Gamma-ray imaging applications of position-sensitive fast scintillators

Biswajit Das

Department of Nuclear and Atomic Physics,
Tata Institute of Fundamental Research (T.I.F.R)
Mumbai, India

Introduction:

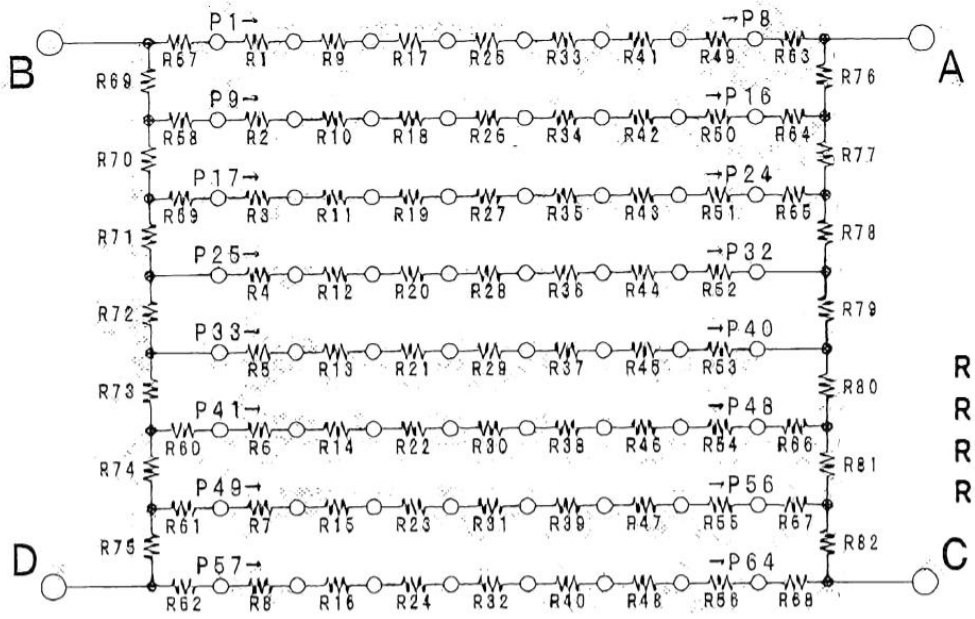
- Position Sensitive Photo Multiplier Tubes(PSPMT) coupled with a scintillator crystal converts the scintillation light into a current signal in the localized photo-cathode.

- The current signal distribution contains important information regarding energy, timing and the interaction position of the γ -ray in the detector crystal.

- The detector can be used in:

i) Pulse shape analysis and scanning of a segmented HPGe detector
ii) Medical imaging
iii) Back scattering imaging
iv) Compton camera
v) Study of nuclear rare decay experiment, polarization

- The PSPMT is equipped with a mesh of 8 horizontal (X) and 8 vertical (Y) anode-wires.
- The PMT signals are distributed through a resistive network.
- The cathode signal of the $LaBr_3$(Ce)-PSPMT gives the γ-ray energy information.
- Four anode signals contain X-Y position information of the γ-ray interaction position in the crystal.



$$X_{position} = \frac{(a_2 B + a_4 D)}{(A+B+C+D)} + b$$

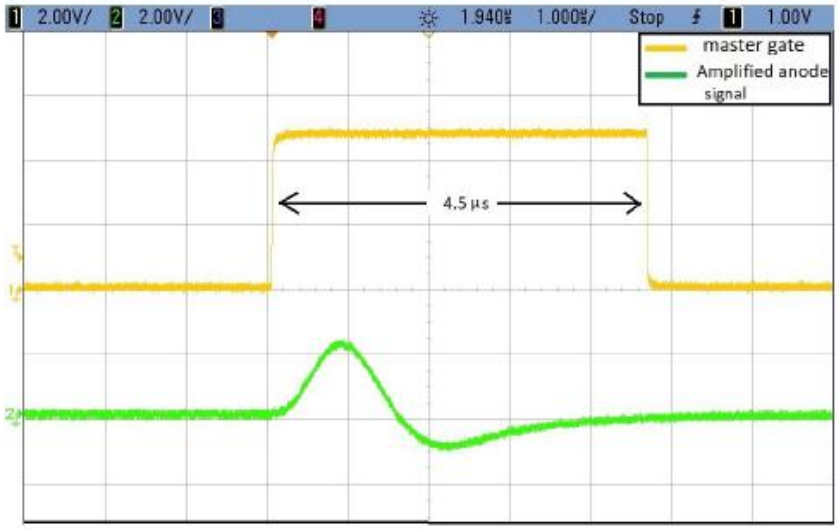
$$Y_{position} = \frac{(a_3 C + a_4 D)}{(A+B+C+D)} + b$$

