Geant4 simulations of a ^{3}He neutron counter

JINR Summer Student Report

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Introduction

Helium-3 neutron counters are broadly used at research facilities, such as the IBR-2 reactor and experimental set-ups at the Joint Institute for Nuclear Research (JINR). This common type of detector is ne of the oldest and quite well studied. Nevertheless, the amplitude spectrum of the detector has some non-obvious features.

Helium-3 neutron detectors use the ^{3}He(n,p)^{3}H nuclear reaction whose cross section at neutron thermal energies is very high ($\sim$ 5327 barn). The proton and tritium produced in this ^{3}He fission reaction (Q = 792 keV) will ionize the medium and the charge will be collected producing an electrig signal that can be registered using some electronic devices.

Regarding the energy deposition spectra, a single full absorption energy peak will be observed for neutron energies that are small compared with 764 keV. On the left of the full absorption energy peak, there are two peaks, from proton and triton, whose shape changes due to the so-called wall effects (see Figure 1)

The wall effect arises because the proton and triton daughter products of the reaction have discrete energies (573 keV and 191 keV respectively) and their ranges in the detector are usually larger than the dimensions of the detector. When one of the daughter products collides with the wall of the detector, its energy is dissipated and does not contribute to the full energy peak, thus creating the discrete steps in the spectrum (see Figure 1).

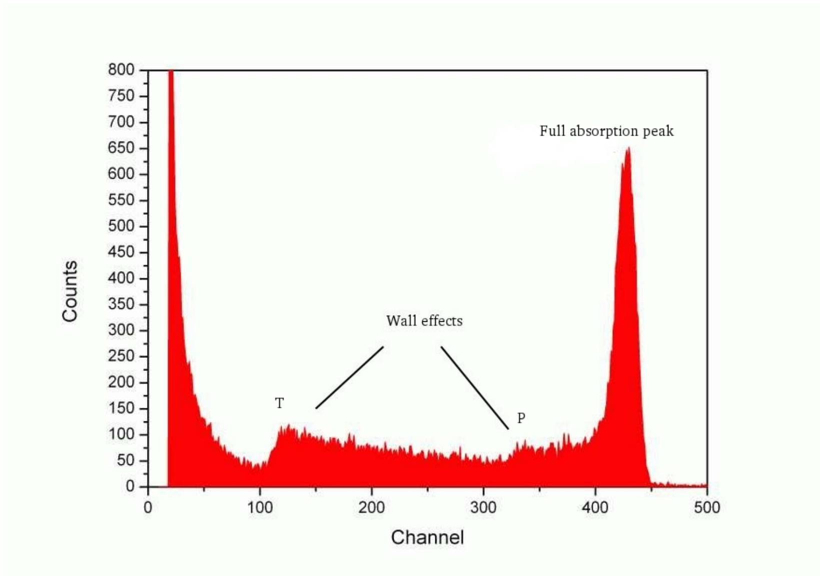

Figure 1: Amplitude spectrum of SNM-17 neutron counter irradiated by the thermal neutrons

Simulating a Helium-3 gas counter detector with Geant4 could be of great interes to understand the arising wall effects on the detector spectrum.

Different gas mix simulations: results and discussion

As it was mentioned before, wall effects are produced by the single or double escape of the proton and triton from the ^{3}He(n,p)^{3}H reaction. Therefore, the magnitude of this wall effects will directly depend on the range of these particles. This range is controlled by the presence of other gasses (together with ^{3}He), whose function is mainly to enlarge it.

In order to understand the dependence of the energy spectrum with the total pressure of the gas mix, several Geant4 simulations of a ^{3}He detector have been performed. The gas mix has been chosen to be the ones given in table 1, and these have been proportionally increased and decreased by a variable factor as it will be shown later.

Gas	Partial pressure (bar)	
	Gas Mix 1	Gas Mix 2
Argon	1,5	1,0
CO_2	0,05	0,05
^{3}He	2,5	7,0
Total gas mix	4,05	8,05

Table 1: Example of a gas mix used in some ^{3}He detectors.

To perform this Geant4 simulations, a cylindrical 5 mm radius and 10 cm length detector has been chosen together with an homogeneus thermal neutron beam covering all of it. Figure 2 is a 3D representation of the simulated detector (left) and an example of one simulation (right).

