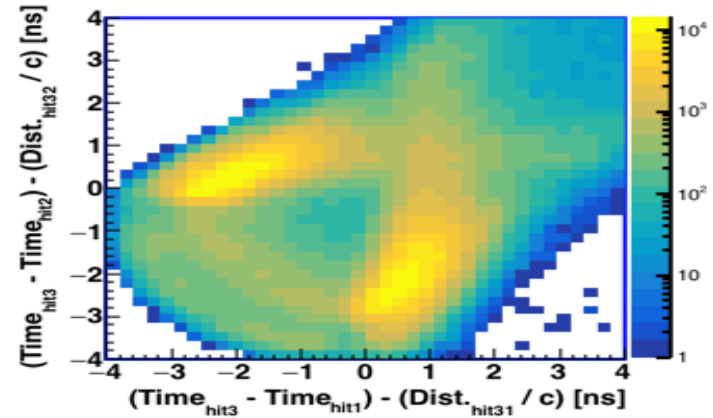
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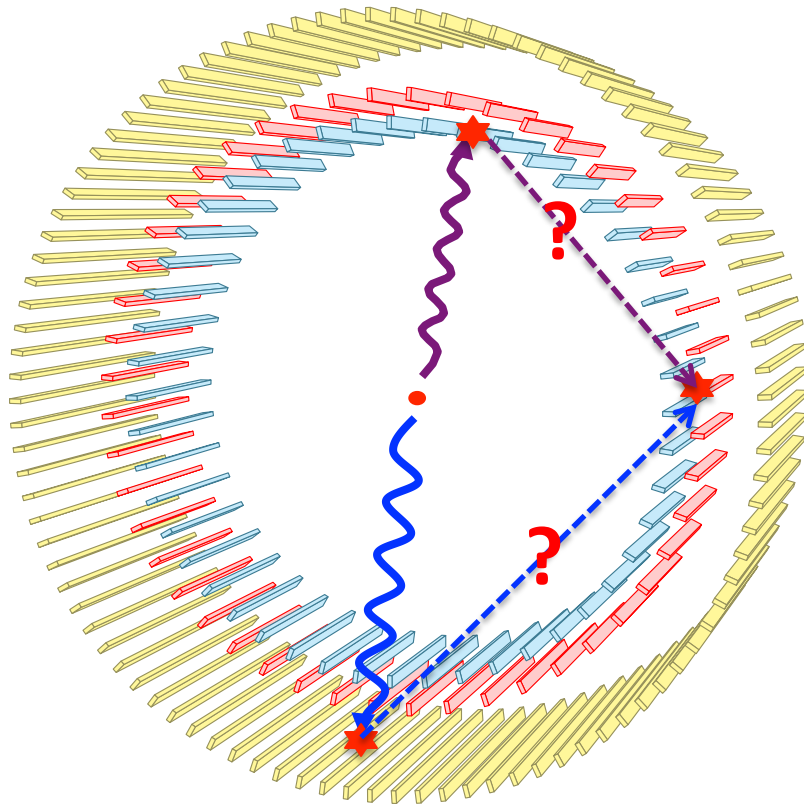
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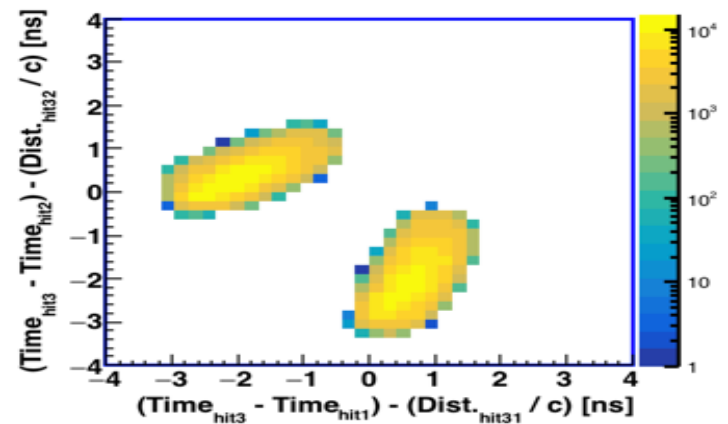
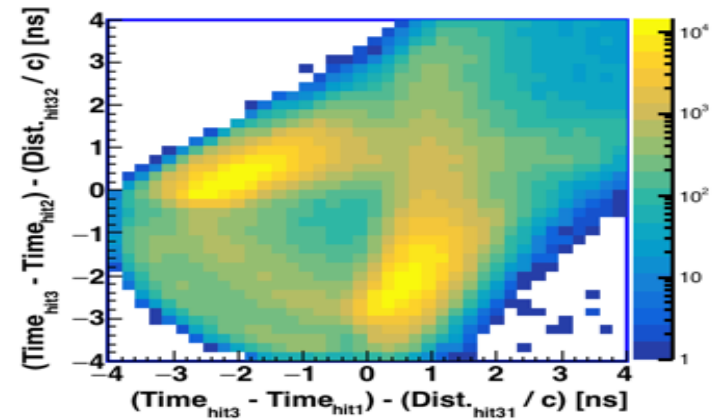
Time **O**ver **T**hreshold as measure of Energy Deposition



Tagging 511 keV



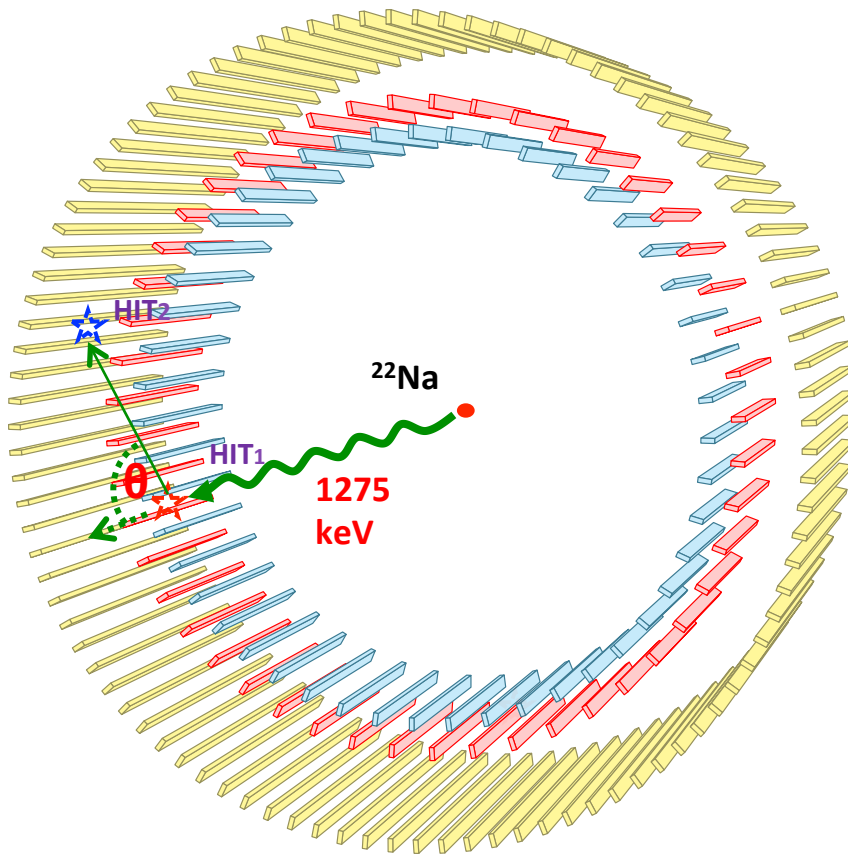
$$\text{Scatter test} = \text{time}_{\text{measured}} - \text{time}_{\text{calculated}}$$



Time Over Threshold as measure of Energy Deposition



Tagging 1274.6 keV

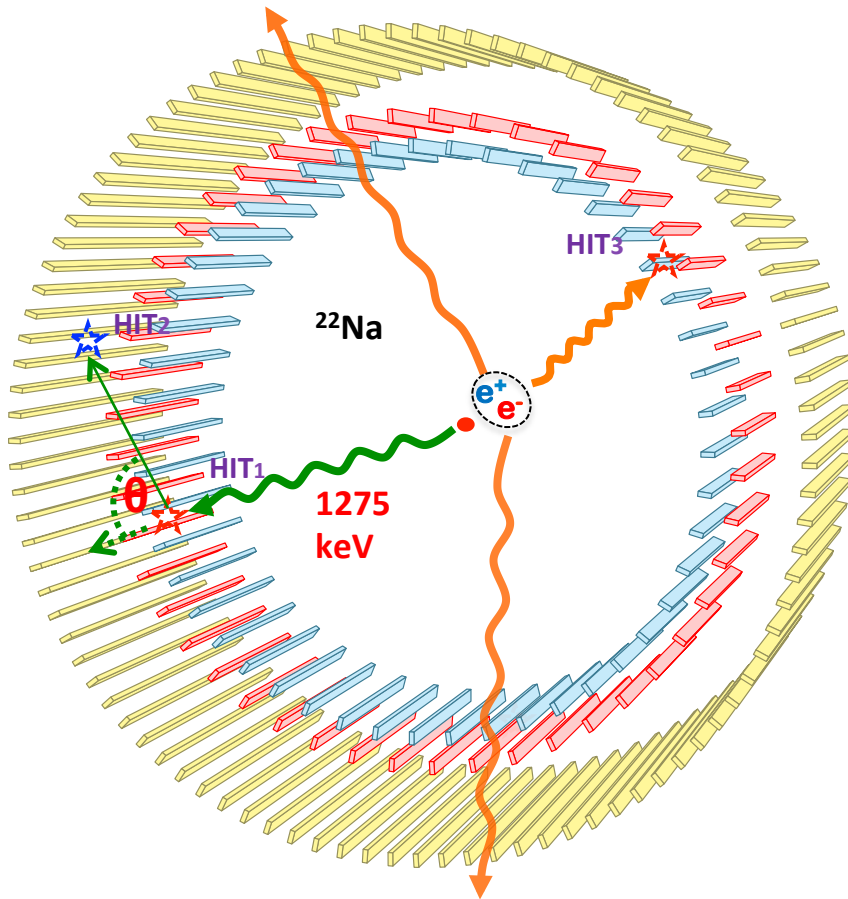


☆ 1st Hit is prompt gamma

☆ 2nd Hit from the scattering of prompt gamma



Time Over Threshold as measure of Energy Deposition



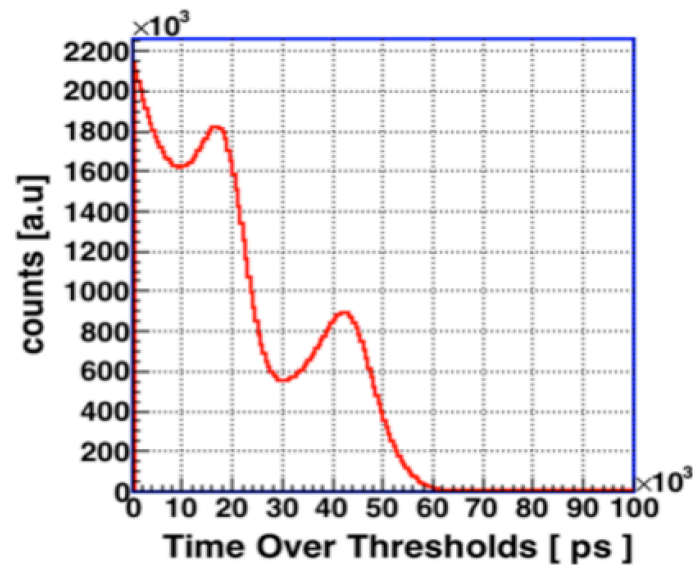
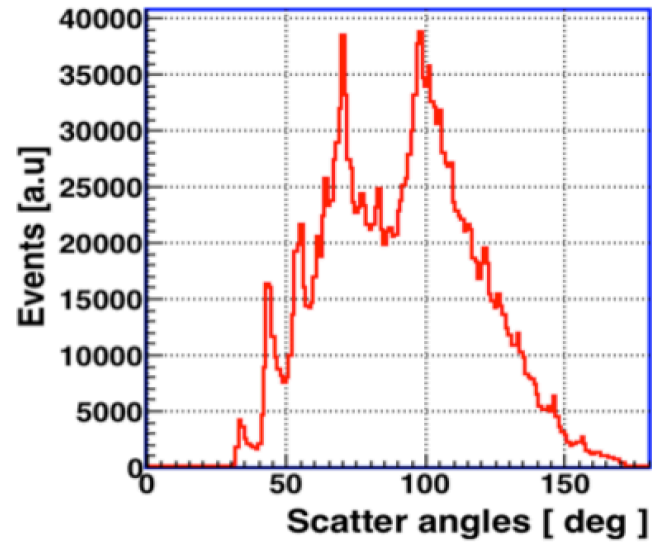
1st Hit is prompt gamma

