TOT method

for the

disentanglement of photons

in

Positron Annihilation Lifetime Spectroscopy

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OUTLINE

Jagiellonian **P**ositron **E**mission **T**omography — Made of Plastic scintillators

Data acquisition and Analysis Framework — Trigger-less, geant4 simulations

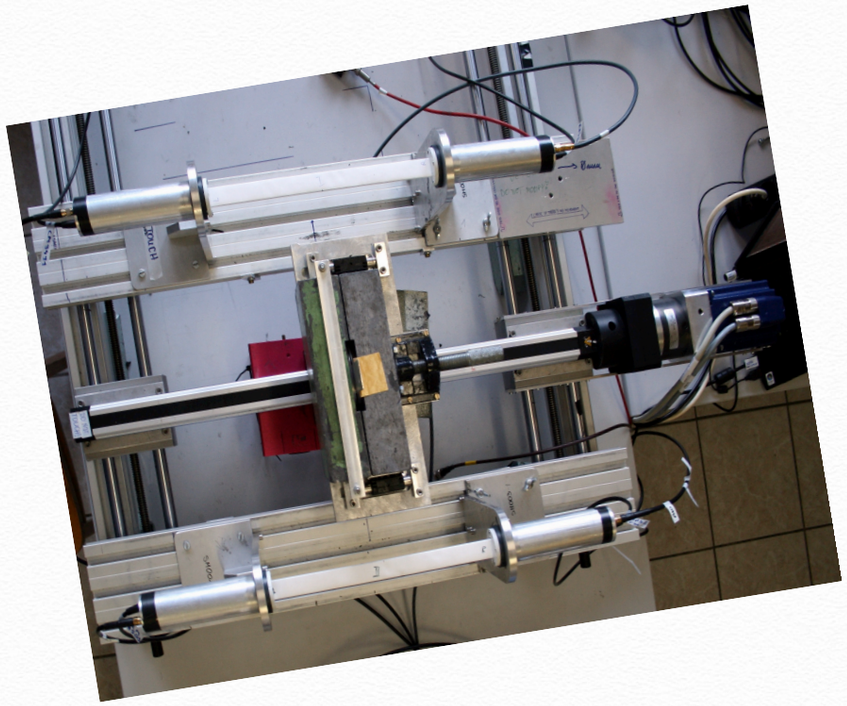
Time Over Threshold (TOT) method — Estimation of charge collection

TOT Utilization — Measure of Energy Deposition

Conclusions — Implications in J-PET

Development cycles of J-PET

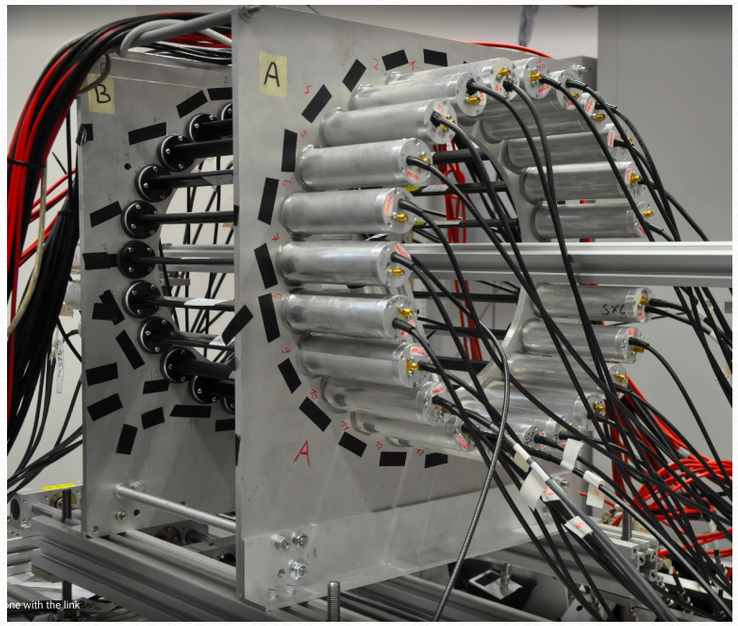
2012



Characterize scintillator properties

Energy resolution, hit time, ..

