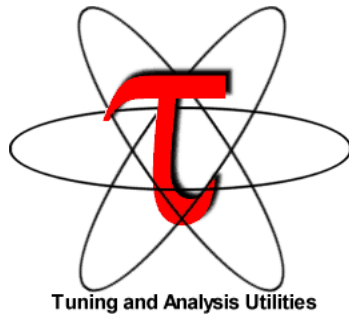


## TAU Performance System®

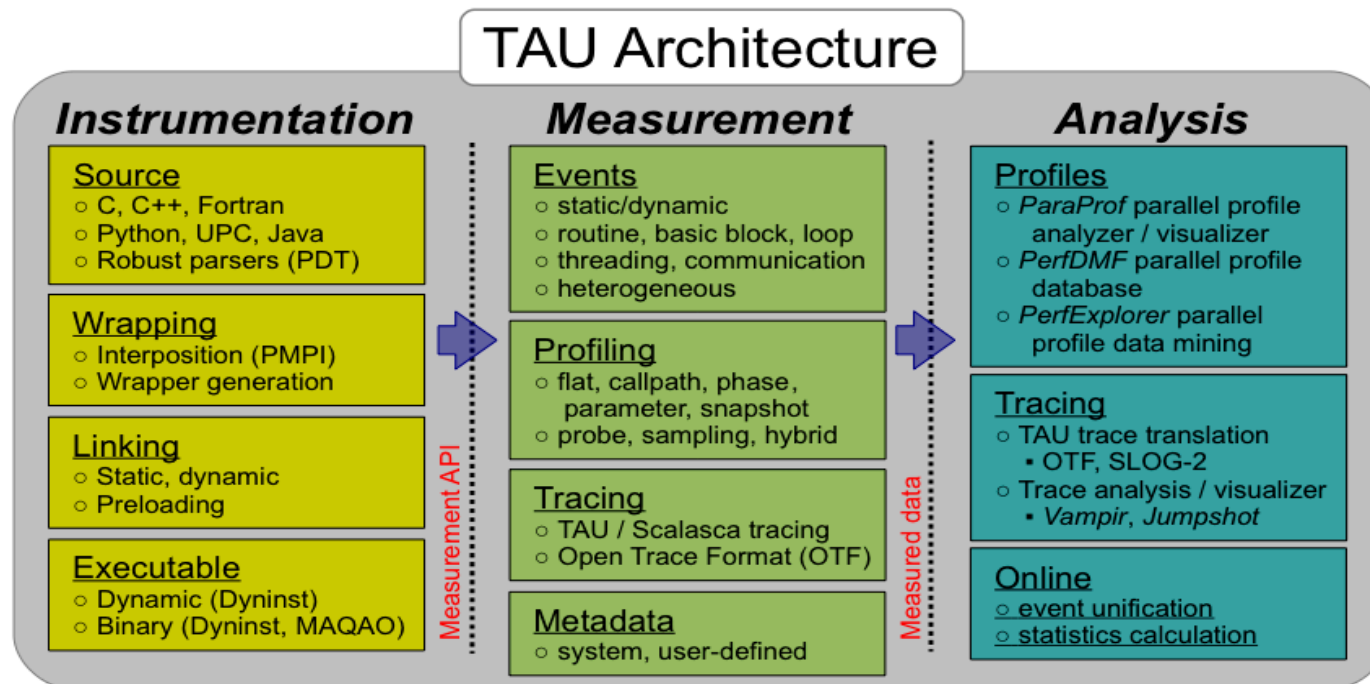
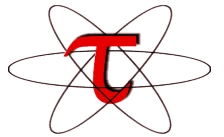


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University of Oregon  
<http://tau.uoregon.edu>



# TAU Performance System®

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



# TAU Performance System

---

- Instrumentation
  - Fortran, C++, C, UPC, Java, Python, Chapel
  - Automatic instrumentation
- Measurement and analysis support
  - MPI, OpenSHMEM, ARMCI, PGAS, DMAP
  - pthreads, OpenMP, OMPT interface, hybrid, other thread models
  - GPU, CUDA, OpenCL, OpenACC, ROCm, HIP
  - Parallel profiling and tracing
  - Use of Score-P for native OTF2 and CUBEX generation
  - Efficient callpath profiles and trace generation using Score-P
- Analysis
  - Parallel profile analysis (ParaProf), data mining (PerfExplorer)
  - Performance database technology (TAUdb)
  - 3D profile browser

# TAU Performance System

---

- TAU supports both sampling and direct instrumentation
- Memory debugging as well as I/O performance evaluation
- Profiling as well as tracing
- Interfaces with Score-P for more efficient measurements
- TAU's instrumentation covers:
  - Runtime library interposition (`tau_exec`)
  - Compiler-based instrumentation
  - Native generation of OTF2 traces (`TAU_TRACE=1`, `TAU_TRACE_FORMAT=otf2`)
  - Callsite instrumentation with profiles and traces (`TAU_CALLSITE=1`)
  - PDT based Source level instrumentation: routine & loop
  - Event based sampling (`TAU_SAMPLING=1` or `tau_exec -ebs`)
  - Callstack unwinding with sampling (`TAU_EBS_UNWIND=1`)
  - OpenMP Tools Interface TR6 (OMPT, `tau_exec -T ompt,tr6`)
  - CUDA CUPTI, OpenCL (`tau_exec -T cupti -cupti`)



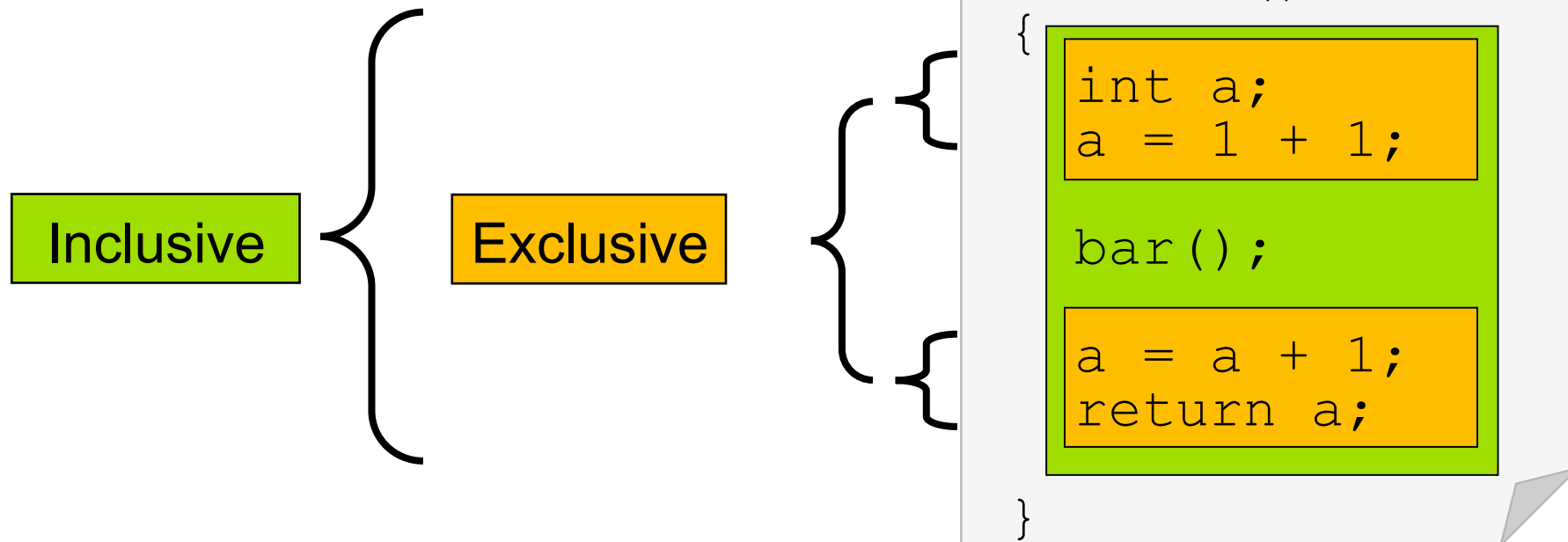
# Application Performance Engineering using TAU

---

- 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?
- 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 on Intel MIC?
- 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?
- 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?

# Inclusive vs. Exclusive values

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



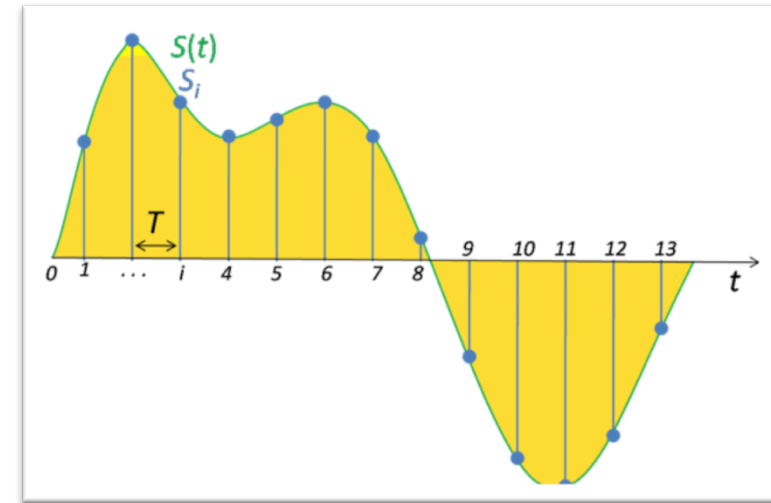
# Performance Data Measurement

## Direct via Probes

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

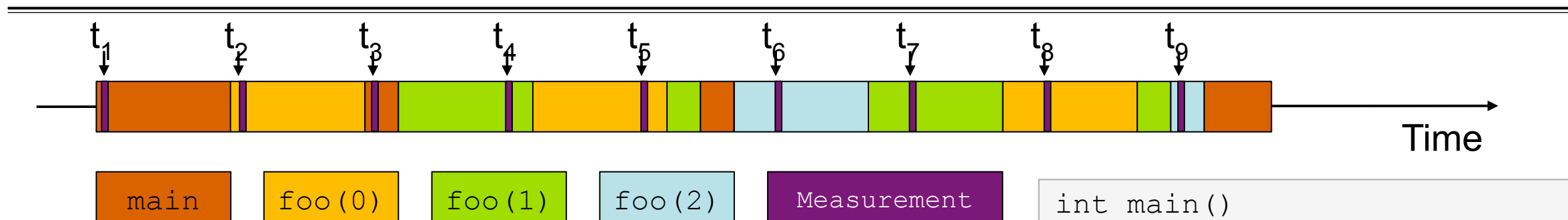
- Exact measurement
- Fine-grain control
- Calls inserted into code

## Indirect via Sampling



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

## Event-Based Sampling (EBS)



- 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 (`tau_exec -ebs`)

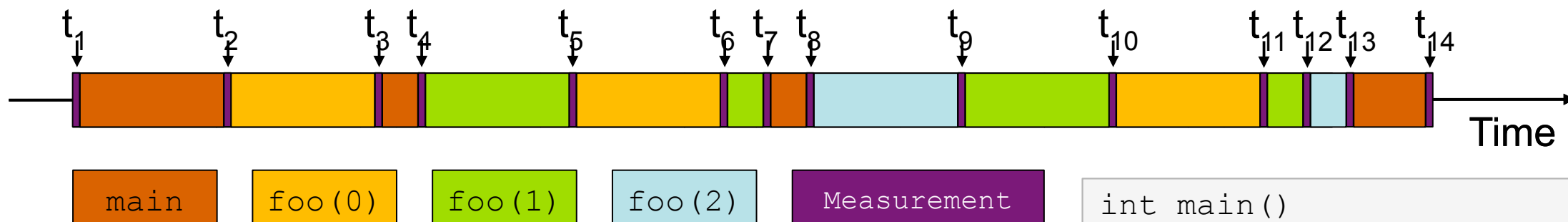
```
int main()
{
    int i;

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

    return 0;
}

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

# Instrumentation



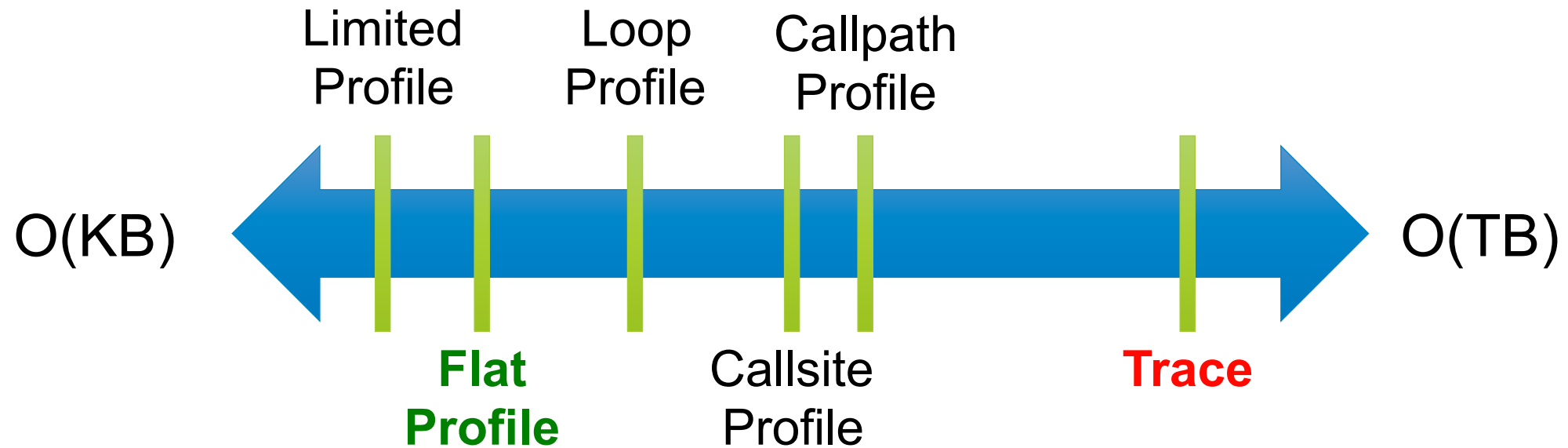
- Measurement code is inserted such that every event of interest is captured directly
  - Can be done in various ways
- Advantage:
  - Much more detailed information
- Disadvantage:
  - Processing of source-code / executable necessary
  - Large relative overheads for small functions

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

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



# How much data do you want?



# 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

# 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)
- Add `tau_exec` before the name of the binary
  - `srun tau_exec ./a.out`
  - `srun tau_exec -T ompt,tr6,mpi,papi -ompt ./a.out`

# tau\_exec

```
$ tau_exec
```

```
Usage: tau_exec [options] [--] <exe> <exe options>
```

Options:

```
-v          Verbose mode
-s          Show what will be done but don't actually do anything (dryrun)
-qsub       Use qsub mode (BG/P only, see below)
-io         Track I/O
-memory     Track memory allocation/deallocation
-memory_debug Enable memory debugger
-cuda       Track GPU events via CUDA
-cupti      Track GPU events via CUPTI (Also see env. variable TAU_CUPTI_API)
-openccl    Track GPU events via OpenCL
-openacc    Track GPU events via OpenACC (currently PGI only)
-ompt       Track OpenMP events via OMPT interface
-armci      Track ARMCI events via PARMCI
-ebs        Enable event-based sampling
-ebs_period=<count> Sampling period (default 1000)
-ebs_source=<counter> Counter (default itimer)
-um         Enable Unified Memory events via CUPTI
-T <DISABLE,GNU,ICPC,MPI,OMPT,OPENMP,PAPI,PDT,PROFILE,PTHREAD,SCOREP,SERIAL> : Specify TAU tags
-loadlib=<file.so> : Specify additional load library
-XrunTAUsh-<options> : Specify TAU library directly
-gdb        Run program in the gdb debugger
```

Notes:

```
Defaults if unspecified: -T MPI
MPI is assumed unless SERIAL is specified
```

- Tau\_exec preloads the TAU wrapper libraries and performs measurements.

No need to recompile the application!

## tau\_exec Example (continued)

Example:

```
mpirun -np 2 tau_exec -T icpc,ompt,mpi -ompt ./a.out
```

```
aprun -n 2 tau_exec -io ./a.out
```

Example - event-based sampling with samples taken every 1,000,000 FP instructions

```
aprun -n 8 tau_exec -ebs -ebs_period=1000000 -ebs_source=PAPI_FP_INS ./ring
```

Examples - GPU:

```
tau_exec -T serial,cupti -cupti ./matmult (Preferred for CUDA 4.1 or later)
```

```
tau_exec -openacc ./a.out
```

```
tau_exec -T serial -opencl ./a.out (OPENCL)
```

```
mpirun -np 2 tau_exec -T mpi,cupti,papi -cupti -um ./a.out (Unified Virtual Memory in CUDA 6.0+)
```

qsub mode (IBM BG/Q only):

Original:

```
qsub -n 1 --mode smp -t 10 ./a.out
```

With TAU:

```
tau_exec -qsub -io -memory -- qsub -n 1 ... -t 10 ./a.out
```

Memory Debugging:

-memory option:

Tracks heap allocation/deallocation and memory leaks.

-memory\_debug option:

Detects memory leaks, checks for invalid alignment, and checks for array overflow. This is exactly like setting TAU\_TRACK\_MEMORY\_LEAKS=1 and TAU\_MEMDBG\_PROTECT\_ABOVE=1 and running with -memory

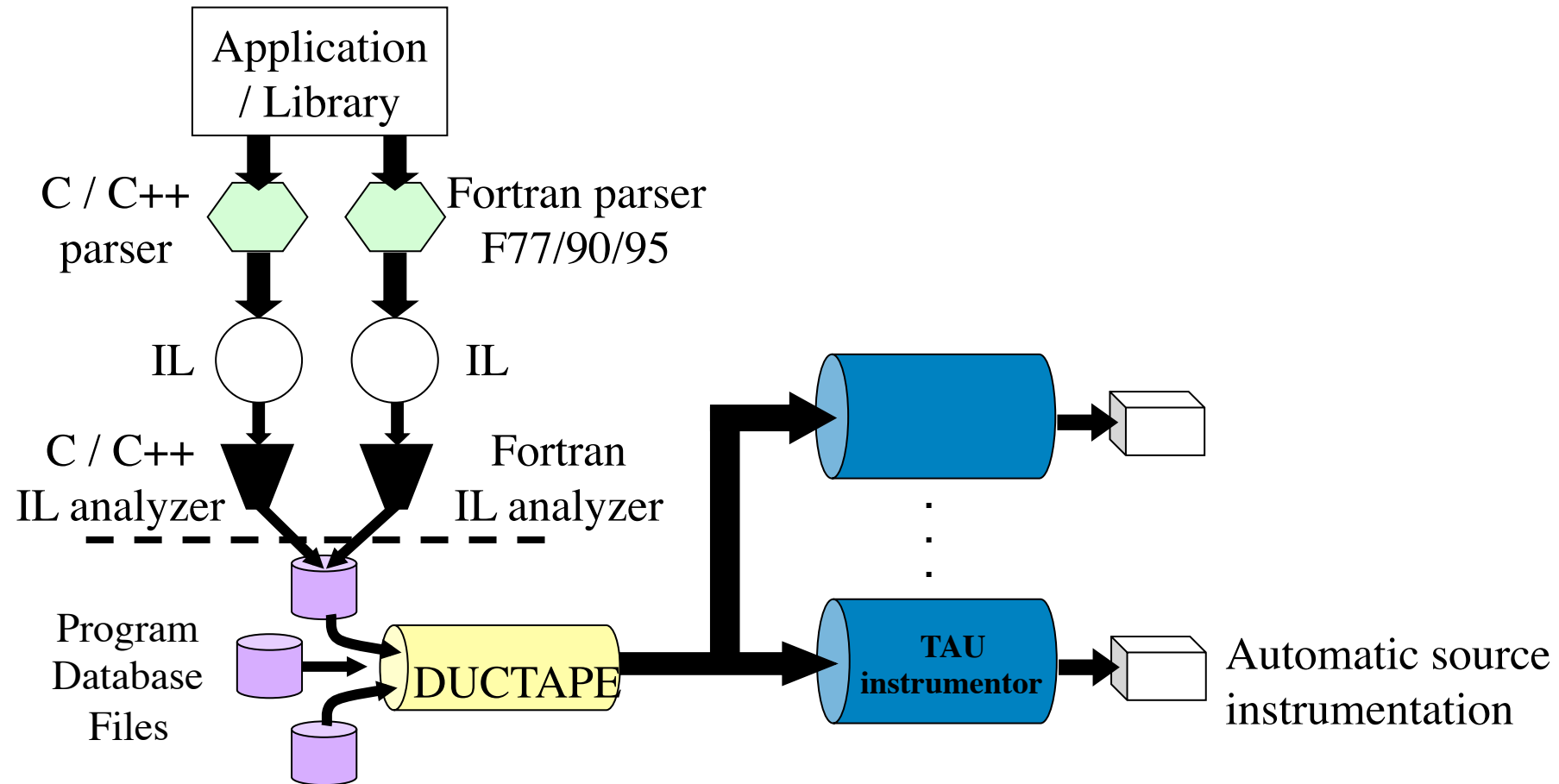
- tau\_exec can enable event based sampling while launching the executable using the **-ebs** flag!



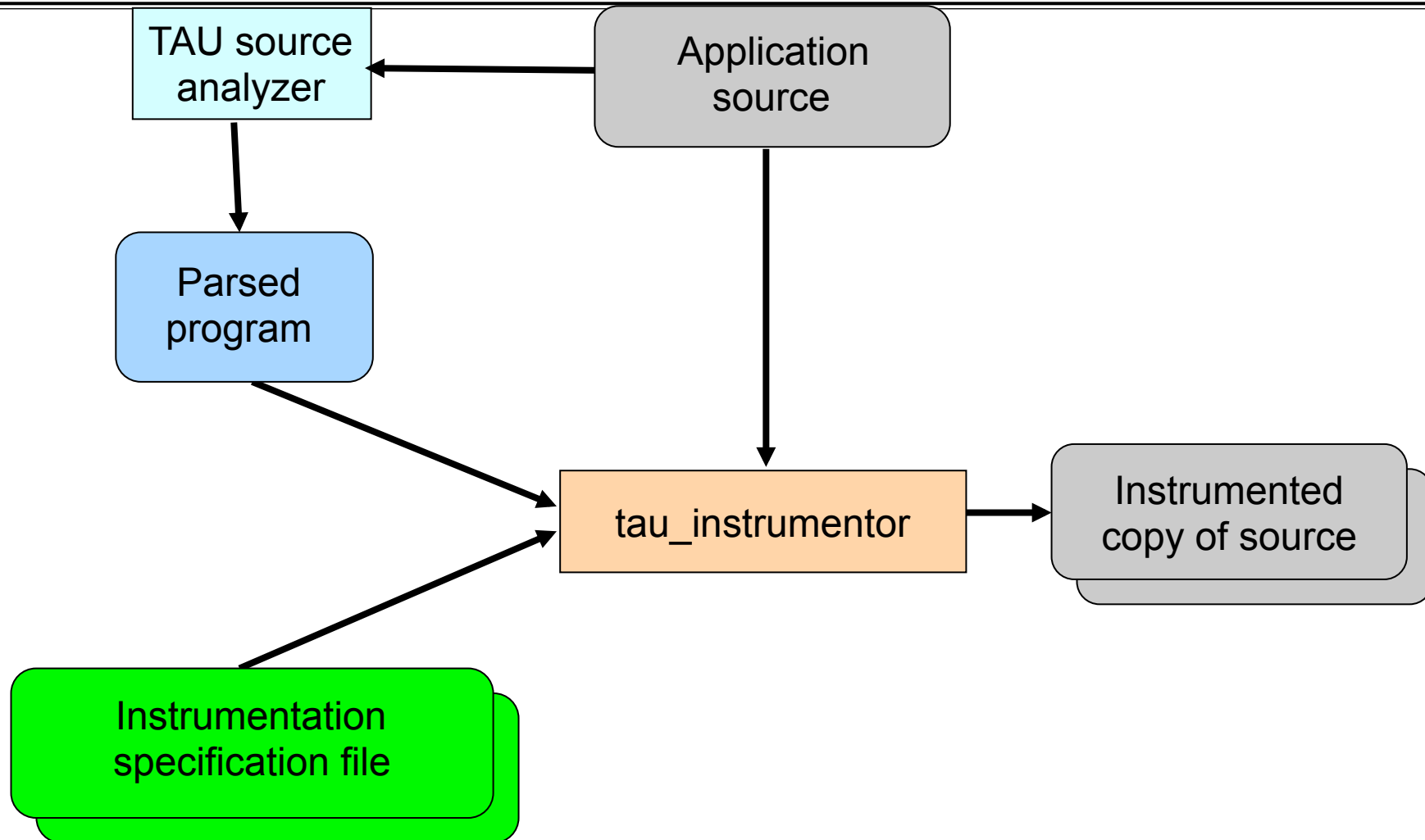
---

# TAU's Source Instrumentation

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



# Automatic Source Instrumentation using PDT



# Installing and Configuring TAU

---

## ■ Installing PDT:

- `wget http://tau.uoregon.edu/pdt.tgz`
- `./configure; make ; make install`

## ■ Installing TAU:

- `wget http://tau.uoregon.edu/tau.tgz`
- `./configure -ompt=download-tr6 -c++=mpiicpc -cc=mpiicc -fortran=mpiifort -mpi -bfd=download -pdt=<dir> -papi=<dir> ...`
- `make install; export PATH=<taudir>/x86_64/bin:$PATH`

## ■ Using TAU for source instrumentation:

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

# Using TAU's Source Code Instrumentation

- TAU supports several compilers, measurement, and thread options

Intel compilers, profiling with hardware counters using PAPI, MPI library, CUDA...

Each measurement configuration of TAU corresponds to a unique stub makefile (configuration file) 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:

- `% jutil env activate -p cjzam11 -A jzam11`
- `% module use /p/scratch/share/VI-HPS/JURECA/mf`
- `% module load tau`
- `% export TAU_MAKEFILE=$TAU/Makefile.tau-icpc-papi-mpi-pdt-openmp-opari`  
`% export TAU_OPTIONS='-optVerbose ...' (see tau_compiler.sh )`

Use `tau_f90.sh`, `tau_f77.sh`, `tau_cxx.sh`, `tau_upc.sh`, or `tau_cc.sh` as F90, F77, 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)



## Makefiles for TAU Compiler and Runtime Options (Jureca)

```
% module use /p/scratch/share/VI-HPS/JURECA/mf; module load tau
% echo $TAU
/p/scratch/share/VI-HPS/JURECA/packages/tau2.28.1-intel-cluster/x86_64/lib
% ls $TAU/Makefile.*
/p/scratch/share/VI-HPS/JURECA/packages/tau2.28.1-intel-cluster/x86_64/lib/Makefile.tau-icpc-papi-mpi-pdt-openmp-opari
/p/scratch/share/VI-HPS/JURECA/packages/tau2.28.1-intel-cluster/x86_64/lib/Makefile.tau-icpc-papi-mpi-pthread-pdt
/p/scratch/share/VI-HPS/JURECA/packages/tau2.28.1-intel-cluster/x86_64/lib/Makefile.tau-icpc-papi-ompt-tr6-mpi-pdt-openmp
/p/scratch/share/VI-HPS/JURECA/packages/tau2.28.1-intel-cluster/x86_64/lib/Makefile.tau-icpc-papi-ompt-tr6-pdt-openmp
/p/scratch/share/VI-HPS/JURECA/packages/tau2.28.1-intel-cluster/x86_64/lib/Makefile.tau-icpc-papi-pdt
/p/scratch/share/VI-HPS/JURECA/packages/tau2.28.1-intel-cluster/x86_64/lib/Makefile.tau-icpc-papi-pthread-pdt
```

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

**Makefile.tau-icpc-papi-mpi-pdt-openmp-opari**

- Supports MPI instrumentation & PDT for automatic source instrumentation

```
% export TAU_MAKEFILE=$TAU/Makefile.tau-icpc-papi-mpi-pdt-openmp-opari
% tau_f90.sh matmult.f90 -o matmult
% aprun -n 16 ./matmult
% 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:

```
% aprun -n 256 ./a.out to
```

```
% aprun -n 256 tau_exec -T <comma_separated_options> ./a.out
```

```
% aprun -n 256 tau_exec -T papi,mpi,pdt ./a.out
```

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

```
% aprun -n 256 tau_exec -T papi ./a.out
```

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

```
% aprun -n 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.

## Simplifying TAU's usage (tau\_exec)

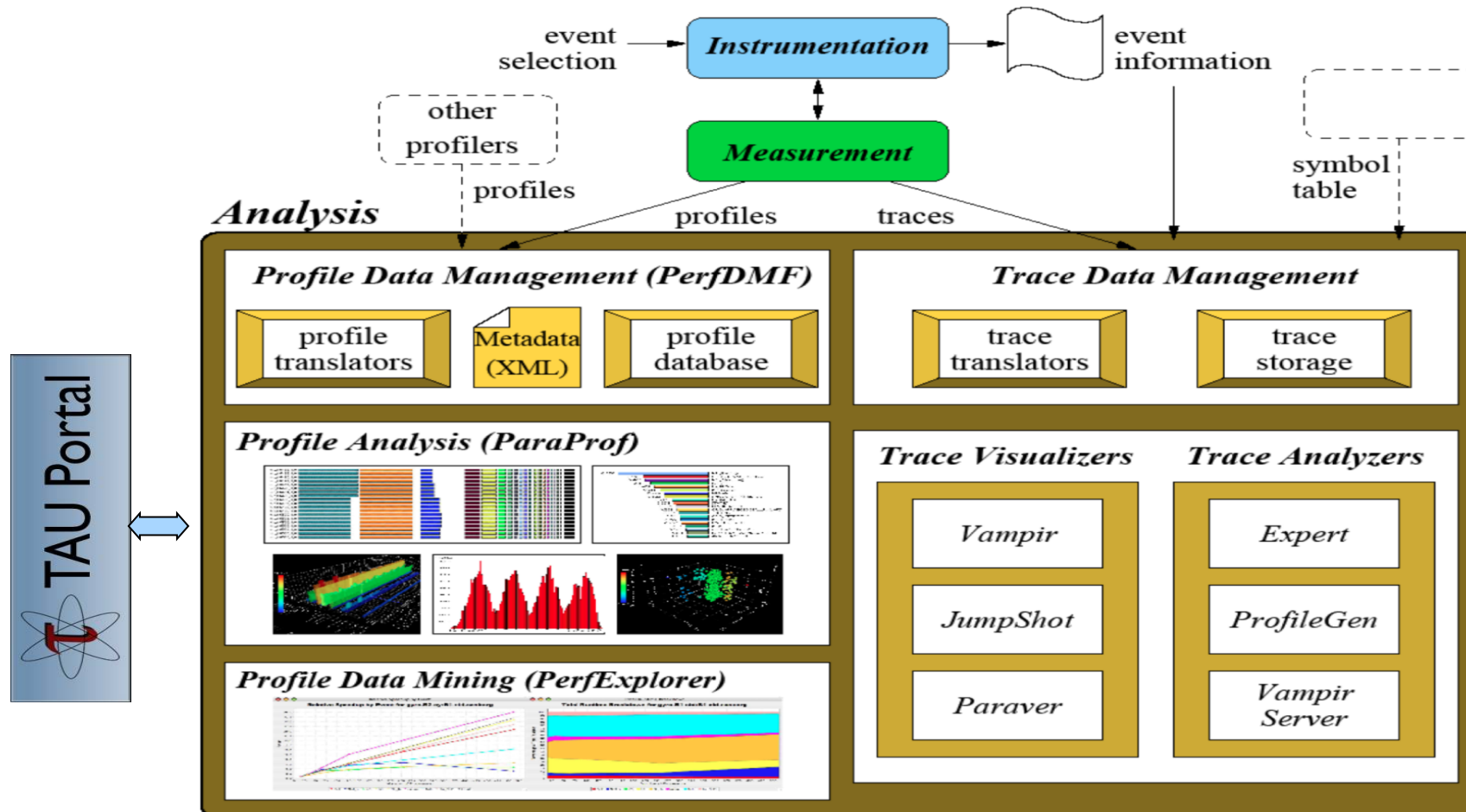
---

- Uninstrumented execution
  - % aprun -n 16 ./a.out
- Track MPI performance
  - % aprun -n 16 **tau\_exec** ./a.out
- Track OpenMP, and MPI performance (MPI enabled by default)
  - % export TAU\_OMPT\_SUPPORT\_LEVEL=full; export TAU\_OMPT\_RESOLVE\_ADDRESS\_EAGERLY=1
  - % aprun -n 16 **tau\_exec -T** mpi,pdt,ompt,papi **-ompt** ./a.out
- Track memory operations
  - % export TAU\_TRACK\_MEMORY\_LEAKS=1
  - % mpirun -np 16 **tau\_exec -memory\_debug** ./a.out (bounds check)
- Use event based sampling (compile with -g)
  - % mpirun -np 16 **tau\_exec -ebs** ./a.out
  - Also -ebs\_source=<PAPI\_COUNTER> -ebs\_period=<overflow\_count> -ebs\_resolution=<file|function|line>
- Load wrapper interposition library
  - % mpirun -np 16 **tau\_exec -loadlib=<path/libwrapper.so>** ./a.out
- **Track GPGPU operations (-rocm, -opencl, -cupti, -cupti -um, -openacc):**
  - % mpirun -np 16 **tau\_exec -cupti** ./a.out

---

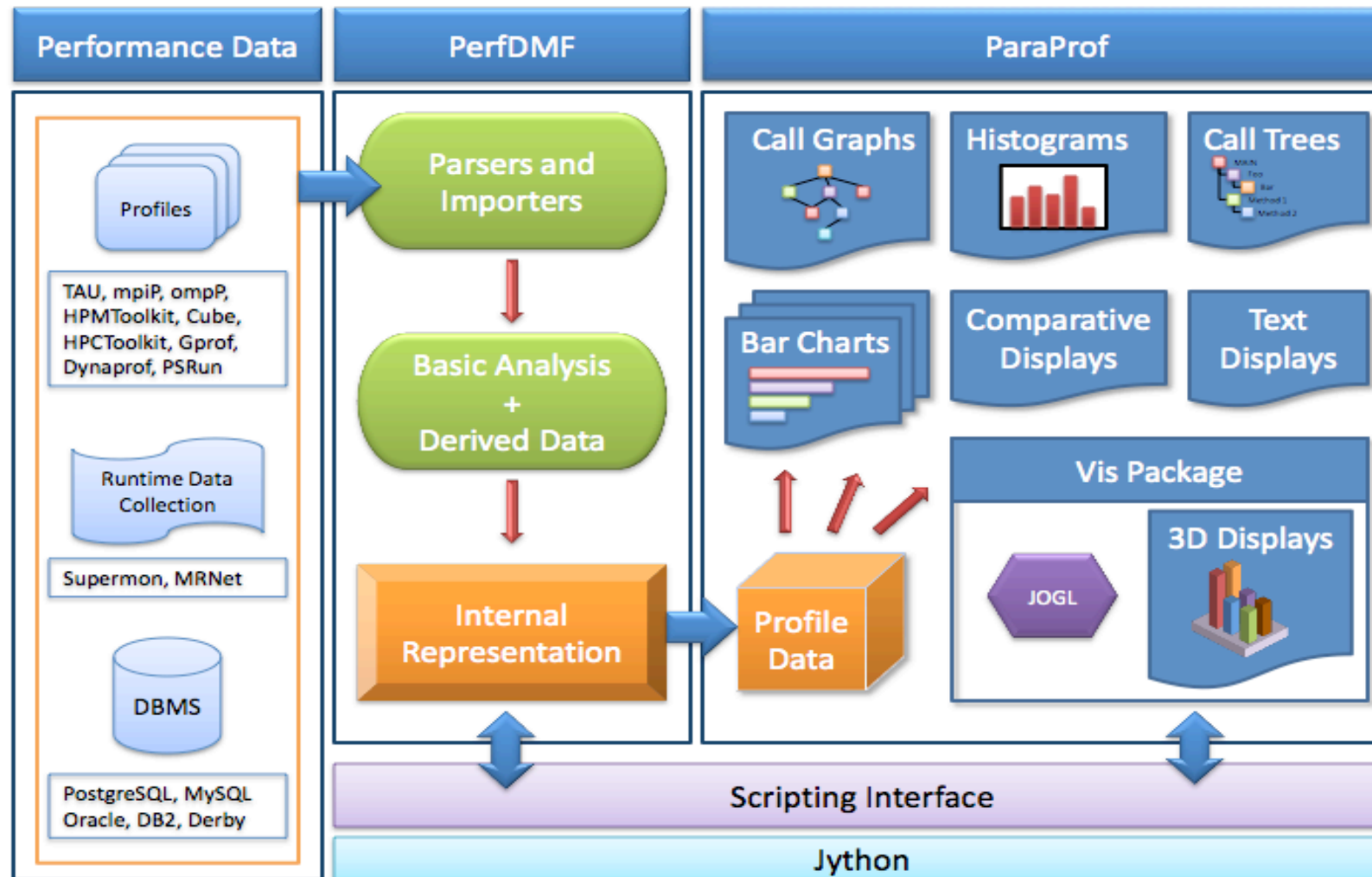
# TAU's Analysis Tools: ParaProf

# TAU Analysis





# ParaProf Profile Analysis Framework



# TAU Analysis Tools: paraprof

## ▪ Launch paraprof

