CERN-LCGAPP-2011-04

Technical report on the validation of Geant4 release 9.5

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Abstract: The following document reports on the validation of the December 2011 Geant4 release (version 9.5). Investigation have been performed with the SimplifiedCaloriemter application. A total of about 300 million events have been simulated under different conditions. Tests focus mainly on the simulation of hadronic showers in Geant4. In section 2.2 the conclusions on the physics quality of Geant4 release 9.5 are presented.

1. Introduction

The validation of a candidate release is done both on the GRID on WLCG and Japanese (KEK) resources. In addition LXBATCH has also been used. Differently from validations done in the past (see for example CERN-LCGAPP-2011-01) a single application has been used for the validation. The application consists of a 10 lambda calorimeter of different materials. Shower properties (response, resolution and shower shapes) are measured.

The following physics lists are tested: *LHEP, QGSP_BERT, FTFP_BERT, CHIPS, QGSP_FTFP_BERT, QGSP_BIC, QGSP_BERT_EMV, LHCbPhysicsList* (very similar to what LHCb experiments uses in production: a variant of LHEP)*, QGSP_BERT_CHIPS, FTFP_BERT_TRV* for the following calorimeter types: *CuLAr , PbWO4 , FeSci , PbLAr , WLAr*.

The beam energies range from 1 to 500 GeV and the following beam species are tested: electrons, negatively charged pions, protons, anti-protons, neutral and both negatively and positively charged kaons.

All four candidate releases that have been prepared during the release phase have been tested with the SimplifiedCalorimeter application (the majority of events have been simulated with the final candidate). For each physics list a total of 10 milions events have been simulated with the five LHC calorimeter types. An additional 20 milions events have been simulated, for each physics list, using the “random” calorimeter. This is a special version of the SimplifiedCalorimeter application that consists of a very large system made of layers of all materials available in Geant4 and for which each primary is generted with a random energy (distributed between 1 and 100 GeV). Several primary species are avialble (all *standard* particles types, hyperons and light-nuclei). The goal of the tests with this special setup is to identify possible rare crashes in setups that are rarely used.

In all cases the simulation is performed in DEBUG mode with Floating Point Exception enabled.

Physics results have been compared to the production verison of Geant4 (9.4.p02).

2. Report on validation of Geant4 Version 9.5

2.1 Stability and performances

Stability

The new version of Geant4 has shown two types of rare instabilities. The first one is in the CHIPS physics list. Rare crashes (with a frequency of $<10^{-6}$). The offending code has been identified but no fix has been provided. It should be noted that the crashes have not been observed in other physics lists that use CHIPS components.
A rare FPE crash (with a frequency of $<10^{-4}$) has been observed in physics list that use FTF cross-sections. The FPE may happen for anti-proton projectile on hydrogen target. A fix has been prepared but is not included in the final release. It should be noted that the crash appears only if Geant4 is compiled with FPE detection turned on (that is not the case for LHC productions).

Performances

Two independent measurements of performances have been done. On a specific architecture (Intel Core 2 Duo E5410) a simple test showed a degradation of CPU performance (at a level of 5%).
A more detailed study, performed profiling both AMD and INTEL architectures, does not show any degradation of performance.
Further studies are ongoing to understand the observed discrepancy.

