



# APPLICATIONS OF MCSHAPE TO DETECTOR RESPONSE COMPUTATIONS

**J.E. Fernandez<sup>1,2</sup> and V. Scot<sup>1</sup>**

<sup>1</sup>Laboratory of Montecuccolino, Alma Mater Studiorum University of Bologna, Italy and  
National Institute for Physics of Matter (CNR/INFM)

<sup>2</sup> National Institute of Nuclear Physics (INFN),

# Summary

- **Outline of Detector Response**
- **Examples with MCSHAPE v2.61**
- **Future developments**
- **Conclusions**

# **OUTLINE OF DETECTOR RESPONSE**

$$I(E) = \int R(E', E) \phi(E') dE'$$

# Detector Response

(Detector influence on radiation measures)

The measured spectrum is given by the following convolution product:

$$I_{measured}(E) = \int R(E', E) \phi(E') I(E') dE'$$

Where

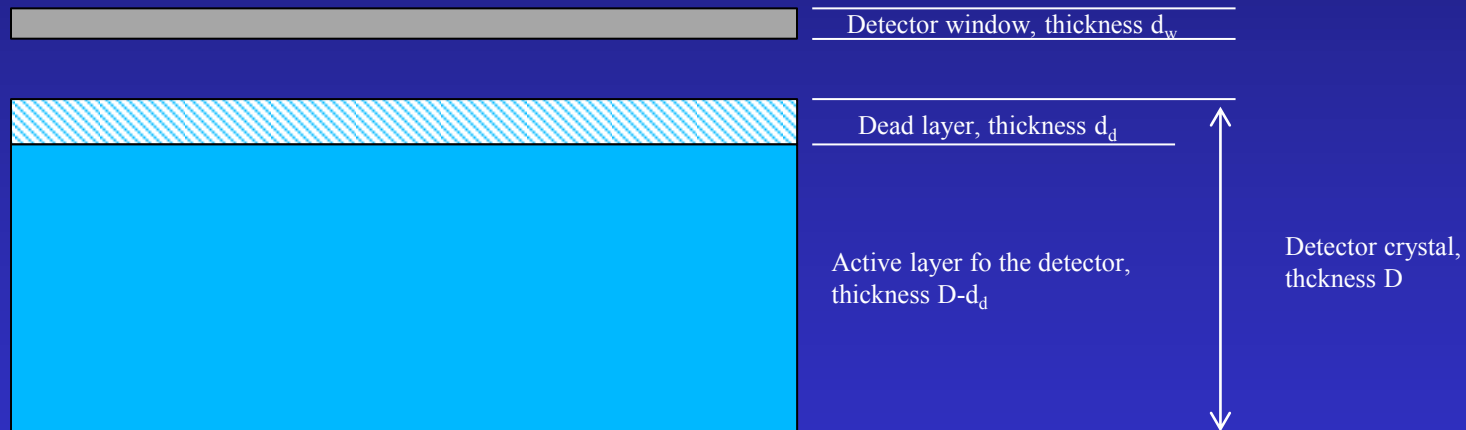
$R(E', E)$  is the **response function**

$\phi(E')$  is the **detector efficiency**

$I(E')$  is the **original spectrum**

# Simple model for the efficiency $\phi(E')$

The efficiency is straightforwardly linked to the probability to interact inside the **active** volume of the detector.



