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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

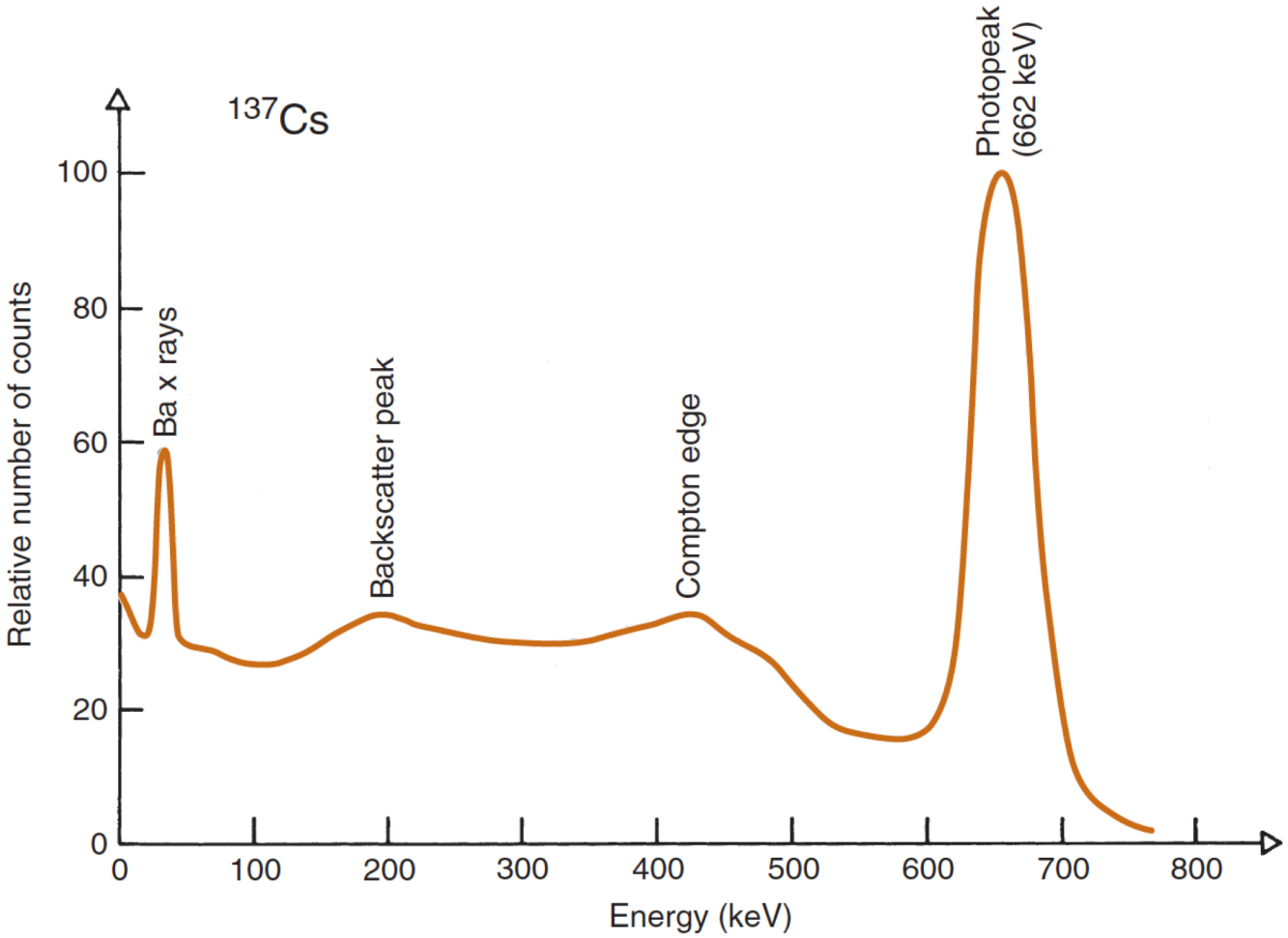
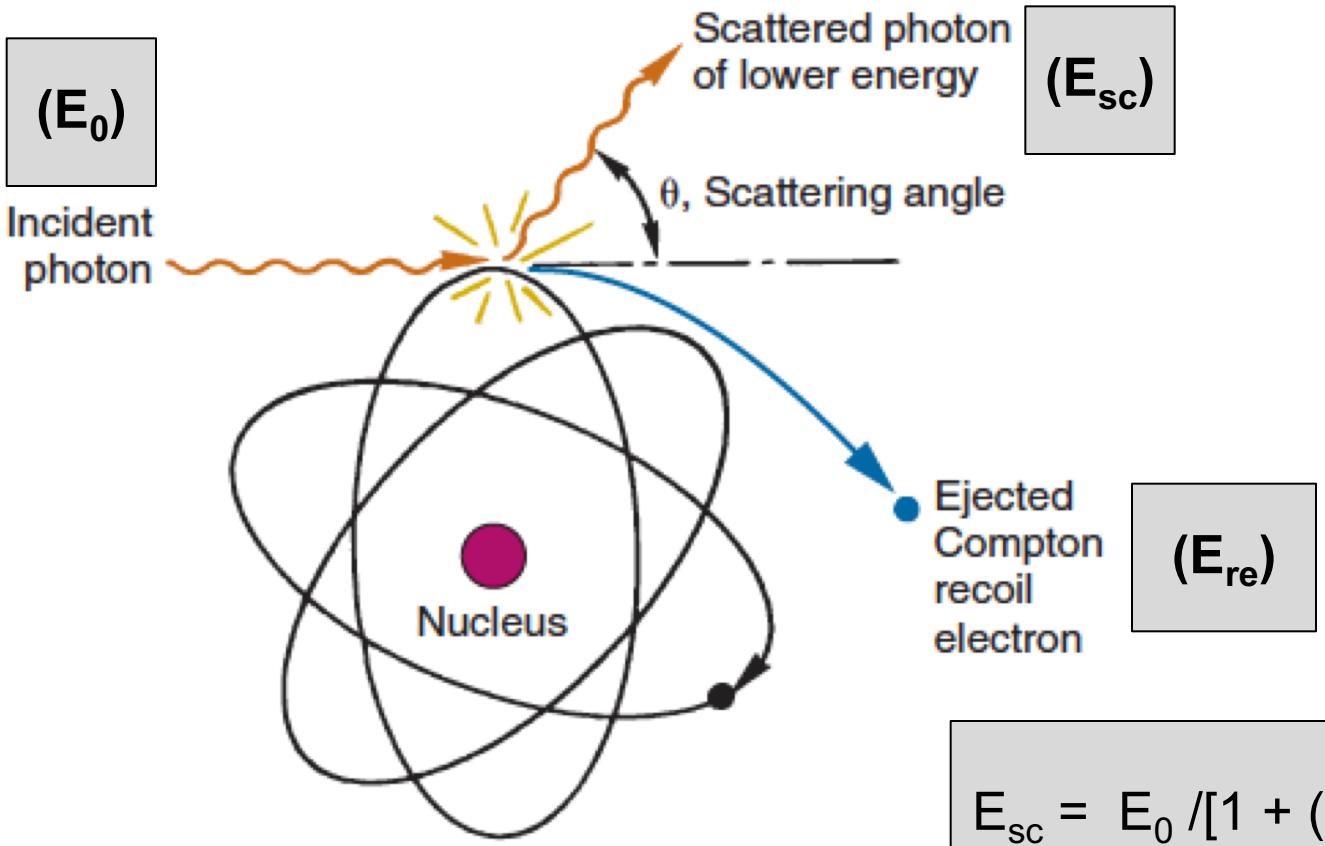


FIGURE 10-3 Actual pulse-height spectrum recorded with a NaI(Tl) detector and ^{137}Cs (662-keV γ rays, ~30 keV Ba x rays). Compare with Figure 10-2B.

