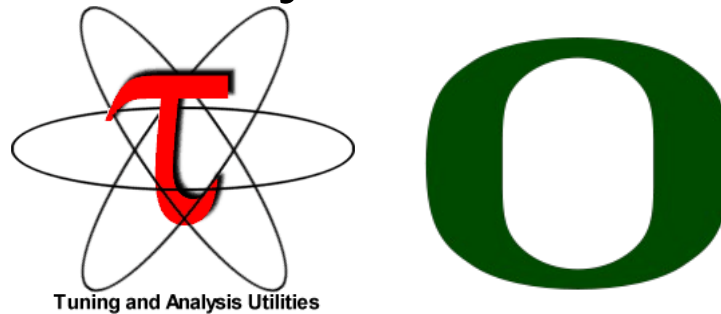# Profile Analysis with ParaProf
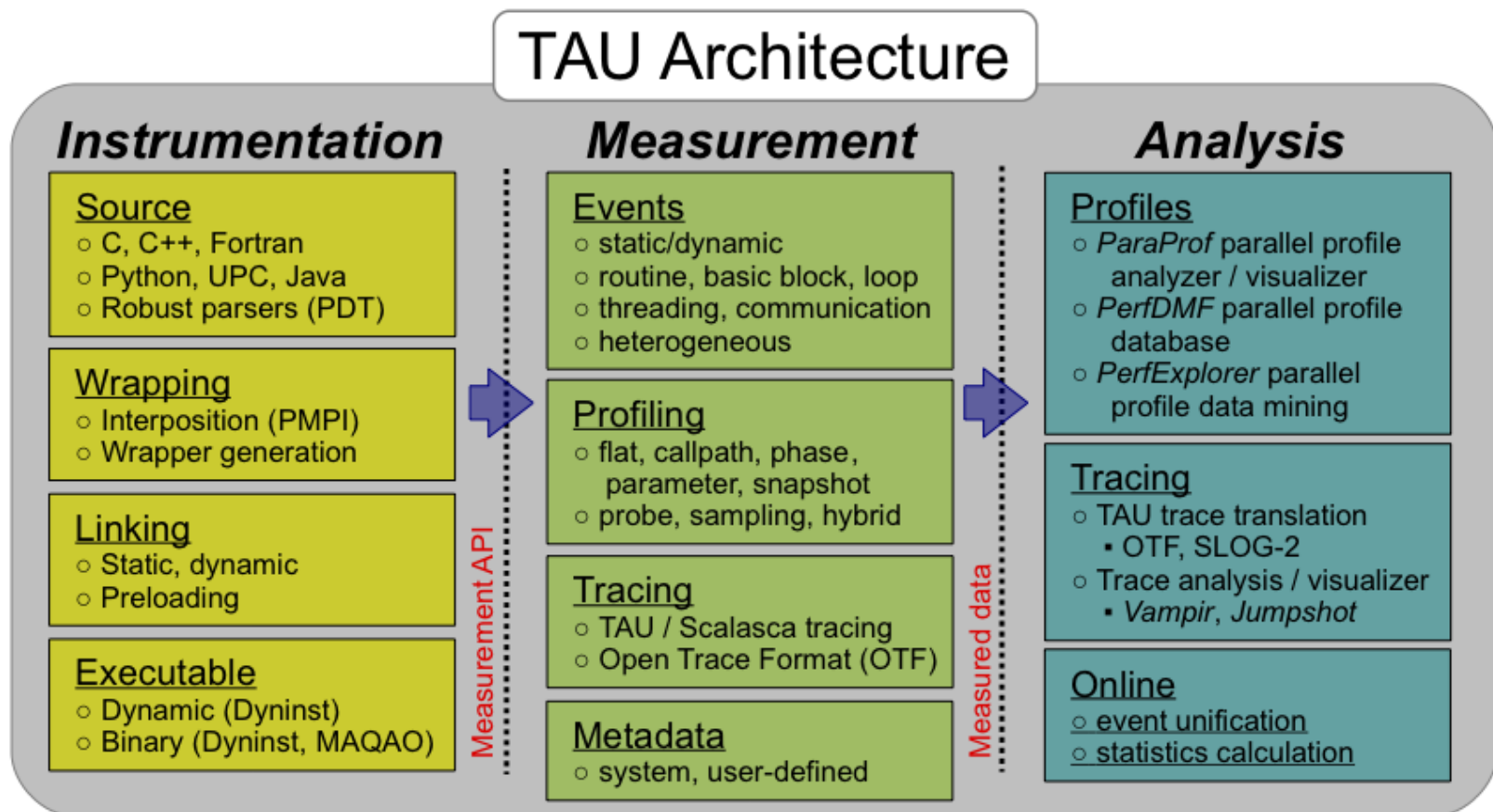
Wyatt Spear
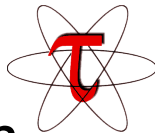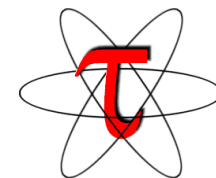
Performance Reseaerch Lab, University of Oregon
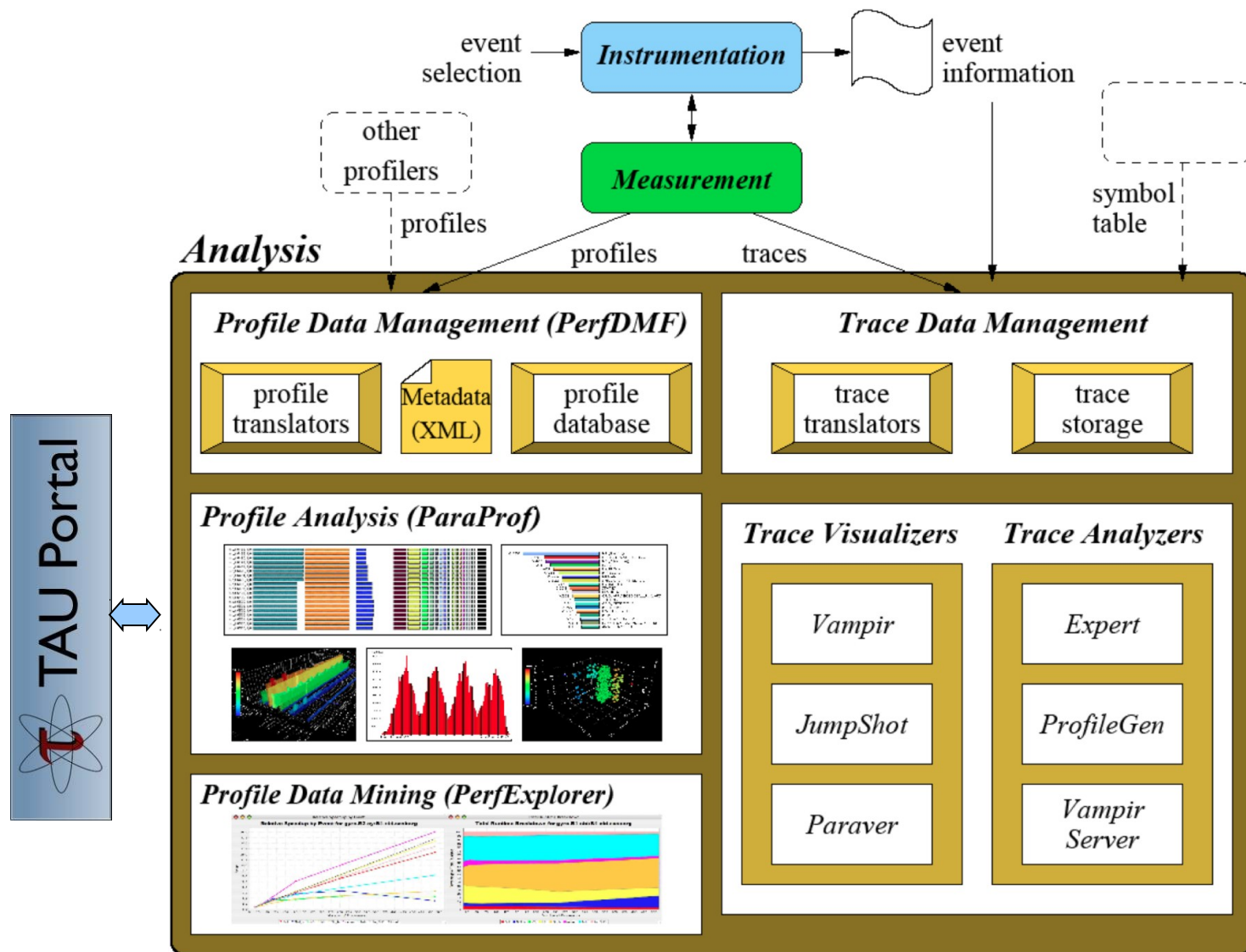
http://TAU.uoregon.edu

- Parallel performance framework and toolkit
  - Supports all HPC platforms, compilers, runtime system
  - Provides portable instrumentation, measurement, analysis

## TAU Architecture

**Instrumentation**

Source
○ C, C++, Fortran
○ Python, UPC, Java
○ Robust parsers (PDT)

Wrapping
○ Interposition (PMPI)
○ Wrapper generation

Linking
○ Static, dynamic
○ Preloading

Executable
○ Dynamic (Dyninst)
○ Binary (Dyninst, MAQAO)

Measurement API

**Measurement**

Events
○ static/dynamic
○ routine, basic block, loop
○ threading, communication
○ heterogeneous

Profiling
○ flat, callpath, phase,
  parameter, snapshot
○ probe, sampling, hybrid

Tracing
○ TAU / Scalasca tracing
○ Open Trace Format (OTF)