$$\phi(E') = \exp(-\mu_w d_w) \exp(-\mu_d d_d) (1 - \exp(-\mu_D (D - d_d)))$$

Attenuation in  
the window

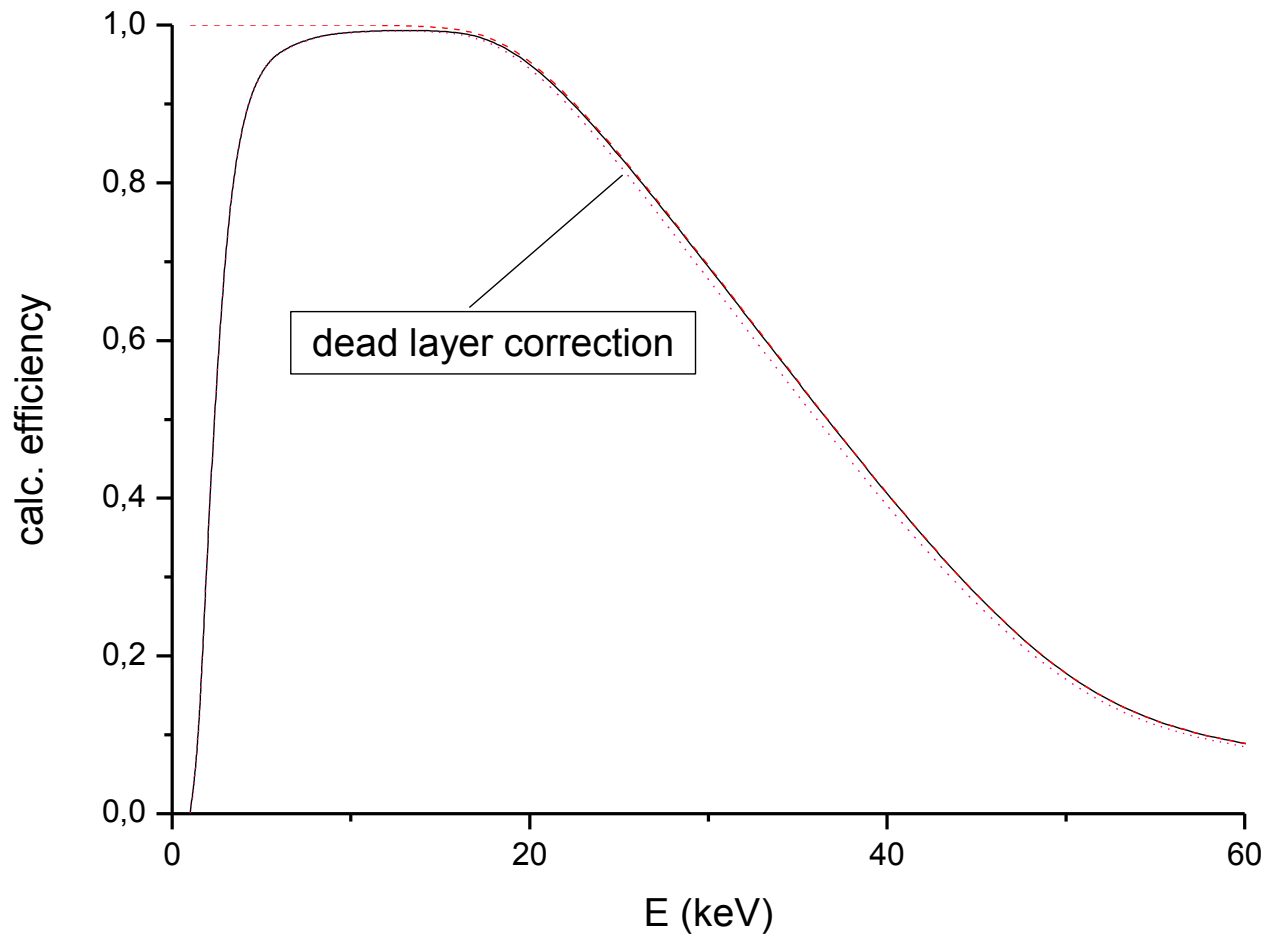
Attenuation in  
the dead layer

Probability of interaction  
in the active volume

# Example for an AMPTEK Si pin detector

- Be window, density  $\rho=1.85 \text{ g cm}^{-3}$
- $d_w = 1 \text{ mil} (=10^{-3} \cdot 2.54 \text{ cm}=0.00254 \text{ cm})$
- Si crystal, density  $\rho= 2.33 \text{ g cm}^{-3}$
- $D=500 \text{ }\mu\text{m}=0.05 \text{ cm}$
- $d_d=?$

# AMPTEK Si pin detector Calculated Efficiency



# Model of detector response

$$R(E_0, E) = \int Q(E'', E_0) G(E'', E) dE''$$

$Q(E'', E_0)$

is the **energy deposition** spectrum

$G(E'', E)$

is the **detector resolution**



# Energy deposition spectrum

- Is built by computing the **escape spectrum distribution**
- Its integral is **normalized**
- It can be calculated using a MC code

# Detector resolution

- Is frequently given by a normalized Gaussian

$$G(E_0, E) = \frac{0.9395}{FWHM(E_0)} \exp \left\{ -2.773 \frac{(E_0 - E)^2}{FWHM^2(E_0)} \right\}$$

- the FWHM is a function of energy

# Detector response computation with MCSHAPE

**MCSHAPE v.2.61**

Calculation type

Transport in the target       Detector response

Simulation

Number of histories: 100000

Number of collisions (MAX 100): 2

Output energy resolution

E max [keV]: 301.00

Channel width [keV]: 0.10000

Transport model

Vector Model       Scalar Model

Target: C:\MCSHAPE\    View

Source: C:\MCSHAPE\    View

Geometry: C:\MCSHAPE\    View

view run.log    view mcshape.log

Plots    About

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**Computes  
the energy  
deposition  
spectrum**

