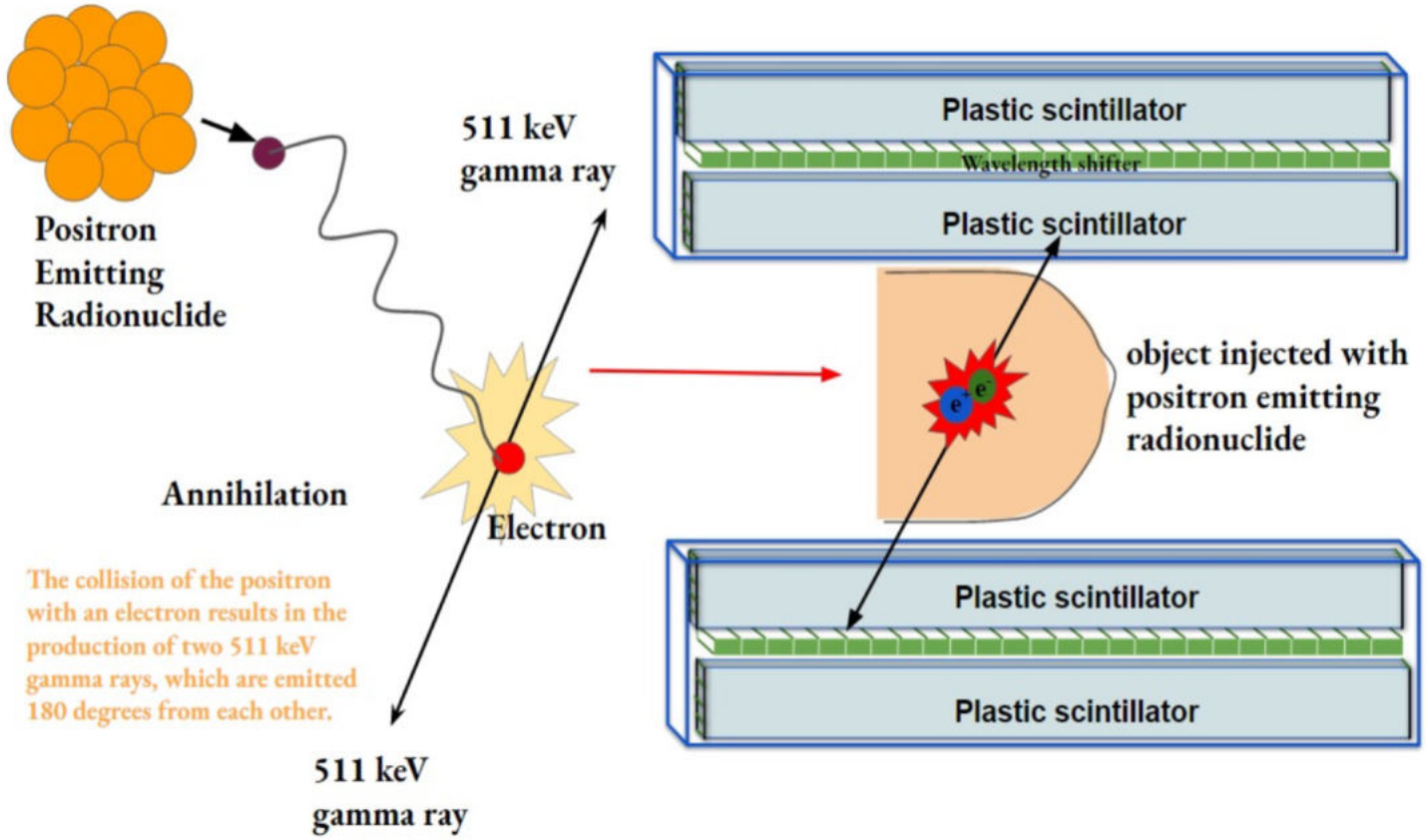
Performance characteristics of J-PEM modality for the breast cancer diagnosis

