

Spectrometry_Gamma

A New Module For The EduGATE Project

Uwe Pietrzyk & Michaela Gaens

Institute of Neurosciences and Medicine (INM), Research Center Juelich, Germany
Department of Mathematics and Natural Sciences, University of Wuppertal, Germany

Contact: u.pietrzyk@fz-juelich.de or uwe.pietrzyk@uni-wuppertal.de

(Basic Paper → „Zeitschrift für Medizinische Physik“ / Z. Med. Phys. 23 (2013) 65-70)

**- *Long is the way of theory,
short and effective by examples –***

(Lucius Annaeus Seneca (the Younger),
Epistulae morales)

- **Spectrometry_Gamma:**
 - introduces to the basics of gamma spectra obtained from a scintillation detector
 - Inspired by **chapter 10** of ***Physics in Nuclear Medicine***
(Cherry, Sorensen & Phelps, 2012)
 - provides GATE-macros
 - comes in two versions: **Basic & Extended**
 - Programme Code in C and for ROOT to calculate and plot relevant parameters during **Compton Scatter**

Pulse-height spectrum for ^{137}Cs showing typical structures

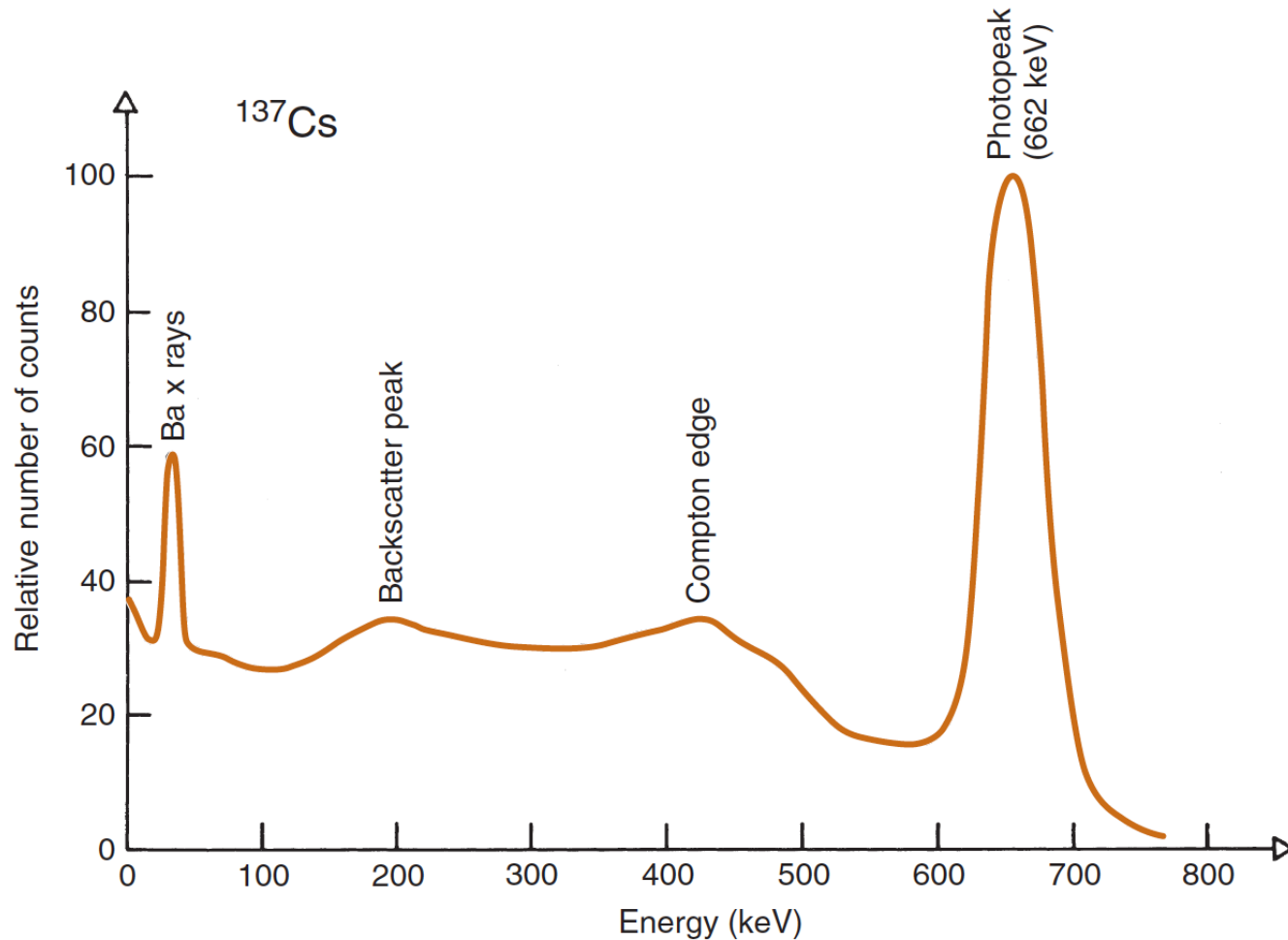
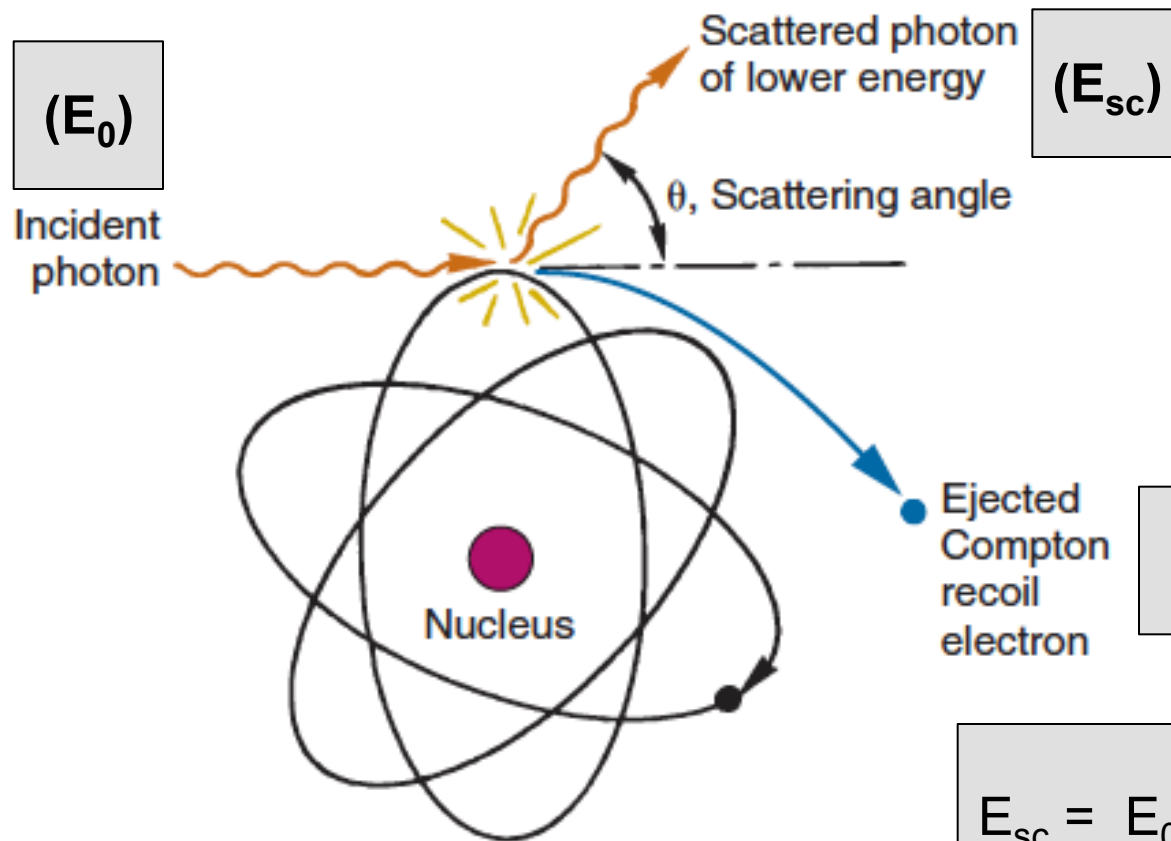


