Does your tool support PAPI SDEs yet?

13th Scalable Tools Workshop

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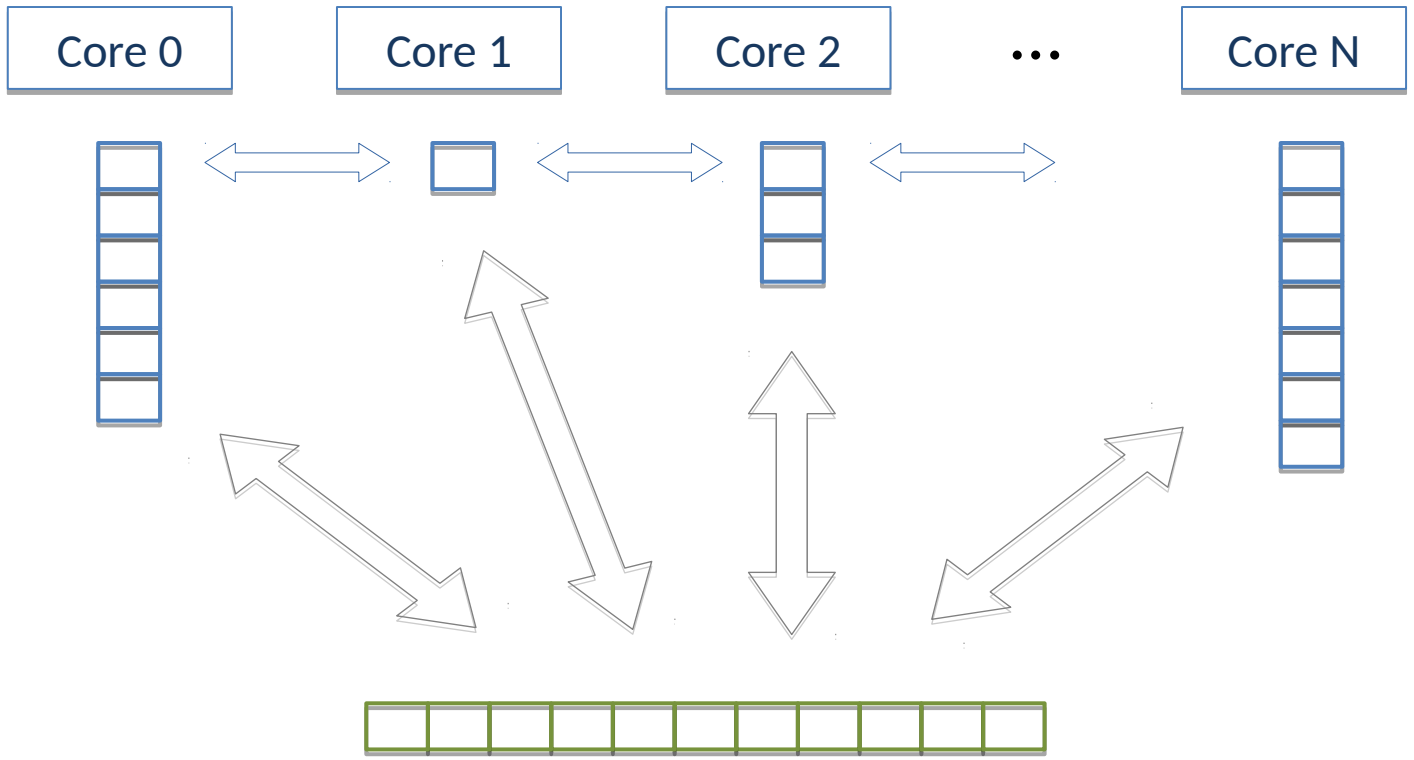
ICL INNOVATIVE COMPUTING LABORATORY

THE UNIVERSITY OF TENNESSEE KNOXVILLE

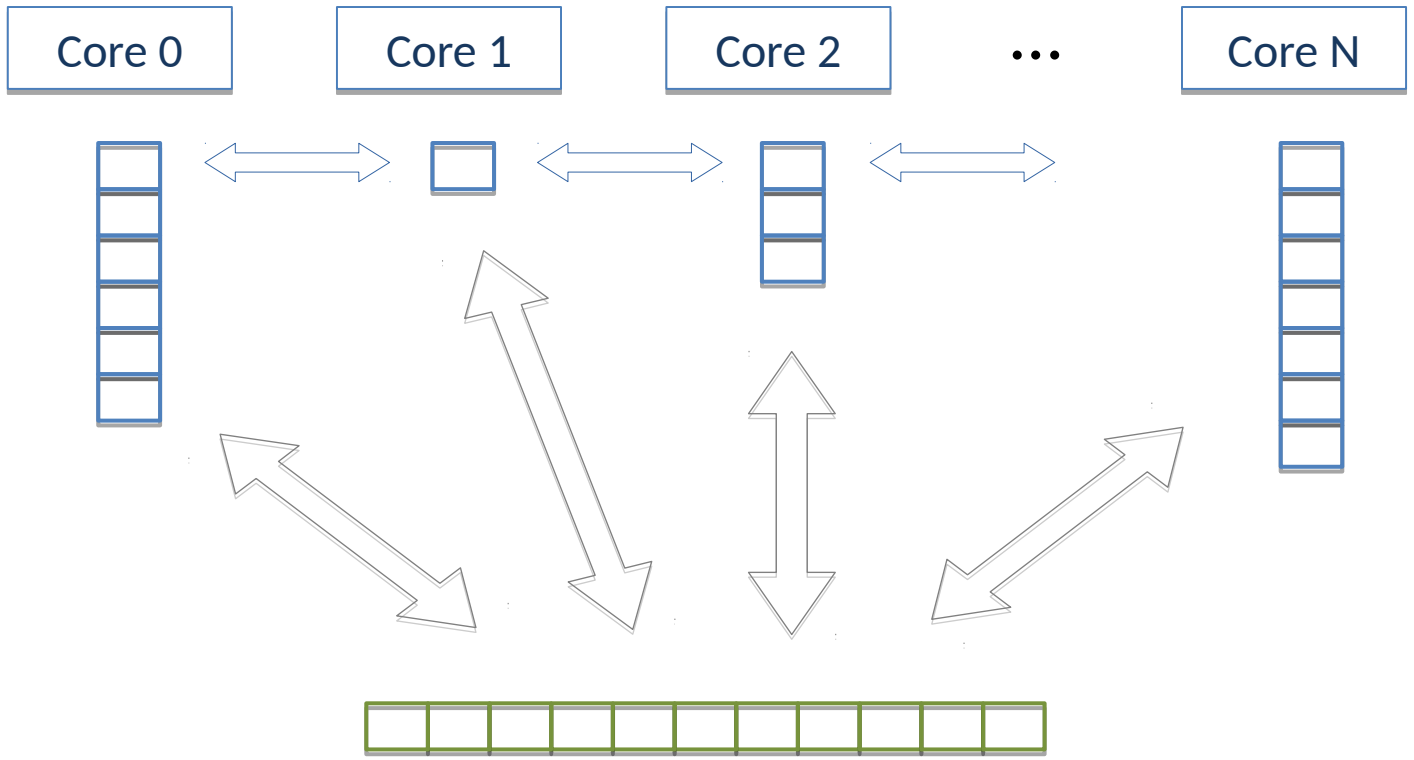
Case study: PaRSEC's task scheduling algorithm



Core local queues

Shared Global queue (overflow)

Case study: PaRSEC's task scheduling algorithm



Core local queues

Shared Global queue (overflow)

Thread Local Queues => High Locality
Overflow & Work Stealing => Load Balance

Parameter selection

Q1: How long should the local queues be?

Q2: Should a thread first steal from a close queue, any queue, or the shared queue?

Parameter selection

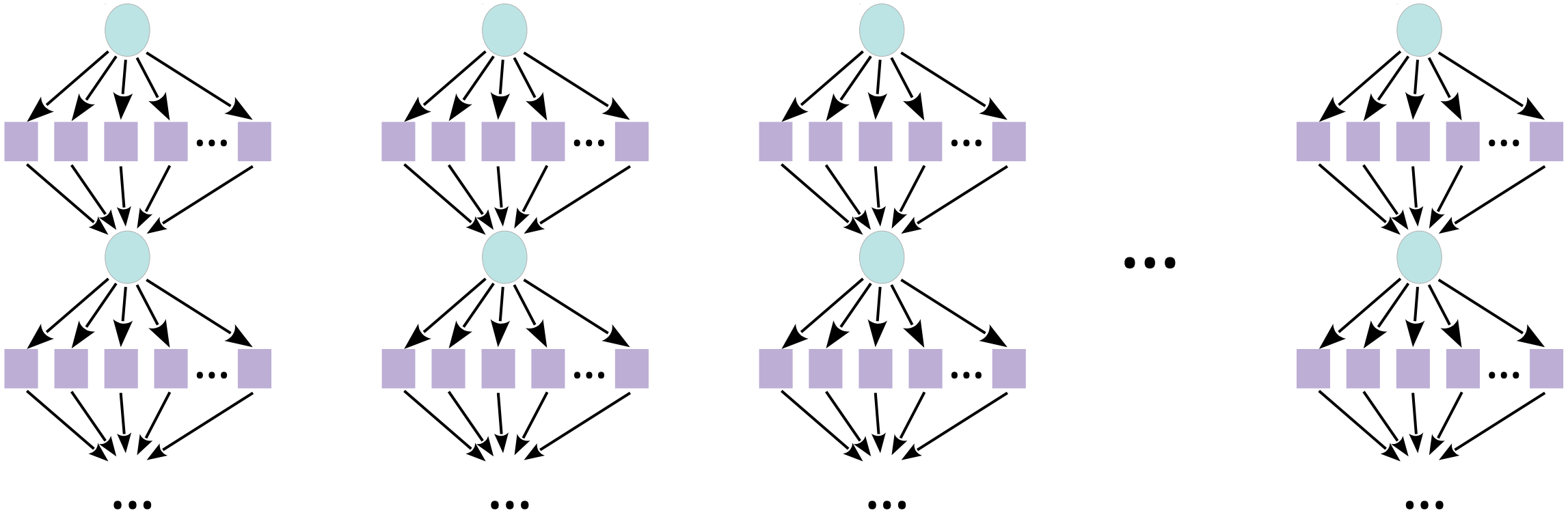
Q1: How long should the local queues be?

A: 4*Core_Count

Q2: Should a thread first steal from a close queue, any queue, or the shared queue?