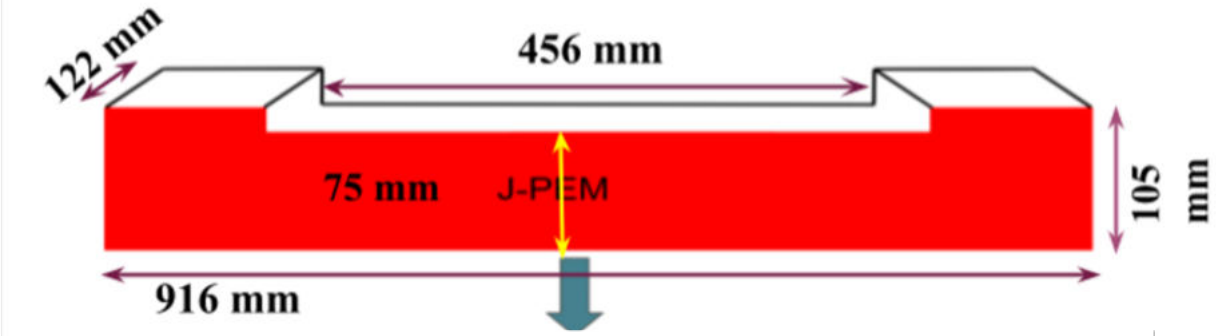
Shivani on behalf of J-PET group

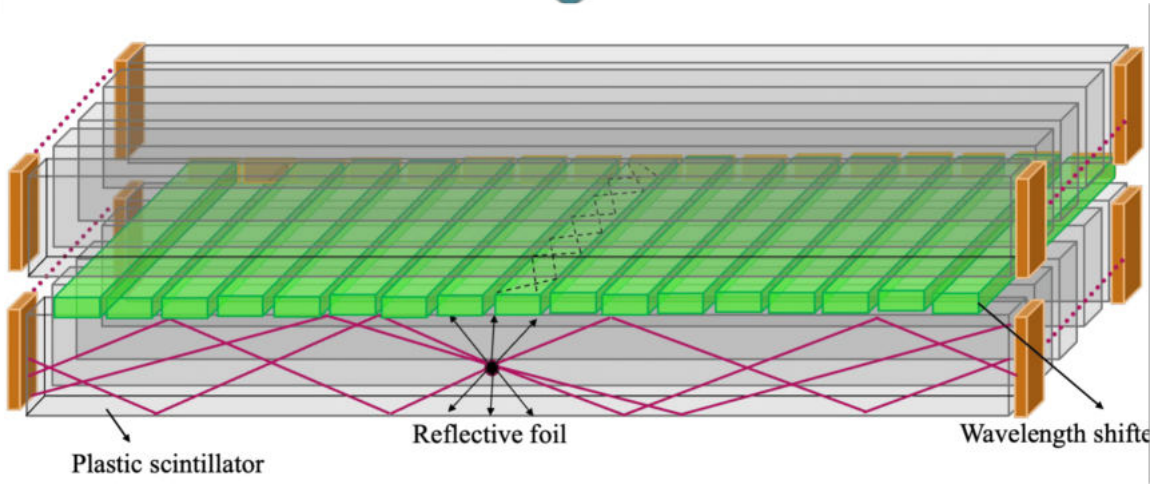
10/05/2023



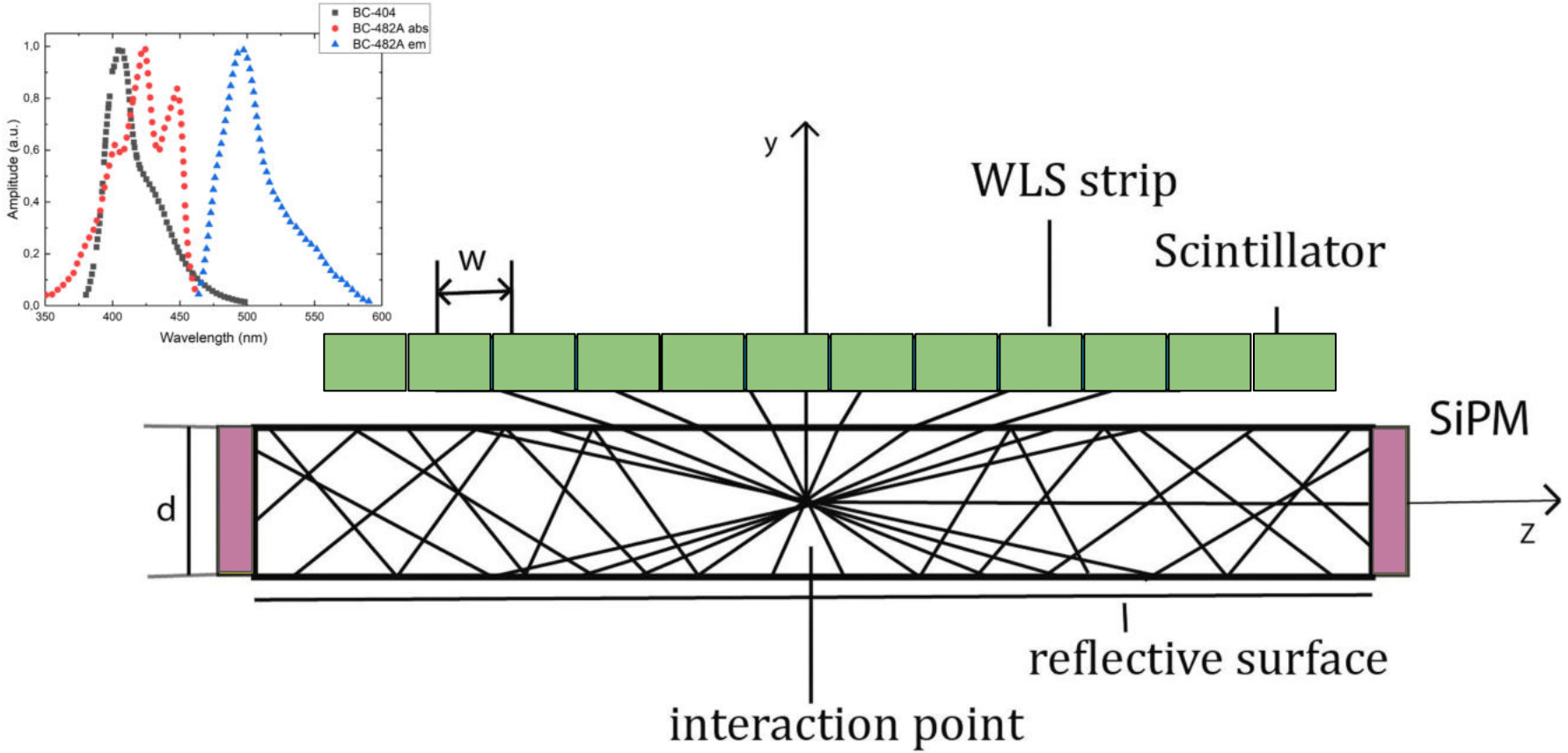
Our aim is to design, construct and to establish the characteristic performance of the J-PEM, based on a novel idea with plastic scintillator and wavelength shifter (WLS) for the detection and early diagnosis of breast cancer

