APPLICATIONS OF MCSHAPE TO DETECTOR RESPONSE COMPUTATIONS

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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

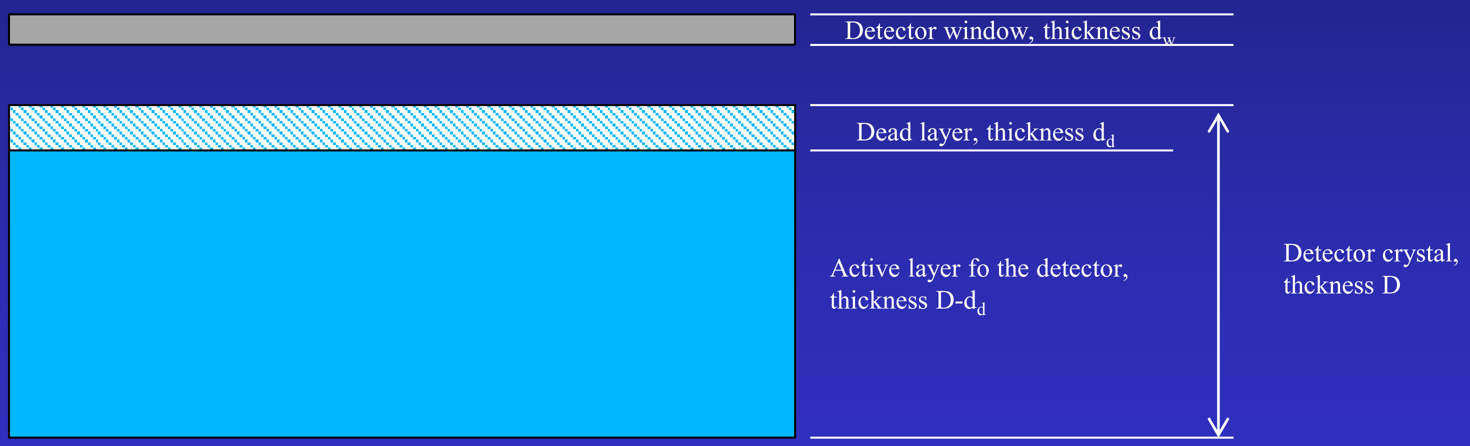
$R(E', E)$ **is the response function**

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

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

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

The efficiency is strightforwardly 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

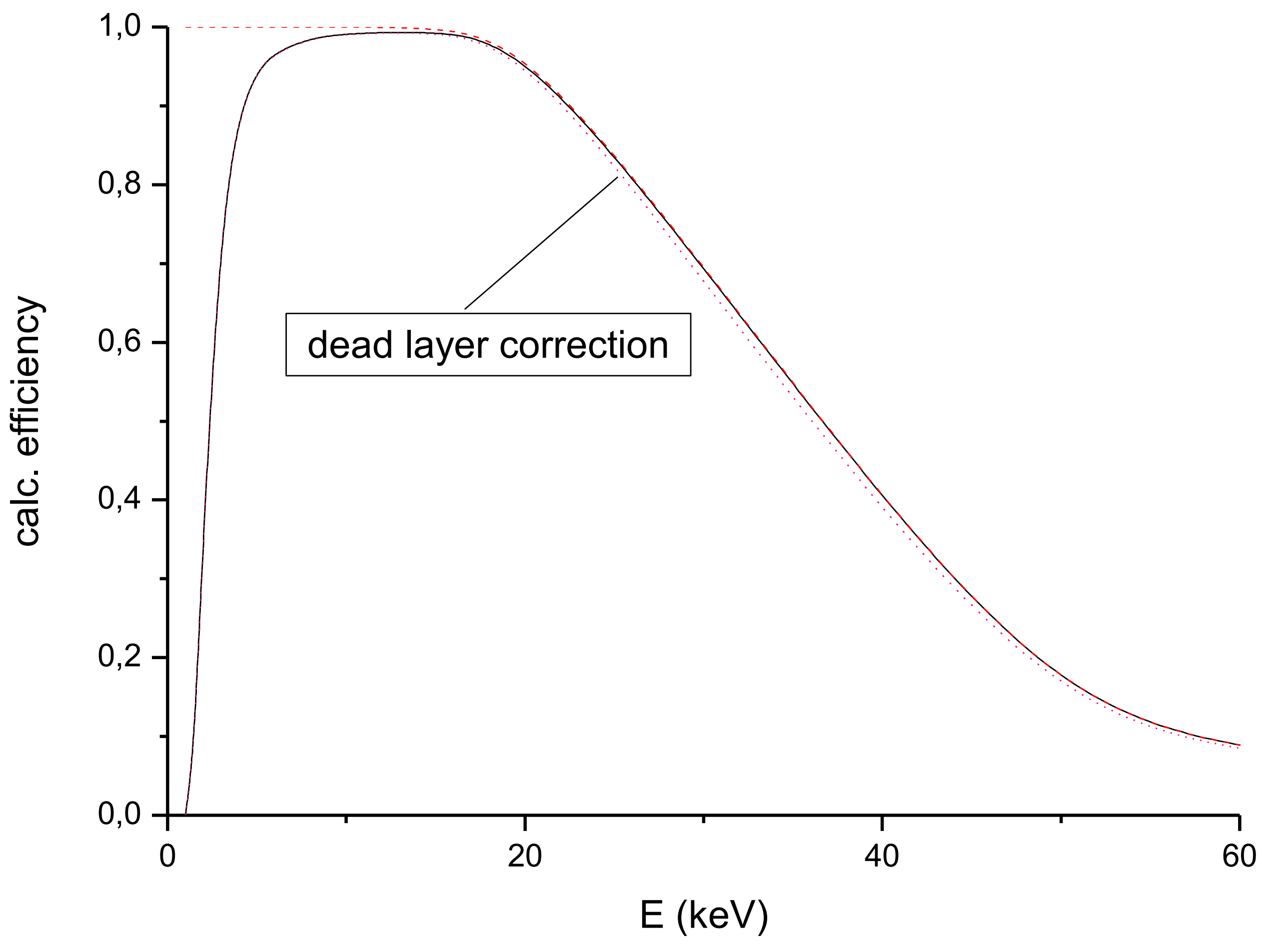
Probability of interaction in the active volume

