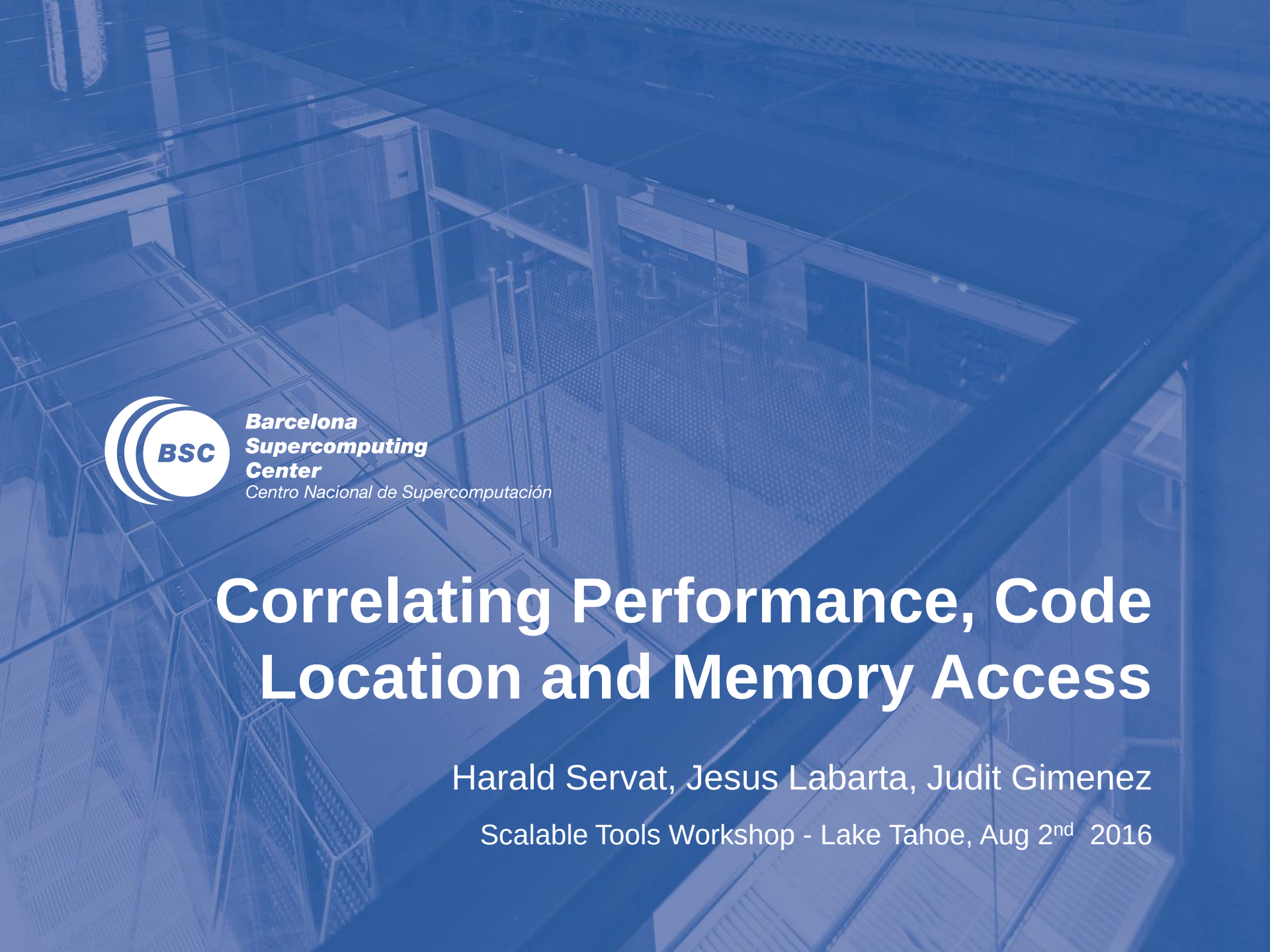


Barcelona Supercomputing Center
Centro Nacional de Supercomputación

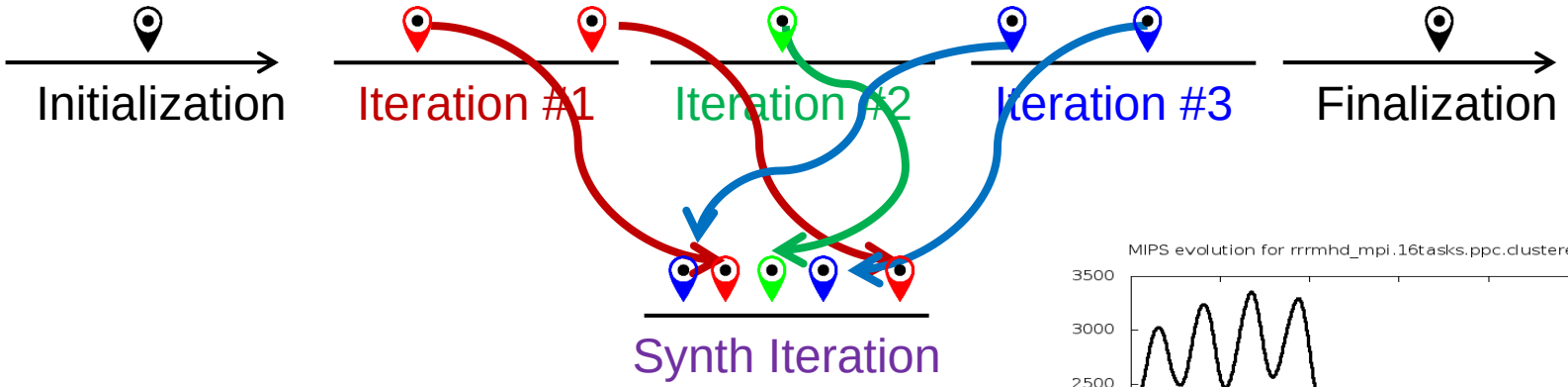
Correlating Performance, Code Location and Memory Access

