Simulate Threshold Energies to Induce Photo-nuclear Reactions for Heavy Metals

1 Abstract

Nuclear reactions take place within a probability that is proportional to cross section. The common unit of cross section is the barn b. Cross section can mathematically be defined as the number of light particles produced per unit time, per unit incident flux of photon (monoenergetic) beam or the incident particles, per target nucleus [1]. Sample activation is one of the nuclear techniques used in this study. In Photon Activation Analysis (PAA), photons are captured by the target nucleus that excites it to the higher energy level. The excited nucleus decays to a lower energy level (possibly the ground state) with the emission of photons, charged particles, or neutrons. The absorption of incident photons by the target nucleus is dependant on nuclear reactions cross section and threshold energy of incident bremsstrahlung photons. Isolated energy states of the target nuclei are excited below 10 MeV however there is a broad resonance region called the Giant Dipole Resonance (GDR) between 10 MeV and 30 MeV in which the collective vibrational motion of nucleons is observed [2].

Goal: To find the GDR and threshold energies of incoming bremsstrahlung photons to induce (gamma, n), and (gamma, 2n) reactions. Target samples such as 23g U-238, 10g Pu-239, and 10g ThC will be used during simulation. By using GEANT4 simulation, my goal is to plot total cross section verses energy of incident photons (1-1000 MeV) and based on the plot I will identify the approximate GDR range for U-238, Pu-239, and ThC that could help to optimize beam energy for PAA experiments. The cross sections obtained from Monte Carlo simulations will be compared with the data published in ”Atomic and Nuclear Data Reprints”.

2 Methods and Materials

Twenty-three grams (23g) U3O8 and 10g ThC, and 10 239Pu, 1g 239Pu in each pellet, were used in the experiment. Fissionable samples could be buried in 55-gallon waste barrel drum filled with sand. The question was could we image fissionable materials burial in a waste barrel using NaI(Tl) scintillators. However, detection of fissionable samples is vital before nuclear imaging and a single or multiple HPGe detectors could be used for detection purposes. The samples were first activated with 20 MeV bremsstrahlung from an electron linac as shown in figure 1-3.

G4-Code: //Pu-239 (Box Target) G4Material *Pu239 = new G4Material("Plutonium", z=94., a= 239.01*g/mole, density= 19.84*g/cm3);
fTargetLength = 10.16 * cm; // Full length of Target
TargetMater = Pu239; ChamberMater = Air;
fWorldLength = 1.2 * (fTargetLength + fTrackerLength);
G4double targetSize = 0.5 * fTargetLength; // Half length of the Target
solidTarget = new G4Box("target", targetSize, 2.0 * targetSize, 2.0 * targetSize);

// U-238 and ThC (Cylindrical Target) Edit DetectorConstruction.hh ========================
// Added class G4Tubs; G4Tubs* cylindricalTarget; // pointer to the cylindrical Target
EDIT DetectorConstruction.cc ====================== // Added #include ”G4Tubs.hh”
solidTarget(0), cylindricalTarget(0), logicTarget(0), physiTarget(0),
G4Material* U238 = new G4Material("DU", z=92., a= 238.0*g/mole, density= 18.95*g/cm3);
TargetMater = U238; ChamberMater = Air;
fWorldLength = 1.2 * (fTargetLength + fTrackerLength);
G4double targetSize = 0.5 * fTargetLength; // Half length of the Target
solidTarget = new G4Box("target", targetSize, 2.0 * targetSize, 2.0 * targetSize);
cylindricalTarget = new G4Tubs("Cylinder", 0, 2.54*cm, 5.08*cm, 0, 6.28);

logicTarget = new G4LogicalVolume(solidTarget, TargetMater, "Target", 0, 0, 0);
logicTarget = new G4LogicalVolume(cylindricalTarget, TargetMater, "Target", 0, 0, 0);
Figure 1: Pu-239 side view: 5.08cm x 10.16cm
Figure 2: Top view of the cylinder’s Radius containing ThC and Pu-239: 2.54cm
Figure 3: Side view of the cylinder containing ThC and U-238: 2.54 cm x 5.08 cm x 5.08 cm
References

