



A novel 3D Scanner for gamma tracking detectors

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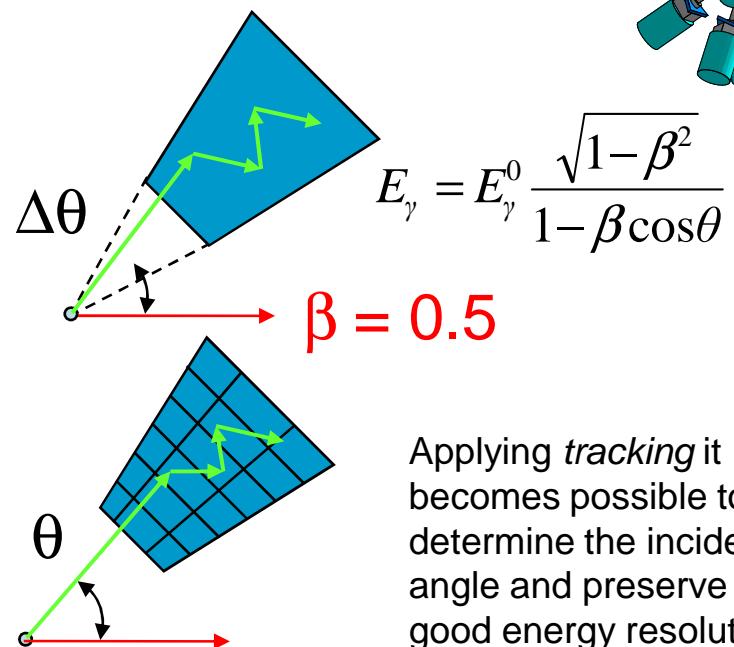
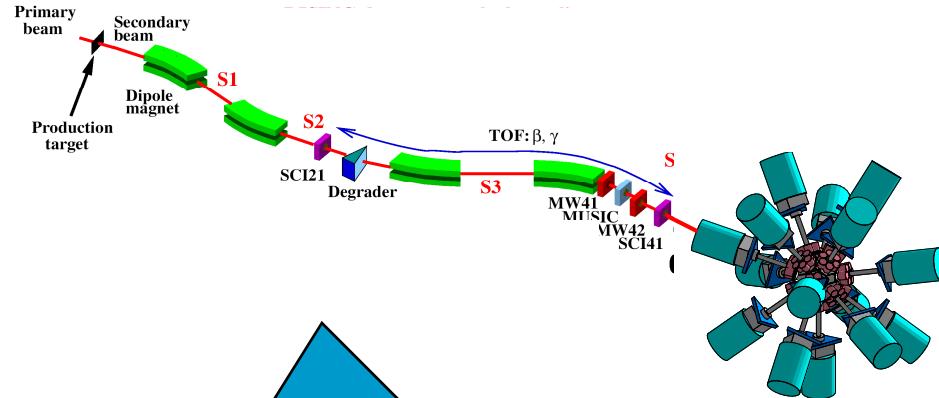
Outline

- Motivation & Introduction
- Novel technique using a γ -camera
- Development of an improved γ -camera
- Implementation in our Scanning system
- Validation of the new method using a Planar HPGe detector
- Outlook

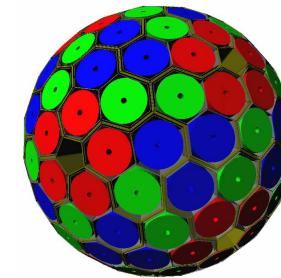


Introduction & Motivation

In-flight γ -ray spectroscopy → HISPEC



Applying *tracking* it becomes possible to determine the incident angle and preserve the good energy resolution.



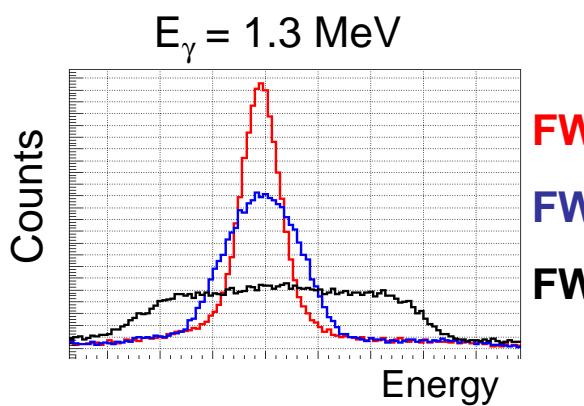
Advanced
Gamma
Tracking
Array

Efficiency: 43% ($M_\gamma=1$) 28% ($M_\gamma=30$)

P/T: 58% ($M_\gamma=1$) 49% ($M_\gamma=30$)

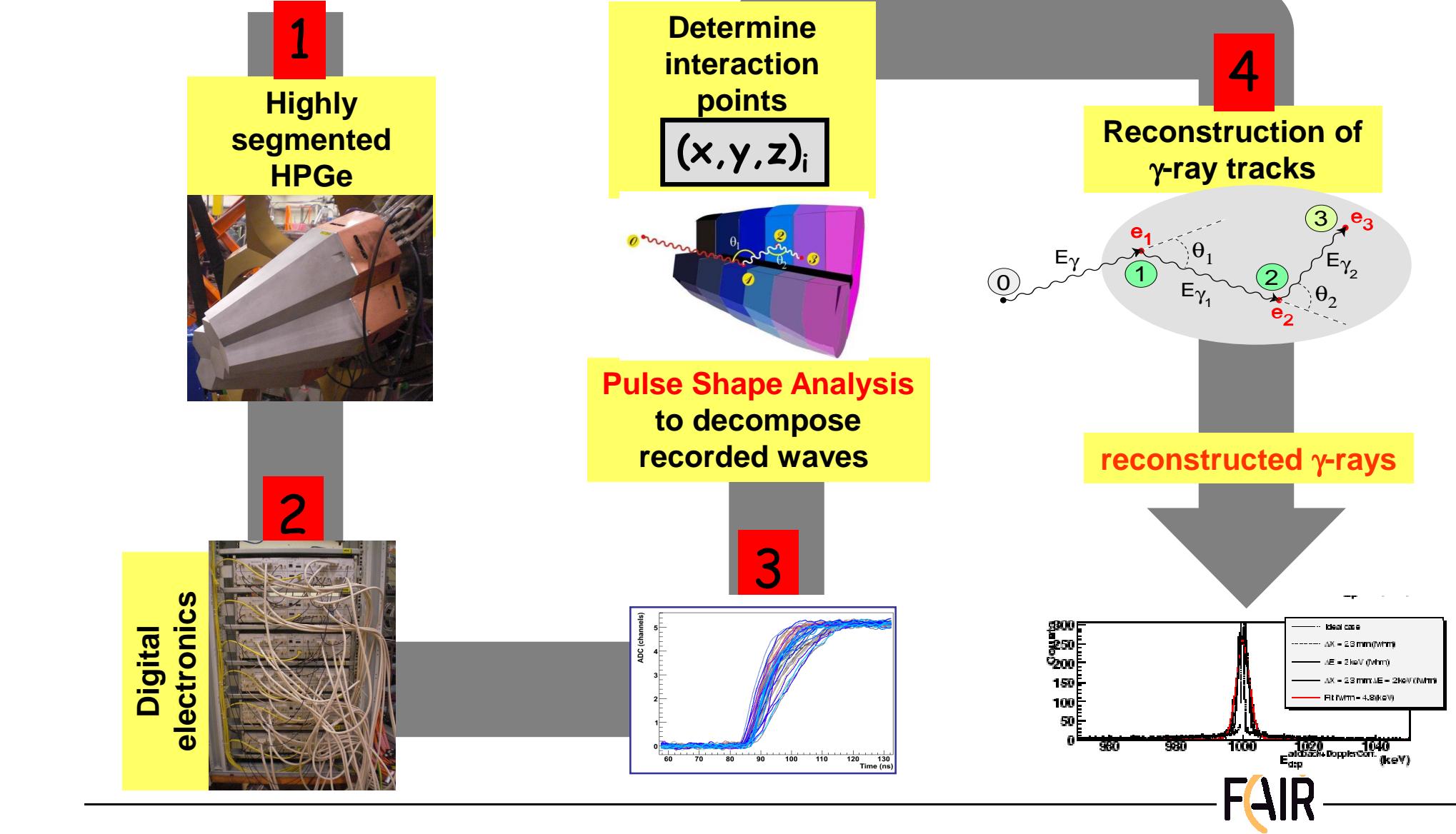
Angular resolution: $\sim 1^\circ$

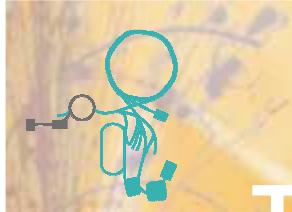
FWHM (1 MeV, $v/c=50\%$) ~ 6 keV



FWHM = 5 keV
FWHM = 12 keV
FWHM = 35 keV

Introduction & Motivation

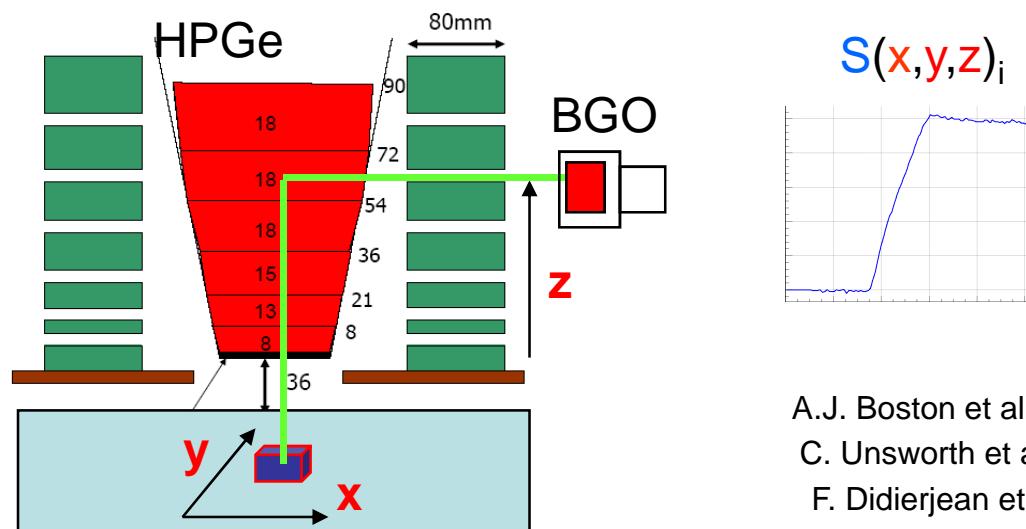
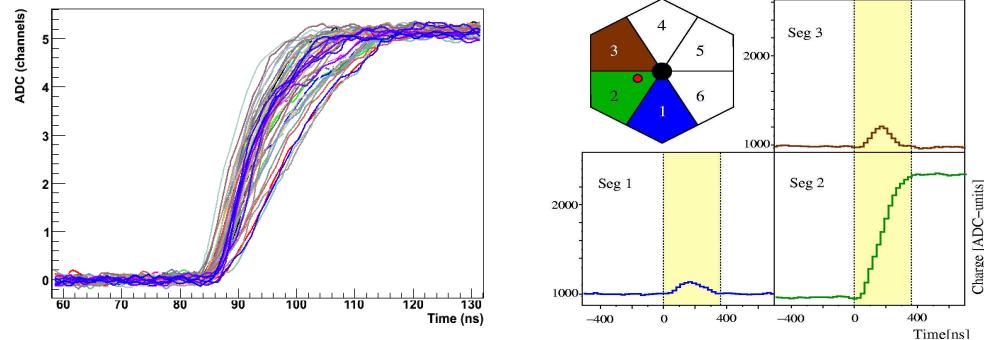




Introduction & Motivation

The conventional scanning method

Determine a data-base of pulse shapes $S(x,y,z)$ which allows one to correlate an arbitrarily measured pulse S , with an interaction position (x,y,z) inside the detector.



