The DFG JIT, Inside & Out

JavaScriptCore's Optimizing Compiler

JSConf.EU 2012

Andy Wingo

wingo@igalia.com

Compiler hacker at Igalia

Contract work on language implementations

V8, JavaScriptCore

Schemer

Hubris

“Now that JavaScriptCore is as fast as V8 on its own benchmark, it’s well past time to take a look inside JSC’s optimizing compiler, the DFG JIT.”

DFG

Optimizing compiler for JSC

LLInt -> Baseline JIT -> **DFG JIT**

Makes hot code run fast

But how good is it?

An empirical approach

Getting good code

What: V8 benchmarks

When: Hacked V8 benchmarks

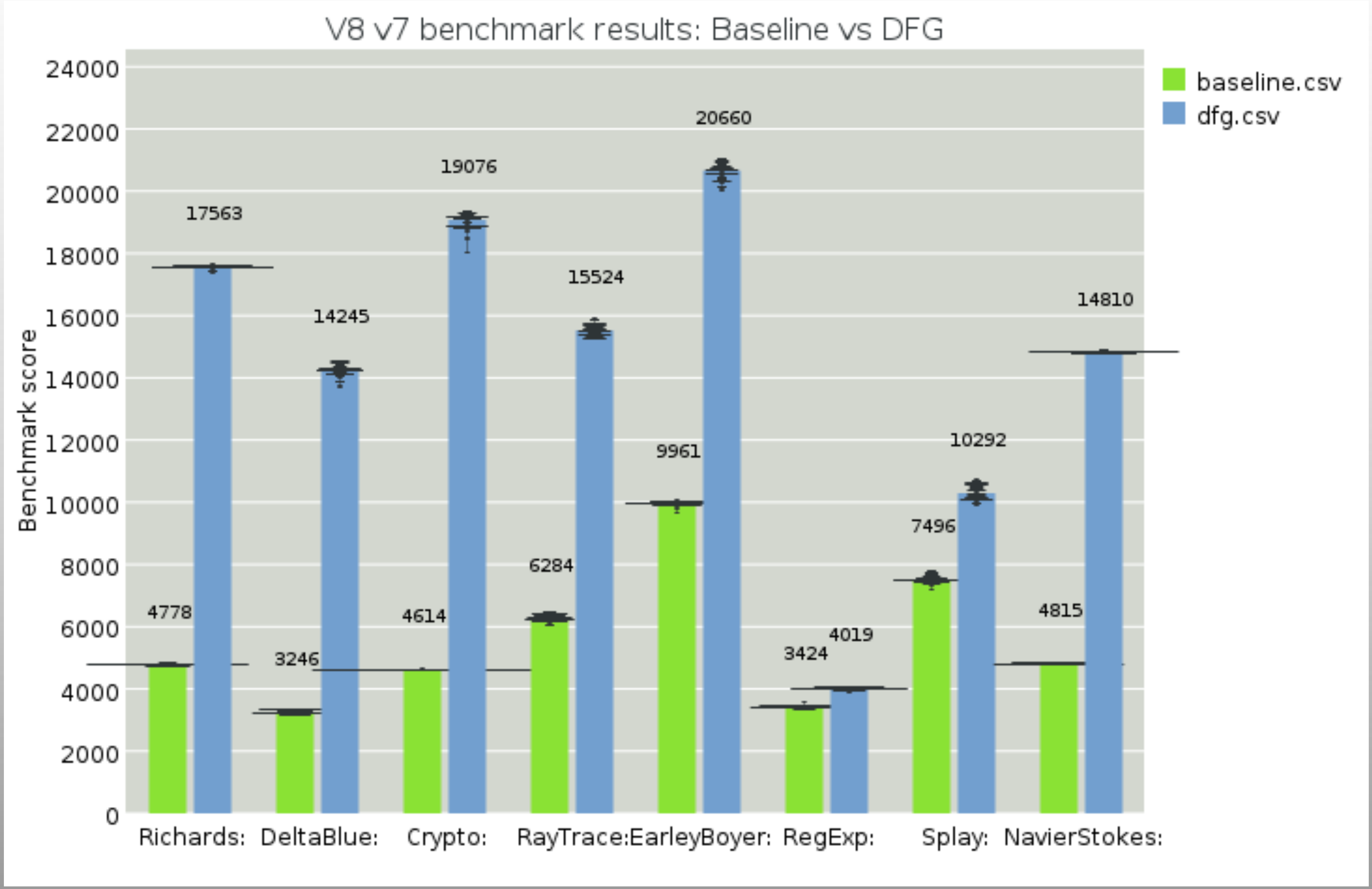
How: Code dive

The V8 benchmarks

The best performance possible from an optimizing compiler

- full second of warmup
- full second of runtime
- long run amortizes GC pauses

Baseline JIT vs DFG



Abusing the V8 benchmarks

When does the DFG kick in?

What does it do?

