Electron Energy Backscatter: Systematic comparison of Geant4 9.3 simulation against experimental data

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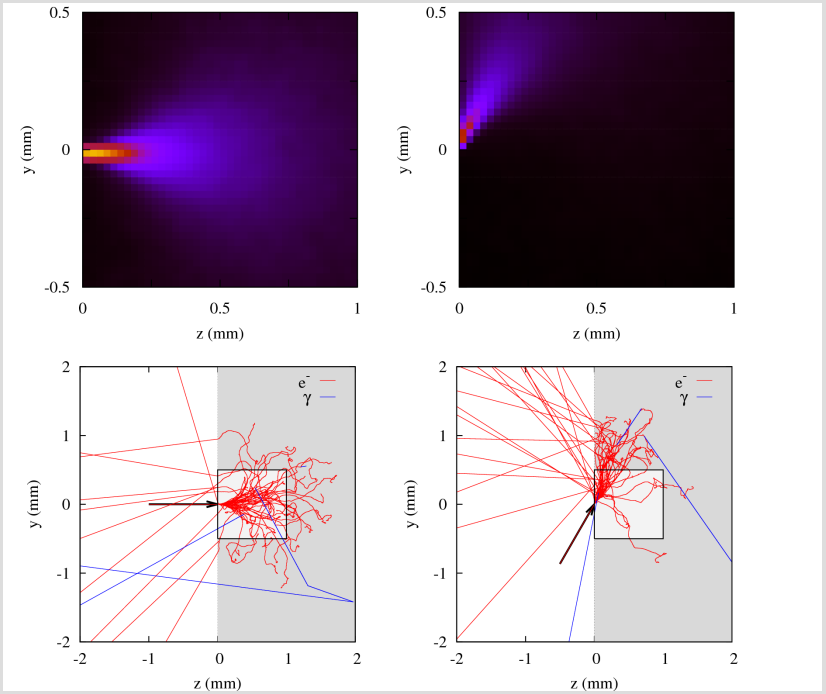
Outline

- Comparison of Geant4 9.3 against exp. electron backscatter data
  - Fraction of incident electron *energy* backscattered from elemental targets
  - Exp. data extracted from Lockwood et al., "*Electron Energy and Charge Albedos – Calorimetric Measurement vs Monte Carlo Theory*", SANDIA Report SAND80-0573 (1984).
- Investigation of different multiple scattering parameters and models
  - Parameters:
    - Range factor
    - Skin
    - Step limit type
  - Models:
    - Urban 93 [1]
    - Urban 92 [1]
    - Goudsmit-Saunderson [2]
- Evaluation of single scattering model



[1] L. Urban, CERN-OPEN-2006-077 (2006).
[2] O. Kadri et al., Nucl. Instr. and Meth. B, 267 (2009), 3624.

A. Impact of MSC parameters

Impact of range factor f_r (`/process/msc/RangeFactor`)

