# TAU Performance System®

April 20, 10am ET, Stony Brook University, Ookami webinar
https://stonybrook.zoom.us/j/96650792359?pwd=dlNNaUd1eXdXYUFHN1h0eHdTNXM2QT09

Sameer Shende
Research Associate Professor and Director
Performance Research Laboratory, OACISS, University of Oregon
http://tau.uoregon.edu/TAU_SBU21.pdf

Tuning and Analysis Utilities

EXASCALE COMPUTING PROJECT

National Nuclear Security Administration

U.S. DEPARTMENT OF ENERGY | Office of Science

# Challenges

- With growing hardware complexity, it is getting harder to accurately measure and optimize the performance of our HPC workloads.
- TAU Performance System®:
  - Deliver a scalable, portable, performance evaluation toolkit for HPC workloads
  - http://tau.uoregon.edu

# TAU Performance System®

http://tau.uoregon.edu

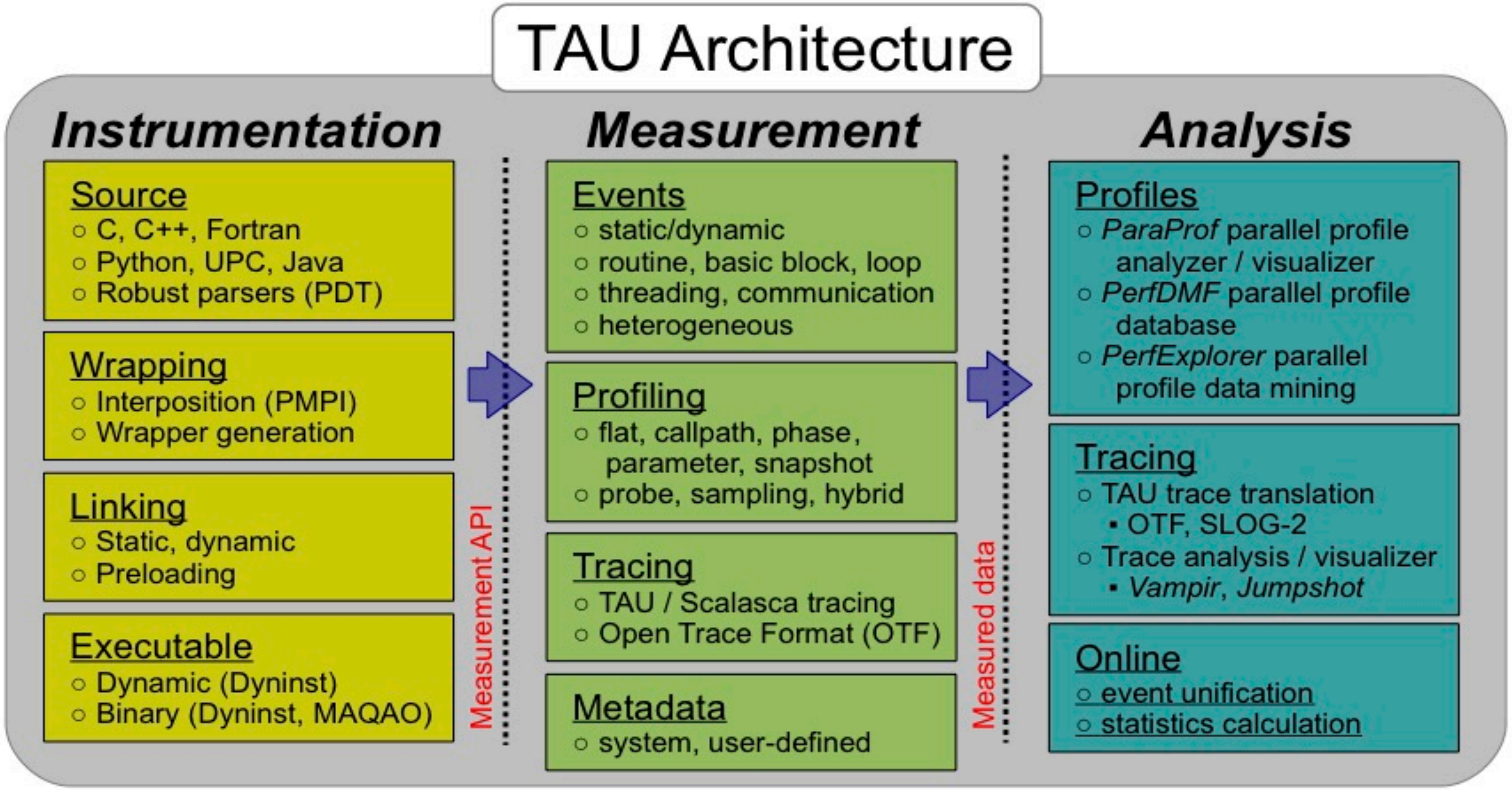
Tuning and Analysis Utilities

# TAU Performance System®

## Parallel performance framework and toolkit

- Aims to support all HPC platforms, compilers, and runtime systems
- Aims to provide portable instrumentation, measurement, and analysis

Tuning and Analysis Utilities




EXASCALE COMPUTING PROJECT

# TAU Performance System® on AMD platforms

Instrumentation

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

Measurement and analysis support

- MPI, OpenSHMEM, ARMCI, PGAS, DMAPP
- pthreads, OpenMP, OMPT interface, hybrid, other thread models
- GPU, ROCm, CUDA, Level Zero, SYCL, OpenCL, OpenACC
- Parallel profiling and tracing

Analysis

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

# Application Performance Engineering using TAU

- How much time is spent in each application routine and outer *loops*? Within loops, what is the contribution of each *statement*? What is the time spent in OpenMP loops? In kernels on GPUs. How long did it take to transfer data between host and device (GPU)?
- How many instructions are executed in these code regions?
  Floating point, Level 1 and 2 *data cache misses*, hits, branches taken? What is the extent of vectorization for loops?
- What is the memory usage of the code? When and where is memory allocated/de-allocated? Are there any memory leaks? What is the memory footprint of the application? What is the memory high water mark?
- How much energy does the application use in Joules? What is the peak power usage?
- What are the I/O characteristics of the code? What is the peak read and write *bandwidth* of individual calls, total volume?
- How does the application *scale*? What is the efficiency, runtime breakdown of performance across different core counts?

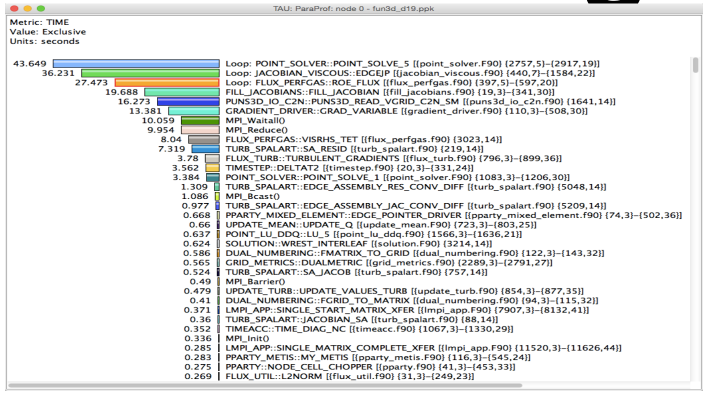
# Instrumentation

## Add hooks in the code to perform measurements

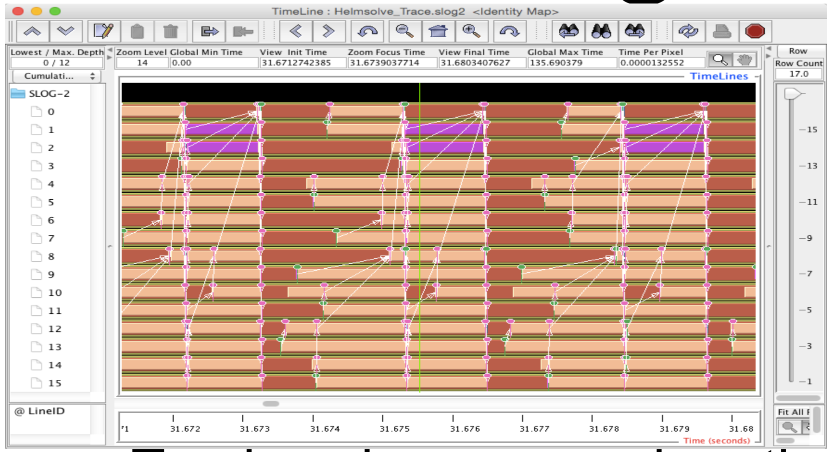
- **Source instrumentation using a preprocessor**
  - Add timer start/stop calls in a copy of the source code.
  - Use Program Database Toolkit (PDT) for parsing source code.
  - Requires recompiling the code using TAU shell scripts (tau_cc.sh, tau_f90.sh)
  - Selective instrumentation (filter file) 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 **mpirun tau_exec ./app** with options.

# Profiling and Tracing

## Profiling




## Tracing




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

- 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

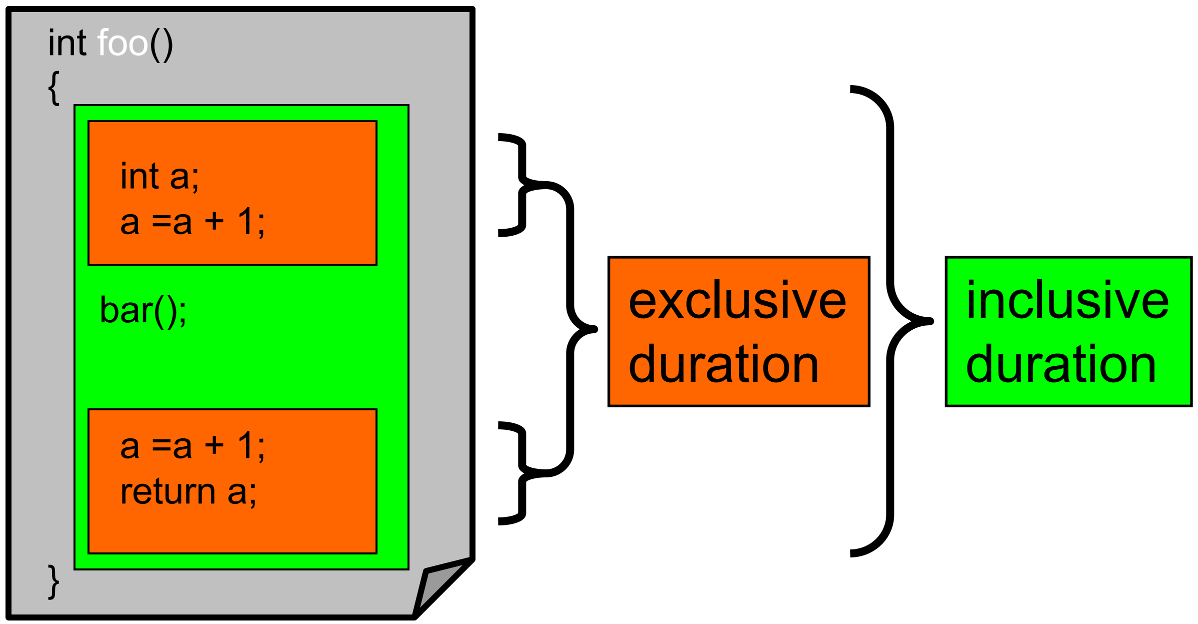
# Instrumentation

- 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.

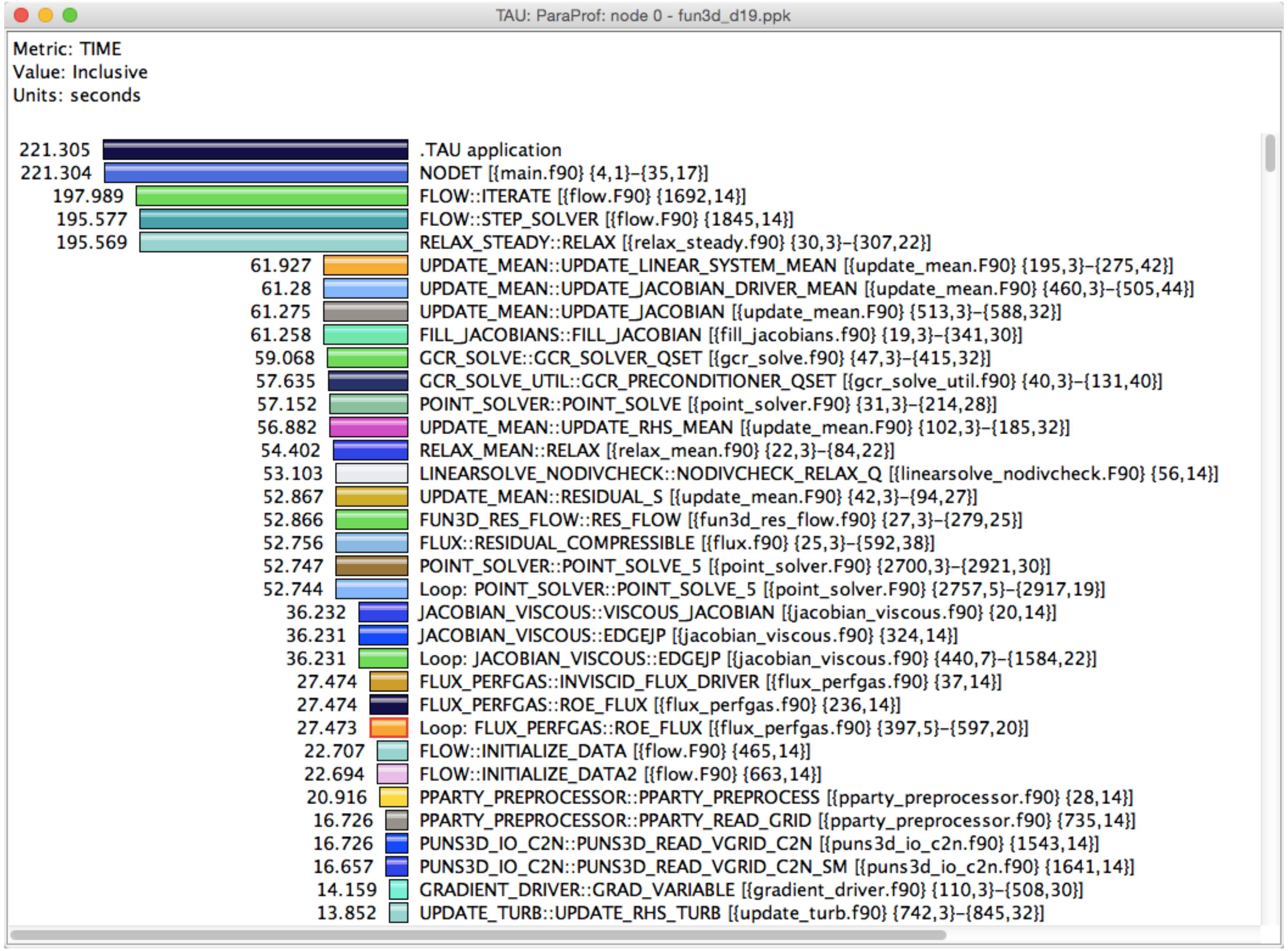
- User-defined events
  - ***Interval*** (start/stop) events to measure exclusive & inclusive duration
  - ***Atomic events*** take measurements at a single point
    - Measures total, samples, min/max/mean/std. deviation statistics
  - ***Context events*** are atomic events with executing context
 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

