Why Aren't More Users More Happy With Our VMs?

Laurence Tratt

Warmup work in collaboration with:
Edd Barrett, Carl Friedrich Bolz, Rebecca Killick, and Sarah Mount

KING'S College LONDON

Software Development Team

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What to expect from this talk

The gap

What we tell users to expect

The gap

What we tell users to expect

The gap

What users experience

The gap

The gap
is bigger than we think

A stroppy user? Or rightfully disappointed?

A stroppy user? Or rightfully disappointed?

"You told me I'd get a 10x speed-up, but I only saw 1.2x"

Background

Dynamic (‘JIT’) compilation utilises information not known statically

Is this just about ‘dynamic typing’?

Is this statically or dynamically typed?

```
fn f(a: Option<i64>) {
  match a {
    Some(i) => ...,
    None    => ...
  };
}
```

Is this just about ‘dynamic typing’?

Is this statically or dynamically typed? Both!

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fn f(a: Option<i64>) {
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```

VM claims

The best VMs are close in performance to,
and sometimes faster than,
gcc -O2

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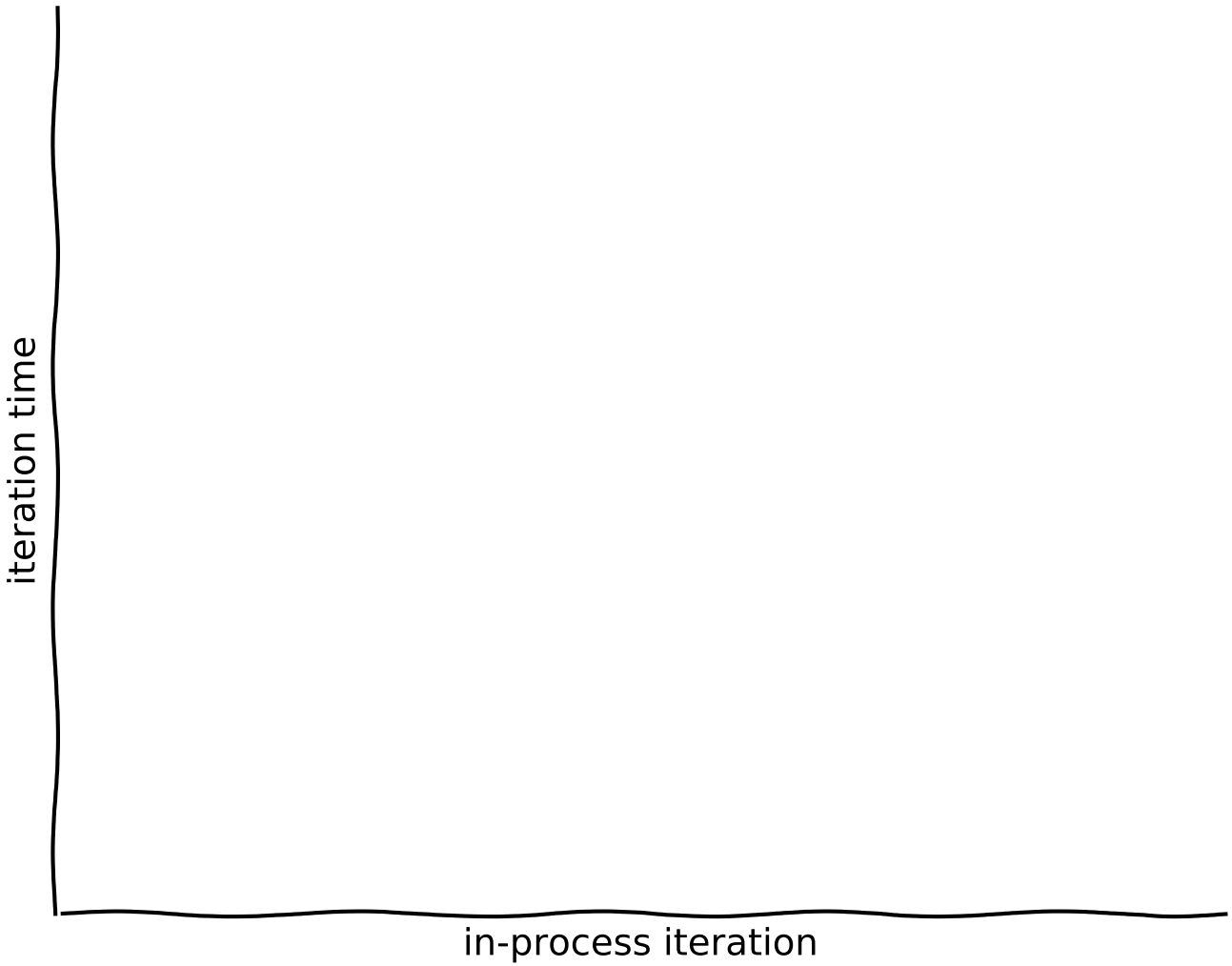
What's being measured?

What our claims pertain to



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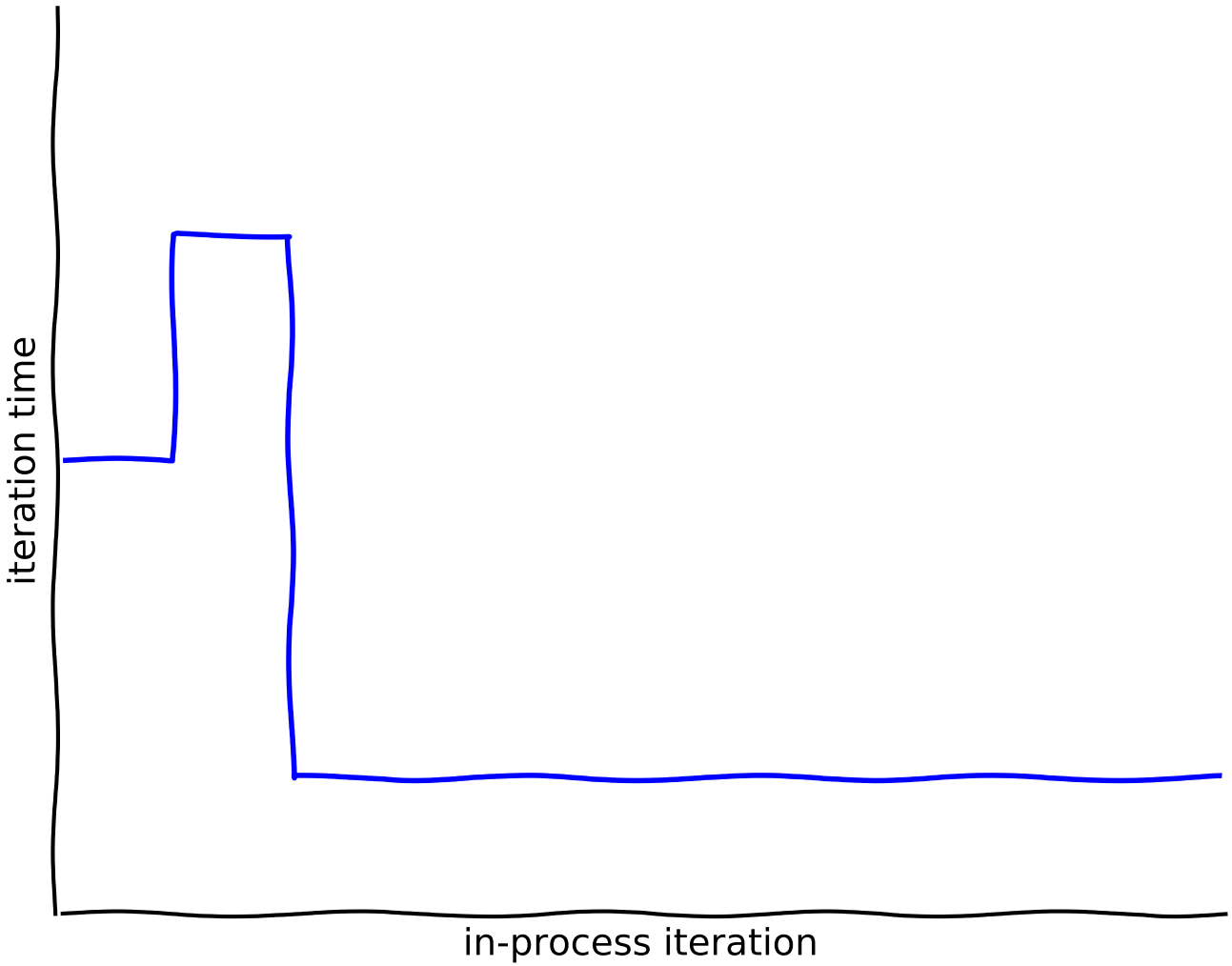

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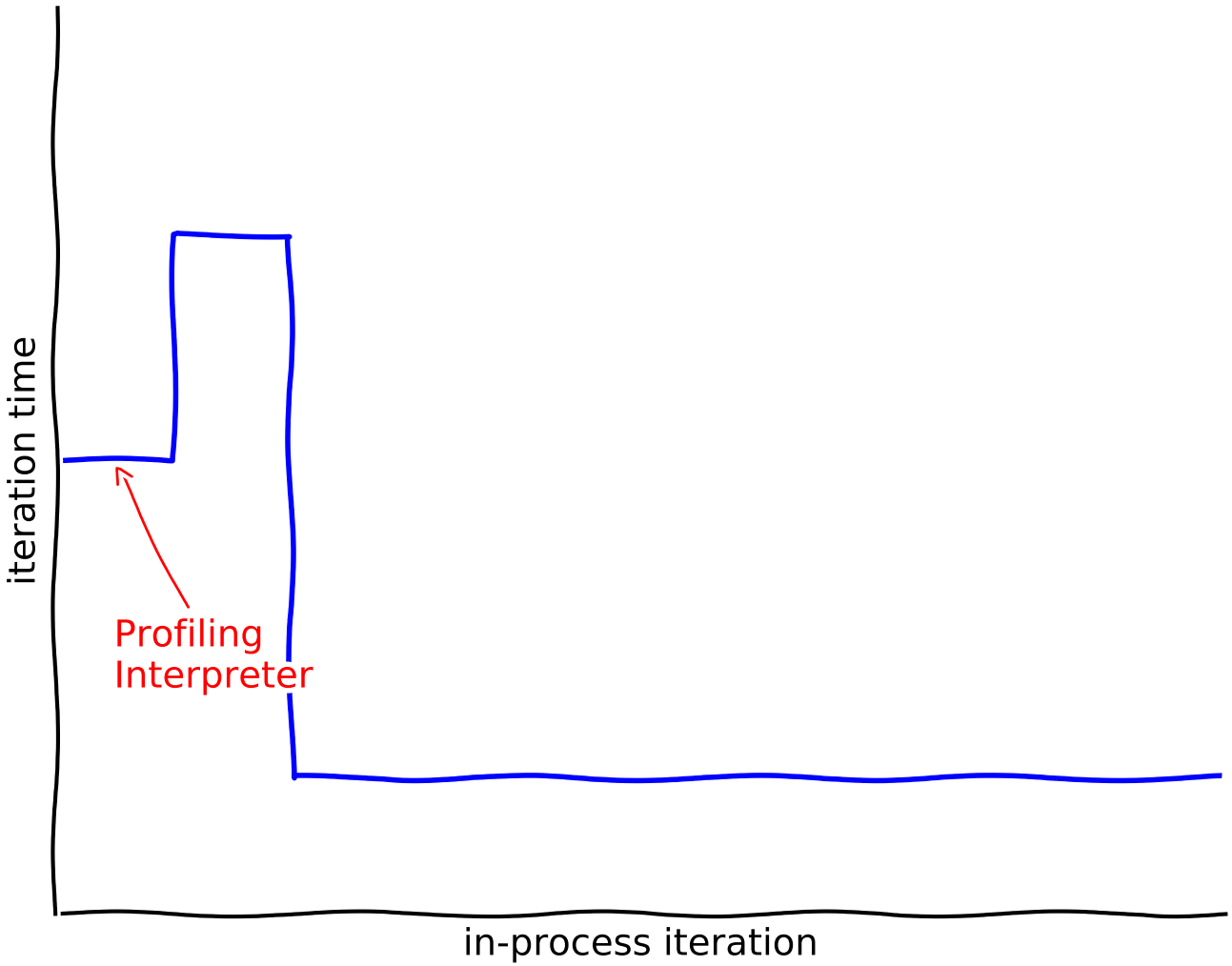

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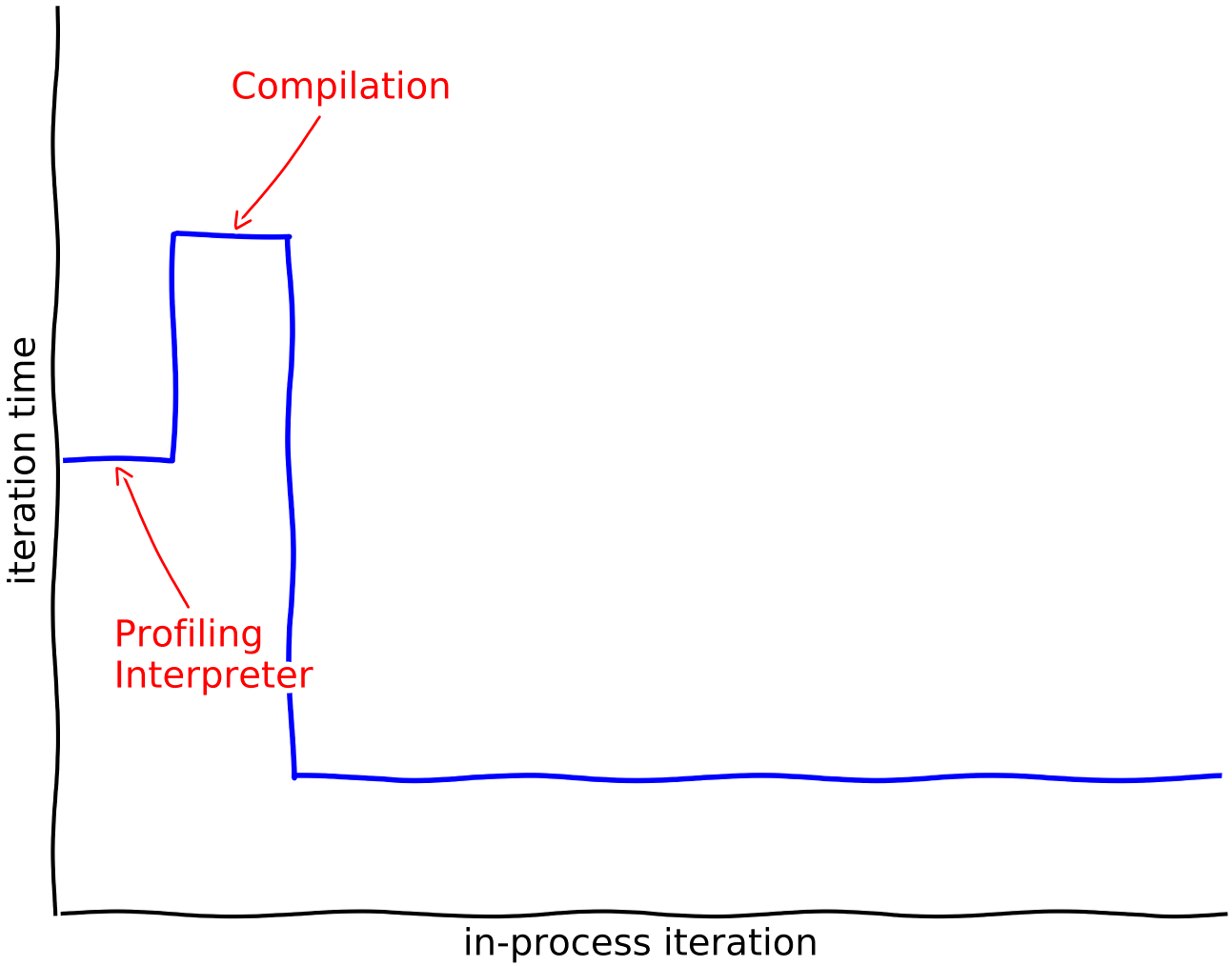