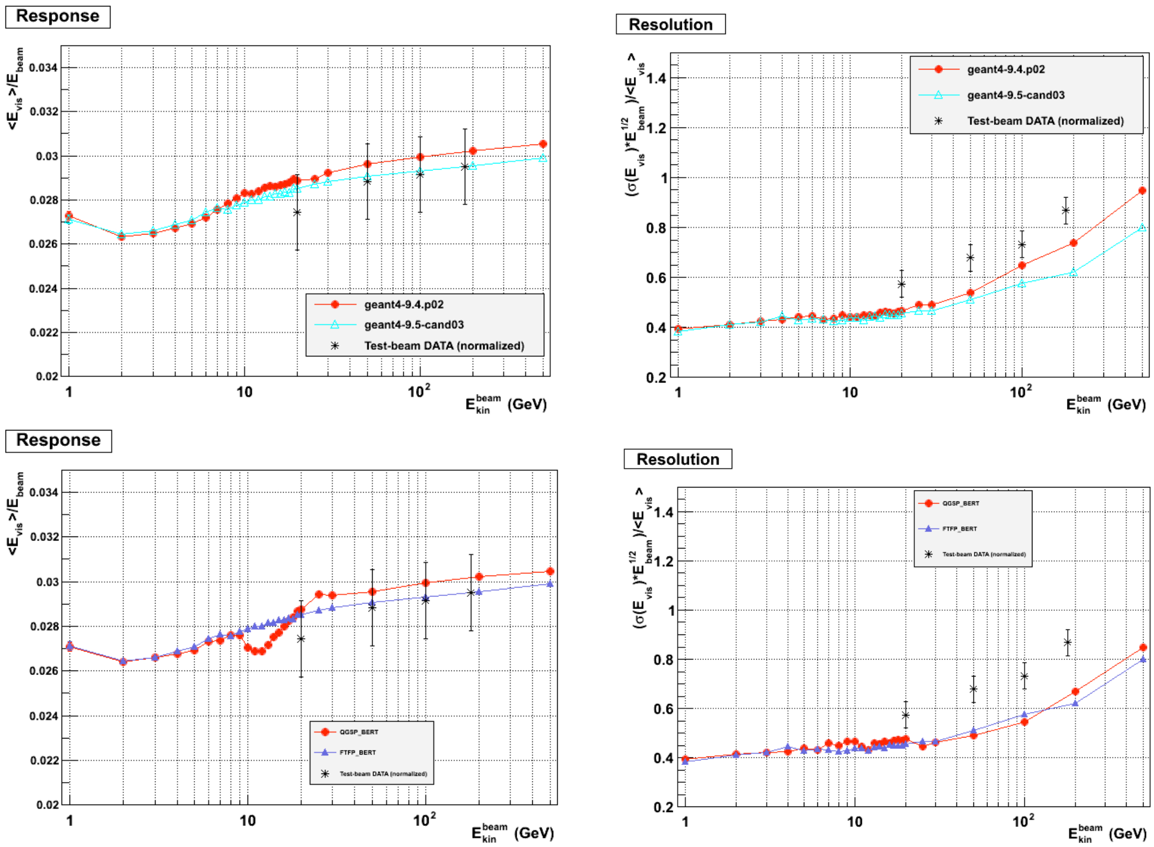


Figure 1: Top: Comparison between ATLAS TileCal test-beam data and simulations obtained with the FTFP_BERT physics list from two different releases. Bottom: Comparison between ATLAS TileCal test-beam data and simulations obtained with Geant4 version 9.5, two physics lists are shown (QGSP_BERT and FTFP_BERT). The response is shown on the left and the resolution on the right.

2.2 Physics results and comparison with previous releases

Although several developments in all aspects of the simulation in Geant4 9.5 (new Fritiof model for anti-nucleaons and light ions and anti-light ions; several technical and physics modeling improvements in Bertini cascade; re-design of hadronic cross-section code) the comparison between the candidate release and the baseline Geant4 9.4.p02 shows very stable results. During the course of 2011 all developments have periodically been validated agains thin-target and test-beam data. Results are collected in the new validation website (prototype available at: http://g4validation.fnal.gov:8080/G4HadronicValidation/index.jsp).

Few differences between 9.4.p02 and 9.5 releases have been observed during the validaiton with the SimplifiedCalorimeter testing suite:

- Small differences (1%) are expected for em showers in low and very-low sampling fraction calorimeters. The origin of this effect is still under investigation (a new multiple scattering model is used in 9.5).
- FTF based physics lists predict less visible energy deposits (1-2%) at high energy (beam energies above 20 GeV). The latest developements and tuning of the Fritiof model are responsible for this effect.

Figure 1 shows the comparison between ATLAS TileCal data and simulations for the *FTFP_BERT* physics list (top plots) for two different Geant4 versrions and a comparison between *QGSP_BERT* and *FTFP_BERT* physics lists (bottom plots) obtained with the candidate Geant4 release. Similar results, obtained for the ATLAS HEC calorimeter are shown in Figure 2. The complete set of plots (175 plots) is available in AFS under:
/afs/cern.ch/user/a/adotti/public/geant4-material/Geant4-9.5-Validation.zip
(a zipped archive is also available online at: http://goo.gl/DGWWV). Detailed reports have been presented during the Monday SFT/Simulation meetings (http://indico.cern.ch/categoryDisplay.py?categId=2965; meetings from 21 November to 12 December 2011).