# Inclusive vs. Exclusive Measurements

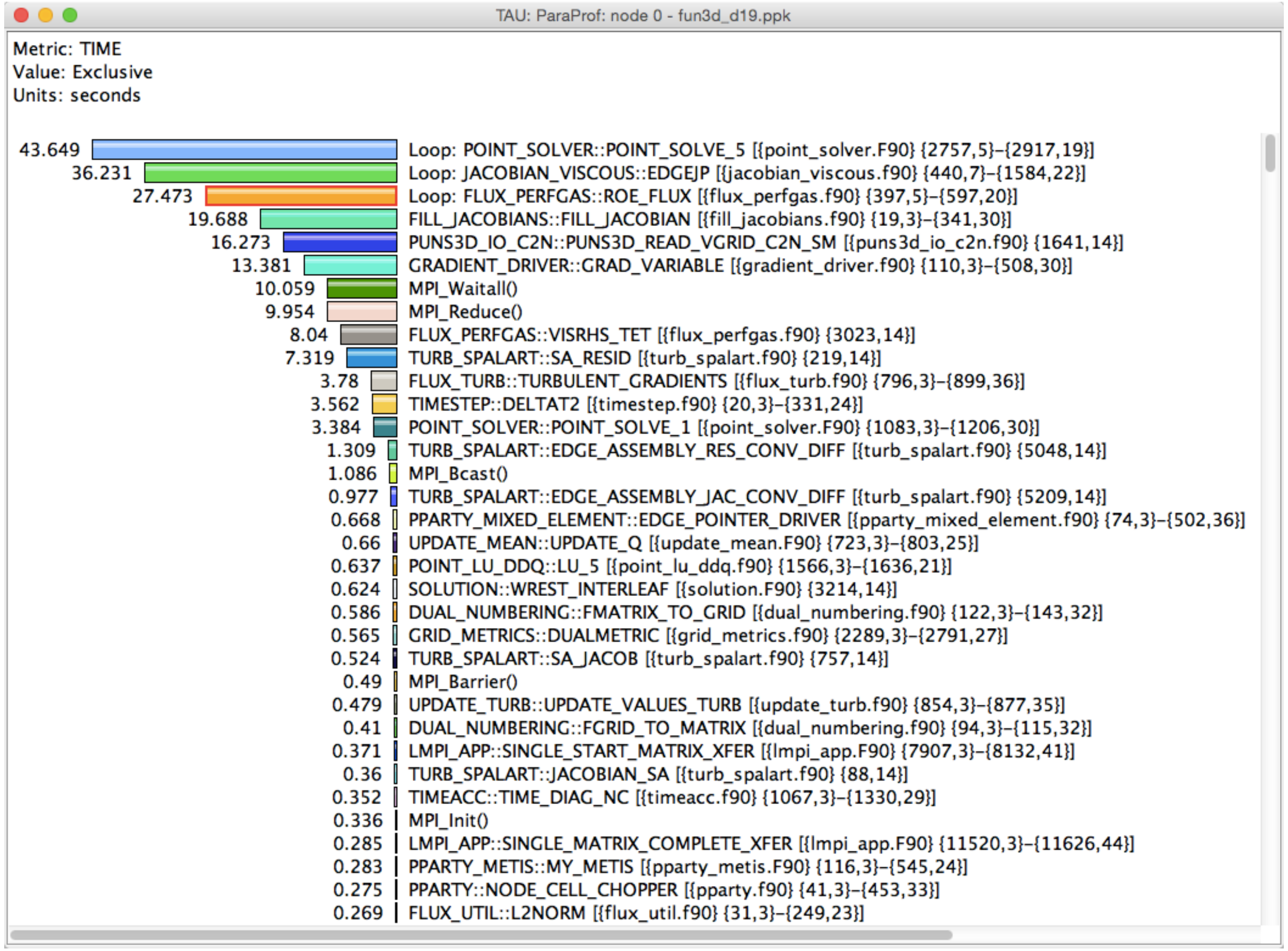
- Performance with respect to code regions
- Exclusive measurements for region only
- Inclusive measurements includes child regions



