Geant4 Hadronic Physics : Highlights of version 10.2 and Work Plan for 2016

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Geant4 version 10.2

Hadronic Data Sets

- G4ENSDFSTATE**1.2**
  - It is now mandatory to define the environmental variable **G4ENSDFSTATE**
    - Needed to build the **G4NuclideTable**, which is used in the **G4IonTable**, which, in turn, is used in both EM and HAD physics
- PhotonEvaporation**3.2**
- RadioactiveDecay**4.3**

- Optional: G4TENDL**1.0**
  - Needed by ParticleHP when used for p, d, t, He3, α

Fritiof (FTF) model

- Improved the preparation of the excited nuclear remnant by the FTF model to hand over to Precompound/de-excitation
  - Affecting the production of low-energy nucleons
  - Resulting in closer agreement with thin-target data
  - Few % increase in the energy response of hadronic showers in Fe and Cu absorbers

Quark-Gluon-String (QGS) model

- Minor changes in G4 10.2 with respect to 10.1

Note: a major development in the final-state model (included in the June beta release) has been postponed to next year (G4 10.3): the algorithm changes require re-tuning of the parameters, and with the current parameter values some thin-target comparisons would get worse.

Intra-nuclear Cascade models

- Bertini (BERT)
  - Extended K+n and K+p up to 32 GeV and 9-body "final" states
  - Introduced (optional) improved nucleon evaporation from giant dipole resonance excitation
- Liege (INCLXX)
  - No significant developments
- Binary (BIC)
  - No significant developments

Precompound / de-excitation

- Revised the computation of evaporation cross sections, unifying between Precompound and de-excitation
  - They share the same cross sections (although used in different kinematical ranges) which are now factorized in one place
- New structure of gamma levels
  - Consistent between PhotonEvaporation and RadioactiveDecay
  - To be extended (in 2016) to FermiBreakUp, GEM and MultiFragmentation
- New gamma de-excitation model
- New data-set: PhotonEvaporation**3.2**

Radioactive Decay

- Now using *G4UAtomicDeexcitation* to handle fluorescence and Auger electrons
- Improved energy conservation for IT and EC modes
  - ~30 eV by using approximate shell energy method of A. Zoglauer
- Adapted to changes in particle category by providing a mass defect check between parent and daughter nuclei
- Removed dependence on local isotope table in favor of that in *G4NuclideTable*
- New data-set: RadioactiveDecay**4.3**

ParticleHP

- Merged **NeutronHP** into **ParticleHP**
  - No changes in user code required !

- **ParticleHP** for ***p*** , ***d*** , ***t*** , ***He3*** , ***α*** below **200 MeV**
  - Validation still on-going
  - Physics List **QGSP_BIC_AllHP** shows how to use it
  - New data set **G4TENDL1.0** to be downloaded from the Geant4 site
    - Derived mostly from **TENDL-2014**, with a few isotopes taken from **ENDF/B-VII.1**

Hadronic Cross Sections

- Bug-fix in *G4NeutronInelasticXS* and *G4NeutronCaptureXS*
  - Affect elements with natural isotopes of comparable fractions
    - e.g. W , Pb , Cu; little effect on Fe
  - Good effect on lateral shower shapes:
    brings FTFP_BERT closer to FTFP_BERT_HP
    - Although FTFP_BERT showers got ~5% narrower
- In physics lists, used now *G4NeutronElasticXS* and *G4ComponentGGHadronNucleusXsc*
  - See next slide

Physics Lists

- Neutron elastic cross section *G4NeutronElasticXS* used in all non-HP physics lists
  - Instead of Chips neutron elastic cross section
- Glauber-Gribov kaon inelastic cross sections used in all physics lists
  - instead of either Chips or Gheisha kaon inelastic cross sections
- In QBBC, transition between FTFP and BERT : [3, 4] GeV
  - Instead of [3, 12] GeV
- FTFP_BERT_TRV uses the new GS msc model; and the transition between FTFP and BERT : [2, 4] GeV
  - Instead of [3, 12] GeV
- QGSP_BIC_AllHP uses ParticleHP for p , d , t , He3 , α below 200 MeV

Hadronic showers

- FTFP_BERT hadronic showers in G4 10.2 have changed with respect to those in G4 10.1 as follows:
  - Higher energy response in non-heavy absorbers (Fe, Cu)
    - Few %
    - Mostly due to the changes in FTF
  - Narrower lateral shapes (W, Pb, Cu)
    - ~5% for Pb and Cu; ~10% for W
    - Due to bug-fix in NeutronXS (inelastic and capture) cross sections, and, for W, to the new de-excitation model

Work plan for 2016

String Models (1/2)

- **FTF** (Fritiof model)
  - Validation & tuning for **nucleus-nucleus** interactions
  - Tuning to improve **baryon spectra** in proton-proton, antiproton-proton, proton-nucleus, antiproton-nucleus, and nucleus-nucleus interactions
  - Tuning and validation for **strange meson and hyperon** production in nucleon-nucleon, and nucleon-nucleus interactions

- **QGS** (Quark-Gluon-String model)
  - Tuning and improvement for hadron-nucleon and hadron-nucleus interactions

String Models (2/2)

- General
  - Code improvements of string models
  - Hadronic shower effects of string models
  - Development and validation of the low-mass diffraction dissociation model, and low-energy extension of hadron string models

Cascade Models

- **BERT** (Bertini-like model)
  - Parameter tuning
  - Completion of kaon improvements
- **INCL++** (Liege intranuclear cascade model)
  - Implementation of Eta and Omega production

PreCompound / De-excitation Models

- Migration of Fermi break-up, GEM, Evaporation, and PreCompound models to use the common data on nuclear levels (which also allows production of isomers)
- Further tuning of de-excitation models
- Revision of Fermi break-up
- Inclusion of simulation of correlated gamma emissions

Radioactive Decay Model

- Extensions to allow the simulation of Super Heavy Elements (SHE)
- Achieve event reproducibility for IT reactions
- Inclusion of beta-delayed emissions of protons and neutrons
- Make it easier the simulation of new level scheme, including E0 transitions and angular effects

High-Precision (HP) Models

- Inclusion of the interference term for charged particles in particleHP
  - Interference between hadron elastic and Coulomb elastic
- Improvements in the treatment of inelastic reactions in C12
- Model low-energy (~meV) neutron scattering in both poly- and single-crystals
- G4LEND/GIDI : further developments

Elastic , Quasi-Elastic , Charge-exchange Models

- Development and validation of hadron elastic scattering
- Implementation of charge-exchange model

Cross Sections

- Inclusion of fast hadronic cross-section system and its validation
- Complete test suite for hadronic cross sections (with data)

Others

- Neutrinos: complete the Geant4 interface to GENIE
- Investigation of problems in selection of elemental scatterings in QMD
- Muon stopping code-factorization and introduction of muonic atoms
- HIJING : updated version - which describes both RHIC and LHC nucleus-nucleus data - available in Geant4 through the interface:
  examples/extended/hadronic/Hadr02