Design study of PET/SPECT detectors built from inorganic scintillators and WLS fibers

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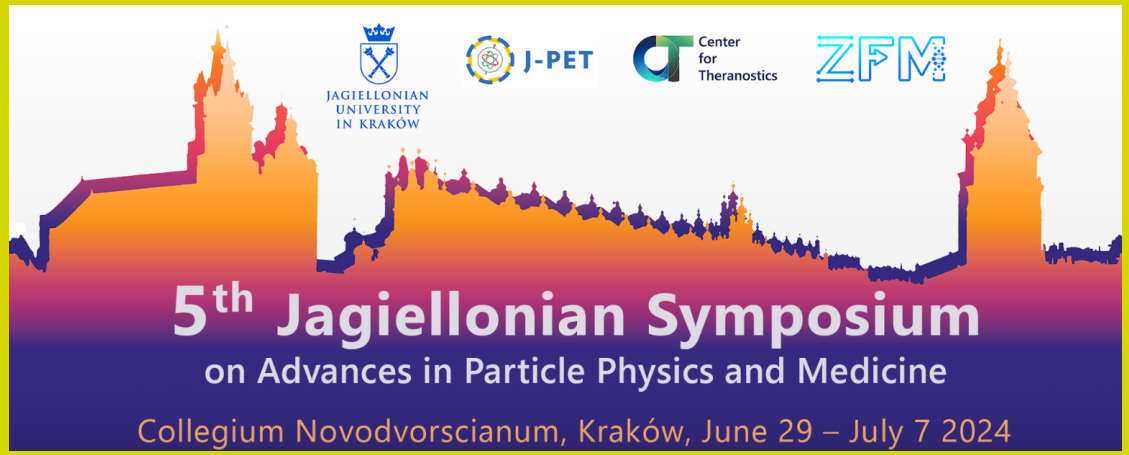
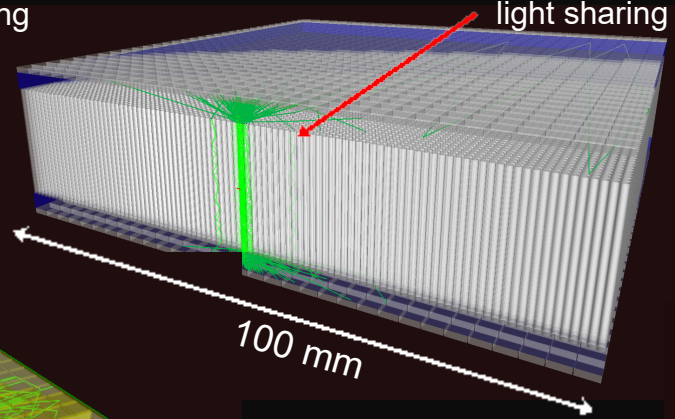


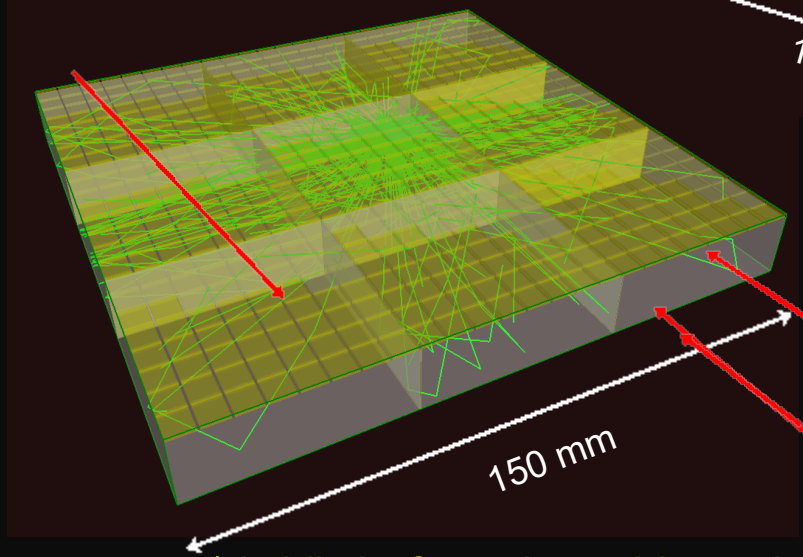
Study of PET detector geometries via Geant4 simulation

1. Array of LYSO monolithic scintillators optically coupled with SiPMs arrays
2. Pixelated scintillator array
3. Monolithic scintillator WLS readout & SiPMs

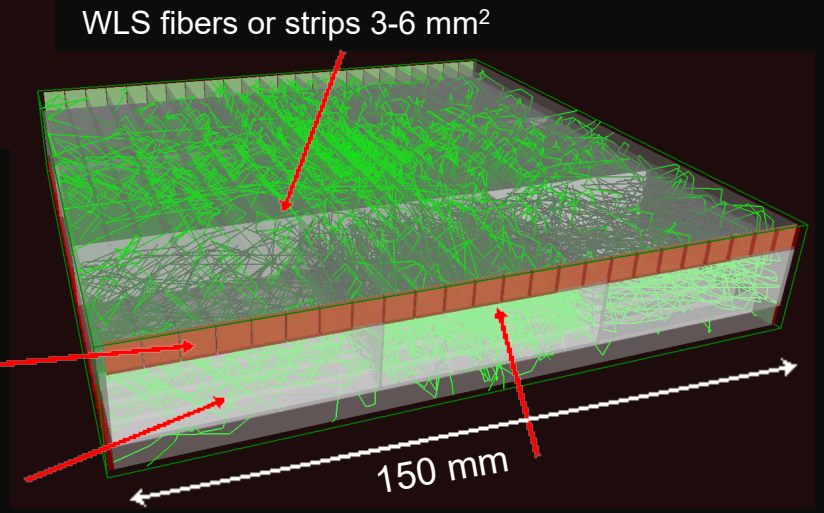
- Pixelated Scintillator Array with SiPM readout via light sharing — 1. 5 × 1.5 × 10 mm^3 LYSO



- Array of monolithic scintillators with SiPM readout

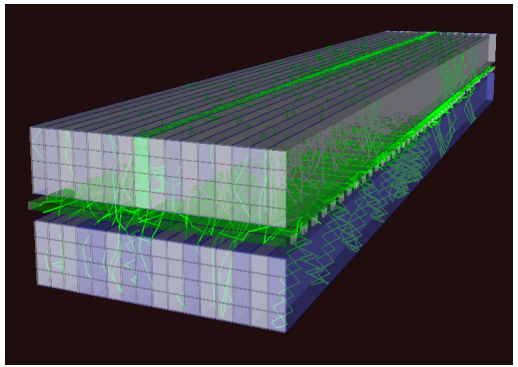


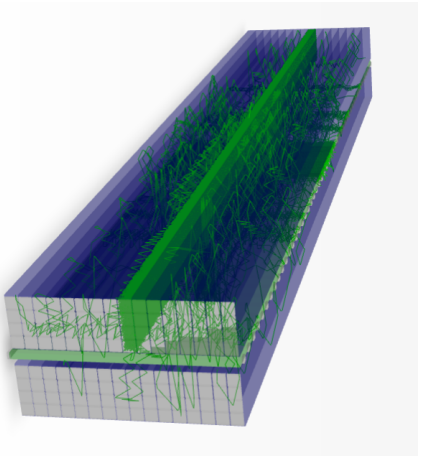
- Monolithic scintillators with WLS fibers readout

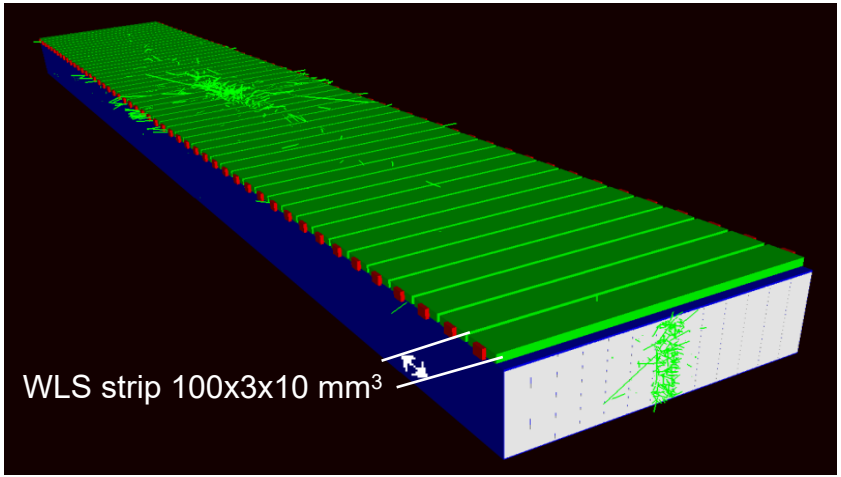


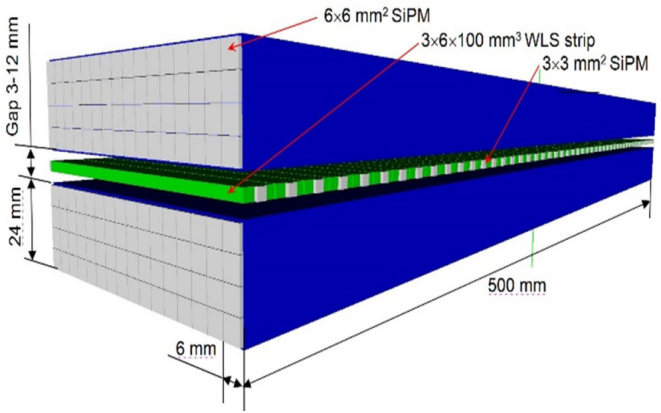
Pecularities of modelling J-PET detection module

