Simulation of an AmBe source and Helium-3 Thermal Neutron Detectors

Using GEANT4

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1 Introduction

1.1 AmBe neutron source

The University of Victoria has a 241-AmBe neutron source, which produces neutrons using the following reaction [2]:

$$^{241}_{95}\mathrm{Am} \rightarrow\ ^{237}_{93}\mathrm{Np} +^{4}_{2}\mathrm{He} + \gamma \tag{1a}$$

$$^{9}_{4}\mathrm{Be} +^{4}_{2}\mathrm{He} \rightarrow\ ^{12}_{6}\mathrm{C} +^{1}_{0}\mathrm{n} + \gamma \tag{1b}$$

with an activity of 168 GBq (measured at 185 GBq in 1966). The energy spectrum of an AmBe source can be found in Fig 1. The configuration of the University of Victoria's AmBe source can be found in [3]. The neutron rates from five different AmBe sources is measured in [4]. From this, it is determined that an AmBe source produces $6.08\pm0.17\times10^4$ neutrons/GBq. For the 168 GBq source, this corresponds to $1.02\pm0.03\times10^7$ neutrons/s.

1.2 Helium-3 Tube

2 Geometry

The centre of the geometry is defined to be the centre of the graphite cube. All other positions are taken relative to this point. The geometry of the pile room is read into the simulation from four files:

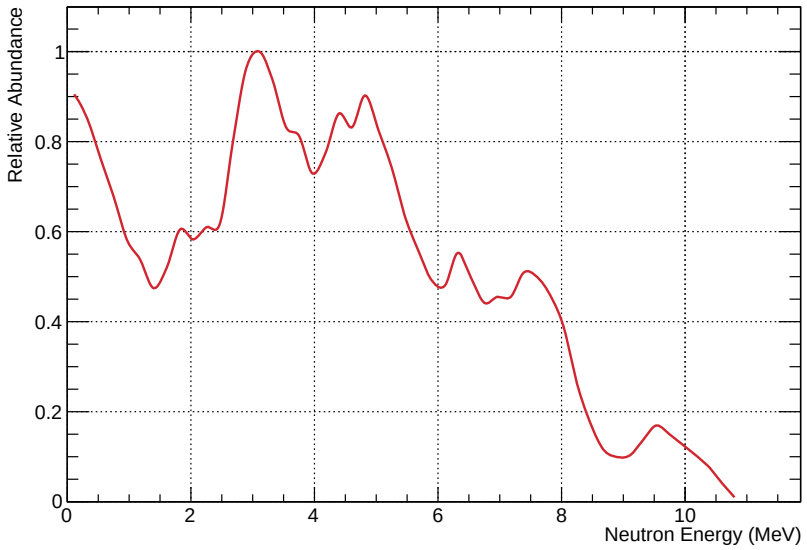


Figure 1: Energy spectrum of neutrons from AmBe source [1].

Room.xml contains geometry of the room. The dimensions of the room, the material the walls are composed of, the thickness of the walls, and the position of the centre of the room relative to the graphite are all contained in this file. The default dimensions are taken from fig 2, the default material is G4_CONCRETE, GEANT4's implementation of concrete, and the thickness is assumed to be 20cm. The door to the room and the small alcove on the left of fig 2 have been omitted from the room description.

Graphite.xml contains the geometry of the graphite. The graphite pile is composed of layers of criss-crossed rods of graphite, as shown in fig 3.

For simplicity, only the dimensions of one rod are defined in the xml file, as well as the number of layers in the pile. The default length of a rod is 92.5 cm with width of 5.285 cm. Each layer is two rods long and 35 wide, as shown in fig 4, with each layer rotated 90° with respect to the previous. The pile is composed of 35 layers. The length and width if each rod is reduced by a Gaussian distributed random number in order to simulate the imperfect stacking and variation in rod dimensions of the actual pile.

The material of the pile is G4_GRAPHITE with a small boron impurity. The density and the purity of the graphite (in %) are specified in the xml file.