FIGURE 10-3 Actual pulse-height spectrum recorded with a NaI(Tl) detector and ^{137}Cs (662-keV γ rays, ~30 keV Ba x rays). Compare with Figure 10-2B.

from: Cherry et al, 2012



(Cherry, et al, 2012)

Basics of Compton_Scatter

$$E_{sc} = E_0 / [1 + (E_0 / 0.511) (1 - \cos \theta)]$$

$$E_{re} = E_0 - E_{sc}$$

for 180-degree scattering:

$$E_{sc}^{min} = E_0 / [1 + (2 E_0 / 0.511)]$$

$$E_{re}^{max} = E_0 - E_{sc}^{min}$$

running: `root -l compton_scatter_root.c`

```
for (int i=0; i<n_values; i++)
{
// energy of the incident gamma
E_gamma[i] = (i+1) * e_step;

// energy of the recoil electron; -> "compton electron" -> "compton edge"
Emax_re[i] = E_gamma[i] * E_gamma[i] / (E_gamma[i] + m_electron_2);

// energy of the back-scattered gamma
Emin_sc[i] = E_gamma[i] - Emax_re[i];

printf( " E_gamma: %f Emax_re: %f Emin_sc: %f (MeV) \n", E_gamma[i], Emax_re[i], Emin_sc[i]);

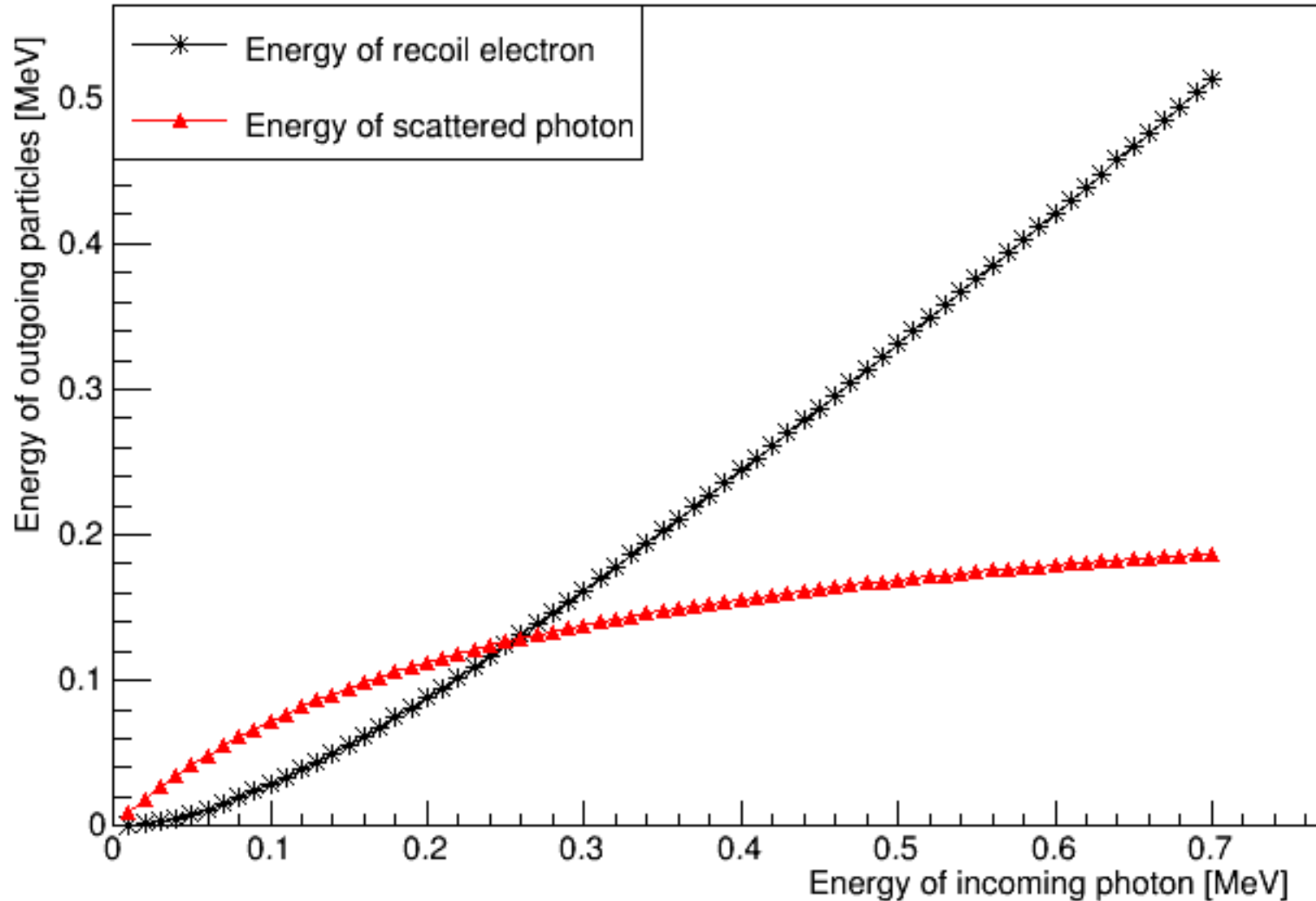
}
```

