Performance profiling of Experiments' Geant4 Simulations

Geant4
Technical Forum

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Outline

- Performance profiling
- Profiler
- New results in 64-bit mode
  - Geant4 novice example 3
  - ATLAS Simulation
- Brief overview of perfmon2 interface and pfmon tool

Performance profiling

- Profiling by sampling
  - profiler probes a source of reference at regular intervals and captures an address where the sample occurred
  - allows the target program to run at near full speed
  - less accurate for short executions
- Source of reference
  - system timer
  - special hardware counters built in modern CPUs which count hardware events: i.e., CPU cycles, cache misses, etc…

Profiler - pfmon

- open source tool developed by HP
  - with CERN openlab contribution
    - support for dynamic libraries
  - without recompiling the application
  - many sources of reference
    - takes advantage of hardware support in recent CPUs and a new perfmon2 interface to CPU resources
  - many users can run simultaneously their jobs
  - portable across many platforms (i.e., Intel, AMD)
  - will be a part of the SLC4 distribution soon
  - more details about pfmon and perfmon2 on the web page http://perfmon2.sourceforge.net/ or later on during this talk

geant4 library

- 64-bit mode
- gcc 3.4.6
- geant4.8.1.p01/examples/extended/electromagnetic/TestEm3
- /run/beamOn 2000
- Xeon/P4, Woodcrest (Core 2 Duo), Itanium2/Montecito

TestEM3@Xeon/P4

```
# counts   %self    %cum function name:file
Samples: 901644
 118736  13.17%  13.17% __ieee754_log:libm-2.3.4.so
  85733   9.51%  22.68% CLHEP::RanecuEngine::flat():libCLHEP-1.9.2.3.so
  50836   5.64%  28.32% __ieee754_exp:libm-2.3.4.so
  46250   5.13%  33.45% G4VProcess::SubtractNumberOfInteractionLengthLeft():ibG4procman.so
  31953   3.54%  36.99% G4SteppingManager::DefinePhysicalStepLength():libG4tracking.so
  26342   2.92%  39.91% G4UniversalFluctuation::SampleFluctuations():libG4emstandard.so
  20830   2.31%  42.22% G4Track::GetVelocity() const:libG4track.so
  16984   1.88%  44.10% cos:libm-2.3.4.so
  14004   1.55%  45.66% G4SteppingManager::InvokePSDIP():libG4tracking.so
  13996   1.55%  47.21% sin:libm-2.3.4.so
  13573   1.51%  48.72% G4UrbanMscModel::ComputeTruePathLengthLimit():libG4emstandard.so
  13560   1.50%  50.22% G4UrbanMscModel::ComputeGeomPathLength():libG4emstandard.so
  13198   1.46%  51.68% G4SteppingManager::Stepping():libG4tracking.so
  12851   1.43%  53.11% G4VEnergyLossProcess::AlongStepDoIt():libG4emutils.so
  12112   1.34%  54.45% G4SteppingManager::InvokeAlongStepDoItProcs():libG4tracking.so
  11825   1.31%  55.76% G4VContinuousDiscreteProcess::PostStepGetPhysicalInteractionLength():libG4muons.so
  11807   1.31%  57.07% G4Transportation::AlongStepGetPhysicalInteractionLength():libG4transportation.so
  11718   1.30%  58.37% G4UrbanMscModel::SampleCosineTheta():ibG4emstandard.so
  11570   1.28%  59.66% G4VEmProcess::GetMeanFreePath():libG4emstandard.so
  11483   1.27%  60.93% G4Navigator::ComputeStep():libG4navigation.so
  11473   1.27%  62.20% SteppingAction::UserSteppingAction():libTestEm3.so
  11189   1.24%  63.44% G4ParticleChange::CheckIt():libG4track.so
   9024   1.00%  64.44% G4VEnergyLossProcess::GetContinuousStepLimit():libG4muons.so
   8748   0.97%  65.41% G4TouchableHistory::GetVolume() const:libG4volumes.so
   8437   0.94%  66.35% G4Transportation::AlongStepDoIt():libG4transportation.so
   8183   0.91%  67.26% G4Navigator::LocateGlobalPointAndSetup():libG4navigation.so
   7440   0.83%  68.08% G4Navigator::LocateGlobalPointWithinVolume():libG4navigation.so
   7380   0.82%  68.90% exp:libm-2.3.4.so
   6795   0.75%  69.65% CLHEP::Hep3Vector::rotateUz():libCLHEP-1.9.2.3.so
   6748   0.75%  70.40% log:libm-2.3.4.so
   6654   0.74%  71.14% G4SteppingManager::InvokePostStepDoItProcs():libG4tracking.so
   6476   0.72%  71.86% G4Transportation::PostStepDoIt():libG4transportation.so
   6460   0.72%  72.57% CLHEP::RandGaussQ::transformQuick():libCLHEP-1.9.2.3.so
```