Metadata
○ system, user-defined

Measured data

**Analysis**

Profiles
○ *ParaProf* parallel profile
  analyzer / visualizer
○ *PerfDMF* parallel profile
  database
○ *PerfExplorer* parallel
  profile data mining

Tracing
○ TAU trace translation
  • OTF, SLOG-2
○ Trace analysis / visualizer
  • *Vampir, Jumpshot*

Online
○ event unification
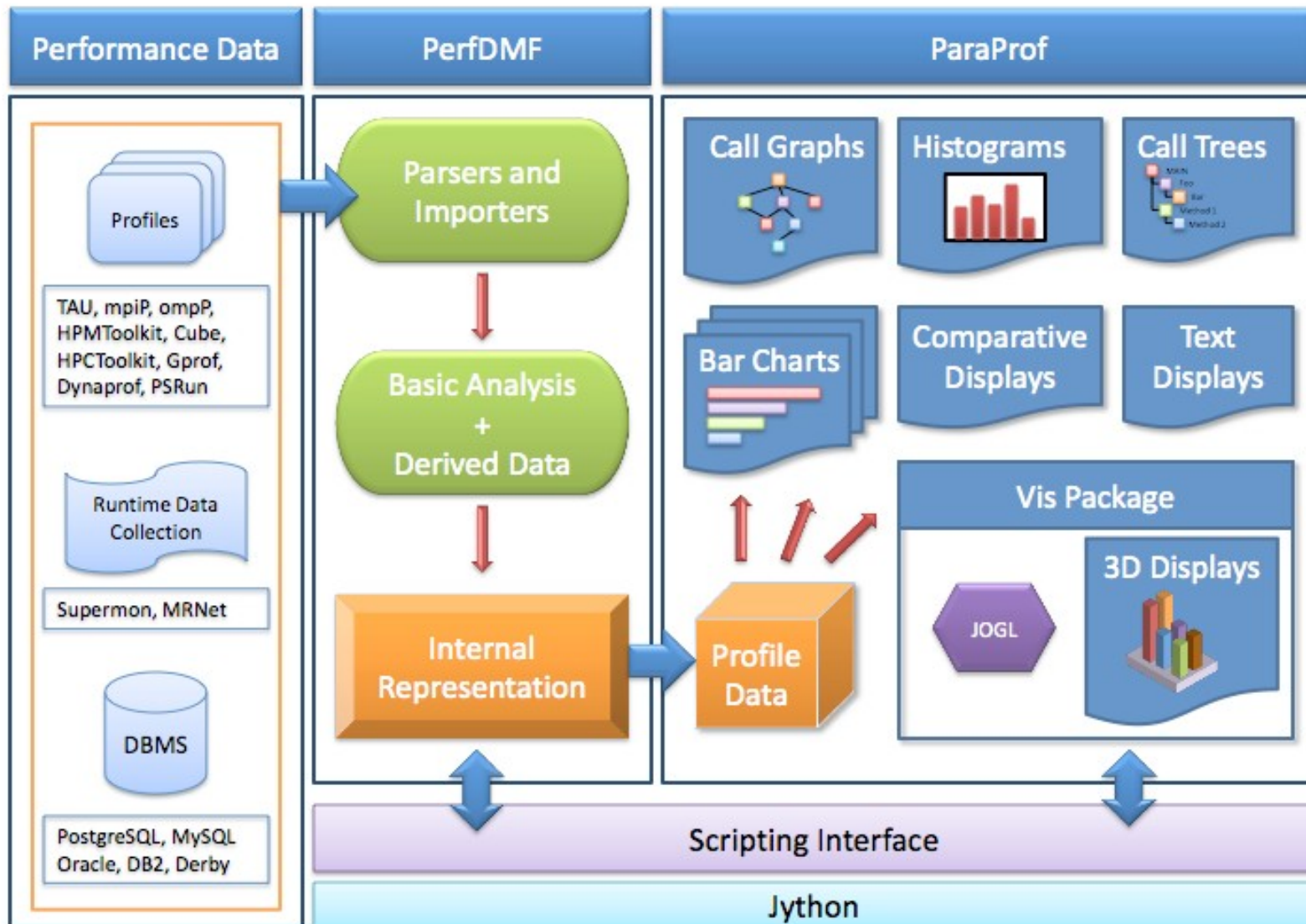○ statistics calculation

# TAU Performance System®

- Instrumentation
  - Fortran, C++, C, UPC, Java, Python, Chapel
  - Automatic instrumentation

- Measurement and analysis support
  - MPI, OpenSHMEM, ARMCI, PGAS, DMAPP
  - pthreads, OpenMP, hybrid, other thread models
  - GPU, CUDA, OpenCL, OpenACC
  - Parallel profiling and tracing
  - Use of Score-P for native OTF2 and CUBEX generation
  - Efficient callpath profiles and trace generation using Score-P

- Analysis
  - Parallel profile analysis (ParaProf), data mining (PerfExplorer)
  - Performance database technology (PerfDMF, TAUdb)
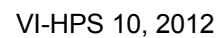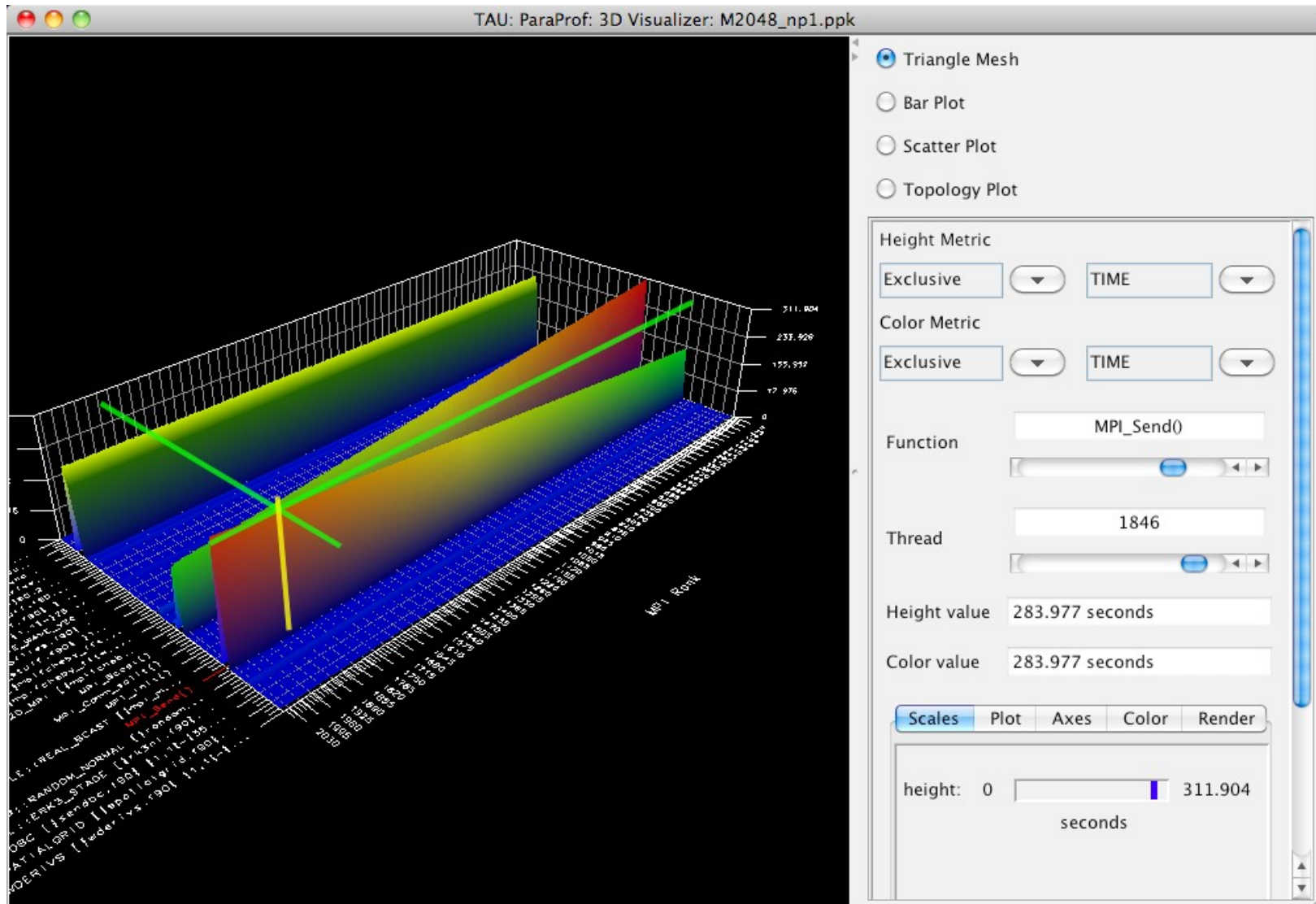  - 3D profile browser

