Adaptation dynamique des optimisations : versions interchangeables

Lénaïc Bagnères, Cédric Bastoul

Laboratoire de Recherche en Informatique (LRI)
Inria Grand Large
Université Paris-Sud 11

Laboratoire ICube - ICPS
Inria CAMUS
Université de Strasbourg

7e rencontres de la communauté française de compilation
6 décembre 2013

Introduction

- Once upon a time, life was easy for parallel programs...
  - One program running, one architecture, one context, one user

- In the multicore era, welcome to the jungle!
  - A large set of target architectures is possible
  - High dataset variations (user and/or architecture dependent)
  - Several parallel programs are executing at the same time

Execution Context & Related Work

Program Must Adapt (Transparently) to the Execution Context

- Target architecture

  (e.g. number of cores, size of caches, accelerator type)
- Dataset properties

  (e.g. dataset size)
- System load

  (e.g. number of running process, processor load, memory access)

Related Work

- Choice based on compile time profiling [Pradelle et al., 2011]

  Possible prediction error, switching not possible during kernel execution
- `LeTSeE` [Pouchet et al., 2008]

  Choses the best version for a given architecture and context
- One application with `VMAD` [Jimborean et al., 2012]

  Select the best version at runtime, hight overhead, user develops and chooses versions
- `EvolveTile` [Tavarageri et al., 2011]

  Perform an dynamic tile size selection
- Number of threads depends on the external workload [Emani et al., 2013]

Our Approach: Switchable Scheduling

In a nutshell:

- Prepare a pertinent set of versions
- Versions have meeting points were it is possible to switch from one to another
- A runtime analysis drives to the "best" version at each meeting point

Properties:

- Static / dynamic approach
- Low overhead
- Benchmarking computations contribute to the final solution:

  no backtrack

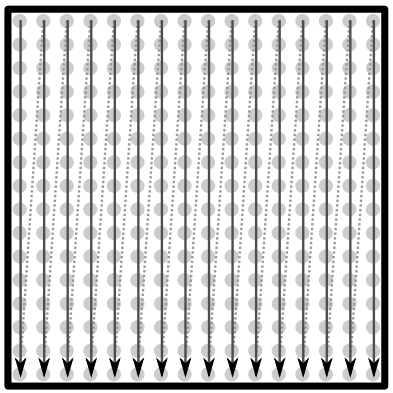
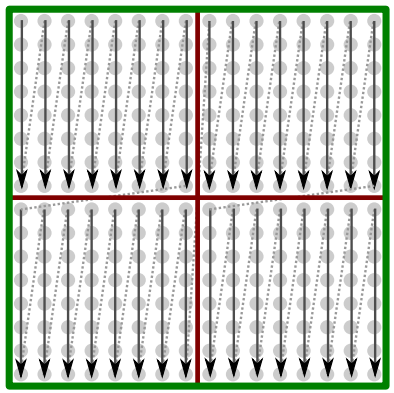
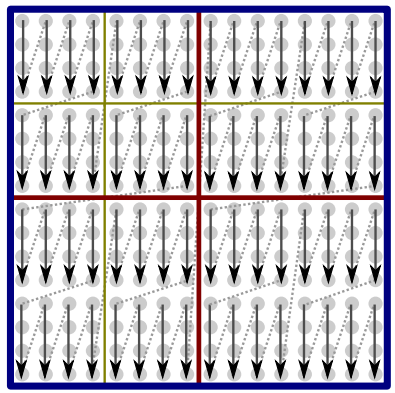
Building Switchable Scheduling

- Leveraging our expertise at generating program versions using the polyhedral model [Pouchet et al., 2007]

- Formal definition:
  - A version is defined as a set of scheduling relations
  - A meeting iteration $\vec{m}$ exists between two versions V and V' iff $\forall S, (\mathcal{T}_s \wedge \vec{x}_S^{out} \preceq \vec{m})_{in} - (\mathcal{T}'_s \wedge \vec{x}_S^{out} \preceq \vec{m})_{in} = \varnothing$

- Pratical building

  First dimensions of the scheduling are either the same, or tiled

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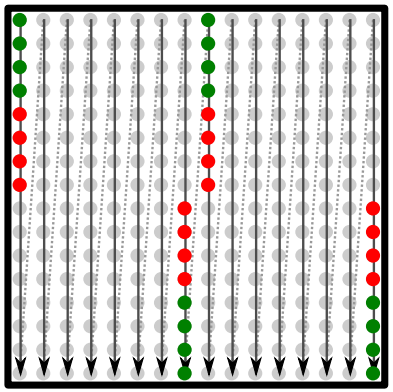
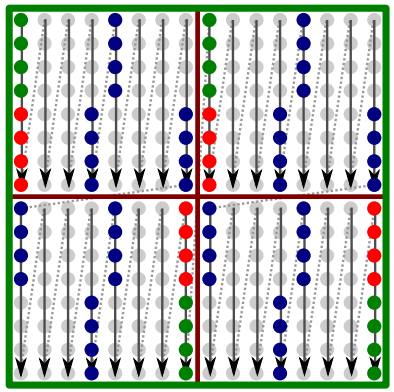
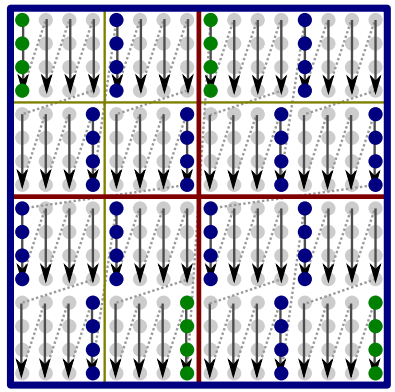
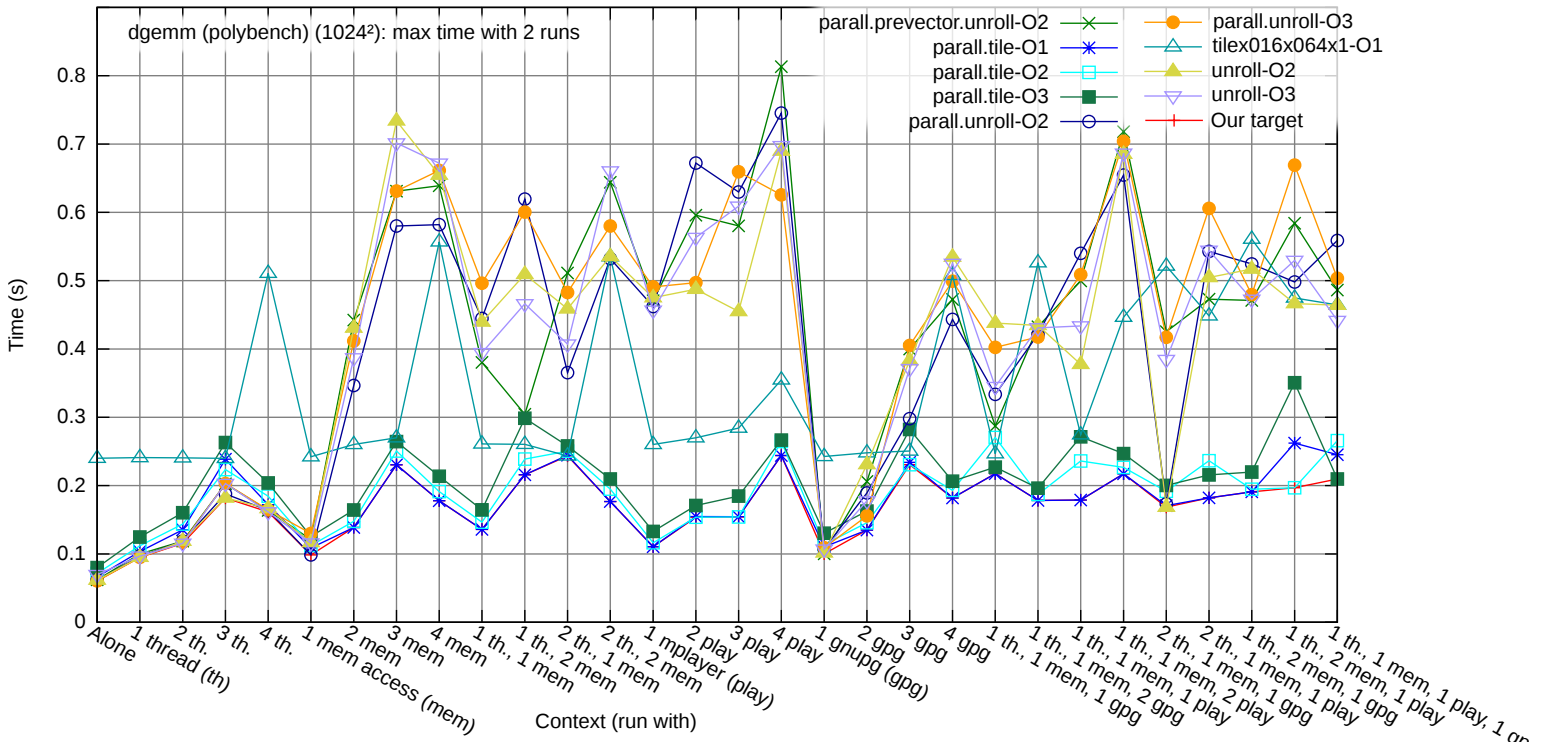