TestEM3@Woodcrest (Core 2 Duo)

```
# counts   %self    %cum function name:file
Samples: 359161
  41046  11.43%  11.43% __ieee754_log:/lib64/tls/libm-2.3.4.so
  38217  10.64%  22.07% CLHEP::RanecuEngine::flat():libCLHEP-1.9.2.3.so
  24457   6.81%  28.88% __ieee754_exp:libm-2.3.4.so
  16188   4.51%  33.39% G4UniversalFluctuation::SampleFluctuations():libG4emstandard.so
  10620   2.96%  36.34% G4Track::GetVelocity() const:libG4track.so
  10155   2.83%  39.17% G4VProcess::SubtractNumberOfInteractionLengthLeft():libG4procman.so
   8337   2.32%  41.49% G4UrbanMscModel::ComputeGeomPathLength():libG4emstandard.so
   7979   2.22%  43.71% G4SteppingManager::DefinePhysicalStepLength():libG4tracking.so
   7558   2.10%  45.82% G4UrbanMscModel::SampleCosineTheta():libG4emstandard.so
   7206   2.01%  47.82% cos:libm-2.3.4.so
   6128   1.71%  49.53% sin:libm-2.3.4.so
   5703   1.59%  51.12% G4SteppingManager::InvokePSDIP():libG4tracking.so
   5564   1.55%  52.67% G4UrbanMscModel::ComputeTruePathLengthLimit():libG4emstandard.so
   5062   1.41%  54.08% G4VEnergyLossProcess::AlongStepDoIt():libG4emutils.so
   4985   1.39%  55.46% G4Navigator::ComputeStep():libG4navigation.so
   4633   1.29%  56.75% G4Transportation::AlongStepGetPhysicalInteractionLength():libG4transportation.so
   4626   1.29%  58.04% G4Transportation::AlongStepDoIt():libG4transportation.so
   4610   1.28%  59.33% G4SteppingManager::Stepping():libG4tracking.so
   4173   1.16%  60.49% G4ParticleChange::CheckIt():libG4track.so
   3723   1.04%  61.52% G4UrbanMscModel::SampleSecondaries():libG4emstandard.so
   3623   1.01%  62.53% G4SteppingManager::InvokeAlongStepDoItProcs():libG4tracking.so
   3252   0.91%  63.44% G4Navigator::LocateGlobalPointAndSetup():libG4navigation.so
   3203   0.89%  64.33% G4UrbanMscModel::SampleDisplacement():libG4emstandard.so
   3186   0.89%  65.22% G4VEmProcess::GetMeanFreePath():libG4emstandard.so
   3103   0.86%  66.08% G4VContinuousDiscreteProcess::PostStepGetPhysicalInteractionLength():libG4muons.so
   3069   0.85%  66.94% G4NormalNavigation::ComputeStep():libG4navigation.so
   2959   0.82%  67.76% G4Navigator::LocateGlobalPointWithinVolume():libG4navigation.so
```