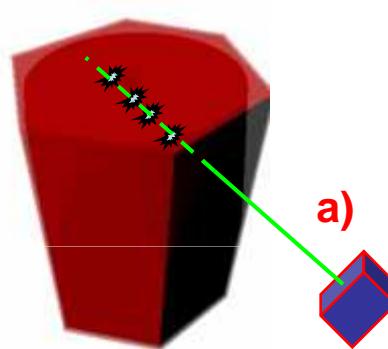
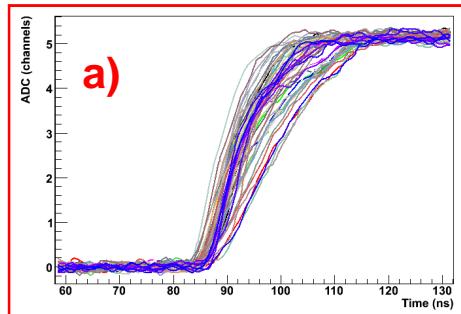
Main drawback: long characterization time, typically 3 months/detector

- A.J. Boston et al., Nucl.Instr.Meth.A, Vol.604, Issues 1-2 (2009)
C. Unsworth et al., Proc. SPIE, Vol. 7449, 74490Z (2009)
F. Didierjean et al., AGATA Week, Koeln (2009)



HPGe Pulse Shape Comparison Scan method

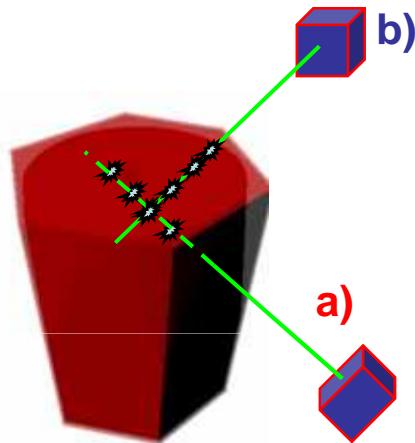
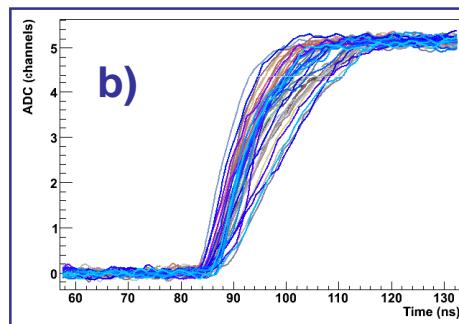
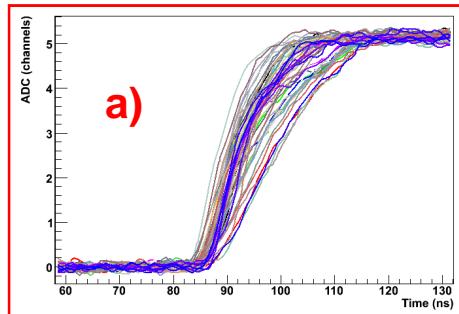
Based on a collimated γ -ray source



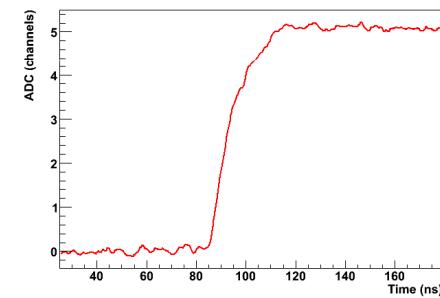


HPGe Pulse Shape Comparison Scan method

Based on a collimated γ -ray source



Pulse Shape
Comparison
Algorithm
 $\min \chi^2(a,b)$

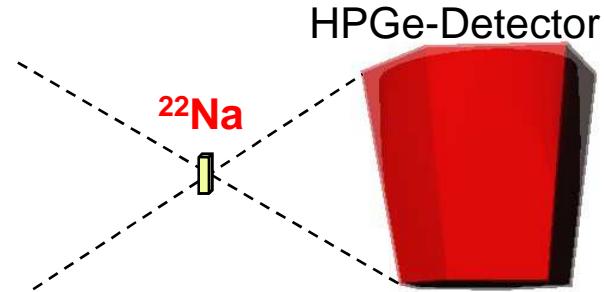


Common pulse out of
these two data sets,
corresponding to the
geometric crossing
point (x,y,z).



HPGe Pulse Shape Comparison Scan method

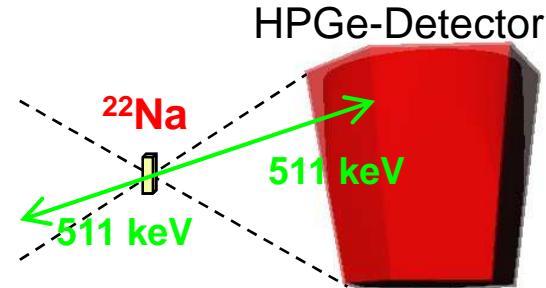
Based on a position sensitive detector





HPGe Pulse Shape Comparison Scan method

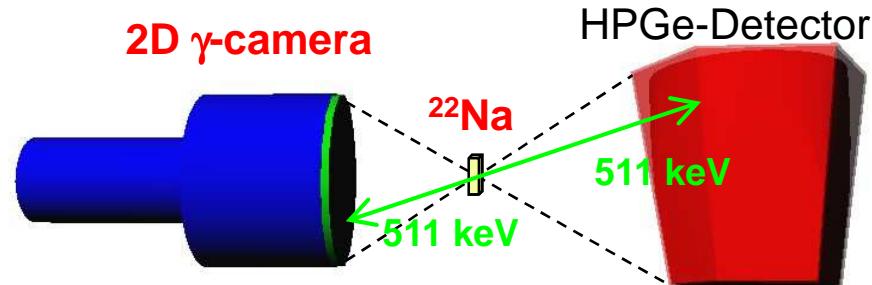
Based on a position sensitive detector





HPGe Pulse Shape Comparison Scan method

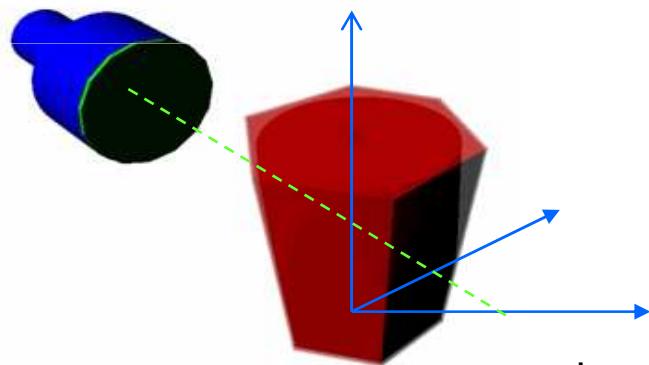
Based on a position sensitive detector



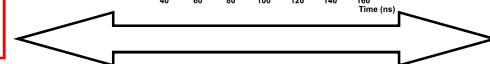
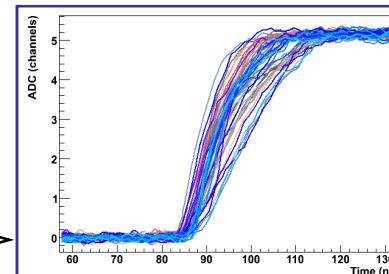
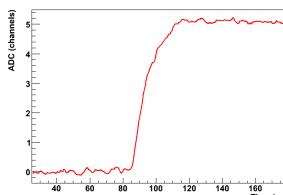
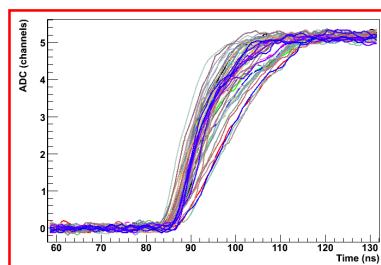
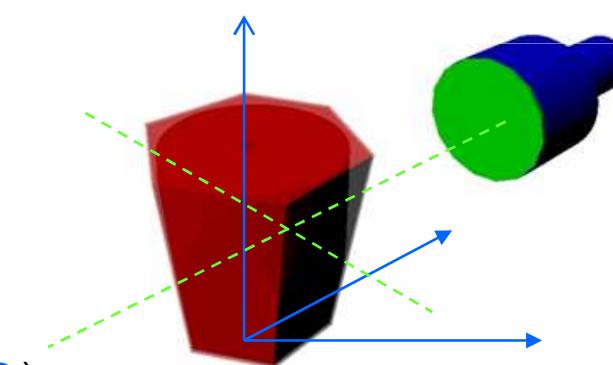
Characteristics:

- Estimated time 20^h
- Precision: 1-2 mm
- *Imaging capability*

Data set “A”)



Data set “B”)



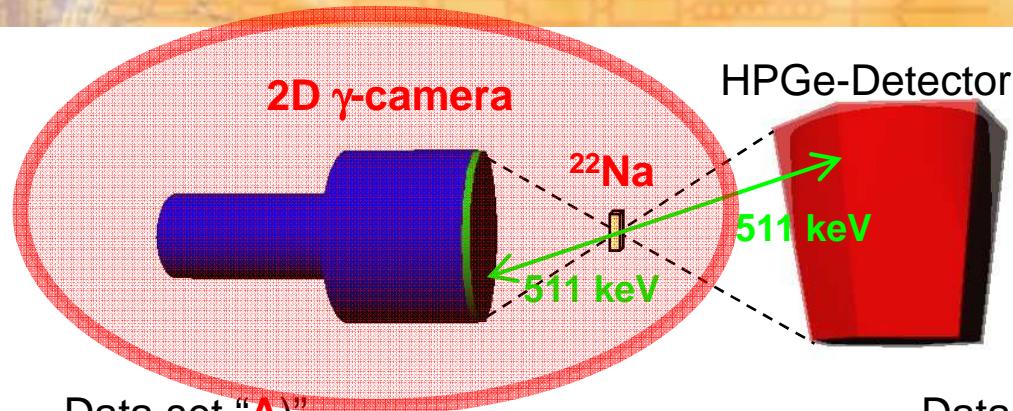
Requirements:

- Excellent $\Delta x/x$
- Large field of view



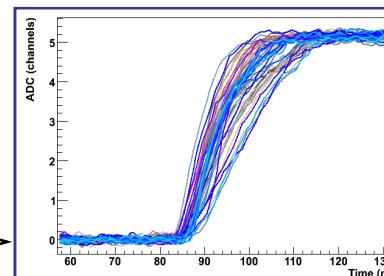
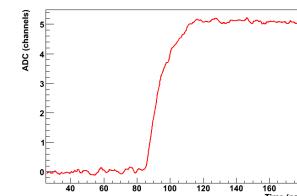
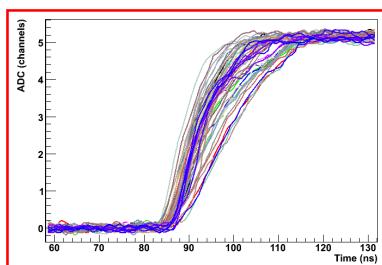
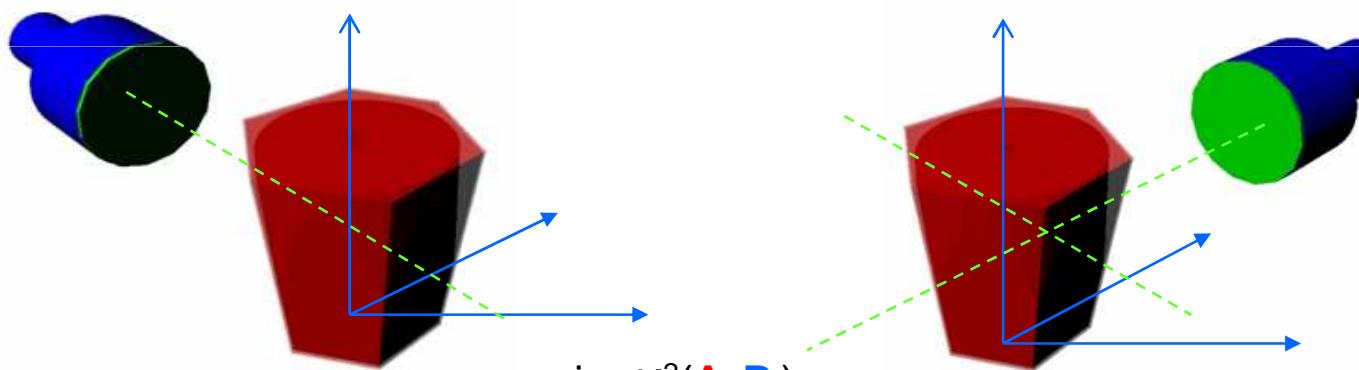
HPGe Pulse Shape Comparison Scan method

Based on a position sensitive detector



Data set "A")"

Data set "B")"



Characteristics:

- Estimated time 20^h
- Precision: 1-2 mm
- *Imaging capability*

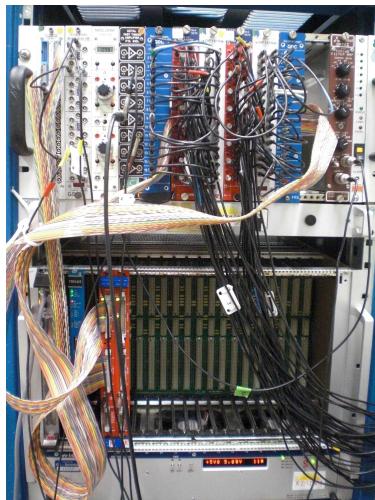
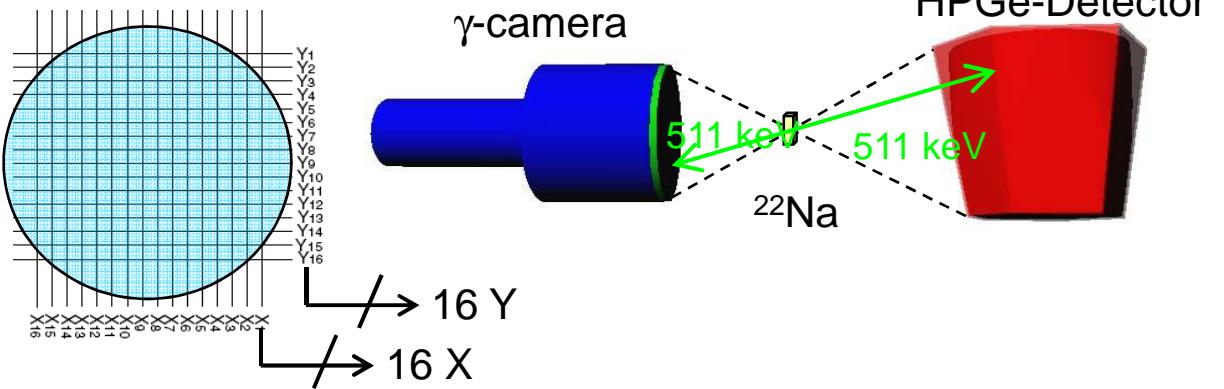
Requirements:

