Cellular Automaton-Based Position Sensitive Detector Equalization

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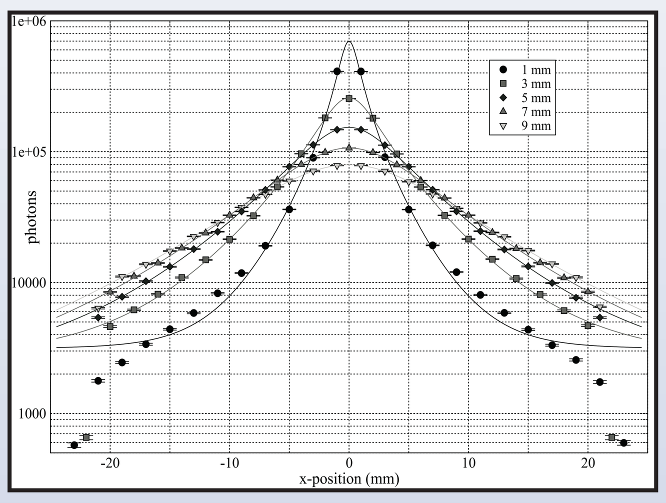
1 Introduction

• Indirect detectors based on scintillator crystals make use of photomultiplier (PM) devices in order to sense visible light generated by gamma ray interactions inside them [1].

• An issue related to the use of multianode PM is the outputs gain factor inhomogeneity which strongly affects energy and spatial resolution.

• Also, In order to measure the interaction depth, it is necessary to paint the borders of the crystal in black. Due to this and the different PM gains, the energy of a ray interaction varies heavily depending on the incidence point.



• Adjusting the gains of a post-amplification stage is not easy because changing the gain of an anode affects the interaction energies of a wide area due to the light diffusion [2].

In this poster, an algorithm for predict the optimal gains is shown. The obained gains, which reduce the interaction energy variations, have to be applied after the PM anodes

2 ¿Cellular Automata?

• Discrete dynamical systems used for modelling and simulation [3].

• Consists of a lattice of identical sites called cells.

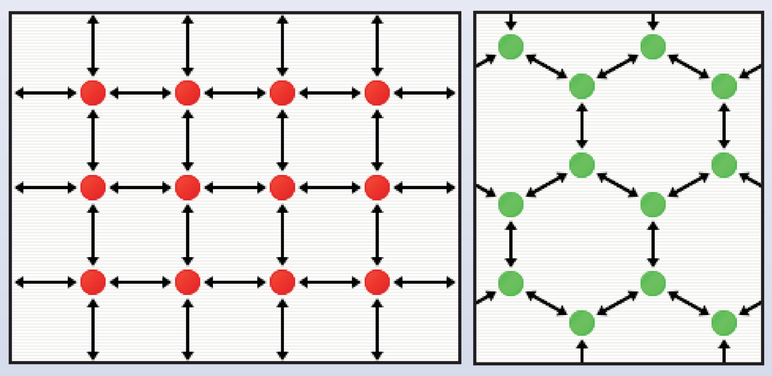
• Each cell is connected to nearby ones, called also *neighbours*.

• All the cells evolve in discrete time steps and each one can take values from a finite set.

• The state of a cell in time *t* is function of its state and the state of its neighborhood at the previous time step.

• All the cells update their state in a synchronous update process. The algorithm used to change the states is called the *evolution rule.*

$$State(t+1)=F(State(t),Neighbours(t))$$



Used in areas like:

• Social Models
• Disease Simulations
• Cryptography
• Computability Theory

3 Theoretical Model

The light distribution created by a gamma ray interaction follows this equation [2]:

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

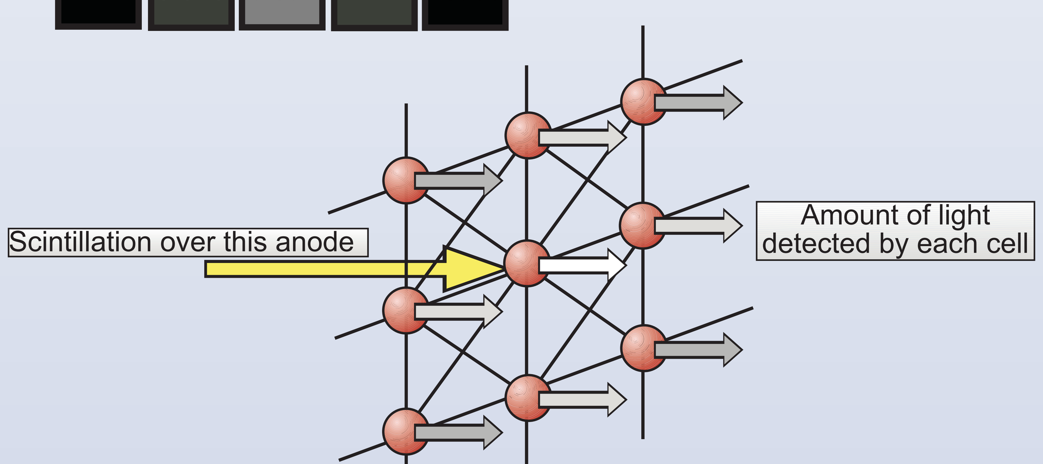
effd: gamma ray interaction depth
x, y: point where light is measured
x0, y0: light origin

Using the appropriate variables for our currently used crystal and photomultiplier, and integrating along the different anode surfaces we get the following light distribution for each anode when an incidence happens:

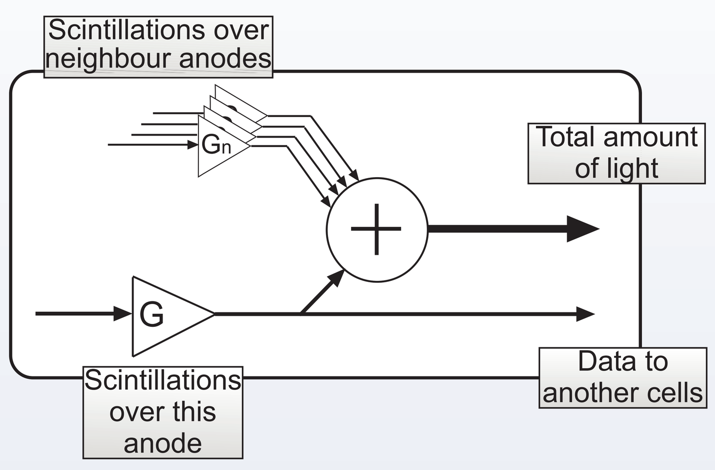
0.041	0.075	0.097	0.075	0.041
0.075	0.197	0.326	0.197	0.075
0.097	0.326	0.645	0.326	0.097
0.075	0.197	0.326	0.197	0.075
0.041	0.075	0.097	0.075	0.041

This can be represented as a cellular automaton, where each cell is a photomultiplier anode.

When a scintillation happens over a cell, it gives part of the light to its neighbour cells following the obtained light distribution.



The logic inside each cell is the following:



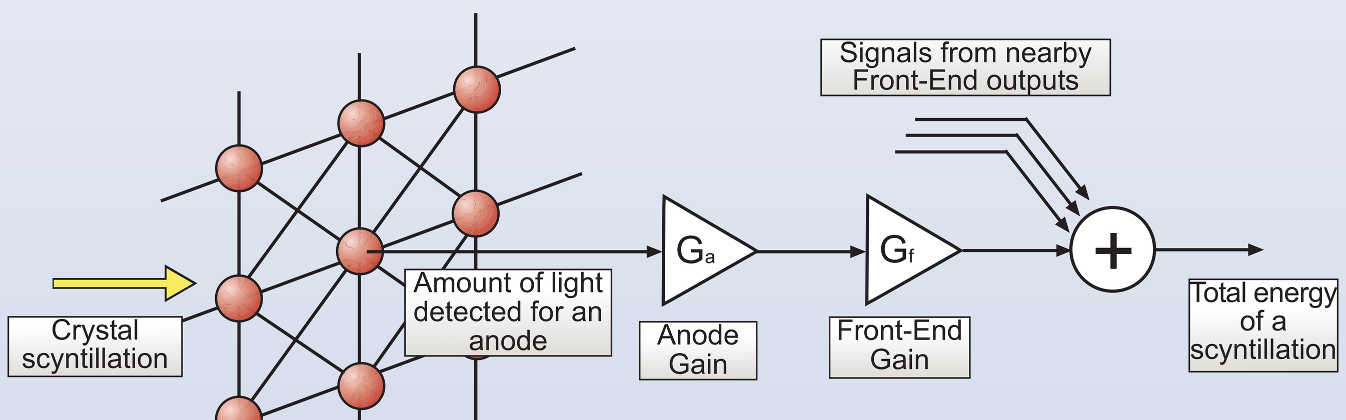
Each cell, when a scintillation happens over it, sends the info to its neighbour cells.

