Correctness and Performance of Apache Spark SQL

Spark + AI Summit, London

October 4, 2018

databricks

About us

BOGDAN GHIT

Databricks, Software Engineer

- SQL performance optimizations

IBM T.J. Watson, Research Intern

- Bid advisor for cloud spot markets

Delft University of Technology, PhD in Computer Science

- Resource management in datacenters
- Performance of Spark, Hadoop

NICOLAS POGGI

Databricks, Performance Engineer

- Spark benchmarking

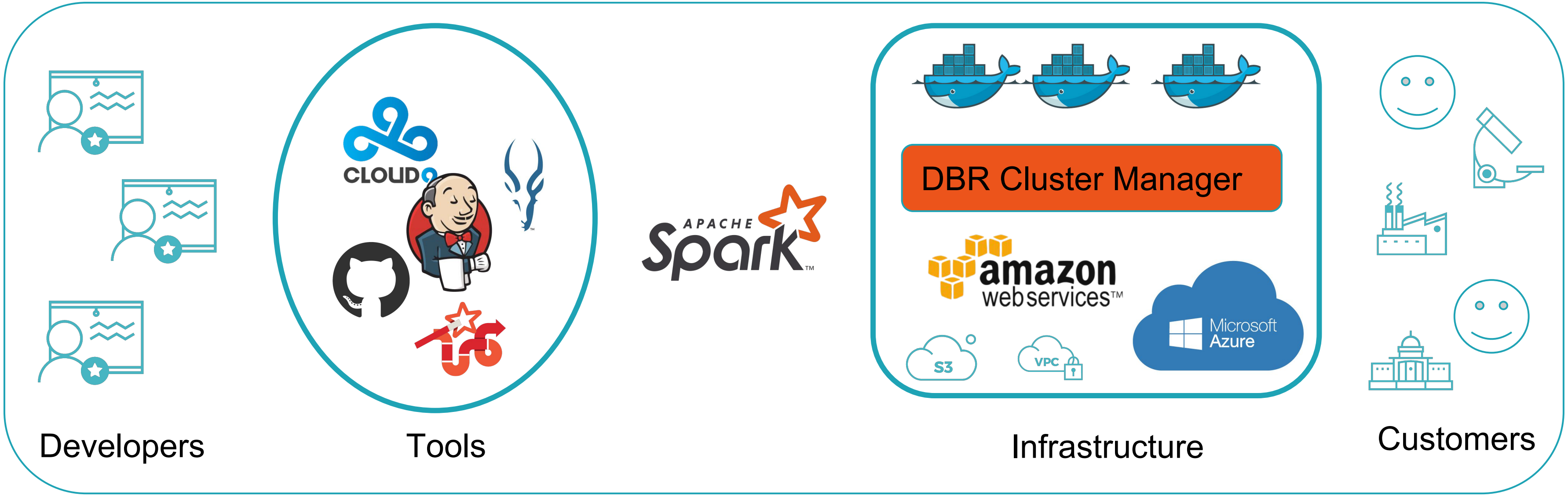
Barcelona Supercomputing - Microsoft Research Centre

- Lead researcher ALOJA project
- New architectures for Big Data

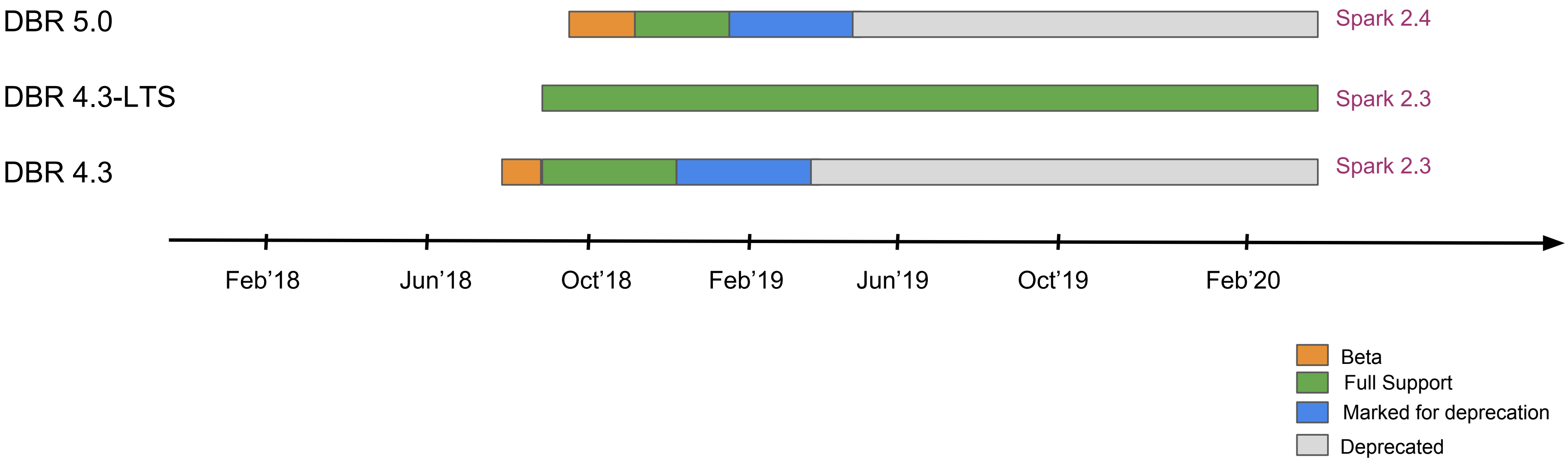
BarcelonaTech (UPC), PhD in Computer Architecture

- Autonomic resource manager for the cloud
- Web customer modeling

Databricks ecosystem

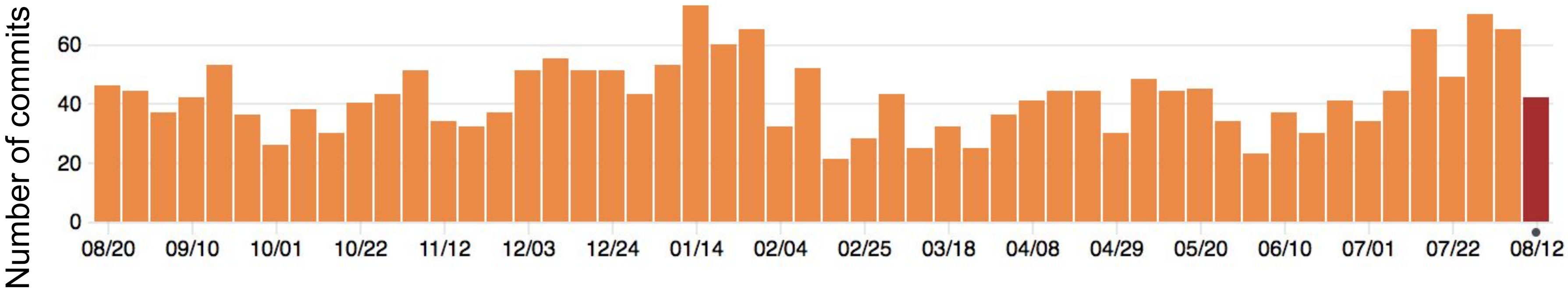


Databricks runtime (DBR) releases



Our goal is to make releases **automatic** and **frequent**

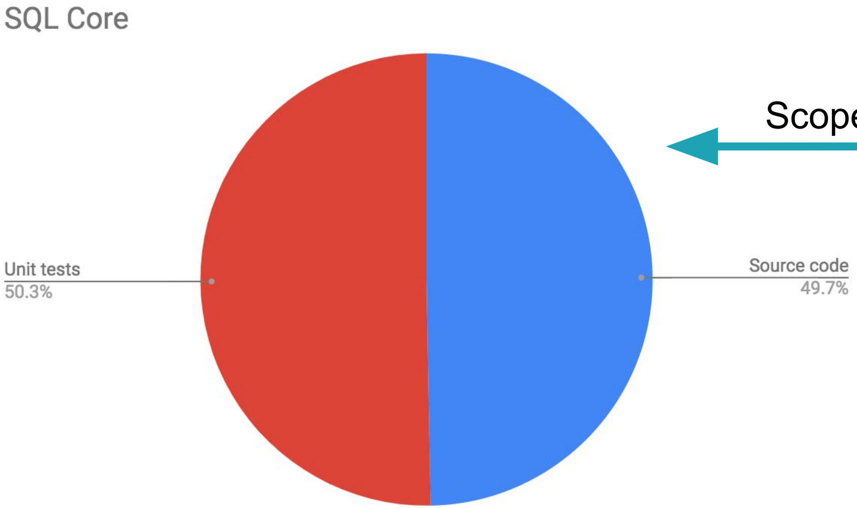
Apache Spark contributions



Hundreds of commits monthly to the Apache Spark project

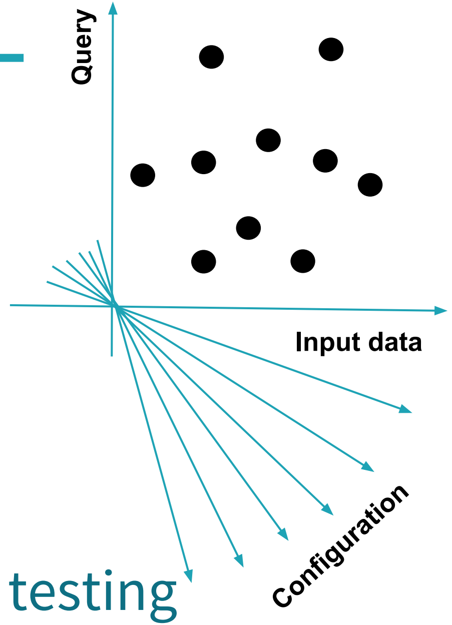
At this pace of development, **mistakes** are bound to happen

Where do these contributions go?



