Testing J-PET detection modules with in-beam measurements

Pawel Moskal

18.12.2024

Riley, Gosia , Ruggero, Ashwin and
other colleagues for their help

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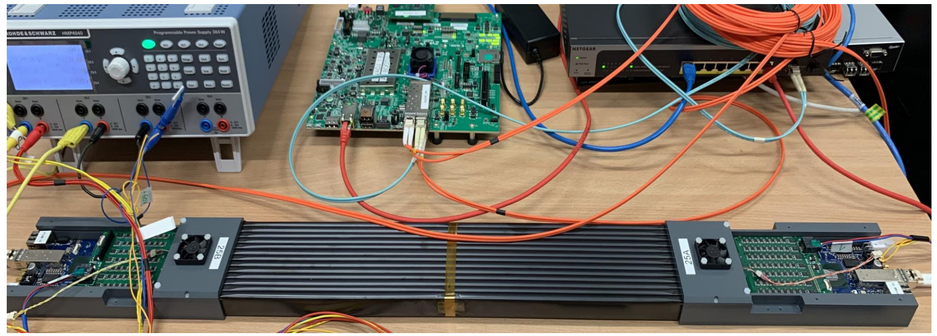
Objective

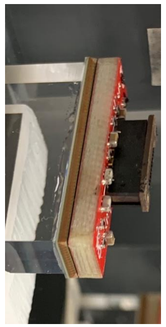
Testing first time the performance of J-PET modules at AEgIS

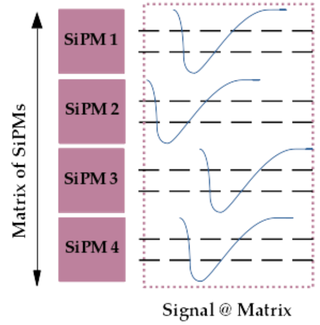
Detecting high energetic pions , produced in antiproton annihilaitions

Key features of J-PET technology based modules -

- *Single module is constructed of 13 plastic scintillators of length 50 cm , width 2.4 cm and thickness 0.6 cm.*







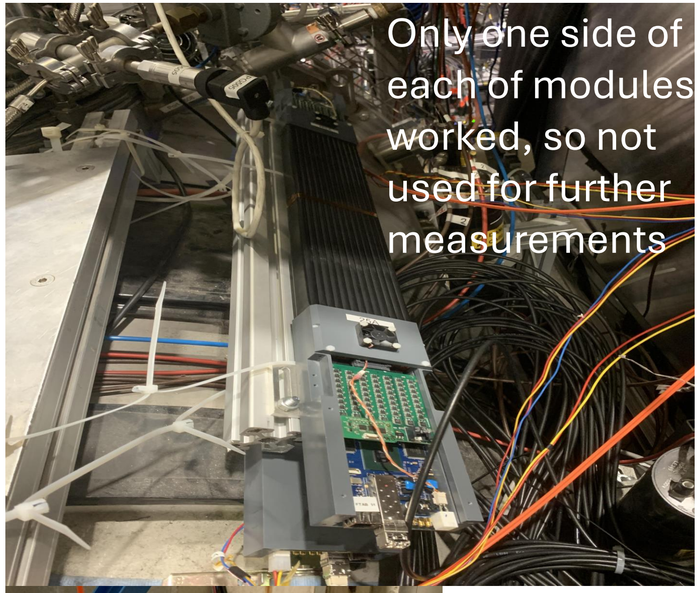
- *No direct energy deposition information*, **T**ime **O**ver **T**hreshold is the measure of energy deposition at predefined thresholds
- Hit positions are reconstructed based on the time difference of light signals at axial ends of scintillators.
- Good time resolution, Module is like segmented detector of 13 individual scintillators.

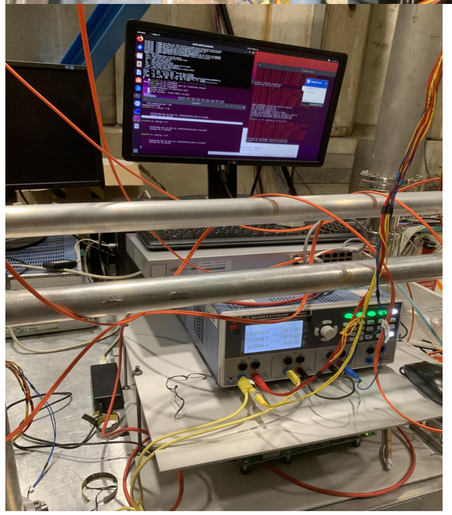
Objective

- **First check,** how the modules will perform in the *magnetic field environment*.
- **Detection of high energetic pions** produced in antiproton annihilation .
- **Two modules (initially), with 10 cm distance apart** were packed together with goal:
  - Measuring the signals, mainly from pions (charged), passing through detector modules.
  - As the ***higher energy deposition*** (~ 2 MeV) expected during the interaction of pion with plastic scintillator, first task was to see if it is reflected in the **TOT spectra**
  - Tracking the interaction of pions (same) passing through both modules, allowing to know the pions incident direction based on hit positions (one hit in each module) and utilizing these information to reconstruct the vertices origin.
    - ✓ Optimizing the selection criteria based on TOF information.
- Magnetic field impeded the operation of cooling fan, insufficient cooling of the Front-End Electronics Boards (FTAB) on one sides of both modules, resulting in overheating (~70°), quitting DAQ.
- Some data is measured in this configuration. **Finally, decided to use one full functional module**, So we use both working FTABs in one module (**module can be characterized for pion detection**)

