# A New Position Reconstruction Method for Position Sensitive Photomultipliers

MIC 2008

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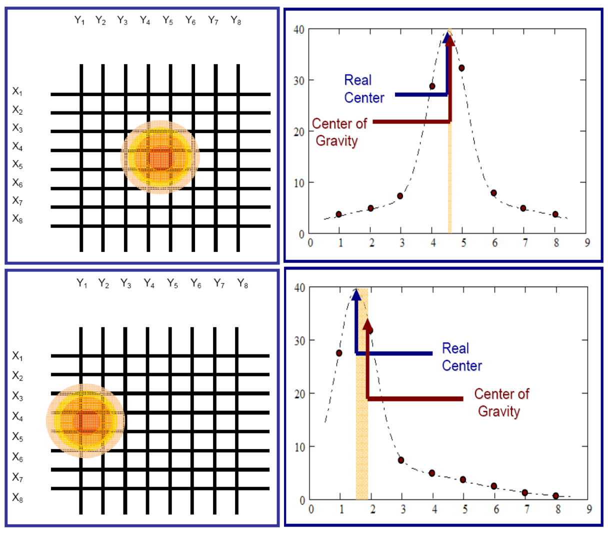
M10-104

A new position reconstruction method for position sensitive photomultiplier tubes is proposed in this work. The algorithm is based on a mathematical model operating on the charge signals recorded from the anode wires of a multi-wired anode system. This method overcomes the usual irregularities produced by the centre of gravity algorithm near the edges of the field of view, especially when a homogeneous scintillation crystal is used. Data are obtained from a small field, high resolution γ-Camera system with a 16X+16Y multi-wired crossed anode using the Position Sensitive Photomultiplier Tube (R2486, HAMAMATSU). The difference in the optical photon distribution for pixelated and homogeneous scintillation crystals is studied with the photon transport system DETECT-2000. Systematic measurements for a group of inorganic homogeneous crystals of CsI(Tl) with 2mm-4mm-8mm-12mm and 20mm in thickness, as well as of BGO with 2mm-3mm-5mm-8mm in thickness, have been performed for different radiation sources ($^{60}$Co, $^{137}$Cs, $^{99m}$Tc). The experimentally obtained parameters for the produced light distribution inside the various crystals are expressed and categorized according to the crystal geometrical characteristics. The developed method seems to drastically improve the resolution of the reconstructed planar information, even when homogeneous scintillation crystals are used.

*Work partially supported by the General Secretariat for Research and Technology Hellas through the Greek-Ukraine bilateral and the PENED (03 EΔ 287) research project, implemented within the framework of the "Reinforcement Programme of Human Research Manpower" (PENED) and co-financed by National and Community Funds (25% from the Greek Ministry of Development-General Secretariat of Research and Technology and 75% from E.U.-European Social Fund).*

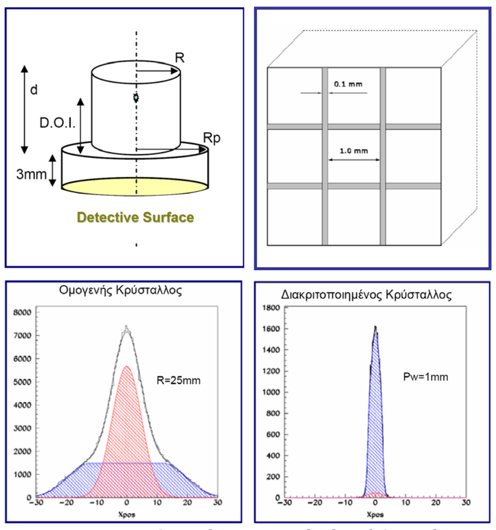
## 1. Definition of the Problem




**Traditional Charge Center of Gravity Algorithm:** Due to the unbalanced charge of a non-central event the traditional (Anger) charge center of gravity algorithm reconstructs incorrectly the position.