Modelling J-PET detection module conclusion was made that larger cross-section of WLS strips resulted in better spatial resolution

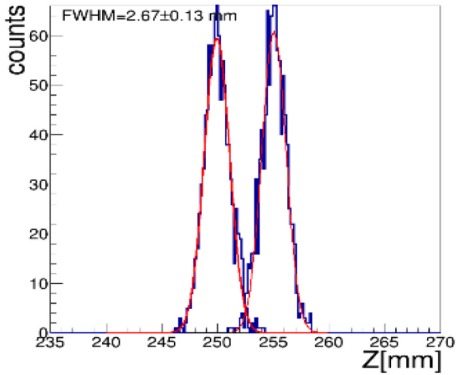




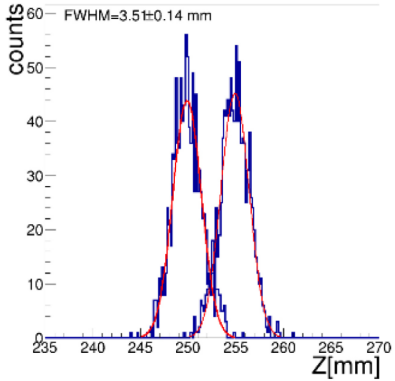




50 - WLS strips 100x3x10 mm^3
FWHM 2.67 mm

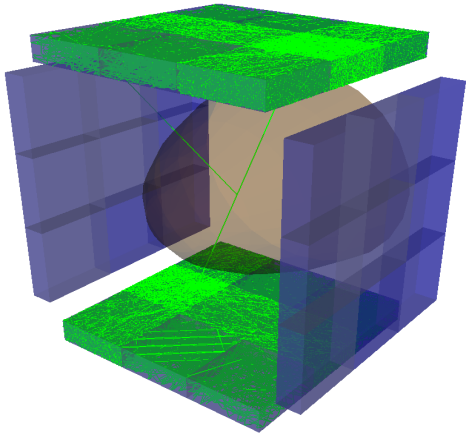


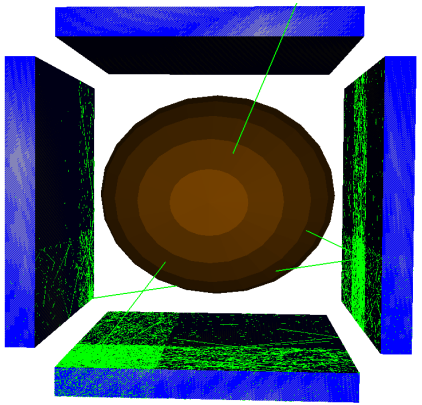
83 of WLS strips 100x3x6 mm^3
FWHM 3.5mm



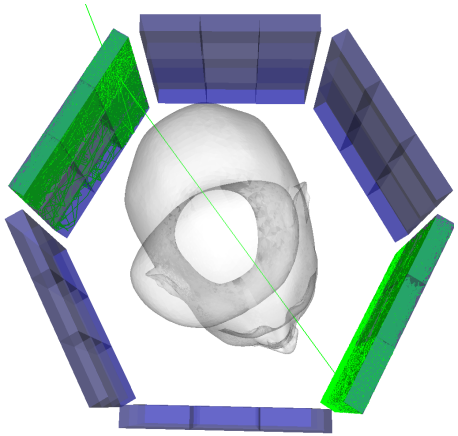
Developing detectors with scintillator and WLS

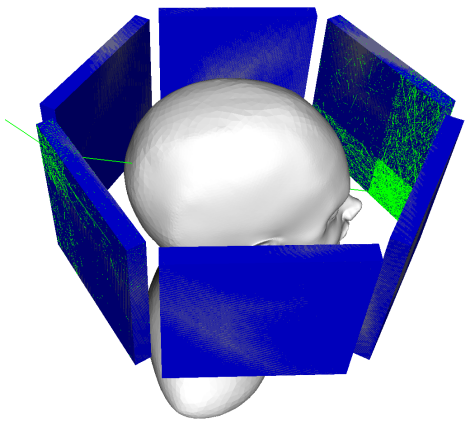
Detector head for positron emission mammography



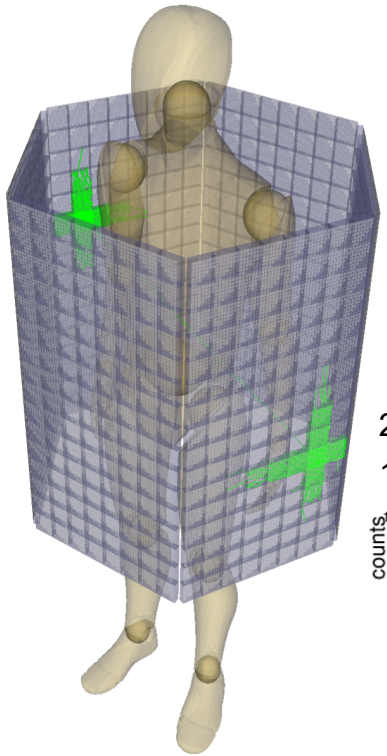


Detector head for brain PET/SPECT

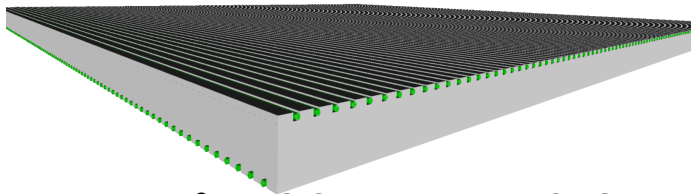




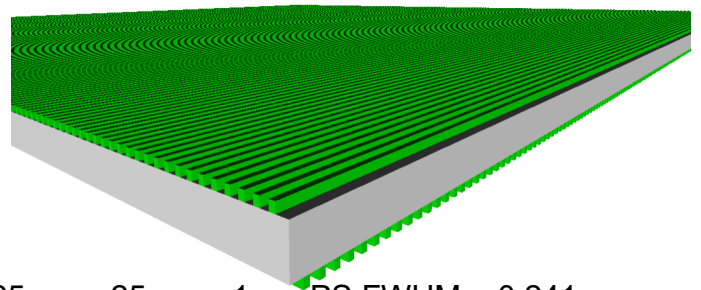
Total body PET



Muon tomography

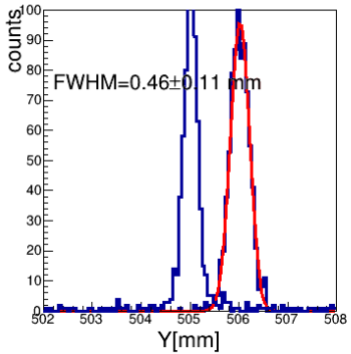


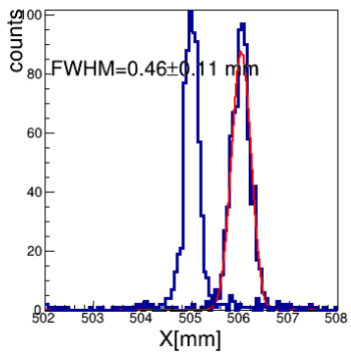
2 x 2 mm^2 WLS fibers on top of PS



25 cm x 25 cm x 1 cm PS FWHM = 0,241 mm

1 m x 1 m x 1 cm PS FWHM = 0,46 mm





Impact of Compton scattering in crystal on position resolution of PET

The probability of multiple Compton scattering (CS) events for 511 keV γ–rays in a monolithic LYSO scintillator is ~84%. Compton scattering events within the crystal degrade the spatial resolution of a PET detector. Using two component Gaussian Mixtue Model we fit the distributions. If two gaussians are fitted and distance between mean mlarge than 2 mm this event is descurded. Without rejection of Compton scattering events the spatial revolution was 0.9 mm FWHM and after rejection the resolution was improved to 0.5 mm. Rejection of Compton scattering events can improve the spatial resolution of PET images, but results in reduced detection efficiency.

