F# Streams

A lightweight F#/C# library for efficient functional-style pipelines on streams of data.

About Me

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About Nessos

- ISV based in Athens, Greece
- .NET experts
- Open source F# projects
  - {m}brace
  - FsPickler, Vagrant, and of course Streams

Motivation

Make functional data query pipelines FAST

LinqOptimizer

An automatic query optimizer-compiler for Sequential and Parallel LINQ.

https://github.com/nessos/LinqOptimizer

LinqOptimizer

- compiles LINQ queries into fast loop-based imperative code
- speedups of up to 15x

Example

The query

```
var query = (from num in nums.AsQueryExpr()
             where num % 2 == 0
             select num * num).Sum();
```

compiles to

```
int sum = 0;
for (int index = 0; index < nums.Length; index++)
{
   int num = nums[index];
   if (num % 2 == 0)
      sum += num * num;
}
```

Disadvantages

- Runtime compilation
  - Overhead (mitigated by caching)
  - Emitting IL not cross-platform (e.g. security restrictions in cloud, mobile)
  - Access to private fields/methods?
- Problematic F# support
- New operations => compiler changes

Should become a Roslyn compile time plugin in future

Clash of the Lamdas

ICOOOLPS'14

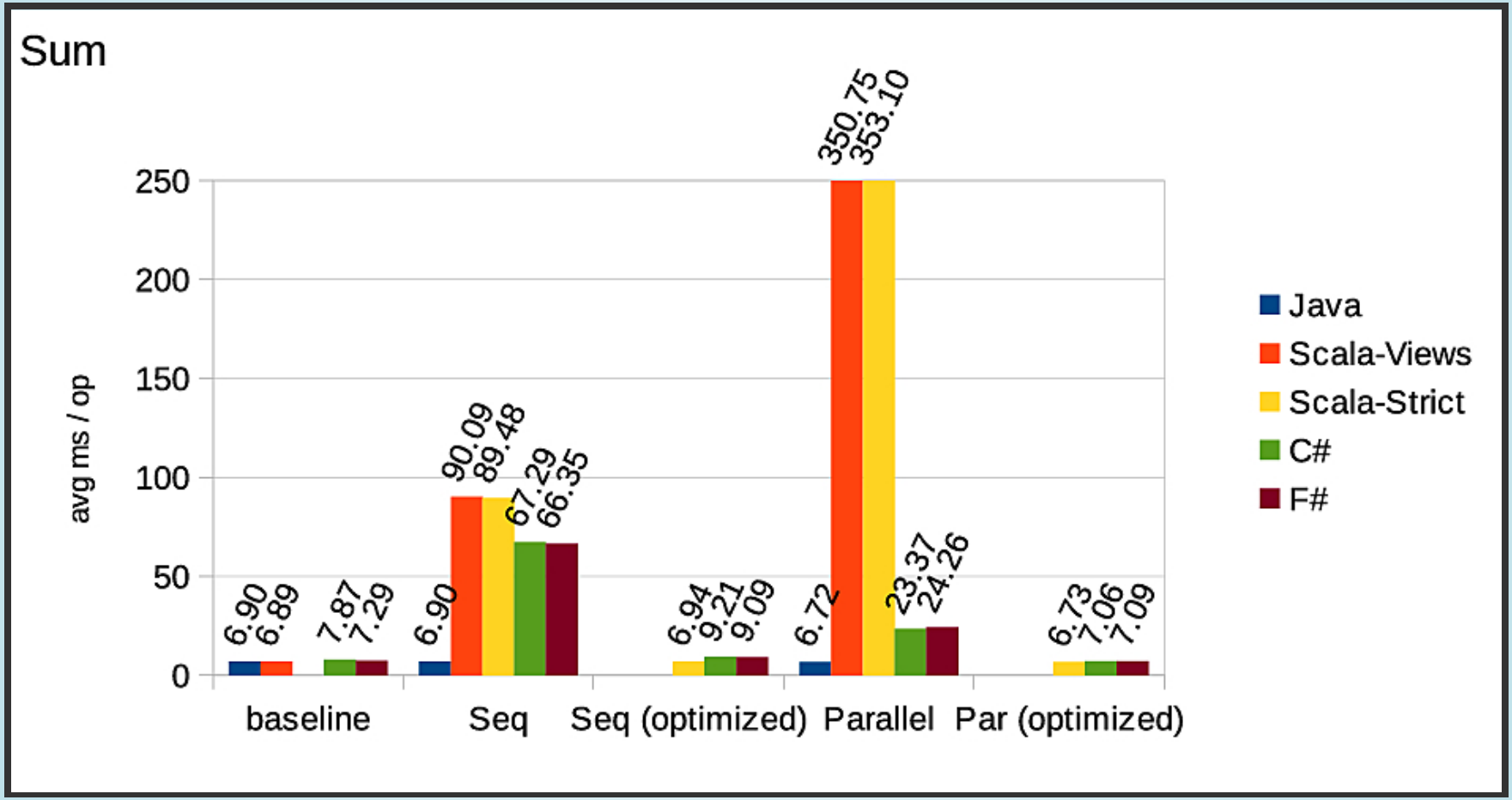
Aggelos Biboudis (@ biboudis)

