Geant4 MT Performance

Soon Yung Jun (Fermilab) 21st Geant4 Collaboration Meeting, Ferrara, Italy Sept. 12 - 16, 2016

Introduction

- Geant4 multi-threading (Geant4 MT) capabilities
 - Event-level parallelism
 - Available since 10.0
 - Status (see Andrea's talk in Plenary 7)
- Readiness for large-scale computing?
 - Validation (not a scope of this talk)
 - Performance
- Basic performance metrics
 - Event throughput (weak scaling)
 - Memory reduction
- Scopes of this talk
 - MT performance on different hardware platforms
 - Profiling results

Performance Profiling Experiments

- Application : a standalone CMS detector simulation
 - the CMS geometry (gdml)
 - a volume based magnetic field map excerpted from CMSSW
 - single particle samples (50 GeV pi-,e-) and PYTHIAH \rightarrow ZZ
 - cmsExp (sequential) and cmsExpMT (multi-threading)
- Platform tested for this talk
 - Intel Xeon X5650: dual-socket 6-core (total 12 cores), 12GB
 - AMD Opertron 6128: quad-socket 8-core (total 32 cores), 64GB
 - Intel Xeon Phi 5110P (MIC, Knight's Corner): 60 cores, 8GB
 - Intel Xeon Phi (Knight's Landing), 64 cores, 96GB+16MCDRAM
- Profiling tools
 - OpenISpeedshop (OSS) v2.2
 - Intel VTune Amplifier XE (VTune) 2016

MT Performance on General Purpose CPUs: Intel vs. AMD

• Event throughput = the number of event processed/time

Speedup efficiency: $\epsilon(Nthreads) =$





- What to understand (Geant4 10.2.r06)
 - MT is (sometimes) faster than sequential
 - Degradation as the number of threads increases in AMD

4

Profiling Comparison: Intel Xeon

- OSS compare: Sequential vs. MT with1 thread (% of time)
 - Reported time: 1951 (s1) vs. 1878 (t1) seconds for 1028 events of 50 GeV pions (10.2.r06)

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[openss]: Legend: -c 2 represents db_intel_pi-_50_1/cmsExpMT-pcsamp.openss
[openss]: Legend: -c 4 represents db_intel_pi-_50_0/cmsExp-pcsamp.openss
-c2,% of -c4,% of Function (defining location)
CPU Time CPU Time
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6.190079
         6.168036
                    cmsExpMagneticField::GetVolumeBaseBfield(double const*
3,899106
         3.807265
         3.215778
                    G4Navigator::LocateGlobalPointAndSetup(CLHEP::Hep3Vect
3.309547
                    _ ieee754_atan2 (libm-2.12.so)
         2.266614
2.335641
                    G4VDiscreteProcess::PostStepGetPhysicalInteractionLeng
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         1,977405
                    G4SteppingManager::DefinePhysicalStepLength() (libG4tr
                    G4Navigator::ComputeStep(CLHEP::Hep3Vector const&, CLH
1,484518
        1.488923
1,420893
        1.413265
                    G4VoxelNavigation::ComputeStep(CLHEP::Hep3Vector const
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         1.857006
                    G4SteppingManager::Stepping() (libG4tracking.so: G4Ste
1.348542
          1.255817
                    G4UniversalFluctuation::SampleFluctuations(G4MaterialC
    t1
              s1
```

- A hint of difference in SteppingManager, but not conclusive
- Need to cross-check the number of steps/tracks (by the particle type)

Profiling Comparison: AMD Opertron

- OSS compare: 32 threads vs. 1 thread (% of time)
 - Experiment with 1028 events of 50 GeV pions (10.2.r06)

[openss]:	Legend: - o	2 represents db_amd_pi50_32/cmsExpMT-pcsamp.openss
[openss]:	Legend: - o	: 4 represents db_amd_pi50_1/cmsExpMT-pcsamp.openss
-c 2, %	-c 4, %	Function (defining location)
CPU Time	CPU Time	
t32	t1	
5.996050	6.249268	G4PhysicsVector::Value(double, unsigned long&) const
3.835966	3.081700	G4Navigator::LocateGlobalPointAndSetup(CLHEP::Hep3Vec
3.777269	4.086459	cmsExpMagneticField::GetVolumeBaseBfield(double const [,]
2.354695	0.528181	G4ParticleChangeForTransport::UpdateStepForAlongStep(
2.338718	2.512992	ieee754_atan2 (libm-2.12.so)
2.100942	1.179980	G4Navigator::ComputeStep(CLHEP::Hep3Vector const&, CL
1.708470	1.828667	G4SteppingManager::DefinePhysicalStepLength() (libG4t)
1.639153	1.369797	G4CrossSectionDataStore::GetCrossSection(G4DynamicPart
1.464572	1.437773	G4VoxelNavigation::ComputeStep(CLHEP::Hep3Vector const
1.423322	1.427549	G4SteppingManager::Stepping() (libG4tracking.so: G4Ste

 Clear signs of difference in G4Navigator and ParticleChangesForTransport::UpdateStepForAlongsStep

$H \rightarrow ZZ$: Intel vs. AMD

- Speedup efficiency (ϵ) as the number of threads (10.2.r06)
 - The number of events processed = 50 x Nthreads



Profiling Comparison: Intel Xeon

- OSS compare: Intel sequential vs. MT 1 thread (% of time)
 - Experiments with 50 events of $H \rightarrow ZZ$ (10.2.r06)

