A non-invasive gamma-camera for 3D gamma-ray imaging

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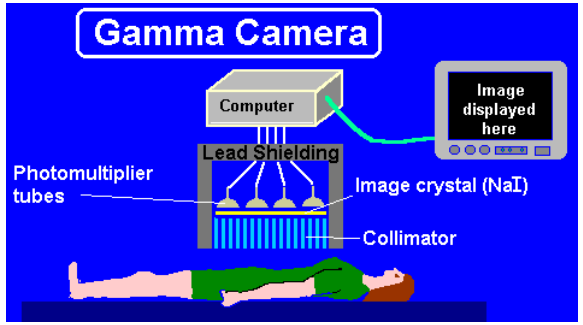
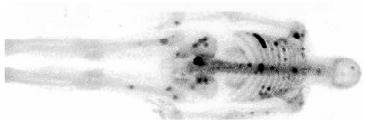
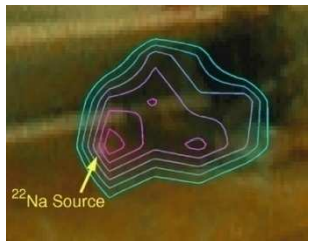
June 24th, 2013

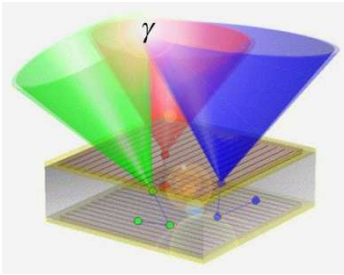
Introduction

o Scintigraphy with gamma-cameras and Compton cameras is an INVASIVE method: a radioactive source needs to be present inside the object (also other 3D techniques like CT, PET, etc).







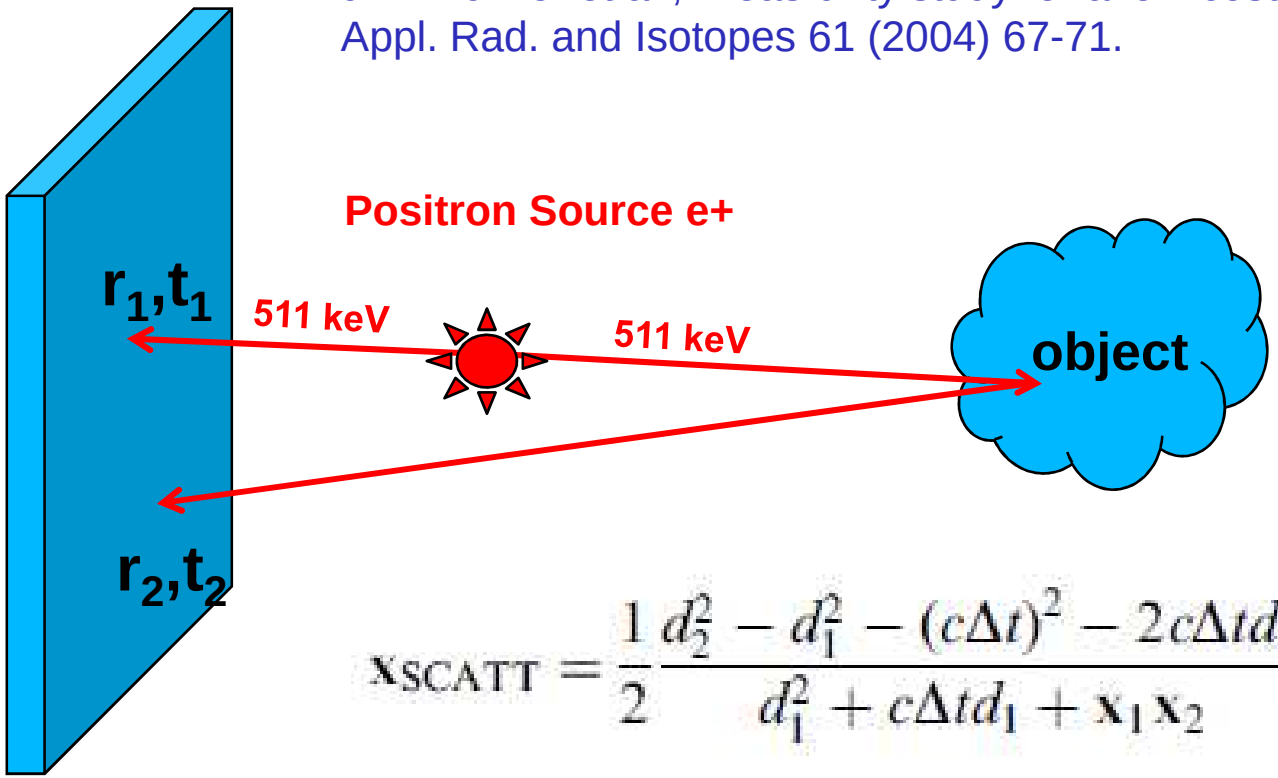


L. Mihailescu, et al., NIM-A 570 (2007) 89-100

The original concept of non-invasive 3D imaging

PACSI (Positron Annihilation Compton Scattering Imaging)