VI-HPS

**Performance Data**

Profiles

TAU, mpiP, ompP,
HPMToolkit, Cube,
HPCToolkit, Gprof,
Dynaprof, PSRun

Runtime Data
Collection

Supermon, MRNet

DBMS

PostgreSQL, MySQL
Oracle, DB2, Derby

**PerfDMF**

Parsers and
Importers

Basic Analysis
+
Derived Data

Internal
Representation

**ParaProf**

Call Graphs

Histograms

Call Trees

Bar Charts

Comparative
Displays

Text
Displays

Vis Package

JOGL

3D Displays

Profile
Data

Scripting Interface

Jython
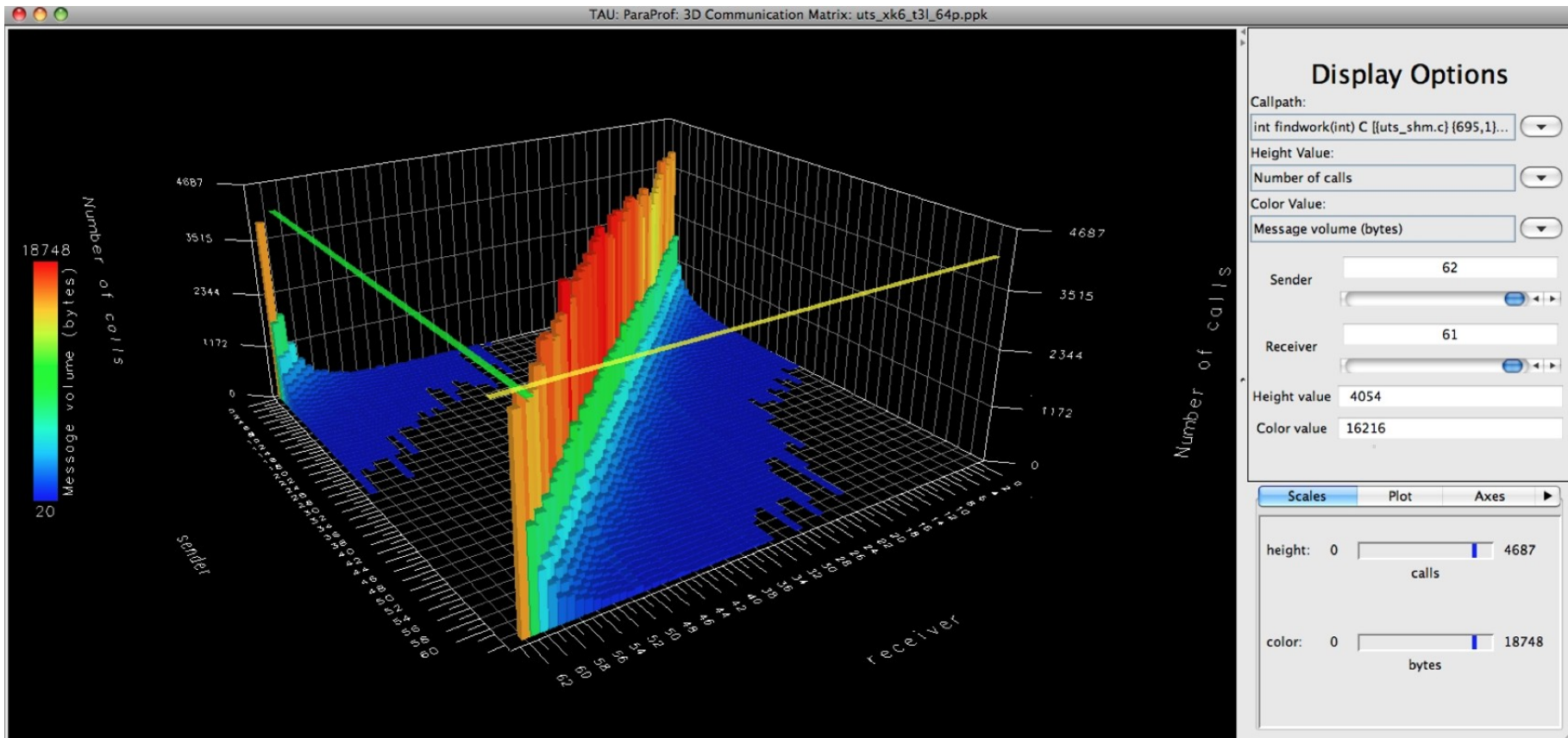
- Examples: Score-P experiments of BT-MZ from LiveDVD
  - Class "B", 4 processes with 4 OpenMP threads each
  - Collected on a dedicated node of the SuperMUC HPC system at Leibniz Rechenzentrum (LRZ), Munich, Germany
  - LiveDVD available at http://tau.uoregon.edu/livedvd/latest64.iso
  - Paraprof available as java webstart appliction at http://tau.uoregon.edu/paraprof

- Start TAU's paraprof GUI with default profile report

```
% module load java
% paraprof scorep-20120913_1740_557443655223384/profile.cubex
OR
% paraprof scorep_bt-mz_B_4x4_trace/scout.cubex
```

**TAU: ParaProf Manager**

File   Options   Help

- Applications
  - Standard Applications
    - Default App
      - Default Exp
        - scout.cubex
          - Time
          - Wait at Barrier
          - Barrier Completion
          - Late Sender
          - Late Sender => Messages in Wrong Order
          - Late Sender => Messages in Wrong Order => Messages from different sources
          - Late Sender => Messages in Wrong Order => Messages from same source
          - Late Receiver
          - Early Reduce
          - Early Scan
          - Late Broadcast
          - Wait at N x N
          - N x N Completion
          - Management
          - Management => Fork
          - P2P send synchronizations
          - P2P send synchronizations => Late Receivers
          - P2P recv synchronizations
          - P2P recv synchronizations => Late Senders
          - P2P recv synchronizations => Late Senders => Messages in Wrong Order
          - Collective synchronizations
          - P2P send communications
          - P2P send communications => Late Receivers
          - P2P recv communications
          - P2P recv communications => Late Senders
          - P2P recv communications => Late Senders => Messages in Wrong Order
          - Collective exchange communications
          - Collective communications as source
          - Collective communications as destination
          - P2P bytes sent
          - P2P bytes received
          - Collective bytes outgoing
          - Collective bytes incoming
          - RMA bytes received
          - RMA bytes put

| TrialField | Value |
|---|---|
| Name | scout.cubex |
| Application ID | 0 |
| Experiment ID | 0 |
| Trial ID | 0 |
| File Type Index | 9 |
| File Type Name | Cube |