Idea: V8 benchmarks with variable warmup

- after 0 ms of warmup
- after 5 ms of warmup
- after *n* ms of warmup

Small fixed runtime (5 ms)

Caveats

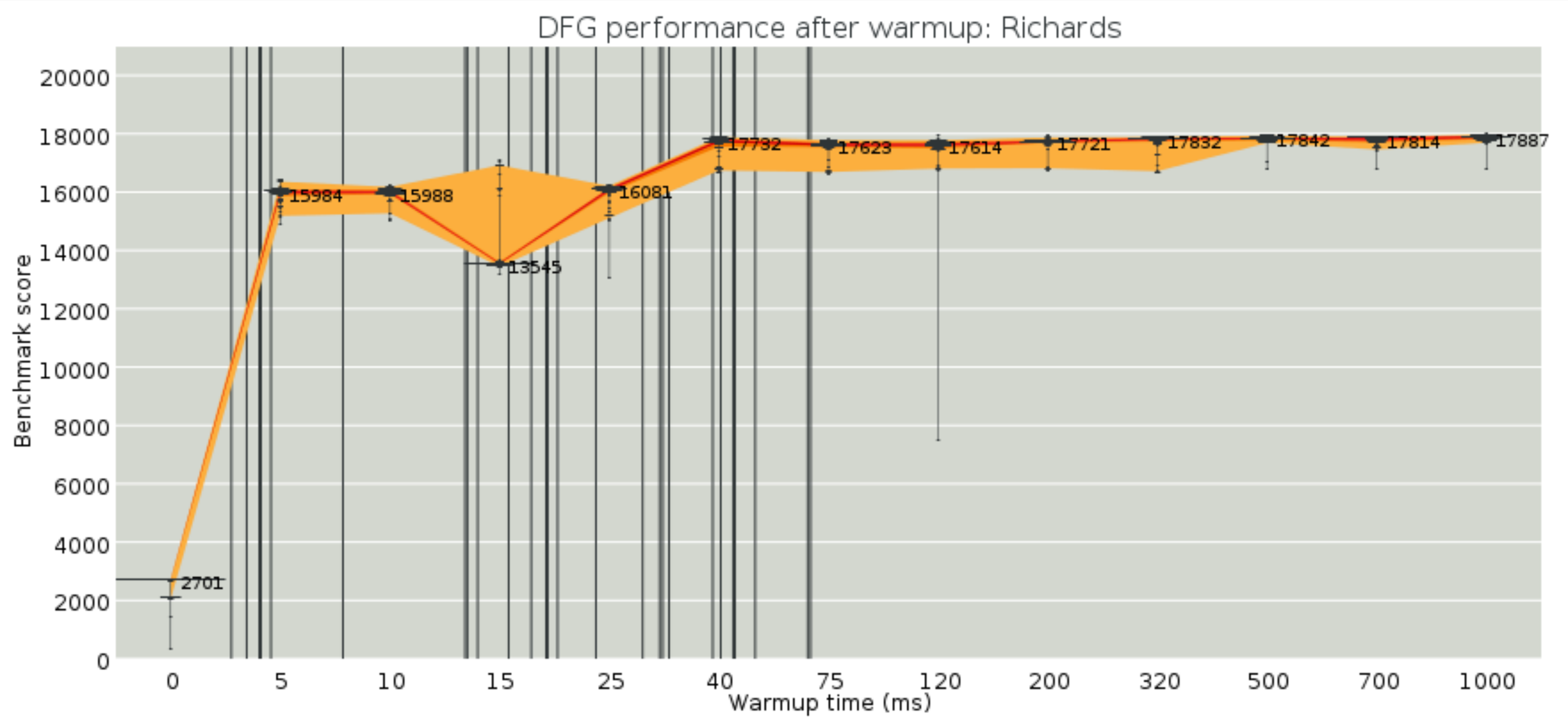
Very sensitive

- GC
- optimization pauses
- timer precision

… but then, so is real code

Keep close eye on distribution of measurements

Richards



Speedup: 3.7X

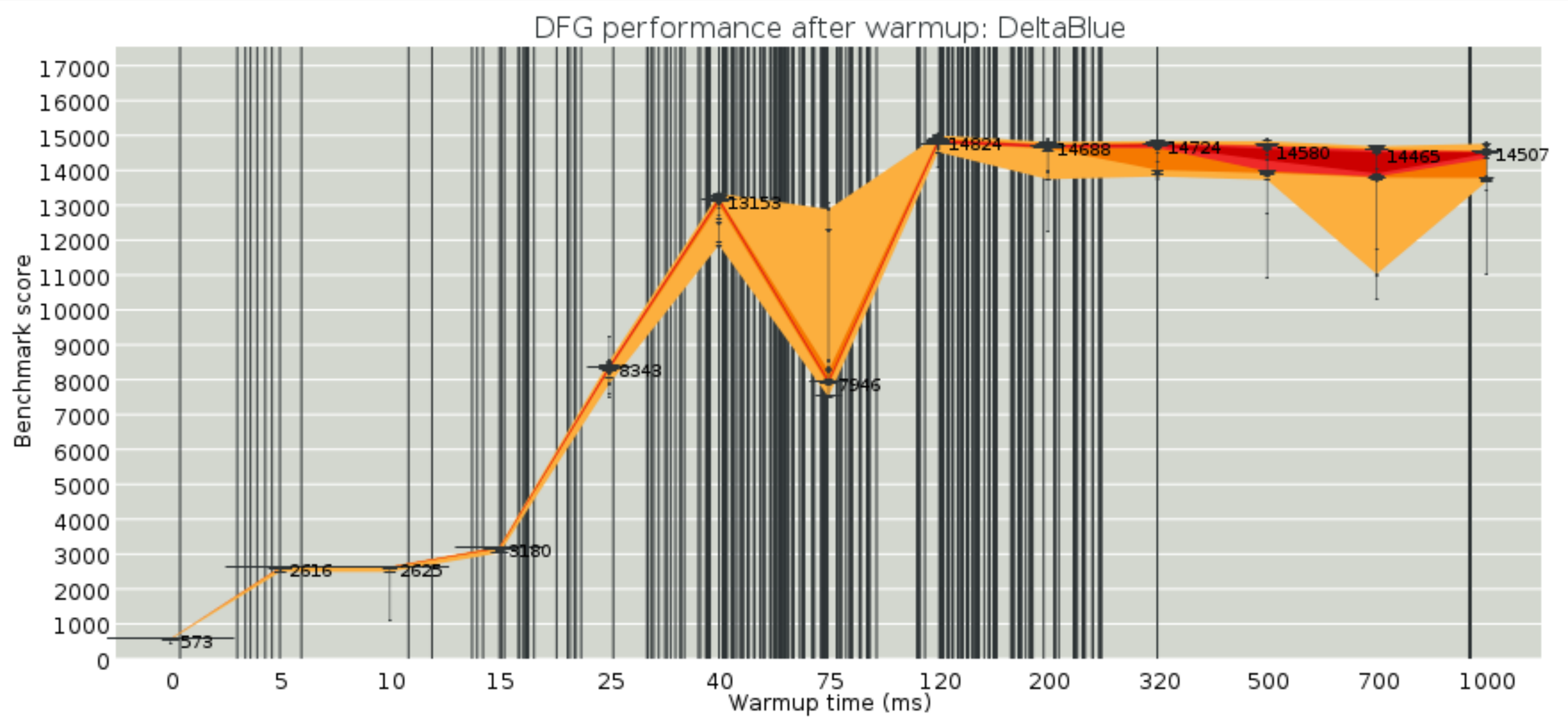
Bit ops, properties, prototypes

```
TaskControlBlock.prototype.isHeldOrSuspended = function () {
  return (this.state & STATE_HELD) != 0
         || (this.state == STATE_SUSPENDED); };

GetLocal
          0x7f4d028abbf4: mov -0x38(%r13), %rax
CheckStructure
          0x7f4d028abbf8: mov $0x7f4d00109c80, %r11
          0x7f4d028abc02: cmp %r11, (%rax)
          0x7f4d028abc05: jnz 0x7f4d028abd15
GetByOffset
          0x7f4d028abc0b: mov 0x38(%rax), %rax
GetGlobalVar
          0x7f4d028abc0f: mov $0x7f4d479cdca8, %rdx
          0x7f4d028abc19: mov (%rdx), %rdx
