Analyzing the Complexity of Auto-Tuning Many-Core Accelerators

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Introduction

Tuning, and auto-tuning, are well known optimization strategies

Research focuses mainly on two aspects:

1. Finding optimal configurations
2. Reducing the size of the optimization space

Our goal is to find a way to determine how difficult tuning is

Tuning, More Formally

- K : kernel
- $P = \{p_0, p_1, \ldots p_n\}$: set of K's tunable parameters
- I : valid input for K
- $C = \{c_0, c_1, \ldots c_m\}$: valid configurations of K's parameters
- P : platform

Tuning means finding $c_i \in C$ that optimizes a function, such as

- minimizing execution time
- maximizing throughput
- minimizing energy consumption

Tuning is Great, But it Takes Time

Tuning is great because the execution time of K running on P with input I using the optimal configuration c_i will be lower or equal than the execution time using any other c_j where $j \neq i$

But tuning can take a long time:

- Big optimization space
- Low performance of suboptimal configurations

Is Tuning Worthwhile?

Scenario 1:

- Optimum: 10% better than the average configuration
- Tuning time: 2 hours
- Future use: few times

Scenario 2:

- Optimum: 10% better than the average configuration
- Tuning time: 2 hours
- Future use: in production for 3 years

Scenario 3:

- Optimum: 200% better than the average configuration
- Tuning time: 2 hours
- Future use: few times

Tuning Difficulty

We say that tuning K is difficult (for platform P and input I) if the performance associated with c_i lies far apart from the performance associated with all the other c_j

Open question:

- How to quantify difficulty with just a number?

Knowing how difficult is tuning K makes it possible to:

- answer the question on how worthwhile tuning is
- steer the optimization process, e.g. pruning search space

Optimum Portability

Optimum portability is the degree to which the optimal configuration c_i of K (for platform P and input I) can be reused:

- on other platforms
- for other inputs

Reuse can be total or partial

Optimum portability modifies tuning difficulty of a kernel:

- low portability makes tuning more difficult
- some degree of portability make tuning easier

TuneBench

To test these ideas we needed a benchmark suite with easily tunable kernels

But we could not find one on the Internet

So we wrote our own, and called it TuneBench

- 5 kernels
  - with tunable parameters
- open-source
- available on GitHub[1]

[1] https://github.com/isazi/TuneBench

Experiments

Measuring tuning difficulty and optimum portability in TuneBench

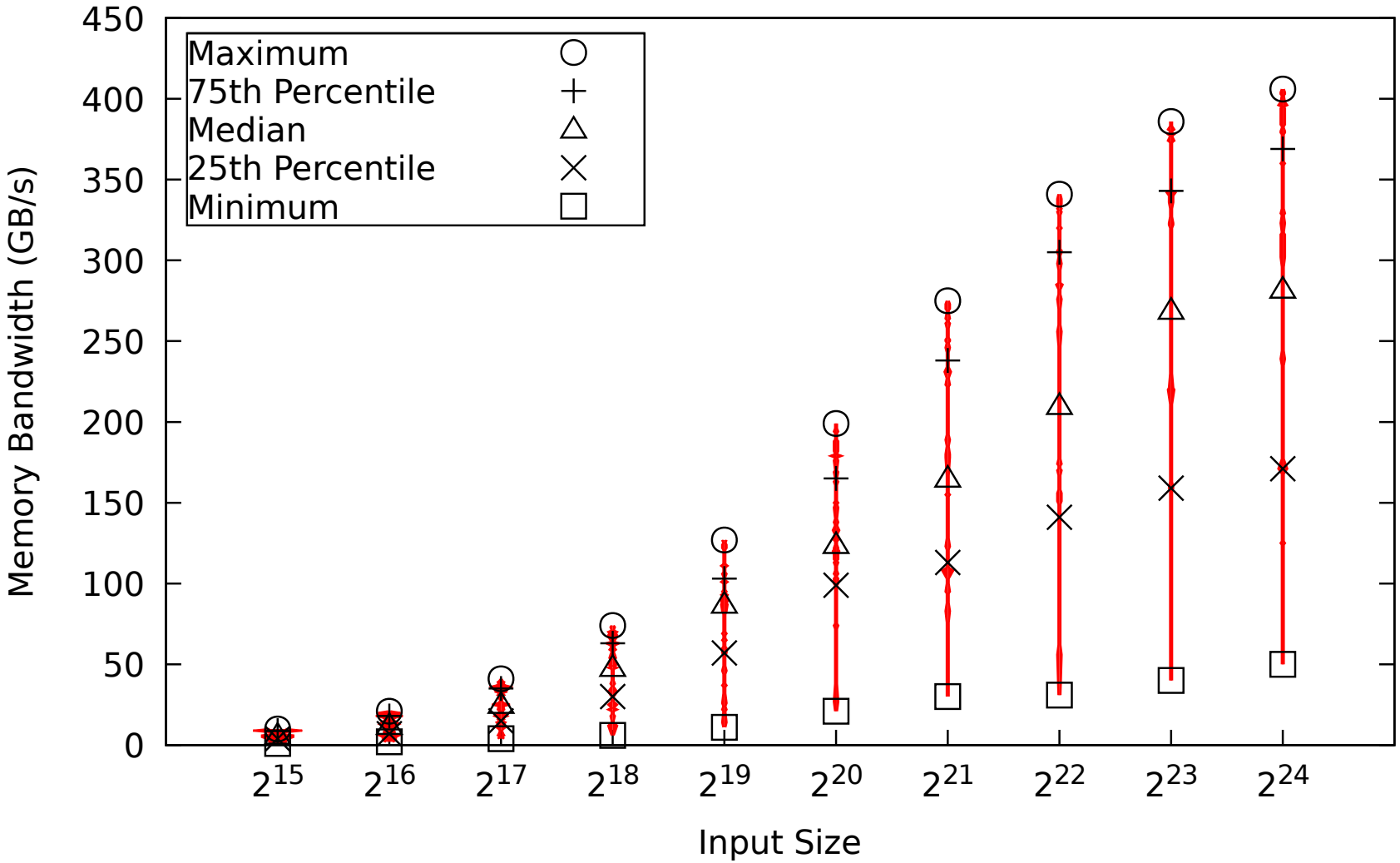
- triad
  - 3 tunable parameters
  - memory-bound
- reduction
  - 4 tunable parameters
  - memory-bound
- stencil
  - 5 tunable parameters
  - data-reuse
- MD
  - 3 tunable parameters
  - data-reuse
- correlator
  - 5 tunable parameters
  - data-reuse

Six different platforms, multiple inputs

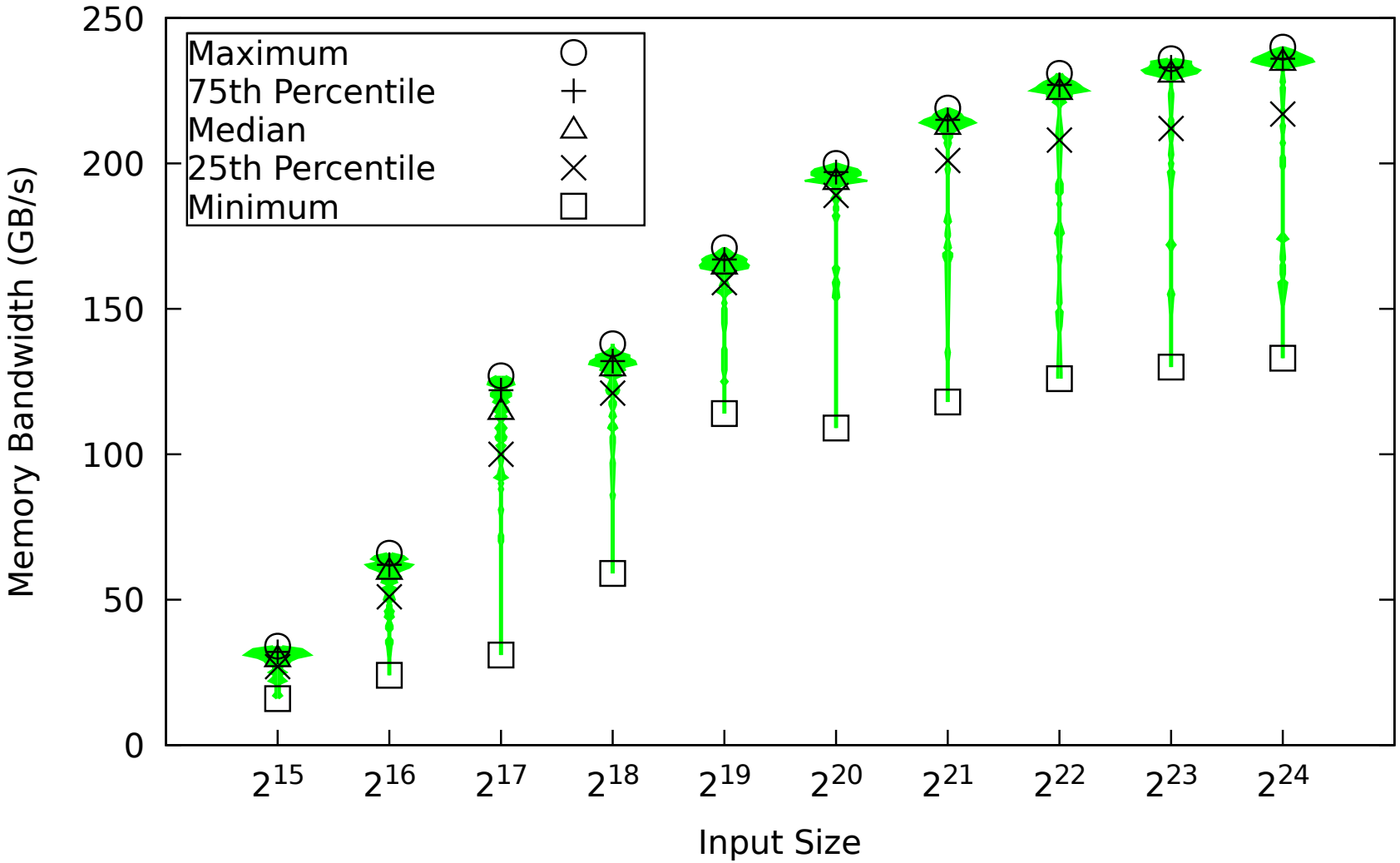
Platforms

Platform	Cores	GFLOP/s	GB/s
AMD FirePro W9100	2816	5237	320
AMD R9 Fury X	4096	8601	512
Intel Xeon Phi 31S1P	112	2006	320
NVIDIA GTX Titan	2688	4499	288
NVIDIA GTX Titan X	3072	6144	336
NVIDIA GTX 1080	2560	8228	320