Example for an AMPTEK Si pin detector

- Be window, density ρ=1.85 g cm^{-3}
- d_w= 1 mil (=10^{-3} 2.54 cm=0.00254 cm)

- Si crystal, density ρ= 2.33 g cm^{-3}
- D=500 μm=0.05 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

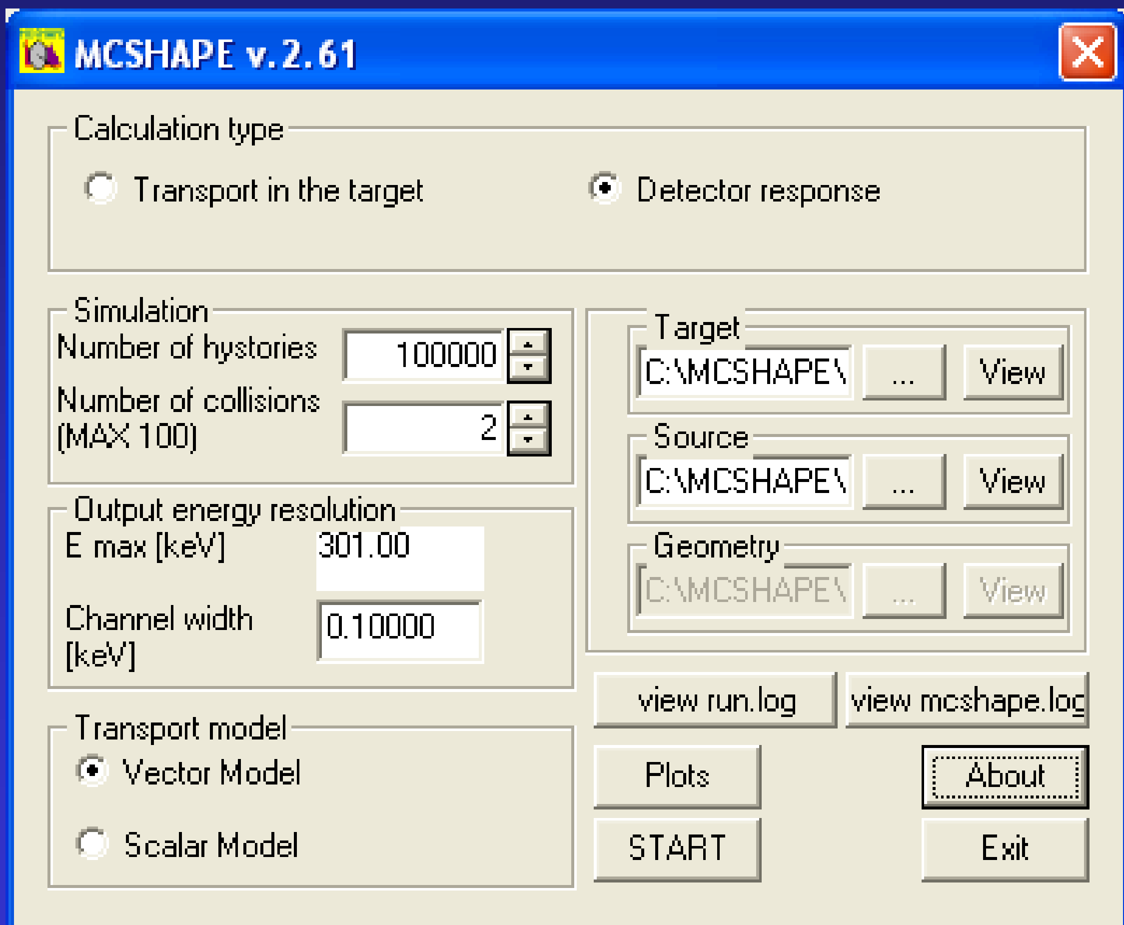
Detector resolution

- 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



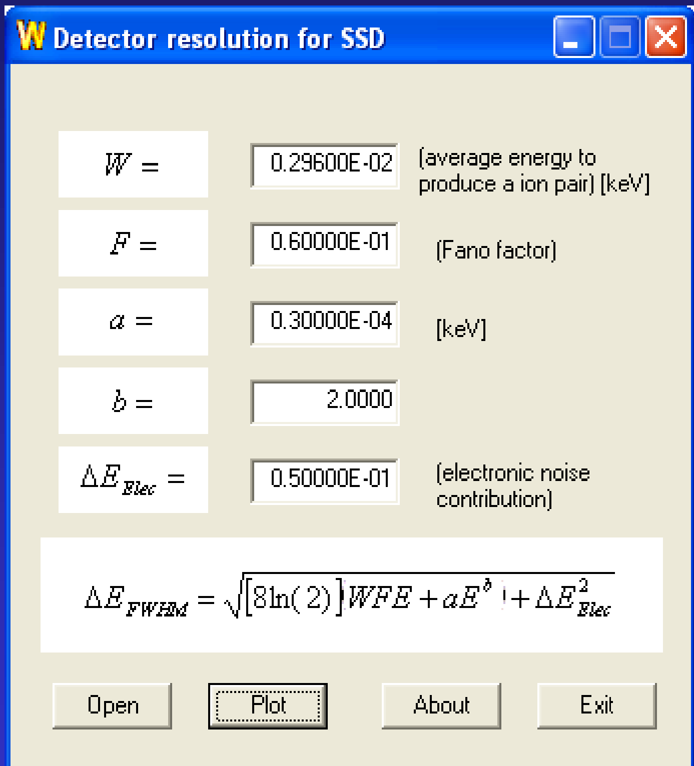
Computes the energy deposition spectrum