Experimental setup

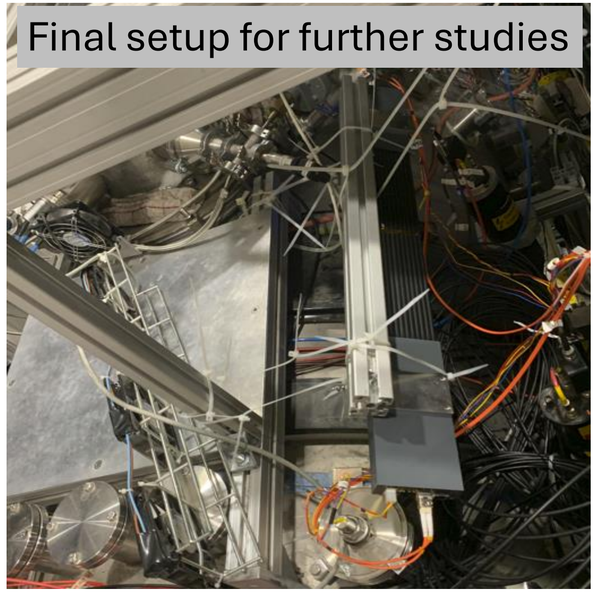
Initial setup (two modules)





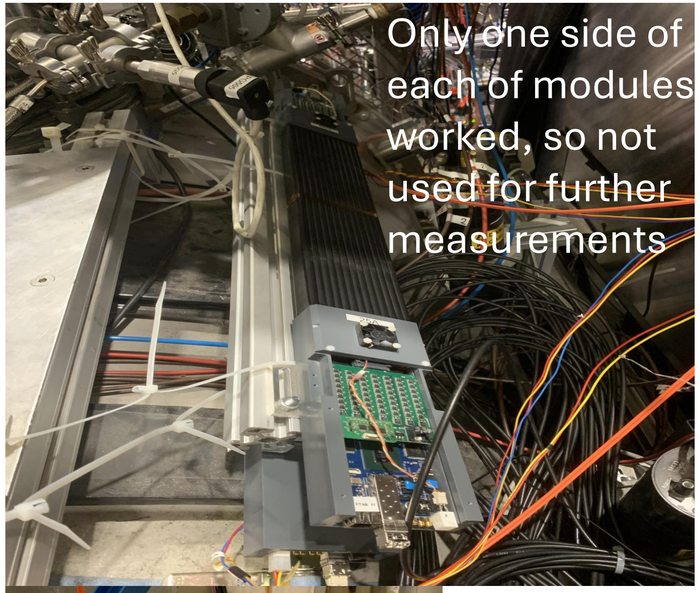
DAQ setup

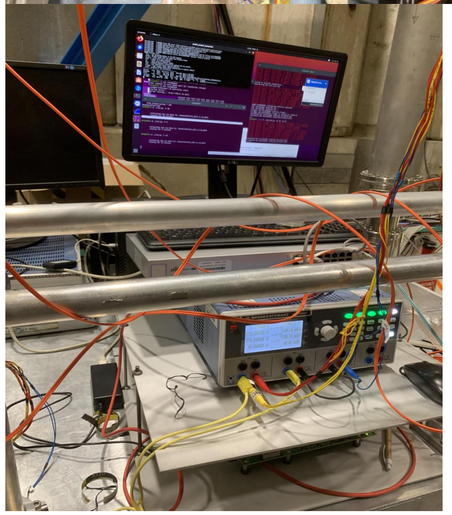
final setup (single full working modules)



Experimental setup

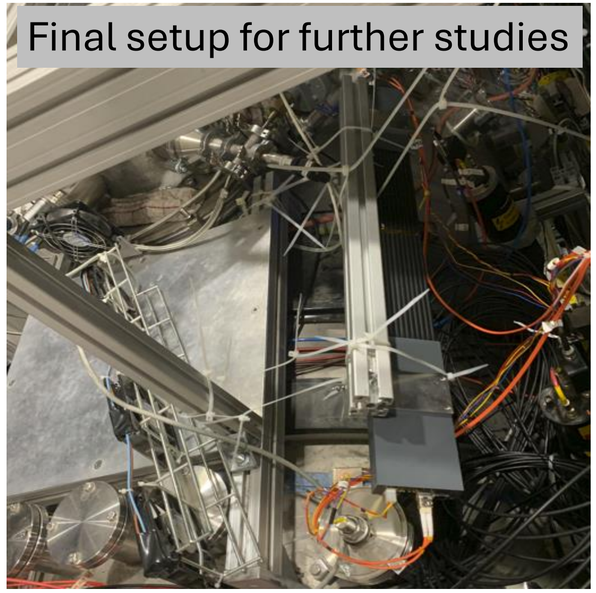
Initial setup (two modules)



