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Determination of the Backscattered Yield Coefficient by Monte Carlo Calculations and Comparison with Experimental Measurements

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Figure 1 shows the variation of the backscattered yield coefficient, η, with the incident electron energy, E, (acceleration voltage) for five elements at low energy (0 to 10 keV). For energy above 10 keV (up to 100 keV), the η is constant with an increase of incident electron energy and the value of η increase with an increase of atomic number. Below 10 keV, the effect of the atomic number can be classified in three ranges: low atomic number (example: 6 for carbon and 13 for aluminum); medium atomic number (example: 29 for copper); high atomic number (example: 47 for silver and 79 for gold). High atomic number elements (figure 1, d and e) are characterized by a fast decrease of η with a decrease of incident electron energy. However, low atomic number elements (figure 1, a and b) present a more complex relation with the incident electron energy, E. They are characterized by an increase with a decrease of E, reach a maximum, and a sharp decrease for very low energy (0 to 1 keV). For medium atomic number (figure 1, c), a mixed effect of the high and low atomic number characterize these elements.

These trends are correctly predicted by two Monte Carlo codes (PENELOPE [2] and CASINO [3]) when compared with experimental measurements [1] as shown in figure 1. These two programs use the same model for electron elastic cross section, Mott cross section, but the cross section are obtain from different calculations. Nevertheless, PENELOPE uses a discrete energy loss model where CASINO uses a continuous energy loss model. Because of the large scatter in the experimental measurements, no assessment on which models give better results can be made. Surprisingly the results from CASINO program are still correct at very low energy (0 to 1 keV), where the continuous energy loss model should be less accurate. This behavior suggests that the electron energy loss is not a predominant factor in the backscattered electron process.

The aim of this study is to understand the physical process that influence the backscattered yield coefficient for all elements and in the energy range used in electron microscopy. With this understanding, theoretical predictions could be made to answer some simple questions like: What is the variation of η with incident electron energy for a compound with low and high atomic number constituents? – What is the effect of a thin film of low atomic number on high atomic number substrate on η?

This study uses four different Monte Carlo codes (PENELOPE [2], CASINO [3], NISTMonte [4], and Win X-ray [5]) to test different physical models and the implementation of these models. These results will be compared with evaluated experimental measurements [1].

References

[1] D. Joy electron solid interaction database: http://web.utk.edu/~srcutk/htm/interact.htm
[2] PENELOPE: http://www.nea.fr/abs/html/nea-1525.html
[3] CASINO: http://www.gel.usherbrooke.ca/casino/
[4] NISTMonte: http://www.duck-and-cover.com/
[5] Win X-ray: http://www.montecarlomodeling.mcgill.ca/

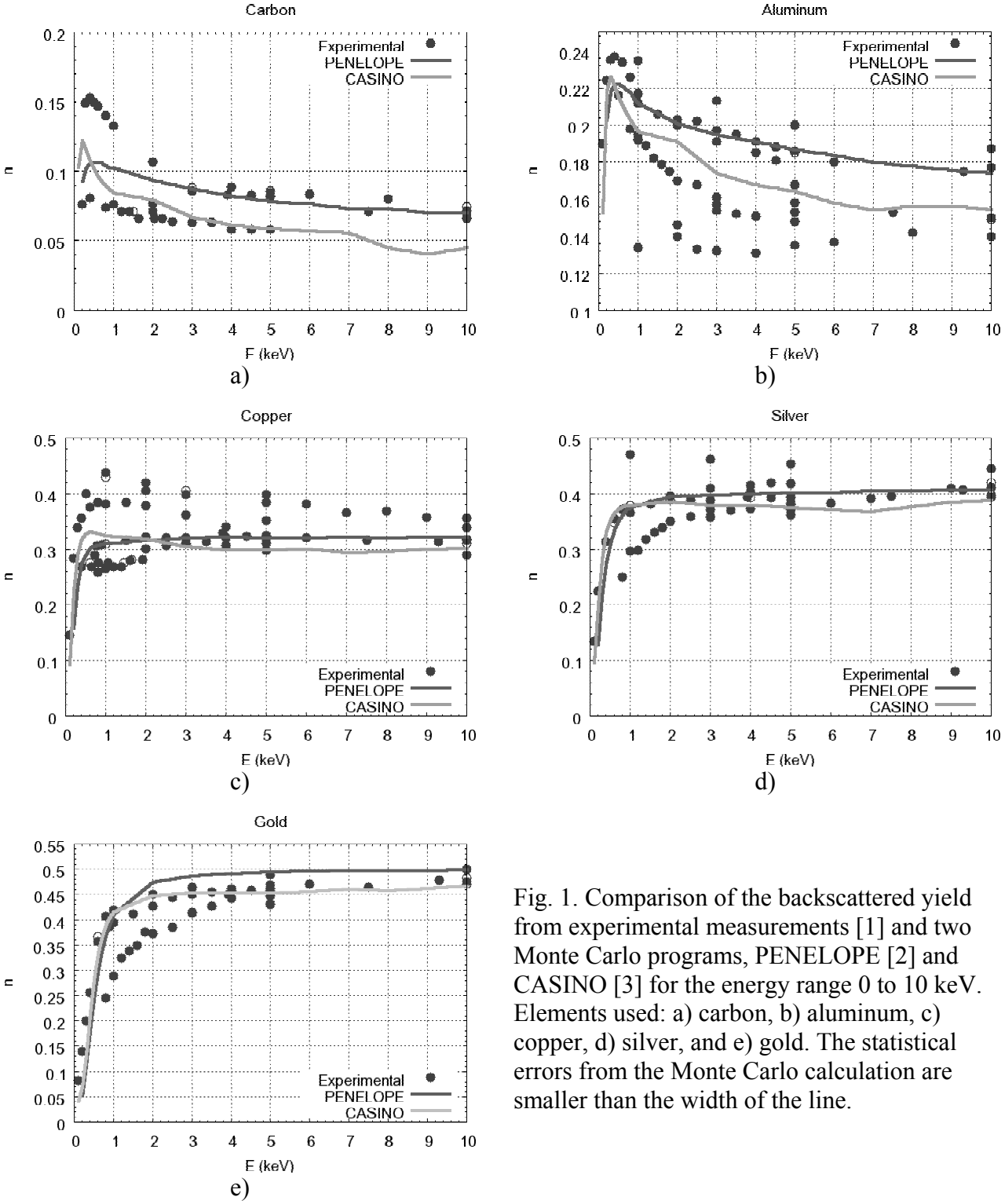

Fig. 1. Comparison of the backscattered yield from experimental measurements [1] and two Monte Carlo programs, PENELOPE [2] and CASINO [3] for the energy range 0 to 10 keV. Elements used: a) carbon, b) aluminum, c) copper, d) silver, and e) gold. The statistical errors from the Monte Carlo calculation are smaller than the width of the line.

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