Recent progress of

Geant4 electromagnetic physics

for LHC and other applications

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Abstract

We report on recent progress of the Geant4 electromagnetic (EM) physics sub-packages. A number of new interfaces and models recently introduced are already used in LHC applications and may be useful for any type of simulation.

Significant developments were carried out to improve the user interface, develop models of single and multiple scattering, and validate high energy models relevant to LHC and FCC. The upper limit of EM models was extended from 10 TeV to 100 TeV.

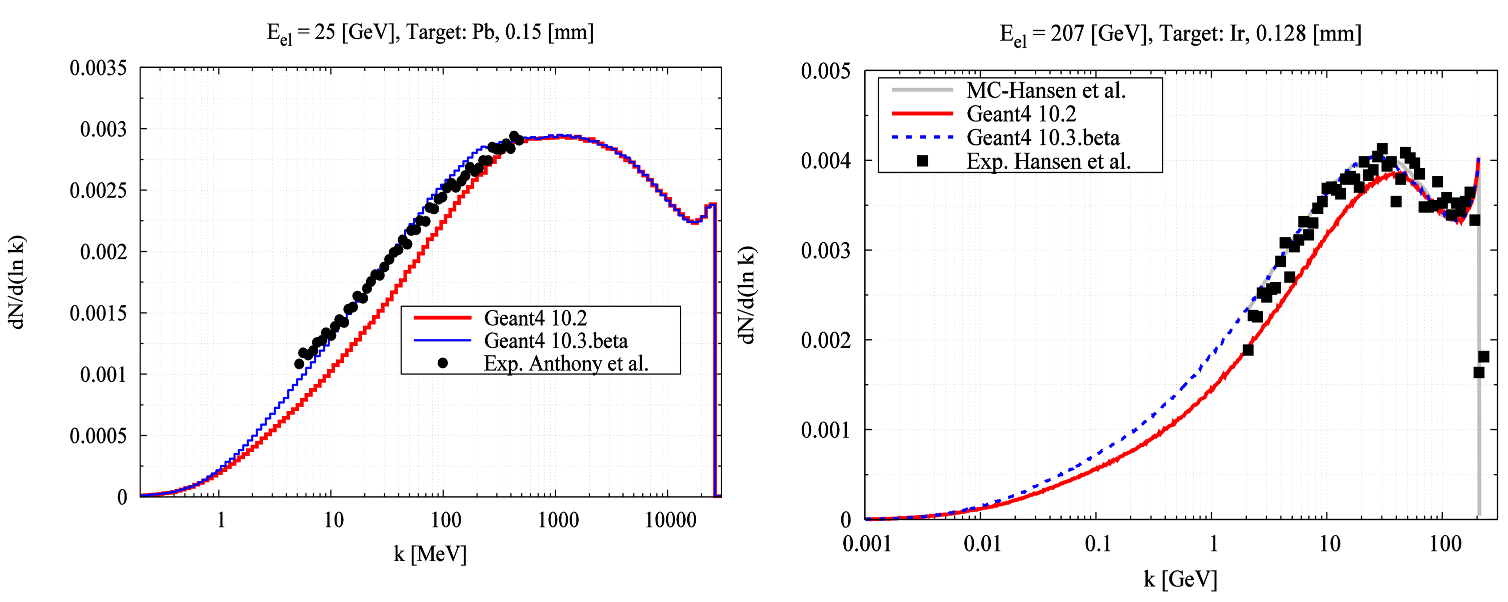
Improvements were also recently made in low-energy EM models, which may be of interest to various application domains. In particular, the possibility of simulating full Auger cascades and a new version of polarized Compton scattering were added.

Part of these developments are included in the recent Geant4 10.2 release and the full set will be available in the new version 10.3 (December, 2016).