J.R. Tickner et al., “Feasibility study for a low-cost 3D gamma-ray camera”, Appl. Rad. and Isotopes 61 (2004) 67-71.



$$x_{SCATT} = \frac{1}{2}\frac{d_2^2 - d_1^2 - (c\Delta t)^2 - 2c\Delta t d_1}{d_1^2 + c\Delta t d_1 + x_1 x_2} x_1$$

$\Delta t = t_2 - t_1$

Position Sensitive Radiation Detector

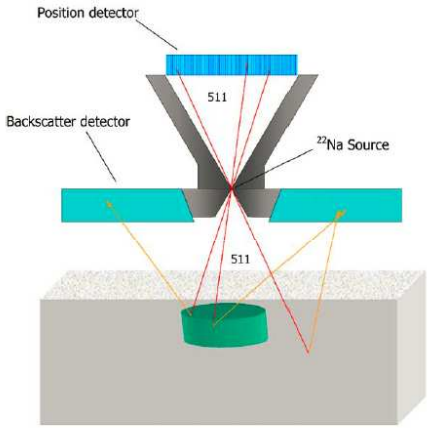
- 3D coordinates measured on an event-by-event basis (real time measurement of the 3D picture)
- NO tomographic alogorithms are required
- Only one side access to the object required

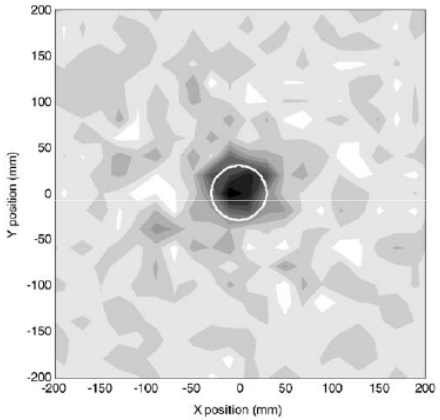
The original concept of non-invasive 3D imaging

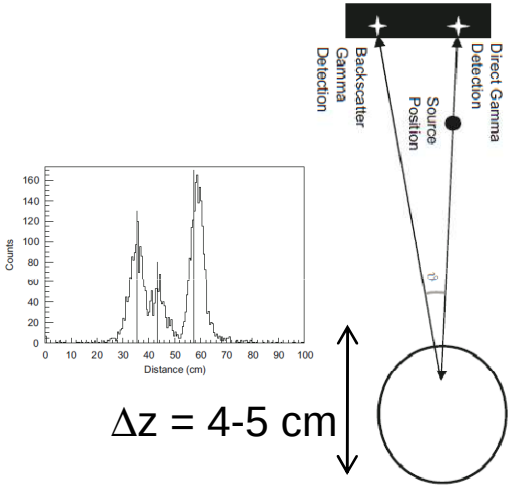
PACSI (Positron Annihilation Compton Scattering Imaging)

- external gamma-ray source
- depth (z) sensitivity via time of flight difference

Buried landmine detection application.







Poor depth resolution: timing resolution of 500 ps lead to >4 cm uncertainty in depth !

