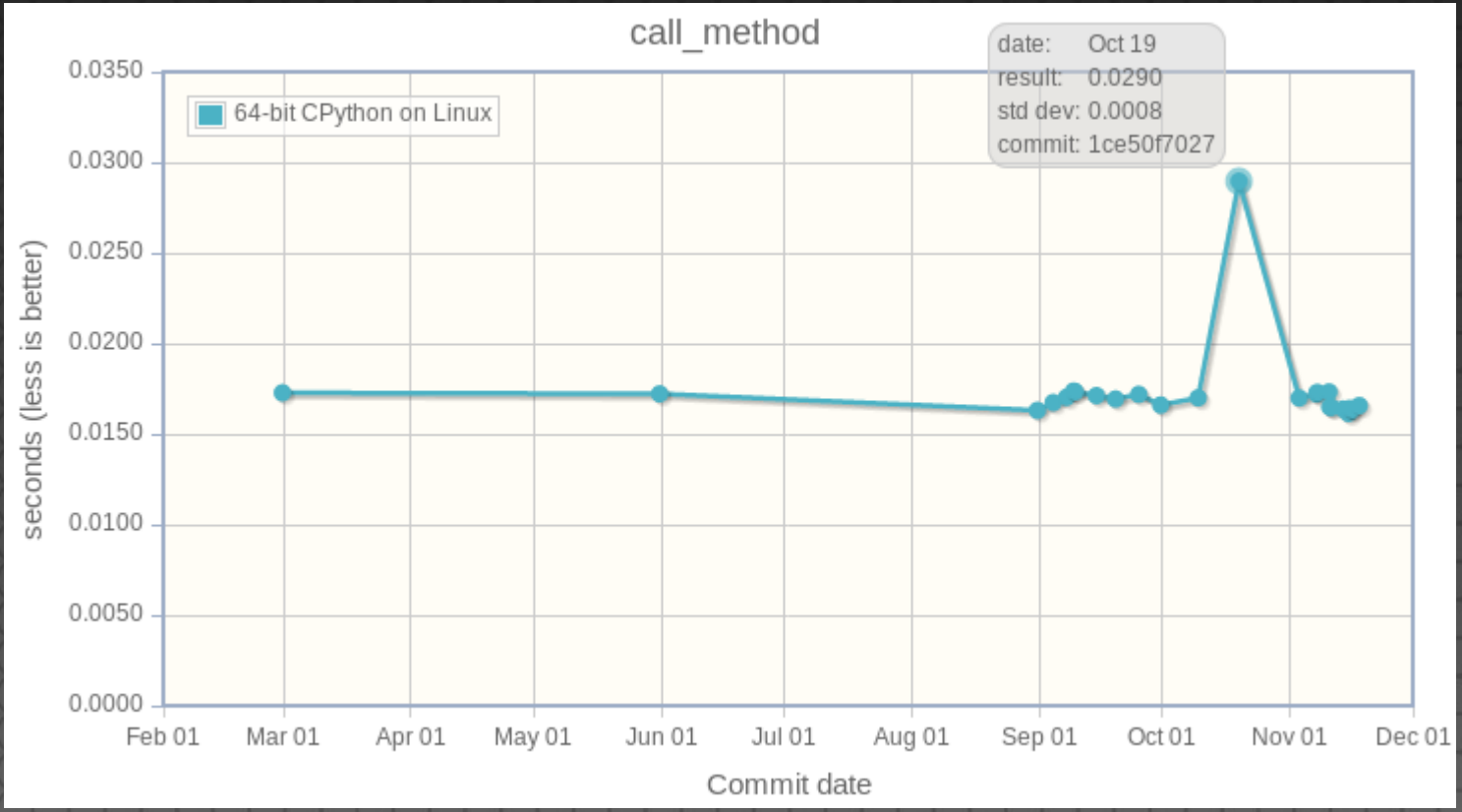
How to run stable benchmarks



FOSDEM 2017, Brussels

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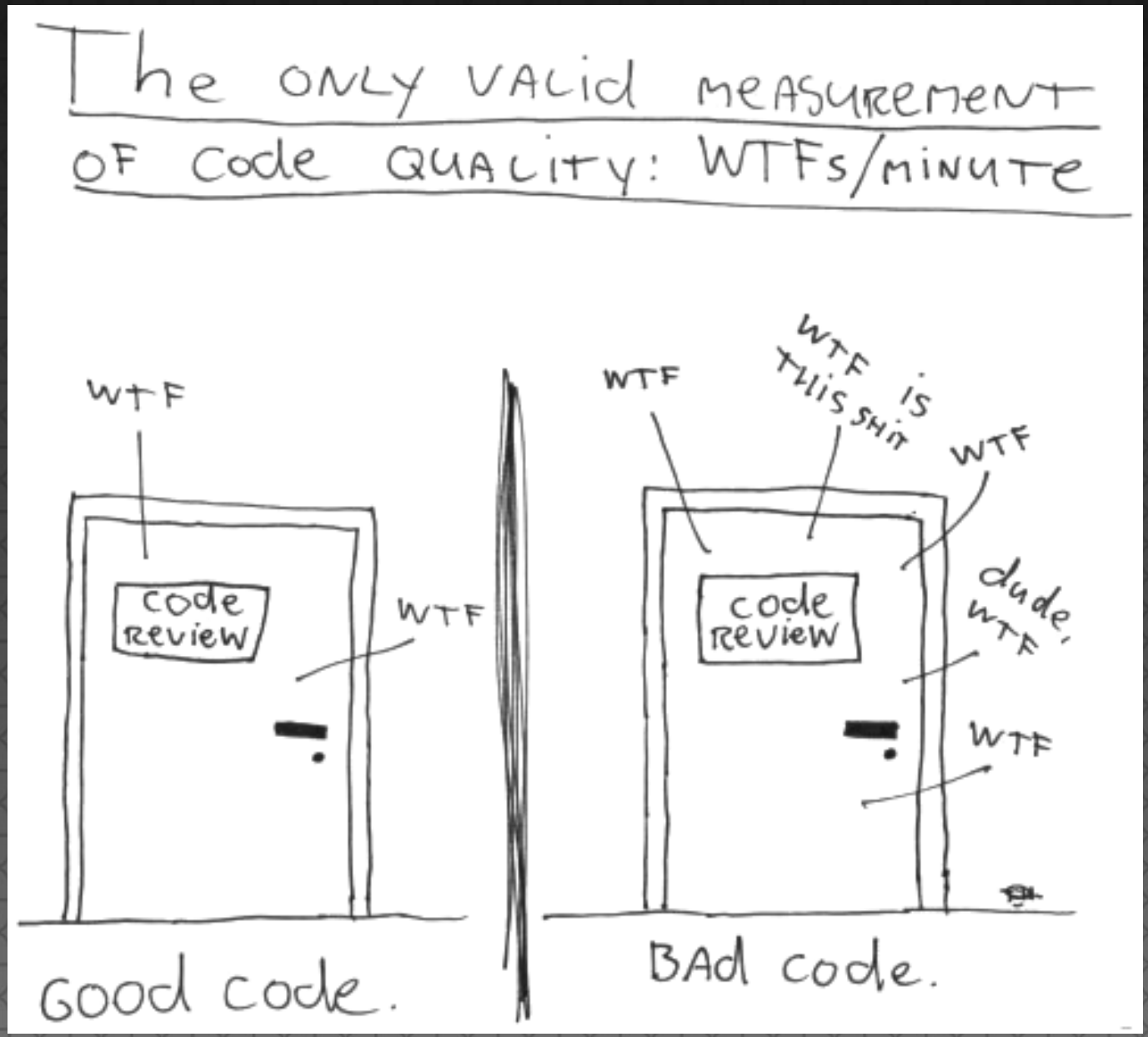
BINARY_ADD optim

- In 2014, int+int optimization proposed: 14 patches, many authors
- Is is faster? Is it worth it?
- *The Grand Unified Python Benchmark Suite*
- Sometimes slower, sometimes faster
- Unreliable and unstable benchmarks?

