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European Commission

Gamma-ray Spectrometry

Low Energy Problems

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Obligatory slide

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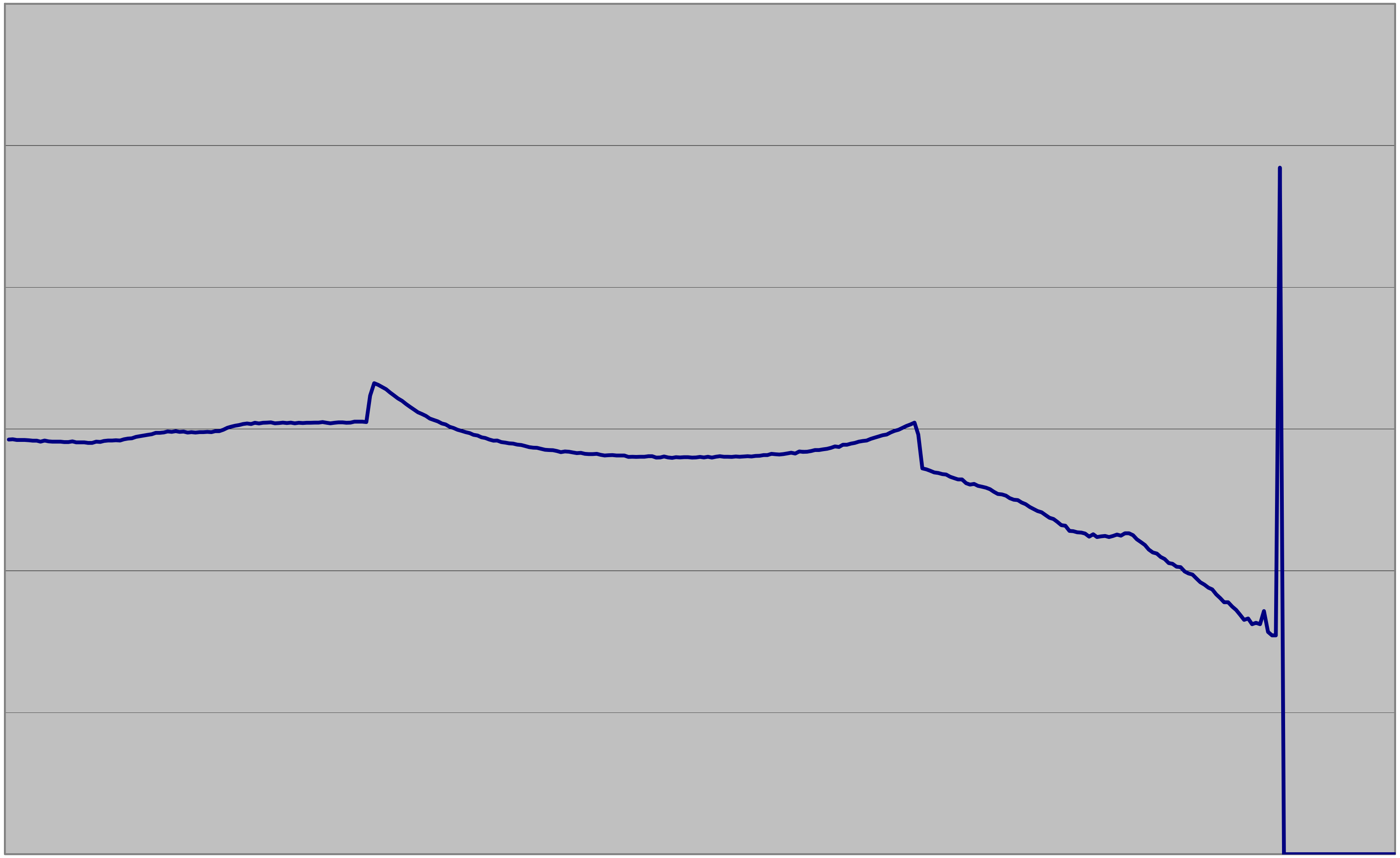
Low energies problems

Problems manifest themselves in numerous situations

- Decay data (see e.g. ^{234}Th)
- Intercomparisons; more scatter at lower energies (e.g. ^{210}Pb, ^{109}Cd, ^{235}U, ^{142}Am,… also ^{133}Ba and ^{152}Eu,….
- Monte Carlo simulations attempting to reproduce measured efficiency (Exemplify w.b.)
- …….
- => part of an ongoing IAEA-CRP. Major review of low-energy gamma-ray spec. in pipe line.

Response at 662 keV



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Response at 92 keV

Exercise

1) Produce the response of a gamma-ray using the mortran code: XXX .mor (with GEDET.DAT) and plot it in e.g. Excel.

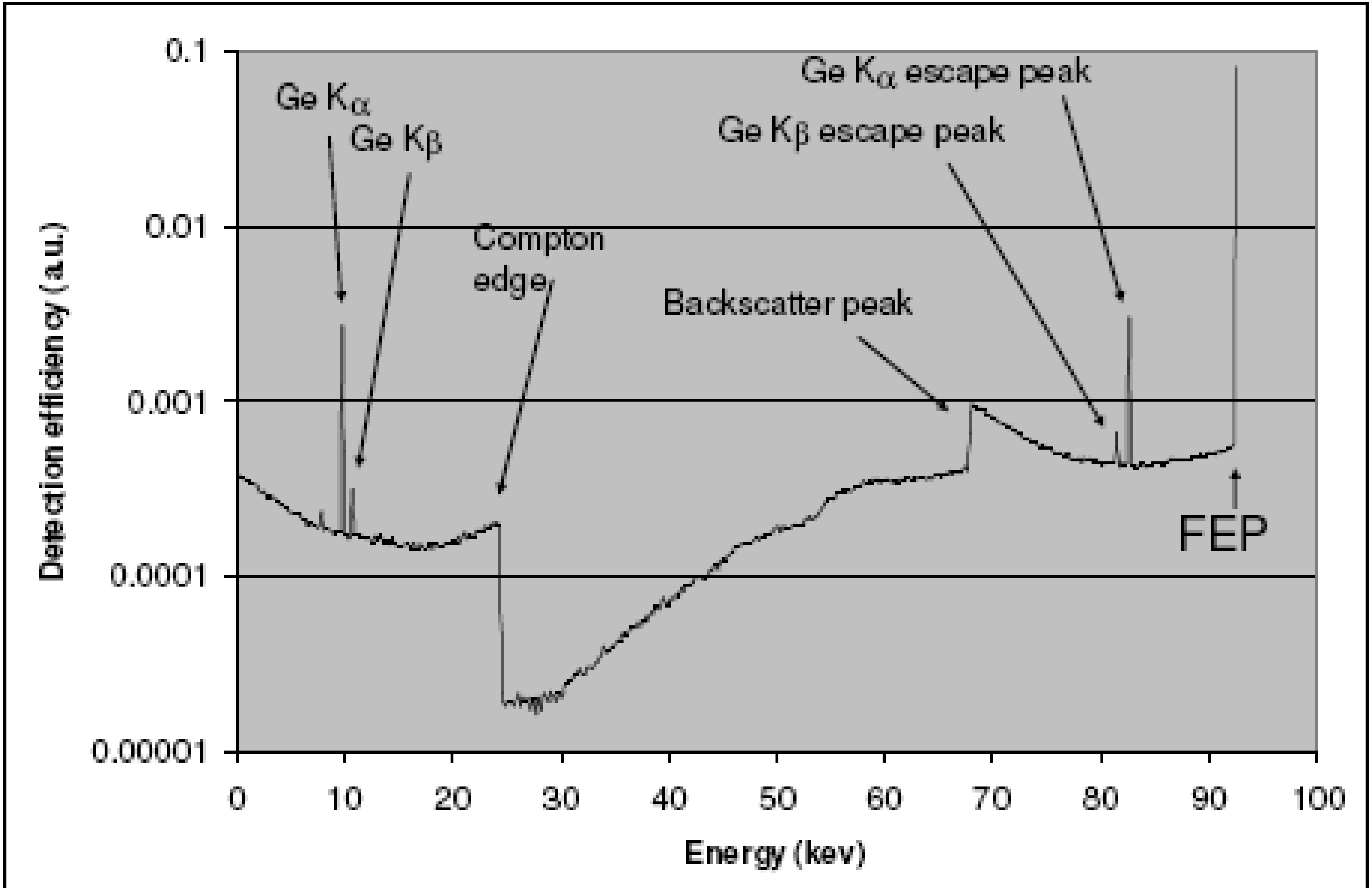
Group 1) E=92.5 keV, bin-width=0.01 keV
Group 2) E=92.5 keV, bin-width=0.3 keV
Group 3) E=92.5 keV, bin-width=3 keV
Group 4) E=9256 keV, bin-width=0.01 keV
Group 5) E=256 keV, bin-width=0.3 keV
Group 6) E=256 keV, bin-width=3 keV

