Parallel Performance Optimization Using TAU Training and Workshop

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http://www.paratools.com/TAU

Download slides and workshop tarball from:

http://tau.uoregon.edu/tau_llnl19.pdf

Quartz.llnl.gov (or Lassen): /usr/global/tools/tau/training/workshop.tgz

Serrano.sandia.gov: /projects/tau/workshop.tgz

LANL: /turquoise/usr/projects/packages/tau/workshop.tgz

TAU: Quickstart Guide

Setup:

```
•  % module load tau (Lasssen, LLNL)
•  % source /usr/global/tools/tau/training/tau.bashrc (Quartz,LLNL)
```

Profiling:

```
MPI: % mpirun -np 16 tau_exec -ebs ./a.out
•  MPI+OpenMP: % export TAU_OMPT_SUPPORT_LEVEL=full;
               % mpirun -np 16 tau_exec -T ompt,v5 -ompt ./a.out
•  Pthread:   % mpirun -np 16 tau_exec -T mpi,pthread -ebs ./a.out
•  Python+MPI+EBS % mpirun -np 16 tau_python -ebs ./a.py
Analysis: % pprof -a -m | more;  % paraprof (GUI)
```

Tracing:

```
•  Vampir: MPI: % export TAU_TRACE=1; export TAU_TRACE_FORMAT=otf2
                % mpirun -np 16 tau_exec ./a.out; vampir traces.otf2 &
•  Chrome: % export TAU_TRACE=1; mpirun -np 64 tau_exec ./a.out
    % tau_treemerge.pl;
% tau_trace2json tau.trc tau.edf -chrome -ignoreatomic -o app.json
   Chrome browser: chrome://tracing   (Load -> app.json)
```

Outline

Day 1:

Morning:

- Introduction to TAU
- Instrumentation: PDT, MPI, OpenMP OMPT, tau_exec
- Hands-on workshop examples using paraprof
- PAPI
- Hands-on using loop level instrumentation, PAPI

Afternoon

- Demonstration of analysis tools: Paraprof, TAUdb and PerfExplorer
- Vampir and Jumpshot
- Hands-on

Breaks

- 10:30am – 10:45am, noon – 1:30pm, 3pm – 3:15pm

Day 2:

Individual Sessions:.

- Applying performance evaluation tools to user codes

TAU's Runtime Environment Variables

Environment Variable	Default	Description
TAU_TRACE	0	Setting to 1 turns on tracing
TAU_CALLPATH	0	Setting to 1 turns on callpath profiling
TAU_TRACK_MEMORY_FOOTPRINT	0	Setting to 1 turns on tracking memory usage by sampling periodically the resident set size and high water mark of memory usage
TAU_TRACK_LOAD	0	Tracks system load on a node (e.g., also seen in tools like w, top, uptime)
TAU_CALLPATH_DEPTH	2	Specifies depth of callpath. Setting to 0 generates no callpath or routine information, setting to 1 generates flat profile and context events have just parent information (e.g., Heap Entry: foo)
TAU_SAMPLING	1	Setting to 1 enables event-based sampling (same as tau_exec –ebs).
TAU_EBS_RESOLUTION	Line	Setting to file | function | line will resolve addresses at the given resolution.
TAU_EBS_UNWIND	0	Setting to 1 enables callstack unwinding during sampling.
TAU_TRACK_SIGNALS	0	Setting to 1 generate debugging callstack info when a program crashes
TAU_COMM_MATRIX	0	Setting to 1 generates communication matrix display using context events
TAU_THROTTLE	1	Setting to 0 turns off throttling. Throttles instrumentation in lightweight routines that are called frequently
TAU_CALLSITE	0	Setting to 1 enables callsite profiling that shows where an instrumented function was called. Also compatible with tracing.
TAU_PROFILE_FORMAT	Profile	Setting to "merged" generates a single file. "snapshot" generates xml format
TAU_METRICS	TIME	Setting to a comma separated list generates other metrics. (e.g., ENERGY,TIME,P_VIRTUAL_TIME,PAPI_FP_INS,PAPI_NATIVE_<event>:<subevent>)

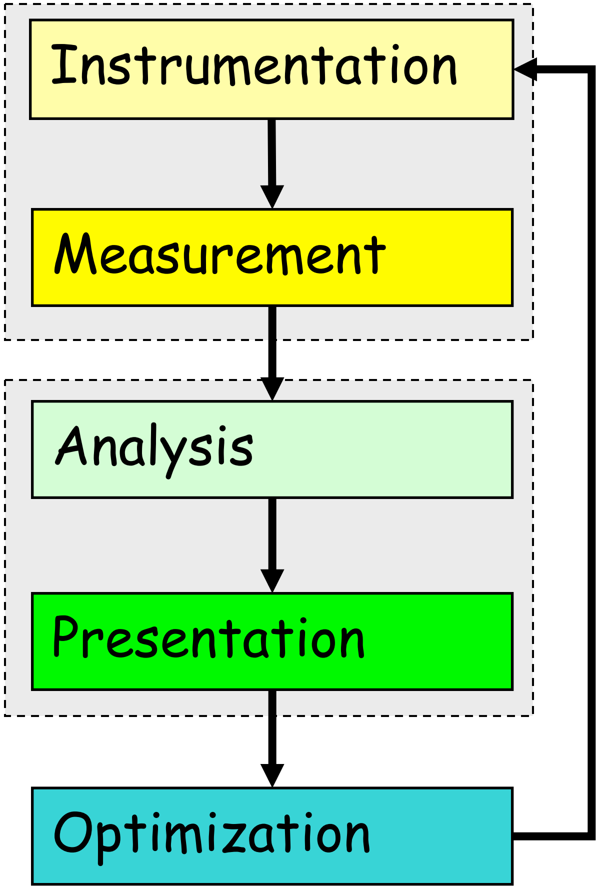
Tutorial Goals

This tutorial is an introduction to portable performance evaluation tools. You should leave here with a better understanding of…

- Concepts and steps involved in performance evaluation
- Understanding key concepts in understanding code performance
- How to collect and analyze data from hardware performance counters (PAPI)
- How to instrument your programs with TAU
- Measurement options provided by TAU
- Environment variables used for choosing metrics, generating performance data
- How to use ParaProf, TAU's profile browser
- General familiarity with TAU use for Fortran, C++, C, and mixed language
- How to generate trace data in different formats

Performance Optimization Cycle

- Expose factors
- Collect performance data
- Calculate metrics
- Analyze results
- Visualize results
- Identify problems
- Tune performance



TAU Performance System®

http://tau.uoregon.edu

- **Tuning and Analysis Utilities (20+ year project)**
- **Comprehensive performance profiling and tracing**
  - Integrated, scalable, flexible, portable
  - Targets all parallel programming/execution paradigms

- **Integrated performance toolkit**
  - Instrumentation, measurement, analysis, visualization
  - Widely-ported performance profiling / tracing system
  - Performance data management and data mining
  - Open source (BSD-style license)

- **Integrates with application frameworks**

Direct Performance Observation

Execution *actions* exposed as *events*

- In general, actions reflect some execution state
  - presence at a code location or change in data
  - occurrence in parallelism context (thread of execution)
- Events encode actions for observation

Observation is *direct*

- Direct instrumentation of program code (probes)
- Instrumentation invokes performance measurement
- Event measurement = performance data + context

Performance experiment

- Actual events + performance measurements

Indirect Performance Observation

Program code instrumentation is not used

Performance is observed indirectly

- Execution is interrupted
  - can be triggered by different events
- Execution state is queried (sampled)
  - different performance data measured
- *Event-based sampling* (EBS)

Performance attribution is inferred

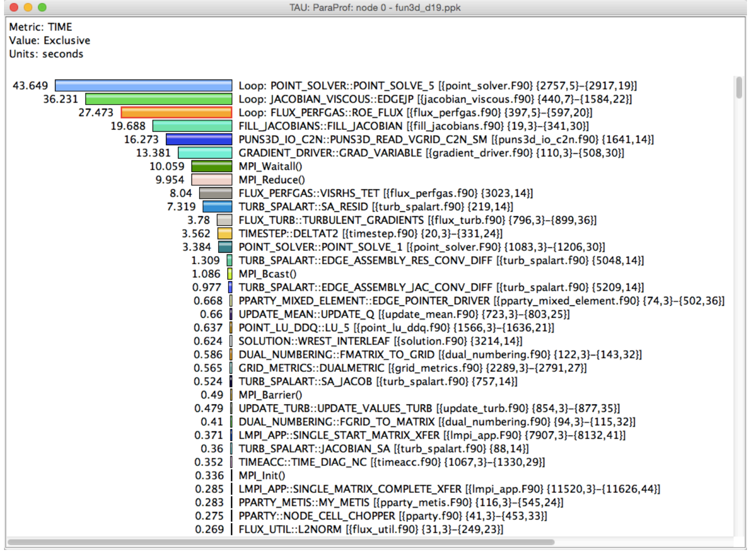
- Determined by execution context (state)
- Observation resolution determined by interrupt period
- Performance data associated with context for period

Understanding Application Performance using TAU

- **How much time** is spent in each application routine and outer *loops*? Within loops, what is the contribution of each *statement*?
- **How many instructions** are executed in these code regions? Floating point, Level 1 and 2 *data cache misses*, hits, branches taken?
- **What is the memory usage** of the code? When and where is memory allocated/de-allocated? Are there any memory leaks?
- **What are the I/O characteristics** of the code? What is the peak read and write *bandwidth* of individual calls, total volume?
- **What is the contribution of each *phase*** of the program? What is the time wasted/spent waiting for collectives, and I/O operations in Initialization, Computation, I/O phases?
- **How does the application *scale***? What is the efficiency, runtime breakdown of performance across different core counts?

Profiling and Tracing

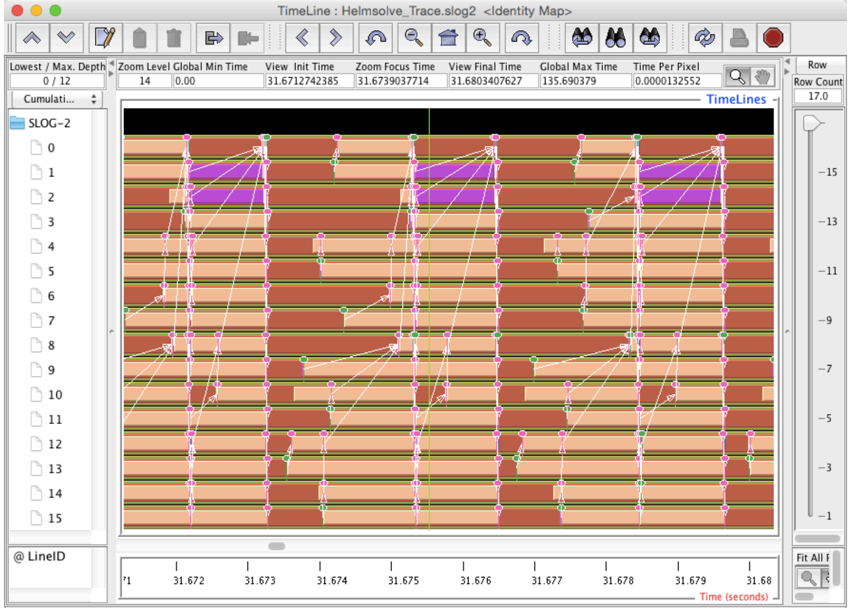
Profiling



TAU: ParaProf: node 0 - fun3d_d19.ppk

```
Metric: TIME
Value: Exclusive
Units: seconds

43.649 Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]
36.231 Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]
27.473 Loop: FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {397,5}-{597,20}]
19.688 FILL_JACOBIANS::FILL_JACOBIAN [{fill_jacobians.f90} {19,3}-{341,30}]
16.273 PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N_SM [{puns3d_io_c2n.f90} {1641,14}]
13.381 GRADIENT_DRIVER::GRAD_VARIABLE [{gradient_driver.f90} {110,3}-{508,30}]
10.059 MPI_Waitall()
 9.954 MPI_Reduce()
  8.04 FLUX_PERFGAS::VISRHS_TET [{flux_perfgas.f90} {3023,14}]
 7.319 TURB_SPALART::SA_RESID [{turb_spalart.f90} {219,14}]
  3.78 FLUX_TURB::TURBULENT_GRADIENTS [{flux_turb.f90} {796,3}-{899,36}]
 3.562 TIMESTEP::DELTAT2 [{timestep.f90} {20,3}-{331,24}]
 3.384 POINT_SOLVER::POINT_SOLVE_1 [{point_solver.F90} {1083,3}-{1206,30}]
 1.309 TURB_SPALART::EDGE_ASSEMBLY_RES_CONV_DIFF [{turb_spalart.f90} {5048,14}]
 1.086 MPI_Bcast()
 0.977 TURB_SPALART::EDGE_ASSEMBLY_JAC_CONV_DIFF [{turb_spalart.f90} {5209,14}]
 0.668 PPARTY_MIXED_ELEMENT::EDGE_POINTER_DRIVER [{pparty_mixed_element.f90} {74,3}-{502,36}]
  0.66 UPDATE_MEAN::UPDATE_Q [{update_mean.F90} {723,3}-{803,25}]
 0.637 POINT_LU_DDQ::LU_5 [{point_lu_ddq.f90} {1566,3}-{1636,21}]
 0.624 SOLUTION::WREST_INTERLEAF [{solution.F90} {3214,14}]
 0.586 DUAL_NUMBERING::FMATRIX_TO_GRID [{dual_numbering.f90} {122,3}-{143,32}]
 0.565 GRID_METRICS::DUALMETRIC [{grid_metrics.f90} {2289,3}-{2791,27}]
 0.524 TURB_SPALART::SA_JACOB [{turb_spalart.f90} {757,14}]
  0.49 MPI_Barrier()
 0.479 UPDATE_TURB::UPDATE_VALUES_TURB [{update_turb.f90} {854,3}-{877,35}]
  0.41 DUAL_NUMBERING::FGRID_TO_MATRIX [{dual_numbering.f90} {94,3}-{115,32}]
 0.371 LMPI_APP::SINGLE_START_MATRIX_XFER [{lmpi_app.F90} {7907,3}-{8132,41}]
  0.36 TURB_SPALART::JACOBIAN_SA [{turb_spalart.f90} {88,14}]
 0.352 TIMEACC::TIME_DIAG_NC [{timeacc.f90} {1067,3}-{1330,29}]
 0.336 MPI_Init()
 0.285 LMPI_APP::SINGLE_MATRIX_COMPLETE_XFER [{lmpi_app.F90} {11520,3}-{11626,44}]
 0.283 PPARTY_METIS::MY_METIS [{pparty_metis.F90} {116,3}-{545,24}]
 0.275 PPARTY::NODE_CELL_CHOPPER [{pparty.f90} {41,3}-{453,33}]
 0.269 FLUX_UTIL::L2NORM [{flux_util.f90} {31,3}-{249,23}]
```

Tracing



TimeLine : Helmsolve_Trace.slog2 <Identity Map>

Lowest / Max. Depth	Zoom Level	Global Min Time	View Init Time	Zoom Focus Time	View Final Time	Global Max Time	Time Per Pixel	Row Count
0 / 12	14	0.00	31.6712742385	31.6739037714	31.6803407627	135.690379	0.0000132552	17.0

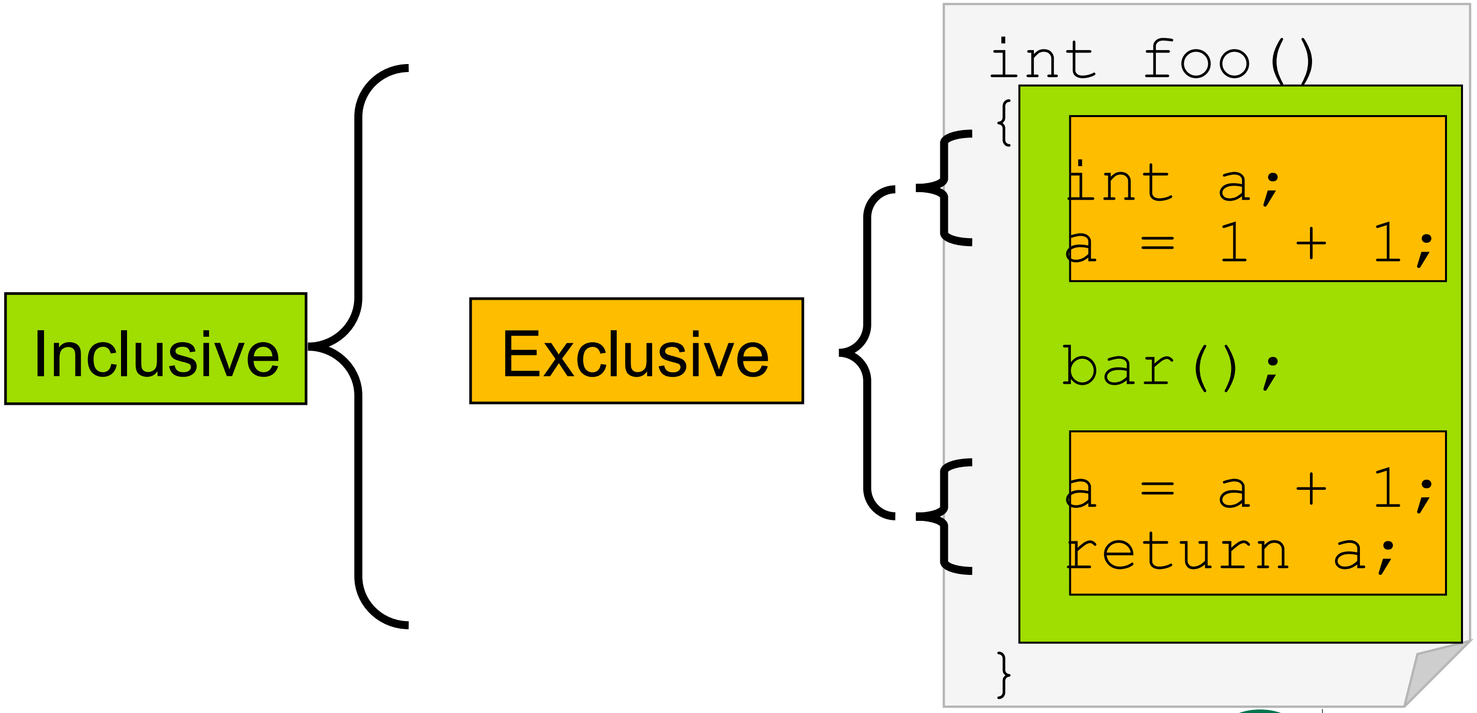
- Profiling and tracing

  Profiling shows you **how much** (total) time was spent in each routine

  Tracing shows you **when** the events take place on a timeline

Inclusive vs. Exclusive values

- **Inclusive**
  - Information of all sub-elements aggregated into single value
- **Exclusive**
  - Information cannot be subdivided further

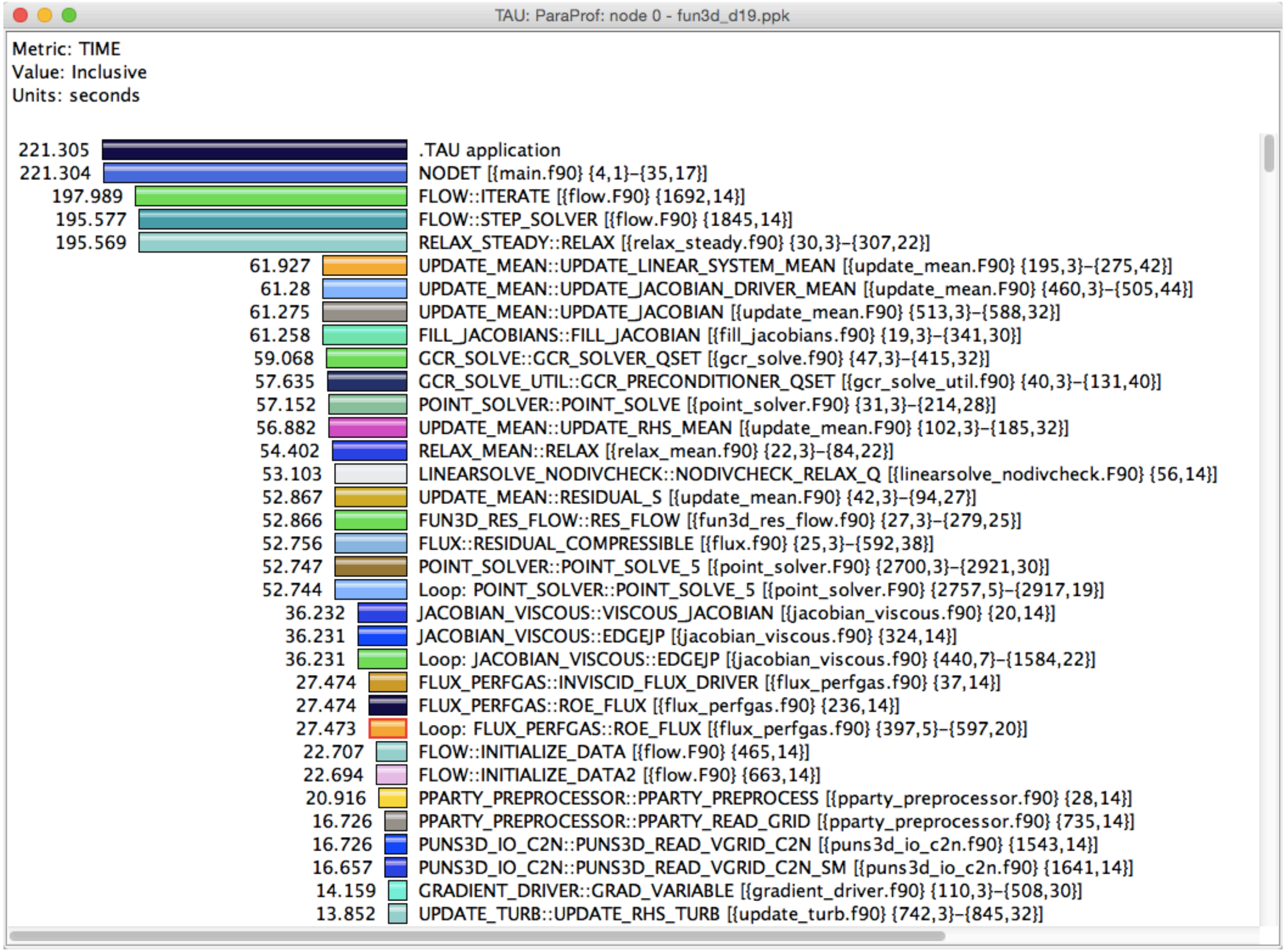


Inclusive

Exclusive

```
int foo()
{
  int a;
  a = 1 + 1;

  bar();

  a = a + 1;
  return a;
}
```

Inclusive Measurements



TAU: ParaProf: node 0 - fun3d_d19.ppk

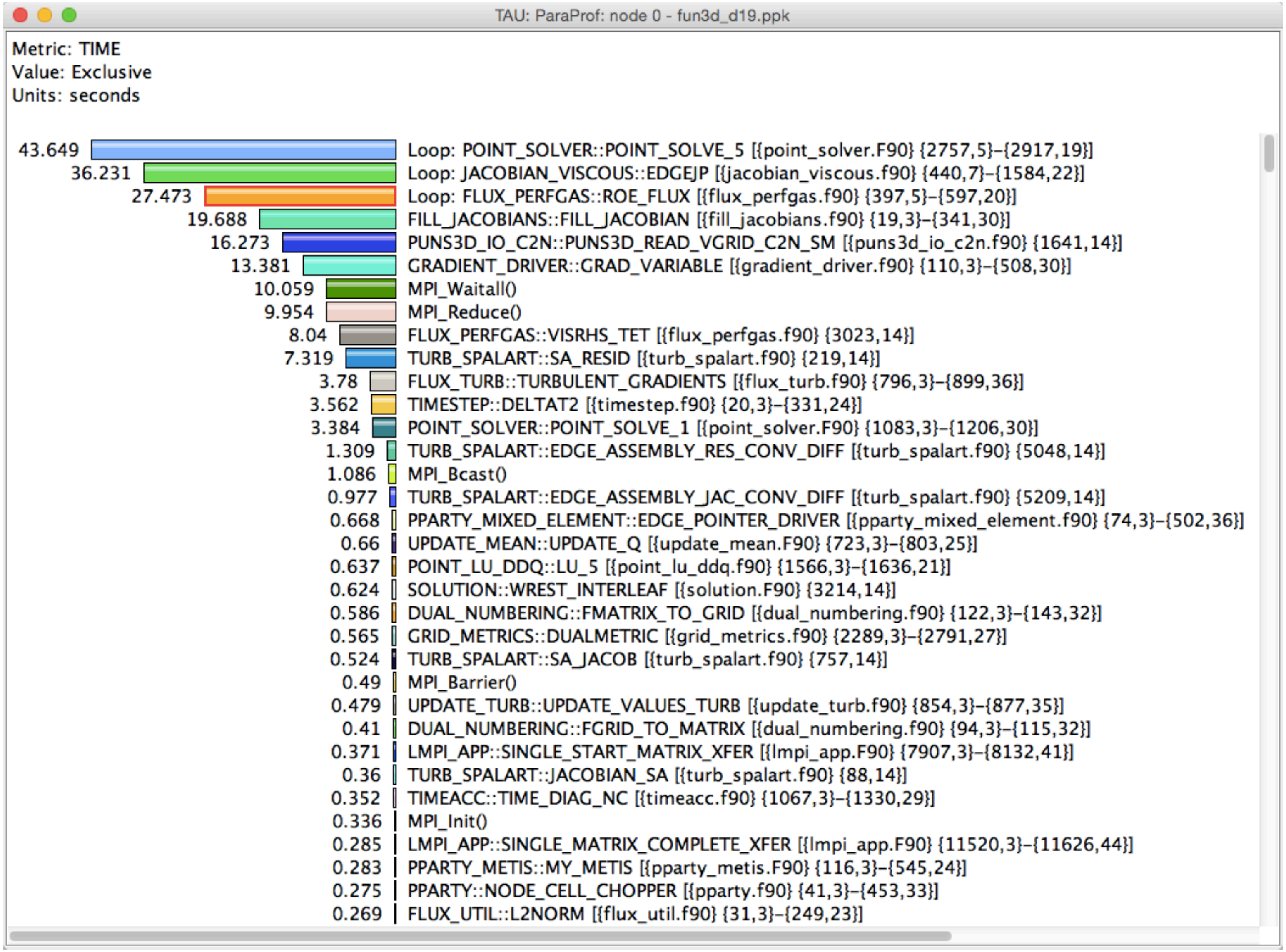
```
Metric: TIME
Value: Inclusive
Units: seconds

221.305  .TAU application
221.304  NODET [{main.f90} {4,1}-{35,17}]
197.989  FLOW::ITERATE [{flow.F90} {1692,14}]
195.577  FLOW::STEP_SOLVER [{flow.F90} {1845,14}]
195.569  RELAX_STEADY::RELAX [{relax_steady.f90} {30,3}-{307,22}]
 61.927  UPDATE_MEAN::UPDATE_LINEAR_SYSTEM_MEAN [{update_mean.F90} {195,3}-{275,42}]
 61.28   UPDATE_MEAN::UPDATE_JACOBIAN_DRIVER_MEAN [{update_mean.F90} {460,3}-{505,44}]
 61.275  UPDATE_MEAN::UPDATE_JACOBIAN [{update_mean.F90} {513,3}-{588,32}]
 61.258  FILL_JACOBIANS::FILL_JACOBIAN [{fill_jacobians.f90} {19,3}-{341,30}]
 59.068  GCR_SOLVE::GCR_SOLVER_QSET [{gcr_solve.f90} {47,3}-{415,32}]
 57.635  GCR_SOLVE_UTIL::GCR_PRECONDITIONER_QSET [{gcr_solve_util.f90} {40,3}-{131,40}]
 57.152  POINT_SOLVER::POINT_SOLVE [{point_solver.F90} {31,3}-{214,28}]
 56.882  UPDATE_MEAN::UPDATE_RHS_MEAN [{update_mean.F90} {102,3}-{185,32}]
 54.402  RELAX_MEAN::RELAX [{relax_mean.f90} {22,3}-{84,22}]
 53.103  LINEARSOLVE_NODIVCHECK::NODIVCHECK_RELAX_Q [{linearsolve_nodivcheck.F90} {56,14}]
 52.867  UPDATE_MEAN::RESIDUAL_S [{update_mean.F90} {42,3}-{94,27}]
 52.866  FUN3D_RES_FLOW::RES_FLOW [{fun3d_res_flow.f90} {27,3}-{279,25}]
 52.756  FLUX::RESIDUAL_COMPRESSIBLE [{flux.f90} {25,3}-{592,38}]
 52.747  POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2700,3}-{2921,30}]
 52.744  Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]
 36.232  JACOBIAN_VISCOUS::VISCOUS_JACOBIAN [{jacobian_viscous.f90} {20,14}]
 36.231  JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {324,14}]
 36.231  Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]
 27.474  FLUX_PERFGAS::INVISCID_FLUX_DRIVER [{flux_perfgas.f90} {37,14}]
 27.474  FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {236,14}]
 27.473  Loop: FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {397,5}-{597,20}]
 22.707  FLOW::INITIALIZE_DATA [{flow.F90} {465,14}]
 22.694  FLOW::INITIALIZE_DATA2 [{flow.F90} {663,14}]
 20.916  PPARTY_PREPROCESSOR::PPARTY_PREPROCESS [{pparty_preprocessor.f90} {28,14}]
 16.726  PPARTY_PREPROCESSOR::PPARTY_READ_GRID [{pparty_preprocessor.f90} {735,14}]
 16.726  PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N [{puns3d_io_c2n.f90} {1543,14}]
 16.657  PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N_SM [{puns3d_io_c2n.f90} {1641,14}]
 14.159  GRADIENT_DRIVER::GRAD_VARIABLE [{gradient_driver.f90} {110,3}-{508,30}]
 13.852  UPDATE_TURB::UPDATE_RHS_TURB [{update_turb.f90} {742,3}-{845,32}]
```

ParaTools

http://tau.uoregon.edu/tau_llnl19.pdf

UNIVERSITY OF OREGON

Exclusive Time



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19.688	FILL_JACOBIANS::FILL_JACOBIAN [{fill_jacobians.f90} {19,3}-{341,30}]
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13.381	GRADIENT_DRIVER::GRAD_VARIABLE [{gradient_driver.f90} {110,3}-{508,30}]
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7.319	TURB_SPALART::SA_RESID [{turb_spalart.f90} {219,14}]
3.78	FLUX_TURB::TURBULENT_GRADIENTS [{flux_turb.f90} {796,3}-{899,36}]
3.562	TIMESTEP::DELTAT2 [{timestep.f90} {20,3}-{331,24}]
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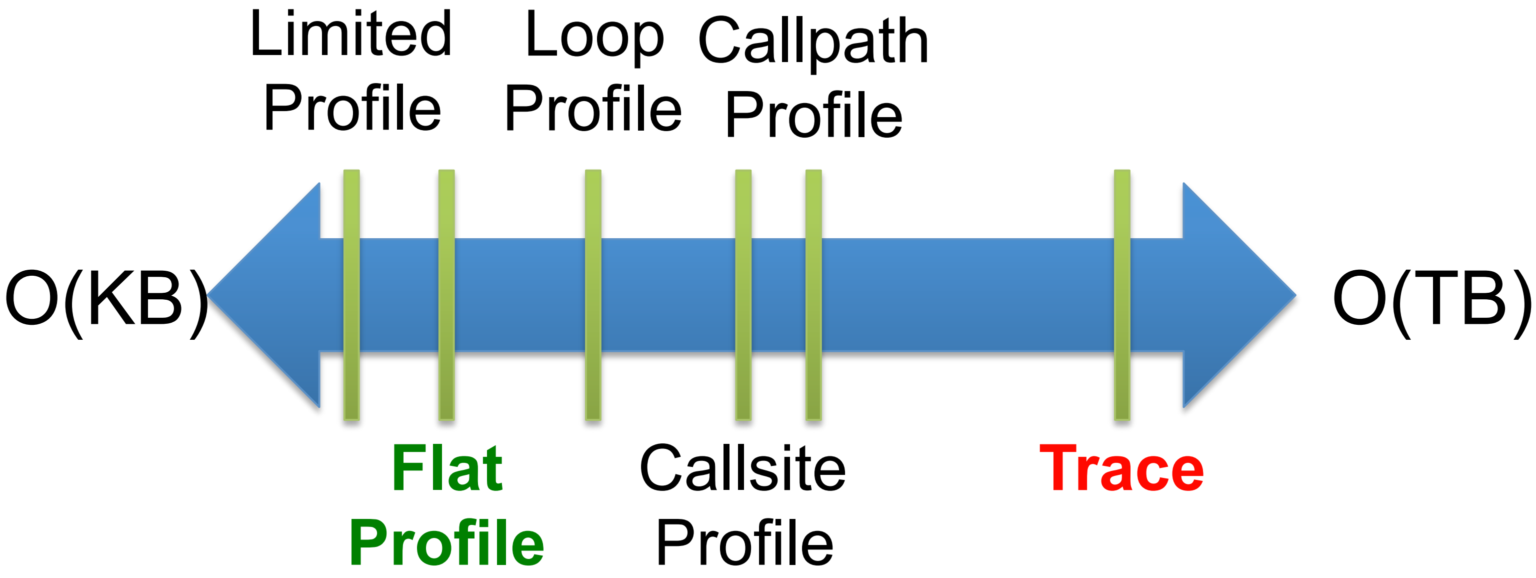
0.977	TURB_SPALART::EDGE_ASSEMBLY_JAC_CONV_DIFF [{turb_spalart.f90} {5209,14}]
0.668	PPARTY_MIXED_ELEMENT::EDGE_POINTER_DRIVER [{pparty_mixed_element.f90} {74,3}-{502,36}]
0.66	UPDATE_MEAN::UPDATE_Q [{update_mean.F90} {723,3}-{803,25}]
0.637	POINT_LU_DDQ::LU_5 [{point_lu_ddq.f90} {1566,3}-{1636,21}]
0.624	SOLUTION::WREST_INTERLEAF [{solution.F90} {3214,14}]
0.586	DUAL_NUMBERING::FMATRIX_TO_GRID [{dual_numbering.f90} {122,3}-{143,32}]
0.565	GRID_METRICS::DUALMETRIC [{grid_metrics.f90} {2289,3}-{2791,27}]
0.524	TURB_SPALART::SA_JACOB [{turb_spalart.f90} {757,14}]
0.49	MPI_Barrier()
0.479	UPDATE_TURB::UPDATE_VALUES_TURB [{update_turb.f90} {854,3}-{877,35}]
0.41	DUAL_NUMBERING::FGRID_TO_MATRIX [{dual_numbering.f90} {94,3}-{115,32}]
0.371	LMPI_APP::SINGLE_START_MATRIX_XFER [{lmpi_app.F90} {7907,3}-{8132,41}]
0.36	TURB_SPALART::JACOBIAN_SA [{turb_spalart.f90} {88,14}]
0.352	TIMEACC::TIME_DIAG_NC [{timeacc.f90} {1067,3}-{1330,29}]
0.336	MPI_Init()
0.285	LMPI_APP::SINGLE_MATRIX_COMPLETE_XFER [{lmpi_app.F90} {11520,3}-{11626,44}]
0.283	PPARTY_METIS::MY_METIS [{pparty_metis.F90} {116,3}-{545,24}]
0.275	PPARTY::NODE_CELL_CHOPPER [{pparty.f90} {41,3}-{453,33}]
0.269	FLUX_UTIL::L2NORM [{flux_util.f90} {31,3}-{249,23}]

How much data do you want?



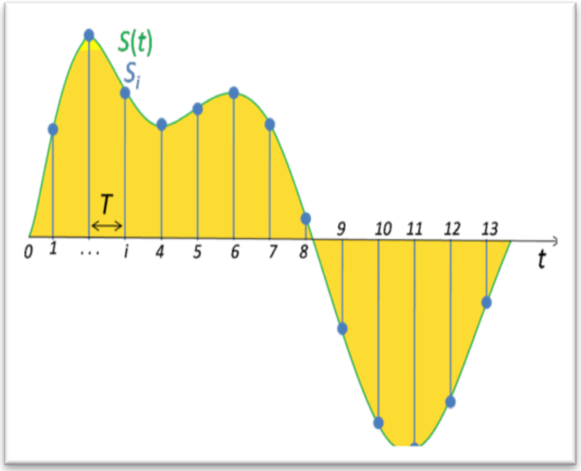
Performance Data Measurement

Direct via Probes

```
Call
START(‘potential’)
// code
Call
STOP(‘potential’)
```

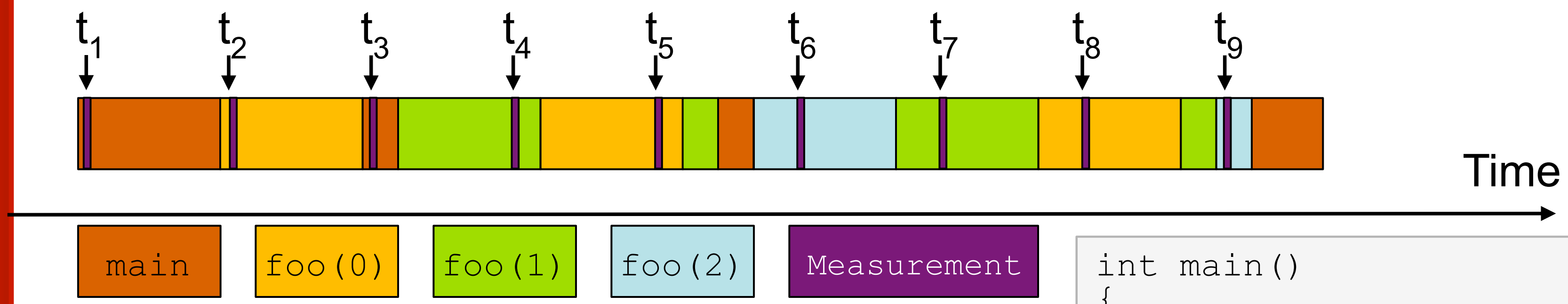
- Exact measurement
- Fine-grain control
- Calls inserted into code

Indirect via Sampling



- No code modification
- Minimal effort
- Relies on debug symbols (**-g**)

Sampling



```
int main()
{
  int i;

  for (i=0; i < 3; i++)
    foo(i);

  return 0;
}

void foo(int i)
{

  if (i > 0)
    foo(i - 1);

}
```

Running program is periodically interrupted to take measurement

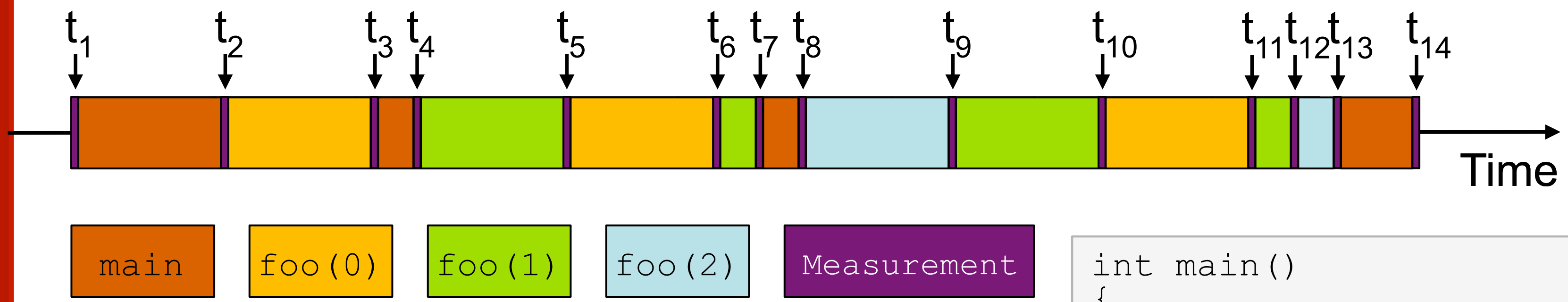
- Timer interrupt, OS signal, or HWC overflow
- Service routine examines return-address stack
- Addresses are mapped to routines using symbol table information

Statistical inference of program behavior

- Not very detailed information on highly volatile metrics
- Requires long-running applications

Works with unmodified executables

Instrumentation



Measurement code is inserted such that every event of interest is captured directly

- Can be done in various ways

Advantage:

- Much more detailed information

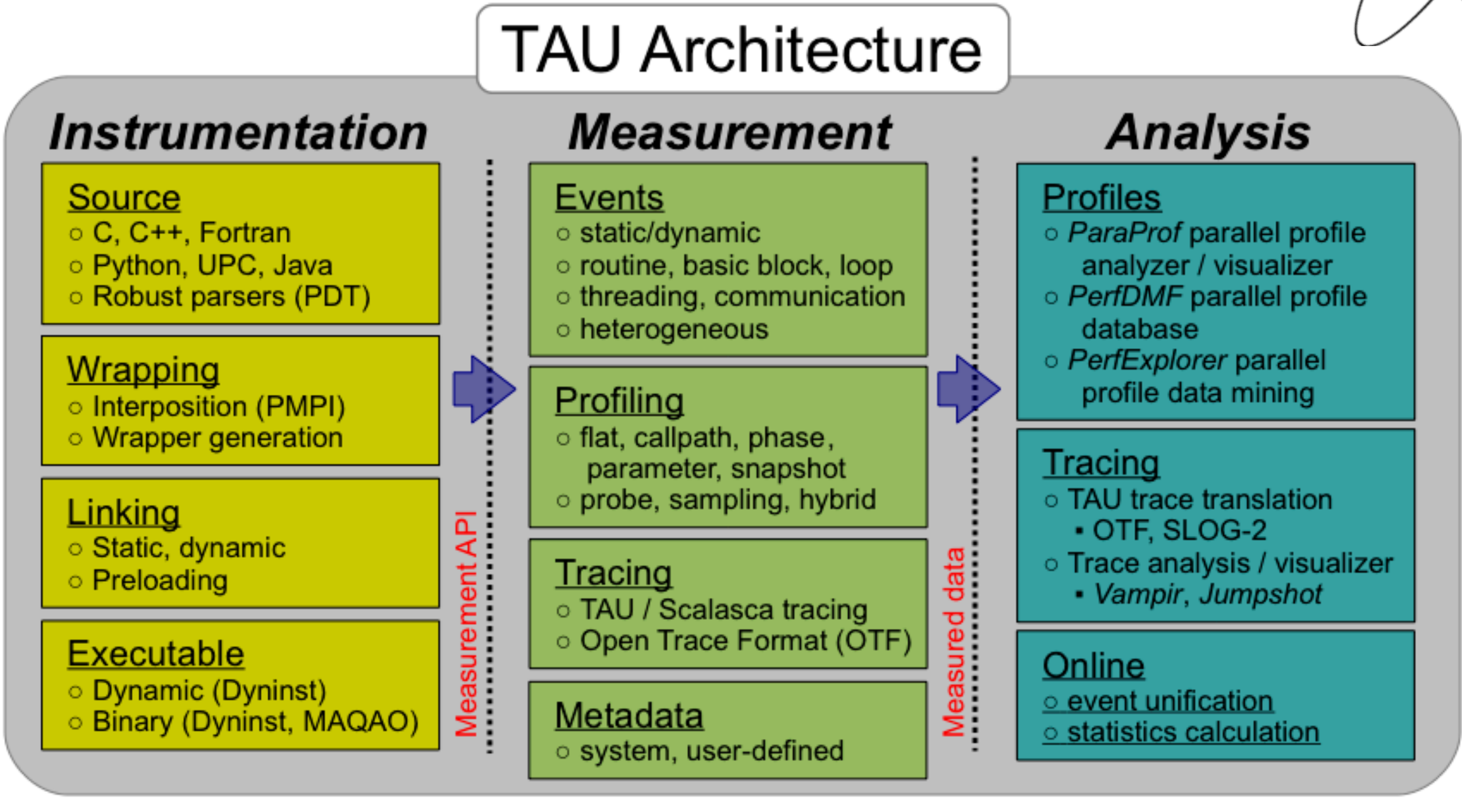
Disadvantage:

- Processing of source-code / executable necessary
- Large relative overheads for small functions

```
int main()
{
  int i;
  Start("main");
  for (i=0; i < 3; i++)
    foo(i);
  Stop("main");
  return 0;
}

void foo(int i)
{
  Start("foo");
  if (i > 0)
    foo(i - 1);
  Stop("foo");
}
```

TAU Architecture and Workflow



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’s Support for Runtime Systems

MPI

- PMPI profiling interface
- MPI_T tools interface using performance and control variables

Pthread

- Captures time spent in routines per thread of execution

OpenMP

- OMPT tools interface to track salient OpenMP runtime events
- Opari source rewriter
- Preloading wrapper OpenMP runtime library when OMPT is not supported

OpenACC

- OpenACC instrumentation API
- Track data transfers between host and device (per-variable)
- Track time spent in kernels

TAU's Support for Runtime Systems (contd.)

OpenCL

- OpenCL profiling interface
- Track timings of kernels

CUDA

- Cuda Profiling Tools Interface (CUPTI)
- Track data transfers between host and GPU
- Track access to uniform shared memory between host and GPU

ROCm

- Rocprofiler and Roctracer instrumentation interfaces
- Track data transfers and kernel execution between host and GPU

Kokkos

- Kokkos profiling API
- Push/pop interface for region, kernel execution interface

Python

- Python interpreter instrumentation API
- Tracks Python routine transitions as well as Python to C transitions

Examples of Multi-Level Instrumentation

MPI + OpenMP

- MPI_T + PMPI + OMPT may be used to track MPI and OpenMP

MPI + CUDA

- PMPI + CUPTI interfaces

OpenCL + ROCm

- Rocprofiler + OpenCL instrumentation interfaces

Kokkos + OpenMP

- Kokkos profiling API + OMPT to transparently track events

Kokkos + pthread + MPI

- Kokkos + pthread wrapper interposition library + PMPI layer

Python + CUDA

- Python + CUPTI + pthread profiling interfaces (e.g., Tensorflow, PyTorch)

MPI + OpenCL

- PMPI + OpenCL profiling interfaces

Simplifying the use of TAU!

Uninstrumented code:

- % make
- % mpirun −np 64 ./a.out

With TAU using event based sampling (EBS):

- % mpirun −np 64 tau_exec −ebs ./lu.B.64
- % paraprof (GUI)
- % pprof −a | more

NOTE:

- Requires dynamic executables (-dynamic link flag on Cray XC systems).
- Source code should be compiled with −g for access to symbol table.
- Replace mpirun with srun on Quartz, LLNL or your appropriate launch command.

TAU Execution Command (tau_exec)

Uninstrumented execution

- % mpirun -np 256 ./a.out

Track GPU operations

- % mpirun –np 256 tau_exec –rocm ./a.out
- % mpirun –np 256 tau_exec –cupti ./a.out
- % mpirun –np 256 tau_exec –cupti -um ./a.out (for Unified Memory)
- % mpirun –np 256 tau_exec –opencl ./a.out
- % mpirun –np 256 tau_exec –openacc ./a.out

Track MPI performance

- % mpirun -np 256   tau_exec ./a.out

Track I/O, and MPI performance (MPI enabled by default)

- % mpirun -np 256 tau_exec -io ./a.out

Track OpenMP and MPI execution (using OMPT for Intel v19)

- % export TAU_OMPT_SUPPORT_LEVEL=full;
  % export TAU_OMPT_RESOLVE_ADDRESS_EAGERLY=1
- % mpirun −np 256 tau_exec −T ompt,v5,mpi -ompt ./a.out

Track memory operations

- % export TAU_TRACK_MEMORY_LEAKS=1
- % mpirun –np 256 tau_exec –memory_debug ./a.out (bounds check)

Use event based sampling (compile with –g)

- % mpirun –np 256 tau_exec –ebs ./a.out
- Also -ebs_source=<PAPI_COUNTER> -ebs_period=<overflow_count>
  -ebs_resolution=<file | function | line>

Types of Performance Profiles

Flat **profiles**

- Metric (e.g., time) spent in an event
- Exclusive/inclusive, # of calls, child calls, …

Callpath **profiles**

- Time spent along a calling path (edges in callgraph)
- *"main=> f1 => f2 => MPI_Send"*
- Set the TAU_CALLPATH and TAU_CALLPATH_DEPTH environment variables

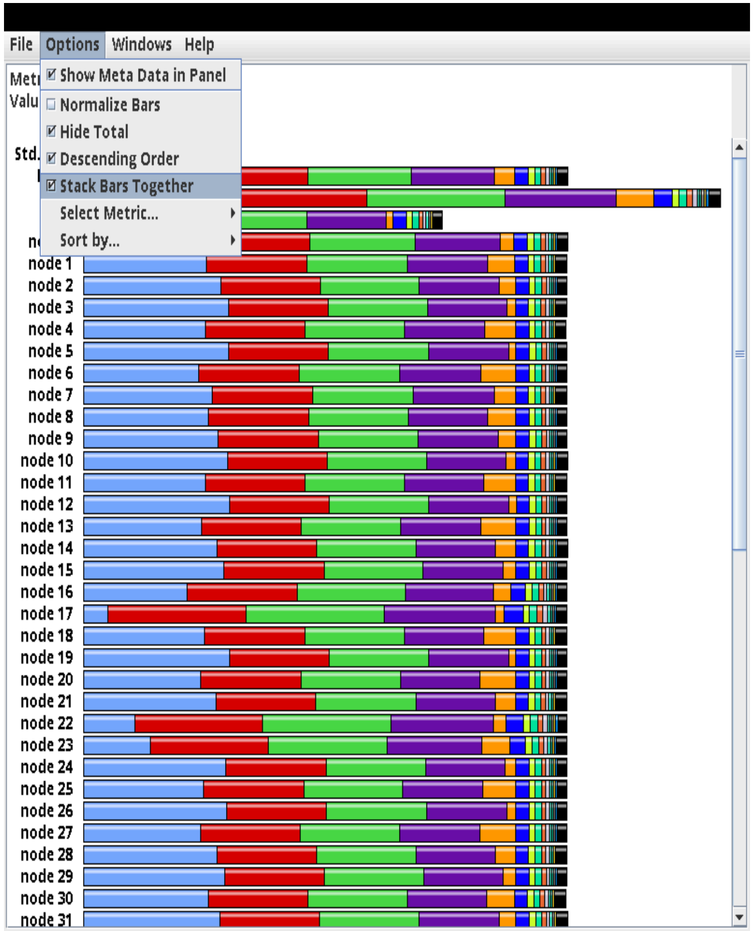
Callsite **profiles**

- Time spent along in an event at a given source location
- Set the TAU_CALLSITE environment variable

Phase **profiles**

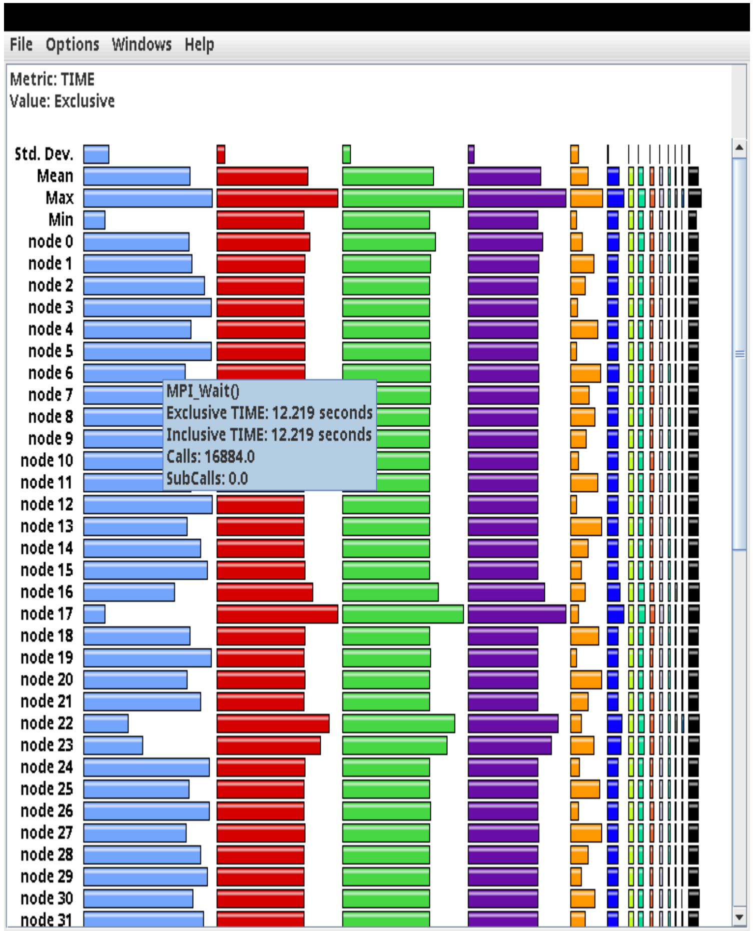
- Flat profiles under a phase (nested phases allowed)
- Default "main" phase
- Supports static or dynamic (e.g. per-iteration) phases

ParaProf Profile Browser



File Options Windows Help

☑ Show Meta Data in Panel
□ Normalize Bars
☑ Hide Total
☑ Descending Order
☑ Stack Bars Together
Select Metric...
Sort by...



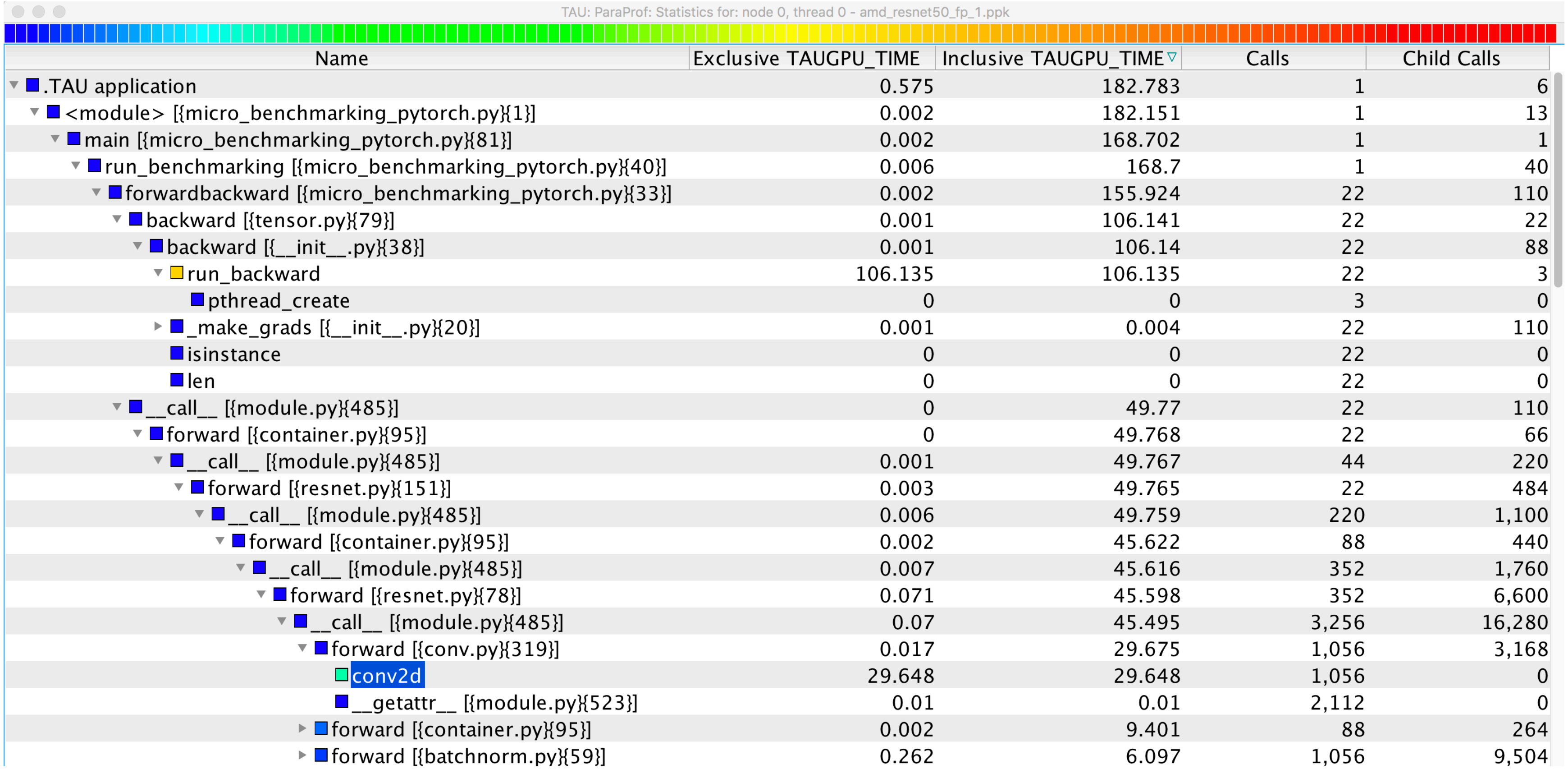
File Options Windows Help

Metric: TIME
Value: Exclusive

MPI_Wait()
Exclusive TIME: 12.219 seconds
Inclusive TIME: 12.219 seconds
Calls: 16884.0
SubCalls: 0.0

Click “node X” next to see details

Python Instrumentation



TAU: ParaProf: Statistics for: node 0, thread 0 - amd_resnet50_fp_1.ppk

Name	Exclusive TAUGPU_TIME	Inclusive TAUGPU_TIME ▽	Calls	Child Calls
.TAU application	0.575	182.783	1	6
<module> [{micro_benchmarking_pytorch.py}{1}]	0.002	182.151	1	13
main [{micro_benchmarking_pytorch.py}{81}]	0.002	168.702	1	1
run_benchmarking [{micro_benchmarking_pytorch.py}{40}]	0.006	168.7	1	40
forwardbackward [{micro_benchmarking_pytorch.py}{33}]	0.002	155.924	22	110
backward [{tensor.py}{79}]	0.001	106.141	22	22
backward [{__init__.py}{38}]	0.001	106.14	22	88
run_backward	106.135	106.135	22	3
pthread_create	0	0	3	0
_make_grads [{__init__.py}{20}]	0.001	0.004	22	110
isinstance	0	0	22	0
len	0	0	22	0
__call__ [{module.py}{485}]	0	49.77	22	110
forward [{container.py}{95}]	0	49.768	22	66
__call__ [{module.py}{485}]	0.001	49.767	44	220
forward [{resnet.py}{151}]	0.003	49.765	22	484
__call__ [{module.py}{485}]	0.006	49.759	220	1,100
forward [{container.py}{95}]	0.002	45.622	88	440
__call__ [{module.py}{485}]	0.007	45.616	352	1,760
forward [{resnet.py}{78}]	0.071	45.598	352	6,600
__call__ [{module.py}{485}]	0.07	45.495	3,256	16,280
forward [{conv.py}{319}]	0.017	29.675	1,056	3,168
conv2d	29.648	29.648	1,056	0
__getattr__ [{module.py}{523}]	0.01	0.01	2,112	0
forward [{container.py}{95}]	0.002	9.401	88	264
forward [{batchnorm.py}{59}]	0.262	6.097	1,056	9,504

```
% tau_python ./foo.py
```

ParaTools

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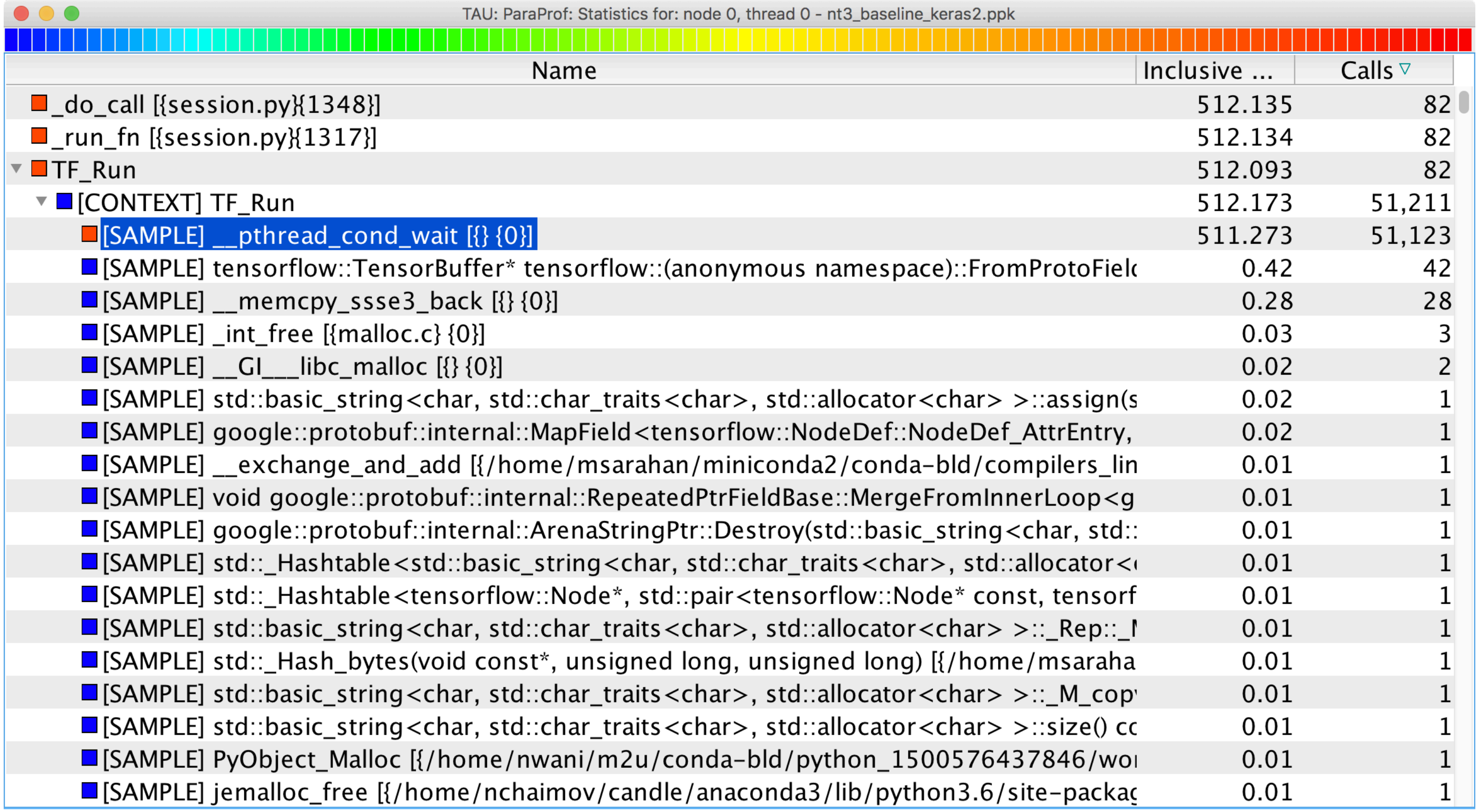
Identifying Wait States Using EBS

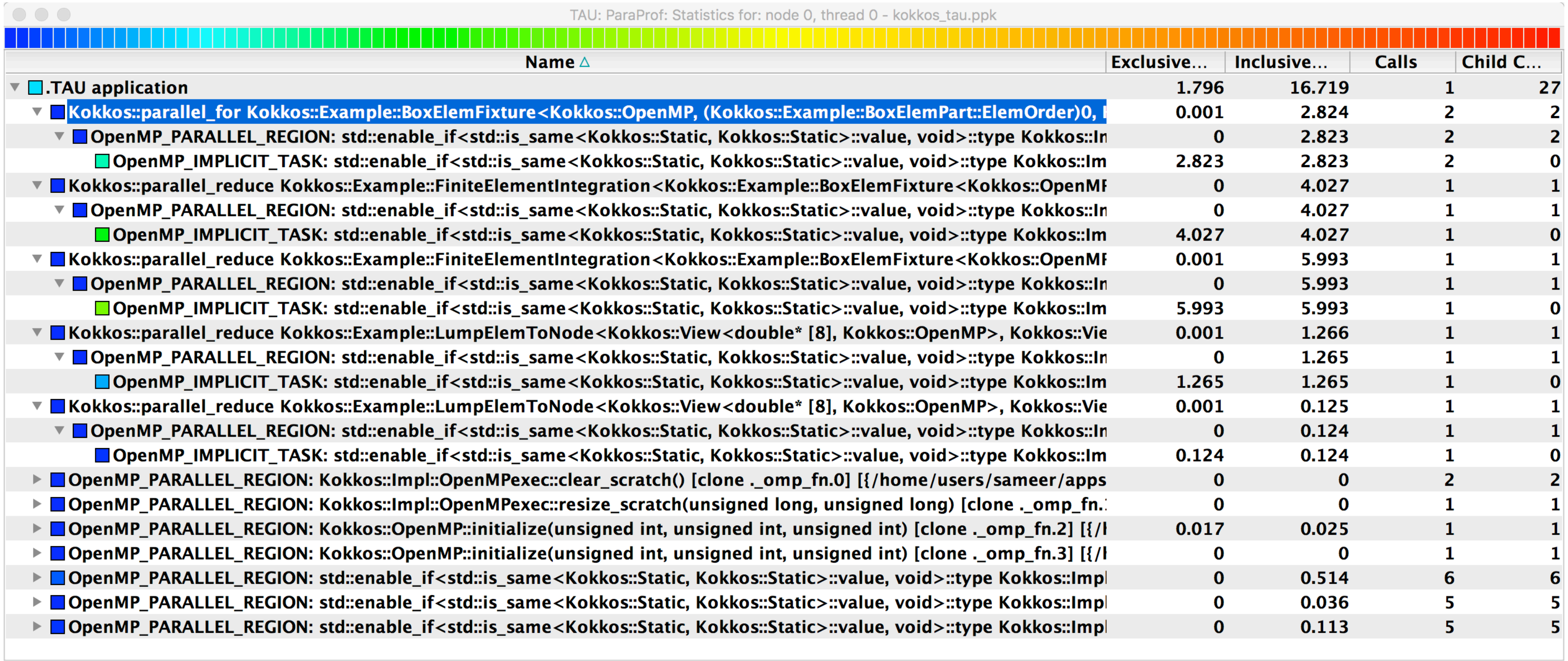


TAU: ParaProf: Statistics for: node 0, thread 0 - nt3_baseline_keras2.ppk

Name	Inclusive ...	Calls ▽
🟧 _do_call [{session.py}{1348}]	512.135	82
🟧 _run_fn [{session.py}{1317}]	512.134	82
▼ 🟧 TF_Run	512.093	82
▼ 🟦 [CONTEXT] TF_Run	512.173	51,211
🟧 [SAMPLE] __pthread_cond_wait [{} {0}]	511.273	51,123
🟦 [SAMPLE] tensorflow::TensorBuffer* tensorflow::(anonymous namespace)::FromProtoFiel	0.42	42
🟦 [SAMPLE] __memcpy_ssse3_back [{} {0}]	0.28	28
🟦 [SAMPLE] _int_free [{malloc.c} {0}]	0.03	3
🟦 [SAMPLE] __GI___libc_malloc [{} {0}]	0.02	2
🟦 [SAMPLE] std::basic_string<char, std::char_traits<char>, std::allocator<char> >::assign(s	0.02	1
🟦 [SAMPLE] google::protobuf::internal::MapField<tensorflow::NodeDef::NodeDef_AttrEntry,	0.02	1
🟦 [SAMPLE] __exchange_and_add [{/home/msarahan/miniconda2/conda-bld/compilers_lin	0.01	1
🟦 [SAMPLE] void google::protobuf::internal::RepeatedPtrFieldBase::MergeFromInnerLoop<g	0.01	1
🟦 [SAMPLE] google::protobuf::internal::ArenaStringPtr::Destroy(std::basic_string<char, std::	0.01	1
🟦 [SAMPLE] std::_Hashtable<std::basic_string<char, std::char_traits<char>, std::allocator<	0.01	1
🟦 [SAMPLE] std::_Hashtable<tensorflow::Node*, std::pair<tensorflow::Node* const, tensorf	0.01	1
🟦 [SAMPLE] std::basic_string<char, std::char_traits<char>, std::allocator<char> >::_Rep::_I	0.01	1
🟦 [SAMPLE] std::_Hash_bytes(void const*, unsigned long, unsigned long) [{/home/msaraha	0.01	1
🟦 [SAMPLE] std::basic_string<char, std::char_traits<char>, std::allocator<char> >::_M_cop	0.01	1
🟦 [SAMPLE] std::basic_string<char, std::char_traits<char>, std::allocator<char> >::size() cc	0.01	1
🟦 [SAMPLE] PyObject_Malloc [{/home/nwani/m2u/conda-bld/python_1500576437846/woi	0.01	1
🟦 [SAMPLE] jemalloc_free [{/home/nchaimov/candle/anaconda3/lib/python3.6/site-packag	0.01	1

```
% tau_python -ebs ./foo.py
```

Kokkos and OpenMP Instrumentation

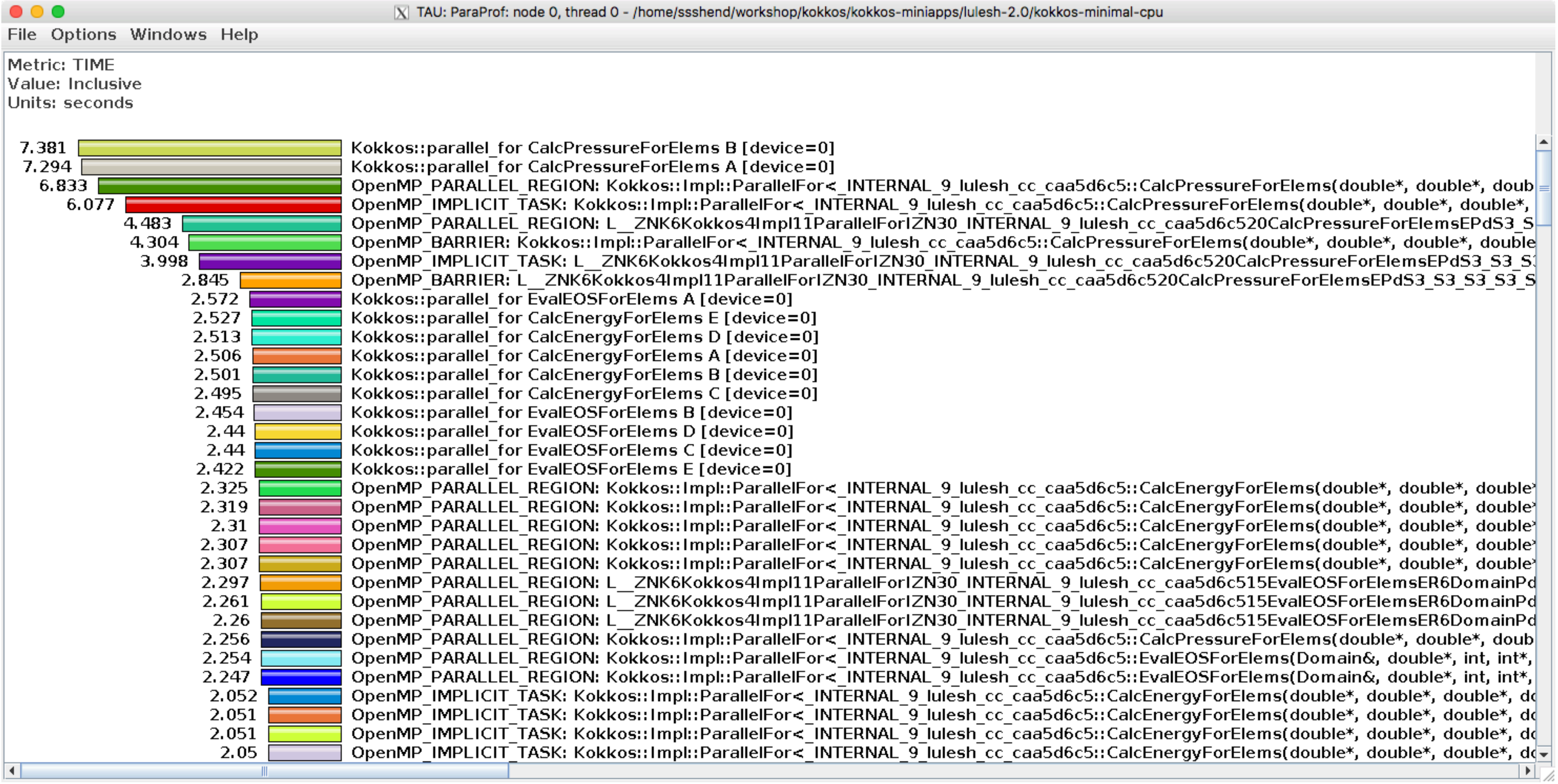


TAU: ParaProf: Statistics for: node 0, thread 0 - kokkos_tau.ppk

Name △	Exclusive...	Inclusive...	Calls	Child C...
▼ .TAU application	1.796	16.719	1	27
▼ Kokkos::parallel_for Kokkos::Example::BoxElemFixture<Kokkos::OpenMP, (Kokkos::Example::BoxElemPart::ElemOrder)0, I	0.001	2.824	2	2
▼ OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::In	0	2.823	2	2
OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Im	2.823	2.823	2	0
▼ Kokkos::parallel_reduce Kokkos::Example::FiniteElementIntegration<Kokkos::Example::BoxElemFixture<Kokkos::OpenMI	0	4.027	1	1
▼ OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::In	0	4.027	1	1
OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Im	4.027	4.027	1	0
▼ Kokkos::parallel_reduce Kokkos::Example::FiniteElementIntegration<Kokkos::Example::BoxElemFixture<Kokkos::OpenMI	0.001	5.993	1	1
▼ OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::In	0	5.993	1	1
OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Im	5.993	5.993	1	0
▼ Kokkos::parallel_reduce Kokkos::Example::LumpElemToNode<Kokkos::View<double* [8], Kokkos::OpenMP>, Kokkos::Vie	0.001	1.266	1	1
▼ OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::In	0	1.265	1	1
OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Im	1.265	1.265	1	0
▼ Kokkos::parallel_reduce Kokkos::Example::LumpElemToNode<Kokkos::View<double* [8], Kokkos::OpenMP>, Kokkos::Vie	0.001	0.125	1	1
▼ OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::In	0	0.124	1	1
OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Im	0.124	0.124	1	0
▶ OpenMP_PARALLEL_REGION: Kokkos::Impl::OpenMPexec::clear_scratch() [clone ._omp_fn.0] [{/home/users/sameer/apps	0	0	2	2
▶ OpenMP_PARALLEL_REGION: Kokkos::Impl::OpenMPexec::resize_scratch(unsigned long, unsigned long) [clone ._omp_fn.	0	0	1	1
▶ OpenMP_PARALLEL_REGION: Kokkos::OpenMP::initialize(unsigned int, unsigned int, unsigned int) [clone ._omp_fn.2] [{/l	0.017	0.025	1	1
▶ OpenMP_PARALLEL_REGION: Kokkos::OpenMP::initialize(unsigned int, unsigned int, unsigned int) [clone ._omp_fn.3] [{/l	0	0	1	1
▶ OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl	0	0.514	6	6
▶ OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl	0	0.036	5	5
▶ OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl	0	0.113	5	5

```
% tau_exec –ompt ./a.out
```

