Attila Code-to-Code Comparison
Gamma Transport in High-Z Materials

Introduction

This calculation compares the total gamma flux calculated by Attila and Monte Carlo (MCNP) through an optically thick slab of commonly used, high-Z material, for a range of source energies and materials. Concrete, steel, and lead are evaluated for gamma source energies of 0.662 MeV (^{137}Cs), 1.17 MeV (^{60}Co), 1.33 MeV (^{60}Co), and 5.5 MeV.

Problem Summary

A **X**x10x10 cm material block is oriented with the **X** cm direction along the x axis. An isotropic volume source is applied in a 10x10x5 cm void region located at the –x end of the block, reflecting boundaries are applied on the four +y/-y and +z/-z surfaces. The slab is divided in the x-direction into segments, where the volume integrated flux in each segment is compared with MCNP. Twelve cases are evaluated for the following conditions:

Case #	Material/Density (g/cc)	E (MeV)	Slab Length (cm)	SN, PN
1	Concrete/2.3	0.662	100	S_8, P_5
2	Concrete/2.3	1.17	100	S_8, P_5
3	Concrete/2.3	1.33	100	S_8, P_5
4	Concrete/2.3	5.5	100	S_8, P_5
5	Steel/8.0	0.662	100	S_{12}, P_9
6	Steel/8.0	1.17	100	S_{12}, P_9
7	Steel/8.0	1.33	100	S_{12}, P_9
8	Steel/8.0	5.5	100	S_{12}, P_9
9	Lead/11.35	0.662	30	S_{12}, P_9
10	Lead/11.35	1.17	50	S_{12}, P_9
11	Lead/11.35	1.33	50	S_{12}, P_9
12	Lead/11.35	5.5	50	S_{12}, P_7

Table 1: List of cases with corresponding source energies and material properties.

The slab length of **X** is shown in the 4th column of Table 1. The discrete energy source capability of Attila was invoked for source energies of 0.662, 1.17, 1.33, and 5.5 MeV, and is specified in each run directory through a file called **.vsrc.inp.eLineData*. Details of how line sources are specified and how they function can be found in Section 7.2.2 of the Attila Solver Manual.

Tables 2 and 3 provide the elemental compositions used for concrete and steel, respectively. Lead was modeled as pure lead (Pb). The Transpire46g library was used for all calculations. This is a gamma-only library created using CEPXS with 46 gamma energy groups, ranging from .001 to 50 MeV.

Concrete (ρ=2.3 g/cc)	
Element	Weight Fraction
H	0.01
C	0.001
O	0.529107
Na	0.016
Mg	0.002
Al	0.033872
Si	0.337021
K	0.013
Ca	0.044
Fe	0.014

Table 2: Elemental composition for concrete

Steel (ρ=8 g/cc)	
Element	Weight Fraction
C	0.008
Si	0.01
P	0.00045
Cr	0.19
Mn	0.02
Fe	0.68375
Ni	0.095

Table 3: Elemental composition for steel

Attila Calculation Summary

The Attila calculation was performed on computational meshes consisting of approximately 7,000 - 11,000 elements. A global mesh size of 0.04 m was applied. X-direction mesh layering was applied through the Advanced Mesh Generation Attributes Window to create variable x-direction layers in each 10 cm segment, providing mesh resolution along the direction of the steepest gradient. All applicable fine energy groups of the Transpire46g library were used in each calculation. Diagonal transport correction was applied. The Triangular Chebychev Lobatto quadrature set was used, with the S_N and P_N order given in Table 1. Galerkin scattering treatment was used in all cases. Solver settings were kept at their default values. Attila and MCNP calculations were performed with a total gamma source strength normalized to 1 gamma/second. The MCNP calculations were performed to a statistical uncertainty of 1% or less. Total gamma flux (integrated over all energies) was compared at each of the axial segments.

Results

A section plot of the gamma flux is provided in Figure 1 for Case 11.

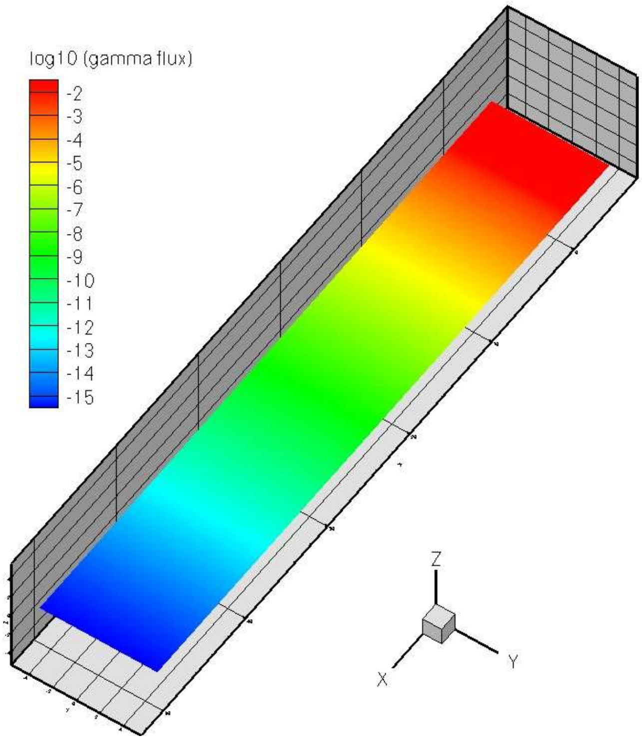

Figure 1: Log_{10} Gamma Flux for 1.33 MeV Gamma Source Incident upon the -x face of a 50 cm Lead Slab

Figures 2-4 show an Attila/Monte Carlo comparison of the gamma flux as a function of depth in the slab for those materials and gamma source energies considered.

