# CUSP Geant4 Toy Model n.2

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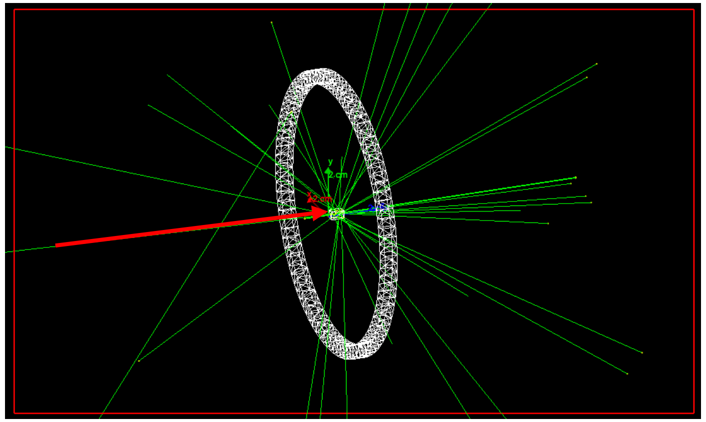
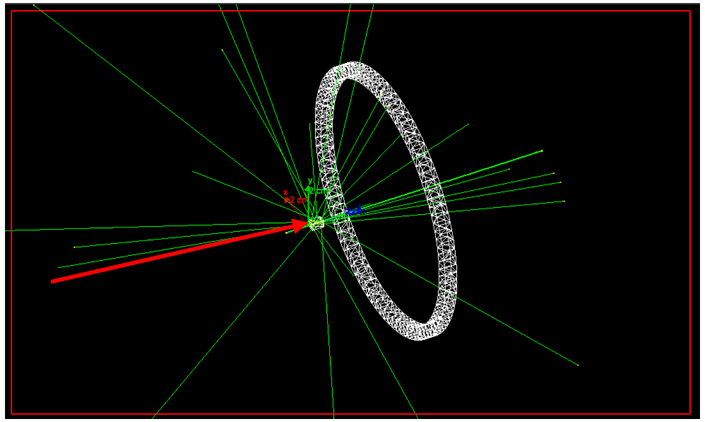
# Three toy model set-ups

- **Scatterer**: cube 5 mm of side made of G4_PLASTIC_SC_VINYLTOLUENE (C and H)
- **Absorber**: ring with squared size 5 mm of side made of GAGG. Internal radius 50mm, external radius 55mm.