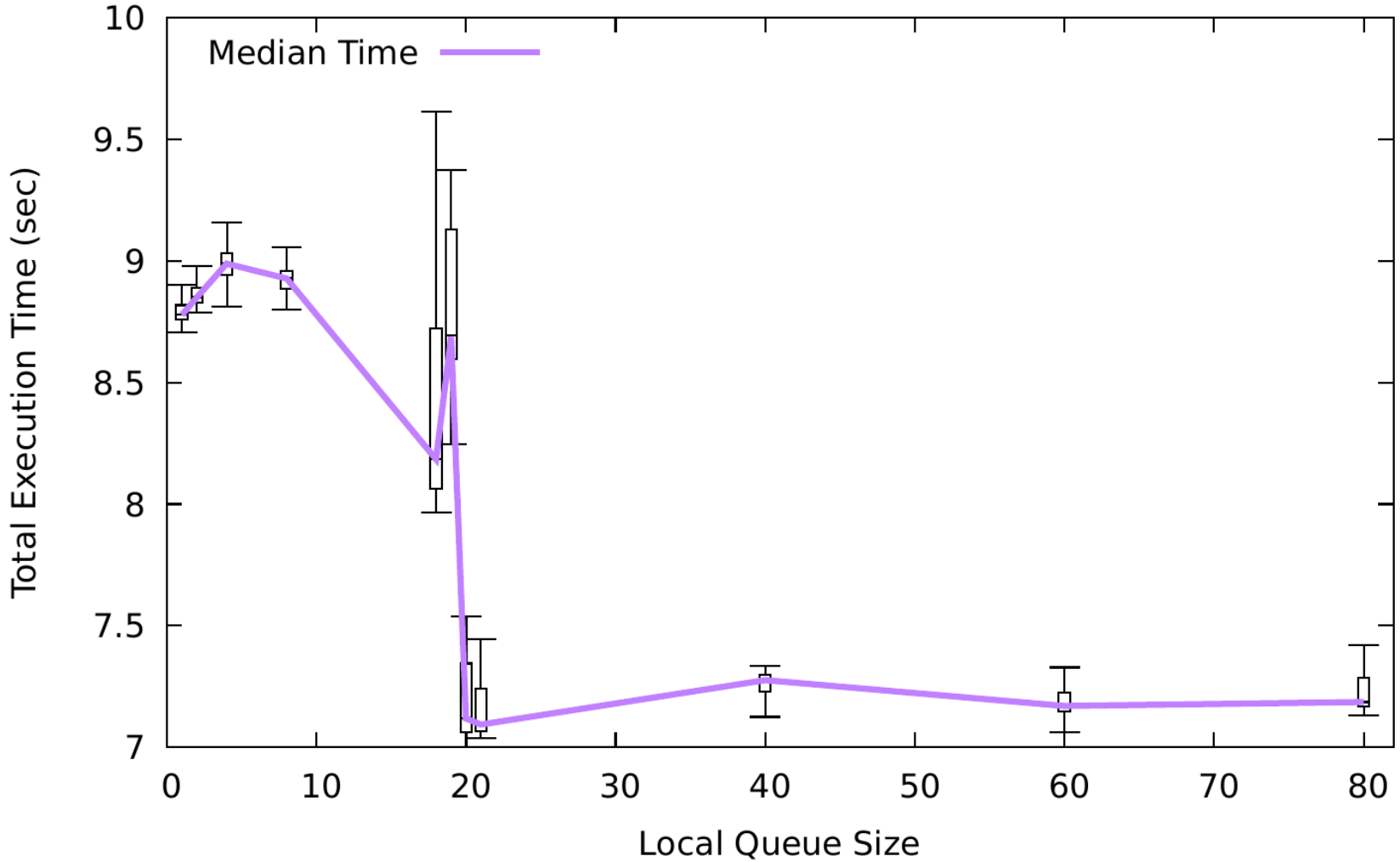
A: Any local queue (closest to farthest), then shared queue.

Testing Benchmark

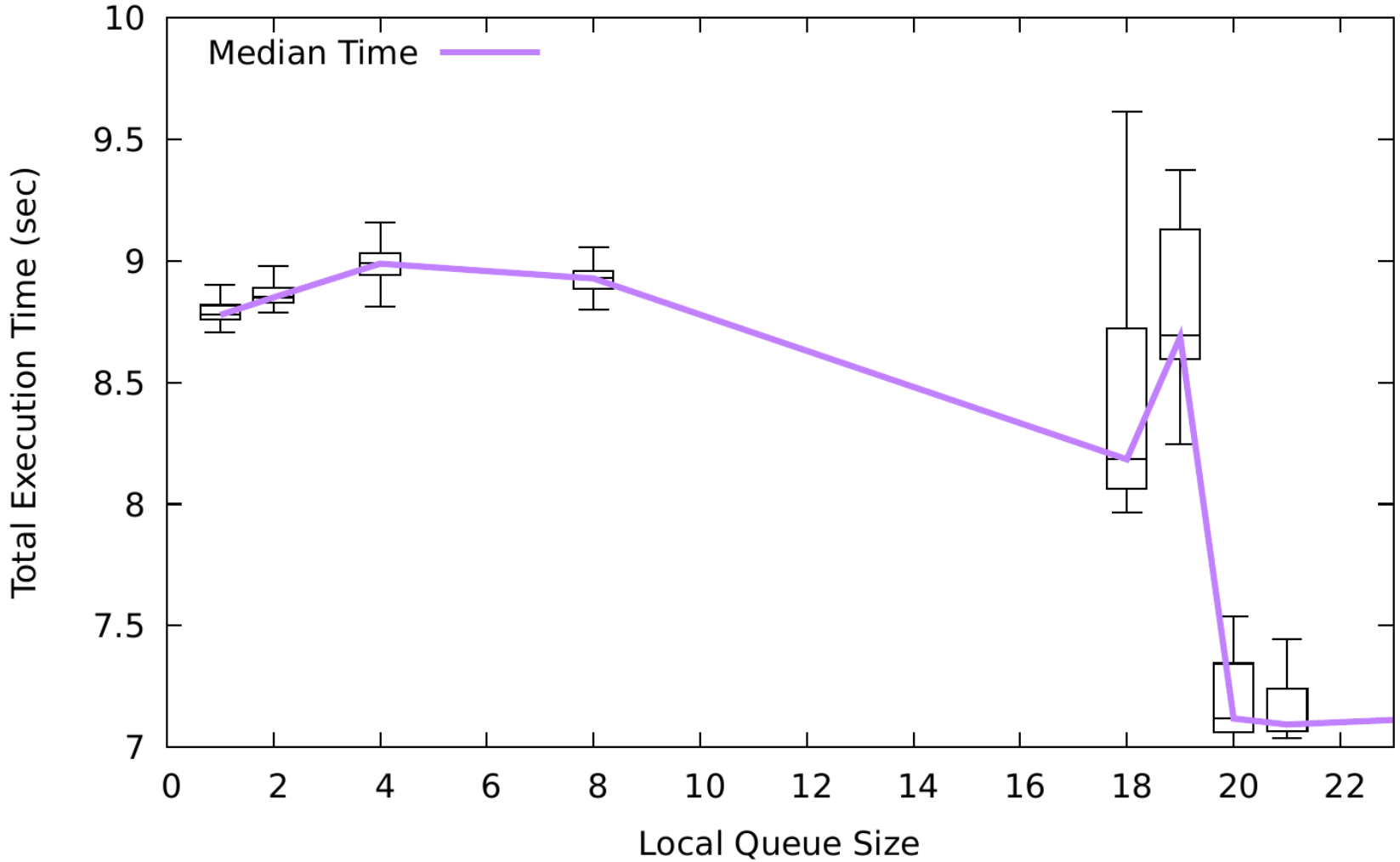


- 20 Independent Fork-Join chains x 20 (or 25) Tasks per fork.
- Memory bound kernel, with good cache locality.
- 20 Cores on testing node.