```
[openss]: Legend: -c 2 represents db intel higgs 0/cmsExp-pcsamp.openss
[openss]: Legend: -c 4 represents db intel higgs 1/cmsExpMT-pcsamp.openss
-c2,% of -c4,% of
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                               CPU Time
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                               2.606530
2.327372
                              2.049718
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2.047615
                               1.520584
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                                                               G4Transportation::AlongStepGetPhysicalInteractionLeng1
1.754896
                            1.365109
1.731395
                                                               G4UniversalFluctuation::SampleFluctuations(G4Material(
                               1.863428
1.641349
                                                               G4Mag UsualEgRhs::EvaluateRhsGivenB(double const*, double const*, 
                              1.640354
                               1.691205
1.615017
                                                               G4PolyconeSide::DistanceAway(CLHEP::Hep3Vector const&,
1.563666
                               1.831518
                                                               G4VDiscreteProcess::PostStepGetPhysicalInteractionLenc
```

Profiling Comparison: AMD Opertron

- OSS compare: MT 2 threads vs. MT 32 thread (% of time)
 - Experiments with 50xNthreads events of H->ZZ (10.2.r06)

[openss]:	Legend: -	c 2 represents db_amd_higgs_2/cmsExpMT-pcsamp.openss
[openss]:	Legend: -	c 4 represents db_amd_higgs_32/cmsExpMT-pcsamp.openss
-c2,% of	-c4,% of	Function (defining location)
CPU Time	CPU Time	
6.487911	6.162949	G4PhysicsVector::Value(double, unsigned long&) const
2.878457	3.341192	G4Navigator::LocateGlobalPointAndSetup(CLHEP::Hep3Vec
2.781600	2.523859	cmsExpMagneticField::GetVolumeBaseBfield(double const
1.973615	1.997436	G4SteppingManager::DefinePhysicalStepLength() (libG41
1.961492	1.804446	G4PolyconeSide::DistanceAway(CLHEP::Hep3Vector const&
1.177427	1.735634	G4Navigator::ComputeStep(CLHEP::Hep3Vector const&, CL
0.872323	1.318057	G4TouchableHistory::GetVolume(int) const (libG4digits
0.749323	1.228093	G4Navigator::LocateGlobalPointWithinVolume(CLHEP::Hep
0.711796	1.712017	G4ParticleChangeForTransport::UpdateStepForAlongStep
0.691357	0.665238	CLHEP::RanecuEngine::flatArray(int, double*) (libG4c1

 Again hints of difference: adding counters for the number of steps tracks by the particle type for MT

MT performance: Xeon Phi 5110 (MIC, Knight's Corner)

- cmsExp on MIC: 5 GeV pi- (Events = 1028 x N-threads)
 - 60 cores (4 way hyper-threading), 1.03 GHz, 7.8 GB memory
 - Significant scalability loss from N threads = 2 to N threads = 4
 - Hit memory limit (~7.3 GB available) @ 120 threads
 - Need to re-measure throughput with physics samples (threshold for the memory limit and the maximal cores to utilize)



MT Performance on KNL

- Performance on Intel Xeon Phi Processor (Knight's Landing)
 - Developer Edition: Single Socket 1.30 GHz, 64 core
 - MEMORY: 96GB, 2133MHz DDR4, 16GB MCDRAM memory
 - Geant4 10.2.p02 with -xMIC-AVX512
 - Experiment with N-threads x1028 Events of 5 GeV pi- (10.2.r06)



Profiling Results: KNL

• Hotspots with N-threads = 256

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	This section lists the m	ost active functions in you	r application. Optim	iizing these hot	spot functions typically	results in improving overall application perform	nance.
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	G4SteppingManager::D	efinePhysicalStepLength	libG4tracking.so	2447.038s		L unlock/lock	
	Llock_791	- Recenter	libpthread.so.0	2038.181s	-		
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Profiling Results: KNL (N threads = 256)

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▷ G4VModularPhysicsList::ConstructProcess ← G4RumManagerKernel::InitializePhysics ← G4 0.010s	Os Os	libG4run.so	G4V						
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_L_lock: also called by G4LogicalVolume::initialiseWorker

Profiling Results: KNL (N threads = 256)

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◊G4SteppingManager::DefinePhysicalStepLength	2447.038s	05	0s libG4tracking.so				
▶_L_lock_791	0.259s	2037.9229	0s libpthread.so.0				
◊G4VoxelNavigation::LevelLocate	1976.582s	05	0s libG4processes.so				
◊G4Navigator::ComputeStep	1691.765s	05	0s libG4geometry.so				
▼G4NavigationLevel::operator=	1580.249s		0s libG4geometry.so				
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64Transportation::AlongStepGetPhysicalInteractionLengt	1499.946s	05	0s libG4processes.so				
	1472 74 05	05	0s libG4geometry.so				
▶G4Navigator::LocateGoobalPointAndSetup	1423.551s	05	0s libG4geometry.so				
♦G4CrossSectionDataStore::GetCrossSection	1390.681s	05	0s libG4processes.so				
♦G4CrossSectionDataStore::GetCrossSection	1372.006s	05	0s libG4processes.so				
♦G4Transportation::PostStepDoIt	1318.793s	05	0s libG4processes.so				
◊G4TouchableHistory::GetVolume	1120.922s	05	0s libG4geometry.so				
▶ZTWN14G4GeomSplitterI8G4LVDataE6offsetE	1084.336s	05	0s libG4Tree.so				
▷cmsExpMagneticField::GetFieldValue	1049.469s	05	0s cmsExpMT				