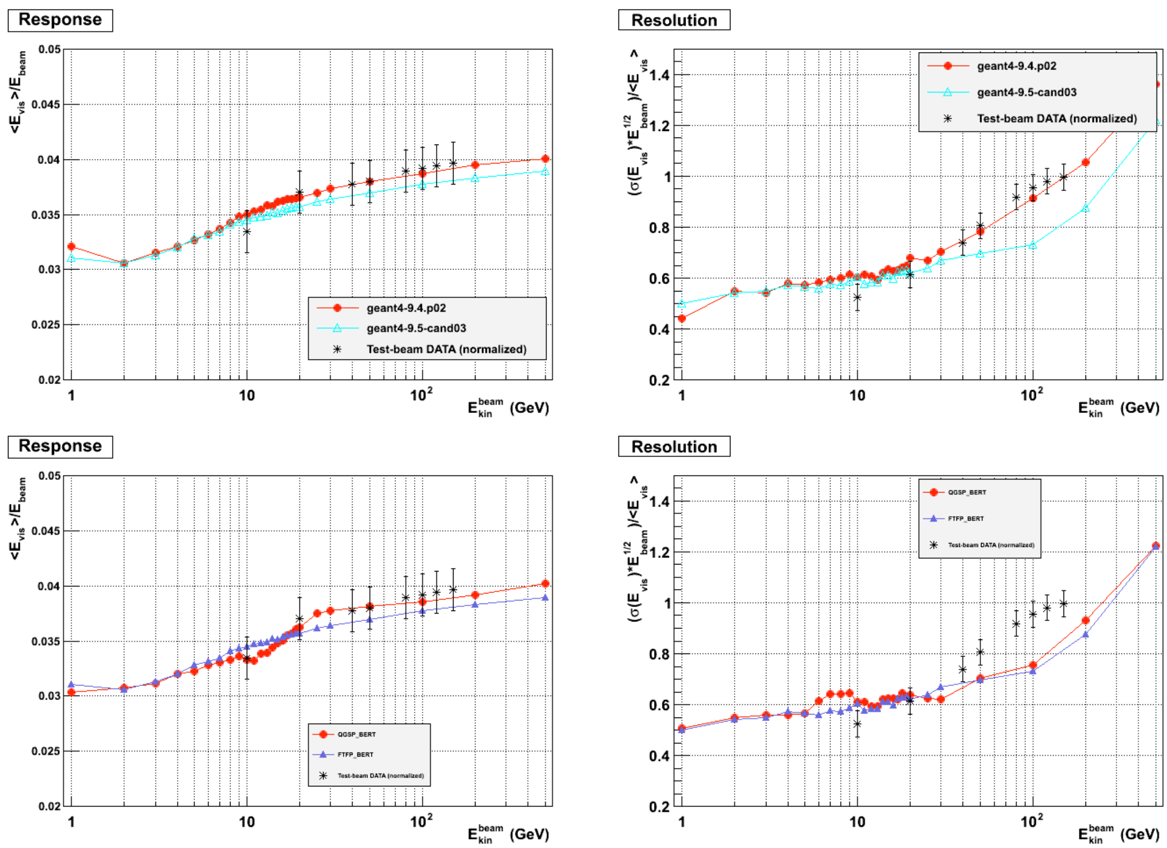


Figure 2: Top: Comparison between ATLAS HEC test-beam data and simulations obtained with the FTFP_BERT physics list from two different releases. Bottom: Comparison between ATLAS ATLAS HEC test-beam data and simulations obtained with Geant4 version 9.5, two physics lists are shown (QGSP_BERT and FTFP_BERT). The response is shown on the left and the resolution on the right.

Conclusions on the quality of physics implementation in Geant4 9.5

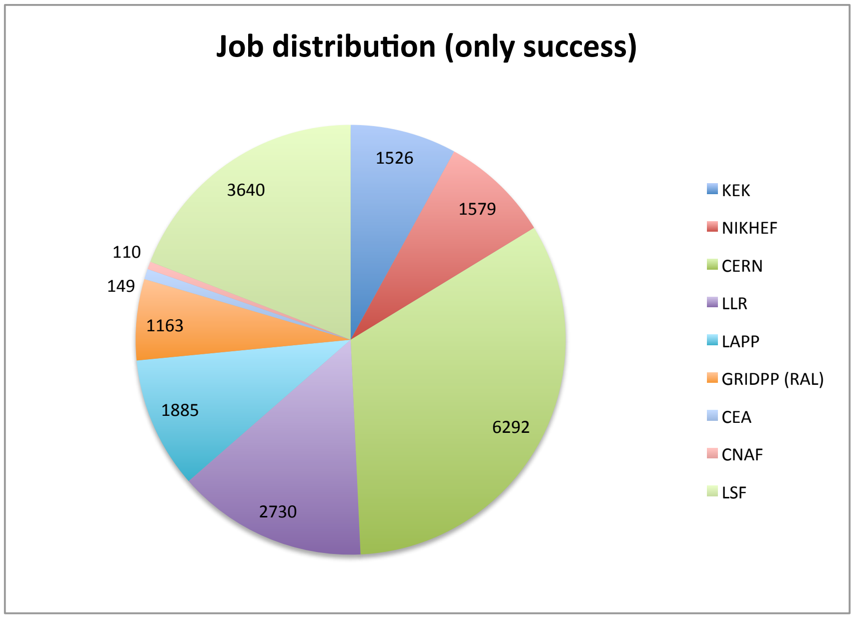
The recomended physics list FTFP_BERT shows the largest changes at high energy with respect to the previous production version of Geant4. This is expected since several improvements have been included in the Fritiof model. Thin-target validations and SimplifiedCalorimeter shows an improvement of the simulation in Geant4 9.5.
A small difference in em showers is seen in Geant4 9.5 for low and very-low sampling fraction calorimeters (ATLAS FCAL). The origin of this is still under investigation.
For Geant4 release 9.5 the recomended physics list for HEP experiments, and in particular for the simulation of calorimeters is the FTFP_BERT physics list.

