```
 1:
 2:                             VPIC Benchmark Results
 3:                               LA-UR-18-29553
 4:
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 8:
 9: ################################################################################
10:
11: Notes:
12:
13: ################################################################################
14:
15: 1. Two problem sizes are used for these runs. One is a large memory problem that uses over 90 GiB of memory
16: and is thus too large to fit in the HBM of a KNL node. The other is a small memory problem that uses just
17: under 16 GiB of memory and is thus small enough for the problem to fit totally within the 16 GiB of HBM on
18: a KNL node.
19:
20: 2. Abbreviations used:
21:
22:    pth  = pthreads
23:    rpc  = ranks/core
24:    tpp  = threads/process
25:    v_01 = non-vectorized version of VPIC kernels
26:    v_04 = vectorized version, via intrinsics, of VPIC kernels with SIMD vector length of 4
27:    v_08 = vectorized version, via intrinsics, of VPIC kernels with SIMD vector length of 8
28:    v_16 = vectorized version, via intrinsics, of VPIC kernels with SIMD vector length of 16
29:
30: 3. On KNL nodes, numactl is used with either the "--preferred=?" or "--membind=?" options to target the
31: desired memory type for the run.
32:
33: 4. These runs are preliminary and should not be assumed to represent optimal performance of the different
34: node types.
35:
36: 5. Results for ARM nodes use the non-vectorized v_01 version of the VPIC kernels. A v_04 implementation
37: using ARM Neon intrinsics is planned. Best results on ARM generally require use of all the hardware threads.
38:
39: 6. Benchmark runs with more compiler types are planned for several node types i.e. IBM XL compilers with IBM
40: Power 9 nodes, AMD AOCC compilers with AMD Epyc nodes, ARM Clang compilers with ARM nodes.
41:
42: 7. Tables 1-6 provide a high level summary of the best results obtained.
43:
44: 8. Tables 7-10 provide maximum detail for the large memory problem as a function of machine node type, SIMD
45: vector length, number of hardware threads per core used and programming model i.e. mpi only or mpi + pthreads.
46: For each node type and SIMD vector length, results in the top half are for mpi only and results in the bottom
47: half are for mpi + pthreads. Number of hardware threads used doubles with each entry going down in the data
48: for a machine node type.
49:
50: 9. Tables 11-14 provide maximum detail for the small memory problem as described in item 8 above.
51:
52: 10. The VPIC problem used was for an LPI particle dominated deck with periodic boundary conditions, an electron
53: species and two ion species and about 1000 particles per cell. The problem was run for 1000 time steps with
54: electrons being sorted every 25 time steps and ions every 100 time steps. The mesh was designed so the same
55: problem could be run on each of the node types. The thread serial, legacy particle sort from the v407 version
56: of VPIC was used for particle sorting. The input deck avoids using diagnostics, I/O and other thread serial
57: functions such as accumulate_rho_p.
58:
59: 11. These were all single node runs.
60:
61: 12. The number of particles per species is as follows:
62:
63:     Large DDR Problem =  900 particles/cell * 272 * 80 * 56 cells = 1,096,704,000 particles/species
64:
65:     Small HBM Problem = 1024 particles/cell * 136 * 40 * 28 cells =   155,975,680 particles/species
66:
67: 13. Using the results of items 10-12, the particle push rate for the large DDR problem is about 3.351 billion
68: particles/second/node. For the small HBM problem, the particle push rate is about 3.371 billion particles/
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 69: second/node.
 70:
 71: 14. Using Intel APS to profile a run on the Intel Skylake Platinum nodes on Darwin gives a result of
 72: about 600 GF/s SP out of a theoretical peak of about 6800 GF/s. The memory bandwidth consumed is about
 73: 190 GB/s out of a theoretical peak of 256 GB/s.
 74:
 75: 15. Results from Darwin ARM nodes were collected using pre-production hardware and pre-production software.
 76: Additionally, results from Darwin ARM nodes should be compared against results from other architectures in
 77: the v_01 column because a VPIC implementation using ARM Neon intrinsics has not yet been completed.
 78:
 79: ################################################################################################################
 80:
 81: Table 1: Best main cycle times for VPIC LPI v_04 large memory DDR problem.
 82:
 83: ################################################################################################################
 84:
 85: =================================================================================================================
 86: machine                 | Main Cycle Time |
 87:                         |    (seconds)    |
 88: =================================================================================================================
 89: darwin amd epyc 32      |      981.80     | intel 18.0.3, v_04, mpi only, 128 ranks, 2 rpc
 90: =================================================================================================================
 91: darwin intel skylake 28 |     1199.04     | intel 18.0.3, v_16, mpi only, 112 ranks, 2 rpc
 92: =================================================================================================================
 93: darwin ibm power9 20    |     1947.53     | gnu 8.2.0, v_04, mpi only, 160 ranks, 4 rpc
 94: =================================================================================================================
 95: tt intel haswell 16     |     2250.84     | intel 18.0.3, v_08, mpi only, 64 ranks, 2 rpc
 96: =================================================================================================================
 97: darwin intel haswell 16 |     2289.13     | intel 18.0.3, v_08, mpi only, 64 ranks, 2 rpc
 98: =================================================================================================================
 99: tt intel knl 68 qf hbm  |     2462.04     | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
100: =================================================================================================================
101: darwin intel knl 68 qf hbm |  2584.04     | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
102: =================================================================================================================
103: darwin intel knl 68 qf ddr |  2751.50     | intel 18.0.3, v_16, mpi only, 136 ranks, 2 rpc, prefer ddr
104: =================================================================================================================
105: darwin arm tx2 32 w/ 4 tpc |  3393.17     | gnu 8.2.0, v_01, mpi+pth, 64 ranks, 1 rpc, 4 tpp
106: =================================================================================================================
107: darwin arm tx2 32 w/ 2 tpc |  4239.03     | gnu 8.2.0, v_01, mpi only, 128 ranks, 2 rpc
108: =================================================================================================================
109:
110: ################################################################################################################
111:
112: Table 2: Best advance_p times for VPIC LPI v_04 large memory DDR problem.
113:
114: ################################################################################################################
115:
116: =================================================================================================================
117: machine                 | advance_p   |
118:                         | (seconds)   |
119: =================================================================================================================
120: darwin amd epyc 32      |    912.10   | intel 18.0.3, v_04, mpi only, 128 ranks, 2 rpc
121: =================================================================================================================
122: darwin intel skylake 28 |   1122.00   | intel 18.0.3, v_16, mpi only, 112 ranks, 2 rpc
123: =================================================================================================================
124: darwin ibm power9 20    |   1856.00   | gnu 8.2.0, v_04, mpi only, 160 ranks, 4 rpc
125: =================================================================================================================
126: tt intel knl 68 qf hbm  |   2019.00   | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
127: =================================================================================================================
128: tt intel haswell 16     |   2026.00   | intel 18.0.3, v_08, mpi only, 64 ranks, 2 rpc
129: =================================================================================================================
130: darwin intel haswell 16 |   2139.00   | intel 18.0.3, v_08, mpi+pth, 32 ranks, 1 rpc, 2 tpp
131: =================================================================================================================
132: darwin intel knl 68 qf hbm |  2195.00  | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 2 tpp, prefer hbm
133: =================================================================================================================
134: darwin intel knl 68 qf ddr |  2446.00  | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 2 tpp, prefer ddr
135: =================================================================================================================
136: darwin arm tx2 32 w/ 4 tpc |  3221.00  | gnu 8.2.0, v_01, mpi+pth, 64 ranks, 1 rpc, 4 tpp
```

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137: ======================================================================================================
138: darwin arm tx2 32 w/ 2 tpc |  4124.00  | gnu 8.2.0, v_01, mpi only, 128 ranks, 2 rpc
139: ======================================================================================================
140:
141: ######################################################################################################
142:
143: Table 3: Best uncenter_p times for VPIC LPI v_04 large memory DDR problem.
144:
145: ######################################################################################################
146:
147: ======================================================================================================
148: machine                 | uncenter_p |
149:                         | (seconds)  |
150: ======================================================================================================
151: darwin intel knl 68 qf hbm |  0.5408  | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
152: ======================================================================================================
153: darwin amd epyc 32      |  0.7722  | intel 18.0.3, v_08, mpi only, 64 ranks, 1 rpc
154: ======================================================================================================
155: darwin intel knl 68 qf ddr |  0.7748  | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer ddr
156: ======================================================================================================
157: tt intel knl 68 qf hbm  |  0.8188  | intel 18.0.3, v_08, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
158: ======================================================================================================
159: darwin intel skylake 28 |  0.8380  | intel 18.0.3, v_16, mpi+pth, 56 ranks, 1 rpc, 2 tpp
160: ======================================================================================================
161: darwin ibm power9 20    |  0.8989  | gnu 8.2.0, v_04, mpi only, 160 ranks, 4 rpc
162: ======================================================================================================
163: darwin intel haswell 16 |  0.9993  | intel 18.0.3, v_04, mpi+pth, 32 ranks, 1 rpc, 2 tpp
164: ======================================================================================================
165: tt intel haswell 16     |  1.0930  | intel 18.0.3, v_08, mpi+pth, 32 ranks, 1 rpc, 1 tpp
166: ======================================================================================================
167: darwin arm tx2 32 w/ 4 tpc |  1.3590  | gnu 8.2.0, v_01, mpi+pth, 64 ranks, 1 rpc, 4 tpp
168: ======================================================================================================
169: darwin arm tx2 32 w/ 2 tpc |  1.4320  | gnu 8.2.0, v_01, mpi only, 128 ranks, 2 rpc
170: ======================================================================================================
171:
172: ######################################################################################################
173:
174: Table 4: Best main cycle times for VPIC LPI v_04 small memory HBM problem.
