



Geant4 computing performance: results and issues from CMS

V.Ivanchenko, **D. Nikolopoulos**

CERN

18th Geant4 Collaboration Workshop

23-27 September 2013

Sevilla, Spain



CMS plans and requirements



- Geant4 9.6p02 is the current development version
 - slc5_amd64_gcc481
 - Slc6_amd64_gcc481
- New challenges for 13 TeV run in 2015
 - higher energy, higher multiplicity, higher pileup
 - larger integral luminosity
- Plan to adopt Geant4 10.0 in 2014
 - Start from sequential build and slc6_amd64_gcc481
 - Parallel development with MT build and TTB
 - This version will be production for the new run in 2015
- CPU speedup of Geant4 simulation is needed, there are results of CMS Simulation profiling

Profiling of the GEN-SIM step

.Performance profiling of the GEN-SIM step was done for **8TeV** and **13TeV** with FullSim.

.Specifications of the profiling for:

.8TeV

- › CMSSW 620pre4
- › 200 MinimumBias, ZEE and TTBar Events
- › No PileUp

.13TeV:

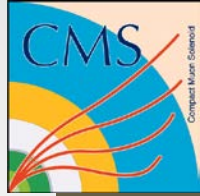
- › CMSSW 620pre8
- › 200 Minimum Bias and Ttbar_Tauola Events
- › No PileUp
- › Modified Eta Cuts to $|\eta| < 6.7$

Profiling of the GEN-SIM step for **8TeV** (1/4)



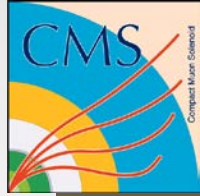
- Profiling of the **cpu** performance, running 200 MinBias, ZEE and TTBar Events.
- Target: Comparison and similarities of the most cpu-consuming functions between MinBias, ZEE and TTBar Events.
- IgProf profiling tool was used for producing web-navigable files which show the cpu time and percentages spent in every function. Two kinds of sortings, cumulative and self time spent.
- Links to the profiling results [igprof]
 - MinBias: <http://dNIKOLop.web.cern.ch/dNIKOLop/cgi-bin/navigator/profiling/620pre4/MinBias/MinBias-620pre4-cputest/>
 - ZEE: <http://dNIKOLop.web.cern.ch/dNIKOLop/cgi-bin/navigator/profiling/620pre4/ZEE/ZEE-620pre4-cputest>
 - TTBar: <http://dNIKOLop.web.cern.ch/dNIKOLop/cgi-bin/navigator/profiling/620pre4/cpu-test>

Profiling of the GEN-SIM step for 8TeV (2/4)



	Events	MinBias Cummulative / Self cpu-time (%)	ZEE Cummulative / Self cpu-time (%)	TTBar Cummulative / Self cpu-time (%)
1	G4Mag_UsualEqRhs:: EvaluateRhsGivenB	<u>3.29 / 3.29</u>	<u>3.32 / 3.32</u>	<u>3.33 / 3.33</u>
2	G4PolyconeSide:: DistanceAway	<u>2.66 / 2.34</u>	<u>2.72 / 2.30</u>	<u>2.55 / 2.02</u>
3	G4Navigator:: LocateGlobalPointAndSetup	<u>5.39 / 1.84</u>	<u>5.66 / 2.00</u>	<u>6.21 / 2.29</u>
4	SimTrackManager:: idSavedTrack	<u>1.20 / 1.20</u>	<u>4.03 / 4.03</u>	<u>1.06 / 1.06</u>
5	G4CrossSectionDataStore:: GetCrossSection	<u>15.06 / 1.54</u>	<u>13.70 / 1.60</u>	<u>14.14 / 1.61</u>
6	G4UrbanMscModel195:: ComputeCrossSectionPerAtom	<u>2.84 / 1.70</u>	<u>2.18 / 1.30</u>	<u>1.80 / 1.09</u>
7	G4ClassicalRK4:: DumbStepper	<u>6.65 / 1.55</u>	<u>6.72 / 1.60</u>	<u>6.33 / 1.58</u>
8	G4hPairProductionModel:: ComputeDMicroscopicCrossSection	<u>1.01 / 0.22</u>	<u>0.37 / 0.08</u>	<u>0.20 / 0.05</u>
9	G4PhysicsLogVector:: FindBinLocation	<u>0.62 / 0.11</u>	<u>0.79 / 0.14</u>	<u>0.93 / 0.17</u>
10	G4BGGNucleonInelasticXS:: CoulombFactor	<u>3.43 / 0.53</u>	<u>2.84 / 0.44</u>	<u>3.10 / 0.47</u>
11	G4ElasticHadrNucleusHE:: HadrNucDifferCrSec	<u>1.34 / 0.26</u>	<u>0.63 / 0.12</u>	<u>0.47 / 0.09</u>
12	G4InuclSpecialFunctions:: G4cbrt	<u>0.88 / 0.04</u>	<u>0.72 / 0.03</u>	<u>0.76 / 0.04</u>