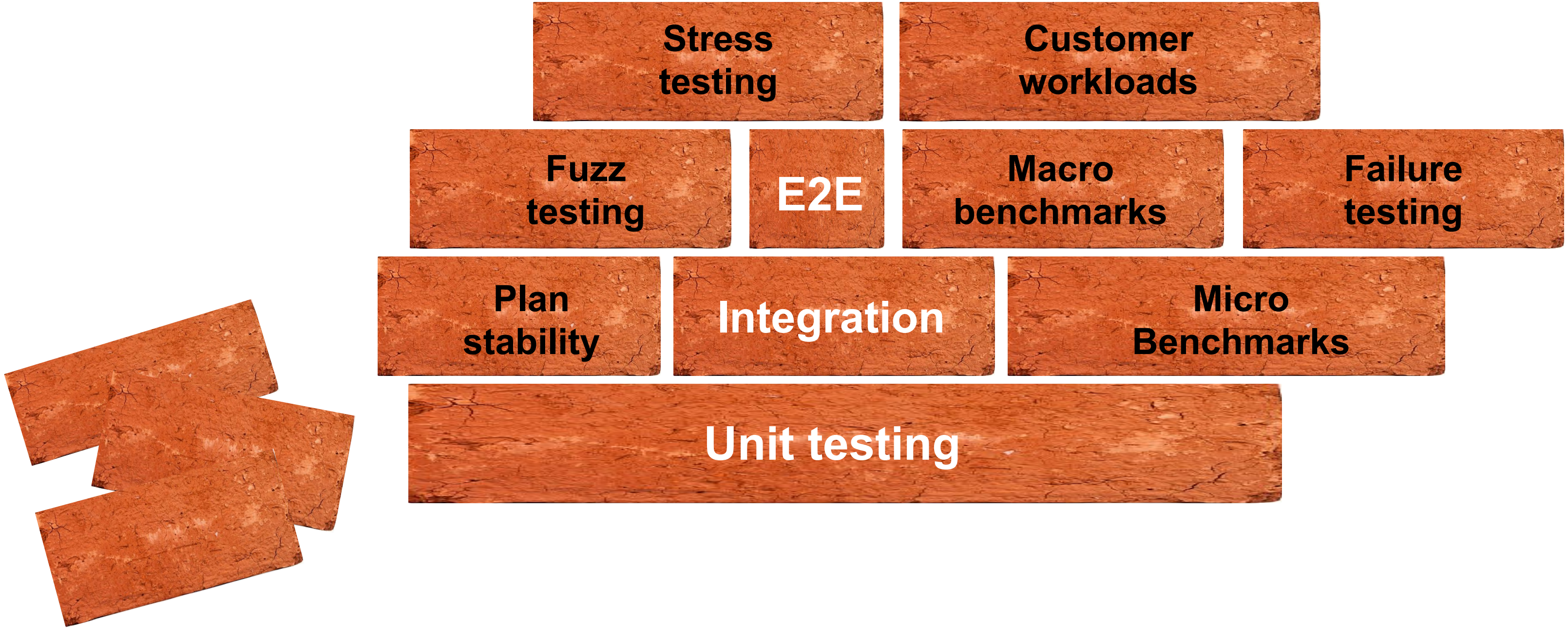
Scope of the testing

Over 200 built-in functions



Developers put a significant **engineering effort** in testing

Yet another brick in the wall



Stress testing

Customer workloads

Fuzz testing

E2E

Macro benchmarks

Failure testing

Plan stability

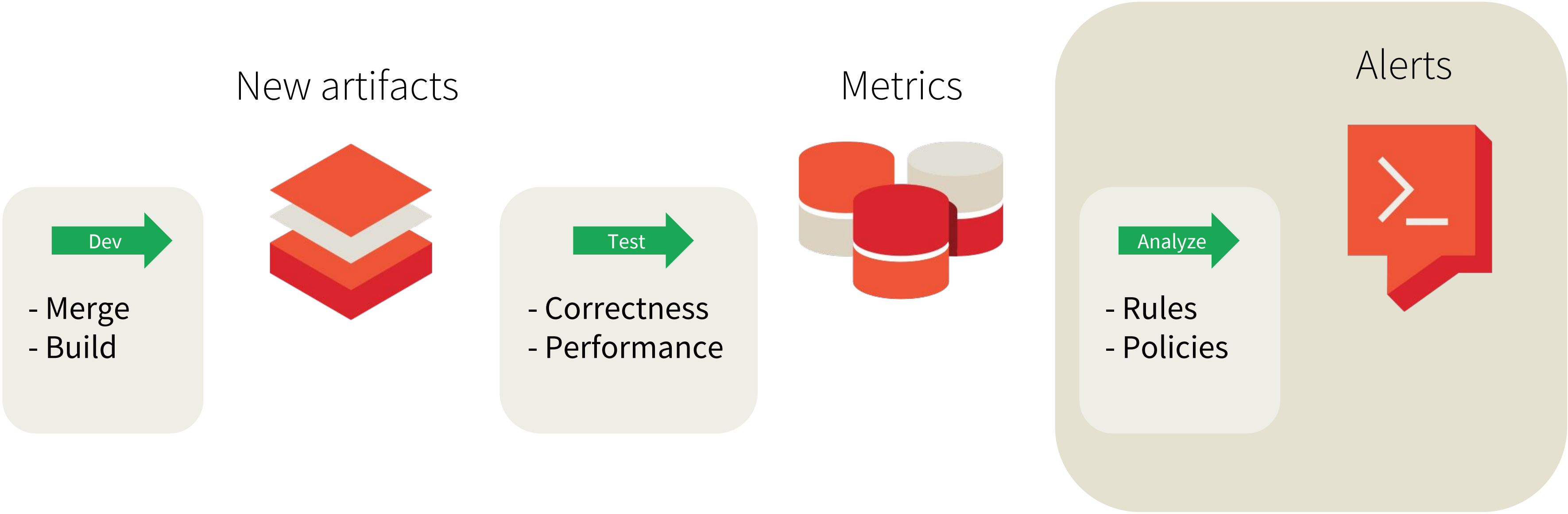
Integration

Micro Benchmarks

Unit testing

Unit testing ***is not enough*** to guarantee correctness and performance

Continuous Integration pipeline



Dev

- Merge
- Build

New artifacts

Test

- Correctness
- Performance

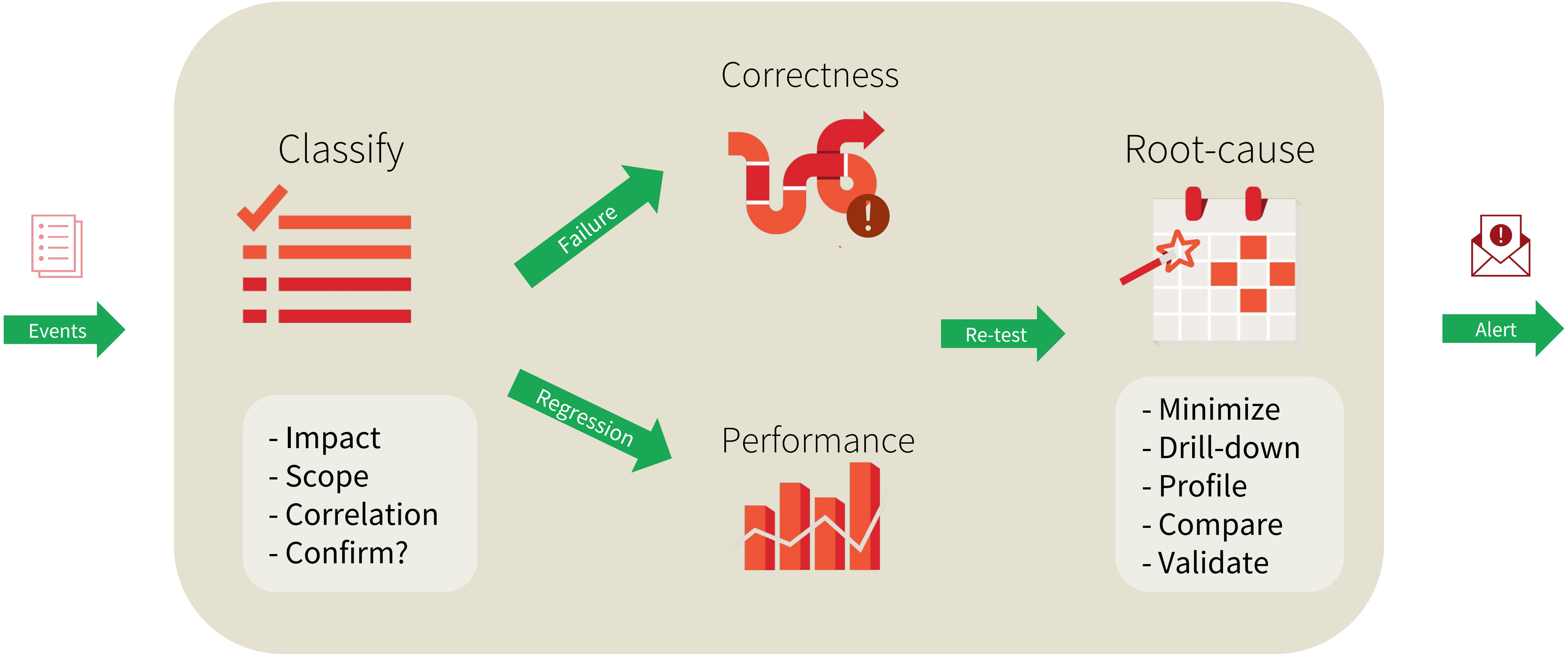
Metrics

Analyze

- Rules
- Policies

Alerts

Classification and alerting



Events

Classify

- Impact
- Scope
- Correlation
- Confirm?

