AutoNUMA

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AutoNUMA components

- knuma_scand
  - If stopped, everything stops
  - Triggers the chain reaction when started
- NUMA hinting page faults
- knuma_migratedN (per node)
- scheduler (CPU follow memory & active idle balancing)
- Memory follow CPU (NUMA hinting page faults)
- False sharing detection (page->autonuma_last_nid)

AutoNUMA data

- sched_autonuma
  - task_struct (per-thread statistical NUMA info)
    - Generated by NUMA hinting page faults
- mm_autonuma
  - mm_struct (per-process statistical NUMA info)
    - Working set or ~RSS
    - Generated by knuma_scand

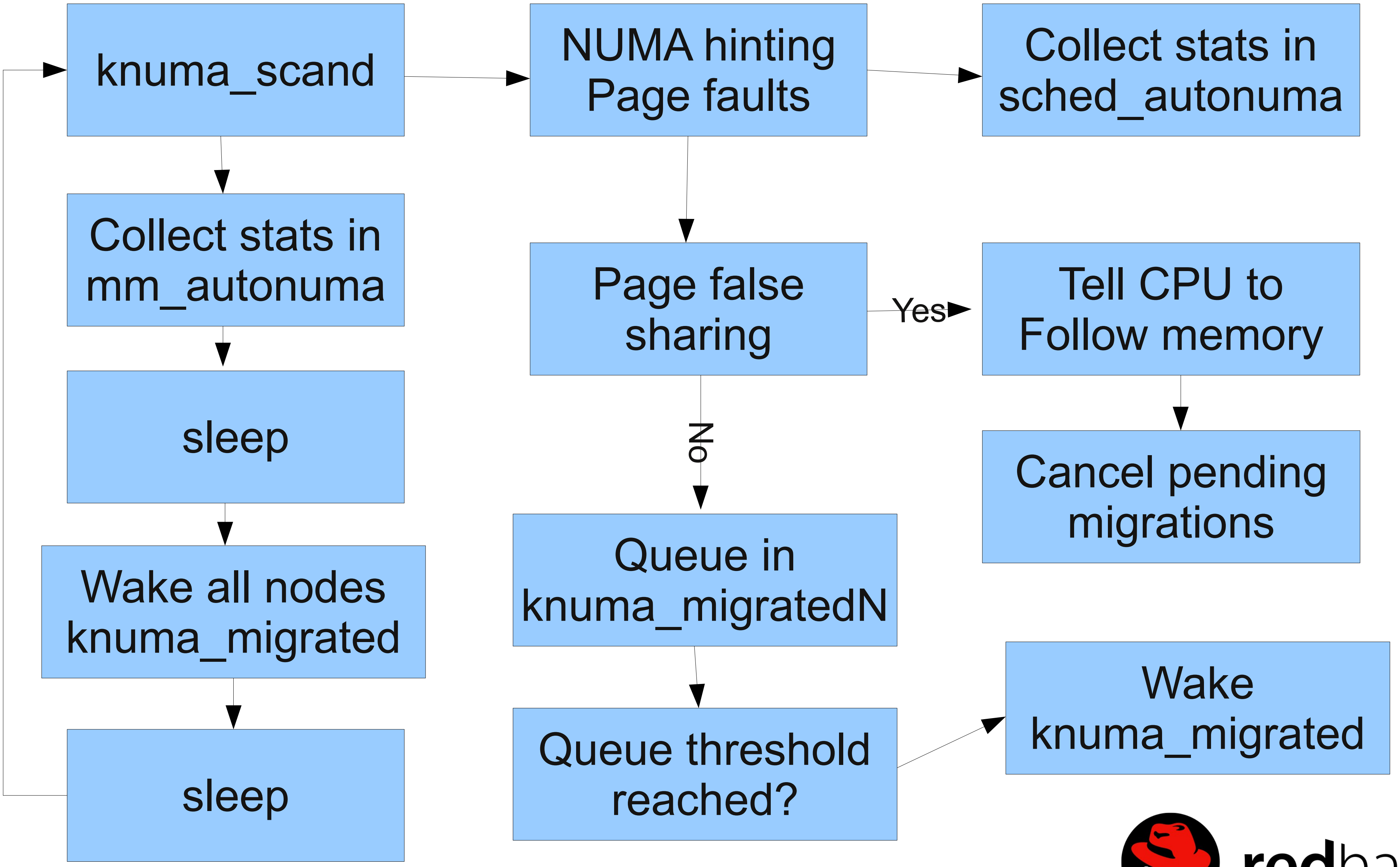
sched_autonuma

```
struct sched_autonuma {
        int autonuma_node;
        bool autonuma_stop_one_cpu;
        unsigned long numa_fault_pass;
        unsigned long numa_fault_tot;
        unsigned long numa_fault[0];
};
```

mm_autonuma

```
struct mm_autonuma {
        struct list_head mm_node;
        struct mm_struct *mm;
        unsigned long numa_fault_tot;
        unsigned long numa_fault_pass;
        unsigned long numa_fault[0];
};
```

AutoNUMA logic



knuma_scand

Collect stats in mm_autonuma

sleep

Wake all nodes knuma_migrated

sleep

NUMA hinting Page faults

Page false sharing

No

Queue in knuma_migratedN

Queue threshold reached?

