

Parallel Session IX: Multiple Scattering

- O.Kadri Incorporation of Goudsmit-Sunderson electron transport theory into Geant4 (was not presented)
- L.Urban (M.Maire) Multiple scattering model upgrade
- J.Perl MSC benchmarking
- Discussion on MSC configuration

O.Kadri Introduction

Multiple scattering « process » of e-/e+ through matter is mainly described with a group of theoretical models of :

- Angular distribution
- Displacement sampling
- Path length limitation

The G4GoudsmitSaunderson model use:

- Goudsmit-Saunderson → Angular distribution
- I. Kawrakow and A. Bielajew → Lewis moments → Displacement sampling
- L. Urban → Path length limitation
- L.Urban → Step Limitation

As a first step the following energy-dependent parameters should be correctly implemented:

- Total elastic cross section
- First transport cross section

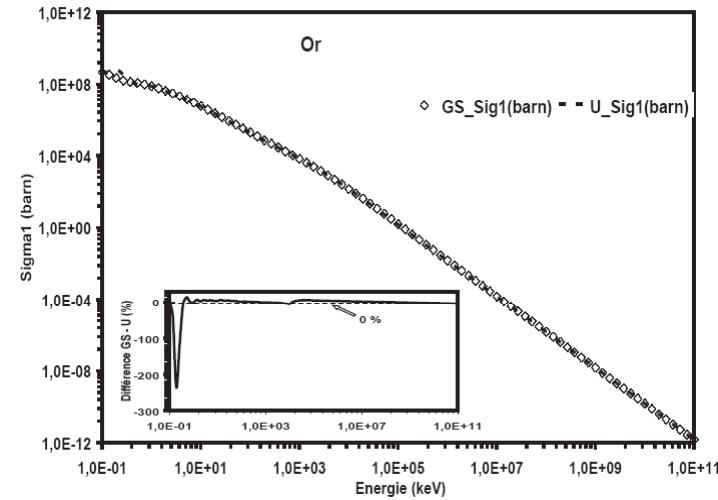
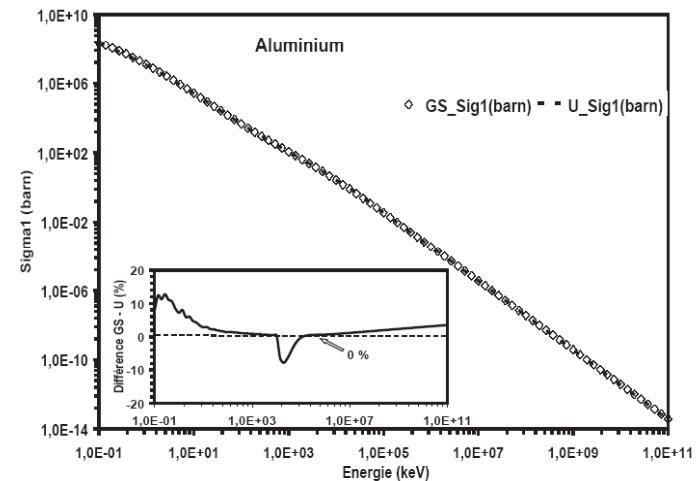
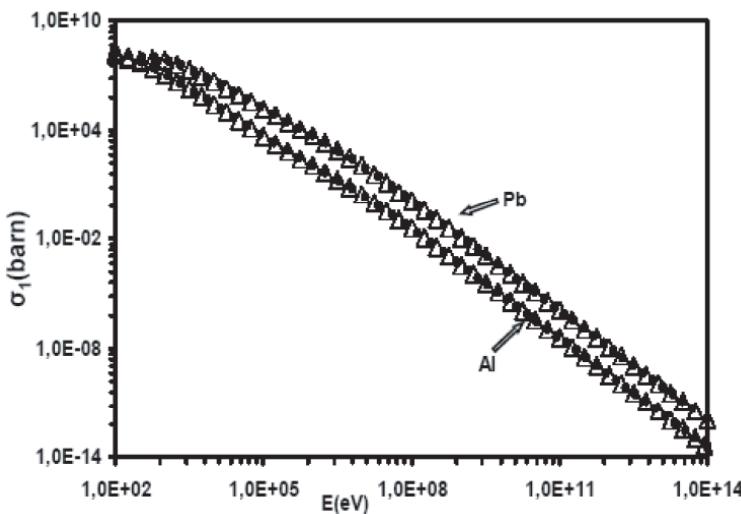