```
% paraprof
```

Metric

TAU: ParaProf Manager

Applications

- Standard Applications
  - Default App
    - Default Exp
      - bt\_ompt.ppk
        - TIME

Default (jdbc:h2:/Users/sameer/.ParaProf/perfdmf/perfdmf;AUTO\_SERVER=TRUE)

TrialField	Value
Name	bt_ompt.ppk
Application ID	0
Experiment ID	0
Trial ID	0
CPU Cores	8
CPU MHz	2600.000
CPU Type	Intel(R) Xeon(R) CPU E5-2670 0 @ 2.60GHz
CPU Vendor	GenuineIntel
CWD	/scratch/sameer/NPB3.3-MZ-MPI/bin
Cache Size	20480 KB
Command Line	./bt-mz_C.8
Executable	/scratch/sameer/NPB3.3-MZ-MPI/bin/bt-mz_C.8
File Type Index	0
File Type Name	ParaProf Packed Profile
Hostname	frog9
Local Time	2015-05-18T00:37:38+02:00
MPI Processor Name	frog9
Memory Size	65944056 kB
Node Name	frog9
OMP_CHUNK_SIZE	1
OMP_DYNAMIC	off
OMP_MAX_THREADS	4
OMP_NESTED	off
OMP_NUM_PROCS	4
OMP_SCHEDULE	UNKNOWN
OS Machine	x86_64
OS Name	Linux
OS Release	2.6.32-279.5.2.el6.Bull.33.x86_64
OS Version	#1 SMP Sat Nov 10 01:48:00 CET 2012

# ParaProf Manager Widow: scout.cubex

TAU: ParaProf Manager

File Options Help

Applications

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

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

Metrics in the profile

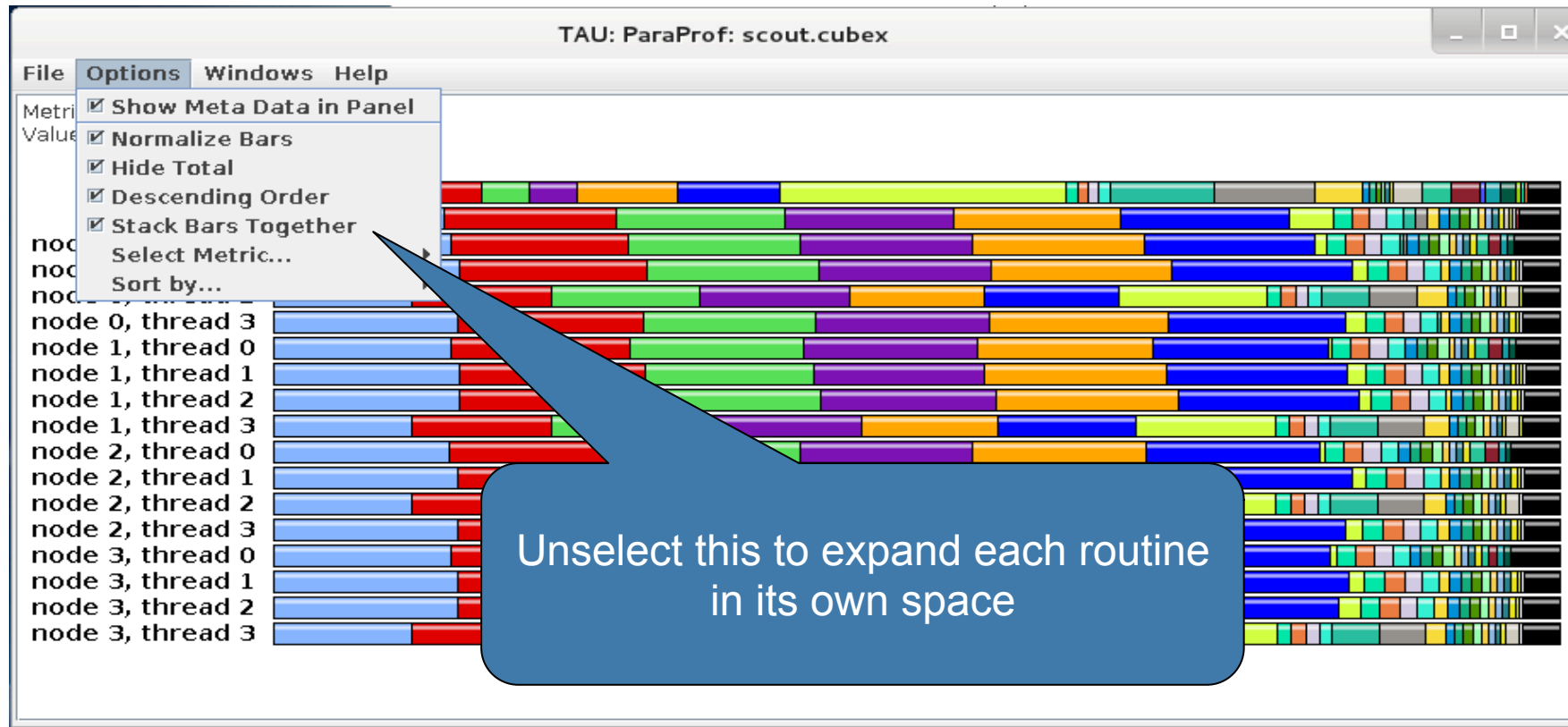
# Paraprof main window



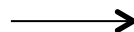
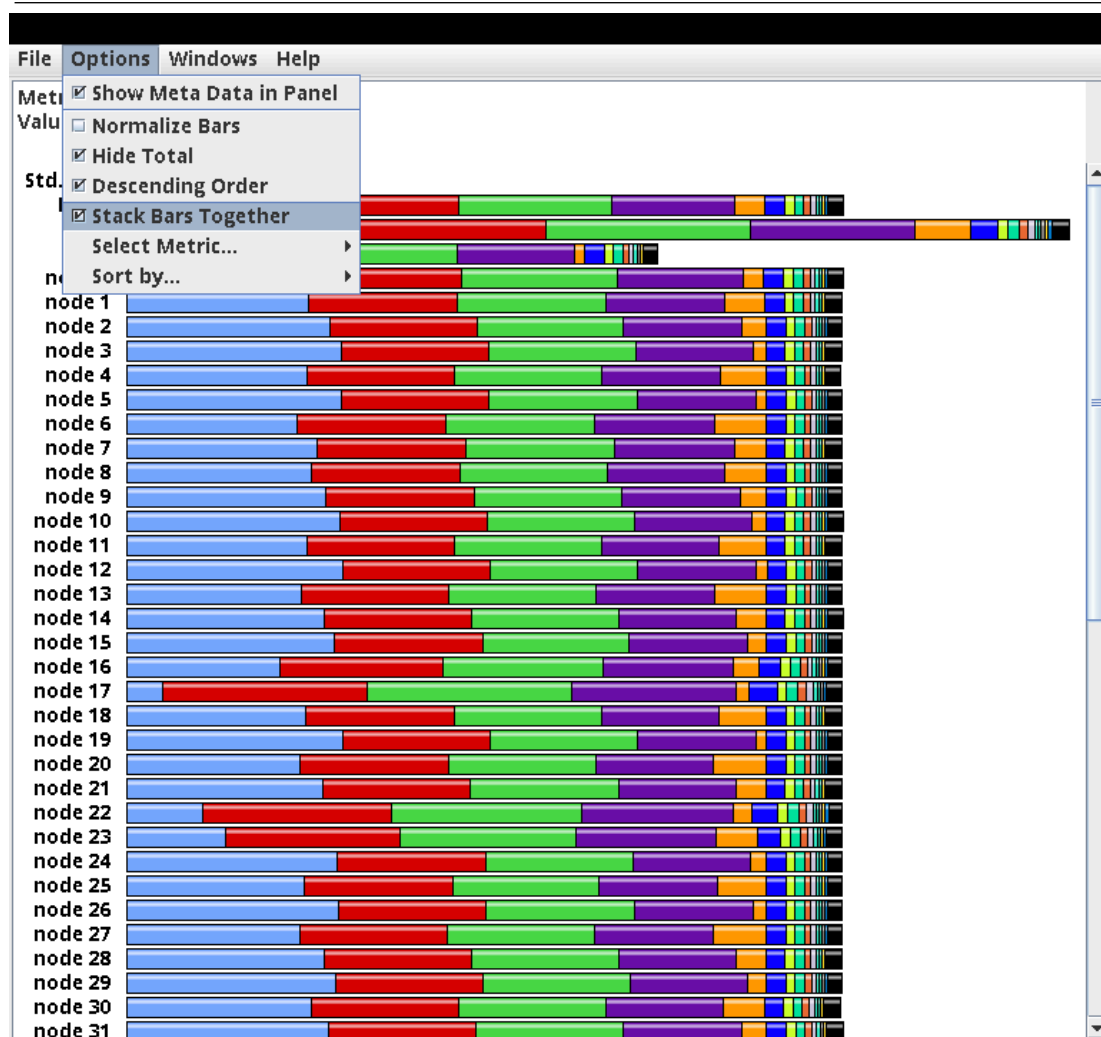
Colors represent code regions

Options -> uncheck Stack Bars Together

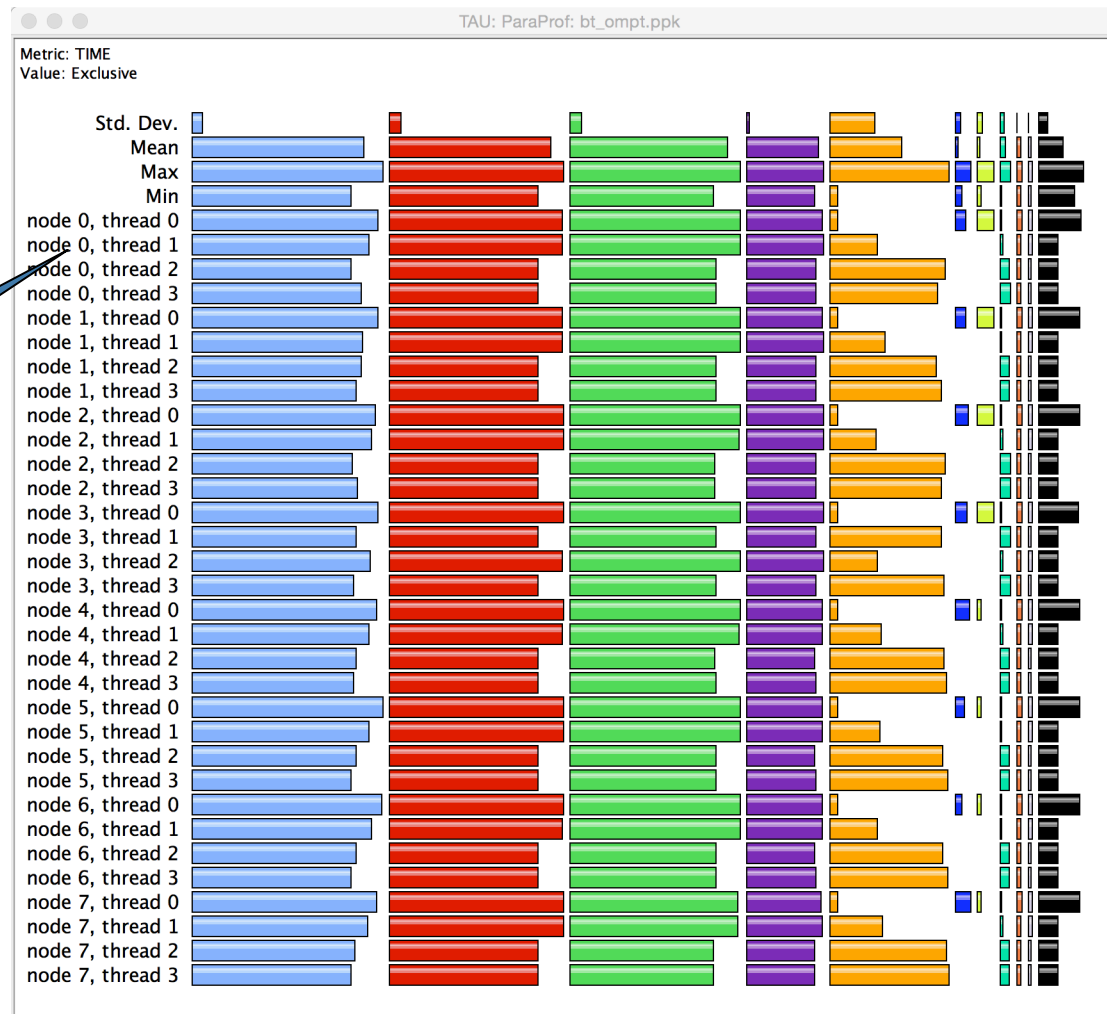
# Paraprof main window



# ParaProf Profile Browser



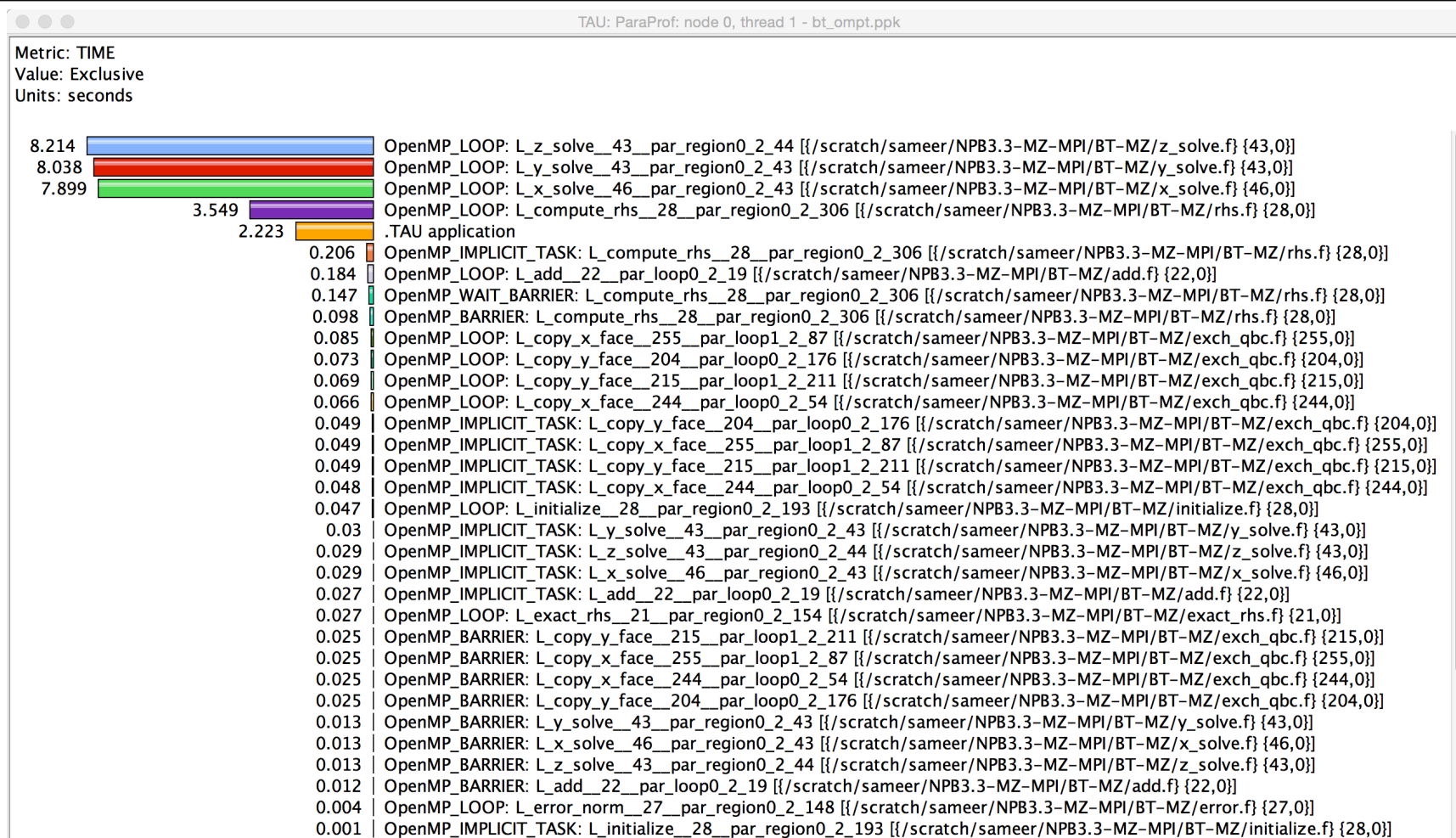
# Paraprof main window



Each routine occupies its own space.  
Can see the extent of imbalance  
across all threads.



# Paraprof node window (function barchart window)

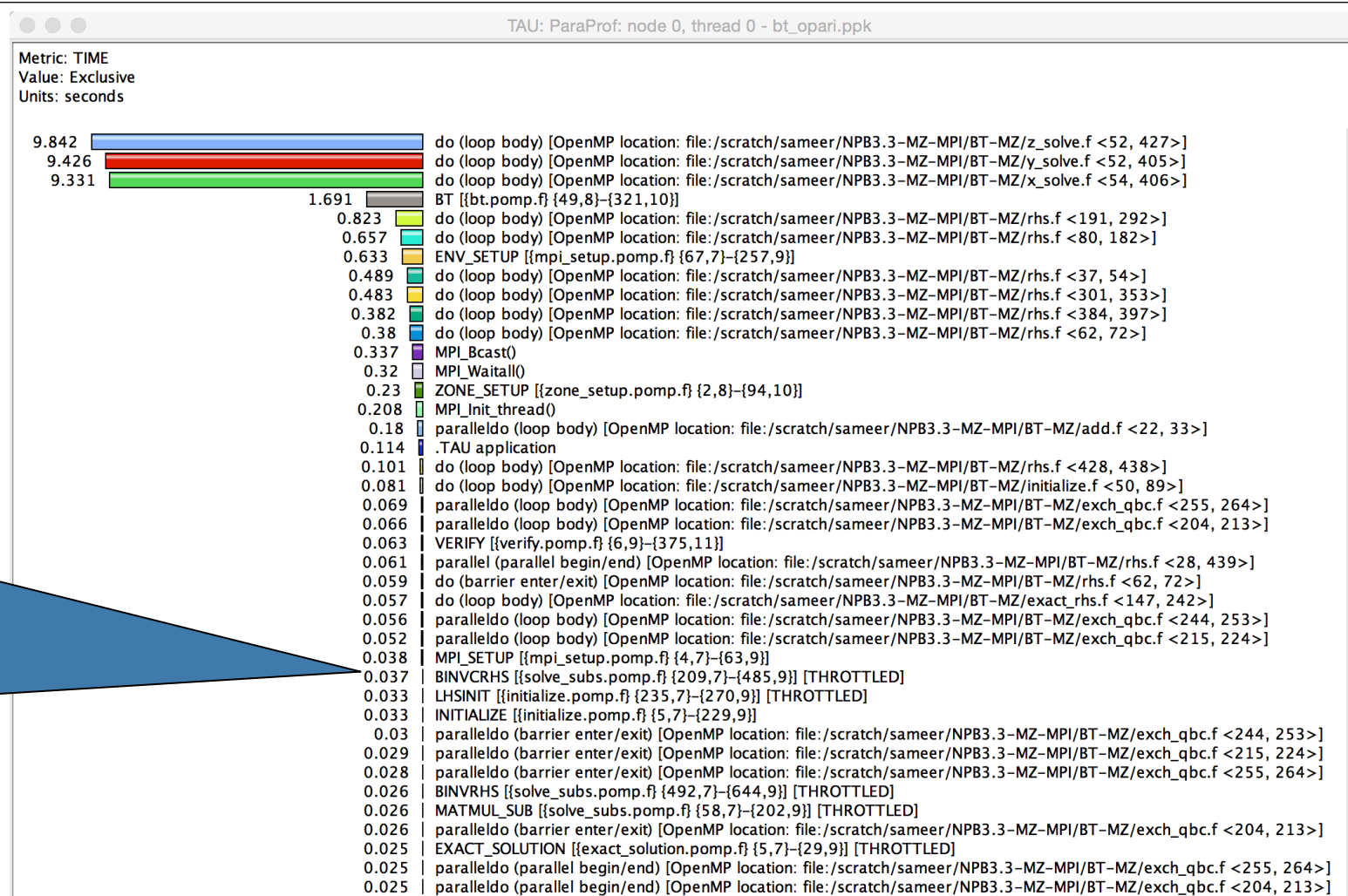


Exclusive time spent in each code region (OpenMP loop) is shown here for MPI rank 0 thread 1

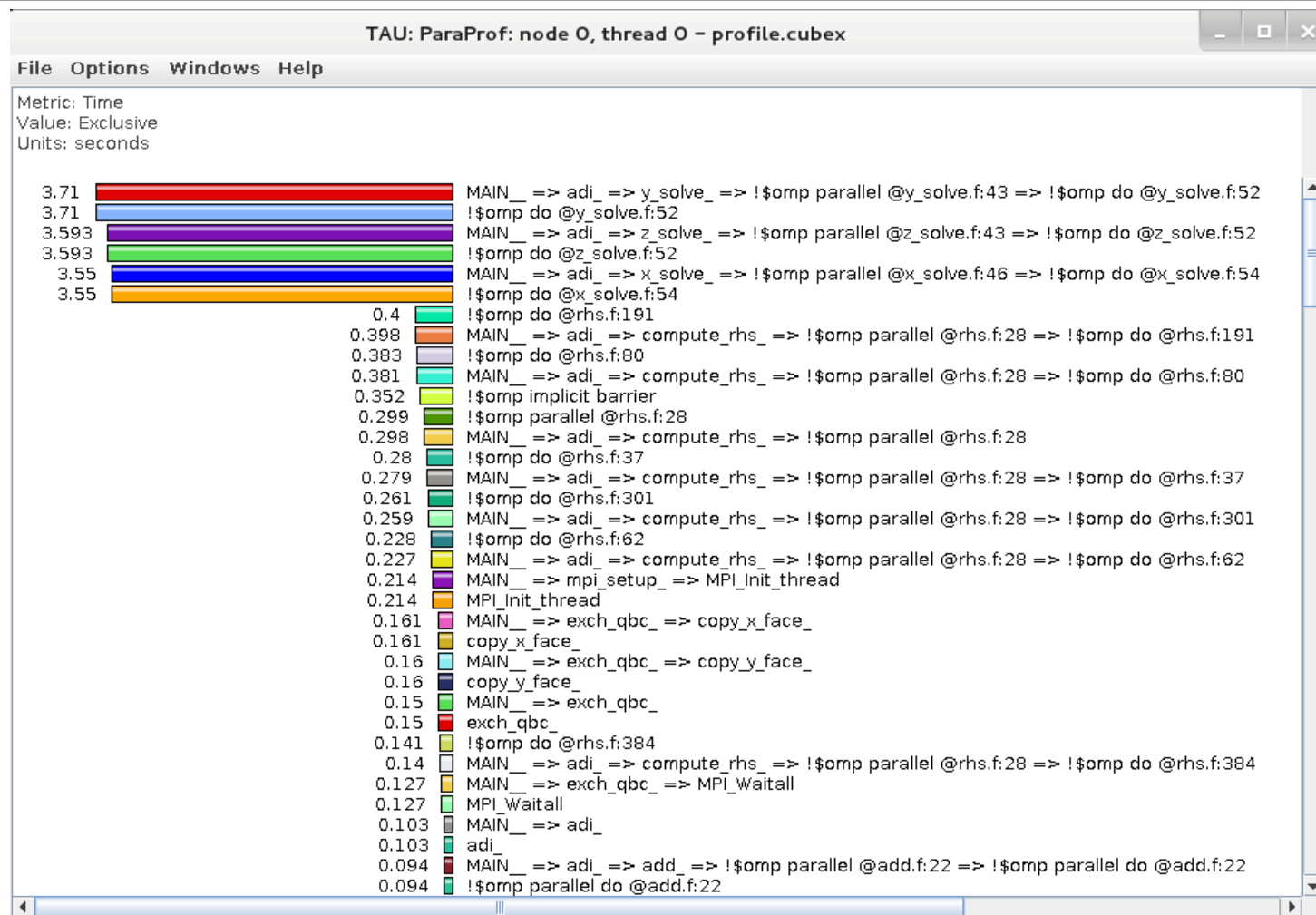


# Instrumenting Source Code with PDT and Opari

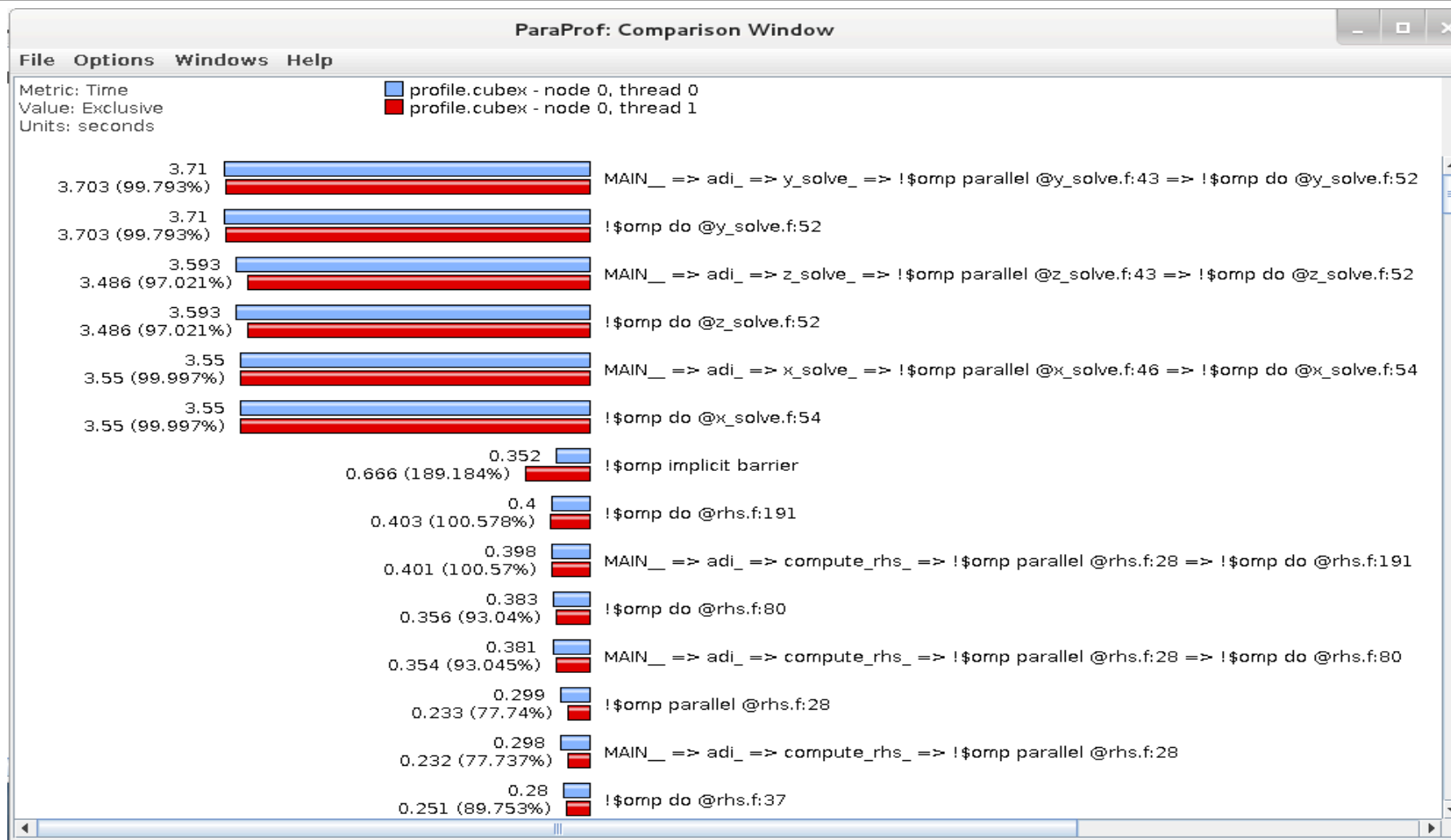
Frequently  
executing  
lightweight  
routines are  
automatically  
throttled at  
runtime.  
Reduces  
runtime  
dilation.



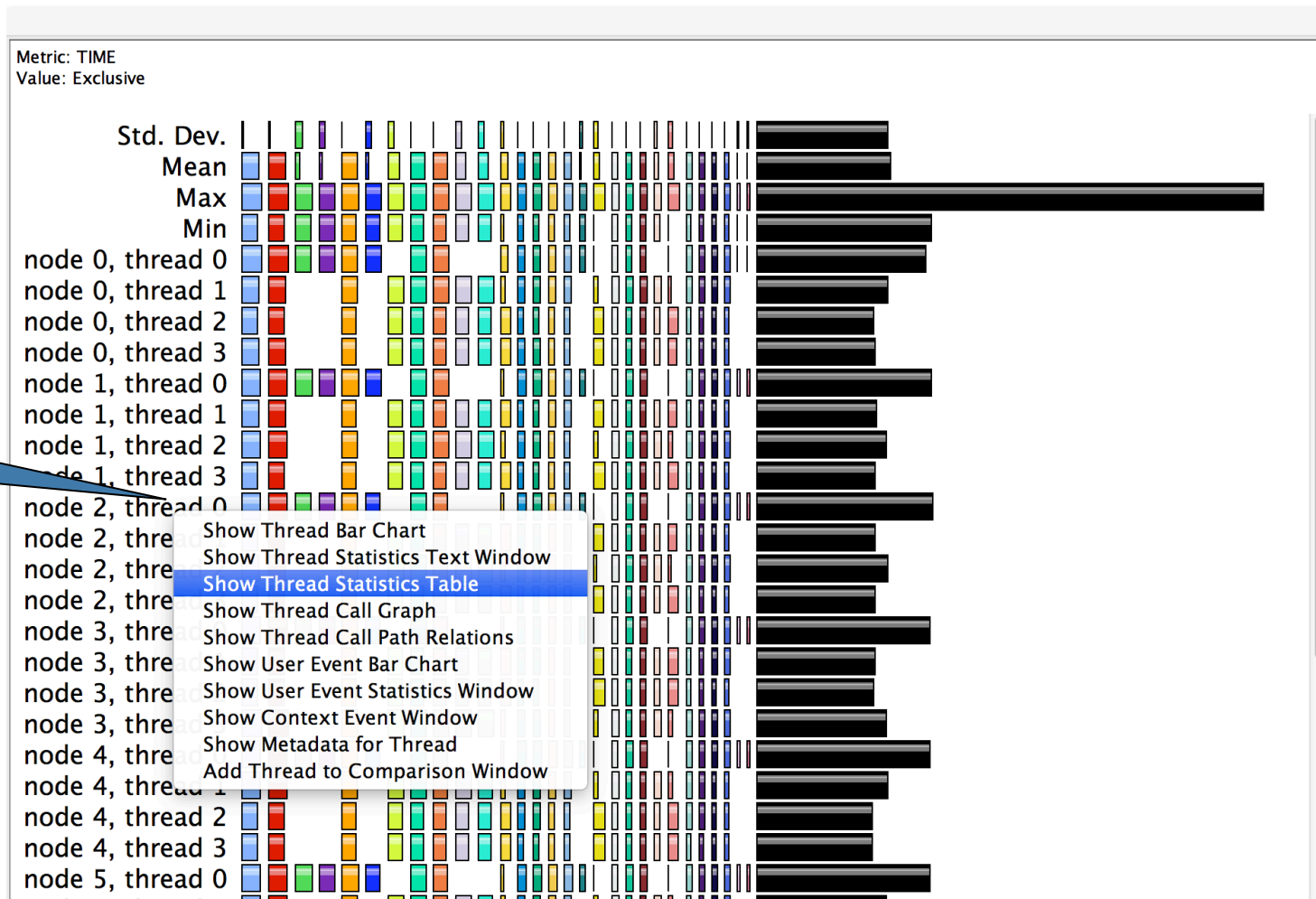
# ParaProf: Node view in a callpath profile



# ParaProf: Add thread to comparison window



## Paraprof Thread Statistics Table with TAU\_SAMPLING=1



Right click  
here

# ParaProf: Thread Statistics Table

TAU: ParaProf: Statistics for: node 0, thread 0 - scout.cubex

File Options Windows Help

Time

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

FinderScreenSnapz003.png

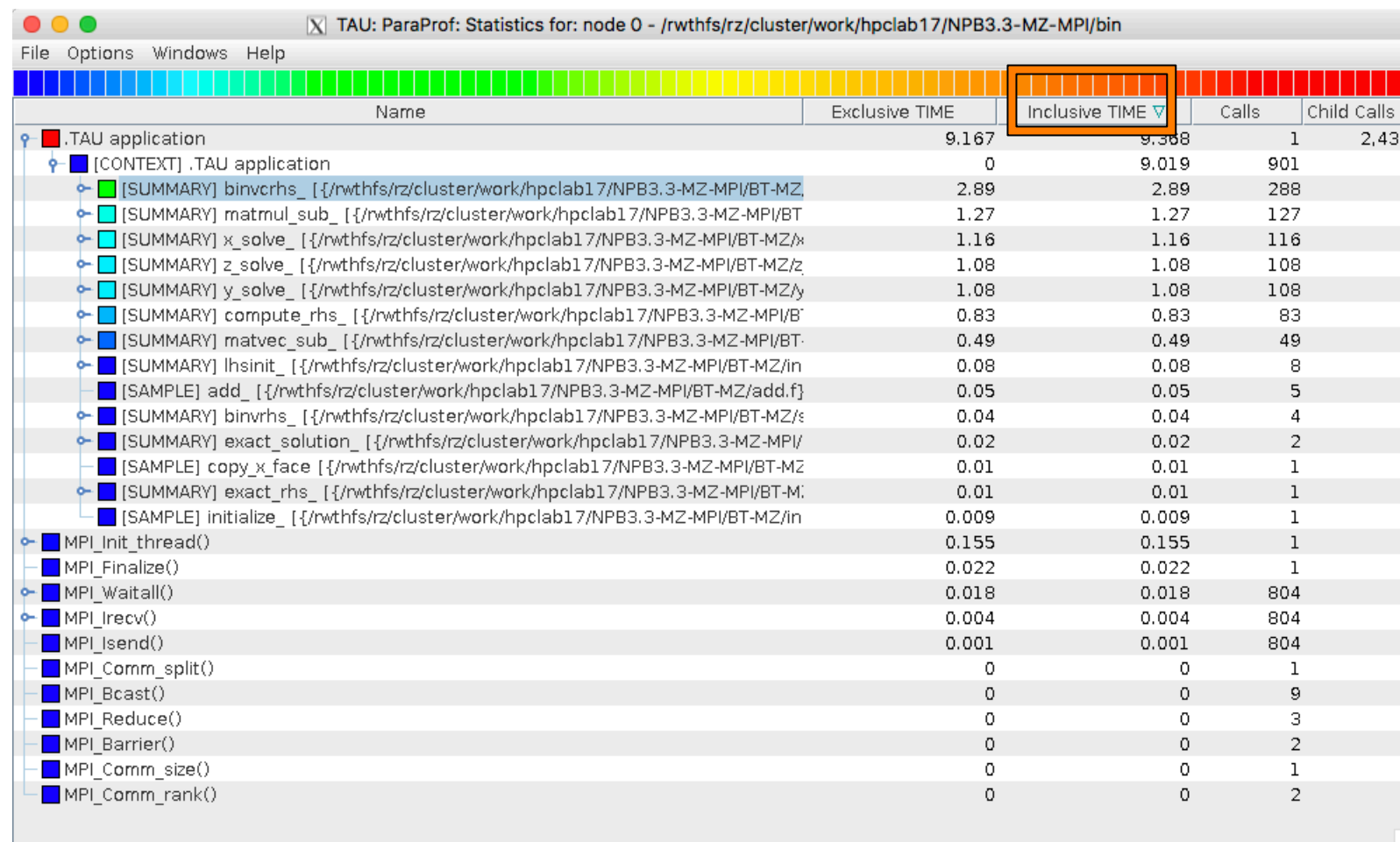
Click to sort by a given metric, drag and move to rearrange columns

# ParaProf

- Click on Columns:
- to sort by incl time
- Open binvrchs
- Click on Sample

TAU: ParaProf: Statistics for: node 0 - /rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/bin

File Options Windows Help



Name	Exclusive TIME	Inclusive TIME	Calls	Child Calls
.TAU application	9.167	9.368	1	2,432
[CONTEXT] .TAU application	0	9.019	901	0
[SUMMARY] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/	2.89	2.89	288	0
[SUMMARY] matmul_sub_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT	1.27	1.27	127	0
[SUMMARY] x_solve_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/x	1.16	1.16	116	0
[SUMMARY] z_solve_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/z	1.08	1.08	108	0
[SUMMARY] y_solve_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/y	1.08	1.08	108	0
[SUMMARY] compute_rhs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/B	0.83	0.83	83	0
[SUMMARY] matvec_sub_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT	0.49	0.49	49	0
[SUMMARY] lhsinit_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/in	0.08	0.08	8	0
[SAMPLE] add_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/add.f}	0.05	0.05	5	0
[SUMMARY] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/s	0.04	0.04	4	0
[SUMMARY] exact_solution_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/	0.02	0.02	2	0
[SAMPLE] copy_x_face [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ	0.01	0.01	1	0
[SUMMARY] exact_rhs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-M	0.01	0.01	1	0
[SAMPLE] initialize_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/in	0.009	0.009	1	0
MPI_Init_thread()	0.155	0.155	1	0
MPI_Finalize()	0.022	0.022	1	0
MPI_Waitall()	0.018	0.018	804	0
MPI_Irecv()	0.004	0.004	804	0
MPI_Isend()	0.001	0.001	804	0
MPI_Comm_split()	0	0	1	0
MPI_Bcast()	0	0	9	0
MPI_Reduce()	0	0	3	0
MPI_Barrier()	0	0	2	0
MPI_Comm_size()	0	0	1	0
MPI_Comm_rank()	0	0	2	0



# Paraprof 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

Right click here and choose "Show Source Code" for a sample

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

# ParaProf

TAU: ParaProf: Statistics for: node 0 - /rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/bin

File Options Windows Help

Name	Exclusive TIME	Inclusive TIME ▾	Calls	Child Calls
.TAU application	9.167	9.368	1	2,432
[CONTEXT] .TAU application	0	9.019	901	0
[SUMMARY] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}]	2.89	2.89	288	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {228}	0.14	0.14	14	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}]	0.09	0.09	9	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}]	0.09	0.09	9	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}]	0.06	0.06	6	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}]	0.06	0.06	6	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}]	0.06	0.06	6	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}]	0.06	0.06	6	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {244}	0.05	0.05	5	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {332}	0.05	0.05	5	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {275}	0.05	0.05	5	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {331}	0.04	0.04	4	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {445}	0.04	0.04	4	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {254}	0.04	0.04	4	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {314}	0.04	0.04	4	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {343}	0.04	0.04	4	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {403}	0.04	0.04	4	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {389}	0.03	0.03	3	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {415}	0.03	0.03	3	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {247}	0.03	0.03	3	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {300}	0.03	0.03	3	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {309}	0.03	0.03	3	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {444}	0.03	0.03	3	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {468}	0.03	0.03	3	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {242}	0.03	0.03	3	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {407}	0.03	0.03	3	0