Goal

- Unstable benchmarks lead to bad decisions
- Patch makes Python faster, slower or... is not significant?
- Need **reproductible** benchmark results on the same computer

WTF meter


The ONLY VALID MEASUREMENT OF CODE QUALITY: WTFs/MINUTE
WTF
code review
WTF
Good code.
WTF
WTF is THIS SHIT
WTF
code review
dude, WTF
WTF
BAd code.

System & noisy apps

- CPU-bound microbenchmark:
  `python3 -m timeit 'sum(range(10**7))'`
- Idle system: 229 ms
- Busy system: 372 ms (1.6x slower, +62%)
  `python3 -c 'while True: pass'`
- *WTF?*

Isolated CPUs

- System and applications share same CPUs , memory and storage
- Linux kernel **`isolcpus=3`** don't schedule processes on CPU 3
- Pin a process to a CPU:
  `taskset -c 3` `python3 script.py`
- Idle system: 229 ms
- Busy system, isolated CPU: 230 ms!

NOHZ_FULL & RCU

- Enter GRUB, modify Linux command line to add: **`isolcpus=`**3
- **`nohz_full=`**3: if only 0 or 1 process running on CPU 3, disable all interruptions on this CPU (WARNING: see later!)
- **`rcu_nocbs=`**3: don't run kernel code on CPU 3

FASTCALL optim

- April 2016, experimental change to avoid temporary tuple to call functions
- Builtin functions **20-50% faster**!
- **But** some **slower** benchmarks
- 20,000 lines patch reduced to adding two unused functions... still slower.
  WTF??

Deadcode

- Reference:

  1201.0 ms +/- 0.2 ms
- Add 2 unused functions:

  1273.0 ms +/- 1.8 ms (slower!)
- Add 1 empty unused function:

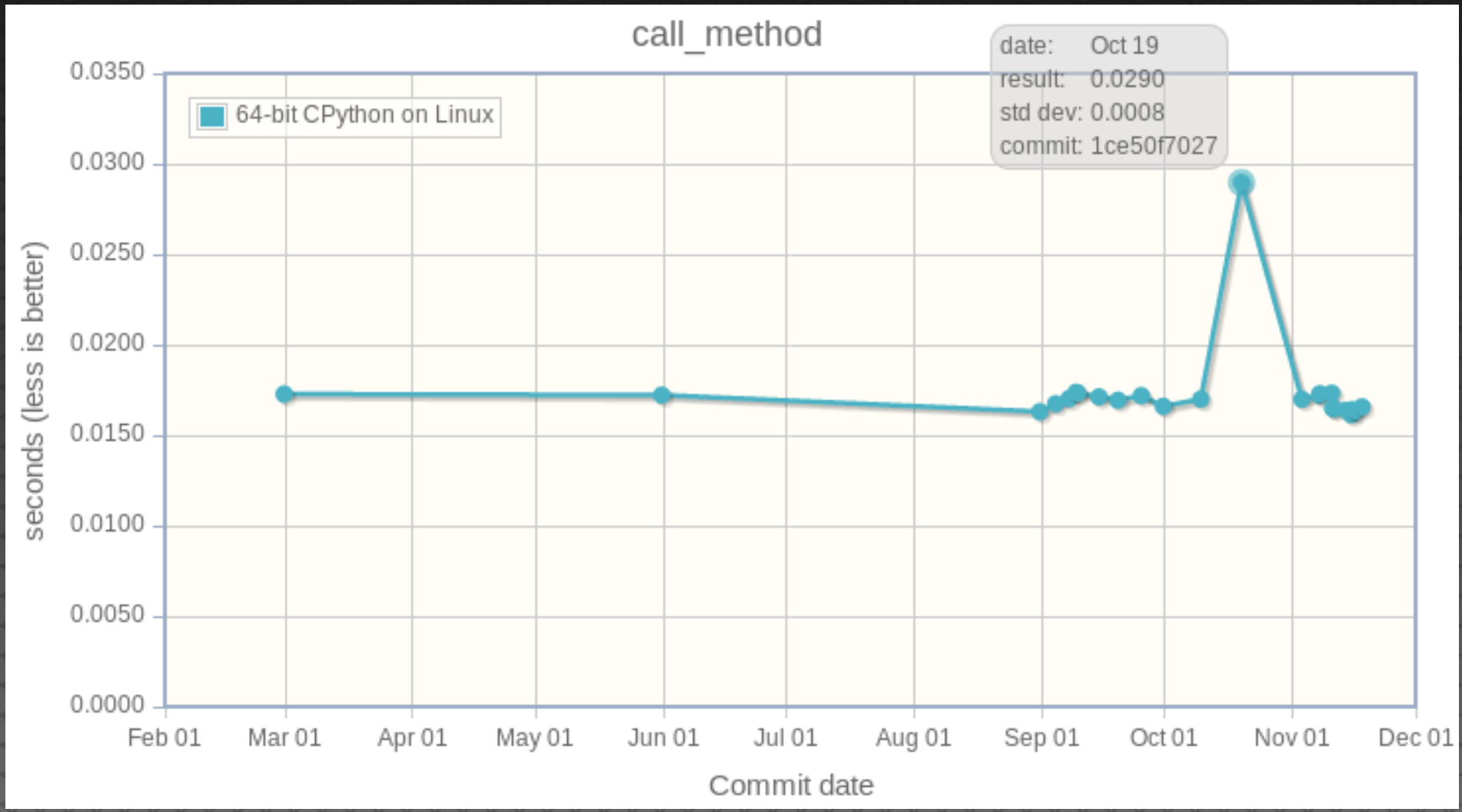
  1169.6 ms +/- 0.2 ms (faster!)

