TAU PERFORMANCE SYSTEM

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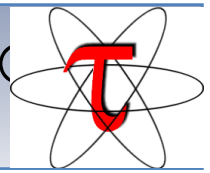
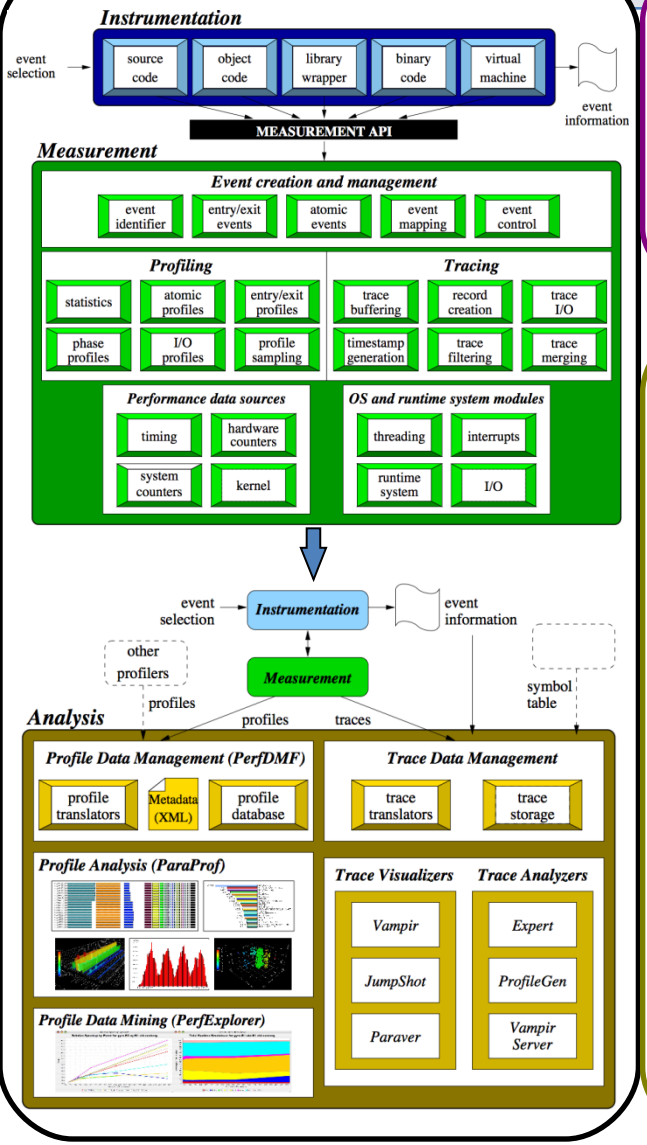
TAU Performance System®



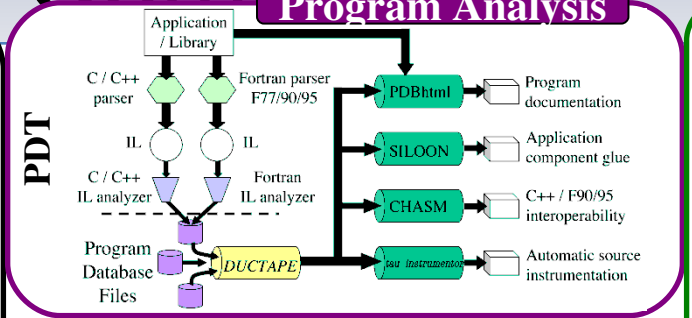
- *T*uning and *A*nalysis *U*tilities (16+ year project)
- Performance problem solving framework for HPC
  - Integrated, scalable, flexible, portable
  - Target all parallel programming / execution paradigms
- Integrated performance toolkit (open source)
  - Instrumentation, measurement, analysis, visualization
  - Widely-ported performance profiling / tracing system
  - Performance data management and data mining

TAU Performance System Components

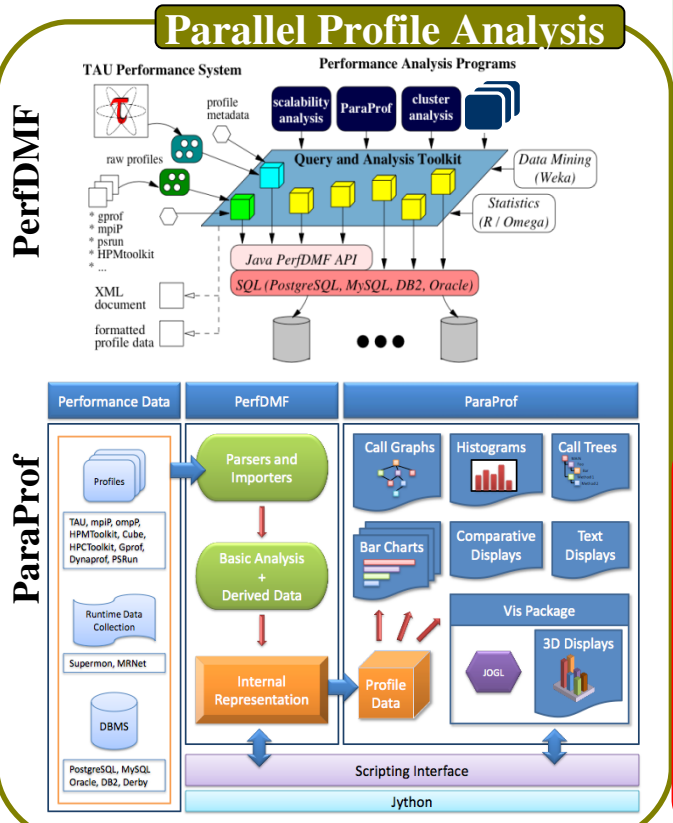
TAU Architecture



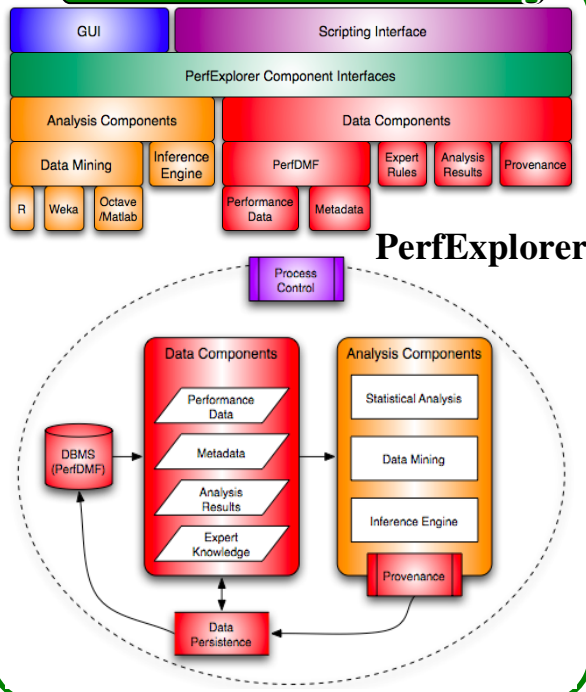
Program Analysis



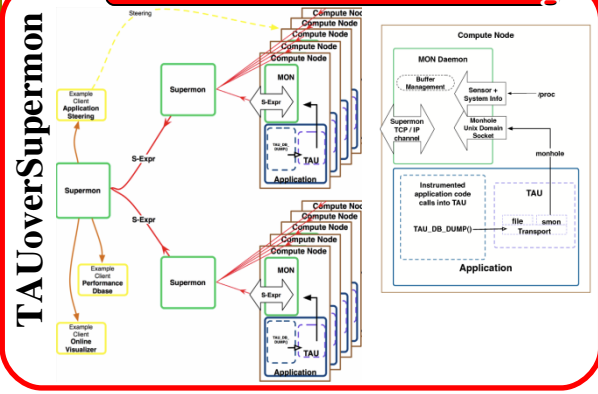
Parallel Profile Analysis



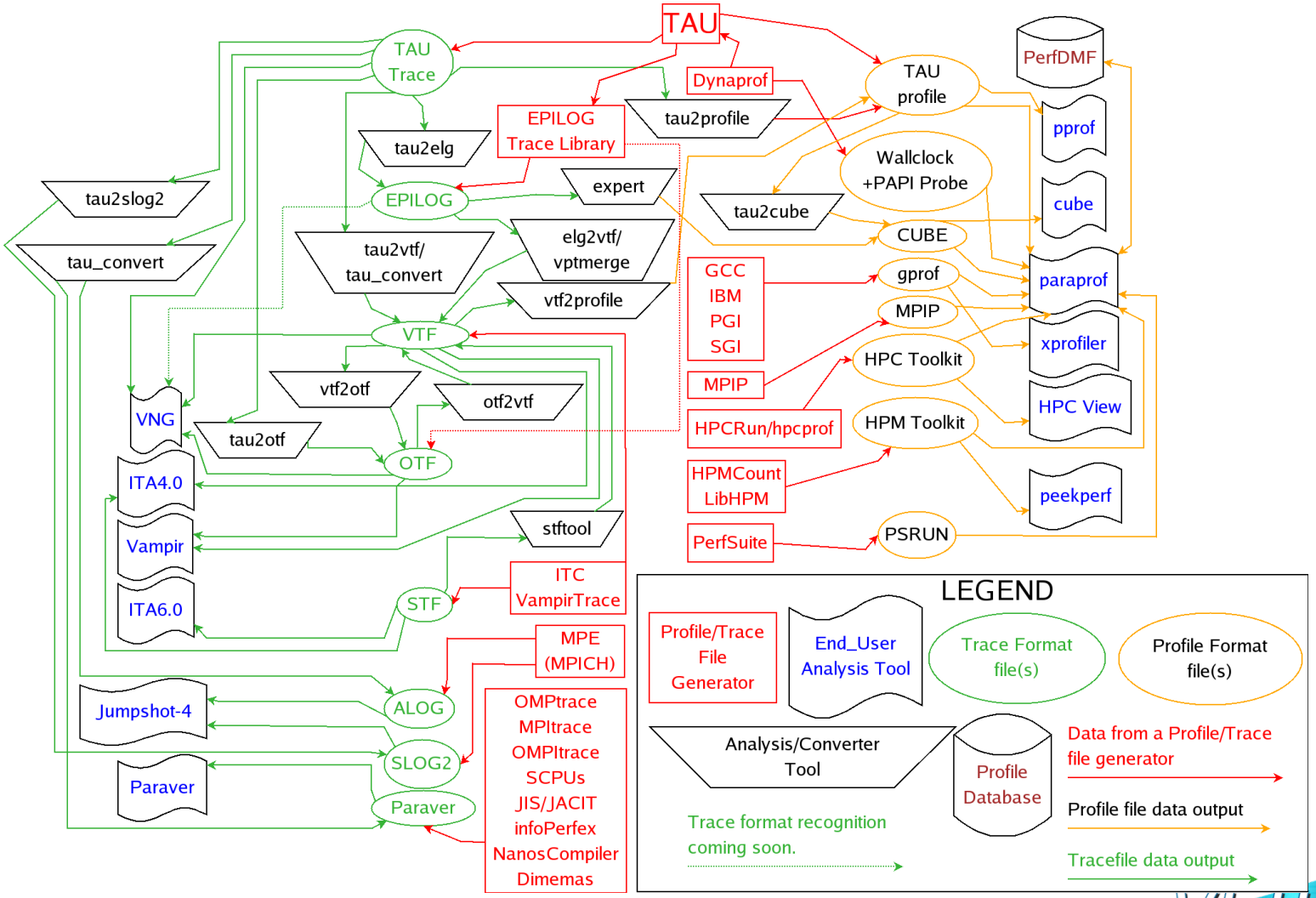
Performance Data Mining



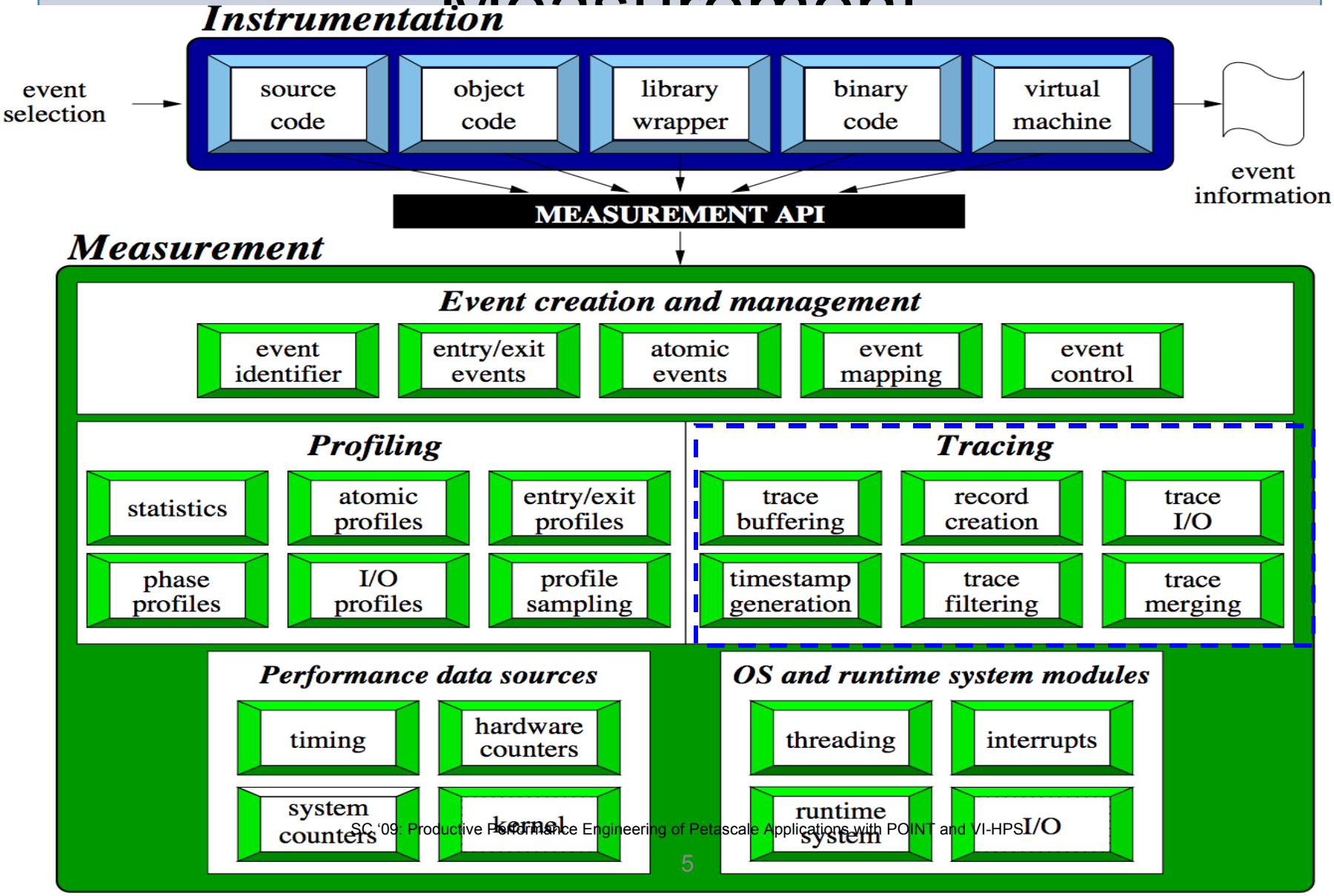
Performance Monitoring



Building Bridges to Other Tools



TAU Instrumentation / Measurement



Direct Performance Observation

- Execution actions of interest exposed as events
  - In general, actions reflect some execution state
    - presence at a code location or change in data
    - occurrence in parallelism context (thread of execution)
  - Events encode actions for performance system to observe
- Observation is direct
  - Direct instrumentation of program (system) code (probes)
  - Instrumentation invokes performance measurement
  - Event measurement: performance data, meta-data, context
- Performance experiment
  - Actual events + performance measurements
- Contrast with (indirect) event-based sampling

TAU Instrumentation Approach

- Support for standard program events
  - Routines, classes and templates
  - Statement-level blocks
  - Begin/End events (Interval events)
- Support for user-defined events
  - Begin/End events specified by user
  - Atomic events (e.g., size of memory allocated/freed)
  - Flexible selection of event statistics
- Provides static events and dynamic events
- Enables “semantic” mapping
- Specification of event groups (aggregation, selection)
- Instrumentation optimization

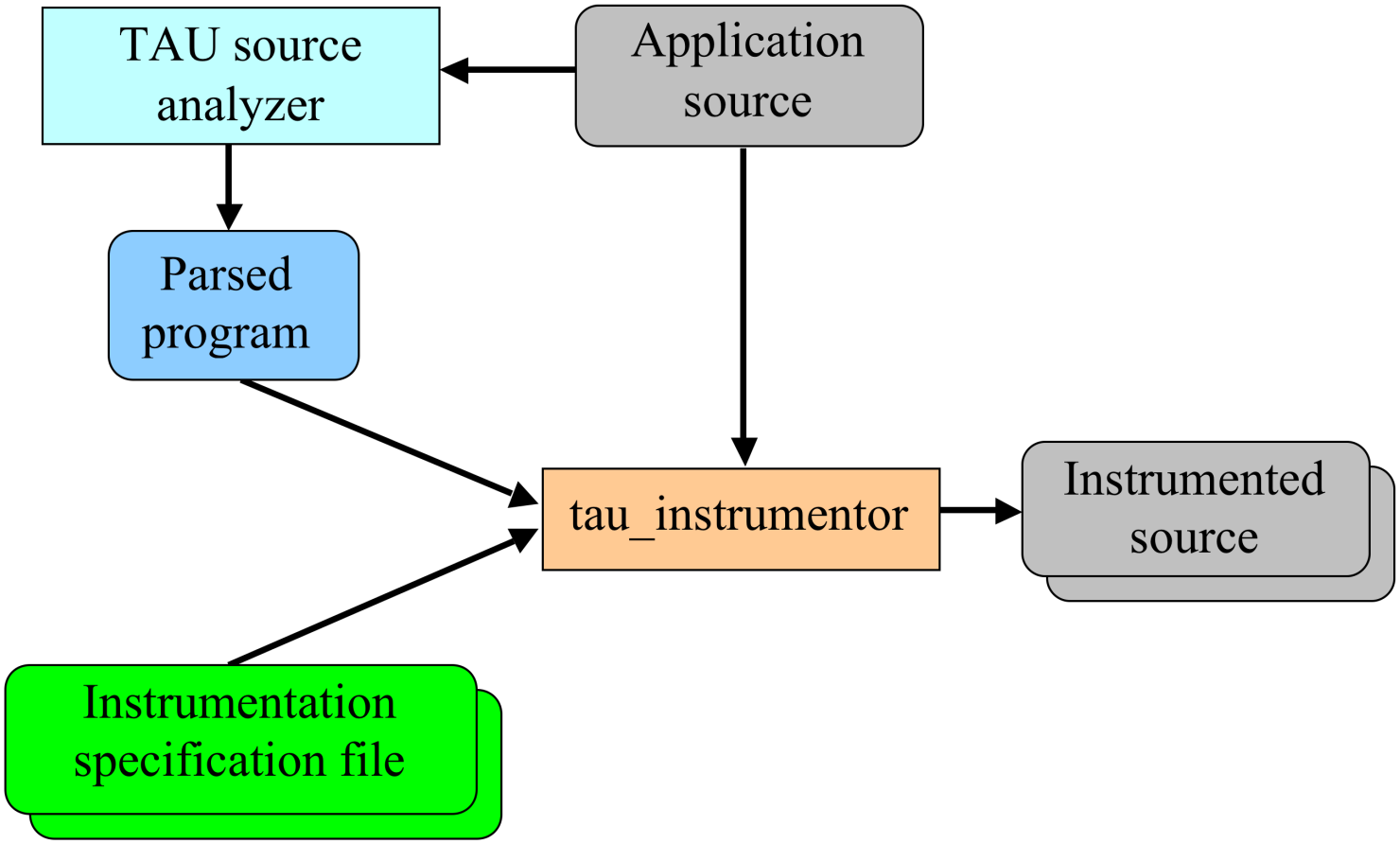
TAU Event Interface

- Events have a type, a group association, and a name
- TAU events names are character strings
  - Powerful way to encode event information
  - Inefficient way to communicate each event occurrence
- TAU maps a new event name to an event ID
  - Done when event is first encountered (get event handle)
  - Event ID is used for subsequent event occurrences
  - Assigning a uniform event ID a priori is problematic
- A new event is identified by a new event name in TAU
  - Can create new event names at runtime
  - Allows for dynamic events (TAU renames events)
  - Allows for context-base, parameter-based, phase events

