PSD8
8TH INTERNATIONAL CONFERENCE ON POSITION SENSITIVE DETECTORS

Position Sensitive Scintillator based Detector Improvements by means of an Integrated Front-End

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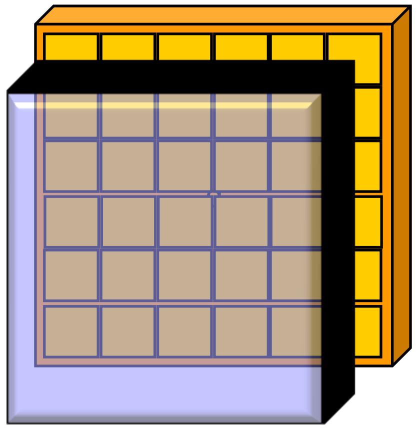
IFIC
INSTITUT DE FÍSICA CORPUSCULAR

1-5 September – University of Glasgow - Scotland

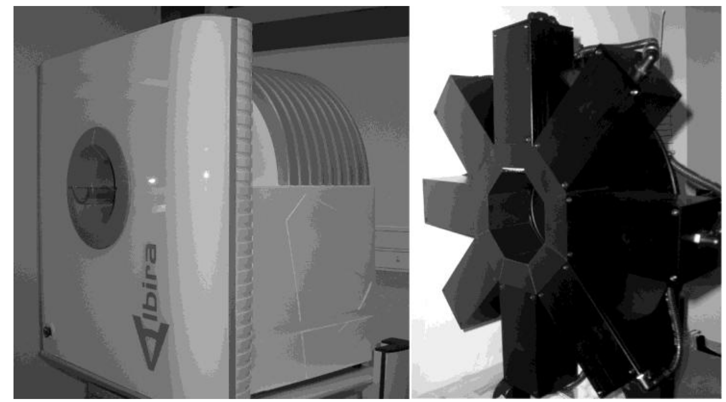
Continuous Scintillator Gamma Ray Detector

LSO :
42x42x10 mm

PMT :
Hamamatsu
H8500



Designed for PET applications



- Lower cost.
- Higher detector sensibility. [1]
- Better energy resolution. [2]
- DOI measurement without detector modifications. [3]
- Geometry and Coating of the crystal can be changed for optimization. [4]

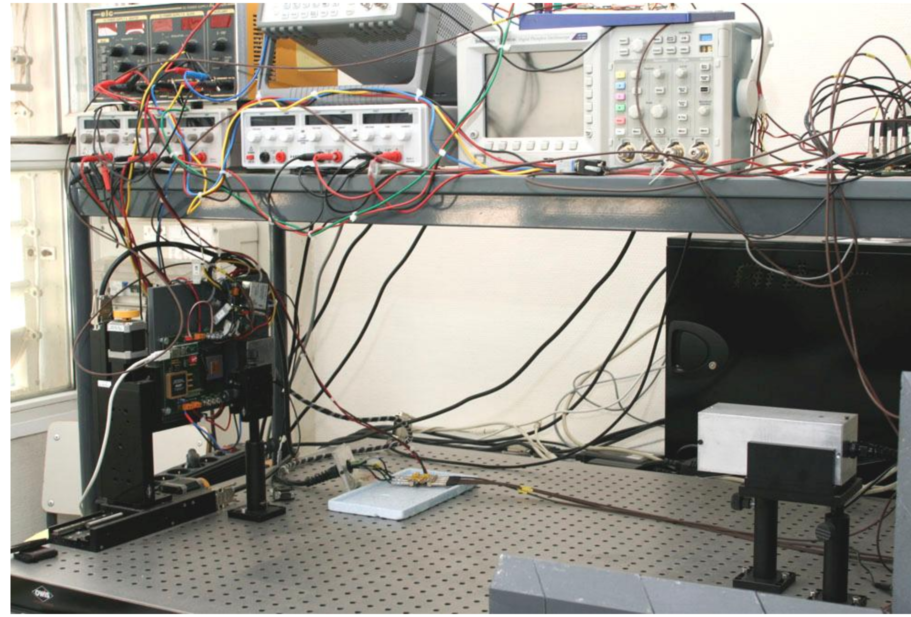
[1] P. Bruyndonckx, et al. "Performance Study of a PET Detector Module Based on a Continuous Scintillator", IEEE Trans. Nucl. Sci., (53), 2536, 2006.