from: Cherry et al, 2012



(Cherry, et al, 2012)

Basics of Compton_Scatter

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

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

for 180-degree scattering:

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

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

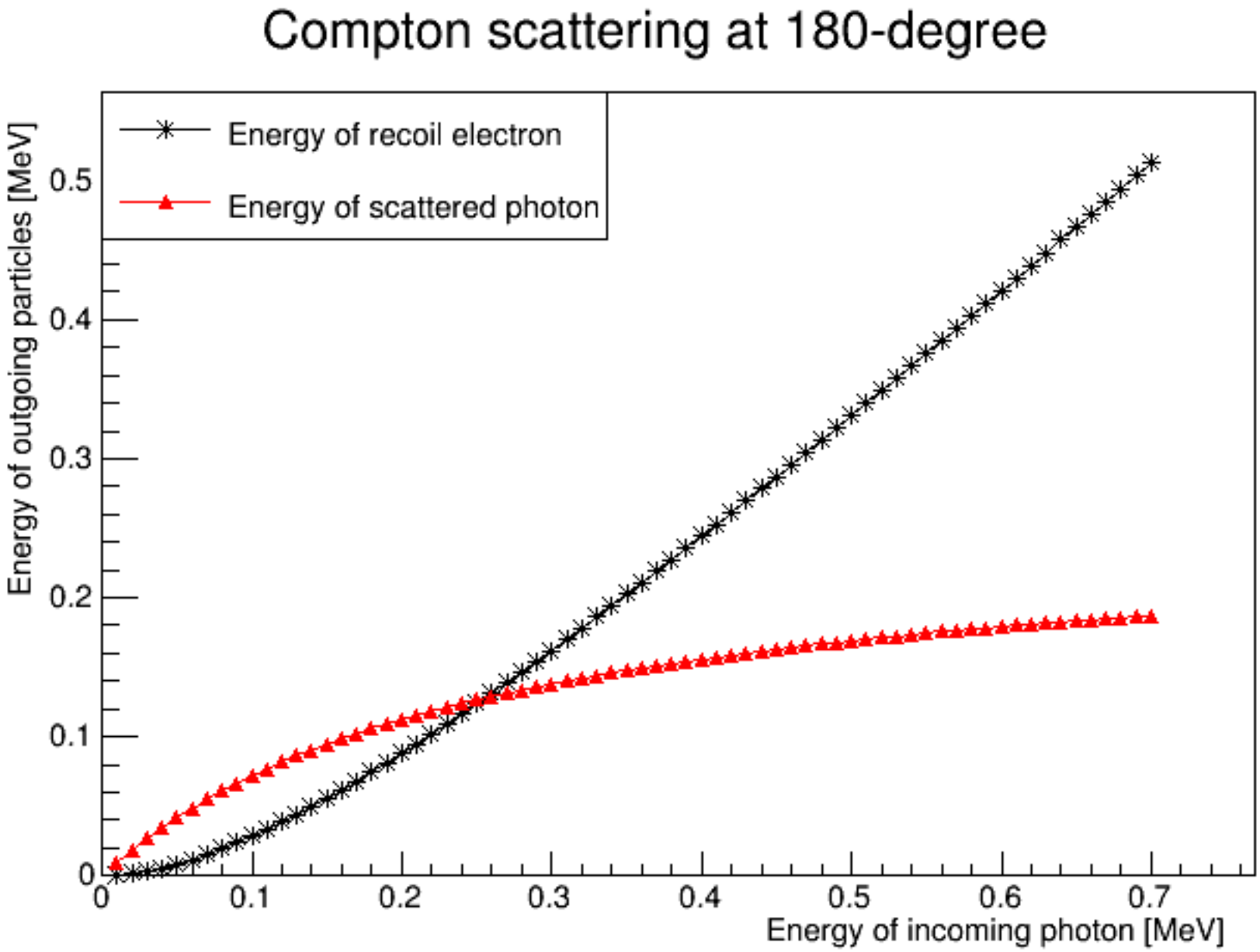