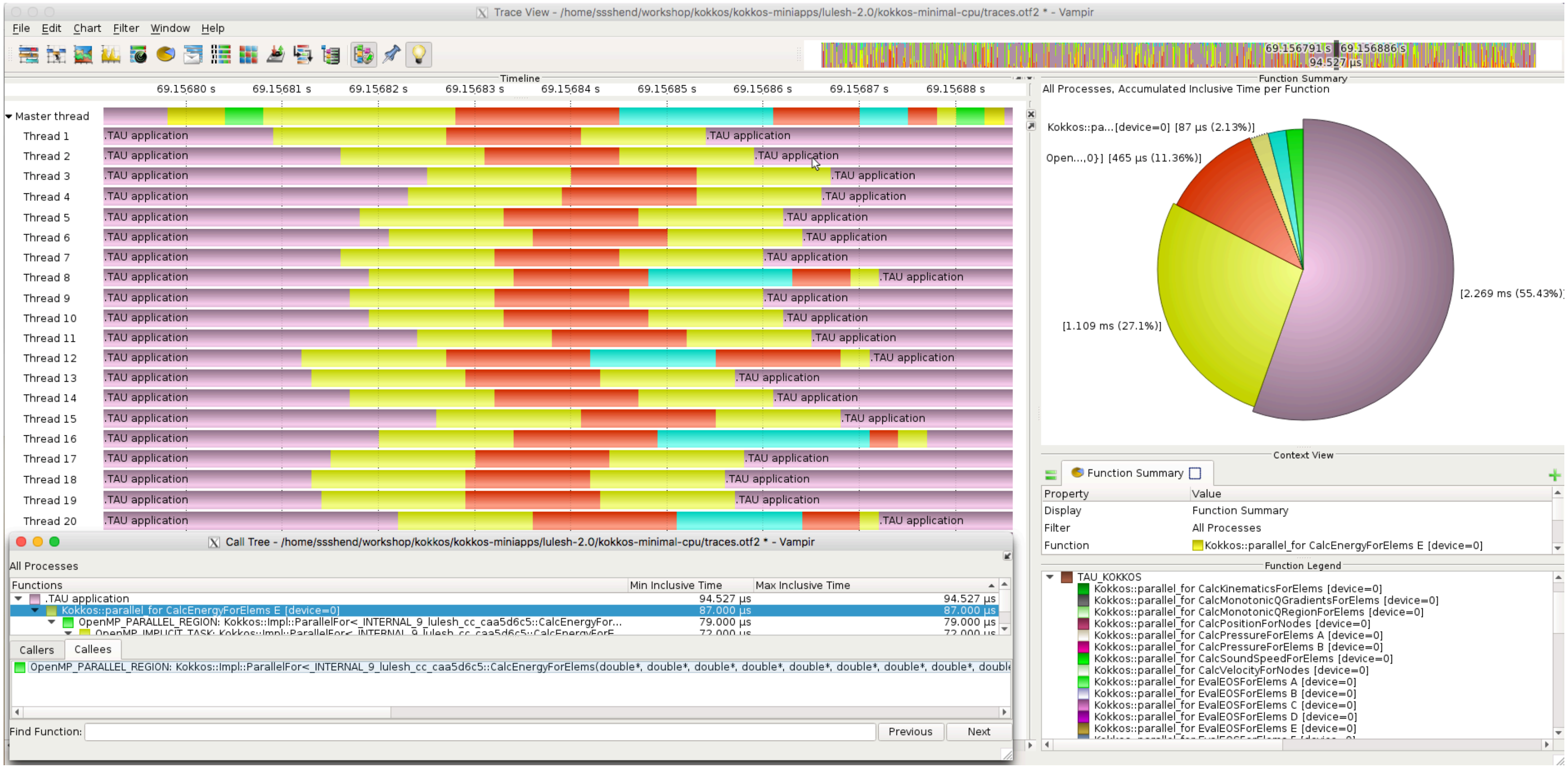
Kokkos Instrumentation with OpenMP



```
TAU: ParaProf: node 0, thread 0 - /home/ssshend/workshop/kokkos/kokkos-miniapps/lulesh-2.0/kokkos-minimal-cpu

Metric: TIME
Value: Inclusive
Units: seconds

7.381  Kokkos::parallel_for CalcPressureForElems B [device=0]
7.294  Kokkos::parallel_for CalcPressureForElems A [device=0]
6.833  OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcPressureForElems(double*, double*, doub
6.077  OpenMP_IMPLICIT_TASK: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcPressureForElems(double*, double*, double*,
4.483  OpenMP_PARALLEL_REGION: L__ZNK6Kokkos4Impl11ParallelForIZN30_INTERNAL_9_lulesh_cc_caa5d6c520CalcPressureForElemsEPdS3_S
4.304  OpenMP_BARRIER: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcPressureForElems(double*, double*, double*, double
3.998  OpenMP_IMPLICIT_TASK: L__ZNK6Kokkos4Impl11ParallelForIZN30_INTERNAL_9_lulesh_cc_caa5d6c520CalcPressureForElemsEPdS3_S3_S
2.845  OpenMP_BARRIER: L__ZNK6Kokkos4Impl11ParallelForIZN30_INTERNAL_9_lulesh_cc_caa5d6c520CalcPressureForElemsEPdS3_S3_S3_S3_S
2.572  Kokkos::parallel_for EvalEOSForElems A [device=0]
2.527  Kokkos::parallel_for CalcEnergyForElems E [device=0]
2.513  Kokkos::parallel_for CalcEnergyForElems D [device=0]
2.506  Kokkos::parallel_for CalcEnergyForElems A [device=0]
2.501  Kokkos::parallel_for CalcEnergyForElems B [device=0]
2.495  Kokkos::parallel_for CalcEnergyForElems C [device=0]
2.454  Kokkos::parallel_for EvalEOSForElems B [device=0]
2.44   Kokkos::parallel_for EvalEOSForElems D [device=0]
2.44   Kokkos::parallel_for EvalEOSForElems C [device=0]
2.422  Kokkos::parallel_for EvalEOSForElems E [device=0]
2.325  OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double
2.319  OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double
2.31   OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double
2.307  OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double
2.307  OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double
2.297  OpenMP_PARALLEL_REGION: L__ZNK6Kokkos4Impl11ParallelForIZN30_INTERNAL_9_lulesh_cc_caa5d6c515EvalEOSForElemsER6DomainPd
2.261  OpenMP_PARALLEL_REGION: L__ZNK6Kokkos4Impl11ParallelForIZN30_INTERNAL_9_lulesh_cc_caa5d6c515EvalEOSForElemsER6DomainPd
2.26   OpenMP_PARALLEL_REGION: L__ZNK6Kokkos4Impl11ParallelForIZN30_INTERNAL_9_lulesh_cc_caa5d6c515EvalEOSForElemsER6DomainPd
2.256  OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcPressureForElems(double*, double*, doub
2.254  OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::EvalEOSForElems(Domain&, double*, int, int*,
2.247  OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::EvalEOSForElems(Domain&, double*, int, int*,
2.052  OpenMP_IMPLICIT_TASK: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double*, dc
2.051  OpenMP_IMPLICIT_TASK: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double*, dc
2.051  OpenMP_IMPLICIT_TASK: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double*, dc
2.05   OpenMP_IMPLICIT_TASK: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double*, dc
```

```
% tau_exec –ompt ./a.out
```

Vampir [TU Dresden] Timeline



Trace View - /home/ssshend/workshop/kokkos/kokkos-miniapps/lulesh-2.0/kokkos-minimal-cpu/traces.otf2 * - Vampir

Call Tree - /home/ssshend/workshop/kokkos/kokkos-miniapps/lulesh-2.0/kokkos-minimal-cpu/traces.otf2 * - Vampir

All Processes

Functions	Min Inclusive Time	Max Inclusive Time
.TAU application	94.527 µs	94.527 µs
Kokkos::parallel_for CalcEnergyForElems E [device=0]	87.000 µs	87.000 µs
OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyFor...	79.000 µs	79.000 µs
OpenMP_IMPLICIT_TASK: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForE...	72.000 µs	72.000 µs

Callers | Callees

OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double*, double*, double*, double*, double*, double*, doubl

Find Function: Previous Next

Context View

Function Summary

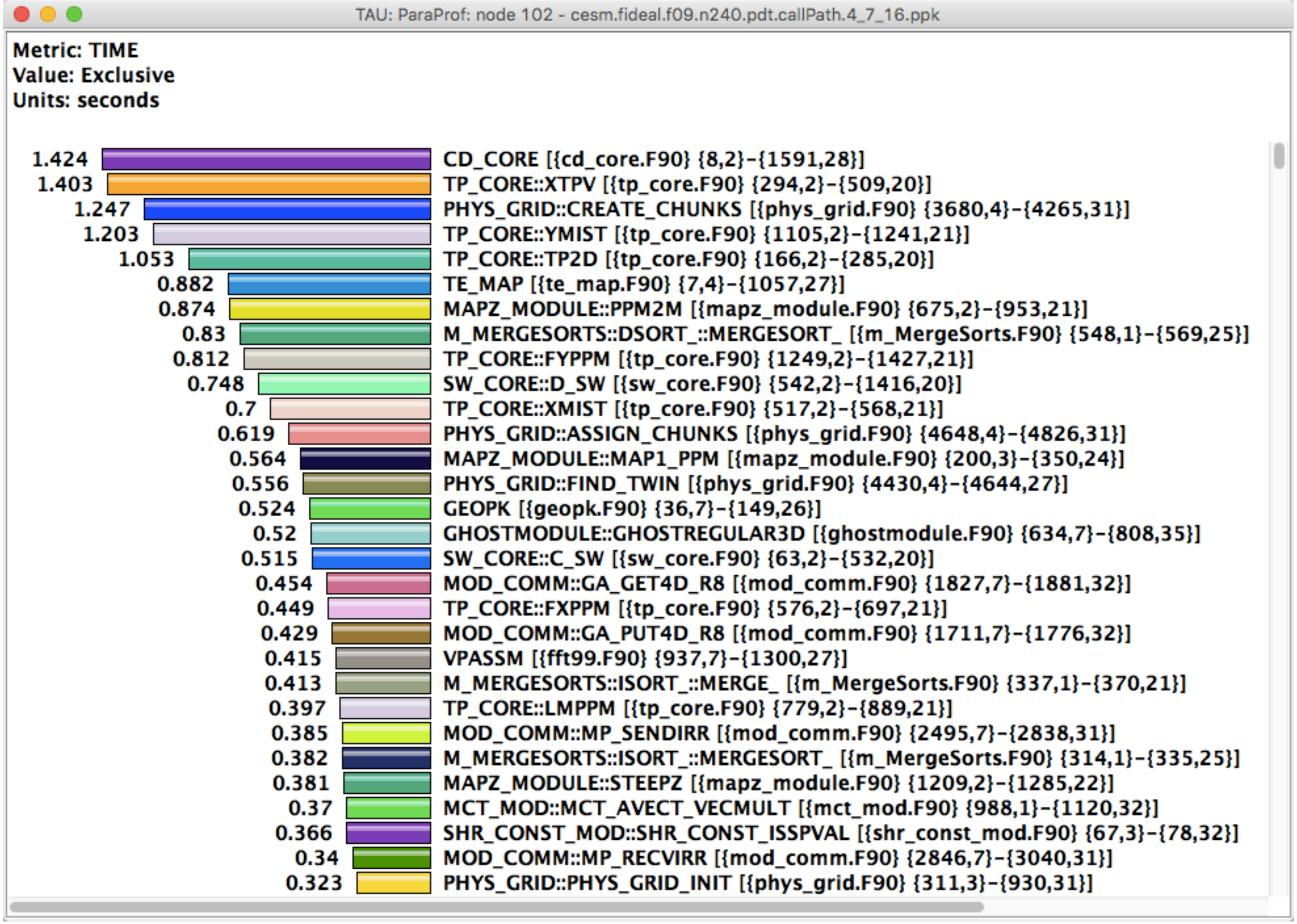
Property	Value
Display	Function Summary
Filter	All Processes
Function	Kokkos::parallel_for CalcEnergyForElems E [device=0]

Function Legend

- TAU_KOKKOS
  - Kokkos::parallel_for CalcKinematicsForElems [device=0]
  - Kokkos::parallel_for CalcMonotonicQGradientsForElems [device=0]
  - Kokkos::parallel_for CalcMonotonicQRegionForElems [device=0]
  - Kokkos::parallel_for CalcPositionForNodes [device=0]
  - Kokkos::parallel_for CalcPressureForElems A [device=0]
  - Kokkos::parallel_for CalcPressureForElems B [device=0]
  - Kokkos::parallel_for CalcSoundSpeedForElems [device=0]
  - Kokkos::parallel_for CalcVelocityForNodes [device=0]
  - Kokkos::parallel_for EvalEOSForElems A [device=0]
  - Kokkos::parallel_for EvalEOSForElems B [device=0]
  - Kokkos::parallel_for EvalEOSForElems C [device=0]
  - Kokkos::parallel_for EvalEOSForElems D [device=0]
  - Kokkos::parallel_for EvalEOSForElems E [device=0]

```
% export TAU_TRACE_FORMAT=otf2
% tau_exec −ompt  ./a.out
% vampir traces.otf2 &
```

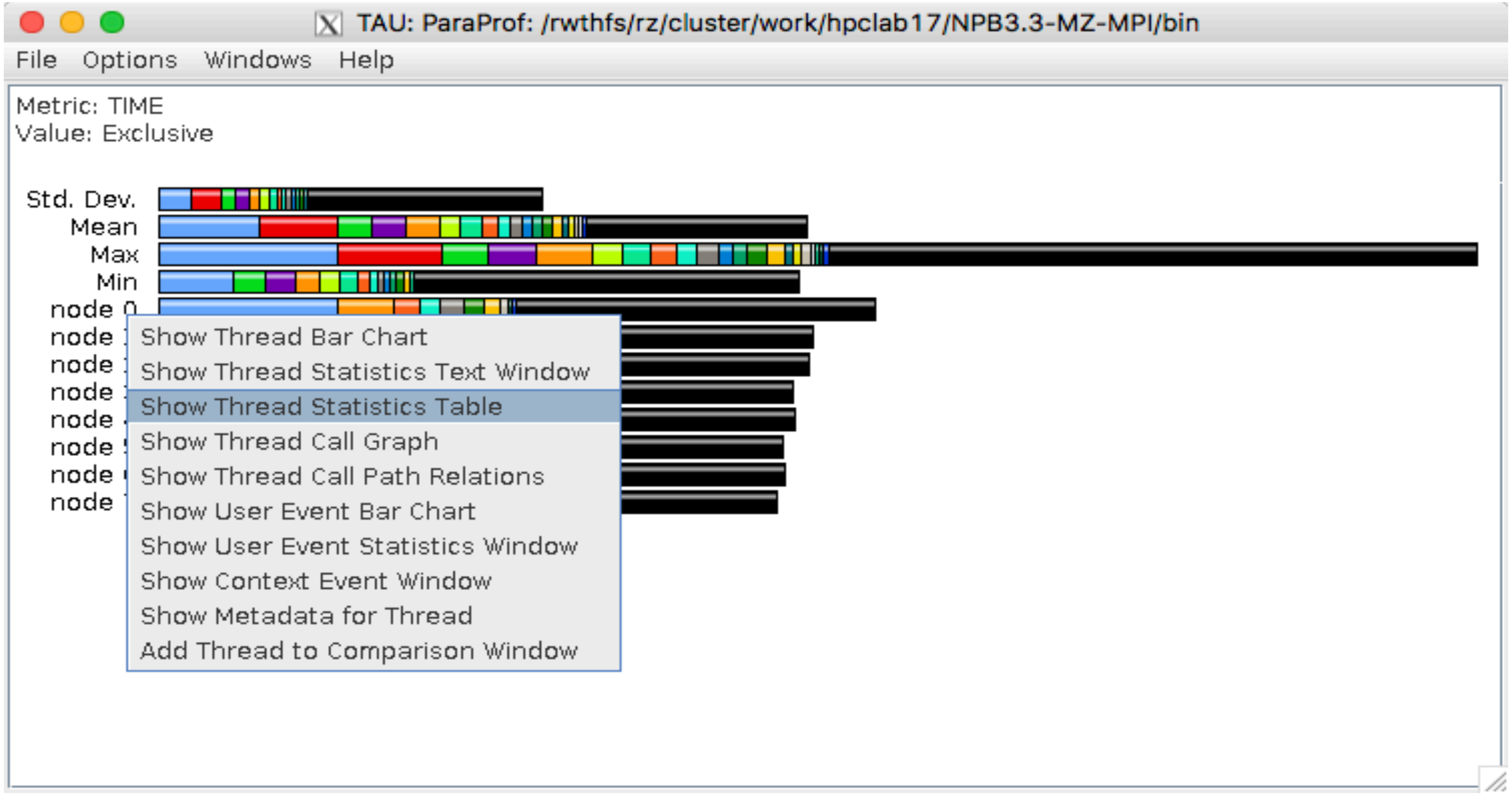
TAU – Flat Profile


TAU: ParaProf: node 102 - cesm.fideal.f09.n240.pdt.callPath.4_7_16.ppk

Metric: TIME
Value: Exclusive
Units: seconds

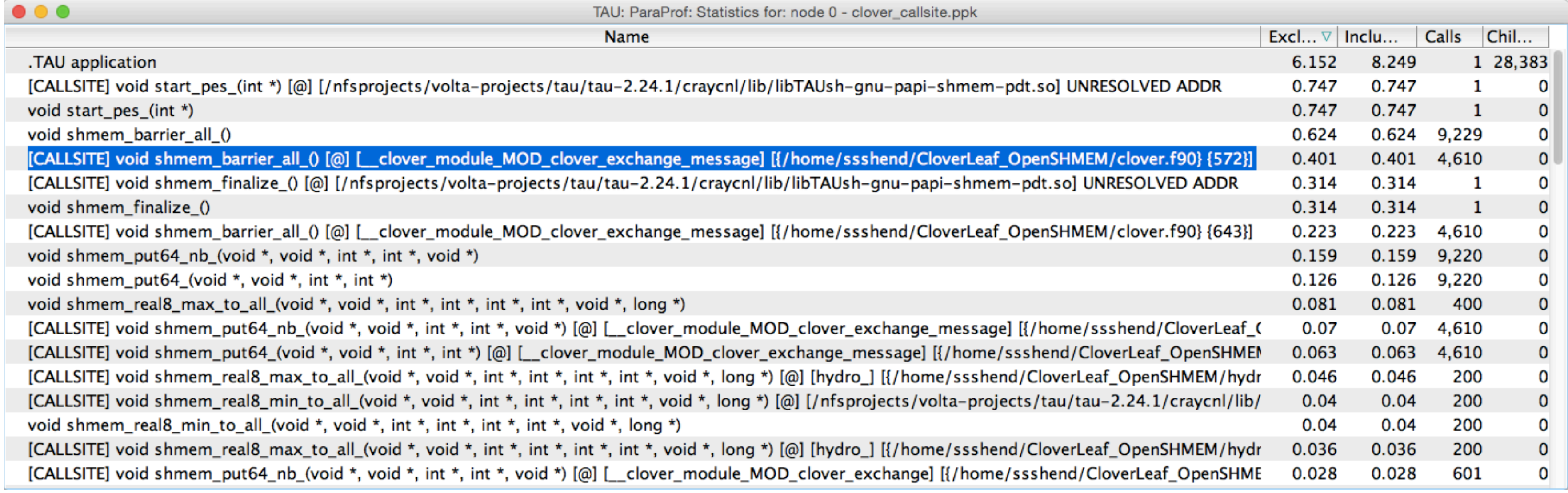
```
1.424  CD_CORE [{cd_core.F90} {8,2}-{1591,28}]
1.403  TP_CORE::XTPV [{tp_core.F90} {294,2}-{509,20}]
1.247  PHYS_GRID::CREATE_CHUNKS [{phys_grid.F90} {3680,4}-{4265,31}]
1.203  TP_CORE::YMIST [{tp_core.F90} {1105,2}-{1241,21}]
1.053  TP_CORE::TP2D [{tp_core.F90} {166,2}-{285,20}]
0.882  TE_MAP [{te_map.F90} {7,4}-{1057,27}]
0.874  MAPZ_MODULE::PPM2M [{mapz_module.F90} {675,2}-{953,21}]
0.83   M_MERGESORTS::DSORT_::MERGESORT_ [{m_MergeSorts.F90} {548,1}-{569,25}]
0.812  TP_CORE::FYPPM [{tp_core.F90} {1249,2}-{1427,21}]
0.748  SW_CORE::D_SW [{sw_core.F90} {542,2}-{1416,20}]
0.7    TP_CORE::XMIST [{tp_core.F90} {517,2}-{568,21}]
0.619  PHYS_GRID::ASSIGN_CHUNKS [{phys_grid.F90} {4648,4}-{4826,31}]
0.564  MAPZ_MODULE::MAP1_PPM [{mapz_module.F90} {200,3}-{350,24}]
0.556  PHYS_GRID::FIND_TWIN [{phys_grid.F90} {4430,4}-{4644,27}]
0.524  GEOPK [{geopk.F90} {36,7}-{149,26}]
0.52   GHOSTMODULE::GHOSTREGULAR3D [{ghostmodule.F90} {634,7}-{808,35}]
0.515  SW_CORE::C_SW [{sw_core.F90} {63,2}-{532,20}]
0.454  MOD_COMM::GA_GET4D_R8 [{mod_comm.F90} {1827,7}-{1881,32}]
0.449  TP_CORE::FXPPM [{tp_core.F90} {576,2}-{697,21}]
0.429  MOD_COMM::GA_PUT4D_R8 [{mod_comm.F90} {1711,7}-{1776,32}]
0.415  VPASSM [{fft99.F90} {937,7}-{1300,27}]
0.413  M_MERGESORTS::ISORT_::MERGE_ [{m_MergeSorts.F90} {337,1}-{370,21}]
0.397  TP_CORE::LMPPM [{tp_core.F90} {779,2}-{889,21}]
0.385  MOD_COMM::MP_SENDIRR [{mod_comm.F90} {2495,7}-{2838,31}]
0.382  M_MERGESORTS::ISORT_::MERGESORT_ [{m_MergeSorts.F90} {314,1}-{335,25}]
0.381  MAPZ_MODULE::STEEPZ [{mapz_module.F90} {1209,2}-{1285,22}]
0.37   MCT_MOD::MCT_AVECT_VECMULT [{mct_mod.F90} {988,1}-{1120,32}]
0.366  SHR_CONST_MOD::SHR_CONST_ISSPVAL [{shr_const_mod.F90} {67,3}-{78,32}]
0.34   MOD_COMM::MP_RECVIRR [{mod_comm.F90} {2846,7}-{3040,31}]
0.323  PHYS_GRID::PHYS_GRID_INIT [{phys_grid.F90} {311,3}-{930,31}]
```

ParaProf Thread Statistics Table


TAU: ParaProf: /rwthfs/rz/cluster/work/hpclab17/NPB3.3-MZ-MPI/bin
File Options Windows Help
Metric: TIME
Value: Exclusive
Std. Dev.
Mean
Max
Min
node 0
node 1
node 2
node 3
node 4
node 5
node 6
node 7
Show Thread Bar Chart
Show Thread Statistics Text Window
Show Thread Statistics Table
Show Thread Call Graph
Show Thread Call Path Relations
Show User Event Bar Chart
Show User Event Statistics Window
Show Context Event Window
Show Metadata for Thread
Add Thread to Comparison Window

Right click over “node X” and choose
Show Thread Statistics Table

TAU – Callsite Profiling

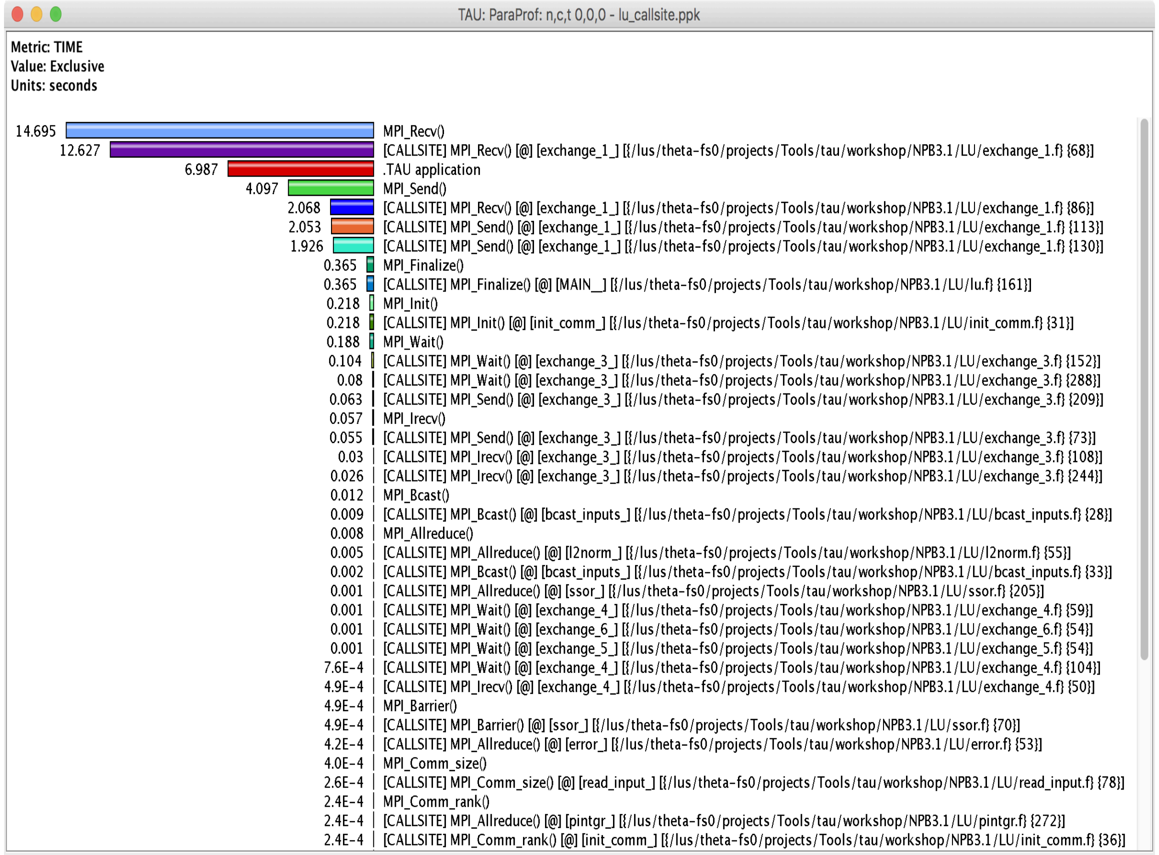


TAU: ParaProf: Statistics for: node 0 - clover_callsite.ppk

Name	Excl... ▽	Inclu...	Calls	Chil...
.TAU application	6.152	8.249	1	28,383
[CALLSITE] void start_pes_(int *) [@] [/nfsprojects/volta-projects/tau/tau-2.24.1/craycnl/lib/libTAUsh-gnu-papi-shmem-pdt.so] UNRESOLVED ADDR	0.747	0.747	1	0
void start_pes_(int *)	0.747	0.747	1	0
void shmem_barrier_all_()	0.624	0.624	9,229	0
[CALLSITE] void shmem_barrier_all_() [@] [__clover_module_MOD_clover_exchange_message] [{/home/ssshend/CloverLeaf_OpenSHMEM/clover.f90} {572}]	0.401	0.401	4,610	0
[CALLSITE] void shmem_finalize_() [@] [/nfsprojects/volta-projects/tau/tau-2.24.1/craycnl/lib/libTAUsh-gnu-papi-shmem-pdt.so] UNRESOLVED ADDR	0.314	0.314	1	0
void shmem_finalize_()	0.314	0.314	1	0
[CALLSITE] void shmem_barrier_all_() [@] [__clover_module_MOD_clover_exchange_message] [{/home/ssshend/CloverLeaf_OpenSHMEM/clover.f90} {643}]	0.223	0.223	4,610	0
void shmem_put64_nb_(void *, void *, int *, int *, void *)	0.159	0.159	9,220	0
void shmem_put64_(void *, void *, int *, int *)	0.126	0.126	9,220	0
void shmem_real8_max_to_all_(void *, void *, int *, int *, int *, int *, void *, long *)	0.081	0.081	400	0
[CALLSITE] void shmem_put64_nb_(void *, void *, int *, int *, void *) [@] [__clover_module_MOD_clover_exchange_message] [{/home/ssshend/CloverLeaf_(	0.07	0.07	4,610	0
[CALLSITE] void shmem_put64_(void *, void *, int *, int *) [@] [__clover_module_MOD_clover_exchange_message] [{/home/ssshend/CloverLeaf_OpenSHMEI	0.063	0.063	4,610	0
[CALLSITE] void shmem_real8_max_to_all_(void *, void *, int *, int *, int *, int *, void *, long *) [@] [hydro_] [{/home/ssshend/CloverLeaf_OpenSHMEM/hydr	0.046	0.046	200	0
[CALLSITE] void shmem_real8_min_to_all_(void *, void *, int *, int *, int *, int *, void *, long *) [@] [/nfsprojects/volta-projects/tau/tau-2.24.1/craycnl/lib/	0.04	0.04	200	0
void shmem_real8_min_to_all_(void *, void *, int *, int *, int *, int *, void *, long *)	0.04	0.04	200	0
[CALLSITE] void shmem_real8_max_to_all_(void *, void *, int *, int *, int *, int *, void *, long *) [@] [hydro_] [{/home/ssshend/CloverLeaf_OpenSHMEM/hydr	0.036	0.036	200	0
[CALLSITE] void shmem_put64_nb_(void *, void *, int *, int *, void *) [@] [__clover_module_MOD_clover_exchange] [{/home/ssshend/CloverLeaf_OpenSHME	0.028	0.028	601	0

```
% export TAU_CALLSITE=1
```

Callsite Profiling and Tracing

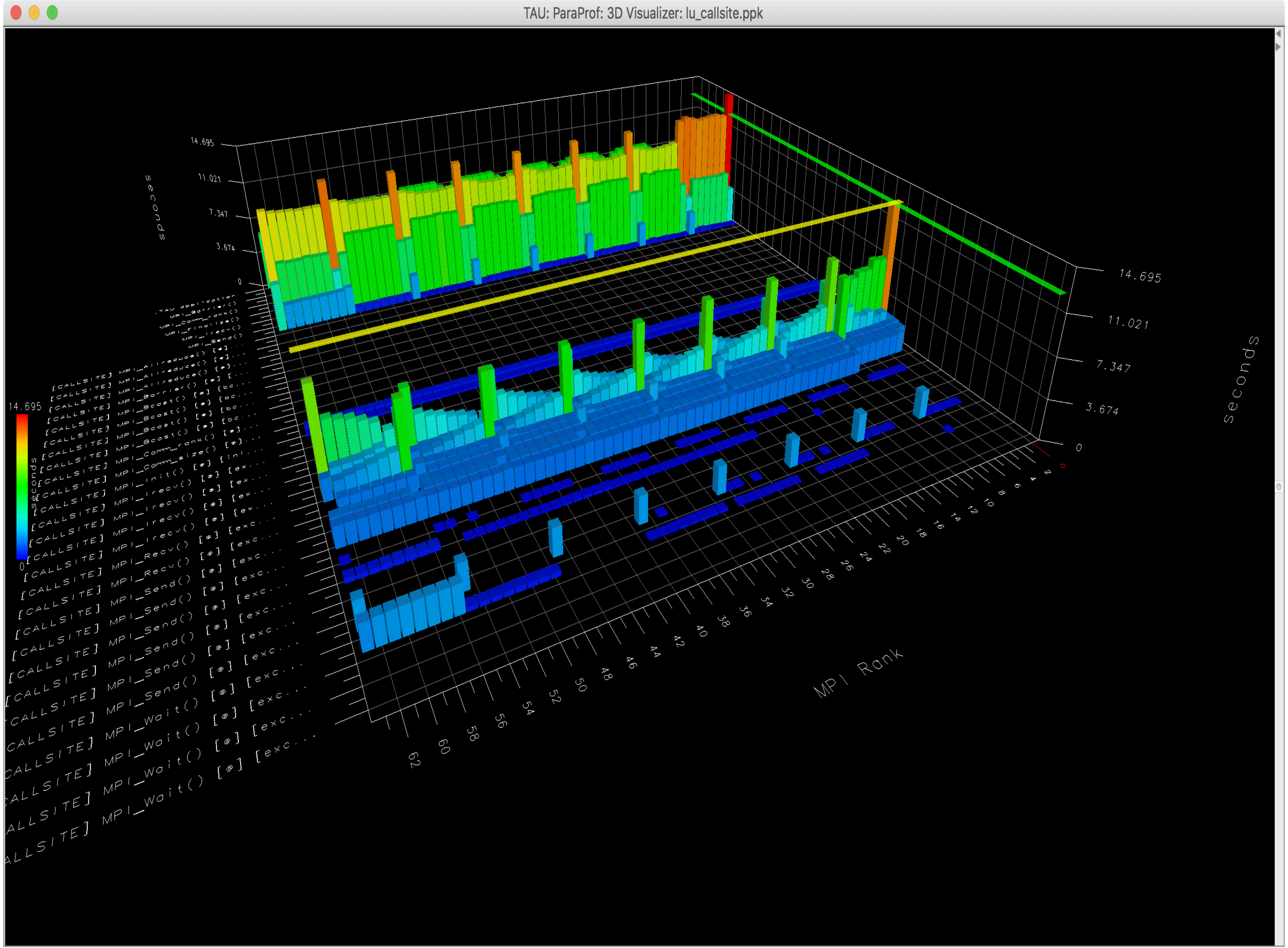


TAU: ParaProf: n,c,t 0,0,0 - lu_callsite.ppk

```
Metric: TIME
Value: Exclusive
Units: seconds

14.695  MPI_Recv()
12.627  [CALLSITE] MPI_Recv() [@] [exchange_1_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_1.f} {68}]
 6.987  .TAU application
 4.097  MPI_Send()
 2.068  [CALLSITE] MPI_Recv() [@] [exchange_1_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_1.f} {86}]
 2.053  [CALLSITE] MPI_Send() [@] [exchange_1_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_1.f} {113}]
 1.926  [CALLSITE] MPI_Send() [@] [exchange_1_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_1.f} {130}]
 0.365  MPI_Finalize()
 0.365  [CALLSITE] MPI_Finalize() [@] [MAIN__] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/lu.f} {161}]
 0.218  MPI_Init()
 0.218  [CALLSITE] MPI_Init() [@] [init_comm_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/init_comm.f} {31}]
 0.188  MPI_Wait()
 0.104  [CALLSITE] MPI_Wait() [@] [exchange_3_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_3.f} {152}]
  0.08  [CALLSITE] MPI_Wait() [@] [exchange_3_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_3.f} {288}]
 0.063  [CALLSITE] MPI_Send() [@] [exchange_3_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_3.f} {209}]
 0.057  MPI_Irecv()
 0.055  [CALLSITE] MPI_Send() [@] [exchange_3_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_3.f} {73}]
  0.03  [CALLSITE] MPI_Irecv() [@] [exchange_3_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_3.f} {108}]
 0.026  [CALLSITE] MPI_Irecv() [@] [exchange_3_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_3.f} {244}]
 0.012  MPI_Bcast()
 0.009  [CALLSITE] MPI_Bcast() [@] [bcast_inputs_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/bcast_inputs.f} {28}]
 0.008  MPI_Allreduce()
 0.005  [CALLSITE] MPI_Allreduce() [@] [l2norm_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/l2norm.f} {55}]
 0.002  [CALLSITE] MPI_Bcast() [@] [bcast_inputs_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/bcast_inputs.f} {33}]
 0.001  [CALLSITE] MPI_Allreduce() [@] [ssor_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/ssor.f} {205}]
 0.001  [CALLSITE] MPI_Wait() [@] [exchange_4_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_4.f} {59}]
 0.001  [CALLSITE] MPI_Wait() [@] [exchange_6_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_6.f} {54}]
 0.001  [CALLSITE] MPI_Wait() [@] [exchange_5_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_5.f} {54}]
7.6E-4  [CALLSITE] MPI_Wait() [@] [exchange_4_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_4.f} {104}]
4.9E-4  [CALLSITE] MPI_Irecv() [@] [exchange_4_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_4.f} {50}]
4.9E-4  MPI_Barrier()
4.9E-4  [CALLSITE] MPI_Barrier() [@] [ssor_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/ssor.f} {70}]
4.2E-4  [CALLSITE] MPI_Allreduce() [@] [error_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/error.f} {53}]
4.0E-4  MPI_Comm_size()
2.6E-4  [CALLSITE] MPI_Comm_size() [@] [read_input_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/read_input.f} {78}]
2.4E-4  MPI_Comm_rank()
2.4E-4  [CALLSITE] MPI_Allreduce() [@] [pintgr_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/pintgr.f} {272}]
2.4E-4  [CALLSITE] MPI_Comm_rank() [@] [init_comm_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/init_comm.f} {36}]
```

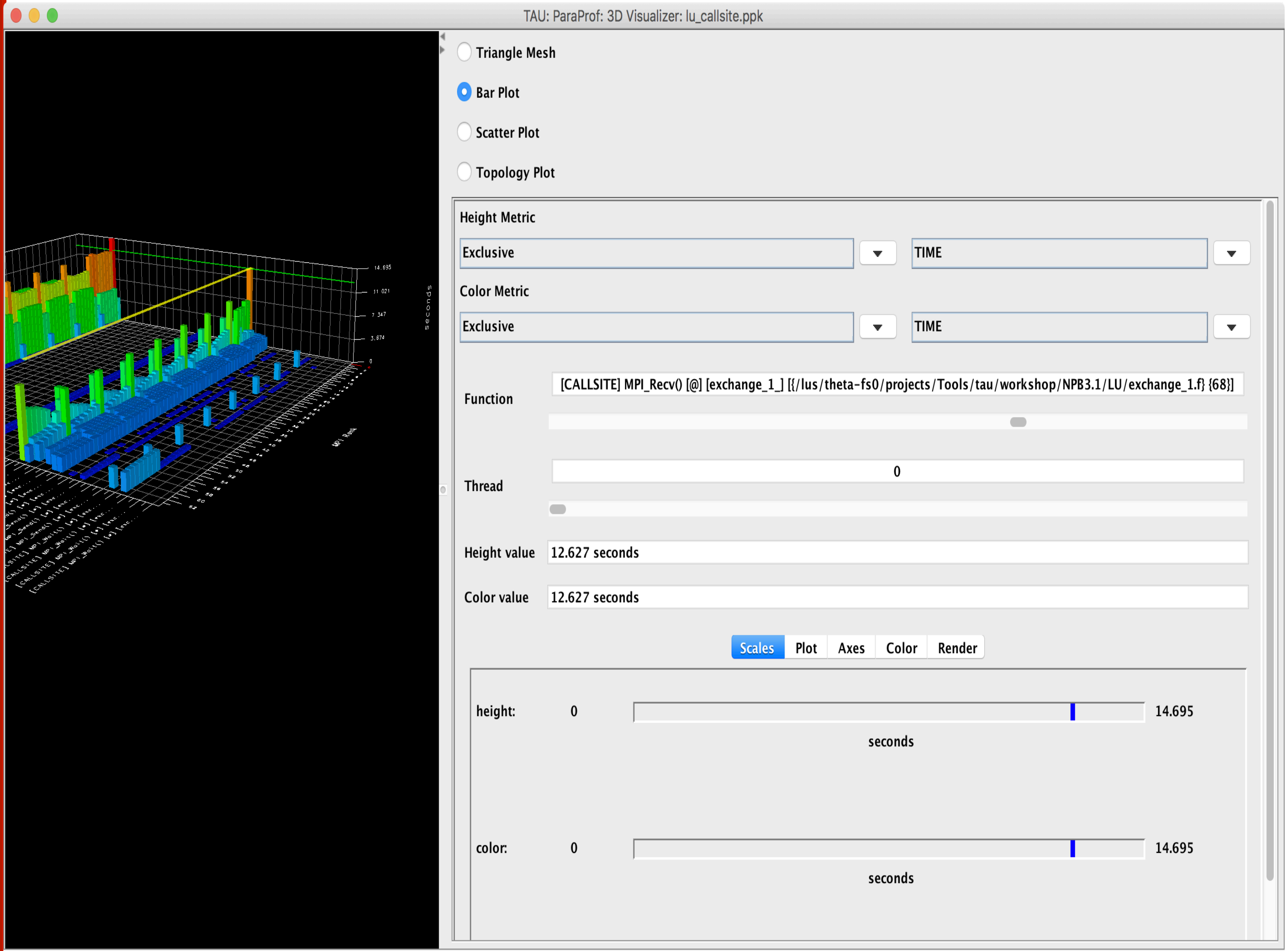
```
% export TAU_CALLSITE=1
```

Callsite Profiling and Tracing


TAU: ParaProf: 3D Visualizer: lu_callsite.ppk
14.695
11.021
7.347
3.674
0
seconds
.TAU application
MPI_Barrier()
MPI_Comm_rank()
MPI_Finalize()
MPI_Irecv()
MPI_Send()
[CALLSITE] MPI_Allreduce() [@]...
[CALLSITE] MPI_Allreduce() [@]...
[CALLSITE] MPI_Allreduce() [@] [...
[CALLSITE] MPI_Barrier() [@] [bc...
[CALLSITE] MPI_Bcast() [@] [bc...
[CALLSITE] MPI_Bcast() [@] [bc...
[CALLSITE] MPI_Bcast() [@] [bc...
[CALLSITE] MPI_Bcast() [@]...
[CALLSITE] MPI_Comm_rank() [@]...
[CALLSITE] MPI_Comm_size() [ini...
[CALLSITE] MPI_Init() [@] [ex...
[CALLSITE] MPI_Irecv() [@] [ex...
[CALLSITE] MPI_Irecv() [@] [ex...
[CALLSITE] MPI_Irecv() [@] [ex...
[CALLSITE] MPI_Irecv() [@] [exc...
[CALLSITE] MPI_Recv() [@] [exc...
[CALLSITE] MPI_Recv() [@] [exc...
[CALLSITE] MPI_Send() [@] [exc...
[CALLSITE] MPI_Send() [@] [exc...
[CALLSITE] MPI_Send() [@] [exc...
[CALLSITE] MPI_Send() [@] [exc...
[CALLSITE] MPI_Send() [@] [exc...
[CALLSITE] MPI_Send() [@] [exc...
[CALLSITE] MPI_Wait() [@] [exc...
[CALLSITE] MPI_Wait() [@] [exc...
[CALLSITE] MPI_Wait() [@] [exc...
[CALLSITE] MPI_Wait()
14.695
seconds
0
14.695
11.021
7.347
3.674
0
seconds
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62
MPI Rank

ParaTools

Callsite Profiling and Tracing



TAU: ParaProf: 3D Visualizer: lu_callsite.ppk

○ Triangle Mesh

● Bar Plot

○ Scatter Plot

○ Topology Plot

Height Metric: Exclusive ▼ TIME ▼

Color Metric: Exclusive ▼ TIME ▼

Function: [CALLSITE] MPI_Recv() [@] [exchange_1_] [{/lus/theta-fs0/projects/Tools/tau/workshop/NPB3.1/LU/exchange_1.f} {68}]

Thread: 0

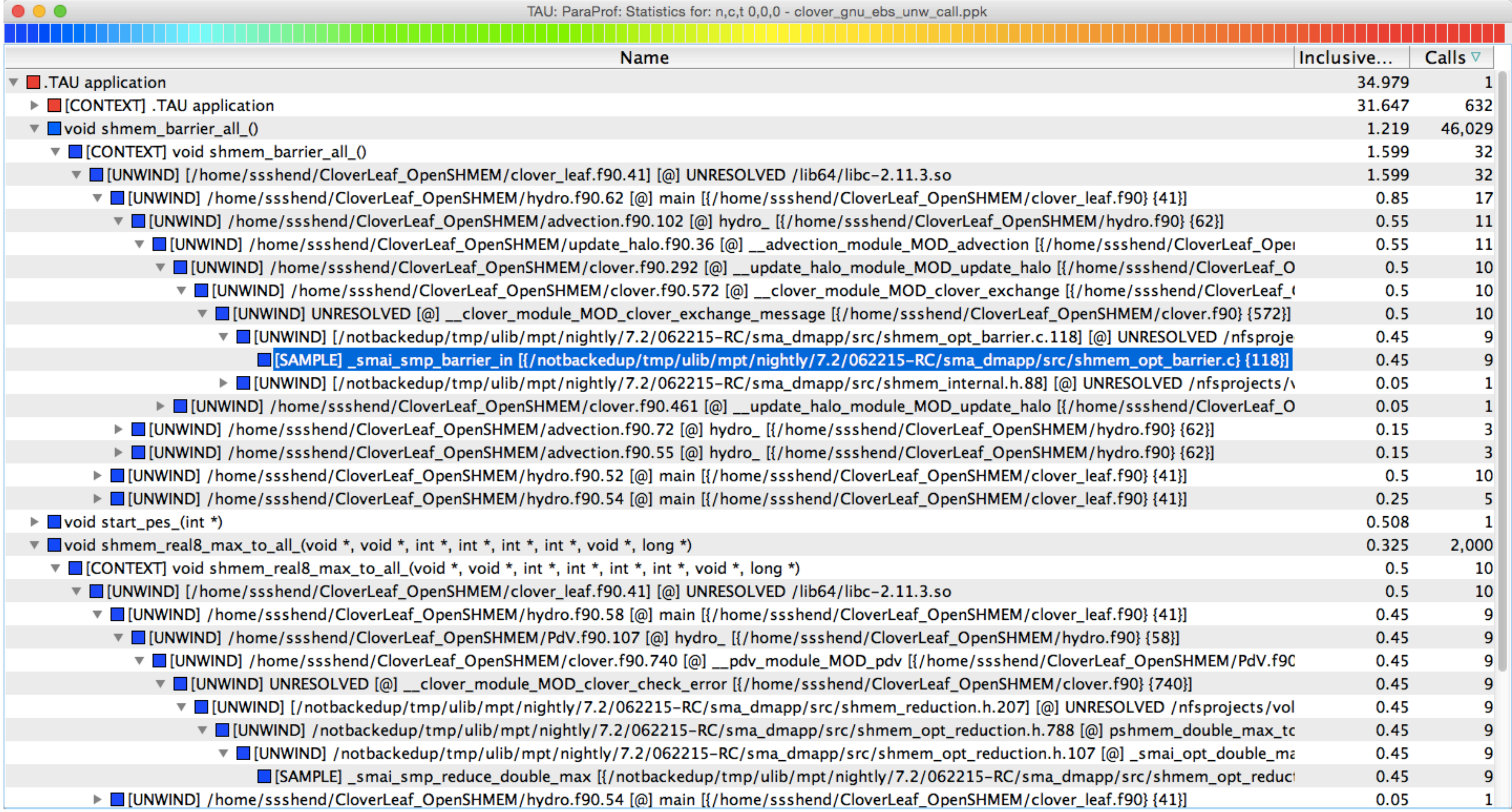
Height value: 12.627 seconds

Color value: 12.627 seconds

height: 0 — 14.695 seconds

color: 0 — 14.695 seconds

TAU – Callstack Sampling

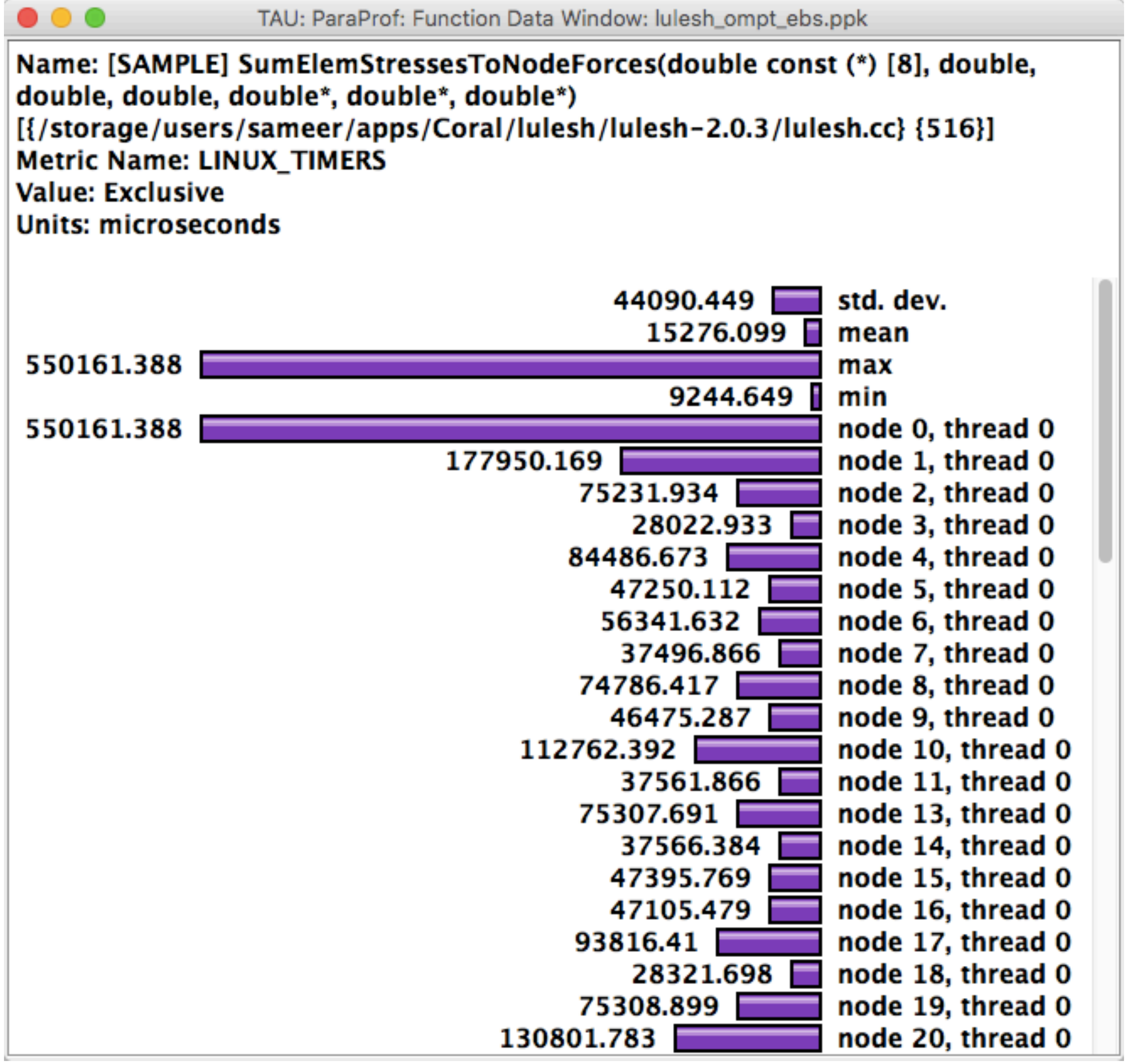


TAU: ParaProf: Statistics for: n,c,t 0,0,0 - clover_gnu_ebs_unw_call.ppk

Name	Inclusive...	Calls ▽
▼ ■ .TAU application	34.979	1
▶ ■ [CONTEXT] .TAU application	31.647	632
▼ ■ void shmem_barrier_all_()	1.219	46,029
▼ ■ [CONTEXT] void shmem_barrier_all_()	1.599	32
▼ ■ [UNWIND] [/home/ssshend/CloverLeaf_OpenSHMEM/clover_leaf.f90.41] [@] UNRESOLVED /lib64/libc-2.11.3.so	1.599	32
▼ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/hydro.f90.62 [@] main [{/home/ssshend/CloverLeaf_OpenSHMEM/clover_leaf.f90} {41}]	0.85	17
▼ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/advection.f90.102 [@] hydro_ [{/home/ssshend/CloverLeaf_OpenSHMEM/hydro.f90} {62}]	0.55	11
▼ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/update_halo.f90.36 [@] __advection_module_MOD_advection [{/home/ssshend/CloverLeaf_Ope	0.55	11
▼ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/clover.f90.292 [@] __update_halo_module_MOD_update_halo [{/home/ssshend/CloverLeaf_O	0.5	10
▼ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/clover.f90.572 [@] __clover_module_MOD_clover_exchange [{/home/ssshend/CloverLeaf_	0.5	10
▼ ■ [UNWIND] UNRESOLVED [@] __clover_module_MOD_clover_exchange_message [{/home/ssshend/CloverLeaf_OpenSHMEM/clover.f90} {572}]	0.5	10
▼ ■ [UNWIND] [/notbackedup/tmp/ulib/mpt/nightly/7.2/062215-RC/sma_dmapp/src/shmem_opt_barrier.c.118] [@] UNRESOLVED /nfsproje	0.45	9
■ [SAMPLE] _smai_smp_barrier_in [{/notbackedup/tmp/ulib/mpt/nightly/7.2/062215-RC/sma_dmapp/src/shmem_opt_barrier.c} {118}]	0.45	9
▶ ■ [UNWIND] [/notbackedup/tmp/ulib/mpt/nightly/7.2/062215-RC/sma_dmapp/src/shmem_internal.h.88] [@] UNRESOLVED /nfsprojects/	0.05	1
▶ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/clover.f90.461 [@] __update_halo_module_MOD_update_halo [{/home/ssshend/CloverLeaf_O	0.05	1
▶ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/advection.f90.72 [@] hydro_ [{/home/ssshend/CloverLeaf_OpenSHMEM/hydro.f90} {62}]	0.15	3
▶ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/advection.f90.55 [@] hydro_ [{/home/ssshend/CloverLeaf_OpenSHMEM/hydro.f90} {62}]	0.15	3
▶ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/hydro.f90.52 [@] main [{/home/ssshend/CloverLeaf_OpenSHMEM/clover_leaf.f90} {41}]	0.5	10
▶ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/hydro.f90.54 [@] main [{/home/ssshend/CloverLeaf_OpenSHMEM/clover_leaf.f90} {41}]	0.25	5
▶ ■ void start_pes_(int *)	0.508	1
▼ ■ void shmem_real8_max_to_all_(void *, void *, int *, int *, int *, int *, void *, long *)	0.325	2,000
▼ ■ [CONTEXT] void shmem_real8_max_to_all_(void *, void *, int *, int *, int *, int *, void *, long *)	0.5	10
▼ ■ [UNWIND] [/home/ssshend/CloverLeaf_OpenSHMEM/clover_leaf.f90.41] [@] UNRESOLVED /lib64/libc-2.11.3.so	0.5	10
▼ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/hydro.f90.58 [@] main [{/home/ssshend/CloverLeaf_OpenSHMEM/clover_leaf.f90} {41}]	0.45	9
▼ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/PdV.f90.107 [@] hydro_ [{/home/ssshend/CloverLeaf_OpenSHMEM/hydro.f90} {58}]	0.45	9
▼ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/clover.f90.740 [@] __pdv_module_MOD_pdv [{/home/ssshend/CloverLeaf_OpenSHMEM/PdV.f90	0.45	9
▼ ■ [UNWIND] UNRESOLVED [@] __clover_module_MOD_clover_check_error [{/home/ssshend/CloverLeaf_OpenSHMEM/clover.f90} {740}]	0.45	9
▼ ■ [UNWIND] [/notbackedup/tmp/ulib/mpt/nightly/7.2/062215-RC/sma_dmapp/src/shmem_reduction.h.207] [@] UNRESOLVED /nfsprojects/vol	0.45	9
▼ ■ [UNWIND] /notbackedup/tmp/ulib/mpt/nightly/7.2/062215-RC/sma_dmapp/src/shmem_opt_reduction.h.788 [@] pshmem_double_max_tc	0.45	9
▼ ■ [UNWIND] /notbackedup/tmp/ulib/mpt/nightly/7.2/062215-RC/sma_dmapp/src/shmem_opt_reduction.h.107 [@] _smai_opt_double_ma	0.45	9
■ [SAMPLE] _smai_smp_reduce_double_max [{/notbackedup/tmp/ulib/mpt/nightly/7.2/062215-RC/sma_dmapp/src/shmem_opt_reduci	0.45	9
▶ ■ [UNWIND] /home/ssshend/CloverLeaf_OpenSHMEM/hydro.f90.54 [@] main [{/home/ssshend/CloverLeaf_OpenSHMEM/clover_leaf.f90} {41}]	0.05	1

```
% export TAU_SAMPLING=1; export TAU_EBS_UNWIND=1
```

TAU – Event Based Sampling (EBS)

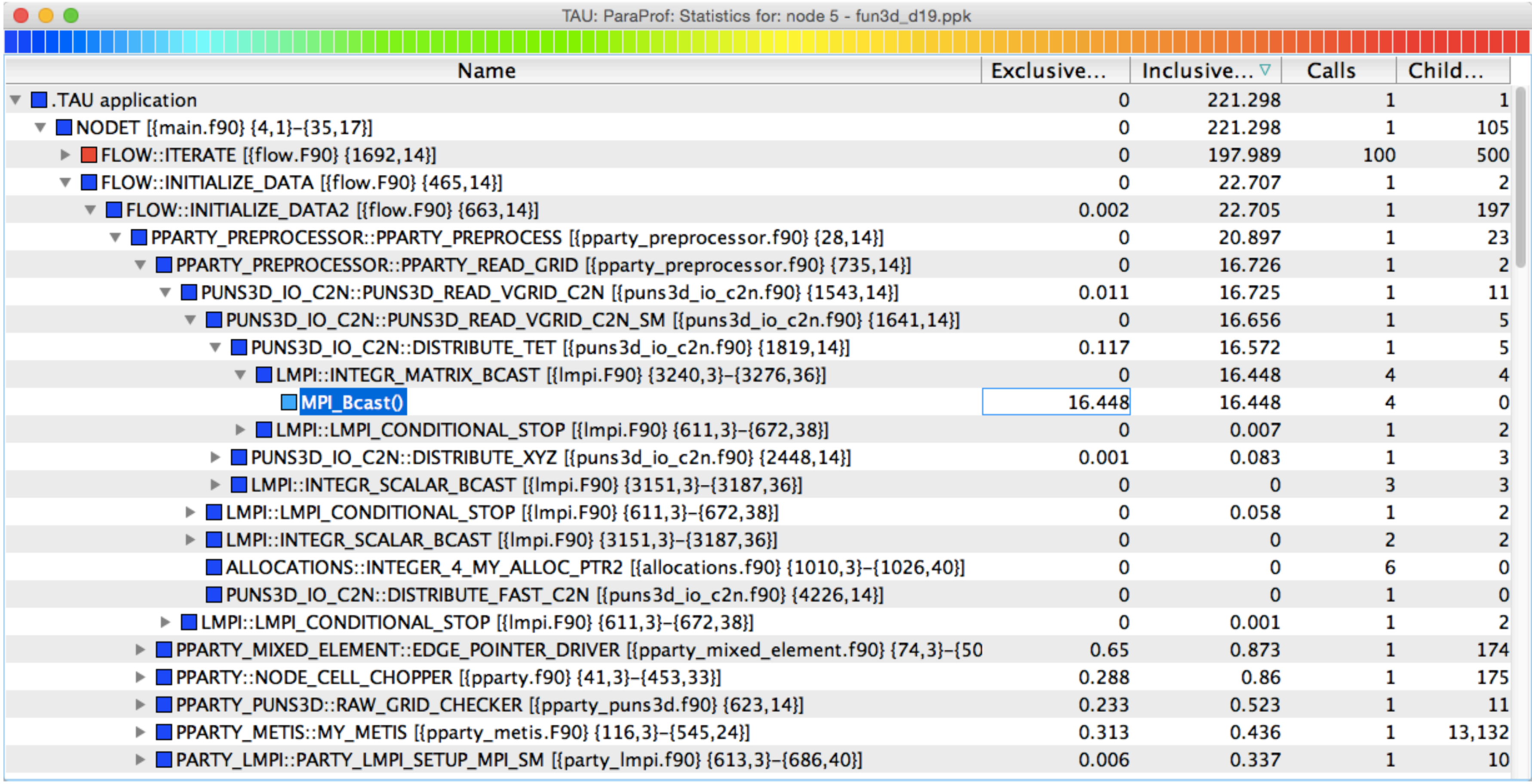


Name: [SAMPLE] SumElemStressesToNodeForces(double const (*) [8], double, double, double, double*, double*, double*) [{/storage/users/sameer/apps/Coral/lulesh/lulesh-2.0.3/lulesh.cc} {516}]
Metric Name: LINUX_TIMERS
Value: Exclusive
Units: microseconds

```
  44090.449  std. dev.
  15276.099  mean
 550161.388  max
   9244.649  min
 550161.388  node 0, thread 0
 177950.169  node 1, thread 0
  75231.934  node 2, thread 0
  28022.933  node 3, thread 0
  84486.673  node 4, thread 0
  47250.112  node 5, thread 0
  56341.632  node 6, thread 0
  37496.866  node 7, thread 0
  74786.417  node 8, thread 0
  46475.287  node 9, thread 0
 112762.392  node 10, thread 0
  37561.866  node 11, thread 0
  75307.691  node 13, thread 0
  37566.384  node 14, thread 0
  47395.769  node 15, thread 0
  47105.479  node 16, thread 0
   93816.41  node 17, thread 0
  28321.698  node 18, thread 0
  75308.899  node 19, thread 0
 130801.783  node 20, thread 0
```

% export TAU_SAMPLING=1

TAU – Callpath Profiling

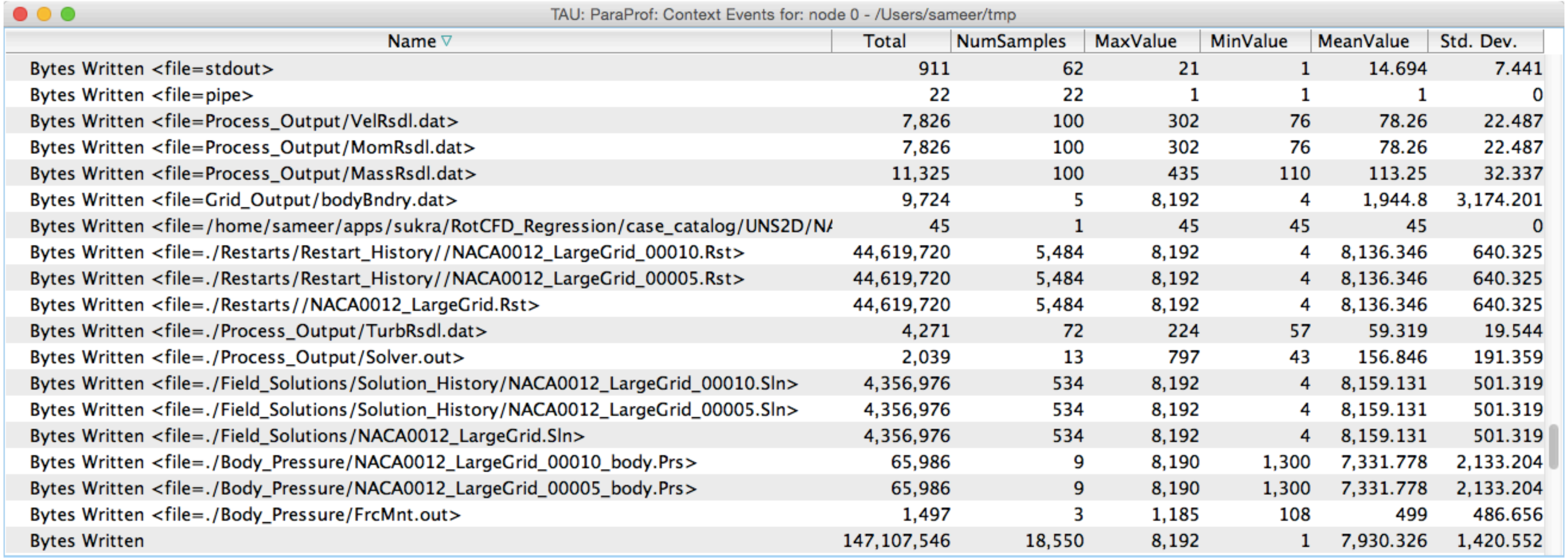


TAU: ParaProf: Statistics for: node 5 - fun3d_d19.ppk

Name	Exclusive...	Inclusive... ▽	Calls	Child...
▼ 🟦 .TAU application	0	221.298	1	1
▼ 🟦 NODET [{main.f90} {4,1}-{35,17}]	0	221.298	1	105
▶ 🟥 FLOW::ITERATE [{flow.F90} {1692,14}]	0	197.989	100	500
▼ 🟦 FLOW::INITIALIZE_DATA [{flow.F90} {465,14}]	0	22.707	1	2
▼ 🟦 FLOW::INITIALIZE_DATA2 [{flow.F90} {663,14}]	0.002	22.705	1	197
▼ 🟦 PPARTY_PREPROCESSOR::PPARTY_PREPROCESS [{pparty_preprocessor.f90} {28,14}]	0	20.897	1	23
▼ 🟦 PPARTY_PREPROCESSOR::PPARTY_READ_GRID [{pparty_preprocessor.f90} {735,14}]	0	16.726	1	2
▼ 🟦 PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N [{puns3d_io_c2n.f90} {1543,14}]	0.011	16.725	1	11
▼ 🟦 PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N_SM [{puns3d_io_c2n.f90} {1641,14}]	0	16.656	1	5
▼ 🟦 PUNS3D_IO_C2N::DISTRIBUTE_TET [{puns3d_io_c2n.f90} {1819,14}]	0.117	16.572	1	5
▼ 🟦 LMPI::INTEGR_MATRIX_BCAST [{lmpi.F90} {3240,3}-{3276,36}]	0	16.448	4	4
🟦 MPI_Bcast()	16.448	16.448	4	0
▶ 🟦 LMPI::LMPI_CONDITIONAL_STOP [{lmpi.F90} {611,3}-{672,38}]	0	0.007	1	2
▶ 🟦 PUNS3D_IO_C2N::DISTRIBUTE_XYZ [{puns3d_io_c2n.f90} {2448,14}]	0.001	0.083	1	3
▶ 🟦 LMPI::INTEGR_SCALAR_BCAST [{lmpi.F90} {3151,3}-{3187,36}]	0	0	3	3
▶ 🟦 LMPI::LMPI_CONDITIONAL_STOP [{lmpi.F90} {611,3}-{672,38}]	0	0.058	1	2
▶ 🟦 LMPI::INTEGR_SCALAR_BCAST [{lmpi.F90} {3151,3}-{3187,36}]	0	0	2	2
🟦 ALLOCATIONS::INTEGER_4_MY_ALLOC_PTR2 [{allocations.f90} {1010,3}-{1026,40}]	0	0	6	0
🟦 PUNS3D_IO_C2N::DISTRIBUTE_FAST_C2N [{puns3d_io_c2n.f90} {4226,14}]	0	0	1	0
▶ 🟦 LMPI::LMPI_CONDITIONAL_STOP [{lmpi.F90} {611,3}-{672,38}]	0	0.001	1	2
▶ 🟦 PPARTY_MIXED_ELEMENT::EDGE_POINTER_DRIVER [{pparty_mixed_element.f90} {74,3}-{50	0.65	0.873	1	174
▶ 🟦 PPARTY::NODE_CELL_CHOPPER [{pparty.f90} {41,3}-{453,33}]	0.288	0.86	1	175
▶ 🟦 PPARTY_PUNS3D::RAW_GRID_CHECKER [{pparty_puns3d.f90} {623,14}]	0.233	0.523	1	11
▶ 🟦 PPARTY_METIS::MY_METIS [{pparty_metis.F90} {116,3}-{545,24}]	0.313	0.436	1	13,132
▶ 🟦 PARTY_LMPI::PARTY_LMPI_SETUP_MPI_SM [{party_lmpi.f90} {613,3}-{686,40}]	0.006	0.337	1	10

% export TAU_CALLPATH=1; export TAU_CALLPATH_DEPTH=100

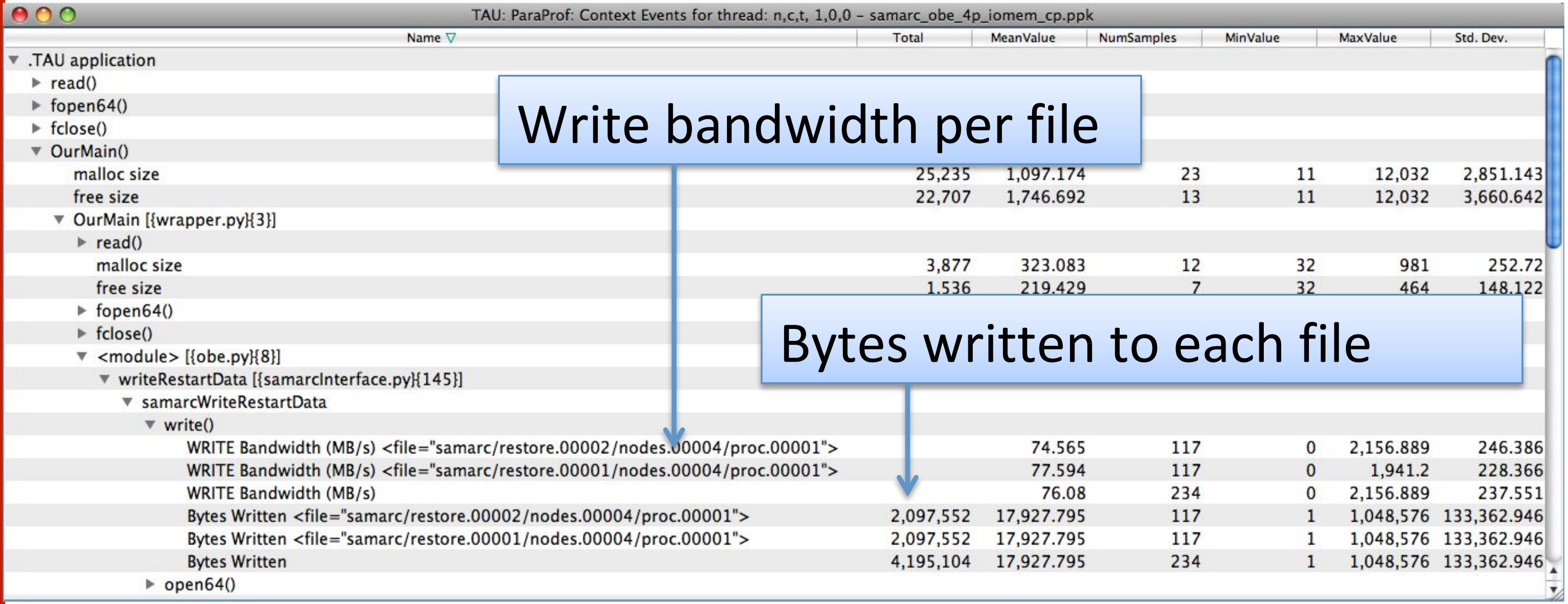
TAU Atomic Events



TAU: ParaProf: Context Events for: node 0 - /Users/sameer/tmp

Name ▽	Total	NumSamples	MaxValue	MinValue	MeanValue	Std. Dev.
Bytes Written <file=stdout>	911	62	21	1	14.694	7.441
Bytes Written <file=pipe>	22	22	1	1	1	0
Bytes Written <file=Process_Output/VelRsdl.dat>	7,826	100	302	76	78.26	22.487
Bytes Written <file=Process_Output/MomRsdl.dat>	7,826	100	302	76	78.26	22.487
Bytes Written <file=Process_Output/MassRsdl.dat>	11,325	100	435	110	113.25	32.337
Bytes Written <file=Grid_Output/bodyBndry.dat>	9,724	5	8,192	4	1,944.8	3,174.201
Bytes Written <file=/home/sameer/apps/sukra/RotCFD_Regression/case_catalog/UNS2D/N	45	1	45	45	45	0
Bytes Written <file=./Restarts/Restart_History//NACA0012_LargeGrid_00010.Rst>	44,619,720	5,484	8,192	4	8,136.346	640.325
Bytes Written <file=./Restarts/Restart_History//NACA0012_LargeGrid_00005.Rst>	44,619,720	5,484	8,192	4	8,136.346	640.325
Bytes Written <file=./Restarts//NACA0012_LargeGrid.Rst>	44,619,720	5,484	8,192	4	8,136.346	640.325
Bytes Written <file=./Process_Output/TurbRsdl.dat>	4,271	72	224	57	59.319	19.544
Bytes Written <file=./Process_Output/Solver.out>	2,039	13	797	43	156.846	191.359
Bytes Written <file=./Field_Solutions/Solution_History/NACA0012_LargeGrid_00010.Sln>	4,356,976	534	8,192	4	8,159.131	501.319
Bytes Written <file=./Field_Solutions/Solution_History/NACA0012_LargeGrid_00005.Sln>	4,356,976	534	8,192	4	8,159.131	501.319
Bytes Written <file=./Field_Solutions/NACA0012_LargeGrid.Sln>	4,356,976	534	8,192	4	8,159.131	501.319
Bytes Written <file=./Body_Pressure/NACA0012_LargeGrid_00010_body.Prs>	65,986	9	8,190	1,300	7,331.778	2,133.204
Bytes Written <file=./Body_Pressure/NACA0012_LargeGrid_00005_body.Prs>	65,986	9	8,190	1,300	7,331.778	2,133.204
Bytes Written <file=./Body_Pressure/FrcMnt.out>	1,497	3	1,185	108	499	486.656
Bytes Written	147,107,546	18,550	8,192	1	7,930.326	1,420.552

TAU – Context Events



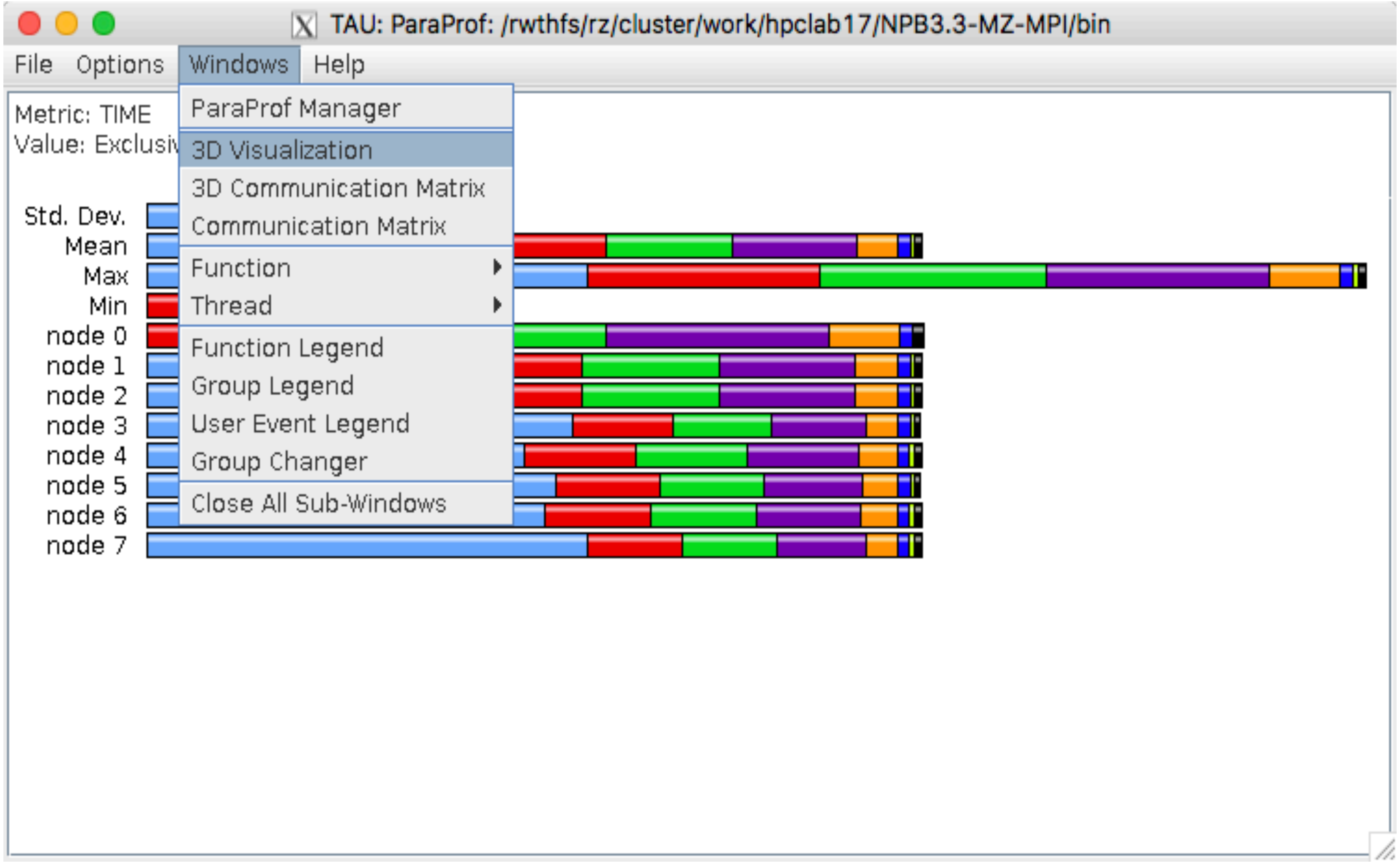
TAU: ParaProf: Context Events for thread: n,c,t, 1,0,0 – samarc_obe_4p_iomem_cp.ppk

Name ▽	Total	MeanValue	NumSamples	MinValue	MaxValue	Std. Dev.
▼ .TAU application						
▶ read()						
▶ fopen64()						
▶ fclose()						
▼ OurMain()						
malloc size	25,235	1,097.174	23	11	12,032	2,851.143
free size	22,707	1,746.692	13	11	12,032	3,660.642
▼ OurMain [{wrapper.py}{3}]						
▶ read()						
malloc size	3,877	323.083	12	32	981	252.72
free size	1,536	219.429	7	32	464	148.122
▶ fopen64()						
▶ fclose()						
▼ <module> [{obe.py}{8}]						
▼ writeRestartData [{samarcInterface.py}{145}]						
▼ samarcWriteRestartData						
▼ write()						
WRITE Bandwidth (MB/s) <file="samarc/restore.00002/nodes.00004/proc.00001">		74.565	117	0	2,156.889	246.386
WRITE Bandwidth (MB/s) <file="samarc/restore.00001/nodes.00004/proc.00001">		77.594	117	0	1,941.2	228.366
WRITE Bandwidth (MB/s)		76.08	234	0	2,156.889	237.551
Bytes Written <file="samarc/restore.00002/nodes.00004/proc.00001">	2,097,552	17,927.795	117	1	1,048,576	133,362.946
Bytes Written <file="samarc/restore.00001/nodes.00004/proc.00001">	2,097,552	17,927.795	117	1	1,048,576	133,362.946
Bytes Written	4,195,104	17,927.795	234	1	1,048,576	133,362.946
▶ open64()						

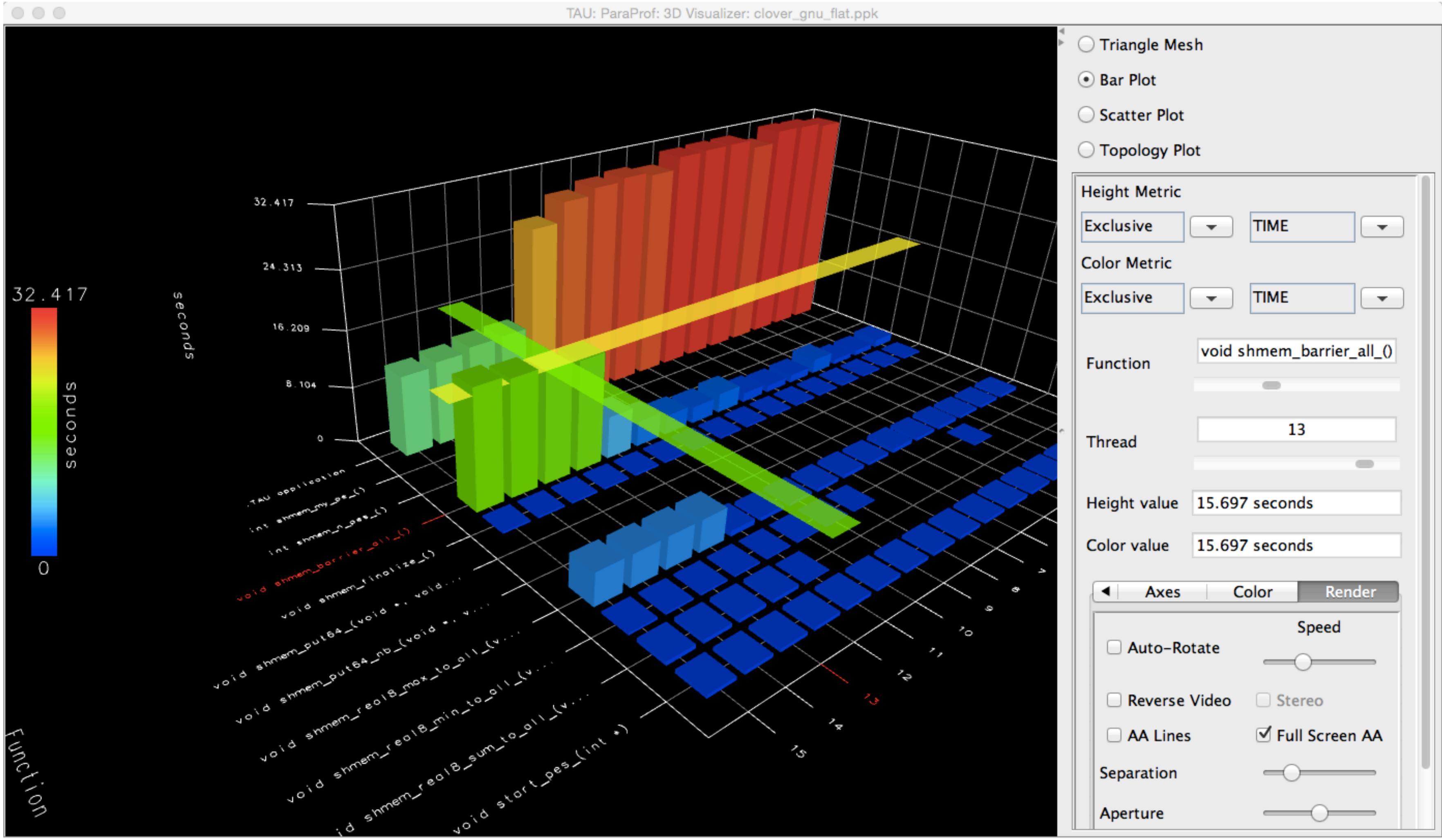
Write bandwidth per file

Bytes written to each file

3D Visualization in ParaProf



TAU – ParaProf 3D Visualization


32.417
24.313
16.209
8.104
0
seconds
32.417
seconds
0
TAU application
int shmem_my_pe_()
int shmem_n_pes_()
void shmem_barrier_all_()
void shmem_finalize_()
void shmem_put64_(void *, void...
void shmem_put64_nb_(void *, v...
void shmem_real8_max_to_all_(v...
void shmem_real8_min_to_all_(v...
void shmem_real8_sum_to_all_(v...
void start_pes_(int *)
Function
7
8
9
10
11
12
13
14
15

TAU: ParaProf: 3D Visualizer: clover_gnu_flat.ppk

○ Triangle Mesh
● Bar Plot
○ Scatter Plot
○ Topology Plot

Height Metric: Exclusive, TIME

Color Metric: Exclusive, TIME

Function: void shmem_barrier_all_()

Thread: 13

Height value: 15.697 seconds

Color value: 15.697 seconds

Axes | Color | Render

☐ Auto-Rotate Speed

☐ Reverse Video ☐ Stereo

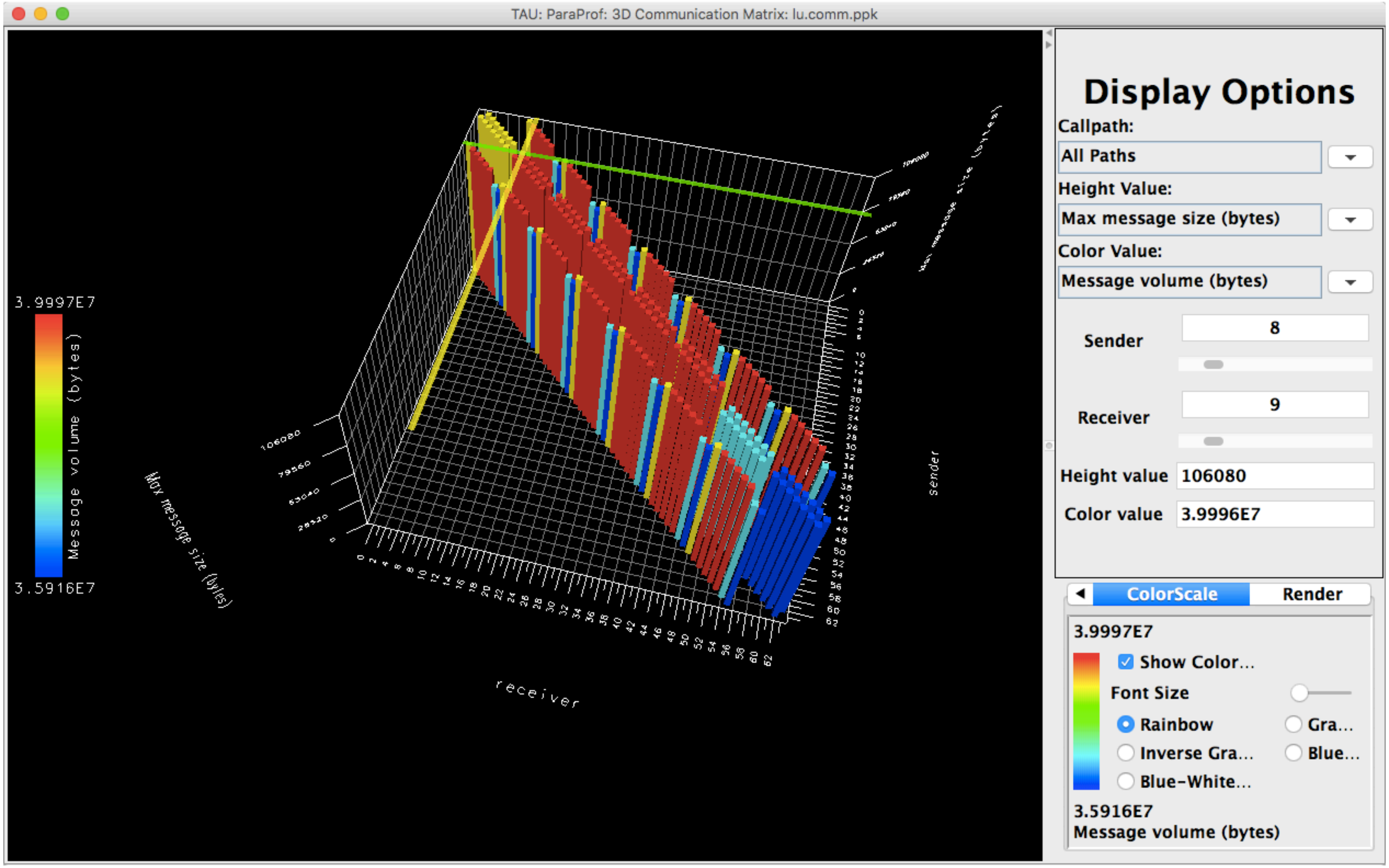
☐ AA Lines ☑ Full Screen AA

Separation

Aperture

% paraprof app.ppk
Windows -> 3D Visualization -> Bar Plot (right pane)

TAU – 3D Communication Window



Display Options

Callpath: All Paths

Height Value: Max message size (bytes)

Color Value: Message volume (bytes)

Sender 8

Receiver 9

Height value 106080

Color value 3.9996E7

3.9997E7

☑ Show Color...