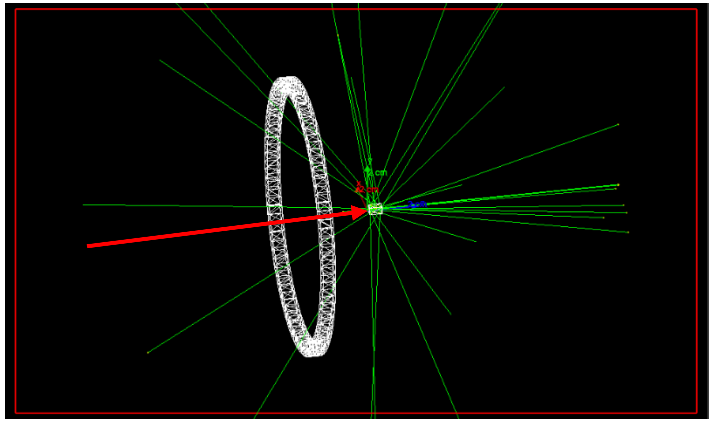
- v1
- 90° scattering



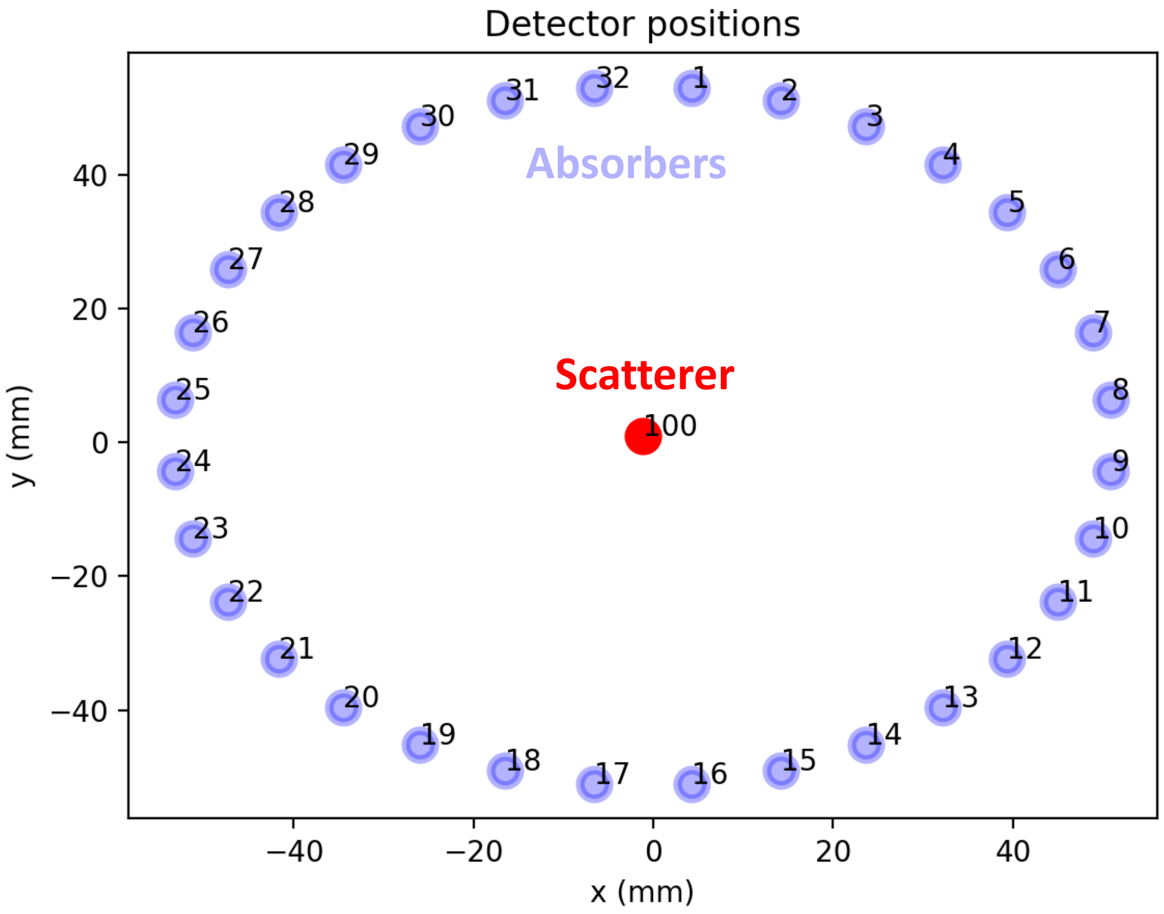
- v2
- forward scattering



- V3
- backward scattering



# Element positions and label



Emission energies

***Table 1-2.*** *Energies of x-ray emission lines (continued).*

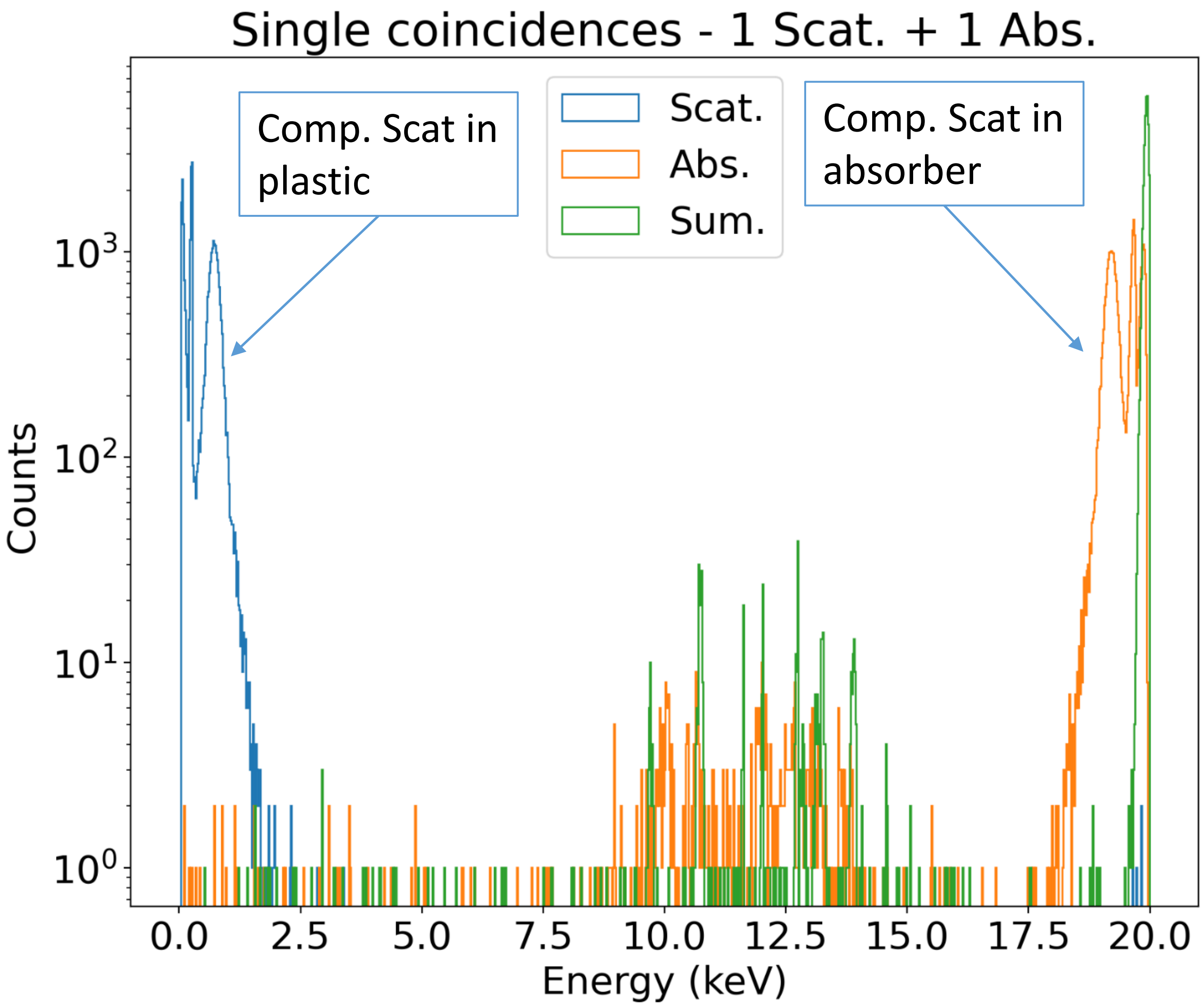
| Element | $K\alpha_1$ | $K\alpha_2$ | $K\beta_1$ | $L\alpha_1$ | $L\alpha_2$ | $L\beta_1$ | $L\beta_2$ | $L\gamma_1$ | $M\alpha_1$ |
|---|---|---|---|---|---|---|---|---|---|
| 6 C | 277 | | | | | | | | |
| 8 O | 524.9 | | | | | | | | |
| 13 Al | 1,486.70 | 1,486.27 | 1,557.45 | | | | | | |
| 31 Ga | 9,251.74 | 9,224.82 | 10,264.2 | 1,097.92 | 1,097.92 | 1,124.8 | | | |
| 58 Ce | 34,719.7 | 34,278.9 | 39,257.3 | 4,840.2 | 4,823.0 | 5,262.2 | 5,613.4 | 6,052 | 883 |
| 64 Gd | 42,996.2 | 42,308.9 | 48,697 | 6,057.2 | 6,025.0 | 6,713.2 | 7,102.8 | 7,785.8 | 1,185 |

