ACCELERATING ASYNCHRONOUS EVENTS FOR HYBRID PARALLEL RUNTIMES

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HOBBES

xstack.sandia.gov/hobbes

ILLINOIS INSTITUTE OF TECHNOLOGY

HOBBES

xstack.sandia.gov/hobbes

nautilus.halek.co

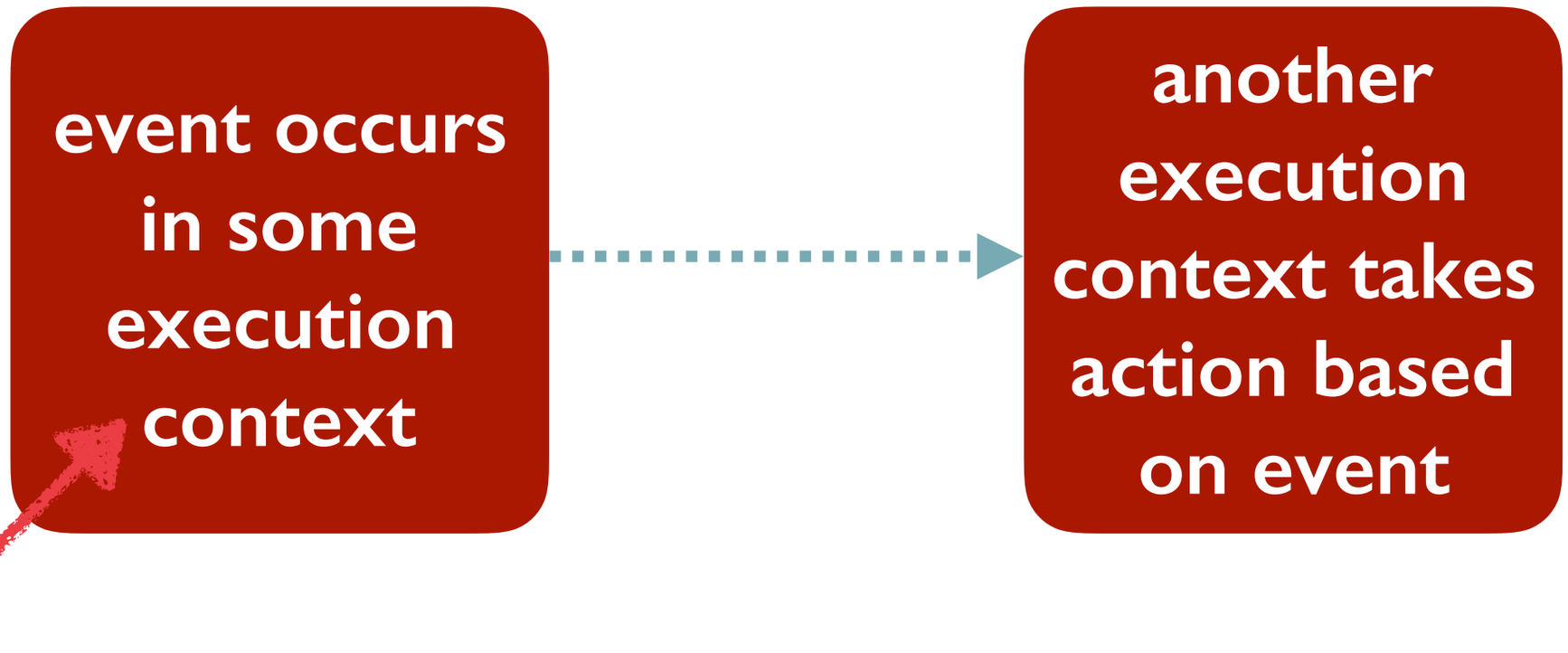
v3vee.org

Palacios

An OS Independent Embeddable VMM

v3vee.org/palacios

SOFTWARE EVENTS



SOME TYPES OF EVENTS

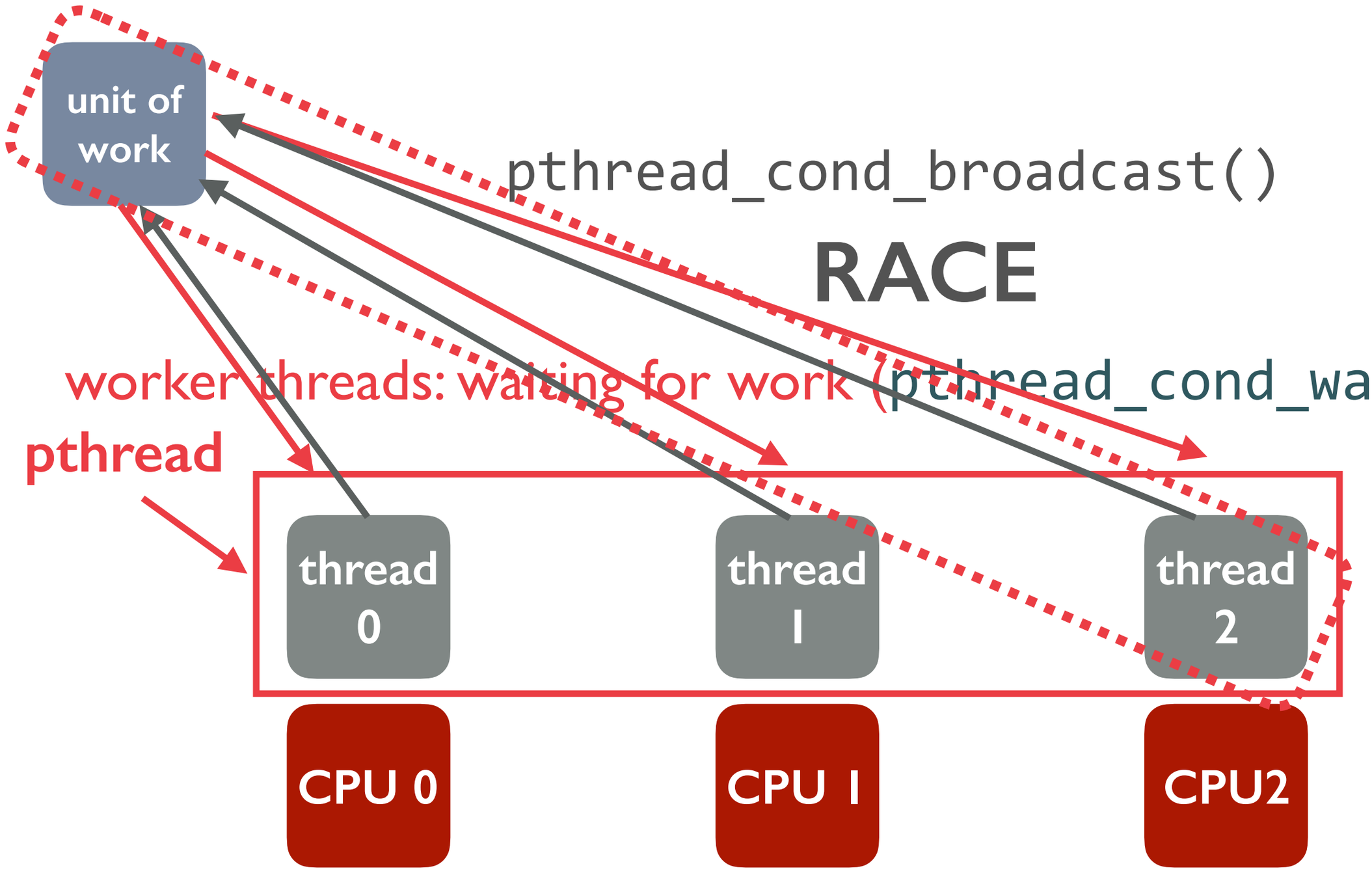
message arrival

work is completed

work is available

something terrible happened

AN EXAMPLE: LEGION

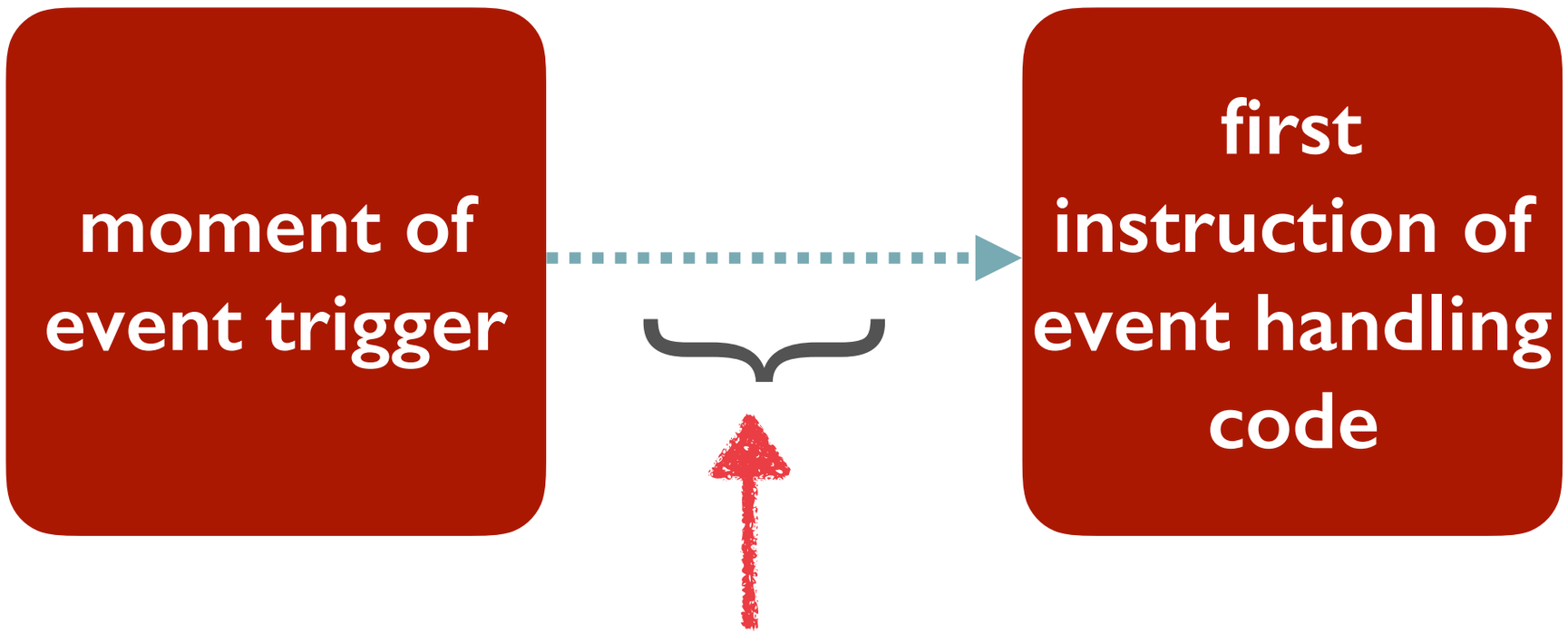


ASYNCHRONOUS EVENTS

the receiving side is **not blocked**

other things can run

WE WANT **FAST** EVENTS



we want to minimize this

WHAT'S THE LOWER LIMIT?

light!