Nick Palladinos (@ NickPalladinos)

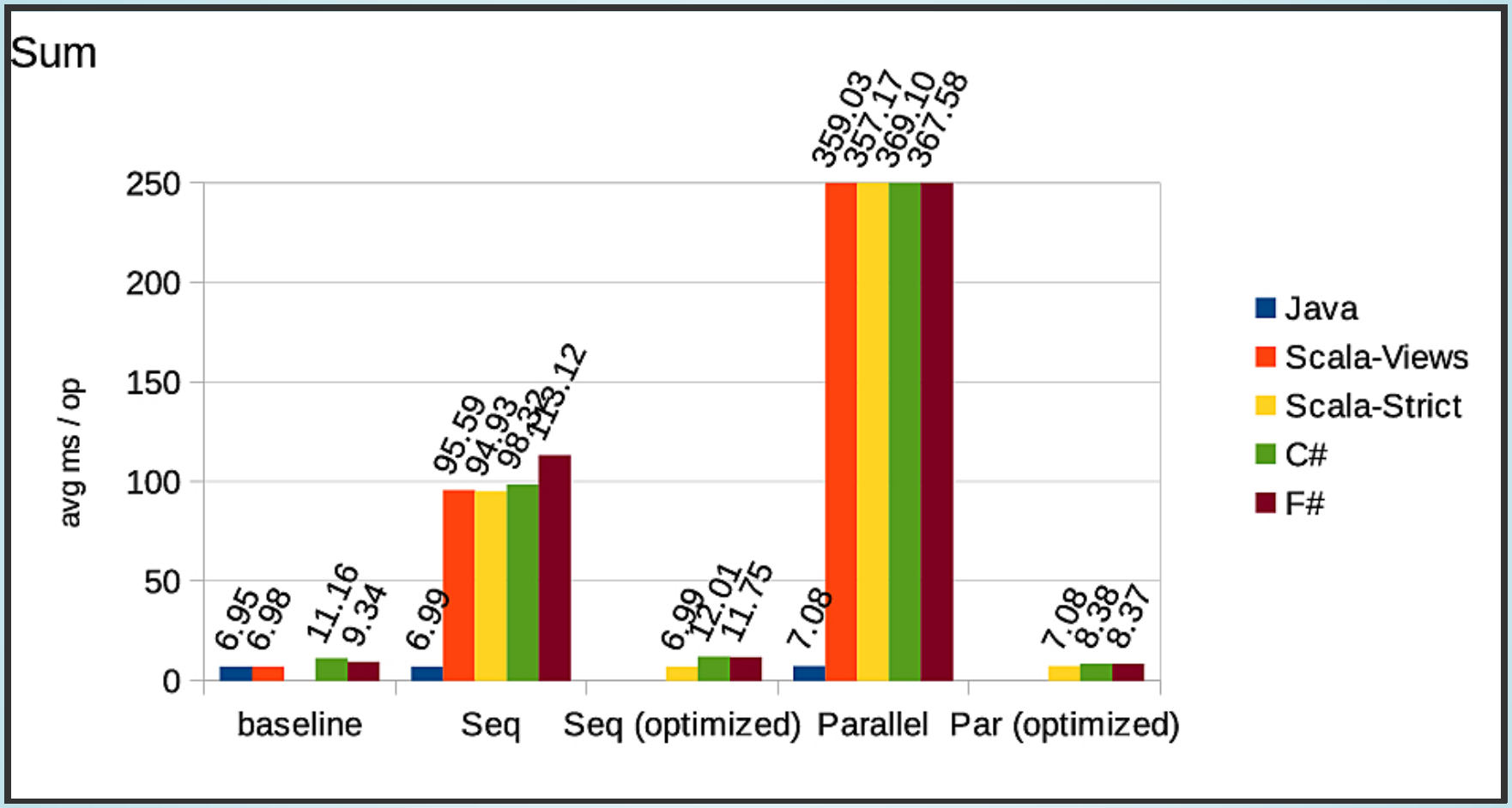
Yannis Smaragdakis