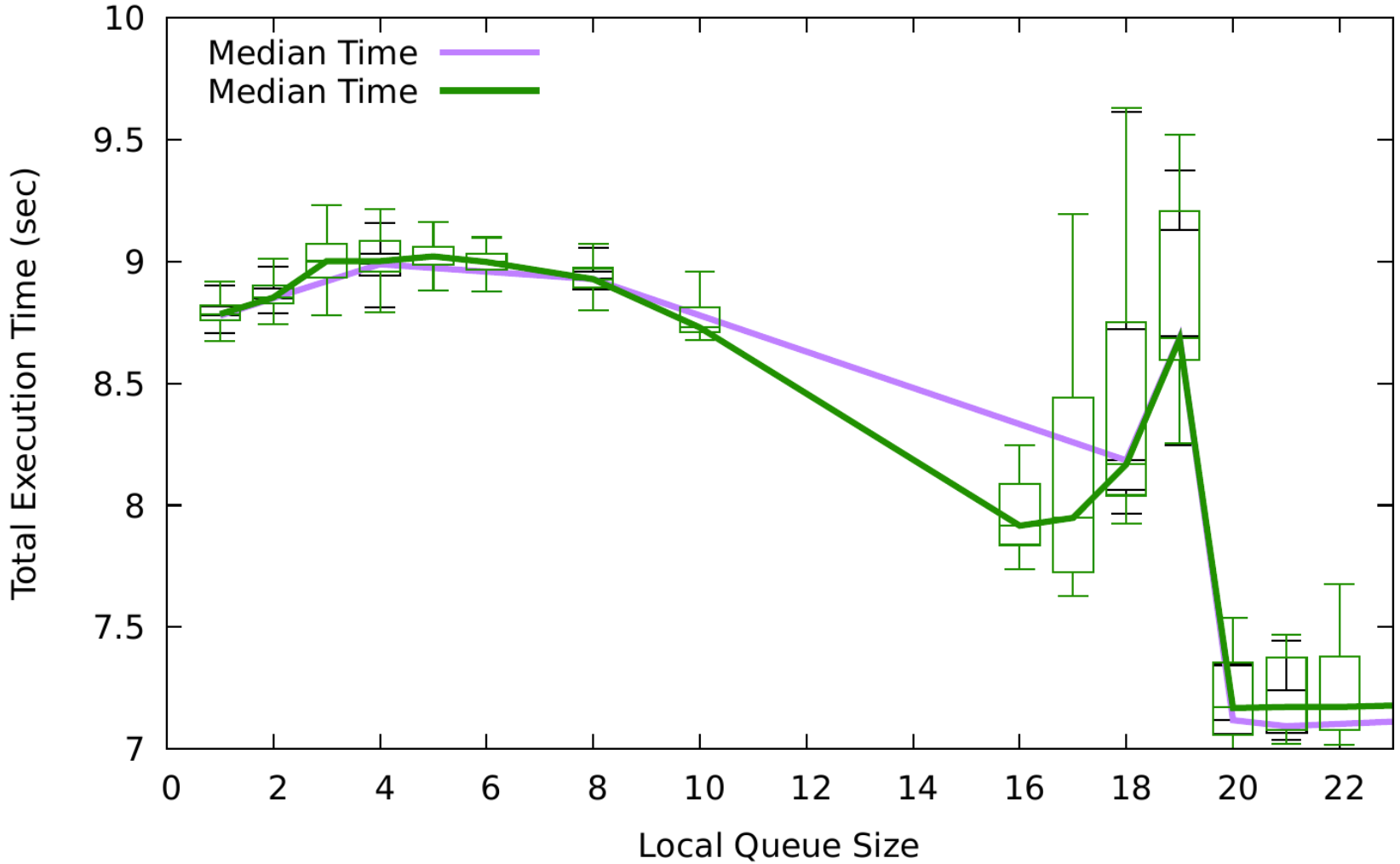
Execution time vs Local Queue Length



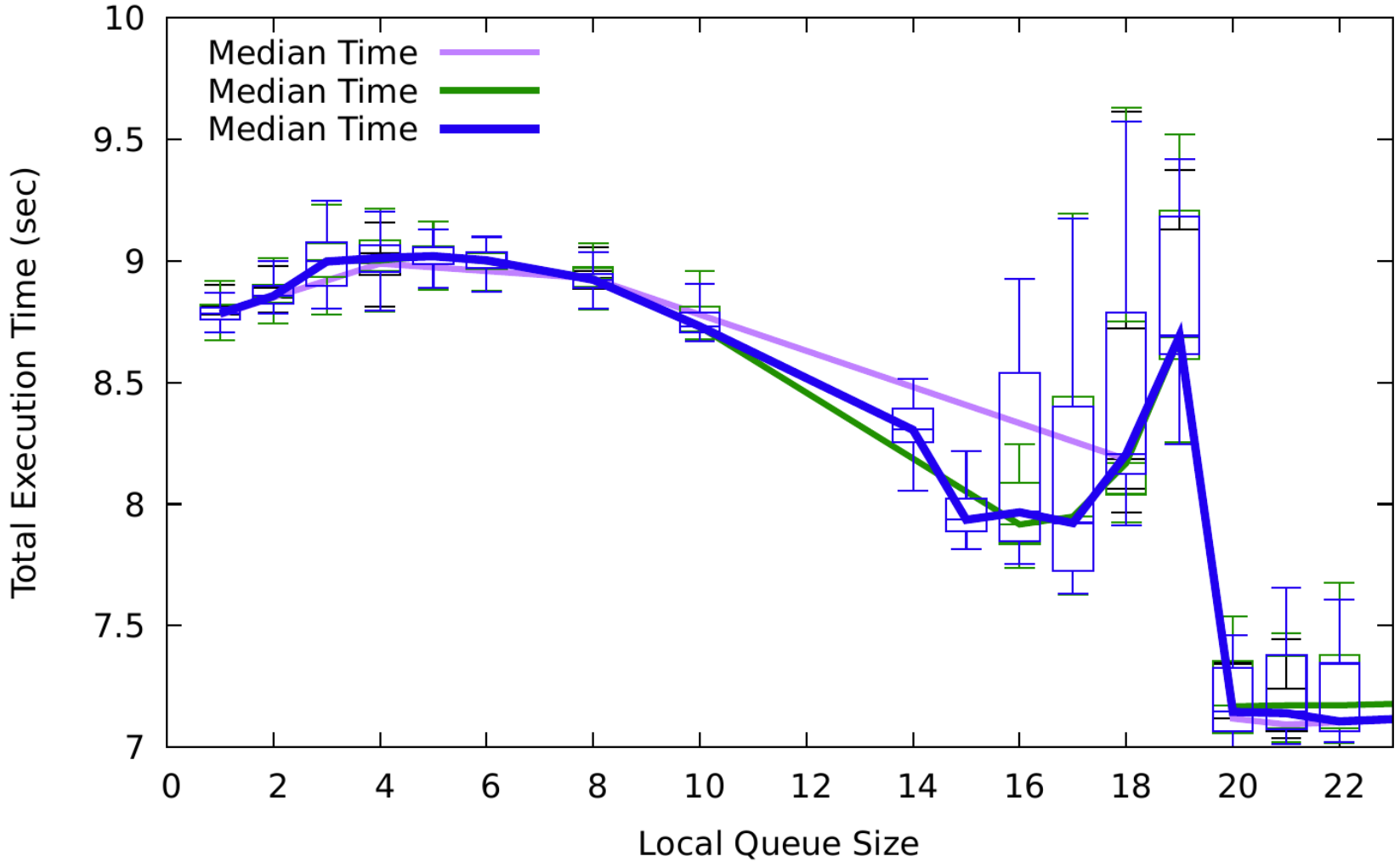
Execution time vs Local Queue Length (zoom)



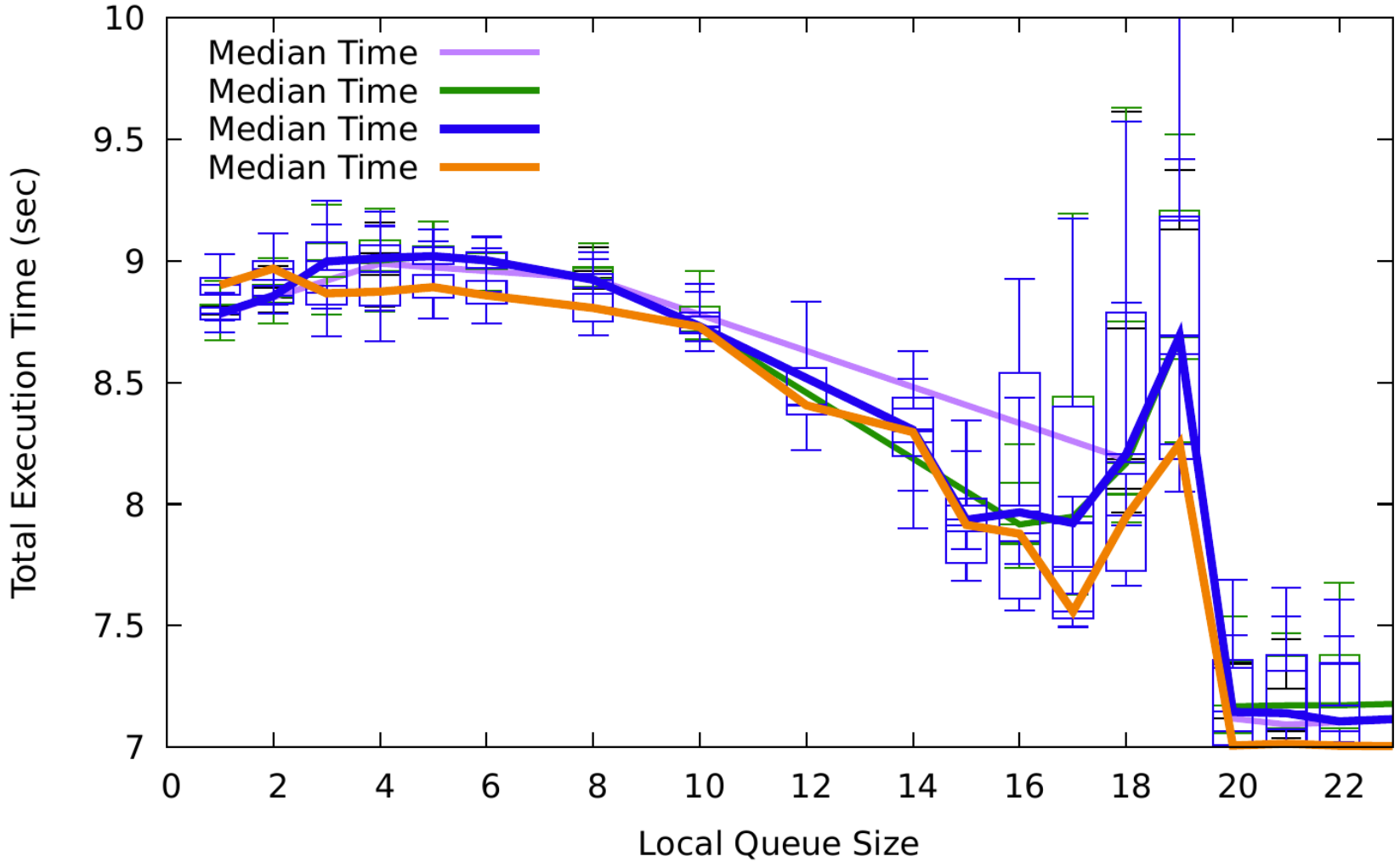
Execution time vs Local Queue Length (zoom 2)



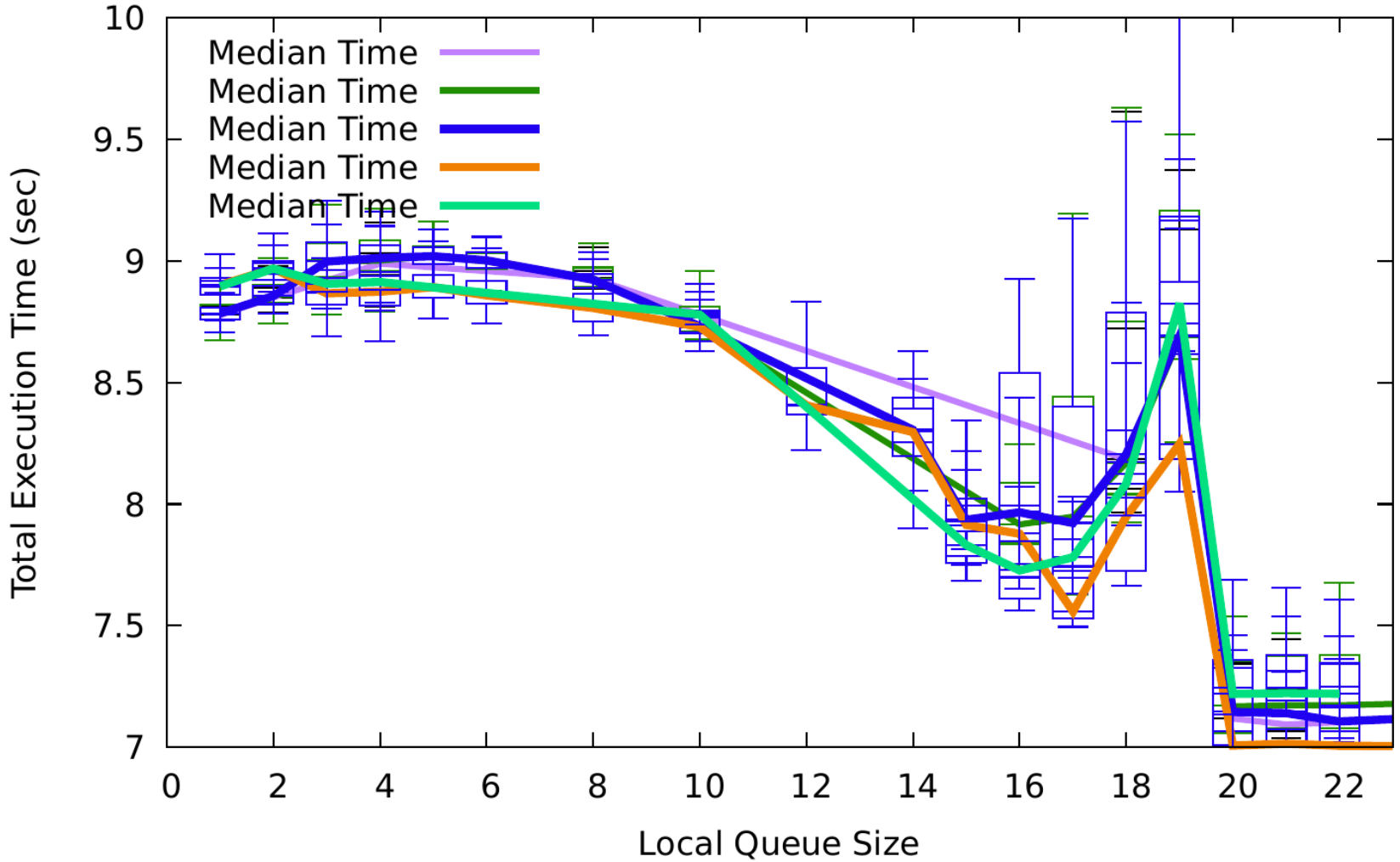
Execution time vs Local Queue Length (zoom 3)