what we want: **SoL**†

what we actually get with existing software events: **SoL**††

†speed of light

††s**t out of luck

OUTLINE

software abstractions for asynchronous events

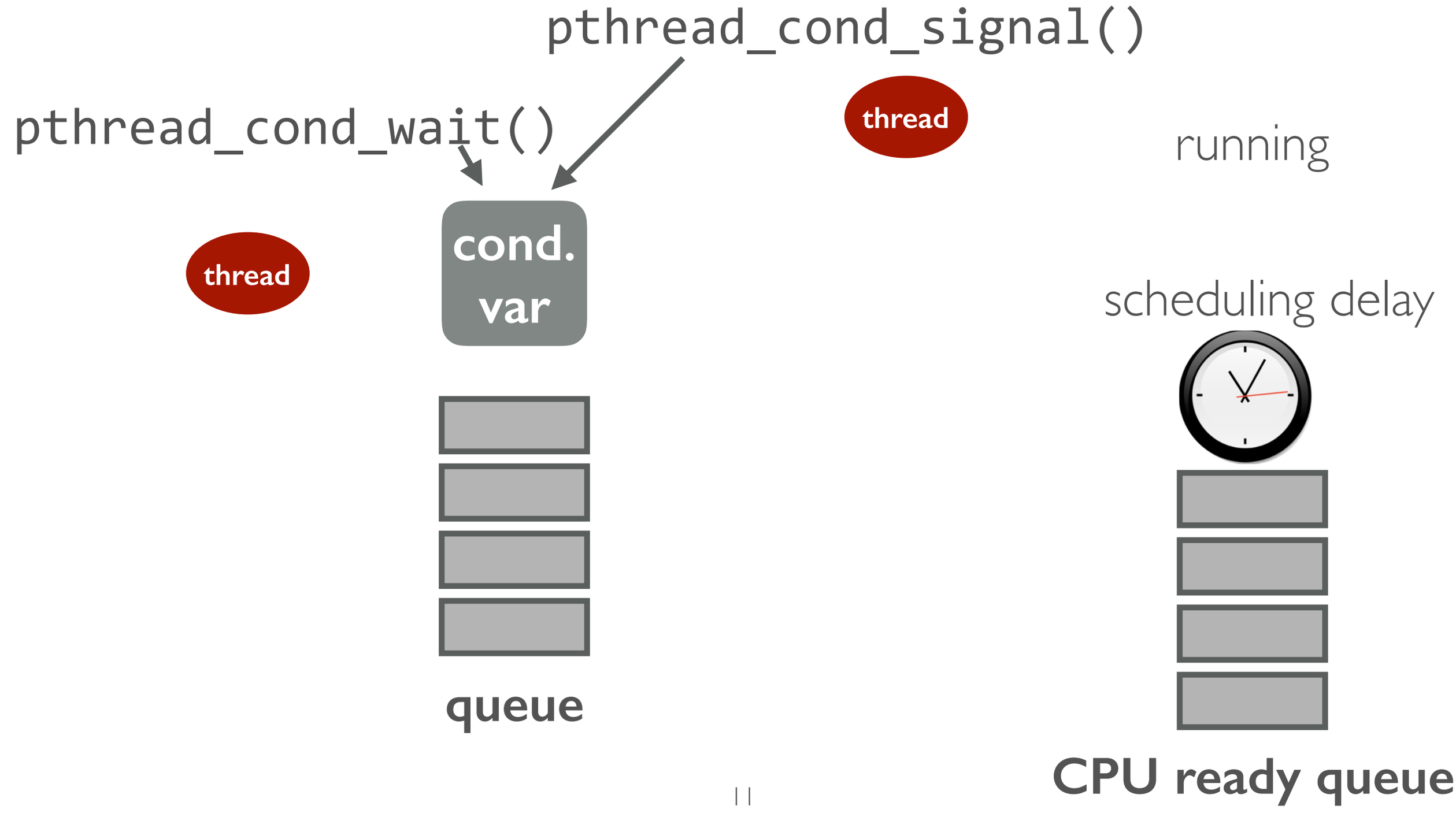
hardware capabilities

event performance

NEMO: benefits of kernel mode

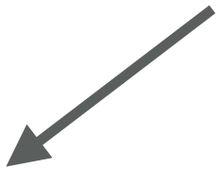
NEMO: closer to the hardware

CONDITION VARIABLES



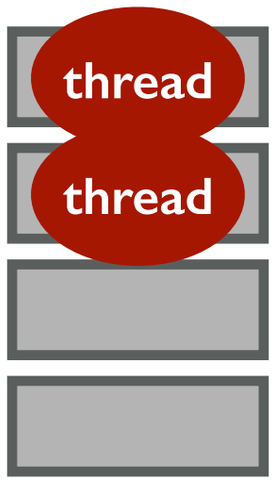
BROADCAST

```
pthread_cond_broadcast()
```

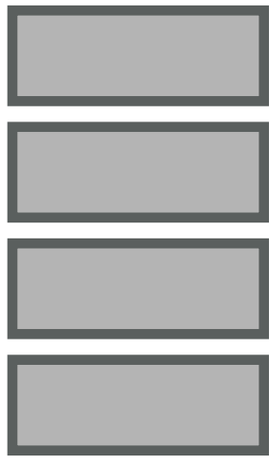


thread

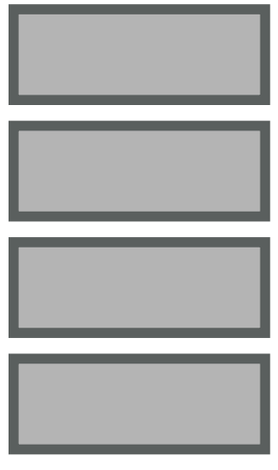
cond. var



queue



CPU 0
ready queue



CPU 1
ready queue

IMMEDIATELY VISIBLE ISSUES

we're at the behest of the scheduler

broadcast is linear in number of waiters

we can't tell scheduler to initiate a "fast" wakeup

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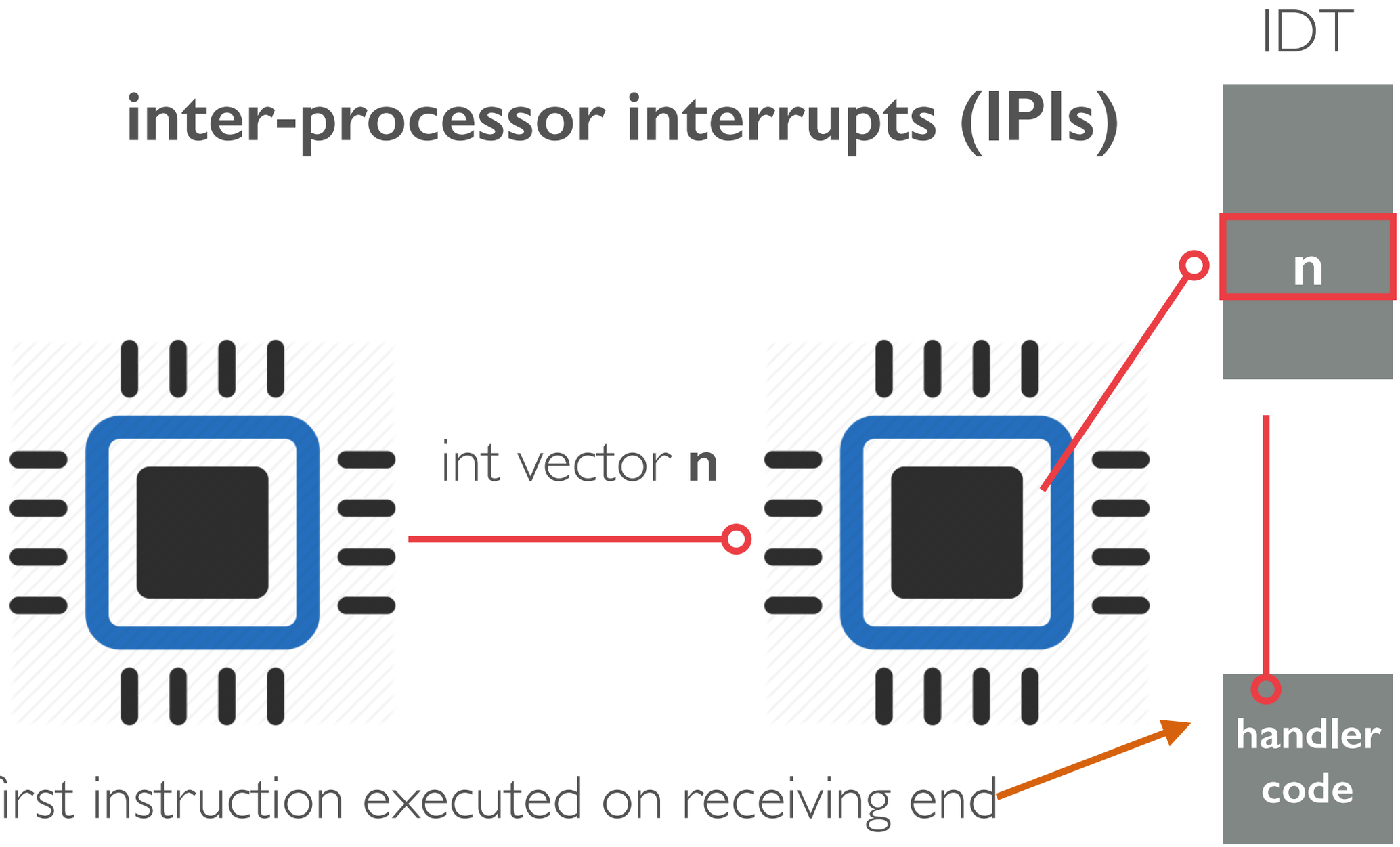
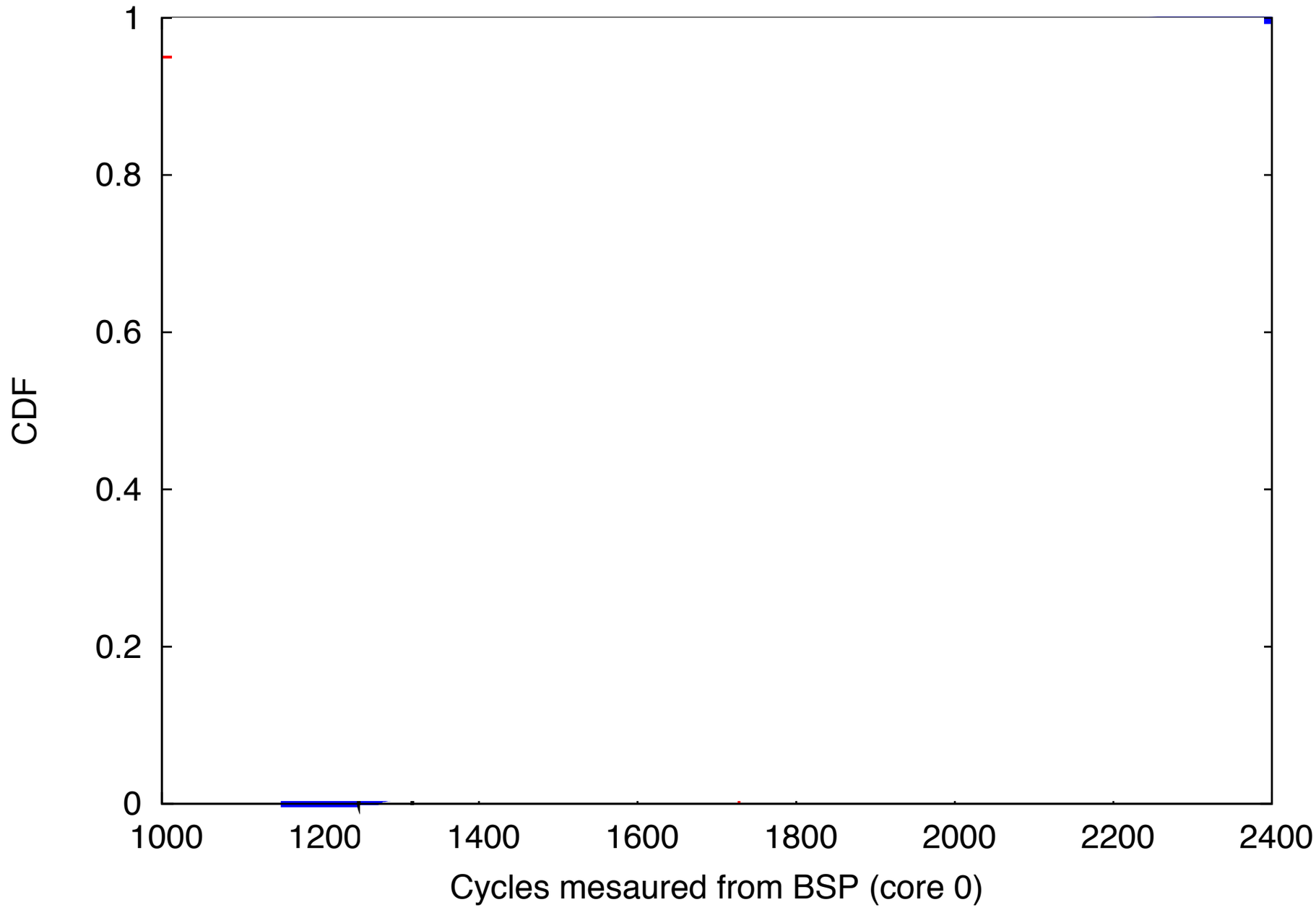
WHAT CAN WE DO IN HARDWARE?

inter-processor interrupts (IPIs)