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Also seen with N threads = 198 and 128

Geant4MT: Profiling Result (N threads =128)

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G4Navigator::ComputeStep	1729.079s	0s	0s	libG4geometry.so	G4Navigator::ComputeStep(CLHEP::Hep3Vect
G4Navigator::LocateGlobalPointAndSetup	1611.797s	0s	0s	libG4geometry.so	G4Navigator::LocateGlobalPointAndSetup(CLH
G4VoxelNavigation::ComputeStep	1539.4685	0s	0s	libG4geometry.so	G4VoxelNavigation::ComputeStep(CLHEP::Hep
G4SteppingManager::Stepping	1534.654s	0s	0s	libG4tracking.so	G4SteppingManager::Stepping(void)
G4Transportation::AlongStepGetPhysicalInt	1345.532s	0s	0s	libG4processes.so	G4Transportation::AlongStepGetPhysicalIntera
G4CrossSectionDataStore::GetCrossSectio	1335.156s	0s	0s	libG4processes.so	G4CrossSectionDataStore::GetCrossSection(G
cmsExpMagneticField::GetFieldValue	1286.392s	0s	0s	cmsExpMT	cmsExpMagneticField::GetFieldValue(double co
G4CrossSectionDataStore::GetCrossSectio	1188.682s	0s	0s	libG4processes.so	G4CrossSectionDataStore::GetCrossSection(G
G4Transportation::PostStepDoIt	1186.326s	0s	0s	libG4processes.so	G4Transportation::PostStepDolt(G4Track const
G4ParticleChange::CheckIt	1156.319s	0s	0s	libG4track.so	G4ParticleChange::CheckIt(G4Track const&)
G4NavigationLevel::operator=	1152.856s	0s	0s	libG4geometry.so	G4NavigationLevel::operator=(G4NavigationLe
G4SteppingManager::InvokeAlongStepDoItP	963.024s	0s	0s	libG4tracking.so	G4SteppingManager::InvokeAlongStepDoItProc
G4SteppingManager::InvokePSDIP	946.570s	0s	0s	libG4tracking.so	G4SteppingManager::InvokePSDIP(unsigned lor
G4TouchableHistory::GetVolume	933.528s	0s	0s	libG4geometry.so	G4TouchableHistory::GetVolume(int) const
G4VEmProcess::PostStepGetPhysicalIntera	889.363s	0s	0s	libG4processes.so	G4VEmProcess::PostStepGetPhysicalInteracti
G4VDiscreteProcess::PostStepGetPhysical	851.415s	0s	0s	libG4processes.so	G4VDiscreteProcess::PostStepGetPhysicalInt
G4NavigationLevel::G4NavigationLevel	796.861s	0s	0s	libG4geometry.so	G4NavigationLevel::G4NavigationLevel(G4VPhy
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G4NormalNavigation::ComputeStep	782.302s	0s	0s	libG4geometry.so	G4NormalNavigation::ComputeStep(CLHEP::H
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Summary

- Reviewed Geant4 MT performance
 - standalone CMS detector simulation (single particle, $H \rightarrow ZZ$)
- Performance on different systems and profiling results
 - No major issues on Intel Xeon
 - Degradation seen on AMD as the number of threads is partially understood
 - Xeon Phi (KNC) shows problems at N-threads > 120
 - Xeon Phi (KNL) shows stable performance
- More tests to understand results of AMD/KNL profiling data
 - Examine stepping information on AMD and KNL (sequential vs. 1-threads and 1-thread vs. N-threads)
 - Test H \rightarrow ZZ on KNL (scalability and memory)

Backup Slides

Intel Xeon vs. AMD Opteron

• NUMA memory nodes, sockets, shared caches cores Xeon X5650 Opteron 6128HE

Machine (12GB)							
NUMANode #0 (6029MB)							
Socket #0							
L3 #0 (12MB)							
L2 #0 (256KB)	L2 #1 (256KB) L2 #2 (256KB) L2 #3 (256KB) L2 #4 (256KB) L2 #5 (256KB)						
L1 #0 (32KB)	L1 #1 (32KB) L1 #2 (32KB) L1 #3 (32KB) L1 #4 (32KB) L1 #5 (32KB)						
Core #0 PU #0	Core #1 Core #2 Core #3 Core #4 Core #5 PU #1 PU #2 PU #3 PU #4 PU #5						
NUMANode #1 (60	60MB)						
Socket #1							
L3 #1 (12MB)							
L2 #6 (256KB)	L2 #7 (256KB) L2 #8 (256KB) L2 #9 (256KB) L2 #10 (256KB) L2 #11 (256KB)						
L1 #6 (32KB)	L1 #7 (32KB) L1 #8 (32KB) L1 #9 (32KB) L1 #10 (32KB) L1 #11 (32KB)						
Core #6 PU #6	Core #7 Core #8 Core #9 Core #10 Core #11 PU #7 PU #8 PU #9 PU #10 PU #11						
L							

achine (63GB)					
Socket ≠0 (16GB)	Socket #1 (16GB)				
NUMANode #0 (8190MB)	NUMANode #2 (8192MB)				
L3 #0 (5118KB)	L3 #2 (5118KB)				
L2 #0 (512KB) L2 #1 (512KB) L2 #2 (512KB) L2 #3 (512KB)	L2 #8 (512KB) L2 #9 (512KB) L2 #10 (512KB L2 #11 (512KB)				
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Core #0 Core #1 Core #2 Core #3 PU #0 PU #1 PU #2 PU #3	Core #8 Core #9 Core #10 Core #11 PU #8 PU #9 PU #10 PU #11				
NUMANode #1 (8192MB)	NUMANode #3 (8192MB)				
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Core #4 Core #5 Core #6 Core #7 PU #4 PU #5 PU #6 PU #7	Core #12 Core #13 Core #14 Core #15 PU #12 PU #13 PU #14 PU #15				
Socket #2 (16GB)	Socket #3 (15GB)				
NUMANode #4 (8192MB)	NUMANode #6 (8192MB)				
L3 #4 (5118KB)	L3 #6 (5118KB)				
L2 #16 (512KB L2 #17 (512KB L2 #18 (512KB L2 #19 (512KB	L2 #24 (512KB) L2 #25 (512KB) L2 #26 (512KB) L2 #27 (512KB)				
L1 #16 (64KB) L1 #17 (64KB) L1 #18 (64KB) L1 #19 (64KB)	L1 #24 (64KB) L1 #25 (64KB) L1 #26 (64KB) L1 #27 (64KB)				
Core #16 Core #17 Core #18 Core #19	Core #24 Core #25 Core #26 Core #27				
P0 #16 P0 #17 P0 #18 P0 #19	PU #24 PU #25 PU #26 PU #27				
NUMANode #5 (8192MB)	NUMANode #7 (7552MB)				
L3 #5 (5118KB)	L3 #7 (5118KB)				
L2 #20 (512KB L2 #21 (512KB L2 #22 (512KB L2 #23 (512KB	L2 #28 (512KB) L2 #29 (512KB) L2 #30 (512KB) L2 #31 (512KB				
L1 #20 (64KB) L1 #21 (64KB) L1 #22 (64KB) L1 #23 (64KB)	L1 #28 (64KB) L1 #29 (64KB) L1 #30 (64KB) L1 #31 (64KB)				
Core #20 Core #21 Core #22 Core #23	Core #28 Core #29 Core #30 Core #31 PU #28 PU #29 PU #30 PU #31				

Exclusive time: Intel Xeon

- OSS compare: 1 threads vs. 12 thread (% of time)
 - Experiment with1028 events of 50 GeV pions (10.2.r06)