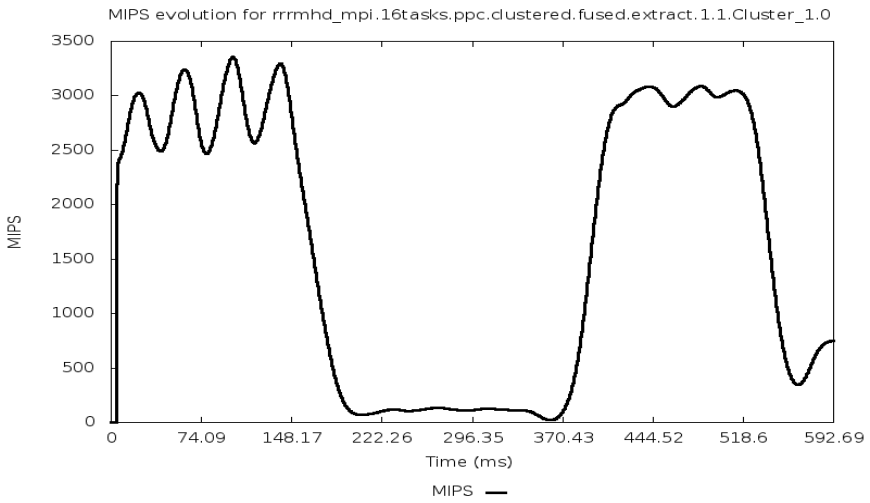
Harald Servat, Jesus Labarta, Judit Gimenez

Scalable Tools Workshop - Lake Tahoe, Aug 2nd 2016

Folding: instantaneous metric with minimum overhead

- Combine instrumentation and sampling
  - Instrumentation delimits regions (routines, loops, …)
  - Sampling exposes progression within a region
- Capture performance counters and call-stack references

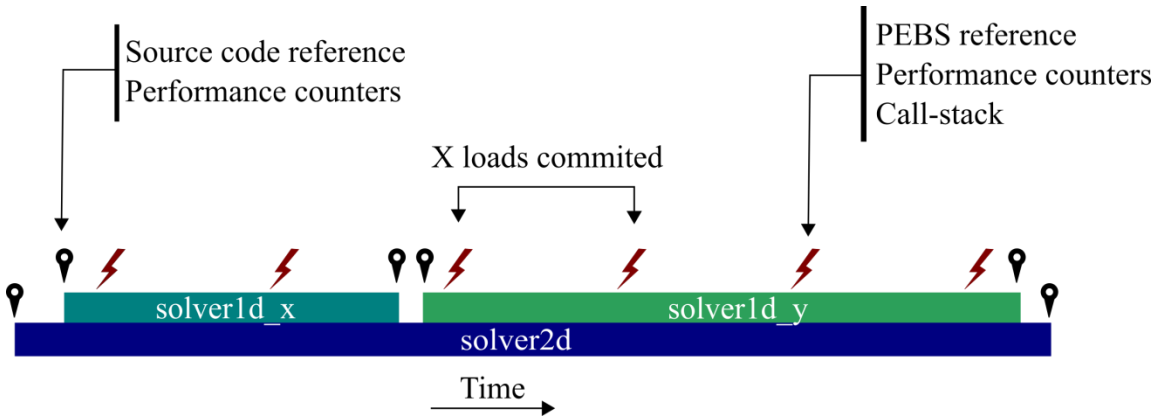




Adding PEBS to Paraver traces

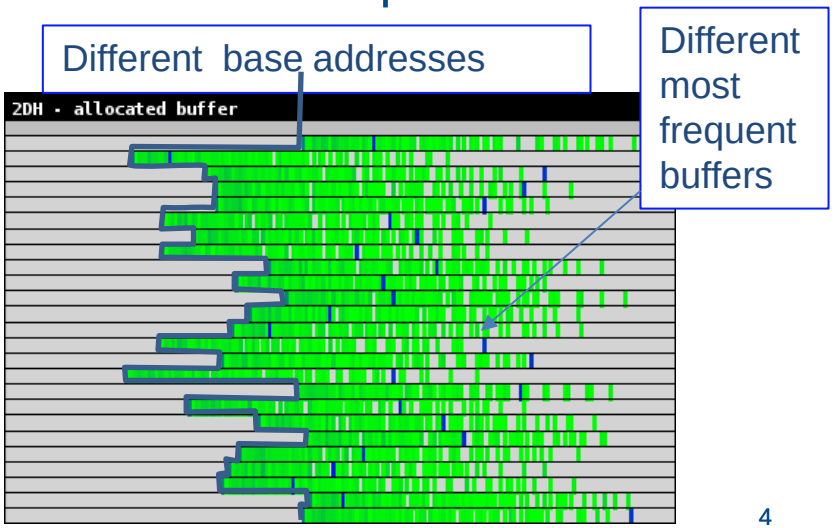
Memory related data in the trace

- PEBS events
  - Loads: address, cost in cycles, level providing the data
  - Stores: only address
  - Sampling frequency:
    - Possibly different rate for both loads and stores
    - One entry PEBS buffer. Signal Extrae on individual event.
  - Multiplexing: alternate periods sampling loads and stores



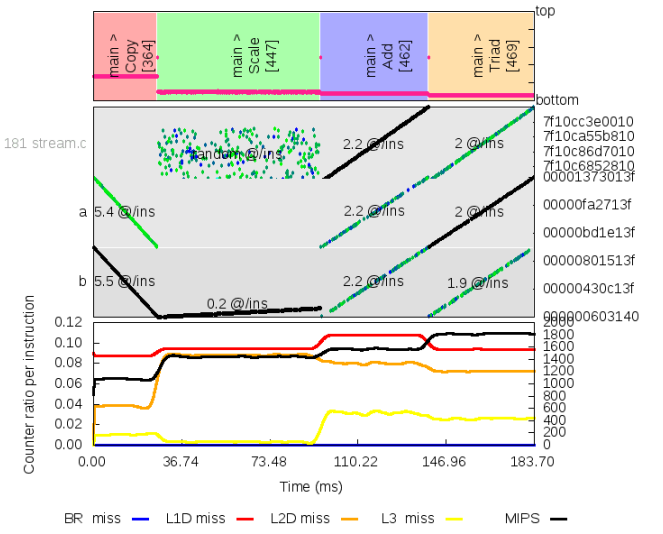
Memory object references

- Memory related data in the trace
  - Interception of mallocs and frees
    - Emit object id/call stack
    - With threshold on allocated size (potential unresolved objects)
  - Identification of memory object on sampled references
    - Static object from symbol table → Identify variable name
    - Dynamic objects from instantaneous memory map → Identify malloc where object was allocated
- Observation
  - Same source code → different per process address space
    - Randomization Linux security
- Insight
  - Folding should be applied on a per process basis