2014

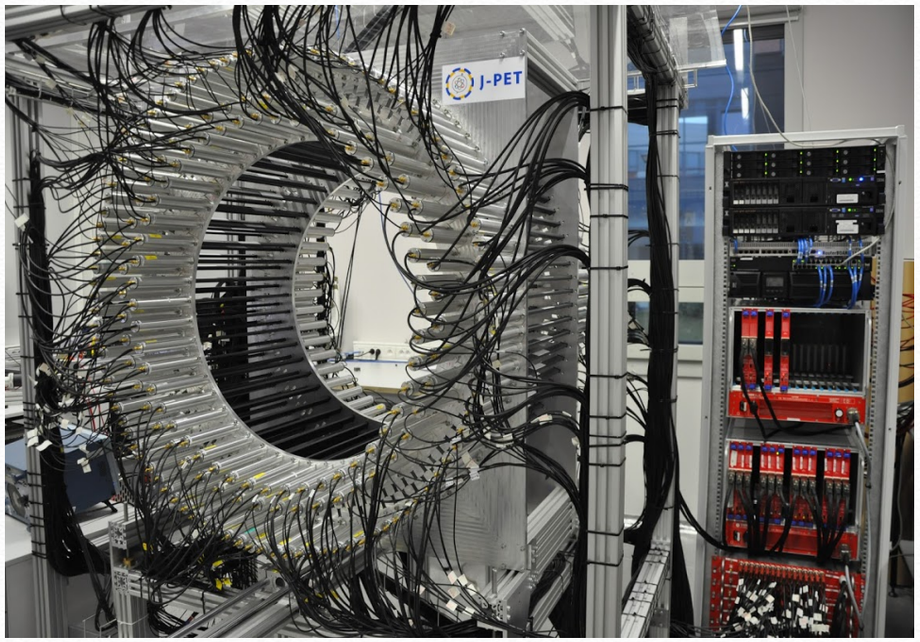


24 strips

Data acquisition validation

for multi-modules

2016



Current version

Fundamental symmetries test and Positronium imaging

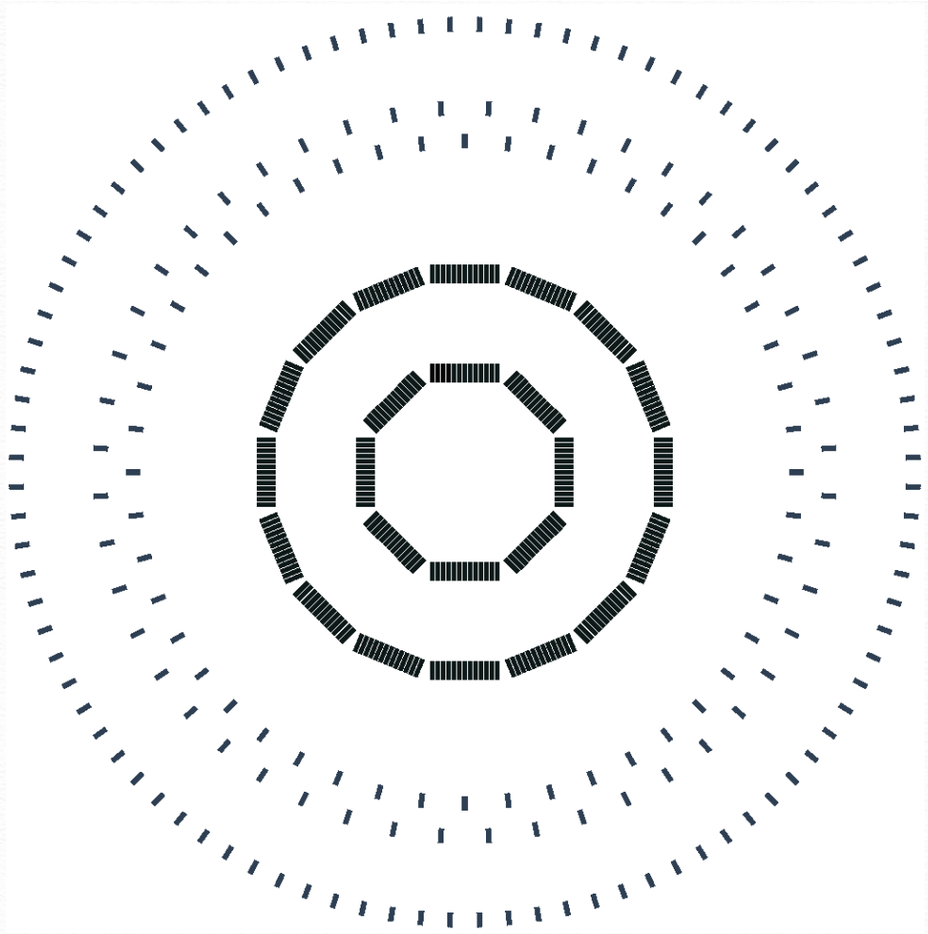
2018

Modular PET

ready for first data campaign

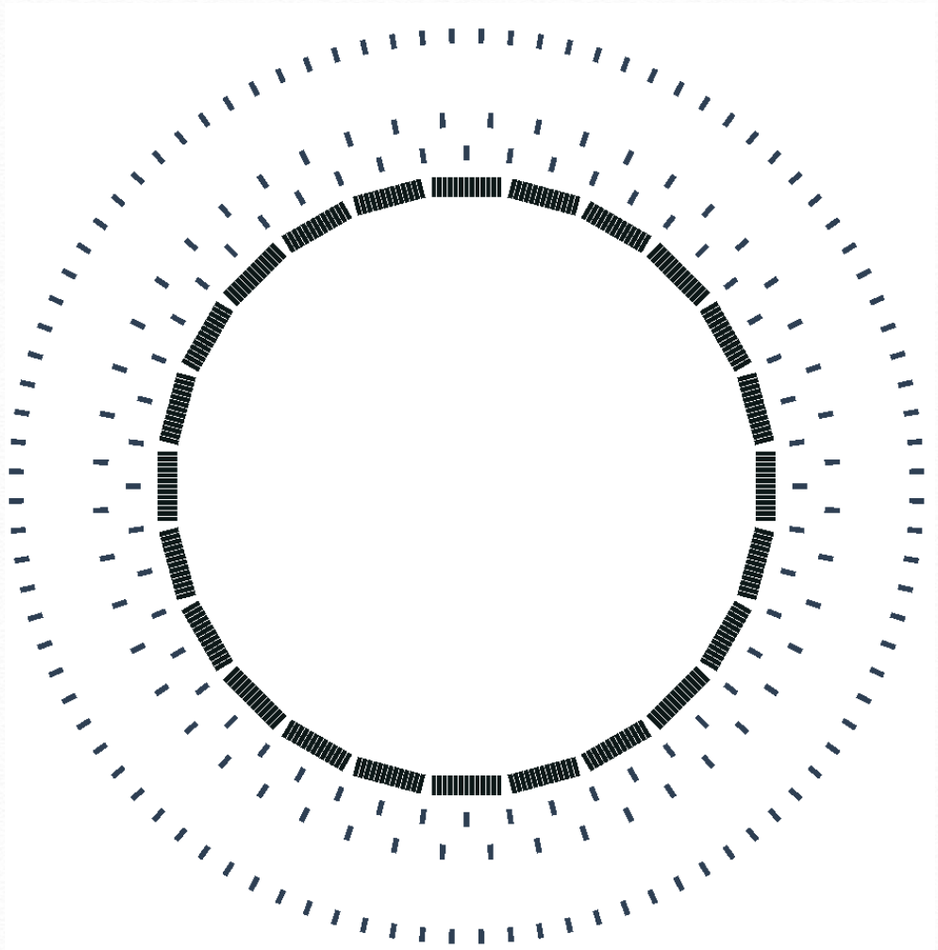
Advantages with Modular J-PET

Stand – Alone



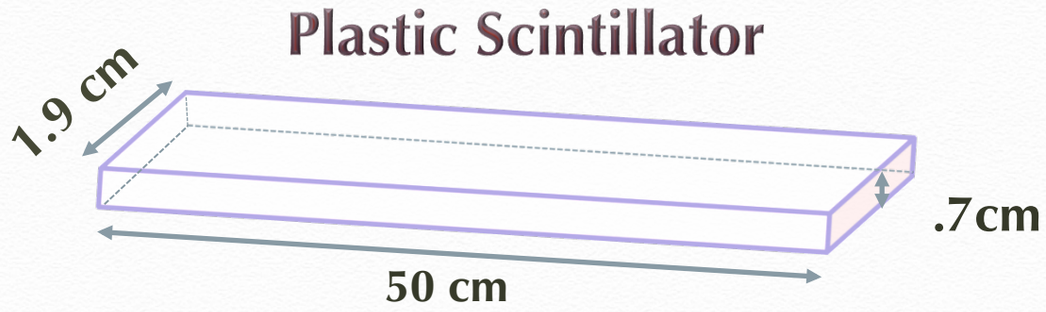
Multi-configurable

As inner layer of 3-Layer prototype

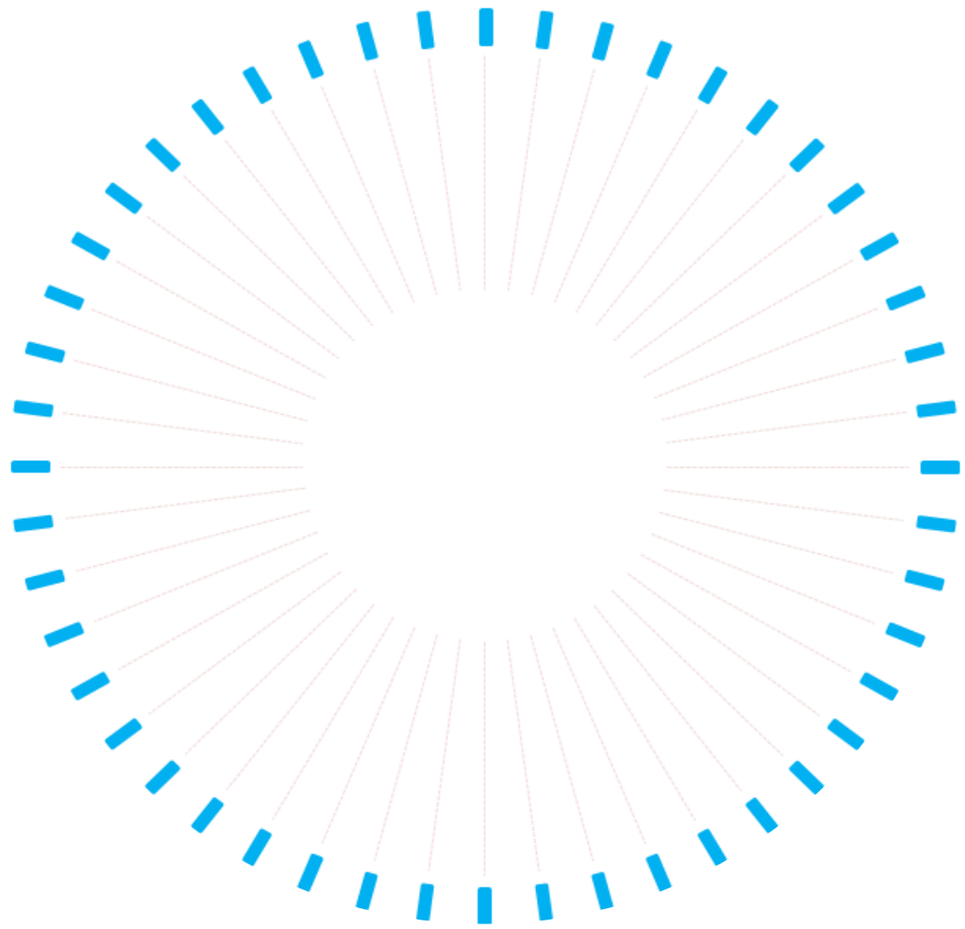


✓ Several times better efficiency [Advantage]