```
[openss]: Legend: -c 2 represents db intel pi- 50 12/cmsExpMT-pcsamp.openss
[openss]: Legend: -c 4 represents db intel pi- 50 1/cmsExpMT-pcsamp.openss
 -c 2, % -c 4, % Function (defining location)
CPU Time CPU Time
6.238938 6.190079
                   G4PhysicsVector::Value(double, unsigned long&) const (1:
4.018038
         3.899106
                   cmsExpMagneticField::GetVolumeBaseBfield(double const*,
3.537249
         3.309547
                   G4Navigator::LocateGlobalPointAndSetup(CLHEP::Hep3Vector
2.378695 2.335641
                    ieee754 atan2 (libm-2.12.so)
         1.707284
                   G4VDiscreteProcess::PostStepGetPhysicalInteractionLengtH
1.735548
1.607452 1.568036
                   G4SteppingManager::DefinePhysicalStepLength() (libG4trac
1.531425 1.484518
                   G4Navigator::ComputeStep(CLHEP::Hep3Vector const&, CLHE)
                   G4SteppingManager::Stepping() (libG4tracking.so: G4Step)
1.474424 1.404688
                   G4VoxelNavigation::ComputeStep(CLHEP::Hep3Vector const&
1.456177
         1.420893
1.410107
         1.336284
                   G4VEmProcess::PostStepGetPhysicalInteractionLength(G4Tra
```

t12 t1

- No changes in call paths
- No significant timing perturbation (a good sanity check!)

AMD

- OSS compare: AMD 32 threads vs. 1 thread (% of time)
 - Persistency in difference (by version, by different samples)?
 - Experiments with 1028 events of 50 GeV e- and pi- (10.2.r07)



Degradation on AMD: Persistency

- OSS compare: AMD 32 threads vs. 1 thread (% of time)
 - Experiment with 1028 events of 50 GeV pi- (10.2.r07)

[openss]:	Legend: -c 2 represents db_amd_pi50_32/cmsExpMT-pcsamp.openss
[openss]:	Legend: -c 4 represents db_amd_pi50_1/cmsExpMT-pcsamp.openss
-c 2, %	-c 4, % Function (defining location)
CPU Time	CPU Time

6.003521	5.902264	G4PhysicsVector::Value(double, unsigned long&) const
3.952595	3.383990	G4Navigator::LocateGlobalPointAndSetup(CLHEP::Hep3Vec
3.684048	3.856901	<pre>cmsExpMagneticField::GetVolumeBaseBfield(double const;</pre>
2.421680	2.385093	ieee754_atan2 (libm-2.12.so)
2.024112	1.030340	G4TouchableHistory::GetVolume(int) const (libG4digits
1.877350	1.926192	G4SteppingManager::DefinePhysicalStepLength() (libG4t
1.762748	1.557561	G4VoxelNavigation::ComputeStep(CLHEP::Hep3Vector cons
1.583220	1.659335	G4VEmProcess::PostStepGetPhysicalInteractionLength(G4
1.533902	1.411287	G4SteppingManager::Stepping() (libG4tracking.so: G4St
1.375139	1.416721	G4SteppingManager::InvokePSDIP(unsigned long) (libG4t

 G4Navigator::LocateGloalPointAndSetup is perturbative (consistent with 10.2.r06)

Degradation on AMD: Persistency

- OSS compare: AMD 32 threads vs. 1 thread (% of time)
 - Experiment with 1028 events of 50 GeV e- (10.2.r07)