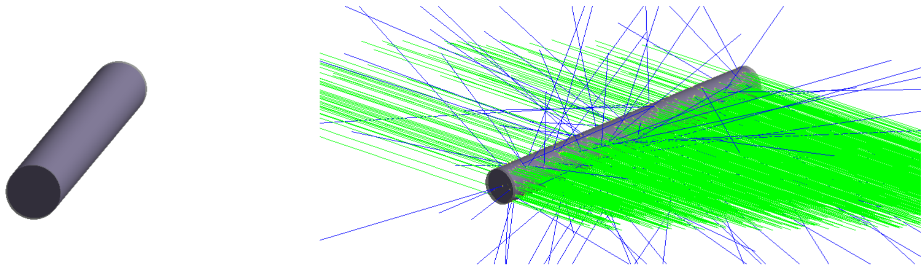

Figure 2: Geant4 simulation geometry illustration

Figures 3, 4, 5 and 6 show the results obtained for the ^{3}He detector simulations with the different total pressure of the different gas mixes. In the first two it is shown how as the pressure increases, the total energy peak also does so while the wall effects decrease. On the other hand, while the total pressure decreases, the total energy peak also doeas and the arising wall effects become predominant in the spectrum.

Figures 4 and 6 shows the positions in which the ^{3}He(n,p)^{3}H reaction takes place at the different gas mix pressures. One can see how, at very low pressure the reaction probability is also very low and therefore an almost homogeneous small amount of reaction points are plotted. This number of points increases with the gas mix pressure and their positions start to get localized in the side of the detector closer in the beamline.

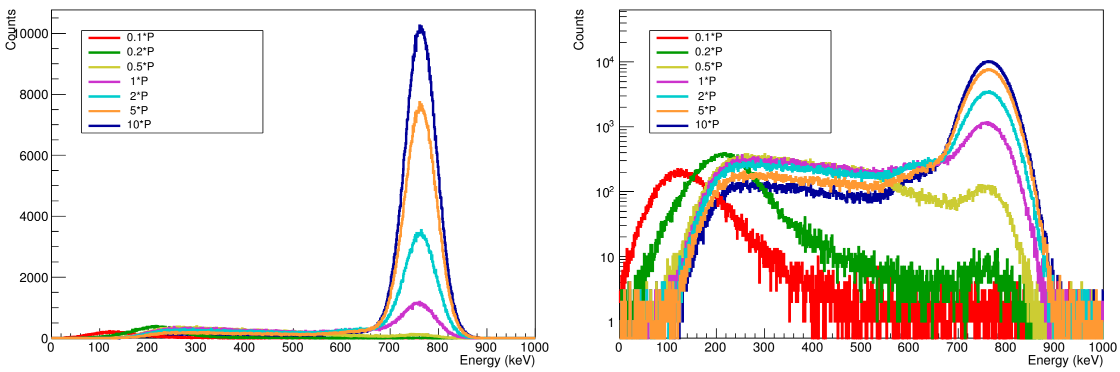

Figure 3: Geant4 simulation of a ^{3}He detector energy spectrum as a function of the gas mix pressure in linear (left) and logaritmic scale (right), P = 4,05 bar (gas mix 1).

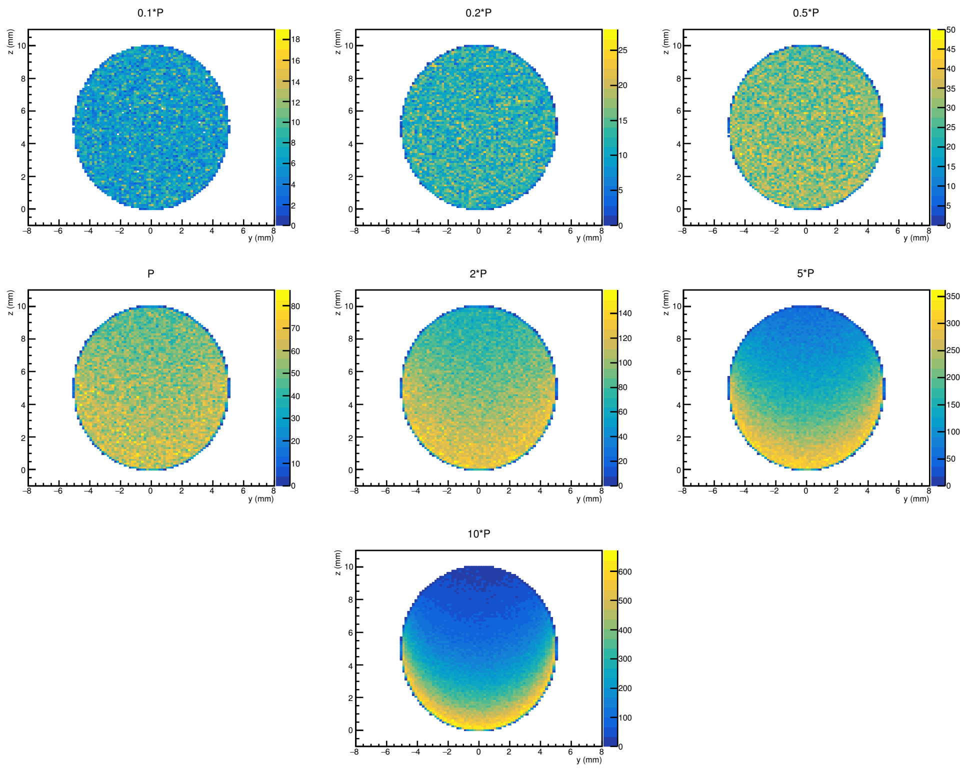

Figure 4: Geant4 simulation of the thermal neutron reaction points inside a ^{3}He detector as a function of the gas mix pressure, P = 4,05 bar (gas mix 1).

