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Geant4 Collaboration Meeting
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Profiling various Geant4 Applications with FAST

Talk Outline

- What is FAST?
- Project Goals
- People Involved
- Profiled Applications
- Results
- Summary

FAST

- **FAST (Flexible Analysis and Storage Toolkit)**
 - set of tools designed to analyze the performance - primarily the speed - of singly-threaded programs written in C++, C
 - It has components for the collection, analysis, and display of the performance data
- Available from
 - <https://cdcvs.fnal.gov/redmine/projects/fast>
- Current releases of FAST include a copy of libunwind which is built automatically when building FAST
 - <http://www.nongnu.org/libunwind>
 - includes many contributions by Lassi Tuura
- **See talk in plenary session 6 for more information**

G4CPT Project Goals

- To make it possible to routinely evaluate the performance of new releases of Geant4, and make the results publicly available
- Technique is to profile “representative Geant4 applications”
- On demand, we want to:
 - build a specific release of Geant4
 - build a specific release of an application
 - repeatedly run a standard sample to produce data for analysis
 - generate selected standard plots/data

People Involved

- People working (usually at a fraction of their time) on some aspects of the project over the last year or so:
 - Marc Paterno
 - Anthony Baldocchi – NIU Intern
 - Jim Kowalkowski
 - Krzysztof Genser

Project Information

- Over last year we have adopted a file system approach to the (profiling) data storage
- In addition to CMSSW cmsRun application we have decided to add a “native” Geant4 application to be able to profile Geant4 releases independent of a given experiment adoption of a specific Geant4 release
 - We have chosen **SimplifiedCalo** from Andrea Dotti as this application
- We also added a Fermilab Mu2e Offline executable to the set of profiled applications

Geant4 Applications we have been profiling

- CMSSW cmsRun
 - recently with patches by Sunanda Banerjee for more recent versions of Geant4
- SimplifiedCalo
 - from Andrea Dotti; minimally modified to add timing printout and to read a PYTHIA event file
- Mu2e Offline program
 - simulating propagation of conversion electrons ($\sim 105\text{MeV}$) in a tracking detector with a magnetic field
- All with **QGSP-BERT** (or a default) physics list

Building and Profiling an Application

- We build Geant4 and the application to be profiled
 - with the debug symbols and frame pointers (esp. in highly optimized builds)
 - e.g. `-g -O2 -fno-omit-frame-pointer`
 - with added a minimal timing printout
- We run the application with the FAST SimpleProfiler:
 - `profrun [options] application [application options]`
 - e.g. `profrun SimplifiedCalo inputfile`

Important Definitions

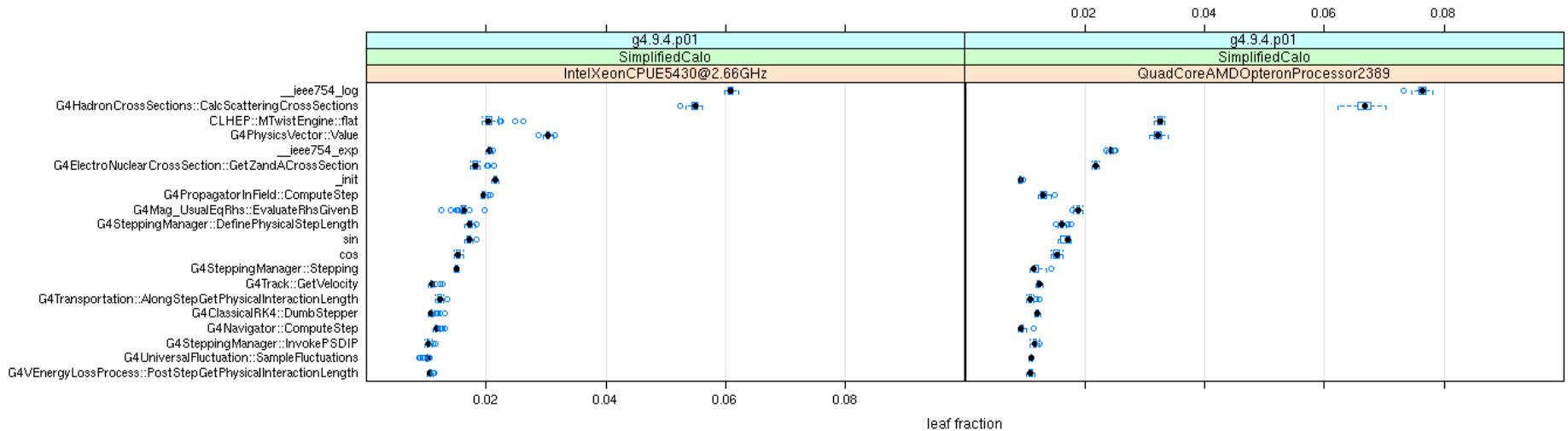
- Function **Path Count**
 - number of samples in which that function was observed anywhere in the call stack
 - not the number of times a function was called
- Function **Total Count**
 - Total number of times that function was observed in the call stacks (it may be more than once per call stack for e.g. in case of recursive calls)
- Function **Leaf Count**
 - number of samples in which that function was observed at the top of the call stack