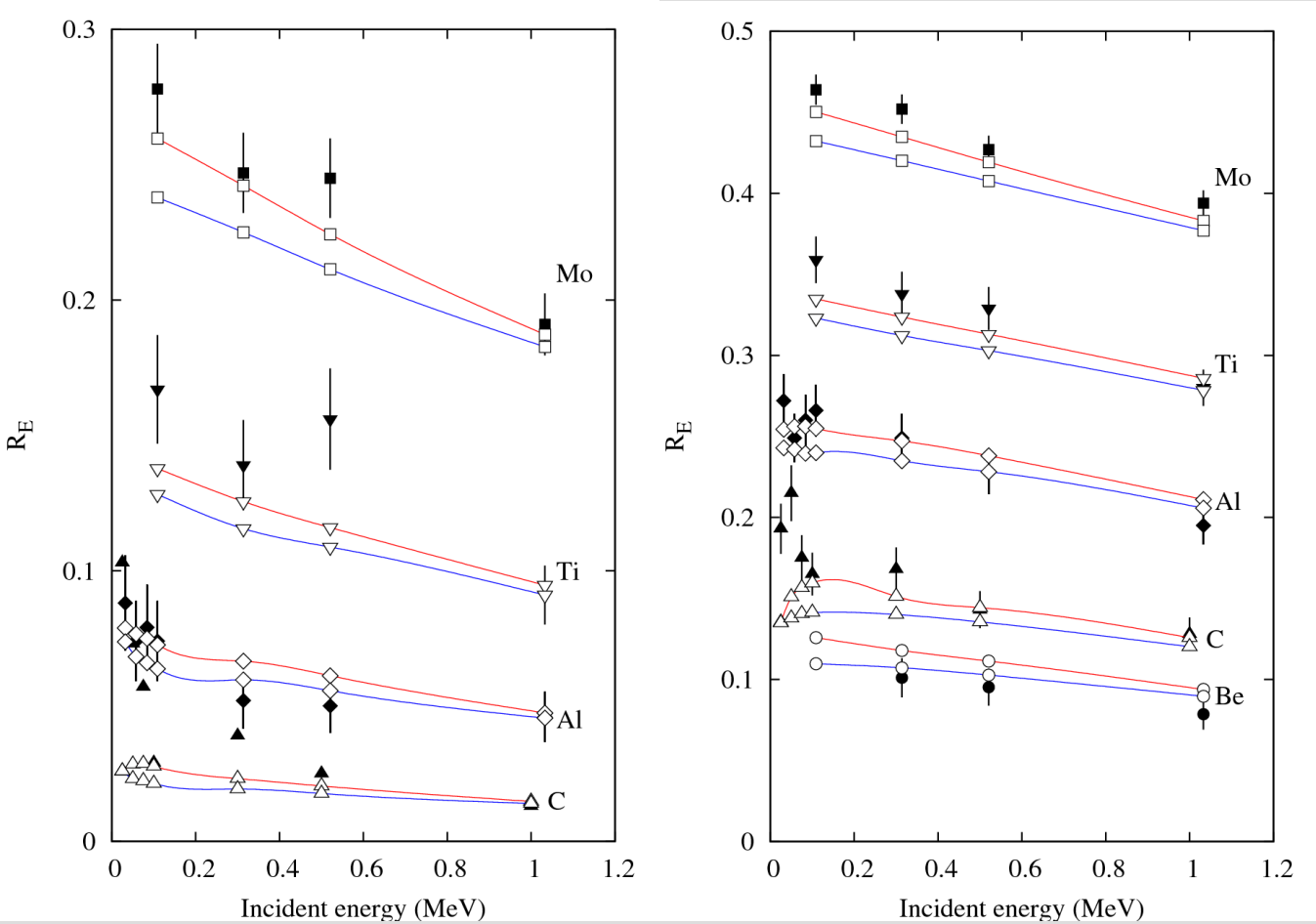


Fig: Fraction of incident electron *energy* backscattered from elemental targets as a function of beam energy, for electrons incident at **0°** (left plot) and **60°** (right plot). Comparison of Geant4 simulation results (open symbols) against experimental data (full symbols). Vertical bars indicate twice the measurement uncertainty.

- MSC: Urban93
  - Step limit type: DistanceToBoundary
  - skin: 3
  - f_g: 2.5
  - f_r: 0.04 or 0.01
- Ioni./Bremsstr.: Livermore
  - T_{cut}: 1 keV
  - Step fkt: 0.2, 100 µm
- Step limiter: None

Blue lines: f_r=0.04

Red lines: f_r=0.01

Impact of skin factor (`/process/msc/Skin`)