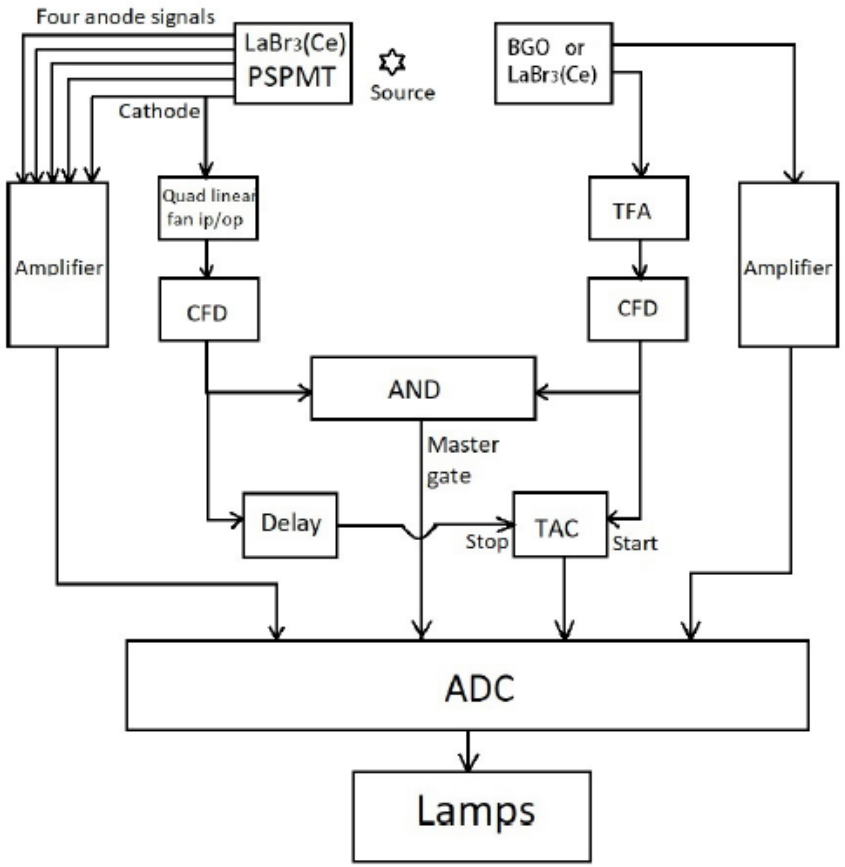
R1−R56 : 1 kΩ (±1 %, 0. 125 W)
R59−R60, R65−R66, R69−R82 : 75 Ω (±1 %, 0. 125 W)
R58, R61, R64, R67 : 220 Ω (±1 %, 0. 125 W)
R57, R62−R63, R68 : 430 Ω (±1 %, 0. 125 W)

Detector set-up

- Image of BGO and $LaBr_3(Ce)$ detectors has been constructed using coincidence technique.

- The master gate has been generated by $LaBr_3(Ce)$-PSPMT and an ancillary detector signal.

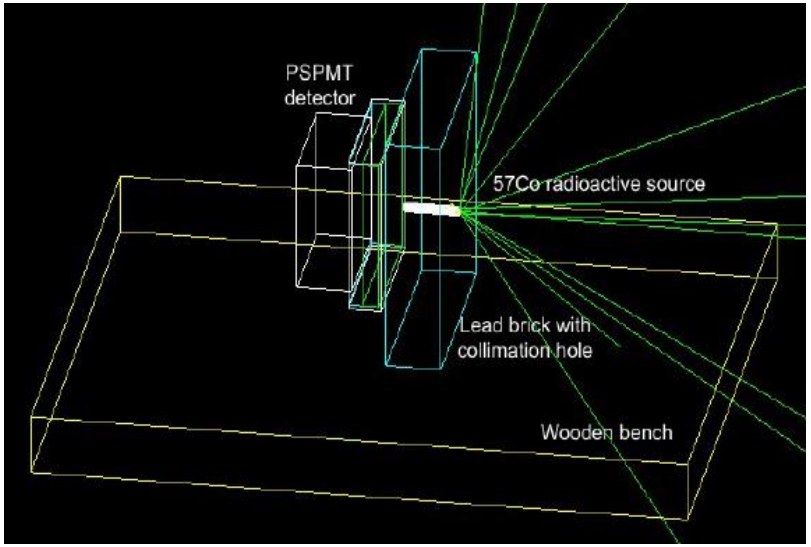


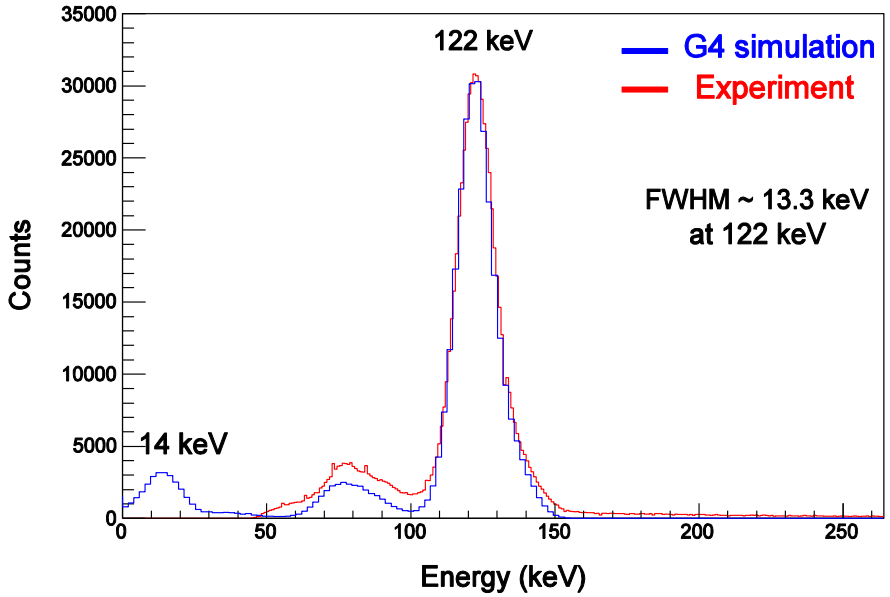


Experiment and simulation results

Crystal calibration:

- Collimated 122 keV γ-ray source (57Co) has been used.
- Data has been taken without coincidence to calibrate the position throughout the crystal .
- Irradiation spots of different positions has been obtained.