running: root -l compton_scatter_root.c

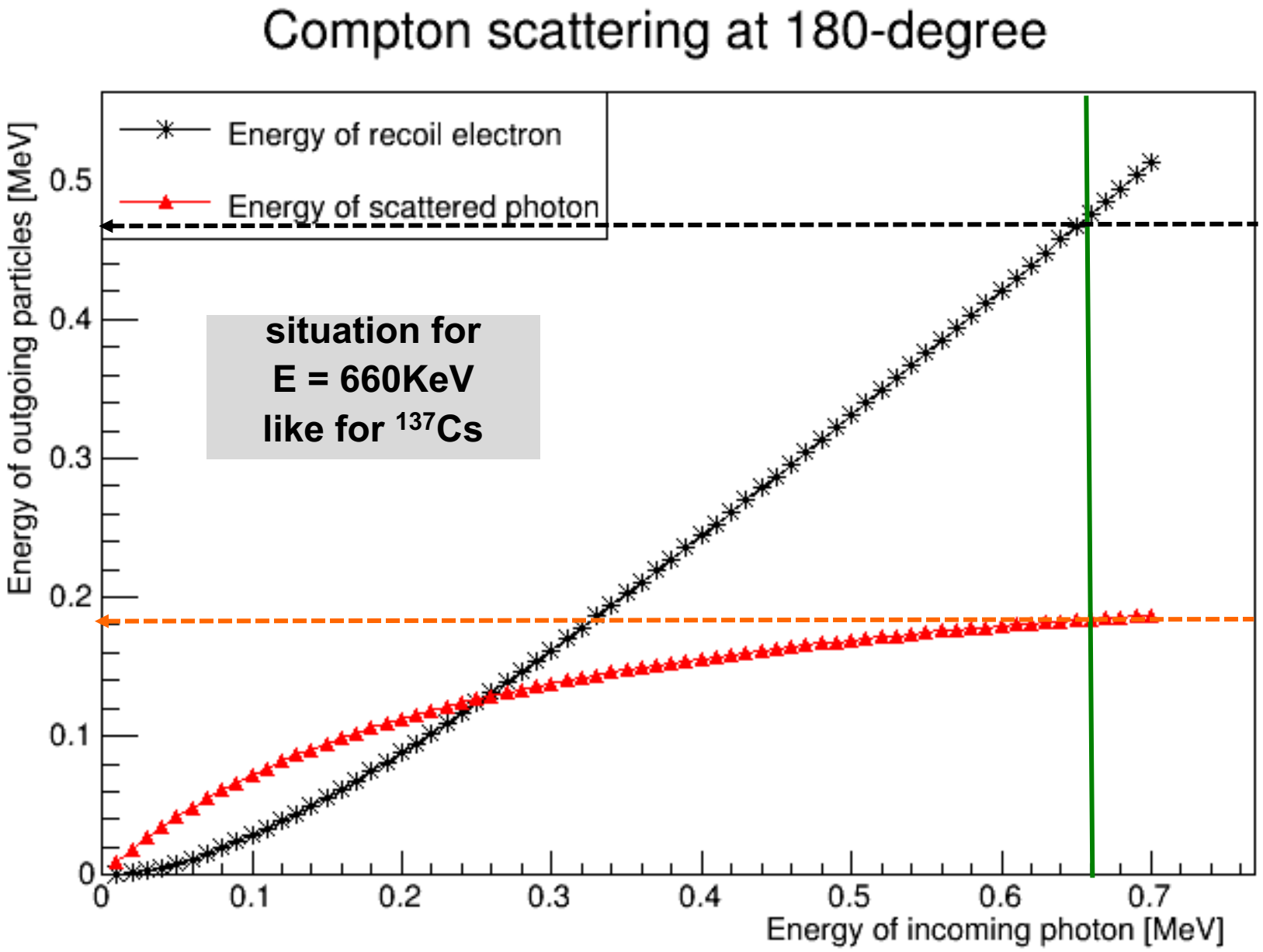
```
for (int i=0; i<n_values; i++)
{
// energy of the incident gamma
E_gamma[i] = (i+1) * e_step;

// 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
Energy of recoil electron
Energy of scattered photon
situation for
E = 660KeV
like for ^{137}Cs
Energy of outgoing particles [MeV]