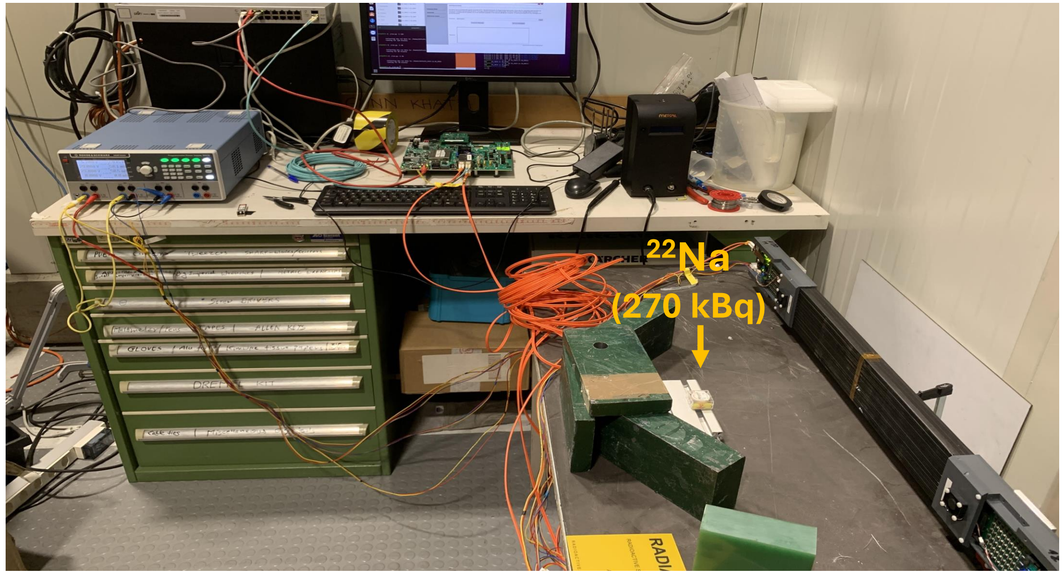


DAQ setup

final setup (single full working modules)



Calibration measurement with ^{22}Na source (~ 270 kBq)



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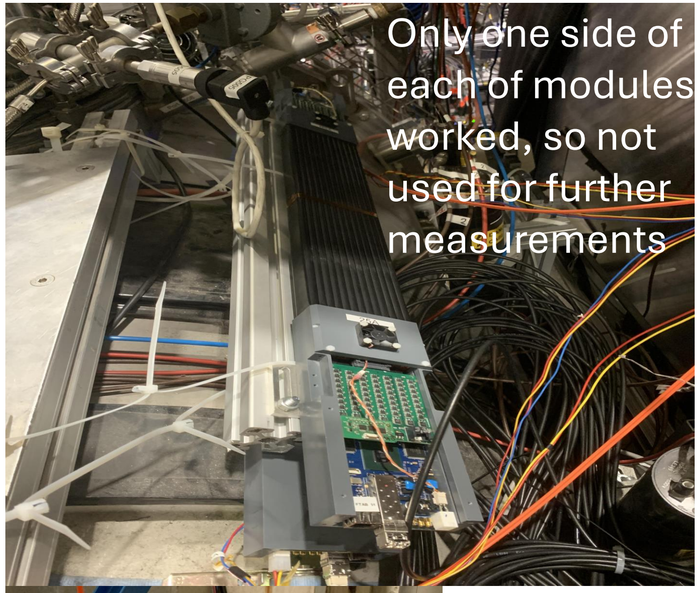
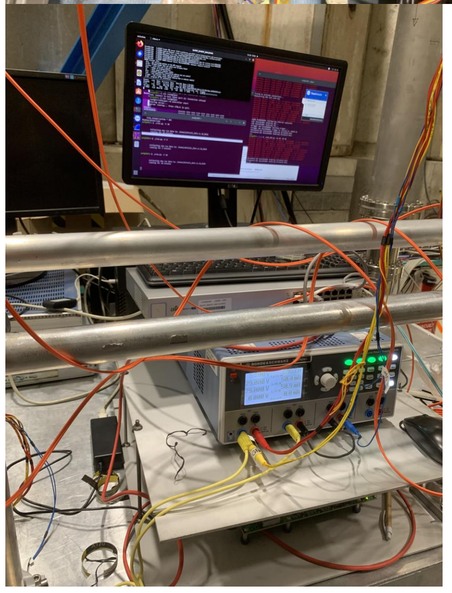
Experimental setup

Initial setup (two modules)