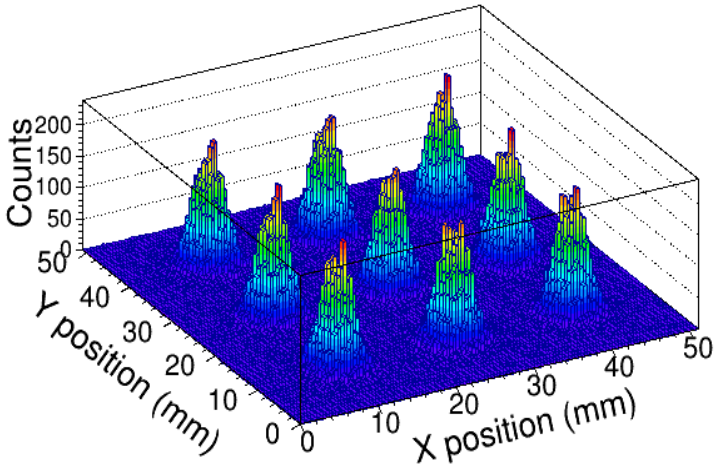




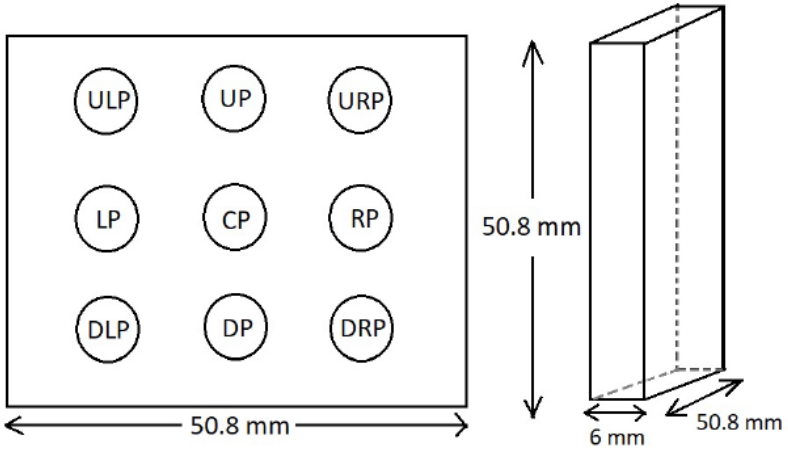
Experiment and simulation results

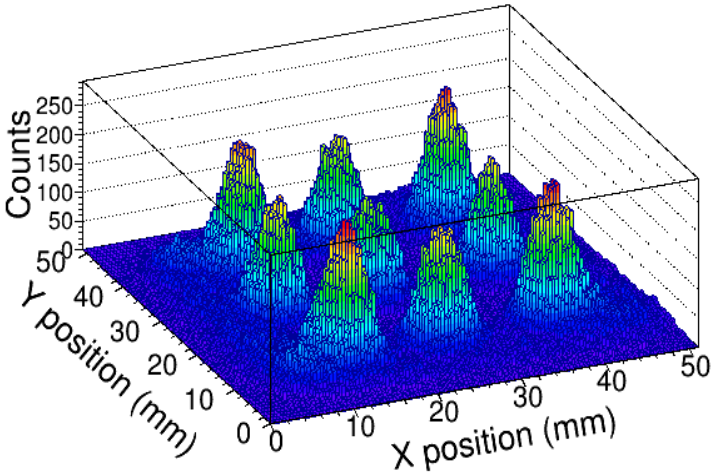
- Irradiation spot is obtain by energy gate condition (at 122 keV).
- The FWHM is found to be 3.0 - 3.5 mm with 2.0 mm collimated gamma rays.

- Thin crystal → better position resolution.
- Position resolution is slightly poor near the edges.



