Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

A Preliminary Study on Time Projection Chamber Simulation for Fission Cross Section Measurements with Geant4

Jong Woon Kim [1*], Young-Ouk Lee [1], and Jae Cheon Kim [2]
[1]Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong-gu, Daejeon, Korea, 305-353
[2]Institute for Basic Science, 70 Yuseong-daero 1689-gil, Yuseong-gu, Daejeon, Korea, 305-811
[*]*Corresponding author: jwkim@kaeri.re.kr*

1. Introduction

The standard in fission cross section measurement is a fission chamber. It is basically just two parallel plates separated by a few centimeters of gas. A power supply connected to the plates sets up a moderate electric field. The target is deposited onto one of the plates. When fission occurs, the fragments ionize the gas, and the electric field causes the produced electrons to drift to the opposite plate, which records the total energy deposited in the chamber.

A Time Projection Chamber (TPC) [1] is a gas ionization detector similar to a fission chamber. However, it can measure the charged particle trajectories in the active volume in three dimensions by adding several readouts on the pad plane (fission chamber has only one readout one a pad plane). The specific ionization for each particle track enables the TPC to distinguish different particle types.

A TPC will be used for fission cross section measurements in the Neutron Science Facility (NSF) at RAON. As a preliminary study, we present details of TPC simulation with Geant4 [2] and discuss the results.

2. Method and results

2.1 Simulation Details

A schematic view of a two-sided TPC is shown in Fig. 1, and typical parameters for the simulation are listed in Table I. A uranium (or plutonium) target is attached on the carbon backing plane.

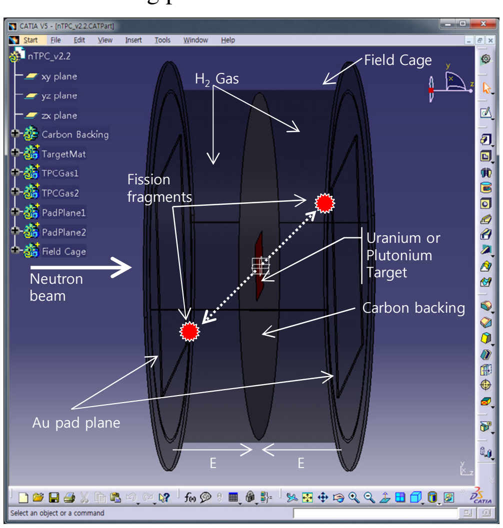

Fig. 1. Schematic view of a two-sided TPC.

An incident neutron from the left side of a TPC causes fission with the target material. Fission fragments are emitted and ionize H_2 gas on each side. Produced electrons are drifted to the readouts on each pad plane. If we know the drift velocity, we can reconstruct the trajectories and ranges of the fission fragments. In this simulation, an electric field is not considered. 20MeV neutrons are used, and we logged the particle name, deposited energy, and length of the trajectory for post-processing.

Table I: Parameters for the TPC simulation

Zone	Material	Parameters
Neutron		20MeV
Field Cage	PMMA ($C_5O_2H_8$)	Density: 1.18 g/cm^3 Radius: 60.51mm
Pad plane	Au	Density: 19.3 g/cm^3 Thickness: 0.5mm
Drift Gas	H_2 Gas	Pressure: 5 bar Density: 5×0.0899e-3 g/cm^3 Radius: 59.51mm Height: 30.5mm
Backing plane	Carbon	Density: 2.267 g/cm^3 Thickness: 0.05μm
Uranium Target	U235 (99.8904%) U238 (0.0512%) U234 (0.0330%) U236 (0.0250%) U233 (0.00005%)	Density: 18.95 g/cm^3 Thickness: 0.1μm Size: 20mm×20mm
Plutonium Target	Pu239 (99.1017%) Pu240 (0.8858%) Pu241 (0.0125%)	Density: 19.84 g/cm^3 Thickness: 0.1μm Size: 20mm×20mm

2.2 Results

With TPC, we can have more information than a fission chamber. The energy vs. range is shown in Fig.2. The line on the left side is not fission fragments but light nuclides produced by neutron-chamber interaction. Two sets of fission fragment clouds are compared. For the plutonium target, the fission fragments are slightly heavier and have a shorter range than those of the uranium target in view of energy and range, respectively.

One of the merits of TPC is that we can distinguish fission fragments. A fission chamber, however, only gives the total deposited energy. Figure 3 is drawn according to the mass number vs. range along the AB line (99.5MeV<E<100.5MeV) in Fig. 2. If the energy of the nuclide is fixed, light nuclides have long trajectories in principle. We can see how this works in this simulation.

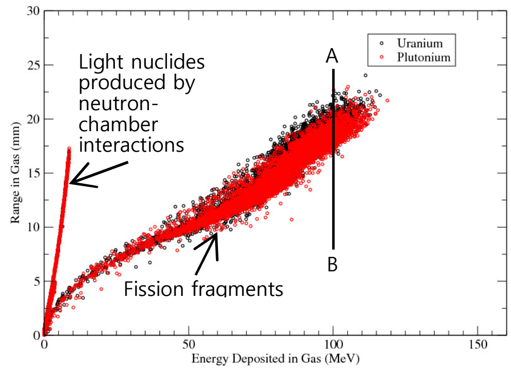

Fig. 2. Energy vs. range.

