Update: Electron Mode in FRENSIE

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February 18, 2015

Outline

Electron Mode

- Single Scattering Events from 100 GeV to 10 eV
- Elastic, Bremsstrahlung, Electroionization, Atomic Excitation
- Secondary particles created, but photons not tracked
- Atomic relaxation implemented

Adjoint Papers

- Hybrid Multigroup/Continuous-Energy Monte Carlo using Boltzmann-Fokker-Planck Equation
- Discrete Scattering Angles and Discrete Energy Losses

Electron Mode

Capabilities

- Single Scattering Events from 100 GeV to 10 eV
- Elastic, Bremsstrahlung, Electroionization, Atomic Excitation
- Secondary particles created, but photons not tracked
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Problems

- Absorption at low energies
- Negative energy from Electroionization

Absorption at low energies

- At energies near the cutoff (10 eV) the reaction cross section is dominated by elastic scattering (by order 10^7 for H)
- It is unlikely the electron will scatter below the cutoff energy
- A temporary fix is to raise the cutoff energy (to 15eV for H) to prevent indefinite elastic scattering
- No mention of this issue in MCNP or Penelope

Negative energy from Electroionization

- ACE tables provide CDF of the knock-on energy, E_{knock}, based on the incident electron energy.
- When the incident electron energy is between two tables a weighted random variable is used to chose the appropriate table
- This can result in a E_{knock} that is larger than physically possible
- In this case the energy of incident electron is reduce to $1E{-}15$
- MCNP avoids this by interpolation between tables, which is more computationally expensive

Next Step

Testing

- Run tests in MCNP and FRENSIE for comparison
- Start with Hydrogen spheres

Possible Further Work

- Create testing mode were no secondary particles are created
- Implement other options for the bremsstrahlung photon ejection angle

Hybrid Multigroup/Continuous-Energy Monte Carlo

Boltzmann-Fokker-Planck Equation

$$\Omega \cdot \nabla \psi + \sigma_t \psi = \int_0^\infty \int_0^{2\pi} \int_{-1}^{+1} \sigma_s(E' \to E, \mu_0) \times \psi(\mu', \phi', E') d\mu' d\phi' dE' + \frac{\alpha}{2}\left\{ \frac{\partial}{\partial \mu}\left[(1-\mu^2)\frac{\partial \psi}{\partial \mu}\right] + \frac{1}{1-\mu^2}\frac{\partial^2 \psi}{\partial \phi^2} \right\} + \frac{\partial}{\partial E}[S\psi] + Q$$

Modify Angular Fokker-Planck Operator

- Replace $F_\alpha \psi = \frac{\alpha}{2}\left\{ \frac{\partial}{\partial \mu}\left[(1-\mu^2)\frac{\partial \psi}{\partial \mu}\right] + \frac{1}{1-\mu^2}\frac{\partial^2 \psi}{\partial \phi^2} \right\}$
- With $B_\alpha \psi = \int_0^{2\pi} \int_{-1}^{+1} \sigma_a(E, \mu_0) \psi(\mu', \phi', E) d\mu' d\phi' - \sigma_a \psi$
- Where $B_\alpha \psi = F_\alpha \psi$ in the limit as $\mu_s \to 1$
- Assume error from high-order flux moments are small with highly forward-peaked scattering (holds for condensed history where the scale lengths are large compared to mfp)

Hybrid Multigroup/Continuous-Energy Monte Carlo

Hybrid Multigroup/Continuous-Energy Approximation

Replace the Stopping Power, S with $\tilde{S}$

$$\tilde{S}(E) = \sum_{g=1}^{N} S_g B_g(E)$$

Where

$B_g(E) = 1.0, \quad \text{for} \quad E \in (E_{g+1/2}, E_{g-1/2}) \quad \text{else } B_g(E) = 0.0$

S_g is the weighted group average of $S(E)$ using Radau quadratures

Legendre Cross-Section Expansion

- Replace S with $\tilde{\mathrm{S}}$
- Where $B_\alpha \psi = F_\alpha \psi$ in the limit as $\mu_s \to 1$
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