Font Size

● Rainbow ○ Gra...

○ Inverse Gra... ○ Blue...

○ Blue-White...

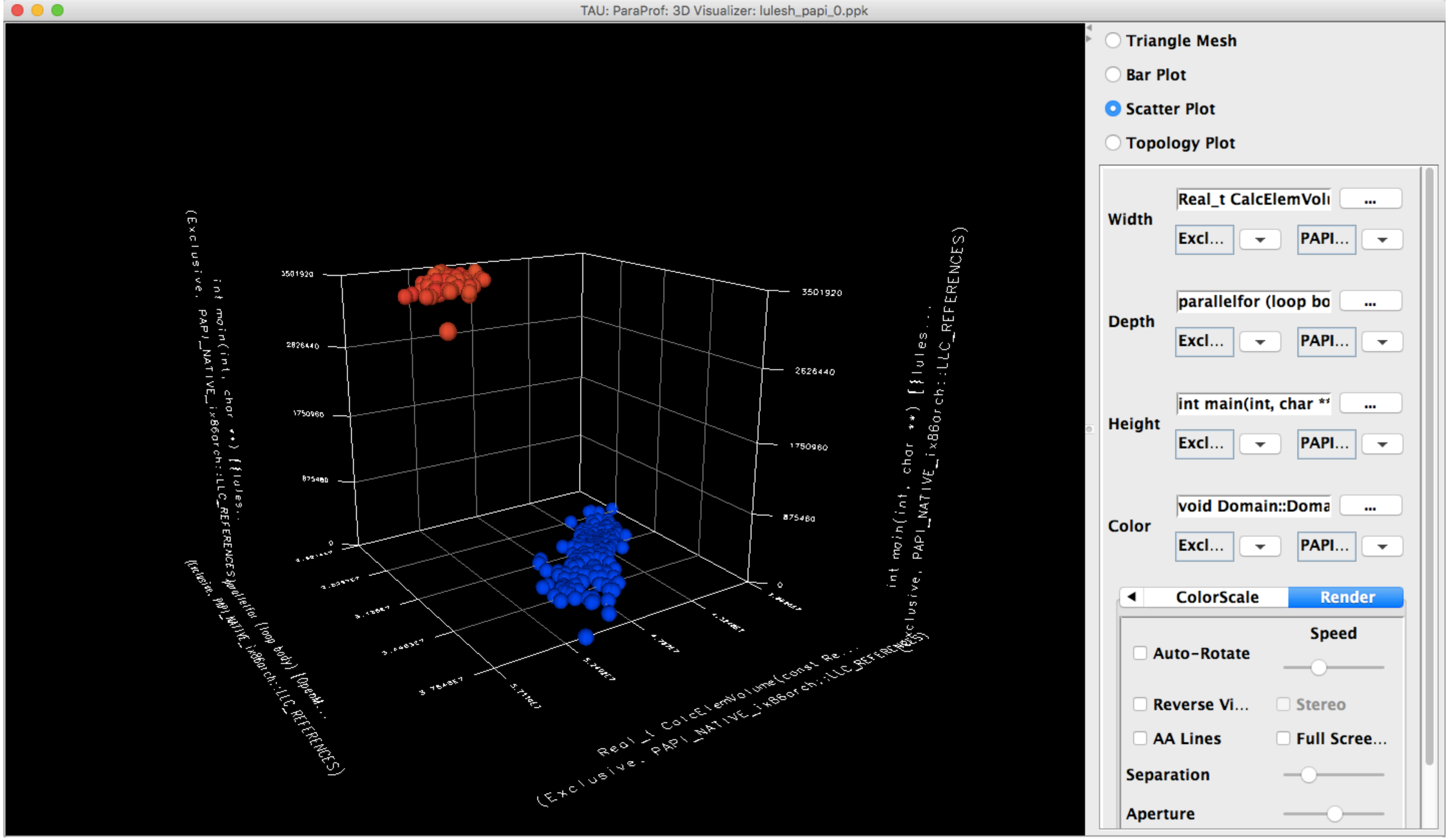
3.5916E7

Message volume (bytes)

```
% export TAU_COMM_MATRIX=1; mpirun ··· tau_exec ./a.out
% paraprof  app.ppk;     Windows -> 3D Communication Matrix
```

http://tau.uoregon.edu/tau_llnl19.pdf

TAU – 3D Scatter Plot



TAU: ParaProf: 3D Visualizer: lulesh_papi_0.ppk
(Exclusive, PAPI_NATIVE_ix86arch::LLC_REFERENCES)
int main(int, char **) [{lules...
3501920
2626440
1750960
875480
0
3.754E7
5.711E7
5.249E7
(Exclusive, PAPI_NATIVE_ix86arch::LLC_REFERENCES)
parallelfor (loop body) [OpenM...
(Exclusive, PAPI_NATIVE_ix86arch::LLC_REFERENCES)
Real_t CalcElemVolume(const Re...
(Exclusive, PAPI_NATIVE_ix86arch::LLC_REFERENCES)
int main(int, char **) [{lules...
3501920
2626440
1750960
875480
0

○ Triangle Mesh
○ Bar Plot
● Scatter Plot
○ Topology Plot

Width: Real_t CalcElemVolı ... Excl... PAPI...
Depth: parallelfor (loop bo ... Excl... PAPI...
Height: int main(int, char ** ... Excl... PAPI...
Color: void Domain::Doma ... Excl... PAPI...

ColorScale | Render

□ Auto-Rotate
Speed
□ Reverse Vi...
□ Stereo
□ AA Lines
□ Full Scree...
Separation
Aperture

% paraprof app.ppk;   Windows -> 3D Visualization -> Scatter Plot

Examples

Setting up Accounts, Examples at Sandia

```
On Serrano.sandia.gov
% tar zxf /projects/tau/workshop.tgz
% cd workshop
% source /projects/tau/tau.bashrc  (or tau.cshrc) for OpenMPI
% echo $TAU_MAKEFILE_BASE
% cat README
And try the examples.

OR:
```

See http://tau.uoregon.edu/workshop_summer19.tgz (cat README)

Setting up Accounts, Examples at LANL

```
On Grizzly gr-fe.lanl.gov:
% tar zxf /usr/projects/packages/tau/workshop.tgz
% cat README
% module load friendly-testing
% module load intel
% module load openmpi
% module load tau/2.28.2
% echo $TAU_MAKEFILE_BASE
/usr/projects/hpcsoft/toss3/grizzly/tau/2.28.2/x86_64/lib/
Makefile.tau-intel-18.0.5-openmpi-2.1.2
% echo $TAU_LTAG
intel-18.0.5-openmpi-2.1.2
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-mpi-pdt
OR:
```

See http://tau.uoregon.edu/workshop_summer19.tgz (cat README)

Setting up Accounts, Examples at LLNL

```
On quartz.llnl.gov:
% tar zxf /usr/global/tools/tau/training/workshop.tgz
% cat workshop/README workshop/handson.txt
% source /usr/global/tools/tau/training/tau.bashrc
% ls $TAU/Makefile*

On Lassen.llnl.gov:
% module load tau

OR:
```

See http://tau.uoregon.edu/workshop_llnl19.tgz (cat README)

Simplifying the use of TAU!

Uninstrumented code:

- % make
- % mpirun –np 256 ./a.out

With TAU:

- % mpirun –np 256 tau_exec ./a.out
- % paraprof

For more information at the statement level:

- % mpirun –np 256 tau_exec –ebs ./a.out
- % paraprof

To rewrite the binary to instrument individual functions (using MAQAO):

- % tau_rewrite a.out a.inst; mpirun –np 256 ./a.inst   (beta)
- % paraprof

TAU for Heterogeneous Measurement

Multiple performance perspectives

Integrate Host-GPU support in TAU measurement framework

- Enable use of each measurement approach
- Include use of PAPI and CUPTI
- Provide profiling and tracing support

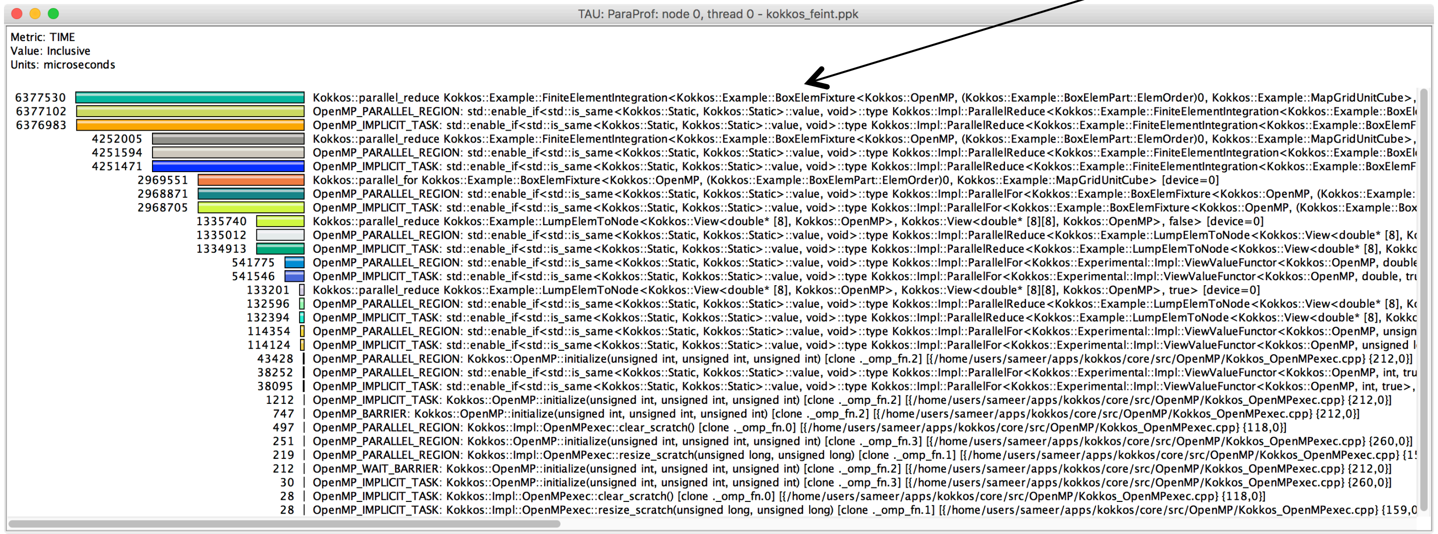
Tutorial

- Use TAU library wrapping of libraries
- Use `tau_exec` to work with binaries

```
% ./a.out    (uninstrumented)
% tau_exec –T <configuration tags> –cupti ./a.out
% paraprof
```

Kokkos profiling in TAU

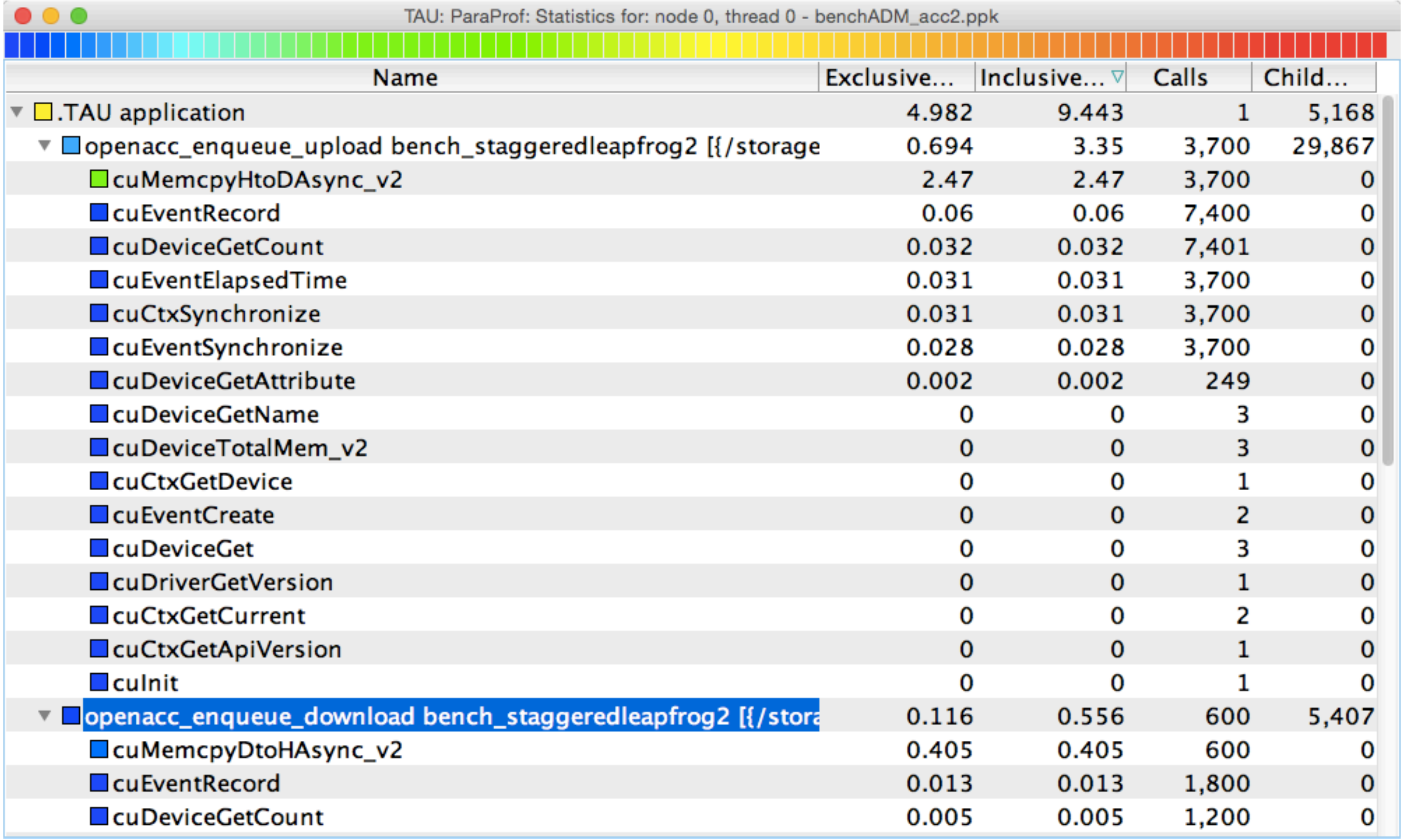
Kokkos kernel


TAU: ParaProf: node 0, thread 0 - kokkos_feint.ppk

```
Metric: TIME
Value: Inclusive
Units: microseconds

6377530  Kokkos::parallel_reduce Kokkos::Example::FiniteElementIntegration<Kokkos::Example::BoxElemFixture<Kokkos::OpenMP, (Kokkos::Example::BoxElemPart::ElemOrder)0, Kokkos::Example::MapGridUnitCube>,
6377102  OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelReduce<Kokkos::Example::FiniteElementIntegration<Kokkos::Example::BoxEl
6376983  OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelReduce<Kokkos::Example::FiniteElementIntegration<Kokkos::Example::BoxElemF
4252005  Kokkos::parallel_reduce Kokkos::Example::FiniteElementIntegration<Kokkos::Example::BoxElemFixture<Kokkos::OpenMP, (Kokkos::Example::BoxElemPart::ElemOrder)0, Kokkos::Example::MapGridUnitCube>,
4251594  OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelReduce<Kokkos::Example::FiniteElementIntegration<Kokkos::Example::BoxEl
4251471  OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelReduce<Kokkos::Example::FiniteElementIntegration<Kokkos::Example::BoxElemF
2969551  Kokkos::parallel_for Kokkos::Example::BoxElemFixture<Kokkos::OpenMP, (Kokkos::Example::BoxElemPart::ElemOrder)0, Kokkos::Example::MapGridUnitCube> [device=0]
2968871  OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelFor<Kokkos::Example::BoxElemFixture<Kokkos::OpenMP, (Kokkos::Example:
2968705  OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelFor<Kokkos::Example::BoxElemFixture<Kokkos::OpenMP, (Kokkos::Example::Box
1335740  Kokkos::parallel_reduce Kokkos::Example::LumpElemToNode<Kokkos::View<double* [8], Kokkos::OpenMP>, Kokkos::View<double* [8][8], Kokkos::OpenMP>, false> [device=0]
1335012  OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelReduce<Kokkos::Example::LumpElemToNode<Kokkos::View<double* [8], Kc
1334913  OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelReduce<Kokkos::Example::LumpElemToNode<Kokkos::View<double* [8], Kokkc
 541775  OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelFor<Kokkos::Experimental::Impl::ViewValueFunctor<Kokkos::OpenMP, double
 541546  OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelFor<Kokkos::Experimental::Impl::ViewValueFunctor<Kokkos::OpenMP, double, tru
 133201  Kokkos::parallel_reduce Kokkos::Example::LumpElemToNode<Kokkos::View<double* [8], Kokkos::OpenMP>, Kokkos::View<double* [8][8], Kokkos::OpenMP>, true> [device=0]
 132596  OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelReduce<Kokkos::Example::LumpElemToNode<Kokkos::View<double* [8], Kc
 132394  OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelReduce<Kokkos::Example::LumpElemToNode<Kokkos::View<double* [8], Kokkc
 114354  OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelFor<Kokkos::Experimental::Impl::ViewValueFunctor<Kokkos::OpenMP, unsign
 114124  OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelFor<Kokkos::Experimental::Impl::ViewValueFunctor<Kokkos::OpenMP, unsigned l
  43428  OpenMP_PARALLEL_REGION: Kokkos::OpenMP::initialize(unsigned int, unsigned int, unsigned int) [clone ._omp_fn.2] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {212,0}]
  38252  OpenMP_PARALLEL_REGION: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelFor<Kokkos::Experimental::Impl::ViewValueFunctor<Kokkos::OpenMP, int, tru
  38095  OpenMP_IMPLICIT_TASK: std::enable_if<std::is_same<Kokkos::Static, Kokkos::Static>::value, void>::type Kokkos::Impl::ParallelFor<Kokkos::Experimental::Impl::ViewValueFunctor<Kokkos::OpenMP, int, true>,
   1212  OpenMP_IMPLICIT_TASK: Kokkos::OpenMP::initialize(unsigned int, unsigned int, unsigned int) [clone ._omp_fn.2] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {212,0}]
    747  OpenMP_BARRIER: Kokkos::OpenMP::initialize(unsigned int, unsigned int, unsigned int) [clone ._omp_fn.2] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {212,0}]
    497  OpenMP_PARALLEL_REGION: Kokkos::Impl::OpenMPexec::clear_scratch() [clone ._omp_fn.0] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {118,0}]
    251  OpenMP_PARALLEL_REGION: Kokkos::OpenMP::initialize(unsigned int, unsigned int, unsigned int) [clone ._omp_fn.3] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {260,0}]
    219  OpenMP_PARALLEL_REGION: Kokkos::Impl::OpenMPexec::resize_scratch(unsigned long, unsigned long) [clone ._omp_fn.1] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {15
    212  OpenMP_WAIT_BARRIER: Kokkos::OpenMP::initialize(unsigned int, unsigned int, unsigned int) [clone ._omp_fn.2] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {212,0}]
     30  OpenMP_IMPLICIT_TASK: Kokkos::OpenMP::initialize(unsigned int, unsigned int, unsigned int) [clone ._omp_fn.3] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {260,0}]
     28  OpenMP_IMPLICIT_TASK: Kokkos::Impl::OpenMPexec::clear_scratch() [clone ._omp_fn.0] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {118,0}]
     28  OpenMP_IMPLICIT_TASK: Kokkos::Impl::OpenMPexec::resize_scratch(unsigned long, unsigned long) [clone ._omp_fn.1] [{/home/users/sameer/apps/kokkos/core/src/OpenMP/Kokkos_OpenMPexec.cpp} {159,0
```

Use tau_exec to launch an uninstrumented binary that uses Kokkos to expose the Kokkos runtime profiling interface.

OpenACC with PGI compilers

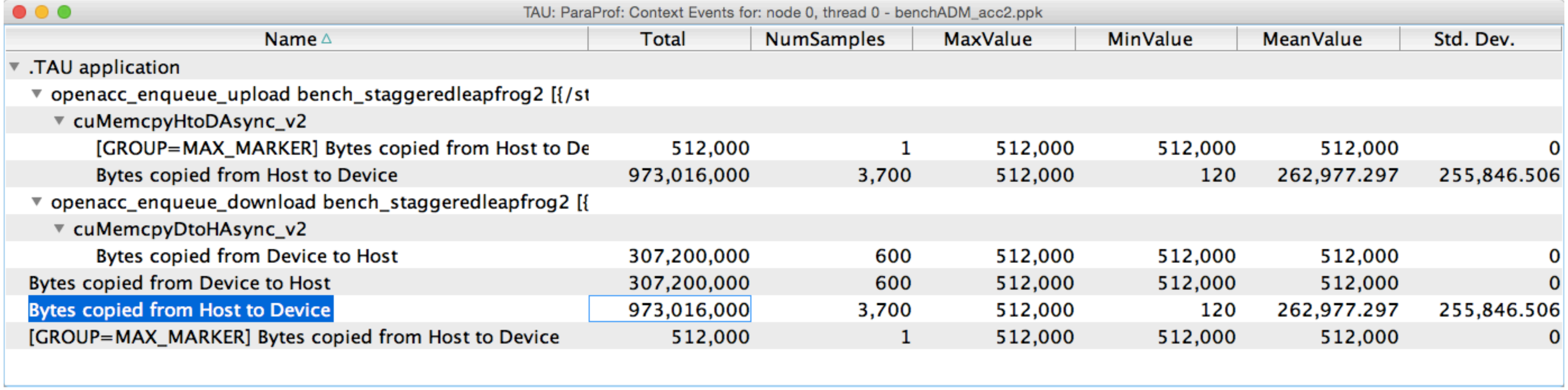


TAU: ParaProf: Statistics for: node 0, thread 0 - benchADM_acc2.ppk

Name	Exclusive...	Inclusive... ▽	Calls	Child...
▼ 🟨 .TAU application	4.982	9.443	1	5,168
▼ 🟦 openacc_enqueue_upload bench_staggeredleapfrog2 [{/storage	0.694	3.35	3,700	29,867
🟩 cuMemcpyHtoDAsync_v2	2.47	2.47	3,700	0
🟦 cuEventRecord	0.06	0.06	7,400	0
🟦 cuDeviceGetCount	0.032	0.032	7,401	0
🟦 cuEventElapsedTime	0.031	0.031	3,700	0
🟦 cuCtxSynchronize	0.031	0.031	3,700	0
🟦 cuEventSynchronize	0.028	0.028	3,700	0
🟦 cuDeviceGetAttribute	0.002	0.002	249	0
🟦 cuDeviceGetName	0	0	3	0
🟦 cuDeviceTotalMem_v2	0	0	3	0
🟦 cuCtxGetDevice	0	0	1	0
🟦 cuEventCreate	0	0	2	0
🟦 cuDeviceGet	0	0	3	0
🟦 cuDriverGetVersion	0	0	1	0
🟦 cuCtxGetCurrent	0	0	2	0
🟦 cuCtxGetApiVersion	0	0	1	0
🟦 cuInit	0	0	1	0
▼ 🟦 openacc_enqueue_download bench_staggeredleapfrog2 [{/stora	0.116	0.556	600	5,407
🟦 cuMemcpyDtoHAsync_v2	0.405	0.405	600	0
🟦 cuEventRecord	0.013	0.013	1,800	0
🟦 cuDeviceGetCount	0.005	0.005	1,200	0

```
% configure –c++=pgCC –cc=pgcc –fortran=pgi …
% tau_exec –T pgi  -openacc -cupti  ./a.out
```

Tracking OpenACC Data Transfers



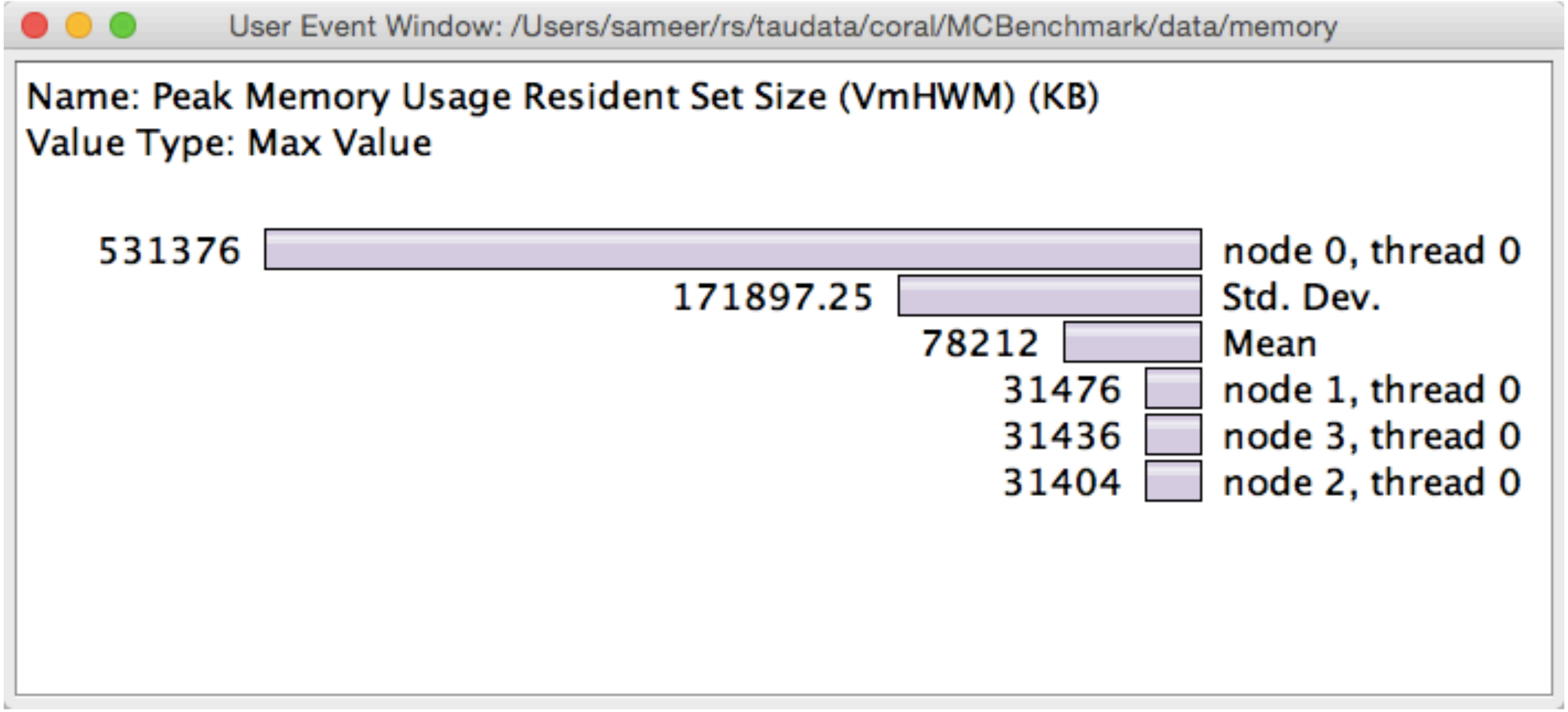
TAU: ParaProf: Context Events for: node 0, thread 0 - benchADM_acc2.ppk

Name △	Total	NumSamples	MaxValue	MinValue	MeanValue	Std. Dev.
▼ .TAU application						
▼ openacc_enqueue_upload bench_staggeredleapfrog2 [{/st						
▼ cuMemcpyHtoDAsync_v2						
[GROUP=MAX_MARKER] Bytes copied from Host to De	512,000	1	512,000	512,000	512,000	0
Bytes copied from Host to Device	973,016,000	3,700	512,000	120	262,977.297	255,846.506
▼ openacc_enqueue_download bench_staggeredleapfrog2 [{						
▼ cuMemcpyDtoHAsync_v2						
Bytes copied from Device to Host	307,200,000	600	512,000	512,000	512,000	0
Bytes copied from Device to Host	307,200,000	600	512,000	512,000	512,000	0
Bytes copied from Host to Device	973,016,000	3,700	512,000	120	262,977.297	255,846.506
[GROUP=MAX_MARKER] Bytes copied from Host to Device	512,000	1	512,000	512,000	512,000	0

```
% configure –c++=pgCC –cc=pgcc –fortran=pgi …
% tau_exec –T pgi  -openacc -cupti  ./a.out
```

Context events show extent of variation

Measuring Memory Footprint



User Event Window: /Users/sameer/rs/taudata/coral/MCBenchmark/data/memory

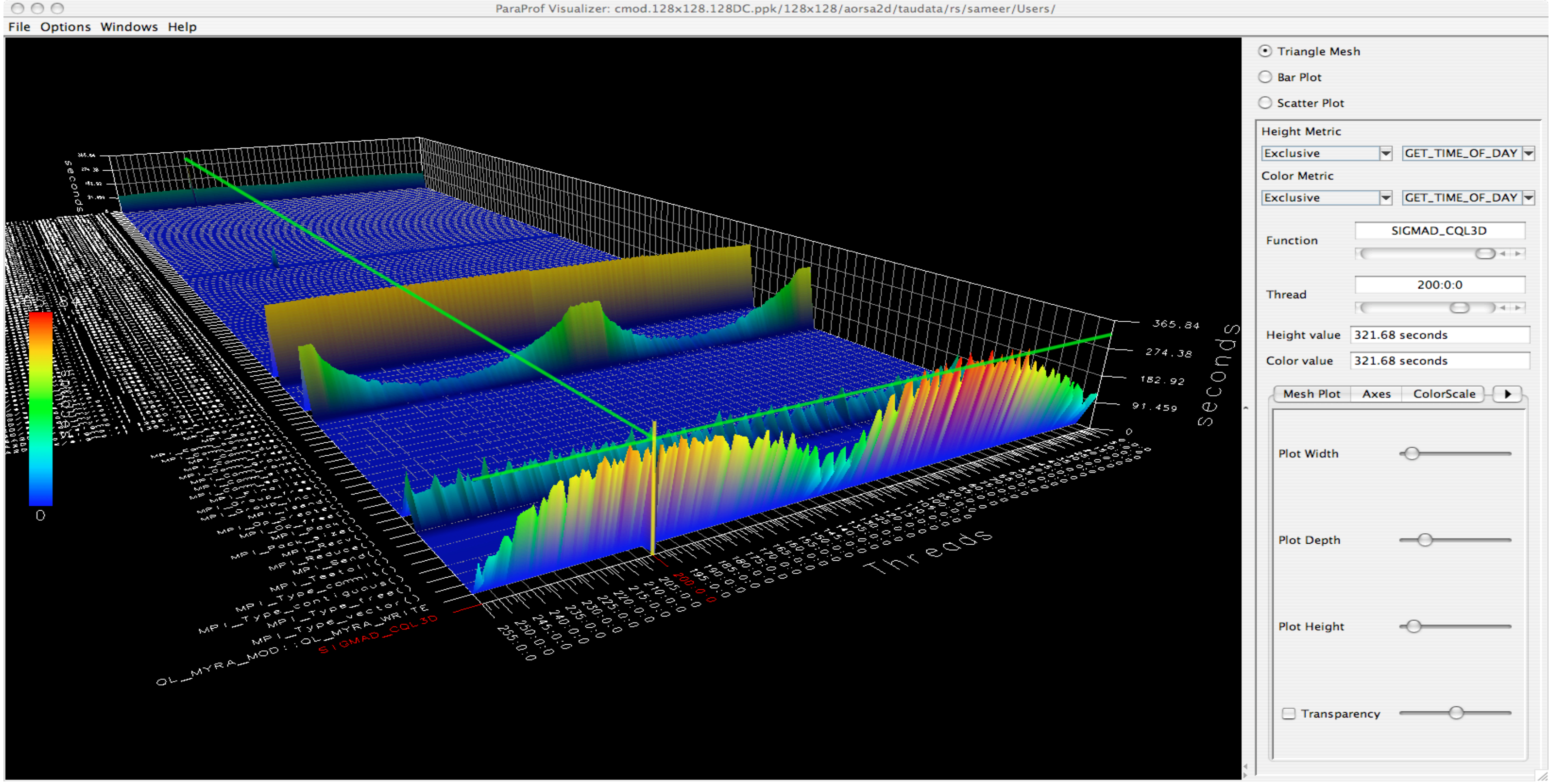
Name: Peak Memory Usage Resident Set Size (VmHWM) (KB)
Value Type: Max Value

```
% export TAU_TRACK_MEMORY_FOOTPRINT=1
```

Paraprof:

Right click on a node -> Show Context Event Window -> see memory events

ParaProf 3D Profile Browser



ParaProf Visualizer: cmod.128x128.128DC.ppk/128x128/aorsa2d/taudata/rs/sameer/Users/

File Options Windows Help

● Triangle Mesh

○ Bar Plot

○ Scatter Plot

Height Metric

Exclusive GET_TIME_OF_DAY

Color Metric

Exclusive GET_TIME_OF_DAY

Function: SIGMAD_CQL3D

Thread: 200:0:0

Height value: 321.68 seconds

Color value: 321.68 seconds

TAU Performance System®

http://tau.uoregon.edu

- **Tuning and Analysis Utilities (20+ year project)**
- **Comprehensive performance profiling and tracing**
  - Integrated, scalable, flexible, portable
  - Targets all parallel programming/execution paradigms
- **Integrated performance toolkit**
  - Instrumentation, measurement, analysis, visualization
  - Widely-ported performance profiling / tracing system
  - Performance data management and data mining
  - Open source (BSD-style license)
- **Integrates with application frameworks**

What does TAU support?

OpenCL

C/C++ CUDA UPC

GPI Python

Fortran

OpenACC Java MPI

pthreads

Intel MIC OpenMP

Intel GNU

PGI Sun

LLVM Cray

MPC

AIX

Linux Windows

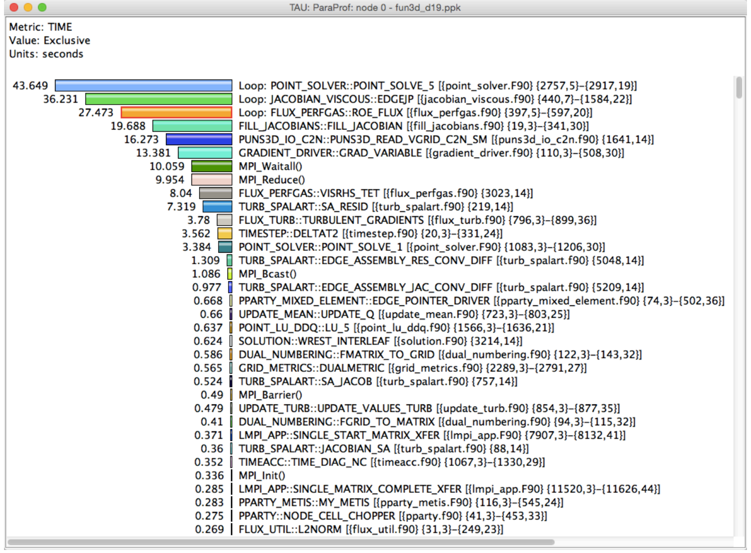
Insert yours here

BlueGene Fujitsu ARM64

NVIDIA Power 8 OS X

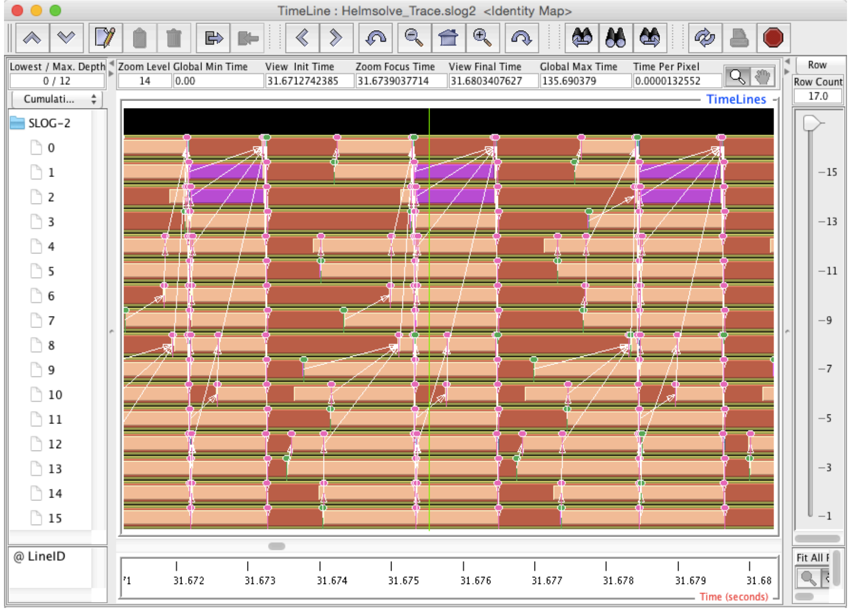
Profiling and Tracing

Profiling



```
Metric: TIME
Value: Exclusive
Units: seconds

43.649  Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]
36.231  Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]
27.473  Loop: FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {397,5}-{597,20}]
19.688  FILL_JACOBIANS::FILL_JACOBIAN [{fill_jacobians.f90} {19,3}-{341,30}]
16.273  PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N_SM [{puns3d_io_c2n.f90} {1641,14}]
13.381  GRADIENT_DRIVER::GRAD_VARIABLE [{gradient_driver.f90} {110,3}-{508,30}]
10.059  MPI_Waitall()
 9.954  MPI_Reduce()
  8.04  FLUX_PERFGAS::VISRHS_TET [{flux_perfgas.f90} {3023,14}]
 7.319  TURB_SPALART::SA_RESID [{turb_spalart.f90} {219,14}]
  3.78  FLUX_TURB::TURBULENT_GRADIENTS [{flux_turb.f90} {796,3}-{899,36}]
 3.562  TIMESTEP::DELTAT2 [{timestep.f90} {20,3}-{331,24}]
 3.384  POINT_SOLVER::POINT_SOLVE_1 [{point_solver.F90} {1083,3}-{1206,30}]
 1.309  TURB_SPALART::EDGE_ASSEMBLY_RES_CONV_DIFF [{turb_spalart.f90} {5048,14}]
 1.086  MPI_Bcast()
 0.977  TURB_SPALART::EDGE_ASSEMBLY_JAC_CONV_DIFF [{turb_spalart.f90} {5209,14}]
 0.668  PPARTY_MIXED_ELEMENT::EDGE_POINTER_DRIVER [{pparty_mixed_element.f90} {74,3}-{502,36}]
  0.66  UPDATE_MEAN::UPDATE_Q [{update_mean.F90} {723,3}-{803,25}]
 0.637  POINT_LU_DDQ::LU_5 [{point_lu_ddq.f90} {1566,3}-{1636,21}]
 0.624  SOLUTION::WREST_INTERLEAF [{solution.F90} {3214,14}]
 0.586  DUAL_NUMBERING::FMATRIX_TO_GRID [{dual_numbering.f90} {122,3}-{143,32}]
 0.565  GRID_METRICS::DUALMETRIC [{grid_metrics.f90} {2289,3}-{2791,27}]
 0.524  TURB_SPALART::SA_JACOB [{turb_spalart.f90} {757,14}]
  0.49  MPI_Barrier()
 0.479  UPDATE_TURB::UPDATE_VALUES_TURB [{update_turb.f90} {854,3}-{877,35}]
  0.41  DUAL_NUMBERING::FGRID_TO_MATRIX [{dual_numbering.f90} {94,3}-{115,32}]
 0.371  LMPI_APP::SINGLE_START_MATRIX_XFER [{lmpi_app.F90} {7907,3}-{8132,41}]
  0.36  TURB_SPALART::JACOBIAN_SA [{turb_spalart.f90} {88,14}]
 0.352  TIMEACC::TIME_DIAG_NC [{timeacc.f90} {1067,3}-{1330,29}]
 0.336  MPI_Init()
 0.285  LMPI_APP::SINGLE_MATRIX_COMPLETE_XFER [{lmpi_app.F90} {11520,3}-{11626,44}]
 0.283  PPARTY_METIS::MY_METIS [{pparty_metis.F90} {116,3}-{545,24}]
 0.275  PPARTY::NODE_CELL_CHOPPER [{pparty.f90} {41,3}-{453,33}]
 0.269  FLUX_UTIL::L2NORM [{flux_util.f90} {31,3}-{249,23}]
```

Tracing

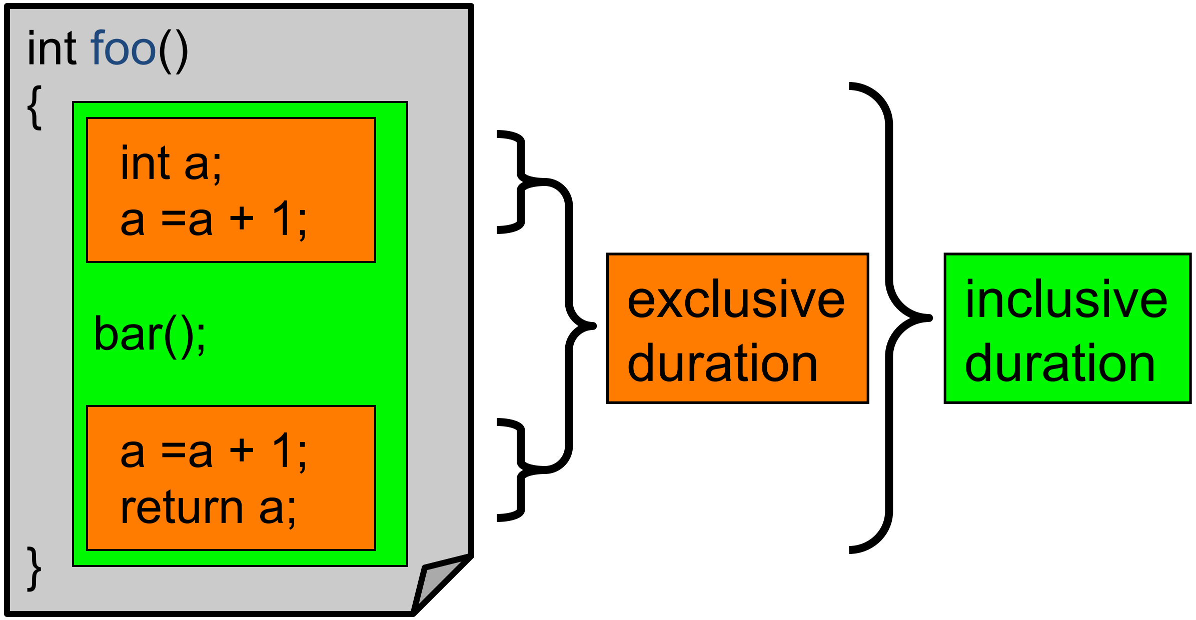


Lowest / Max. Depth	Zoom Level	Global Min Time	View Init Time	Zoom Focus Time	View Final Time	Global Max Time	Time Per Pixel	Row Count
0 / 12	14	0.00	31.6712742385	31.6739037714	31.6803407627	135.690379	0.0000132552	17.0

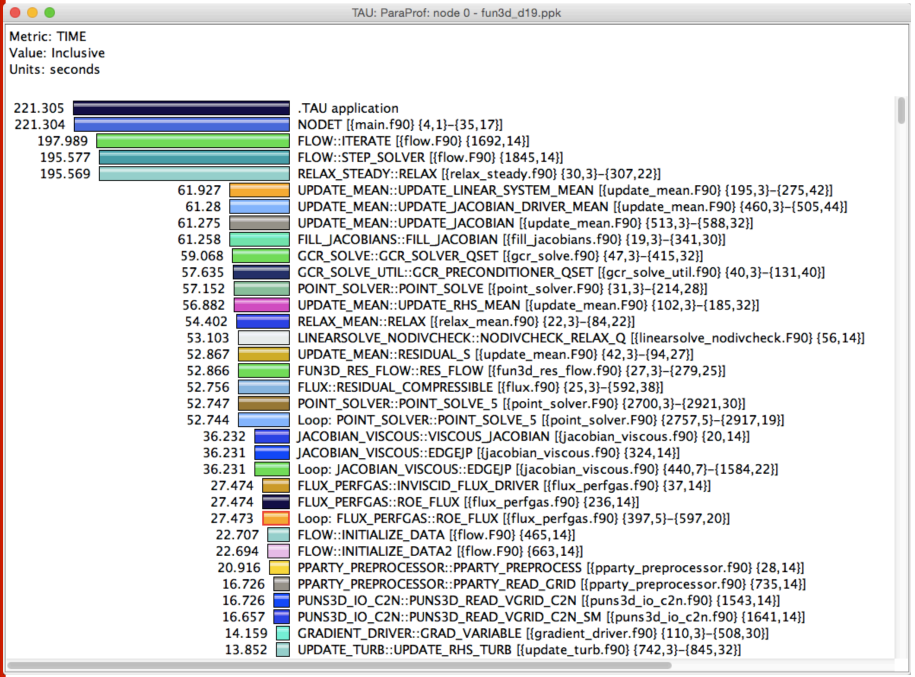
- Profiling and tracing
  - **Profiling** shows you **how much** (total) time was spent in each routine
  - **Tracing** shows you **when** the events take place on a timeline

Inclusive vs. Exclusive Measurements

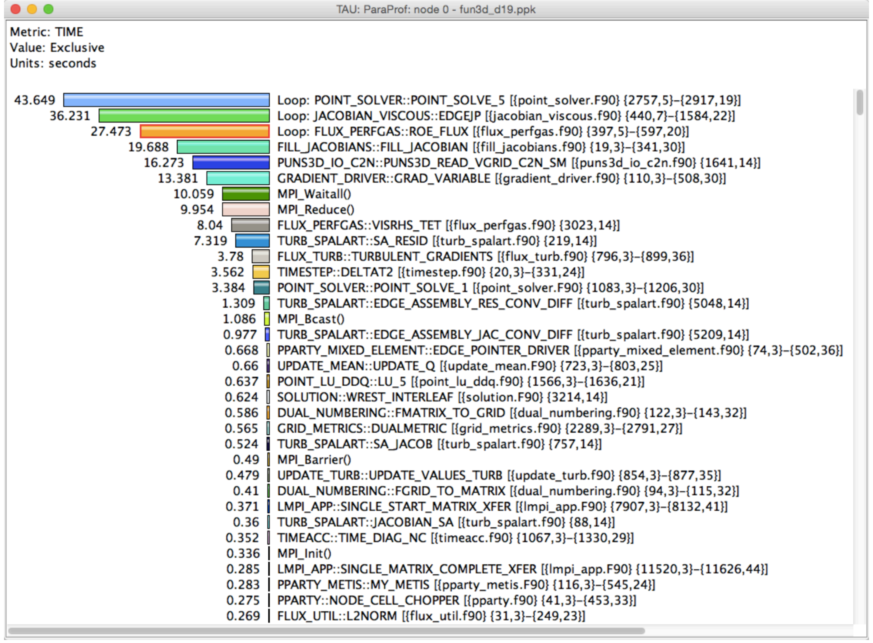
- Performance with respect to code regions
- Exclusive measurements for region only
- Inclusive measurements includes child regions



Inclusive vs. Exclusive Measurements



```
Metric: TIME
Value: Inclusive
Units: seconds

221.305 .TAU application
221.304 NODET [{main.f90} {4,1}-{35,17}]
197.989 FLOW::ITERATE [{flow.F90} {1692,14}]
195.577 FLOW::STEP_SOLVER [{flow.F90} {1845,14}]
195.569 RELAX_STEADY::RELAX [{relax_steady.f90} {30,3}-{307,22}]
 61.927 UPDATE_MEAN::UPDATE_LINEAR_SYSTEM_MEAN [{update_mean.F90} {195,3}-{275,42}]
 61.28  UPDATE_MEAN::UPDATE_JACOBIAN_DRIVER_MEAN [{update_mean.F90} {460,3}-{505,44}]
 61.275 UPDATE_MEAN::UPDATE_JACOBIAN [{update_mean.F90} {513,3}-{588,32}]
 61.258 FILL_JACOBIANS::FILL_JACOBIAN [{fill_jacobians.f90} {19,3}-{341,30}]
 59.068 GCR_SOLVE::GCR_SOLVER_QSET [{gcr_solve.f90} {47,3}-{415,32}]
 57.635 GCR_SOLVE_UTIL::GCR_PRECONDITIONER_QSET [{gcr_solve_util.f90} {40,3}-{131,40}]
 57.152 POINT_SOLVER::POINT_SOLVE [{point_solver.F90} {31,3}-{214,28}]
 56.882 UPDATE_MEAN::UPDATE_RHS_MEAN [{update_mean.F90} {102,3}-{185,32}]
 54.402 RELAX_MEAN::RELAX [{relax_mean.f90} {22,3}-{84,22}]
 53.103 LINEARSOLVE_NODIVCHECK::NODIVCHECK_RELAX_Q [{linearsolve_nodivcheck.F90} {56,14}]
 52.867 UPDATE_MEAN::RESIDUAL_S [{update_mean.F90} {42,3}-{94,27}]
 52.866 FUN3D_RES_FLOW::RES_FLOW [{fun3d_res_flow.f90} {27,3}-{279,25}]
 52.756 FLUX::RESIDUAL_COMPRESSIBLE [{flux.f90} {25,3}-{592,38}]
 52.747 POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2700,3}-{2921,30}]
 52.744 Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]
 36.232 JACOBIAN_VISCOUS::VISCOUS_JACOBIAN [{jacobian_viscous.f90} {20,14}]
 36.231 JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {324,14}]
 36.231 Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]
 27.474 FLUX_PERFGAS::INVISCID_FLUX_DRIVER [{flux_perfgas.f90} {37,14}]
 27.474 FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {236,14}]
 27.473 Loop: FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {397,5}-{597,20}]
 22.707 FLOW::INITIALIZE_DATA [{flow.F90} {465,14}]
 22.694 FLOW::INITIALIZE_DATA2 [{flow.F90} {663,14}]
 20.916 PPARTY_PREPROCESSOR::PPARTY_PREPROCESS [{pparty_preprocessor.f90} {28,14}]
 16.726 PPARTY_PREPROCESSOR::PPARTY_READ_GRID [{pparty_preprocessor.f90} {735,14}]
 16.726 PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N [{puns3d_io_c2n.f90} {1543,14}]
 16.657 PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N_SM [{puns3d_io_c2n.f90} {1641,14}]
 14.159 GRADIENT_DRIVER::GRAD_VARIABLE [{gradient_driver.f90} {110,3}-{508,30}]
 13.852 UPDATE_TURB::UPDATE_RHS_TURB [{update_turb.f90} {742,3}-{845,32}]
```

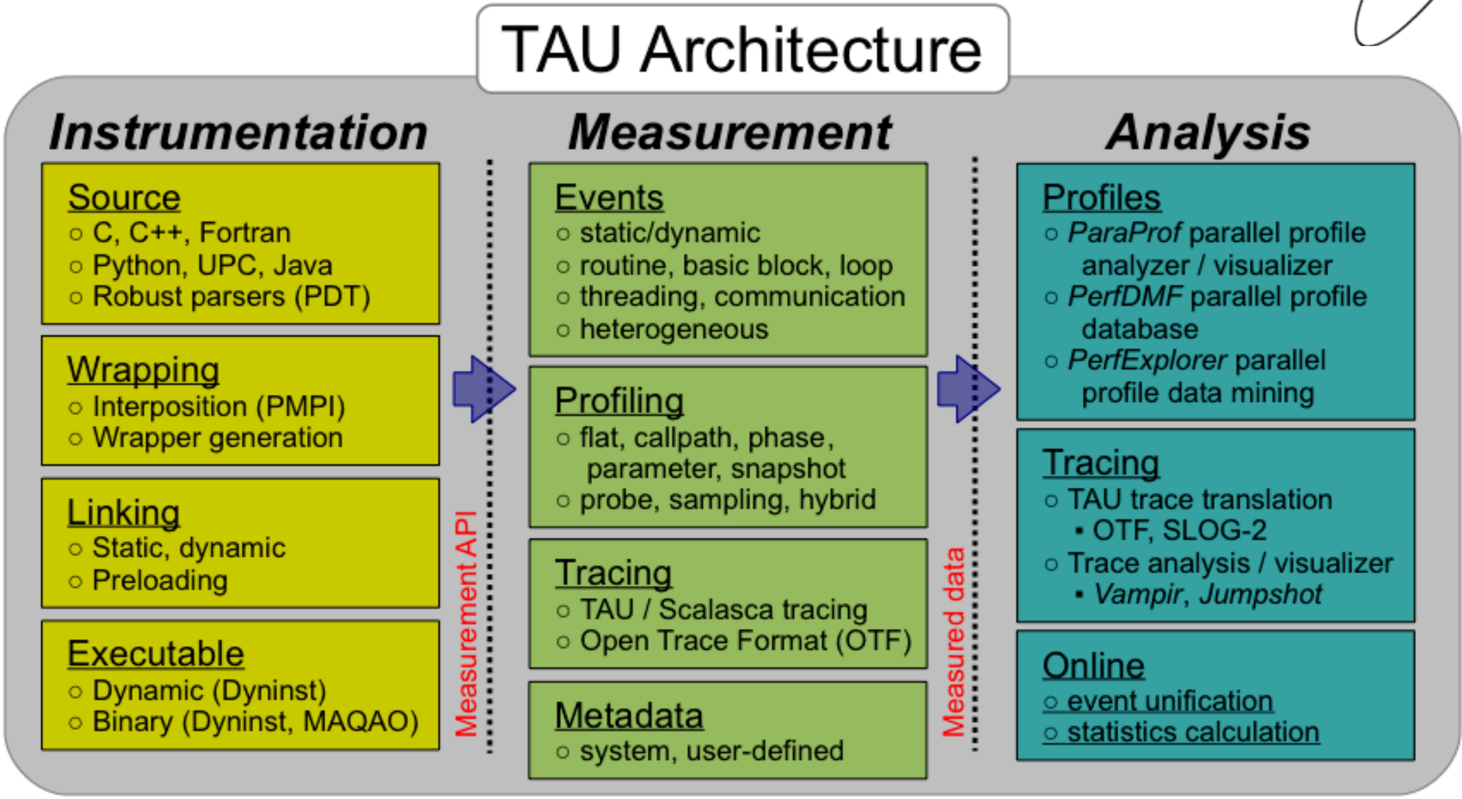


```
Metric: TIME
Value: Exclusive
Units: seconds

43.649 Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]
36.231 Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]
27.473 Loop: FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {397,5}-{597,20}]
19.688 FILL_JACOBIANS::FILL_JACOBIAN [{fill_jacobians.f90} {19,3}-{341,30}]
16.273 PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N_SM [{puns3d_io_c2n.f90} {1641,14}]
13.381 GRADIENT_DRIVER::GRAD_VARIABLE [{gradient_driver.f90} {110,3}-{508,30}]
10.059 MPI_Waitall()
 9.954 MPI_Reduce()
 8.04  FLUX_PERFGAS::VISRHS_TET [{flux_perfgas.f90} {3023,14}]
 7.319 TURB_SPALART::SA_RESID [{turb_spalart.f90} {219,14}]
 3.78  FLUX_TURB::TURBULENT_GRADIENTS [{flux_turb.f90} {796,3}-{899,36}]
 3.562 TIMESTEP::DELTAT2 [{timestep.f90} {20,3}-{331,24}]
 3.384 POINT_SOLVER::POINT_SOLVE_1 [{point_solver.F90} {1083,3}-{1206,30}]
 1.309 TURB_SPALART::EDGE_ASSEMBLY_RES_CONV_DIFF [{turb_spalart.f90} {5048,14}]
 1.086 MPI_Bcast()
 0.977 TURB_SPALART::EDGE_ASSEMBLY_JAC_CONV_DIFF [{turb_spalart.f90} {5209,14}]
 0.668 PPARTY_MIXED_ELEMENT::EDGE_POINTER_DRIVER [{pparty_mixed_element.f90} {74,3}-{502,36}]
 0.66  UPDATE_MEAN::UPDATE_Q [{update_mean.F90} {723,3}-{803,25}]
 0.637 POINT_LU_DDQ::LU_5 [{point_lu_ddq.f90} {1566,3}-{1636,21}]
 0.624 SOLUTION::WREST_INTERLEAF [{solution.F90} {3214,14}]
 0.586 DUAL_NUMBERING::FMATRIX_TO_GRID [{dual_numbering.f90} {122,3}-{143,32}]
 0.565 GRID_METRICS::DUALMETRIC [{grid_metrics.f90} {2289,3}-{2791,27}]
 0.524 TURB_SPALART::SA_JACOB [{turb_spalart.f90} {757,14}]
 0.49  MPI_Barrier()
 0.479 UPDATE_TURB::UPDATE_VALUES_TURB [{update_turb.f90} {854,3}-{877,35}]
 0.41  DUAL_NUMBERING::FGRID_TO_MATRIX [{dual_numbering.f90} {94,3}-{115,32}]
 0.371 LMPI_APP::SINGLE_START_MATRIX_XFER [{lmpi_app.F90} {7907,3}-{8132,41}]
 0.36  TURB_SPALART::JACOBIAN_SA [{turb_spalart.f90} {88,14}]
 0.352 TIMEACC::TIME_DIAG_NC [{timeacc.f90} {1067,3}-{1330,29}]
 0.336 MPI_Init()
 0.285 LMPI_APP::SINGLE_MATRIX_COMPLETE_XFER [{lmpi_app.F90} {11520,3}-{11626,44}]
 0.283 PPARTY_METIS::MY_METIS [{pparty_metis.F90} {116,3}-{545,24}]
 0.275 PPARTY::NODE_CELL_CHOPPER [{pparty.f90} {41,3}-{453,33}]
 0.269 FLUX_UTIL::L2NORM [{flux_util.f90} {31,3}-{249,23}]
```

Inclusive time

Exclusive time

TAU Architecture and Workflow



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

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

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 Architecture and Workflow

Instrumentation: **Add probes to perform measurements**

- Source code instrumentation using pre-processors and compiler scripts
- Wrapping external libraries (I/O, MPI, Memory, CUDA, OpenCL, pthread)
- Rewriting the binary executable

Measurement: **Profiling or tracing using various metrics**

- Direct instrumentation (Interval events measure exclusive or inclusive duration)
- Indirect instrumentation (Sampling measures statement level contribution)
- Throttling and runtime control of low-level events that execute frequently
- Per-thread storage of performance data
- Interface with external packages (e.g. PAPI hw performance counter library)

Analysis: **Visualization of profiles and traces**

- 3D visualization of profile data in paraprof or perfexplorer tools
- Trace conversion & display in external visualizers (Vampir, Jumpshot, ParaVer)

Instrumentation

Direct and indirect performance observation

- Instrumentation invokes performance measurement
- Direct measurement with *probes*
- Indirect measurement with periodic sampling or hardware performance counter overflow interrupts
- Events measure performance data, metadata, context, etc.

User-defined events

- ***Interval*** (start/stop) events to measure exclusive & inclusive duration
- ***Atomic events*** take measurements at a single point
  - Measures total, samples, min/max/mean/std. deviation statistics
- ***Context events*** are atomic events with executing context
  - Measures above statistics for a given calling path

Instrumentation

Add hooks in the code to perform measurements

Source instrumentation using a preprocessor

- Add timer start/stop calls in a copy of the source code.
- Use Program Database Toolkit (PDT) for parsing source code.
- Requires recompiling the code using TAU shell scripts (tau_cc.sh, tau_f90.sh)
- Selective instrumentation (filter file) can reduce runtime overhead and narrow instrumentation focus.

Compiler-based instrumentation

- Use system compiler to add a special flag to insert hooks at routine entry/exit.
- Requires recompiling using TAU compiler scripts (tau_cc.sh, tau_f90.sh…)

Runtime preloading of TAU's Dynamic Shared Object (DSO)

- No need to recompile code! Use **aprun tau_exec ./app** with options.
- Requires dynamic executable (link using **−dynamic** on Cray).

Examples

Using TAU

TAU supports several measurement and thread options

Phase profiling, profiling with hardware counters, MPI library, CUDA…

Each measurement configuration of TAU corresponds to a unique stub makefile and library that is generated when you configure it

To instrument source code automatically using PDT

Choose an appropriate TAU stub makefile in <arch>/lib:

(or module load tau…)

```
% export TAU_MAKEFILE=$TAU/Makefile.tau-icpc-papi-mpi-pdt
% export TAU_OPTIONS=‘-optVerbose …’ (see tau_compiler.sh )
% export PATH=$TAUDIR/x86_64/bin:$PATH
```

Use tau_f90.sh, tau_cxx.sh, tau_upc.sh, or tau_cc.sh as F90, C++, UPC, or C compilers respectively:

```
% mpif90 foo.f90        changes to
% tau_f90.sh foo.f90
```

Set runtime environment variables, execute application and analyze performance data:

```
% pprof   (for text based profile display)
% paraprof  (for GUI)
```

Choosing TAU_MAKEFILE

```
At LLNL (Quartz):
% source /usr/global/tools/tau/training/tau.bashrc
% echo $TAU
/usr/global/tools/tau/training//tau_latest/x86_64/lib
% ls $TAU/Makefile*
/usr/global/tools/tau/training//tau_latest/x86_64/lib/Makefile.tau-icpc-mpi-pdt
/usr/global/tools/tau/training//tau_latest/x86_64/lib/Makefile.tau-icpc-papi-mpi-pdt-openmp-opari
/usr/global/tools/tau/training//tau_latest/x86_64/lib/Makefile.tau-icpc-papi-mpi-pthread-pdt
/usr/global/tools/tau/training//tau_latest/x86_64/lib/Makefile.tau-icpc-papi-mpi-pthread-python-pdt
/usr/global/tools/tau/training//tau_latest/x86_64/lib/Makefile.tau-icpc-papi-ompt-v5-mpi-pdt-openmp
/usr/global/tools/tau/training//tau_latest/x86_64/lib/Makefile.tau-icpc-papi-ompt-v5-pdt-openmp
/usr/global/tools/tau/training//tau_latest/x86_64/lib/Makefile.tau-icpc-pdt
```

For an MPI+F90 application with Intel MPI, you may choose

`$TAU/Makefile.tau-icpc-mpi-pdt`

- Supports MPI instrumentation & PDT for automatic source instrumentation

```
% export TAU_MAKEFILE=$TAU/Makefile.tau-icpc-mpi-pdt

% tau_f90.sh matrix.f90 -o matrix
OR with build systems:
% make CC=tau_cc.sh CXX=tau_cxx.sh F90=tau_f90.sh
% cmake -DCMAKE_Fortran_COMPILER=tau_f90.sh
       -DCMAKE_C_COMPILER=tau_cc.sh -DCMAKE_CXX_COMPILER=tau_cxx.sh
% <ALLOCATE a NODE>
% mpirun -np 256 ./matrix   (lrun on lassen/srun on Quartz)
% paraprof
```

Configuration tags for tau_exec

```
% ./configure -pdt=<dir> -mpi -papi=<dir>; make install
```

Creates in $TAU:

```
Makefile.tau-papi-mpi-pdt(Configuration parameters in stub makefile)
shared-papi-mpi-pdt/libTAU.so
```

```
% ./configure -pdt=<dir> -mpi; make install
```

creates

```
Makefile.tau-mpi-pdt
shared-mpi-pdt/libTAU.so
```

To explicitly choose preloading of shared-<options>/libTAU.so change:

```
% mpirun -np 256 ./a.out      to
% mpirun -np 256  tau_exec –T <comma_separated_options> ./a.out
```

```
% mpirun -np 256  tau_exec –T papi,mpi,pdt ./a.out
```

Preloads `$TAU/shared-papi-mpi-pdt/libTAU.so`

```
% mpirun -np 256  tau_exec –T papi ./a.out
```

Preloads `$TAU/shared-papi-mpi-pdt/libTAU.so by matching.`

```
% mpirun -np 256 tau_exec –T papi,mpi,pdt –s ./a.out
```

Does not execute the program. Just displays the library that it will preload if executed without the –s option.

NOTE: -mpi configuration is selected by default. Use –T serial for Sequential programs.