Energy of incoming photon [MeV]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

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

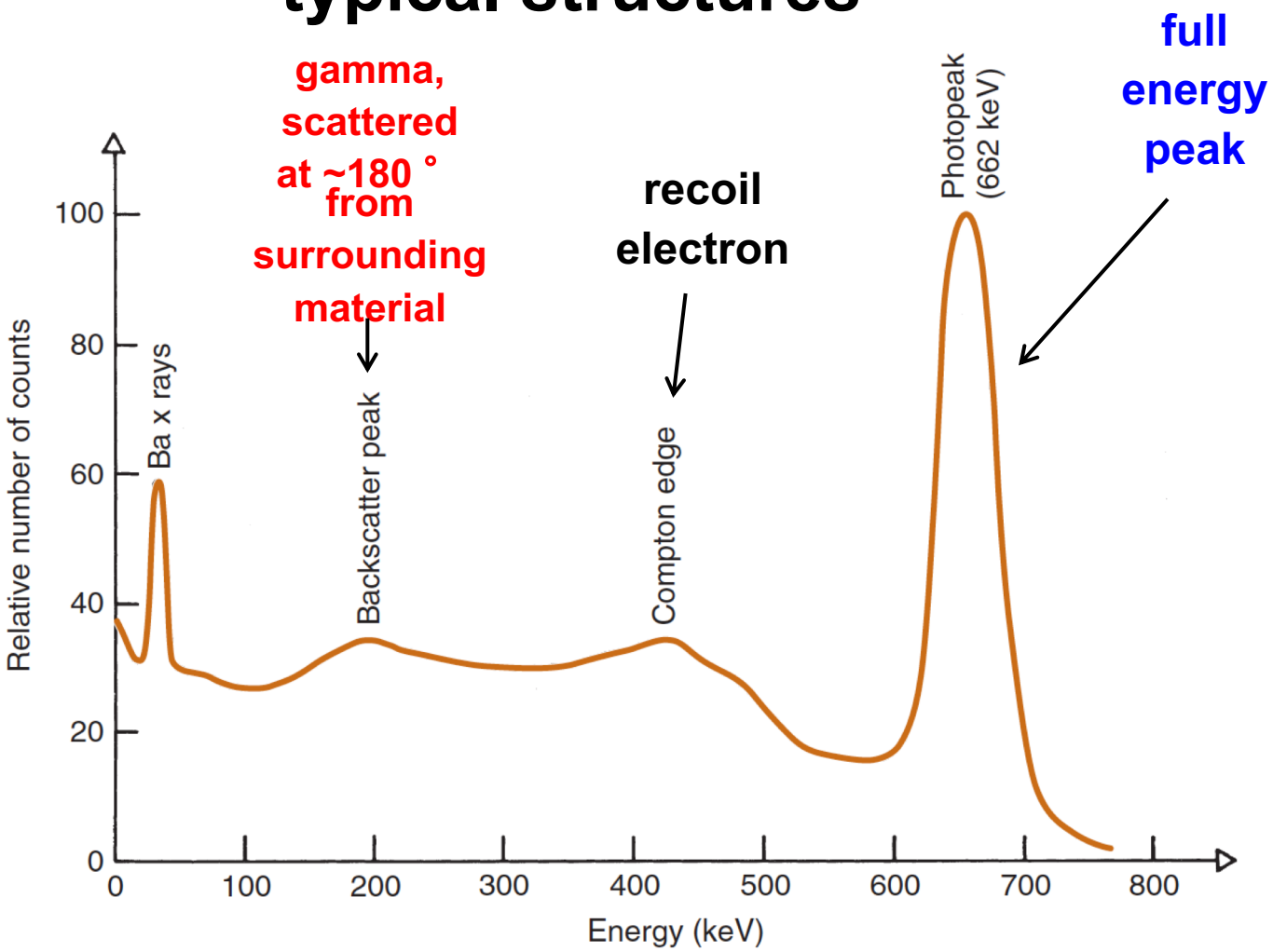
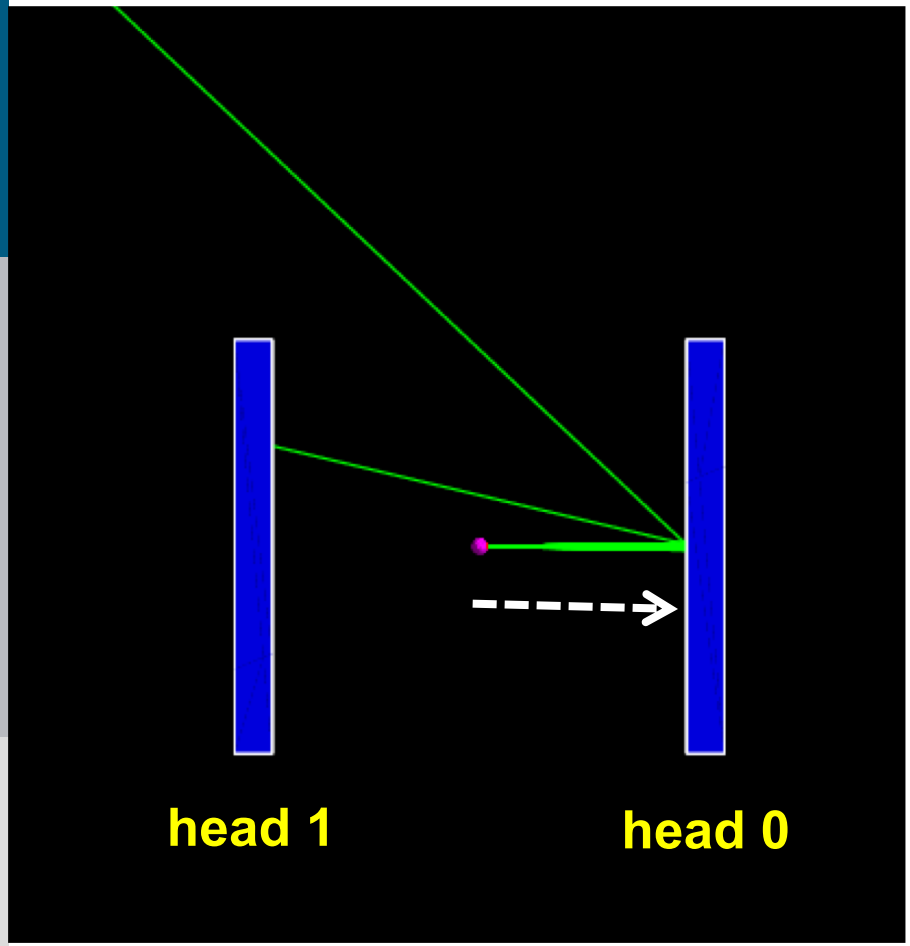
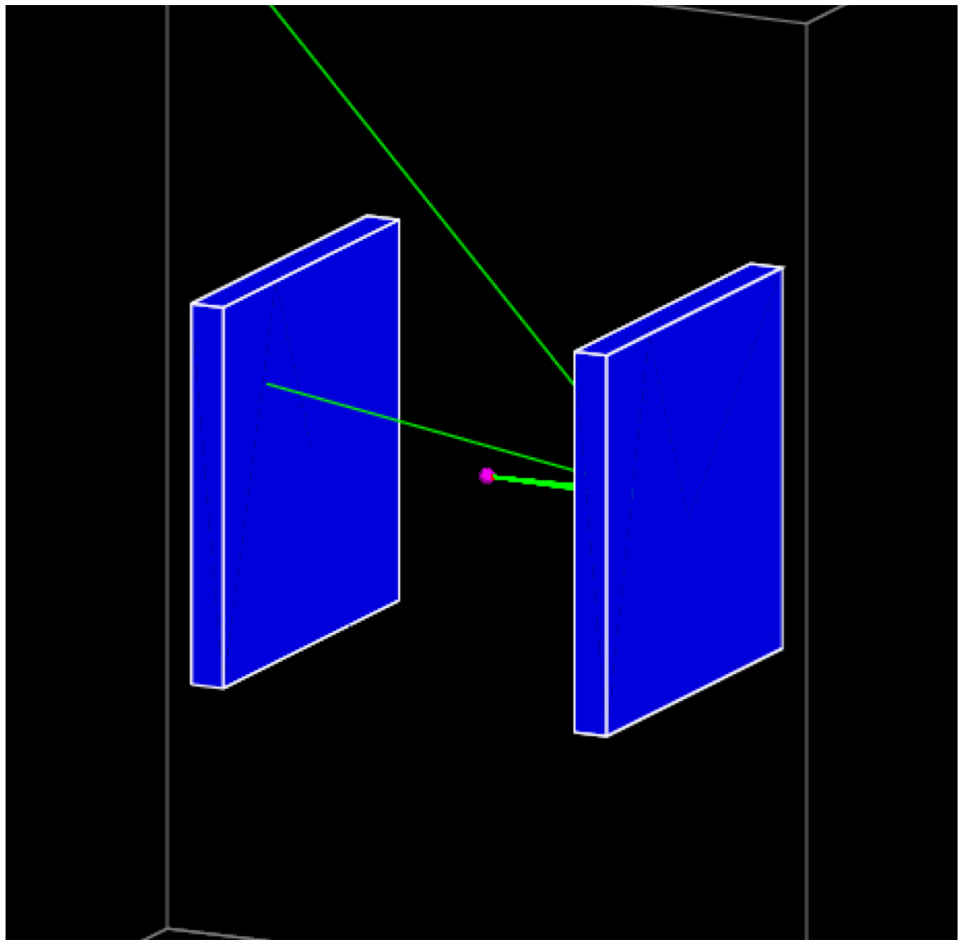


FIGURE 10-3 Actual pulse-height spectrum recorded with a NaI(Tl) detector and ^{137}Cs (662-keV γ rays, ~30 keV Ba x rays). Compare with Figure 10-2B.