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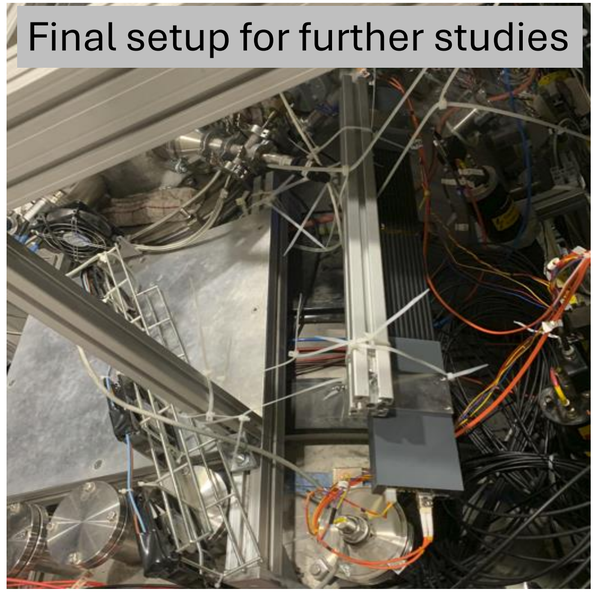

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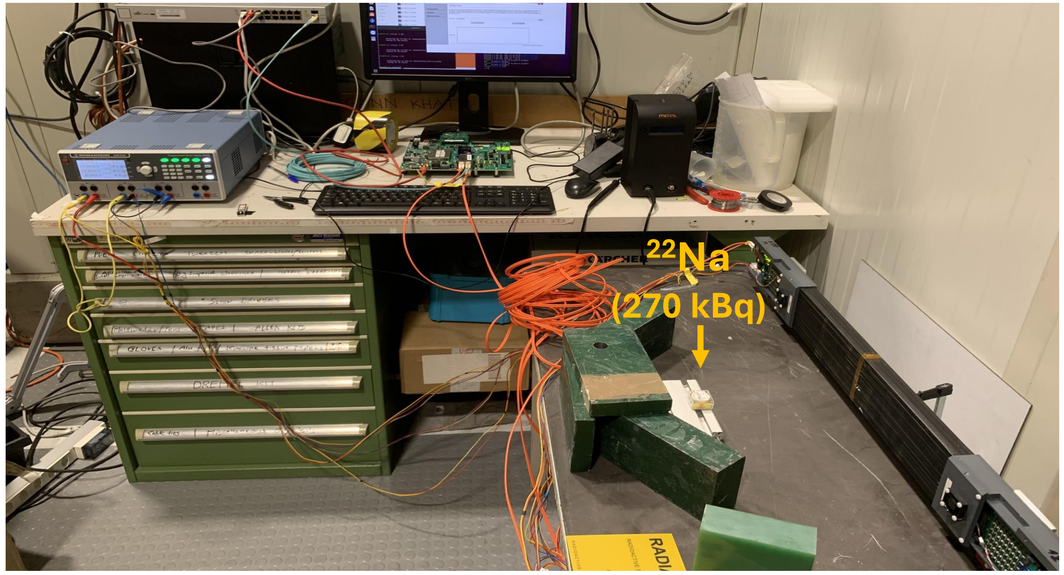
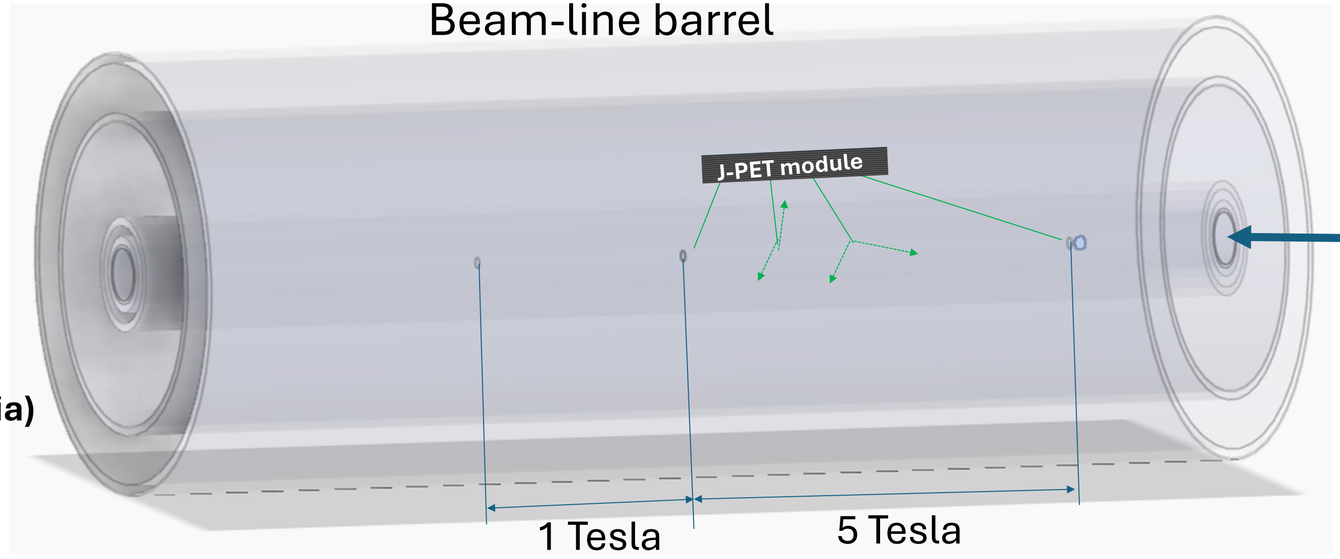