Analytics

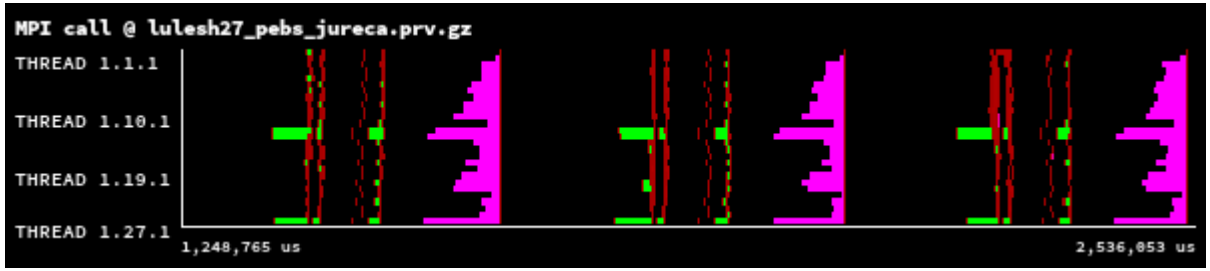
- Identification of coarse grain repetitive structure (prerequisite)
  - Computation bursts
    - Between calls to the runtime (MPI, OpenMP)
    - Clustering
  - Iteration (longer intervals with runtime calls)
    - Manually:
      - Extrae_event API call
      - Paraver analysis
    - Automatic: Using spectral analysis (WIP)
    - Clustering
      - Isolate different modes, eliminate outliers



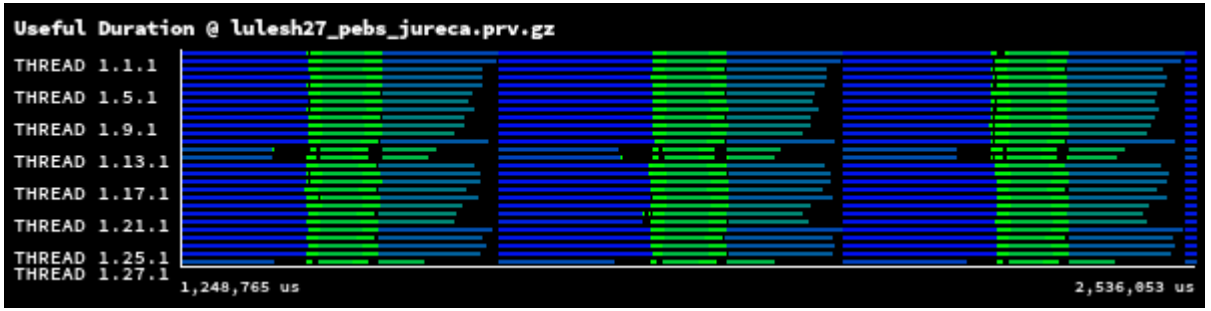
- Folding generates:
  - Gnuplot
  - Paraver trace
    - **All** PEBS related events are projected and **ordered** into a representative instance of the repetitive region
    - The same Paraver configuration files can be applied

Looking at Lulesh: 1. Performance

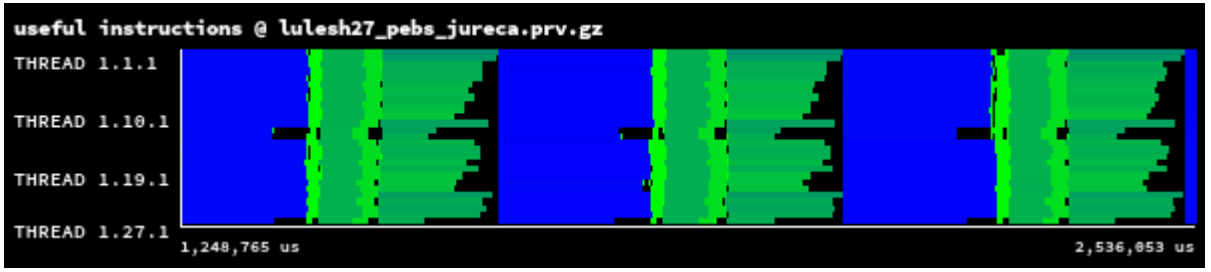
27 MPI ranks in 2 nodes (2 sockets x 12 cores each node)