[SAMPLE] binvrchs_ [{/rwthfs/rz/cluster/work/hpclub17/NPB3.3-MZ-MPI/BT-MZ/solve_subs.f}] {412}	0.03	0.03	3	0

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

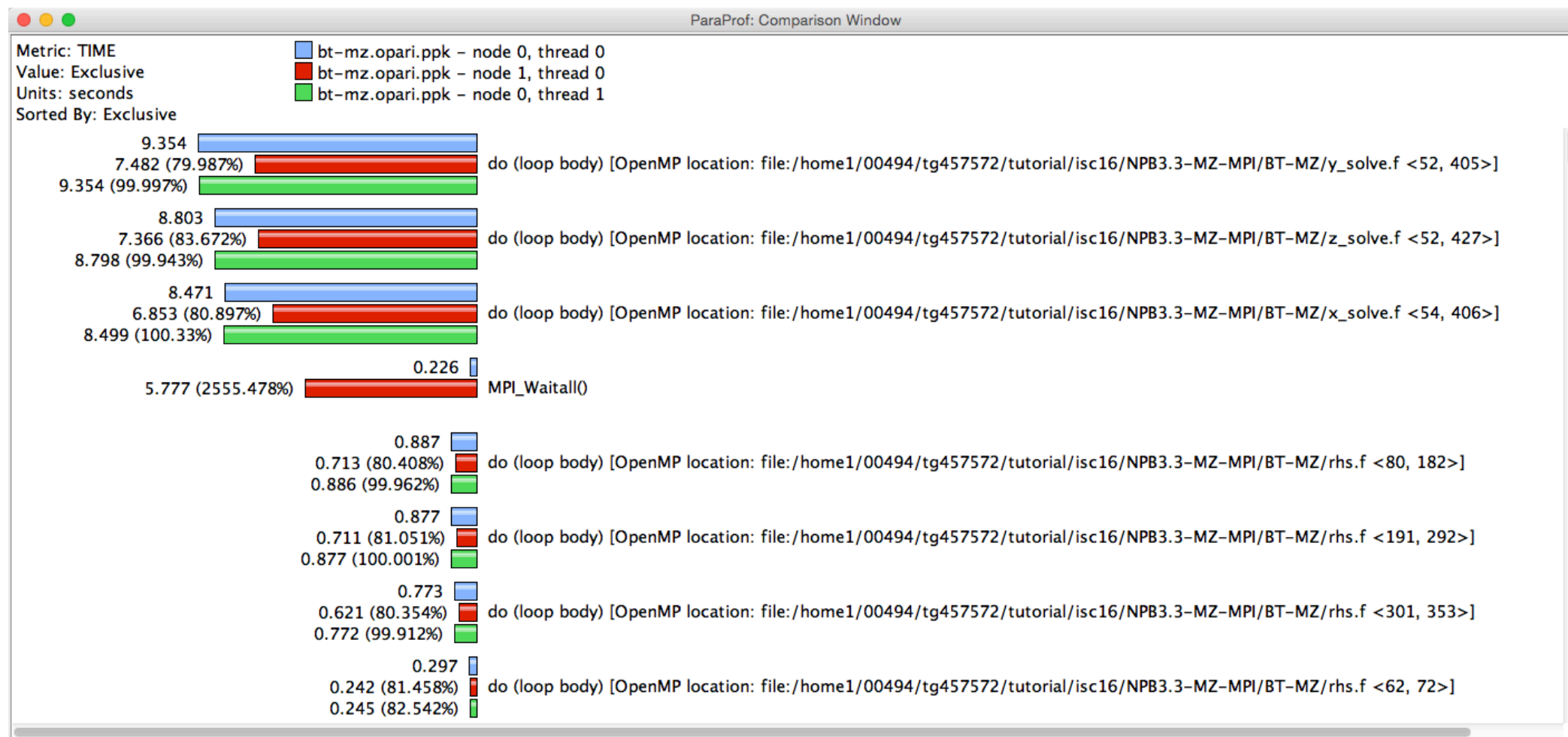


# Statement Level Profiling with TAU

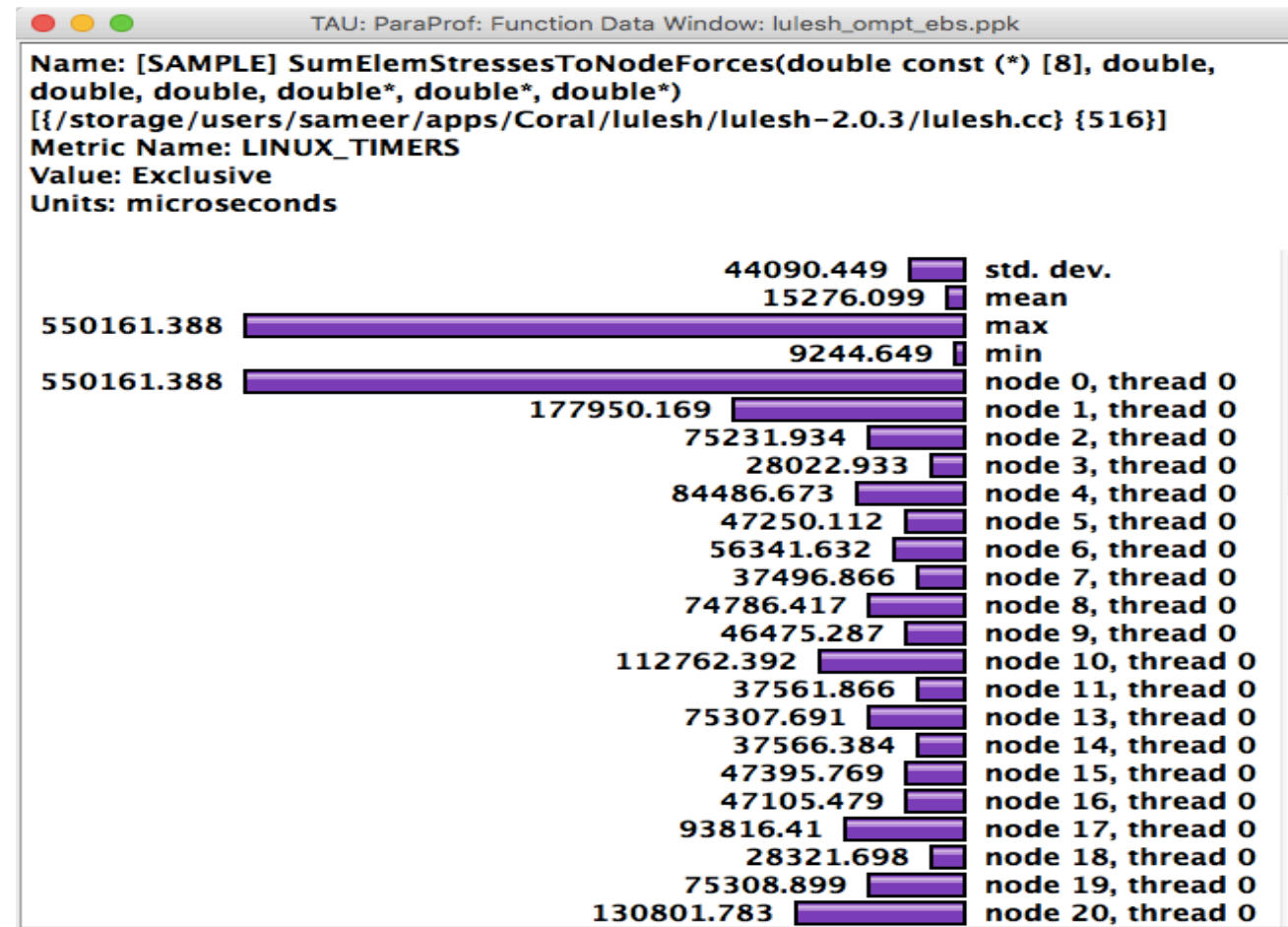
```
TAU: ParaProf: Source Browser: /scratch/sameer/NPB3.3-MZ-MPI/BT-MZ/x_solve.f
File Help
353      call matmul_sub(lhs(1,1,aa,i),
354      v      lhs(1,1,cc,i-1),
355      v      lhs(1,1,bb,i))
356
357
358 C-----
359 c      multiply c(i,j,k) by b_inverse and copy back to c
360 c      multiply rhs(1,j,k) by b_inverse(1,j,k) and copy to rhs
361 C-----
362      call binvrhs( lhs(1,1,bb,i),
363      v      lhs(1,1,cc,i),
364      v      rhs(1,i,j,k) )
365
366      enddo
367
368 C-----
369 c      rhs(isize) = rhs(isize) - A*rhs(isize-1)
370 C-----
371      call matvec_sub(lhs(1,1,aa, isize),
372      v      rhs(1, isize-1,j,k), rhs(1, isize,j,k))
373
374 C-----
375 c      B(isize) = B(isize) - C(isize-1)*A(isize)
376 C-----
377      call matmul_sub(lhs(1,1,aa, isize),
378      v      lhs(1,1,cc, isize-1),
379      v      lhs(1,1,bb, isize))
380
381 C-----
382 c      multiply rhs() by b_inverse() and copy to rhs
383 C-----
384      call binvrhs( lhs(1,1,bb, isize),
385      v      rhs(1, isize,j,k) )
386
387 C-----
388 c      back solve: if last cell, then generate U(isize)=rhs(isize)
389 c      else assume U(isize) is loaded in un pack backsub_info
390 c      so just use it
391 c      after call u(istart) will be sent to next cell
392 C-----
393
394      do i=isize-1,0,-1
395      do m=1,BLOCK_SIZE
396      do n=1,BLOCK_SIZE
397      rhs(m,i,j,k) = rhs(m,i,j,k)
398      v      - lhs(m,n,cc,i)*rhs(n,i+1,j,k)
399      enddo
400      enddo
401      enddo
402
```

Source  
location  
where  
samples are  
taken.  
Compute  
intensive  
region.

# ParaProf Comparison Window



## TAU – Event Based Sampling (EBS)



% export TAU\_SAMPLING=1

# Examples: Callstack Sampling in TAU

TAU: ParaProf: Statistics for: n,c,t 2,0,0 - gamess\_unw\_call\_ebs.ppk

Name	Inclusive TIME ▾	Calls
■ .TAU application	79.592	1
▾ ■ MPI_Recv()	75.607	6,870
▾ ■ [CONTEXT] MPI_Recv()	74.848	1,497
▸ ■ [UNWIND] /gpfs/mira-home/sameer/gamess-theta-tau/object/unport.f.410 [ @ ] MAIN__ [ { /gpfs/mira-home/sameer/gamess-theta-t	26.196	524
▸ ■ [UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_fortran.c.67 [ @ ] beging_ [ { /gpfs/mira-home/sameer/g	21.7	434
▸ ■ [UNWIND] /gpfs/mira-home/sameer/gamess-theta-tau/object/gamess.f.538 [ @ ] main [ { /gpfs/mira-home/sameer/gamess-theta-ta	11.85	237
▸ ■ [UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_init.c.113 [ @ ] ddi_init_ [ { /gpfs/mira-home/yuri/dist/Gi	8.701	174
▸ ■ [UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_server.c.99 [ @ ] DDI_Init [ { /gpfs/mira-home/yuri/dist/C	5.75	115
▸ ■ [UNWIND] /lib64/libc-2.22.so.0 [ @ ] _start [ { /home/abuild/rpmbuild/BUILD/glibc-2.22/csu/./sysdeps/x86_64/start.S } { 118 } ]	0.2	4
▸ ■ [SAMPLE] GNII_DlaProgress [ { /opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0 } { 0 } ]	0.2	4
▸ ■ [UNWIND] [ /opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0.0 ] [ @ ] UNRESOLVED UNKNOWN	0.15	3
▸ ■ [SAMPLE] GNI_CqGetEvent [ { /opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0 } { 0 } ]	0.051	1
▸ ■ [UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [ @ ] MPIDI_CH3I_Progress [ { /opt/cray/pe/mpt/7	0.05	1
▸ ■ MPI_Finalize()	3.601	1
▸ ■ MPI_Send()	0.122	6,866
▸ ■ MPI_Init_thread()	0.112	1
▸ ■ [CONTEXT] .TAU application	0.05	1
▸ ■ MPI_Bcast()	0.014	6
▸ ■ MPI_Allgather()	0.004	3
▸ ■ MPI_Barrier()	0.003	7
▸ ■ MPI_Comm_create()	0.002	4
▸ ■ MPI_Gather()	0.002	1
▸ ■ MPI_Comm_split()	0.002	1
▸ ■ MPI_Group_intersection()	0.001	1
▸ ■ MPI_Comm_group()	0.001	1
▸ ■ MPI_Group_incl()	0	3
▸ ■ MPI_Comm_rank()	0	6
▸ ■ MPI_Comm_size()	0	2

% export TAU\_SAMPLING=1; export TAU\_EBS\_UNWIND=1

Name	Inclusive TIME	Calls
.TAU application	79.592	1
MPI_Recv()	75.607	6,870
[CONTEXT] MPI_Recv()	74.848	1,497
[UNWIND] /gpfs/mira-home/sameer/gamess-theta-tau/object/unport.f.410 [MAIN__]	26.196	524
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_fortran.c.67 [beging_]	21.7	434
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_init.c.113 [ddi_init_]	21.7	434
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_server.c.99 [DDI_Init]	21.7	434
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_recv.c.65 [DDI_Server]	21.7	434
[UNWIND] /lus/theta-fs0/software/perftools/tau/tau-2.26.3/src/Profile/TauMpi.c.2371 [DDI_Recv_request]	21.7	434
[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [MPI_Recv]	21.7	434
[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [PMPI_Recv]	21.7	434
[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [MPIDI_CH3I_Progress]	21.45	429
[UNWIND] /opt/cray/ugni/6.0.14-6.0.4.0_14.1_ge7db4a2.ari/lib64/libugni.so.0.6.0 [MPID_nem_gni_poll]	15.95	319
[SAMPLE] GNI_SmsgGetNextWTag	10.349	207
[SAMPLE] GNI_CqGetEvent	5.6	112
[UNWIND] gni_poll.c.0 [MPID_nem_gni_poll]	5.25	105
[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [MPID_nem_gni_poll]	0.25	5
[UNWIND] UNRESOLVED [MPIDI_CH3I_Progress]	0.25	5
[UNWIND] /gpfs/mira-home/sameer/gamess-theta-tau/object/gamess.f.538 [main]	11.85	237
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_init.c.113 [ddi_init_]	8.701	174
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_server.c.99 [DDI_Init]	5.75	115
[UNWIND] /lib64/libc-2.22.so.0 [_start]	0.2	4
[SAMPLE] GNI_DlaProgress	0.2	4
[UNWIND] /opt/cray/ugni/6.0.14-6.0.4.0_14.1_ge7db4a2.ari/lib64/libugni.so.0.6.0 [UNRESOLVED UNKNOWN]	0.15	3