examples of reconstructed events in monolithic LYSO scintillator with SiPMs readout

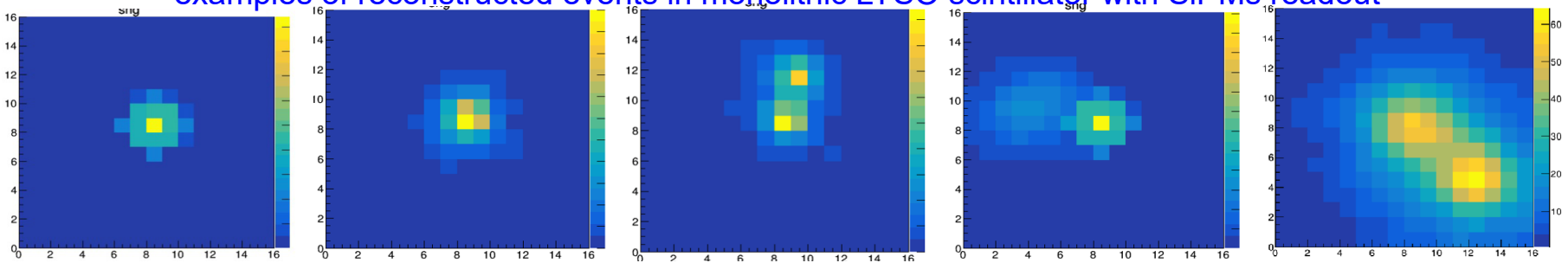
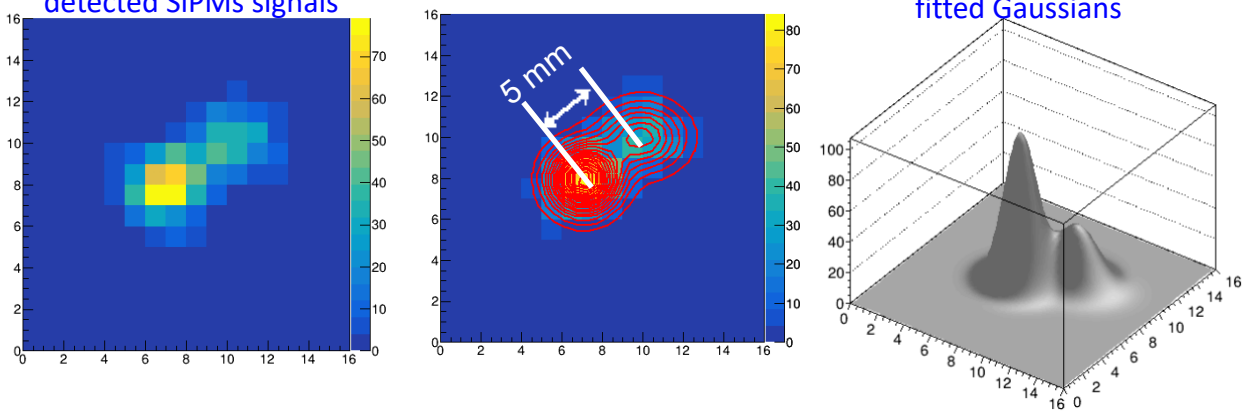


photo photoelectric absorption events

Compton scattering events

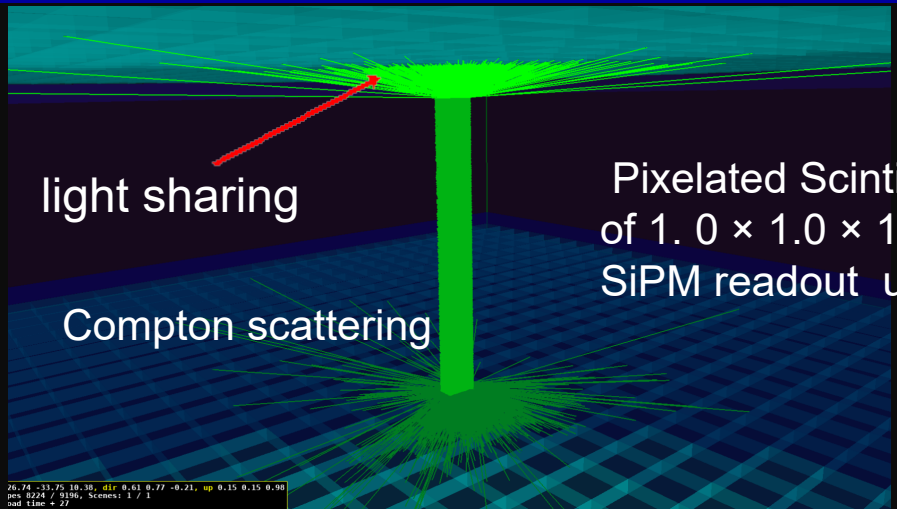
Two component Gaussian Mixtue Model used to fit the distribution