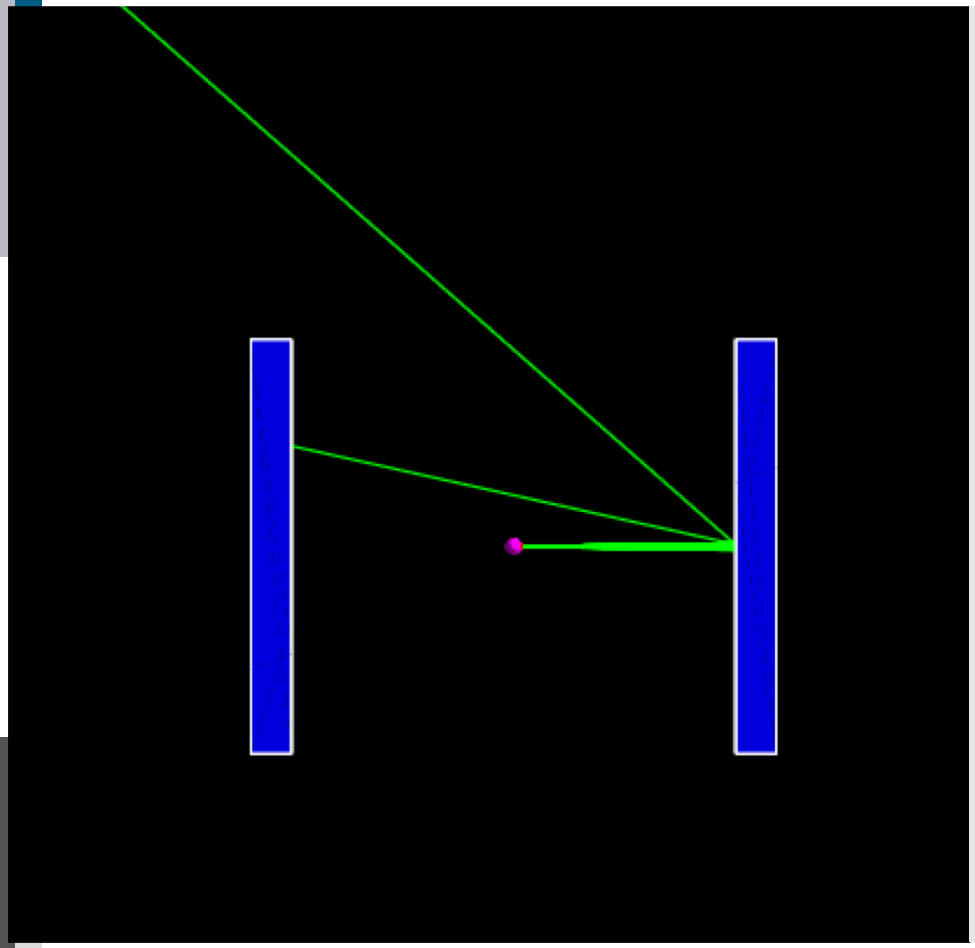
from: Cherry et al, 2012

Spectrometry_Gamma_Basic



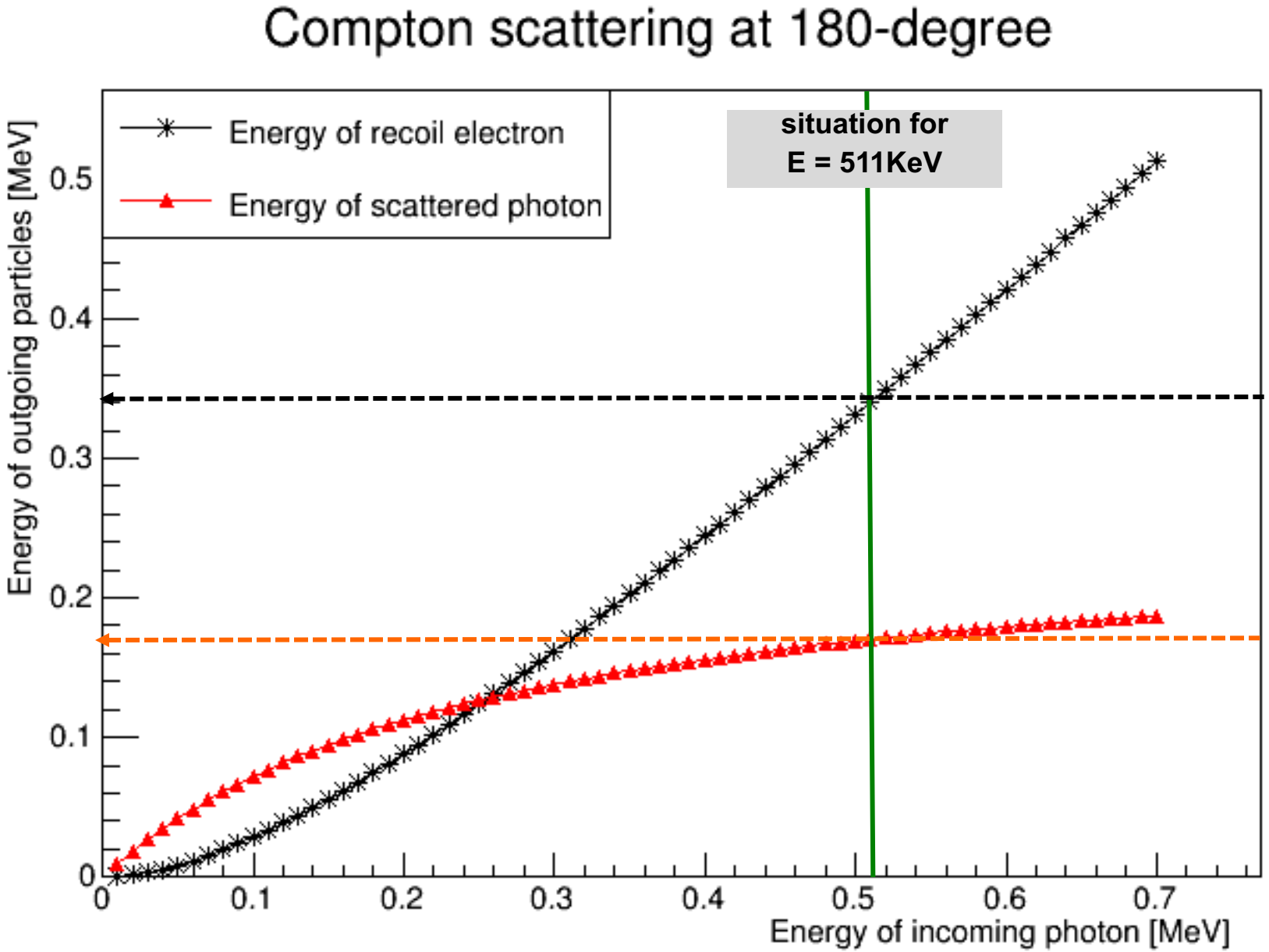


Basic Setup



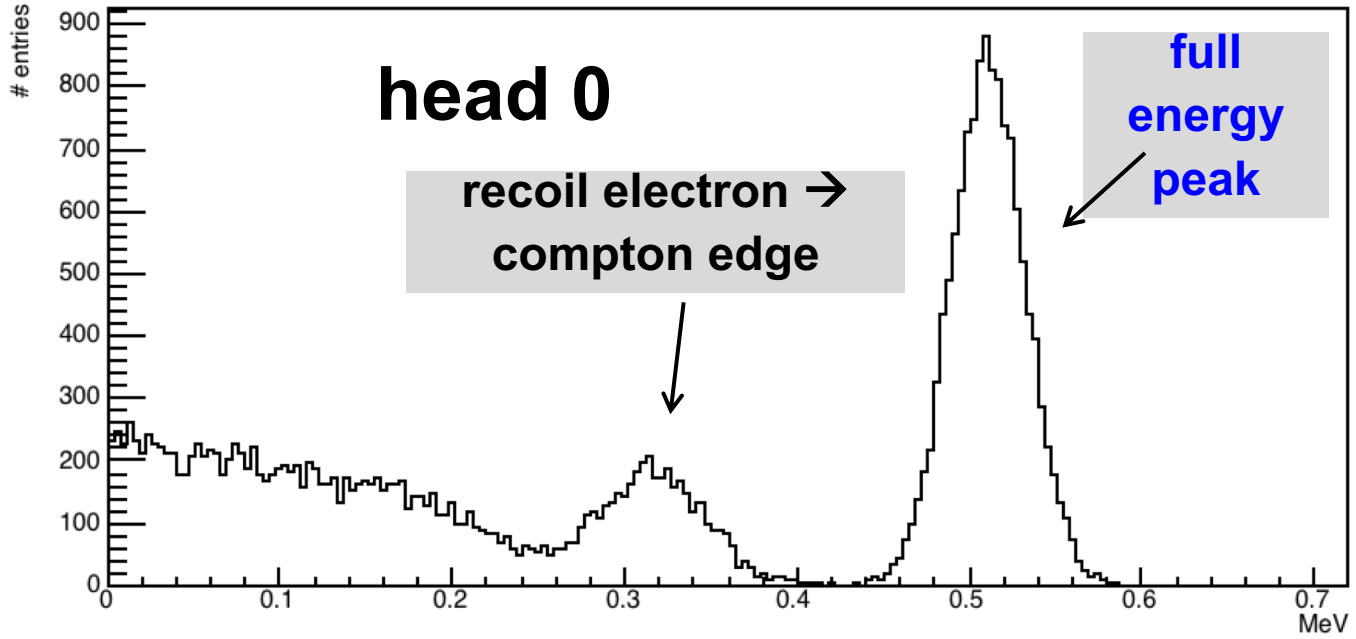
- Two opposing NaI-crystals allow to detect:
  - back-scattered gamma
  - characteristic X-ray, escaping from the crystal (head 0)