175:
176: ######################################################################################################
177:
178: ======================================================================================================
179: machine                 | Main Cycle Time |
180:                         |    (seconds)    |
181: ======================================================================================================
182: darwin amd epyc 32      |     138.793     | intel 18.0.3, v_04, mpi only, 128 ranks, 2 rpc
183: ======================================================================================================
184: darwin intel skylake 28 |     170.030     | intel 18.0.3, v_08, mpi only, 112 ranks, 2 rpc
185: ======================================================================================================
186: tt intel knl 68 qf hbm  |     198.517     | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
187: ======================================================================================================
188: darwin intel knl 68 qf hbm |     218.339     | intel 18.0.3, v_16, mpi only, 68 ranks, 4 rpc, prefer hbm
189: ======================================================================================================
190: darwin ibm power9 20    |     277.281     | gnu 8.2.0, v_04, mpi only, 160 ranks, 4 rpc
191: ======================================================================================================
192: tt intel haswell 16     |     304.966     | intel 18.0.3, v_08, mpi only, 64 ranks, 2 rpc
193: ======================================================================================================
194: darwin intel haswell 16 |     319.394     | intel 18.0.3, v_08, mpi only, 64 ranks, 2 rpc
195: ======================================================================================================
196: darwin intel knl 68 qf ddr |     402.685     | intel 18.0.3, v_16, mpi only, 68 ranks, 1 rpc, prefer ddr
197: ======================================================================================================
198: darwin arm tx2 32 w/ 4 tpc |     471.634     | gnu 8.2.0, v_01, mpi+pth, 64 ranks, 1 rpc, 4 tpp
199: ======================================================================================================
200: darwin arm tx2 32 w/ 2 tpc |     603.862     | gnu 8.2.0, v_01, mpi+pth only, 64 ranks, 1 rpc, 2 tpp
201: ======================================================================================================
202:
203: ######################################################################################################
204:
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205: Table 5: Best advance_p times for VPIC LPI v_04 small memory HBM problem.
206:
207: #################################################################################################
208:
209: ===============================================================================================
210: machine                 | advance_p |
211:                         | (seconds) |
212: ===============================================================================================
213: darwin amd epyc 32      |   130.2   | intel 18.0.3, v_04, mpi only, 128 ranks, 2 rpc
214: ===============================================================================================
215: darwin intel skylake 28 |   160.3   | intel 18.0.3, v_16, mpi+pth, 56 ranks, 1 rpc, 2 tpp
216: ===============================================================================================
217: tt intel knl 68 qf hbm  |   173.8   | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
218: ===============================================================================================
219: darwin intel knl 68 qf hbm |  193.9 | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
220: ===============================================================================================
221: darwin ibm power9 20    |   265.0   | gnu 8.2.0, v_04, mpi only, 160 ranks, 4 rpc
222: ===============================================================================================
223: tt intel haswell 16     |   289.2   | intel 18.0.3, v_08, mpi only, 64 ranks, 2 rpc
224: ===============================================================================================
225: darwin intel haswell 16 |   305.0   | intel 18.0.3, v_08, mpi+pth, 32 ranks, 1 rpc, 2 tpp
226: ===============================================================================================
227: darwin intel knl 68 qf ddr |  366.8 | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 2 tpp, prefer ddr
228: ===============================================================================================
229: darwin arm tx2 32 w/ 4 tpc |  450.3 | gnu 8.2.0, v_01, mpi only, 256 ranks, 4 rpc
230: ===============================================================================================
231: darwin arm tx2 32 w/ 2 tpc |  586.6 | gnu 8.2.0, v_01, mpi+pth, 64 ranks, 1 rpc, 2 tpp
232: ===============================================================================================
233:
234: #################################################################################################
235:
236: Table 6: Best uncenter_p times for VPIC LPI v_04 small memory HBM problem.
237:
238: #################################################################################################
239:
240: ===============================================================================================
241: machine                 | uncenter_p |
242:                         | (seconds)  |
243: ===============================================================================================
244: darwin amd epyc 32      |   0.0788   | intel 18.0.3, v_04, mpi+pth, 64 ranks, 1 rpc, 2 tpp
245: ===============================================================================================
246: tt intel knl 68 qf hbm  |   0.0888   | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
247: ===============================================================================================
248: darwin intel knl 68 qf hbm |  0.0903 | intel 18.0.3, v_16, mpi+pth, 68 ranks, 1 rpc, 4 tpp, prefer hbm
249: ===============================================================================================
250: darwin intel skylake 28 |   0.1180   | intel 18.0.3, v_16, mpi+pth, 56 ranks, 1 rpc, 2 tpp
251: ===============================================================================================
252: darwin ibm power9 20    |   0.1263   | gnu 8.2.0, v_04, mpi only, 160 ranks, 4 rpc
253: ===============================================================================================
254: tt intel haswell 16     |   0.1565   | intel 18.0.3, v_08, mpi+pth, 32 ranks, 1 rpc, 2 tpp
255: ===============================================================================================
256: darwin intel knl 68 qf ddr |  0.1636 | intel 18.0.3, v_04, mpi only, 136 ranks, 2 rpc, prefer ddr
257: ===============================================================================================
258: darwin arm tx2 32 w/ 4 tpc |  0.1932 | gnu 8.2.0, v_01, mpi, 256 ranks, 4 rpc
259: ===============================================================================================
260: darwin arm tx2 32 w/ 2 tpc |  0.2034 | gnu 8.2.0, v_01, mpi+pth, 64 ranks, 1 rpc, 2 tpp
261: ===============================================================================================
262: darwin intel haswell 16 |   0.2781   | intel 18.0.3, v_08, mpi+pth, 32 ranks, 1 rpc, 2 tpp
263: ===============================================================================================
264:
265: #################################################################################################
266:
267: Table 7: Main cycle times for VPIC LPI v_04 large memory DDR problem.
268:
269: #################################################################################################
270:
271: ===============================================================================================
272:                         |    v_01    |    v_04    |    v_08    |    v_16    |
```

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273: --------------------------------------------------------------------------------
274: machine        | Main Cycle Time | Main Cycle Time | Main Cycle Time | Main Cycle Time |
275:                |   (seconds)     |   (seconds)     |   (seconds)     |   (seconds)     |
276: ================================================================================
277: darwin intel   |    3593.86      |    1524.83      |    1278.52      |    1303.63      |
278: skylake 28     |    2370.48      |    1222.38      |    1218.54      |    1199.04      |
279:                --------------------------------------------------------------------------------
280: intel 18.0.3   |    3594.03      |    1525.85      |    1275.05      |    1301.91      |
281:                |    2382.38      |    1240.43      |    1237.99      |    1220.42      |
282: ================================================================================
283: darwin intel   |    9537.85      |    4630.58      |    3506.34      |    2796.11      |
284: knl 68 qf hbm  |    5953.26      |    3031.37      |    2792.66      |    2615.67      |
285:                |    4525.66      |    2865.83      |    2823.16      |    2695.62      |
286:                --------------------------------------------------------------------------------
287:                |    9538.79      |    4631.50      |    3512.86      |    2798.68      |
288:                |    6036.69      |    3115.72      |    2835.28      |    2592.16      |
289:                |    4655.12      |    2839.17      |    2664.94      |    2584.04      |
290: ================================================================================
291: darwin intel   |    9519.77      |    4596.15      |    3503.60      |    2843.01      |
292: knl 68 qf ddr  |    5932.01      |    3085.76      |    2910.53      |    2751.50      |
293:                |    4534.96      |    3021.89      |    2954.40      |    2857.92      |
294:                --------------------------------------------------------------------------------
295:                |    9504.55      |    4600.95      |    3505.95      |    2848.51      |
296:                |    6007.36      |    3132.46      |    2939.44      |    2777.58      |
297:                |    4674.90      |    2988.27      |    2899.71      |    2857.74      |
298: ================================================================================
299: tt intel       |    9590.46      |    4619.66      |    3469.28      |    2790.40      |
300: knl 68 qf hbm  |    5930.79      |    2937.96      |    2757.05      |    2548.94      |
301:                |    4299.39      |    2757.78      |    2651.44      |    2531.97      |
302:                --------------------------------------------------------------------------------
303:                |    9617.61      |    4624.29      |    3472.57      |    2793.22      |
304:                |    5988.47      |    3003.96      |    2757.29      |    2502.77      |
305:                |    4502.71      |    2701.74      |    2505.29      |    2462.04      |
306: ================================================================================
307: tt intel       |                 |                 |                 |                 |
308: knl 68 qf ddr  |                 |                 |                 |                 |
309:                |                 |                 |                 |                 |
310:                --------------------------------------------------------------------------------
311:                |                 |                 |                 |                 |
312:                |                 |                 |                 |                 |
313:                |                 |                 |                 |                 |
314: ================================================================================
315: darwin intel   |    7402.72      |    3396.38      |    2500.14      |      N/A        |
316: haswell 16     |    4747.54      |    2344.28      |    2289.13      |      N/A        |
317:                --------------------------------------------------------------------------------
318: intel 18.0.3   |    7395.86      |    3395.91      |    2467.70      |      N/A        |
319:                |    4755.87      |    2396.19      |    2343.88      |      N/A        |
320: ================================================================================