- Excellent $\Delta x/x$
- Large field of view



Development of a position sensitive detector

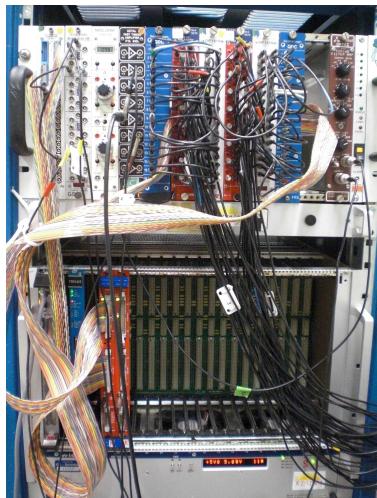
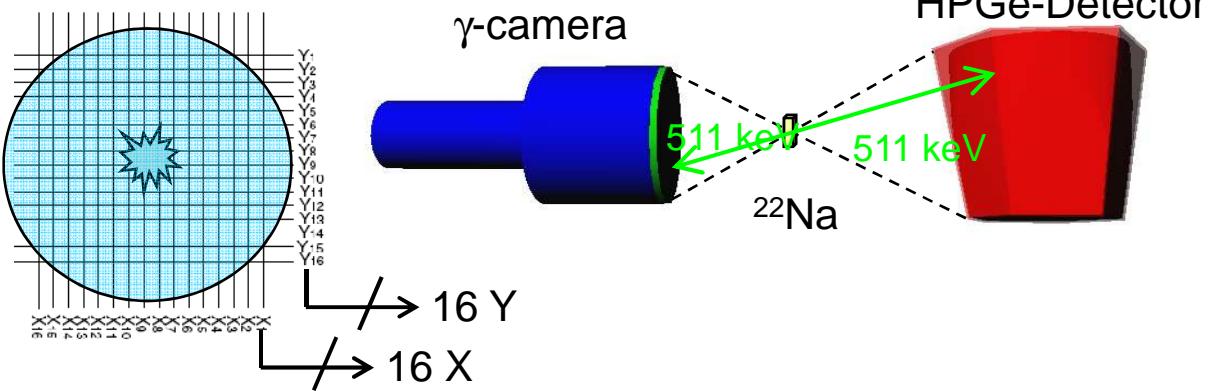
IMAR (Individual Multi Anode Readout) Technique



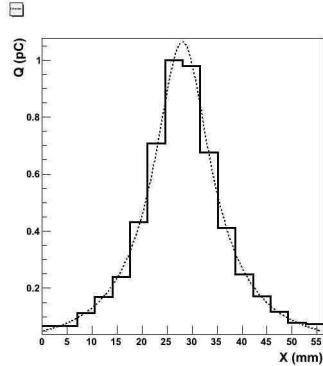


Development of a position sensitive detector

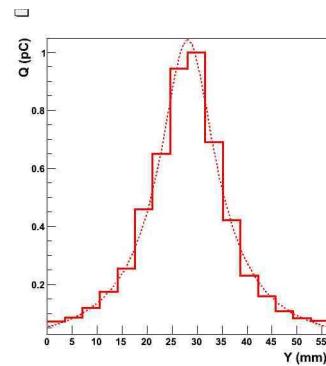
IMAR (Individual Multi Anode Readout) Technique



Anodes X



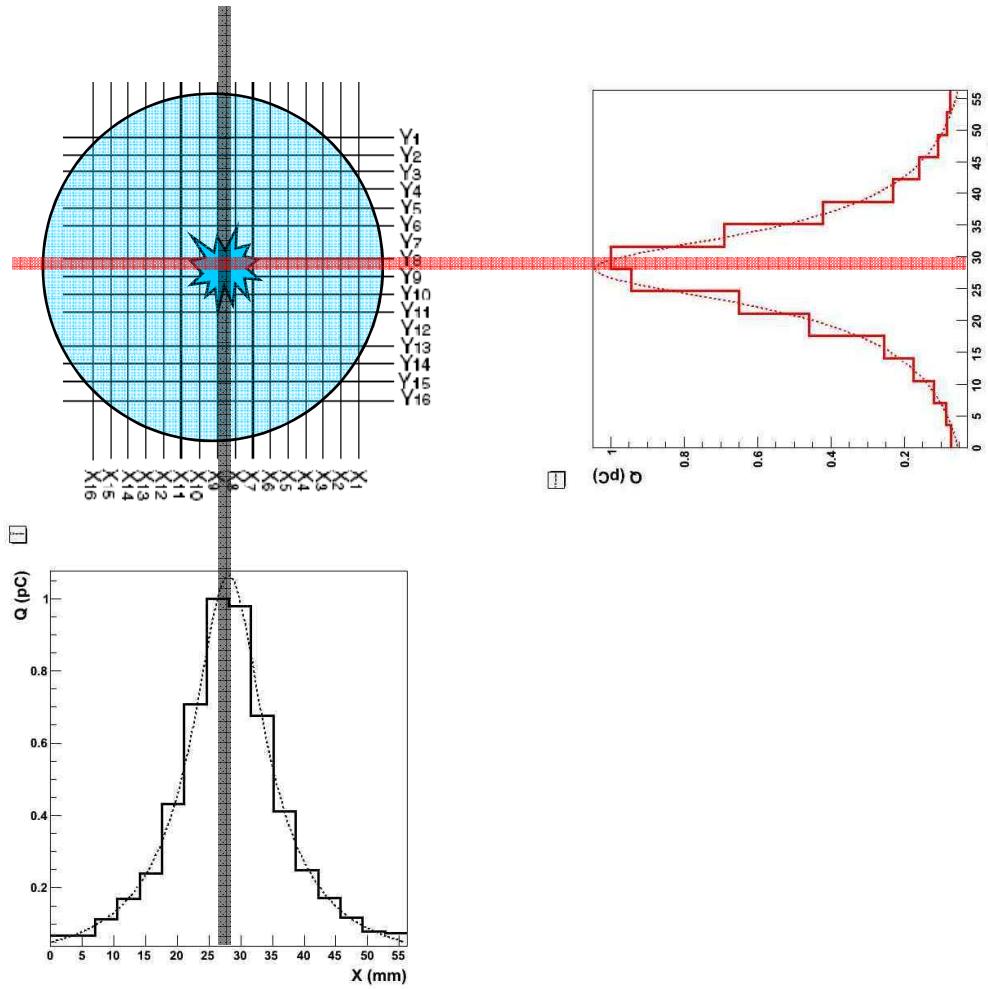
Anodes Y





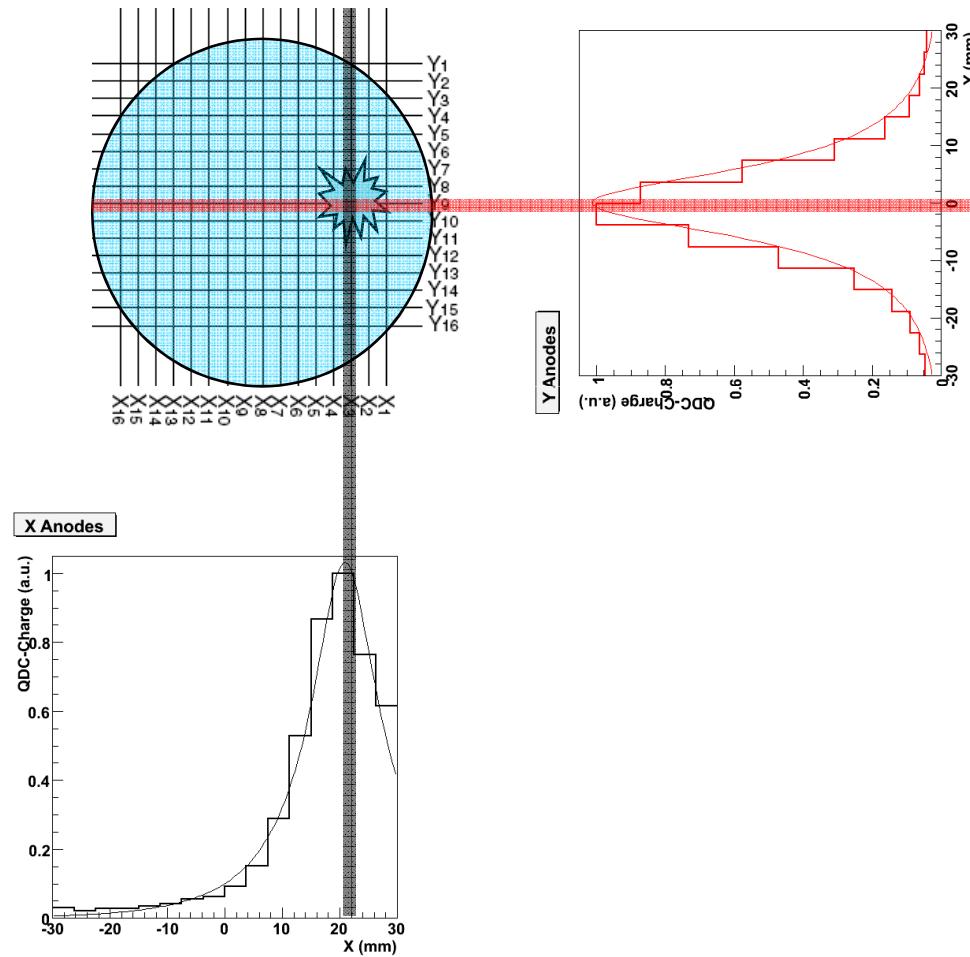
Characterization of the position sensitive detector

IMAR (Individual Multi Anode Readout) Technique





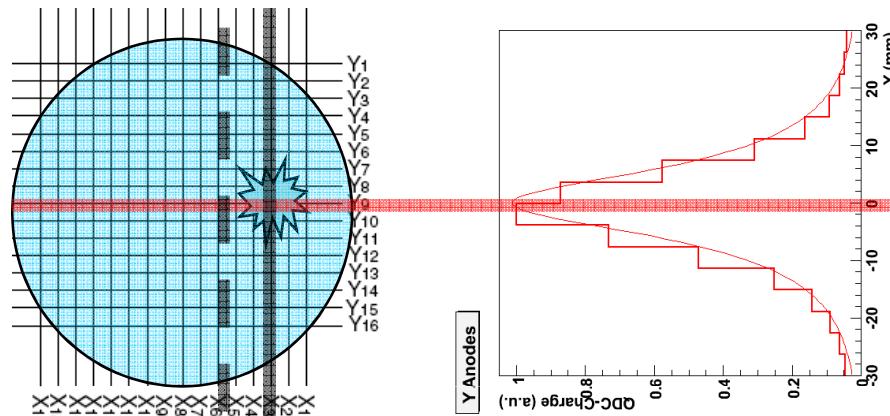
IMAR (Individual Multi Anode Readout) Technique



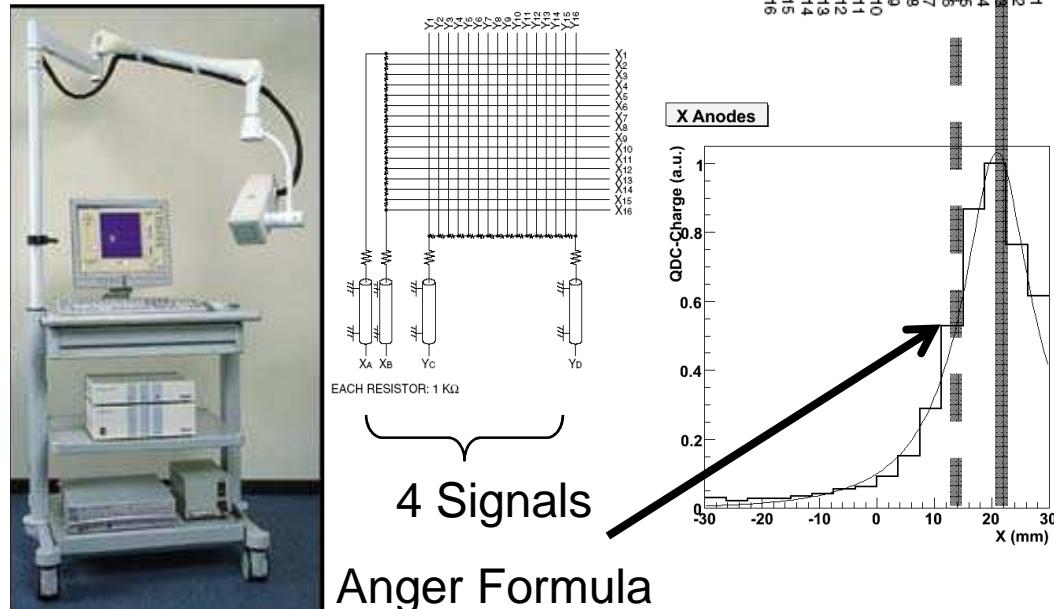


Characterization of the position sensitive detector

IMAR (Individual Multi Anode Readout) Technique



Resistor Network Technique

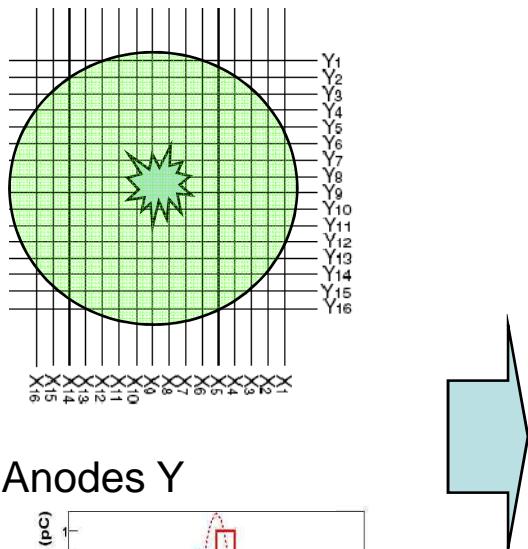


Conventional methods only reproduce the **centroid** of the scintillation light distribution, which may differ from the maximum

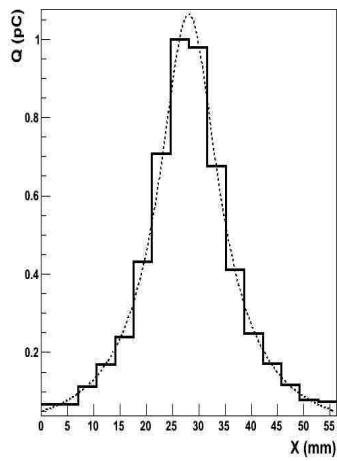


Characterization of the position sensitive detector

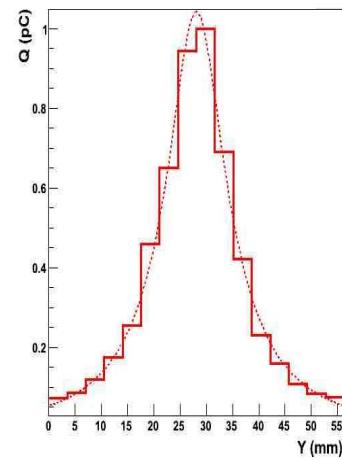
IMAR (Individual Multi Anode Readout) Technique