Performance Benchmarks

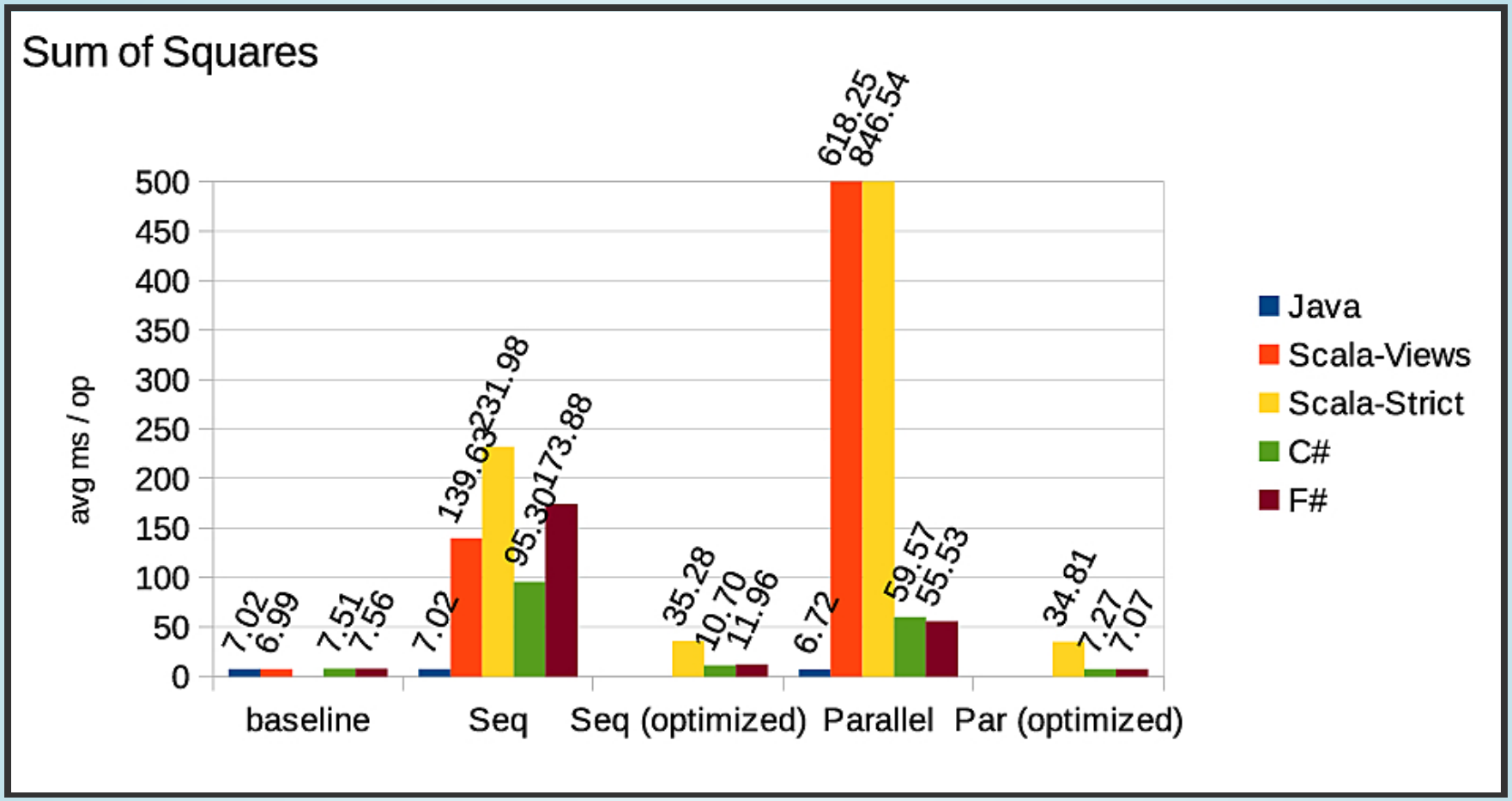
Sum (windows)



