Electron Hard Scattering in FRENSIE

Luke J. Kersting
NEEP
University of Wisconsin - Madison
FRENSIE Meeting

May 11, 2015

Introduction

- Simulation of hard electron transport events
- Atomic excitation events
- Hard elastic scattering events
- Electroionization events
- Bremmstrahlung events

Electron Transport in Monte Carlo Codes

MCNP

- Historically has only used a condensed-history approched with mutiple scattering techniques.
- MCNP6 implemented a single-event method for energies below 1 keV, were the condensed-history method no longer holds.

Penelope

- Implenments a mixed method that simulates soft (condensed-history) events below a cutoff energy/angle and hard (single-events) above.

Frensie

- Ultimately working towards implementing a mixed method while using the cross-sectional data from MCNP6 for hard events

Atomic Excitation

- There is no angular deflection.
- There are no secondary particles.
- Energy dependent electron energy loss are tabulated in ACE tables.
- No sampling is required for this process.

Hard Elastic Scattering

- There is no energy loss.
- There are no secondary particles.
- ACE tables provide histogram CDF of the outgoing angle cosine, μ, for $14-16$ energy groups.
- for $\mu > 0.999999$ an analytical function, $f(\mu)$, is used to compute the scattering angle

$$f(\mu) = \frac{A}{(\eta + 1 - \mu)^2}$$

$$\eta(E, Z) = \frac{1}{4}\left(\frac{\alpha mc}{0.885p}\right)^2 Z^{2/3}[1.13 + 3.76(\alpha Z/\beta)^2]$$

Electroionization

- The subshell is directly sampled.
- A knock-on electron is ejected.
- ACE tables provide CDF of the knock-on energy, E_{knock}, based on the incident electron energy.
- The incident electron energy is reduced by the $E_{knock} + E_{binding}$.
- Conservation of momentum is used to find the scattering and ejection angles (need to double check).
- Vacancy will be filled using atomic relaxation data (still need to implement).

Electroionization Scattering Angle

- Conservation of Momentum

$$(p_{knock}c + p_a c)^2 = (pc)^2 + (p'c)^2 - 2pp'cos(\theta)$$

$$(pc)^2 + (p'c)^2 - 2pp'cos(\theta) = (p_{knock}c)^2 = E_{knock}^2 - (m_{knock}c^2)^2$$

- Conservation of Energy

$$T + m_e c^2 + M_a c^2 = T' + m_e c^2 + T_a + M_a' c^2 + T_k nock + m_e c^2$$

$$T = T' + T_{knock} + E_{binding} = T' + W$$

Bremmstrahlung

- A photon is ejected.
- ACE tables provide CDF of the photon energy, E_γ, based on the incident electron energy.
- The incident electron energy is reduced by the E_γ.
- The electron direction is assumed to be essentially unchanged.
- For $1keV < E_\gamma < 1GeV$ the direction of the photon is sampled using a table based scheme from the condensed-history method (still need to implement).
- For all other energies a analytical function, $p(\mu)$, is used (not really appropriate for low energies).

$$p(\mu)d\mu = \frac{(1-\beta^2)}{2(1-\beta\mu)^2}d\mu$$

Conclusion

- Once finished Frensie should be capable of forward electron transport below 1 keV.
- The ACE tables has cross-sectional data for energies between 10 eV and 100 GeV, but bin sizes may be too course for used above 1 keV.
- Next step is to implement condensed-history method.