Collect stats in sched_autonuma

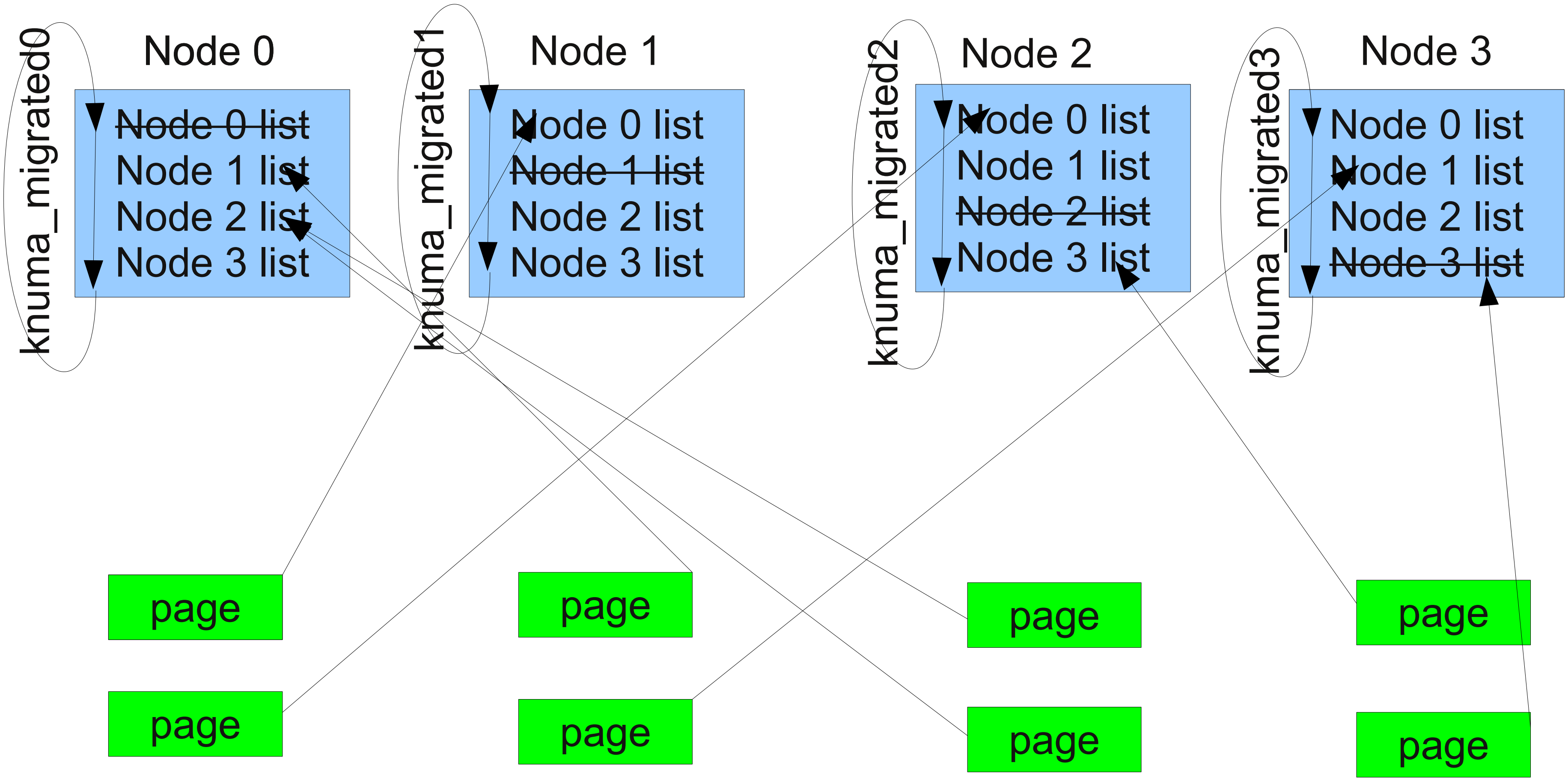
Yes

Tell CPU to Follow memory

Cancel pending migrations

Wake knuma_migrated

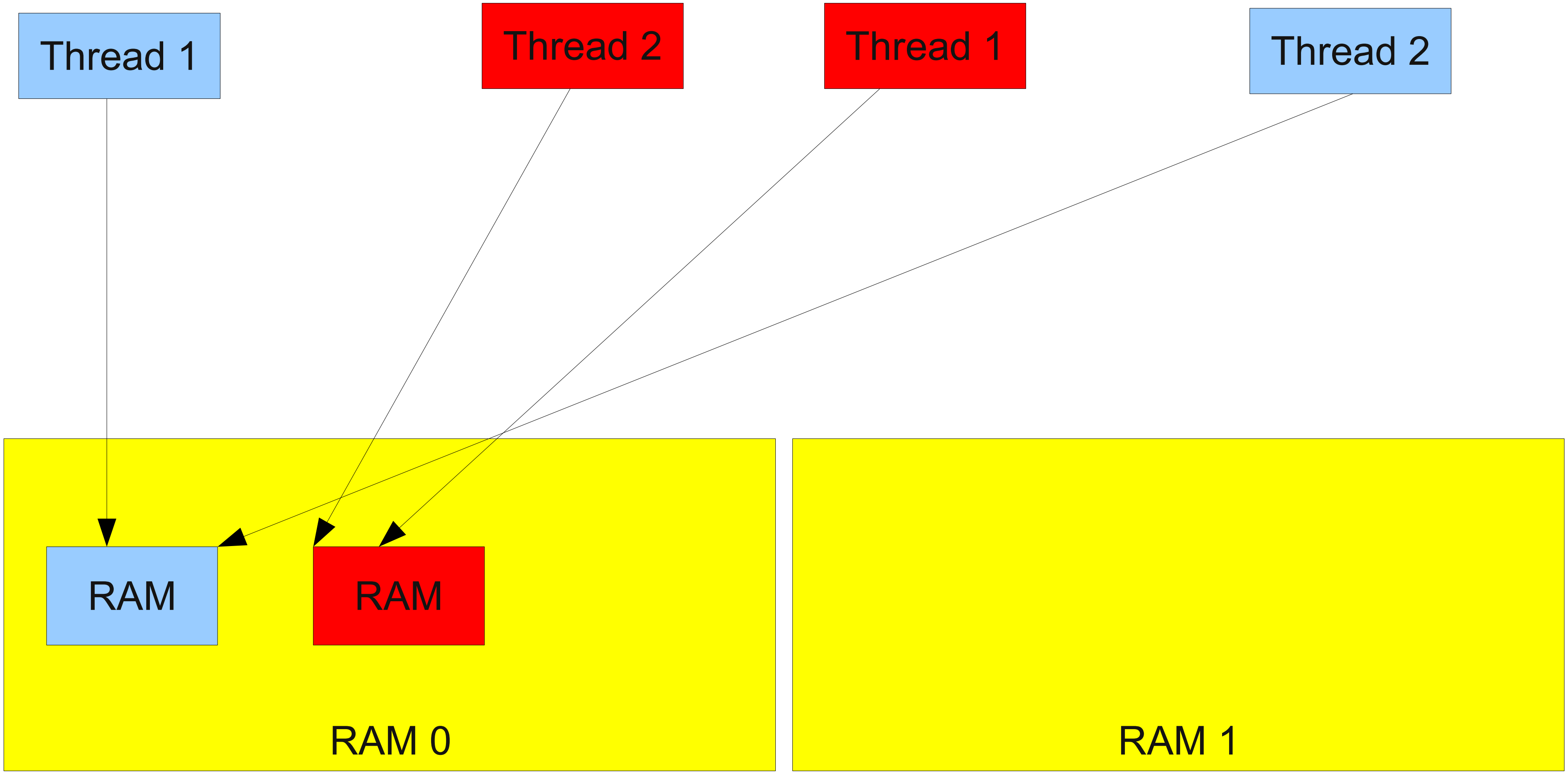
AutoNUMA knuma_migratedN



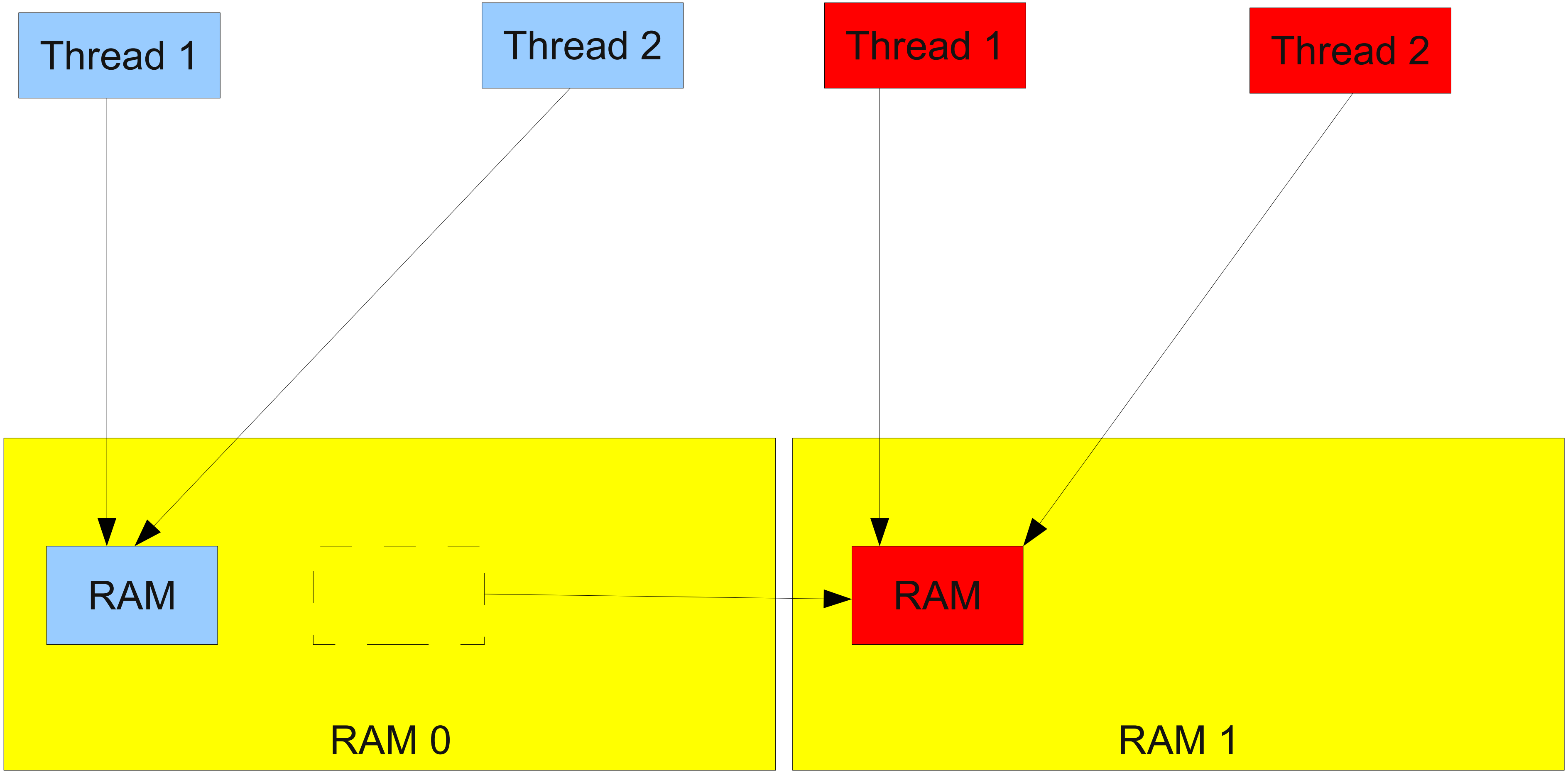
Hardware