detected SiPMs signals

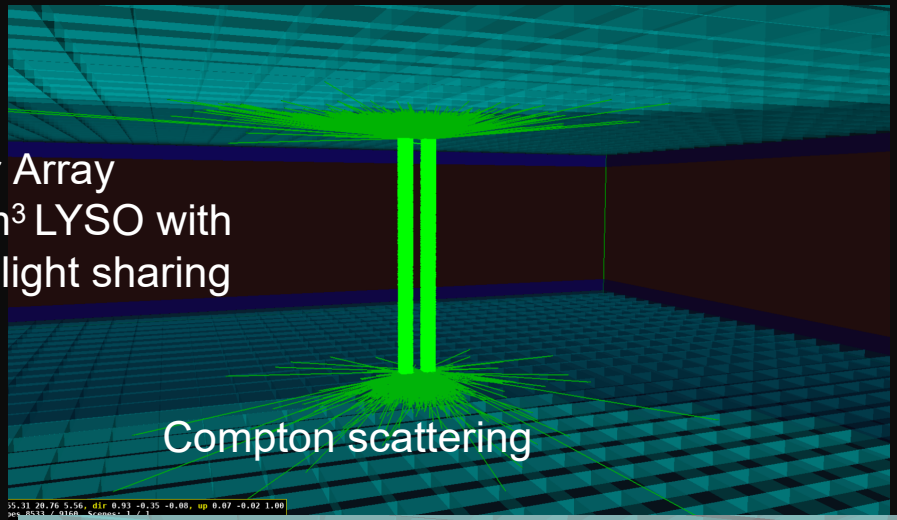


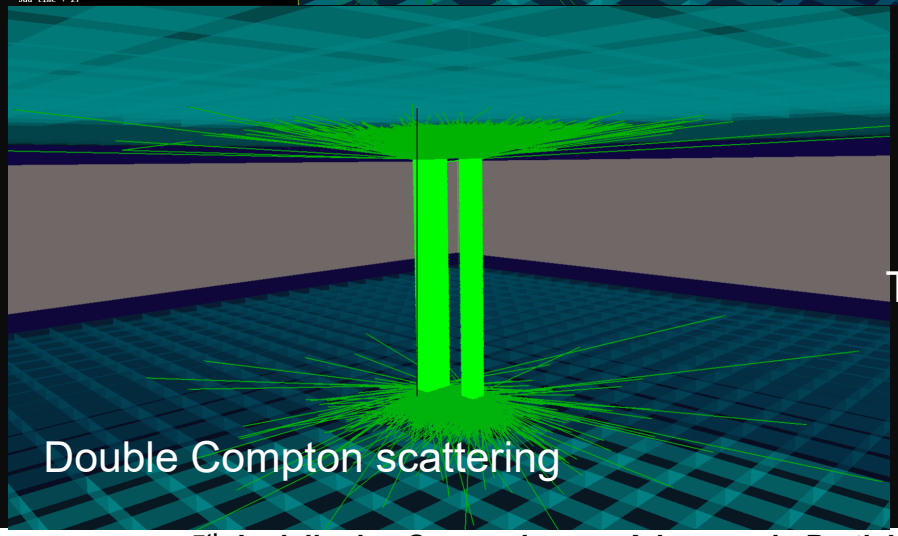
fitted Gaussians

Modeling the pixelated LYSO scintillator PET detector

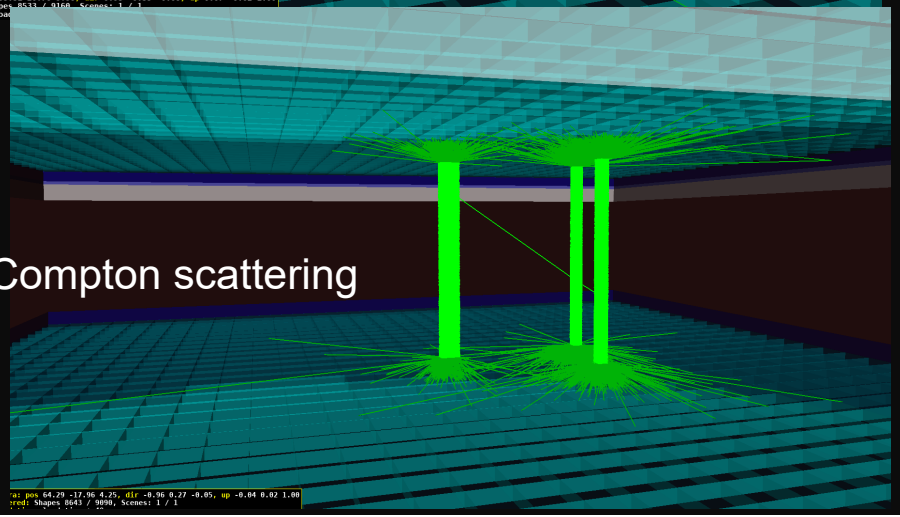


Pixelated Scintillator Array
of 1. 0 × 1.0 × 15 mm^3 LYSO with
SiPM readout using light sharing



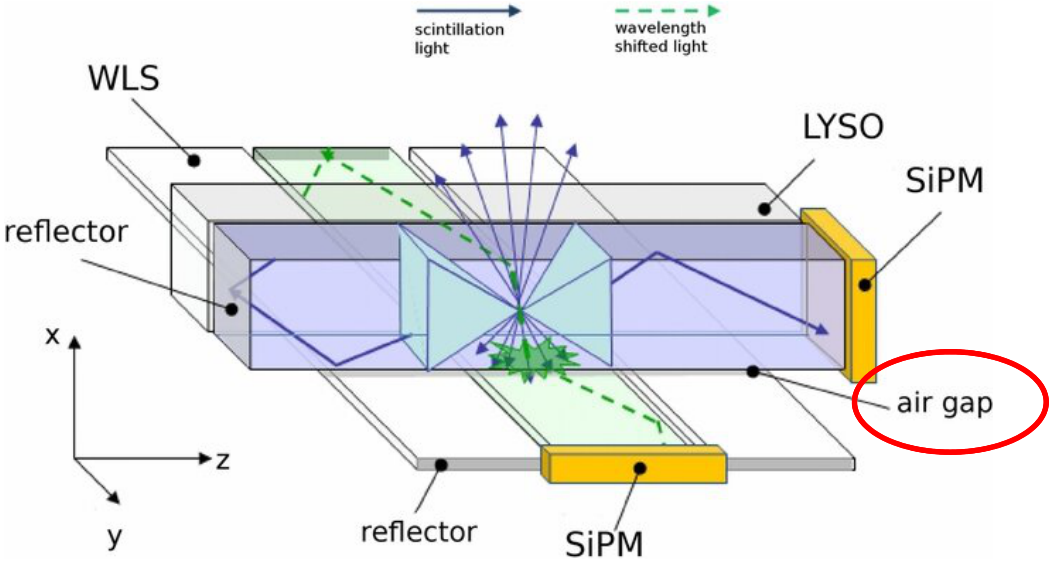


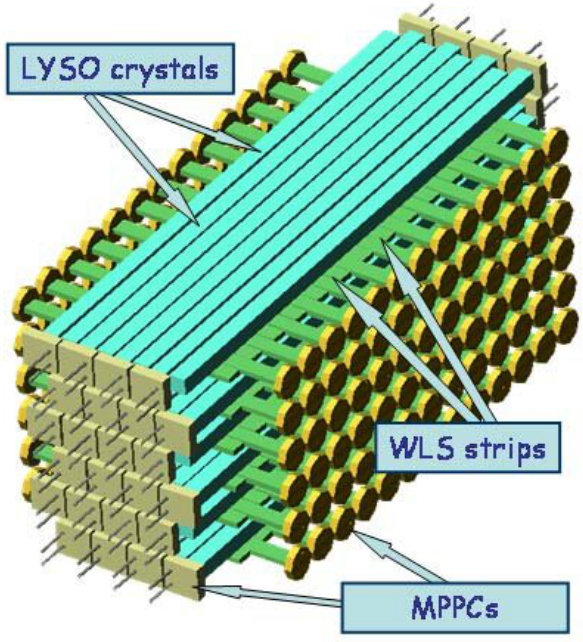
Triple Compton scattering



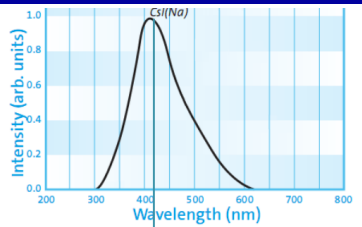
Previous works: AX-PET detector with LYSO and WLS-strips

AX-PET is a PET detector based on axially oriented **LYSO** crystals and orthogonal wavelength shifter (WLS) strips, both individually read out by silicon photo-multipliers. Its design decouples sensitivity and spatial resolution, by reducing the parallax error due to the layered arrangement of the crystals.



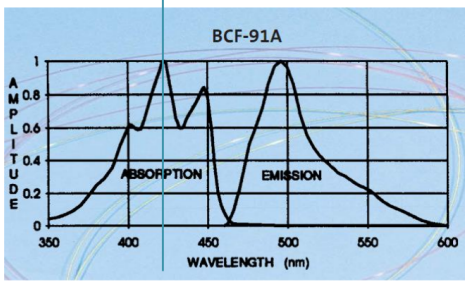


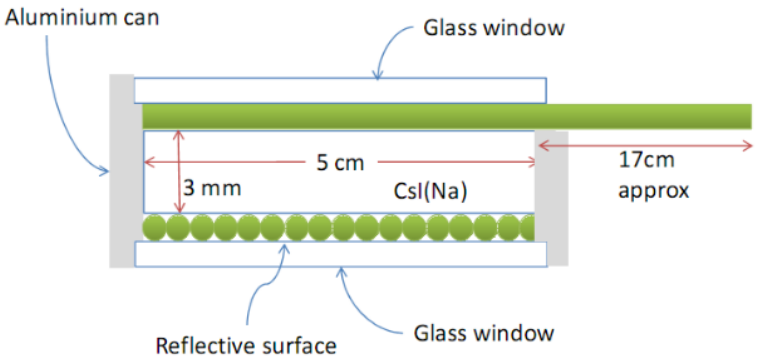
Previous works: SPECT CsI(Na) with WLS fibers & SiPMs