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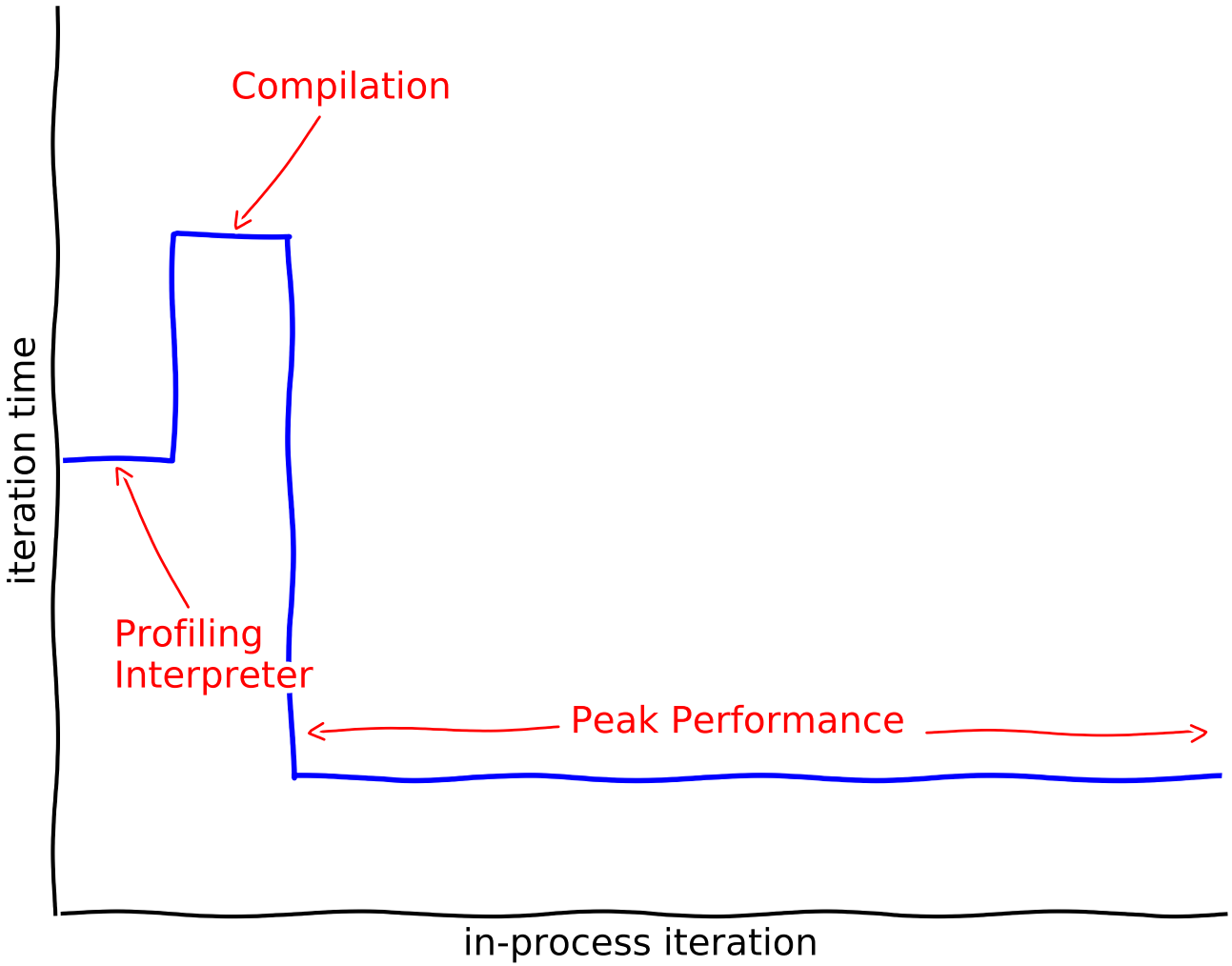

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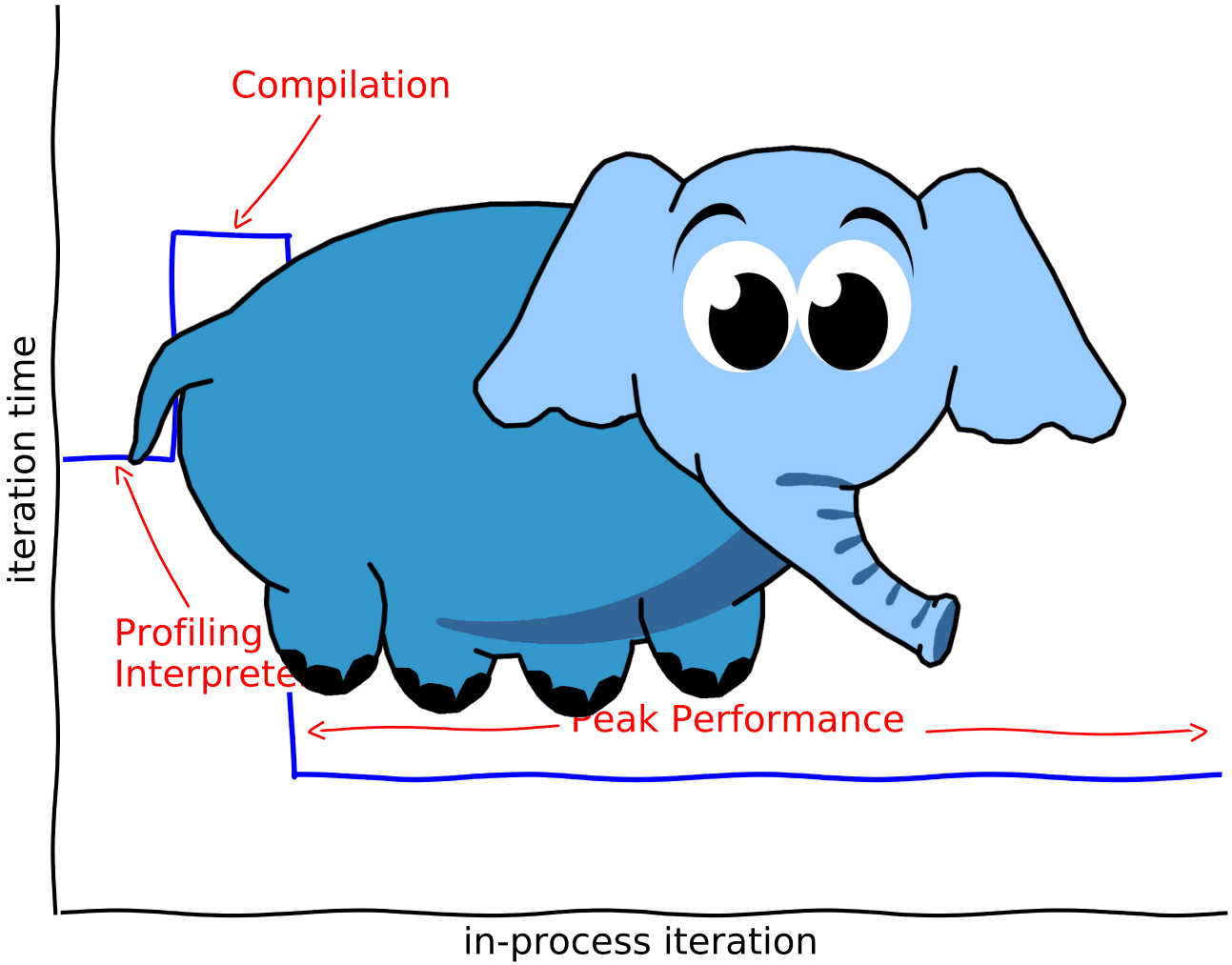

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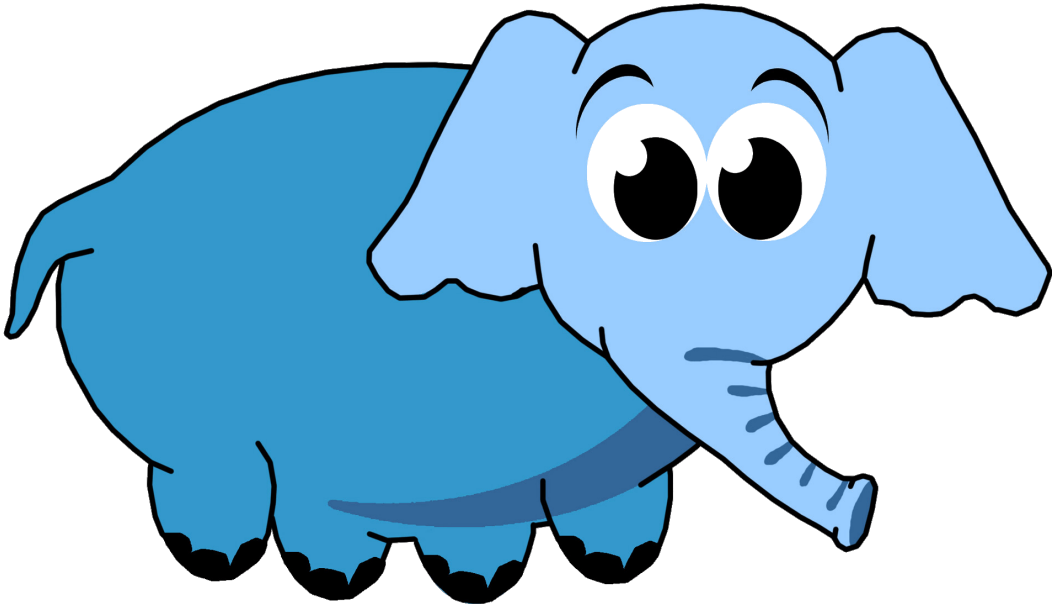
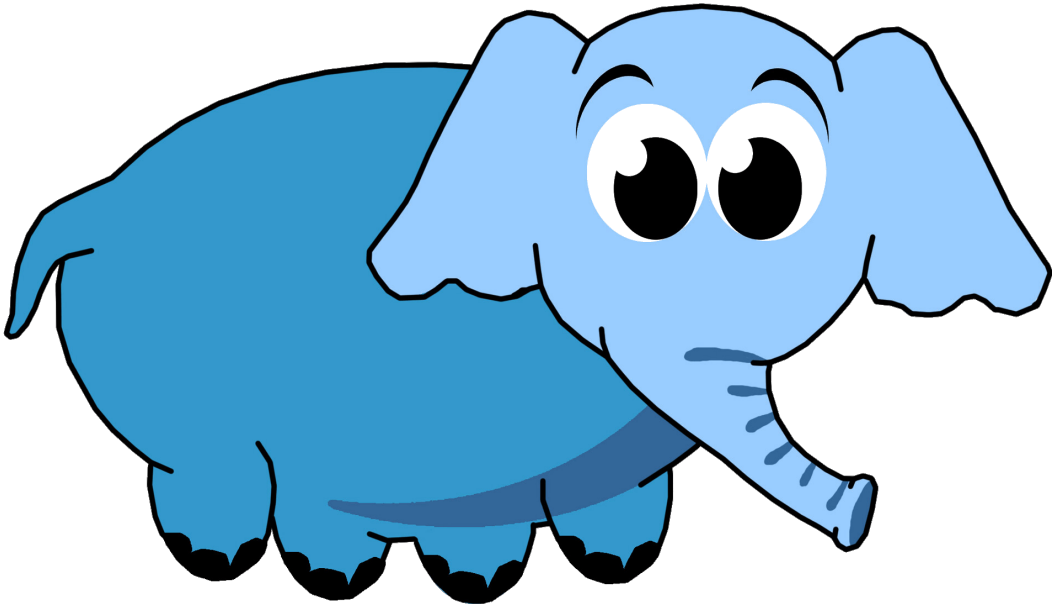


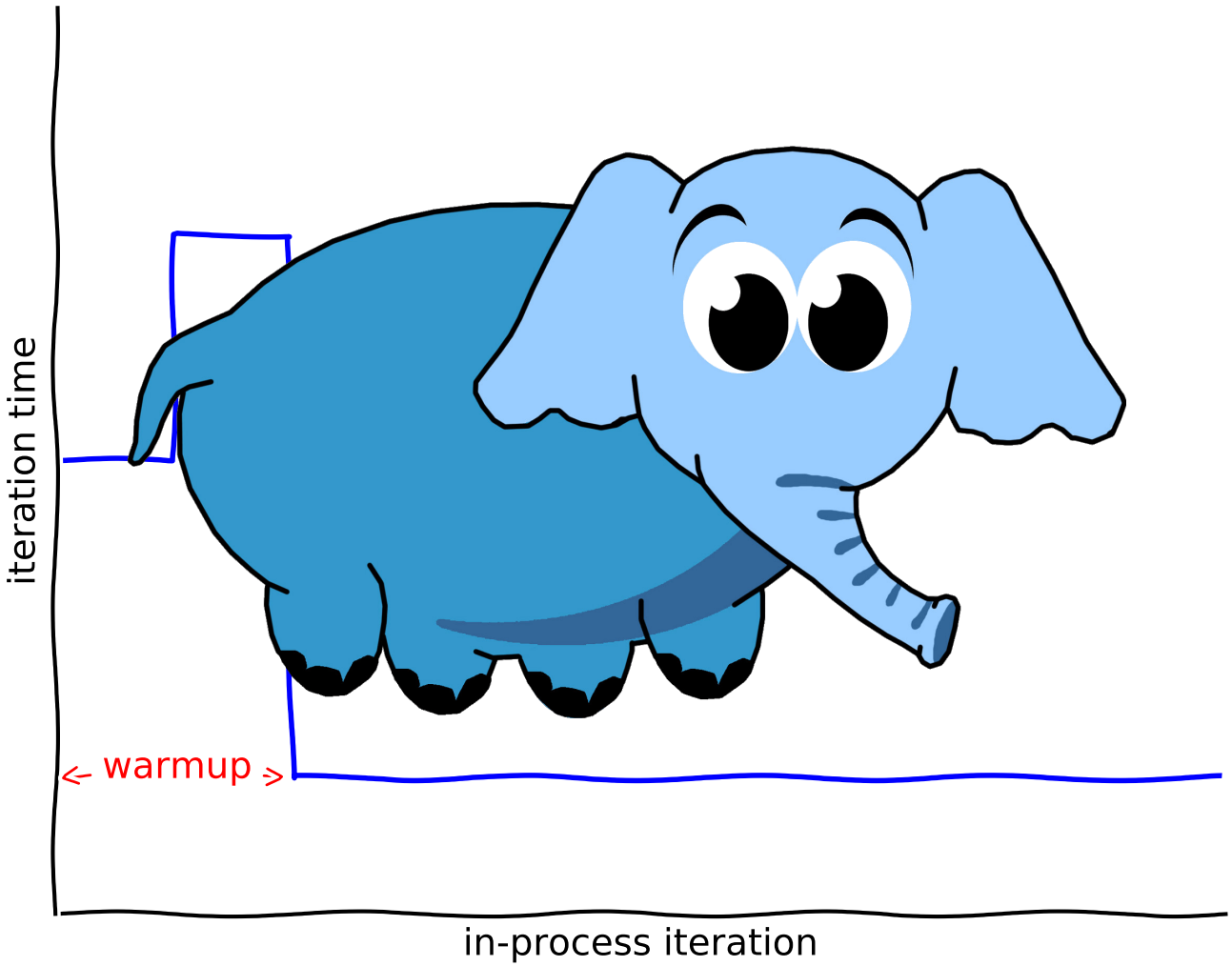
This is Barry

What our claims pertain to



This is Barry: the benchmarking elephant in the room

What our claims pertain to



Users *always* perceive warmup

Warmup

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Maybe we should know how long it is?

The Warmup Experiment

Measure warmup of modern language implementations

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Hypothesis: Small, deterministic programs reach a steady state of peak performance.

Method 1: Which benchmarks?

The language benchmark games are perfect for us (unusually)

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We removed any CFG non-determinism

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The language benchmark games are perfect for us (unusually)

We removed any CFG non-determinism

We added checksums to all benchmarks

Method 2: How long to run?