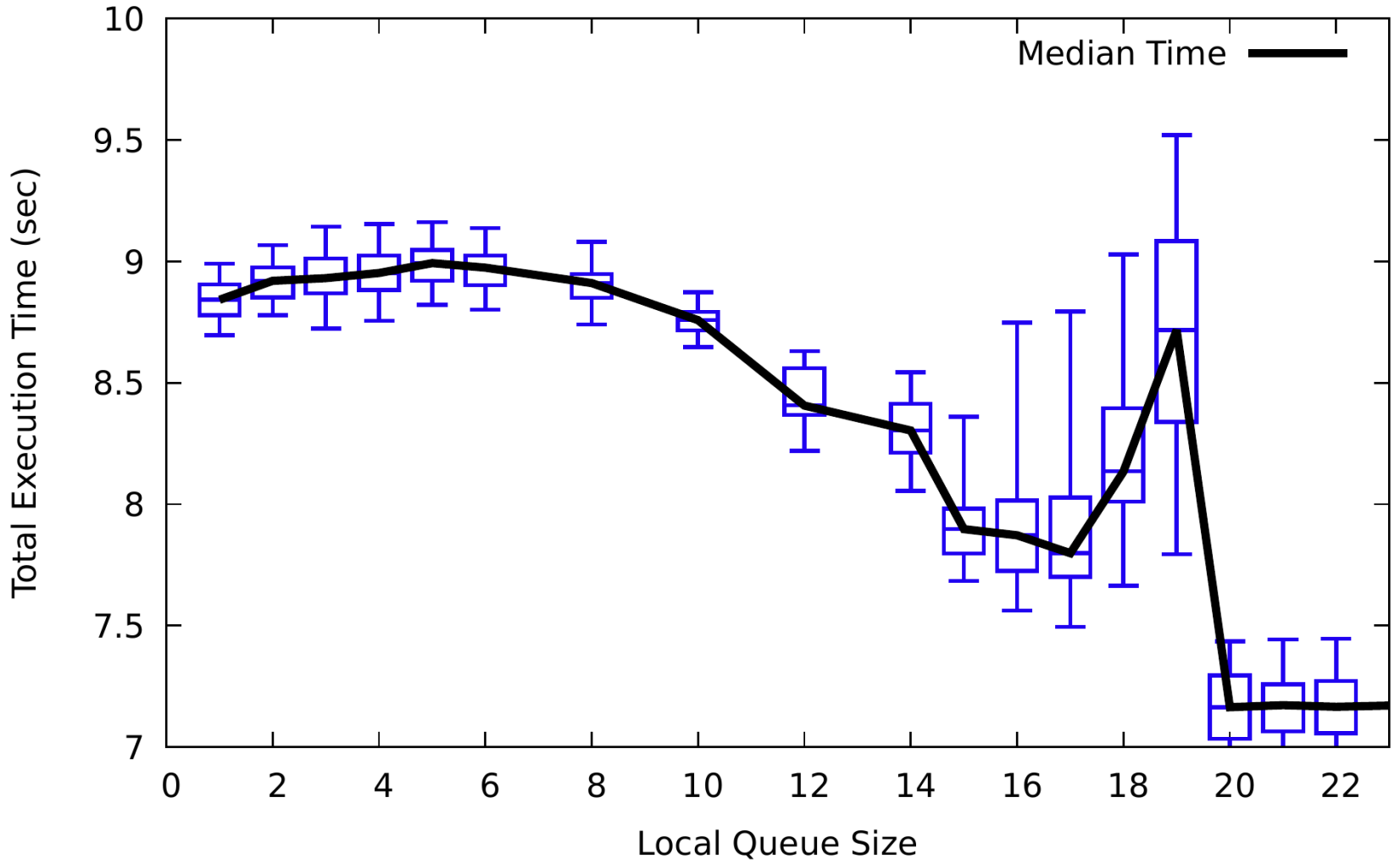
Execution time vs Local Queue Length (zoom 4)



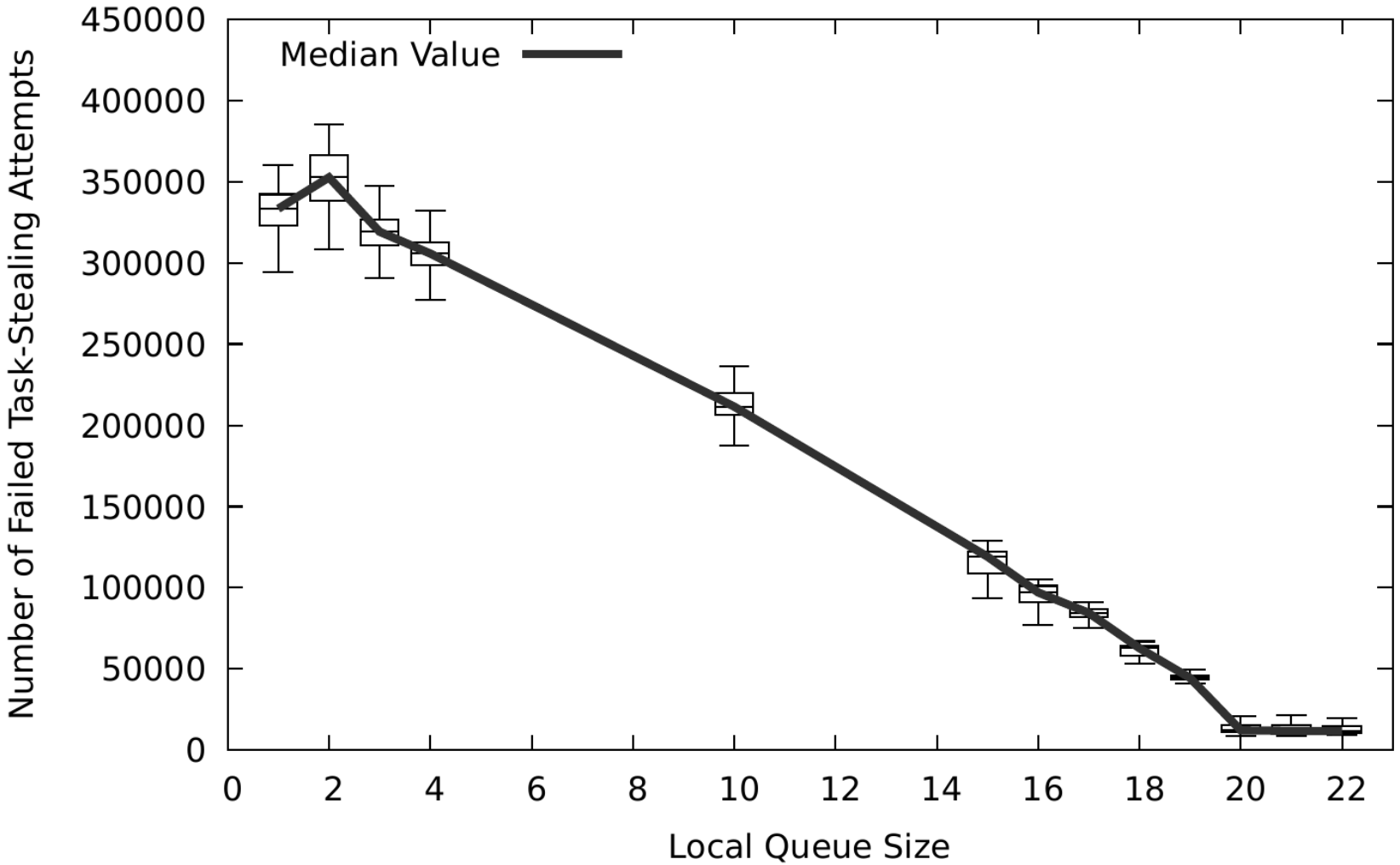
Execution time vs Local Queue Length (zoom 5)



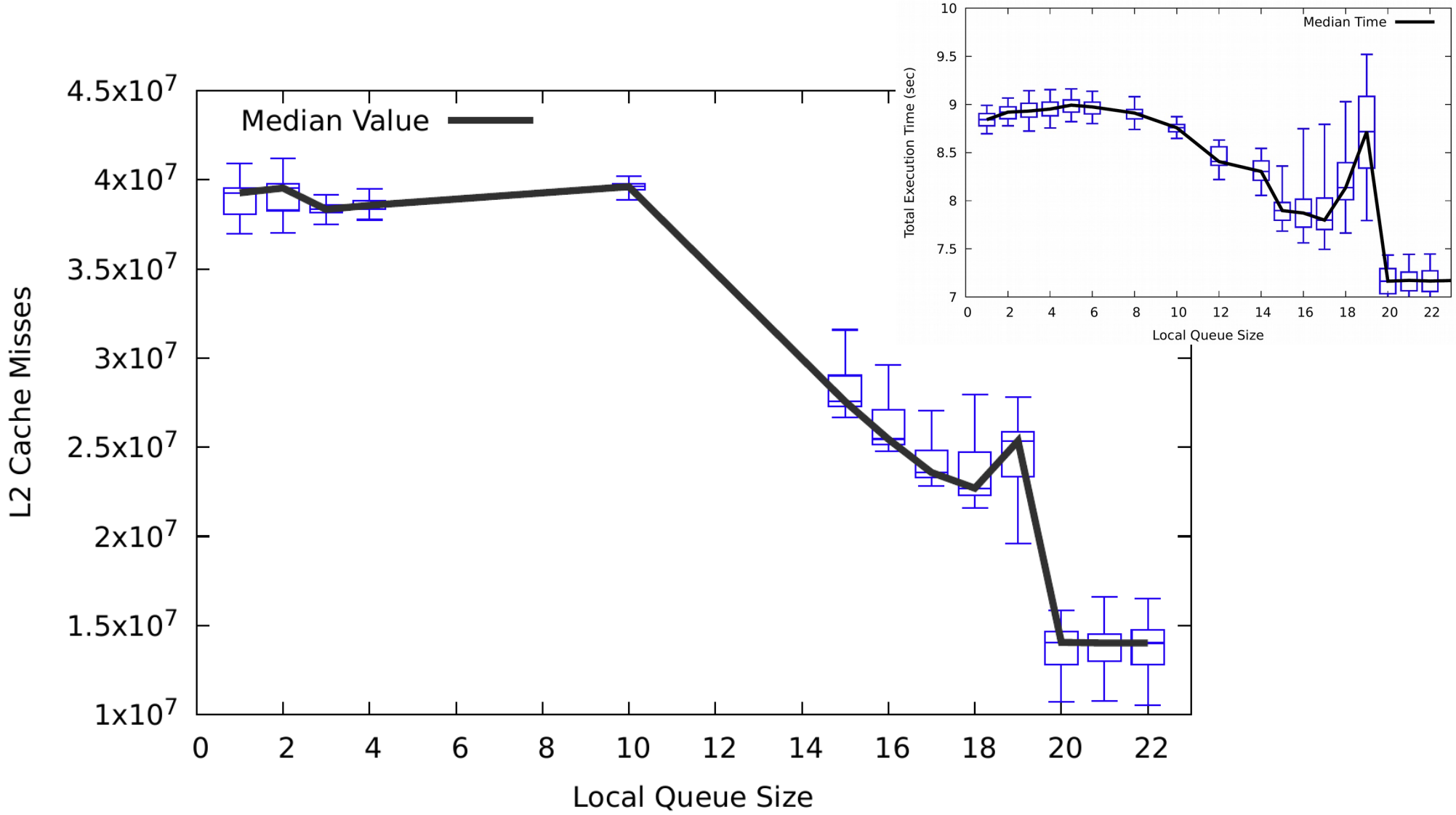
Execution time vs Local Queue Length (combined)