[SAMPLE] GNI_CqGetEvent	0.051	1
[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [MPIDI_CH3I_Progress]	0.05	1
MPI_Finalize()	3.601	1
MPI_Send()	0.122	6,866
MPI_Init_thread()	0.112	1
[CONTEXT] .TAU application	0.05	1

% export TAU SAMPLING=1; export TAU EBS UNWIND=1



Name	Inclusive TIME ▾	Calls
.TAU application	79.592	1
MPI_Recv()	75.607	6,870
[CONTEXT] MPI_Recv()	74.848	1,497
[UNWIND] /gpfs/mira-home/sameer/gamess-theta-tau/object/unport.f.410 [ @ ] MAIN__ [ { /gpfs/mira-home/sameer/gamess-theta-	26.196	524
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_fortran.c.67 [ @ ] beging_ [ { /gpfs/mira-home/sameer/g	21.7	434
[UNWIND] /gpfs/mira-home/sameer/gamess-theta-tau/object/gamess.f.538 [ @ ] main [ { /gpfs/mira-home/sameer/gamess-theta-ta	11.85	237
[UNWIND] /gpfs/mira-home/sameer/gamess-theta-tau/object/unport.f.410 [ @ ] MAIN__ [ { /gpfs/mira-home/sameer/gamess-thet	11.85	237
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_fortran.c.67 [ @ ] beging_ [ { /gpfs/mira-home/sam	11.85	237
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_init.c.113 [ @ ] ddi_init_ [ { /gpfs/mira-home/yur	11.85	237
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_server.c.99 [ @ ] DDI_Init [ { /gpfs/mira-home/	11.85	237
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_recv.c.65 [ @ ] DDI_Server [ { /gpfs/mira-ho	11.85	237
[UNWIND] /lus/theta-fs0/software/perftools/tau/tau-2.26.3/src/Profile/TauMpi.c.2371 [ @ ] DDI_Recv_request [ { /gpfs	11.85	237
[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [ @ ] MPI_Recv [ { /lus/theta-fs	11.85	237
[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [ @ ] PMPI_Recv [ { /opt/cray,	11.7	234
[SAMPLE] MPIDI_CH3I_Progress [ { /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1 } { 0	11.3	226
[SAMPLE] MPIDU_Sched_are_pending [ { /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0	0.2	4
[SAMPLE] MPID_nem_gni_poll [ { /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1 } { 0 }	0.15	3
[SAMPLE] MPID_nem_network_poll [ { /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1	0.05	1
[UNWIND] ch3_progress.c.0 [ @ ] PMPI_Recv [ { /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.	0.15	3
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_init.c.113 [ @ ] ddi_init_ [ { /gpfs/mira-home/yuri/dist/G	8.701	174
[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_server.c.99 [ @ ] DDI_Init [ { /gpfs/mira-home/yuri/dist/i	5.75	115
[UNWIND] /lib64/libc-2.22.so.0 [ @ ] _start [ { /home/abuild/rpmbuild/BUILD/glibc-2.22/csu/../sysdeps/x86_64/start.S } { 118 } }	0.2	4
[SAMPLE] GNII_DlaProgress [ { /opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0 } { 0 }	0.2	4
[UNWIND] [/opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0.0] [ @ ] UNRESOLVED UNKNOWN	0.15	3
[SAMPLE] GNI_CqGetEvent [ { /opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0 } { 0 }	0.051	1
[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [ @ ] MPIDI_CH3I_Progress [ { /opt/cray/pe/mpt/	0.05	1
MPI_Finalize()	3.601	1
MPI_Send()	0.122	6,866
MPI_Init_thread()	0.112	1
[CONTEXT] .TAU application	0.05	1

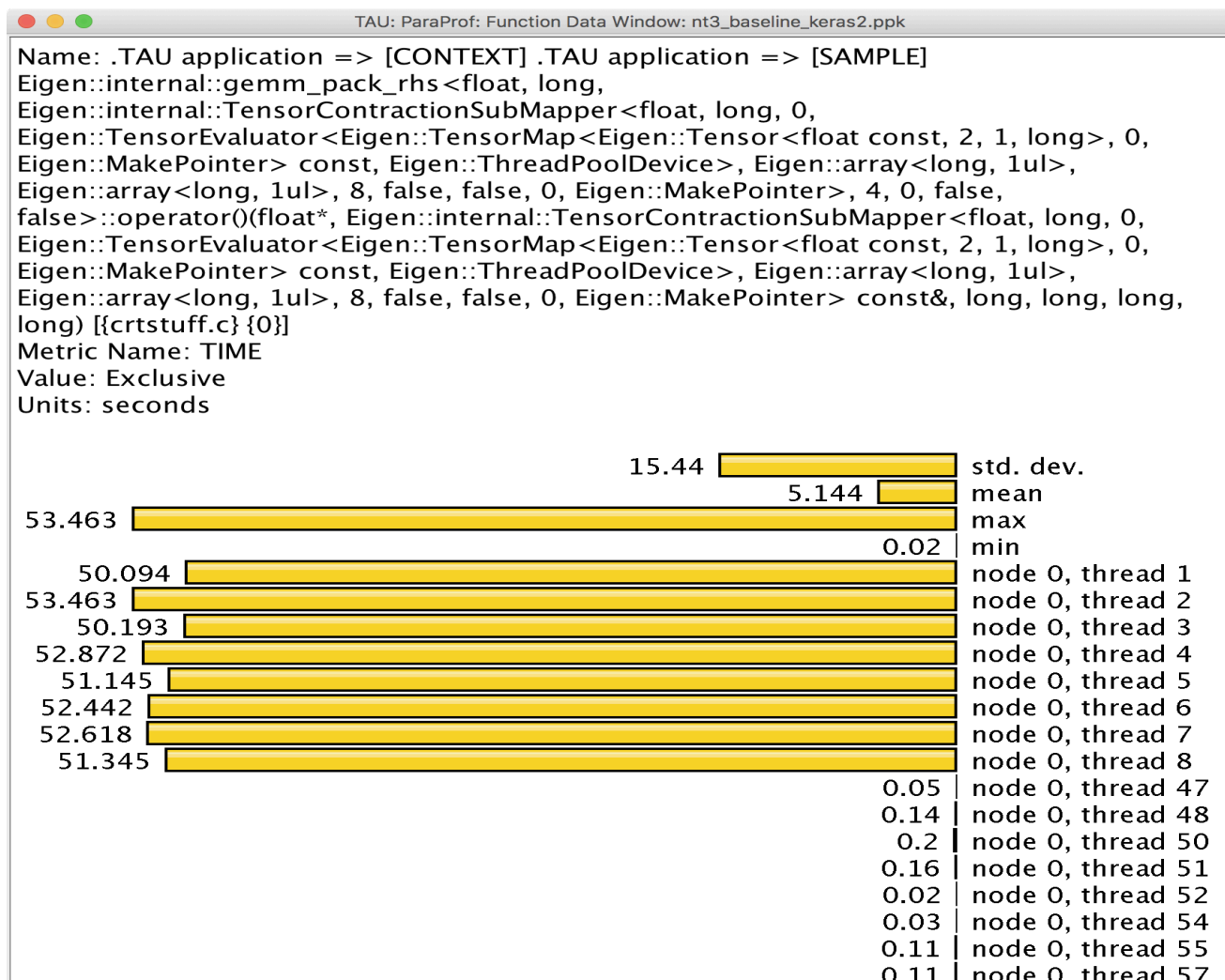
# Deep Learning: Tensorflow

TAU: ParaProf: Statistics for: node 0, thread 8 - nt3\_baseline\_keras2.ppk

Name	Inclusiv...	Calls ▾
▾ .TAU application	519.211	1
▾ [CONTEXT] .TAU application	509.222	50,915
▾ [SAMPLE] Eigen::internal::gebp_kernel<float, float, long, Eigen::internal::blas_data_mapper<float, long, 0, 0>,	240.632	24,089
[SAMPLE] __pthread_cond_wait [{ } {0}]	86.384	8,634
[SAMPLE] Eigen::internal::gemm_pack_rhs<float, long, Eigen::internal::TensorContractionSubMapper<float, lor	51.345	5,135
[SAMPLE] Eigen::internal::gemm_pack_rhs<float, long, Eigen::internal::TensorContractionSubMapper<float, lor	24.375	2,416
[SAMPLE] void tensorflow::SpatialMaxPoolWithArgMaxHelper<Eigen::ThreadPoolDevice, float>(tensorflow::OpK	16.301	1,630
[SAMPLE] __memset_sse2 [{ } {0}]	13.446	1,336
[SAMPLE] Eigen::TensorEvaluator<Eigen::TensorContractionOp<Eigen::array<Eigen::IndexPair<long>, 1ul> co	5.99	599
[SAMPLE] long Eigen::internal::operator/ <long, false>(long const&, Eigen::internal::TensorIntDivisor<long, fals	5.843	585
[SAMPLE] std::_Function_handler<void (long, long), Eigen::internal::TensorExecutor<Eigen::TensorAssignOp<l	5.377	538
[SAMPLE] float __vector Eigen::TensorEvaluator<Eigen::TensorBroadcastingOp<Eigen::IndexList<int, Eigen::typ	4.862	487
[SAMPLE] Eigen::TensorEvaluator<Eigen::TensorContractionOp<Eigen::array<Eigen::IndexPair<long>, 1ul> co	4.775	478
[SAMPLE] Eigen::TensorEvaluator<Eigen::TensorAssignOp<Eigen::TensorMap<Eigen::Tensor<float, 1, 1, long>	4.037	404
[SAMPLE] Eigen::internal::gemm_pack_lhs<float, long, Eigen::internal::TensorContractionSubMapper<float, lon	3.679	367
[SAMPLE] Eigen::internal::EvalRange<Eigen::TensorEvaluator<Eigen::TensorAssignOp<Eigen::TensorMap<Eigei	2.981	298
[SAMPLE] tensorflow::MaxPoolingOp<Eigen::ThreadPoolDevice, float>::SpatialMaxPool(tensorflow::OpKernelCo	2.915	295
[SAMPLE] std::_Function_handler<void (long, long), Eigen::internal::TensorExecutor<Eigen::TensorAssignOp<l	2.91	291
[SAMPLE] std::_Function_handler<void (long, long), Eigen::internal::TensorExecutor<Eigen::TensorAssignOp<l	2.772	277
[SAMPLE] Eigen::internal::gemm_pack_lhs<float, long, Eigen::internal::TensorContractionSubMapper<float, lon	2.481	248
[SAMPLE] std::_Function_handler<void (long, long), Eigen::internal::TensorExecutor<Eigen::TensorAssignOp<l	2.148	215
[SAMPLE] void Eigen::internal::call_dense_assignment_loop<Eigen::Map<Eigen::Matrix<float, -1, -1, 0, -1, -1>	2.008	197
[SAMPLE] Eigen::NonBlockingThreadPoolTempl<tensorflow::thread::EigenEnvironment>::WorkerLoop(int) [{/hc	1.999	200
[SAMPLE] Eigen::internal::ptrtranspose(Eigen::internal::PacketBlock<float __vector, 4>&) [{crtstuff.c} {0}]	1.919	192
[SAMPLE] Eigen::internal::gemm_pack_rhs<float, long, Eigen::internal::TensorContractionSubMapper<float, lor	1.607	160
[SAMPLE] Eigen::TensorEvaluator<Eigen::TensorContractionOp<Eigen::array<Eigen::IndexPair<long>, 1ul> co	1.518	152

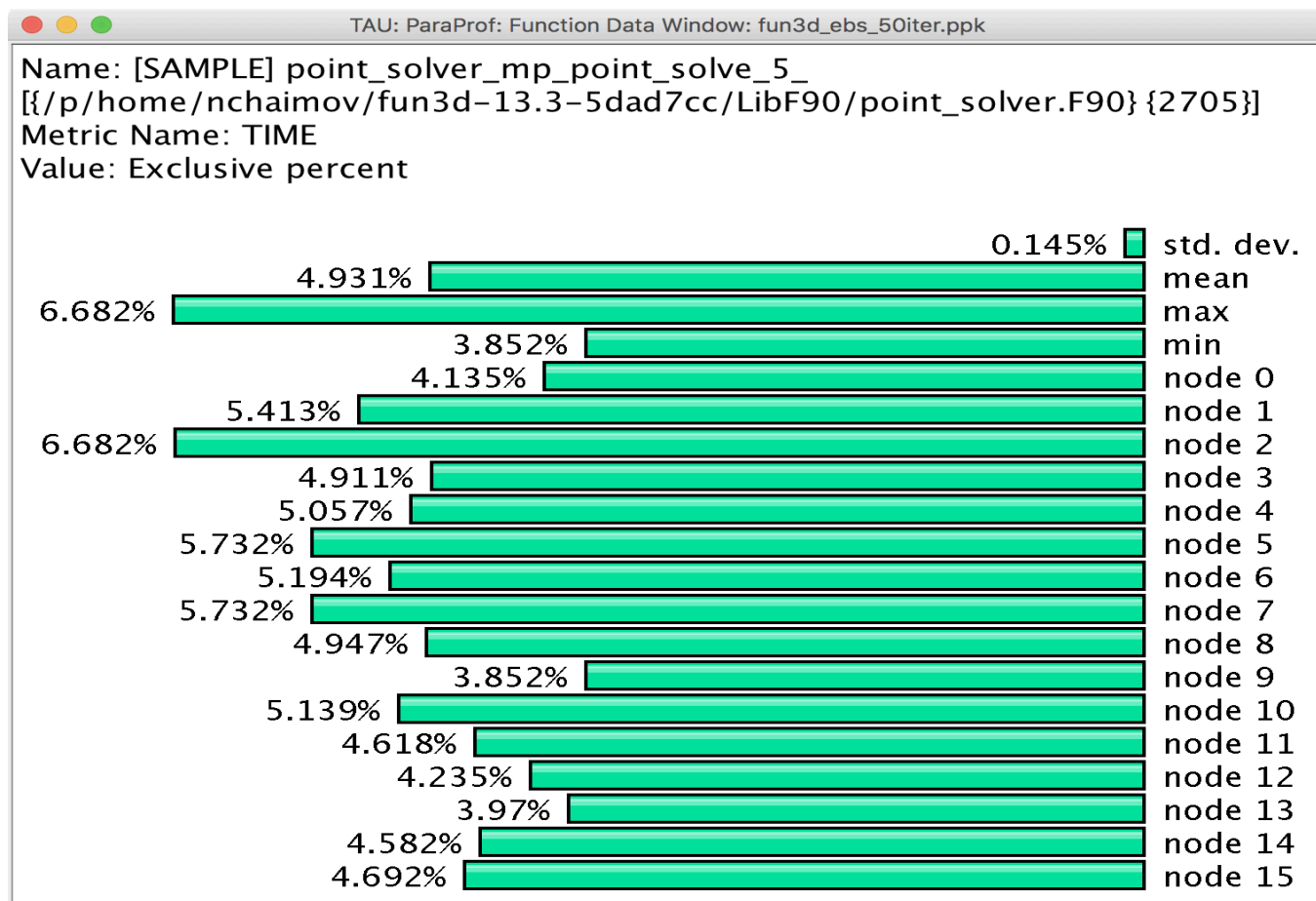
% tau\_python -ebs nt3\_baseline\_keras2.py (CANDLE)

# Sampling Tensorflow





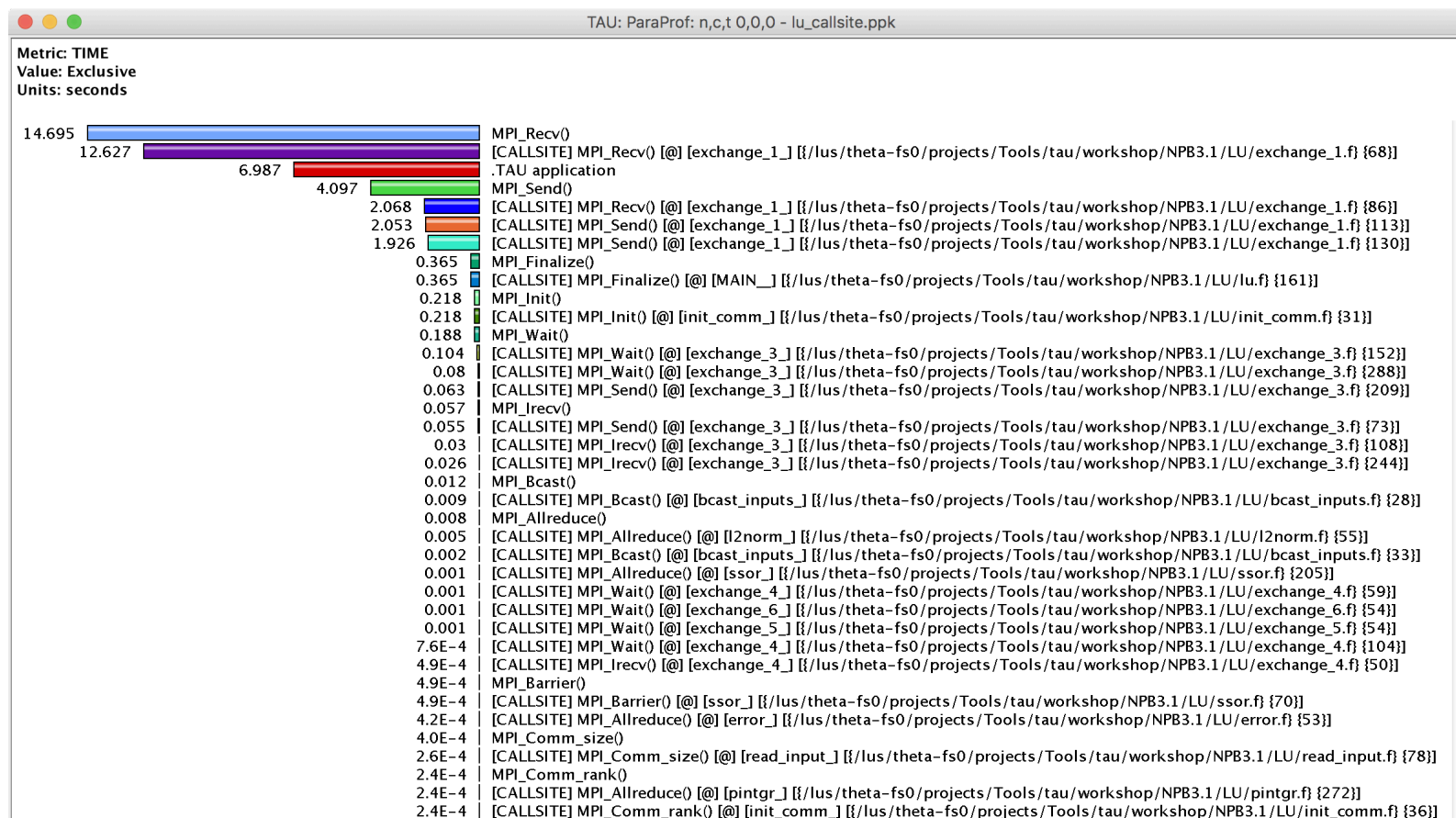
# Event Based Sampling (EBS)



Uninstrumented!