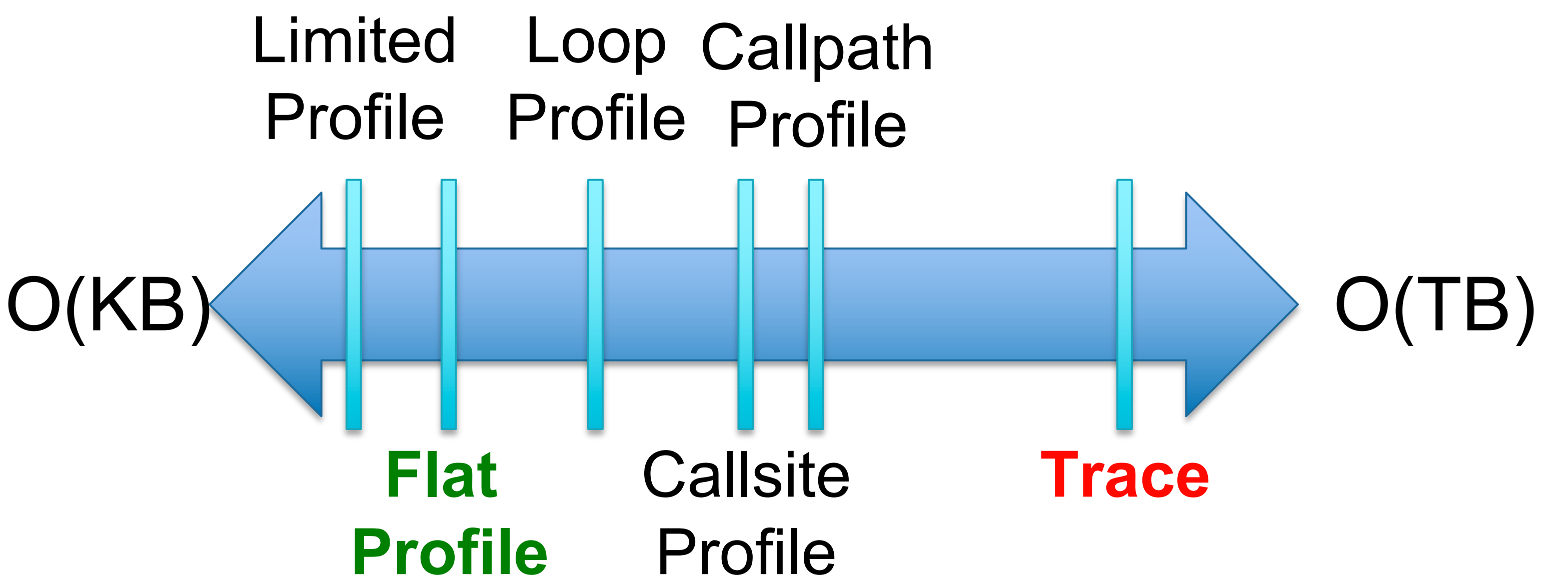
# Inclusive Measurements



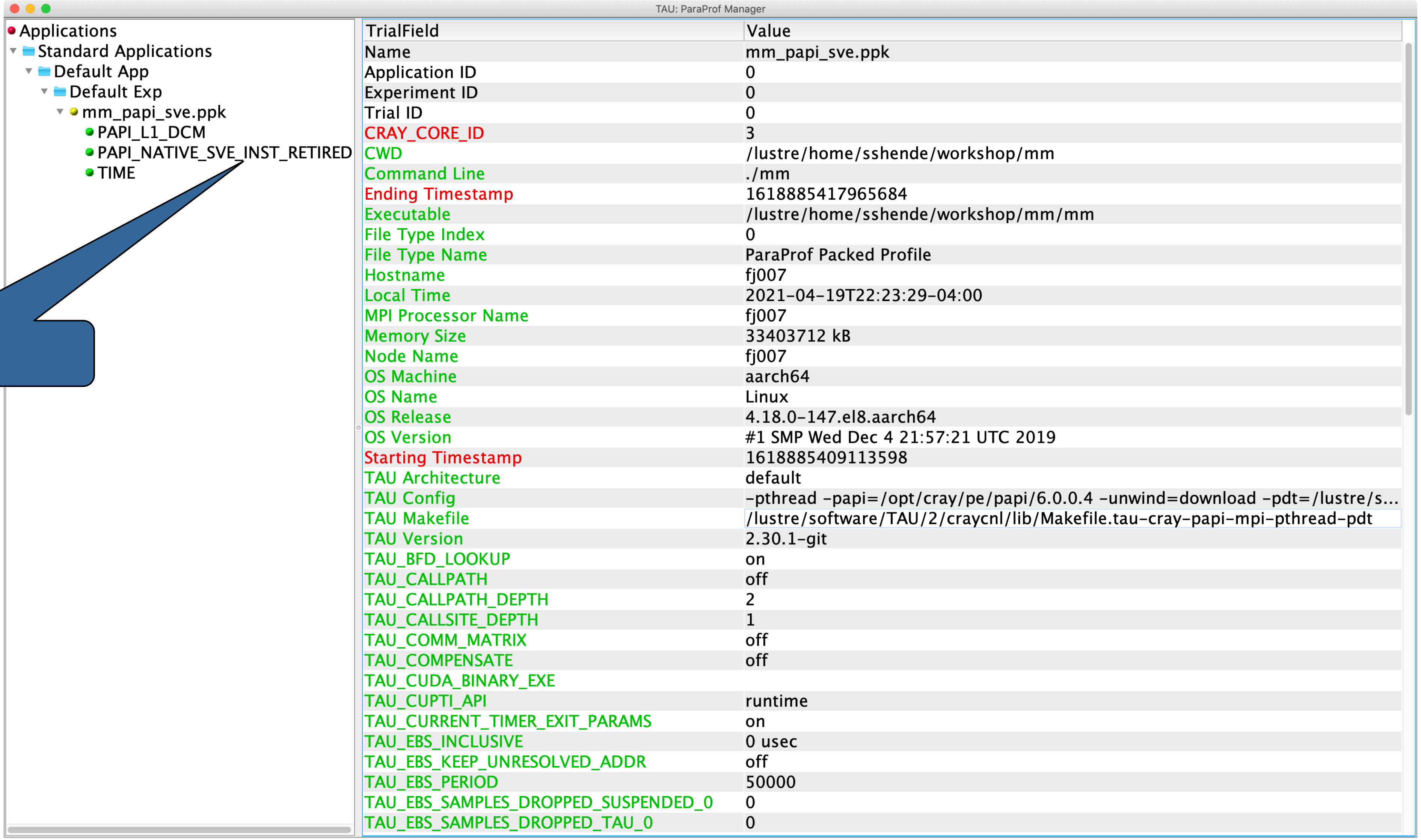
# Exclusive Time



# How much data do you want?



# ParaProf Profile Browser



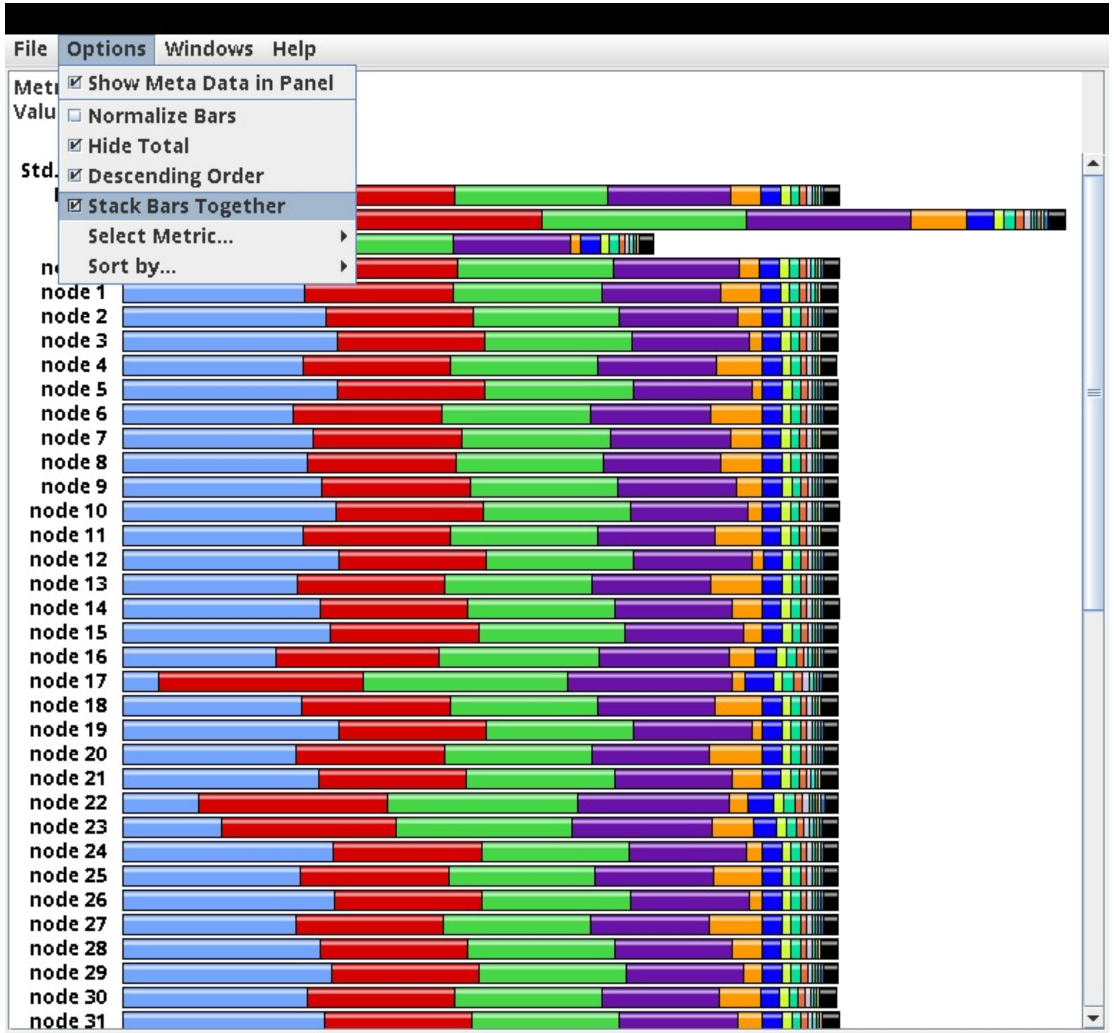

Metric

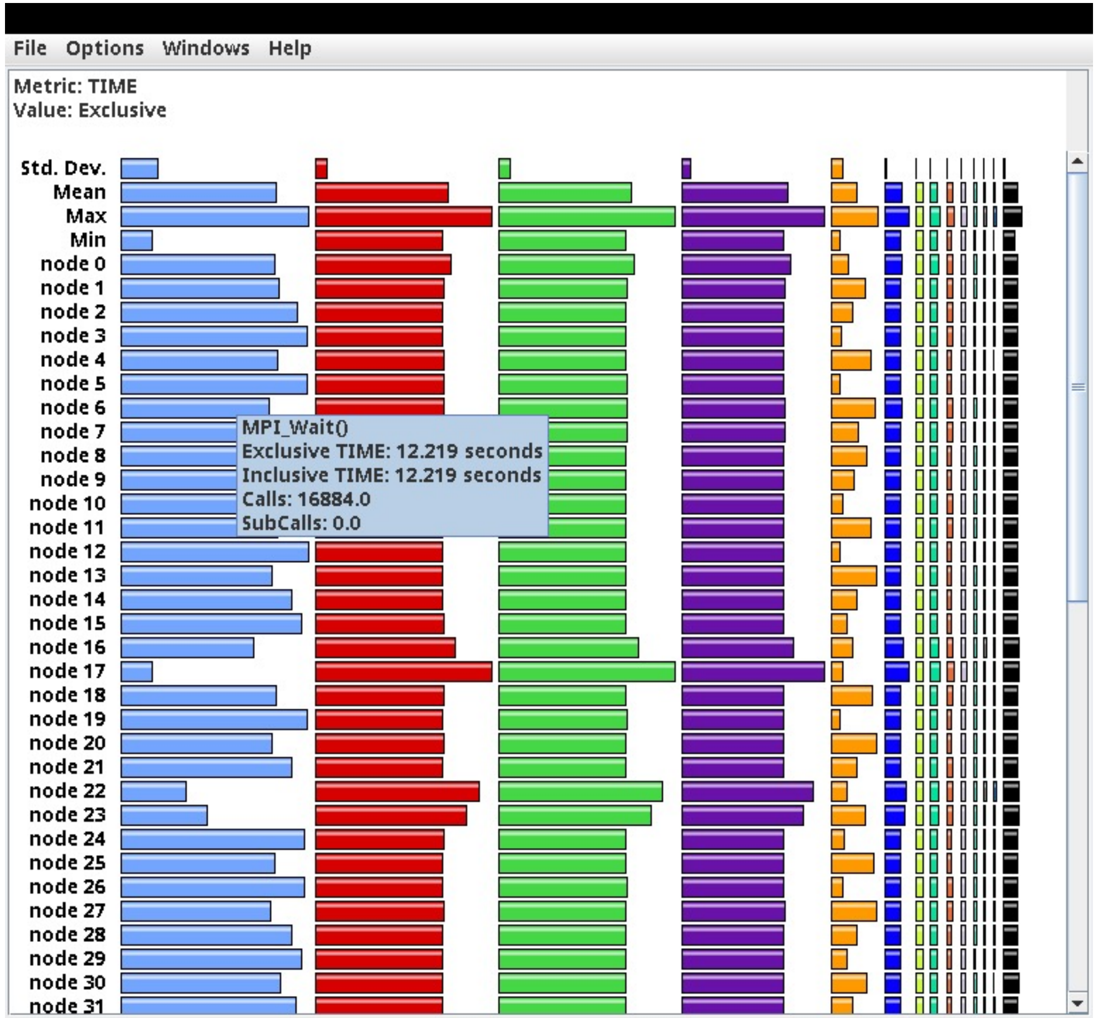
```
% paraprof
```

# ParaProf Profile Browser

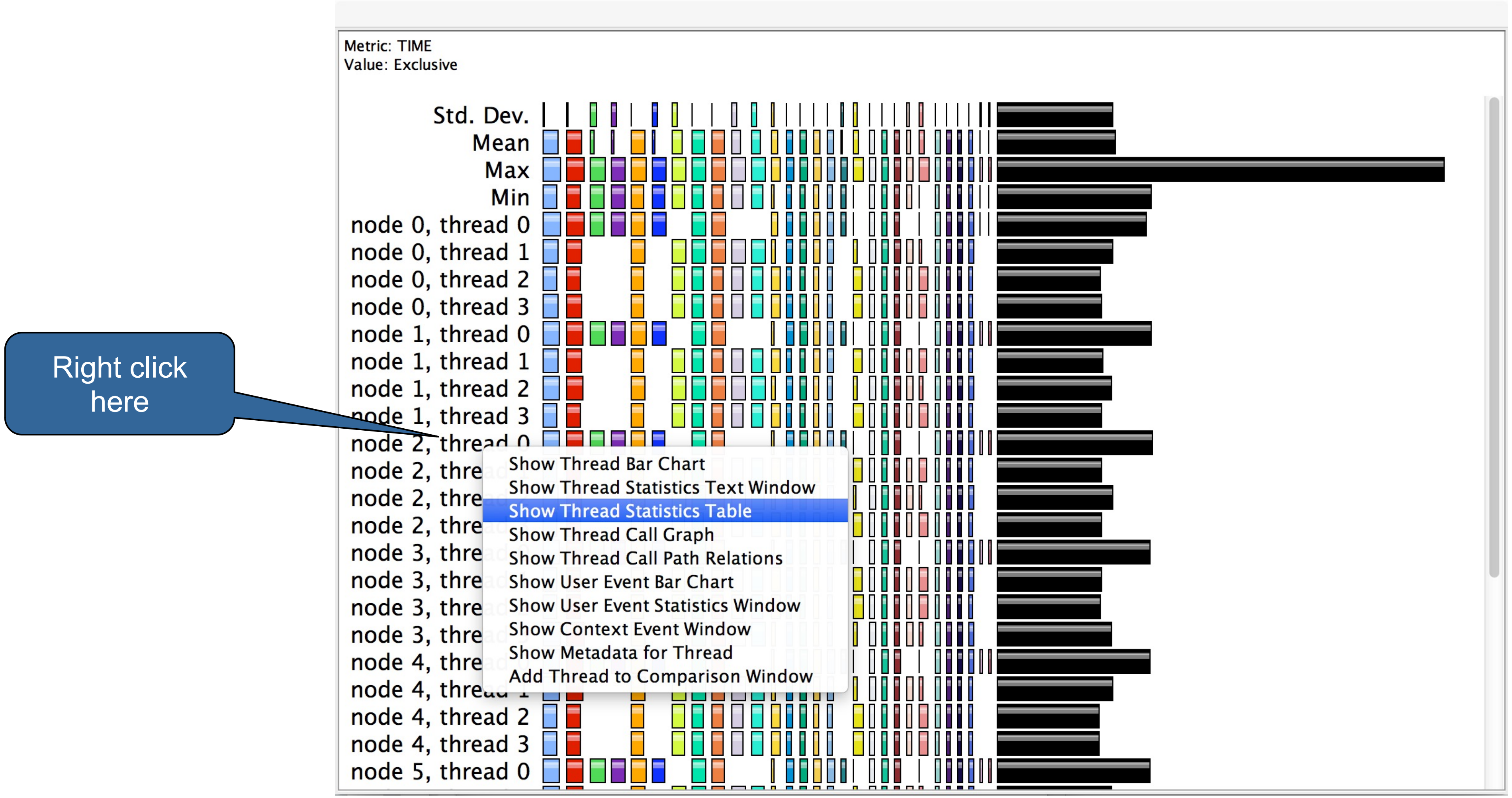

```
% paraprof
```

# ParaProf Profile Browser



# ParaProf Profile Browser – Thread Statistics Table




EXASCALE COMPUTING PROJECT

# ParaProf Profile Browser – Thread Statistics Table

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

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

TIME

| Name | Inclusive PAPI_L1_DCM | Inclusive PAPI_NATIVE_SVE_INST_RETIRED ▽ | Inclusive TIME | Calls |
|---|---|---|---|---|
| .TAU application | 1,209,111,746 | 1,201,325 | 8.737 | 1 |
| [CONTEXT] .TAU application | 1,208,329,519 | 1,193,019 | 8.55 | 171 |
| [SAMPLE] compute [{/lustre/home/sshende/workshop/mm/matmult.c} {110}] | 1,044,207,196 | 1,187,012 | 6.05 | 121 |
| [SAMPLE] compute_interchange [{/lustre/home/sshende/workshop/mm/matmult.c} {131}] | 33,540,265 | 5,415 | 1.7 | 34 |
| [SAMPLE] compute [{/lustre/home/sshende/workshop/mm/matmult.c} {109}] | 129,621,064 | 567 | 0.75 | 15 |
| [SAMPLE] compute_interchange [{/lustre/home/sshende/workshop/mm/matmult.c} {130}] | 960,994 | 25 | 0.05 | 1 |
| MPI_Finalize() | 34,585 | 1,261 | 0.05 | 1 |
| MPI_Init() | 238,027 | 56 | 0.11 | 1 |
| MPI_Comm_rank() | 52 | 13 | 0 | 1 |

# ParaProf Profile Browser – Thread Statistics Table

TAU: ParaProf: Statistics for: node 2, thread 0 - bt_ebs.ppk

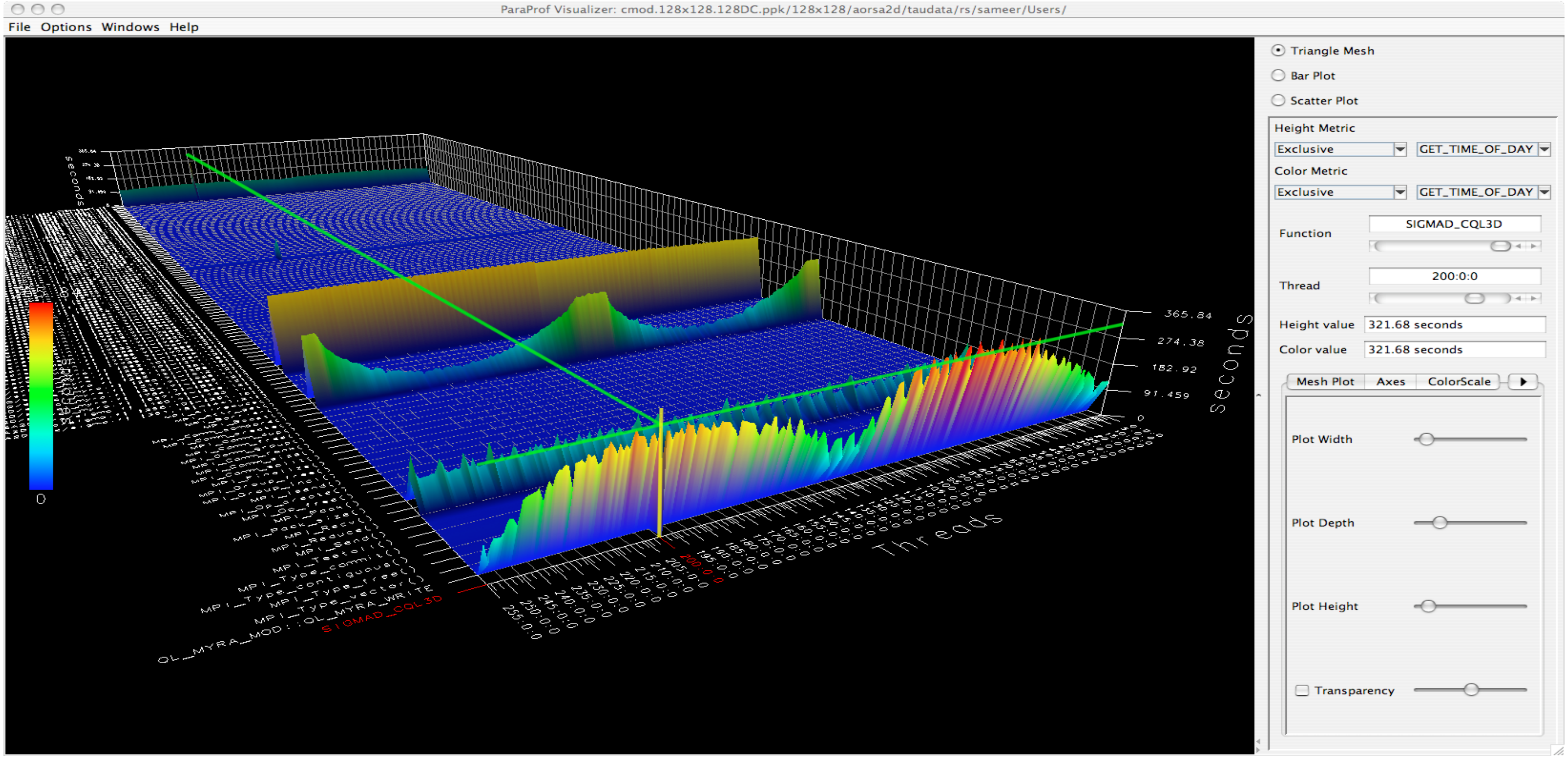
| Name | Exclusive TIME | Inclusive TIME ▽ | Calls | Child Calls |
|---|---|---|---|---|
| .TAU application | 1.754 | 36.26 | 1 | 88,049 |
| OpenMP_PARALLEL_REGION: L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {43,0}] | 0.061 | 8.692 | 6,432 | 12,864 |
| OpenMP_IMPLICIT_TASK: L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {43,0}] | 0.04 | 8.568 | 6,432 | 6,432 |
| OpenMP_LOOP: L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {43,0}] | 8.528 | 8.528 | 6,432 | 0 |
| [CONTEXT] OpenMP_LOOP: L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {43,0}] | 0 | 9.23 | 847 | 0 |
| [SUMMARY] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f}] | 3.67 | 3.67 | 340 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f}] | 3.67 | 3.67 | 340 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {419}] | 0.22 | 0.22 | 21 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {58}] | 0.17 | 0.17 | 16 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {418}] | 0.16 | 0.16 | 12 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {123}] | 0.11 | 0.11 | 11 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {193}] | 0.08 | 0.08 | 5 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {126}] | 0.07 | 0.07 | 7 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {247}] | 0.07 | 0.07 | 6 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {158}] | 0.06 | 0.06 | 5 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {313}] | 0.06 | 0.06 | 4 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {230}] | 0.06 | 0.06 | 4 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {308}] | 0.05 | 0.05 | 3 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {191}] | 0.05 | 0.05 | 3 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {81}] | 0.05 | 0.05 | 4 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {301}] | 0.05 | 0.05 | 5 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {67}] | 0.05 | 0.05 | 5 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {175}] | 0.04 | 0.04 | 4 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {89}] | 0.04 | 0.04 | 4 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {55}] | 0.04 | 0.04 | 4 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {275}] | 0.04 | 0.04 | 4 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {129}] | 0.04 | 0.04 | 4 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {168}] | 0.04 | 0.04 | 4 | 0 |
| [SAMPLE] L_z_solve__43__par_region0_2_44 [{/scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/z_solve.f} {238}] | 0.04 | 0.04 | 4 | 0 |

Show Source Code
Show Function Bar Chart
Show Function Histogram
Assign Function Color
Reset to Default Color

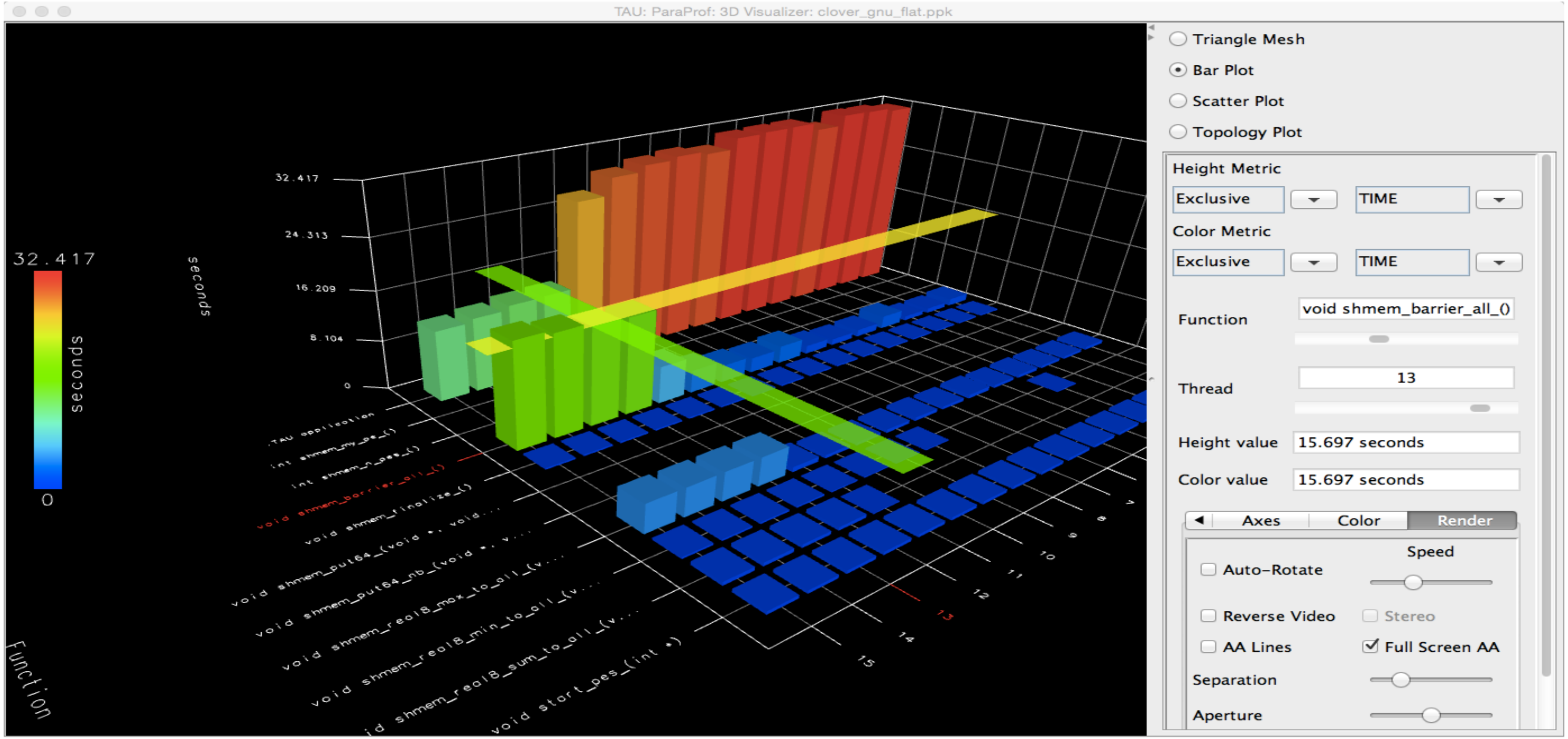
Right click here and choose “Show Source Code” for a sample