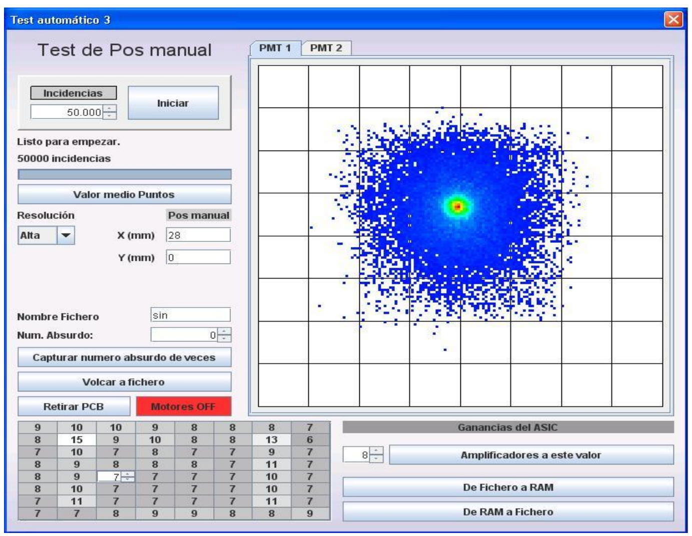
[2] P. Bruyndonckx, et al. "Initial Characterization of a Nonpixelated Scintillator Detector in a PET Prototype Demonstrator", IEEE Trans. Nucl. Sci., (53), 2543, 2006.

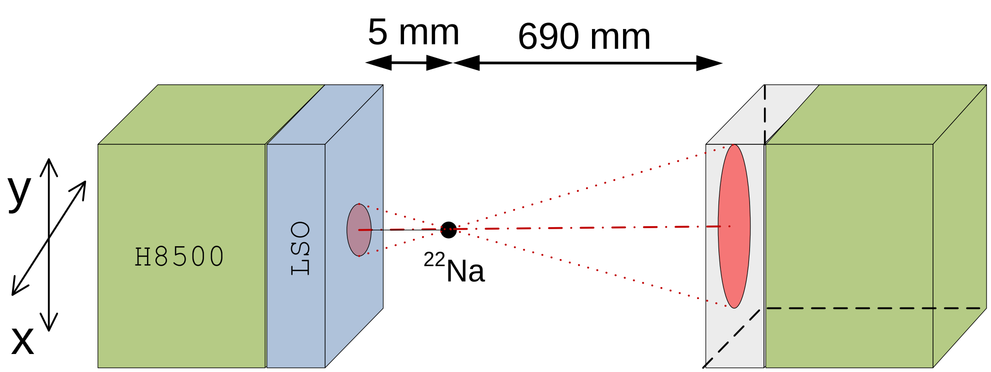
[3] C. W. Lerche, et al. **"**Depth of gamma-ray interaction within continuous crystals from the width of its scintillation light-distribution**"** *IEEE Trans. Nucl. Sci.*, (52), 560, 2005.

[4] C. W. Lerche, et al. **"**Dependency of Energy, Position and Depth of Interaction on Scintillation Crystal Coating and Geometry**"**, IEEE Trans. Nucl. Sci., 55, (2008) 1344.