# What is computed with MCSHAPE v 2.61

$$\begin{aligned} I_{\text{measured}}(E) &= \int R(E', E) \phi(E') I(E') dE' \\ &= \int \left( \int Q(E'', E') G(E'', E) dE'' \right) \phi(E') I(E') dE' \\ &= \int \underbrace{\left( \int Q(E'', E') \phi(E') I(E') dE' \right)}_{\text{computed by MCSHAPE v 2.61}} G(E'', E) dE'' \\ &\quad \underbrace{\hspace{15em}}_{\text{computed by postprocessor RESOLUTION}} \end{aligned}$$

**EXAMPLES USING BOTH  
MCSHAPE v2.61 AND  
THE POSTPROCESSOR  
RESOLUTION**

# FWHM for Ge

**W** Detector resolution for SSD

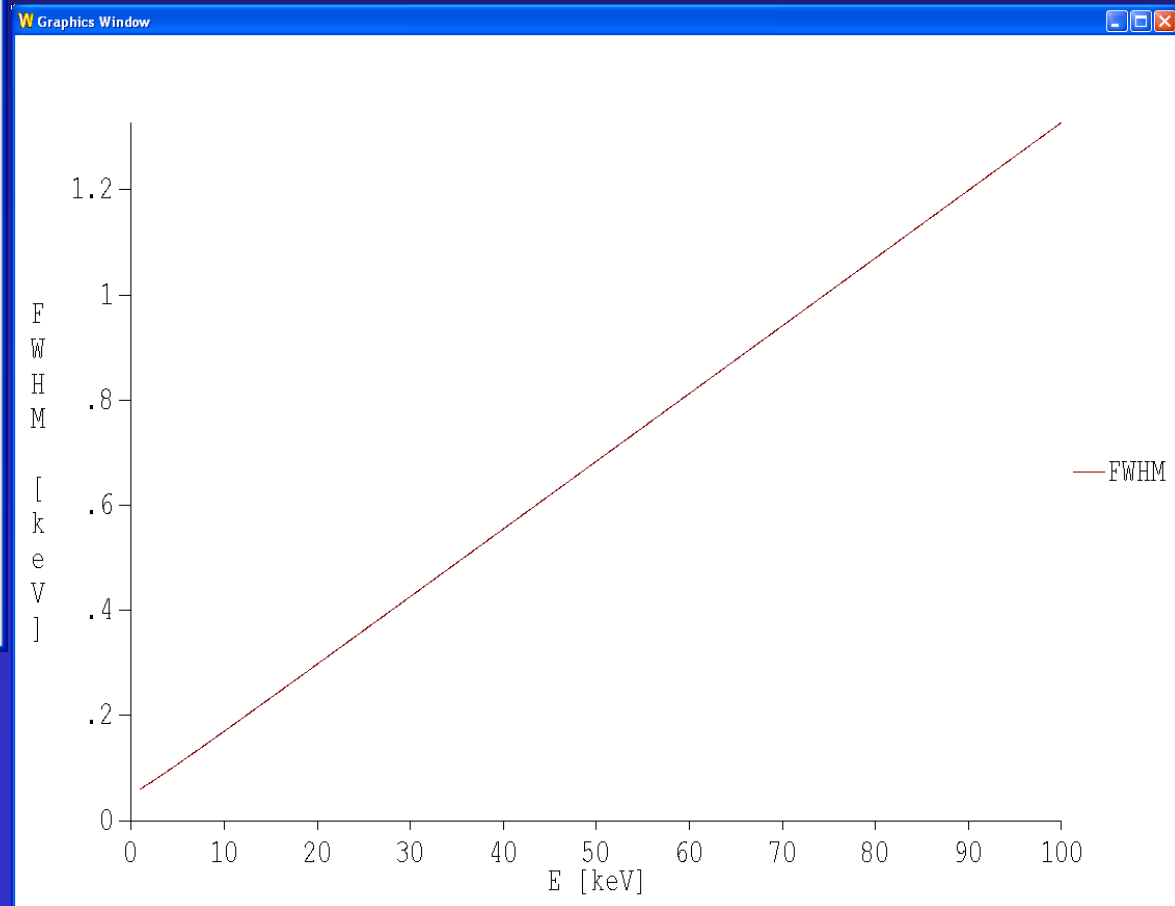
$W =$   (average energy to produce a ion pair) [keV]

$F =$   (Fano factor)

$a =$   [keV]