IPIS ARE *FAST*



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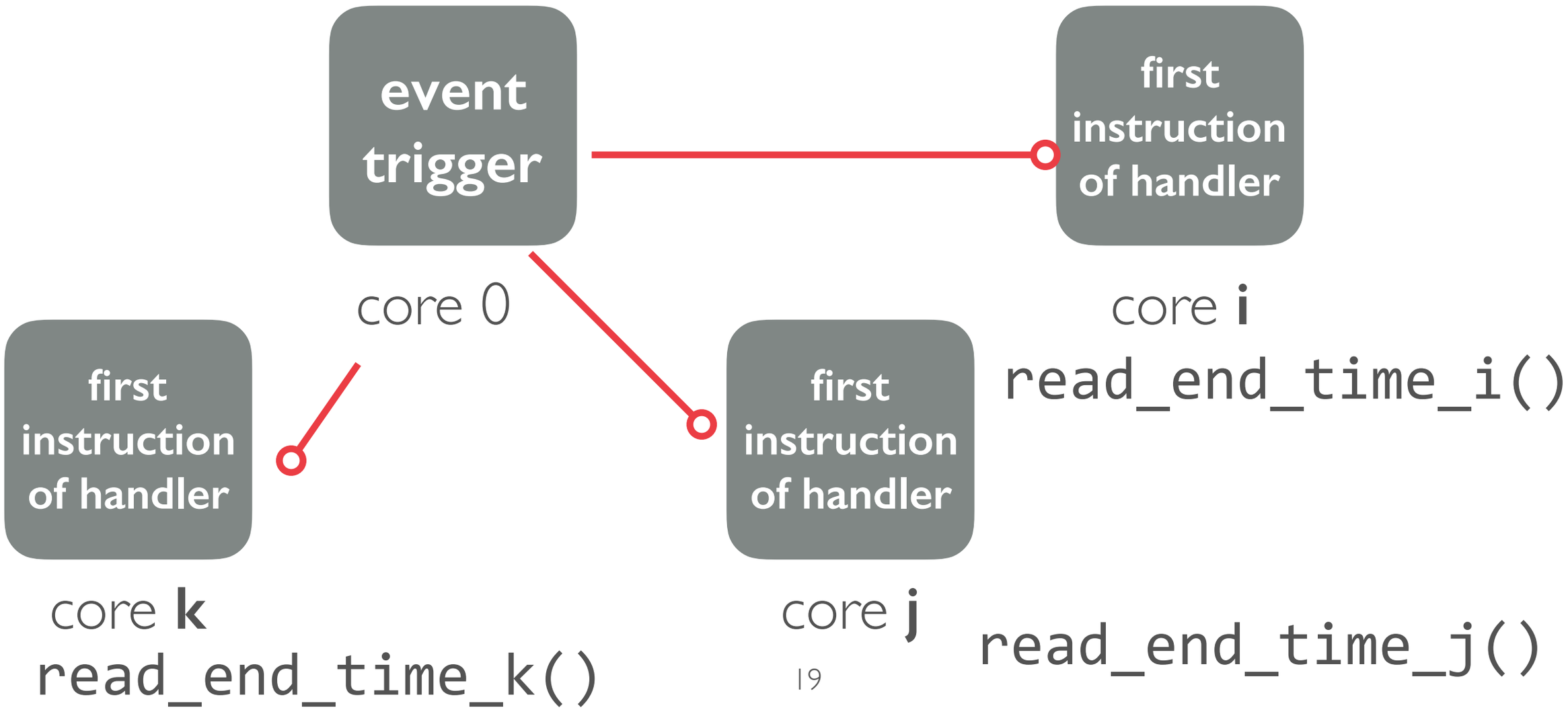
MEASURING EVENT WAKEUP LATENCY

`read_start_time()`

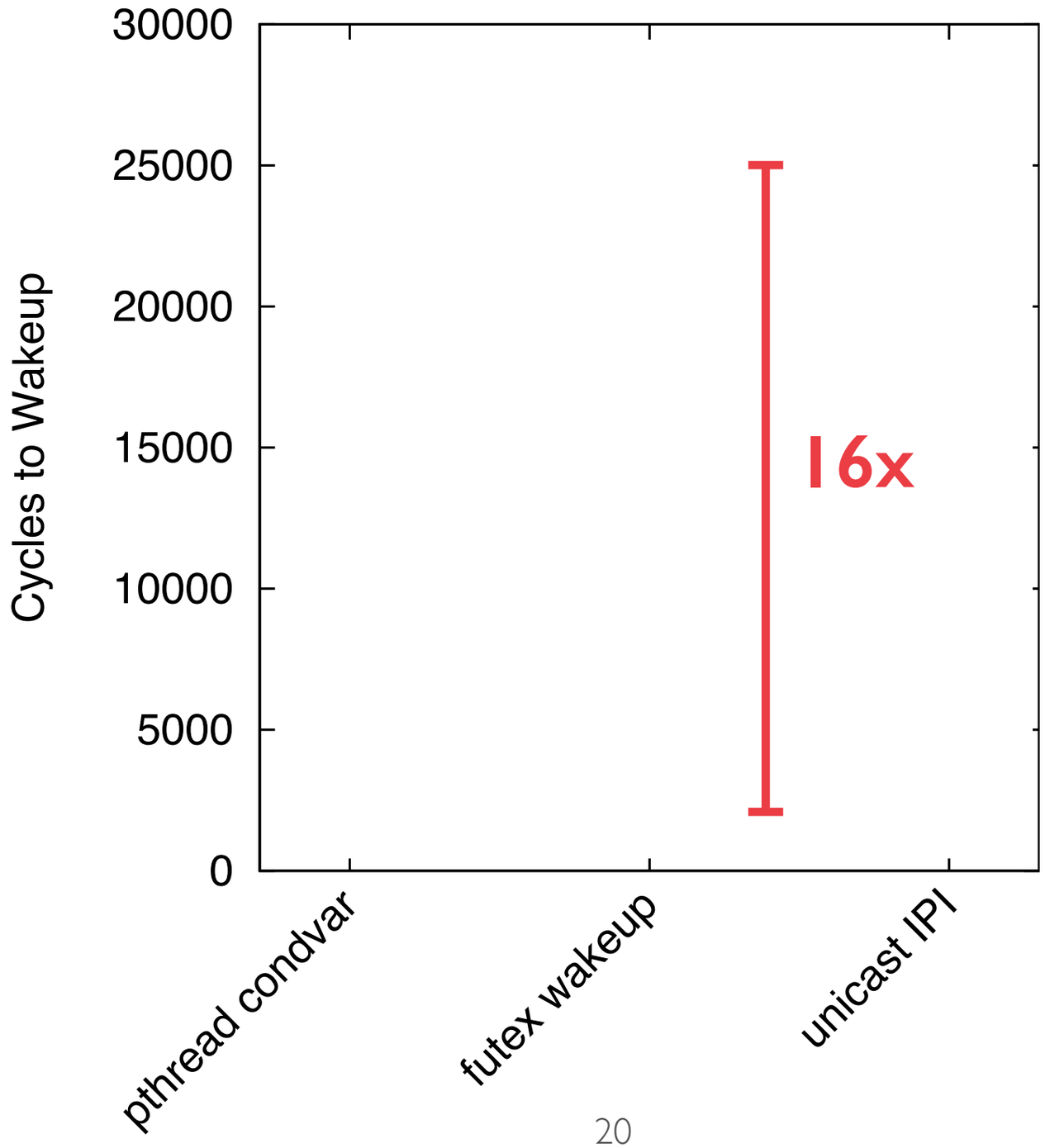
`read_end_time()`

MEASURING EVENT BROADCAST LATENCY

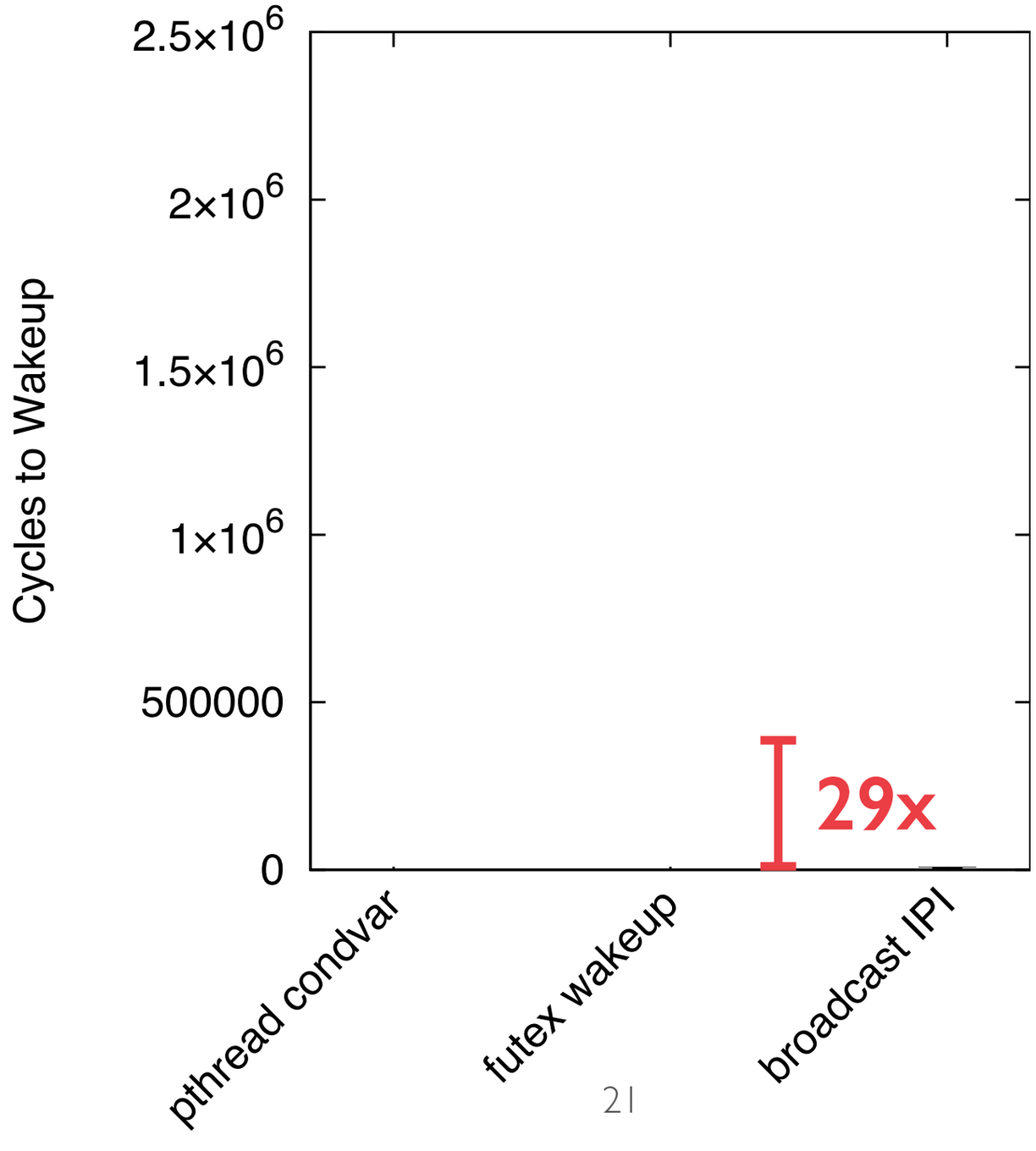
`read_start_time()`



EXISTING SOFTWARE EVENTS ARE **SLOW**



BROADCASTS ARE ALSO TERRIBLE



SYNCHRONY

for broadcasts, we want events to be delivered to all cores at the same time

useful for, e.g. BSP apps with events

measure the *deviation* of wakeup time across cores in a broadcast

SYNCHRONY

70x difference between hardware IPIs and software mechanisms

hardly any predictability!

