

# Geant4 Computing Performance Benchmarking and Monitoring

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## Geant4

Geant4 is a toolkit for the simulation of particles passing through and interacting with matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in space science, material science, medicine and biology, and also in security and industrial applications. In high energy physics, the Geant4 toolkit fulfills a critical need for the simulation of detectors at the LHC and at other existing and future experiments and facilities.



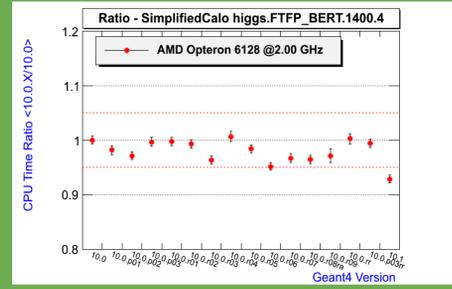
High Energy and Nuclear

Space Science

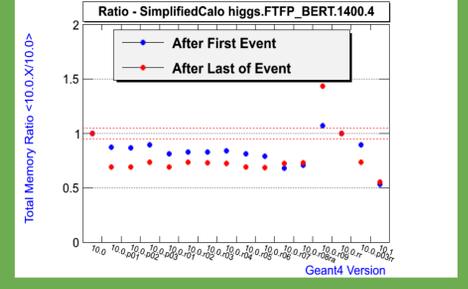
Medicine and Biology

## Geant4 Computing Performance Task

Performance evaluation and analysis of large-scale computing applications is essential for optimizing the use of resources. As detector simulation is one of the most compute-intensive tasks and Geant4 is the simulation toolkit most widely used in contemporary high energy physics (HEP) experiments, it is important to monitor Geant4 through its development cycle for changes in computing performance and to identify problems and opportunities for code improvements.



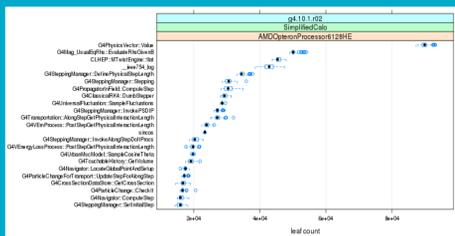
CPU Performance



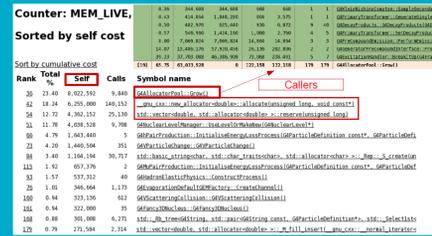
Memory Performance

## Profiling Tools

The set of software tools used in the performance evaluation procedure, both in sequential and multi-threaded modes, include FAST, IgProf and Open|Speedshop. TAU and HPCToolkits are also used for internal code reviews and other performance studies



CPU: FAST



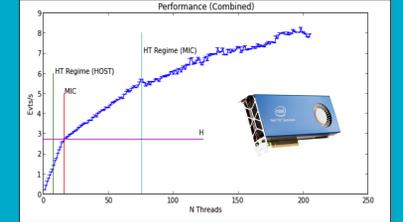
Memory: IgProf

## Profiling Platform

The Wilson cluster at Fermilab is the main set of worker nodes used for profiling and benchmarking. A standalone AMD 32 core and Intel Xeon Phi nodes are also used for benchmarking multithreaded Geant4 applications.



Sequential Application



Multithreaded Application

## Performance Monitoring

All development and public releases are being profiled using a set of applications that utilize different input event samples, physics parameters, and detector configurations. Results from multiple benchmarking runs are compared to the previous ones to monitor changes in CPU and memory usages.

### Geant4 Profiling and Benchmarking

1) The **Current** profiling activity is a part of **Geant4 Computing Performance Task**

2) Profiling Results

Geant4 Version	Application	Performance	Summary
10.1.r02	SimplifiedCalo	Simple Profiler	CPU MEM
10.1.r01	SimplifiedCalo	Simple Profiler	CPU MEM
10.1.r00	SimplifiedCalo	Simple Profiler	CPU MEM
10.0.p04	SimplifiedCalo	Simple Profiler	CPU MEM
10.0.p03	SimplifiedCalo	Simple Profiler	CPU MEM
10.0	SimplifiedCalo	Simple Profiler	CPU MEM
9.6.p04	SimplifiedCalo	Simple Profiler	CPU MEM

Geant4 Version	Application	Performance	Summary
10.0	cmsExp (Calo)	Simple Profiler	GPU MEM
9.6	cmsExp (Calo)	Simple Profiler	CPU MEM

Old Profiling Results: 9.4 9.5 9.6 10.0

3) CPU per Event: Summary Plots by Versions

Application	Physics List	Performance	Summary
SimplifiedCalo	PYTHIA H-ZZ	electrons	Summary
SimplifiedCalo	PYTHIA H-ZZ	pi0s	Summary
SimplifiedCalo	PYTHIA H-ZZ	protons	Summary
SimplifiedCalo	PYTHIA H-ZZ	anti-protons	Summary

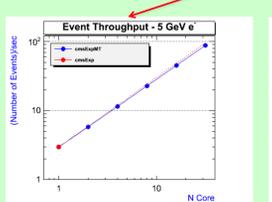
4) Total Memory Count: Summary Plots by Versions