Example Results/Plots/Call Graphs

- top functions (count fractions)
- top libraries (counts)
- top 5 Geant4 functions across applications

SimplifiedCalo/g4.9.4.p01

Top Functions



- Leaf count fractions for top functions

SimplifiedCalo/g4.9.4.p01

Top Functions

- 5 top functions and their leaf count fractions
 - based on 112 runs with 50 events each

<code>__ieee754_log</code>	0.076
<code>G4HadronCrossSections::CalcScatteringCrossSections</code>	0.067
<code>CLHEP::MTwistEngine::flat</code>	0.033
<code>G4PhysicsVector::Value</code>	0.032
<code>__ieee754_exp</code>	0.024

SimplifiedCalo/g4.9.4.p01

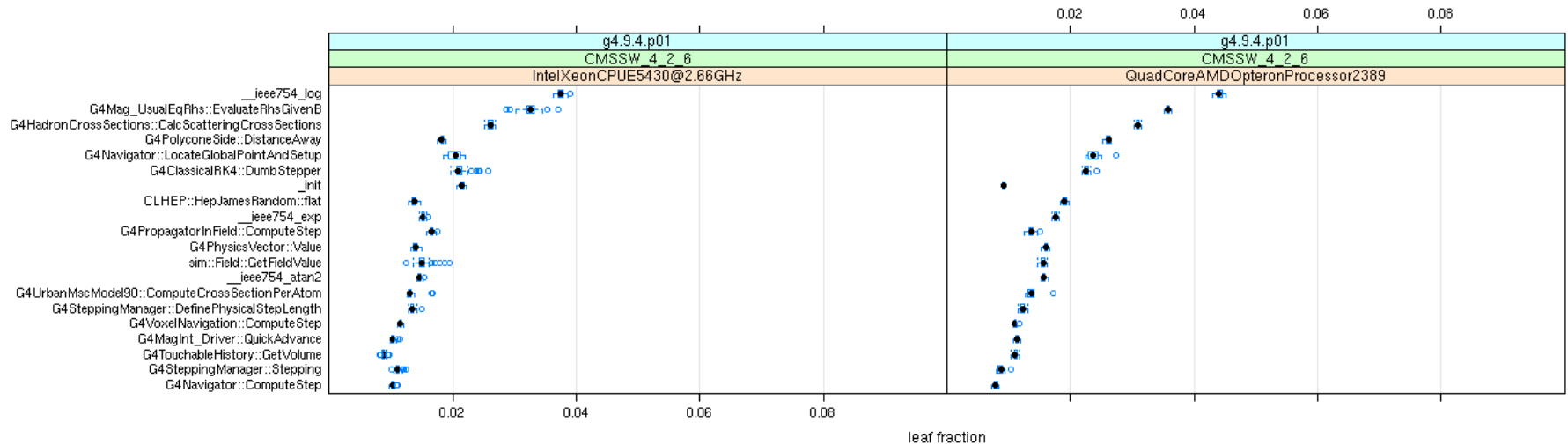
Top Geant4 Functions

- 5 top Geant4 functions and their leaf count fractions
 - based on 112 runs with 50 events each

G4HadronCrossSections::CalcScatteringCrossSections	0.067
G4PhysicsVector::Value	0.032
G4ElectroNuclearCrossSection::GetZandACrossSection	0.022
G4PropagatorInField::ComputeStep	0.020
G4Mag_UsualEqRhs::EvaluateRhsGivenB	0.019

cmssw426/g4.9.4.p01

Top Functions



- Leaf count fractions for top functions
 - based on 112 runs with 50 events each

cmssw426/g4.9.4.p01

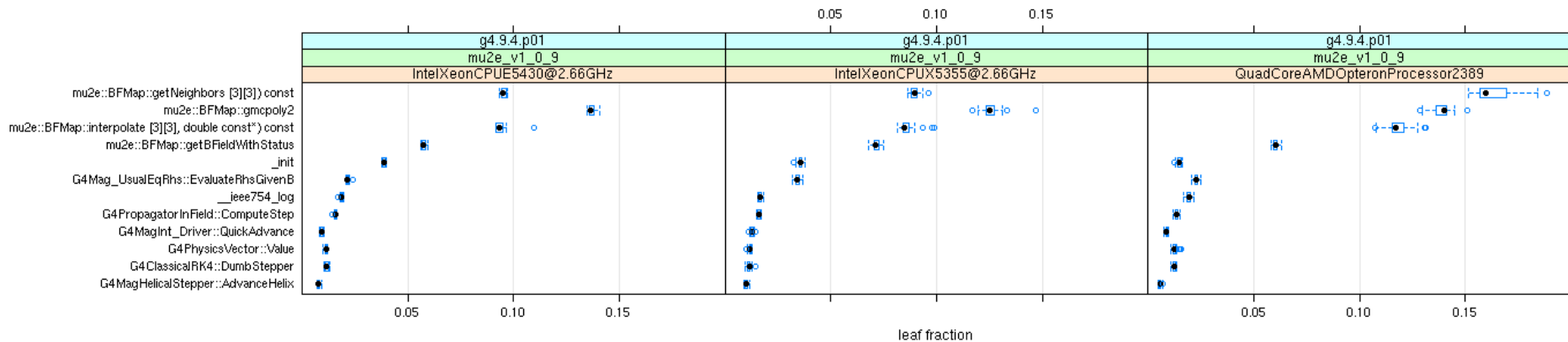
Top Geant4 Functions

- 5 top Geant4 functions and their leaf count fractions
 - based on 93 runs with 100 events each

