Geant4 11.3 work-plan for the EM physics and patches 11.2.1 and 11.1.3

V. Ivantchenko, CERN & Princeton University

for the Geant4 EM physics group

11 April 2024

Agenda

- Updates for Geant4 11.1.3
- Updates for Geant4 11.2.1
- Working plan of the EM group for 2024

Modifications in EM for11.1.3

- **utils**
  - *In G4TransportationWithMsc, always update momentum direction.*
  - *Fixed problem #2572 - computation of Birks saturation for compounds in G4EmSaturation.*
- **lowenergy**
  - *Fix for (rare) infinite loops in G4PenelopeComptonModel. Reported in GitHub PR#61 (https://github.com/Geant4/geant4/pull/61).*
- **xrays**
  - *Fixed problem #2555 - Added protection against potential infinite loops in G4Cerenkov*
- **dna**
  - *Use std::erfc() to avoid precision loss. Fix imported from GitHub PR#58 (https://github.com/Geant4/geant4/pull/58)*

Modifications in EM for11.2.1 (1/2)

- **utils**
  - *G4VEmProcess, G4VEnergyLossProcess: minor CPU optimization with reduction of number of calls for log() of kinetic energy..*
- **standard**
  - *Fixed problem #2586 - G4IonICRU73Data: fix for the case when target material has an element with Z>92; improved debug printouts. In the Lindhard-Sorensen model to compute dEdx the first try is to take it from ICRU73 or ICRU90 data, if this class returns zero, then dEdx is computed from G4GenericIon and effective charge.*
- **lowenergy**
  - *G4MicroElecInelasticModel_new: fixed Coverity report for memory leak at exit.*
- **xrays**
  - *G4GaussXTRadiator, G4VXTRenergyLoss: flexible summation in SpectralXTRdEdx; clean-up in GetStackFactor() based on std::complex methods.*
  - *In G4Scintillation::sample_time(), refactored the scintillation time sampling.*

Modifications in EM for11.2.1 (2/2)

- **dna**
  - *G4DNABornAngle: fixed numerical problem; added protection for cosTheta; use relativistic formula for maximum energy transfer to delta-electrons*
- **constructors/electromagnetic**
  - *Fixed problem #2543 - G4GammaGeneralProcess: fixed sampling of muon pair production.*
  - *G4EmStandardPhysics_option3: restore step limit type to use 'fUseDistanceToBoundary' and set default RangeFactor from 0.03 to 0.04, fixing inaccuracy in medical benchmarks.*
- **constructors/gamma_lepto_nuclear**
  - *Fixed problem #2594 G4NeutrinoPhysics: fixed tau-neutrino physics instantiation.*

EM physics work plan for 2024

Infrastructure and general support for EM physics

- Conduct regular execution and regression analysis using the existing testing suites.
- Maintenance of EM libraries, continue applying clang-tidy and clang-format to EM classes.
- Migration of EM tests from SLC7 to AlmaLinux9.
- Contribution to development of ATLAS validation suite for EM physics.
- Substitute calls IsMaster() from all classes and sub-packages.
  - *Needed for effective handling of shared data*

Extended functionality of G4HepEm package

- Refactor some of the data structures in G4HepEm, especially the macroscopic cross sections: move from plain arrays to more structured data.
- Configuration per detector region: e.g. provide the possibility to use different MSC stepping in different detector regions (as used by CMS).
- Add the missing gamma- and lepton-nuclear cross section and implement connection layer for tracks from G4HepEm to native Geant4 tracking for sampling of final state of nuclear processes.
- Implement the “general process” like handling of the macroscopic cross sections.
- Implement the possibility of Woodcock tracking of gamma per region.
- Extend and optimize tracking algorithms per particle type.
- Prepare G4HepEm to be used by ATLAS and CMS.

Developments for LHC and other HEP experiments

- Further development on EM models for beam transport and interactions in bending crystals, implementation of coherent pair production model.
- Implementation of new examples demonstrated crystal based positron source, crystal-based extraction of electron beam from a synchrotron, crystalline undulator.
- Implementation of extended example to illustrate simulation of the coherent interactions of charged particles and strong field effects in oriented crystals.
- Calculation in LO and NLO of QED-corrected cross sections of electron and muon scattering on nuclei.
- Development of a new 5D angular generator for e+e- pair production.
- Support and R&D for the ATLAS TRT (X-Ray transition radiation).
- Develop a new example for simulation of inverse Compton scattering.
- Provide an option to use EPICS-2017 data for standard gamma processes.
- Include 3-gamma annihilation models into EM physics lists.

Updates of low-energy EM models

- Addition of revised momentum profiles for the Compton scattering.
- Addition of extra materials to MicroElec models.
- Development of a new example for demonstration of MicroElec models.
- Evaluation of a possibility of introducing of plasma state and energy loss models in plasma.
- Evaluation for low-energy extension of the PAI model.
- Extension of quantum entanglement effect on the Compton scattering for full gamma scattering history.
- Continue development of computations for heavy ion ionisation and de-excitation using full j-j approach. Preparation of precomputed tables of cross sections.
- Verification of reverse/adjoint physics models for thin and thick shielding and application to space scenarios.
- Integration of processes of production and decay of orto- and para- positronium.

G4-Med developments

- Validation of EM and hadronic models for medical applications.

Optical photon and X-ray physics

- Maintenance and optimisation of optical classes.
- Development of a processes of Bragg reflection of X-Rays from outer and inner crystals surfaces for slabs and for cylinder shells.
- Implement UI commands and builders to include X-ray refraction and reflection on top of standard physics.
- Integration of quantum entanglement effect to optical photons.
- Continue integration of Opticks package
  - *Provide example of optical processes implemented on GPU and other processes at CPU.*
  - *Demonstration of tracing of optical photons in liquid Argon TPC.*
  - *Addition of Scintillation and Wavelength Shifting processes.*

DNA physics and chemistry developments (1/2)

- Improve DNA physics models for ions.
- Integration of Li cross sections.
- Extension of Geant4-DNA to be used for space radiation protection
- Implementation of the option4 relativistic electron inelastic model.
- Benchmarking ELSEPA and Uehara elastic models.
- Implement propane cross sections.
- Implementation electron impact inelastic cross sections for gold nanoparticles using relativistic plane wave approximation and considering surface effects.

DNA physics and chemistry developments (2/2)

- Develop models for electron interactions in atmosphere.
  - *Provide an example to compute density of ionisation depending on altitude.*
- Validation of Geant4-DNA using radiobiological experiments on human skin fibroblasts at ANSTO.
- Validation of human normal and malignant cell irradiation with ion species for estimation of RBE dependence on LET and evaluation of DSB as a function of post-irradiation time.
- Development of Fricke dosimeter example.
- Validation of IRT-syn at different dose rates.
- Optimization of thermalization distance of water displacement for chemistry applications.
- Study on homogeneous chemistry and boundary conditions.

Thank you