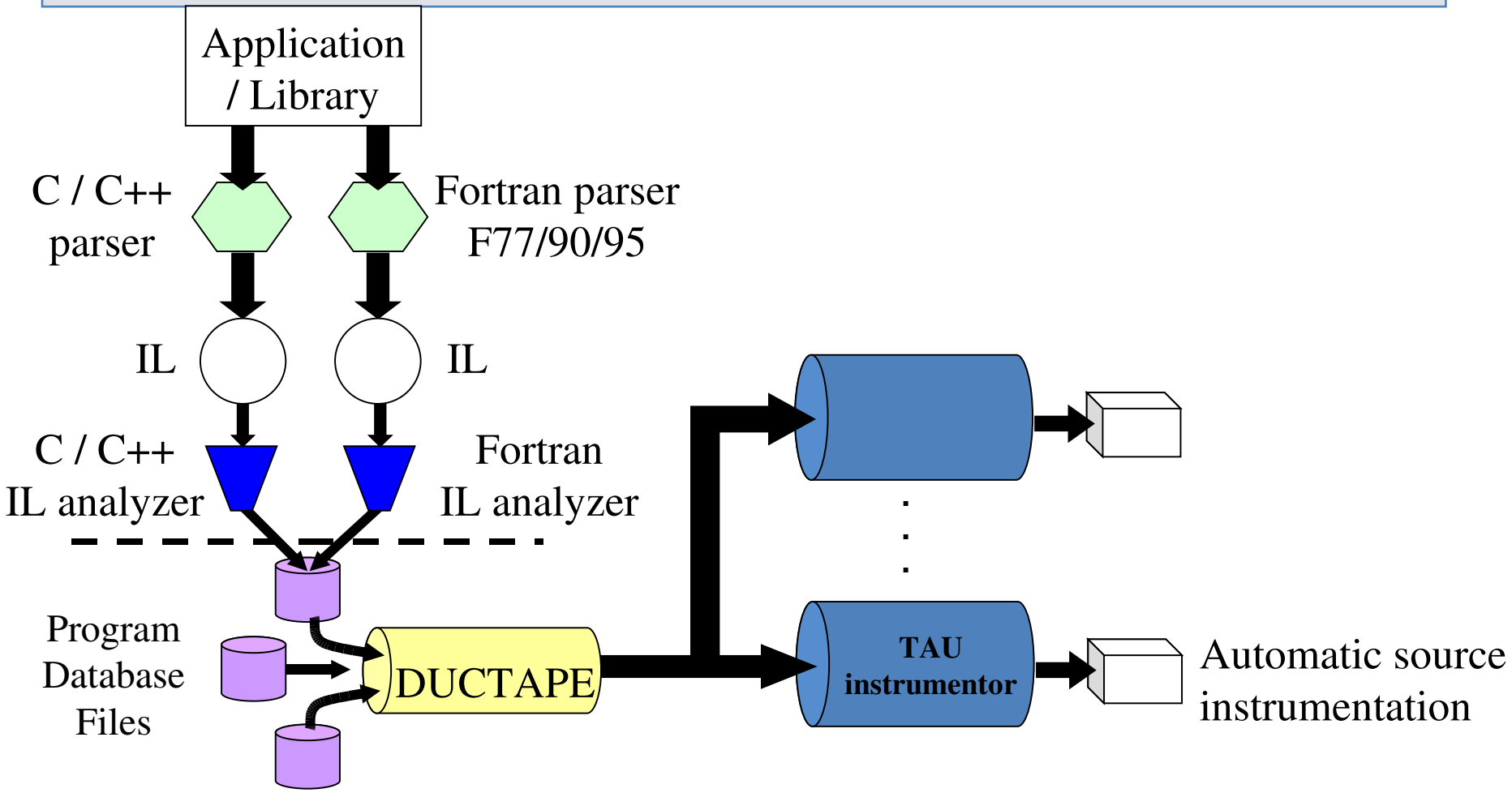
TAU Instrumentation Mechanisms

- Source code
  - Manual (TAU API, TAU component API)
  - Automatic (robust)
    - C, C++, F77/90/95 (Program Database Toolkit (PDT))
    - OpenMP (directive rewriting (Opari), POMP2 spec)
    - Library header wrapping
- Object code
  - Pre-instrumented libraries (e.g., MPI using PMPI)
  - Statically- and dynamically-linked (with LD_PRELOAD)
- Executable code
  - Binary and dynamic instrumentation (Dyninst)
  - Virtual machine instrumentation (e.g., Java using JVMPI)
- TAU_COMPILER to automate instrumentation process

Automatic Source-level Instrumentation



Program Database Toolkit (PDT)



MPI Wrapper Interposition Library

- Uses standard MPI Profiling Interface
  - Provides name shifted interface
    - MPI_Send = PMPI_Send
    - Weak bindings
- Create TAU instrumented MPI library
  - Interpose between MPI and TAU
  - Done during program link
    - -lmpi replaced by –lTauMpi –lpmpi –lmpi
  - No change to the source code!
  - Just re-link application to generate performance data

MPI Shared Library Instrumentation

- Interpose the MPI wrapper library for applications that have already been compiled
  - Avoid re-compilation or re-linking
- Requires shared library MPI
  - Uses LD_PRELOAD for Linux
  - On AIX use MPI_EUILIB / MPI_EUILIBPATH
  - Does not work on XT3
- Approach will work with other shared libraries
- Use TAU tauex
  - % mpirun -np 4 tauex a.out

Selective Instrumentation File

- Specify a list of events to exclude or include
- # is a wildcard in a routine name

```
BEGIN_EXCLUDE_LIST
Foo
Bar
D#EMM
END_EXCLUDE_LIST
BEGIN_INCLUDE_LIST
int main(int, char **)
F1
F3
END_INCLUDE_LIST
```

Selective Instrumentation File

- Optionally specify a list of files
- * and ? may be used as wildcard characters

```
BEGIN_FILE_EXCLUDE_LIST
f*.f90
Foo?.cpp
END_FILE_EXCLUDE_LIST
BEGIN_FILE_INCLUDE_LIST
main.cpp
foo.f90
END_FILE_INCLUDE_LIST
```

Selective Instrumentation File

- User instrumentation commands
  - Placed in INSTRUMENT section
  - Routine entry/exit
  - Arbitrary code insertion
  - Outer-loop level instrumentation

```
BEGIN_INSTRUMENT_SECTION
loops file="foo.f90" routine="matrix#"
memory file="foo.f90" routine="#"
io routine="matrix#"
[static/dynamic] phase routine="MULTIPLY"
dynamic [phase/timer] name="foo" file="foo.cpp" line=22 to line=35
file="foo.f90" line = 123 code = "  print *, \" Inside foo\""
exit routine = "int foo()" code = "cout <<\"exiting foo\"<<endl;"
END_INSTRUMENT_SECTION
```

TAU Measurement Approach

- Portable and scalable parallel profiling solution
  - Multiple profiling types and options
  - Event selection and control (enabling/disabling, throttling)
  - Online profile access and sampling
  - Online performance profile overhead compensation
- Portable and scalable parallel tracing solution
  - Trace translation to OTF, EPILOG, Paraver, and SLOG2
  - Trace streams (OTF) and hierarchical trace merging
- Robust timing and hardware performance support
- Multiple counters (hardware, user-defined, system)
- Performance measurement of I/O and Linux kernel

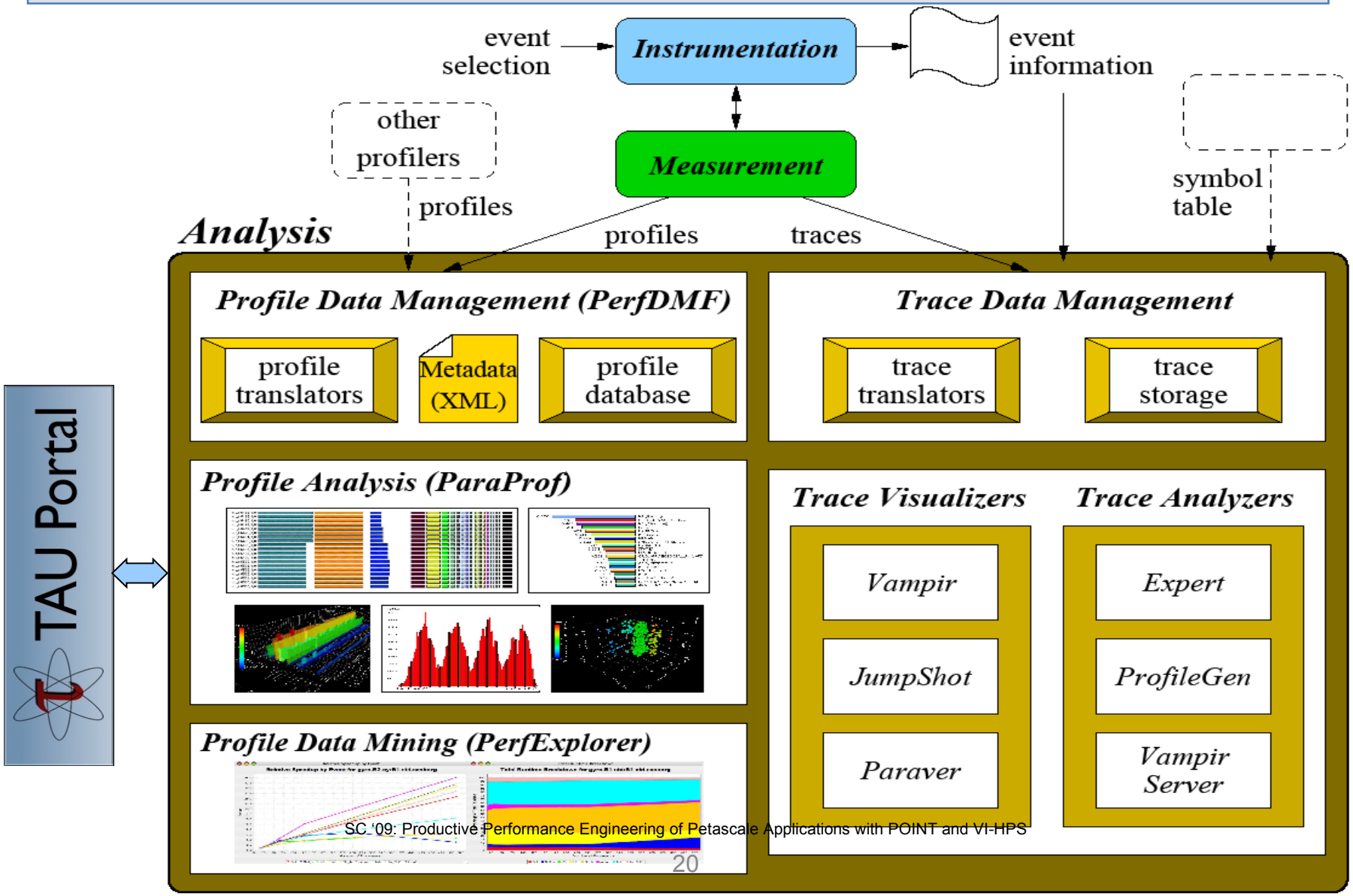
TAU Measurement Mechanisms

- Parallel profiling
  - Function-level, block-level, statement-level
  - Supports user-defined events and mapping events
  - Support for flat, callgraph/callpath, phase profiling
  - Support for parameter and context profiling
  - Support for tracking I/O and memory (library wrappers)
  - Parallel profile stored (dumped, shapshot) during execution
- Tracing
  - All profile-level events
  - Inter-process communication events
  - Inclusion of multiple counter data in traced events

Types of Parallel Performance Profiling

- Flat profiles
  - Metric (e.g., time) spent in an event (callgraph nodes)
  - Exclusive/inclusive, # of calls, child calls
- Callpath profiles (Calldepth profiles)
  - Time spent along a calling path (edges in callgraph)
  - “main=> f1 => f2 => MPI_Send” (event name)
  - TAU_CALLPATH_DEPTH environment variable
- Phase profiles
  - Flat profiles under a phase (nested phases are allowed)
  - Default “main” phase
  - Supports static or dynamic (per-iteration) phases

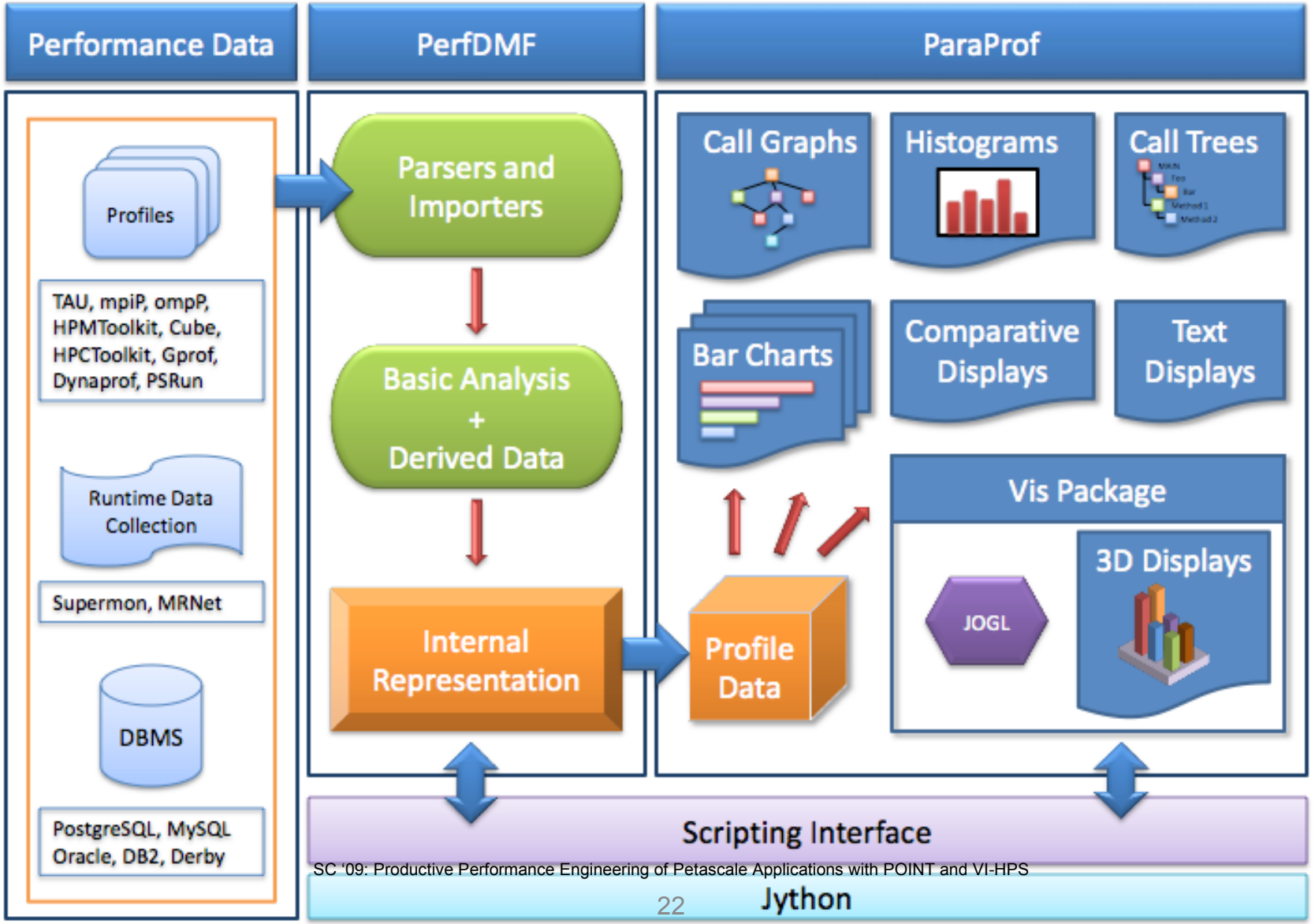
TAU Analysis



Performance Analysis

- Analysis of parallel profile and trace measurement
- Parallel profile analysis (ParaProf)
  - Java-based analysis and visualization tool
  - Support for large-scale parallel profiles
- Performance data management framework (PerfDMF)
- Parallel trace analysis
  - Translation to VTF (V3.0), EPILOG, OTF formats
  - Integration with Vampir / Vampir Server (TU Dresden)
  - Profile generation from trace data
- Online parallel analysis and visualization
- Integration with CUBE browser (Scalasca, UTK / FZJ)

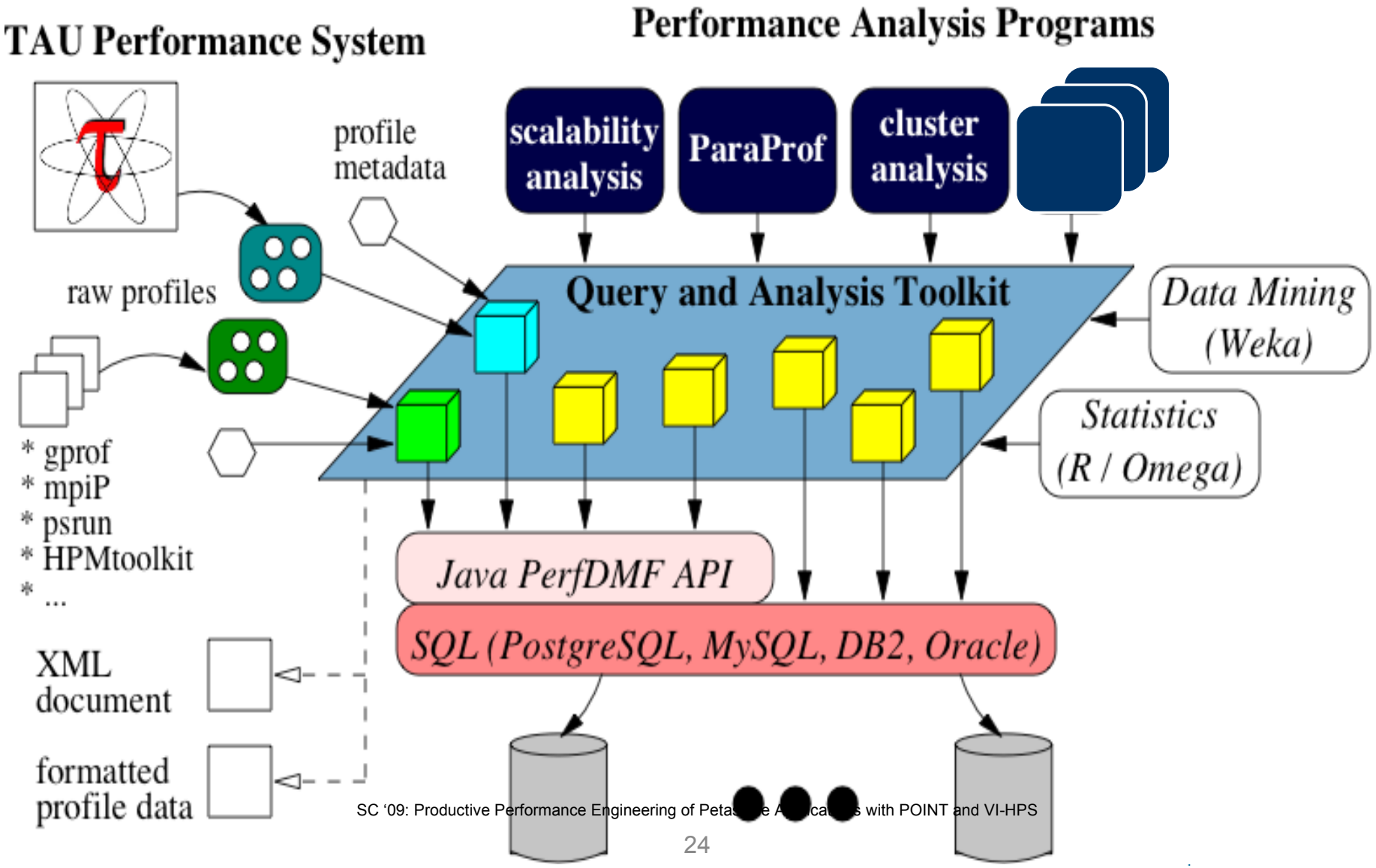
ParaProf Profile Analysis Framework



Performance Data Management

- Provide an open, flexible framework to support common data management tasks
  - Foster multi-experiment performance evaluation
- Extensible toolkit to promote integration and reuse across available performance tools (PerfDMF)
  - Originally designed to address critical TAU requirements
  - Supported profile formats:
    TAU, CUBE (Scalasca), HPC Toolkit (Rice), HPM Toolkit (IBM), gprof, mpiP, psrun (PerfSuite), Open|SpeedShop, …
  - Supported DBMS:
    PostgreSQL, MySQL, Oracle, DB2, Derby/Cloudscape
  - Profile query and analysis API
- Reference implementation for PERI-DB project