Jagellonian Positron Emission Mammography

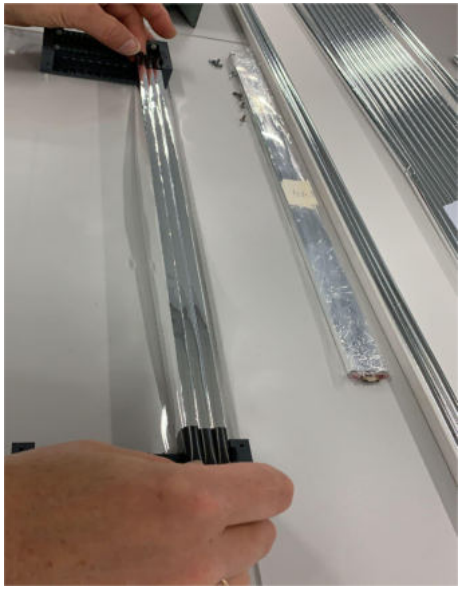


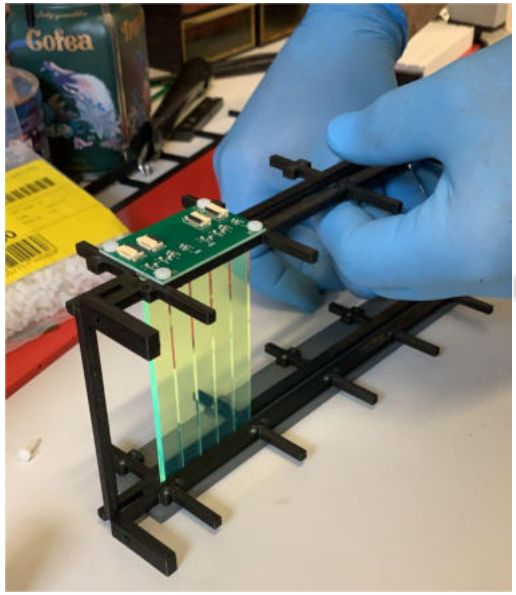


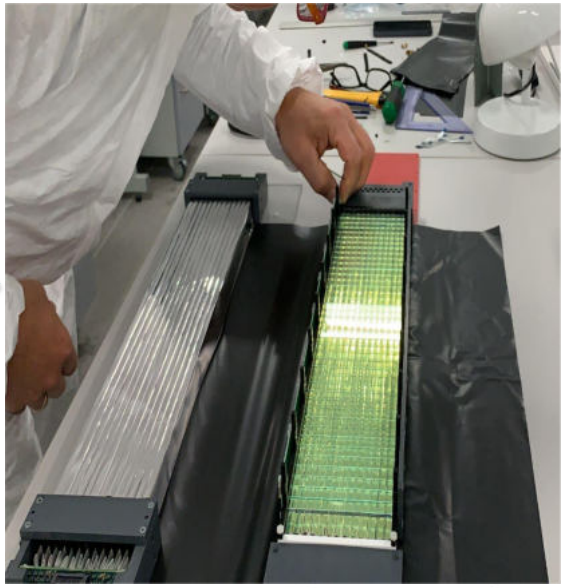
26 Plastic Scintillators - 6 * 24 * 500 mm
40 Wavelength shifters - 3 * 10 * 100 mm



Side view of a scintillator strip and a set of parallel WLS strips placed above the scintillator







Electronics (FEE)

Electronics (FEE)

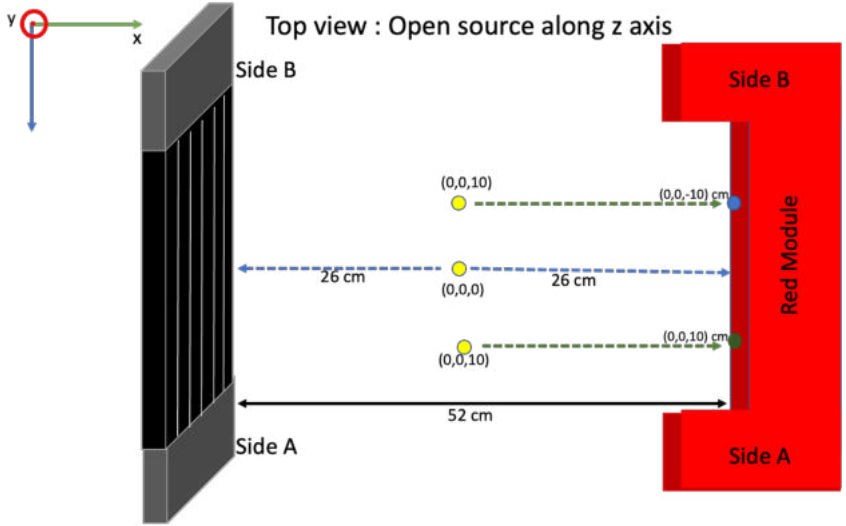
Measurements

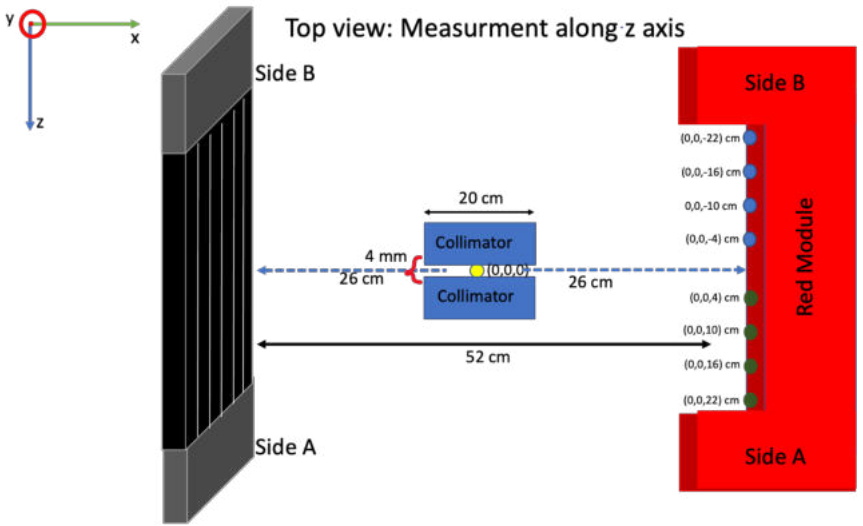
1. **Open source**

➔ Calibration of the detector (time synchronization and TOT normalization)