Experimental Setup



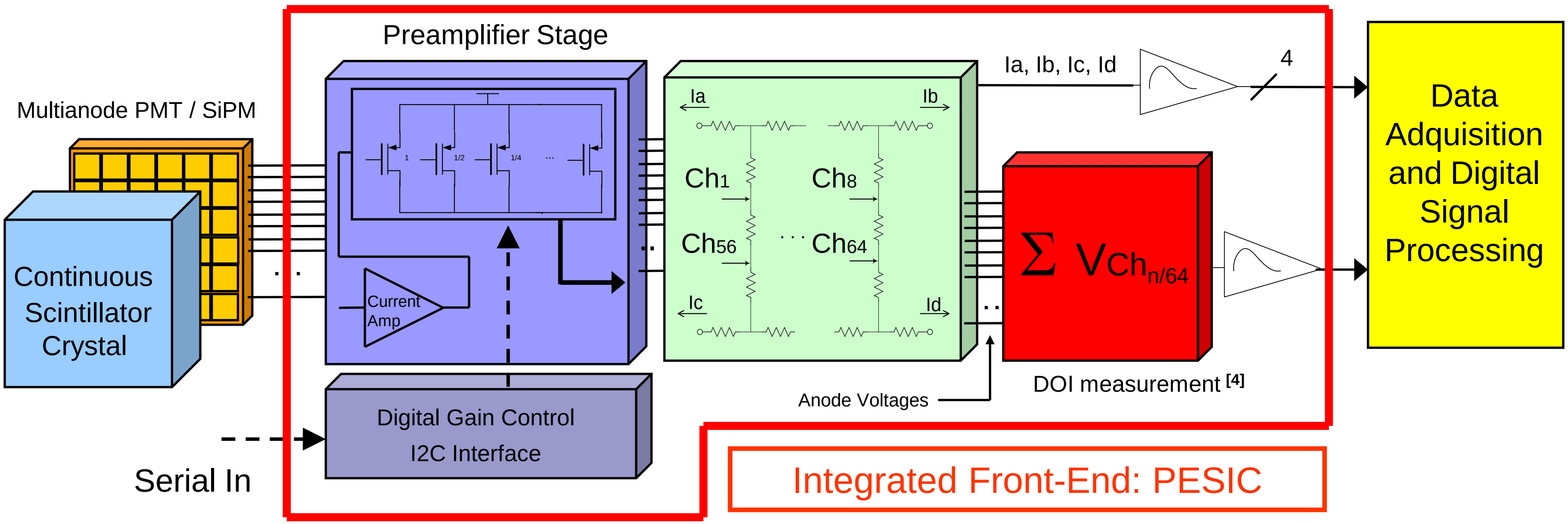




$r_{\text{collimation spot}} = 0.75$ mm

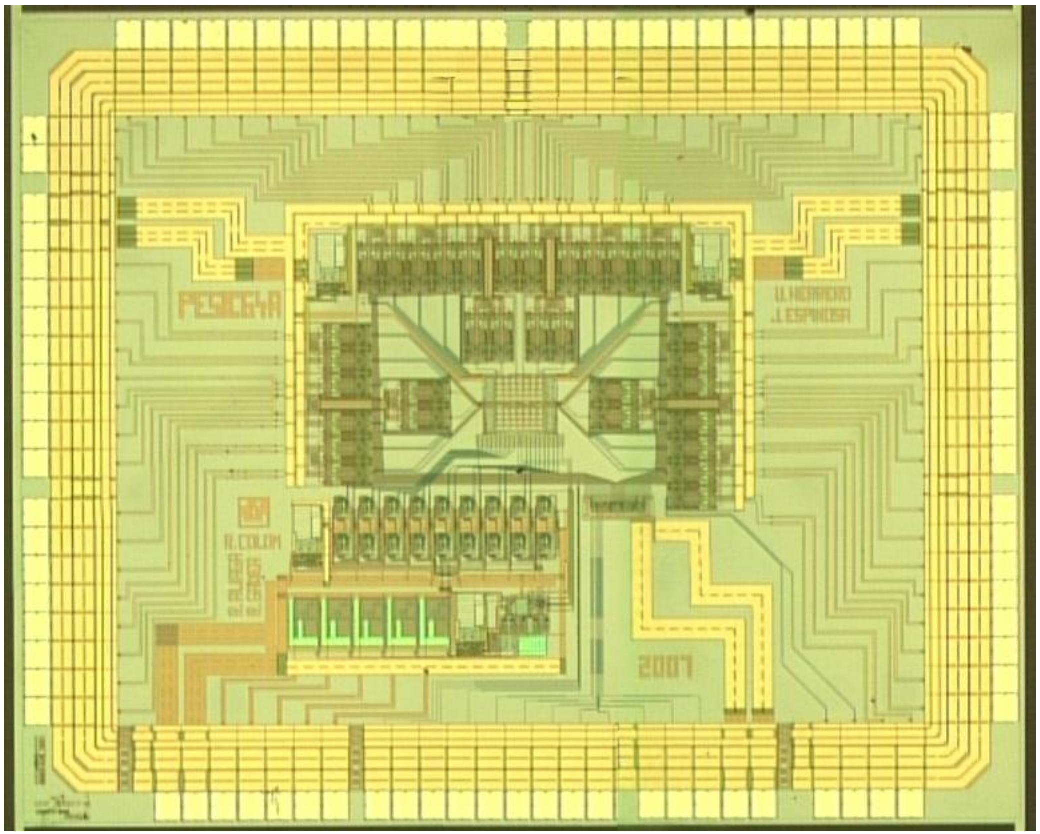
$R_{\text{collimation restriction}} = 10$ mm

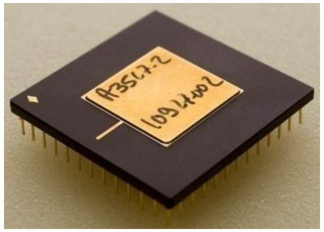
Analog Front-End Electronics



- Individual Anode Gain Adjustment for Detector Equalization.
- Possible use of other Photomultipliers (SiPMs).
- Reduce Front-End delay.
- Depth of Interaction Measurement.

PESIC





- AMS 0.35um Technology.
- Low Power consumption (17 mA – 56 mW).
- 4 bits Preamplifier Gain Factor.
- Simplified Implementation of DOI Algorithm

[5] V.Herrero, et al. "PESIC: An Integrated Front-End for PET applications", IEEE Trans. Nucl. Sci., 55, (2008) 27

