Nuclear instrumentation: Exercise 1

Arthur Adriaens

Ghent University

1. Determine the thickness of theΔE detector (a)

To determine the thickness of the ΔE detector, we'll take a look at the requirements: "Deuterons need to have an energy of at least 13.3 MeV to be detected by the system", This means that either of the tresholds isn't reached. I.e either the deposited energy in the silicium detector isn't above the threshold or the one in the Germanium detector isn't above 5.2 MeV. we'll vary the width of the ΔE detector and see when the threshold energy of the Ge E detector is no longer reached:

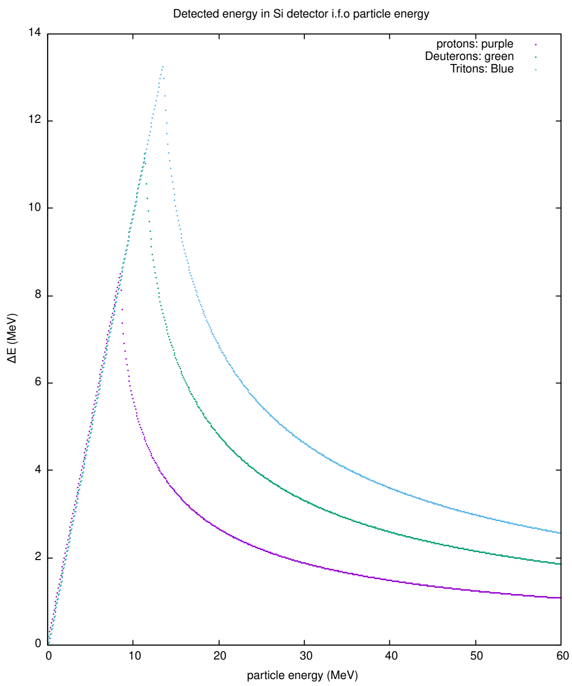
13.3 MeV Deuteron

A deuteron with this energy still barely gets detected, looking at the energy deposit in function of the width we can see that the Germanium detector gets past it's threshold for a width of 0.0533 cm:

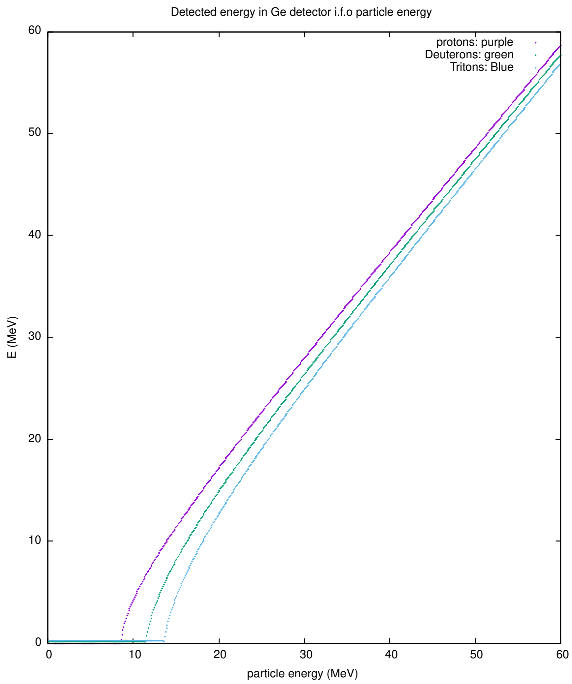
Width (cm)	Energy loss ΔE Detector (MeV)	Energy loss E detector (MeV)
0.0533	7.772	5.20667
0.05335	7.78273	5.19593

So we conclude the width to be 0.0533 cm or 533μm.

2. Proton, Deuteron and Triton Energy Loss (b & c)



It's clearly visible on the above plot that a ΔE-E detector can discriminate between the different particles as soon as the energy is high enough for the lines above to be seperate. An example of how this identification would work is, say we have a proton of 30 MeV that falls in onto the detector. From the ΔE detector we see an energy transfer of 1.88MeV, this could be identified with a proton of 30 MeV or with a Deuterion or Triton of super high energy, way above 60 MeV. But let's now say we have a proton of 10 MeV, this would produce a signal of 5.63 MeV in the Si detector. We could also identify this with a 17.1MeV Deuteron or a 24.3 MeV Triton, if we then really wanted to make sure, in effect we need the two plots, also the energy loss in the Germanium detector:



We would receive a signal of 4.2 MeV in the Germanium detector as this corresponds to the proton of 10 MeV, however this doesn't correspond at all with a 17.1 MeV Deuteron or a 24.3 MeV Triton.