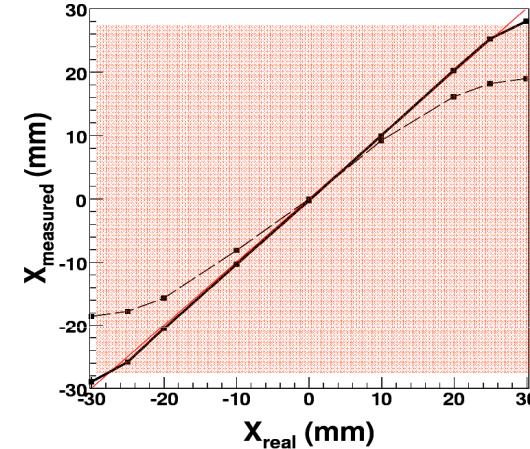
Anodes X



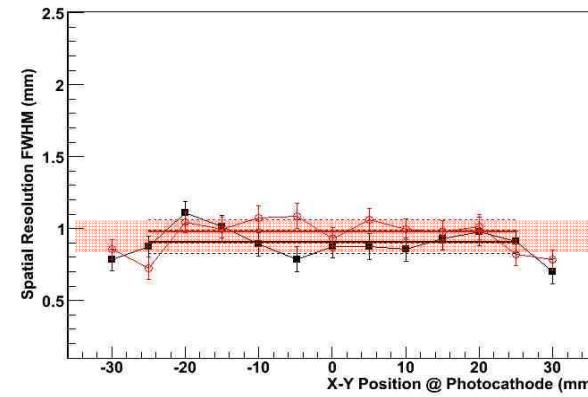
Anodes Y



Field of View = **20 cm²**



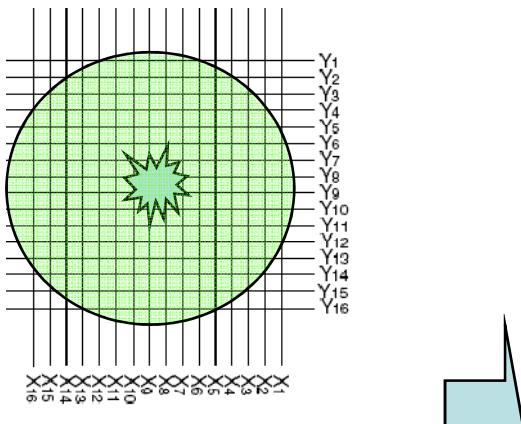
Spatial resolution (fwhm) **0.945 +/- 0.08 mm**



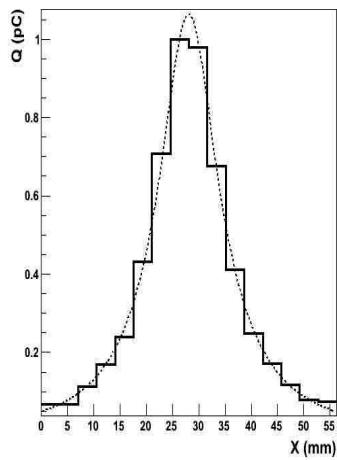


Characterization of the position sensitive detector

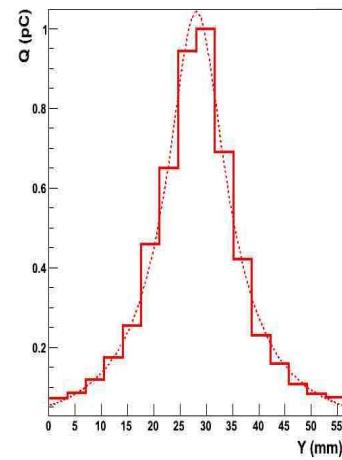
IMAR (Individual Multi Anode Readout) Technique



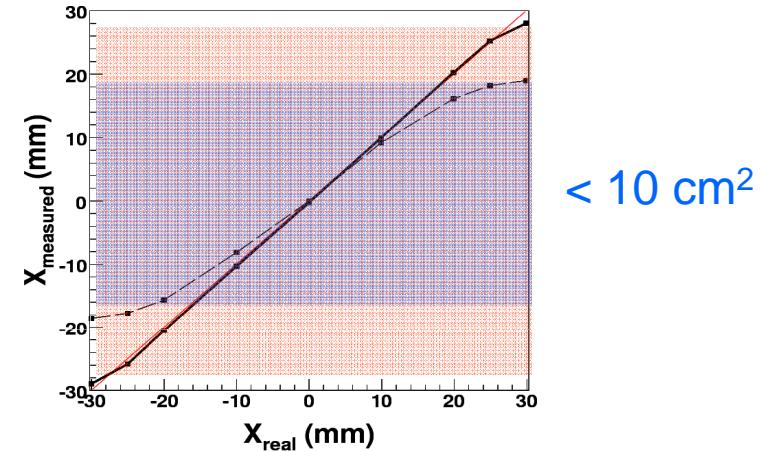
Anodes X



Anodes Y

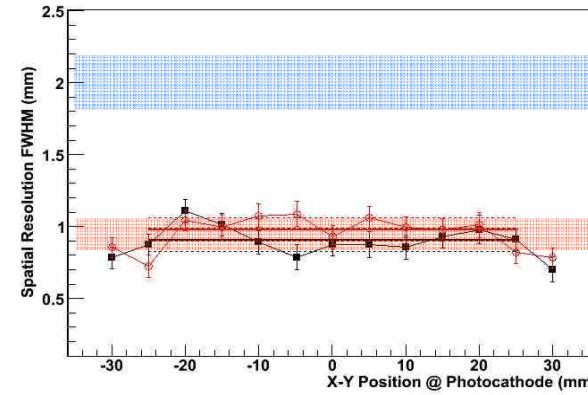


Field of View = **20 cm²**



< 10 cm²

Spatial resolution (fwhm) **0.945 +/- 0.08 mm**



2 mm



Characterization of the position sensitive detector

IEEE TRANSACTIONS ON MEDICAL IMAGING

A Position Sensitive γ -Ray Scintillator Detector With Enhanced Spatial Resolution, Linearity, and Field of View

César Domingo-Pardo*, Namita Goel, Tobias Engert, Juergen Gerl, Masahiro Isaka, Ivan Kojouharov, Member, IEEE, and Henning Schaffner

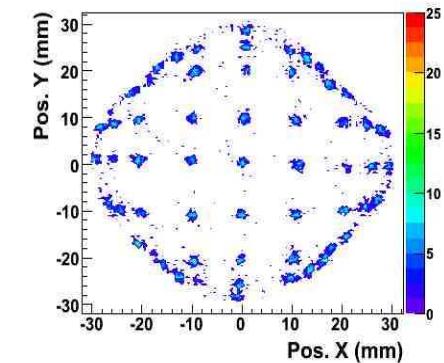
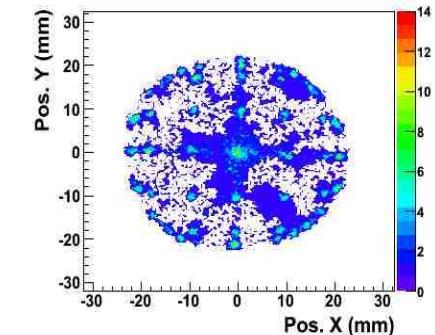
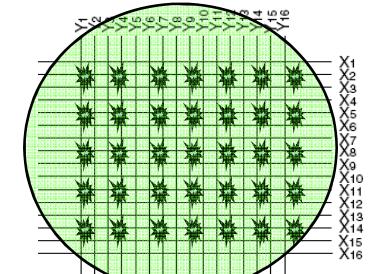
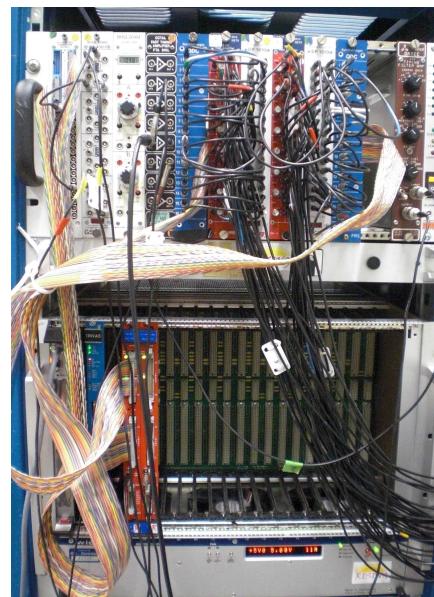
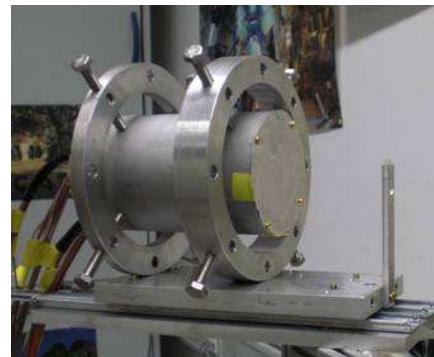
Abstract—The performance of a position sensitive γ -ray scintillator detector (PSD) is described. This PSD is based on a lutetium yttrium oxyorthosilicate (LYSO) crystal read out by a crossed-wire anode position sensitive photomultiplier tube (PSPMT). The main difference with respect to similar existing devices is the individual multi-anode readout (IMAR) approach that is followed here. This method allows to exploit better the intrinsic characteristics of the PSPMT, thus yielding better linearity, improved spatial resolution, and a larger field of view. The new detector is intended for the characterization of 3-D position sensitive germanium detectors.

Index Terms—Gamma detector.

I. INTRODUCTION

AMMA-RAY detectors with imaging capability were originally developed mainly for scintigraphy in medical imaging [1], [2]. More recently, when position-sensitive photomultiplier tubes (PSPMTs) became commercially available, small and inexpensive gamma cameras have been deployed and further improved for medicine [3], [4] and also for atomic and particle physics or astronomy [5]. There exist several research and commercial positron emission tomography (PET) scanners which also use PSPMTs [6]–[11]. This new generation of small position sensitive detectors (PSDs) are normally made from a relatively thin scintillation crystal, which is optically coupled to a PSPMT. One of the most commonly used PSPMT is based on a crossed wire anode structure. The aim of making such systems easily portable and commercially attractive has led to the common approach of using a charge division circuit coupled

Manuscript received April 17, 2009; revised June 24, 2009. A asterisk indicate corresponding author.
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 T. Engert, J. Gerl, I. Kojouharov, and H. Schaffner are with the Gamma-ray Spectroscopy Group, GSI Helmholtzzentrum für Schwerionenforschung mbH, 64291 Darmstadt, Germany.
 N. Goel is with the Gamma-ray Spectroscopy Group, GSI Helmholtzzentrum für Schwerionenforschung mbH, 64291 Darmstadt, Germany, and also with the Technische Universität Darmstadt, 64289 Darmstadt, Germany.

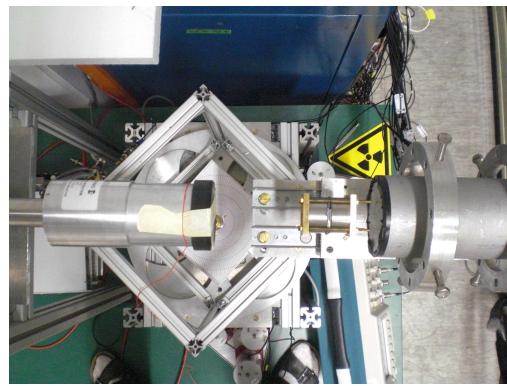
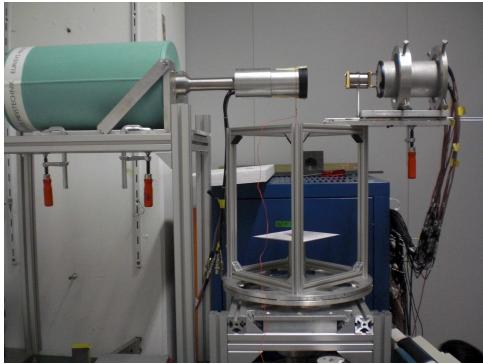


FAIR

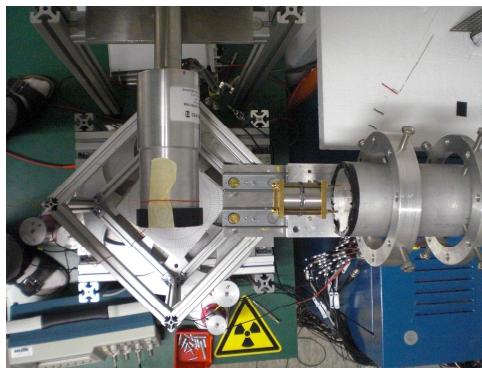
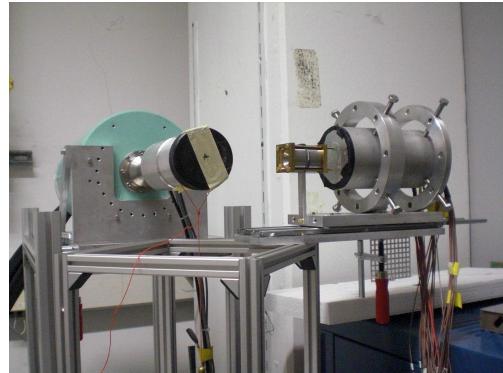


Planar HPGe Detector Scan

A) Front view (0 deg):