G4Mag_UsualEqRhs::EvaluateRhsGivenB	0.036
G4HadronCrossSections::CalcScatteringCrossSections	0.031
G4PolyconeSide::DistanceAway	0.026
G4Navigator::LocateGlobalPointAndSetup	0.024
G4ClassicalRK4::DumbStepper	0.022

Mu2e109/g4.9.4.p01

Top Functions



- Leaf count fractions for top functions
 - based on 95 runs with 10000 events each

Muze/g4.9.4.p01

Top Geant4 Functions

- 5 top Geant4 functions and their leaf count fractions
 - based on 95 runs with 10000 events each

G4Mag_UsualEqRhs::EvaluateRhsGivenB	0.034
G4PropagatorInField::ComputeStep	0.016
G4MagInt_Driver::QuickAdvance	0.022
G4PhysicsVector::Value	0.012
G4ClassicalRK4::DumbStepper	0.012

g4.9.4.p01

Top Geant4 Functions

- logical sum of top Geant4 functions for the three applications (unordered)

G4Mag_UsualEqRhs::EvaluateRhsGivenB

G4MagInt_Driver::QuickAdvance

G4PhysicsVector::Value

G4ClassicalRK4::DumbStepper

G4PropagatorInField::ComputeStep

G4PolyconeSide::DistanceAway

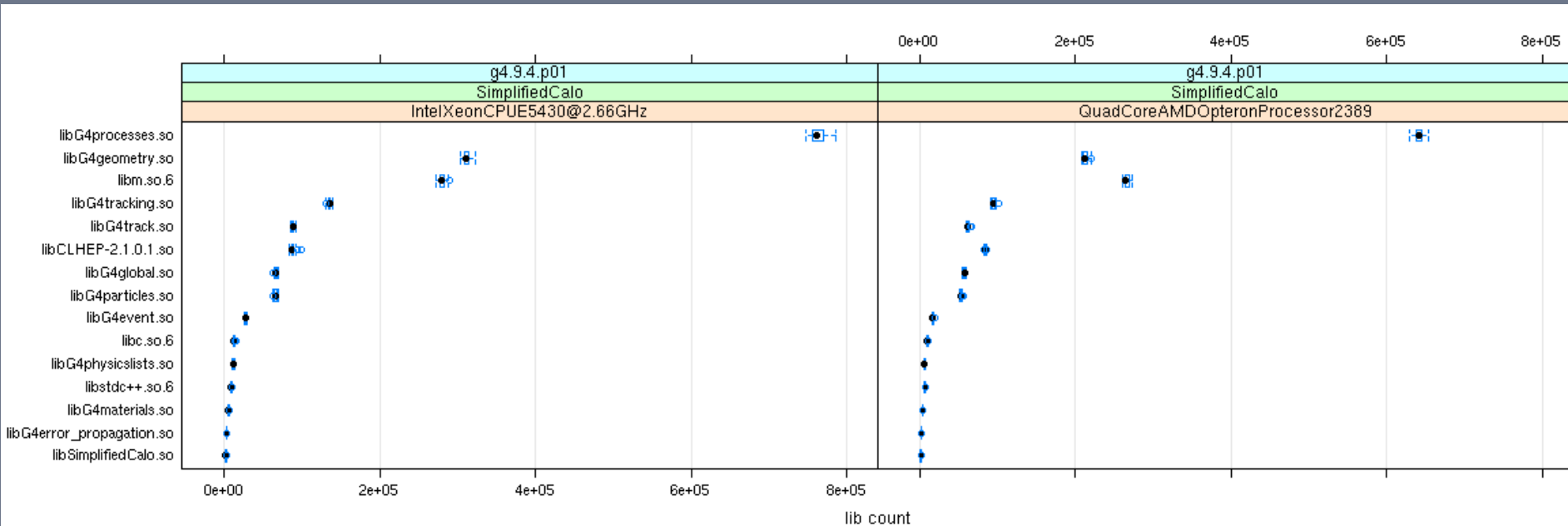
G4Navigator::LocateGlobalPointAndSetup

G4HadronCrossSections::CalcScatteringCrossSections

G4ElectroNuclearCrossSection::GetZandACrossSection

SimplifiedCalo/g4.9.4.p01

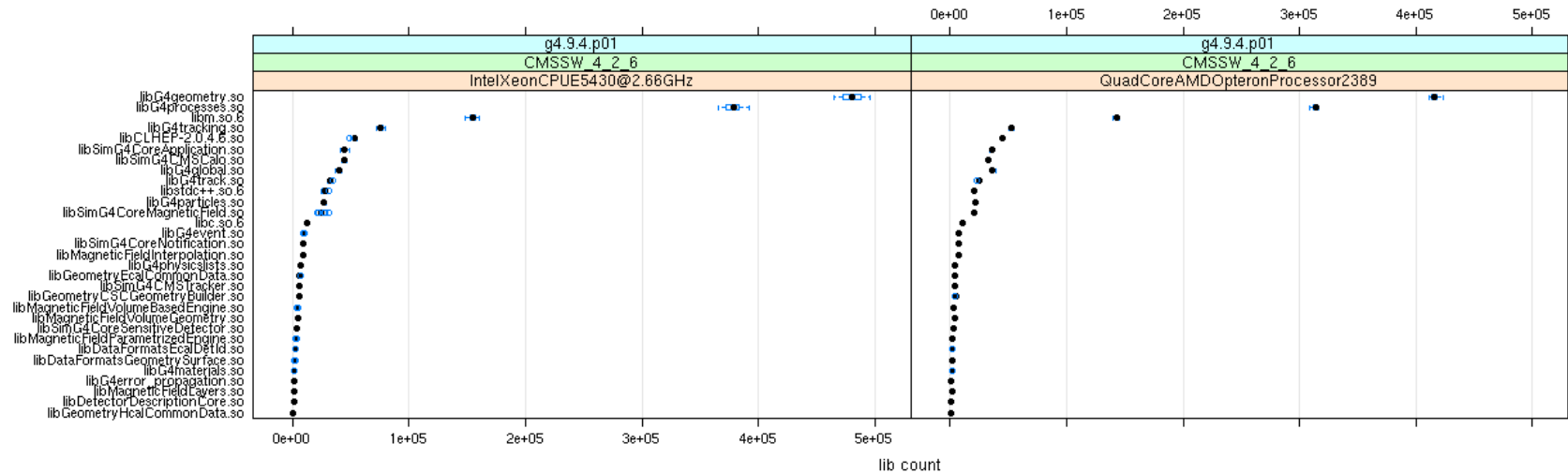
Top Libraries



- top libraries plot and top 3 Geant4 libraries (global)
 - based on 112 runs with 50 events each
 - libG4processes
 - libG4geometry
 - libG4tracking