- 2 NUMA nodes
- 2 CPU sockets
- 6 CPU cores per socket
- 2 HT CPU threads per core (total 24 CPUs)
- 8GB of RAM per node (total 16 GB of RAM)

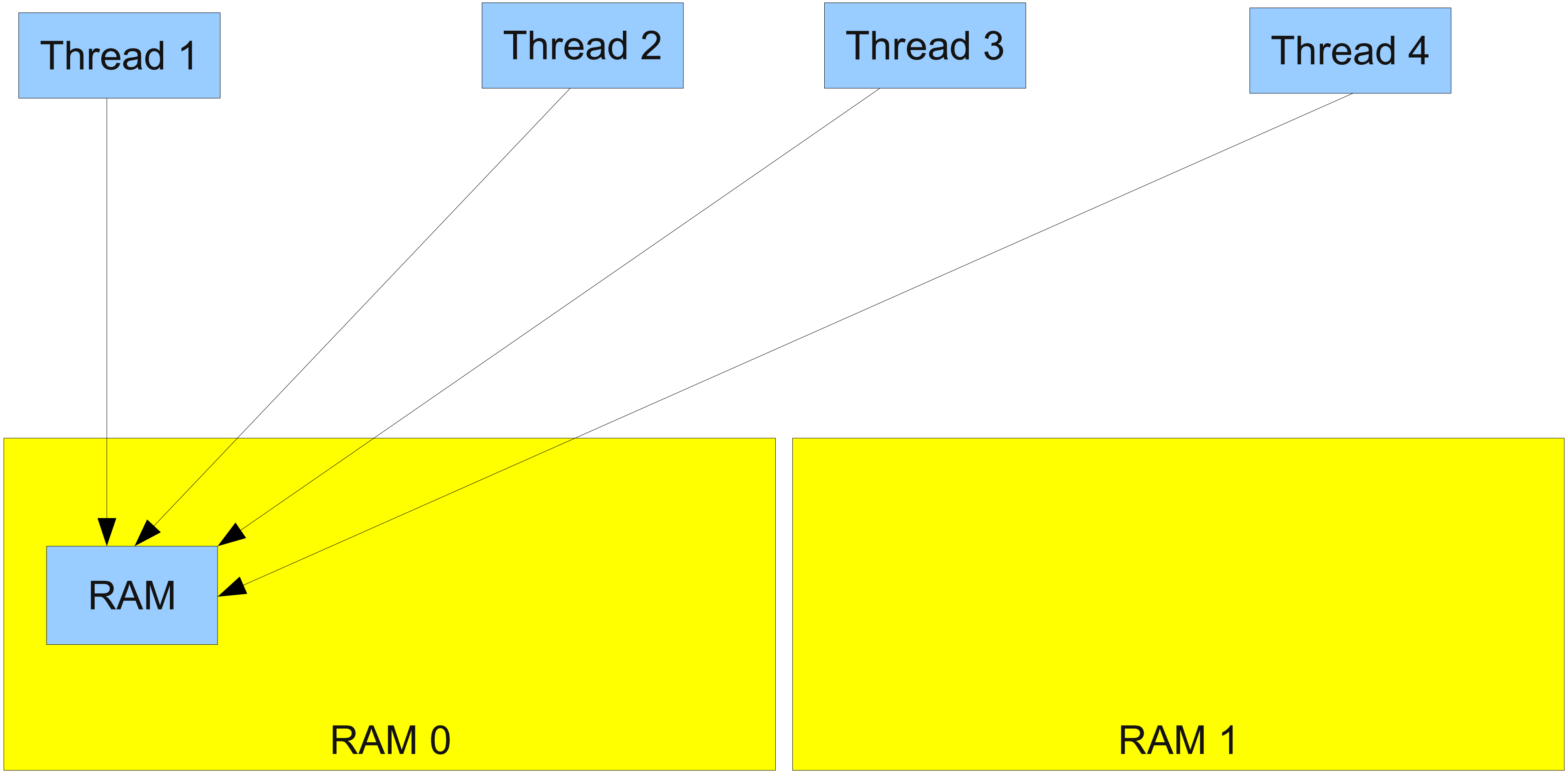
Numa01 (same node)



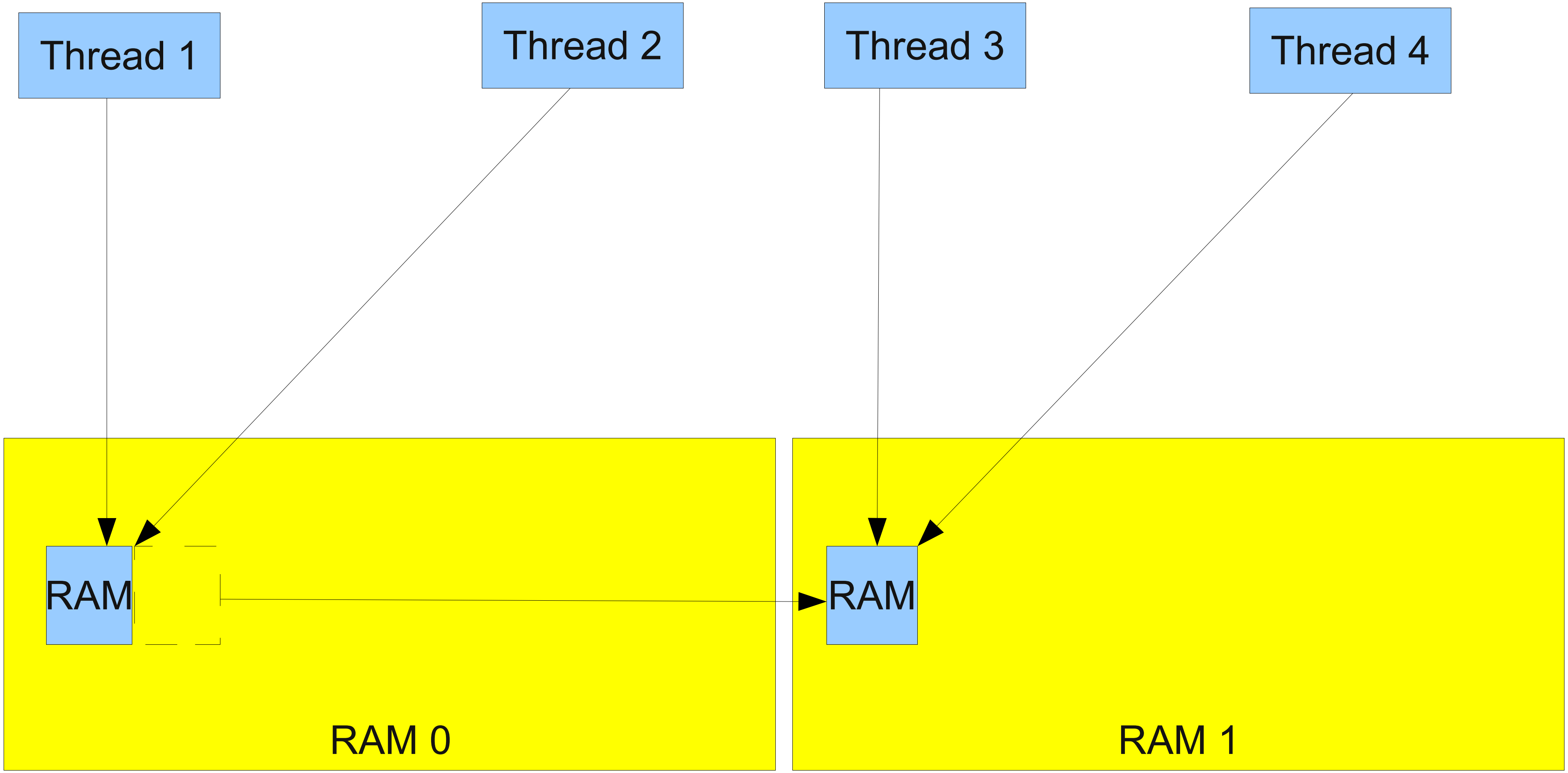
Numa01 (same node)