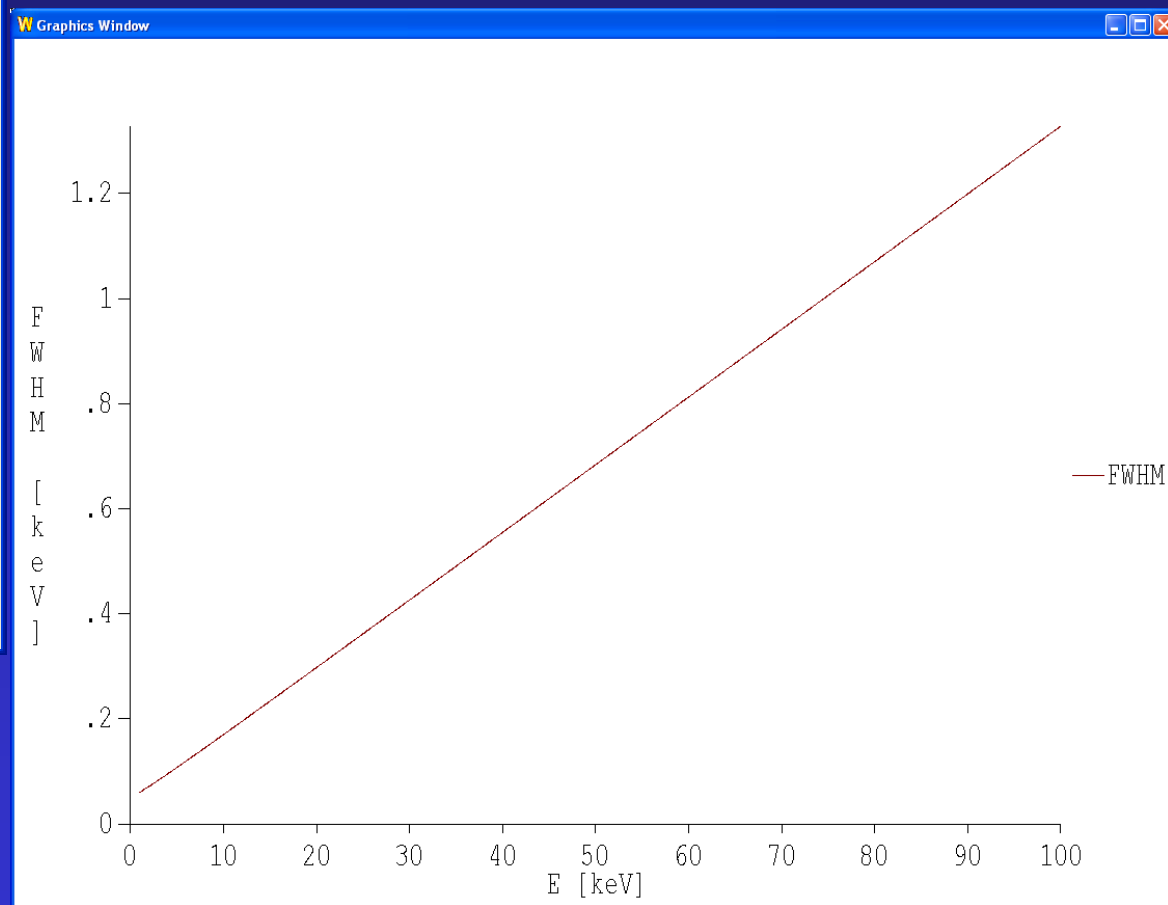
What is computed with MCSHAPE v 2.61

$$
\begin{aligned}
I_{measured}(E) &= \int R(E',E)\,\phi(E')\,I(E')\,dE' \\
&= \int \left(\int Q(E'',E')\,G(E'',E)\,dE'' \right) \phi(E')\,I(E')\,dE' \\
&= \underbrace{\int \underbrace{\left(\int Q(E'',E')\,\phi(E')\,I(E')\,dE' \right)}_{computed\,by\,MCSHAPE\,v2.61} G(E'',E)\,dE''}_{computed\,by\,postprocessor\,RESOLUTION}
\end{aligned}
$$

