2022 Work-plan: Electromagnetic physics part

V. Ivanchenko, CERN & Tomsk State University, Russia

for the Geant4 Collaboration

Geant4 Technical Forum

24 March 2022

Outline

- Infrastructure and general support for EM physics
- R&D for EM physics
- Developments for HEP applications
- Updates of low-energy EM models
- Developments for medicine
- Optical photon and X-ray physics
- DNA physics and chemistry developments

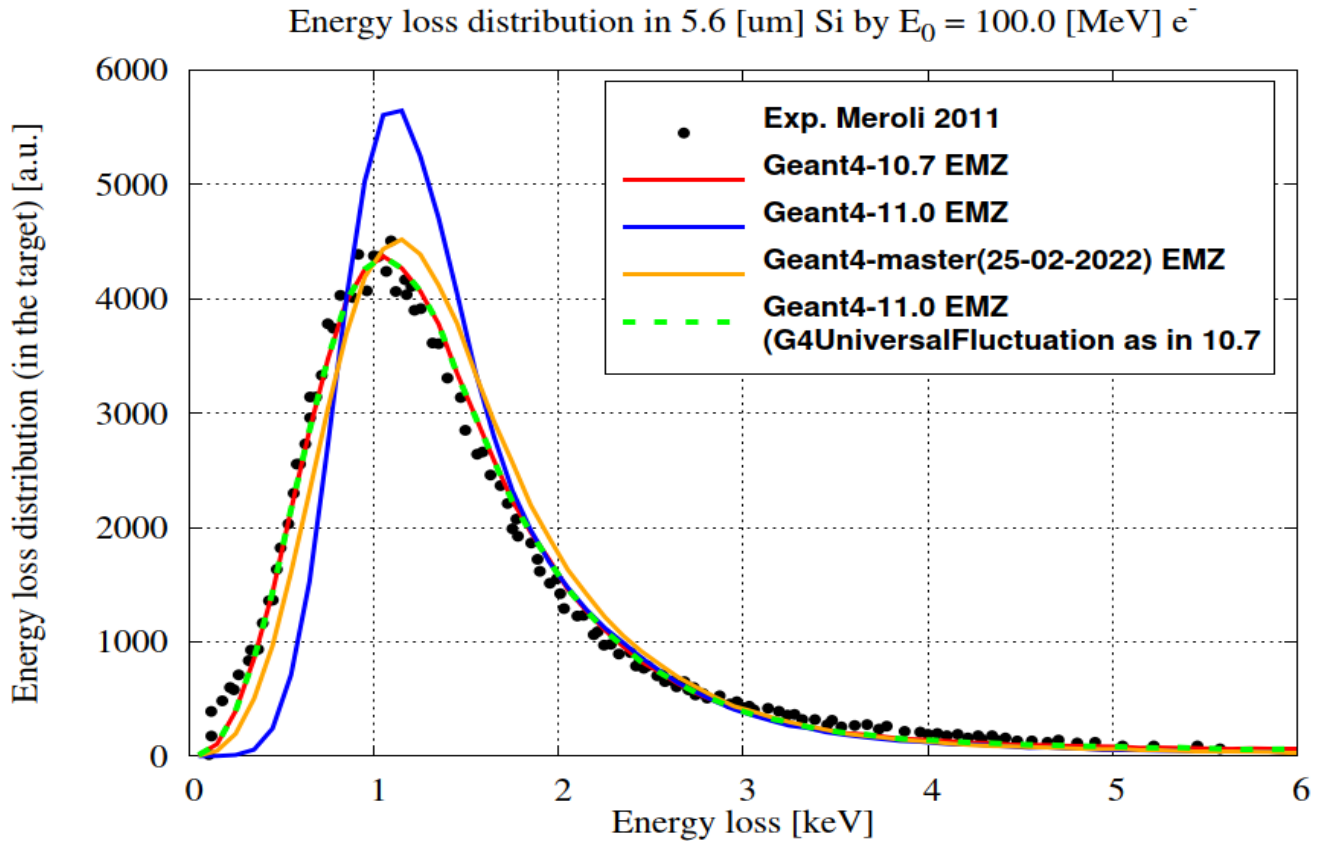
(1) – first half of 2022, will be available with 11.1.beta

