BEAM SUMMIT

2021

Relational Beam:
Automatically optimize your pipeline

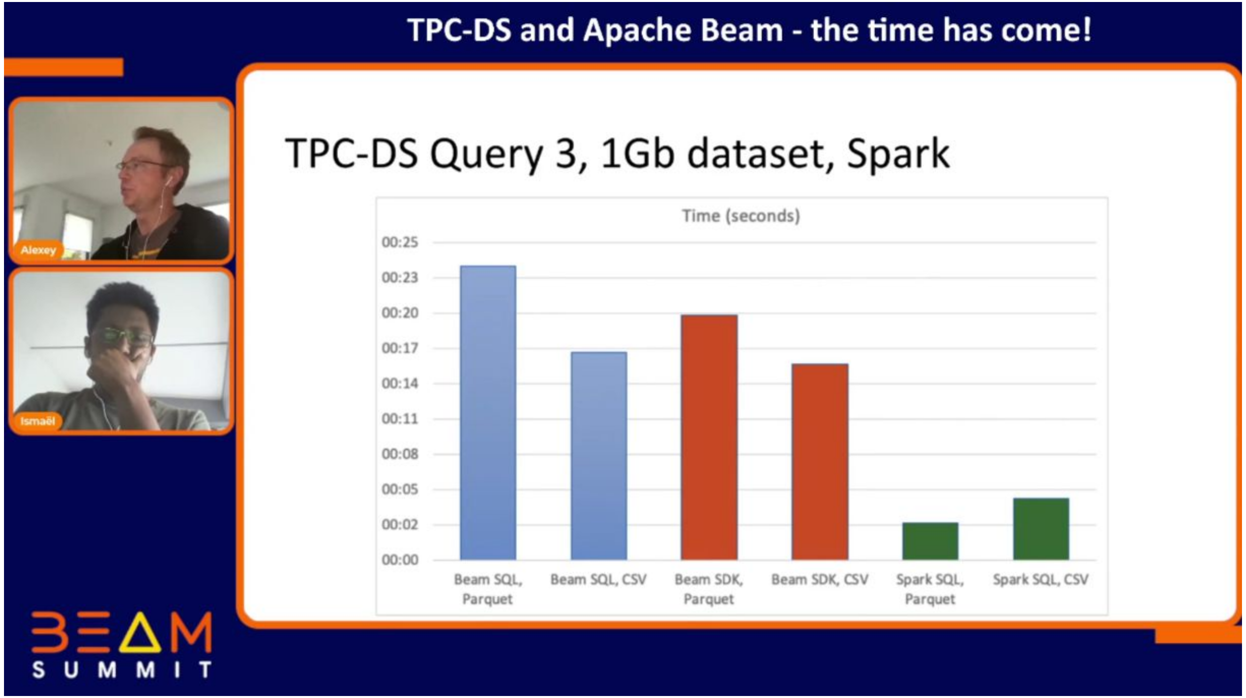
Andrew Pilloud
https://s.apache.org/beam-relational-2021

2021

Agenda

1. What is Relational?
2. How can we optimize?
3. Today: Beam SQL
4. Tomorrow: Relational Beam

Beam is falling behind!



TPC-DS and Apache Beam - the time has come!

TPC-DS Query 3, 1Gb dataset, Spark

Beam is falling behind!

- Beam model has been mostly stable since 2015.
    - Schemas came out of SQL in 2018.
- What is the next big thing?

Beam is falling behind!

- Beam model has been mostly stable since 2015.
    - Schemas came out of SQL in 2018.
- What is the next big thing?

Relational in Beam Core

- The underlying runners have many of these features... since 2015!

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What is Relational?