321: tt intel       |    7495.77      |    3536.42      |    2507.40      |      N/A        |
322: haswell 16     |    4728.20      |    2312.81      |    2250.84      |      N/A        |
323:                --------------------------------------------------------------------------------
324:                |    7491.30      |    3525.96      |    2511.91      |      N/A        |
325:                |    7484.04      |    3516.10      |    2497.79      |      N/A        |
326: ================================================================================
327: darwin amd     |    3529.36      |    1417.16      |    1450.72      |      N/A        |
328: epyc 32        |    2182.23      |     981.80      |    1133.94      |      N/A        |
329:                --------------------------------------------------------------------------------
330: intel 18.0.3   |    3527.42      |    1414.02      |    1454.37      |      N/A        |
331:                |    2222.29      |    1039.46      |    1164.92      |      N/A        |
332: ================================================================================
333: darwin ibm     |    7860.07      |    3192.13      |      N/A        |      N/A        |
334: power9 20      |    5116.33      |    2721.00      |      N/A        |      N/A        |
335:                |    3527.73      |    1947.53      |      N/A        |      N/A        |
336: gnu 8.2.0      --------------------------------------------------------------------------------
337:                |    7892.81      |                 |      N/A        |      N/A        |
338:                |                 |                 |      N/A        |      N/A        |
339:                |    3599.59      |                 |      N/A        |      N/A        |
340: ================================================================================
```

```
341: darwin ibm       |           |           |           |     N/A     |     N/A     |
342: power9 20        |           |           |           |     N/A     |     N/A     |
343:                  |           |           |           |     N/A     |     N/A     |
344: ibm xl 16.1.0    -----------------------------------------------------------------
345:                  |           |           |           |     N/A     |     N/A     |
346:                  |           |           |           |     N/A     |     N/A     |
347:                  |           |           |           |     N/A     |     N/A     |
348: =================================================================================
349: darwin ibm       |           |           |           |     N/A     |     N/A     |
350: power8 10        |           |           |           |     N/A     |     N/A     |
351:                  |           |           |           |     N/A     |     N/A     |
352:                  |           |           |           |     N/A     |     N/A     |
353:                  -----------------------------------------------------------------
354:                  |           |           |           |     N/A     |     N/A     |
355:                  |           |           |           |     N/A     |     N/A     |
356:                  |           |           |           |     N/A     |     N/A     |
357:                  |           |           |           |     N/A     |     N/A     |
358: =================================================================================
359: darwin arm       |  7480.86  |           |           |     N/A     |     N/A     |
360: tx2 32 w/ 4 tpc  |  4388.36  |           |           |     N/A     |     N/A     |
361:                  |  3423.11  |           |           |     N/A     |     N/A     |
362: gnu 8.2.0        -----------------------------------------------------------------
363:                  |  7486.79  |           |           |     N/A     |     N/A     |
364:                  |  4449.61  |           |           |     N/A     |     N/A     |
365:                  |  3393.17  |           |           |     N/A     |     N/A     |
366: =================================================================================
367: darwin arm       |  6539.23  |           |           |     N/A     |     N/A     |
368: tx2 32 w/ 2 tpc  |  4239.03  |           |           |     N/A     |     N/A     |
369:                  -----------------------------------------------------------------
370: gnu 8.2.0        |  6535.84  |           |           |     N/A     |     N/A     |
371:                  |  4312.37  |           |           |     N/A     |     N/A     |
372: =================================================================================
373:
374: ################################################################################################
375:
376: Table 8: Particle advance loop times for VPIC LPI v_04 large memory DDR problem.
377:
378: ################################################################################################
379:
380: =================================================================================
381:                  |    v_01   |    v_04   |    v_08   |    v_16   |
382:                  -----------------------------------------------------------------
383: machine          | advance_p | advance_p | advance_p | advance_p |
384:                  | (seconds) | (seconds) | (seconds) | (seconds) |
385: =================================================================================
386: darwin intel     |  3504.00  |  1443.00  |  1180.00  |  1215.00  |
387: skylake 28       |  2295.00  |  1145.00  |  1138.00  |  1122.00  |
388:                  -----------------------------------------------------------------
389: intel 18.0.3     |  3505.00  |  1440.00  |  1195.00  |  1214.00  |
390:                  |  2294.00  |  1147.00  |  1144.00  |  1125.00  |
391: =================================================================================
392: darwin intel     |  9005.00  |  4290.00  |  3172.00  |  2472.00  |
393: knl 68 qf hbm    |  5762.00  |  2735.00  |  2460.00  |  2315.00  |
394:                  |  4266.00  |  2587.00  |  2475.00  |  2341.00  |
395:                  -----------------------------------------------------------------
396:                  |  9012.00  |  4295.00  |  3171.00  |  2476.00  |
397:                  |  5551.00  |  2729.00  |  2429.00  |  2195.00  |
398:                  |  4261.00  |  2450.00  |  2281.00  |  2201.00  |
399: =================================================================================
400: darwin intel     |  9000.00  |  4285.00  |  3200.00  |  2553.00  |
401: knl 68 qf ddr    |  5531.00  |  2776.00  |  2549.00  |  2497.00  |
402:                  |  4290.00  |  2691.00  |  2597.00  |  2601.00  |
403:                  -----------------------------------------------------------------
404:                  |  9001.00  |  4293.00  |  3205.00  |  2547.00  |
405:                  |  5542.00  |  2771.00  |  2515.00  |  2446.00  |
406:                  |  4299.00  |  2636.00  |  2548.00  |  2494.00  |
407: =================================================================================
408: tt intel         |  9342.00  |  4365.00  |  3212.00  |  2527.00  |
```

```
409: knl 68 qf hbm  |   5742.00 |   2749.00 |   2563.00 |   2234.00 |
410:               |   4049.00 |   2420.00 |   2267.00 |   2154.00 |
411:               -----------------------------------------------------------
412:               |   9250.00 |   4369.00 |   3216.00 |   2530.00 |
413:               |   5688.00 |   2747.00 |   2358.00 |   2217.00 |
414:               |   4207.00 |   2378.00 |   2117.00 |   2019.00 |
415: ==================================================================
416: tt intel      |           |           |           |           |
417: knl 68 qf ddr |           |           |           |           |
418:               |           |           |           |           |
419:               -----------------------------------------------------------
420:               |           |           |           |           |
421:               |           |           |           |           |
422:               |           |           |           |           |
423: ==================================================================
424: darwin intel  |   7242.00 |   3233.00 |   2270.00 |    N/A     |
425: haswell 16    |   4584.00 |   2202.00 |   2151.00 |    N/A     |
426:               -----------------------------------------------------------
427: intel 18.0.3  |   7225.00 |   3215.00 |   2274.00 |    N/A     |
428:               |   4573.00 |   2204.00 |   2139.00 |    N/A     |
429: ==================================================================
430: tt intel      |   7223.00 |   3253.00 |   2209.00 |    N/A     |
431: haswell 16    |   4528.00 |   2100.00 |   2026.00 |    N/A     |
432:               -----------------------------------------------------------
433:               |   7221.00 |   3244.00 |   2215.00 |    N/A     |
434:               |   7205.00 |   3228.00 |   2194.00 |    N/A     |
435: ==================================================================
436: darwin amd    |   3401.00 |   1318.00 |   1349.00 |    N/A     |
437: epyc 32       |   2117.00 |    912.10 |   1068.00 |    N/A     |
438:               -----------------------------------------------------------
439: intel 18.0.3  |   3408.00 |   1332.00 |   1347.00 |    N/A     |
440:               |   2128.00 |    923.70 |   1051.00 |    N/A     |
441: ==================================================================
442: darwin ibm    |   7700.00 |   3015.00 |    N/A     |    N/A     |
443: power9 20     |   4991.00 |   2618.00 |    N/A     |    N/A     |
444:               |   3423.00 |   1856.00 |    N/A     |    N/A     |
445: gnu 8.2.0     -----------------------------------------------------------
446:               |   7723.00 |           |    N/A     |    N/A     |
447:               |           |           |    N/A     |    N/A     |
448:               |   3455.00 |           |    N/A     |    N/A     |
449: ==================================================================
450: darwin ibm    |           |           |    N/A     |    N/A     |
451: power9 20     |           |           |    N/A     |    N/A     |
452:               |           |           |    N/A     |    N/A     |
453: ibm xl 16.1.0 -----------------------------------------------------------
454:               |           |           |    N/A     |    N/A     |
455:               |           |           |    N/A     |    N/A     |
456:               |           |           |    N/A     |    N/A     |
457: ==================================================================
458: darwin ibm    |           |           |    N/A     |    N/A     |
459: power8 10     |           |           |    N/A     |    N/A     |
460:               |           |           |    N/A     |    N/A     |
461:               |           |           |    N/A     |    N/A     |
462:               -----------------------------------------------------------
463:               |           |           |    N/A     |    N/A     |
464:               |           |           |    N/A     |    N/A     |
465:               |           |           |    N/A     |    N/A     |
466:               |           |           |    N/A     |    N/A     |
467: ==================================================================
468: darwin arm    |   7263.00 |           |    N/A     |    N/A     |
469: tx2 32 w/ 4 tpc|  4249.00 |           |    N/A     |    N/A     |
470:               |   3229.00 |           |    N/A     |    N/A     |
471: gnu 8.2.0     -----------------------------------------------------------
472:               |   7263.00 |           |    N/A     |    N/A     |
473:               |   4251.00 |           |    N/A     |    N/A     |
474:               |   3221.00 |           |    N/A     |    N/A     |
475: ==================================================================
476: darwin arm    |   6358.00 |           |    N/A     |    N/A     |
```

```
477: tx2 32 w/ 2 tpc |   4124.00  |           |    N/A    |    N/A    |
478:                  -------------------------------------------------------------
479: gnu 8.2.0        |   6357.00  |           |    N/A    |    N/A    |
480:                  |   4158.00  |           |    N/A    |    N/A    |
481: ==========================================================================
482:
483: ####################################################################################################
484:
485: Table 9: Particle uncenter loop times for VPIC LPI v_04 large memory DDR problem.