(2) – second half of 2022, will be available with 11.1

Infrastructure and general support for EM physics

- Perform regular execution and regression analysis using existing testing suites (1/2)
  - Performed monthly (see geant-val and EM web)
- Further optimisation of code used by EM processes/models at initialisation (1)
  - Remove remaining duplications in the MT mode
  - Improve code to be transparent for custom physics configurations
- Reorganize code for integral method to be applicable for high energy EM and hadronic processes (1)
  - Cross section shape should be considered for transport of charged particles
  - In **10.7** and before only the first maximum in the cross section was considered
  - In **11.0** two maxima are considered (improved in **11.0.1**)
  - It will be allowed 3 maxima in **11.1** and prepared for use in hadronics
- Establish mechanism of usage of alternative models/algorithms for sampling of energy loss fluctuations for different particle types and G4Region
  - Already done

Problem in 11.0 (M. Novak)



- **G4UniversalFluctuation** class includes parameterization of the shape of energy deposition – there may be configurations in which agreement with data is not ideal.
- For **11.0.1** it is fixed and a new alternative **G4UrbanFluctuation** class is available (equivalent to **10.7**) and another **G4LossFluctuationDummy** is added.
- Alternative classes may be configured in custom physics lists per G4Region.

R&D for EM physics

- Evaluation of G4HepEm project and adopt it for Geant4 including specialized tracking (1/2)
- Addition of missing components to G4HepEm (1/2)
- Evaluation of G4HepEM for ATLAS and CMS (2)
- Investigate further optimisation possibilities provided by the G4HepEm environment such as opportunistic multi-particle tracking (1/2)
- Keep supporting the G4HepEm based AdePT GPU based EM shower simulation R&D (1/2)
- Investigate possibilities that might accelerate the EM shower simulation in HEP including high granularity detectors and sampling calorimeters (1/2)
- Implement optional Woodcock tracking of photons per G4Region (1)
- DPM like MSC modelling and complete DPM like EM simulation per particle type and detector region (1/2)

G4HepEm preliminary results
(M.Novak, J.Handfeld, B. Morgan)

G4HepEm: motivations (just a reminder, more details in the initial or in the latest reports)

- the main goal is to investigate the **possible computing performance benefits of**
  - **providing alternative, highly specialised** (for particle types, e^-/e^+, γ and HEP applications) **optional stepping loops** beyond the current general one
    $\Longrightarrow$ **giving up the** *"unutilised"* **flexibility with the hope of some performance gain**
  - having a very **compact and efficient implementation of** all the related **run time functionalities** required for an EM shower simulation
    $\Longrightarrow$ **compact run time library** and **data layout with the hope of some performance gain**

G4HepEm: results and current state

- **specialised tracking:**
  - a **great computing performance gain** (see later) that made it to be in the last `Geant4` release
  - the possibility of specialised (even external) tracking became available in `Geant4-11.0` through the new `G4VTrackingManager` **interface**
  - **an excellent result** and a nice R&D example: **less than one year form idea to release!**
- **`G4HepEm` library:**
  - the core part of the EM shower modelling is completed and verified (**also on GPU**)
  - already a **great initial computing performance gain** (see later)

Performance: $N = 100\,000, E_0 = 10[GeV], e^-$ (24 threads on `AMD Ryzen 9 3900`)

TestEm3

	Physics List	Spec. Tracking	difference
G4Em-Native	471 [s]	402 [s]	-14.6 %
G4HepEm	404 [s]	326 [s]	-19.3 %
difference	-14.2 %	-18.9 %	-30.8 %