2) Explain all the features of the spectrum

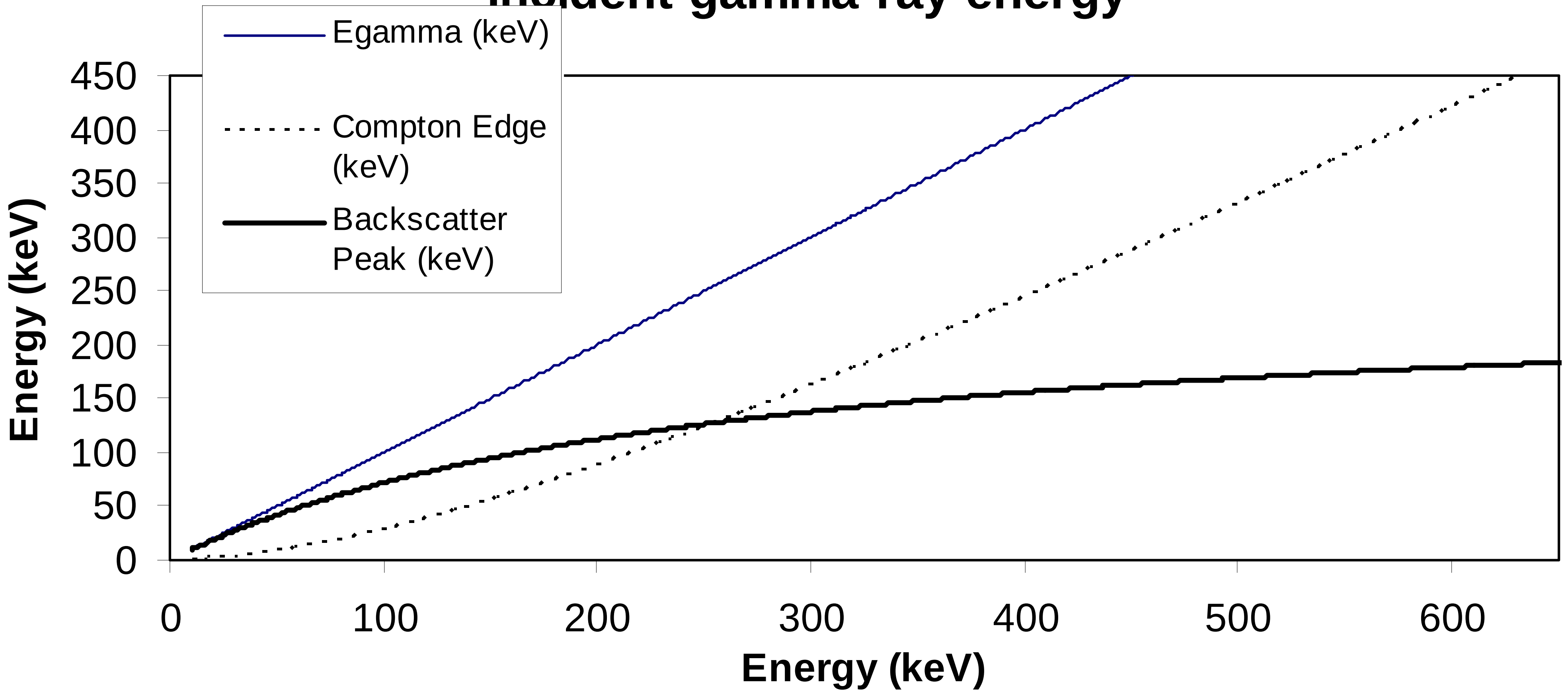
ANSWER

Detector response of 92.5 keV

Useful with Monte Carlo simulation, can "isolate" contriutions

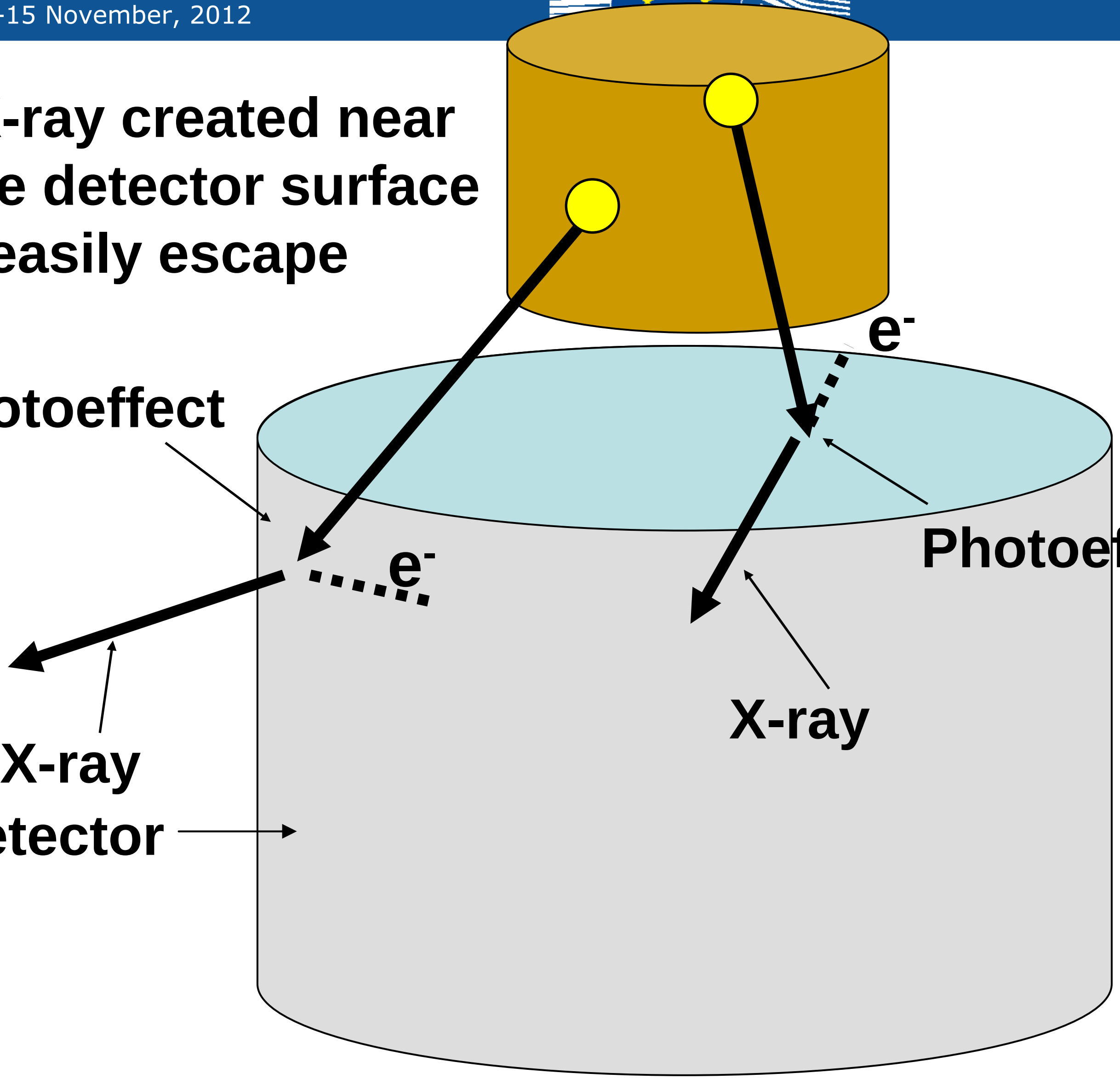


Compton Edge and Backscatter peak as a function of incident gamma-ray energy

