

# Measurement of gamma quantum interaction point in plastic scintillator with WLS strips

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## Abstract

The feasibility of measuring the axial coordinate of a gamma quantum interaction point in a plastic scintillator bar via the detection of scintillation photons escaping from the scintillator with an array of wavelength-shifting (WLS) strips is demonstrated. Using a test setup comprising of a BC-420 scintillator bar and an array of 16 BC-482A WLS strips we achieved a spatial resolution of 5 mm ( $\sigma$ ) for annihilation photons from a  $^{22}\text{Na}$  isotope. The studied method can be used to improve the spatial resolution of the plastic-scintillator based PET scanner which is being developed by the J-PET collaboration.



## Introduction

- J-PET collaboration developed a whole-body PET scanner based on plastic scintillators. This technology offers an improvement of the time of flight (TOF) resolution and also constitutes a promising solution for a whole-body PET imaging at a moderate price.
- Even with a high precision of the time difference measurement of 140 ps ( $\sigma$ ) obtained with a prototype of the J-PET scanner, the corresponding position resolution in the axial direction is only moderate and amounts to about 10 mm [9–11].
- In order to obtain higher resolution, we propose to register scintillation light escaping the scintillator bar through a side wall using an array of wavelength-shifting (WLS) strips [12].
- WLS is a photo-fluorescent material that absorbs light at one wavelength and re-emits the light isotropically at longer wavelength to provide useful modes of light collection.

## Methodology

- For determination of the position of the interaction point in a plastic scintillator we propose to use a set of parallel WLS strips which register scintillation photons escaping the scintillator (for emission angles smaller than the critical angle) [1].
- The axial coordinate of the interaction point along the scintillator bar can be determined on the basis of amplitudes measured in individual WLS strips e.g. by the center of gravity method. It is expected, that with a width of the WLS strip of  $w = 5$  mm the resolution of the z coordinate should be of about 5 mm [12].
- Position of the interaction point along the y-axis is determined from the number of WLS strips which registered the photons.

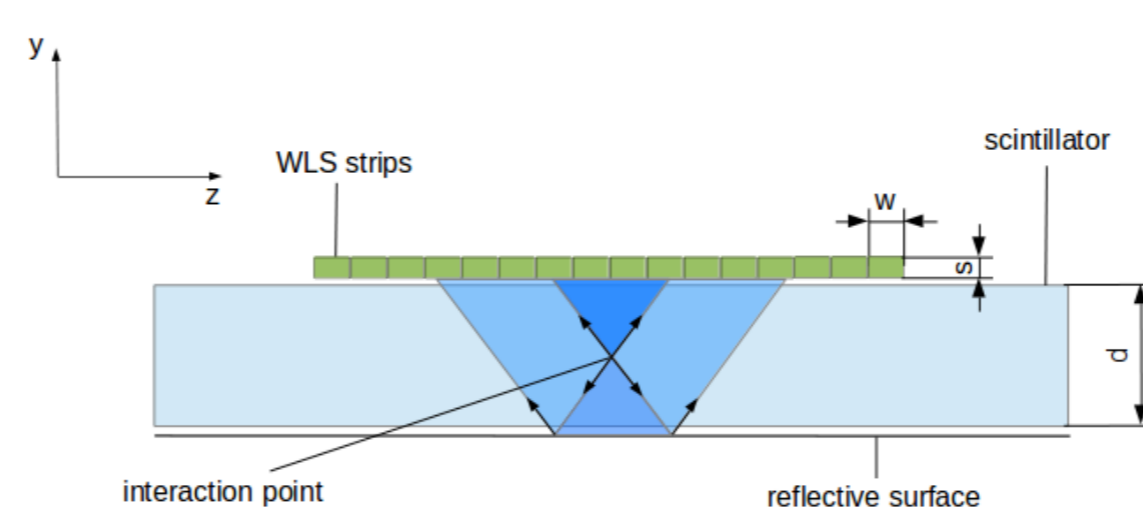


Fig. 1. Principle of measuring the axial coordinate of the gamma quantum interaction point in a plastic scintillator bar using an array of WLS strips.