Binary Rewriting Instrumentation

- Support for both **static and dynamic** executables
- Specify a list of routines to instrument
- Specify the TAU measurement library to be injected
- **Dyninst [U. Wisconsin, U. Maryland]**:

```
% tau_run -T [tags] a.out -o a.inst
```

- **MAQAO [Intel Exascale Labs, UVSQ]**:

```
% tau_rewrite -T [tags] a.out -o a.inst
```

- **Pebil [SDSC]**:

```
% tau_pebil_rewrite -T [tags] a.out \
  -o a.inst
```

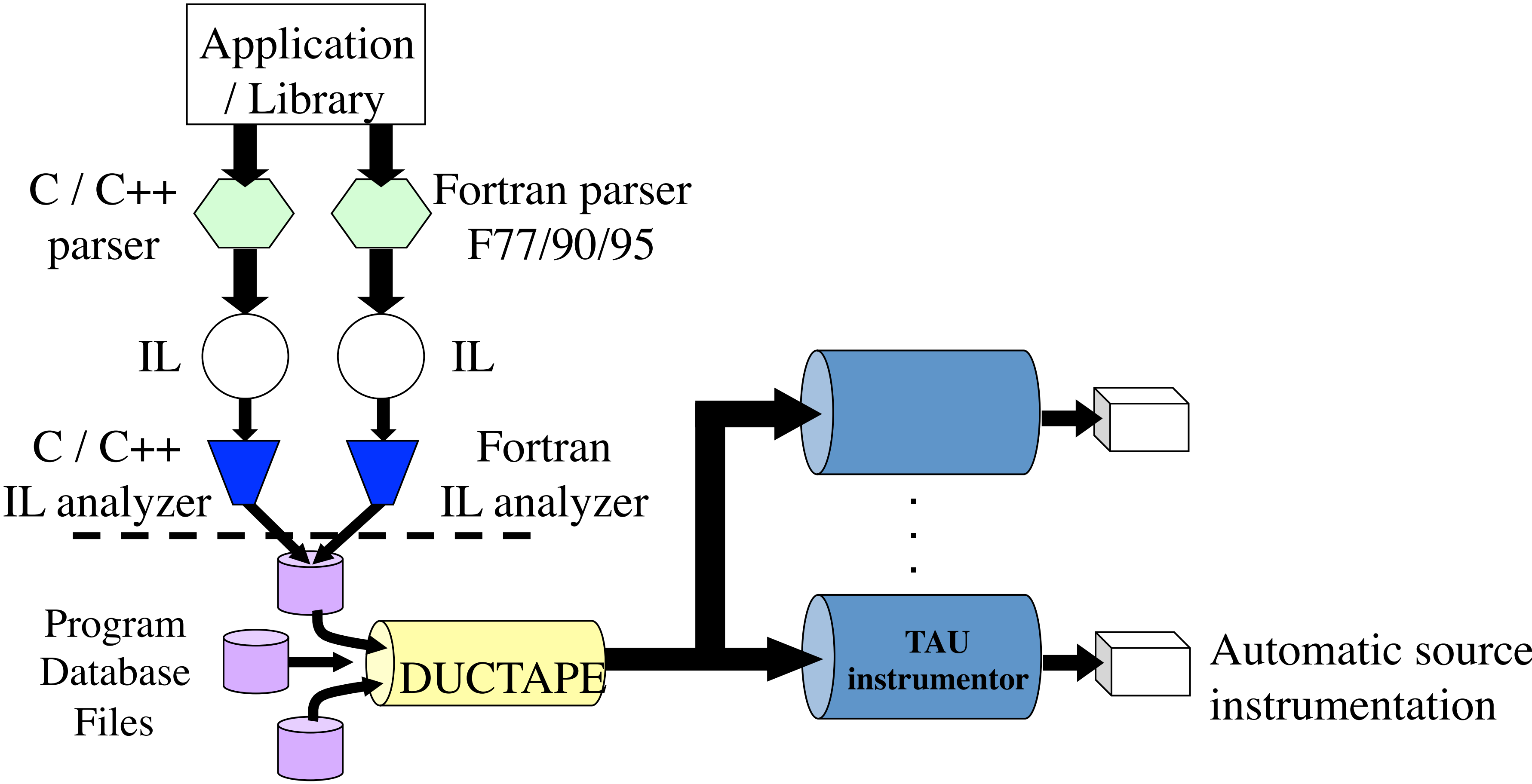
- Execute the application to get measurement data:

```
% mpirun -np 4  ./a.inst
```

Binary Rewriting Instrumentation

```
% mpif90 -g matmult.f90 -o matmult
% tau_rewrite matmult matmult.i

Or use a selective instrumentation file (include/exclude lists)
% tau_rewrite -f select.tau -T icpc,papi \
       ./matmult -o matmult.i
% mpirun -np 256  ./matmult.i
% paraprof
```

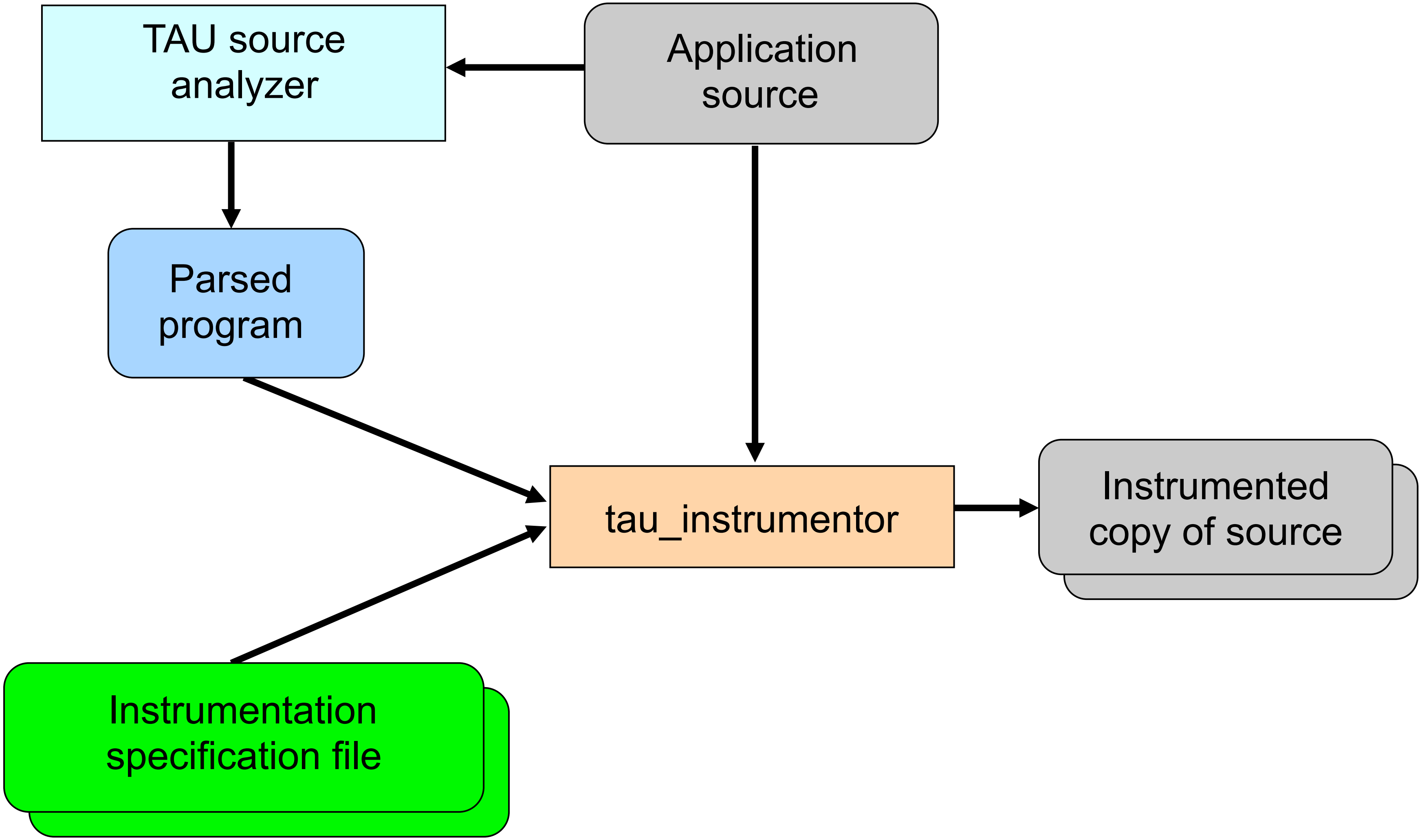
TAU's Static Analysis System: Program Database Toolkit (PDT)



ParaTools

http://tau.uoregon.edu/tau_llnl19.pdf

Automatic Source Instrumentation using PDT



Selective Instrumentation File

```
% export TAU_OPTIONS=‘-optTauSelectFile=select.tau …’
% cat select.tau
BEGIN_INCLUDE_LIST
int main#
int dgemm#
END_INCLUDE_LIST
BEGIN_FILE_INCLUDE_LIST
Main.c
Blas/*.f77
END_FILE_INCLUDE_LIST
# replace include with exclude list

BEGIN_INSTRUMENT_SECTION
loops routine=“foo”
loops routine=“int main#”
END_INSTRUMENT_SECTION
% export TAU_SELECT_FILE=select.tau    (to use at runtime)
```

Automatic Instrumentation

- **Use TAU's compiler wrappers**
  - Simply replace `CXX` with `tau_cxx.sh, etc.`
  - Automatically instruments source code, links with TAU libraries.
- **Use `tau_cc.sh` for C, `tau_f90.sh` for Fortran, `tau_upc.sh` for UPC, etc.**

Before

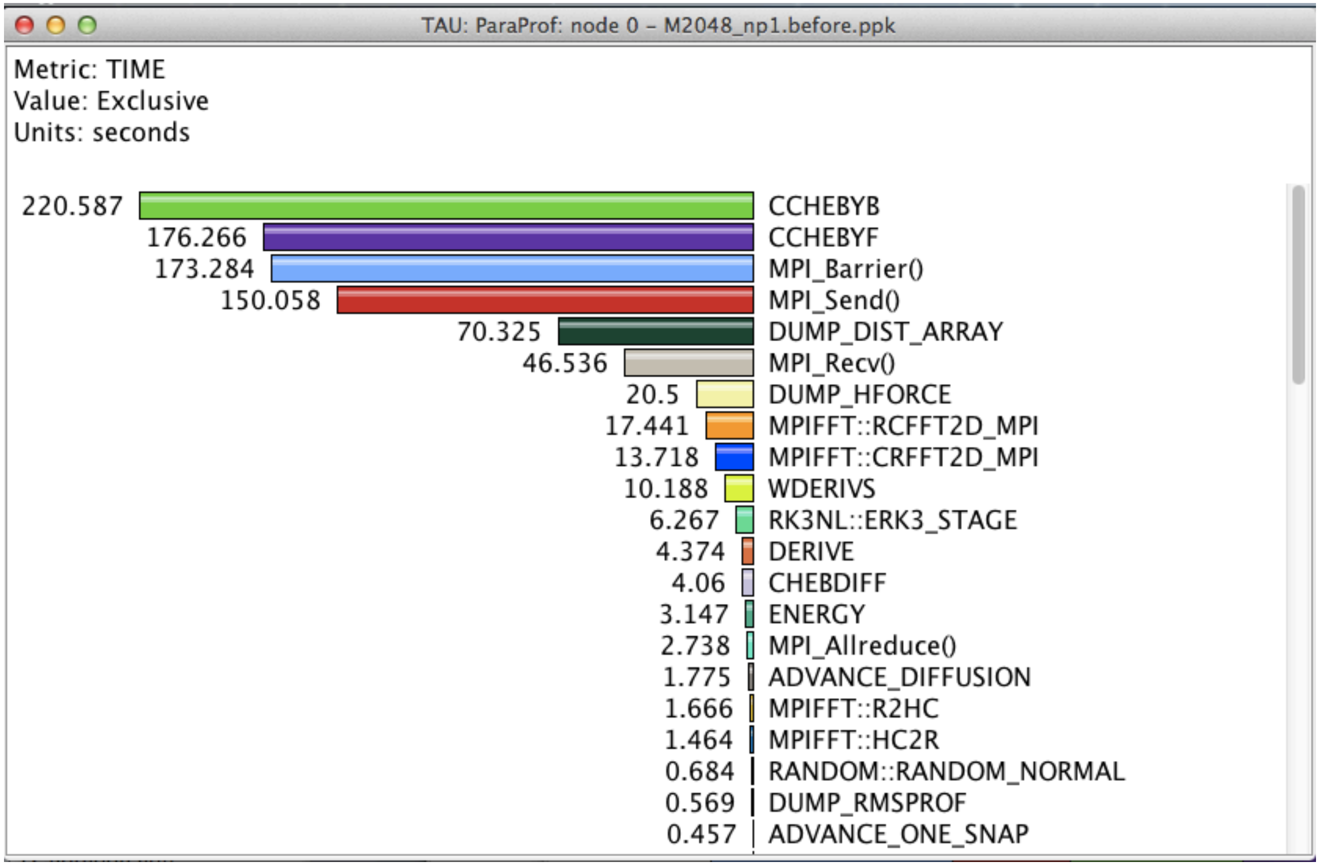
```
CXX = mpicxx
F90 = mpif90
CXXFLAGS =
LIBS = -lm
OBJS = f1.o f2.o f3.o … fn.o

app: $(OBJS)
      $(CXX) $(LDFLAGS) $(OBJS) -o $@
      $(LIBS)
.cpp.o:
      $(CXX) $(CXXFLAGS) -c $<
```

After

```
CXX = tau_cxx.sh
F90 = tau_f90.sh
CXXFLAGS =
LIBS = -lm
OBJS = f1.o f2.o f3.o … fn.o

app: $(OBJS)
      $(CXX) $(LDFLAGS) $(OBJS) -o $@
      $(LIBS)
.cpp.o:
      $(CXX) $(CXXFLAGS) -c $<
```

Routine Level Profile

How much time is spent in each application routine?



TAU: ParaProf: node 0 – M2048_np1.before.ppk

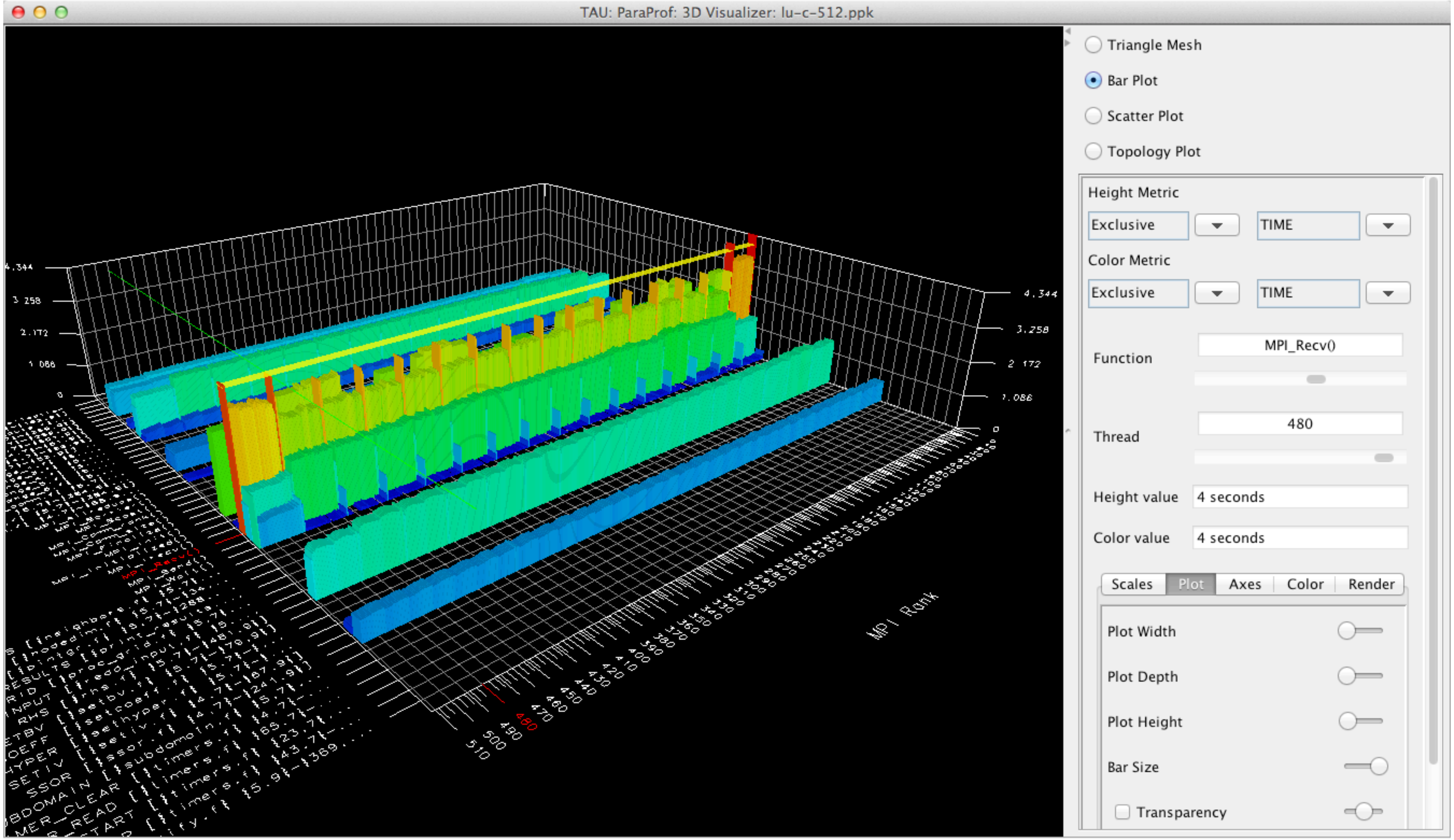
Metric: TIME
Value: Exclusive
Units: seconds

Generating a flat profile with MPI

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% make F90=tau_f90.sh
Or
% tau_f90.sh matmult.f90
; mpirun –np 16  ./a.out
% paraprof
To view. To view the data locally on the workstation,
% paraprof --pack app.ppk
  Move the app.ppk file to your desktop.
% paraprof app.ppk
```

Click on the “node 0” label to see profile for that node. Right click to see other options. Windows -> 3D Visualization for 3D window.

ParaProf 3D Profile Browser



TAU: ParaProf: 3D Visualizer: lu-c-512.ppk

○ Triangle Mesh

● Bar Plot

○ Scatter Plot

○ Topology Plot

Height Metric: Exclusive, TIME

Color Metric: Exclusive, TIME

Function: MPI_Recv()

Thread: 480

Height value: 4 seconds

Color value: 4 seconds

Scales | Plot | Axes | Color | Render

Plot Width

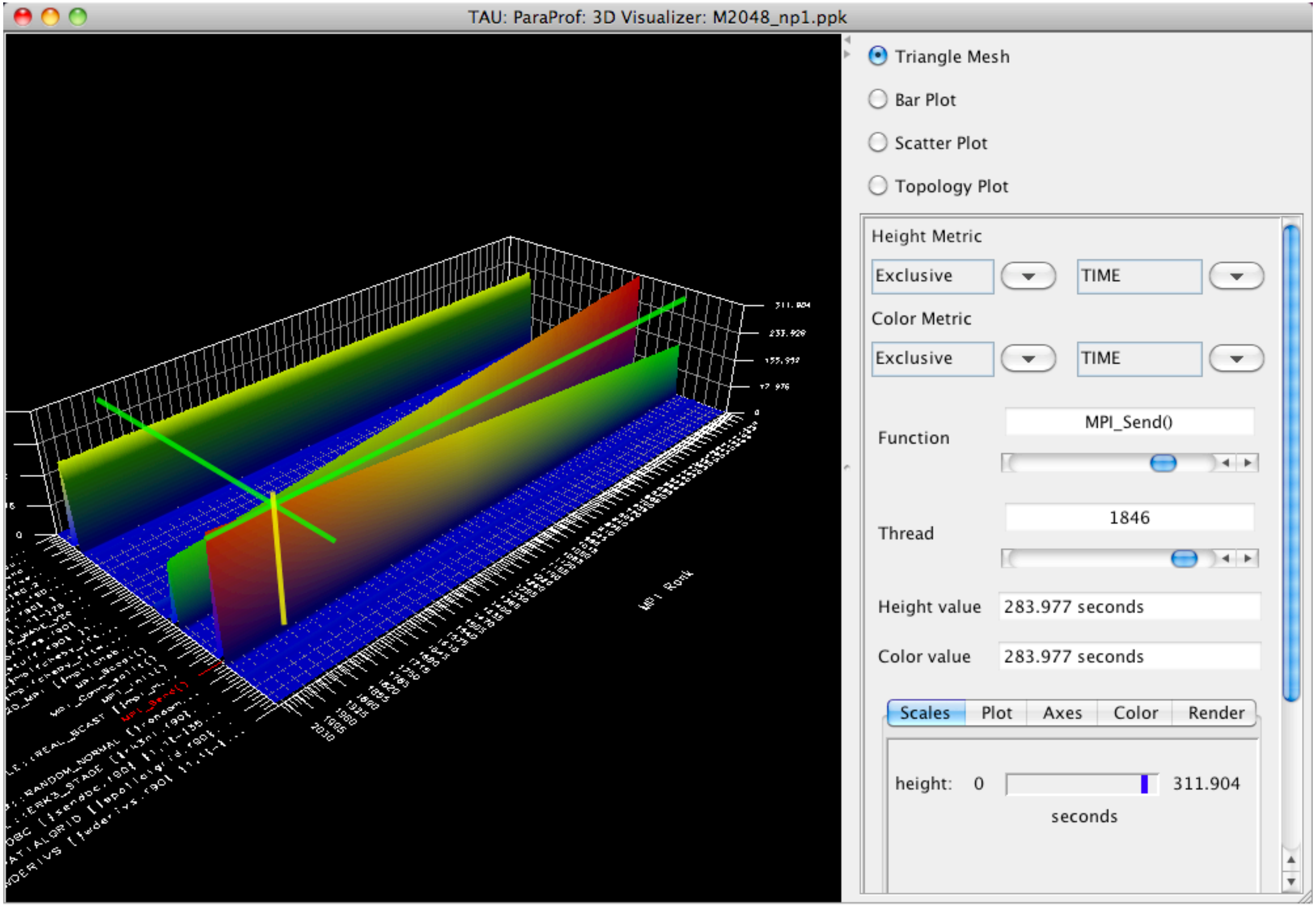
Plot Depth

Plot Height

Bar Size

□ Transparency

ParaProf



TAU: ParaProf: 3D Visualizer: M2048_np1.ppk

● Triangle Mesh

○ Bar Plot

○ Scatter Plot

○ Topology Plot

Height Metric

Exclusive TIME

Color Metric

Exclusive TIME

Function MPI_Send()

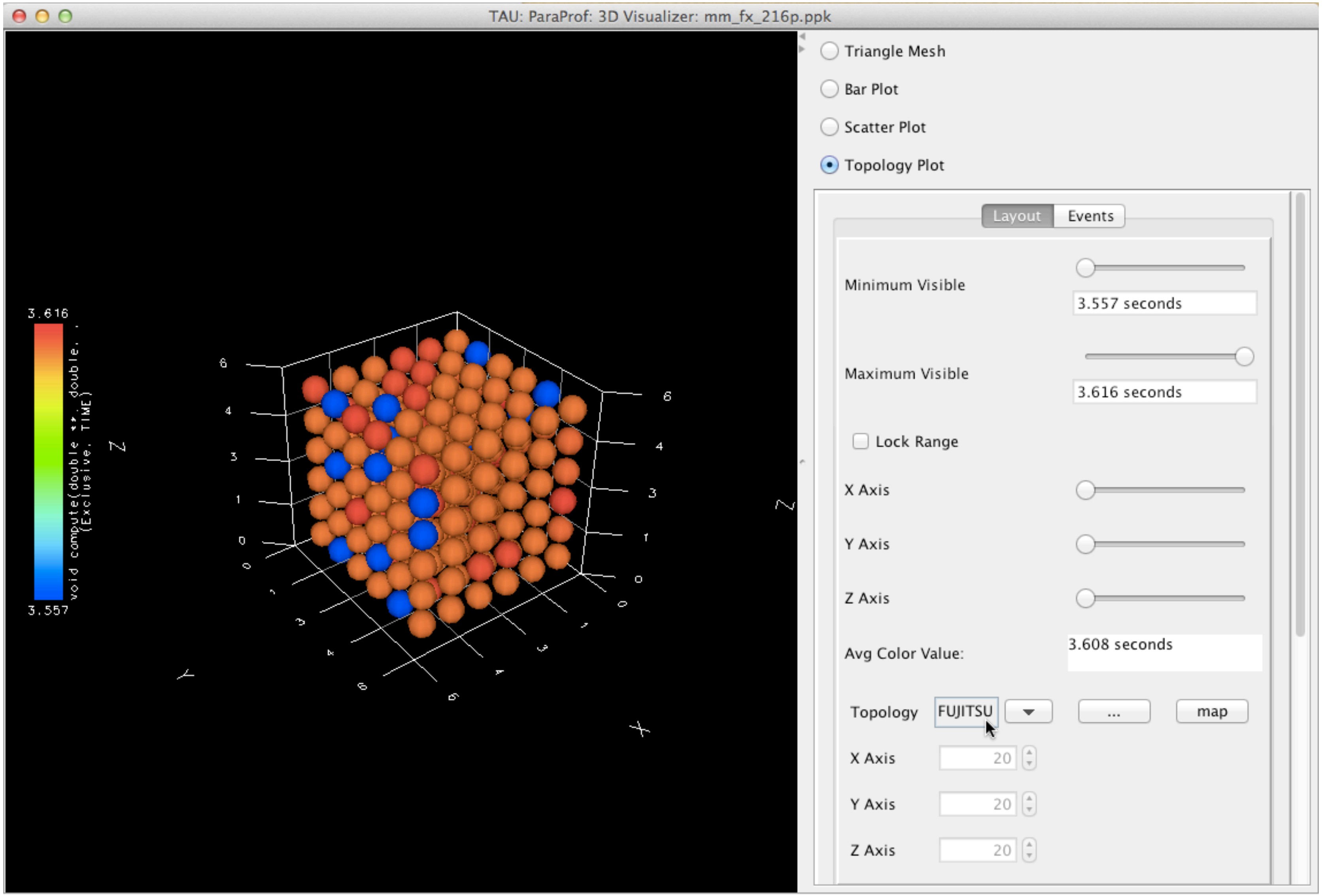
Thread 1846

Height value 283.977 seconds

Color value 283.977 seconds

height: 0 311.904 seconds

ParaProf 3D Topology Display



TAU: ParaProf: 3D Visualizer: mm_fx_216p.ppk

○ Triangle Mesh

○ Bar Plot

○ Scatter Plot

● Topology Plot

Layout | Events

Minimum Visible: 3.557 seconds

Maximum Visible: 3.616 seconds

□ Lock Range

X Axis

Y Axis

Z Axis

Avg Color Value: 3.608 seconds

Topology: FUJITSU

X Axis: 20

Y Axis: 20

Z Axis: 20

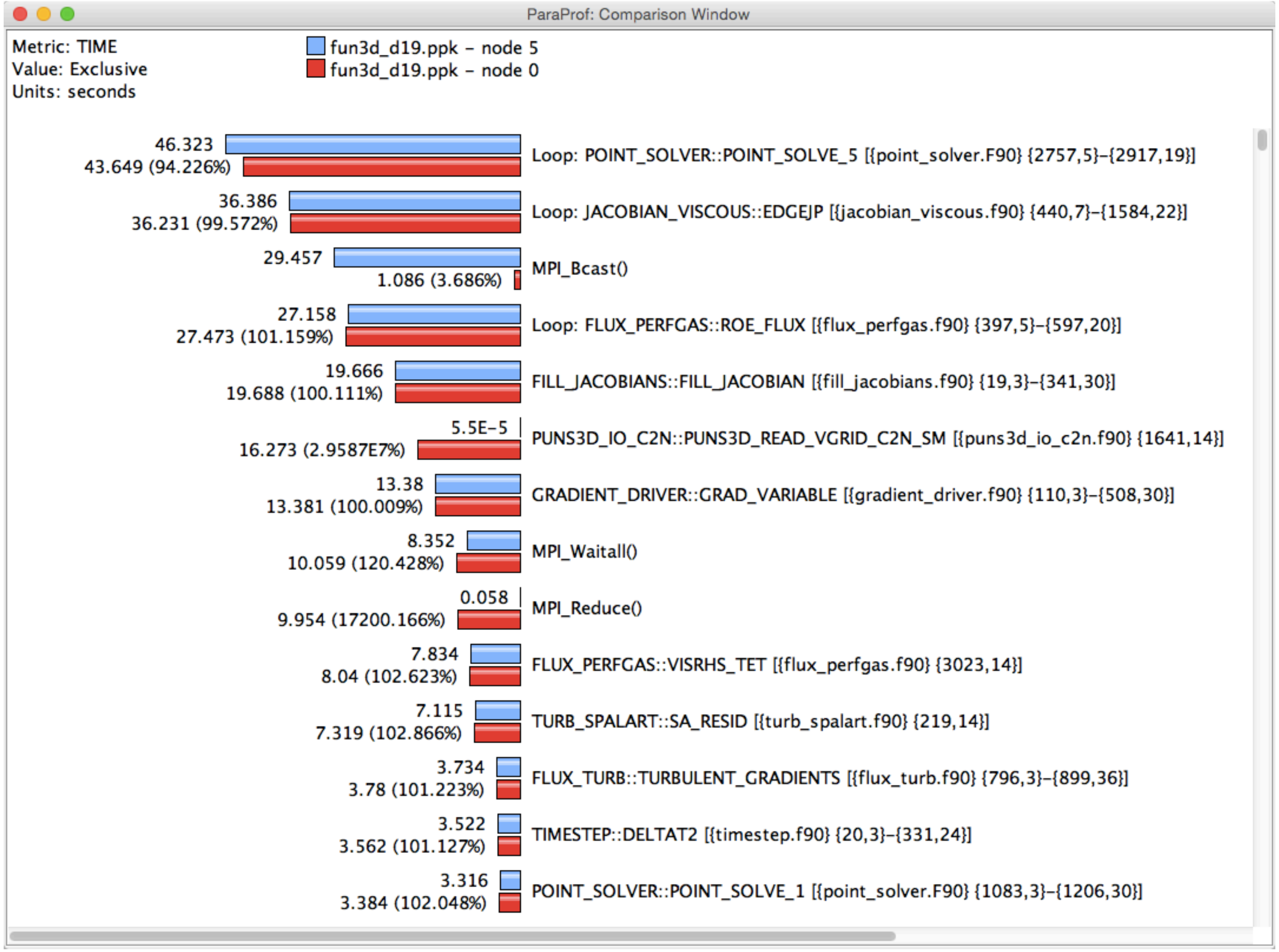
3.616
3.557
void compute(double **, double **, double **) (Exclusive, TIME)
Z
Y
X
...
map

ParaTools

http://tau.uoregon.edu/tau_llnl19.pdf

UNIVERSITY OF OREGON

ParaProf Comparison Window


ParaProf: Comparison Window

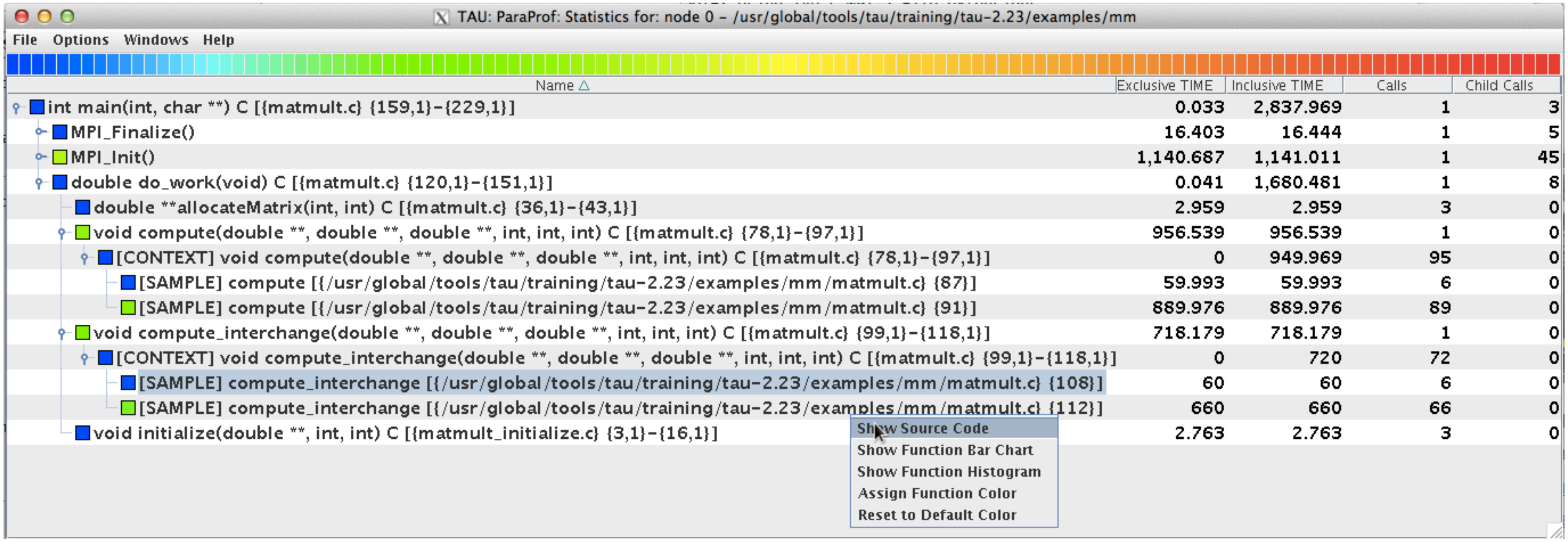
Metric: TIME
Value: Exclusive
Units: seconds

🟦 fun3d_d19.ppk – node 5
🟥 fun3d_d19.ppk – node 0

46.323
43.649 (94.226%)
Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]
36.386
36.231 (99.572%)
Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]
29.457
1.086 (3.686%)
MPI_Bcast()
27.158
27.473 (101.159%)
Loop: FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {397,5}-{597,20}]
19.666
19.688 (100.111%)
FILL_JACOBIANS::FILL_JACOBIAN [{fill_jacobians.f90} {19,3}-{341,30}]
5.5E-5
16.273 (2.9587E7%)
PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N_SM [{puns3d_io_c2n.f90} {1641,14}]
13.38
13.381 (100.009%)
GRADIENT_DRIVER::GRAD_VARIABLE [{gradient_driver.f90} {110,3}-{508,30}]
8.352
10.059 (120.428%)
MPI_Waitall()
0.058
9.954 (17200.166%)
MPI_Reduce()
7.834
8.04 (102.623%)
FLUX_PERFGAS::VISRHS_TET [{flux_perfgas.f90} {3023,14}]
7.115
7.319 (102.866%)
TURB_SPALART::SA_RESID [{turb_spalart.f90} {219,14}]
3.734
3.78 (101.223%)
FLUX_TURB::TURBULENT_GRADIENTS [{flux_turb.f90} {796,3}-{899,36}]
3.522
3.562 (101.127%)
TIMESTEP::DELTAT2 [{timestep.f90} {20,3}-{331,24}]
3.316
3.384 (102.048%)
POINT_SOLVER::POINT_SOLVE_1 [{point_solver.F90} {1083,3}-{1206,30}]

Comparing Rank 0 with 5.
Right click on “node 5” -> Add node to comparison window

Event Based Sampling in TAU

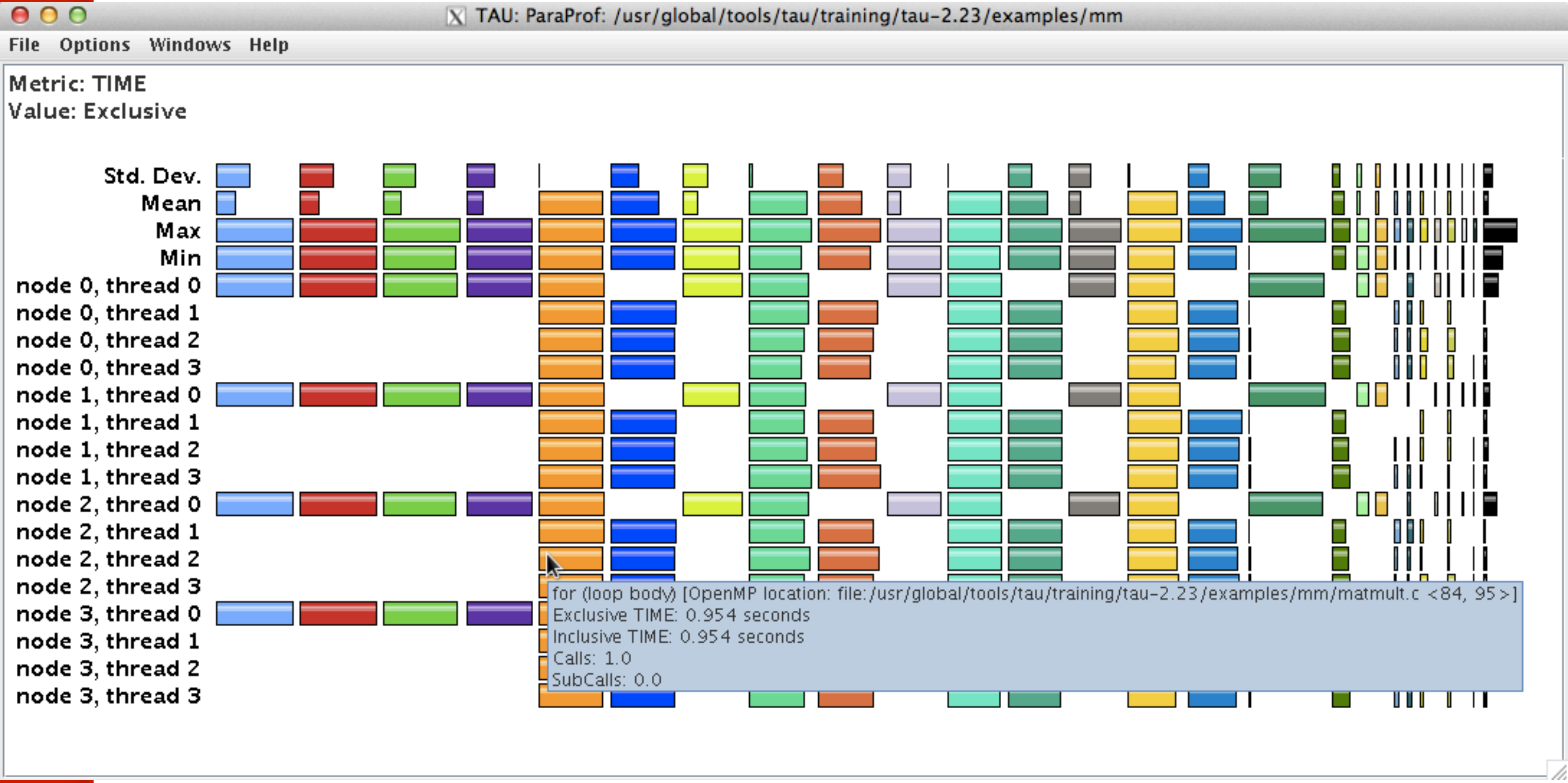


TAU: ParaProf: Statistics for: node 0 – /usr/global/tools/tau/training/tau-2.23/examples/mm

Name △	Exclusive TIME	Inclusive TIME	Calls	Child Calls
🟦 int main(int, char **) C [{matmult.c} {159,1}-{229,1}]	0.033	2,837.969	1	3
🟦 MPI_Finalize()	16.403	16.444	1	5
🟩 MPI_Init()	1,140.687	1,141.011	1	45
🟦 double do_work(void) C [{matmult.c} {120,1}-{151,1}]	0.041	1,680.481	1	8
🟦 double **allocateMatrix(int, int) C [{matmult.c} {36,1}-{43,1}]	2.959	2.959	3	0
🟩 void compute(double **, double **, double **, int, int, int) C [{matmult.c} {78,1}-{97,1}]	956.539	956.539	1	0
🟦 [CONTEXT] void compute(double **, double **, double **, int, int, int) C [{matmult.c} {78,1}-{97,1}]	0	949.969	95	0
🟦 [SAMPLE] compute [{/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c} {87}]	59.993	59.993	6	0
🟩 [SAMPLE] compute [{/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c} {91}]	889.976	889.976	89	0
🟩 void compute_interchange(double **, double **, double **, int, int, int) C [{matmult.c} {99,1}-{118,1}]	718.179	718.179	1	0
🟦 [CONTEXT] void compute_interchange(double **, double **, double **, int, int, int) C [{matmult.c} {99,1}-{118,1}]	0	720	72	0
🟦 [SAMPLE] compute_interchange [{/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c} {108}]	60	60	6	0
🟩 [SAMPLE] compute_interchange [{/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c} {112}]	660	660	66	0
🟦 void initialize(double **, int, int) C [{matmult_initialize.c} {3,1}-{16,1}]	2.763	2.763	3	0

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% make CC=tau_cc.sh CXX=tau_cxx.sh
% export TAU_SAMPLING=1
% mpirun –np 256 ./a.out
% paraprof
```

Mixed MPI and OpenMP Instrumentation

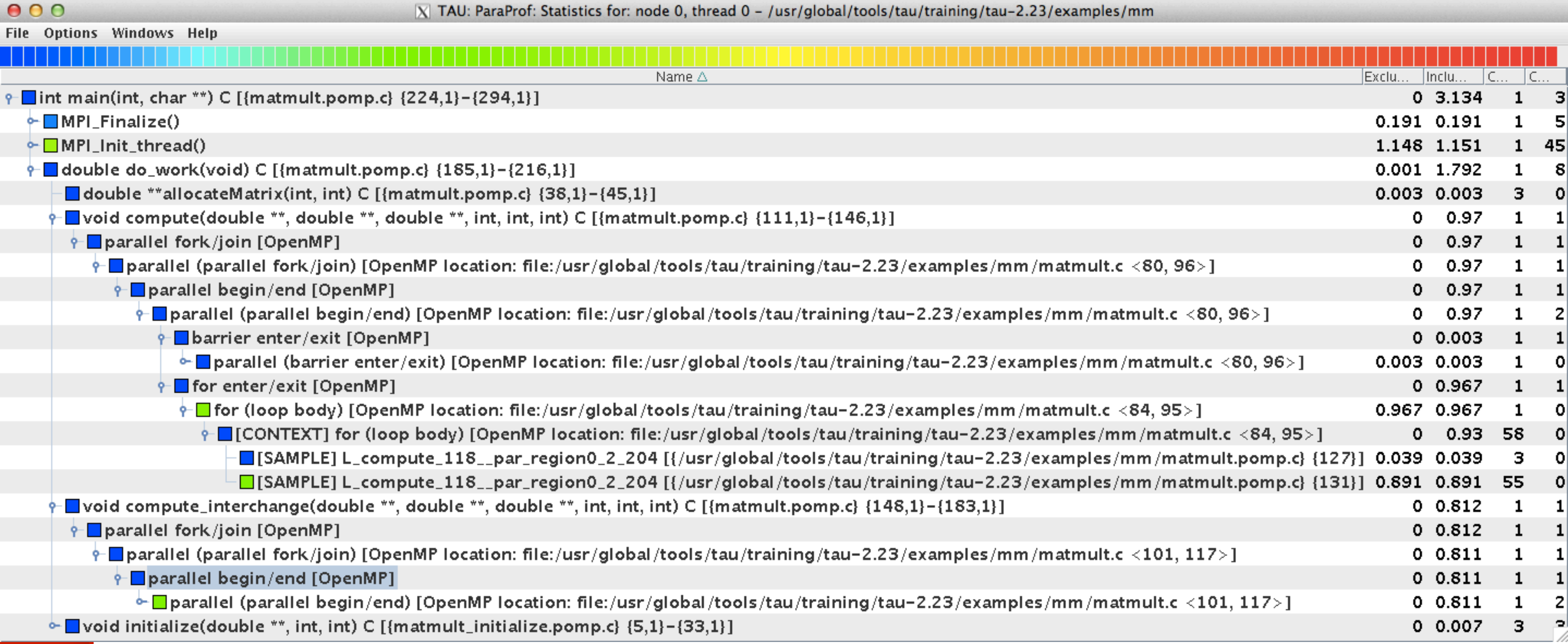


Metric: TIME
Value: Exclusive

```
for (loop body) [OpenMP location: file:/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c <84, 95>]
Exclusive TIME: 0.954 seconds
Inclusive TIME: 0.954 seconds
Calls: 1.0
SubCalls: 0.0
```

Options -> Uncheck “Stack Bars Together”

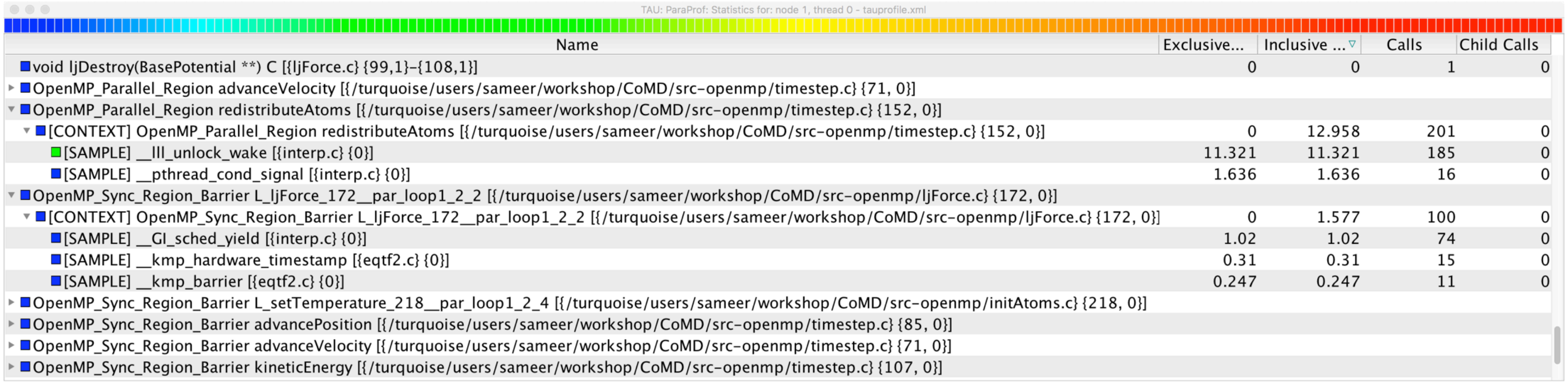
Opari OpenMP Instrumentation, Sampling


TAU: ParaProf: Statistics for: node 0, thread 0 - /usr/global/tools/tau/training/tau-2.23/examples/mm
File Options Windows Help

Name △	Exclu...	Inclu...	C...	C...
int main(int, char **) C [{matmult.pomp.c} {224,1}-{294,1}]	0	3.134	1	3
MPI_Finalize()	0.191	0.191	1	5
MPI_Init_thread()	1.148	1.151	1	45
double do_work(void) C [{matmult.pomp.c} {185,1}-{216,1}]	0.001	1.792	1	8
double **allocateMatrix(int, int) C [{matmult.pomp.c} {38,1}-{45,1}]	0.003	0.003	3	0
void compute(double **, double **, double **, int, int, int) C [{matmult.pomp.c} {111,1}-{146,1}]	0	0.97	1	1
parallel fork/join [OpenMP]	0	0.97	1	1
parallel (parallel fork/join) [OpenMP location: file:/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c <80, 96>]	0	0.97	1	1
parallel begin/end [OpenMP]	0	0.97	1	1
parallel (parallel begin/end) [OpenMP location: file:/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c <80, 96>]	0	0.97	1	2
barrier enter/exit [OpenMP]	0	0.003	1	1
parallel (barrier enter/exit) [OpenMP location: file:/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c <80, 96>]	0.003	0.003	1	0
for enter/exit [OpenMP]	0	0.967	1	1
for (loop body) [OpenMP location: file:/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c <84, 95>]	0.967	0.967	1	0
[CONTEXT] for (loop body) [OpenMP location: file:/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c <84, 95>]	0	0.93	58	0
[SAMPLE] L_compute_118__par_region0_2_204 [{/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.pomp.c} {127}]	0.039	0.039	3	0
[SAMPLE] L_compute_118__par_region0_2_204 [{/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.pomp.c} {131}]	0.891	0.891	55	0
void compute_interchange(double **, double **, double **, int, int, int) C [{matmult.pomp.c} {148,1}-{183,1}]	0	0.812	1	1
parallel fork/join [OpenMP]	0	0.812	1	1
parallel (parallel fork/join) [OpenMP location: file:/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c <101, 117>]	0	0.811	1	1
parallel begin/end [OpenMP]	0	0.811	1	1
parallel (parallel begin/end) [OpenMP location: file:/usr/global/tools/tau/training/tau-2.23/examples/mm/matmult.c <101, 117>]	0	0.811	1	2
void initialize(double **, int, int) C [{matmult_initialize.pomp.c} {5,1}-{33,1}]	0	0.007	3	3

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt-opari-openmp
% make CC=tau_cc.sh CXX=tau_cxx.sh
% export TAU_SAMPLING=1; export OMP_NUM_THREADS=16
% mpirun –np 256 ./a.out
% paraprof
```

TAU’s support for OMPT TR6



TAU: ParaProf: Statistics for: node 1, thread 0 - tauprofile.xml

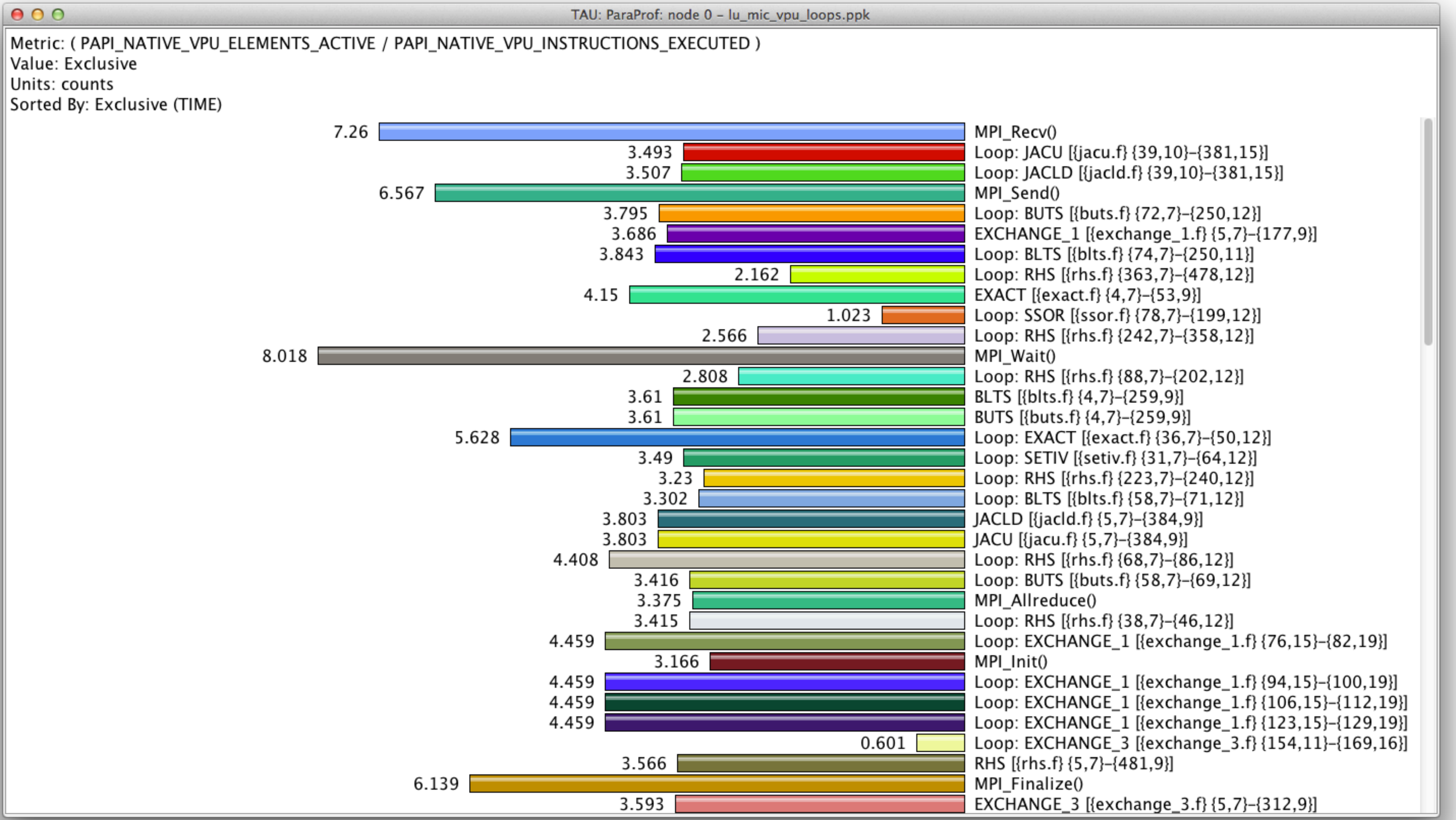
Name	Exclusive...	Inclusive ...▿	Calls	Child Calls
■ void ljDestroy(BasePotential **) C [{ljForce.c} {99,1}-{108,1}]	0	0	1	0
▸ ■ OpenMP_Parallel_Region advanceVelocity [{/turquoise/users/sameer/workshop/CoMD/src-openmp/timestep.c} {71, 0}]				
▾ ■ OpenMP_Parallel_Region redistributeAtoms [{/turquoise/users/sameer/workshop/CoMD/src-openmp/timestep.c} {152, 0}]				
▾ ■ [CONTEXT] OpenMP_Parallel_Region redistributeAtoms [{/turquoise/users/sameer/workshop/CoMD/src-openmp/timestep.c} {152, 0}]	0	12.958	201	0
■ [SAMPLE] __lll_unlock_wake [{interp.c} {0}]	11.321	11.321	185	0
■ [SAMPLE] __pthread_cond_signal [{interp.c} {0}]	1.636	1.636	16	0
▾ ■ OpenMP_Sync_Region_Barrier L_ljForce_172__par_loop1_2_2 [{/turquoise/users/sameer/workshop/CoMD/src-openmp/ljForce.c} {172, 0}]				
▾ ■ [CONTEXT] OpenMP_Sync_Region_Barrier L_ljForce_172__par_loop1_2_2 [{/turquoise/users/sameer/workshop/CoMD/src-openmp/ljForce.c} {172, 0}]	0	1.577	100	0
■ [SAMPLE] __GI_sched_yield [{interp.c} {0}]	1.02	1.02	74	0
■ [SAMPLE] __kmp_hardware_timestamp [{eqtf2.c} {0}]	0.31	0.31	15	0
■ [SAMPLE] __kmp_barrier [{eqtf2.c} {0}]	0.247	0.247	11	0
▸ ■ OpenMP_Sync_Region_Barrier L_setTemperature_218__par_loop1_2_4 [{/turquoise/users/sameer/workshop/CoMD/src-openmp/initAtoms.c} {218, 0}]				
▸ ■ OpenMP_Sync_Region_Barrier advancePosition [{/turquoise/users/sameer/workshop/CoMD/src-openmp/timestep.c} {85, 0}]				
▸ ■ OpenMP_Sync_Region_Barrier advanceVelocity [{/turquoise/users/sameer/workshop/CoMD/src-openmp/timestep.c} {71, 0}]				
▸ ■ OpenMP_Sync_Region_Barrier kineticEnergy [{/turquoise/users/sameer/workshop/CoMD/src-openmp/timestep.c} {107, 0}]				

Configure TAU with –ompt=download (without –opari)

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-ompt-tr6-mpi-pdt-openmp
% export TAU_OMPT_SUPPORT_LEVEL=full
% export TAU_OMPT_RESOLVE_ADDRESS_EAGERLY=1
% make CC=tau_cc.sh CXX=tau_cxx.sh
% export OMP_NUM_THREADS=16
% mpirun –np 256 tau_exec –T ompt,tr6,papi,pdt  –ompt −ebs ./a.out
% paraprof
```

NOTE: Instrumentation is at the source, MPI, and OpenMP levels with sampling

Evaluating Extent of Vectorization on MIC



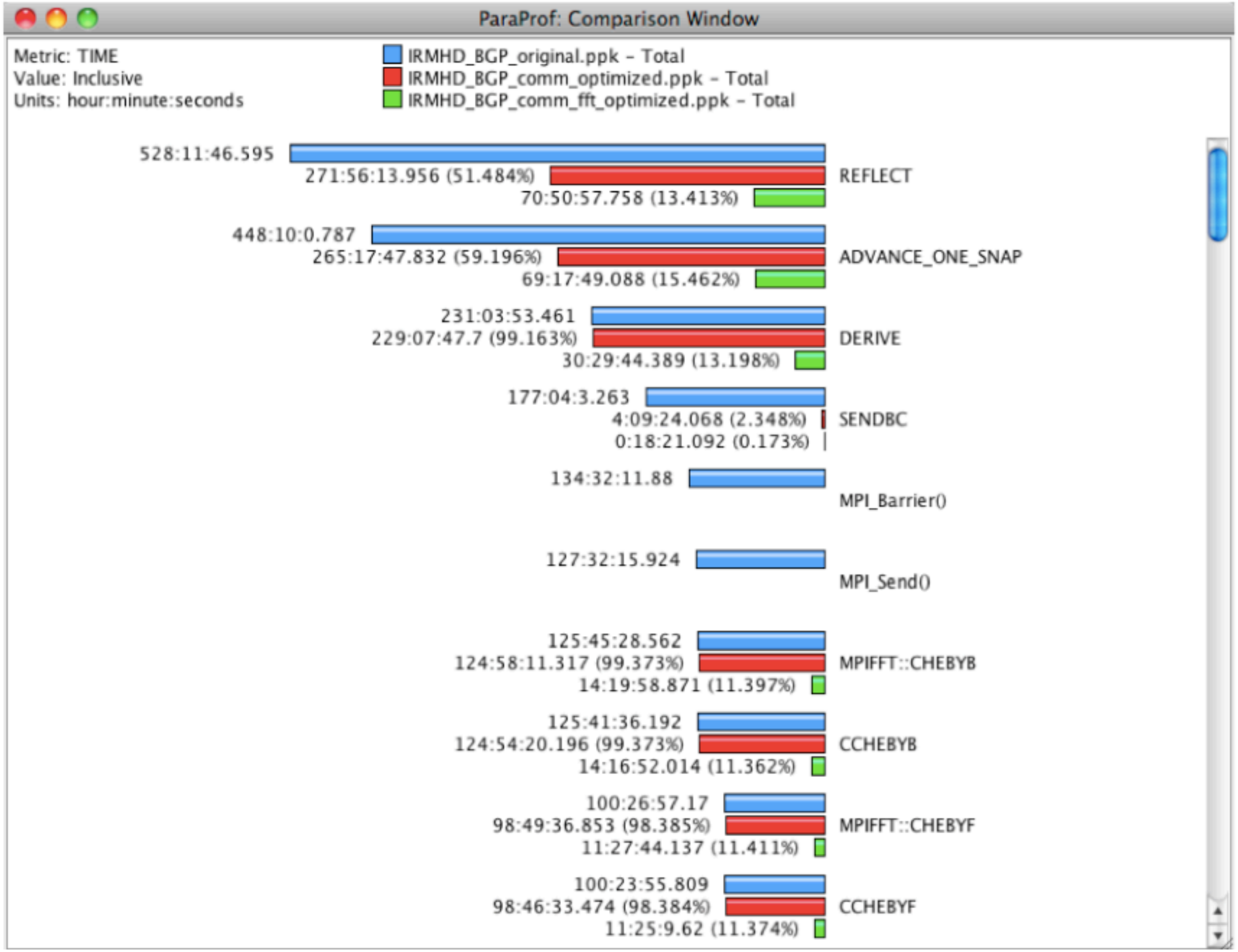
TAU: ParaProf: node 0 – lu_mic_vpu_loops.ppk

Metric: (PAPI_NATIVE_VPU_ELEMENTS_ACTIVE / PAPI_NATIVE_VPU_INSTRUCTIONS_EXECUTED)
Value: Exclusive
Units: counts
Sorted By: Exclusive (TIME)

```
7.26   MPI_Recv()
3.493  Loop: JACU [{jacu.f} {39,10}-{381,15}]
3.507  Loop: JACLD [{jacld.f} {39,10}-{381,15}]
6.567  MPI_Send()
3.795  Loop: BUTS [{buts.f} {72,7}-{250,12}]
3.686  EXCHANGE_1 [{exchange_1.f} {5,7}-{177,9}]
3.843  Loop: BLTS [{blts.f} {74,7}-{250,11}]
2.162  Loop: RHS [{rhs.f} {363,7}-{478,12}]
4.15   EXACT [{exact.f} {4,7}-{53,9}]
1.023  Loop: SSOR [{ssor.f} {78,7}-{199,12}]
2.566  Loop: RHS [{rhs.f} {242,7}-{358,12}]
8.018  MPI_Wait()
2.808  Loop: RHS [{rhs.f} {88,7}-{202,12}]
3.61   BLTS [{blts.f} {4,7}-{259,9}]
3.61   BUTS [{buts.f} {4,7}-{259,9}]
5.628  Loop: EXACT [{exact.f} {36,7}-{50,12}]
3.49   Loop: SETIV [{setiv.f} {31,7}-{64,12}]
3.23   Loop: RHS [{rhs.f} {223,7}-{240,12}]
3.302  Loop: BLTS [{blts.f} {58,7}-{71,12}]
3.803  JACLD [{jacld.f} {5,7}-{384,9}]
3.803  JACU [{jacu.f} {5,7}-{384,9}]
4.408  Loop: RHS [{rhs.f} {68,7}-{86,12}]
3.416  Loop: BUTS [{buts.f} {58,7}-{69,12}]
3.375  MPI_Allreduce()
3.415  Loop: RHS [{rhs.f} {38,7}-{46,12}]
4.459  Loop: EXCHANGE_1 [{exchange_1.f} {76,15}-{82,19}]
3.166  MPI_Init()
4.459  Loop: EXCHANGE_1 [{exchange_1.f} {94,15}-{100,19}]
4.459  Loop: EXCHANGE_1 [{exchange_1.f} {106,15}-{112,19}]
4.459  Loop: EXCHANGE_1 [{exchange_1.f} {123,15}-{129,19}]
0.601  Loop: EXCHANGE_3 [{exchange_3.f} {154,11}-{169,16}]
3.566  RHS [{rhs.f} {5,7}-{481,9}]
6.139  MPI_Finalize()
3.593  EXCHANGE_3 [{exchange_3.f} {5,7}-{312,9}]
```

```
% export TAU_MAKEFILE=$TAUROOT/mic_linux/lib/Makefile.tau-papi-mpi-pdt
% export TAU_METRICS=TIME,
          PAPI_NATIVE_VPU_ELEMENTS_ACTIVE,PAPI_NATIVE_VPU_INSTRUCTIONS_EXECUTED
```

ParaProf Comparison Window

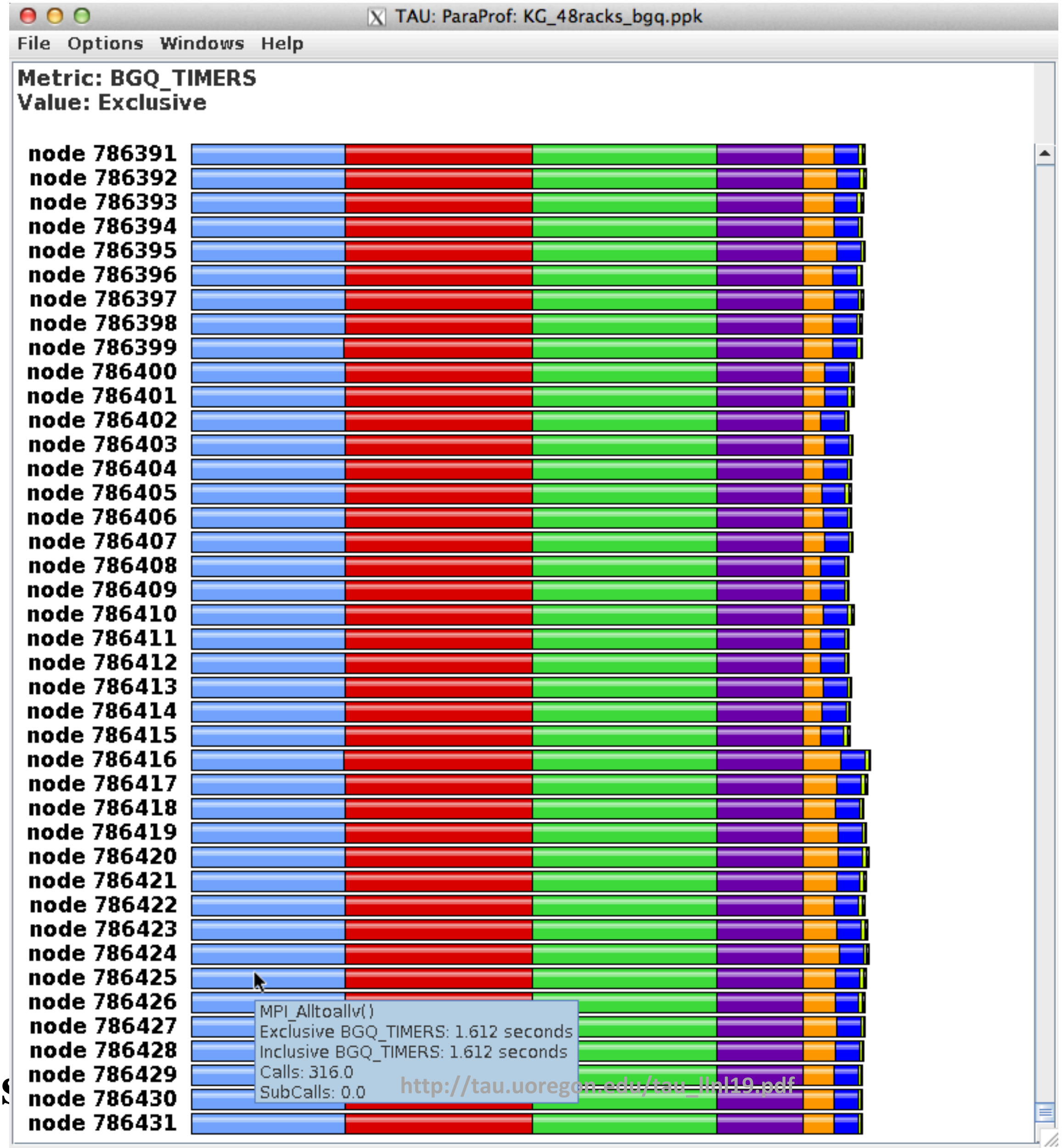


ParaProf: Comparison Window

Metric: TIME
Value: Inclusive
Units: hour:minute:seconds

🟦 IRMHD_BGP_original.ppk – Total
🟥 IRMHD_BGP_comm_optimized.ppk – Total
🟩 IRMHD_BGP_comm_fft_optimized.ppk – Total

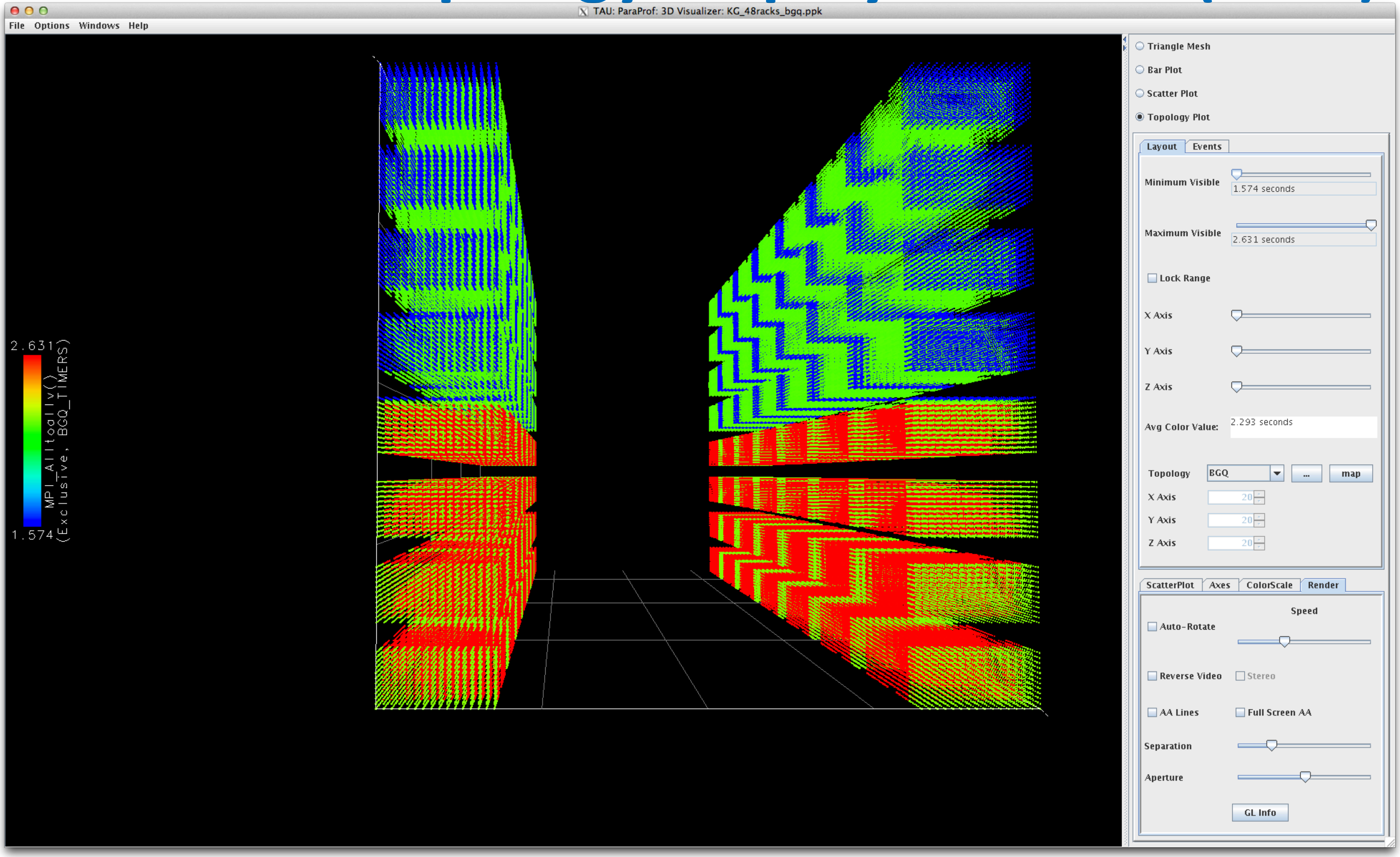
TAU’s ParaProf Profile Browser



Metric: BGQ_TIMERS
Value: Exclusive

```
MPI_Alltoallv()
Exclusive BGQ_TIMERS: 1.612 seconds
Inclusive BGQ_TIMERS: 1.612 seconds
Calls: 316.0
SubCalls: 0.0
```

ParaProf’s Topology Display Window (BGQ)



○ Triangle Mesh
○ Bar Plot
○ Scatter Plot
● Topology Plot

Minimum Visible: 1.574 seconds

Maximum Visible: 2.631 seconds

☐ Lock Range

X Axis

Y Axis

Z Axis

Avg Color Value: 2.293 seconds

Topology: BGQ

X Axis: 20

Y Axis: 20

Z Axis: 20

Speed

☐ Auto-Rotate

☐ Reverse Video ☐ Stereo

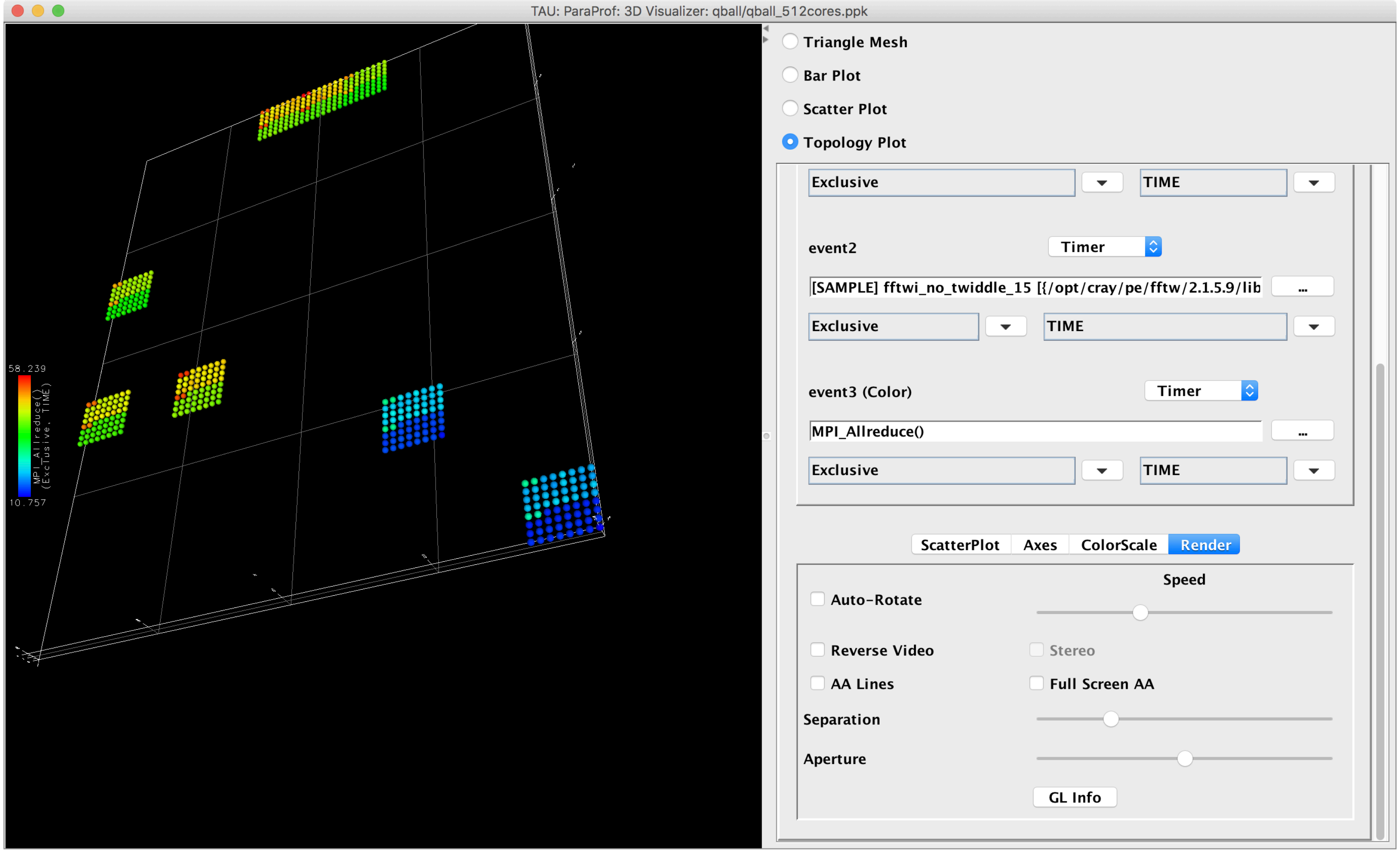
☐ AA Lines ☐ Full Screen AA

Separation

Aperture

ParaTools

ParaProf Topology Display



TAU: ParaProf: 3D Visualizer: qball/qball_512cores.ppk

○ Triangle Mesh

○ Bar Plot

○ Scatter Plot

● Topology Plot

Exclusive ▾ TIME ▾

event2 Timer

[SAMPLE] fftwi_no_twiddle_15 [{/opt/cray/pe/fftw/2.1.5.9/lib ...

Exclusive ▾ TIME ▾

event3 (Color) Timer

MPI_Allreduce() ...