Failure

Regression

Correctness

Performance

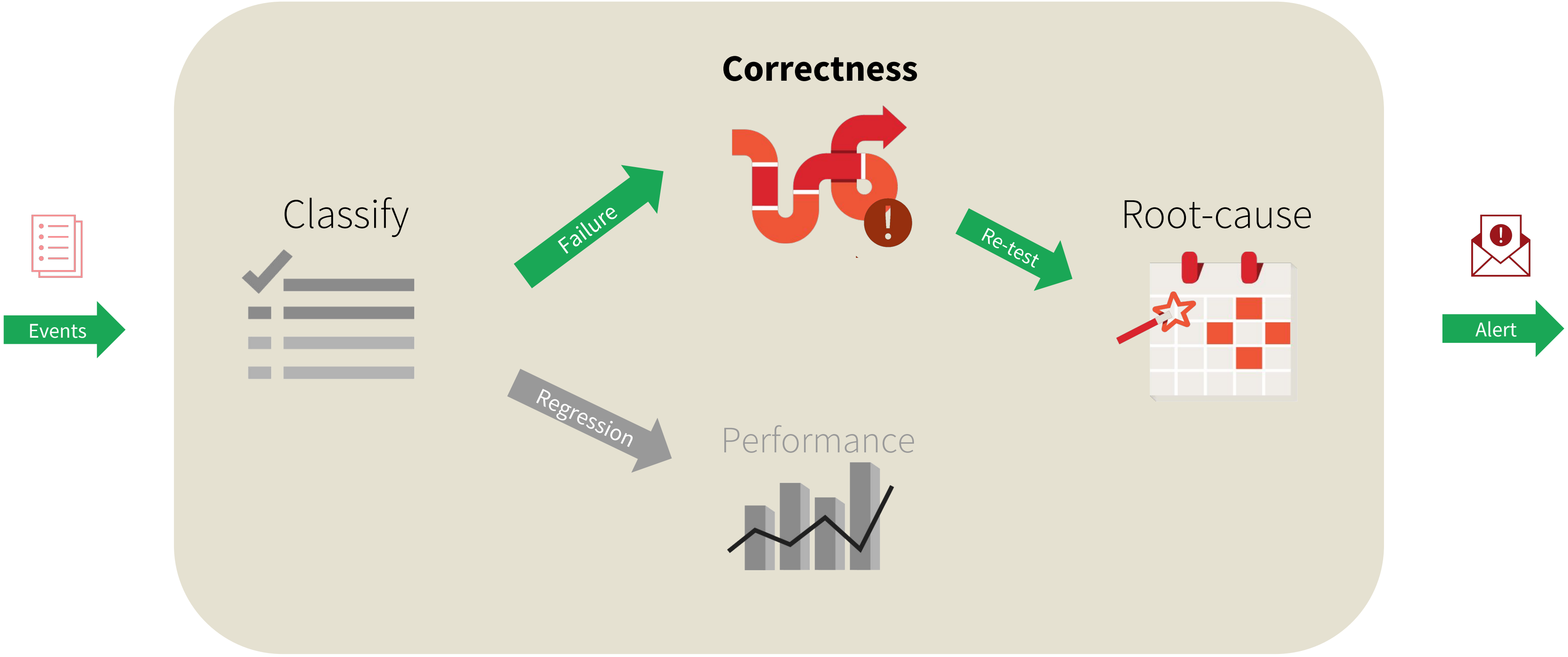
Re-test

Root-cause

- Minimize
- Drill-down
- Profile
- Compare
- Validate

Alert

Correctness



Events

Classify

Failure

Regression

Correctness

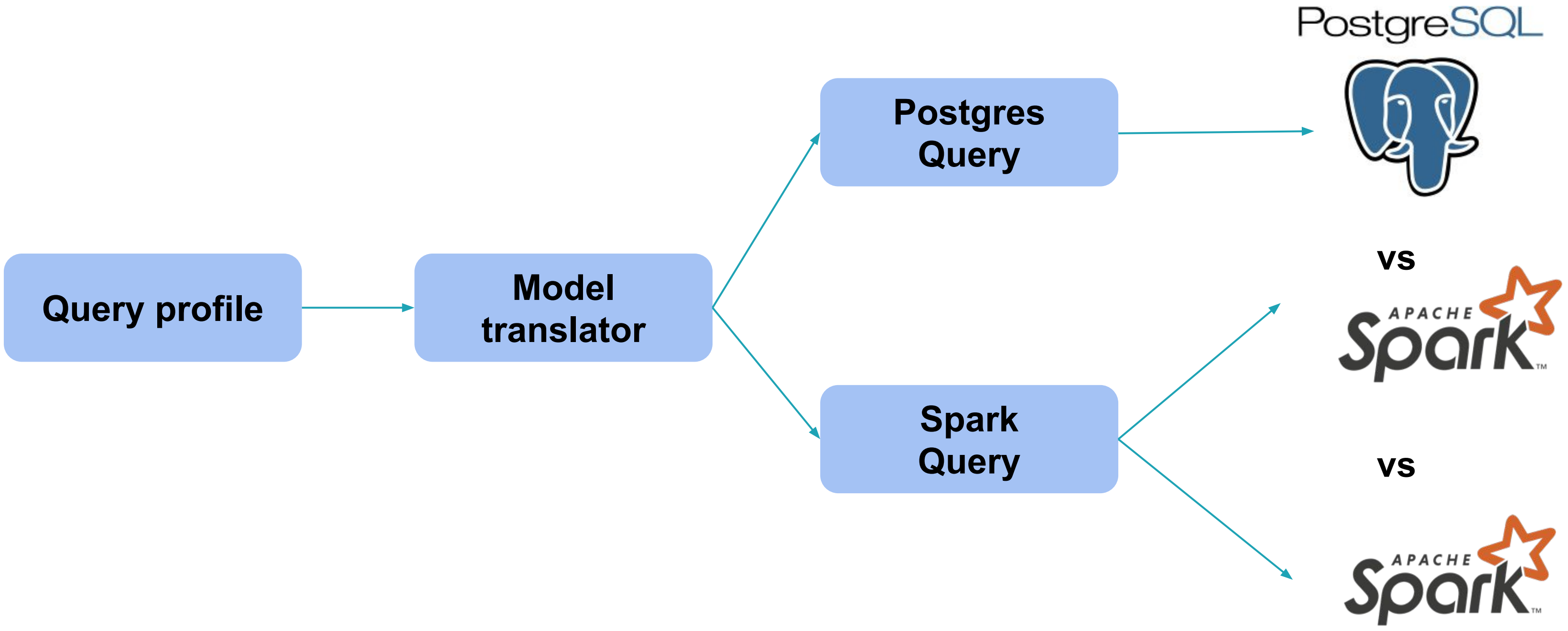
Performance

Re-test

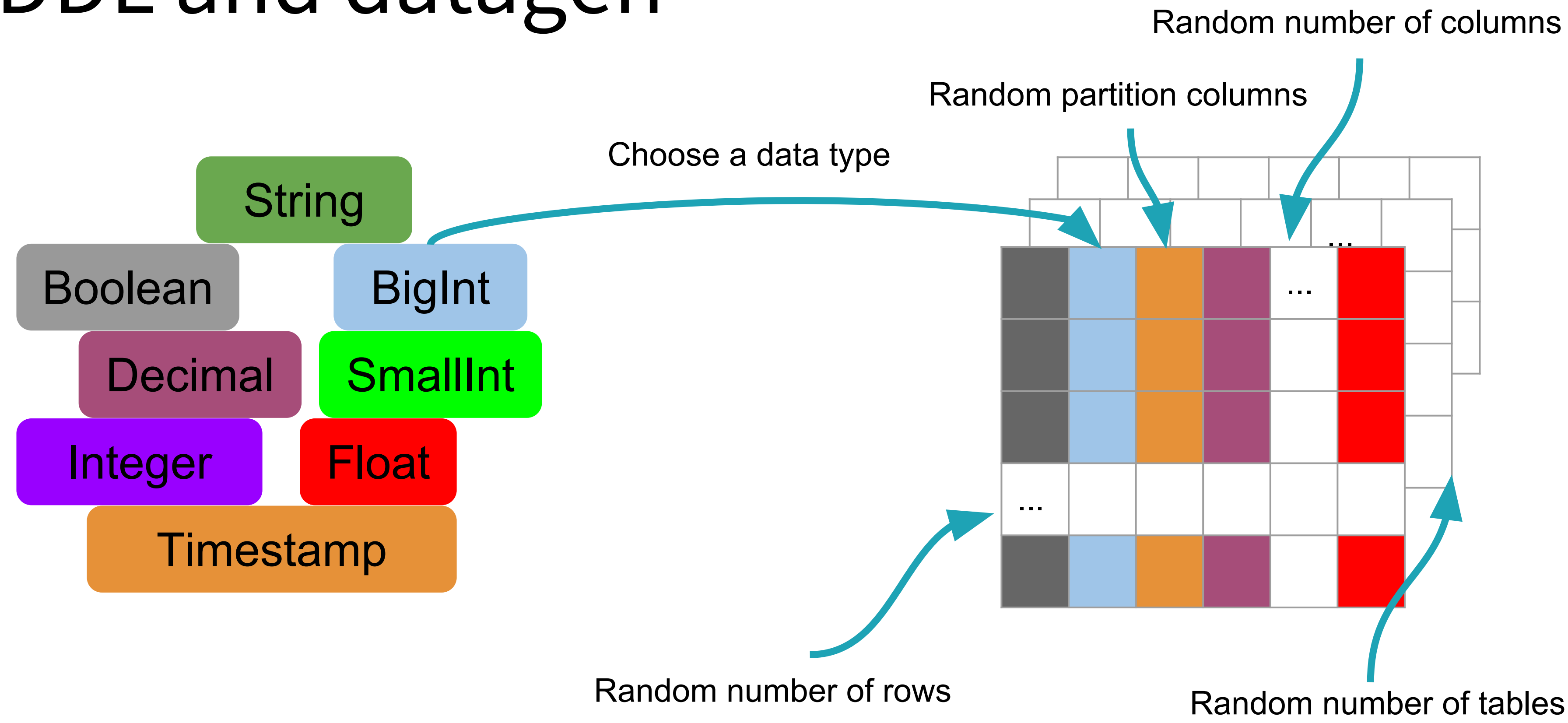
Root-cause

Alert

Random query generation



DDL and datagen



String

Boolean

BigInt

Decimal

SmallInt

Integer

Float

Timestamp

Choose a data type

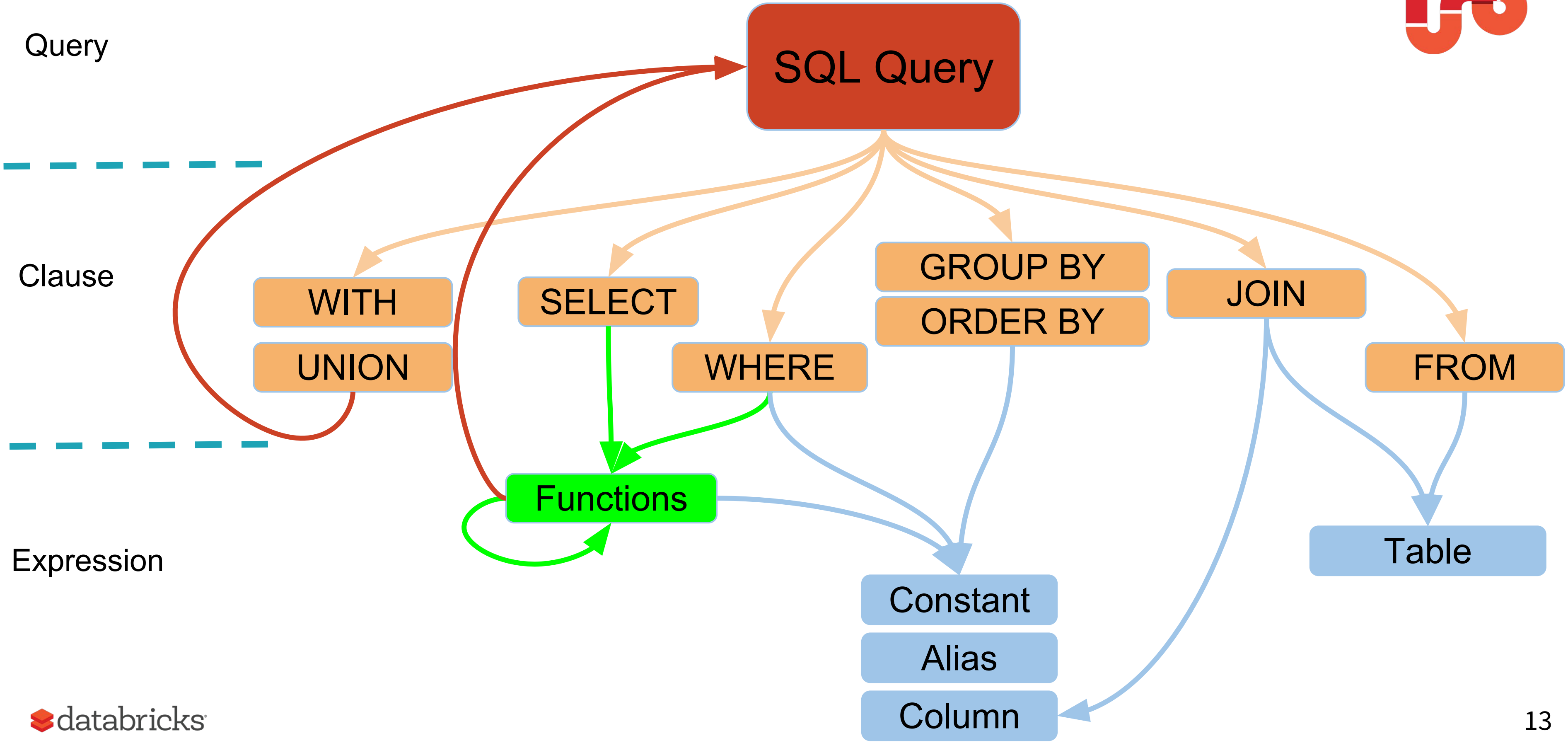
Random partition columns

Random number of columns

Random number of rows

Random number of tables

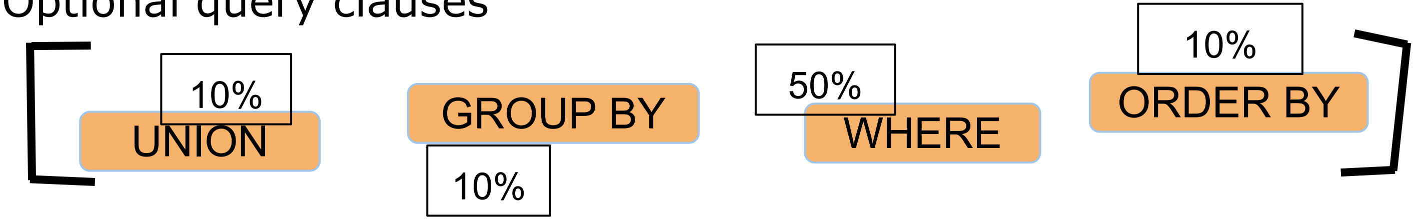
Recursive query model



Probabilistic query profile

Independent weights

- Optional query clauses



10%
UNION

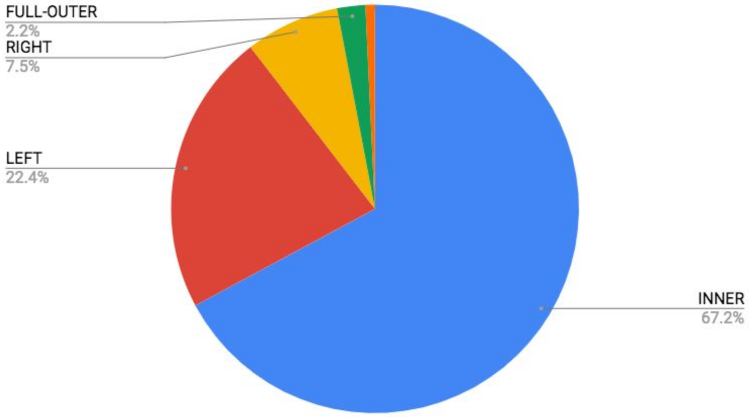
GROUP BY
10%

50%
WHERE

10%
ORDER BY

Inter-dependent weights

- Join types
- Select functions



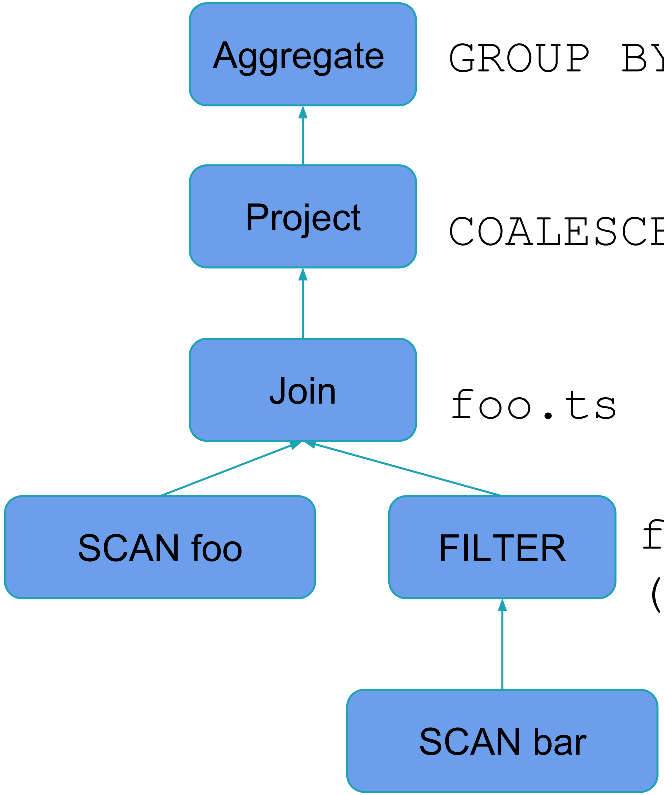
Coalesce flattening (1/4)

```
SELECT COALESCE(t2.smallint_col_3, t1.smallint_col_3, t2.smallint_col_3) AS int_col,
