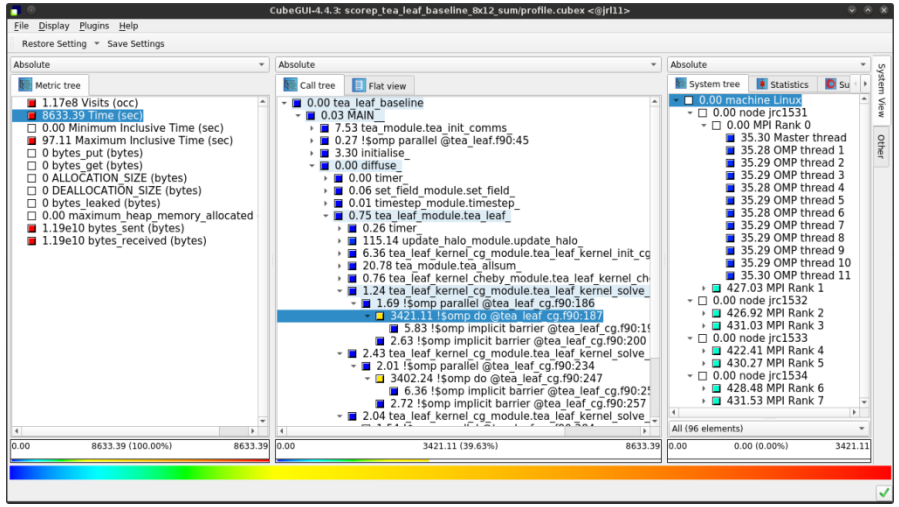
Analysis report examination with Cube

Ilya Zhukov
Jülich Supercomputing Centre

Cube

CubeLib DOI 10.5281/zenodo.7737408
CubeGUI DOI 10.5281/zenodo.7737411

- Parallel program analysis report exploration tools
  - Libraries for XML+binary report reading & writing
  - Algebra utilities for report processing
  - GUI for interactive analysis exploration
    - Requires Qt ≥ 5



- Originally developed as part of the Scalasca toolset

- Now available as a separate components
  - Can be installed independently of Score-P, e.g., on laptop or desktop
  - Latest release: Cube v4.8.2 (Sept 2023)

Note: source distribution tarballs for Linux, as well as binary packages provided for Windows & MacOS, from **www.scalasca.org** website in software/Cube-4x

Cube GUI

- Run ***remote*** *(ssh)*
  - start X server (e.g., Xming) locally
  - connect to system with X forwarding enabled
  - load cube module and start cube remotely

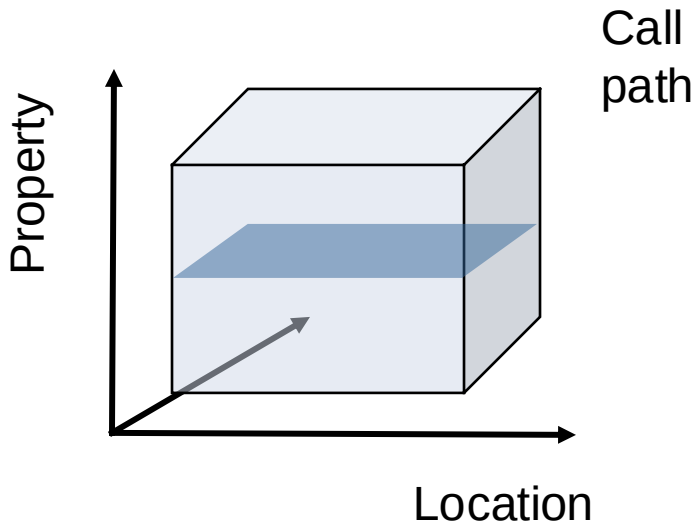
```
laptop$ ssh –X <yourid>@login.leonardo.cineca.it
Welcome to Leonardo …
[leonardologin~]$ source /leonardo/pub/userexternal/\
/bwylie00/tools/nvompi/setup.sh
[leonardologin~]$ cube ./scorep-*/profile.cubex
```

- Install & run ***local***
  - Install Cube GUI locally on desktop
    - binary packages available for MacOS & Windows and externally provided by OpenHPC and various Linux distributions
    - source package available for Linux, requires Qt
      - configure/build/install manually or use your favourite framework (e.g. Spack or EasyBuild)
  - copy .cubex file (or entire scorep directory) to desktop from remote system
    OR locally mount remote filesystem
  - start cube locally

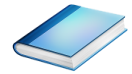
```
desk$ mkdir $HOME/mnt
desk$ sshfs [user@]remote.sys:[dir] $HOME/mnt
desk$ cd $HOME/mnt
desk$ cube ./scorep-*/profile.cubex
```

Analysis presentation and exploration

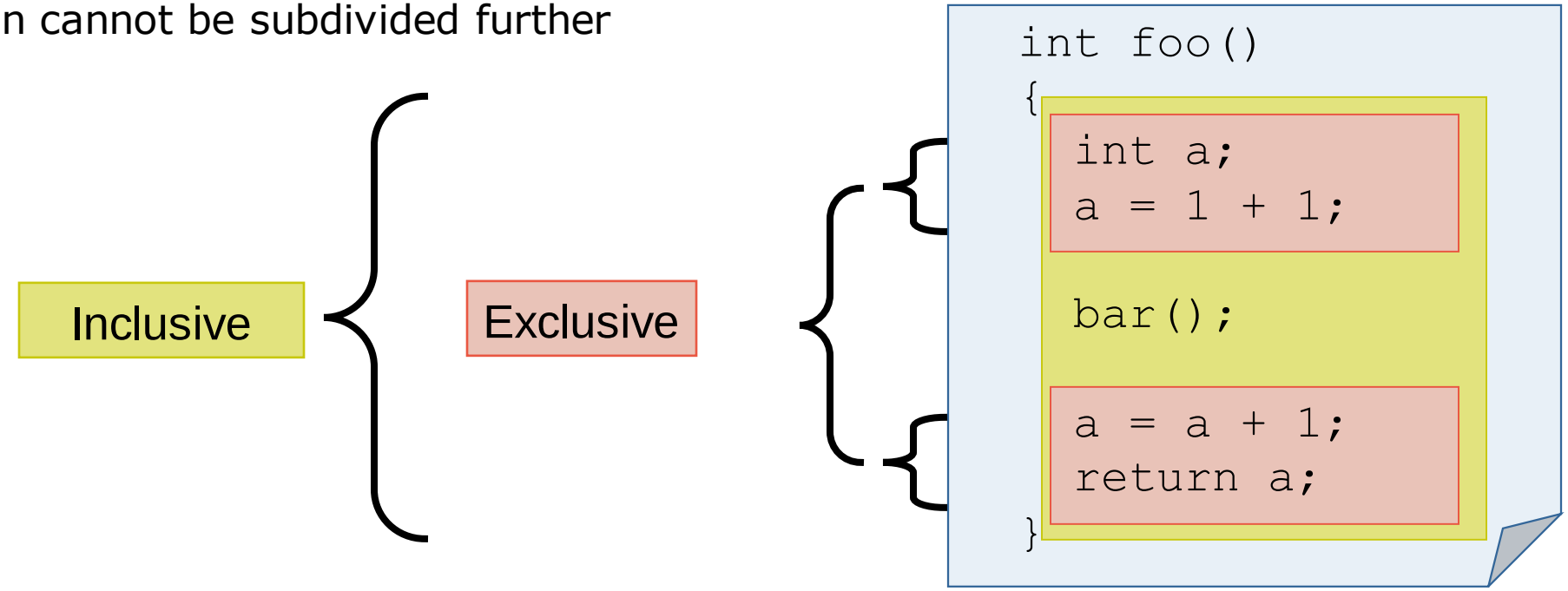
- Representation of values (severity matrix) on three hierarchical axes
  - Performance property (metric)
  - Call path (program location)
  - System location (process/thread)
- Three coupled tree browsers
- Cube displays severities
  - As *value*: for precise comparison
  - As *colour*: for easy identification of hotspots
  - *Inclusive* value when closed & *exclusive* value when expanded
  - Customizable via display *modes*



Inclusive vs. exclusive values



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



Demo:
TeaLeaf case study

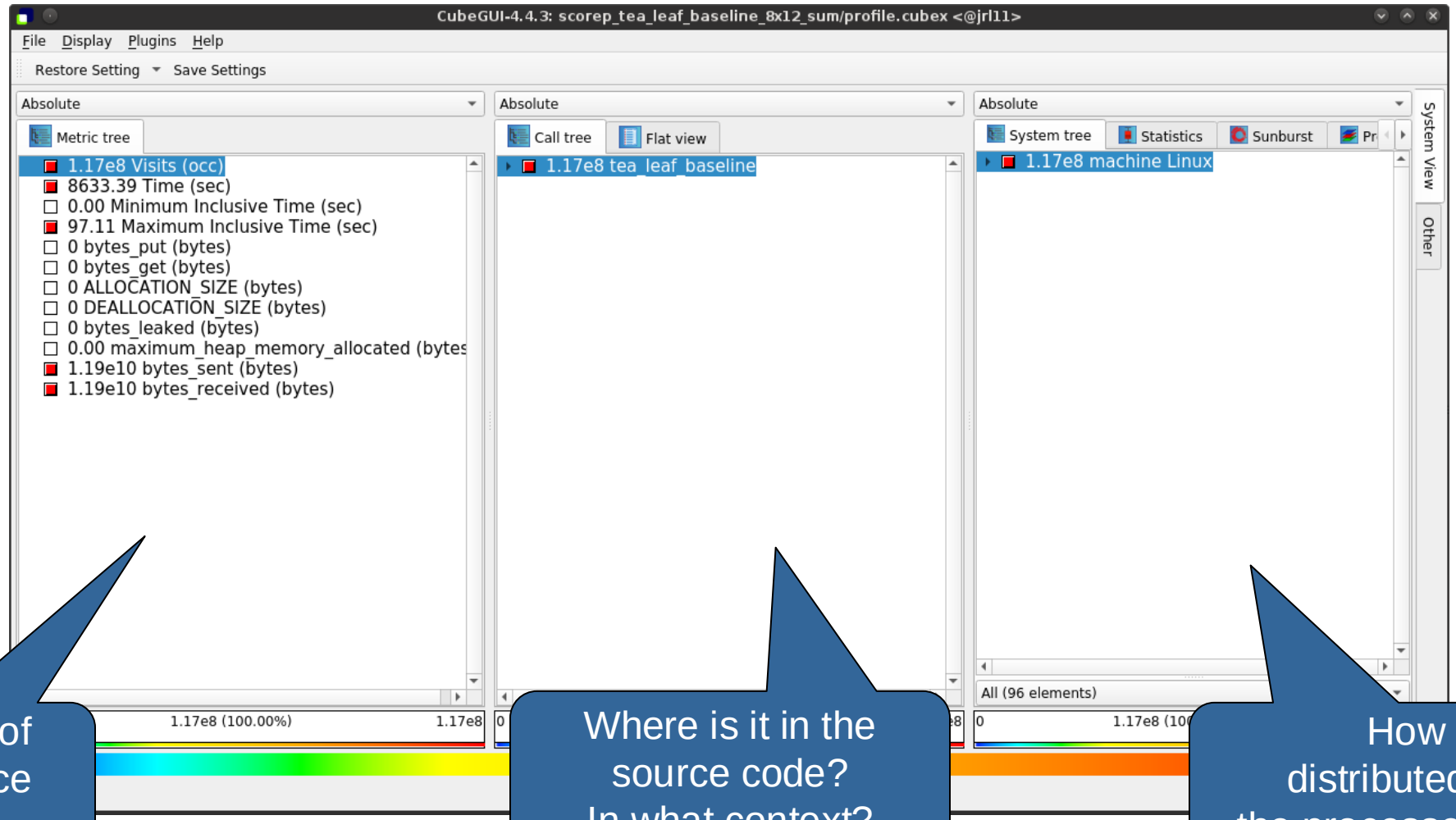
Case study: TeaLeaf

- HPC mini-app developed by the UK Mini-App Consortium
  - Solves the linear 2D heat conduction equation on a spatially decomposed regular grid using a 5 point stencil with implicit solvers
  - Part of the Mantevo 3.0 suite
  - Available on GitHub: http://uk-mac.github.io/TeaLeaf/

