# Reconstruction of photon interactions in plastic scintillators in J-PET detectors


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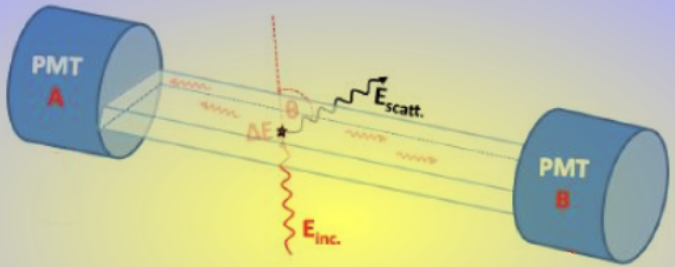
Is Quantum Theory exact? From quantum foundations to quantum applications
Frascati September 2019

## Outline

- Compton scattering in plastic scintillators
- J-PET detector prototypes
- Software Framework
- Reconstruction steps
- Usage examples
- Summary

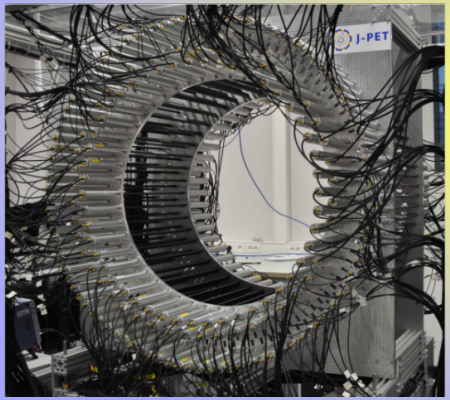
# Compton scattering in plastic scintillators

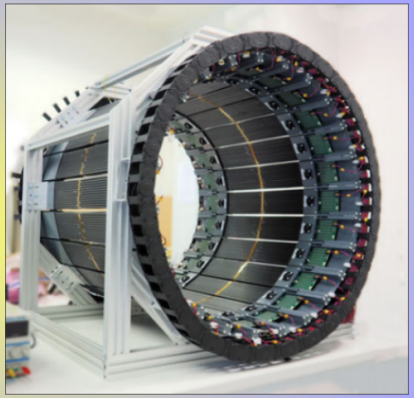



- The goal is to reconstruct particle interactions in plastic scintillators
- Gamma quanta is scattered via Compton effect
- Absorbed energy is emitted via fluorescence
- Light travels like in a optical link through the scintillator