$$X = \frac{\sum_i x_i \cdot Qx_i}{\sum_i Qx_i}$$

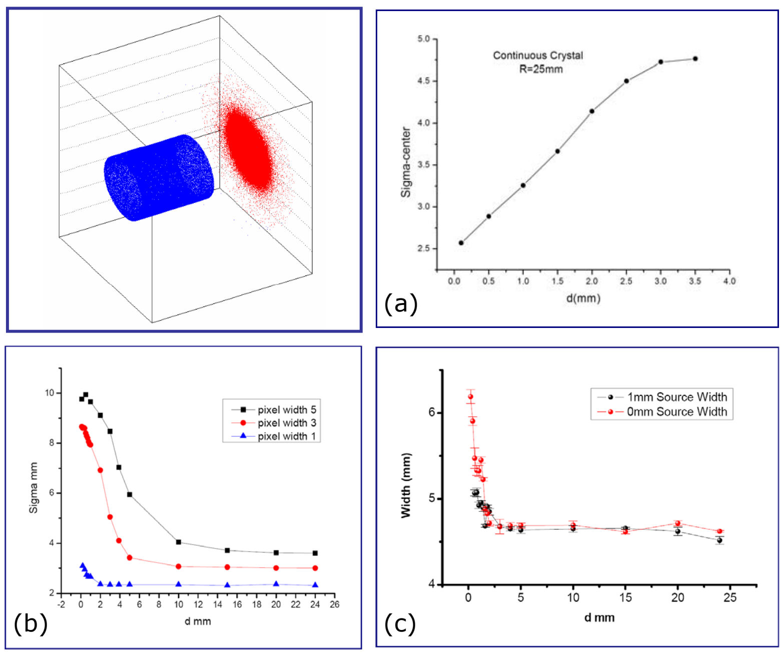
## 2. DETECT-2000 Simulations




**Homogeneous Crystal** **Pixelated Crystal**

**Optical Photon Distribution:** The optical photon distribution inside the scintillation crystal from a γ-ray absorption can be approximated with an overlap of two Gauss curves due to the different number of inner reflections.

## 3. Dependence on DOI and Geometry




**DETECT-2000 Simulation Results**

According to the analyzed data, both, continuous and pixelated crystals, show a dependence of the optical photon distribution on the following parameters:

(a) Depth of Interaction (DOI) for homogeneous crystals

(b) Pixel-size for pixelated crystals

(c) Dimension of the photon source

## 4. Modeling the Electron Cloud

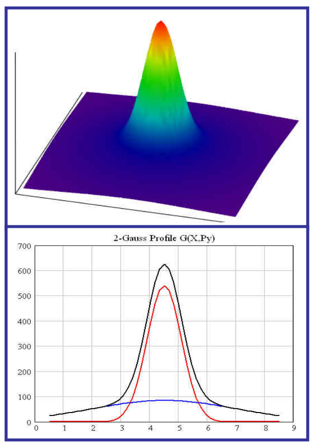
$$G(P_x,P_y,x,y)=G_1(P_x,P_y,x,y)+G_2(P_x,P_y,x,y)$$

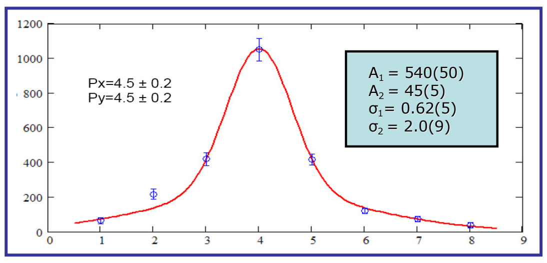
$$G_1(P_x,P_y,x,y)=A_1\cdot e^{-\frac{(x-P_x)^2+(y-P_y)^2}{2\sigma_1^2}}$$