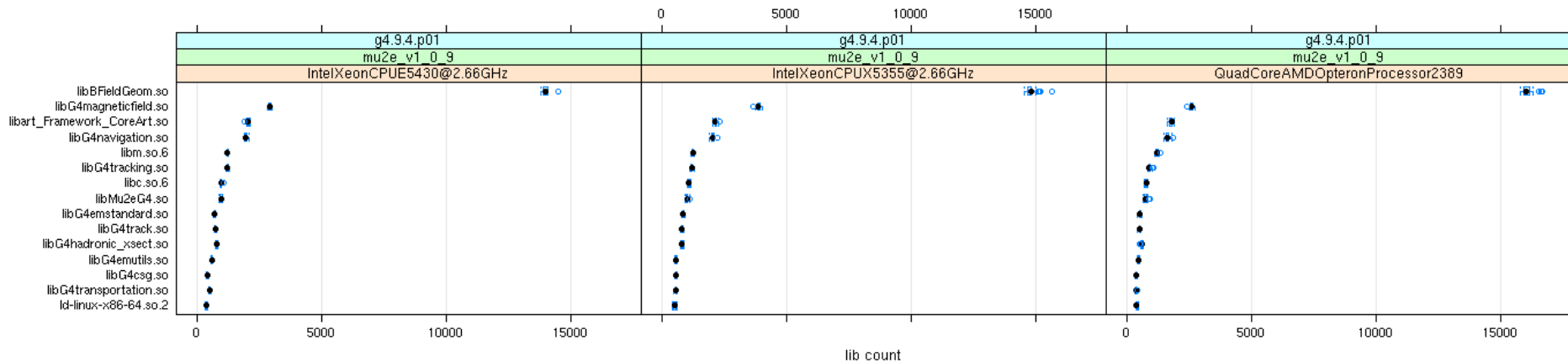
cmssw426/g4.9.4.p01

Top Libraries



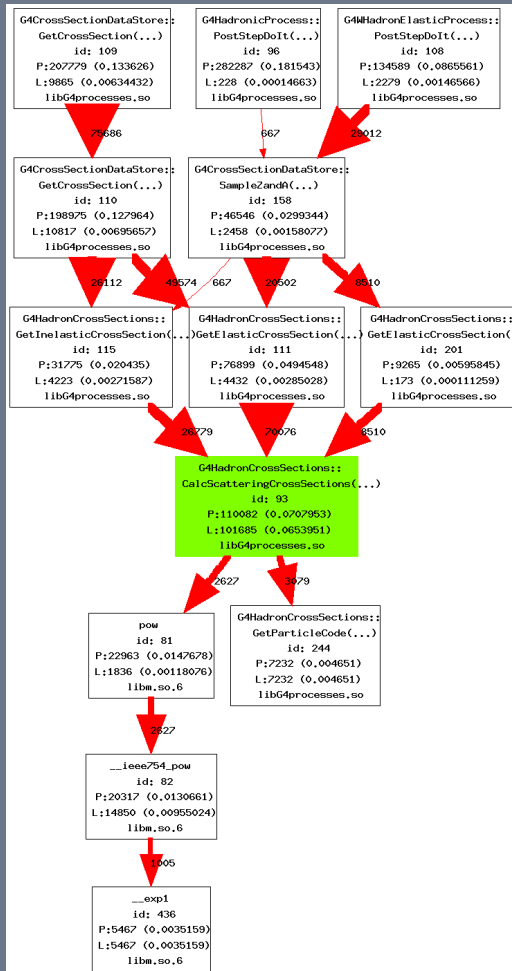
- top libraries plot and top 3 Geant4 libraries (granular)
 - based on 93 runs with 100 events each
 - libG4geometry
 - libG4processes
 - libG4tracking

Mu2e109/g4.9.4.p01 Top Libraries



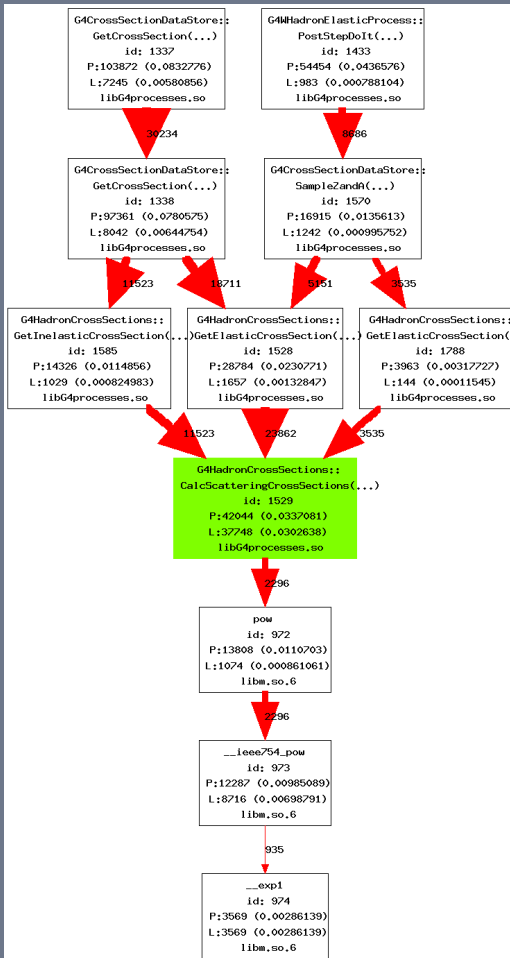
- top libraries plot and top 3 Geant4 libraries (granular)
 - based on 95 runs with 10000 events each
 - libG4magneticfield
 - libG4navigation
 - libG4tracking