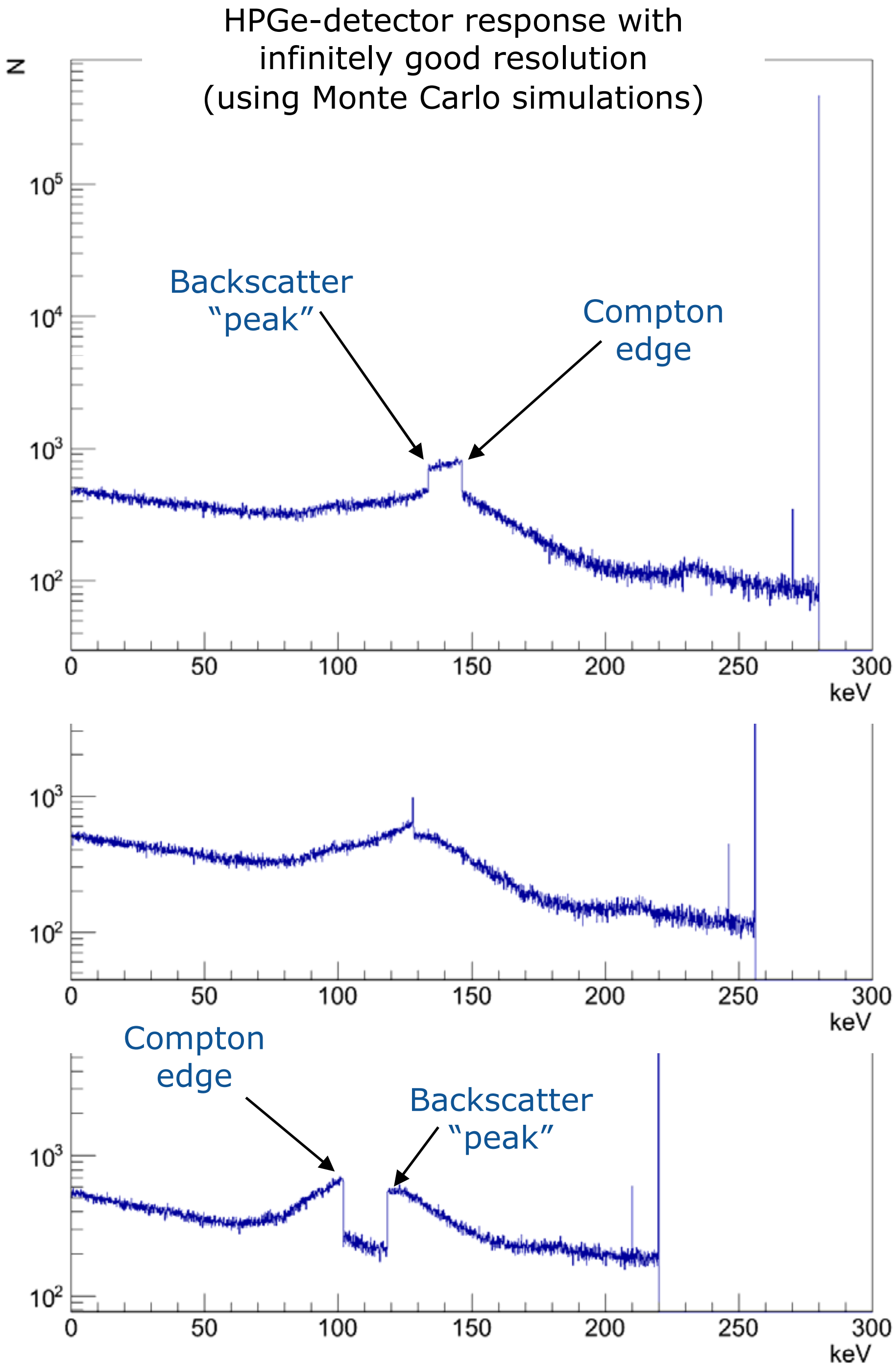


Explanation of X-rays

An X-ray created near to the detector surface can easily escape

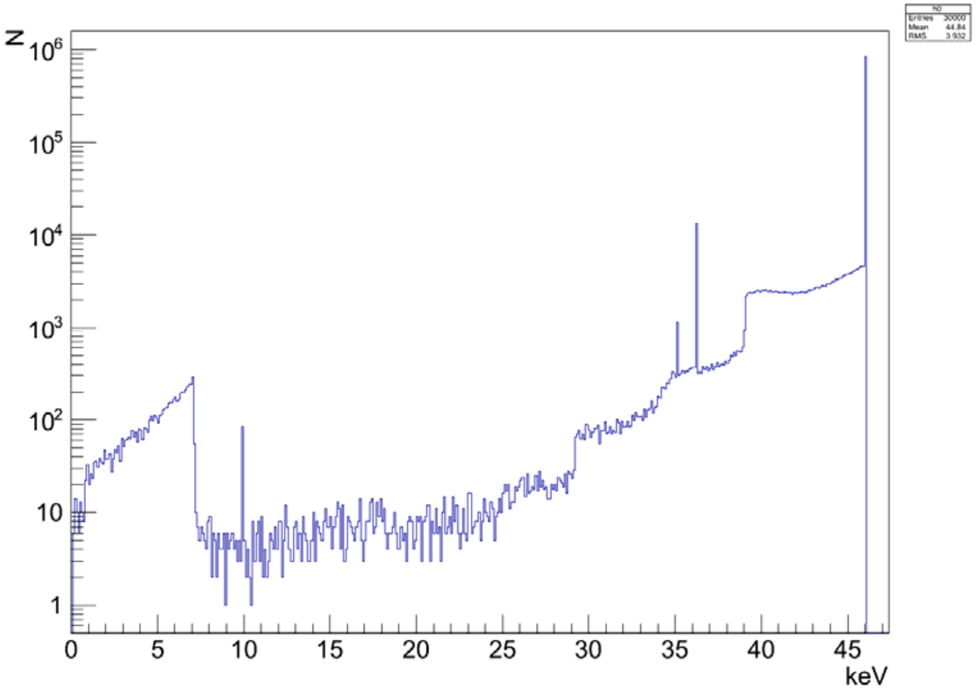


Deadlayer (also on the sides!!!). Interactions in deadlayer can result in Ge X-ray peak.