--> output

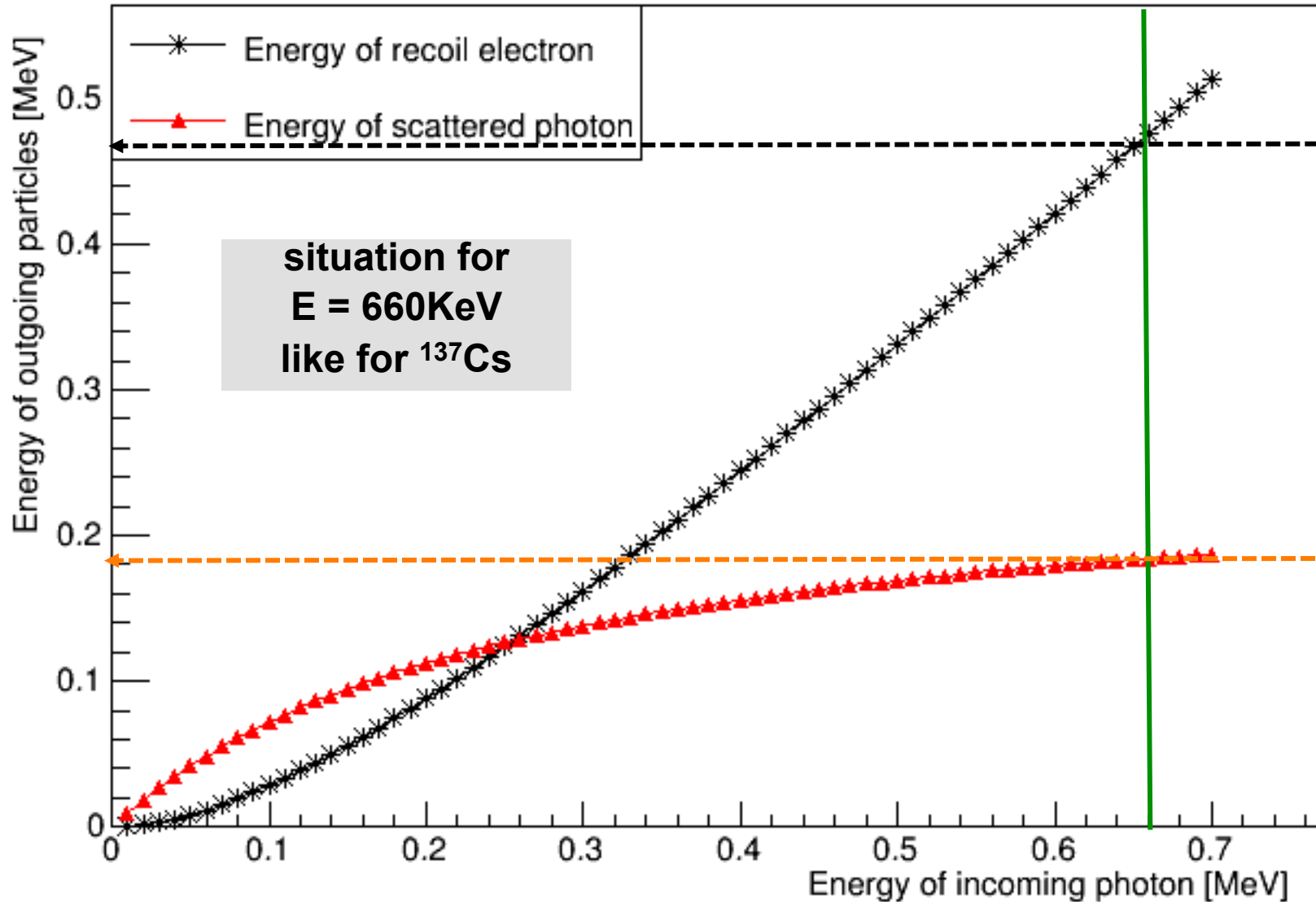
```
E_gamma: 0.010000 Emax_re: 0.000377 Emin_sc: 0.009623 (MeV)
E_gamma: 0.020000 Emax_re: 0.001452 Emin_sc: 0.018548 (MeV)
E_gamma: 0.030000 Emax_re: 0.003152 Emin_sc: 0.026848 (MeV)
E_gamma: 0.040000 Emax_re: 0.005415 Emin_sc: 0.034585 (MeV)
.
.
E_gamma: 0.660000 Emax_re: 0.475806 Emin_sc: 0.184194 (MeV)
E_gamma: 0.670000 Emax_re: 0.485035 Emin_sc: 0.184965 (MeV)
E_gamma: 0.680000 Emax_re: 0.494281 Emin_sc: 0.185719 (MeV)
E_gamma: 0.690000 Emax_re: 0.503543 Emin_sc: 0.186457 (MeV)
E_gamma: 0.700000 Emax_re: 0.512820 Emin_sc: 0.187180 (MeV)
```