486:
487: ####################################################################################################
488:
489: ======================================================================
490:                  |    v_01    |    v_04    |    v_08    |    v_16    |
491:                  -------------------------------------------------------
492: machine          | uncenter_p | uncenter_p | uncenter_p | uncenter_p |
493:                  |  (seconds) |  (seconds) |  (seconds) |  (seconds) |
494: ======================================================================
495: darwin intel     |   1.0980   |   1.0730   |   1.0530   |   1.0430   |
496: skylake 28       |   1.0790   |   1.0250   |   1.0610   |   1.0550   |
497:                  -------------------------------------------------------
498: intel 18.0.3     |   1.1040   |   1.0650   |   1.0370   |   0.9712   |
499:                  |   0.9990   |   0.9045   |   0.9468   |   0.8380   |
500: ======================================================================
501: darwin intel     |   2.8790   |   2.2620   |   1.7840   |   1.6060   |
502: knl 68 qf hbm    |   2.5590   |   1.9850   |   1.8160   |   1.4610   |
503:                  |   2.2810   |   2.0340   |   2.0700   |   1.6520   |
504:                  -------------------------------------------------------
505:                  |   2.8870   |   2.2480   |   1.6620   |   1.7230   |
506:                  |   2.2110   |   1.7590   |   1.2170   |   1.1980   |
507:                  |   1.6920   |   0.9435   |   0.6012   |   0.5408   |
508: ======================================================================
509: darwin intel     |   2.8880   |   2.2930   |   1.9080   |   1.8550   |
510: knl 68 qf ddr    |   2.2790   |   2.1510   |   2.0580   |   2.0970   |
511:                  |   2.2810   |   2.1600   |   2.0870   |   2.2370   |
512:                  -------------------------------------------------------
513:                  |   2.8870   |   2.3090   |   1.9920   |   1.9600   |
514:                  |   2.3380   |   1.5180   |   1.5200   |   1.3930   |
515:                  |   1.2670   |   1.0040   |   0.8675   |   0.7748   |
516: ======================================================================
517: tt intel         |   3.2520   |   2.3370   |   1.5240   |   1.3660   |
518: knl 68 qf hbm    |   2.4410   |   1.9980   |   1.7580   |   1.5420   |
519:                  |   2.0900   |   1.8590   |   1.5430   |   1.4530   |
520:                  -------------------------------------------------------
521:                  |   3.2640   |   2.3450   |   1.5150   |   1.3560   |
522:                  |   2.0570   |   1.4310   |   1.0840   |   1.0870   |
523:                  |   1.4950   |   1.0760   |   0.8188   |   1.0660   |
524: ======================================================================
525: tt intel         |            |            |            |            |
526: knl 68 qf ddr    |            |            |            |            |
527:                  |            |            |            |            |
528:                  -------------------------------------------------------
529:                  |            |            |            |            |
530:                  |            |            |            |            |
531:                  |            |            |            |            |
532: ======================================================================
533: darwin intel     |   2.2850   |   1.7530   |   1.1200   |    N/A     |
534: haswell 16       |   2.0720   |   1.7990   |   1.7150   |    N/A     |
535:                  -------------------------------------------------------
536: intel 18.0.3     |   2.1940   |   1.6170   |   1.2840   |    N/A     |
537:                  |   1.9270   |   0.9993   |   1.2060   |    N/A     |
538: ======================================================================
539: tt intel         |   2.2220   |   1.5900   |   1.1180   |    N/A     |
540: haswell 16       |   1.7980   |   1.6040   |   1.2010   |    N/A     |
541:                  -------------------------------------------------------
542:                  |   2.1340   |   1.4370   |   1.0930   |    N/A     |
543:                  |   2.1230   |   1.3600   |   1.1170   |    N/A     |
544: ======================================================================
```

```
545: darwin amd       │   1.2430   │   0.7764   │   0.7722   │     N/A    │
546: epyc 32          │   0.9042   │   0.7897   │   0.8398   │     N/A    │
547:                  ----------------------------------------------------
548: intel 18.0.3     │   1.2430   │   0.8512   │   0.8313   │     N/A    │
549:                  │   1.0150   │   1.0320   │   0.8983   │     N/A    │
550: =======================================================================
551: darwin ibm       │   1.9510   │   1.2820   │     N/A    │     N/A    │
552: power9 20        │   1.8350   │   1.1020   │     N/A    │     N/A    │
553:                  │   1.4920   │   0.8989   │     N/A    │     N/A    │
554: gnu 8.2.0        ----------------------------------------------------
555:                  │   1.9620   │            │     N/A    │     N/A    │
556:                  │            │            │     N/A    │     N/A    │
557:                  │   1.4780   │            │     N/A    │     N/A    │
558: =======================================================================
559: darwin ibm       │            │            │     N/A    │     N/A    │
560: power9 20        │            │            │     N/A    │     N/A    │
561:                  │            │            │     N/A    │     N/A    │
562: ibm xl 16.1.0    ----------------------------------------------------
563:                  │            │            │     N/A    │     N/A    │
564:                  │            │            │     N/A    │     N/A    │
565:                  │            │            │     N/A    │     N/A    │
566: =======================================================================
567: darwin ibm       │            │            │     N/A    │     N/A    │
568: power8 10        │            │            │     N/A    │     N/A    │
569:                  │            │            │     N/A    │     N/A    │
570:                  │            │            │     N/A    │     N/A    │
571:                  ----------------------------------------------------
572:                  │            │            │     N/A    │     N/A    │
573:                  │            │            │     N/A    │     N/A    │
574:                  │            │            │     N/A    │     N/A    │
575:                  │            │            │     N/A    │     N/A    │
576: =======================================================================
577: darwin arm       │   2.5650   │            │     N/A    │     N/A    │
578: tx2 32 w/ 4 tpc  │   1.7420   │            │     N/A    │     N/A    │
579:                  │   1.3780   │            │     N/A    │     N/A    │
580: gnu 8.2.0        ----------------------------------------------------
581:                  │   2.5670   │            │     N/A    │     N/A    │
582:                  │   1.8260   │            │     N/A    │     N/A    │
583:                  │   1.3590   │            │     N/A    │     N/A    │
584: =======================================================================
585: darwin arm       │   1.6720   │            │     N/A    │     N/A    │
586: tx2 32 w/ 2 tpc  │   1.4320   │            │     N/A    │     N/A    │
587:                  ----------------------------------------------------
588: gnu 8.2.0        │   1.6750   │            │     N/A    │     N/A    │
589:                  │   1.4680   │            │     N/A    │     N/A    │
590: =======================================================================
591:
592: #######################################################################################################################
593:
594: Table 10: Consolidation of Tables 1-3 for VPIC LPI v_04 large memory DDR problem.