       IF(NULL, VARIANCE(COALESCE(t2.smallint_col_3, t1.smallint_col_3, t2.smallint_col_3)),
       COALESCE(t2.smallint_col_3, t1.smallint_col_3, t2.smallint_col_3)) AS int_col_1,
       STDDEV(t2.double_col_2) AS float_col,
       COALESCE(MIN((t1.smallint_col_3) - (COALESCE(t2.smallint_col_3, t1.smallint_col_3,
       t2.smallint_col_3))), COALESCE(t2.smallint_col_3, t1.smallint_col_3, t2.smallint_col_3),
       COALESCE(t2.smallint_col_3, t1.smallint_col_3, t2.smallint_col_3)) AS int_col_2
FROM table_4 t1
INNER JOIN table_4 t2 ON (t2.timestamp_col_7) = (t1.timestamp_col_7)
WHERE (t1.smallint_col_3) IN (CAST('0.04' AS DECIMAL(10,10)), t1.smallint_col_3)
GROUP BY COALESCE(t2.smallint_col_3, t1.smallint_col_3, t2.smallint_col_3)
```

Small dataset with 2 tables of 5x5 size
Within 10 randomly generated queries

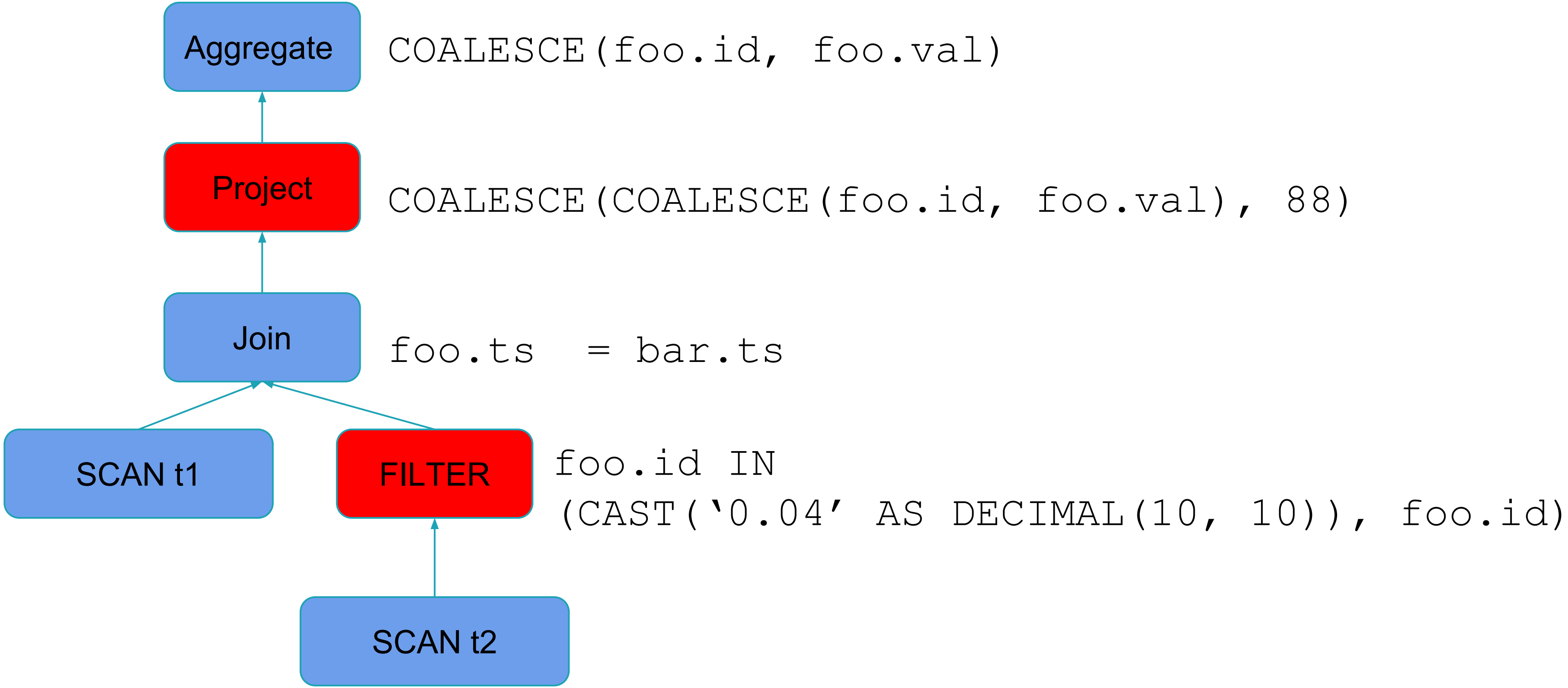
Error: Operation is in ERROR_STATE

Coalesce flattening (2/3)



```
GROUP BY COALESCE(foo.id, foo.val)

COALESCE(COALESCE(foo.id, foo.val), 88)

foo.ts  = bar.ts

foo.id IN
(CAST(‘0.04’ AS DECIMAL(10, 10)), foo.id)
```