CAD geometry
(for relative placement)

(courtesy of Gosia)



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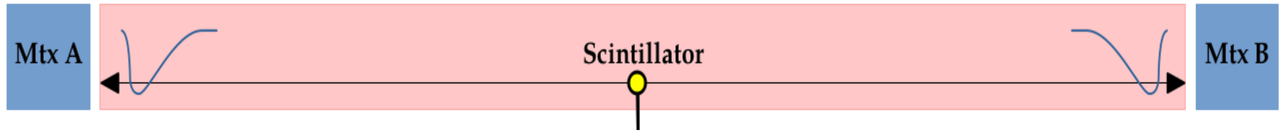
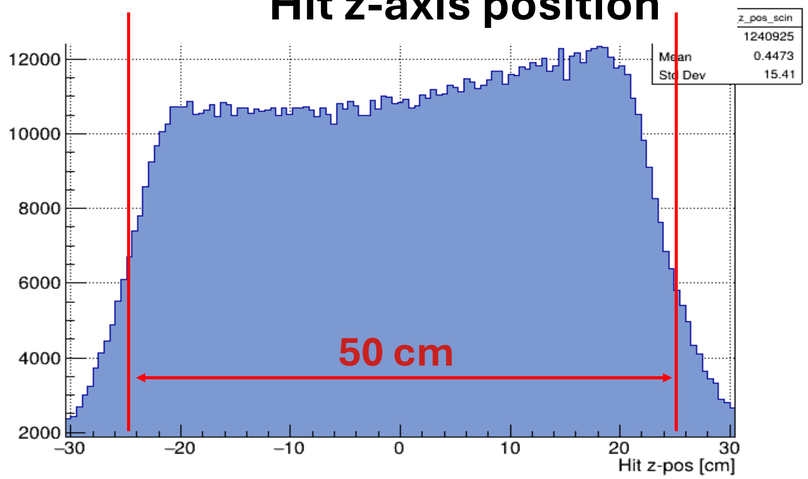
Time calibration using ^{22}Na source