J. Kostamovaara, “Distance Determination by Gamma-Ray Time-of-Flight Method”, IEEE Tran. Instr. Meas. 41 (1992) 616-621.

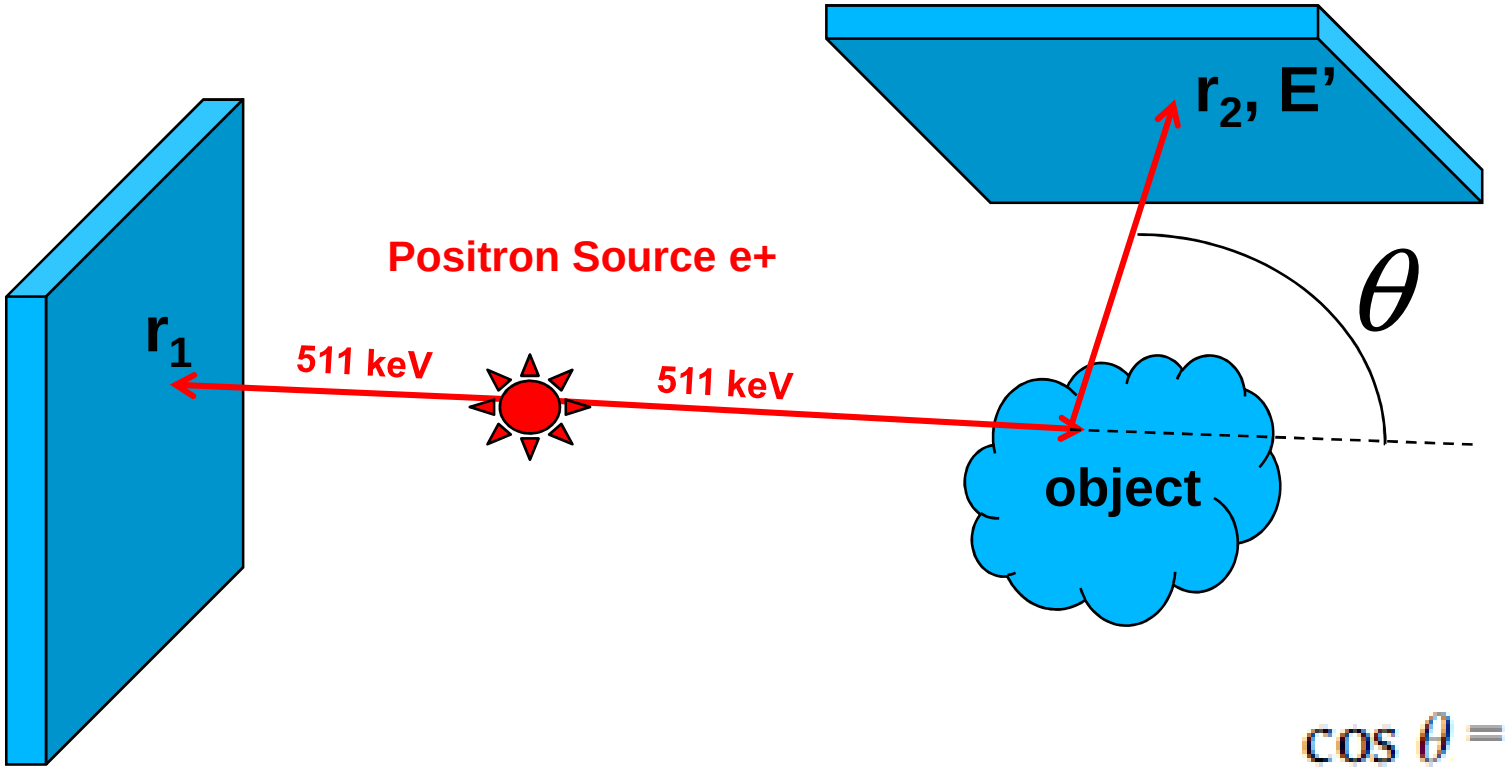
J.R. Tickner et al., “Feasibility study for a low-cost 3D gamma-ray camera”, Appl. Rad. and Isotopes 61 (2004) 67-71.

J. Gerl, et al. “High-resolution gamma backscatter imaging for technical applications”, NIM-A 525 (2004) 328-331.

Q. Looker, et al., “Demonstration of imaging via backscattering of annihilation gamma rays”, NIM-A 615 (2010) 295-300

A novel concept for non-invasive 3D imaging

PACSI (Positron Annihilation Compton Scattering Imaging)



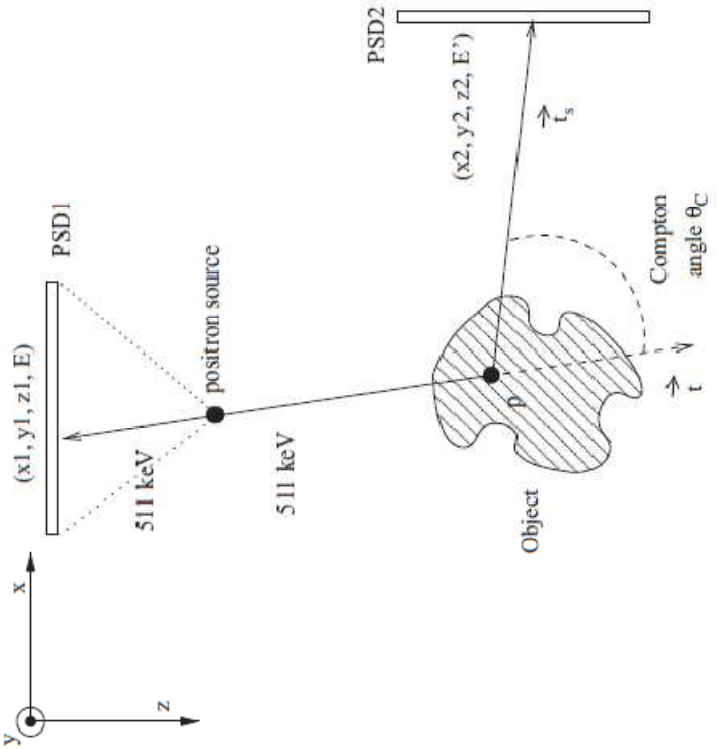
$$\cos\theta = 1 + \frac{511}{E} - \frac{511}{E'}$$