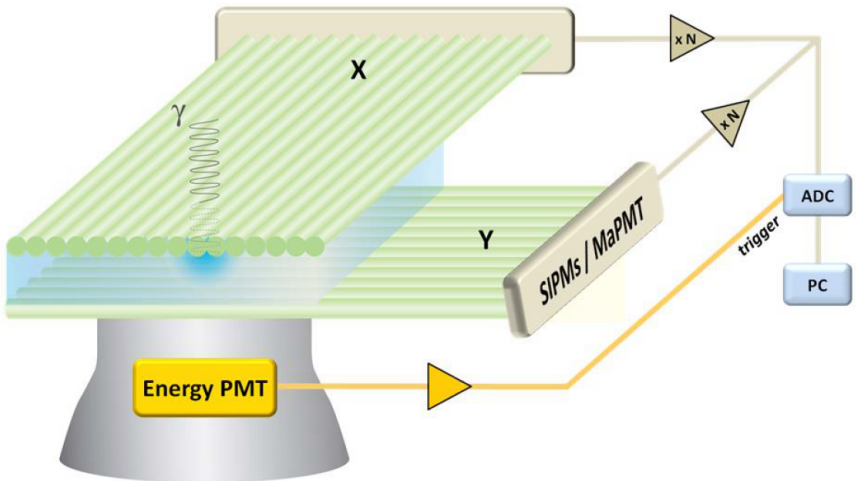


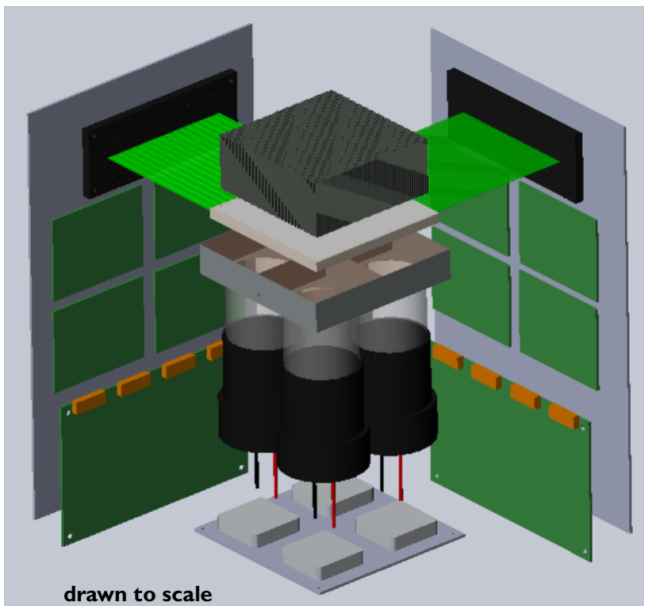
Optical spectra of CsI(Na) emission

WSF absorption/re-emission



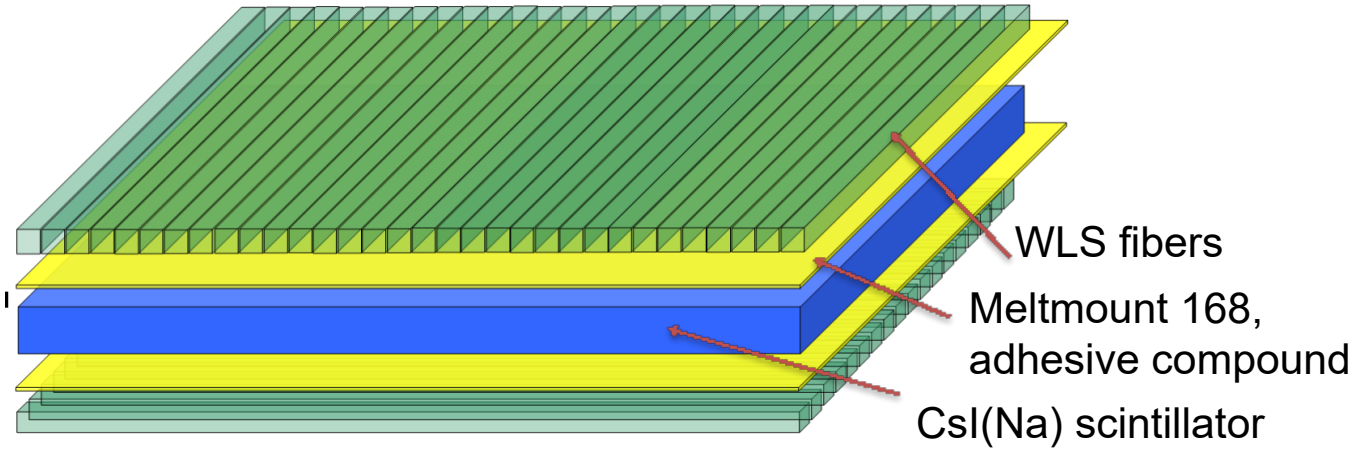






Simulated: SPECT detector with CsI(Na) & WLS-fibers/strips

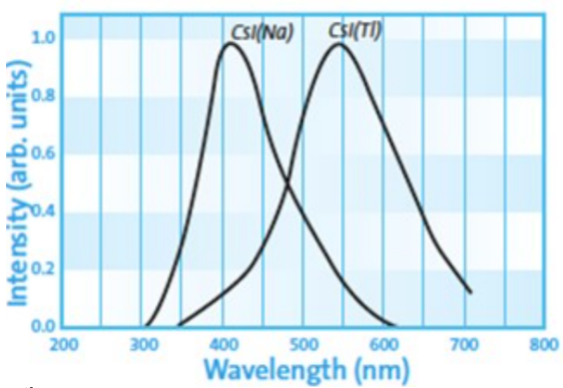
Intrinsic DOI using signals from upper and lower WLS fibers

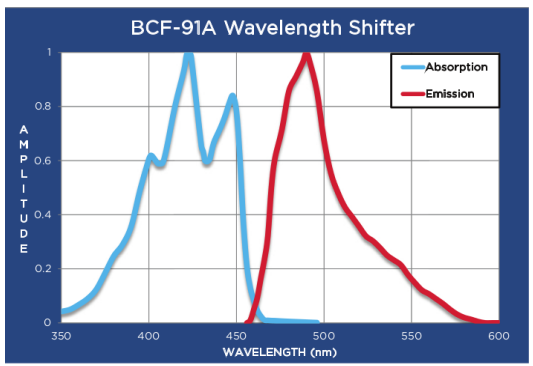


Current sizes of WLS fibers range from 0.25 mm to 5 mm square or round cross-sections.

CsI(Na) Scintillation Crystals

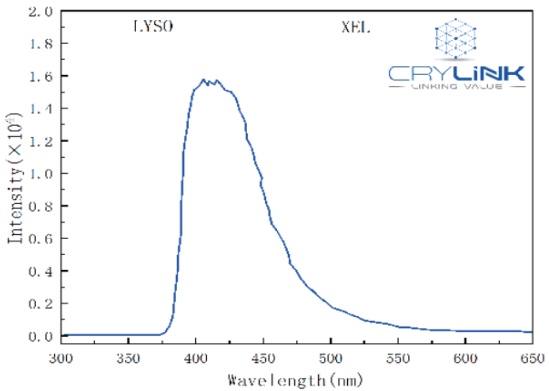
Wavelength(Max.emission) (nm)	410
Wavelength range (nm)	TBA
Decay time (ns)	40
Light output (photons/MeV)	30000
Refractive index	1.84@420nm
Radiation length (cm)	1.86

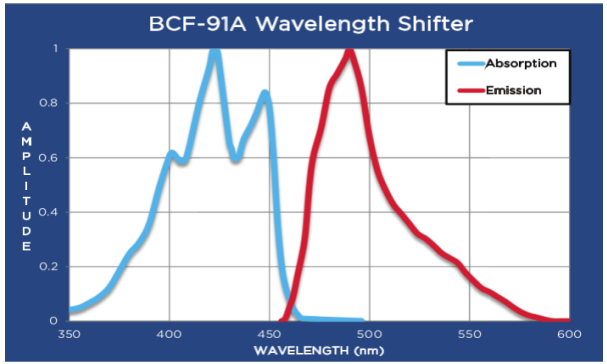


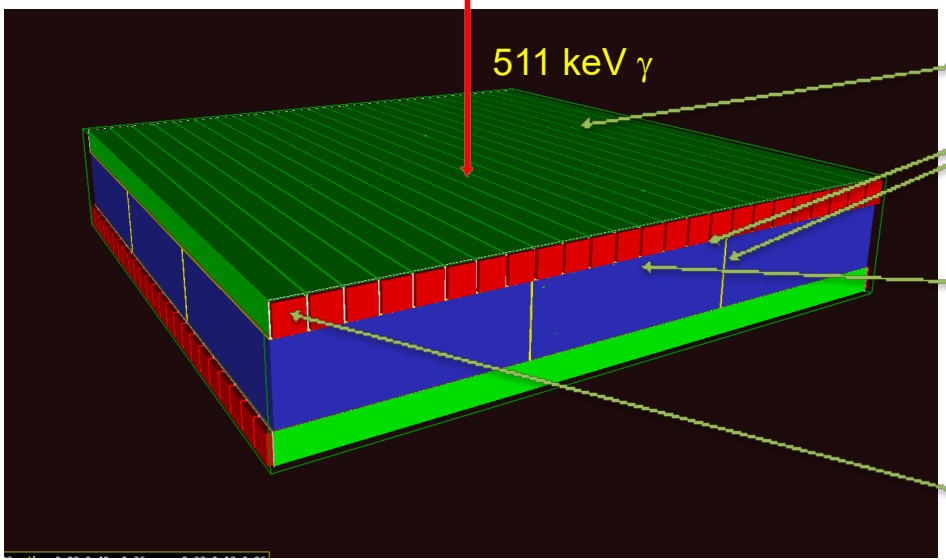


PET detector LYSO crystal scintilator & WLS-fibers

Detector geometry modeled using Geant4 simulation of an array of LYSO monolithic scintillators optically coupled for PET and other applications readout with WLS-fibers or WLS-strips wrapped with ESR or Teflon. Also WLS fibers were modelled. Upper and lower WLS are orthogonal each to other.

