Geant4 Physics Work Plan for 2013

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Geant4 Technical Forum, CERN, 26 March 2013

Outline

Summary of the program of work for 2013 for the following areas of Geant4, related to physics:

- Standard Electromagnetics Physics
- Low-Energy Electromagnetic Physics
- Hadronic Physics
- Physics Lists
- Validation

Note: (1) means first semester
(i.e. to be included in June G4 10.beta release)

(2) means second semester
(i.e. to be included in December G4 10 release)

(2+) means starting in the second semester but could continue next year

STANDARD ELECTROMAGNETIC PHYSICS

Multiple and Single Scattering

- Finalize the tuning of **Urban** model (1)
  - In G4 10.beta (June release) there will be a consolidated Urban model: G4UrbanMscModel
  - In the G4 10 (December release) older Urban models will be removed (G4UrbanMscModel93 and G4UrbanMscModel95)
- Finalize the multiple scattering migration to *AlongStep* (1)
  - Allowing sampling of lateral displacement when a charged track crosses a geometrical boundary
- Addition of the next order corrections to **WentzelVI** model (1)
- Review and fix of **Goudsmit-Saunderson** model (2+)
  - Potentially the most accurate model for low-energy (<= 100 MeV) electrons and positrons

Ionisation processes

- Investigation of alternative fluctuation models (1 & 2)
  - Currently the default model is Urban, and a more precise (but slow) alternative is PAI. We are looking for something in between...
- Refinement of the effective ion charge approach (2)
  - To be applicable simultaneously for both dense and low-density media (including vacuum)
- Alternative ion-ionisation models for moderate energies (2+)
  - More accurate than Bethe-Bloch model for ~100 MeV/u heavy ions

Bremsstrahlung and Compton models

- Improvement of the parameterisation of the positron cross sections in the Seltzer-Berger model (2+)
  - Likely important for ~MeV positrons

- Update of the Compton scattering model, with the addition of radiative corrections (2+)

High Energy processes

- Improvement of the cross-section for e+e- production by muons and hadrons (1)
- Improvement of the cross section for photo-nuclear production by muons (2)
  - To be included in the production physics lists (currently available only on-demand)
- Migration of gamma to mu+mu- production process to model design (2)
- Addition of an angular generator for synchrotron radiation (2)

Optical photon processes

- Transmission/Reflection probabilities dependent on both wavelength and incident angle (1)
- Extension to the unified surface model to have both specular and diffuse components for the transmitted photons (2)
- Modeling of optical transport in a volume that has different optical treatments on different sides (2)

LOW-ENERGY ELECTROMAGNETIC PHYSICS

Livermore models

- Improvement of pair production by polarized gamma rays, pair production in electron field, and radiative correction in pair production (2)
  - Important for the simulation of Compton polarimeters
- Finalize migration of Livermore unpolarized Compton (2)
  - Aimed for CPU speed-up and multi-threading capabilities

Monash University models

- Development of a polarized version of Compton scattering (2)
  - Unpolarized Monash University model was released in G4 9.6
- Development of a new photoelectric absorption package (2)

Atomic Deexcitation

- Semi-empirical corrections for K, L and M cross sections (2)

RBE (Relative Biological Effectiveness)

- Development of classes for dose average LET (Linear Energy Transfer) computing (2)
  - Useful for medical applications

MuElec (micro-electronics) models

- Addition of models for other target materials (2)
  - Released for Silicon in G4 9.6

Geant4-DNA

- Development of alternative Geant4-DNA physics models (2)
- Extension of Geant4-DNA physics models to other materials (2)
  - Currently most of the models are applicable only for liquid water
- Development of a multiple scattering process below keV range (2)
- Geant4-DNA example for radiolysis modelling (2)

HADRONIC PHYSICS

String models: FTF and QGS

- Documentation and code improvements of **FTF** (1 & 2)
- Consolidation and extension of the validation suite of **FTF**
  - Regular deployment (1)
  - Better tuning, w/o Bertini re-scattering (2)
  - Validation of anti-proton and light anti-nucleus interactions (1)
  - Validation of nucleus-nucleus interactions (2)
- Improve the excitation energies of nuclear residuals in **FTF** (1)
- Validation and improvements of **QGS** (1)
  - Extension to lower energy with Reggeon Cascade
  - Study of diffraction dissociation