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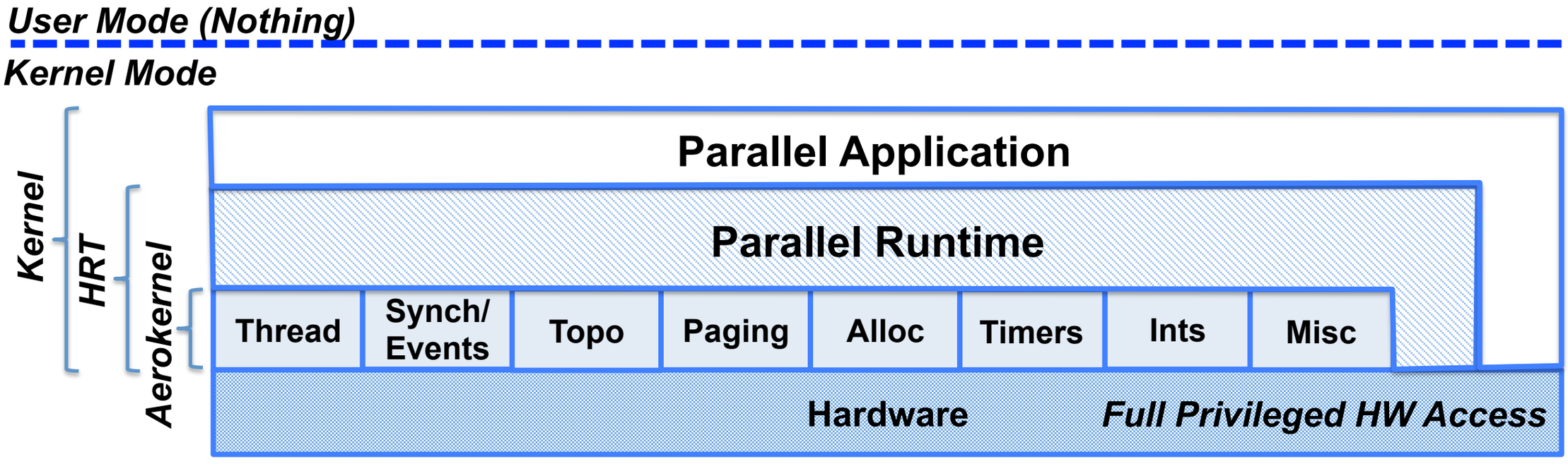
NAUTILUS



[Hale, Dinda HPDC '15]

[Hale, Dinda VEE '16]

[Hale, Hetland, Dinda FRIDAY]


nemo
accelerated, asynchronous software events

RETAINING FAMILIAR INTERFACES

use a lightweight, kernel-mode framework (like Nautilus) to eliminate overheads

maintain userspace interfaces (e.g. condition variable wait,signal,broadcast etc.)

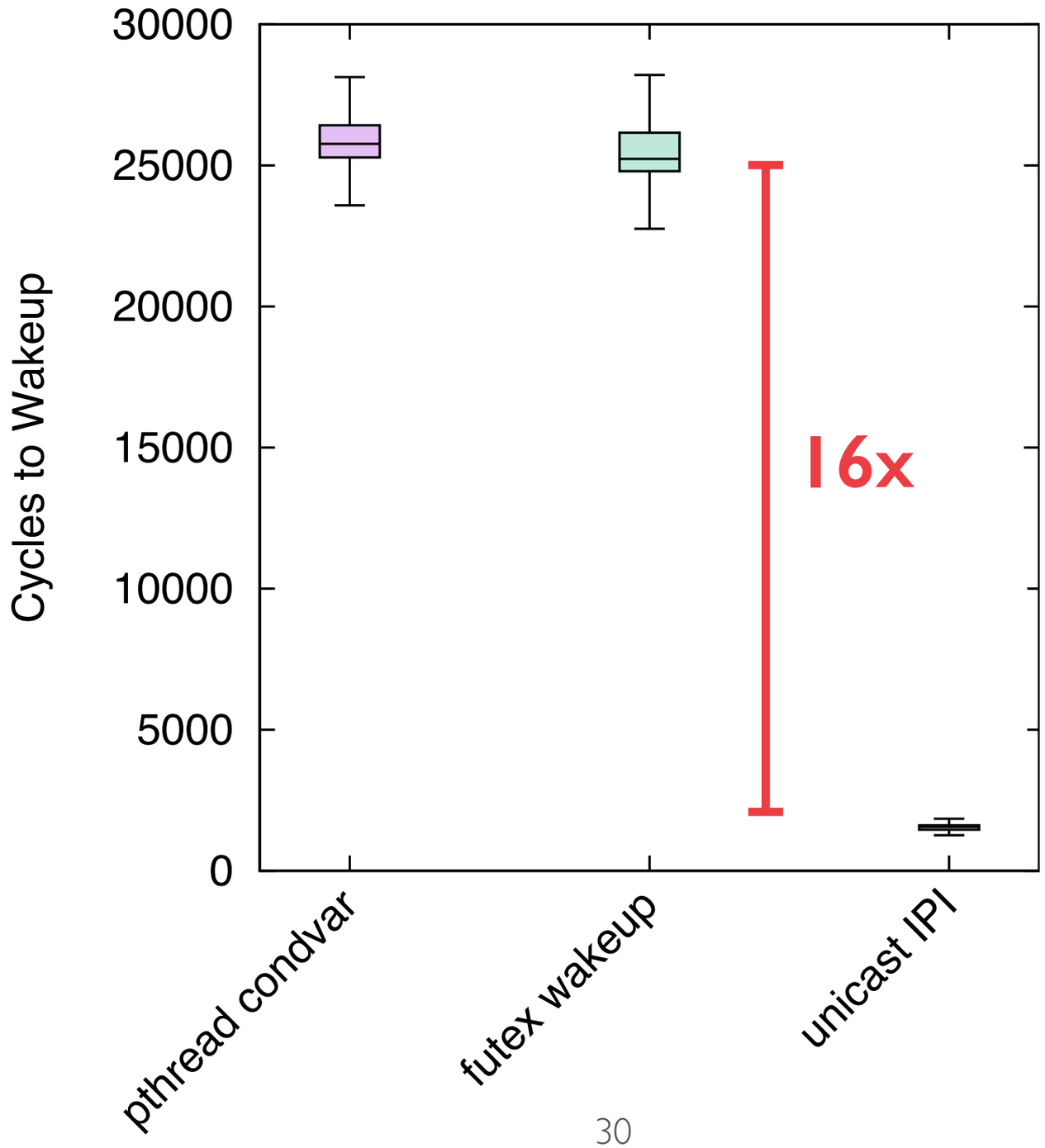
if we build our kernel from scratch, how fast can we get?