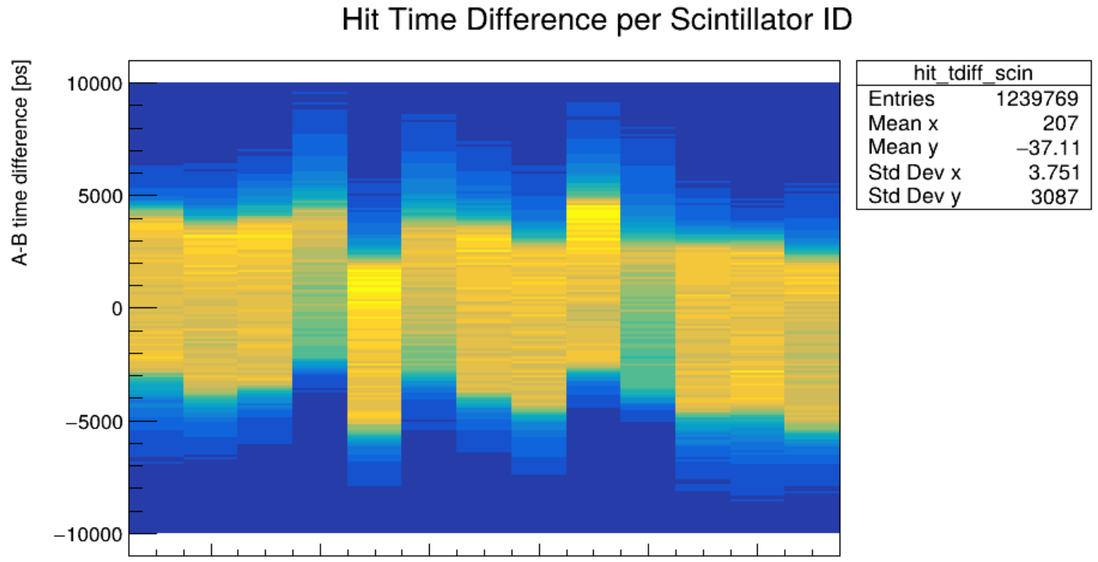


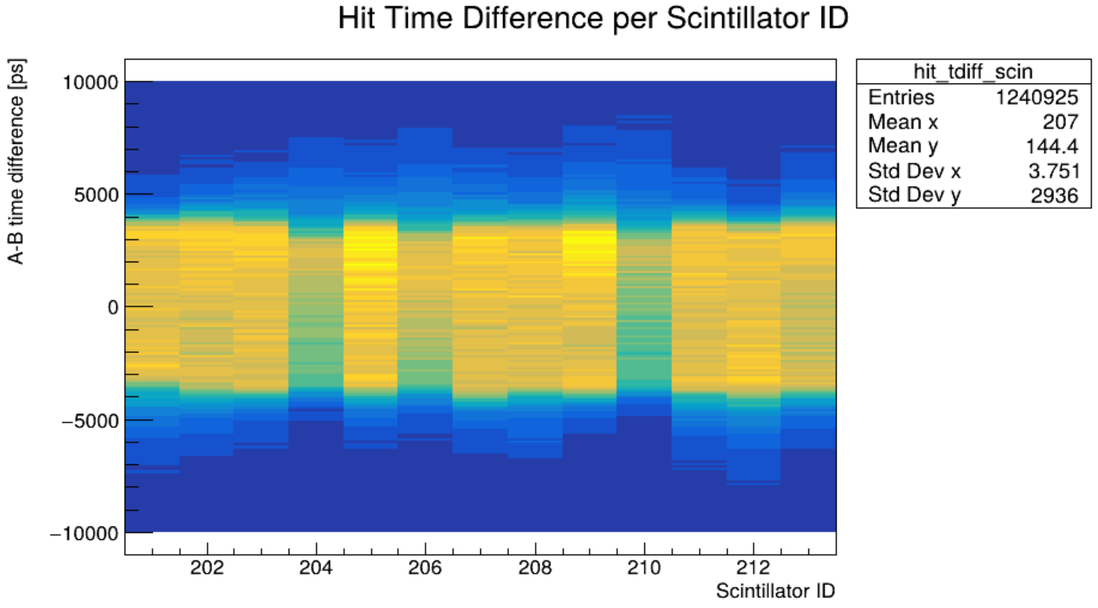
- Source (22Na) produces photons that interact with all the strips
- we reconstruct the position of the hit based on the time difference of the signals arriving to the ends of the strips
- the time measurement needs to be synchronized