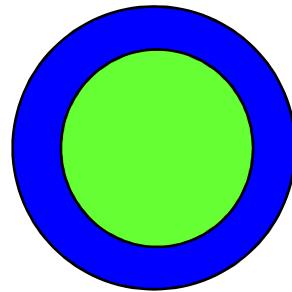
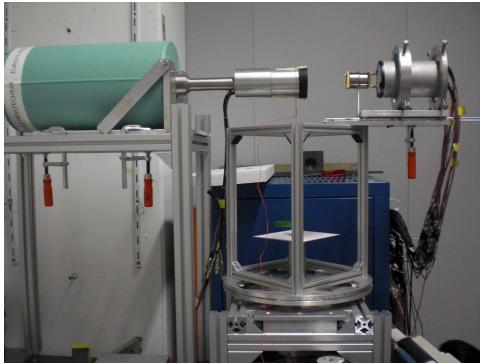
B) Side view (90 deg):



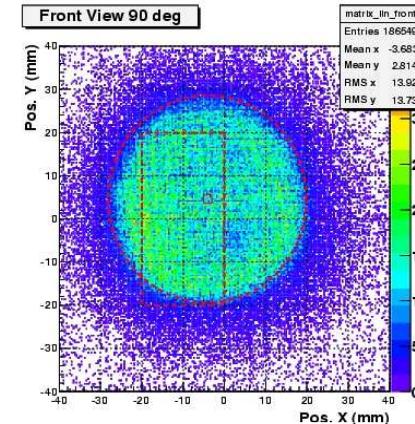


Planar HPGe Detector Scan

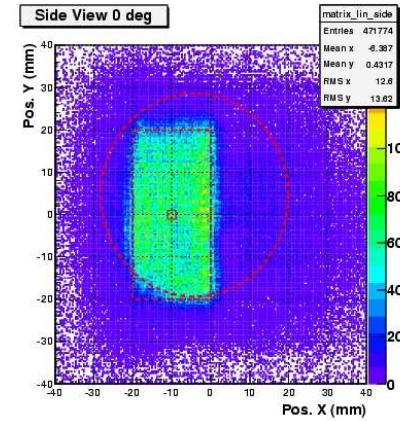
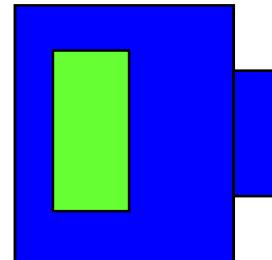
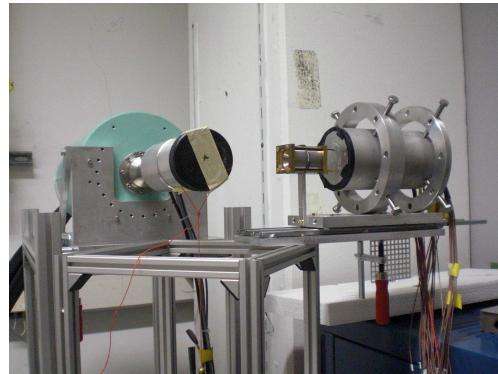
A) Front view (0 deg):



HPGe Sensitive
Volume

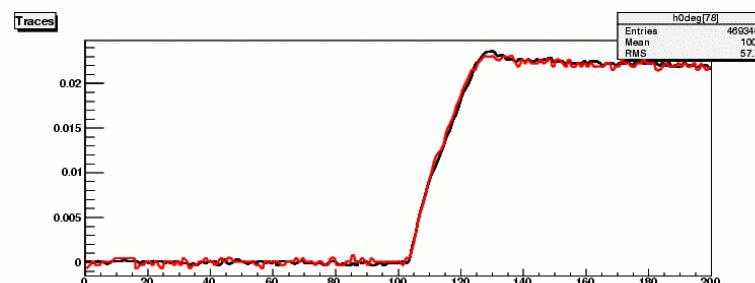
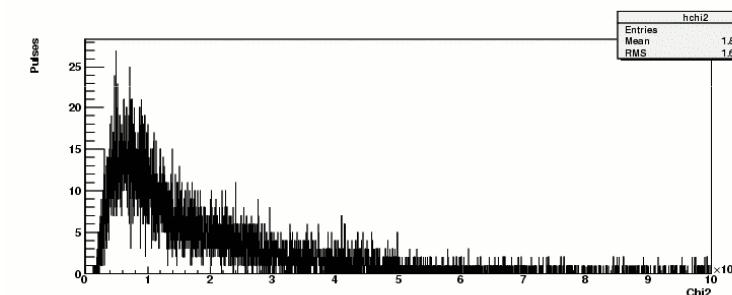
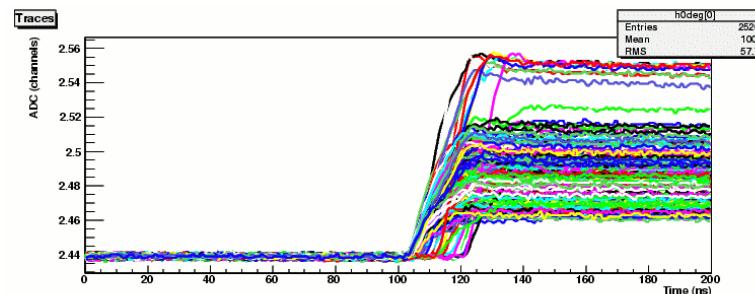
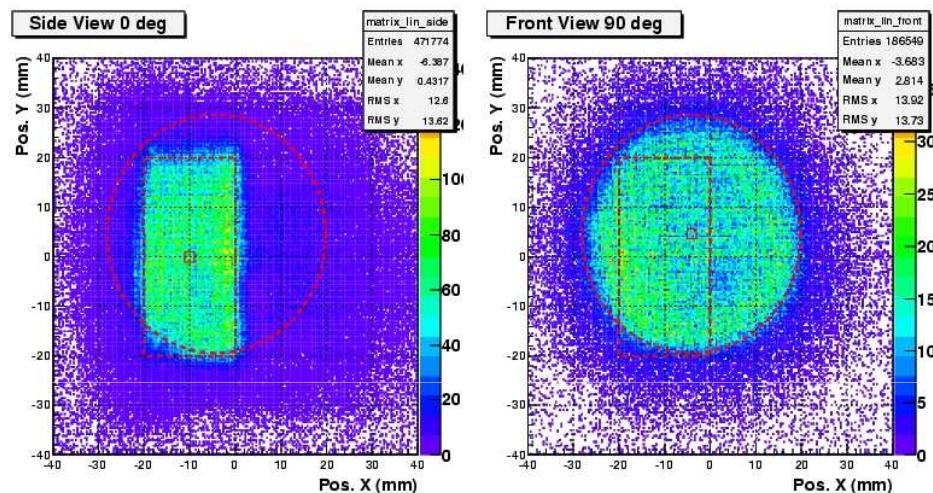


B) Side view (90 deg):



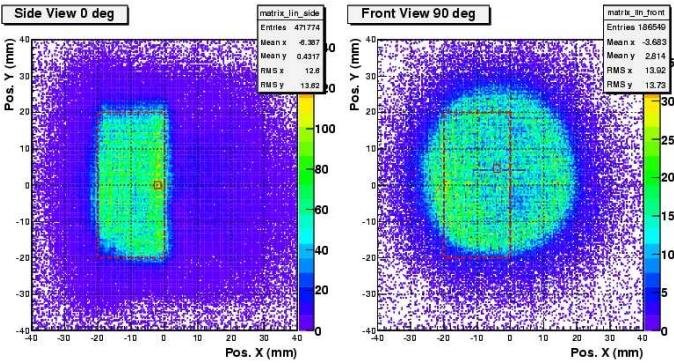
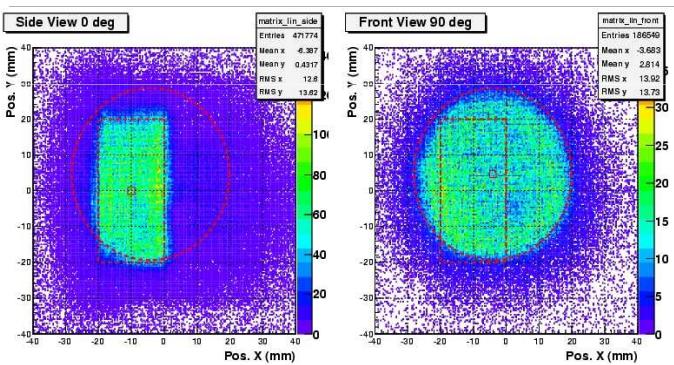
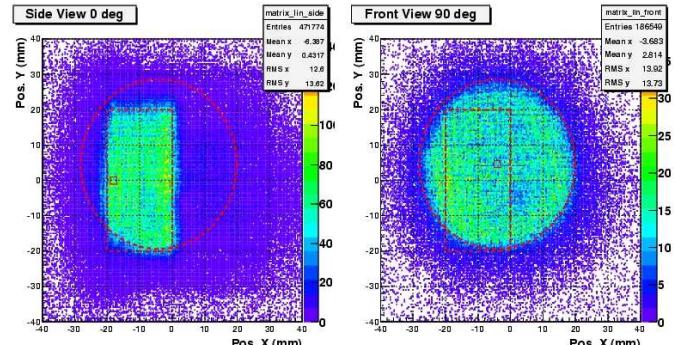


Planar HPGe Detector Scan

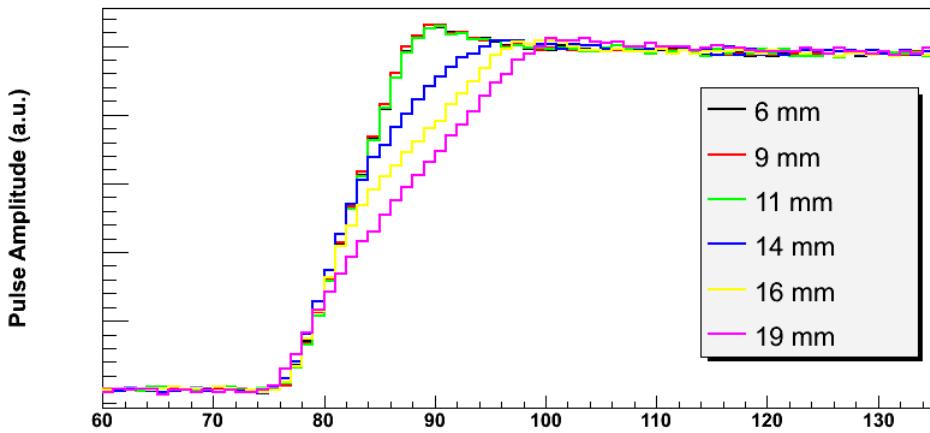




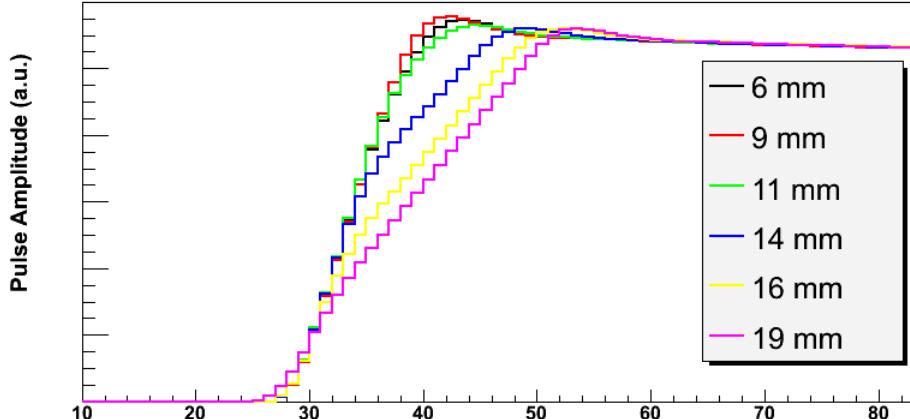
Planar HPGe Detector Scan



GSI Method



Conventional Approach





Summary & Outlook

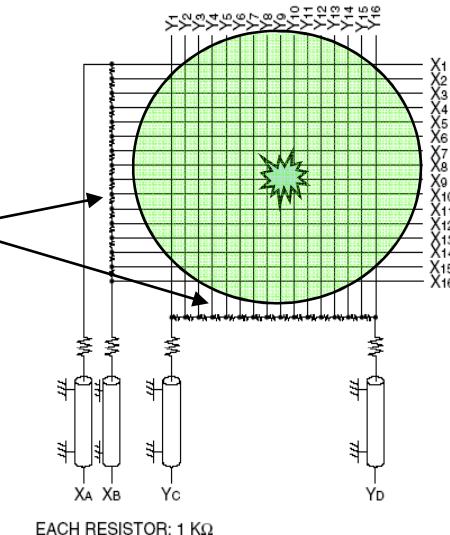
- A new pulse shape scanning system has been developed, which will allow for a much shorter characterization time (days).
- This system has been tested preliminarily with planar HPGe detectors.
- A suitable PS-data analysis method based on the PSCS is being developed
- A large volume HPGe coaxial detector has been scanned, and the PSCS will be applied to it in order to validate our scanning approach completely.