Exclusive ▾ TIME ▾

ScatterPlot | Axes | ColorScale | **Render**

Speed

□ Auto-Rotate

□ Reverse Video □ Stereo

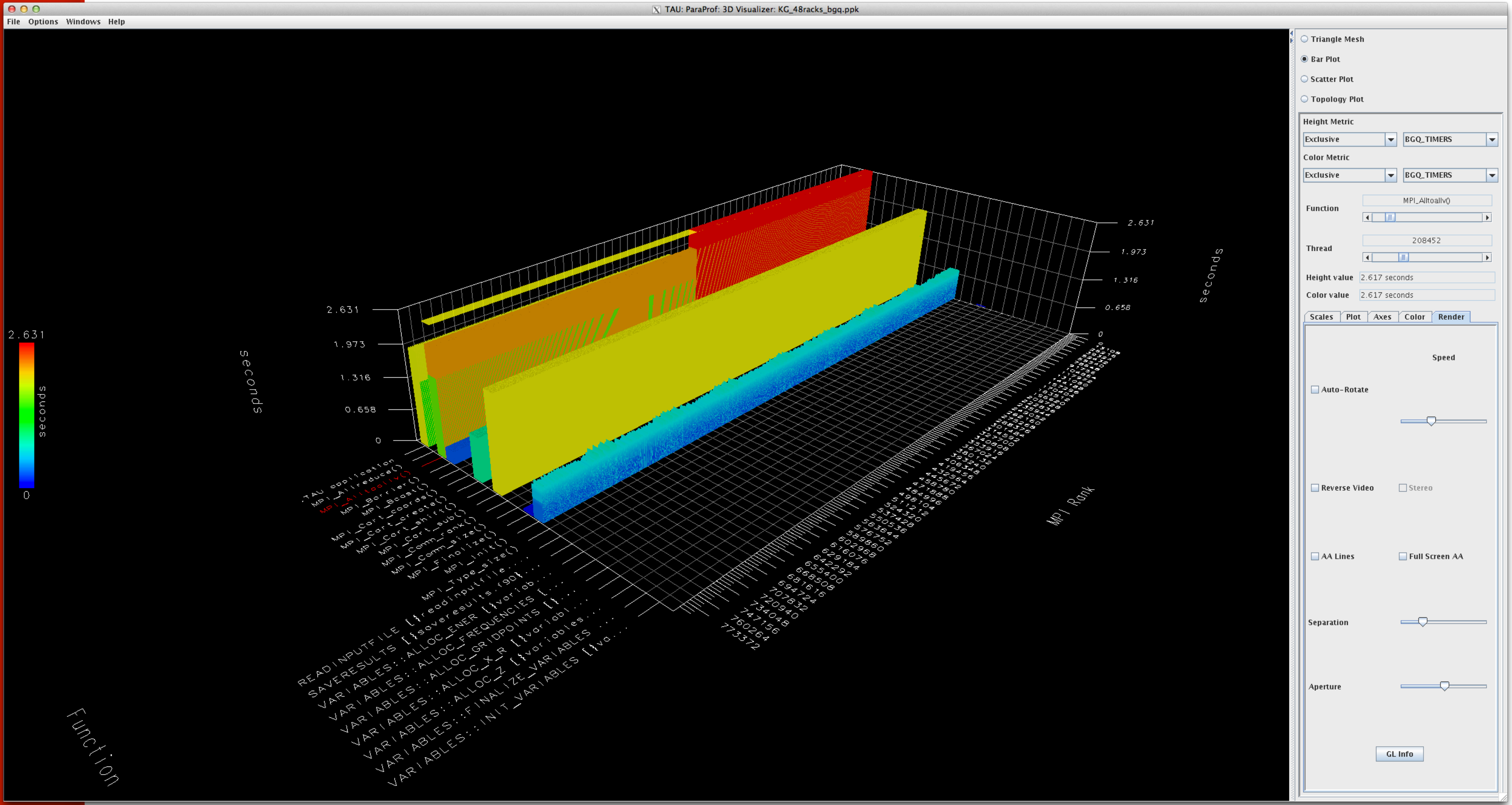
□ AA Lines □ Full Screen AA

Separation

Aperture

GL Info

ParaProf’s Scalable 3D Visualization (BGQ)



○ Triangle Mesh

● Bar Plot

○ Scatter Plot

○ Topology Plot

Height Metric: Exclusive | BGQ_TIMERS

Color Metric: Exclusive | BGQ_TIMERS

Function: MPI_Alltoallv()

Thread: 208452

Height value: 2.617 seconds

Color value: 2.617 seconds

□ Auto-Rotate

□ Reverse Video □ Stereo

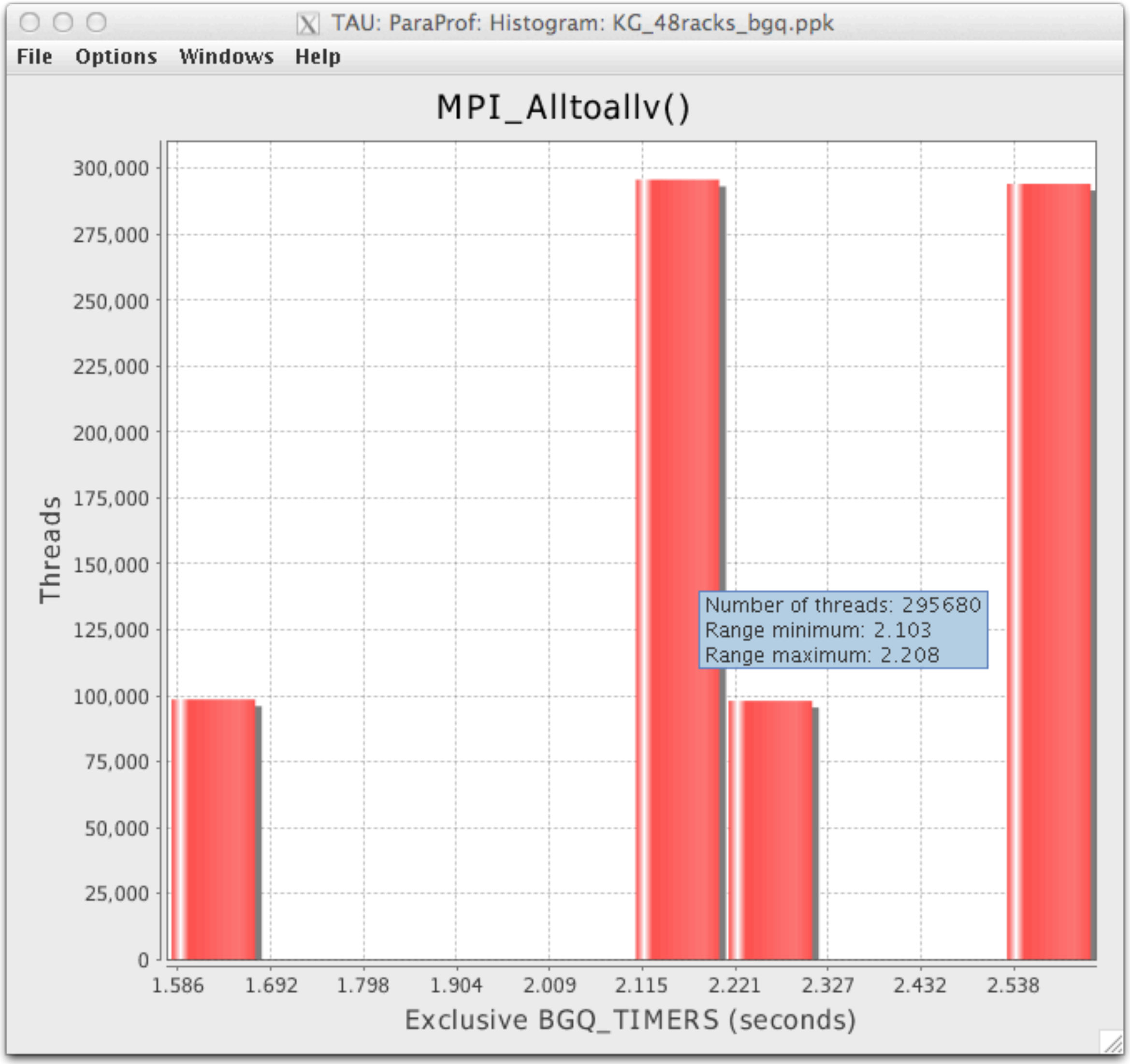
□ AA Lines □ Full Screen AA

Separation

Aperture

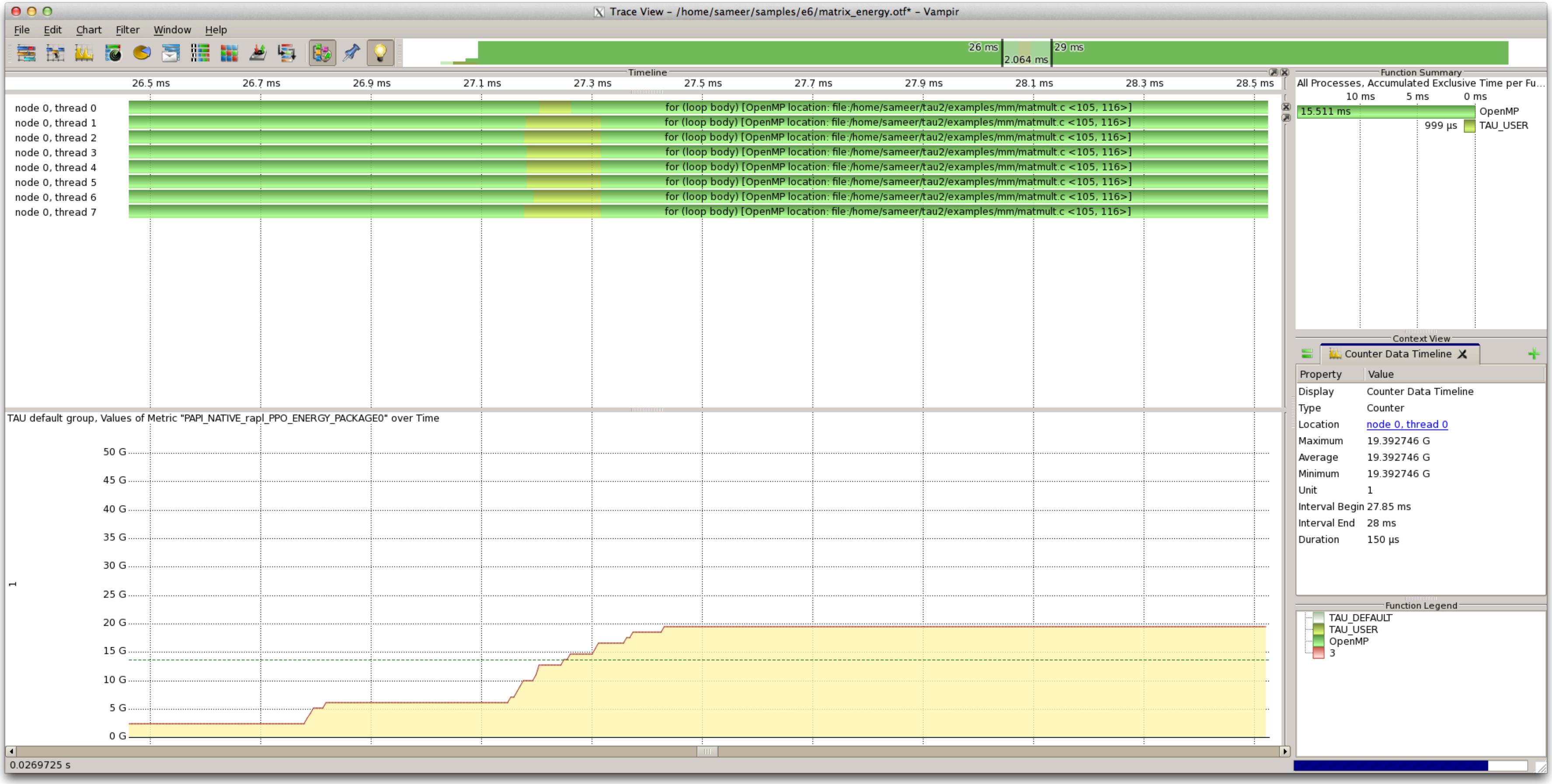
786,432 ranks

ParaProf Histogram Display



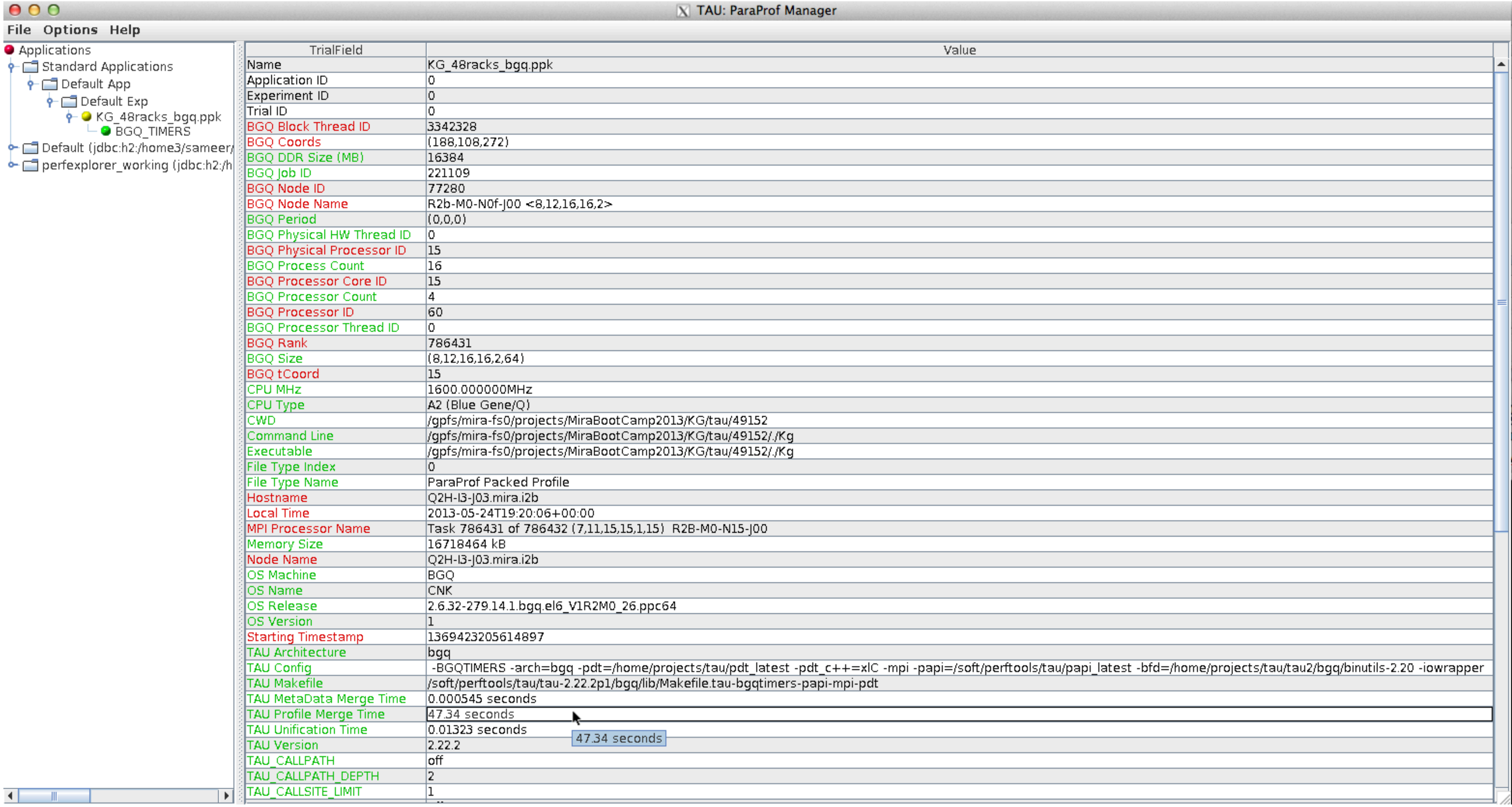
Number of threads: 295680
Range minimum: 2.103
Range maximum: 2.208

Tracing Energy Usage with TAU and Vampir



Property	Value
Display	Counter Data Timeline
Type	Counter
Location	node 0, thread 0
Maximum	19.392746 G
Average	19.392746 G
Minimum	19.392746 G
Unit	1
Interval Begin	27.85 ms
Interval End	28 ms
Duration	150 µs

TAU’s Runtime Merging of Profile Data

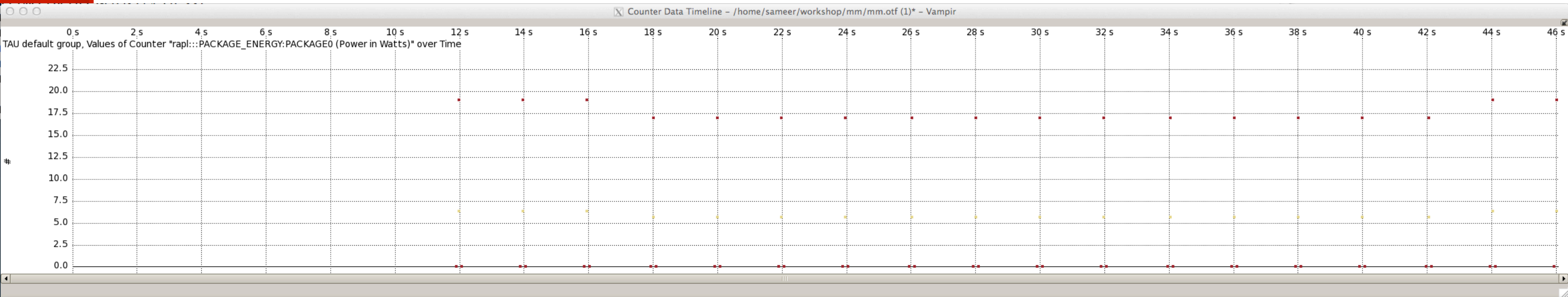


TrialField	Value
Name	KG_48racks_bgq.ppk
Application ID	0
Experiment ID	0
Trial ID	0
BGQ Block Thread ID	3342328
BGQ Coords	(188,108,272)
BGQ DDR Size (MB)	16384
BGQ Job ID	221109
BGQ Node ID	77280
BGQ Node Name	R2b-M0-N0f-J00 <8,12,16,16,2>
BGQ Period	(0,0,0)
BGQ Physical HW Thread ID	0
BGQ Physical Processor ID	15
BGQ Process Count	16
BGQ Processor Core ID	15
BGQ Processor Count	4
BGQ Processor ID	60
BGQ Processor Thread ID	0
BGQ Rank	786431
BGQ Size	(8,12,16,16,2,64)
BGQ tCoord	15
CPU MHz	1600.000000MHz
CPU Type	A2 (Blue Gene/Q)
CWD	/gpfs/mira-fs0/projects/MiraBootCamp2013/KG/tau/49152
Command Line	/gpfs/mira-fs0/projects/MiraBootCamp2013/KG/tau/49152/./Kg
Executable	/gpfs/mira-fs0/projects/MiraBootCamp2013/KG/tau/49152/./Kg
File Type Index	0
File Type Name	ParaProf Packed Profile
Hostname	Q2H-I3-J03.mira.i2b
Local Time	2013-05-24T19:20:06+00:00
MPI Processor Name	Task 786431 of 786432 (7,11,15,15,1,15) R2B-M0-N15-J00
Memory Size	16718464 kB
Node Name	Q2H-I3-J03.mira.i2b
OS Machine	BGQ
OS Name	CNK
OS Release	2.6.32-279.14.1.bgq.el6_V1R2M0_26.ppc64
OS Version	1
Starting Timestamp	1369423205614897
TAU Architecture	bgq
TAU Config	-BGQTIMERS -arch=bgq -pdt=/home/projects/tau/pdt_latest -pdt_c++=xlC -mpi -papi=/soft/perftools/tau/papi_latest -bfd=/home/projects/tau/tau2/bgq/binutils-2.20 -iowrapper
TAU Makefile	/soft/perftools/tau/tau-2.22.2p1/bgq/lib/Makefile.tau-bgqtimers-papi-mpi-pdt
TAU MetaData Merge Time	0.000545 seconds
TAU Profile Merge Time	47.34 seconds
TAU Unification Time	0.01323 seconds
TAU Version	2.22.2
TAU_CALLPATH	off
TAU_CALLPATH_DEPTH	2
TAU_CALLSITE_LIMIT	1

```
% export TAU_PROFILE_FORMAT=merged
```

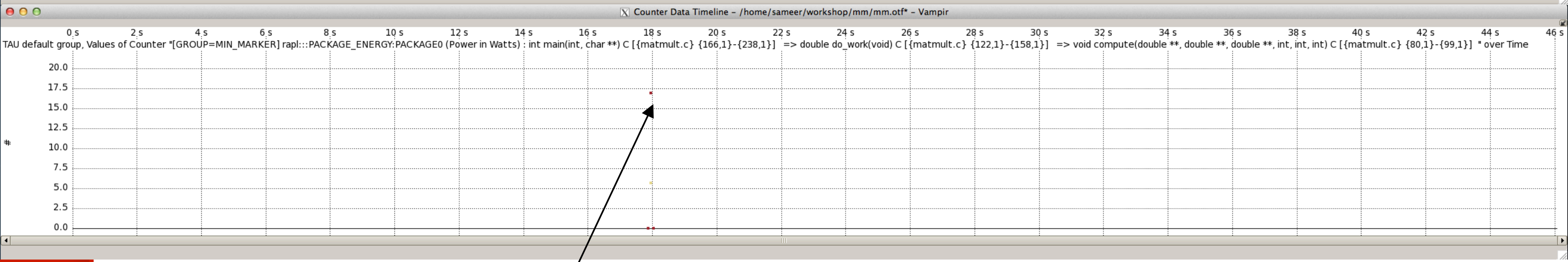
It took ~48 seconds to merge and write profiles from 786,432 ranks

Marker Events: Tracing



Counter Data Timeline – /home/sameer/workshop/mm/mm.otf (1)* – Vampir

TAU default group, Values of Counter "rapl:::PACKAGE_ENERGY:PACKAGE0 (Power in Watts)" over Time

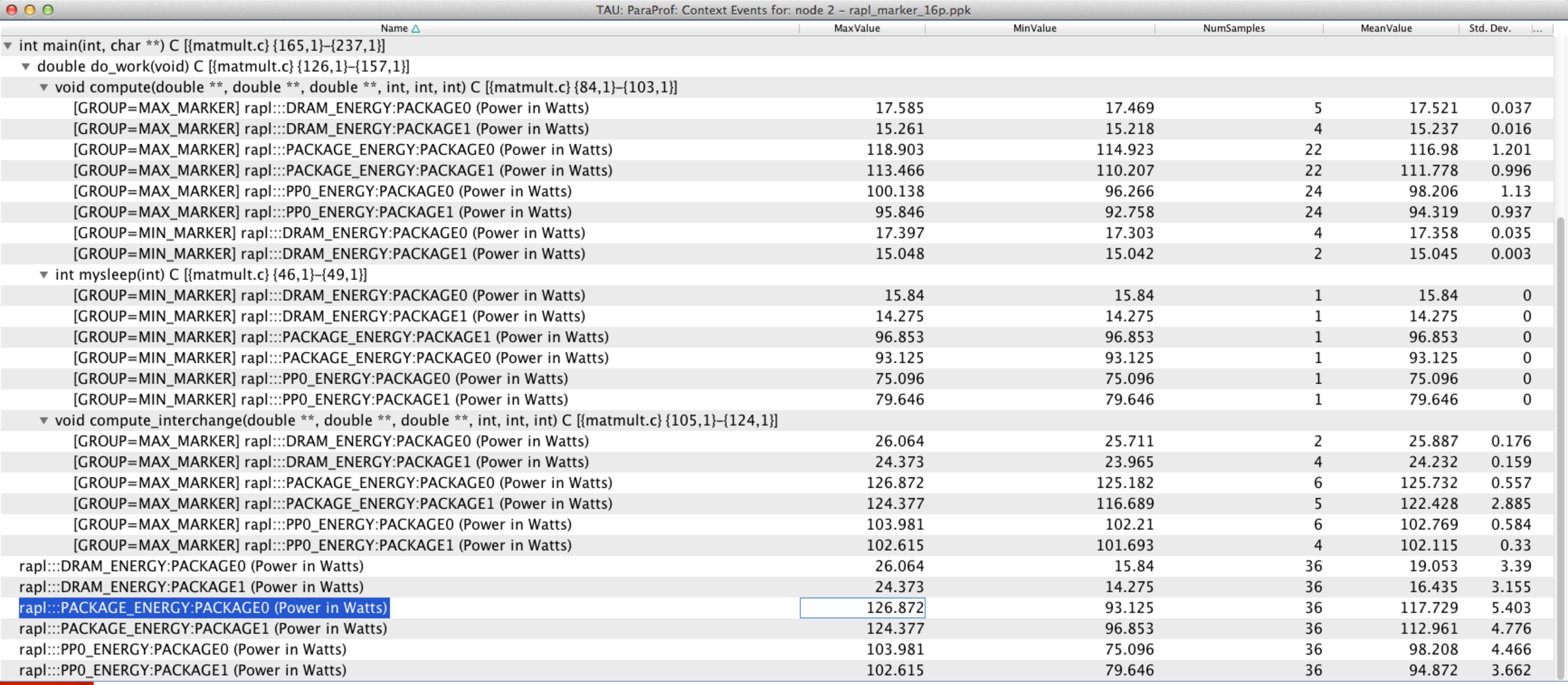


Counter Data Timeline – /home/sameer/workshop/mm/mm.otf* – Vampir

TAU default group, Values of Counter "[GROUP=MIN_MARKER] rapl:::PACKAGE_ENERGY:PACKAGE0 (Power in Watts) : int main(int, char **) C [{matmult.c} {166,1}-{238,1}]   => double do_work(void) C [{matmult.c} {122,1}-{158,1}]   => void compute(double **, double **, double **, int, int, int) C [{matmult.c} {80,1}-{99,1}] " over Time

When an atomic event exceeds the max or min value by a threshold (say 20%), a marker context event is triggered to record the callstack.

Marker events show sudden spikes



TAU: ParaProf: Context Events for: node 2 – rapl_marker_16p.ppk

Name △	MaxValue	MinValue	NumSamples	MeanValue	Std. Dev.
▼ int main(int, char **) C [{matmult.c} {165,1}-{237,1}]					
▼ double do_work(void) C [{matmult.c} {126,1}-{157,1}]					
▼ void compute(double **, double **, double **, int, int, int) C [{matmult.c} {84,1}-{103,1}]					
[GROUP=MAX_MARKER] rapl:::DRAM_ENERGY:PACKAGE0 (Power in Watts)	17.585	17.469	5	17.521	0.037
[GROUP=MAX_MARKER] rapl:::DRAM_ENERGY:PACKAGE1 (Power in Watts)	15.261	15.218	4	15.237	0.016
[GROUP=MAX_MARKER] rapl:::PACKAGE_ENERGY:PACKAGE0 (Power in Watts)	118.903	114.923	22	116.98	1.201
[GROUP=MAX_MARKER] rapl:::PACKAGE_ENERGY:PACKAGE1 (Power in Watts)	113.466	110.207	22	111.778	0.996
[GROUP=MAX_MARKER] rapl:::PP0_ENERGY:PACKAGE0 (Power in Watts)	100.138	96.266	24	98.206	1.13
[GROUP=MAX_MARKER] rapl:::PP0_ENERGY:PACKAGE1 (Power in Watts)	95.846	92.758	24	94.319	0.937
[GROUP=MIN_MARKER] rapl:::DRAM_ENERGY:PACKAGE0 (Power in Watts)	17.397	17.303	4	17.358	0.035
[GROUP=MIN_MARKER] rapl:::DRAM_ENERGY:PACKAGE1 (Power in Watts)	15.048	15.042	2	15.045	0.003
▼ int mysleep(int) C [{matmult.c} {46,1}-{49,1}]					
[GROUP=MIN_MARKER] rapl:::DRAM_ENERGY:PACKAGE0 (Power in Watts)	15.84	15.84	1	15.84	0
[GROUP=MIN_MARKER] rapl:::DRAM_ENERGY:PACKAGE1 (Power in Watts)	14.275	14.275	1	14.275	0
[GROUP=MIN_MARKER] rapl:::PACKAGE_ENERGY:PACKAGE1 (Power in Watts)	96.853	96.853	1	96.853	0
[GROUP=MIN_MARKER] rapl:::PACKAGE_ENERGY:PACKAGE0 (Power in Watts)	93.125	93.125	1	93.125	0
[GROUP=MIN_MARKER] rapl:::PP0_ENERGY:PACKAGE0 (Power in Watts)	75.096	75.096	1	75.096	0
[GROUP=MIN_MARKER] rapl:::PP0_ENERGY:PACKAGE1 (Power in Watts)	79.646	79.646	1	79.646	0
▼ void compute_interchange(double **, double **, double **, int, int, int) C [{matmult.c} {105,1}-{124,1}]					
[GROUP=MAX_MARKER] rapl:::DRAM_ENERGY:PACKAGE0 (Power in Watts)	26.064	25.711	2	25.887	0.176
[GROUP=MAX_MARKER] rapl:::DRAM_ENERGY:PACKAGE1 (Power in Watts)	24.373	23.965	4	24.232	0.159
[GROUP=MAX_MARKER] rapl:::PACKAGE_ENERGY:PACKAGE0 (Power in Watts)	126.872	125.182	6	125.732	0.557
[GROUP=MAX_MARKER] rapl:::PACKAGE_ENERGY:PACKAGE1 (Power in Watts)	124.377	116.689	5	122.428	2.885
[GROUP=MAX_MARKER] rapl:::PP0_ENERGY:PACKAGE0 (Power in Watts)	103.981	102.21	6	102.769	0.584
[GROUP=MAX_MARKER] rapl:::PP0_ENERGY:PACKAGE1 (Power in Watts)	102.615	101.693	4	102.115	0.33
rapl:::DRAM_ENERGY:PACKAGE0 (Power in Watts)	26.064	15.84	36	19.053	3.39
rapl:::DRAM_ENERGY:PACKAGE1 (Power in Watts)	24.373	14.275	36	16.435	3.155
rapl:::PACKAGE_ENERGY:PACKAGE0 (Power in Watts)	126.872	93.125	36	117.729	5.403
rapl:::PACKAGE_ENERGY:PACKAGE1 (Power in Watts)	124.377	96.853	36	112.961	4.776
rapl:::PP0_ENERGY:PACKAGE0 (Power in Watts)	103.981	75.096	36	98.208	4.466
rapl:::PP0_ENERGY:PACKAGE1 (Power in Watts)	102.615	79.646	36	94.872	3.662

```
% export TAU_EVENT_THRESHOLD 0.5
```

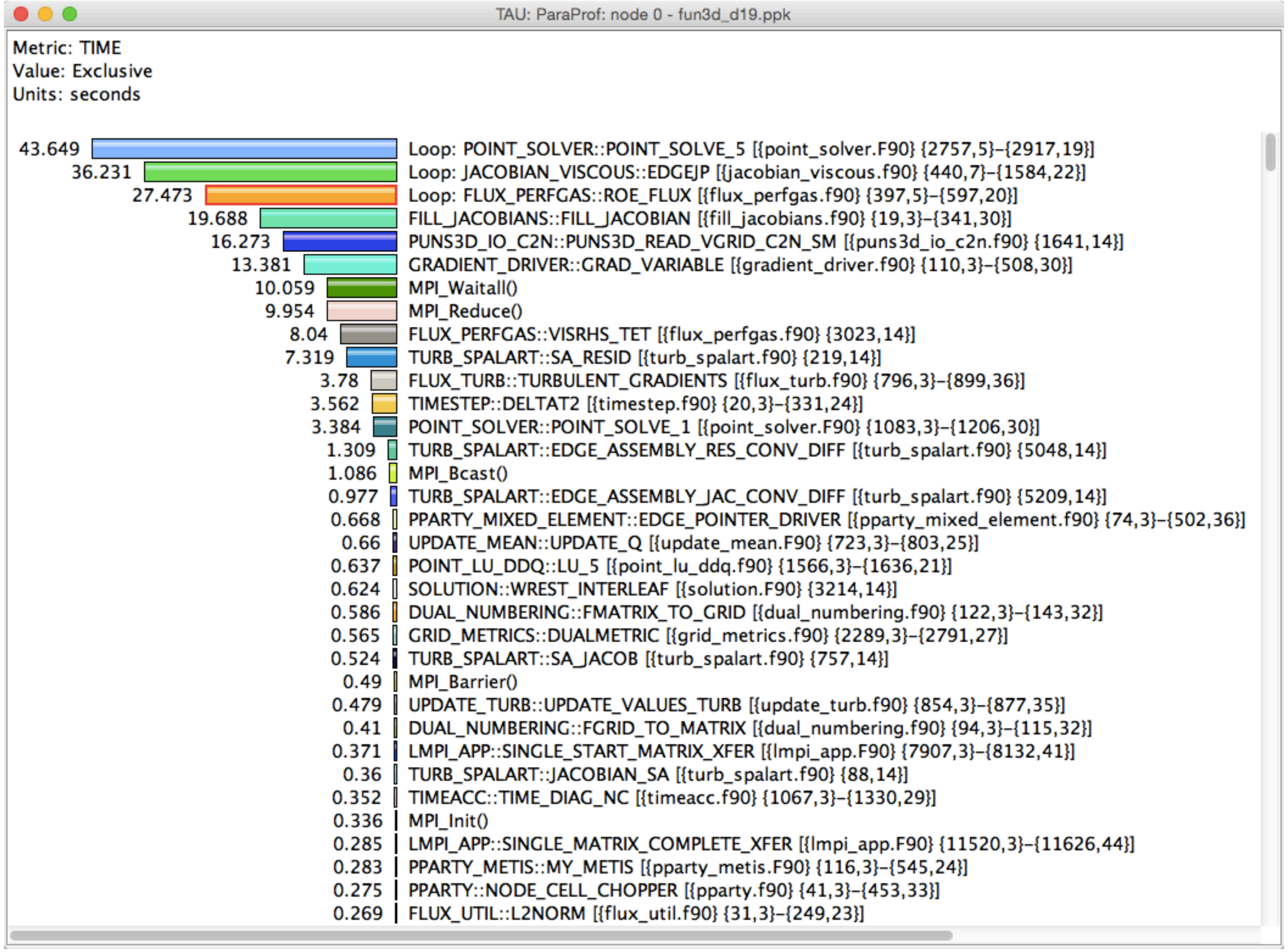
Generating a loop level profile

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% export TAU_OPTIONS=‘-optTauSelectFile=select.tau -optVerbose’
% cat select.tau
  BEGIN_INSTRUMENT_SECTION
  loops routine=“#”
  END_INSTRUMENT_SECTION

% module load tau
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)

% paraprof --pack app.ppk
  Move the app.ppk file to your desktop.

% paraprof app.ppk
Also, you may use export TAU_SELECT_FILE=select.tau to
filter events at runtime!
```

Loop Level Instrumentation

Goal: What loops account for the most time? How much?

Flat profile with wallclock time with loop instrumentation:



TAU: ParaProf: node 0 - fun3d_d19.ppk

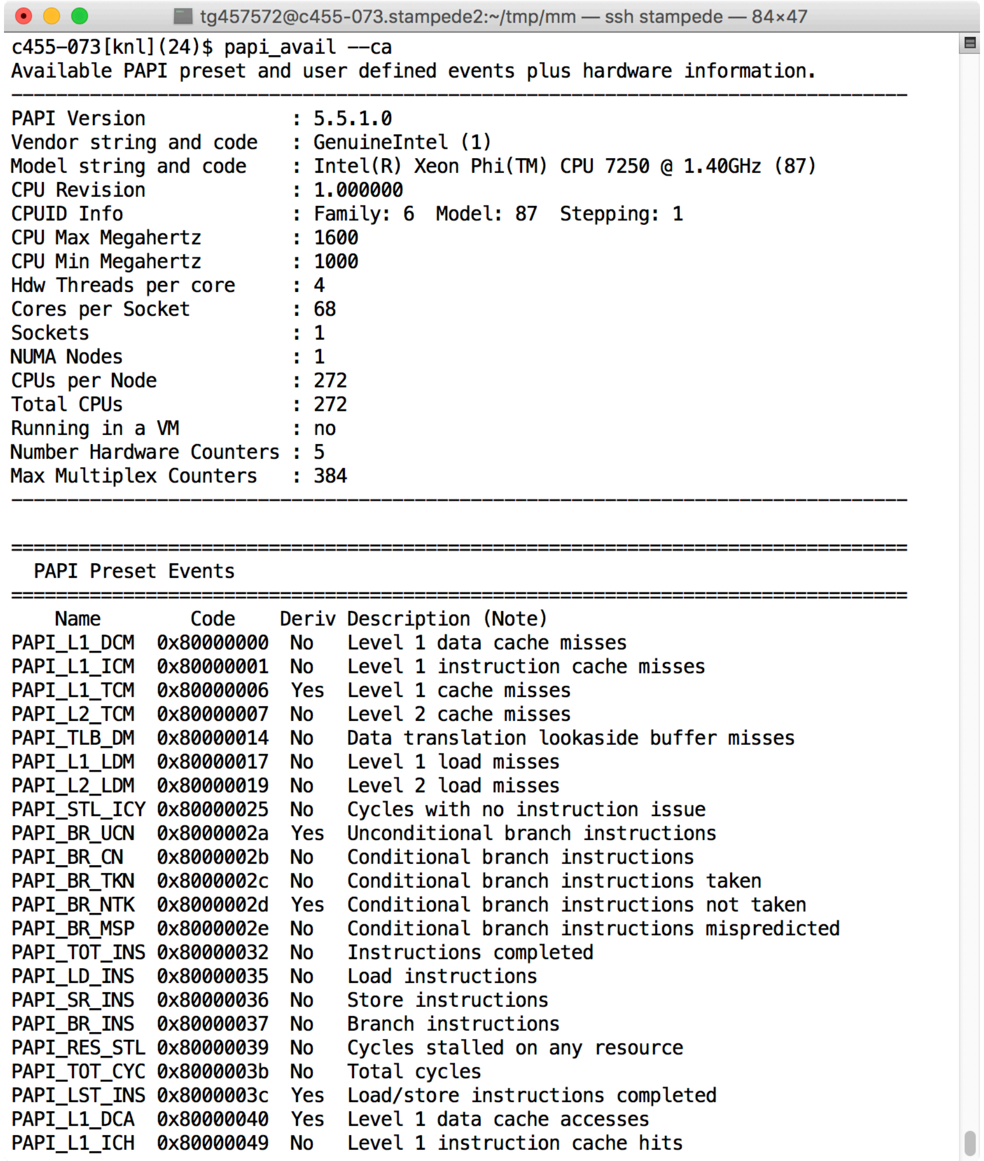
```
Metric: TIME
Value: Exclusive
Units: seconds

43.649  Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]
36.231  Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]
27.473  Loop: FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {397,5}-{597,20}]
19.688  FILL_JACOBIANS::FILL_JACOBIAN [{fill_jacobians.f90} {19,3}-{341,30}]
16.273  PUNS3D_IO_C2N::PUNS3D_READ_VGRID_C2N_SM [{puns3d_io_c2n.f90} {1641,14}]
13.381  GRADIENT_DRIVER::GRAD_VARIABLE [{gradient_driver.f90} {110,3}-{508,30}]
10.059  MPI_Waitall()
 9.954  MPI_Reduce()
  8.04  FLUX_PERFGAS::VISRHS_TET [{flux_perfgas.f90} {3023,14}]
 7.319  TURB_SPALART::SA_RESID [{turb_spalart.f90} {219,14}]
  3.78  FLUX_TURB::TURBULENT_GRADIENTS [{flux_turb.f90} {796,3}-{899,36}]
 3.562  TIMESTEP::DELTAT2 [{timestep.f90} {20,3}-{331,24}]
 3.384  POINT_SOLVER::POINT_SOLVE_1 [{point_solver.F90} {1083,3}-{1206,30}]
 1.309  TURB_SPALART::EDGE_ASSEMBLY_RES_CONV_DIFF [{turb_spalart.f90} {5048,14}]
 1.086  MPI_Bcast()
 0.977  TURB_SPALART::EDGE_ASSEMBLY_JAC_CONV_DIFF [{turb_spalart.f90} {5209,14}]
 0.668  PPARTY_MIXED_ELEMENT::EDGE_POINTER_DRIVER [{pparty_mixed_element.f90} {74,3}-{502,36}]
  0.66  UPDATE_MEAN::UPDATE_Q [{update_mean.F90} {723,3}-{803,25}]
 0.637  POINT_LU_DDQ::LU_5 [{point_lu_ddq.f90} {1566,3}-{1636,21}]
 0.624  SOLUTION::WREST_INTERLEAF [{solution.F90} {3214,14}]
 0.586  DUAL_NUMBERING::FMATRIX_TO_GRID [{dual_numbering.f90} {122,3}-{143,32}]
 0.565  GRID_METRICS::DUALMETRIC [{grid_metrics.f90} {2289,3}-{2791,27}]
 0.524  TURB_SPALART::SA_JACOB [{turb_spalart.f90} {757,14}]
  0.49  MPI_Barrier()
 0.479  UPDATE_TURB::UPDATE_VALUES_TURB [{update_turb.f90} {854,3}-{877,35}]
  0.41  DUAL_NUMBERING::FGRID_TO_MATRIX [{dual_numbering.f90} {94,3}-{115,32}]
 0.371  LMPI_APP::SINGLE_START_MATRIX_XFER [{lmpi_app.F90} {7907,3}-{8132,41}]
  0.36  TURB_SPALART::JACOBIAN_SA [{turb_spalart.f90} {88,14}]
 0.352  TIMEACC::TIME_DIAG_NC [{timeacc.f90} {1067,3}-{1330,29}]
 0.336  MPI_Init()
 0.285  LMPI_APP::SINGLE_MATRIX_COMPLETE_XFER [{lmpi_app.F90} {11520,3}-{11626,44}]
 0.283  PPARTY_METIS::MY_METIS [{pparty_metis.F90} {116,3}-{545,24}]
 0.275  PPARTY::NODE_CELL_CHOPPER [{pparty.f90} {41,3}-{453,33}]
 0.269  FLUX_UTIL::L2NORM [{flux_util.f90} {31,3}-{249,23}]
```

Tools: PAPI

PAPI

- Consistent interface to hardware performance counters
- Preset and native events
- Higher level tools use PAPI
  - TAU, Score-P, HPCToolkit, VampirTrace, Open|SpeedShop
- API, Library, Tools
  - papi_avail - shows the list of preset counters
  - papi_native_avail – shows the list of native processor specific counters
  - papi_event_chooser – allows you to find a list of compatible events
  - papi_decode – shows how a preset event is comprised of native events
  - Components – perf, RAPL for energy, network counters
- ***From University of Tenessee, Knoxville***
  - http://icl.cs.utk.edu/papi

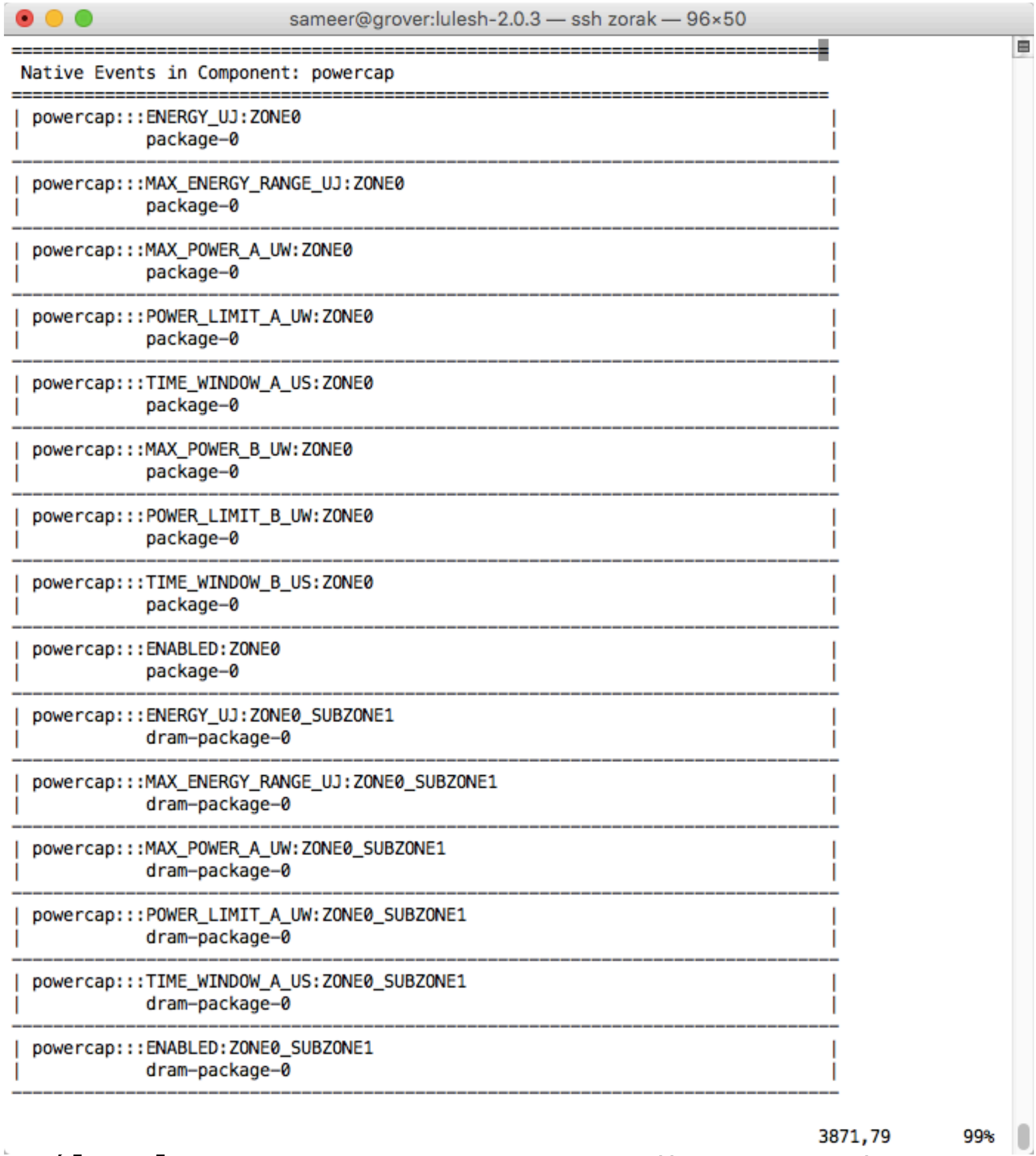
PAPI’s Preset Cache Events on KNL



```
c455-073[knl](24)$ papi_avail --ca
Available PAPI preset and user defined events plus hardware information.
--------------------------------------------------------------------------------
PAPI Version             : 5.5.1.0
Vendor string and code   : GenuineIntel (1)
Model string and code    : Intel(R) Xeon Phi(TM) CPU 7250 @ 1.40GHz (87)
CPU Revision             : 1.000000
CPUID Info               : Family: 6  Model: 87  Stepping: 1
CPU Max Megahertz        : 1600
CPU Min Megahertz        : 1000
Hdw Threads per core     : 4
Cores per Socket         : 68
Sockets                  : 1
NUMA Nodes               : 1
CPUs per Node            : 272
Total CPUs               : 272
Running in a VM          : no
Number Hardware Counters : 5
Max Multiplex Counters   : 384
--------------------------------------------------------------------------------


================================================================================
  PAPI Preset Events
================================================================================
    Name        Code    Deriv Description (Note)
PAPI_L1_DCM  0x80000000  No   Level 1 data cache misses
PAPI_L1_ICM  0x80000001  No   Level 1 instruction cache misses
PAPI_L1_TCM  0x80000006  Yes  Level 1 cache misses
PAPI_L2_TCM  0x80000007  No   Level 2 cache misses
PAPI_TLB_DM  0x80000014  No   Data translation lookaside buffer misses
PAPI_L1_LDM  0x80000017  No   Level 1 load misses
PAPI_L2_LDM  0x80000019  No   Level 2 load misses
PAPI_STL_ICY 0x80000025  No   Cycles with no instruction issue
PAPI_BR_UCN  0x8000002a  Yes  Unconditional branch instructions
PAPI_BR_CN   0x8000002b  No   Conditional branch instructions
PAPI_BR_TKN  0x8000002c  No   Conditional branch instructions taken
PAPI_BR_NTK  0x8000002d  Yes  Conditional branch instructions not taken
PAPI_BR_MSP  0x8000002e  No   Conditional branch instructions mispredicted
PAPI_TOT_INS 0x80000032  No   Instructions completed
PAPI_LD_INS  0x80000035  No   Load instructions
PAPI_SR_INS  0x80000036  No   Store instructions
PAPI_BR_INS  0x80000037  No   Branch instructions
PAPI_RES_STL 0x80000039  No   Cycles stalled on any resource
PAPI_TOT_CYC 0x8000003b  No   Total cycles
PAPI_LST_INS 0x8000003c  Yes  Load/store instructions completed
PAPI_L1_DCA  0x80000040  Yes  Level 1 data cache accesses
PAPI_L1_ICH  0x80000049  No   Level 1 instruction cache hits
```

% papi_avail −ca

PAPI's Native Events for powercap



```
================================================================================
 Native Events in Component: powercap
================================================================================
| powercap:::ENERGY_UJ:ZONE0                                                    |
|            package-0                                                          |
--------------------------------------------------------------------------------
| powercap:::MAX_ENERGY_RANGE_UJ:ZONE0                                          |
|            package-0                                                          |
--------------------------------------------------------------------------------
| powercap:::MAX_POWER_A_UW:ZONE0                                               |
|            package-0                                                          |
--------------------------------------------------------------------------------
| powercap:::POWER_LIMIT_A_UW:ZONE0                                             |
|            package-0                                                          |
--------------------------------------------------------------------------------
| powercap:::TIME_WINDOW_A_US:ZONE0                                             |
|            package-0                                                          |
--------------------------------------------------------------------------------
| powercap:::MAX_POWER_B_UW:ZONE0                                               |
|            package-0                                                          |
--------------------------------------------------------------------------------
| powercap:::POWER_LIMIT_B_UW:ZONE0                                             |
|            package-0                                                          |
--------------------------------------------------------------------------------
| powercap:::TIME_WINDOW_B_US:ZONE0                                             |
|            package-0                                                          |
--------------------------------------------------------------------------------
| powercap:::ENABLED:ZONE0                                                      |
|            package-0                                                          |
--------------------------------------------------------------------------------
| powercap:::ENERGY_UJ:ZONE0_SUBZONE1                                           |
|            dram-package-0                                                     |
--------------------------------------------------------------------------------
| powercap:::MAX_ENERGY_RANGE_UJ:ZONE0_SUBZONE1                                 |
|            dram-package-0                                                     |
--------------------------------------------------------------------------------
| powercap:::MAX_POWER_A_UW:ZONE0_SUBZONE1                                      |
|            dram-package-0                                                     |
--------------------------------------------------------------------------------
| powercap:::POWER_LIMIT_A_UW:ZONE0_SUBZONE1                                    |
|            dram-package-0                                                     |
--------------------------------------------------------------------------------
| powercap:::TIME_WINDOW_A_US:ZONE0_SUBZONE1                                    |
|            dram-package-0                                                     |
--------------------------------------------------------------------------------
| powercap:::ENABLED:ZONE0_SUBZONE1                                             |
|            dram-package-0                                                     |
--------------------------------------------------------------------------------

                                                              3871,79       99%
```

% papi_native_avail

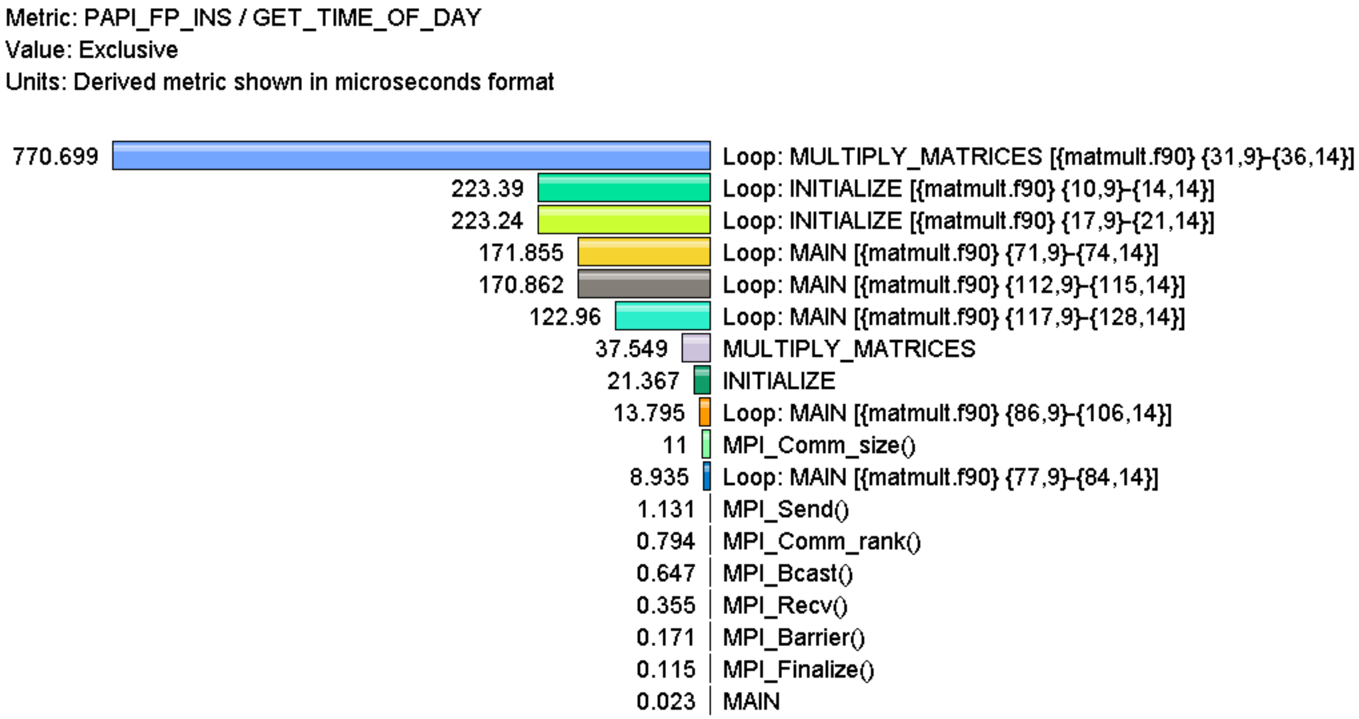
Profiling with multiple counters

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% export TAU_OPTIONS=‘-optTauSelectFile=select.tau -optVerbose’
% cat select.tau
  BEGIN_INSTRUMENT_SECTION
  loops routine=“#”
  END_INSTRUMENT_SECTION
% make F90=tau_f90.sh

% export TAU_METRICS=TIME,PAPI_TOT_CYC,PAPI_L1_DCM
% mpirun -np 4  ./matmult
% paraprof --pack app.ppk
  Move the app.ppk file to your desktop.
% paraprof app.ppk
  Choose Options -> Show Derived Panel -> Click PAPI_TOT_CYC,
 Click “/”,  Click TIME, Apply, Choose new metric by double
clicking.
```

Computing FLOPS per loop

Goal: What is the execution rate of my loops in MFLOPS?

Flat profile with PAPI_FP_INS and time with loop instrumentation:



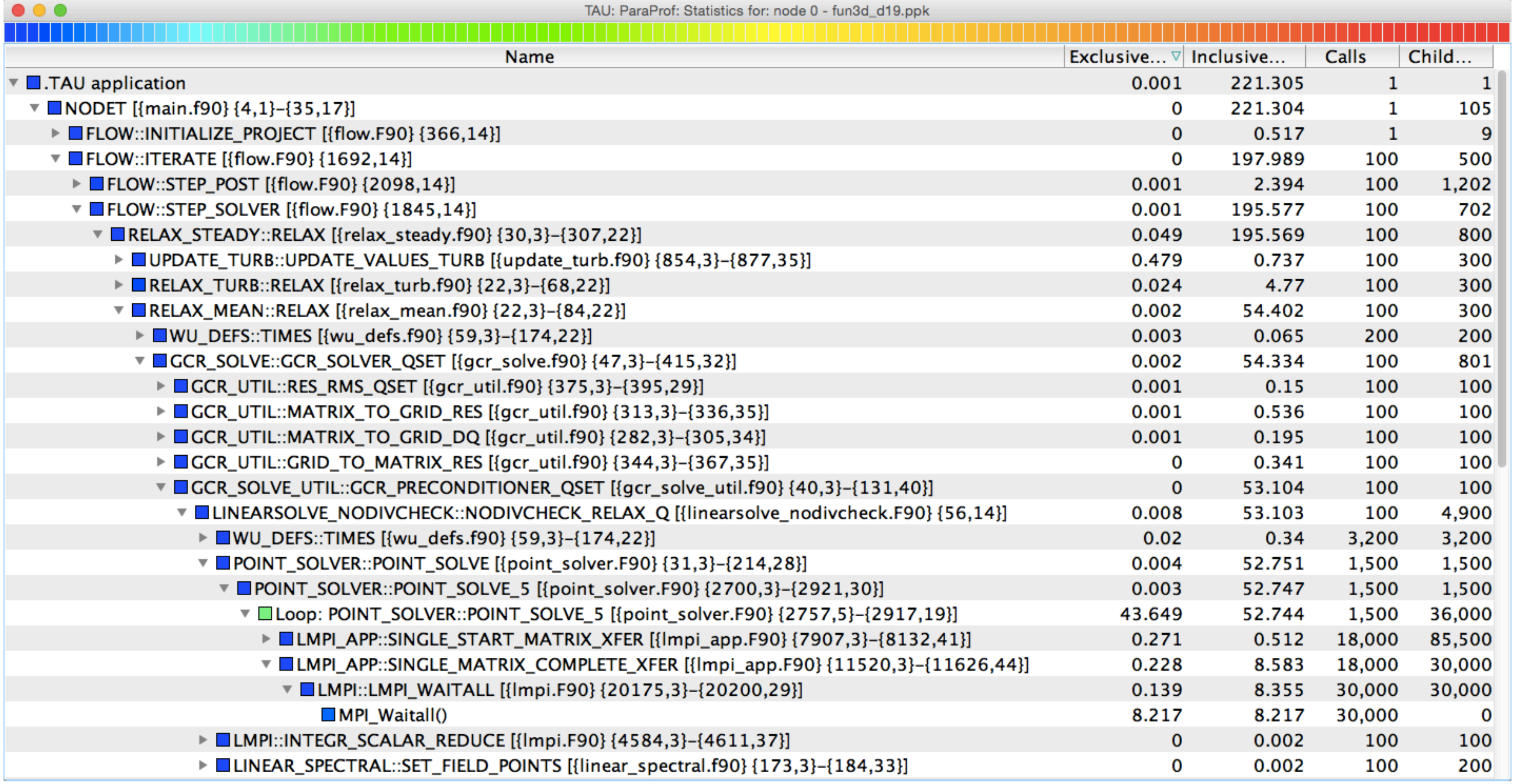
Metric: PAPI_FP_INS / GET_TIME_OF_DAY
Value: Exclusive
Units: Derived metric shown in microseconds format

```
770.699  Loop: MULTIPLY_MATRICES [{matmult.f90} {31,9}-{36,14}]
223.39   Loop: INITIALIZE [{matmult.f90} {10,9}-{14,14}]
223.24   Loop: INITIALIZE [{matmult.f90} {17,9}-{21,14}]
171.855  Loop: MAIN [{matmult.f90} {71,9}-{74,14}]
170.862  Loop: MAIN [{matmult.f90} {112,9}-{115,14}]
122.96   Loop: MAIN [{matmult.f90} {117,9}-{128,14}]
37.549   MULTIPLY_MATRICES
21.367   INITIALIZE
13.795   Loop: MAIN [{matmult.f90} {86,9}-{106,14}]
11       MPI_Comm_size()
8.935    Loop: MAIN [{matmult.f90} {77,9}-{84,14}]
1.131    MPI_Send()
0.794    MPI_Comm_rank()
0.647    MPI_Bcast()
0.355    MPI_Recv()
0.171    MPI_Barrier()
0.115    MPI_Finalize()
0.023    MAIN
```

Generate a Callpath Profile

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)



% export TAU_CALLPATH=1
% export TAU_CALLPATH_DEPTH=100
(truncates all calling paths to a specified depth)
% mpirun -np 4   ./a.out
% paraprof --pack app.ppk
  Move the app.ppk file to your desktop.
% paraprof app.ppk
(Windows -> Thread -> Call Graph)
```

Callpath Profiling: FUN3D

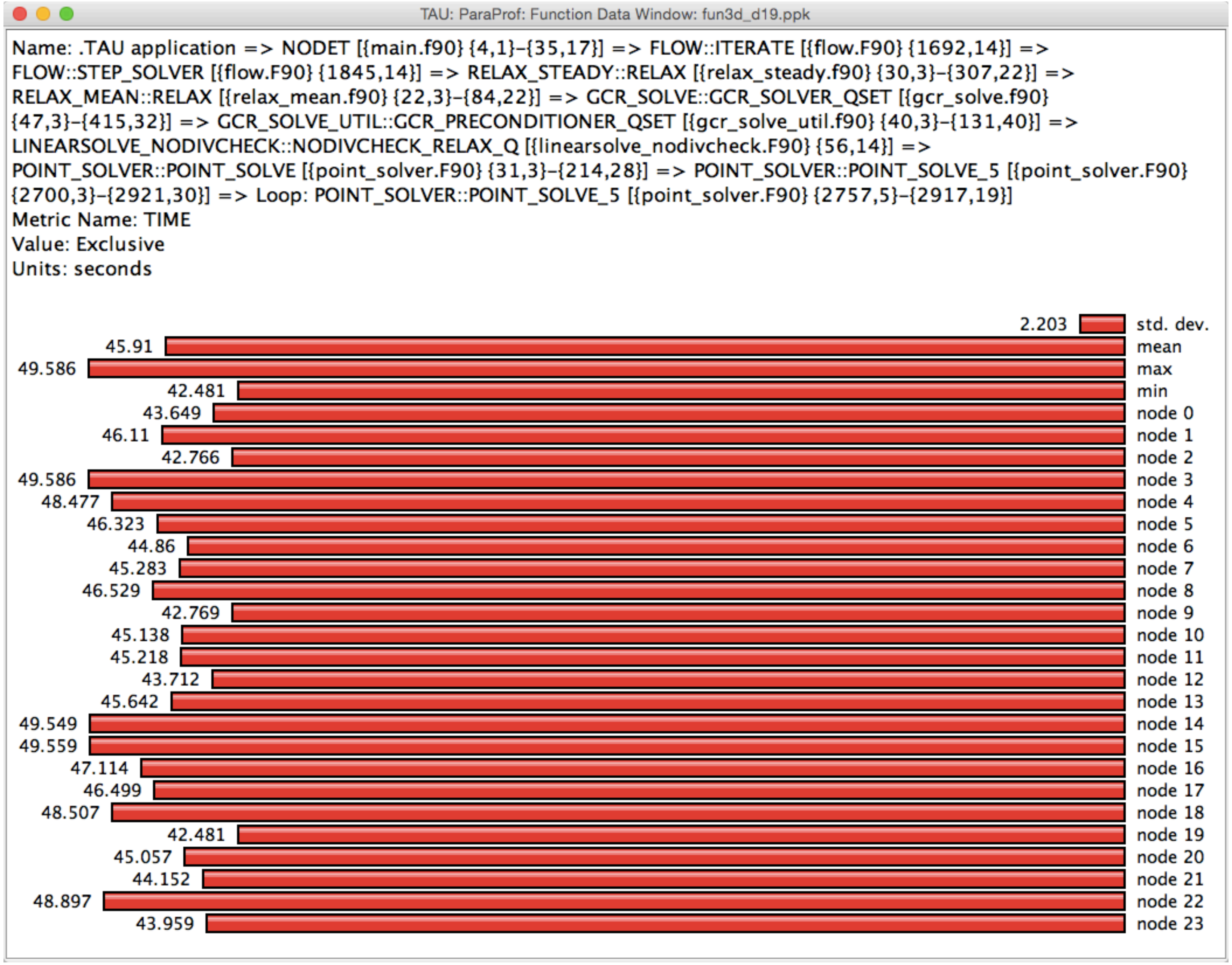


TAU: ParaProf: Statistics for: node 0 - fun3d_d19.ppk

Name	Exclusive... ▽	Inclusive...	Calls	Child...
▼ .TAU application	0.001	221.305	1	1
▼ NODET [{main.f90} {4,1}-{35,17}]	0	221.304	1	105
▶ FLOW::INITIALIZE_PROJECT [{flow.F90} {366,14}]	0	0.517	1	9
▼ FLOW::ITERATE [{flow.F90} {1692,14}]	0	197.989	100	500
▶ FLOW::STEP_POST [{flow.F90} {2098,14}]	0.001	2.394	100	1,202
▼ FLOW::STEP_SOLVER [{flow.F90} {1845,14}]	0.001	195.577	100	702
▼ RELAX_STEADY::RELAX [{relax_steady.f90} {30,3}-{307,22}]	0.049	195.569	100	800
▶ UPDATE_TURB::UPDATE_VALUES_TURB [{update_turb.f90} {854,3}-{877,35}]	0.479	0.737	100	300
▶ RELAX_TURB::RELAX [{relax_turb.f90} {22,3}-{68,22}]	0.024	4.77	100	300
▼ RELAX_MEAN::RELAX [{relax_mean.f90} {22,3}-{84,22}]	0.002	54.402	100	300
▶ WU_DEFS::TIMES [{wu_defs.f90} {59,3}-{174,22}]	0.003	0.065	200	200
▼ GCR_SOLVE::GCR_SOLVER_QSET [{gcr_solve.f90} {47,3}-{415,32}]	0.002	54.334	100	801
▶ GCR_UTIL::RES_RMS_QSET [{gcr_util.f90} {375,3}-{395,29}]	0.001	0.15	100	100
▶ GCR_UTIL::MATRIX_TO_GRID_RES [{gcr_util.f90} {313,3}-{336,35}]	0.001	0.536	100	100
▶ GCR_UTIL::MATRIX_TO_GRID_DQ [{gcr_util.f90} {282,3}-{305,34}]	0.001	0.195	100	100
▶ GCR_UTIL::GRID_TO_MATRIX_RES [{gcr_util.f90} {344,3}-{367,35}]	0	0.341	100	100
▼ GCR_SOLVE_UTIL::GCR_PRECONDITIONER_QSET [{gcr_solve_util.f90} {40,3}-{131,40}]	0	53.104	100	100
▼ LINEARSOLVE_NODIVCHECK::NODIVCHECK_RELAX_Q [{linearsolve_nodivcheck.F90} {56,14}]	0.008	53.103	100	4,900
▶ WU_DEFS::TIMES [{wu_defs.f90} {59,3}-{174,22}]	0.02	0.34	3,200	3,200
▼ POINT_SOLVER::POINT_SOLVE [{point_solver.F90} {31,3}-{214,28}]	0.004	52.751	1,500	1,500
▼ POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2700,3}-{2921,30}]	0.003	52.747	1,500	1,500
▼ Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]	43.649	52.744	1,500	36,000
▶ LMPI_APP::SINGLE_START_MATRIX_XFER [{lmpi_app.F90} {7907,3}-{8132,41}]	0.271	0.512	18,000	85,500
▼ LMPI_APP::SINGLE_MATRIX_COMPLETE_XFER [{lmpi_app.F90} {11520,3}-{11626,44}]	0.228	8.583	18,000	30,000
▼ LMPI::LMPI_WAITALL [{lmpi.F90} {20175,3}-{20200,29}]	0.139	8.355	30,000	30,000
MPI_Waitall()	8.217	8.217	30,000	0
▶ LMPI::INTEGR_SCALAR_REDUCE [{lmpi.F90} {4584,3}-{4611,37}]	0	0.002	100	100
▶ LINEAR_SPECTRAL::SET_FIELD_POINTS [{linear_spectral.f90} {173,3}-{184,33}]	0	0.002	100	200

```
% export TAU_CALLPATH=1
% export TAU_CALLPATH_DEPTH=100
```

ParaProf Function Window



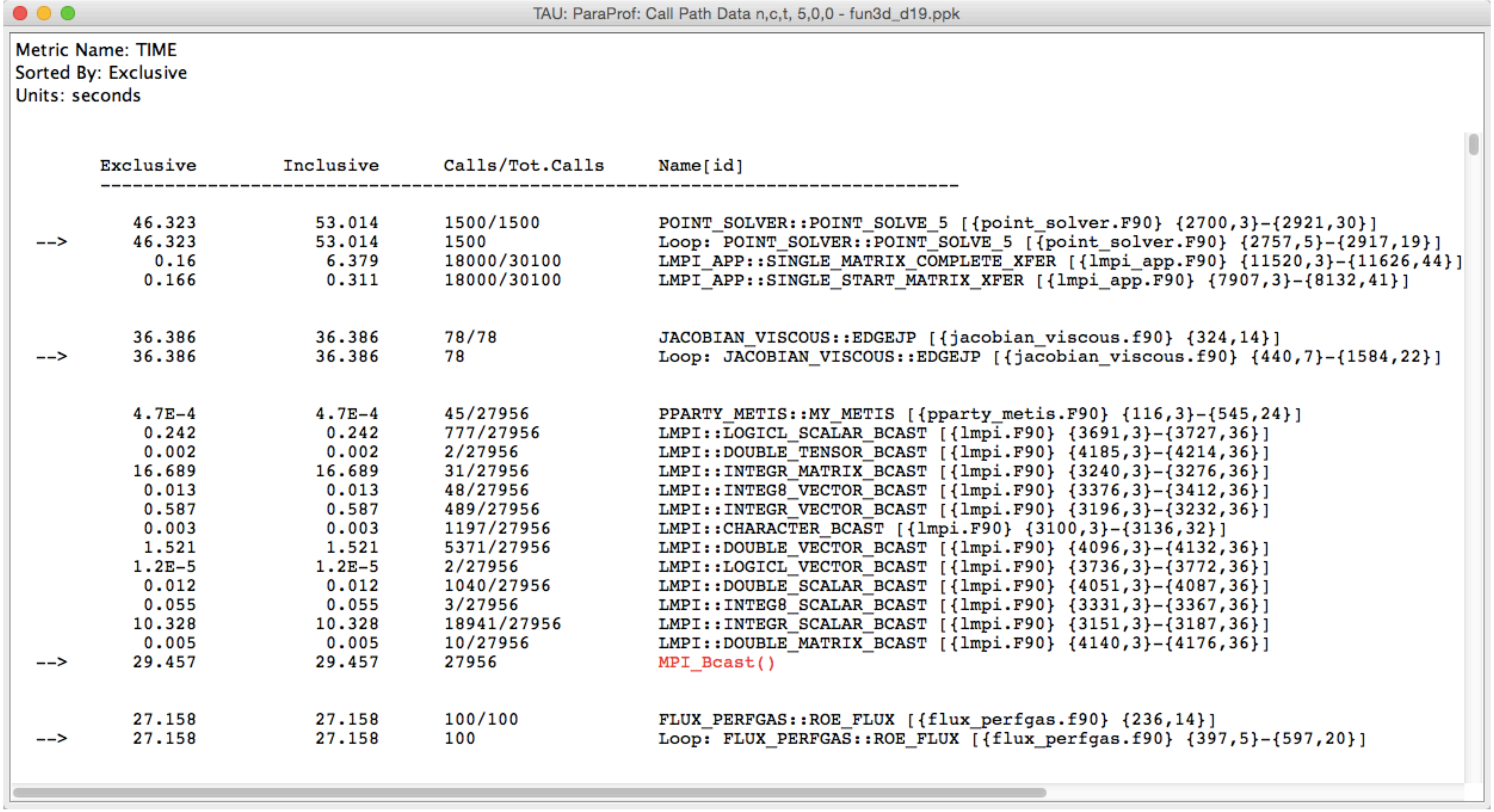
Name: .TAU application => NODET [{main.f90} {4,1}-{35,17}] => FLOW::ITERATE [{flow.F90} {1692,14}] => FLOW::STEP_SOLVER [{flow.F90} {1845,14}] => RELAX_STEADY::RELAX [{relax_steady.f90} {30,3}-{307,22}] => RELAX_MEAN::RELAX [{relax_mean.f90} {22,3}-{84,22}] => GCR_SOLVE::GCR_SOLVER_QSET [{gcr_solve.f90} {47,3}-{415,32}] => GCR_SOLVE_UTIL::GCR_PRECONDITIONER_QSET [{gcr_solve_util.f90} {40,3}-{131,40}] => LINEARSOLVE_NODIVCHECK::NODIVCHECK_RELAX_Q [{linearsolve_nodivcheck.F90} {56,14}] => POINT_SOLVER::POINT_SOLVE [{point_solver.F90} {31,3}-{214,28}] => POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2700,3}-{2921,30}] => Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]

Metric Name: TIME

Value: Exclusive

Units: seconds

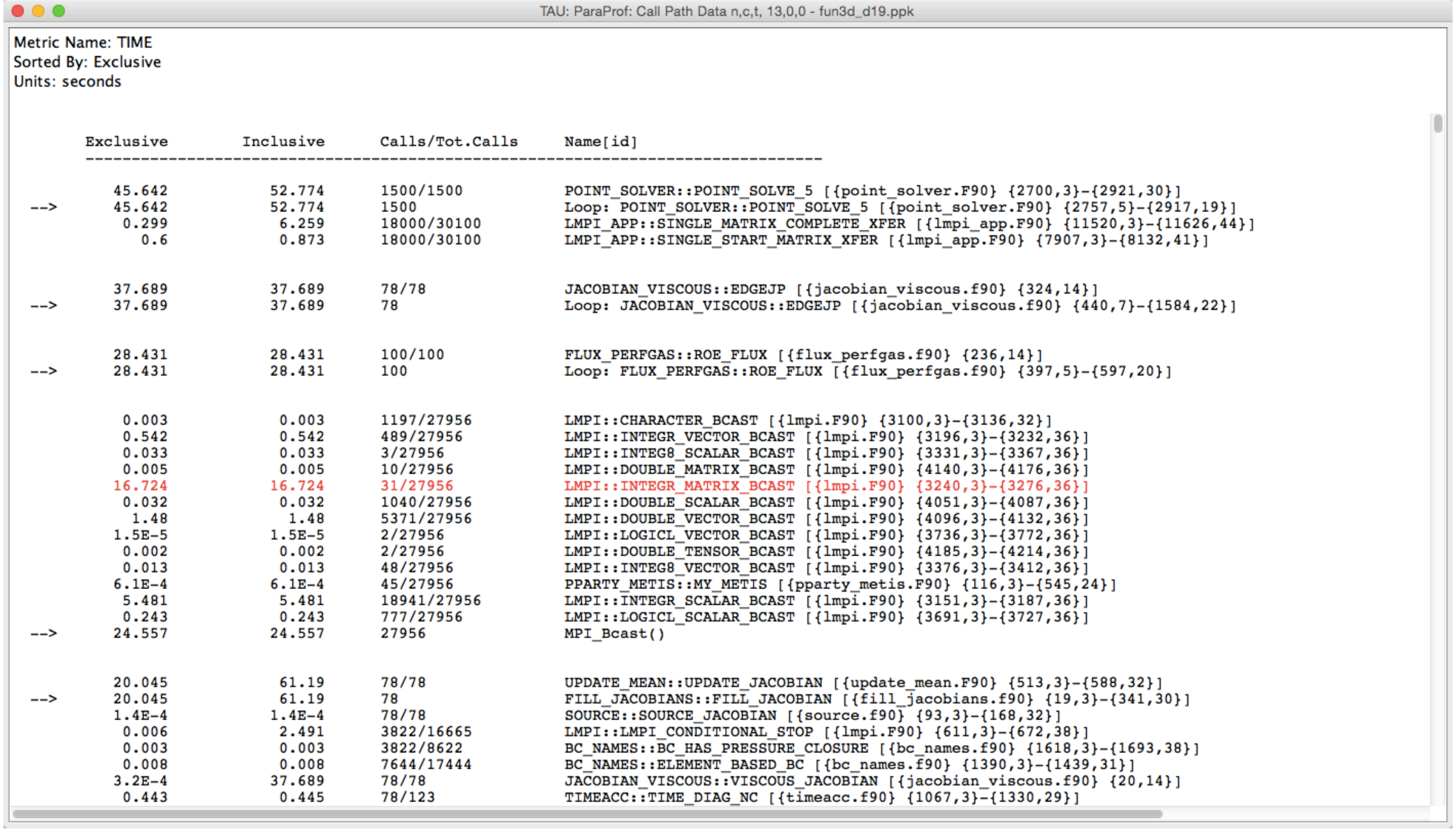
ParaProf Callpath Thread Relations Window



```
Metric Name: TIME
Sorted By: Exclusive
Units: seconds


      Exclusive        Inclusive      Calls/Tot.Calls     Name[id]
      ----------------------------------------------------------------------------------

         46.323           53.014      1500/1500           POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2700,3}-{2921,30}]
-->      46.323           53.014      1500                Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]
           0.16            6.379      18000/30100         LMPI_APP::SINGLE_MATRIX_COMPLETE_XFER [{lmpi_app.F90} {11520,3}-{11626,44}]
          0.166            0.311      18000/30100         LMPI_APP::SINGLE_START_MATRIX_XFER [{lmpi_app.F90} {7907,3}-{8132,41}]


         36.386           36.386      78/78               JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {324,14}]
-->      36.386           36.386      78                  Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]


         4.7E-4           4.7E-4      45/27956            PPARTY_METIS::MY_METIS [{pparty_metis.F90} {116,3}-{545,24}]
          0.242            0.242      777/27956           LMPI::LOGICL_SCALAR_BCAST [{lmpi.F90} {3691,3}-{3727,36}]
          0.002            0.002      2/27956             LMPI::DOUBLE_TENSOR_BCAST [{lmpi.F90} {4185,3}-{4214,36}]
         16.689           16.689      31/27956            LMPI::INTEGR_MATRIX_BCAST [{lmpi.F90} {3240,3}-{3276,36}]
          0.013            0.013      48/27956            LMPI::INTEG8_VECTOR_BCAST [{lmpi.F90} {3376,3}-{3412,36}]
          0.587            0.587      489/27956           LMPI::INTEGR_VECTOR_BCAST [{lmpi.F90} {3196,3}-{3232,36}]
          0.003            0.003      1197/27956          LMPI::CHARACTER_BCAST [{lmpi.F90} {3100,3}-{3136,32}]
          1.521            1.521      5371/27956          LMPI::DOUBLE_VECTOR_BCAST [{lmpi.F90} {4096,3}-{4132,36}]
         1.2E-5           1.2E-5      2/27956             LMPI::LOGICL_VECTOR_BCAST [{lmpi.F90} {3736,3}-{3772,36}]
          0.012            0.012      1040/27956          LMPI::DOUBLE_SCALAR_BCAST [{lmpi.F90} {4051,3}-{4087,36}]
          0.055            0.055      3/27956             LMPI::INTEG8_SCALAR_BCAST [{lmpi.F90} {3331,3}-{3367,36}]
         10.328           10.328      18941/27956         LMPI::INTEGR_SCALAR_BCAST [{lmpi.F90} {3151,3}-{3187,36}]
          0.005            0.005      10/27956            LMPI::DOUBLE_MATRIX_BCAST [{lmpi.F90} {4140,3}-{4176,36}]
-->      29.457           29.457      27956               MPI_Bcast()


         27.158           27.158      100/100             FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {236,14}]
-->      27.158           27.158      100                 Loop: FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {397,5}-{597,20}]
```

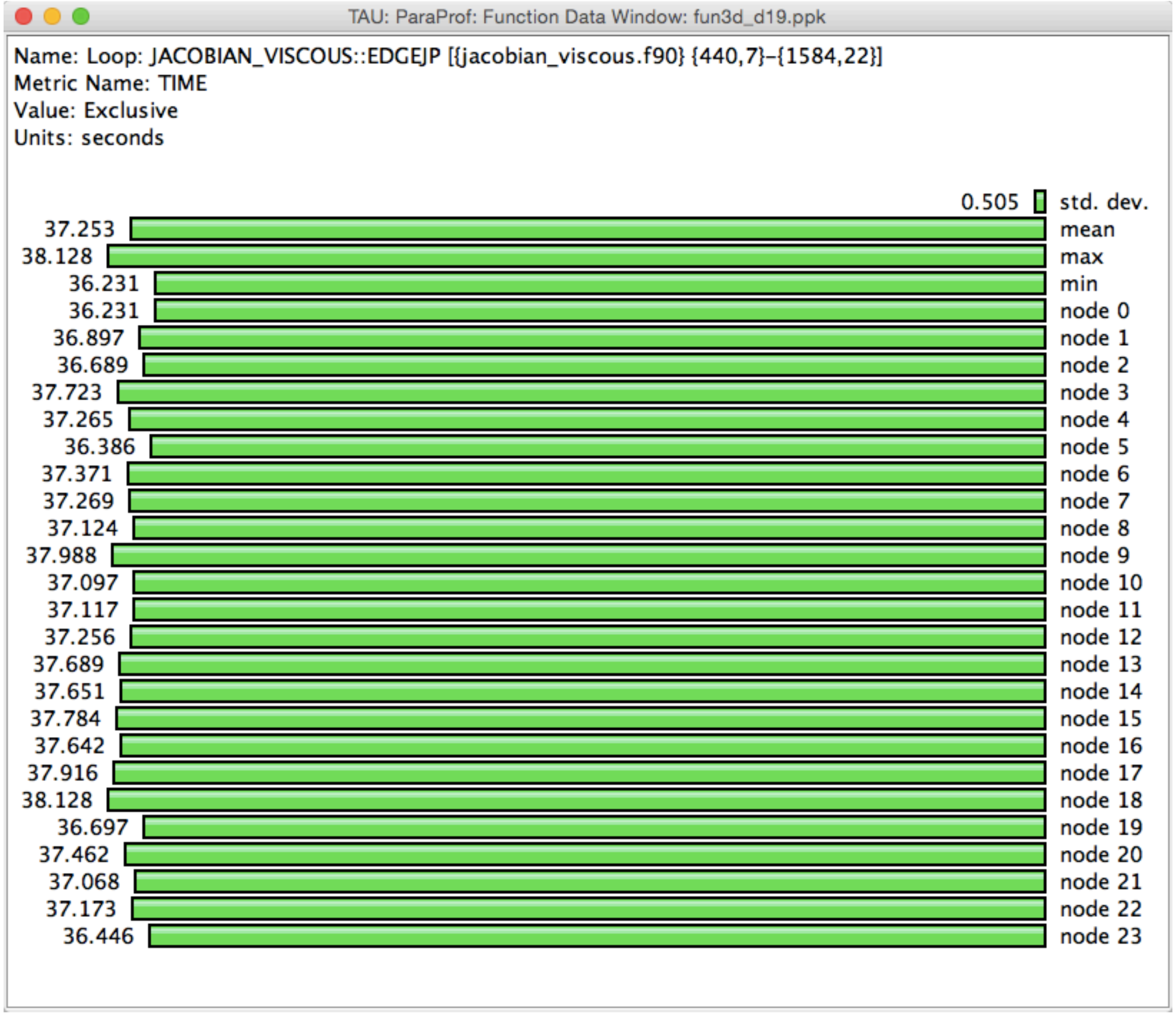
Shows the contribution of parents and children for each routine (marked by an arrow)

ParaProf Callpath Thread Relations Window



```
Metric Name: TIME
Sorted By: Exclusive
Units: seconds


      Exclusive        Inclusive      Calls/Tot.Calls     Name[id]
      --------------------------------------------------------------------------------

         45.642           52.774      1500/1500           POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2700,3}-{2921,30}]
 -->     45.642           52.774      1500                Loop: POINT_SOLVER::POINT_SOLVE_5 [{point_solver.F90} {2757,5}-{2917,19}]
          0.299            6.259      18000/30100         LMPI_APP::SINGLE_MATRIX_COMPLETE_XFER [{lmpi_app.F90} {11520,3}-{11626,44}]
            0.6            0.873      18000/30100         LMPI_APP::SINGLE_START_MATRIX_XFER [{lmpi_app.F90} {7907,3}-{8132,41}]


         37.689           37.689      78/78               JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {324,14}]
 -->     37.689           37.689      78                  Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]


         28.431           28.431      100/100             FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {236,14}]
 -->     28.431           28.431      100                 Loop: FLUX_PERFGAS::ROE_FLUX [{flux_perfgas.f90} {397,5}-{597,20}]


          0.003            0.003      1197/27956          LMPI::CHARACTER_BCAST [{lmpi.F90} {3100,3}-{3136,32}]
          0.542            0.542      489/27956           LMPI::INTEGR_VECTOR_BCAST [{lmpi.F90} {3196,3}-{3232,36}]
          0.033            0.033      3/27956             LMPI::INTEG8_SCALAR_BCAST [{lmpi.F90} {3331,3}-{3367,36}]
          0.005            0.005      10/27956            LMPI::DOUBLE_MATRIX_BCAST [{lmpi.F90} {4140,3}-{4176,36}]
         16.724           16.724      31/27956            LMPI::INTEGR_MATRIX_BCAST [{lmpi.F90} {3240,3}-{3276,36}]
          0.032            0.032      1040/27956          LMPI::DOUBLE_SCALAR_BCAST [{lmpi.F90} {4051,3}-{4087,36}]
           1.48             1.48      5371/27956          LMPI::DOUBLE_VECTOR_BCAST [{lmpi.F90} {4096,3}-{4132,36}]
         1.5E-5           1.5E-5      2/27956             LMPI::LOGICL_VECTOR_BCAST [{lmpi.F90} {3736,3}-{3772,36}]
          0.002            0.002      2/27956             LMPI::DOUBLE_TENSOR_BCAST [{lmpi.F90} {4185,3}-{4214,36}]
          0.013            0.013      48/27956            LMPI::INTEG8_VECTOR_BCAST [{lmpi.F90} {3376,3}-{3412,36}]
         6.1E-4           6.1E-4      45/27956            PPARTY_METIS::MY_METIS [{pparty_metis.F90} {116,3}-{545,24}]
          5.481            5.481      18941/27956         LMPI::INTEGR_SCALAR_BCAST [{lmpi.F90} {3151,3}-{3187,36}]
          0.243            0.243      777/27956           LMPI::LOGICL_SCALAR_BCAST [{lmpi.F90} {3691,3}-{3727,36}]
 -->     24.557           24.557      27956               MPI_Bcast()


         20.045            61.19      78/78               UPDATE_MEAN::UPDATE_JACOBIAN [{update_mean.F90} {513,3}-{588,32}]
 -->     20.045            61.19      78                  FILL_JACOBIANS::FILL_JACOBIAN [{fill_jacobians.f90} {19,3}-{341,30}]
         1.4E-4           1.4E-4      78/78               SOURCE::SOURCE_JACOBIAN [{source.f90} {93,3}-{168,32}]
          0.006            2.491      3822/16665          LMPI::LMPI_CONDITIONAL_STOP [{lmpi.F90} {611,3}-{672,38}]
          0.003            0.003      3822/8622           BC_NAMES::BC_HAS_PRESSURE_CLOSURE [{bc_names.f90} {1618,3}-{1693,38}]
          0.008            0.008      7644/17444          BC_NAMES::ELEMENT_BASED_BC [{bc_names.f90} {1390,3}-{1439,31}]
         3.2E-4           37.689      78/78               JACOBIAN_VISCOUS::VISCOUS_JACOBIAN [{jacobian_viscous.f90} {20,14}]
          0.443            0.445      78/123              TIMEACC::TIME_DIAG_NC [{timeacc.f90} {1067,3}-{1330,29}]
```

ParaProf Function Window



TAU: ParaProf: Function Data Window: fun3d_d19.ppk

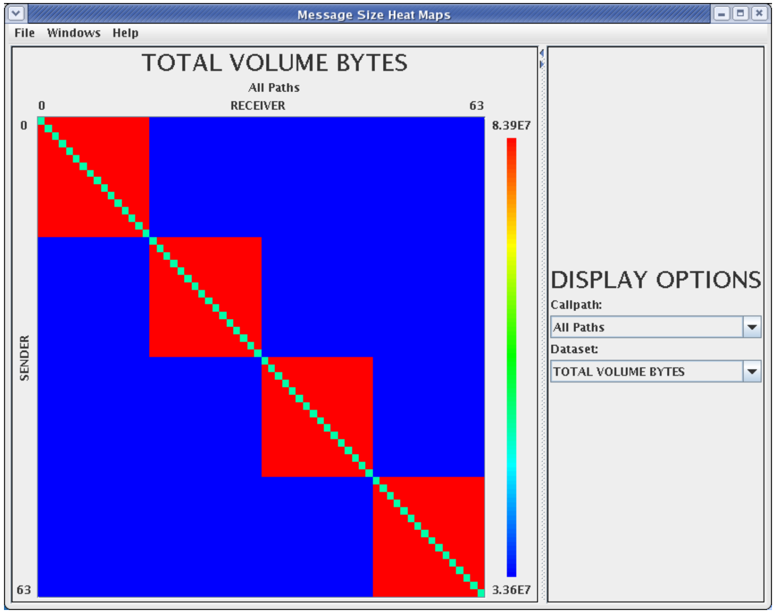
Name: Loop: JACOBIAN_VISCOUS::EDGEJP [{jacobian_viscous.f90} {440,7}-{1584,22}]
Metric Name: TIME
Value: Exclusive
Units: seconds

Generating Communication Matrix

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)

% export TAU_COMM_MATRIX=1
% mpirun -np 4   ./a.out

% paraprof
(Windows -> Communication Matrix)
(Windows -> 3D Communication Matrix)
```

Communication Matrix Display

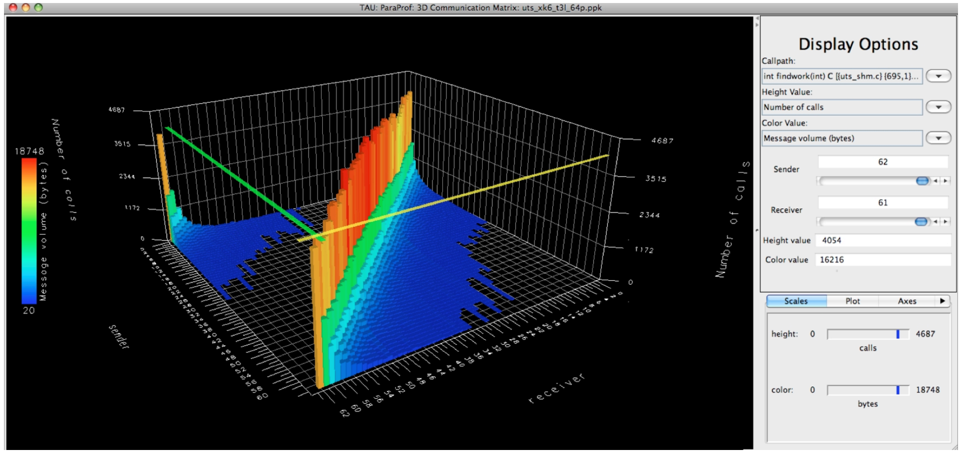
Goal: What is the volume of inter-process communication? Along which calling path?