Cross section DB

From the ELSEPA code (Salvat et al.),
a cross section DB was generated covering:

- Z (1-103)
- E(0.1 keV – 1 GeV)
- e-/e+

- Cubic spline for interpolation in log-log
- linear log-log for extrapolation ($E > 1\text{GeV}$)



Figures show a comparison between Xsections of the GSModel and those of Urban → good agreement for E between (1 keV-1GeV) for all elements



Angular sampling

GS PDF
(probability density function) →

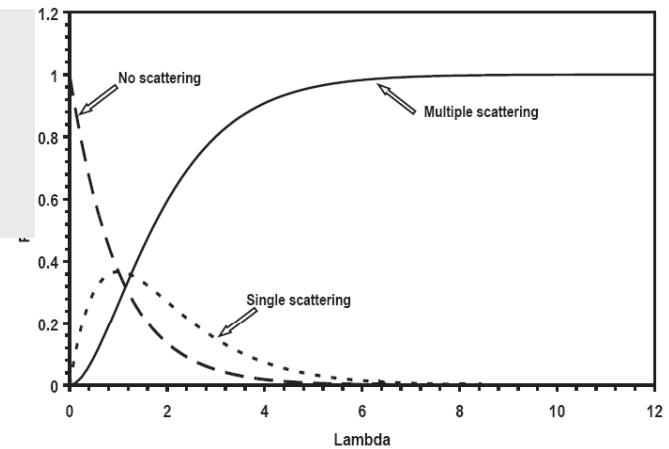
$$F_{GS}(\theta, s) = \sum_{l=0}^{\infty} (l + 1/2) e^{-sQ_l} P_l(\cos(\theta))$$

$$Q_l = 1 - y K_1(y) \left\{ 1 + 0.5y^2 \left\{ 1 + \frac{1}{2} + \dots + \frac{1}{l} - 0.5 \ln(l(l+1)) - 0.5772 \right\} \right\} \quad y = 2\sqrt{l(l+1)A}$$

A:screening parameter

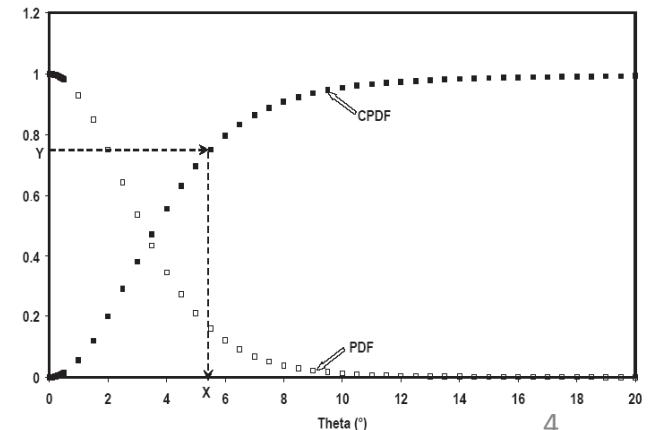
$$F_{GS}(\theta, s) = \exp^{-s} \delta(1 - \cos(\theta)) + s \exp^{-s} f_1(\theta)$$

$$+ (1 - s - s \exp^{-s}) \sum_{l=0}^{\infty} (l + 1/2) \frac{\exp^{-sQ_l} - [1 + s(1 - Q_l)] \exp^{-s}}{1 - (1 + s) \exp^{-s}} P_l(\cos(\theta))$$



No, simple and multiple scattering probabilities

Lambda (path length in terms of mean free path)



Illustrative example for the inverse cumulative method used to generate angular sampling



Angular sampling

The look-up table (angular distributions DB):