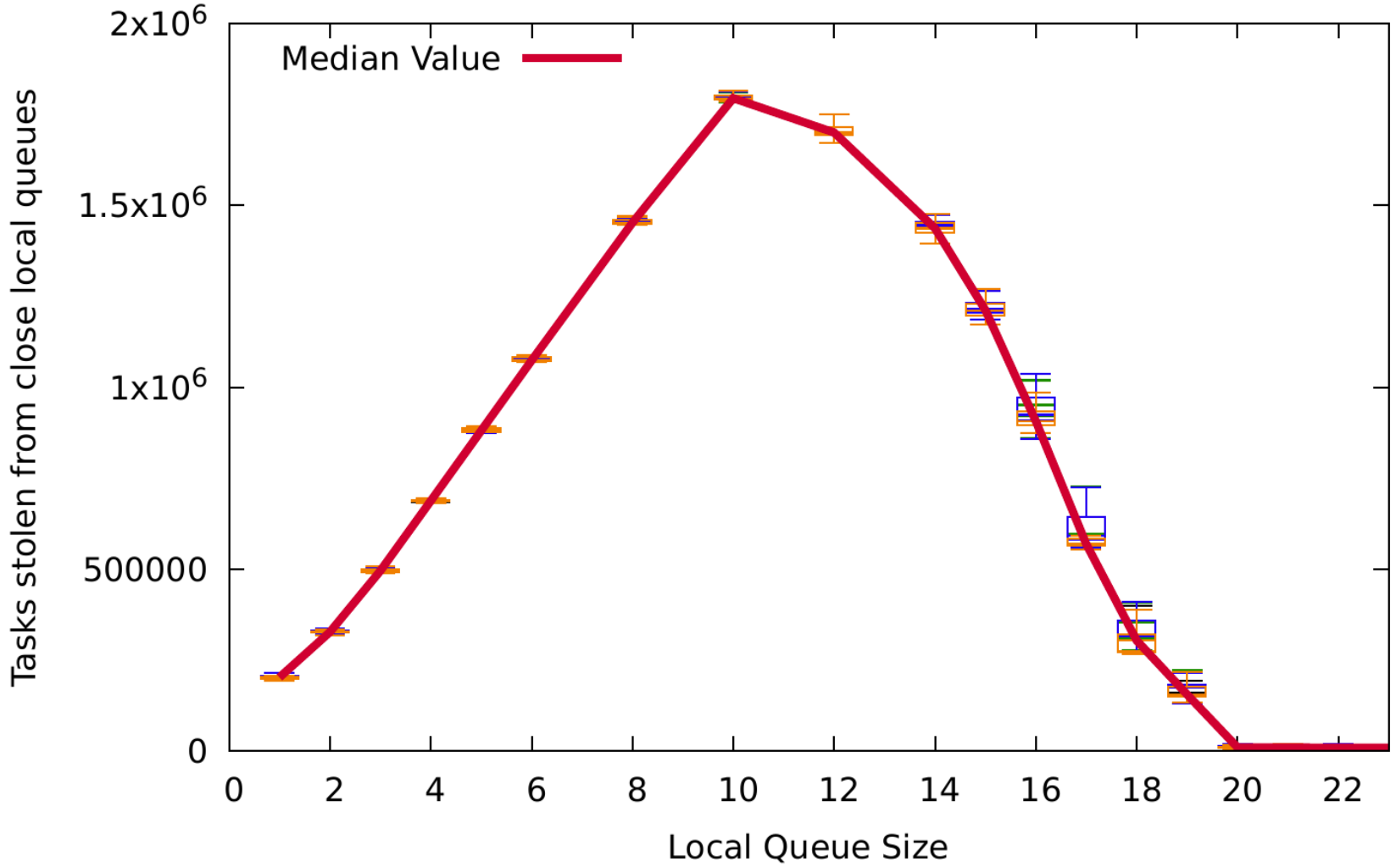
Failed Stealing Attempts



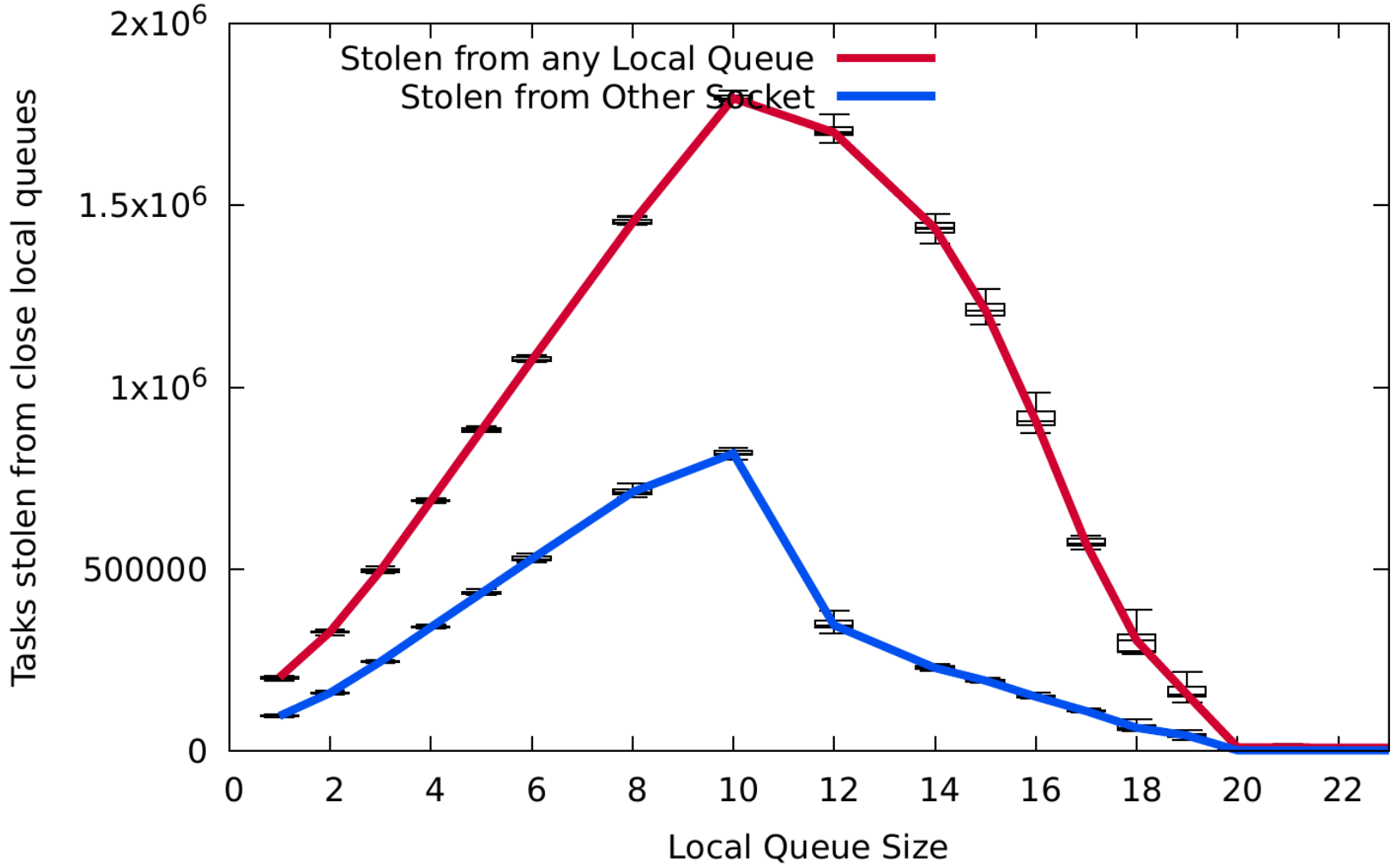
L2 Cache Misses (L3 show same pattern)