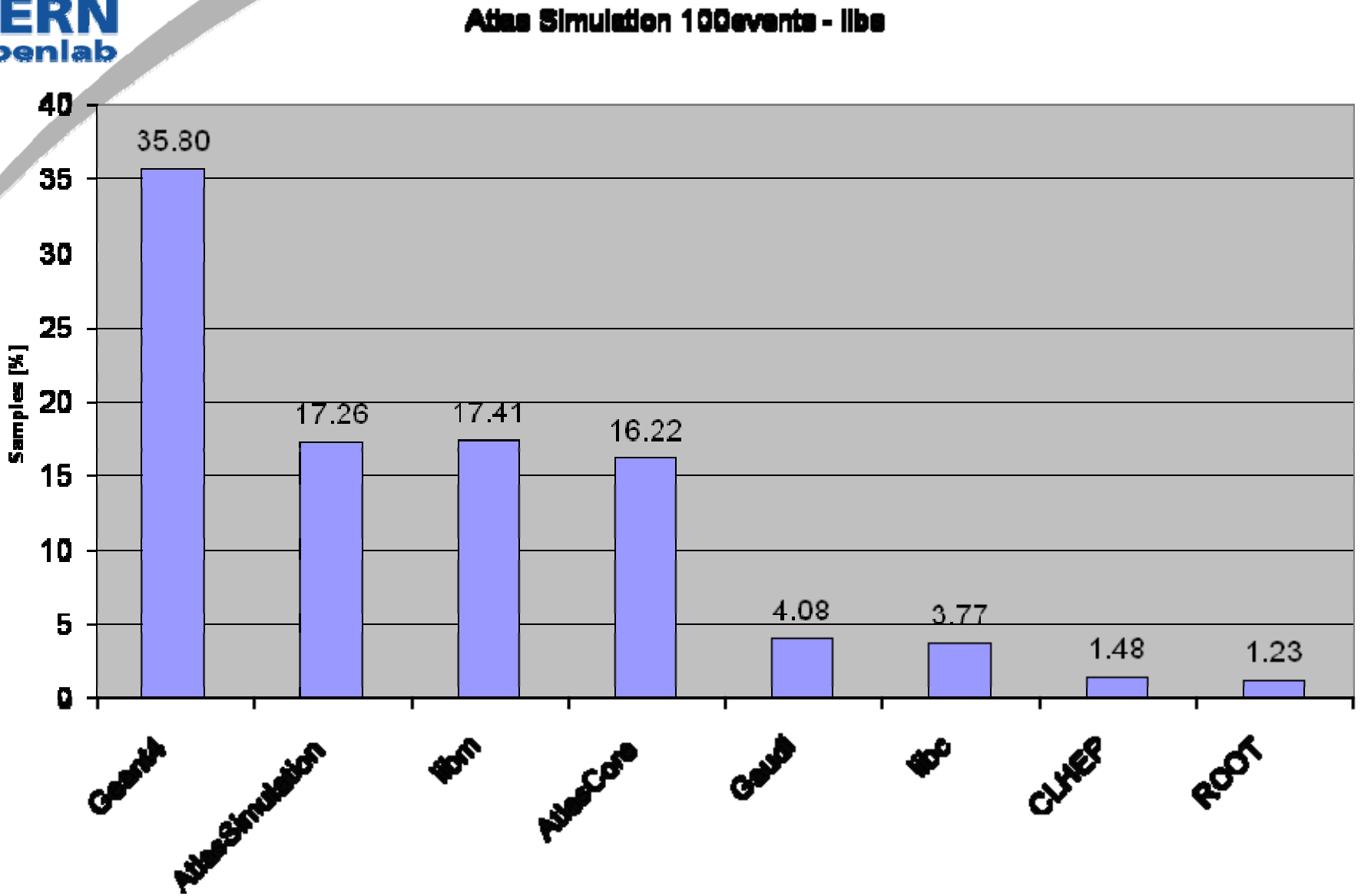
TestEM3@Itanium2/Montecito

```
# counts   %self    %cum function name:file
Samples: 408514
  43914  10.75%  10.75% __divdf3:/lib/libgcc_s-3.4.6-20060404.so.1
  32918   8.06%  18.81% CLHEP::RanecuEngine::flat():libCLHEP-1.9.2.3.so
  24958   6.11%  24.92% __divdi3:libgcc_s-3.4.6-20060404.so.1
  16176   3.96%  28.88% G4SteppingManager::DefinePhysicalStepLength():libG4tracking.so
  10846   2.65%  31.53% exp:libm-2.3.4.so
  10776   2.64%  34.17% sqrt:libm-2.3.4.so
  10276   2.52%  36.69% G4UniversalFluctuation::SampleFluctuations():libG4emstandard.so
  10118   2.48%  39.16% G4SteppingManager::InvokePSDIP():libG4tracking.so
   9199   2.25%  41.41% G4SteppingManager::Stepping():libG4tracking.so
   8541   2.09%  43.50% log:libm-2.3.4.so
   8483   2.08%  45.58% G4SteppingManager::InvokeAlongStepDoItProcs():libG4tracking.so
   7618   1.86%  47.45% G4VEnergyLossProcess::AlongStepDoIt():libG4emutils.so
   7034   1.72%  49.17% G4Track::GetVelocity() const:libG4track.so
   6013   1.47%  50.64% G4Transportation::AlongStepGetPhysicalInteractionLength():libG4transportation.so
   5992   1.47%  52.11% G4Navigator::ComputeStep():libG4navigation.so
   5732   1.40%  53.51% G4UrbanMscModel::ComputeGeomPathLength():libG4emstandard.so
   5212   1.28%  54.79% G4UrbanMscModel::ComputeTruePathLengthLimit():libG4emstandard.so
   4457   1.09%  55.88% G4VContinuousDiscreteProcess::PostStepGetPhysicalInteractionLength():libG4muons.so
   4414   1.08%  56.96% G4UrbanMscModel::SampleCosineTheta():libG4emstandard.so
   4363   1.07%  58.02% CLHEP::HepRandom::getTheEngine():libCLHEP-1.9.2.3.so
   4322   1.06%  59.08% G4VEmProcess::GetMeanFreePath():libG4emstandard.so
   4286   1.05%  60.13% G4ParticleChangeForTransport::UpdateStepForAlongStep(G4Step*):libG4track.so
   4225   1.03%  61.17% G4Transportation::AlongStepDoIt():/libG4transportation.so
   4031   0.99%  62.15% G4Transportation::PostStepDoIt():libG4transportation.so
   3883   0.95%  63.10% SteppingAction::UserSteppingAction():libTestEm3.so
   3880   0.95%  64.05% G4TouchableHistory::GetVolume() const:libG4volumes.so
   3820   0.94%  64.99% G4Navigator::LocateGlobalPointAndSetup():libG4navigation.so
   3635   0.89%  65.88% cos:/lib/tls/libm-2.3.4.so
```

