Geant4 11.2.p01 and 11.1.p03 & Hadronic Physics Group Work Plan for 2024

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On behalf of the Geant4 Hadronic Physics Working Group

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G4 11.**2**.p0**1**

Main Changes in Hadronics : G4 11.2.p01 *vs.* 11.2

- *cross_sections/*
  - *G4ElectroNuclearCrossSection* : added low-energy limit of **100 MeV** for the cross-section
    - Below this threshold, it returns immediately 0.
- *models/de_excitation/*
  - ***G4FermiBreakUpVI*, *G4FermiFragmentsPoolVI* : fixed production of fake excited nuclear states**
    - Addressing problem report #2584
- *models/particle_hp/*
  - *G4ParticleHPFissionFS*, *G4ParticleHPFFFissionFS* : added extra protections against cases when fission data are not available for some isotopes
    - Addressing problem report #2590
- *models/radioactive_decay/*
  - *G4Radioactivation* : added *DBL_EPSILON* check on transition energy for metastable nuclides
    - To prevent the creation of zero energy levels which have no decay products
  - ***G4BetaPlusDecay, G4BetaMinusDecay* : fixed sampling algorithm**
    - Addressing problem report #2588

G4 11.**1**.p0**3**

Main Changes in Hadronics : G4 11.1.p03 *vs.* 11.1.p02

- No changes in *processes/hadronic/* !

- *physics_lists/constructors/decay/*
  - *G4RadioactiveDecayPhysics* : replaced *G4RadioactiveDecay* with *G4Radioactivation* to allow running also in biasing mode

Hadronic **Work Plan**

Hadronic String models (1/2)

- Verification of pion-nuclear interactions in **FTF** and **QGS** models;
  revision of fragmentations in both models and of probabilities of FTF processes
- Validation of charm production for **FTF** and **QGS** models
  - In proton-proton, proton-nucleus, nucleus-nucleus interactions
- Improvement and validation of antiproton, antineutron and light anti-nuclei annihilations in **FTF**
- Validation of **FTF** nucleus-nucleus interactions, including the new diffraction dissociation description, in the range $3 < E_{cms} < 20$ GeV
  - d-d, d-A, t-A, He4-He4, He4-A, C12-A, *etc.*

Hadronic String models (2/2)

- Review of Birks' treatment in hadronic calorimeters to take into account the interplay between string (FTF) and intra-nuclear cascade (BERT) models
  - To tackle a recent issue (lower energy response at low energies) reported by ATLAS TileCal test-beam
- Continue the model parameter studies of **FTF**
  - And other models (Preco, Bertini, *etc.*) as well
- Maintenance and improvement of the hadronic framework;
  code improvements of **FTF** and **QGS** models

Intra-nuclear Cascade models

- Bertini-like (**BERT**) model
  - Improvement of the Feynman-x distribution
  - Maintenance and user-support
- Binary (**BIC**) model
  - Code review and maintenance
- Liege (**INCLXX**) model
  - Maintenance and user-support
  - Extension of ABLA nuclear de-excitation for super-heavy nuclei up to Z=118

Precompound / De-excitation models

- Maintenance and user support
  - Continue the effort of resolving bug reports related to de-excitation
  - Continue the reorganization of de-excitation module: improve design, make de-excitation handler be flexible to consider internal conversions

Radioactive Decay model

- Maintenance, user support and improvement
- Maintenance of the database

New Hadronic Datasets

- G4ENSDFSTATEDATA, G4LEVELGAMMADATA, G4RADIOACTIVEDATA
  - They are not fully consistent, in particular for nuclear levels with incomplete information
  - There are also some unphysical nuclear levels
  - Several open bugs in hadronics are due to these shortcomings
- Create new versions of the above hadronic datasets
  - That are consistent between them, and with fewer (ideally none) unphysical nuclear levels

ParticleHP model

- Validation, maintenance and user support
- Extend ParticleHP model to higher energies
- Insert in Geant4 the NuDEX code (to generate EM de-excitation cascades)
- Support for thermal scattering data;
  implementation of the description of the Unresolved Resonance Region (URR) with probability tables (PT);
  building a data library of Doppler-broaden cross-sections at room temperature;
  development of new variance reduction techniques (Adaptive Multilevel Splitting)
- Continue revision of the code implementation;
  use *G4PhotoEvaporation* for nuclear de-excitation via gamma emissions

LEND and NCrystal models

- LEND and GIDI update
- Updating NCrystal-Geant4 hooks

Other Hadronic models

- Development and validation of neutrino / lepton – nuclear physics
  - In particular, neutrino oscillation in matter
- Use of Pythia8 as an external generator in Geant4
  - Application for LDMX experiment
- Continue the development of the muonic atoms code
  - In particular, muon catalyzed fusion, and improvements in atomic capture physics
- Emulating hadronic models with generative graph neural networks
  - *E.g.* precise but very slow models like BLOB
- Continue the development of Light-Ion QMD (LIQMD)
  - Quantum Molecular Dynamics (QMD) model for light ions, in particular for medical applications
  - Tuning of the parameters

Hadronic Validation and Testing

- Continue integrating calorimeter test-beams for hadronic validation in *geant-val*
  - *E.g.* Dual Readout calorimeter, CMS HGCal and others
- Hadronic validation of releases using thin-target data
- Support, monitoring and documentation of physics lists with the focus on Intensity Frontier (IF) experiments
- Studying the sensitivity of the MC predictions to the variations of various parameters and development of needed infrastructure
- Validation of Geant4 with n_TOF
  - In particular, investigation of the apparent bug observed in the calculation of the neutron flux (non-physical peak at ~42 MeV when thermal scattering of neutrons is activated)
- Tests and user support via public Geant4 examples
- Validation of electro-production using electron beam at JLab's energies