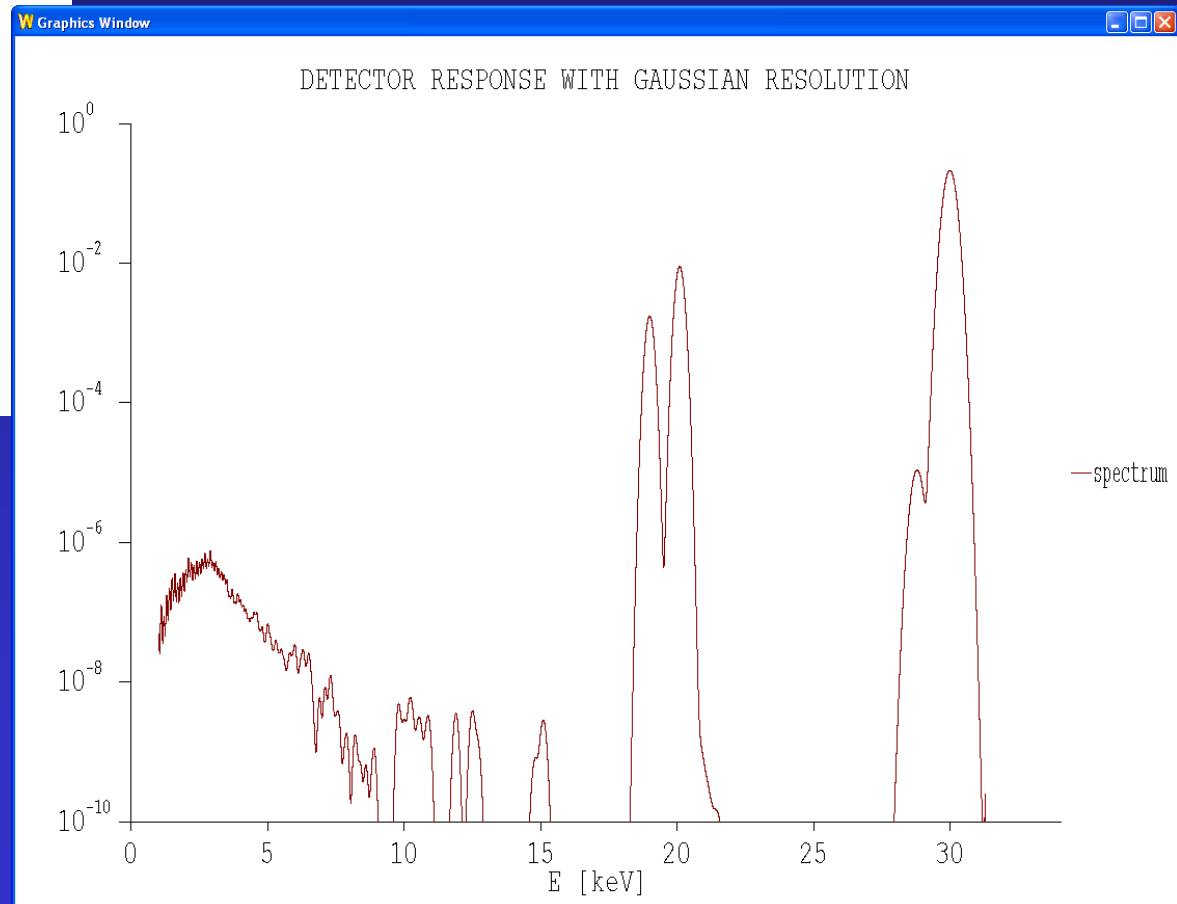
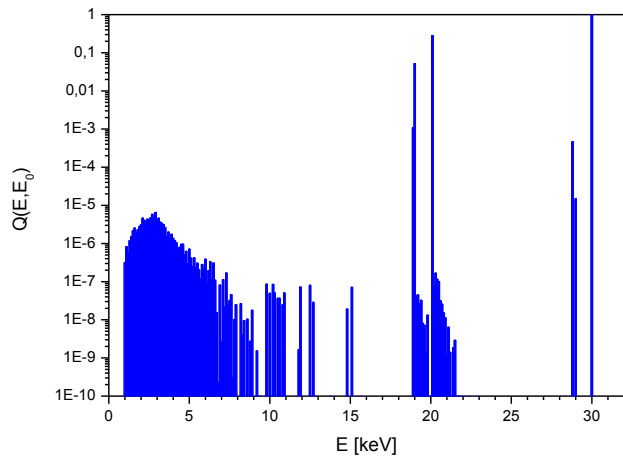
$b =$

$\Delta E_{Elec} =$   (electronic noise contribution)