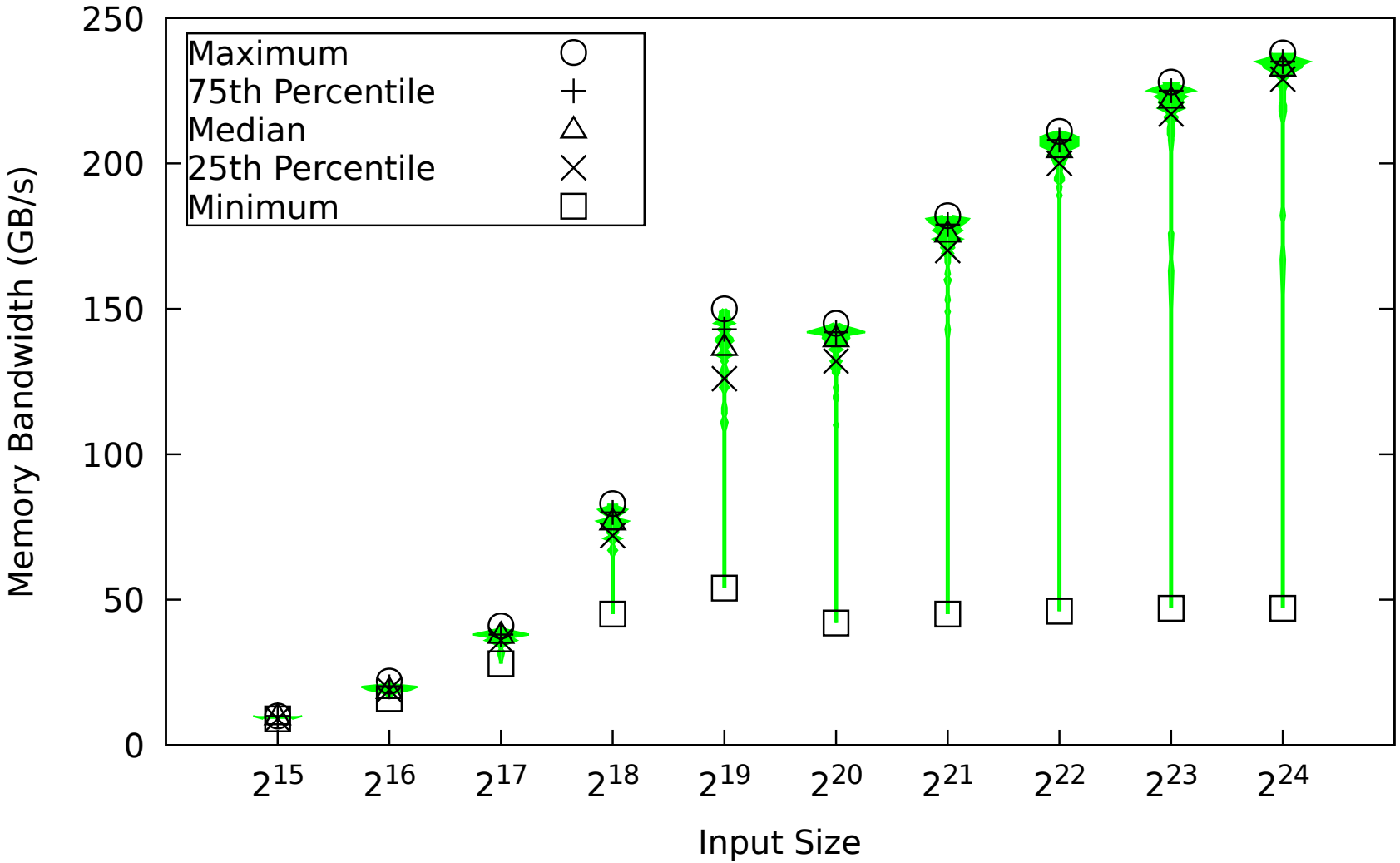
Tuning Difficulty: Fury X, triad



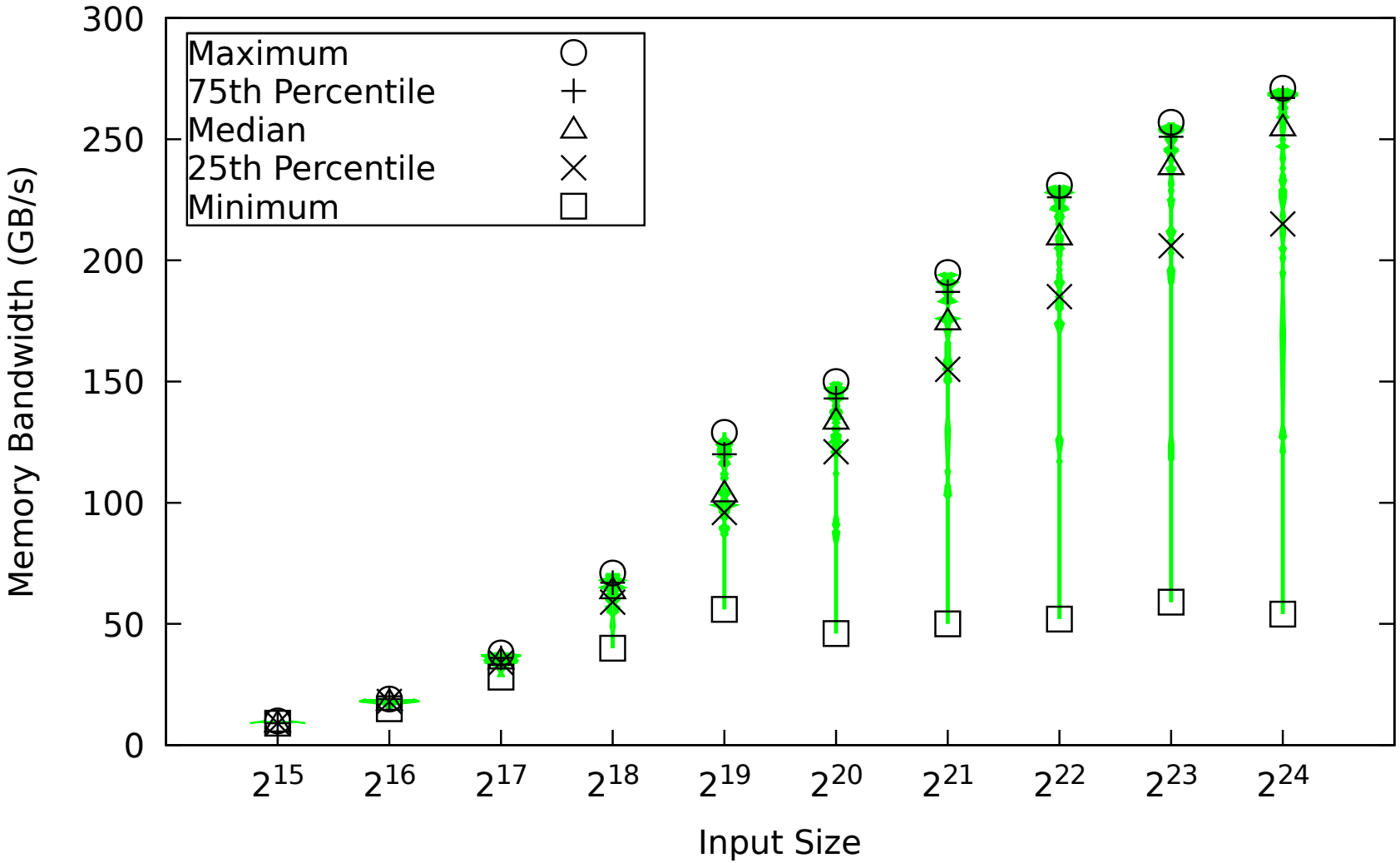
Tuning Difficulty: GTX 1080, triad



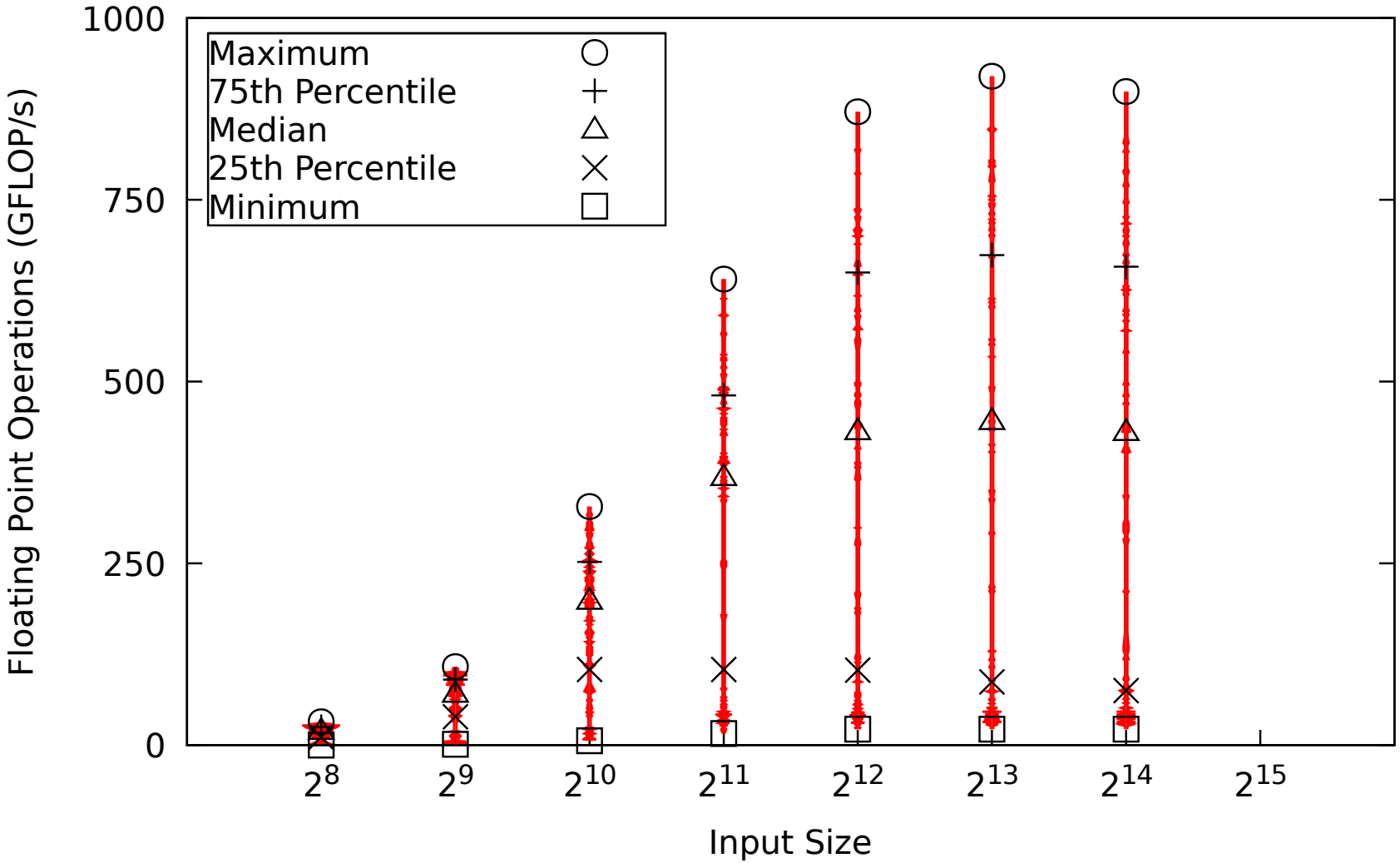
Tuning Difficulty: GTX 1080, reduction



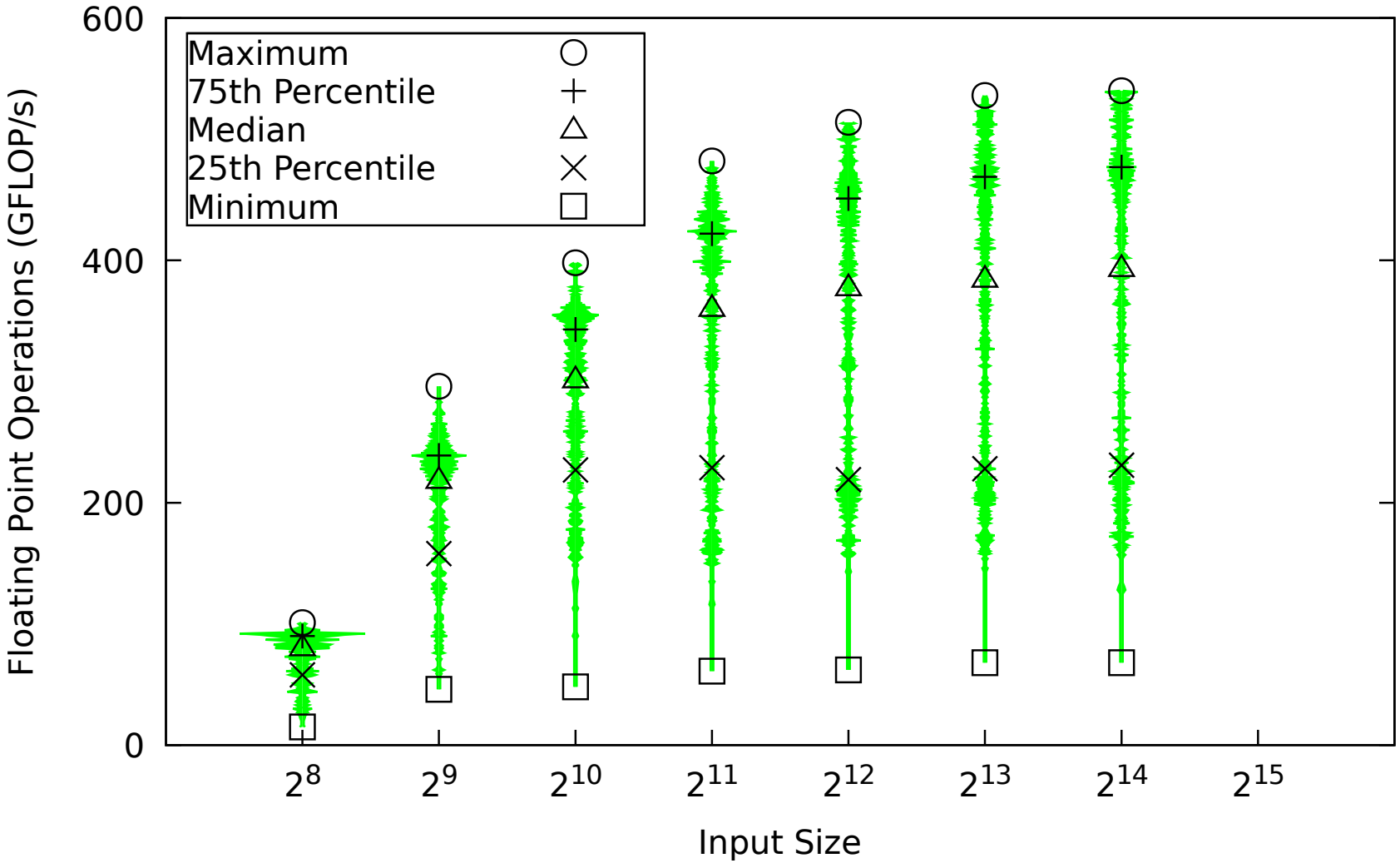