Metrics in the profile

**VI-HPS**
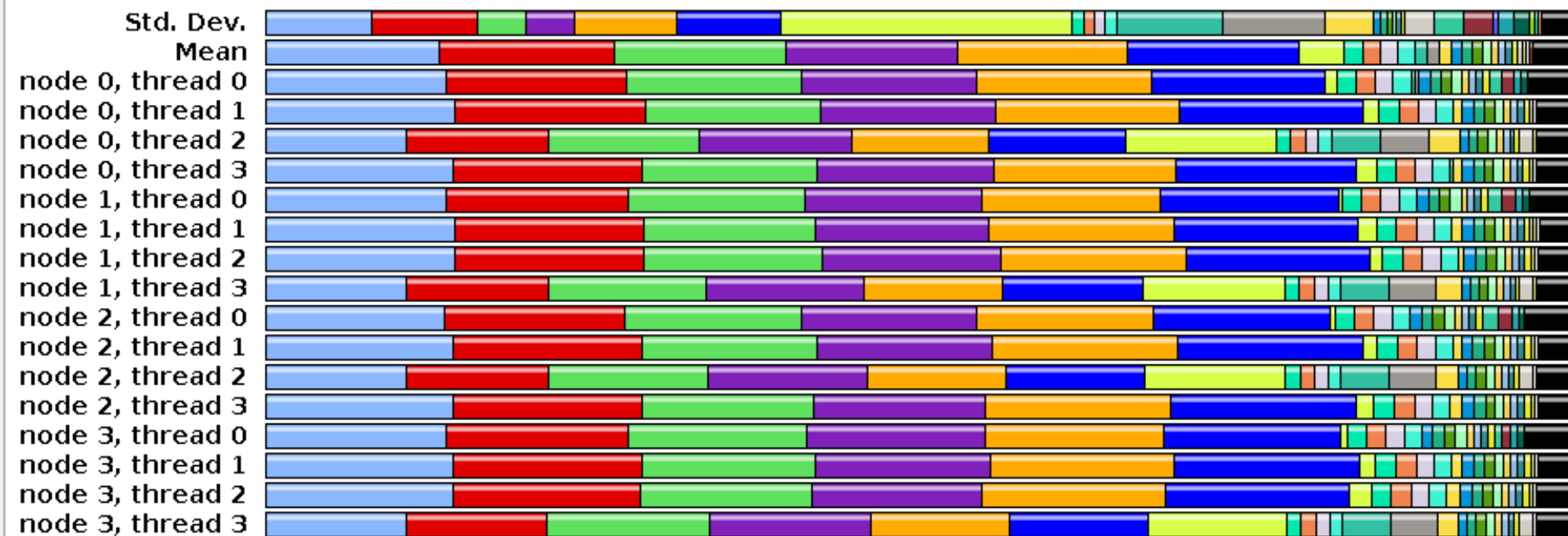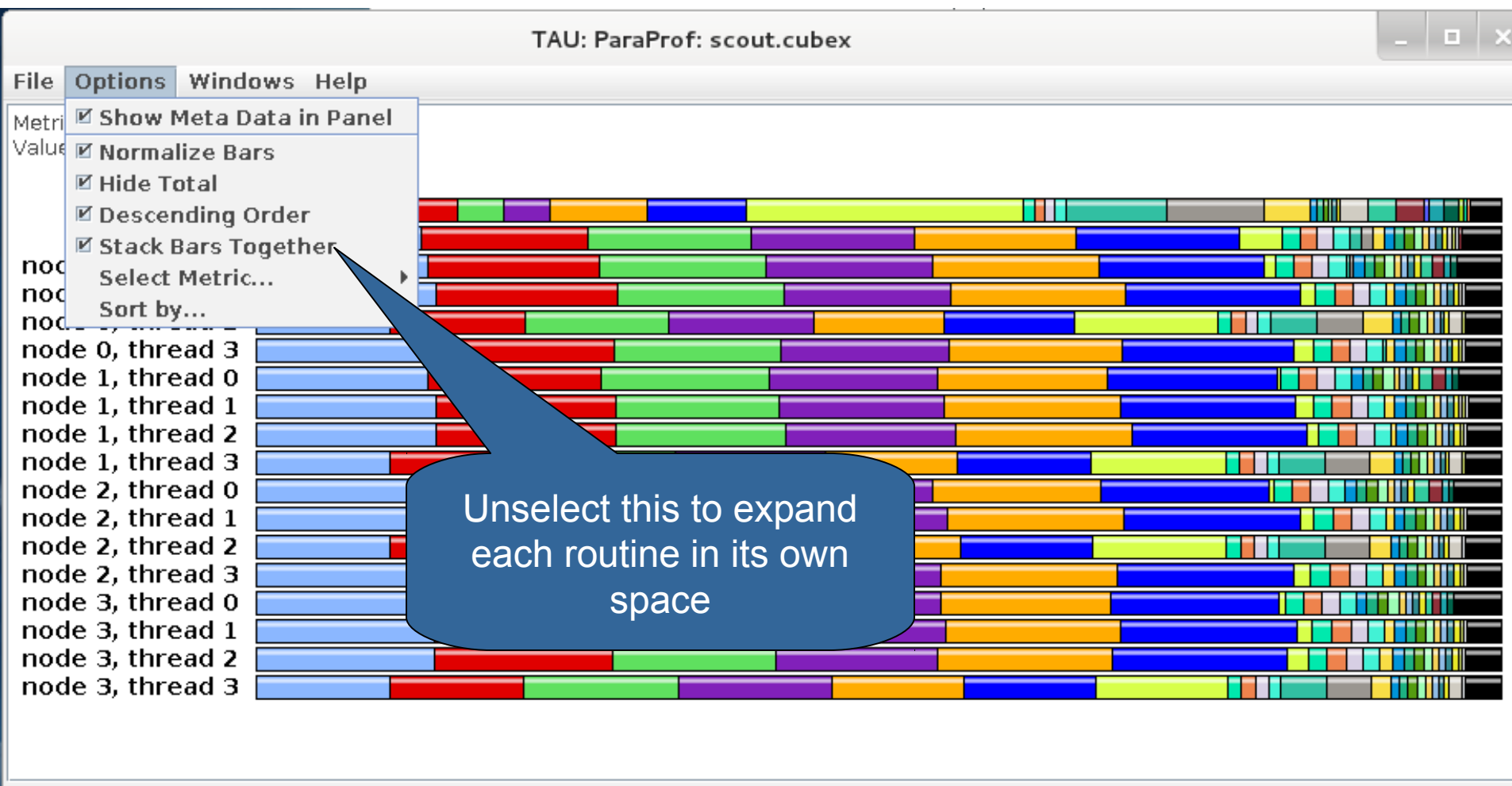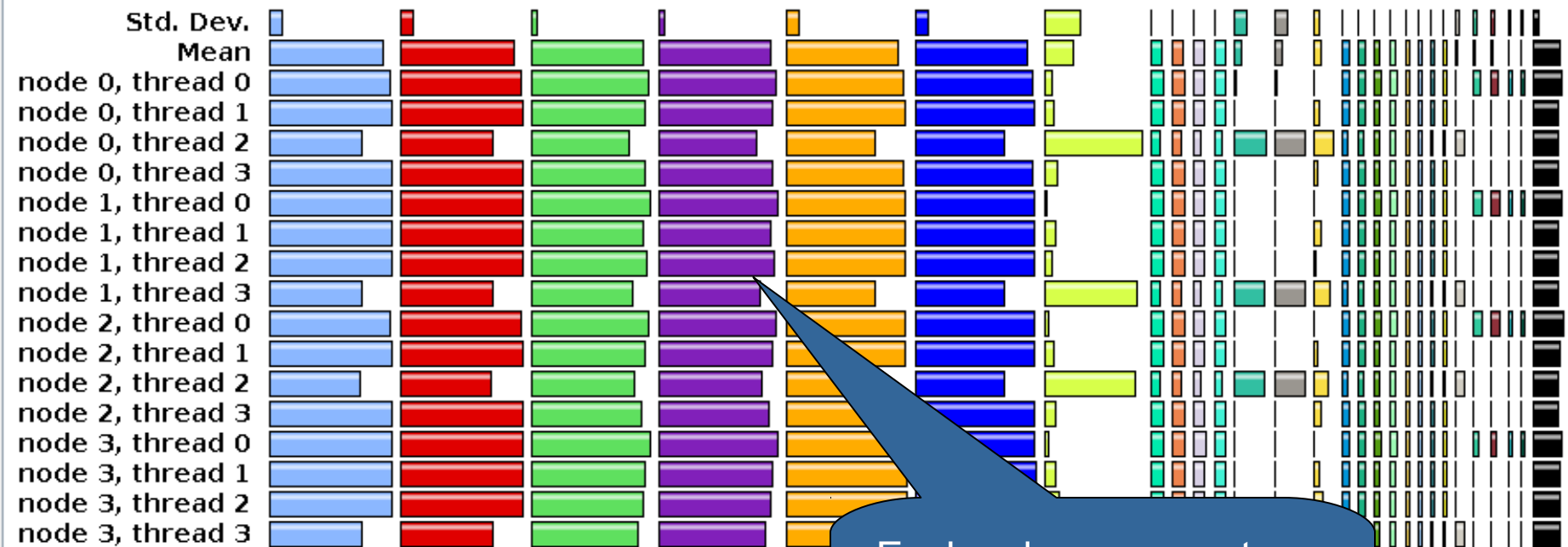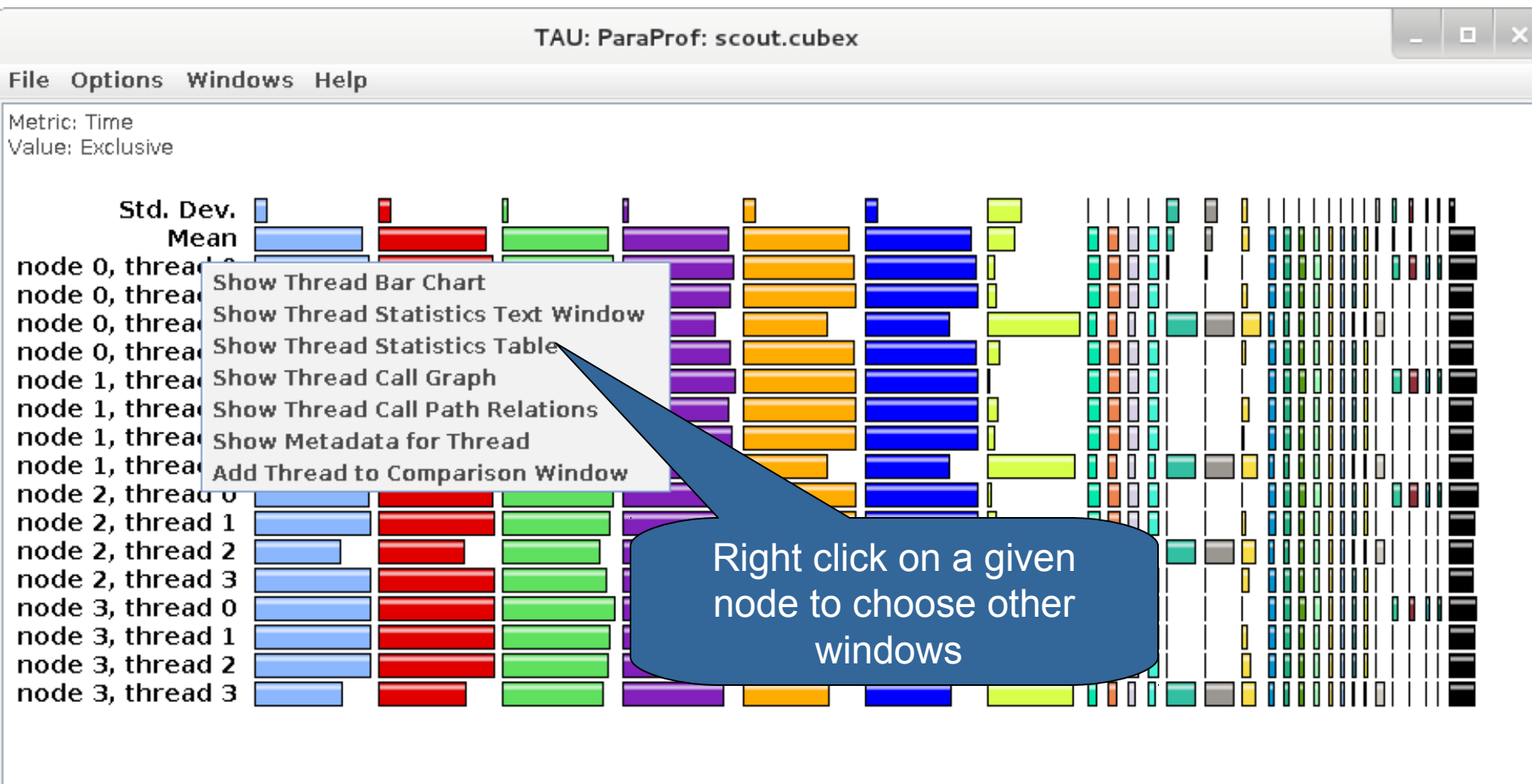
**TAU: ParaProf: Statistics for: node 0, thread 0 – scout.cubex**