HE3TUBE.xml contains the geometry of the helium-3 tubes. The dimensions of the tubes are based on fig 5. The xml file can contain several tubes, each of which is implemented in the simulation.

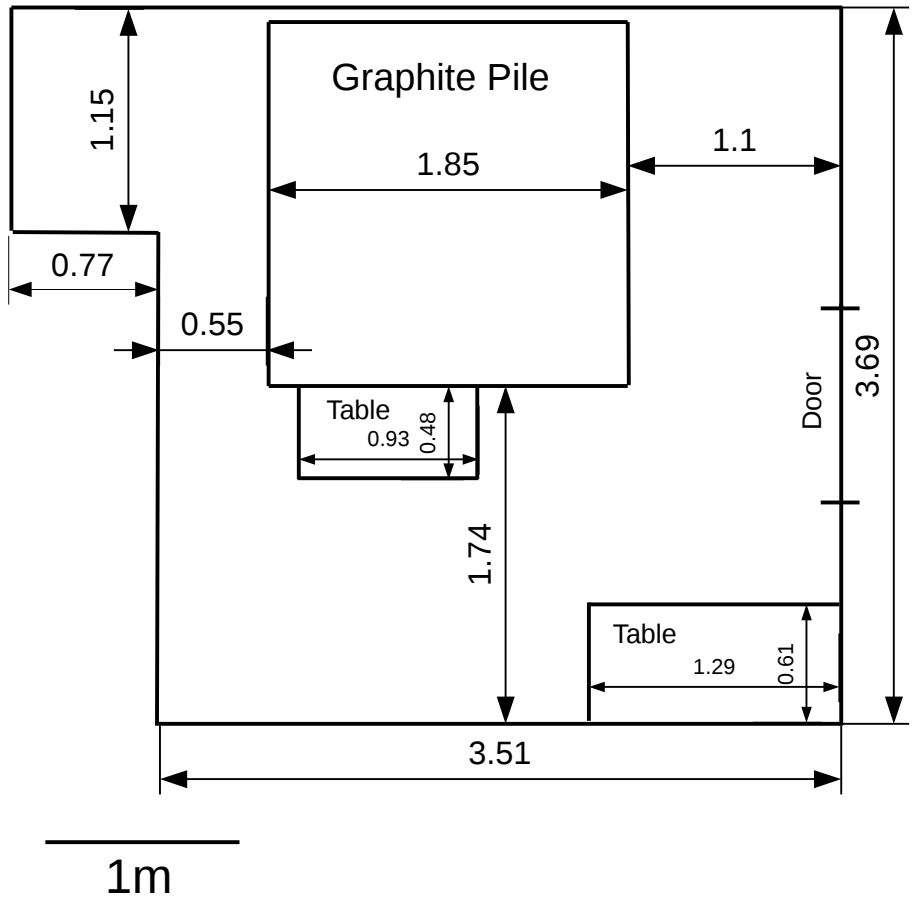


Figure 2: Scale drawing of the pile room

misc.xml contains the geometry of any other object, such as a polyethylene shield. Both boxes and cylinders can be implemented. The position of the object can be with respect to the origin (the centre of the graphite) or with respect to one of the helium-3 tubes. The xml file can contan several objects, all of which will be implemented in the simulation.

3 Output Ntuples

A root file containing two ntuples is produced by the simulation:

geometry contains the geometry of the room, graphite cube, helium-3 tubes, and the miscellaneous objects. This ntuple has only one entry.