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

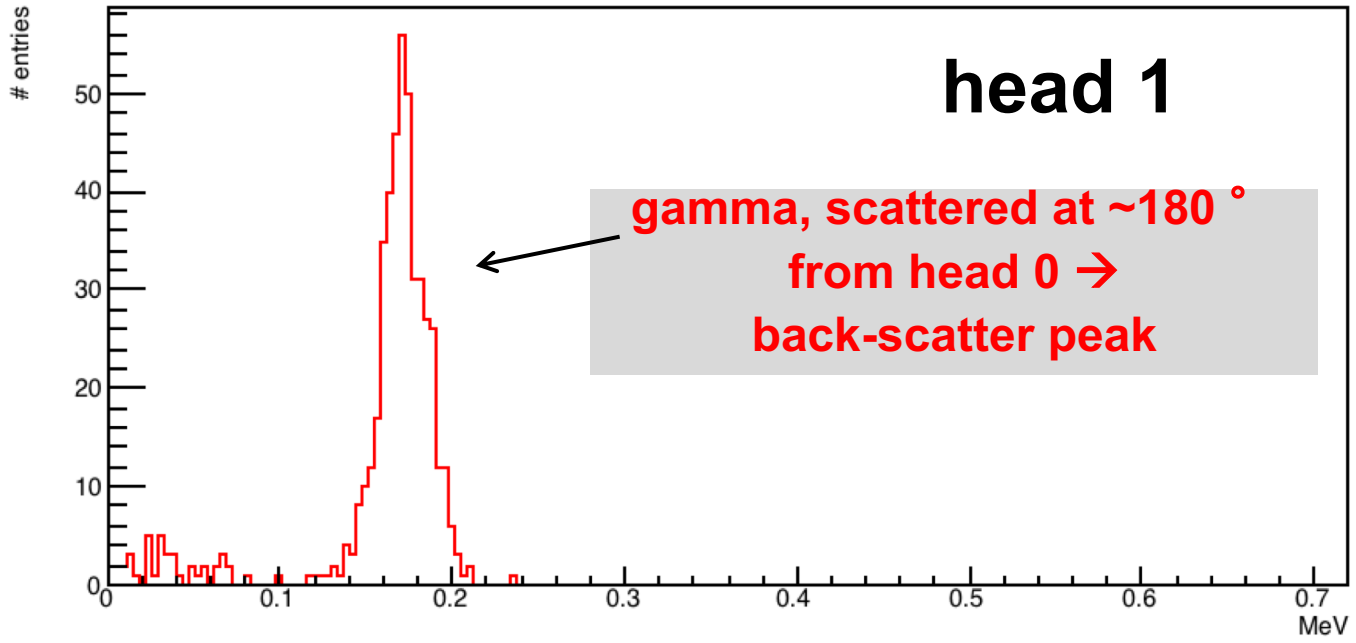


E_gamma: **0.510000** Emax_re: **0.339778** Emin_sc: **0.170222** (MeV)

511 keV



note: different scales!!



Pulse-height spectrum for ^{197}Hg

→

some more details!!