DISPLAY OPTIONS

Callpath: All Paths

Dataset: TOTAL VOLUME BYTES



Display Options

Callpath: int findwork(int) C [{uts_shm.c} {695,1}...

Height Value: Number of calls

Color Value: Message volume (bytes)

Sender 62

Receiver 61

Height value 4054

Color value 16216

height: 0 4687 calls

color: 0 18748 bytes

ParaTools

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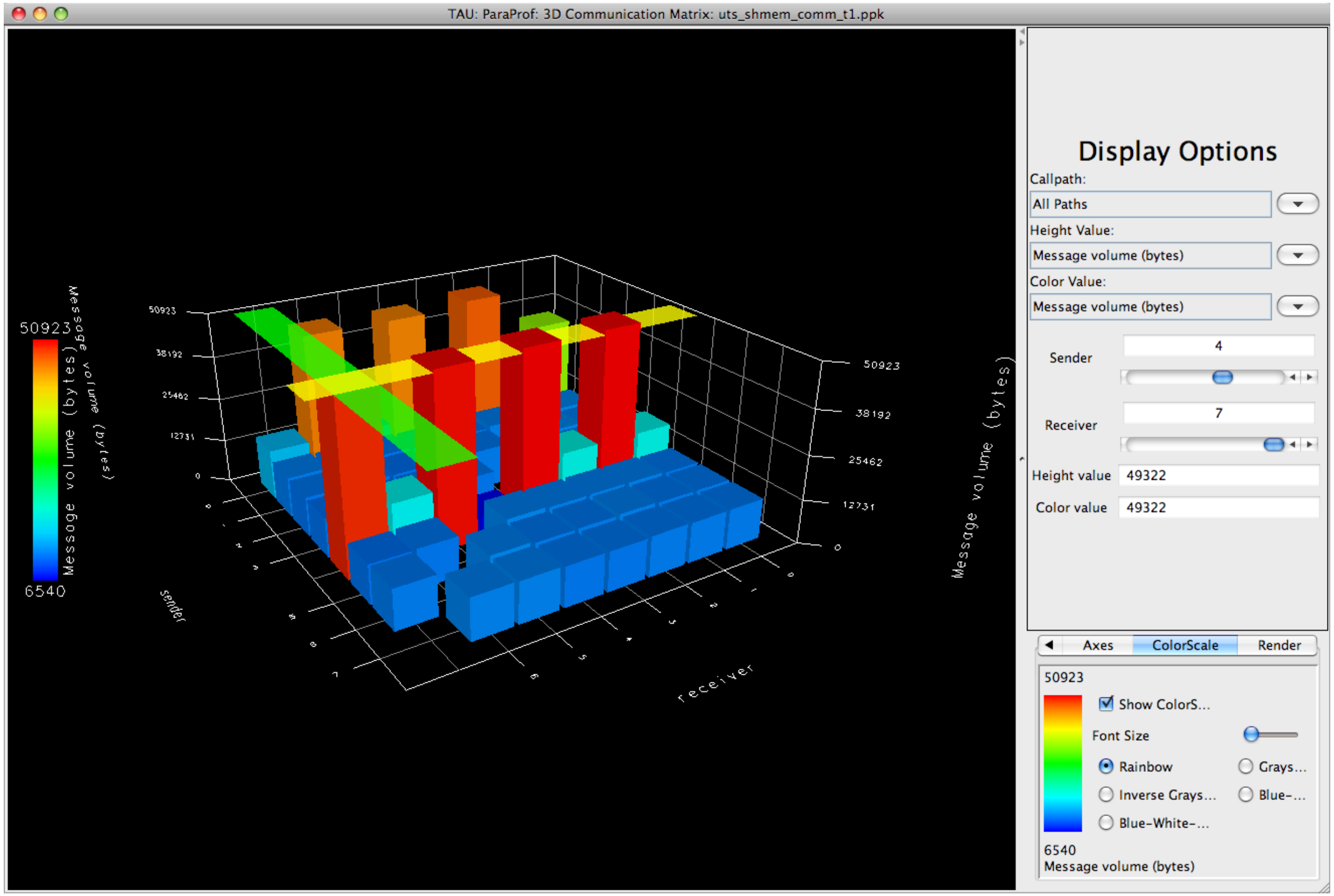
SHMEM Communication Matrix



TAU: ParaProf: 3D Communication Matrix: uts_shmem_comm_t1.ppk

Display Options

Callpath: All Paths

Height Value: Message volume (bytes)

Color Value: Message volume (bytes)

Sender: 4

Receiver: 7

Height value: 49322

Color value: 49322

☑ Show ColorS...

● Rainbow

○ Grays...

○ Inverse Grays...

○ Blue-...

○ Blue-White-...

Compiler-based Instrumentation

- Compiler automatically **emits instrumentation calls** in the object code instead of parsing the source code using PDT
- To enable: export TAU_OPTIONS="-optCompInst"
- Configure TAU with "-bfd=download" for best results

Use Compiler-Based Instrumentation

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% export TAU_OPTIONS=‘-optCompInst –optQuiet’

% make CC=tau_cc.sh CXX=tau_cxx.sh F90=tau_f90.sh
```

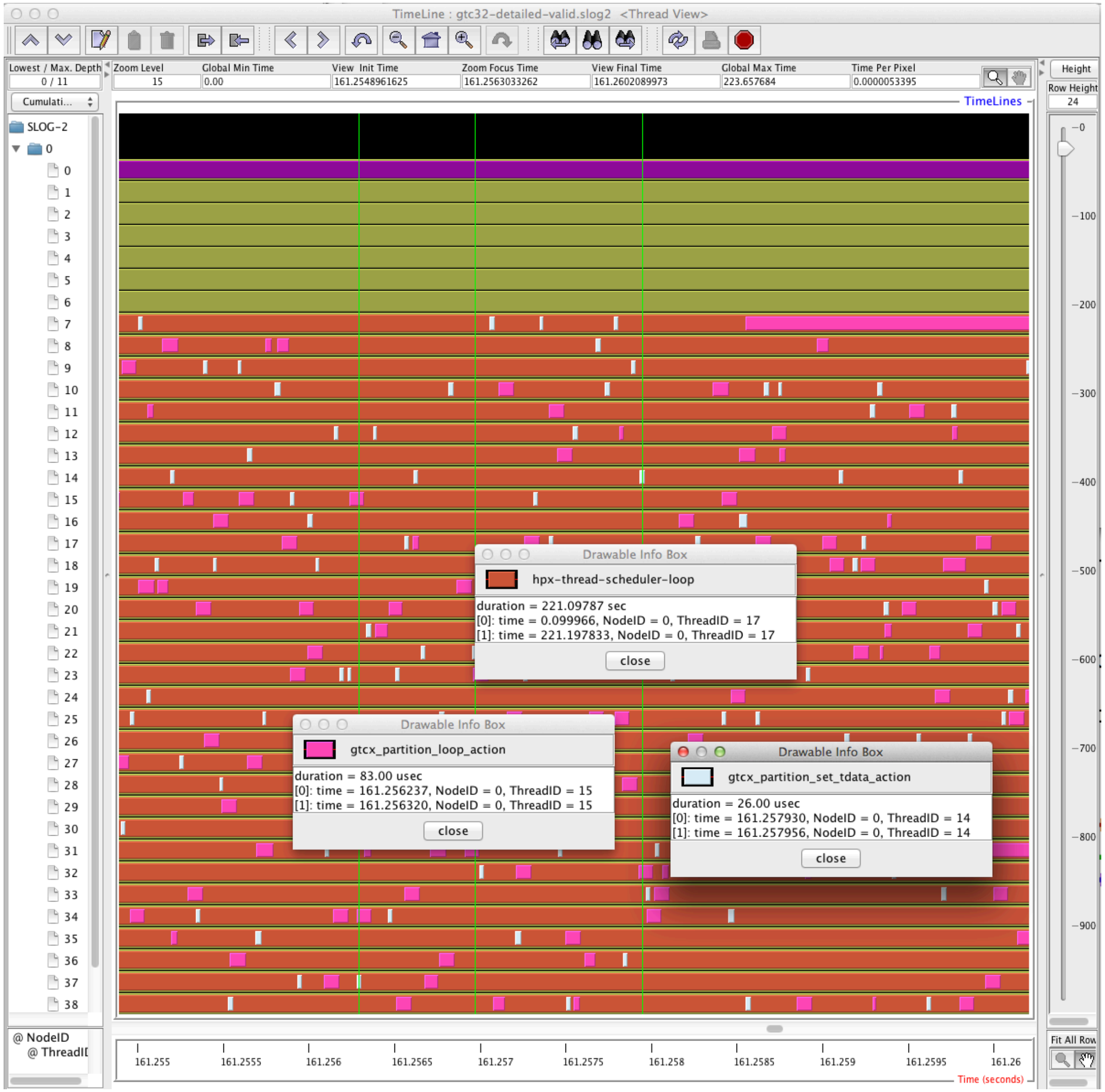
NOTE: You may also use the short-hand scripts taucc, tauf90, taucxx instead of specifying TAU_OPTIONS and using the traditional tau_<cc,cxx,f90>.sh scripts. These scripts use compiler-based instrumentation by default.

```
% make CC=taucc CXX=taucxx F90=tauf90

% mpirun -np 4 ./a.out
% paraprof --pack app.ppk
  Move the app.ppk file to your desktop.
% paraprof app.ppk
```

Compiler-based Instrumentation

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% export TAU_OPTIONS=‘-optCompInst -optQuiet’

% make CC=tau_cc.sh CXX=tau_cxx.sh F90=tau_f90.sh

NOTE: You may also use the short-hand scripts taucc, tauf90,
taucxx instead of specifying TAU_OPTIONS and using the
traditional tau_<cc,cxx,f90>.sh scripts. These scripts use
compiler-based instrumentation by default.

% make CC=taucc CXX=taucxx F90=tauf90

% mpirun -np 4 ./a.out
% paraprof --pack app.ppk
  Move the app.ppk file to your desktop.
% paraprof app.ppk
```

Jumpshot Trace Visualizer in TAU



Lowest / Max. Depth	Zoom Level	Global Min Time	View Init Time	Zoom Focus Time	View Final Time	Global Max Time	Time Per Pixel
0 / 11	15	0.00	161.2548961625	161.2563033262	161.2602089973	223.657684	0.0000053395

Row Height 24

Drawable Info Box

hpx-thread-scheduler-loop

duration = 221.09787 sec
[0]: time = 0.099966, NodeID = 0, ThreadID = 17
[1]: time = 221.197833, NodeID = 0, ThreadID = 17

close

Drawable Info Box

gtcx_partition_loop_action

duration = 83.00 usec
[0]: time = 161.256237, NodeID = 0, ThreadID = 15
[1]: time = 161.256320, NodeID = 0, ThreadID = 15

close

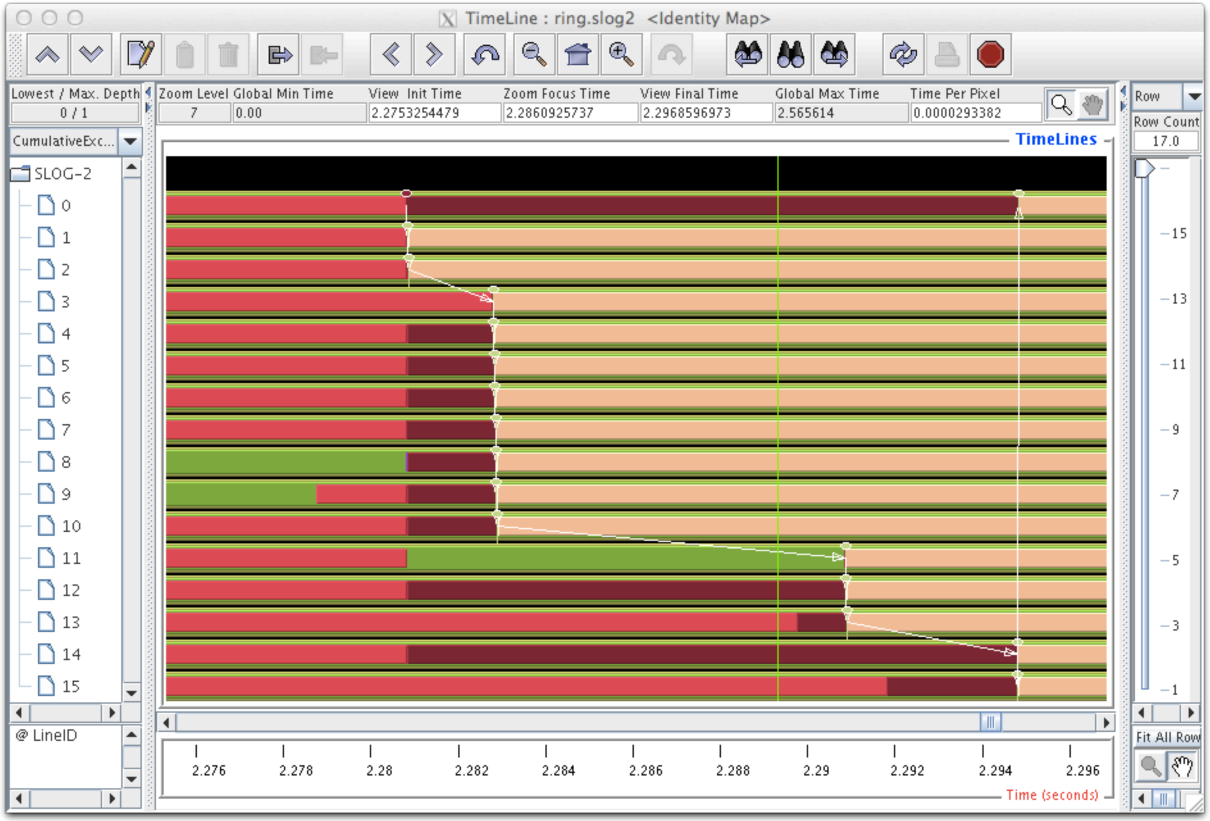
Drawable Info Box

gtcx_partition_set_tdata_action

duration = 26.00 usec
[0]: time = 161.257930, NodeID = 0, ThreadID = 14
[1]: time = 161.257956, NodeID = 0, ThreadID = 14

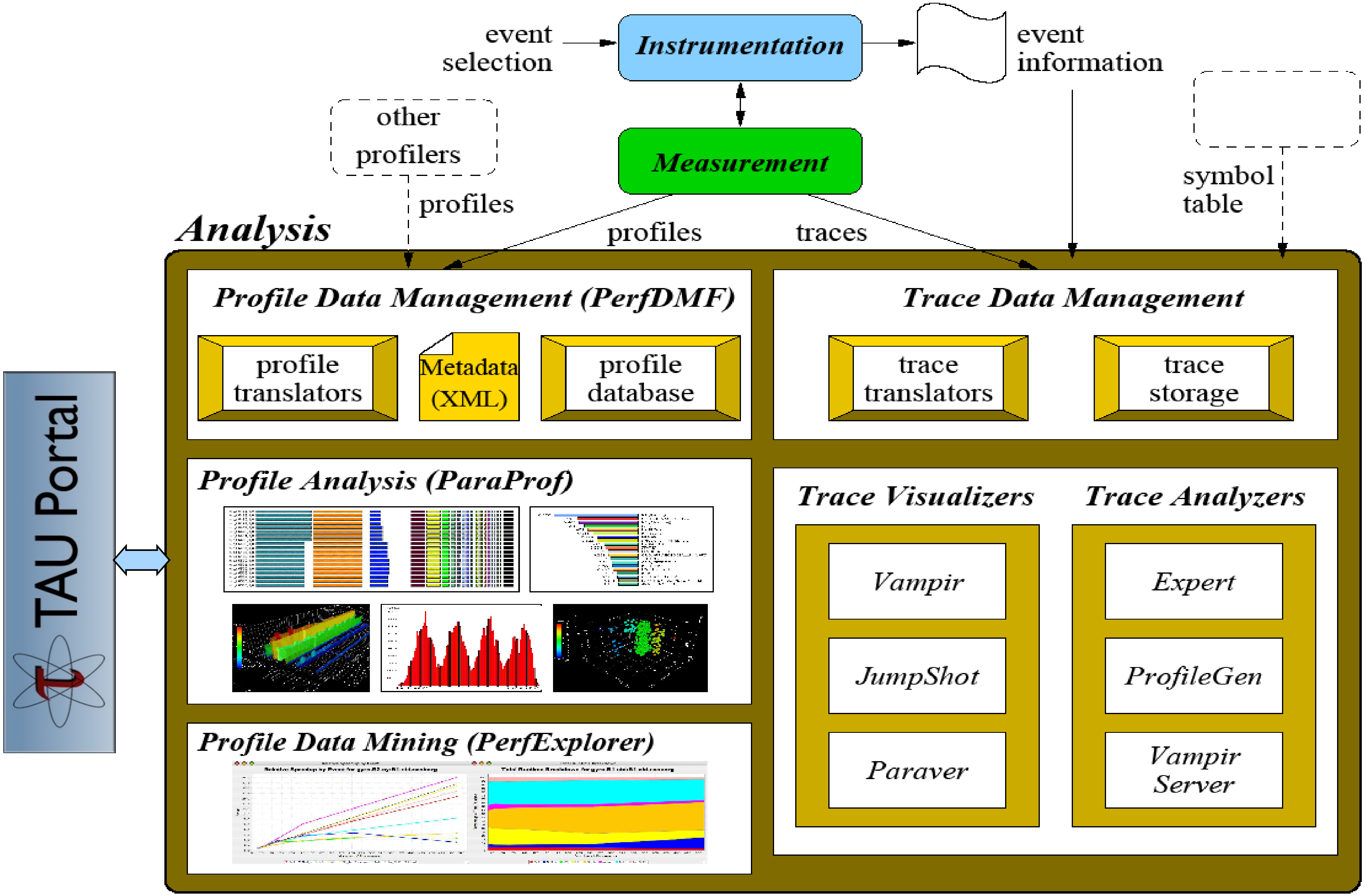
close

Tracing Communication in Jumpshot



```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% cmake –DCMAKE_CXX_COMPILER=tau_cxx.sh; make –j 8
% export TAU_TRACE=1
% mpirun –np 16 ./a.out ; tau_treemerge.pl; tau2slog2 tau.trc tau.edf –o a.slog2
% jumpshot a.slog2 &
```

Performance Analysis



Tools: Vampir

Vampir

Alternative and supplement to automatic analysis

Show dynamic run-time behavior graphically at any level of detail

Provide statistics and performance metrics

Timeline charts

- **Show application activities and communication along a time axis**

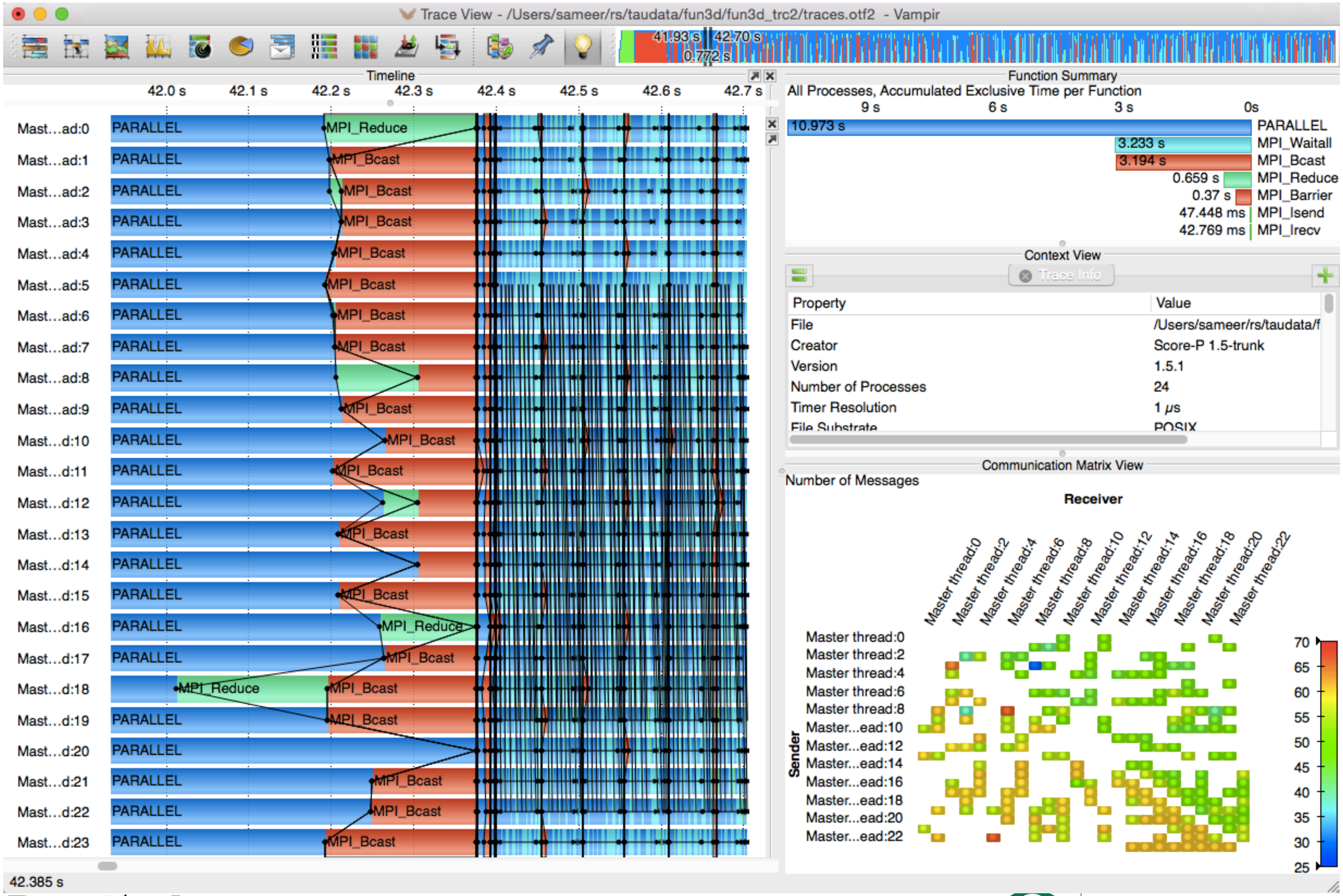
Summary charts

- **Provide quantitative results for the currently selected time interval**
- **Commercial trace visualization tool**

From TU Dresden, Germany

http://www.vampir.eu

Vampir – Trace Visualization



All Processes, Accumulated Exclusive Time per Function

10.973 s	PARALLEL
3.233 s	MPI_Waitall
3.194 s	MPI_Bcast
0.659 s	MPI_Reduce
0.37 s	MPI_Barrier
47.448 ms	MPI_Isend
42.769 ms	MPI_Irecv

Property	Value
File	/Users/sameer/rs/taudata/f
Creator	Score-P 1.5-trunk
Version	1.5.1
Number of Processes	24
Timer Resolution	1 μs
File Substrate	POSIX

ParaTools

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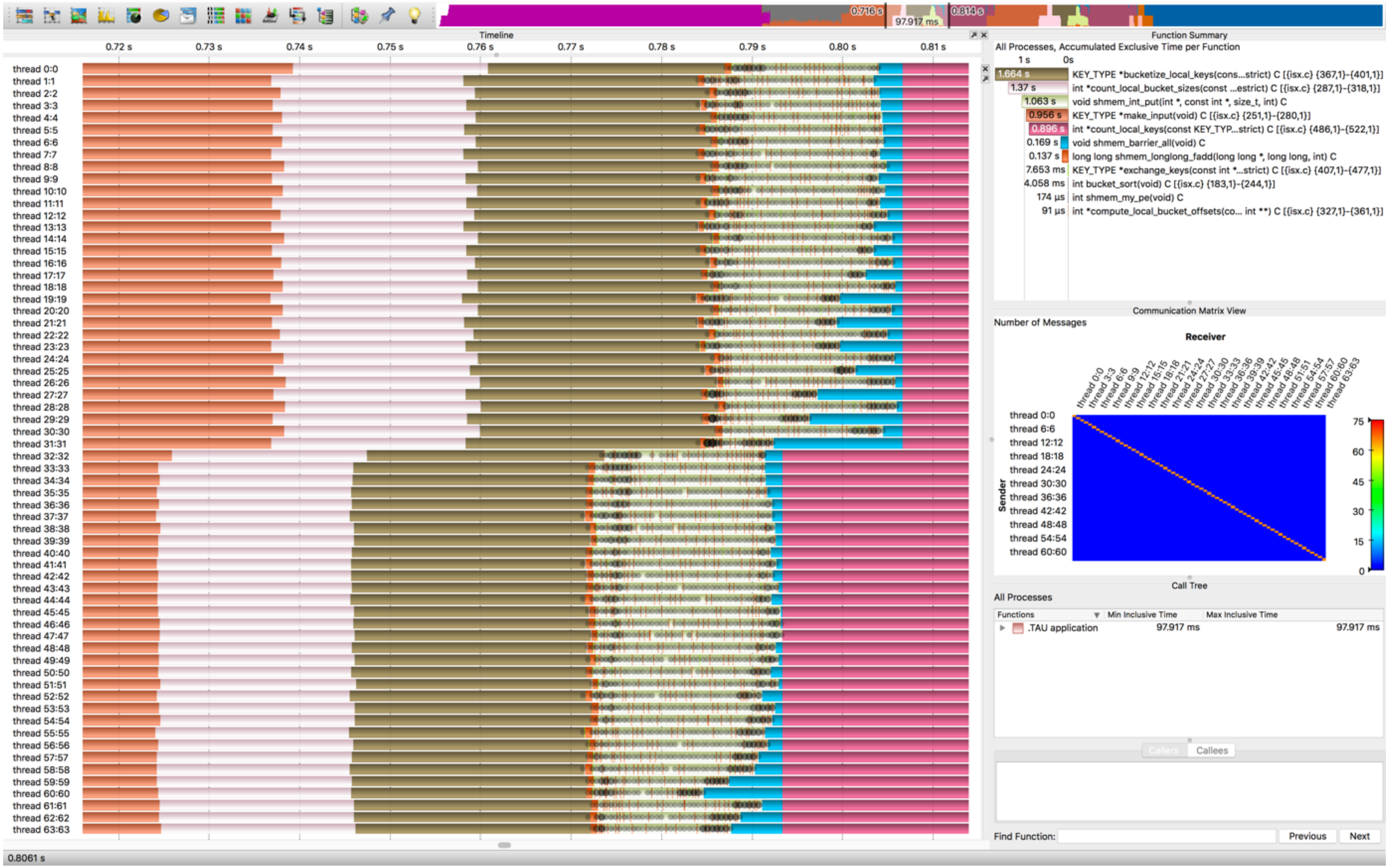
Vampir – Trace Visualization



Function Summary

All Processes, Accumulated Exclusive Time per Function

1 s 0s	
1.664 s	KEY_TYPE *bucketize_local_keys(cons...strict) C [{isx.c} {367,1}-{401,1}]
1.37 s	int *count_local_bucket_sizes(const ...estrict) C [{isx.c} {287,1}-{318,1}]
1.063 s	void shmem_int_put(int *, const int *, size_t, int) C
0.956 s	KEY_TYPE *make_input(void) C [{isx.c} {251,1}-{280,1}]
0.896 s	int *count_local_keys(const KEY_TYP...strict) C [{isx.c} {486,1}-{522,1}]
0.169 s	void shmem_barrier_all(void) C
0.137 s	long long shmem_longlong_fadd(long long *, long long, int) C
7.653 ms	KEY_TYPE *exchange_keys(const int *...strict) C [{isx.c} {407,1}-{477,1}]
4.058 ms	int bucket_sort(void) C [{isx.c} {183,1}-{244,1}]
174 µs	int shmem_my_pe(void) C
91 µs	int *compute_local_bucket_offsets(co... int **) C [{isx.c} {327,1}-{361,1}]

Call Tree

All Processes

Functions	Min Inclusive Time	Max Inclusive Time
▶ .TAU application	97.917 ms	97.917 ms

ParaTools

http://tau.uoregon.edu/tau_llnl19.pdf

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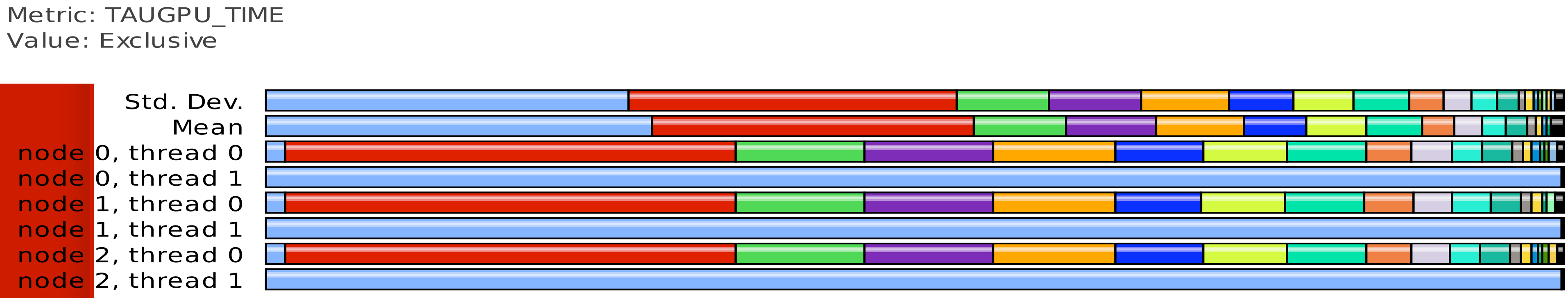
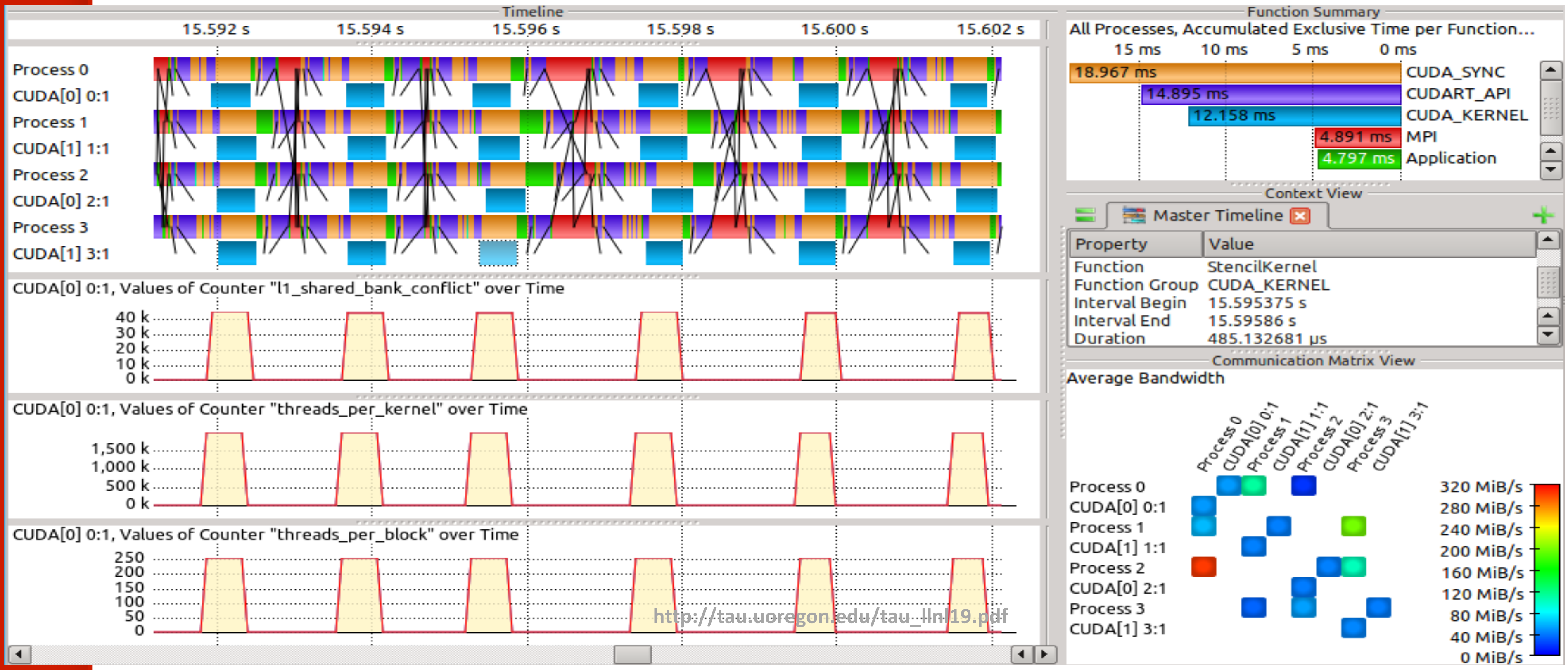
Stencil2D Parallel Profile / Trace in Vampir


Metric: TAUGPU_TIME
Value: Exclusive



CUDA[0] 0:1, Values of Counter "l1_shared_bank_conflict" over Time

CUDA[0] 0:1, Values of Counter "threads_per_kernel" over Time

CUDA[0] 0:1, Values of Counter "threads_per_block" over Time

All Processes, Accumulated Exclusive Time per Function...

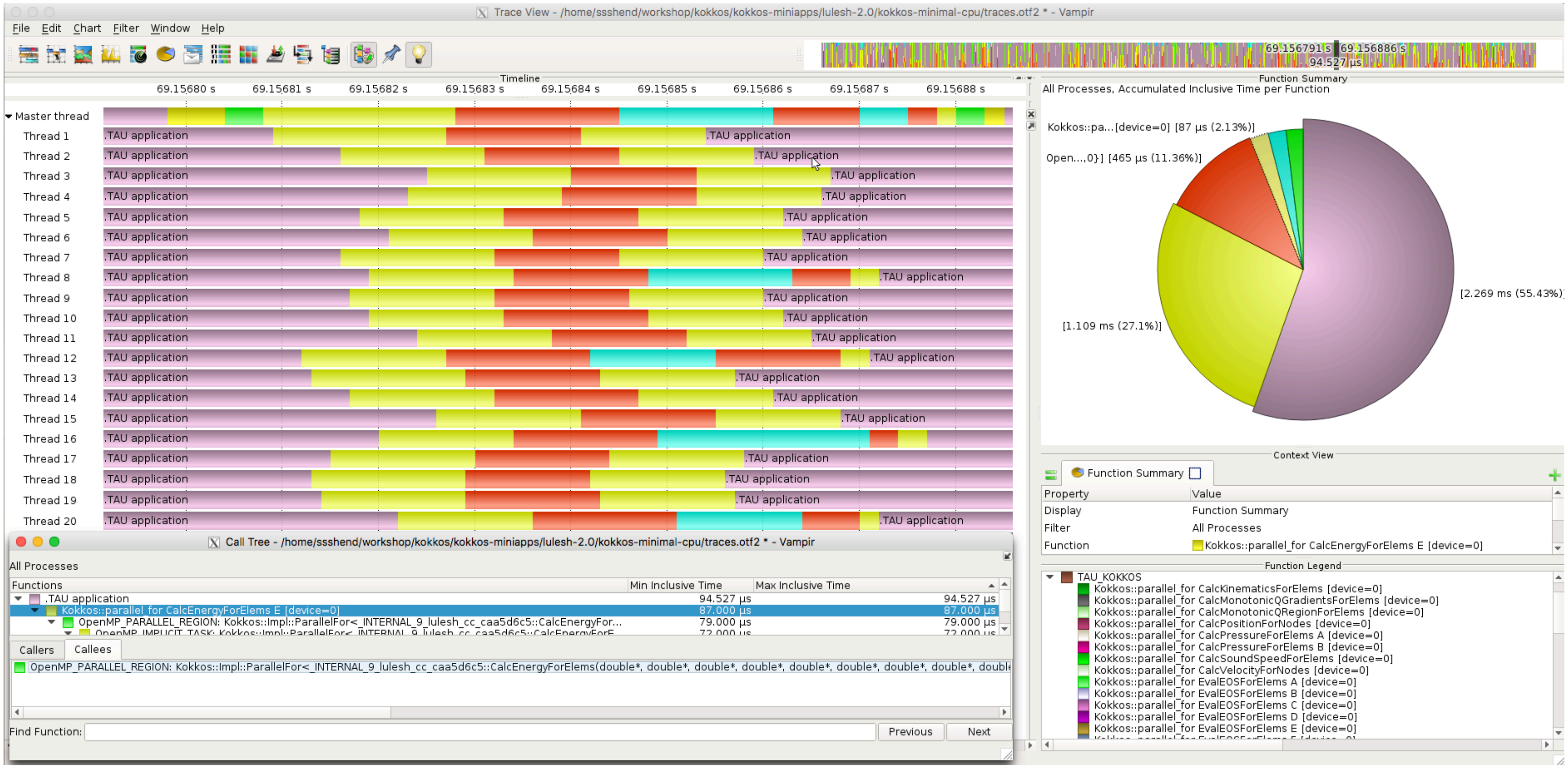
18.967 ms	CUDA_SYNC
14.895 ms	CUDART_API
12.158 ms	CUDA_KERNEL
4.891 ms	MPI
4.797 ms	Application

Property	Value
Function	StencilKernel
Function Group	CUDA_KERNEL
Interval Begin	15.595375 s
Interval End	15.59586 s
Duration	485.132681 µs

Average Bandwidth

http://tau.uoregon.edu/tau_llnl19.pdf

Vampir – TAU's Kokkos Profiling Interface



Call Tree - /home/ssshend/workshop/kokkos/kokkos-miniapps/lulesh-2.0/kokkos-minimal-cpu/traces.otf2 * - Vampir

All Processes

Functions	Min Inclusive Time	Max Inclusive Time
.TAU application	94.527 µs	94.527 µs
Kokkos::parallel_for CalcEnergyForElems E [device=0]	87.000 µs	87.000 µs
OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyFor...	79.000 µs	79.000 µs
OpenMP_IMPLICIT_TASK: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForE...	72.000 µs	72.000 µs

Callers | Callees

OpenMP_PARALLEL_REGION: Kokkos::Impl::ParallelFor<_INTERNAL_9_lulesh_cc_caa5d6c5::CalcEnergyForElems(double*, double*, double*, double*, double*, double*, double*, double*, doubl

Find Function: Previous Next

Property	Value
Display	Function Summary
Filter	All Processes
Function	Kokkos::parallel_for CalcEnergyForElems E [device=0]

TAU_KOKKOS
- Kokkos::parallel_for CalcKinematicsForElems [device=0]
- Kokkos::parallel_for CalcMonotonicQGradientsForElems [device=0]
- Kokkos::parallel_for CalcMonotonicQRegionForElems [device=0]
- Kokkos::parallel_for CalcPositionForNodes [device=0]
- Kokkos::parallel_for CalcPressureForElems A [device=0]
- Kokkos::parallel_for CalcPressureForElems B [device=0]
- Kokkos::parallel_for CalcSoundSpeedForElems [device=0]
- Kokkos::parallel_for CalcVelocityForNodes [device=0]
- Kokkos::parallel_for EvalEOSForElems A [device=0]
- Kokkos::parallel_for EvalEOSForElems B [device=0]
- Kokkos::parallel_for EvalEOSForElems C [device=0]
- Kokkos::parallel_for EvalEOSForElems D [device=0]
- Kokkos::parallel_for EvalEOSForElems E [device=0]

Tools: Jumpshot

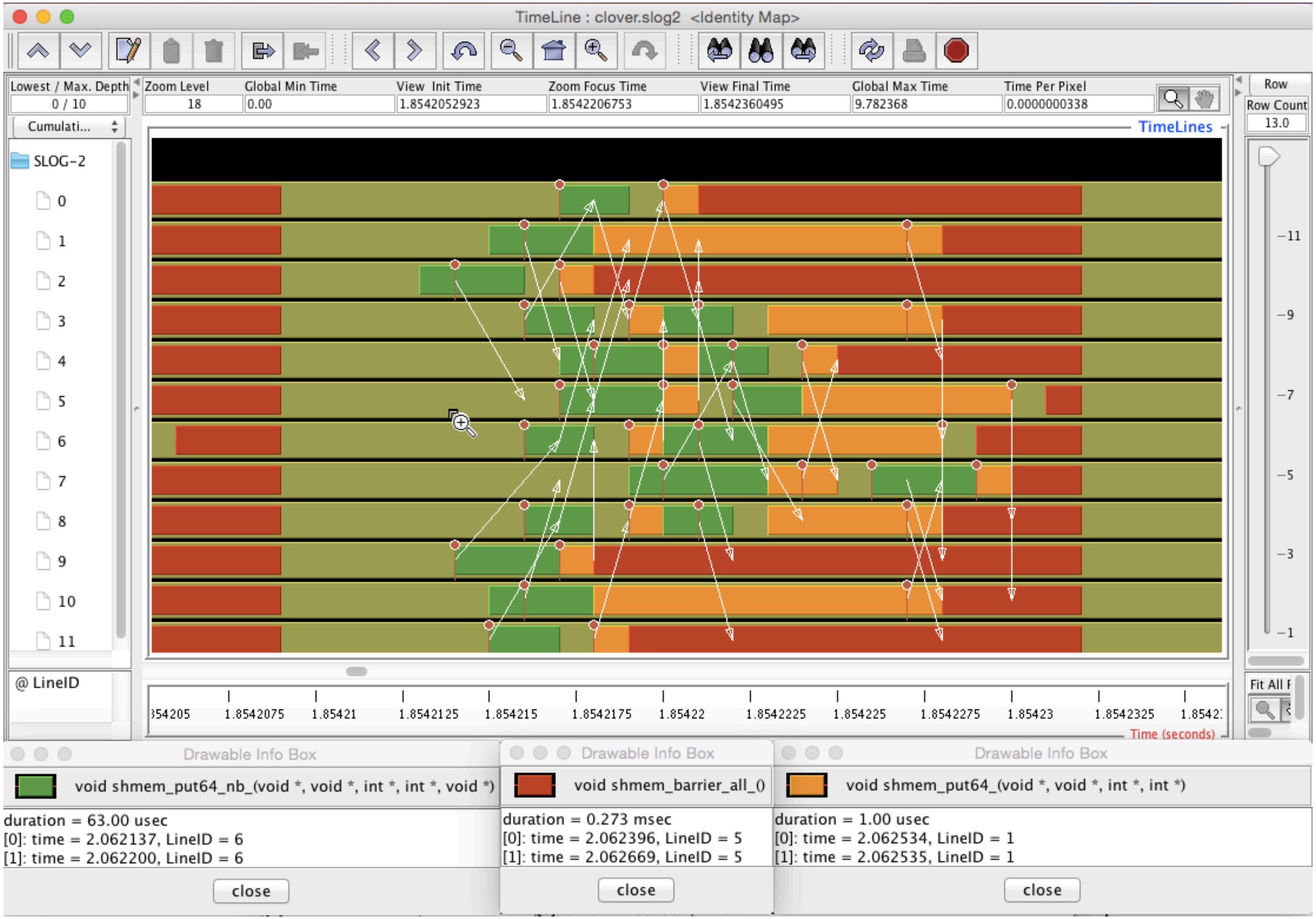
Jumpshot

- Open source alternative to Vampir
- Developed by Argonne National Laboratory
- Packaged with TAU

Timeline charts

- Show application activities and communication along a time axis
- Shows boxes within boxes to show nesting of events

Jumpshot



Lowest / Max. Depth 0 / 10

Zoom Level 18

Global Min Time 0.00

View Init Time 1.8542052923

Zoom Focus Time 1.8542206753

View Final Time 1.8542360495

Global Max Time 9.782368

Time Per Pixel 0.0000000338

Row Count 13.0

🟩 void shmem_put64_nb_(void *, void *, int *, int *, void *)

duration = 63.00 usec
[0]: time = 2.062137, LineID = 6
[1]: time = 2.062200, LineID = 6

🟥 void shmem_barrier_all_()

duration = 0.273 msec
[0]: time = 2.062396, LineID = 5
[1]: time = 2.062669, LineID = 5

🟧 void shmem_put64_(void *, void *, int *, int *)

duration = 1.00 usec
[0]: time = 2.062534, LineID = 1
[1]: time = 2.062535, LineID = 1

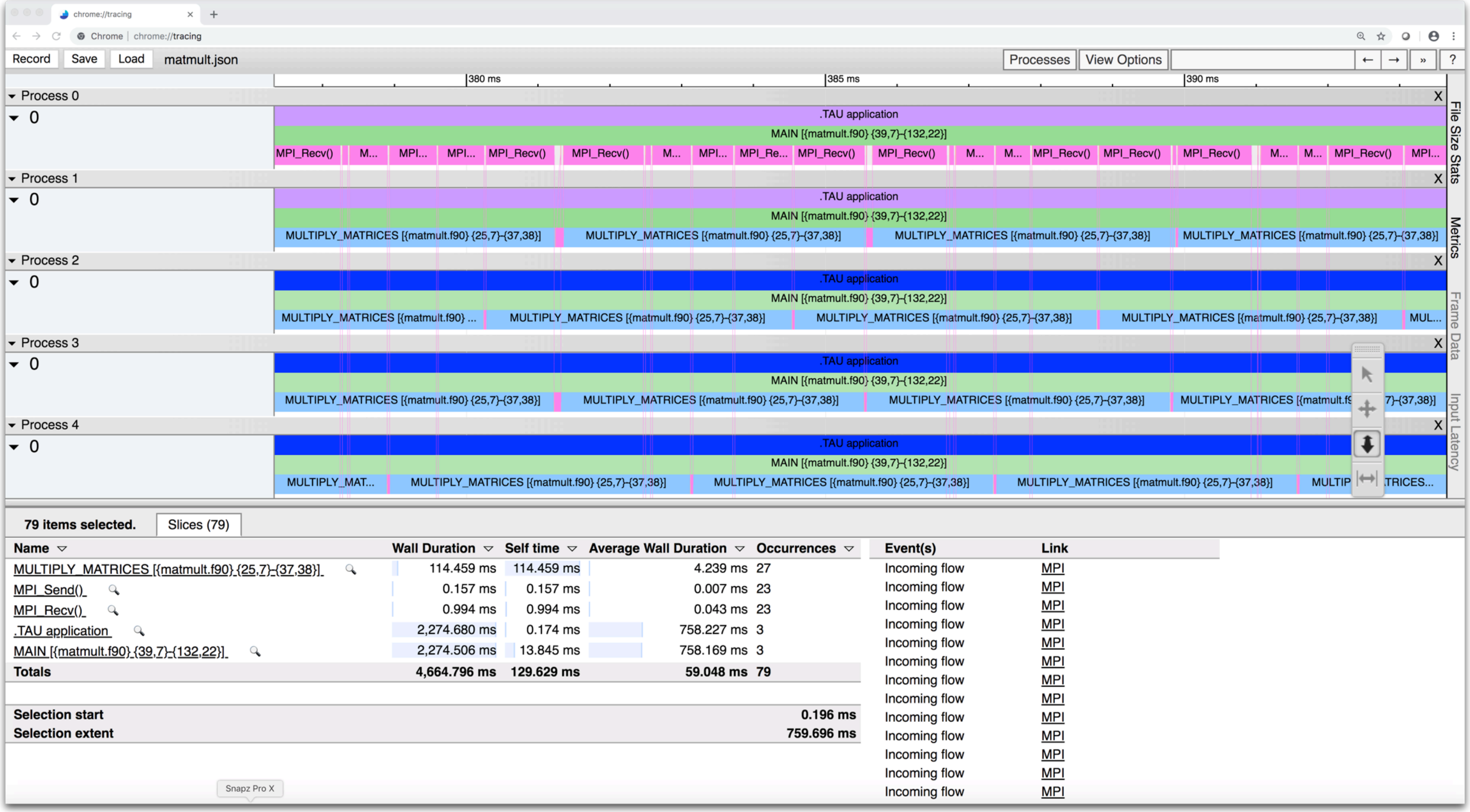
Generating Event Traces

```
% export TAU_MAKEFILE=$TAU/Makefile.tau-icpc-mpi-pdt
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)

For Jumpshot:
% export TAU_TRACE=1
% mpirun -np 64   ./a.out

% tau_treemerge.pl
% tau_treemerge; tau2slog2 tau.trc tau.edf -o app.slog2;
% jumpshot app.slog2 &

For Vampir:
% export TAU_TRACE_FORMAT=otf2
# TAU’s native OTF2 trace generation capability!
% mpirun -np 64  ./a.out
% vampir traces.otf2 &

For ParaVer:
% tau_convert -paraver tau.trc tau.edf app.prv; paraver app.prv
```

Chrome Browser

```
% export TAU_MAKEFILE=$TAU/Makefile.tau-icpc-mpi-pdt
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)

For Chrome:
% export TAU_TRACE=1
% mpirun -np 64   ./a.out

% tau_treemerge.pl
% tau_trace2json tau.trc tau.edf -chrome -ignoreatomic -o app.json
Copy app.json to your laptop and launch Chrome browser and in address:
chrome://tracing
Load -> app.json
```

Chrome Browser



79 items selected. Slices (79)

Name	Wall Duration	Self time	Average Wall Duration	Occurrences
MULTIPLY_MATRICES [{matmult.f90} {25,7}-{37,38}]	114.459 ms	114.459 ms	4.239 ms	27
MPI_Send()	0.157 ms	0.157 ms	0.007 ms	23
MPI_Recv()	0.994 ms	0.994 ms	0.043 ms	23
.TAU application	2,274.680 ms	0.174 ms	758.227 ms	3
MAIN [{matmult.f90} {39,7}-{132,22}]	2,274.506 ms	13.845 ms	758.169 ms	3
Totals	**4,664.796 ms**	**129.629 ms**	**59.048 ms**	**79**

Selection start 0.196 ms
Selection extent 759.696 ms

Event(s)	Link
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI
Incoming flow	MPI

Tags in tau_exec and other tools

```
% cd $TAU; ls Makefile.*
Makefile.tau-icpc-papi-mpi-pdt
% mpirun -np 4 ./matrix
% tau_exec -T icpc,mpi,pdt ./a.out
```

Chooses Makefile.tau-icpc-mpi,pdt and associated libraries.

```
% tau_exec -T serial,pdt ./a.out
```

Chooses Makefile.tau-pdt or the shortest Makefile name without -mpi.

-T <list_of_tags> is used in several TAU tools:

- tau_run
  - tau_python
- tau_rewrite
- tau_exec
- tau_gen_wrapper

Three Instrumentation Techniques for Wrapping External Libraries

Pre-processor based substitution by re-defining a call (e.g., read)

- Tool defined header file with same name <*unistd.h*> takes precedence
- Header redefines a routine as a different routine using macros
- Substitution: *read()* substituted by preprocessor as *tau_read()* at callsite

Preloading a library at runtime

- Library preloaded (*LD_PRELOAD* env var in Linux) in the address space of executing application intercepts calls from a given library
- Tool's wrapper library defines *read(),* gets address of global *read()* symbol (dlsym), internally calls timing calls around call to global read

Linker based substitution

- Wrapper library defines __*wrap_read* which calls __*real_read* and linker is passed *-Wl,-wrap,read* to substitute all references to read from application's object code with the __*wrap_read* defined by the tool

Preprocessor based substitution

Pre-processor based substitution by re-defining a call

- Compiler replaces read() with tau_read() in the body of the source code

Advantages:

- Simple to instrument
  - Preprocessor based replacement
  - A header file redefines the calls
  - No special linker or runtime flags required

Disadvantages

- Only works for C & C++ for replacing calls in the body of the code.
- Incomplete instrumentation: fails to capture calls in uninstrumented libraries (e.g., libhdf5.a)

Linker based substitution

Linker based substitution

- Wrapper library defines __wrap_read which calls __real_read and linker is passed -Wl,-wrap, read

Advantages

- Tool can intercept all references to a given call
- Works with static as well as dynamic executables
- No need to recompile the application source code, just re-link the application objects and libraries with the tool wrapper library

Disadvantages

- Wrapping an entire library can lengthen the linker command line with multiple –Wl,-wrap,<func> arguments. It is better to store these arguments in a file and pass the file to the linker
- Approach does not work with un-instrumented binaries

tau_gen_wrapper

Automates creation of wrapper libraries using TAU

Input:

- header file (foo.h)
- library to be wrapped (/path/to/libfoo.a)
- technique for wrapping
  - Preprocessor based redefinition (-d)
  - Runtime preloading (-r)
  - Linker based substitution (-w: default)
- Optional selective instrumentation file (-f select)
  - Exclude list of routines, or
  - Include list of routines

Output:

- wrapper library
- optional *link_options.tau* file (-w), pass –optTauWrapFile=<file> in TAU_OPTIONS environment variable

Design of wrapper generator (tau_gen_wrapper)

tau_gen_wrapper **shell script:**

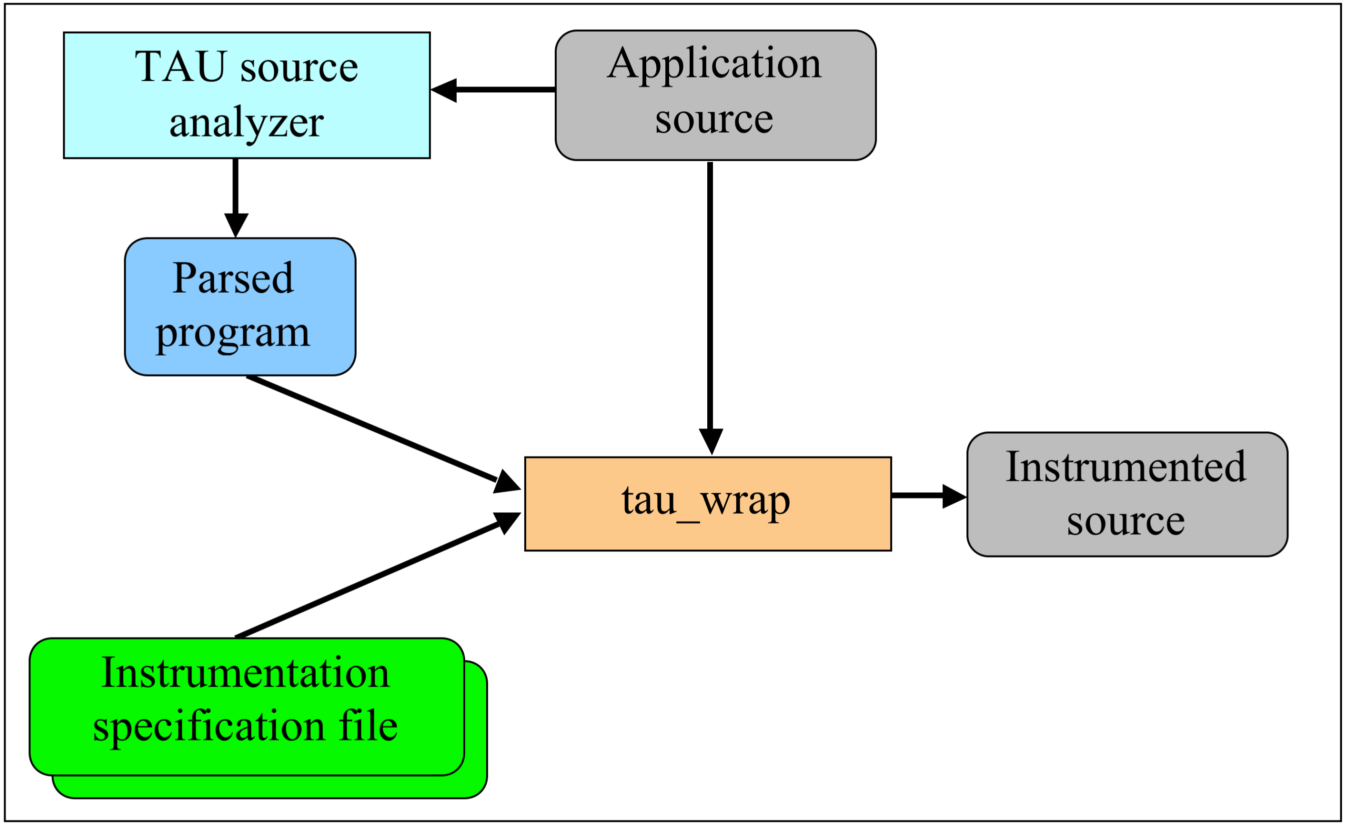
- parses source of header file using static analysis tool Program Database Toolkit (PDT)
- Invokes *tau_wrap*, a tool that generates
  - instrumented wrapper code,
  - an optional *link_options.tau* file (for linker-based substitution, -w)
  - Makefile for compiling the wrapper interposition library
- Builds the wrapper library using make

Use TAU_OPTIONS environment variable to pass location of link_options.tau file using

```
% export TAU_OPTIONS='-optTauWrapFile=<path/to/link_options.tau> -optVerbose'
```

Use ***tau_exec –loadlib=<wrapperlib.so>*** **to pass location of wrapper library for preloading based substitution**

tau_wrap


TAU source analyzer
Application source
Parsed program
tau_wrap
Instrumented source
Instrumentation specification file

Using POSIX I/O wrapper library

Setting environment variable TAU_OPTIONS=-optTrackIO links in TAU's wrapper interposition library using linker-based substitution

Instrumented application generates bandwidth, volume data

Workflow:

- % export TAU_OPTIONS= '-optTrackIO –optVerbose'
- % export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
- % make CC=tau_cc.sh CXX=tau_cxx.sh F90=tau_f90.sh
- % mpirun –np 8 ./a.out
- % paraprof

Get additional data regarding individual arguments by setting environment variable TAU_TRACK_IO_PARAMS=1 prior to running

Preloading a wrapper library

Preloading a library at runtime

- Tool defines read(), gets address of global read() symbol (dlsym), internally calls timing calls around call to global read
- *tau_exec* tool uses this mechanism to intercept library calls

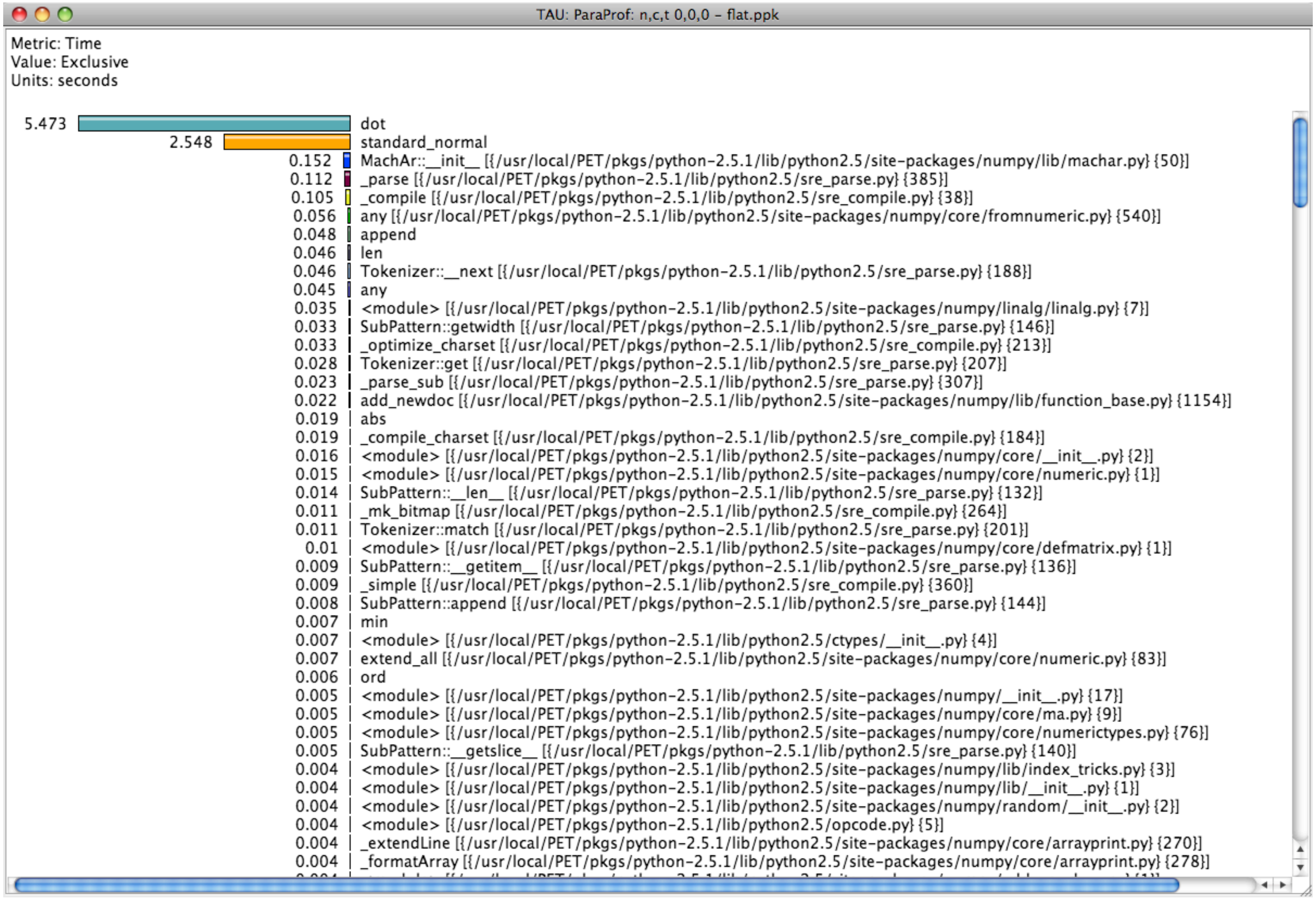
Advantages

- No need to re-compile or re-link the application source code
- Drop-in replacement library implemented using LD_PRELOAD environment variable under Linux, Cray CNL, IBM BG/P CNK, Solaris…

Disadvantages

- Only works with dynamic executables. Default compilation mode under Cray XE6 and IBM BG/P is to use static executables
- Not all operating systems support preloading of dynamic shared objects (DSOs)

Profiling Python using tau_python



```
Metric: Time
Value: Exclusive
Units: seconds

5.473  dot
2.548  standard_normal
0.152  MachAr::__init__ [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/lib/machar.py} {50}]
0.112  _parse [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {385}]
0.105  _compile [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_compile.py} {38}]
0.056  any [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/core/fromnumeric.py} {540}]
0.048  append
0.046  len
0.046  Tokenizer::__next [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {188}]
0.045  any
0.035  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/linalg/linalg.py} {7}]
0.033  SubPattern::getwidth [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {146}]
0.033  _optimize_charset [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_compile.py} {213}]
0.028  Tokenizer::get [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {207}]
0.023  _parse_sub [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {307}]
0.022  add_newdoc [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/lib/function_base.py} {1154}]
0.019  abs
0.019  _compile_charset [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_compile.py} {184}]
0.016  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/core/__init__.py} {2}]
0.015  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/core/numeric.py} {1}]
0.014  SubPattern::__len__ [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {132}]
0.011  _mk_bitmap [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_compile.py} {264}]
0.011  Tokenizer::match [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {201}]
 0.01  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/core/defmatrix.py} {1}]
0.009  SubPattern::__getitem__ [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {136}]
0.009  _simple [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_compile.py} {360}]
0.008  SubPattern::append [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {144}]
0.007  min
0.007  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/ctypes/__init__.py} {4}]
0.007  extend_all [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/core/numeric.py} {83}]
0.006  ord
0.005  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/__init__.py} {17}]
0.005  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/core/ma.py} {9}]
0.005  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/core/numerictypes.py} {76}]
0.005  SubPattern::__getslice__ [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/sre_parse.py} {140}]
0.004  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/lib/index_tricks.py} {3}]
0.004  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/lib/__init__.py} {1}]
0.004  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/random/__init__.py} {2}]
0.004  <module> [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/opcode.py} {5}]
0.004  _extendLine [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/core/arrayprint.py} {270}]
0.004  _formatArray [{/usr/local/PET/pkgs/python-2.5.1/lib/python2.5/site-packages/numpy/core/arrayprint.py} {278}]
```

ParaTools

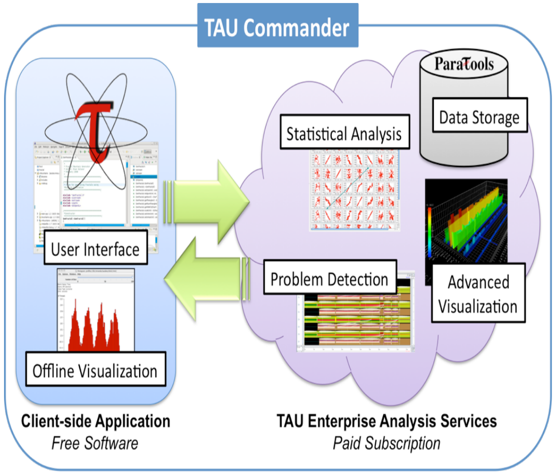
http://tau.uoregon.edu/tau_llnl19.pdf

UNIVERSITY OF OREGON

Profiling Python codes

```
On Quartz:
% source /usr/global/tools/tau/training/tau.bashrc
% tar xf /usr/global/tools/tau/training/workshop.tgz
% cd workshop/py-c++-f90
% make clean; make
% mpirun -np 4 python ./samarcrun.py
With TAU:
% mpirun -np 4 tau_python ./samarcrun.py
% paraprof
```

TAU Commander



Universal tool or integrated toolkit

Unbiased, accurate measurements

- File I/O: serial and parallel
- Communication: inter- and intra-node
- Memory: allocation and access
- CPU: vectorization, cache utilization, etc.

Minimal overhead

- Provide multiple measurement methods
- Focus on one performance aspect at a time

Easy to use

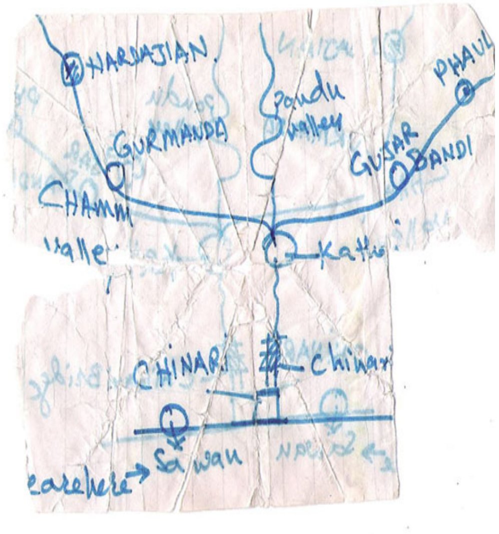
- Intuitive, systematic, and well documented
- Easy to understand and configure

TAU Commander’s Approach

Say where you’re going, not how to get there

Experiments give context to the user’s actions

- Defines desired metrics and measurement approach
- Defines operating environment
- Establishes a baseline for error checking



vs.

T-A-M Model for Performance Engineering

Target

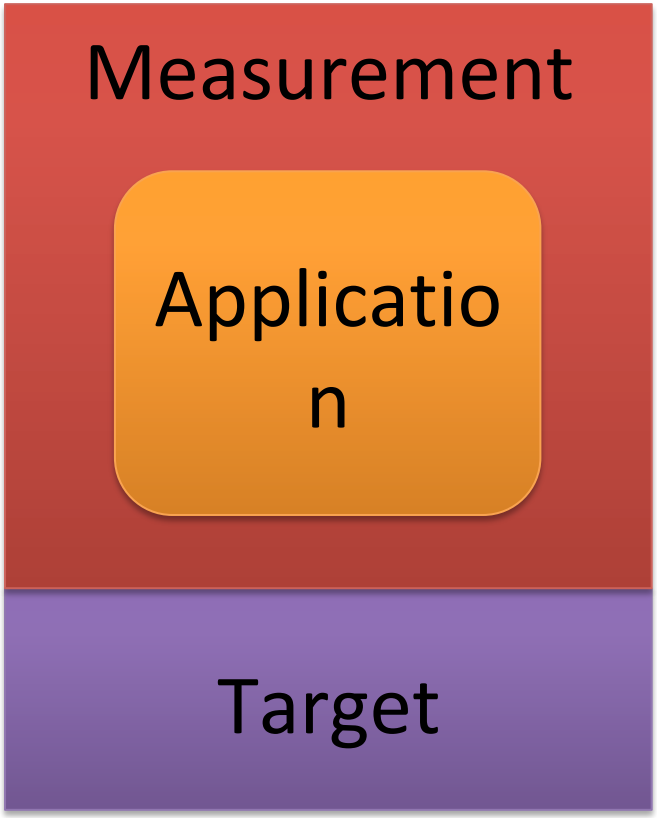
- Installed software
- Available compilers
- Host architecture/ OS

Application

- MPI, OpenMP, CUDA, OpenACC, etc.