2nd Hit from the scattering of prompt gamma

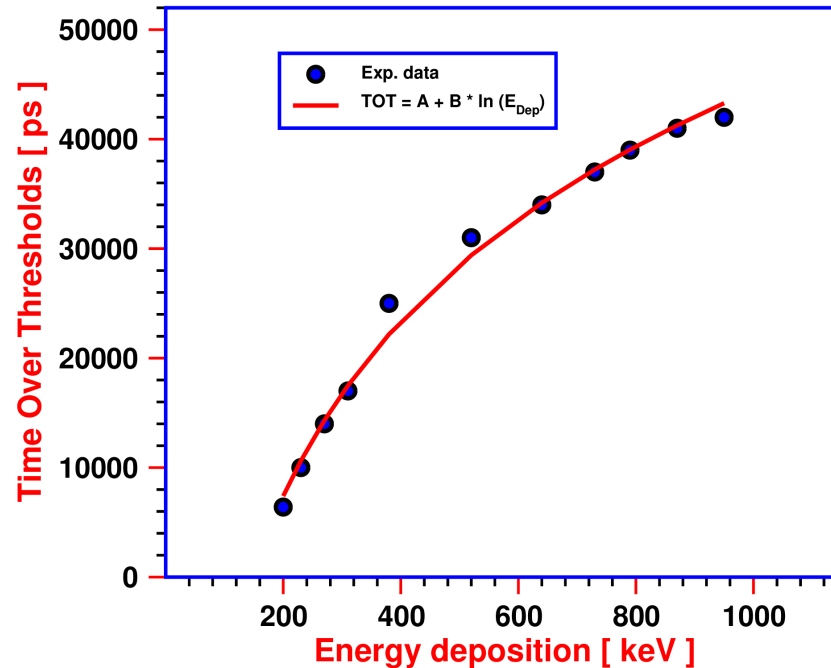
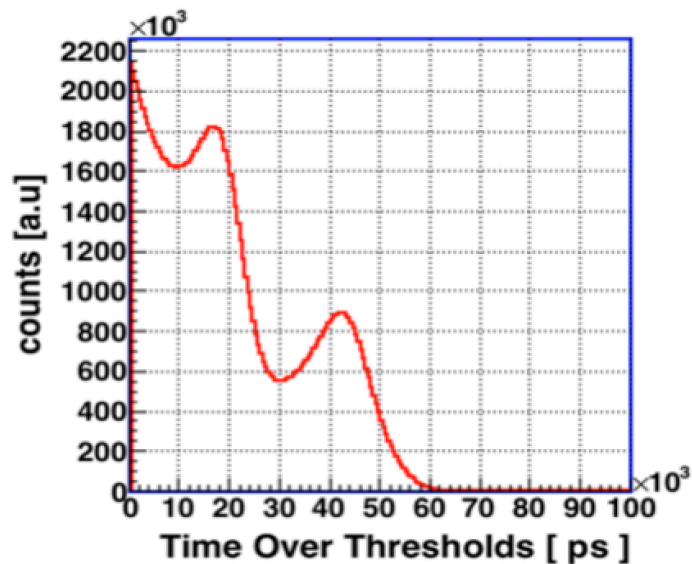
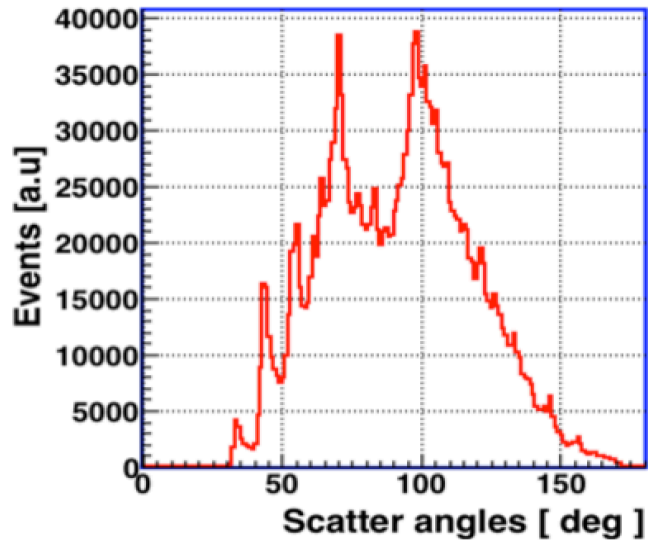
3rd hit is assumed as one of the annihilation gamma



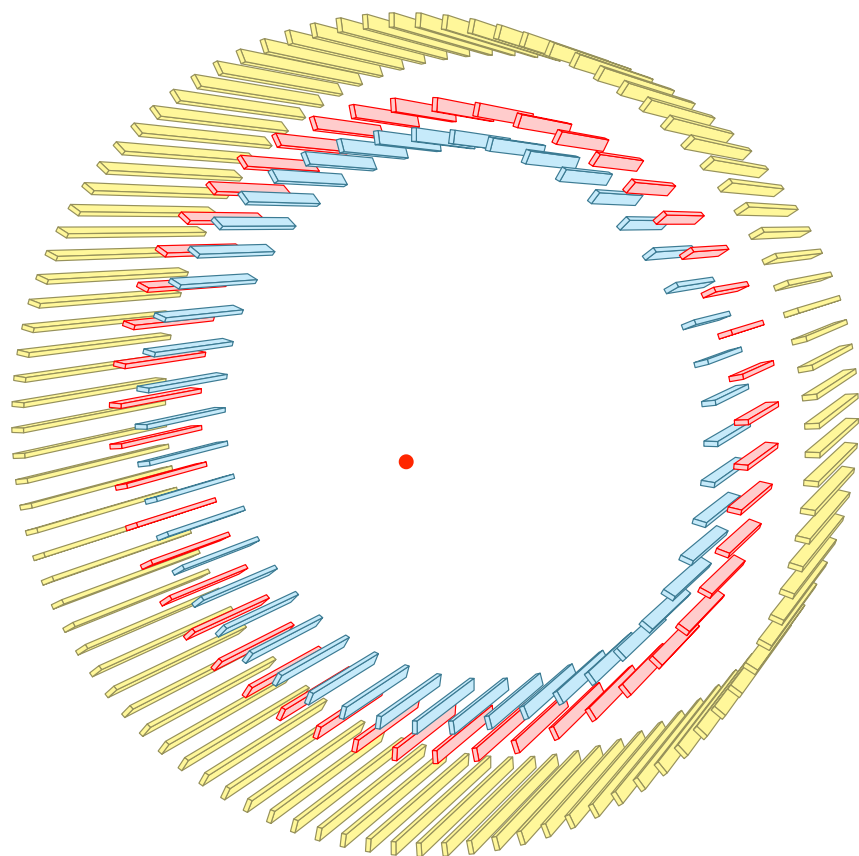
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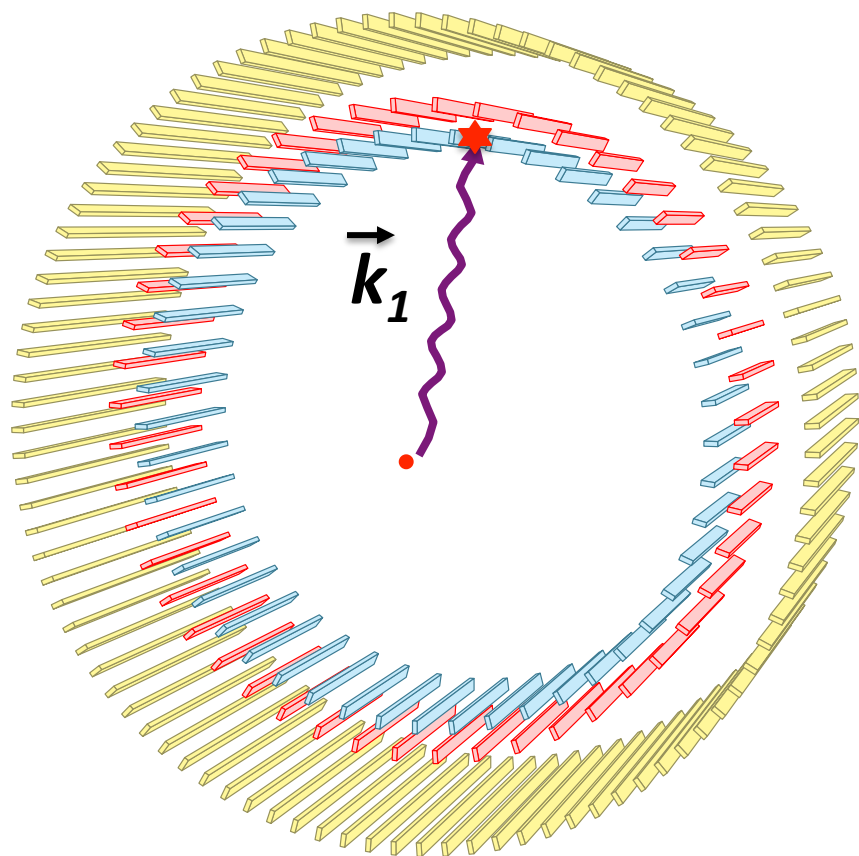
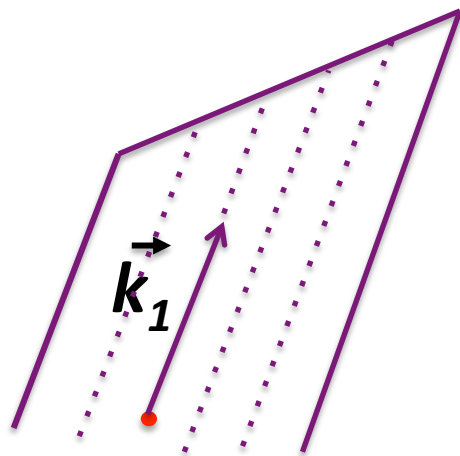
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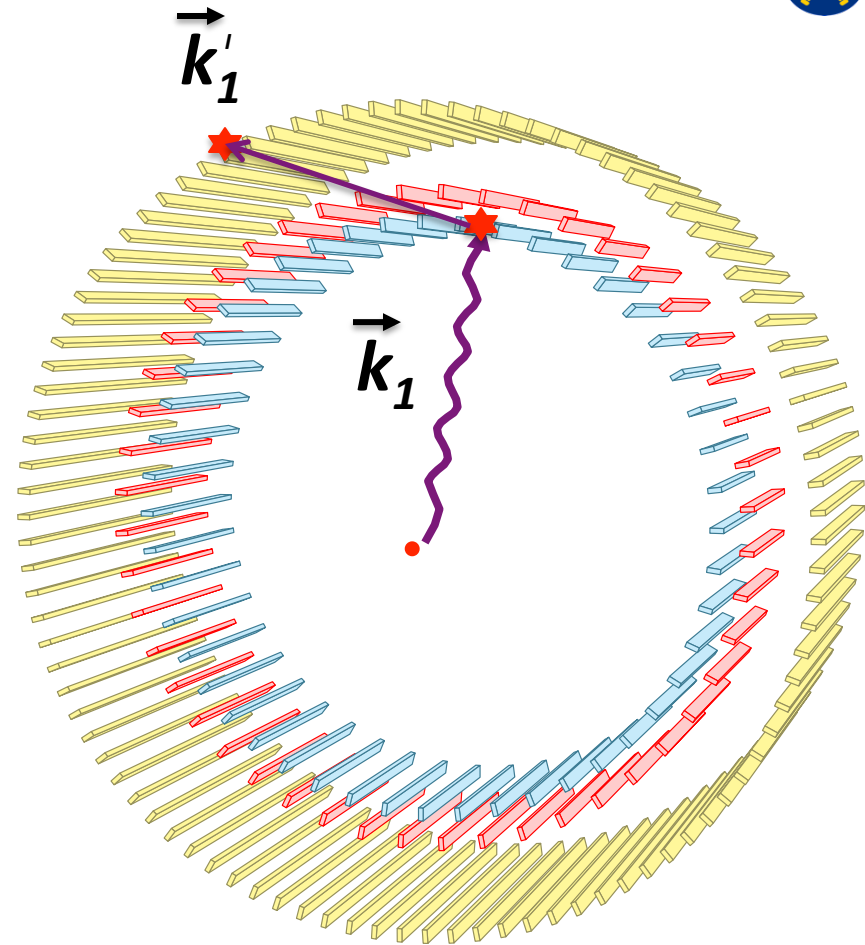
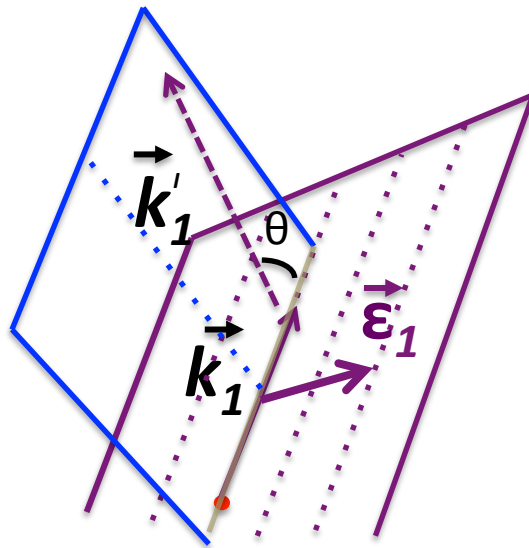
J-PET potentialities to measure photon's polarization