Numa02

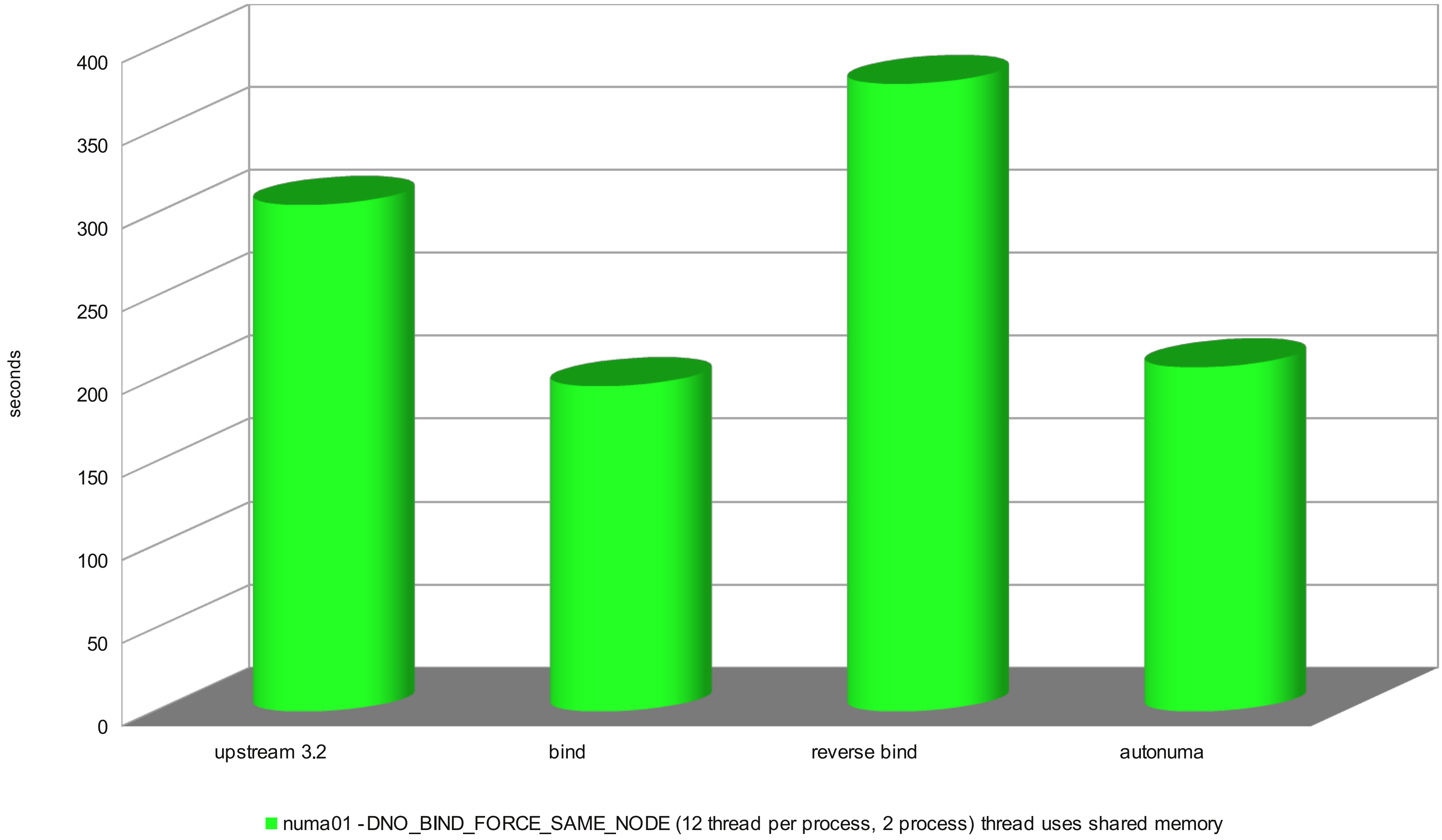


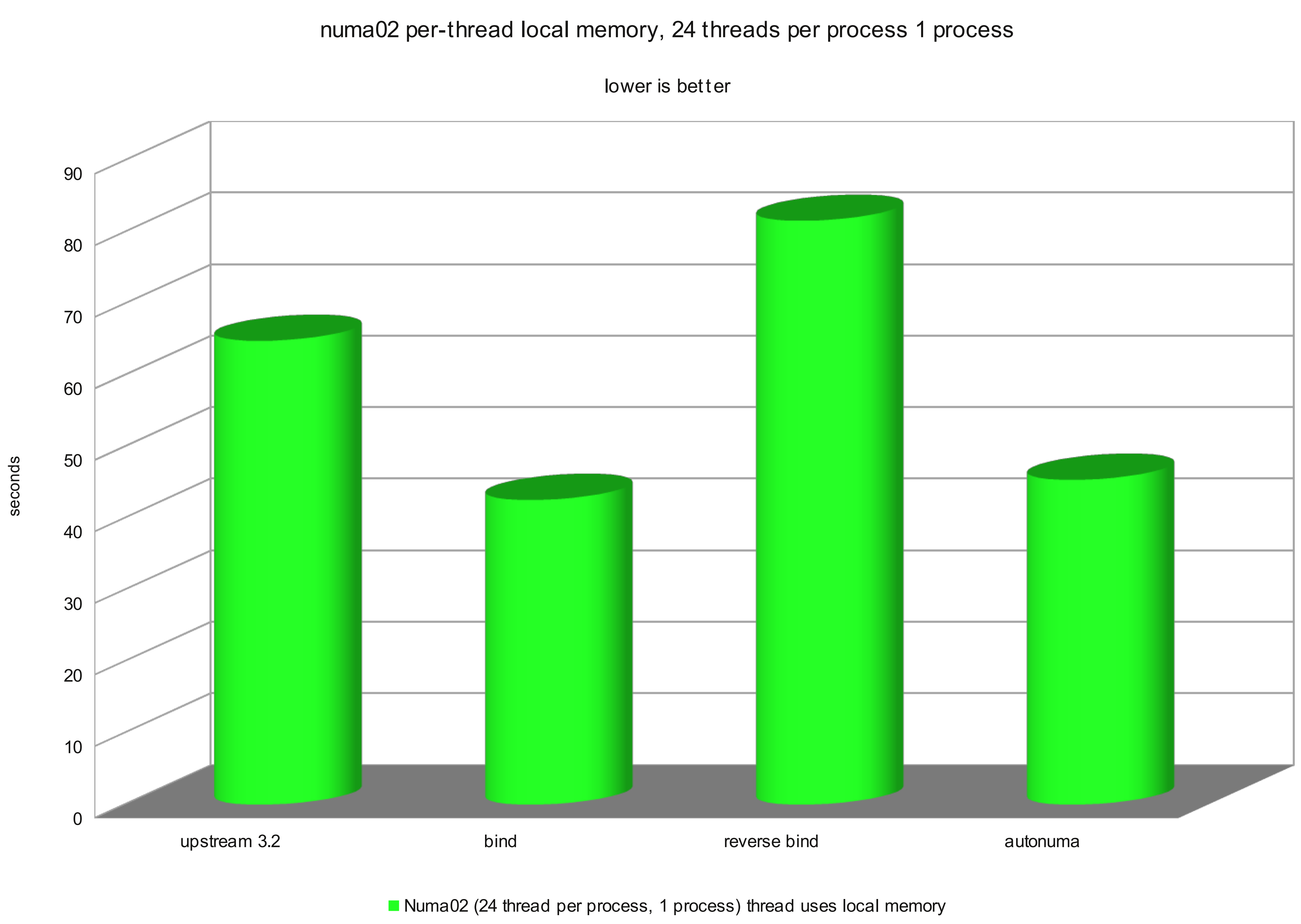
Numa02



numa01 -DNO_BIND_FORCE_SAME_NODE
all threads shares the same memory, 12 threads per process, 2 processes

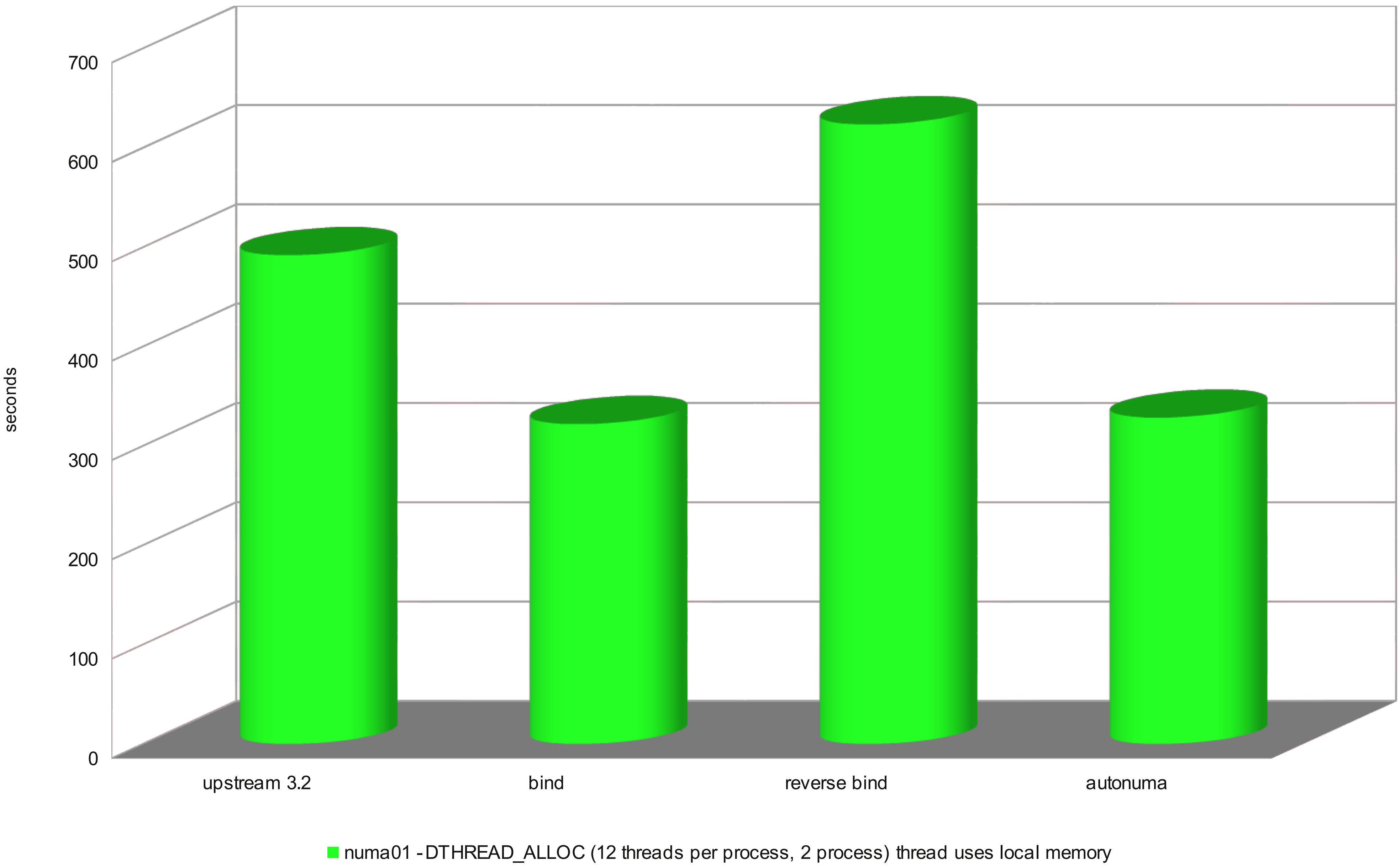
lower is better




numa02 per-thread local memory, 24 threads per process 1 process