Coalesce flattening (3/4)



Aggregate

```
COALESCE(foo.id, foo.val)
```

Project

```
COALESCE(COALESCE(foo.id, foo.val), 88)
```

Join

```
foo.ts  = bar.ts
```

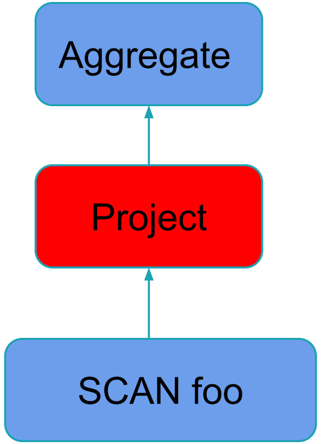
SCAN t1

FILTER

```
foo.id IN
(CAST(‘0.04’ AS DECIMAL(10, 10)), foo.id)
```

SCAN t2

Coalesce flattening (4/4)



Minimized query:

```
SELECT
   COALESCE(COALESCE(foo.id, foo.val), 88)
FROM foo
GROUP BY
   COALESCE(foo.id, foo.val)
```

Analyzing the error

- The optimizer flattens the nested coalesce calls
- The SELECT clause doesn’t contain the GROUP BY expression
- Possibly a problem with any GROUP BY expression that can be optimized

Lead function (1/3)

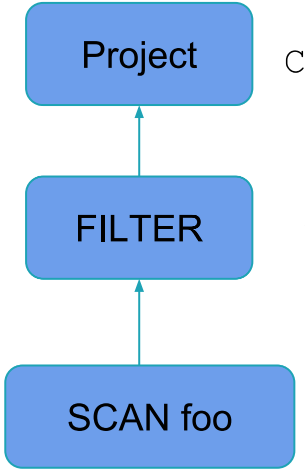
```
SELECT (t1.decimal0803_col_3) / (t1.decimal0803_col_3) AS decimal_col,
        CAST(696 AS STRING) AS char_col, t1.decimal0803_col_3,
       (COALESCE(CAST('0.02' AS DECIMAL(10,10)),
                 CAST('0.47' AS DECIMAL(10,10)),
                 CAST('-0.53' AS DECIMAL(10,10)))) +
       (LEAD(-65, 4) OVER (ORDER BY (t1.decimal0803_col_3) / (t1.decimal0803_col_3),
                 CAST(696 AS STRING))) AS decimal_col_1,
                 CAST(-349 AS STRING) AS char_col_1

FROM table_16 t1
WHERE (943) > (889)
```

Error: Column 4 in row 10 does not match:

[1.0, 696, -871.81, <<-64.98>>, -349] SPARK row

[1.0, 696, -871.81, <<None>>, -349] POSTGRESQL row

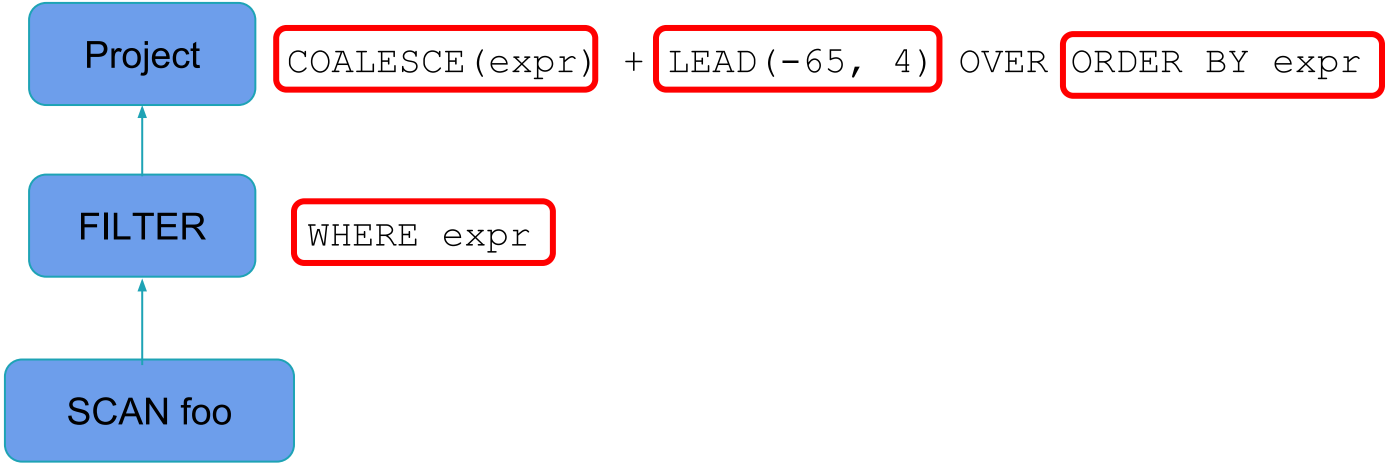
Lead function (2/3)



```
COALESCE(expr) + LEAD(-65, 4) OVER ORDER BY expr
```

```
WHERE expr
```

Lead function (3/3)



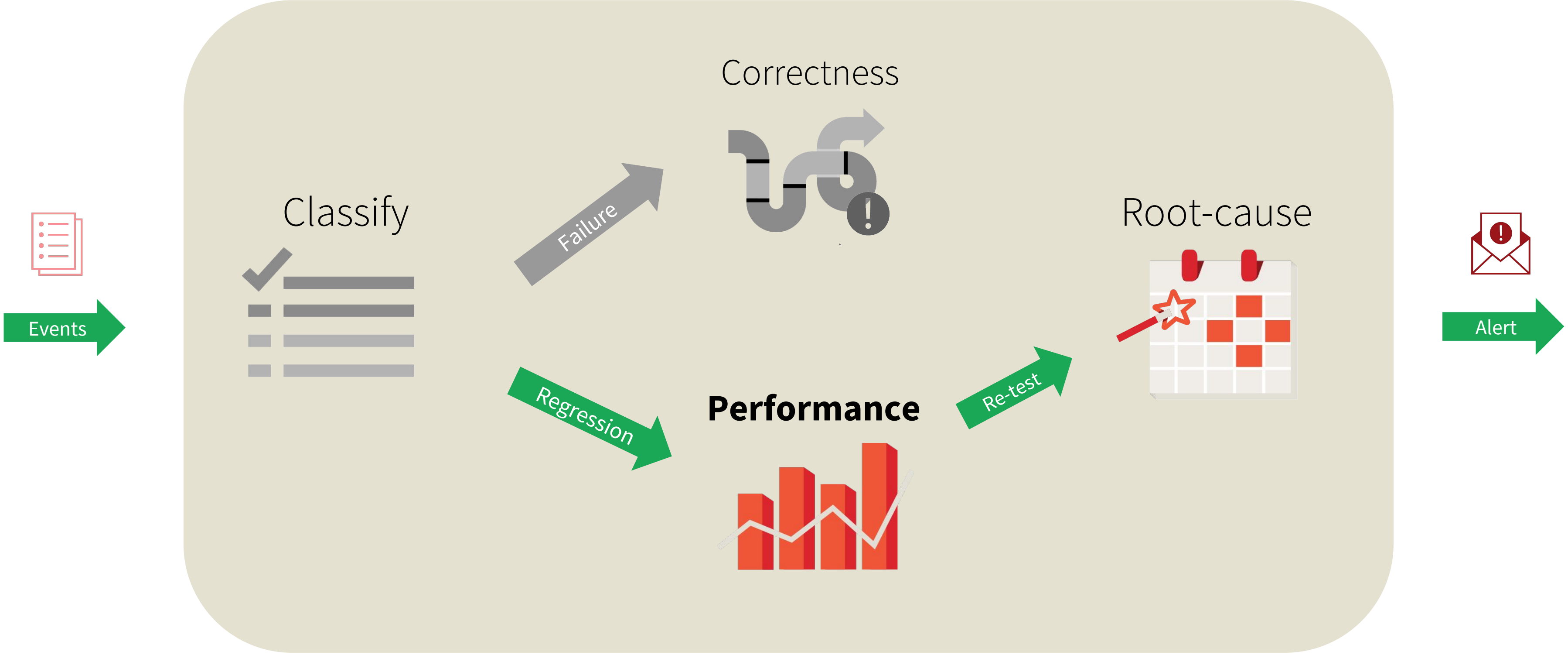
```
COALESCE(expr) + LEAD(-65, 4) OVER ORDER BY expr
```

```
WHERE expr
```

Analyzing the error

- Using constant input values breaks the behaviour of the LEAD function
- SC-16633: https://github.com/apache/spark/pull/14284

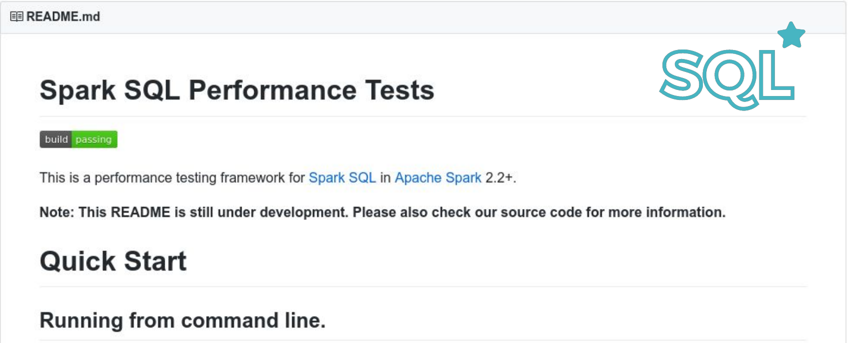
Performance



Benchmarking tools

- We use spark-sql-perf public library for TPC workloads
  - Provides datagen and import scripts
  - local, cluster, S3
  - Dashboards for analyzing results

- The Spark micro benchmarks
- And the async-profiler
  - to produce flamegraphs



README.md

Spark SQL Performance Tests

build passing

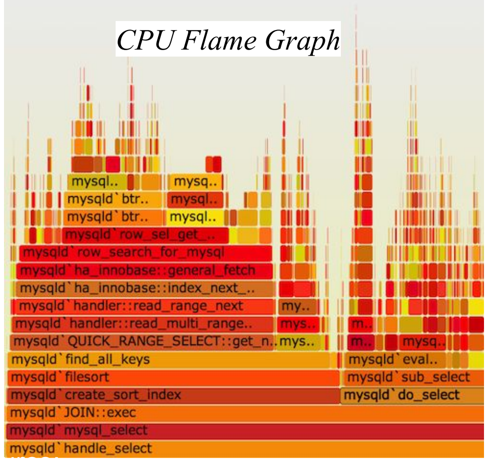
This is a performance testing framework for Spark SQL in Apache Spark 2.2+.