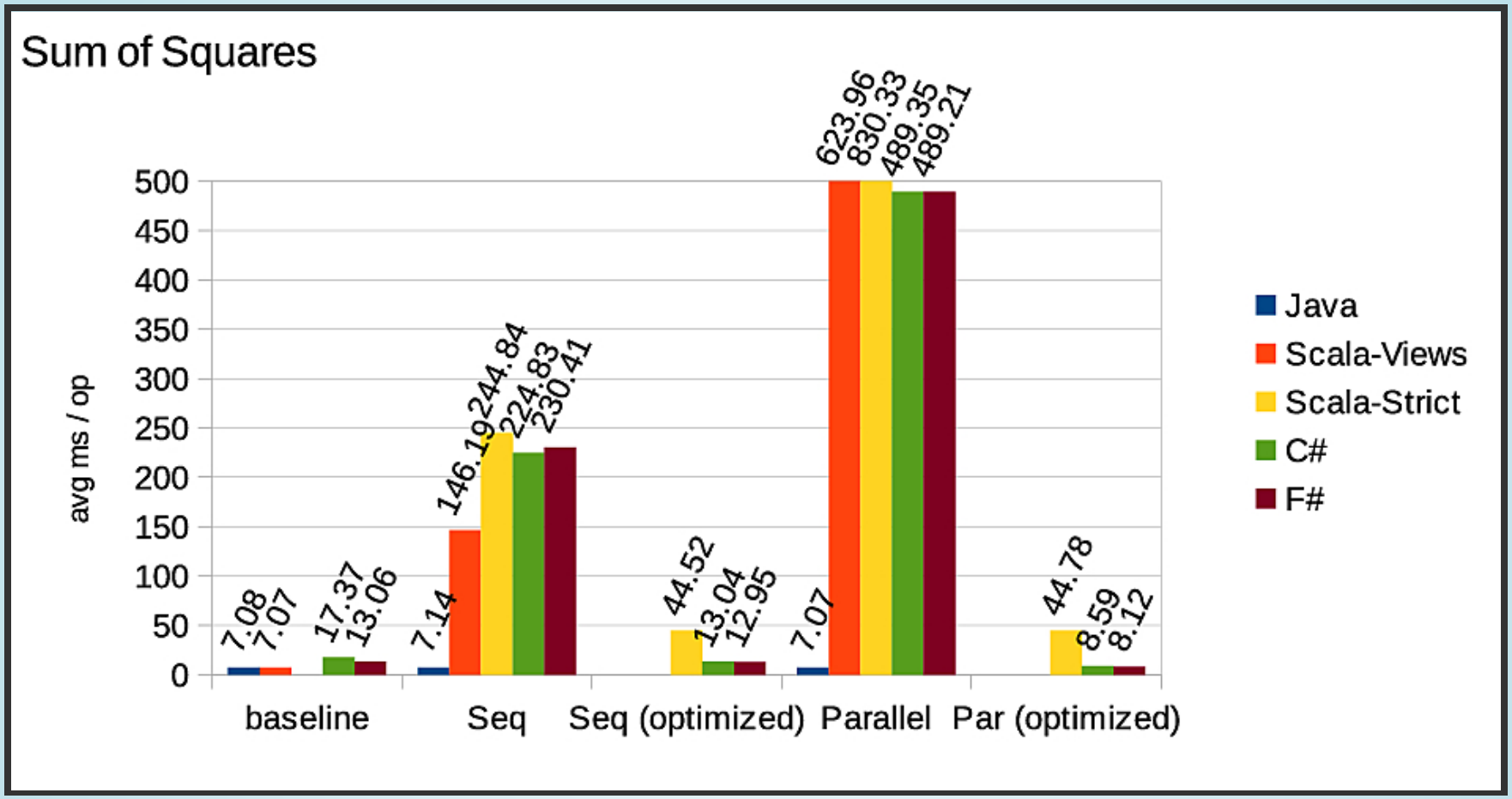
Sum (linux)


Sum
avg ms / op
250
200
150
100
50
0
6.95
6.98
11.16
9.34
6.99
95.59
94.93
98.32
113.12
6.99
12.01
11.75
7.08
359.03
357.17
369.10
367.58
7.08
8.38
8.37
baseline
Seq
Seq (optimized)
Parallel
Par (optimized)
Java
Scala-Views
Scala-Strict
C#
F#