$$\Delta E_{FWHM} = \sqrt{[8\ln(2)]WFE + aE^b + \Delta E_{Elec}^2}$$


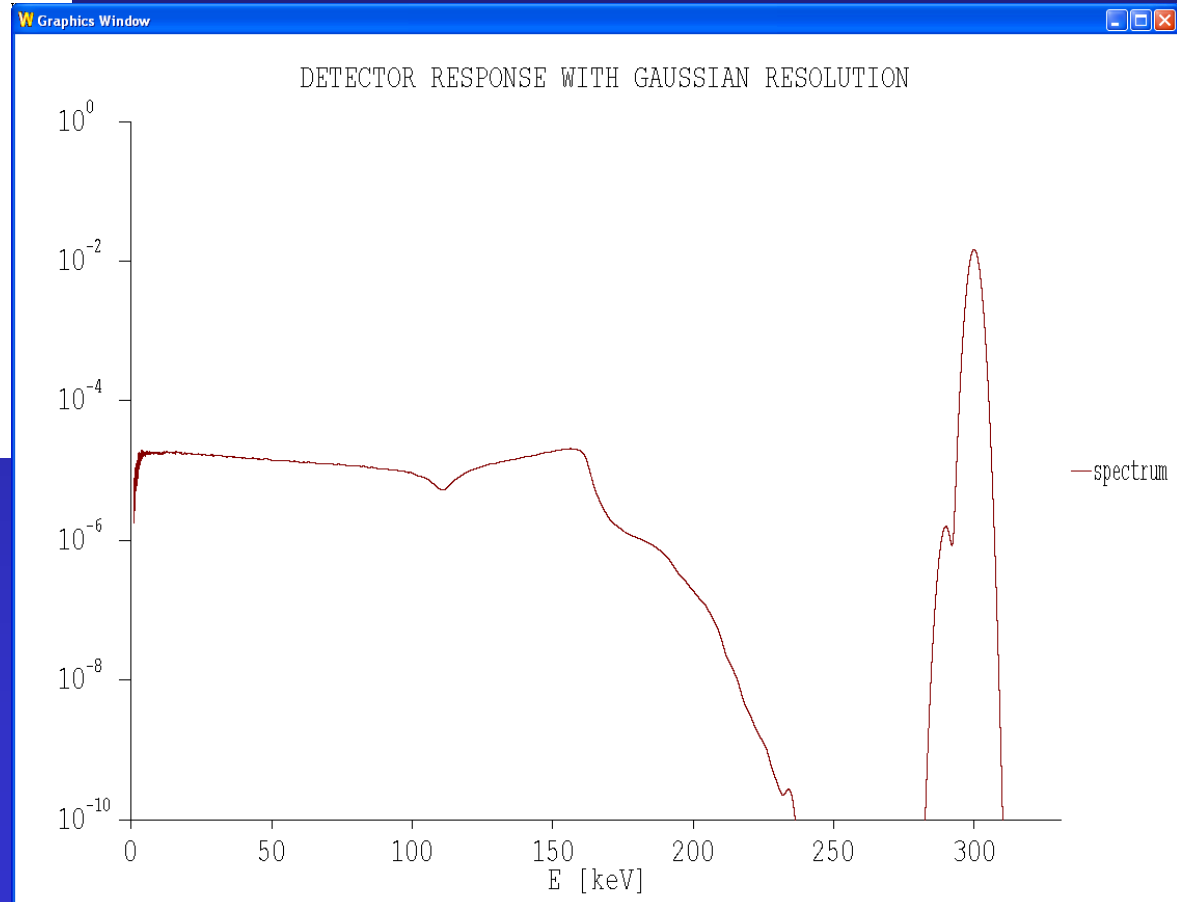
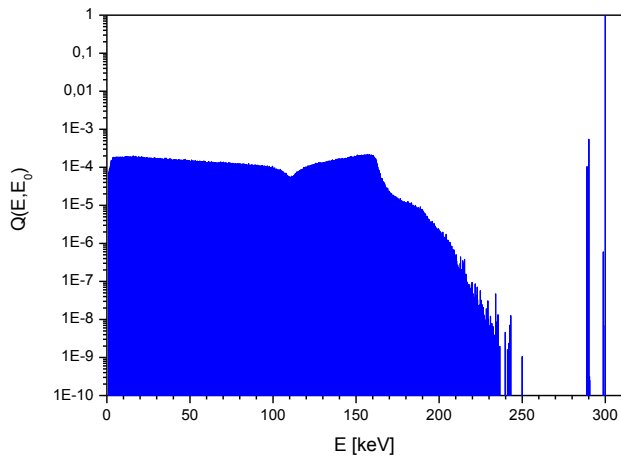
# Ge (1 mm thickness)