# J-PET detector prototypes

**Big Barrel**
**192 scintillators**
**384 vacuum tube PMs**
**probing on 4 thresholds**



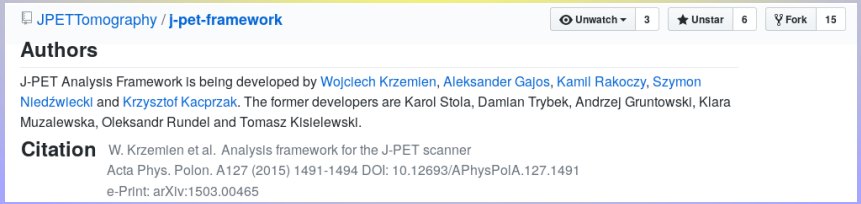



**Modular Detector**
**24 modules x 13 scintillators**
**2496 SiPMs (8 per scintillator)**
**probing on 2 thresholds**

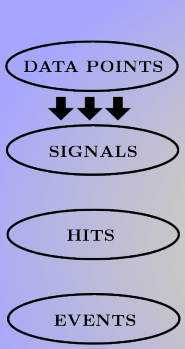
# Software Framework

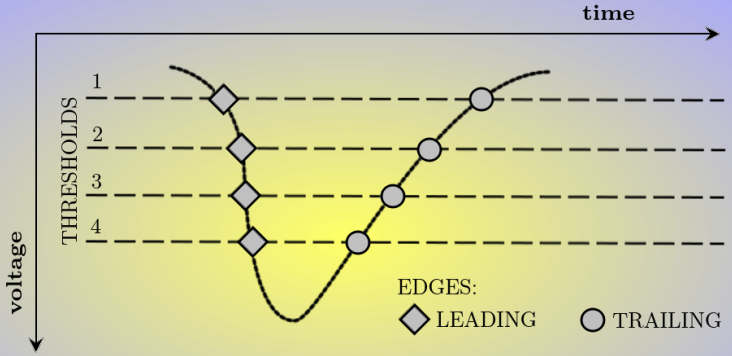
- Members of the J-PET collaboration develop software project for the data reconstruction and analysis in our experiment
- Repository is maintained on GitHub, contains the set of data reconstruction procedures
- As well as other programs to perform calibrations, basic data selection for event reconstruction, analyze data from different setups

www.github.com/JPETTomography/j-pet-framework-examples

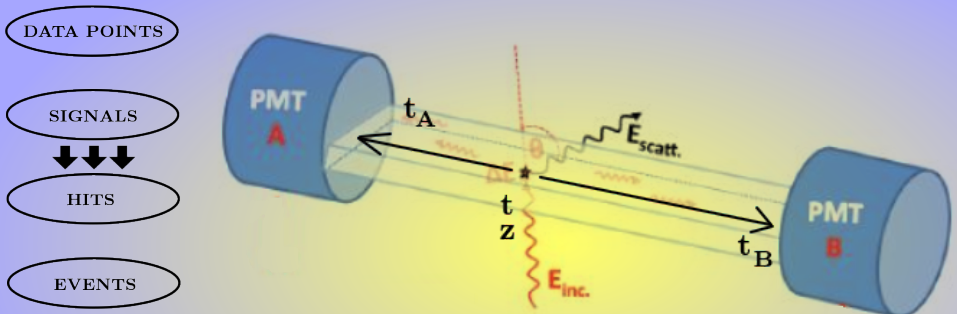


# Reconstruction steps (1)




- **Trigerless DAQ** $\Longrightarrow$ **Time Slots** $\ni$ **data points** (time, edge, channel)
  Bio-Algorithms & Med-Systems, Vol. 10, No. 1, 37-40 (2014)
- Procedure iterates over data points from connected channels and matches them into signals




- Procedure matching signals from the photomultipliers on the opposite sides into scintillator hits - points of interaction of the particle with the material

$$\texttt{time difference}\ \Delta t = |t_{signalB} - t_{signalA}| \qquad \texttt{interaction z-position} = \Delta t \cdot c_{eff}/2$$

$$\texttt{interaction time} = (t_{signalA} + t_{signalB})/2$$

# Reconstruction steps (3)

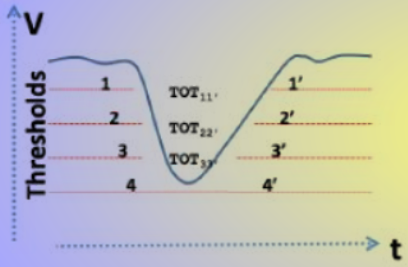

Additional elements:

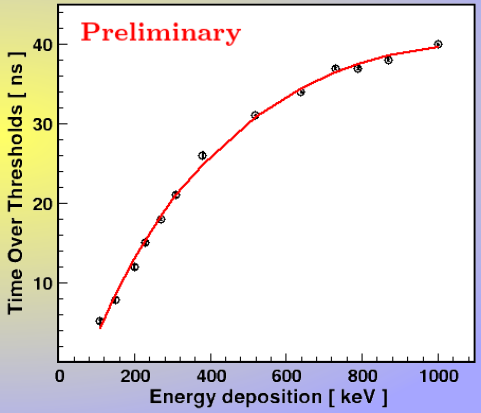
- reading the detector configuration
- noise filtering
- time synchronization of channels across the whole detector
- effective velocity of light in scintillators

The results of reconstruction procedures:

- 3-dimensional position in the detector
- interaction time
- Time-over-Threshold

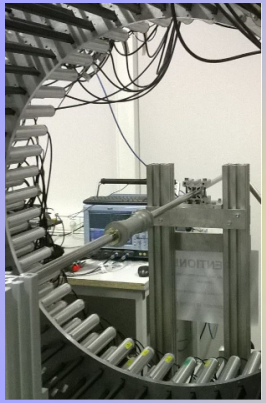
- Time-over-Threshold can be used as a measure of energy deposited in the scintillator by some particle

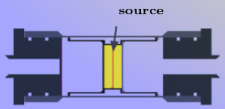



- Analysis of TOT and deposited energy relation [work by S. Sharma - publication in preparation]

# Examples (1)






Measurement description:

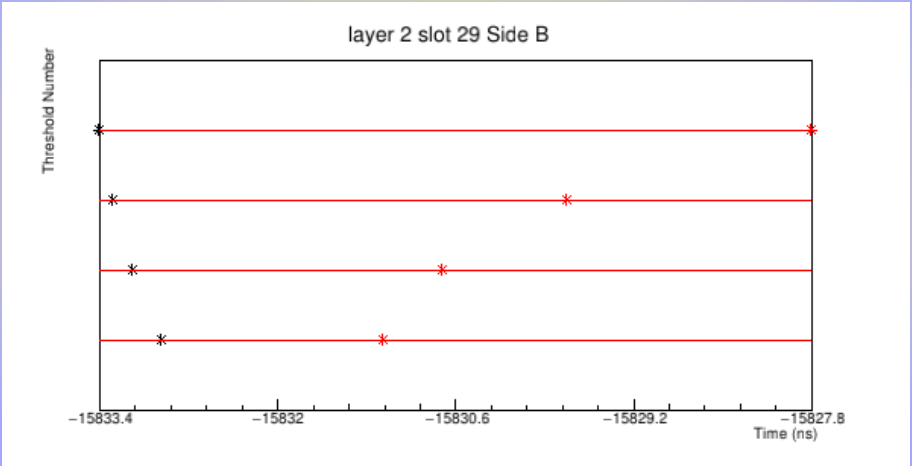
- Vacuum chamber was inserted into the detector
- Radioactive source $Na^{22}$ of activity of 1 MBq was used,
- It was surrounded with porous material XAD4 - enhancing rate of positronium creation
- Time slot parameter: 300 $\mu s$
- Measurement lasted 22 days - 3590 files were written on disk

Reconstruction performance:

- 40 cores of 2.7 GHz were utilized
- Average execution time for one file: 18 minutes
- Elapsed time: 28 hours