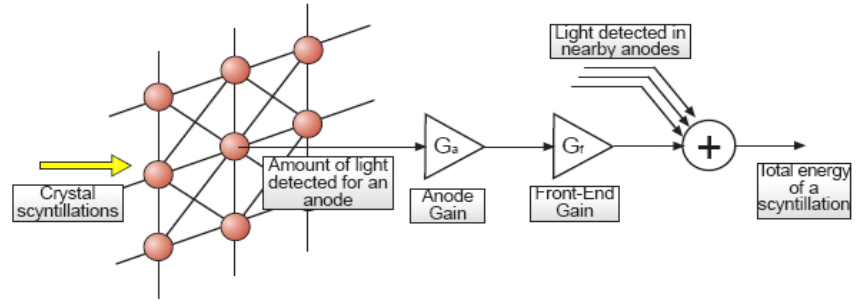
Equalization Method

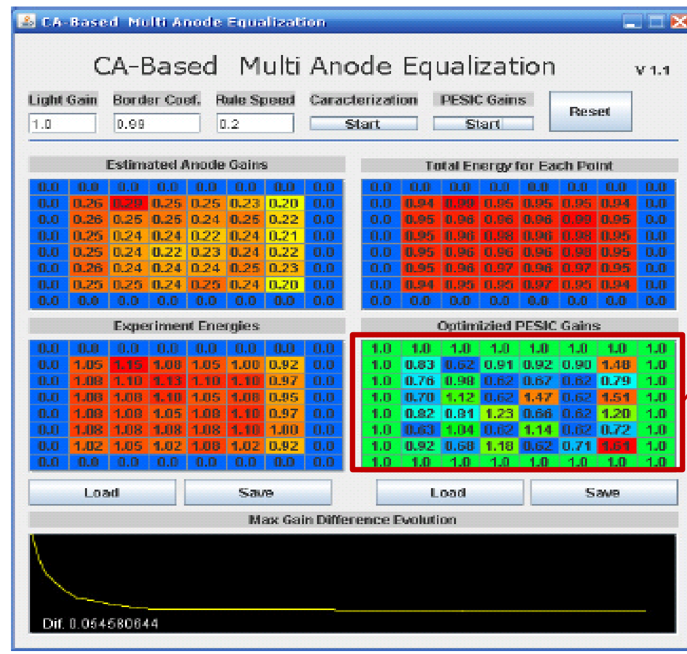
0.041	0.075	0.097	0.075	0.041
0.075	0.197	0.326	0.197	0.075
0.097	0.326	0.645	0.326	0.097
0.075	0.197	0.326	0.197	0.075
0.041	0.075	0.097	0.075	0.041

Theoretical Model

Scintillation Light distribution on detector surface

$$L = \frac{effd}{\sqrt{((x-x_0)^2+(y_0-y)^2+effd^2)^3}}$$





Set of Gains

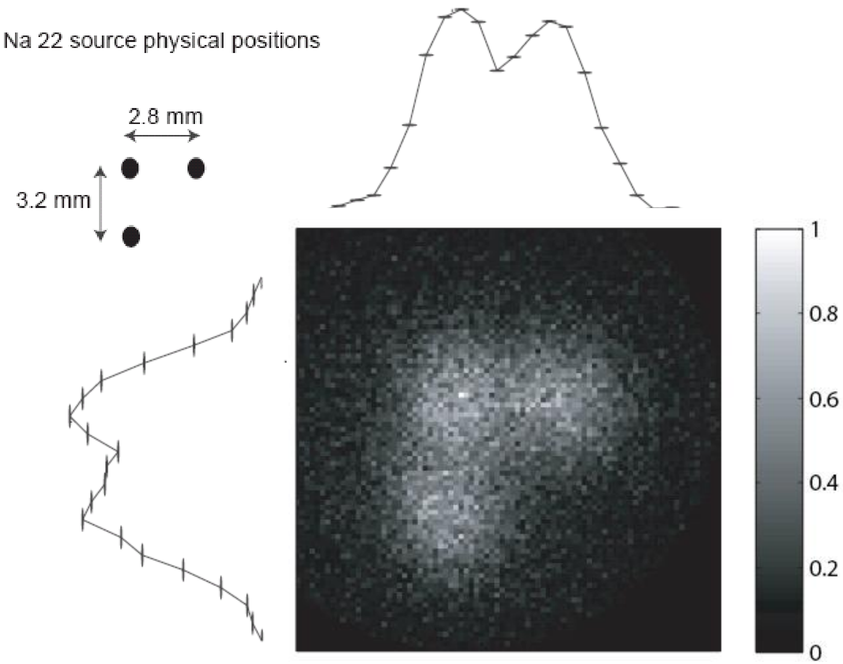
[6] N. Ferrando, et al. "Cellular Automaton-Based Position Sensitive Detector Equalization", POSTER SESSION 1 (15:00)