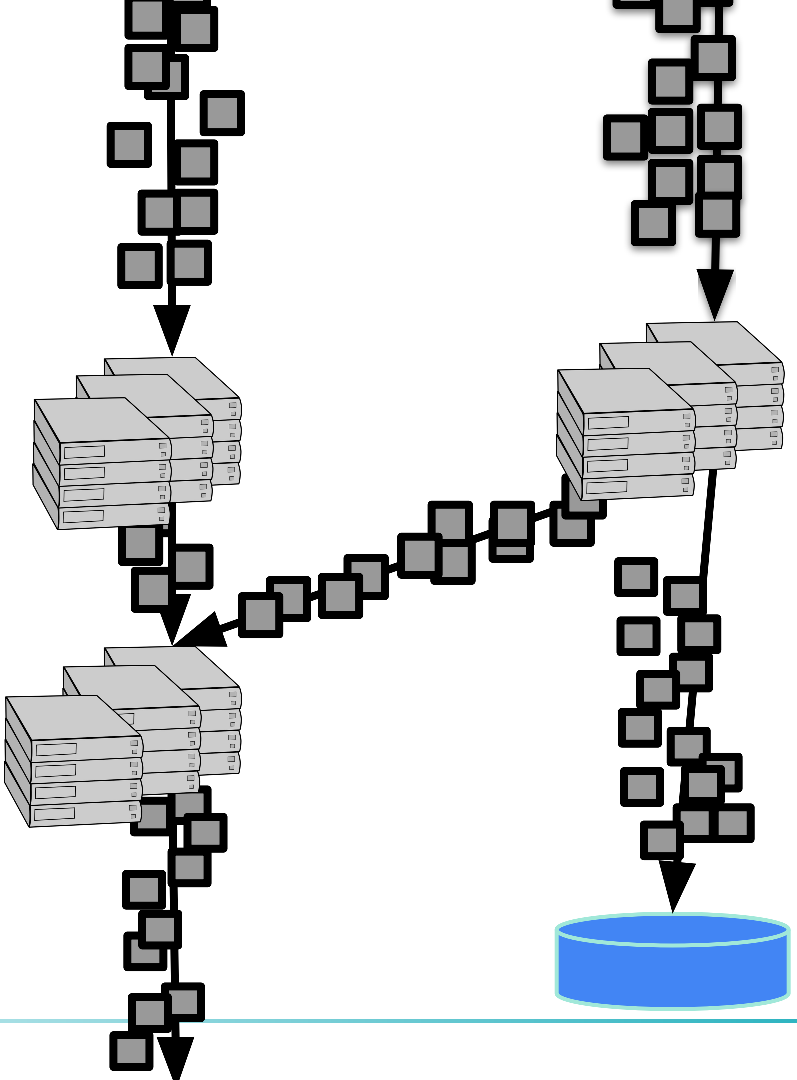
What is Relational?

- Relational Processing involves focusing on similarities among pieces of information
- Relational Optimization involves taking advantage of these similarities to reduce work
- Think traditional relational databases: Postgres, Oracle

