Shielding benchmarks for Geant4 version 10

KOI, Tatsumi on behalf of the Geant4 collaboration
SLAC NATIONAL ACCELERATOR LABORATORY
Outline

Geant4 version 10
Support of multi-threaded application
  Testing its performance
Geant4 results for SATIF12 Inter-comparison
  Neutron production on Al, Cu and Au targets
Geant4 results for SATIF BNL Benchmarks
Summary
The latest version of Geant4 is 10.00

- The first major release of Geant4 in 7 years
- Major release may require modification of user code.
- Patch Geant4.10.00.p01 is released the end of Feb 2014.

Multi-threading

- This release includes support for multi-threaded Geant4 applications.
- Parallelism is achieved at the event level, with events dispatched to different threads.
- The default build of Geant4 is still sequential.

Updated physics models and new physics lists

- The Fritiof(FTF) model can now handle nucleus-nucleus collisions.
- Three new physics lists (all making use of the intra-nuclear cascade INCLXX) have been introduced: QGSP_INCLXX_HP, FTFP_INCLXX, FTFP_INCLXX_HP.
Two public releases since SATIF11

Geant4 v9.6 and Geant4 v10.00

Selected new developments and capabilities

- The INCL cascade model (INCL++) was updated and can now handle heavy-ion collisions.
- New model for lepton-nuclear interactions using Bertini and Fritiof/Pre-compound has been introduced in most physics list.
- Introduced Bertini model for nuclear capture at rest of pi-, K-, Sigma-, Xi- and Omega- in most physics lists.
- Fritiof/Pre-compound model for anti-proton, anti-Sigma+ and light anti-nucleus capture at rest in the same physics lists.
- Barashenkov-Glauber-Gribov nucleon-nucleus inelastic cross sections are now used in most physics lists.
- In all physics lists, the neutron capture process has been significantly improved, both for the cross section (replacing Gheisha with G4NeutronCaptureXS) and the final-state modelling (now using G4NeutronRadCapture instead of G4LCapture). This affects the response and lateral width of hadronic showers in tungsten-based simplified calorimeters.
- A new biasing capability has been introduced to allow physics-based biasing --process interaction occurrence biasing, process final state production biasing-- and non-physics-based biasing --e.g. splitting, killing-- to be handled through a set of common classes: G4VBiasingOperator, G4VBiasingOperation.
Geant4 version 10.00 supports (optional) event-level parallelism for multi-threaded application

- In a multi-threaded application, at the end of first kernel initialization, worker threads are started and initialized.
- These worker threads are responsible for simulating events.

The objects that consume the largest fraction of memory (geometry and Electromagnetic physics tables) are shared among threads, while all other objects (in particular user-action and sensitive detectors) are thread-private.

- Exploits full performance of multi-core CPU(s) with less memory consumption
Testing MT performance on application for SATIF12 Inter-comparison problem

CPUs
- Intel Xeon CPU E5620 @ 2.40GHz x 2
  - total 8 physical core

Memory size
- 48 GB

OS
- Red Hat Enterprise Linux 6.3-64

Compiler
- gcc 4.4.7

Testing application
- Multi-threaded application for SATIF12 inter-comparison problem running on Geant4.10.00.p01
  - 16k events of 100GeV proton bombarding thick Au target

Result
- Single thread application uses 370MB at beginning and 290MB (80%) of them are shared in multithreading calculation
- Power law index of -0.896 (where -1 ideal) is gotten in multithreading performance within the number of physical cores (see next slide)
- The result of single thread calculation is identical to the result of 8 threads (see next slide)
MT performances on Inter-comparison problem

\[ y = 2089.2x^{-0.896} \]

Solid lines are single thread calculation
Broken lines are 8 threads calculation
1. Incident particle
   Pencil beam of protons with following energy
   (a) 1 GeV
   (b) 10 GeV
   (c) 100 GeV

2. Target materials and their size
   Targets geometry is the cylinder.
   Source protons incident on the center of the cylinder bottom.
   Target detector distance from the center of the cylinder is 500 cm.
   (a) Al : length 40 cm, diameter 4.0 cm and density 2.7 g/cm^3
   (b) Cu : length 16 cm, diameter 1.6 cm and density 8.63 g/cm^3
   (c) Au : length 10 cm, diameter 1.0 cm and density 19.3 g/cm^3

3. Quantities to be calculated
   Neutron spectrum above 20 MeV in n/MeV/sr/proton
   at 15, 30, 45, 60, 90, 120, 150 degrees with angular width ±0.5 degrees.