```
[openss]: Legend: -c 2 represents db amd e- 50 32/cmsExpMT-pcsamp.openss
[openss]: Legend: -c 4 represents db amd e- 50 1/cmsExpMT-pcsamp.openss
 -c 2, % -c 4, % Function (defining location)
CPU Time CPU Time
6.164769
          6.643990
                    cmsExpMagneticField::GetVolumeBaseBfield(double const
                    G4PhysicsVector::Value(double, unsigned long&) const
5.847023
         6.061244
3.995152
                    G4Navigator::LocateGlobalPointAndSetup(CLHEP::Hep3Vec
          3.008473
2.851305
          2.983996
                    G4UniversalFluctuation::SampleFluctuations(G4Material
2.551915
         1.009077
                    G4TouchableHistory::GetVolume(int) const (libG4digits
                    G4VEmProcess::PostStepGetPhysicalInteractionLength(G4
         2.591272
2.451316
         2.251656
                    G4SteppingManager::DefinePhysicalStepLength() (libG4t
1.982036
                    G4UrbanMscModel::SampleCosineTheta(double, double) (1
          1.875131
1.922636
                    CLHEP::RanecuEngine::flat() (libG4clhep.so: RanecuEnc
1.785764
         1.304073
```

- 1.664950 1.822590 G4PropagatorInField::ComputeStep(G4FieldTrack&, doubl
- G4TouchableHistory::GetVolume

Geant4 MT Performance: Xeon Phi (Andrea Dotti)

- CMS geometry, uniform (4T) B-filed (10.2.r06)
- Total number of events processed = 10*(number of threads)
- Intel Xeon Phi 3210A (57 cores), 6GB



Geant4MT: Profiling Result (N threads = 256)

eno current project> - Intel VTune Amplifier (on mic.fnal.gov)			
📫 📴 😥 🕨 🗗 🛱 🕐 🖉 Welcome hotspot 🗙			=
Basic Hotspots Hotspots by CPU Usage viewpoint (<u>change</u>) ③	ntel VTune	Amplifie	er XE 2016
🖪 📟 Collection Log 🕀 Analysis Target 🛆 Analysis Type 🛍 Summary 😪 Bottom-up 🚭 Caller/Callee 🚭 Top-down Tree 🛃 Platform	m		
Grouping: Function / Call Stack		\$ 4	Q (%)
CPU Time -			
Function / Call Stack Effective Time by Utilization	ania Tina I	Overhead	Modu
🗍 Idle 📕 Poor 📋 Ok 📕 Ideal 📕 Over	Spin Time	Time	
▷G4PhysicsVector::Value 3105.414s	0s	0s	libG4global.
▶_L_unlock_697 2663.291s	0s	0s	libpthread.
▷G4SteppingManager::DefinePhysicalStepLength 2447.038s	0s	0s	libG4trackir
▼_L_lock_791 0.259s	2037.922s	0s	libpthread.
▷ \sigma G4LogicalVolume::InitialiseWorker \le G4GeometryWorkspace::InitialisePhysicalVolumes \le 0.259s	2037.032s	0s	libG4geom
▷ \cap G4GeometryWorkspace::InitialiseWorkspace 0s	0.672s	0s	libG4geom
\land G4CrossSectionFactoryRegistry::Instance \leftarrow G4CrossSectionDataSetRegistry::GetCross 0s	0.118s	0s	libG4proces
▶ ⊂ G4IonTable::GetIon 0s	0.070s	0s	libG4particl
K G4VModularPhysicsList::ConstructProcess ← G4RunManagerKernel::InitializePhysics ← G4	0.020s	0s	libG4run.so
尽 G4CrossSectionFactoryRegistry::GetFactory ← G4CrossSectionDataSetRegistry::GetCrc 0s	0.010s	0s	libG4proces
♦G4VoxelNavigation::LevelLocate 1976.582s	0s	0s	libG4proces
♦G4Navigator::ComputeStep 1691.765s	0s	0s	libG4geom
Selected 1 row(s): 2663 291s	Ôs	Ôs	
	03	03	>
)s 650s	Thr	ead 🗸
G4MTBunM			Running
G4MTRunM			CPU Time
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CPU Usage			
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Geant4MT: Profiling Result (Sequential)

#	<no current="" project=""> - Intel VTune An</no>	nplifier (o	on mic.fnal.gov)	
🕼 🖄 🖙 🕨 💀 🕕 🚔 🕜 🗰 Welc	ome hotspots-t192 hotspots-t240 hotspo	ots-t32	hotspots-t128 hotsp	oots-t64 hotspot 🗙
Basic Hotspots Hotspots b	v CPU Usage viewpoint (change)	(?)		Intel VTune Amplifier XE 2016
	, el e esuge vienpenne (<u>enange</u>)	<u> </u>		
Collection Log 😌 Analysis Target	Analysis Type 📓 Summary 😚 Bottom-up	😽 Caller/C	Callee 🌄 🥵 Top-down	Tree Platform
Grouping: Function / Call Stack				≎] t₊, Q (%)
	CPU Time 🗸		≪	
Function / Call Stack	Effective Time by Utilization		Module	=
fairecióir) can ocació		Tim. Tim	. House	
NG4Physics Vector: Value	Idle Poor Ok Ideal Over	05 0	ibC4alabal.co	C4Physics\/actor.\/alua/daubla_unsigned lang5.) ca
C4bPairBroductionModeluCompute DMicroso	70.0915	05 0	is libG4giobal.so	G4PhysicsVector::Value(double, unsigned long&) co
PG4/exelNavigation - LevelLecate	22 574	05 0	ibG4processes.so	G4/(excl/havigation) avail acato(G4) avigation Hist
	21 5550	05 0	ibG4processes.so	G4Novigator: ComputeStop(CLHEP: Hop2)/octor c
C4ProductionCutsTableuScanAndSatCouple	30,580	05 0	libG4geometry.so	G4DradustionCutsTableuScapAndSatCouple(G4Lag
C4StoppingMapager: DofineBhysicalStopLog	29.5805	05 0	ibG4processes.so	G4StoppingMapagery Define Device Standard SetCouple(G4Log