595:
596: #######################################################################################################################
597:
598: ====================================================================================================================================
599:                  │            v_01            │            v_04            │            v_08            │            v_16            │
600:                  ------------------------------------------------------------------------------------------------------------------
601: machine          │ Cycle Time │ advance_p  │ uncenter_p │ Cycle Time │ advance_p  │ uncenter_p │ Cycle Time │ advance_p  │ uncenter_p │ Cycle Time │ advance_p  │ uncenter_p │
602:                  │ (seconds)  │ (seconds)  │ (seconds)  │ (seconds)  │ (seconds)  │ (seconds)  │ (seconds)  │ (seconds)  │ (seconds)  │ (seconds)  │ (seconds)  │ (seconds)  │
603: ====================================================================================================================================
604: darwin intel     │  3593.86   │  3504.00   │   1.0980   │  1524.83   │  1443.00   │   1.0730   │  1278.52   │  1180.00   │   1.0530   │  1303.63   │  1215.00   │   1.0430   │
605: skylake 28       │  2370.48   │  2295.00   │   1.0790   │  1222.38   │  1145.00   │   1.0250   │  1218.54   │  1138.00   │   1.0610   │  1199.04   │  1122.00   │   1.0550   │
606:                  ------------------------------------------------------------------------------------------------------------------
607: intel 18.0.3     │  3594.03   │  3505.00   │   1.1040   │  1525.85   │  1440.00   │   1.0650   │  1275.05   │  1195.00   │   1.0370   │  1301.91   │  1214.00   │   0.9712   │
608:                  │  2382.38   │  2294.00   │   0.9990   │  1240.43   │  1147.00   │   0.9045   │  1237.99   │  1144.00   │   0.9468   │  1220.42   │  1125.00   │   0.8380   │
609: ====================================================================================================================================
610: darwin intel     │  9537.85   │  9005.00   │   2.8790   │  4630.58   │  4290.00   │   2.2620   │  3506.34   │  3172.00   │   1.7840   │  2796.11   │  2472.00   │   1.6060   │
611: knl 68 qf hbm    │  5953.26   │  5762.00   │   2.5590   │  3031.37   │  2735.00   │   1.9850   │  2792.66   │  2460.00   │   1.8160   │  2615.67   │  2315.00   │   1.4610   │
612:                  │  4525.66   │  4266.00   │   2.2810   │  2865.83   │  2587.00   │   2.0340   │  2823.16   │  2475.00   │   2.0700   │  2695.62   │  2341.00   │   1.6520   │
```

```
613: ----------------------------------------------------------------------------------------------------------------------------------------------------
614:          | 9538.79 | 9012.00 | 2.8870 | 4631.50 | 4295.00 | 2.2480 | 3512.86 | 3171.00 | 1.6620 | 2798.68 | 2476.00 | 1.7230 |
615:          | 6036.69 | 5551.00 | 2.2110 | 3115.72 | 2729.00 | 1.7590 | 2835.28 | 2429.00 | 1.2170 | 2592.16 | 2195.00 | 1.1980 |
616:          | 4655.12 | 4261.00 | 1.6920 | 2839.17 | 2450.00 | 0.9435 | 2664.94 | 2281.00 | 0.6012 | 2584.04 | 2201.00 | 0.5408 |
617: ================================================================================================================================================
618: darwin intel | 9519.77 | 9000.00 | 2.8880 | 4596.15 | 4285.00 | 2.2930 | 3503.60 | 3200.00 | 1.9080 | 2843.01 | 2553.00 | 1.8550 |
619: knl 68 qf ddr | 5932.01 | 5531.00 | 2.2790 | 3085.76 | 2776.00 | 2.1510 | 2910.53 | 2549.00 | 2.0580 | 2751.50 | 2497.00 | 2.0970 |
620:          | 4534.96 | 4290.00 | 2.2810 | 3021.89 | 2691.00 | 2.1600 | 2954.40 | 2597.00 | 2.0870 | 2857.92 | 2601.00 | 2.2370 |
621: ----------------------------------------------------------------------------------------------------------------------------------------------------
622:          | 9504.55 | 9001.00 | 2.8870 | 4600.95 | 4293.00 | 2.3090 | 3505.95 | 3205.00 | 1.9920 | 2848.51 | 2547.00 | 1.9600 |
623:          | 6007.36 | 5542.00 | 2.3380 | 3132.46 | 2771.00 | 1.5180 | 2939.44 | 2515.00 | 1.5200 | 2777.58 | 2446.00 | 1.3930 |
624:          | 4674.90 | 4299.00 | 1.2670 | 2988.27 | 2636.00 | 1.0040 | 2899.71 | 2548.00 | 0.8675 | 2857.74 | 2494.00 | 0.7748 |
625: ================================================================================================================================================
626: tt intel | 9590.46 | 9342.00 | 3.2520 | 4619.66 | 4365.00 | 2.3370 | 3469.28 | 3212.00 | 1.5240 | 2790.40 | 2527.00 | 1.3660 |
627: knl 68 qf hbm | 5930.79 | 5742.00 | 2.4410 | 2937.96 | 2749.00 | 1.9980 | 2757.05 | 2563.00 | 1.7580 | 2548.94 | 2234.00 | 1.5420 |
628:          | 4299.39 | 4049.00 | 2.0900 | 2757.78 | 2420.00 | 1.8590 | 2651.44 | 2267.00 | 1.5430 | 2531.97 | 2154.00 | 1.4530 |
629: ----------------------------------------------------------------------------------------------------------------------------------------------------
630:          | 9617.61 | 9250.00 | 3.2640 | 4624.29 | 4369.00 | 2.3450 | 3472.57 | 3216.00 | 1.5150 | 2793.22 | 2530.00 | 1.3560 |
631:          | 5988.47 | 5688.00 | 2.0570 | 3003.96 | 2747.00 | 1.4310 | 2757.29 | 2358.00 | 1.0840 | 2502.77 | 2217.00 | 1.0870 |
632:          | 4502.71 | 4207.00 | 1.4950 | 2701.74 | 2378.00 | 1.0760 | 2505.29 | 2117.00 | 0.8188 | 2462.04 | 2019.00 | 1.0660 |
633: ================================================================================================================================================
634: tt intel |         |         |        |         |         |        |         |         |        |         |         |        |
635: knl 68 qf ddr |         |         |        |         |         |        |         |         |        |         |         |        |
636:          |         |         |        |         |         |        |         |         |        |         |         |        |
637: ----------------------------------------------------------------------------------------------------------------------------------------------------
638:          |         |         |        |         |         |        |         |         |        |         |         |        |
639:          |         |         |        |         |         |        |         |         |        |         |         |        |
640:          |         |         |        |         |         |        |         |         |        |         |         |        |
641: ================================================================================================================================================
642: darwin intel | 7402.72 | 7242.00 | 2.2850 | 3396.38 | 3233.00 | 1.7530 | 2500.14 | 2270.00 | 1.1200 | N/A | N/A | N/A |
643: haswell 16 | 4747.54 | 4584.00 | 2.0720 | 2344.28 | 2202.00 | 1.7990 | 2289.13 | 2151.00 | 1.7150 | N/A | N/A | N/A |
644: ----------------------------------------------------------------------------------------------------------------------------------------------------
645: intel 18.0.3 | 7395.86 | 7225.00 | 2.1940 | 3395.91 | 3215.00 | 1.6170 | 2467.70 | 2274.00 | 1.2840 | N/A | N/A | N/A |
646:          | 4755.87 | 4573.00 | 1.9270 | 2396.19 | 2204.00 | 0.9993 | 2343.88 | 2139.00 | 1.2060 | N/A | N/A | N/A |
647: ================================================================================================================================================
648: tt intel | 7495.77 | 7223.00 | 2.2220 | 3536.42 | 3253.00 | 1.5900 | 2507.40 | 2209.00 | 1.1180 | N/A | N/A | N/A |
649: haswell 16 | 4728.20 | 4528.00 | 1.7980 | 2312.81 | 2100.00 | 1.6040 | 2250.84 | 2026.00 | 1.2010 | N/A | N/A | N/A |
650: ----------------------------------------------------------------------------------------------------------------------------------------------------
651:          | 7491.30 | 7221.00 | 2.1340 | 3525.96 | 3244.00 | 1.4370 | 2511.91 | 2215.00 | 1.0930 | N/A | N/A | N/A |
652:          | 7484.04 | 7205.00 | 2.1230 | 3516.10 | 3228.00 | 1.3600 | 2497.79 | 2194.00 | 1.1170 | N/A | N/A | N/A |
653: ================================================================================================================================================
654: darwin amd | 3529.36 | 3401.00 | 1.2430 | 1417.16 | 1318.00 | 0.7764 | 1450.72 | 1349.00 | 0.7722 | N/A | N/A | N/A |
655: epyc 32 | 2182.23 | 2117.00 | 0.9042 | 981.80 | 912.10 | 0.7897 | 1133.94 | 1068.00 | 0.8398 | N/A | N/A | N/A |
656: ----------------------------------------------------------------------------------------------------------------------------------------------------
657: intel 18.0.3 | 3527.42 | 3408.00 | 1.2430 | 1414.02 | 1332.00 | 0.8512 | 1454.37 | 1347.00 | 0.8313 | N/A | N/A | N/A |
658:          | 2222.29 | 2128.00 | 1.0150 | 1039.46 | 923.70 | 1.0320 | 1164.92 | 1051.00 | 0.8983 | N/A | N/A | N/A |
659: ================================================================================================================================================
660: darwin ibm | 7860.07 | 7700.00 | 1.9510 | 3192.13 | 3015.00 | 1.2820 | N/A | N/A | N/A | N/A | N/A | N/A |
661: power9 20 | 5116.33 | 4991.00 | 1.8350 | 2721.00 | 2618.00 | 1.1020 | N/A | N/A | N/A | N/A | N/A | N/A |
662:          | 3527.73 | 3423.00 | 1.4920 | 1947.53 | 1856.00 | 0.8989 | N/A | N/A | N/A | N/A | N/A | N/A |
663: gnu 8.2.0 ----------------------------------------------------------------------------------------------------------------------------------------------
664:          | 7892.81 | 7723.00 | 1.9620 |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
665:          |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
666:          | 3599.59 | 3455.00 | 1.4780 |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
667: ================================================================================================================================================
668: darwin ibm |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
669: power9 20 |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
670:          |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
671: ibm xl 16.1.0 ------------------------------------------------------------------------------------------------------------------------------------------
672:          |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
673:          |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
674:          |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
675: ================================================================================================================================================
676: darwin ibm |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
677: power8 10 |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
678:          |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
679:          |         |         |        |         |         |        | N/A | N/A | N/A | N/A | N/A | N/A |
680: ----------------------------------------------------------------------------------------------------------------------------------------------------
```

681:							N/A	N/A	N/A	N/A	N/A	N/A
682:							N/A	N/A	N/A	N/A	N/A	N/A
683:							N/A	N/A	N/A	N/A	N/A	N/A
684:							N/A	N/A	N/A	N/A	N/A	N/A
685: ====												
686: darwin arm	7480.86	7263.00	2.5650				N/A	N/A	N/A	N/A	N/A	N/A
687: tx2 32 w/ 4 tpc	4388.36	4249.00	1.7420				N/A	N/A	N/A	N/A	N/A	N/A
688:	3423.11	3229.00	1.3780				N/A	N/A	N/A	N/A	N/A	N/A
689: gnu 8.2.0												
690:	7486.79	7263.00	2.5670				N/A	N/A	N/A	N/A	N/A	N/A
691:	4449.61	4251.00	1.8260				N/A	N/A	N/A	N/A	N/A	N/A
692:	3393.17	3221.00	1.3590				N/A	N/A	N/A	N/A	N/A	N/A
693: ====												
694: darwin arm	6539.23	6358.00	1.6720				N/A	N/A	N/A	N/A	N/A	N/A
695: tx2 32 w/ 2 tpc	4239.03	4124.00	1.4320				N/A	N/A	N/A	N/A	N/A	N/A
696:												
697: gnu 8.2.0	6535.84	6357.00	1.6750				N/A	N/A	N/A	N/A	N/A	N/A
698:	4312.37	4158.00	1.4680				N/A	N/A	N/A	N/A	N/A	N/A
699: ====												

```
700:
701: ################################################################################################
702:
703: Table 11: Main cycle times for VPIC LPI v_04 small memory HBM problem.