$$G_2(P_x,P_y,x,y)=A_2\cdot e^{-\frac{(x-P_x)^2+(y-P_y)^2}{2\sigma_2^2}}$$

$$X_{Wire}:\quad Qx_i(P_x,P_y,x_i)=k\int_{y_1}^{y_2}G(P_x,P_y,x_i,y)\,dy$$

$$Y_{Wire}:\quad Qy_i(P_x,P_y,y_i)=k\int_{x_1}^{x_2}G(P_x,P_y,x,y_i)\,dx$$

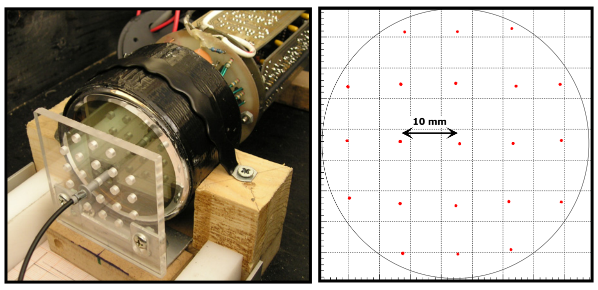



**Experimental Determination of the Model Parameters:**

The charge is parameterized with two Gaussian shaped distributions. Comparison with experimental results fixes the model free parameters ($A_1$, $A_2$, $\sigma_1$, $\sigma_2$) and introduces a new position [$P_x$,$P_y$] reconstruction algorithm through the inverse procedure.

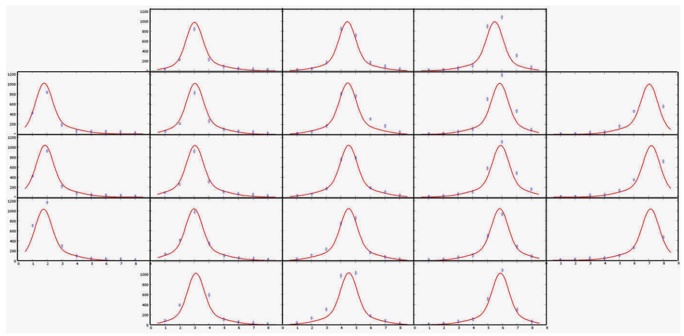
## 5. Experimental Control



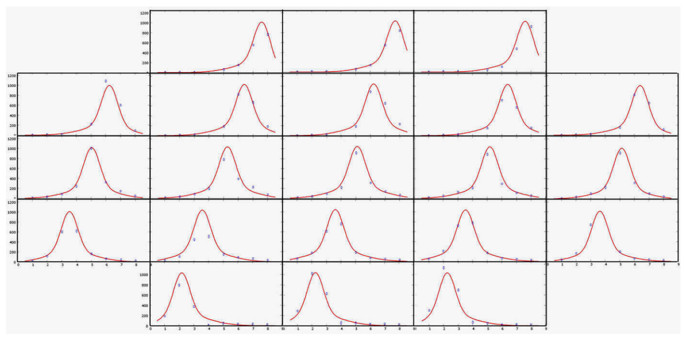

**Results of a Global 2-Gauss Fit Inverse Procedure**

$A_1$ = 593(7) $A_2$ = 56(5)
$\sigma_1$ = 0.546(8) $\sigma_2$ = 1.69(6)

**Experimental Control with Light Pulses:** A grid with equidistance holes is used to guide control light pulses produced by a green LED. The charge distribution is measured for all positions and with an inverse procedure, based on the previous model, the light emission parameters are best estimated. With a fixed set of the ($A_1$, $A_2$, $\sigma_1$, $\sigma_2$) values the charge distribution is re-calculated (red lines) and directly compared to the measured values (blue points). A reasonable agreement for the whole effective area of the Position Sensitive Photo-Multiplier Tube is achieved.