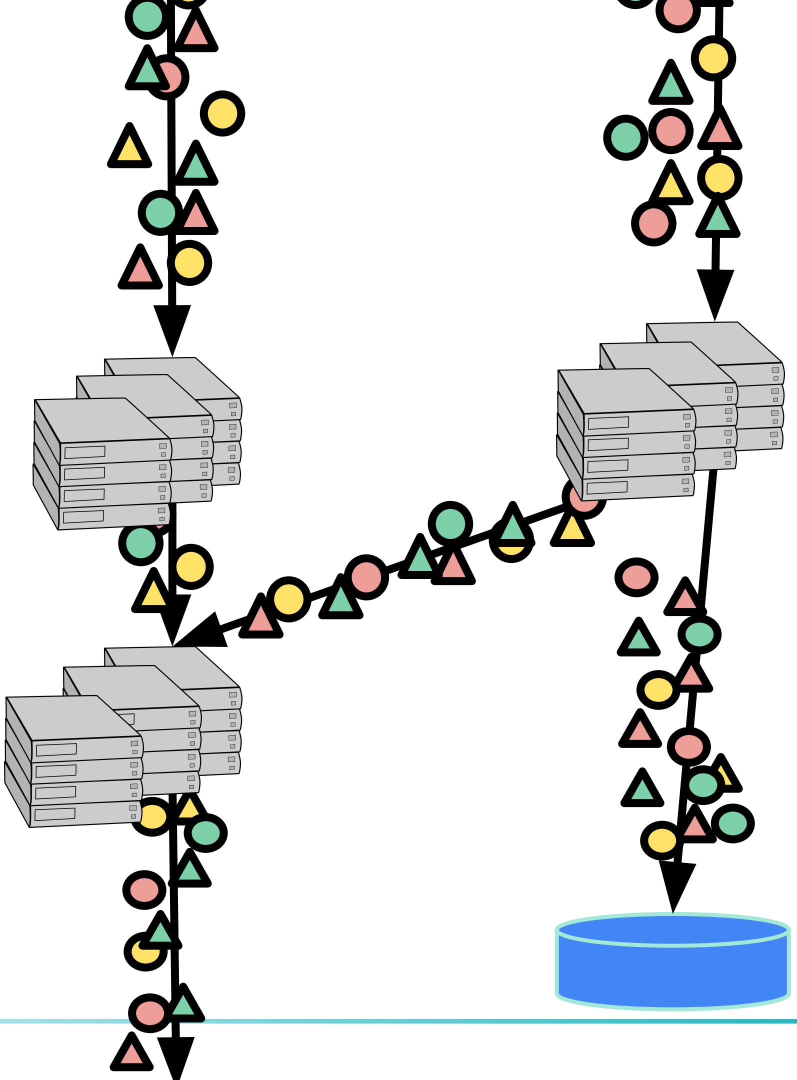
(Traditional) Beam is not Relational

- Beam processes opaque records
  - Internally represented as byte[] or Object
  - Object form provided for user convenience
- Sometimes it processes <byte[] key, byte[] value>
  - Structure still opaque, only aware of equality
- Beam focuses on item-specific information

Beam is not Relational



Your data is Relational



Beam can be Relational

- We need metadata about the structure of your data
    - What is the structure of that byte[]?
    - How much data can we expect?
- We need metadata about the computations performed
    - What columns do you access?
    - What transforms are performed?

Beam Schemas enable Relational

```
Schema.builder()
    .addInt64Field("foo").addInt32Field("baz").build();
```

- Beam Schemas expose the structure of your data
  - This can often be inferred!
- Provides an abstraction on of data access (Row)
- Doesn’t provide metadata about computations

Beam SchemaIO enables Relational

```