NEMO HAS 2 COMPATIBLE CONDITION VARIABLE IMPLEMENTATIONS

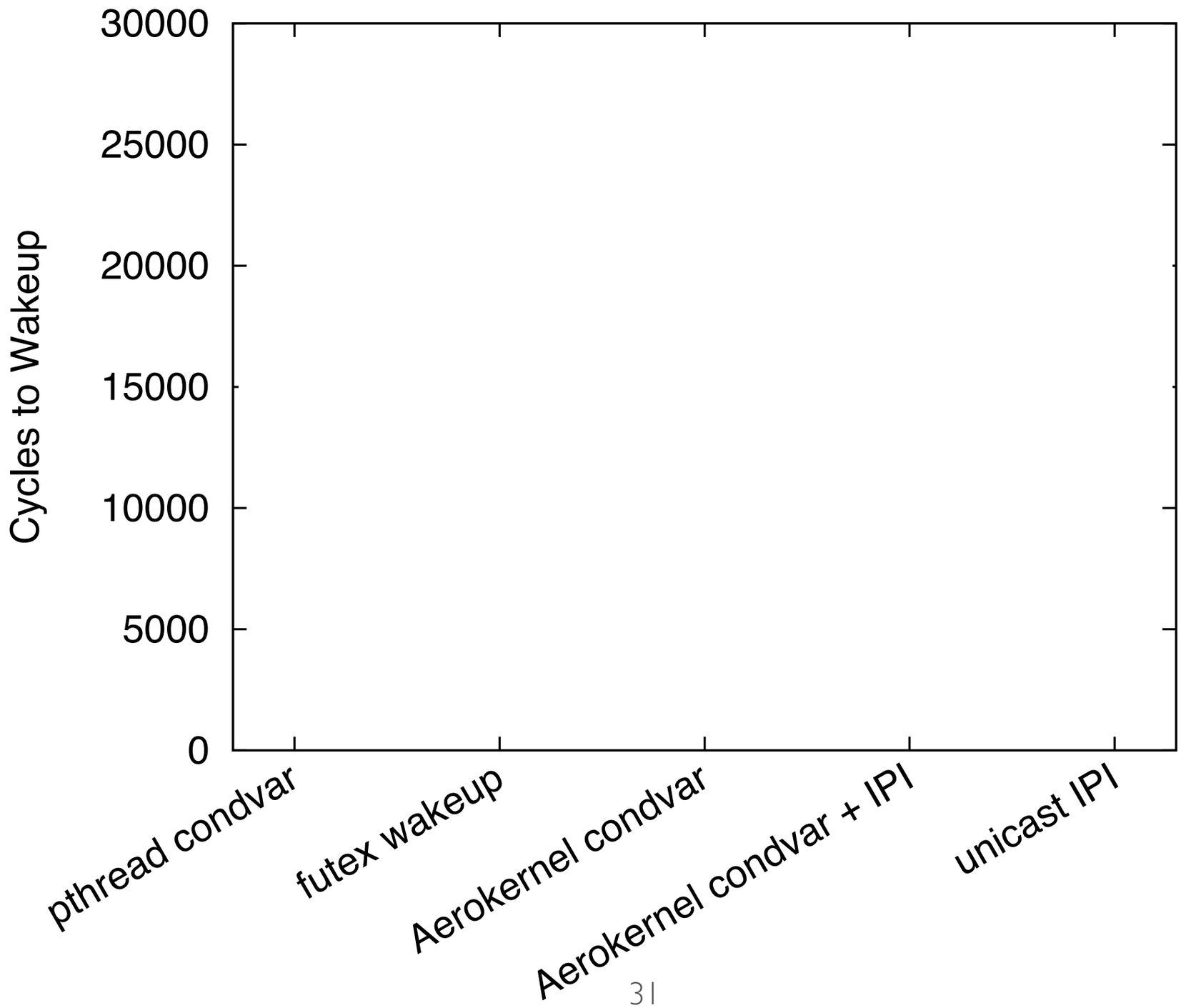
lightweight condition variables

leverage IPI access to “kick” the scheduler

EXISTING SOFTWARE EVENTS ARE **SLOW**



NEMO SPEEDS THINGS UP



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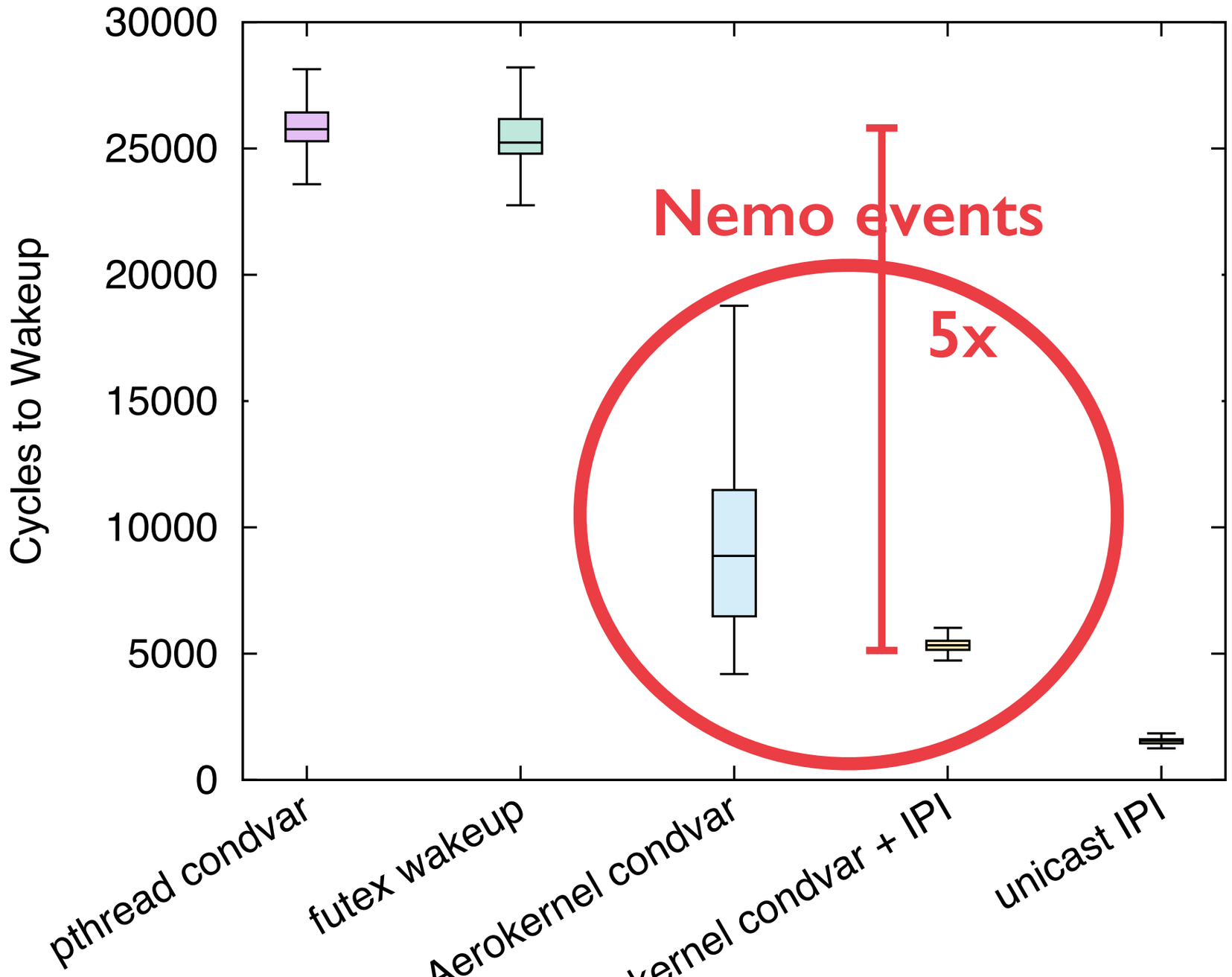
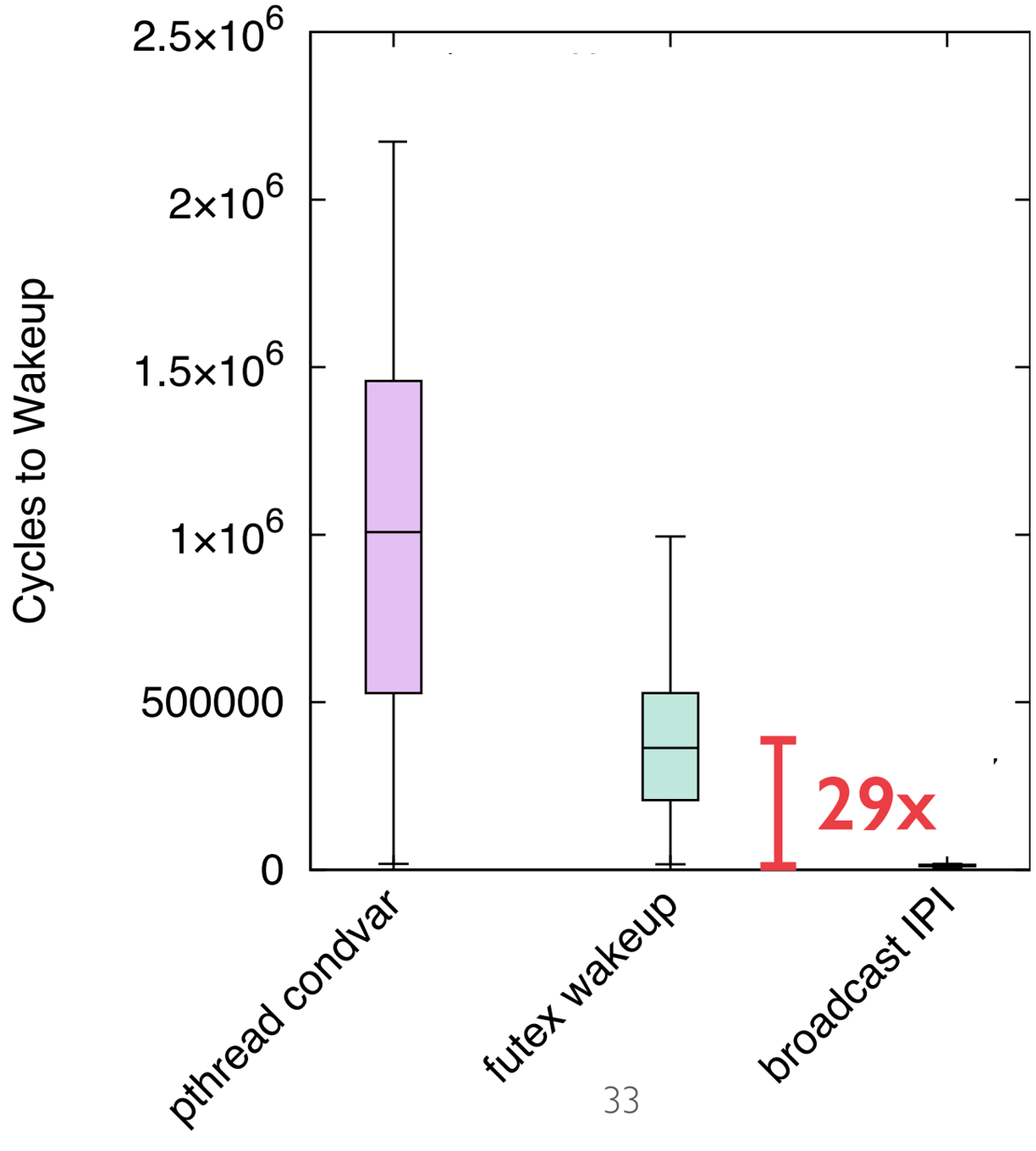
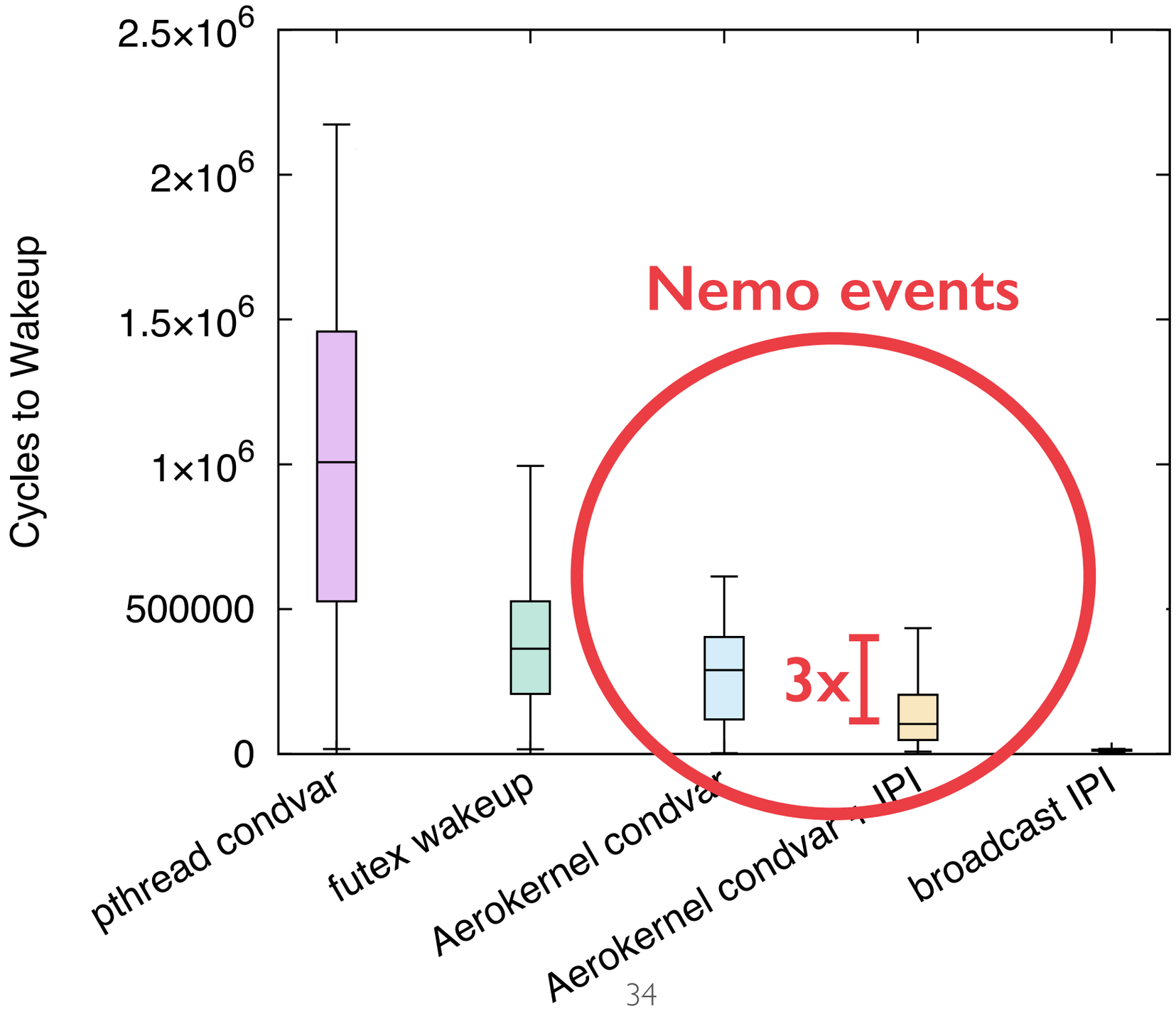


BROADCASTS ARE ALSO TERRIBLE



NEMO BRINGS US CLOSER TO IPI BROADCAST LATENCY



SYNCHRONY

we can do 2x better than user-space mechanisms

(with compatible interfaces)

OUTLINE

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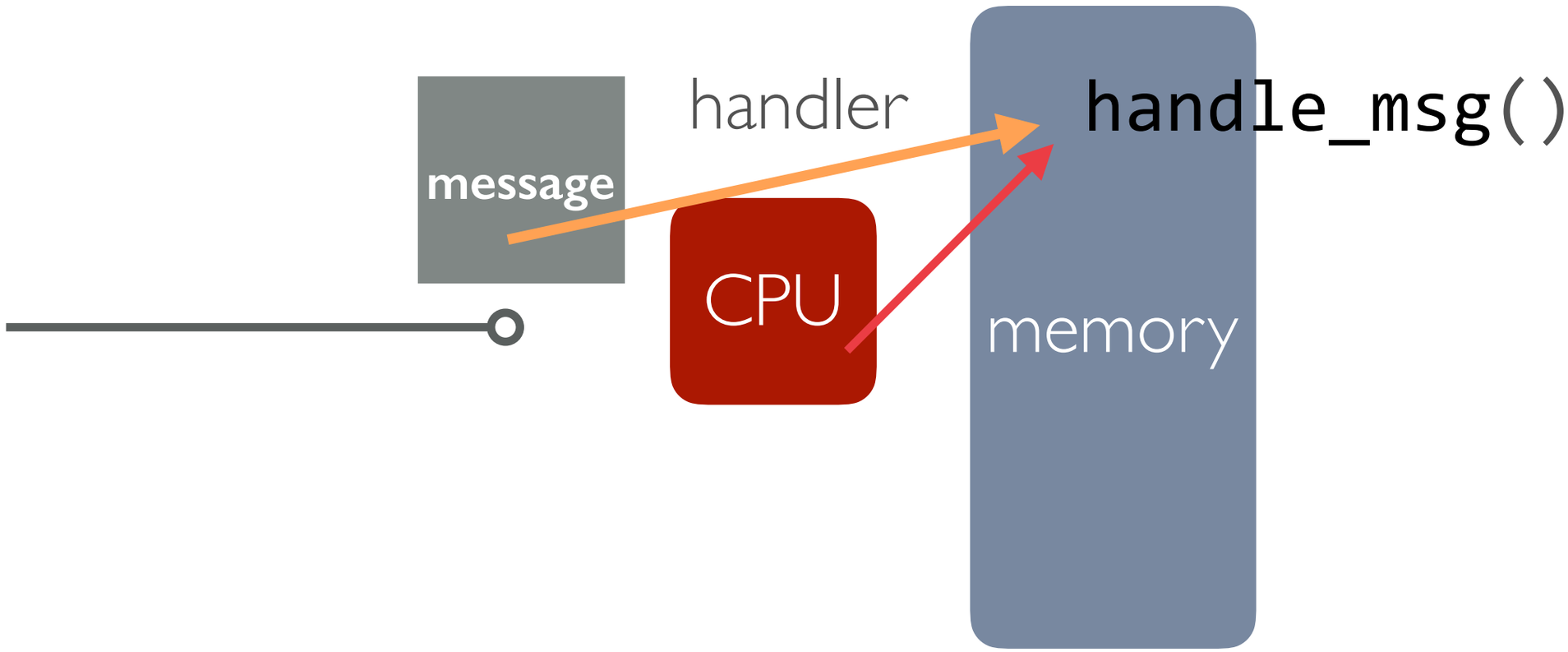
WHAT IF WE GIVE UP THE FAMILIAR INTERFACE?