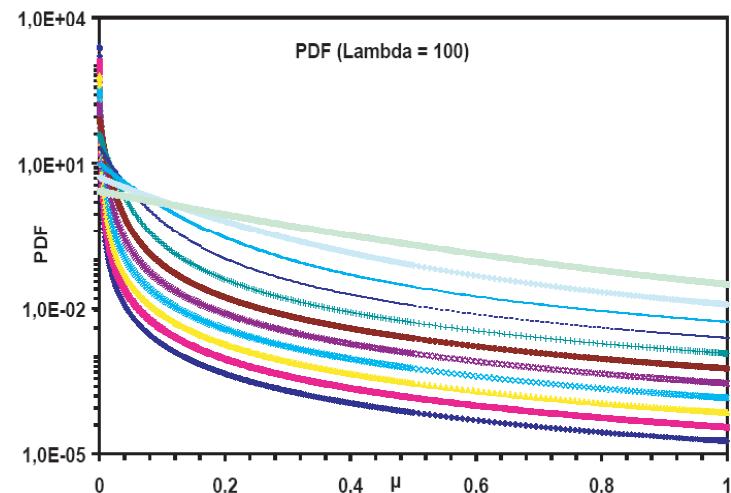
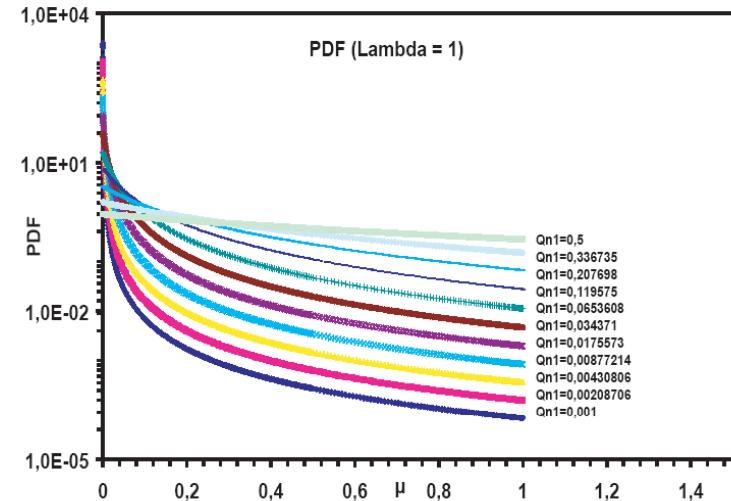
- 76 values of Lambda covering 1- 10^5
- 11 dynamic values of A
- 320 values of theta

→ Dynamic value: covering the range of Q1 from 0.001 to 0.5

$Q_1 < 0.001 \rightarrow$ small angle approximation (exponential distribution)

$Q_1 > 0.5 \rightarrow$ isotropic distribution

Figures are part of the DB
For lambda=1 and 100 as examples



L.Urban talk – description of recent modifications for electron scattering

The parameter a was chosen according to a modified Highland-Lynch-Dahl formula for the width of the angular distribution

$$a = \frac{0.5}{1 - \cos(\theta_0)} \quad (5)$$

where θ_0 is

$$\theta_0 = \frac{13.6 \text{ MeV}}{\beta c p} z_{ch} \sqrt{\frac{t}{X_0}} \left[a_1 + a_2 \ln \left(\frac{t}{X_0} \right) \right] \quad (6)$$

where p , βc and z_{ch} are the momentum, velocity and charge number of the incident particle, t/X_0 is the true path length in radiation length units. Here the parameters a_1 and a_2 are function of the target atomic number (Z) only. (In the Highland formula $a_1 = 1$, $a_2 = 0.038$)

TUNING : try to choose a_1 , a_2 in such a way that MC results reproduce the width of the measured angular distributions.