Deadcode

Code placement

- Root cause: *code placement*
- Memory layout and function addresses impact CPU cache usage
- It's very hard to get the best placement and so reproductible benchmarks

70% slower!


call_method
date: Oct 19
result: 0.0290
std dev: 0.0008
commit: 1ce50f7027
64-bit CPython on Linux
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
seconds (less is better)
Feb 01
Mar 01
Apr 01
May 01
Jun 01
Jul 01
Aug 01
Sep 01
Oct 01
Nov 01
Dec 01
Commit date

PGO fix deadcode

Profiled Guided Optimizations (PGO):

```
./configure --with-optimizations
```

(1) Compile with instrumentation

(2) Run the test suite to collect statistics on branches and code paths (hot code)

(3) Use statistics to recompile Python

Python hash function

Hash function randomized by default.

- PYTHONHASHSEED=1: 198 ms
- PYTHONHASHSEED=3: 207 ms (slower!)
- PYTHONHASHSEED=4: 187 ms (faster!)

WTF???

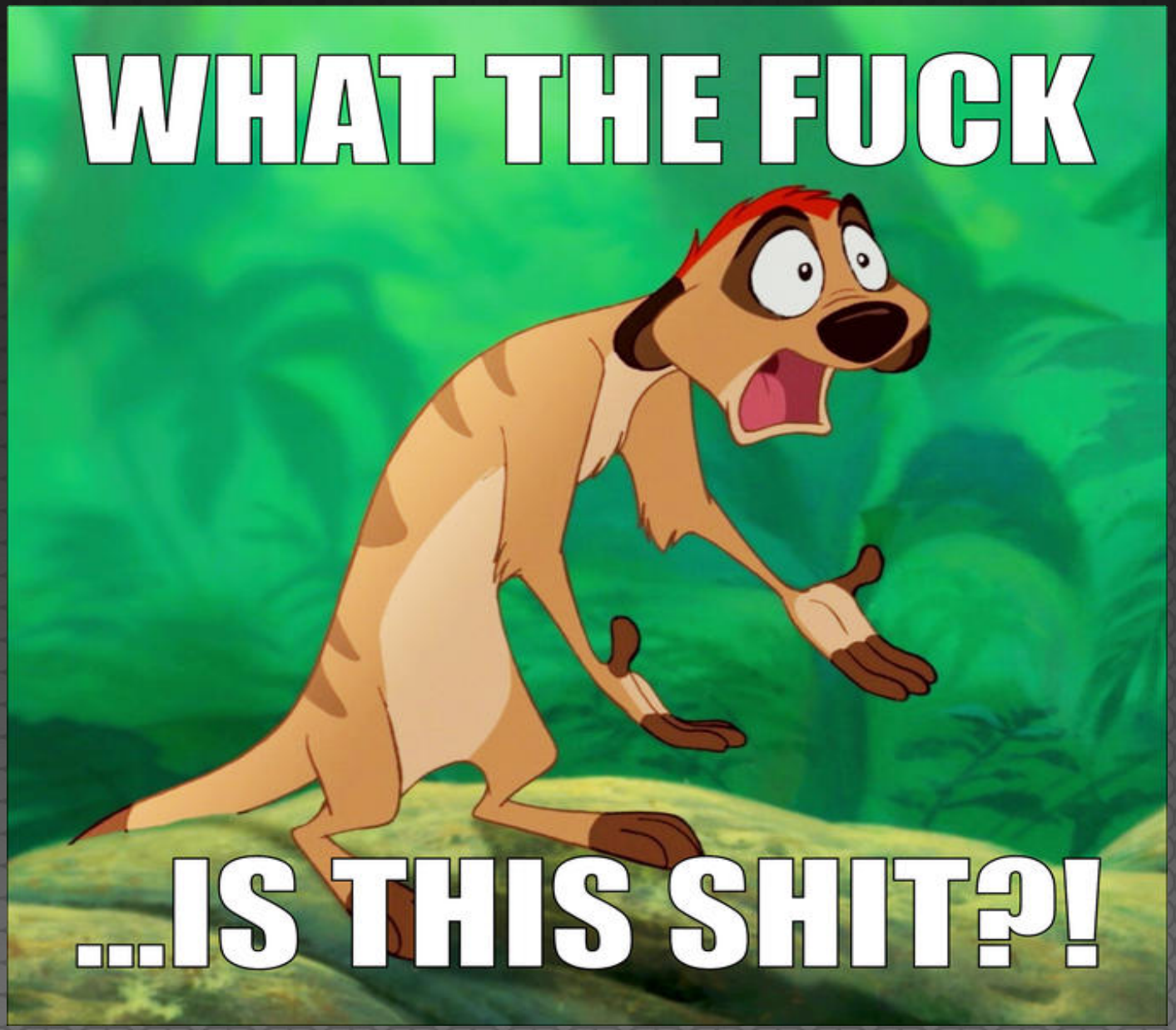
Different number of hash collisions

More fun

Performance also impacted by:

- Unused **environment variables**
- Current working **directory**
- Unused **command line arguments**
- etc.

WTF????



Average

- First, I disabled Address Space Layout Randomization (ASLR), randomizing Python hash function, etc.
- Lost cause: too many factors impact **randomly** performances
- Solution to random noise: compute **average of multiple samples**

perf

- Spawn multiple processes
- Compute average and standard deviation
- Store all individual run timings as JSON
- Command line tool to display, compare and analyze data

`http://perf.rtfd.io/`

New drama

Everything was fine for days, until... the new drama:

Suddenly, a benchmark became **20% faster**

WHAT-THE-FUCK ?????

Modern Intel CPUs

Since 2005, the frequency of Intel CPUs changes **anytime** for various reasons:

- Workload
- CPU temperature
- and... the **number of active cores**

Turbo Button?

Turbo Boost

My laptop: 4 cores (HyperThreading)

- 2-4 active cores: 3.4 GHz
- 1 active core: 3.6 GHz (+5%)

```
sudo cpupower frequency-info
```

Disable Turbo Boost in BIOS, or write 1 into:

```
/sys/devices/system/cpu/
intel_pstate/no_turbo
```

And now?

I ran different benchmarks for days and even for **weeks**

Everything was **SUPER STABLE**

Stable benchmarks!

Nightmare never ends

But...

... one friday afternoon after I **closed my GNOME session**

... the benchmark became **2.0x faster**

WTF?????? (sorry, this one should really be the last one... right?)