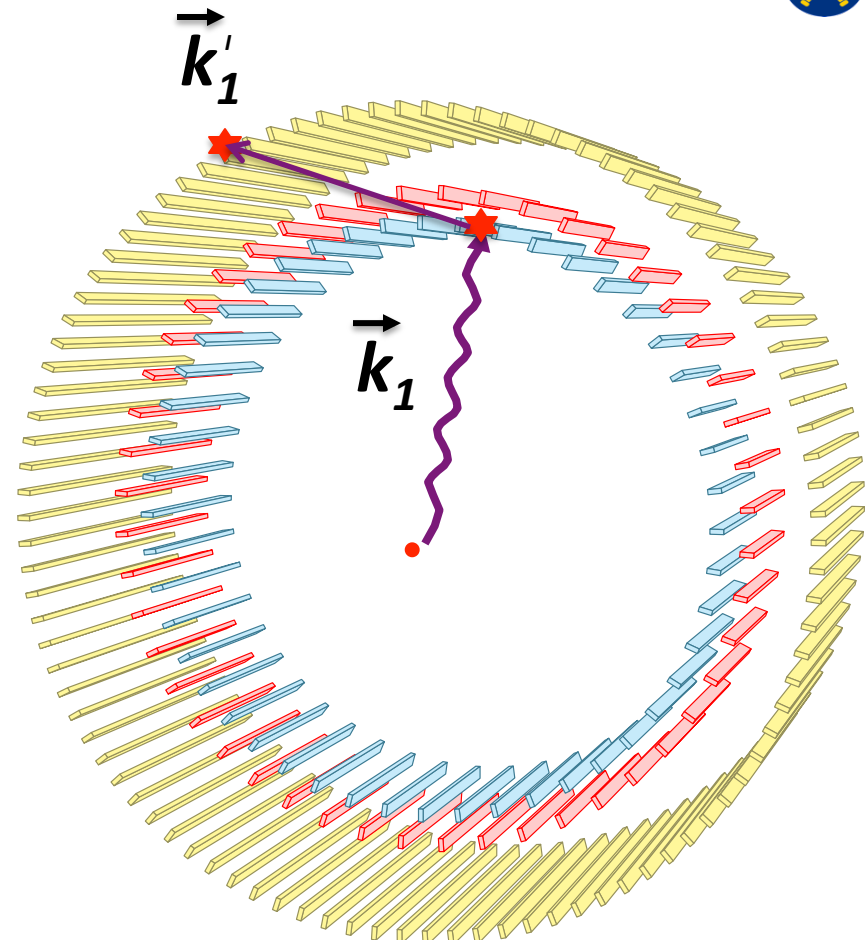
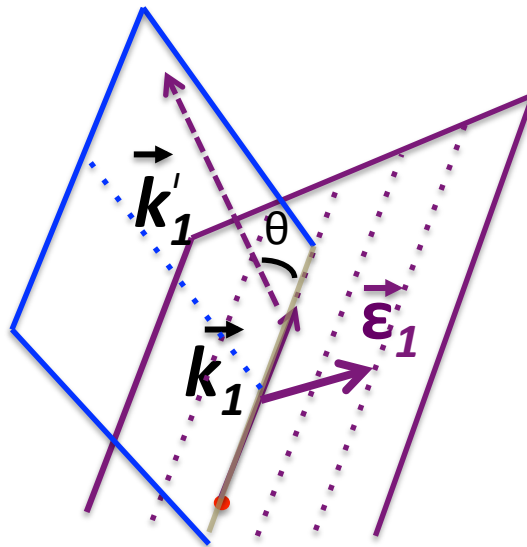
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Photon's Polarization

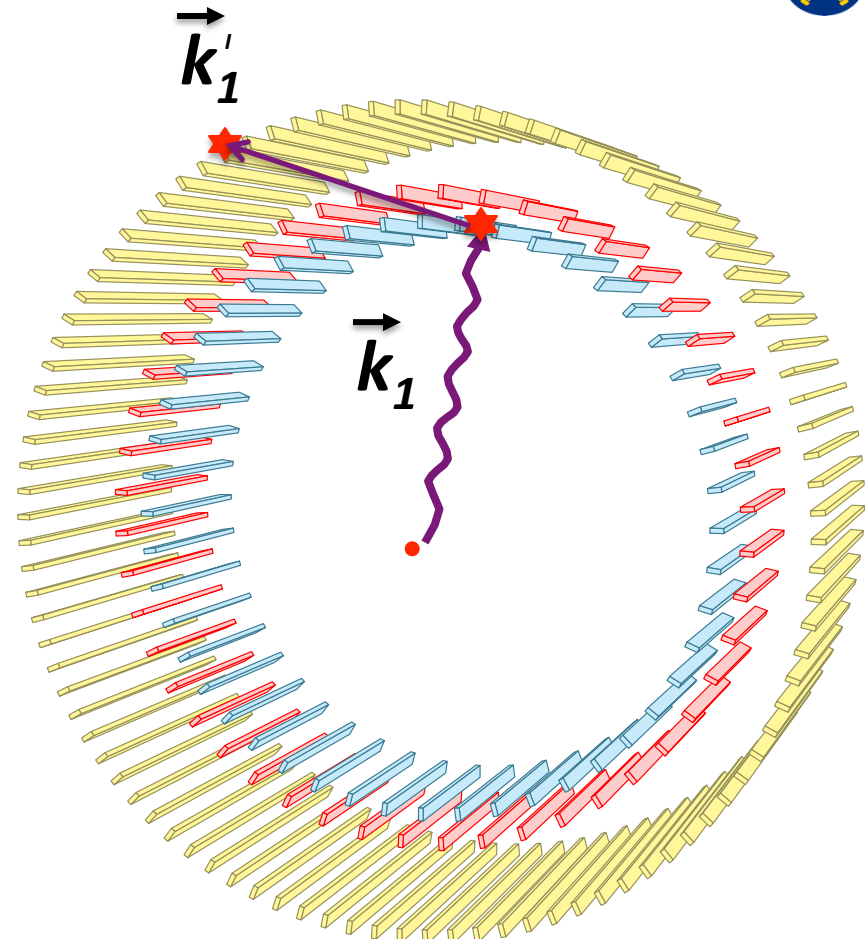
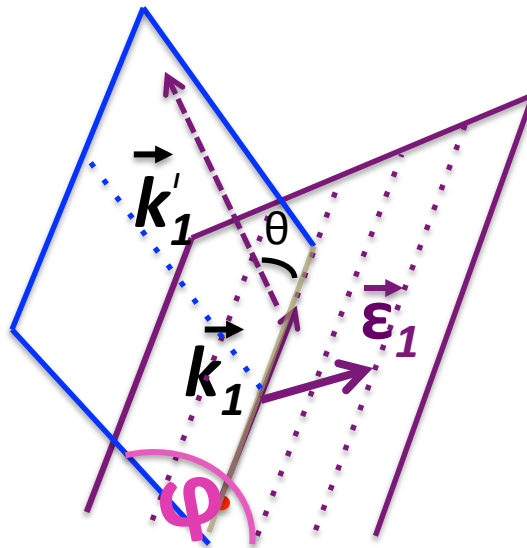
$$\vec{\epsilon}_1 = \vec{k}_1 \times \vec{k}'_1$$