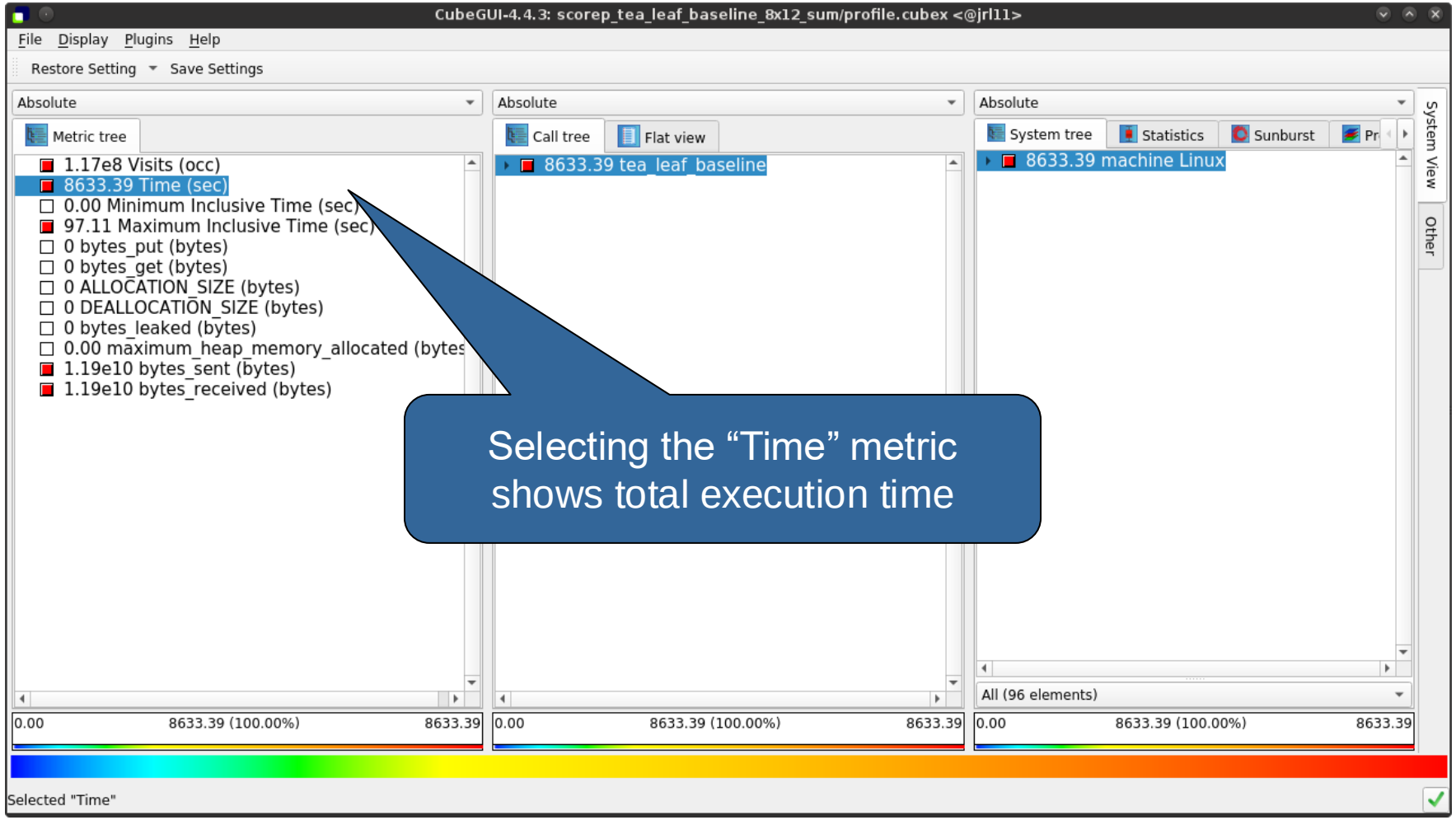
- Measurements of TeaLeaf reference v1.0 taken on Jureca cluster @ JSC
  - Using Intel 19.0.3 compilers, Intel MPI 2019.3, and Score-P 5.0
  - Run configuration
    - 8 MPI ranks with 12 OpenMP threads each

```
% cd ~/workshop-vihps/Experiments
% cube scorep_tea_leaf_baseline_8x12_sum/profile.cubex
                                    [GUI showing summary analysis report]
```

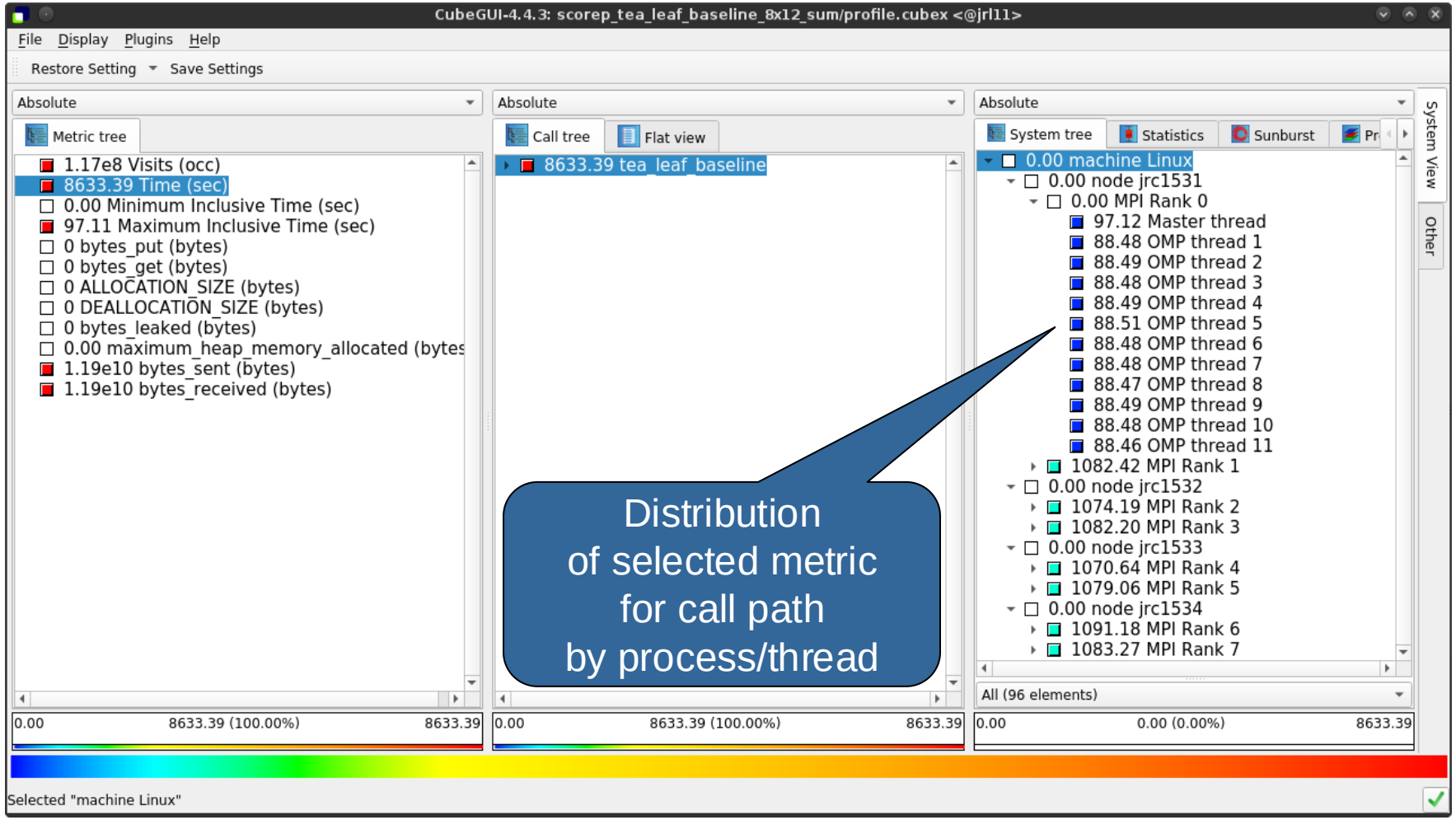
Score-P analysis report exploration (opening view)