2000 *in-process iterations*

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2000 *in-process iterations*

30 *process executions*

Method 3: VMs

- Graal-0.22
- HHVM-3.19.1
- JRuby/Truffle (git #6e9d5d381777)
- Hotspot-8u121b13
- LuaJit-2.0.4
- PyPy-5.7.1
- V8-5.8.283.32
- GCC-4.9.4

Note: same GCC (4.9.4) used for all compilation

Method 4: Machines

- Linux_{4790}, Debian 8, 24GiB RAM
- $\text{Linux}_{\text{E3-1240v5}}$, Debian 8, 32GiB RAM
- OpenBSD_{4790}, OpenBSD 6.0, 32GiB RAM

Method 4: Machines

- Linux_{4790}, Debian 8, 24GiB RAM
- $\text{Linux}_{\text{E3-1240v5}}$, Debian 8, 32GiB RAM
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- Turbo boost and hyper-threading disabled
- Network card turned off.
- Daemons disabled (cron, smtpd)

Method 5: Krun

Benchmark runner: tries to control as many confounding variables as possible

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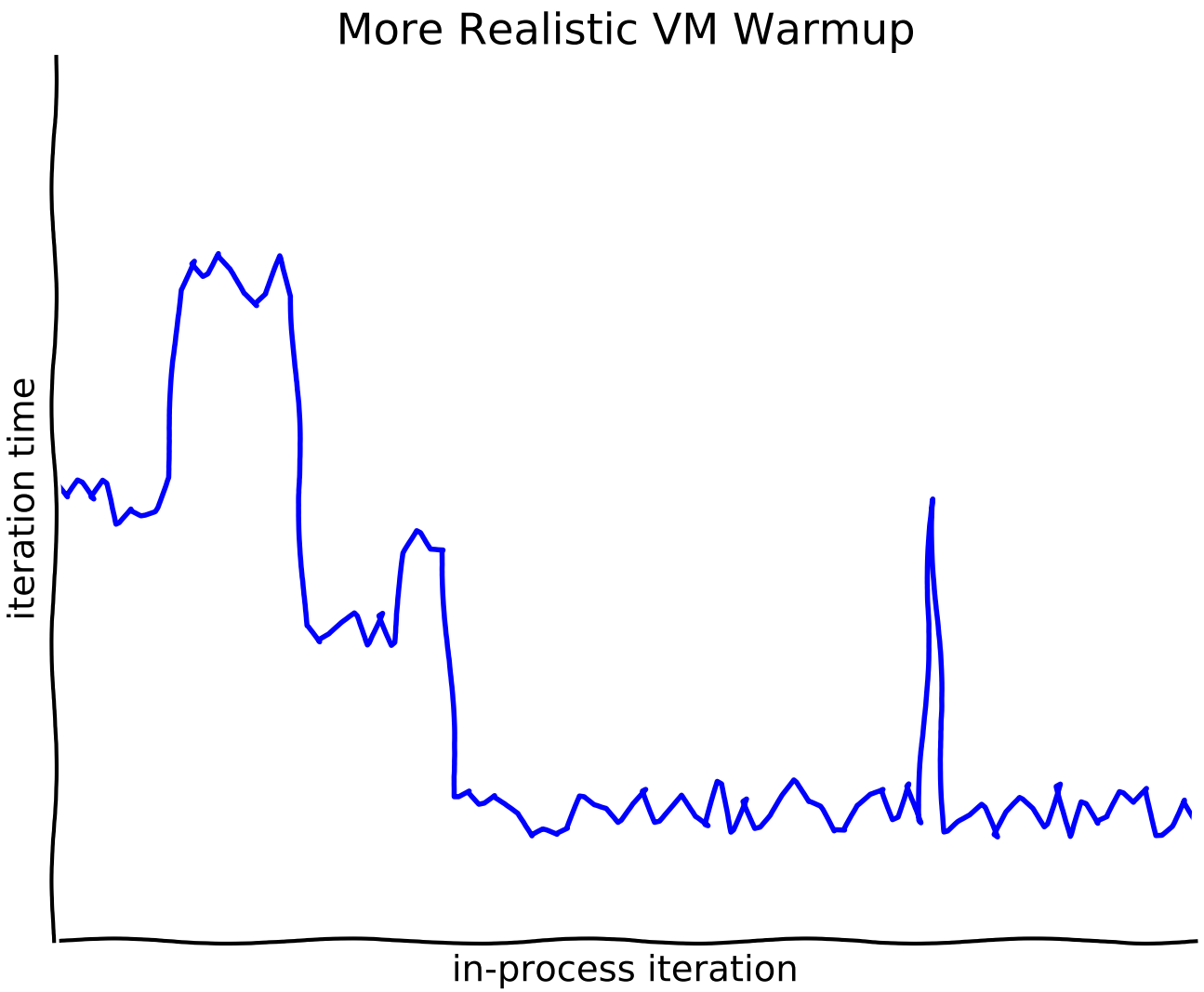
Benchmark runner: tries to control as many confounding variables as possible e.g.:

- Minimises I/O
- Sets fixed heap and stack ulimits
- Drops privileges to a 'clean' user account
- Automatically reboots the system prior to each proc. exec
- Checks `dmesg` for changes after each proc. exec
- Checks system at (roughly) same temperature for proc. execs
- Enforces kernel settings (tickless mode, CPU governors, ...)

Method 6: Expectations



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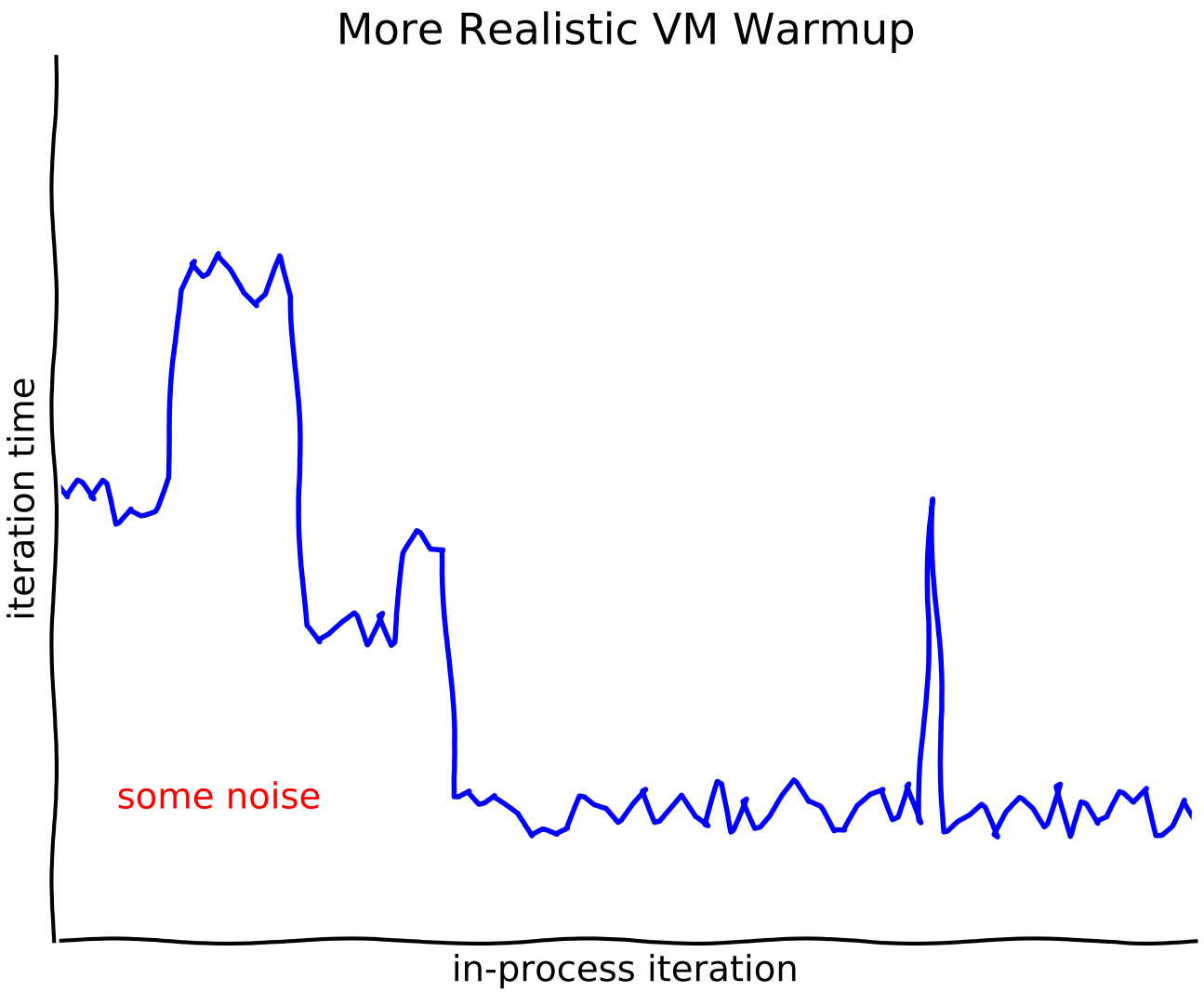

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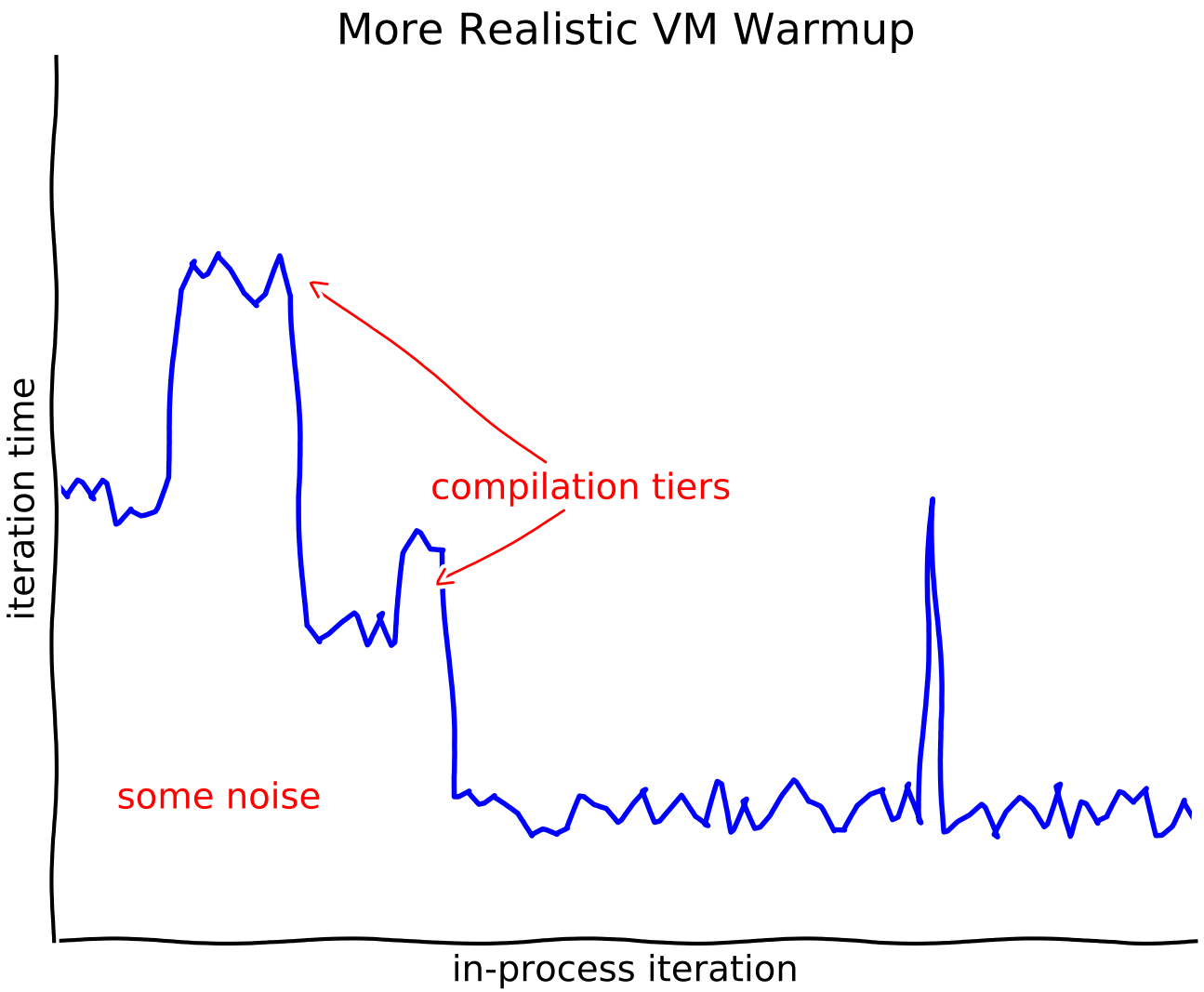