modify condition variable semantics

we don't necessarily care which context (thread) receives the event, as long as it's handled at a particular core

not appropriate for all situations

ACTIVE MESSAGES



claim: better fit than, e.g. cond vars, for many event-based schemes

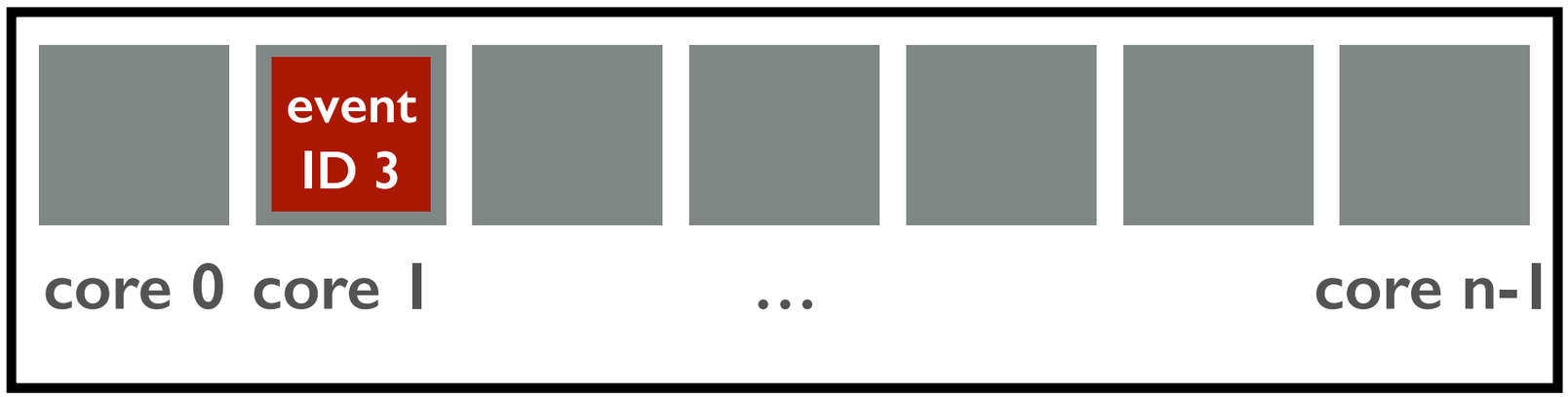
we want to use IPIs as an active message substrate

problem: IPIs don't have a payload!

allocate several **event IDs**

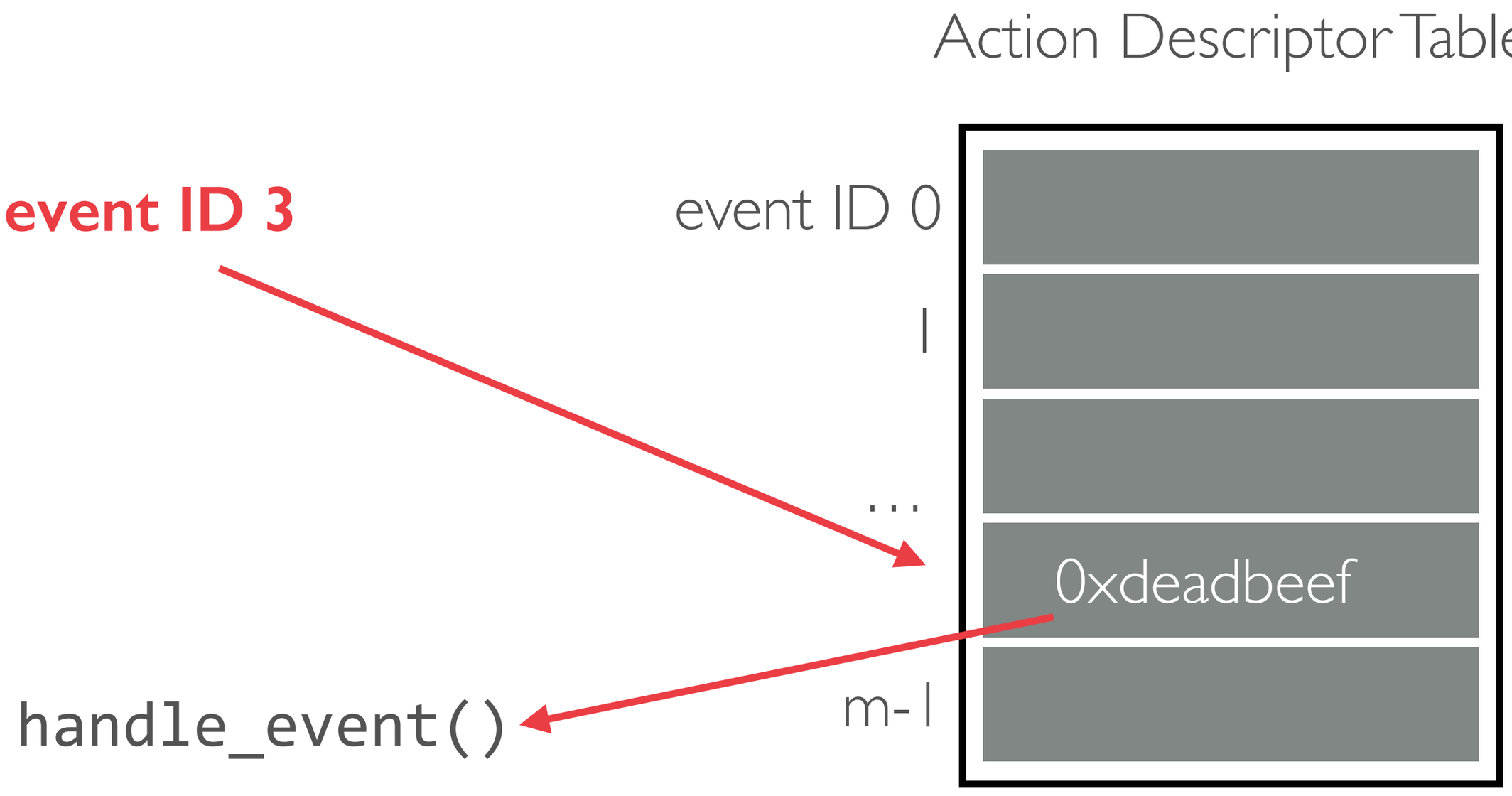
when core receives interrupt,
lookup the event ID in a table indexed on core ID

Action Lookup Table

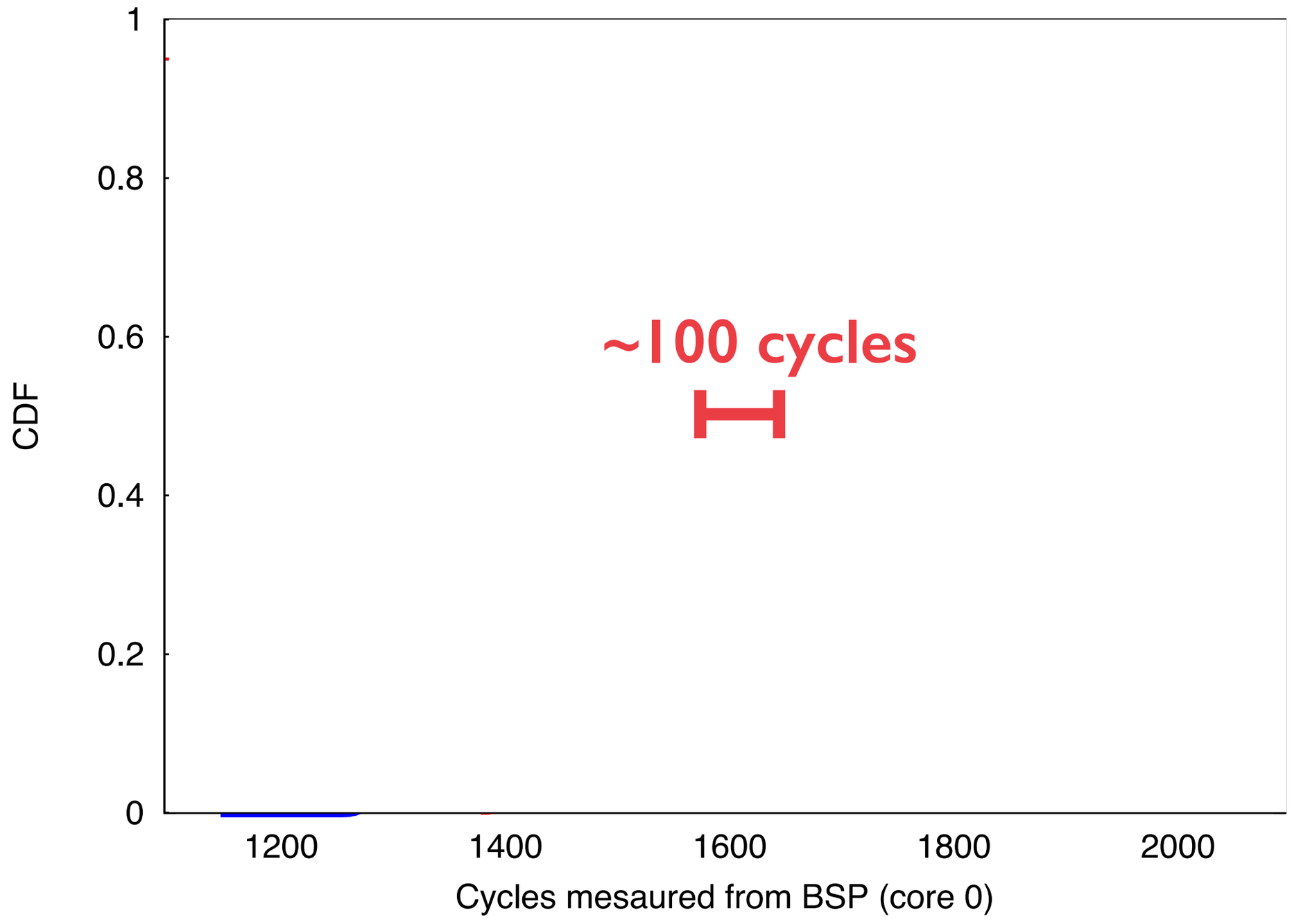



```
nemo_notify_event(core=1, event=3)
```

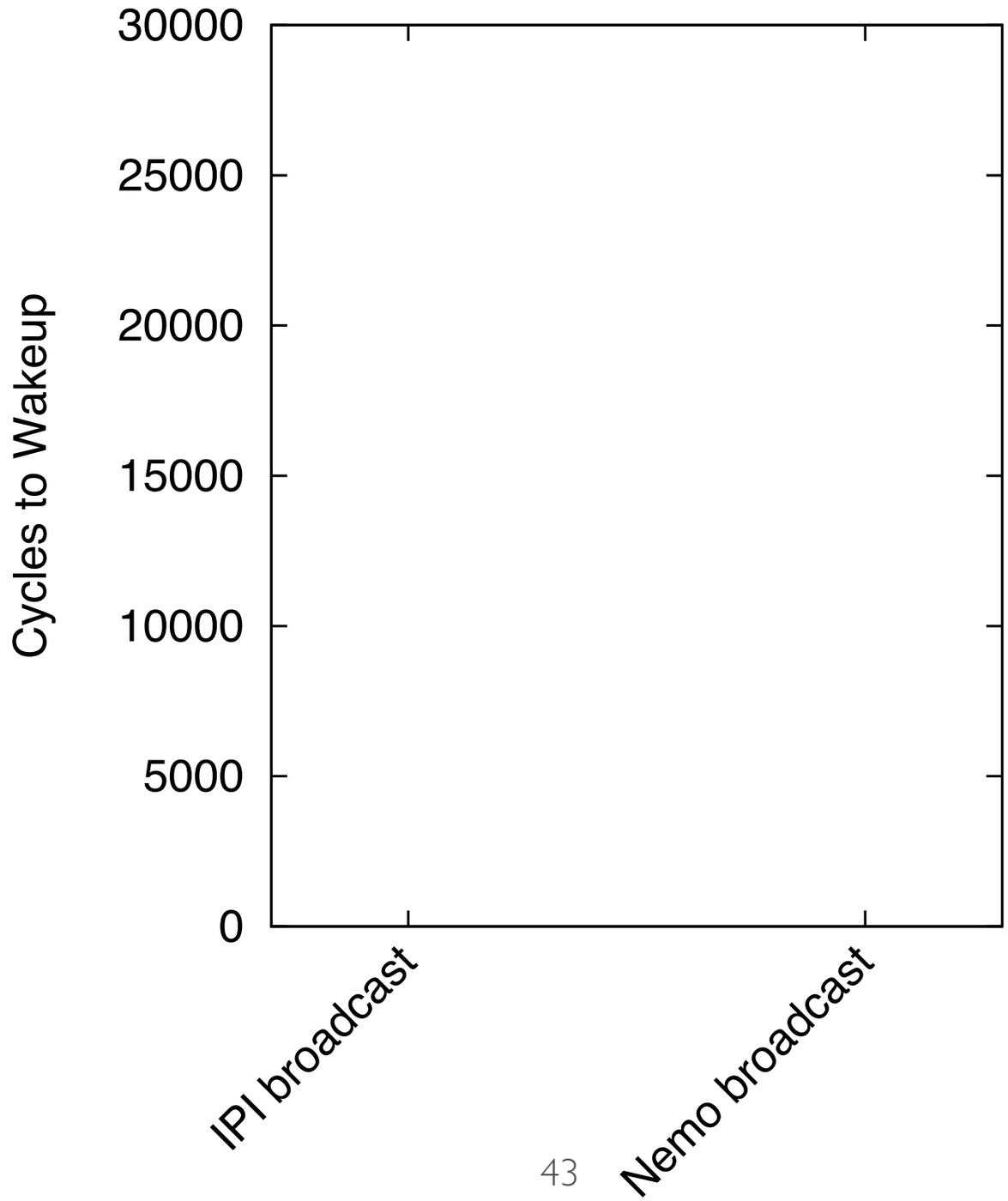
event ID corresponds to an "action" (a handler)



NEMO WAKEUPS HAVE CONSTANT OFFSET FROM IPIS



BROADCAST LATENCY ALSO ON PAR WITH IPIS



NEMO ACHIEVES TIGHT SYNCHRONY

< 50 cycles variation in broadcast wakeups between cores

SUMMARY

if you want asynch. event delivery close to hardware latency…

existing mechanisms are pretty terrible

SOME WAYS TO FIX IT:

throw out general purpose OS abstractions (e.g. user/kernel boundary)

throw out typical event abstractions

use the hardware directly!