Plot created via: `root -l compton_scatter_root.c`

Compton scattering at 180-degree



Compton scattering at 180-degree



Pulse-height spectrum for ^{137}Cs showing typical structures

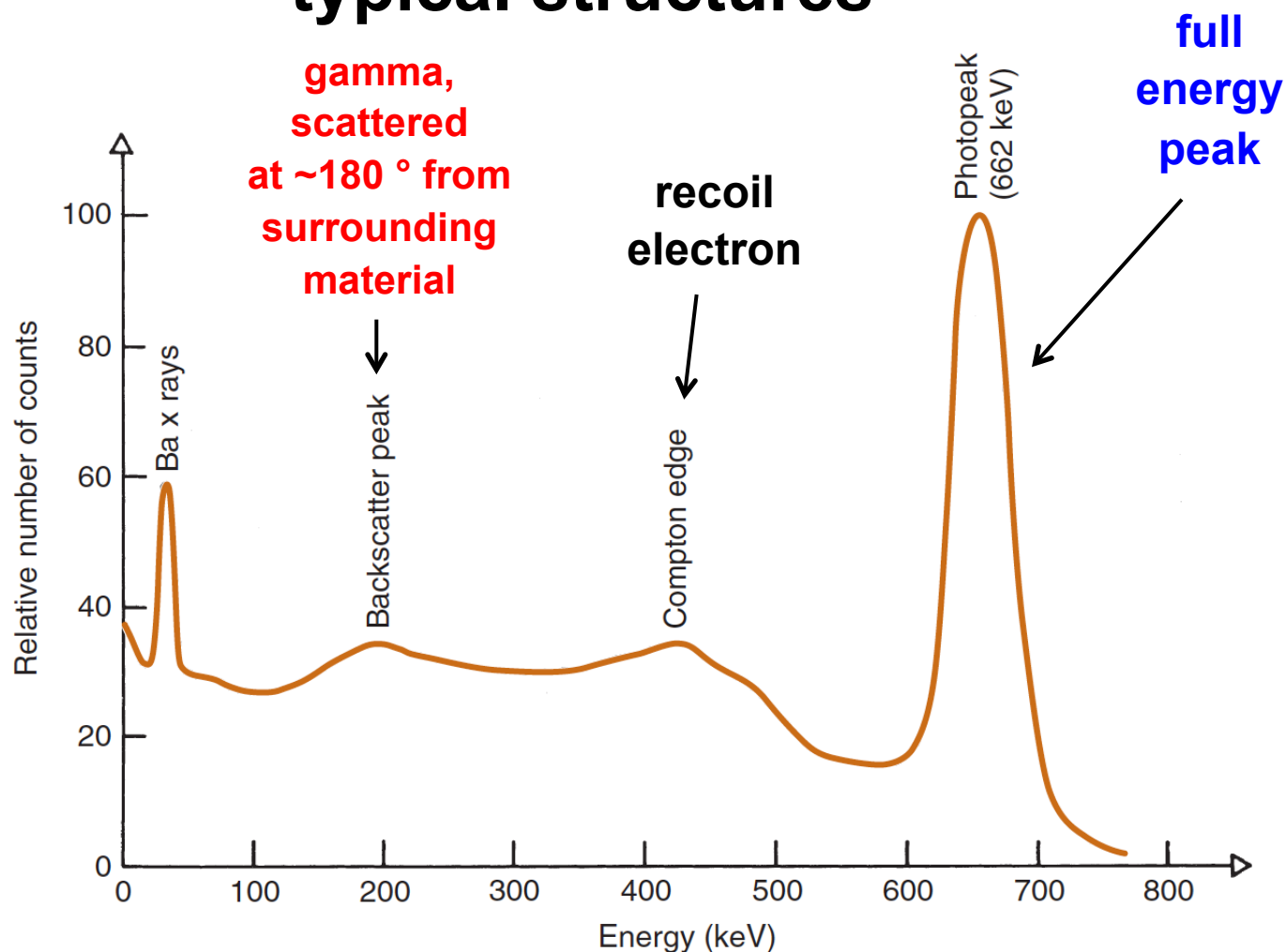
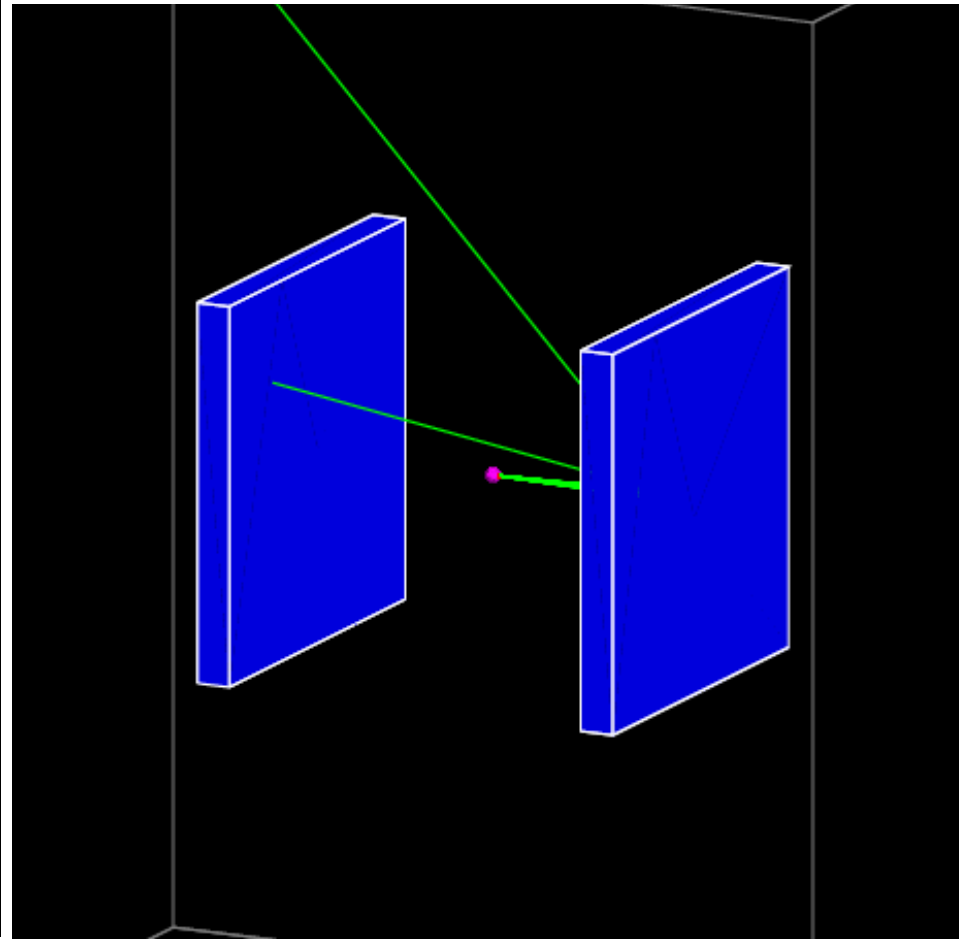
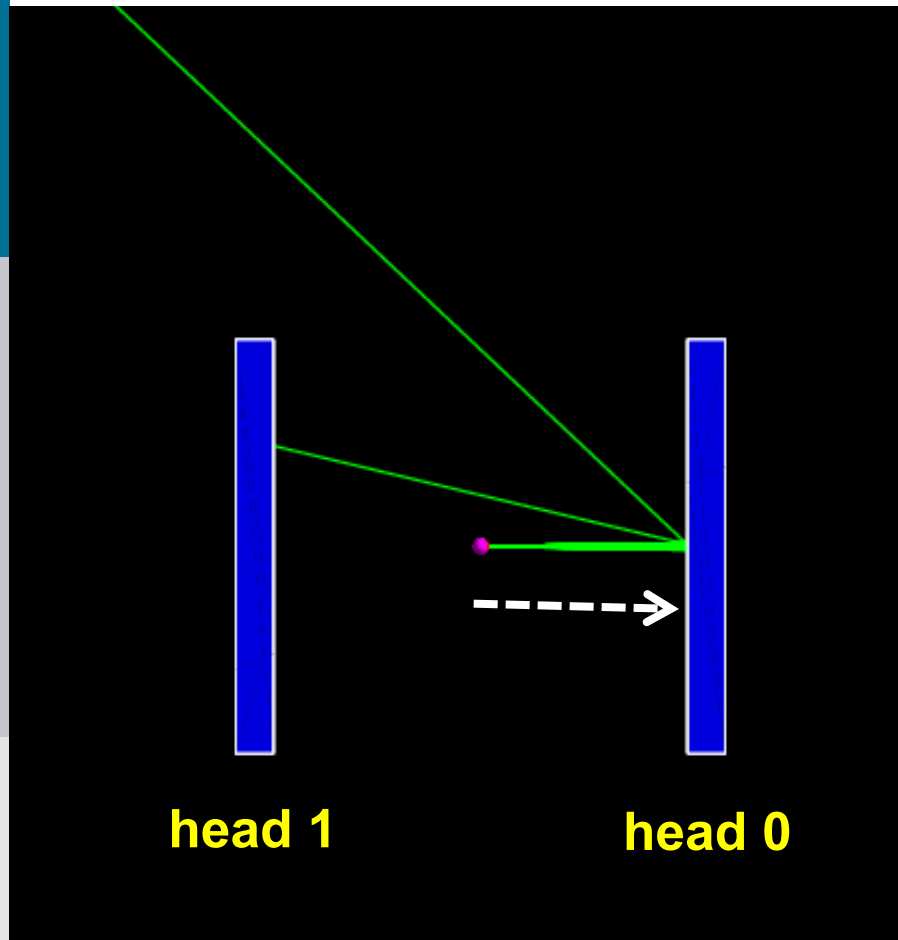