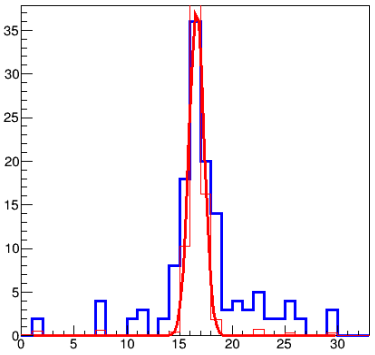




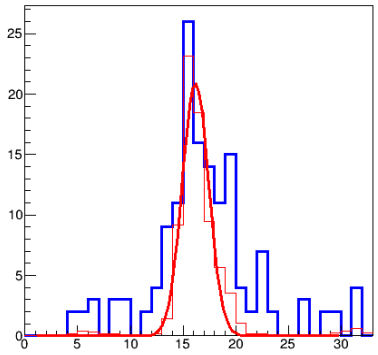


Wavelength(Max.emission) (nm)	410
Wavelength range (nm)	TBA
Decay time (ns)	40
Light output (photons/MeV)	30000
Refractive index	1.82@410nm
Radiation length (cm)	1.1

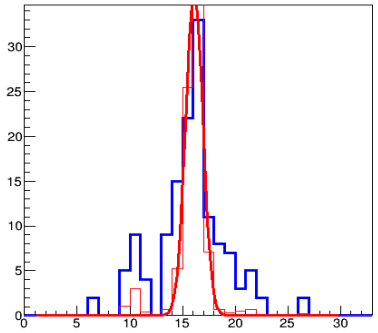
Fitting distribution of detected photoelectrons in WLS fibers



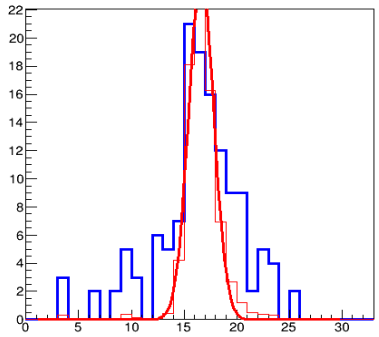
upper array of WLS strips



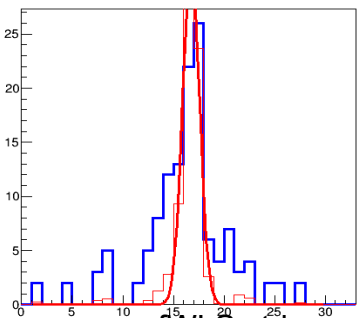
lower array of WLS strips



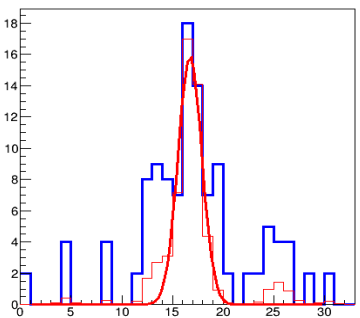
upper array of WLS strips



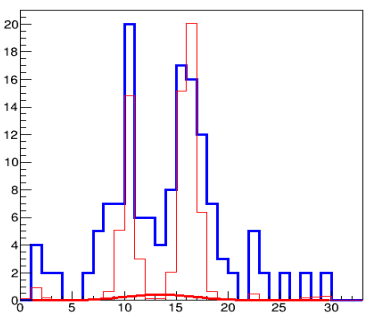
loweer array of WLS strips



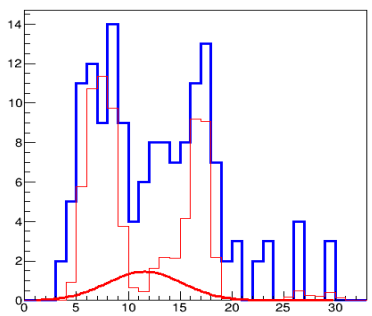
upper array ofWLS strips



lower array of WLS strips

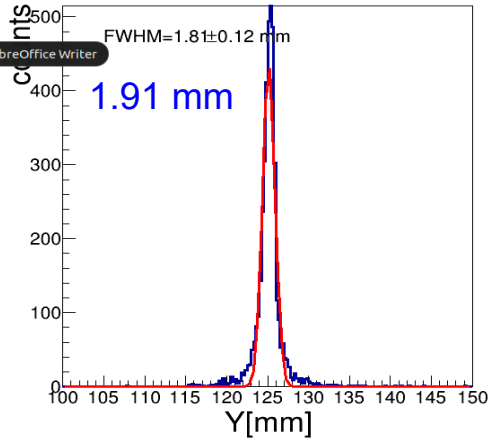


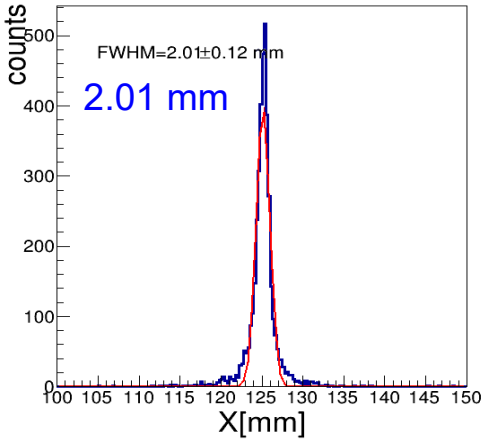
upper array of WLS strips



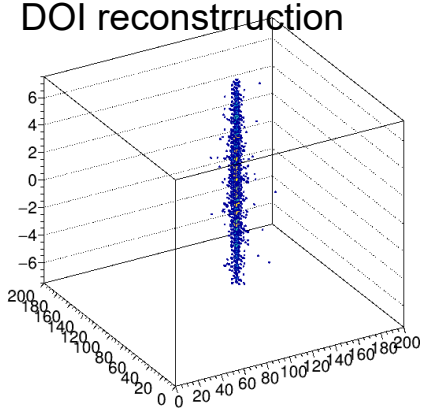
lower array of WLS strips

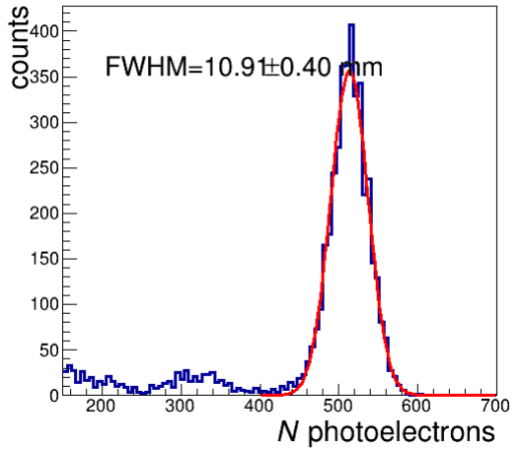
Simulation of 20cm x 20cm x 1.5 cm - 4 x 4 array of LYSO readout 3 mm^2 WLS