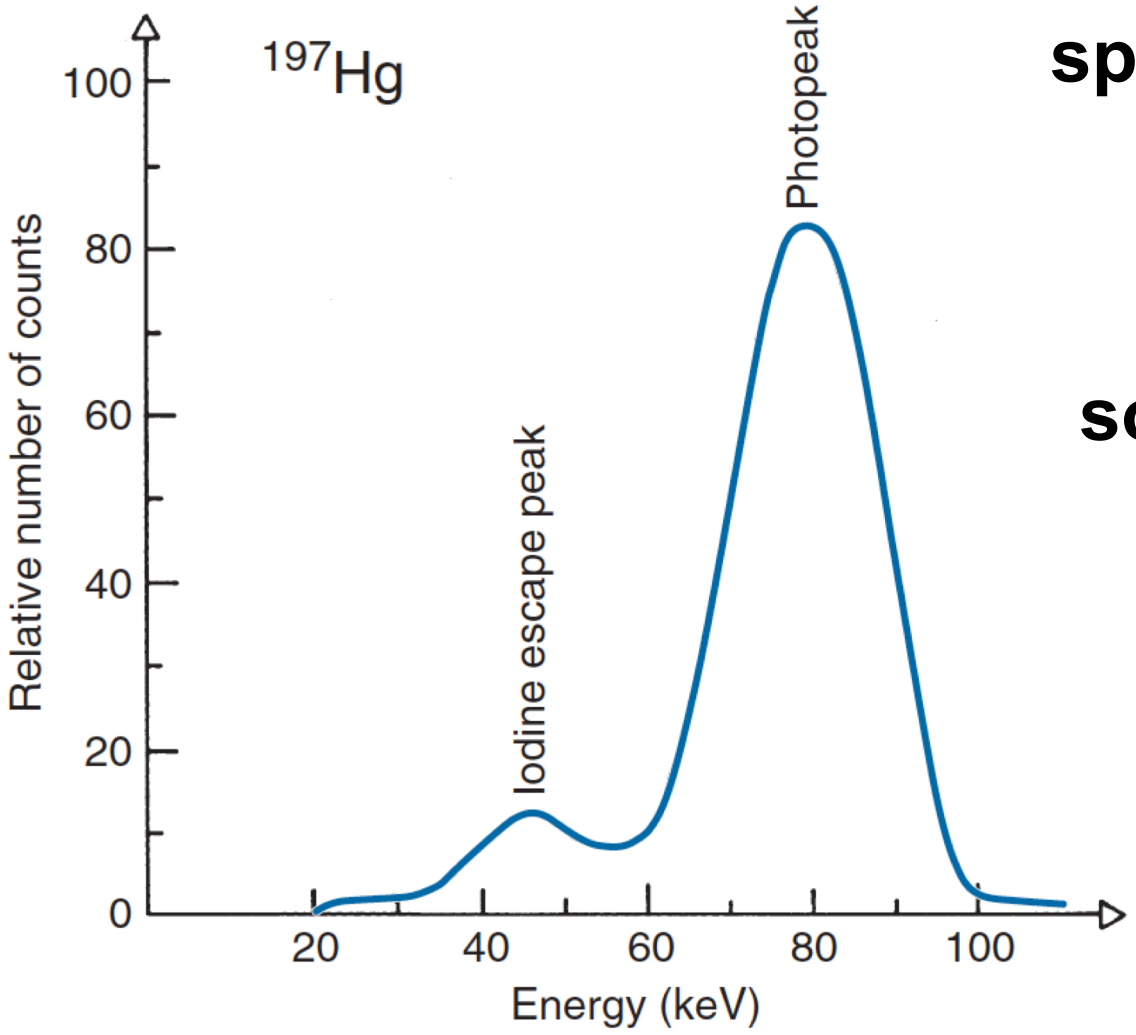
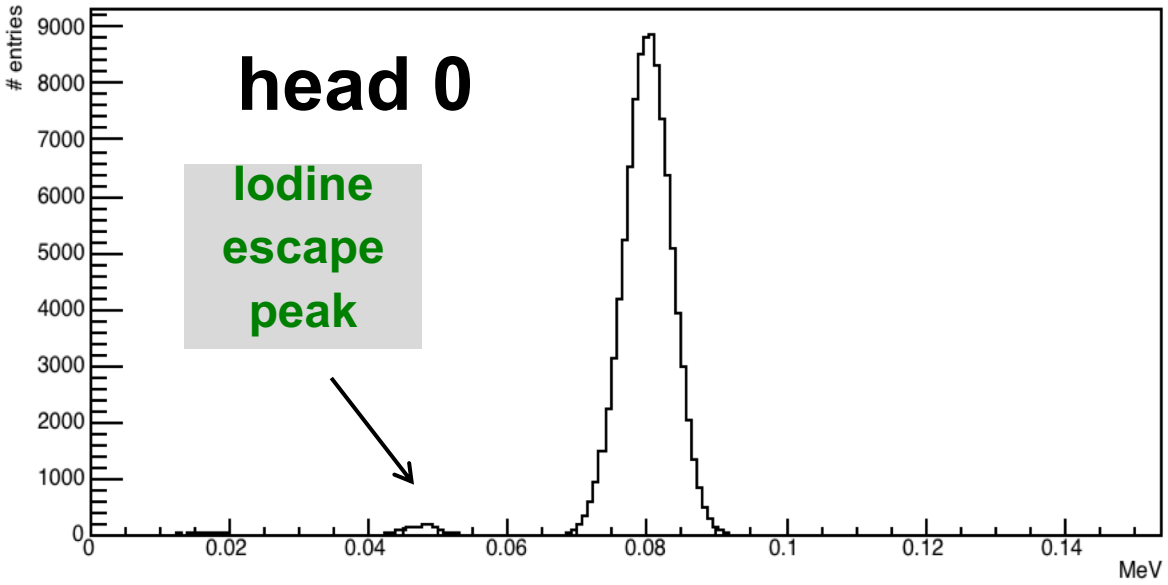


FIGURE 10-4 Pulse-height spectrum for ^{197}Hg (E_γ = 77.3 keV) recorded with NaI(Tl). Iodine escape peak (45-50 keV) is due to escape of characteristic iodine x ray (~30 keV) following a photoelectric absorption event in detector.

from: Cherry et al, 2012

80 keV



Iodine escape peak

note: different scales!!

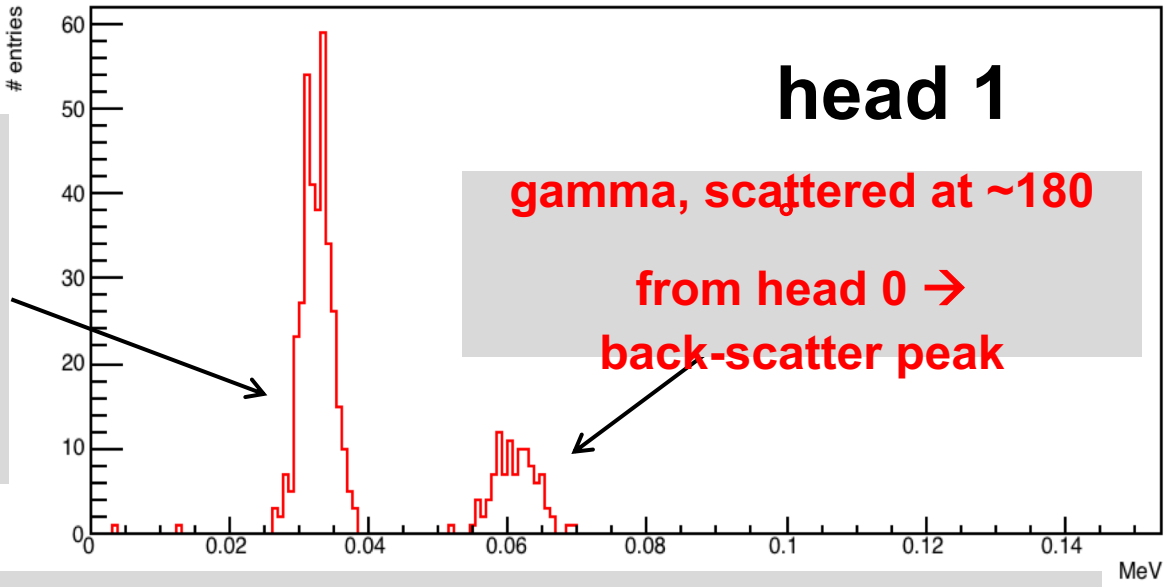
escape peak: $E_0 - E_{X\text{-rays}}$

Iodine (in NaI-crystal):

characteristic X-rays following

photoelectric

absorption

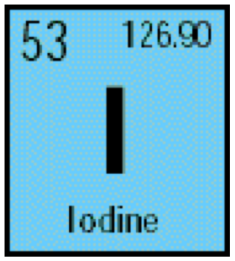


gamma, scattered at ~180

from head 0 →

