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Spectrometry_Gamma

A New Module For The

EduGATE Project

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(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 <u>Seneca</u> (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

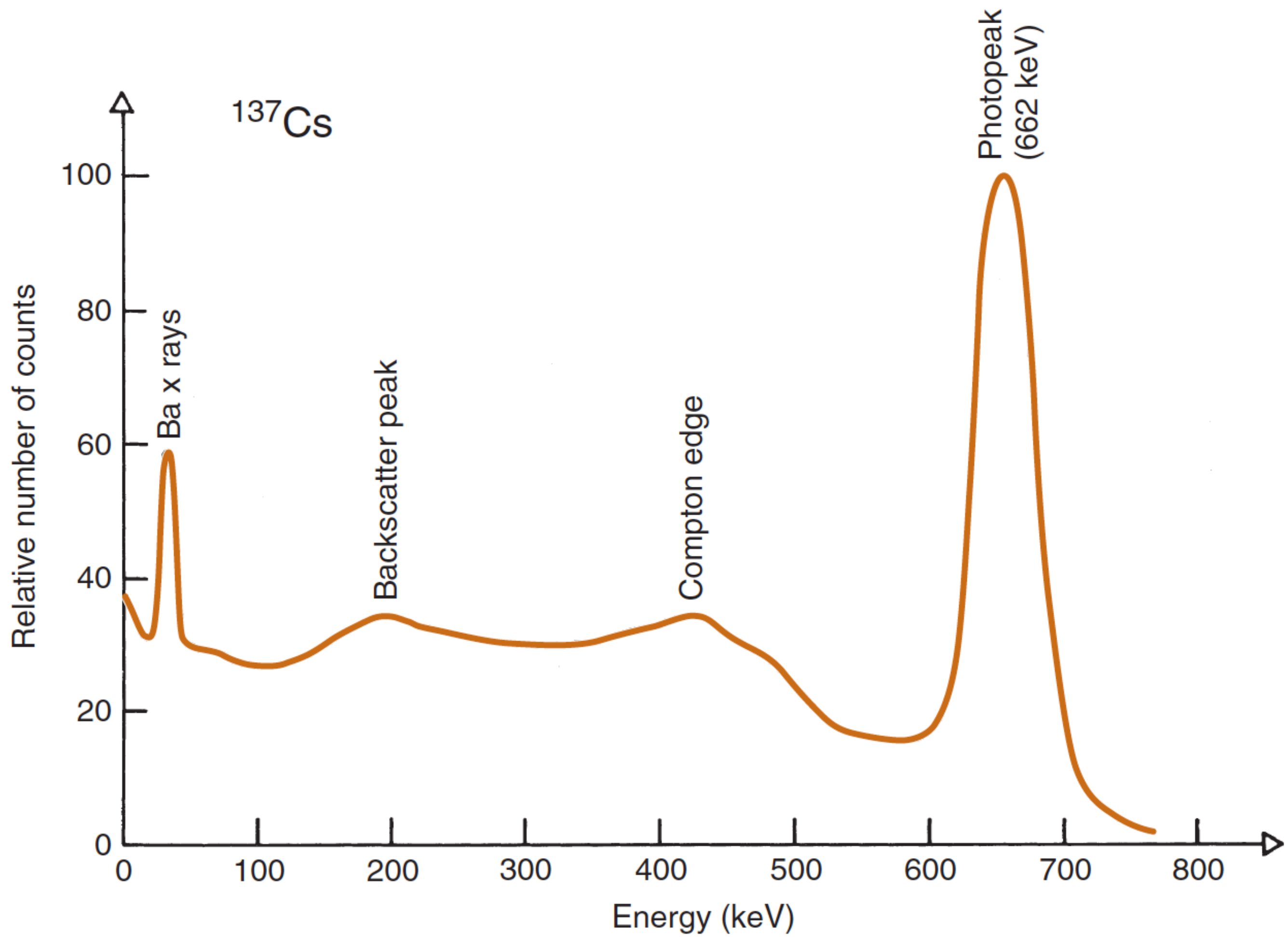
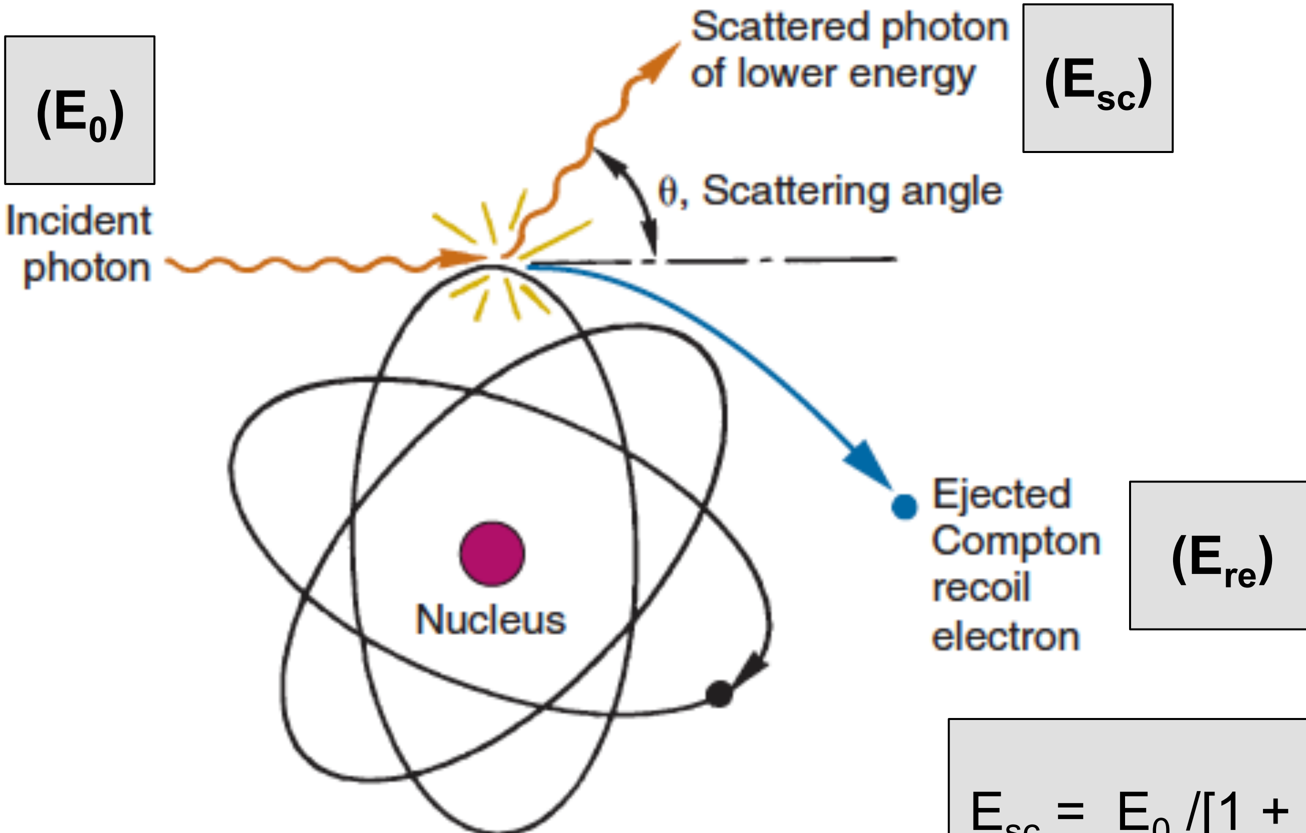


FIGURE 10-3 Actual pulse-height spectrum recorded with a NaI(Tl) detector and ^{137}Cs (662-keV γ rays, ~30 keV Ba x rays). Compare with Figure 10-2B.

