How to model the inactive layer in p-type detectors in Monte-Carlo codes

Henrik Persson

hpersson@mirion.com

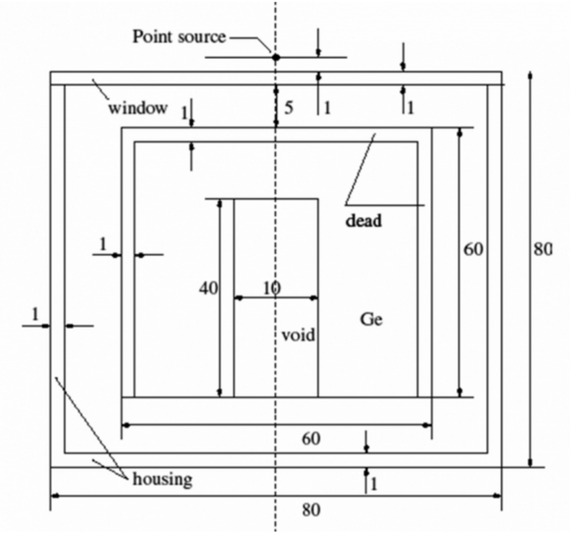
MIRION TECHNOLOGIES

Outline

- Introduction
- Observation
- Investigation
- Summary

Monte-Carlo model of crystal

- P-type detectors has an inactive layer of the HPGe crystal
  - ~0.5 mm or thicker
- One of the most important parameters when making a detector model.
  - In particular for low energies
- Typically use the assumption that none of the energy that is deposited in the inactive layer contributes to the pulse height
- All of the energy that is deposited in the active crystal contributes to the pulse height.
- There is a sharp boundary between the inactive layer and the active.
- This have been a successful approach for determining the full energy peak efficiency.

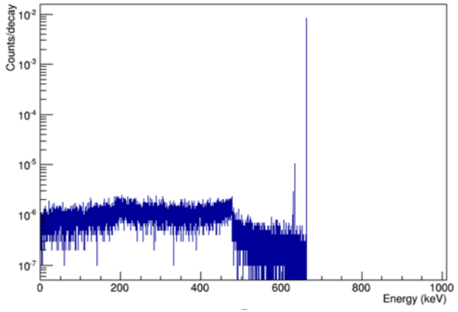


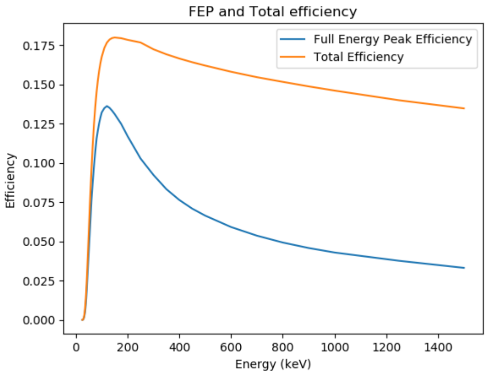
From the GSWG Monte-Carlo benchmark

Total efficiency

- Total efficiency is the number of counts generated in the spectrum per emitted gamma-ray.
- It is very important for true coincidence summing correction.
- The thickness of the inactive layer is still one of the most important parameters for low energies
- Harder to measure than the full energy peak efficiency