lower is better
seconds
90
80
70
60
50
40
30
20
10
0
upstream 3.2
bind
reverse bind
autonuma
🟩 Numa02 (24 thread per process, 1 process) thread uses local memory

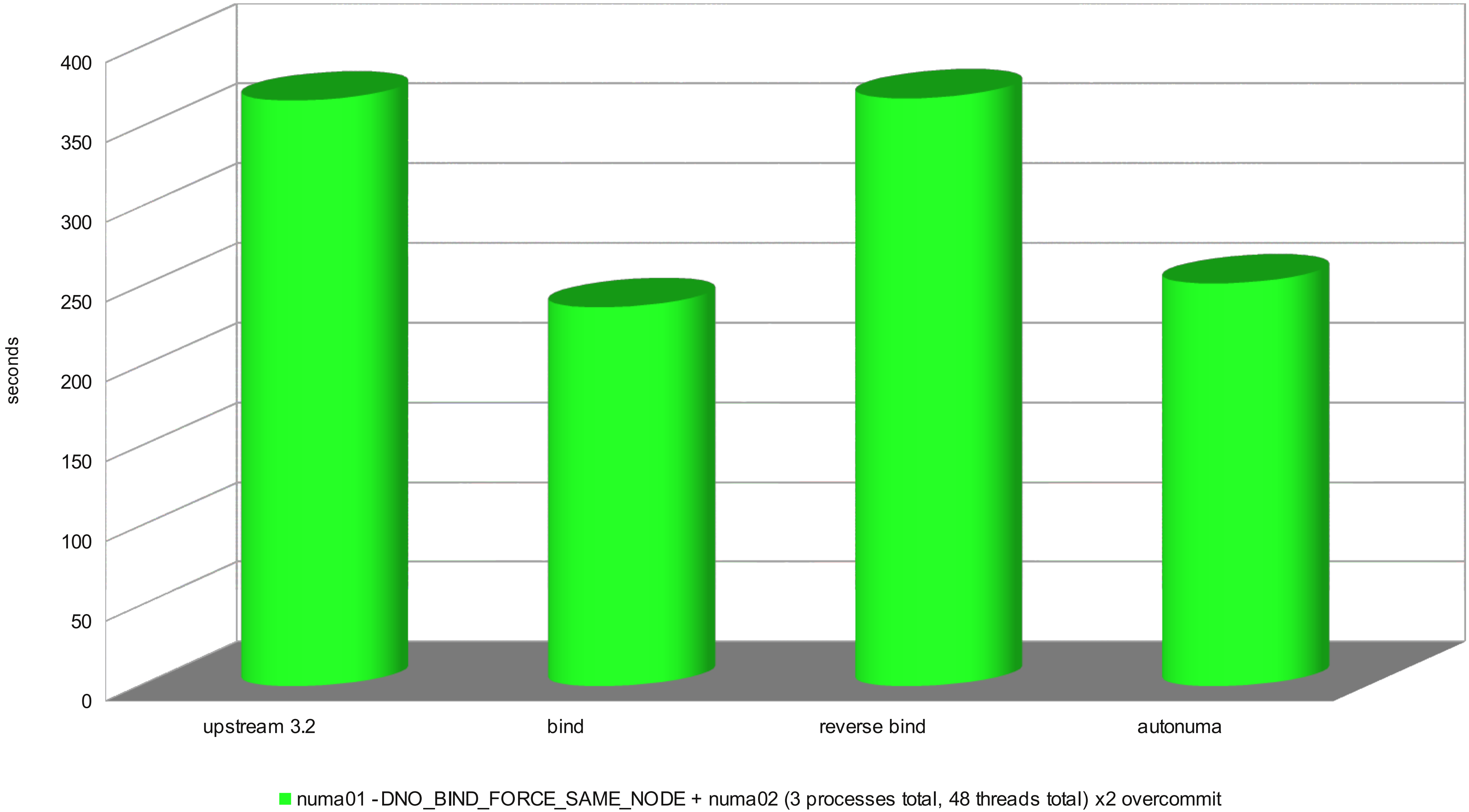
numa01 per-thread local memory, 12 threads per process, 2 processes