C4Navigatorul acato Clobal Deint And Satur	26.9575	05 0		G4Navigatorul esateClebalDeintAndSetup(CLUED)
	20.5595	05 0	s ibo4geometry.so	G4Navigator::LocateGiobarPointAndSetup(CLHEP:
C4StoppingManageruStopping	24.9635	05 0		CHSExpMagneticField::GetFieldValue(double const
C4TransportationAlongStonCotDhysicalInte	23.8905	05 0		G45ceppingManager::Scepping(Vold)
	23.5905	05 0	is libG4processes.so	G4 Iransportation:: AlongstepGetPhysicalInteractio
	23.2005	05 0	is libG4geometry.so	G4VoxelNavigation::Computestep(CLHEP::Hep3ve
NG4CrossSectionDataSterou.CotCrossSection	21.0105	05 0		G4CrossSectionDataSterou.GetCrossSection(G4D)
NG4CrossSectionDataStoreGetCrossSection	17.150	05 0	ibG4processes.so	G4CrossSectionDataStore::GetCrossSection(G4D)
C4ElacticHadrNuclousHErrHadrNucDifforCrS	16.652	05 0	ibG4processes.so	G4ElasticHadrNucleusHEvHadrNucDifferCrEes(int
C4TransportationDectStonDelt	16,114	05 0	ibG4processes.so	G4Elastic Hadr Nucleus HE:: Hadr NucleUnter Crisec(Inc,
C4V/Discrete Presesser PastStepCot Physical	10.1145	05 0	is libG4processes.so	G4 Iransportation:: PostStepDoit(G4 Irack consta, C
C4StoppingManagerulpyckeAlengStopDeltD	14.6146	05 0	is libG4processes.so	G4V Discrete Process:: Poststep Get Physical Interac
C4SteppingManager::InvokeAlongStepDoitP	12.075	05 0	IbG4tracking.so	G4SteppingManager::InvokeAlongStepDoitProcs(V
	13.9755	05 0		G4SteppingManager::InvokePSDIP(unsigned long)
	13.7425	05 0	ibG4geometry.so	G4NormalNavigation::Computestep(CLHEP::Hep3
C4PropagatoripField. ComputeStop	13.2705	05 0	libG4geometry.so	G4NavigationLevel::operator=(G4NavigationLevel
C4MuDairBroductionMedoluCompute DMicro		05 0	libG4procoscos co	G4MuBairBreductionMedeluCompute DMicroscopiet
C4//EmprocessupestStenCetPhysicsUpters	12,0005	05 0	libG4processes.so	G4Wural Production Model: ComputeD Microscopic
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Geant4MT: Profiling Result (N thread = 1)

#	<no current="" project=""> - Intel VTu</no>	ne Amplifier (or	n mic.fnal.gov)		_ • ×
և 🖄 😥 🕨 🖇 🐠 😅 🕐 Weld	ome hotspots-t256 hotspots-t64	hotspots-t128 h	otspot 🗙		=
Basic Hotspots Hotspots h	v CPU Usage viewpoint (chan	nde) (0		Ir	ntel VTune Amplifier XE 2016
	y er o osage viewpoint (<u>enan</u>	<u>igc</u> / ©			iter v rune Amptiner XE 2010
🔄 🔛 Collection Log \varTheta 🕀 Analysis Target	Analysis Type 🛛 🛍 Summary 🛛 🗞 Bottom	i-up 😪 Caller/Ca	allee 😽 Top-down	Tree 🔣 Platforn	n D
Grouping: Function / Call Stack			\$	4. Q 🛠	CPU Time 😂
	CPU Time -	 [«	3		Viewing 👌 1 of 48 🕨 selected stac
Employ (Coll Charles			Madula	=	23.8% (17.207s of 72.154s)
Function / Call Stack	Effective Time by Utilization	Spin Ove	. Module	-	libG4global.so!G4PhysicsVector::Va
	🔲 Idle 📕 Poor 📙 Ok 📕 Ideal 📕 Over		•		libG4processes.so! <u>G4NeutronCaptu</u>
DG4PhysicsVector::Value	72.154s	0s 0s	s libG4global.so	G4PhysicsVec	libG4processes.so! <u>G4CrossSection</u>
DG4ProductionCutsTable::ScanAndSetCouple	63.835s	0s 0s	s libG4processes.so	G4Production	libG4processes.so! <u>G4CrossSection</u>
DG4hPairProductionModel::ComputeDMicroso	34.360s	0s 0s	s libG4processes.so	G4hPairProdu	libG4processes.so! <u>G4HadronicProc</u>
DG4VoxelNavigation::LevelLocate	34.091s	0s 0s	s libG4processes.so	G4VoxelNavig	libG4processes.so! <u>G4VDiscreteProc</u>
DG4Navigator::ComputeStep	31.475s	0s 0s	s libG4geometry.so	G4Navigator:	libG4tracking.so! <u>G4SteppingManag</u>
DG4SteppingManager::DefinePhysicalStepLe	31.467s	0s 0s	s libG4tracking.so	G4SteppingM	libG4tracking.so! <u>G4SteppingManag</u>
▷G4Navigator::LocateGlobalPointAndSetup	28.6925	0s 0s	s libG4geometry.so	G4Navigator:	libG4tracking.so! <u>G4TrackingManage</u>
▶G4VoxelNavigation::ComputeStep	26.701s	0s 0s	s libG4geometry.so	G4VoxelNavig	libG4event.so! <u>G4EventManager::D</u>
▷cmsExpMagneticField::GetFieldValue	25.348s	0s 0s	s cmsExpMT	cmsExpMagn	libG4run.so! <u>G4WorkerRunManager::</u>
▷G4SteppingManager::Stepping	23.170s	0s 0s	s libG4tracking.so	G4SteppingM	libG4run.so! <u>G4WorkerRunManager::</u>
▶G4Transportation::AlongStepGetPhysicalInte	23.151s	0s 0s	libG4processes.so	G4Transporta	libG4run.so! <u>G4RunManager::Beam</u>
◊G4ParticleChange::CheckIt	22.266s	0s 0s	s libG4track.so	G4ParticleCh	libG4run.so! <u>G4WorkerRunManager::</u>
♦G4CrossSectionDataStore::GetCrossSection	20.126s	0s 0s	s libG4processes.so	G4CrossSecti	libG4run.so! <u>G4MTRunManagerKerne</u>
♦G4Transportation::PostStepDoIt	19.837s	0s 0s	s libG4processes.so	G4Transporta	libpthread.so.0! <u>start_thread</u> +0xc4