Electron binding energies

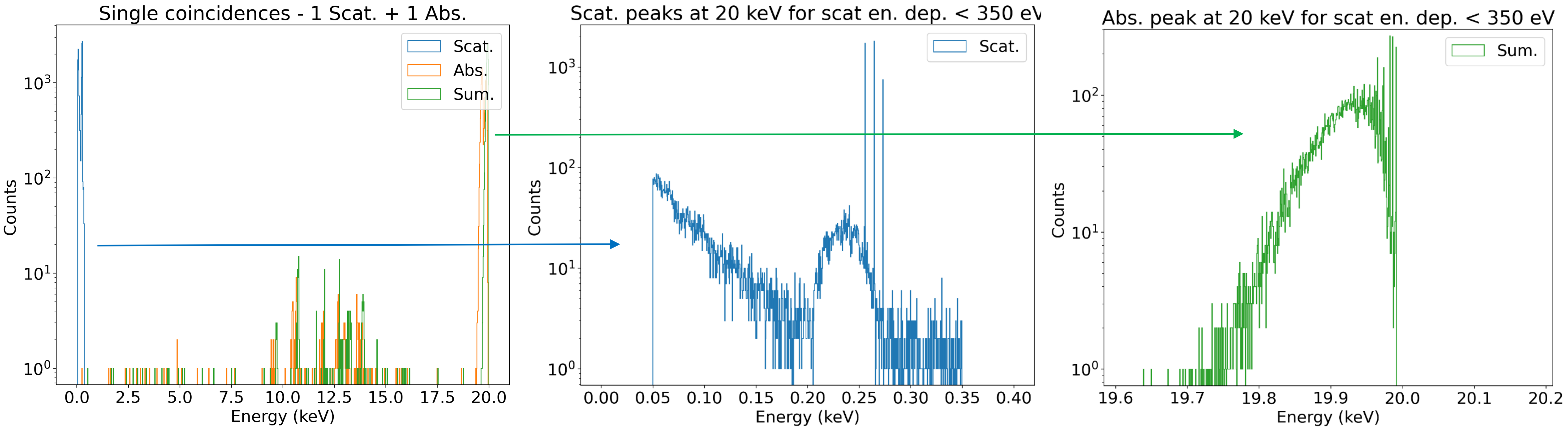
***Table 1-1.*** *Electron binding energies, in electron volts,*