## Source: monochromatic 30 keV



# Ge (1 mm thickness)

## Source: monochromatic 300 keV





# FWHM for CdTe

**W** Detector resolution for SSD

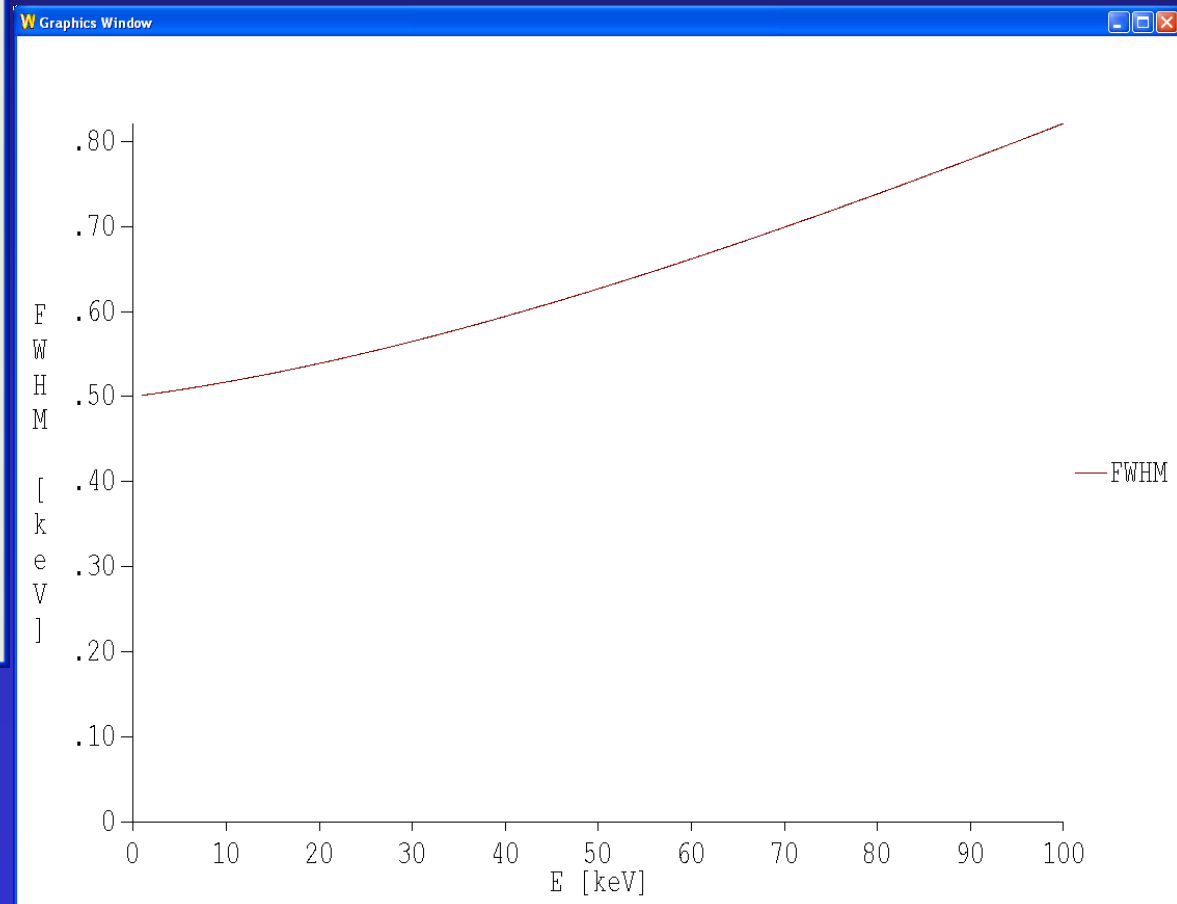
$W =$   (average energy to produce a ion pair) [keV]

$F =$   (Fano factor)

$a =$   [keV]