◊G4SteppingManager::InvokeAlongStepDoItP	17.275s	0s 0s	s libG4tracking.so	G4SteppingM	libc.so.6! <u>cione</u> +0x6c - [unknown
♦G4CrossSectionDataStore::GetCrossSection	16.537s	0s 0s	s libG4processes.so	G4CrossSecti	
◊G4ElasticHadrNucleusHE::HadrNucDifferCrS	16.175s	0s 0s	s libG4processes.so	G4ElasticHad	
◊G4VDiscreteProcess::PostStepGetPhysical	15.896s	0s 0s	s libG4processes.so	G4VDiscretel	
◊G4SteppingManager::InvokePSDIP	14.812s	0s 0s	s libG4tracking.so	G4SteppingM	
◊G4NormalNavigation::ComputeStep	14.620s	0s 0s	s libG4geometry.so	G4NormalNav	
▶_ZTWN14G4GeomSplitterI8G4LVDataE6offs	14.233s	0s 0s	s libG4Tree.so	_ZTWN14G4C	4
♦G4VEmProcess::PostStepGetPhysicalIntera	14.225s	0s 0s	s libG4processes.so	G4VEmProce	1
▷G4NavigationLevel::G4NavigationLevel	14.125s	0s 0s	s libG4geometry.so	G4Navigation	4
◊G4NavigationLevel::operator=	14.0985	0s 0s	s libG4geometry.so	G4Navigation	1
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Geant4MT: Profiling Result (N threads = 32)

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🔥 🖄 🖙 🕨 🖗 🍅 🕐 🖉 Welcome 🛛 hotspots-t192 hotspots-t240	hotspot X			=
Basic Hotspots Hotspots by CPU Usage viewpoint (cha	ange) @	Intel \	/Tune An	nplifier XE 2016
🕢 📟 Collection Log \varTheta Analysis Target 🛕 Analysis Type 📓 Summary 🚱 Botto	om-up 😪 Caller/Callee 😪 Top-down Tree 🛃	l Platform		
Grouping: Function / Call Stack				
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Function / Call Stack	Effective Time by Utilization	Spin Time	verhead	Module
	📄 Idle 📕 Poor 📋 Ok 📕 Ideal 🛑 Over		Time	
▶G4PhysicsVector::Value	2205.880s	Os	0s li	bG4global.so
◊G4VoxelNavigation::LevelLocate	1265.234s	0s	0s li	bG4processes.so
▶G4Navigator::ComputeStep	1039.628s	0s	0s li	bG4geometry.so
▷G4SteppingManager::DefinePhysicalStepLength	1025.788s	0s	0s li	bG4tracking.so
▷G4Navigator::LocateGlobalPointAndSetup	956.609s	0s	0s li	bG4geometry.so
◊G4VoxelNavigation::ComputeStep	906.709s	0s	0s li	bG4geometry.so
▷cmsExpMagneticField::GetFieldValue	853.327s	0s	0s c	msExpMT
♦G4Transportation::AlongStepGetPhysicalInteractionLength	770.904s	0s	0s li	bG4processes.so
▷G4SteppingManager::Stepping	759.489s	0s	0s li	bG4tracking.so
◊G4CrossSectionDataStore::GetCrossSection	726.539s	0s	0s li	bG4processes.so
◊G4ParticleChange::CheckIt	725.542s	0s	0s li	bG4track.so
▷G4Transportation::PostStepDoIt	660.977s	0s	0s li	bG4processes.so
▷G4CrossSectionDataStore::GetCrossSection	568.154s	0s	0s li	bG4processes.so
▷G4SteppingManager::InvokeAlongStepDoItProcs	535.923s	0s	0s li	bG4tracking.so
▷G4VDiscreteProcess::PostStepGetPhysicalInteractionLength	526.171s	0s	0s li	bG4processes.so
▷G4NavigationLevel::operator=	519.924s	0s	0s li	bG4geometry.so
▷G4NormalNavigation::ComputeStep	489.584s	0s	0s li	bG4geometry.so
▷G4SteppingManager::InvokePSDIP	481.878s	0s	0s li	bG4tracking.so
◊G4VEmProcess::PostStepGetPhysicalInteractionLength	464.903s	0s	0s li	bG4processes.so
◊G4PropagatorInField::ComputeStep	459.010s	0s	0s li	bG4geometry.so
▷G4NavigationLevel::G4NavigationLevel	453.453s	0s	0s li	bG4geometry.so
◊G4TouchableHistory::GetVolume	442.766s	0s	0s li	bG4geometry.so
◊G4UniversalFluctuation::SampleFluctuations	439.680s	0s	0s li	bG4processes.so
▷G4VoxelNavigation::LocateNextVoxel	434.751s	0s	0s li	bG4geometry.so
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Geant4MT: Profiling Result (N threads = 64)

(<u>A</u>	<no current="" project=""> - Intel VTune Ar</no>	nplifier (on mic.fnal.gov)	
🚹 🖄 🖙 🕨 💀 🕕 🚅 🕐 Weld	ome hotspots-t192 hotspots-t240 hotsp	ots-t32	hotspots-t128 hots	pot X
💯 Basic Hotspots Hotspots b	y CPU Usage viewpoint (change)	0		Intel VTune Amplifier XE 2010
		🐣 Caller/	Callee 🐣 Ton-down	Tree 🔄 Platform
		Caller/		
Grouping: Function / Call Stack				\$
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Function / Call Stack	Effective Time by Utilization	Spin Ov	Module	
		Tim. Tir	n.	
♦ G4PhysicsVector::Value		05	0s libG4global.so	G4PhysicsVector::Value(double_unsigned long&) cc
♦ G4VoxelNavigation::LevelLocate	2190.6695	05	0s libG4processes.so	G4VoxelNavigation::LevelLocate(G4NavigationHist
▶G4Navigator::ComputeStep	1838.4475	05	0s libG4geometry.so	G4Navigator::ComputeStep(CLHEP::Hep3Vector c
♦ G4SteppingManager::DefinePhysicalStepLep	1825.080s	05	0s libG4tracking.so	G4SteppingManager::DefinePhysicalStepLength(v
▶G4Navigator::LocateGlobalPointAndSetup	1690.7825	05	0s libG4geometrv.so	G4Navigator::LocateGlobalPointAndSetup(CLHEP:
▶G4VoxelNavigation::ComputeStep	1623.0325	0s	0s libG4geometrv.so	G4VoxelNavigation::ComputeStep(CLHEP::Hep3Ve