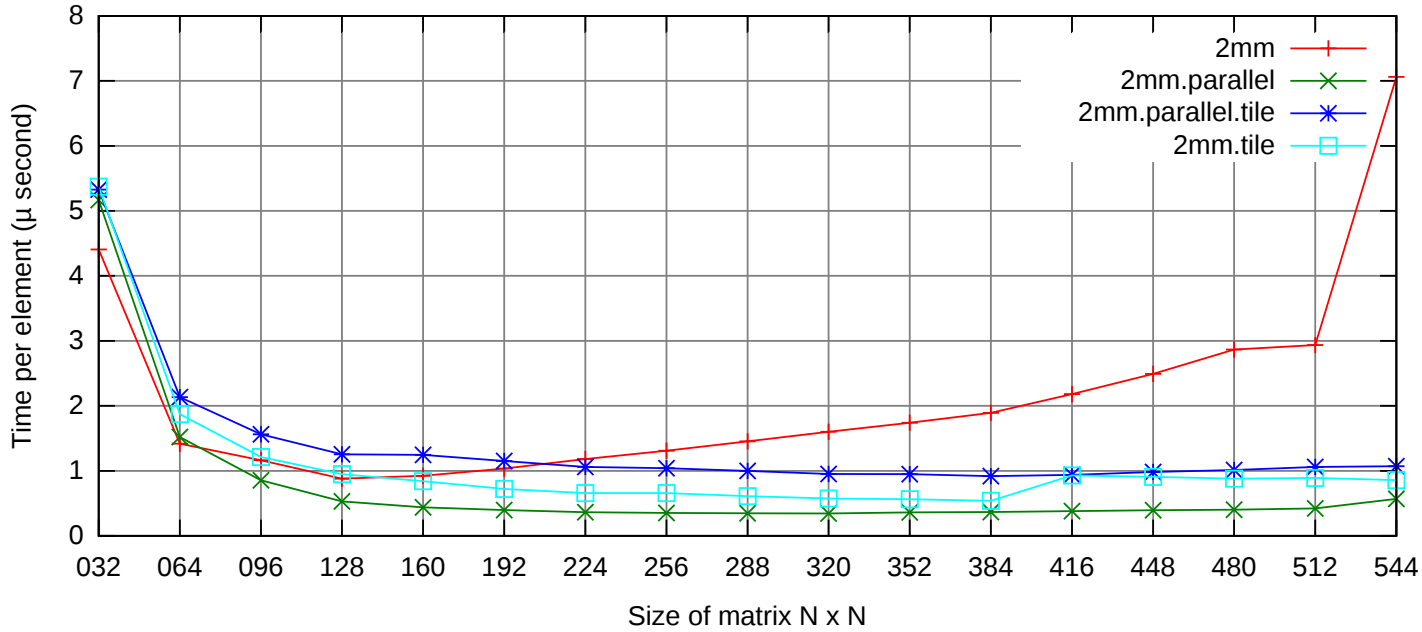
Building Switchable Scheduling: Static Part

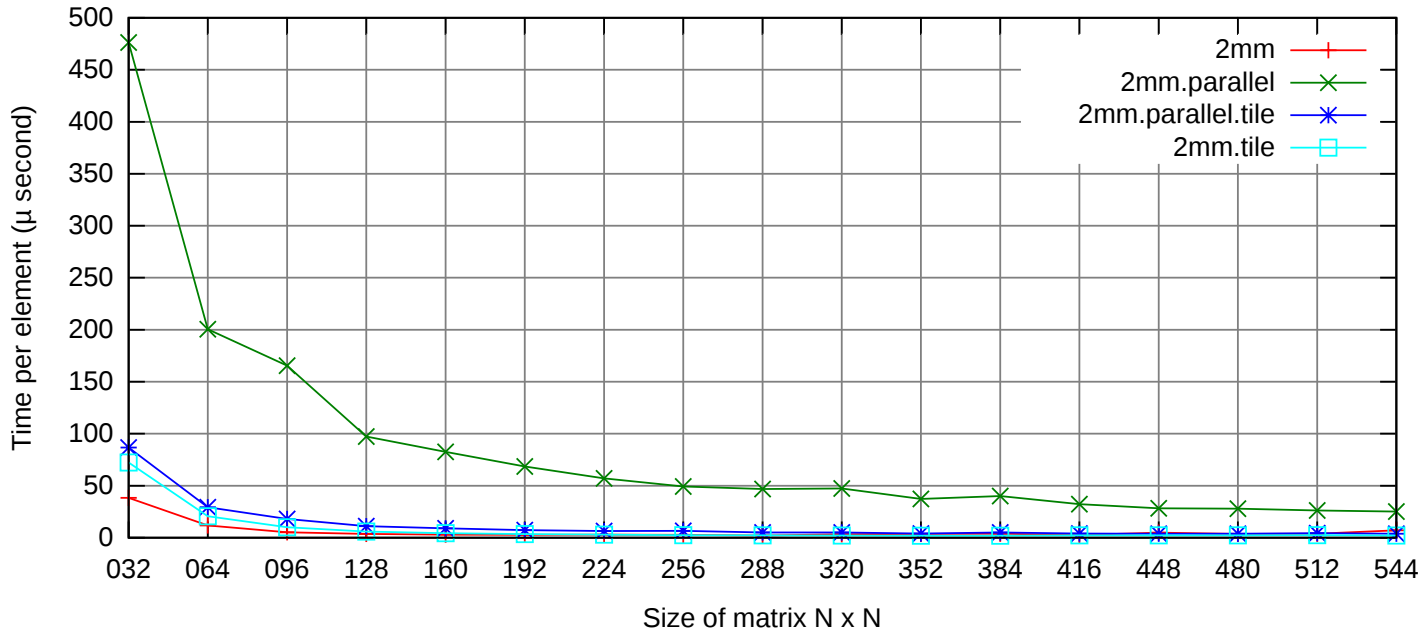
- Pre-selection of versions:
  - Switchable versions building engine based on `PoCC` and `Pluto`
  - Generate versions: sequential, parallel, tiled, etc.
- Pre-selected pertinents contexts
  - Architecture (number of cores, size of caches)
  - Aggressive processor use or/and memory access processes
- Selecting pertinents versions:
  - Execution on artificial contexts
  - Selection of a restricted set of complementary "well-behaving" versions