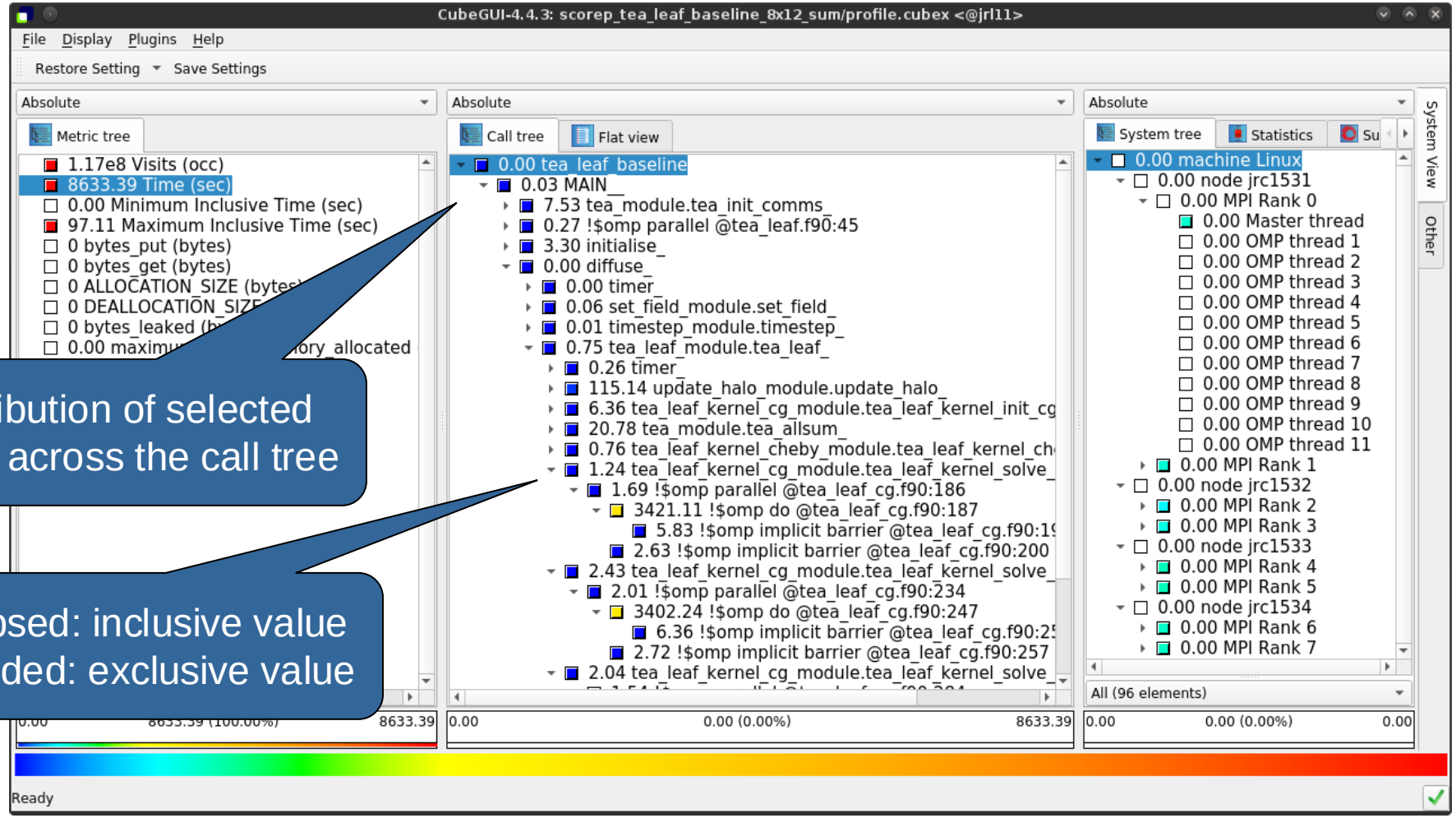
Metric selection



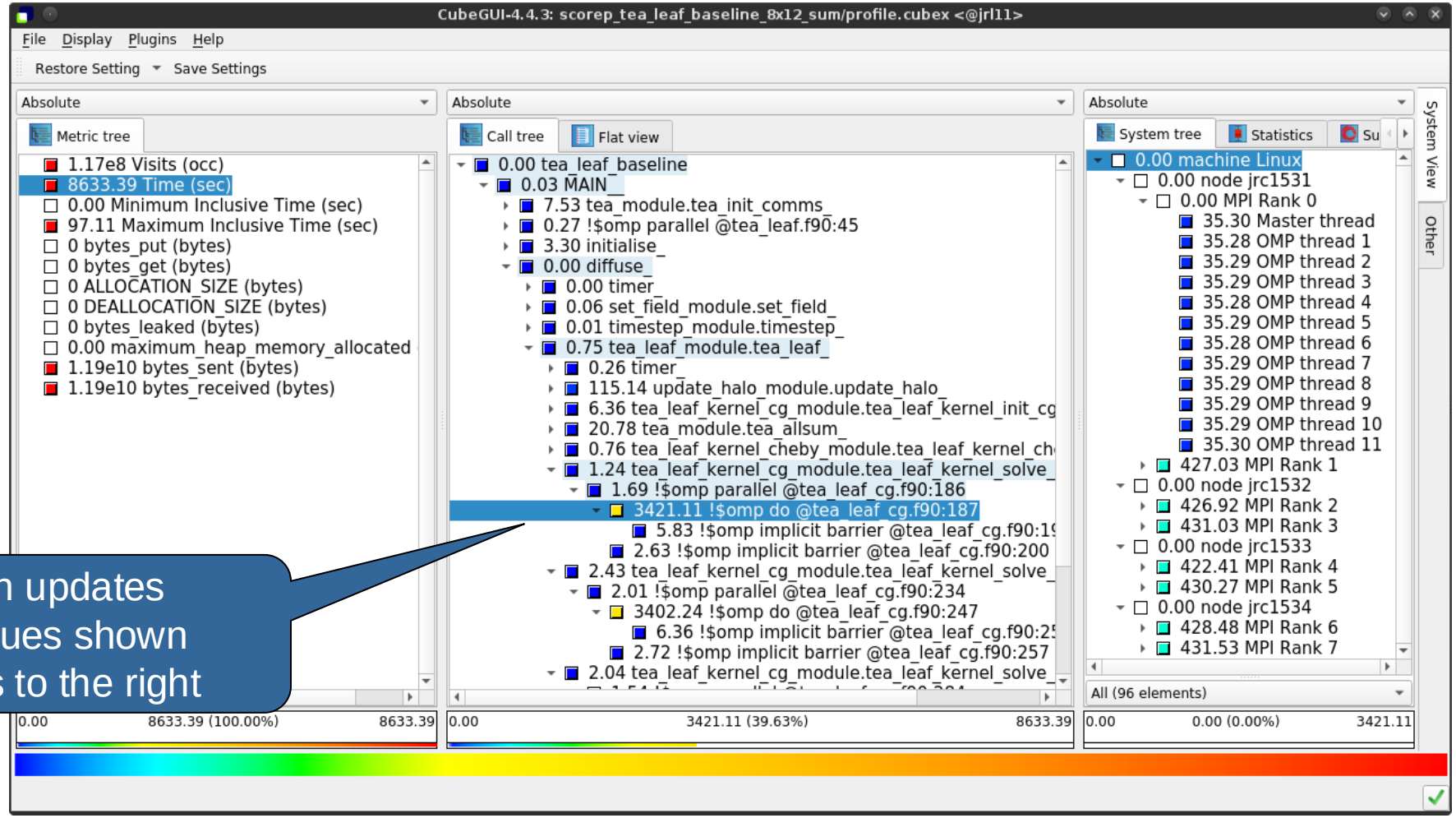
Expanding the system tree



Expanding the call tree

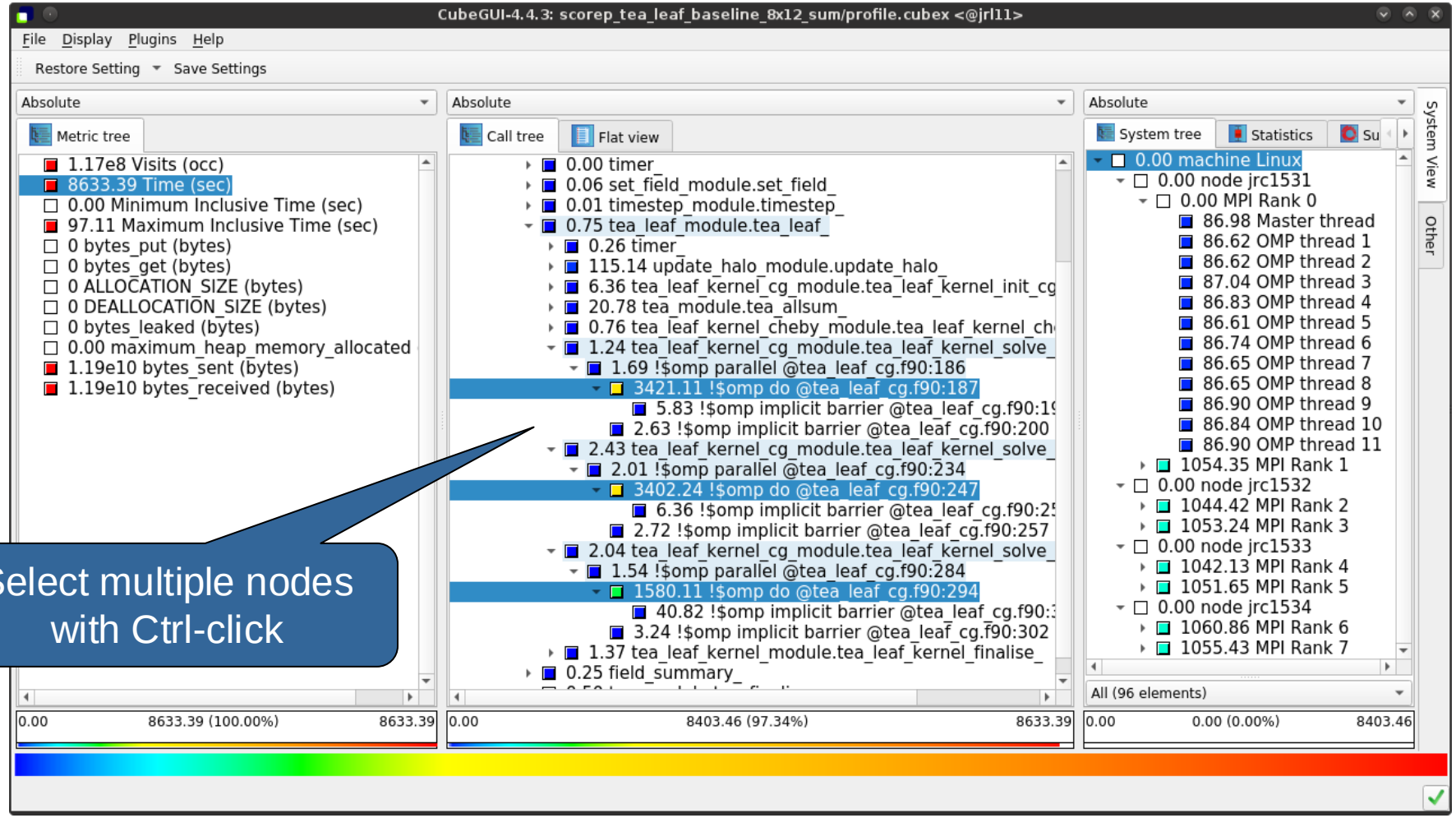


Selecting a call path

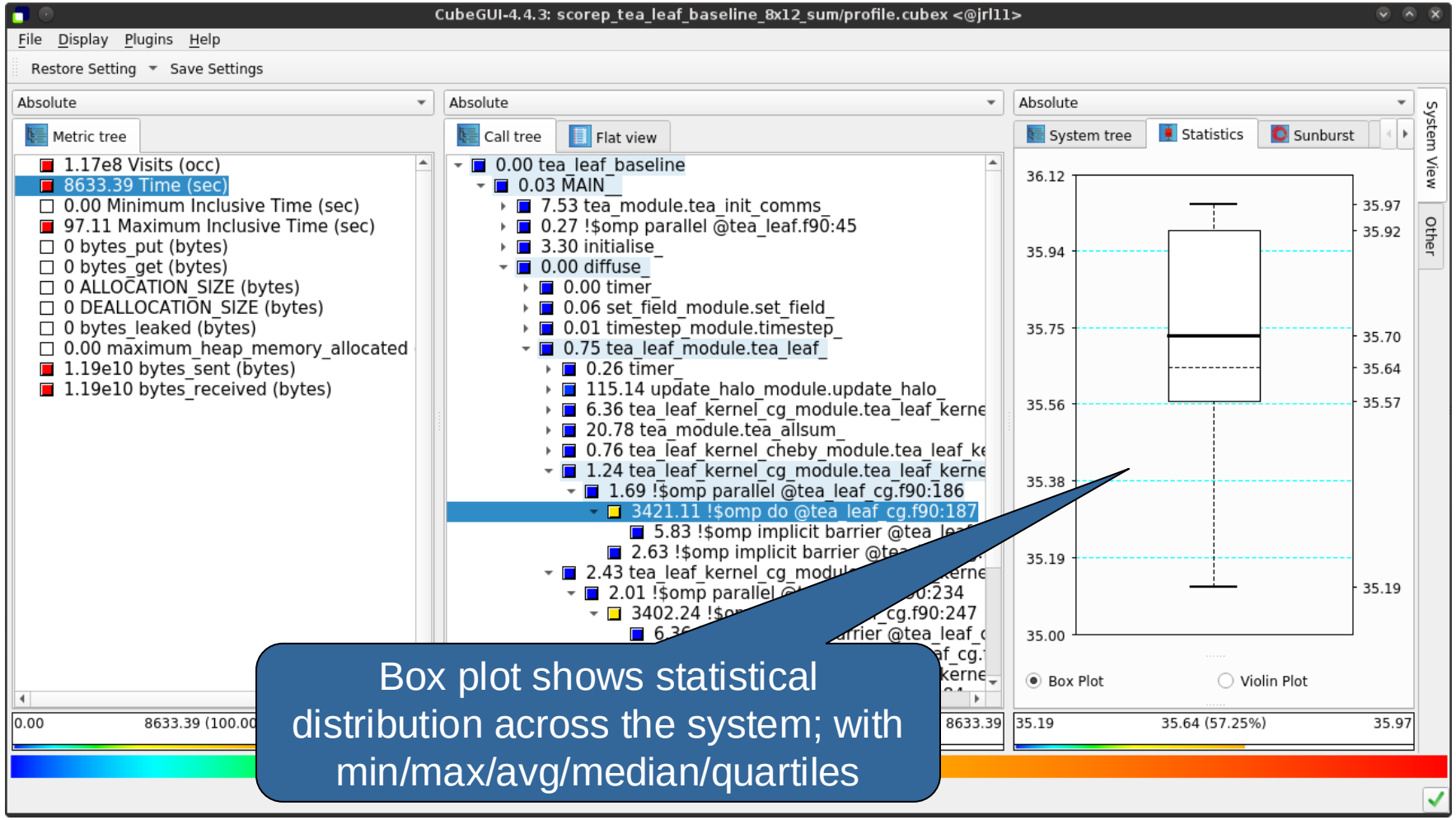


Selection updates metric values shown in columns to the right