EM sub-packages infrastructure upgrades

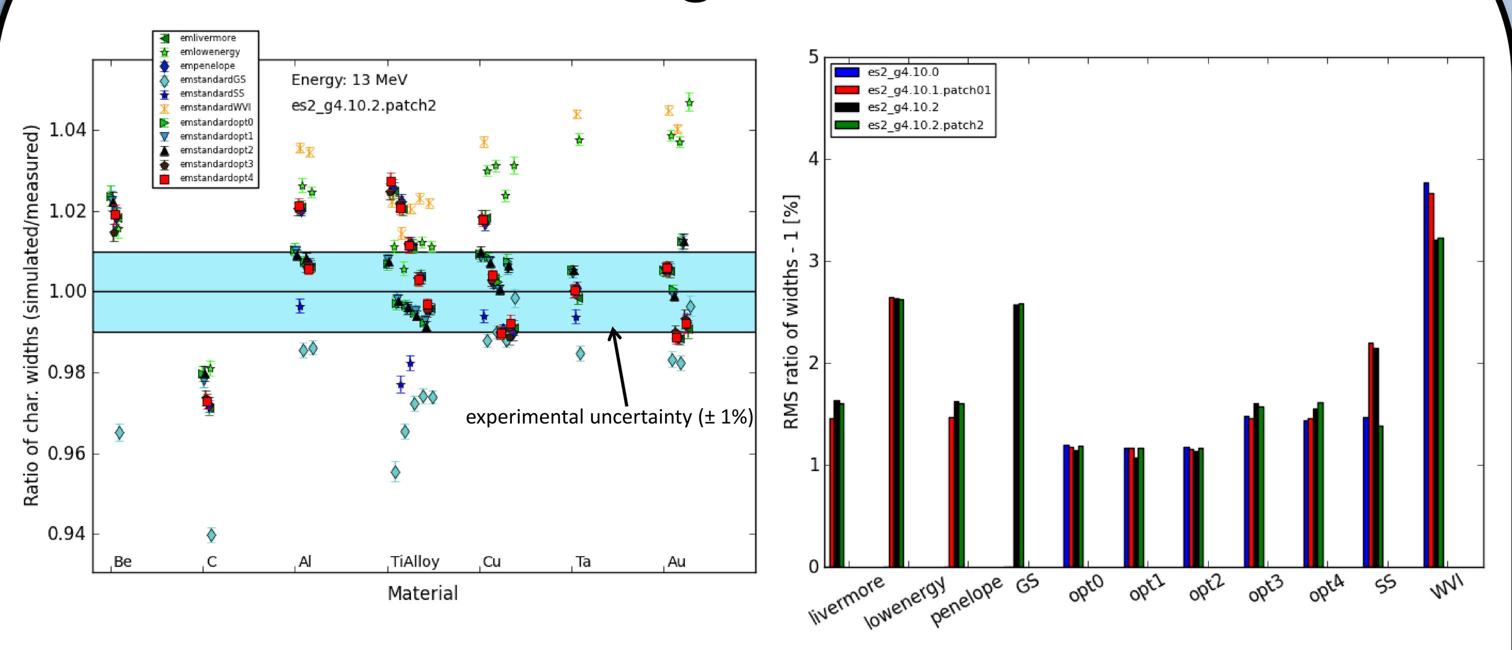
- New EM parameter definition concept completed
- All EM parameters may now be defined by C++ or UI interfaces in PreInit and Idle states
- New parameters added, allowing user to define:
  - Lowest energies for tracking of e+- and muons/hadrons
  - Specific models per geometry region: PAI, MicroElec, DNA
  - Specific EM physics configuration per geometry region
- Now may use Geant4 reference Physics Lists for an application with modification of EM physics configuration for a specific region, e.g. tracker or calorimeter, in which higher precision is required
- C++ interface is active only for the master thread
- Recommended to first instantiate Physics List, then define parameters

Bremsstrahlung: improved implementation of the LPM effect



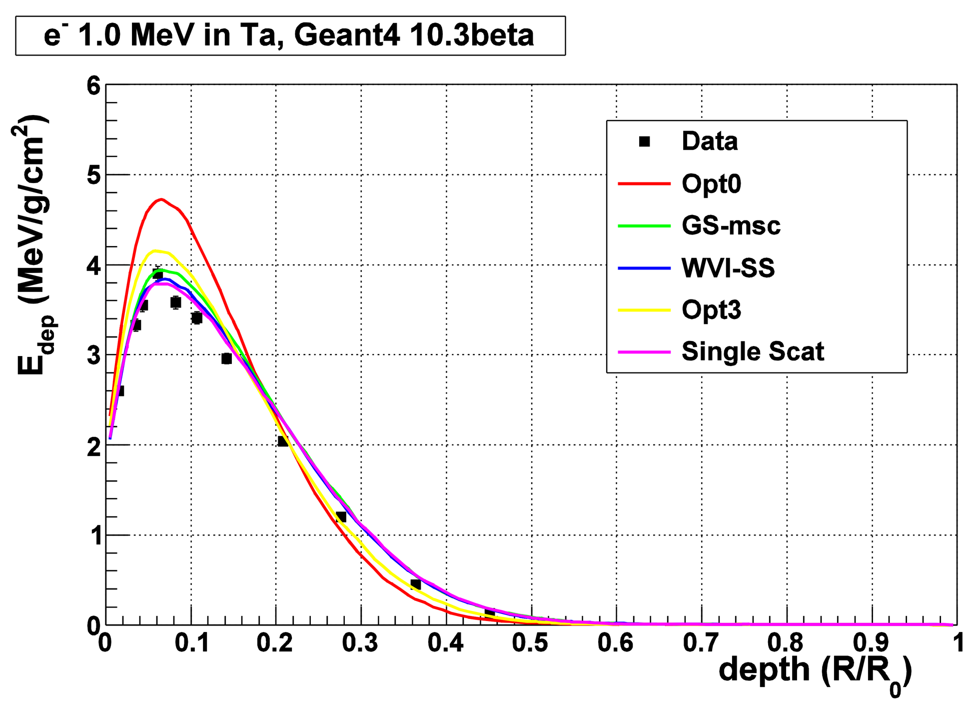
- Gamma emission for electron/positron bremsstrahlung reviewed, with focus on Landau-Pomeranchuk-Migdal (LPM) effect
- LPM model now fully consistent with Migdal model
- Improved agreement between simulation and data