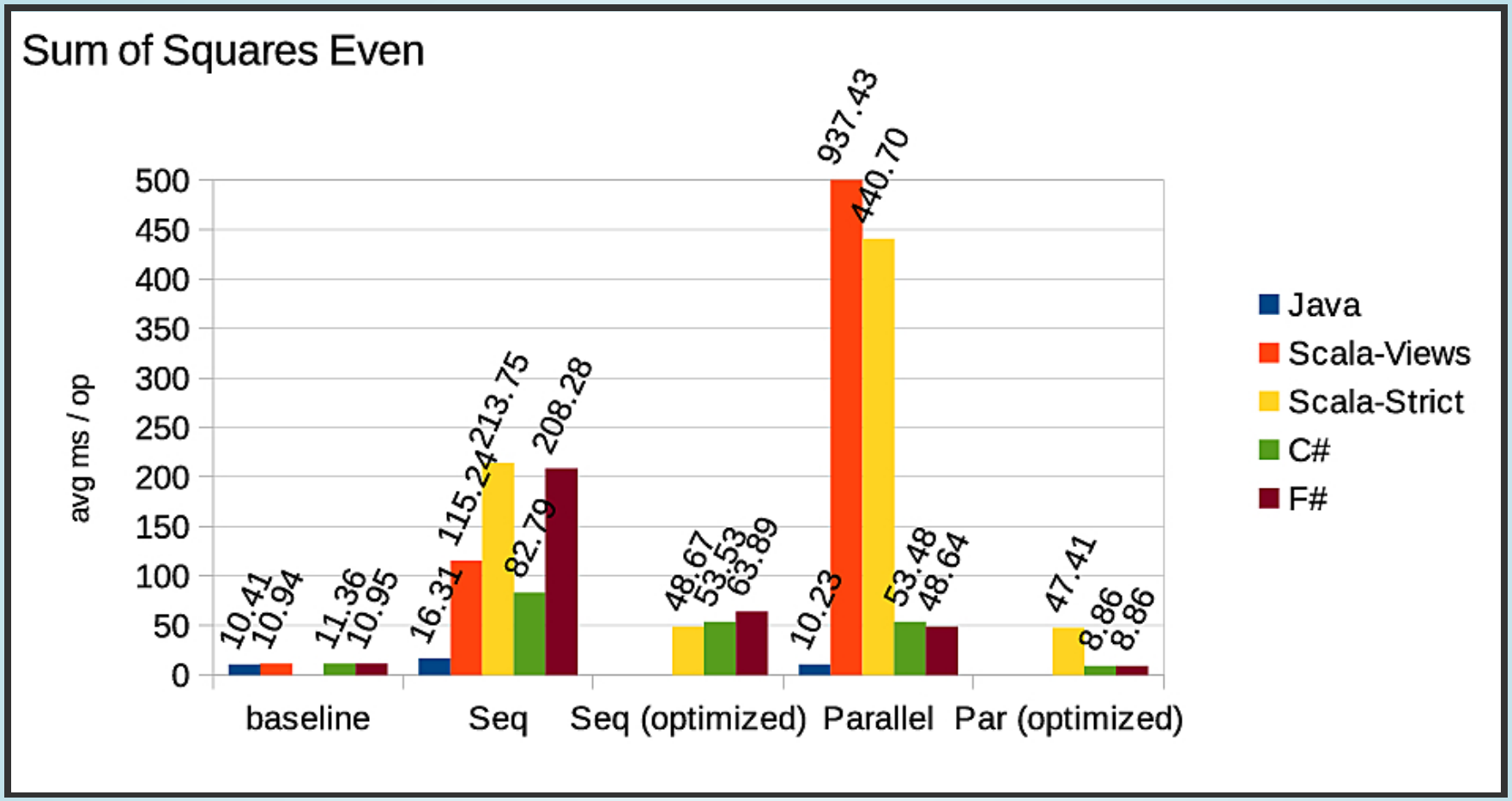
Sum of squares (windows)



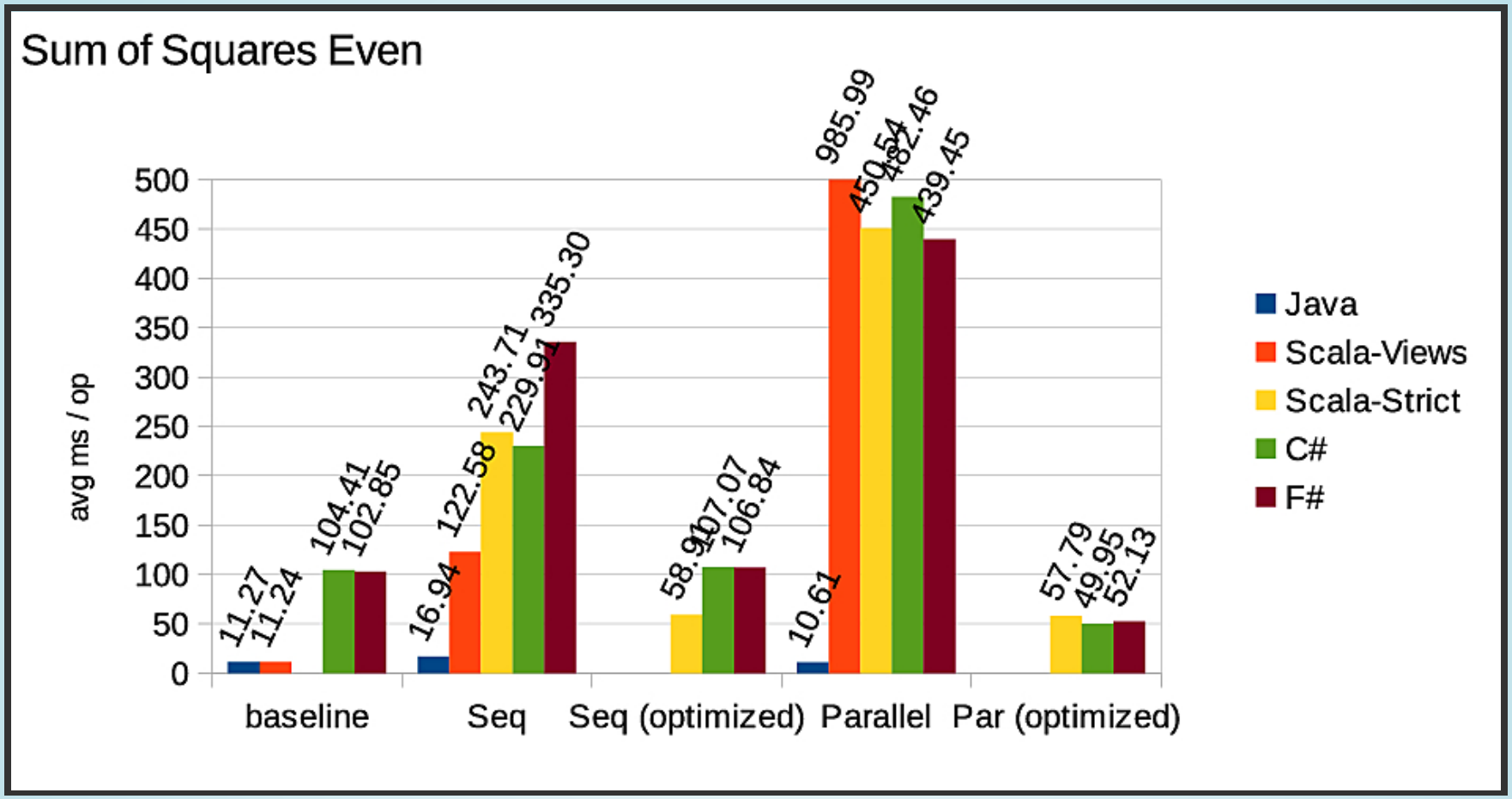
Sum of squares (linux)