THANKS

ありがとう

http://halek.co ← **me**

http://presciencelab.org ← **our lab**

http://nautilus.halek.co ← **Nautilus**

http://xstack.sandia.gov/hobbes

Hobbes Exascale OS/R project

Northwestern University

HOBBES

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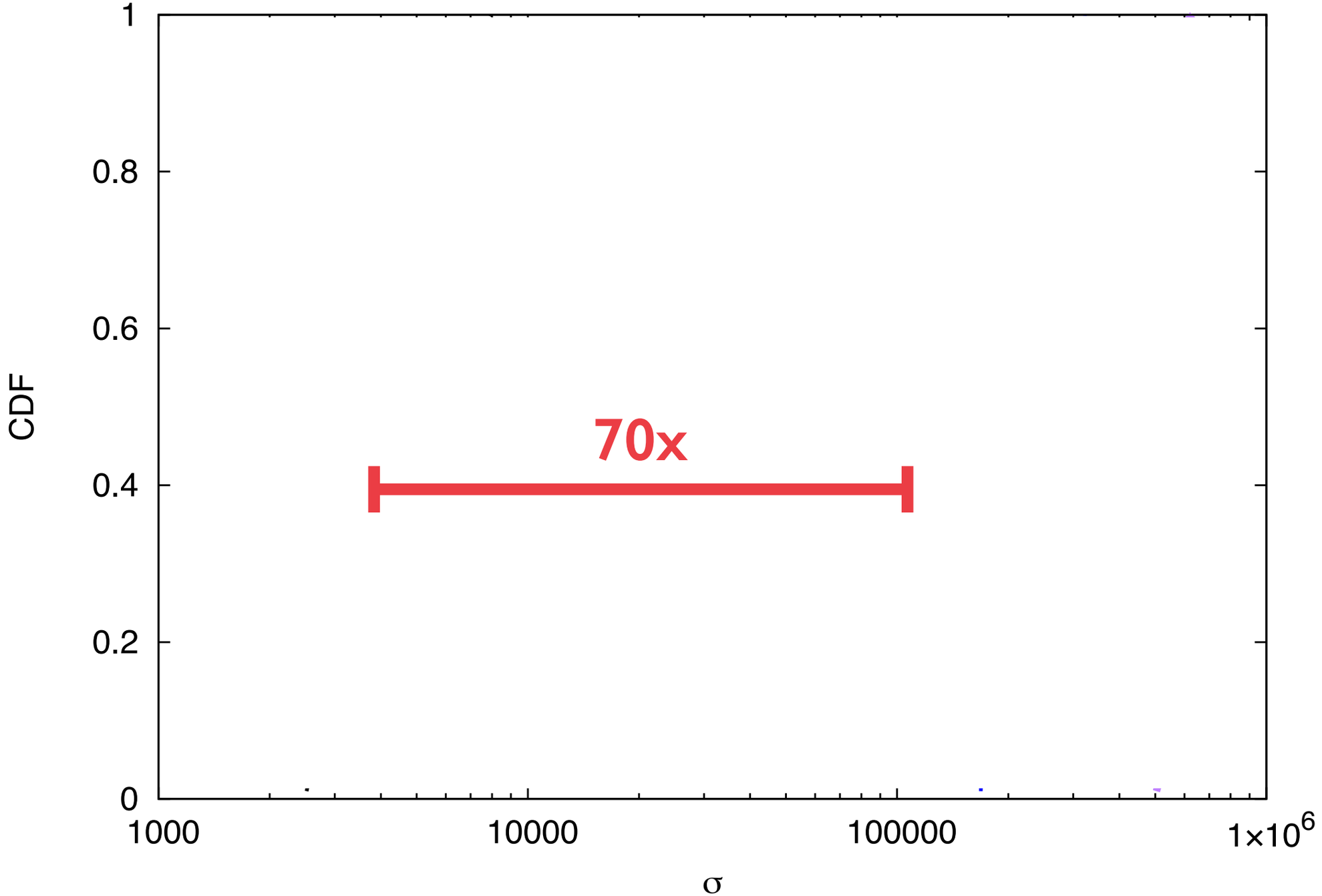
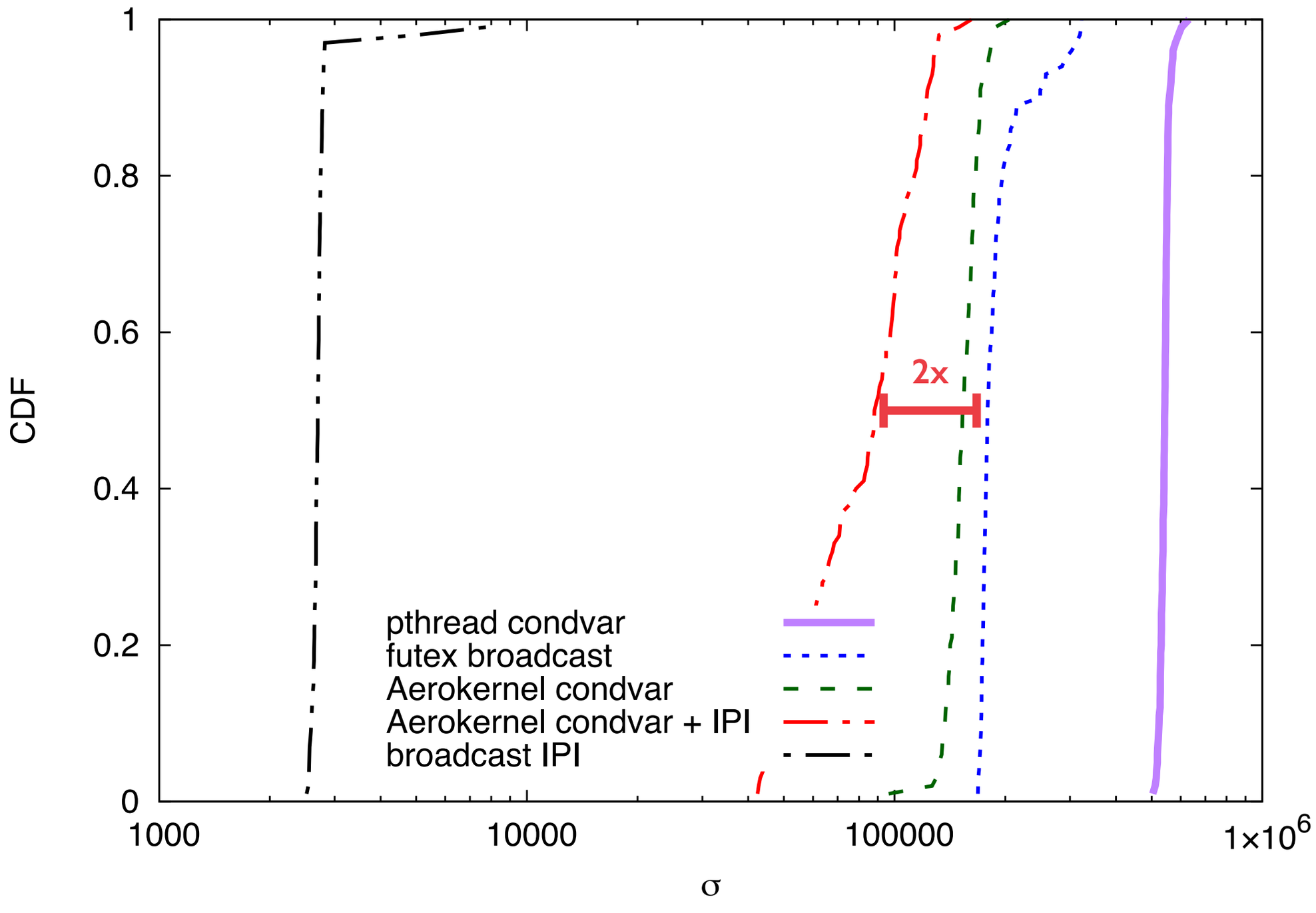
BACKUPS