On Intel Quad Core Q6600 2.4GHz, Linux 3.2, GCC 4.7.2

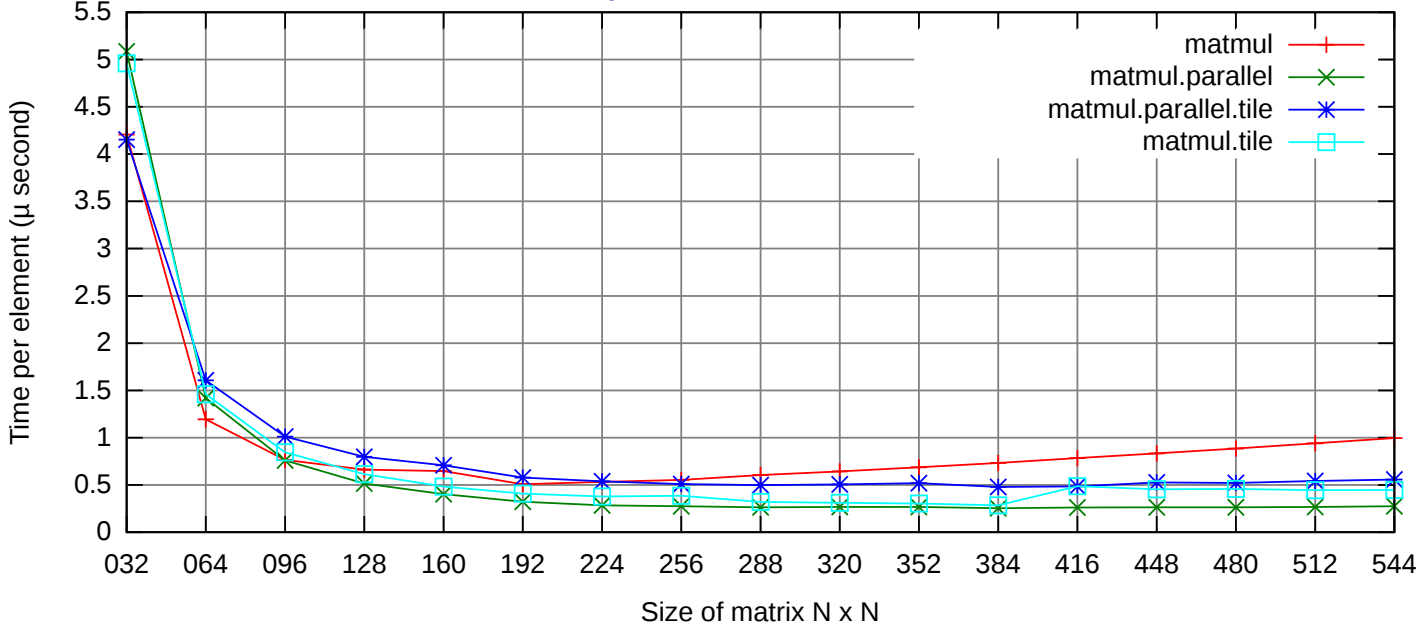
System load context: 2mm without and with strong system load on Xeon[1]

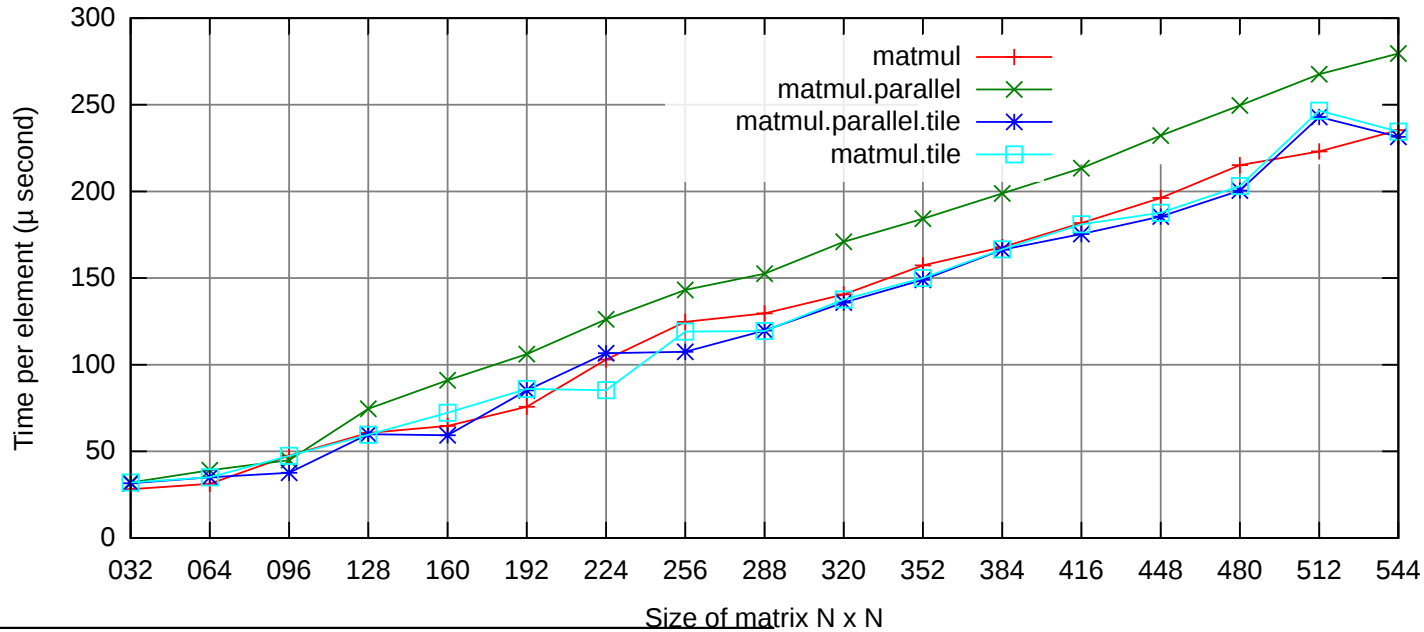




[1] Xeon: Two Intel Xeon CPU E5645 6 cores 2.40GHz, Linux 3.2, GCC 4.6.3

Architecture context: Multiplication matrix on Xeon[2] and ARMv6[3]





[2]Xeon: Two Intel Xeon CPU E5645 6 cores 2.40GHz, Linux 3.2, GCC 4.6.3

[3]ARMv6: LG GW620, ARMv6 1 core 600Mhz, Linux 2.6.32, GCC ARM Linux GNU ABI 4.7.2

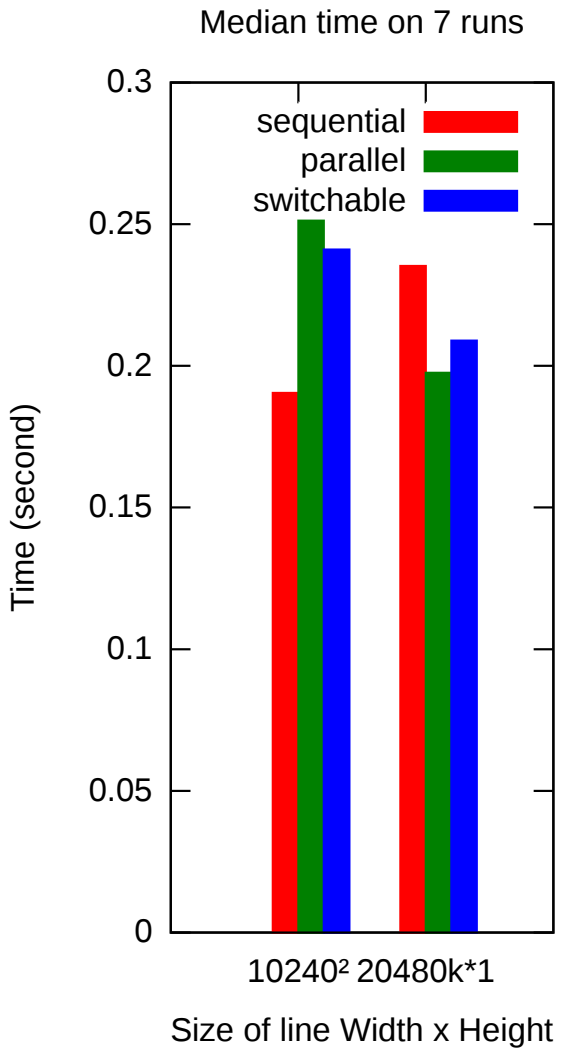
Building Switchable Scheduling: Dynamic Part

(a) selecting a version and switching at runtime

```
while (i < N)
// Sampling
for (v = 0 → versions.size())
    t0 = now()
    // Execute one version
    versions[v](i, i + sample_size)
    t1 = now()
    times[v] = t1 - t0

// Computing
// Execute previous best version
version[min(times)](i, i + compute_size)
```

(b) actual performance on line bench



On Intel Core 2 Quad Q9000 2.00GHz, Linux 3.2, GCC 4.7.2

Conclusion

- Lessons learned so far:
  - Already useful to converge to the best version with respect to the context
  - Low overhead techniques demonstrated essential (but we are not good enough...)
  - Too often, we still get one version to rule them all (no switching after convergence)

- Ongoing work and todo list:
  - More aggressive selection of versions
  - Refinement of switchable version set study at compile time using collective tuning ([Fursin, 2009], `http://ctuning.org`)
  - Refinement of switchable version set at runtime using dynamic tests à la [Pradelle et al., 2011]
  - Background pre-sampling