Measurement

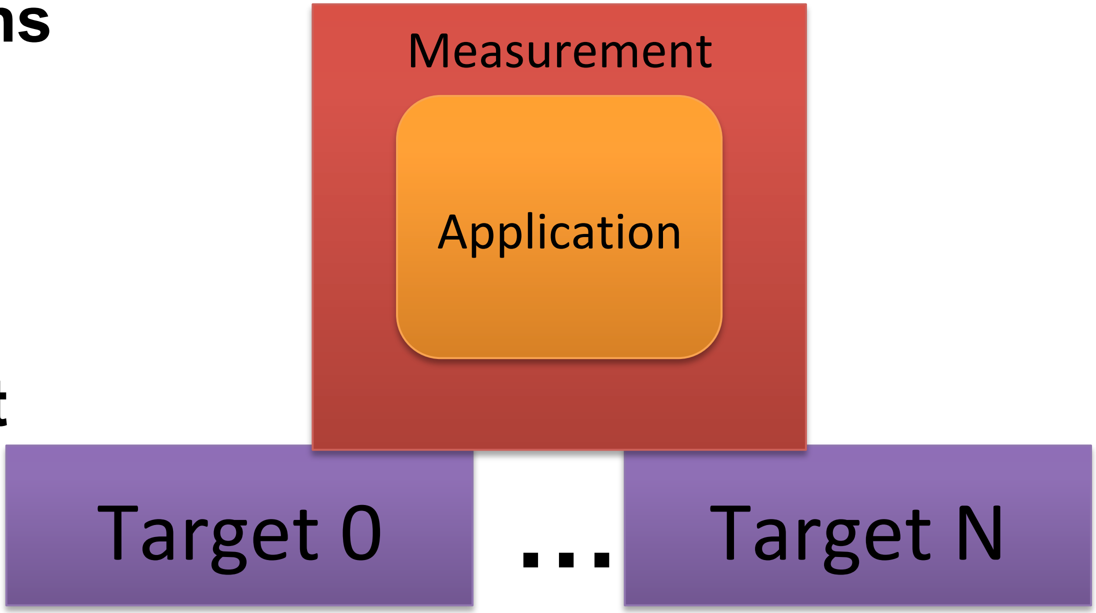
- Profile, trace, or both
- Sample, source inst…



Experiment = (Target, Application, Measurement)

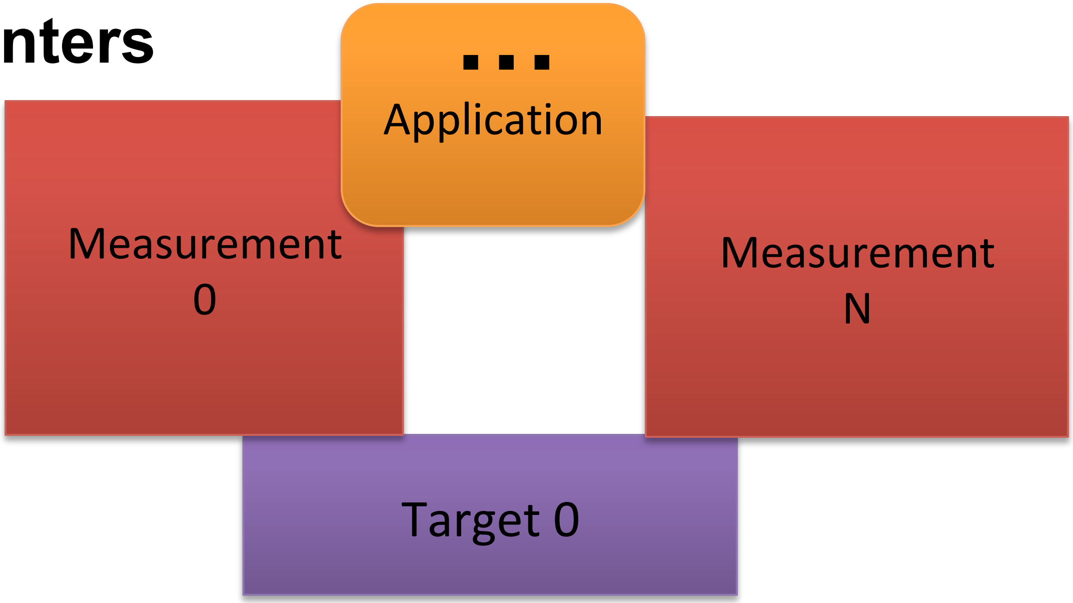
Which platform is best for my application?

- Many targets:
  - Different MPI implementations
  - Different CPU architectures
  - GPU vs MIC
  - Cray vs SGI
- One measurement
- One application



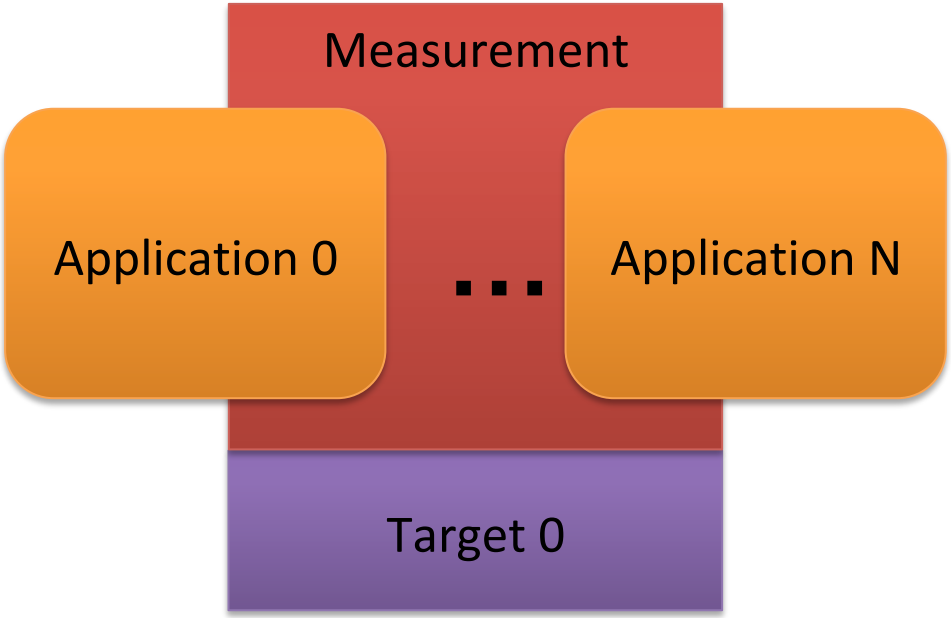
What are the performance characteristics of my application?

- One target
- Many measurements:
  - File I/O
  - Communication
  - Memory allocation
  - Performance counters
  - Vectorization
- One application



How well does my target perform various tasks?

- One target
- One measurement
- Many applications:
  - Compute bound
    - Dense LA
  - Memory bound
    - Sparse LA
    - Graph
  - Scaling
    - Thread-level
    - Process-level



Getting Started with TAU Commander

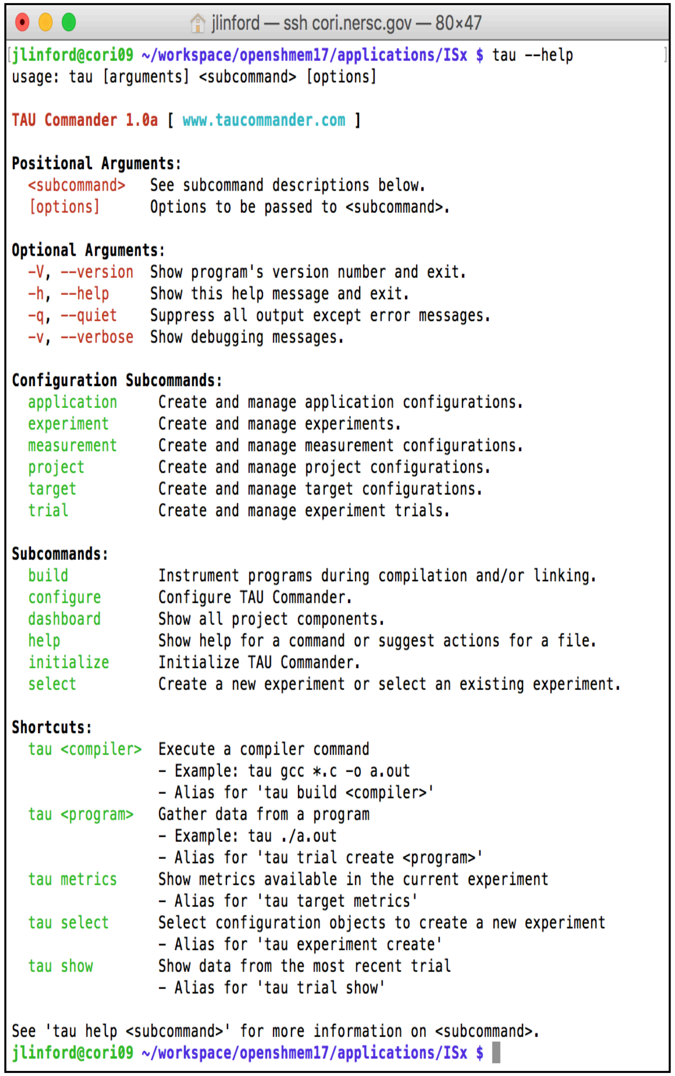
1. tau init –mpi –compilers Intel
2. tau mpif90 *.f90 -g -o foo
3. tau srun –n 64 ./foo
4. tau show

Just put `tau` in front of everything and see what happens.

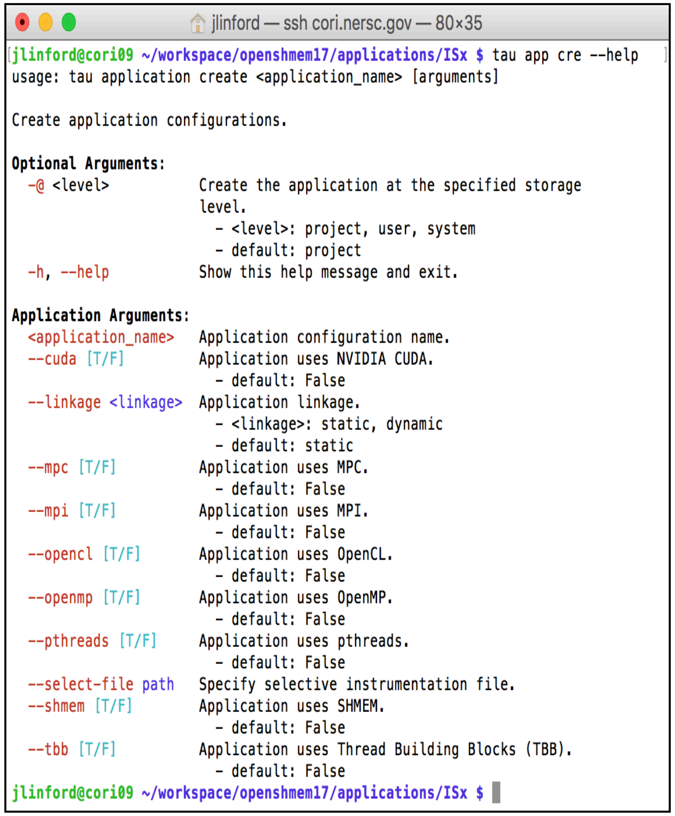
This works on any supported system, even if TAU is not installed or has not been configured appropriately.

TAU and all its dependencies will be downloaded and installed if required.

TAU Commander Online Help



```
jlinford@cori09 ~/workspace/openshmem17/applications/ISx $ tau --help
usage: tau [arguments] <subcommand> [options]

TAU Commander 1.0a [ www.taucommander.com ]

Positional Arguments:
  <subcommand>   See subcommand descriptions below.
  [options]      Options to be passed to <subcommand>.

Optional Arguments:
  -V, --version  Show program's version number and exit.
  -h, --help     Show this help message and exit.
  -q, --quiet    Suppress all output except error messages.
  -v, --verbose  Show debugging messages.

Configuration Subcommands:
  application     Create and manage application configurations.
  experiment      Create and manage experiments.
  measurement     Create and manage measurement configurations.
  project         Create and manage project configurations.
  target          Create and manage target configurations.
  trial           Create and manage experiment trials.

Subcommands:
  build           Instrument programs during compilation and/or linking.
  configure       Configure TAU Commander.
  dashboard       Show all project components.
  help            Show help for a command or suggest actions for a file.
  initialize      Initialize TAU Commander.
  select          Create a new experiment or select an existing experiment.

Shortcuts:
  tau <compiler>  Execute a compiler command
                  - Example: tau gcc *.c -o a.out
                  - Alias for 'tau build <compiler>'
  tau <program>   Gather data from a program
                  - Example: tau ./a.out
                  - Alias for 'tau trial create <program>'
  tau metrics     Show metrics available in the current experiment
                  - Alias for 'tau target metrics'
  tau select      Select configuration objects to create a new experiment
                  - Alias for 'tau experiment create'
  tau show        Show data from the most recent trial
                  - Alias for 'tau trial show'

See 'tau help <subcommand>' for more information on <subcommand>.
jlinford@cori09 ~/workspace/openshmem17/applications/ISx $
```



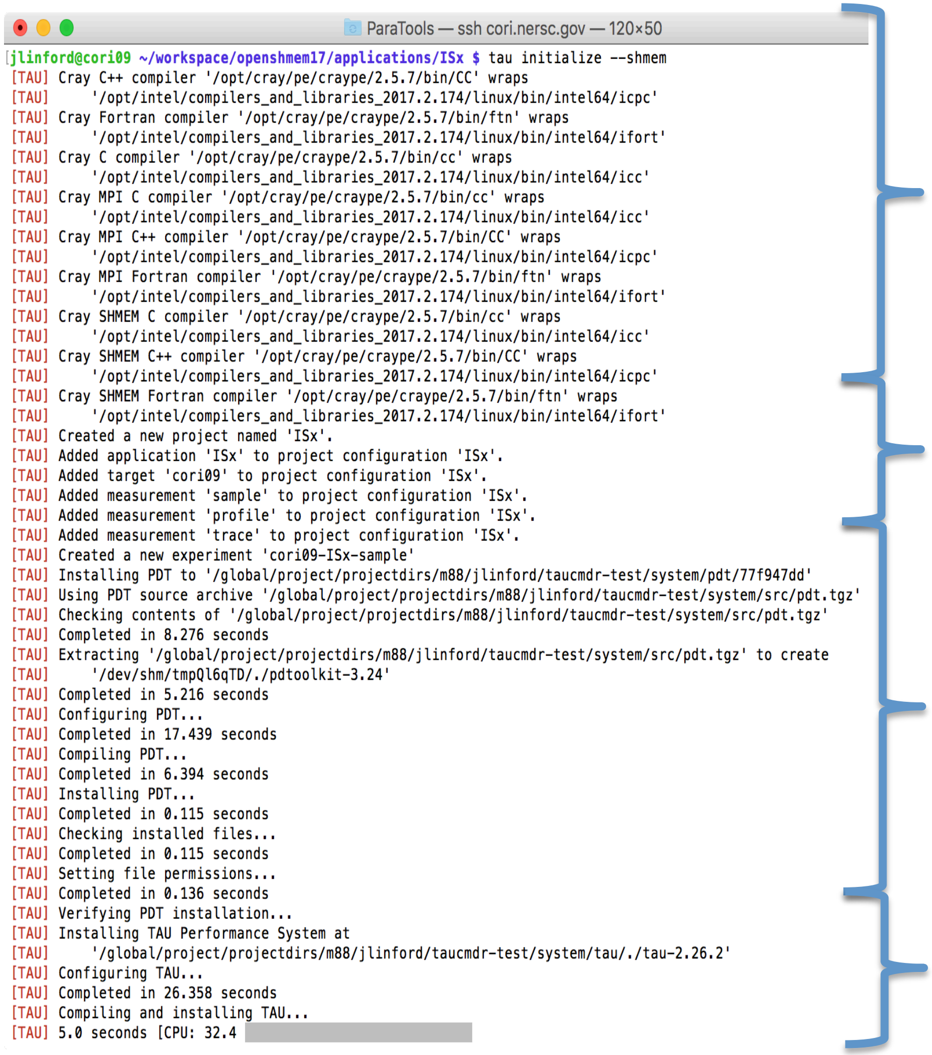
```
jlinford@cori09 ~/workspace/openshmem17/applications/ISx $ tau app cre --help
usage: tau application create <application_name> [arguments]

Create application configurations.

Optional Arguments:
  -@ <level>            Create the application at the specified storage
                        level.
                          - <level>: project, user, system
                          - default: project
  -h, --help            Show this help message and exit.

Application Arguments:
  <application_name>    Application configuration name.
  --cuda [T/F]          Application uses NVIDIA CUDA.
                          - default: False
  --linkage <linkage>   Application linkage.
                          - <linkage>: static, dynamic
                          - default: static
  --mpc [T/F]           Application uses MPC.
                          - default: False
  --mpi [T/F]           Application uses MPI.
                          - default: False
  --opencl [T/F]        Application uses OpenCL.
                          - default: False
  --openmp [T/F]        Application uses OpenMP.
                          - default: False
  --pthreads [T/F]      Application uses pthreads.
                          - default: False
  --select-file path    Specify selective instrumentation file.
  --shmem [T/F]         Application uses SHMEM.
                          - default: False
  --tbb [T/F]           Application uses Thread Building Blocks (TBB).
                          - default: False
jlinford@cori09 ~/workspace/openshmem17/applications/ISx $
```

Step 1: Initialize TAU Project

```
$ tau initialize --mpi --compilers Intel

$ tau init --mpi  --compilers Intel
```

- Creates a new project configuration using defaults
- Project files exist in a directory named “.tau”
- Like git, all directories below the directory containing the “.tau” directory can access the project
  - E.g. `tau dashboard` works in miniapp1/baseline

Project Initialization



```
jlinford@cori09 ~/workspace/openshmem17/applications/ISx $ tau initialize --shmem
[TAU] Cray C++ compiler '/opt/cray/pe/craype/2.5.7/bin/CC' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/icpc'
[TAU] Cray Fortran compiler '/opt/cray/pe/craype/2.5.7/bin/ftn' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/ifort'
[TAU] Cray C compiler '/opt/cray/pe/craype/2.5.7/bin/cc' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/icc'
[TAU] Cray MPI C compiler '/opt/cray/pe/craype/2.5.7/bin/cc' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/icc'
[TAU] Cray MPI C++ compiler '/opt/cray/pe/craype/2.5.7/bin/CC' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/icpc'
[TAU] Cray MPI Fortran compiler '/opt/cray/pe/craype/2.5.7/bin/ftn' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/ifort'
[TAU] Cray SHMEM C compiler '/opt/cray/pe/craype/2.5.7/bin/cc' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/icc'
[TAU] Cray SHMEM C++ compiler '/opt/cray/pe/craype/2.5.7/bin/CC' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/icpc'
[TAU] Cray SHMEM Fortran compiler '/opt/cray/pe/craype/2.5.7/bin/ftn' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/ifort'
[TAU] Created a new project named 'ISx'.
[TAU] Added application 'ISx' to project configuration 'ISx'.
[TAU] Added target 'cori09' to project configuration 'ISx'.
[TAU] Added measurement 'sample' to project configuration 'ISx'.
[TAU] Added measurement 'profile' to project configuration 'ISx'.
[TAU] Added measurement 'trace' to project configuration 'ISx'.
[TAU] Created a new experiment 'cori09-ISx-sample'
[TAU] Installing PDT to '/global/project/projectdirs/m88/jlinford/taucmdr-test/system/pdt/77f947dd'
[TAU] Using PDT source archive '/global/project/projectdirs/m88/jlinford/taucmdr-test/system/src/pdt.tgz'
[TAU] Checking contents of '/global/project/projectdirs/m88/jlinford/taucmdr-test/system/src/pdt.tgz'
[TAU] Completed in 8.276 seconds
[TAU] Extracting '/global/project/projectdirs/m88/jlinford/taucmdr-test/system/src/pdt.tgz' to create
[TAU]     '/dev/shm/tmpQl6qTD/./pdtoolkit-3.24'
[TAU] Completed in 5.216 seconds
[TAU] Configuring PDT...
[TAU] Completed in 17.439 seconds
[TAU] Compiling PDT...
[TAU] Completed in 6.394 seconds
[TAU] Installing PDT...
[TAU] Completed in 0.115 seconds
[TAU] Checking installed files...
[TAU] Completed in 0.115 seconds
[TAU] Setting file permissions...
[TAU] Completed in 0.136 seconds
[TAU] Verifying PDT installation...
[TAU] Installing TAU Performance System at
[TAU]     '/global/project/projectdirs/m88/jlinford/taucmdr-test/system/tau/./tau-2.26.2'
[TAU] Configuring TAU...
[TAU] Completed in 26.358 seconds
[TAU] Compiling and installing TAU...
[TAU] 5.0 seconds [CPU: 32.4
```

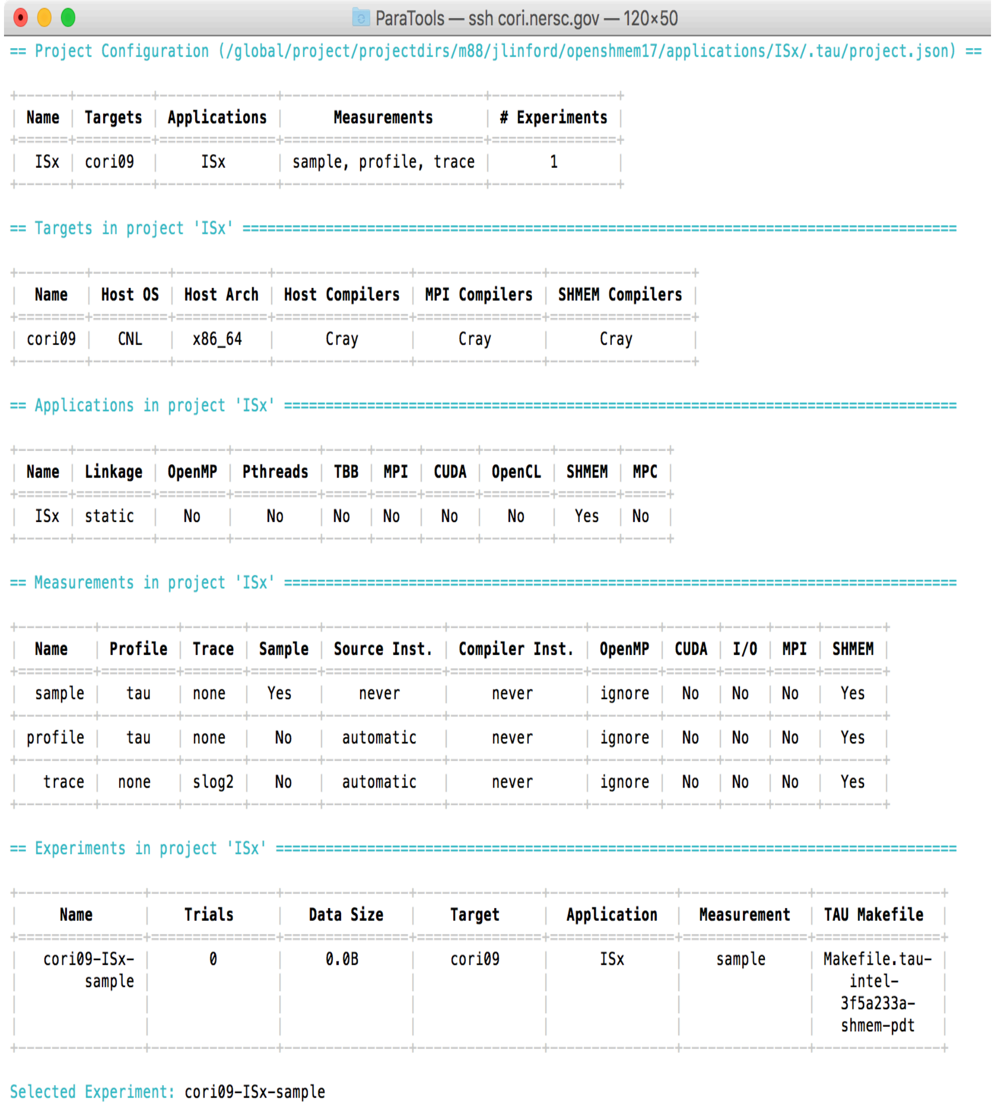
Compiler detection

Project initialization

Download and install PDT

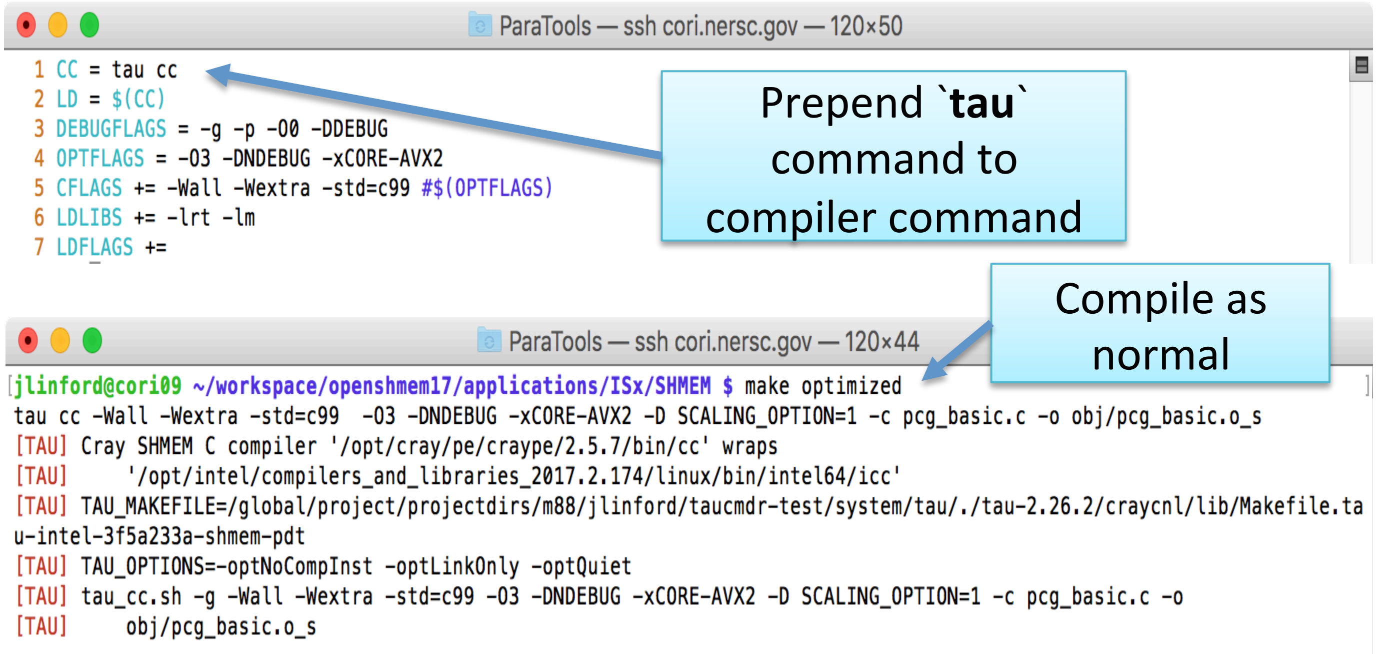
TAU installation progress

Project Dashboard (`tau dashboard`)



```
== Project Configuration (/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/.tau/project.json) ==

+------+---------+--------------+-------------------------+---------------+
| Name | Targets | Applications |      Measurements       | # Experiments |
+======+=========+==============+=========================+===============+
|  ISx | cori09  |     ISx      | sample, profile, trace  |       1       |
+------+---------+--------------+-------------------------+---------------+

== Targets in project 'ISx' ==========================================================================

+--------+---------+-----------+----------------+---------------+-----------------+
|  Name  | Host OS | Host Arch | Host Compilers | MPI Compilers | SHMEM Compilers |
+========+=========+===========+================+===============+=================+
| cori09 |   CNL   |  x86_64   |      Cray      |     Cray      |      Cray       |
+--------+---------+-----------+----------------+---------------+-----------------+

== Applications in project 'ISx' =====================================================================

+------+---------+--------+----------+-----+-----+------+--------+-------+-----+
| Name | Linkage | OpenMP | Pthreads | TBB | MPI | CUDA | OpenCL | SHMEM | MPC |
+======+=========+========+==========+=====+=====+======+========+=======+=====+
|  ISx | static  |   No   |    No    | No  | No  |  No  |   No   |  Yes  | No  |
+------+---------+--------+----------+-----+-----+------+--------+-------+-----+

== Measurements in project 'ISx' =====================================================================

+---------+---------+-------+--------+--------------+----------------+--------+------+-----+-----+-------+
|  Name   | Profile | Trace | Sample | Source Inst. | Compiler Inst. | OpenMP | CUDA | I/O | MPI | SHMEM |
+=========+=========+=======+========+==============+================+========+======+=====+=====+=======+
|  sample |   tau   | none  |  Yes   |    never     |     never      | ignore |  No  | No  | No  |  Yes  |
+---------+---------+-------+--------+--------------+----------------+--------+------+-----+-----+-------+
| profile |   tau   | none  |   No   |  automatic   |     never      | ignore |  No  | No  | No  |  Yes  |
+---------+---------+-------+--------+--------------+----------------+--------+------+-----+-----+-------+
|   trace |  none   | slog2 |   No   |  automatic   |     never      | ignore |  No  | No  | No  |  Yes  |
+---------+---------+-------+--------+--------------+----------------+--------+------+-----+-----+-------+

== Experiments in project 'ISx' ======================================================================

+-------------+---------+-----------+---------+-------------+-------------+--------------+
|    Name     | Trials  | Data Size | Target  | Application | Measurement | TAU Makefile |
+=============+=========+===========+=========+=============+=============+==============+
|  cori09-ISx-|    0    |   0.0B    | cori09  |     ISx     |   sample    | Makefile.tau-|
|       sample|         |           |         |             |             |    intel-    |
|             |         |           |         |             |             |  3f5a233a-   |
|             |         |           |         |             |             |  shmem-pdt   |
+-------------+---------+-----------+---------+-------------+-------------+--------------+

Selected Experiment: cori09-ISx-sample
```

Step 2: Use `tau` to compile


ParaTools — ssh cori.nersc.gov — 120×50

```
CC = tau cc
LD = $(CC)
DEBUGFLAGS = -g -p -O0 -DDEBUG
OPTFLAGS = -O3 -DNDEBUG -xCORE-AVX2
CFLAGS += -Wall -Wextra -std=c99 #$(OPTFLAGS)
LDLIBS += -lrt -lm
LDFLAGS +=
```

Prepend `**tau**` command to compiler command

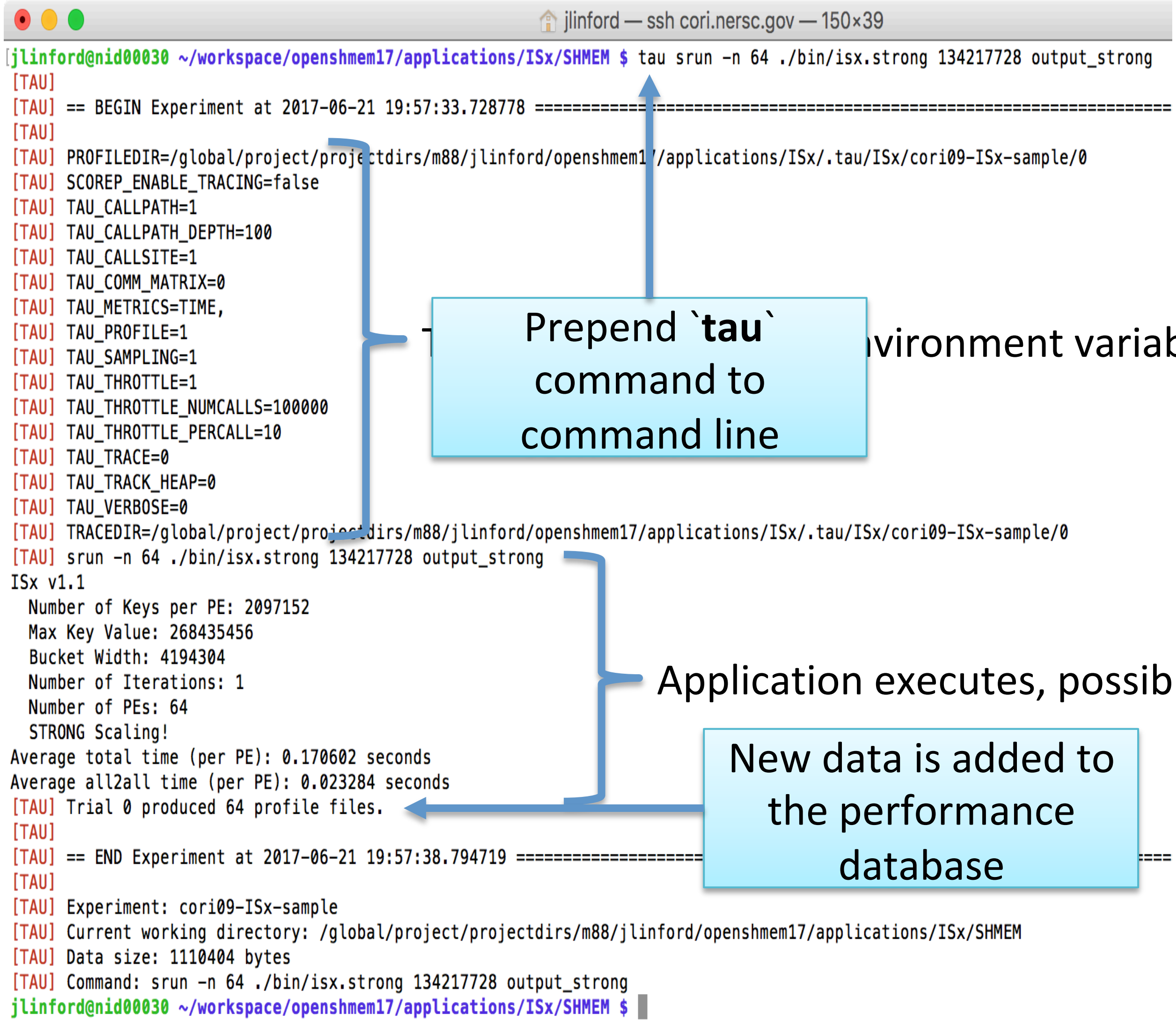
ParaTools — ssh cori.nersc.gov — 120×44

```
jlinford@cori09 ~/workspace/openshmem17/applications/ISx/SHMEM $ make optimized
tau cc -Wall -Wextra -std=c99  -O3 -DNDEBUG -xCORE-AVX2 -D SCALING_OPTION=1 -c pcg_basic.c -o obj/pcg_basic.o_s
[TAU] Cray SHMEM C compiler '/opt/cray/pe/craype/2.5.7/bin/cc' wraps
[TAU]     '/opt/intel/compilers_and_libraries_2017.2.174/linux/bin/intel64/icc'
[TAU] TAU_MAKEFILE=/global/project/projectdirs/m88/jlinford/taucmdr-test/system/tau/./tau-2.26.2/craycnl/lib/Makefile.ta
u-intel-3f5a233a-shmem-pdt
[TAU] TAU_OPTIONS=-optNoCompInst -optLinkOnly -optQuiet
[TAU] tau_cc.sh -g -Wall -Wextra -std=c99 -O3 -DNDEBUG -xCORE-AVX2 -D SCALING_OPTION=1 -c pcg_basic.c -o
[TAU]     obj/pcg_basic.o_s
```

Compile as normal

- TAU Commander constructs a new compilation command line.
  - May replace compiler commands with TAU's compiler wrapper scripts.
  - May set environment variables, parse configuration files, etc.
  - If no changes are required then nothing is changed.

Step 3: Use `tau` to run



```
jlinford@nid00030 ~/workspace/openshmem17/applications/ISx/SHMEM $ tau srun -n 64 ./bin/isx.strong 134217728 output_strong
[TAU]
[TAU] == BEGIN Experiment at 2017-06-21 19:57:33.728778 ===================================================================
[TAU]
[TAU] PROFILEDIR=/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/.tau/ISx/cori09-ISx-sample/0
[TAU] SCOREP_ENABLE_TRACING=false
[TAU] TAU_CALLPATH=1
[TAU] TAU_CALLPATH_DEPTH=100
[TAU] TAU_CALLSITE=1
[TAU] TAU_COMM_MATRIX=0
[TAU] TAU_METRICS=TIME,
[TAU] TAU_PROFILE=1
[TAU] TAU_SAMPLING=1
[TAU] TAU_THROTTLE=1
[TAU] TAU_THROTTLE_NUMCALLS=100000
[TAU] TAU_THROTTLE_PERCALL=10
[TAU] TAU_TRACE=0
[TAU] TAU_TRACK_HEAP=0
[TAU] TAU_VERBOSE=0
[TAU] TRACEDIR=/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/.tau/ISx/cori09-ISx-sample/0
[TAU] srun -n 64 ./bin/isx.strong 134217728 output_strong
ISx v1.1
  Number of Keys per PE: 2097152
  Max Key Value: 268435456
  Bucket Width: 4194304
  Number of Iterations: 1
  Number of PEs: 64
  STRONG Scaling!
Average total time (per PE): 0.170602 seconds
Average all2all time (per PE): 0.023284 seconds
[TAU] Trial 0 produced 64 profile files.
[TAU]
[TAU] == END Experiment at 2017-06-21 19:57:38.794719 ====================================================================
[TAU]
[TAU] Experiment: cori09-ISx-sample
[TAU] Current working directory: /global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM
[TAU] Data size: 1110404 bytes
[TAU] Command: srun -n 64 ./bin/isx.strong 134217728 output_strong
jlinford@nid00030 ~/workspace/openshmem17/applications/ISx/SHMEM $
```

Prepend `**tau**` command to command line

vironment variables

Application executes, possibly with tau_exec

New data is added to the performance database

ParaTools

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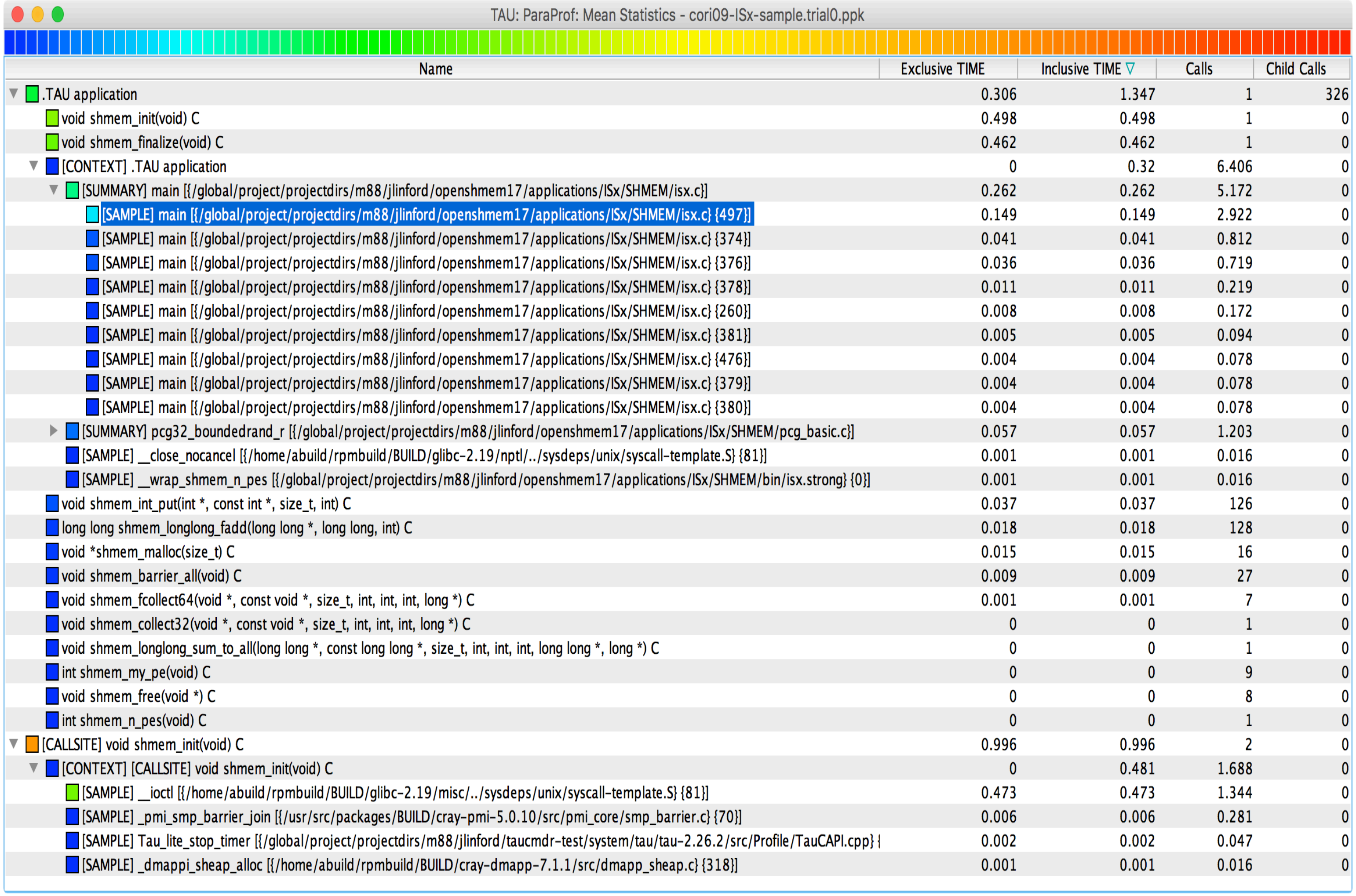
Step 4: Use `tau` to view data (`tau show`)

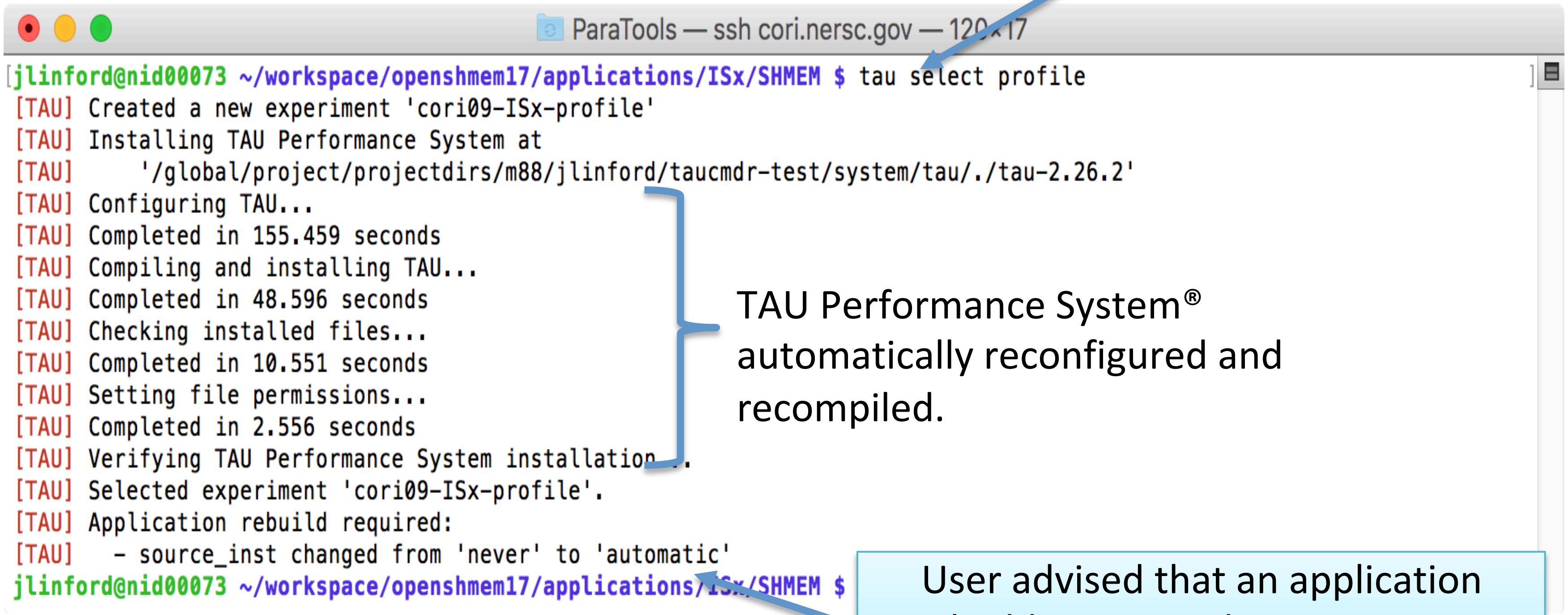


TAU: ParaProf: Mean Statistics - cori09-ISx-sample.trial0.ppk

Name	Exclusive TIME	Inclusive TIME ▽	Calls	Child Calls
▼ 🟩 .TAU application	0.306	1.347	1	326
🟩 void shmem_init(void) C	0.498	0.498	1	0
🟩 void shmem_finalize(void) C	0.462	0.462	1	0
▼ 🟦 [CONTEXT] .TAU application	0	0.32	6.406	0
▼ 🟩 [SUMMARY] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c}]	0.262	0.262	5.172	0
🟦 [SAMPLE] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c} {497}]	0.149	0.149	2.922	0
🟦 [SAMPLE] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c} {374}]	0.041	0.041	0.812	0
🟦 [SAMPLE] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c} {376}]	0.036	0.036	0.719	0
🟦 [SAMPLE] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c} {378}]	0.011	0.011	0.219	0
🟦 [SAMPLE] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c} {260}]	0.008	0.008	0.172	0
🟦 [SAMPLE] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c} {381}]	0.005	0.005	0.094	0
🟦 [SAMPLE] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c} {476}]	0.004	0.004	0.078	0
🟦 [SAMPLE] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c} {379}]	0.004	0.004	0.078	0
🟦 [SAMPLE] main [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/isx.c} {380}]	0.004	0.004	0.078	0
▶ 🟦 [SUMMARY] pcg32_boundedrand_r [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/pcg_basic.c}]	0.057	0.057	1.203	0
🟦 [SAMPLE] __close_nocancel [{/home/abuild/rpmbuild/BUILD/glibc-2.19/nptl/../sysdeps/unix/syscall-template.S} {81}]	0.001	0.001	0.016	0
🟦 [SAMPLE] __wrap_shmem_n_pes [{/global/project/projectdirs/m88/jlinford/openshmem17/applications/ISx/SHMEM/bin/isx.strong} {0}]	0.001	0.001	0.016	0
🟦 void shmem_int_put(int *, const int *, size_t, int) C	0.037	0.037	126	0
🟦 long long shmem_longlong_fadd(long long *, long long, int) C	0.018	0.018	128	0
🟦 void *shmem_malloc(size_t) C	0.015	0.015	16	0
🟦 void shmem_barrier_all(void) C	0.009	0.009	27	0
🟦 void shmem_fcollect64(void *, const void *, size_t, int, int, int, long *) C	0.001	0.001	7	0
🟦 void shmem_collect32(void *, const void *, size_t, int, int, int, long *) C	0	0	1	0
🟦 void shmem_longlong_sum_to_all(long long *, const long long *, size_t, int, int, int, long long *, long *) C	0	0	1	0
🟦 int shmem_my_pe(void) C	0	0	9	0
🟦 void shmem_free(void *) C	0	0	8	0
🟦 int shmem_n_pes(void) C	0	0	1	0
▼ 🟧 [CALLSITE] void shmem_init(void) C	0.996	0.996	2	0
▼ 🟦 [CONTEXT] [CALLSITE] void shmem_init(void) C	0	0.481	1.688	0
🟩 [SAMPLE] __ioctl [{/home/abuild/rpmbuild/BUILD/glibc-2.19/misc/../sysdeps/unix/syscall-template.S} {81}]	0.473	0.473	1.344	0
🟦 [SAMPLE] _pmi_smp_barrier_join [{/usr/src/packages/BUILD/cray-pmi-5.0.10/src/pmi_core/smp_barrier.c} {70}]	0.006	0.006	0.281	0
🟦 [SAMPLE] Tau_lite_stop_timer [{/global/project/projectdirs/m88/jlinford/taucmdr-test/system/tau/tau-2.26.2/src/Profile/TauCAPI.cpp} {	0.002	0.002	0.047	0
🟦 [SAMPLE] _dmappi_sheap_alloc [{/home/abuild/rpmbuild/BUILD/cray-dmapp-7.1.1/src/dmapp_sheap.c} {318}]	0.001	0.001	0.016	0

Create a New Experiment

Select a new measurement to create a new experiment



```
[jlinford@nid00073 ~/workspace/openshmem17/applications/ISx/SHMEM $ tau select profile
 [TAU] Created a new experiment 'cori09-ISx-profile'
 [TAU] Installing TAU Performance System at
 [TAU]     '/global/project/projectdirs/m88/jlinford/taucmdr-test/system/tau/./tau-2.26.2'
 [TAU] Configuring TAU...
 [TAU] Completed in 155.459 seconds
 [TAU] Compiling and installing TAU...
 [TAU] Completed in 48.596 seconds
 [TAU] Checking installed files...
 [TAU] Completed in 10.551 seconds
 [TAU] Setting file permissions...
 [TAU] Completed in 2.556 seconds
 [TAU] Verifying TAU Performance System installation...
 [TAU] Selected experiment 'cori09-ISx-profile'.
 [TAU] Application rebuild required:
 [TAU]   - source_inst changed from 'never' to 'automatic'
 jlinford@nid00073 ~/workspace/openshmem17/applications/ISx/SHMEM $
```

TAU Performance System® automatically reconfigured and recompiled.

User advised that an application rebuild is required to use source-based instrumentation.

TAU Commander

```
% which tau
% cd workshop/matmult
% tau init --mpi --compilers Intel
% make clean;
% make F90=‘tau mpif90’
% salloc −N 1 [args]
% tau mpirun −np 16 ./matmult
% tau show
And try the examples. Try:
% tau --help
% tau meas edit --help
```

TAU Commander: MPI + OpenMP

```
% which tau
% cd workshop/mm
% tau init --mpi --openmp ompt --compilers Intel
% make clean;
% mpicc –DTAU_MPI –DTAU_OPENMP *.c –g –qopenmp –o mm
% salloc –N 1 [args]
% tau mpirun –np 16 ./mm
% tau show
And try the examples. Try:
% tau --help
% tau meas edit --help
```

TAU and PDT for Source Instrumentation

```
% which tau
% cd workshop/matmult
% tau init --mpi --compilers Intel
% tau dash
% tau select profile
% make clean
% make F90=‘tau mpif90’
% salloc –N 1 [args]
% tau mpirun –np 16 ./matmult
% tau show
```

Selective Instrumentation File

```
% tau dash
% tau application edit <app_name> --select-file select.tau
% cat select.tau
BEGIN_INCLUDE_LIST
int main#
int dgemm#
END_INCLUDE_LIST
BEGIN_FILE_INCLUDE_LIST
Main.c
Blas/*.f77
END_FILE_INCLUDE_LIST
# replace include with exclude list (BEGIN_EXCLUDE_LIST/END…)

BEGIN_INSTRUMENT_SECTION
loops routine=“foo”
loops routine=“int main#”
END_INSTRUMENT_SECTION
% export TAU_SELECT_FILE=select.tau    (to use at runtime)
```

Use Compiler-Based Instrumentation

```
% tau init --mpi --compilers Intel
% tau dash
% tau meas edit profile --compiler-inst always
% tau select profile
% make CC=‘tau mpicc’
% salloc –N 1 [args]
% tau mpirun –np 16 ./a.out
% tau show
% tau show --help
% tau show --profile-tools pprof | more
```

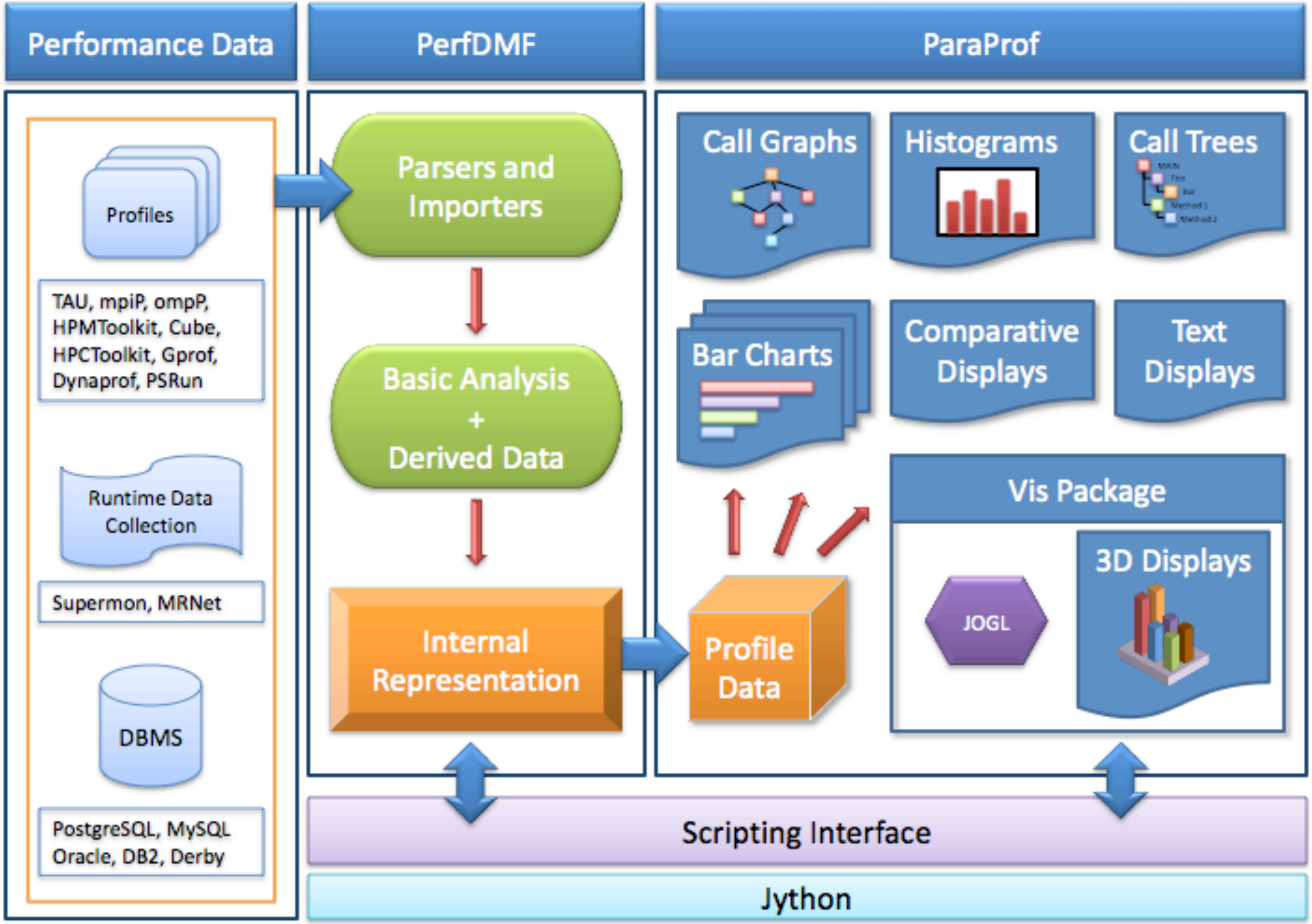
Generating Event Traces for Vampir

```
% cd workshop/matmult
% tau init --mpi --compilers Intel
% tau select trace
% make clean
% make F90=‘tau mpif90’
% salloc –N 1 [args]
% tau mpirun –np 16 ./matmult
% module load vampir
% tau show
```

Generating Event Traces for Jumpshot

```
% cd workshop/matmult
% tau init --mpi --compilers Intel
% tau meas edit profile --trace slog2
    (if it is profiling is being used in another experiment, you may
    have to delete it:
    tau experiment delete <exp_name>
    and retry

% make F90=‘tau mpif90’
% salloc –N 1 [args]
% tau mpirun –np 16 ./matmult
% tau show

NOTE: For OTF2 traces replace slog2 with otf2.
```

ParaProf Profile Analysis Framework



Performance Data

PerfDMF

ParaProf

Profiles

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

Runtime Data Collection

Supermon, MRNet

DBMS

PostgreSQL, MySQL Oracle, DB2, Derby

Parsers and Importers

Basic Analysis + Derived Data

Internal Representation

Profile Data

Call Graphs

Histograms

Call Trees

Bar Charts

Comparative Displays

Text Displays

Vis Package

JOGL

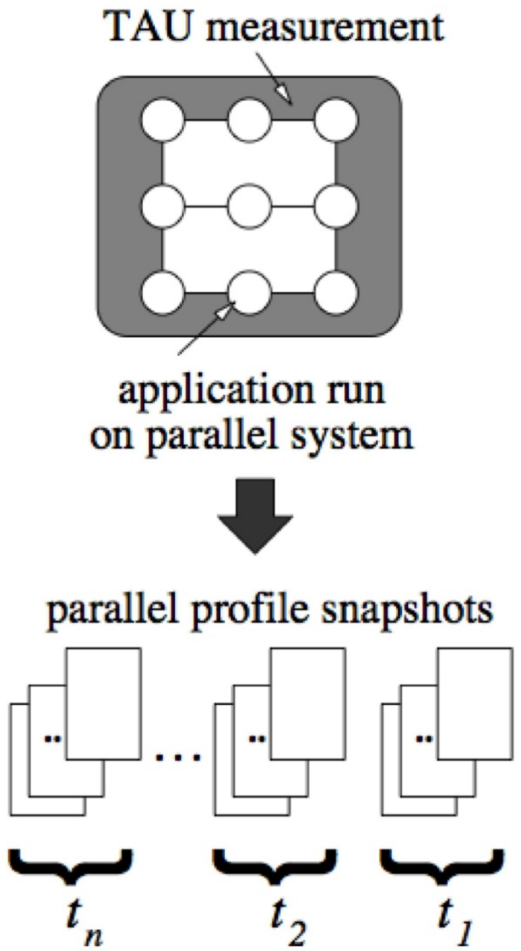
3D Displays

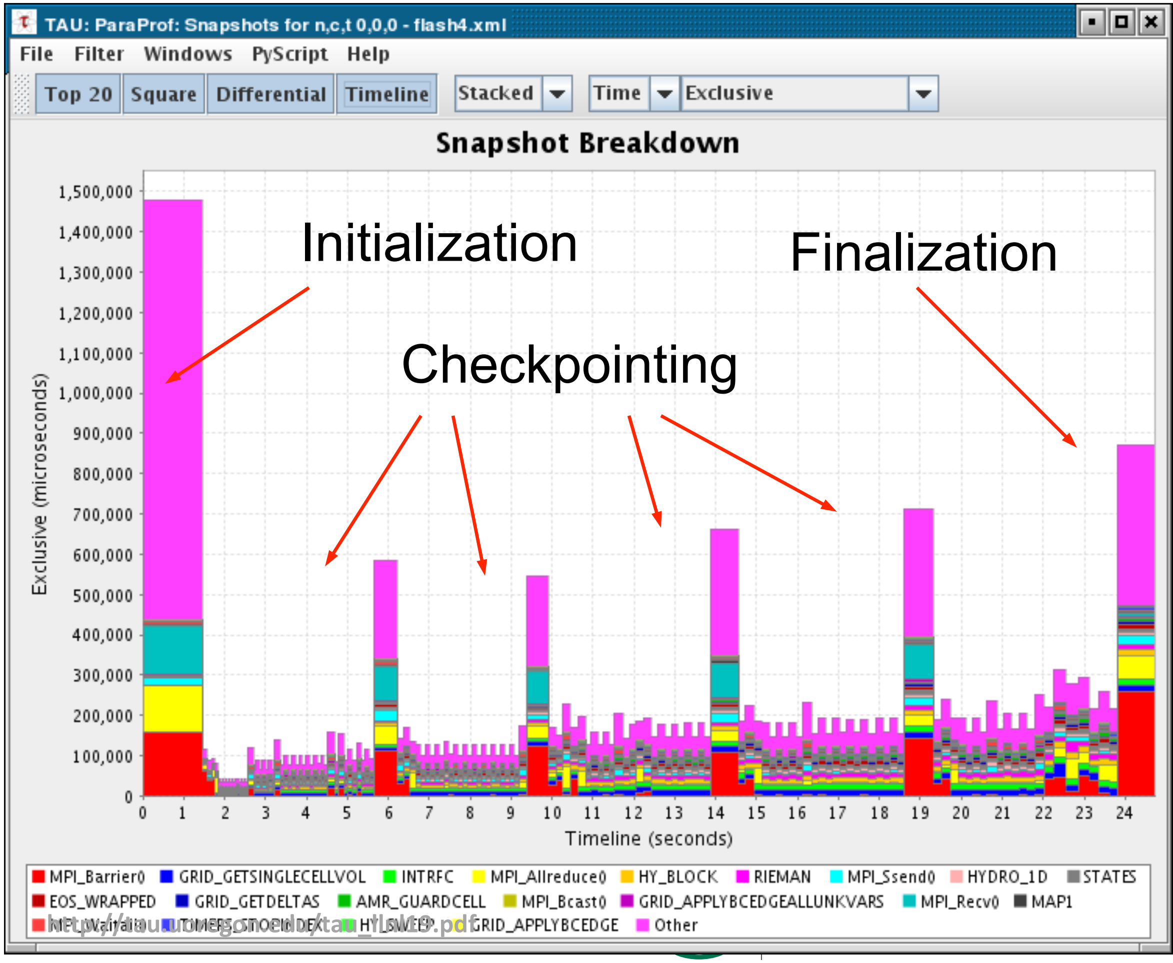
Scripting Interface

Jython

Profile Snapshots in ParaProf

- Profile snapshots are profiles recorded at runtime
- Shows performance profile dynamics (all types allowed)





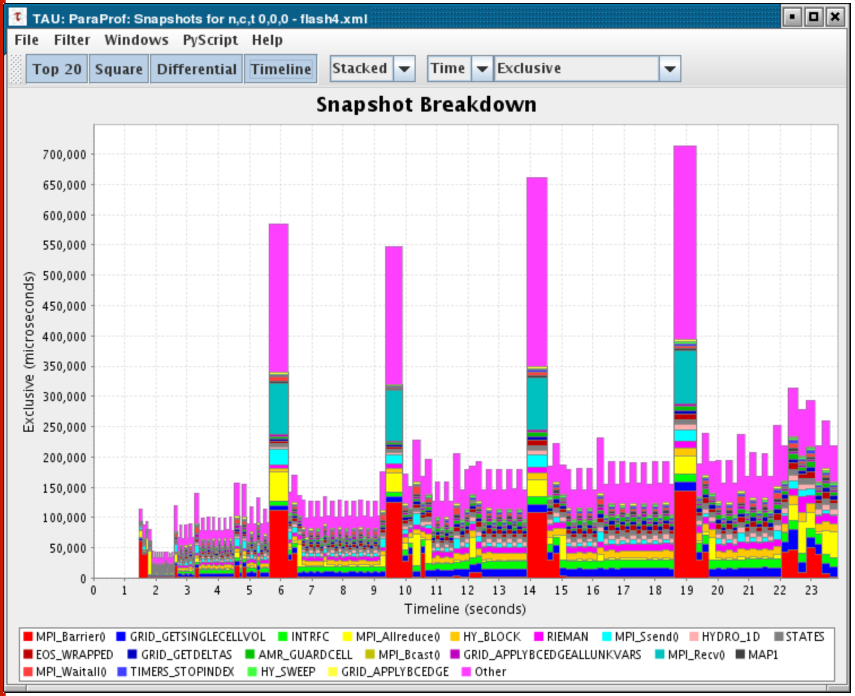
Initialization

Checkpointing

Finalization

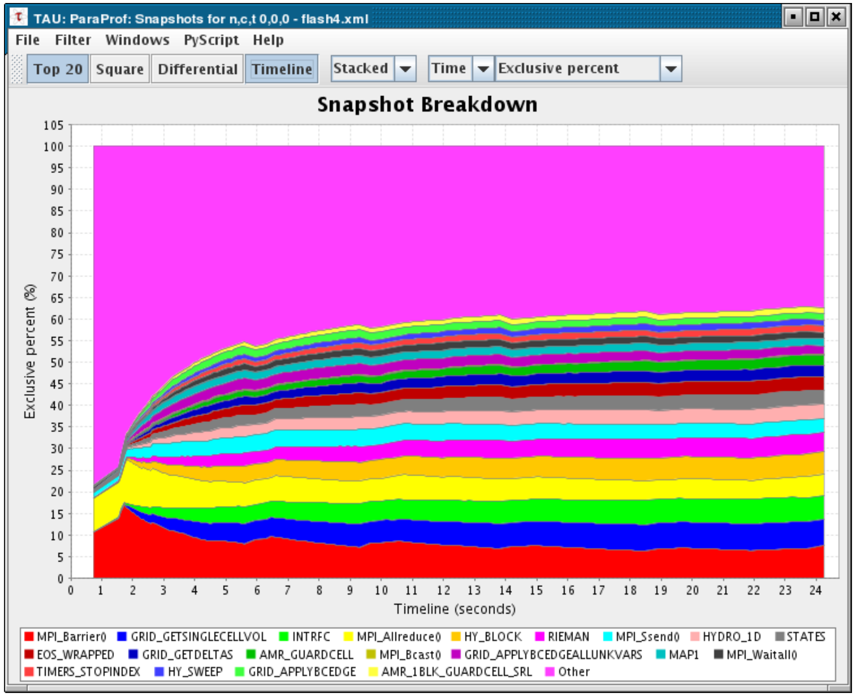
Profile Snapshot Views

Percentage breakdown



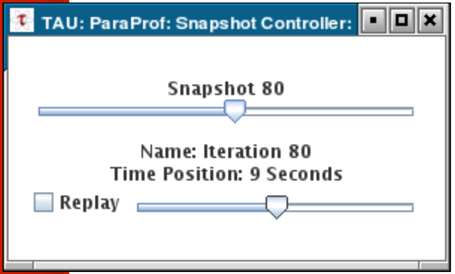
Stacked | Time | Exclusive

Only show main loop



Stacked | Time | Exclusive percent

Snapshot Replay in ParaProf

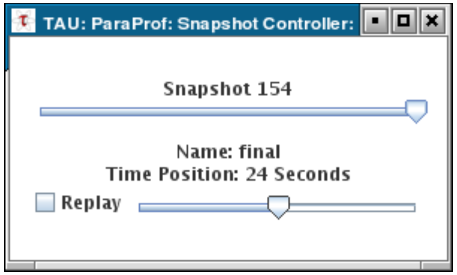


Snapshot 80

Name: Iteration 80
Time Position: 9 Seconds

□ Replay

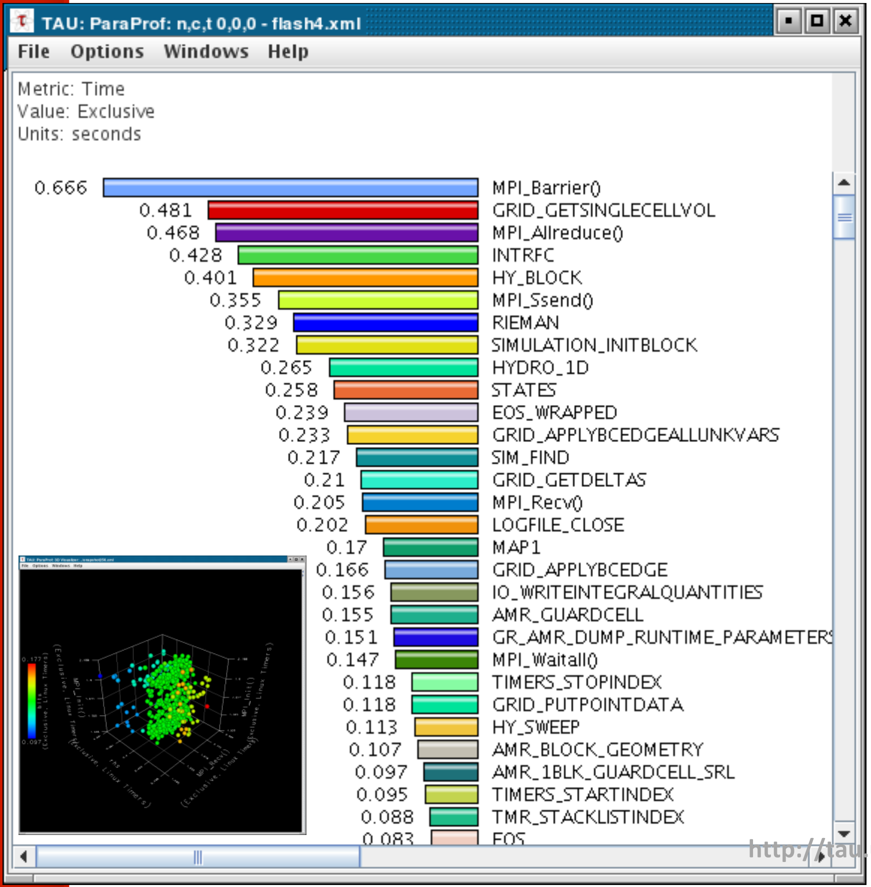
All windows dynamically update



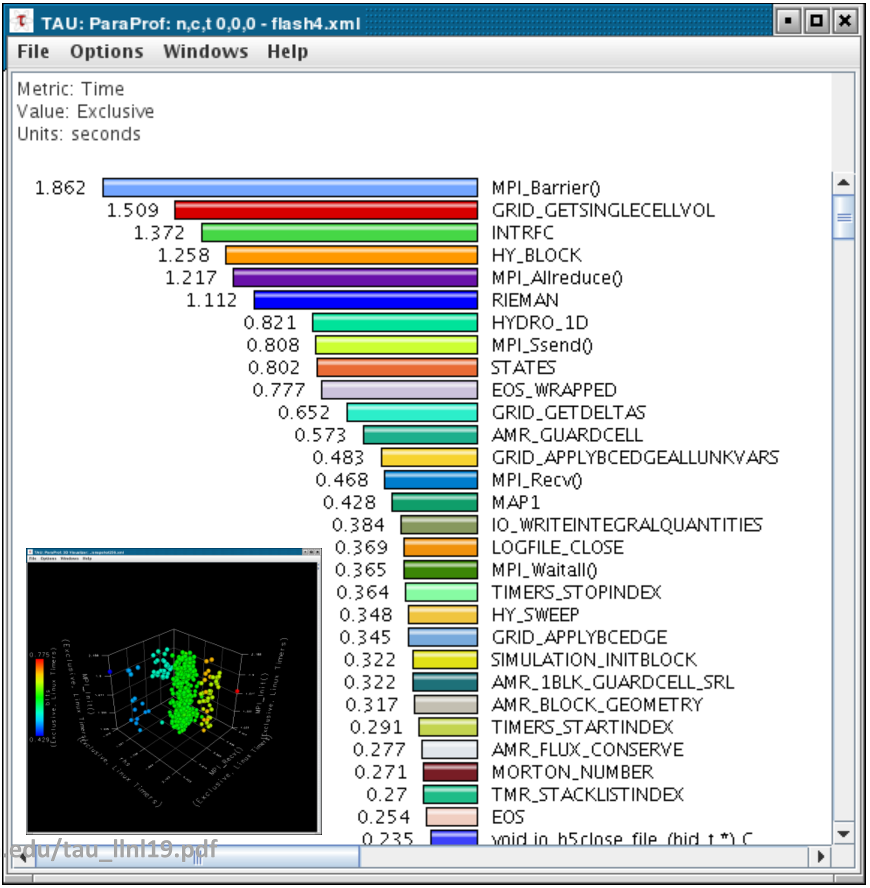
Snapshot 154

Name: final
Time Position: 24 Seconds

□ Replay

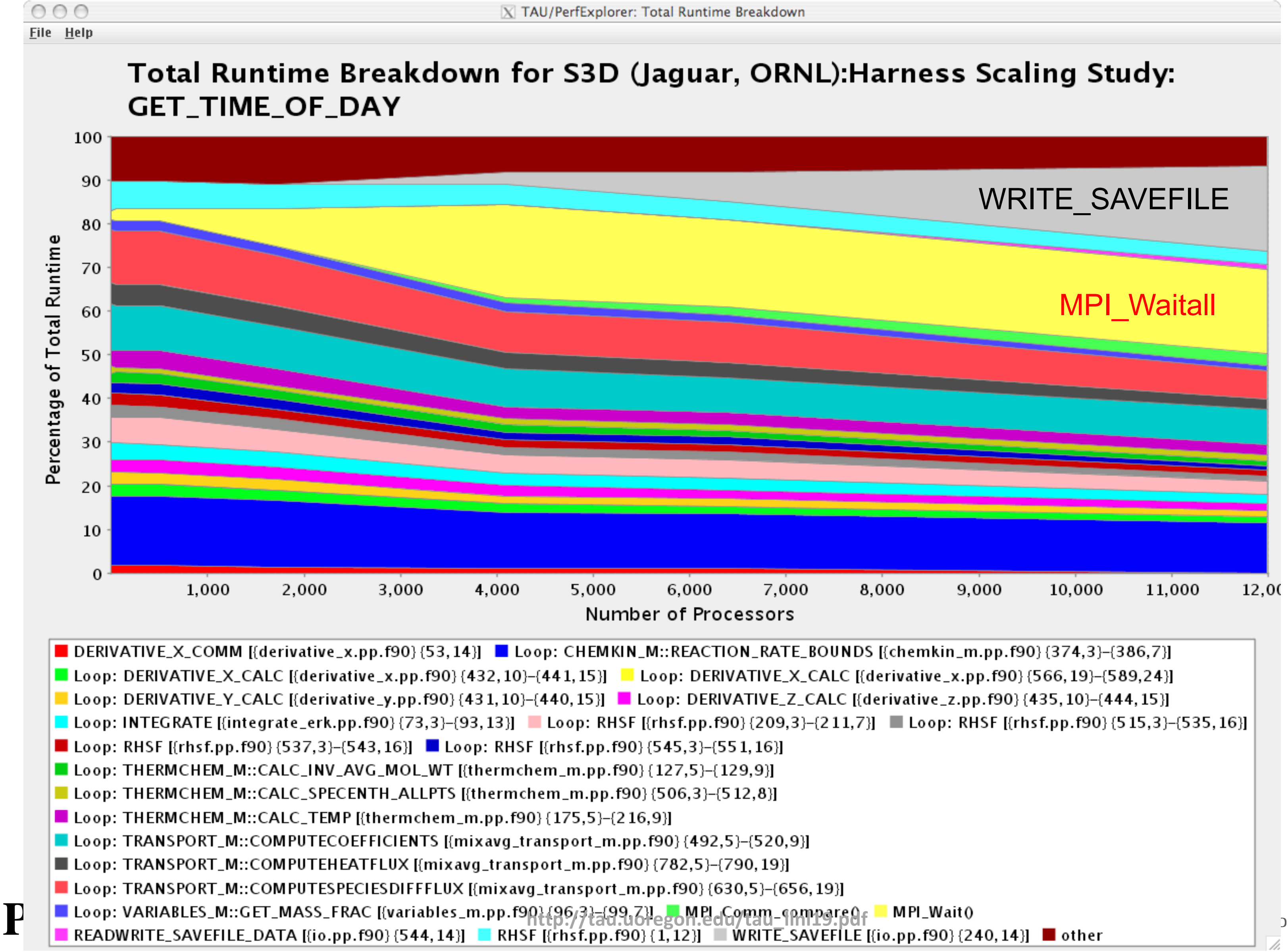


```
Metric: Time
Value: Exclusive
Units: seconds

0.666  MPI_Barrier()
0.481  GRID_GETSINGLECELLVOL
0.468  MPI_Allreduce()
0.428  INTRFC
0.401  HY_BLOCK
0.355  MPI_Ssend()
0.329  RIEMAN
0.322  SIMULATION_INITBLOCK
0.265  HYDRO_1D
0.258  STATES
0.239  EOS_WRAPPED
0.233  GRID_APPLYBCEDGEALLUNKVARS
0.217  SIM_FIND
0.21   GRID_GETDELTAS
0.205  MPI_Recv()
0.202  LOGFILE_CLOSE
0.17   MAP1
0.166  GRID_APPLYBCEDGE
0.156  IO_WRITEINTEGRALQUANTITIES
0.155  AMR_GUARDCELL
0.151  GR_AMR_DUMP_RUNTIME_PARAMETERS
0.147  MPI_Waitall()
0.118  TIMERS_STOPINDEX
0.118  GRID_PUTPOINTDATA
0.113  HY_SWEEP
0.107  AMR_BLOCK_GEOMETRY
0.097  AMR_1BLK_GUARDCELL_SRL
0.095  TIMERS_STARTINDEX
0.088  TMR_STACKLISTINDEX
0.083  EOS
```