Profiling of the GEN-SIM step for 8TeV (3/4)



.Short Comments on Functions

[1] G4Mag_UsualEqRhs::EvaluateRhsGivenB

.No child functions but still **quite consuming (~3.3%)**

[2] G4PolyconeSide::DistanceAway

.About **0.3~0.5%** is consumed by calling G4PolyconeSide::GetPhi Use of atan2.

[3] G4Navigator::LocateGlobalPointAndSetup

.Several non-mathematical calles here but needs a deeper look.

[4] SimTrackManager::idSavedTrack

.This function is more consuming for ZEE (~4%) rather in MinBias-TTBar(~1%) and does not have any callees.

[5] G4CrossSectionDataStore::GetCrossSection

.Several functions called as well. One of the most consuming.

[6] G4UrbanMscModel95::ComputeCrossSectionPerAtom

.**0.7~1%** calling **log** and **pow**

[7] G4ClassicalRK4::DumbStepper

.Most of the time spent calling [1] **EvaluateRhsGivenB (~2.7%)**.

[8] G4hPairProductionModel::ComputeDMicroscopicCrossSection

.1% spent for Min Bias and ~0.2-0.4% spent on the other events. Most of the time consumed in **log (~60% of the time spent in function)** and **exp (the rest)**.

[9] G4PhysicsLogVector::FindBinLocation

.Most of the time consumed in **log10 (~0.5-0.6%)**.

[10] G4BGGNucleonInelasticXS::CoulombFactor

.Most of the time consumed by **exp (~2%)** and **log10 (~0.6%)**.

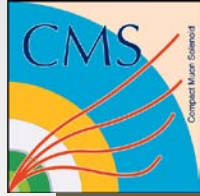
[11] G4ElasticHadrNucleusHE::HadrNucDifferCrSec

.**exp** function is the more consuming for MinBias (~1%). For the other events **~0.45%**

[12] G4InuclSpecialFunctions::G4cbrt

.Most of the time consumed in **log(~0.4-0.5%)** and **exp(~0.3%)**.

Profiling of the GEN-SIM step for 8TeV (4/4)



- Cmath log(~4%) and exp(~2-3%) stay high.
- feraiseexcept is the most consuming (~5-6%) and is called by cmath functions like cos, sin, tan, exp and pow.
- Possible gain using VDT functions instead of cmath in particular places.

Profiling of the GEN-SIM step for 13TeV (1/5)

- Profiling the performance (**cpu and memory**) of the GEN-SIM step with modified eta cut: **|EtaCut| < 6.7**
- Results received for MinBias13TeV, TTbar_Tauola13TeVcase.
- Links for web-navigable cpu-profiling results
- MinBias : <http://dNIKOLop.web.cern.ch/dNIKOLop/cgi-bin/navigator/profiling/620pre8/GEN-SIM/cpu-MinBias-200e/self>
- TTbar : <http://dNIKOLop.web.cern.ch/dNIKOLop/cgi-bin/navigator/profiling/620pre8/GEN-SIM/cpu-TTbar-200e/self>
- More information for the GEN-SIM step can be found on a twiki page created for the
- Full Simulation profiling, under the GEN-SIM step label:
<https://twiki.cern.ch/twiki/bin/viewauth/CMS/Cmssw620pre8Perf>
- Total cumulative time spent by mathematical functions is ~ **12%** for all cases.
Most consuming function is SimTrackManager::idSavedTrack a simple, “six-lines”, recursive function.

