Open requirements and Geant4 usage by HEP Intensity and Cosmic Frontier experiments

Krzysztof Genser/Fermilab
with Dennis Wright/SLAC

24th Geant4 Collaboration Meeting, Jefferson Lab, Newport News, VA, USA
September 23, 2019

Outline

- Selected aspects of Geant4 Usage by experiments
- Requirements currently in Jira
- Other requirements

Thanks to all who provided input (directly or indirectly):

R. Fatemi, L. Fields, R. Hatcher, J. Hewes, T. Junk, M. Kelsey, L. Kreczko, R. Kutschke, C. Marshall, M. E. Monzani, M. S. O'Flaherty, M. Strait, H. Wenzel, …

Geant4 Usage by Intensity Frontier Experiments

- Most of the IF experiments currently use Geant4 10.3.p03 and QGSP_BERT physics list (e.g. DUNE and subgroups)
  - Most experiments use CLHEP 2.4.1.x or 2.3.4.x (most if not all use Classical RK4 stepper and HepJamesRandom RNG)
  - Many groups compile with gcc 7.3.0 and use c++17; some groups use gcc 6.4.0 and c++11 or c++14 (DUNE uses clang 5.0.1 in addition to gcc)
  - Run on Scientific Linux (SL) SL6, SL7 in sequential mode (DUNE has macOS10.13,14 builds, to be discontinued, in addition to SL6 & SL7); Some experiments use containers, mainly Docker
- Muon g-2 uses Geant4 10.3.p03 (with a patch correcting a spin tracking aspect), FTFP_BERT physics list, VecGeom and CADMesh (https://github.com/christopherpoole/CADMesh)
- Mu2e uses Geant4 10.4.p03 with ShieldingM physics list running in both sequential or MT mode
  - Currently testing 10.5.p01 and DormandPrince745 stepper
- ANNIE uses Geant4 10.1.p02 and 10.2 with FTFP_BERT_HP physics list with the optical physics enabled; uses CLHEP 2.2.0.8; compiles with gcc 4.9.2,3 using c++11; In addition to using SL, some development is done on Debian 9
- NOvA uses Geant4 10.4.p02 (with a patch for density effect correction for the ionization loss), QGSP_BERT_HP physics list; In addition to using SL, some development is done on Darwin
- Liquid Argon experiments have an option to use NEST (http://nest.physics.ucdavis.edu) when not using simpler algorithms applied after Geant4 stage
- If optical processes are needed, experiments usually pregenerate and use lookup tables to simulate photon effects due to high CPU cost of those calculations

Geant4 Usage by Dark Matter Search Experiments

- LZ (LUX-ZEPLIN)
  - Uses Geant4 10.3.p02 with Shielding_LIV physics list, enables Geant4 optical physics (pregenerate/use lookup tables) and augments Geant4 with NEST
  - Uses CLHEP 2.4.1.0
  - Compiles with gcc 7.3.0 and use c++17; Runs on CentOS 7 in sequential mode
  - Currently testing 10.5.p01 and running in MT mode; Planning to look into using multi-union volumes; Would like to have ways to speed up photon transport
- SuperCDMS
  - Uses Geant4 10.3.p03, 10.4.p03, 10.5.p01 with FTFP_BERT or Shielding physics list, adds EM Option4, RDM, tritium decay, optical physics, G4CMP (https://github.com/kelseymh/G4CMP), and some internally developed physics processes for fractionally charged particles; Developed two internally distributed physics databases, for photon evaporation and for radioactive decay, to address some limitations of the evaluated data libraries; Uses private libraries to patch code before official patches are released
  - Uses internal CLHEP
  - Compiles with gcc 4.8.5 and use c++11 (experimenting with c++14); Runs on RedHat EL6 and CentOS 7 in sequential mode
  - Plans to move to Geant4 10.6 when available

Open or recently modified requirements in JIRA

- UR-28 Anti-proton production from proton beam
  - Correct the discrepancy in anti-proton production for proton beam at about 10 GeV on various targets
- UR-29 Reweightable uncertainties for systematic uncertainties estimation
  - An ability to vary model parameters (and interaction cross sections), including the reweigthability aspect
  - In progress; Bertini, Precompound & FTF models being looked at and the impact of parameter variation studied; an API is being worked on; See Soon's talks in Sessions 4 & 3A and Julia's talk in 3A
- For the full list please see:
  - https://jira-geant4.kek.jp/projects/UR

Other requirements: IF experiments

- NOvA: Incorporate precise calculation of the Fermi density effect using atomic data as described in:

  R.M. Sternheimer et al. "Density Effect For The Ionization Loss of Charged Particles in Various Substances" Atom. Data Nucl. Data Tabl. 30 (1984) 261-271

  based on the code submitted by M. Strait as described in his EM Working Group meeting talk: https://indico.cern.ch/event/825436/

Other Requirements: Dark Matter Experiments

- Implement simulation of neutron self-shielding effect
  - Neutron flux through a material can be significantly modified when the neutron energy is in the resonance region
  - The capture process can reduce the flux at one position in a crystal creating a kind of shadow in which the downstream atoms see a different background flux (a ~10% effect)
- Improve simulation of gamma induced neutron background
  - Low energy gammas producing neutrons in various materials can be a significant background
    - Photo-nuclear process does not model this well below 30 MeV
      - An improved process using the G4LEND gamma models is required