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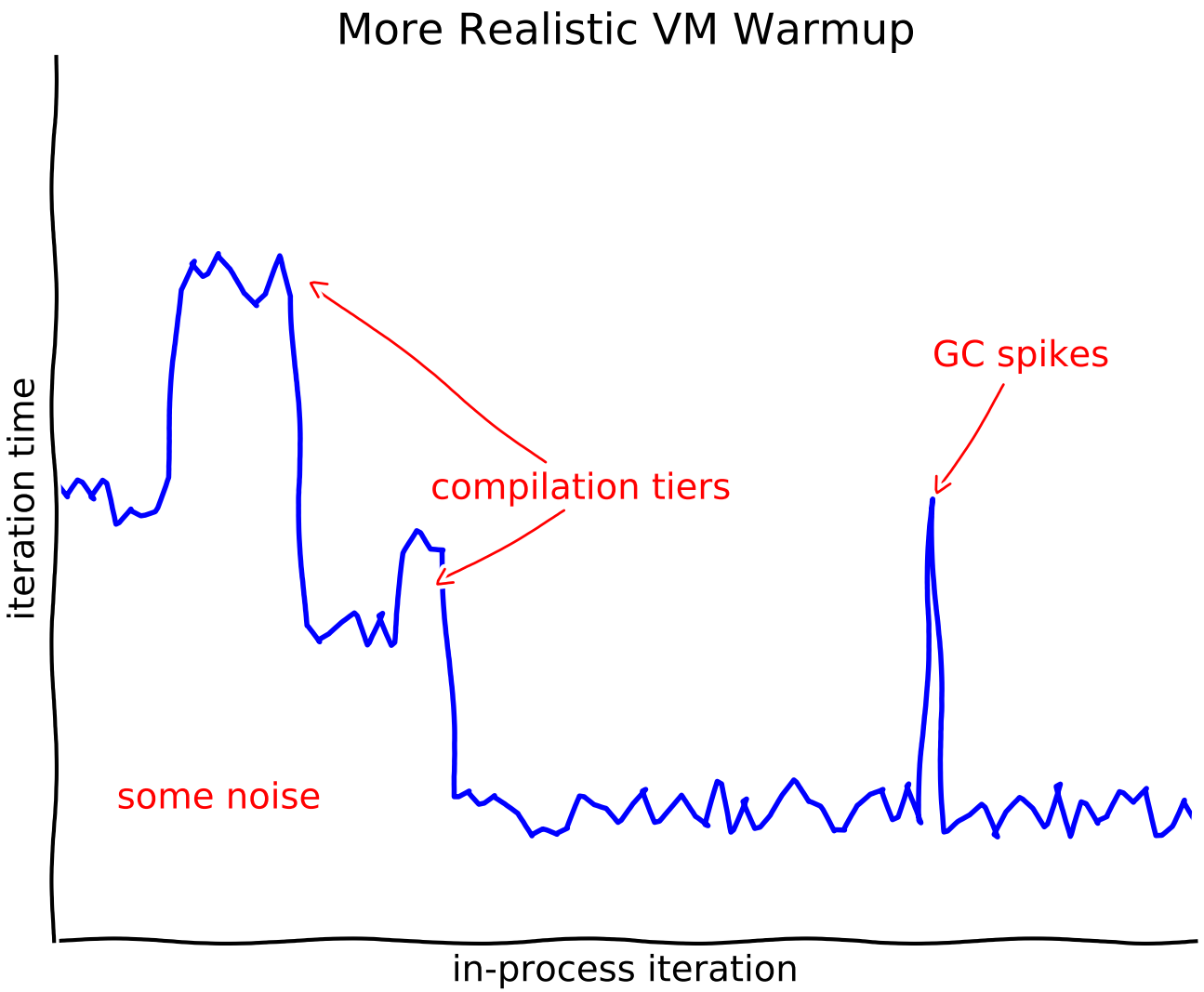
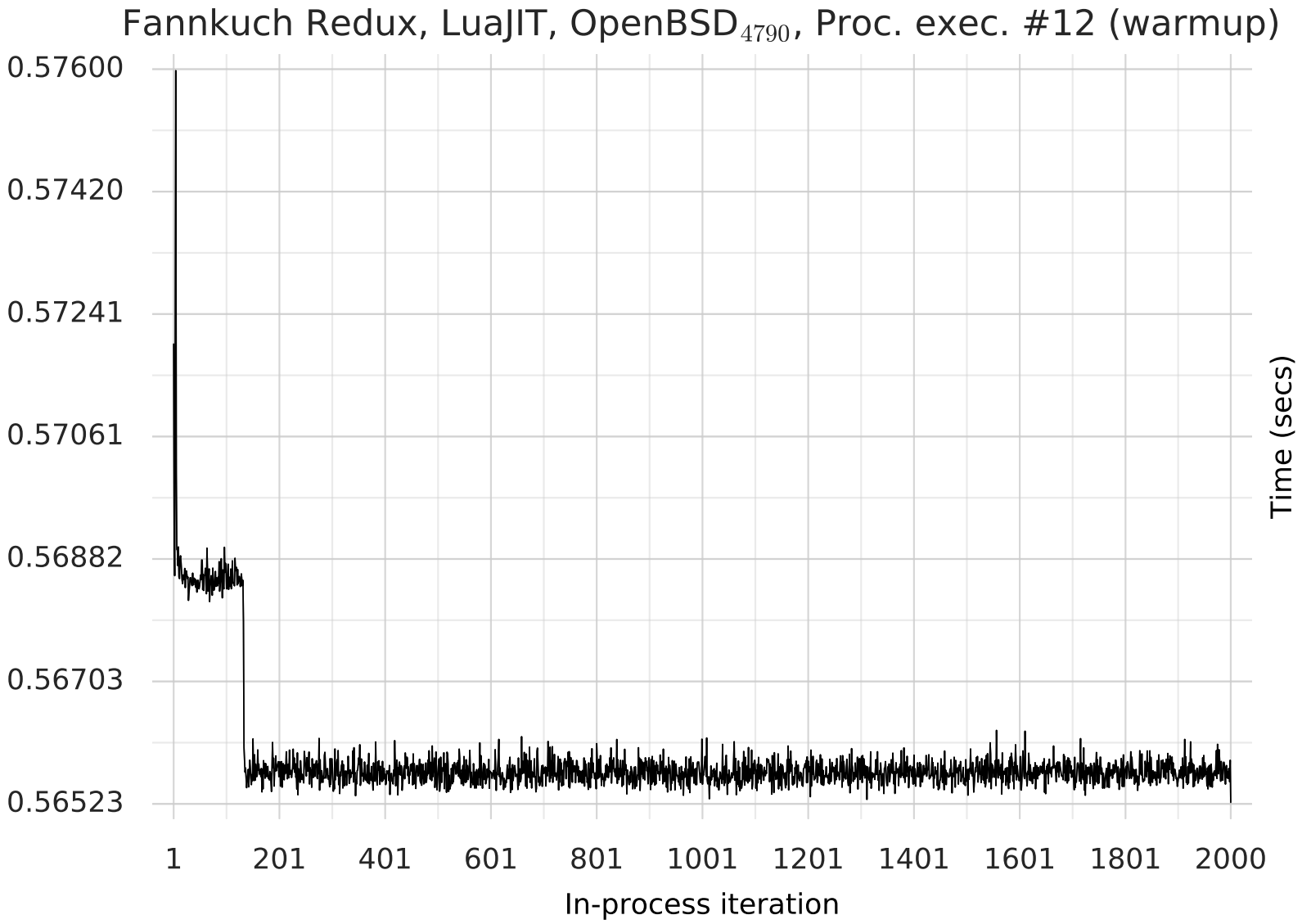


Warmup & flat (1)



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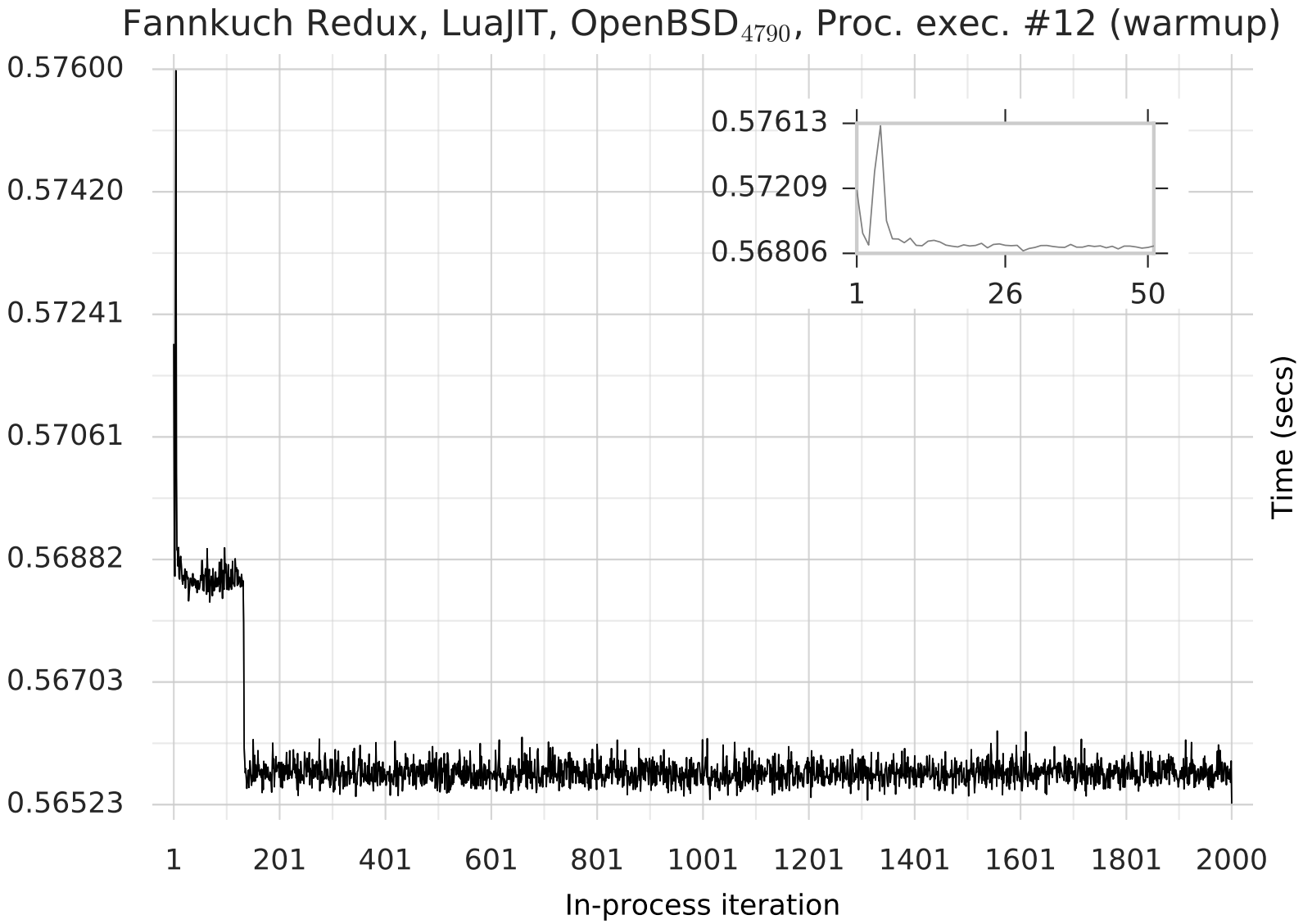

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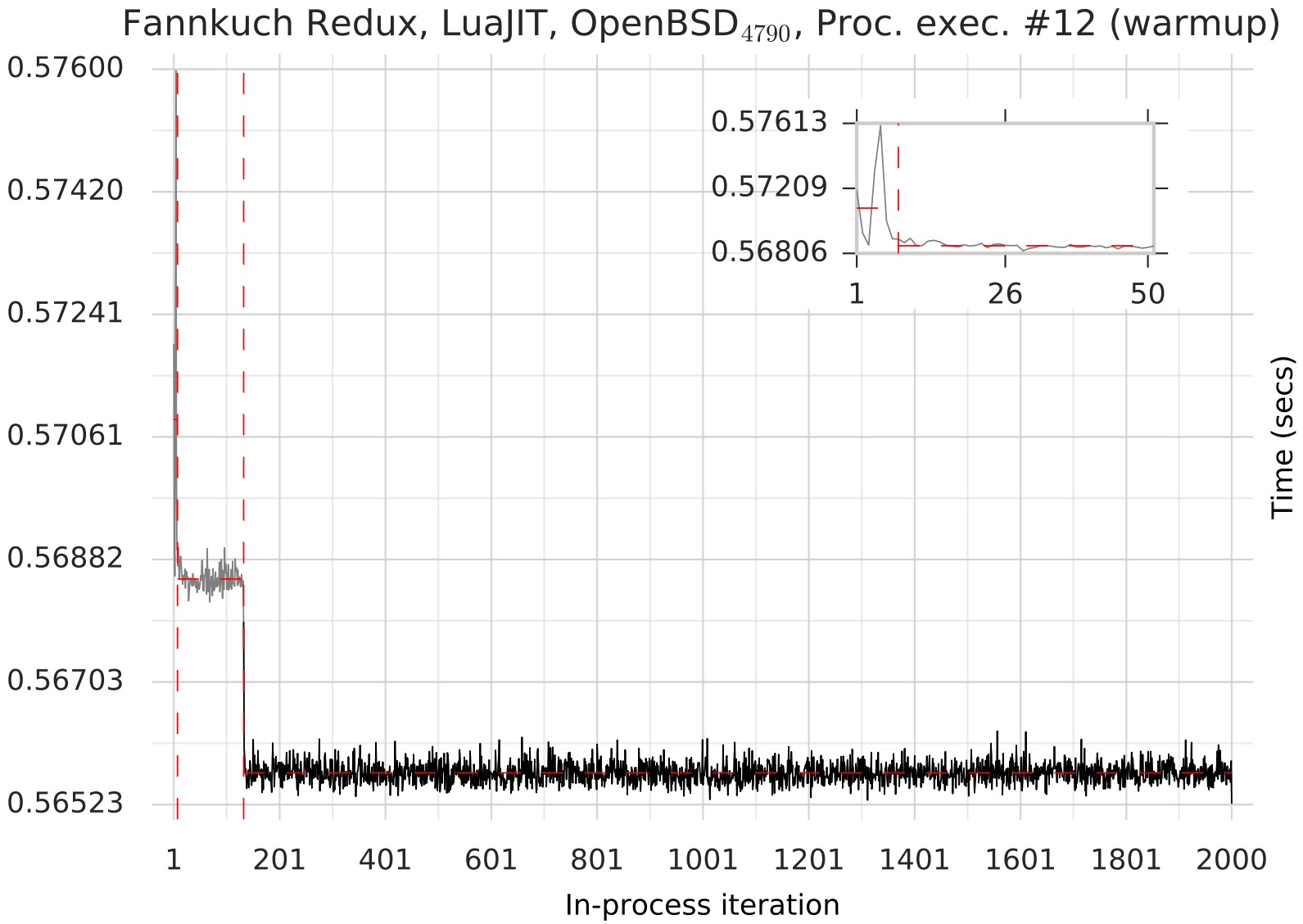

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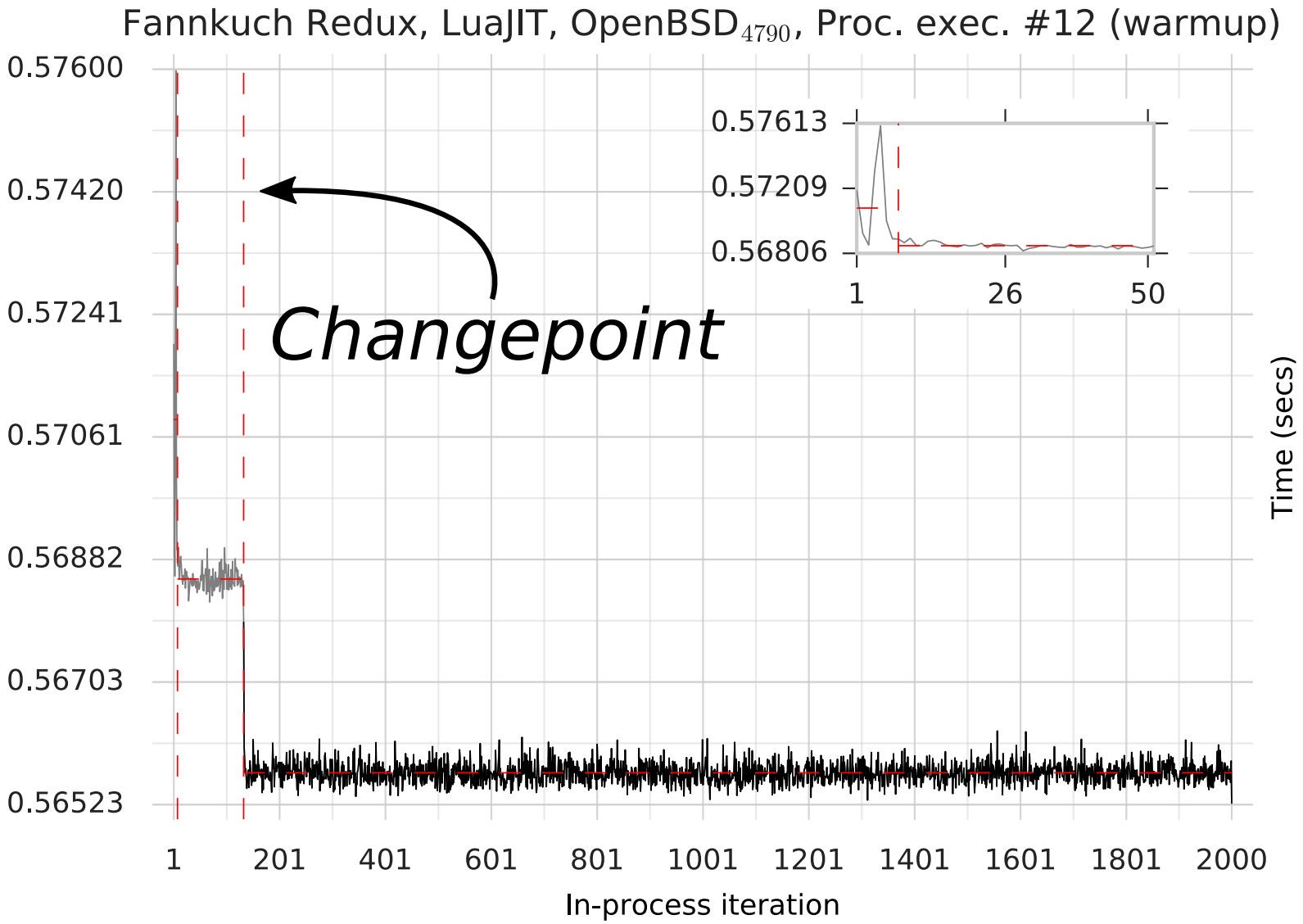