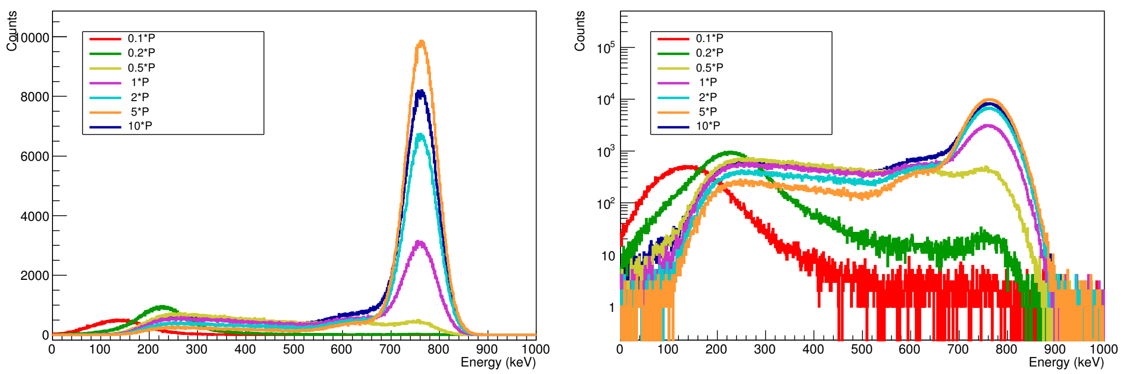

Figure 5: Geant4 simulation of a ^{3}He detector energy spectrum as a function of the gas mix pressure in linear (top) and logaritmic scale (bottom), P = 8,05 bar (gas mix 2).

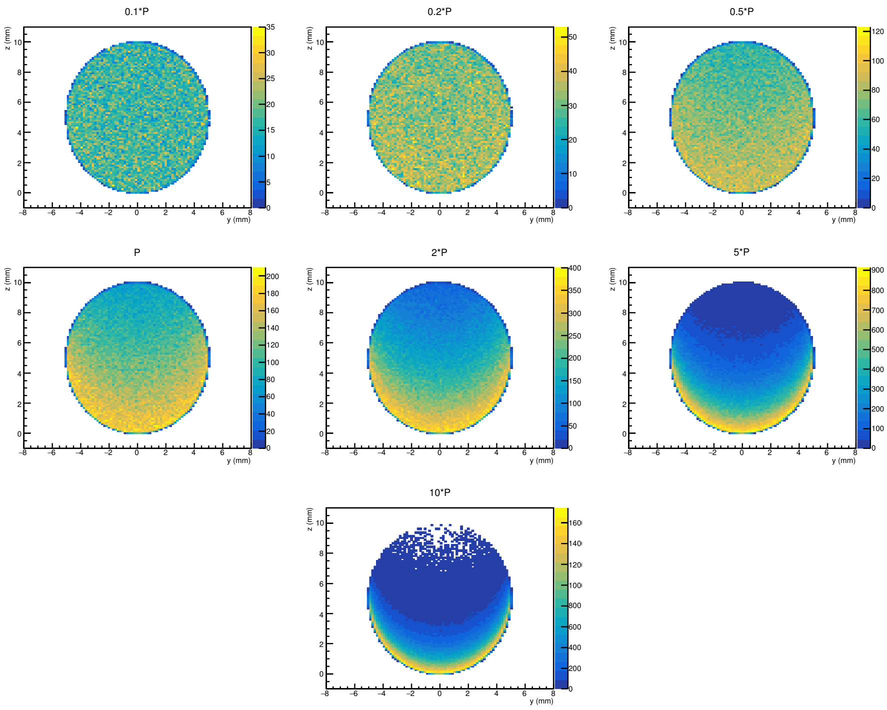

Figure 6: Geant4 simulation of the thermal neutron reaction points inside a ^{3}He detector as a function of the gas mix pressure, P = 8,05 bar (gas mix 2).

Conclusion

We simulated amplitude spectra of the neutron counter with various gas pressures. It is seen that at low pressure the shape of the spectrum changes significantly. This can be explained by the fact that the track of charged particles considerably exceeds the diameter of the detector. It is curious that the distribution of energies in this case has a pronounced peak at low energies,with the almost complete suppression of the full absorption peak . This fact can be of interest when working with monitor counters, as well as in assessing the state of the gas mixture.