Spatial Resolution Measurements before Equalization

DETECTOR CENTER AREA

Rx (intrinsic) = 1.78 mm ± 0.1
Ry (intrinsic) = 2.08 mm ± 0.15

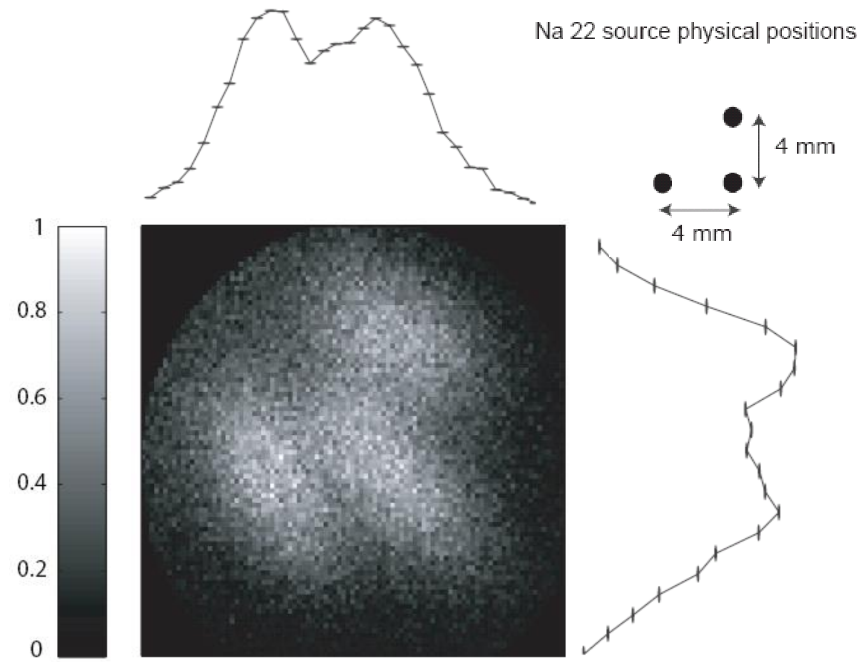
$\boxed{\text{Rcombined} = 2.73\text{ mm} \pm 0.18}$
Compression Factor = 1.55



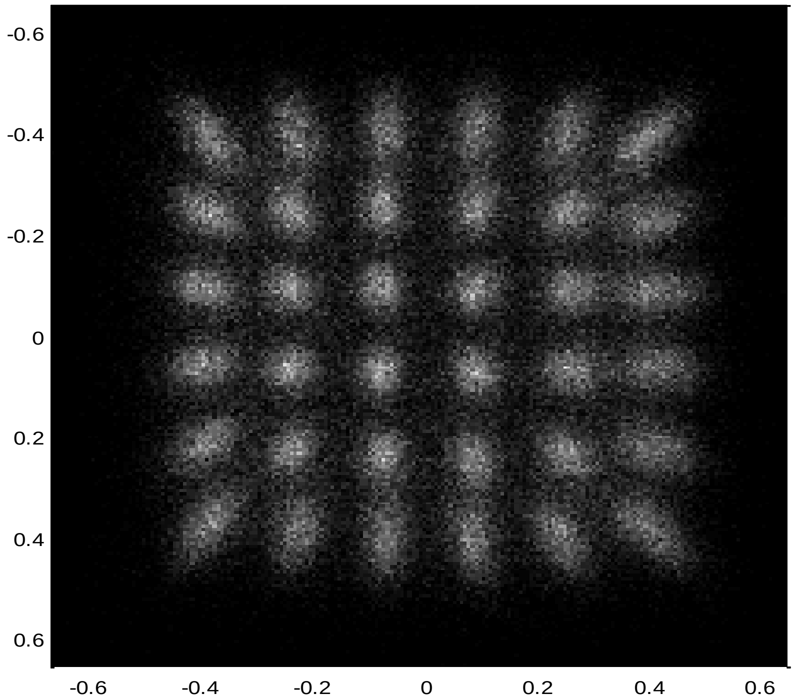
DETECTOR CORNER AREA

Rx (intrinsic) = 2.74 mm ± 0.3
Ry (intrinsic) = 2.67 mm ± 0.25

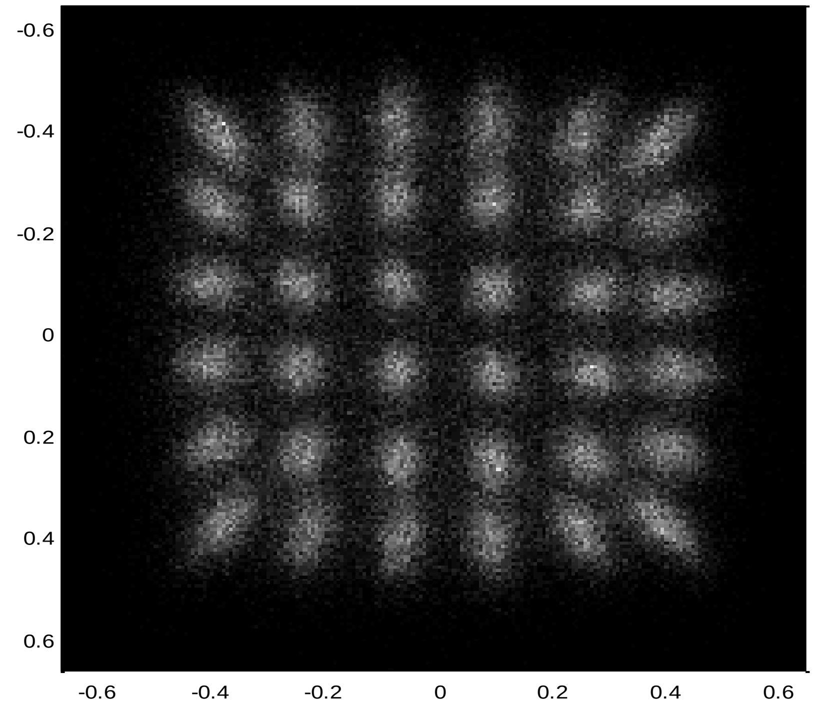
$\boxed{\text{Rcombined} = 3.82\text{ mm} \pm 0.39}$
Compression Factor = 1.55