$t_{DIFF} = t_{SIG\_B} - t_{SIG\_A}$

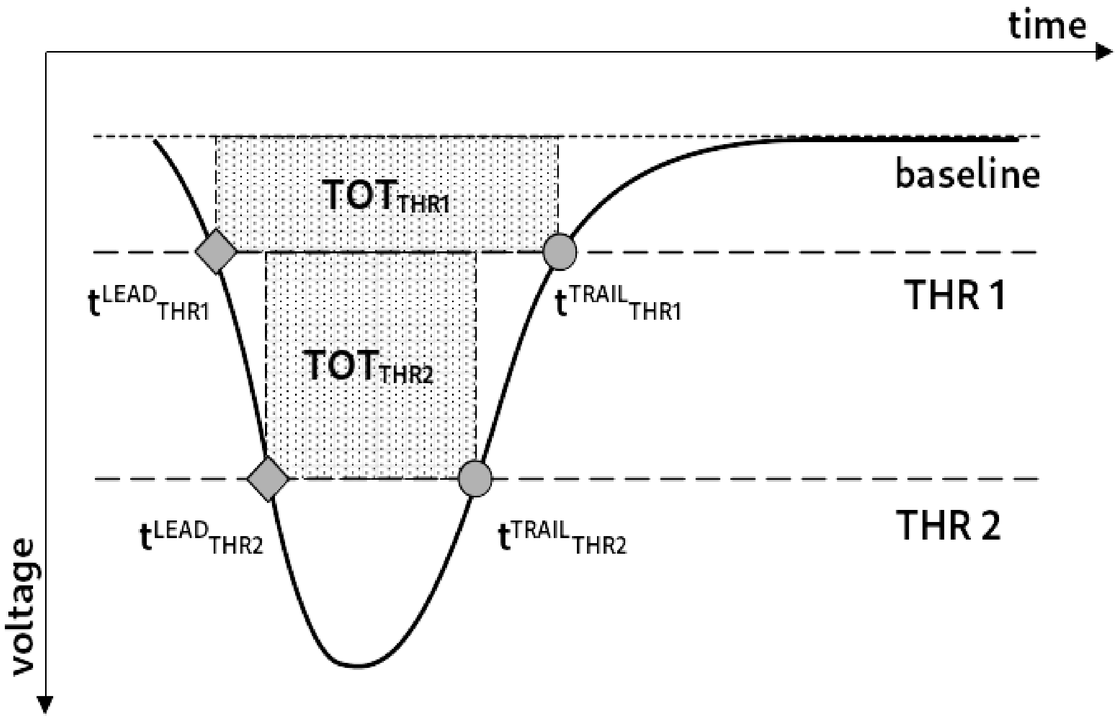
$z_{POS} = v_{EFF} * t_{DIFF} / 2$

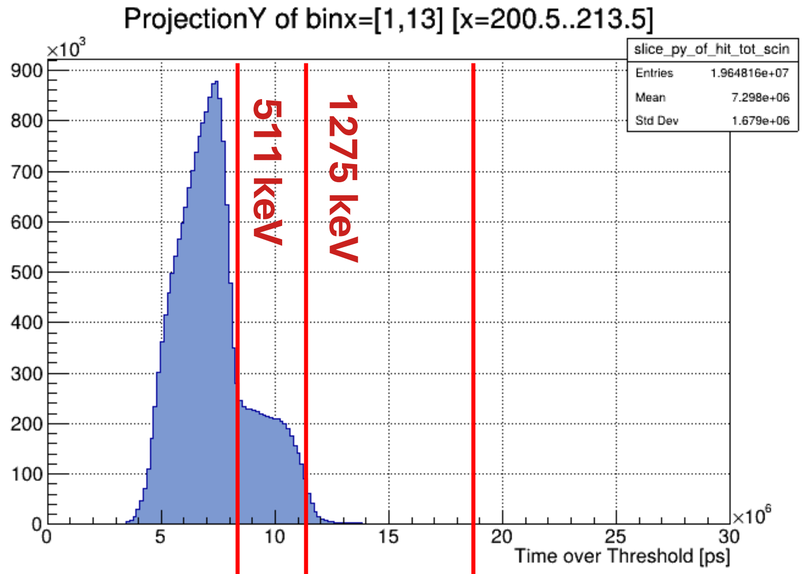




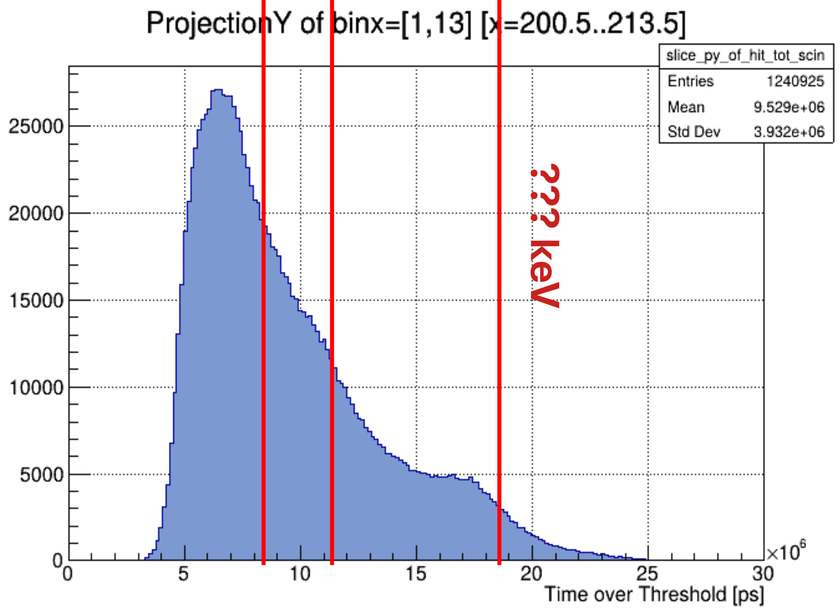


Time Over Threshold (measure of energy deposition) Spectra





^{22}Na source
- 511 keV
  e^+e^- annihilation
- 1275 keV
  deexcitation photon



In-beam
- higher energy deposition

TOT is a measure of **deposited energy**

- estimation of the area above the signal curve
- selection of energies based on Compton edges-like spectra
- relation TOT-energy is non linear

