Desarrollo de detectores de CdTe para aplicaciones espaciales en el ICE-CSIC

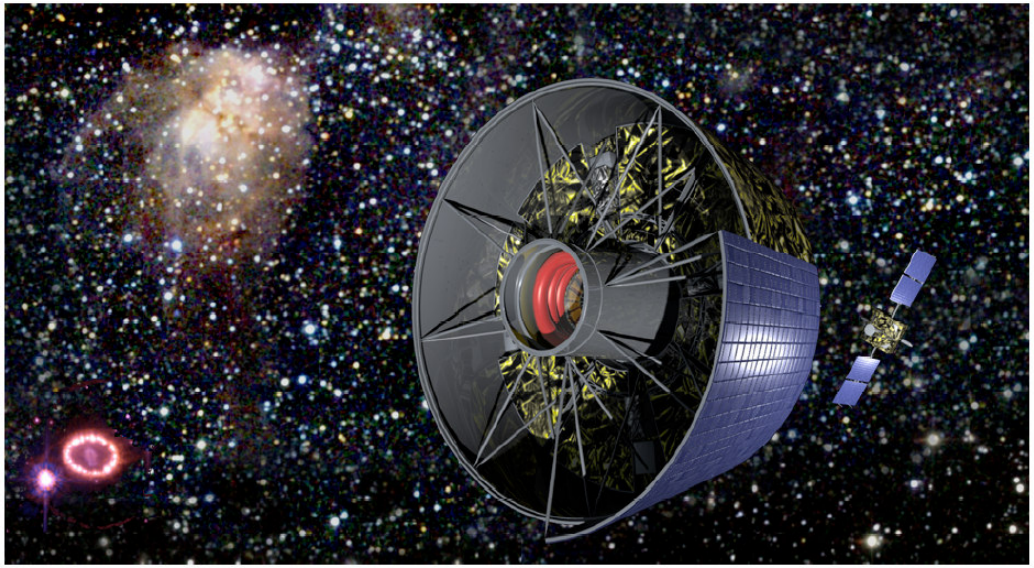
Margarita Hernanz

Instituto de Ciencias del Espacio (CSIC-IEEC)

Doble interés en XEUS: científico y tecnológico

- Antecedentes científicos:
  - Explosiones estelares (novas y supernovas): modelos, nucleosíntesis y emisión a altas energías (X y γ)
  - Usuarios asiduos de XMM-Newton
  - Propuestas ToO para INTEGRAL
  - Participación en el equipo científico de la propuesta de NASA ACT (y GRASP)
- Instrumentación para astrofísica de altas energías
  - Prototipo de lente de focalización de rayos γ CLAIRE (colaboración CESR, Toulouse)
  - Participación en la propuesta de misión Gamma-Ray Imager (GRI), Cosmic Vision 2015-2025

exploring the extremes **GRI**



Jürgen Knödlseder, Peter von Ballmoos (CESR, France)
Filippo Frontera (UNIFE, Italy), Angela Bazzano (INAF/IASF-Rome, Italy)
Finn Christensen (DNSC, Denmark)
Margarida Hernanz (IEEC/CSIC, Spain)
Cornelia B. Wunderer (UCB, USA)

This proposal has been prepared by the GRI consortium, formed by about 100 scientists from the following countries (in alphabetical order): Belgium, China, Denmark, France, Germany, Ireland, Italy, Poland, Portugal, Russia, The Netherlands, Spain, Turkey, United Kingdom, and USA
A complete list of consortium members can be found at http://gri.iasf-roma.inaf.it/GRIMemberList.asp

Proyecto R&D PNE (2008)

Diseño, desarrollo y test de un prototipo de cámara Compton Si/CdTe

Si y CdTe apilado – ref. Takahashi

Colaboración con IMB/CNM (CSIC)

