# IMPROVING GEANT4 COHERENT SCATTERING BY ADDING NUCLEAR THOMSON AND DELBRÜCK PROCESSES

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**Introduction:** This paper proposes an improvement to the Geant4 coherent scattering by implementing additional physics processes that are not currently taken into account. Coherent or elastic scattering is treated in Geant4 in a way such that only Rayleigh process (R) is the unique contributor to the entire elastic scattering of gamma rays [1]. However, there are competing processes such as nuclear Thomson (NT) and Delbrück (D) processes which are treated for the first time in the present work.

A significant aspect encountered at implementing elastic scattering simulation is the interference among the different scattering amplitudes of R, NT, and D. Therefore; we prepared the required amplitudes of R based on the scattering matrix calculations [2-3] while D amplitudes are based on the lowest order Born approximation [4].

**Materials and Methods:** With the aid of the G4EmProcess, we drove a new process that handles the elastic scattering simulation in Geant4. In this process, the inverse transform method is used to sample the final states of the scattering interaction based on the differential cross section as the probability distribution function. A two-dimensional array of the differential cross section as a function of the energy and the scattering angle of the photon was built for that purpose [5].

Computational performance of the newly developed process was estimated in comparison with the similar processes in Geant4 such as G4Rayleigh and G4PenelopeRayleigh. Eight timestamps were implemented to measure the time consumed in the initialization phase, $T_i$ as well as the sampling phase, $T_s$. Also, the memory footprint (*MF*) was estimated for our simulation against the available Rayleigh scattering models in Geant4.

We tested our simulation using earlier experimental observations from literature for five elements whose atomic number (*Z*) ranges from 50 to 92.

**Results:** Figure 1 shows angular distributions of elastically scattered gamma rays by five different elements. Histograms resulted from the simulation are overlaid on the same figure. $10^9$ photons could produce good statistics with $\chi^2$ ranging from 0.019 for tin to 0.099 for uranium.

Table 1 demonstrates how the execution time of our simulation is compatible with the simulations of Rayleigh scattering in Geant4. Although our data sizes are larger than the standard data sizes used in Geant4, the execution time of our process is still practical.

The validation tests show that differential cross section is well reproducible for low-*Z* elements. A slight deviation was observed when high-*Z* elements are tested, e.g. $Z$ = 82 and $Z$ = 92. This is probably due to the absence of higher orders calculations regarding D scattering amplitudes [5].

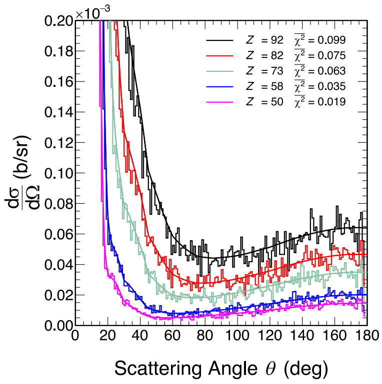


Figure 1. Angular distributions of 2.754 MeV-photons scattered by different elements (histograms). Smooth curves are the differential cross section. Each histogram is normalized to the corresponding differential cross section at 0°.

Table 1: An example of time metrics obtained by our ElasticScattering process in comparison with those obtained by the current Rayleigh processes in Geant4. In this test, $10^7$ photons of 3 MeV are scattered off a lead target.

| Process | $T_i$ (s) | $T_s$ (μs) | *MF* (*MB*) |
|---|---|---|---|
| ElasticScattering | 0.42±0.03 | 2.57±0.06 | 24.3±1.54 |
| G4PenelopeRayleigh-Scattering | 0.43±0.05 | 1.99±0.08 | 21.4±1.04 |
| G4RayeleighScattering | 0.41±0.02 | 2.14±0.09 | 21.3±0.93 |

**Conclusion**: A collective simulation of gamma ray elastic scattering in Geant4 has been implemented taking into account all significant processes contributing to the entire elastic scattering. The simulation covers all elements with the full angular domain and up to 3 MeV.

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**References:**

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