lower is better



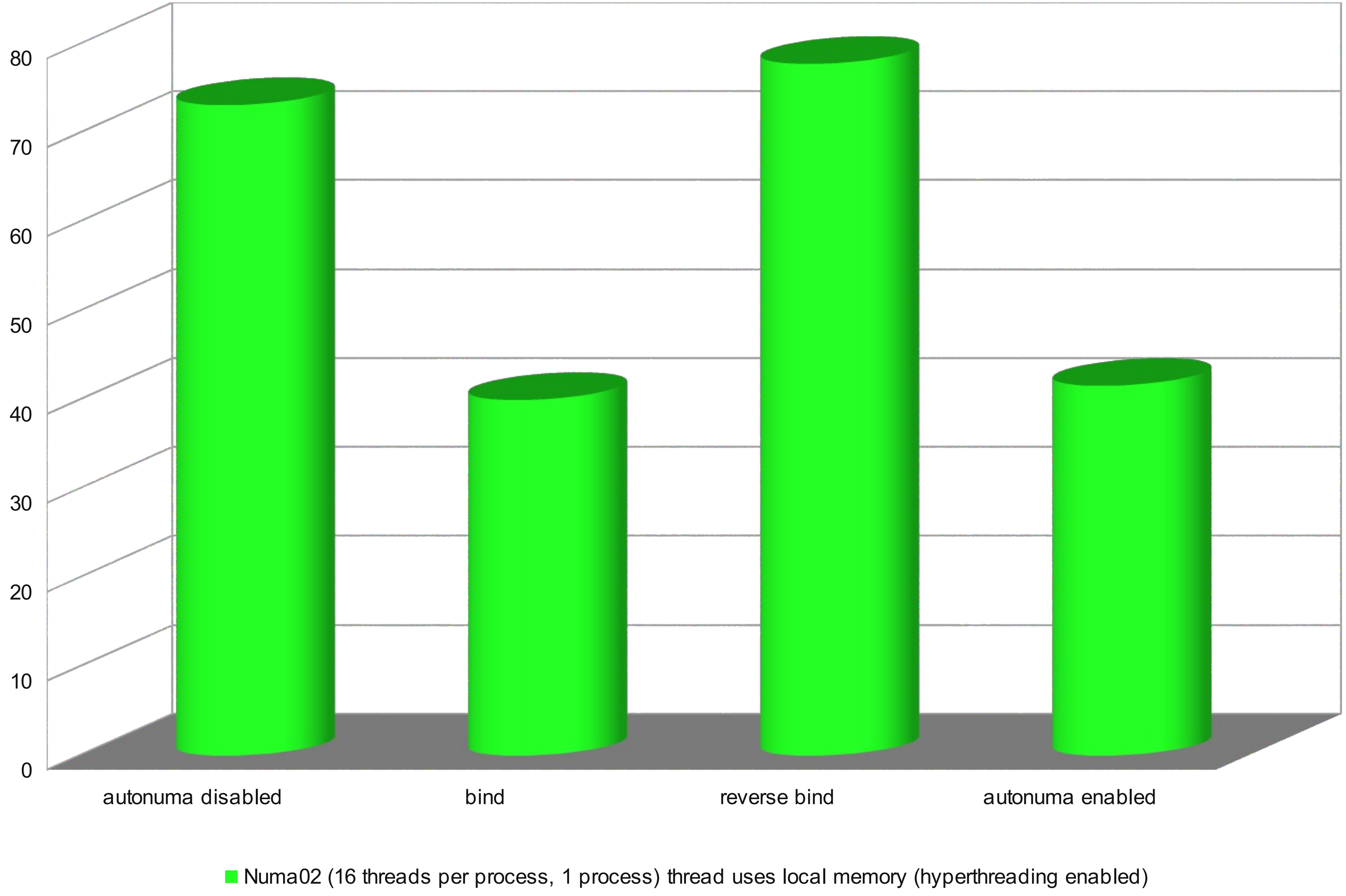
x2 CPU overcommit: numa01 -DNO_BIND_FORCE_SAME_NODE + numa02
24 threads using local memory +
12 threads using shared memory +
12 threads using shared memory

lower is better



numa02 per-thread local memory, 12 threads per process 1 process (HT enabled)
SMT testcase

lower is better



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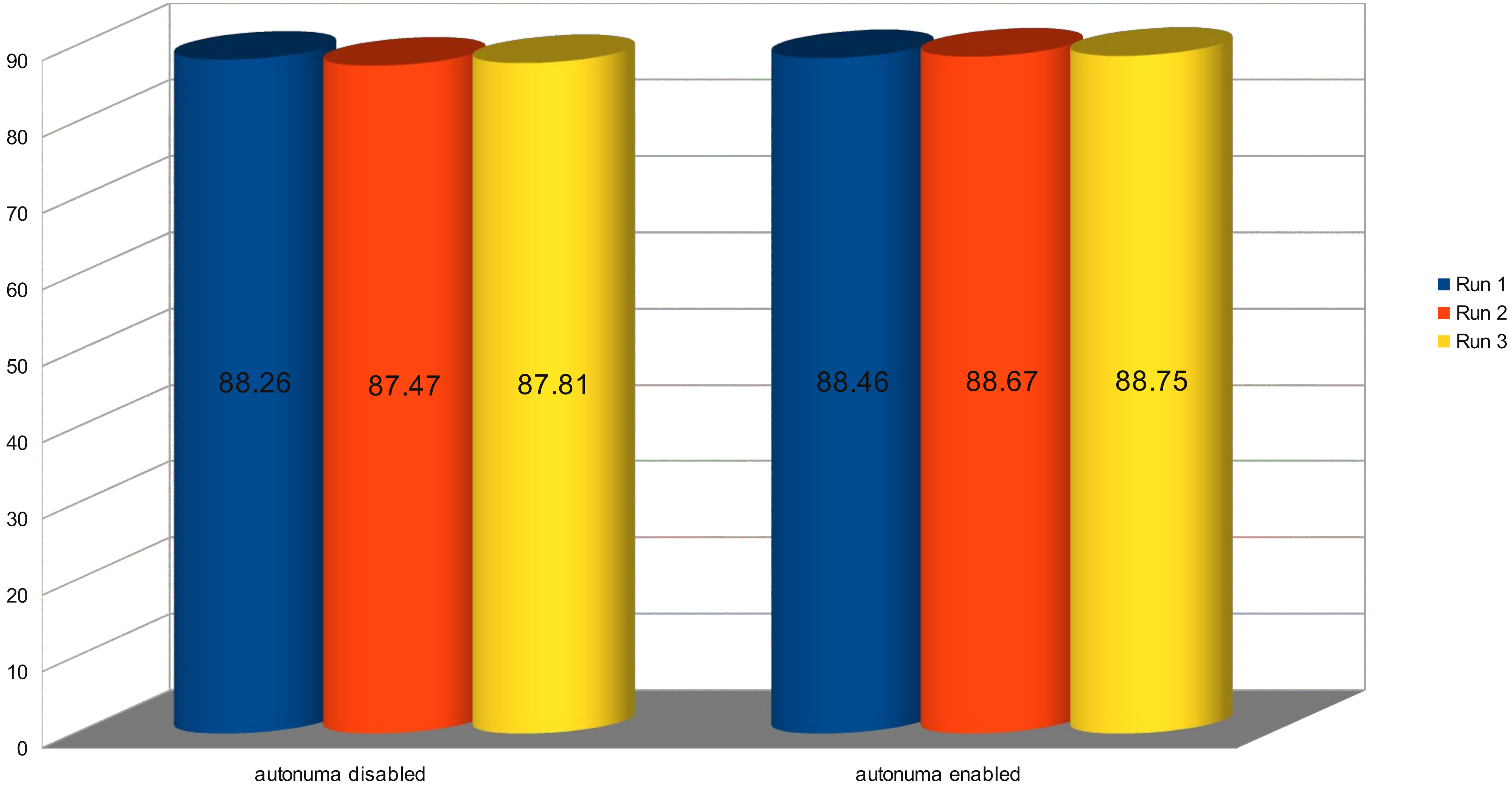
autonuma benchmark (hash 7e4dc3dbbda23b873ca7771b5cf296078e6ed1f7 vs 3.2 upstream default vs 3.2 upstream bind vs upstream inverse bind)				
	autonuma off	bind	reverse bind	autonuma
numa01 -DNO_BIND_FORCE_SAME_NODE (12 thread per process, 2 process) thread uses shared memory	305.36	196.07	378.34	207.47
Numa02 (24 thread per process, 1 process) thread uses local memory	64.81	42.58	81.6	45.39
numa01 -DTHREAD_ALLOC (12 threads per process, 2 process) thread uses local memory	491.88	321.94	623.62	328.43
numa01 -DNO_BIND_FORCE_SAME_NODE + numa02 (3 processes total, 48 threads total) x2 overcommit	366.96	237.43	368.35	252.31