Jagiellonian - Positron Emission Tomograph



192



Arranged axially in
3 layers

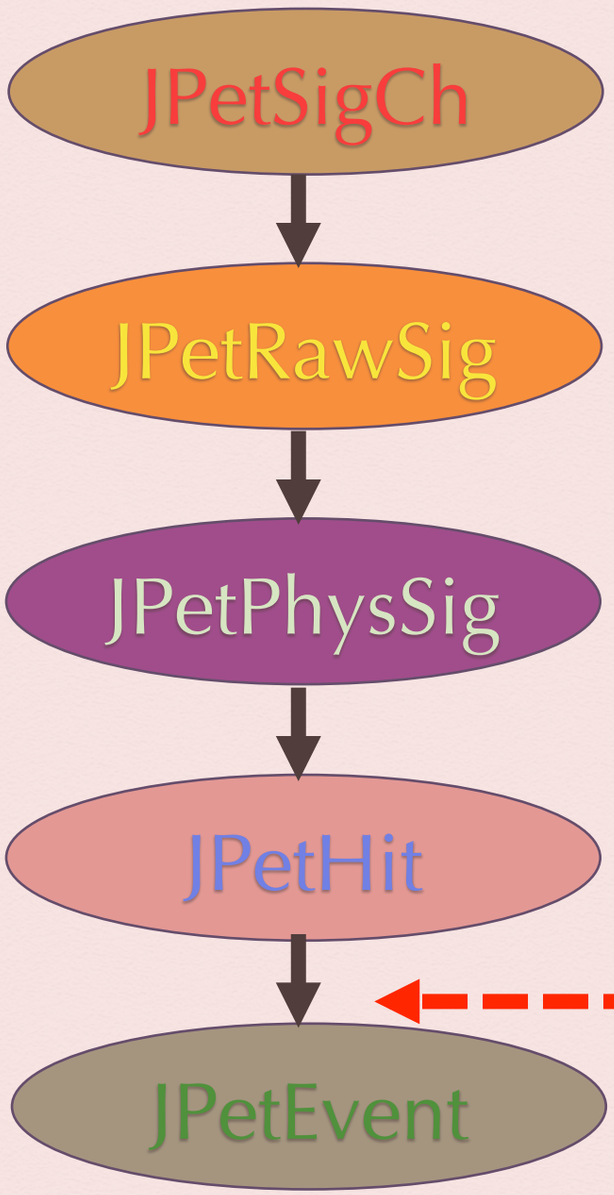
(48,48,96)

Trigger less
DAQ

TOT as measure of
energy deposition

J-PET Analysis Framework : Open-source platform

Data Analysis



JPetTimeWindow

MC simulation

Dedicated simulation package

Source :
Photons beam, **Ps decays**,..

Relative angles and energy distributions of primary photons
(e.g., decay of Ps into Multi-photons)

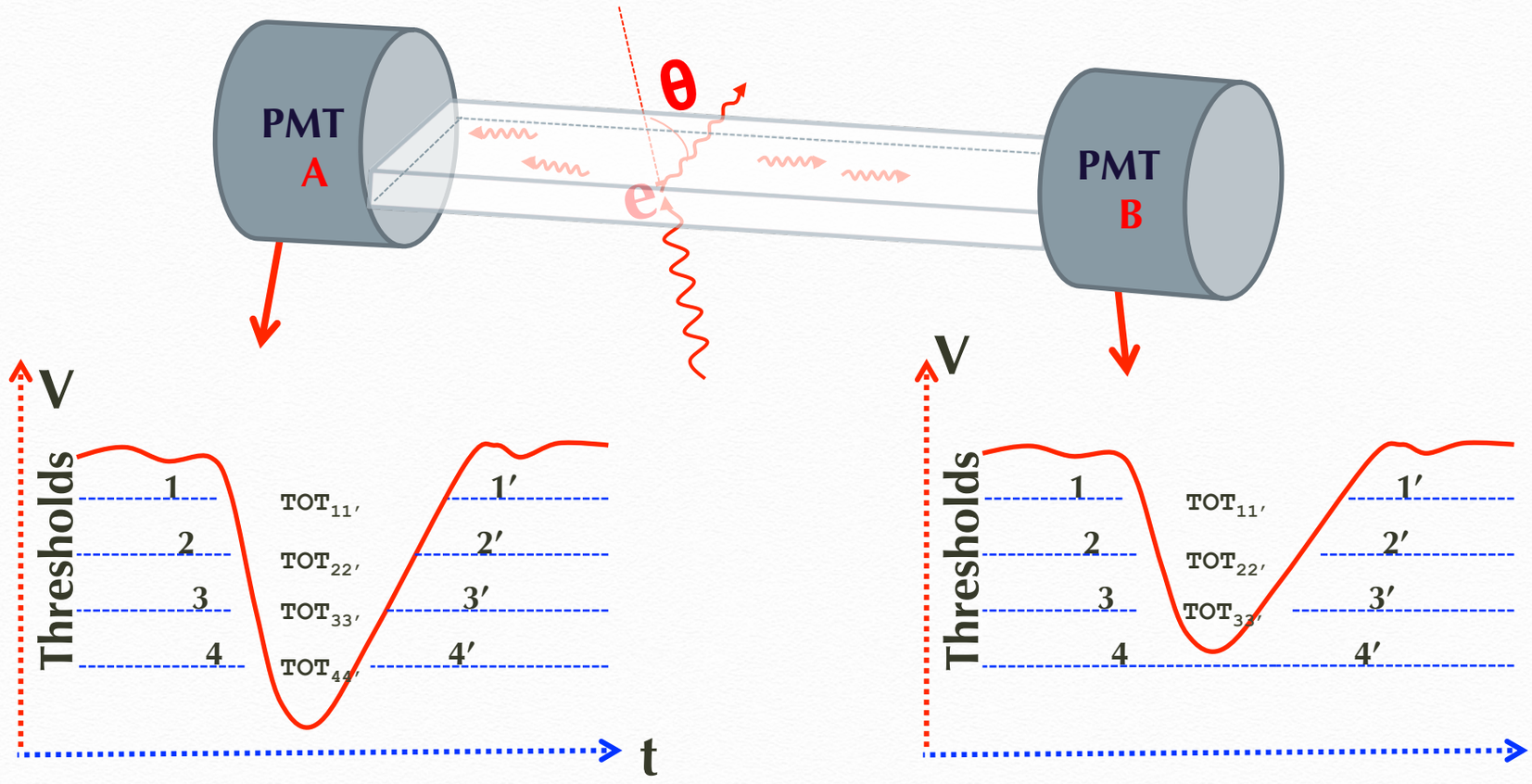
Interaction of Gamma quanta : (**Comp. Scatt**)
hit – position , hit time, Scattering angle
Multiple-scattering