Application	Physics List	Performance	Summary
SimplifiedCalo	PYTHIA H-ZZ	electrons	Summary
SimplifiedCalo	PYTHIA H-ZZ	pi0s	Summary
SimplifiedCalo	PYTHIA H-ZZ	protons	Summary
SimplifiedCalo	PYTHIA H-ZZ	anti-protons	Summary

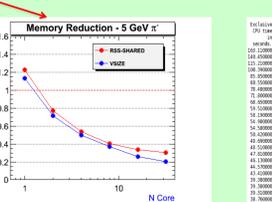
5) CPU Summary Plots by Physics Lists: 9.6 10.0

6) Geant4 MT Performance

Geant4 Version	Application	Performance	Summary
10.1.r02	cmsExpMT	Summary	OpenSpeedShop
10.1.r01	cmsExpMT	Summary	OpenSpeedShop
10.1	cmsExpMT	Summary	OpenSpeedShop
10.0.p04	cmsExpMT	Summary	OpenSpeedShop
10.0	cmsExpMT	Summary	OpenSpeedShop



Event Throughput

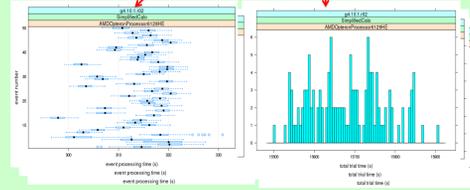


Memory Reduction

### Simple Profiler/FAST

Geant4.10.1.r02 SimplifiedCalo

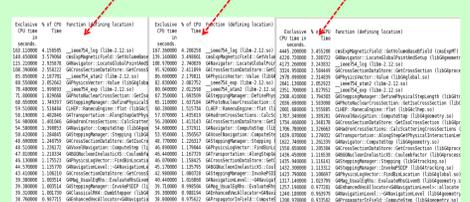
Sample	Physics List	B-Field	Energy
Higgs-ZZ	FTFP_BERT	ON (4.0T)	14 TeV PYTHIA
Electrons	FTFP_BERT	OFF (0 T)	1 GeV 5 GeV 10 GeV 50 GeV
Pions-	FTFP_BERT	ON (4.0T)	1 GeV 5 GeV 10 GeV 50 GeV
Protons	FTFP_BERT	ON (4.0T)	1 GeV 5 GeV 10 GeV 50 GeV
Anti-Protons	FTFP_BERT	ON (4.0T)	1 GeV 5 GeV 10 GeV 50 GeV



### OpenSpeedShop (osspsamp)

Geant4.10.1.r02 cmsExpMT

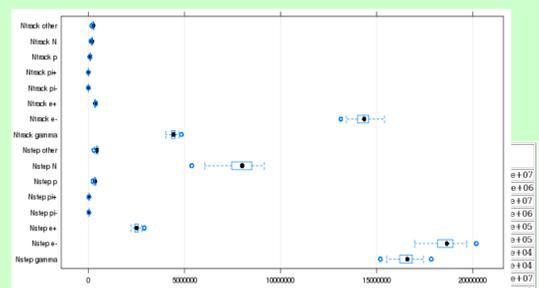
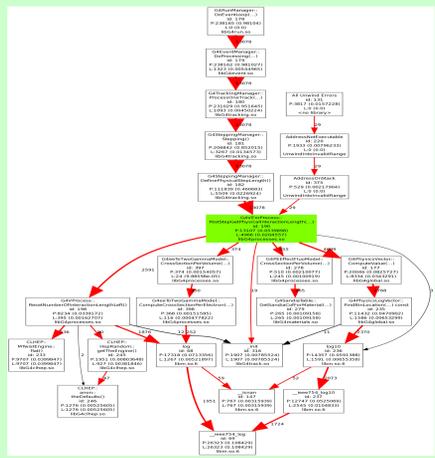
Sample	Energy	Sequential	Multi Thread
Electrons	5 GeV	S1	T1 T2 T4 T8 T16 T32
Electrons	50 GeV	S1	T1 T2 T4 T8 T16 T32
Pions	5 GeV	S1	T1 T2 T4 T8 T16 T32
Pions	50 GeV	S1	T1 T2 T4 T8 T16 T32



OSS Exclusive Time for Multi-threaded Application

## Performance Analysis

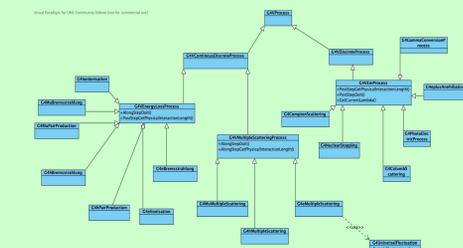
Besides the full summary of call stack and memory footprint, a detailed call graph is available to Geant4 developers for further analysis. Other information for probing any performance changes in physics processes or particle transport is also collected.



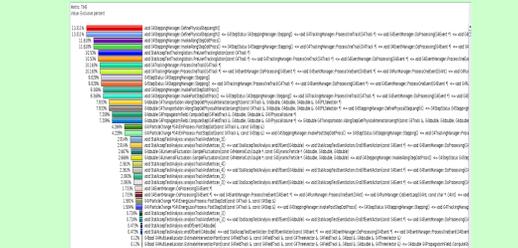
Number of Particles and Steps

## Code Reviews

Computational aspects of a subset of Geant4 classes are occasionally inspected and analyzed in order to look for optimization opportunities.



Review Class Hierarchy



TAU Exclusive Time