BitAnd
          0x7f4d028abc1c: cmp %r14, %rax
          0x7f4d028abc1f: jb 0x7f4d028abd2b
          0x7f4d028abc25: cmp %r14, %rdx
          0x7f4d028abc28: jb 0x7f4d028abd41
          0x7f4d028abc2e: and %edx, %eax
```

```
CompareEq
          0x7f4d028abc30: xor %ecx, %ecx
          0x7f4d028abc32: cmp %ecx, %eax
          0x7f4d028abc34: setz %al
          0x7f4d028abc37: movzx %al, %eax
          0x7f4d028abc3a: or $0x6, %eax
LogicalNot
          0x7f4d028abc3d: xor $0x1, %rax
SetLocal
          0x7f4d028abc41: mov %rax, 0x0(%r13)
Branch
          0x7f4d028abc45: test $0x1, %eax
          0x7f4d028abc4b: jnz 0x7f4d028abc87
...
          0x7f4d028abc97: ret
(End Of Main Path)
...
```

DeltaBlue



Speedup: 4.4X

Prototypes, inlining

Inlining

At 20ms:

```
Delaying optimization for
  Constraint.prototype.satisfy (in loop)
  because of insufficient profiling.
```

Eventually succeeds after 4 more times and 20 more ms; see `--maximumOptimizationDelay`.