Characterization of the position sensitive detector



Resistor Network



X_A, X_B, Y_C, Y_D (Anger Formula)	Centroid of sci. Light (charge) distribution	Position X,Y
RMS (RN-modification)	Width of ligt (charge) distribution	γ -ray depth of interaction (DOI)

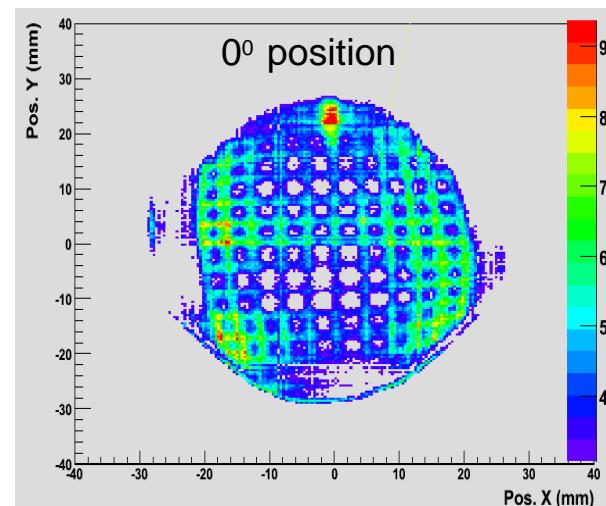
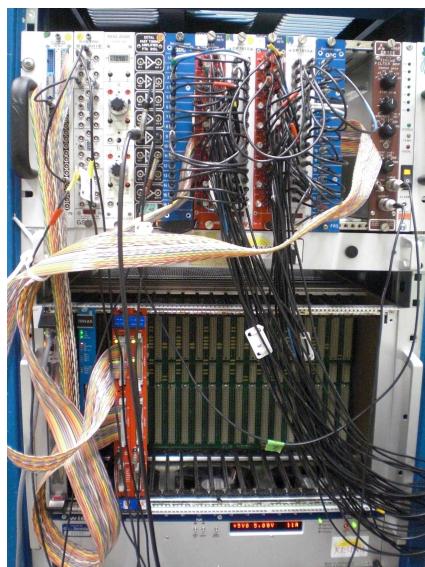
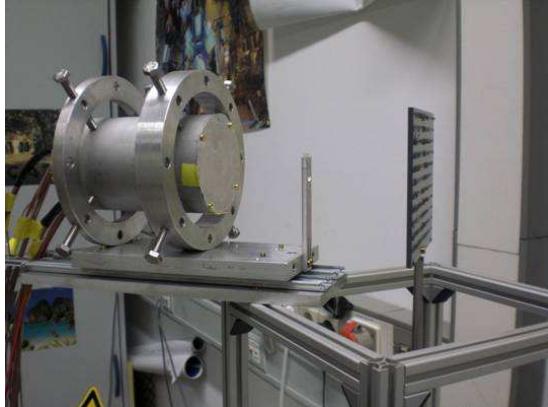
Resolution	2 mm
Field of View	7 cm^2

Position calibration



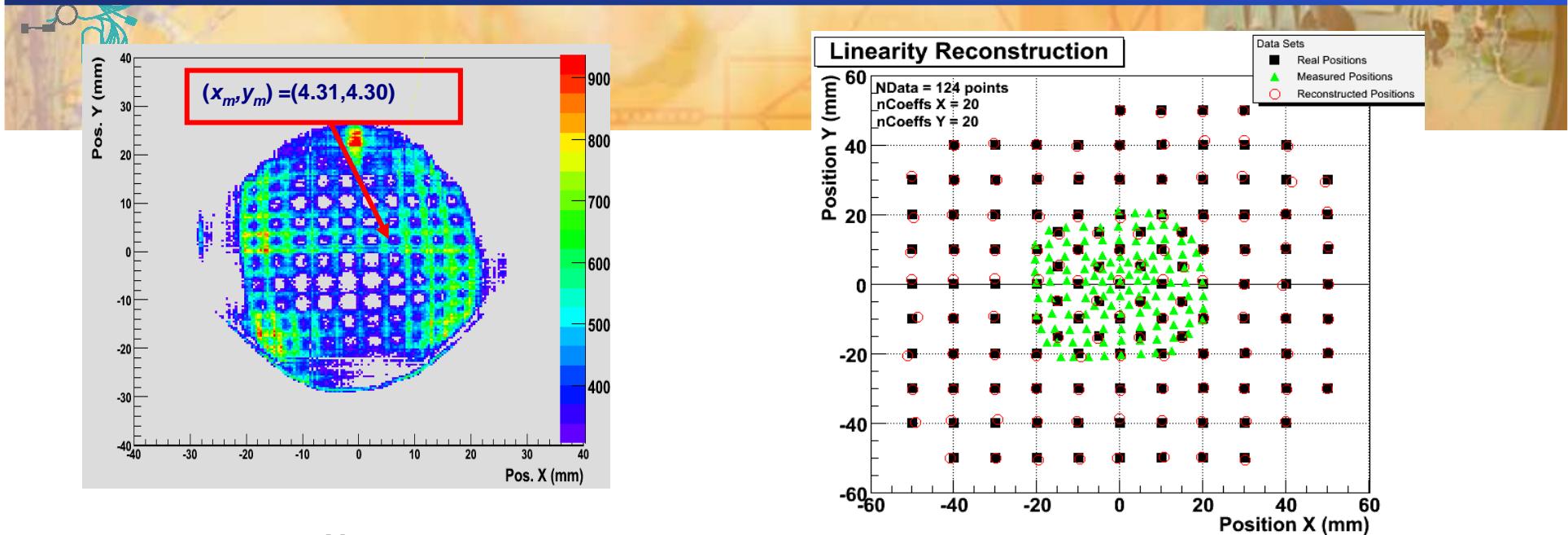
- Determine: $X_r(x_m, y_m)$, $Y_r(x_m, y_m)$

Gamma-ray
scattering technique



Grid **raw image** when it is
parallel to PSD surface (0deg)

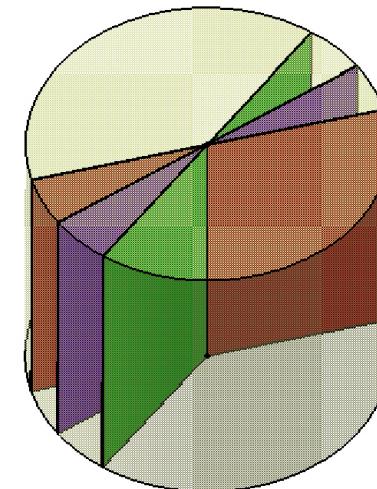
Position calibration



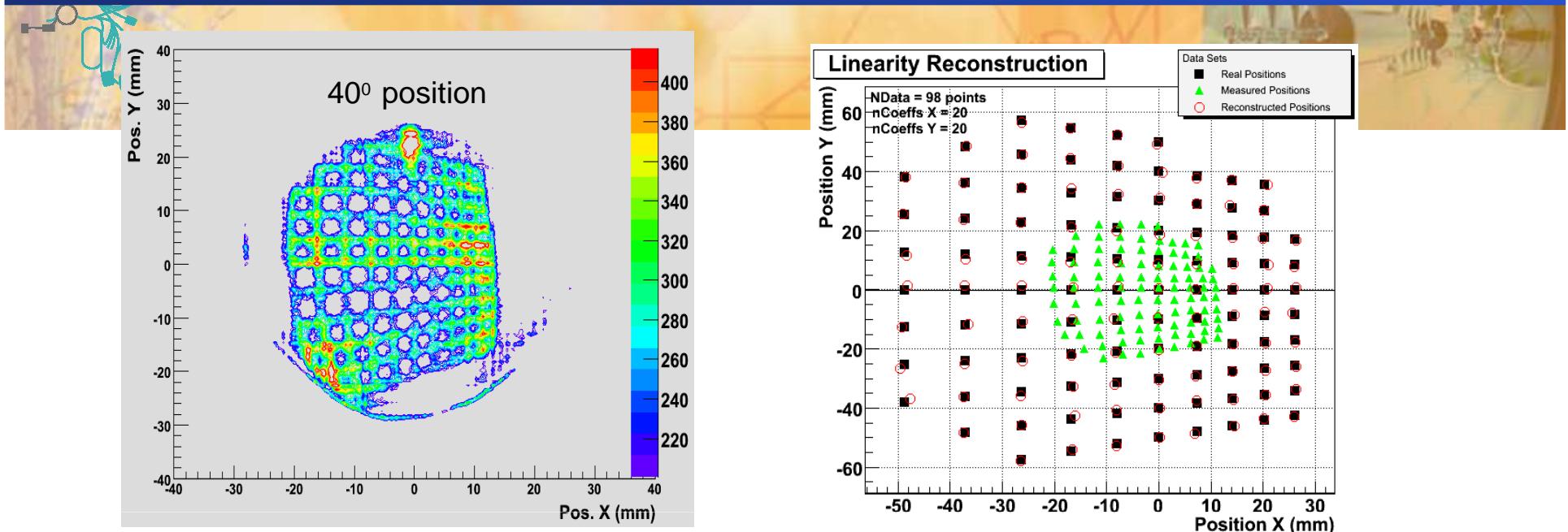
$$f'(x_m, y_m) = \sum_{j=1}^M C_j f'_j(x_m, y_m)$$

$$g'(x_m, y_m) = \sum_{j=1}^N D_j g'_j(x_m, y_m)$$

Calibration made from all data taken at multiple planes



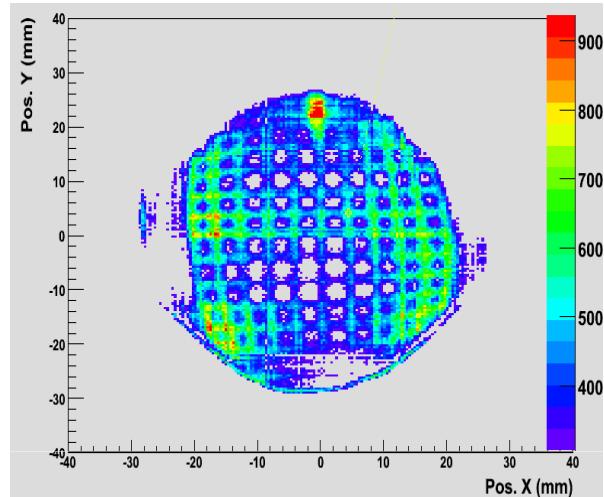
Position calibration



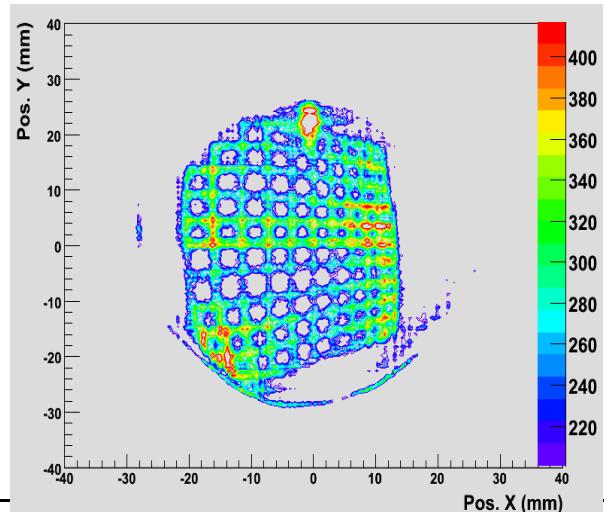
$$x_r' = \frac{D_{SG} x_r \cos(\theta)}{D_{SG} - x_r \sin(\theta)}$$

$$y_r' = \frac{y_r D_{SG}}{D_{SG} - x_r \sin(\theta)}$$

Position calibration

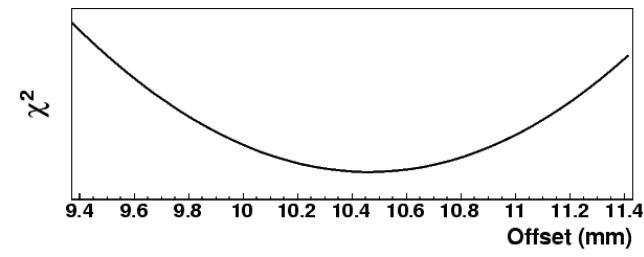
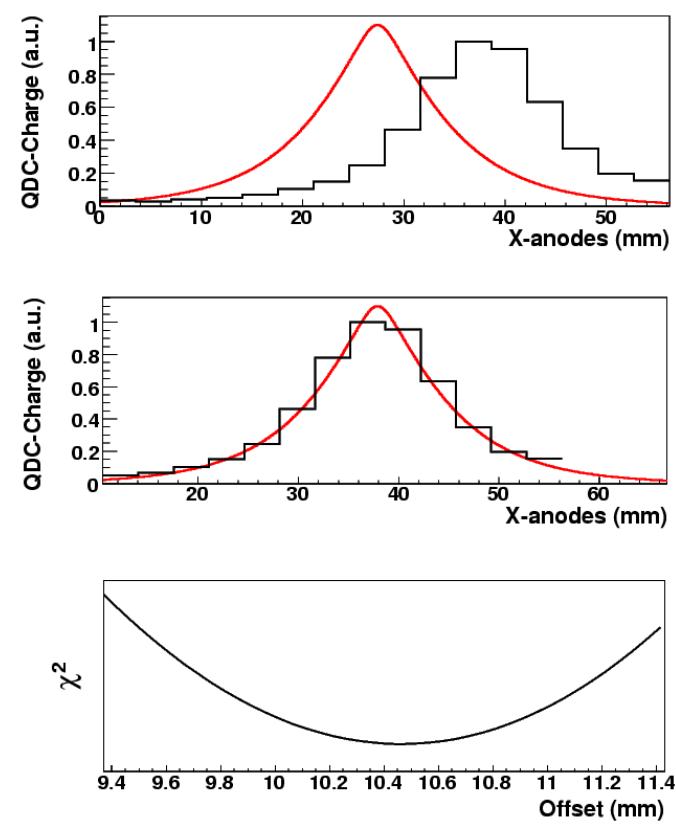
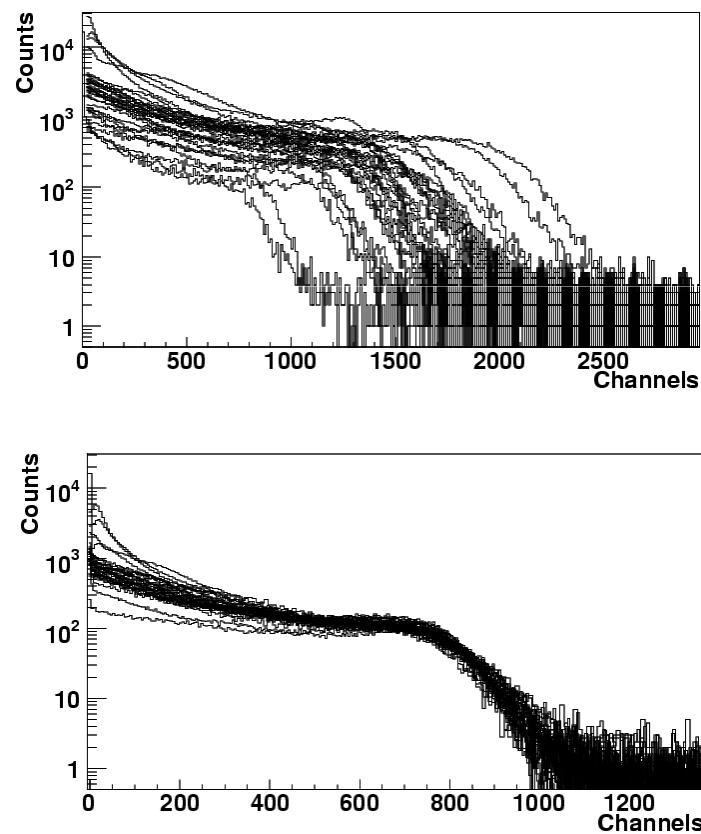