Tuning Difficulty: Titan X, reduction



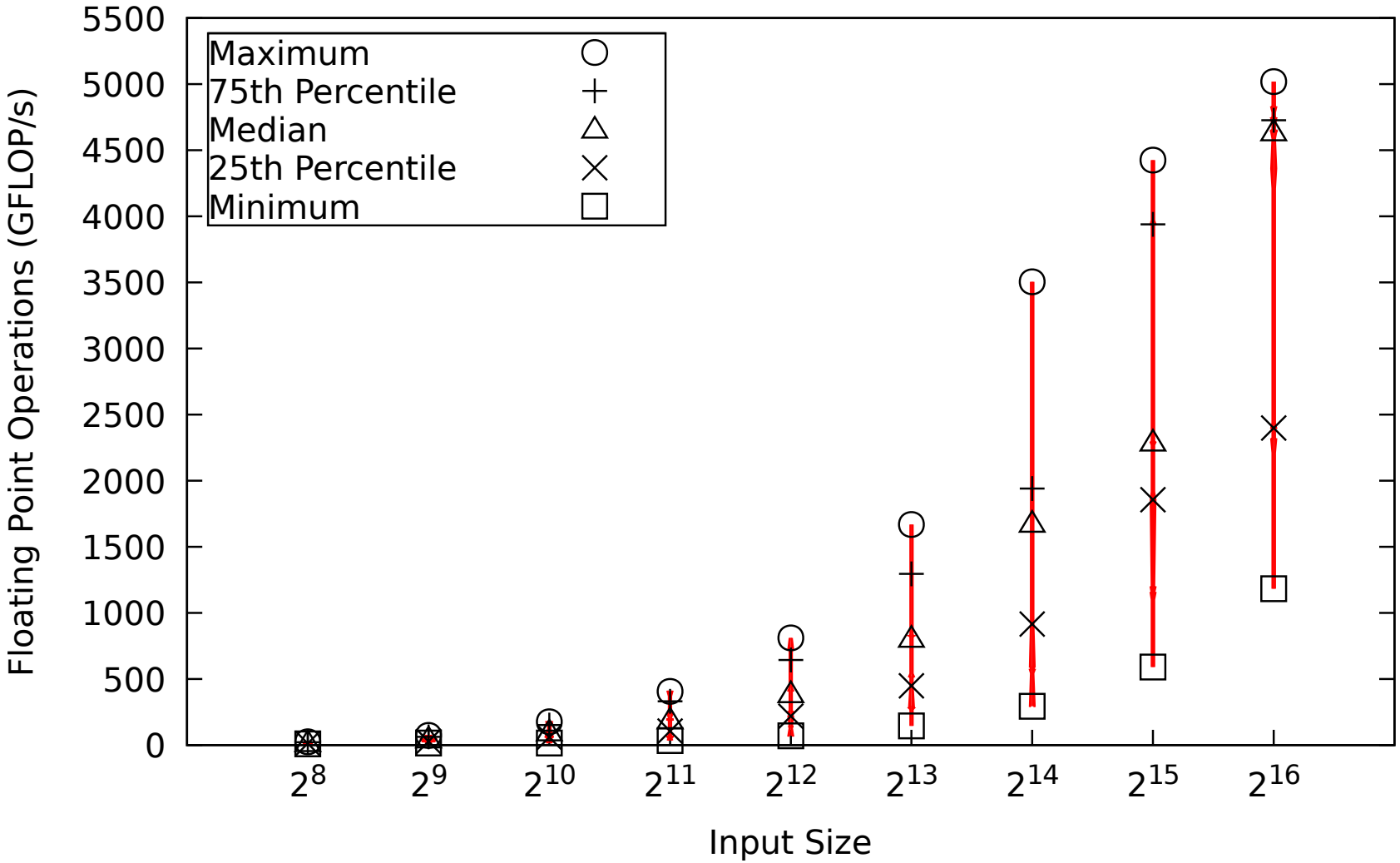
Tuning Difficulty: Fury X, stencil



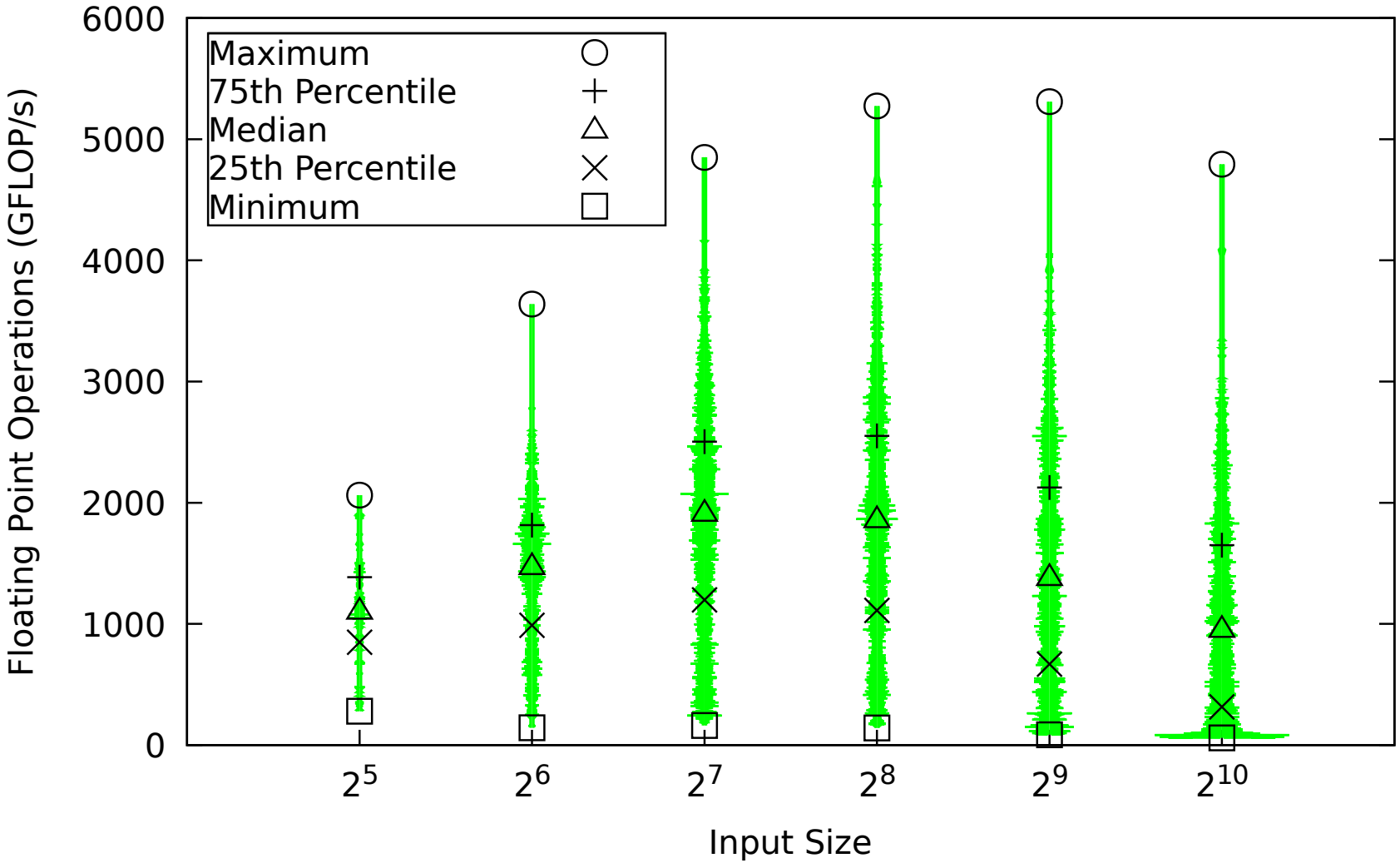
Tuning Difficulty: GTX 1080, stencil



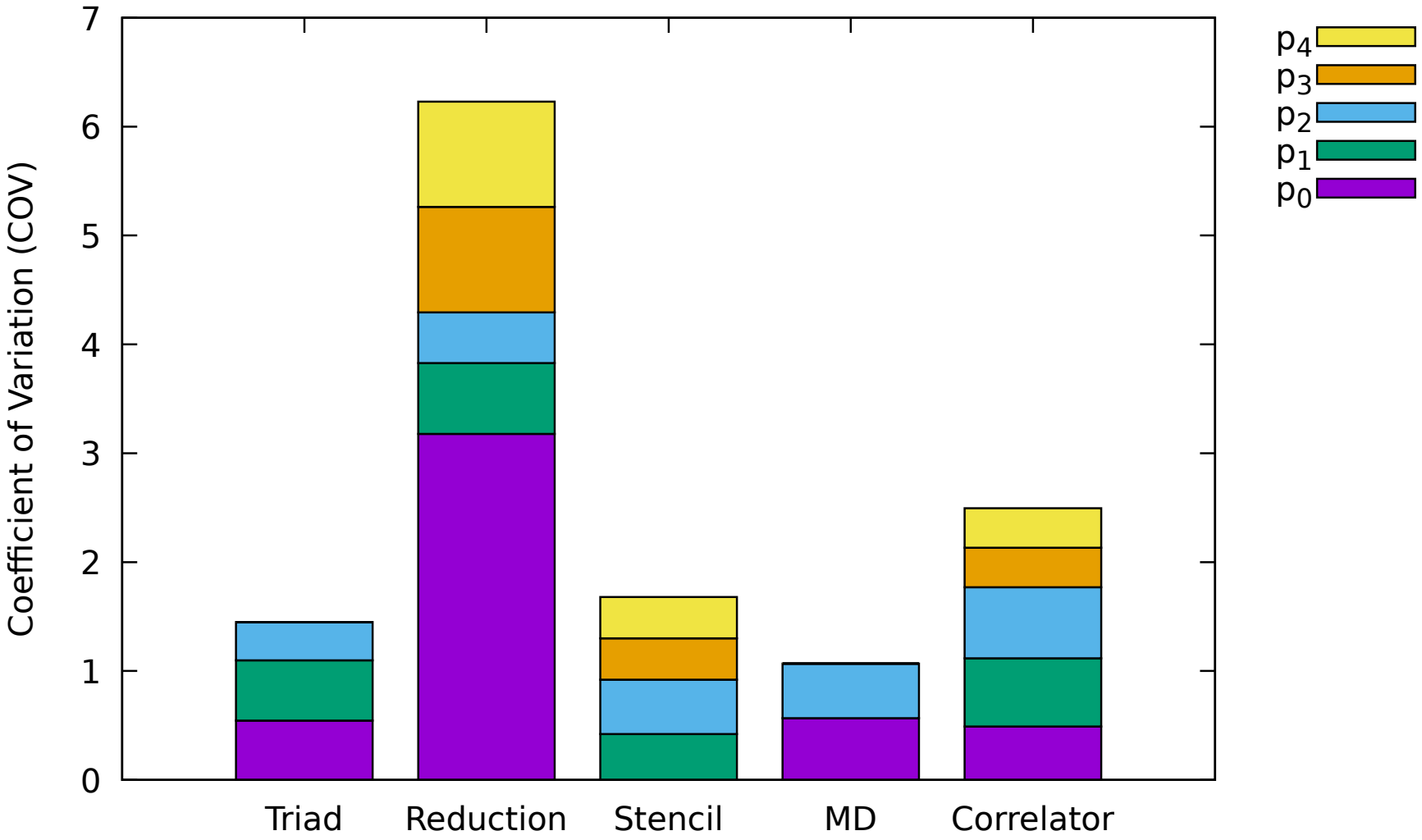
Tuning Difficulty: Fury X, MD



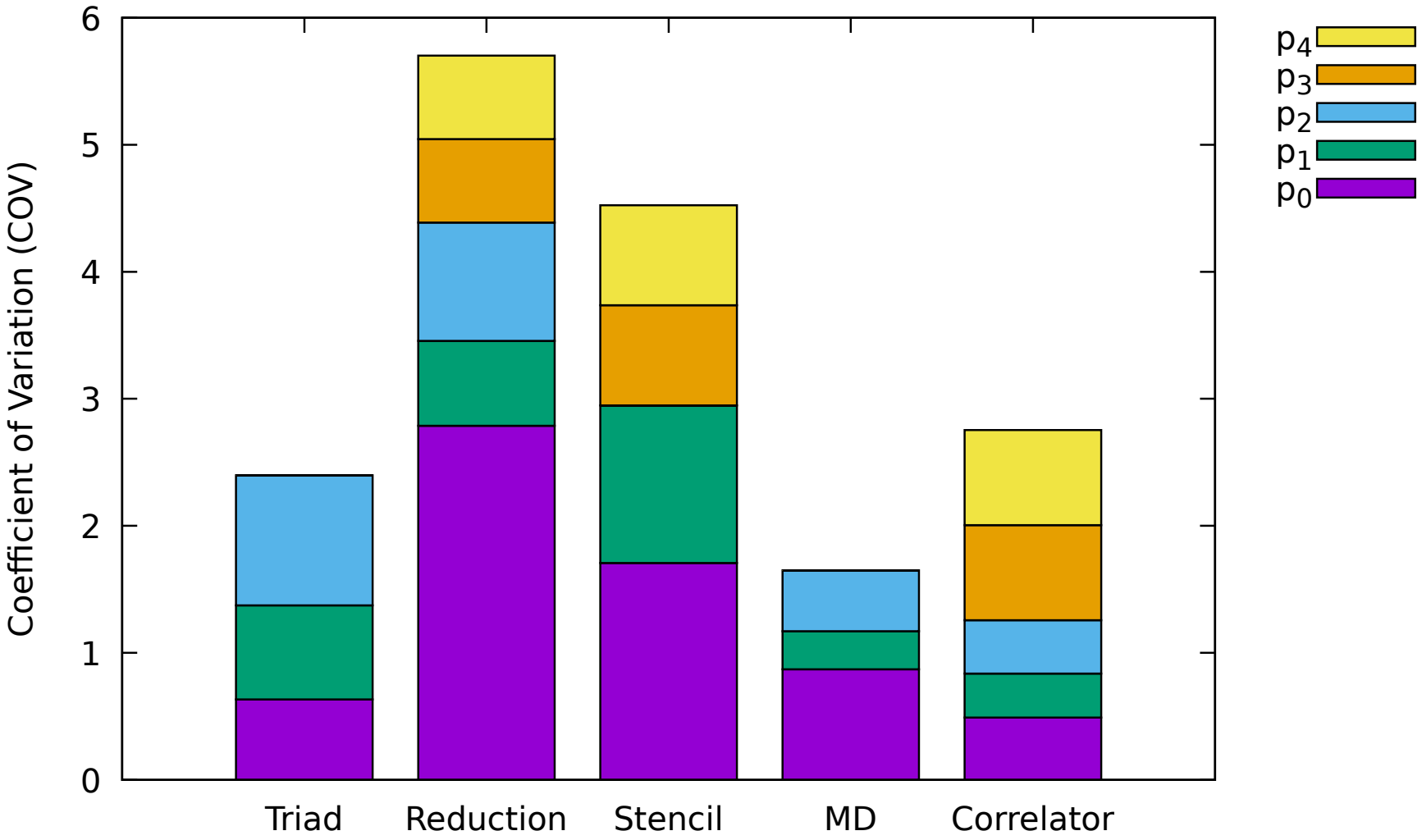