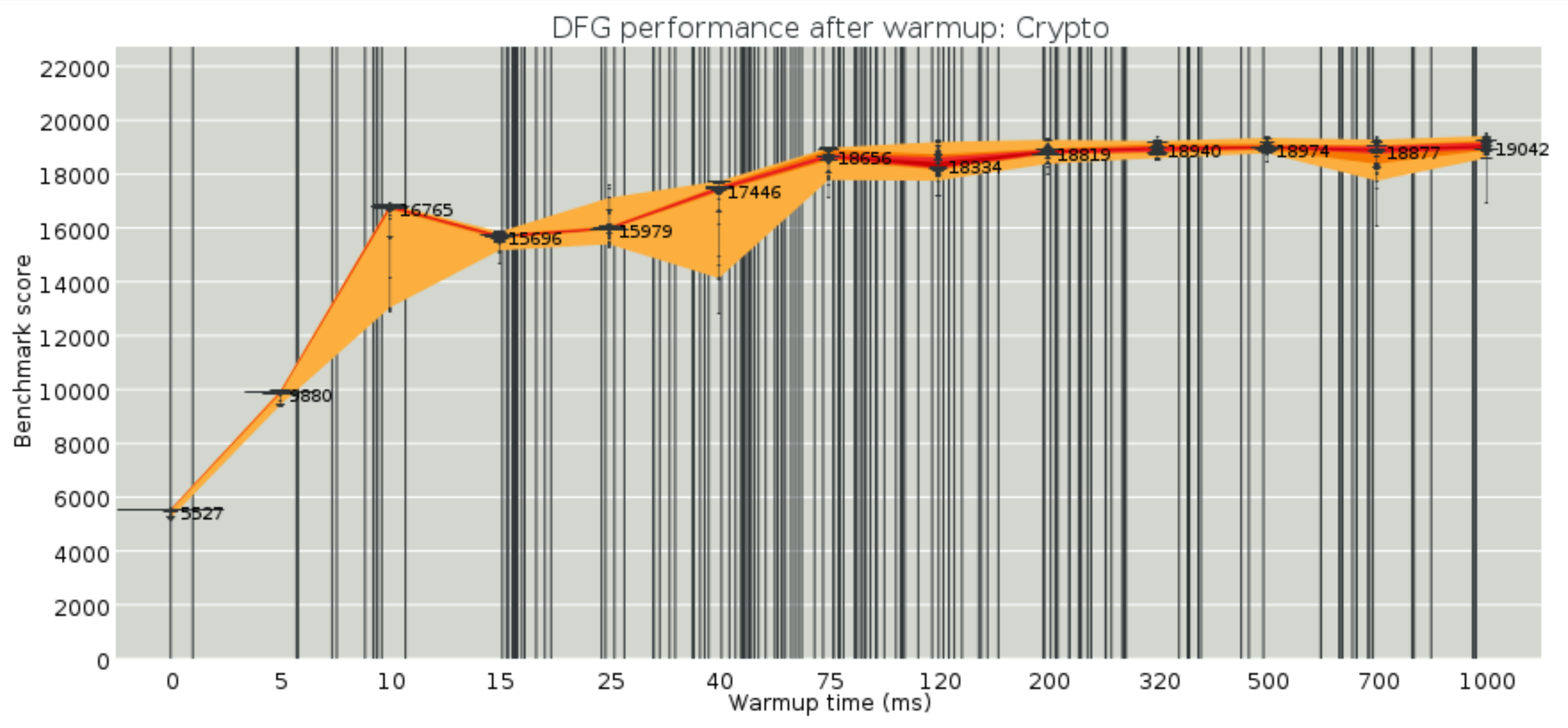
1000 cuts

One function optimized about 20ms in:

```
Planner.prototype.addConstraintsConsumingTo =
  function (v, coll) {
    var determining = v.determinedBy;
    var cc = v.constraints;
    for (var i = 0; i < cc.size(); i++) {
      var c = cc.at(i);
      if (c != determining && c.isSatisfied(
        coll.add(c);
    }
}
```

Many small marginal gains

Crypto



Speedup: 4.1X

Integers, arrays

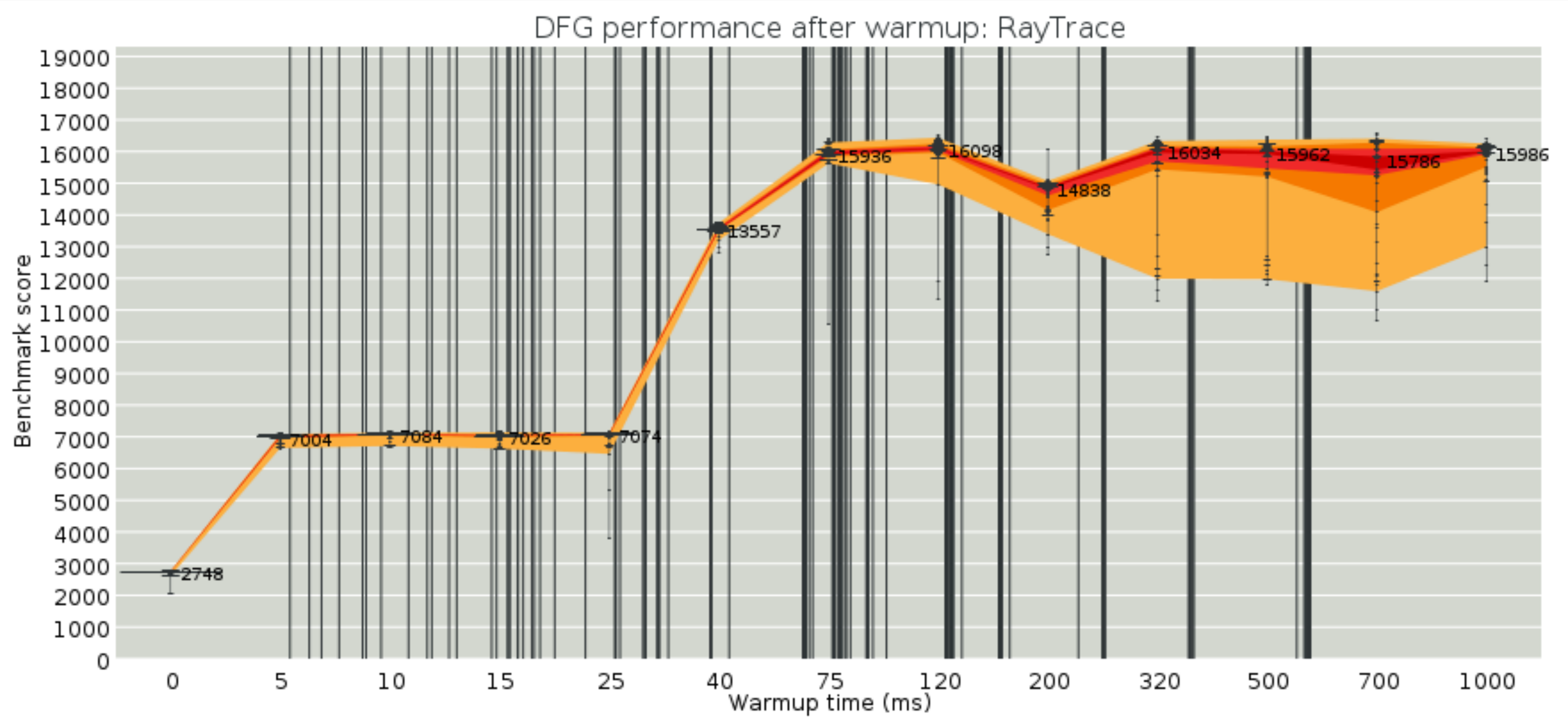
```
function am3(i,x,w,j,c,n) {
  var this_array = this.array;
  var w_array    = w.array;

  var xl = x&0x3fff, xh = x>>14;
  while(--n >= 0) {
    var l = this_array[i]&0x3fff;
    var h = this_array[i++]>>14;
    var m = xh*l+h*xl;
    l = xl*l+((m&0x3fff)<<14)+w_array[j]+c;
    c = (l>>28)+(m>>14)+xh*h;
    w_array[j++] = l&0xfffffff;
  }
  return c;
}
```