3. What is the energy of protons that are stopped in the ΔE detector? (d)

We thus wish to know when there's no longer an energy deposit in the E detector, for this we'll just have to run a simulation over the energies for the early (<10 MeV) part, first a crude calculation we see the following:

Kinetic Energy (MeV)	Energy loss ΔE Detector (MeV)	Energy loss E detector (MeV)
8.4	8.4	0
8.5	8.5	0
8.6	8.12009	0.319205
8.7	7.67421	0.865086

I.e zero energy loss up until $E_{kin} = 8.5$ MeV so it should be between 8.5 and 8.6 MeV, after doing multiple 'zooms' we get:

Kinetic Energy (MeV)	Energy loss ΔE Detector (MeV)	Energy loss E detector (MeV)
8.5492	8.5492	0
8.5493	8.5493	0
8.5494	8.44907	0.100328
8.5495	8.44875	0.100752

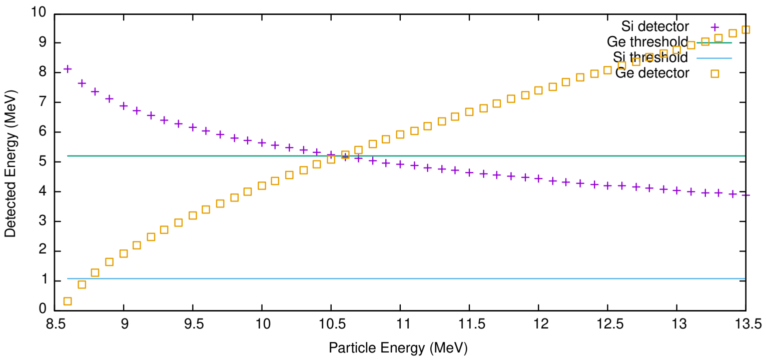
I.e all protons up until Kinetic Energy of about 8.5493MeV are stopped in the ΔE detector.

4. Determine the energy threshold of the ΔE-detector (e)

This can be found by looking at the moment the protons are no longer detectable, it was given that this was at a kinetic energy of 60 MeV so that corresponds to a threshold of 1.06916 MeV.

5. Determine the low energy threshold of proton detection in the ΔE-E detector (f)

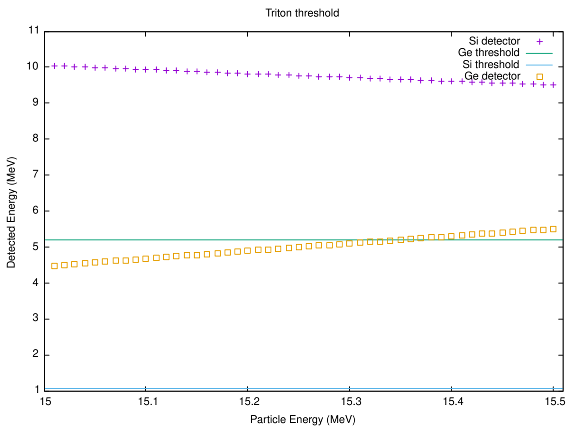
As the ΔE-E detector is used in coincidence mode, the proton needs to be detected both in the ΔE and E block. Looking at a simulation:



We find the low energy threshold of a proton to be at an energy of about 10.56 MeV.

6. Determine the low energy threshold of Triton detection in the ΔE-E detector (g)

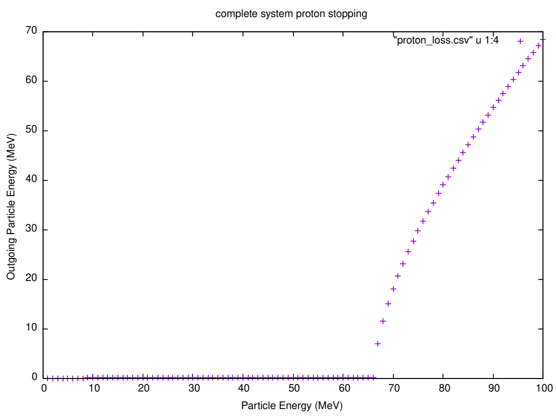
Again, looking at a simulation:



We find the low energy threshold of a Triton to be at an energy of about 15.35 MeV.