MPI calls



Useful duration

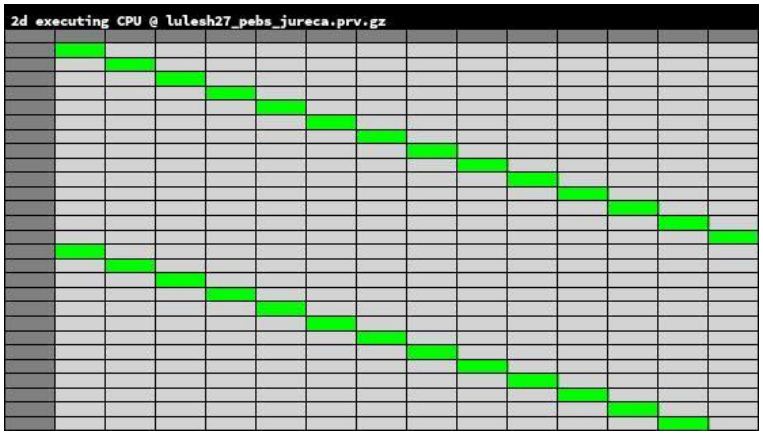


Useful instructions

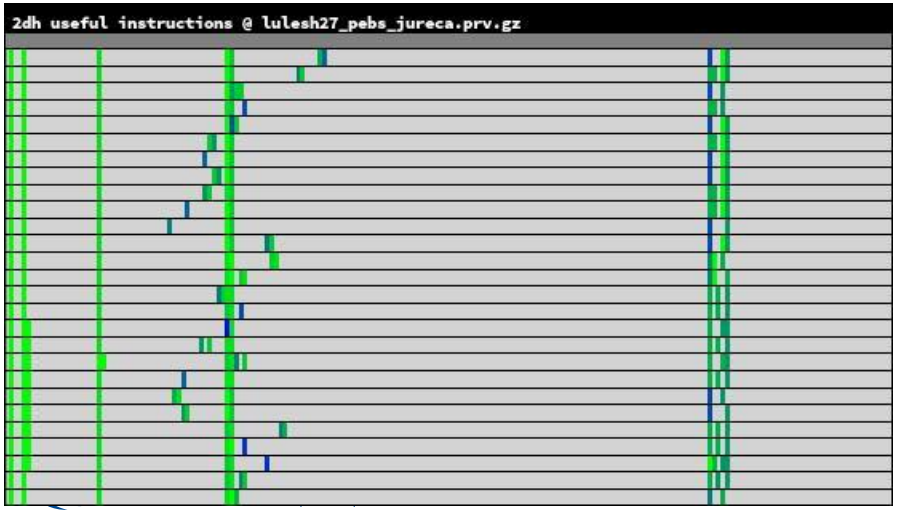
Looking at Lulesh: 1. Performance

Histogram useful duration

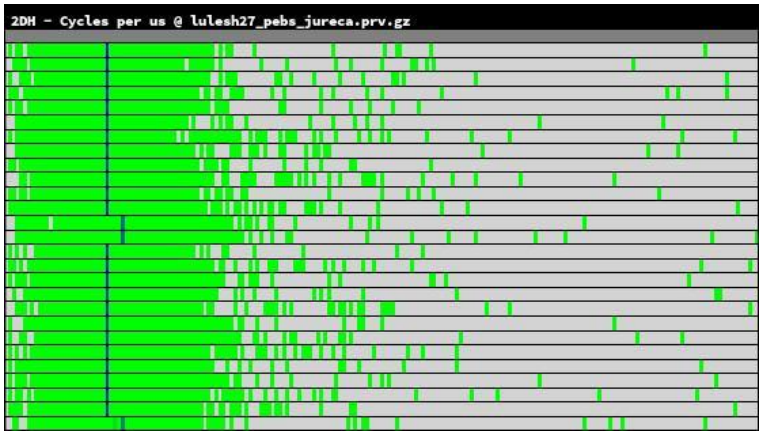
Process mapping



Histogram useful instructions

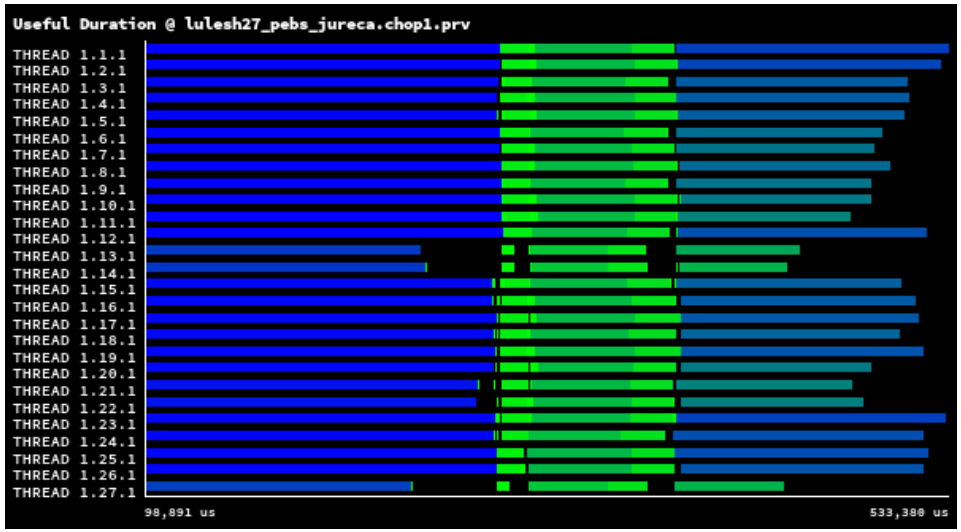


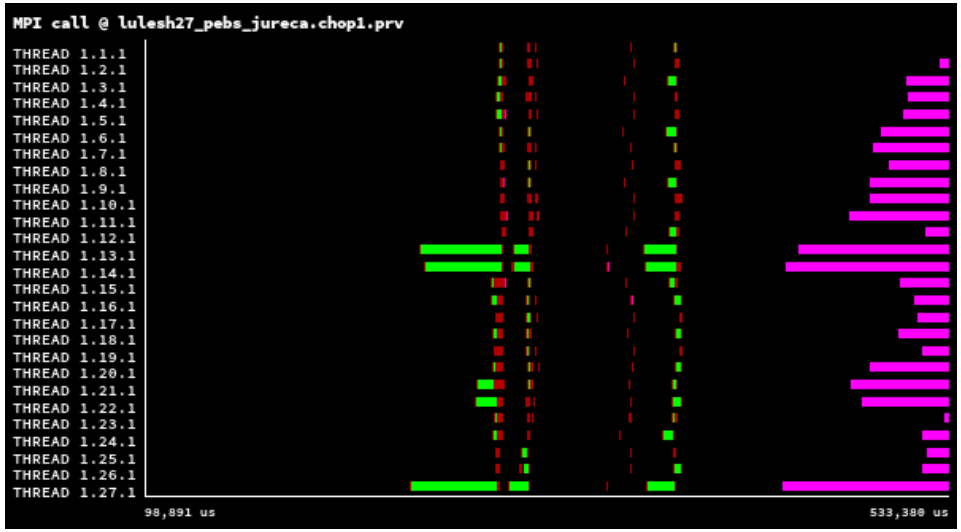