Position Sensitive Radiation Detector

- 3D coordinates measured on an event-by-event basis (real time measurement of the 3D picture) **with high accuracy**
- NO tomographic alogorithms are required
- **At least two-sides** access to the object required

A novel concept for non-invasive 3D imaging

- external g-ray source
- accurate depth (z) via accurate energy and position measurement



$$\vec{t} \cdot \vec{t_s} = |\vec{t}| \cdot |\vec{t_s}| \cdot \cos\theta$$

$$\frac{(\vec{r_s} - \vec{r_1}) \cdot (\vec{r_2} - \vec{r_p})}{|\vec{r_s} - \vec{r_1}| \cdot |\vec{r_2} - \vec{r_p}|} = 1 + \frac{511}{E} - \frac{511}{E'}$$

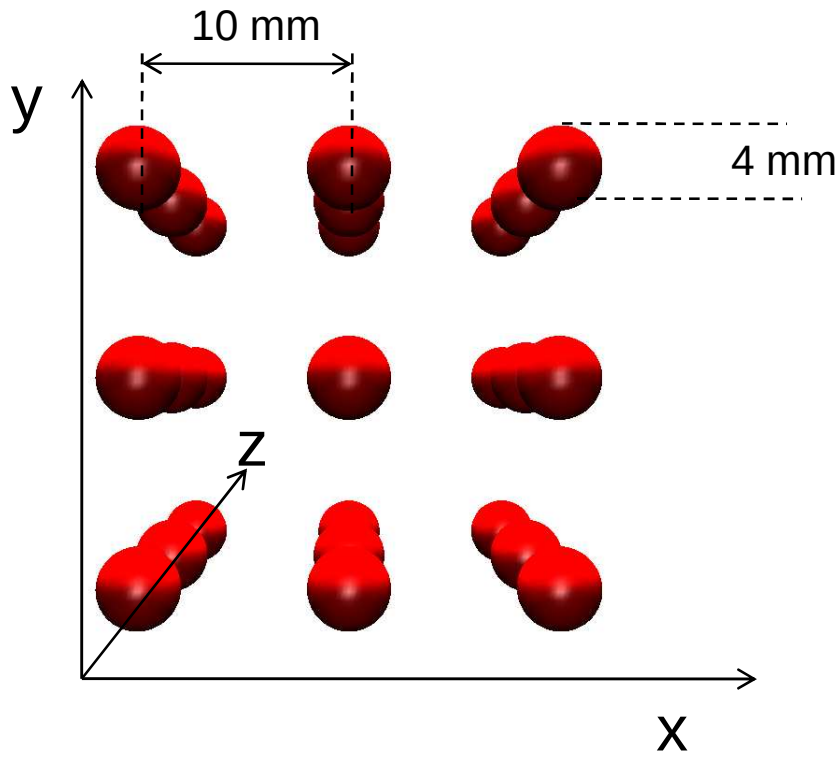
$$\delta\theta = \frac{E}{\sin\theta}\left(\frac{1}{E'^2}\left(\frac{\delta E'}{E'}\right)^2 + 2\sin^2\theta\left(\frac{\delta r}{r}\right)^2\right)^{1/2}$$

Constraint: at least two-side access to the object

C. Domingo-Pardo, "A new technique for 3D gamma-ray imaging: conceptual study of a 3D camera", NIM-A 615 (2012) 123-132

Example: MC Simulation of a non-invasive 3D camera

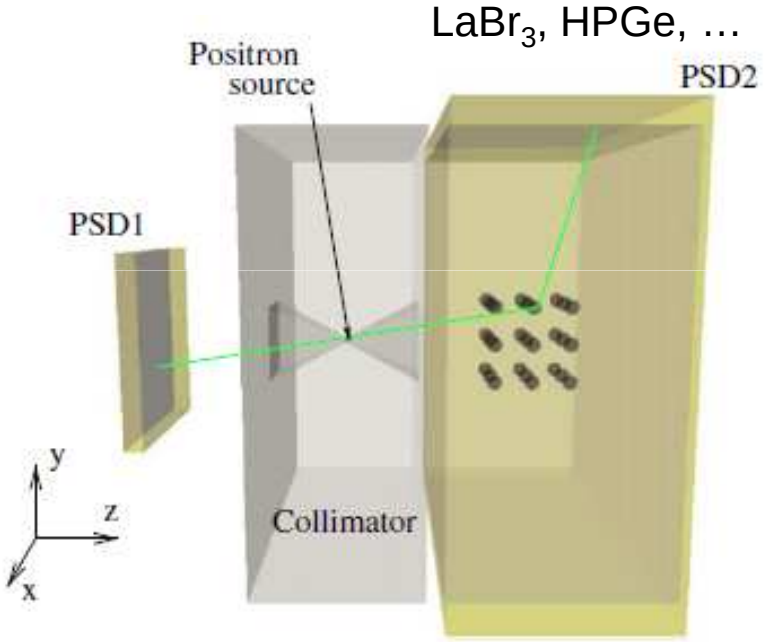
- Object: array of 3 x 3 x 3 iron spheres