36 Points Sweep Over Detector Area



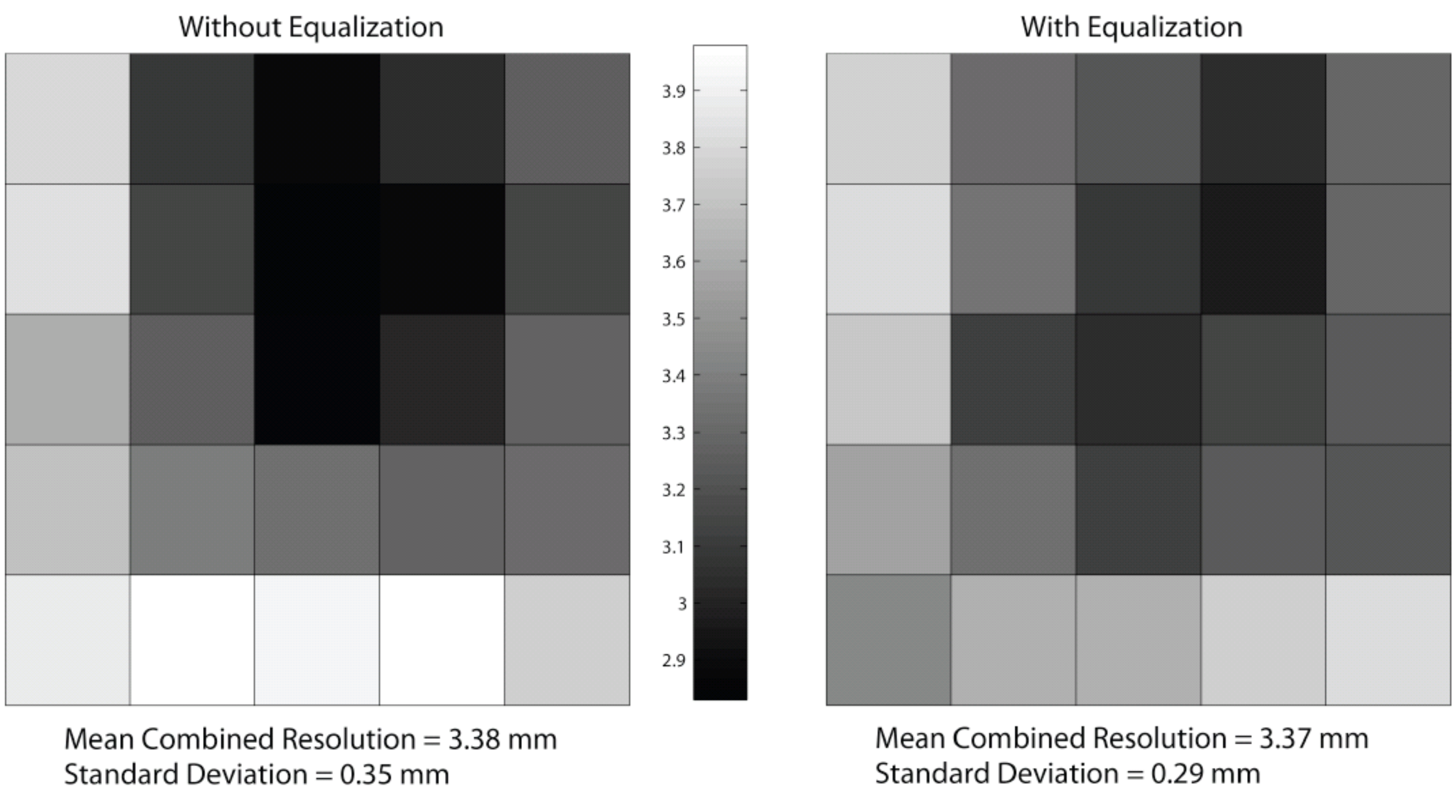
Without Equalization



With Equalization

IMPROVEMENT??