40° position



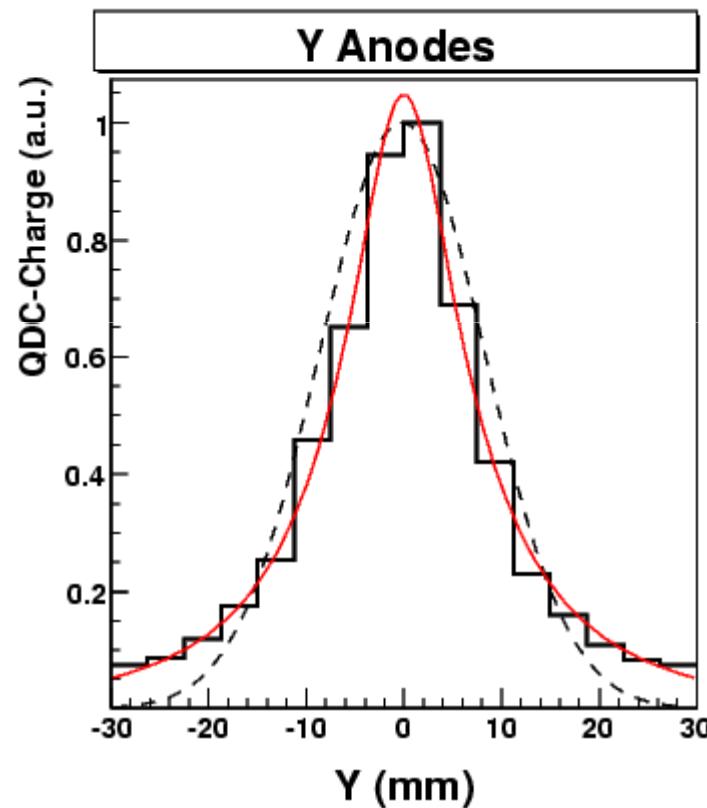
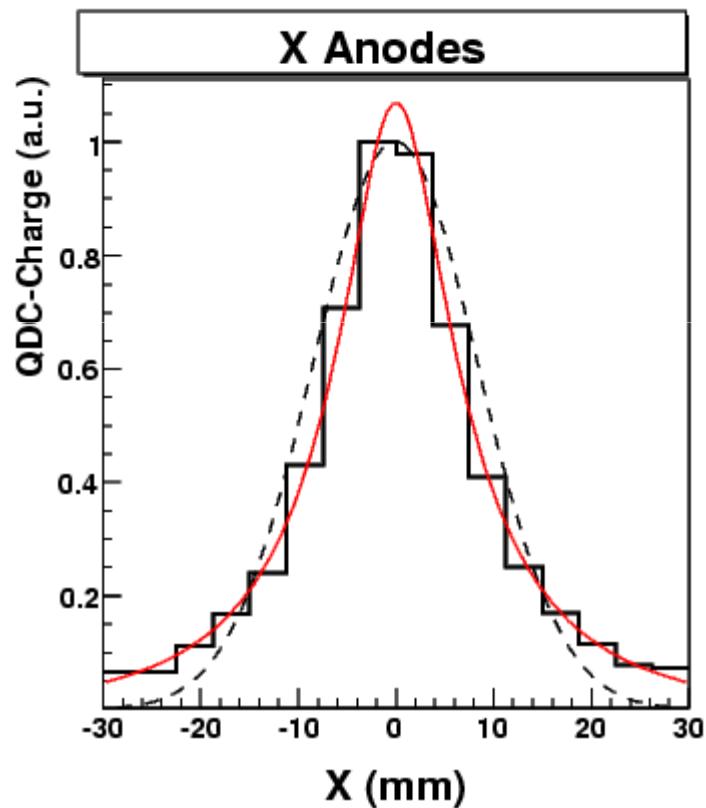


Position calibration



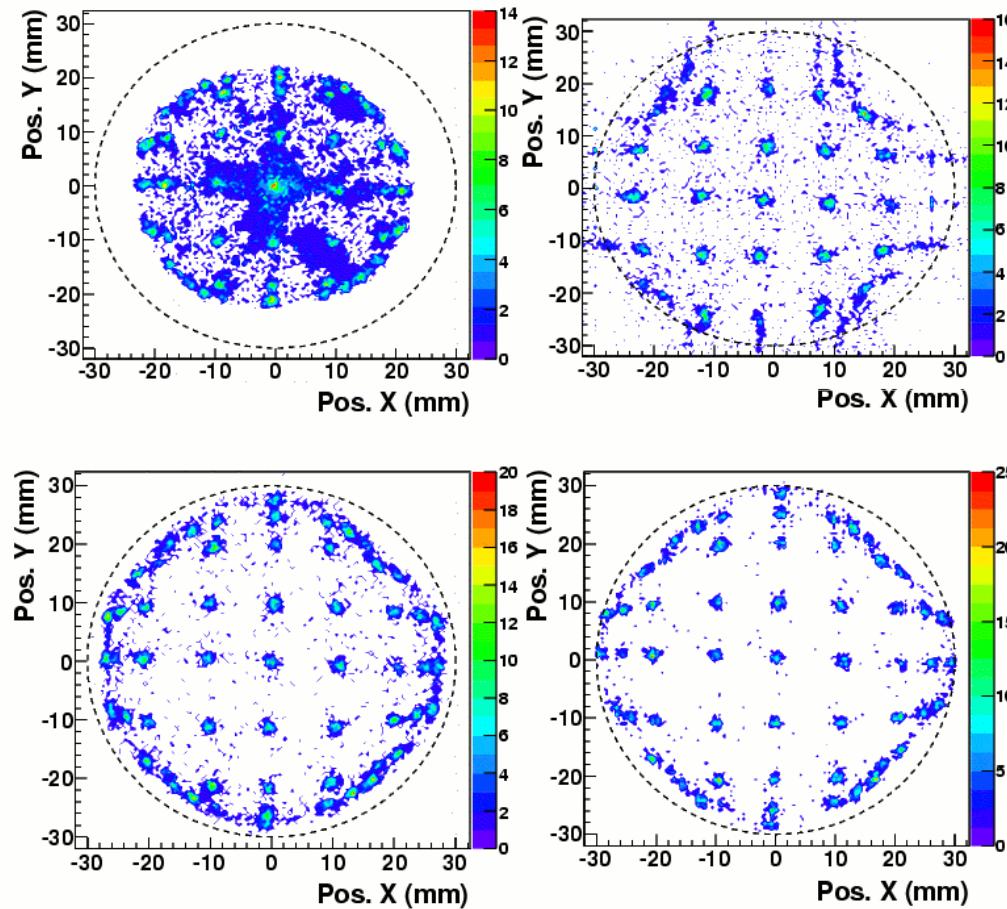


Position calibration



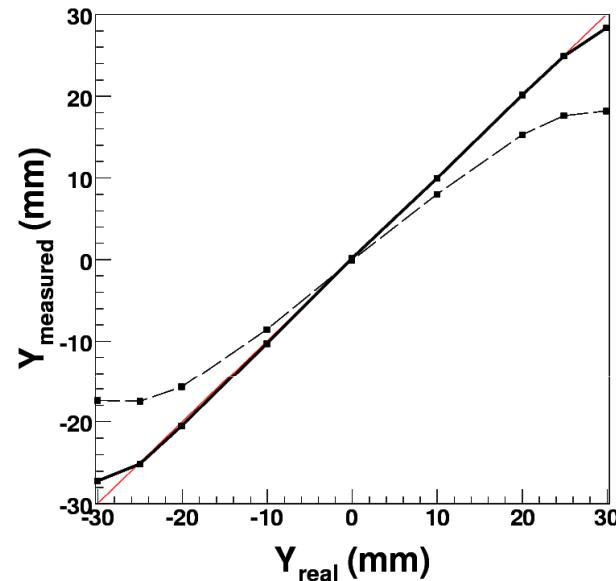
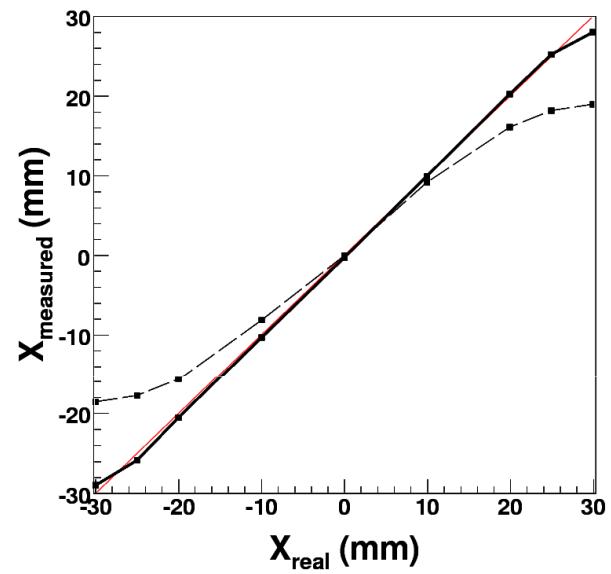