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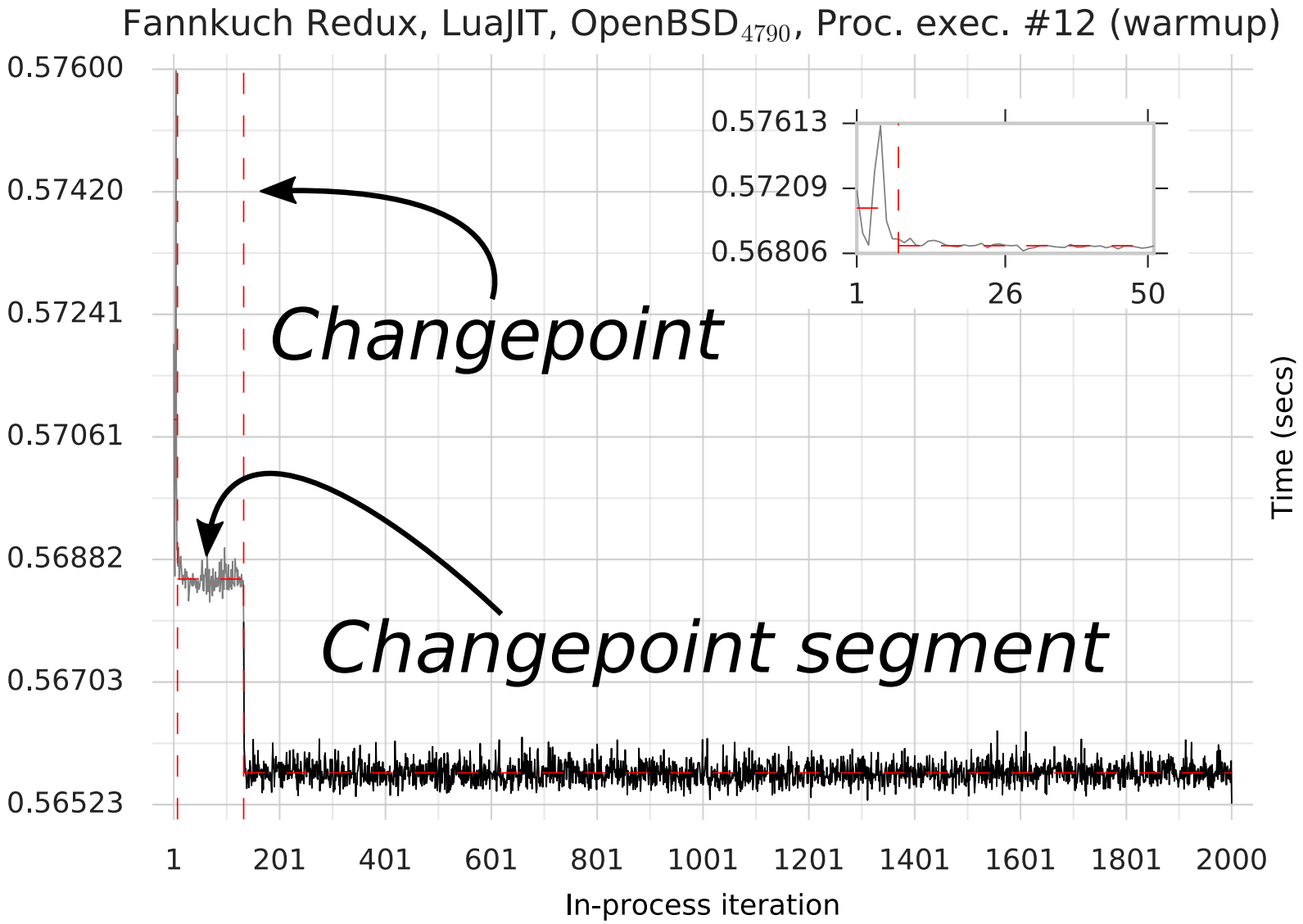

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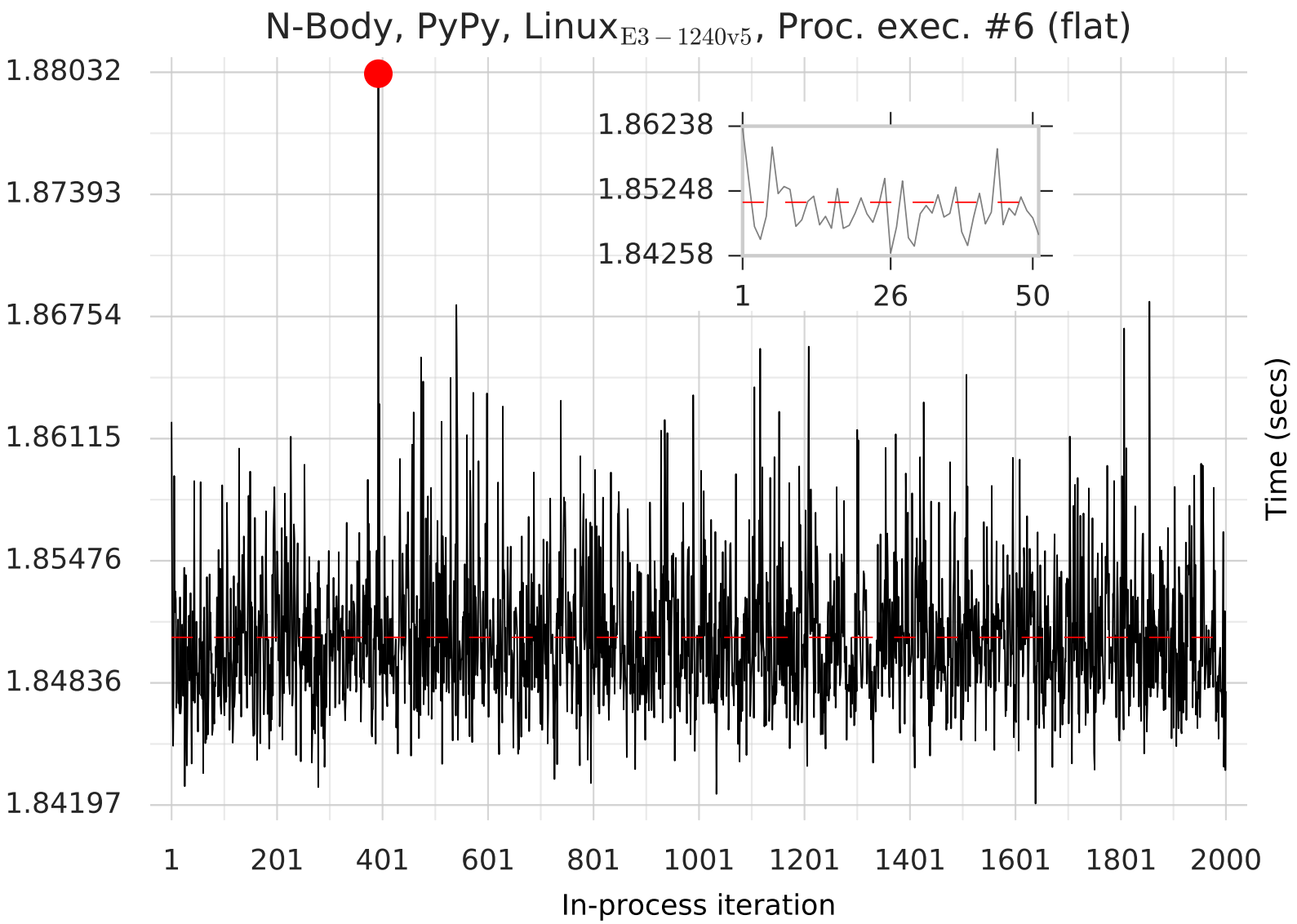

Method 7: Classification

Classification algorithm (steps in order):

- All segs are equivalent: *flat*

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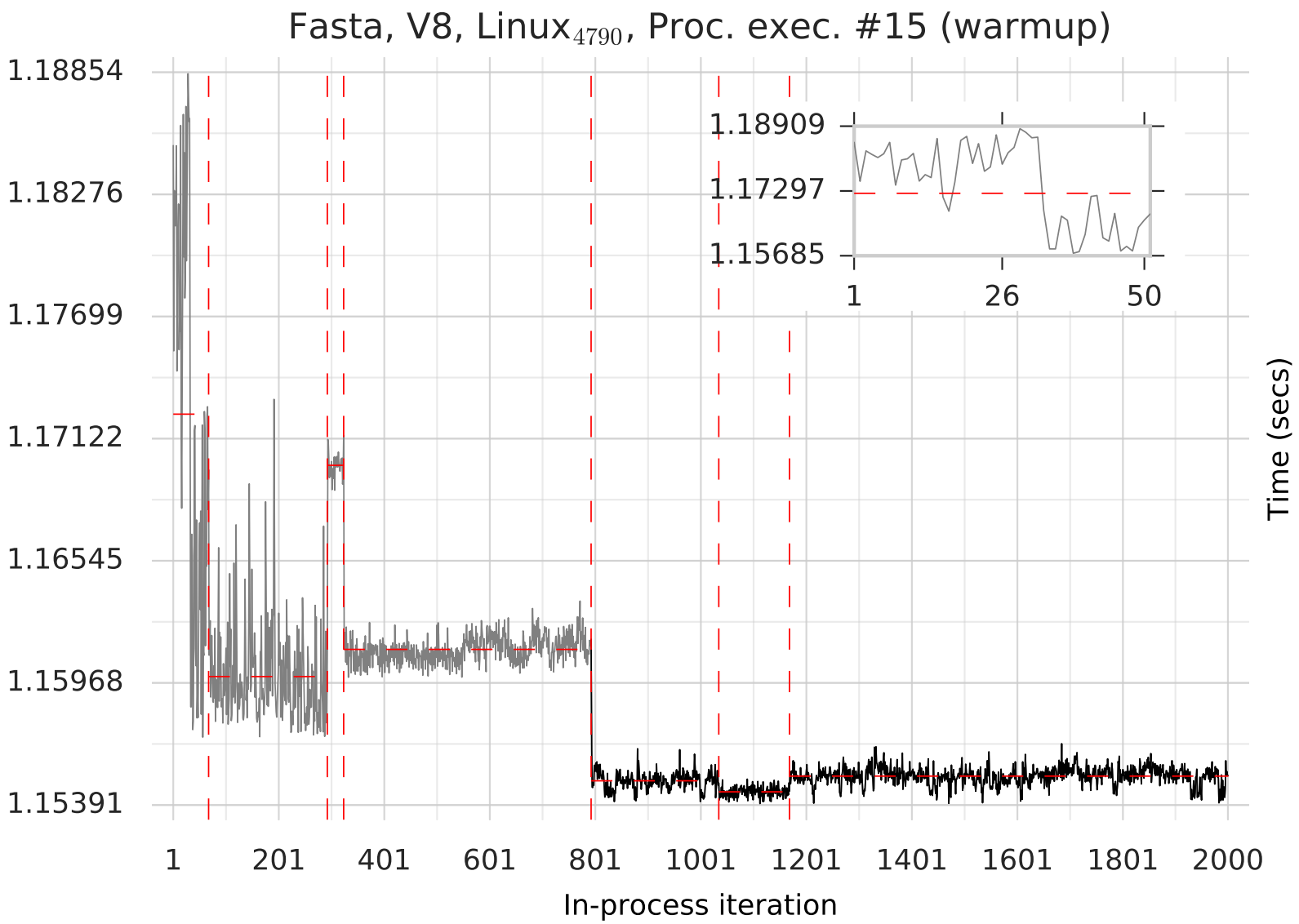
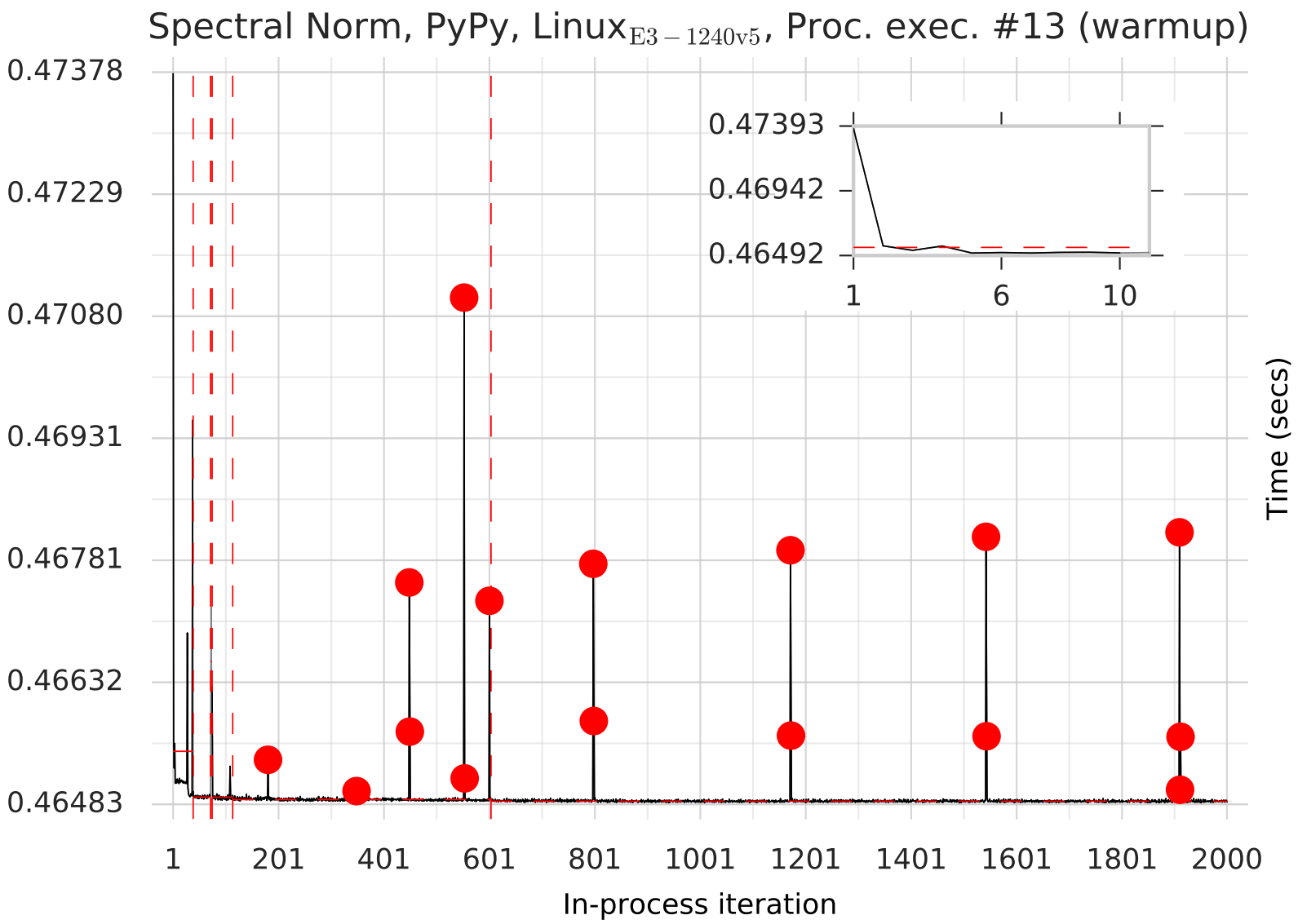
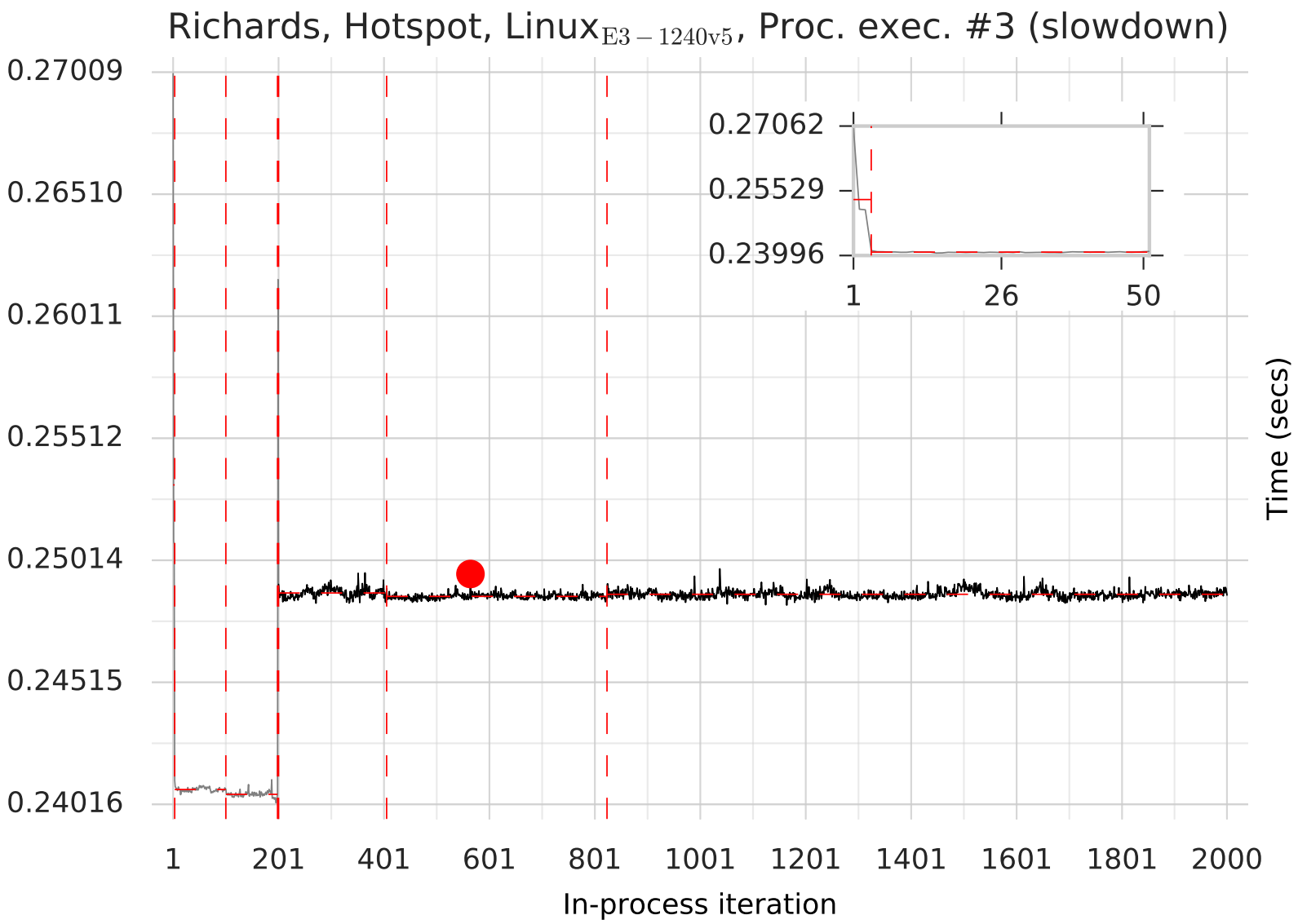
Warmup & flat (2)