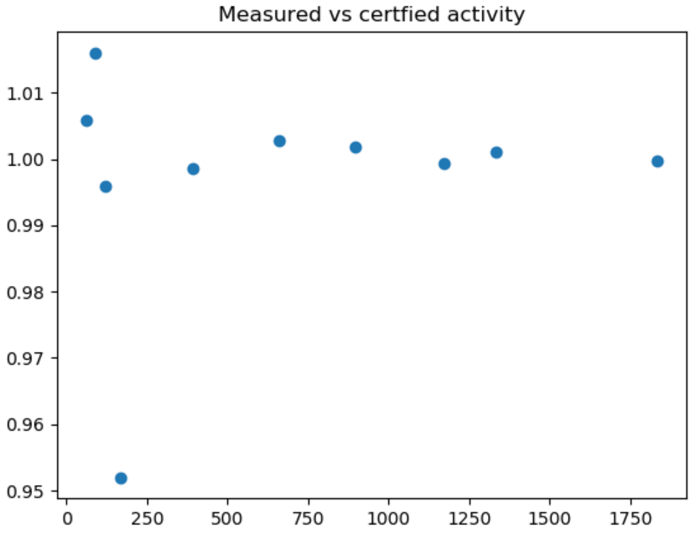
661 keV





Observation

- The efficiency measured at 165 keV from Ce-139 doesn't agree with the expected efficiency for a 100% relative efficiency p-type detector for a liquid scintillation vial on the endcap
- Using the same source the measured efficiency for the same energy and nuclide agrees with the expected efficiency for a planar detector with a very thin inactive layer.
  - And a lot more true coincidence summing
- Ce-139 is in typical mixed gamma sources and the gamma energy is close to the highest efficiency.



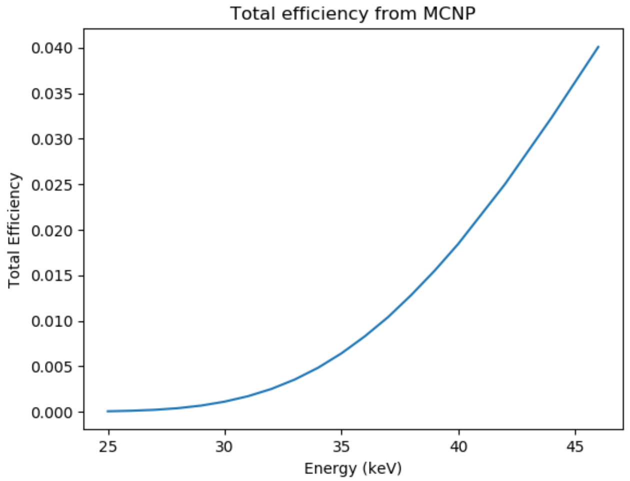
MIRION TECHNOLOGIES

True coincidence summing correction for Ce-139

- The true coincidence summing correction factor for Ce-139 is easy to calculate:

$$F_C = \frac{1}{1 - \sum_i \omega_i \eta_i}$$

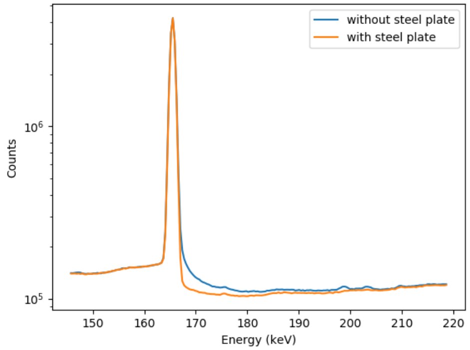
- It depends on the total efficiency at the energy of the x-rays (33 – 38 keV)
- The total efficiency from MCNP in the X-ray region is too low to account for the difference in peak efficiency
- When I use MCNP-CP to calculate the true coincidence summing correction factor it is close to 1.