back-scatter peak

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



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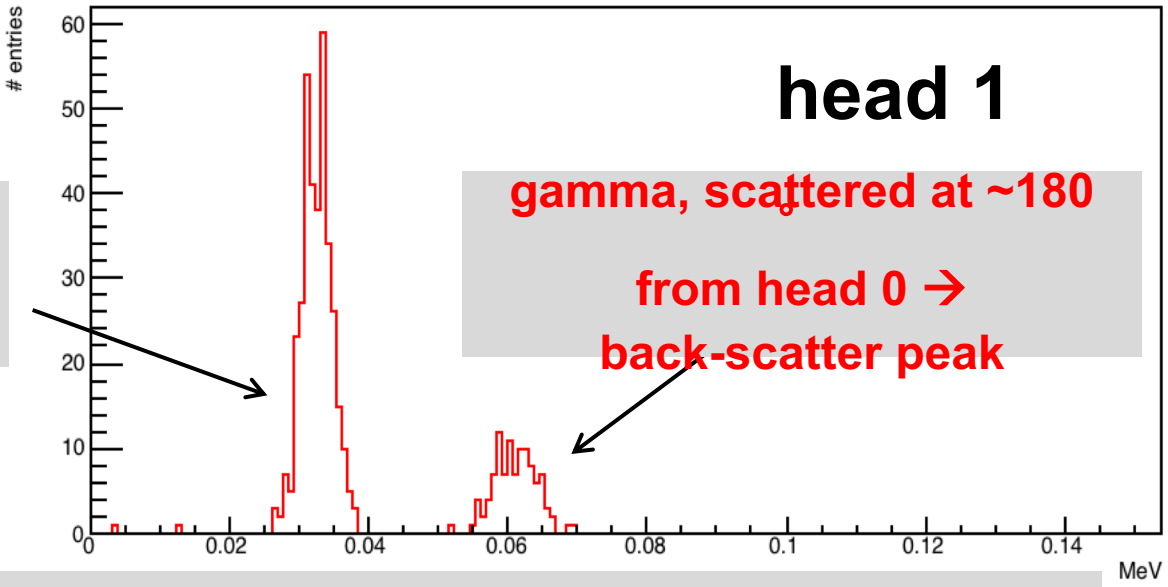
http://xdb.lbl.gov/Section1/Periodic_Table/I_Web_data.htm

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)

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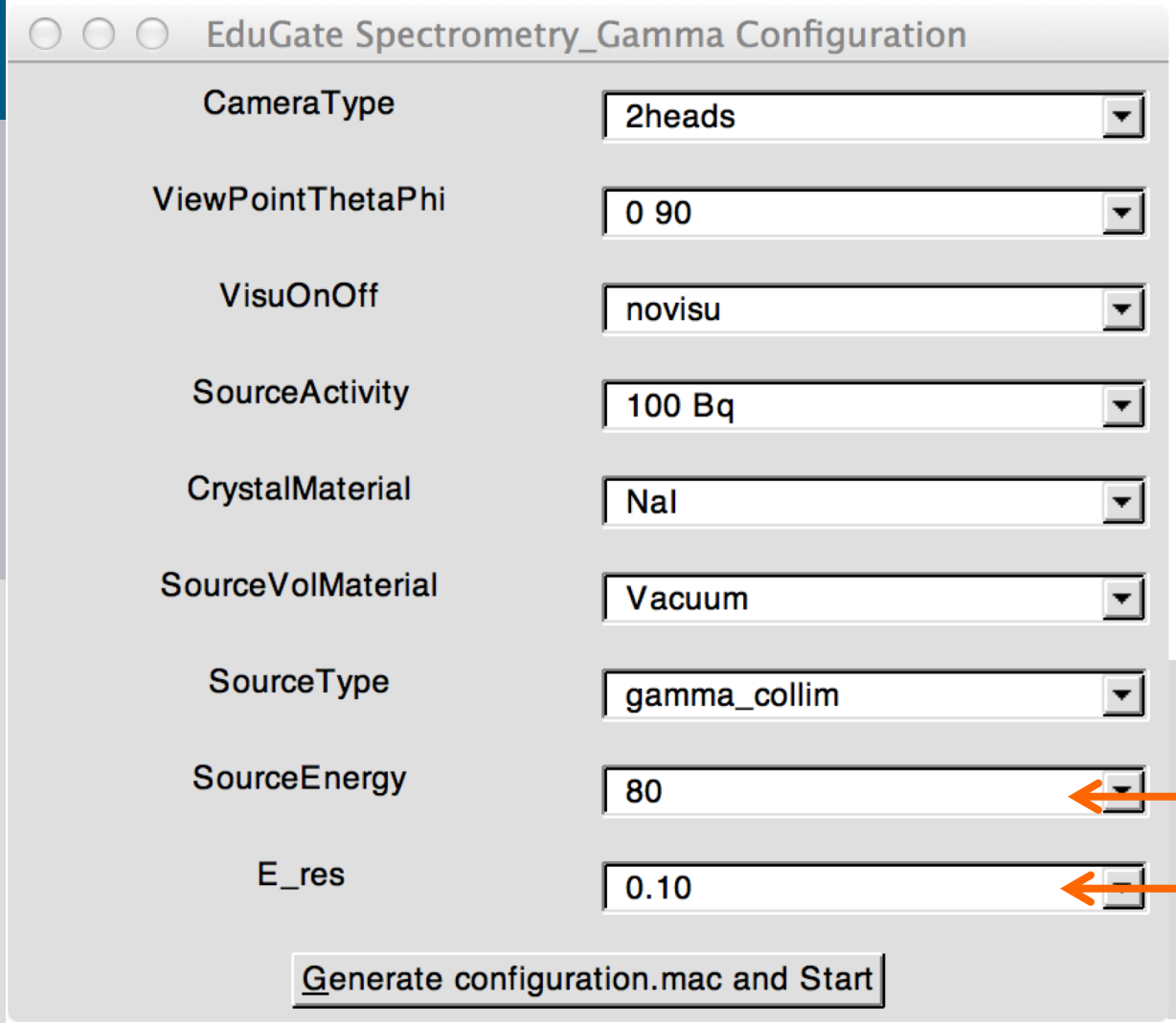
in a shell-window type:
config_starter_mac_70.sh



specify:

energy &

energy resolution

Starting Basic Setup (Gate_v7.0)

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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)

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