Call Graph centered on G4HadronCrossSections::CalcScatteringCrossSections in SimplifiedCalo



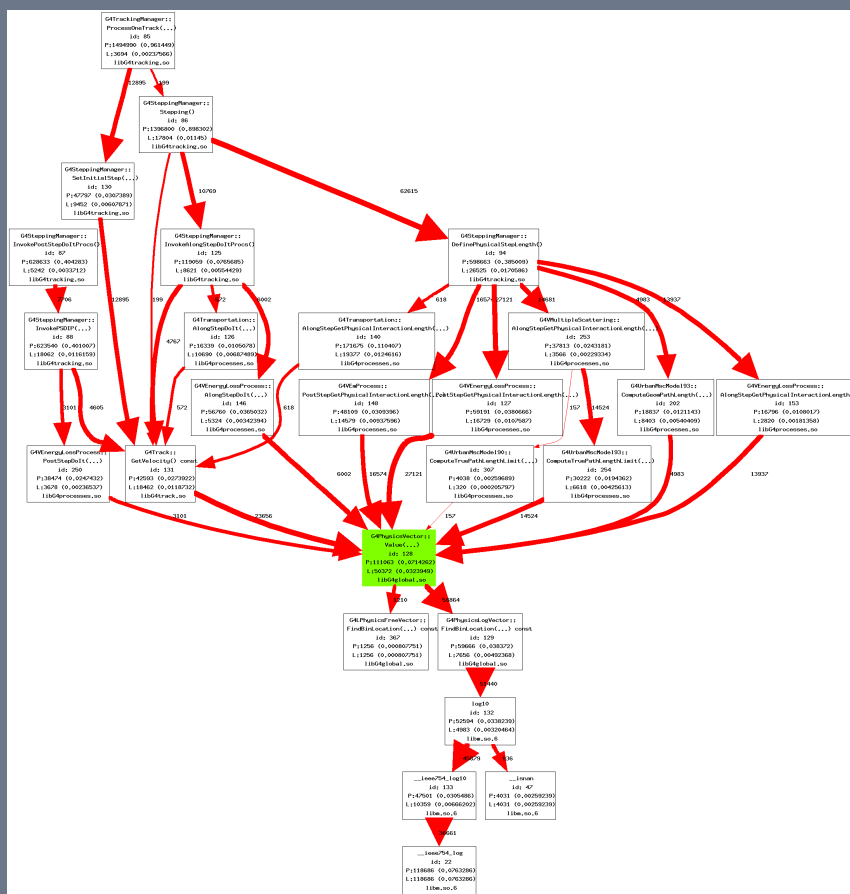
- A Geant4 function with a very significant time spent in it: `G4HadronCrossSections::CalcScatteringCrossSections` (`G4DynamicParticle const*, int, int`)
 - Path Count 110082 (7.1%)
 - Leaf Count 101685 (6.5%)
- profgraph -n profdata... 93 3 5 400
 - All paths with a count smaller than 400 were removed
 - this affects the edges(arrows) which are removed
 - the numbers in the boxes are unaffected