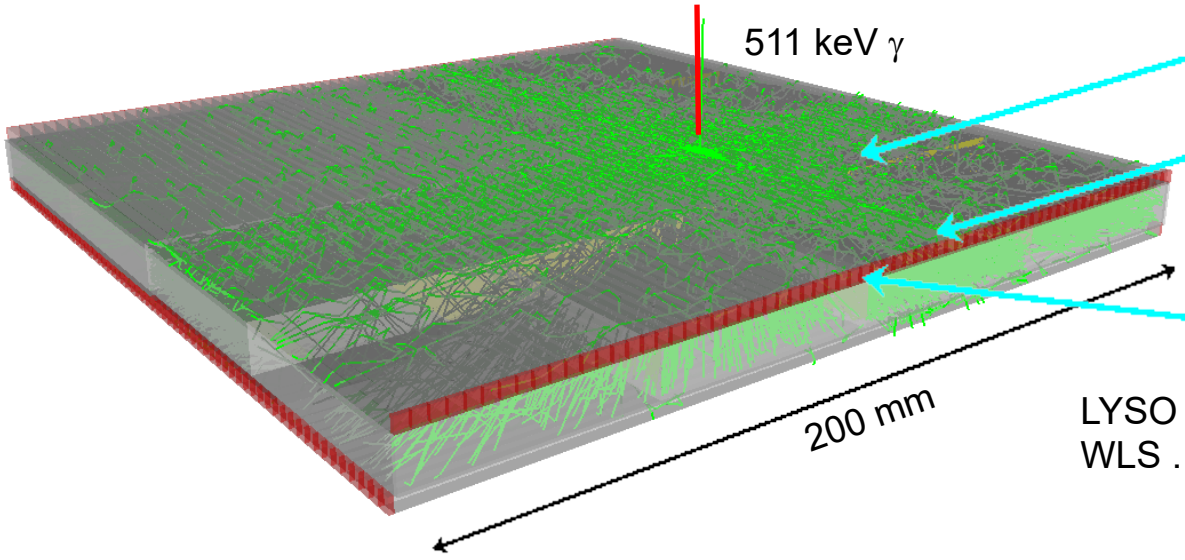




DOI reconstrruction







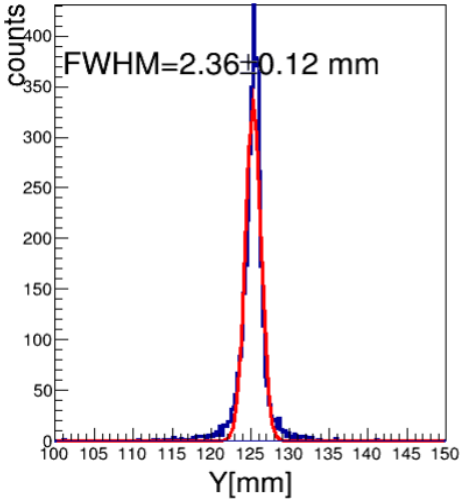
WLS strips

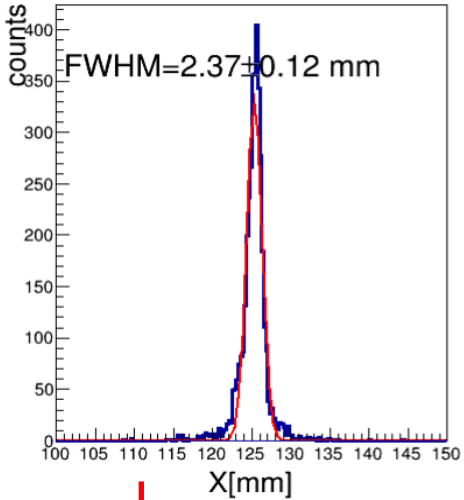
Array of 4x4 LYSO monolithic scintillators optically connected

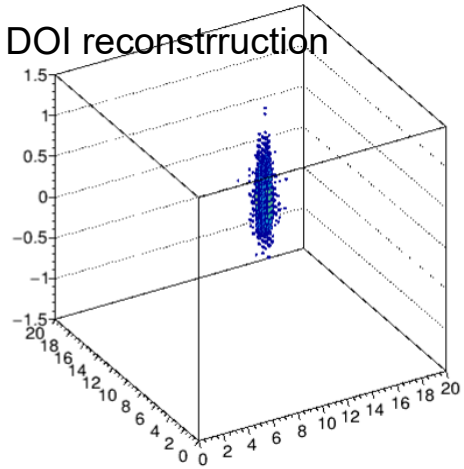
SiPMs

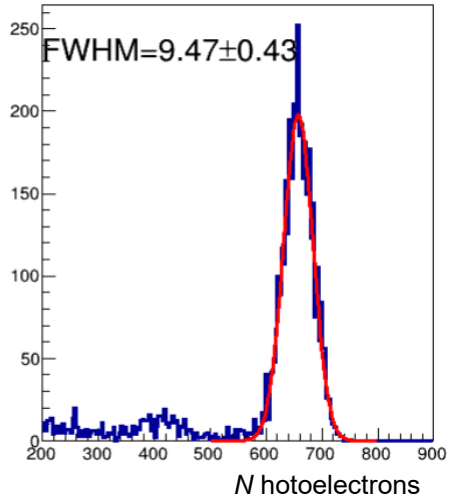
LYSO readout 264 of 3x3 mm^2 of SiPMs with 66+66 WLS .

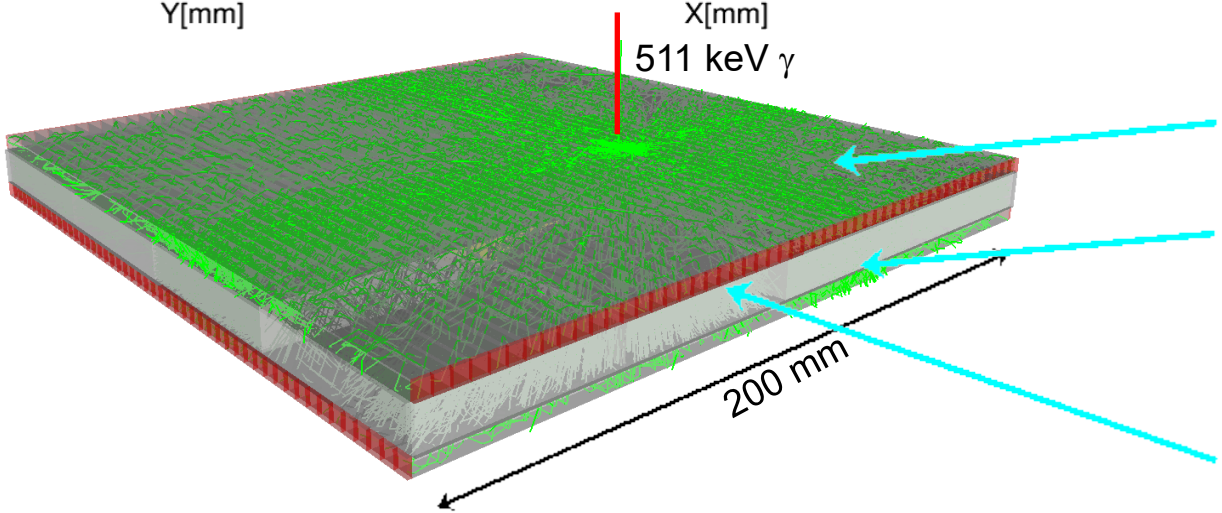
Simulation of 20cm x 20cm x 1.5 cm - 4 x 4 array of LYSO readout 4 mm^2 WLS









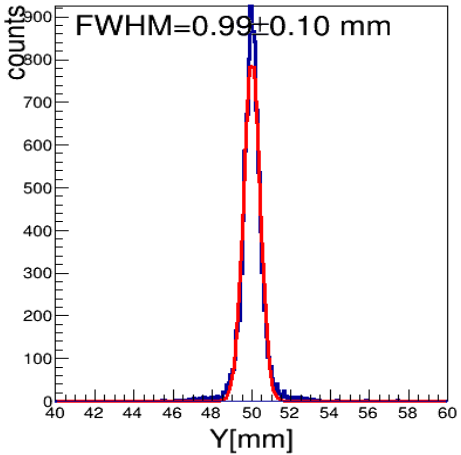


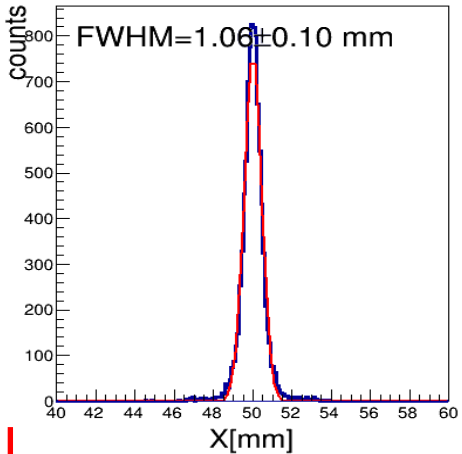
WLS strips

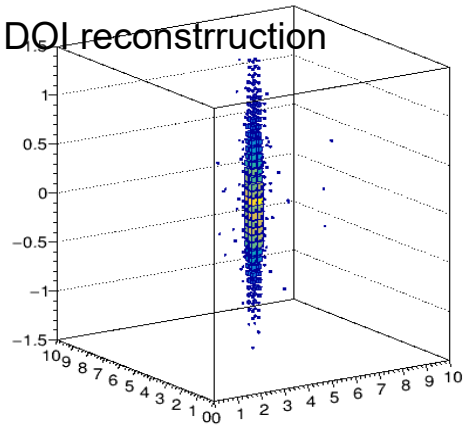
Array of 4x4 LYSO monolithic scintillators optically connected