Profiling of the GEN-SIM step for 13TeV (2/5)

Most cpu-consuming functions for GEN-SIM step

	Functions	Cumulative / Self time spent (%) (MinBias13TeV)	Cumulative / Self time spent (%) (MinBias13TeV + RR)	Cumulative / Self time spent (%) (TTBar13TeV)	Cumulative / Self time spent (%) (TTbar13TeV + RR)	Short Comments
1	SimTrackManager::idSavedTrack	18.62 / 18.62	16.65 / 16.65	10.08 / 10.08	10.32 / 10.32	The most consuming function. Recursive.
2	G4Mag_UsualEqRhs::EvaluateRhsGivenB	2.38 / 2.38	2.58 / 2.58	2.82 / 2.82	2.88 / 2.88	-
3	G4PolyconeSide::DistanceAway	2.41 / 2.19	2.38 / 2.18	2.44 / 2.01	2.21 / 1.85	About 0.3% of cumulative is used by atan2.
4	G4Navigator::LocateGlobalPointAndSetup	6.67 / 1.76	6.70 / 1.80	6.63 / 2.20	2.27 / 2.12	Calls several functions
5	G4ClassicalRK4::DumbStepper	5.24 / 1.17	5.64 / 1.25	5.89 / 1.46	5.88 / 1.38	sim::Field::GetFieldValue and function #2 of the table are called the most.
6	G4ElectroNuclearCrossSection::GetIsoCrossSection	1.33 / 1.10	1.45 / 1.20	1.49 / 1.23	1.57 / 1.29	About 0.25% of cumulative spent in log

*(clicking the numbers redirects to web profile)

Profiling of the GEN-SIM step for 13TeV (3/5)

Summary of most consuming cmath functions for GEN-SIM step

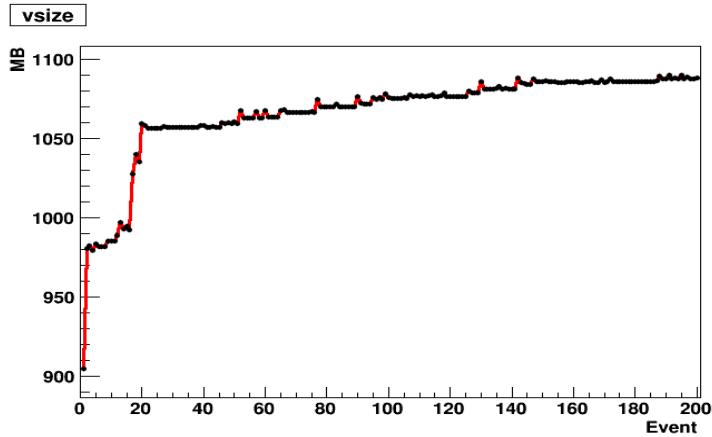
	Functions	Cumulative time spent (%) (MinBias13TeV)	Cumulative time spent (%) (TTbar13TeV)
1	log	2.55	2.65
2	exp	3.08	3.26
3	atan2	2.85	2.87
4	log10	1.30	1.51
5	pow	0.89	0.96
6	sincos	0.54	0.54
7	atan2f	0.23	0.26
8	atanf	0.11	0.12
9	cos	0.10	0.09
+	TOTAL	11.65 %	12.26 %

*(clicking the numbers redirects to web profile)