EXASCALE COMPUTING PROJECT

# ParaProf 3D Profile Browser



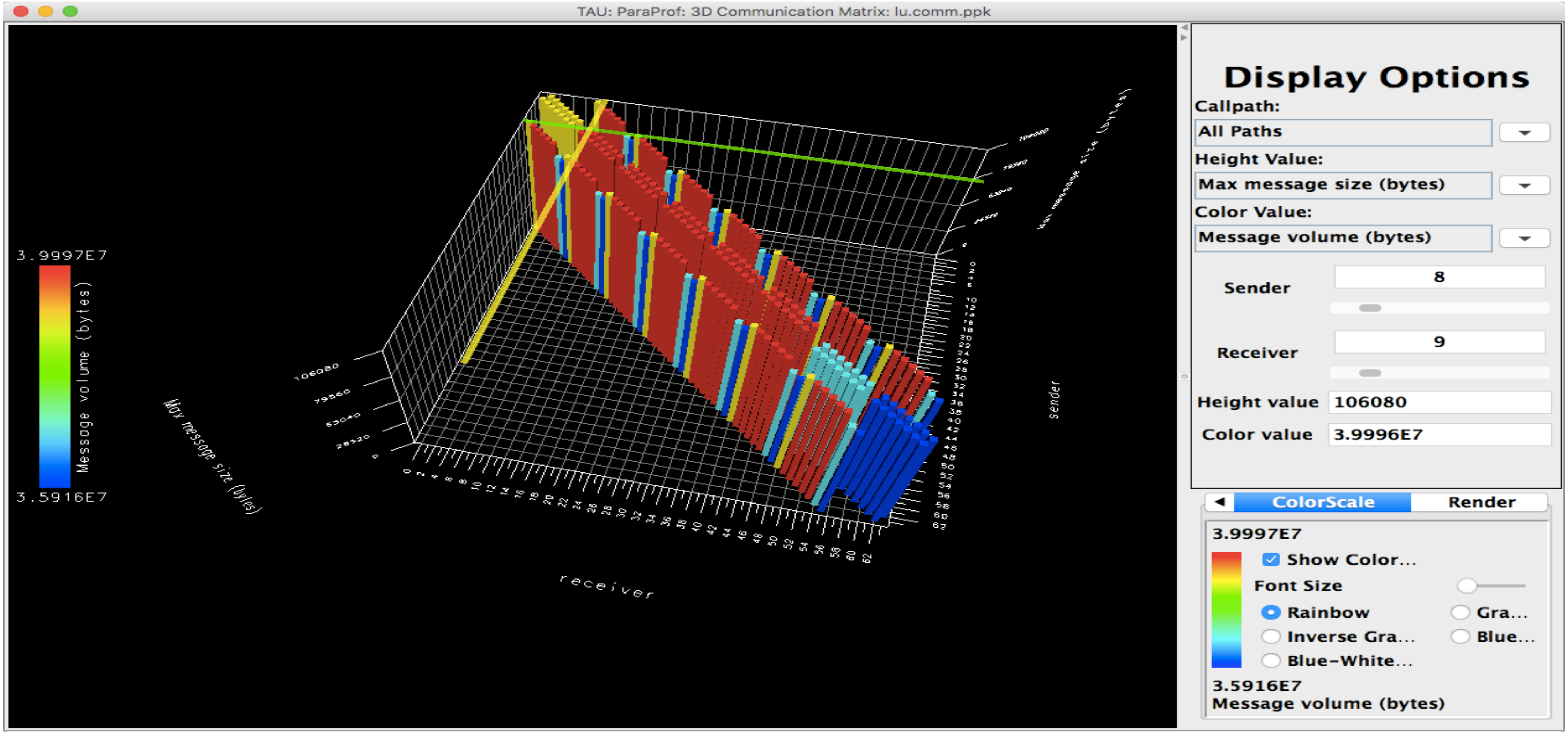
# TAU – ParaProf 3D Visualization




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

EXASCALE COMPUTING PROJECT

# TAU – 3D Communication Window

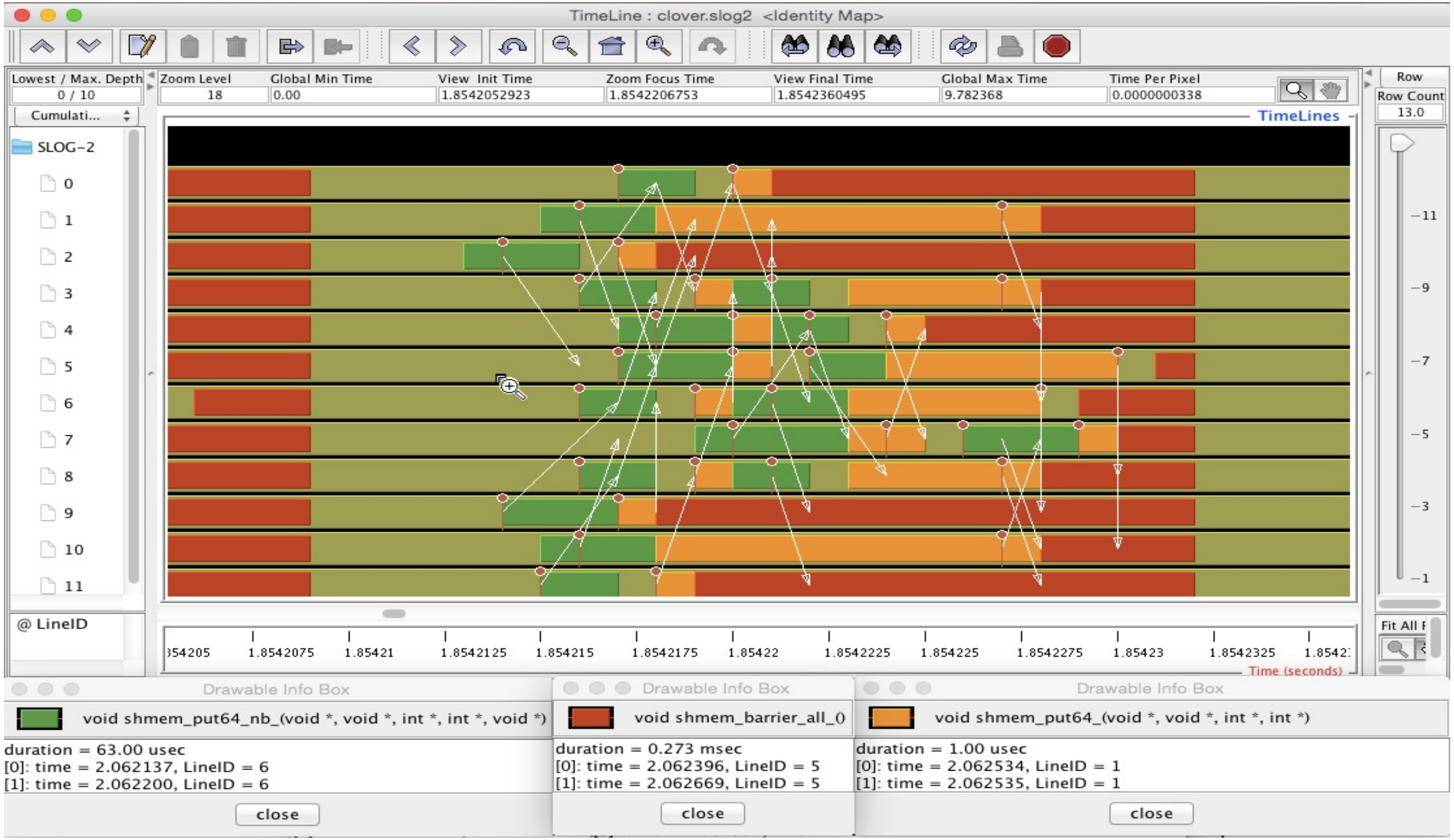



% export TAU_COMM_MATRIX=1; mpirun … tau_exec ./a.out

% paraprof ; Windows -> 3D Communication Matrix

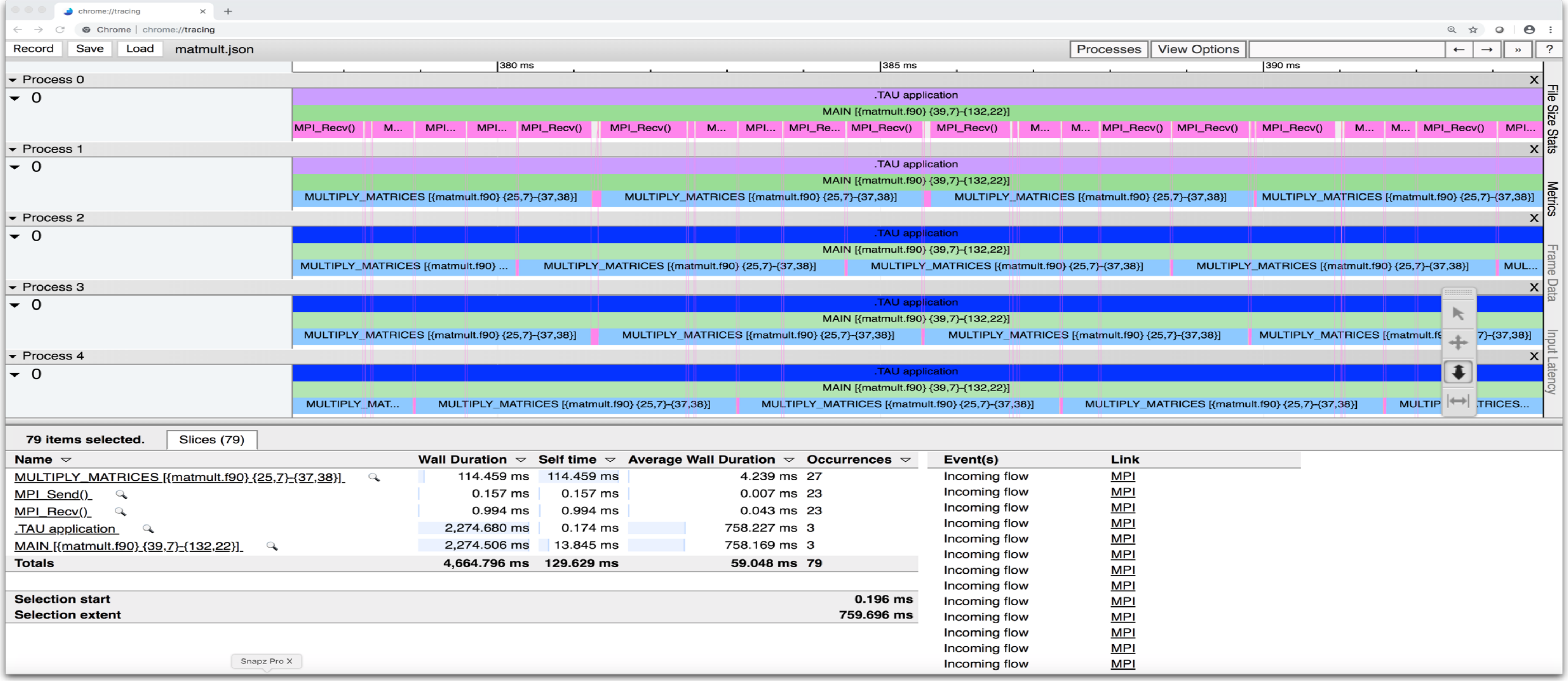
EXASCALE COMPUTING PROJECT

# Tracing: Jumpshot (ships with TAU)




EXASCALE COMPUTING PROJECT

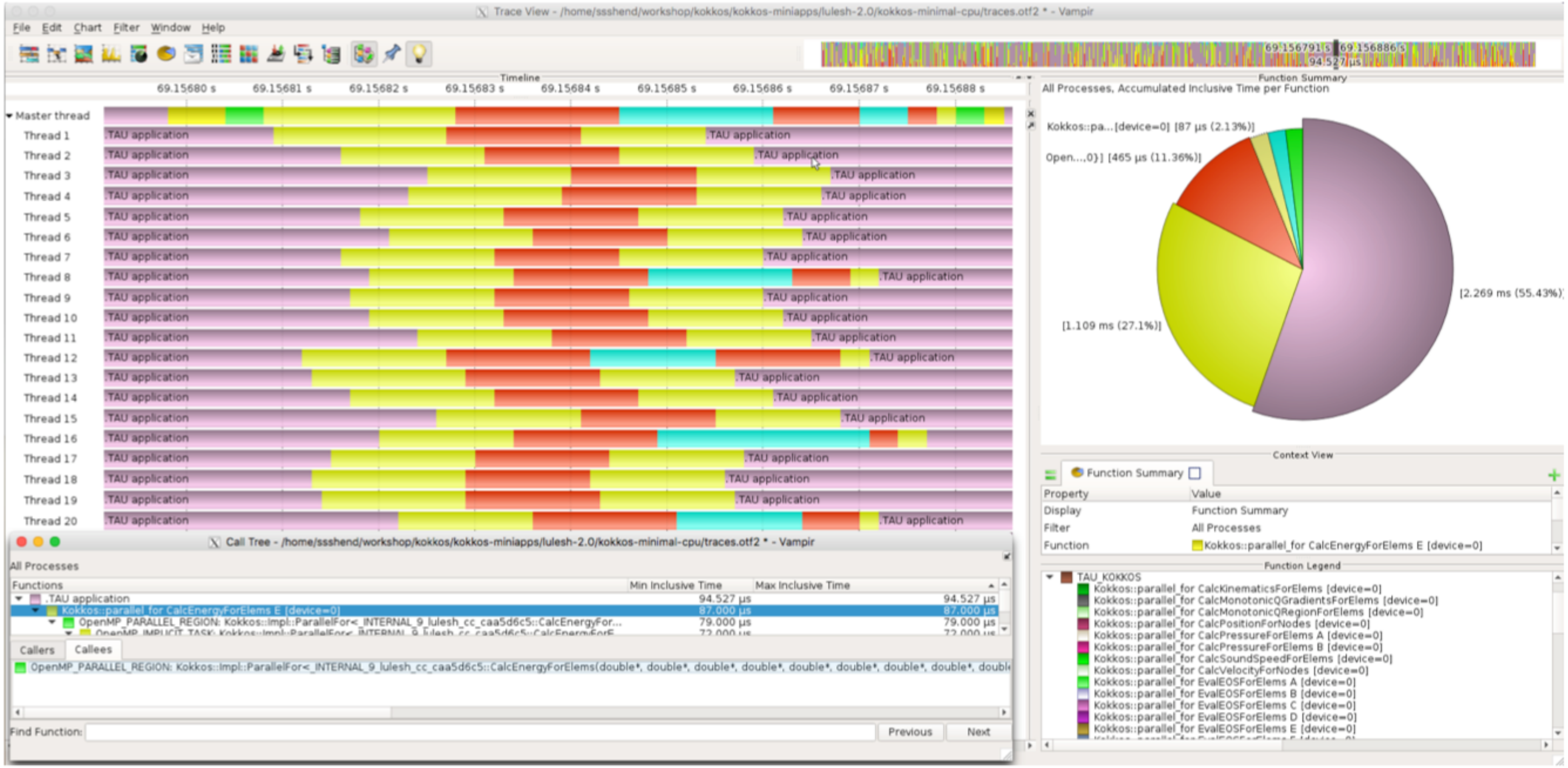
# Tracing: Chrome Browser




**% export TAU_TRACE=1**
**% mpirun –np 256 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)**

# Vampir [TU Dresden] Timeline: Kokkos



% export TAU_TRACE=1; export TAU_TRACE_FORMAT=otf2
% tau_exec –ompt ./a.out
% vampir traces.otf2 &