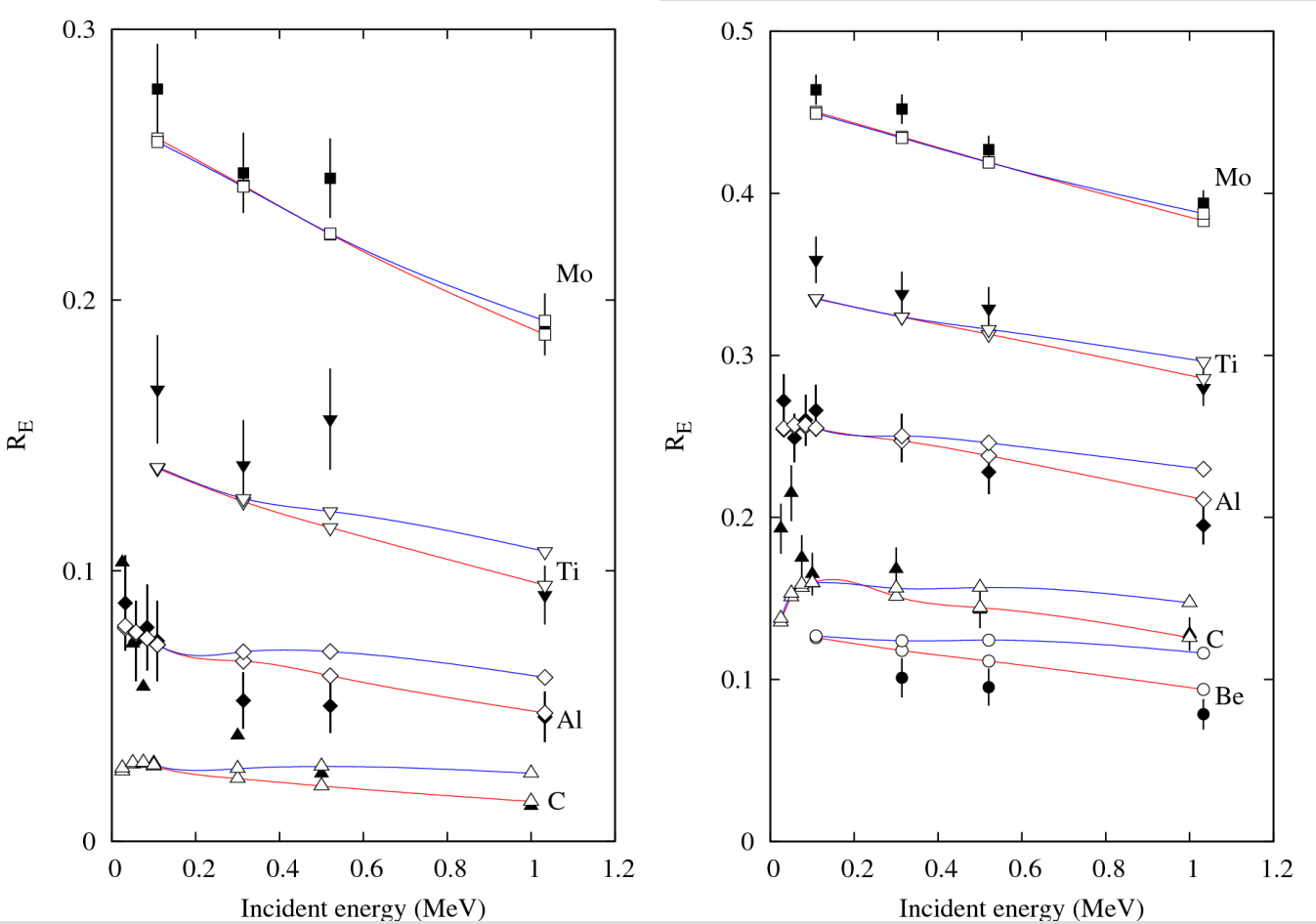


Fig: Fraction of incident electron *energy* backscattered from elemental targets as a function of beam energy, for electrons incident at **0°** (left plot) and **60°** (right plot). Comparison of Geant4 simulation results (open symbols) against experimental data (full symbols). Vertical bars indicate twice the measurement uncertainty.

- MSC: Urban93
  - Step limit type: DistanceToBoundary
  - skin: 1 or 3
  - f_g: 2.5
  - f_r: 0.01
- Ioni./Bremsstr.: Livermore
  - T_{cut}: 1 keV
  - Step fkt: 0.2, 100 µm
- Step limiter: None

Blue lines: skin = 1
Red lines: skin = 3

Impact of step limit type (`/process/msc/StepLimit`)