Histogram clock frequency



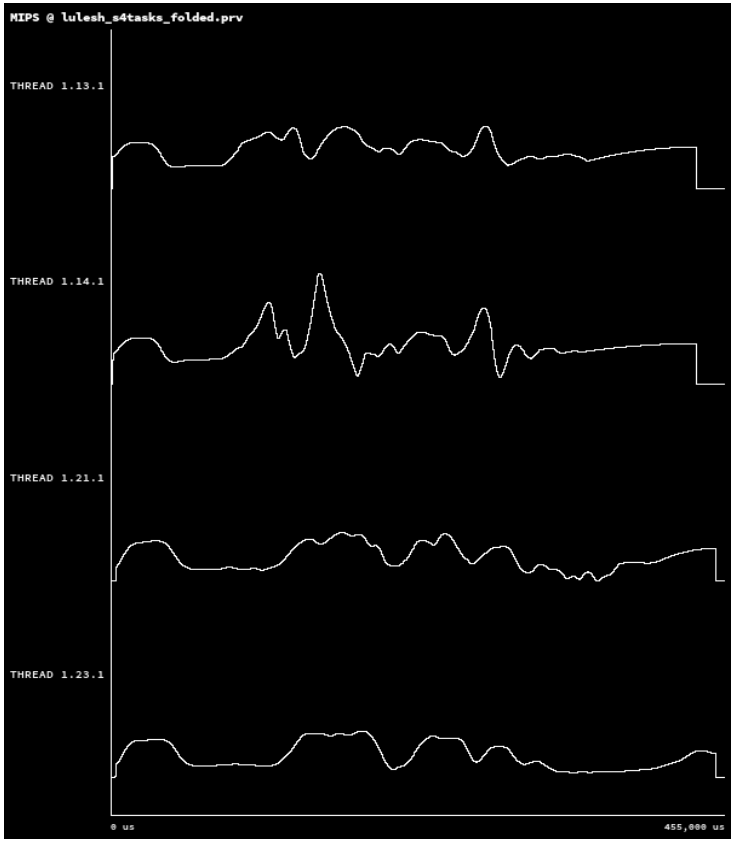
Looking at Lulesh: 1. Performance

One iteration



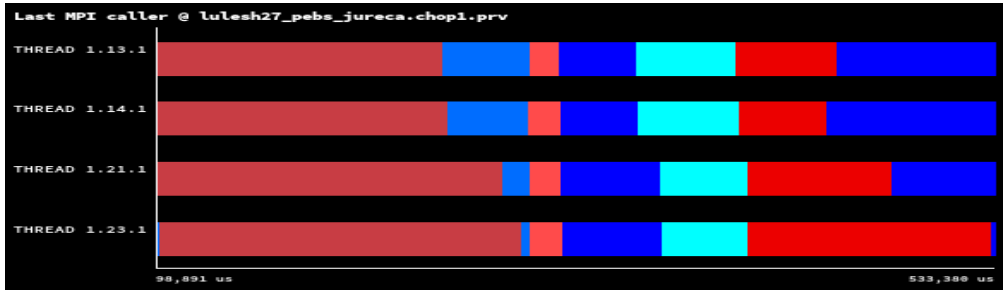


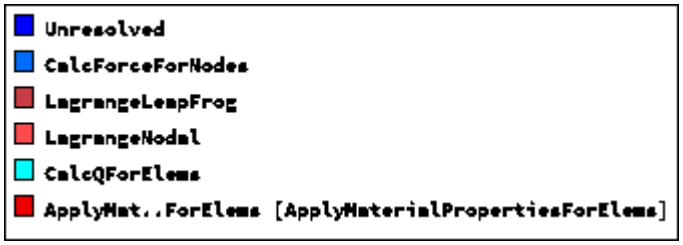
4 tasks selected



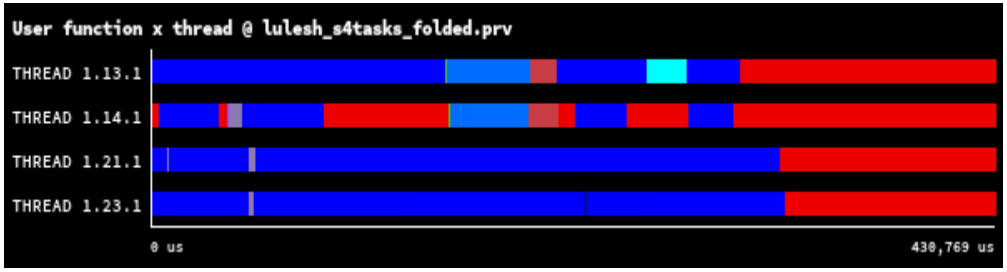
Looking at Lulesh: 2. Code location

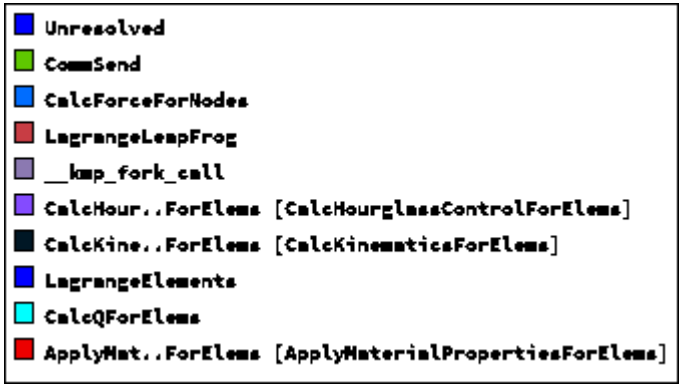
Approximation based on call stack @ MPI calls