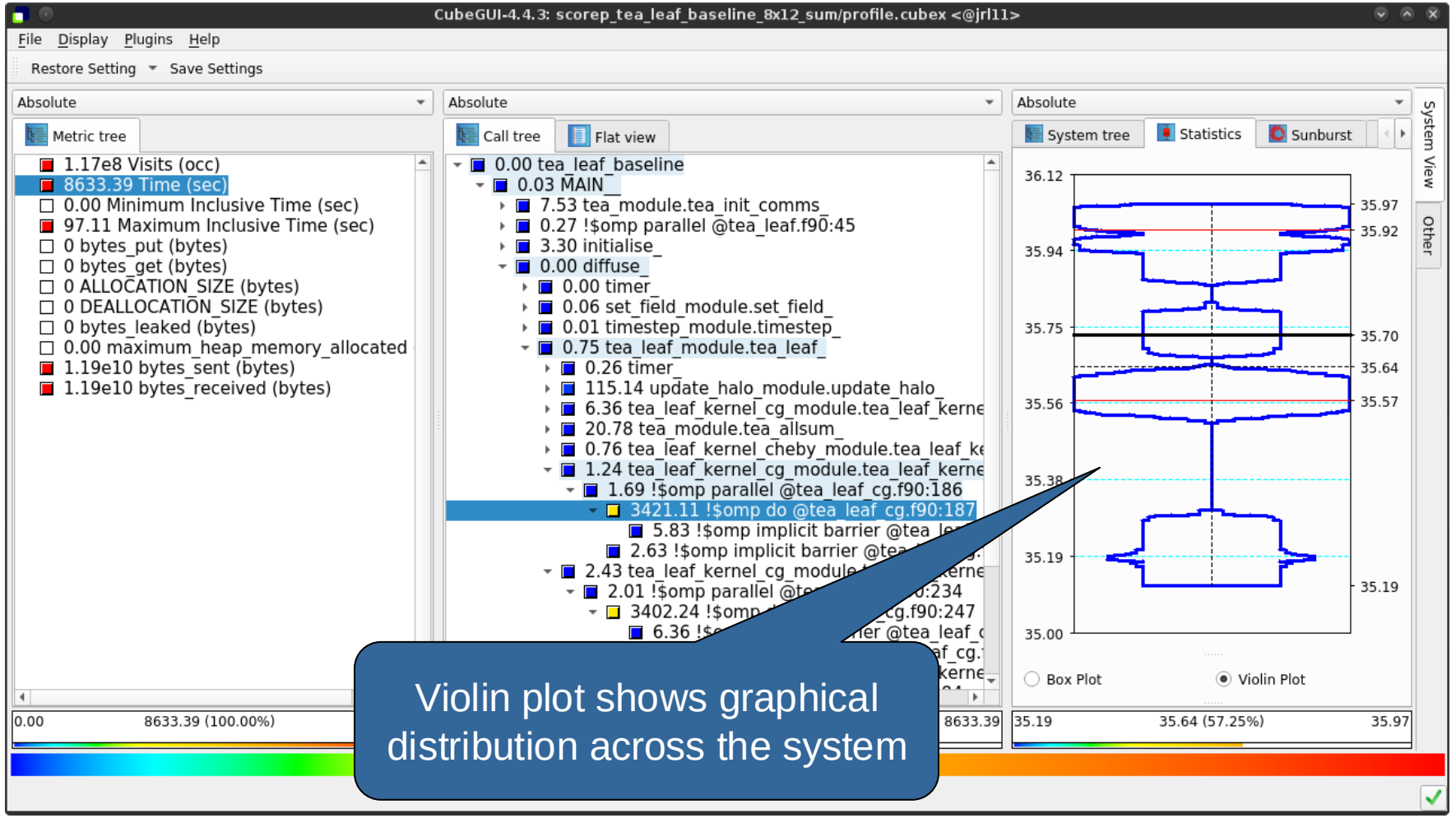
Multiple selection



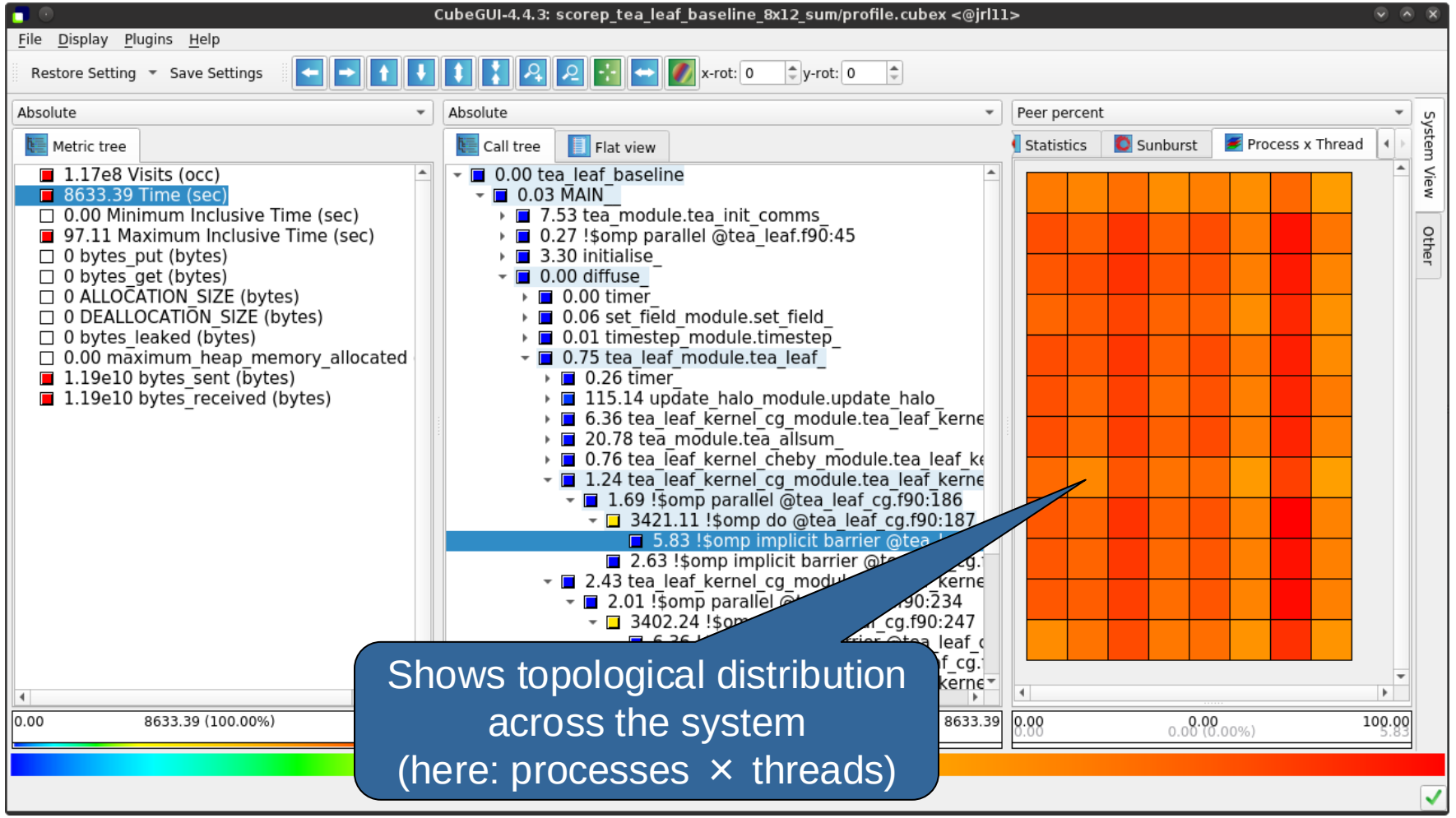
Box plot view



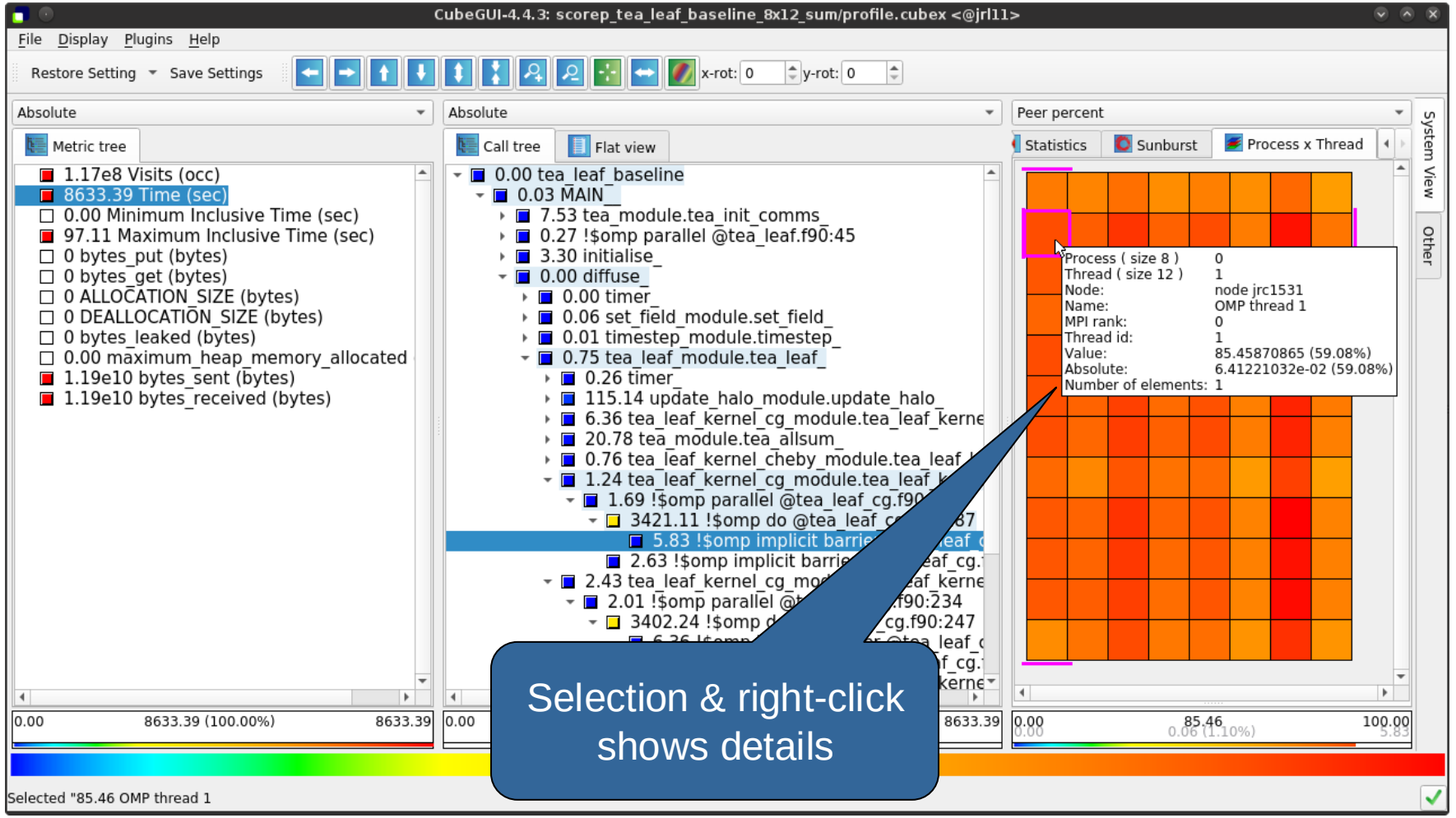
Violin plot view



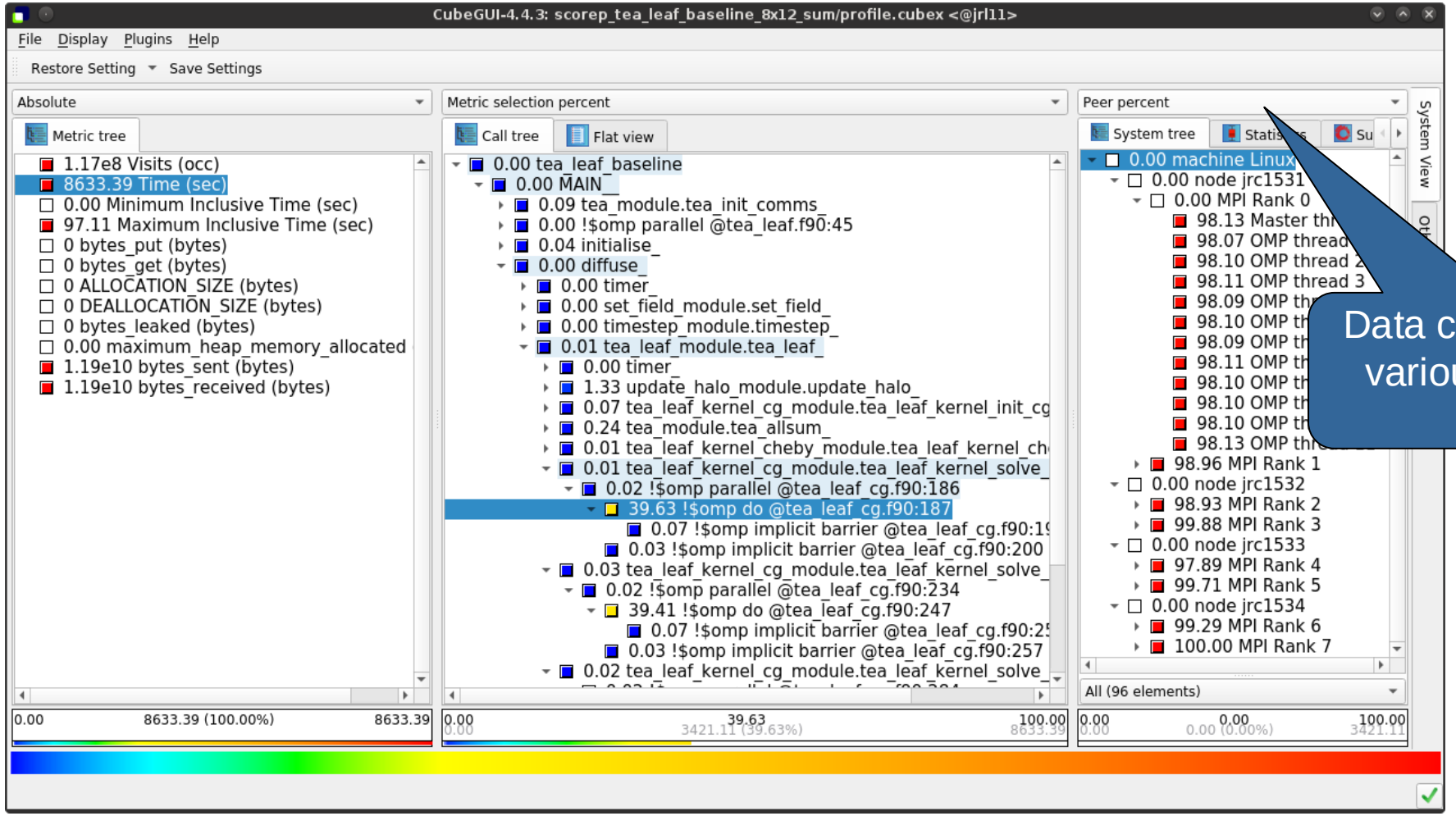
Topology view



Topology view (cont.)



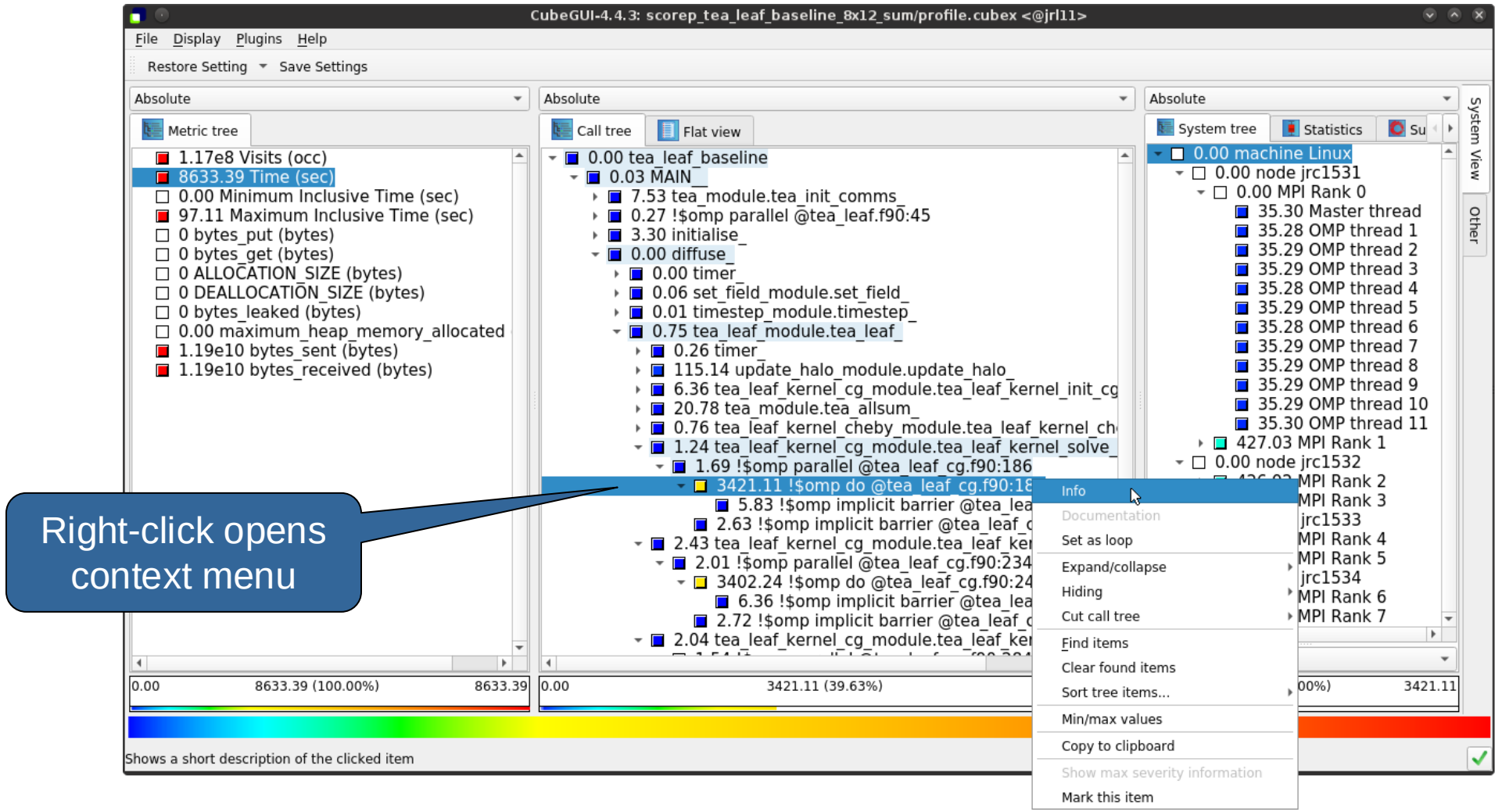
Alternative display modes