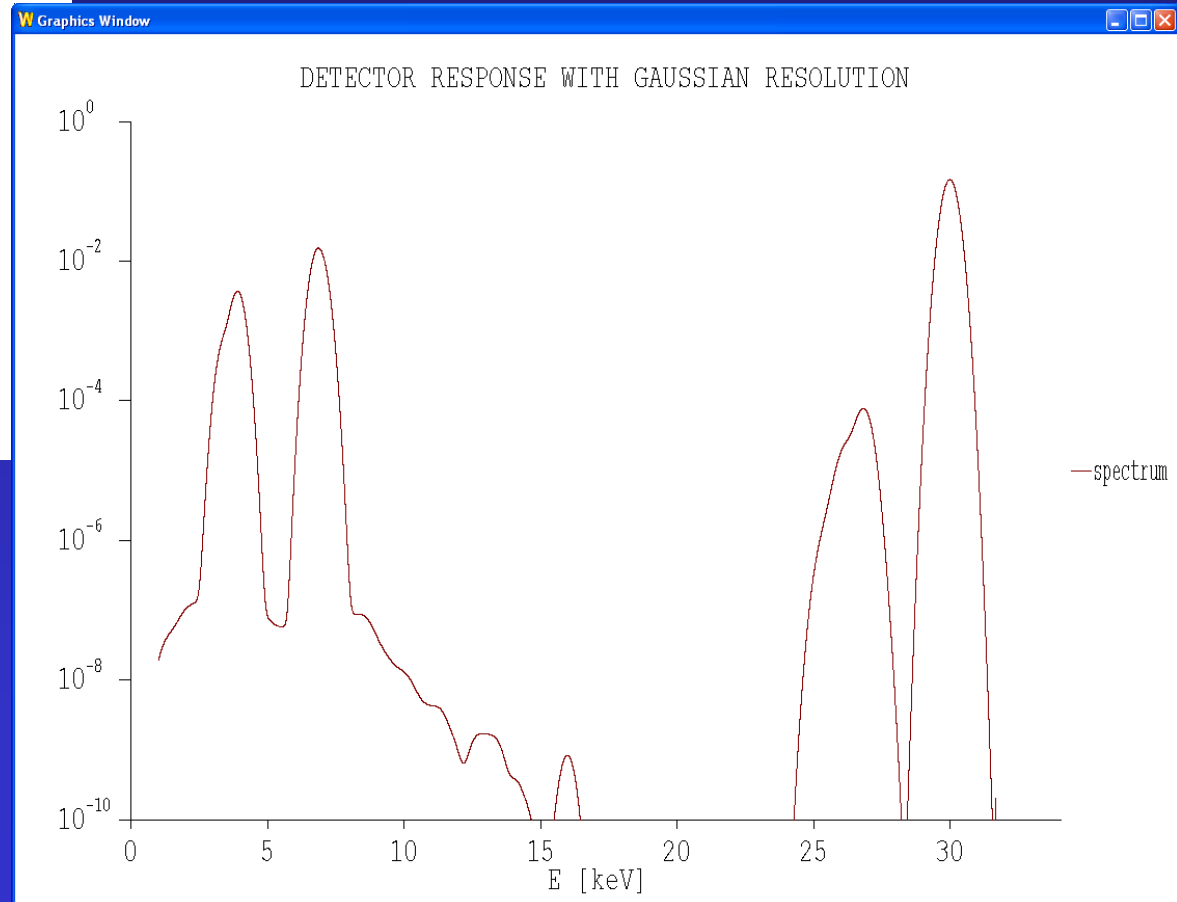
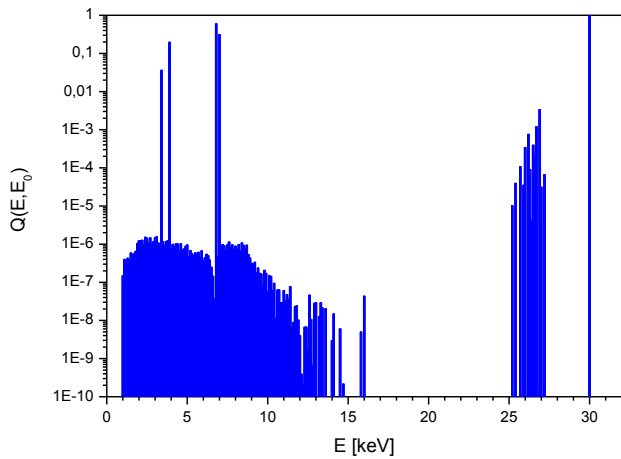
$b =$

$\Delta E_{Elec} =$   (electronic noise contribution)