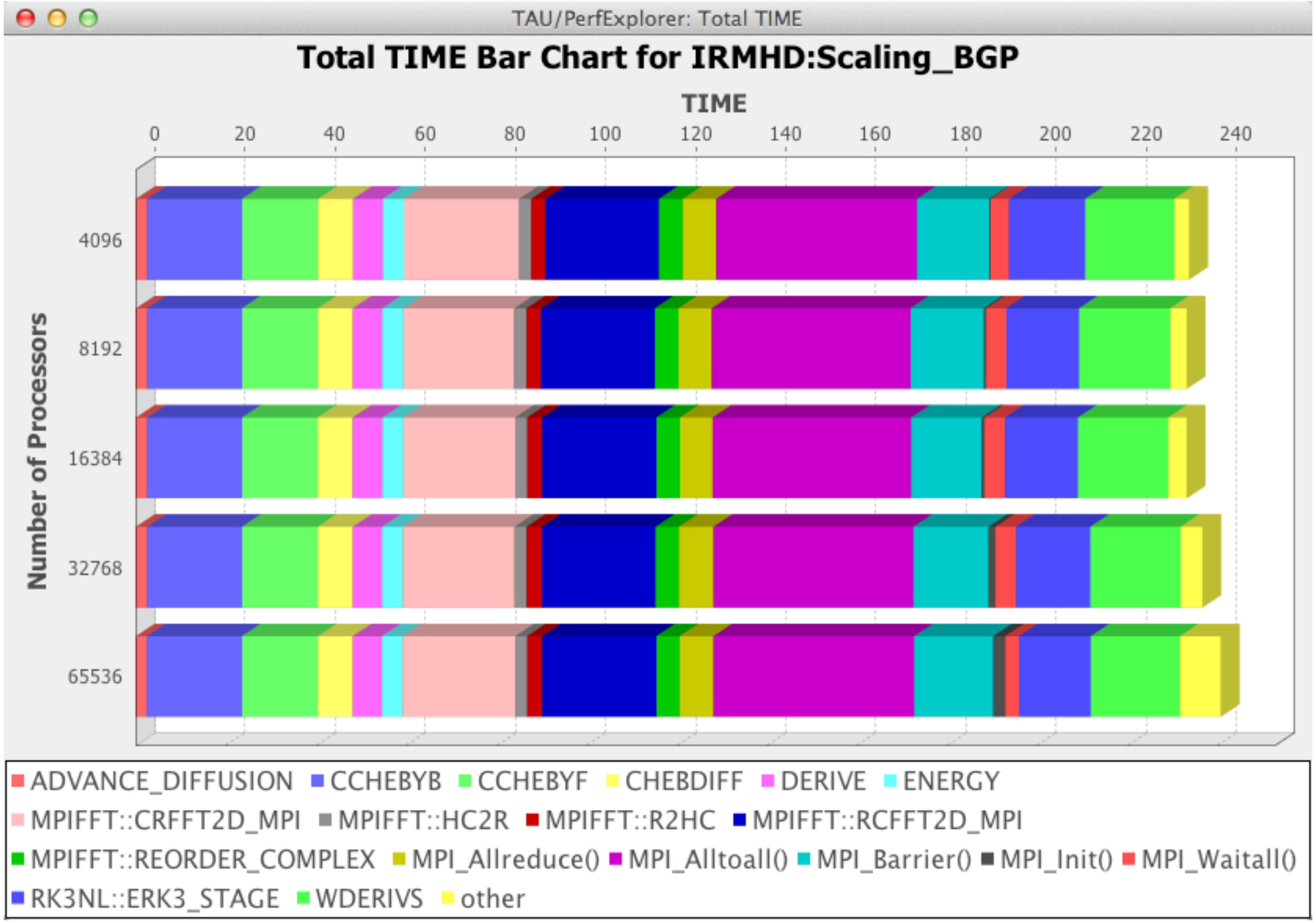


```
Metric: Time
Value: Exclusive
Units: seconds

1.862  MPI_Barrier()
1.509  GRID_GETSINGLECELLVOL
1.372  INTRFC
1.258  HY_BLOCK
1.217  MPI_Allreduce()
1.112  RIEMAN
0.821  HYDRO_1D
0.808  MPI_Ssend()
0.802  STATES
0.777  EOS_WRAPPED
0.652  GRID_GETDELTAS
0.573  AMR_GUARDCELL
0.483  GRID_APPLYBCEDGEALLUNKVARS
0.468  MPI_Recv()
0.428  MAP1
0.384  IO_WRITEINTEGRALQUANTITIES
0.369  LOGFILE_CLOSE
0.365  MPI_Waitall()
0.364  TIMERS_STOPINDEX
0.348  HY_SWEEP
0.345  GRID_APPLYBCEDGE
0.322  SIMULATION_INITBLOCK
0.322  AMR_1BLK_GUARDCELL_SRL
0.317  AMR_BLOCK_GEOMETRY
0.291  TIMERS_STARTINDEX
0.277  AMR_FLUX_CONSERVE
0.271  MORTON_NUMBER
0.27   TMR_STACKLISTINDEX
0.254  EOS
0.235  void in_h5close_file_(hid_t *) C
```

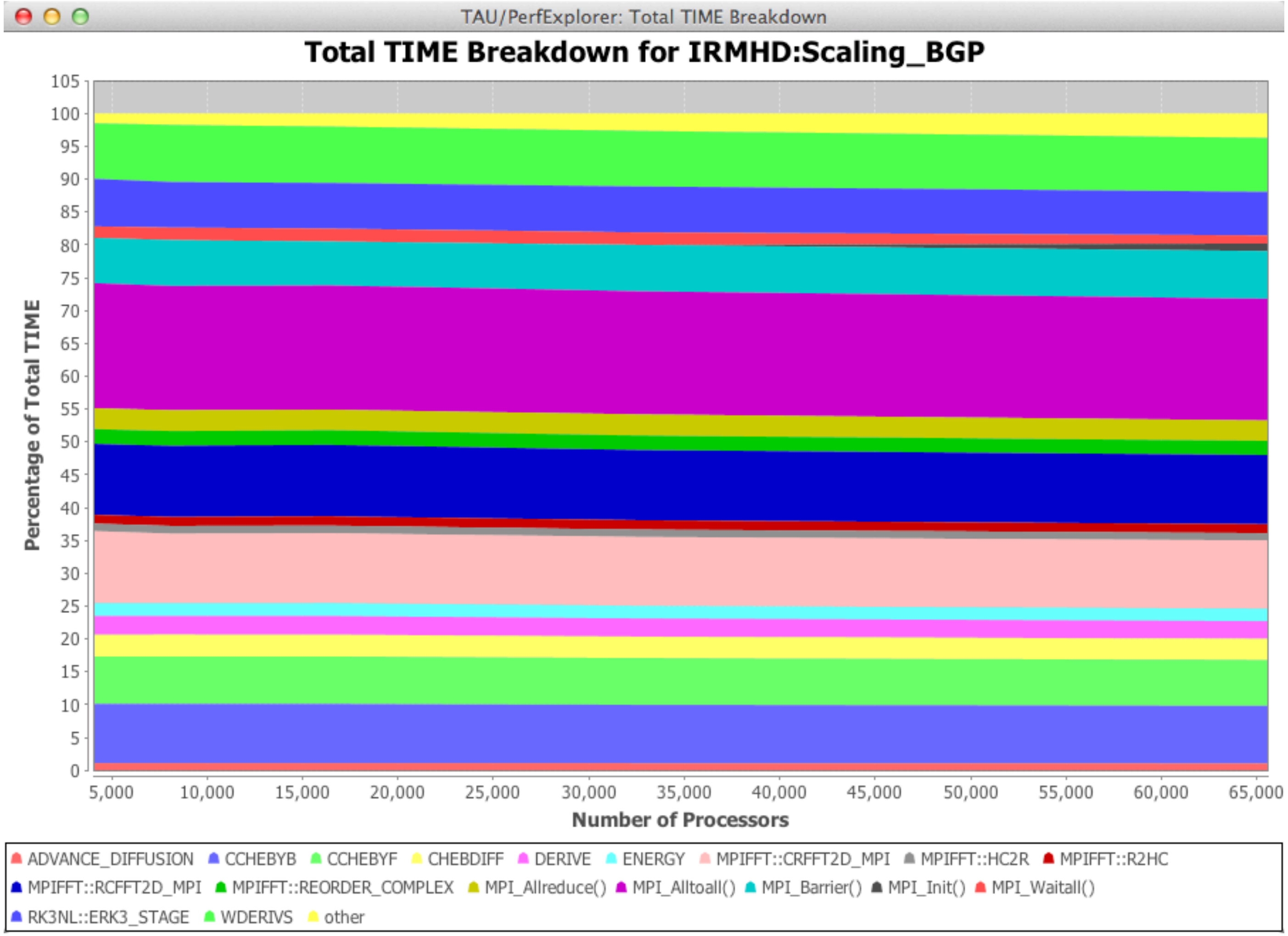
PerfExplorer – Runtime Breakdown



Evaluate Scalability

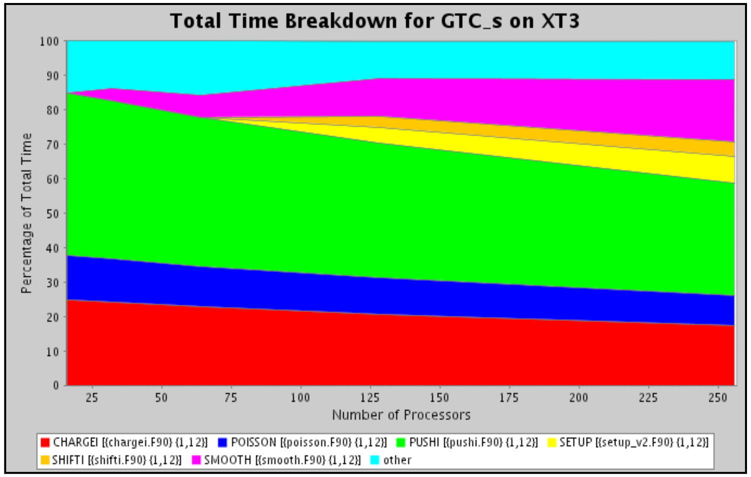


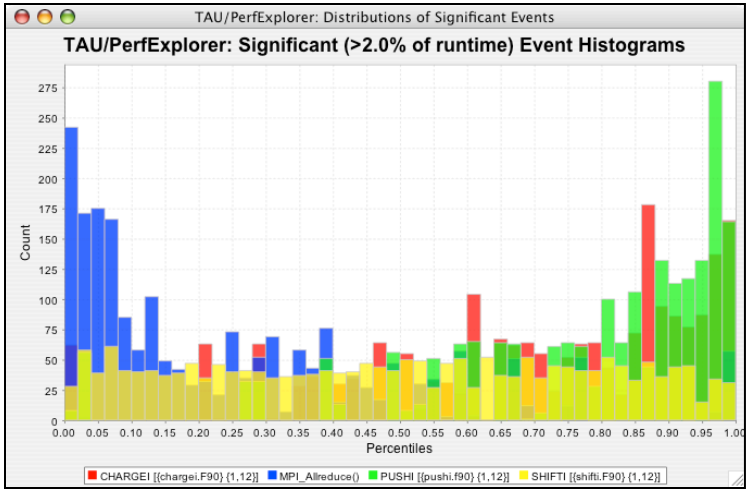
Runtime Breakdown



PerfExplorer – Relative Comparisons

- Total execution time
- Timesteps per second
- Relative efficiency
- Relative efficiency per event
- Relative speedup
- Relative speedup per event
- Group fraction of total
- Runtime breakdown
- Correlate events with total runtime
- Relative efficiency per phase
- Relative speedup per phase
- Distribution visualizations





ParaTools

http://tau.uoregon.edu/tau_llnl19.pdf

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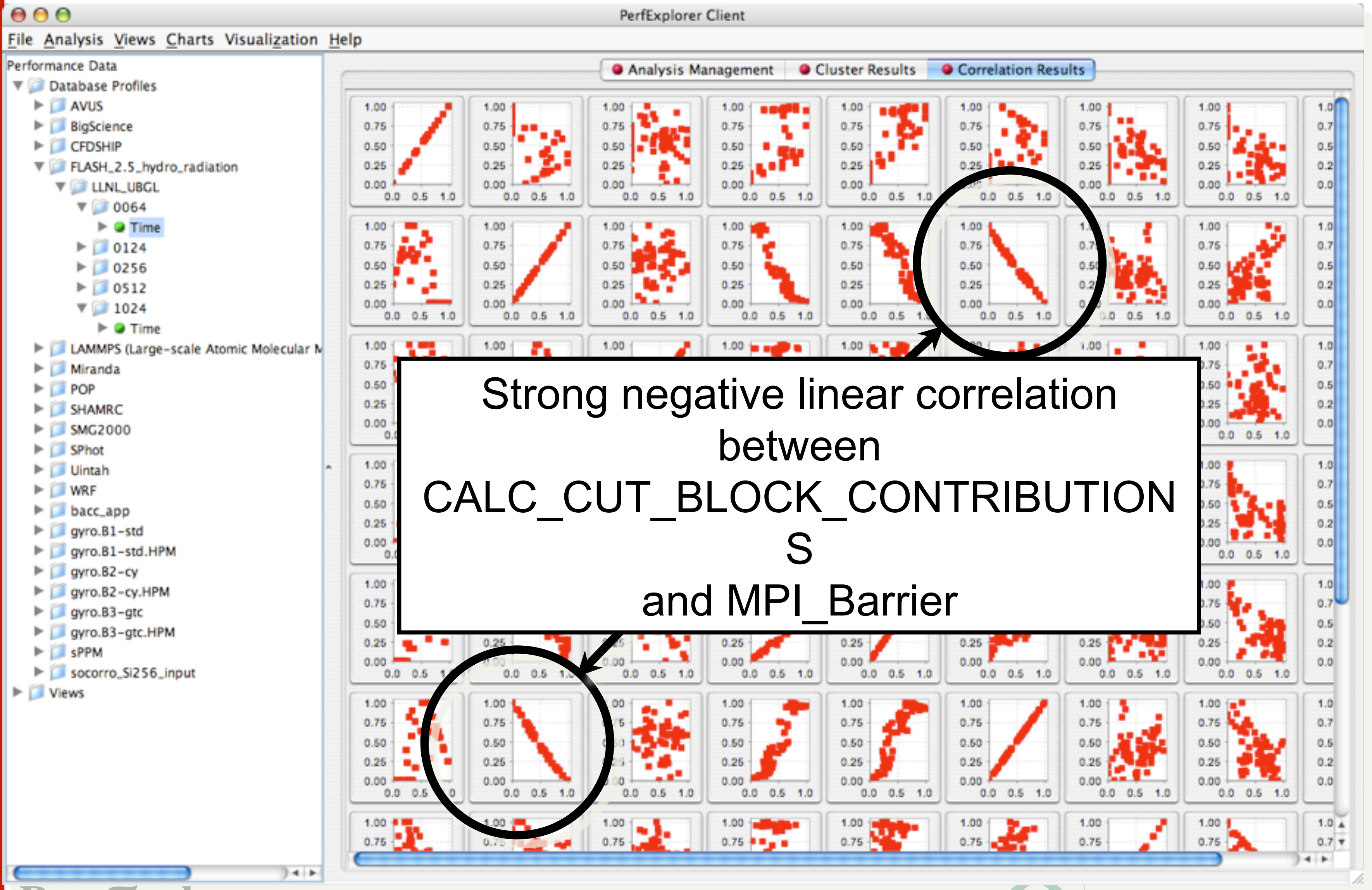
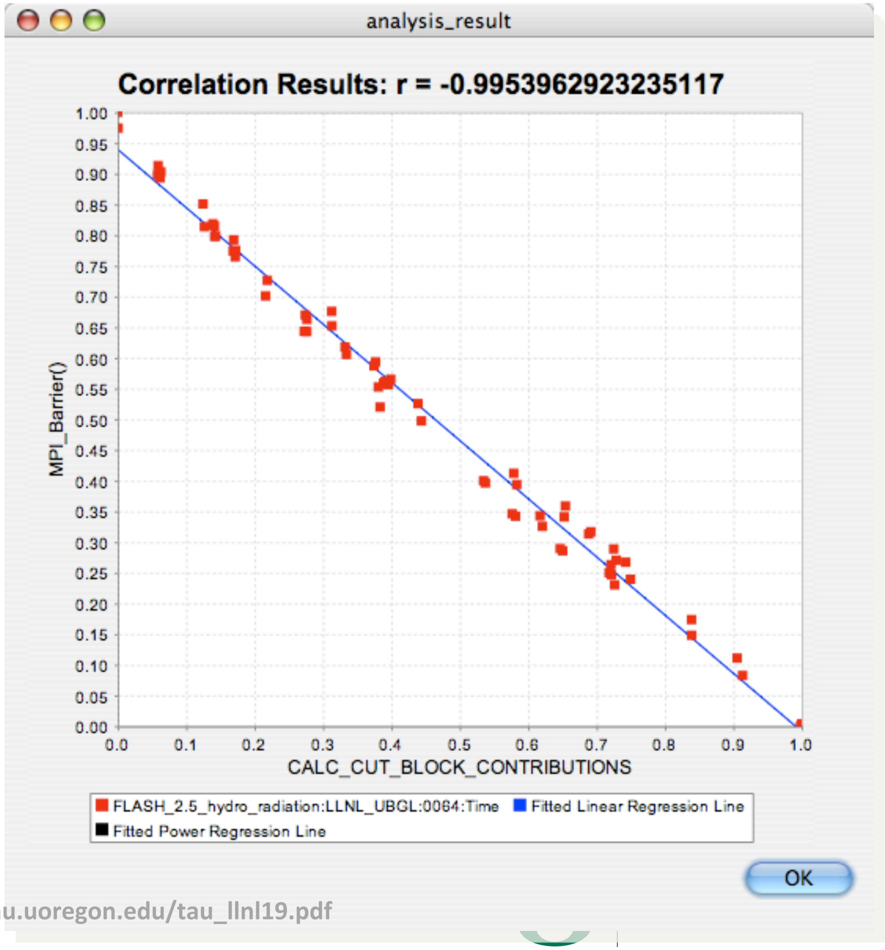
PerfExplorer – Correlation Analysis



Strong negative linear correlation between CALC_CUT_BLOCK_CONTRIBUTIONS and MPI_Barrier

PerfExplorer – Correlation Analysis

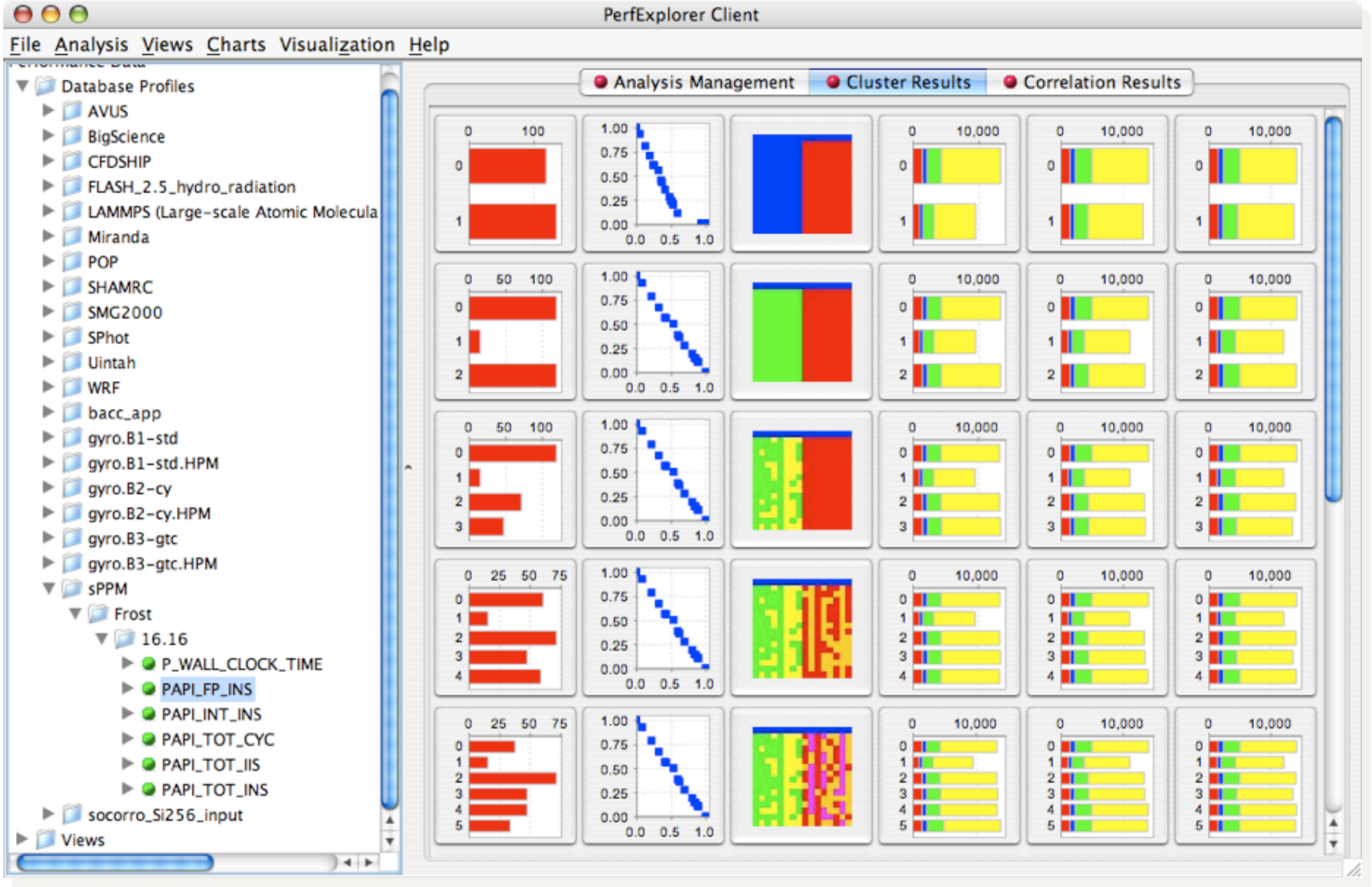
-0.995 indicates strong, negative relationship. As CALC_CUT_BLOCK_CONTRIBUTIONS() increases in execution time, MPI_Barrier() decreases



ParaTools

http://tau.uoregon.edu/tau_llnl19.pdf

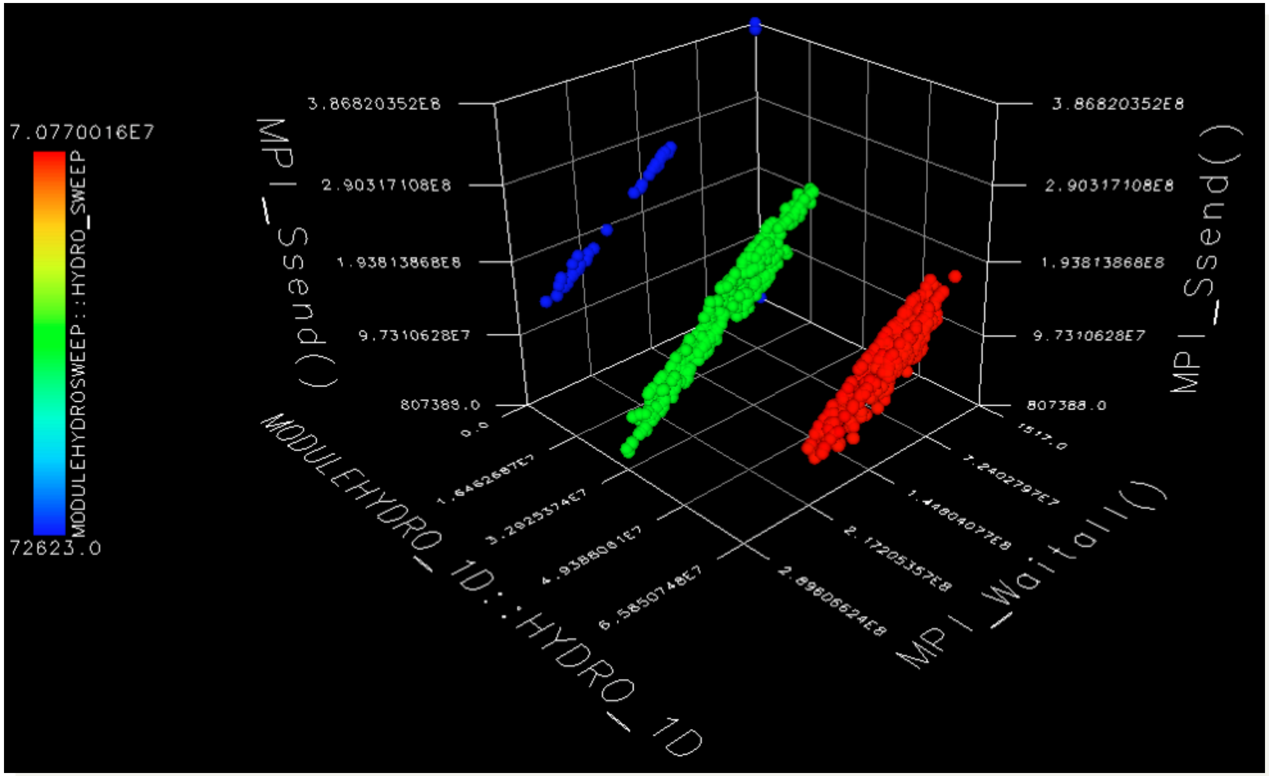
PerfExplorer – Cluster Analysis



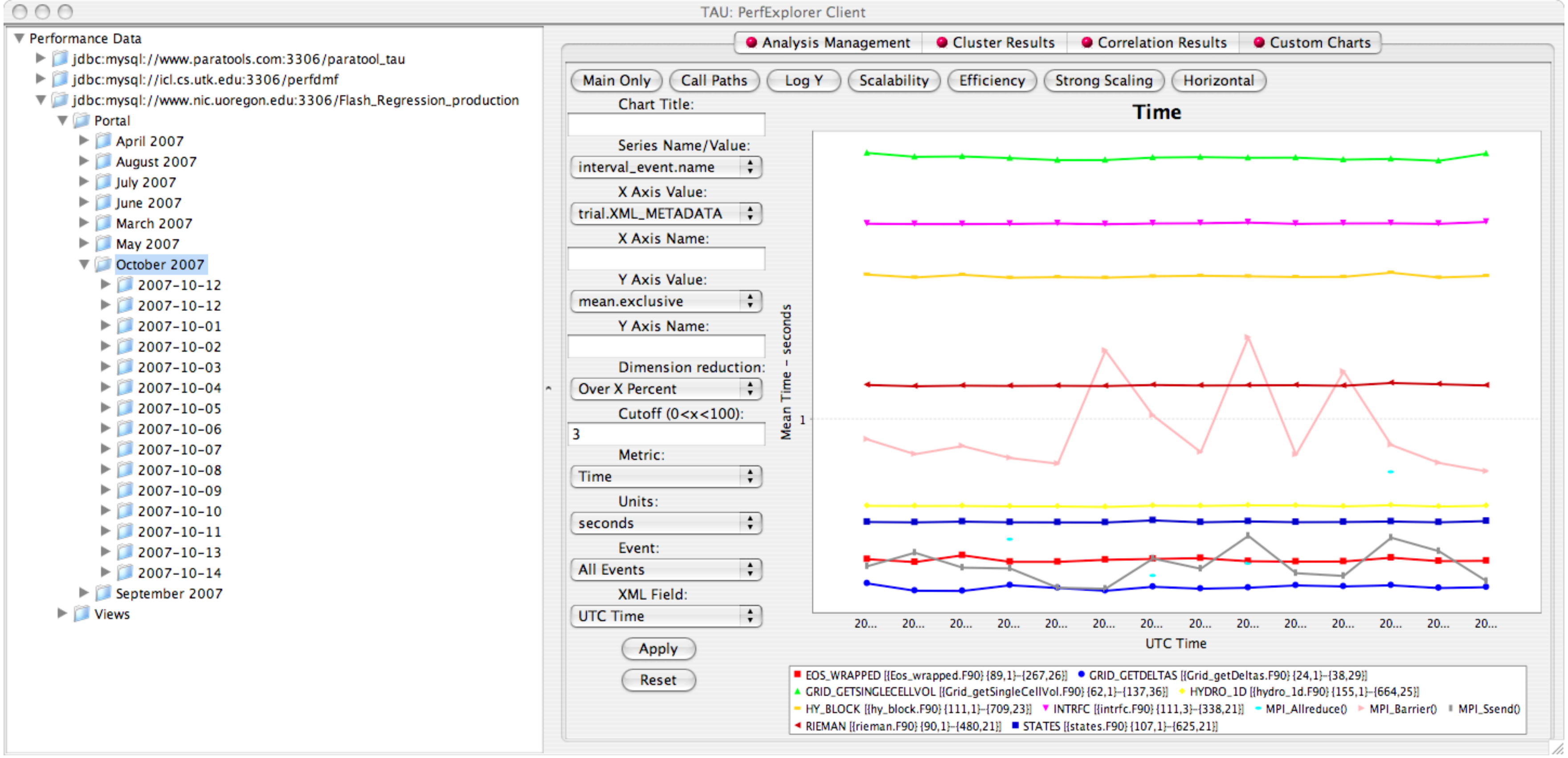
PerfExplorer – Cluster Analysis

Four significant events automatically selected

Clusters and correlations are visible



PerfExplorer – Performance Regression



TAU: PerfExplorer Client

- Performance Data
  - jdbc:mysql://www.paratools.com:3306/paratool_tau
  - jdbc:mysql://icl.cs.utk.edu:3306/perfdmf
  - jdbc:mysql://www.nic.uoregon.edu:3306/Flash_Regression_production
    - Portal
      - April 2007
      - August 2007
      - July 2007
      - June 2007
      - March 2007
      - May 2007
      - October 2007
        - 2007-10-12
        - 2007-10-12
        - 2007-10-01
        - 2007-10-02
        - 2007-10-03
        - 2007-10-04
        - 2007-10-05
        - 2007-10-06
        - 2007-10-07
        - 2007-10-08
        - 2007-10-09
        - 2007-10-10
        - 2007-10-11
        - 2007-10-13
        - 2007-10-14
      - September 2007
    - Views

Chart Title:

Series Name/Value: interval_event.name

X Axis Value: trial.XML_METADATA

X Axis Name:

Y Axis Value: mean.exclusive

Y Axis Name:

Dimension reduction: Over X Percent

Cutoff (0<x<100): 3

Metric: Time

Units: seconds

Event: All Events

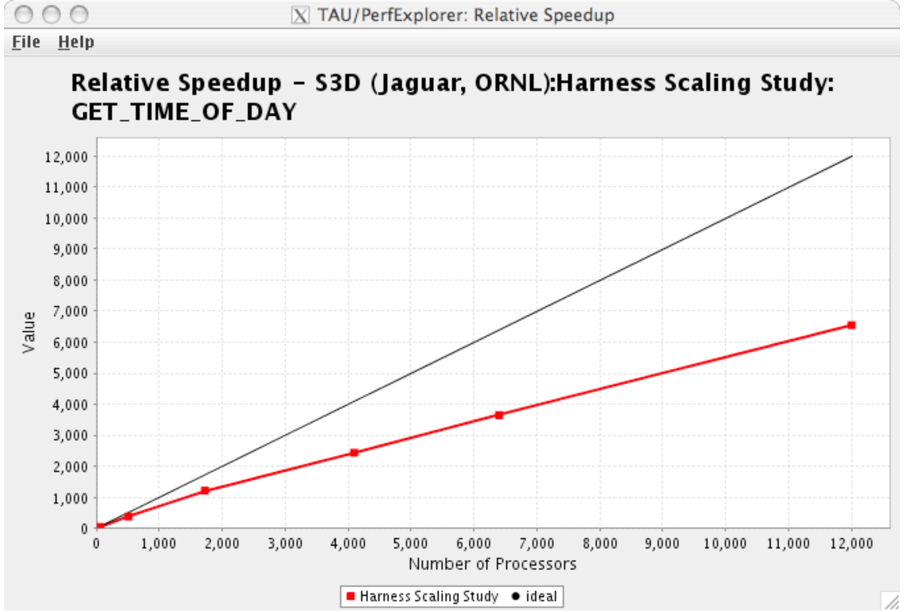
XML Field: UTC Time

Analysis Management
Cluster Results
Correlation Results
Custom Charts
Main Only
Call Paths
Log Y
Scalability
Efficiency
Strong Scaling
Horizontal
Apply
Reset
Time
Mean Time – seconds
1
20...
20...
20...
20...
20...
20...
20...
20...
20...
20...
20...
20...
20...
20...
UTC Time
■ EOS_WRAPPED [{Eos_wrapped.F90} {89,1}-{267,26}]
● GRID_GETDELTAS [{Grid_getDeltas.F90} {24,1}-{38,29}]
▲ GRID_GETSINGLECELLVOL [{Grid_getSingleCellVol.F90} {62,1}-{137,36}]
◆ HYDRO_1D [{hydro_1d.F90} {155,1}-{664,25}]
▬ HY_BLOCK [{hy_block.F90} {111,1}-{709,23}]
▼ INTRFC [{intrfc.F90} {111,3}-{338,21}]
▬ MPI_Allreduce()
▶ MPI_Barrier()
▮ MPI_Ssend()
◀ RIEMAN [{rieman.F90} {90,1}-{480,21}]
■ STATES [{states.F90} {107,1}-{625,21}]

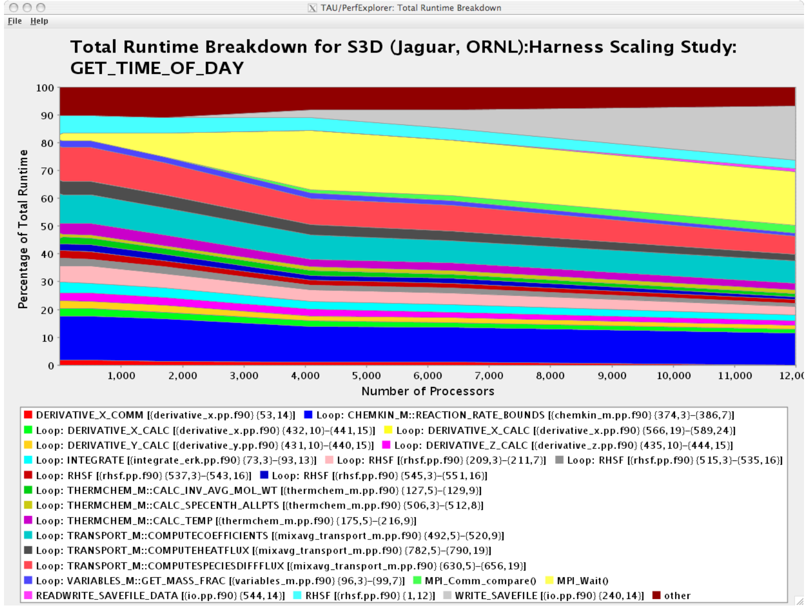
Evaluate Scalability

Goal: How does my application scale? What bottlenecks at what CPU counts?

Load profiles in PerfDMF database and examine with PerfExplorer

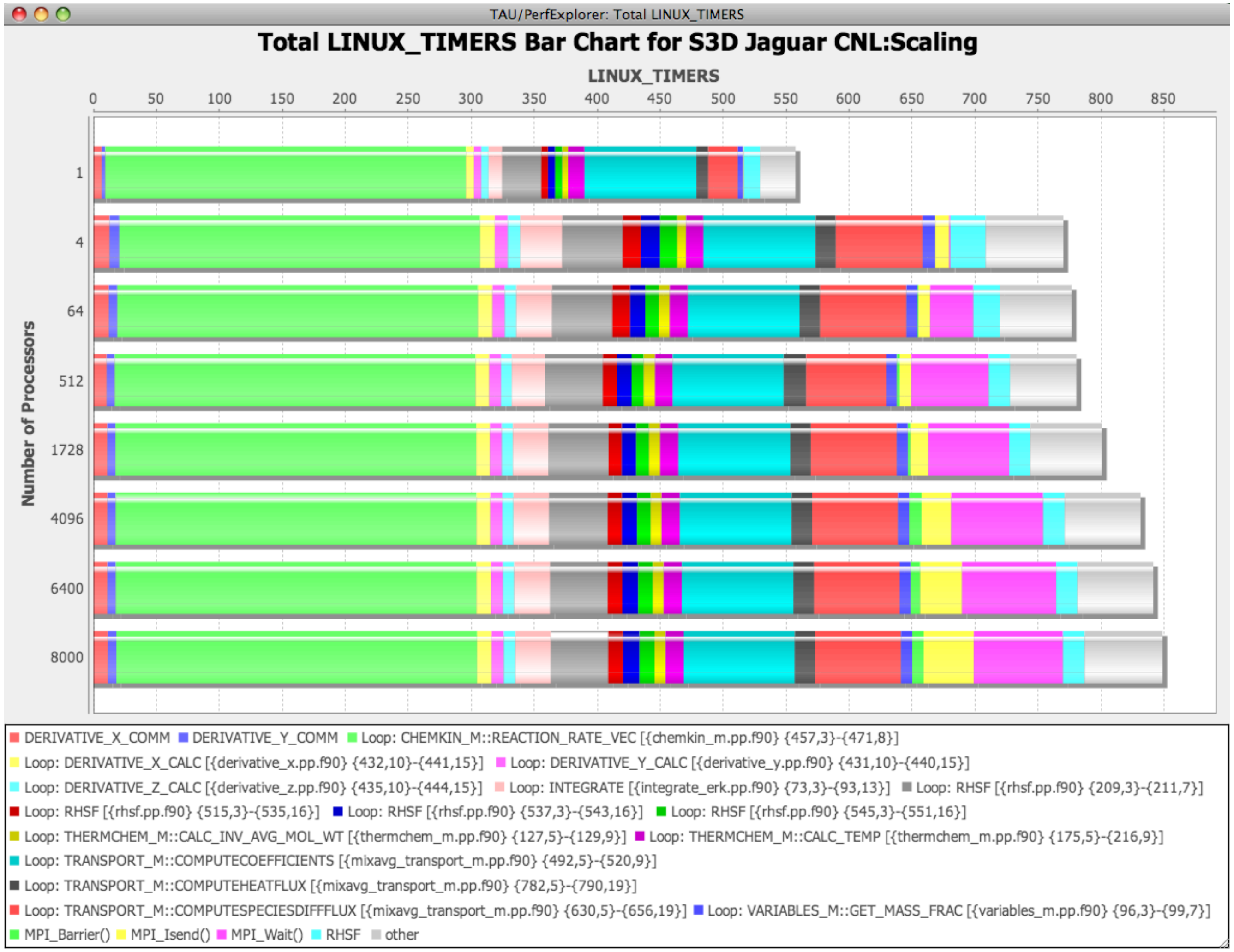


Relative Speedup – S3D (Jaguar, ORNL):Harness Scaling Study: GET_TIME_OF_DAY

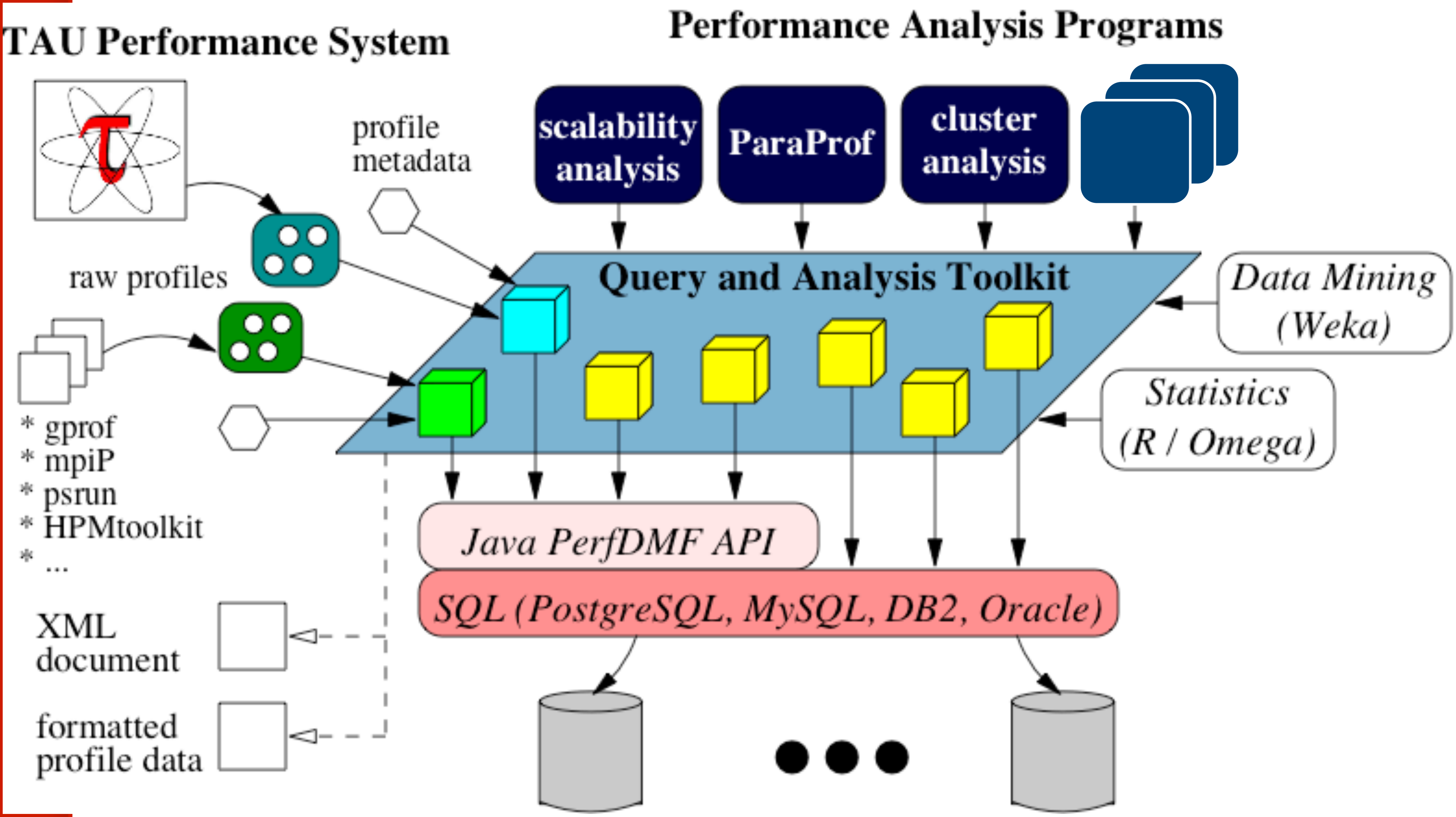


Total Runtime Breakdown for S3D (Jaguar, ORNL):Harness Scaling Study: GET_TIME_OF_DAY

Usage Scenarios: Evaluate Scalability



TAUdb: Framework for Managing Performance Data



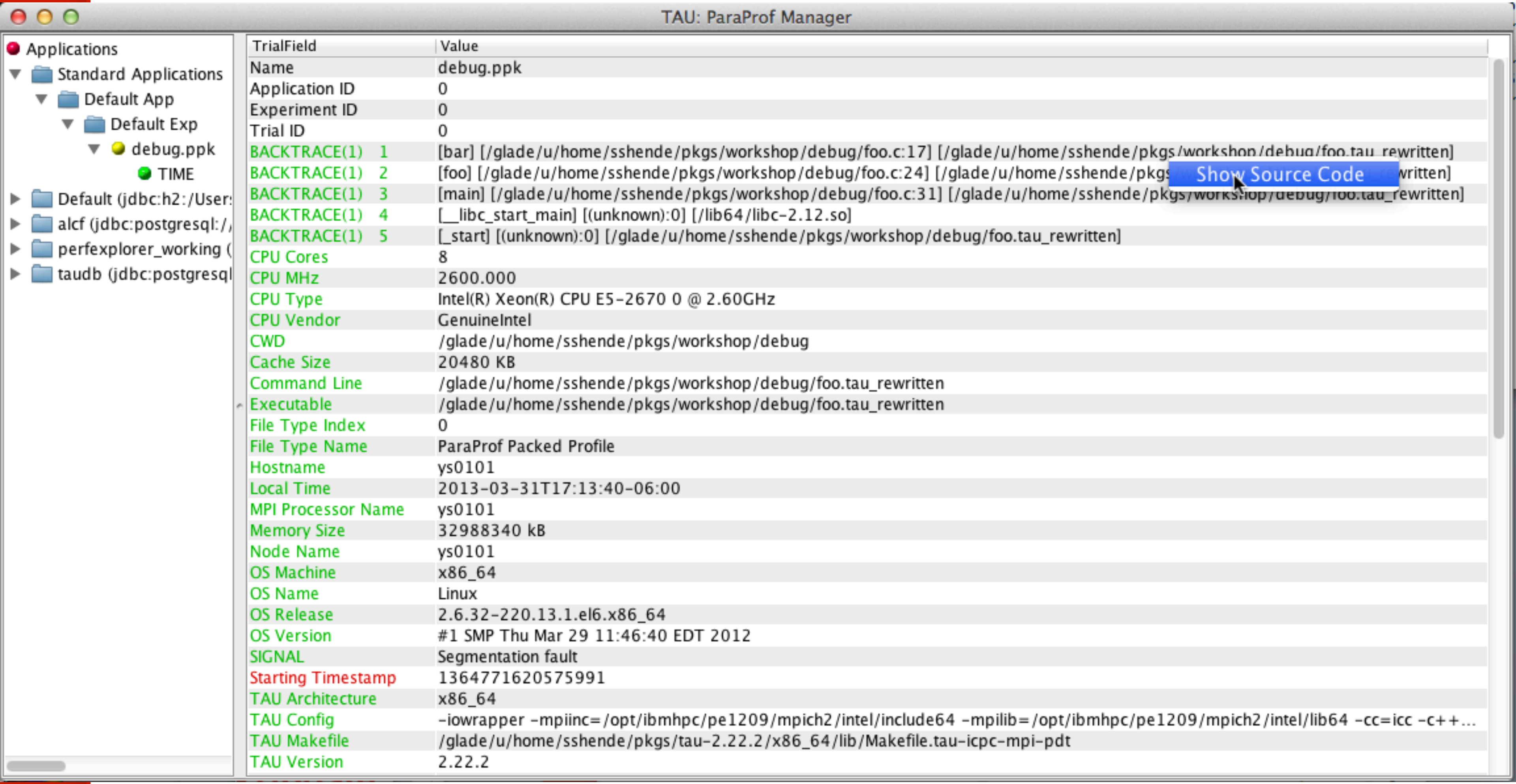
Evaluate Scalability using PerfExplorer Charts

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)
% qsub  run1p.job
% paraprof --pack 1p.ppk
% qsub  run2p.job …
% paraprof --pack 2p.ppk … and so on.
On your client:
% taudb_configure --create-default
% perfexplorer_configure
(Enter, y to load schema, defaults)
% paraprof
(load each trial: DB -> Add Trial -> Type (Paraprof Packed
Profile) -> OK, OR use taudb_loadtrial on the commandline)
% taudb_loadtrial -a App -x MyExp -n 4p 4p.ppk
% perfexplorer
(Charts -> Speedup)
OR:
wget http://tau.uoregon.edu/data.tgz; cat README in data
```

Multi-language Application Debugging

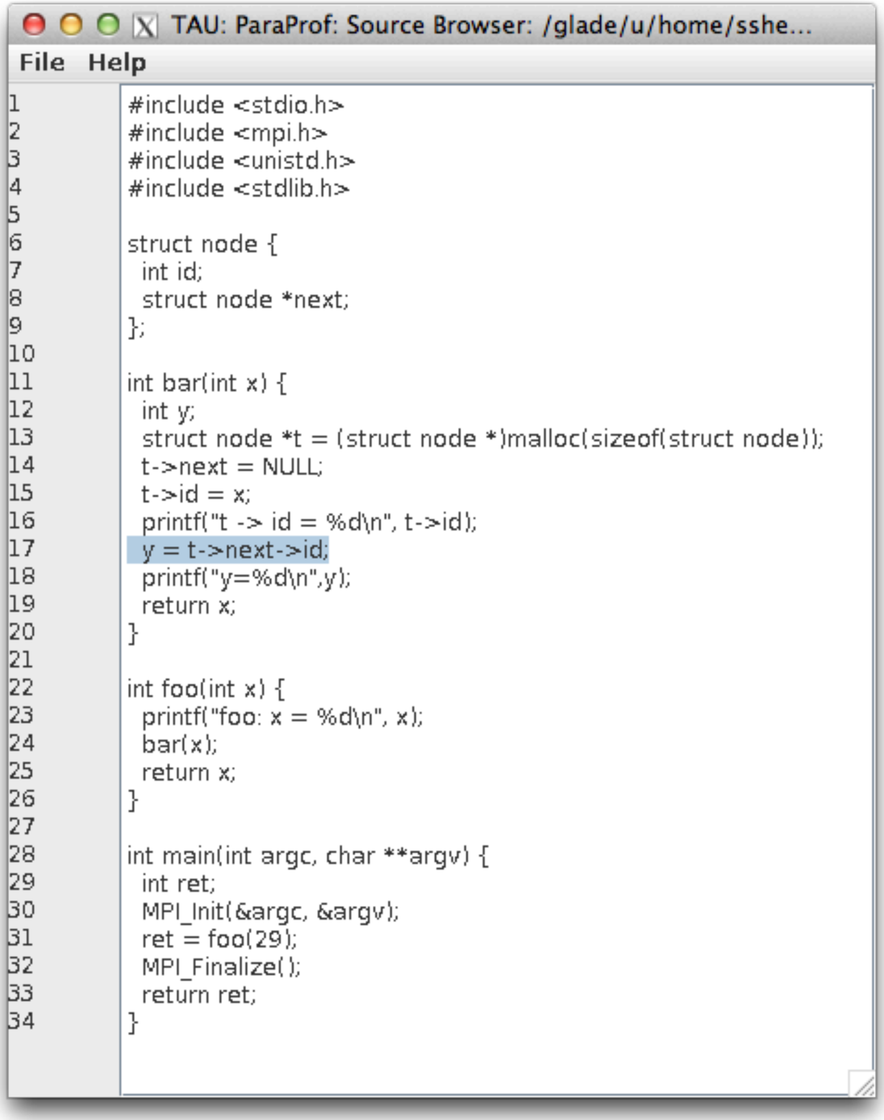
```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% export TAU_OPTIONS=‘-optMemDbg -optVerbose’
% make F90=tau_f90.sh CC=tau_cc.sh CXX=tau_cxx.sh

% export TAU_MEMDBG_PROTECT_ABOVE=1
% export TAU_MEMDBG_PROTECT_BELOW=1
% export TAU_MEMDBG_PROTECT_FREE=1
% mpirun -np 4  ./matmult
% paraprof
```

Multi-language Application Debugging



TrialField	Value
Name	debug.ppk
Application ID	0
Experiment ID	0
Trial ID	0
BACKTRACE(1) 1	[bar] [/glade/u/home/sshende/pkgs/workshop/debug/foo.c:17] [/glade/u/home/sshende/pkgs/workshop/debug/foo.tau_rewritten]
BACKTRACE(1) 2	[foo] [/glade/u/home/sshende/pkgs/workshop/debug/foo.c:24] [/glade/u/home/sshende/pkgs written]
BACKTRACE(1) 3	[main] [/glade/u/home/sshende/pkgs/workshop/debug/foo.c:31] [/glade/u/home/sshende/pkgs/workshop/debug/foo.tau_rewritten]
BACKTRACE(1) 4	[__libc_start_main] [(unknown):0] [/lib64/libc-2.12.so]
BACKTRACE(1) 5	[_start] [(unknown):0] [/glade/u/home/sshende/pkgs/workshop/debug/foo.tau_rewritten]
CPU Cores	8
CPU MHz	2600.000
CPU Type	Intel(R) Xeon(R) CPU E5-2670 0 @ 2.60GHz
CPU Vendor	GenuineIntel
CWD	/glade/u/home/sshende/pkgs/workshop/debug
Cache Size	20480 KB
Command Line	/glade/u/home/sshende/pkgs/workshop/debug/foo.tau_rewritten
Executable	/glade/u/home/sshende/pkgs/workshop/debug/foo.tau_rewritten
File Type Index	0
File Type Name	ParaProf Packed Profile
Hostname	ys0101
Local Time	2013-03-31T17:13:40-06:00
MPI Processor Name	ys0101
Memory Size	32988340 kB
Node Name	ys0101
OS Machine	x86_64
OS Name	Linux
OS Release	2.6.32-220.13.1.el6.x86_64
OS Version	#1 SMP Thu Mar 29 11:46:40 EDT 2012
SIGNAL	Segmentation fault
Starting Timestamp	1364771620575991
TAU Architecture	x86_64
TAU Config	-iowrapper -mpiinc=/opt/ibmhpc/pe1209/mpich2/intel/include64 -mpilib=/opt/ibmhpc/pe1209/mpich2/intel/lib64 -cc=icc -c++...
TAU Makefile	/glade/u/home/sshende/pkgs/tau-2.22.2/x86_64/lib/Makefile.tau-icpc-mpi-pdt
TAU Version	2.22.2

Location of segmentation violation

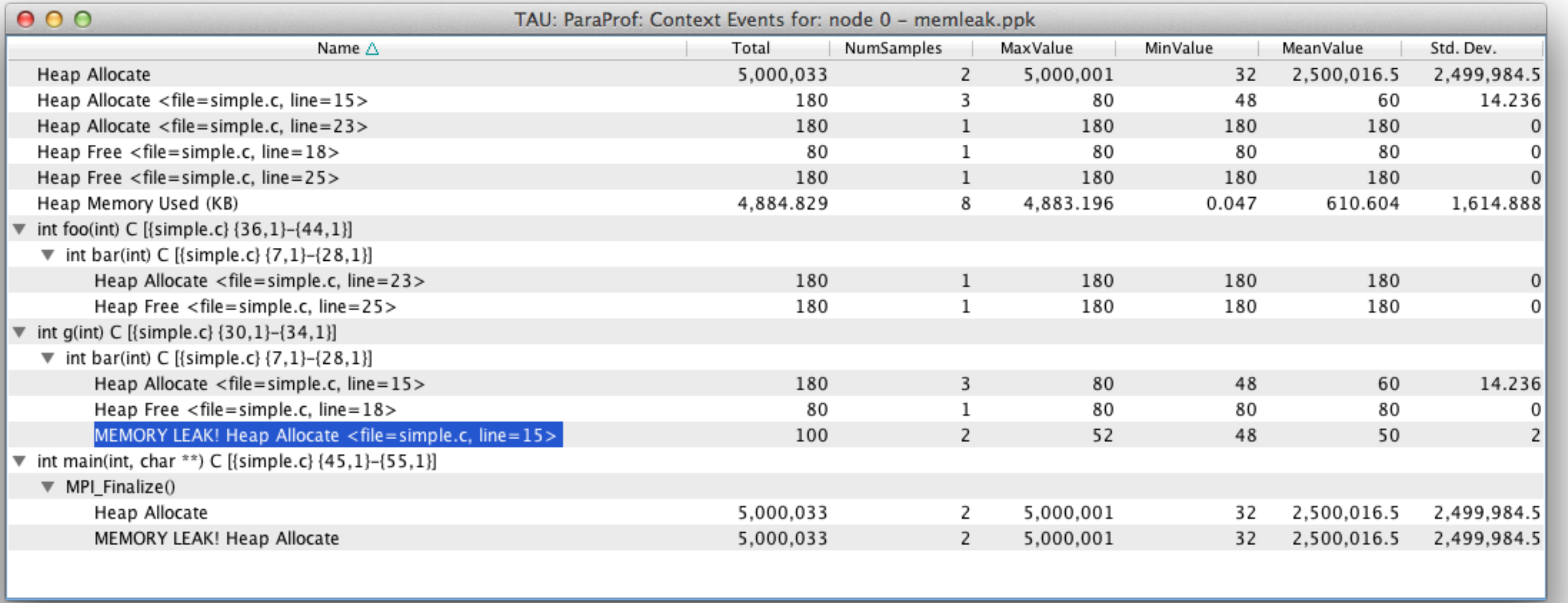


```
#include <stdio.h>
#include <mpi.h>
#include <unistd.h>
#include <stdlib.h>

struct node {
  int id;
  struct node *next;
};

int bar(int x) {
  int y;
  struct node *t = (struct node *)malloc(sizeof(struct node));
  t->next = NULL;
  t->id = x;
  printf("t -> id = %d\n", t->id);
  y = t->next->id;
  printf("y=%d\n",y);
  return x;
}

int foo(int x) {
  printf("foo: x = %d\n", x);
  bar(x);
  return x;
}

int main(int argc, char **argv) {
  int ret;
  MPI_Init(&argc, &argv);
  ret = foo(29);
  MPI_Finalize();
  return ret;
}
```

Memory Leak Detection

```
% export TAU_MAKEFILE=$TAU_MAKEFILE_BASE-icpc-papi-mpi-pdt
% export TAU_OPTIONS=‘-optMemDbg -optVerbose’
% make F90=tau_f90.sh CC=tau_cc.sh CXX=tau_cxx.sh



% export TAU_TRACK_MEMORY_LEAKS=1
% mpirun -np 4  ./matmult
% paraprof
```

Multi-language Memory Leak Detection



TAU: ParaProf: Context Events for: node 0 – memleak.ppk

Name △	Total	NumSamples	MaxValue	MinValue	MeanValue	Std. Dev.
Heap Allocate	5,000,033	2	5,000,001	32	2,500,016.5	2,499,984.5
Heap Allocate <file=simple.c, line=15>	180	3	80	48	60	14.236
Heap Allocate <file=simple.c, line=23>	180	1	180	180	180	0
Heap Free <file=simple.c, line=18>	80	1	80	80	80	0
Heap Free <file=simple.c, line=25>	180	1	180	180	180	0
Heap Memory Used (KB)	4,884.829	8	4,883.196	0.047	610.604	1,614.888
▼ int foo(int) C [{simple.c} {36,1}-{44,1}]						
▼ int bar(int) C [{simple.c} {7,1}-{28,1}]						
Heap Allocate <file=simple.c, line=23>	180	1	180	180	180	0
Heap Free <file=simple.c, line=25>	180	1	180	180	180	0
▼ int g(int) C [{simple.c} {30,1}-{34,1}]						
▼ int bar(int) C [{simple.c} {7,1}-{28,1}]						
Heap Allocate <file=simple.c, line=15>	180	3	80	48	60	14.236
Heap Free <file=simple.c, line=18>	80	1	80	80	80	0
MEMORY LEAK! Heap Allocate <file=simple.c, line=15>	100	2	52	48	50	2
▼ int main(int, char **) C [{simple.c} {45,1}-{55,1}]						
▼ MPI_Finalize()						
Heap Allocate	5,000,033	2	5,000,001	32	2,500,016.5	2,499,984.5
MEMORY LEAK! Heap Allocate	5,000,033	2	5,000,001	32	2,500,016.5	2,499,984.5

Extreme-scale Scientific Software Stack (E4S) https://e4s.io

- E4S is a community effort to provide open source software packages for developing, deploying, and running scientific applications on HPC platforms.
- E4S provides both source builds and containers of a broad collection of HPC software packages.
- E4S exists to accelerate the development, deployment and use of HPC software, lowering the barriers for HPC users.
- E4S provides containers and turn-key, from-source builds of 80+ popular HPC software packages:
  - MPI: MPICH and OpenMPI
  - Development tools: TAU, HPCToolkit, and PAPI
  - Math libraries: PETSc and Trilinos
  - Data and Viz tools: Adios, HDF5, and Paraview

Extreme-scale Scientific Software Stack (E4S) https://e4s.io

Spack [http://spack.io] is the primary means for software delivery

SDKs: collection of related ECP ST products where coordination across package teams will improve usability and practicies, and foster community growth among teams that develop similar and complimentary capabilities. An SDK involves several products.

Containers of pre-built binaries of ECP ST products.

Container runtimes supported

- Docker: Dockerhub: exascaleproject/sdk:AHM19
- Charliecloud
- Shifter
- Singularity
- Inception at NCAR

VirtualBox Open Virtualization Appliance (OVA) image that contains these runtimes

MPI replacement strategies to use native network interconnect

Spack

- E4S uses the Spack package manager for software delivery
- Spack provides the ability to specify versions of software packages that are and are not interoperable.
- Spack is a build layer for not only E4S software, but also a large collection of software tools and libraries outside of ECP ST.
- Spack supports achieving and maintaining interoperability between ST software packages.

The Spack community is growing rapidly

Spack simplifies HPC software for:

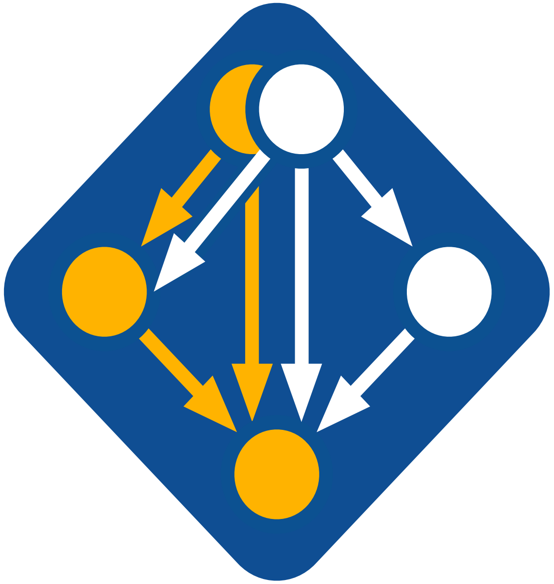
- Users
- Developers
- Cluster installations
- The largest HPC facilities

Spack is central to ECP's software strategy

- Enable software reuse for developers and users
- Allow the facilities to consume the entire ECP stack

The roadmap is packed with new features:

- Building the ECP software distribution
- Better workflows for building containers
- Stacks for facilities
- Chains for rapid dev workflow
- Optimized binaries
- Better dependency resolution



Visit spack.io

github.com/spack/spack

@spackpm

ParaTools

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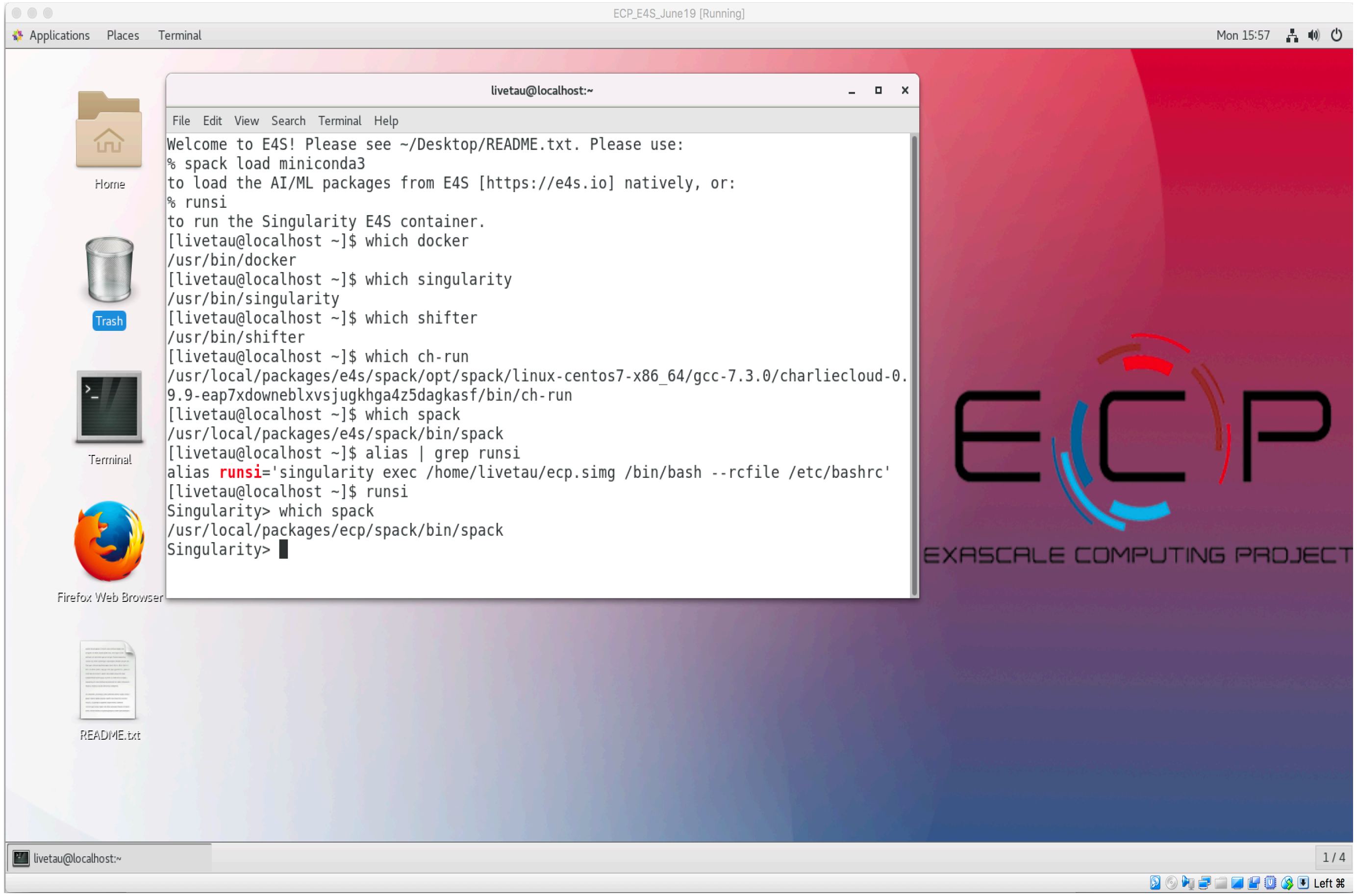
E4S VirtualBox OVA image

Contains all four container runtimes and the E4S Singularity image!

- **Docker**
- **Singularity**
- **Shifter**
- **Charliecloud**



```
Welcome to E4S! Please see ~/Desktop/README.txt. Please use:
% spack load miniconda3
to load the AI/ML packages from E4S [https://e4s.io] natively, or:
% runsi
to run the Singularity E4S container.
[livetau@localhost ~]$ which docker
/usr/bin/docker
[livetau@localhost ~]$ which singularity
/usr/bin/singularity
[livetau@localhost ~]$ which shifter
/usr/bin/shifter
[livetau@localhost ~]$ which ch-run
/usr/local/packages/e4s/spack/opt/spack/linux-centos7-x86_64/gcc-7.3.0/charliecloud-0.
9.9-eap7xdowneblxvsjugkhga4z5dagkasf/bin/ch-run
[livetau@localhost ~]$ which spack
/usr/local/packages/e4s/spack/bin/spack
[livetau@localhost ~]$ alias | grep runsi
alias runsi='singularity exec /home/livetau/ecp.simg /bin/bash --rcfile /etc/bashrc'
[livetau@localhost ~]$ runsi
Singularity> which spack
/usr/local/packages/ecp/spack/bin/spack
Singularity> 
```

Docker container of E4S

```
% docker pull exascaleproject/sdk:AHM19
```

Using USB stick or images from https://e4s.io:

```
% gunzip –c ecp.tgz | docker load
% docker images
```

Mount home directory:

```
% docker –i –v $HOME:$HOME –t exascaleproject/sdk:AHM19 /bin/bash
% which spack
% cp –r /usr/local/packages/ecp/demo . ; cd demo; cat README
```

Running MPI applications on other systems

- Applications built with MPI in the E4S container can replace the MPI in the container with the system MPI!
- This allows fast inter-node communication using the native interconnect.
- Application and data are external to the E4S container.
- Programming models, compilers, runtime libraries, and tools are inside the container.
- We can replace MPI using the MPICH ABI compatibility layer.
- Goal: Build an MPI binary once and run it un-modified on all HPC Linux x86_64 clusters!

Using E4S Singularity Image on Quartz

MVAPICH2 needs /lib. Mount it as /hostlib64 and add it to LD_LIBRARY_PATH

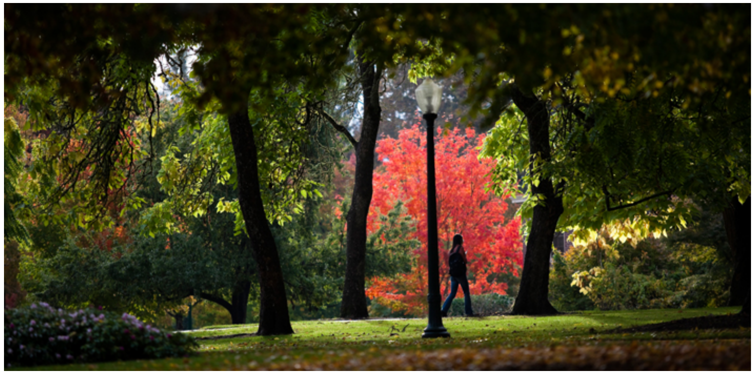
```
% salloc –N 2 –p pdebug
% /usr/workspace/ecpsdk/apps/Zoltan/run_sing.sh
% paraprof &
% cat /usr/workspace/ecpsdk/apps/Zoltan/run_sing.sh
#!/bin/bash
srun -n 8 -N 2 --ntasks-per-node=4 singularity exec  -B /usr/workspace/ecpsdk:/usr/workspace/
ecpsdk -B /lib64:/hostlib64 -B $SLURM_SUBMIT_DIR:$SLURM_SUBMIT_DIR -B /usr/tce:/usr/tce /usr/
workspace/ecpsdk/ecp.simg /bin/bash -c ' . /etc/bashrc ; spack load   trilinos hypre parmetis
hdf5 metis openblas superlu zlib netcdf matio boost@1.66.0 scalapack suite-sparse tau; spack
unload openmpi mpich; export LD_LIBRARY_PATH=/usr/tce/packages/mvapich2/mvapich2-2.3-
intel-19.0.4/lib:$LD_LIBRARY_PATH:/hostlib64; /usr/workspace/ecpsdk/apps/Zoltan/Zoltan'
echo "Running with TAU:"
echo "----------------"
srun -n 8 -N 2 --ntasks-per-node=4 singularity exec  -B /usr/workspace/ecpsdk:/usr/workspace/
ecpsdk -B /lib64:/hostlib64 -B $SLURM_SUBMIT_DIR:$SLURM_SUBMIT_DIR -B /usr/tce:/usr/tce /usr/
workspace/ecpsdk/ecp.simg /bin/bash -c ' . /etc/bashrc ; spack load   trilinos hypre parmetis
hdf5 metis openblas superlu zlib netcdf matio boost@1.66.0 scalapack suite-sparse tau; spack
unload openmpi mpich; export LD_LIBRARY_PATH=/usr/tce/packages/mvapich2/mvapich2-2.3-
intel-19.0.4/lib:$LD_LIBRARY_PATH:/hostlib64; tau_exec -ebs /usr/workspace/ecpsdk/apps/Zoltan/
Zoltan'
```

Replacing MPI using Shifter on Cori.nersc.gov

```
% shifterimg images
exascaleproject/sdk:AHM19 …
% To replace MPI with system MPI:
# salloc -N 2 -q interactive -t 00:30:00 \
--image=exascaleproject/sdk:AHM19 -C haswell -L SCRATCH

# cat ~sameer/run_shifter.sh
srun -n 32 shifter  -- /bin/bash  -c 'unset CRAYPE_VERSION;  . /
etc/bashrc ; spack load   trilinos hypre parmetis hdf5 metis
openblas superlu zlib netcdf matio boost@1.66.0 scalapack suite-
sparse tau; spack unload openmpi mpich; ./Zoltan'
# ~sameer/run_shifter.sh
```

PRL, University of Oregon, Eugene



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Download TAU from U. Oregon

http://tau.uoregon.edu

http://taucommander.com

http://www.hpclinux.com [OVA for VirtualBox]

https://e4s.io [Extreme-Scale Scientific Software Stack, Containers for HPC]

Free download, open source, BSD license

Reference

Installing and Configuring TAU

•Installing PDT:

- wget tau.uoregon.edu/pdt_lite.tgz
- ./configure –prefix=<dir>; make ; make install

•Installing TAU:

- wget tau.uoregon.edu/tau.tgz;   tar zxf tau.tgz; cd tau-2.<ver>
- wget http://tau.uoregon.edu/ext.tgz ; tar xf ext.tgz
- ./configure -bfd=download -pdt=<dir> -papi=<dir> -mpi −pthread −c++=mpicxx −cc=mpicc −fortran=mpif90 −dwarf=download −unwind=download −otf=download −iowrapper −papi=<dir>
- make install

•Using TAU:

- export TAU_MAKEFILE=<taudir>/x86_64/lib/Makefile.tau-<TAGS>
- make CC=tau_cc.sh   CXX=tau_cxx.sh   F90=tau_f90.sh

Compile-Time Options

Optional parameters for the TAU_OPTIONS environment variable:
% tau_compiler.sh

-optVerbose	Turn on verbose debugging messages
-optCompInst	Use compiler based instrumentation
-optNoCompInst	Do not revert to compiler instrumentation if source instrumentation fails.
-optTrackIO	Wrap POSIX I/O call and calculates vol/bw of I/O operations (Requires TAU to be configured with –*iowrapper*)
-optTrackGOMP	Enable tracking GNU OpenMP runtime layer (used without –opari)
-optMemDbg	Enable runtime bounds checking (see TAU_MEMDBG_* env vars)
-optKeepFiles	Does not remove intermediate .pdb and .inst.* files
-optPreProcess	Preprocess sources (OpenMP, Fortran) before instrumentation
-optTauSelectFile=”<file>"	Specify selective instrumentation file for *tau_instrumentor*
-optTauWrapFile=”<file>"	Specify path to *link_options.tau* generated by *tau_gen_wrapper*
-optHeaderInst	Enable Instrumentation of headers
-optTrackUPCR	Track UPC runtime layer routines (used with tau_upc.sh)
-optLinking=""	Options passed to the linker. Typically $(TAU_MPI_FLIBS) $(TAU_LIBS) $(TAU_CXXLIBS)
-optCompile=""	Options passed to the compiler. Typically $(TAU_MPI_INCLUDE) $(TAU_INCLUDE) $(TAU_DEFS)
-optPdtF95Opts=""	Add options for Fortran parser in PDT (f95parse/gfparse) …

Compile-Time Options (contd.)

Optional parameters for the TAU_OPTIONS environment variable:
% tau_compiler.sh

-optShared	Use TAU's shared library (libTAU.so) instead of static library (default)
-optPdtCxxOpts=""	Options for C++ parser in PDT (cxxparse).
-optPdtF90Parser=""	Specify a different Fortran parser
-optPdtCleanscapeParser	Specify the Cleanscape Fortran parser instead of GNU gfparser
-optTau=""	Specify options to the tau_instrumentor
-optTrackDMAPP	Enable instrumentation of low-level DMAPP API calls on Cray
-optTrackPthread	Enable instrumentation of pthread calls

See tau_compiler.sh for a full list of TAU_OPTIONS.

…

TAU's Runtime Environment Variables

Environment Variable	Default	Description
TAU_TRACE	0	Setting to 1 turns on tracing
TAU_CALLPATH	0	Setting to 1 turns on callpath profiling
TAU_TRACK_MEMORY_FOOTPRINT	0	Setting to 1 turns on tracking memory usage by sampling periodically the resident set size and high water mark of memory usage
TAU_TRACK_POWER	0	Tracks power usage by sampling periodically.
TAU_CALLPATH_DEPTH	2	Specifies depth of callpath. Setting to 0 generates no callpath or routine information, setting to 1 generates flat profile and context events have just parent information (e.g., Heap Entry: foo)
TAU_SAMPLING	1	Setting to 1 enables event-based sampling.
TAU_TRACK_SIGNALS	0	Setting to 1 generate debugging callstack info when a program crashes
TAU_COMM_MATRIX	0	Setting to 1 generates communication matrix display using context events
TAU_THROTTLE	1	Setting to 0 turns off throttling. Throttles instrumentation in lightweight routines that are called frequently
TAU_THROTTLE_NUMCALLS	100000	Specifies the number of calls before testing for throttling
TAU_THROTTLE_PERCALL	10	Specifies value in microseconds. Throttle a routine if it is called over 100000 times and takes less than 10 usec of inclusive time per call
TAU_CALLSITE	0	Setting to 1 enables callsite profiling that shows where an instrumented function was called. Also compatible with tracing.
TAU_PROFILE_FORMAT	Profile	Setting to “merged” generates a single file. “snapshot” generates xml format
TAU_METRICS	TIME	Setting to a comma separated list generates other metrics. (e.g., ENERGY,TIME,P_VIRTUAL_TIME,PAPI_FP_INS,PAPI_NATIVE_<event>:<subevent>)

Runtime Environment Variables

Environment Variable	Default	Description
TAU_TRACE	0	Setting to 1 turns on tracing
TAU_TRACE_FORMAT	Default	Setting to “otf2” turns on TAU’s native OTF2 trace generation (configure with –otf=download)
TAU_EBS_UNWIND	0	Setting to 1 turns on unwinding the callstack during sampling (use with tau_exec –ebs or TAU_SAMPLING=1)
TAU_EBS_RESOLUTION	line	Setting to “function” or “file” changes the sampling resolution to function or file level respectively.
TAU_TRACK_LOAD	0	Setting to 1 tracks system load on the node
TAU_SELECT_FILE	Default	Setting to a file name, enables selective instrumentation based on exclude/include lists specified in the file.
TAU_OMPT_SUPPORT_LEVEL	basic	Setting to “full” improves resolution of OMPT TR6 regions on threads 1.. N-1. Also, “lowoverhead” option is available.
TAU_OMPT_RESOLVE_ADDRESS_EAGERLY	1	Setting to 1 is necessary for event based sampling to resolve addresses with OMPT. Setting to 0 allows the user to do offline address translation.

Runtime Environment Variables

Environment Variable	Default	Description
TAU_TRACK_MEMORY_LEAKS	0	Tracks allocates that were not de-allocated (needs –optMemDbg or tau_exec –memory)
TAU_EBS_SOURCE	TIME	Allows using PAPI hardware counters for periodic interrupts for EBS (e.g., TAU_EBS_SOURCE=PAPI_TOT_INS when TAU_SAMPLING=1)
TAU_EBS_PERIOD	100000	Specifies the overflow count for interrupts
TAU_MEMDBG_ALLOC_MIN/MAX	0	Byte size minimum and maximum subject to bounds checking (used with TAU_MEMDBG_PROTECT_*)
TAU_MEMDBG_OVERHEAD	0	Specifies the number of bytes for TAU's memory overhead for memory debugging.
TAU_MEMDBG_PROTECT_BELOW/ABOVE	0	Setting to 1 enables tracking runtime bounds checking below or above the array bounds (requires –optMemDbg while building or tau_exec –memory)
TAU_MEMDBG_ZERO_MALLOC	0	Setting to 1 enables tracking zero byte allocations as invalid memory allocations.
TAU_MEMDBG_PROTECT_FREE	0	Setting to 1 detects invalid accesses to deallocated memory that should not be referenced until it is reallocated (requires –optMemDbg or tau_exec –memory)
TAU_MEMDBG_ATTEMPT_CONTINUE	0	Setting to 1 allows TAU to record and continue execution when a memory error occurs at runtime.
TAU_MEMDBG_FILL_GAP	Undefined	Initial value for gap bytes
TAU_MEMDBG_ALINGMENT	Sizeof(int)	Byte alignment for memory allocations
TAU_EVENT_THRESHOLD	0.5	Define a threshold value (e.g., .25 is 25%) to trigger marker events for min/max