| Element | K 1s | $L_1$ 2s | $L_2$ $2p_{1/2}$ | $L_3$ $2p_{3/2}$ | $M_1$ 3s | $M_2$ $3p_{1/2}$ | $M_3$ $3p_{3/2}$ | $M_4$ $3d_{3/2}$ | $M_5$ $3d_{5/2}$ | $N_1$ 4s | $N_2$ $4p_{1/2}$ | $N_3$ $4p_{3/2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H | 13.6 | | | | | | | | | | | |
| 6 C | 284.2* | | | | | | | | | | | |
| 8 O | 543.1* | 41.6* | | | | | | | | | | |
| 31 Ga | 10367 | 1299.0*b | 1143.2† | 1116.4† | 159.5† | 103.5† | 100.0† | 18.7† | 18.7† | | | |
| 58 Ce | 40443 | 6549 | 6164 | 5723 | 1436*b | 1274*b | 1187*b | 902.4* | 883.8* | 291.0* | 223.2 | 206.5* |
| 64 Gd | 50239 | 8376 | 7930 | 7243 | 1881 | 1688 | 1544 | 1221.9* | 1189.6* | 378.6* | 286 | 271 |

# V1, 20 kev, polarized

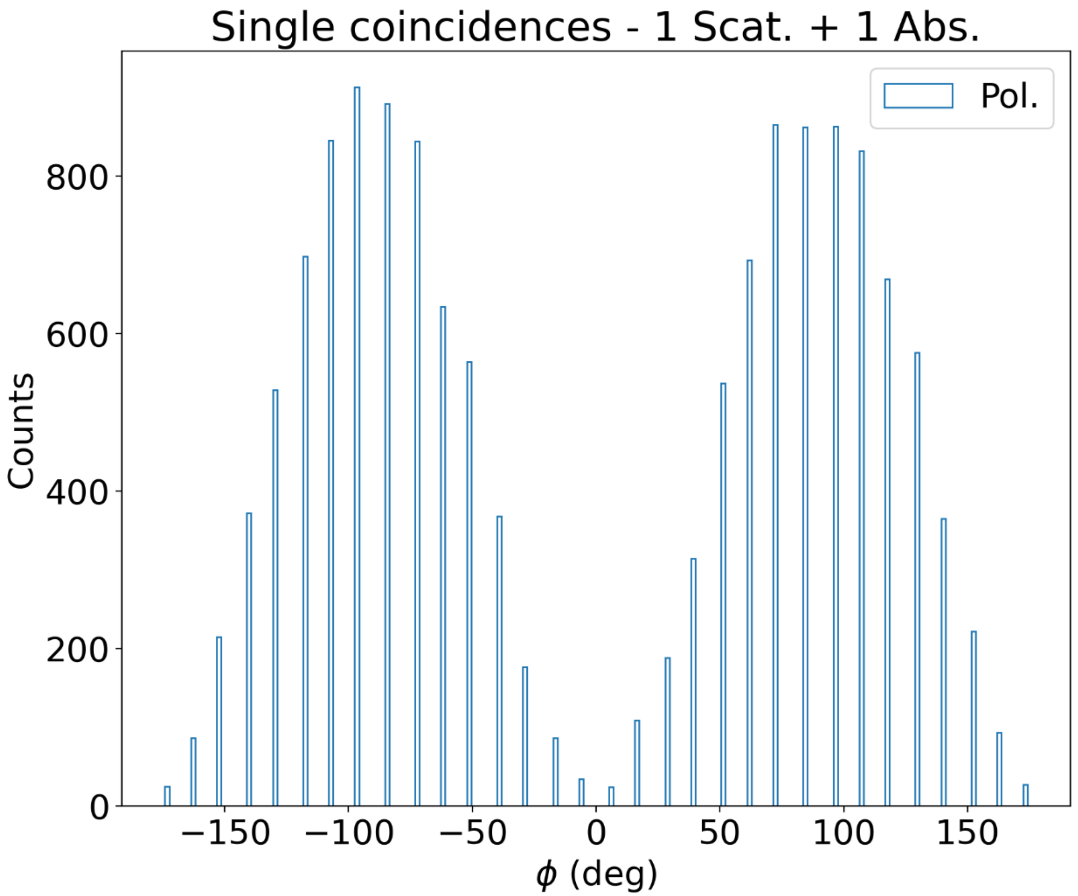


# V1, 20 kev, polarized

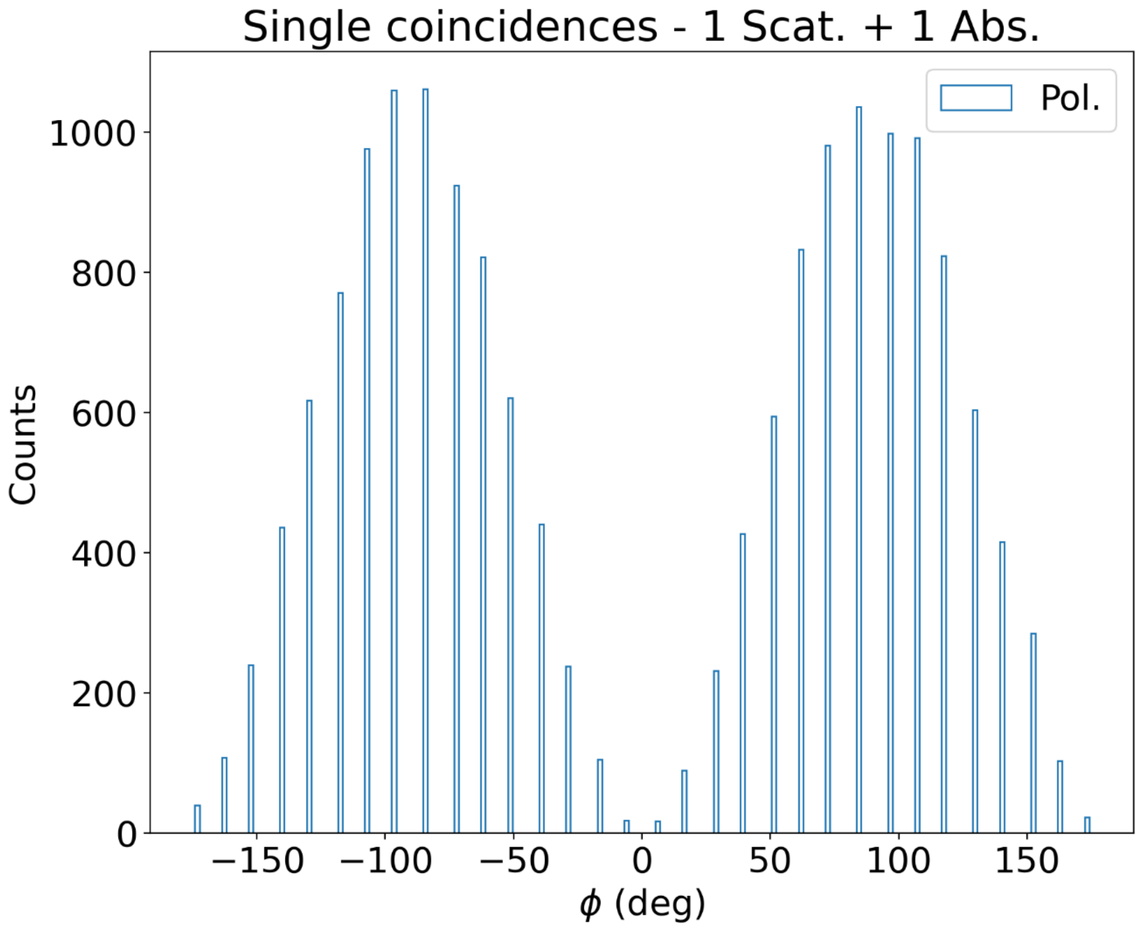



- Energy deposit of coincidence events in scatterer (blue) below 350 eV, absorber (orange) and the **sum of the energy deposits in scatterers and absorbers (green)**
- Blue histogram: monocromatic energy deposits in the scatterer at 273 eV, 265 eV and 256 eV, plus wide peak at about 238 eV, plus continuum
- Green histogram is not a line a 20 keV for energy deposits in scatterer lower than 350 eV, but a continuum. There is an energy loss of the events that is not recorded nor in the scatterer nor in the absorber (except few cases of escape and fluorescences in the absorber)