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:

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

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

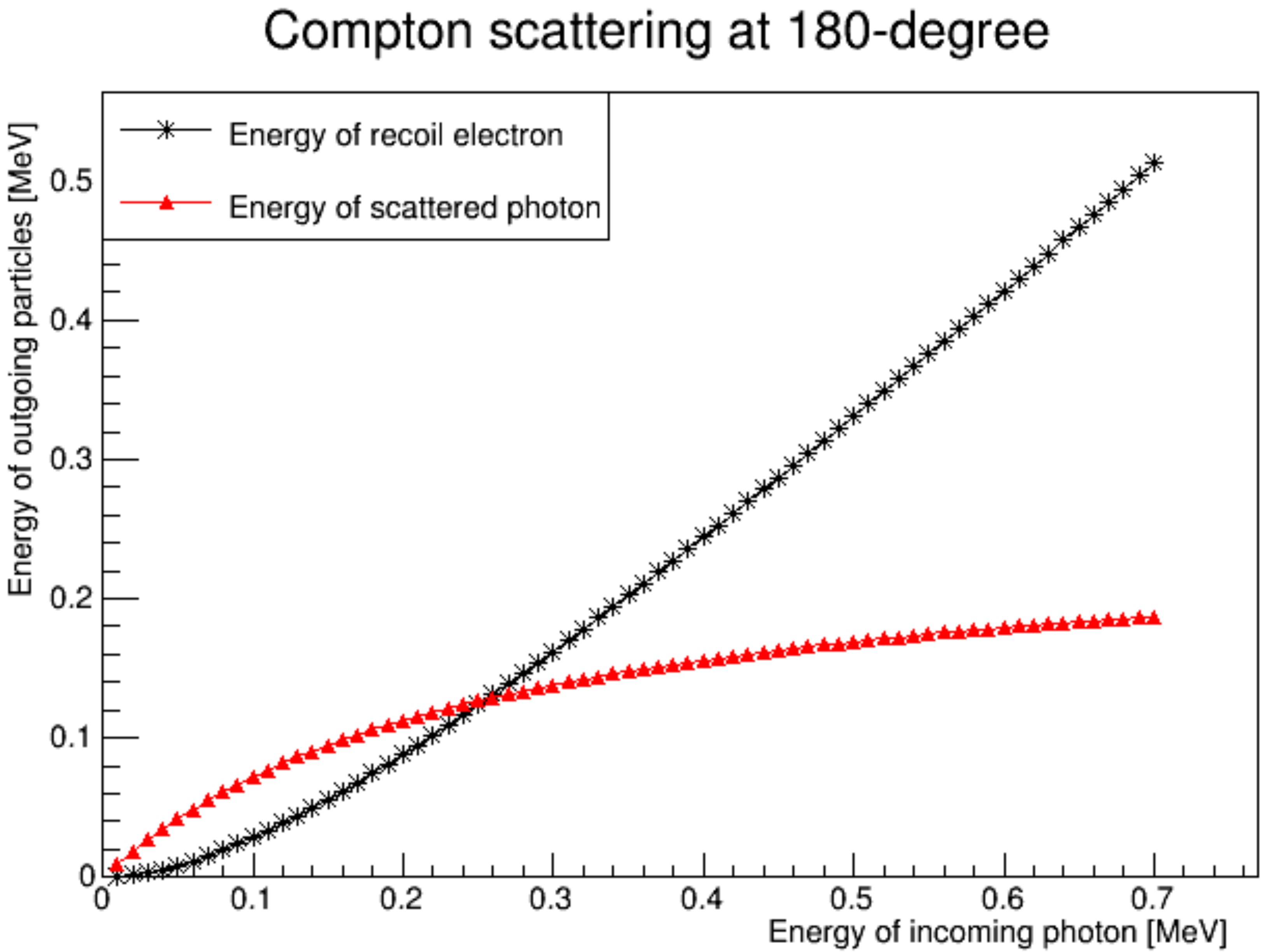
running: root -l compton_scatter_root.c