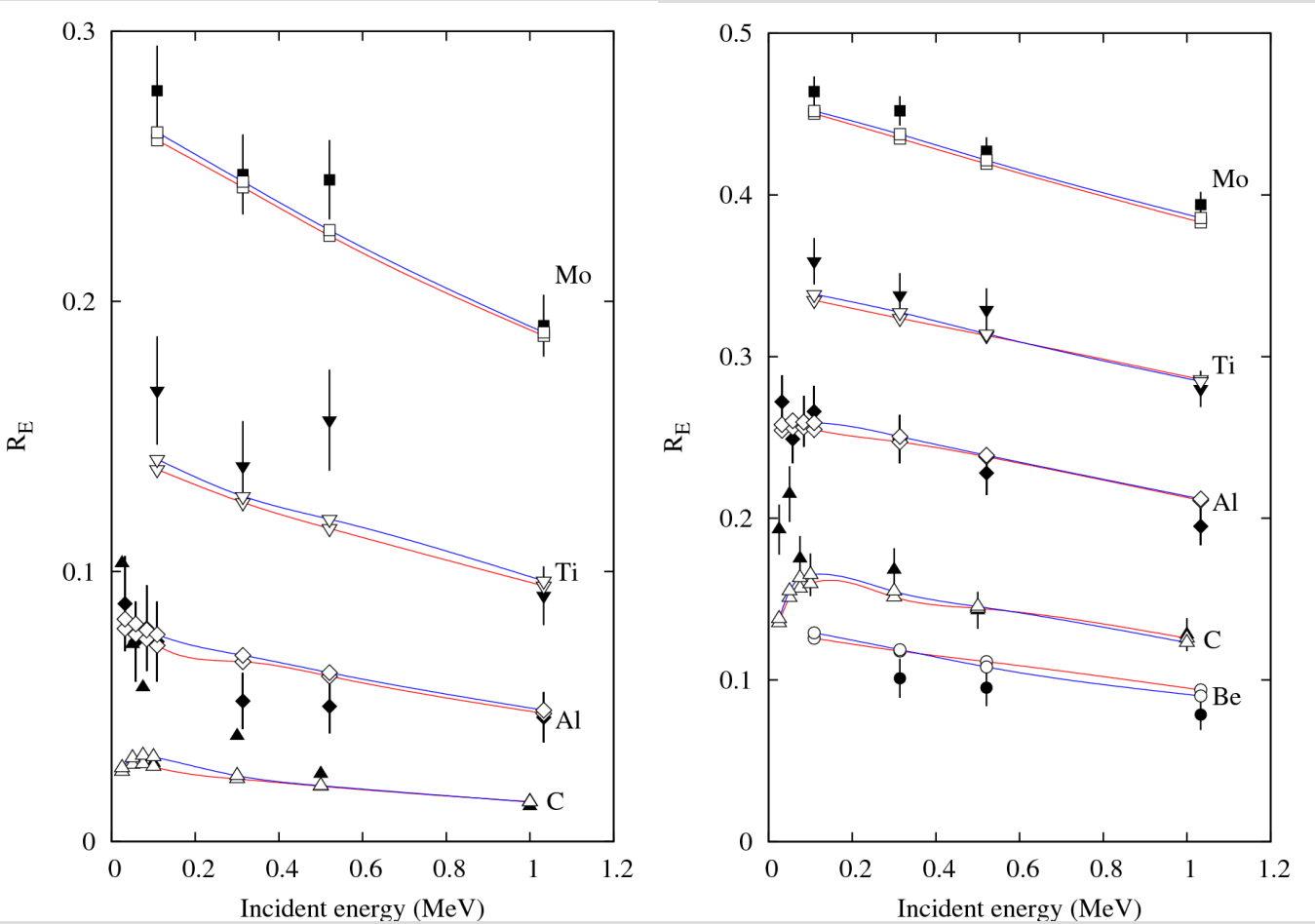


Fig: Fraction of incident electron *energy* backscattered from elemental targets as a function of beam energy, for electrons incident at **0°** (left plot) and **60°** (right plot). Comparison of Geant4 simulation results (open symbols) against experimental data (full symbols). Vertical bars indicate twice the measurement uncertainty.

- MSC: Urban93
  - Step limit type: DistanceToBoundary or Safety
  - skin: 3 (for step type DistanceToBoundary)
  - f_g: 2.5
  - f_r: 0.01
- Ioni./Bremsstr.: Livermore
  - T_{cut}: 1 keV
  - Step fkt: 0.2, 100 µm
- Step limiter: None