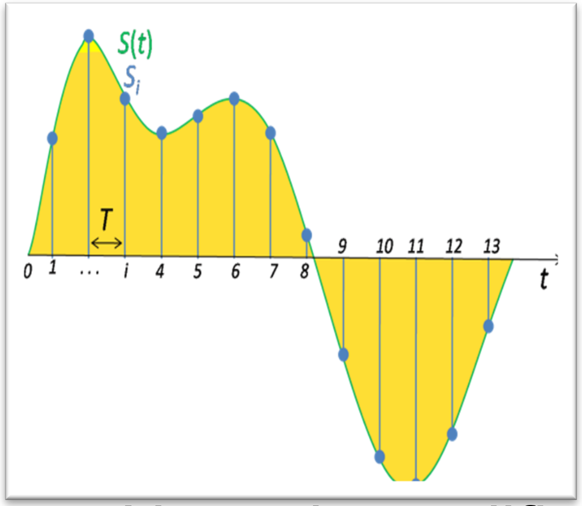
# Performance Data Measurement

**Direct via Probes**

```
Call START('potential')
// code
Call STOP('potential')
```

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

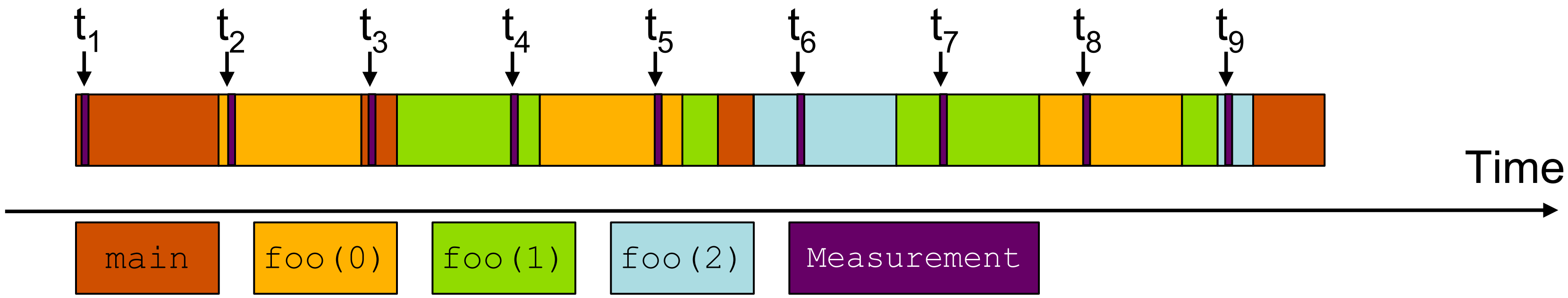
**Indirect via Sampling**




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

EXASCALE COMPUTING PROJECT

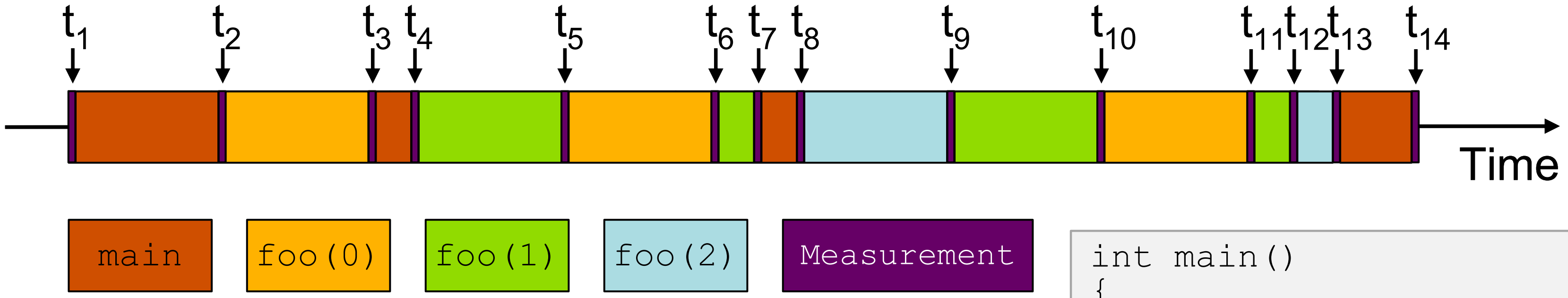
# Sampling




- 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

```
int main()
{
  int i;

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

  return 0;
}

void foo(int i)
{

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

}
```

# 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

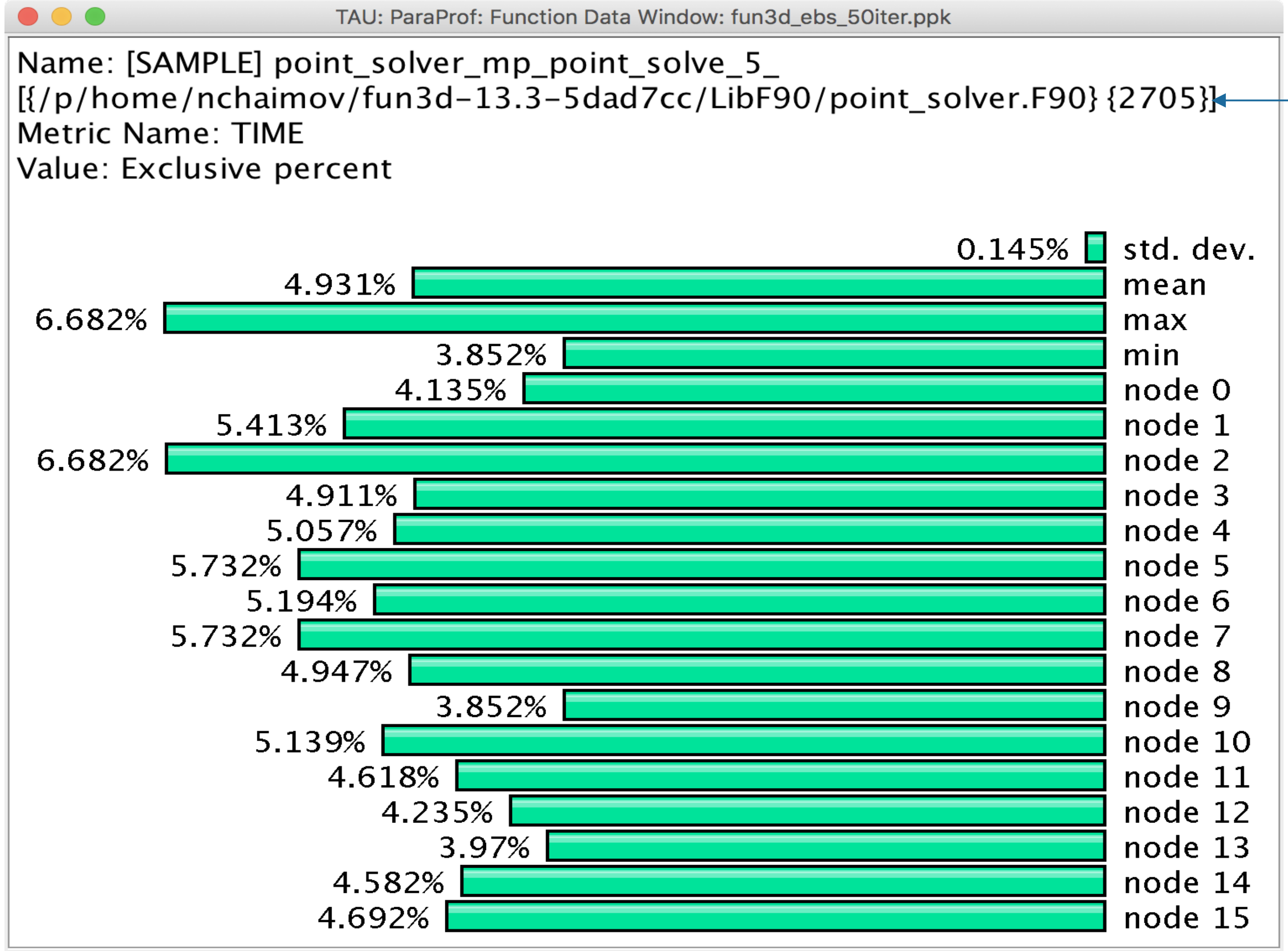
```
int main()
{
   int i;
   Start("main");
   for (i=0; i < 3; i++)
      foo(i);
   Stop("main");
   return 0;
}

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

EXASCALE COMPUTING PROJECT

# Using TAU's Runtime Preloading Tool: tau_exec

- Preload a wrapper that intercepts the runtime system call and substitutes with another
  - **MPI**
  - **OpenMP**
  - **POSIX I/O**
  - **Memory allocation/deallocation routines**
  - **Wrapper library for an external package**
- No modification to the binary executable!
- Enable other TAU options (communication matrix, OTF2, event-based sampling)

# Event Based Sampling (EBS)




File: point_solver.F90
Line: 2705

Uninstrumented!

