
Time performance of experiment simulations

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**contributions by:
ATLAS, CMS and LHCb simulation teams**

- Performance measurements
 - ATLAS
 - CMS
- 64 bit mode
- Global robustness
 - G4.8.1
 - G4.8.2

Performance measurements

- All LHC experiments are now concentrating their efforts in validating the G4.8.* releases
 - physics validation (not covered here)
 - computing performance measurements
- Comparison of different results is not straightforward
 - Different set of production cuts
 - Very different geometry (accordion/crystals)
 - Different units used (ATLAS: kSI2K; CMS and LHCb: seconds@ a certain machine)
- Will present here recent results obtained by ATLAS, CMS and LHCb

Production cuts

- CMS:
 - BeamPipe: 0.01mm in the beryllium, 10m elsewhere
 - Tracker: 5mm in the TIB_Ledge, 1mm in the pixel dead regions, 0.1mm in the tracker sensitive parts, 0.01mm in the pixel sensitive parts, 10cm elsewhere
 - ECAL: 0.1mm in the PreShower sensitive parts, 1mm elsewhere
 - HCAL: 1mm for e's, 10mm for gamma's
 - Muon: ranging from 0.002mm to 10cm
- ATLAS:
 - 0.03mm in LAr calorimeter
 - 0.005mm in Muon drift tubes
 - 1mm elsewhere

Results (ATLAS)

- Several tests done in order to understand the impact on computing performance of the new msc implementation
- **The same** ATLAS simulation software (Athena release 11.5.0) has been built **twice**, using G4.7.1.p01 and G4.8.0.p01
- G4.8.0.p01 was tested with several different configurations:
 - Default: with the new msc and ATLAS standard cuts
 - Special cuts: new msc and 1mm cut for all volumes
 - Msc71: plugging in g4.8.0 the msc implementation from g4.7.1
 - Nsl: same as “Default” but inhibiting the step limitation by the msc
- Timing results for full physics events are shown (~250 events per sample), as obtained in the different configurations. Ratios wrt G4.7.1 timing results are reported as well.

Results (ATLAS)

CPU time per event (kSI2K)

	G4.7	G4.8	G4.8 1mm	G4.8 msc71	G4.8 nsl
Susy	896.46	2019.66	1690.29		849.62
Zee	890.47	1916.37	1573.31	850.41	760.2
Zmumu	713.76	1369.27	1201.99	642.02	671.32
Ztautau	750.73	1427.59	1253.83	743.69	677.34
H4l	862.15	1788.29	1429.86	884.07	783.73
Jets	685.8	1442.15	1364.75	701.05	753.6

	Ratio	Ratio 1mm	Ratio msc71	Ratio nsl
Susy	2.25	1.89		0.95
Zee	2.15	1.77	0.96	0.85
Zmumu	1.92	1.68	0.9	0.94
Ztautau	1.9	1.67	0.99	0.9
H4l	2.07	1.66	1.03	0.91
Jets	2.1	1.99	1.02	1.1

Results (ATLAS)

Channel	CPU time per event (kSI2K)				
	G4.7.1	G4.8.1 QGSP_GN	G4.8.1 QGSP	G4.8.1 QGSP_EMX	G4.8.1 QGSP_EMV
Susy	1000.06	1001.26	1942.03	1532.55	1546.07
Zmumu	723.4	797.72	1452.4	1083.35	
Ztautau	799.96	837.02	1553.93	1145.75	867.05
H4l	884.52	920.03	1821.68	2082.7	903.45
MB	284.59	313.33	574.6	420.1	325.47

- G4.8.1.p01 has been tested too, using Athena 12.0.2
- Different physics lists have been tested:

QGSP_GN: same EM physics as g4.7.1

QGSP: new msc

QGSP_EM*: special low CPU consumption lists

- Further tests show that G4.8.2/QGSP_EMV reproduces the computing performance of G4.7.1/QGSP_GN

Results (CMS)

- **Parallel builds** of official CMS software:
 - CMSSW_0_9_0_pre3 and CMSSW_1_0_0 using G4.7.1 and G4.8.1.p01
 - CMSSW_1_2_0 using G4.8.1.p02
- Several physics channels were studied
- Also performed tests using single particles, with or without magnetic field
- Physics lists used are QGSP (new Msc) and QGSP_EMV (expected to revert physics and computing performance to the ones observed in G4.7.1)

Results (CMS)

Channel	CPU time per event (sec)		
	G4.7.1	G4.8.1 QGSP	G4.8.1 QGSP_EMV
H300eemm	247.2	423.26	197.39
MB	47.59	61.66	37.07
Heavy Ions	5976	8064	5256

- tests are based on 50 events for minbias and Higgs samples, 10 events for Heavy Ions.
- performed on a 3.6GHz processor (CMS development machine lxcmsg1, at CERN)
- a slowdown of the CMS simulation based on G4.8.1.p01 is observed, ranging from ~30% to ~70%
- when using QGSP_EMV, the speed not only reverts back to the level of G4.7.1, but appears to improve by ~15-25%

Results (CMS)

CPU time per event (s)

Release	mu 1 GeV		mu 10 GeV		mu 100 GeV	
	MagFld OFF	MagFld ON	MagFld OFF	MagFld ON	MagFld OFF	MagFld ON
G4.7.1/QGSP	0.07	0.14	0.54	0.8	1.09	1.27
G4.8.1/QGSP	0.18	0.26	0.63	0.8	1.1	1.28
G4.8.1/QGSP_EMV	0.1	0.14	0.47	0.61	0.77	1.04

CPU time per event (s)