```
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]);

}
```

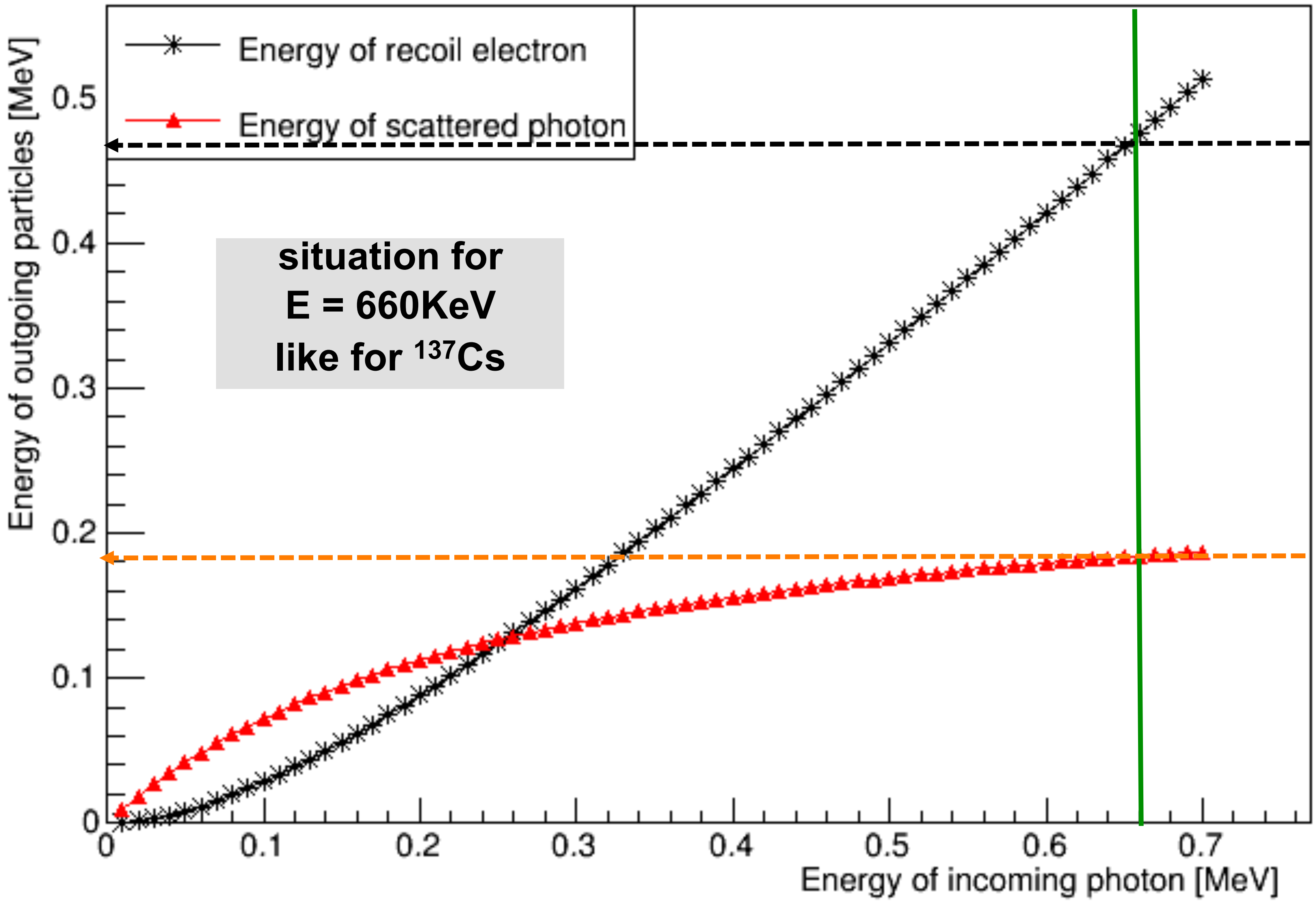
--> output

```
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



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