```
% mpirun -n 16 tau_exec –ebs a.out
```

# Event Based Sampling (EBS): QMCPack

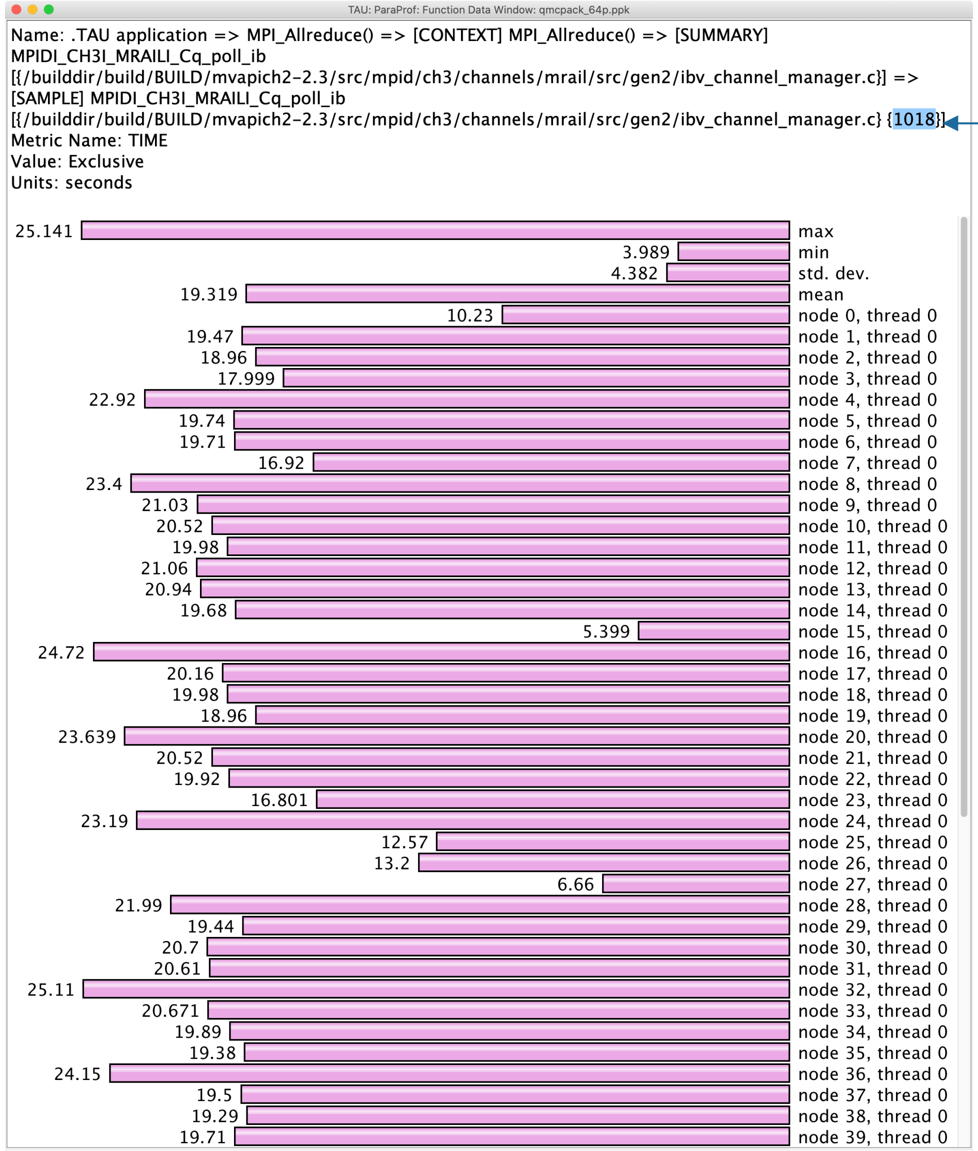
TAU: ParaProf: Statistics for: node 0, thread 0 - qmcpack_64p.ppk

| Name | Exclusive TIME | Inclusive TIME | Calls | Child Calls |
|---|---|---|---|---|
| .TAU application | 979.071 | 1,066.528 | 1 | 493 |
| [CONTEXT] .TAU application | 0 | 975.151 | 32,481 | 0 |
| MPI_Allreduce() | 35.346 | 35.346 | 52 | 0 |
| [CONTEXT] MPI_Allreduce() | 0 | 35.37 | 1,179 | 0 |
| [SUMMARY] MPIDI_CH3I_MRAILI_Get_next_vbuf [{/builddir/build/BUILD/mvapich2-2.3/src/m | 16.109 | 16.109 | 537 | 0 |
| [SUMMARY] MPIDI_CH3I_MRAILI_Cq_poll_ib [{/builddir/build/BUILD/mvapich2-2.3/src/mpid | 10.71 | 10.71 | 357 | 0 |
| [SAMPLE] MPIDI_CH3I_MRAILI_Cq_poll_ib [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ | 10.23 | 10.23 | 341 | 0 |
| [SAMPLE] MPIDI_CH3I_MRAILI_Cq_poll_ib [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ | 0.27 | 0.27 | 9 | 0 |
| [SAMPLE] MPIDI_CH3I_MRAILI_Cq_poll_ib [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ | 0.09 | 0.09 | 3 | 0 |
| [SAMPLE] MPIDI_CH3I_MRAILI_Cq_poll_ib [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ | 0.03 | 0.03 | 1 | 0 |
| [SAMPLE] MPIDI_CH3I_MRAILI_Cq_poll_ib [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ | 0.03 | 0.03 | 1 | 0 |
| [SAMPLE] MPIDI_CH3I_MRAILI_Cq_poll_ib [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ | 0.03 | 0.03 | 1 | 0 |
| [SAMPLE] MPIDI_CH3I_MRAILI_Cq_poll_ib [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ | 0.03 | 0.03 | 1 | 0 |
| [SUMMARY] MPIDI_CH3I_SMP_read_progress [{/builddir/build/BUILD/mvapich2-2.3/src/mpi | 1.98 | 1.98 | 66 | 0 |
| [SUMMARY] MPIDI_CH3I_SMP_pull_header [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ | 1.77 | 1.77 | 59 | 0 |
| [SAMPLE] GetSeqNumVbuf [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ch3/channels/m | 1.23 | 1.23 | 41 | 0 |
| [SAMPLE] UNRESOLVED /usr/lib64/libmlx5.so.1.0.0 | 1.05 | 1.05 | 35 | 0 |
| [SAMPLE] ibv_poll_cq [{/usr/include/infiniband/verbs.h} {2456}] | 0.96 | 0.96 | 32 | 0 |
| [SUMMARY] MPIDI_CH3I_Progress [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ch3/cha | 0.6 | 0.6 | 20 | 0 |
| [SUMMARY] MPIDI_CH3I_MRAILI_Test_pkt [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/c | 0.24 | 0.24 | 8 | 0 |
| [SUMMARY] MPIDU_Sched_progress [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/comm | 0.21 | 0.21 | 7 | 0 |
| [SAMPLE] pthread_spin_lock [{/usr/lib64/libpthread-2.17.so} {0}] | 0.18 | 0.18 | 6 | 0 |
| [SUMMARY] MPIDI_CH3I_read_progress [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ch3 | 0.15 | 0.15 | 5 | 0 |
| [SUMMARY] MPIDU_Sched_progress_state [{/builddir/build/BUILD/mvapich2-2.3/src/mpid/ | 0.09 | 0.09 | 3 | 0 |
| [SUMMARY] MPIDI_CH3I_SHMEM_COLL_GetShmemBuf [{/builddir/build/BUILD/mvapich2-2.3 | 0.09 | 0.09 | 3 | 0 |
| MPI_Reduce() | 31.996 | 31.996 | 9 | 0 |
| MPI_Gatherv() | 9.433 | 9.433 | 230 | 0 |
| MPI_Bcast() | 5.452 | 5.452 | 71 | 0 |
| MPI_Init() | 2.356 | 2.356 | 1 | 2 |
| MPI_Finalize() | 1.333 | 1.351 | 1 | 4 |

Ran for 1066.528 seconds. Outside of MPI calls, TAU can explain 975.151 seconds out of 979.071 seconds of exclusive time using EBS!

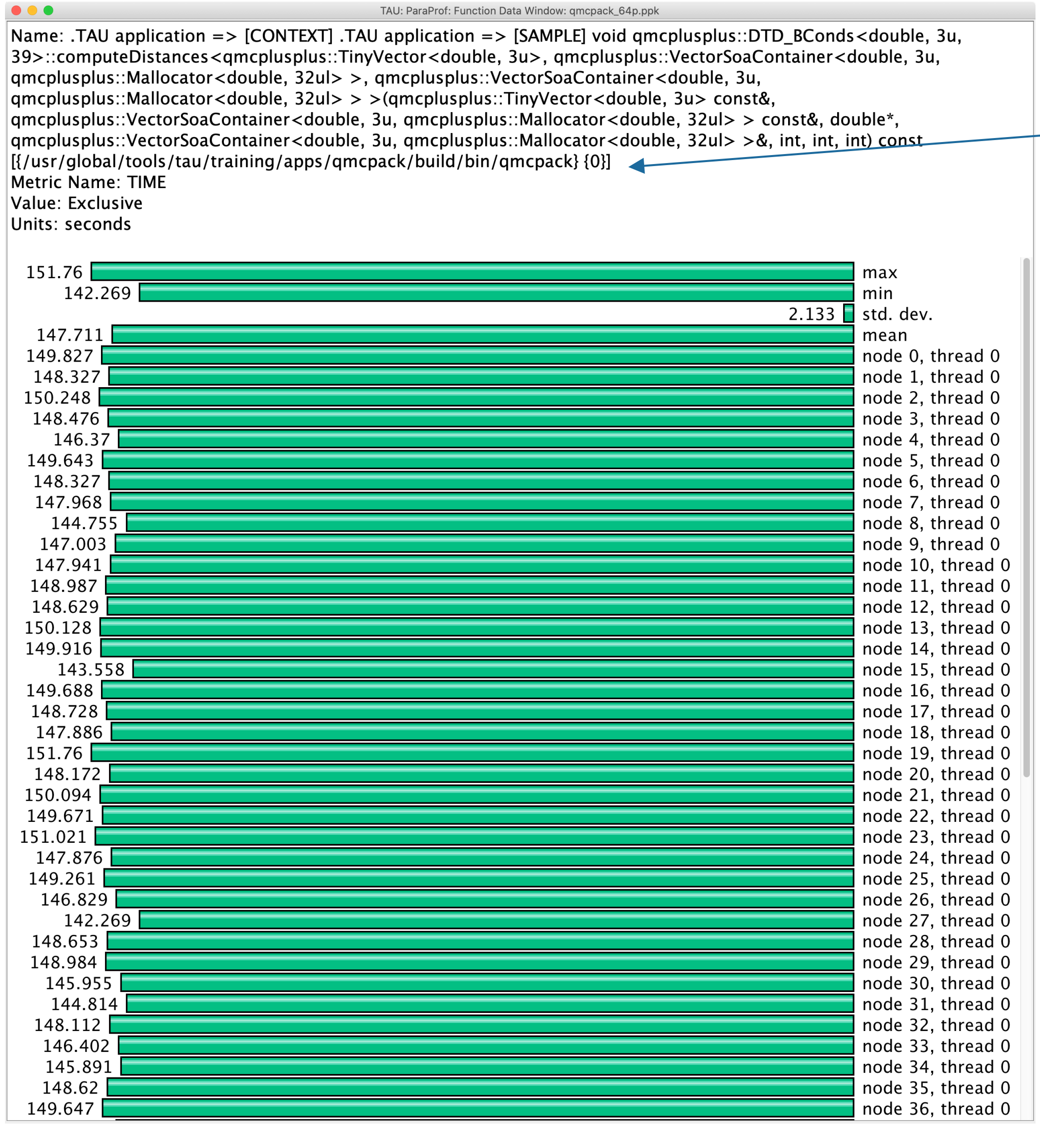
EXASCALE COMPUTING PROJECT

# Event Based Sampling (EBS) shows statement level information




File: ibv_channel_manager.c
Line: 1018

# Event Based Sampling without symbol information (-g): QMCPack




Line number is 0!

~147.71 seconds are spent in Qmcplusplus:DTD_Bconds:: computeDistances method

# TAU Performance System®

## Hands-on exercises on Ookami, SBU

Tuning and Analysis Utilities

EXASCALE COMPUTING PROJECT

# Installing TAU on your laptop for paraprof (GUI)

- Microsoft Windows
  Install Java from Oracle.com
    http://tau.uoregon.edu/tau.exe
    Install, click on a ppk file to launch paraprof
- macOS (x86_64)
    Install Java 11.0.3:
      Download and install http://tau.uoregon.edu/java.dmg
      If you have multiple Java installations, add to your ~/.zshrc (or ~/.bashrc as appropriate):
      export PATH=/Library/Java/JavaVirtualMachines/jdk-11.0.3.jdk/Contents/Home/bin:$PATH
      java -version
    Download and install TAU (copy to /Applications from dmg):
      http://tau.uoregon.edu/tau.dmg
      export PATH=/Applications/TAU/tau/apple/bin:$PATH
      paraprof  app.ppk &
- macOS (arm64, M1)
      http://tau.uoregon.edu/java_arm64.dmg
- Linux (http://tau.uoregon.edu/tau.tgz)
    ./configure; make install; export PATH=<taudir>/x86_64/bin:$PATH; paraprof app.ppk &

# Installing TAU on your laptop for paraprof (GUI)

- Microsoft Windows

  Install Java from Oracle.com

  http://tau.uoregon.edu/tau.exe

  Install, click on a ppk file to launch paraprof

- macOS (x86_64)

  Install Java 11.0.3:

  Download and install http://tau.uoregon.edu/java.dmg

  If you have multiple Java installations, add to your ~/.zshrc (or ~/.bashrc as appropriate):

  ```
  export PATH=/Library/Java/JavaVirtualMachines/jdk-11.0.3.jdk/Contents/Home/bin:$PATH
  java -version
  ```

  Download and install TAU (copy to /Applications from dmg):

  ```
  http://tau.uoregon.edu/tau.dmg
  export PATH=/Applications/TAU/tau/apple/bin:$PATH
  paraprof  app.ppk &
  ```

- macOS (arm64, M1)

  http://tau.uoregon.edu/java_arm64.dmg

- Linux (http://tau.uoregon.edu/tau.tgz)