```
% aprun -n 16 tau_exec -ebs a.out
```

# Callsite Profiling and Tracing



% export TAU\_CALLSITE=1

# CALLPATH THREAD RELATIONS WINDOW

TAU: ParaProf: Call Path Data n,c,t, 2,0,0 - gamess\_unw\_call\_ebs.ppk

Metric Name: TIME  
Sorted By: Inclusive  
Units: seconds

	Exclusive	Inclusive	Calls/Tot.Calls	Name[id]
-->	0.121	79.592	1	.TAU application
	0.002	0.002	1/1	MPI_Gather()
	0.004	0.004	3/3	MPI_Allgather()
	0.122	0.122	6866/6866	MPI_Send()
	0.002	0.002	1/1	MPI_Comm_split()
	8.9E-5	8.9E-5	2/2	MPI_Comm_size()
	4.6E-4	4.6E-4	3/3	MPI_Group_incl()
	75.607	75.607	6870/6870	MPI_Recv()
	0.002	0.002	4/4	MPI_Comm_create()
	9.5E-5	9.5E-5	6/6	MPI_Comm_rank()
	5.4E-4	5.4E-4	1/1	MPI_Comm_group()
	0.003	0.003	7/7	MPI_Barrier()
	0.112	0.112	1/1	MPI_Init_thread()
	6.3E-4	6.3E-4	1/1	MPI_Group_intersection()
	0	0.05	1/1	[CONTEXT] .TAU application
	3.601	3.601	1/1	MPI_Finalize()
	0.014	0.014	6/6	MPI_Bcast()
-->	75.607	75.607	6870/6870	.TAU application
	75.607	75.607	6870	MPI_Recv()
	0	74.848	1497/1497	[CONTEXT] MPI_Recv()
-->	0	74.848	1497/1497	MPI_Recv()
	0	74.848	1497	[CONTEXT] MPI_Recv()
	0	8.701	174/1371	[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_init.c.113 [0] ddi_i
	0	26.196	524/763	[UNWIND] /gpfs/mira-home/sameer/gamess-theta-tau/object/unport.f.410 [0] MAIN_ [0] gpfs/mir
	0.2	0.2	4/138	[SAMPLE] GNII_DlaProgress [0] /opt/cray/ugni/6.0.14-6.0.4.0_14.1_ge7db4a2.ari/lib64/libugni.
	0	5.75	115/1484	[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_server.c.99 [0] DDI_
	0	0.2	4/5	[UNWIND] /lib64/libc-2.22.so.0 [0] _start [0] /home/abuild/rpmbuild/BUILD/glibc-2.22/csu/./s
	0	11.85	237/239	[UNWIND] /gpfs/mira-home/sameer/gamess-theta-tau/object/gamess.f.538 [0] main [0] gpfs/mira-
	0.051	0.051	1/273	[SAMPLE] GNI_CqGetEvent [0] /opt/cray/ugni/6.0.14-6.0.4.0_14.1_ge7db4a2.ari/lib64/libugni.so
	0	0.05	1/1197	[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [0] MPID:
	0	0.15	3/7	[UNWIND] [/opt/cray/ugni/6.0.14-6.0.4.0_14.1_ge7db4a2.ari/lib64/libugni.so.0.6.0.0] [0] UNI
	0	21.7	434/1197	[UNWIND] /gpfs/mira-home/yuri/dist/Github/gamess-theta-tau/ddi/src/ddi_fortran.c.67 [0] beg

# CALLPATH THREAD RELATIONS WINDOW

TAU: ParaProf: Call Path Data n,c,t, 2,0,0 - gamess\_unw\_call\_ebs.ppk

Metric Name: TIME  
Sorted By: Exclusive  
Units: seconds

	Exclusive	Inclusive	Calls/Tot.Calls	Name[id]
-->	75.607	75.607	6870/6870	.TAU application
	75.607	75.607	6870	MPI_Recv()
	0	74.848	1497/1497	[CONTEXT] MPI_Recv()
	0.15	0.15	3/444	[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [0] PMPI_Recv
	22.046	22.046	441/444	[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [0] MPIDI_CH3I
-->	22.196	22.196	444	[SAMPLE] MPID_nem_gni_poll [{/opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3
	5.6	5.6	112/273	[UNWIND] /opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0.0 [0] MPID_nem_g
	0.051	0.051	1/273	[CONTEXT] MPI_Recv()