Warmup & flat (2)



Slowdown (1)


Richards, Hotspot, Linux$_{E3-1240v5}$, Proc. exec. #3 (slowdown)
0.27009
0.26510
0.26011
0.25512
0.25014
0.24515
0.24016
1
201
401
601
801
1001
1201
1401
1601
1801
2000
In-process iteration
Time (secs)
0.27062
0.25529
0.23996
1
26
50

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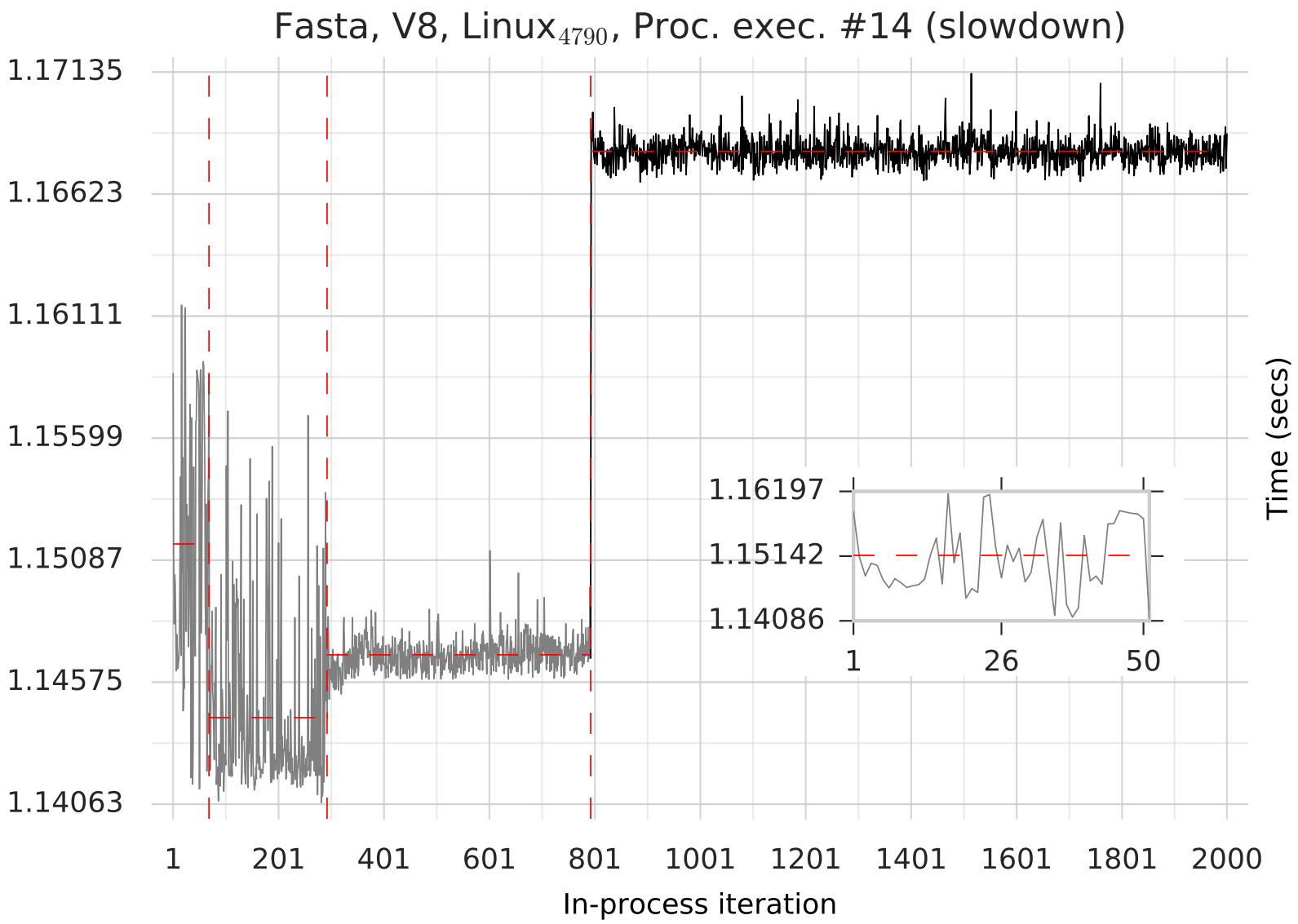
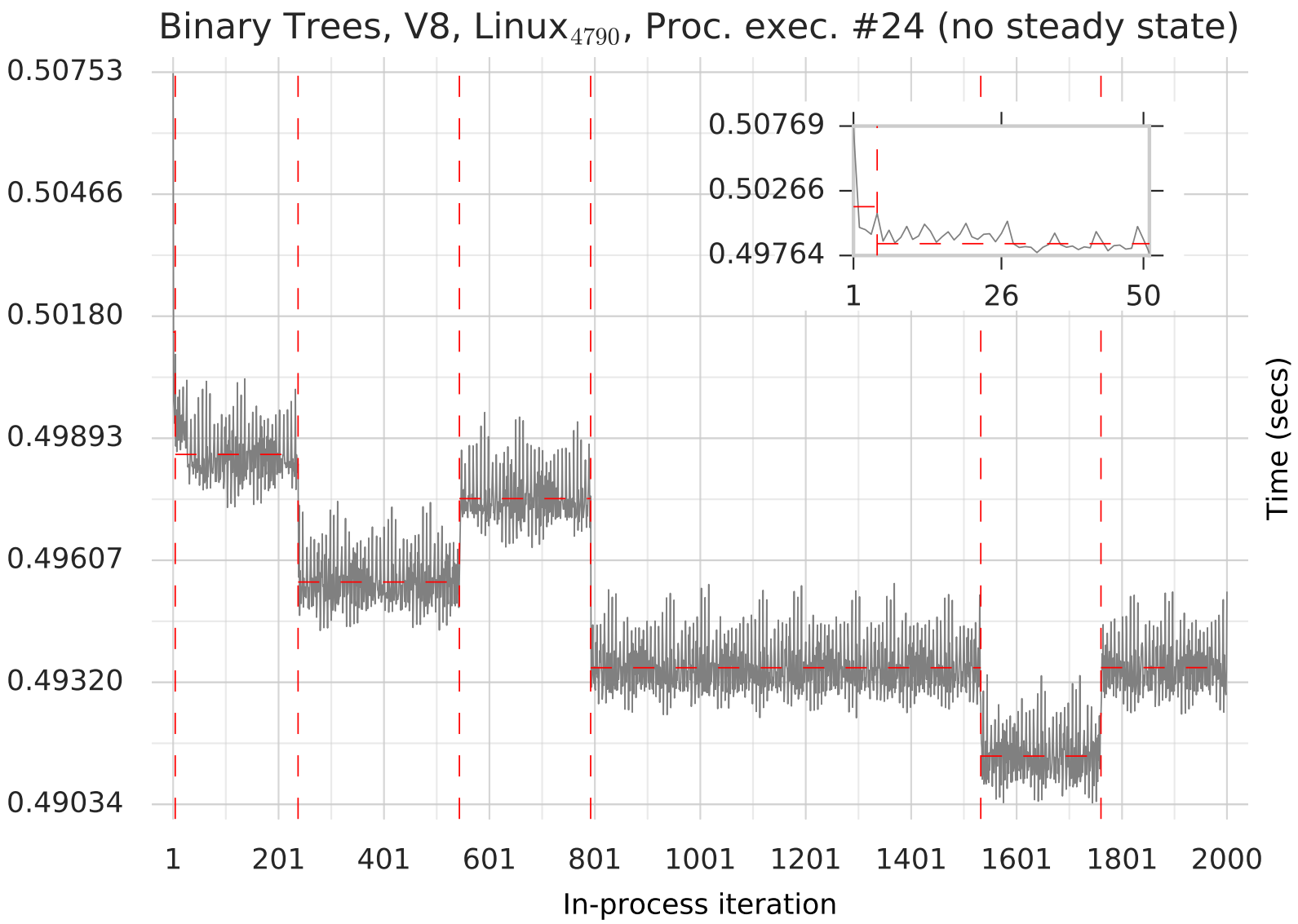
Slowdown (2)


Fasta, V8, Linux4790, Proc. exec. #14 (slowdown)
1.17135
1.16623
1.16111
1.15599
1.15087
1.14575
1.14063
1
201
401
601
801
1001
1201
1401
1601
1801
2000
In-process iteration
Time (secs)
1.16197
1.15142
1.14086
1
26
50

No steady state (1)



Classification (3)

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Classification (3)

Classification algorithm, in order:

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- Final seg is not in fastest set: *slowdown*
- Else: *no steady state*

Good

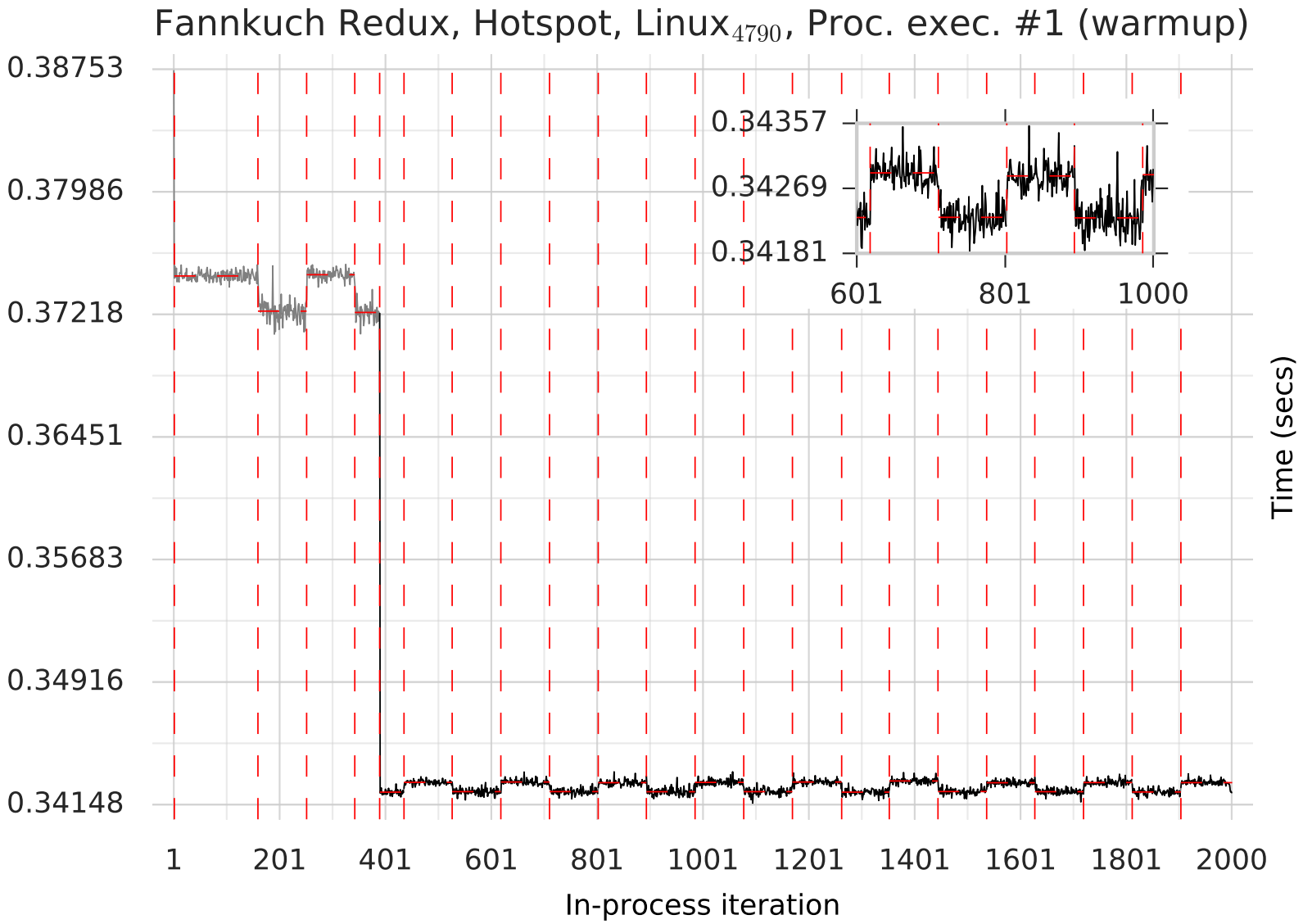
Classification (3)

Classification algorithm, in order:

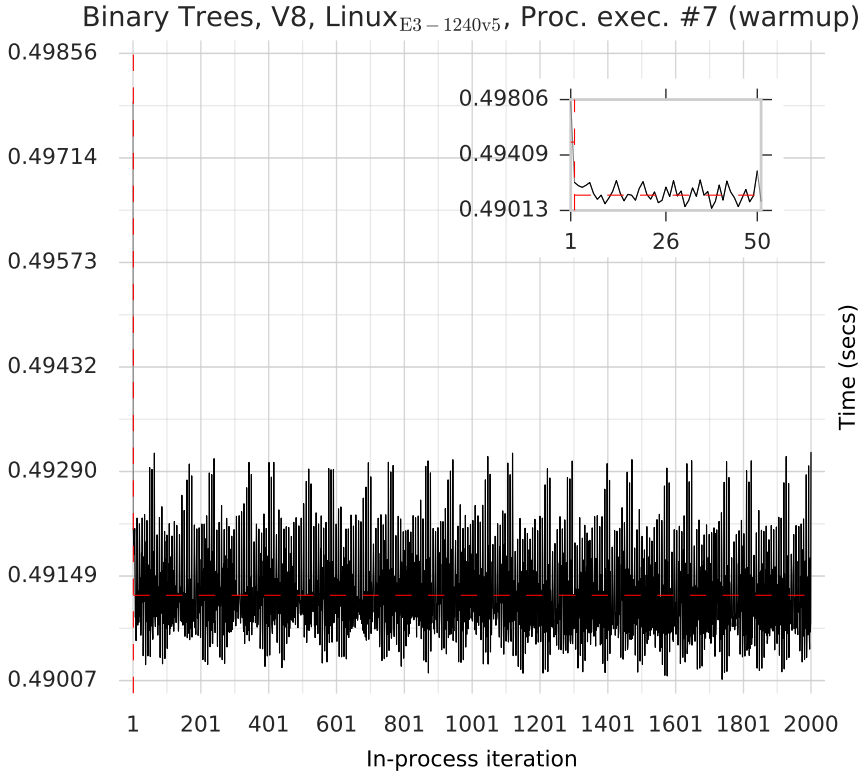
- All segs are equivalent: *flat*
- Final seg is in fastest set: *warmup*
- Final seg is not in fastest set: *slowdown*
- Else: *no steady state*