Tuning Difficulty: GTX 1080, correlator



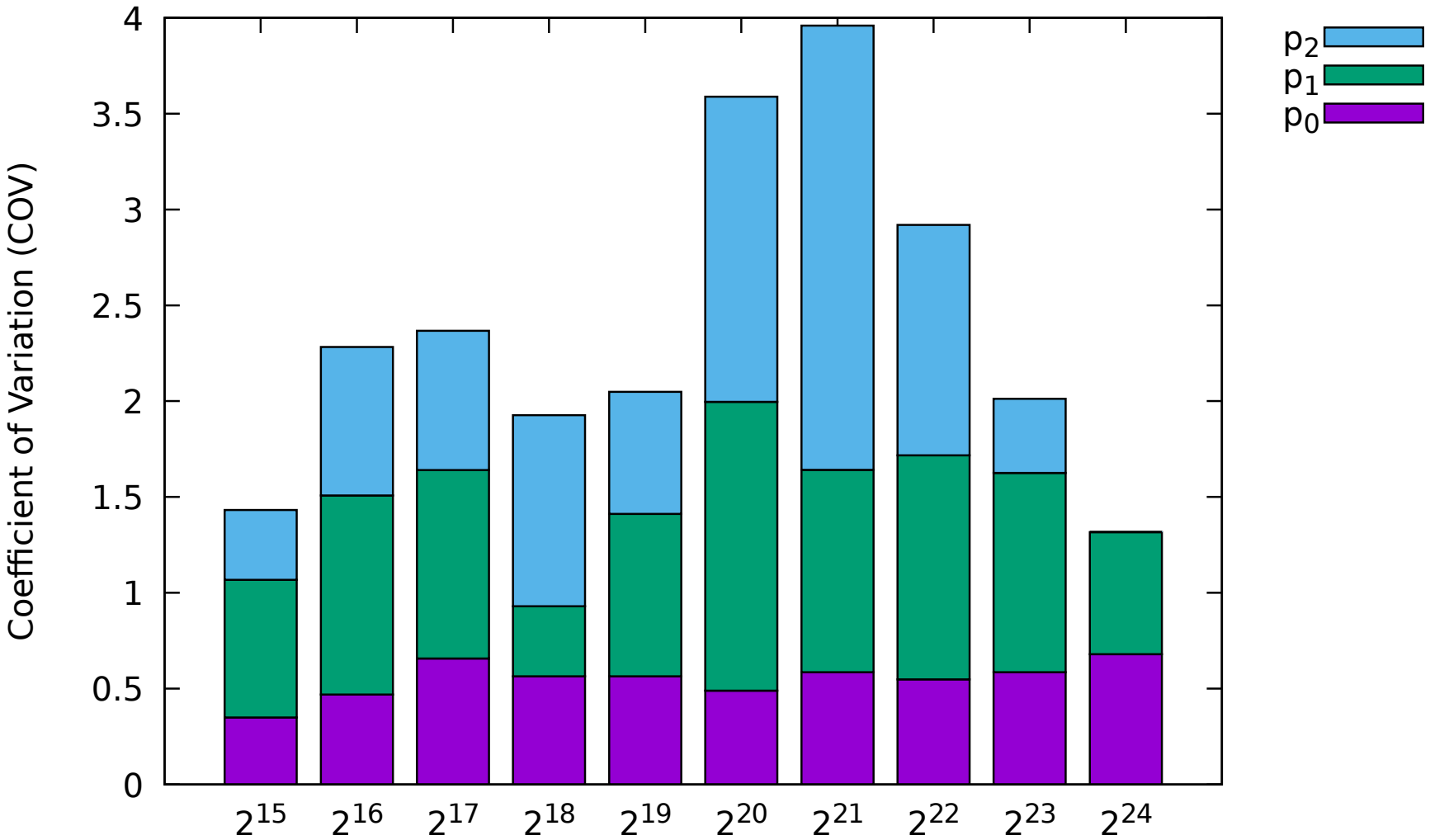
Optimum Portability: Fury X



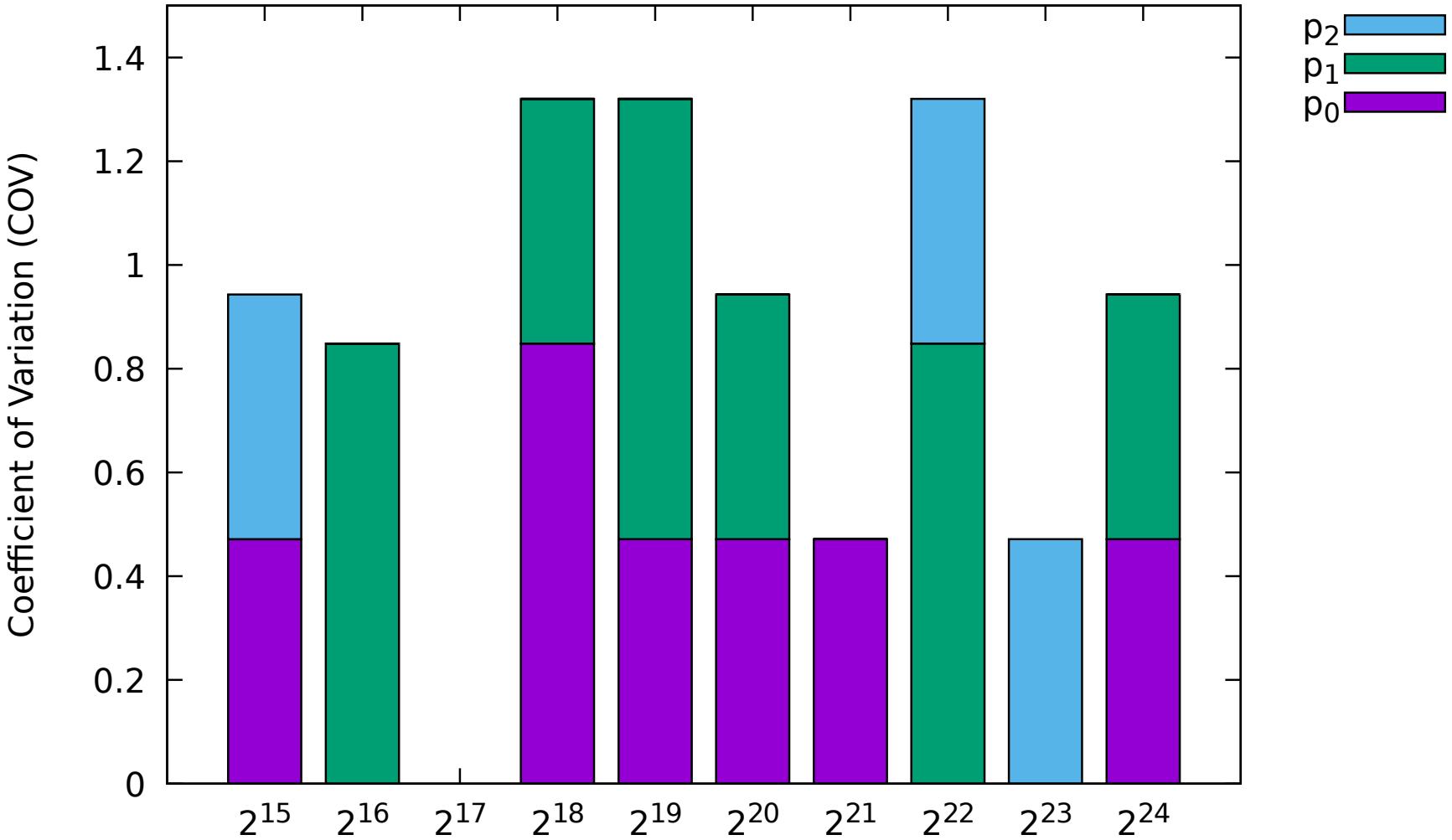
Optimum Portability: GTX 1080



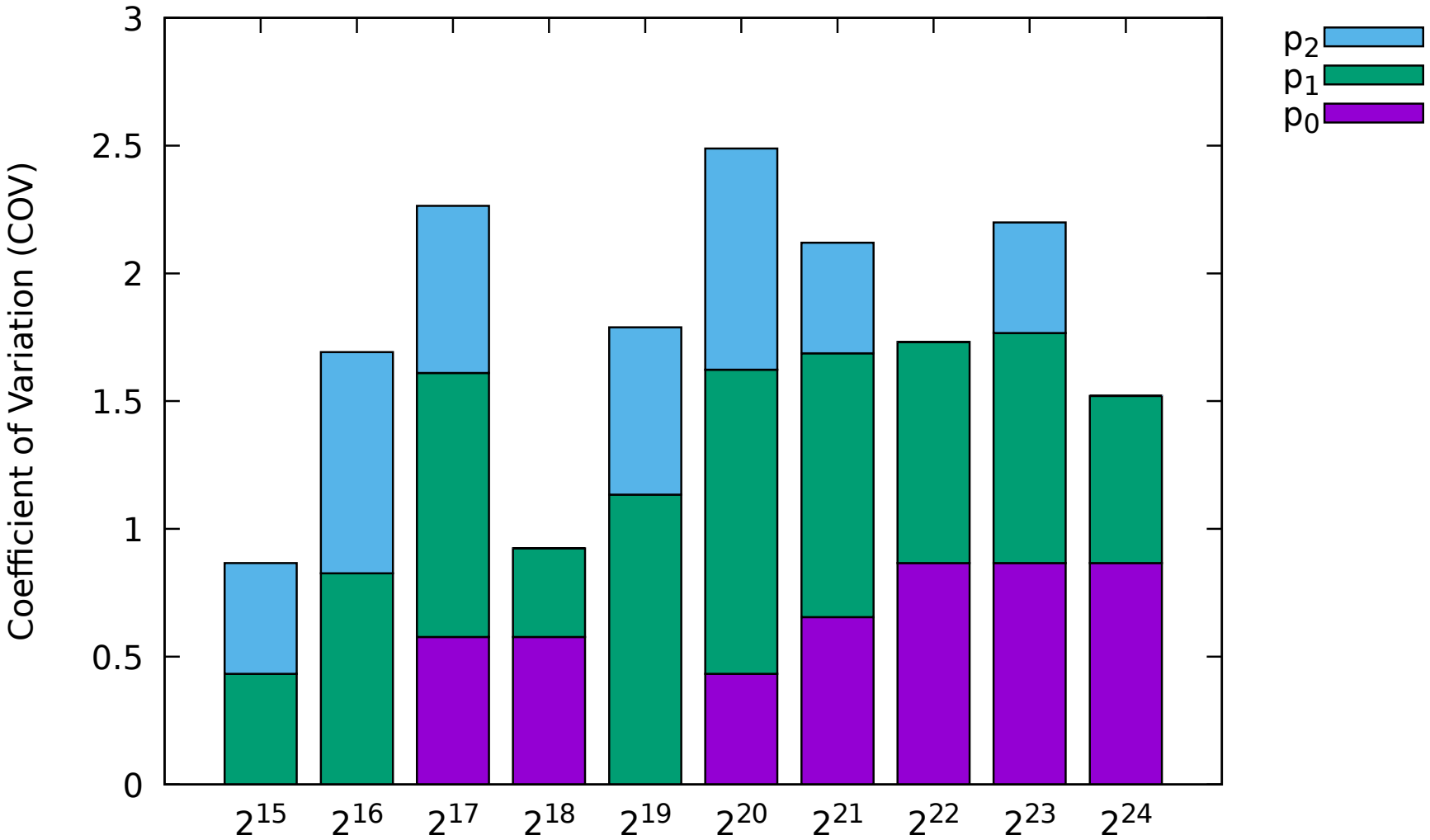
Optimum Portability: triad