	7.651	7.651	153/273	[UNWIND] /opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0.0 [0] MPID_nem_g
	0.35	0.35	7/273	[UNWIND] [/opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0.0] [0] UNRESOLV
-->	13.652	13.652	273	[SAMPLE] GNI_CqGetEvent [{/opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0.0}
	11.3	11.3	226/226	[UNWIND] /opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so.3.0.1.0 [0] PMPI_Recv
-->	11.3	11.3	226	[SAMPLE] MPIDI_CH3I_Progress [{/opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/libmpich_intel.so
	10.349	10.349	207/207	[UNWIND] /opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0.0 [0] MPID_nem_g
-->	10.349	10.349	207	[SAMPLE] GNI_SmsgGetNextWTag [{/opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so
	0.2	0.2	4/138	[CONTEXT] MPI_Recv()
	6.701	6.701	134/138	[UNWIND] /opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0.0 [0] GNI_CqGetE
-->	6.901	6.901	138	[SAMPLE] GNI_DlaProgress [{/opt/cray/ugni/6.0.14-6.0.4.0_14.1__ge7db4a2.ari/lib64/libugni.so.0.6.0.0}
	5.25	5.25	105/109	[UNWIND] gni_poll.c.0 [0] MPID_nem_gni_poll [{/opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/li
	0.2	0.2	4/109	[UNWIND] gni_poll.c.0 [0] MPIDI_CH3I_Progress [{/opt/cray/pe/mpt/7.6.3/gni/mpich-intel/16.0/lib/
-->	5.45	5.45	109	[SAMPLE] MPID_nem_gni_check_localCQ [{gni_poll.c} {0}]
	3.601	3.601	1/1	.TAU application
-->	3.601	3.601	1	MPI_Finalize()

# ParaProf: Callpath Thread Relations Window

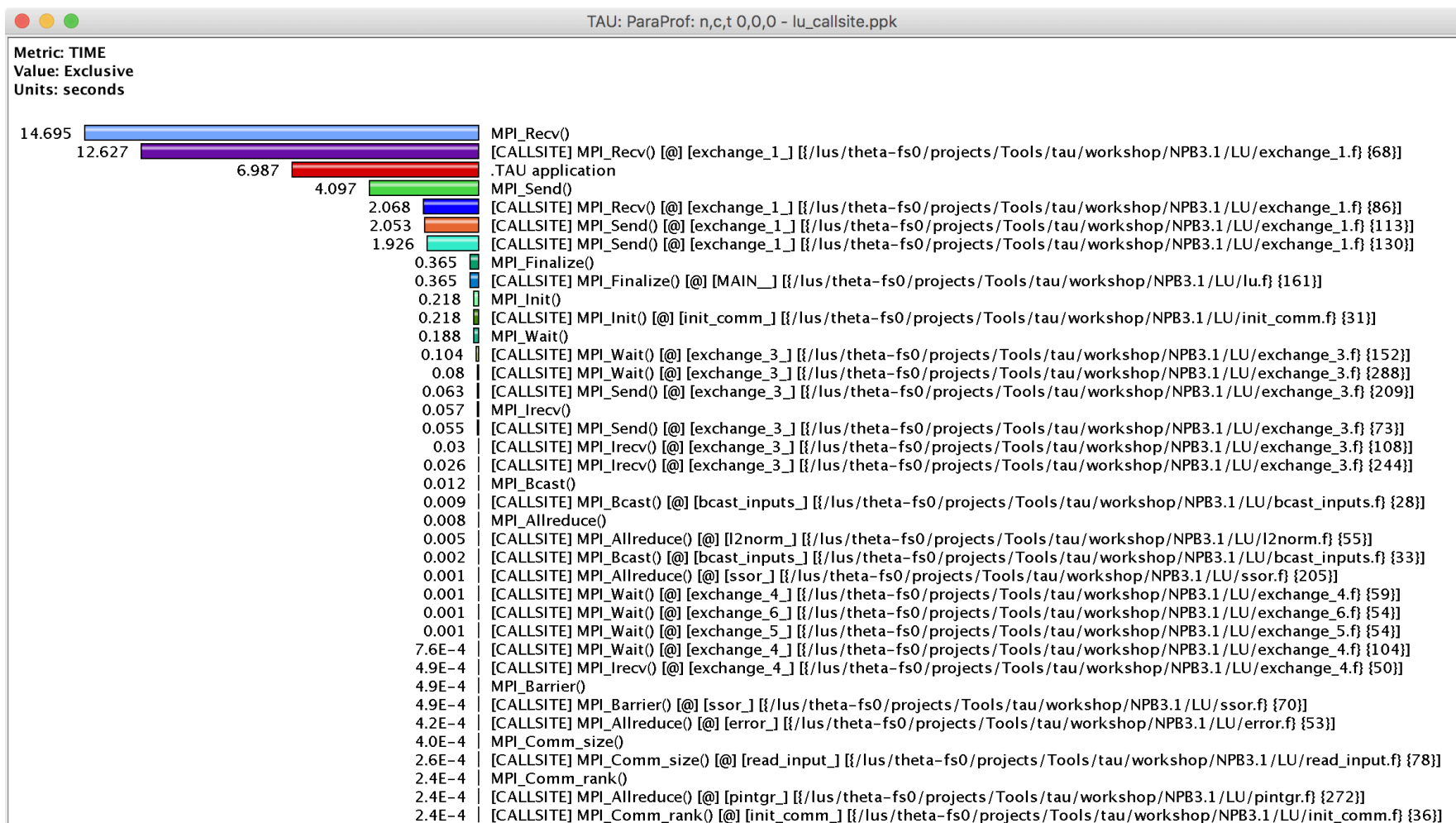
TAU: ParaProf: Call Path Data n,c,t, 0,0,0 – scout.cubex

File Options Windows Help

Metric Name: Time  
Sorted By: Exclusive  
Units: seconds

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

# Callsite Profiling and Tracing (TAU\_CALLSITE=1)





## TAU – Context Events

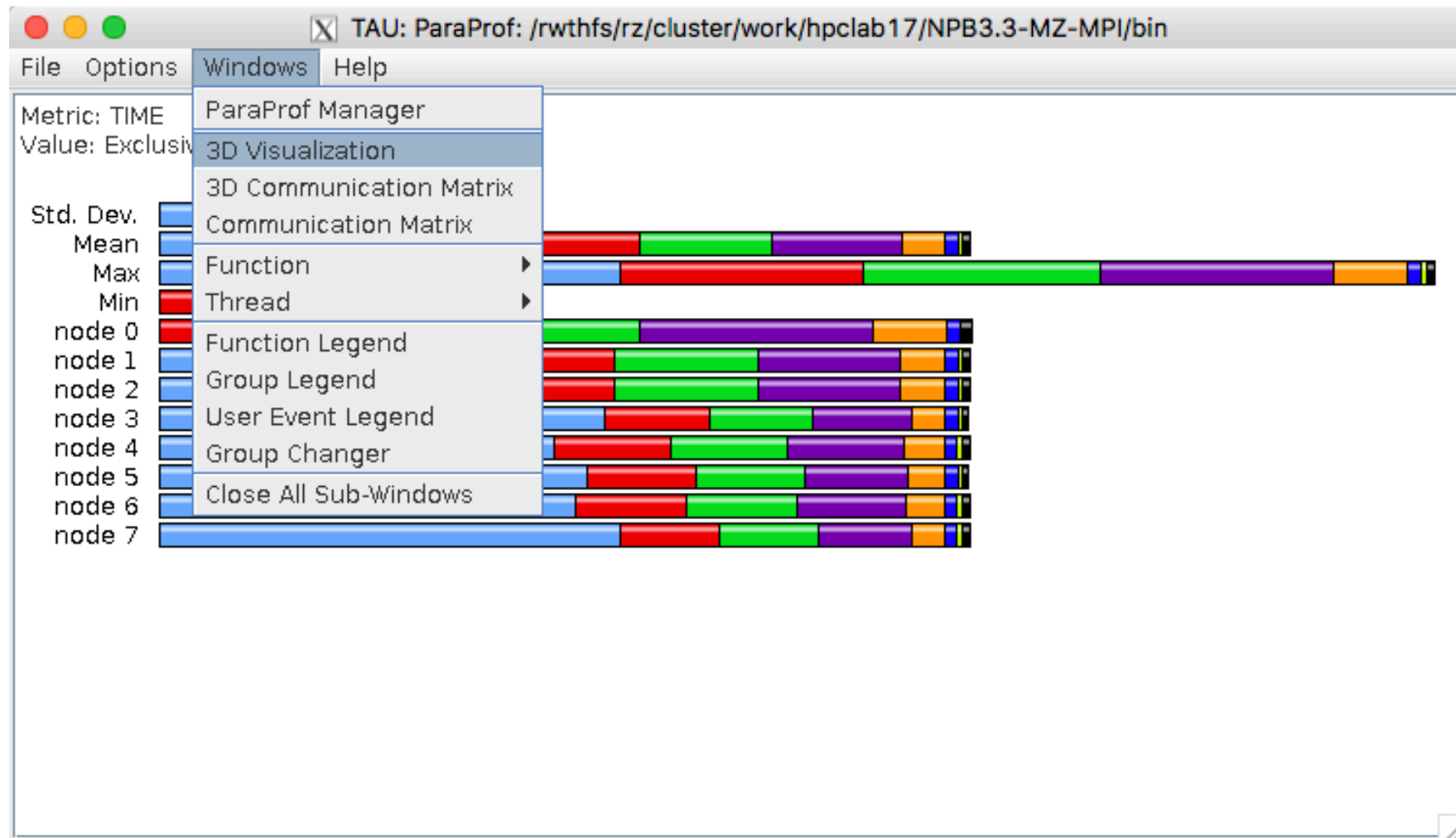
TAU: ParaProf: Context Events for thread: n,c,t, 1,0,0 – samarc\_obe\_4p\_iomem\_cp.ppk

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						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

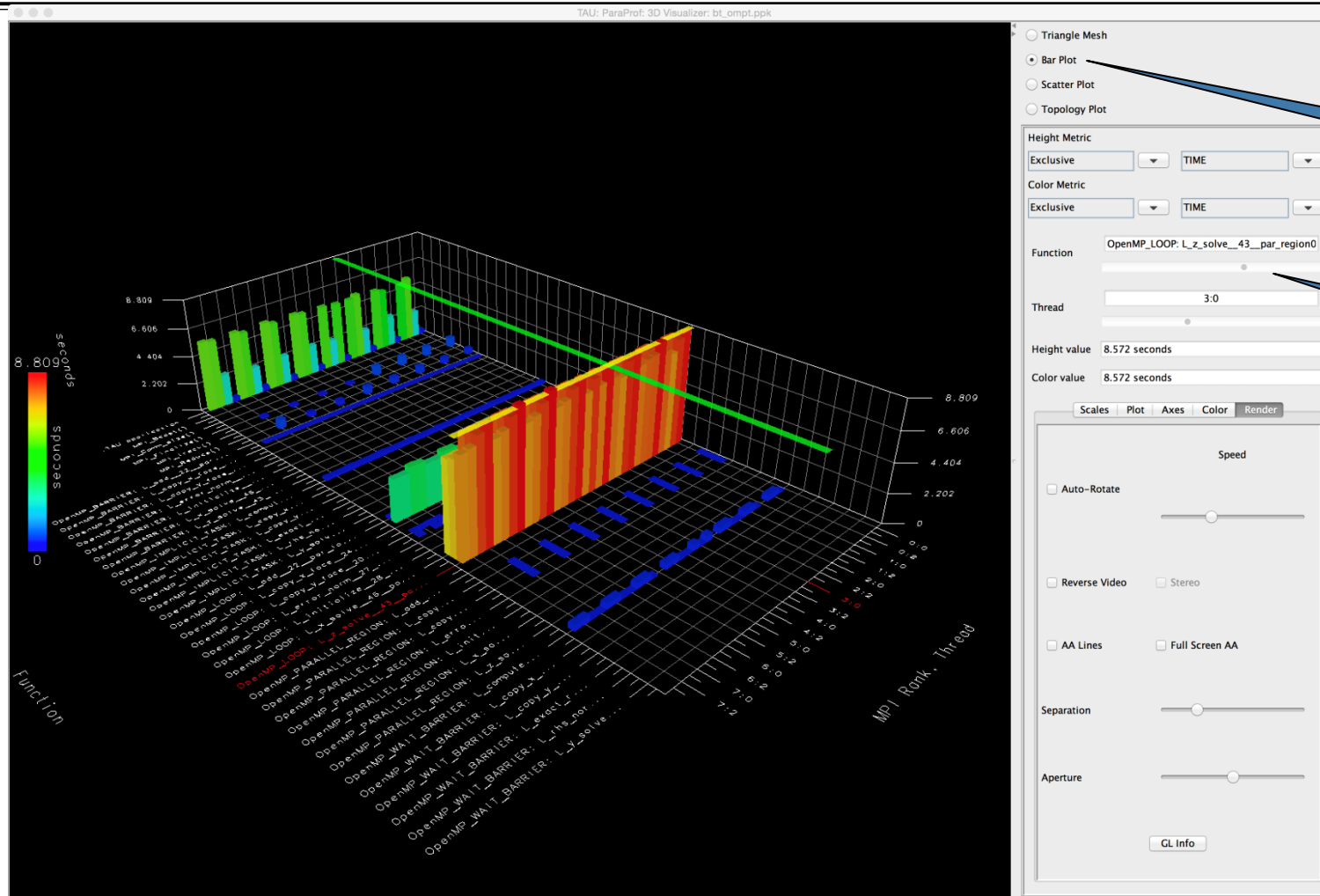
Bytes written to each file

# ParaProf with Optimized Instrumentation





# Paraprof 3D visualization window

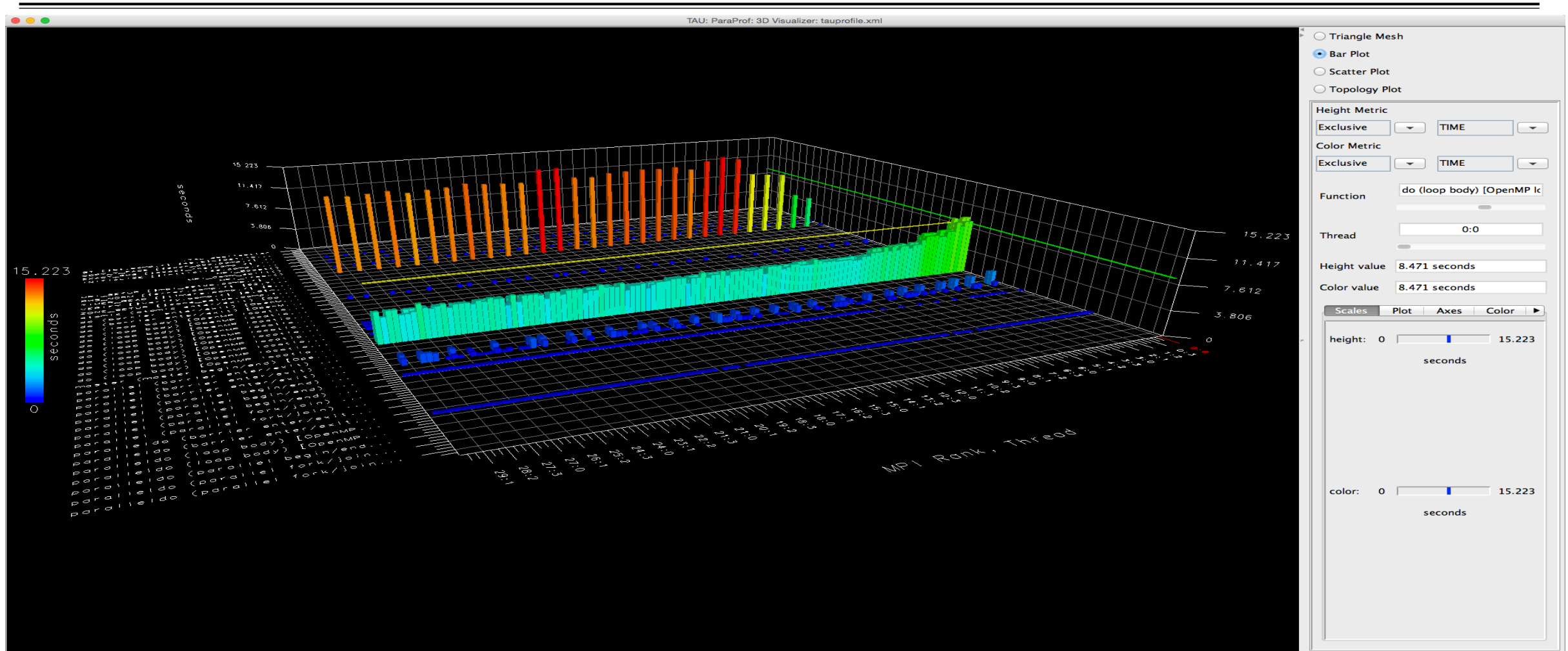


Click Bar Plot

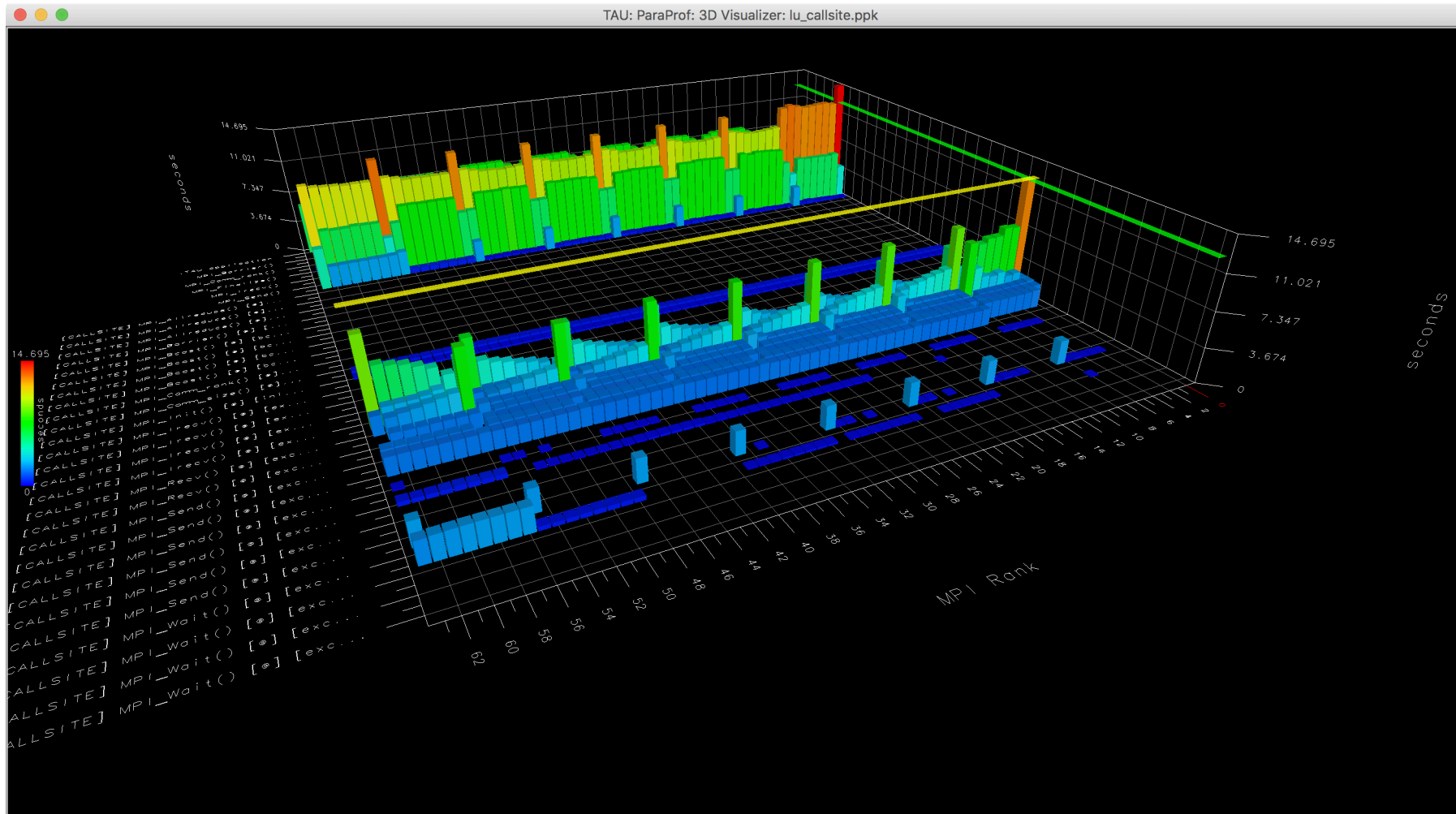
Move Function  
and Thread Sliders

Windows ->  
3D visualization

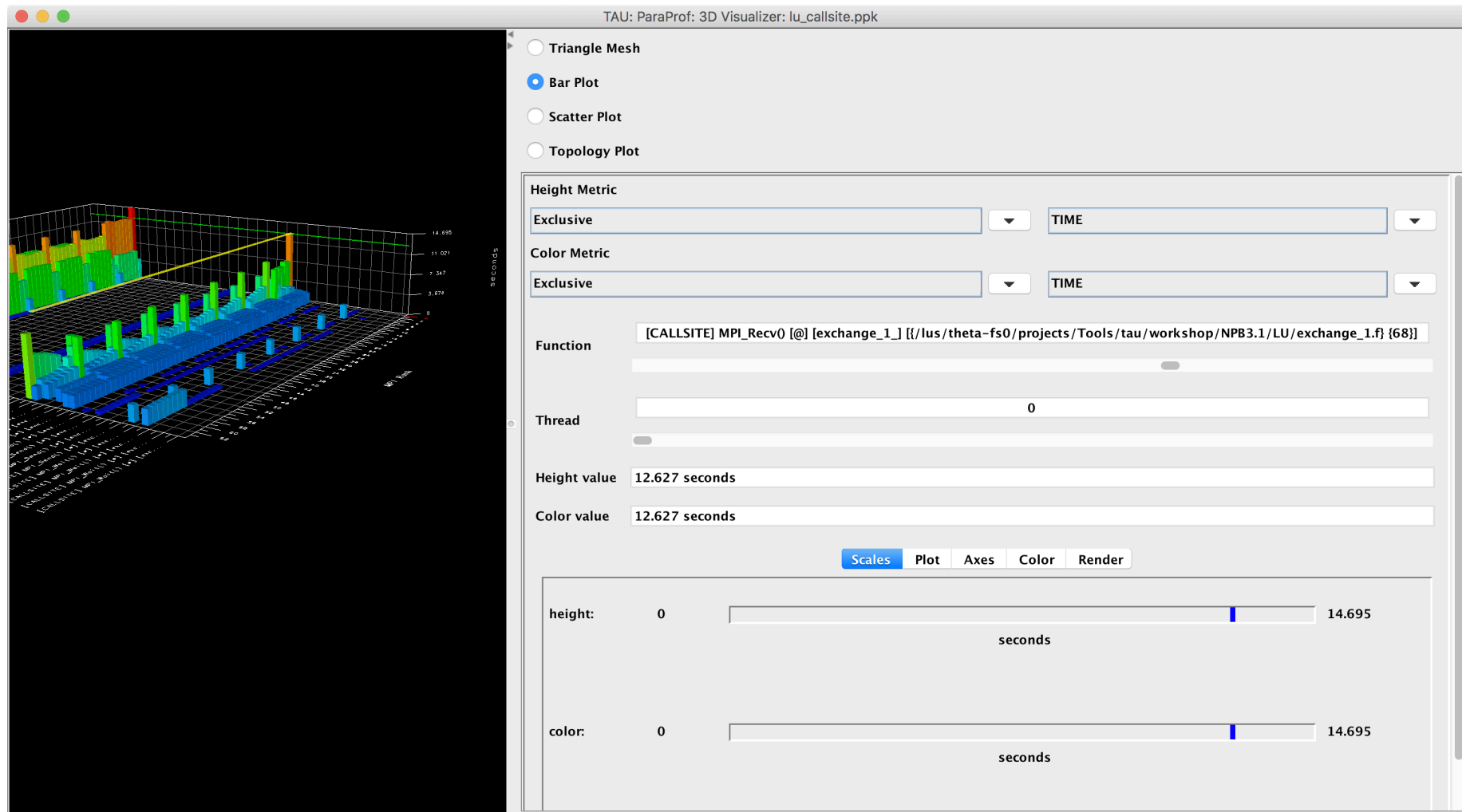
## ParaProf: 3D Visualization Window Showing Entire Profile



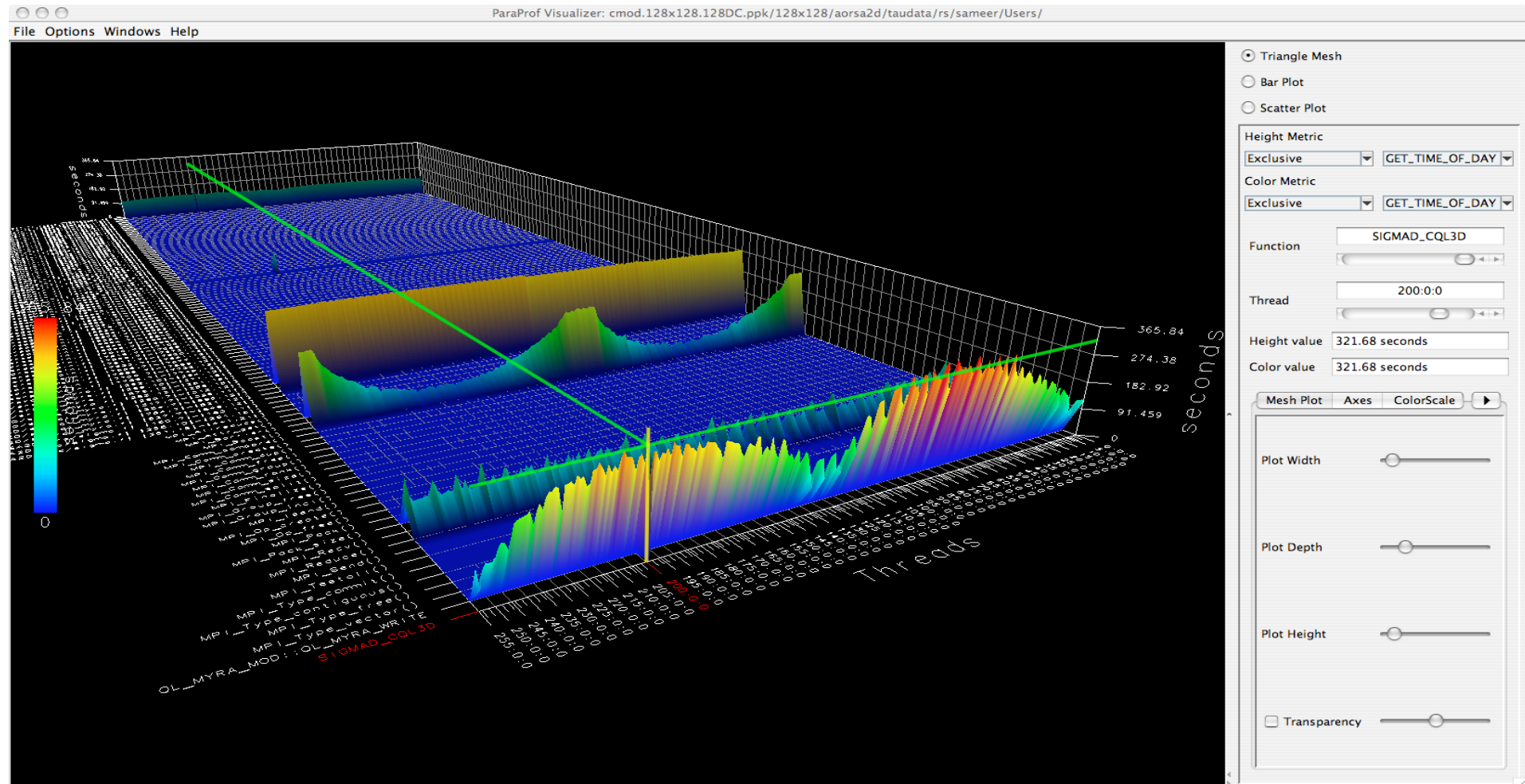
# Callsite Profiling and Tracing



# Callsite Profiling and Tracing

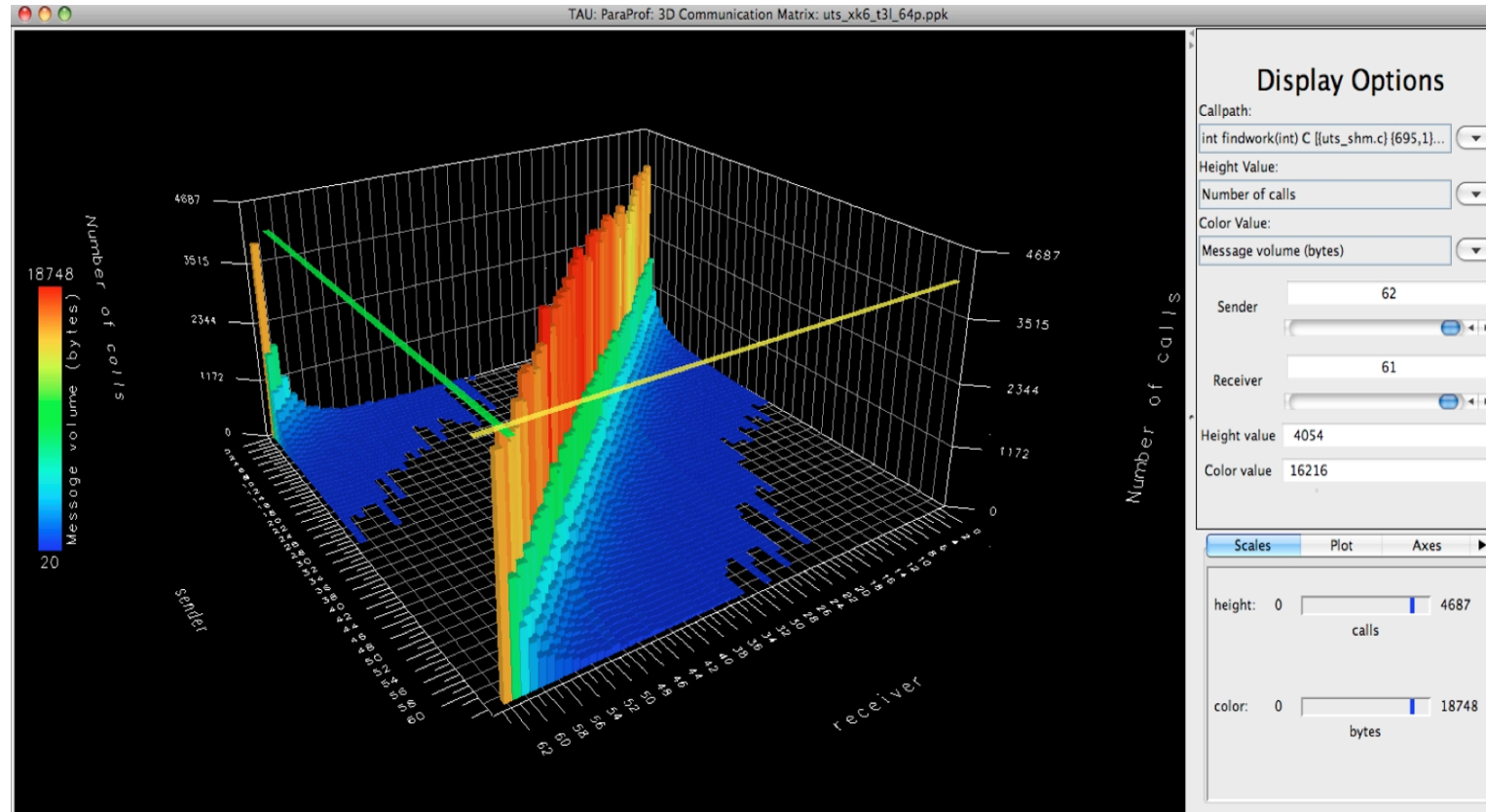


# Parallel Profile Visualization: ParaProf



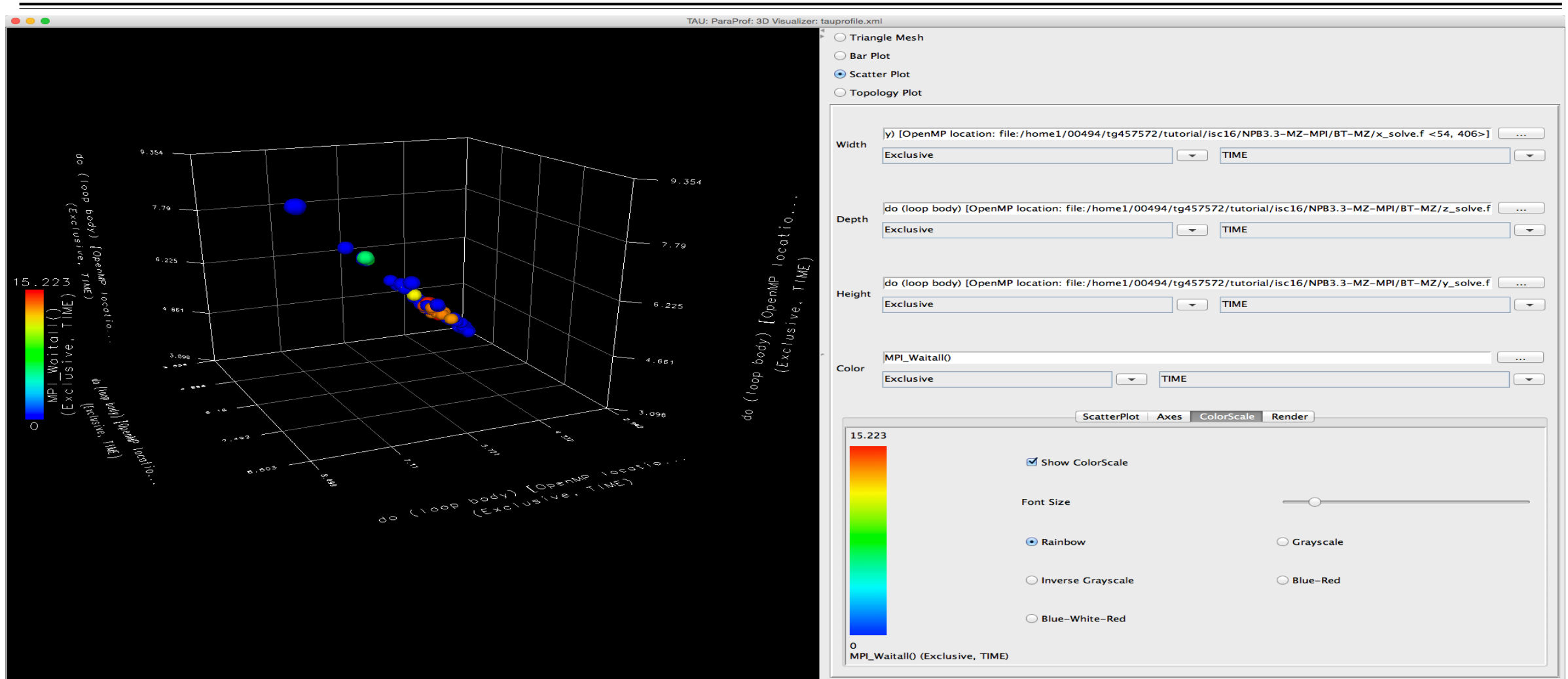


# ParaProf 3D Communication Matrix



% export TAU\_COMM\_MATRIX=1

# ParaProf: 3D Scatter Plot





# ParaProf: Score-P Profile Files, Database

TAU: ParaProf Manager

File Options Help

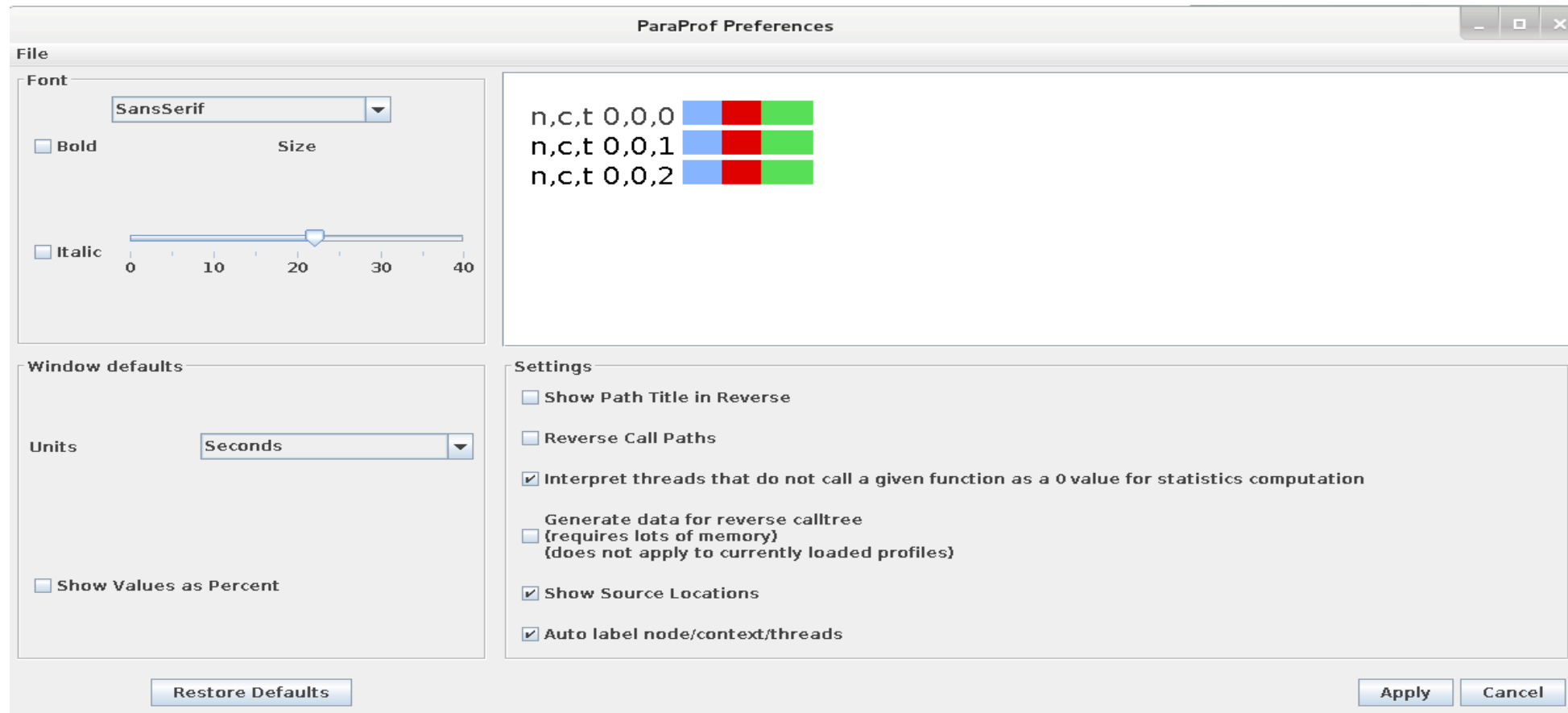
Applications

- Standard Applications
  - Default App