Geant4 –Parsar (empowered to introduce experimental resolution

Bonus

Adjusted to utilize the multiple-threading feature

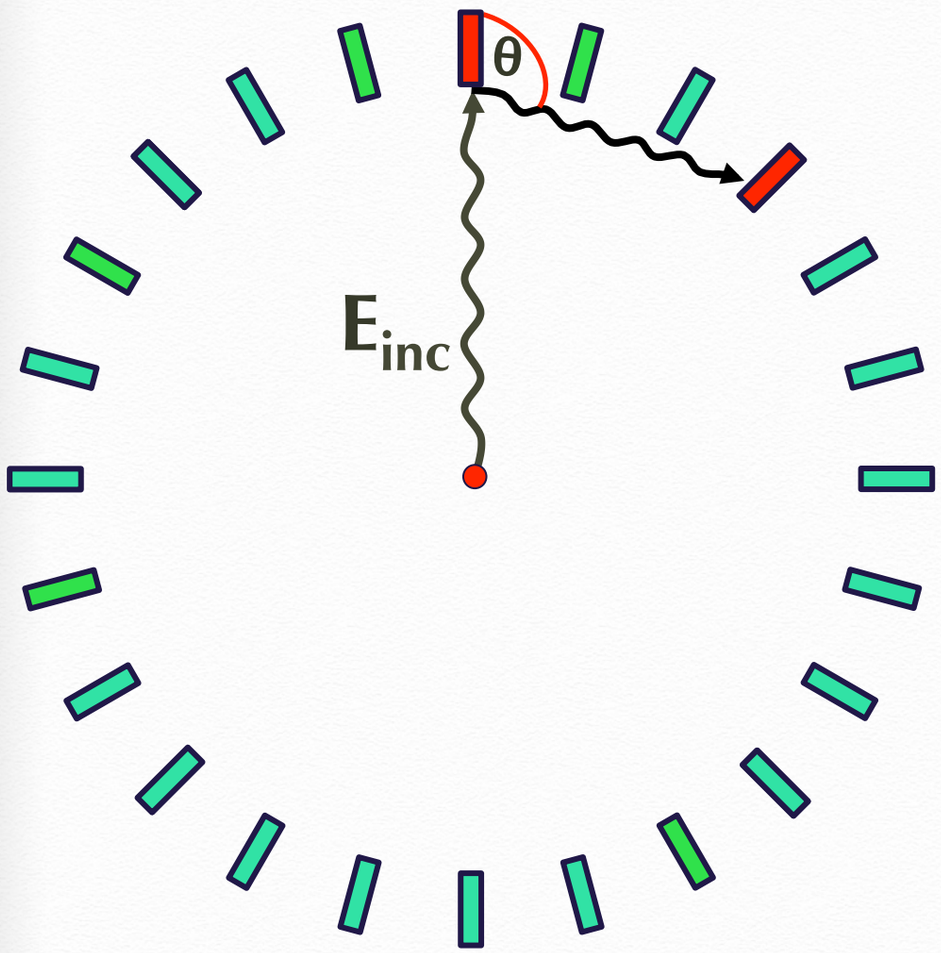
TOT definition in framework of J-PET



Signals from each photomultiplier are ***probed at four fixed thresholds***

$$TOT = \sum_{PMT=A,B} \sum_{Thr_{1-4}} TOT_{PMT,Thr}$$

Methodology :



What we measure :

✓**TOT** values

✓Hit positions of primary and scattered photon gives **access to the θ** values

What can be extracted :