Note: This README is still under development. Please also check our source code for more information.

Quick Start

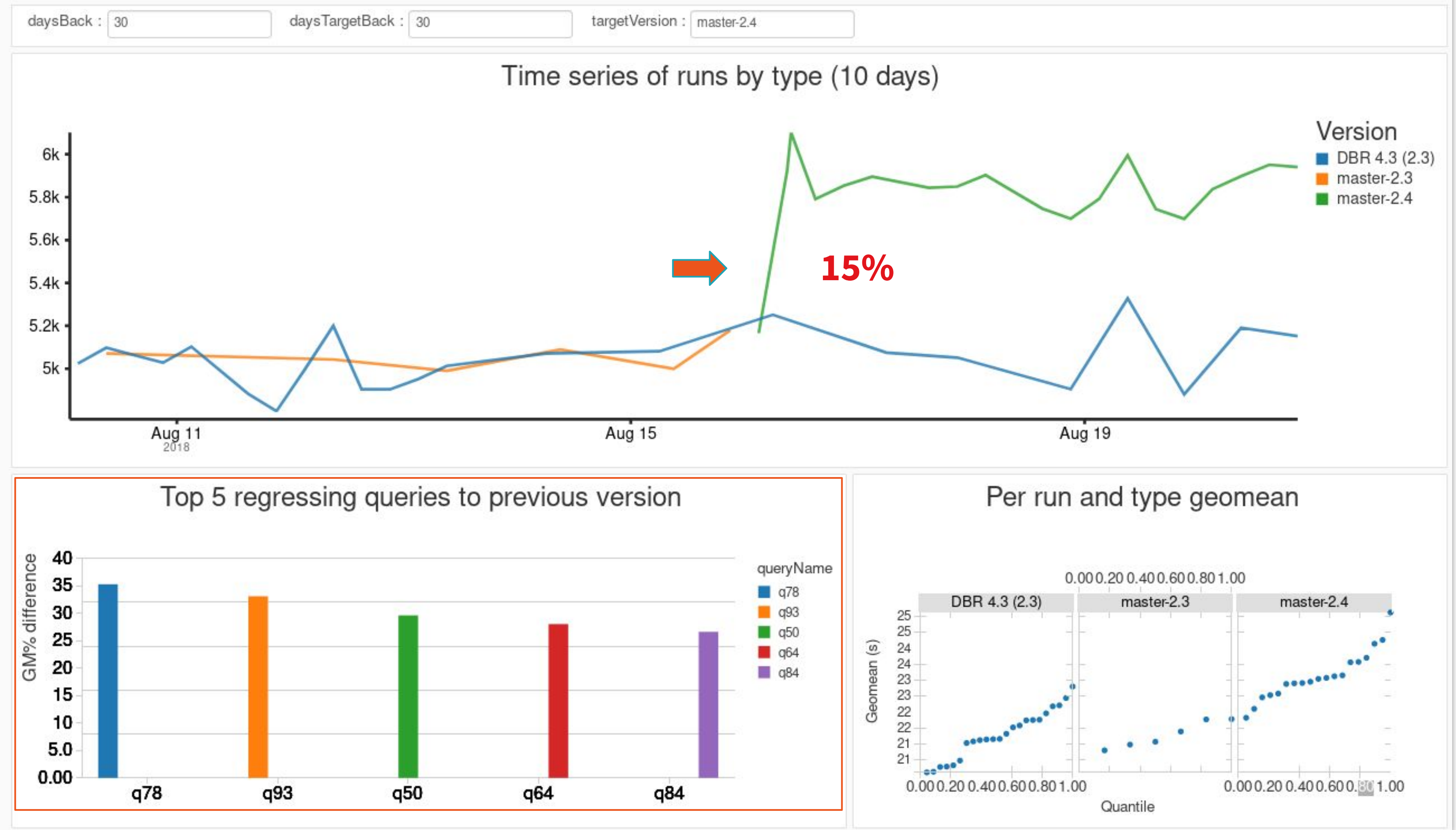
Running from command line.

https://github.com/databricks/spark-sql-perf



http://www.brendangregg.com/flamegraphs.html

DBR 5.0-beta (v2.4) performance ~~tracking~~-- journey



daysBack : 30

daysTargetBack : 30

targetVersion : master-2.4

Time series of runs by type (10 days)