var l = this_array[i]&0x3fff

```
GetLocal: this_array
          0x7f4d02909bf6: mov 0x0(%r13), %r10
GetLocal: i (int32; type check hoisted)
          0x7f4d02909bfa: mov -0x40(%r13), %eax
GetButterfly: this_array
          0x7f4d02909bfe: mov 0x8(%r10), %rdx
GetByVal: this_array[i] (array check hoisted)
          0x7f4d02909c02: cmp -0x4(%rdx), %eax
          0x7f4d02909c05: jae 0x7f4d02909ed2
          0x7f4d02909c0b: mov 0x10(%rdx,%rax,8), %rcx
          0x7f4d02909c10: test %rcx, %rcx
          0x7f4d02909c13: jz 0x7f4d02909ee8
BitAnd:
          0x7f4d02909c19: cmp %r14, %rcx
          0x7f4d02909c1c: jb 0x7f4d02909efe
          0x7f4d02909c22: mov %rcx, %rbx
          0x7f4d02909c25: and $0x3fff, %ebx
```

RayTrace



Speedup: 2.5X

Floating point, objects with floating-point fields

normalize()

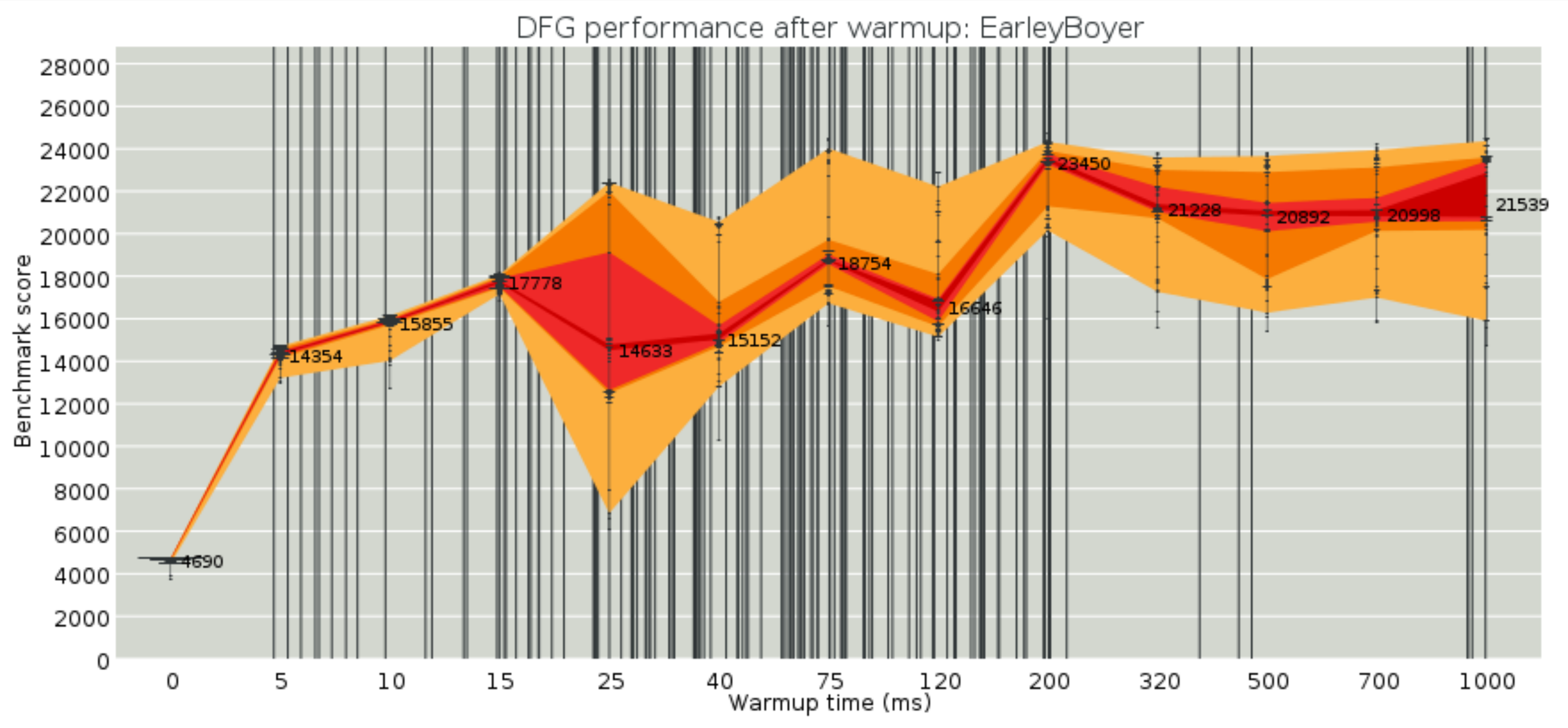
```
normalize : function() {
    var m = this.magnitude();
    return new Flog.RayTracer.Vector(this.x / m,
                                     this.y / m,
                                     this.z / m); },
```

DFG inlines as it compiles: inlines `this.magnitude()`

```
ArithDiv:
          0x7f4d0298164b: divsd %xmm1, %xmm0
SetLocal:
          0x7f4d0298164f: movd %xmm0, %rdx
          0x7f4d02981654: sub %r14, %rdx
          0x7f4d02981657: mov %rdx, 0x20(%r13)
```

No typed fields (yet)