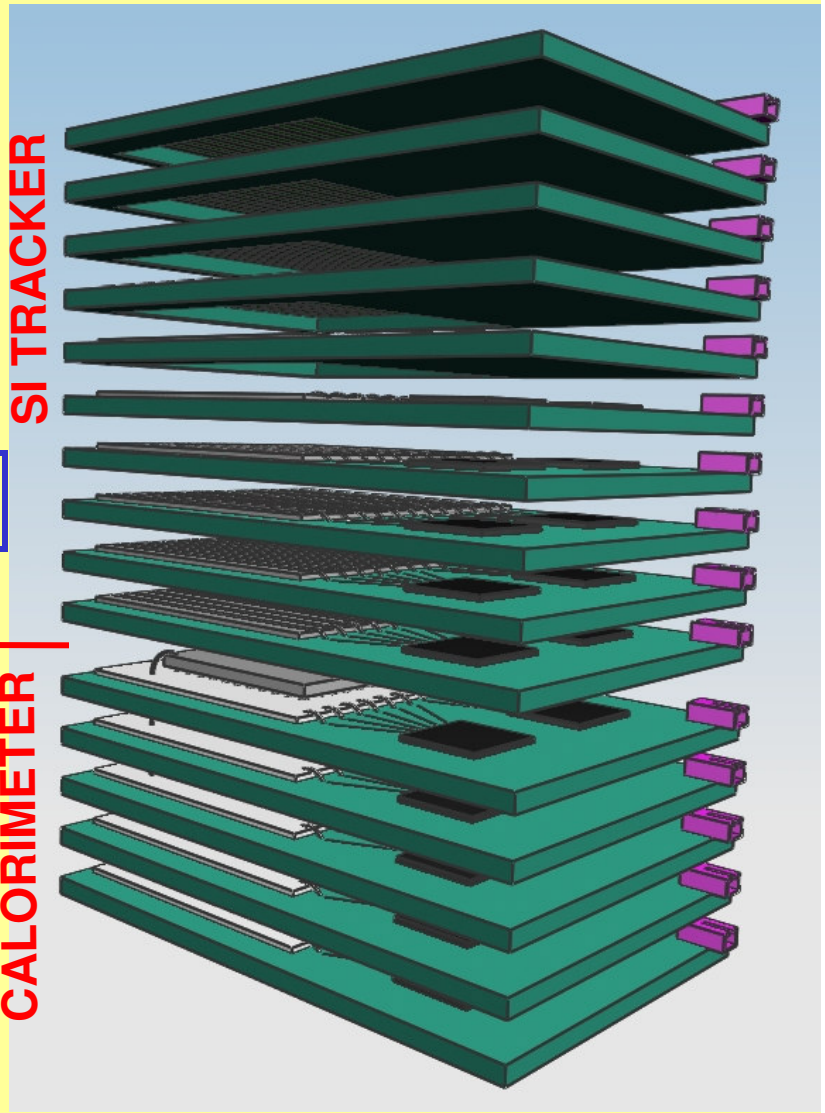
OBJETIVO: contribuir al estudio conceptual del detector de GRI

Optimizar el diseño mediante simulaciones con GEANT4.

Reto: detectar γ's con E hasta 1(-2) MeV con resolución energética óptima

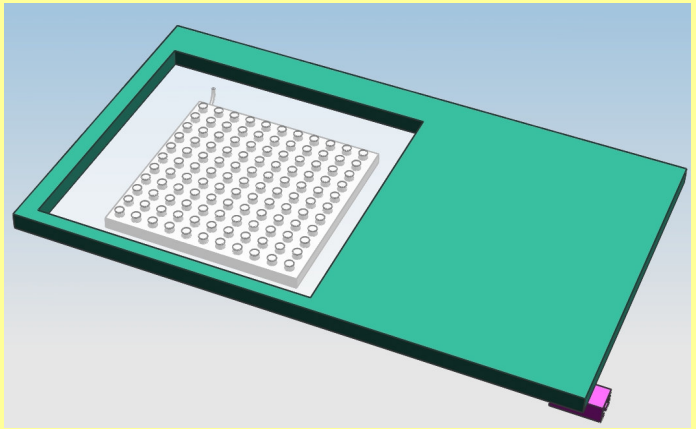
Compton camera

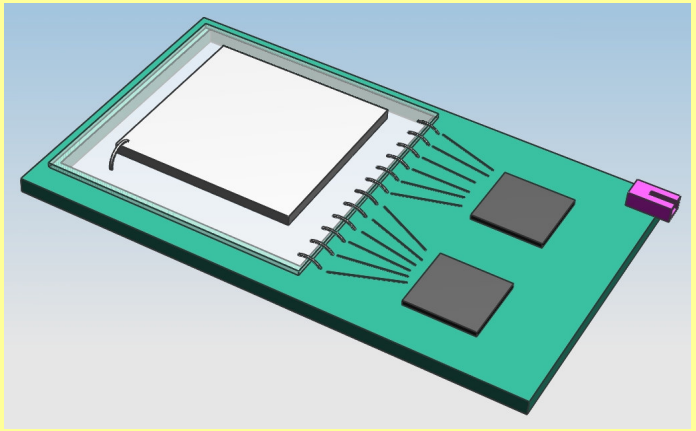
- Tracker/moderator: Si
- Calorimeter/absorber: stacked CdTe
- Read out electronics
  - Make use of adapted LHC electronics for Si detectors
  - NuCam chip from RAL for CdTe
- Readout DAQ based on National Instruments and LabView
- GEANT4 simulations:
  - optimization of the design
  - comparison of simulations with measurements
  - simulations in space environment