Table 1 - Scintillator and WLS matching

SCINTILLATOR	WLS
BC-420	BC-482A
5 mm x 19 mm x 300 mm	3 mm x 5 mm x 100 mm
Decay time 1.5 ns	Decay time 12 ns
wavelength of maximum emission - 391 nm	wavelength of maximum emission - 494 nm

## Experimental Set-Up

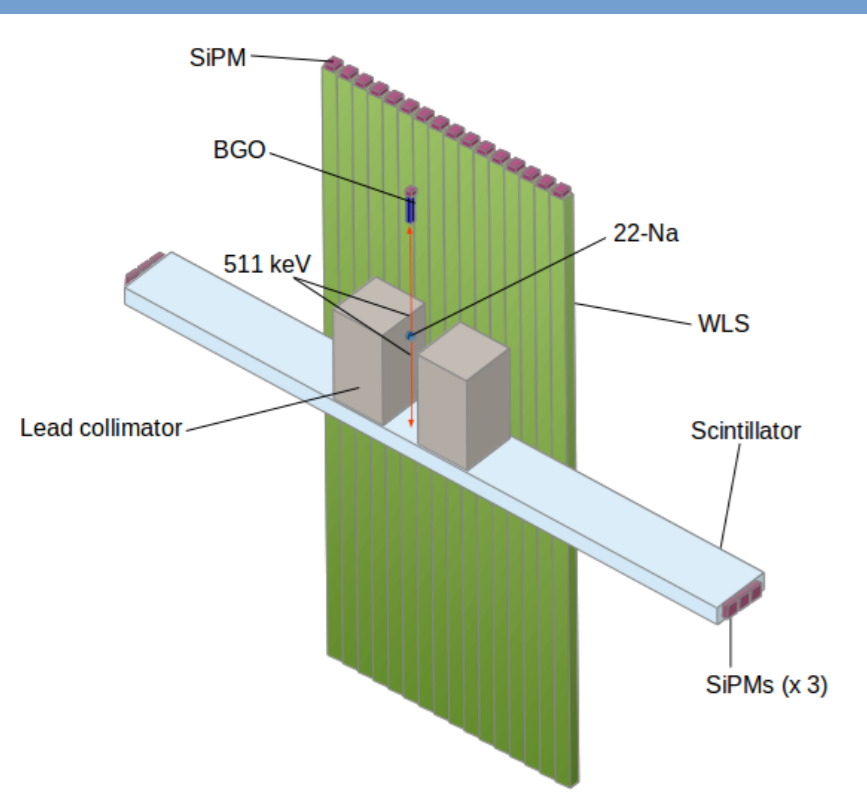


Fig. 2. Schematic view of the test set-up.

- The WLS strips are arranged orthogonally to the scintillator bar which is placed at the center of the length of the WLS strips.
- A  $^{22}\text{Na}$  source is placed at a distance of 30 mm above the scintillator. The radioactive part of the source takes the form of a disc with a diameter of about 1 mm.
- The BGO detector is placed at a distance of about 60 mm from the scintillator.
- A straight line defined by the center of the BGO crystal and the  $^{22}\text{Na}$  source intersects the scintillator bar in the center of its width. The 1275 keV gamma quanta from the  $^{22}\text{Na}$  source were suppressed by a lead collimator with a 4 mm slit.