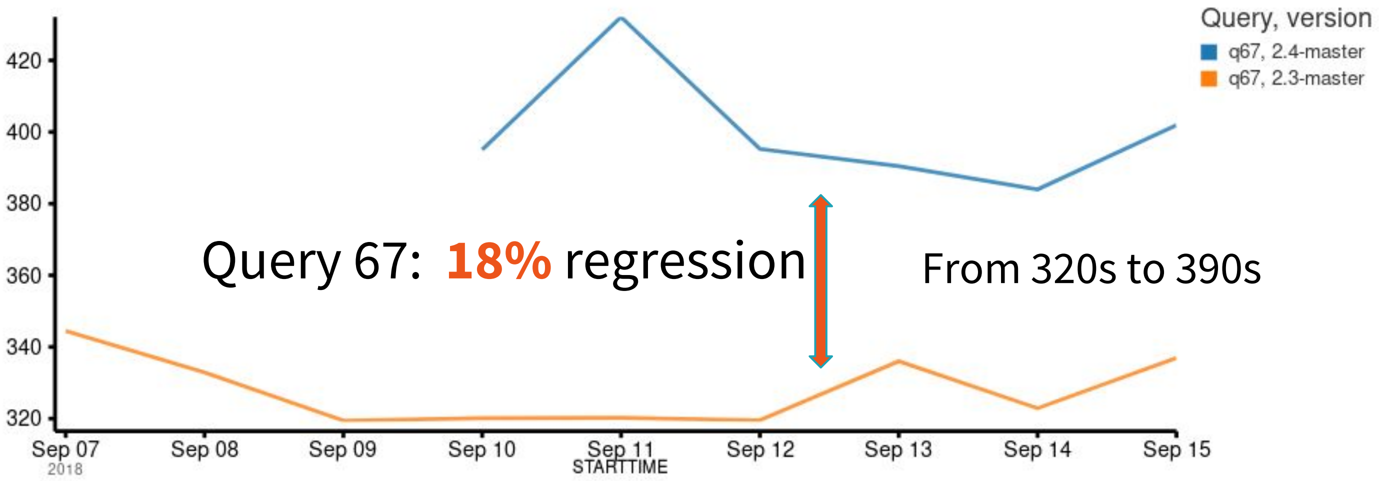
15%

Top 5 regressing queries to previous version

Per run and type geomean

Per query drill-down: 67

First, **scope** and **validate**

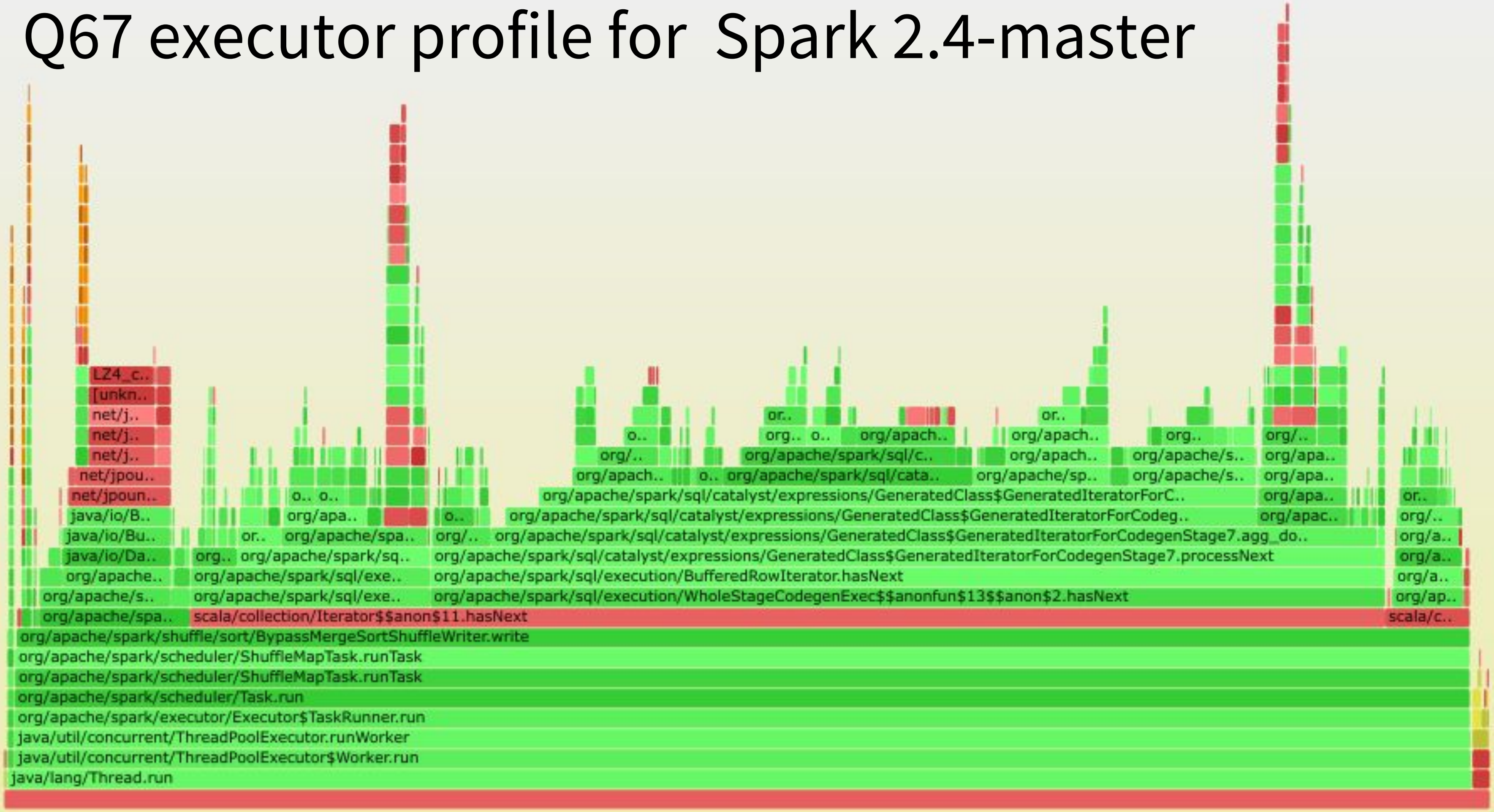


Query 67: **18%** regression

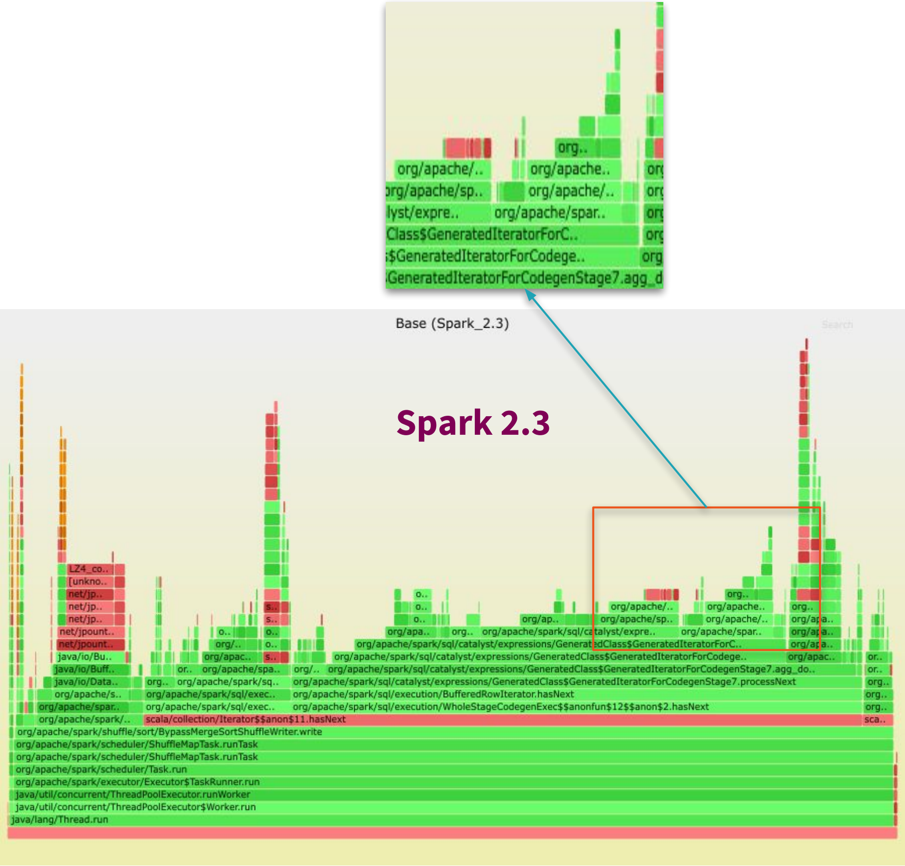
From 320s to 390s

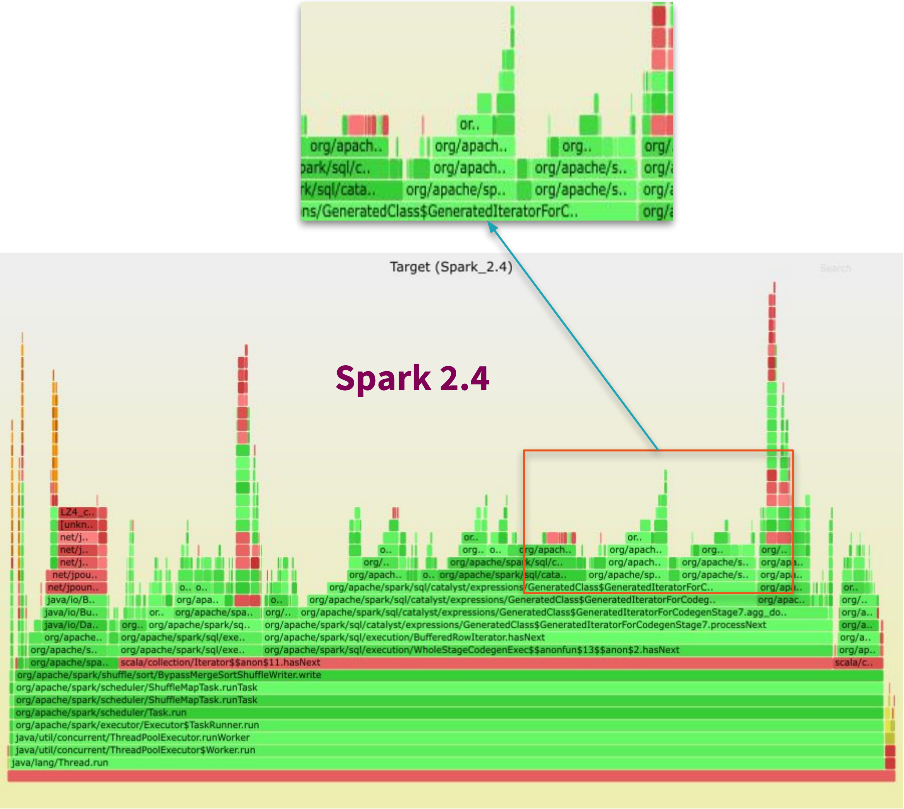
- in 2.4-master (dev) compared
- to 2.3 in DBR 4.3 (prod)

Q67 executor profile for Spark 2.4-master



Side-by-side 2.3 vs 2.4: find the differences



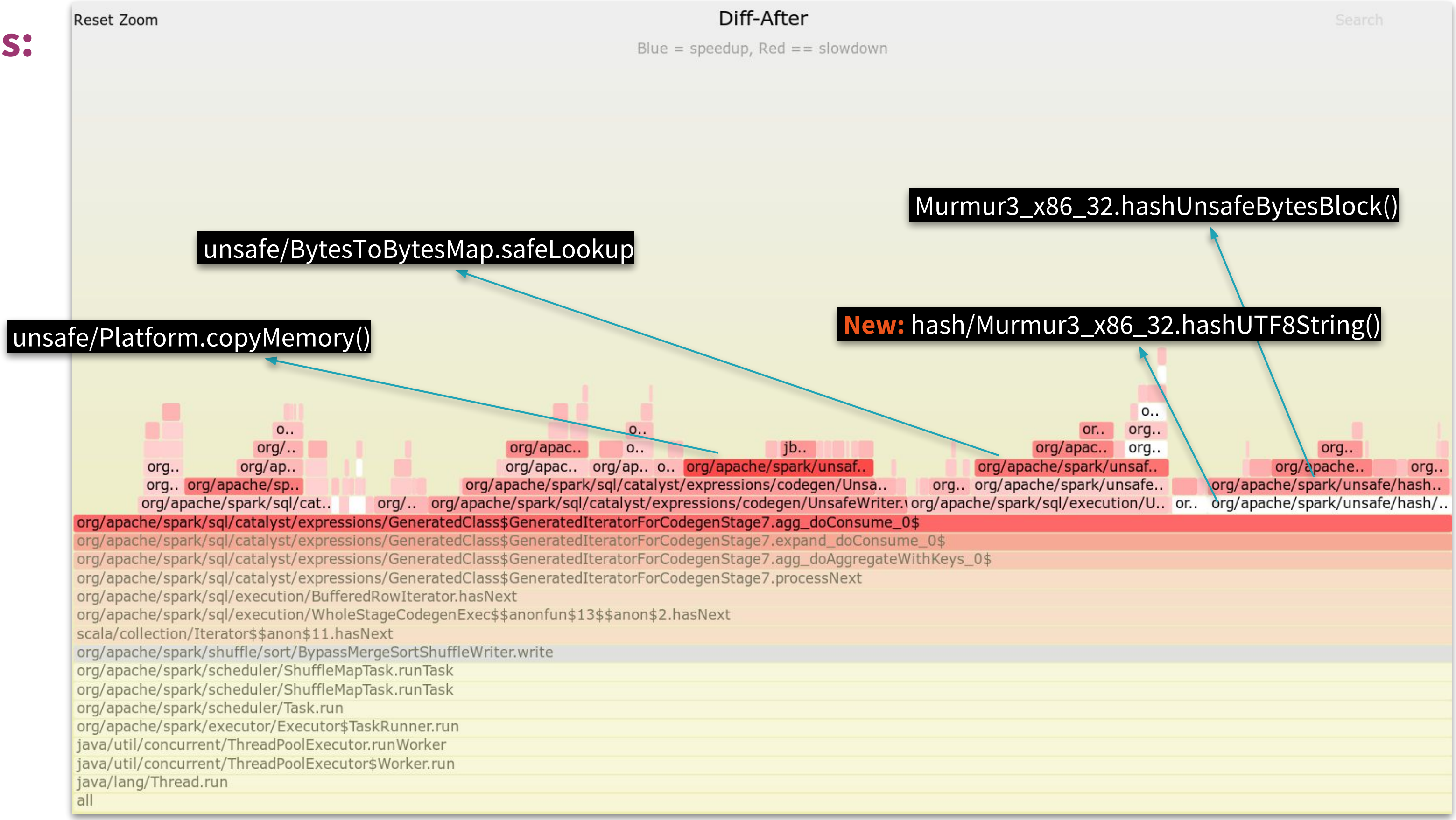


Framegraph diff zoom

Red slower **White** new

Look for hints:

- Mem mgmt
- Hashing
- unsafe



Reset Zoom
Diff-After
Blue = speedup, Red == slowdown
Search
o..
org/..
org..
org/ap..
org..
org/apache/sp..
org/apache/spark/sql/cat..
org/..
org/apac..
o..
org/apac..
org/ap..
o..
jb..
org/apache/spark/unsaf..
org/apache/spark/sql/catalyst/expressions/codegen/Unsa..
org/apache/spark/sql/catalyst/expressions/codegen/UnsafeWriter.
org..
org/apache/spark/sql/execution/U..
or..
org..
org/apac..
org..
org/apache/spark/unsaf..
org/apache/spark/unsafe..
o..
org..
org/apache..
org..
org/apache/spark/unsafe/hash..
or..
org/apache/spark/unsafe/hash/..
org/apache/spark/sql/catalyst/expressions/GeneratedClass$GeneratedIteratorForCodegenStage7.agg_doConsume_0$
org/apache/spark/sql/catalyst/expressions/GeneratedClass$GeneratedIteratorForCodegenStage7.expand_doConsume_0$
org/apache/spark/sql/catalyst/expressions/GeneratedClass$GeneratedIteratorForCodegenStage7.agg_doAggregateWithKeys_0$
org/apache/spark/sql/catalyst/expressions/GeneratedClass$GeneratedIteratorForCodegenStage7.processNext
org/apache/spark/sql/execution/BufferedRowIterator.hasNext
org/apache/spark/sql/execution/WholeStageCodegenExec$$anonfun$13$$anon$2.hasNext
scala/collection/Iterator$$anon$11.hasNext
org/apache/spark/shuffle/sort/BypassMergeSortShuffleWriter.write
org/apache/spark/scheduler/ShuffleMapTask.runTask
org/apache/spark/scheduler/ShuffleMapTask.runTask
org/apache/spark/scheduler/Task.run
org/apache/spark/executor/Executor$TaskRunner.run
java/util/concurrent/ThreadPoolExecutor.runWorker
java/util/concurrent/ThreadPoolExecutor$Worker.run
java/lang/Thread.run
all