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All version of benchmark jacobi_2d_imper (867 versions, 56 contexts)
1000
900
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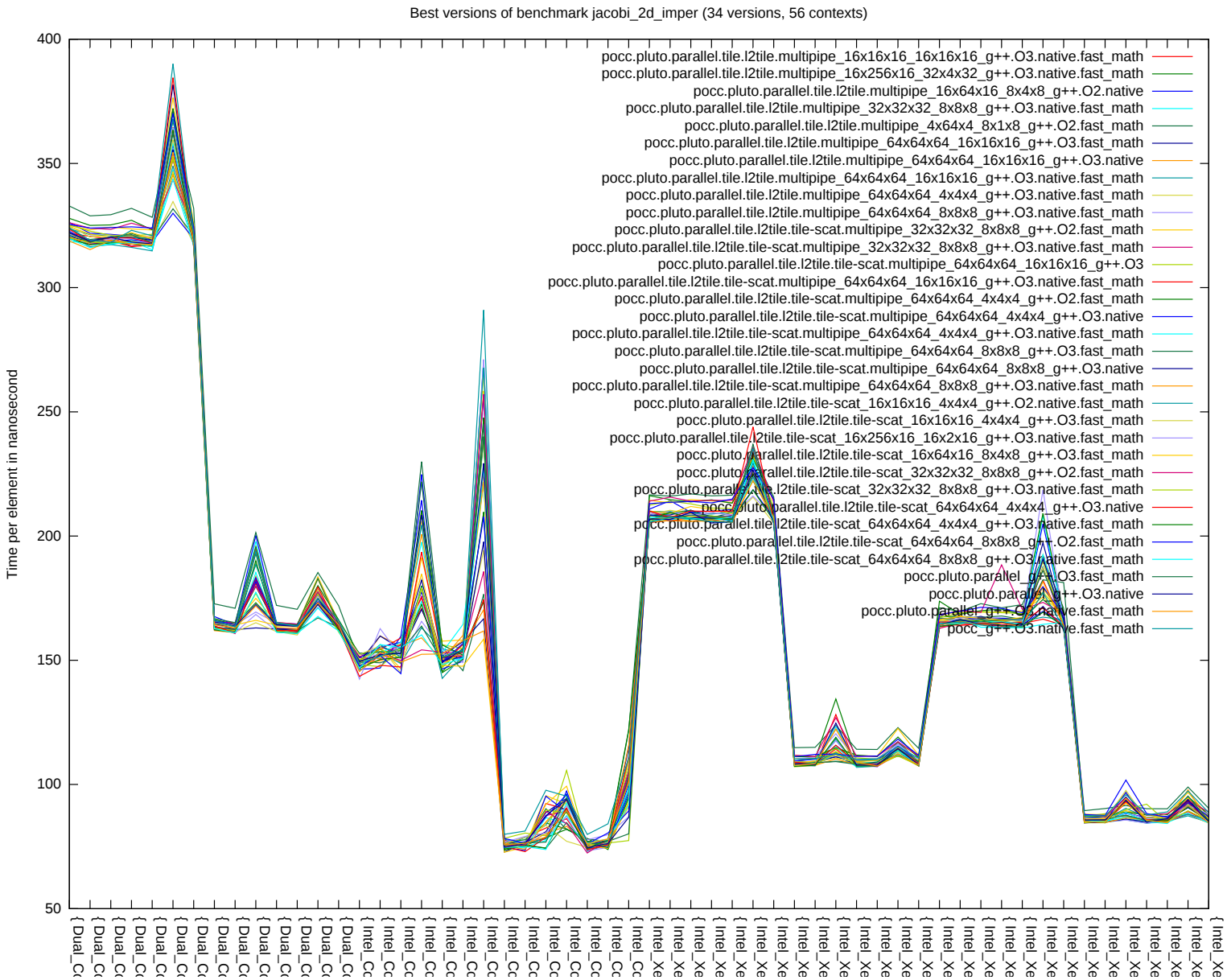
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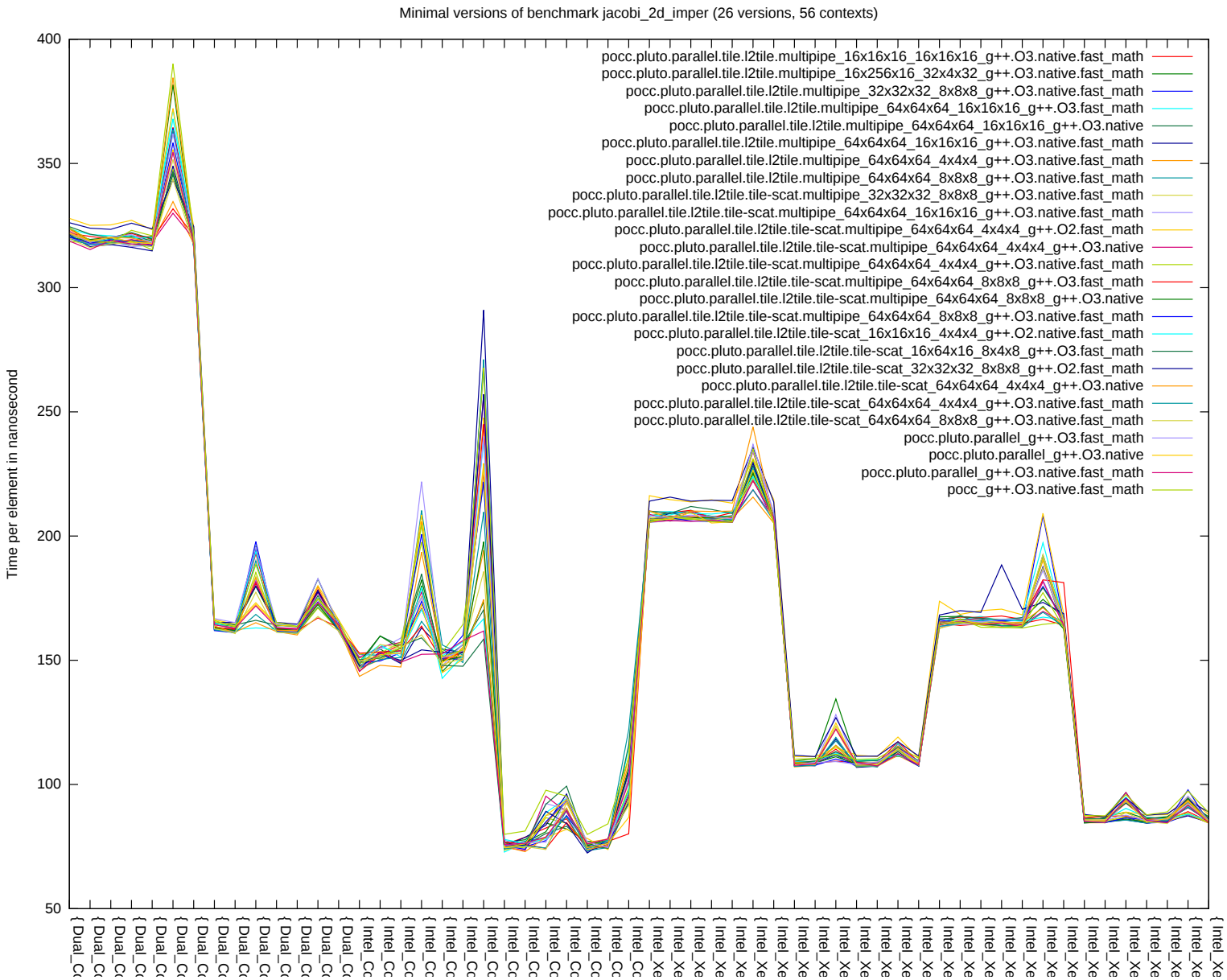
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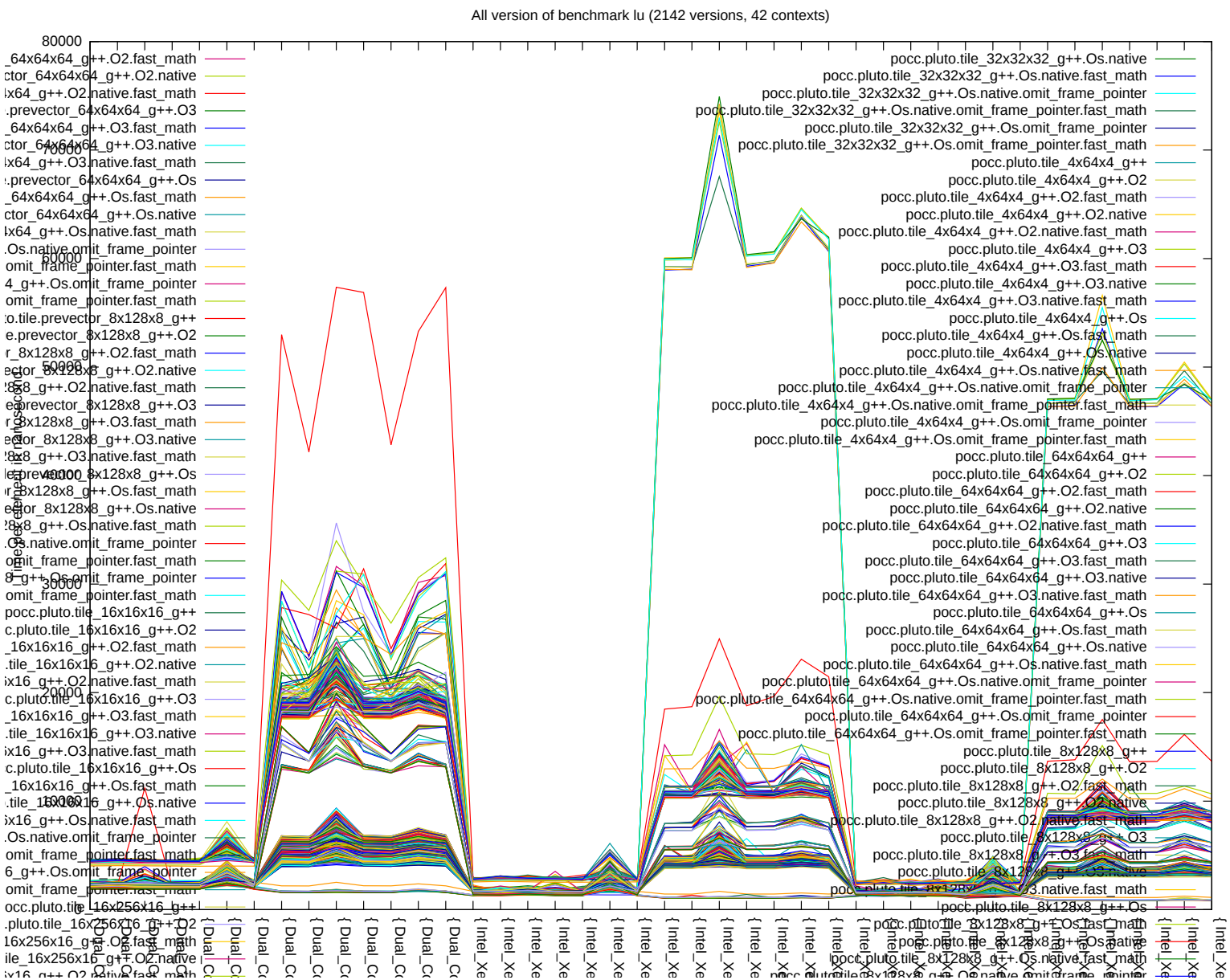