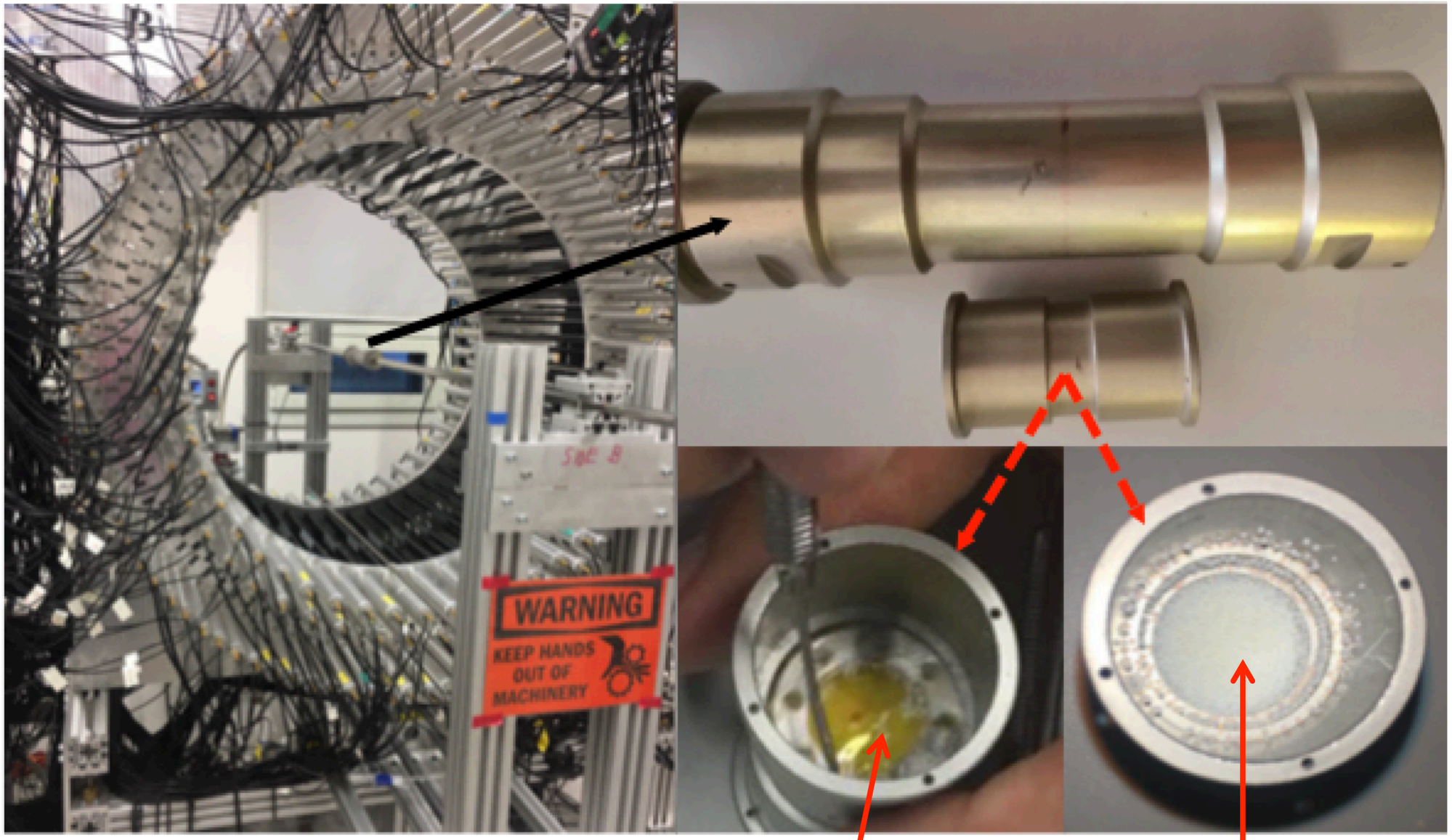
Energy of the **incident photon**

True **scattering angle**

$$E_{dep} = f(E_{inc}, \theta)$$

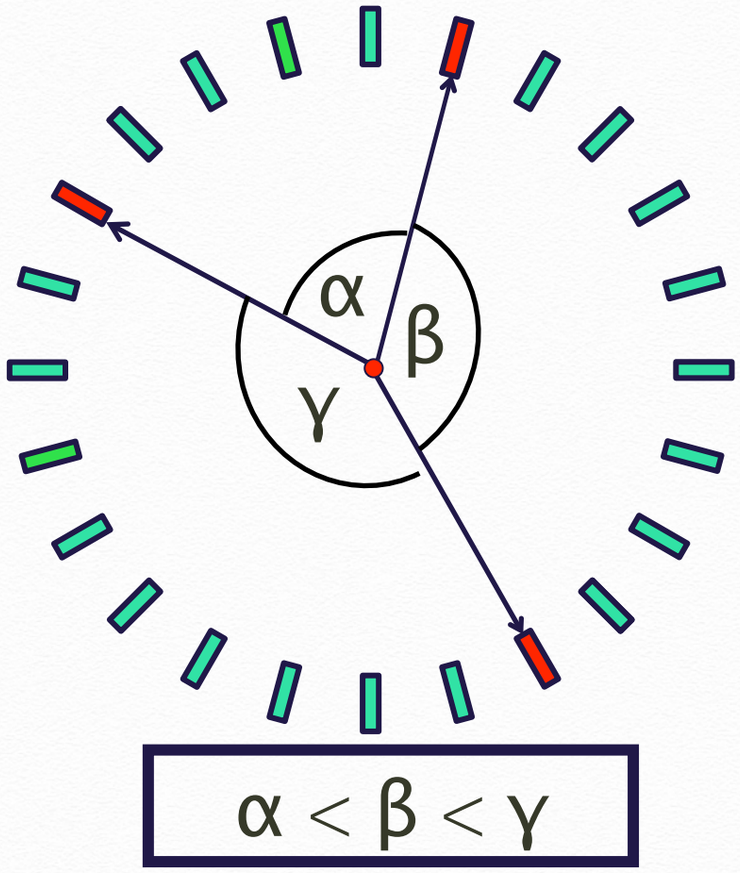
Experimental details

Small chamber in the center

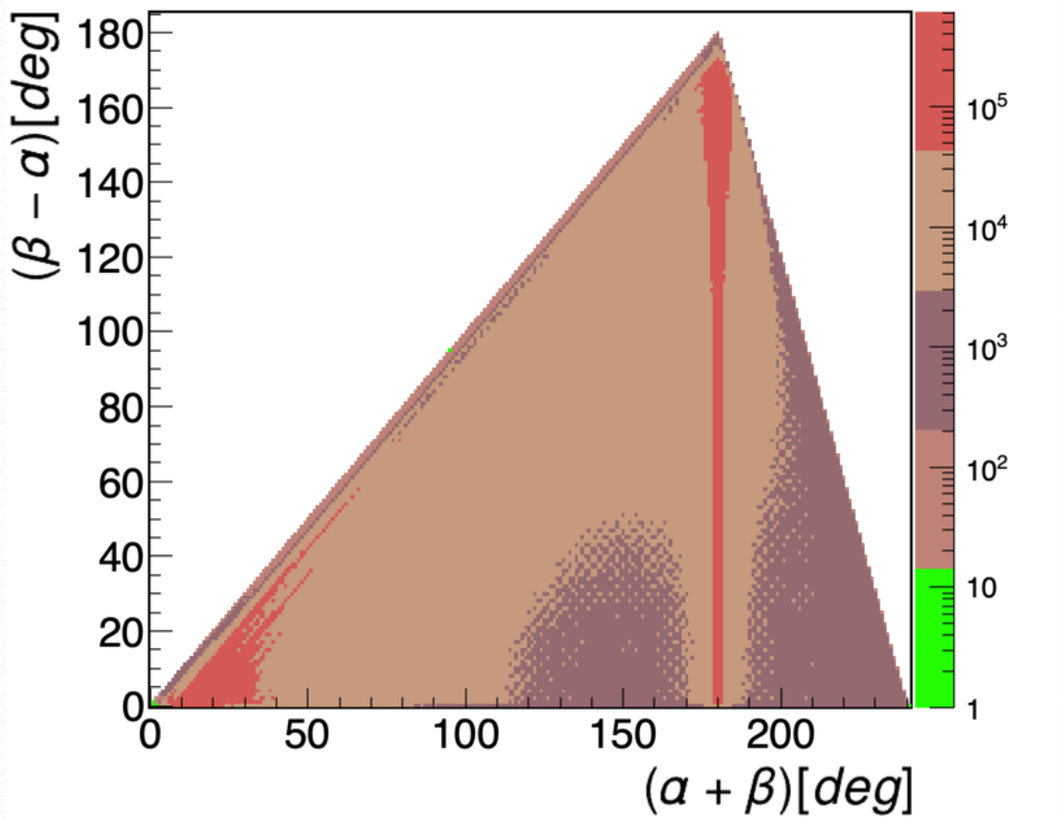


Selection of photons of diff. energies : Angular dist. based

Events (3Hits ordered in time) were studied



$\alpha < \beta < \gamma$



Annihillation photons 511 keV

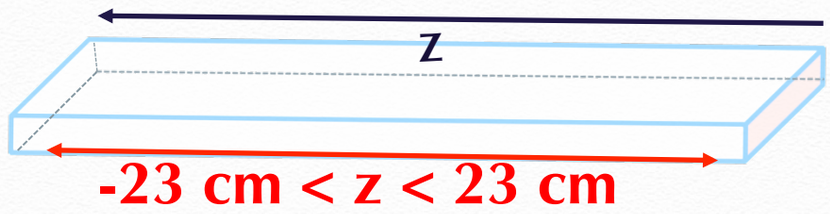
179 < (α+β) < 181

All 3 Hits are in different scintillators

Prompt photons 1275 keV

179 < (α+β) < 165 && (α+β) > 185

All 3 Hits are in different scintillators



-23 cm < z < 23 cm

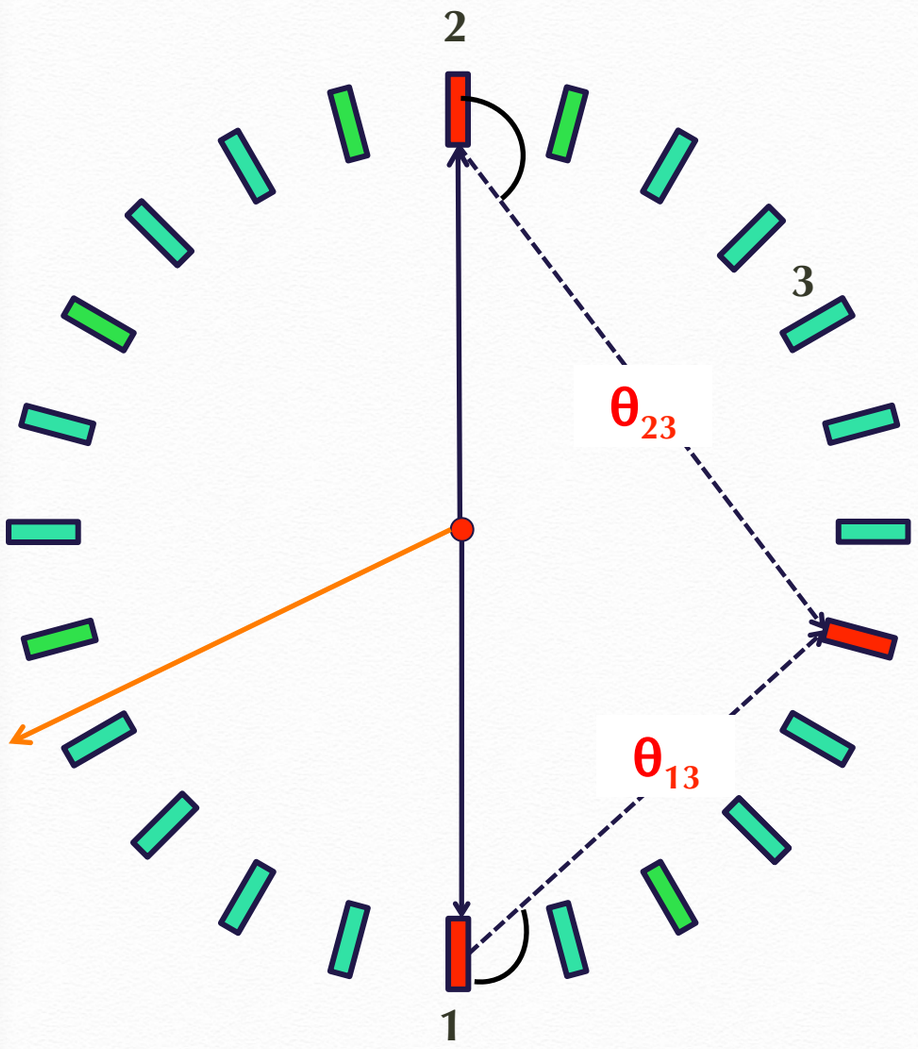
No cuts were applied explicitly on TOT in identification of photons