PerfDMF Architecture



Metadata Collection

- Integration of XML metadata for each parallel profile
- Three ways to incorporate metadata
  - Measured hardware/system information (TAU, PERI-DB)
    - CPU speed, memory in GB, MPI node IDs, …
  - Application instrumentation (application-specific)
    - TAU_METADATA() used to insert any name/value pair
    - Application parameters, input data, domain decomposition
  - PerfDMF data management tools can incorporate an XML file of additional metadata
    - Compiler flags, submission scripts, input files, …
- Metadata can be imported from / exported to PERI-DB

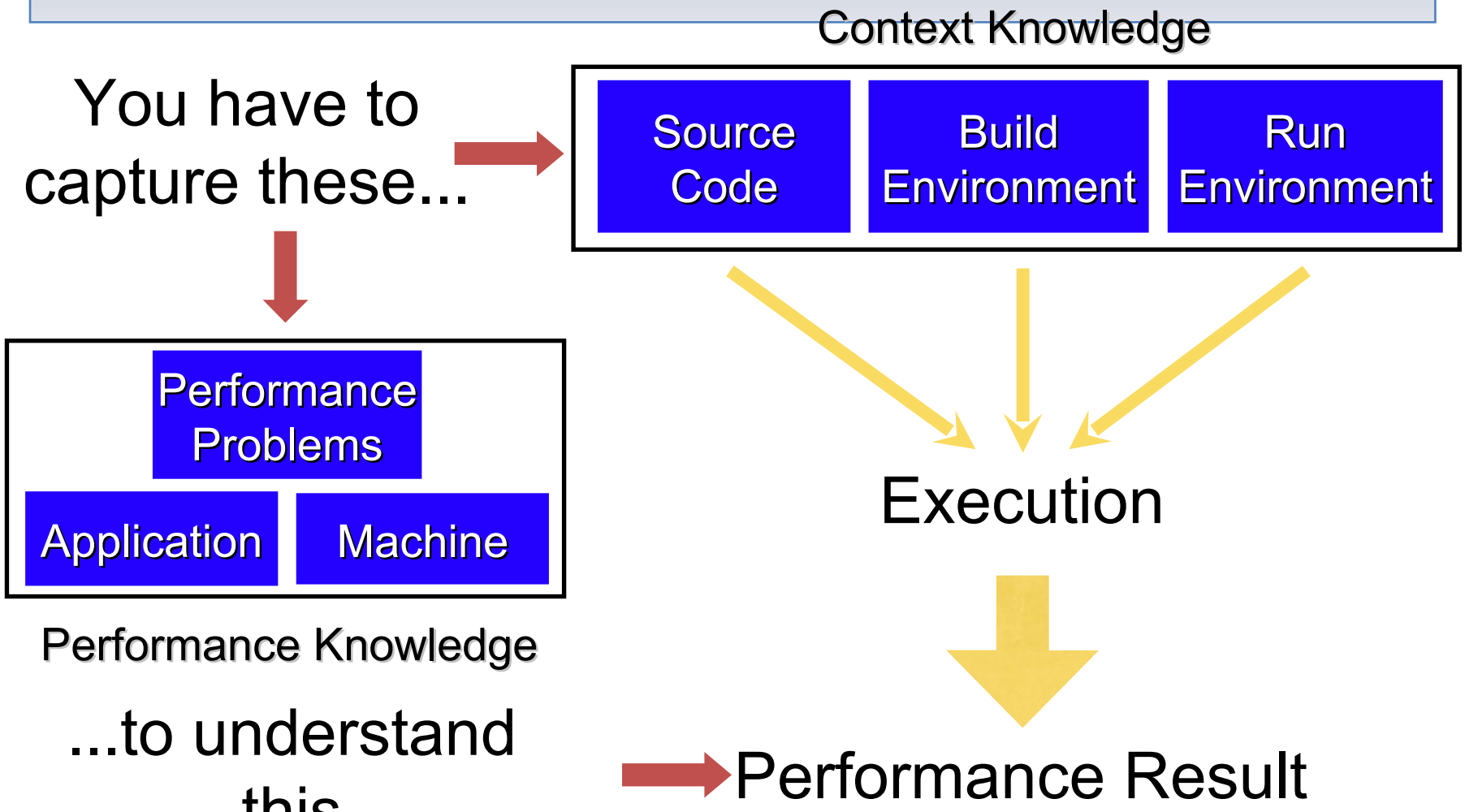
Performance Data Mining / Analytics

- Conduct systematic and scalable analysis process
  - Multi-experiment performance analysis
  - Support automation, collaboration, and reuse
- Performance knowledge discovery framework
  - Data mining analysis applied to parallel performance data
    - comparative, clustering, correlation, dimension reduction, …
  - Use the existing TAU infrastructure
- PerfExplorer v1 performance data mining framework
  - Multiple experiments and parametric studies
  - Integrate available statistics and data mining packages
    - Weka, R, Matlab / Octave
  - Apply data mining operations in interactive enviroment

How to explain performance?

- Should not just redescribe the performance results
- Should explain performance phenomena
  - What are the causes for performance observed?
  - What are the factors and how do they interrelate?
  - Performance analytics, forensics, and decision support
- Need to add knowledge to do more intelligent things
  - Automated analysis needs good informed feedback
    - iterative tuning, performance regression testing
  - Performance model generation requires interpretation
- We need better methods and tools for
  - Integrating meta-information
  - Knowledge-based performance problem solving

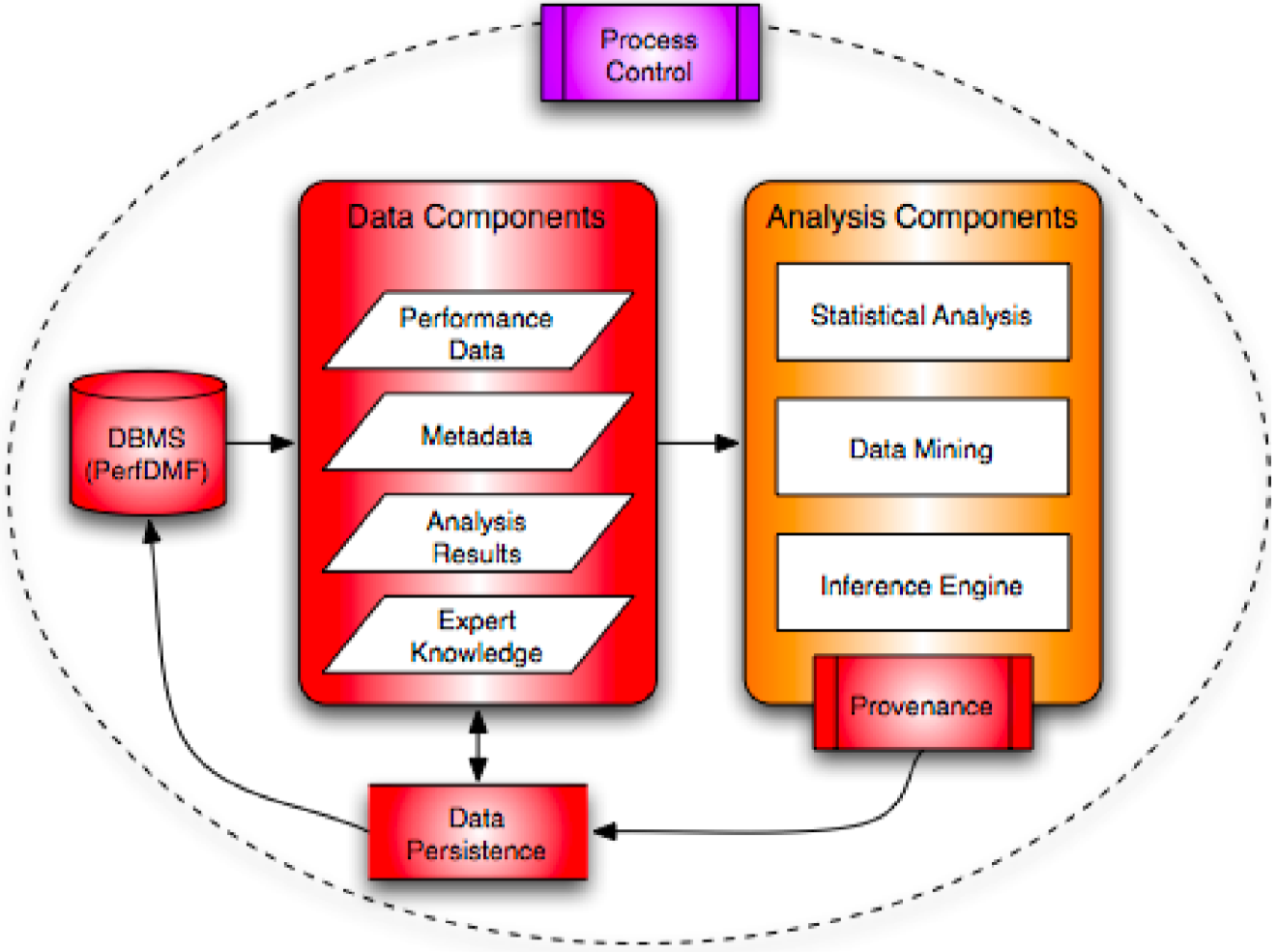
Role of Metadata and Knowledge Role



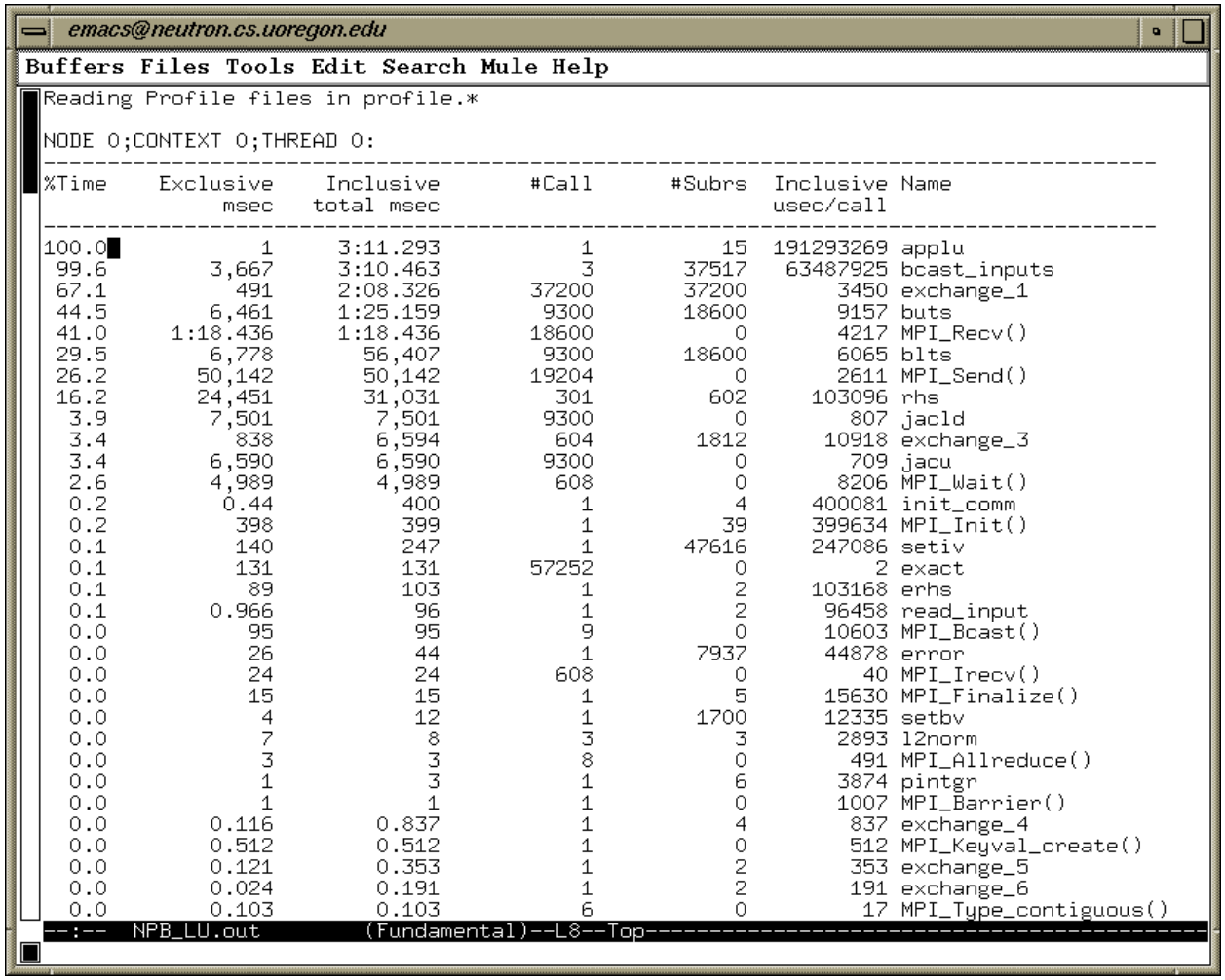
PerfExplorer v2 – Requirements

- Component-based analysis process
  - Analysis operations implemented as modules
  - Linked together in analysis process and workflow
- Scripting
  - Provides process/workflow development and automation
- Metadata input, management, and access
- Inference engine
  - Reasoning about causes of performance phenomena
  - Analysis knowledge captured in expert rules
- Persistence of intermediate analysis results
- Provenance
  - Provides historical record of analysis results