Blue lines: Safety
Red lines: DistanceToBoundary

B. Comparison of MSC models

Differences between MSC models

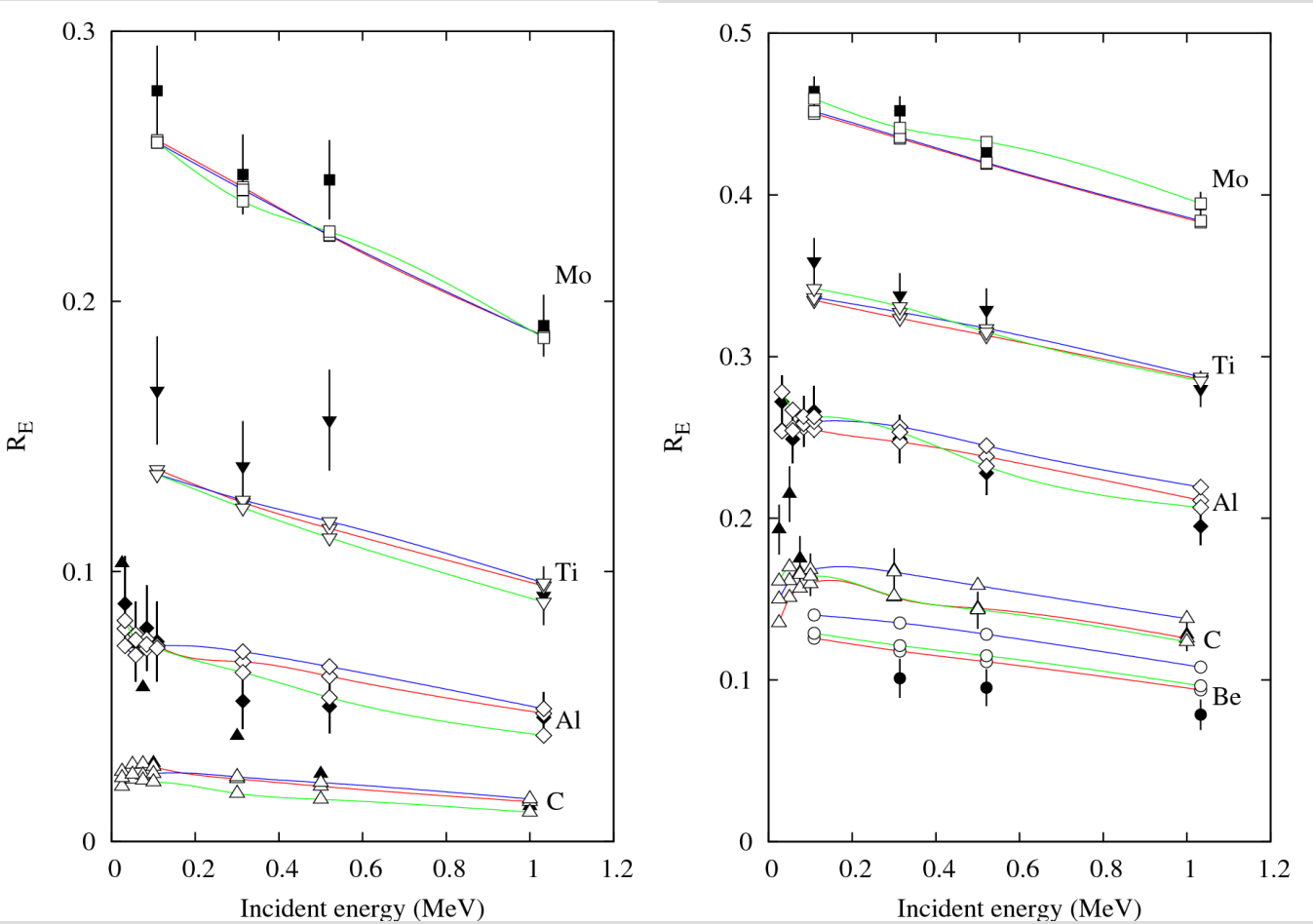


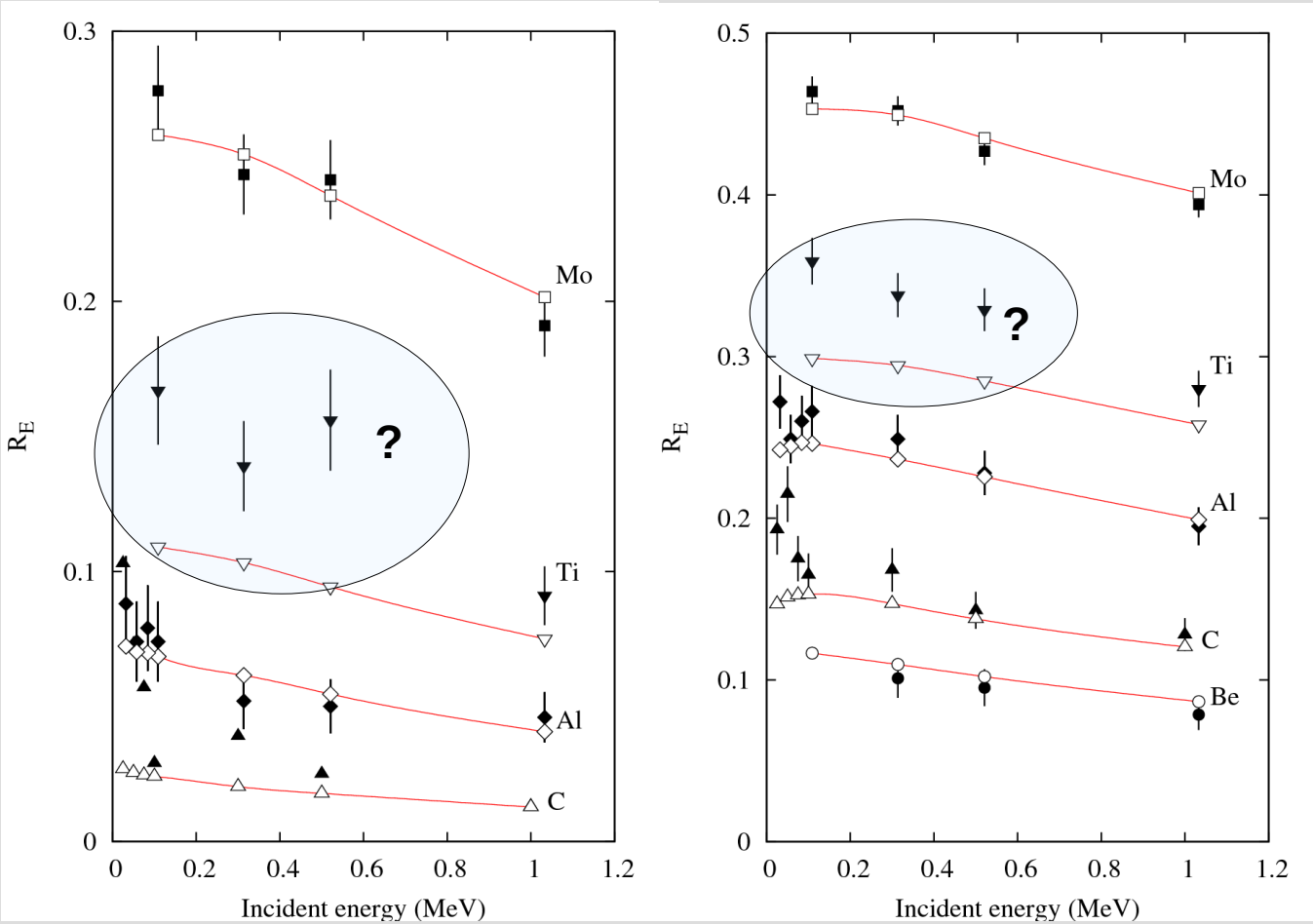
Fig: Fraction of incident electron *energy* backscattered from elemental targets as a function of beam energy, for electrons incident at **0°** (left plot) and **60°** (right plot). Comparison of Geant4 simulation results (open symbols) against experimental data (full symbols). Vertical bars indicate twice the measurement uncertainty.

- MSC: Urban92, Urban93 or GoudsmitSaunderson
  - Step limit type: DistanceToBoundary
  - skin: 3
  - f_g: 2.5
  - f_r: 0.01
- Ioni./Bremsstr.: Livermore
  - T_{cut}: 1 keV
  - Step fkt: 0.2, 100 µm
- Step limiter: None

Blue lines: Urban92
Red lines: Urban93
Green lines: GoudsmitSaunderson

C. Single Scattering (SS) model

Single scattering model



- SSC: eCoulombScattering
- Ioni./Bremsstr.: Livermore
  - T_{cut}: 250 eV
  - Step fkt: 0.2, 100 µm

Fig: Fraction of incident electron *energy* backscattered from elemental targets as a function of beam energy, for electrons incident at **0°** (left plot) and **60°** (right plot). Comparison of Geant4 simulation results (open symbols) against experimental data (full symbols). Vertical bars indicate twice the measurement uncertainty.