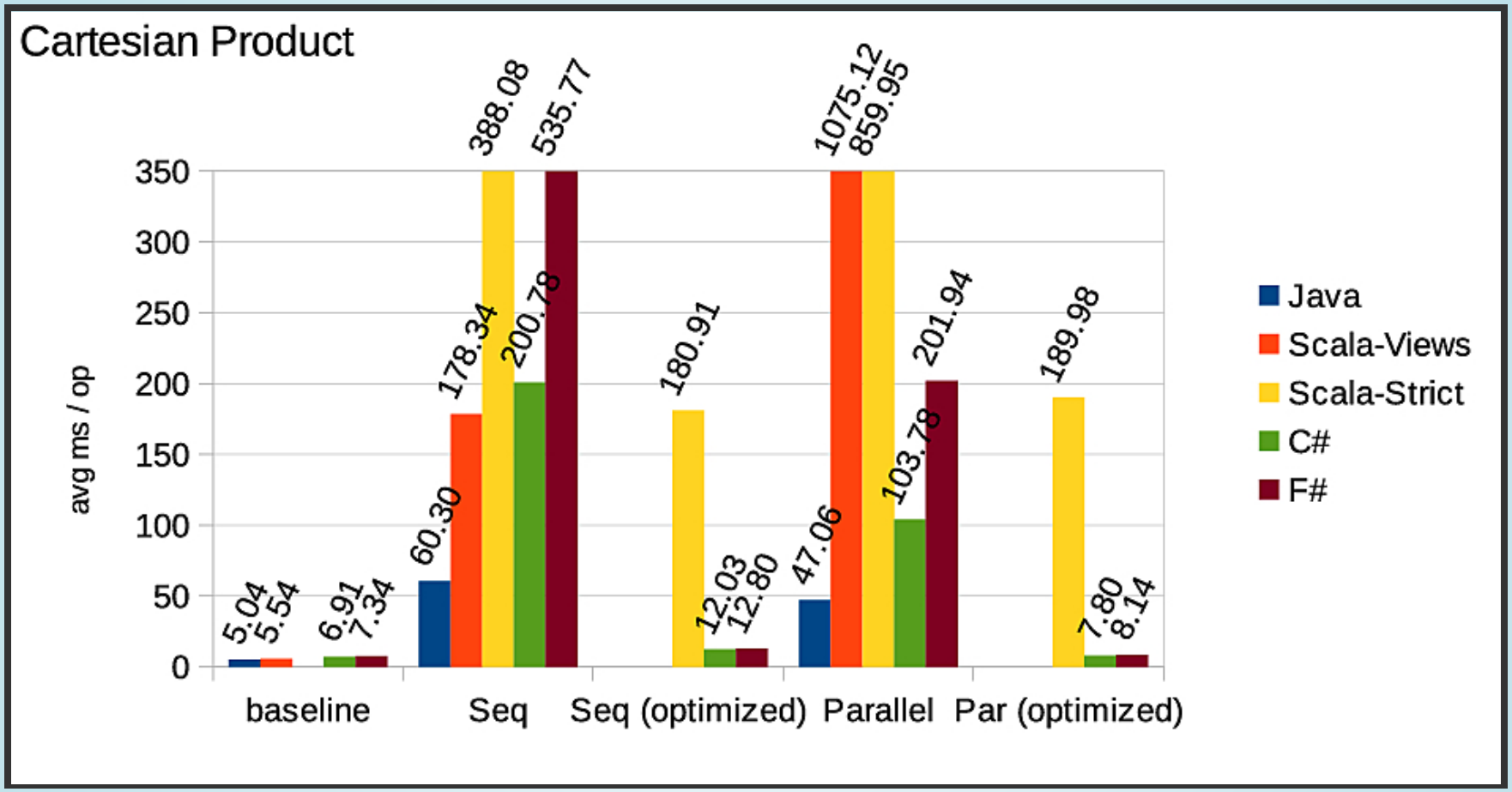
Sum of even squares (windows)