EarleyBoyer



Speedup: 2.0X

Function calls, small short-lived allocations

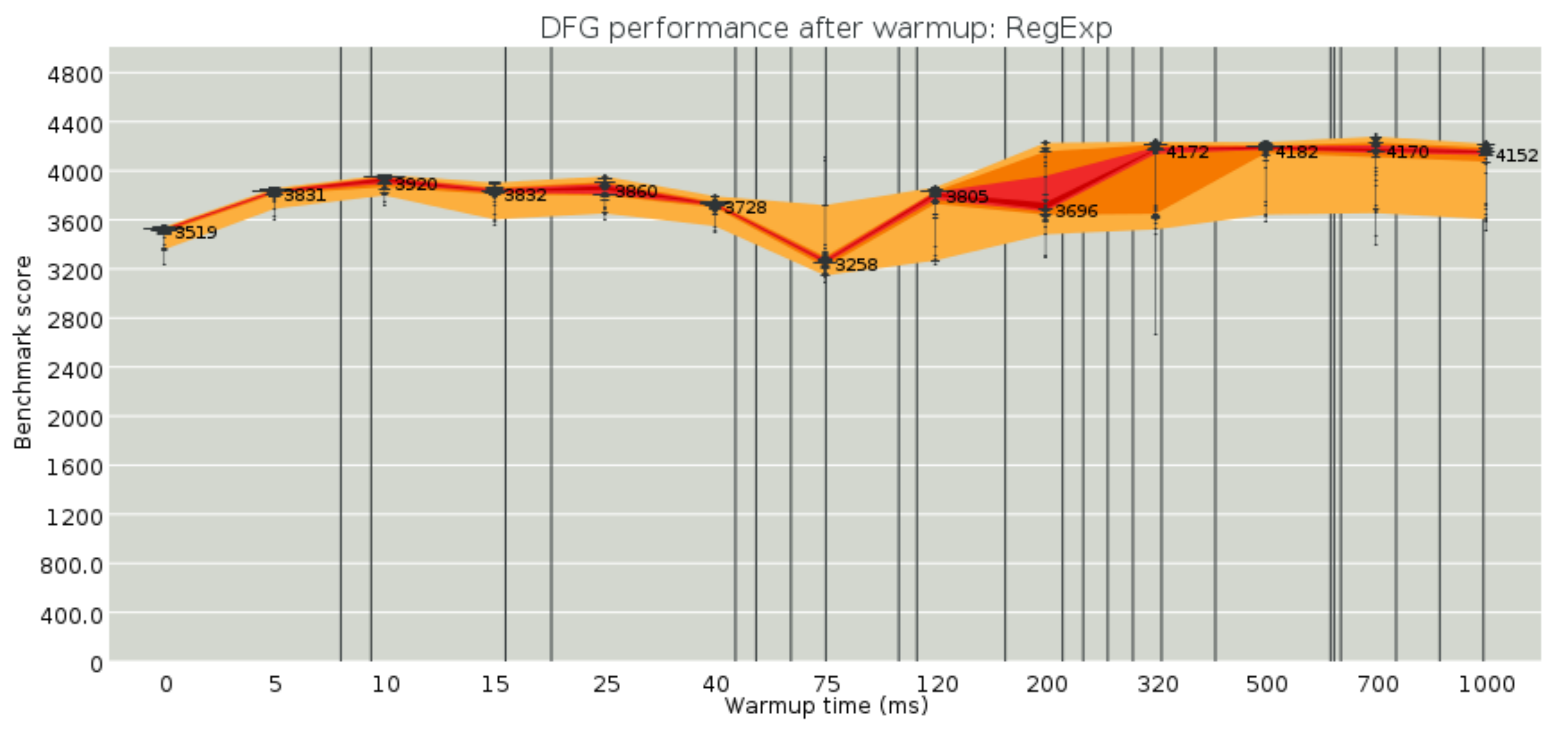
EarleyBoyer

“Performance is a distribution, not a value”