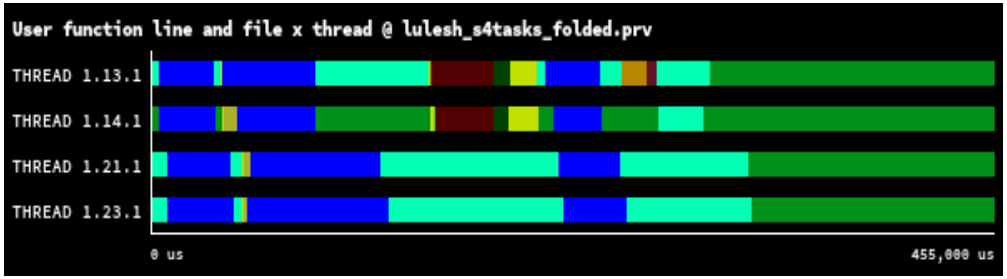


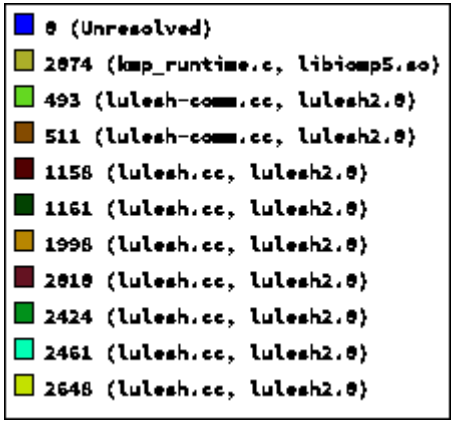


Approximation based on folded call stack



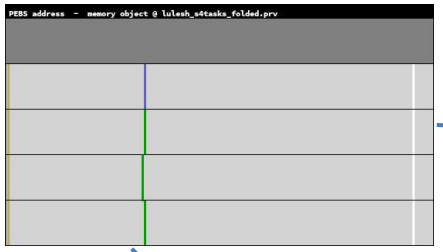


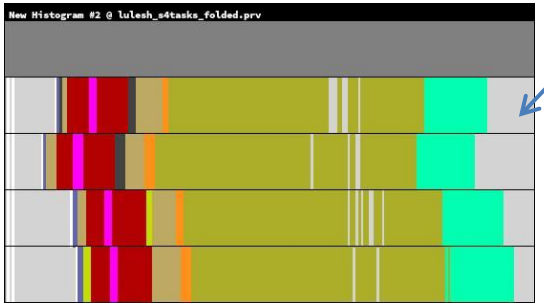


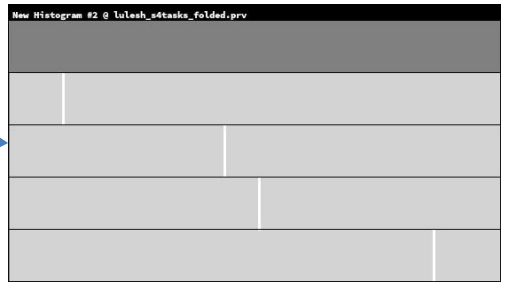


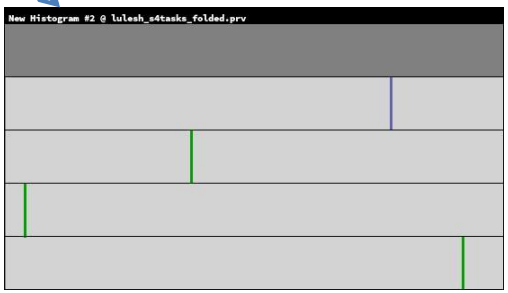
Looking at Lulesh: 3. Memory access

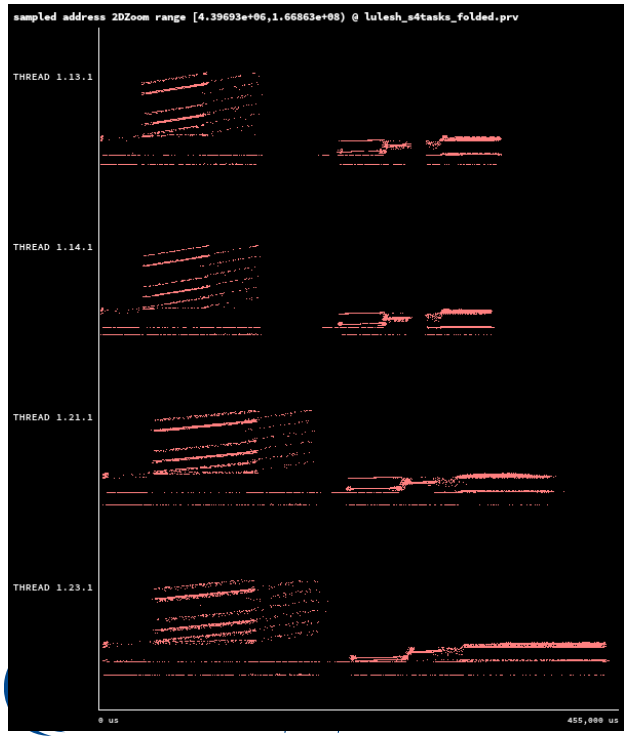
PEBS address

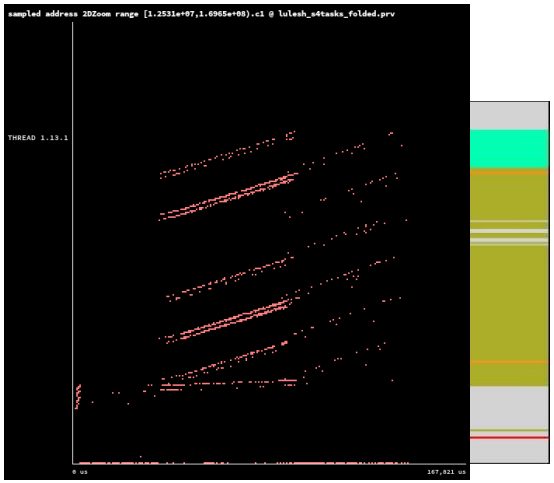


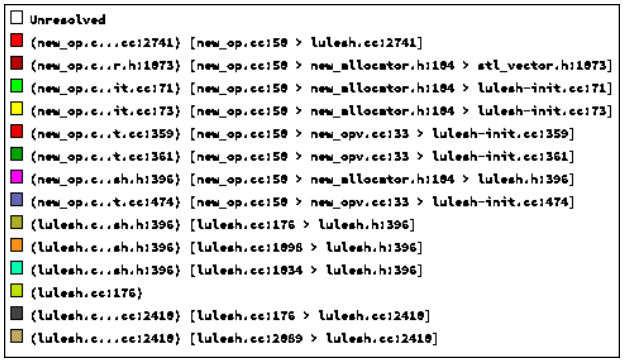


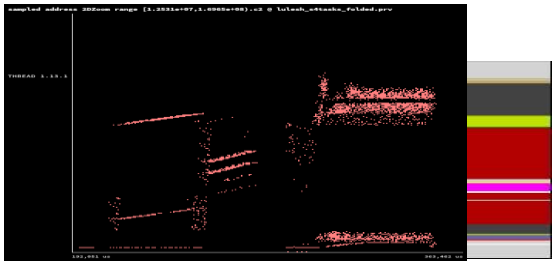






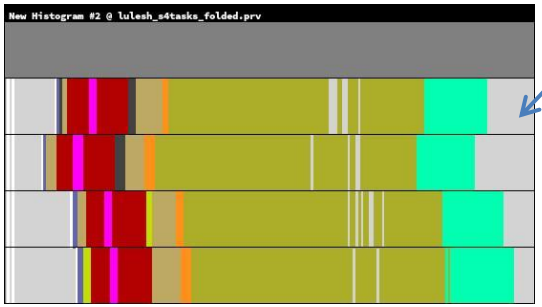


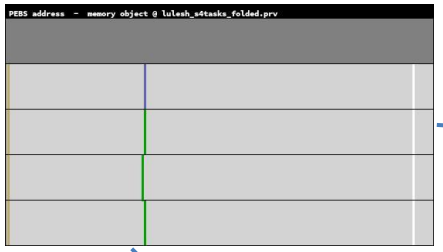


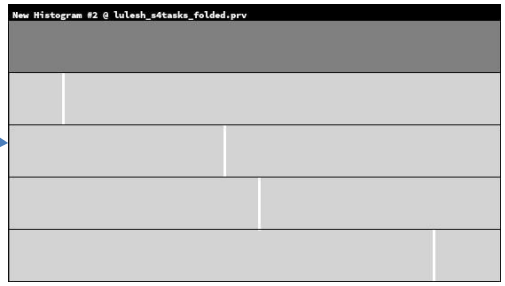


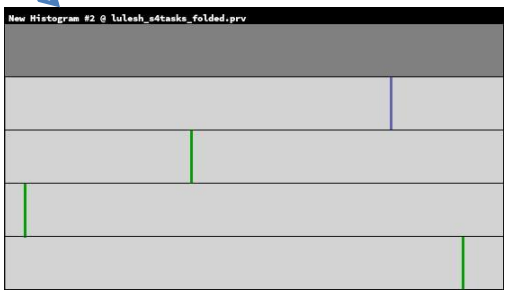
Looking at Lulesh: 3. Memory access

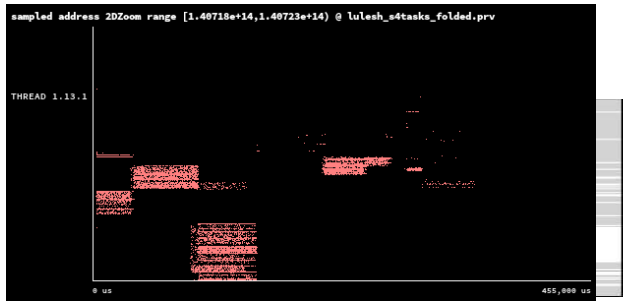
PEBS address

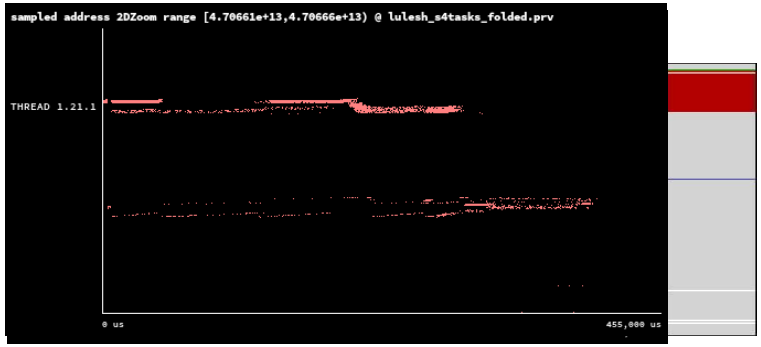






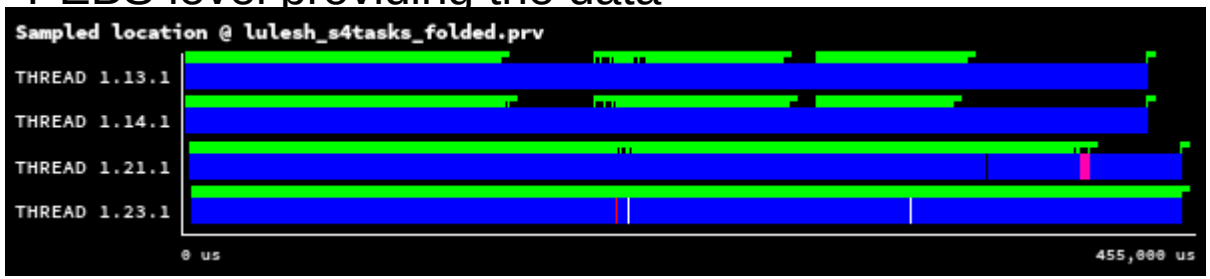


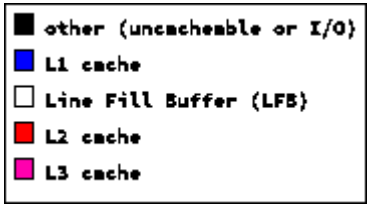




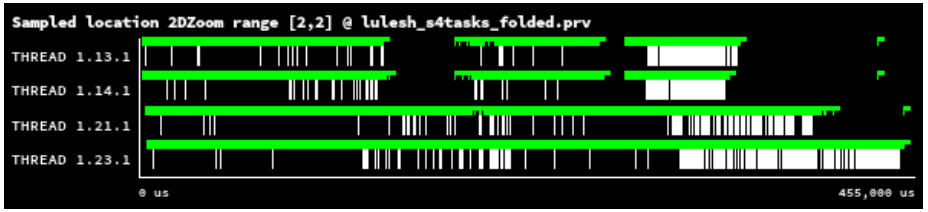
Looking at Lulesh: 3. Memory access

PEBS level providing the data





LFB



L2

L3

DRAM

New Histogram #1 @ lulesh_s4tasks_folded.prv <2>

	L1 cache	Line Fill Buffer (LFB)	L2 cache	L3 cache	DRAM (local)
THREAD 1.13.1	6,487	160	42	11	7
THREAD 1.14.1	7,580	172	58	12	11
THREAD 1.21.1	6,860	131	27	12	9
THREAD 1.23.1	9,523	359	60	23	14
Total	30,450	822	187	58	41
Average	7,612.500000	205.500000	46.750000	14.500000	10.250000
Maximum	9,523	359	60	23	14
Minimum	6,487	131	27	11	7
StDev	1,170.904885	89.867959	13.367404	4.924429	2.586020
Avg/Max	0.799380	0.572423	0.779167	0.630435	0.732143

L2 cache

Looking at Lulesh: 3. Memory access

PEBS cost in cycles (avg.)

New Histogram #3 @ lulesh_s4tasks_folded.prv

	L1 cache	Line Fill Buffer (LFB)	L2 cache	L3 cache	DRAM (local)
THREAD 1.13.1	7.951	40.089	18.649	62.559	129.148
THREAD 1.14.1	7.667	42.436	18.486	72.550	80.468
THREAD 1.21.1	7.769	84.112	16.750	567.189	487.700
THREAD 1.23.1	8.604	109.264	20.556	78.679	371.227