Electron scattering validation benchmark



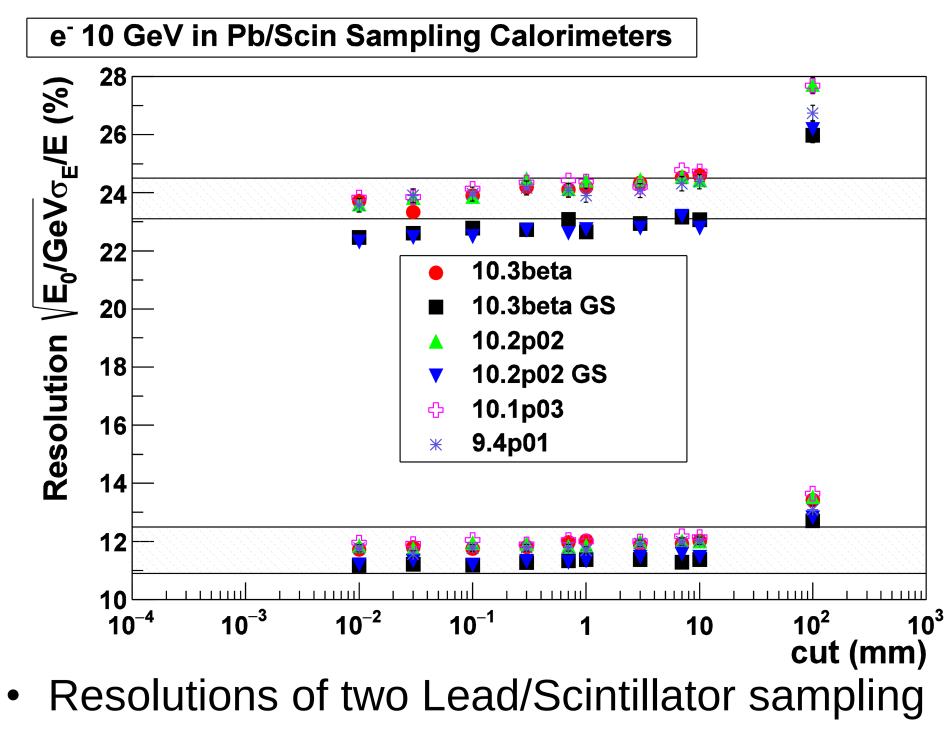
- Thin foil scattering validation benchmark compares simulations to measurement (Ross *et al*., Med. Phys. **35**, 4121 (2008)) at 13, 20 MeV
- Left plot shows ratio simulated /measured peak widths for v. 10.2.patch2
- Right, RMS width ratio for different versions
- Goudsmit-Saunderson now competitive with Urban model