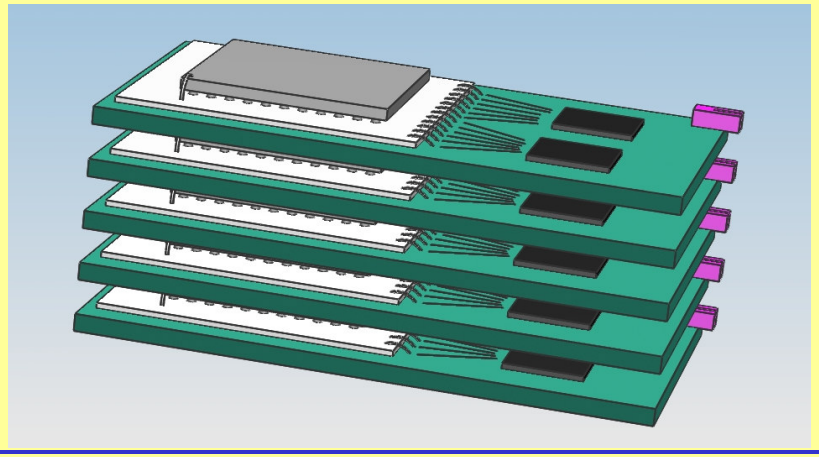


Compton camera: CdTe calorimeter

- Pixellated CdTe: 11×11=121 pixels pixel sixe ~1mm
- 5 layers
  - thickness 0.5, 1.0, 2.0, 4.0, and 8.0 mm
  - goal: good energy resolution for gamma rays in the range 150 keV to 1-2MeV