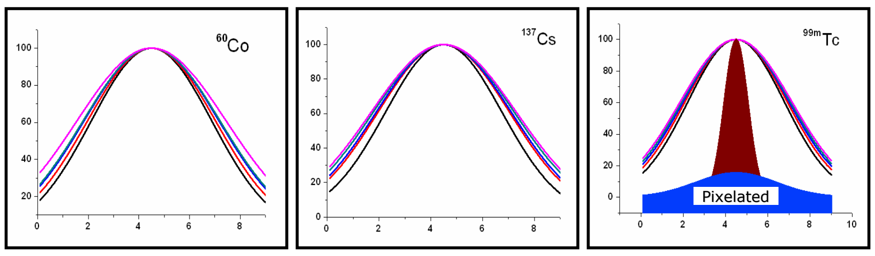


Charge across X-Wires ($Q_x$)



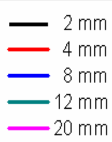
Charge across Y-Wires ($Q_y$)

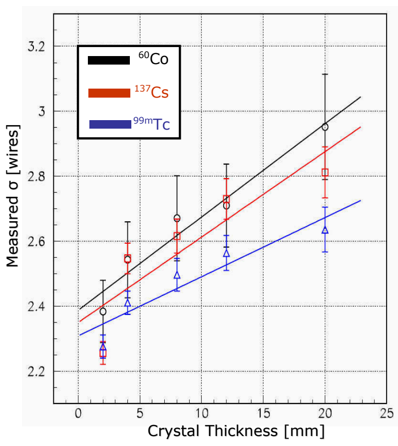
## 6. Measured Light Distribution in Scintillation Crystals




**Crystals Tested**

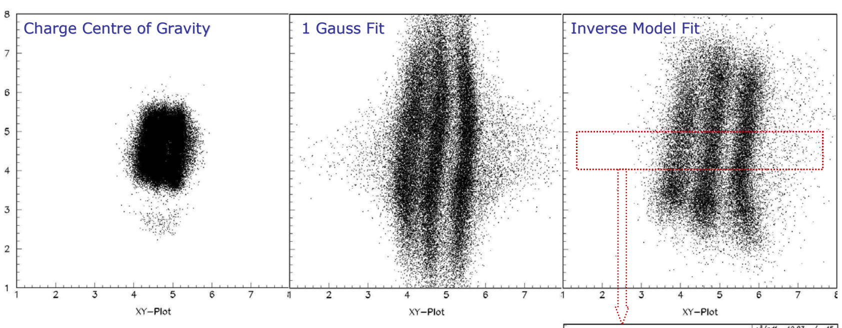
| | |
|---|---|
| **CsI(Tl) Homogeneous Crystals:** | **2mm – 4mm – 8mm – 12mm – 20mm** |
| **BGO Homogeneous Crystals:** | **2mm – 3mm – 5mm – 8mm** |
| **CsI(Tl) Pixelated Crystal:** | **4mm (1mm pixel size)** |



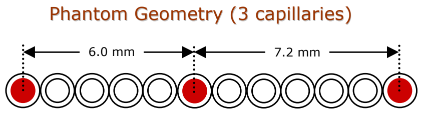



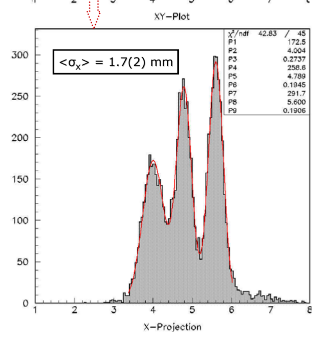

**Light Distribution in Scintillation Crystals:** Various inorganic homogeneous crystals (CsI(Tl), BGO), as well as a CsI(Tl) pixelated one, have been irradiated with γ-sources. Based on the previously described procedure the generated light distribution inside the scintillators has been investigated from the measured charge distribution on the multi-wired PSPMT anode. One gauss distribution is sufficient to describe the light in all homogeneous crystals; due to the strong reflective effects the pixelated crystal demands the full set of the two-gaussian distribution. The best fitted set of the (A,σ) parameters is plotted against the crystal thickness in the diagrams above.

## 7. Reconstruction with Homogenous Crystal




Phantom Geometry (3 capillaries)




**Experimental Results:** Raw planar images from three capillaries filled with $^{99m}$Tc solution using a homogenous CsI(Tl) crystal for various reconstruction algorithms. Only the new algorithm can resolve the capillaries.