  ```
  ./configure; make install; export PATH=<taudir>/x86_64/bin:$PATH; paraprof app.ppk &
  ```

# 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 –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 HIP/clang compilers)

% export TAU_OMPT_SUPPORT_LEVEL=full;

% 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 export TAU_METRICS=TIME,PAPI_L1_DCM… -ebs_resolution=<file | function | line>

# TAU: Quickstart Guide on Ookami (MPI only)

**Setup:**

- `% srun -p short --qos short --pty bash`
- `% module use /lustre/shared/modulefiles`
- `% module load tau`
- `% tar xf /lustre/home/sshende/workshop.tgz ; cd workshop/CoMD/src-mpi; make ; cd ../bin; ./r.sh`

**Profiling with an un-instrumented application:**

- `MPI:` `% mpirun -np 64 tau_exec -ebs ./a.out`
- `PAPI counters:` `% export TAU_METRICS=TIME,PAPI_NATIVE_SVE_INST_RETIRED`
  `% mpirun -np 64 tau_exec -ebs ./a.out`

**Analysis:** `% pprof -a -m | more;  % paraprof (GUI)`

`% paraprof --pack app.ppk;  <SCP app.ppk to laptop>; paraprof app.ppk &`

**Tracing:**

- `Vampir: MPI:` `% export TAU_TRACE=1; export TAU_TRACE_FORMAT=otf2`
  `% mpirun -np 64 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)`
- `Jumpshot:` `% export TAU_TRACE=1; mpirun -np 64 tau_exec ./a.out; tau_treemerge.pl;`
  `% tau2slog2 tau.trc tau.edf -o app.slog2; jumpshot app.slog2 &`

EXASCALE COMPUTING PROJECT

# TAU Performance System®

## Runtime systems supported

Tuning and Analysis Utilities

# 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

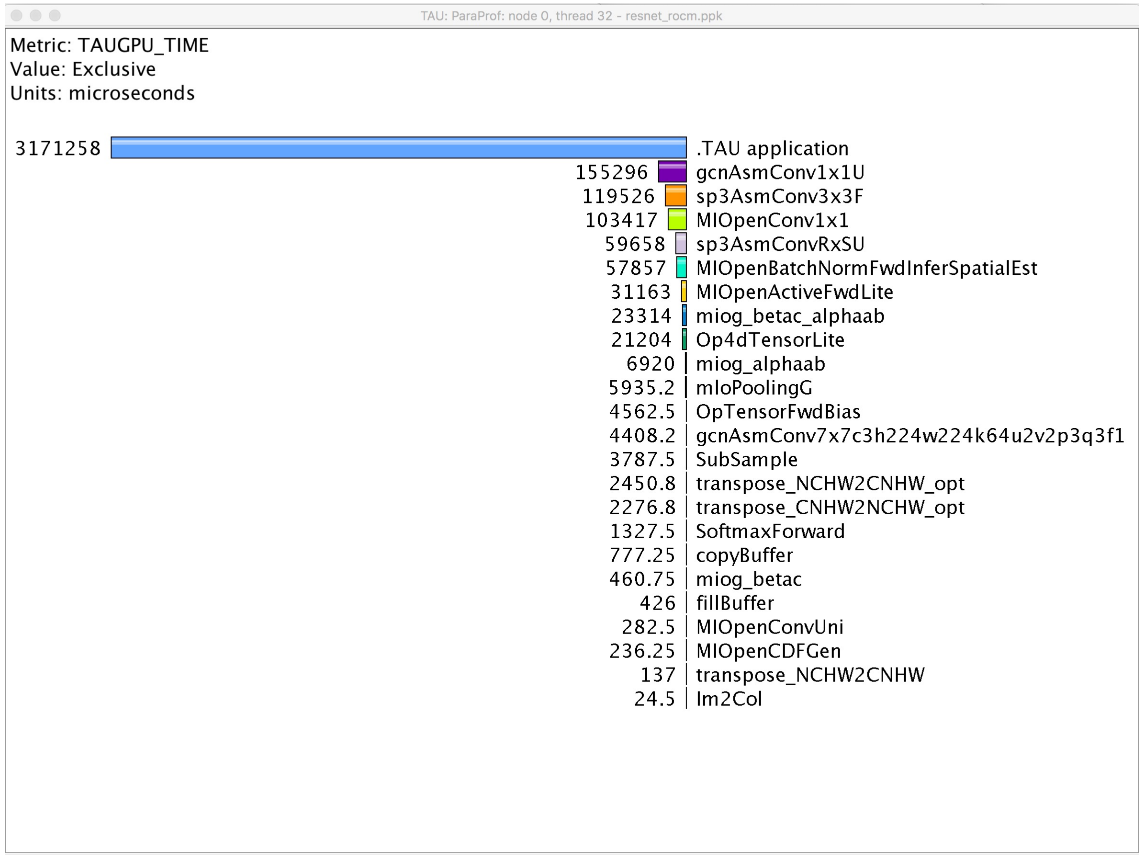
# TAU's Support for Runtime Systems (contd.)

- *OpenCL*
  - OpenCL profiling interface
  - Track timings of kernels
- *Intel® OneAPI*
  - Level Zero
  - Track time spent in kernels executing on GPU
  - Track time spent in OneAPI runtime calls
- *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
- *MPI + Intel ® OneAPI DPC++/SYCL*
  - PMPI + Level Zero interfaces
- *MPI + pthread*
  - PMPI + pthread wrapper instrumentation interfaces
- *Kokkos + OpenMP*
  - Kokkos profiling API + OMPT to transparently track events
- *Kokkos + pthread + MPI*
  - Kokkos + pthread wrapper interposition library + PMPI layer
- *Python + CUDA + MPI*
  - Python + CUPTI + pthread profiling interfaces (e.g., Tensorflow, PyTorch) + MPI
- *MPI + OpenCL*
  - PMPI + OpenCL profiling interfaces

# TAU Profiles ResNet50 using tau_python



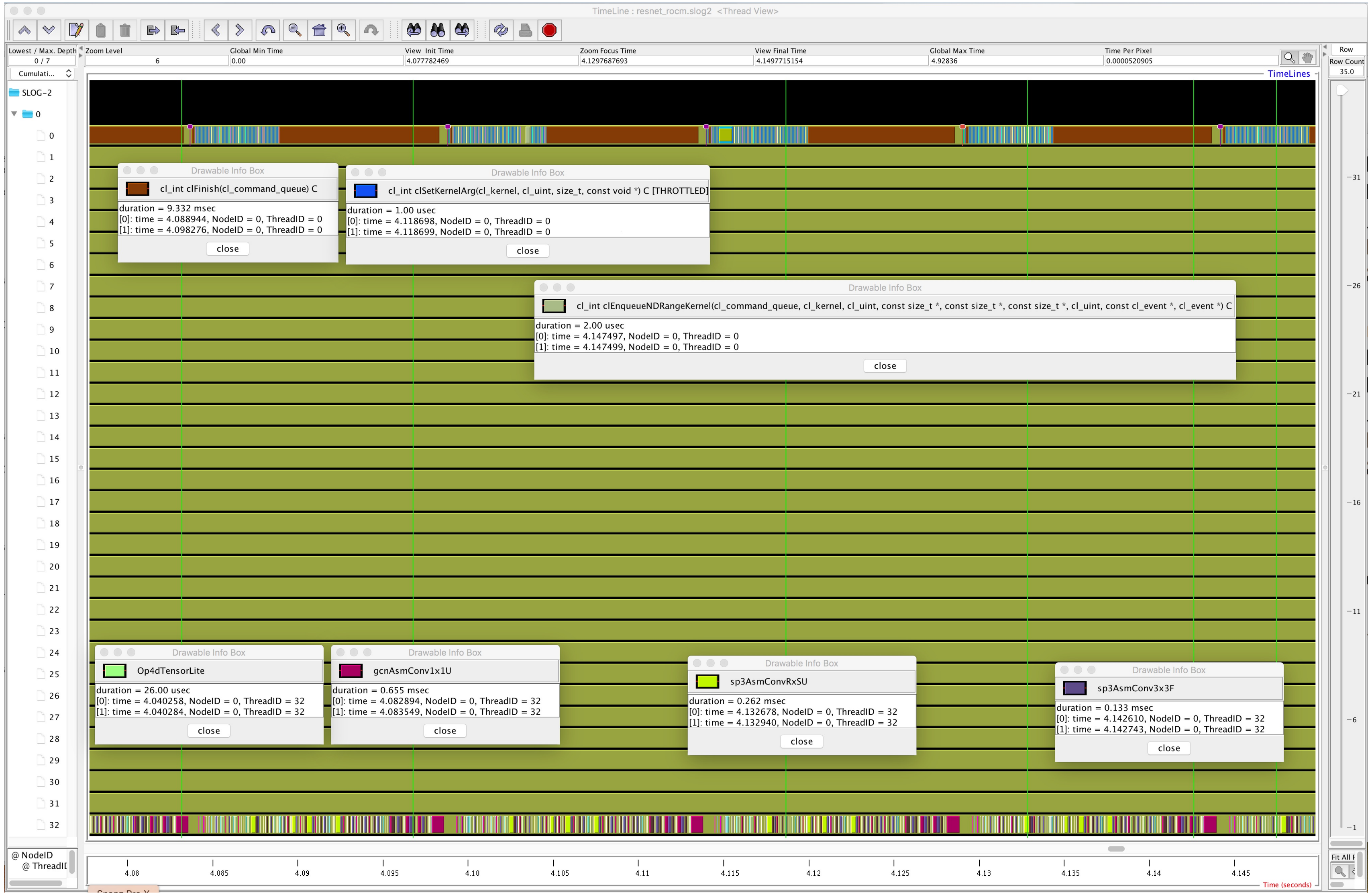

TAU: ParaProf: Statistics for: node 0, thread 32 - resnet_Profile.ppk

| Name | Exclusive TAUGPU_TIME | Inclusive TAUGPU_TIME | Calls | Child Calls |
|---|---|---|---|---|
| .TAU application | 8.84 | 9.425 | 1 | 20,380 |
| gcnAsmConv1x1U | 0.127 | 0.127 | 1,238 | 0 |
| sp3AsmConv3x3F | 0.118 | 0.118 | 1,624 | 0 |
| sp3AsmConvRxSU | 0.072 | 0.072 | 336 | 0 |
| MIOpenBatchNormFwdInferSpatialEst | 0.056 | 0.056 | 5,217 | 0 |
| miog_betac_alphaab | 0.052 | 0.052 | 1,234 | 0 |
| MIOpenConv1x1 | 0.038 | 0.038 | 542 | 0 |
| MIOpenActiveFwdLite | 0.032 | 0.032 | 4,936 | 0 |
| miog_alphaab | 0.024 | 0.024 | 414 | 0 |
| Op4dTensorLite | 0.021 | 0.021 | 1,612 | 0 |
| MIOpenConvUni | 0.016 | 0.016 | 101 | 0 |
| transpose_CNHW2NCHW_opt | 0.007 | 0.007 | 931 | 0 |
| transpose_NCHW2CNHW_opt | 0.006 | 0.006 | 824 | 0 |
| mloPoolingG | 0.005 | 0.005 | 202 | 0 |
| OpTensorFwdBias | 0.005 | 0.005 | 202 | 0 |
| miog_betac | 0.002 | 0.002 | 414 | 0 |
| SubSample | 0.002 | 0.002 | 208 | 0 |
| SoftmaxForward | 0.001 | 0.001 | 101 | 0 |
| copyBuffer | 0.001 | 0.001 | 118 | 0 |
| transpose_NCHW2CNHW | 0.001 | 0.001 | 99 | 0 |
| fillBuffer | 0 | 0 | 24 | 0 |
| MIOpenCDFGen | 0 | 0 | 1 | 0 |
| gcnAsmConv7x7c3h224w224k64u2v2p3q | 0 | 0 | 1 | 0 |
| Im2Col | 0 | 0 | 1 | 0 |

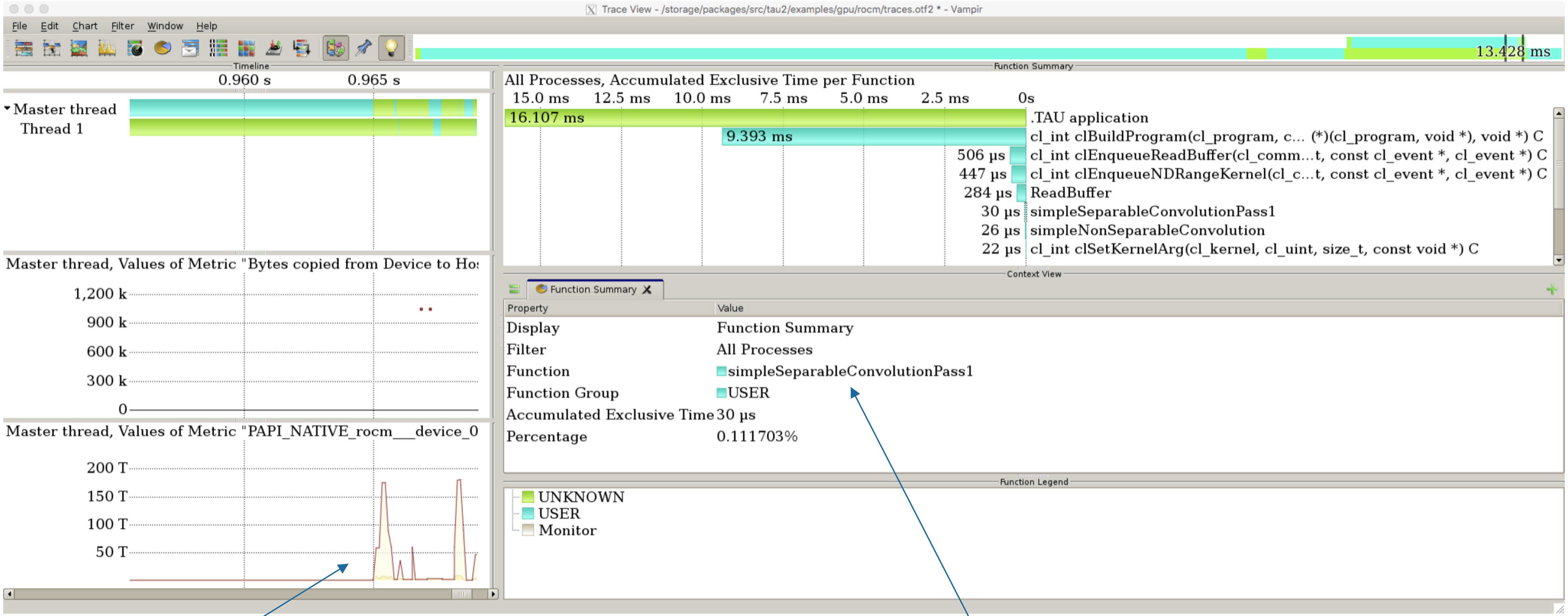
% tau_python –rocm ./anntest weights.bin tensor_1_224x224.f32 out.f32

EXASCALE COMPUTING PROJECT

# TAU’s Jumpshot Trace Visualizer’s Timeline View



# TAU's OTF2 traces visualized in Vampir




Kernel name

Hardware performance counters from PAPI

% export TAU_TRACE_FORMAT=otf2; export TAU_TRACE=1
% tau_exec –rocm ./SimpleConvolution
% vampir traces.otf2

EXASCALE COMPUTING PROJECT

# Kokkos

- Provides abstractions for node level parallelism (X in MPI+X)
- Productive, portable, and performant shared-memory programming model
- Helps you create single source performance portable codes
- Provides data abstractions
- C++ API for expressing parallelism in your program
- Aggressive compiler transformations using C++ templates
- Low level code targets backends such as OpenMP, Pthread, CUDA
- Creates a problem for performance evaluation tools
- Gap: performance data and higher-level abstractions
- Solution: Kokkos profiling API for mapping performance data
- https://kokkos.org    Sandia National Laboratories, NM

# Kokkos API use in ExaMiniMD

20. sameer@pegasus:~/pkgs/ORNL/DEMO/BUILD/ExaMiniMD-pthread/ExaMiniMD/src/comm_types (ssh)

```
void CommMPI::update_halo() {

  Kokkos::Profiling::pushRegion("Comm::update_halo");

  N_ghost = 0;
  s=*system;

  pack_buffer_update = t_buffer_update((T_X_FLOAT*)pack_buffer.data(),pack_indicies_all.extent(1));
  unpack_buffer_update = t_buffer_update((T_X_FLOAT*)unpack_buffer.data(),pack_indicies_all.extent(1));

  for(phase = 0; phase<6; phase++) {
    pack_indicies = Kokkos::subview(pack_indicies_all,phase,Kokkos::ALL());
    if(proc_grid[phase/2]>1) {

      Kokkos::parallel_for("CommMPI::halo_update_pack",
         Kokkos::RangePolicy<TagHaloUpdatePack, Kokkos::IndexType<T_INT> >(0,proc_num_send[phase]),
         *this);
      MPI_Request request;
      MPI_Status status;
      MPI_Irecv(unpack_buffer.data(),proc_num_recv[phase]*sizeof(T_X_FLOAT)*3/sizeof(int),MPI_INT, proc_neighbors_recv[phase],100002,MPI_COMM_WORLD,&request);
      MPI_Send (pack_buffer.data(),proc_num_send[phase]*sizeof(T_X_FLOAT)*3/sizeof(int),MPI_INT, proc_neighbors_send[phase],100002,MPI_COMM_WORLD);
      s = *system;
      MPI_Wait(&request,&status);
      const int count = proc_num_recv[phase];
      if(unpack_buffer_update.extent(0)<count) {
        unpack_buffer_update = t_buffer_update((T_X_FLOAT*)unpack_buffer.data(),count);
      }
      Kokkos::parallel_for("CommMPI::halo_update_unpack",
                Kokkos::RangePolicy<TagHaloUpdateUnpack, Kokkos::IndexType<T_INT> >(0,proc_num_recv[phase]),
                *this);

    } else {
      //printf("HaloUpdateCopy: %i %i %i\n",phase,proc_num_send[phase],pack_indicies.extent(0));
      Kokkos::parallel_for("CommMPI::halo_update_self",
        Kokkos::RangePolicy<TagHaloUpdateSelf, Kokkos::IndexType<T_INT> >(0,proc_num_send[phase]),
        *this);
    }
    N_ghost += proc_num_recv[phase];
  }

  Kokkos::Profiling::popRegion();
};
```

pushRegion("Comm::update_halo")

Kokkos::parallel_for

popRegion

EXASCALE COMPUTING PROJECT

# ExaMiniMD: TAU Phase

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

| Name △ | Exclusive TIME | Inclusive TIME | Calls | Child Calls |
|---|---|---|---|---|
| .TAU application | 0.143 | 96.743 | 1 | 832 |
| Comm::exchange | 0.001 | 0.967 | 6 | 142 |
| Comm::exchange_halo | 0.001 | 4.702 | 6 | 184 |
| Comm::update_halo | 0.004 | 31.347 | 95 | 1,330 |
| Kokkos::parallel_for CommMPI::halo_update_pack [device=0] | 0.002 | 0.506 | 190 | 190 |
| Kokkos::parallel_for CommMPI::halo_update_self [device=0] | 0.003 | 0.597 | 380 | 380 |
| Kokkos::parallel_for CommMPI::halo_update_unpack [device=0] | 0.002 | 0.97 | 190 | 190 |
| MPI_Irecv() | 0.001 | 0.001 | 190 | 0 |
| MPI_Send() | 29.268 | 29.268 | 190 | 0 |
| MPI_Wait() | 0.001 | 0.001 | 190 | 0 |
| OpenMP_Implicit_Task | 0.041 | 1.985 | 760 | 760 |
| OpenMP_Parallel_Region parallel_for<Kokkos::RangePolicy<CommMPI::Ta | 0 | 0.504 | 190 | 190 |
| OpenMP_Parallel_Region parallel_for<Kokkos::RangePolicy<CommMPI::Ta | 0.08 | 0.968 | 190 | 190 |
| OpenMP_Parallel_Region void Kokkos::parallel_for<Kokkos::RangePolicy<( | 0.001 | 0.594 | 380 | 380 |
| OpenMP_Sync_Region_Barrier parallel_for<Kokkos::RangePolicy<CommMF | 0.489 | 0.489 | 190 | 0 |
| OpenMP_Sync_Region_Barrier parallel_for<Kokkos::RangePolicy<CommMF | 0.875 | 0.875 | 190 | 0 |
| OpenMP_Sync_Region_Barrier void Kokkos::parallel_for<Kokkos::RangePol | 0.58 | 0.58 | 380 | 0 |

Comm::update_halo phase in TAU ParaProf's Thread Statistics Table

EXASCALE COMPUTING PROJECT

# MPI Tools Interface: PVARs and CVARs on Corona (LLNL AMD system)

TAU: ParaProf: Context Events for: node 2, thread 0 - comb_mpit_ebs.ppk

| Name | Total | NumSamples | MaxValue | MinValue | MeanValue | Std. Dev. |
|---|---|---|---|---|---|---|
| Message size for broadcast | 4 | 1 | 4 | 4 | 4 | 0 |
| Message size for reduce | 608 | 20 | 48 | 8 | 30.4 | 15.513 |
| mpit_progress_poll (CH3 RDMA progress engine polling count) | 474,499 | 1 | 474,499 | 474,499 | 474,499 | 0 |
| mv2_coll_allgather_bytes_recv (Number of bytes recv by default algorithm of allgathe | 612 | 1 | 612 | 612 | 612 | 0 |
| mv2_coll_allgather_bytes_send (Number of bytes send by default algorithm of allgath | 252 | 1 | 252 | 252 | 252 | 0 |
| mv2_coll_allgather_count_recv (Count of messages recv by default algorithm of allgat | 21 | 1 | 21 | 21 | 21 | 0 |
| mv2_coll_allgather_count_send (Count of messages send by default algorithm of allga | 21 | 1 | 21 | 21 | 21 | 0 |
| mv2_coll_allgather_rd (Number of times recursive doubling Allgather was invoked) | 7 | 1 | 7 | 7 | 7 | 0 |
| mv2_coll_allgather_rd_bytes_recv (Number of bytes recv by rd algorithm of allgather | 612 | 1 | 612 | 612 | 612 | 0 |
| mv2_coll_allgather_rd_bytes_send (Number of bytes send by rd algorithm of allgather | 252 | 1 | 252 | 252 | 252 | 0 |
| mv2_coll_allgather_rd_count_recv (Count of messages recv by rd algorithm of allgath | 21 | 1 | 21 | 21 | 21 | 0 |
| mv2_coll_allgather_rd_count_send (Count of messages send by rd algorithm of allgat | 21 | 1 | 21 | 21 | 21 | 0 |
| mv2_coll_allreduce_2lvl (Number of times MV2 two-level allreduce algorithm was invc | 5 | 1 | 5 | 5 | 5 | 0 |
| mv2_coll_allreduce_bytes_recv (Number of bytes recv by allreduce collective) | 7,080 | 1 | 7,080 | 7,080 | 7,080 | 0 |
| mv2_coll_allreduce_bytes_send (Number of bytes send by allreduce collective) | 7,080 | 1 | 7,080 | 7,080 | 7,080 | 0 |
| mv2_coll_allreduce_count_recv (Count of messages recv by allreduce collective) | 42 | 1 | 42 | 42 | 42 | 0 |
| mv2_coll_allreduce_count_send (Count of messages send by allreduce collective) | 42 | 1 | 42 | 42 | 42 | 0 |
| mv2_coll_allreduce_pt2pt_rd_bytes_recv (Number of bytes recv by pt2pt rd algorithm | 7,080 | 1 | 7,080 | 7,080 | 7,080 | 0 |
| mv2_coll_allreduce_pt2pt_rd_bytes_send (Number of bytes send by pt2pt rd algorithn | 7,080 | 1 | 7,080 | 7,080 | 7,080 | 0 |
| mv2_coll_allreduce_pt2pt_rd_count_recv (Count of messages recv by pt2pt rd algorith | 42 | 1 | 42 | 42 | 42 | 0 |
| mv2_coll_allreduce_pt2pt_rd_count_send (Count of messages send by pt2pt rd algorit | 42 | 1 | 42 | 42 | 42 | 0 |
| mv2_coll_allreduce_shm_intra (Number of times MV2 shm intra allreduce algorithm w | 3 | 1 | 3 | 3 | 3 | 0 |
| mv2_coll_allreduce_shm_rd (Number of times MV2 shm rd allreduce algorithm was in | 14 | 1 | 14 | 14 | 14 | 0 |
| mv2_coll_allreduce_subcomm (Number of times MV2 allreduce was invoked at a sub- | 10 | 1 | 10 | 10 | 10 | 0 |
| mv2_coll_barrier_count_recv (Count of messages recv by barrier collective) | 24 | 1 | 24 | 24 | 24 | 0 |
| mv2_coll_barrier_count_send (Count of messages send by barrier collective) | 24 | 1 | 24 | 24 | 24 | 0 |
| mv2_coll_barrier_pairwise (Number of times pairwise barrier was invoked) | 8 | 1 | 8 | 8 | 8 | 0 |
| mv2_coll_barrier_pairwise_count_recv (Count of messages recv by pairwise algorithm | 24 | 1 | 24 | 24 | 24 | 0 |
| mv2_coll_barrier_pairwise_count_send (Count of messages send by pairwise algorithn | 24 | 1 | 24 | 24 | 24 | 0 |