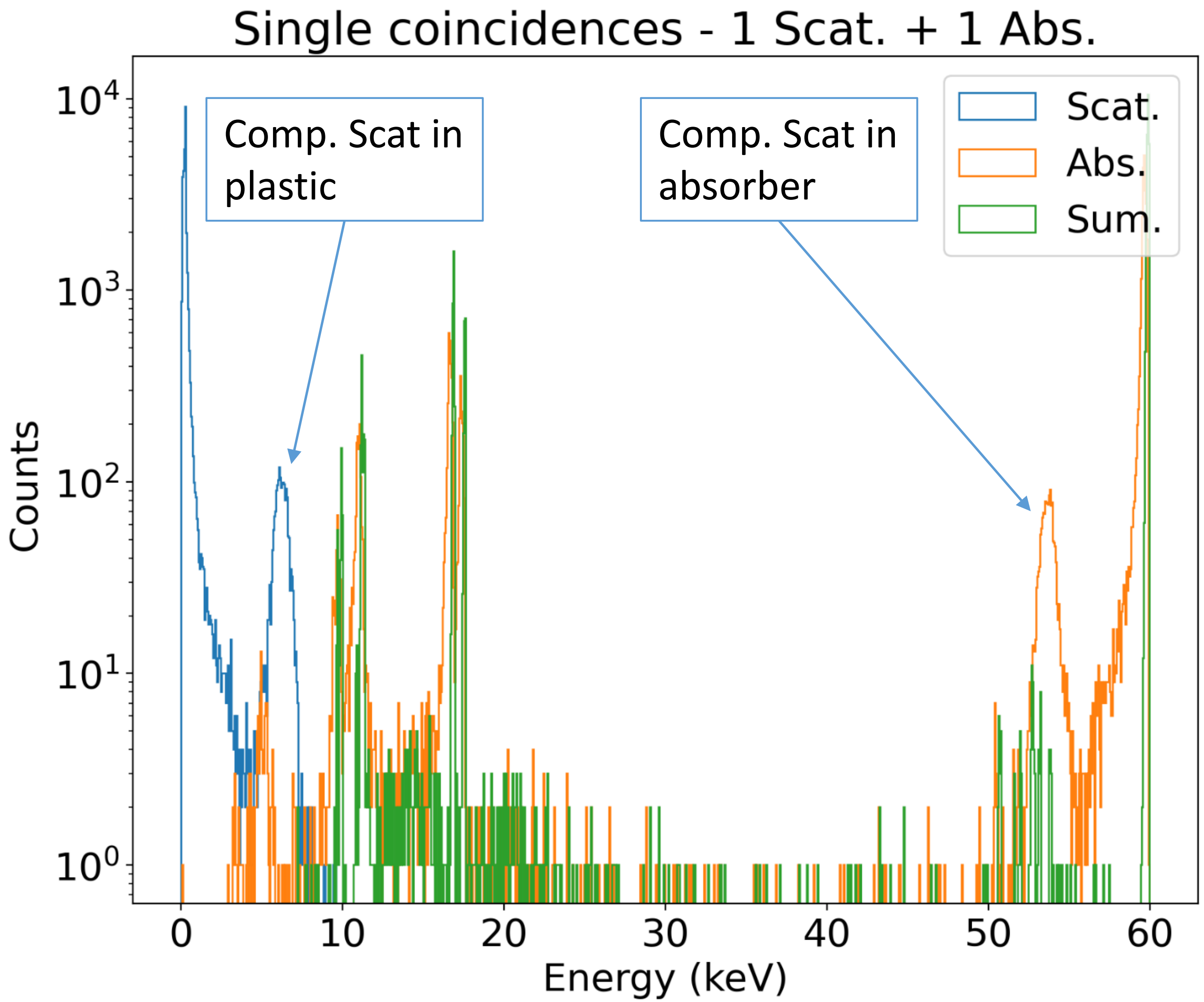
Modulation curve coinc. Less than 350 eV in scatterer



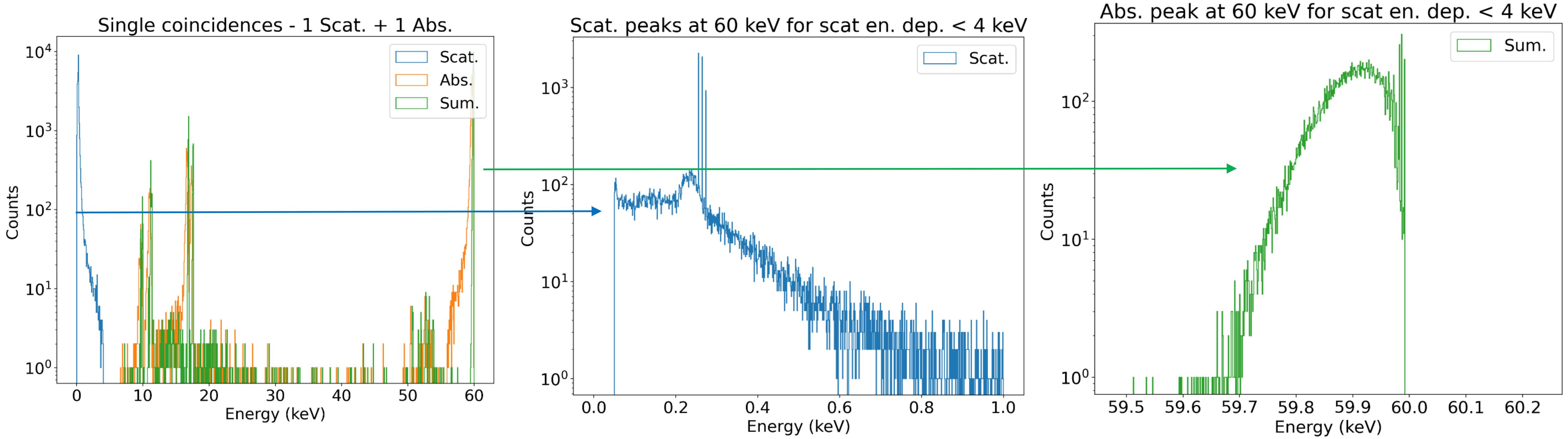

Modulation curve coinc. more than 350 eV in scatterer (good Compton scattering)