2. **Collimator in z axis**

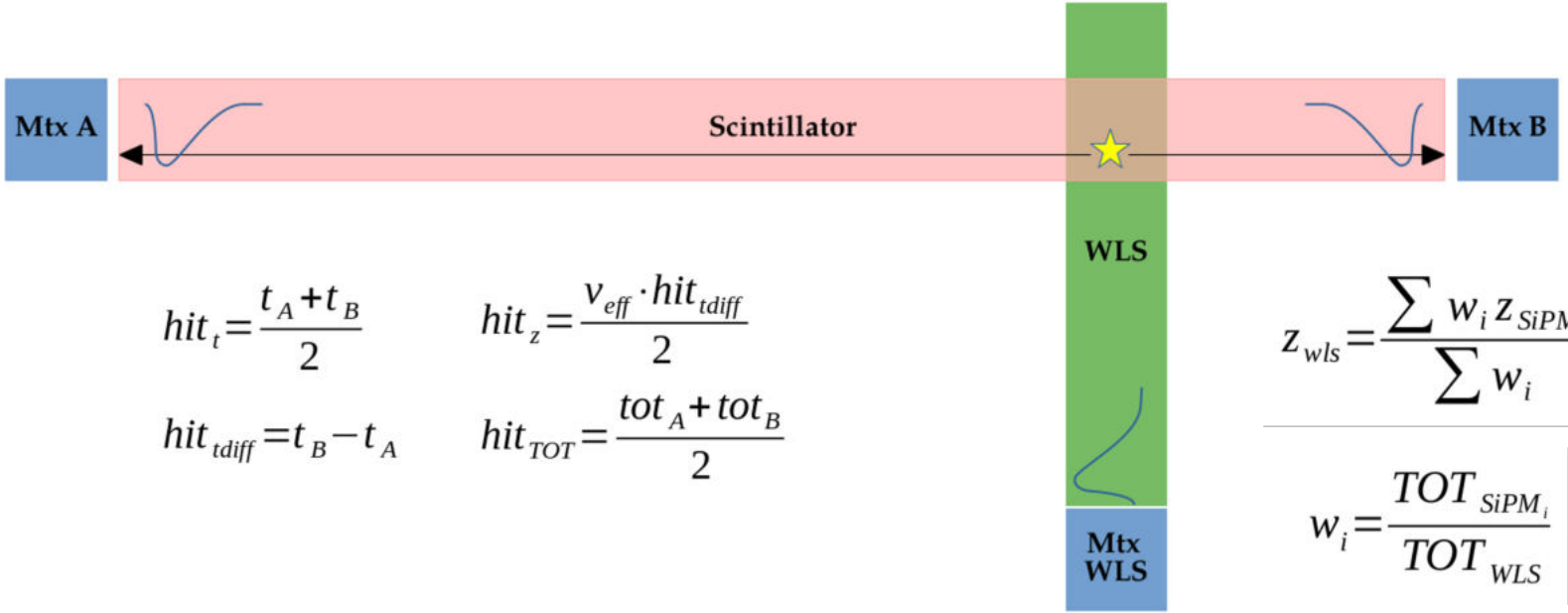
➔ Reconstruction of the z-position in scintillators and WLS layers





Data reconstruction

- Creating hits in the scintillators from Side A and B signals
- Finding coincidence between hits in the scintillators and WLS signals



$$hit_t = \frac{t_A + t_B}{2} \qquad hit_z = \frac{v_{eff} \cdot hit_{tdiff}}{2}$$

$$hit_{tdiff} = t_B - t_A \qquad hit_{TOT} = \frac{tot_A + tot_B}{2}$$

$$z_{wls} = \frac{\sum w_i z_{SiPM\,i}}{\sum w_i}$$

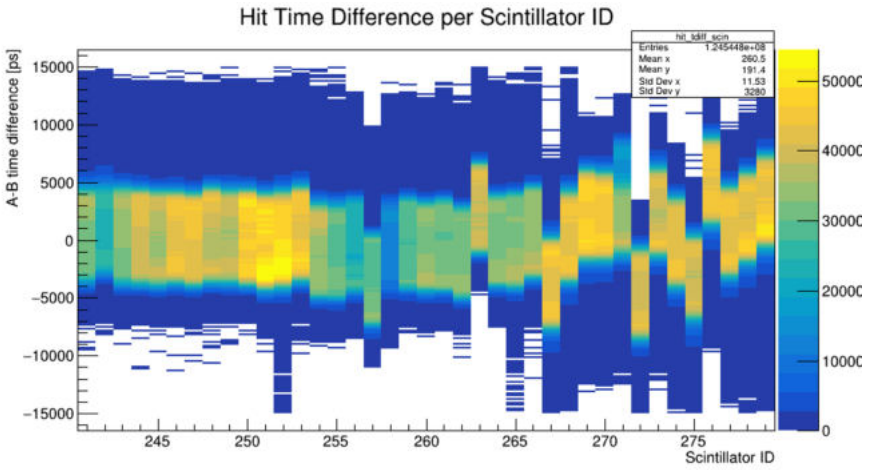
$$w_i = \frac{TOT_{SiPM_i}}{TOT_{WLS}}$$

Data calibration with open source measurements

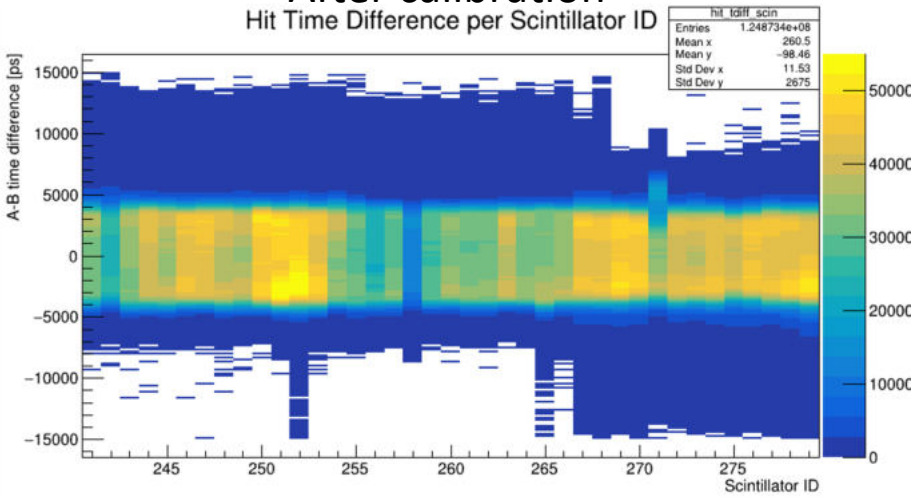
1. Hit A-B time difference offsets

- Centring the spectra of time difference between A-B sides of each strip.
- Offsets can be due to the delays of signal in cables or electronics.