Release	pi 1 GeV		pi 10 GeV		pi 100 GeV	
	MagFld OFF	MagFld ON	MagFld OFF	MagFld ON	MagFld OFF	MagFld ON
G4.7.1/QGSP	0.24	0.37	1.02	1.16	9.04	13.11
G4.8.1/QGSP	0.33	0.44	1.45	1.56	11.78	14.53
G4.8.1/QGSP_EMV	0.19	0.31	1.03	1.22	8.96	10.99

- eta-range (-3.0, +3.0), 2000 events per sample, on a 3.2GHz processor (CMS development machine lpcdt023, at FNAL).
- Low statistics test on single electrons also performed:
 - degradation of performance by ~60% at 10GeV and by ~40% at 50GeV when using G4.8.1/QGSP wrt G4.7.1/QGSP
 - G4.8.1/QGSP_EMV shows performance similar to G4.7.1/QGSP

Results (LHCb)

- Many performance studies done by LHCb, mainly on G4.7.1, and already presented at previous G4TFs
 - CPU time per event is about 28s for minbias and 86s for B events (@ a 2.8 GHz Xeon or equivalent)
 - about $300 \cdot 10^6$ events produced in data challenge DC06 using G4.7.1
 - 1% of events aborted due to stuck tracks
 - studies on optimization of compiler flags (-sse2) are ongoing

Summary: CMS/ATLAS

	G4.8_QGSP/G4.7_QGSP ATLAS	CMS
H300eemm		1.71
H1304I	2.07	
MB	2.02	1.3
Heavy Ions		1.35
Susy	2.25	
Zee	2.15	
Zmumu	1.92	
Ztautau	1.9	
jets	2.1	

- Different units used in the measurements
 - only comparison of ratios is meaningful
- Unfortunately, did not agree in advance on samples to test...

64 bit mode (ATLAS)

- Tests on full physics samples, using three configurations:
 - 32/32 = 32bit build on 32bit machines
 - 32/64 = 32bit build on 64bit machines
 - 64/64 = 64bit build on 64bit machines
- Only dbg build available at the time these measurements were done
- MuonSpectrometer simulation not working, due to a run time problem in geometry description
- Choice to normalize all time values to kSI2K, using the conversions factor provided by LSF
 - may not be 100% accurate when comparing 64bit and 32bit architectures

64 bit mode (ATLAS)

channel	CPU time per event (kSI2K)			channel	CPU time per event (seconds)		
	32/32	32/64	64/64		32/32	32/64	64/64
susy	1337.77	1715.65	1578.6	susy	1210.9	866.49	797.27
Zee		1780.69	1692.98	Zee		899.34	855.04
Ztautau	1199.69	1506.2	1393.33	Ztautau	1084.01	760.71	703.7
H4I	1378.48	1825.1	1543.82	H4I	1280.23	921.77	779.71
MB	450.51	575.53	542.54	MB	418.29	290.67	274.01
jets	1501.99	1608.5	1404.59	jets	1458.25	812.38	709.39

- InDet+Calo, G4.8.1.p02 (new msc without step limitation)

channel	Ratio of kSI2K wrt 32/32		channel	Ratio of seconds wrt 32/32	
	32/64	64/64		32/64	64/64
susy	1.28	1.18	susy	0.72	0.66
Zee			Zee		
Ztautau	1.26	1.16	Ztautau	0.7	0.65
H4I	1.32	1.12	H4I	0.72	0.61
MB	1.28	1.2	MB	0.69	0.66
jets	1.07	0.94	jets	0.56	0.49

Global robustness

- ATLAS is using for performance measurements about 100 jobs of full physics events (50 events per job).
 - some estimation of the G4.8 robustness can already be done before going into production
- CMS is concentrating in very large scale productions, with use of grid resources and MCProd machinery
 - will allow higher statistics, and ease the chasing of rare bugs
- Will report here on robustness issues arisen with the G4.8 releases
 - work still in progress, in close contact with the G4 developers

- CMS reports a high number of jobs crashing
 - crashes only present when using QGSP
 - segmentation fault in G4Navigator,
 - G4UrbanMscModel in in the stack of a significant number of the problematic jobs (~20%)
- Out of 100 ATLAS jobs, 10 crashed with messages similar to

```
G4HadronElastic WARNING ekin= -1.1368684e-13 after scattering of neutron
p(GeV/c)= 8.7697033e-05 on proton
In src/G4ReactionDynamics.cc, line 3877:
====> G4ReactionDynamics::NuclearReaction: inelastic reaction
kinematically not possible
G4HadronicProcess failed in ApplyYourself call for
- Particle energy[GeV] = 2.2737368e-16
- Material = LiquidArgon
- Particle type = neutron
```

- Presently, only ATLAS testing G4.8.2
 - LHCb and CMS are about to start their tests as well
- ATLAS reports an incredibly high number of aborted events (**track stuck**):
 - about 76% of full physics events, with G4.8.2 out-of-the-box and QGSP
 - aborted events drop to zero when using QGSP_GN
 - a detailed parsing of the logs obtained with G4.8.1 showed that even there, about 5% of events were aborted
 - several patches proposed by the G4 developers are being tested
 - The lowest abort rate obtained is ~10%

Conclusions

- ATLAS CMS and LHCb are actively measuring the computing performance of their G4-based software
- G4.8/QGSP shows as expected an increase in processing time wrt G4.7.1/QGSP
 - increase is bigger in ATLAS than in CMS
- G4.8/QGSP_EMV reproduces the usual computing performance
 - in CMS, it seems to perform even better than G4.7.1
- Many tests ongoing to better estimate the overall robustness of the new G4.8 releases