Geant4 models for simulation of multiple scattering

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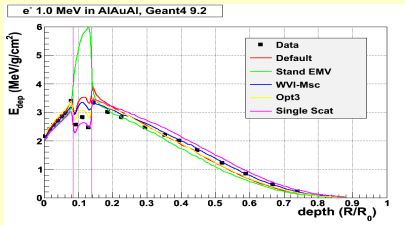
The process of multiple scattering (MSC) is an important component of Monte Carlo transport. At high energy it defines deviation of particles from ideal tracks and limitation of spatial resolution. MSC of low-energy electrons defines energy response and resolution of HEP calorimeters. The original Geant4 model (Urban 2006) based on Lewis approach and is tuned to the available data. As an alternative a number of new scattering models have been developed using theories established for Penelope and EGSnrc codes. The purpose of the new developments was to reach maximum accuracy of Geant4 particle transport for different applications (calorimetry, low-density media, thin layers, very high energies, scattering in high magnetic field).

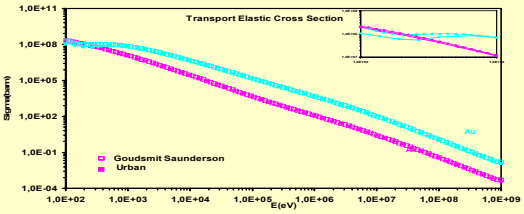


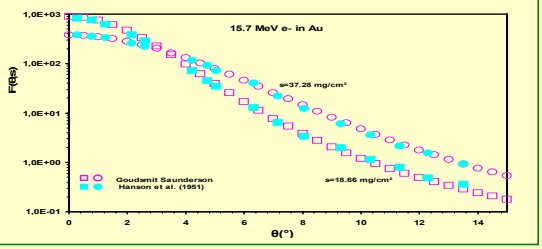
Dose deposition profile in Al with thin Au layer inside

Model	Particle type	Energy limit	Specifics and applicability
Urban (Urban 2006)	any	-	Default model, (Lewis1950) approach, tuned to data, LHC production
Screened Nuclear Recoil (Mendenhall and Weller 2005)	p, ions	< 100 MeV/A	Theory based, providing simulation of nuclear recoil for sampling of radiation damage, focused on space applications
Goudsmit-Saunderson-Kawrakov (new)	e^+, e^-	< 1 GeV	Theory based cross sections (Goudsmit and Saunderson 1950), final state using EGSnrc method (Kawrakov et al. 1998), precise electron transport
Coulomb Scattering (new)	any	-	Theory based (Wentzel 1927) single scattering model, uses nuclear form-factorsfor high energy (Butkevich et al. 2002)
WentzelVI (new)	any	-	MSC for small angles, Coulomb Scattering (WEntzel 1927) for large angles, focused on simulation for muons and hadrons

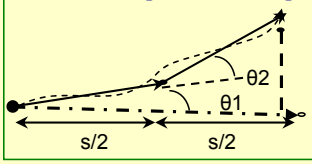
Goudsmit-Saunderson-Kawrakov MSC model

Using the ELSEPA code (Salvat et al. 2001), a **data base** of σ_0 (total) and σ_1 (transport) was generated. Taking into account that the cross section depends on the particle type, the energy of and the atomic number of a target, this DB covers all elements Z<103 and the energy range of 100eV-1GeV for electrons and positrons. The right upper plot demonstrates a good agreement between Urban and Goudsmit-Saunderson-Kawrakov models for σ_1.





Using the EGSnrc procedure (Kawrakow et al. 1998), each simulation step is splitted into two sub-steps. The same procedure is used in the WentzelVI model.



For sampling of the final state the probability density function is used in a form (Goudsmit and Saunderson 1940):

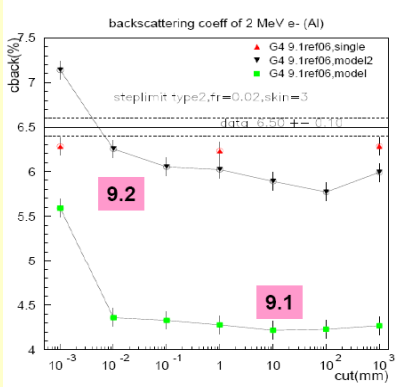
$$F(\mu,\lambda) = e^{-\lambda}\delta(\mu) + \lambda e^{-\lambda}\frac{A(1+A)}{2(A+\mu)^2} + (1-e^{-\lambda}(1+\lambda))\sum_{l=0}^{\infty}(l+\frac{1}{2})P_l(1-2\mu)\left(\frac{e^{\lambda g_l}-1-\lambda g_l}{e^{\lambda}-1-\lambda}\right)$$

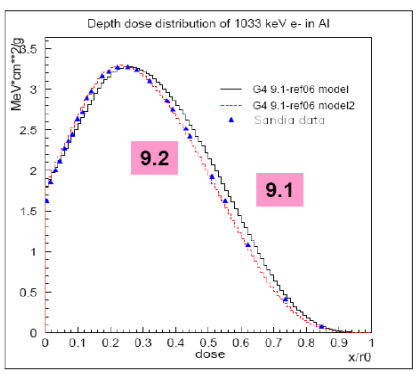
A - screening parameter, λ – transport mean free path.

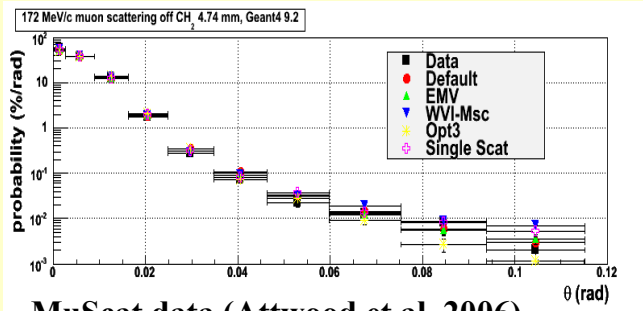
Validation of MSC models

Comparisons with the data and single scattering model

Upgrade of the Urban model for Geant4 9.2: shower profile is sensitive to low-energy electron transport







MuScat data (Attwood et al. 2006)