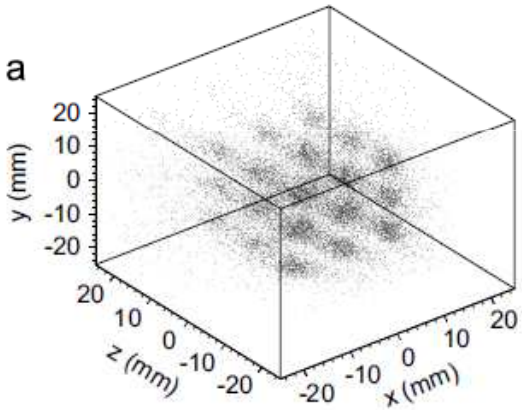
C. Domingo-Pardo, “A new technique for 3D gamma-ray imaging: conceptual study of a 3D camera”, NIM-A 615 (2012) 123-132

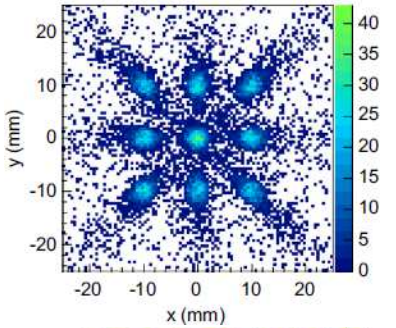
Example: MC Simulation of a non-invasive 3D camera

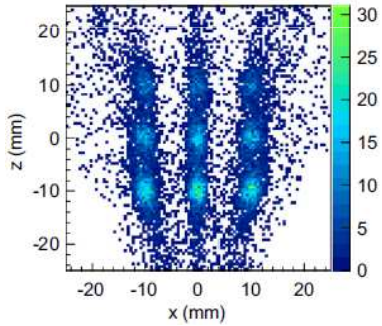
- Object: array of 3 x 3 x 3 iron spheres
- PSD1: LYSO 5x5x1 cm^3, PSD2: $LaBr_3$ or HPGe

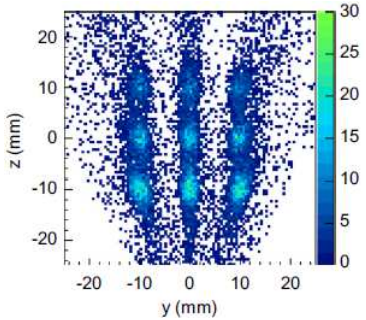


$2x10^8$ Events
3 min for 1 MBq (27 μCi)
5 s for 37 MBq (1 mCi)