$$\Delta E_{FWHM} = \sqrt{[8\ln(2)]WFE + aE^b + \Delta E_{Elec}^2}$$


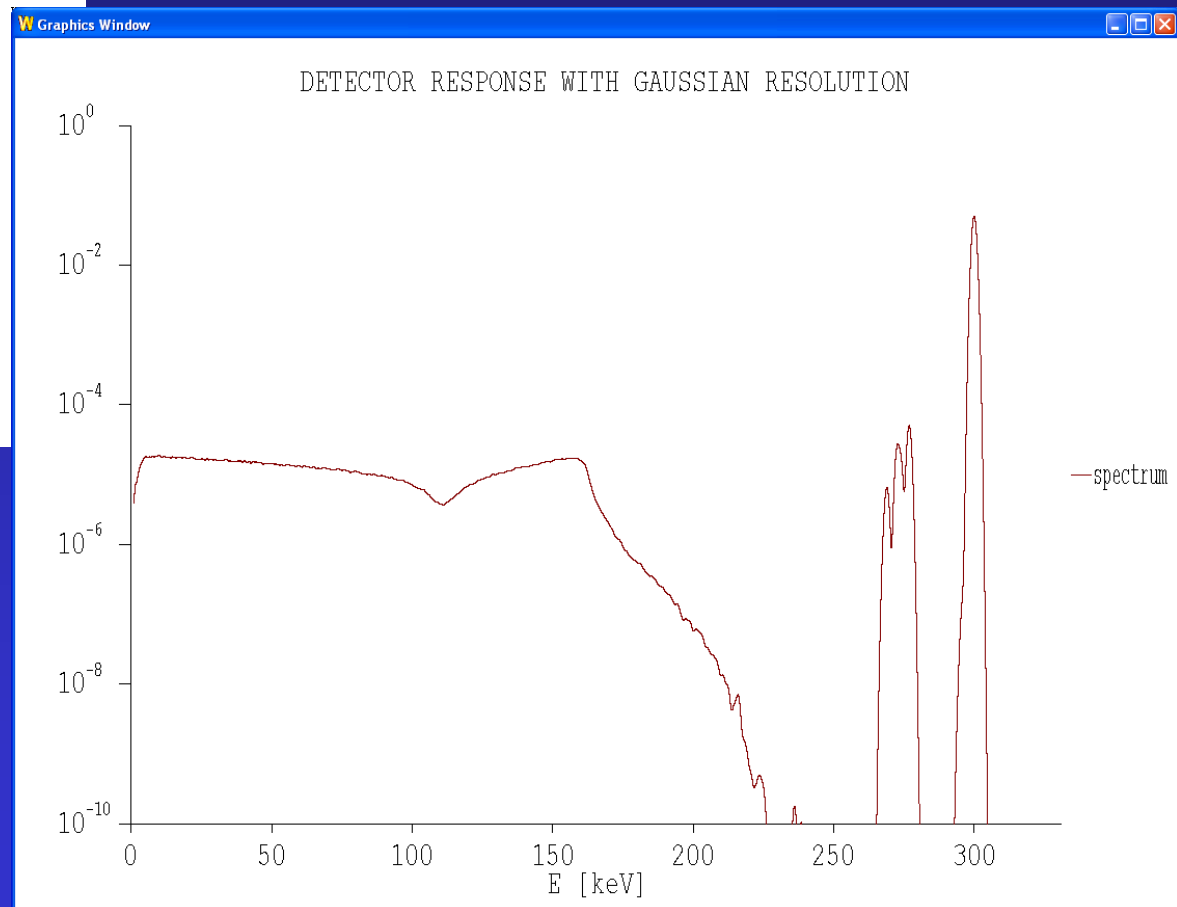
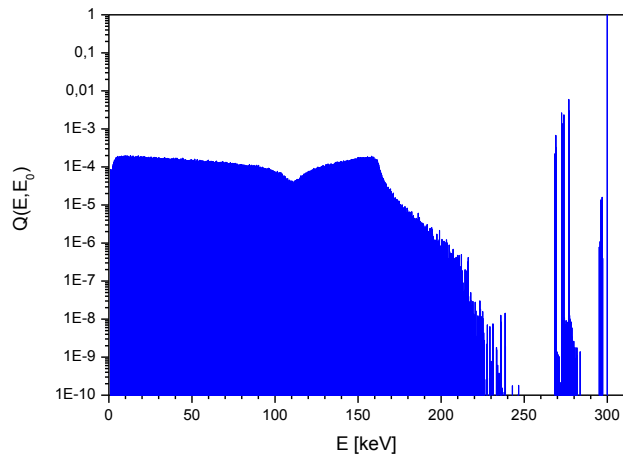
# CdTe (1 mm thickness)

## Source: monochromatic 30 keV



# CdTe (1 mm thickness)

## Source: monochromatic 300 keV



# **FUTURE DEVELOPMENTS OF THE CODE**

# **Future developments of MC SHAPE3D**

**Treatment of coupled transport of photons-  
electrons, in particular including**

- Bremsstrahlung emission (Under study)**
- Inner-Shell Impact Ionization by electrons  
(Ready!!!)**

**In fact, the influence of electrons interactions  
can:**

- Increase the detected background**
- Increase the intensity of the characteristics lines**

# CONCLUSIONS

# Conclusions


- MCSHAPE code:
  - proper description of photon-matter interactions in the 1 KeV-1 MeV regime (polarization state, multiple scattering)
  - useful instrument in the interpretation of experimental results (using both X-ray and synchrotron sources)
- 3D implementation (only in MCSHAPE3D) permits to simulate:
  - Scanning XRF experiments
  - XRF tomography
  - Scattering experiments
  - Dosimetry applications (taking advantage of the proper description of the angular distribution for polarized photons)

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# SHAPe codes for radiation transport

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### Deterministic and Monte Carlo photon transport codes

The multiple scattering description of polarised photon diffusion represents a unified approach to describe attenuation of photon beams maintaining the optical properties which are related to the polarisation state.

Several codes for photon transport with high level of refinement on the description of the interactions photon-atom and the evolution of the polarisation state have been developed along the years by our group.

[more...](#)



### LATEST VERSIONS

MCSHAPe v2.50
MCINPUT V2.10
SHAPe v2.20
MUPLOT V1.03

### NEWS

September 9th, 2005 - **MCSHAPe v2.50** for both, Windows and Linux, ready to download

March 9th 2005 - **MCINPUT v2.10** for both, Windows and Linux, ready to download

October 28th 2004 - **MUPLOT v1.03** for both, Windows and Linux, ready to download.

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