Autonuma SMT fix uses hash 6e7267f0c9973f207a826c6b1fdae4e69c54ea80 Numa02 (16 threads per process, 1 process) thread uses local memory (hyperthreading enabled)	73.16	39.99	77.8	41.59

Kernel build time in seconds on tmpfs (make -j32)
Autonuma enabled includes one knuma_scand pass every 10sec

Worst possible case for AutoNUMA (gcc too short lived)
Average increase in build time 0.88%



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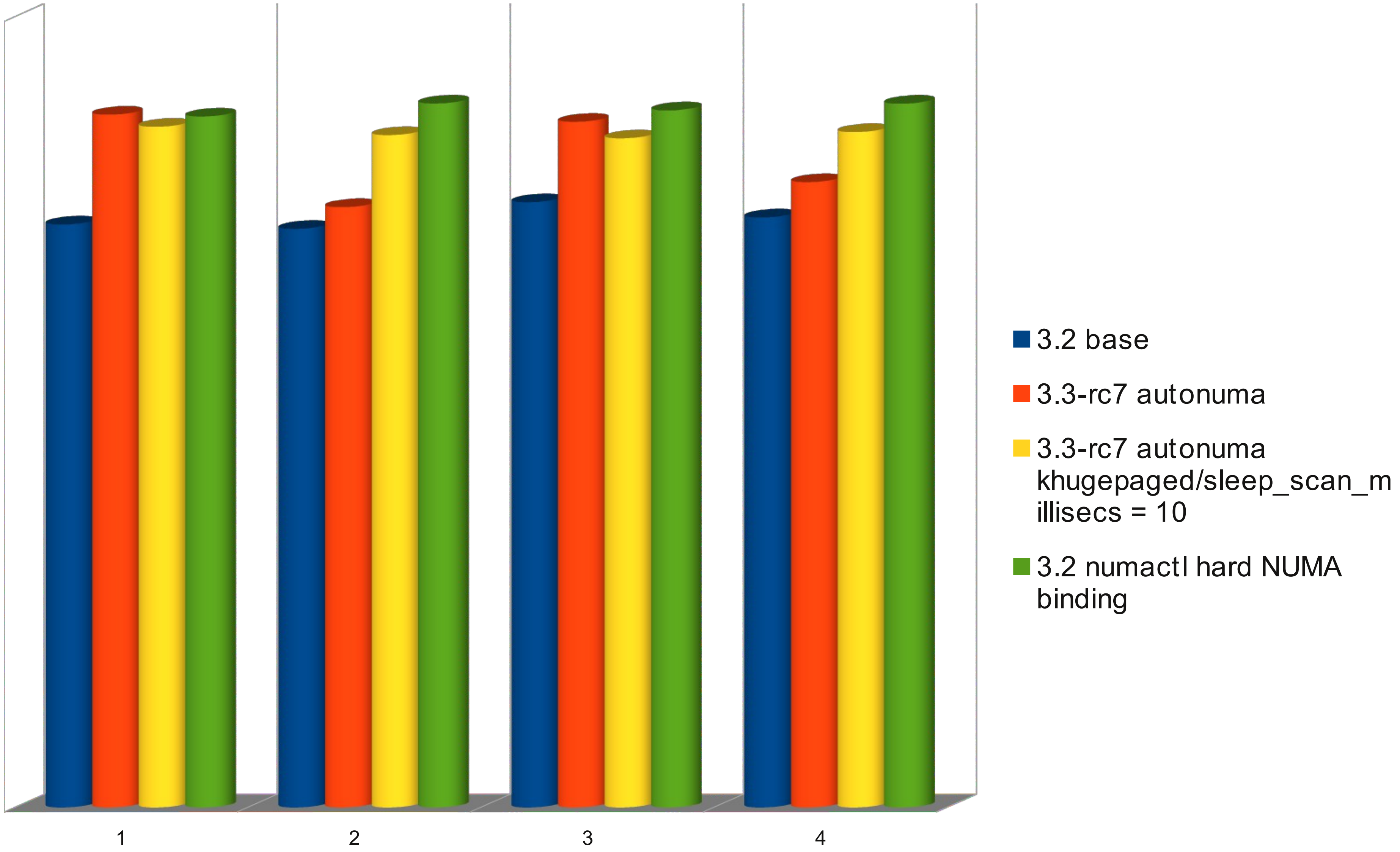
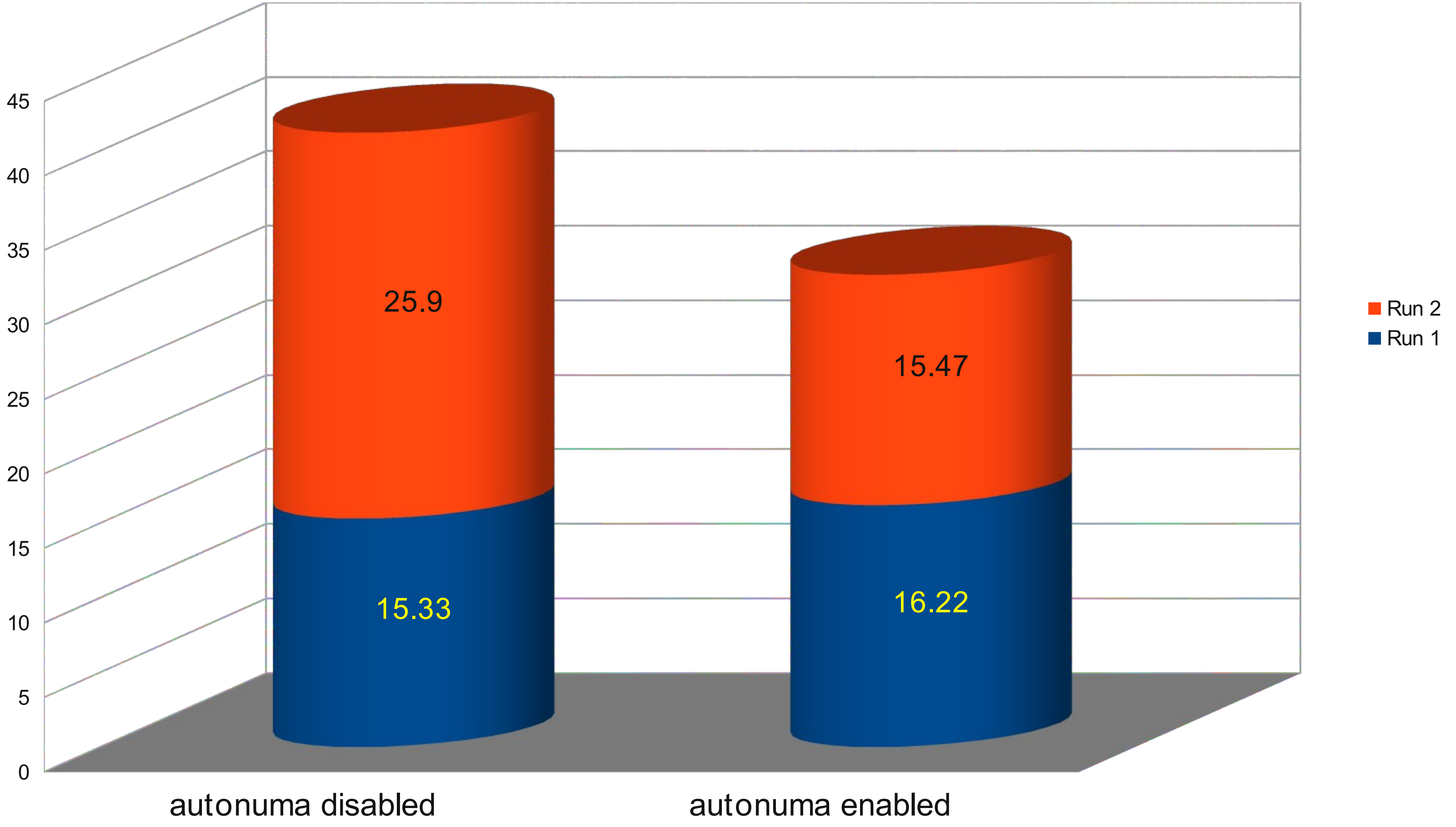
autonuma overhead kernel build tmpfs (make -j32)	Run 1	Run 2	Run 3
autonuma disabled	88.262	87.465	87.807
autonuma enabled	88.459	88.669	88.745