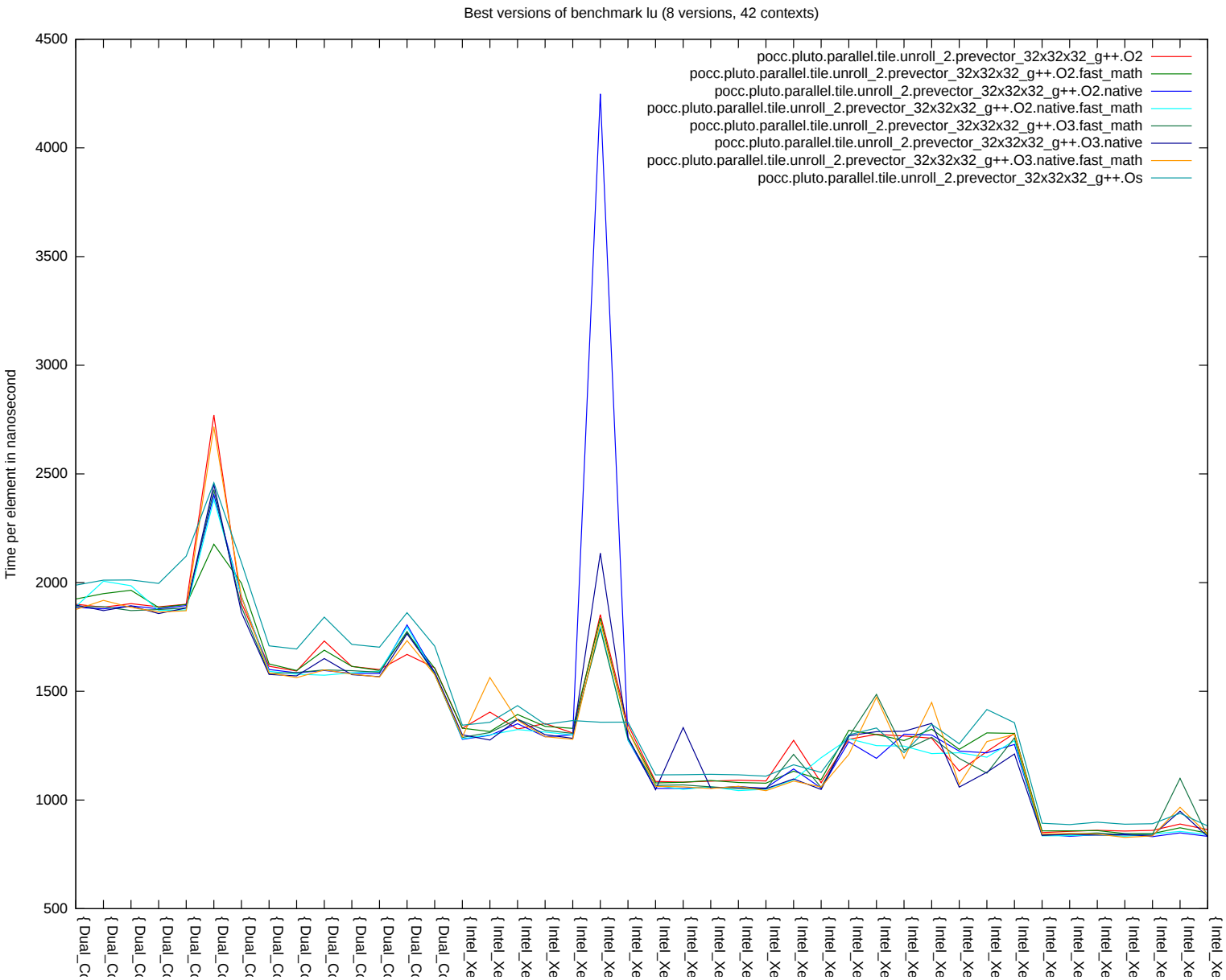
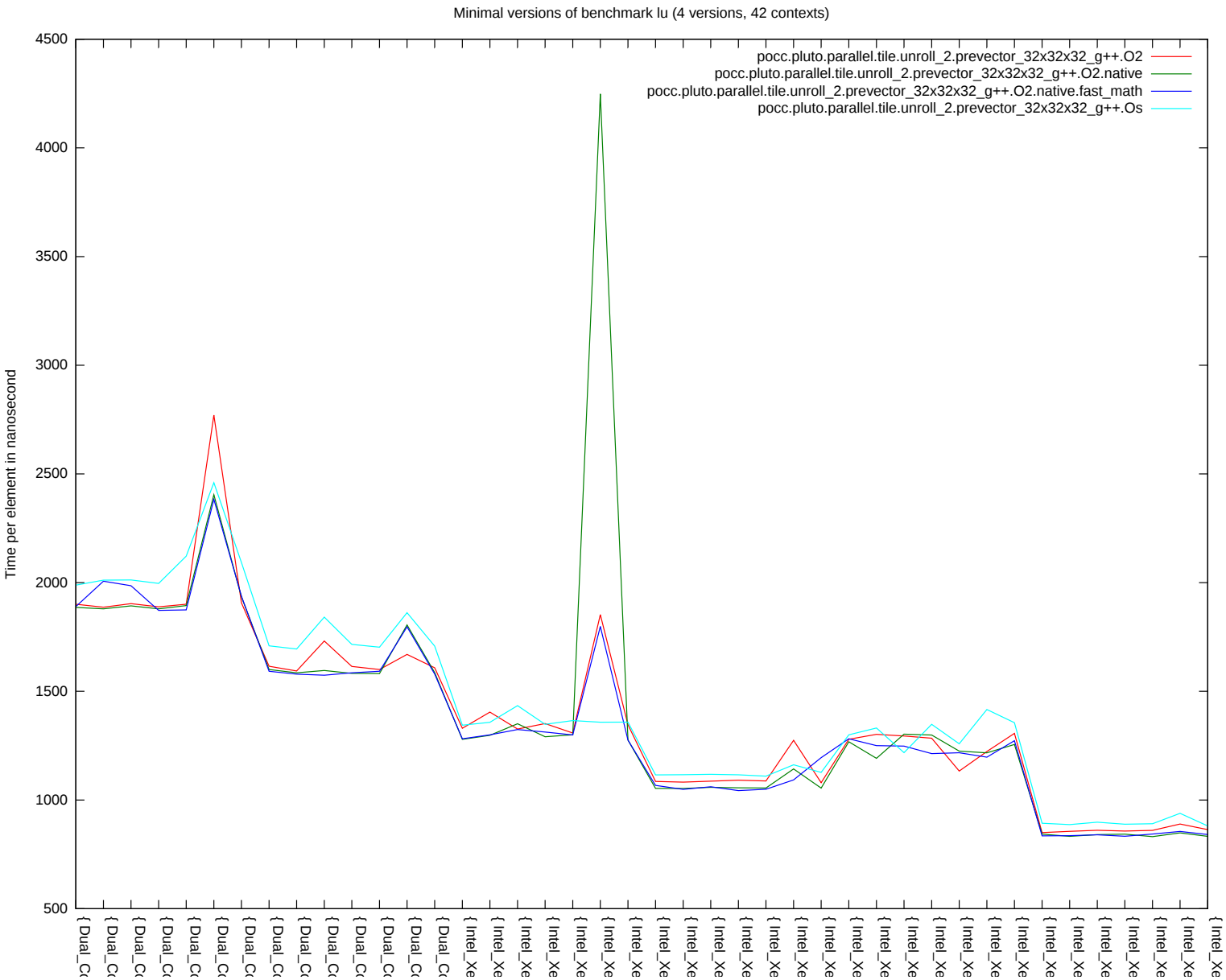
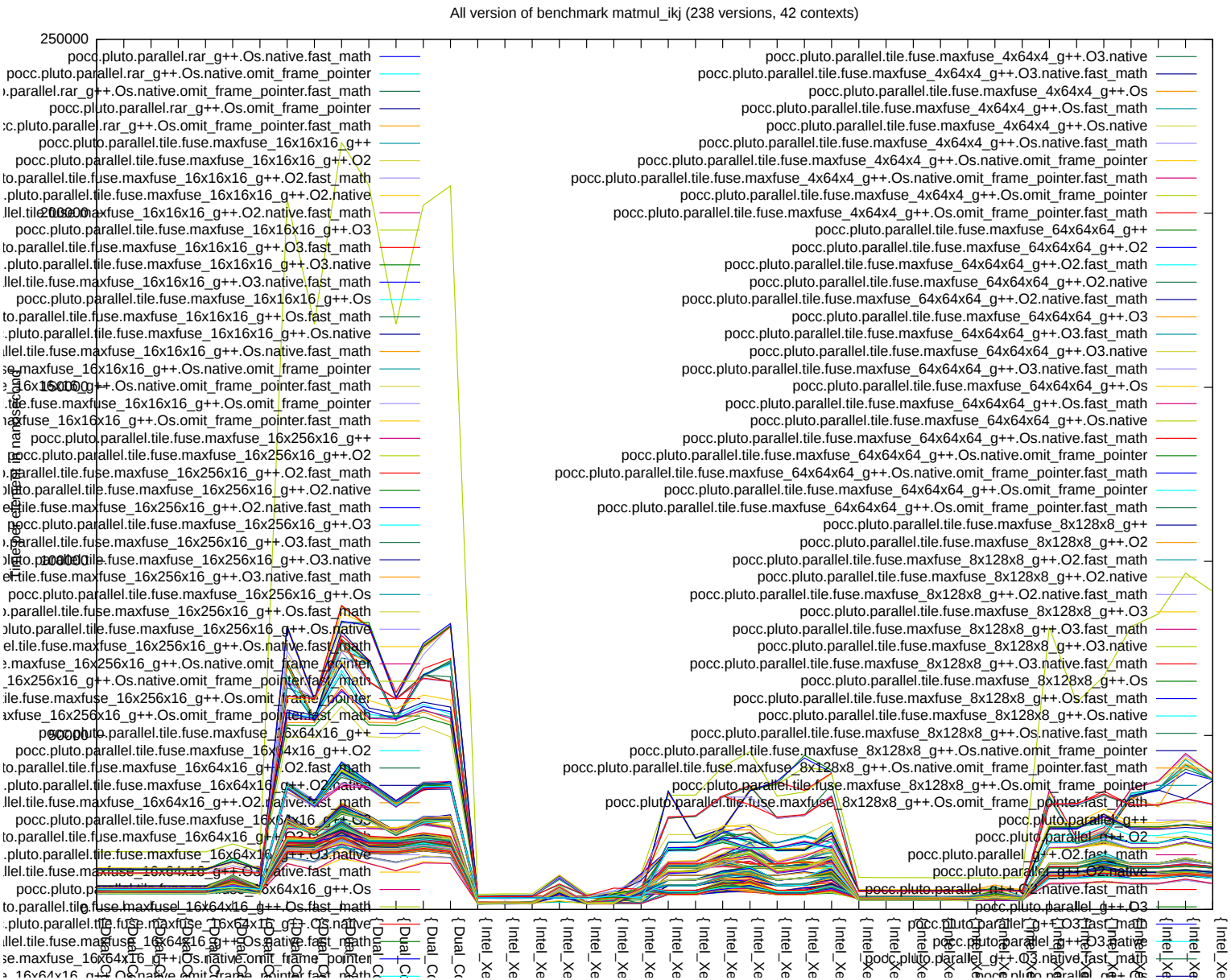
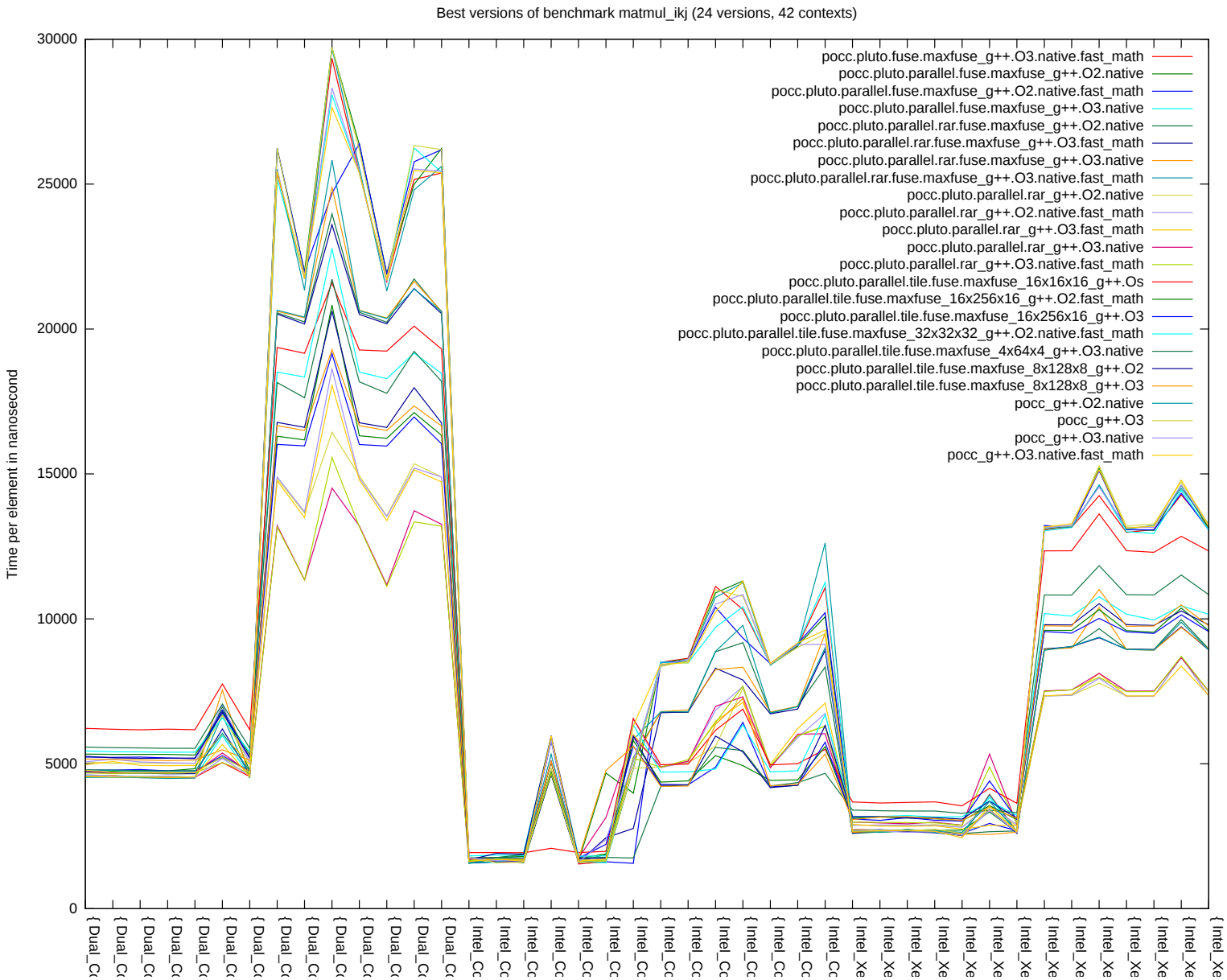
pocc.pluto.parallel.tile.l2tile.tile-scat_16x16x16_4x4x4_g++.O2.native.fast_math
pocc.pluto.parallel.tile.l2tile.tile-scat_16x64x16_8x4x8_g++.O3.fast_math
pocc.pluto.parallel.tile.l2tile.tile-scat_32x32x32_8x8x8_g++.O2.fast_math
pocc.pluto.parallel.tile.l2tile.tile-scat_64x64x64_4x4x4_g++.O3.native
pocc.pluto.parallel.tile.l2tile.tile-scat_64x64x64_4x4x4_g++.O3.native.fast_math
pocc.pluto.parallel.tile.l2tile.tile-scat_64x64x64_8x8x8_g++.O3.native.fast_math
pocc.pluto.parallel_g++.O3.fast_math
pocc.pluto.parallel_g++.O3.native
pocc.pluto.parallel_g++.O3.native.fast_math
pocc_g++.O3.native.fast_math