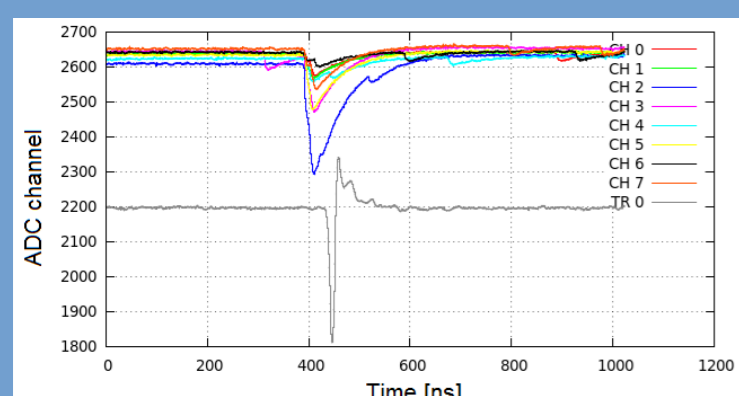


Fig. 3. Waveforms registered within a 1000 ns time window for eight consecutive WLS strips and for the scintillator bar.

## Results

For each registered event, the distribution of amplitudes of WLS pulses presented as a function of the WLS coordinates was fitted with a Gaussian function. The center of the function was taken as the reconstructed position of the gamma quantum interaction point shown in fig. 5. Distributions of reconstructed positions for three locations of the  $^{22}\text{Na}$  source differing by 10 mm shown in fig. 6. A spatial resolution obtained by fitting the Gaussian function to these distributions is about 5 mm ( $\sigma$ ). The centers of the fitted functions reproduce the real positions of the  $^{22}\text{Na}$  source within a positioning accuracy of the source of  $\pm 0.5$  mm.

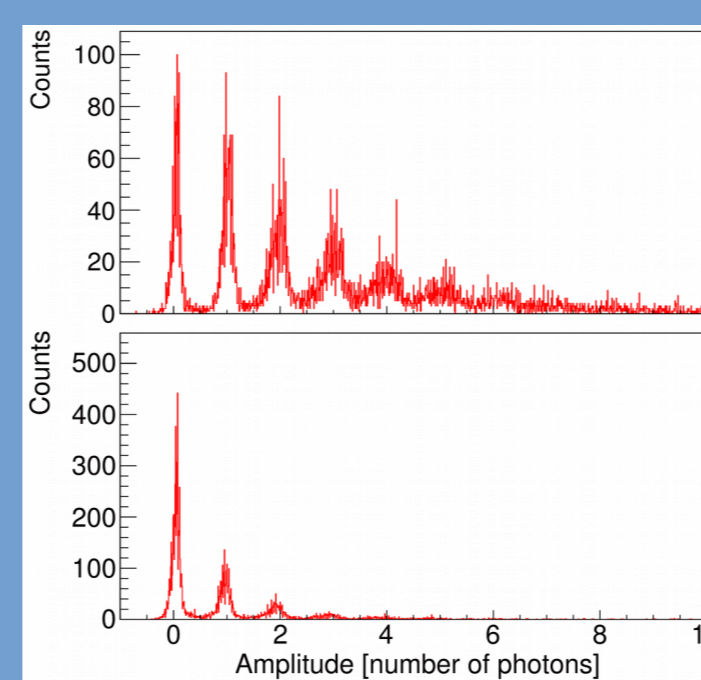


Fig. 4. Amplitude spectra for two WLS strips – one located in front of the interaction point and the other lying 30 mm aside.