Before calibration



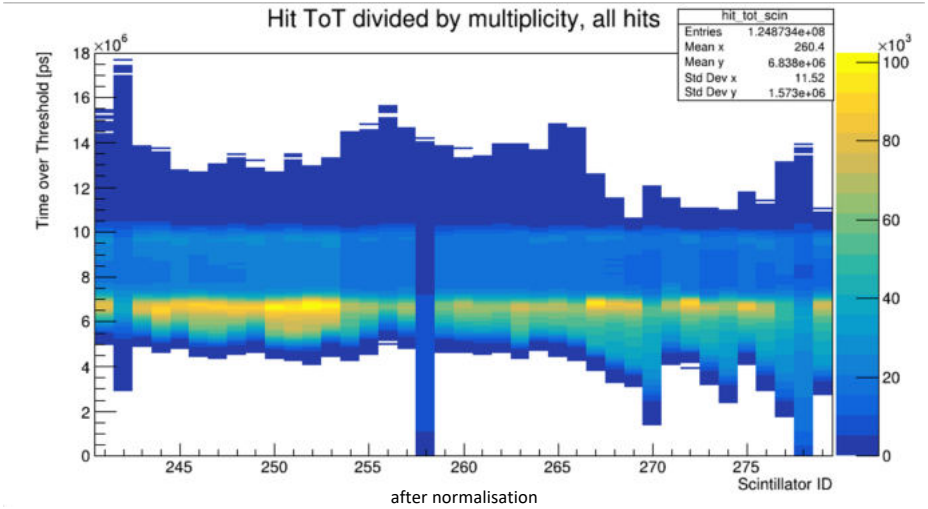
After calibration

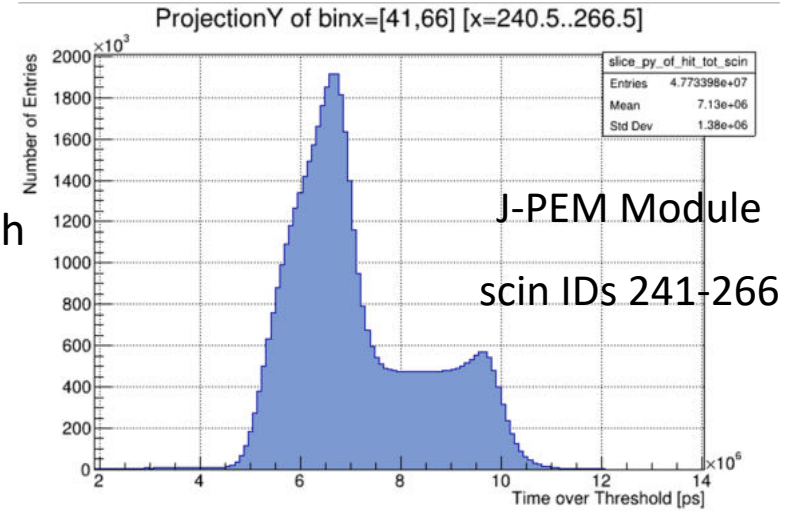


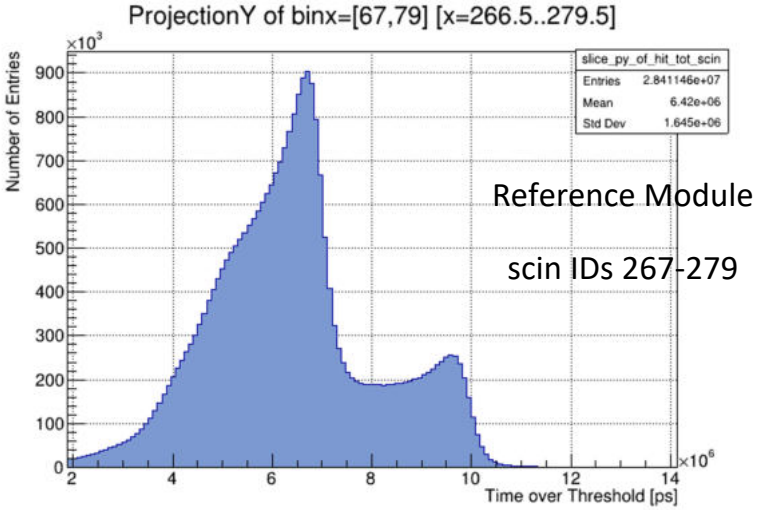
Courtsey to Krzysztof Kacprzak

2. Scintillator hit TOT normalization

➔ effective correction to the TOT spectra for each scintillator, annihilation and de-excitation Compton edges in the same range