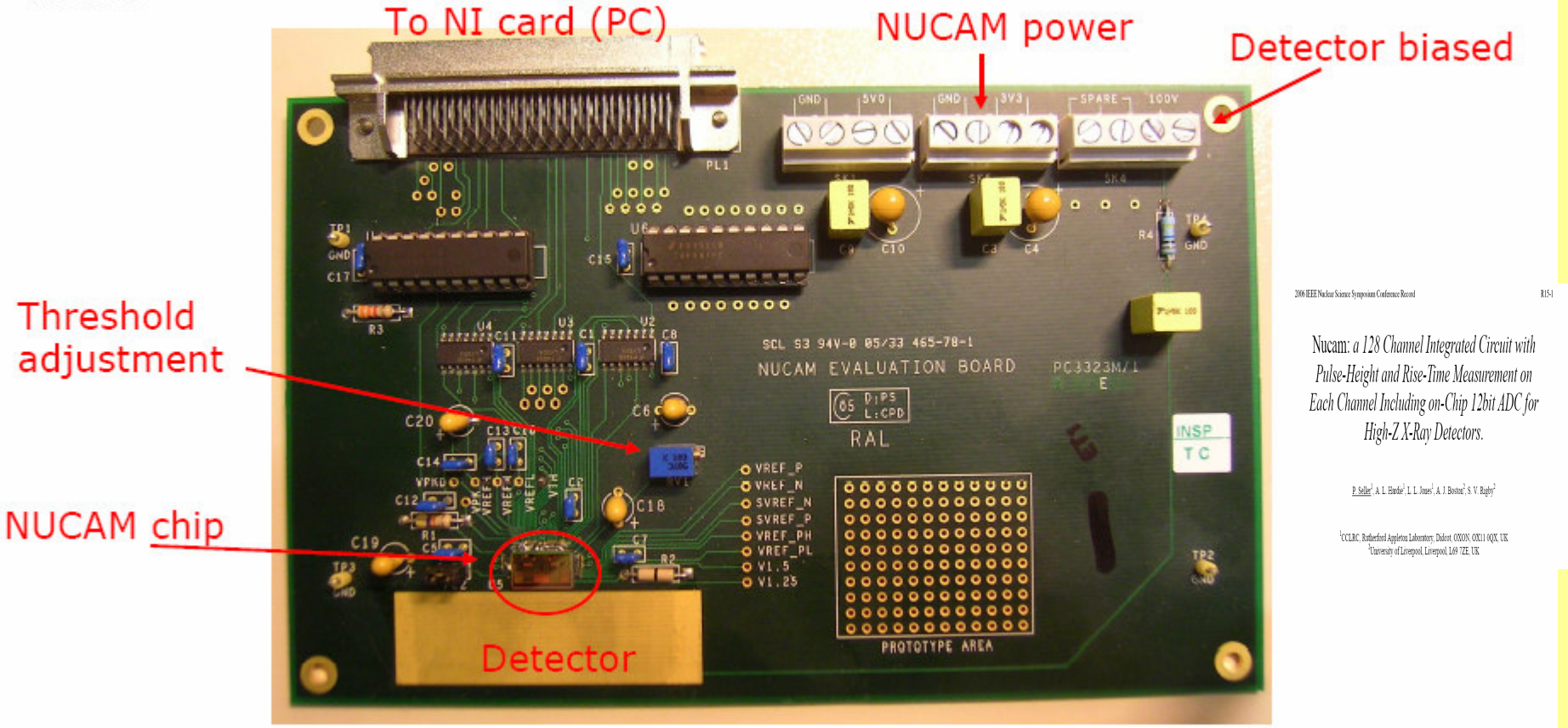






NUCAM ASICs on Labview system

A Labview based test system has been built including an interface card for ASIC.



2006 IEEE Nuclear Science Symposium Conference Record R15-1

Nucam: a 128 Channel Integrated Circuit with Pulse-Height and Rise-Time Measurement on Each Channel Including on-Chip 12bit ADC for High-Z X-Ray Detectors.

P. Seller[1], A. L. Hardie[2], L. L. Jones[1], A. J. Bostou[2], S. V. Rigby[2]

[1]CCLRC, Rutherford Appleton Laboratory, Didcot, OXON. OX11 0QX, UK
[2]University of Liverpool, Liverpool, L69 7ZE, UK

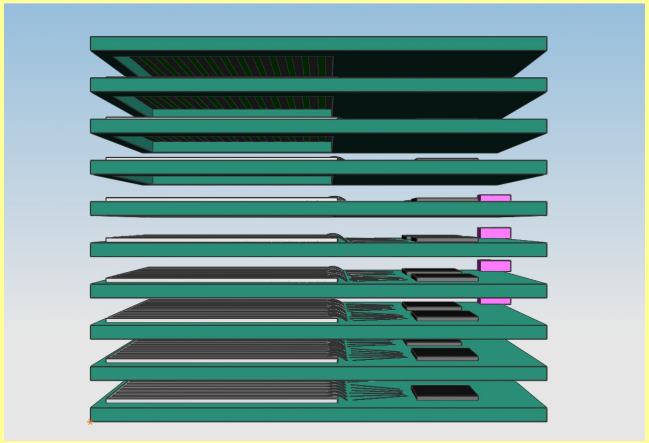
It allows us to control the ASIC and input calibration signals as well as to display raw data and perform simple statistical analysis of the values readout.

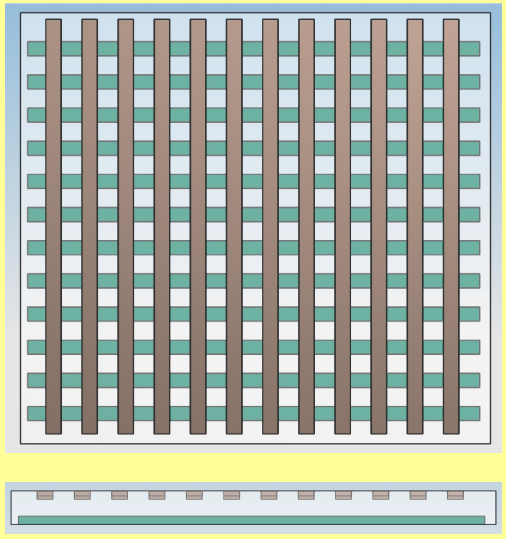
RAL/ICE/IMB collaboration

José Luis Gálvez ICE

Compton camera

- Moderator: Silicon
  - Double side 128 strips with a pitch of 200 µm
  - 10 layers