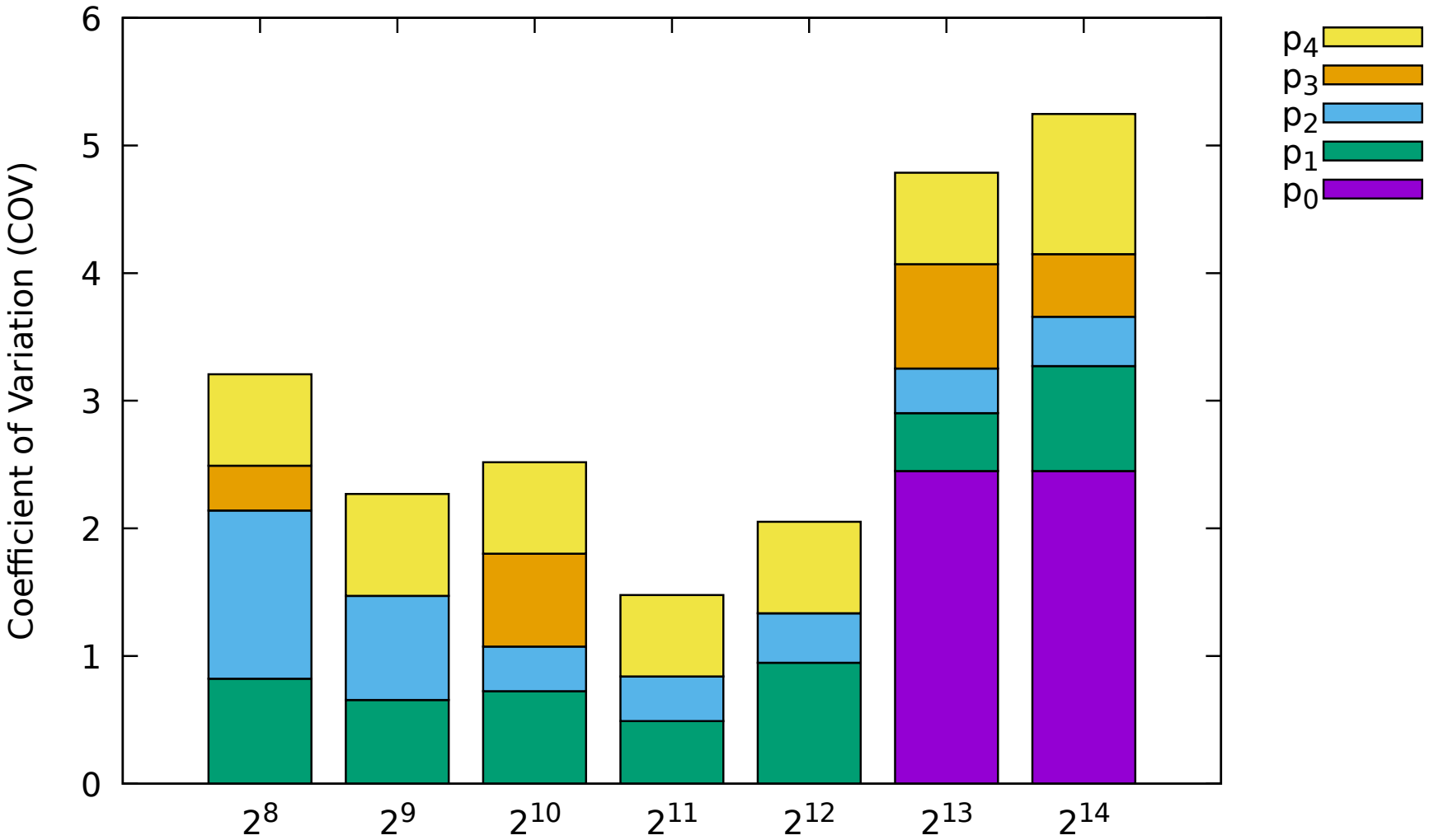
Optimum Portability: AMD GPUs, triad



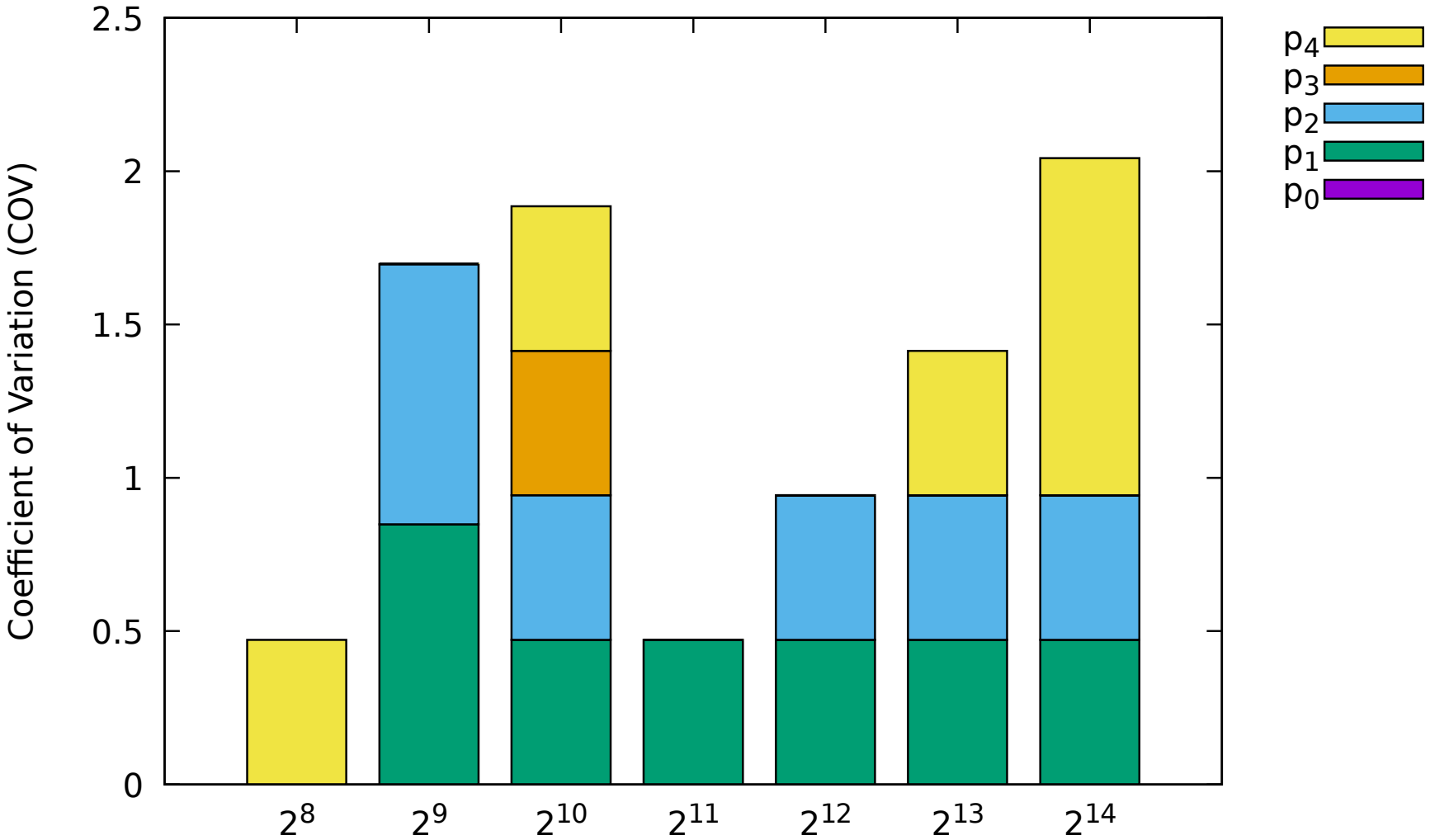
Optimum Portability: NVIDIA GPUs, triad



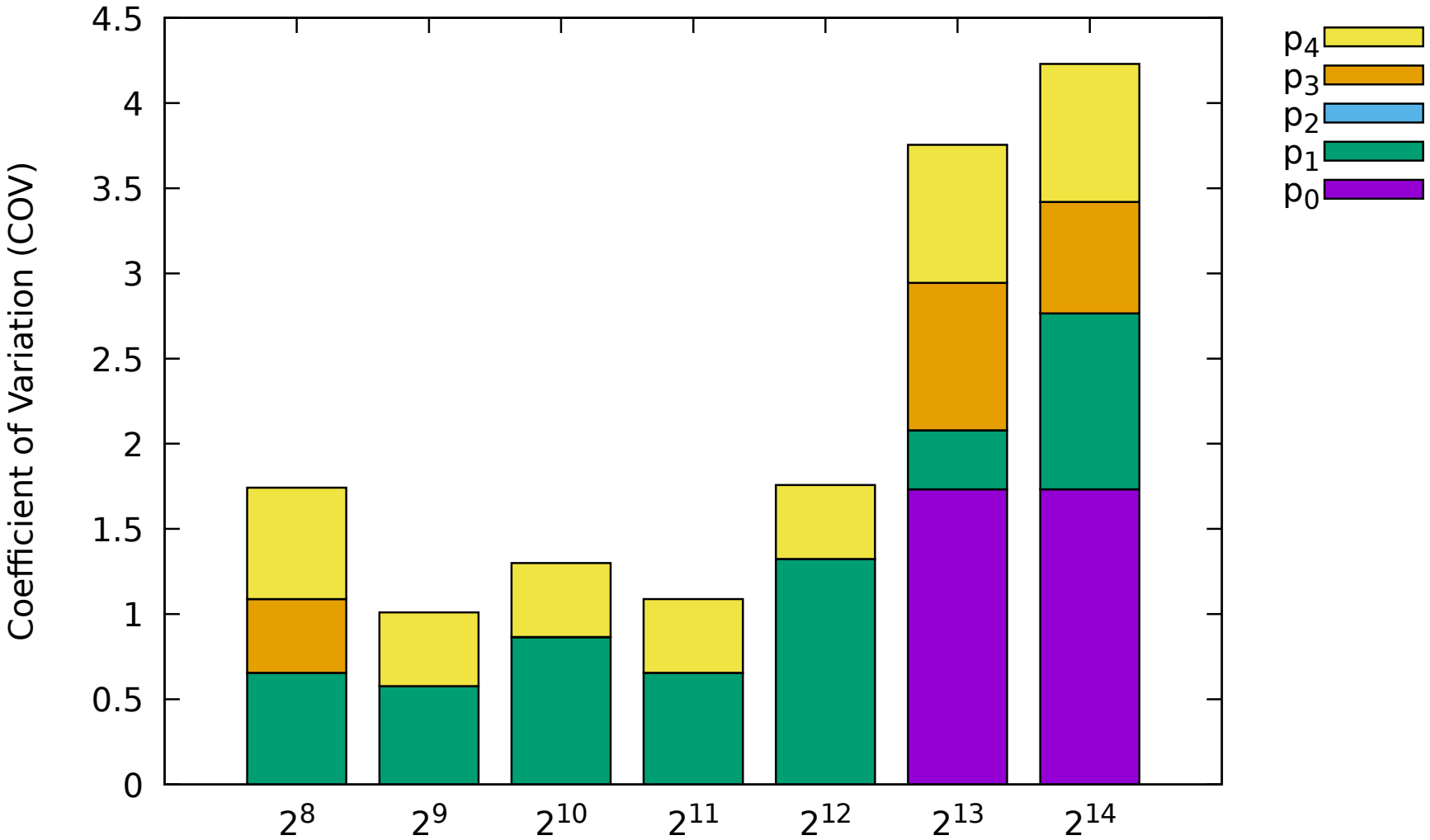
Optimum Portability: stencil



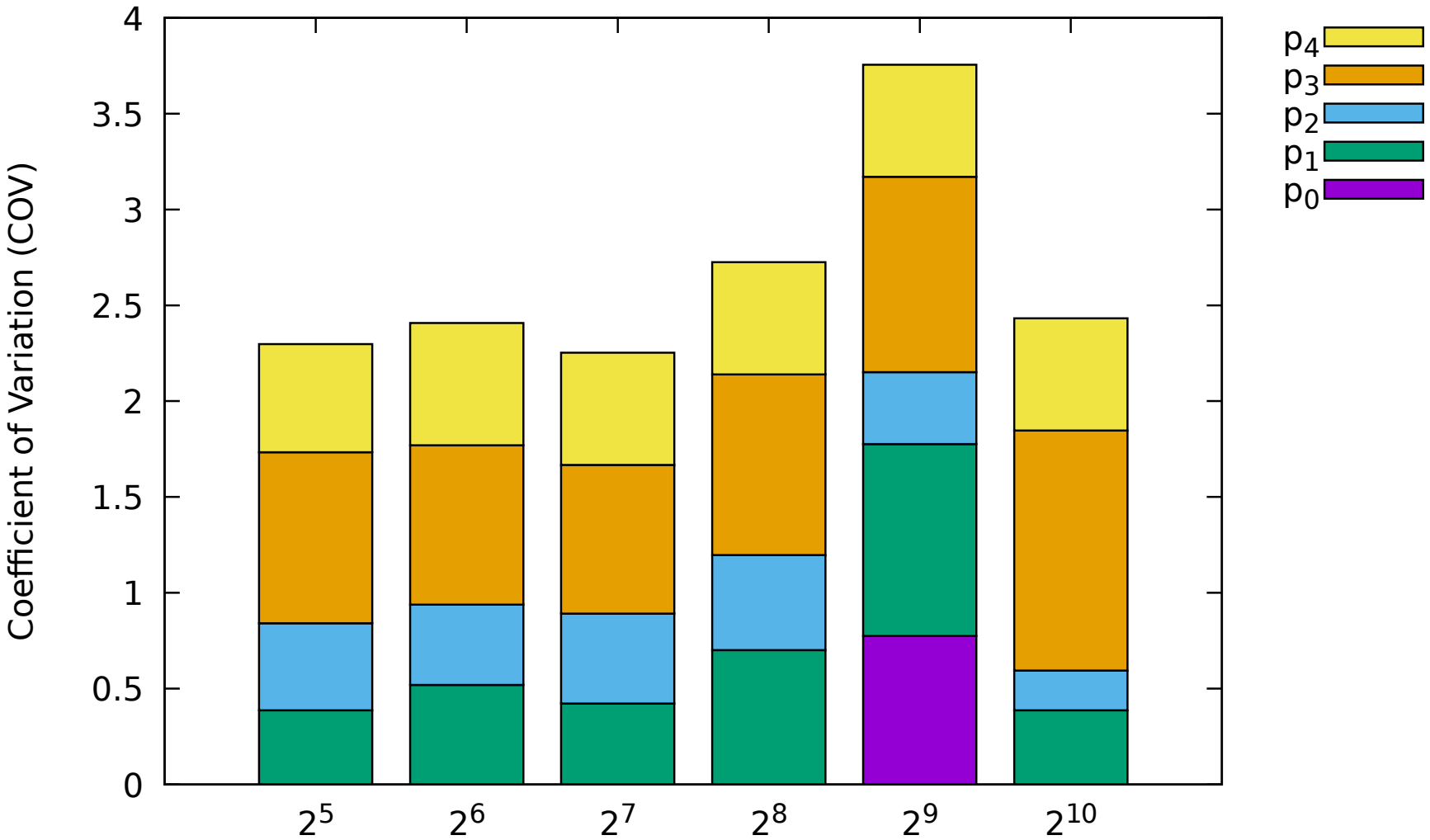
Optimum Portability: AMD GPUs, stencil