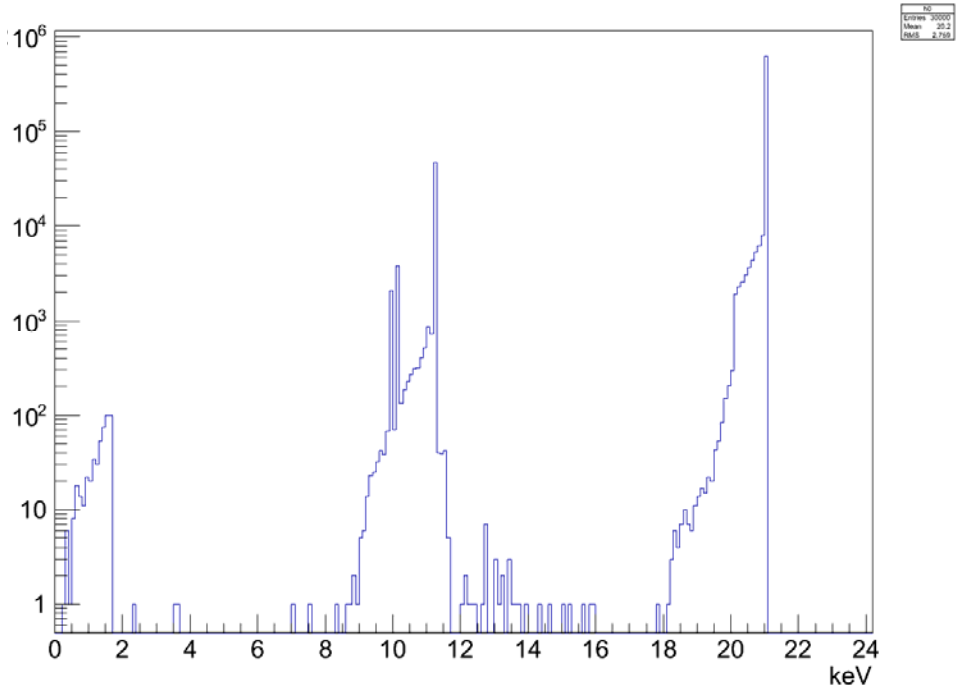


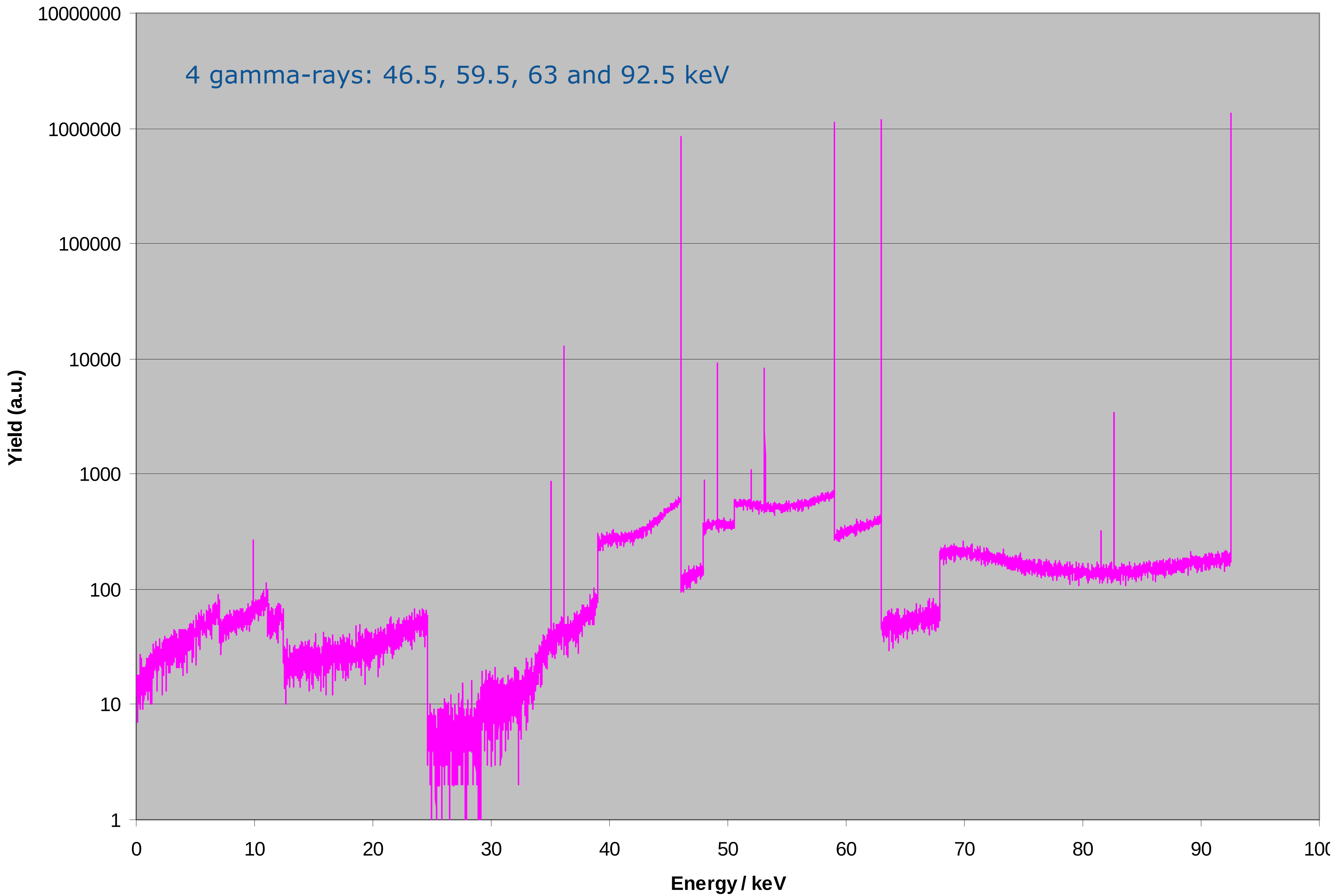
Gamma-ray (keV)	Compton edge (keV)	Backscatter peak (keV)
280	146	134
256	128	128
220	102	118