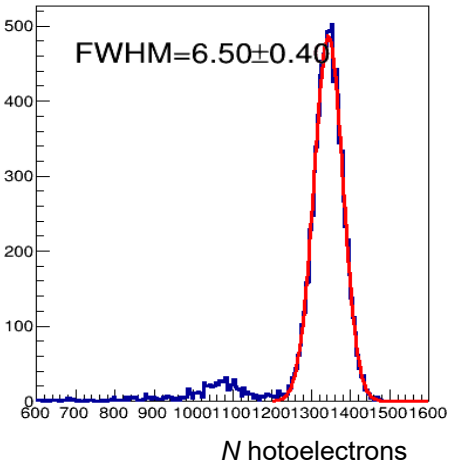
SiPMs

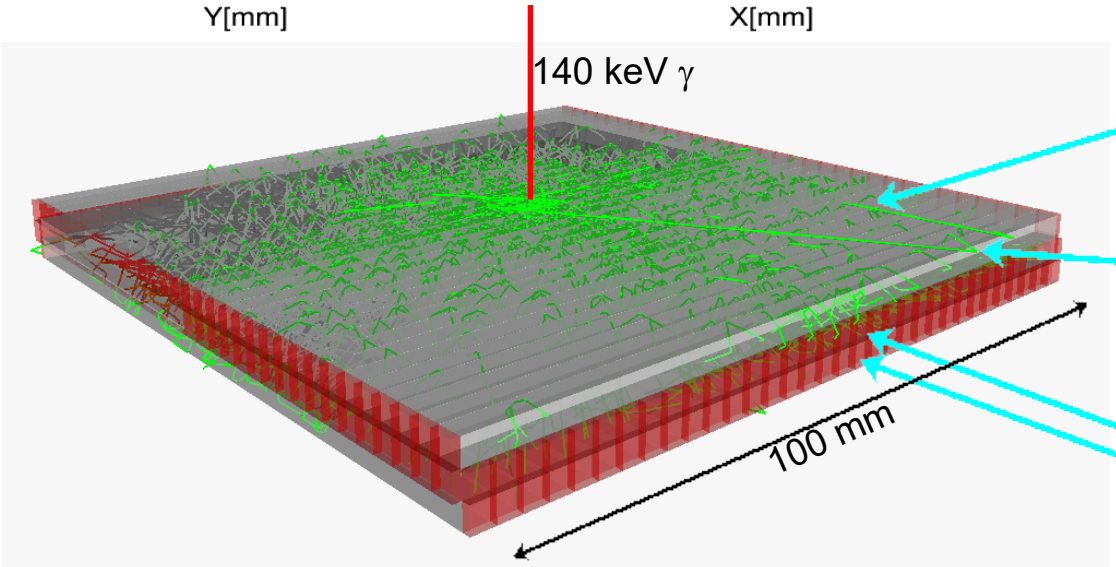
Simulation of 10cm x 10cm x 3 mm CsI(Na) readout 3mm^2 WLS fibers









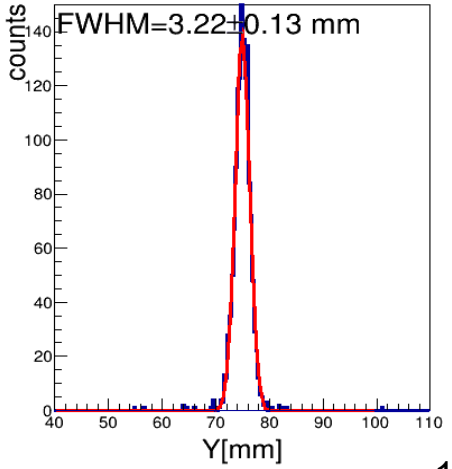


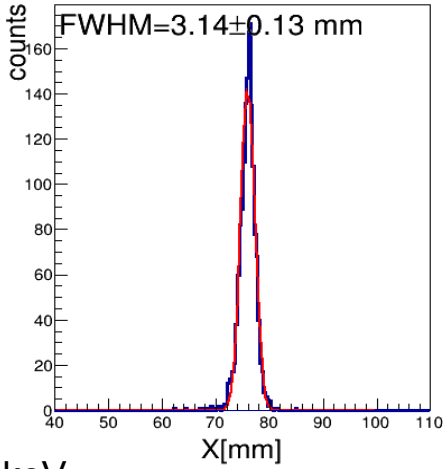
WLS strips

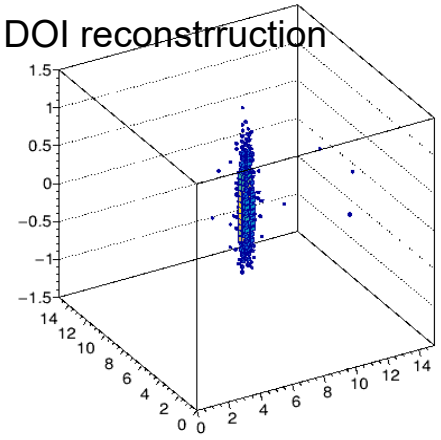
CsI(Na) monolithic scintillator

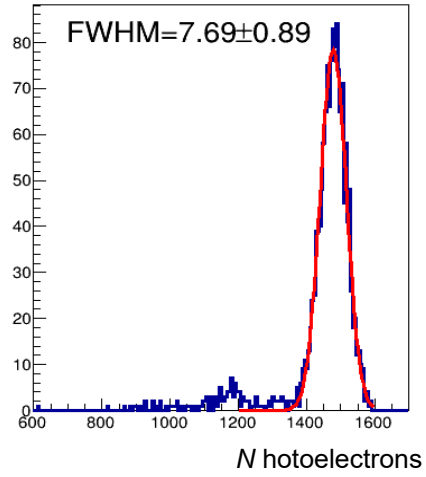
SiPMs

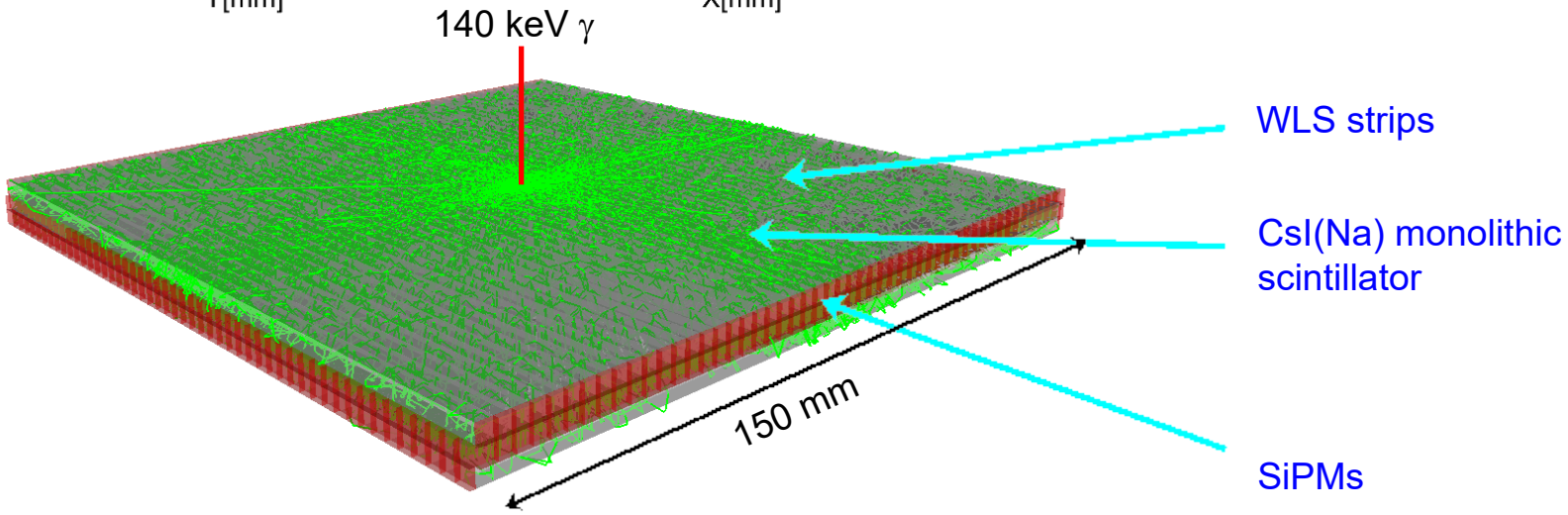
Simulation of 15cm x 15cm x 3 mm CsI(Na) readout 3mm^2 WLS fibers and SiPM











Summary and future work

1. We simulated **LYSO** scintillators 50 mm x 50 mm x 15 mm optically coupled to array and **CsI(Na)** scintillators both readout with square shape WLS fibers connected to silicon photomultipliers (SiPMs).

2. **LYSO** scintillators: best obtained spatial resolution is 2 mm FWHM for PET detector of 200 mm x 200 mm combined of four 50 mm x 50 mm x 10 mm optically coupled crystals readout by 3 mm square shape WLS fibers connected to 264 - 3 mm^2 SiPMs.

3. **CsI(Na)** scintillator: best spatial resolution is 1 mm FWHM is obtained for SPECT detector consisting of a monolithic 100 mm x 100 mm x 15 mm read out with the same size WLS fibers and SiPMs

4. An advantage of the WLS fiber readout technique over direct readout with SiPMs is the reduced number of photodetectors and data acquisition channels. For example direct readout with SiPM of 200 mm x 200 mm PET require 6x6 mm^2 of 1089 SiPMs against 264 of 3x3 mm^2 of SiPMs with 66+66 WLS readout.

5.Inherent DOI of WLS readout detection system.

Prospects for future work:

- developing hit position reconstruction algorithm for WLS system

- simulating double cludding WLS fibers

Thank you for your attention

Questions?