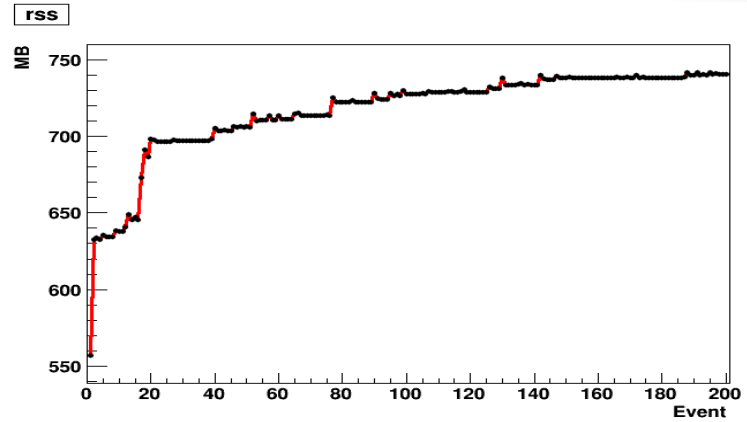
Profiling of the GEN-SIM step for 13TeV (4/5)

Plots - MinBias

vsize graph

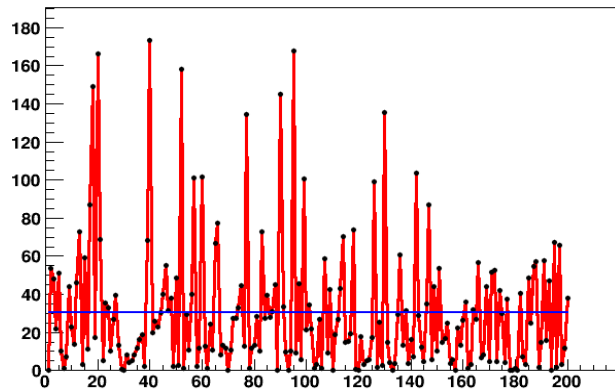


rss graph



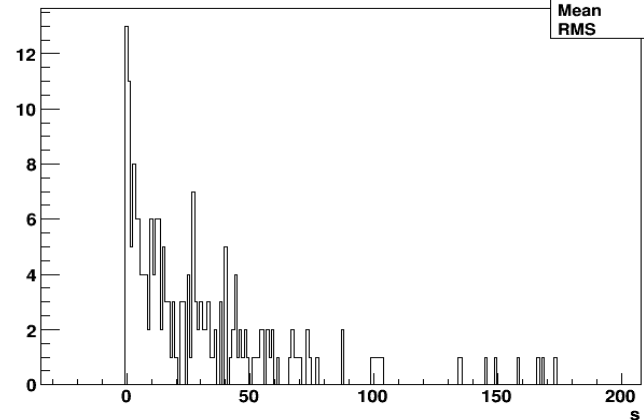
time graph

Seconds per event



time histogram

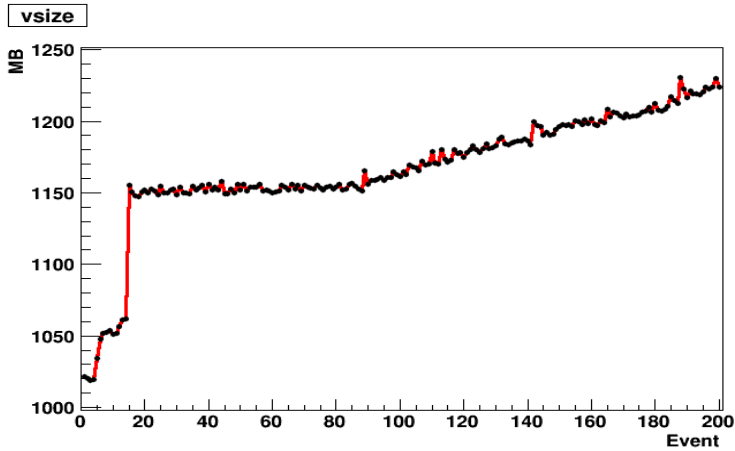
Seconds per event



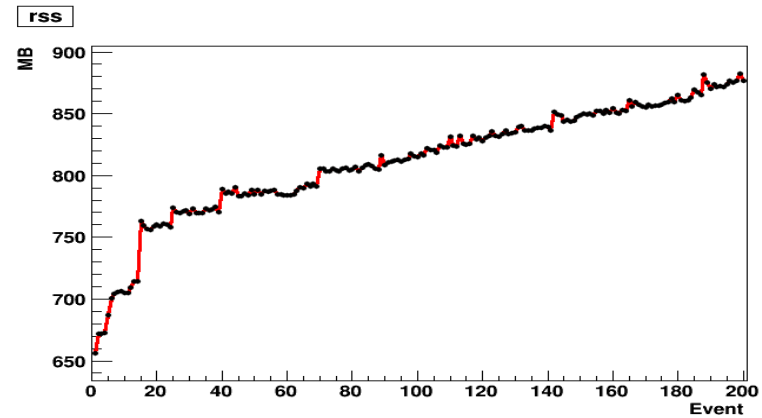
Profiling of the GEN-SIM step for 13TeV (5/5)

Plots – TTbar

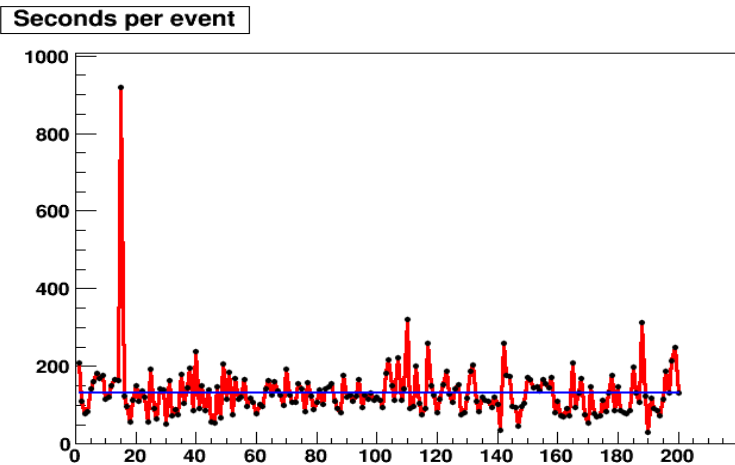
vsize graph



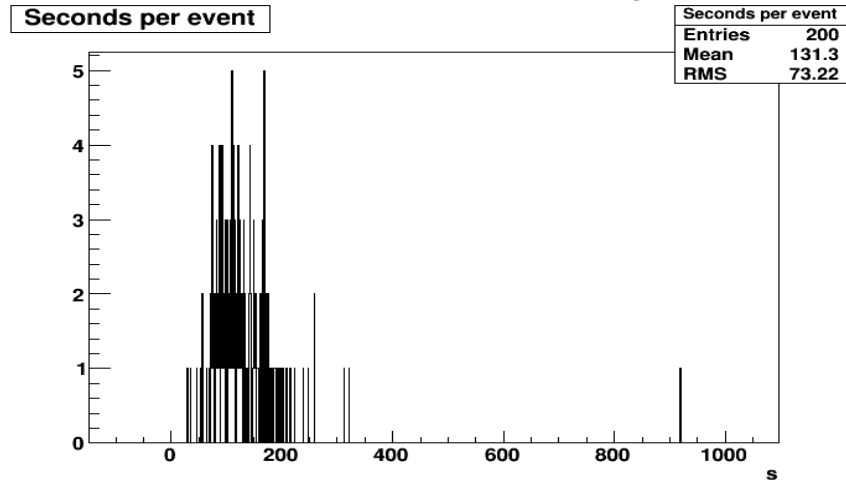
rss graph



time graph



time histogram



Summary

- CPU profiling for 8 TeV and 13 TeV are very similar
- CMS has plan to adopt Geant4 10.0 as a production version for the next run – due to that there is a strong requirement to improve CPU performance o Geant4 :
 - Math functions
 - Hadronic cross sections
 - Leader electro-nuclear and proton/neutron cross sections
 - G4PhysicsVector
 - G4UrbanMscModel
 - G4UniversalFluctuations
 - G4Polycone
- CMS required Geant4 10.0 is checked even for small memory leaks
- CMS requires that full tests are performed for QGSP_FTFP_BERT_EMV