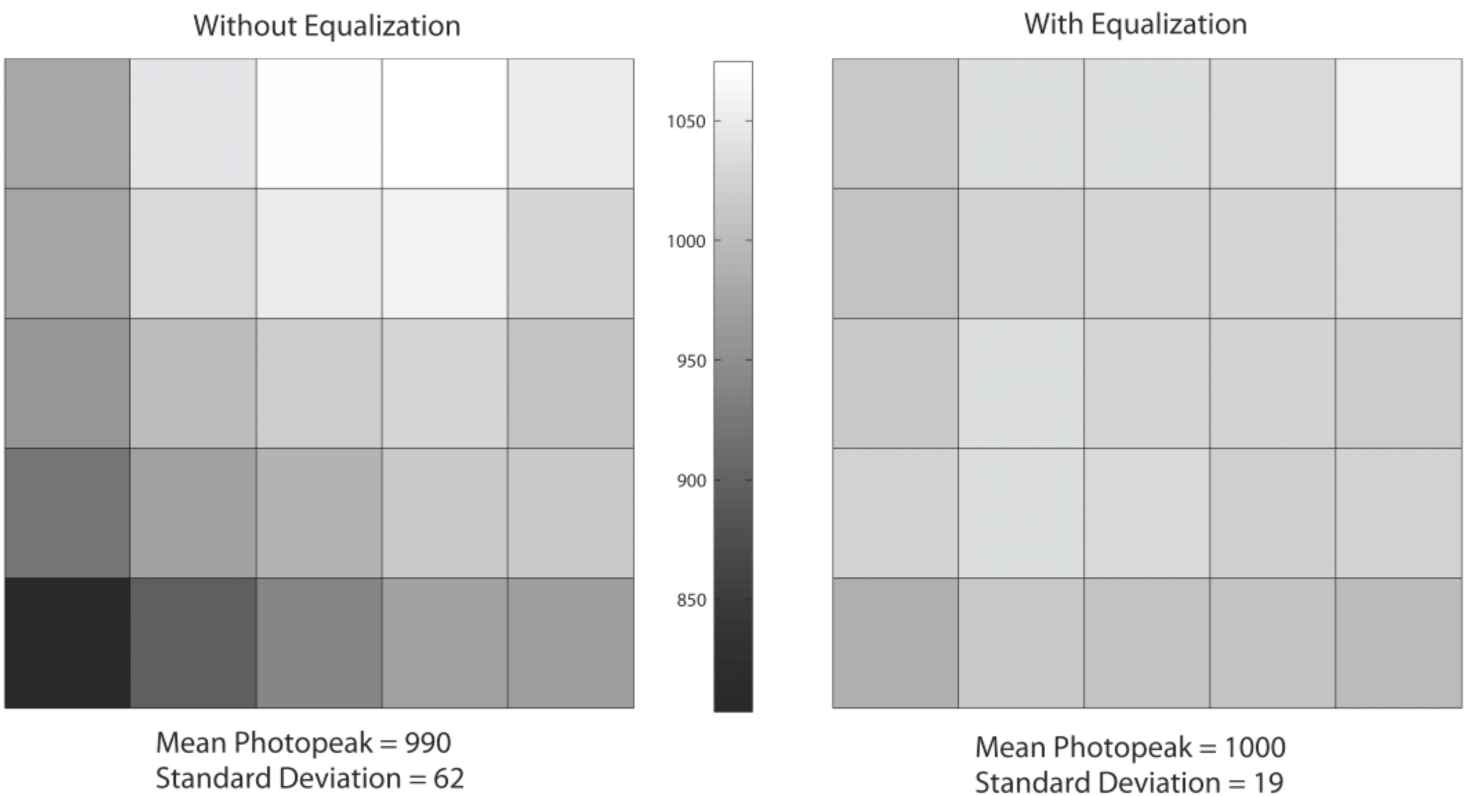
Effect of Equalization on Spatial Resolution



More Homogeneous Response Over Area

4 bits → LSB ~ 6.25% STD_{eq} ~ 8.6 %

Effect of Equalization on Energy Measurements (I)



More Homogeneous Response Over Area

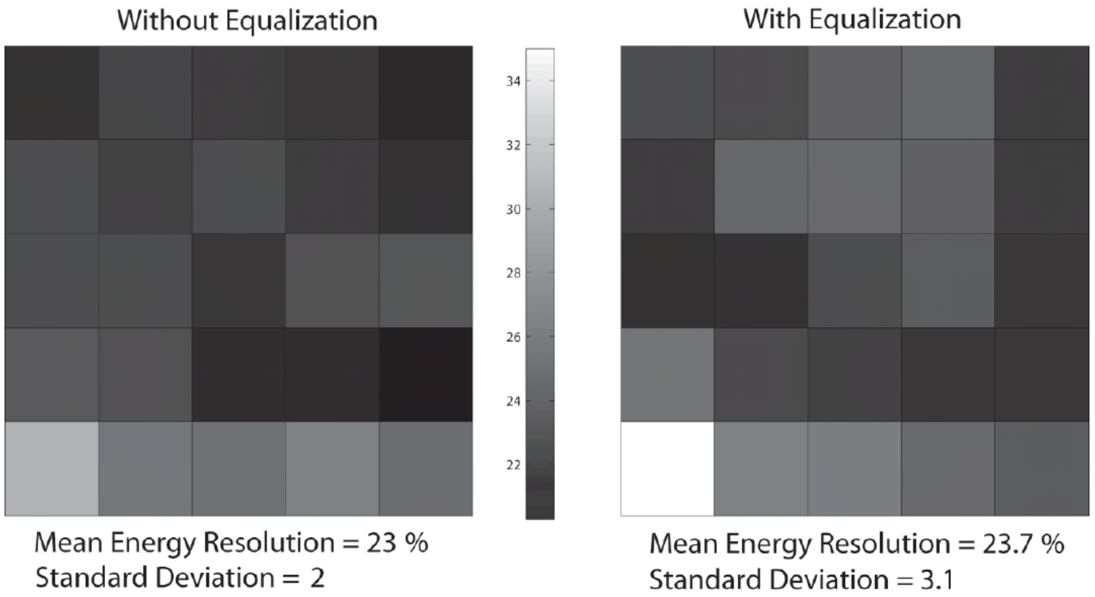
Effect of Equalization on Energy Measurements (II)