P. Moskal et al.,

Acta. Phys. Polon. B 47 (2016) 509



J-PET potentialities to measure photon's polarization



Photon's Polarization

$$\vec{\epsilon}_1 = \vec{k}_1 \times \vec{k}'_1$$

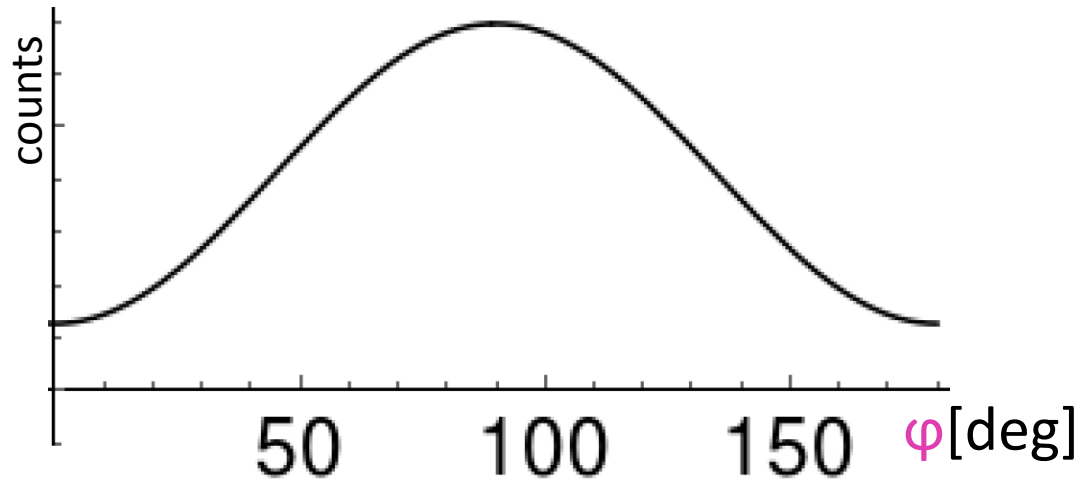
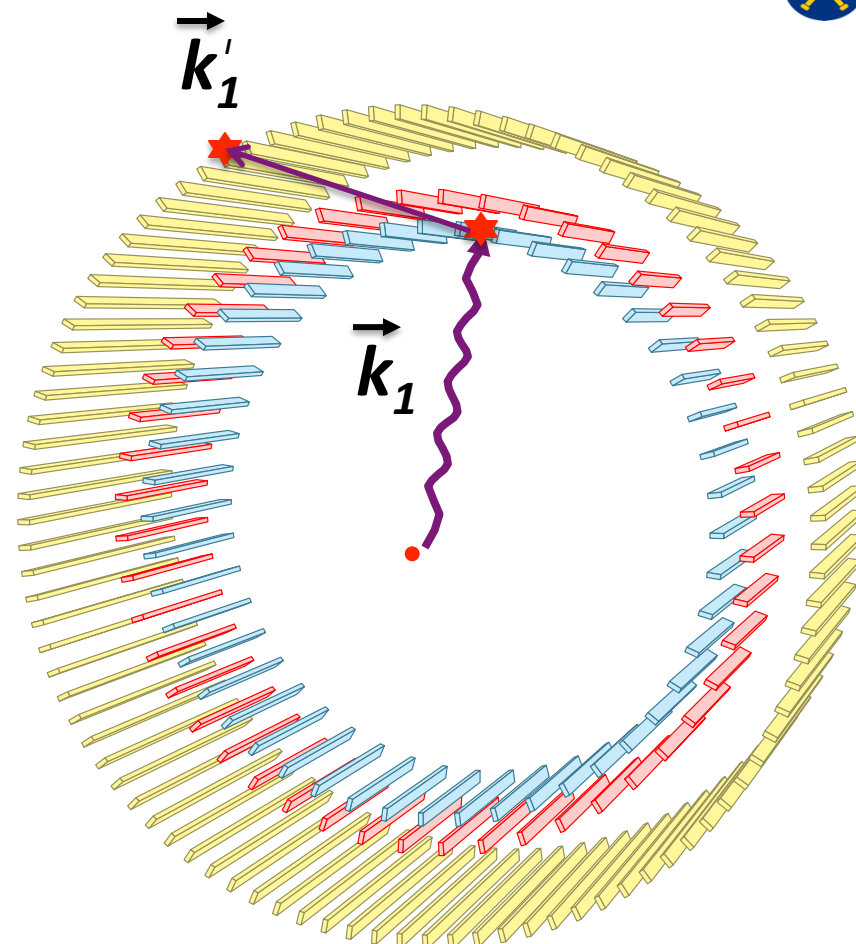
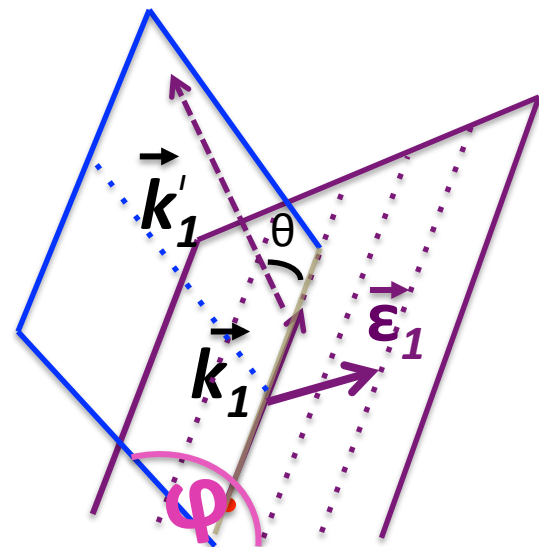
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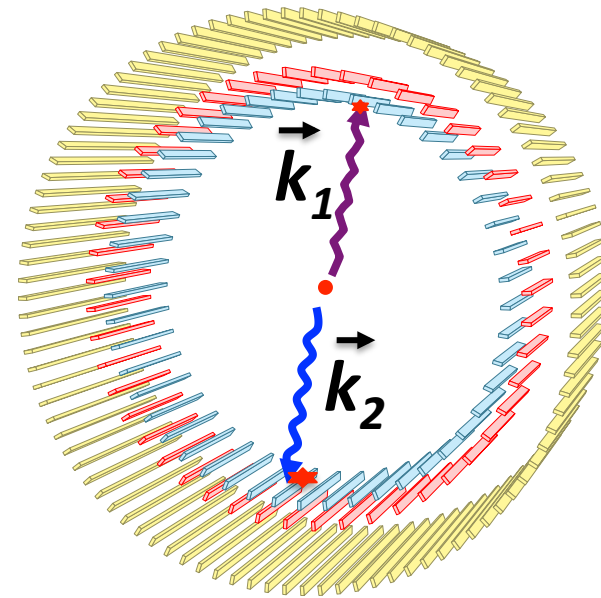
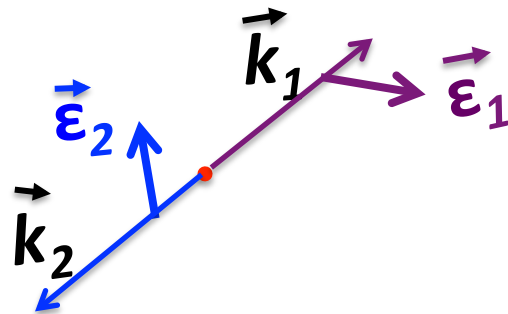
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J-PET potentialities to measure photon's polarization



- Angle between polarization vectors of annihilation photons is 90° .

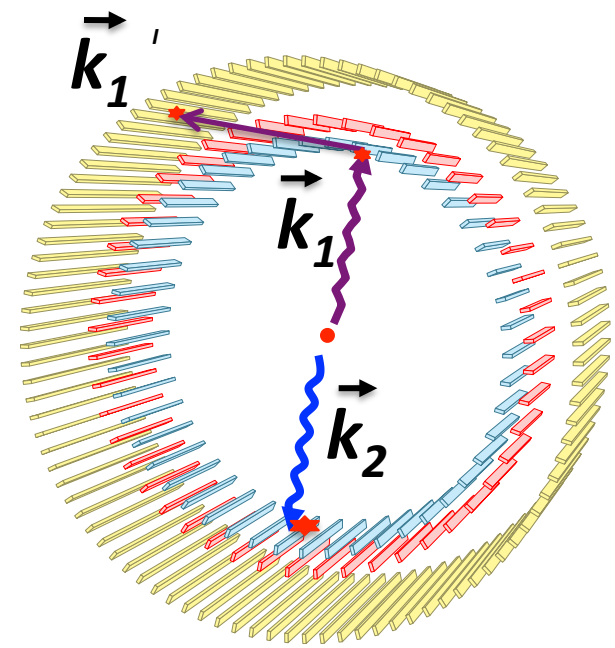
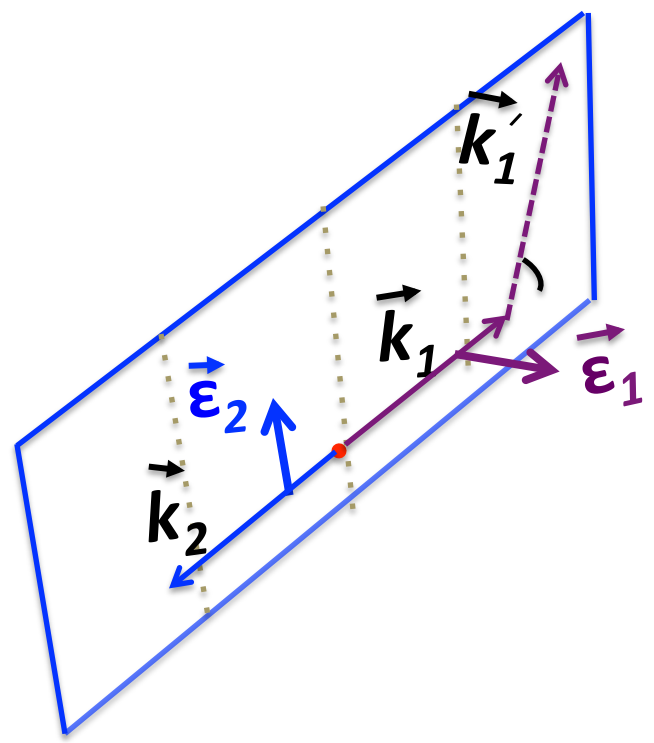
B. Hiesmayr and P. Moskal, **Scientific Reports** 7: 15349 (2017)

B. Hiesmayr and P. Moskal, **arXiv: 1807.04934**





J-PET potentialities to measure photon's polarization



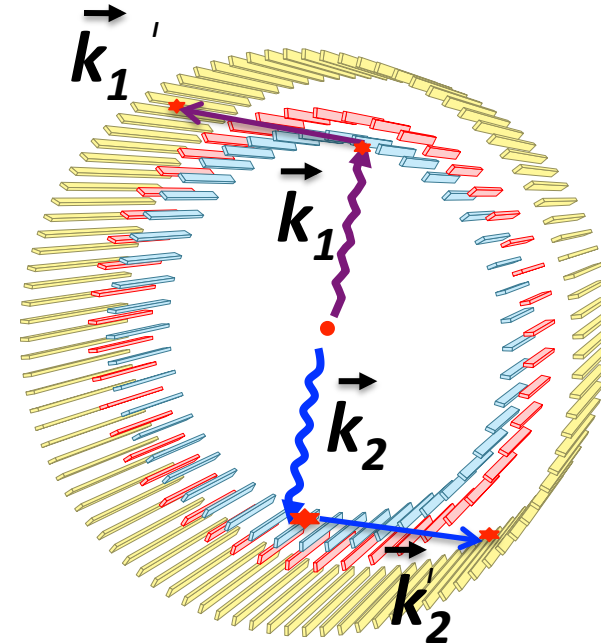
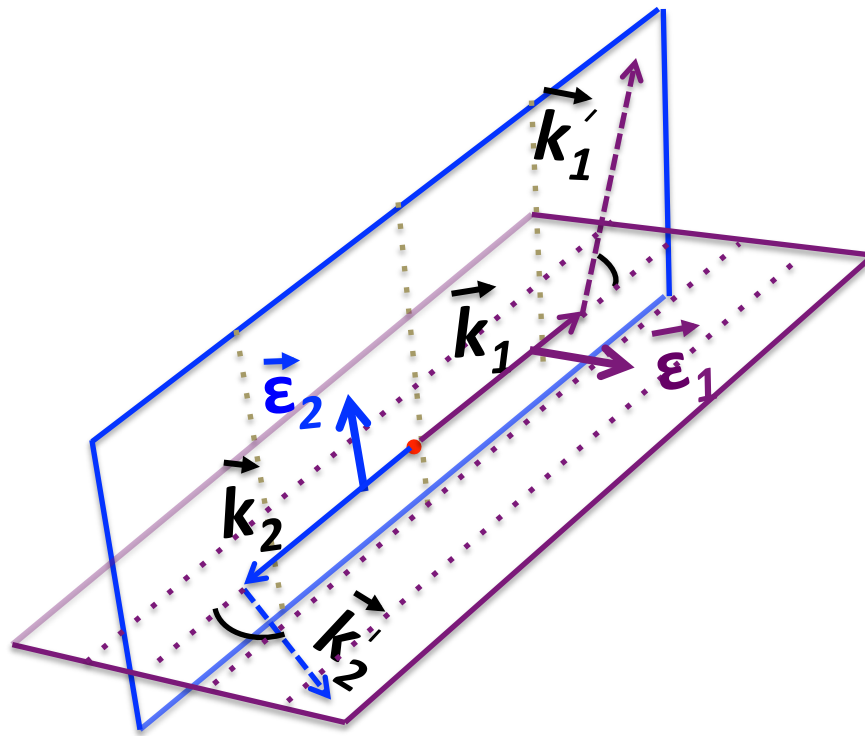
- Angle between polarization vectors of annihilation photons is 90° .
- Photons mostly scatter at right angles to their electric field vector

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J-PET potentialities to measure photon's polarization