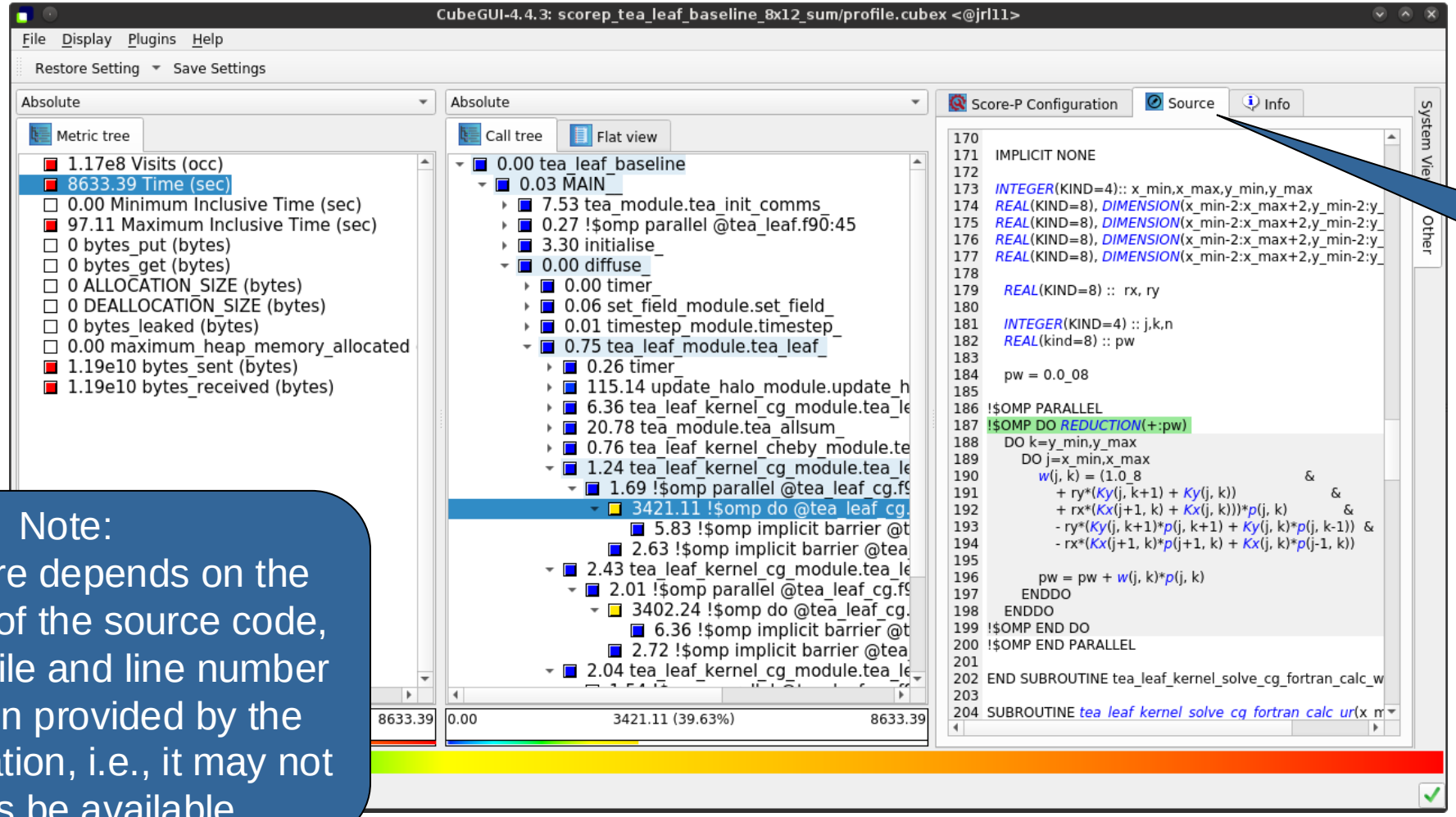
Important display modes

- Absolute
  - Absolute value shown in seconds/bytes/counts
- Selection percent
  - Value shown as percentage w.r.t. the selected node "on the left" (metric/call path)
- Peer percent (system tree only)
  - Value shown as percentage relative to the maximum peer value