## Examples (2)

- Examples of data points matched into signals - event display software



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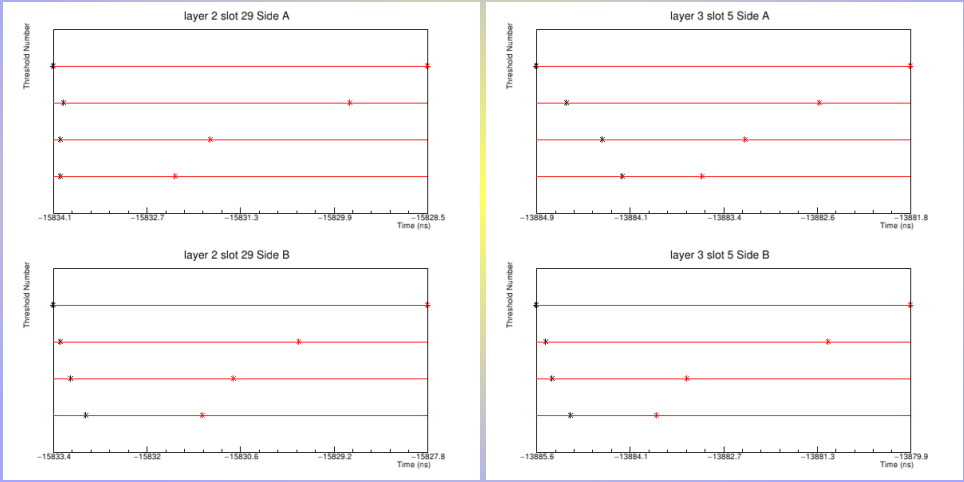
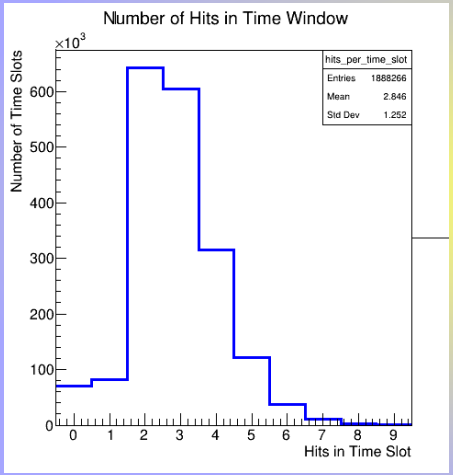
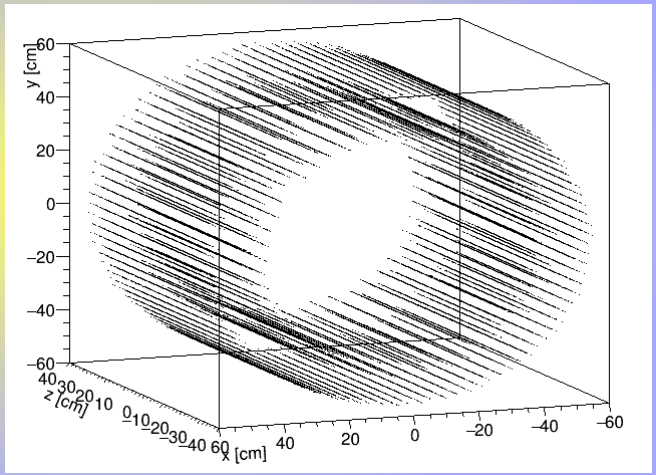


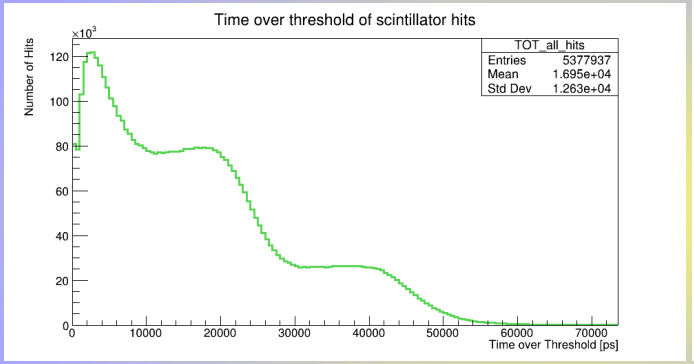
# Examples (4)

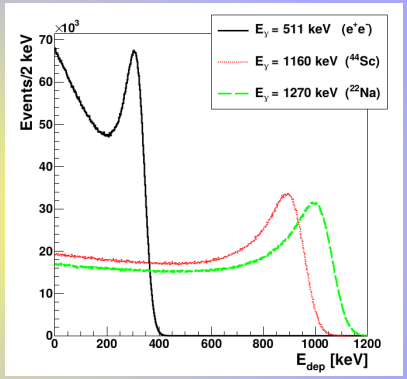
- Examples of reconstructed hits - multiplicity in time slots and 3D position