$$R^2_{PMT} = \frac{\sigma^2_{PMT}.(2.35)^2}{E^2_{PMT}} = \frac{5,56}{N\eta\alpha}\frac{\delta}{\delta - 1}$$ [6]

$$\sigma^2_{PMT} = \sum_{i=0}^{m} \sigma_i^2 = (N\eta\alpha)\sum_{i=0}^{m} \delta_i^{2n}\frac{\delta_i}{\delta_i - 1}$$

δ ~ [2.5 , 3]

$\boxed{\delta \downarrow \; \rightarrow \; \sigma \uparrow}$



Equalization Process

$$\overline{\sigma^2_{PMT}} = (N\eta\alpha)\sum_{i=0}^{m} A_i^2\delta_i^{2n}\frac{\delta_i}{\delta_i - 1}$$

$$A_0\delta_0^n = A_1\delta_1^n = \ldots = A_m\delta_m^n$$

$$E_{PMT} = \overline{E_{PMT}}$$

More Preamp Gain to anodes with higher σ

Energy Resolution Degraded

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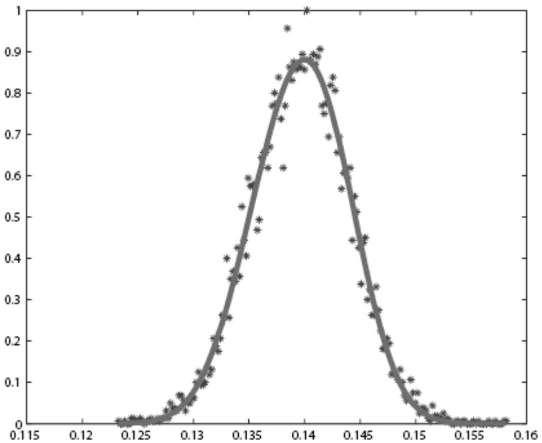
[6] R. Pani, et al. “Factors Aecting Hamamatsu H8500 Flat Panel PMT Calibration for Gamma Ray Imaging" IEEE Trans. Nucl. Sci., 54 (2007) 438.

Depth of Interaction Measurements

Without Equalization



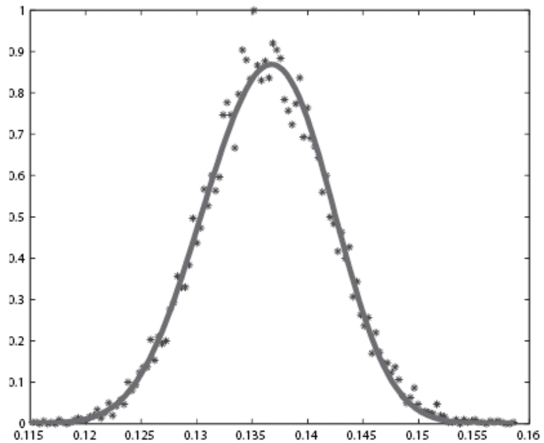
ΔDOI = 8.48 mm $\pm$ 1.77

a = 0.133 $\pm$ 6E-4

b = 0.142 $\pm$ 5E-4

σ = 3.38E-3 $\pm$ 2.9E-4

With Equalization



ΔDOI = 8.21 mm $\pm$ 2.58

a = 0.127 $\pm$ 1.9E-3

b = 0.140 $\pm$ 2.3E-3

σ = 4.29E-3 $\pm$ 4.6E-4

Fitting Model [4]

$$F(z) = Ae^{Kz}\left(Erf\left\{\frac{b-z}{\sqrt{2}\sigma}\right\} - Erf\left\{\frac{a-z}{\sqrt{2}\sigma}\right\}\right)$$

$$\Delta DOI = 2.35\sigma\frac{scintillator\ thickness}{|a-b|}$$

[4] C. W. Lerche, et al. **"**Dependency of Energy, Position and Depth of Interaction on Scintillation Crystal Coating and Geometry**"**, IEEE Trans. Nucl. Sci., 55, (2008) 1344.

- DOI can be estimated but ...
- Poor resolution for 10 mm thick scintillator
  - Simplified version of the original algorithm
  - More inputs in DOI block increase resolution (only 8 are taken)
  - Resolution bellow 3 mm has been reported [4]

Thank you for your attention