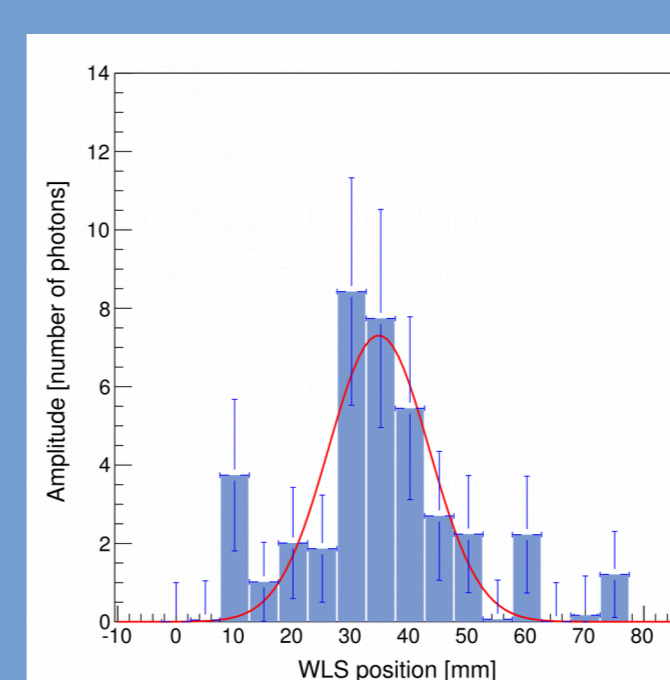


Fig. 5. Amplitudes measured in individual WLS strips.

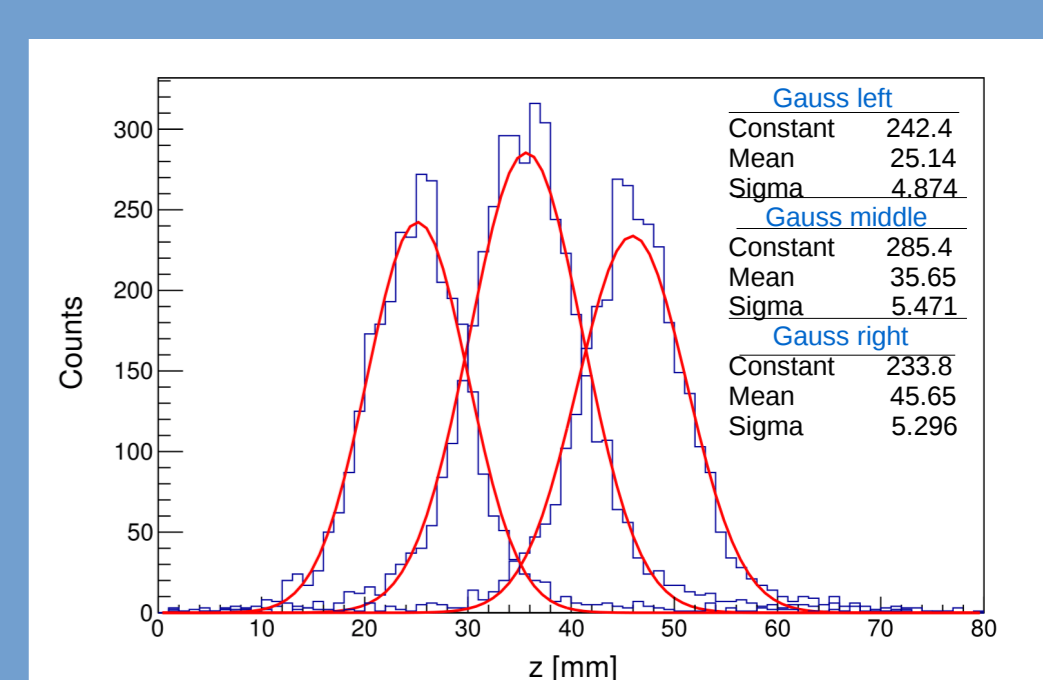


Fig. 6. Distributions of reconstructed z-coordinates of the gamma quantum interaction for three different positions of the  $^{22}\text{Na}$  source.

## Future Plan

- Fig. 7. is the design of first prototype module with WLS which will be used in Jagiellonian Positron Emission Tomography (J-PET) for the metabolic imaging of the whole human body.
- The type and dimensions of the scintillator bar are identical with the ones used in the J-PET prototype scanner and WLS strips were made of BC-482A with three times enhanced dye concentration [10].
- WLS strips are 100 mm long, their width is 6 mm and thickness is 3 mm and the separation between neighbouring strips is 0.2 mm. The array of 40 scintillator WLS strips place parallel in between the two layers of scintillators with 0.1mm gap in between.
- Each WLS strip will be read out at one end with a Hamamatsu S12572-050P SiPM.