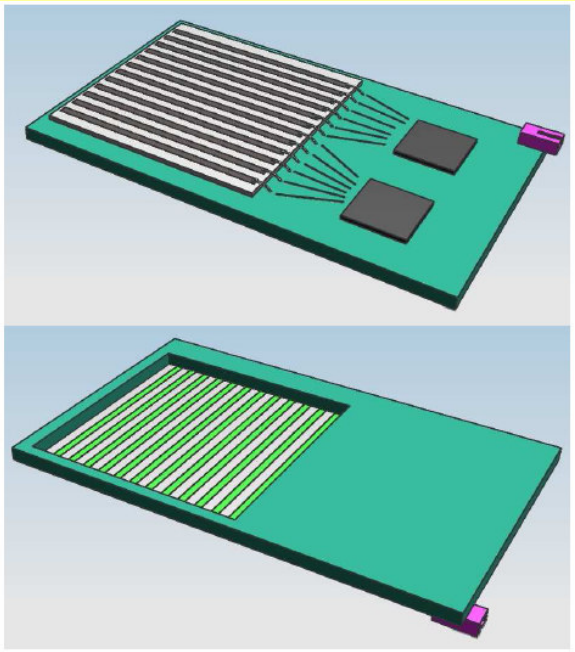


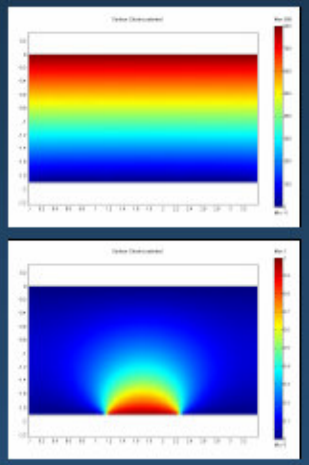
Figure 3. Top and bottom side of silicon modules

Geant4 SIMULATIONS

Simulation with Geant4 — Modelling of pixelated CdTe detectors

GEANT4:
Monte Carlo simulation of the interactions inside the CdTe substrate.

FEMLAB:
Determination of the electric field inside the pixelated CdTe detector with the finite-difference method.



Hit position: (x,y,z)
Energy: E (keV)

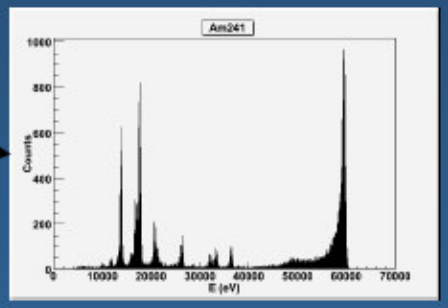
Electric potential
Weighting potential

Tracking code
To track the electron and the hole through the detector. Determine the induced signals on anode/cathode as function of time.

Modelling of read-out electronics

Comparison with a measured spectra

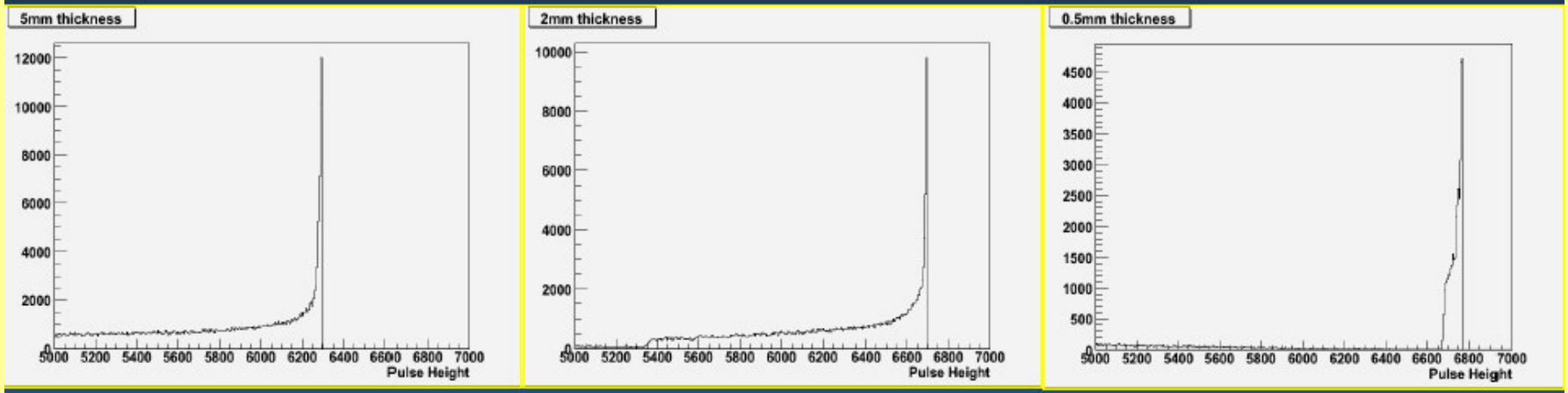
Full detector simulations



Simulation with Geant4

A CdTe diode detector

Pulse height spectra: tailing effect



Pulse Height spectra for various thicknesses of CdTe (5mm,2mm, and 0,5mm).