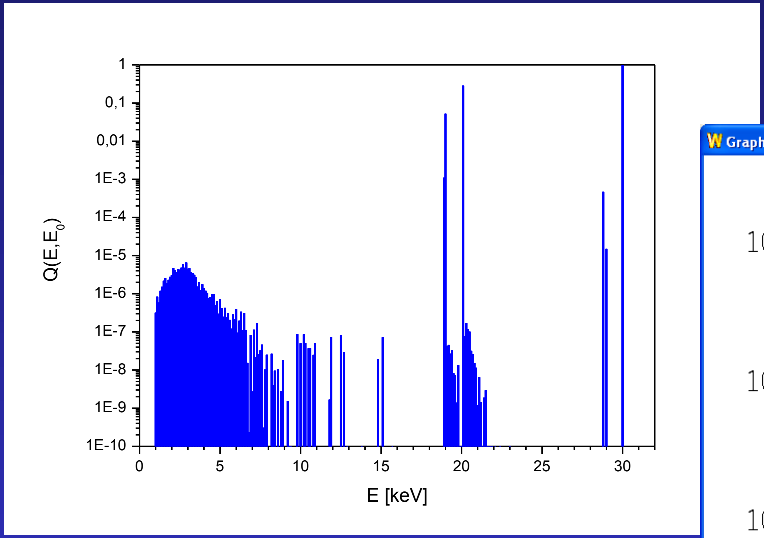
EXAMPLES USING BOTH MCSHAPE v2.61 AND THE POSTPROCESSOR RESOLUTION

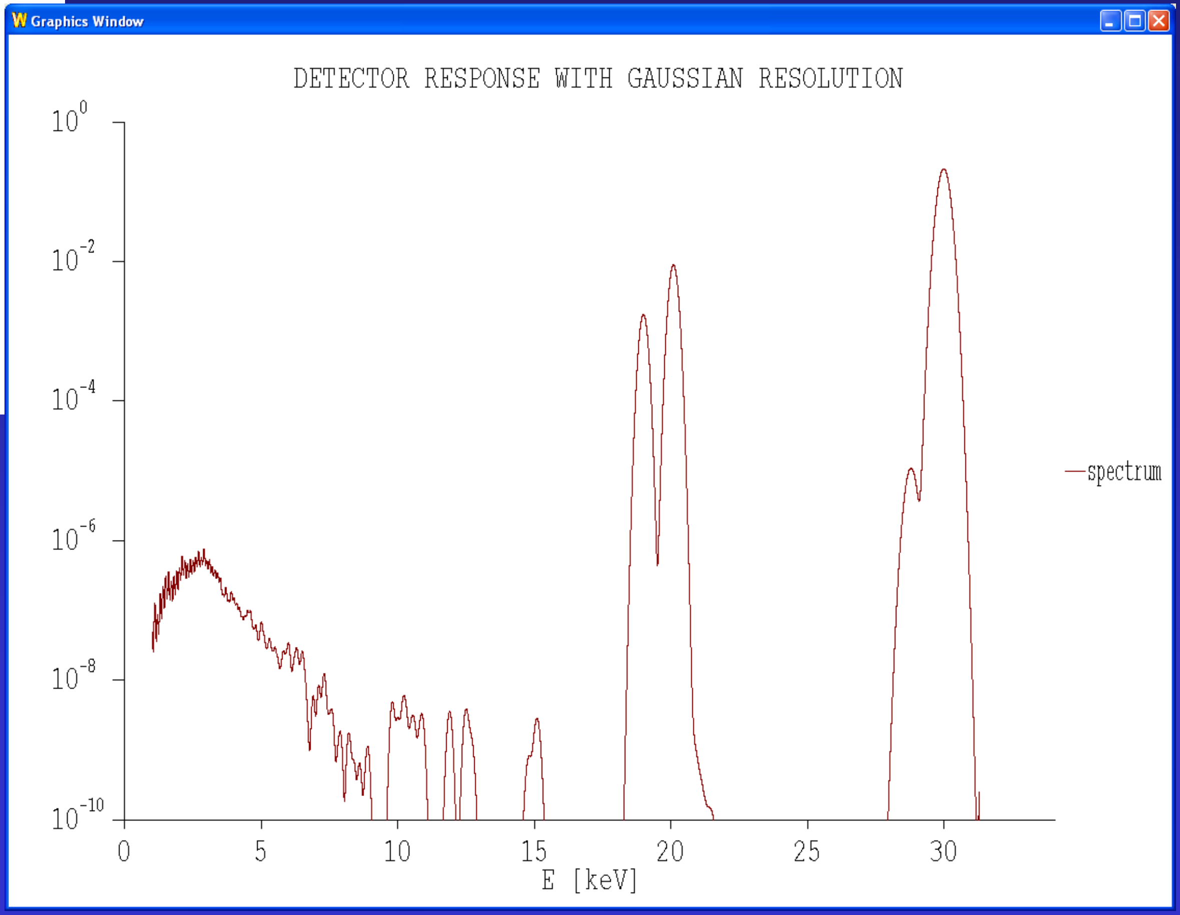
FWHM for Ge


Detector resolution for SSD
W = 0.29600E-02 (average energy to produce a ion pair) [keV]
F = 0.60000E-01 (Fano factor)
a = 0.30000E-04 [keV]
b = 2.0000
ΔE_Elec = 0.50000E-01 (electronic noise contribution)
$\Delta E_{FWHM} = \sqrt{[8\ln(2)]WFE + aE^{b} + \Delta E_{Elec}^{2}}$
Open
Plot
About
Exit