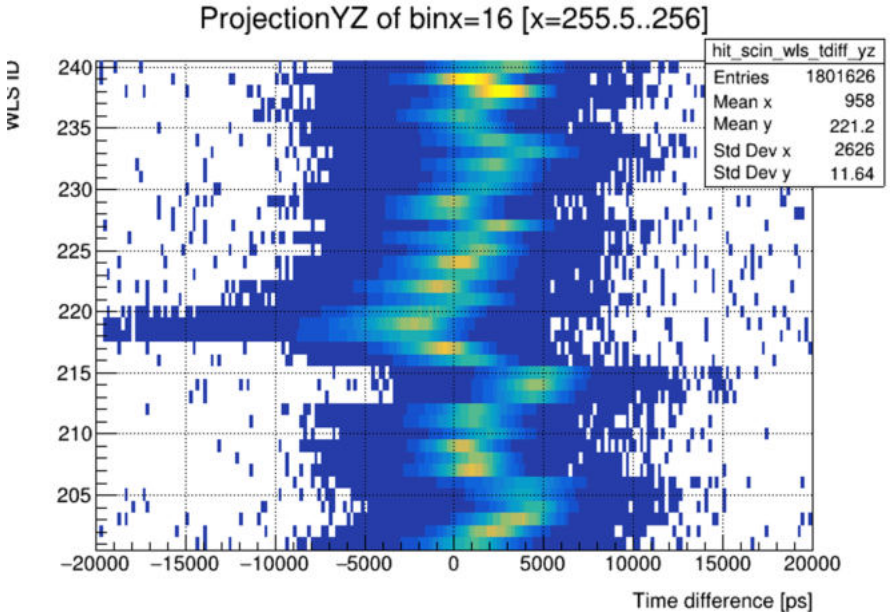


Courtsey to Krzysztof Kacprzak

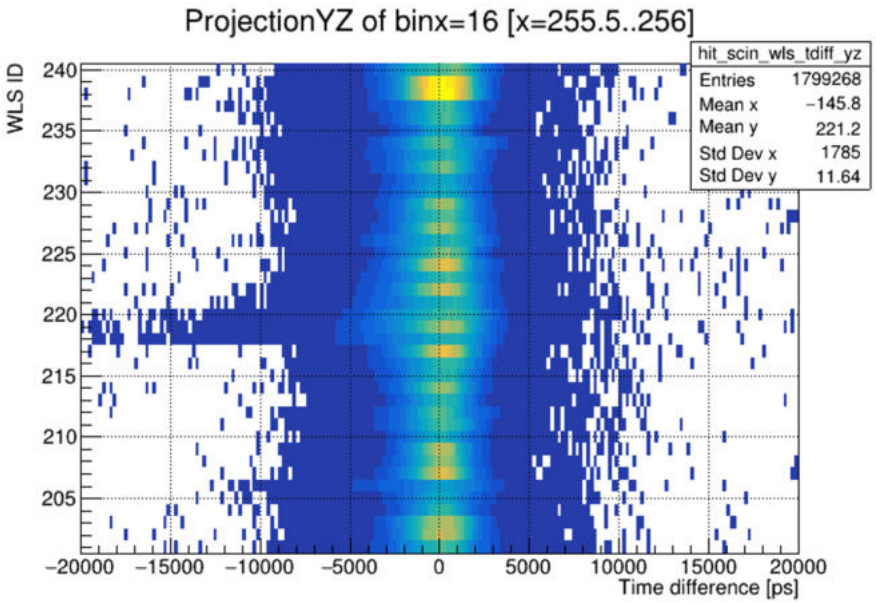
3. Scintillator Hit and WLS signals offsets

- Centring the spectra of time difference between hit and signal times.

Before calibration



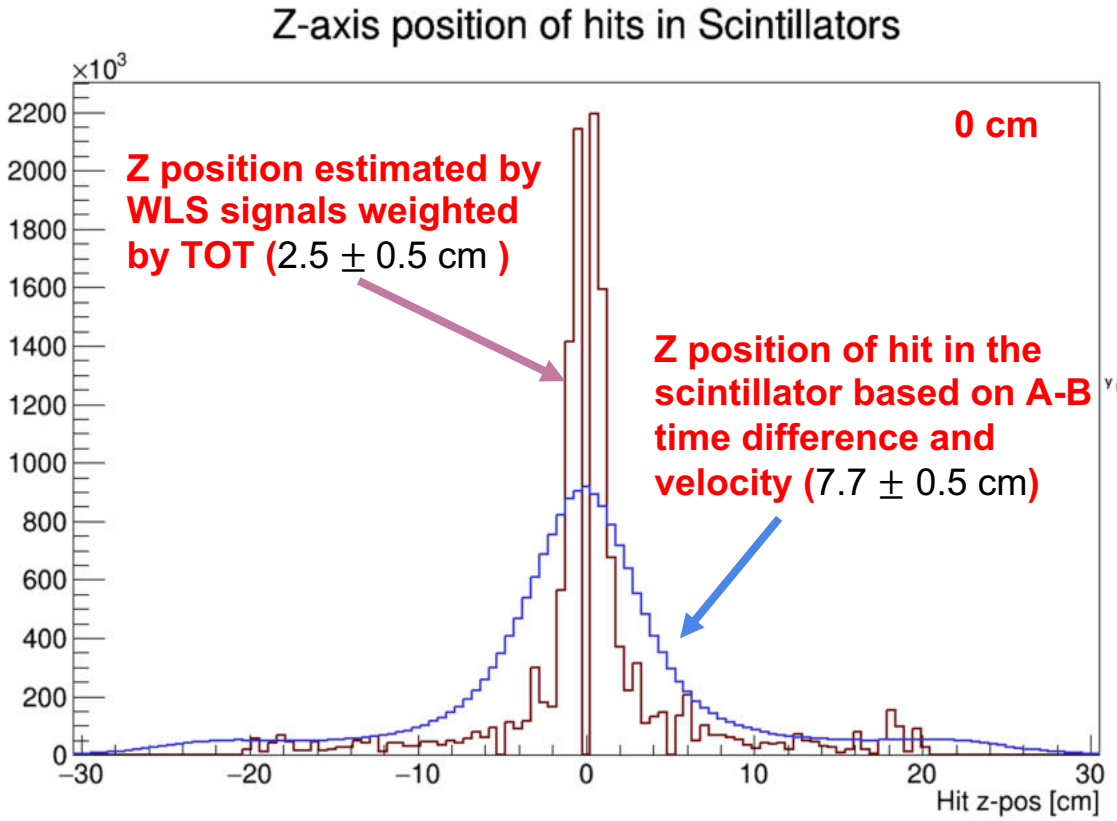
After calibration



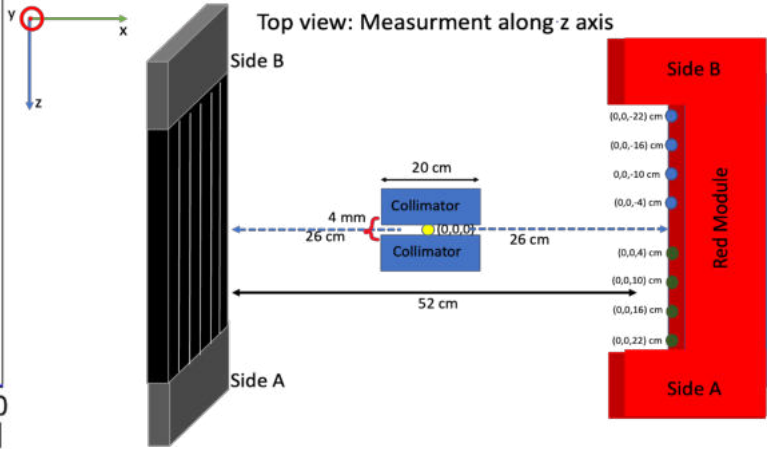
Example for scintillator ID 255 and all the WLS

Collimator Scan Results

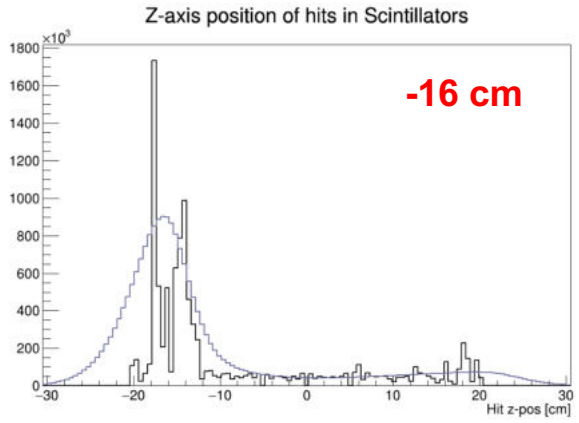
Collimator positions - hits and WLS signals in coincidence