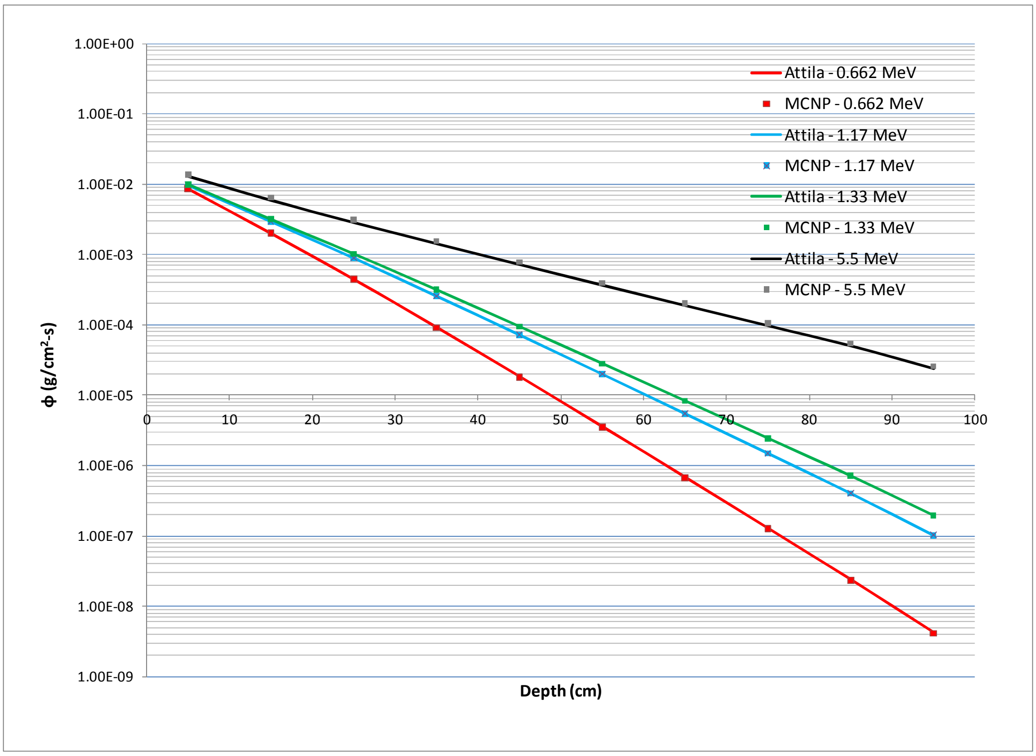

Figure 2: Comparison of Attila and MCNPX for gamma flux as a function of depth for concrete

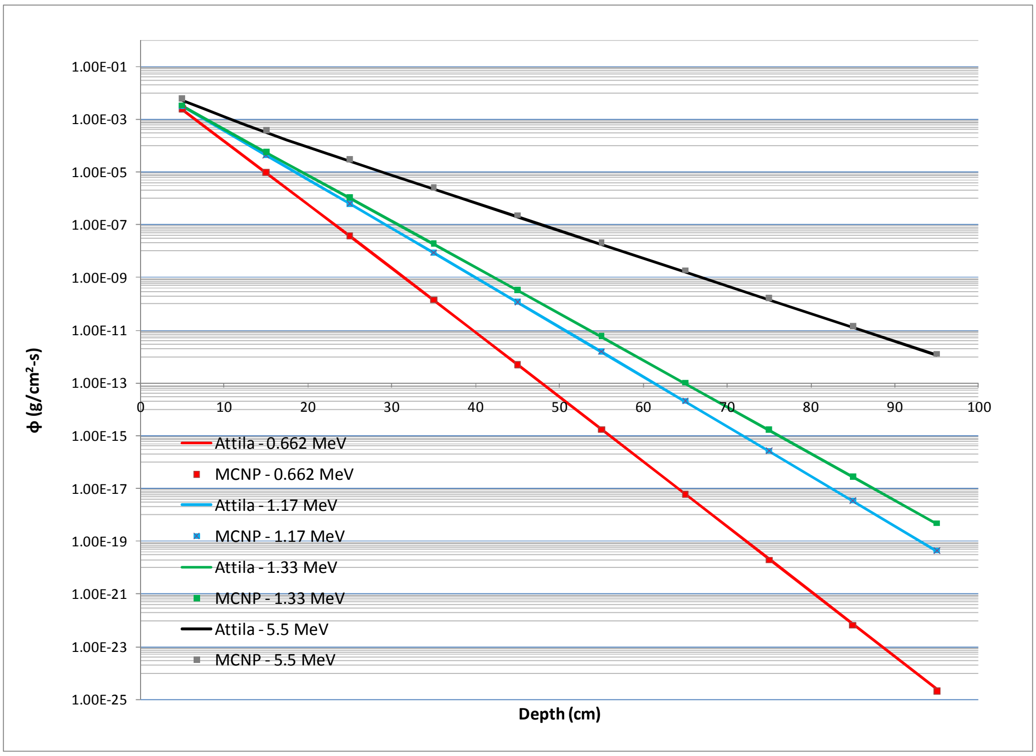

Figure 3: Comparison of Attila and MCNPX for gamma flux as a function of depth for steel