Total	31.992	275.901	74.441	780.977	1,068.542
Average	7.998	68.975	18.610	195.244	267.136
Maximum	8.604	109.264	20.556	567.189	487.700
Minimum	7.667	40.089	16.750	62.559	80.468
StDev	0.365	29.116	1.348	214.819	168.352
Avg/Max	0.930	0.631	0.905	0.344	0.548

New Histogram #1 @ lulesh_s4tasks_folded.prv <2>

	THREAD 1.13.1	THREAD 1.14.1	THREAD 1.21.1	THREAD 1.23.1
Unresolved	8.421	7.894	8.563	8.329
(new_op.c...cc:2741) [new_op.cc:50 > lulesh.cc:2741]	7.286	7.550	9.791	9.199
(new_op.c..it.cc:68) [new_op.cc:50 > new_opv.cc:33 > lulesh-init.cc:68]	-	-	-	-
(new_op.c..r.h:1073) [new_op.cc:50 > new_allocator.h:104 > stl_vector.h:1073]	8.319	8.564	49.044	19.812
(new_op.c..it.cc:71) [new_op.cc:50 > new_allocator.h:104 > lulesh-init.cc:71]	7	8.998	256.564	7
(new_op.c..it.cc:73) [new_op.cc:50 > new_allocator.h:104 > lulesh-init.cc:73]	21.294	20.568	14.157	19.357
(new_op.c..t.cc:359) [new_op.cc:50 > new_opv.cc:33 > lulesh-init.cc:359]	7.113	7.285	71.140	13.900
(new_op.c..t.cc:361) [new_op.cc:50 > new_opv.cc:33 > lulesh-init.cc:361]	7.243	7.008	11.449	184.014
(new_op.c..sh.h:396) [new_op.cc:50 > new_allocator.h:104 > lulesh.h:396]	7.625	9.455	63.011	8.497
(new_op.c..t.cc:474) [new_op.cc:50 > new_opv.cc:33 > lulesh-init.cc:474]	7.343	7.179	7.001	9.081
(lulesh.c..sh.h:396) [lulesh.cc:176 > lulesh.h:396]	8.758	7.247	7.185	7.252
(lulesh.c..sh.h:396) [lulesh.cc:1098 > lulesh.h:396]	8.828	7.312	7.197	7.214
(lulesh.c..sh.h:396) [lulesh.cc:1034 > lulesh.h:396]	8.366	8.979	7.484	7.165
(lulesh.cc:176)	13.970	13.416	23.714	72.325
(lulesh.c...cc:2410) [lulesh.cc:176 > lulesh.cc:2410]	11.432	12.959	19.289	25.314
(lulesh.c...cc:2410) [lulesh.cc:2089 > lulesh.cc:2410]	9.542	11.208	21.497	19.731
Total	142.541	145.623	577.086	418.192
Average	9.503	9.708	38.472	27.879
Maximum	21.294	20.568	256.564	184.014
Minimum	7	7.008	7.001	7
StDev	3.631	3.523	61.734	44.675
Avg/Max	0.446	0.472	0.150	0.152