Wide distribution indicates nonuniform performance

Cause in this case: nonincremental mark GC

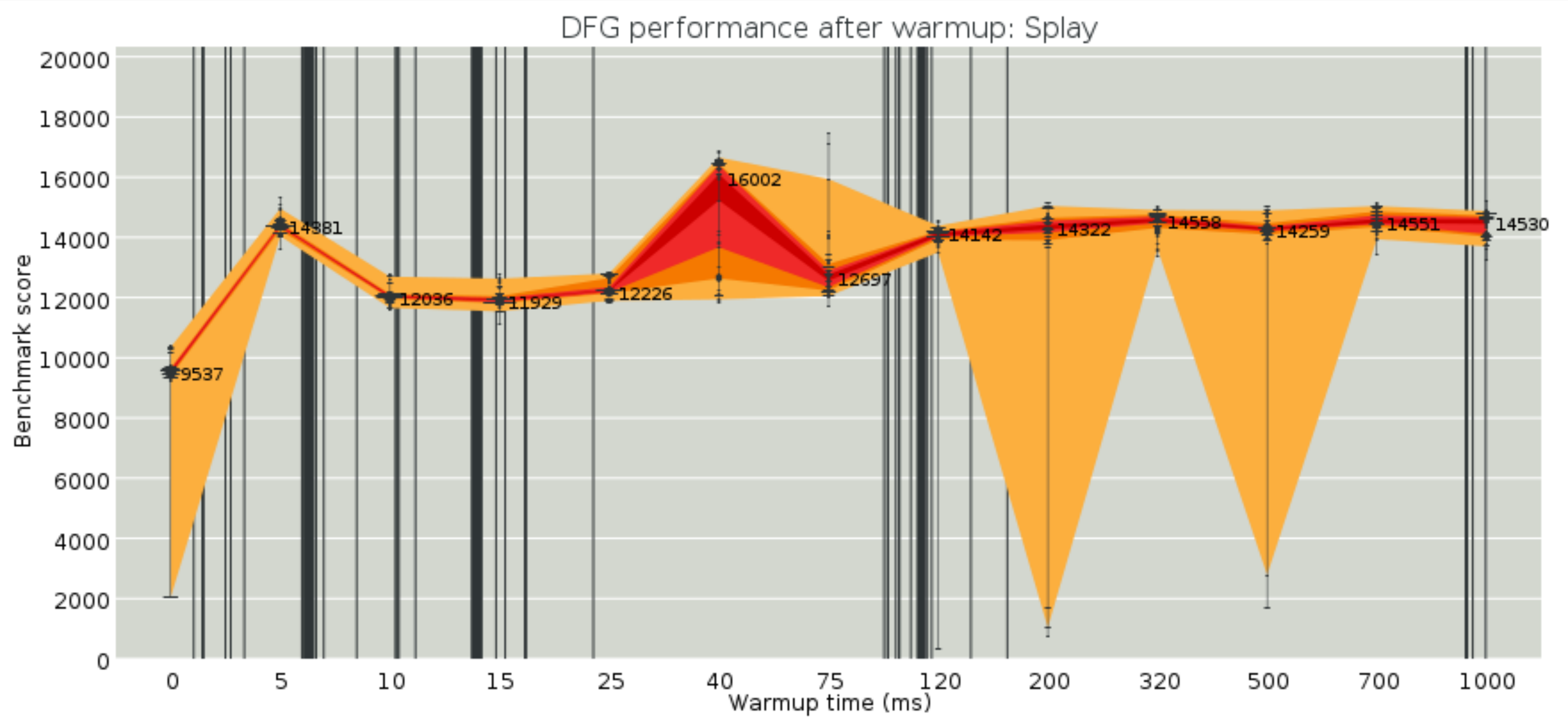
RegExp



Speedup: 1.2X

Regexp compiler test; DFG of no help

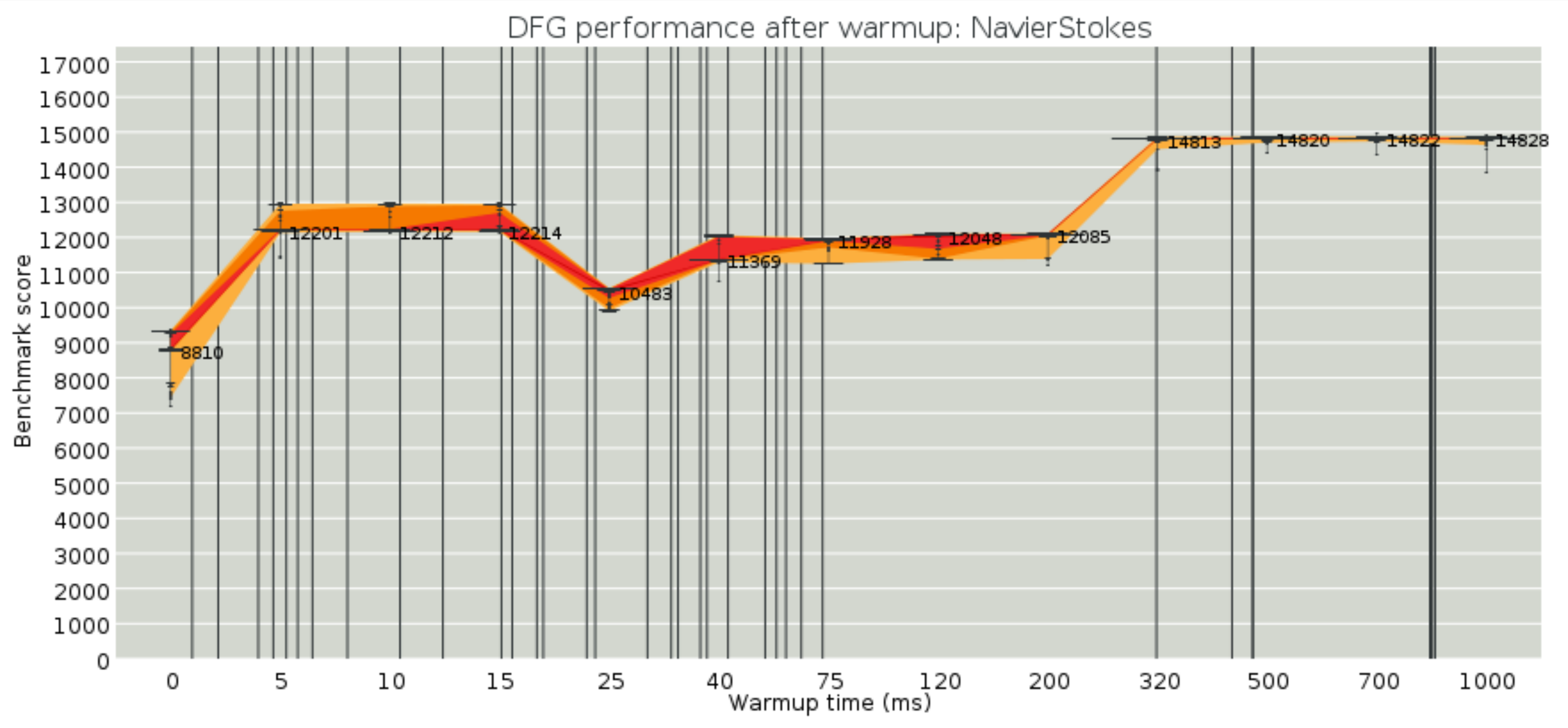
Splay



Speedup: 1.4X

GC test, huge variance

NavierStokes



Speedup: 3.0X

Floating point arrays, large floating-point functions

No automagic double arrays

```
GetByVal:
          0x7f4d02acec1f: cmp -0x4(%rcx), %r9d
          0x7f4d02acec23: jae 0x7f4d02acee0b
          0x7f4d02acec29: mov 0x10(%rcx,%r9,8), %rbx
          0x7f4d02acec2e: test %rbx, %rbx
          0x7f4d02acec31: jz 0x7f4d02acee21
GetLocal:
          0x7f4d02acec37: mov -0x50(%r13), %rdi
Int32ToDouble:
          0x7f4d02acec3b: cmp %r14, %rbx
          0x7f4d02acec3e: jae 0x7f4d02acec5d
          0x7f4d02acec44: test %rbx, %r14
          0x7f4d02acec47: jz 0x7f4d02acee37
          0x7f4d02acec4d: mov %rbx, %rsi