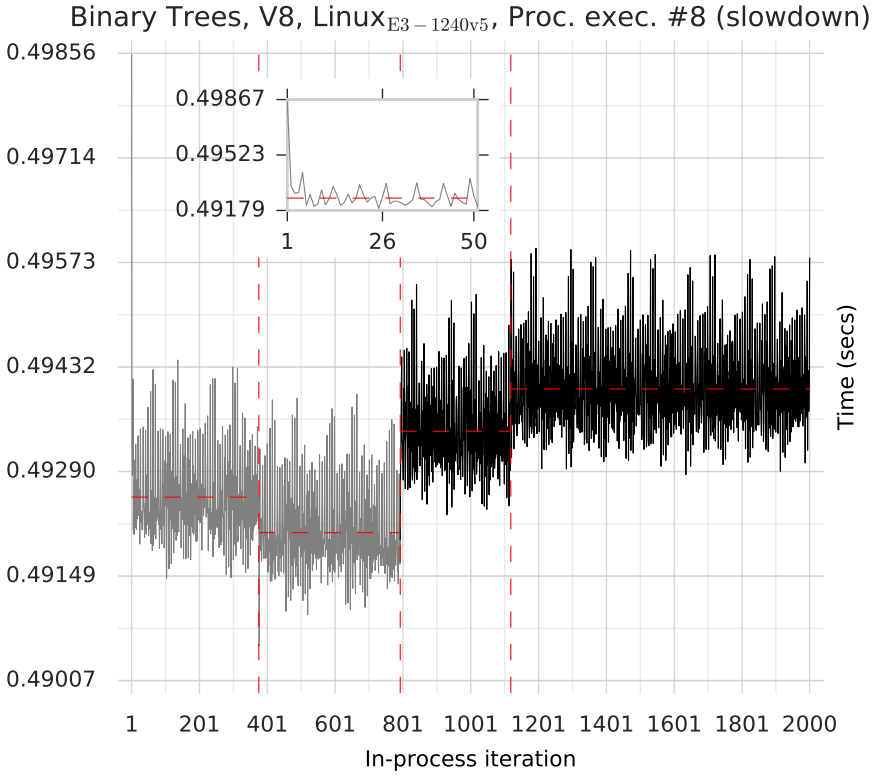
Bad

Warmup or no steady state?



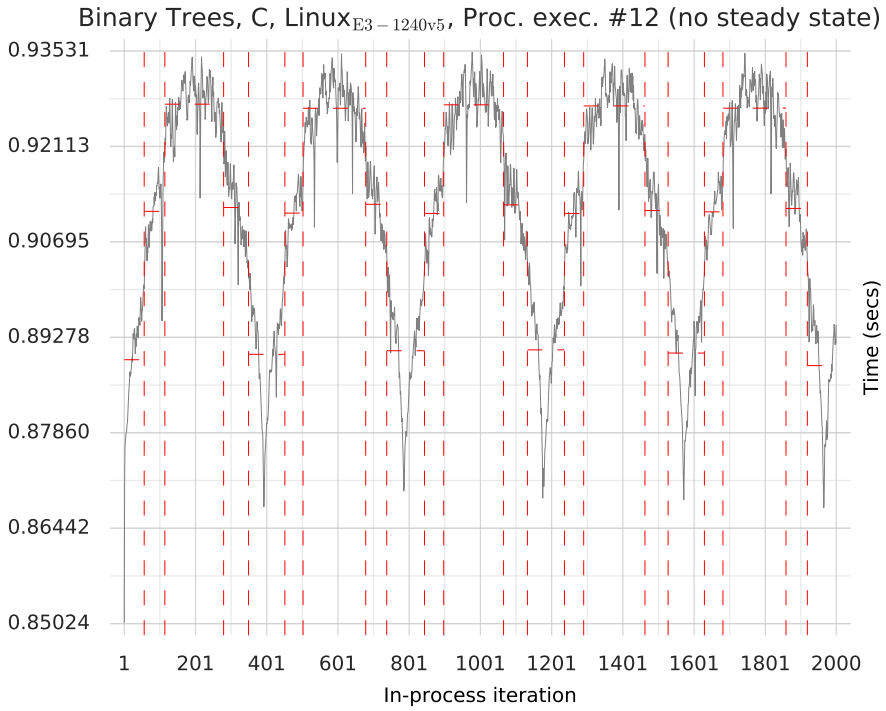
Inconsistent Process-executions

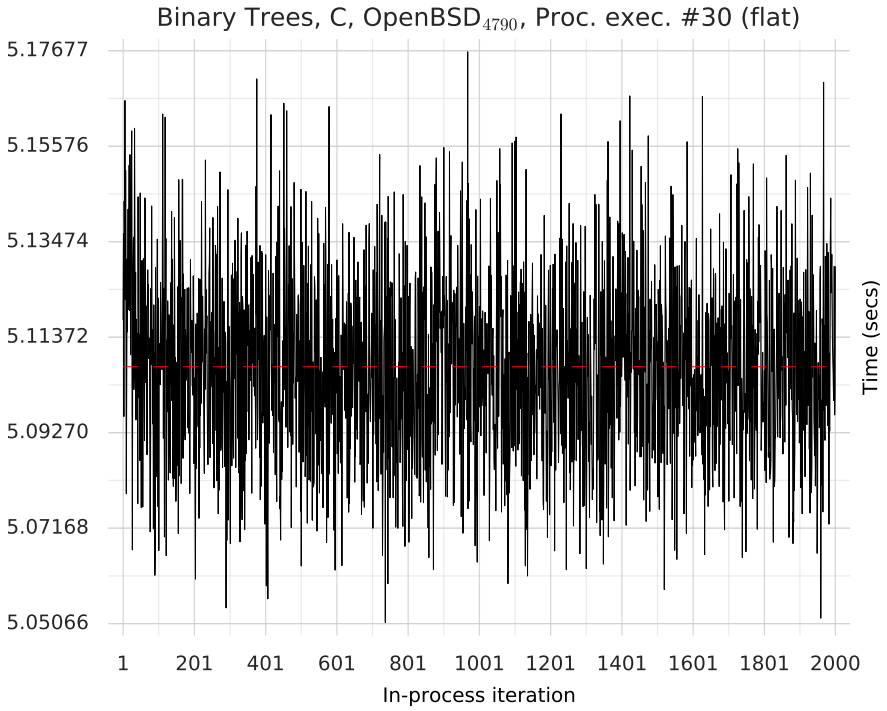




(Same machine)

Inconsistent Process-executions





(Different machines. Bouncing ball Linux-specific)

Stats example

		Class.	Steady iter (#)	Steady iter (s)	Steady perf (s)
C		⩘			
Graal		⩕ (27⎣, 3⎡)	32.0 (17.0, 193.8)	6.60 (3.729, 36.608)	0.18594 ±0.000316
HHVM		⩕ (24⎣, 4⎡, 2⩘)			
HotSpot		⩕ (25⎣, 5⎡)	7.0 (7.0, 53.5)	1.19 (1.182, 9.703)	0.18279 ±0.000116
JRuby+Truffle		⎡	1082.0 (999.0, 1232.5)	2219.59 (2039.304, 2516.021)	2.05150 ±0.017737
LuaJIT		⩕ (23⎣, 4⎡, 2–, 1⩘)			
PyPy		⩕ (27⎡, 3⩘)			
V8		⩕ (15–, 9⎣, 6⎡)	1.5 (1.0, 794.0)	0.25 (0.000, 391.026)	0.49237 ±0.003198

binary trees

Summary

Classical warmup occurs for only:

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77% of process executions

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39% of (VM, benchmark) pairs

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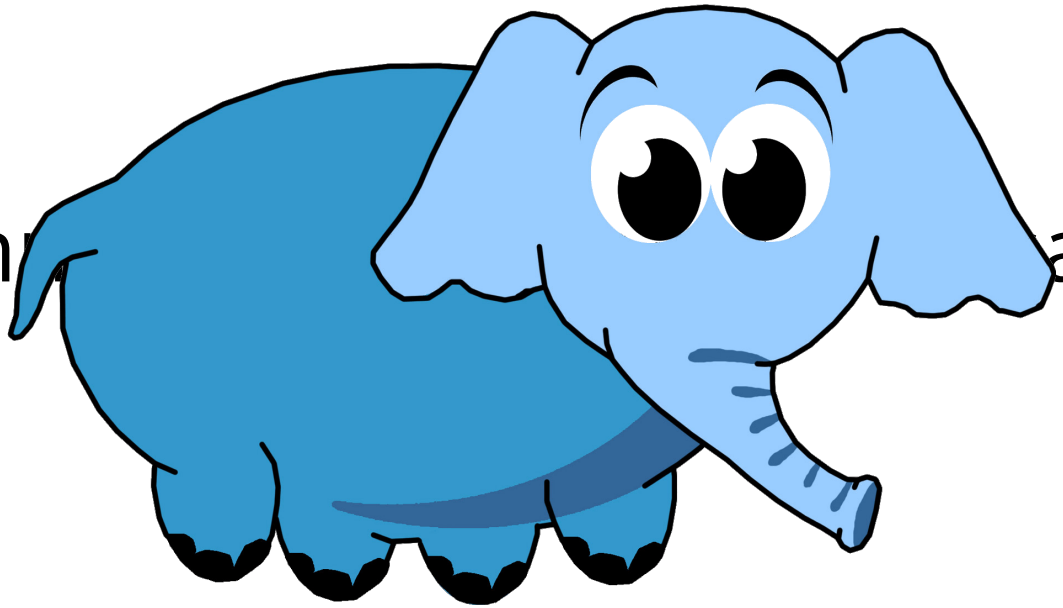
0% of benchmarks for (VM, benchmark, machine) triples

Benchmark suites

Benchmarks guide our optimisations

Benchmark suites

Bench  ations

Benchmarks guide our optimisations

Are they complete guides?

A war story

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Symptom: poor performance of a Pyston benchmark on PyPy

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Cause: RPython traces recursion

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Symptom: poor performance of a Pyston benchmark on PyPy

Cause: RPython traces recursion

Fix: Check for recursion before tracing

A war story: the basis of a fix

```
diff --git a/rpython/jit/metainterp/pyjitpl.py b/rpython/jit/metainterp/pyjitpl.py
--- a/rpython/jit/metainterp/pyjitpl.py
+++ b/rpython/jit/metainterp/pyjitpl.py
@@ -951,9 +951,31 @@
         if warmrunnerstate.inlining:
             if warmrunnerstate.can_inline_callable(greenboxes):
+                # We've found a potentially inlinable function; now we need to
+                # see if it's already on the stack. In other words: are we about
+                # to enter recursion? If so, we don't want to inline the
+                # recursion, which would be equivalent to unrolling a while
+                # loop.
                 portal_code = targetjitdriver_sd.mainjitcode
-                return self.metainterp.perform_call(portal_code, allboxes,
-                                                    greenkey=greenboxes)
+                inline = True
+                if self.metainterp.is_main_jitcode(portal_code):
+                    for gk, _ in self.metainterp.portal_trace_positions:
+                        if gk is None:
+                            continue
+                        assert len(gk) == len(greenboxes)
+                        i = 0
+                        for i in range(len(gk)):
+                            if not gk[i].same_constant(greenboxes[i]):
+                                break
+                        else:
+                            # The greenkey of a trace position on the stack
+                            # matches what we have, which means we're definitely
+                            # about to recurse.
+                            inline = False
+                            break
+                if inline:
+                    return self.metainterp.perform_call(portal_code, allboxes,
+                                        greenkey=greenboxes)
```

A war story: mixed fortunes

Success: slow benchmark now 13.5x faster

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Failure: some PyPy benchmarks slow down

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Success: slow benchmark now 13.5x faster

Failure: some PyPy benchmarks slow down

Solution: allow *some* tracing into recursion

A war story: data

#unrollings	1	2	3	5	7	10
hexiom2	1.3	1.4	1.1	1.0	1.0	1.0
raytrace-simple	3.3	3.1	2.8	1.4	1.0	1.0
spectral-norm	3.3	1.0	1.0	1.0	1.0	1.0
sympy_str	1.5	1.0	1.0	1.0	1.0	1.0
telco	4	2.5	2.0	1.0	1.0	1.0
polymorphism	0.07	0.07	0.07	0.07	0.08	0.09

http://marc.info/?l=pypy-dev&m=141587744128967&w=2

A war story: conclusion

The benchmark suite said 7 levels, so that's what I suggested

A war story: conclusion

The benchmark suite said 7 levels, so that's what I suggested

Even though I doubted it was the right global value

Benchmark suites (2)

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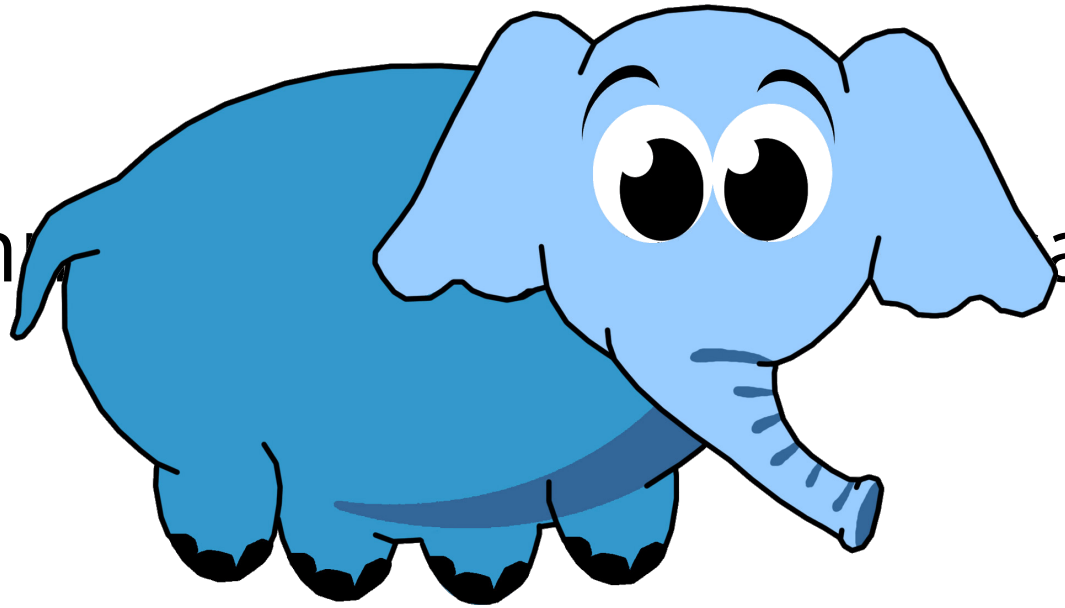
Benchmarks guide our optimisations

Benchmark suites (2)

Bench ations



Benchmark suites (2)

Benchmarks guide our optimisations

Are they correct guides?