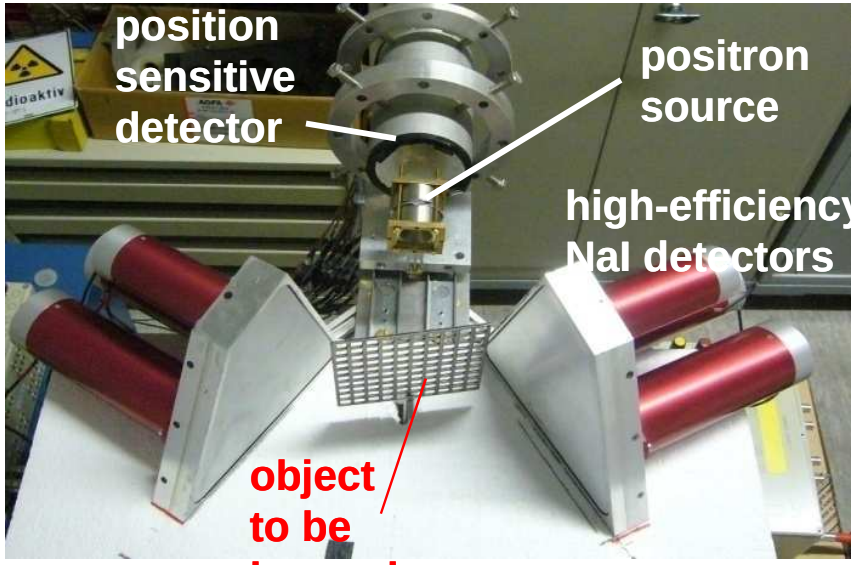


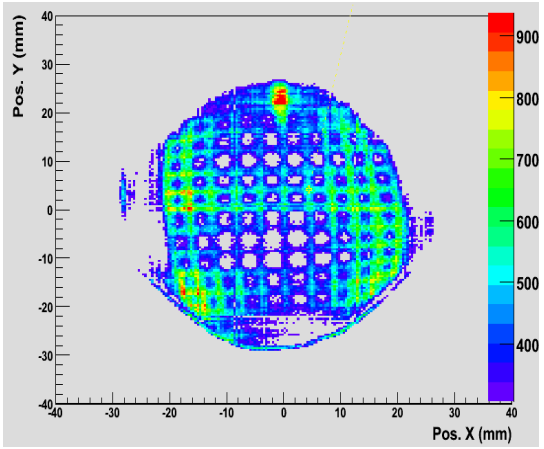




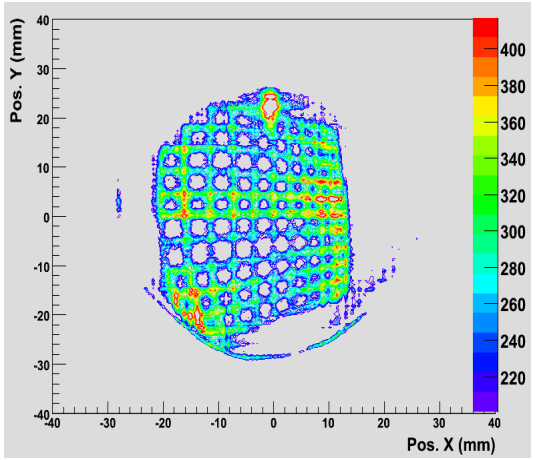
C. Domingo-Pardo, “A new technique for 3D gamma-ray imaging: conceptual study of a 3D camera”, NIM-A 615 (2012) 123-132

Demonstration, 2D imaging tests





0º



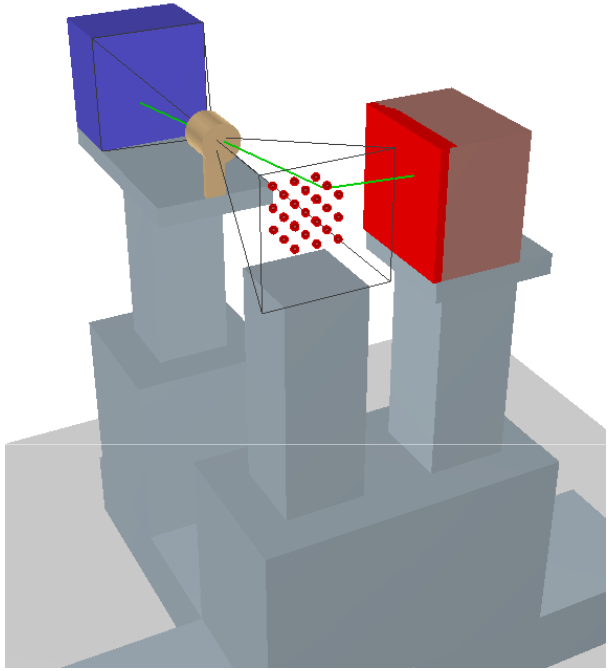
40º

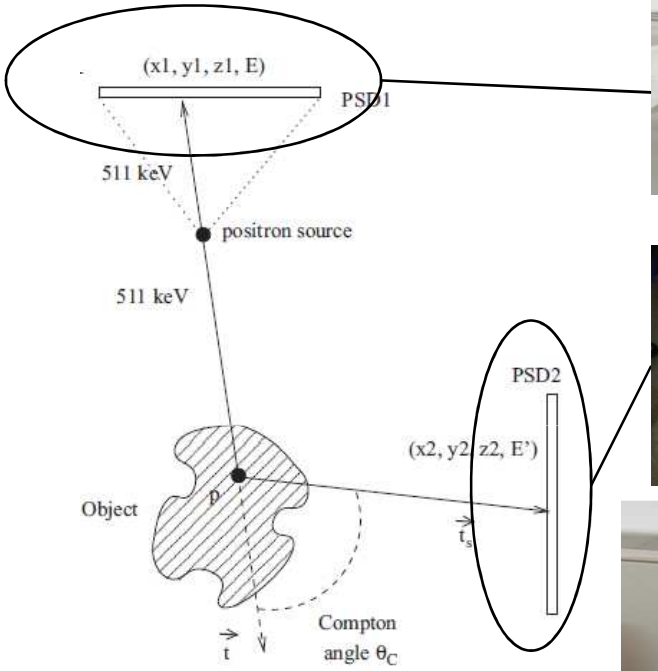
N.Goel, C. Domingo-Pardo et al., “Spatial calibration via imaging techniques of a novel scanning system for the pulse-shape characterization of HPGe detectors”, NIM-A 652 (2011) 591-594