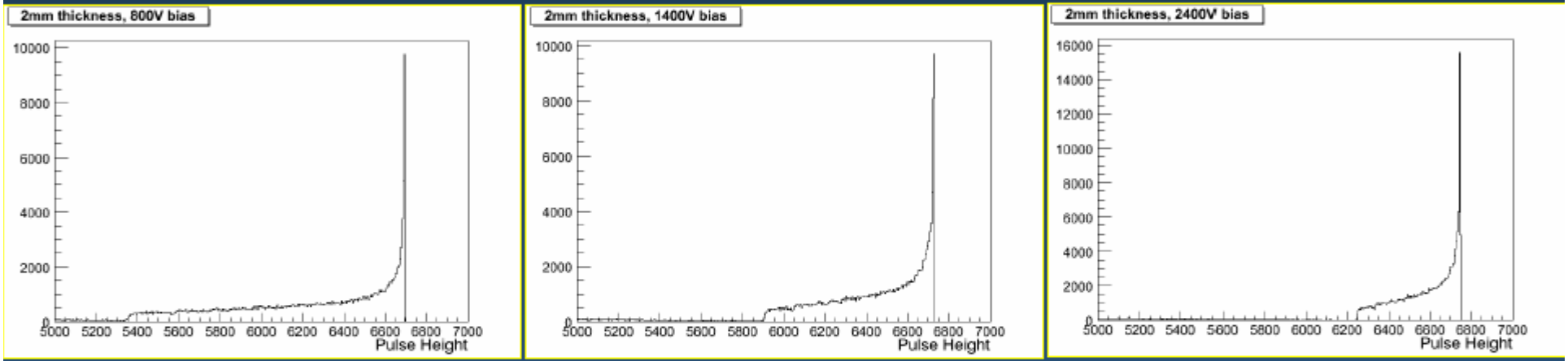
Hecht equation: $$PH(z) \propto n_0 \left[\lambda_e \left(1 - \exp\left(-\frac{d-z}{\lambda_e} \right) \right) + \lambda_h \left(1 - \exp\left(-\frac{z}{\lambda_h} \right) \right) \right]$$

Uniform electric field: E= V/d $\quad \lambda_e = \mu_e \tau_e E \ , \ \lambda_h = \mu_h \tau_h E$

The number of photons injected 10^6 for each simulation with an energy of 300keV. The applied bias voltage is 800V, and we assumed an uniform electric field.