Octane

17 JavaScript benchmarks from V8

Octane

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Let’s make each benchmark run for 2000 iterations

Octane: pdf.js explodes

```
$ d8 run.js
Richards
DeltaBlue
Encrypt
Decrypt
RayTrace
Earley
Boyer
RegExp
Splay
NavierStokes
PdfJS

<--- Last few GCs --->

14907865 ms: Mark-sweep 1093.9 (1434.4) -> 1093.4 (1434.4) MB, 274.8 / 0.0 ms [allocation failure] [GC in old space
14908140 ms: Mark-sweep 1093.4 (1434.4) -> 1093.3 (1434.4) MB, 274.4 / 0.0 ms [allocation failure] [GC in old space
14908421 ms: Mark-sweep 1093.3 (1434.4) -> 1100.5 (1418.4) MB, 280.9 / 0.0 ms [last resort gc].
14908703 ms: Mark-sweep 1100.5 (1418.4) -> 1107.8 (1418.4) MB, 282.1 / 0.0 ms [last resort gc].


<--- JS stacktrace --->

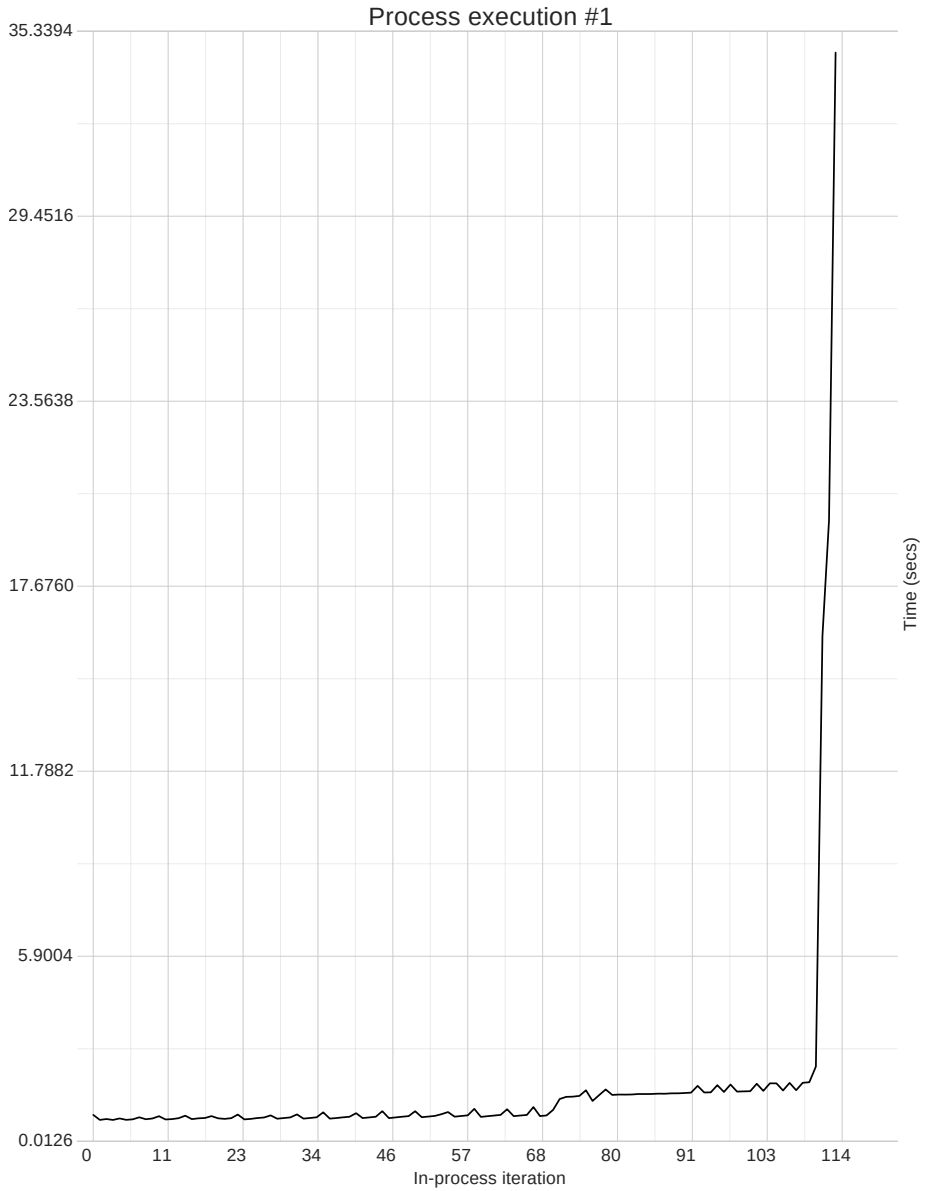
==== JS stack trace =========================================

Security context: 0x20d333ad3ba9 <JS Object>
    2: extractFontProgram(aka Type1Parser_extractFontProgram) [pdfjs.js:17004] [pc=0x3a13b275421b] (this=0x3de358283
    3: new Type1Font [pdfjs.js:17216] [pc=0x3a13b2752078] (this=0x4603fbdaea9 <a Type1Font with map 0x1f822134f7e1>,

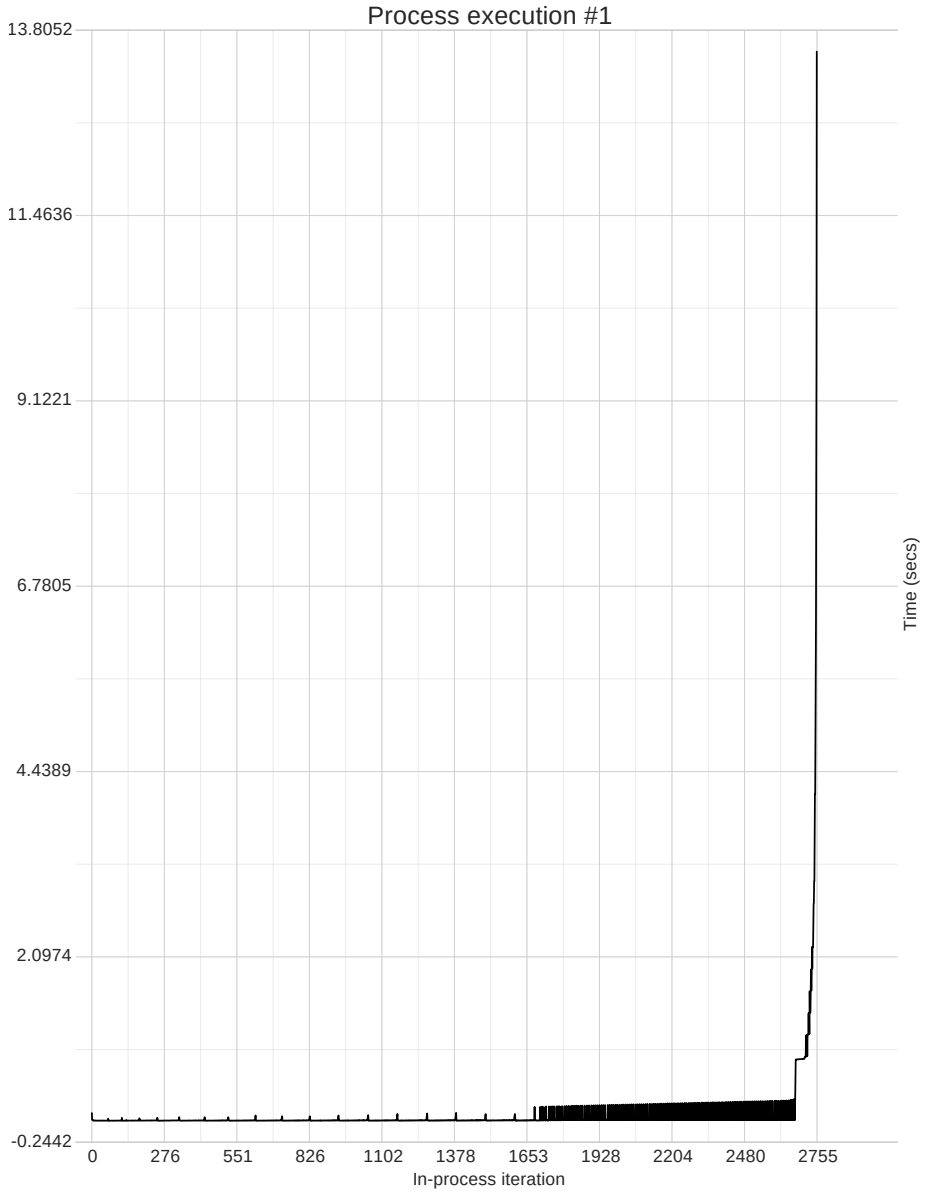

#
# Fatal error in CALL_AND_RETRY_LAST
# Allocation failed - process out of memory
#

zsh: illegal hardware instruction  d8 run.js
```

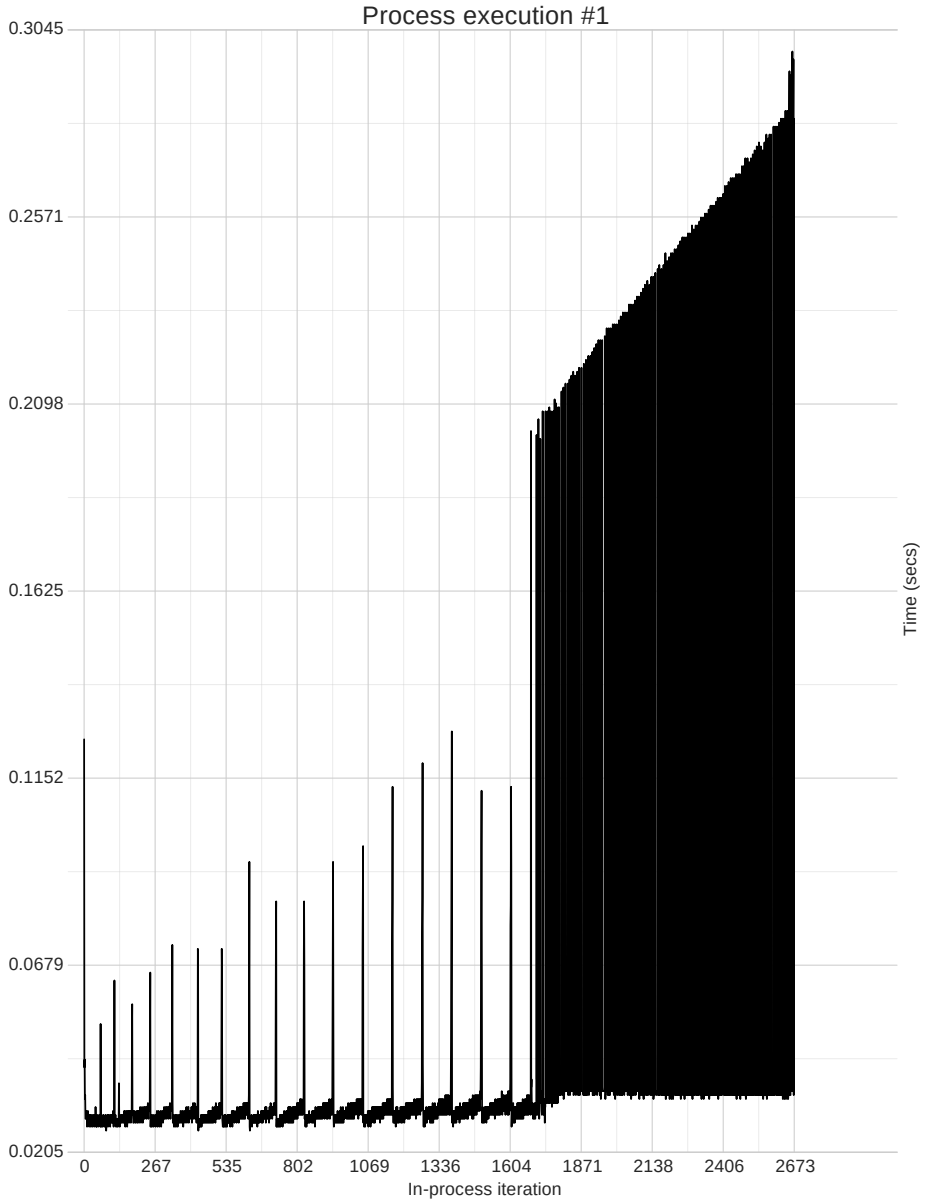
Octane: analysing pdf.js



Octane: analysing pdf.js



Octane: analysing pdf.js



Octane: debugging

pdfjs.js (/tmp/octane) - GVIM2

pdfjs.js buffers

```
//////// Benchmark set-up. (c) by Google. ////////

var pdf_file = "test.pdf";
var canvas_logs = [];

var PdfJS = new BenchmarkSuite("PdfJS", [10124921], [
  new Benchmark("PdfJS", false, false, 24,
    runPdfJS, setupPdfJS, tearDownPdfJS, null, 4)
]);
```

NORMAL master pdfjs.js jav… utf-8[unix] 0% ¶ 28/33053 : 1

```
function runPdfJS() {
  PDFJS.getDocument(pdf_file).then(function(pdf) {
    var canvas = PdfJS_window.document.getElementById('canvas');
    var context = canvas.getContext('2d');
    var renderContext = {canvasContext: context};
    canvas_logs.push(context.__log__);

    // Cycle through all pages.
    function renderPages(i, j) {
      if (i > j) return;
      context.clearRect(0, 0, canvas.width, canvas.height);
      pdf.getPage(i).then(function(page) {
        renderContext.viewport = page.getViewport(1);
        canvas.height = renderContext.viewport.height;
        canvas.width = renderContext.viewport.width;
        page.render(renderContext).then(renderPages.bind(null, i + 1, j));
      });
    }
    renderPages(1, pdf.numPages);
  });

  // Wait for everything to complete.
  PdfJS_window.flushTimeouts();
}
```

pdfjs.js jav… utf-8[unix] 0% ¶ 50/33053 : 38

Octane: fixing

Fix memory leak in

Secure https://github.com/chromium/octane/pull/42/file

Fix memory leak in pdfjs.js. #42

Open **ltratt** wants to merge 2 commits into `chromium:master` from `ltratt:master`

Conversation 5 | Commits 2 | Files changed 1

Changes from **all commits** | **1 file** | **+1 −0**

1 pdfjs.js

```
@@ -43,6 +43,7 @@ function setupPdfJS() {
43 43  }
44 44
45 45  function runPdfJS() {
   46 +  canvas_logs.length = 0;
46 47    PDFJS.getDocument(pdf_file).then(function(pdf) {
47 48      var canvas = PdfJS_window.document.getElementById('canvas');
48 49      var context = canvas.getContext('2d');
```

Octane: other issues

pdfjs isn’t the only problem

Octane: other issues

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CodeLoadClosure also has a memory leak

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zlib complains that `Cannot enlarge memory arrays in asm.js` (a memory leak? I don't know)

Octane: other issues

pdfjs isn't the only problem

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Timings are made with a non-monotonic microsecond timer

Summary

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Why aren’t more users more happy with our VMs?

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My thesis: our benchmarking *and* our benchmarks have misled us

What we can do

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1. Run benchmarks for longer to uncover issues.
2. Accept that peak performance may not occur.
3. Always report warmup time.
4. Stop over-training on small benchmark suites.
5. The more benchmarks, the better.
6. Focus on predictable performance.

References

VM Warmup Blows Hot and Cold
E. Barrett, C. F. Bolz, R. Killick, V. Knight, S. Mount and L. Tratt.

Rigorous Benchmarking in Reasonable Time
T. Kalibera and R. Jones

Specialising Dynamic Techniques for Implementing the Ruby Programming Language
C. Seaton (Chapter 4)

Quantifying performance changes with effect size confidence intervals
T. Kalibera and R. Jones

Thanks

- EPSRC: *COOLER* and *Lecture*.
- Oracle: various.

K Whiteford for Barry, the Benchmarking Elephant in the Room

Thanks for listening

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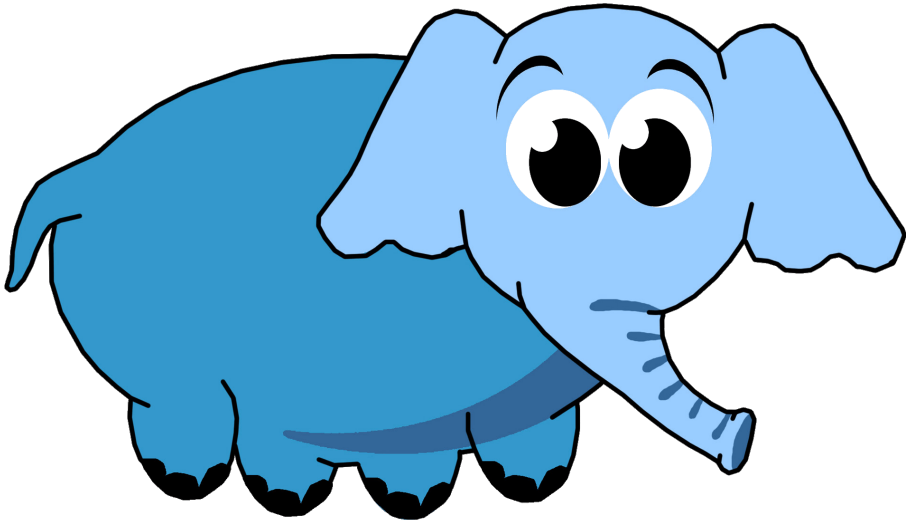

And don’t forget Barry