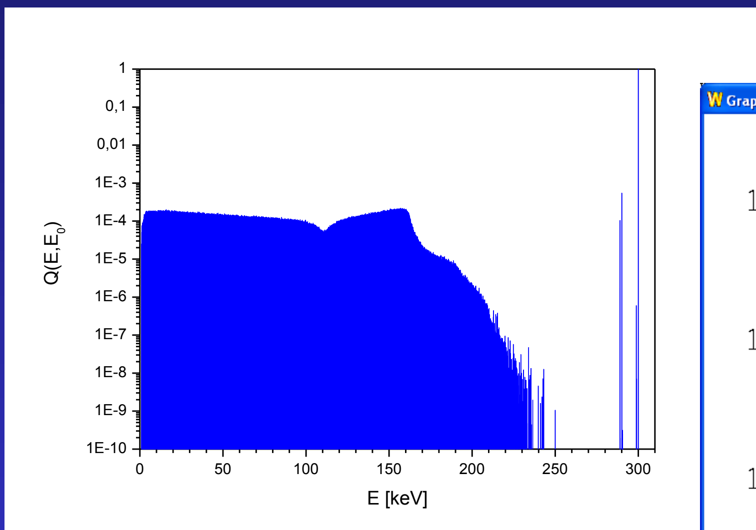

Graphics Window
FWHM [keV]
0
.2
.4
.6
.8
1
1.2
0
10
20
30
40
50
60
70
80
90
100
E [keV]
FWHM

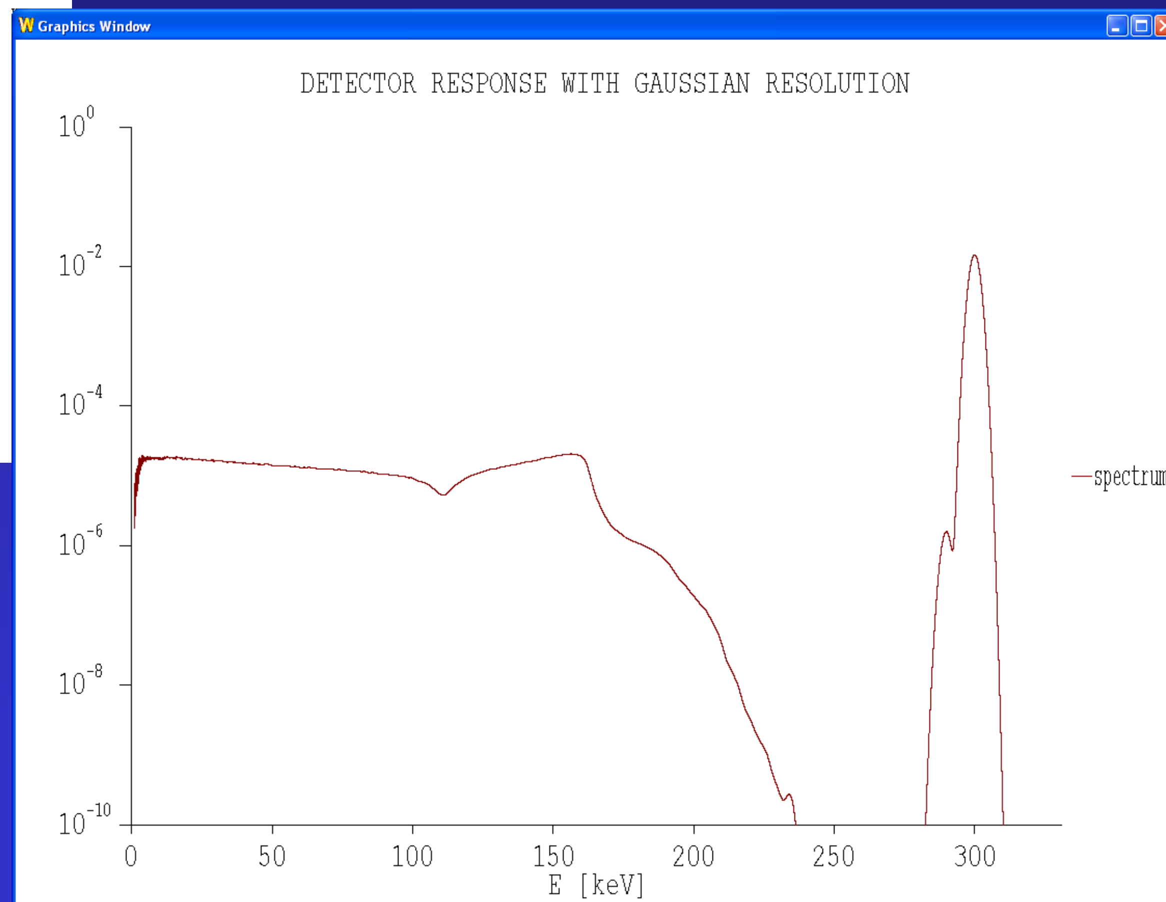
Ge (1 mm thickness)
Source: monochromatic 30 keV