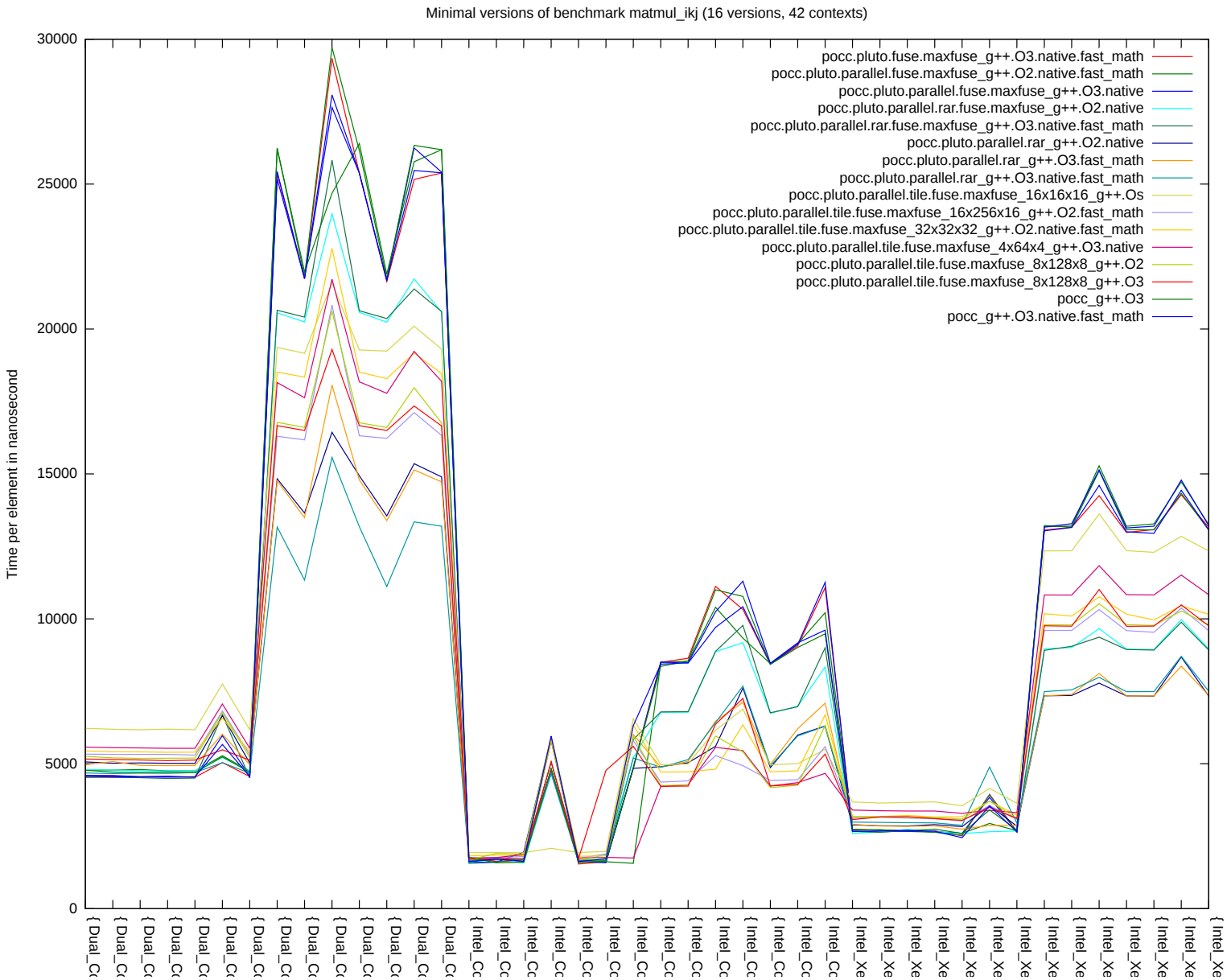

All version of benchmark lu (2142 versions, 42 contexts)
80000
70000
60000
50000
40000
30000
20000
10000
pocc.pluto.tile_32x32x32_g++.Os.native
pocc.pluto.tile_32x32x32_g++.Os.native.fast_math
pocc.pluto.tile_32x32x32_g++.Os.native.omit_frame_pointer
pocc.pluto.tile_32x32x32_g++.Os.native.omit_frame_pointer.fast_math
pocc.pluto.tile_32x32x32_g++.Os.omit_frame_pointer
pocc.pluto.tile_32x32x32_g++.Os.omit_frame_pointer.fast_math
pocc.pluto.tile_4x64x4_g++
pocc.pluto.tile_4x64x4_g++.O2
pocc.pluto.tile_4x64x4_g++.O2.fast_math
pocc.pluto.tile_4x64x4_g++.O2.native
pocc.pluto.tile_4x64x4_g++.O2.native.fast_math
pocc.pluto.tile_4x64x4_g++.O3
pocc.pluto.tile_4x64x4_g++.O3.fast_math
pocc.pluto.tile_4x64x4_g++.O3.native
pocc.pluto.tile_4x64x4_g++.O3.native.fast_math
pocc.pluto.tile_4x64x4_g++.Os
pocc.pluto.tile_4x64x4_g++.Os.fast_math
pocc.pluto.tile_4x64x4_g++.Os.native
pocc.pluto.tile_4x64x4_g++.Os.native.fast_math
pocc.pluto.tile_4x64x4_g++.Os.native.omit_frame_pointer
pocc.pluto.tile_4x64x4_g++.Os.native.omit_frame_pointer.fast_math
pocc.pluto.tile_4x64x4_g++.Os.omit_frame_pointer
pocc.pluto.tile_4x64x4_g++.Os.omit_frame_pointer.fast_math
pocc.pluto.tile_64x64x64_g++
pocc.pluto.tile_64x64x64_g++.O2
pocc.pluto.tile_64x64x64_g++.O2.fast_math
pocc.pluto.tile_64x64x64_g++.O2.native
pocc.pluto.tile_64x64x64_g++.O2.native.fast_math
pocc.pluto.tile_64x64x64_g++.O3
pocc.pluto.tile_64x64x64_g++.O3.fast_math
pocc.pluto.tile_64x64x64_g++.O3.native
pocc.pluto.tile_64x64x64_g++.O3.native.fast_math
pocc.pluto.tile_64x64x64_g++.Os
pocc.pluto.tile_64x64x64_g++.Os.fast_math
pocc.pluto.tile_64x64x64_g++.Os.native
pocc.pluto.tile_64x64x64_g++.Os.native.fast_math
pocc.pluto.tile_64x64x64_g++.Os.native.omit_frame_pointer
pocc.pluto.tile_64x64x64_g++.Os.native.omit_frame_pointer.fast_math
pocc.pluto.tile_64x64x64_g++.Os.omit_frame_pointer
pocc.pluto.tile_64x64x64_g++.Os.omit_frame_pointer.fast_math
pocc.pluto.tile_8x128x8_g++
pocc.pluto.tile_8x128x8_g++.O2
pocc.pluto.tile_8x128x8_g++.O2.fast_math
pocc.pluto.tile_8x128x8_g++.O2.native
pocc.pluto.tile_8x128x8_g++.O2.native.fast_math
pocc.pluto.tile_8x128x8_g++.O3
pocc.pluto.tile_8x128x8_g++.O3.fast_math
pocc.pluto.tile_8x128x8_g++.O3.native
pocc.pluto.tile_8x128x8_g++.O3.native.fast_math
pocc.pluto.tile_8x128x8_g++.Os
pocc.pluto.tile_8x128x8_g++.Os.fast_math
pocc.pluto.tile_8x128x8_g++.Os.native
pocc.pluto.tile_8x128x8_g++.Os.native.fast_math
Dual_C
Intel_Xe


Best versions of benchmark lu (8 versions, 42 contexts)
Time per element in nanosecond
4500
4000
3500
3000
2500
2000
1500
1000
500
pocc.pluto.parallel.tile.unroll_2.prevector_32x32x32_g++.O2
pocc.pluto.parallel.tile.unroll_2.prevector_32x32x32_g++.O2.fast_math
pocc.pluto.parallel.tile.unroll_2.prevector_32x32x32_g++.O2.native
pocc.pluto.parallel.tile.unroll_2.prevector_32x32x32_g++.O2.native.fast_math
pocc.pluto.parallel.tile.unroll_2.prevector_32x32x32_g++.O3.fast_math
pocc.pluto.parallel.tile.unroll_2.prevector_32x32x32_g++.O3.native
pocc.pluto.parallel.tile.unroll_2.prevector_32x32x32_g++.O3.native.fast_math
pocc.pluto.parallel.tile.unroll_2.prevector_32x32x32_g++.Os




All version of benchmark matmul_ikj (238 versions, 42 contexts)
250000
200000
150000
100000
50000
0
Time (cycles)
pocc.pluto.parallel.rar_g++.Os.native.fast_math
pocc.pluto.parallel.rar_g++.Os.native.omit_frame_pointer
pocc.pluto.parallel.rar_g++.Os.native.omit_frame_pointer.fast_math
pocc.pluto.parallel.rar_g++.Os.omit_frame_pointer
pocc.pluto.parallel.rar_g++.Os.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.O2
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.O2.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.O2.native
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.O2.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.O3
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.O3.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.O3.native
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.O3.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os.native
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os.native.omit_frame_pointer
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os.native.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os.omit_frame_pointer
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O2
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O2.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O2.native
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O2.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O3
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O3.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O3.native
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O3.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.Os
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.Os.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.Os.native
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.Os.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.Os.native.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.Os.omit_frame_pointer
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.Os.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.O2
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.O2.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.O2.native
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.O2.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.O3