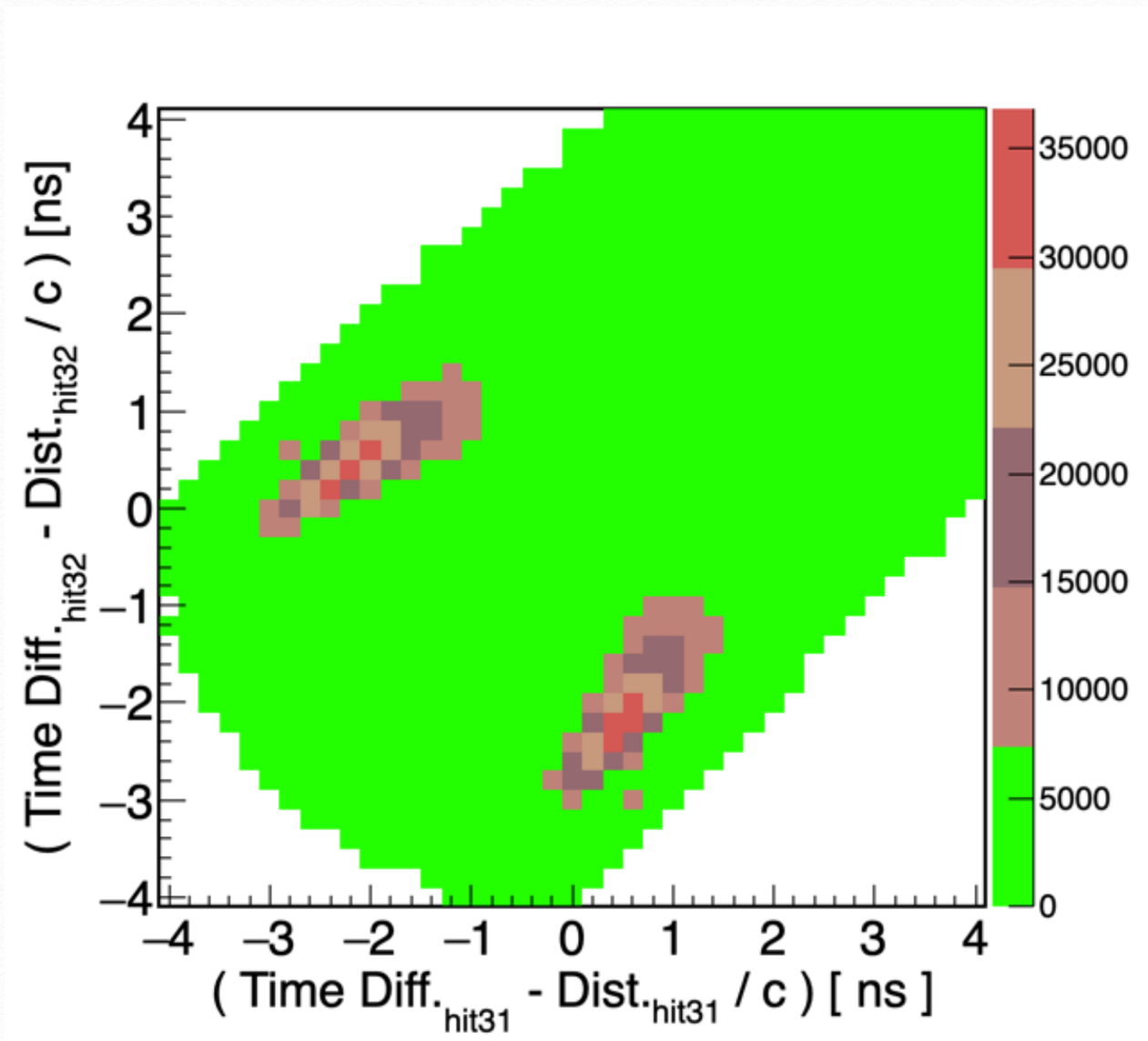
Measurement of 511 keV photon : (TOT vs Scatt. Ang (Edep))

- ☑ 1, 2 Hits are Back-to-Back gamma
- ☑ 3RD Hit from the scattering of gamma either after Hit 1 or Hit2

For **the assignment of scattered** hit to its origin, ***scatter test***(**S**) was applied:

$$S = (time_{scatter} - time_{origin}) - Distance_{scatter\text{-}origin} / c$$



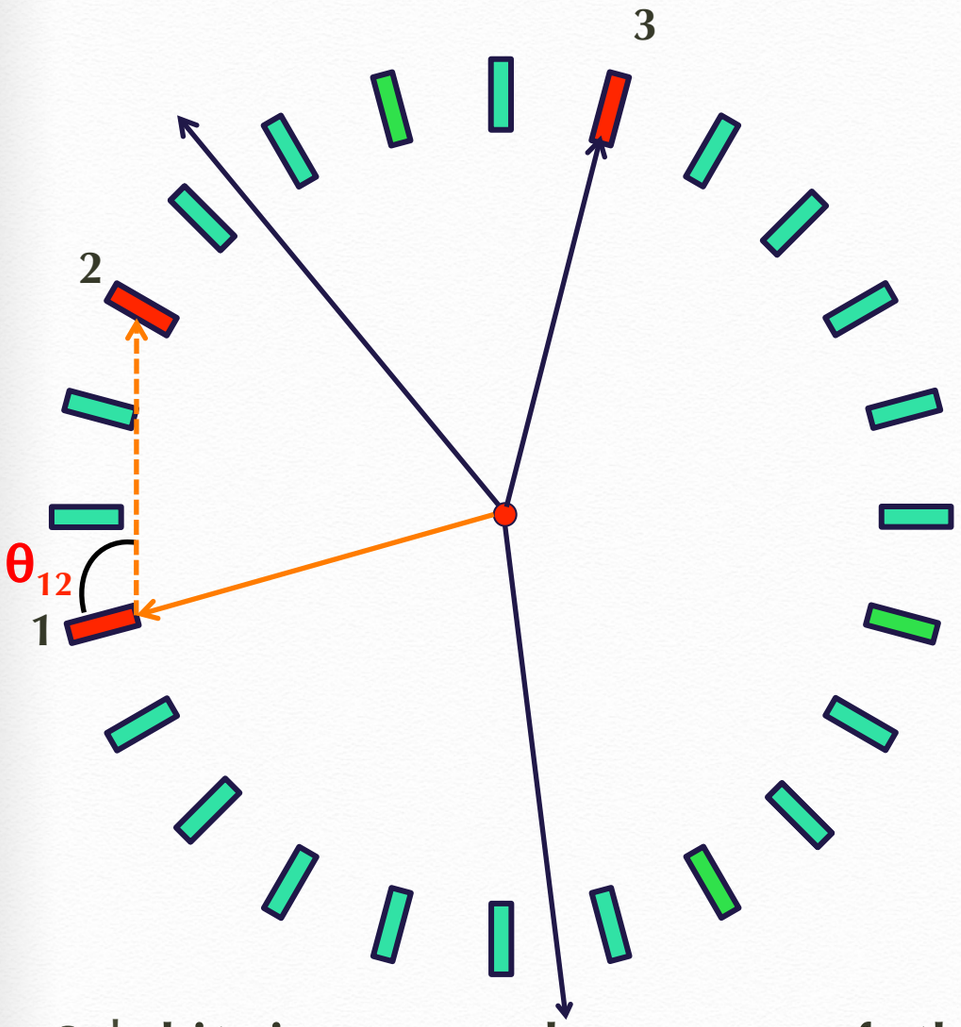


Measurement of 1275 keV photon : (TOT vs Scatt. Ang (Edep))