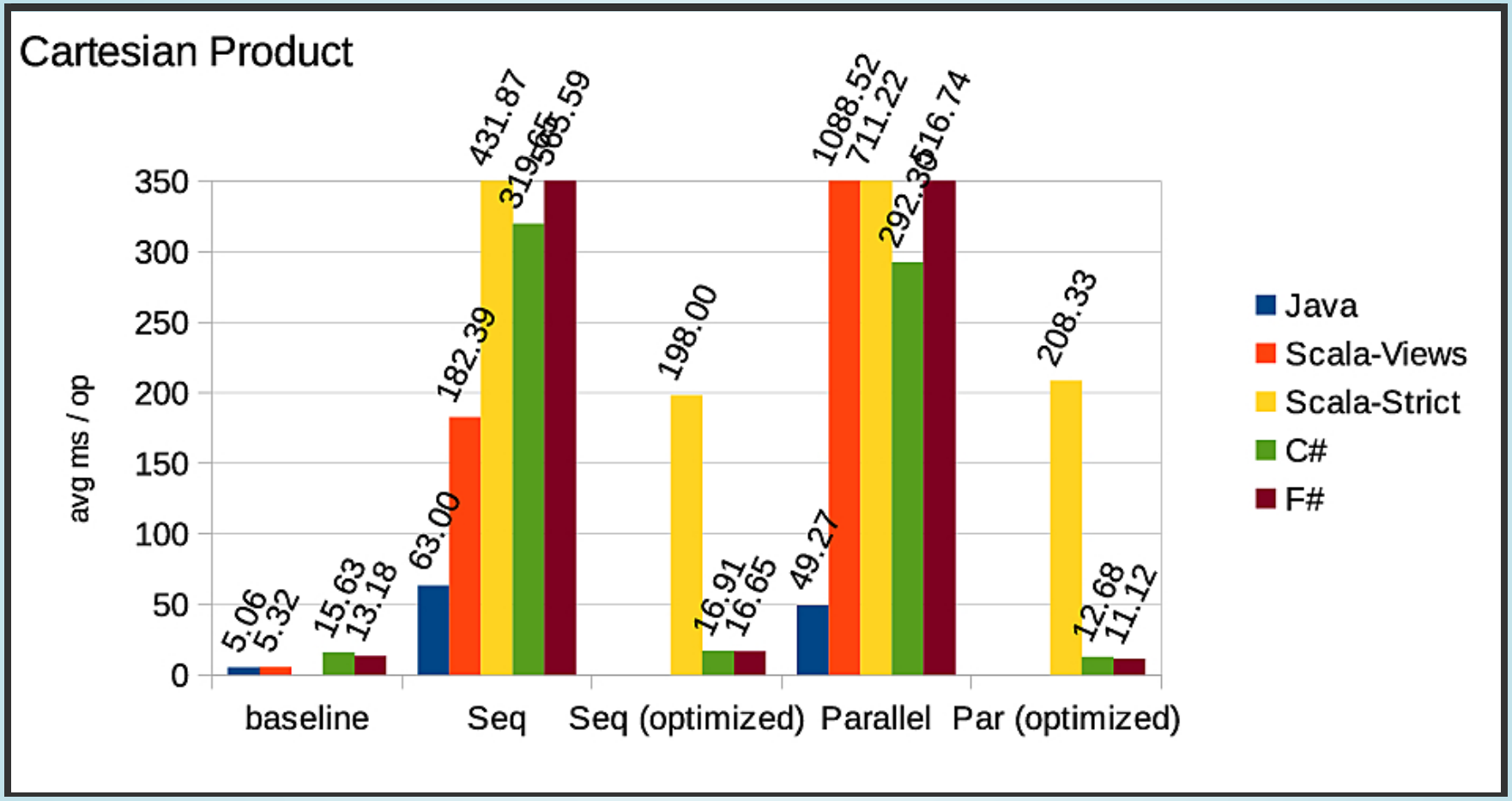
Sum of even squares (linux)



Cartesian product (windows)



Cartesian product (linux)



Java 8 very fast

LinqOptimizer improving F#/C# performance

What makes Java 8 faster?