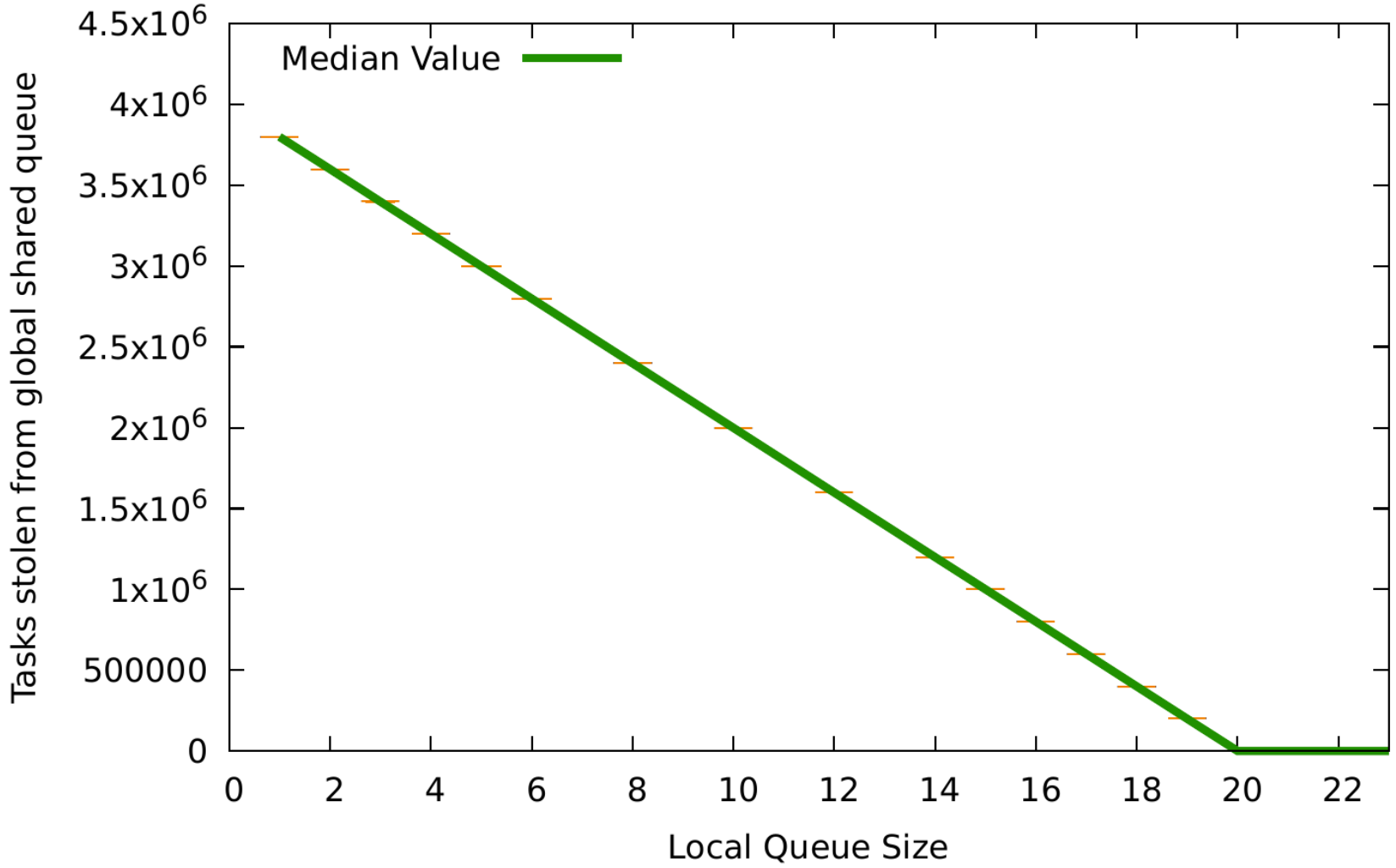
Successful Close Stealing



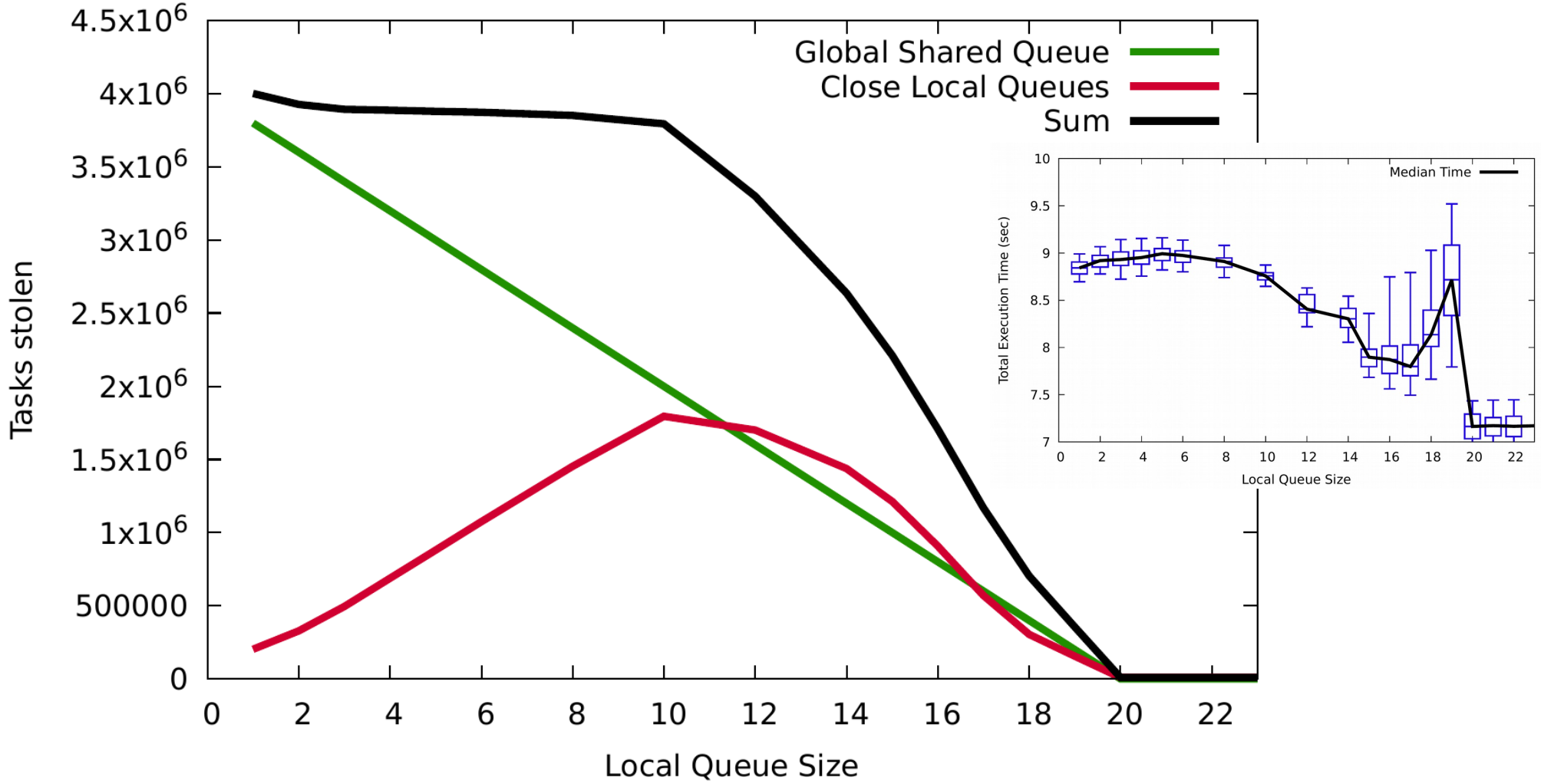
Successful Close & Far Stealing



Successful Shared Queue Stealing



Successful Local + Shared Queue Stealing



Unanswered questions

Q: So, what causes the bump?

Q: How did you measure all these things?

Unanswered questions

Q: So, what causes the bump?

A: I don’t know!

Q: How did you measure all these things?

Unanswered questions

Q: So, what causes the bump?

A: I don’t know!

Q: How did you measure all these things?

A: I am glad you asked.

What is missing from current infrastructure?

Events that occurred inside the software stack

There is no standardized way for a software layer to export information about its behavior such that other, independently developed, software layers can read it.

HPC Application	Quantum Chemistry Method
Math library	Distributed Factorization
Task runtime	Data Dependency
MPI	One Sided Communication
Libibverbs	RDMA completion

PAPI Software Defined Events

- De facto standard:

  SDEs from your library can be read using the standard PAPI_start()/PAPI_stop()/PAPI_read().

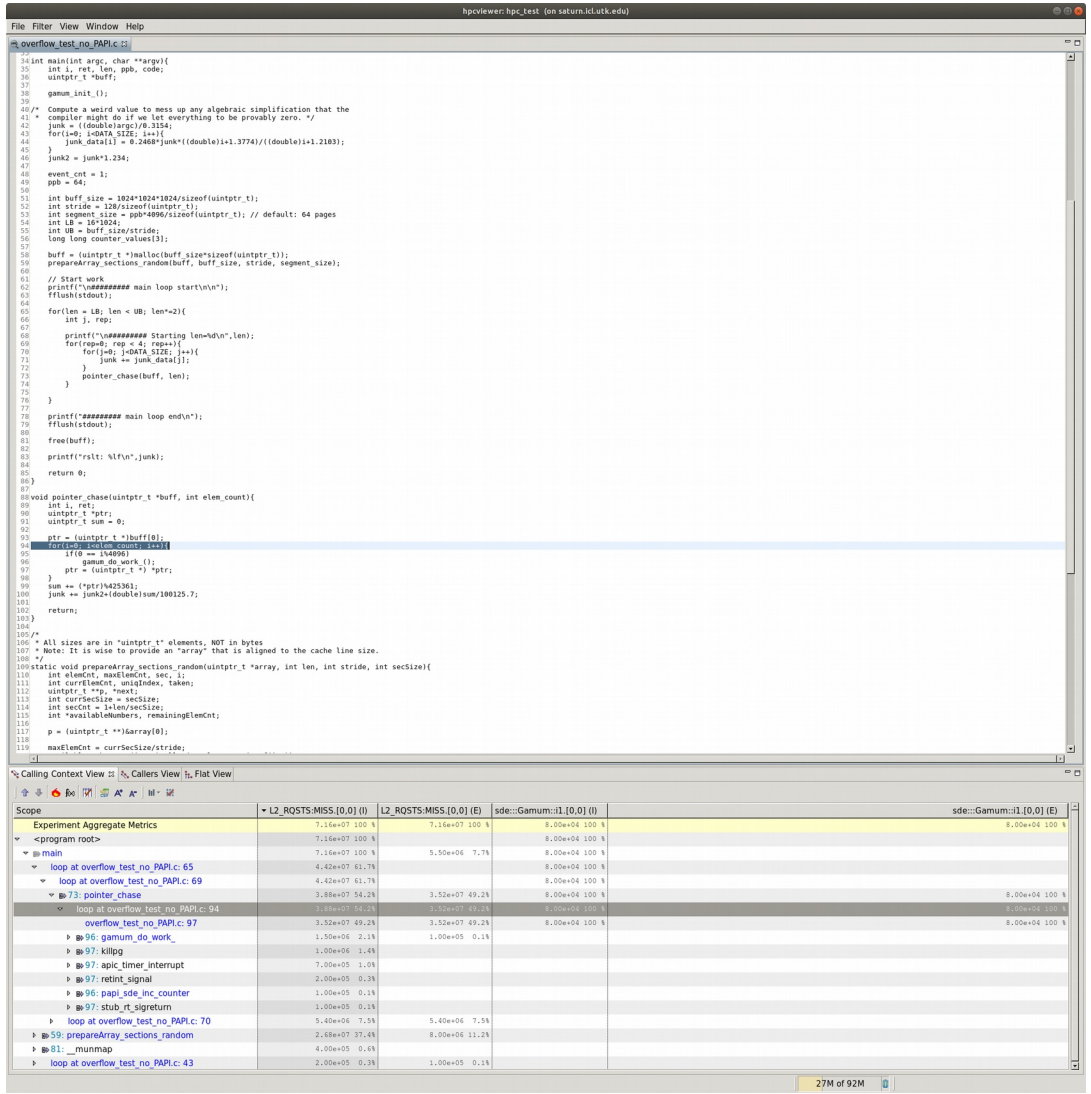
- Low overhead:

  Performance critical codes can implement SDEs with zero overhead by exporting existing code variables without adding any new instructions in the fast path.

- Rich feature set:

  PAPI SDE supports counters, groups, recordings, simple statistics, thread safety, custom callbacks.