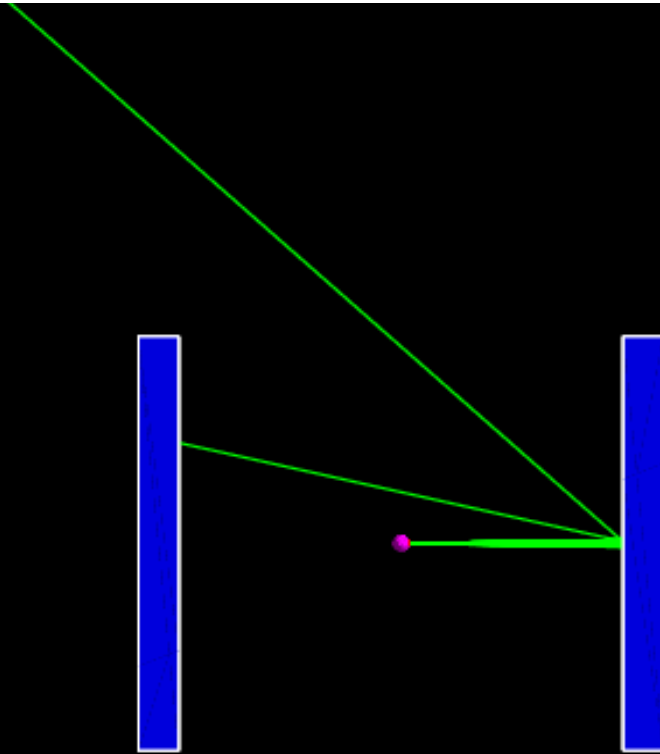
FIGURE 10-3 Actual pulse-height spectrum recorded with a NaI(Tl) detector and ^{137}Cs (662-keV γ rays, ~30 keV Ba x rays). Compare with Figure 10-2B.

from: Cherry et al, 2012

Spectrometry_Gamma_Basic



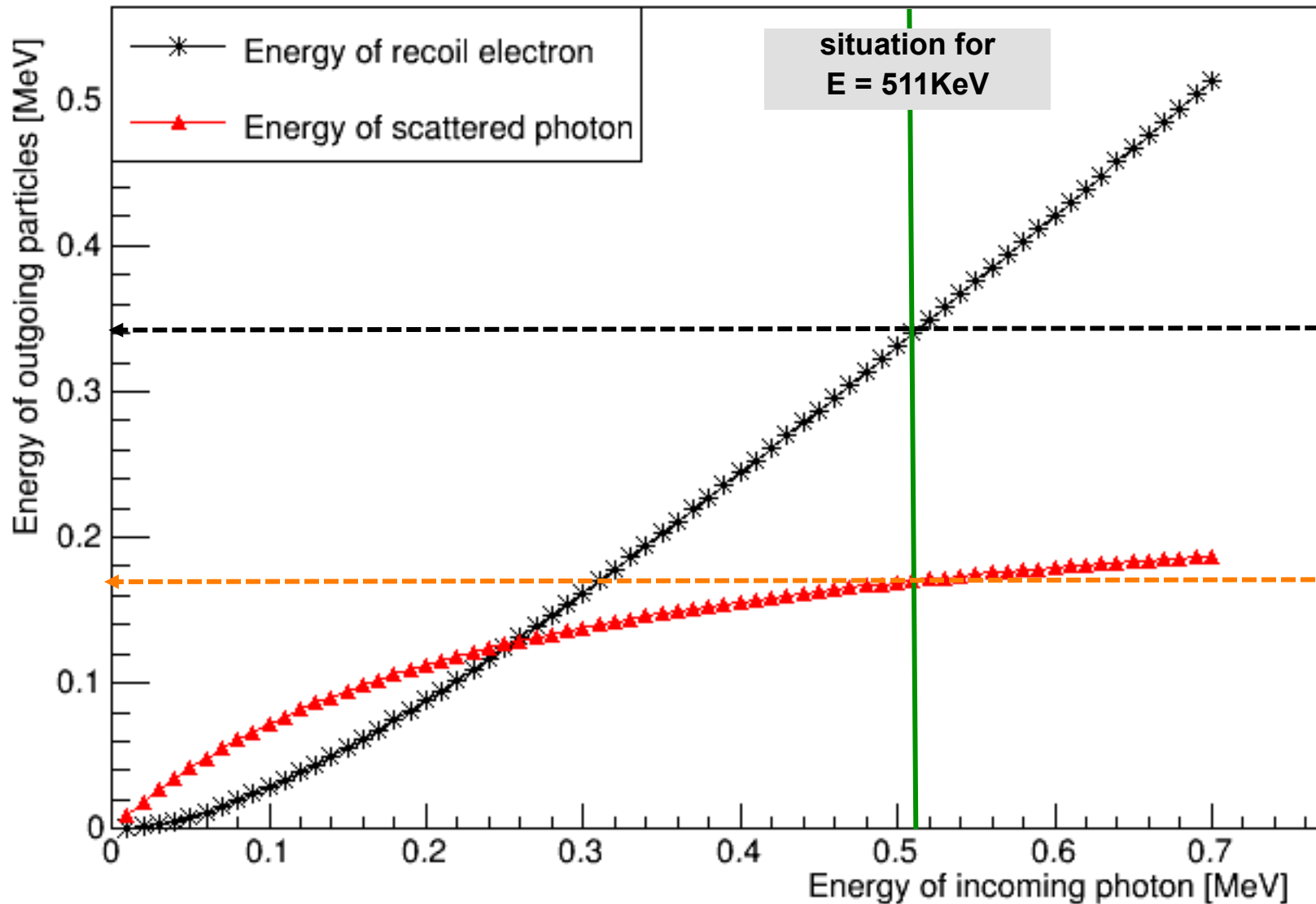
Basic Setup



- Two opposing NaI-crystals allow to detect:
 - back-scattered gamma
 - characteristic X-ray, escaping from the crystal (head 0)