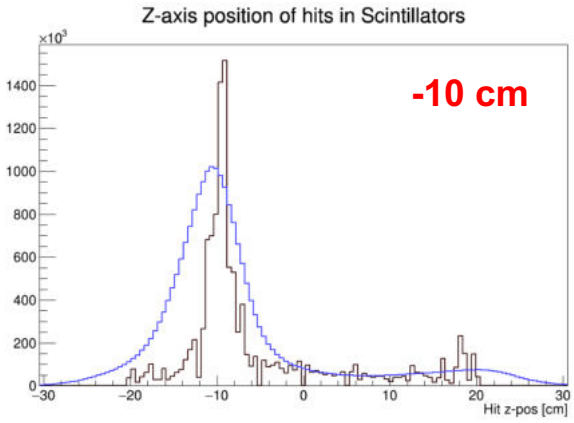


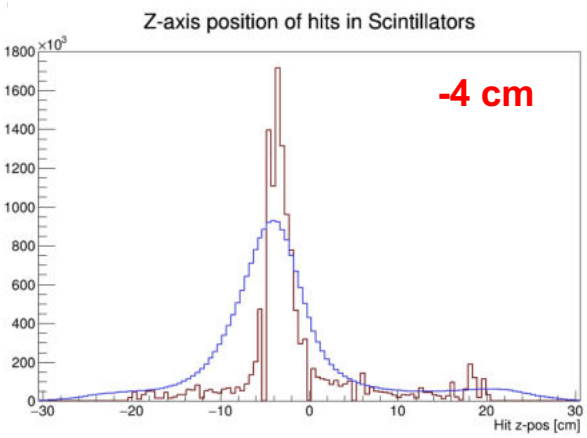
- Collimated beam at 0 cm position
- Comparing two methods for eastimating the hit axial position
- With WLS signal, position estimation is better.

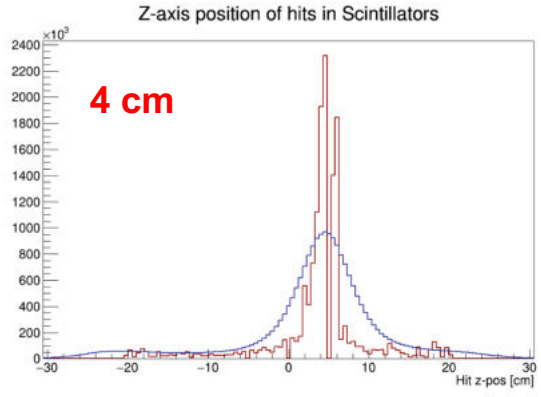


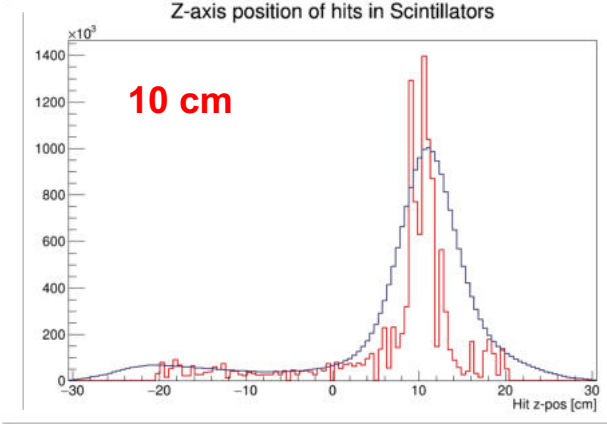
Collimator positions - hits and WLS signals in coincidence