          0x7f4d02acec50: add %r14, %rsi
          0x7f4d02acec53: movd %rsi, %xmm0
          0x7f4d02acec58: jmp 0x7f4d02acec61
          0x7f4d02acec5d: cvtsi2sd %ebx, %xmm0
```

Getting data out of JSC

```
jsc --options
```

```
jsc -d
```

```
jsc --showDFGDisassembly=true
```

`-DJIT_ENABLE_VERBOSE=1`, `-DJIT_ENABLE_VERBOSE_OSR=1` and timestamping hacks on `dataLog`

Comparative Literature

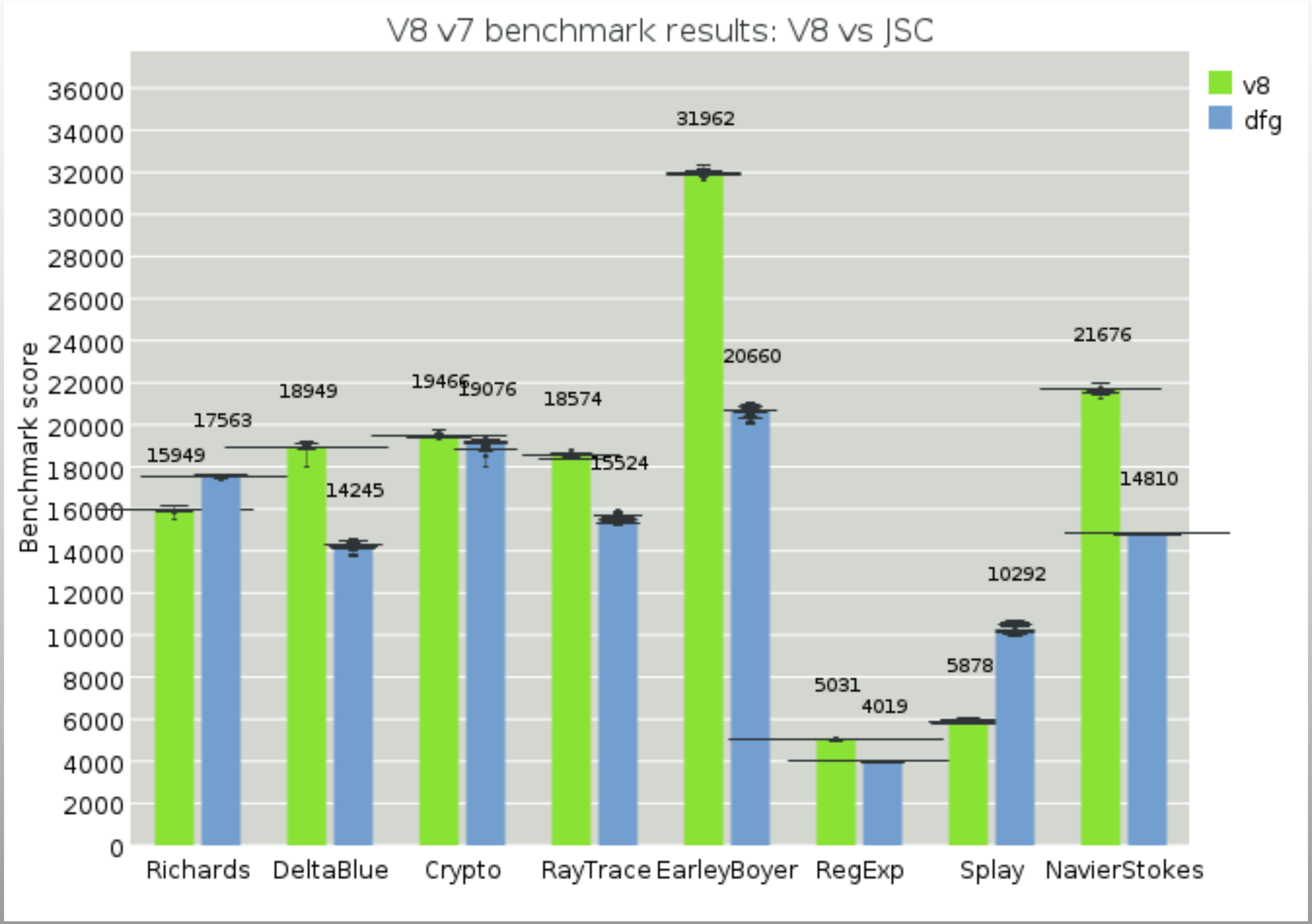
V8 vs JSC: fight!

Does JSC beat V8?

Does JSC meet V8?

Does V8 beat JSC?

Yes


V8 v7 benchmark results: V8 vs JSC
Benchmark score
36000
34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
v8
dfg
15949
17563
18949
14245
19466
19076
18574
15524
31962
20660
5031
4019
5878
10292
21676
14810
Richards
DeltaBlue
Crypto
RayTrace
EarleyBoyer
RegExp
Splay
NavierStokes

Questions?

- `igalia.com/compilers`
- `wingolog.org`
- `@andywingo`
- `wingolog.org/pub/jsconf-eu-2012-slides.pdf`