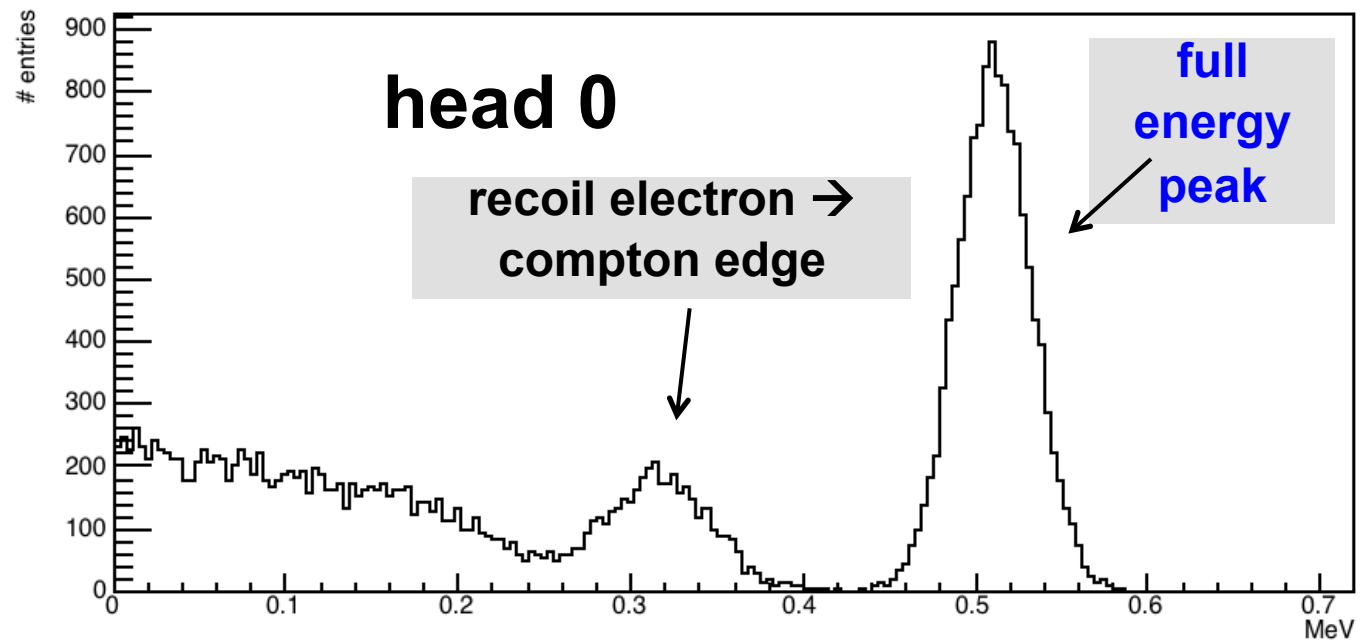
simplified Gamma Camera → 2 *crystals*, no collimator,
collimated gamma source (rays directed towards head 0 !!)