Streams!

Typical Pipeline Pattern

```
1: source |> inter |> inter |> inter |> terminal
```

- inter : intermediate (lazy) operations, e.g. map, filter
- terminal : produces result or side-effects, e.g. reduce, iter

Seq example

```
1: let data = [| 1..10000000 |] |> Array.map int64
2: data
3: |> Seq.filter (fun i -> i % 2L = 0L) //lazy
4: |> Seq.map (fun i -> i + 1L) //lazy
5: |> Seq.sum //eager, forcing evaluation
```

Seq is pulling

```
1: let data = [| 1..10000000 |] |> Array.map int64
2: data
3: |> Seq.filter (fun i -> i % 2L = 0L) //lazy inter
4: |> Seq.map (fun i -> i + 1L) //lazy inter
5: |> Seq.sum //eager terminal, forcing evaluation
```

The terminal is pulling data from the pipeline via IEnumerator.Current and IEnumerator.MoveNext()

With Streams

```
1: let data = [| 1..10000000 |] |> Array.map int64
2: Stream.ofArray data //source
3: |> Stream.filter (fun i -> i % 2L = 0L) //lazy
4: |> Stream.map (fun i -> i + 1L) //lazy
5: |> Stream.sum //eager, forcing evaluation
```

Streams are pushing!

Streams are pushing

```
1: Stream.ofArray data //source
2: |> Stream.filter (fun i -> i % 2L = 0L) //lazy
3: |> Stream.map (fun i -> i + 1L) //lazy
4: |> Stream.sum //eager, forcing evaluation
```

The source is pushing data down the pipeline.

How does it work?

Starting from Seq.iter

```
1: Seq.iter : ('T -> unit) -> seq<'T> -> unit
```

Flip the args

```
1: seq<'T> -> ('T -> unit) -> unit
```

Stream!

```
1: type Stream<'T> = ('T -> unit) -> unit
```

Continuation passing style!

Let's make us some (simple) Streams!

Simple Streams

```
1: type Stream = ('T -> unit) -> unit
```

Can do map, filter, fold, iter

When to stop pushing?

```
1: type Stream = ('T -> unit) -> unit
```

Stopping push required for e.g.

```
1: Stream.takeWhile : ('T -> bool) -> Stream<'T> -> Stream<'T>
```

Stopping push

Change

```
1: type Stream = ('T -> unit) -> unit
```

to

```
1: type Stream = ('T -> bool) -> unit
```

What about zip?

```
1: Stream.zip : Stream<'T> -> Stream<'S> -> Stream<'T * 'S>
```

Zip needs to synchronise the flow of values.

Zip needs to pull!

Streams can push and pull

```
1: // ('T -> bool) is the composed continutation with 'T for the current value
2: // and bool is a flag for early termination
3: // (unit -> unit) is a function for bulk processing
4: // (unit -> bool) is a function for on-demand processing
5:
6: /// Represents a Stream of values.
7: type Stream<'T> = Stream of (('T -> bool) -> (unit -> unit) * (unit -> bool))
```

The Streams library

Implements a rich set of operations

More examples

Parallel Streams

```
1: let data = [| 1..10000000 |] |> Array.map int64
2: data
3: |> ParStream.ofArray
4: |> ParStream.filter (fun x -> x % 2L = 0L)
5: |> ParStream.map (fun x -> x + 1L)
6: |> ParStream.sum
```

Cloud Streams!

Example: a word count

Streams are lightweight and powerful

In sequential, parallel and distributed flavors.

The holy grail is in reach

We can write functional pipelines with the performance of imperative code.

Stream fusion: from lists to streams to nothing at all, Duncan Coutts, Roman Leshchinskiy, and Don Stewart, ICFP '07

Almost

Depends on the compiler's ability to inline.

Inlining continuations = stream fusion

Stream operations are non-recursive

In principal, can be always fused (in-lined).

Not always done by F# compiler.

Experiments with MLton

by @biboudis

https://github.com/biboudis/sml-streams

MLton appears to always be fusing.

Can we make the F# compiler smarter?

Questions?