46 keV

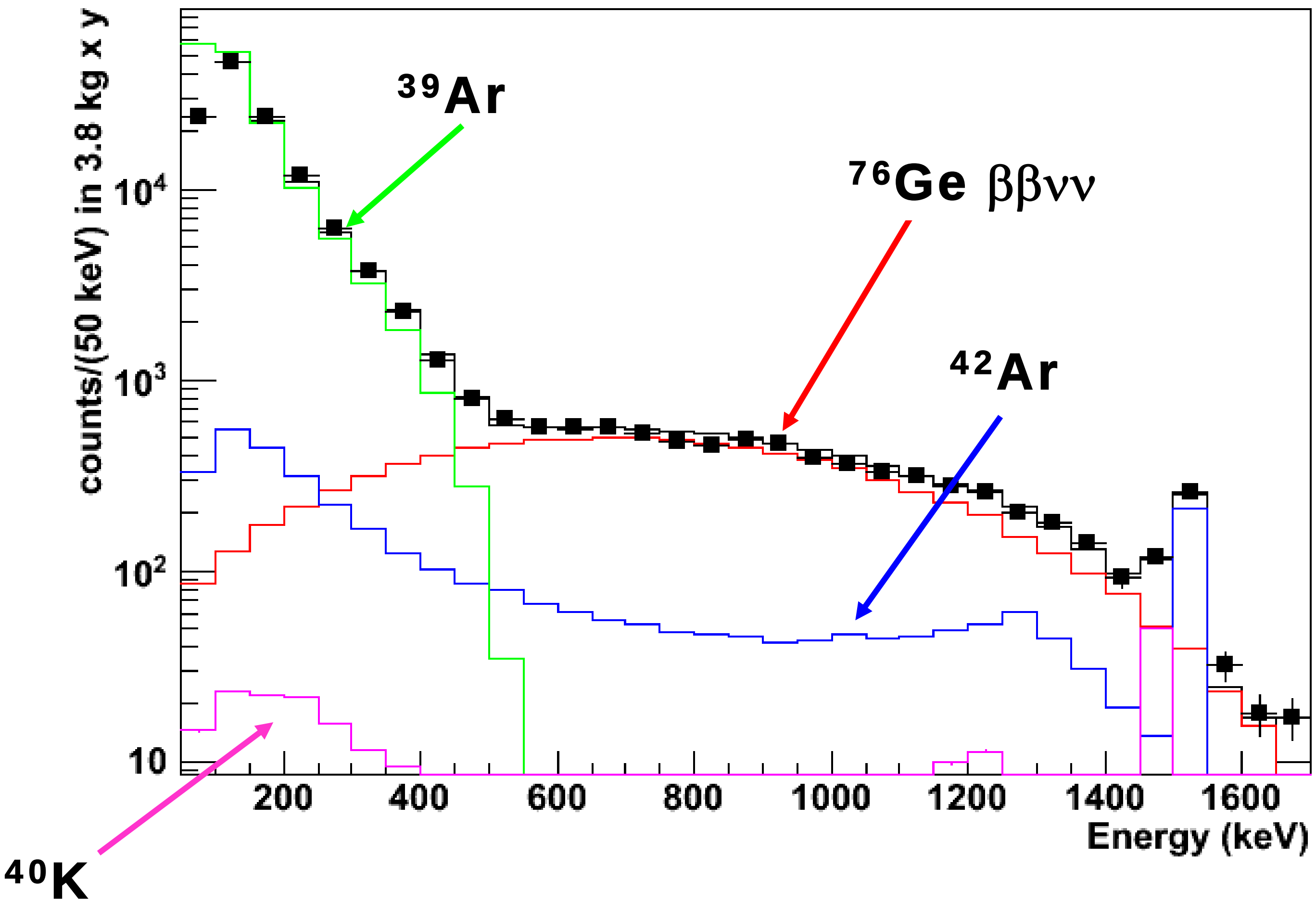

N
1
10
10^2
10^3
10^4
10^5
10^6
0
5
10
15
20
25
30
35
40
45
keV

21 keV


1
10
10^2
10^3
10^4
10^5
10^6
0
2
4
6
8
10
12
14
16
18
20
22
24
keV



4 gamma-rays: 46.5, 59.5, 63 and 92.5 keV
Yield (a.u.)
10000000
1000000
100000
10000
1000
100
10
1
0
10
20
30
40
50
60
70
80
90
100
Energy / keV


counts/(50 keV) in 3.8 kg x y
10⁴
10³
10²
10
200
400
600
800
1000
1200
1400
1600
Energy (keV)
39Ar
76Ge ββνν
42Ar
40K

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The basic equation

$$A = \frac{C_{TOT} - C_{Peak}^{Bkg} - C_{Continuum}}{\varepsilon_{REF}^{Exp} \dfrac{\varepsilon_{Sample}^{MC}}{\varepsilon_{REF}^{MC}} P_{\gamma}} e^{\lambda t_d} \frac{\lambda}{(1 - e^{-\lambda t_m})} K_1 K_2 K_3$$

Combined activities from several gamma-rays and from several daughters to activity for one radionuclide

K_1 = summing correction

K_2 = Branching correction

K_3 = Equilibrium correction

t_d = decay time (to a reference date)
t_m = measurement live time

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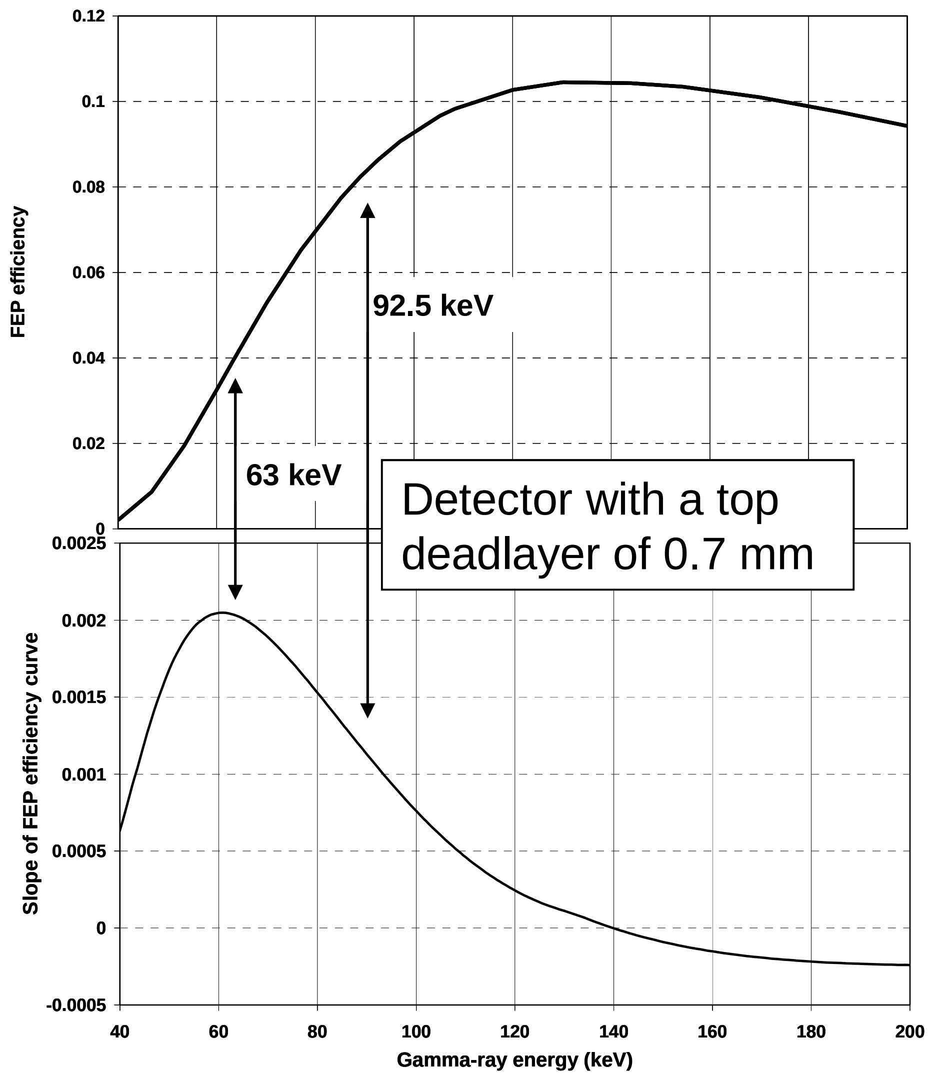
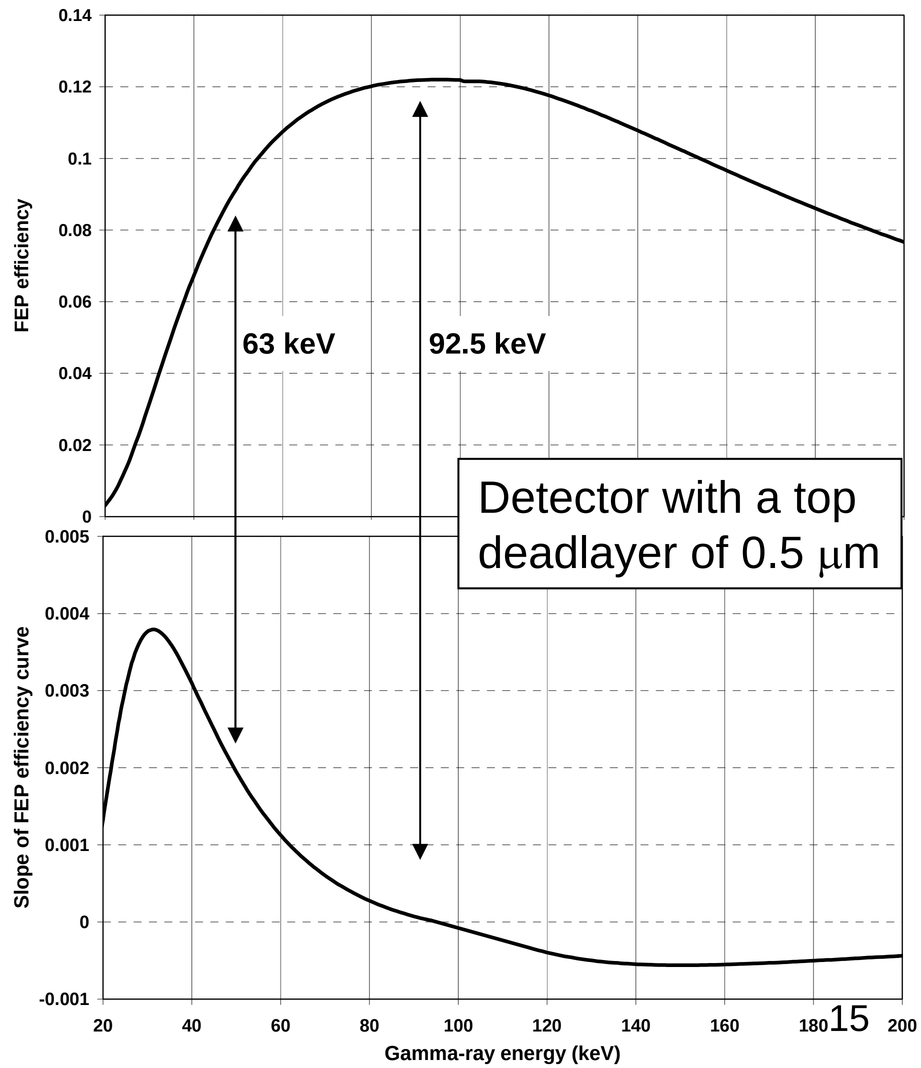
Efficiency variations at low-E: thick deadlayer vs. thin