G4 simulation

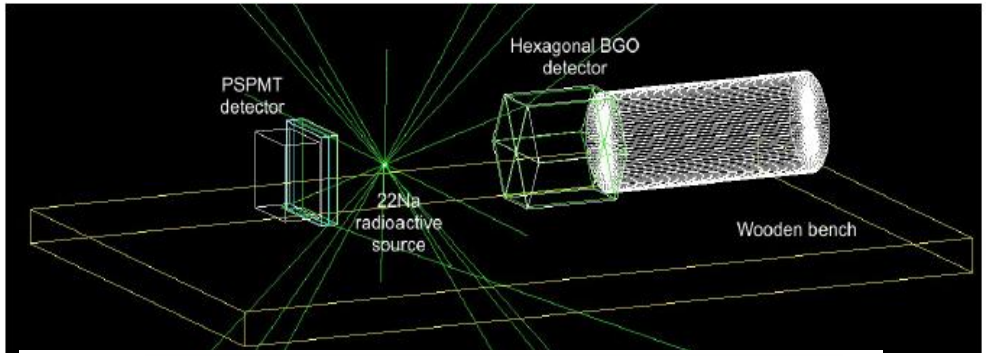


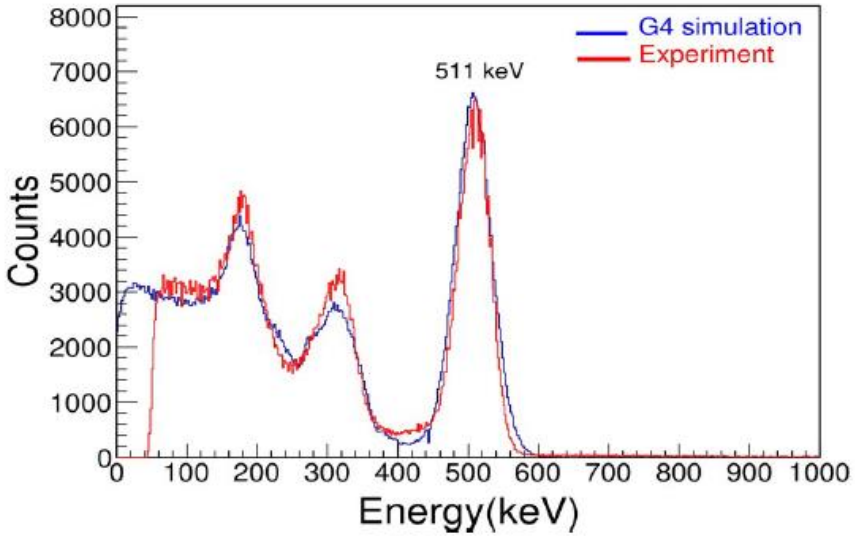


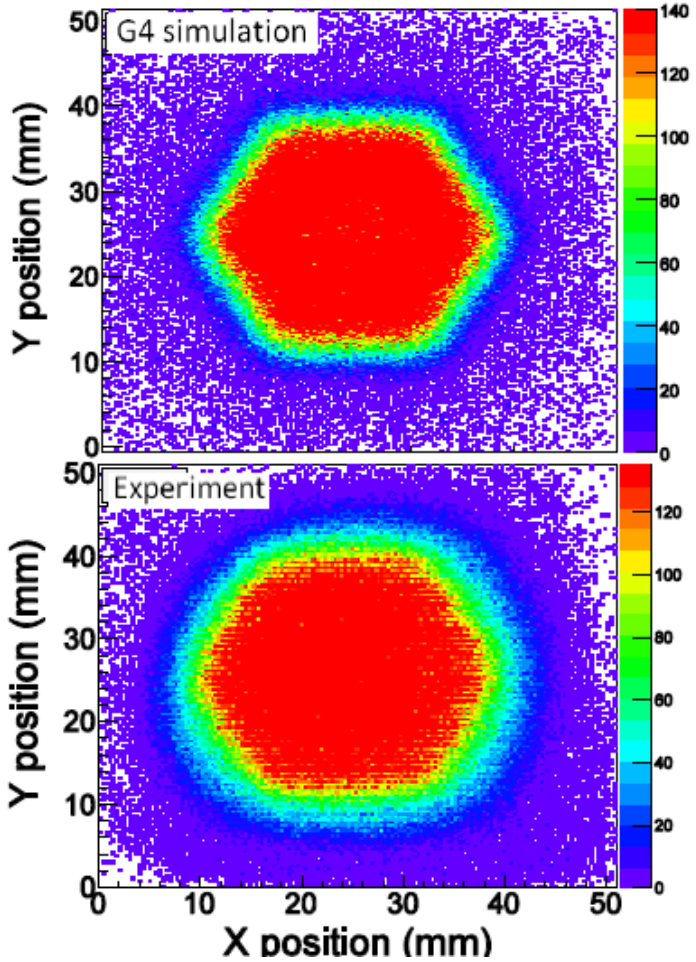
Experiment

Imaging in coincidence

- Coincidence between position sensitive detector and a hexagonal BGO detector.
- Image reconstructed → Energy gate on 511 keV.

