

**VERIFYING DIFFERENT METHODS OF GEOMETRY DEFINITION IN MCNP5
ON CALCULATING MASS ATTENUATION COEFFICIENT OF A LEAD SLAB**

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ABSTRACT

The two common methods for geometry definition in MCNP5 coding viz. detailed cell by cell method vs. repeated structure method were compared when defining the geometry of a Pb slab to calculate its photon mass attenuation coefficient μ_m . The Pb slab was assumed to be formed of a lattice of cubes and sphere. All materials were Pb, so in effect this geometry should work essentially as homogenous Pb slab, since dividing the geometry shouldn't have impact on the results. However, results were somewhat different from those for homogenous Pb slab. Moreover, it was found that results were significantly different for cubes & sphere lattice Pb slab defined by cell by cell geometry compared with results of the same geometry defined by repeated structure. The differences between the first and the second were between +4.34% to -21.9%. This raises questions on the precision of MCNP5 simulation using different geometry definition algorithms for complex structures.

KEYWORDS:

MCNP Modeling, Cell by Cell Geometry, Repeated Structure Geometry, Attenuation Coefficient

INTRODUCTION

It was always believed that when modeling a complex geometry using MCNP5 code (MCNP5 user manual, 2003), no matter how the structure's geometry was defined, the results will not vary. This was satisfactory to MCNP5 users especially those dealing with large or very complex geometries of repeated units, e.g. micro and nano structures. Using repeated structure geometry definition to simulate structures such as crystalline metals, granular materials, micro and nano structures were much easier and shorter using repeated structure definition. MCNP5 code's manual didn't mention any probable difference in the results obtained by detailed cell-by-cell geometry definition compared to those obtainable by repeated structure geometry definition.

OBJECTIVES

This work investigated the precision of MCNP5 modeling using cell-by-cell geometry definition vs. repeated structure geometry definition. Specifically, this work investigated the degree of agreement between photon's mass attenuation coefficients (μ_m) of a lead slab; once simulated as one piece i.e. homogenous Pb slab, and at two other times as lattice of Pb cubes containing central Pb spheres of micro dimensions defined as cell-by-cell at one time, and by repeated structure definition at another time. Though such geometry is far different from the real crystalline structure of lead, yet it was complex enough to test the precision of the three methods of lead slab modeling in MCNP5.

MATERIAL

The conventional experimental set up for estimating photon's mass attenuation coefficient (μ_m) of a Pb slab was modeled using MCNP5 code. This composed of an isotropic point photon source inside a thick Pb shield, with a narrow ray exit tunnel. Rays were received into a completely shielded detector except for a narrow tunnel facing and in line with the ray exit tunnel from the source. The Pb slab was located perpendicularly at the exit of the source ray tunnel. See figure 1.

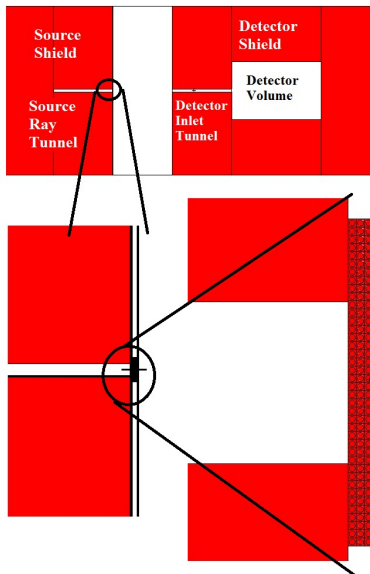


Fig. :: Model details.

Modeled Experimental Setup

The isotropic point photon source was enclosed in a thick Pb shield. Rays were allowed out in only one direction through a narrow collimator tunnel heading perpendicularly onto the investigated Pb slab. The detector was located on the other side of the Pb slab, defined as a right cylinder enclosed in a thick Pb shield. Photons reach the detector volume only through a long narrow tunnel in its shield that faces and is in line with the source exit tunnel. See figure 1.

The Pb Slab

The Pb slab was modeled in three different ways using MCNP5 geometry definition methods, viz.:

- Homogenous Pb slab.
- A cubic lattice defined cell-by-cell with cubes of 0.25 mm side length, each containing one central sphere 0.2 mm in diameter, with materials of the cubes and the spheres set as Pb.
- A similar cubic lattice defined, but defined by repeated structure geometry definition of MCNP5, i.e. using LAT, Fill, and U keywords.

These models were used to tally the un-collided photon flux (I) inside the detector. To tally the un-attenuated photon flux inside the detector (I_0), the following models were used:

- No attenuator at all.
- Voided slab attenuator composed of cubes & spheres lattice defined cell-by-cell, with same dimensions as above, but material was 0.
- Voided slab attenuator composed of cubes & spheres lattice defined by repeated structure geometry definition of MCNP5, with same dimensions as above, but material was 0.

The Source

Point isotropic photon source was modeled at the dead end of the ray exit tunnel in source shield. The photon energies used were: 50, 60, ... , 90, 100 keV, 0.5, 1.0, 5.0, and 10.0 MeV.

METHODOLOGY

MCNP5 code was used to tally the un-attenuated (Φ_0) and un-collided (Φ) photon fluxes inside the detector without and with the Pb slab respectively. This was repeated for all photon energies listed above. For the un-attenuated photon flux tallies (Φ_0); the no shield model, the voided cube & sphere cell-by-cell lattice slab model, and the voided cube & sphere repeated structure lattice slab model were used. While for the un-collided flux tallies (Φ); the homogenous Pb slab model, the voided cube & sphere cell-by-cell lattice Pb slab model, and the voided cube & sphere repeated structure lattice Pb slab models were used. These tallies were used to calculate the photon mass attenuation coefficients (μ_m) of Pb slab for different Pb slab geometry definition methods, at the

all investigated energies. Calculated photon mass attenuation coefficients (μ_m) were compared with tabulated values for Pb.