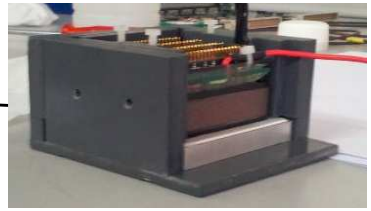
Proof of principle prototype for non-invasive 3D-imaging

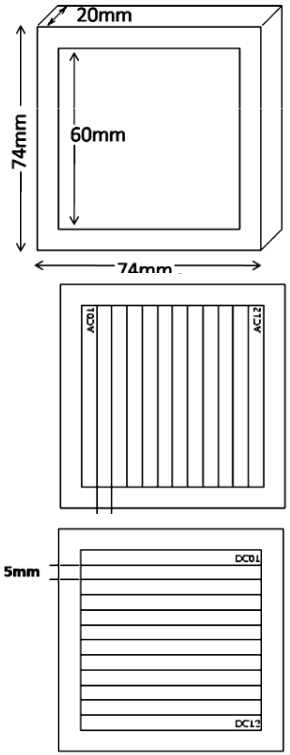
o Non-Invasive 3D Imaging Prototype (2 detectors)

$LaBr_3(Ce)$ 51x51x6 mm^3
Hamamatsu H10966 PS-PMT 64 anodes









Goals:

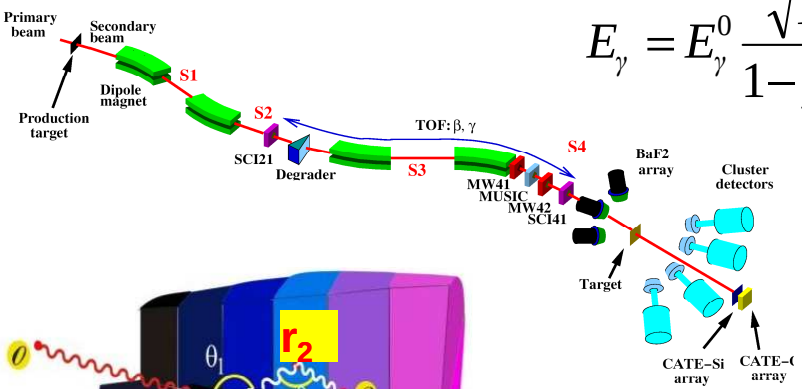
- First experimental proof-of-principle of the 3D method
- Attainable spatial resolution
- Detection sensitivity for different materials (density profiles)

With the support of:

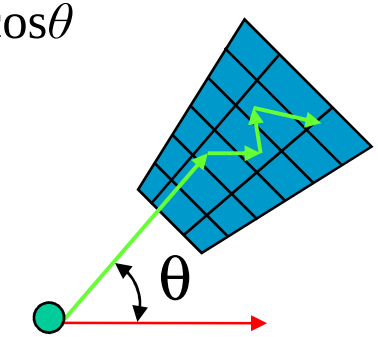
- Projectes Precompetitius Generalitat Valenciana
- Ayudas Grupos Emergentes Generalitat Valenciana

Applications

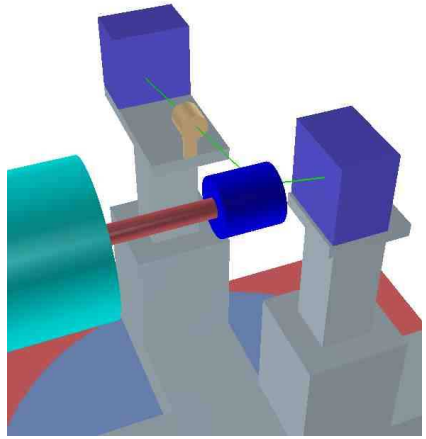
- Spatial characterization of position sensitive HPGe detectors

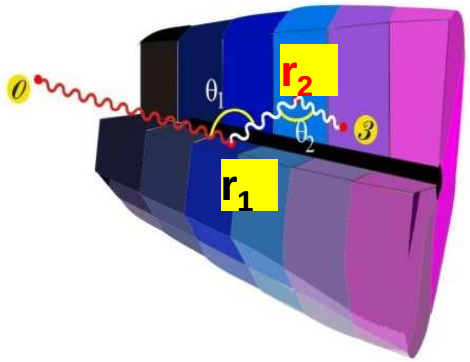


$$E_\gamma = E_\gamma^0 \frac{\sqrt{1-\beta^2}}{1-\beta\cos\theta}$$

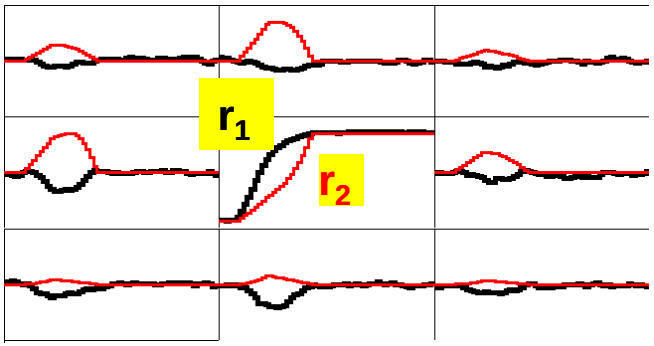


Simultaneous measurement of γ–ray hit position and detector response.