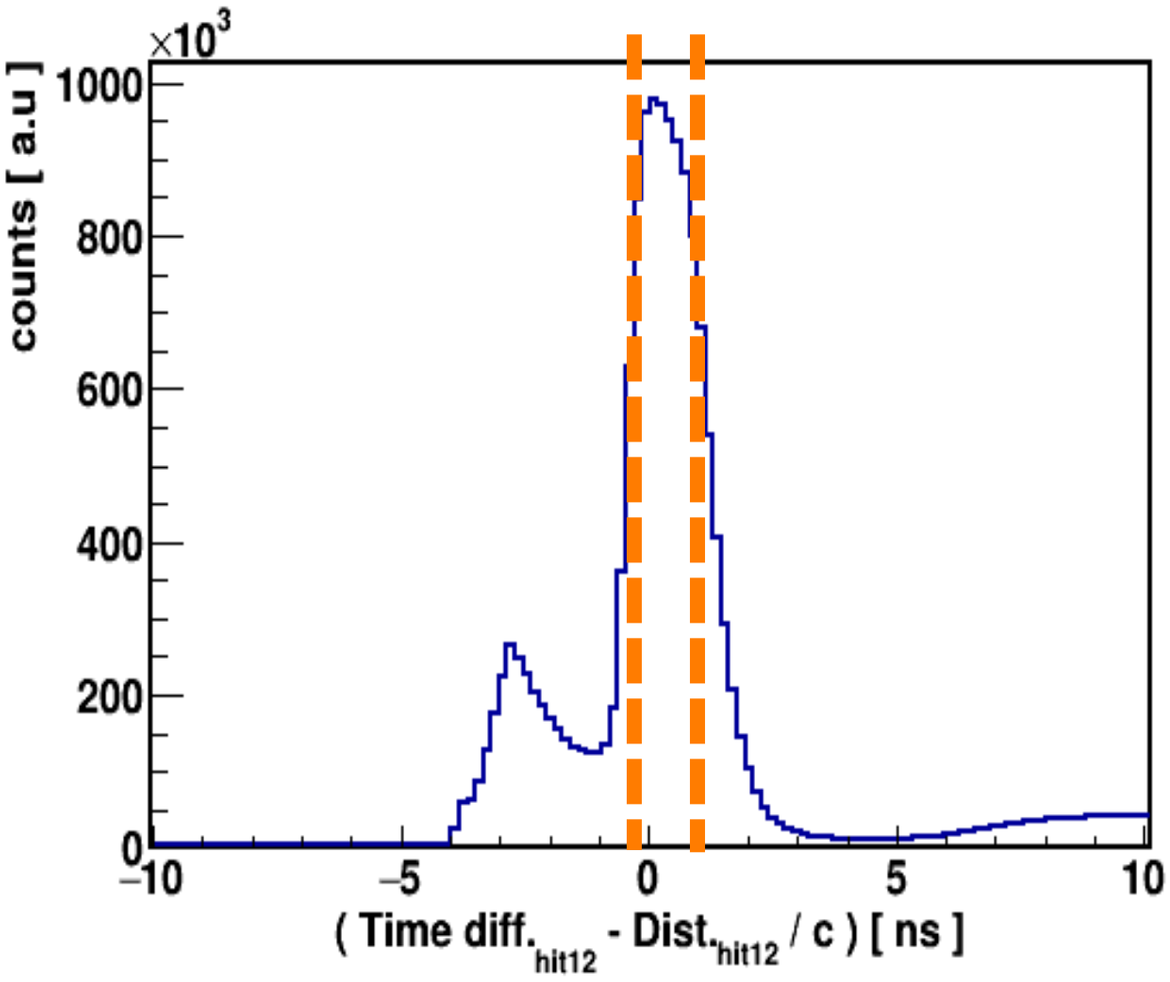
- ☑ Ist Hit is prompt gamma
- ☑ 2nd Hit from the scattering of prompt gamma

For **the assignment of scattered** hit to its origin, ***scatter test***(**S**) was applied:

$$S = (time_{scatter} - time_{origin}) - Distance_{scatter\text{-}origin} / c$$

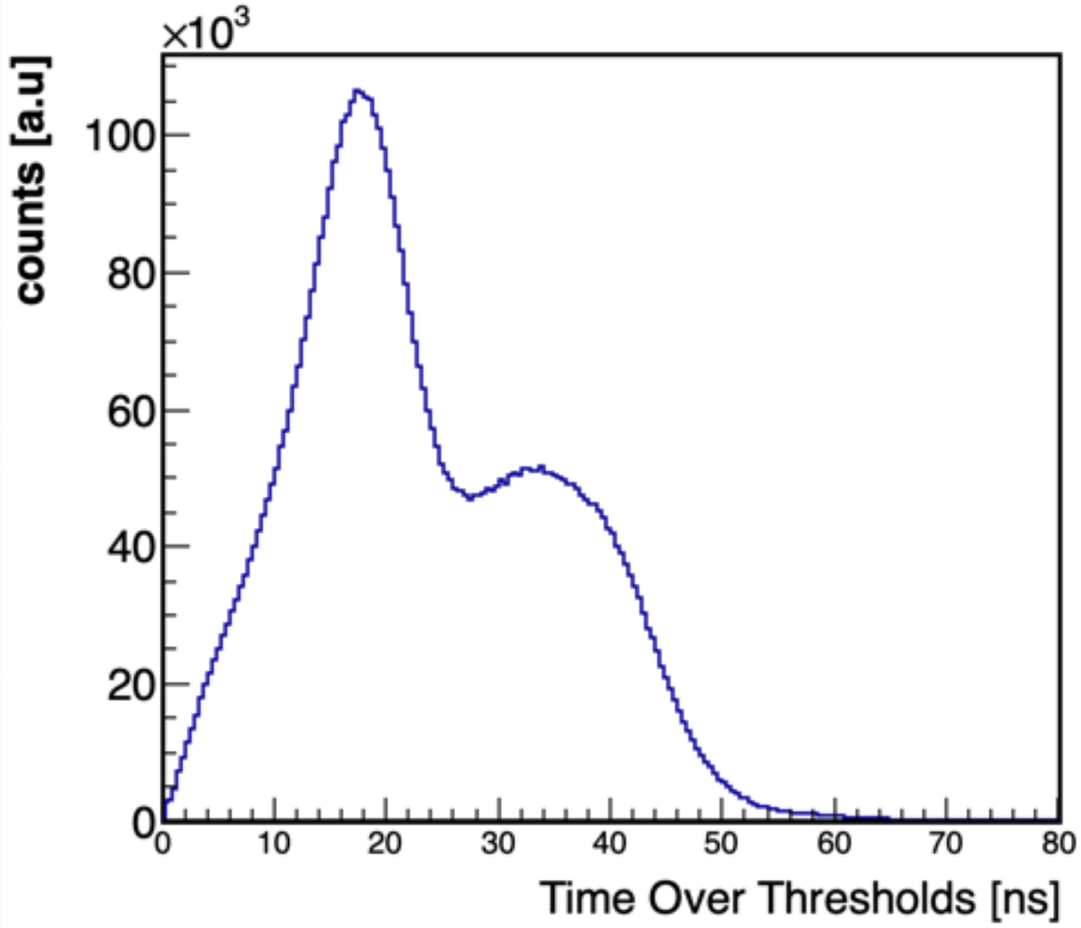


3rd hit is assumed as one of the annihillation gamma from oPs decay as the time difference b/w Ist hit and 3rd hit is in-between 10 – 100 ns

