New Geant4 Bremsstrahlung Model

With the goal to describe EM shower shape and high energy gamma emission with higher accuracy, the description of the Bremsstrahlung process in Geant4 has been improved for two main models:
- Seltzer-Berger model, new with Geant4 9.5;
- Relativistic model, available since Geant4 9.2 [3].

We report about recent upgrades in these models and a newly developed Parametrized model.

Seltzer-Berger model

A model based on theoretical data tables has been introduced in Geant4 version 9.5.
- It is based on tabulated single-differential cross-section from Seltzer & Berger [5]. (31 points in electron and 14 in photons energy)
- It is available for all elements, and covers electron energies from 1 keV to 10 GeV
- It uses interpolation between data points.

Relativistic Bremsstrahlung Model

Bethe-Heitler cross-section, complete screening approximation
- Includes Landau-Pomeranchuk-Migdal effect (LPM);
- Consistent combination with polarization effect;
- Good description of SLAC and CERN LPM experimental data [3].

Model is currently being improved to use Thomas-Fermi screening functions.

Parametrized Bremsstrahlung model

Until Geant4 version 9.4, the standard EM model used independent parametrizations for total cross-section, energy-loss, and differential cross-section.
- The newly proposed model uses one parametrization for the differential cross-section:

\[ F(x) = c((1-ax)F_1(\delta) + bx^2 F_2(\delta))] \]

- Total cross-section and energy-loss are evaluated by numerical integration [6];
- This model guarantees a smooth transition to the relativistic model;
- Has a good description of Seltzer-Berger data;
- Applicable from 1 MeV to 10 GeV.

\[ \text{Where } x = k/T, k, a, b, c \text{ and } T \text{ are photons and electron energy resp., } F_1(\delta) \text{ and } F_2(\delta) \text{ the Thomas-Fermi screening functions, and } a, b \text{ and } c \text{ the parameters of the model.} \]

Results

A Parametrized Bremsstrahlung model for the newly proposed model uses one parametrization for the differential cross-section:
- Good description of Seltzer-Berger data;
- Applicable from 1 MeV to 10 GeV;
- Has a smooth transition to the relativistic model;
- Consistent combination with polarization effect;
- Provides good description of SLAC and CERN LPM experimental data.

Multiple Scattering

The Geant4 toolkit offers several models of multiple scattering (MSC). G4UrbanMscModel95 provides better agreement with the scattering data for electrons than previous versions of the model.

The list of upgrades includes:
- New tuning of tail of scattering function;
- Added sampling of correlations between scattering angle and lateral displacement at a step;
- This new variant of MSC model is the default for Geant4 9.5.

Validation

Geant4 EM physics is validated on a regular basis using an extensive validation suite. Results are stored for each subsequent Geant4 release, and are available on a web interface.

The test suite includes among others:
- Resolution and visible energy in simplified calorimeter tests with different setups (Atlas LAr, Atlas Tile, CMS crystal);
- Bremsstrahlung distributions of different Geant4 models.
- Electron scattering benchmarks including back scatter fractions and differential cross-section.

Photo-electric effect

A new photo-electric effect model with fluorescence which uses implementation of atomic de-excitation G4UAtomicDeexcitation has been developed.

- All models provide better than 5% accuracy on average in the photon energy range 1 keV - 10 MeV;
- Speed of the new model is similar to the previous one, but faster than Livermore or Penelope models.

This model is default for production physics lists since Geant4 9.5.

References