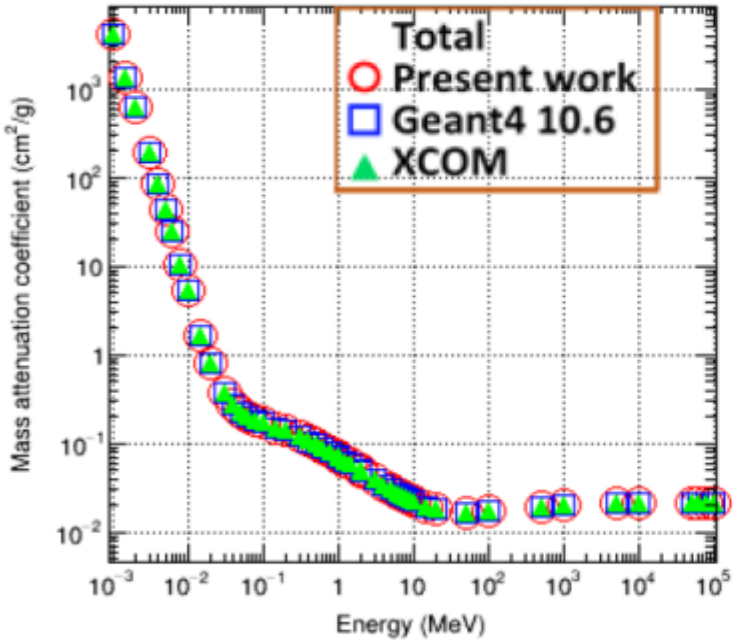
Developments for HEP applications

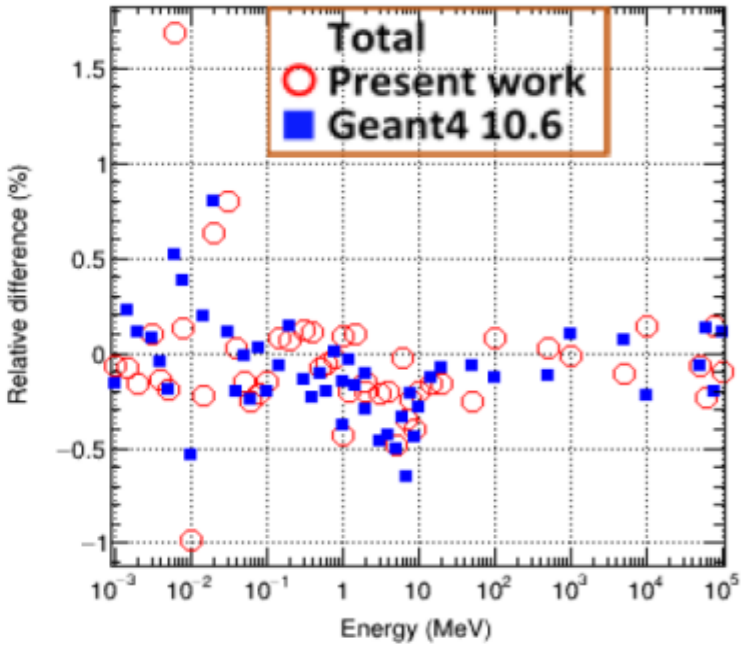
- Evaluate Linhard-Sorensen ion ionisation model (1)
  - Expected improved accuracy and CPU
- Evaluate new ion energy fluctuations model based on Linhard-Sorensen theory (2)
  - SPS data for relativistic ions will be used
- Introduce EPICS2017 cross sections as an option for standard gamma models (1)
  - In 11.0 it is available only to Livermore EM models
- Further Developments and testing for polarized gamma transport (1/2)
- Introduce bremsstrahlung on atomic electrons at high and moderate energies with triplet production (2)
- Extend energy limit for positron annihilation to hadrons (2)
- Implement muon pair production by e+- (2)
  - summer student project

Improved accuracy of parameterisation of gamma cross sections

Comparative study: mass attenuation coefficient

- Example: material = water, for total (all processes)
- A good agreement with XCOM data was observed





Updates of low-energy EM models

- Introduce EPICS2017 electron ionisation model (1)
- Using EPICS2017 cross section in G4LowEPComptonModel (2)
- Development of the new advanced example for x-ray polarimetry (2)
- Providing ionization cross-sections for 0.1 to 100 MeV for Li, C and O ions based on ECPSSR (2)
- Deployment of new model of the three-gamma annihilation (2)
- Validation of ANSTO PIXE data (1/2)
- Improve implementation of MicroElec models and extend list of materials (1/2)
- Migration of Pol01 extended example to the MT mode (1)

Developments for medicine (G4-Med project)

- Integration of DNA Physics Lists in some geant-val tests (1)
- Introduce extra tests to geant-val (1/2)
  - radioactive decay
  - nuclear medicine
  - X-ray radiotherapy
- Add new radiobiology extended example (2)
- Validation for Human normal and malignant cell irradiations by ions (1/2)
- Radiobiological Data Acquisition (1/2)

Optical photon and X-ray physics

- Maintenance and optimisation of optical classes (1/2)
- Continue integration of Opticks package (GPU based) (1/2)

DNA physics and chemistry developments

- Improvement DNA physics model for ions (1/2)
- Implementation in Geant4-DNA, of electron physics models in deoxyribose and phosphate (2)
- Implementation of the Relativistic Option 4 electron inelastic model (1/2)
- Development of a discrete model for protons using dielectric response function up to 100 MeV (1/2)
- Study of the effect of step size and cuts on radiation dose in small size volumes using Standard and DNA physics (1/2)
- Incorporation of proton cross-sections in liquid water above 100 MeV for Geant4-DNA models (1)
- Development N2 and C3H8 DNA cross sections (1)
- Development on an alternative chemistry framework using IRT and Gillespie in a single simulation (2)