The total amount of light detected by a cell is the accumulation of scintillations over it plus all the scintillations happened near, multiplied by the appropriate light diffusion coefficient.

After this stage, the output of each anode is connected to two gains: the PM anode gain and the corresponding Front-End gain.

The total energy of a scintillation is calculated by accumulating all the outputs of the Front-End that are near of the scintillation.

The complete model is shown below.



Finally, the use of the model requires two steps:

From experimentally measured energies the anode gains are estimated and then, with the estimated anode gains, the Front-End gains are adjusted in order to reduce the energy variance.

These two steps can be translated into two different evolution rules. Each cell of the complete Cellular Automaton is composed by the light diffusion cell plus the two gains and the accumulator that calculates the total energy.

1st step: Bypassing the Front-End gain, adjust the Anode Gain for make the energy calculated for this cell similar to the experimentally measured one:

$$G_a(t+1)=G_a(t)-K\left[Energy(t)-Measured\ Energy\right]$$

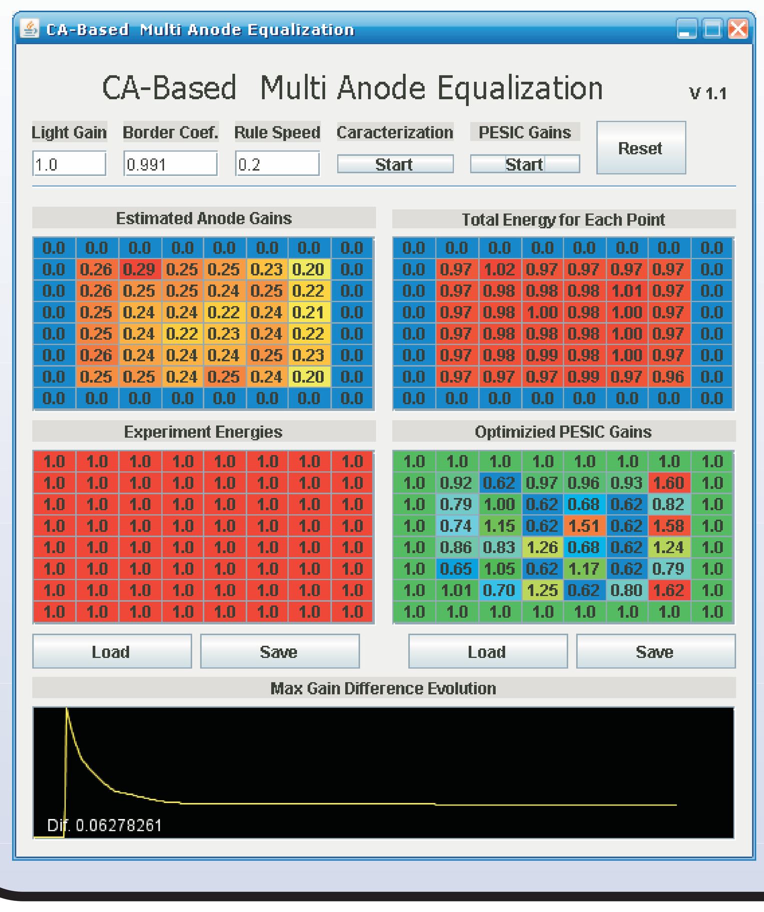
2nd step: adjust the front-end Gain in order to make the energy calculated for this cell similar to the energy obtained for neighbour cells:

$$G_f(t+1)=G_f(t)-K\left[Energy(t)-\overline{Neighbour\ Energies(t)}\right]$$

-These evolution rules are applied to all the cells of the system each step time.

-The applied rule depends on what is being done at the moment.