SchemaIO from(String location, Row configuration, @Nullable Schema dataSchema);
```

```
public interface SchemaIO {
  PTransform<PBegin, PCollection<Row>> buildReader();
}
```

```
public interface PushdownProjector {
    PTransform<? extends PInput, PCollection<Row>> withProjectionPushdown(FieldAccessDescriptor);
}
```

- Beam SchemaIO exposes the structure of your IOs
- Doesn’t provide metadata... yet.

Beam SQL is Relational

```
SELECT SUM(foo) AS baz, end_of_window
FROM my_topic WHERE something_is_true(bizzle)
GROUP BY TUMBLING(timestamp, 1 HOUR)
HAVING baz > my_magic_number LIMIT 3;
```

- Relational model: Projection, Filter, Aggregation
- ... and advanced bits like nested ROW, ARRAY, UNNEST
- Optimizations only within SqlTransform

Java Schema Transforms are Relational Too!

```
my_topic
   .apply(Select.fieldNames("foo", "end_of_window"))
```

- Not all operators generate metadata for optimization
- No optimizations yet

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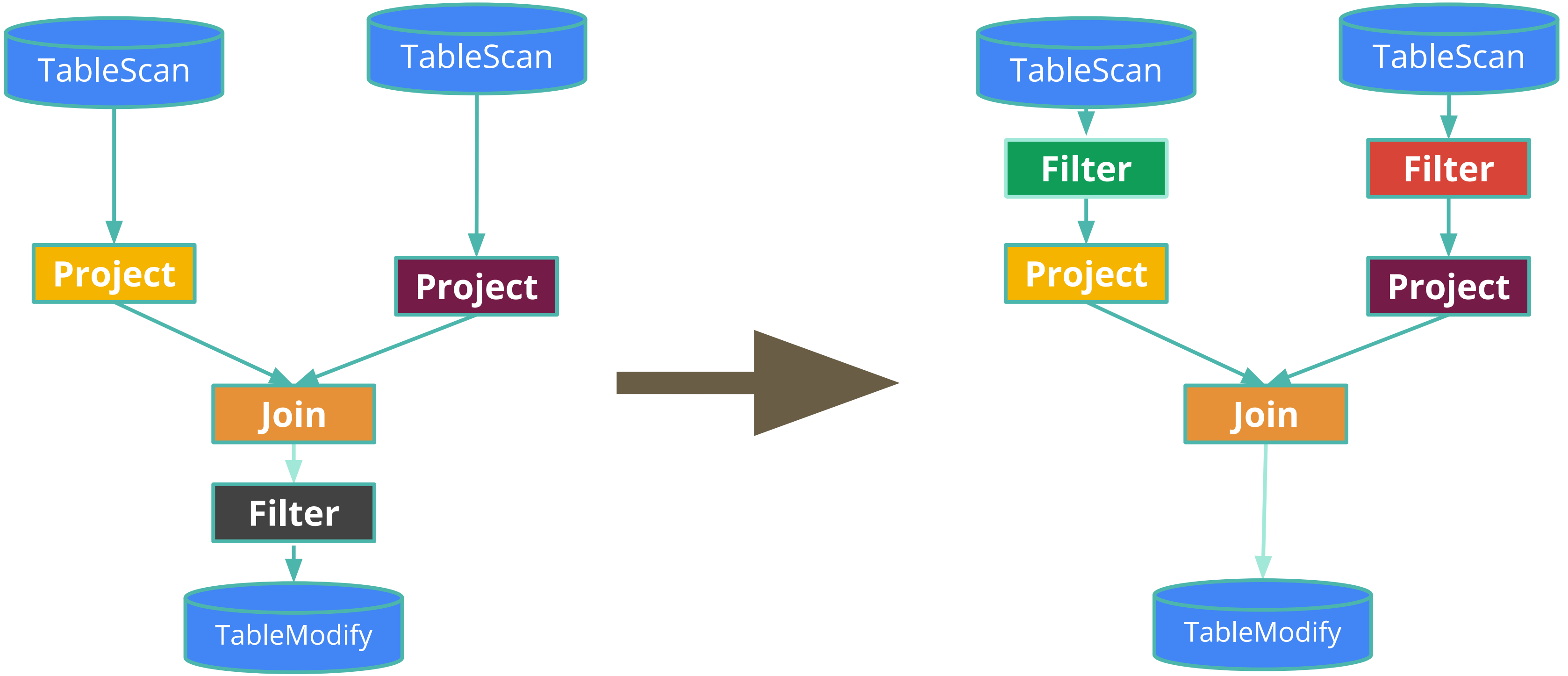
How can we optimize?