Problems with thin deadlayers

- Beta particles can reach the sensitive volume
- Higher background at low energy
- Coincidence summing with X-rays

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Focus on ^{238}U

- **Gamma-ray spectrometry not the best technique to quantify U-238!**
- **Still, gamma-ray spectrometry often used since one can get results for many radionuclides in one analysis.**
- **Sometimes, gamma-ray spectrometry is dangerously simple to use.**
- **There is no data analysis software that does “it all” for you.**
- **It is still necessary with some hard work and know-how to obtain robust results and good quality data.**

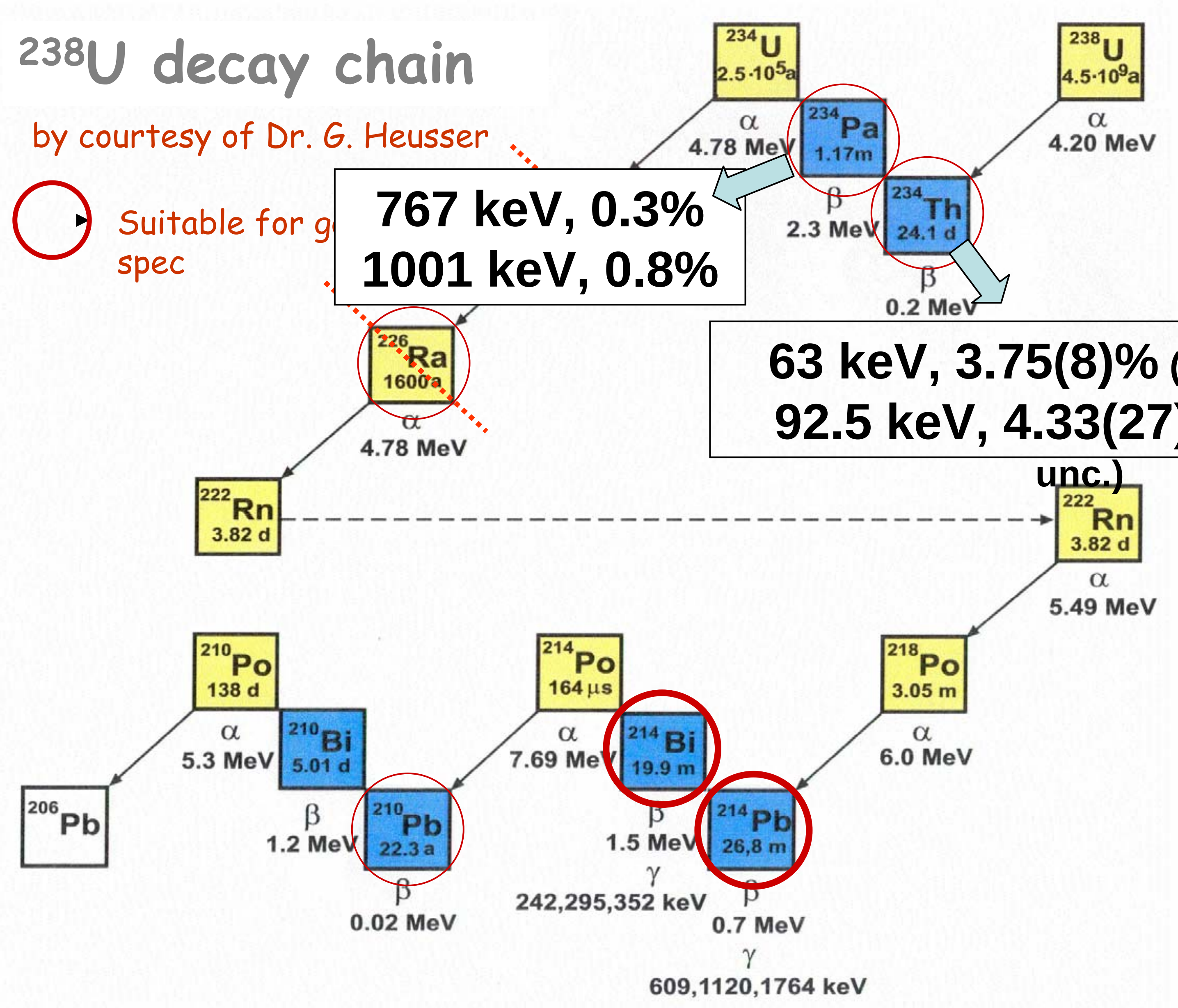
^{238}U decay chain

by courtesy of Dr. G. Heusser

Suitable for gamma spec

767 keV, 0.3%
1001 keV, 0.8%

63 keV, 3.75(8)% (2% rel unc.)
92.5 keV, 4.33(27)% (6% rel unc.)