PerfExplorer v2 Architecture



Parallel Profile Analysis – pprof



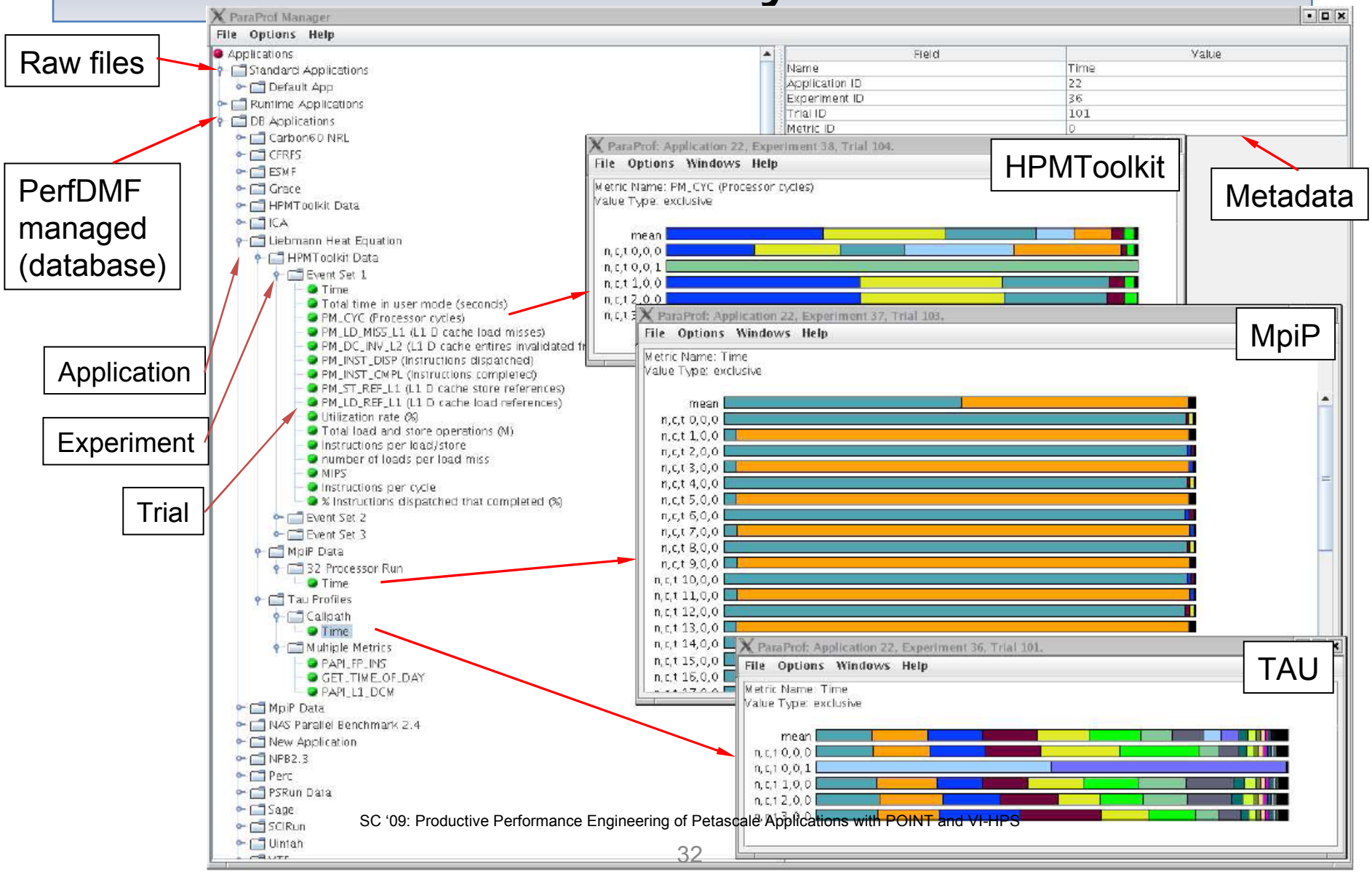
emacs@neutron.cs.uoregon.edu

Buffers Files Tools Edit Search Mule Help

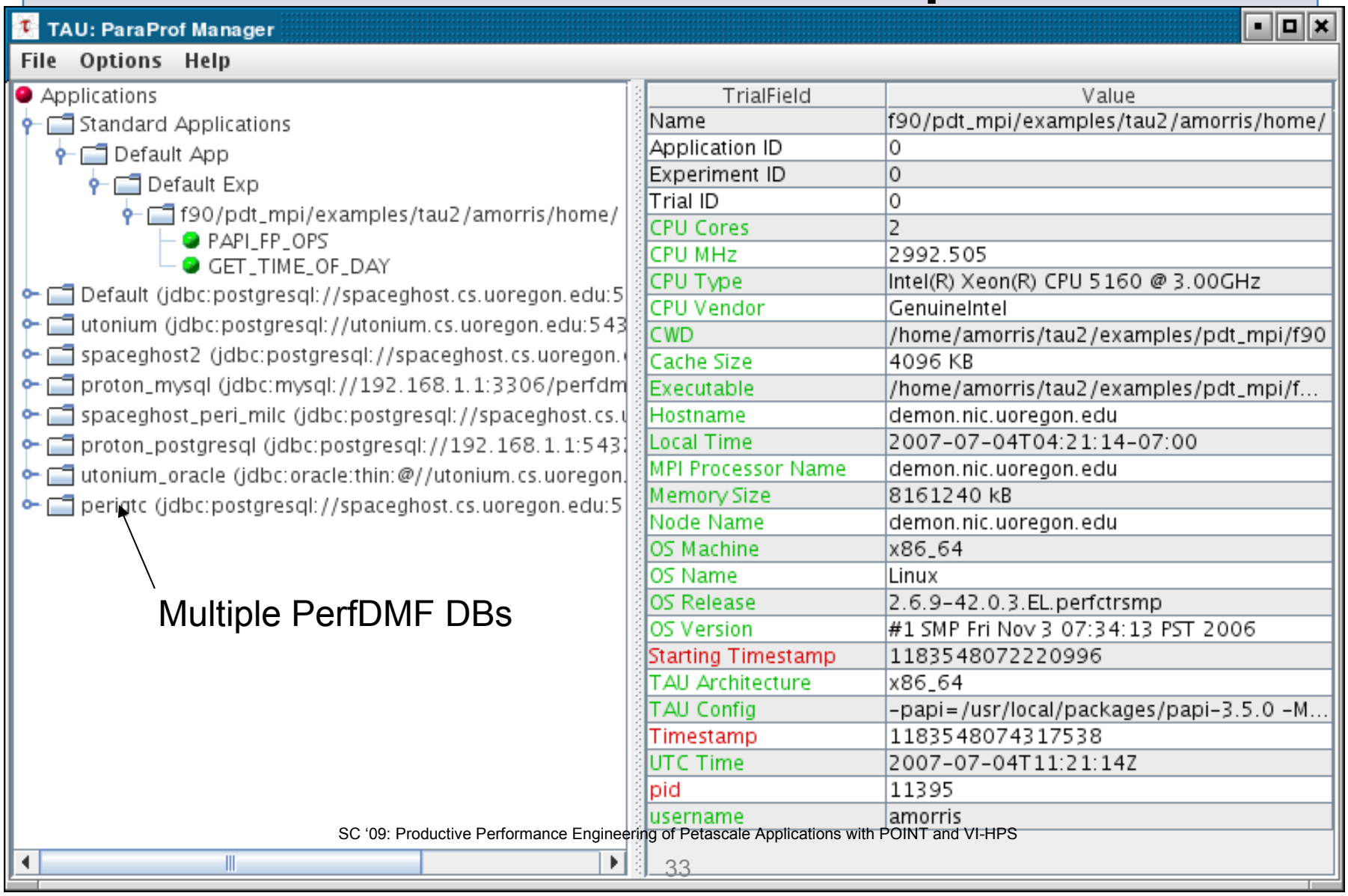
```
Reading Profile files in profile.*

NODE 0;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0           1     3:11.293           1          15  191293269 applu
 99.6       3,667     3:10.463           3       37517   63487925 bcast_inputs
 67.1         491     2:08.326       37200       37200       3450 exchange_1
 44.5       6,461     1:25.159        9300       18600       9157 buts
 41.0    1:18.436     1:18.436       18600           0       4217 MPI_Recv()
 29.5       6,778       56,407        9300       18600       6065 blts
 26.2      50,142       50,142       19204           0       2611 MPI_Send()
 16.2      24,451       31,031         301         602     103096 rhs
  3.9       7,501        7,501        9300           0        807 jacld
  3.4         838        6,594         604        1812      10918 exchange_3
  3.4       6,590        6,590        9300           0        709 jacu
  2.6       4,989        4,989         608           0       8206 MPI_Wait()
  0.2        0.44          400           1           4     400081 init_comm
  0.2         398          399           1          39     399634 MPI_Init()
  0.1         140          247           1       47616     247086 setiv
  0.1         131          131       57252           0          2 exact
  0.1          89          103           1           2     103168 erhs
  0.1       0.966           96           1           2      96458 read_input
  0.0          95           95           9           0      10603 MPI_Bcast()
  0.0          26           44           1        7937      44878 error
  0.0          24           24         608           0         40 MPI_Irecv()
  0.0          15           15           1           5      15630 MPI_Finalize()
  0.0           4           12           1        1700      12335 setbv
  0.0           7            8           3           3       2893 l2norm
  0.0           3            3           8           0        491 MPI_Allreduce()
  0.0           1            3           1           6       3874 pintgr
  0.0           1            1           1           0       1007 MPI_Barrier()
  0.0       0.116        0.837           1           4        837 exchange_4
  0.0       0.512        0.512           1           0        512 MPI_Keyval_create()
  0.0       0.121        0.353           1           2        353 exchange_5
  0.0       0.024        0.191           1           2        191 exchange_6
  0.0       0.103        0.103           6           0         17 MPI_Type_contiguous()
--:--  NPB_LU.out       (Fundamental)--L8--Top-----------------------------------------
```