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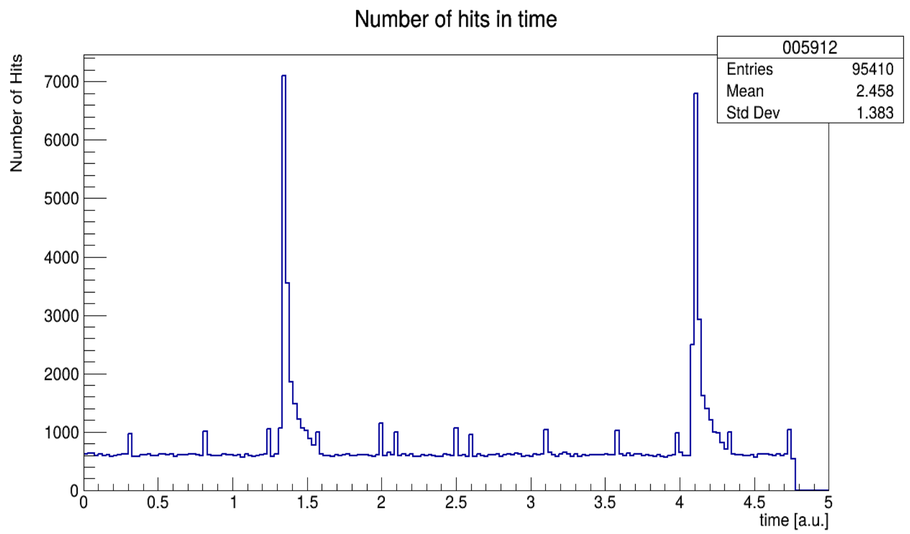
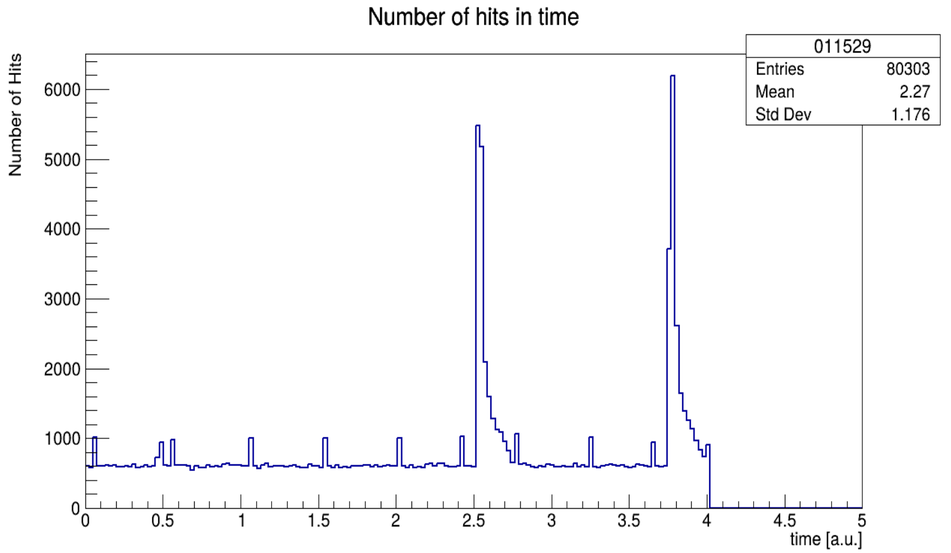
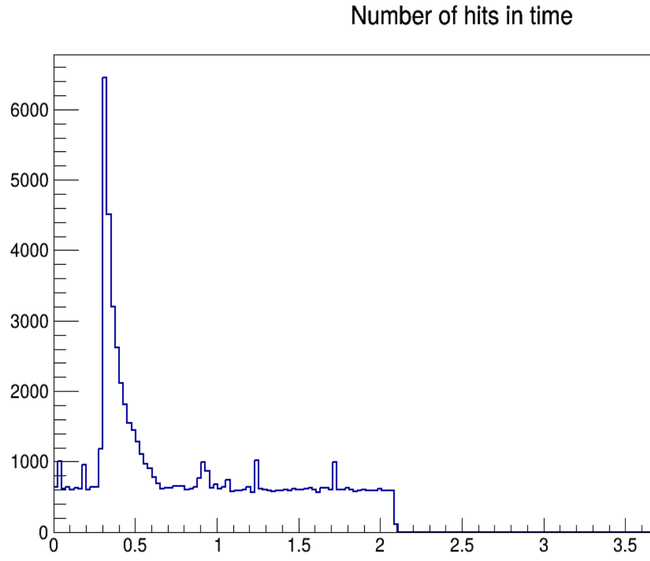
Count rate in time

Spectra are collected in **3 different measured file** for different acquisition time.







In current **DAQ system, data is collected in window of 50 uSec**. The **hit multiplicity** can be **evaluated as function of beam propagation/annihilation time**.

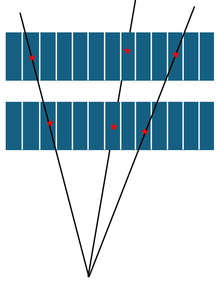
Test measurements with the module attached to the beam barrel, shows that we can observe the **rate of particles in time** and the moment of the beam injection.

Data analysis can be limited only to the selected periods of beam injections, here we showed for the full acquisition time – exploring it further with all measured data. (we are exploring further)

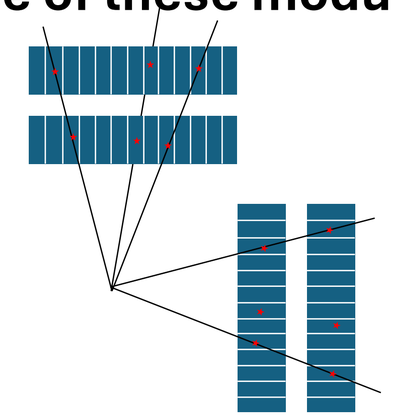
Future perspectives

- **Analysis** of **all the data** collected during the run. For runs **thresholds** were set at **30** and **60** mV. However, in order to understand the TOT spectra obtained, the **threshold for pion registration must be tuned** correctly.
- **Geant4 simulation** are being carried out (in parallel), to understand the registration efficiency **for pions emitting from multiple origin**, as in experimental situation.
- Unfortunately, the ***vertexing capabilities of the detection modules were not tested***, *due to the FTAB failure*. However, **Geant4 simulations are being carried out** (taking into account the barrel attenuation) **to verify the feasibility and reconstruction performance of these modules**.

Different configuration will be checked:



OR



- With experience in using modules in the magnetic field environment, we have a good understanding of what needs to be improved for their final usability.
- The detailed analysis will be done in coming weeks to present full report from the test run.

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