Source-code view via context menu



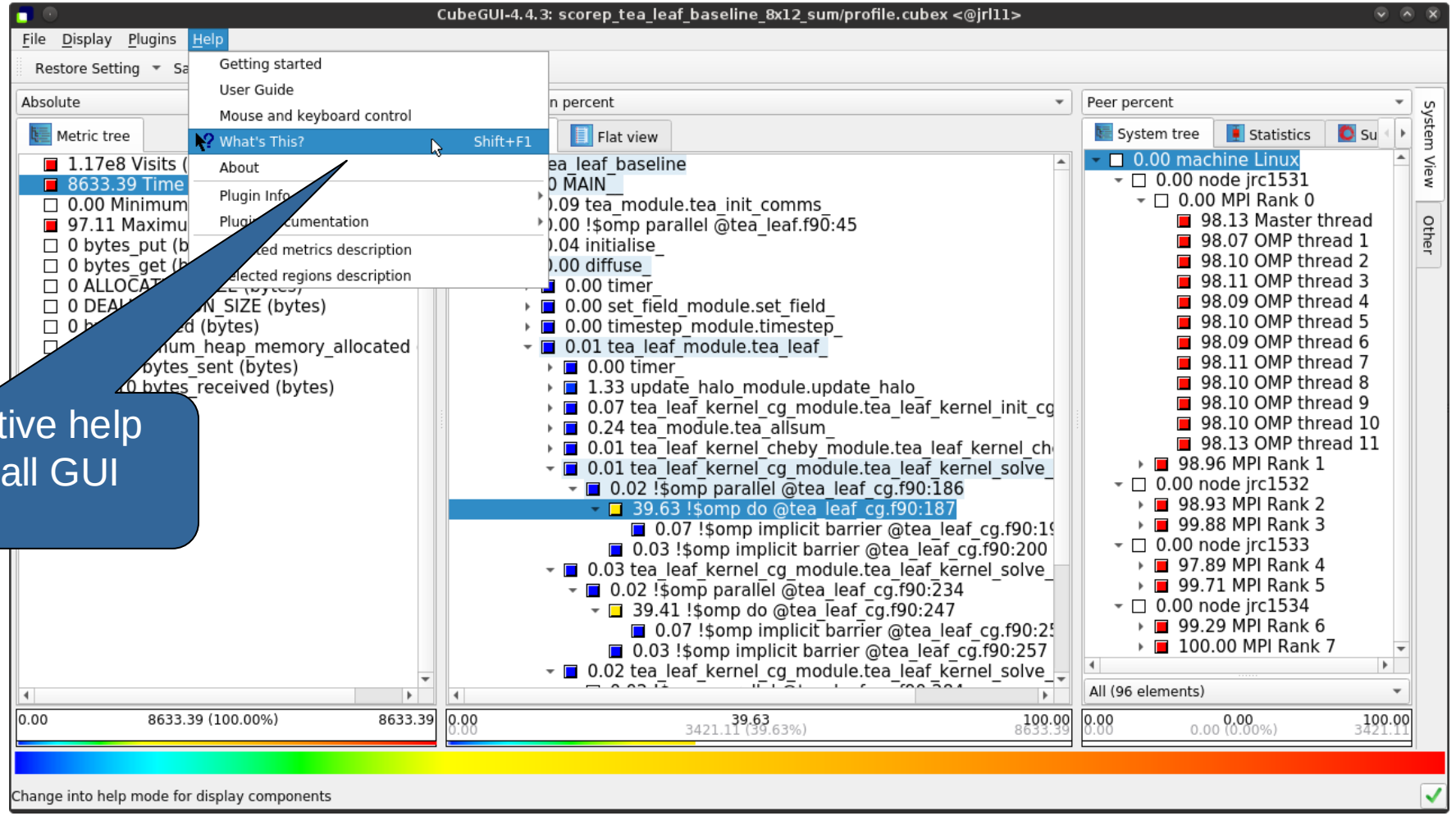
Source-code view



Select “Source” tab

Note:
This feature depends on the availability of the source code, as well as file and line number information provided by the instrumentation, i.e., it may not always be available

Context-sensitive help



Context-sensitive help available for all GUI items

Scalasca report post-processing

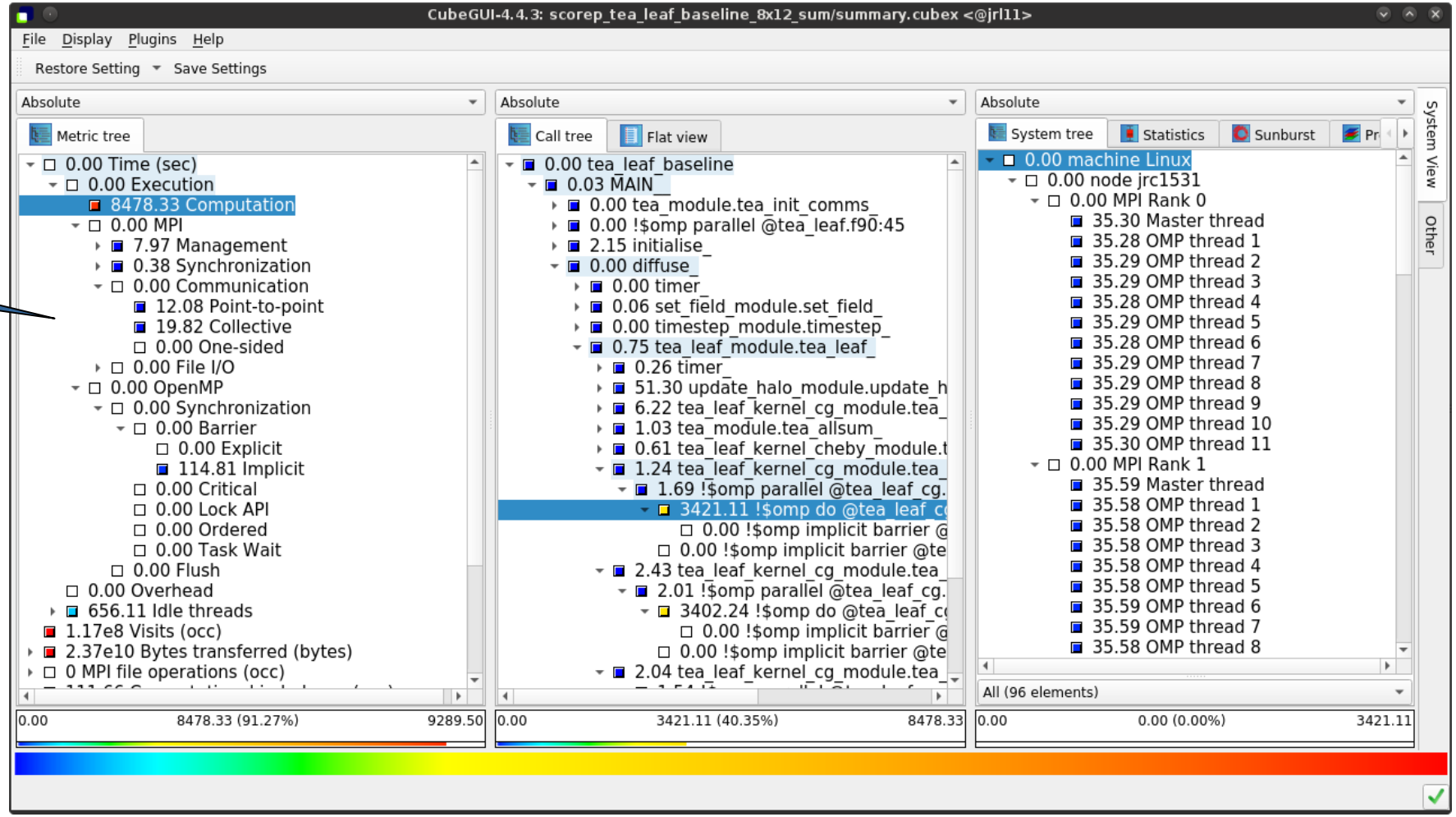
- Scalasca's report post-processing derives additional metrics and generates a structured metric hierarchy
- Automatically run (if needed) when using the **square** convenience command:

```
% square scorep_tea_leaf_baseline_8x12_sum
INFO: Post-processing runtime summarization report (profile.cubex)...
INFO: Displaying ./scorep_tea_leaf_baseline_8x12_sum/summary.cubex...

                          [GUI showing post-processed summary analysis report]
```

Post-processed summary analysis report

Split base metrics into more specific metrics, e.g. computation vs parallelization costs

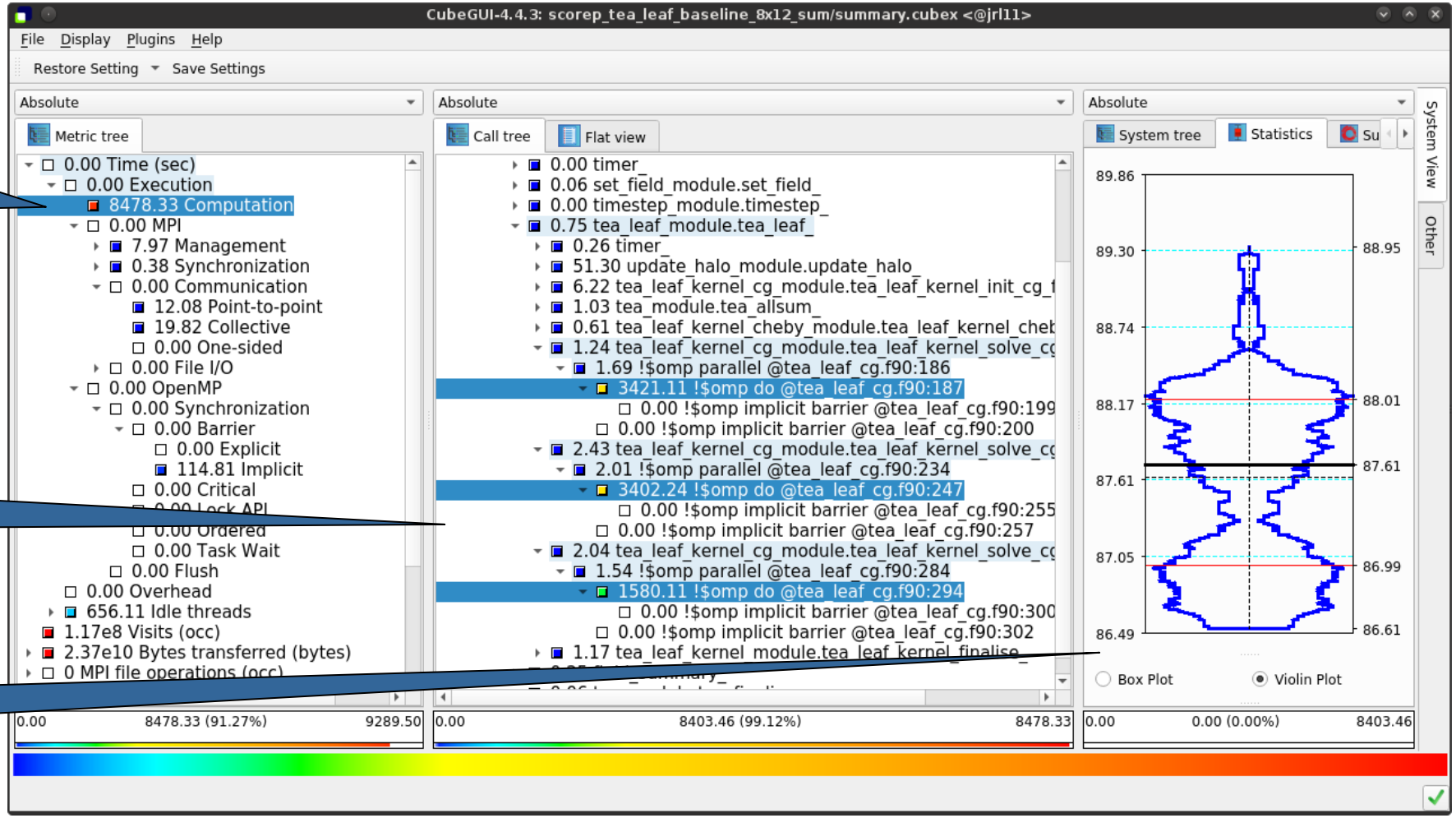


TeaLeaf summary report analysis (I)