Call Graph centered on G4HadronCrossSections::CalcScatteringCrossSections in cmssw426



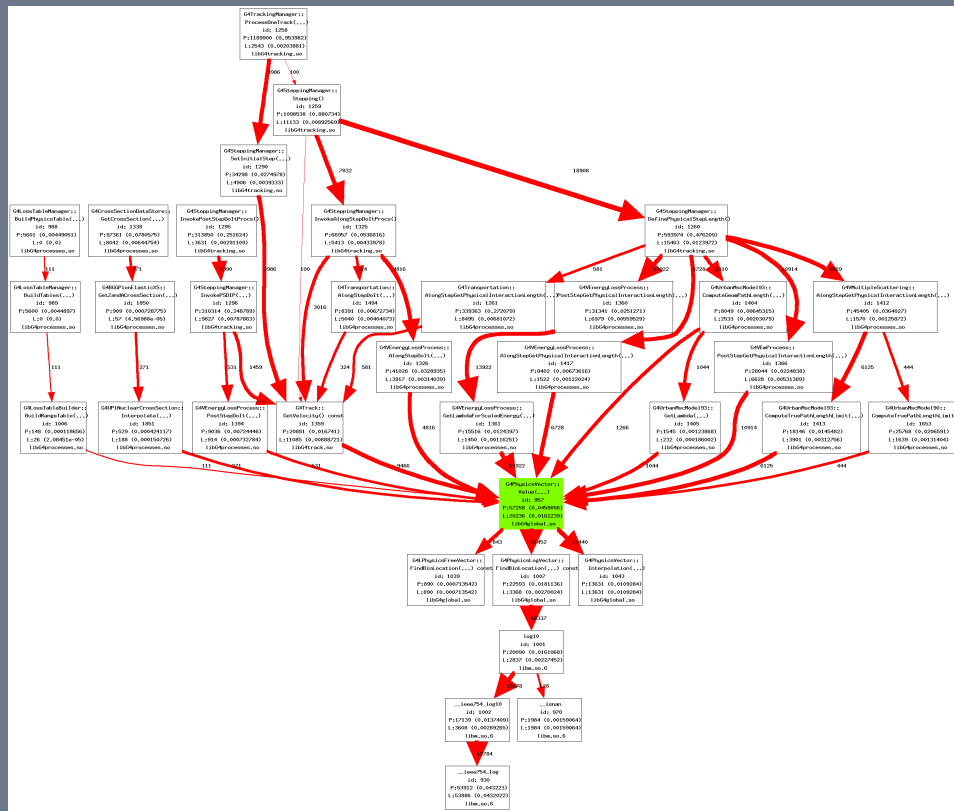
- A slightly differently looking call graph in cmssw426 case:
 - `G4HadronCrossSections::CalcScatteringCrossSections` (`G4DynamicParticle const*, int, int`)
 - Path Count 42044 (3.4%)
 - Leaf Count 37748 (3.0%)
 - `profgraph -n profdata... 1529 3 5 400`
 - All paths with a count smaller than 400 were removed
 - this affects the edges(arrows) which are removed
 - the numbers in the boxes are unaffected
 - the cut should be adjusted based on the number of samples for a specific function

Call Graph centered on G4PhysicsVector::Value in SimplifiedCalo



- A function called by many callers, calling other functions itself, with a significant time spent in it:
 - `G4PhysicsVector::Value (double)`
 - Path Count 111063 (7.1%)
 - Leaf Count 50372 (3.2%)
- `profgraph -n profdata...`
- Quad Core AMD Opteron 2389 at 2915MHz (exp6g,10,1)