704:
705: ################################################################################################
706:
```

machine	v_01 Main Cycle Time (seconds)	v_04 Main Cycle Time (seconds)	v_08 Main Cycle Time (seconds)	v_16 Main Cycle Time (seconds)
darwin intel skylake 28	507.196	213.314	177.263	181.540
	337.250	172.655	170.030	171.446
intel 18.0.3	506.857	213.755	176.974	181.446
	338.459	173.598	172.880	171.306
darwin intel knl 68 qf hbm	1339.280	637.590	475.752	339.160
	828.772	405.235	331.186	244.721
	610.590	346.080	294.293	218.339
	1339.580	637.986	475.982	339.390
	882.901	450.991	351.434	256.806
	664.145	361.950	306.848	223.709
darwin intel knl 68 qf ddr	1343.000	644.369	491.712	402.685
	844.296	440.312	425.737	413.471
	651.674	442.923	446.271	451.313
	1343.340	644.605	491.856	403.491
	869.062	468.022	441.303	421.692
	673.380	454.689	445.288	437.815
tt intel knl 68 qf hbm	1341.550	640.090	472.199	338.104
	828.697	399.007	321.985	232.563
	594.570	339.157	286.610	203.872
	1352.490	641.294	474.720	340.071
	831.866	406.891	331.340	236.655
	605.658	342.522	284.629	198.517
tt intel knl 68 qf ddr				

```
749:        |           |           |           |           |
750: ========================================================================
751: darwin intel  |  1042.670 |   472.874 |   338.549 |    N/A    |
752: haswell 16    |   671.411 |   326.916 |   319.394 |    N/A    |
753:        ------------------------------------------------------------
754:        |  1042.740 |   472.333 |   343.555 |    N/A    |
755:        |   667.475 |   329.354 |   321.333 |    N/A    |
756: ========================================================================
757: tt intel      |  1044.120 |   479.213 |   331.760 |    N/A    |
758: haswell 16    |   660.077 |   313.805 |   304.966 |    N/A    |
759:        ------------------------------------------------------------
760:        |  1043.230 |   477.471 |   329.958 |    N/A    |
761:        |  1042.910 |   477.329 |   330.375 |    N/A    |
762: ========================================================================
763: darwin amd    |   498.664 |   197.943 |   204.796 |    N/A    |
764: epyc 32       |   309.554 |   138.793 |   161.232 |    N/A    |
765:        ------------------------------------------------------------
766: intel 18.0.3  |   496.540 |   197.772 |   204.360 |    N/A    |
767:        |   321.130 |   156.152 |   170.778 |    N/A    |
768: ========================================================================
769: darwin ibm    |  1112.790 |   448.676 |    N/A    |    N/A    |
770: power9 20     |   727.907 |   385.067 |    N/A    |    N/A    |
771:        |   502.348 |   277.281 |    N/A    |    N/A    |
772: gnu 8.2.0     ------------------------------------------------------------
773:        |  1115.720 |           |    N/A    |    N/A    |
774:        |           |           |    N/A    |    N/A    |
775:        |           |           |    N/A    |    N/A    |
776: ========================================================================
777: darwin ibm    |           |           |    N/A    |    N/A    |
778: power9 20     |           |           |    N/A    |    N/A    |
779:        |           |           |    N/A    |    N/A    |
780: ibm xl 16.1.0 ------------------------------------------------------------
781:        |           |           |    N/A    |    N/A    |
782:        |           |           |    N/A    |    N/A    |
783:        |           |           |    N/A    |    N/A    |
784: ========================================================================
785: darwin ibm    |           |           |    N/A    |    N/A    |
786: power8 10     |           |           |    N/A    |    N/A    |
787:        |           |           |    N/A    |    N/A    |
788:        |           |           |    N/A    |    N/A    |
789:        ------------------------------------------------------------
790:        |           |           |    N/A    |    N/A    |
791:        |           |           |    N/A    |    N/A    |
792:        |           |           |    N/A    |    N/A    |
793:        |           |           |    N/A    |    N/A    |
794: ========================================================================
795: darwin arm    |  1056.110 |           |    N/A    |    N/A    |
796: tx2 32 w/ 4 tpc|  621.973 |           |    N/A    |    N/A    |
797:        |   485.062 |           |    N/A    |    N/A    |
798: gnu 8.2.0     ------------------------------------------------------------
799:        |  1056.120 |           |    N/A    |    N/A    |
800:        |   626.386 |           |    N/A    |    N/A    |
801:        |   471.634 |           |    N/A    |    N/A    |
802: ========================================================================
803: darwin arm    |   921.431 |           |    N/A    |    N/A    |
804: tx2 32 w/ 2 tpc|  604.701 |           |    N/A    |    N/A    |
805:        ------------------------------------------------------------
806: gnu 8.2.0     |   921.891 |           |    N/A    |    N/A    |
807:        |   603.862 |           |    N/A    |    N/A    |
808: ========================================================================
809:
810: ################################################################################
811:
812: Table 12: Particle advance loop times for VPIC LPI v_04 small memory HBM problem.