91% of the execution time is computation…

…almost entirely spent in 3 OpenMP `do` loops…

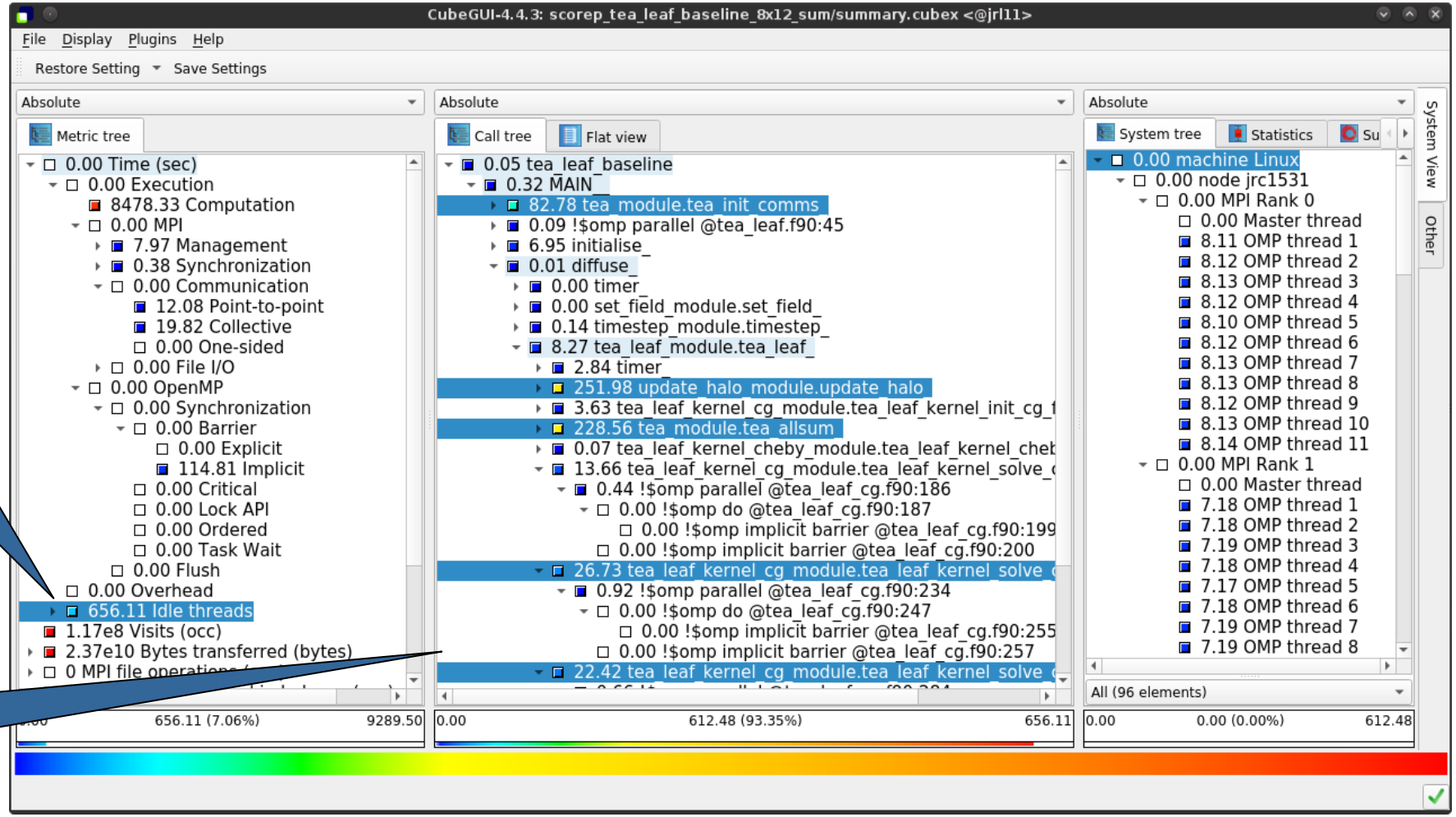
…with a slight imbalance across ranks & threads



TeaLeaf summary report analysis (II)

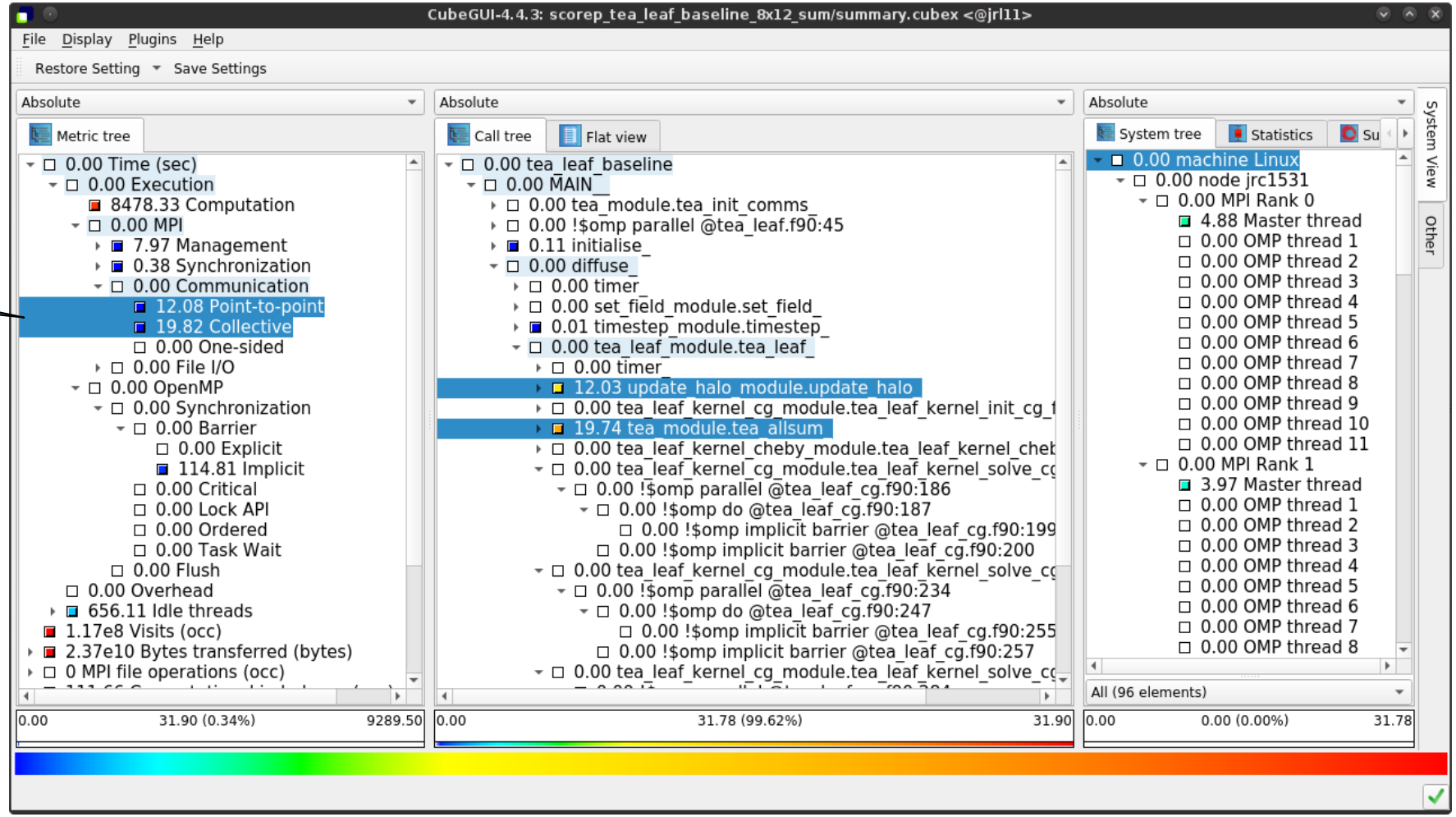
7% of the total CPU execution time is due due to "idle threads"…

… when not within OpenMP-parallelized code regions



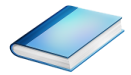
TeaLeaf summary report analysis (III)

MPI communication time is negligible (0.34%); but communication is only on the master threads (MPI_THREAD_FUNNELED)

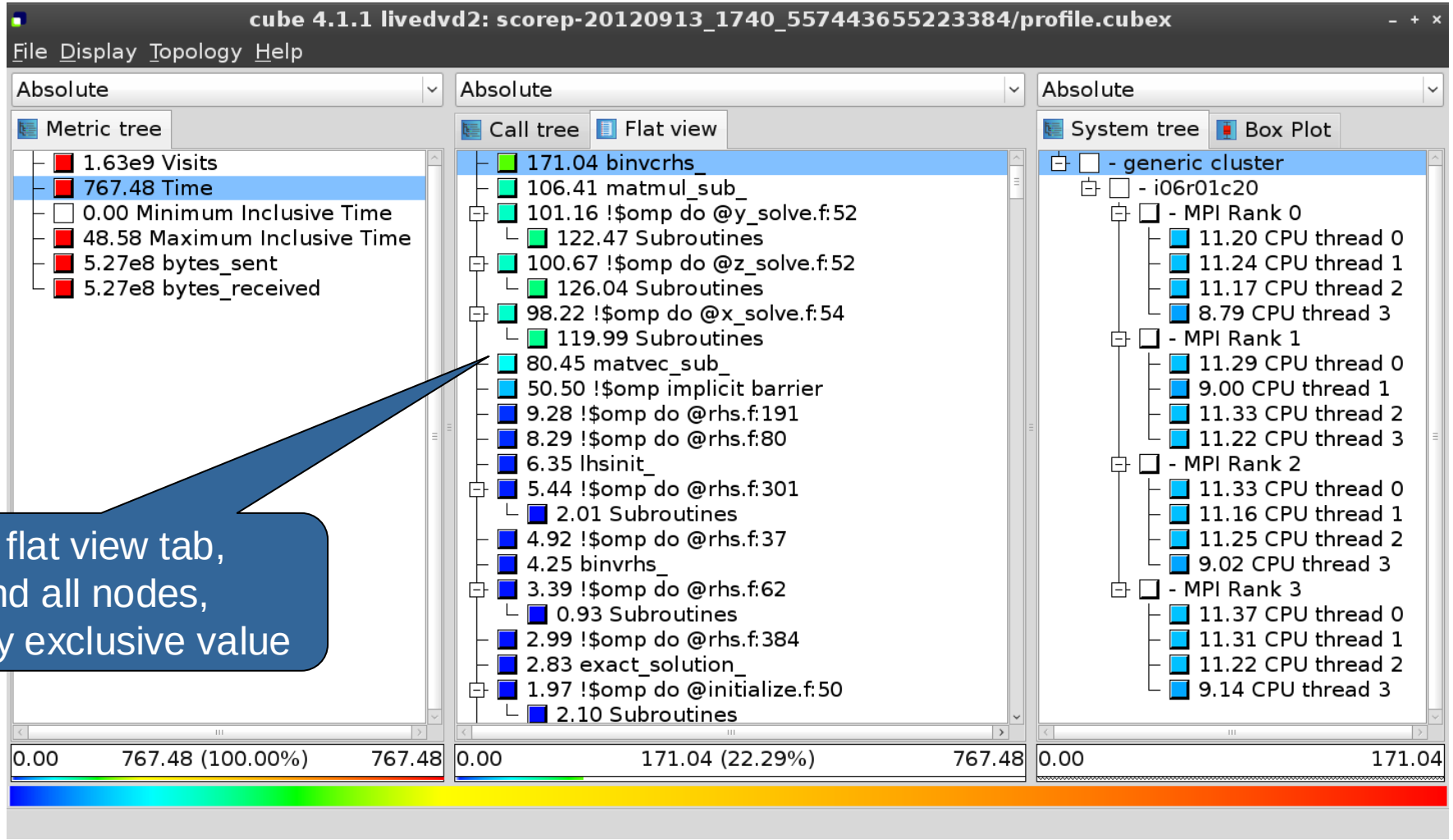


Cube: Further information

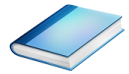
- Parallel program analysis report exploration tools
  - Libraries for Cube report reading & writing
  - Algebra utilities for report processing
  - GUI for interactive analysis exploration
- Available under 3-clause BSD open-source license
- Documentation & sources:
  - https://www.scalasca.org
- User guide also part of installation:
  - <prefix>/share/doc/cubegui/CubeUserGuide.pdf
- Contact:
  - mailto: scalasca@fz-juelich.de

Reference material 

Flat profile view



Derived metrics



- Derived metrics are defined using CubePL expressions, e.g.:

metric::time(i)/metric::visits(e)