José M. Alvarez, ICE

Pulse height spectra: tailing effect

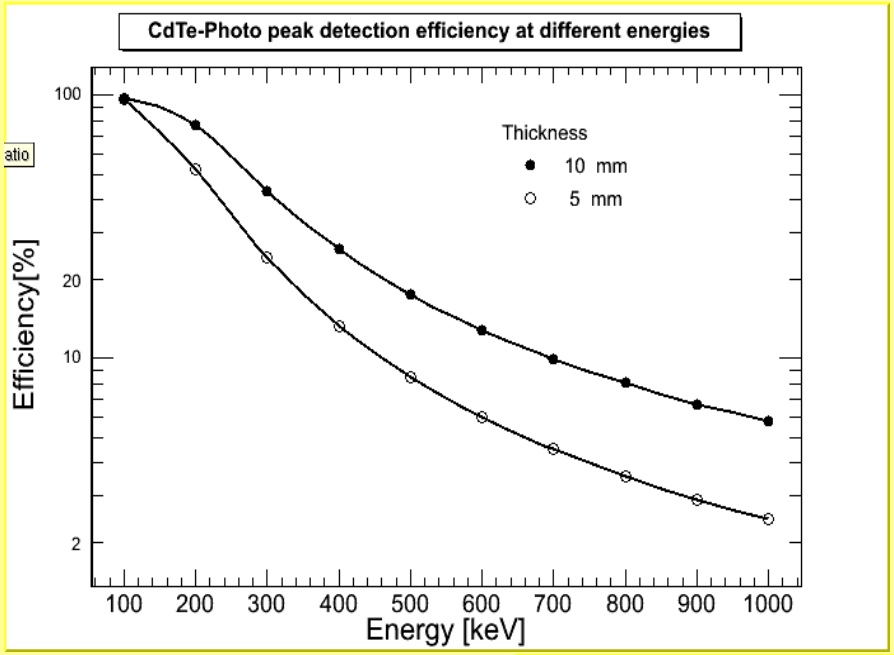


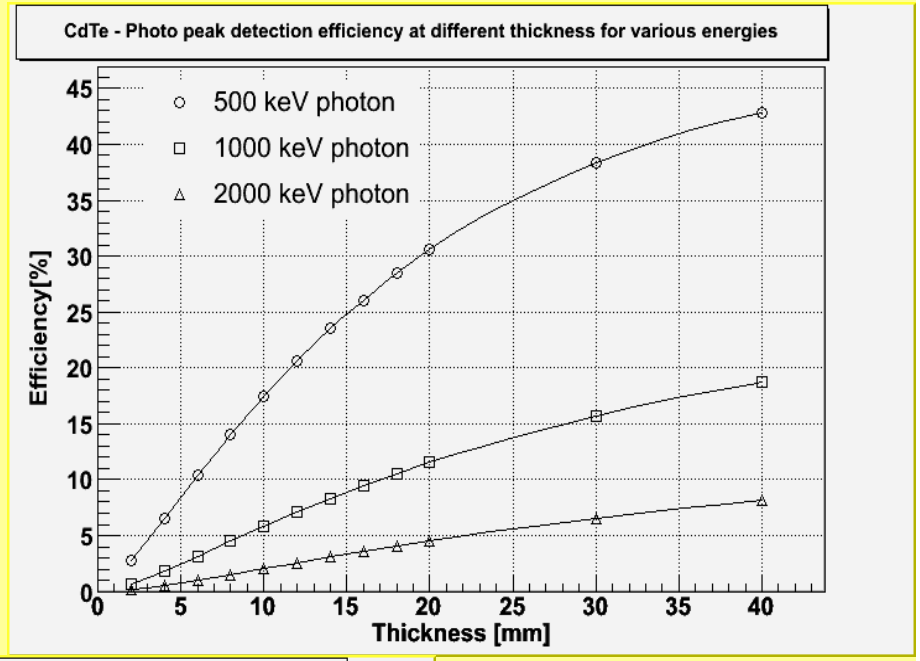
Pulse Height spectra for CdTe detector of 2 mm thickness for various applied bias voltage (800V,1400V and 2400V).

For a certain detector thickness (2mm) the charge collection efficiency improves as the applied bias voltage increase.