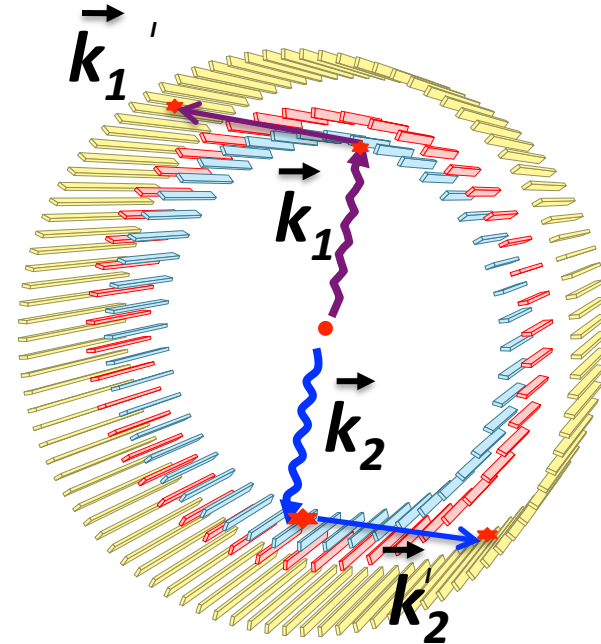
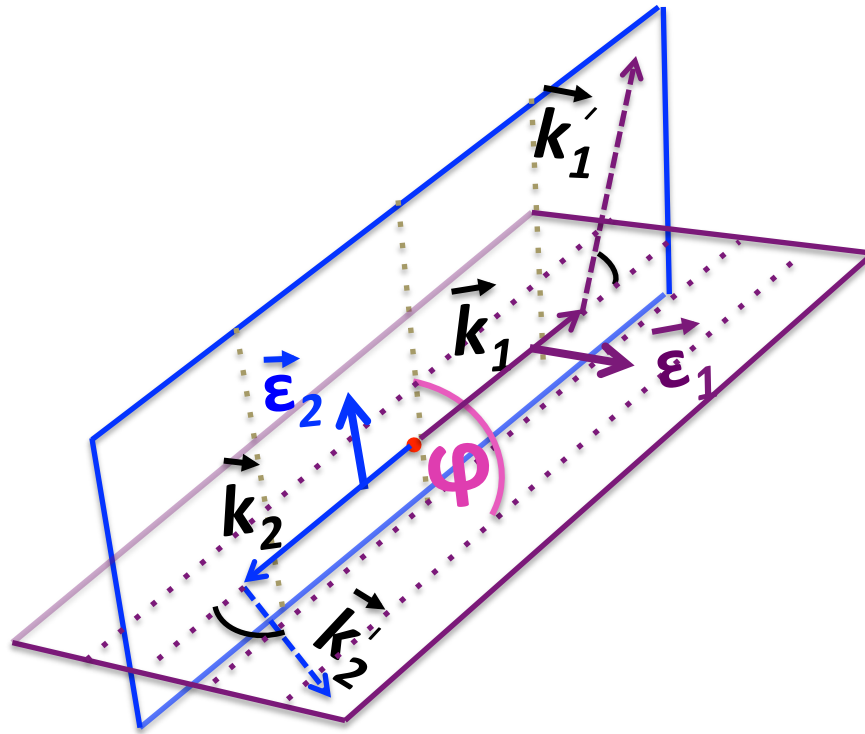
- Angle between polarization vectors of annihilation photons is 90° .
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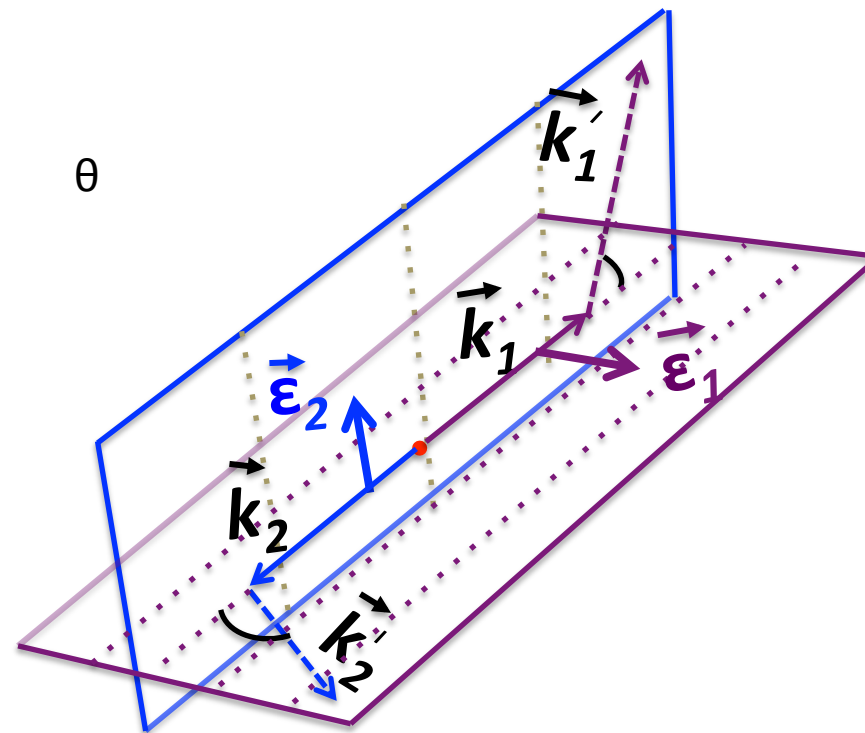
- Angle between polarization vectors of annihilation photons is 90° .
- Photons mostly scatter at right angles to their electric field vector and this impose an **Expected angular correlation** between the scattering angles.
- With the J-PET detector we can measure scatterings of back-to-back photons originating from the decay of positronium atoms and thus can study the angular correlation between the scattering angles.

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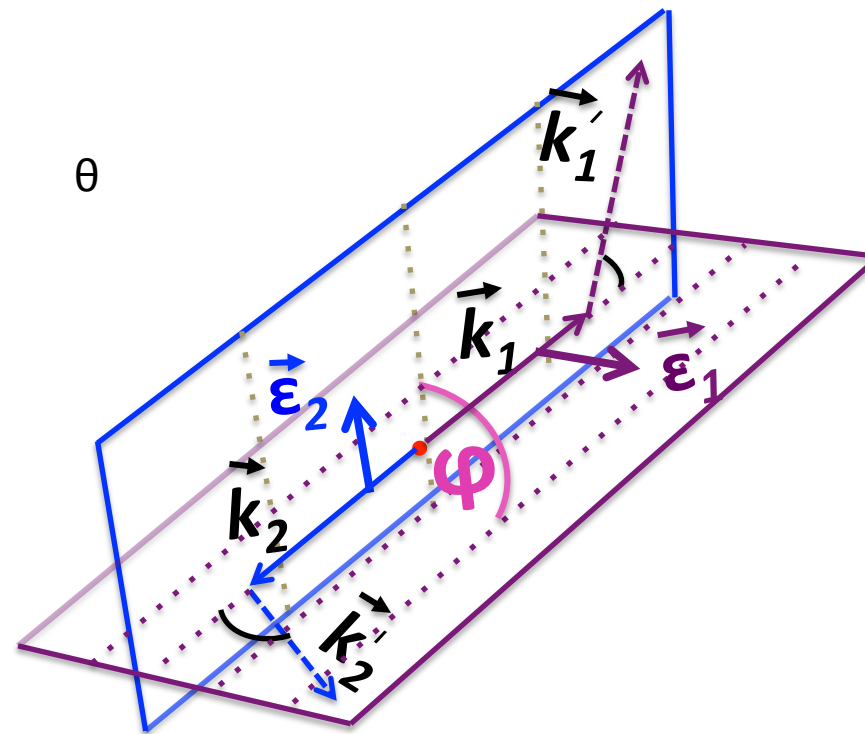


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B. Hiesmayr and P. Moskal, **Scientific Reports** 7: 15349 (2017)

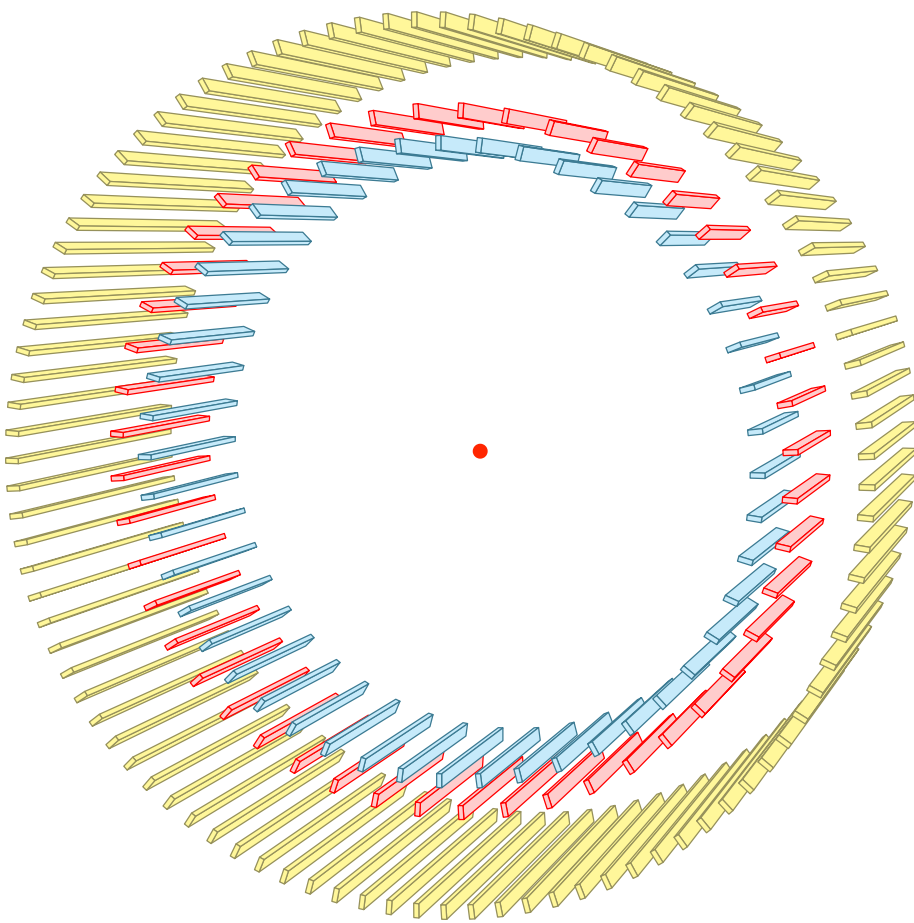
B. Hiesmayr and P. Moskal, **arXiv: 1807.04934**



**First experimental observation showing the
capabilities of J-PET detector for the
measurement of photon's polarization**
(based on N. Krawczyk and J. Raj studies)

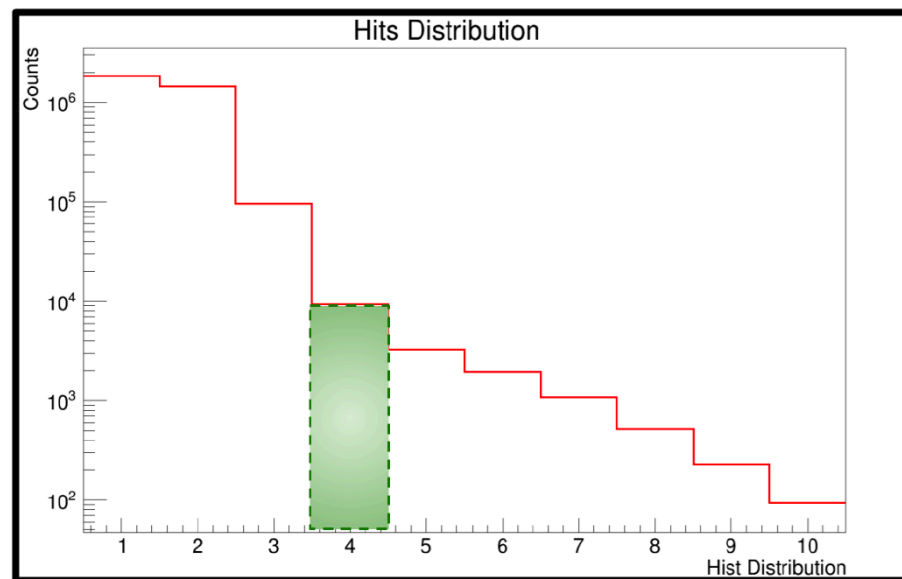
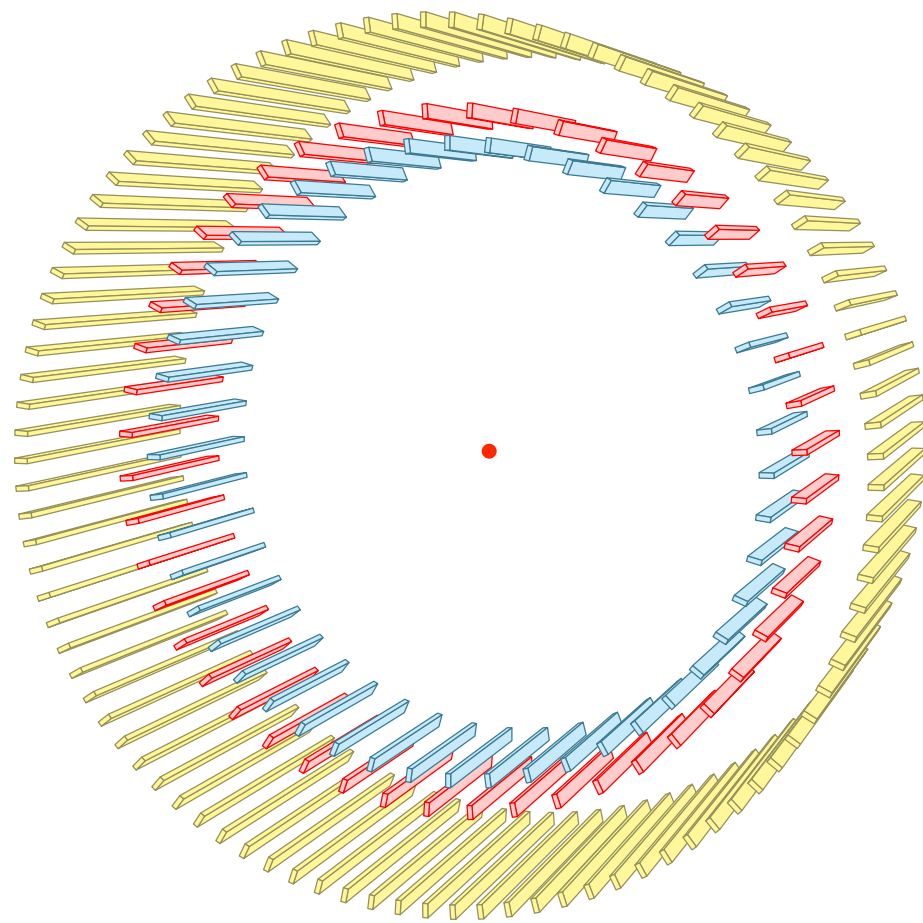