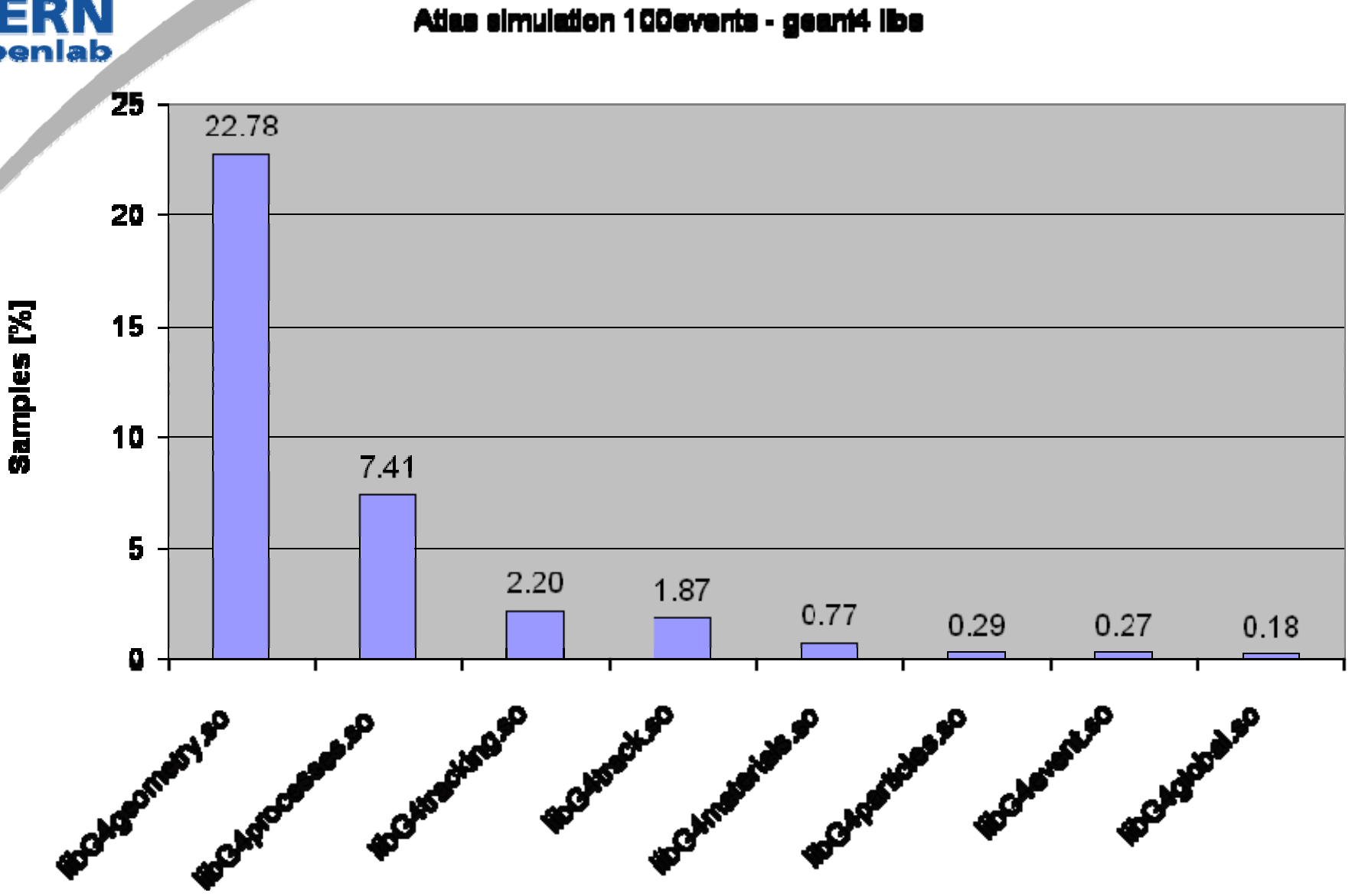
Atlas Simulation

- 64-bit mode
- Woodcrest (Core 2 Duo) 2.66GHz
- theApp.EvtMax = 100
- started from ApplicationMgr::executeRun(int)
- execution time 585s