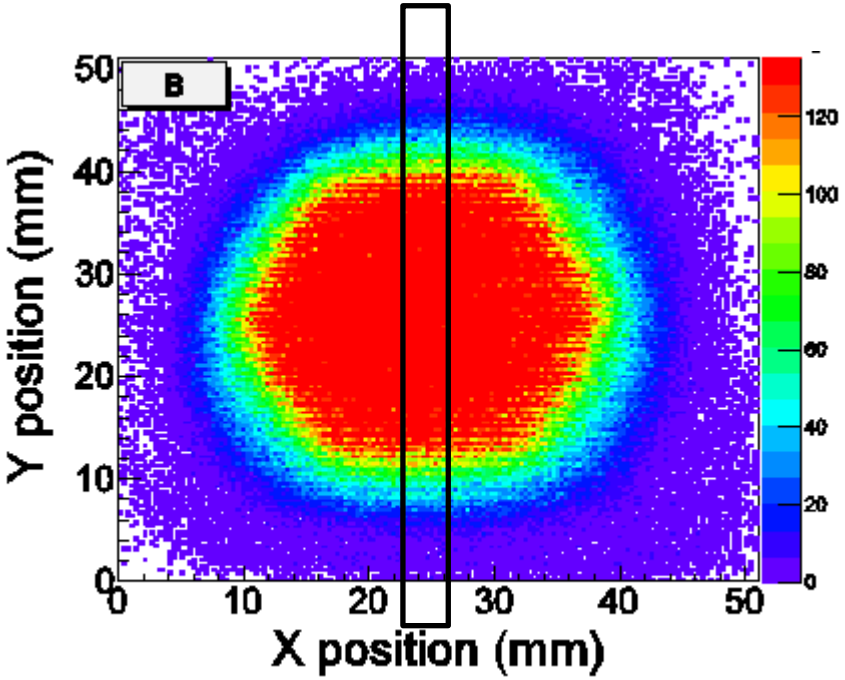


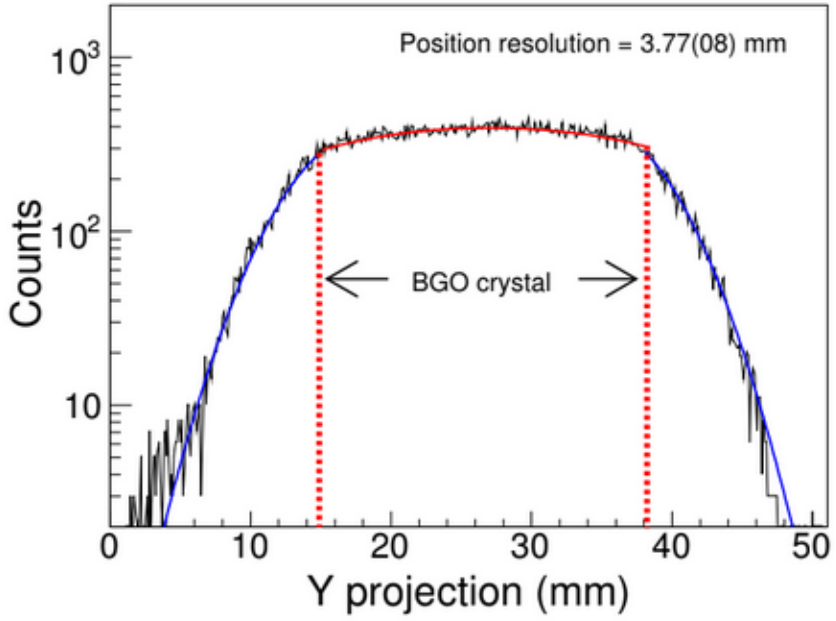




Imaging in coincidence

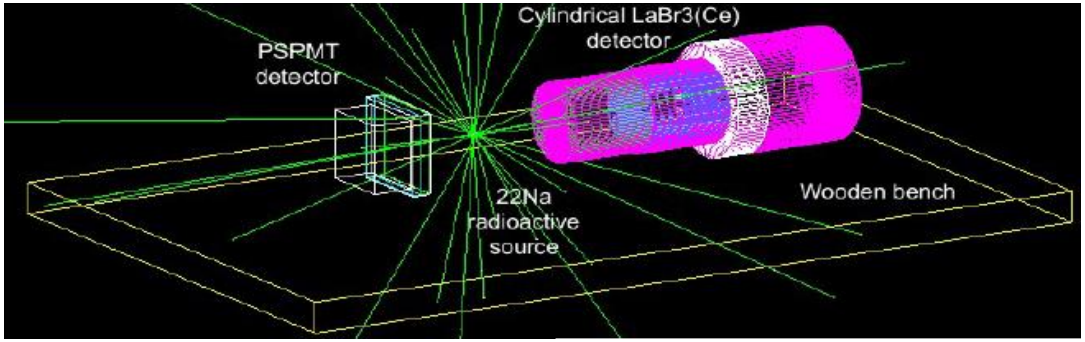
- Position resolution from → fitting of a projection of a slice of BGO image.
- FWHM = 3.77(08) mm.
- Efficiency at various point of the ancillary detector volume has been studied.
- Edge effect of the PSPMT detector can be studied.

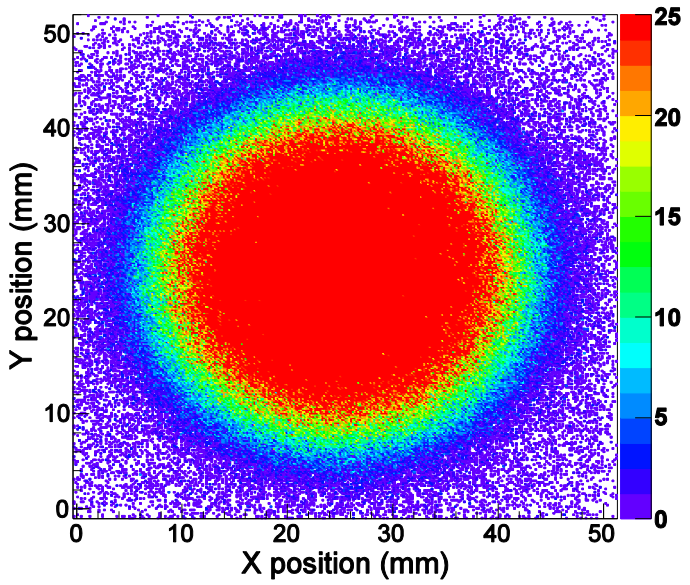




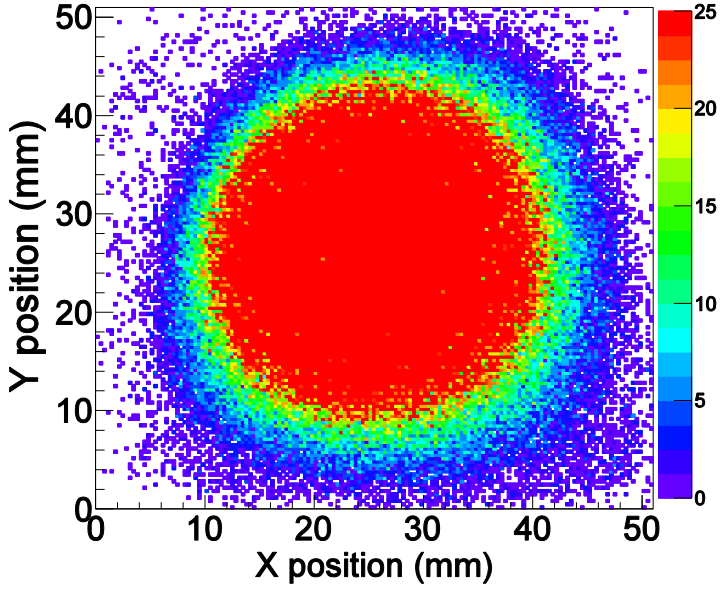
Imaging in coincidence

- Image reconstructed of $LaBr_3$(cylindrical) detector in coincidence with PSPMT detector.
- Image obtained → energy gate on 511 keV on both detectors.