Murmur3_x86_32.hashUnsafeBytesBlock()

unsafe/BytesToBytesMap.safeLookup

New: hash/Murmur3_x86_32.hashUTF8String()

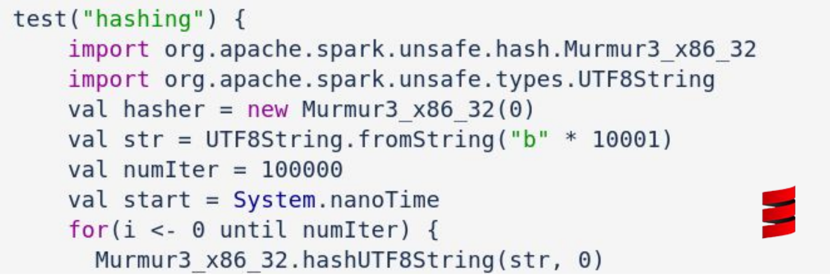
unsafe/Platform.copyMemory()

databricks

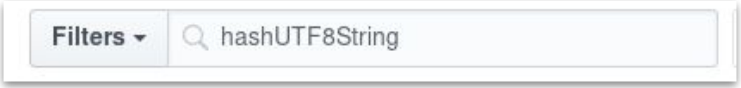
Root-causing

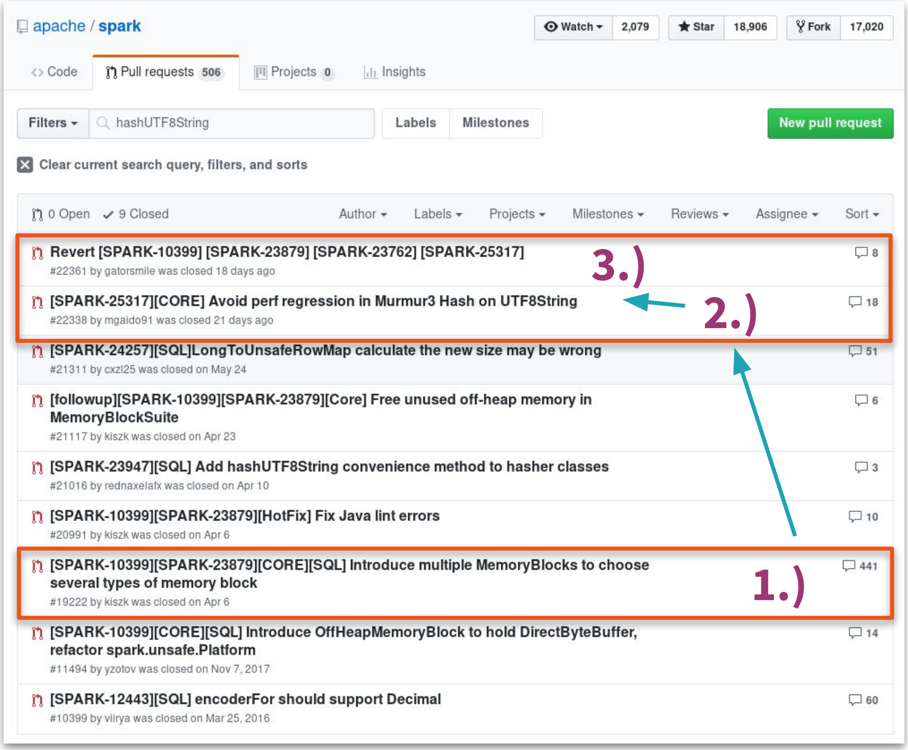
GIT BISECT

Microbenchmark for UTF8String



```
test("hashing") {
    import org.apache.spark.unsafe.hash.Murmur3_x86_32
    import org.apache.spark.unsafe.types.UTF8String
    val hasher = new Murmur3_x86_32(0)
    val str = UTF8String.fromString("b" * 10001)
    val numIter = 100000
    val start = System.nanoTime
    for(i <- 0 until numIter) {
      Murmur3_x86_32.hashUTF8String(str, 0)
```





Revert [SPARK-10399] [SPARK-23879] [SPARK-23762] [SPARK-25317] — 8
#22361 by gatorsmile was closed 18 days ago

[SPARK-25317][CORE] Avoid perf regression in Murmur3 Hash on UTF8String — 18
#22338 by mgaido91 was closed 21 days ago

[SPARK-24257][SQL]LongToUnsafeRowMap calculate the new size may be wrong — 51
#21311 by cxzl25 was closed on May 24

[followup][SPARK-10399][SPARK-23879][Core] Free unused off-heap memory in MemoryBlockSuite — 6
#21117 by kiszk was closed on Apr 23

[SPARK-23947][SQL] Add hashUTF8String convenience method to hasher classes — 3
#21016 by rednaxelafx was closed on Apr 10

[SPARK-10399][SPARK-23879][HotFix] Fix Java lint errors — 10
#20991 by kiszk was closed on Apr 6

[SPARK-10399][SPARK-23879][CORE][SQL] Introduce multiple MemoryBlocks to choose several types of memory block — 441
#19222 by kiszk was closed on Apr 6

[SPARK-10399][CORE][SQL] Introduce OffHeapMemoryBlock to hold DirectByteBuffer, refactor spark.unsafe.Platform — 14
#11494 by yzotov was closed on Nov 7, 2017

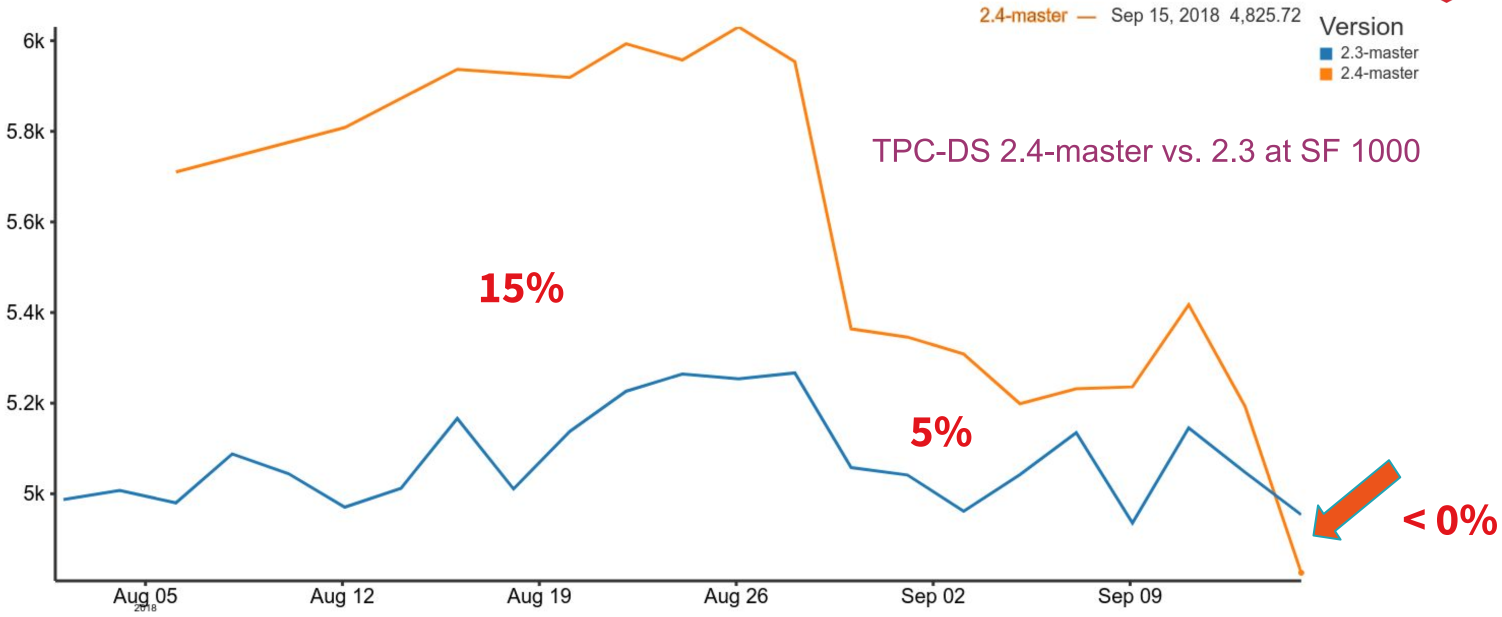
[SPARK-12443][SQL] encoderFor should support Decimal — 60
#10399 by viirya was closed on Mar 25, 2016

Results:

- Spark 2.3: hashUnsafeBytes() -> **40µs**
- Spark 2.4 *hashUnsafeBytesBlock()* -> **140µs**

- also slower *UTF8String.getBytes()*

It is a journey to get a release out



DBR and Spark testing and performance are a **continuous effort**

- **Over a month** effort to bring performance to improving

Conclusion

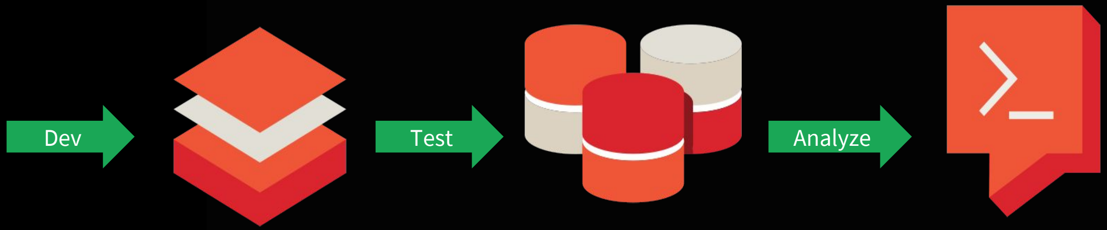
Spark in production is *not just the framework*

Unit and integration testing are not enough

We need Spark specific tools to automate the process

to ensure both correctness and performance

Thanks!



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October 2018

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