# Examples (5)



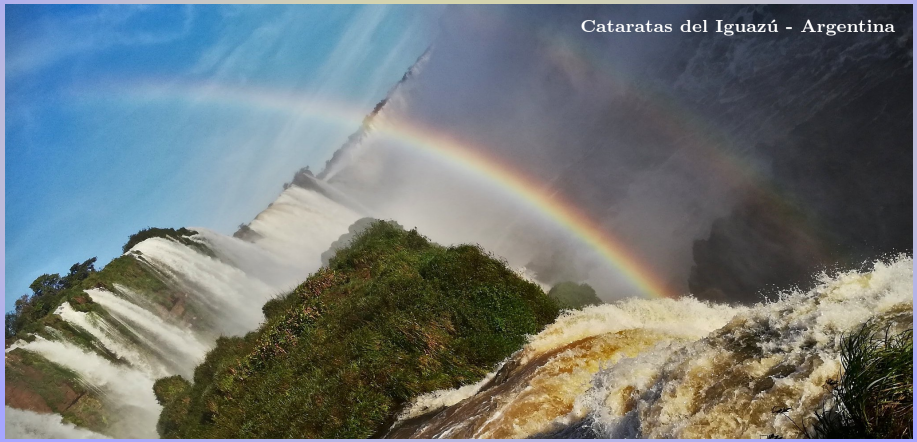

▶ TOT spectrum has a structure of Compton edges. Left is a TOT spectrum of all the hits reconstructed in the measurement (one file). Right is a simulation of deposited energy in a scintillator by photons of different energies (derived from Eur. Phys. J. C (2016) 76:445)

## Summary

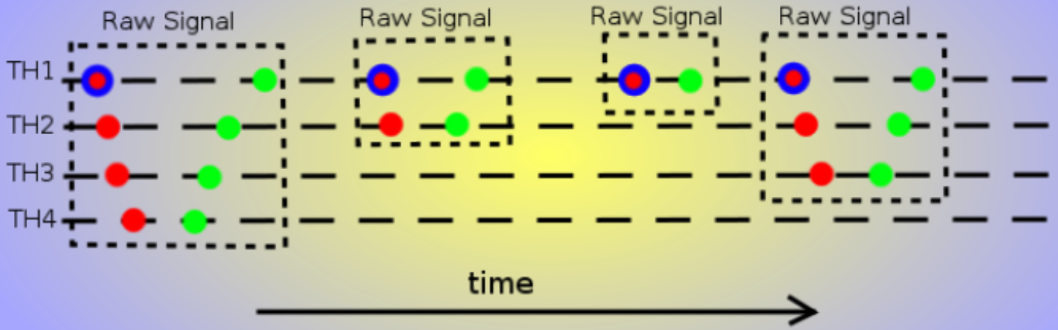
- Data analysis Framework for J-PET experiment is a flexible environment for offline data reconstruction
- Series of procedures within the J-PET Framework reconstructs interactions of photons in plastic scintillators from raw binary data to the level of data structures with physical interpretation.
- Our collaborators are using Framework for data analysis from measurements with Big Barrel Detector and after slight modifications - the procedures can be used with the data from next prototypes.
- Results of reconstruction procedures is a starting point for variety of investigations in physics analyses, medical imaging, detector calibration - applications that are based on physical phenomena occurring on a quantum level.