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.O3.native
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.Os
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.Os.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.Os.native
pocc.pluto.parallel.tile.fuse.maxfuse_16x64x16_g++.Os.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.O3.native
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.O3.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.Os
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.Os.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.Os.native
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.Os.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.Os.native.omit_frame_pointer
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.Os.native.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.Os.omit_frame_pointer
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.Os.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.O2
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.O2.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.O2.native
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.O2.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.O3
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.O3.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.O3.native
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.O3.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.Os
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.Os.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.Os.native
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.Os.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.Os.native.omit_frame_pointer
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.Os.native.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.Os.omit_frame_pointer
pocc.pluto.parallel.tile.fuse.maxfuse_64x64x64_g++.Os.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O2
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O2.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O2.native
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O2.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O3
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O3.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O3.native
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O3.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.Os
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.Os.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.Os.native
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.Os.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.Os.native.omit_frame_pointer
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.Os.native.omit_frame_pointer.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.Os.omit_frame_pointer
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.Os.omit_frame_pointer.fast_math
pocc.pluto.parallel_g++
pocc.pluto.parallel_g++.O2
pocc.pluto.parallel_g++.O2.fast_math
pocc.pluto.parallel_g++.O2.native
pocc.pluto.parallel_g++.O2.native.fast_math
pocc.pluto.parallel_g++.O3
pocc.pluto.parallel_g++.O3.fast_math
pocc.pluto.parallel_g++.O3.native
pocc.pluto.parallel_g++.O3.native.fast_math
Dual_Core_AMD_Opteron_tm_2222_SE
Intel_Xeon_X5570


Best versions of benchmark matmul_ikj (24 versions, 42 contexts)
Time per element in nanosecond
30000
25000
20000
15000
10000
5000
0
pocc.pluto.fuse.maxfuse_g++.O3.native.fast_math
pocc.pluto.parallel.fuse.maxfuse_g++.O2.native
pocc.pluto.parallel.fuse.maxfuse_g++.O2.native.fast_math
pocc.pluto.parallel.fuse.maxfuse_g++.O3.native
pocc.pluto.parallel.rar.fuse.maxfuse_g++.O2.native
pocc.pluto.parallel.rar.fuse.maxfuse_g++.O3.fast_math
pocc.pluto.parallel.rar.fuse.maxfuse_g++.O3.native
pocc.pluto.parallel.rar.fuse.maxfuse_g++.O3.native.fast_math
pocc.pluto.parallel.rar_g++.O2.native
pocc.pluto.parallel.rar_g++.O2.native.fast_math
pocc.pluto.parallel.rar_g++.O3.fast_math
pocc.pluto.parallel.rar_g++.O3.native
pocc.pluto.parallel.rar_g++.O3.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O2.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O3
pocc.pluto.parallel.tile.fuse.maxfuse_32x32x32_g++.O2.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.O3.native
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O2
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O3
pocc_g++.O2.native
pocc_g++.O3
pocc_g++.O3.native
pocc_g++.O3.native.fast_math


Minimal versions of benchmark matmul_ikj (16 versions, 42 contexts)
Time per element in nanosecond
30000
25000
20000
15000
10000
5000
0
pocc.pluto.fuse.maxfuse_g++.O3.native.fast_math
pocc.pluto.parallel.fuse.maxfuse_g++.O2.native.fast_math
pocc.pluto.parallel.fuse.maxfuse_g++.O3.native
pocc.pluto.parallel.rar.fuse.maxfuse_g++.O2.native
pocc.pluto.parallel.rar.fuse.maxfuse_g++.O3.native.fast_math
pocc.pluto.parallel.rar_g++.O2.native
pocc.pluto.parallel.rar_g++.O3.fast_math
pocc.pluto.parallel.rar_g++.O3.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_16x16x16_g++.Os
pocc.pluto.parallel.tile.fuse.maxfuse_16x256x16_g++.O2.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_32x32x32_g++.O2.native.fast_math
pocc.pluto.parallel.tile.fuse.maxfuse_4x64x4_g++.O3.native
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O2
pocc.pluto.parallel.tile.fuse.maxfuse_8x128x8_g++.O3
pocc_g++.O3
pocc_g++.O3.native.fast_math