TIGHT SYNCHRONY FOR IPIS, NOT FOR SOFTWARE EVENTS



NEMO GETS US CLOSER



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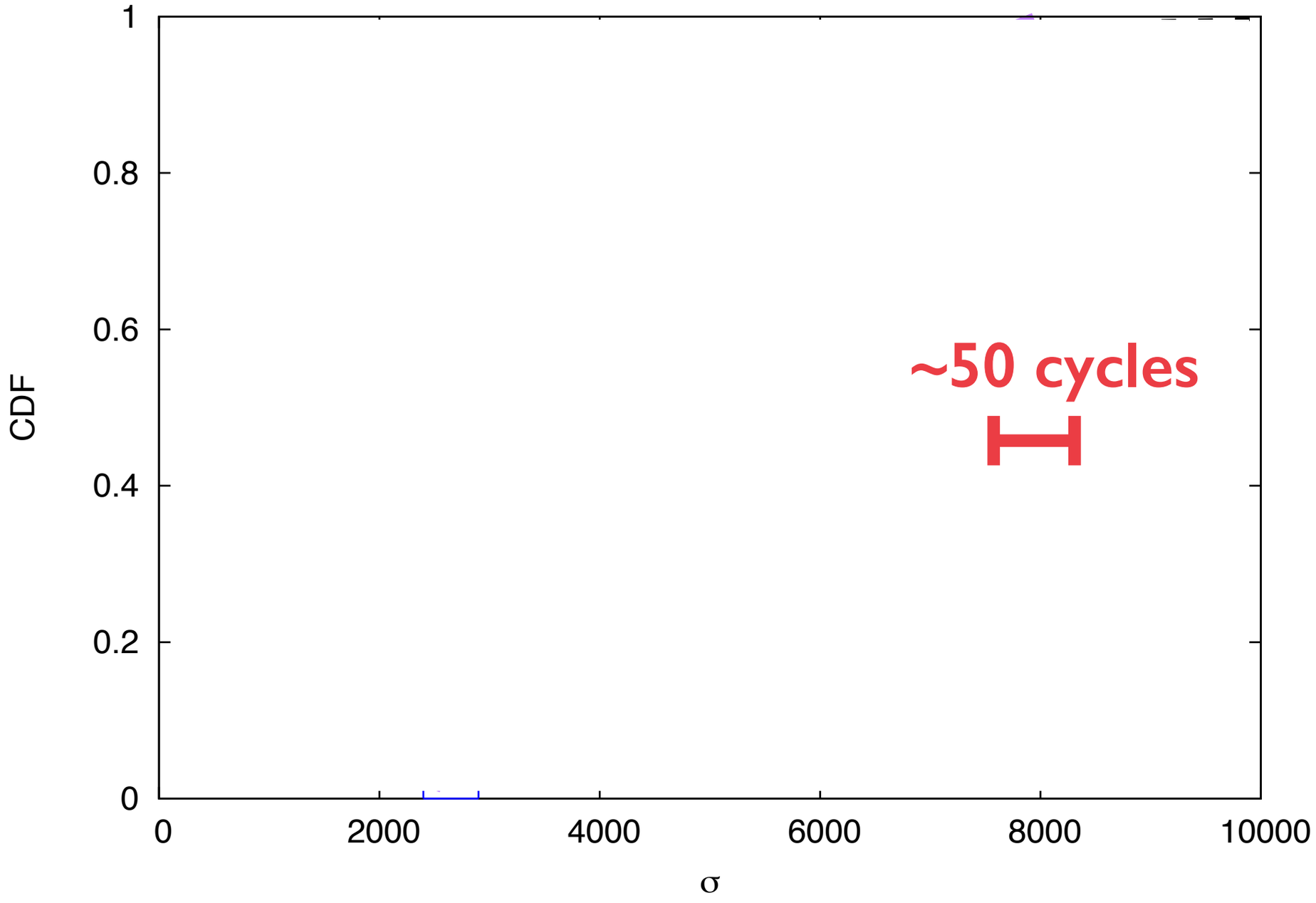
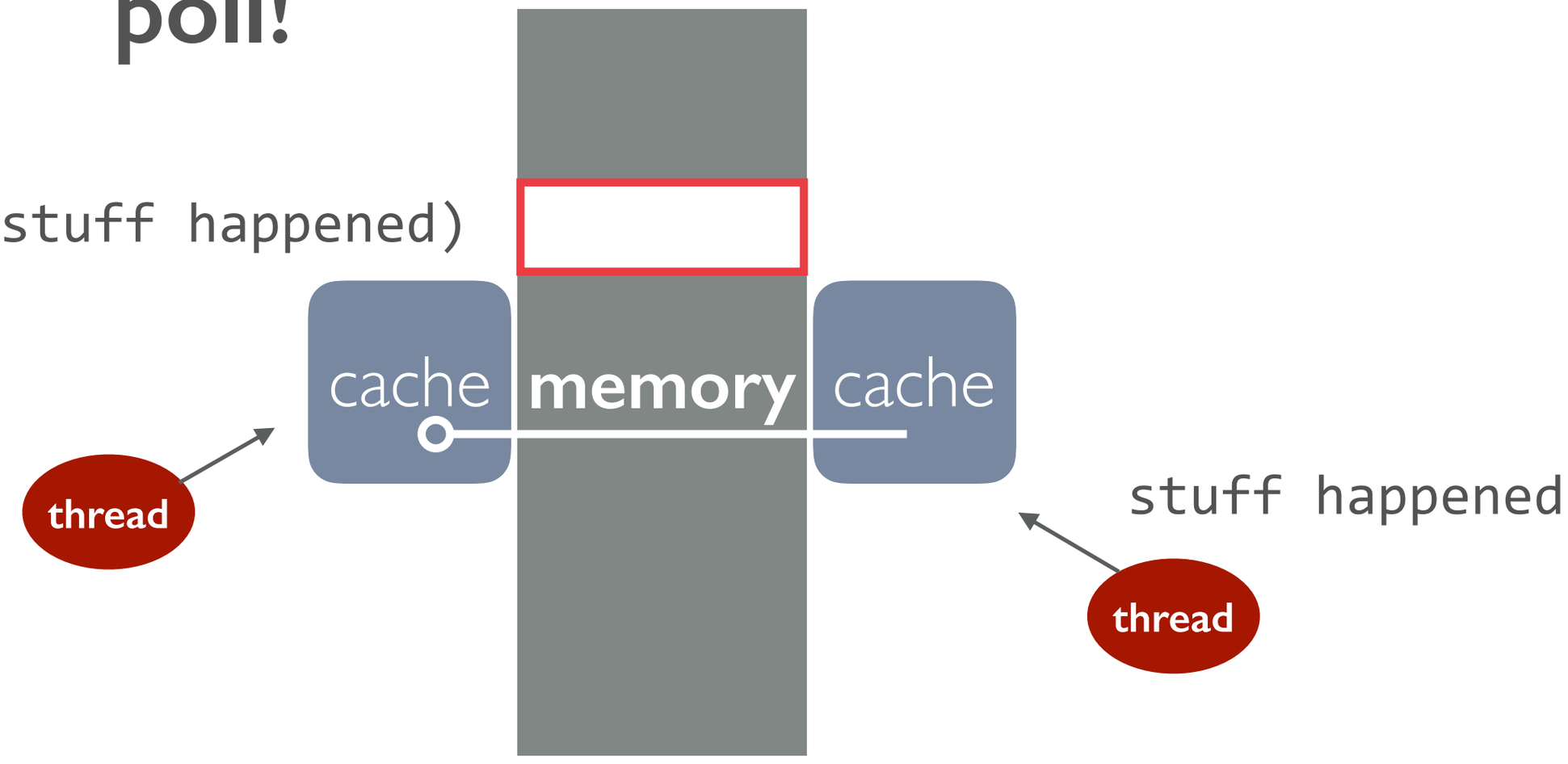


HOW FAST CAN A NOTIFICATION BE IN H/W?

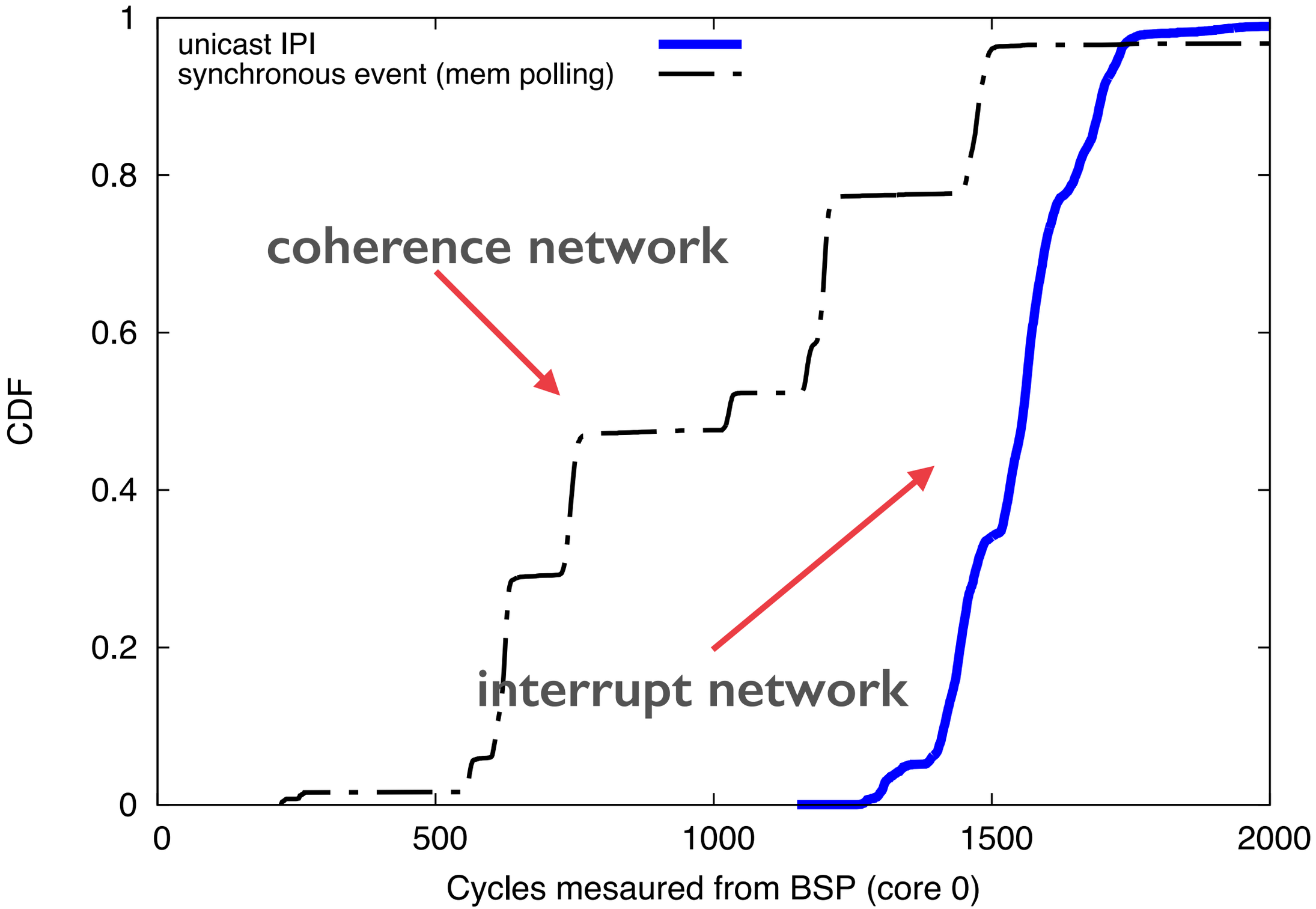
poll!

```
while (!stuff happened)
```



cache invalidation (10s of cycles)

Unicast IPI vs memory polling



WHY THE GAP?

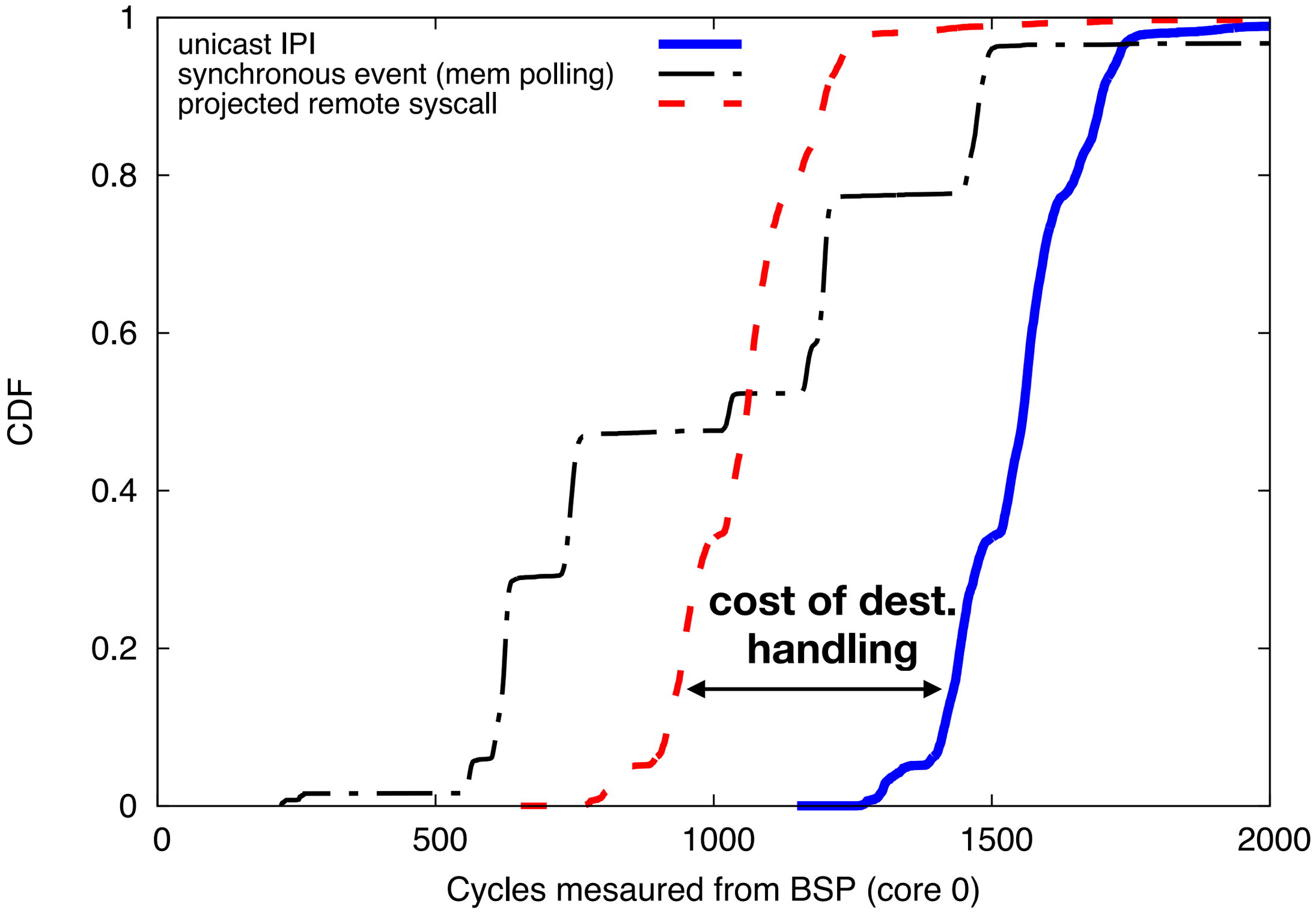
we're bounded by interrupt handling logic in the hardware

IPI cost breakdown

note: these are indirectly measured

we used to have a problem like this with INT80 syscalls…

solution: introduce a new instruction, skip a lot of the interrupt handling logic


unicast IPI
synchronous event (mem polling)
projected remote syscall
cost of dest. handling
CDF
Cycles mesaured from BSP (core 0)
0
0.2
0.4
0.6
0.8
1
0
500
1000
1500
2000