File   Options   Windows   Help

Time

| Name | Exclusive Time ▽ | Inclusive Time | Calls | Child Calls |
|---|---|---|---|---|
| 🟩 !$omp do @y_solve.f:52 | 5.817 | 5.817 | 3,216 | 0 |
| 🟩 !$omp do @z_solve.f:52 | 5.657 | 5.657 | 3,216 | 0 |
| 🟩 !$omp do @x_solve.f:54 | 5.609 | 5.609 | 3,216 | 0 |
| 🟦 !$omp do @rhs.f:191 | 0.609 | 0.609 | 3,232 | 0 |
| 🟦 !$omp do @rhs.f:80 | 0.583 | .583 | 3,232 | 0 |
| 🟦 MPI_Waitall | 0.402 | | | 0 |
| 🟦 !$omp implicit barrier | 0.402 | | | |
| 🟦 !$omp do @rhs.f:301 | 0.36 | | | |
| 🟦 !$omp implicit barrier | 0.026 | | | |
| 🟦 !$omp implicit barrier | 0 | | | |
| 🟦 !$omp do @rhs.f:37 | 0.343 | | | 0 |
| 🟦 !$omp do @rhs.f:62 | 0.225 | 0.228 | 3,232 | 3,232 |
| 🟦 !$omp implicit barrier | 0.004 | 0.004 | 3,216 | 0 |
| 🟦 !$omp implicit barrier | 0 | 0 | 16 | 0 |
| 🟦 MPI_Init_thread | 0.218 | 0.218 | 1 | 0 |
| 🟦 !$omp do @rhs.f:384 | 0.199 | 0.199 | 3,232 | 0 |
| 🟦 !$omp parallel do @add.f:22 | 0.099 | 0.111 | 3,216 | 3,216 |
| 🟦 !$omp do @rhs.f:428 | 0.069 | 0.069 | 3,232 | 0 |
| 🟦 MPI_Isend | 0.043 | 0.043 | 603 | 0 |
| 🟦 !$omp do @initialize.f:50 | 0.04 | 0.04 | 32 | 0 |
| 🟦 !$omp parallel @rhs.f:28 | 0.03 | 2.536 | 3,232 | 51,712 |
| 🟦 !$omp parallel do @exch_qbc.f:215 | 0.021 | 0.029 | 6,432 | 6,432 |
| 🟦 !$omp parallel do @exch_qbc.f:255 | 0.02 | 0.033 | 6,432 | 6,432 |
| 🟦 !$omp parallel @exch_qbc.f:255 | 0.02 | 0.053 | 6,432 | 6,432 |
| 🟦 !$omp parallel @exch_qbc.f:244 | | | | |

> Click to sort by a given metric, drag and move to rearrange columns

FinderScreenSnapz003.png

TAU: ParaProf: Statistics for: node 0, thread 0 – profile.cubex

File   Options   Windows   Help

| Name | Exclusive Time ▽ | Inclusive Time | Calls | Child Calls |
|------|-----------------|----------------|-------|-------------|
| APPLU [{lu.f} {46,7}-{162,9}] | 0 | 8.035 | 1 | 19 |
| SSOR [{ssor.f} {4,7}-{241,9}] | 0.064 | 6.225 | 2 | 37,643 |
| RHS [{rhs.f} {5,7}-{504,9}] | 0.743 | 2.524 | 303 | 606 |
| BLTS [{blts.f} {4,7}-{259,9}] | 0.613 | 0.658 | 9,331 | 18,662 |
| BUTS [{buts.f} {4,7}-{259,9}] | 0.612 | 1.871 | 9,331 | 18,662 |
| EXCHANGE_1 [{exchange_1.f} {5,7}-{177,9}] | 0.024 | 1.259 | 18,662 | 18,662 |
| MPI_Recv | 1.235 | 1.235 | 18,662 | 0 |
| MPI_Send | 0 | 0 | 0 | 0 |
| JACU [{jacu.f} {5,7}-{384,9}] | 0.532 | 0.532 | 9,331 | 0 |
| JACLD [{jacld.f} {5,7}-{384,9}] | 0.522 | 0.522 | 9,331 | 0 |
| MPI_Allreduce | 0.018 | 0.018 | 2 | 0 |
| L2NORM [{l2norm.f} {4,7}-{68,9}] | 0 | 0.035 | 4 | 4 |
| MPI_Barrier | 0 | 0 | 2 | 0 |
| TIMER_START [{timers.f} {23,7}-{37,9}] | 0 | 0 | 2 | 0 |
| TIMER_STOP [{timers.f} {43,7}-{59,9}] | 0 | 0 | 2 | 0 |
| TIMER_CLEAR [{timers.f} {4,7}-{17,9}] | 0 | 0 | 2 | 0 |
| TIMER_READ [{timers.f} {65,7}-{77,9}] | 0 | 0 | 2 | 0 |
| SETIV [{setiv.f} {4,7}-{67,9}] | 0.043 | 0.111 | 2 | 95,232 |
| PROC_GRID [{proc_grid.f} {5,7}-{34,9}] | 0.011 | 0.011 | 1 | 0 |
| ERHS [{erhs.f} {4,7}-{536,9}] | 0.004 | 0.108 | 1 | 2 |
| ERROR [{error.f} {4,7}-{81,9}] | 0.004 | 0.009 | 1 | 7,937 |
| SETBV [{setbv.f} {5,7}-{79,9}] | 0.002 | 0.004 | 2 | 3,400 |
| READ_INPUT [{read_input.f} {5,7}-{125,9}] | 0 | 0.001 | 1 | 2 |
| VERIFY [{verify.f} {5,9}-{403,11}] | 0 | 0 | 1 | 0 |
| PRINT_RESULTS [{print_results.f} {2,7}-{115,12}] | 0 | 0 | 1 | 0 |
| PINTGR [{pintgr.f} {5,7}-{288,9}] | 0 | 0 | 1 | 6 |
| INIT_COMM [{init_comm.f} {5,7}-{57,9}] | 0 | 1.565 | 1 | 4 |
| MPI_Finalize | 0 | 0 | 1 | 0 |
| SETHYPER [{sethyper.f} {5,7}-{94,9}] | 0 | 0 | 1 | 0 |
| NEIGHBORS [{neighbors.f} {5,7}-{48,9}] | 0 | 0 | 1 | 0 |
| SETCOEFF [{setcoeff.f} {5,7}-{157,9}] | 0 | 0 | 1 | 0 |
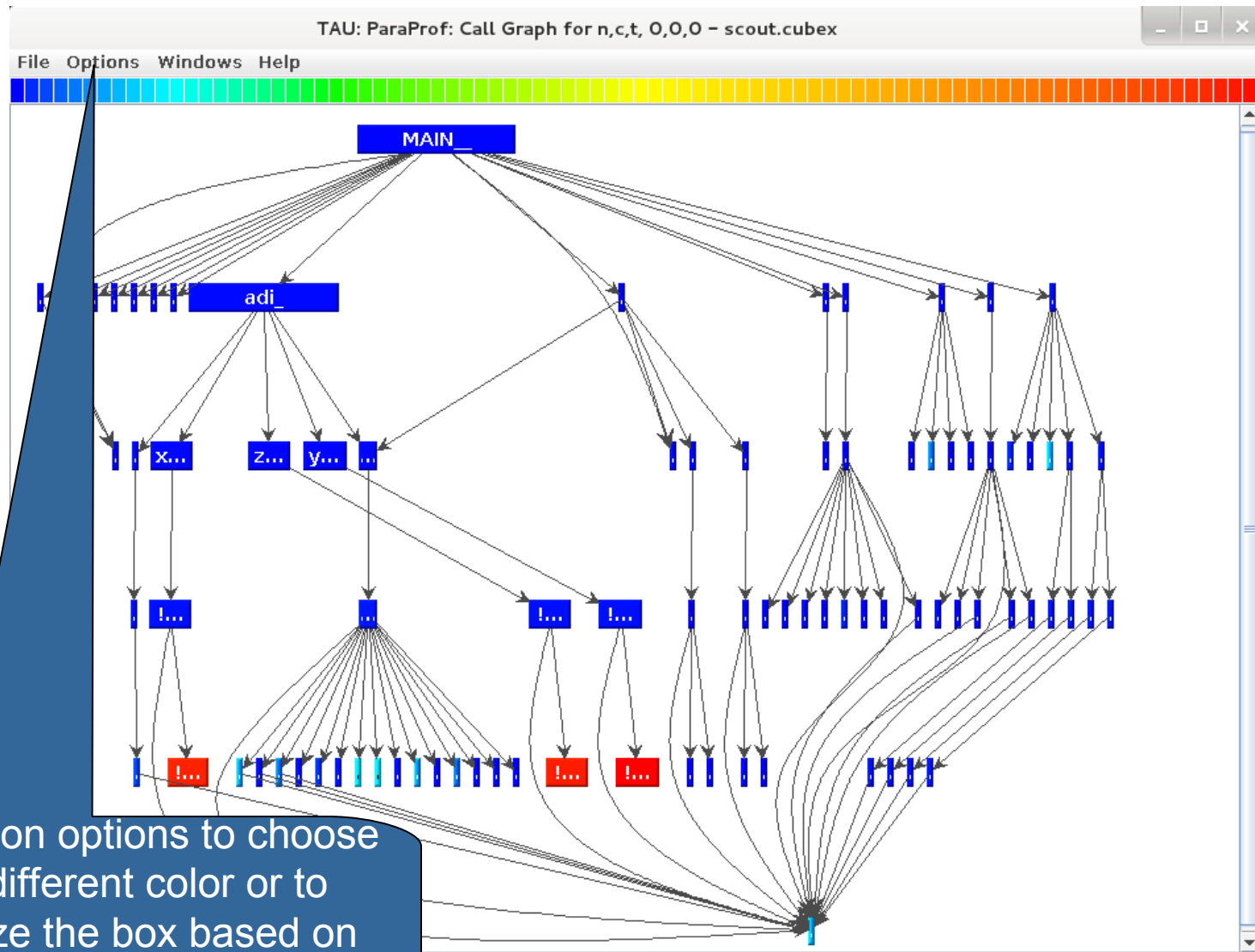
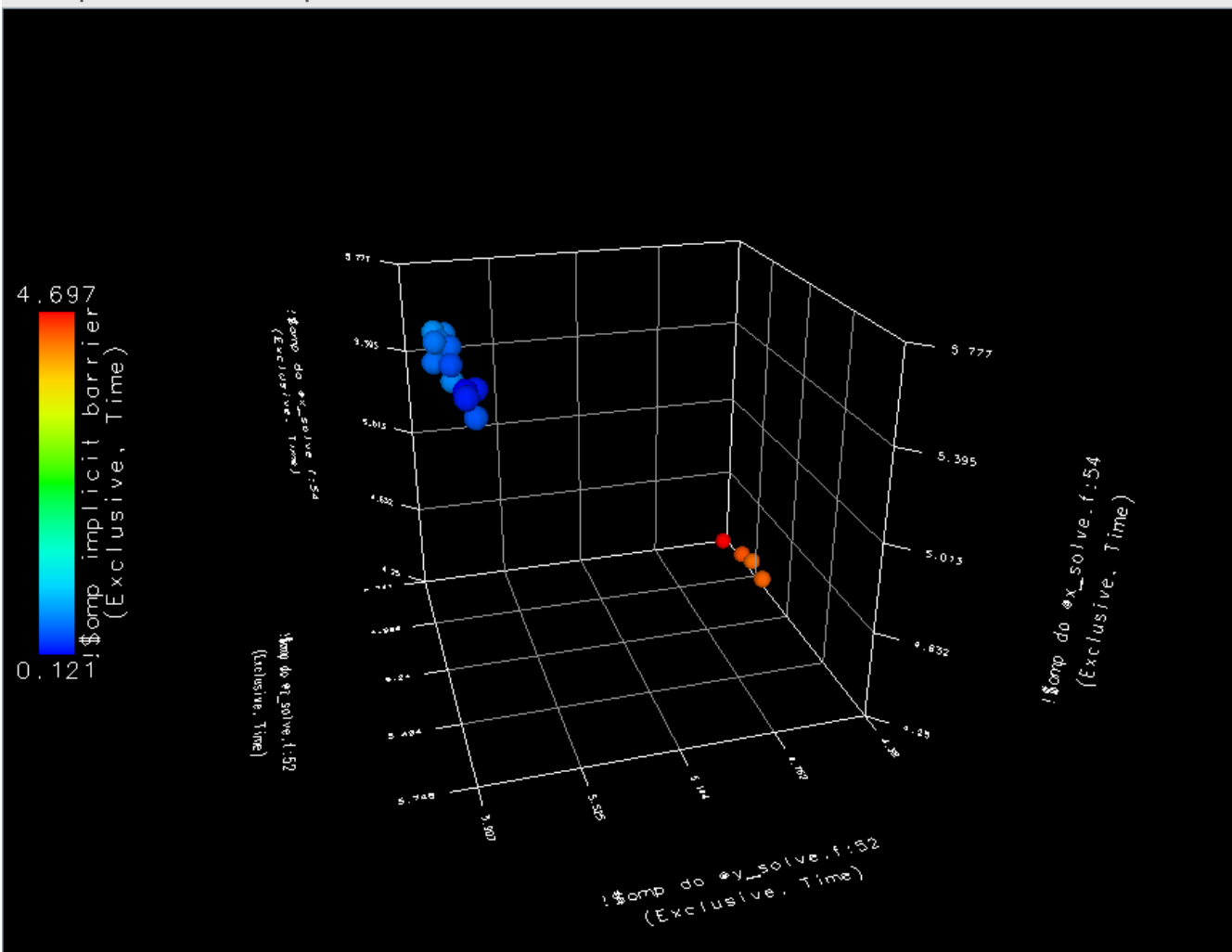Click on options to choose a different color or to resize the box based on metrics