4 Software Implementation



A program was made in order to apply the model

Application programmed in Java

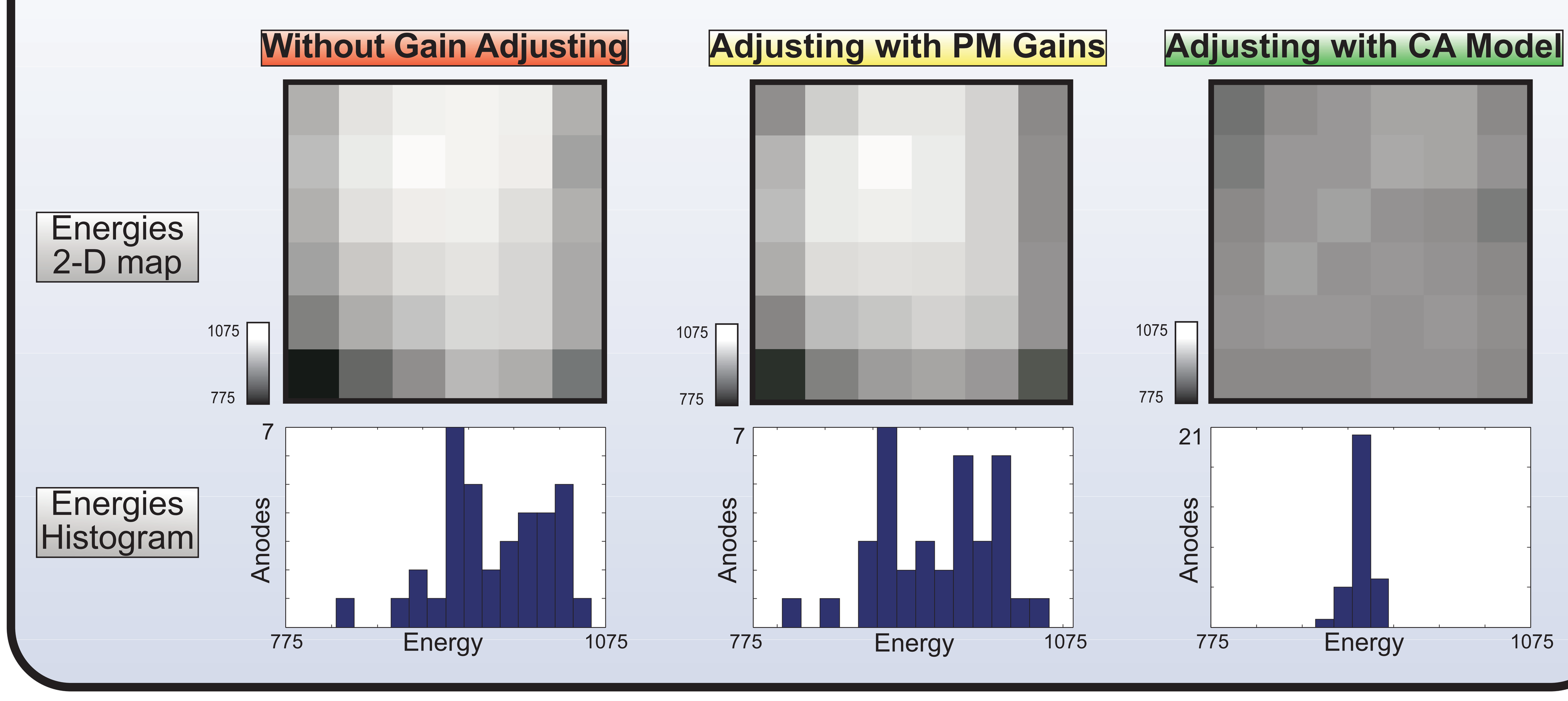
With this application we are able to:

• Load data from an experiment
• Estimate Anode Gains
• Get best Front-End Gains for reduce energy variance
• Change several model parameters
• View the resulting energy variance evolution
• View graphically the estimated gains.

Executable and source code are avaiable at
www.upv.es/dsd

5 Results

A Na22 radioactive source was placed over each PM anode. For each position the energy of the incidences was calculated. The obtained gains were applied using PESIC[4]



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[2] C. W. Lerche, J. M. Benlloch, F. Sanchez, N. Pavon, B. Escat, E. N. Gimenez, M. Fernandez, I. Torres, M. Gimenez, A. Sebastia, and J. Martinez, **"Depth of gamma-ray interaction within continuous crystals from the width of its scintillation light-distribution,"** IEEE Trans. Nucl. Sci., vol. 52, no. 3, pp. 560–572, 2005.

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