Reported value	Reference
4.8 (6)%	Nucléide - 2000
4.80%	Mini Table de Radionucléides, 2007
4.49%	Genie-2000
4.1 (7)%	αβγ-Table, Wahl
4.1 (7)%	PTB-bericht 1998
4.00 (6)%	Nuclides2000
3.75 (8)%	DDEP - 2009
3.7 (2)%	The **Radiochemical Manual (1988)**
3.7 (4)%	NNDC
3.69 (7)%	NDS - 2007
3.6 (1)%	PTB-Ra-16/3, 1989

Std.dev: 0.45

Rel Std. dev. 11%

(Max-min)/average: 30%

More Problems / optimisation

- **Doublets (both 63 keV and 92.5 keV) ⇒ broad peaks**
- **Suitable detector – size, deadlayer thickness**
  - **Resolution,**
  - **Amplifications (also in simulations)**
  - **background,**
  - **efficiency**

  ⇒ Use "All purpose detectors" with care

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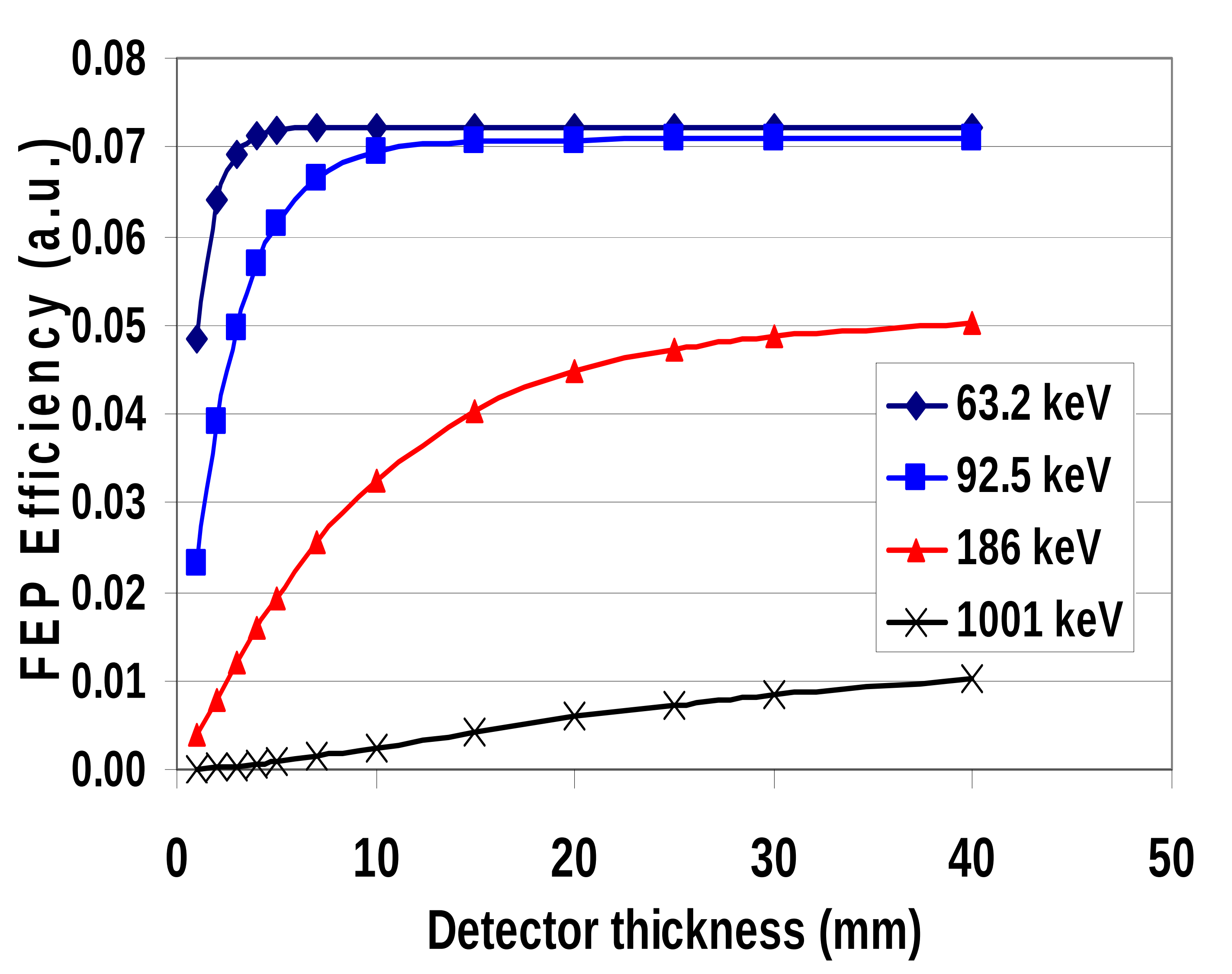
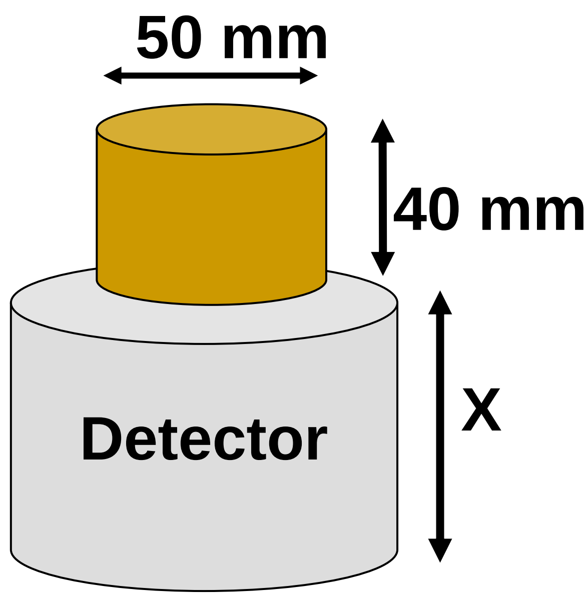
- **Optimising sample size and geometry**
- **Subtraction of interfering peaks**
  - **(93.3 keV Th $K_{\alpha 1}$X-ray – mainly from ^{228}Ac – also ^{235}U and ^{238}U)**
- **Reference Materials (Reference value? Stable? Hot spots?)**
- **Efficiency Transfer, Monte Carlo simulations**
  - **Accuracy of model, bin-width, coincidences, algorithm at low-E?**
- **Extrapolation of efficiency curve**
- **Eff. Curve coincidence summing corrections**
- **Background – variations of cosmic rays, radon, contamination (detector, shield, sample), nearby activities**