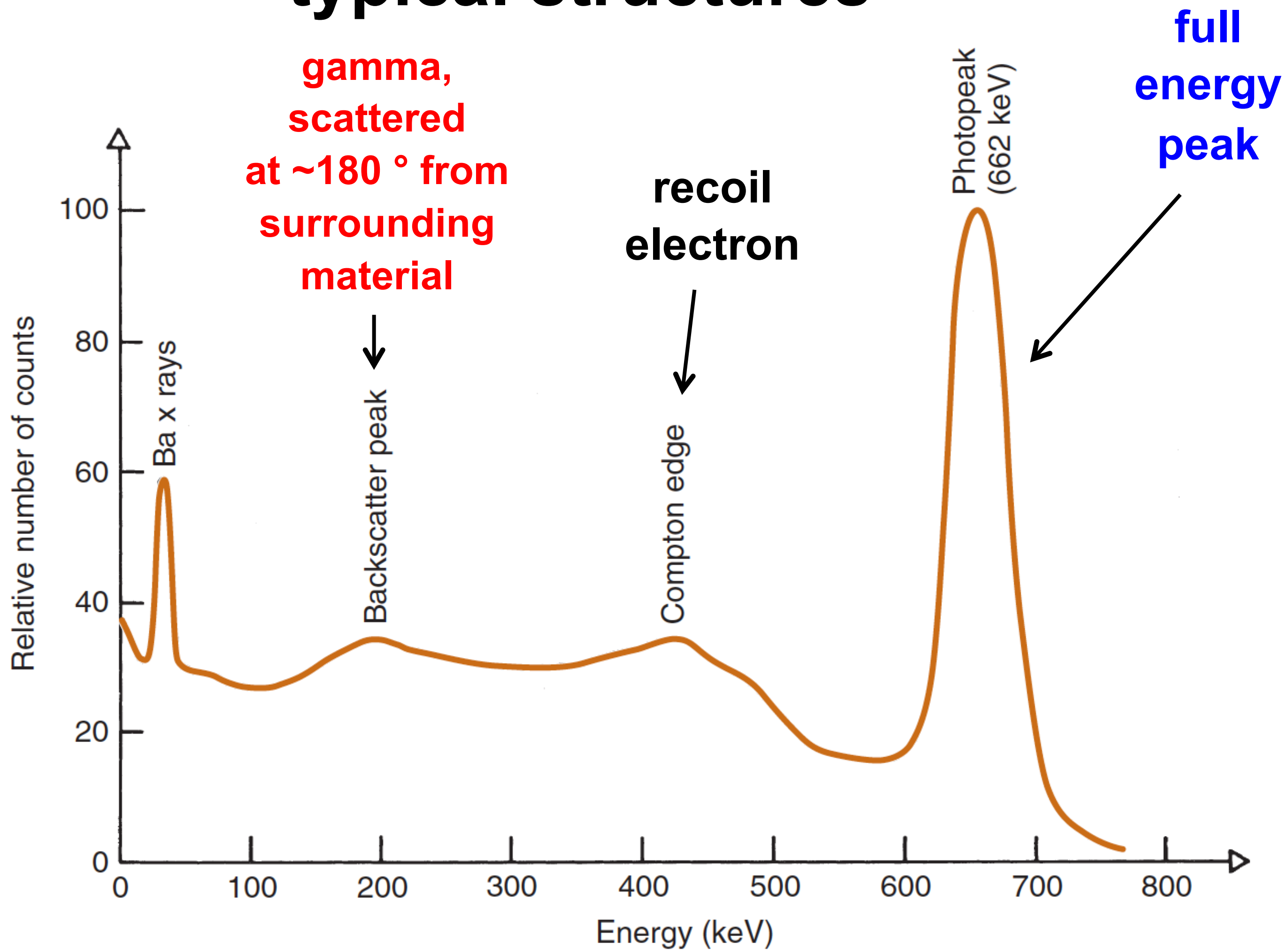
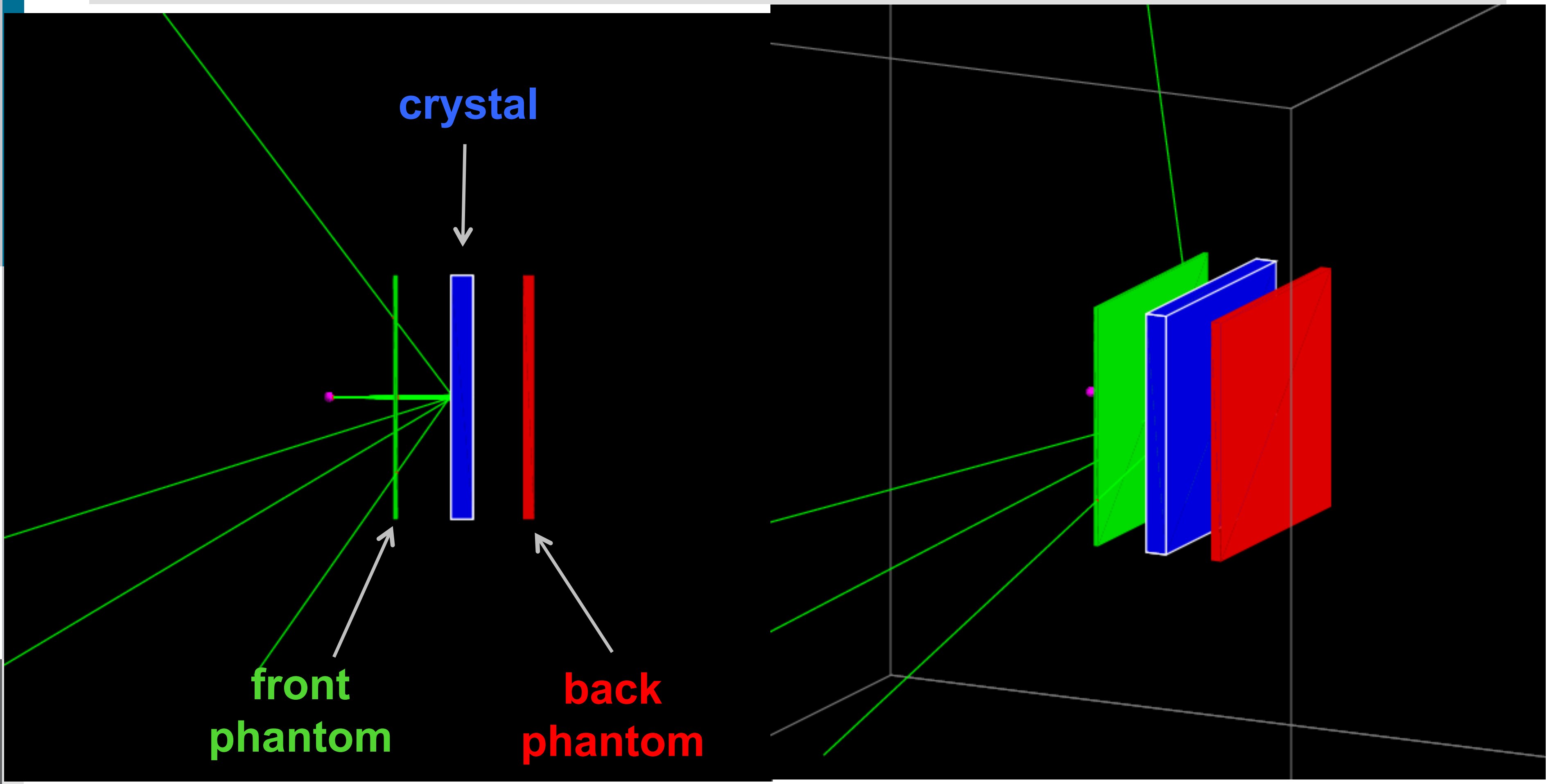


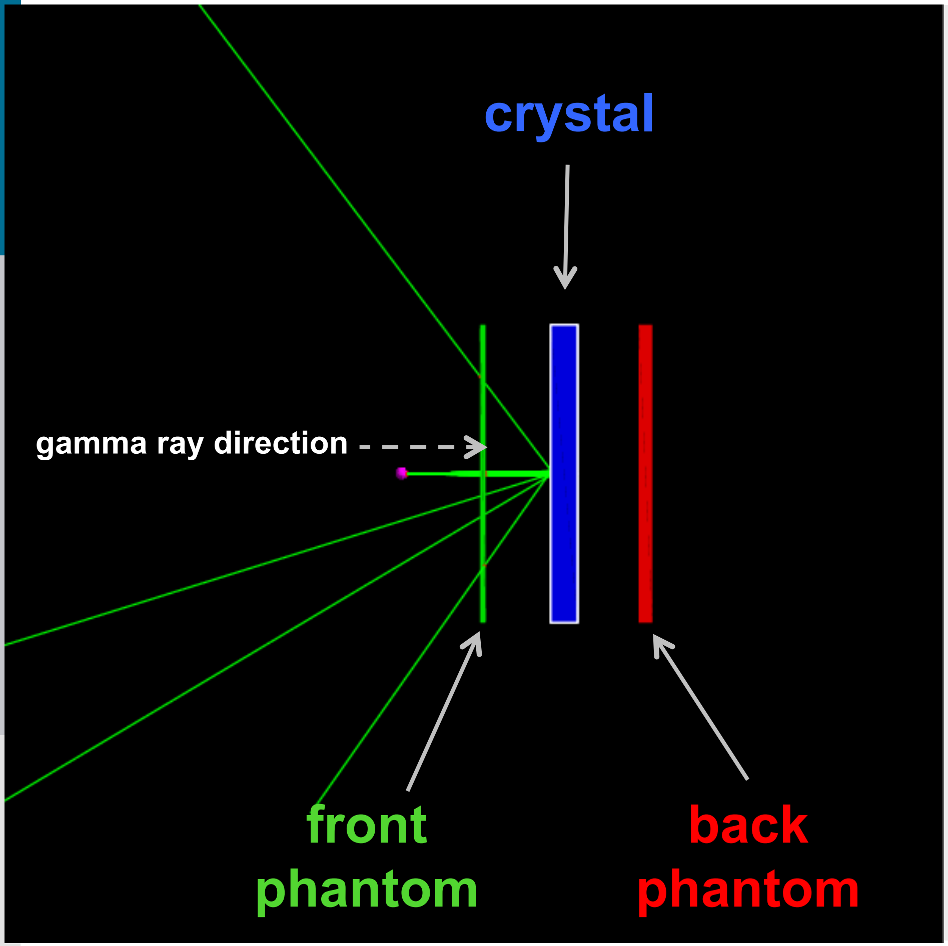
FIGURE 10-3 Actual pulse-height spectrum recorded with a NaI(Tl) detector and ^{137}Cs (662-keV γ rays, ~30 keV Ba x rays). Compare with Figure 10-2B.