Compton scattering at 180-degree

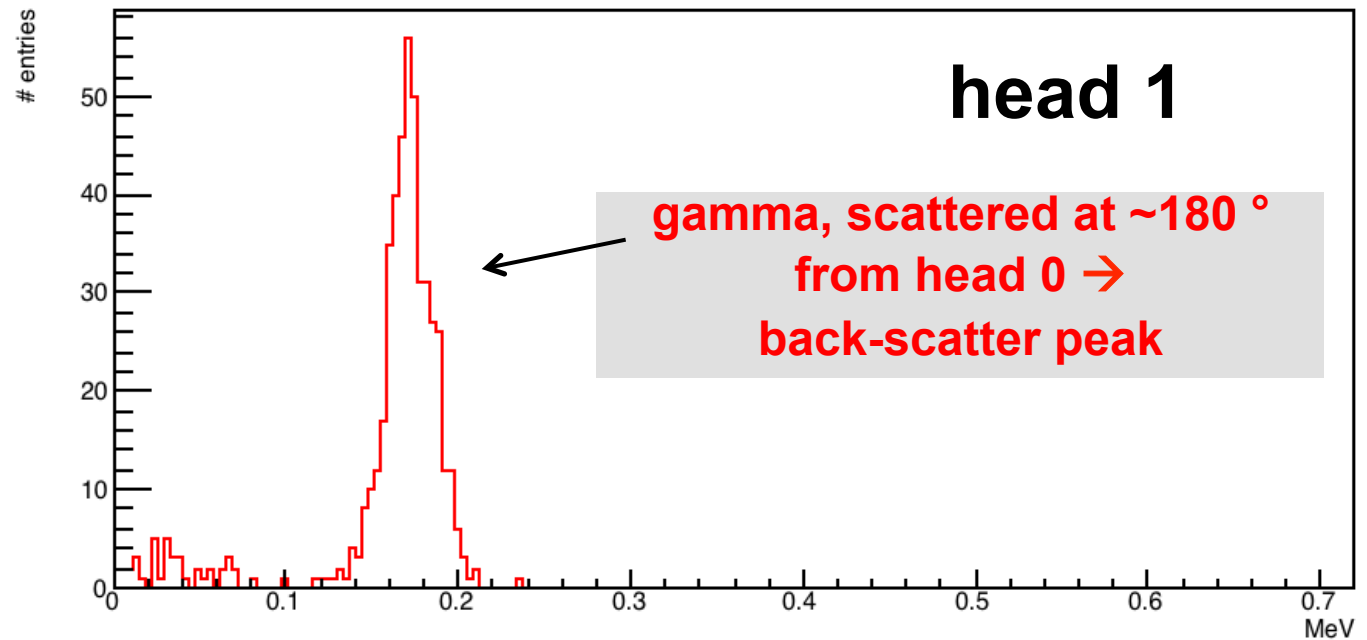


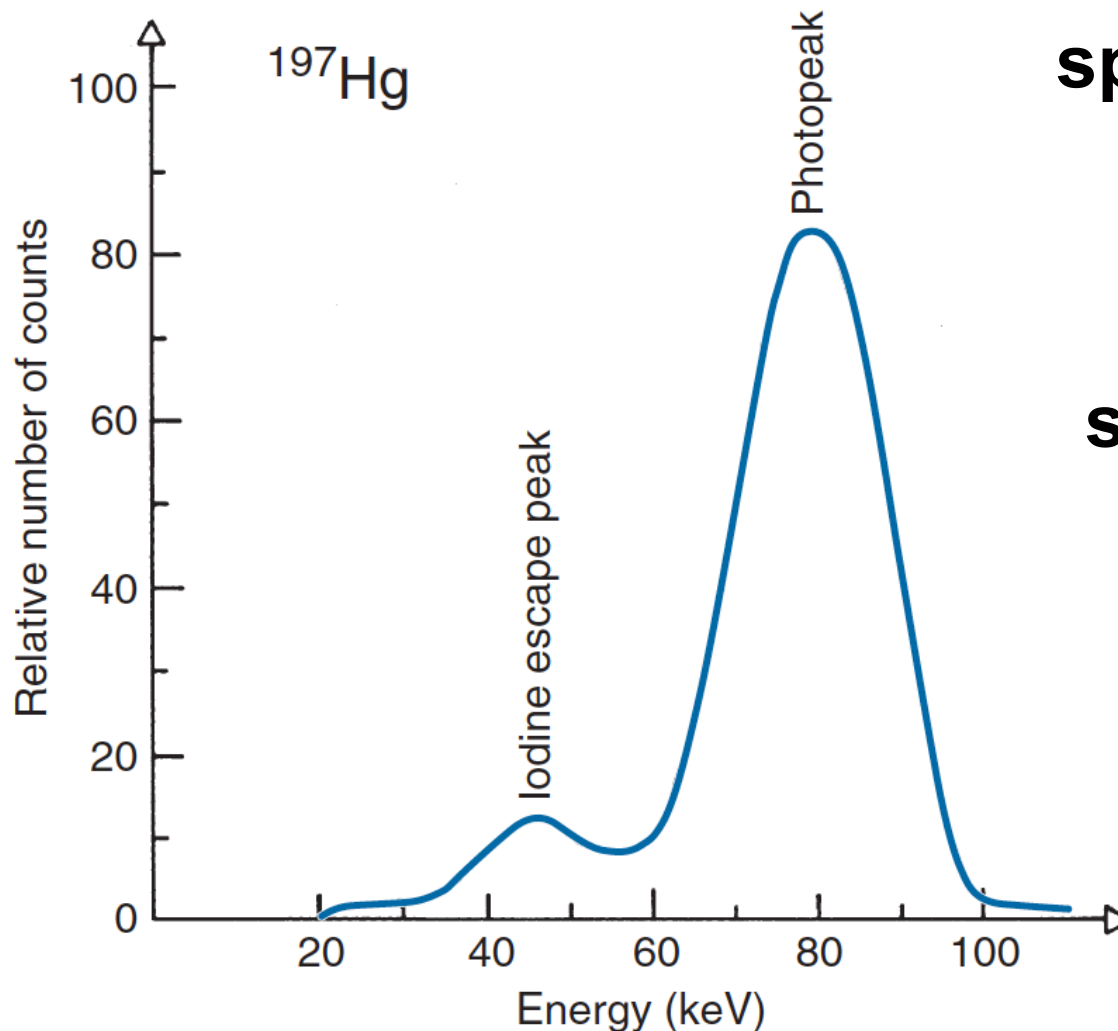
E_{gamma} : **0.510000** $E_{\text{max_re}}$: **0.339778** $E_{\text{min_sc}}$: **0.170222** (MeV)

511 keV



note: different scales!!





Pulse-height spectrum for ^{197}Hg

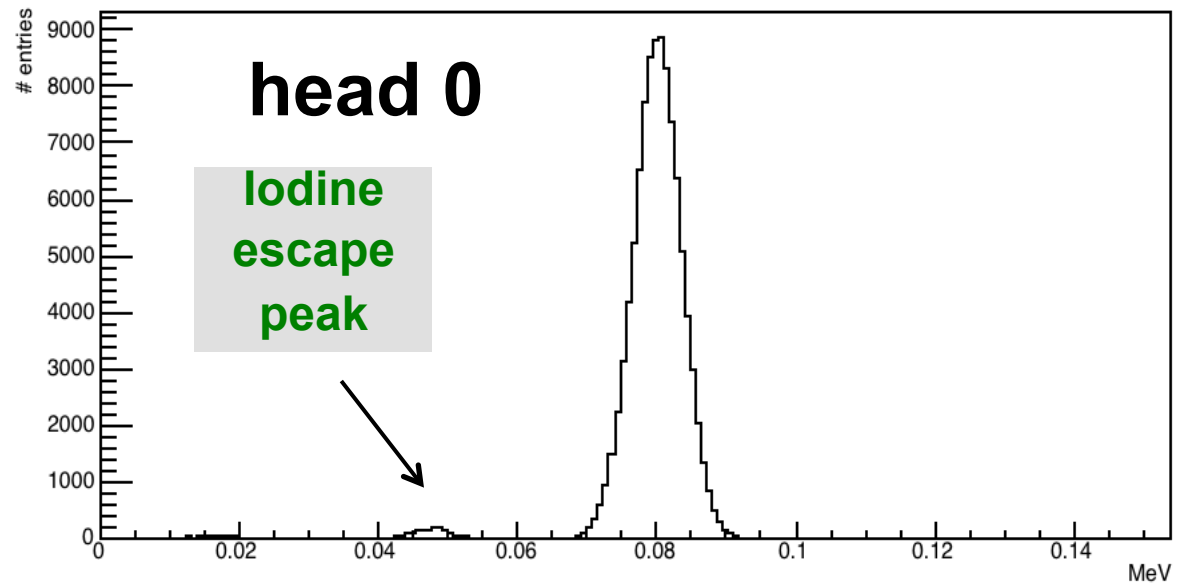


some more details!!