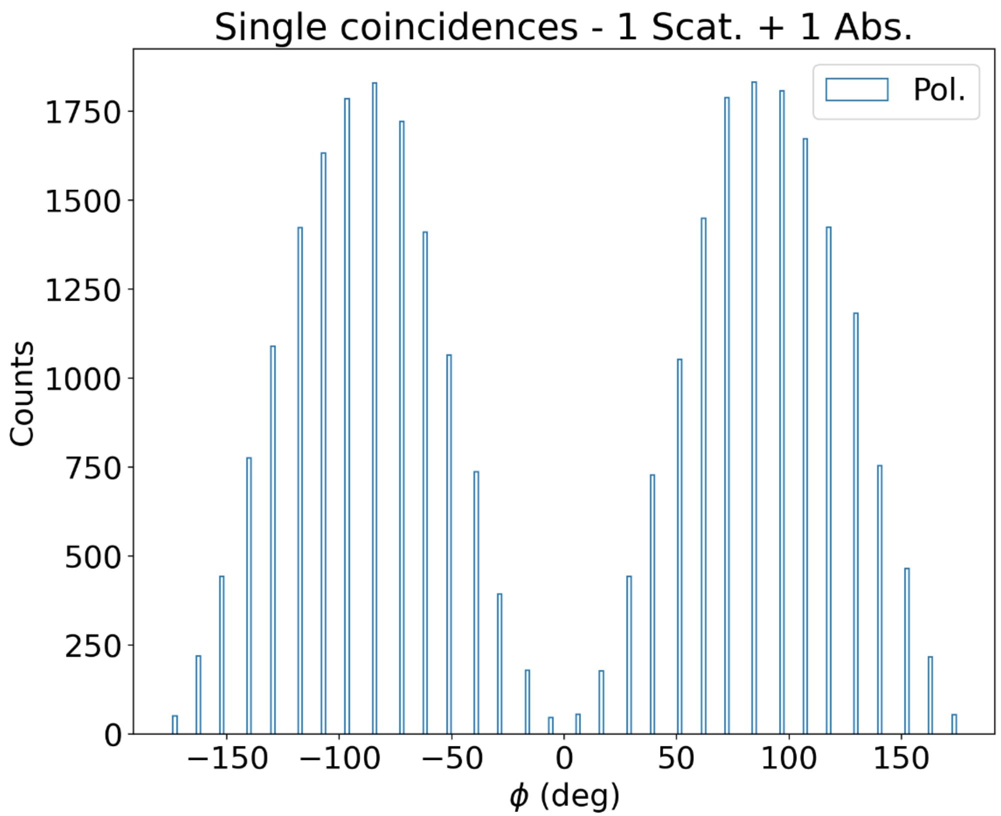
# V1, 60 keV, polarized



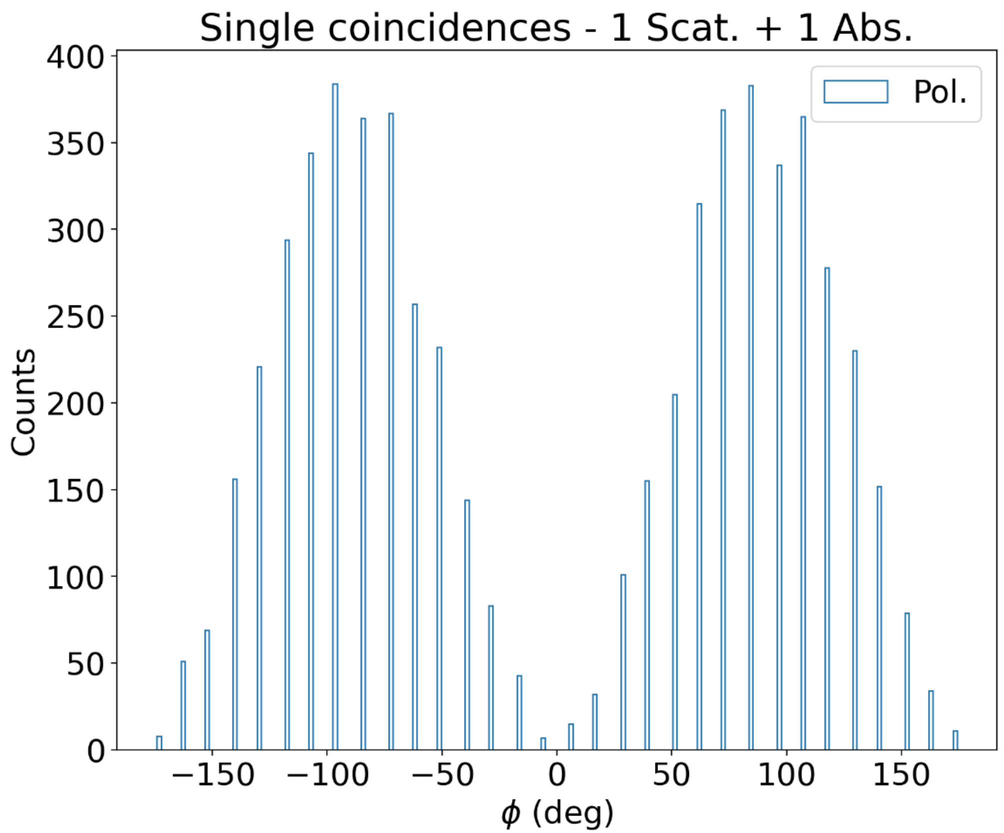
# V1, 60 kev, polarized



Modulation curve coinc. Less than 4 keV in scatterer




Modulation curve coinc. more than 4 keV in scatterer (good Compton scattering)