Conclusions

- **Range factor** has systematic impact on backscattered energy for all considered incident beam energies
  - Range factor of 0.01 is found to yield considerably better results than the default value in 9.3 (0.04)
- **Skin** value has larger impact when beam energy increases
  - Skin value of 3 (=default in 9.3) gives better results than skin equals 1
- All multiple scattering models yield acceptable results
- Single scattering model predicts accurate results (except for Ti)
  - Restriction arises from CPU requirements

Fraction of *energy* backscattered vs incident angle

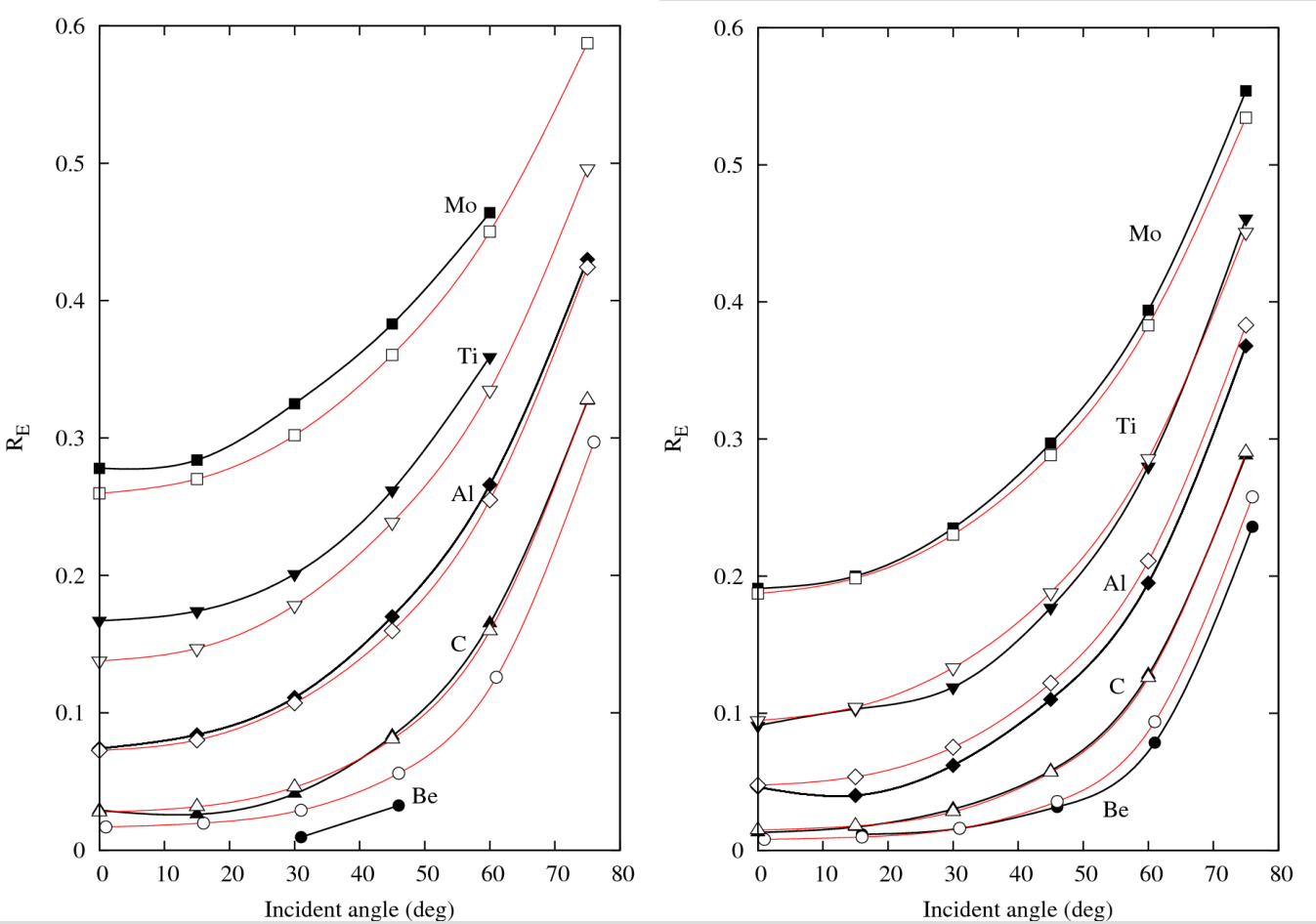
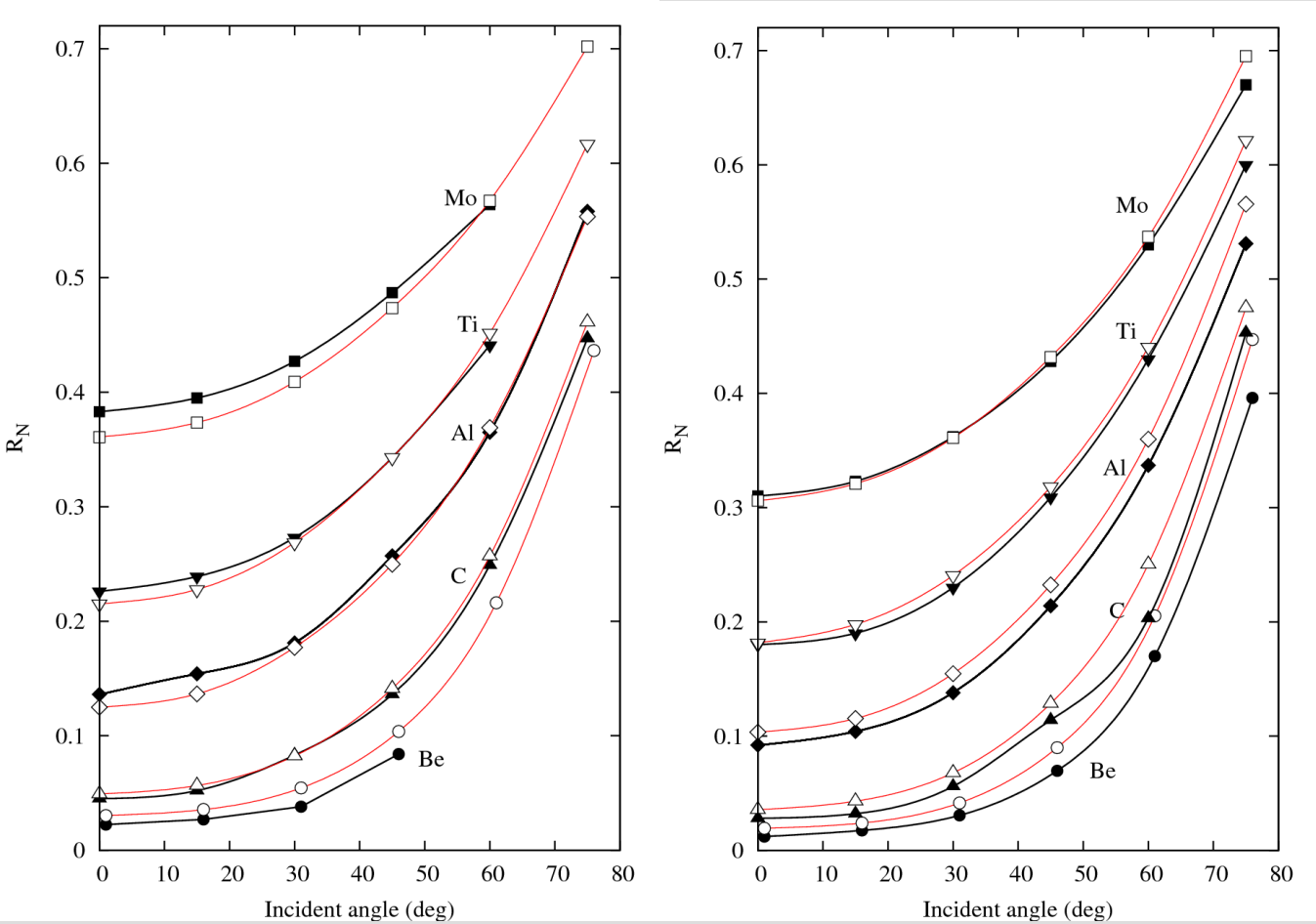


Fig: Fraction of electron *energy* backscattered from elemental targets as a function of incident angle, for electrons beams of **0.1 MeV** (left plot) and **1.0 MeV** (right plot). Comparison of Geant4 simulation results (red lines) against experimental data (black lines).

- MSC: Urban 93
  - Step limit type: DistanceToBoundary
  - skin: 3
  - f_g: 2.5
  - f_r: 0.01
- Ioni./Bremsstr.: Livermore
  - T_{cut}: 1 keV
  - Step fkt: 0.2, 100 µm
- Step limiter: None

Fraction of *electrons* backscattered vs incident angle



- MSC: Urban 93
  - Step limit type: DistanceToBoundary
  - skin: 3
  - f_g: 2.5
  - f_r: 0.01
- Ioni./Bremsstr.: Livermore
  - T_{cut}: 1 keV
  - Step fkt: 0.2, 100 µm
- Step limiter: None

Fig: Fraction of *electrons* backscattered from elemental targets as a function of incident angle, for electrons beams of **0.1 MeV** (left plot) and **1.0 MeV** (right plot). Comparison of Geant4 simulation results (red lines) against experimental data (black lines).