813:
814: ################################################################################
815:
816: ==============================================================
```

```
817:                │    v_01    │    v_04    │    v_08    │    v_16    │
818:                ----------------------------------------------------------
819: machine        │  advance_p │  advance_p │  advance_p │  advance_p │
820:                │  (seconds) │  (seconds) │  (seconds) │  (seconds) │
821: ==================================================================================
822: darwin intel   │    498.1   │    204.5   │    168.3   │    171.6   │
823: skylake 28     │    327.5   │    163.0   │    160.7   │    161.7   │
824:                ----------------------------------------------------------
825: intel 18.0.3   │    498.7   │    204.8   │    166.6   │    172.0   │
826:                │    327.6   │    162.4   │    161.3   │    160.3   │
827: ==================================================================================
828: darwin intel   │   1280.0   │    607.5   │    448.0   │    312.8   │
829: knl 68 qf hbm  │    784.4   │    379.5   │    308.9   │    224.5   │
830:                │    586.8   │    328.2   │    276.5   │    201.5   │
831:                ----------------------------------------------------------
832:                │   1280.0   │    608.4   │    448.5   │    312.3   │
833:                │    788.7   │    381.5   │    310.8   │    221.7   │
834:                │    588.6   │    326.6   │    275.5   │    193.9   │
835: ==================================================================================
836: darwin intel   │   1278.0   │    609.8   │    455.5   │    368.4   │
837: knl 68 qf ddr  │    787.0   │    397.2   │    370.6   │    375.0   │
838:                │    611.0   │    395.5   │    396.2   │    392.6   │
839:                ----------------------------------------------------------
840:                │   1280.0   │    609.7   │    455.9   │    373.4   │
841:                │    788.2   │    398.2   │    370.8   │    366.8   │
842:                │    613.6   │    390.4   │    384.8   │    383.6   │
843: ==================================================================================
844: tt intel       │   1320.0   │    618.1   │    450.1   │    315.9   │
845: knl 68 qf hbm  │    812.4   │    382.9   │    305.9   │    210.7   │
846:                │    568.3   │    317.2   │    266.0   │    182.9   │
847:                ----------------------------------------------------------
848:                │   1330.0   │    619.1   │    452.1   │    317.6   │
849:                │    781.5   │    383.9   │    308.7   │    213.9   │
850:                │    576.3   │    316.8   │    259.9   │    173.8   │
851: ==================================================================================
852: tt intel       │            │            │            │            │
853: knl 68 qf ddr  │            │            │            │            │
854:                │            │            │            │            │
855:                ----------------------------------------------------------
856:                │            │            │            │            │
857:                │            │            │            │            │
858:                │            │            │            │            │
859: ==================================================================================
860: darwin intel   │   1030.0   │    457.9   │    323.0   │    N/A     │
861: haswell 16     │    653.6   │    312.4   │    305.6   │    N/A     │
862:                ----------------------------------------------------------
863:                │   1027.0   │    458.7   │    322.6   │    N/A     │
864:                │    648.8   │    313.3   │    305.0   │    N/A     │
865: ==================================================================================
866: tt intel       │   1027.0   │    462.2   │    314.3   │    N/A     │
867: haswell 16     │    643.6   │    297.9   │    289.2   │    N/A     │
868:                ----------------------------------------------------------
869:                │   1026.0   │    461.3   │    313.5   │    N/A     │
870:                │   1025.0   │    458.7   │    311.2   │    N/A     │
871: ==================================================================================
872: darwin amd     │    483.2   │    187.2   │    193.3   │    N/A     │
873: epyc 32        │    300.8   │    130.2   │    153.4   │    N/A     │
874:                ----------------------------------------------------------
875: intel 18.0.3   │    483.1   │    187.2   │    193.0   │    N/A     │
876:                │    305.0   │    132.9   │    151.6   │    N/A     │
877: ==================================================================================
878: darwin ibm     │   1094.0   │    428.1   │    N/A     │    N/A     │
879: power9 20      │    710.6   │    373.9   │    N/A     │    N/A     │
880:                │    488.3   │    265.0   │    N/A     │    N/A     │
881: gnu 8.2.0      ----------------------------------------------------------
882:                │   1097.0   │            │    N/A     │    N/A     │
883:                │            │            │    N/A     │    N/A     │
884:                │            │            │    N/A     │    N/A     │
```

```
885: ==================================================================
886: darwin ibm        |              |              |    N/A      |    N/A      |
887: power9 20         |              |              |    N/A      |    N/A      |
888:                   |              |              |    N/A      |    N/A      |
889: ibm xl 16.1.0     -------------------------------------------------------------
890:                   |              |              |    N/A      |    N/A      |
891:                   |              |              |    N/A      |    N/A      |
892:                   |              |              |    N/A      |    N/A      |
893: ==================================================================
894: darwin ibm        |              |              |    N/A      |    N/A      |
895: power8 10         |              |              |    N/A      |    N/A      |
896:                   |              |              |    N/A      |    N/A      |
897:                   |              |              |    N/A      |    N/A      |
898:                   -------------------------------------------------------------
899:                   |              |              |    N/A      |    N/A      |
900:                   |              |              |    N/A      |    N/A      |
901:                   |              |              |    N/A      |    N/A      |
902:                   |              |              |    N/A      |    N/A      |
903: ==================================================================
904: darwin arm        |   1033.0     |              |    N/A      |    N/A      |
905: tx2 32 w/ 4 tpc   |    602.2     |              |    N/A      |    N/A      |
906:                   |    450.3     |              |    N/A      |    N/A      |
907: gnu 8.2.0         -------------------------------------------------------------
908:                   |   1038.0     |              |    N/A      |    N/A      |
909:                   |    604.3     |              |    N/A      |    N/A      |
910:                   |    453.5     |              |    N/A      |    N/A      |
911: ==================================================================
912: darwin arm        |    903.8     |              |    N/A      |    N/A      |
913: tx2 32 w/ 2 tpc   |    591.3     |              |    N/A      |    N/A      |
914:                   -------------------------------------------------------------
915: gnu 8.2.0         |    904.0     |              |    N/A      |    N/A      |
916:                   |    586.6     |              |    N/A      |    N/A      |
917: ==================================================================
918:
919: ###############################################################################################################
920:
921: Table 13: Particle uncenter loop times for VPIC LPI v_04 small memory HBM problem.
922:
923: ###############################################################################################################
924:
925: ==================================================================
926:                   |    v_01      |    v_04      |    v_08      |    v_16      |
927:                   -------------------------------------------------------------
928: machine           |  uncenter_p  |  uncenter_p  |  uncenter_p  |  uncenter_p  |
929:                   |  (seconds)   |  (seconds)   |  (seconds)   |  (seconds)   |
930: ==================================================================
931: darwin intel      |    0.1695    |    0.1530    |    0.1535    |    0.1544    |
932: skylake 28        |    0.1582    |    0.1577    |    0.1567    |    0.1552    |
933:                   -------------------------------------------------------------
934: intel 18.0.3      |    0.1590    |    0.1571    |    0.1552    |    0.1540    |
935:                   |    0.1471    |    0.1430    |    0.1387    |    0.1180    |
936: ==================================================================
937: darwin intel      |    0.4071    |    0.3126    |    0.2073    |    0.1520    |
938: knl 68 qf hbm     |    0.2936    |    0.1940    |    0.1397    |    0.1092    |
939:                   |    0.2281    |    0.1626    |    0.1221    |    0.0989    |
940:                   -------------------------------------------------------------
941:                   |    0.4069    |    0.3167    |    0.2084    |    0.1512    |
942:                   |    0.3559    |    0.1956    |    0.1766    |    0.1298    |
943:                   |    0.2430    |    0.1599    |    0.1173    |    0.0903    |
944: ==================================================================
945: darwin intel      |    0.4129    |    0.3480    |    0.3394    |    0.3403    |
946: knl 68 qf ddr     |    0.3498    |    0.1636    |    0.3362    |    0.3360    |
947:                   |    0.3944    |    0.3944    |    0.3413    |    0.3612    |
948:                   -------------------------------------------------------------
949:                   |    0.4136    |    0.3499    |    0.3453    |    0.3480    |
950:                   |    0.3188    |    0.2887    |    0.3358    |    0.3189    |
951:                   |    0.3454    |    0.3313    |    0.3133    |    0.2896    |
952: ==================================================================
```

```
 953: tt intel        |  0.4287   |   0.3104    |   0.1986    |   0.1522    |
 954: knl 68 qf hbm   |  0.2976   |   0.1922    |   0.1363    |   0.1054    |
 955:                 |  0.2132   |   0.1513    |   0.1135    |   0.0930    |
 956:                 -----------------------------------------------------
 957:                 |  0.4338   |   0.3111    |   0.1991    |   0.1520    |
 958:                 |  0.2859   |   0.1871    |   0.1360    |   0.1083    |
 959:                 |  0.2118   |   0.1517    |   0.1127    |   0.0888    |
 960: ================================================================
 961: tt intel        |           |             |             |             |
 962: knl 68 qf ddr   |           |             |             |             |
 963:                 |           |             |             |             |
 964:                 -----------------------------------------------------
 965:                 |           |             |             |             |
 966:                 |           |             |             |             |
 967:                 |           |             |             |             |
 968: ================================================================
 969: darwin intel    |  0.3305   |   0.2952    |   0.2863    |    N/A      |
 970: haswell 16      |  0.3039   |   0.2945    |   0.2906    |    N/A      |
 971:                 -----------------------------------------------------
 972:                 |  0.3247   |   0.2940    |   0.2843    |    N/A      |
 973:                 |  0.2943   |   0.2869    |   0.2781    |    N/A      |
 974: ================================================================
 975: tt intel        |  0.3133   |   0.2037    |   0.1987    |    N/A      |
 976: haswell 16      |  0.2773   |   0.2781    |   0.2715    |    N/A      |
 977:                 -----------------------------------------------------
 978:                 |  0.3138   |   0.2597    |   0.2576    |    N/A      |
 979:                 |  0.3138   |   0.1944    |   0.1565    |    N/A      |
 980: ================================================================
 981: darwin amd      |  0.1768   |   0.1105    |   0.1079    |    N/A      |
 982: epyc 32         |  0.1306   |   0.1201    |   0.1194    |    N/A      |
 983:                 -----------------------------------------------------
 984: intel 18.0.3    |  0.1779   |   0.1105    |   0.1165    |    N/A      |
 985:                 |  0.1491   |   0.0788    |   0.0834    |    N/A      |
 986: ================================================================
 987: darwin ibm      |  0.2715   |   0.1811    |    N/A      |    N/A      |
 988: power9 20       |  0.2610   |   0.1613    |    N/A      |    N/A      |
 989:                 |  0.2085   |   0.1263    |    N/A      |    N/A      |
 990: gnu 8.2.0       -----------------------------------------------------
 991:                 |  0.2767   |             |    N/A      |    N/A      |
 992:                 |           |             |    N/A      |    N/A      |
 993:                 |           |             |    N/A      |    N/A      |
 994: ================================================================
 995: darwin ibm      |           |             |    N/A      |    N/A      |
 996: power9 20       |           |             |    N/A      |    N/A      |
 997:                 |           |             |    N/A      |    N/A      |
 998: ibm xl 16.1.0   -----------------------------------------------------
 999:                 |           |             |    N/A      |    N/A      |
1000:                 |           |             |    N/A      |    N/A      |
1001:                 |           |             |    N/A      |    N/A      |
1002: ================================================================
1003: darwin ibm      |           |             |    N/A      |    N/A      |
1004: power8 10       |           |             |    N/A      |    N/A      |
1005:                 |           |             |    N/A      |    N/A      |
1006:                 |           |             |    N/A      |    N/A      |
1007:                 -----------------------------------------------------
1008:                 |           |             |    N/A      |    N/A      |
1009:                 |           |             |    N/A      |    N/A      |
1010:                 |           |             |    N/A      |    N/A      |
1011:                 |           |             |    N/A      |    N/A      |
1012: ================================================================
1013: darwin arm      |  0.3678   |             |    N/A      |    N/A      |
1014: tx2 32 w/ 4 tpc |  0.2479   |             |    N/A      |    N/A      |
1015:                 |  0.1932   |             |    N/A      |    N/A      |
1016: gnu 8.2.0       -----------------------------------------------------
1017:                 |  0.3948   |             |    N/A      |    N/A      |
1018:                 |  0.3165   |             |    N/A      |    N/A      |
1019:                 |  0.1939   |             |    N/A      |    N/A      |
1020: ================================================================
```

```
1021: darwin arm     |  0.2390  |          |          |   N/A    |   N/A    |
1022: tx2 32 w/ 2 tpc|  0.2148  |          |          |   N/A    |   N/A    |
1023:                ----------------------------------------------------------------
1024: gnu 8.2.0      |  0.2353  |          |          |   N/A    |   N/A    |
1025:                |  0.2034  |          |          |   N/A    |   N/A    |
1026: ============================================================================
1027:
1028: ####################################################################################
1029:
1030: Table 14: Consolidation of Tables 1-3 for VPIC LPI v_04 small memory HBM problem.