# End

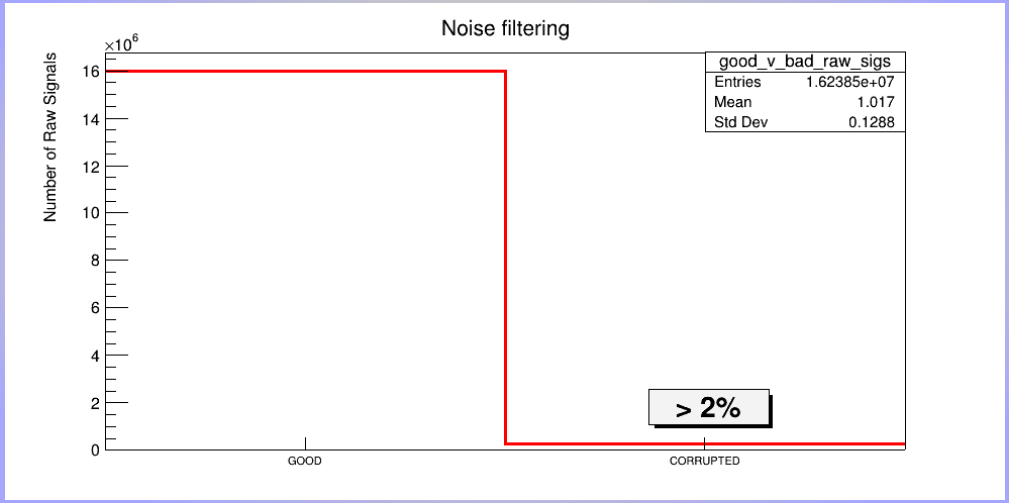
Thank you for your attention



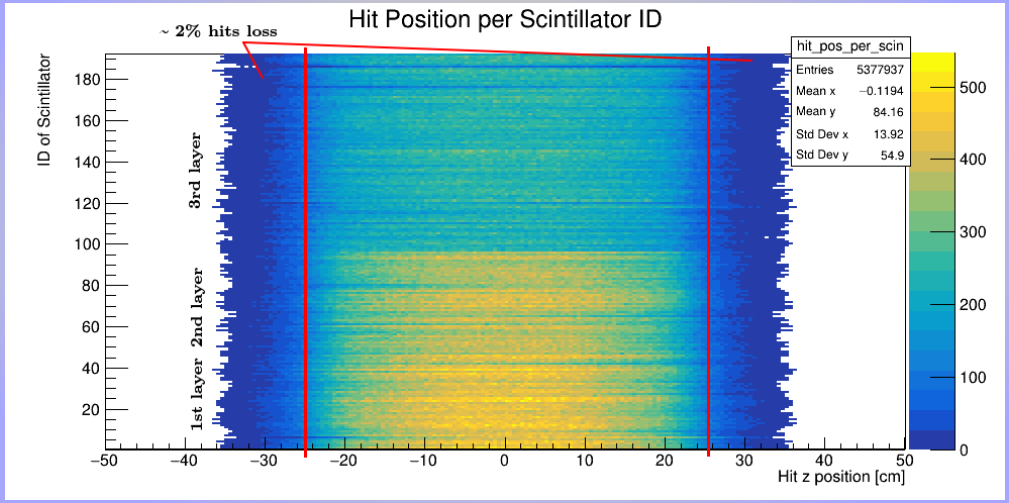
## Backup slides (1 - matching data points)



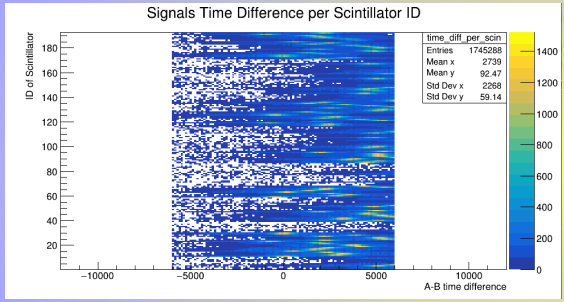
# Backup slides (2) - noise filtering

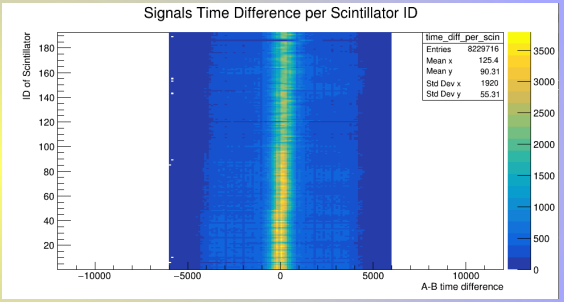


# Backup slides (3) - z position reconstruction



# Backup slides (4) - time synchronization




M. Skurzok, M. Silarski et al. Acta Phys. Polon. A 132, no. 5, 1641 (2017)