from: Cherry et al, 2012

Spectrometry_Gamma_Extended



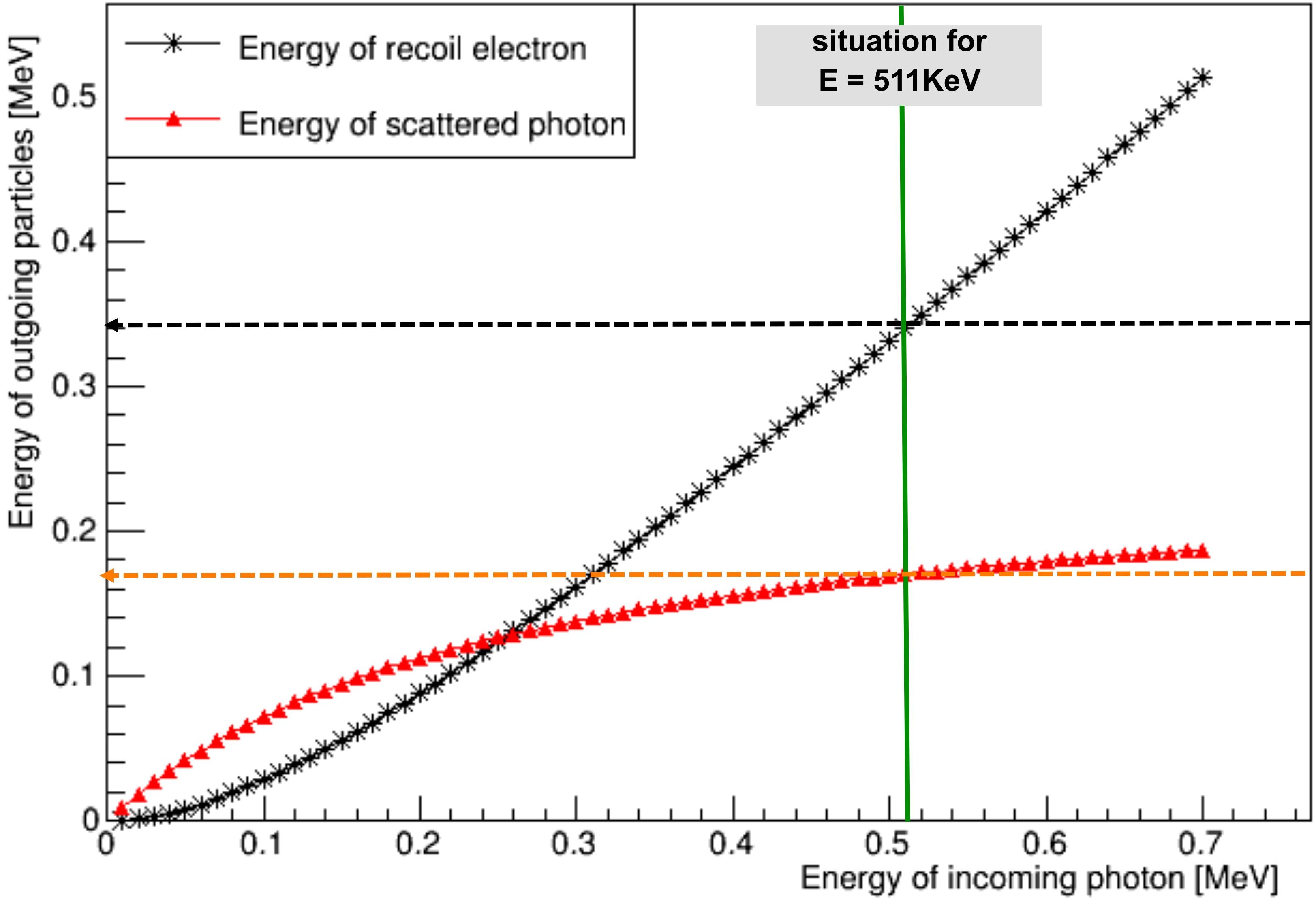
Extended Setup



- **Gamma Camera:**
- ***Phantom* in front to enforce scatter and to simulate effects of collimator material like characteristic X-rays**
- ***Phantom* in the back to enforce back-scatter**

Gamma Camera → 1 crystal, no collimator,
***collimated* gamma source (rays directed towards crystal)**
two phantoms (front & back)

Compton scattering at 180-degree



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

Starting Extended Setup (Gate_v7.0)

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in a shell-window type:
config_starter_mac_70.sh

EduGate Spectrometry_Gamma Configuration

ViewPointThetaPhi	0 90
VisuOnOff	novisu
SourceActivity	100 Bq
PhanThicknessFront	2. mm
PhantomMaterialFront	Vacuum
PhanThicknessBack	5. mm
PhantomMaterialBack	Lead
CrystalMaterial	NaI
SourceVolMaterial	Vacuum