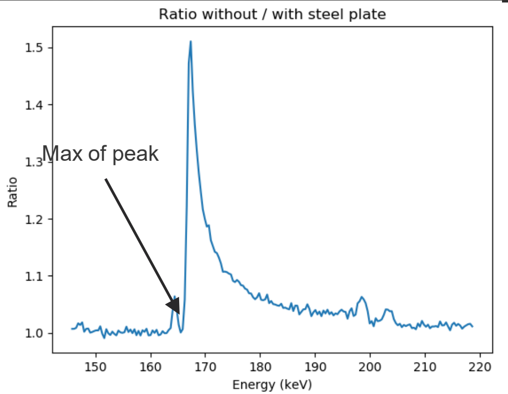


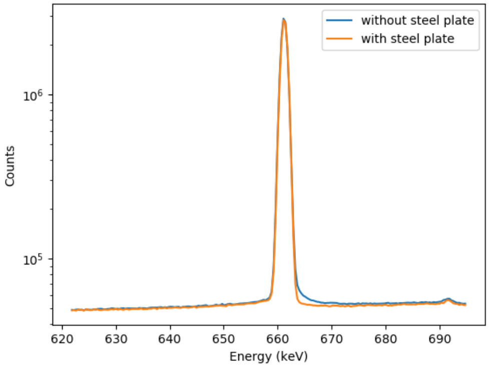
MIRION TECHNOLOGIES

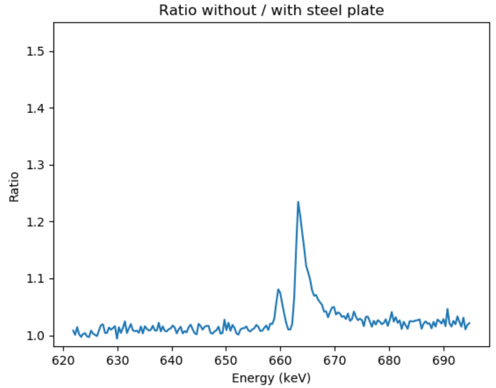
Filter out X-rays

- Measured the same source with a steel plate to filter out the x-rays
- Similar dead time
- There is a significant extra contribution between the peak energy and the peak + X-rays energy
- Cs-137 peak shows much less of an increase on the high energy side
  - Makes me believe it is not pile-up
- Why are these summing out counts not predicted by MCNP-CP
  - The only interpretation that I have left is that the x-rays deposit their energy in the inactive layer but still contribute to the pulse height
  - The inactive layer is not completely inactive!





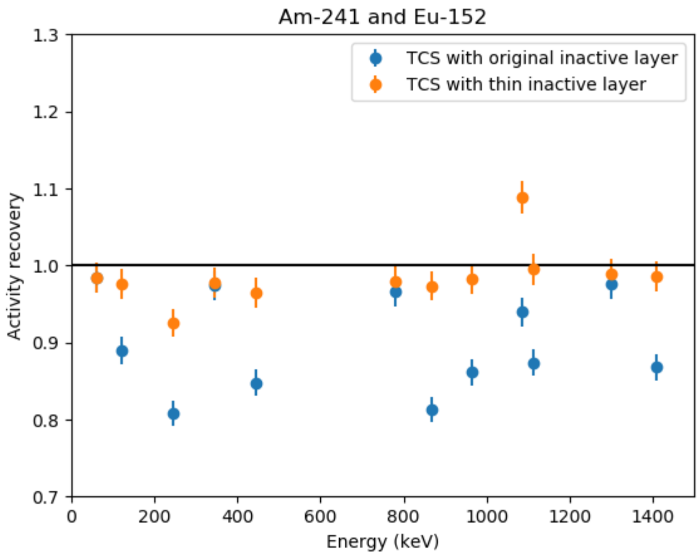




MIRION TECHNOLOGIES

Eu-152

- Eu-152 is another interesting case
- Electron capture and β^- branches
- The β^- decay branch agrees with the certificate activity
- The electron capture decay branch shows significant deviation
- If I calculate the True coincidence summing correction with MCNP-CP and a thinner inactive layer the agreement is improved significantly
- Not the case for a planar detector with thin inactive layer.



MIRION TECHNOLOGIES

Summary

- Modeling the inactive layer as completely inactive with a sharp boundary has proven to work for peak efficiencies
- It may not be accurate for total efficiency for p-type detectors with large relative efficiency
- Can have impact on true coincidence summing correction
  - In particular for Ce-139 which is included in mixed gamma sources
- I would love to hear comments from gamma spectrometry community
  - Am I wrong in interpret the extra counts on the high energy side as contribution from the inactive layer?
  - Have other people experienced the same?
  - Are there ways to account for the extra counts in Monte-Carlo simulations?