Global Relational Optimizer

- Allow a pipeline to be transformed after expand
    - Eventually optimizing portability protos
- No core model for this yet!
    - Where does the optimizer run?
- Beam Java design mailed Tuesday!

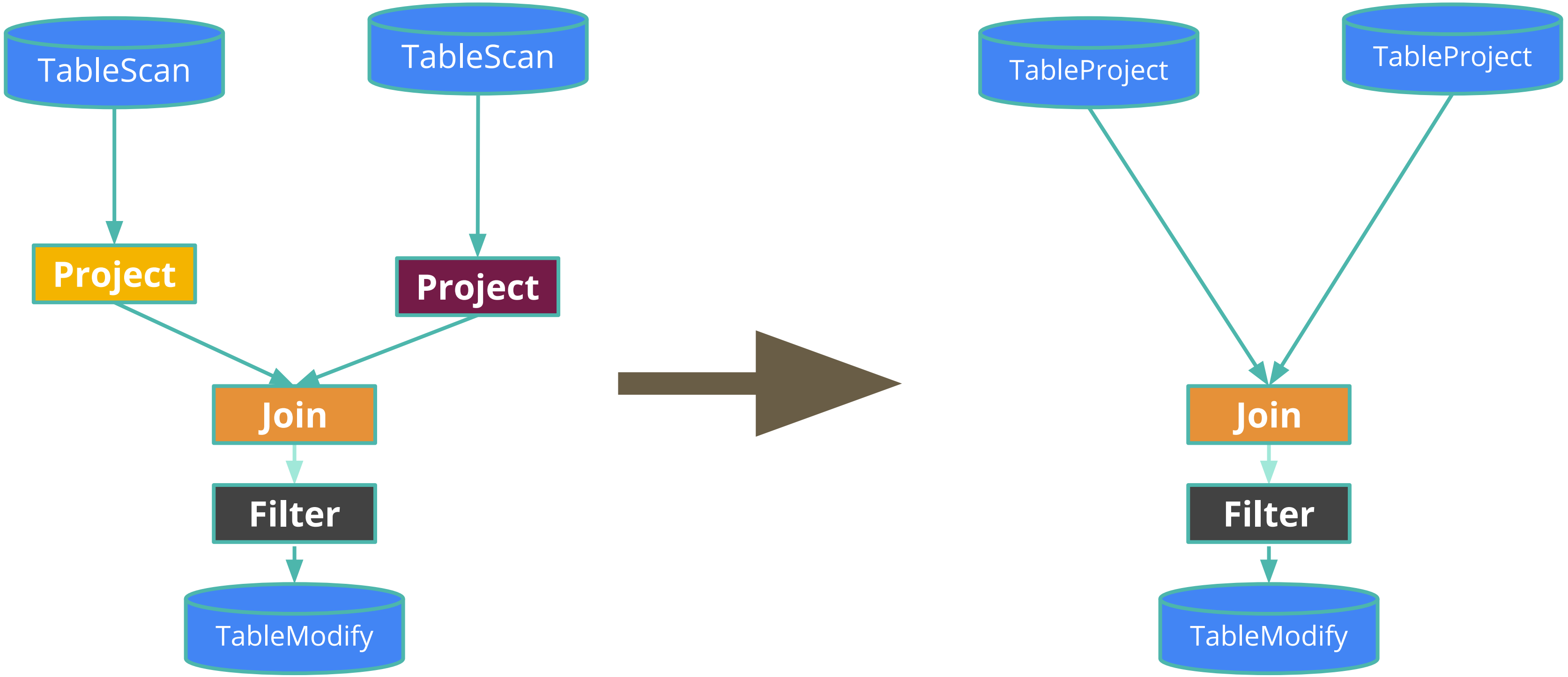
Global Relational Optimizer



Column Pruning

- Stop passing unused fields as soon as possible
  - Ideally at the source IO but also before shuffles
- Beam Java has a model for this: FieldAccessDescriptor
  - PTransform provides a list of accessed columns
- Beam Java has a new implementation on Schema IO!

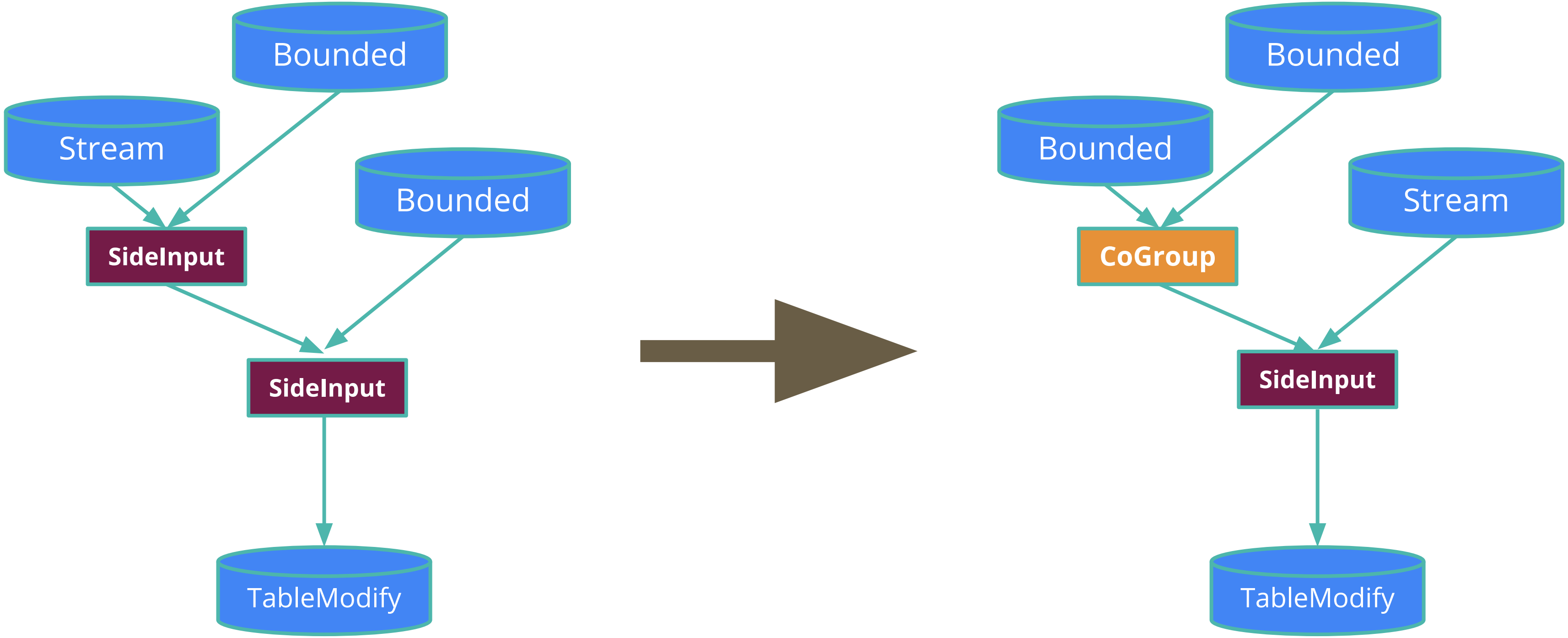
Column Pruning



Join Algorithm Selection and Reordering

- Automatically choose optimal joins
  - Also reorder joins
- No core model for this yet!
  - Need an interface to query IOs for statistics
- Beam SQL has an implementation