SourceType	gamma_collim
SourceEnergy	662
E_res	0.10

Generate configuration.mac and Start

specify:

energy &

energy resolution

Starting Extended Setup (Gate_v7.0)

can change selection presets in Spectrometry_Gamma.txt

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;
PhanThicknessFront: 2. mm; 0.1 mm; 0.2 mm; 0.5 mm; 1. mm; 5. mm; 10. mm; 20. mm; 30. mm;
PhantomMaterialFront: Vacuum; Water; Plexiglass; Air; Lead; Copper; Tungsten; Iodine;
PhanThicknessBack: 5. mm; 0.1 mm; 0.2 mm; 0.5 mm; 1. mm; 2. mm; 10. mm; 20. mm; 30. mm;
PhantomMaterialBack: Lead; Vacuum; Water; Plexiglass; Air; Copper; Tungsten; Iodine;
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; 662; 1000; 1600;
E_res: 0.10; 0.00; 0.01; 0.05; 0.15; 0.20; 0.25;

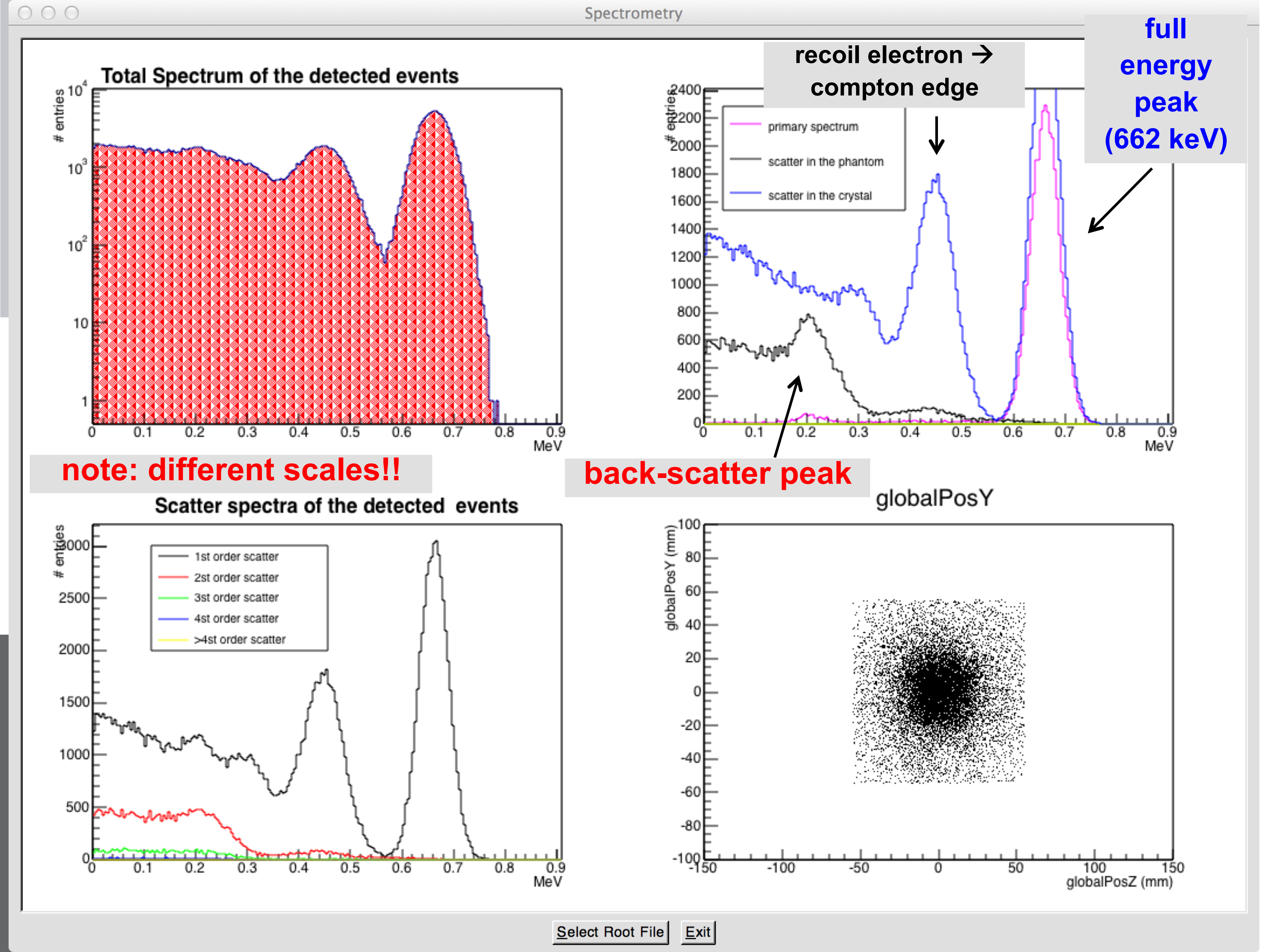
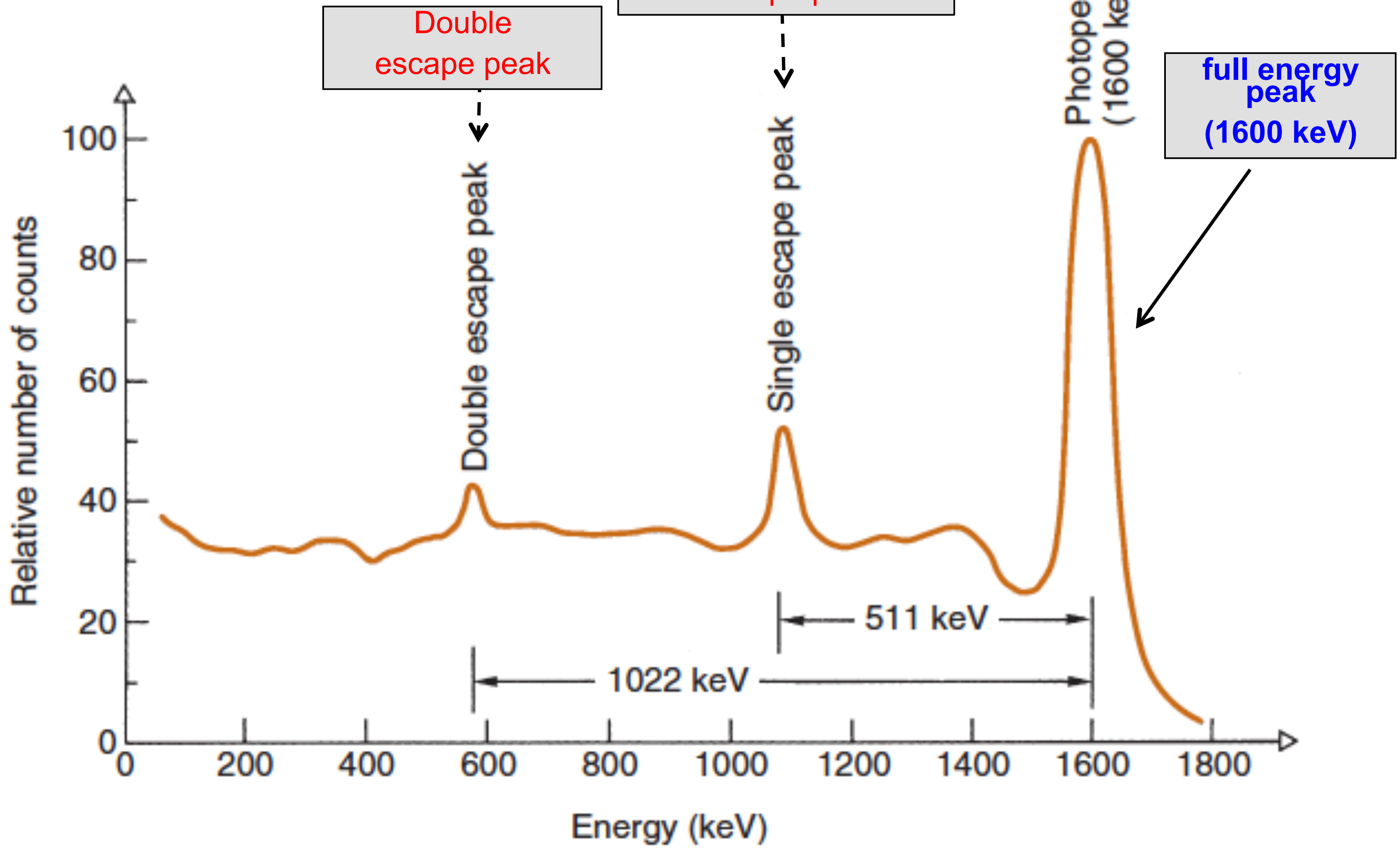
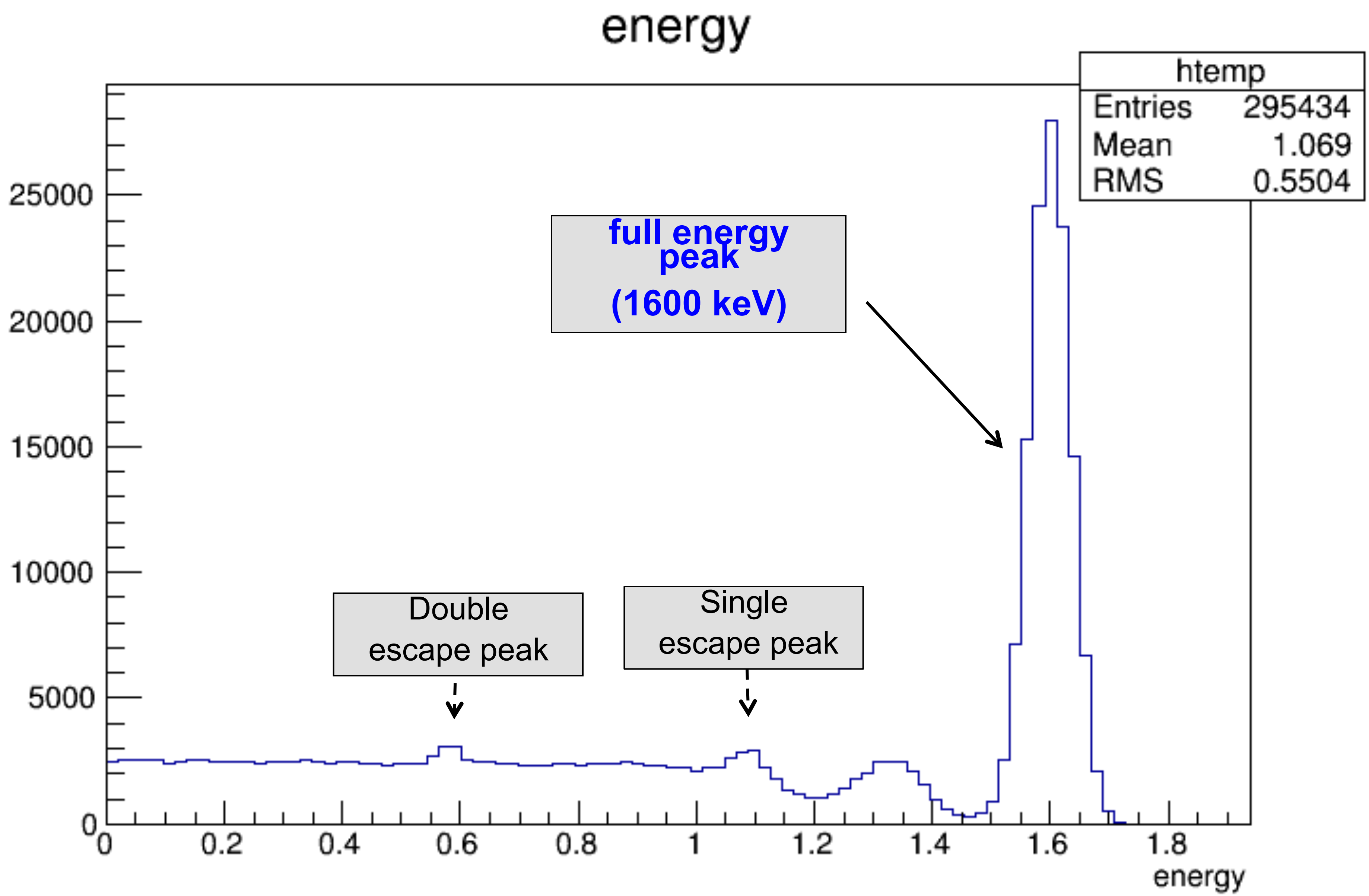

Spectrometry
Total Spectrum of the detected events
entries
MeV
recoil electron → compton edge
full energy peak (662 keV)
primary spectrum
scatter in the phantom
scatter in the crystal
note: different scales!!
back-scatter peak
Scatter spectra of the detected events
1st order scatter
2st order scatter
3st order scatter
4st order scatter
>4st order scatter
globalPosY
globalPosY (mm)
globalPosZ (mm)
Select Root File
Exit

Fig 10.5 from Cherry et al, 2012



The high energy of the incident photon (1600 keV) allows the production of **e^+-e^-** -pairs. Subsequently, the positron annihilates with an electron to produce two annihilation photons of 511 keV each. If one or both annihilation photons escape, this gives rise for the escape peaks.


energy
htemp
Entries 295434
Mean 1.069
RMS 0.5504
full energy peak
(1600 keV)
Double escape peak
Single escape peak
25000
20000
15000
10000
5000
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
energy