4 – hit events were studied



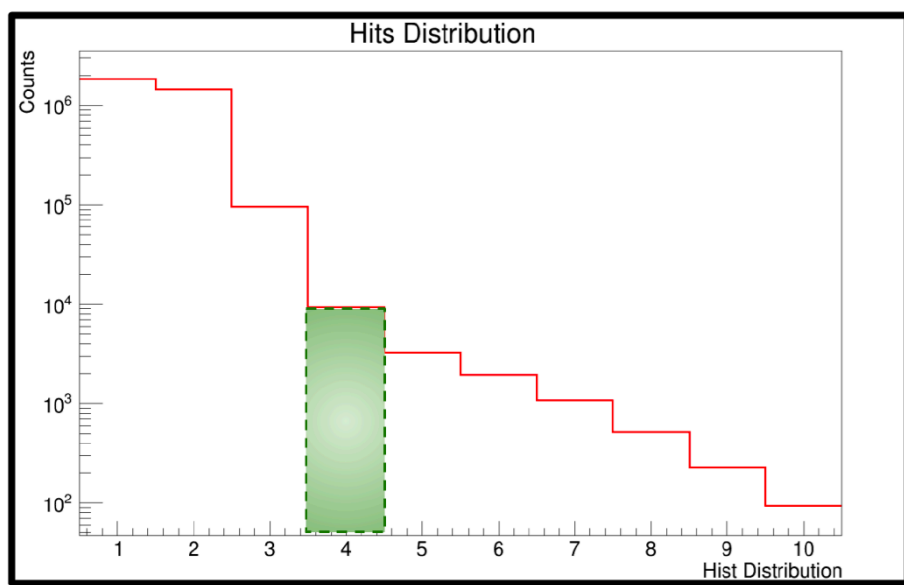
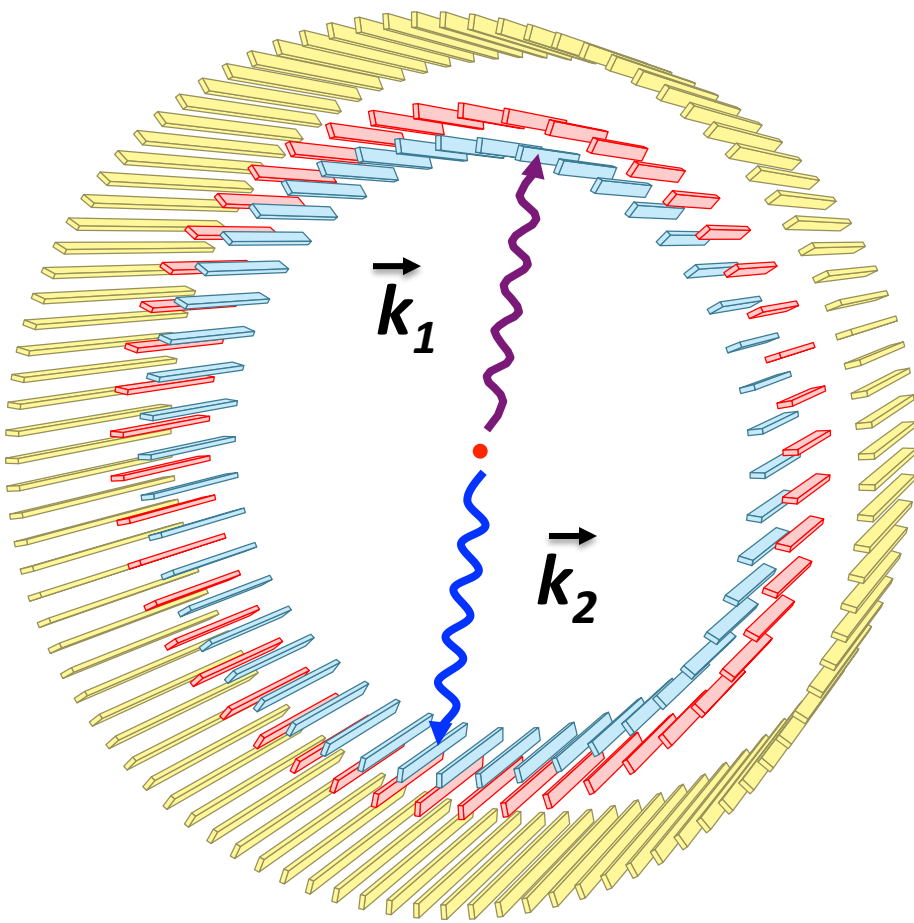


4 – hit events were studied



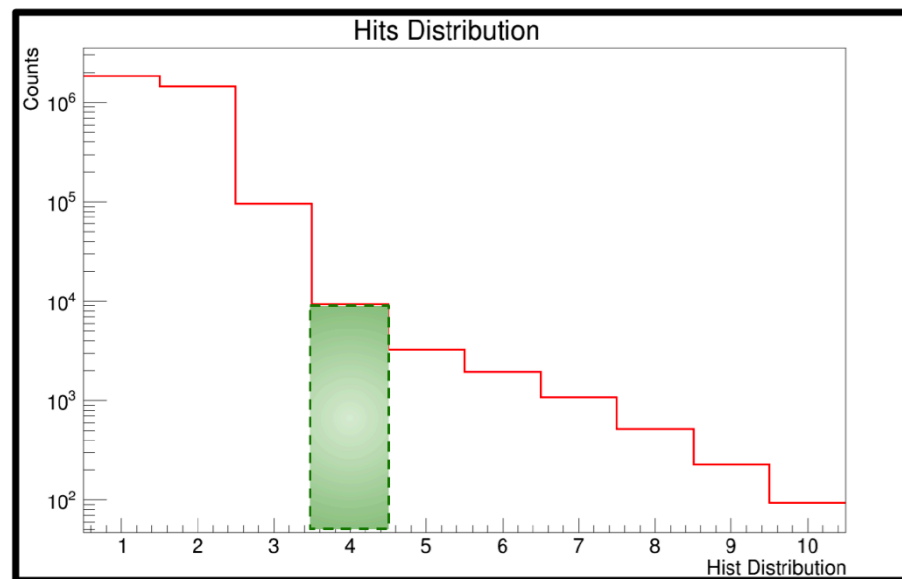
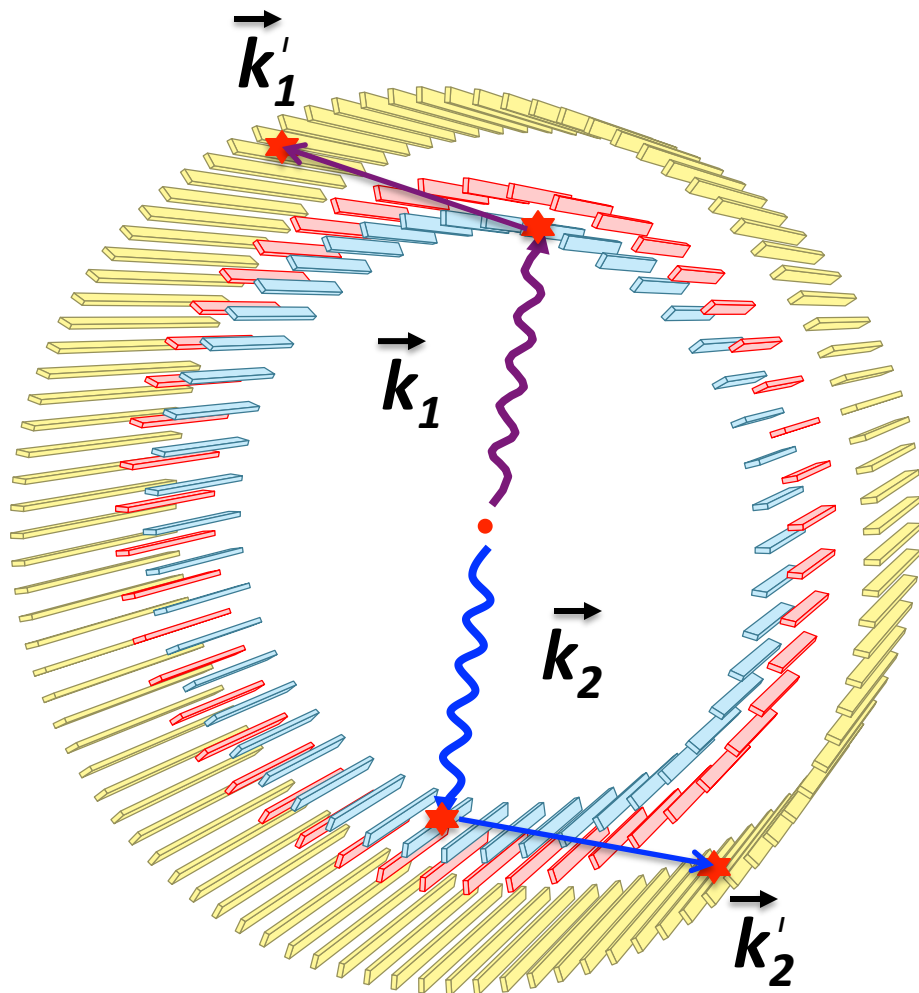