José M. Alvarez, ICE

Photo peak detection efficiency: monolithic CdTe detector





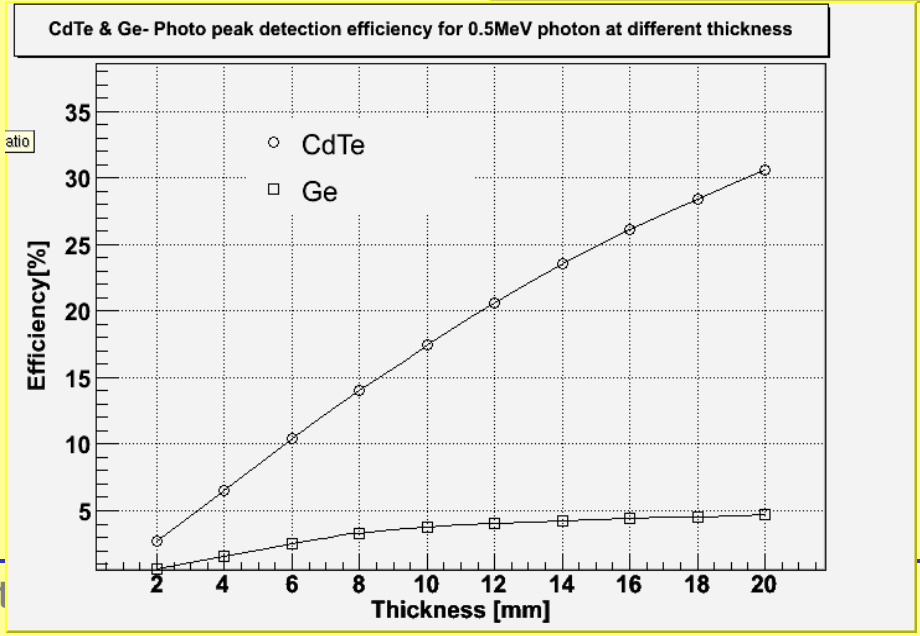
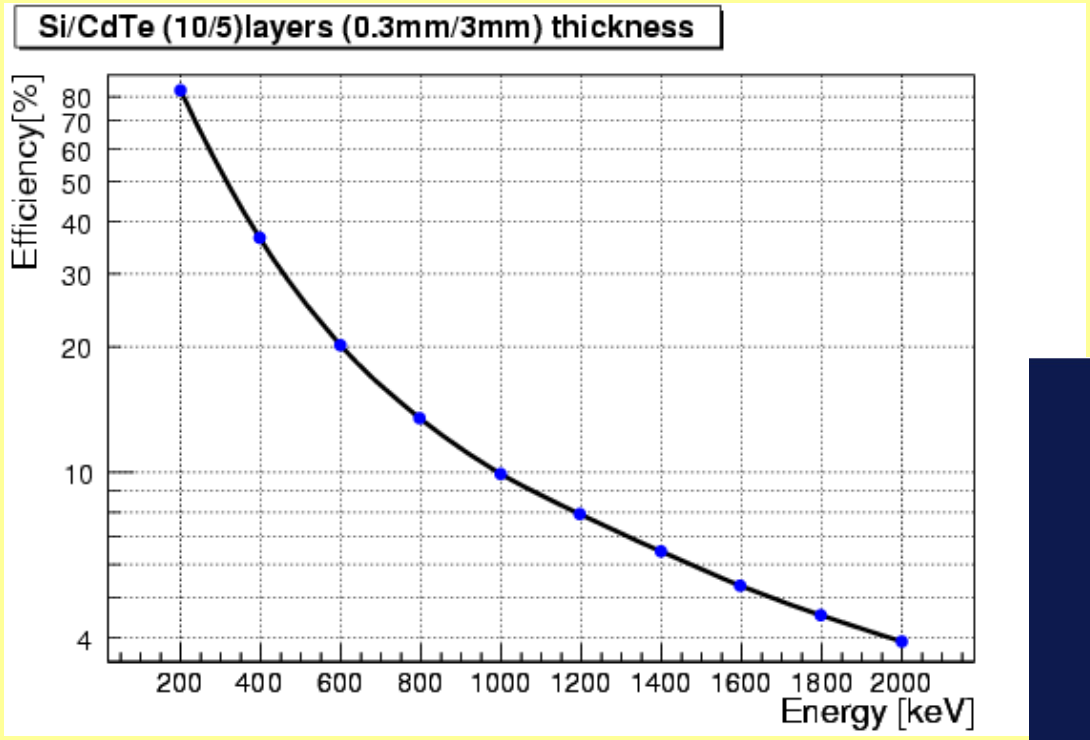
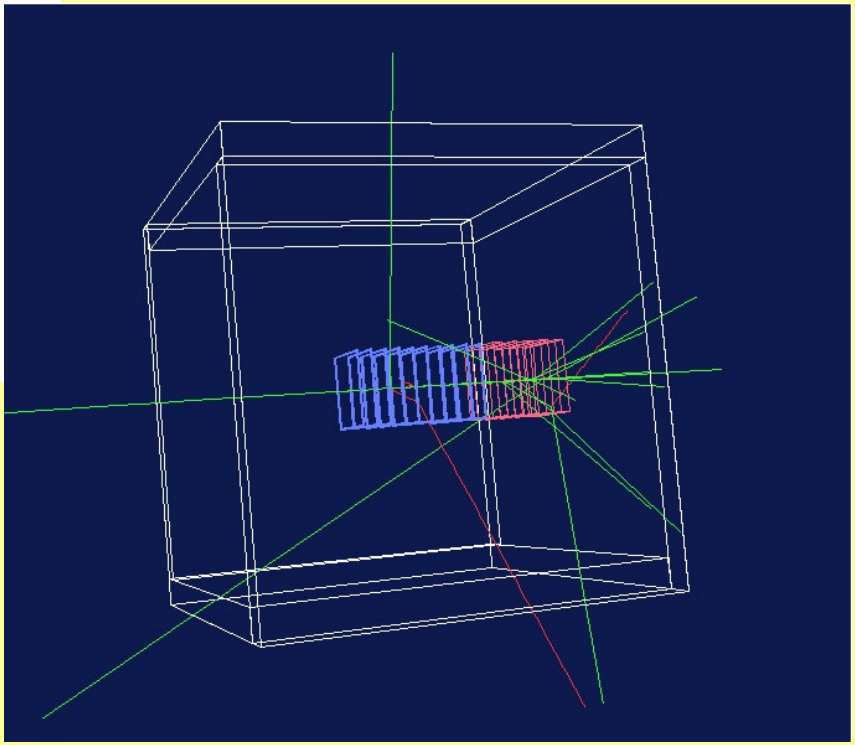


Photo peak detection efficiency: Si/CdTe stacked detector



Geant4 Geometry
10 layers of Si + 5 layers of CdTe



Ongoing and near future simulations

• Optimize readout electronics to improve the energy resolution

➢ electric field inside the CdTe pixellated detector, to track the electrons and holes: *the 3D electric field will be calculated with a finite-difference method (FEMLAB)*

• *Event reconstruction: Compton sequence reconstruction with/without electron tracking (MEGAlib)*

• *Simulation of orbital background environment (MGGPOD)*