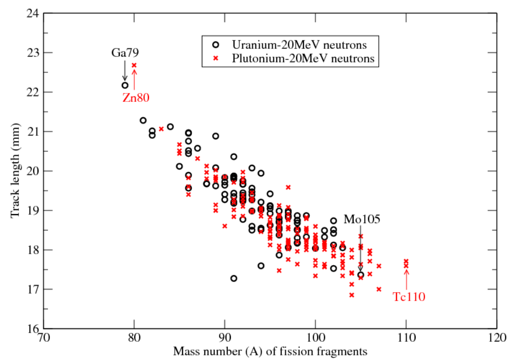

Fig. 3. Mass number of fission fragments vs. track length along the AB line (99.5MeV<E<100.5MeV) in Fig.2.

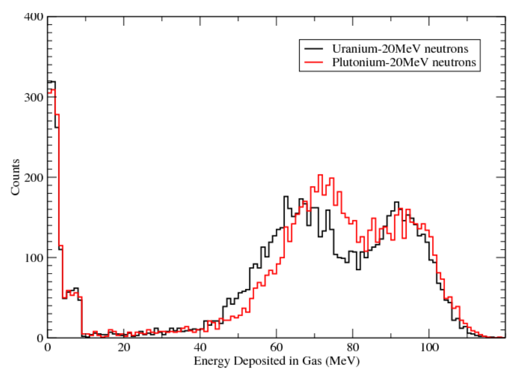

Fig. 4. Energy vs. count.

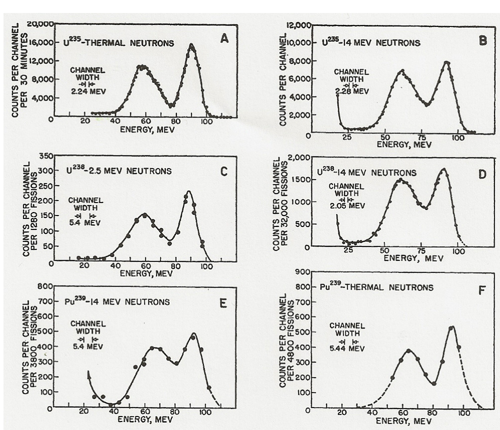

Fig. 5. Single-chamber energy distributions of fission fragments [3].

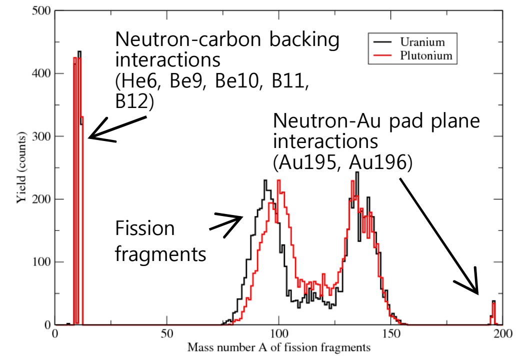

Fig. 6. Mass number of fission fragments vs. count.

Figure 4 shows the energy deposited in the gas of each target with 20MeV neutrons. The tails on the left side are caused by neutron-chamber interactions. Compared with figures B and E in Fig. 5, we can see a similar behavior in view of the energies where the peaks are, and the maximum energy is almost vanished above 110MeV.

Figure 6 shows the mass number distribution of the fission fragments. The left peaks in Fig. 6 are produced by neutron-carbon backing interactions and the right most peaks in Fig. 6 are caused by neutron-Au pad interactions.

3. Conclusions

We present the details of the TPC simulation with Geant4 and show the results. TPC can provide more information than a fission chamber in that it is possible to distinguish different particle types. Simulations are conducted for uranium and plutonium targets with 20MeV neutrons. The simulation results are compared with the reference and show reasonable results.

This is the first phase of study for realizing a TPC in the NFS at RAON, and we have more work to do, such as applying an electric field, signal processing in the simulation, and manufacturing of a TPC.

Acknowledgement

This work is supported by Research Program for Heavy Ion Accelerator.

REFERENCES

[1] M.D. Heffner, P.D. Barnes, and J.L. Klay, "Innovative Fission Measurements with a Time Projection Chamber," UCRL-TR-217600, 2005.
[2] S. Agostinelli (Geant4 Collaboration), Nucl. Instrum. Methods A, Vol.506, pp.250, 2003; J. Allison (Geant4 Collaboration), IEEE Trans. Nucl. Sci. Vol.53, pp.270, 2006.
[3] John S. Wahl, "Energy Distributions of Fragments from Fission of U^{235}, U^{238}, and Pu^{239} by Fast Neutrons," Physical Review, Vol.95, No.1, pp.126-132, 1954.