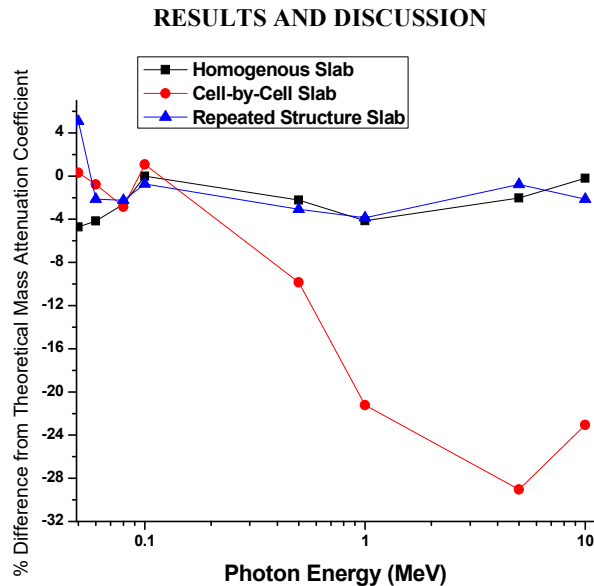


Fig.2. Differences between mass attenuation coefficients (μ_m) for homogenous slab, cell-by-cell lattice, and repeated structure lattice and the theoretical values.

Figure 2 shows great differences between the values of mass attenuation coefficients (μ_m) calculated using MCNP5 for Pb slab defined as homogenous slab, or defined as micro scale cubes & spheres lattice whether defined by cell-by-cell geometry definition or by repeated structure geometry definition, and theoretical mass attenuation coefficient (μ_m) [2].

It was noted that the un-attenuated flux (Φ_0) was constant for all of the three models viz. no attenuator, voided cell-by-cell lattice, and voided repeated structure lattice at all of the investigated photon energies.

Repeated structure lattice slab showed the least differences between MCNP5 calculated μ_m and theoretical, with mean difference = -1.23845% and standard deviation = 2.75766 over the investigated photon energy range between 50 keV – 10 MeV.

Homogenous slab showed small differences between MCNP5 calculated μ_m and theoretical ones, with mean difference = -2.50976% and standard deviation = 1.77358.

Cell-by-Cell lattice slab showed the greatest differences between MCNP5 calculated μ_m and theoretical ones, with mean difference = -10.67833% and standard deviation = 12.07232.

To explore the cause of the significant differences between the calculated μ_m and the theoretical μ_m for the cell-by-cell defined lattice slab, calculated mass attenuation coefficient μ_m and $(-1 \times \text{theoretical mean free path of photon in Pb /mm})$ were plotted vs. photon energy, see figure 3. It was found that the difference between the calculated μ_m and the theoretical μ_m was proportional to the mean free path. This signifies that if the dimensions of the MCNP5 lattice cell were smaller than the mean free path of the photon being tracked, MCNP5 will yield large error in photon tracking, which will yield significant error in estimating mass attenuation coefficient for photons.

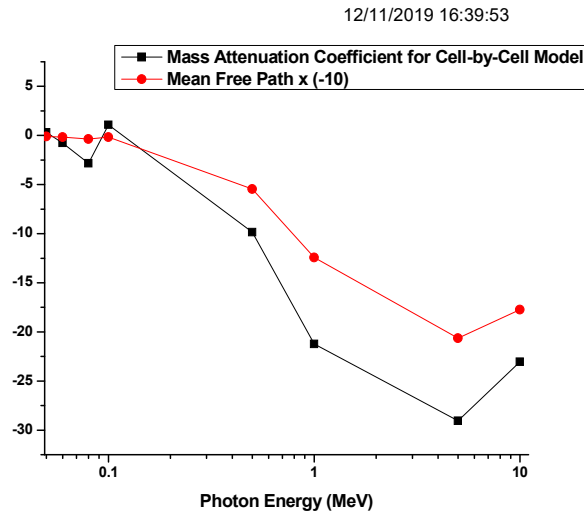


Fig.3. Mass attenuation coefficient μ_m and $(-1 \times$ theoretical mean free path of photon in Pb /mm) vs. photon energy.

CONCLUSION

Methods of defining geometry in MCNP5 models significantly affect the accuracy of photon tracking, and consequently affect the accuracy of dependent parameters such as mass attenuation coefficient for photons μ_m . Repeated structure lattice slab showed the least error in the calculated μ_m with mean difference from theoretical $\mu_m = -1.23845\%$ and standard deviation $= 2.75766$. Homogenous slab showed slightly larger error in the calculated μ_m with mean difference from theoretical $= -2.50976\%$ and standard deviation $= 1.77358$. Cell-by-Cell lattice slab showed the largest error in the calculated μ_m with mean difference from theoretical $= -10.67833\%$ and standard deviation $= 12.07232$.

It was also found that the difference between the calculated μ_m and the theoretical μ_m was proportional to the mean free path, i.e. if the dimensions of the MCNP5 lattice cell were smaller than the mean free path of the photon being tracked, MCNP5 will yield large error in photon tracking, producing significant error in estimating mass attenuation coefficient μ_m for photons.

REFERENCES

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