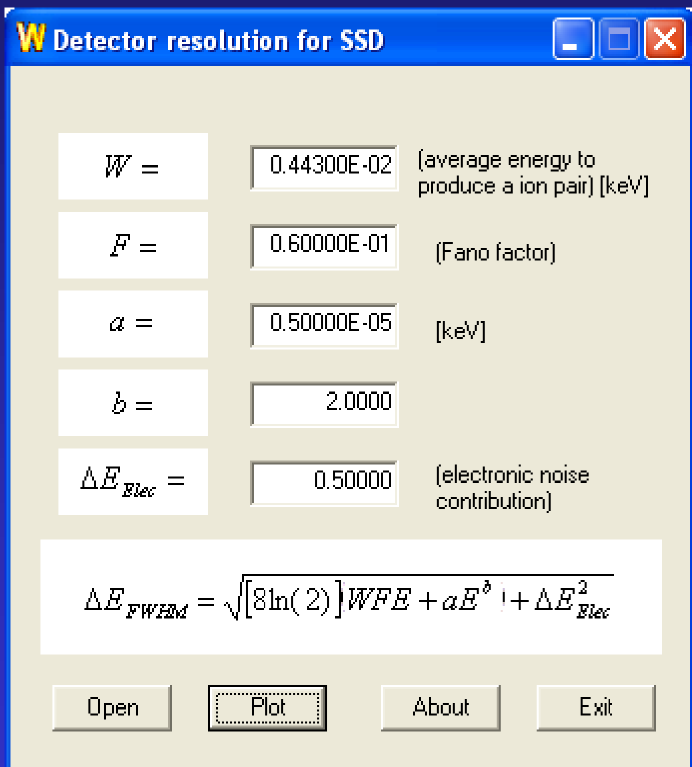


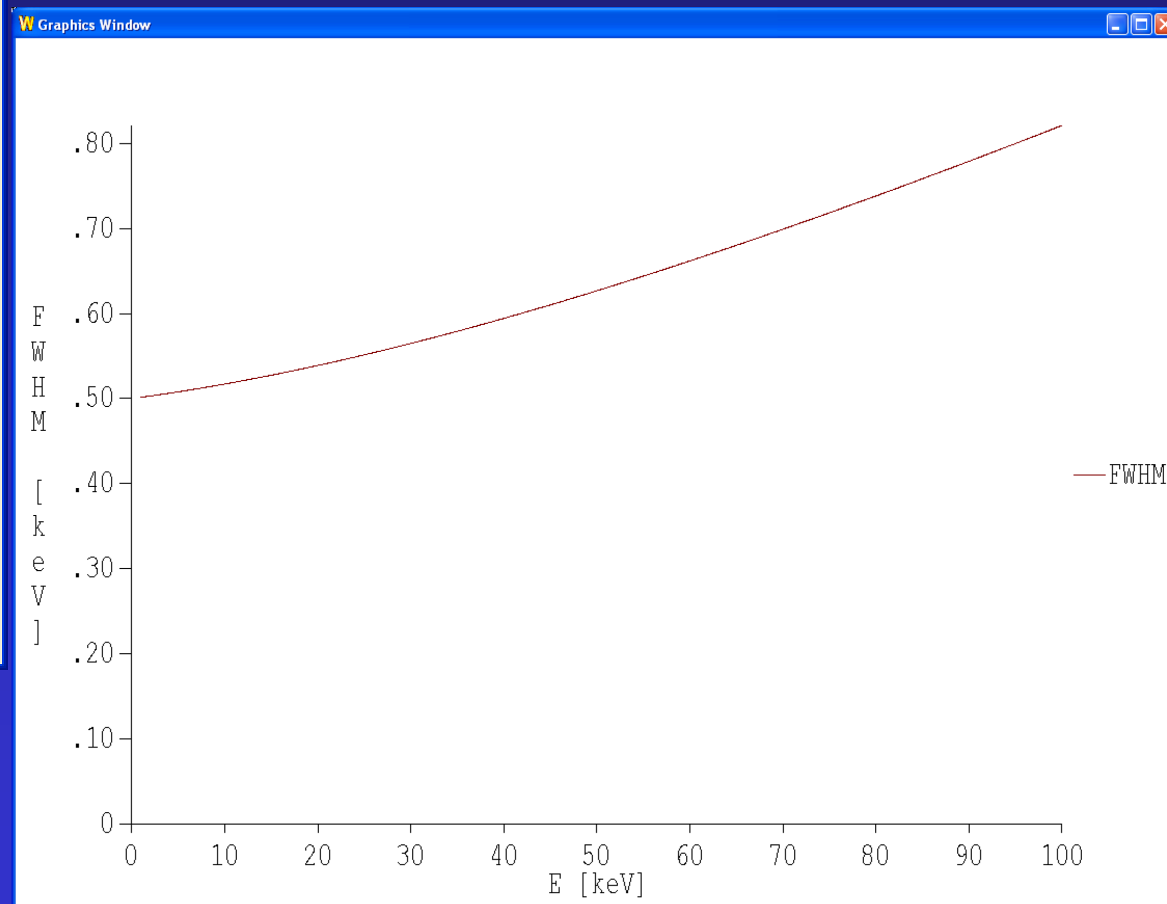
Ge (1 mm thickness)
Source: monochromatic 300 keV