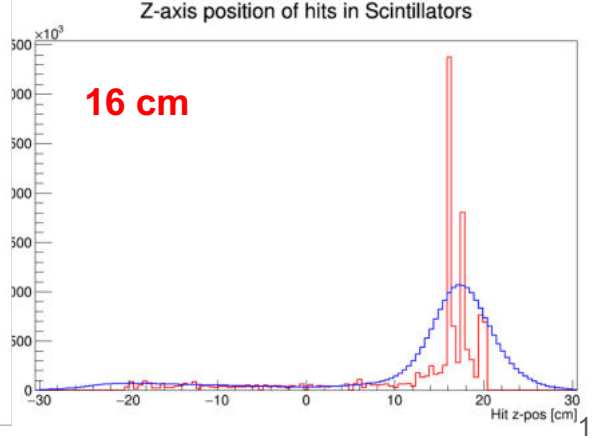












Alternative way of estimation of the hit position

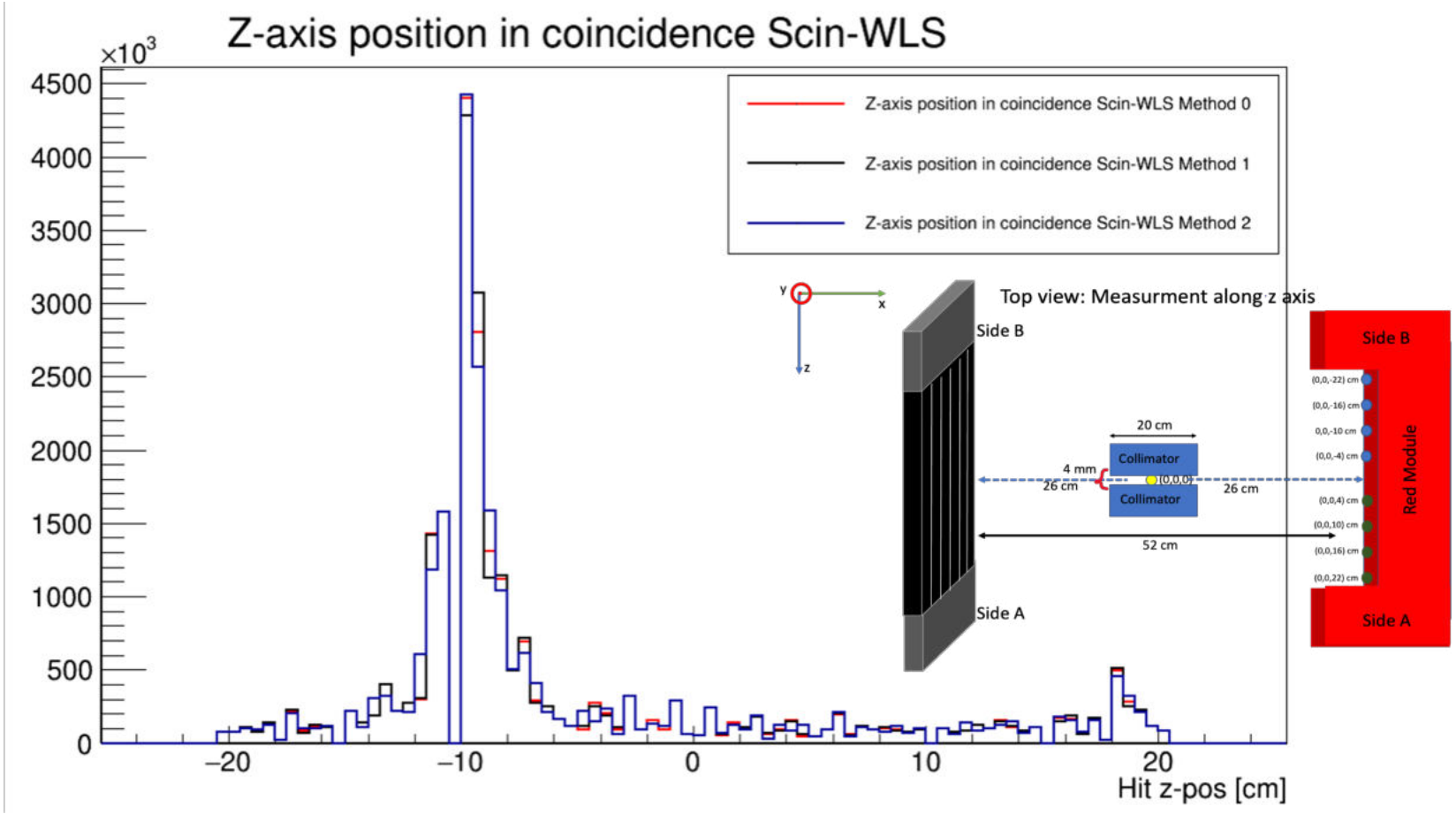
Method 0 : TOT weights :

$$\textbf{Axial position} = z = \frac{\sum_i w_i Z_{SiPMi}}{\sum w_i} \qquad w_i = \frac{TOT_{SiPMi}}{\sum TOT_{SiPMi}}$$

Method 1 : TOT weights squared : $z = \frac{\sum_i w_i^2 Z_{SiPMi}}{\sum w_i^2}$

Method 2 : TOT and coverage weights : $w_i = \frac{TOT_{SiPMi}}{\sum TOT_{SiPMi}} \times$ percentage of the surface that given SiPM in the matrix covers the WLS

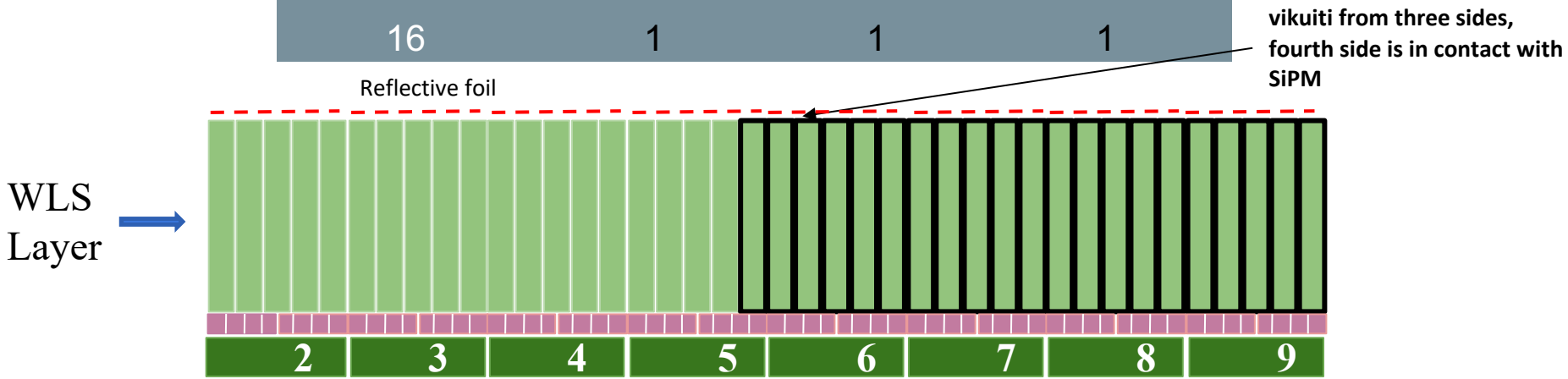
Z position for B10



FWHM comparison

Black – with reflective side

Position (cm)	Method 0 (cm)	Method 1 (cm)	Method 2 (cm)
-16	**2,5**	**2,5**	**2,5**
-10	**0.5**	**0,5**	**0,5**
-4	**1,5**	**1,5**	**1,0**
0	1,5	1,5	1,5
4	2,5	2,5	2,5
10	2	2	2
16	1	1	1



Detector	Resolution (FWHM)	FOV (cm)	Biopsy possibility
Naviscan Solo II:	1.5 mm to 2.0 mm	24×16.4	FDA-approved
MAMMI-PET	1.9 mm to 2.6 mm	17 (diameter)	Prototype
J-PEM	~5 mm	12 × 50 cm	Prototype

https://cmr-naviscan.com/naviscan-solo-2/
https://cmr-naviscan.com/lumagem/
https://doi.org/10.1109/NSSMIC.2013.6829103

Summary

- It was show that the J-PEM detector prototype is commissioned successfully.
- The measurement data was calibrated and reconstructed using dedicated analysis procedures.
- We are able to distinguish between the different position of the source based on scintillators and WLS.

Challenges:

- small amount of optical photons interacting with WLS strips
- background from scatterings photons in Red layer 1-2
- no Time-of-flight synchronization between strips

Thank you