The tool infrastructure is already there



The tool infrastructure is already there

```
94      for(i=0; i<elem_count; i++){
95          if(0 == i%4096)
96              gamum_do_work_();
97          ptr = (uintptr_t *) *ptr;
98      }
99      sum += (*ptr)%425361;
100     junk += junk2+(double)sum/100125.7;
101
102     return;
103 }
104
105 /*
106  * All sizes are in "uintptr_t" elements, NOT in bytes
107  * Note: It is wise to provide an "array" that is aligned to the cache line size.
108  */
109 static void prepareArray_sections_random(uintptr_t *array, int len, int stride, int secSize){
110     int elemCnt, maxElemCnt, sec, i;
111     int currElemCnt, uniqIndex, taken;
112     uintptr_t **p, *next;
113     int currSecSize = secSize;
114     int secCnt = 1+len/secSize;
115     int *availableNumbers, remainingElemCnt;
116
117     p = (uintptr_t **)&array[0];
118
119     maxElemCnt = currSecSize/stride;
```

Calling Context View | Callers View | Flat View

Scope	L2_RQSTS:MISS.[0,0] (I)	L2_RQSTS:MISS.[0,0] (E)	sde:::Gamum::i1.[0,0] (I)
Experiment Aggregate Metrics	7.16e+07 100 %	7.16e+07 100 %	8.00e+04 100 %
<program root>	7.16e+07 100 %		8.00e+04 100 %
main	7.16e+07 100 %	5.50e+06 7.7%	8.00e+04 100 %
loop at overflow_test_no_PAPI.c: 65	4.42e+07 61.7%		8.00e+04 100 %
loop at overflow_test_no_PAPI.c: 69	4.42e+07 61.7%		8.00e+04 100 %
73: pointer_chase	3.88e+07 54.2%	3.52e+07 49.2%	8.00e+04 100 %
loop at overflow_test_no_PAPI.c: 94	3.88e+07 54.2%	3.52e+07 49.2%	8.00e+04 100 %

Simplest SDE code (library side)

```
static long long local_var;

void small_test_init( void ){
    local_var = 0;
    papi_handle_t *handle = papi_sde_init("TEST");
    papi_sde_register_counter( handle, "Evnt",
                               PAPI_SDE_RO|PAPI_SDE_DELTA,
                               PAPI_SDE_long_long,
                               &local_var );
    ...
}
```

SDE code for registering a callback function

```
sometype_t *data;

void small_test_init( void ){
    data = ...
    papi_handle_t *handle = papi_sde_init(”TEST");
    papi_sde_register_fp_counter(handle, "Evnt",
                                 PAPI_SDE_RO|PAPI_SDE_DELTA,
                                 PAPI_SDE_long_long,
                                 accessor, data);
    ...
}
```

SDE code for creating a counter (push mode)

```
void *counter_handle;

void small_test_init( void ){
    papi_handle_t *handle = papi_sde_init(”TEST");
    papi_sde_create_counter(handle, "Evnt",
                            PAPI_SDE_long_long,
                            &counter_handle);
    ...
}
```

SDE code for creating a recorder (push mode)

```
void *recorder_handle;

void small_test_init( void ){
    papi_handle_t *handle = papi_sde_init(”TEST");
    papi_sde_create_recorder(handle, "RCRDR",
                             sizeof(double),
                             cmpr_func_ptr,
                             &recorder_handle);
    ...
}
```

SDE code for creating a recorder (push mode)

```
void *recorder_handle;
```

sde:::TEST::RCRDR

```
void small_test_init( void ){
    papi_handle_t *handle = papi_sde_init("TEST");
    papi_sde_create_recorder(handle, "RCRDR",
                                     sizeof(double),
                                     cmpr_func_ptr,
                                     &recorder_handle);
    ...
}
```

SDE code for creating a recorder (push mode)

```
void *recorder_handle;

void small_test_init(void)
{
    papi_handle_t *handle = papi_sde_init("TEST");
    papi_sde_create_recorder(handle, "RCRDR",
                                     sizeof(double),
                                     cmpr_func_ptr,
                                     &recorder_handle);
    ...
}
```

sde:::TEST::RCRDR

sde:::TEST::RCRDR:CNT

SDE code for creating a recorder (push mode)

```
void *recorder_handle;

void small_test()
{
    papi_handle_t *handle = papi_sde_init("TEST");
    papi_sde_create_recorder(handle, "RCRDR",
                             sizeof(double),
                             comparator,
                             &recorder_handle);
    ...
}
```

sde:::TEST::RCRDR

sde:::TEST::RCRDR:CNT

sde:::TEST::RCRDR:MIN

sde:::TEST::RCRDR:Q1

sde:::TEST::RCRDR:MED

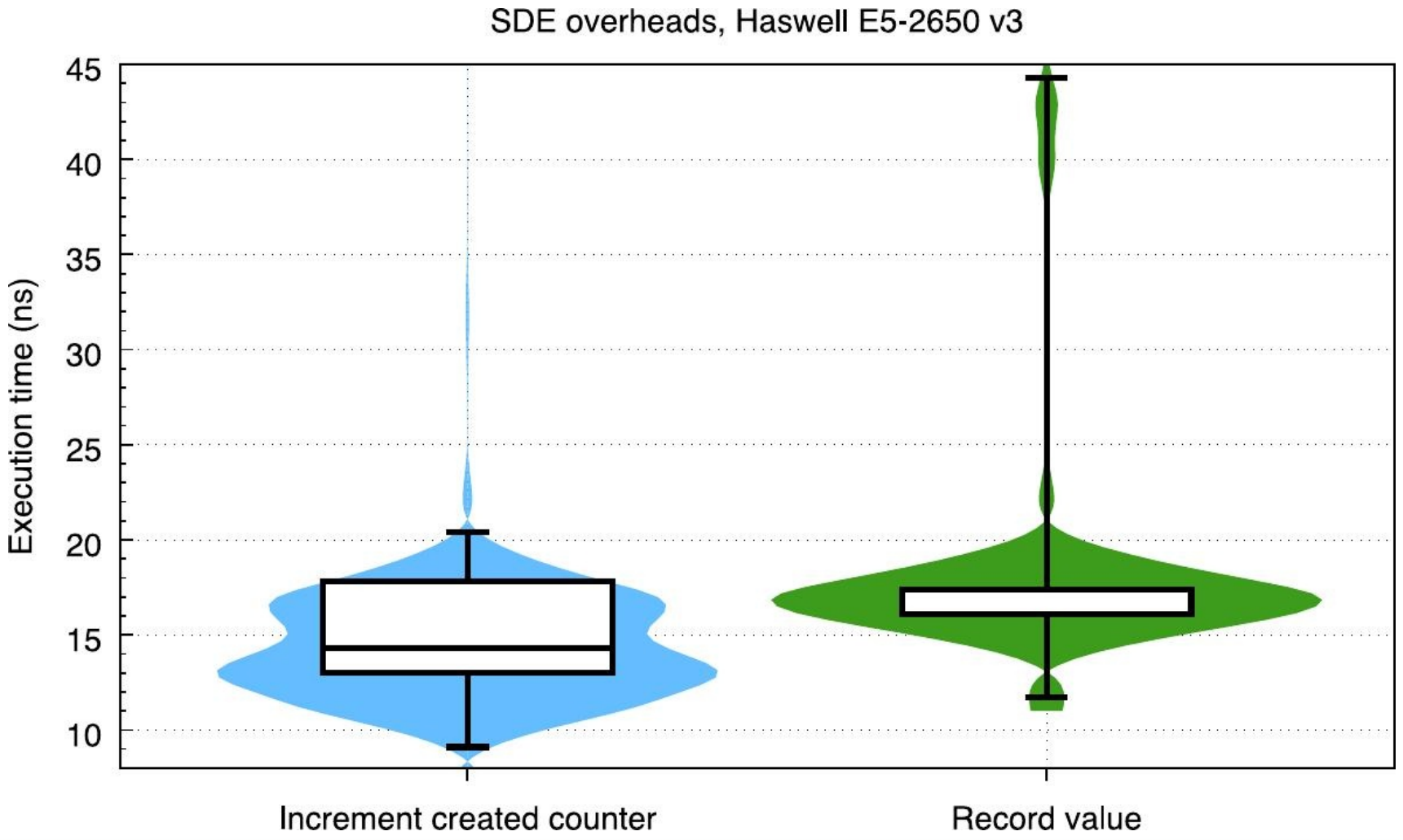
sde:::TEST::RCRDR:Q3

sde:::TEST::RCRDR:MAX

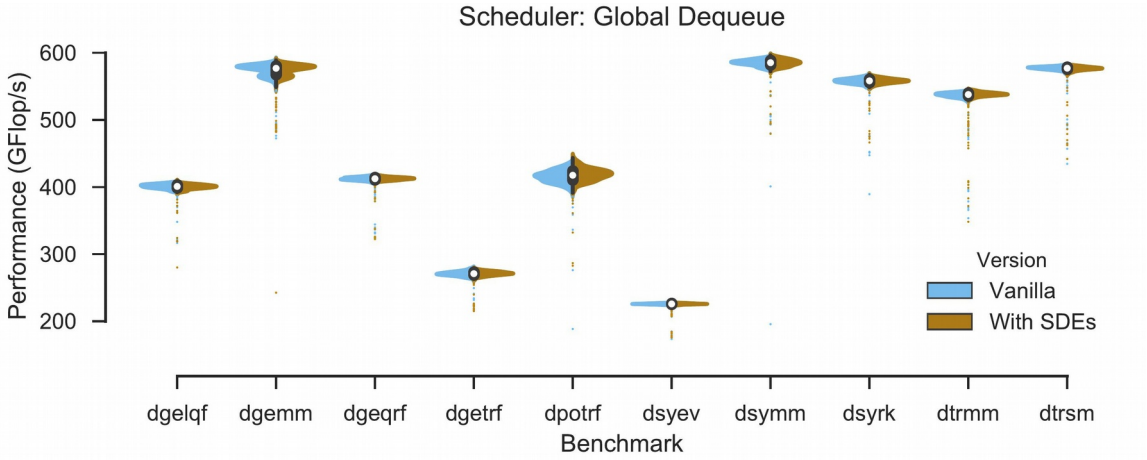
SDE code for updating created counters/recorders

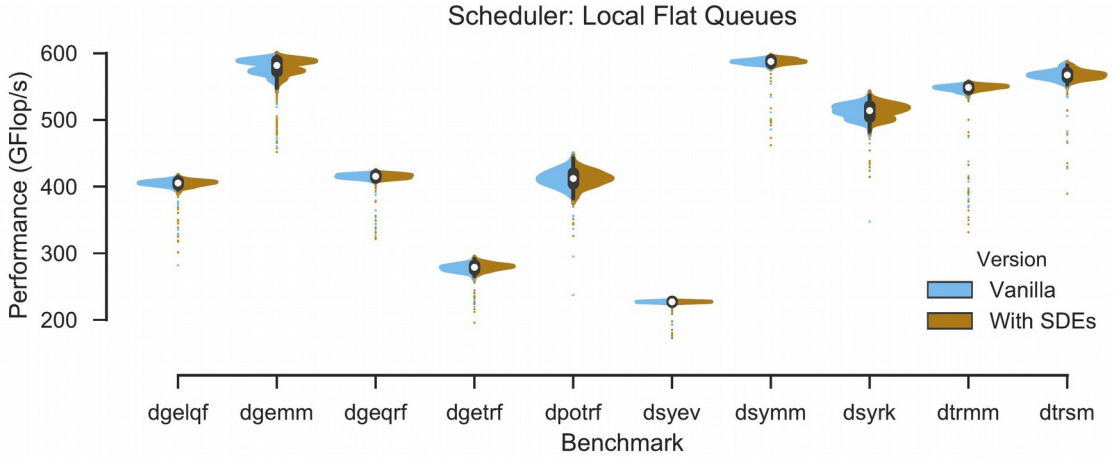
```
void *counter_handle;
void *recorder_handle;

void push_test_dowork(void){
    double val;
    long long increment = 3;

    val = perform_useful_work();
    papi_sde_inc_counter(counter_handle, increment);
    papi_sde_record(recorder_handle, sizeof(val), &val);
}
```