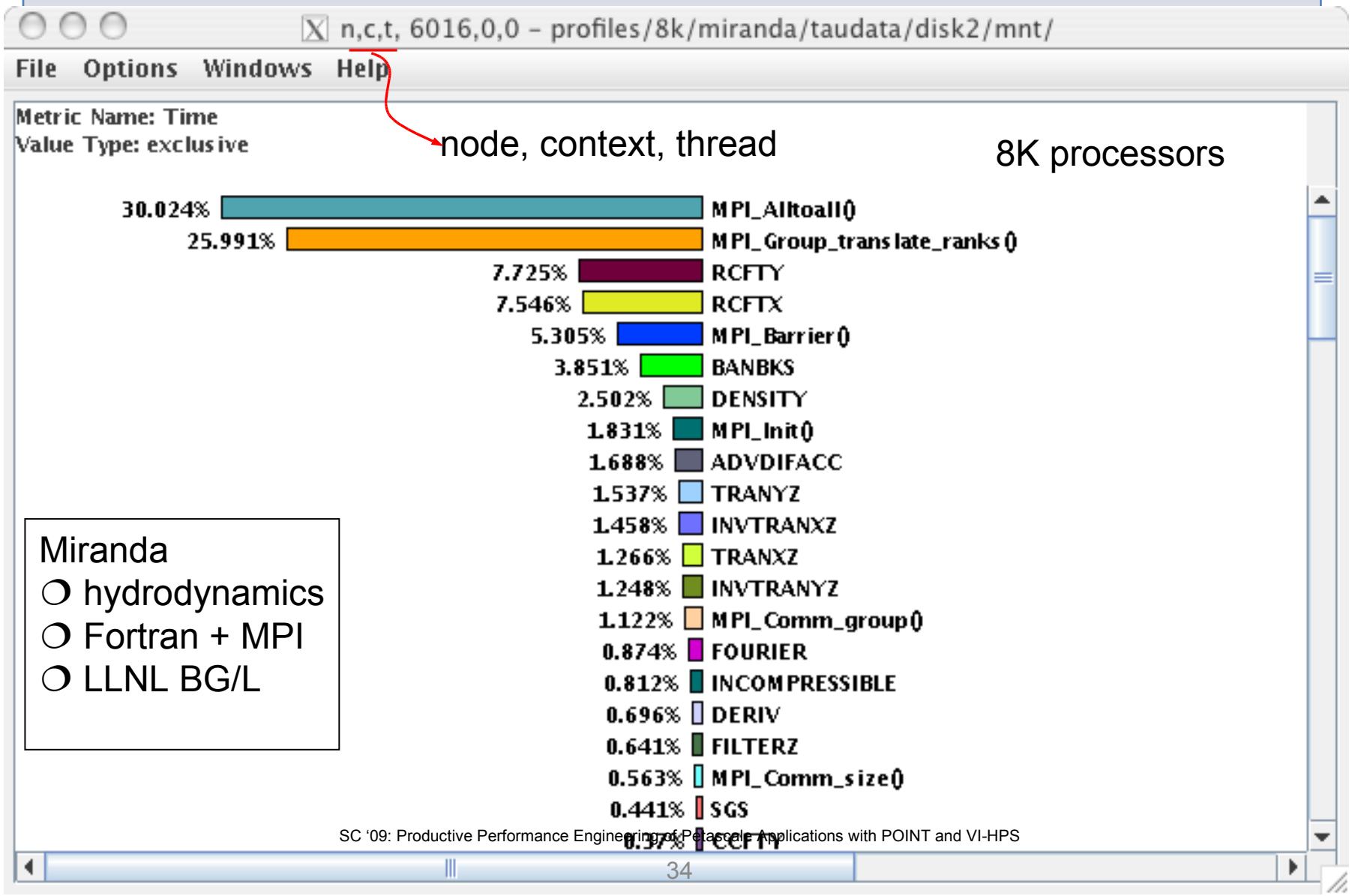
Parallel Profile Analysis – ParaProf



Metadata for Each Experiment

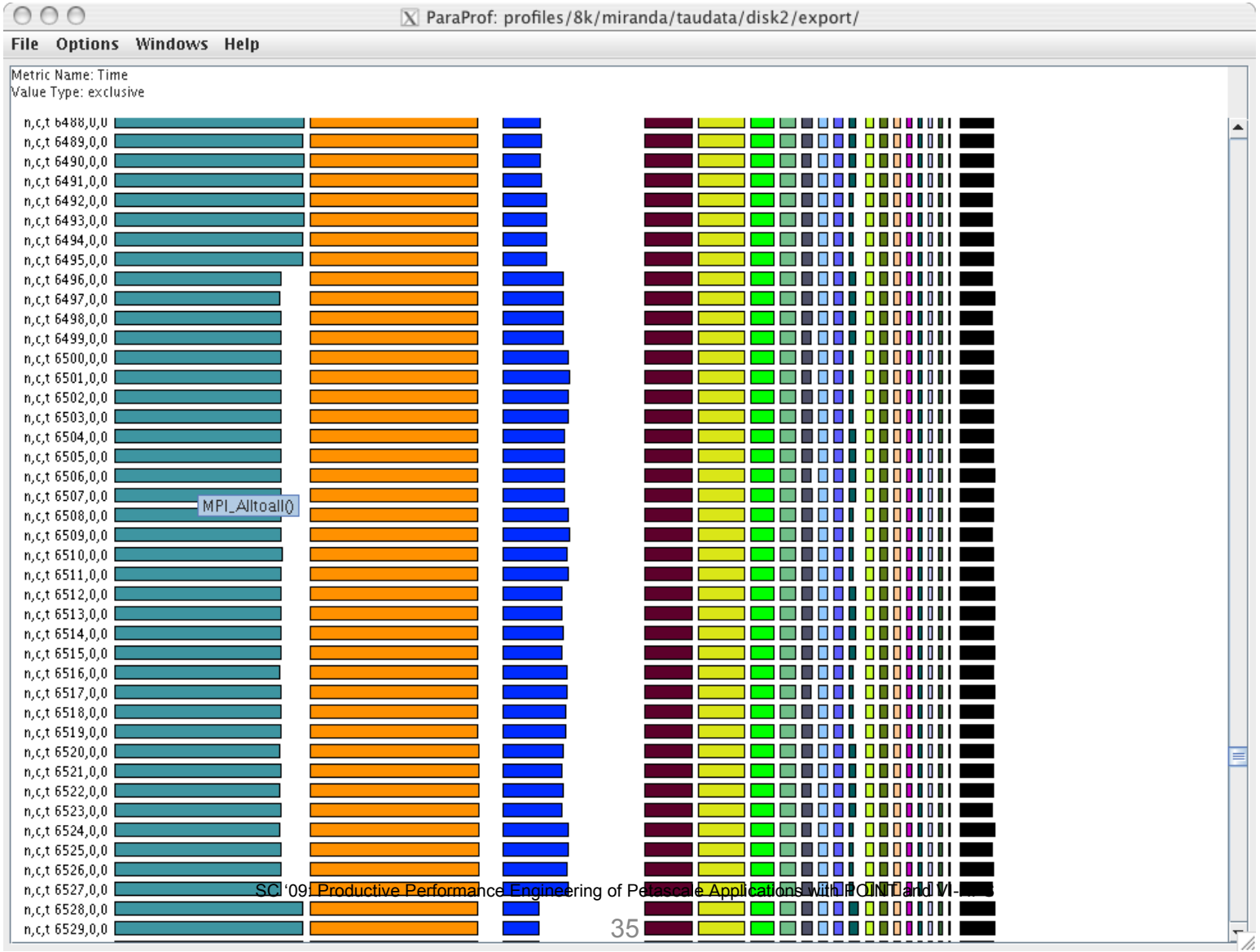


ParaProf – Flat Profile

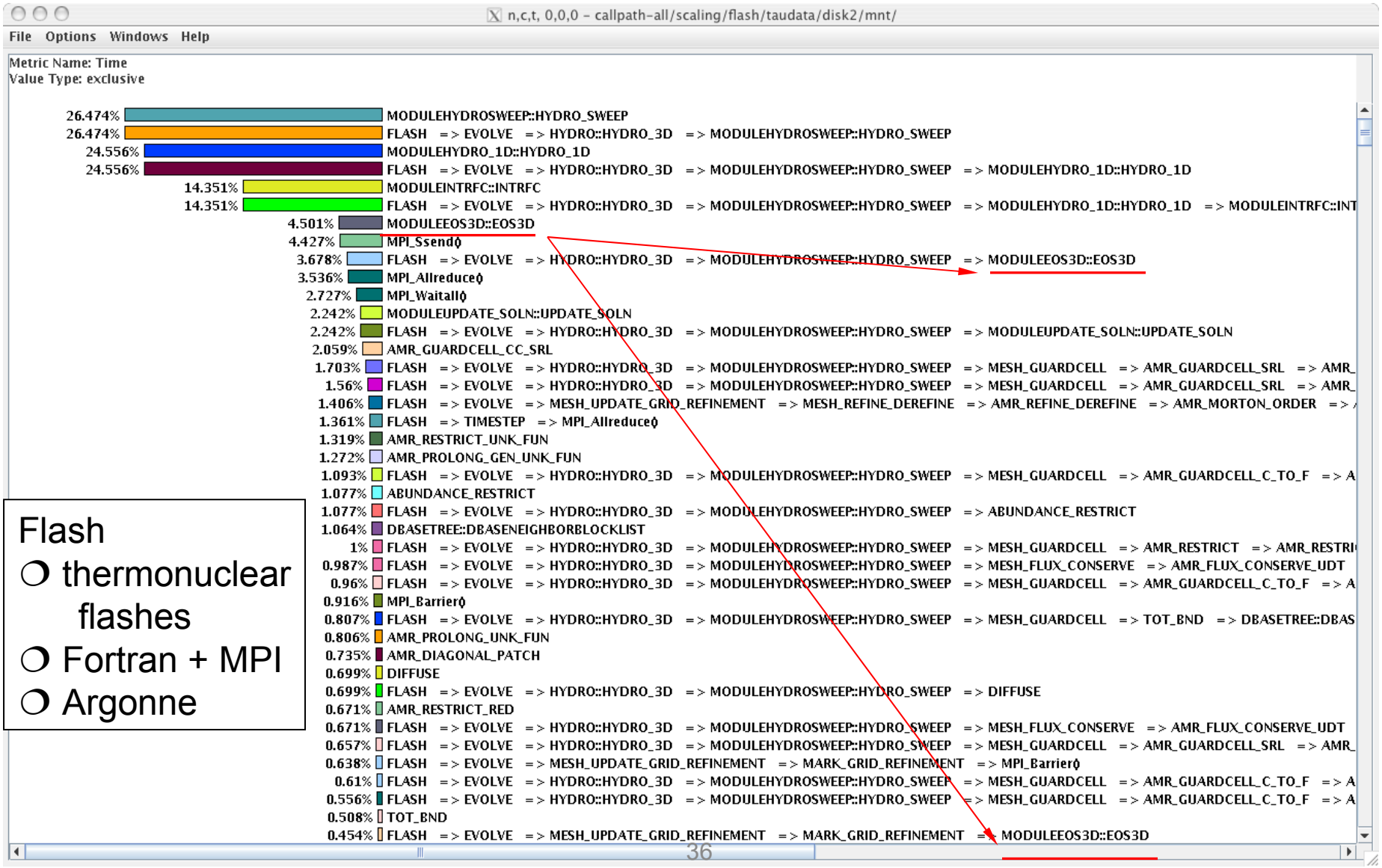


Miranda
- hydrodynamics
- Fortran + MPI
- LLNL BG/L

ParaProf – Stacked View

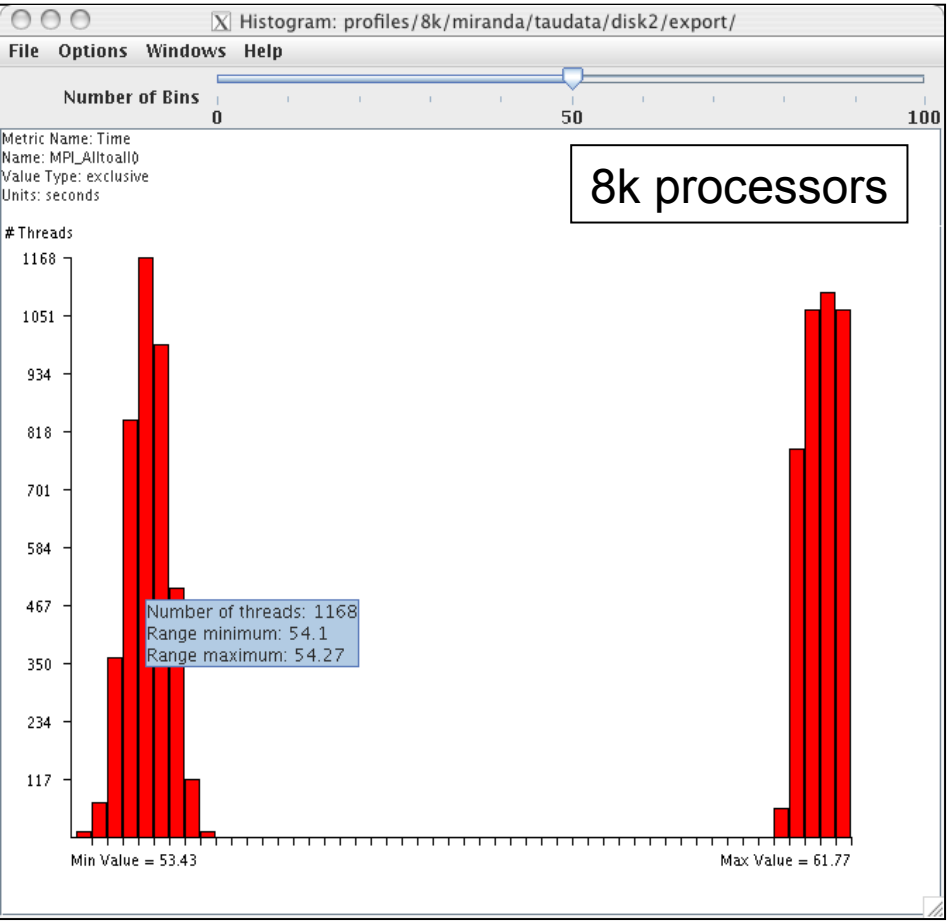


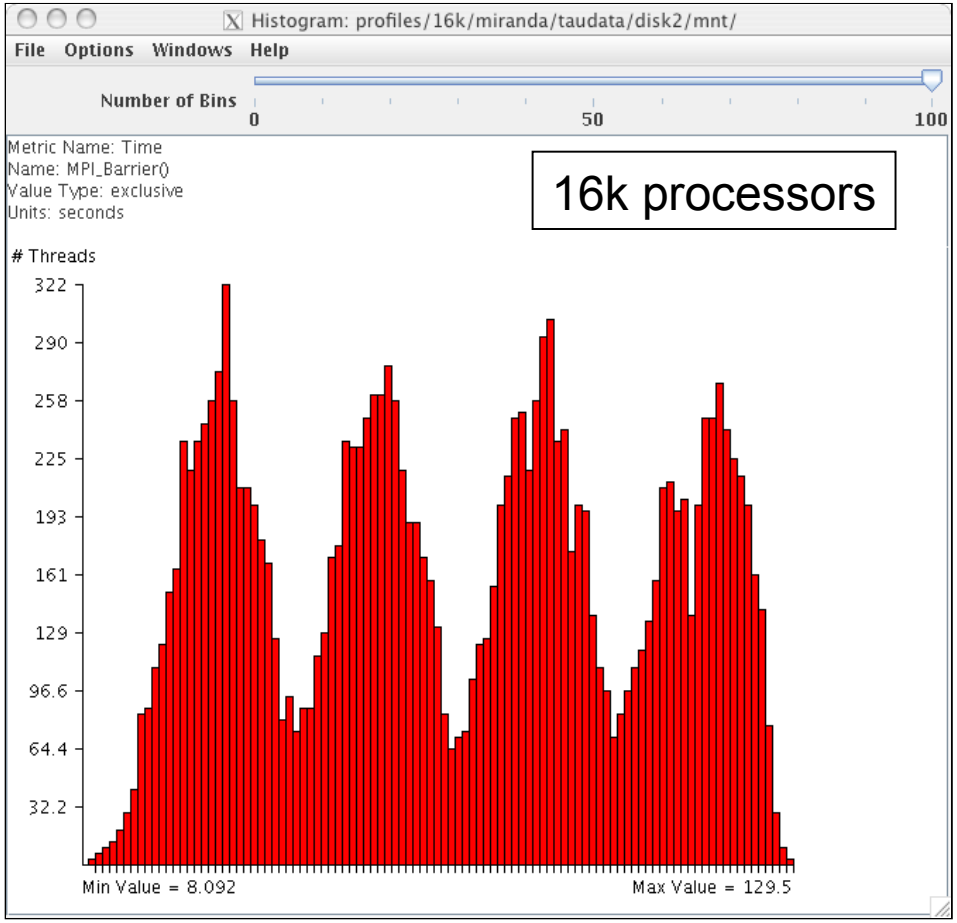
ParaProf – Callpath Profile



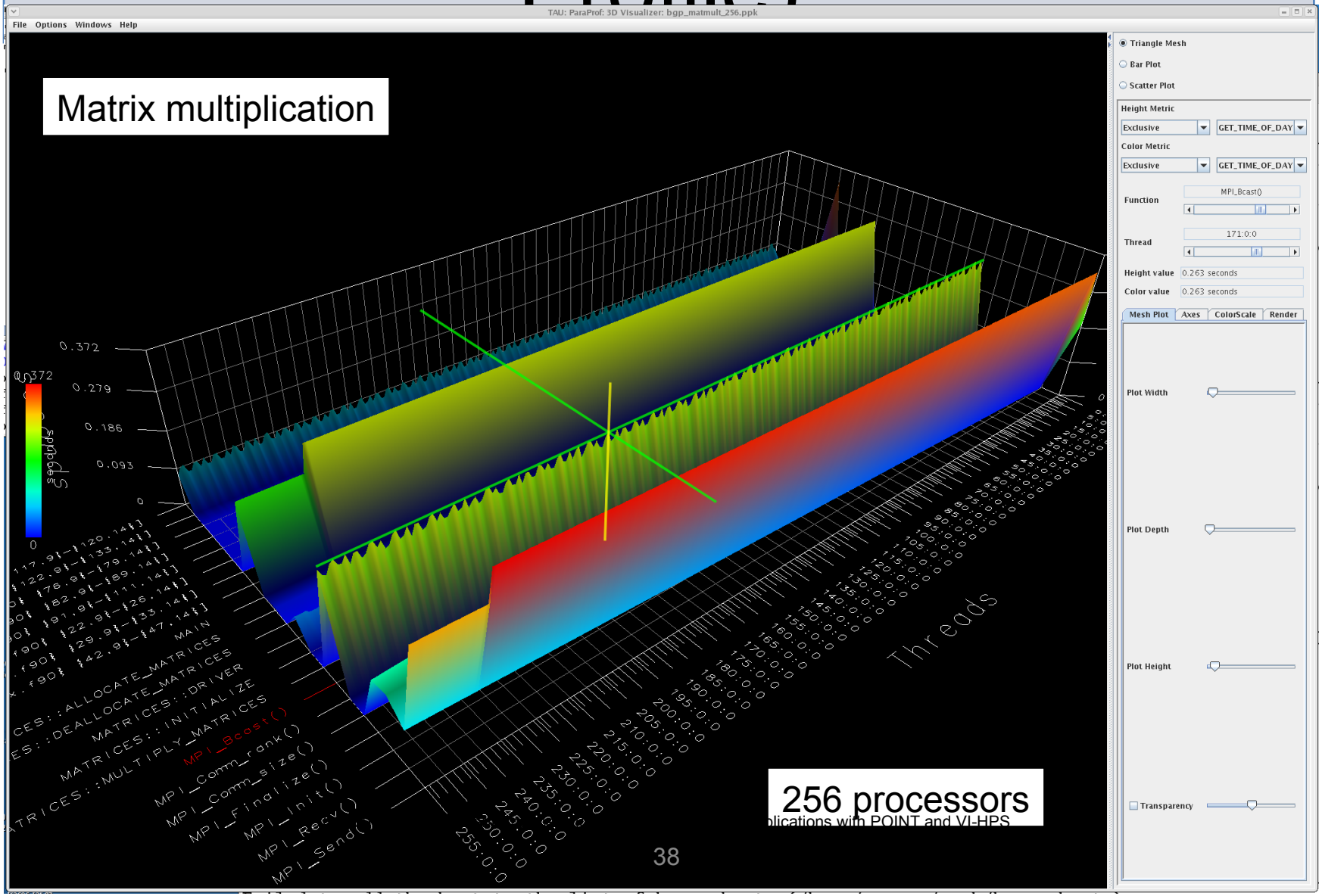
Flash
- thermonuclear flashes
- Fortran + MPI
- Argonne

ParaProf – Scalable Histogram

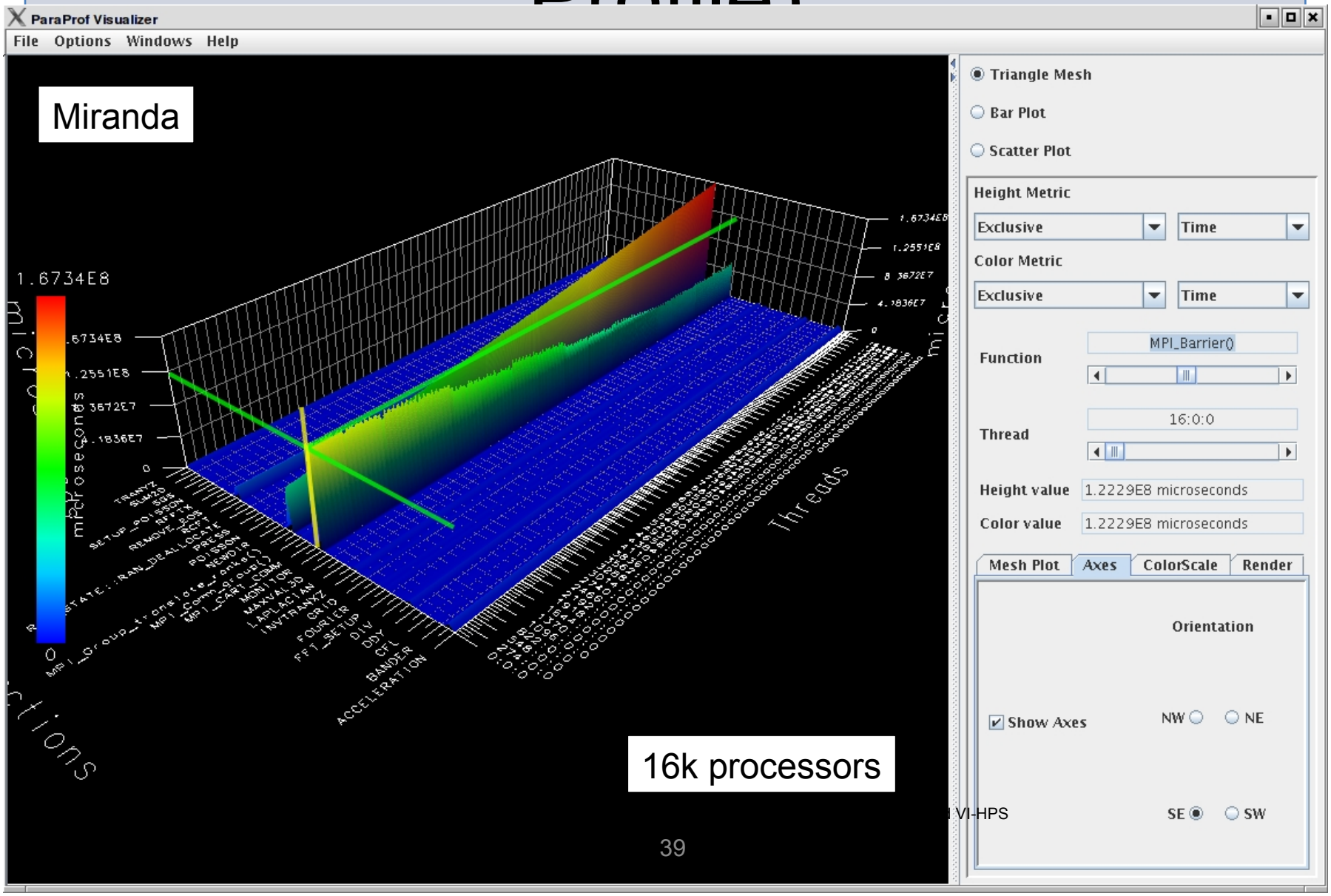




ParaProf – 3D View (Full Profile)

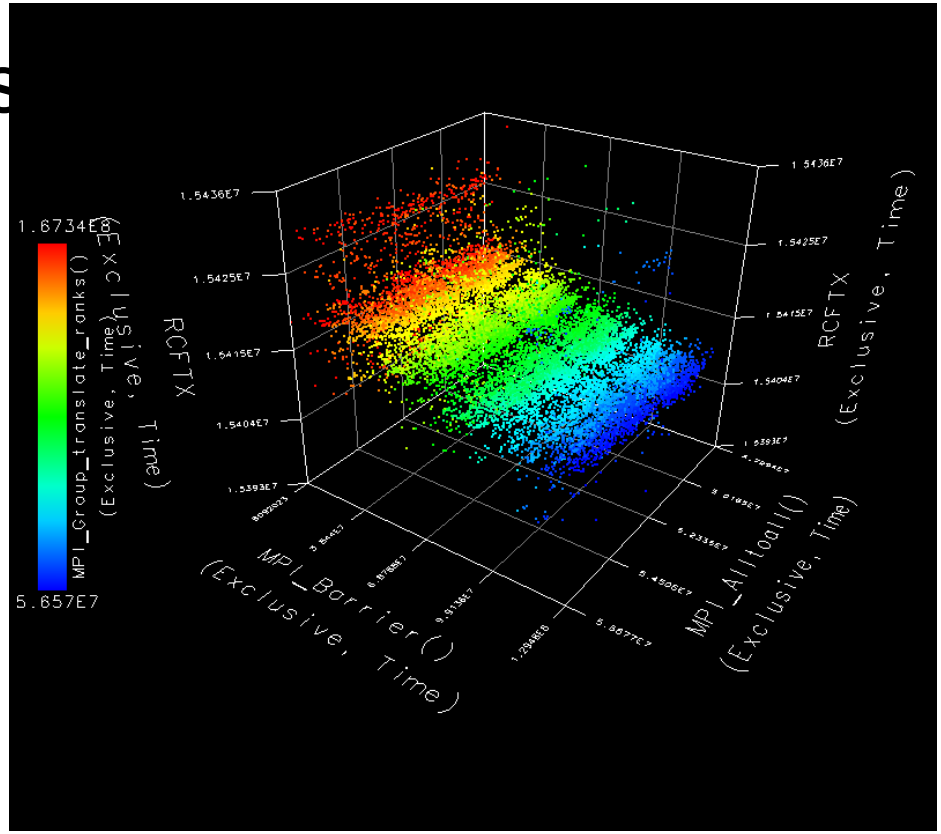


ParaProf – 3D View (Full Profile)



ParaProf – 3D Scatterplot

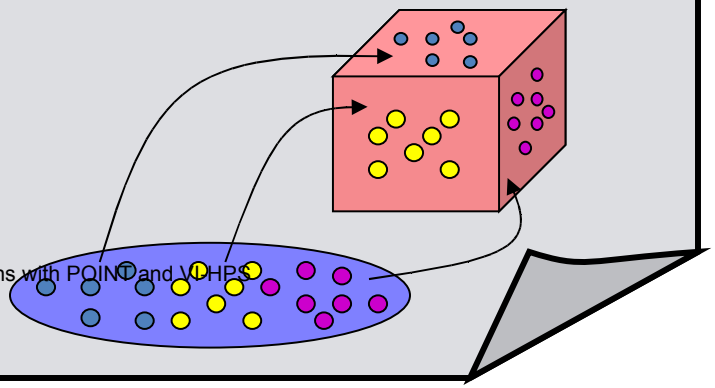
- Each point is a “thread” of execution
- A total of four metrics shown in relation
- ParaProf’s visualization library
  - JOGL
- Miranda



Performance Mapping

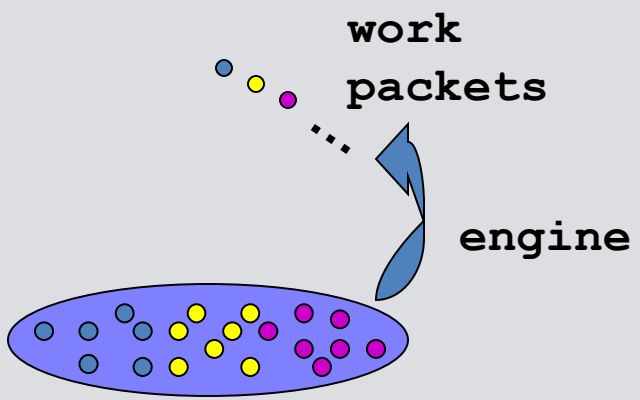
- Example: Particles distributed on cube

```
Particle* P[MAX]; /* Array of particles */
int GenerateParticles() {
  /* distribute particles over all faces of the cube */
  for (int face=0, last=0; face < 6; face++){
    /* particles on this face */
    int particles_on_this_face = num(face);
    for (int i=last; i < particles_on_this_face; i++) {
      /* particle properties are a function of face */
    P[i] = ... f(face);
      ...
    }
    last+= particles_on_this_face;
  }
}
```



Performance Mapping

```
int ProcessParticle(Particle *p) {
  /* perform some computation on p */
}
int main() {
  GenerateParticles();
  /* create a list of particles */
  for (int i = 0; i < N; i++)
    /* iterates over the list */
    ProcessParticle(P[i]);
}
```



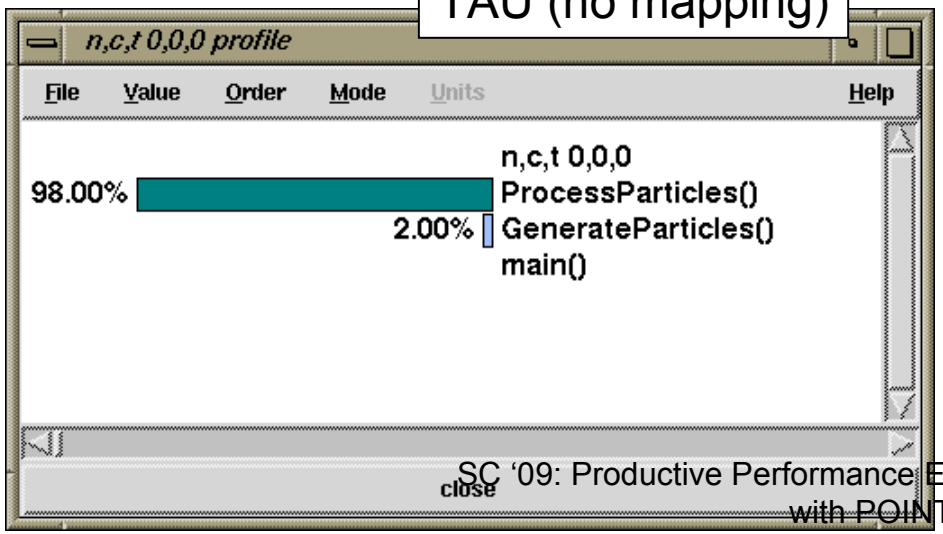
- How much time (flops) spent processing face i particles?
- What is the distribution of performance among faces?

No Mapping versus Mapping

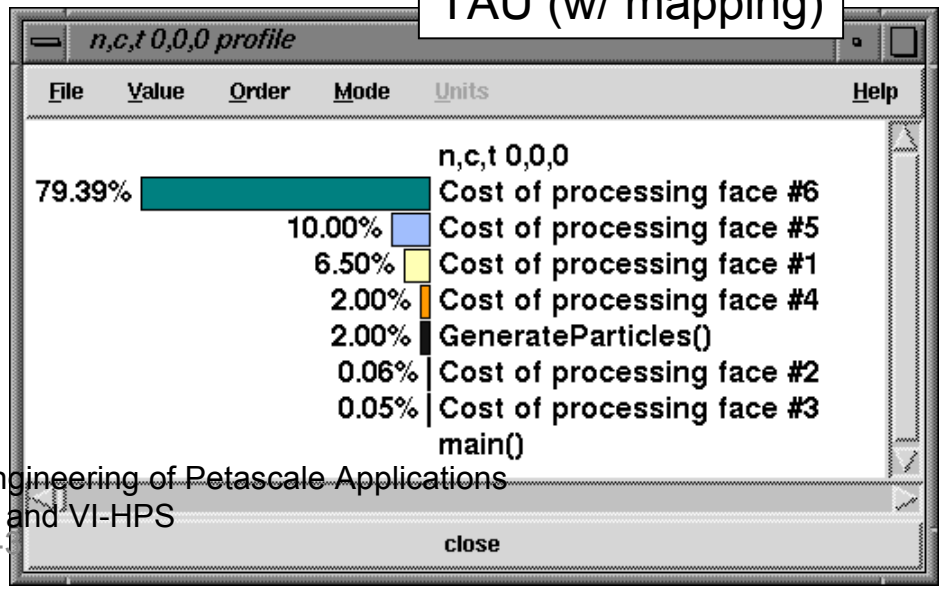
- Typical performance tools report performance with respect to routines
- Does not provide support for mapping

- TAU's performance mapping can observe performance with respect to scientist's programming and problem abstractions

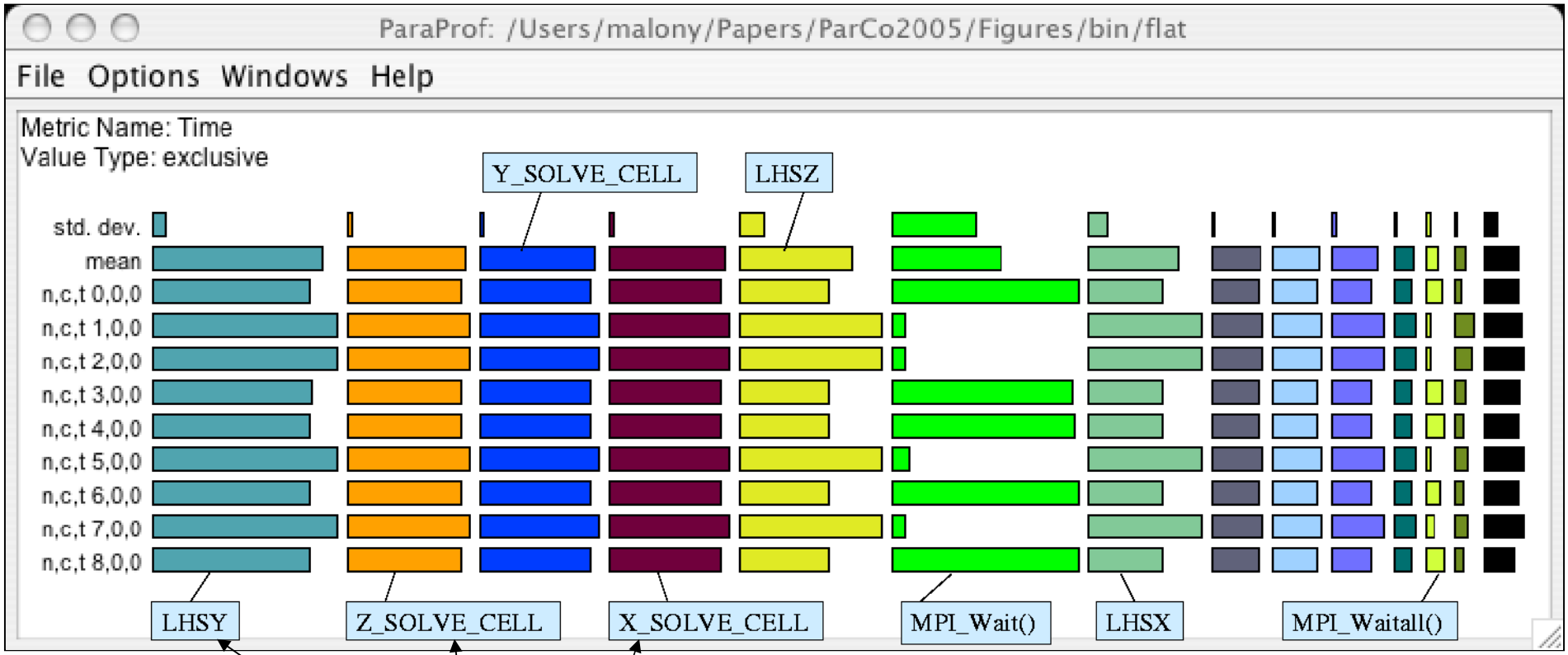
TAU (no mapping)