3. Report on GRID usage

A new version of the code for the validation of Geant4 releases on distributed resources has been prepared. The code is now available in the SVN g4tests repository. Documentation on how to run the application on the GRID is available online at: http://goo.gl/yvxx1.
The new system uses CernVM-FS file system to distribute the needed software to GRID sites. At the moment the deployment of CernVM-FS is still limited and avilable only on few european sites. Geant4 collegues from KEK laboratories have also deployed CernVM-FS during the release validation phase.
The following CEs have been used for production:

- LSF - LXBATCH
- CERN
- LAPP (IN2P3)
- LLR (IN2P3)
- CEA (*)
- NIKHEF
- RAL
- CNAF (INFN)
- KEK (*)

Sites marked with (*) have been used only at the end of the release period.
Figure 3 shows the distribution of succesful jobs and of failures. For RAL the very high level of failures is due to a problem in configuration appeared towards the end of the produciton. CEA was used only at the very end of the validation period.
The releative large number of failures also include some initial debugging phase.
During the release phase about 1000 workers have been running on the sites. This number is enough to produce all needed statistics with fast feedback.



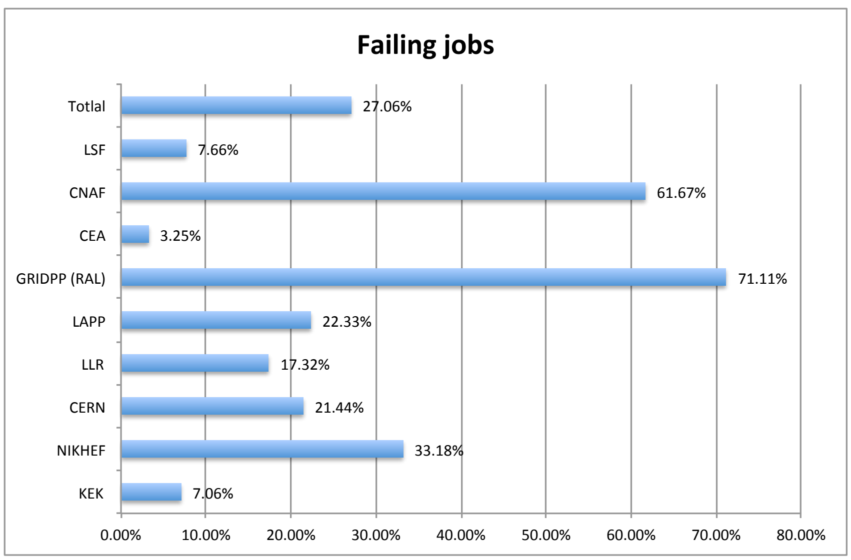


Figure 3: Top: distribution of jobs (accounting only succesful jobs) for the different sites. Bottom: fraction of failing jobs for each CE.

Conclusions

The physics performance of the 9.5 release is in general in good agreement with respect to the production release 9.4.p02.

Some minor issues remains to be investigated (FTF at very high energy, em response in ATLAS FCAL). The release is robust: excluding the experimental physics list CHIPS, no crashes in $300*10^6$ simulated events have been observed (only floating point exceptions have been observed, a fix has been prepared and will be included in future releases).

Further studies are currently ongoing to understand CPU performances. Preliminary results from the Geant4 Performance Task Force do not show changes with respect to 9.4.p02 version.

The release validation was performed on both local resources and on the GRID. With respect to previous validation cycles the GRID usage has improved substantially. This is mainly due to the improved software and to the increased ability to monitor and debug jobs.