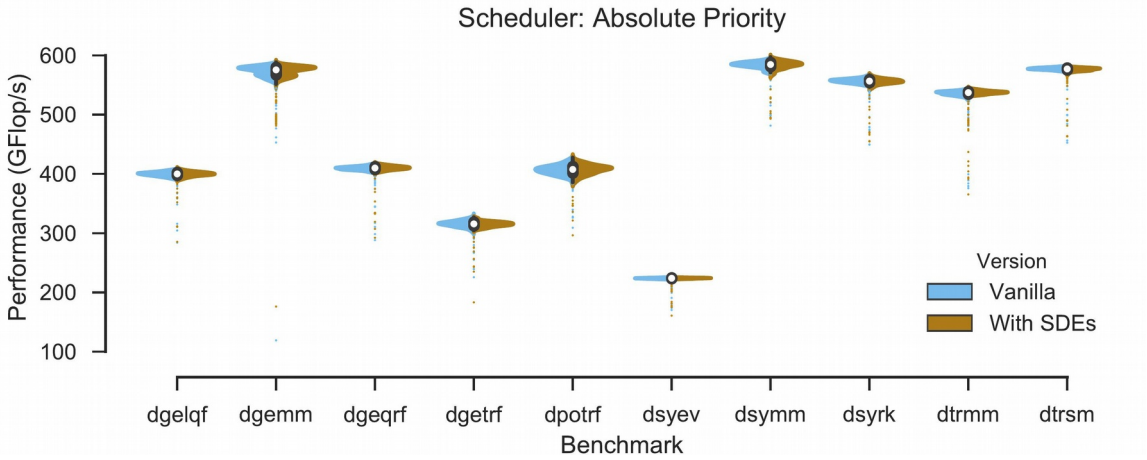
Performance overheads in simple benchmark

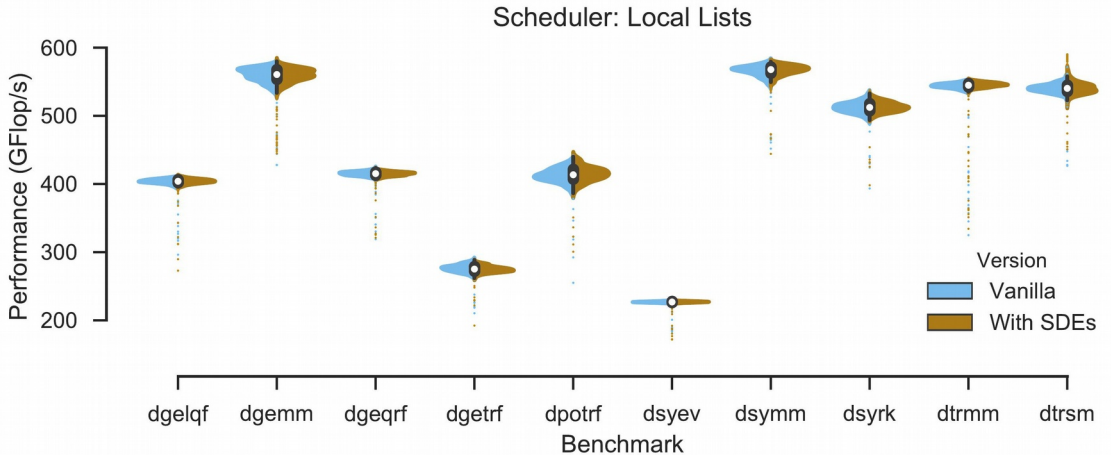


Performance overhead in PaRSEC

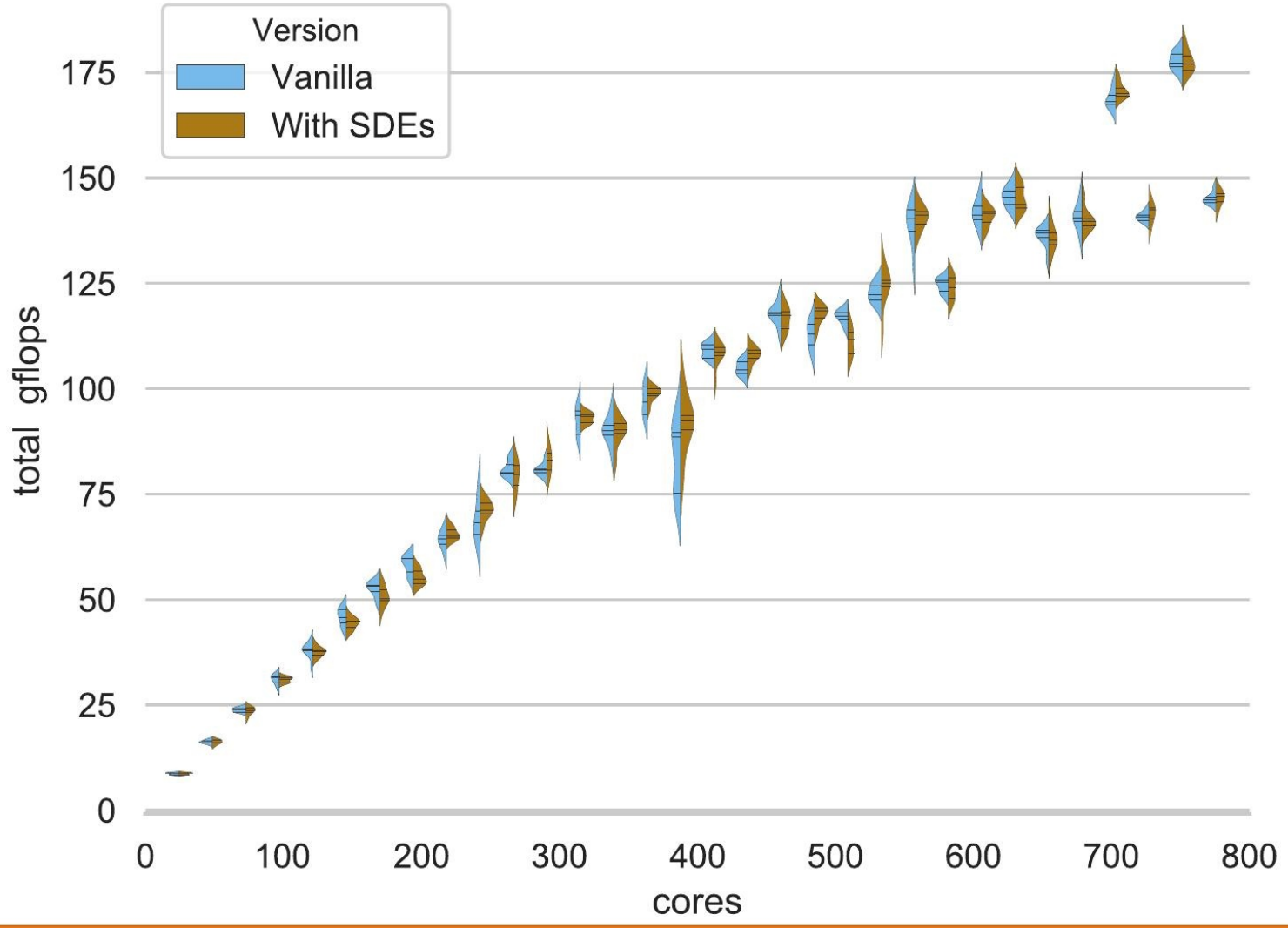




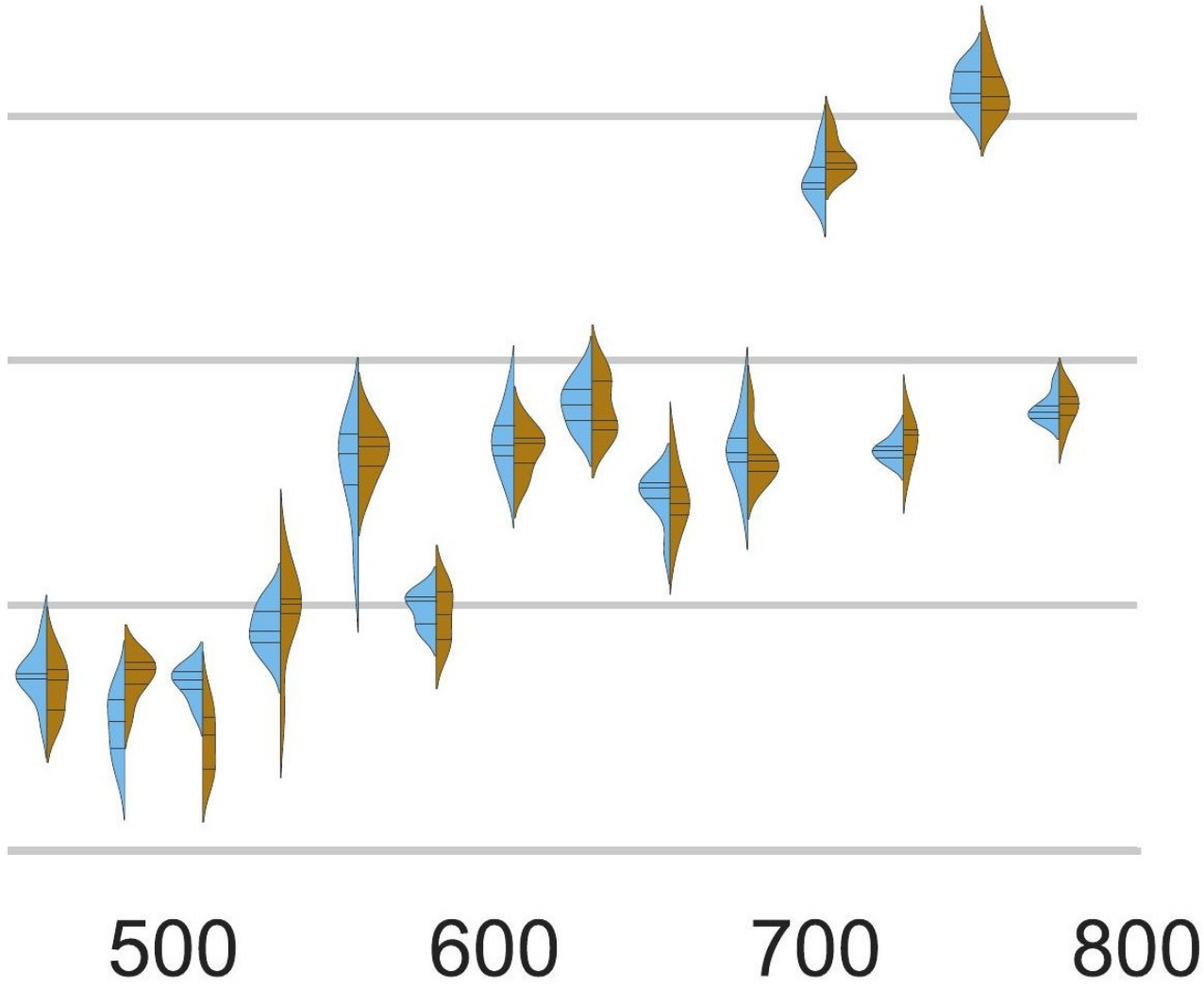




Performance overhead in HPCG



Performance overhead in HPCG (zoom)



Open Problem for our Community:

How do we associate useful context information with SDEs?

What meaningful information to associate with “TASKS_STOLEN”?

- ~~Code location~~
- Hardware events (e.g. cache misses)
- Patterns in history (e.g. last task before stealing event)
- Patterns in call-path/stack/originating thread

Conclusions

- Libraries/runtimes generate multiple useful software “events”.
- PAPI SDE allows any software layer to export events.
- SDEs can be read using the standard PAPI functionality.
- SDEs have minimal to **zero** performance overhead.
- SDEs might require different types of analysis by tools.