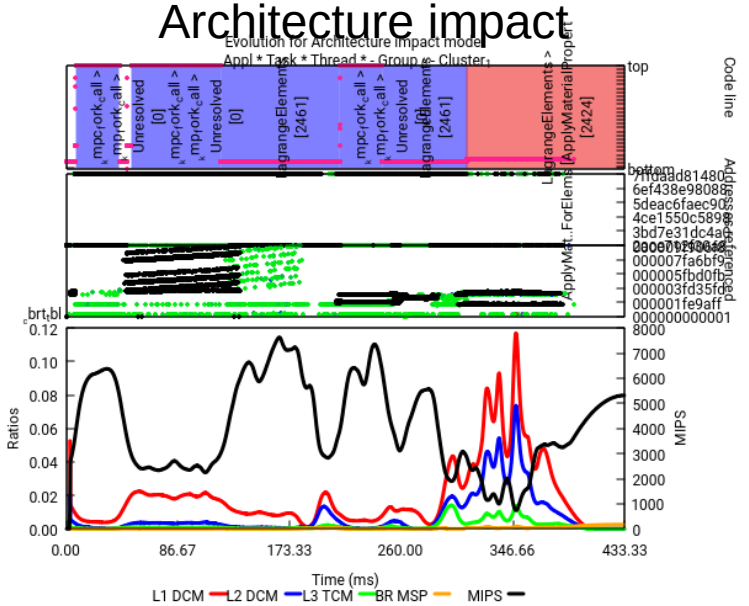
Unresolved

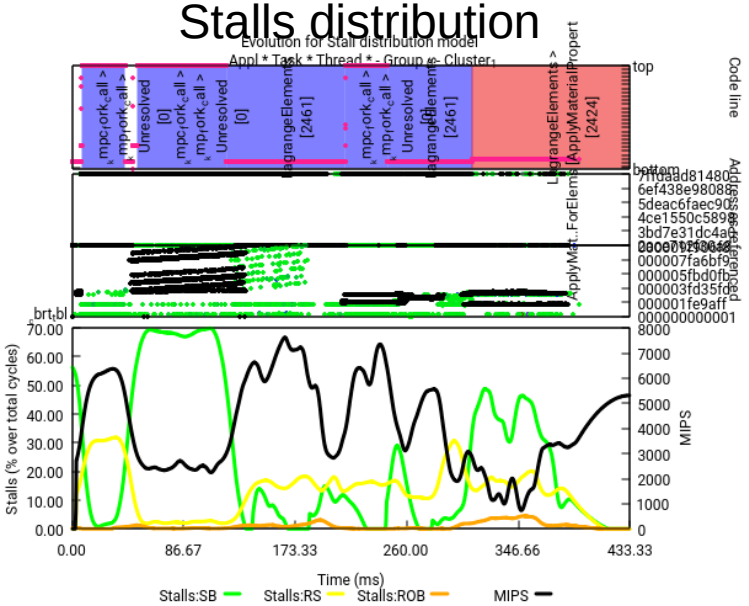
Looking at Lulesh: Comparing gnuplots

Architecture impact

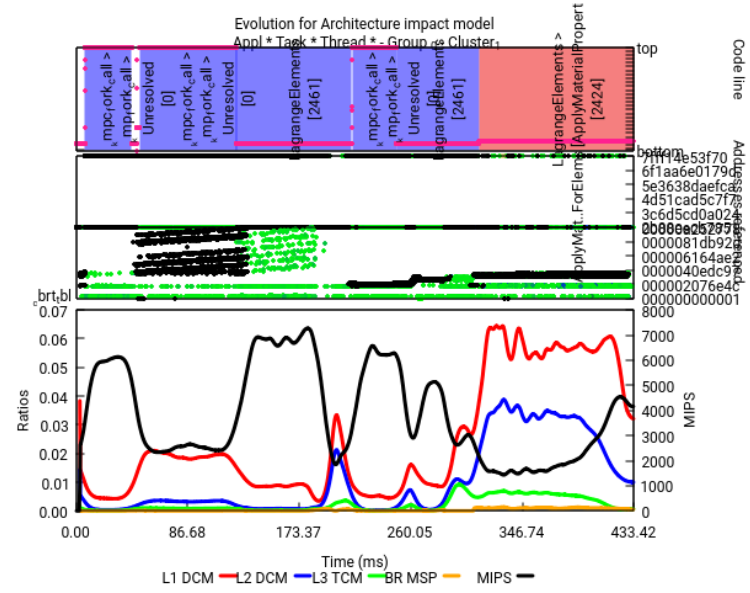
Stalls distribution

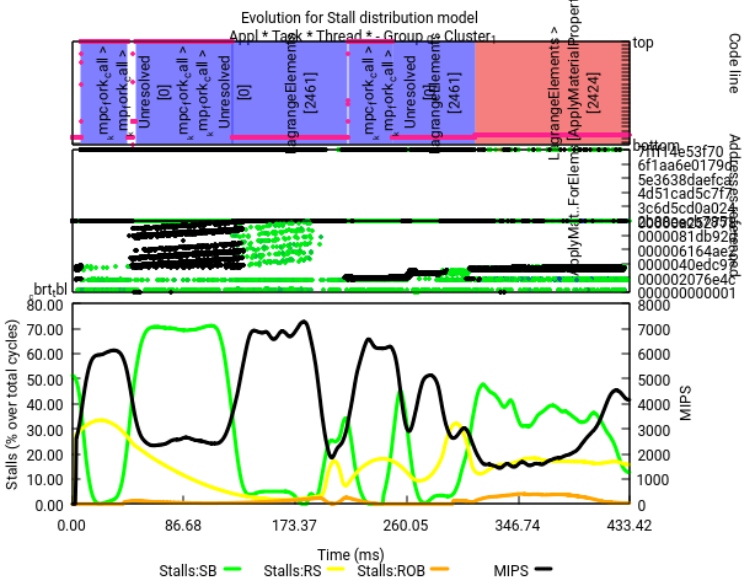
Task 21





Task 23





Conclusions

- Folding can provide low overhead detailed analysis on accesses to memory
  - Wide range of new metrics: access pattern, memory objects, memory level, cost in cycles,…
- Paraver provides huge flexibility combining and correlating the new data :)
  - Only required to implement new “paint as” punctual information
- How much far/close to reverse engineering?