Tuning of the Urban model

this tuning can be done independently from the d tuning for a thin layer and using 1 step to cross the layer Using the classical measurements of Hansen et al. (15.7 MeV e- in Be,Au) and of Latyshev at al (2.25 MeV e- in Al,Fe,Cu,Mo,Ag,Ta,Au and Pb)

in model2 we got

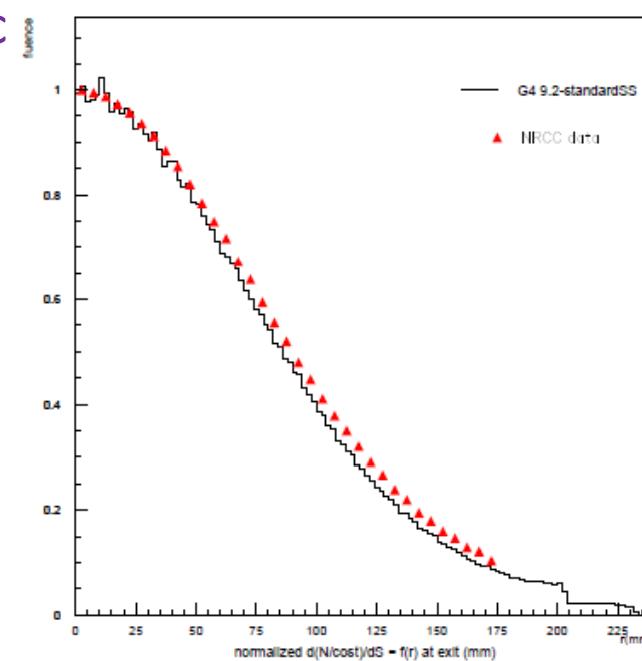
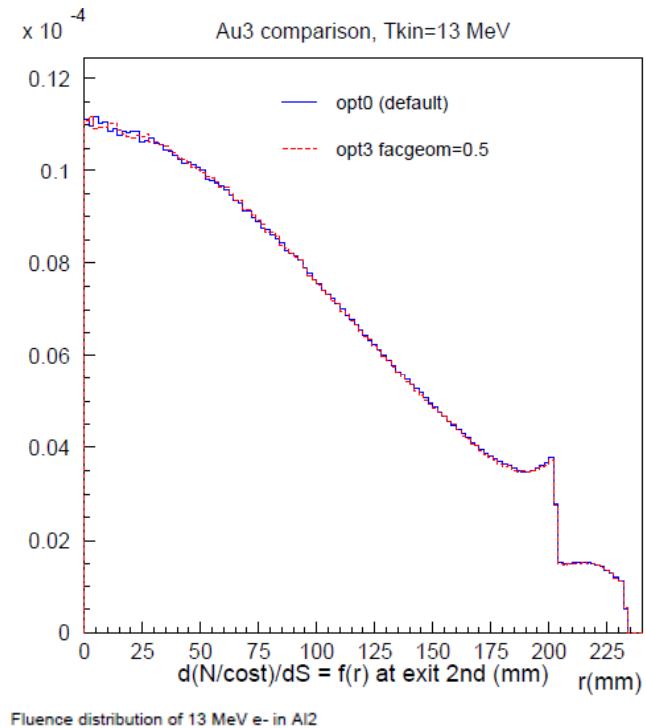
$$a_1 = \left(1 - \frac{0.08778}{Z}\right) * (0.87 + 0.03 * \ln Z) \quad (7)$$

$$a_2 = (0.04078 + 0.00017315 * Z) * (0.87 + 0.03 * \ln Z) \quad (8)$$

Electron benchmark

J.Perl

- New electron msc benchmark results B.A.Faddegon, I.Kawrakov, Yu.Kubyshin, J.Perl, J.Sampau, L.Urban Phys.Med.Biol. 54 (2009) 6151
- Detailed data for electron scattering at 13 – 20 MeV
- Geant4 9.2 is not bad but EGSnrc and Penelope statistically better
- See details in J.Perl talk
- New examples *electronScattering* are released (traditional scoring versus G4Scorer facility)



Discussion on MSC options

- To avoid user confusions it is proposed to use processes per particle type:
 - G4eMultipleScattering for e^\pm
 - G4MuMultipleScattering for μ^\pm
 - G4hMultipleScattering for hadrons and ions
- Mark *G4MultipleScattering* process as an obsolete99
- Rename Urban models
 - G4UrbanMscModel92 – use in default and Opt1
 - G4UrbanMscModel93 – in all others