SPECjbb results 2 NUMA nodes, 8 CPUs per node, 16 CPUs total
THP enabled, no virt

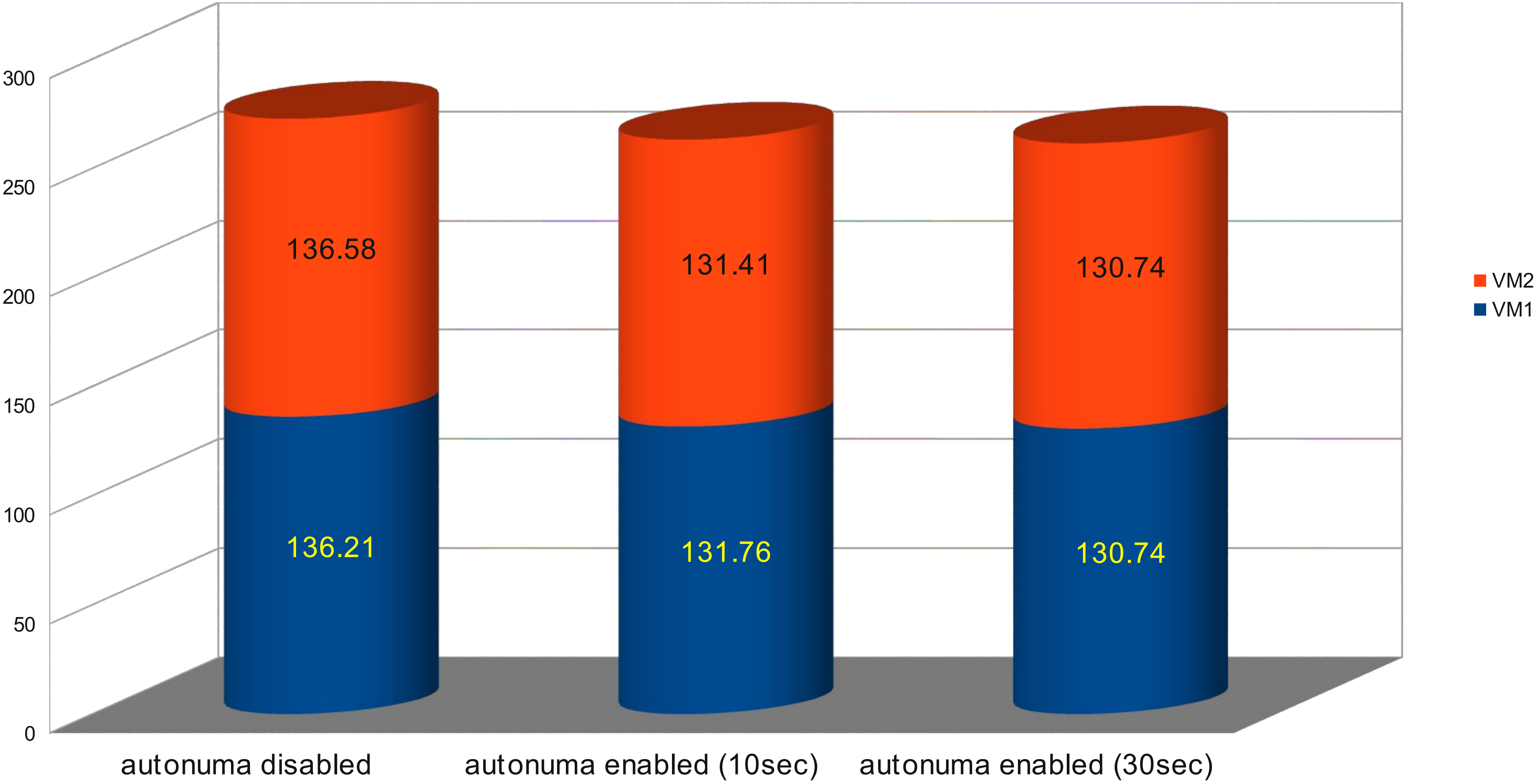


Virt guest "memhog -r100 1g" (autonuma includes 1 knuma_scand pass every 10 sec) KVM host autonuma enabled/disabled, THP enabled Guest VM fits in one host NUMA node



kernel build -j16 in parallel in 2 KVM (both in tmpfs, in a loop started in sync)
Both guest VM fits in one host NUMA node
autonuma/knuma_scand/scan_sleep_pass_millisecs = 5000 | 15000 (10sec | 30sec)

Host autonuma enabled/disabled, THP on, 12 vcpu per guest, 24 CPUs total on host



TODO: THP native migration

- THP native migration
  - SPECjbb results with khugepaged boosted shows the main bottleneck left is lack of THP native migration:
    - One copy in migration
    - One copy in khugepaged to rebuild the hugepage
  - Once this feature is added, AutoNUMA should perform even closer to numactl than it does now with khugepaged boosted (3rd column for every SPECjbb pass).
  - Urgent

TODO: scheduler

- Reduce autonuma_balance invocation frequency
  - Possibly run it from softirq like the load balance
- Possibly integrate it more closely into CFS

TODO: struct page

- Allocate the 24 bytes per page only when booted on NUMA hardware

TODO: document sched/numa.c

- And write proper high level documentation to put in Documentation/vm/autonuma.txt .