Call Graph centered on G4PhysicsVector::Value in cmssw426



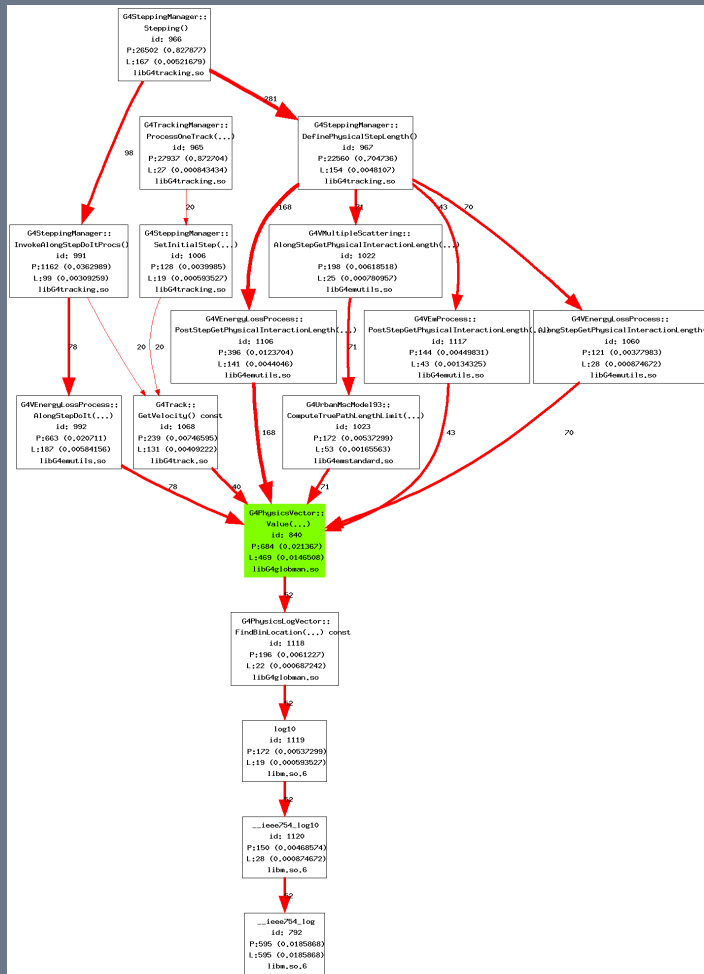
A more complicated graph compared to SimplifiedCalo case and a relatively smaller leaf fraction

G4PhysicsVector::Value (double)

- Path Count 57258 (4.6%)
- Leaf Count 20236 (1.6%)

profgraph -n profdata...
957 3 5 100
Quad Core AMD Opteron
2389g at 2915MHz (exp83,10,1)

Call Graph centered on G4PhysicsVector::Value in Mu2e10g



- A less complicated graph compared to SimplifiedCalo case and a relatively larger leaf fraction

G4PhysicsVector::Value (double)

- Path Count 684(2.1%)
- Leaf Count 469(1.5%)

profgraph -n profdata...
840 3 5 20
Quad Core AMD Opteron
2389 at 2915MHz (exp81,10,1)

Recently Profiled Geant4 Applications

Geant4 version	SimplifiedCalo	cmssw426	Mu2e109
9.4	√	√	
9.4.p01	√	√	√
9.4.p02	√	√	
9.4.ro6	√		
9.5.b.01	√		

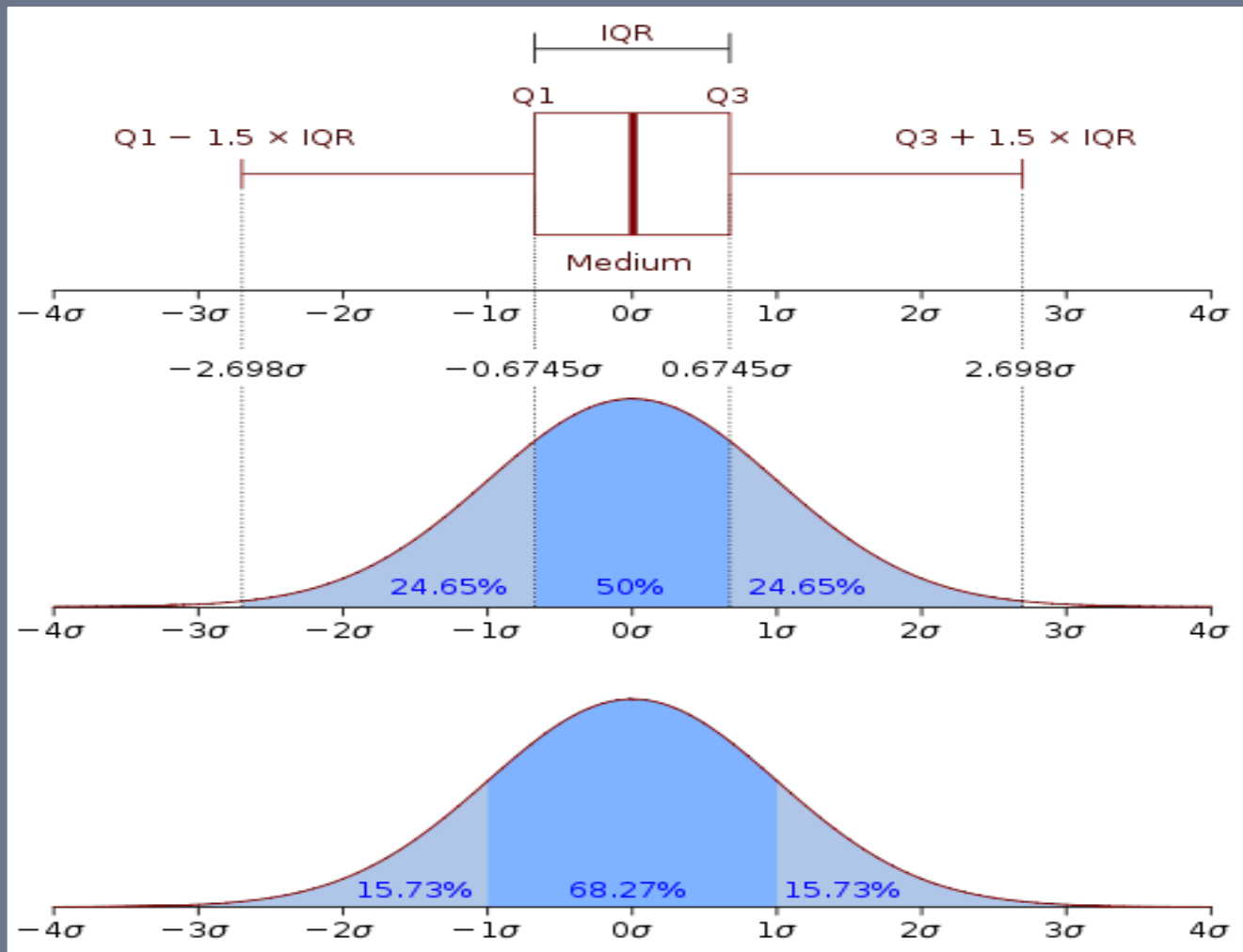
- Preliminary profiling results are available at:
 - <http://oink.fnal.gov/perfanalysis/g4p>
 - the location is likely to change