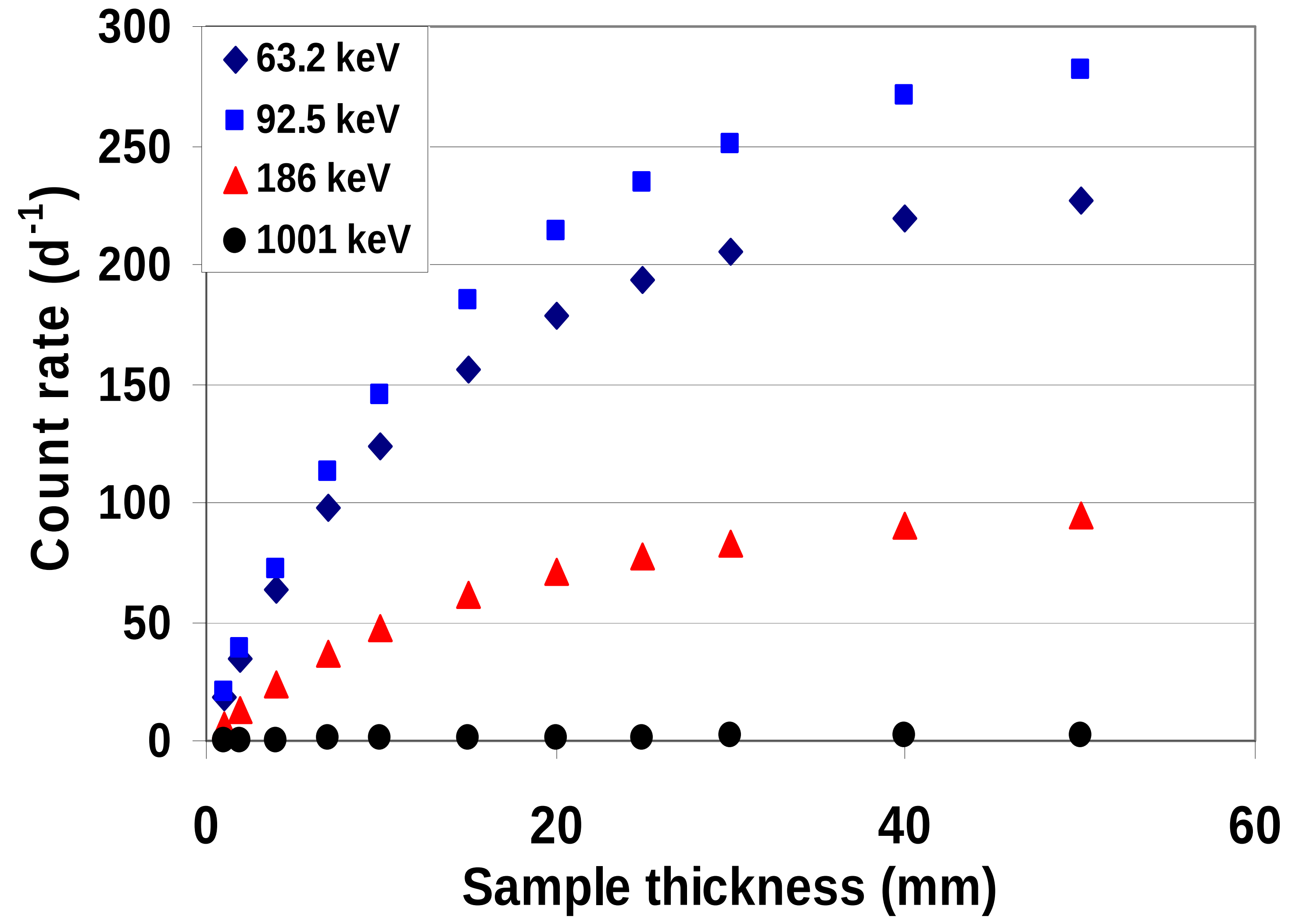
Interference free detection limit in HADES of pure U-sample in swipe sample ~ 1 ng



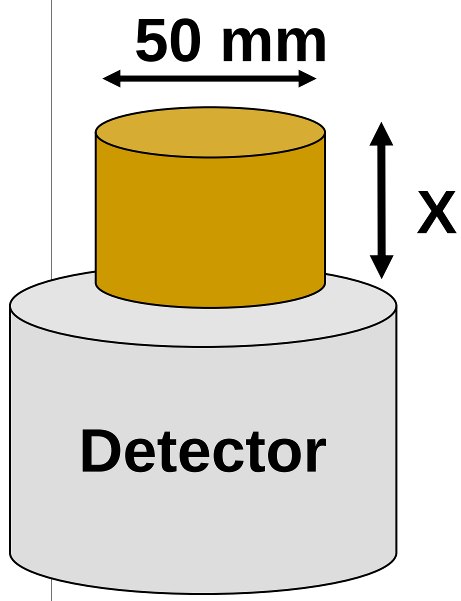
Sample:
Density 1.3 g/cm³
Dried soil



FEP count rate from U-238 decay



Sample:
Density 1.5 g/cm³
Dried soil
Detector: 50% rel. eff. BEGe



Facts and figures

^{238}U measured using gamma-ray spectrometry

Impact: ???

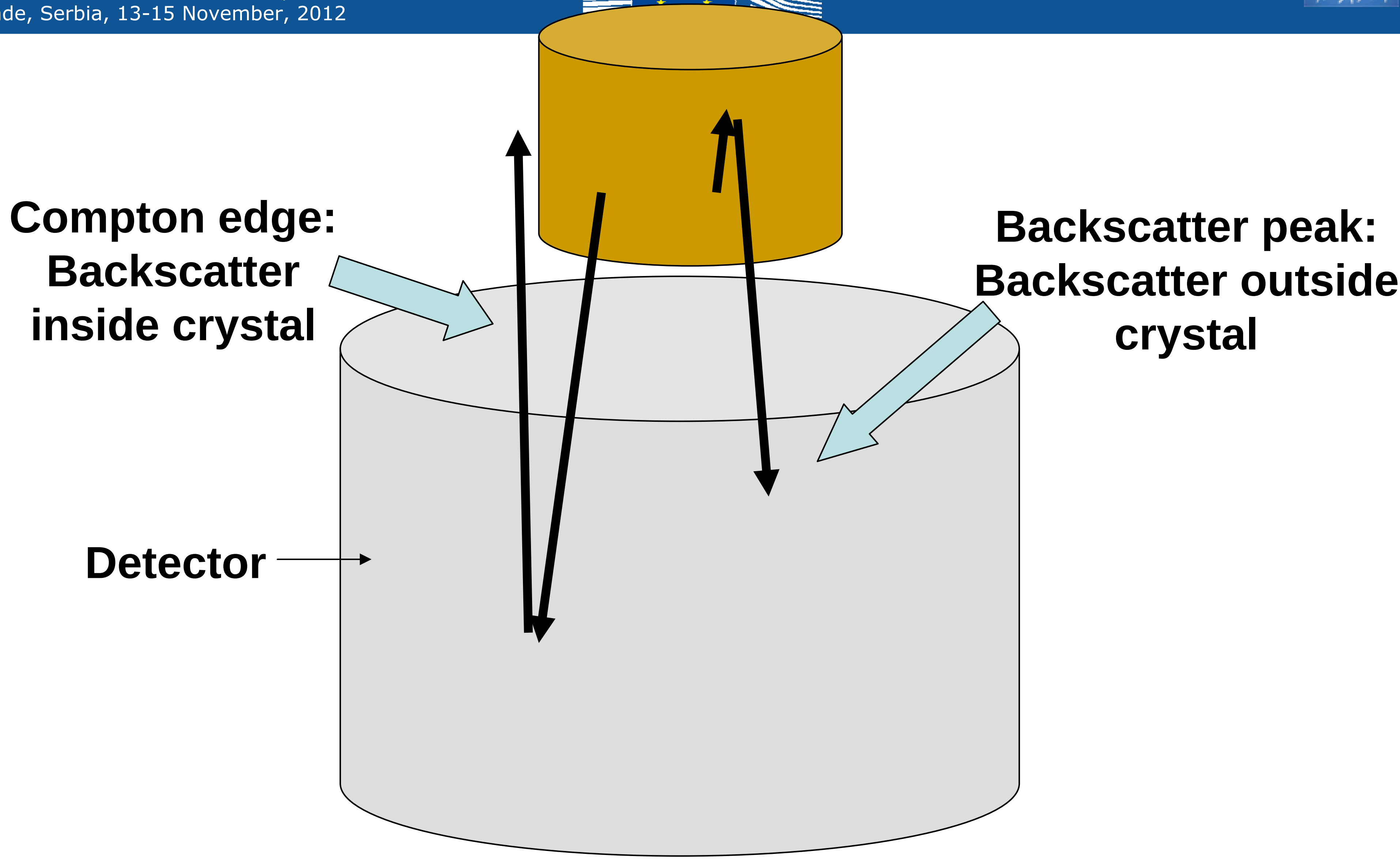
Not finalised task of the IAEA-CRP

What can an erroneous measurement lead to?

Numbers of samples measured per year?

What will better measurements lead to?

Maybe you can contribute?


Compton edge:
Backscatter
inside crystal
Backscatter peak:
Backscatter outside
crystal
Detector