FIGURE 10-4 Pulse-height spectrum for ^{197}Hg ($E_\gamma = 77.3$ keV) recorded with NaI(Tl). Iodine escape peak (45-50 keV) is due to escape of characteristic iodine x ray (~30 keV) following a photoelectric absorption event in detector.

from: Cherry et al, 2012

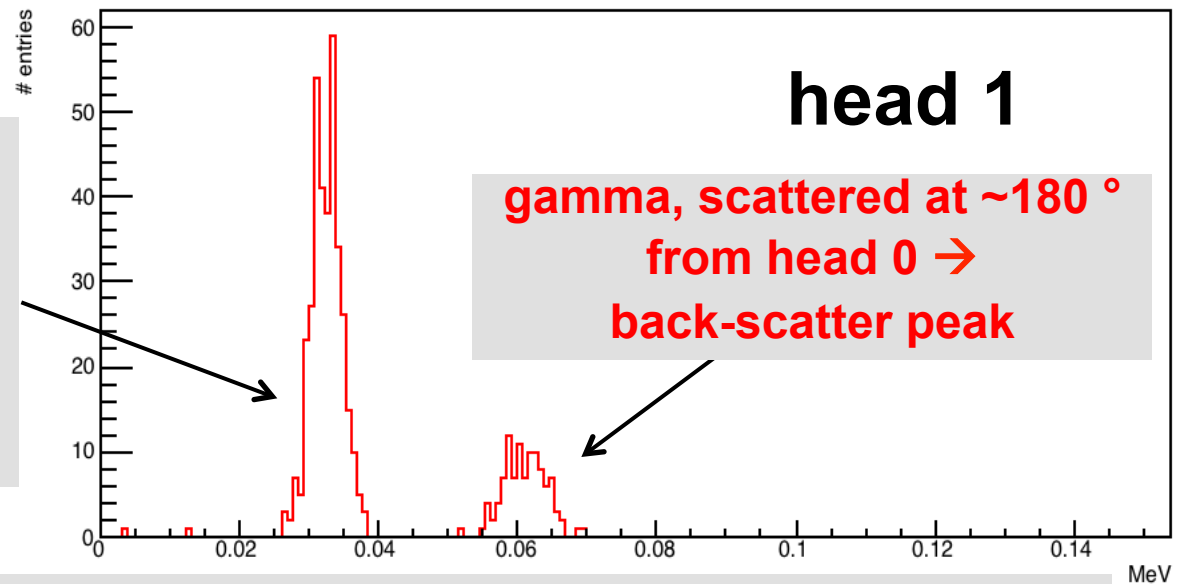
80 keV



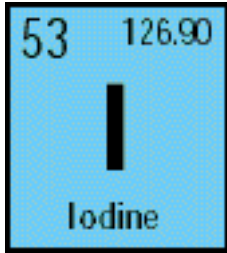
note: different scales!!

escape peak: $E_0 - E_{X\text{-rays}}$

Iodine (in NaI-crystal):
characteristic X-rays
following
photoelectric
absorption



E_{gamma} : 0.080 $E_{\text{max_re}}$: 0.019076 $E_{\text{min_sc}}$: 0.060924 (MeV)

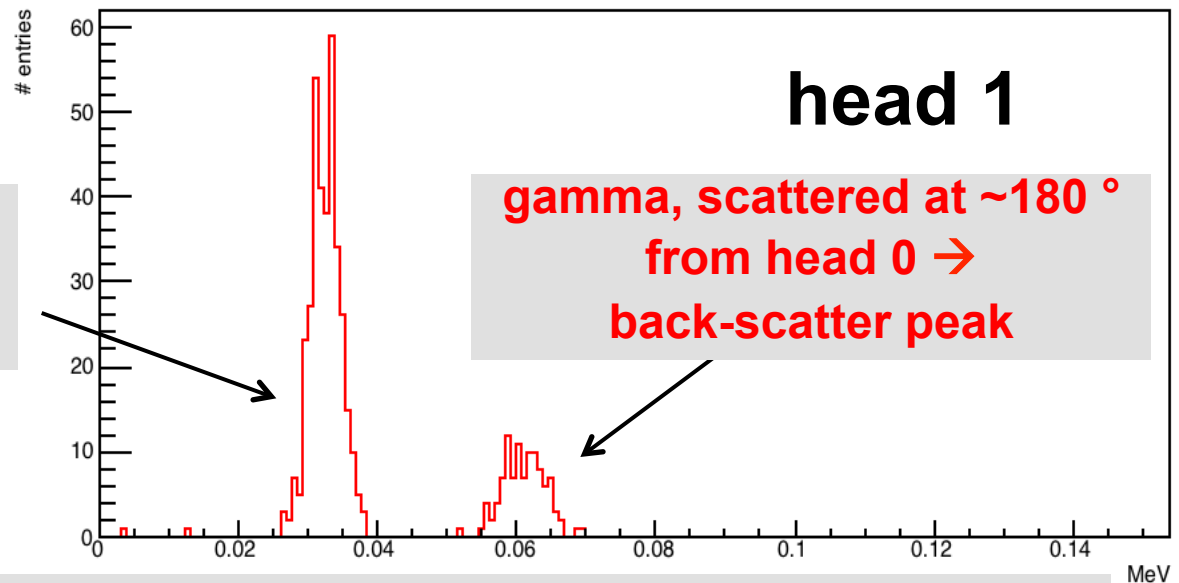


http://xdb.lbl.gov/Section1/Periodic_Table/I_Web_data.htm

K and L shell emission lines in electron volts

Ka ₁	Ka ₂	Kb ₁	La ₁	La ₂	Lb ₁	Lb ₂	Lg ₁
28,612.0	28,317.2	32,294.7	3,937.65	3,926.04	4,220.72	4,507.5	4,800.9

**Iodine
characteristic
x-rays**



E_gamma: **0.080** Emax_re: 0.019076 Emin_sc: 0.060924 (MeV)

Starting Basic Setup (Gate_v7.0)

in a shell-window type:
`config_starter_mac_70.sh`

EduGate Spectrometry_Gamma Configuration

CameraType	2heads
ViewPointThetaPhi	0 90
VisuOnOff	novisu
SourceActivity	100 Bq
CrystalMaterial	NaI
SourceVolMaterial	Vacuum
SourceType	gamma_collim
SourceEnergy	80
E_res	0.10

Generate configuration.mac and Start

specify:

energy &

energy resolution

Starting Basic Setup (Gate_v7.0)

can change selection presets in **Spectrometry_Gamma.txt**



```
CameraType: 2heads; 1head; 4heads;  
ViewPointThetaPhi: 0 90; 90 0; -90 0; 89 90; 15 30; 30 30; 45 45; 60 60;  
VisuOnOff: novisu; visu;  
SourceActivity: 100 Bq; 1000. Bq; 10000. Bq; 100000. Bq;  
CrystalMaterial: NaI; BGO; LSO; GSO; PWO; LuAP; YAP; CZT; Silicon; Lead; Tungsten;  
SourceVolMaterial: Vacuum; Water; Plexiglass; Air; PVC;  
SourceType: gamma_collim; gamma;  
SourceEnergy: 80; 10; 50; 60; 90; 100; 120; 140; 160; 200; 240; 364; 511; 1000; 1600;  
E_res: 0.10; 0.00; 0.01; 0.05; 0.15; 0.20; 0.25;
```

Result: Basic Setup (Gate_v7.0)