Position calibration



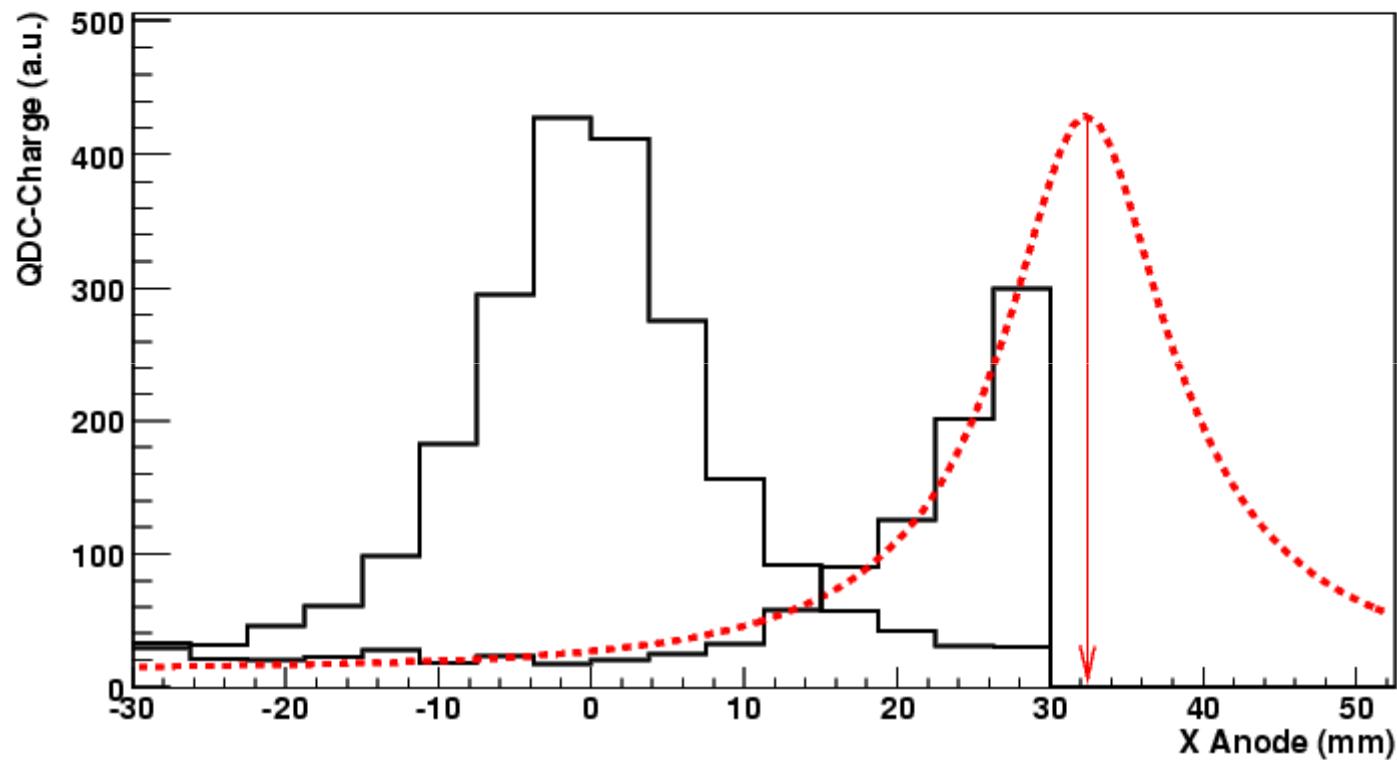


Position calibration



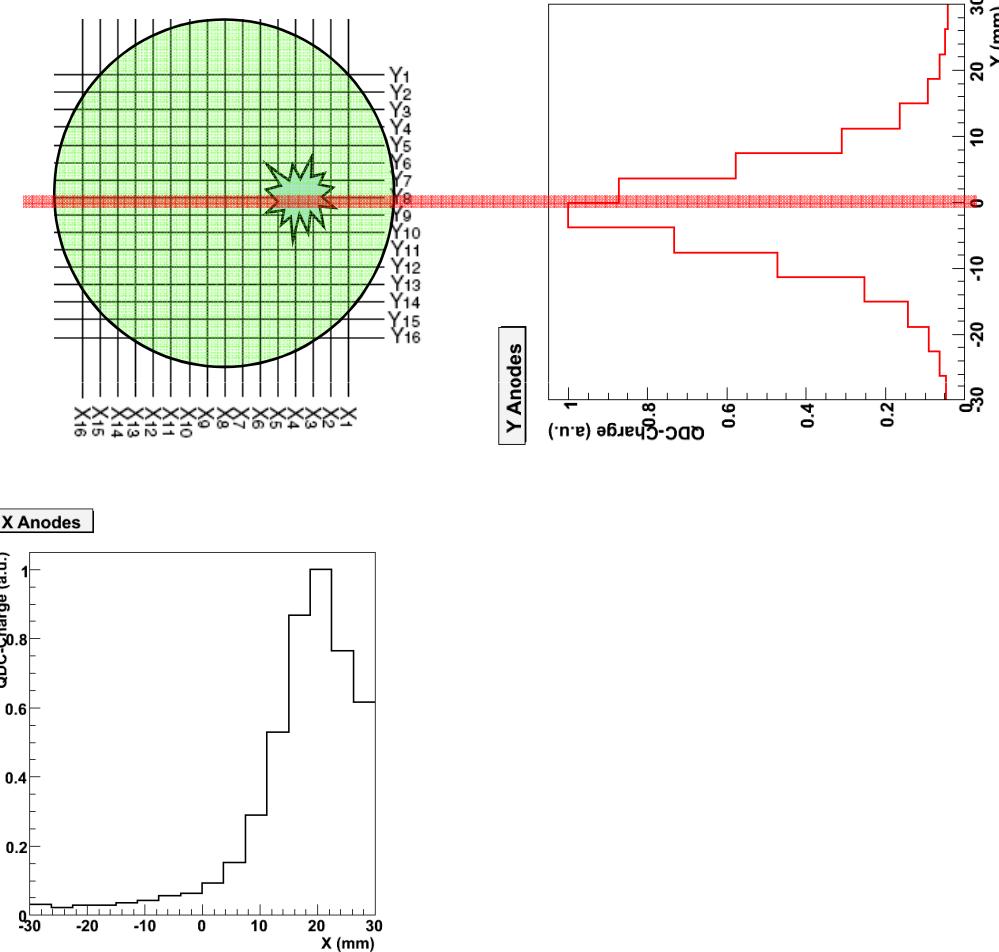
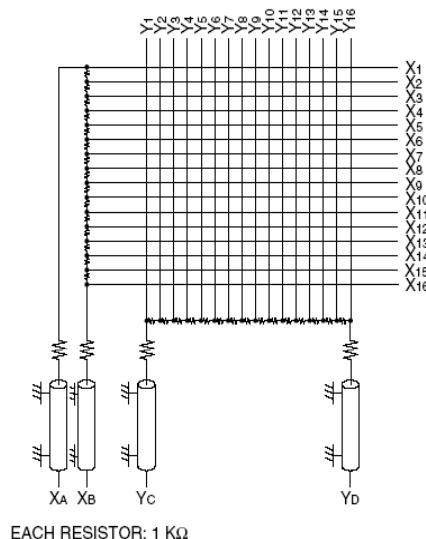


Position calibration



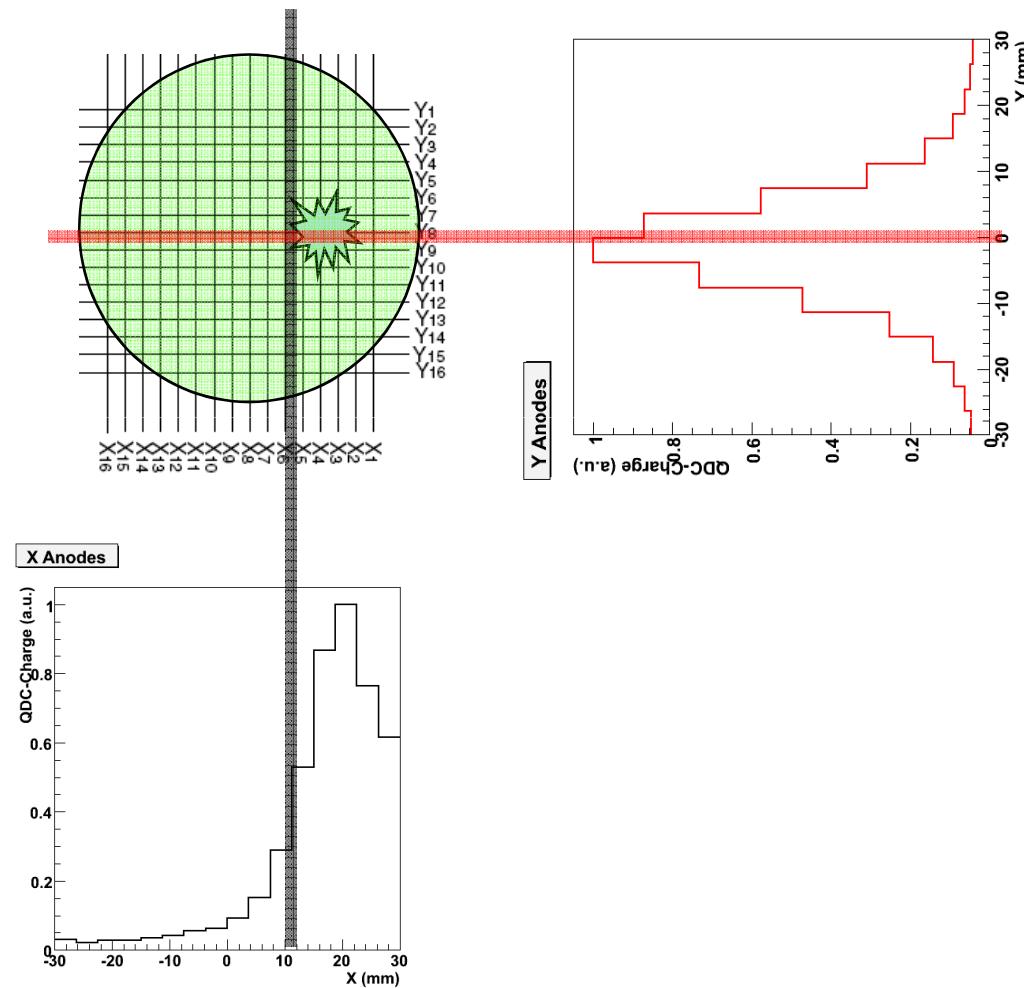
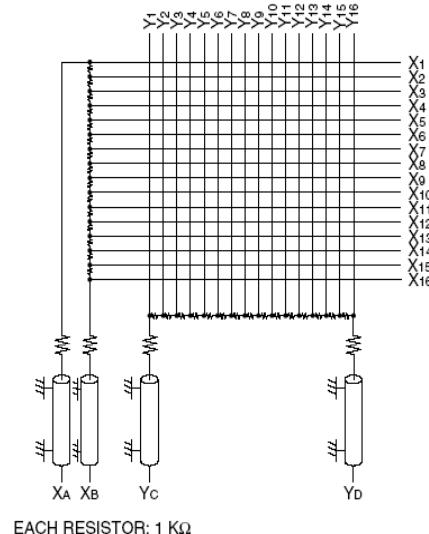


Resistor Network Technique





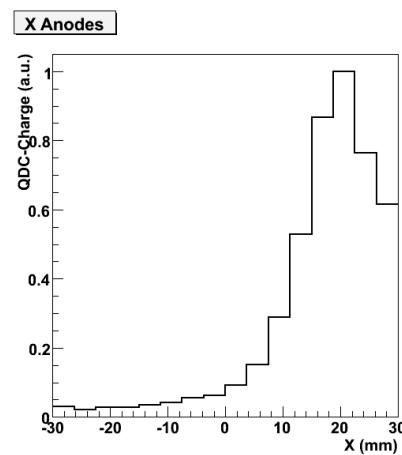
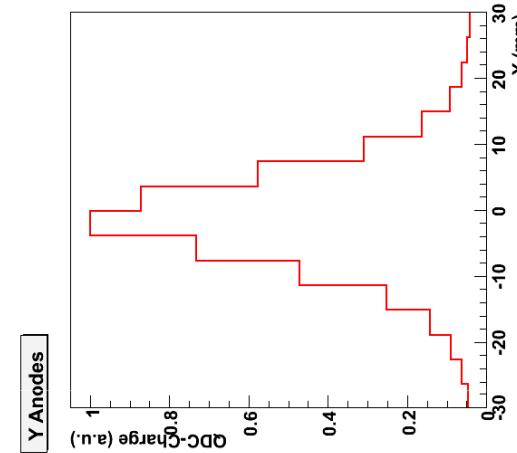
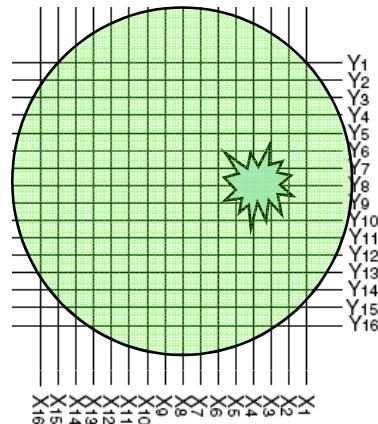
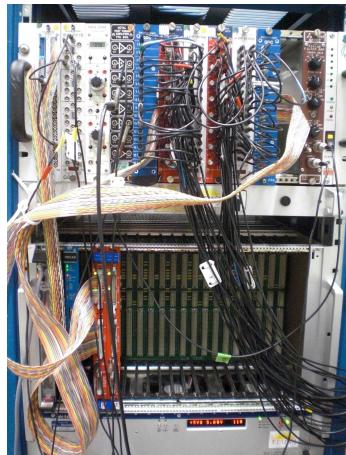
Resistor Network Technique





Characterization of the position sensitive detector

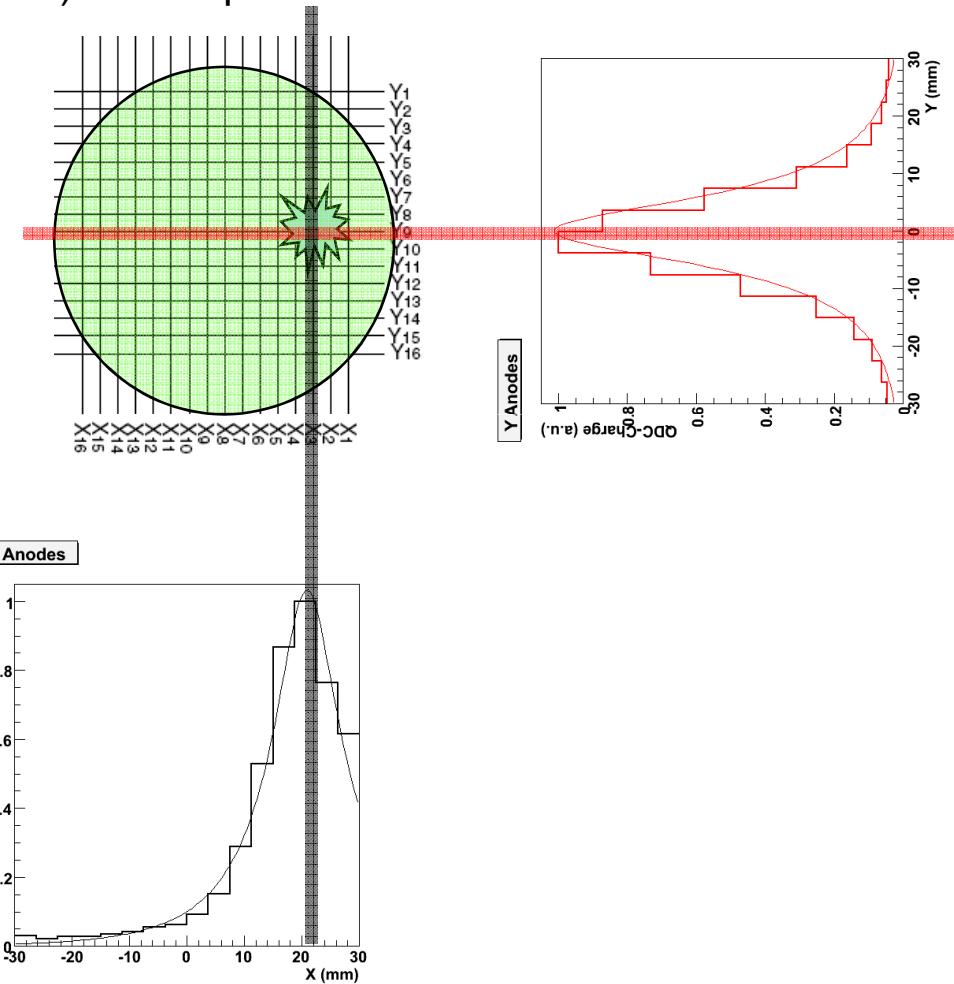
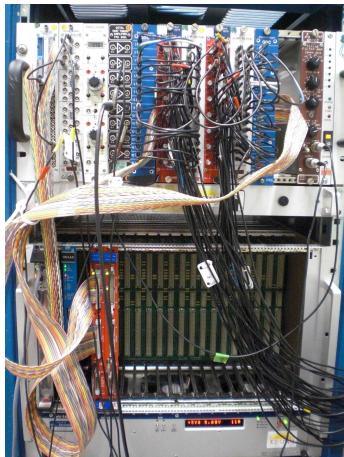
IMAR (Individual Multi Anode Readout) Technique





Characterization of the position sensitive detector

IMAR (Individual Multi Anode Readout) Technique





Position calibration



Position calibration