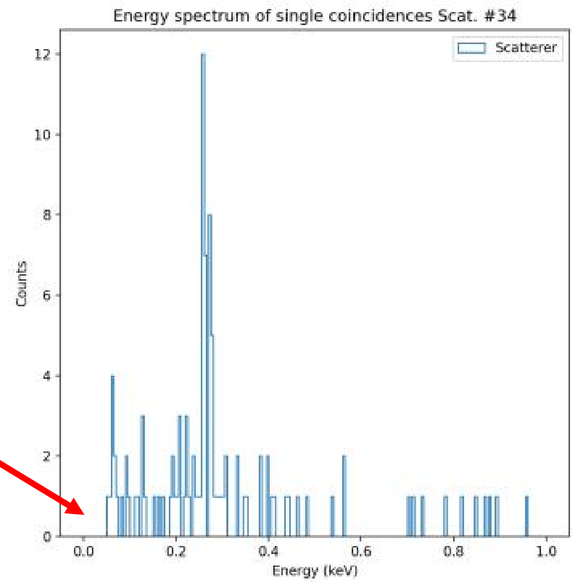


- It seems we lose some energy at least for events with very low amplitide in the scatterer.
- Which thressold de we apply? What do they do?

**1) SensitiveDetector.cc**

```
// Retrieve the energy deposited from the step
 G4double energyDeposit = step -> GetTotalEnergyDeposit();
G4double energy_threshold = 0.05 * keV;
if (energyDeposit < energy_threshold)
                return false;
```

It seems to produce a low energy threshold in the energy scpectrum plots of scatterers.




**2) PhysicsList.cc**

```
// Constructor
PhysicsList::PhysicsList()
:   fEmPhysicsList(0),
fHadronPhys(),
fDecPhysicsList(0)
{
    SetVerboseLevel(0);
    // Default cut value  (1.0 mm is the Geant4 default)
    defaultCutValue = 100*um;
```

Notes:

- 10 keV electron range in plastic is 2.5 um (CSDA range 2.495E-04 g/cm^2), Compton recoil electrons remains within the scatterer 5 mm of side.

# Production cuts from the user manual

## 2.4.2 Range Cuts

To avoid infrared divergence, some electromagnetic processes require a threshold below which no secondary will be generated. Because of this requirement, gammas, electrons and positrons require production threshold. This threshold should be defined as a distance, or range cut-off, which is internally converted to an energy for individual materials. The range threshold should be defined in the initialization phase using the `SetCuts()` method of `G4VUserPhysicsList`. *Cuts per Region* discusses threshold and tracking cuts in detail.

# Production cuts from the user manual

## Setting the cuts

Production threshold values should be defined in `SetCuts()` which is a virtual method of the `G4VUserPhysicsList`. Construction of particles, materials, and processes should precede the invocation of `SetCuts()`. `G4RunManager` takes care of this sequence in usual applications.

This range cut value is converted threshold energies for each material and for each particle type (i.e. electron, positron and gamma) so that the particle with threshold energy stops (or is absorbed) after traveling the range cut distance. In addition, from the 9.3 release ,this range cut value is applied to the proton as production thresholds of nuclei for hadron elastic processes. In this case, the range cut value does not means the distance of traveling. Threshold energies are calculated by a simple formula from the cut in range.

Note that the upper limit of the threshold energy is defined as 10 GeV. If you want to set higher threshold energy, you can change the limit by using "/cuts/setMaxCutEnergy" command before setting the range cut.

The idea of a "unique cut value in range" is one of the important features of GEANT4 and is used to handle cut values in a coherent manner. For most applications, users need to determine only one cut value in range, and apply this value to gammas, electrons and positrons alike. (and proton too)

The default implementation of `SetCuts()` method provides a `defaultCutValue` member as the unique range cut-off value for all particle types. The `defaultCutValue` is set to 1.0 mm by default. User can change this value by `SetDefaultCutValue()` The "/run/setCut" command may be used to change the default cut value interactively.

**Warning:** DO NOT change cut values inside the event loop. Cut values may however be changed between runs.

It is possible to set different range cut values for gammas, electrons and positrons by using `SetCutValue()` methods (or using "/run/setCutForAGivenParticle" command). However, user must be careful with physics outputs because GEANT4 processes (especially energy loss) are designed to conform to the "unique cut value in range" scheme.

Beginning with GEANT4 version 5.1, it is now possible to set production thresholds for each geometrical region. This new functionality is described in *Cuts per Region*.

- Simulations with different cuts:
  - G4double energy_threshold = 0.01 * keV; ??
  - defaultCutValue = 0.5*um; ??

- Do we want to test physics list of Polarization advanced example ?
  - /examples/extended/polarisation/Pol01