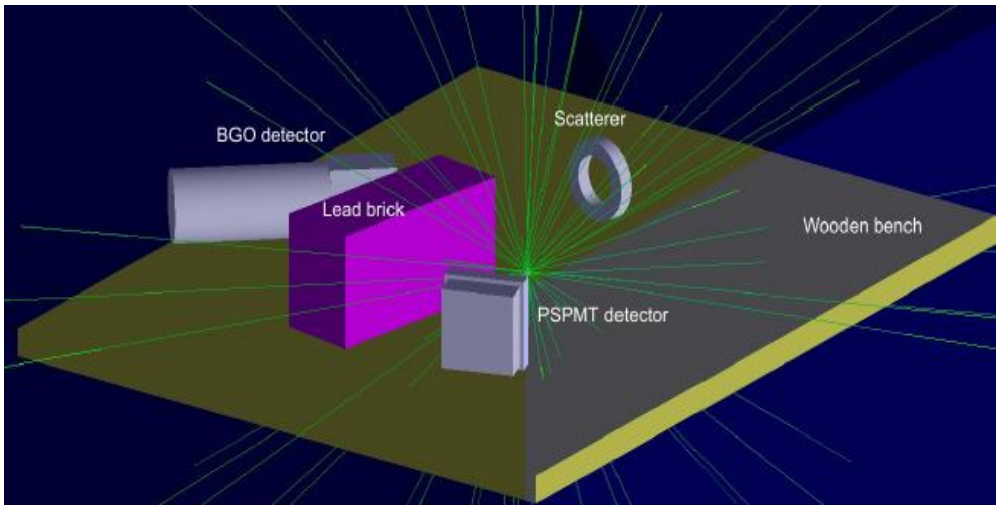
simulation

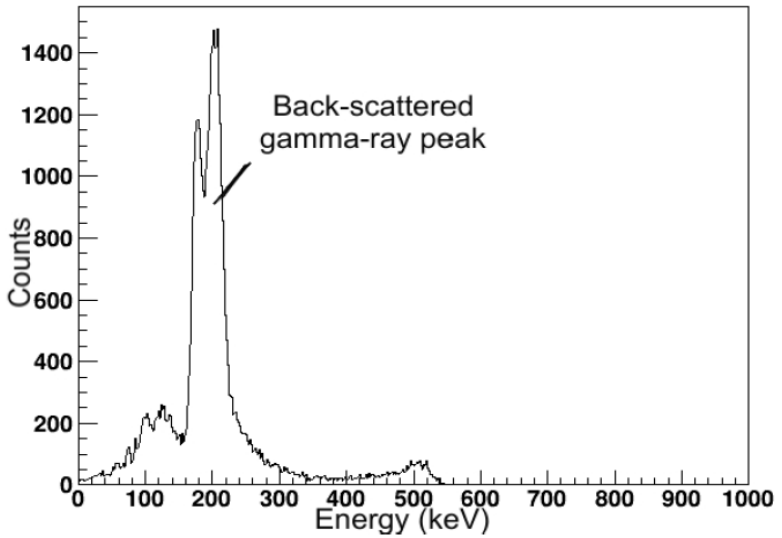


Experiment

Imaging by back scattering:

- Gamma-backscattering experiment → useful technique to obtain the image and in determining density, thickness, and composition of backscattering material.
- Useful in industry as well.
- An optimum geometry in GEANT4 → for image reconstruction.
- Two 511 keV from e^--e^+ annihilation from ^{22}Na source have been used.

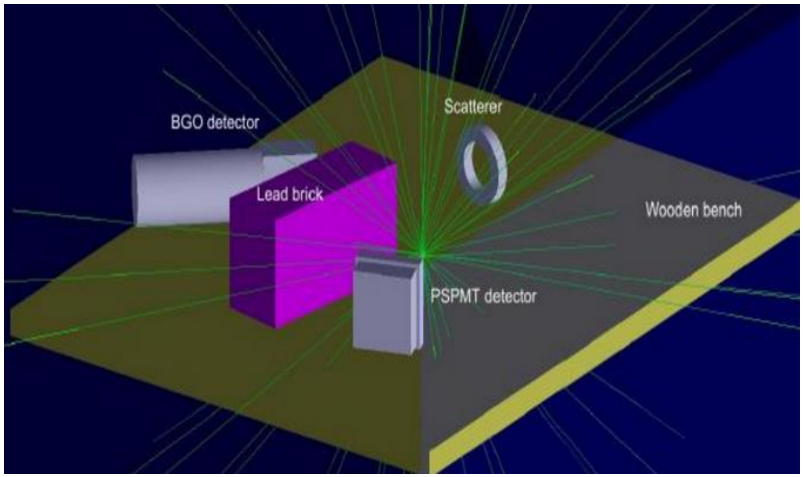


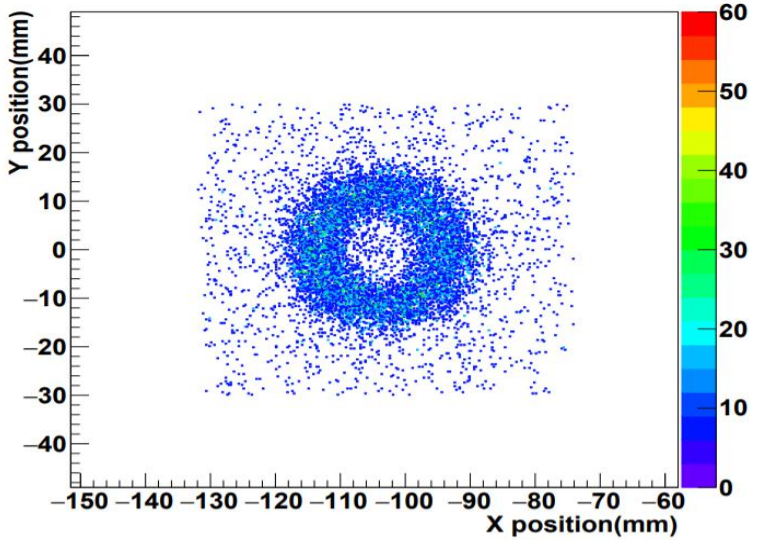


Imaging by back scattering:

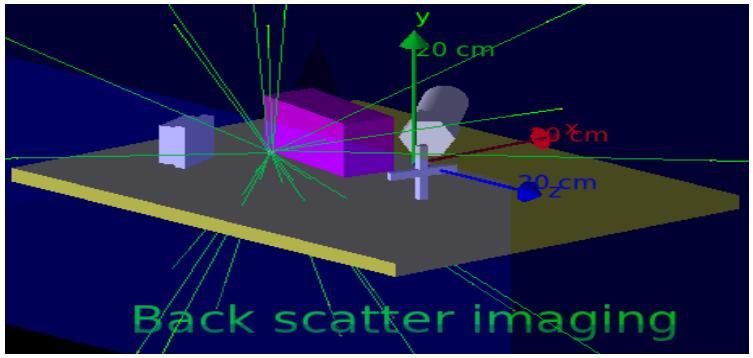
- Image reconstructed of a metallic ring.
- Compton scattered events were collected by BGO/$LaBr_3$(Ce) detector.