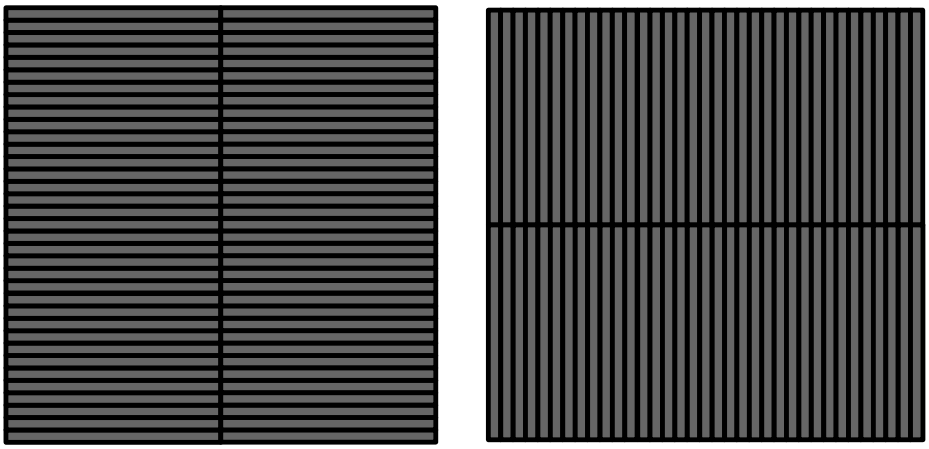
PileRoomSim contains the simulation results. By default, only events containing a neutron hit in a helium-3 tube are saved, but it is possible to save all events. The branches in this ntuple summarized in table 1

Branch	Description
Ekin_n_PostGraphite	Kinetic energy of a neutron after leaving the graphite
Etot_n_initial	Initial energy of neutron
TotalEnergyDeposited	Total energy deposited by a proton and tritium
leftWall	1 if the neutron left the wall of the room
he3TubeXPos	X position of tube containing a neutron hit
he3TubeYPos	Y position of tube containing a neutron hit
he3TubeZPos	Z position of tube containing a neutron hit
EDEPinHe3	a vector of the energy deposits in the helium-3 tubes
PIDinHe3	a vector of the PID of particles causing energy deposits in the helium-3 tubes
neutronHits	The channel number of a tube where a hit occured
diffusionRadius	a vector containing 100 radius values between 30 and 70 cm
diffusionFlux	a vector containing the number of neutrons which cross a sphere defined by each entry in diffusionRadius

Table 1: Branches in the PileRoomSim ntuple

4 Determination of Boron Contamination

Figure 3: Photograph of the graphite pile showing rods



(a) layer 1 (b) layer 2

Figure 4: Arrangement of rods in alternating layers

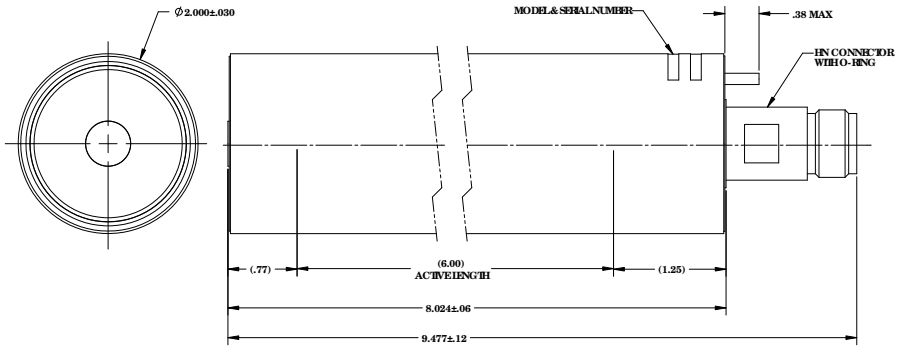


Figure 5: Schematic of helium-3 tube

References

[1] Kluge H and Weise K. The neutron energy spectrum of a 241Am-Be (alpha, n) source and resulting mean fluence to dose equivalent conversion factors. *Radiation Protection Dosimetry*, 2(2):85–93, 1982.

[2] Barschall HH. *Neutron sources: for basic physics and applications*, volume 2. Pergamon, 1983.

[3] Geiger KW and Hargrove CK. Neutron spectrum of an Am241-Be (α, n) source. *Nuclear Physics*, 53:204–208, 1964.

[4] Lebreton L, Zimbal A, and Thomas D. Experimental comparison of 241Am–Be neutron fluence energy distributions. *Radiation protection dosimetry*, 2007.