▷cmsExpMagneticField::GetFieldValue	1526.110s	0s	0s cmsExpMT	cmsExpMagneticField::GetFieldValue(double const
▶G4Transportation::AlongStepGetPhysicalInte	1391.231s	0s	0s libG4processes.so	G4Transportation::AlongStepGetPhysicalInteractio
▷G4SteppingManager::Stepping	1362.393s	0s	0s libG4tracking.so	G4SteppingManager::Stepping(void)
▶G4CrossSectionDataStore::GetCrossSection	1346.887s	0s	0s libG4processes.so	G4CrossSectionDataStore::GetCrossSection(G4D)
▶G4ParticleChange::CheckIt	1290.853s	0s	0s libG4track.so	G4ParticleChange::CheckIt(G4Track const&)
♦G4Transportation::PostStepDolt	1171.614s	0s	0s libG4processes.so	G4Transportation::PostStepDoIt(G4Track const&, C
▶G4CrossSectionDataStore::GetCrossSection	1038.698s	0s	0s libG4processes.so	G4CrossSectionDataStore::GetCrossSection(G4D)
▷G4SteppingManager::InvokeAlongStepDoItP	961.736s	0s	0s libG4tracking.so	G4SteppingManager::InvokeAlongStepDoItProcs(v
▷G4NavigationLevel::operator=	932.751s	0s	0s libG4geometry.so	G4NavigationLevel::operator=(G4NavigationLevel
▶G4VDiscreteProcess::PostStepGetPhysical	932.585s	0s	0s libG4processes.so	G4VDiscreteProcess::PostStepGetPhysicalInterac
▷G4NormalNavigation::ComputeStep	865.091s	0s	0s libG4geometry.so	G4NormalNavigation::ComputeStep(CLHEP::Hep3'
▷G4SteppingManager::InvokePSDIP	856.726s	0s	0s libG4tracking.so	G4SteppingManager::InvokePSDIP(unsigned long)
▷G4VEmProcess::PostStepGetPhysicalIntera	821.535s	0s	0s libG4processes.so	G4VEmProcess::PostStepGetPhysicalInteractionL
▷G4PropagatorInField::ComputeStep	810.505s	0s	0s libG4geometry.so	G4PropagatorInField::ComputeStep(G4FieldTrack&,
▷G4NavigationLevel::G4NavigationLevel	809.357s	0s	0s libG4geometry.so	G4NavigationLevel::G4NavigationLevel(G4VPhysic
▷G4UniversalFluctuation::SampleFluctuations	803.147s	0s	0s libG4processes.so	G4UniversalFluctuation::SampleFluctuations(G4Ma
▷G4TouchableHistory::GetVolume	789.134s	0s	0s libG4geometry.so	G4TouchableHistory::GetVolume(int) const
▷G4VoxelNavigation::LocateNextVoxel	768.308s	0s	0s libG4geometry.so	G4VoxelNavigation::LocateNextVoxel(CLHEP::Hep
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Geant4MT: Profiling Result (N threads = 192)

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Basic Hotspots Hotspots by CPU Usage view	point (<u>change</u>)	Inte	l VTune A	mplifier XE 2
🛯 📟 Collection Log 🛛 🕹 Analysis Target 🛛 🗛 Analysis Type 🛛 🛍 Summa	ary 🚱 Bottom-up 🏼 🍪 Caller/Callee 🗣 Top-down Tree	🔣 Platform 🧹		
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Function / Call Stack	Effective Time by Utilization	2	Overhead	Module
		Spin Time	Time	
G4PhysicsVector··Value		05	05	libG4global so
G4SteppingManager::DefinePhysicalStepLength	2226 6055	05	05	libG4tracking so
G4VoxelNavigation::LevelLocate	2071.1135	05	05	libG4processes.
G4Navigator::ComputeStep	1724.2825	05	05	libG4geometry.s
G4SteppingManager::Stepping	1499.5335	05	05	libG4tracking.so
G4VoxelNavigation::ComputeStep	1487.9405	0s	05	libG4geometrv.s
G4Navigator::LocateGlobalPointAndSetup	1478.4235	0s	0s	libG4geometry.s
G4NavigationLevel::operator=	1467.4025	0s	0s	libG4geometry.s
G4Transportation::AlongStepGetPhysicalInteractionLength	1430.2665	0s	0s	libG4processes.
G4CrossSectionDataStore::GetCrossSection	1364.1715	0s	0s	libG4processes.
G4CrossSectionDataStore::GetCrossSection	1351.919s	0s	0s	libG4processes.
G4Transportation::PostStepDoIt	1243.881s	0s	0s	libG4processes.
L_unlock_697	1214.4725	0s	0s	libpthread.so.0
msExpMagneticField::GetFieldValue	1123.4875	0s	0s	cmsExpMT
64VEmProcess::PostStepGetPhysicalInteractionLength	980.554s	0s	0s	libG4processes.
64TouchableHistory::GetVolume	980.103s	0s	0s	libG4geometry.s
ZTWN14G4GeomSplitterI8G4LVDataE6offsetE	978.336s	0s	0s	libG4Tree.so
64ParticleChange::CheckIt	975.724s	0s	0s	libG4track.so
G4SteppingManager::InvokePSDIP	954.782s	0s	0s	libG4tracking.so
G4SteppingManager::InvokeAlongStepDoItProcs	930.626s	0s	0s	libG4tracking.so
64NavigationLevel::G4NavigationLevel	883.123s	0s	0s	libG4geometry.s
L_lock_791	0.119s	858.867s	0s	libpthread.so.0
G4VDiscreteProcess::PostStepGetPhysicalInteractionLength	856.845s	0s	0s	libG4processes.
CLHEP::RanecuEngine::flat	815.359s	0s	0s	libG4clhep.so
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Geant4MT Performance on KNL: icc (16.0.3) vs. gcc (4.9.1)

- Performance on Intel Xeon Phi Processor (Knight's Landing)
 - KNL triples both scalar and vector performance compared with KNC and offers, up to 3.0 TFlop/sec (double) per processor.