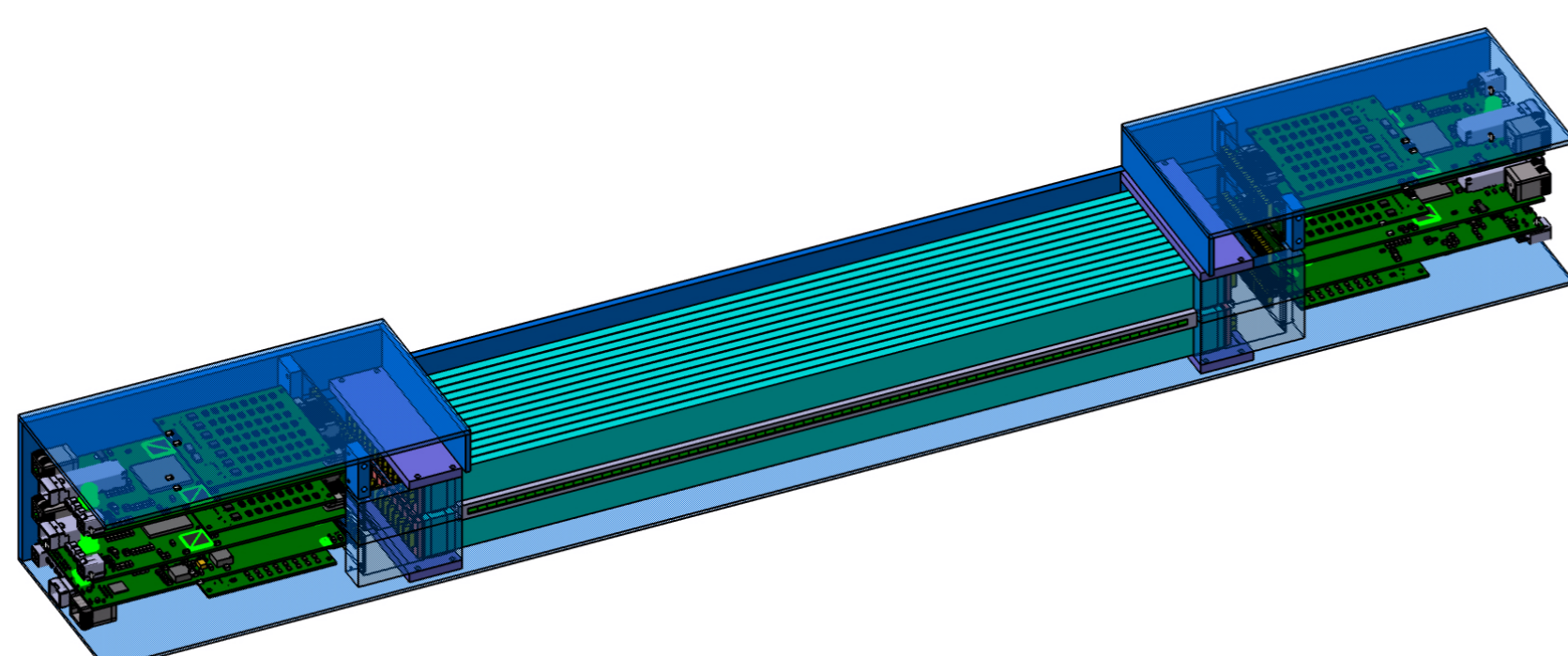


Fig. 7. Prototype module with array of WLS strips sandwiched between two layers of scintillator.

## Conclusions

- It has been demonstrated that the interaction point of an annihilation gamma-quantum in a plastic scintillator bar can be localized by means of an array of WLS strips measuring scintillation photons escaping from the scintillator through a side wall.
- With our test set-up we reached a position resolution of 5 mm ( $\sigma$ ) for the coordinate along the scintillator bar. The achieved precision may be further improved e.g. by increasing the coverage of WLS face with SiPM (which was only 60%).
- These modules will be used to build a full scale J-PET scanner which will enable experiments in the field of nuclear medical imaging and tests of the discrete symmetries in the decays of positronium atoms.

## References

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