7. What is the energy of protons that are stopped in the complete ΔE-E system? (h)

This corresponds to particles with such kinetic energies that the outgoing kinetic energy is zero, a quick simulation gives the following:

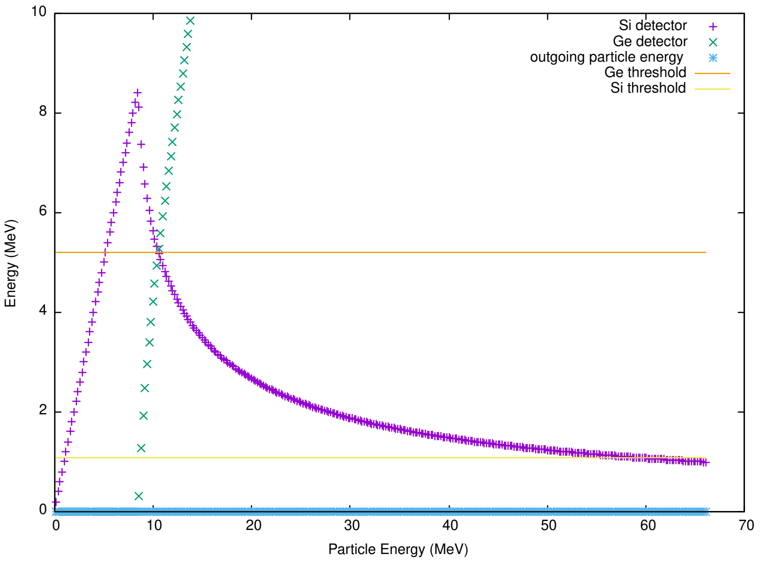


We can zoom in on the region where the energy starts to increase, i.e when the particle starts being able to leave the detector and we find that this is at an energy of about 66.2 MeV.

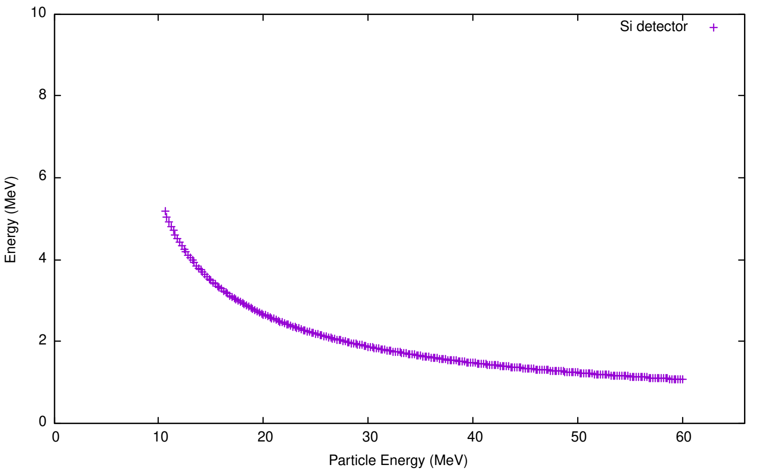
We can thus conclude that all protons of energies less than this will be stopped by the complete ΔE-E system

8. What energy do such protons deposit in the ΔE detector and are they still detected in the ΔE-E system? (i)

In a plot, everything together over the range where the protons get completely blocked looks like this:



The ΔE detected deposit will look like this:



Everything that is cut away from the previous plot wasn't detected by the system.

9. What step size did you use for your calculations? (j)

A step size of 0.0000001 centimeter (0.1 micrometer) was used, as one of the first tasks asked to micrometer precision I decided to take at least a tenth of that to get an accurate prediction. I later on checked if this was a good step size by redoing some calculations with a smaller step size but I didn't notice any significant differences.