TAU (w/ mapping)



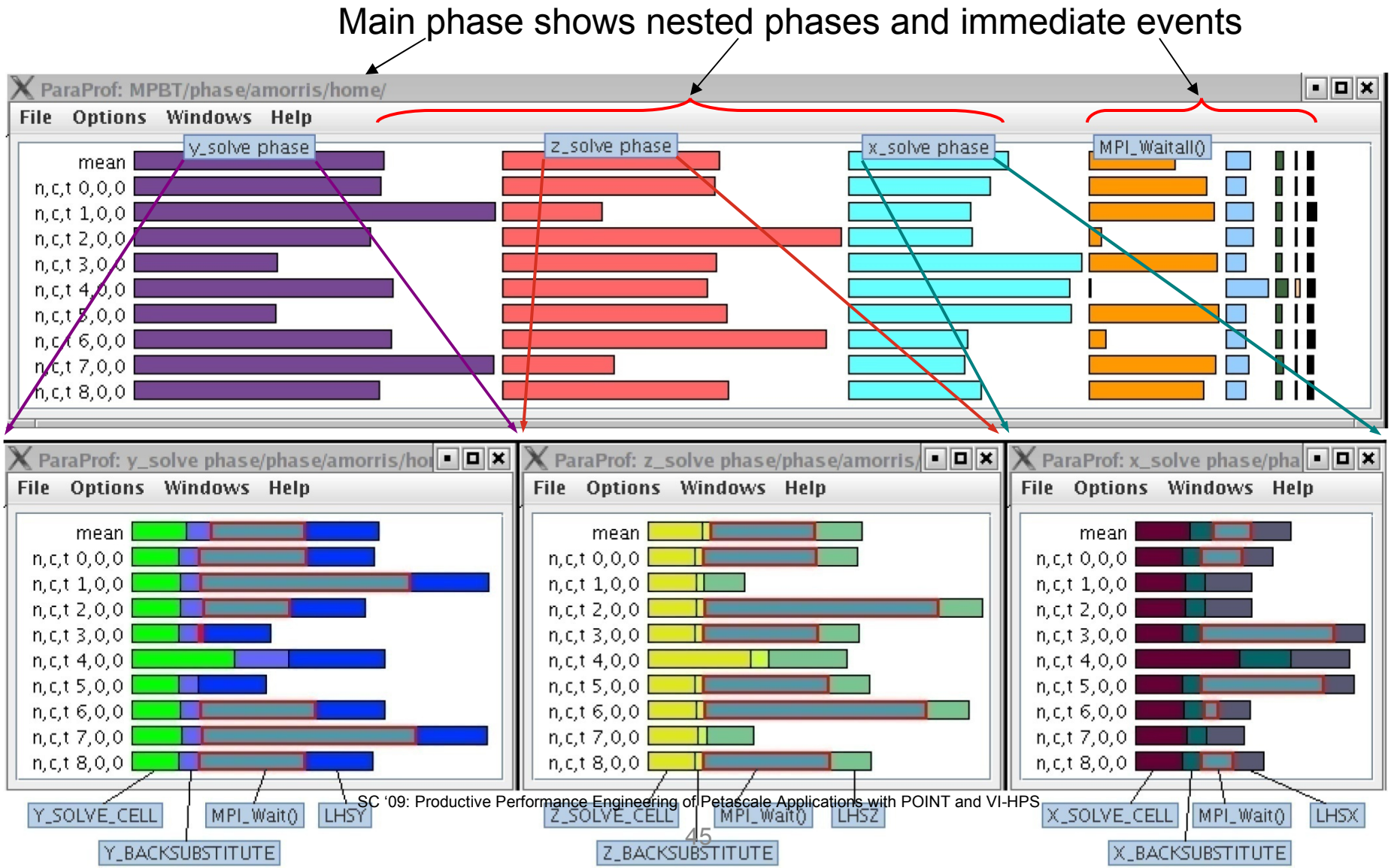
NAS BT – Flat Profile



Application routine names reflect phase semantics

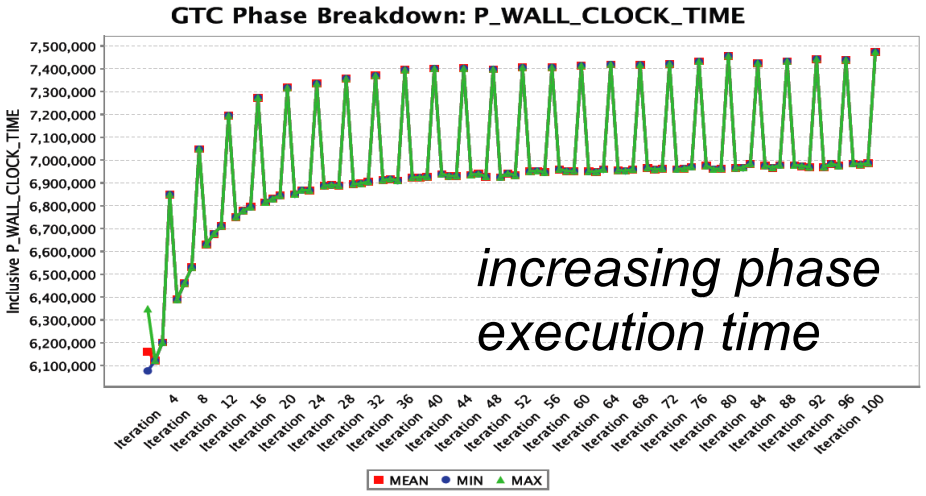
How is MPI_Wait() distributed relative to solver direction?

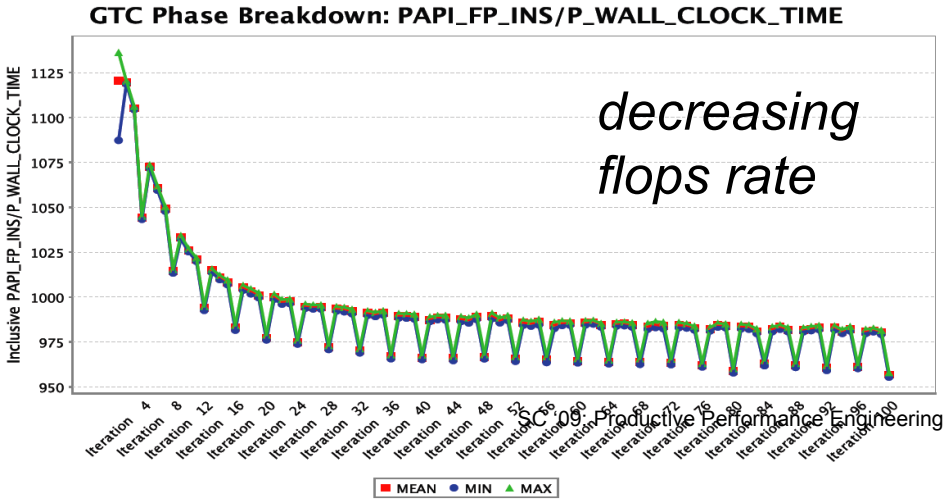
NAS BT – Phase Profile

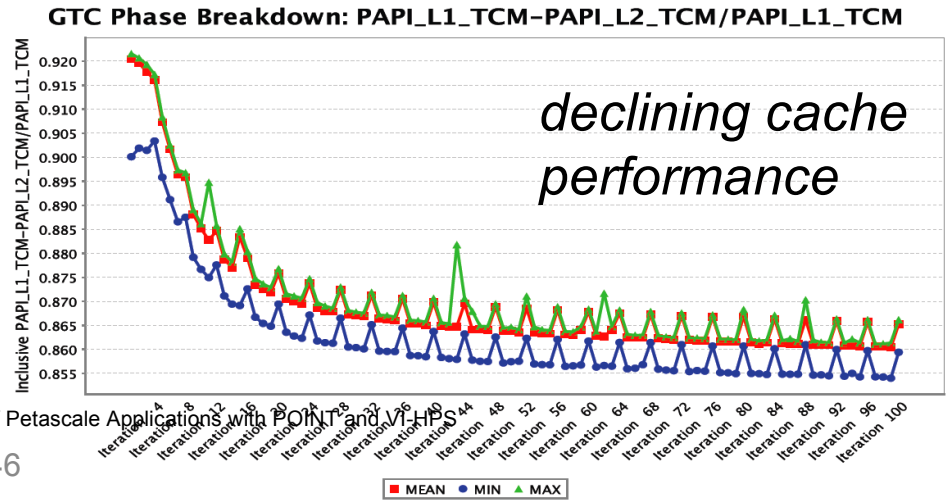


Phase Profiling of HW Counters

- GTC particle-in-cell simulation of fusion turbulence
- Phases assigned to iterations
- Poor temporal locality for one important data
- Automatically generated by PE2 python script

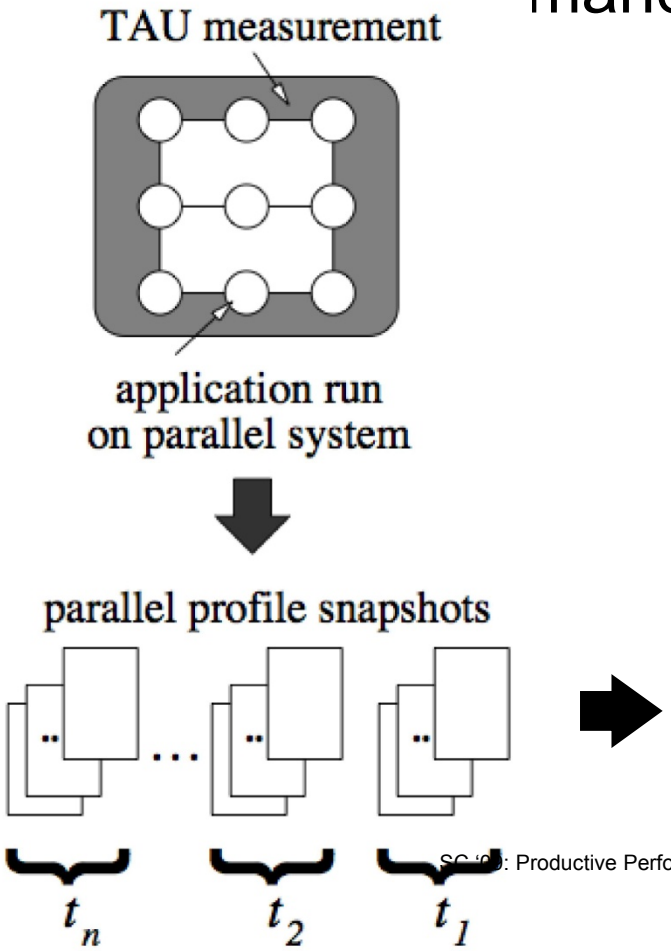


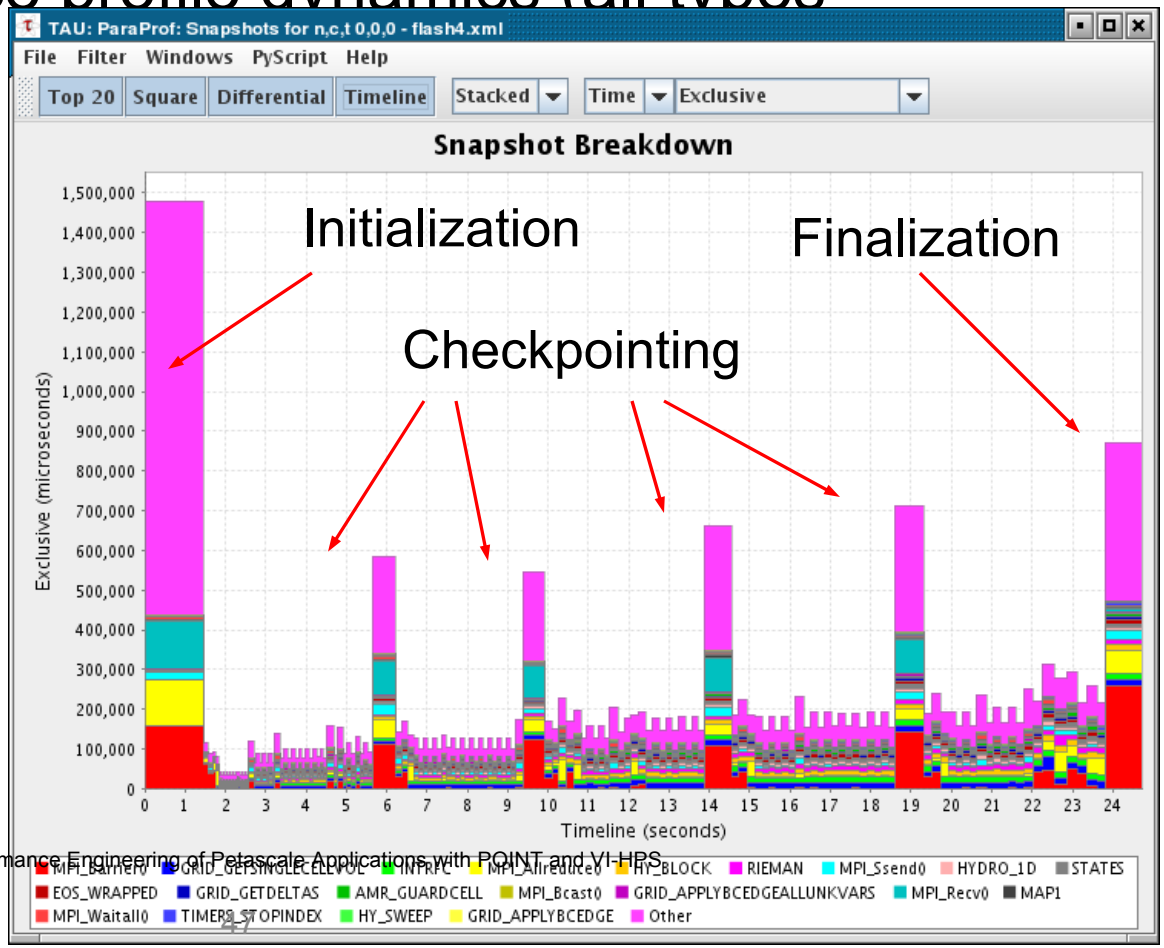




Profile Snapshots in ParaProf

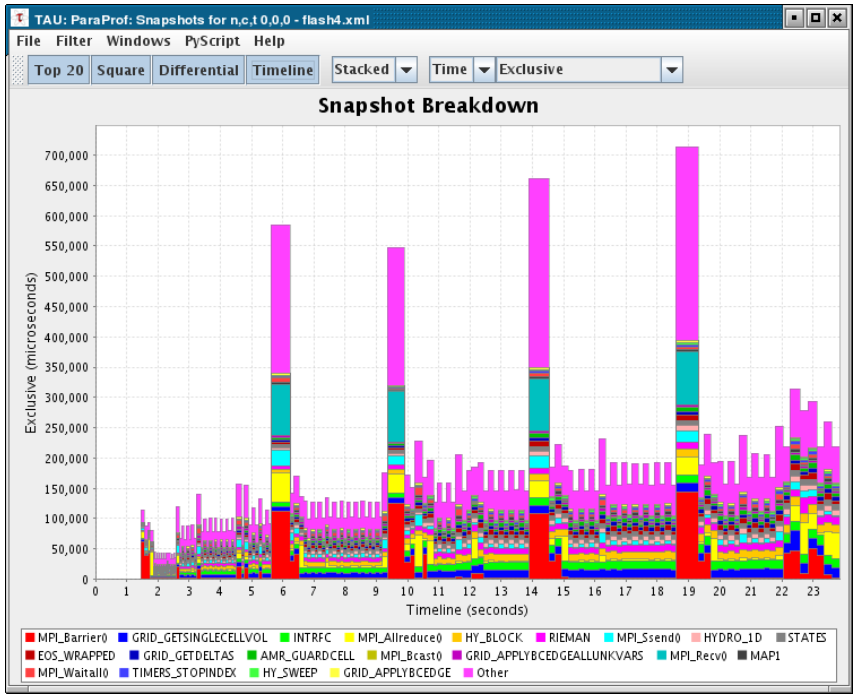
- Profile snapshots are parallel profiles recorded at runtime
- Shows performance profile dynamics (all types