```
% export TAU_TRACK_MPI_T_PVARS=1
% mpirun –np 64 tau_exec –T mpit ./a.out
```

EXASCALE COMPUTING PROJECT

# MPI Tools Interface: Control Variables (CVARs)

TAU: ParaProf Manager

- Applications
  - Standard Applications
    - Default App
      - Default Exp
        - comb_mpit_ebs.ppk
          - TIME

| TrialField | Value |
|---|---|
| Name | comb_mpit_ebs.ppk |
| Application ID | 0 |
| Experiment ID | 0 |
| Trial ID | 0 |
| CPU Cores | 24 |
| CPU MHz | 2000.000 |
| CPU Type | AMD EPYC 7401 24-Core Processor |
| CPU Vendor | AuthenticAMD |
| CWD | /usr/global/tools/tau/training/apps/COMB_LLNL/Comb/build_lc_toss3_gcc_8_3_1/bin |
| Cache Size | 512 KB |
| Command Line | ./comb -comm post_recv wait_all -comm post_send wait_all -comm wait_recv wait_all -comm wait_send wait_all 200_200_20... |
| Ending Timestamp | 1612559352834401 |
| Executable | /usr/global/tools/tau/training/apps/COMB_LLNL/Comb/build_lc_toss3_gcc_8_3_1/bin/comb |
| File Type Index | 0 |
| File Type Name | ParaProf Packed Profile |
| Hostname | corona107 |
| Local Time | 2021-02-05T13:09:08-08:00 |
| MPI Processor Name | corona107 |
| MPI_T CVAR: MPIR_CVAR_ABORT_ON_LEAKED_HANDLES | If true, MPI will call MPI_Abort at MPI_Finalize if any MPI object handles have been leaked. For example, if MPI_Comm_dup is c... |
| MPI_T CVAR: MPIR_CVAR_ALLGATHERV_PIPELINE_MSG_SIZE | The smallest message size that will be used for the pipelined, large-message, ring algorithm in the MPI_Allgatherv implement... |
| MPI_T CVAR: MPIR_CVAR_ALLGATHER_COLLECTIVE_ALGORITHM | This CVAR selects proper collective algorithm for allgather operation. |
| MPI_T CVAR: MPIR_CVAR_ALLGATHER_LONG_MSG_SIZE | For MPI_Allgather and MPI_Allgatherv, the long message algorithm will be used if the send buffer size is >= this value (in byte... |
| MPI_T CVAR: MPIR_CVAR_ALLGATHER_SHORT_MSG_SIZE | For MPI_Allgather and MPI_Allgatherv, the short message algorithm will be used if the send buffer size is < this value (in bytes... |
| MPI_T CVAR: MPIR_CVAR_ALLREDUCE_COLLECTIVE_ALGORITHM | This CVAR selects proper collective algorithm for allreduce operation. |
| MPI_T CVAR: MPIR_CVAR_ALLREDUCE_SHORT_MSG_SIZE | the short message algorithm will be used if the send buffer size is <= this value (in bytes) |
| MPI_T CVAR: MPIR_CVAR_ALLTOALLV_COLLECTIVE_ALGORITHM | This CVAR selects proper collective algorithm for alltoallv operation. |
| MPI_T CVAR: MPIR_CVAR_ALLTOALL_COLLECTIVE_ALGORITHM | This CVAR selects proper collective algorithm for alltoall operation. |
| MPI_T CVAR: MPIR_CVAR_ALLTOALL_MEDIUM_MSG_SIZE | the medium message algorithm will be used if the per-destination message size (sendcount*size(sendtype)) is <= this value a... |
| MPI_T CVAR: MPIR_CVAR_ALLTOALL_SHORT_MSG_SIZE | the short message algorithm will be used if the per-destination message size (sendcount*size(sendtype)) is <= this value (See... |
| MPI_T CVAR: MPIR_CVAR_ALLTOALL_THROTTLE | max no. of irecvs/isends posted at a time in some alltoall algorithms. Setting it to 0 causes all irecvs/isends to be posted at o... |
| MPI_T CVAR: MPIR_CVAR_ASYNC_PROGRESS | If set to true, MPICH will initiate an additional thread to make asynchronous progress on all communication operations includi... |
| MPI_T CVAR: MPIR_CVAR_BCAST_COLLECTIVE_ALGORITHM | This CVAR selects proper collective algorithm for broadcast operation. |
| MPI_T CVAR: MPIR_CVAR_BCAST_LONG_MSG_SIZE | Let's define short messages as messages with size < MPIR_CVAR_BCAST_SHORT_MSG_SIZE, and medium messages as message... |
| MPI_T CVAR: MPIR_CVAR_BCAST_MIN_PROCS | Let's define short messages as messages with size < MPIR_CVAR_BCAST_SHORT_MSG_SIZE, and medium messages as message... |
| MPI_T CVAR: MPIR_CVAR_BCAST_SHORT_MSG_SIZE | Let's define short messages as messages with size < MPIR_CVAR_BCAST_SHORT_MSG_SIZE, and medium messages as message... |
| MPI_T CVAR: MPIR_CVAR_CH3_EAGER_MAX_MSG_SIZE | This cvar controls the message size at which CH3 switches from eager to rendezvous mode. |
| MPI_T CVAR: MPIR_CVAR_CH3_ENABLE_HCOLL | If true, enable HCOLL collectives. |
| MPI_T CVAR: MPIR_CVAR_CH3_INTERFACE_HOSTNAME | If non-NULL, this cvar specifies the IP address that other processes should use when connecting to this process. This cvar is m... |
| MPI_T CVAR: MPIR_CVAR_CH3_NOLOCAL | If true, force all processes to operate as though all processes are located on another node. For example, this disables shared ... |

# MPI Tools Interface: Performance Variables (PVARs)

TAU: ParaProf Manager

- Applications
  - Standard Applications
    - Default App
      - Default Exp
        - comb_mpit_ebs.ppk
          - TIME

| TrialField | Value |
|---|---|
| MPI_T CVAR: MPIR_CVAR_USE_CUDA | This option enables the CUDA library. |
| MPI_T CVAR: MPIR_CVAR_USE_GPUDIRECT | This option enables use of GPUDIRECT in CUDA library. |
| MPI_T CVAR: MPIR_CVAR_USE_GPUDIRECT_GDRCOPY | This option enables use of GPUDIRECT_GDRCOPY in CUDA library. |
| MPI_T CVAR: MPIR_CVAR_USE_GPUDIRECT_GDRCOPY_LIMIT | This option sets limit on Gpudirect GDRCOPY in CUDA library. |
| MPI_T CVAR: MPIR_CVAR_USE_GPUDIRECT_LOOPBACK | This option enables use of GPUDIRECT_LOOPBACK in CUDA library. |
| MPI_T CVAR: MPIR_CVAR_USE_GPUDIRECT_LOOPBACK_LIMIT | This option sets limit on GPUDIRECT LOOPBACK in CUDA library. |
| MPI_T CVAR: MPIR_CVAR_USE_GPUDIRECT_RECEIVE_LIMIT | This option sets limit on MV2_USE_GPUDIRECT_RECEIVE_LIMIT in CUDA library. |
| MPI_T CVAR: MPIR_CVAR_USE_IWARP_MODE | This parameter enables the library to run in iWARP mode. |
| MPI_T CVAR: MPIR_CVAR_USE_MCAST | Set this to 1, to enable hardware multicast support in collective communication. |
| MPI_T CVAR: MPIR_CVAR_USE_RDMA_CM | This parameter enables the use of RDMA CM for establishing the connections. |
| MPI_T CVAR: MPIR_CVAR_USE_SHARED_MEM | Use shared memory for intra-node communication. |
| MPI_T PVAR[0]: mv2_pt2pt_mpid_send | bucket level counters for mpid send |
| MPI_T PVAR[100]: mv2_coll_timer_alltoall_rd | total time spent on the MV2 alltoall_rd algorithm |
| MPI_T PVAR[101]: mv2_coll_timer_alltoall_rd | total time spent on the MV2 alltoall_rd algorithm |
| MPI_T PVAR[102]: mv2_coll_timer_alltoall_sd | total time spent on the MV2 alltoall_sd algorithm |
| MPI_T PVAR[103]: mv2_coll_timer_alltoall_sd | total time spent on the MV2 alltoall_sd algorithm |
| MPI_T PVAR[104]: mv2_coll_timer_alltoall_pw | total time spent on the MV2 alltoall_pw algorithm |
| MPI_T PVAR[105]: mv2_coll_timer_alltoall_pw | total time spent on the MV2 alltoall_pw algorithm |
| MPI_T PVAR[106]: mv2_coll_alltoall_inplace | Number of times MV2 in-place alltoall algorithm was invoked |
| MPI_T PVAR[107]: mv2_coll_alltoall_bruck | Number of times MV2 brucks alltoall algorithm was invoked |
| MPI_T PVAR[108]: mv2_coll_alltoall_rd | Number of times MV2 recursive-doubling alltoall algorithm was invoked |
| MPI_T PVAR[109]: mv2_coll_alltoall_sd | Number of times MV2 scatter-destination alltoall algorithm was invoked |
| MPI_T PVAR[10]: mv2_smp_read_progress_poll_success | Unsuccessful CH3 SMP read progress engine polling count |
| MPI_T PVAR[110]: mv2_coll_alltoall_pw | Number of times MV2 pairwise alltoall algorithm was invoked |
| MPI_T PVAR[111]: mv2_coll_alltoall_inplace_bytes_send | Number of bytes send by inplace algorithm of alltoall collective |
| MPI_T PVAR[112]: mv2_coll_alltoall_bruck_bytes_send | Number of bytes send by bruck algorithm of alltoall collective |
| MPI_T PVAR[113]: mv2_coll_alltoall_sd_bytes_send | Number of bytes send by sd algorithm of alltoall collective |
| MPI_T PVAR[114]: mv2_coll_alltoall_pw_bytes_send | Number of bytes send by pw algorithm of alltoall collective |
| MPI_T PVAR[115]: mv2_coll_alltoall_inplace_bytes_recv | Number of bytes recv by inplace algorithm of alltoall collective |
| MPI_T PVAR[116]: mv2_coll_alltoall_bruck_bytes_recv | Number of bytes recv by bruck algorithm of alltoall collective |
| MPI_T PVAR[117]: mv2_coll_alltoall_sd_bytes_recv | Number of bytes recv by sd algorithm of alltoall collective |
| MPI_T PVAR[118]: mv2_coll_alltoall_pw_bytes_recv | Number of bytes recv by pw algorithm of alltoall collective |
| MPI_T PVAR[119]: mv2_coll_alltoall_inplace_count_send | Count of messages send by inplace algorithm of alltoall collective |
| MPI_T PVAR[11]: mv2_smp_write_progress_poll_success | Unsuccessful CH3 SMP write progress engine polling count |
| MPI_T PVAR[120]: mv2_coll_alltoall_bruck_count_send | Count of messages send by bruck algorithm of alltoall collective |
| MPI_T PVAR[121]: mv2_coll_alltoall_sd_count_send | Count of messages send by sd algorithm of alltoall collective |
| MPI_T PVAR[122]: mv2_coll_alltoall_pw_count_send | Count of messages send by pw algorithm of alltoall collective |
| MPI_T PVAR[123]: mv2_coll_alltoall_inplace_count_recv | Count of messages recv by inplace algorithm of alltoall collective |
| MPI_T PVAR[124]: mv2_coll_alltoall_bruck_count_recv | Count of messages recv by bruck algorithm of alltoall collective |

EXASCALE COMPUTING PROJECT

# 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 |

# Download TAU from U. Oregon

Tuning and Analysis Utilities

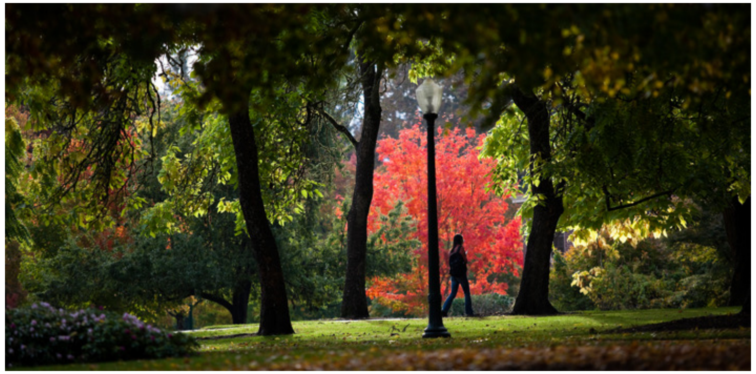
http://tau.uoregon.edu

https://e4s.io [TAU in Docker/Singularity containers]

for more information

Free download, open source, BSD license

# Performance Research Laboratory, University of Oregon, Eugene




www.uoregon.edu

# Support Acknowledgements

- US Department of Energy (DOE)
  - ANL
  - Office of Science contracts, ECP
  - SciDAC, LBL contracts
  - LLNL-LANL-SNL ASC/NNSA contract
  - Battelle, PNNL and ORNL contract
- Department of Defense (DoD)
  - PETTT, HPCMP
- National Science Foundation (NSF)
  - SI2-SSI, Glassbox
- NASA
- CEA, France
- Partners:
  - University of Oregon
  - The Ohio State University
  - ParaTools, Inc.
  - University of Tennessee, Knoxville
  - T.U. Dresden, GWT
  - Jülich Supercomputing Center

# Acknowledgment

"This research was supported by the Exascale Computing Project (17-SC-20-SC), a collaborative effort of two U.S. Department of Energy organizations (Office of Science and the National Nuclear Security Administration) responsible for the planning and preparation of a capable exascale ecosystem, including software, applications, hardware, advanced system engineering, and early testbed platforms, in support of the nation's exascale computing imperative."