1031:
1032: ####################################################################################
1033:
```

1034:		v_01			v_04			v_08			v_16		
1037: machine	Cycle Time (seconds)	advance_p (seconds)	uncenter_p (seconds)	Cycle Time (seconds)	advance_p (seconds)	uncenter_p (seconds)	Cycle Time (seconds)	advance_p (seconds)	uncenter_p (seconds)	Cycle Time (seconds)	advance_p (seconds)	uncenter_p (seconds)
1040: darwin intel	507.196	498.1	0.1695	213.314	204.5	0.1530	177.263	168.3	0.1535	181.540	171.6	0.1544
1041: skylake 28	337.250	327.5	0.1582	172.655	163.0	0.1577	170.030	160.7	0.1567	171.446	161.7	0.1552
1043: intel 18.0.3	506.857	498.7	0.1590	213.755	204.8	0.1571	176.974	166.6	0.1552	181.446	172.0	0.1540
1044:	338.459	327.6	0.1471	173.598	162.4	0.1430	172.880	161.3	0.1387	171.306	160.3	0.1180
1046: darwin intel	1339.280	1280.0	0.4071	637.590	607.5	0.3126	475.752	448.0	0.2073	339.160	312.8	0.1520
1047: knl 68 qf hbm	828.772	784.4	0.2936	405.235	379.5	0.1940	331.186	308.9	0.1397	244.721	224.5	0.1092
1048:	610.590	586.8	0.2281	346.080	328.2	0.1626	294.293	276.5	0.1221	218.339	201.5	0.0989
1050:	1339.580	1280.0	0.4069	637.986	608.4	0.3167	475.982	448.5	0.2084	339.390	312.3	0.1512
1051:	882.901	788.7	0.3559	450.991	381.5	0.1956	351.434	310.8	0.1766	256.806	221.7	0.1298
1052:	664.145	588.6	0.2430	361.950	326.6	0.1599	306.848	275.5	0.1173	223.709	193.9	0.0903
1054: darwin intel	1343.000	1278.0	0.4129	644.369	609.8	0.3480	491.712	455.5	0.3394	402.685	368.4	0.3403
1055: knl 68 qf ddr	844.296	787.0	0.3498	440.312	397.2	0.1636	425.737	370.6	0.3362	413.471	375.0	0.3360
1056:	651.674	611.0	0.3944	442.923	395.5	0.3944	446.271	396.2	0.3413	451.313	392.6	0.3612
1058:	1343.340	1280.0	0.4136	644.605	609.7	0.3499	491.856	455.9	0.3453	403.491	373.4	0.3480
1059:	869.062	788.2	0.3188	468.022	398.2	0.2887	441.303	370.8	0.3358	421.692	366.8	0.3189
1060:	673.380	613.6	0.3454	454.689	390.4	0.3313	445.288	384.8	0.3133	437.815	383.6	0.2896
1062: tt intel	1341.550	1320.0	0.4287	640.090	618.1	0.3104	472.199	450.1	0.1986	338.104	315.9	0.1522
1063: knl 68 qf hbm	828.697	812.4	0.2976	399.007	382.9	0.1922	321.985	305.9	0.1363	232.563	210.7	0.1054
1064:	594.570	568.3	0.2132	339.157	317.2	0.1513	286.610	266.0	0.1135	203.872	182.9	0.0930
1066:	1352.490	1330.0	0.4338	641.294	619.1	0.3111	474.720	452.1	0.1991	340.071	317.6	0.1520
1067:	831.866	781.5	0.2859	406.891	383.9	0.1871	331.340	308.7	0.1360	236.655	213.9	0.1083
1068:	605.658	576.3	0.2118	342.522	316.8	0.1517	284.629	259.9	0.1127	198.517	173.8	0.0888
1070: tt intel												
1071: knl 68 qf ddr												
1078: darwin intel	1042.670	1030.0	0.3305	472.874	457.9	0.2952	338.549	323.0	0.2863	N/A	N/A	N/A
1079: haswell 16	671.411	653.6	0.3039	326.916	312.4	0.2945	319.394	305.6	0.2906	N/A	N/A	N/A
1081:	1042.740	1027.0	0.3247	472.333	458.7	0.2940	343.555	322.6	0.2843	N/A	N/A	N/A
1082:	667.475	648.8	0.2943	329.354	313.3	0.2869	321.333	305.0	0.2781	N/A	N/A	N/A
1084: tt intel	1044.120	1027.0	0.3133	479.213	462.2	0.2037	331.760	314.3	0.1987	N/A	N/A	N/A
1085: haswell 16	660.077	643.6	0.2773	313.805	297.9	0.2781	304.966	289.2	0.2715	N/A	N/A	N/A
1087:	1043.230	1026.0	0.3138	477.471	461.3	0.2597	329.958	313.5	0.2576	N/A	N/A	N/A
1088:	1042.910	1025.0	0.3138	477.329	458.7	0.1944	330.375	311.2	0.1565	N/A	N/A	N/A

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1089: ================================================================================================================================
1090: darwin amd     |  498.664 |  483.2 | 0.1768 | 197.943 | 187.2 | 0.1105 | 204.796 | 193.3 | 0.1079 | N/A | N/A | N/A |
1091: epyc 32        |  309.554 |  300.8 | 0.1306 | 138.793 | 130.2 | 0.1201 | 161.232 | 153.4 | 0.1194 | N/A | N/A | N/A |
1092:                ----------------------------------------------------------------------------------------------------------------
1093: intel 18.0.3   |  496.540 |  483.1 | 0.1779 | 197.772 | 187.2 | 0.1105 | 204.360 | 193.0 | 0.1165 | N/A | N/A | N/A |
1094:                |  321.130 |  305.0 | 0.1491 | 156.152 | 132.9 | 0.0788 | 170.778 | 151.6 | 0.0834 | N/A | N/A | N/A |
1095: ================================================================================================================================
1096: darwin ibm     | 1112.790 | 1094.0 | 0.2715 | 448.676 | 428.1 | 0.1811 |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1097: power9 20      |  727.907 |  710.6 | 0.2610 | 385.067 | 373.9 | 0.1613 |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1098:                |  502.348 |  488.3 | 0.2085 | 277.281 | 265.0 | 0.1263 |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1099: gnu 8.2.0      ----------------------------------------------------------------------------------------------------------------
1100:                | 1115.720 | 1097.0 | 0.2767 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1101:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1102:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1103: ================================================================================================================================
1104: darwin ibm     |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1105: power9 20      |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1106:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1107: ibm xl 16.1.0  ----------------------------------------------------------------------------------------------------------------
1108:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1109:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1110:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1111: ================================================================================================================================
1112: darwin ibm     |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1113: power8 10      |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1114:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1115:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1116:                ----------------------------------------------------------------------------------------------------------------
1117:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1118:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1119:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1120:                |          |        |        |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1121: ================================================================================================================================
1122: darwin arm     | 1056.110 | 1033.0 | 0.3678 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1123: tx2 32 w/ 4 tpc|  621.973 |  602.2 | 0.2479 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1124:                |  485.062 |  450.3 | 0.1932 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1125: gnu 8.2.0      ----------------------------------------------------------------------------------------------------------------
1126:                | 1056.120 | 1038.0 | 0.3948 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1127:                |  626.386 |  604.3 | 0.3165 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1128:                |  471.634 |  453.5 | 0.1939 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1129: ================================================================================================================================
1130: darwin arm     |  921.431 |  903.8 | 0.2390 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1131: tx2 32 w/ 2 tpc|  604.701 |  591.3 | 0.2148 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1132:                ----------------------------------------------------------------------------------------------------------------
1133: gnu 8.2.0      |  921.891 |  904.0 | 0.2353 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1134:                |  603.862 |  586.6 | 0.2034 |         |       |        |   N/A   |  N/A  |  N/A   | N/A | N/A | N/A |
1135: ================================================================================================================================
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