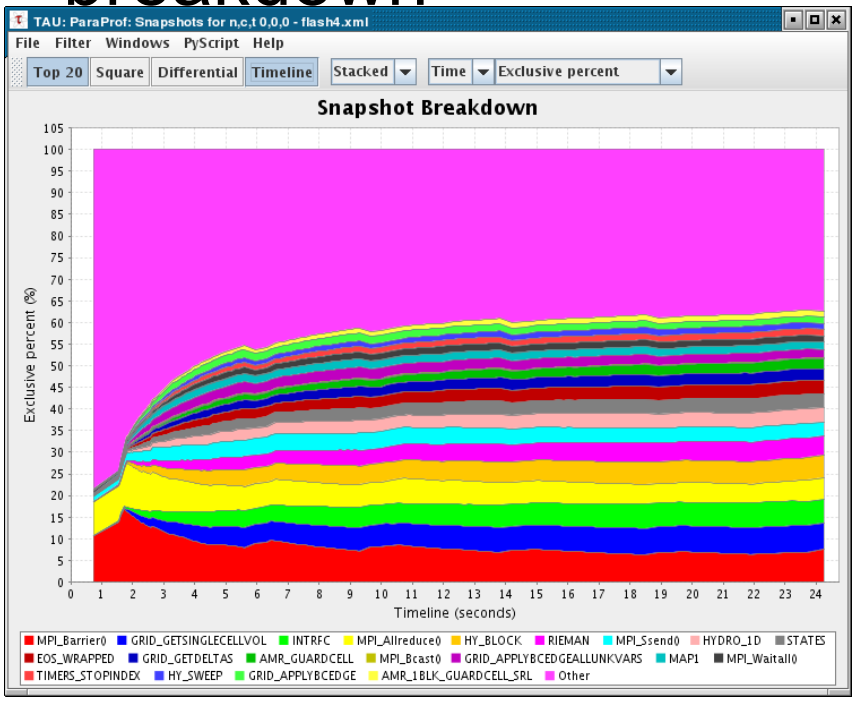




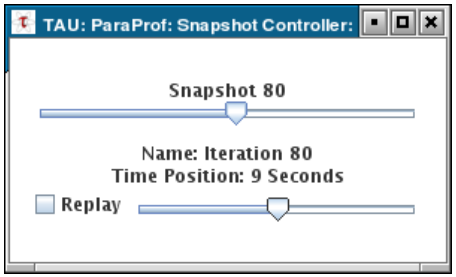
Profile Snapshot Views

- Only show main loop
- Percentage breakdown

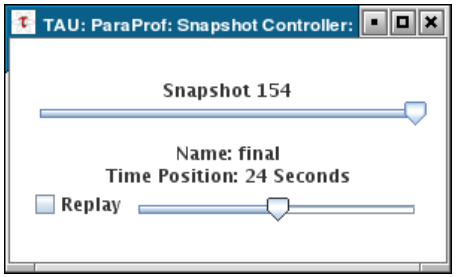


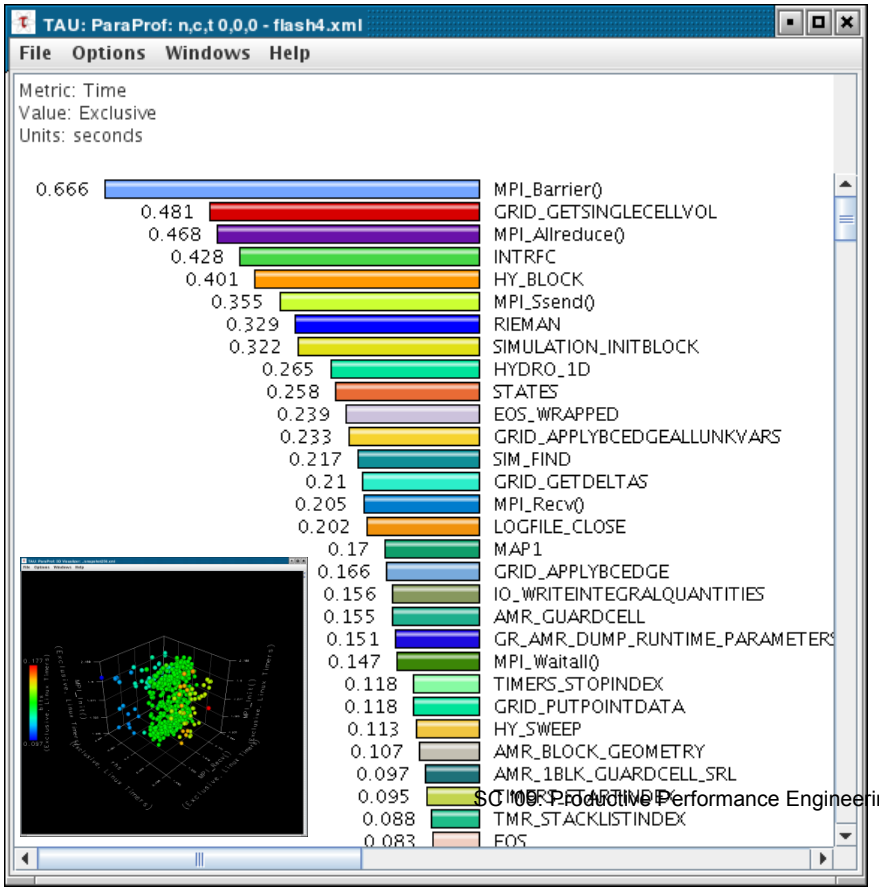


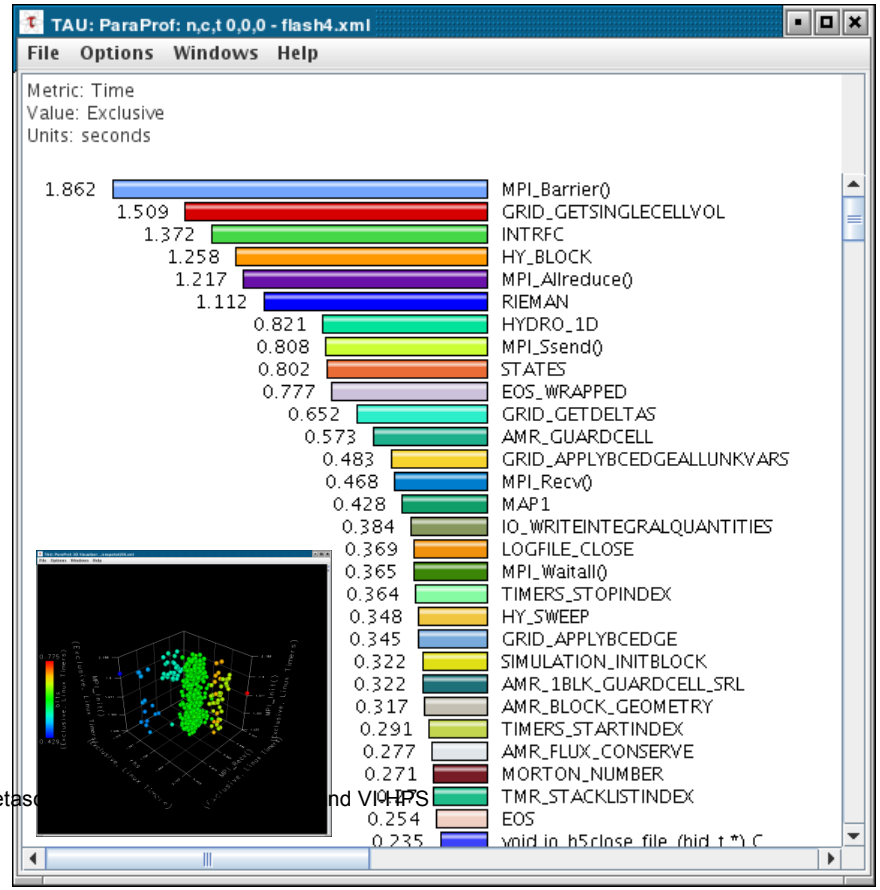
Snapshot Replay in ParaProf



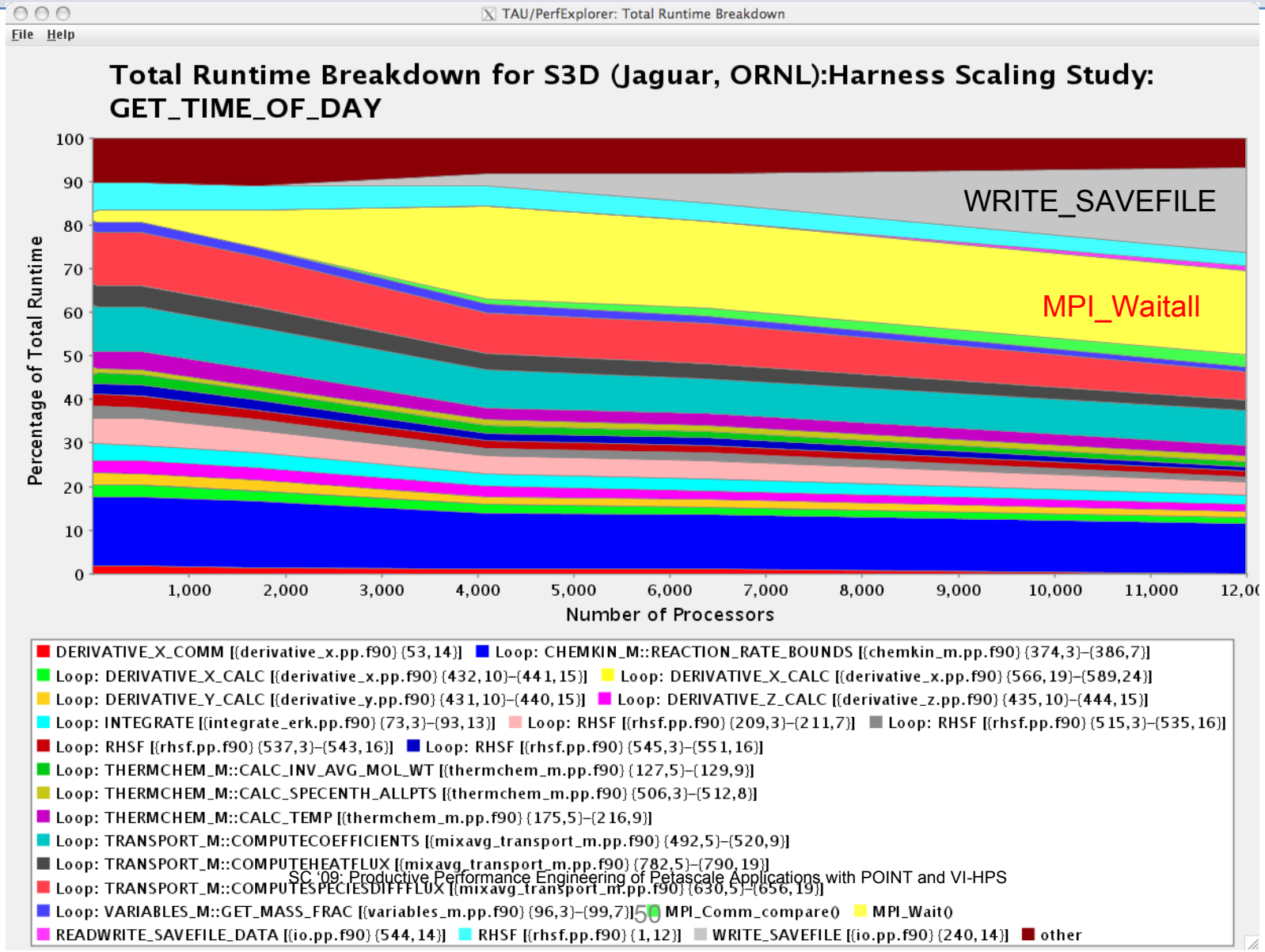
All windows dynamically update





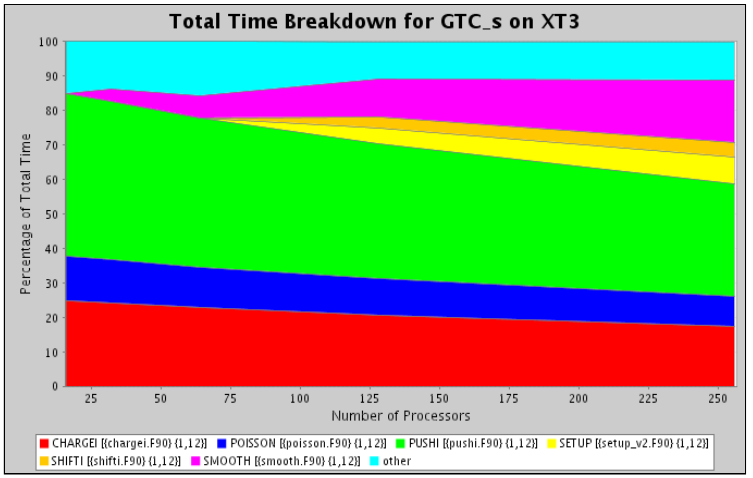


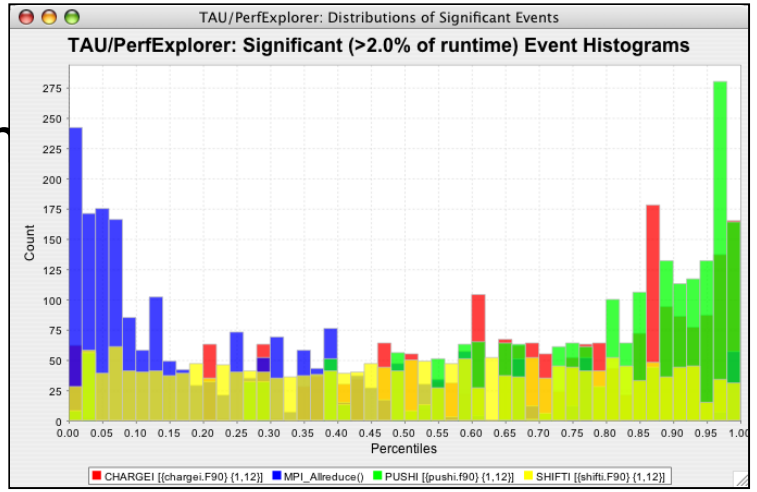
PerfExplorer – Runtime Breakdown



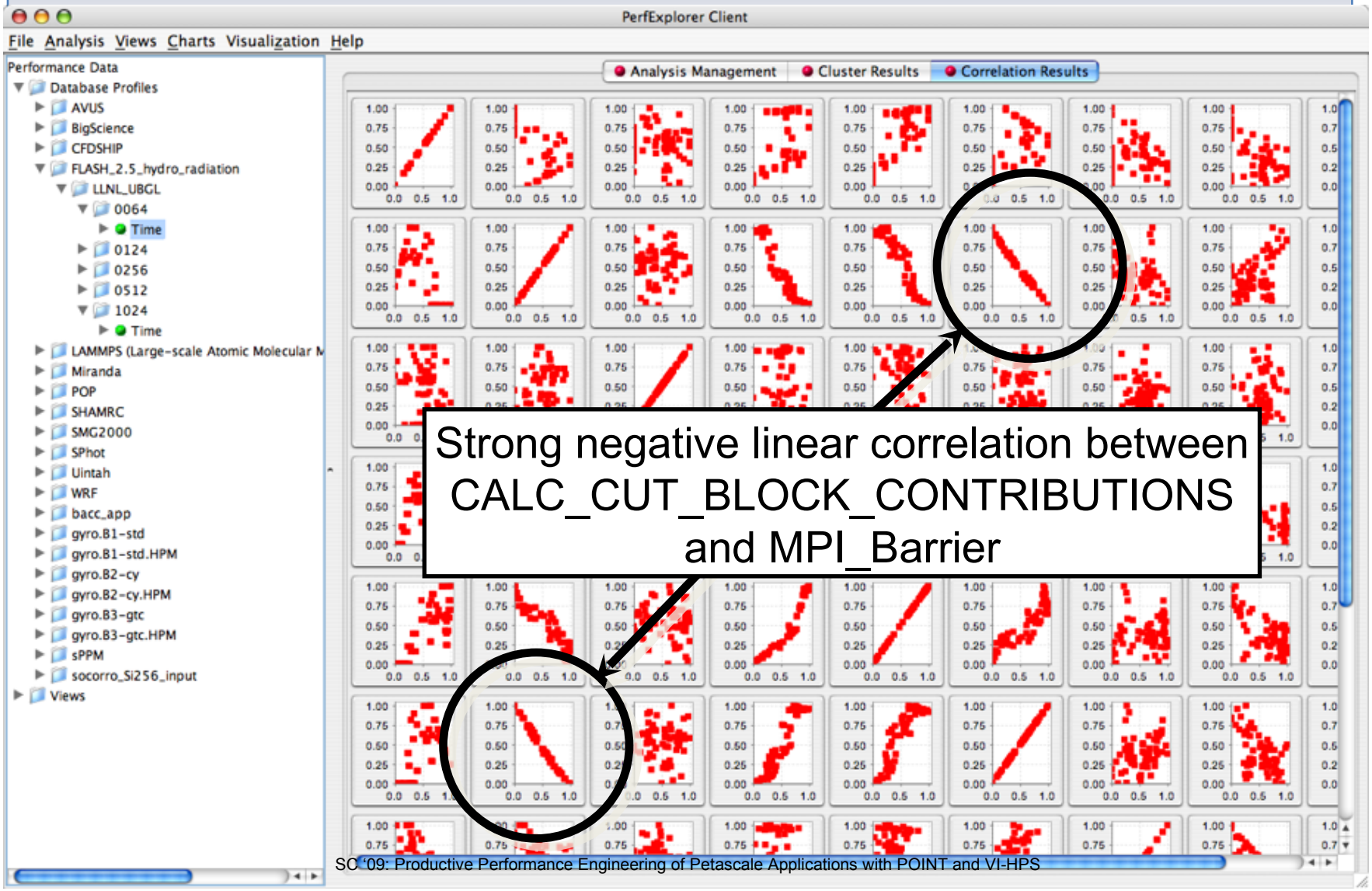
PerfExplorer – Relative Comparisons

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



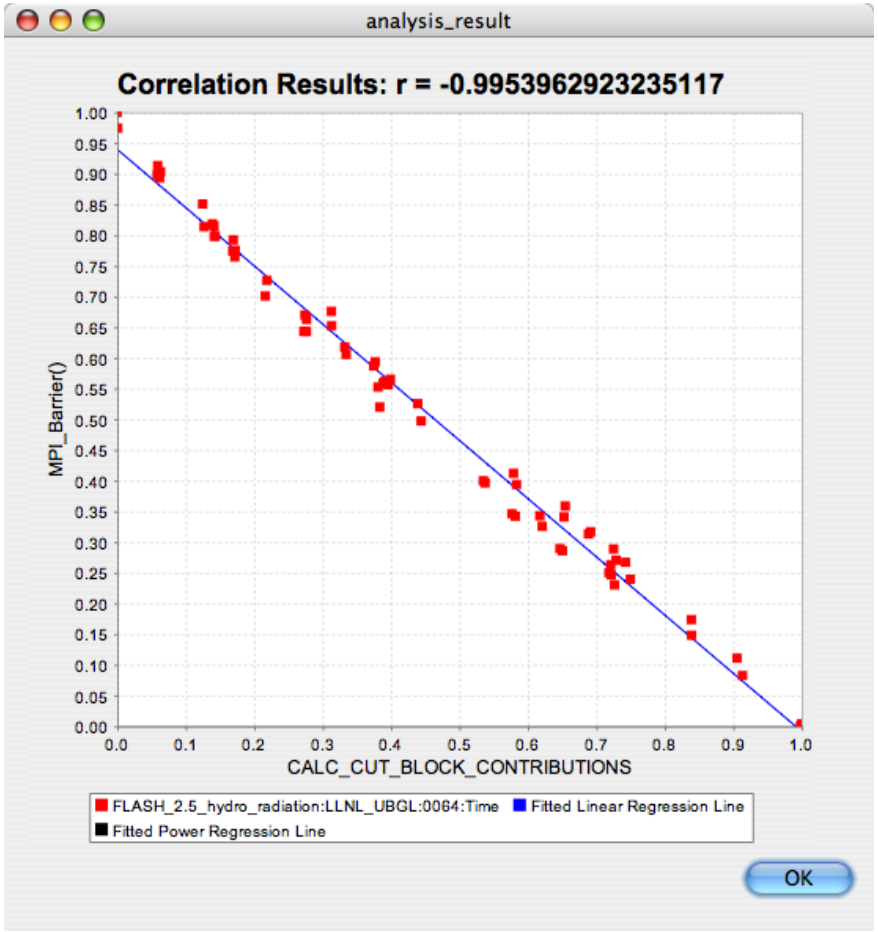


PerfExplorer – Correlation Analysis



PerfExplorer – Correlation Analysis

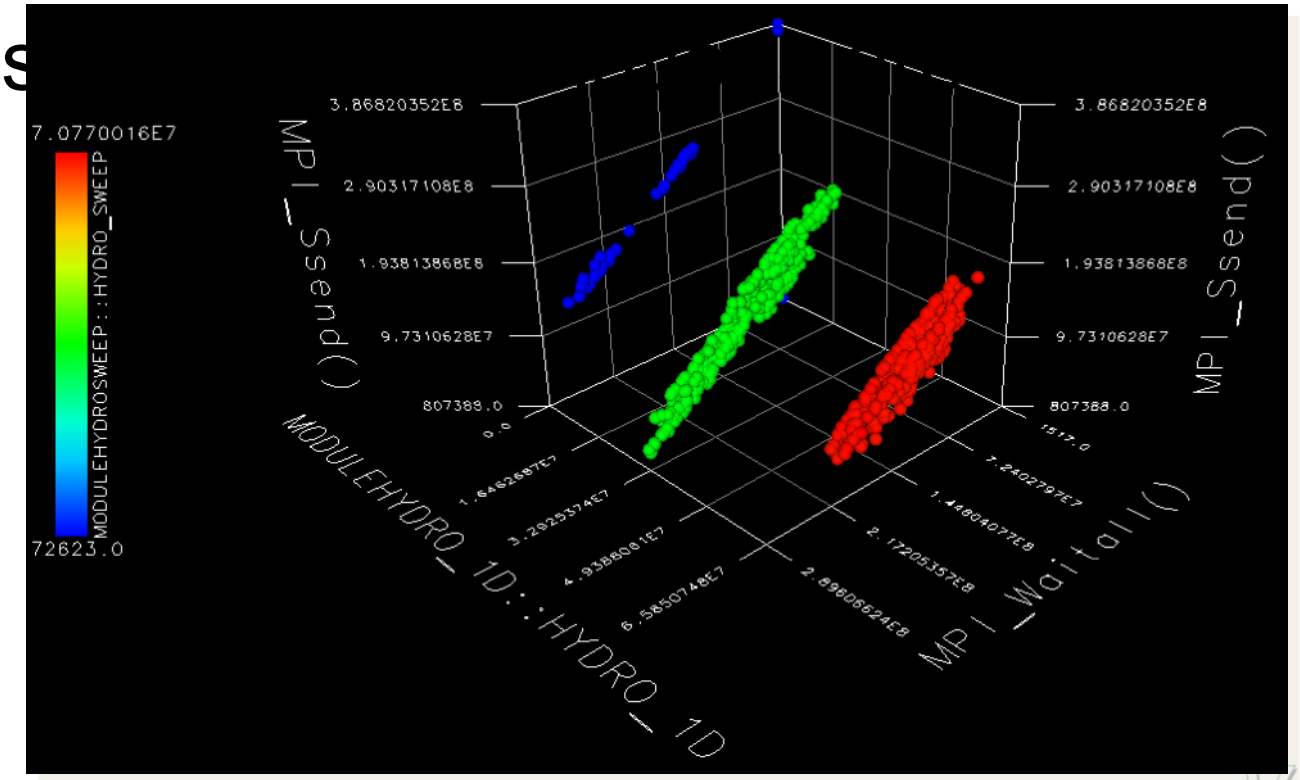
- -0.995 indicates strong, negative relationship
- As CALC_CUT_BLOCK_CONTRIBUTIONS() increases in execution time, MPI_Barrier() decreases