TAU: ParaProf: Call Path Data n,c,t, 0,0,0 – scout.cubex

File  Options  Windows  Help

Metric Name: Time
Sorted By: Exclusive
Units: seconds

| | | | |
|---|---|---|---|
| 0.04 | 0.04 | 32/32 | !$omp parallel @initialize.f:28 |
| --> 0.04 | 0.04 | 32 | !$omp do @initialize.f:50 |
| | | | |
| 0.03 | 2.536 | 3232/3232 | compute_rhs_ |
| --> 0.03 | 2.536 | 3232 | !$omp parallel @rhs.f:28 |
| 9.8E-4 | 9.8E-4 | 3232/3232 | !$omp master @rhs.f:424 |
| 0.225 | 0.228 | 3232/3232 | !$omp do @rhs.f:62 |
| 0.002 | 0.002 | 3232/3232 | !$omp master @rhs.f:74 |
| 0.002 | 0.002 | 3232/3232 | !$omp master @rhs.f:293 |
| 0.199 | 0.199 | 3232/3232 | !$omp do @rhs.f:384 |
| 0.002 | 0.002 | 3232/3232 | !$omp master @rhs.f:183 |
| 0.343 | 0.343 | 3232/3232 | !$omp do @rhs.f:37 |
| 0.016 | 0.016 | 3232/3232 | !$omp do @rhs.f:372 |
| 0.014 | 0.027 | 3232/3232 | !$omp do @rhs.f:413 |
| 0.609 | 0.609 | 3232/3232 | !$omp do @rhs.f:191 |
| 0.36 | 0.386 | 3232/3232 | !$omp do @rhs.f:301 |
| 0.583 | 0.583 | 3232/3232 | !$omp do @rhs.f:80 |
| 0.019 | 0.019 | 3232/3232 | !$omp do @rhs.f:400 |
| 0.006 | 0.006 | 3232/51680 | !$omp implicit barrier |
| 0.069 | 0.069 | 3232/3232 | !$omp do @rhs.f:428 |
| 0.015 | 0.015 | 3232/3232 | !$omp do @rhs.f:359 |
| | | | |
| 0.021 | 0.029 | 6432/6432 | !$omp parallel @exch_qbc.f:215 |
| --> 0.021 | 0.029 | 6432 | !$omp parallel do @exch_qbc.f:215 |
| 0.007 | 0.007 | 6432/51680 | !$omp implicit barrier |
| | | | |
| 0.02 | 0.033 | 6432/6432 | !$omp parallel @exch_qbc.f:255 |
| --> 0.02 | 0.033 | 6432 | !$omp parallel do @exch_qbc.f:255 |
| 0.013 | 0.013 | 6432/51680 | !$omp implicit barrier |
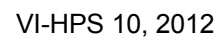
# ParaProf: Node View