Nightmare never ends

Let me recall

- System and noisy apps: **isolcpus**
- Deadcode, code placement: **PGO**
- ASLR, Python hash function, env vars, cmdline, ...: **average** + std dev
- Turbo Boost: **disable TB**

CPU temperature?

CPU temperature?

NOHZ_FULL and Pstate

- `nohz_full=3` (...) disables all interruptions
- intel_pstate and intel_idle CPU drivers registers a scheduler callback
- No interruption means no scheduler interruption (LOC in `/proc/interrupts`)
- CPU 3 Pstate doesn't depend on isolated CPUs workload, but other CPUs workload

NOHZ_FULL and Pstate

- intel_pstate and intel_idle drivers maintainer never tried `NOHZ_FULL`
- Linux real time (RT) developers: « it's not a bug, **it's a feature!** »

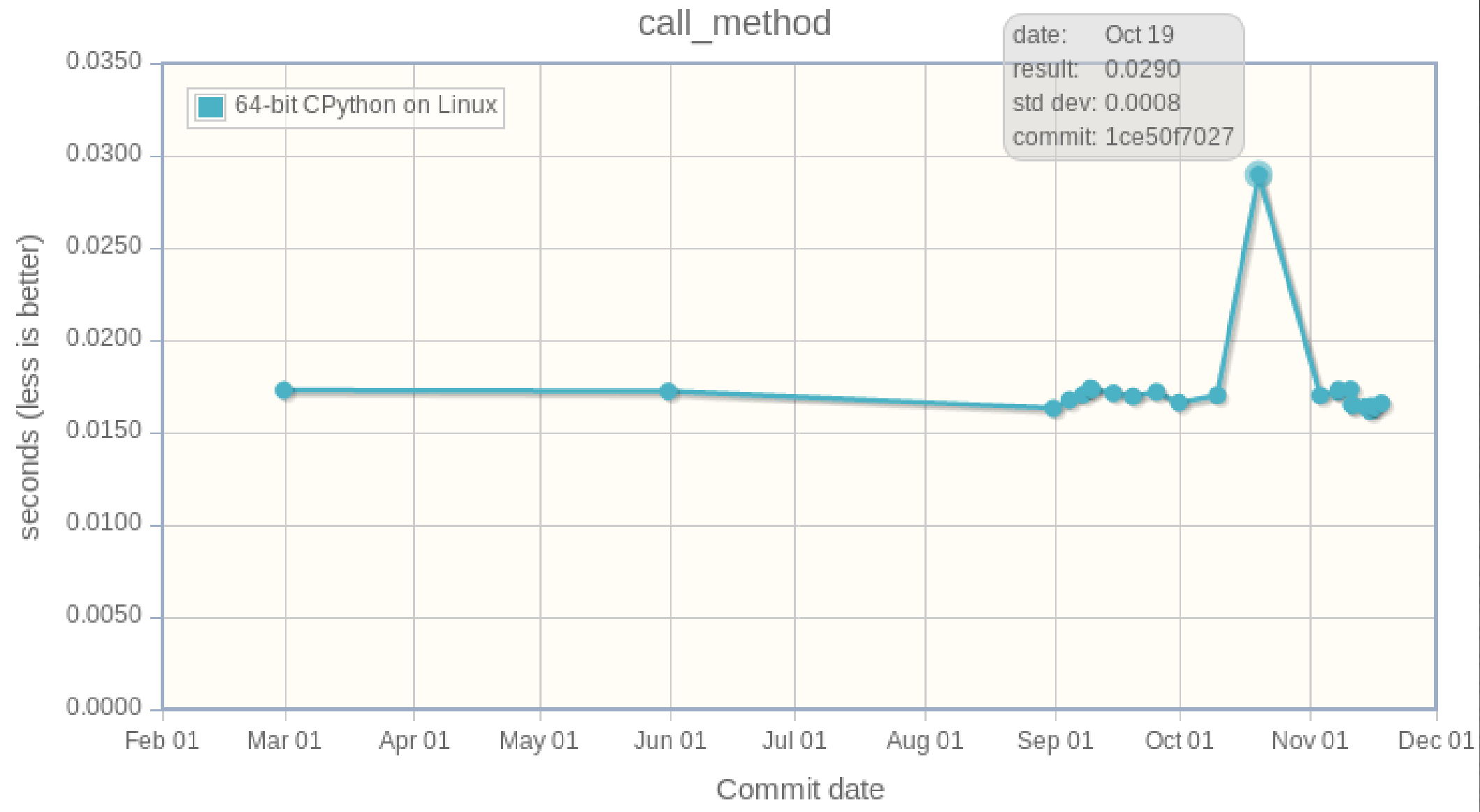
  ⇒ Use a **fixed CPU frequency**

  ⇒ or: **don't use `NOHZ_FULL`**

Takeaway

- Tune system to run benchmarks:
  `python3 -m perf system tune`
- Stop using `timeit`! Replace:
  `python3 -m timeit -s SETUP STMT`
  with:
  `python3 -m perf timeit -s SETUP STMT`
- Read perf documentation!
  http://perf.rtfd.io/