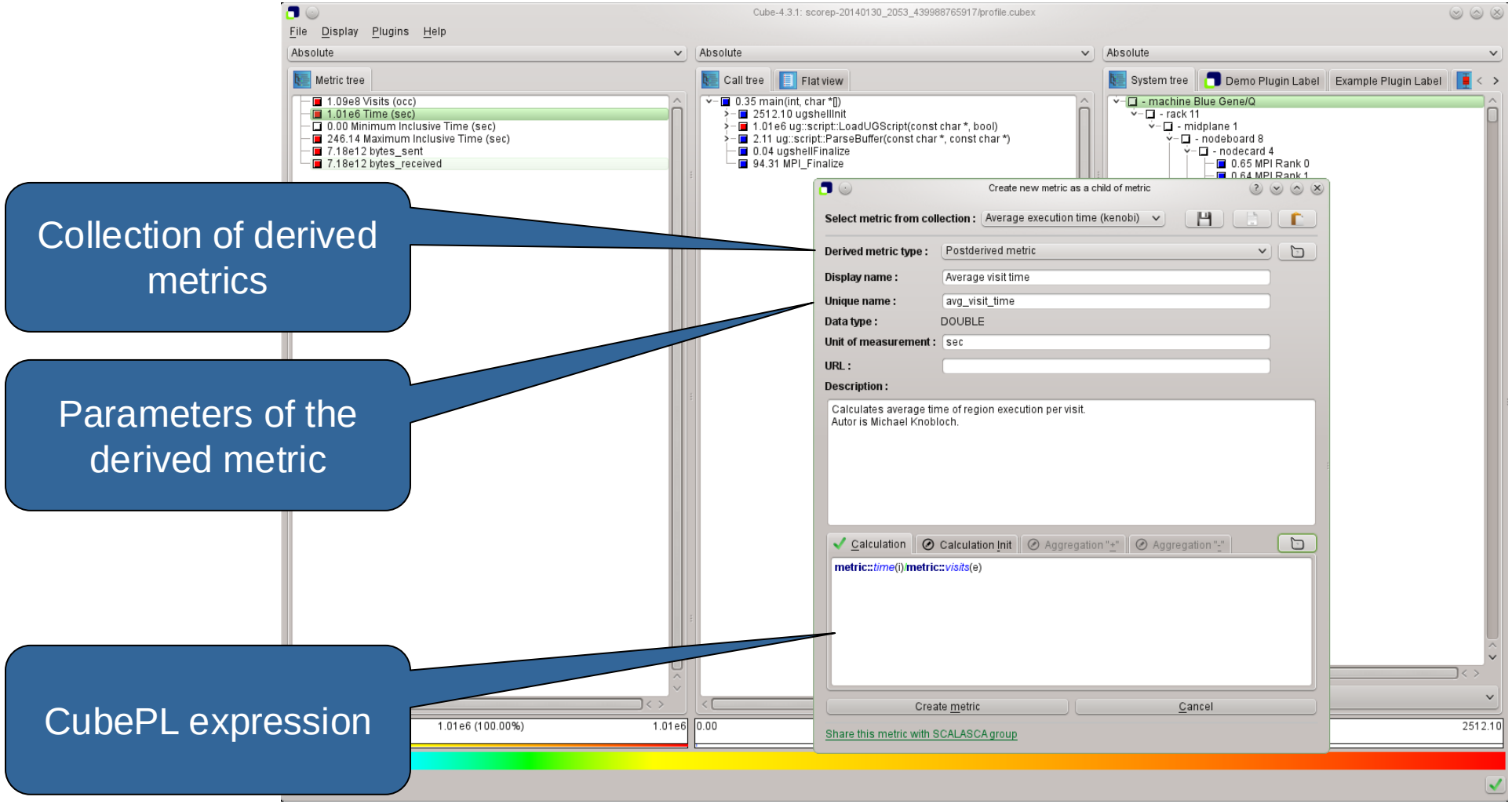
- Values of derived metrics are not stored, but calculated on-the-fly
- Types of derived metrics:
  - Prederived: evaluation of the CubePL expression is performed before aggregation
  - Postderived: evaluation of the CubePL expression is performed after aggregation

- Examples:
  - "Average execution time": Postderived metric with expression

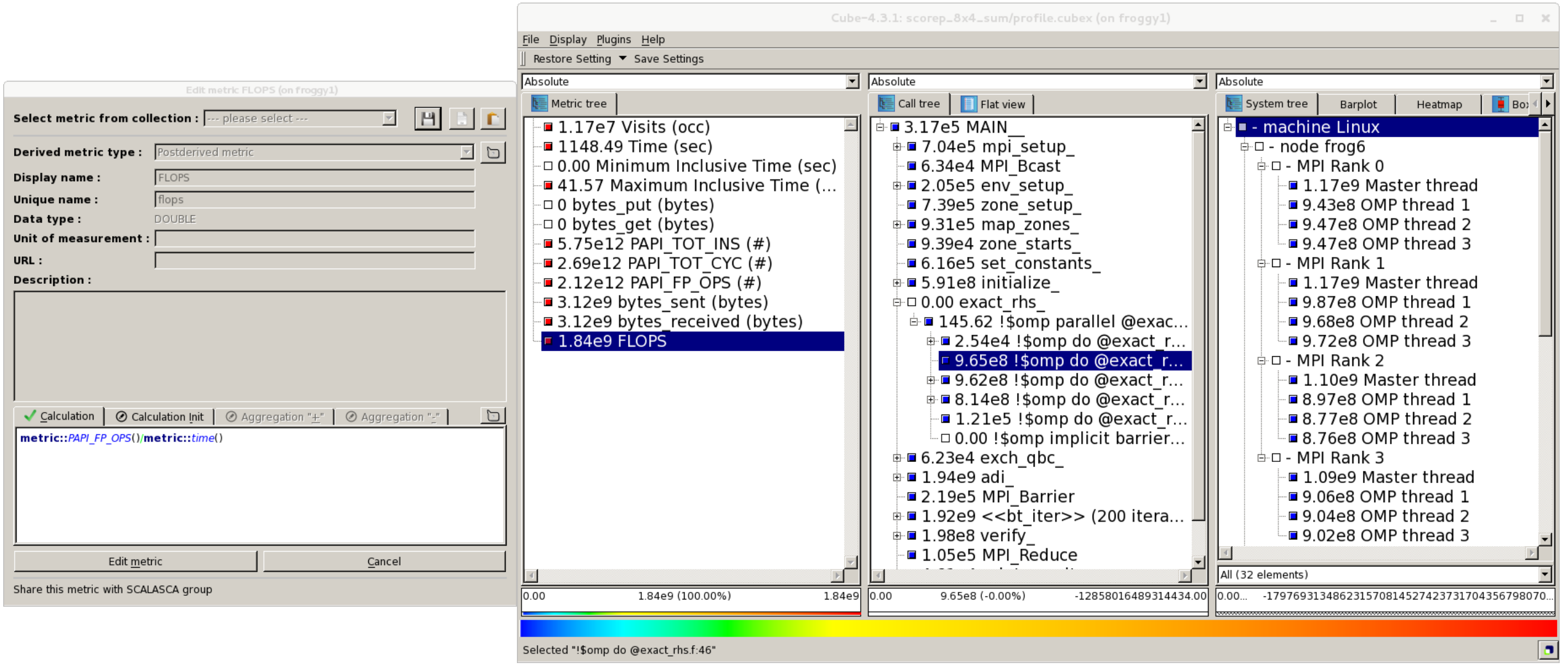
metric::time(i)/metric::visits(e)

  - "Number of FLOP per second": Postderived metric with expression

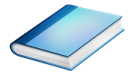
Derived metrics in Cube GUI



Example: FLOPS based on PAPI_FP_OPS and time



CUBE algebra utilities



- Extracting solver sub-tree from analysis report

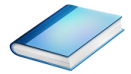
```
% cube_cut  -r '<<ITERATION>>'  scorep_bt-mz_C_32x4_sum/profile.cubex
Writing cut.cubex... done.
```

- Calculating difference of two reports

```
% cube_diff  scorep_bt-mz_C_32x4_sum/profile.cubex  cut.cubex
Writing diff.cubex... done.
```

- Additional utilities for merging, calculating mean, etc.
- Default output of cube_*utility* is a new report *utility*.cubex
- Further utilities for report scoring & statistics
- Run utility with `-h' (or no arguments) for brief usage info

Iteration profiling



- Show time dependent behavior by “unrolling” iterations
- Preparations:
  - Mark loop body by using Score-P instrumentation API in your source code

```
SCOREP_USER_REGION_DEFINE( scorep_bt_loop )
SCOREP_USER_REGION_BEGIN( scorep_bt_loop, "<<bt_iter>>", SCOREP_USER_REGION_TYPE_DYNAMIC )
SCOREP_USER_REGION_END( scorep_bt_loop )
```

- Result in the Cube profile:
  - Iterations shown as separate call trees

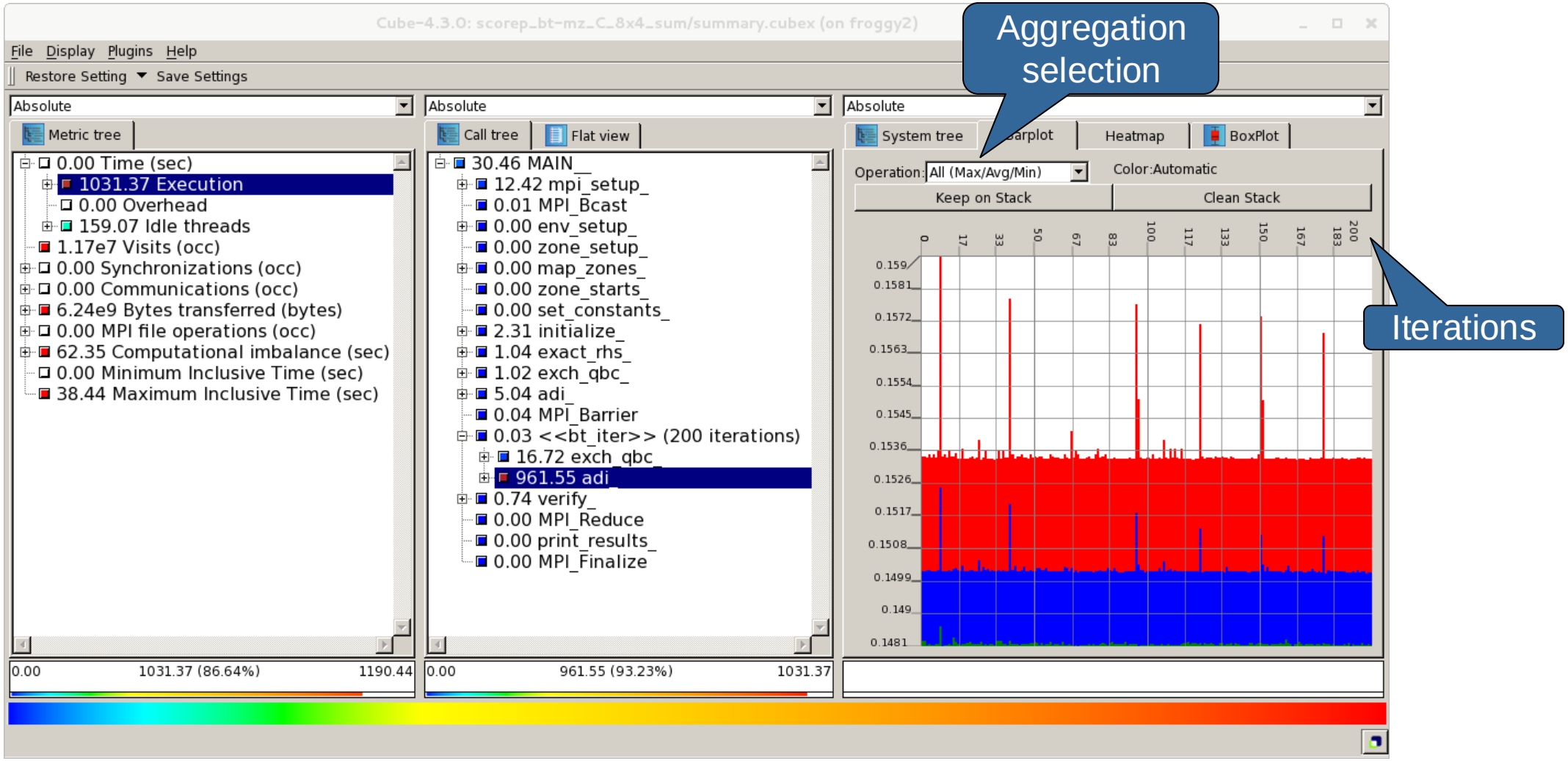
➢Useful for checking results for specific iterations

or

  - Select your user-instrumented region and mark it as loop
  - Choose “Hide iterations”

➢View the Barplot statistics or the (thread x iterations) Heatmap

Iteration profiling: Barplot



Iteration profiling: Heatmap