TAU: ParaProf: node 0, thread 0 – profile.cubex

File   Options   Windows   Help

Metric: Time
Value: Exclusive
Units: seconds

| | |
|---|---|
| 3.71 | MAIN__ => adi_ => y_solve_ => !$omp parallel @y_solve.f:43 => !$omp do @y_solve.f:52 |
| 3.71 | !$omp do @y_solve.f:52 |
| 3.593 | MAIN__ => adi_ => z_solve_ => !$omp parallel @z_solve.f:43 => !$omp do @z_solve.f:52 |
| 3.593 | !$omp do @z_solve.f:52 |
| 3.55 | MAIN__ => adi_ => x_solve_ => !$omp parallel @x_solve.f:46 => !$omp do @x_solve.f:54 |
| 3.55 | !$omp do @x_solve.f:54 |
| 0.4 | !$omp do @rhs.f:191 |
| 0.398 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:191 |
| 0.383 | !$omp do @rhs.f:80 |
| 0.381 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:80 |
| 0.352 | !$omp implicit barrier |
| 0.299 | !$omp parallel @rhs.f:28 |
| 0.298 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 |
| 0.28 | !$omp do @rhs.f:37 |
| 0.279 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:37 |
| 0.261 | !$omp do @rhs.f:301 |
| 0.259 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:301 |
| 0.228 | !$omp do @rhs.f:62 |
| 0.227 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:62 |
| 0.214 | MAIN__ => mpi_setup_ => MPI_Init_thread |
| 0.214 | MPI_Init_thread |
| 0.161 | MAIN__ => exch_qbc_ => copy_x_face_ |
| 0.161 | copy_x_face_ |
| 0.16 | MAIN__ => exch_qbc_ => copy_y_face_ |
| 0.16 | copy_y_face_ |
| 0.15 | MAIN__ => exch_qbc_ |
| 0.15 | exch_qbc_ |
| 0.141 | !$omp do @rhs.f:384 |
| 0.14 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:384 |
| 0.127 | MAIN__ => exch_qbc_ => MPI_Waitall |
| 0.127 | MPI_Waitall |
| 0.103 | MAIN__ => adi_ |
| 0.103 | adi_ |
| 0.094 | MAIN__ => adi_ => add_ => !$omp parallel @add.f:22 => !$omp parallel do @add.f:22 |
| 0.094 | !$omp parallel do @add.f:22 |
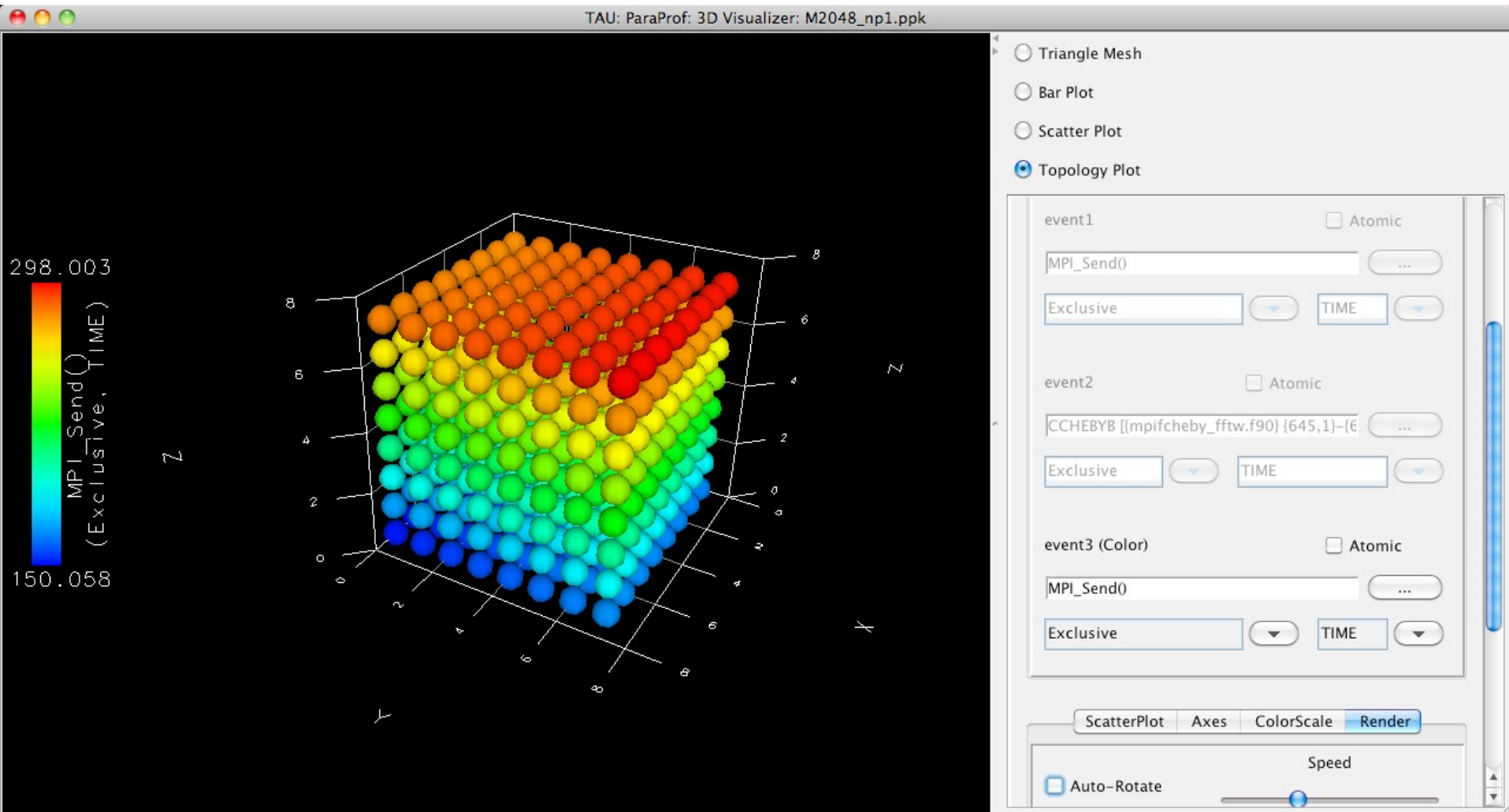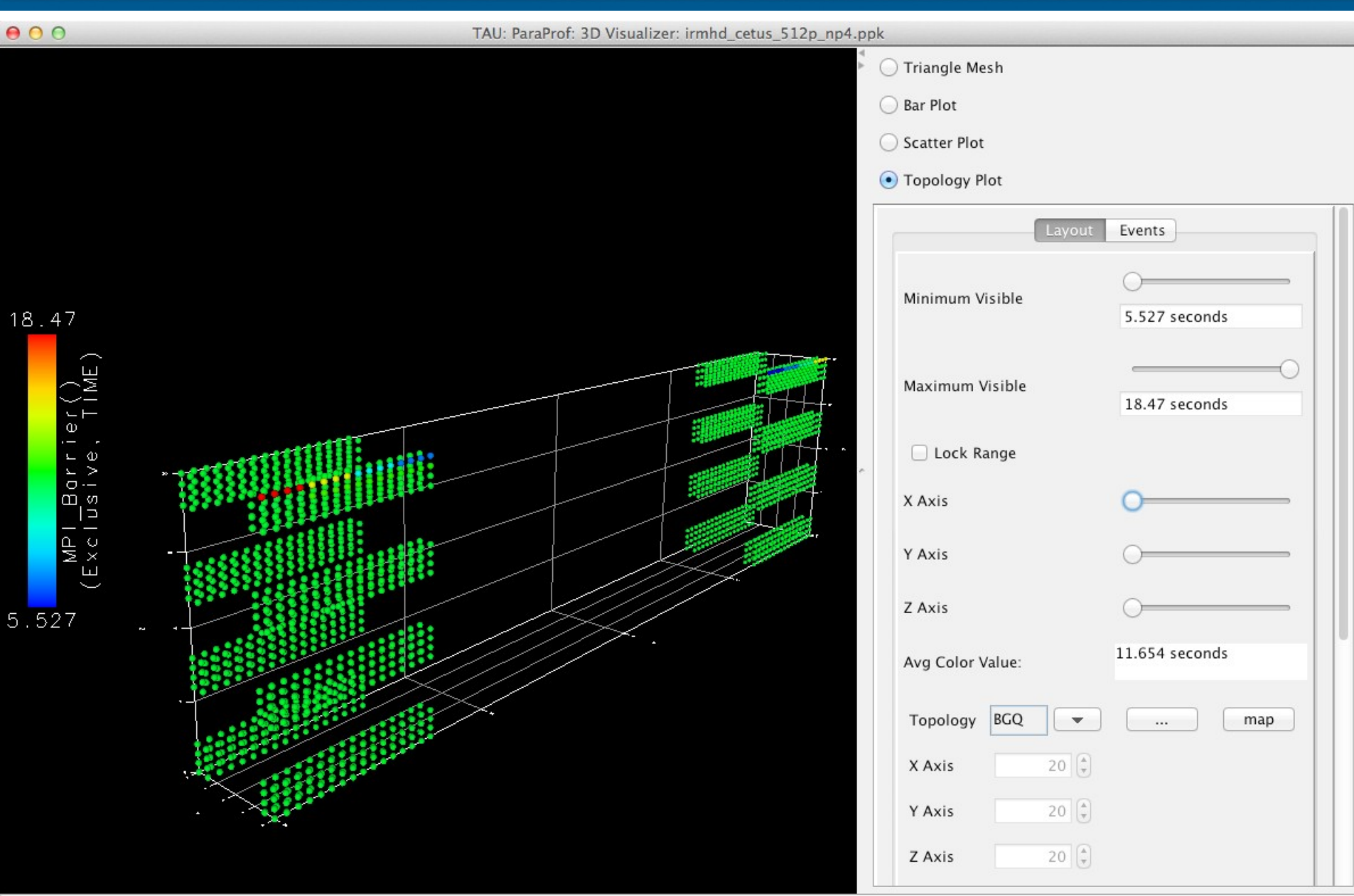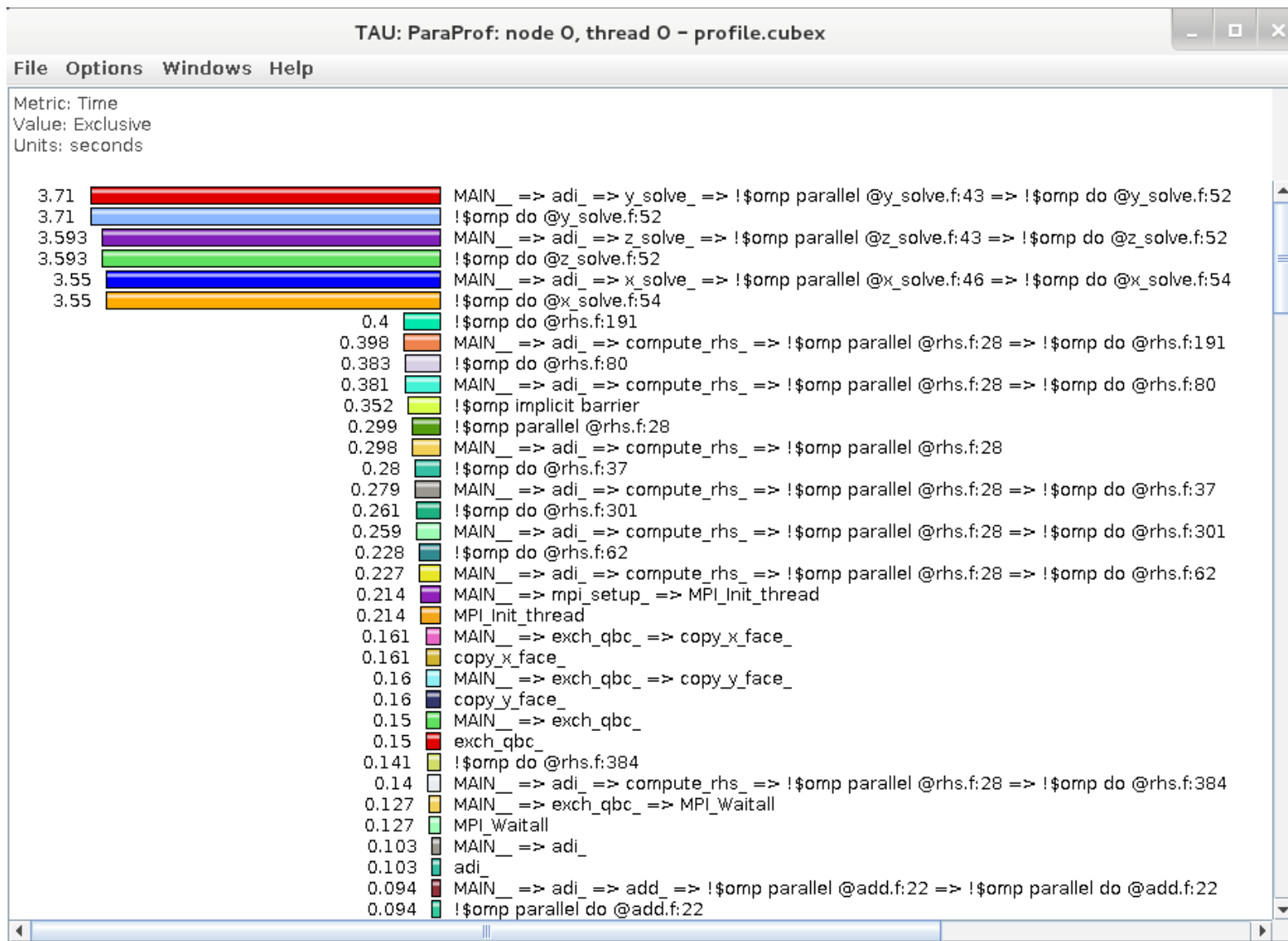
# ParaProf: Add Thread to Comparison Window