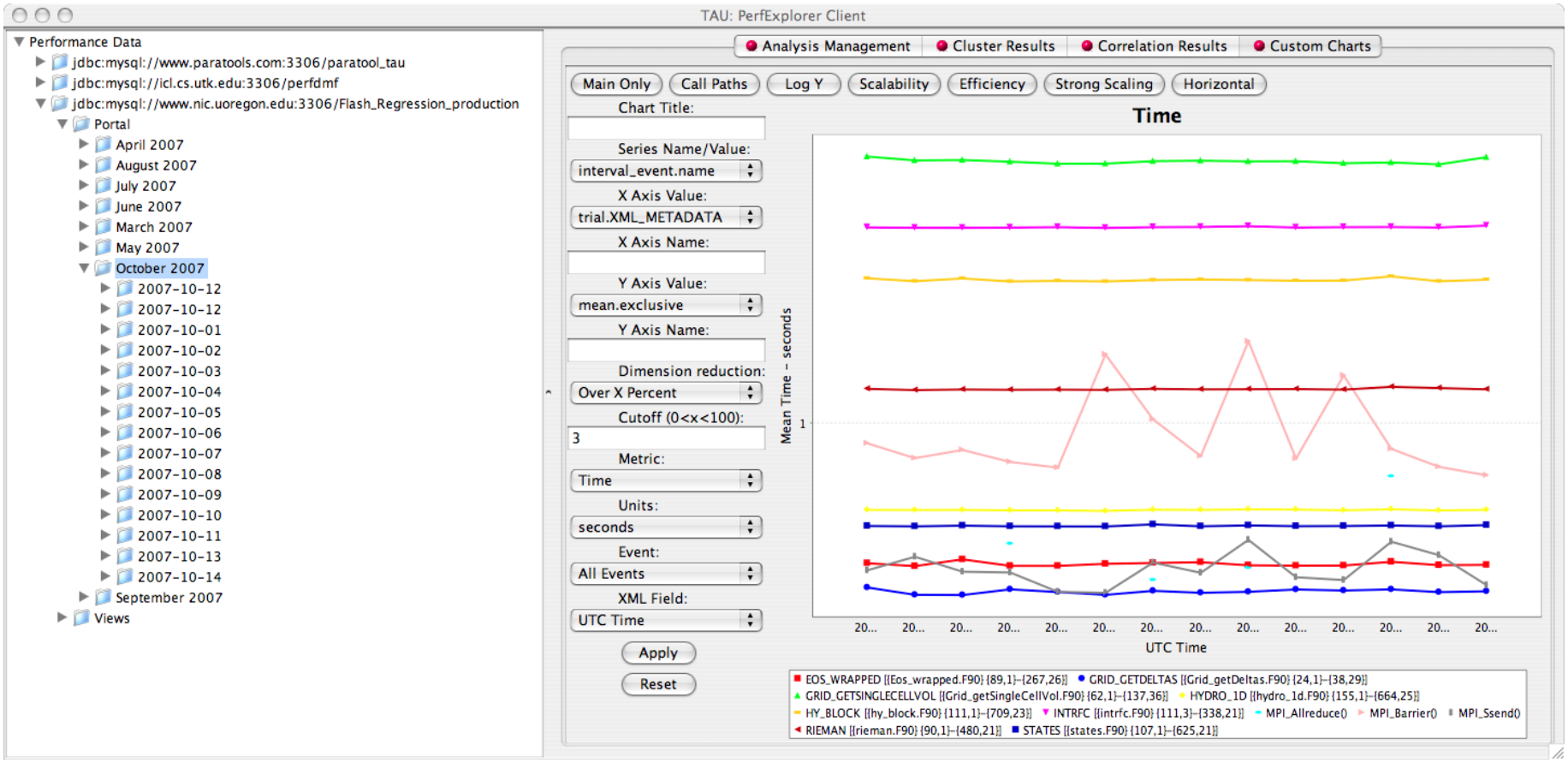
PerfExplorer – Cluster Analysis

PerfExplorer – Cluster Analysis

- Four significant events automatically selected
- Clus



PerfExplorer – Performance Regression



Other Projects in TAU

- TAU Portal
  - Support collaborative performance study
- Kernel-level system measurements (KTAU)
  - Application to OS noise analysis and I/O system analysis
- TAU performance monitoring
  - TAUoverSupermon and TAUoverMRNet
- PerfExplorer integration and expert-based analysis
  - OpenUH compiler optimizations
  - Computational quality of service in CCA
- Eclipse CDT and PTP integration
- Performance tools integration (NSF POINT project)

Using TAU

- Install TAU
  - % configure [options]; make clean install
- Modify application makefile and choose TAU configuration
  - Select TAU's stub makefile
  - Change name of compiler in makefile
- Set environment variables
  - Directory where profiles/traces are to be stored/counter selection
  - TAU options
- Execute application
  - % mpirun –np <procs> a.out;
- Analyze performance data
  - paraprof, vampir, pprof, paraver …

Application Build Environment

- Minimize impact on user's application build procedures
- Handle parsing, instrumentation, compilation, linking
- Dealing with Makefiles
  - Minimal change to application Makefile
  - Avoid changing compilation rules in application Makefile
  - No explicit inclusion of rules for process stages
- Some applications do not use Makefiles
  - Facilitate integration in whatever procedures used
- Two techniques:
  - TAU shell scripts (tau_<compiler>.sh)
    - Invokes all PDT parser, TAU instrumenter, and compiler
  - TAU_COMPILER

Configuring TAU

- TAU can measure several metrics with profiling and tracing approaches
- Different tools can also be invoked to instrument programs for TAU measurement
- Each configuration of TAU produces a measurement library for an architecture
- Each measurement configuration of TAU also creates a corresponding stub makefile that can be used to compile programs
- Typically configure multiple measurement libraries

TAU Measurement System Configuration

- configure [OPTIONS]
  - {-c++=<CC>, -cc=<cc>} Specify C++ and C compilers
  - -pdt=<dir> Specify location of PDT
  - -opari=<dir> Specify location of Opari OpenMP tool
  - -papi=<dir> Specify location of PAPI
  - -vampirtrace=<dir> Specify location of VampirTrace
  - -mpi[inc/lib]=<dir> Specify MPI library instrumentation
  - -dyninst=<dir> Specify location of DynInst Package
  - -shmem[inc/lib]=<dir> Specify PSHMEM library instrumentation
  - -python[inc/lib]=<dir> Specify Python instrumentation
  - -tag=<name> Specify a unique configuration name
  - -epilog=<dir> Specify location of EPILOG
  - -slog2 Build SLOG2/Jumpshot tracing package
  - -otf=<dir> Specify location of OTF trace package
  - -arch=<architecture> Specify architecture explicitly (bgl, xt3,ibm64,ibm64linux…)
  - {-pthread, -sproc} Use pthread or SGI sproc threads
  - -openmp Use OpenMP threads
  - -jdk=<dir> Specify Java instrumentation (JDK)
  - -fortran=[vendor] Specify Fortran compiler

TAU Measurement System Configuration

- configure [OPTIONS]
  - -TRACE Generate binary TAU traces
  - -PROFILE (default) Generate profiles (summary)
  - -PROFILECALLPATH Generate call path profiles
  - -PROFILEPHASE Generate phase based profiles
  - -PROFILEMEMORY Track heap memory for each routine
  - -PROFILEHEADROOM Track memory headroom to grow
  - -MULTIPLECOUNTERS Use hardware counters + time
  - -COMPENSATE Compensate timer overhead
  - -CPUTIME Use usertime+system time
  - -PAPIWALLCLOCK Use PAPI's wallclock time
  - -PAPIVIRTUAL Use PAPI's process virtual time
  - -SGITIMERS Use fast IRIX timers
  - -LINUXTIMERS Use fast x86 Linux timers

TAU Configuration – Examples

- Configure using PDT and MPI for x86_64 Linux

  ./configure –pdt=/usr/pkgs/pkgs/pdtoolkit-3.14
  -mpiinc=/usr/pkgs/mpich/include -mpilib=
  /usr/pkgs/mpich/lib
  -mpilibrary='-lmpich -L/usr/gm/lib64 -lgm -lpthread -ldl'

- Use PAPI counters (one or more) with C/C++/F90 automatic instrumentation for Cray CNL. Also instrument the MPI library. Use PGI compilers.

  ./configure -arch=craycnl -cc=cc -c++=CC -fortran=pgi -papi=
  /opt/xt-tools/papi/3.2.1 -mpi -MULTIPLECOUNTERS; make
  clean install

- Stub makefiles

/usr/pkgs/tau/x86_64/lib/Makefile.tau-mpi-pdt-pgi

/usr/pkgs/tau/x86_64/lib/Makefile.tau-multiplecounters-mpi-papi-pdt-pgi

Stub Makefiles Configuration Parameters

- TAU scripts use stub makefiles to select performance measurements
- Variables:
  - TAU_CXX Specify the C++ compiler used by TAU
  - TAU_CC, TAU_F90 Specify the C, F90 compilers
  - TAU_DEFS Defines used by TAU (add to CFLAGS)
  - TAU_LDFLAGS Linker options (add to LDFLAGS)
  - TAU_INCLUDE Header files include path (add to CFLAGS)
  - TAU_LIBS Statically linked TAU library (add to LIBS)
  - TAU_SHLIBS Dynamically linked TAU library
  - TAU_MPI_LIBS TAU's MPI wrapper library for C/C++
  - TAU_MPI_FLIBS TAU's MPI wrapper library for F90
  - TAU_FORTRANLIBS Must be linked in with C++ linker for F90
  - TAU_CXXLIBS Must be linked in with F90 linker
  - TAU_INCLUDE_MEMORY Use TAU's malloc/free wrapper lib
  - TAU_DISABLE TAU's dummy F90 stub library
  - TAU_COMPILER Instrument using tau_compiler.sh script

TAU Measurement Configuration

- % cd /opt/tau-2.18/x86_64/lib; ls Makefile.*
  - Makefile.tau-pdt
  - Makefile.tau-mpi-pdt
  - Makefile.tau-callpath-mpi-pdt
  - Makefile.tau-mpi-pdt-trace
  - Makefile.tau-mpi-compensate-pdt
  - Makefile.tau-multiplecounters-mpi-papi-pdt
  - Makefile.tau-multiplecounters-mpi-papi-pdt-trace
  - Makefile.tau-pthread-pdt…
- For an MPI+F90 application, you may want to start with:
  - Makefile.tau-mpi-pdt
  - Supports MPI instrumentation & PDT for automatic source instrumentation
- % setenv TAU_MAKEFILE /opt/tau-2.18/x86_64/lib/Makefile.tau-mpi-pdt

-PROFILE Option

- Generates flat profiles
  - One for each MPI process
  - It is the default option.
- Uses wallclock time
  - gettimeofday() sys call
- Calculates exclusive, inclusive time spent in each timer and number of calls

Generating a Flat Profile with MPI

```
% setenv TAU_MAKEFILE /opt/tau-2.18/x86_64
                     /lib/Makefile.tau-mpi-pdt
% set path=(/opt/tau-2.18/x86_64/bin $path)
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)

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

% paraprof app.ppk
```

Generating a Loop-level Profile

```
% setenv TAU_MAKEFILE /opt/tau-2.18/x86_64
                      /lib/Makefile.tau-mpi-pdt
% setenv TAU_OPTIONS '-optTauSelectFile=select.tau -optVerbose'
% cat select.tau
  BEGIN_INSTRUMENT_SECTION
  loops routine="#"
  END_INSTRUMENT_SECTION

% set path=(/opt/tau-2.18/x86_64/bin $path)
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)
% qsub  run.job
% paraprof --pack app.ppk
  Move the app.ppk file to your desktop.

% paraprof app.ppk
```

Compiler-based Instrumentation

```
% setenv TAU_MAKEFILE /opt/tau-2.18/x86_64
                      /lib/Makefile.tau-mpi
% setenv TAU_OPTIONS '-optCompInst -optVerbose'
% % set path=(/opt/tau-2.18/x86_64/bin $path)
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)

% qsub  run.job
% paraprof --pack app.ppk
  Move the app.ppk file to your desktop.
% paraprof app.ppk
```

-MULTIPLECOUNTERS Option

- Instead of one metric, profile or trace with more than one metric
  - Set environment variables COUNTER[1-25] to specify the metric
    - % setenv COUNTER1 GET_TIME_OF_DAY
    - % setenv COUNTER2 PAPI_L2_DCM
    - % setenv COUNTER3 PAPI_FP_OPS
    - % setenv COUNTER4 PAPI_NATIVE_<native_event>
    - % setenv COUNTER5 P_WALL_CLOCK_TIME …
- When used with –TRACE option, the first counter must be GET_TIME_OF_DAY
    - % setenv COUNTER1 GET_TIME_OF_DAY
    - Provides a globally synchronized real time clock for tracing
- -multiplecounters appears in the name of the stub Makefile
- Often used with –papi=<dir> to measure hardware performance counters and time
- papi_native_avail and papi_avail are two useful tools

Generate a PAPI profile

```
% setenv TAU_MAKEFILE /opt/tau-2.18/x86_64
                        /lib/Makefile.tau-multiplecounters-papi-mpi-pdt
% setenv TAU_OPTIONS '-optTauSelectFile=select.tau -optVerbose'
% cat select.tau
  BEGIN_INSTRUMENT_SECTION
  loops routine="#"
  END_INSTRUMENT_SECTION

% set path=(/opt/tau-2.18/x86_64/bin $path)
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)
% setenv COUNTER1 GET_TIME_OF_DAY
% setenv COUNTER2 PAPI_FP_INS
% qsub  run.job
% paraprof --pack app.ppk
   Move the app.ppk file to your desktop.
% paraprof app.ppk
  Choose Options -> Show Derived Panel -> Arg 1 = PAPI_FP_INS,
    Arg 2 = GET_TIME_OF_DAY, Operation = Divide -> Apply, choose.
```

-PROFILECALLPATH Option

- Generates profiles that show the calling order (edges and nodes in callgraph)
  - A=>B=>C shows the time spent in C when it was called by B and B was called by A
  - Control the depth of callpath using TAU_CALLPATH_DEPTH environment variable
  - -callpath in the name of the stub Makefile name or setting TAU_CALLPATH= 1 at runtime
    (TAU v2.18.1+)

-DEPTHLIMIT Option

- Allows users to enable instrumentation at runtime based on the depth of a calling routine on a callstack
  - Disables instrumentation in all routines a certain depth away from the root in a callgraph
- TAU_DEPTH_LIMIT environment variable specifies depth
  - % setenv TAU_DEPTH_LIMIT 1
  - enables instrumentation in only “main”
  - % setenv TAU_DEPTH_LIMIT 2
  - enables instrumentation in main and routines that are directly called by main
- Stub makefile has -depthlimit in its name:
  - setenv TAU_MAKEFILE <taudir>/<arch>/lib/Makefile.tau-icpc-mpi-depthlimit-pdt

Generate a Callpath Profile

```
% setenv TAU_MAKEFILE /opt/tau-2.18/x86_64
                      /lib/Makefile.tau-callpath-mpi-pdt
% set path=(/opt/tau-2.18/x86_64/bin $path)
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)
% setenv TAU_CALLPATH_DEPTH 100

NOTE: In TAU v2.18.1+ you may simply use:
% setenv TAU_CALLPATH 1
to generate the callpath profiles without any recompilation.
% qsub  run.job
% paraprof --pack app.ppk
   Move the app.ppk file to your desktop.
% paraprof app.ppk
(Windows -> Thread -> Call Graph)
```

-TRACE Configuration Option

- Generates event-trace logs, rather than summary profiles
- Traces show when and where an event occurred in terms of location and the process that executed it
- Traces from multiple processes are merged:
  - % tau_treemerge.pl
    - generates tau.trc and tau.edf as merged trace and event definition file
- TAU traces can be converted to Vampir's OTF/VTF3, Jumpshot SLOG2, Paraver trace formats:
  - % tau2otf tau.trc tau.edf app.otf
  - % tau2vtf tau.trc tau.edf app.vpt.gz
  - % tau2slog2 tau.trc tau.edf -o app.slog2
  - % tau_convert -paraver tau.trc tau.edf app.prv
- Stub Makefile has -trace in its name
  - % setenv TAU_MAKEFILE <taudir>/<arch>/lib/Makefile.tau-icpc-mpi-pdt-trace

Generate a Trace File

```
% setenv TAU_MAKEFILE /opt/tau-2.18/x86_64
                /lib/Makefile.tau-mpi-pdt-trace
% set path=(/opt/tau-2.18/x86_64/bin $path)
% make F90=tau_f90.sh
(Or edit Makefile and change F90=tau_f90.sh)
% qsub  run.job
% tau_treemerge.pl
(merges binary traces to create tau.trc and tau.edf files)
JUMPSHOT:
% tau2slog2 tau.trc tau.edf -o app.slog2
% jumpshot app.slog2
   OR
VAMPIR:
% tau2otf tau.trc tau.edf app.otf -n 4 -z
(4 streams, compressed output trace)
% vampir app.otf
(or vng client with vngd server)
```

Instrumentation Specification

```
% tau_instrumentor
Usage : tau_instrumentor <pdbfile> <sourcefile> [-o <outputfile>] [-noinline]
[-g groupname] [-i headerfile] [-c|-c++|-fortran] [-f <instr_req_file> ]
For selective instrumentation, use -f option
% tau_instrumentor foo.pdb foo.cpp -o foo.inst.cpp -f selective.dat
% cat selective.dat
# Selective instrumentation: Specify an exclude/include list of routines/files.
BEGIN_EXCLUDE_LIST
void quicksort(int *, int, int)
void sort_5elements(int *)
void interchange(int *, int *)
END_EXCLUDE_LIST

BEGIN_FILE_INCLUDE_LIST
Main.cpp
Foo?.c
*.C
END_FILE_INCLUDE_LIST
# Instruments routines in Main.cpp, Foo?.c and *.C files only
# Use BEGIN_[FILE]_INCLUDE_LIST with END_[FILE]_INCLUDE_LIST
```

Outer Loop Level Instrumentation

```
BEGIN_INSTRUMENT_SECTION
loops file="loop_test.cpp" routine="multiply"
# it also understands # as the wildcard in routine name
# and * and ? wildcards in file name.
# You can also specify the full
# name of the routine as is found in profile files.
#loops file="loop_test.cpp" routine="double multiply#"
END_INSTRUMENT_SECTION

% pprof
NODE 0;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0         0.12       25,162           1           1   25162827 int main(int, char **)
100.0        0.175       25,162           1           4   25162707 double multiply()
 90.5       22,778       22,778           1           0   22778959 Loop: double multiply()[
file = <loop_test.cpp> line,col = <23,3> to <30,3> ]
  9.3        2,345        2,345           1           0    2345823 Loop: double multiply()[
file = <loop_test.cpp> line,col = <38,3> to <46,7> ]
  0.1           33           33           1           0      33964 Loop: double
multiply()[ file = <loop_test.cpp> line,col = <16,10> to <21,12> ]
```

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  - Office of Science
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  - ASC/NNSA
    - University of Utah ASC/NNSA Level 1
    - ASC/NNSA, Lawrence Livermore National La
- Department of Defense (DoD)
  - HPC Modernization Office (HPCMO)
- NSF Software Development for Cyberinfrastructure (SD
- Research Centre Juelich
- Los Alamos National Laboratory
- TU Dresden
- ParaTools, Inc.

For more information

- TAU Website:
  http://tau.uoregon.edu
  - Software
  - Release notes
  - Documentation