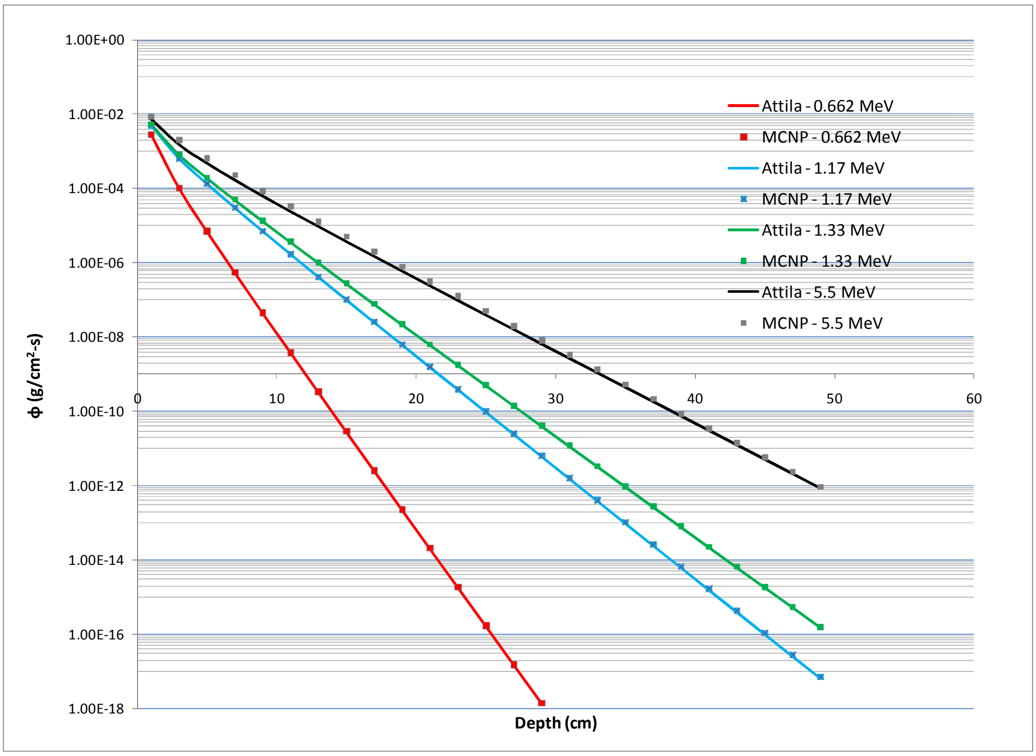

Figure 4: Comparison of Attila and MCNPX for gamma flux as a function of depth for lead

The Transpire46g cross section set was created by CEPXS with no electron coupling which assumes that all energy that would have gone into charged secondaries is deposited locally. This assumption can be significant when considering high-Z materials shielding high energy gammas. These charged secondaries will create high energy gammas through Bremsstrahlung, which will transport from the collision site. By default, MCNP includes the thick target Bremsstrahlung model (TTBM), which approximately accounts for additional gammas which would have been created by charged secondaries for gamma only calculations. Better agreement is achieved for high energy gamma sources in high-Z materials if the TTBM model is excluded in the MCNP simulation, or if gamma-electron coupling is accounted for in the Transpire46g library and in MCNP.

If both MCNP and Attila calculations take into account full gamma-electron coupling, the two solutions approach much better agreement for high energies in high-Z materials. For studies in concrete (Cases 1-4), no significant difference in agreement was achieved accept for the 5.5 MeV case (Case 4), where the largest discrepancy was ~3% with an overall reduction in discrepancy between the two solutions of ~5-8%. For studies in steel (Cases 5-8), no significant difference in agreement was achieved accept for the 5.5 MeV case (Case 8), where the largest discrepancy was ~4% with an overall reduction in discrepancy between the two solutions of ~9-12%. For studies in lead (Cases 9-12), no significant difference in agreement was achieved for the 0.662 MeV case (Case 9). However, for the 1.17 MeV case (Case 10), the largest discrepancy was ~7% with an overall reduction in the discrepancy between the two codes of ~1-3%. For the 1.33 MeV case (Case 11), the largest discrepancy was ~1% with an overall reduction in discrepancy between the two solutions of ~2-3%. For the 5.5 MeV case (Case 12), the largest discrepancy was ~15% with an overall reduction in discrepancy between the two solutions of ~0-23%.