4 – hit events were studied



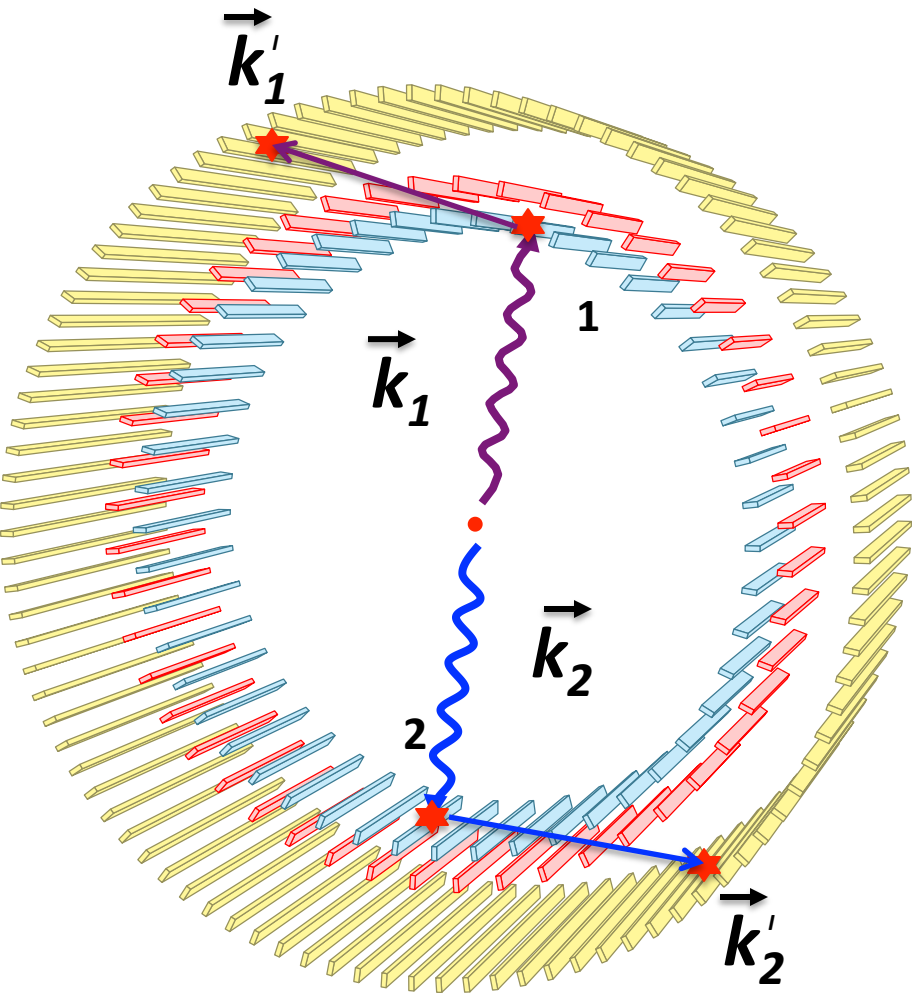


4 – hit events were studied



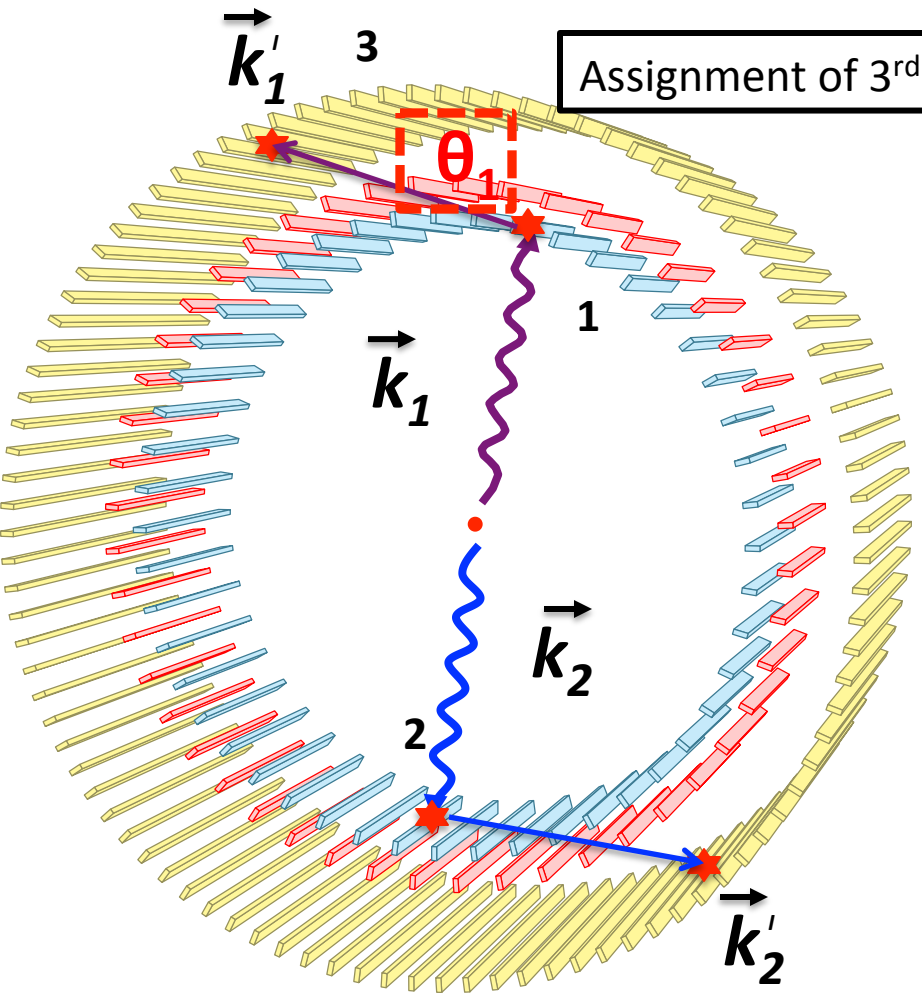


$$\text{Scatter test} = \text{time}_{\text{measured}} - \text{time}_{\text{calculated}}$$

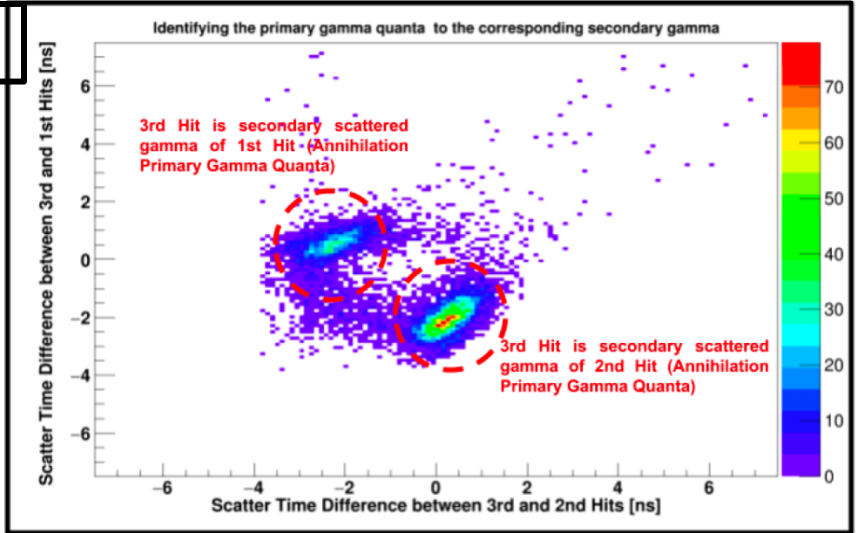




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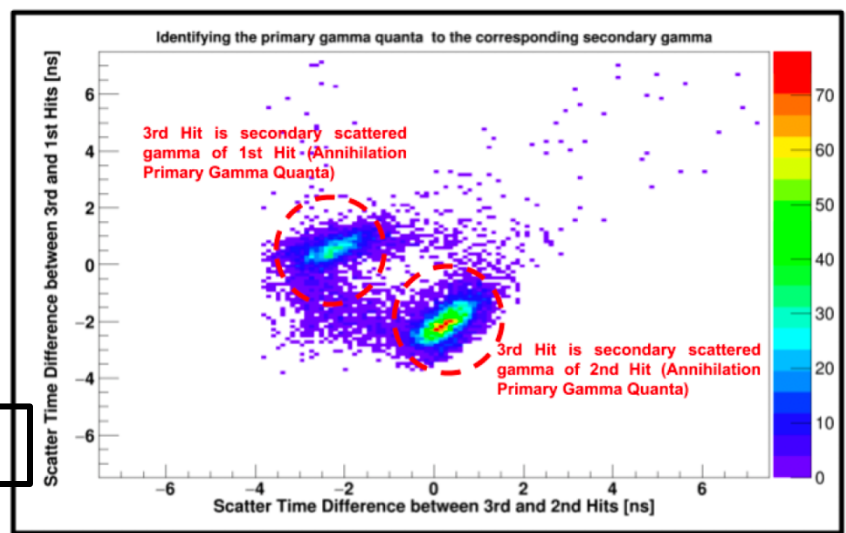
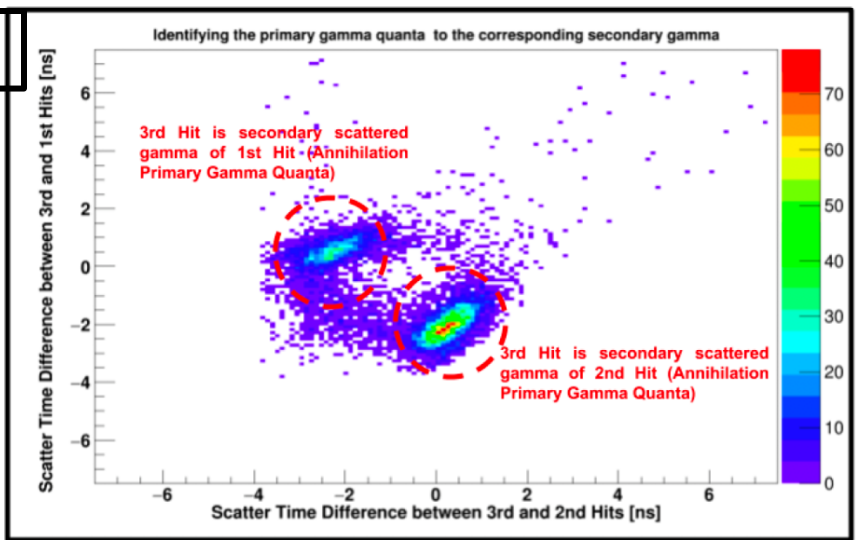
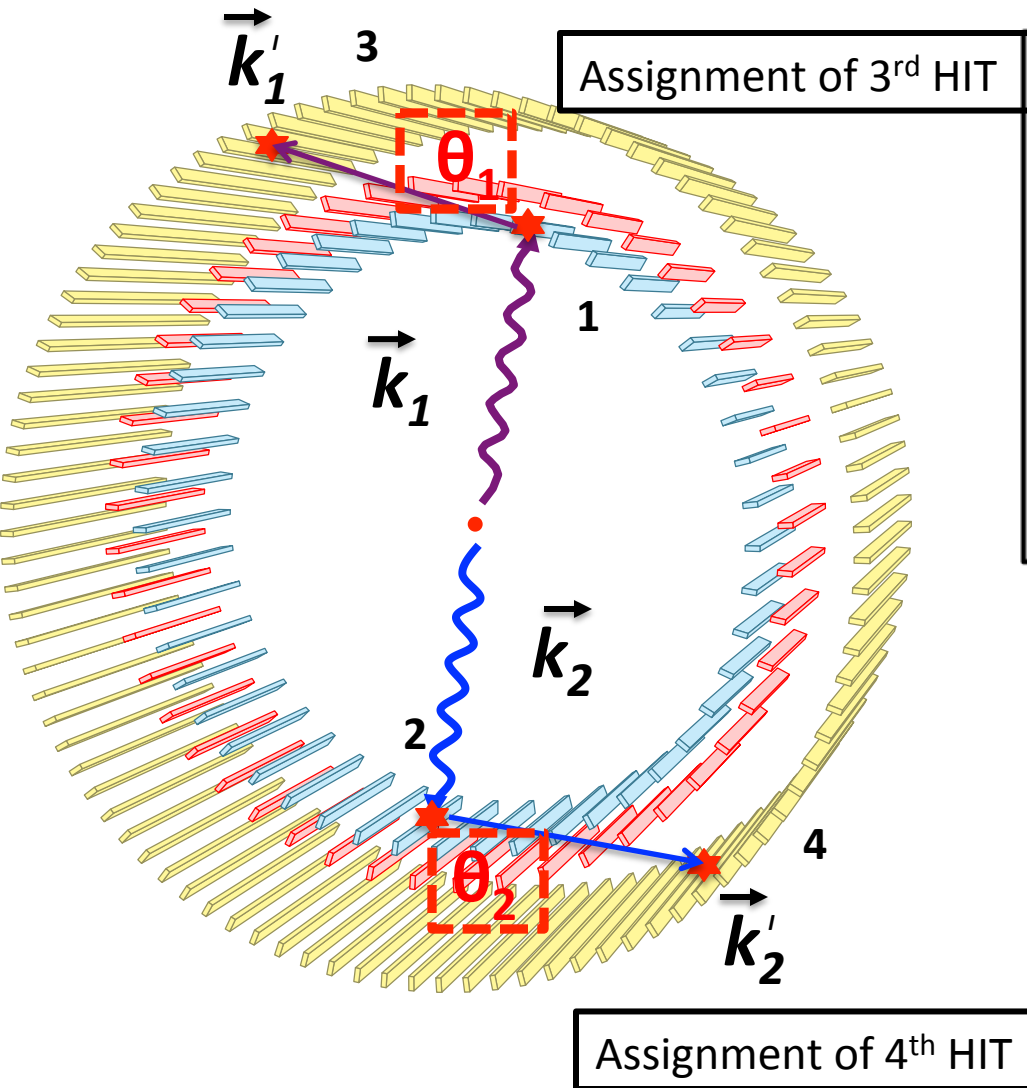