Summary

- FAST set of tools has been available for some time and can be used to profile Geant4 applications
- Evolving infrastructure exists to generate standard plots for selected applications with a small effort
- We have chosen SimplifiedCalo as a native Geant4 application to be able to profile all Geant4 releases independent of the adoption of a specific release by a user group
- Preliminary profiling results are available

Backup Slides

Box & Whisker Plot



from
Wikipedia

Software/Hardware Versions

- SimplifiedCalo
 - As obtained from Andrea Dotti in May this year
 - minimally modified to add timing printout and to read a PYTHIA event file
 - PYTHIA 14TeV pp, 500 GeV Higgs to ZZ (all decays) input file
 - magnetic field turned on (see next page for exact parameters)
- Geant4/CLHEP
 - 9.4.p01/2.1.0.1
- Compiler
 - gcc 4.1.2 with -g -O2
- OS/Hardware
 - Scientific Linux SL release 5.4 (Boron)
 - kernel 2.6.18-238.12.1.el5
 - processors/memory
 - Intel Xeon E5430 @ 2.66GHz/16GB
 - Quad-Core AMD Opteron Processor 2389 (2.9GHz) /24GB

SimplifiedCalo Parameters

- ...
- /mygen/generator PYTHIA
- /mydet/setField 4.0 tesla
- /mydet/absorberMaterial AHCALWalloy
- /mydet/activeMaterial Scintillator
- /mydet/isCalHomogeneous 0
- /mydet/isUnitInLambda 0
- /mydet/absorberTotalLength 7000
- /mydet/calorimeterRadius 3000
- /mydet/activeLayerNumber 100
- /mydet/readoutLayerNumber 20
- /mydet/activeLayerSize 4.0
- /mydet/radiusBinSize 0.1
- /mydet/radiusBinNumber 10
- /mydet/update
- /run/beamOn 50

Software/Hardware Versions

- CMSSW cmsRun
 - 4.2.6 with patches by Sunanda Banerjee for more recent versions of Geant4
 - PYTHIA 14TeV pp, 700GeV Z' to dijets (dusc quarks) input file
- Geant4/CLHEP
 - 9.4.p01/2.0.4.6-cms
- Compiler
 - gcc 4.3.4-cms with -g -O2
- OS/Hardware
 - Scientific Linux SL release 5.4 (Boron)
 - kernel 2.6.18-238.12.1.el5
 - processors/memory
 - Intel Xeon E5430 @ 2.66GHz/16GB
 - Quad-Core AMD Opteron Processor 2389 (2.9GHz) /24GB

Software/Hardware Versions

- Mu2e Offline
 - 1.09
- Geant4/CLHEP
 - 9.4.p01/2.1.0.1
- Compiler
 - gcc 4.5.1 with -g -O2
- OS/Hardware
 - Scientific Linux SLF release 5.3 (Lederman)
 - kernel 2.6.18-238.19.1.el5
 - processors/memory
 - Intel Xeon E5430 @ 2.66GHz/16GB
 - Intel Xeon X5355 @ 2.66GHz/16GB
 - Quad-Core AMD Opteron Processor 2389 (2.9GHz) /24GB