Goudsmit-Saunderson model



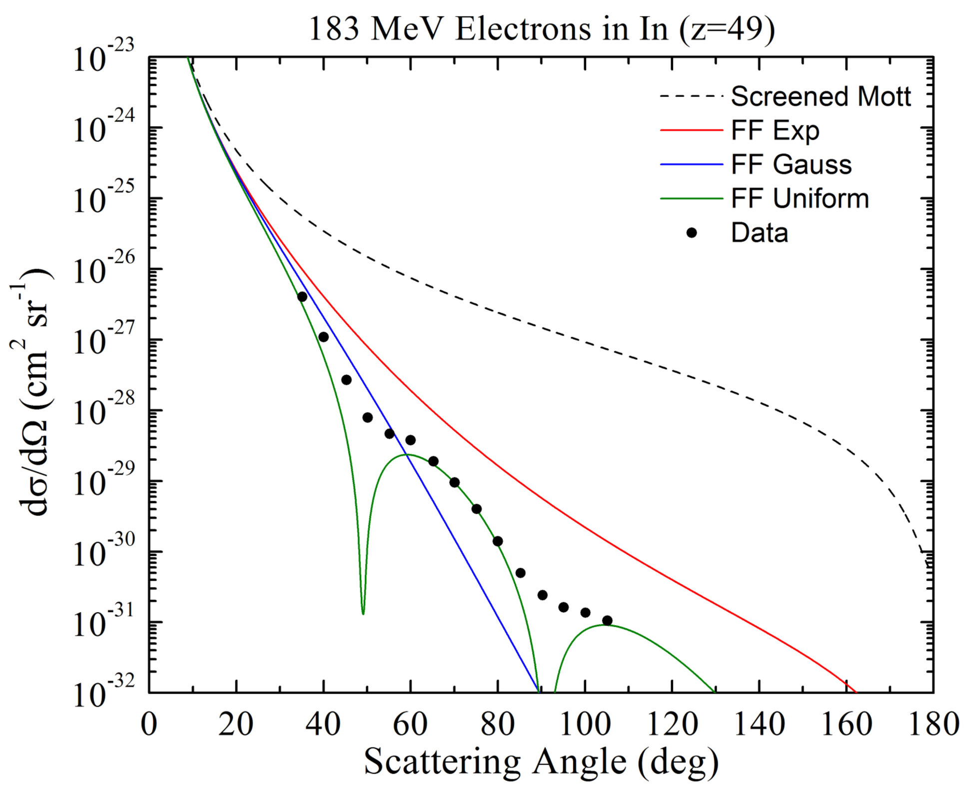
- New implementation of Goudsmit-Saunderson (GS) model for multiple scattering of electrons and positrons
- Incorporates all important elements of theoretical model
- Angular variable transformation makes precomputed GS angular distributions smooth enough to apply accurate run time interpolation and fast sampling algorithm
- Performance competitive with standard Urban model for multiple scattering for both computation time and physics accuracy
- Plot shows accuracy of GS model for heavy media comparable to single scattering model

High energy calorimeter response



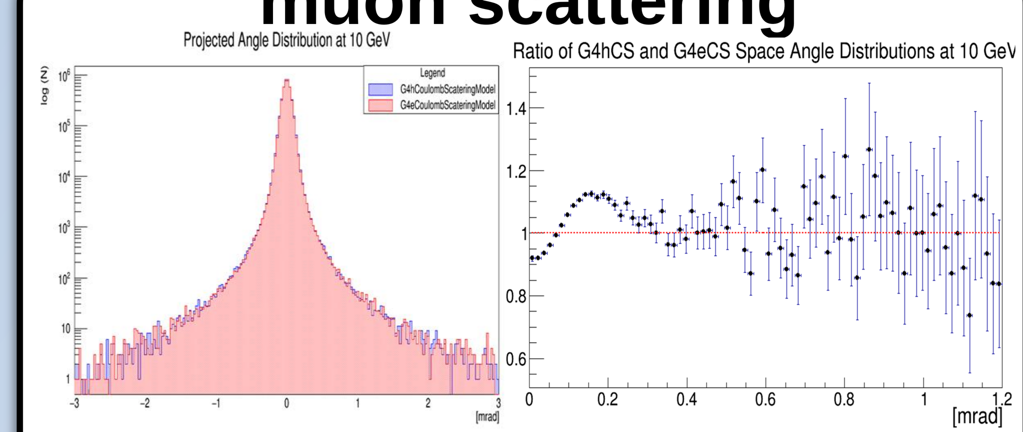
- Resolutions of two Lead/Scintillator sampling calorimeters vs. range cut are shown for Urban and GS multiple scattering models
- Shower shape is stable against cut, Geant4 version
- GS model competitive for low sampling fraction calorimeter, below measurement for high sampling fraction
- Studies of factors affecting simulation resolution are ongoing

Nuclear form-factor parameterisation



- New single scattering class G4eSingleCoulombScatteringModel implements screened relativistic treatment of Mott cross section for electrons incident on nuclei
- Accounts for screened Coulomb fields, finite sizes, rest masses of nuclei
- Calculation of scattering parameters performed in center of mass system
- Differential cross section includes nuclear form factor (FF) accounting for spatial distribution of charge density
- Until now, form factor for exponential charge distribution was in all scattering models
- Plot shows effects of usage of Gaussian and flat nuclear FF parameterisations. Inclusion of these FF under investigation

Relativistic corrections for muon scattering



- For scattering of high energy charged particles, nuclear recoil may be important
- Plots show data for relativistic correction and no correction, and ratio, for scattering of 10 GeV muon in a 300 μm silicon layer
- Corrections affect only central part of angular distribution