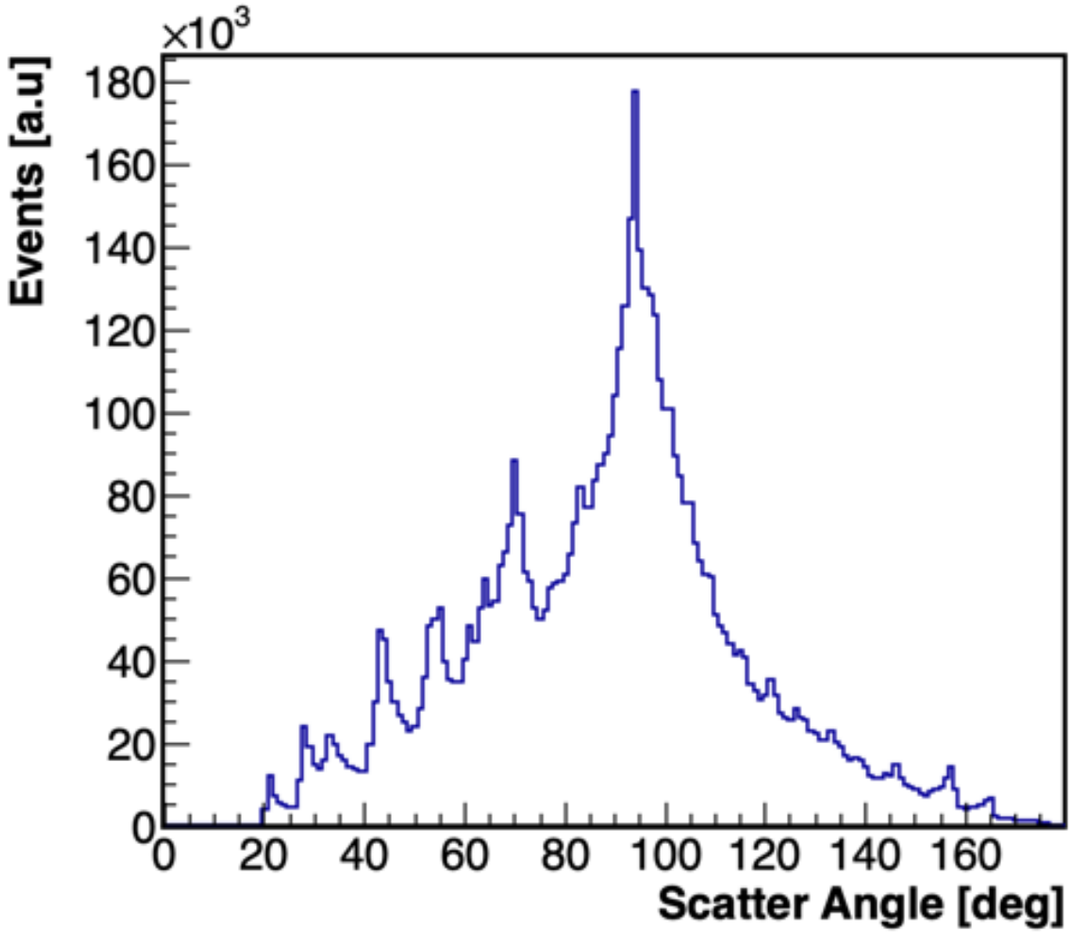


Results

TOT spectra

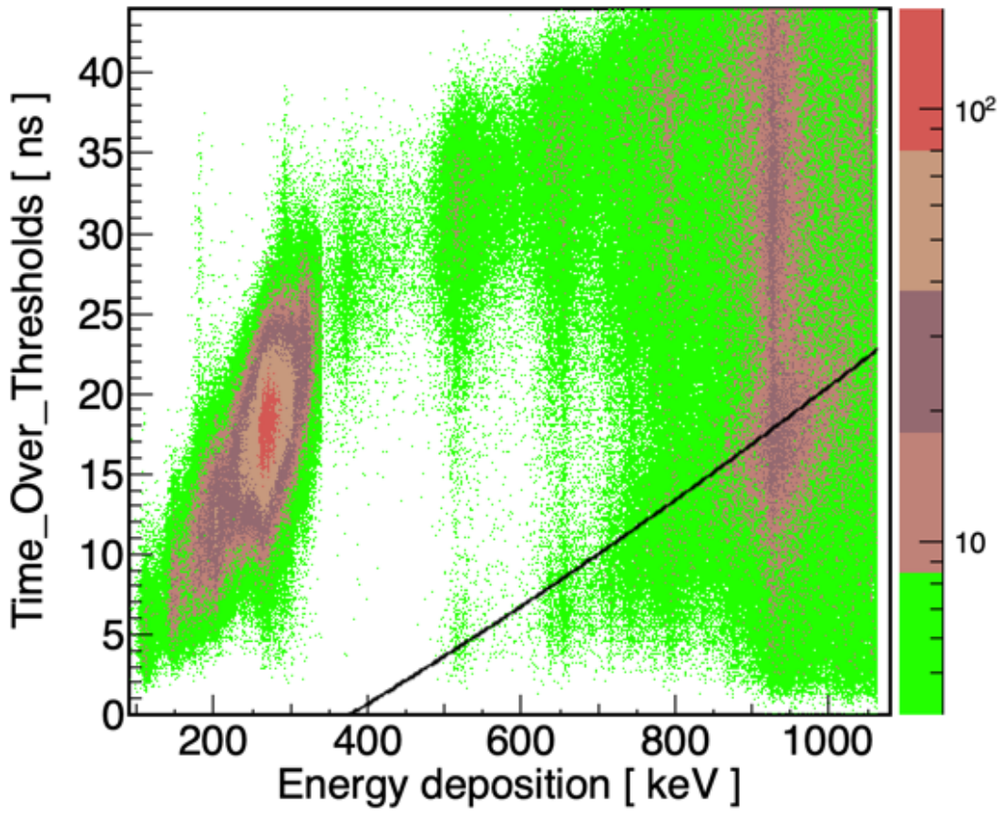


TOT 3-hits spectra



- **Event-wise** TOT spectra estimated for 511 keV photon and 1275 keV Photons.
- **TOT spectra** resemble the Compton like structure, where *TOT is the measure of energy deposition*.
- **Event-wise** estimated scattering angles of 511 keV and 1275 keV photons.
- Using **developed algorithm** to identify the Photons (511 or 1275) and ***measured scattering angle*** allow to calculated the energy deposition.

TOT vs Edep



- ✓ 2-D spectrum of TOT versus energy deposition
- ✓ For the final relation the profile histograms for the most populated energy bins are selected and fitted.
- ✓ Mean value of TOT distribution as a function of the center value of the energy interval is plotted.
- ✓ The experimental data (black triangles) are nicely fit by the function of form:

$$TOT = A0 + A1 * ln(Edep + A2) + A3 * (ln(Edep + A2))^2$$

Conclusions

- J-PET is made of plastic scintillators which is being developed to utilize in medical field and to perform the precision tests on the fundamental symmetries
  Detailed studies will be shown in talks and poster presentations by members of J-PET group

- The analysis was aimed to establish a **relationship** between energy loss and the measured Time Over Threshold utilizing the developed algorithm for the uniquely identification of the primary photons emitted from the source and their corresponding scattering photon.

- The **relationship** provide sensitivity for the energy loss determination and to suppress the background due to multiple scattered photons.

- The study of scattering angles (energy deposition) used in the present analysis can be extended to estimated the efficiency calibration of the J-PET detector for energy range 100 – 1000 keV

Thank you on behalf of J-PET collaboration