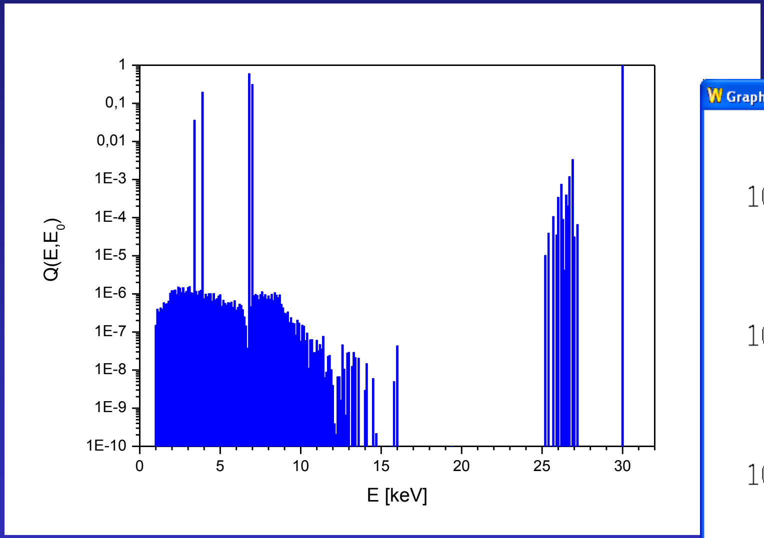


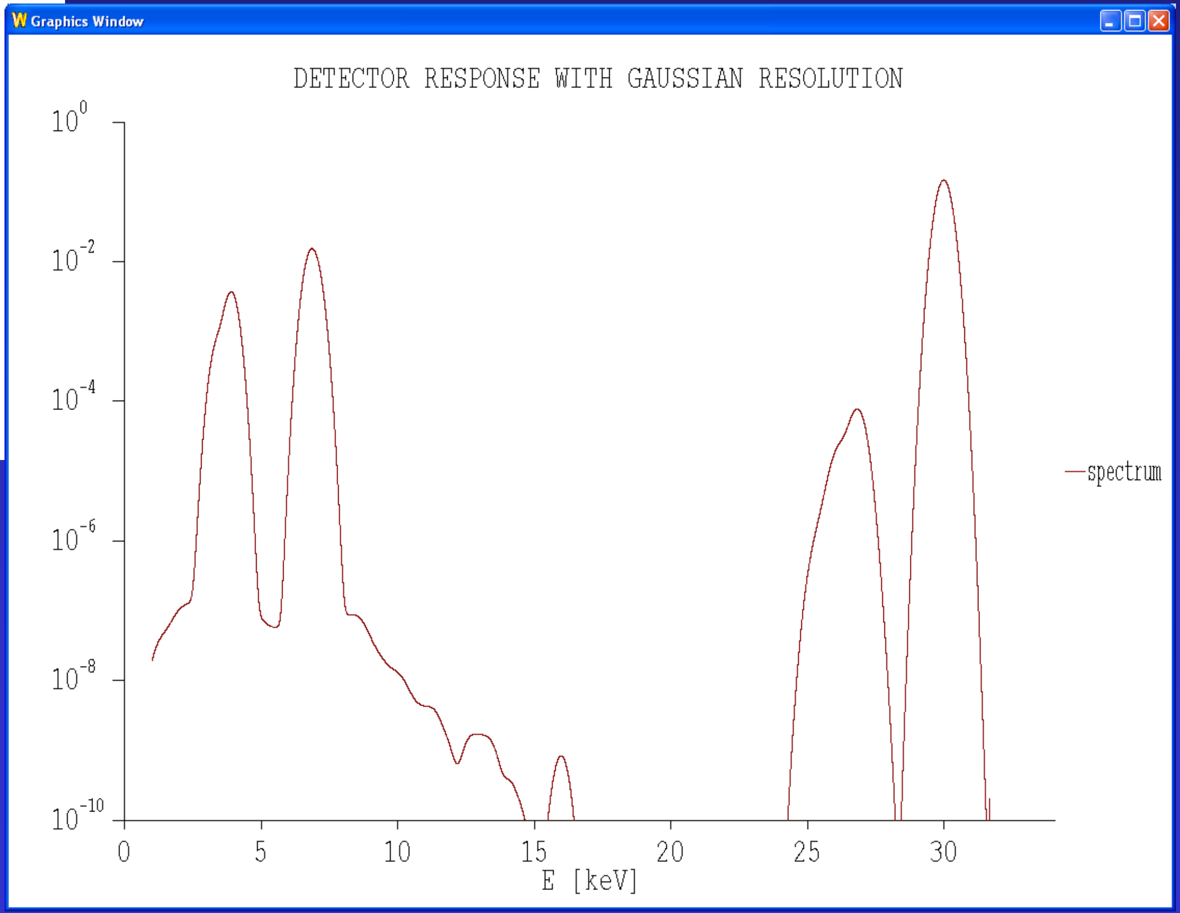
FWHM for CdTe



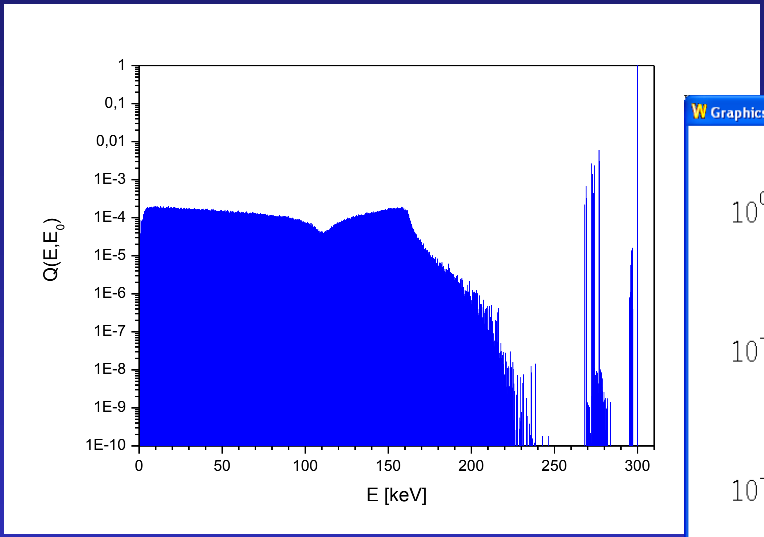


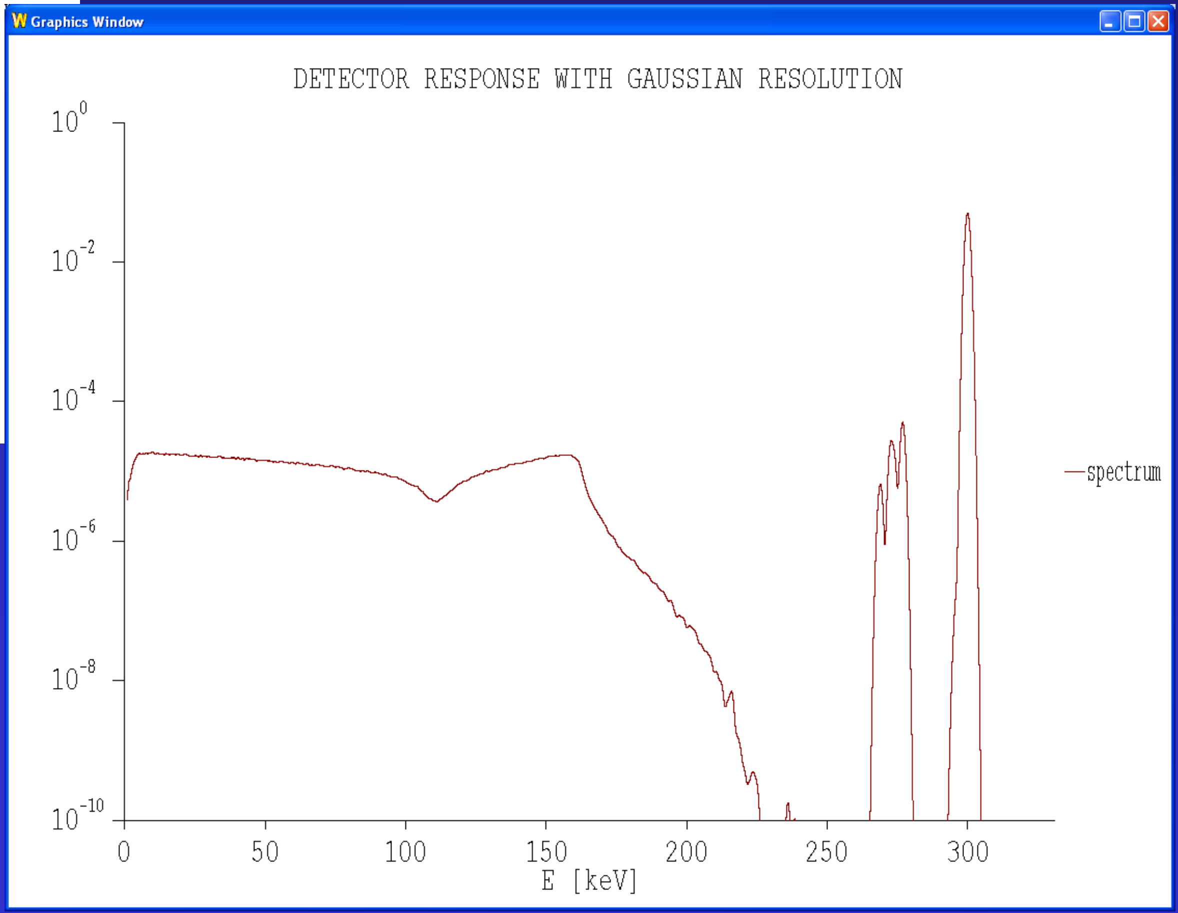
CdTe (1 mm thickness) Source: monochromatic 30 keV





CdTe (1 mm thickness)
Source: monochromatic 300 keV





FUTURE DEVELOPMENTS OF THE CODE

Future developments of MCSHAPE3D

- 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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