    - Default Exp
      - profile.cubex
        - Time
        - Minimum Inclusive Time
        - Maximum Inclusive Time
        - PAPI\_TOT\_CYC
        - PAPI\_TOT\_INS
        - PAPI\_FP\_INS
        - ru\_utime
        - ru\_stime
        - ru\_maxrss
        - ru\_ixrss
        - ru\_idrss
        - ru\_isrss
        - ru\_minflt
        - ru\_majflt
        - ru\_nswap
        - ru\_inblock
        - ru\_oublock
        - ru\_msgsnd
        - ru\_msgrcv
        - ru\_nsignals
        - ru\_nvcsw
        - ru\_nivcsw
        - bytes\_sent
        - bytes\_received
- Default (jdbc:h2:/home/livetau/.ParaProf/perfdmf;AUTO\_SERVER=TRUE)
- perfexplorer\_working (jdbc:h2:/home/livetau/.ParaProf/perfexplorer\_wo

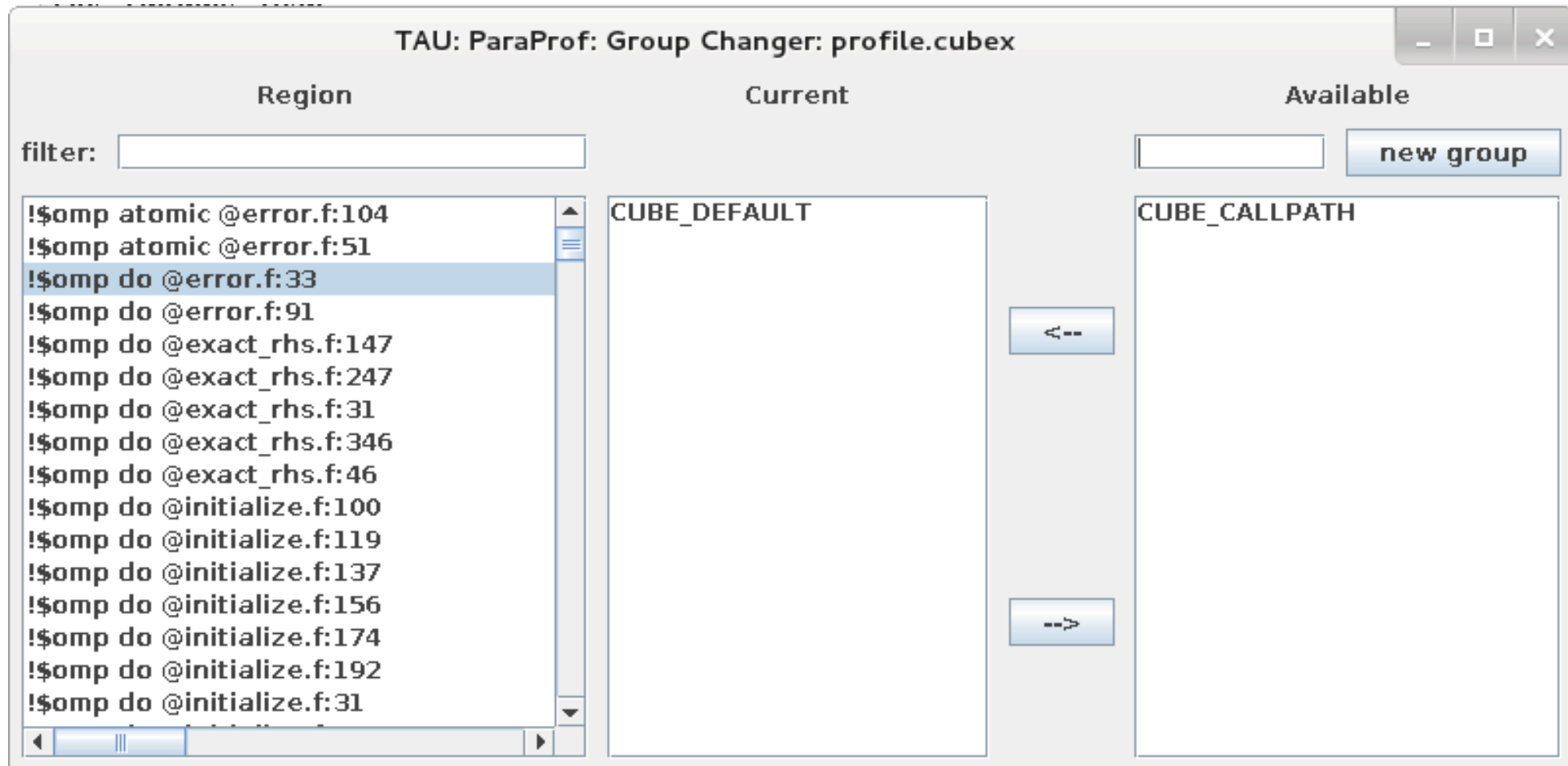
Add Application  
Add Experiment  
Add Trial

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

# ParaProf: File Preferences Window



# ParaProf: Group Changer Window



# ParaProf: Derived Metric Panel in Manager Window

The screenshot shows the TAU: ParaProf Manager window. The left pane displays a tree view of applications and metrics. The right pane shows a table of derived metrics.

**Applications Tree View:**

- Applications
  - Standard Applications
    - Default App
      - Default Exp
        - profile.cubex
          - Time** (selected)
          - Minimum Inclusive Time
          - Maximum Inclusive Time
          - PAPI\_TOT\_CYC
          - PAPI\_TOT\_INS
          - PAPI\_FP\_INS
          - ru\_ftime
          - ru\_stime
          - ru\_maxrss
          - ru\_ixrss
          - ru\_idrss
          - ru\_isrss
          - ru\_minflt
          - ru\_majflt
          - ru\_nswap
          - ru\_inblock
          - ru\_oublock
          - ru\_msgsnd
          - ru\_msgrcv
          - ru\_nsignals
          - ru\_nvcsw

**Derived Metric Table:**

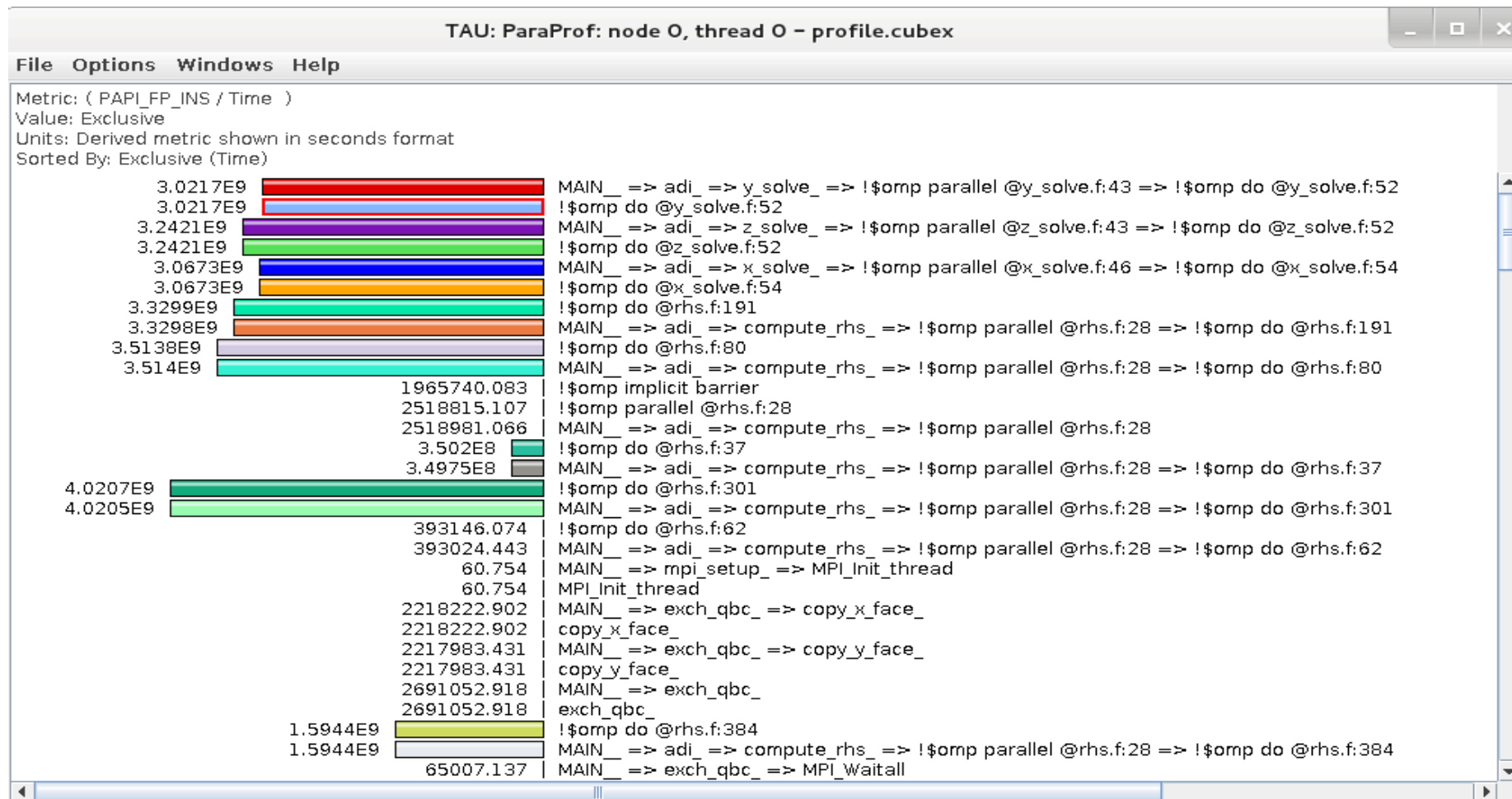
MetricField	Value
Name	Time
Application ID	0
Experiment ID	0
Trial ID	0
Metric ID	0

**Expression Panel:**

Expression: "PAPI\_FP\_INS"/"Time"

Buttons: +, -, \*, /, =, {, }, Apply, Clear

# Sorting Derived FLOPS metric by Exclusive Time



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# TAU hands-on exercises



# Performance Research Lab, University of Oregon, Eugene, USA



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  - PETTT, HPCMP
- National Science Foundation (NSF)
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  - ParaTools, Inc., ParaTools, SAS
  - The Ohio State University
  - University of Tennessee, Knoxville
  - T.U. Dresden, GWT
  - Juelich Supercomputing Center



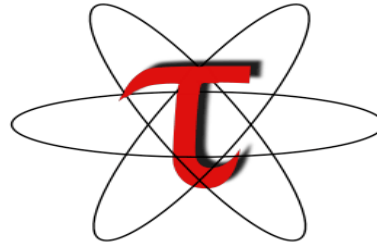
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# Download TAU from U. Oregon

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<http://tau.uoregon.edu>

<http://www.hpclinux.com> [LiveDVD, OVA]

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

Free download, open source, BSD license