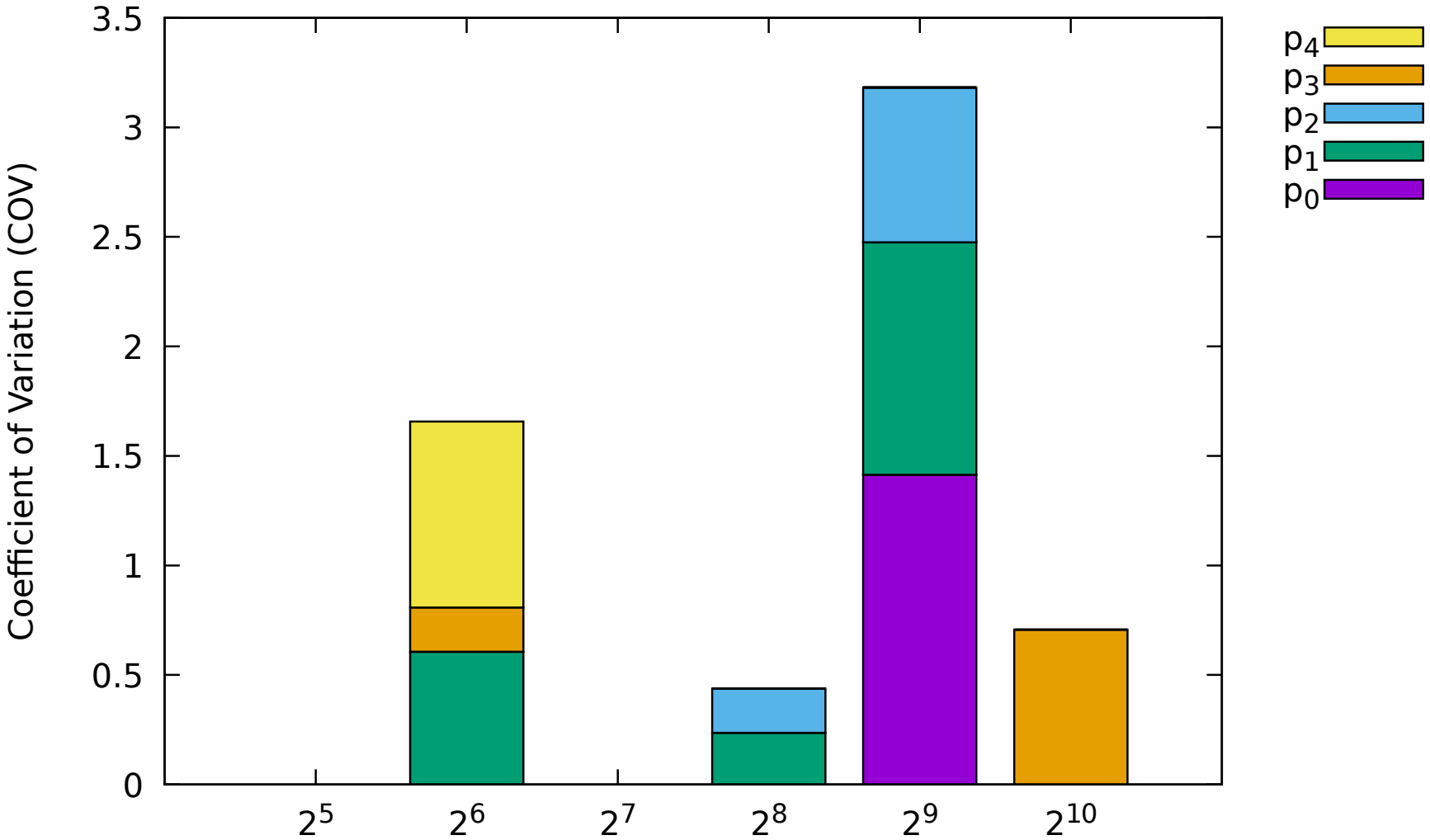
Optimum Portability: NVIDIA GPUs, stencil



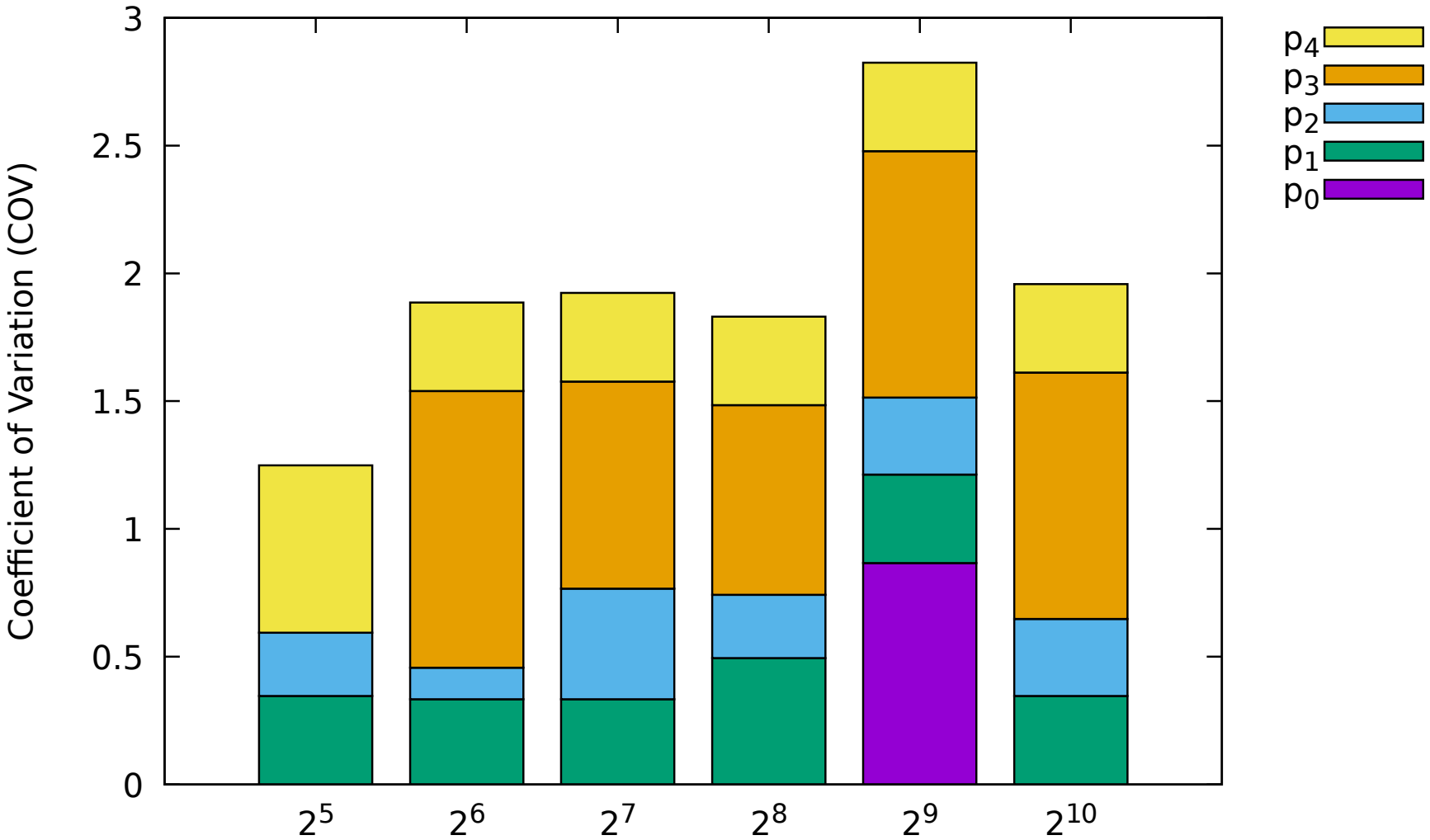
Optimum Portability: correlator



Optimum Portability: AMD GPUs, correlator



Optimum Portability: NVIDIA GPUs, correlator



Conclusions

- Tuning memory-bound applications on GPUs can be easy
  - NVIDIA GPUs are almost trivial to tune
  - It is not always the case with the Xeon Phi
- Tuning applications with data-reuse is more difficult
  - It applies to both GPUs and the Xeon Phi
  - Difficulty can be a function of the input size (e.g. MD)

- Optimum Portability is generally low
  - No much difference between memory-bound and data-reuse
  - Optimums are rarely portable among different platforms
    - But they are more portable for a single vendor
  - Optimums can be portable among inputs on the same platform