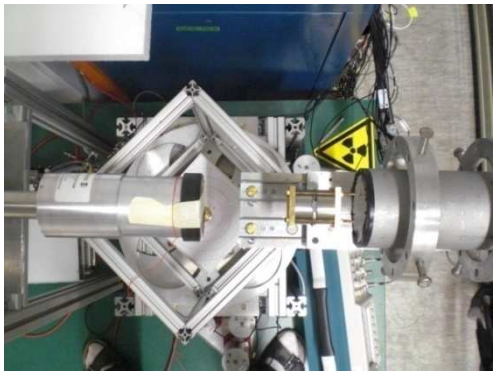
Electric response of the HPGe segments:

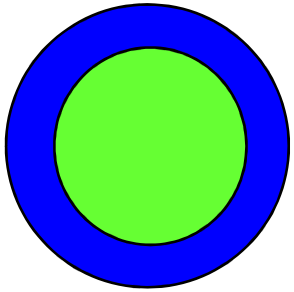


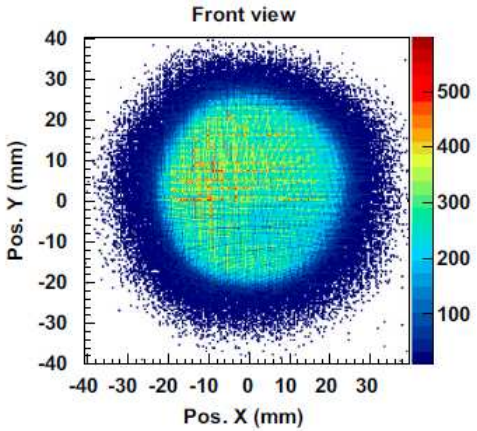
X	Y	Z	Electric detector response
0	0	0	
4	0	0	
4	4	0	

Applications

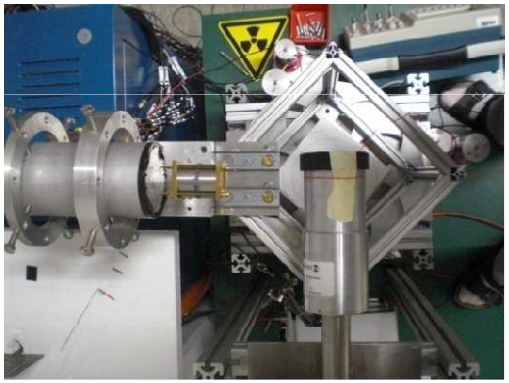
Front view (0 deg):

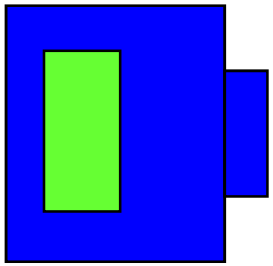


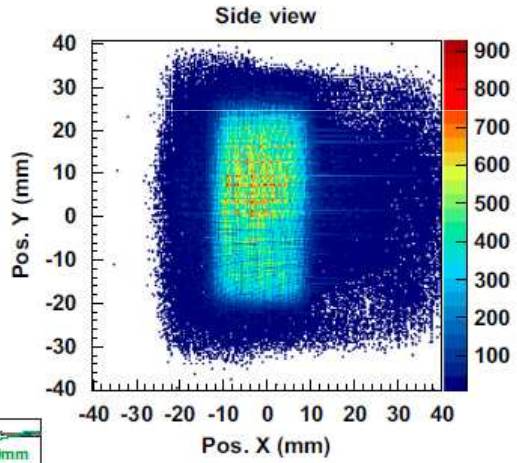




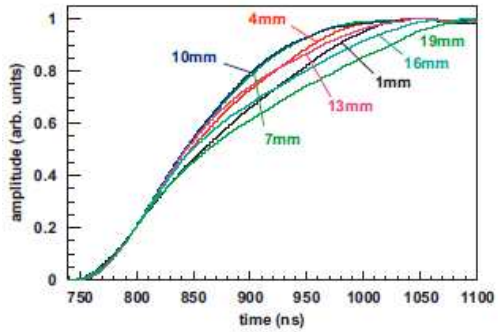
Side view (90 deg):







C. Domingo-Pardo et al., “A novel gamma-ray method for the pulse-shape characterization of position sensitive semiconductor radiation detectors”, NIM-A 643 (2011) 79-88



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Thanks for your attention!