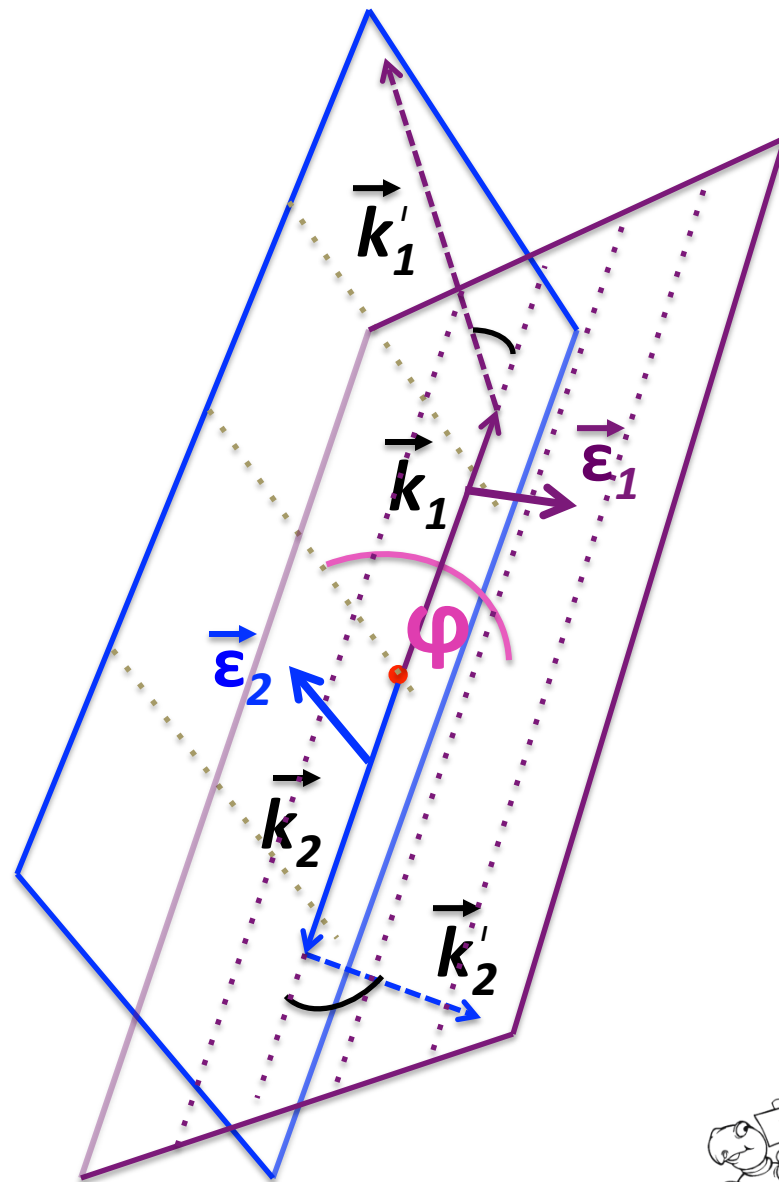
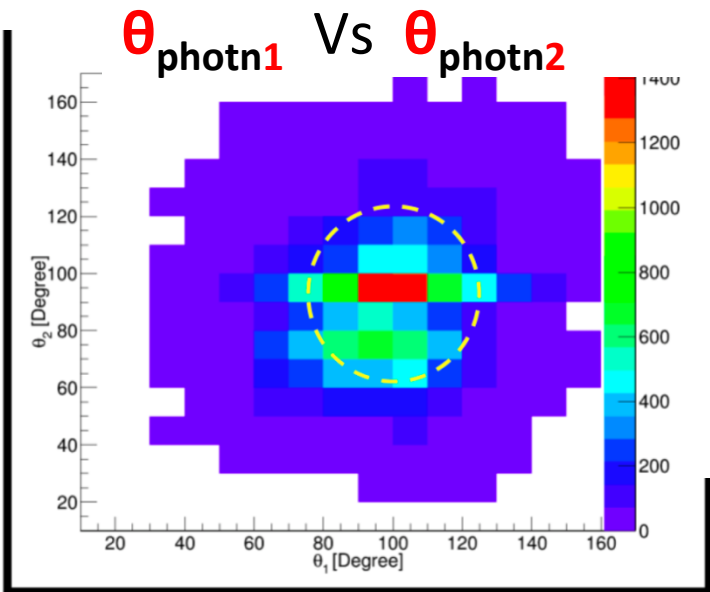
Assignment of 3rd HIT





Scatter test = $\text{time}_{\text{measured}} - \text{time}_{\text{calculated}}$

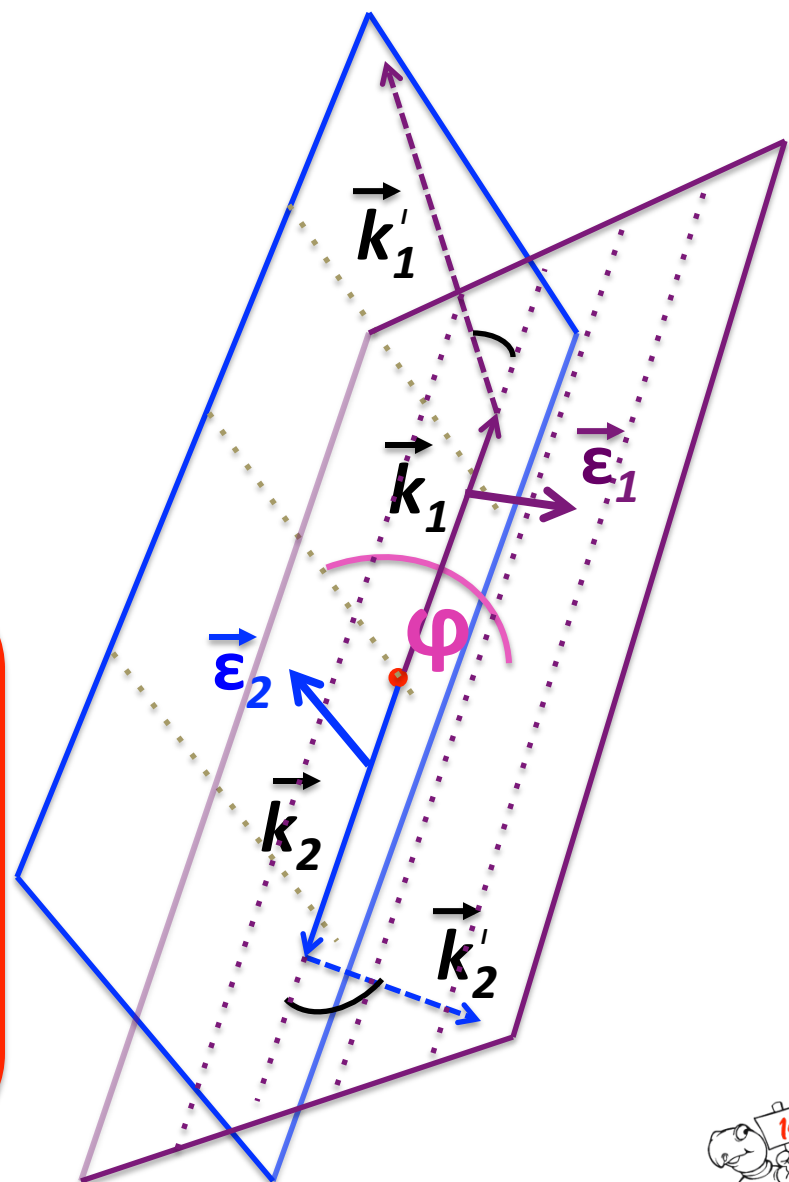
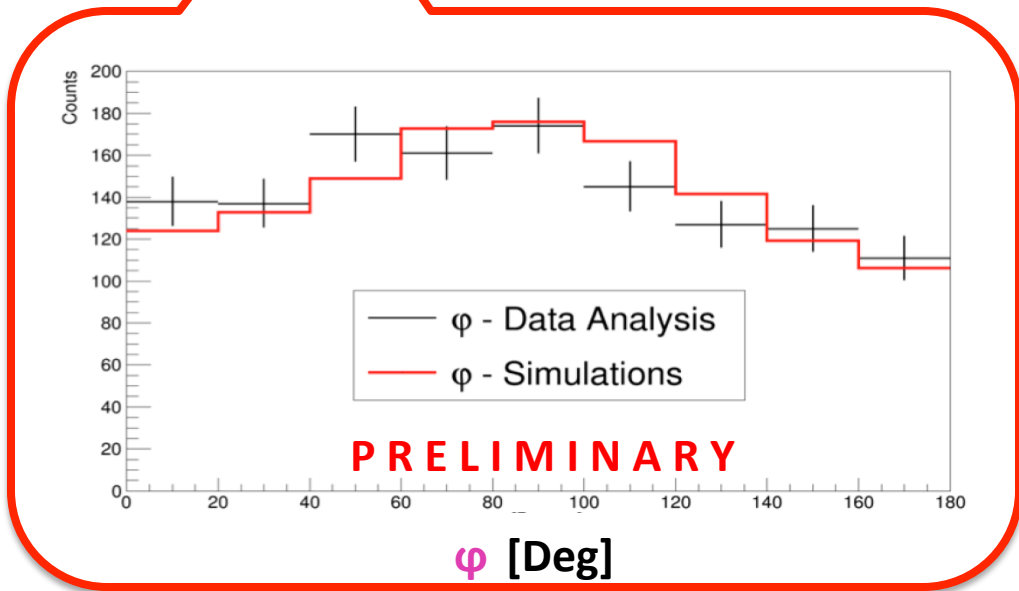
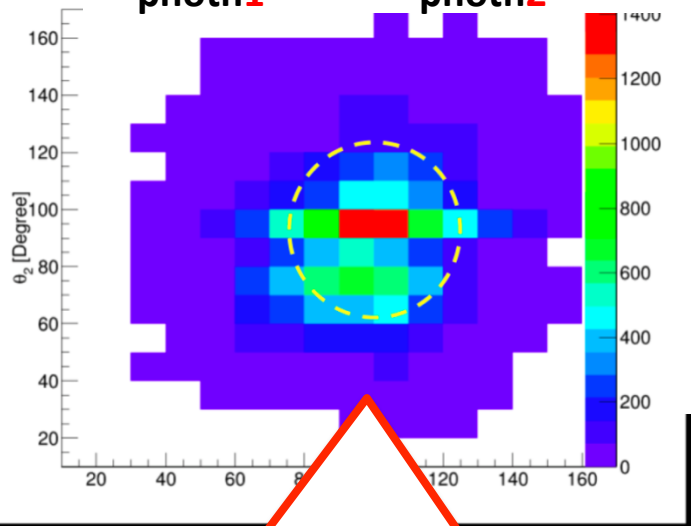






Relative angles between scattered planes *as a measure of* Relative polarization of **annihilation photons**

θ_{photon1} Vs θ_{photon2}



Summary and Outlook



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-



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Detailed applications of J-PET detector –

Thursday Morning session

- Potential of J-PET tomograph for total body positronium imagings- **Pawel Moskal**
- Status and prospects of discrete symmet. tests in the positronium decays- **Michal Silarski**
- Molecular characterization of nanostructures of normal and cancer cells in vitro using Positron Annihilation Lifetime Spectroscopy – **Ewelina Kubicz**



J-PET collaboration



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