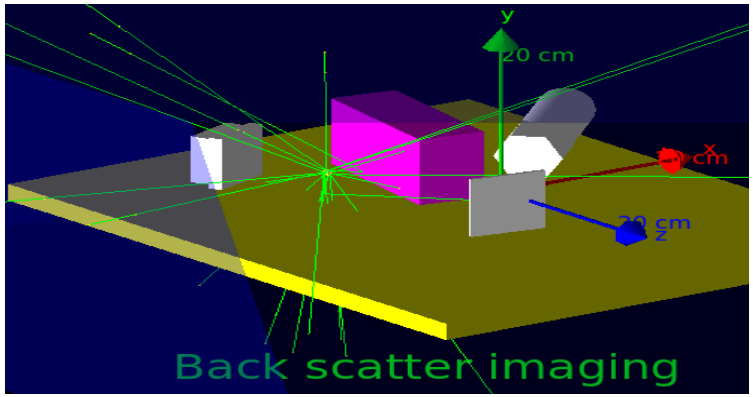
- Interaction positions of the γ -rays on the scatterer has been obtained in energy gated condition:
  - i) $490 < E_{pspmt} < 530$ keV and
  - ii) $150 < E_{BGO/LaBr3(Ce)} < 300$ keV

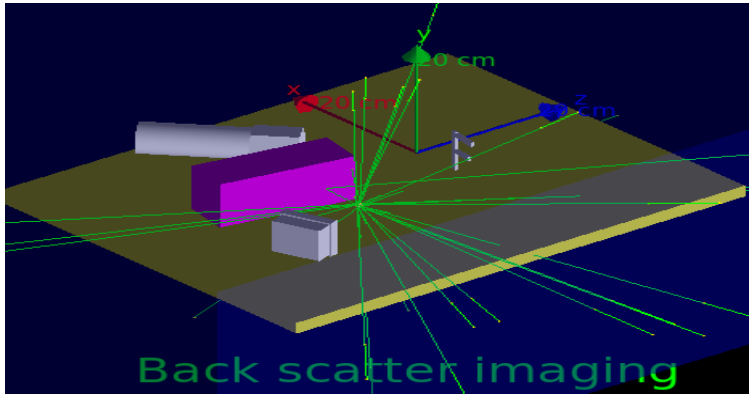


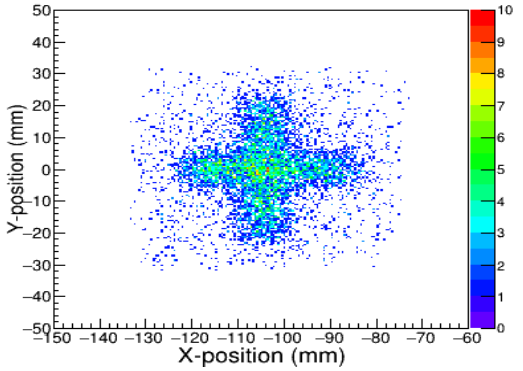


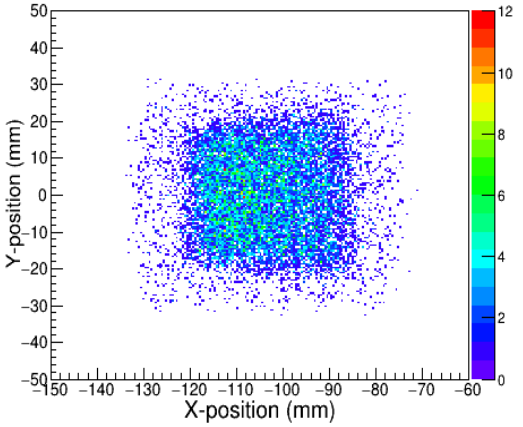
Imaging by Compton's back-scattering

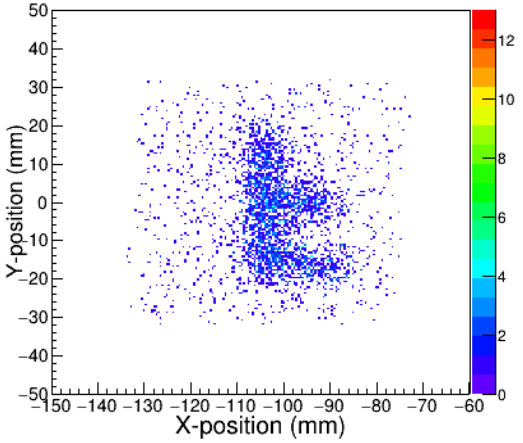




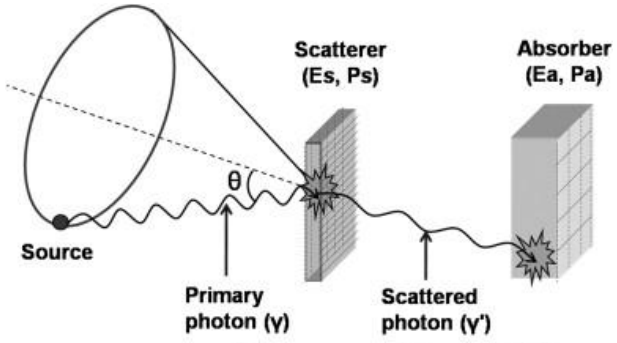






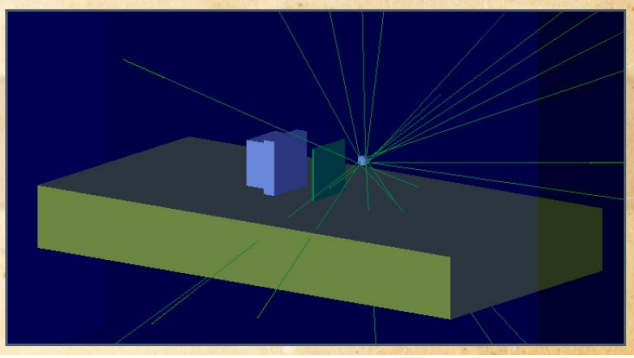


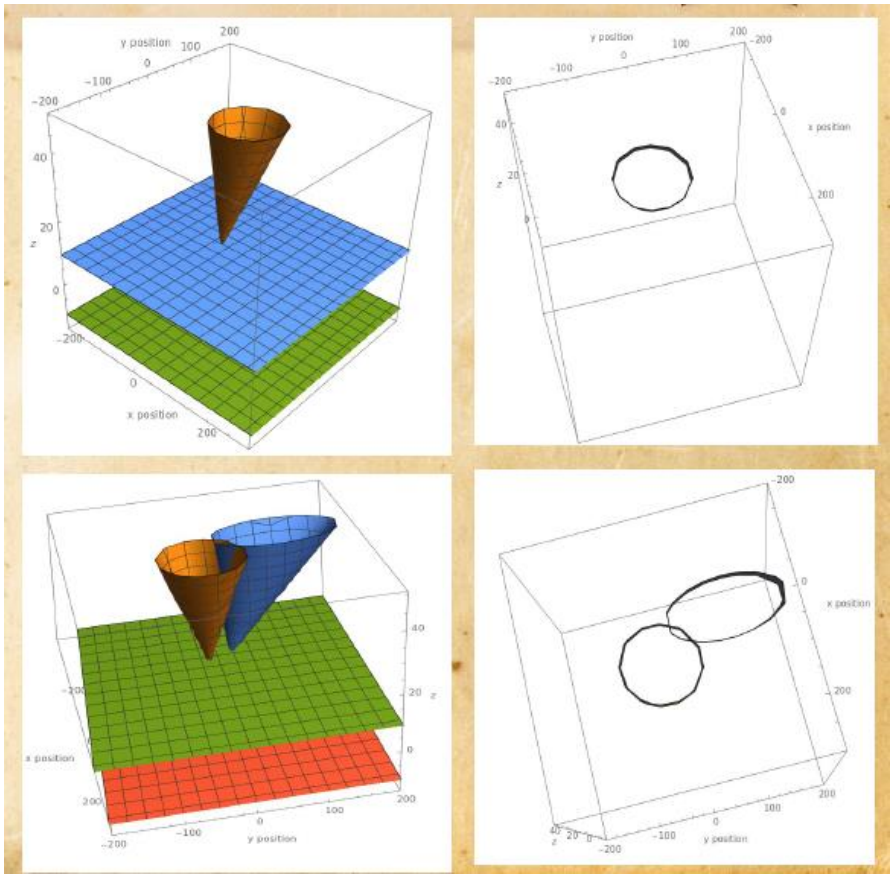
- Compton camera:

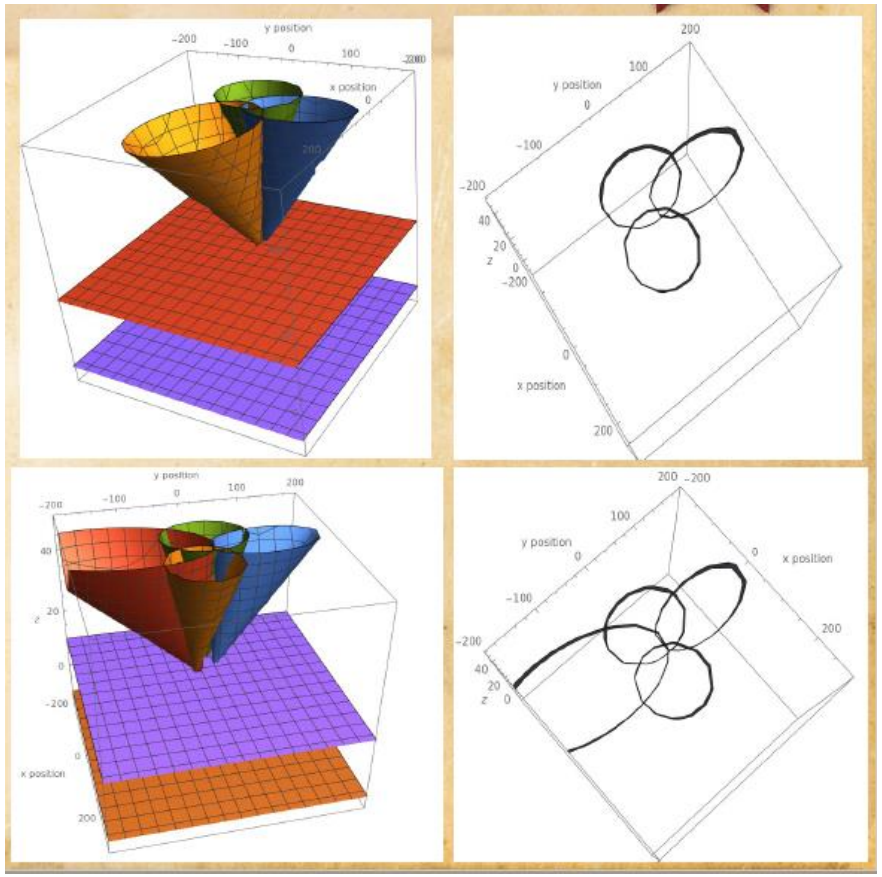


$$\theta = \cos^{-1}\left[1 + m_0 c^2\left(\frac{1}{E_\gamma} - \frac{1}{E_{\gamma'}}\right)\right]$$

Geant4 simulation result on Compton camera







Summary

- A small $LaBr_3$(Ce)-PSPMT detector setup has been developed for γ- ray tracking and imaging applications.
- The position resolution has been obtained to be about 3.0-3.5 mm, enough for rare decay experiment looking to efficiency.
- A smaller thickness of detector crystal can give better position resolution because of less spread of scintillation light in the crystal volume.
- The 2d image of hexagonal shaped BGO and a cylindrical $LaBr_3$(Ce) crystal have been successfully reconstructed in the $LaBr_3$(Ce)-PSPMT detector by coincidence technique. The results agree well with GEANT4 simulations.
- Image of various shape of scatterer have been reconstructed in the $LaBr_3$(Ce)-PSPMT detector by coincidence technique in back scattering mode.
- Coupling of GAGG and LYSO crystal with PSPMT, and preliminary testing are in progess.

Thank you for your attention

- **Collaborators:**

  R. Palit
  R. Donthi
  A. Kundu
  P. Dey
  Md. S. R. Laskar
  F. S. Babra
  V. Malik
  D. Negi
  S. Jadhav
  B. S. Naidu
  A. T. Vazhappilly