Cascade models (1/2)

- **BERT**
  - Improve gamma-N (1)
    - More validation
    - New two-body angular distributions
    - Revise "forced first interaction"
  - Re-evaluate nucleon-nucleon in-medium cross-sections. Improve two-body angular distributions. Study physically-motivated nuclear model parameters (1)
  - Implement at-rest mu- capture (1)
  - Validate coalescence and enable by default (2)
  - Extension to higher energies and multi-body final states (2+)
  - Study secondary propagation in a smooth (1D) nuclear potential, with stepwise curved trajectories (2+)

Cascade models (2/2)

- **BIC**
  - Add coalescence to BIC (1)
  - Investigate BIC for pi- stopping at rest and gamma-nuclear (2)
- **INCL++**
  - Tuning of the nucleus-nucleus sector (1)
  - Set up a suite of physics tests (1)
  - Get ABLA++ up and running again (1)
  - Start the development of the high-energy (up to 12 GeV) extension of INCL++ (2+)

De-excitation models

- Introduction of production and transportation of isomers (1)
  - Needs corresponding changes in base hadronic classes
  - Needs update of photo-evaporation model
    - including modifications needed for gamma decay angular correlations
  - Needs to use RadioactiveDecay
    - its CPU impact should be carefully considered
- Refinements of de-excitation models and code optimization (1 & 2)
- Correlated neutron-gamma emission in fission (1 & 2)
  - In spontaneous-, neutron-induced- and photo-fission

High-precision (HP) neutron model

- Work on data libraries (1 & 2)
  - New data processing by NJOY2012
  - Compression of neutron data libraries
  - Maintenance of IAEA Geant4 neutron data libraries website
  - Creation and validation of new neutron data libraries (ENDF/B-VII.1, JEFF 3.2 and others)
  - Creation of the TENDL2012 incident charged particle data library
- Merging neutron_hp and particle_hp (2)
- New models for secondary-particle production in neutron-induced reactions. New fission fragment model (1 & 2)
- Compare Geant4 HP with MCNPX (1 & 2)
  - Data files for all individual isotopes
  - Implementation of the thermal treatment

Elastic & Quasi-Elastic models

- Combine electromagnetic & hadronic elastic scattering for hadrons and ions (2)
  - Validate the existing model (G4DiffuseElastic) with proton-nucleus elastic data
  - Test and look for validation data for the ion-ion elastic model (G4NuclNuclDiffuseElastic)
- Code improvement of CHIPS-extracted quasi-elastic (2)

Cross Sections

- Design and code improvements of hadronic cross sections (1)
- Complete test suite for hadronic cross sections (with data) (1)
- Validation of pion-nucleus cross sections (1)
- Validation of kaon- and hyperon-nucleus cross sections (2)
- Updates and new cross sections from SAID (1 & 2)

Dropping models

Deprecated but still present in G4 9.6, the following models will disappear in G4 10 :

- **CHIPS** package (already gone in G4 9.6.ref01) (1)
  - Extracted its useful components
    - elastic, quasi-elastic, cross sections

    and replaced with BERT + FTFP
    - for nuclear capture at rest and gamma/electron-nuclear

    already in G4 9.6

- **LEP/HEP** (parameterized, GHEISHA-equivalent) models (1)
  - Replaced with FTFP + BERT

PHYSICS LISTS

Physics Lists

- Improvements in design, implementation and documentation of physics lists (1 & 2)
- Replace LEP with FTFP+BERT in QGS-based P.L. (1)
  - If QGS is extended to lower energies, then FTF can be removed
- Fix remaining non-reproducibility of G4 (2)
  - neutron HP
- Study of the effects of Bertini rescattering, and Bertini + Precompound in hadronic showers (2)

VALIDATION

Validation & Testing

- Continuous effort to extend and improve the tests
- Extension and improvement of the GRID validation suite (1&2)
  - Improve the machinery
  - Extend to electromagnetics and other thin-target tests
- Development of the Validation Framework (1 & 2)
  - Central database repository at FNAL
  - Streamline the uploading of validation results
- Physics highlights release page (1 & 2)
- Improve software and physics robustness of physics models
  - Consider light target nuclei
  - More stringent energy-momentum checks
  - Improve tests to check the output, or perform regression, instead of simply “run to the end without crashing”