VI-HPS 10, 2012
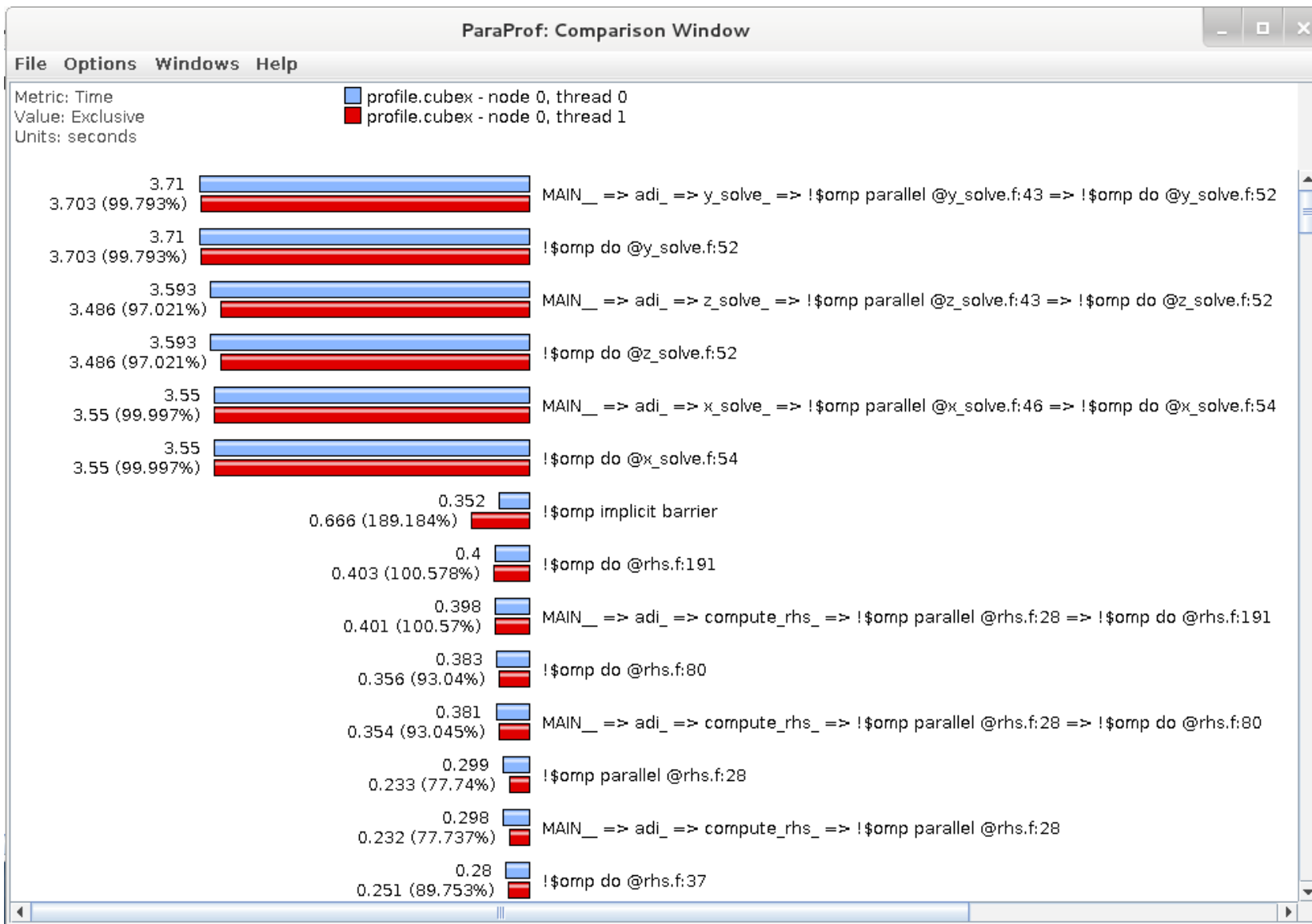
# ParaProf: Score-P Profile Files, Database



TAU: ParaProf Manager

File   Options   Help

- ● Applications
  - ○ 🗀 Standard Applications
    - ○ 🗀 Default App
      - ○ 🗀 Default Exp
        - ○ 🗀 profile.cubex
          - ● Time
          - ● Minimum Inclusive Time
          - ● Maximum Inclusive Time
          - ● PAPI_TOT_CYC
          - ● PAPI_TOT_INS
          - ● PAPI_FP_INS
          - ● ru_utime
          - ● ru_stime
          - ● ru_maxrss
          - ● ru_ixrss
          - ● ru_idrss
          - ● ru_isrss
          - ● ru_minflt
          - ● ru_majflt
          - ● ru_nswap
          - ● ru_inblock
          - ● ru_oublock
          - ● ru_msgsnd
          - ● ru_msgrcv
          - ● ru_nsignals
          - ● ru_nvcsw
          - ● ru_nivcsw
          - ● bytes_sent
          - ● bytes_received
- ○ 🗀 Default (jdbc:h2:/home/livetau/.ParaProf//perfdmf;AUTO_SERVER=TRUE)
- ○ 🗀 perfexplorer_working (jdbc:h2:/home/livetau/.ParaProf/perfexplorer_wo      TRUE)

| TrialField | Value |
|---|---|
| Name | profile.cubex |
| Application ID | 0 |
| Experiment ID | 0 |
| Trial ID | 0 |
| File Type Index | 9 |
| File Type Name | Cube |

Add Application
Add Experiment
Add Trial

## TAU: ParaProf: Group Changer: profile.cubex

| Region | Current | Available |
|---|---|---|
| filter: | | new group |

**Region:**
- !$omp atomic @error.f:104
- !$omp atomic @error.f:51
- !$omp do @error.f:33
- !$omp do @error.f:91
- !$omp do @exact_rhs.f:147
- !$omp do @exact_rhs.f:247
- !$omp do @exact_rhs.f:31
- !$omp do @exact_rhs.f:346
- !$omp do @exact_rhs.f:46
- !$omp do @initialize.f:100
- !$omp do @initialize.f:119
- !$omp do @initialize.f:137
- !$omp do @initialize.f:156
- !$omp do @initialize.f:174
- !$omp do @initialize.f:192
- !$omp do @initialize.f:31

**Current:** CUBE_DEFAULT

**Available:** CUBE_CALLPATH

<--

-->

# Sorting Derived Flops Metric by Exclusive Time

VI-HPS

## TAU: ParaProf: node 0, thread 0 − profile.cubex

File   Options   Windows   Help

Metric: ( PAPI_FP_INS / Time )
Value: Exclusive
Units: Derived metric shown in seconds format
Sorted By: Exclusive (Time)

| Value | Description |
|---|---|
| 3.0217E9 | MAIN__ => adi_ => y_solve_ => !$omp parallel @y_solve.f:43 => !$omp do @y_solve.f:52 |
| 3.0217E9 | !$omp do @y_solve.f:52 |
| 3.2421E9 | MAIN__ => adi_ => z_solve_ => !$omp parallel @z_solve.f:43 => !$omp do @z_solve.f:52 |
| 3.2421E9 | !$omp do @z_solve.f:52 |
| 3.0673E9 | MAIN__ => adi_ => x_solve_ => !$omp parallel @x_solve.f:46 => !$omp do @x_solve.f:54 |
| 3.0673E9 | !$omp do @x_solve.f:54 |
| 3.3299E9 | !$omp do @rhs.f:191 |
| 3.3298E9 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:191 |
| 3.5138E9 | !$omp do @rhs.f:80 |
| 3.514E9 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:80 |
| 1965740.083 | !$omp implicit barrier |
| 2518815.107 | !$omp parallel @rhs.f:28 |
| 2518981.066 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 |
| 3.502E8 | !$omp do @rhs.f:37 |
| 3.4975E8 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:37 |
| 4.0207E9 | !$omp do @rhs.f:301 |
| 4.0205E9 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:301 |
| 393146.074 | !$omp do @rhs.f:62 |
| 393024.443 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:62 |
| 60.754 | MAIN__ => mpi_setup_ => MPI_Init_thread |
| 60.754 | MPI_Init_thread |
| 2218222.902 | MAIN__ => exch_qbc_ => copy_x_face_ |
| 2218222.902 | copy_x_face_ |
| 2217983.431 | MAIN__ => exch_qbc_ => copy_y_face_ |
| 2217983.431 | copy_y_face_ |
| 2691052.918 | MAIN__ => exch_qbc_ |
| 2691052.918 | exch_qbc_ |
| 1.5944E9 | !$omp do @rhs.f:384 |
| 1.5944E9 | MAIN__ => adi_ => compute_rhs_ => !$omp parallel @rhs.f:28 => !$omp do @rhs.f:384 |
| 65007.137 | MAIN__ => exch_qbc_ => MPI_Waitall |

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