Before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seconds (less is better)
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Mar 01
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Oct 01
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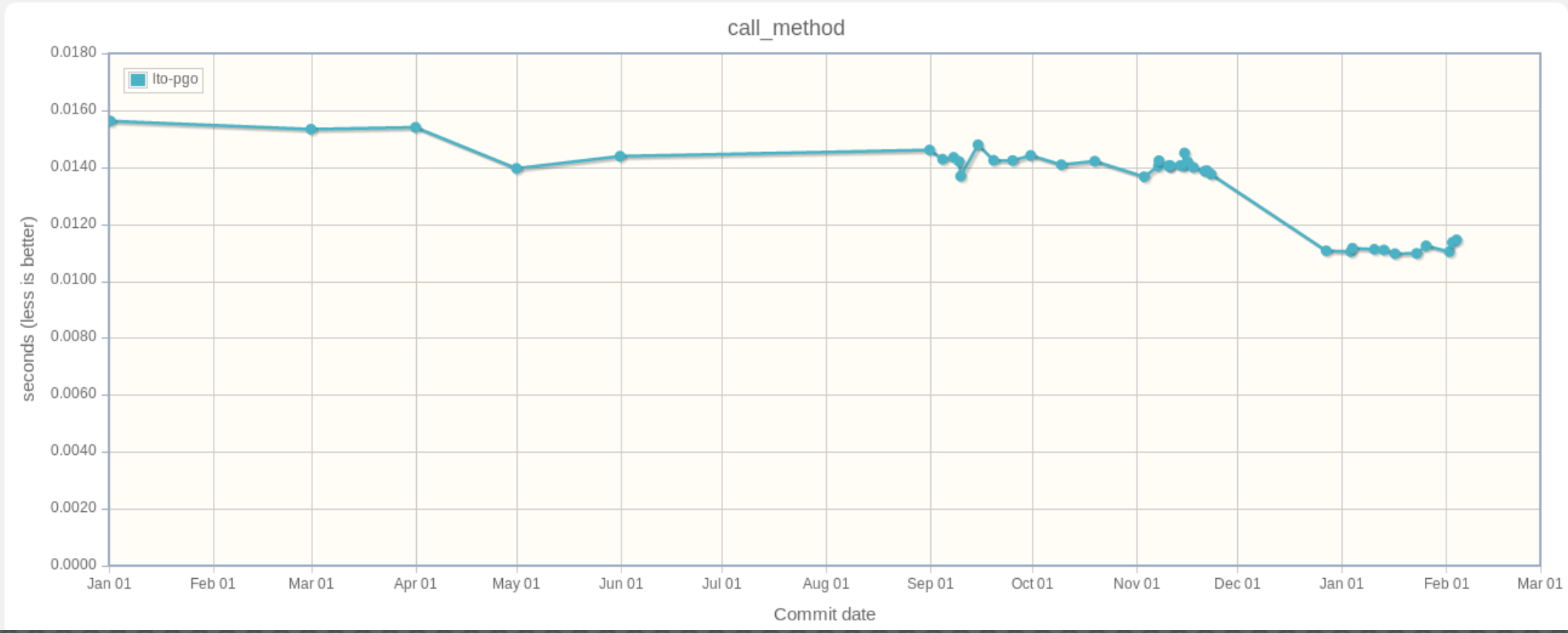
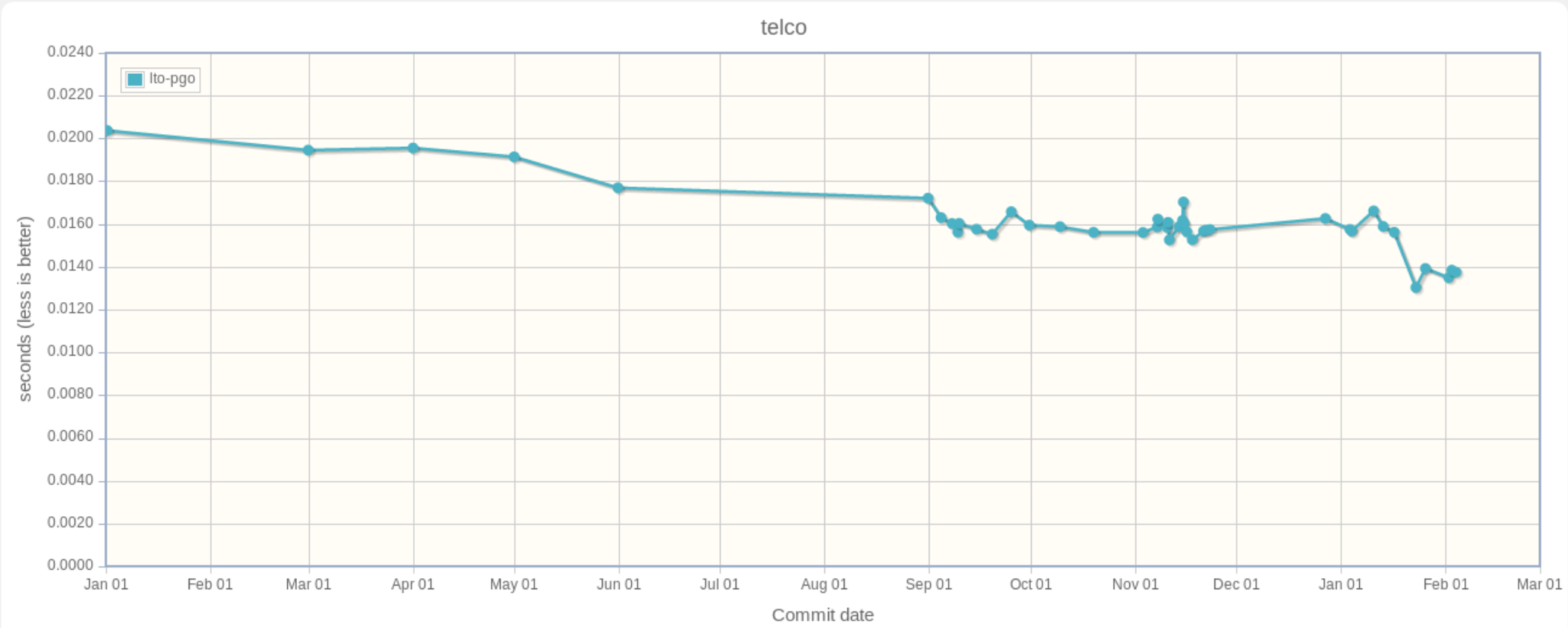
Commit date

After (with PGO)



Telco benchmark



Questions?

http://perf.rtfd.io/

https://github.com/python/performance/

https://speed.python.org/

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Perf features

- Collect **metadata**: CPU speed, uptime, Python version, kernel task#, ...
- Compare two results, check if **significant**
- **Stats**: min/max, mean/median, sample#, ...
- Dump all timings including **warmup**
- **Check** stability, render **histogram**, ...