Atlas Simulation – Summary of libs



Atlas Simulation – geant4 libs



Atlas Simulation@Woodcrest (Core 2 Duo)

```
#   counts   %self    %cum function name:file
Samples: 62400359
   3853150   6.17%   6.17% LArWheelCalculator::DistanceToTheNeutralFibre() const:libGeoSpecialShapes.so
   3363708   5.39%  11.57% __ieee754_atan2:libm-2.3.4.so
   2898193   4.64%  16.21% G4PolyconeSide::DistanceAway():libG4geometry.so
   2724866   4.37%  20.58% cos:libm-2.3.4.so
   2647220   4.24%  24.82% sin:libm-2.3.4.so
   2170627   3.48%  28.30% bfelix_:libG4Field.so
   1957847   3.14%  31.44% LArWheelCalculator::parameterized_slant_angle() const:libGeoSpecialShapes.so
   1019438   1.63%  33.07% G4PolyconeSide::PointOnCone():libG4geometry.so
   1012955   1.62%  34.69% G4PolyconeSide::Inside():libG4geometry.so
    871197   1.40%  36.09% G4IntersectingCone::LineHitsCone1():libG4geometry.so
    835073   1.34%  37.43% __ieee754_log:libm-2.3.4.so
    799517   1.28%  38.71% G4Mag_UsualEqRhs::EvaluateRhsGivenB() const:libG4geometry.so
    774924   1.24%  39.95% AtlasField::FieldValue()const:libG4Field.so
    719954   1.15%  41.10% CLHEP::Hep3Vector::operator=():libAtlasSealCLHEP.so
    653149   1.05%  42.15% gbmagl_:libG4Field.so
    599985   0.96%  43.11% bprepa_:libG4Field.so
    579772   0.93%  44.04% CLHEP::Hep3Vector::y() const:libGeoModelKernel.so
    534460   0.86%  44.90% G4PolyconeSide::Intersect():libG4geometry.so
    523761   0.84%  45.74% G4ClassicalRK4::DumbStepper():libG4geometry.so
    515473   0.83%  46.56% CLHEP::Hep3Vector::x() const:libGeoModelKernel.so
    512346   0.82%  47.38% __libc_malloc:libc-2.3.4.so
    480003   0.77%  48.15% G4SandiaTable::GetSandiaCofPerAtom():libG4materials.so
    473077   0.76%  48.91% free:libc-2.3.4.so
    470060   0.75%  49.66% CLHEP::Hep3Vector::z() const:libGeoModelKernel.so
    466184   0.75%  50.41% CLHEP::Hep3Vector::Hep3Vector():libGeoModelSvcLib.so
    426264   0.68%  51.09% CLHEP::Hep3Vector::operator*=(double):libGeoModelKernel.so
    411540   0.66%  51.75% _init:libGeo2G4.so
    389988   0.62%  52.38% G4VoxelNavigation::ComputeStep():libG4geometry.so
```

overview of perfmon2 interface

- portable across all recent Intel & AMD CPUs
  - Works with all Performance Monitoring Unit models
- without recompiling the application
- supports for per-thread and for system-wide monitoring
- in user or kernel domain
- supports for counting and sampling
- supports for event multiplexing
- secure
- well documented

overview of pfmon

- available across multiple processors
  - Xeon, Woodcrest, Itanium, …
- basic counting, sampling
- per thread (fork, exec, pthread_create)
- can attach to process
- multiple coexisted user sessions
- system wide-mode
- triggering monitoring at specific location (start, stop, repeat)
- profiling
  - CERN openlab contribution into symbol resolving (will be available soon in CVS)
    - support for shared libraries
      - linked against application
    - dynamically loaded during an execution (dlopen/dlclose)
    - resolving across multiple processes/threads
      - can follow fork, exec, pthread_create
    - results aggregation

Conclusions

- as soon as perfmon2 is in the mainline kernel source, we will get it in Scientific Linux at CERN
- with perfmon2 and pfmon we get one common interface to all supported processors and their performance units
- one common performance monitoring and profiling tool pfmon across all supported processors