Submitted Geant4 results are calculated on Geant4 10.00.p01 with Shielding physics list
Configuration of Shielding physics list now close to FTFP_BERT_HP which uses BERT style cascade, FTF
model in high energy and neutronHP models for low energy (<20 MeV) neutron transportation
Geant4 results for SATIF12 inter-comparison
Al target

SATIF12, 2014-Apr-30, FNAL
Geant4 results for SATIF12 inter-comparison
Cu target

Shielding Cu 1GeV

Shielding Cu 10GeV

Shielding Cu 100GeV

Neutrons [MeV/s/proton]

Neutron Energy [MeV]

Neutrons [MeV/s/proton]

Neutron Energy [MeV]

Neutrons [MeV/s/proton]

Neutron Energy [MeV]
Geant4 results for SATIF12 inter-comparison
Au target

Shielding Au 1GeV

Shielding Au 10GeV

Shielding Au 100GeV

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Deep penetration experiments through steel and concrete shields for neutrons generated at mercury target irradiated by 2.83- and 24-GeV protons

Benchmark problem

- 1) Accelerator (Organization): AGS (Brookhaven National Laboratory)
- 2) Projectile (Energy): Proton (2.83 and 24 GeV)
- 3) Target Material: Mercury
- 4) Shielding Material: Steel and Concrete
- 5) Geometry: Slab Geometry
  - implemented as Cylindrical Geometry for better simulation efficiency
- 6) Instruments: Activation Detector (Bi) with HP-Ge Detectors
- 7) Measured Quantities: Neutron Reaction Rate
  - $^{209}$Bi(n,4n)$^{206}$Bi Threshold Energy of 22.6 MeV
  - $^{209}$Bi(n,6n)$^{204}$Bi Threshold Energy of 38.1 MeV
  - Reaction rate of them are given as a function of neutron flux from SATIF organizer
Benchmark overview

Proton 2.83 and 24 GeV

Shielding Material

Iron

Bi Activation Detector

Secondary Particles

Mercury Target

Concrete

Secondary Particles

Shielding Material
Results of Shielding Physics List

- $^{209}\text{Bi}(n,4n)^{206}\text{Bi}$ Threshold Energy of 22.6 MeV
  - data        simulation

- $^{209}\text{Bi}(n,6n)^{204}\text{Bi}$ Threshold Energy of 38.1 MeV
  - data        simulation
Results from other physics lists

- **QBBC**
- **FTFP_INCL++**
- **FTFP_BERT**

209Bi(n,4n)206Bi
- data — simulation

209Bi(n,6n)204Bi
- data — simulation

SATIF12, 2014-Apr-30, FNAL
Summary

Geant4 version 10 is released
- This is a major update after 7 years
Multi-threaded applications are supported on this version
- Easily use full CPU power with smaller amount of memory
Tested performance of multi-threaded application for SATIF12 inter-comparison problem
- Power law index of 0.896 for multi threading performance
- 80% of memory consumption are shared on beginning
- Result of 8 threads calculation is equivalent to 1 thread calculation
We submitted results from Shielding physics list, however, judging from results of BNL benchmark
- QBBC and INCLXX gives even better result in concrete shielings
Newly introduced INCL cascade shows promising physics performance, however, it requires more CPU power than other cascade models
Comparison against measurement of thick target neutron production

- “Measurement of Neutron-Production Double-Differential Cross Sections for Nuclear Spallation Reaction Induced by 0.8, 1.5 and 3.0 GeV Protons”, K. Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)
- Thickness of target
  - Al 4cm
  - Fe 2cm
  - Pb 1.2cm

- FTFP_BERT
- QGSP_BIC
- FTFP_INCLXX
FTFP_BERT
neutron production from proton on Al

Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)

Lines are results of simulation Geant4 v10.00.p01
Boxes are result of measurement
- data 15deg.
- data 30deg.
- data 60deg.
- data 90deg.
- data 120deg.
- data 150deg.

No measurement data on 45 deg.
Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)

FTFP_BERT
neutron production from proton on Fe

FTFP_BERT Fe 1.5GeV

FTFP_BERT Fe 3GeV

Lines are results of simulation Geant4 v10.00.p01
Boxes are result of measurement
■ data 15deg.
■ data 30deg.
■ data 60deg.
■ data 90deg.
■ data 120deg.
■ data 150deg.
No measurement data on 45 deg.
**FTFP_BERT**

neutron production from proton on Pb

Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)

Lines are results of simulation Geant4 v10.00.p01
Boxes are result of measurement

- data 15deg.
- data 30deg.
- data 60deg.
- data 90deg.
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Boxes are result of measurement

No measurement data on 45 deg.
FTFP_INCLXX
neutron production from proton on Al

Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)

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