Join Algorithm Selection and Reordering



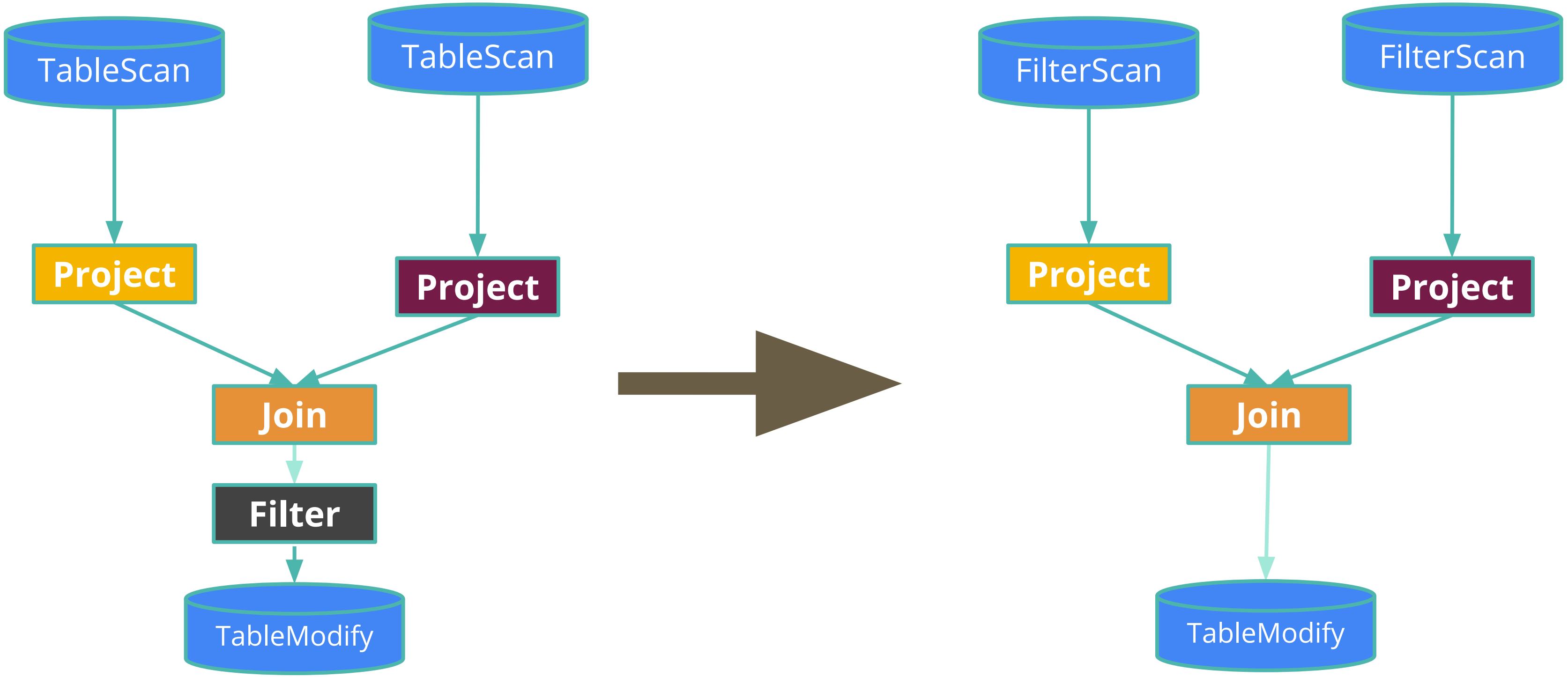
Row Expression

- Calcite calls this a RexNode
  - `SELECT <row>` and `WHERE <bool>`from SQL
- Three Required Operators
  - Field Access (FieldAccessDescriptor)
  - Constant (Schema Value)
  - Call (Arbitrary function call, the difficult one)

Filter Pushdown

- Apply filters as early as possible
  - Ideally at the source IO but also before shuffles
- No core model for this yet!
  - Need a “row expression” language
- Beam SQL has an implementation

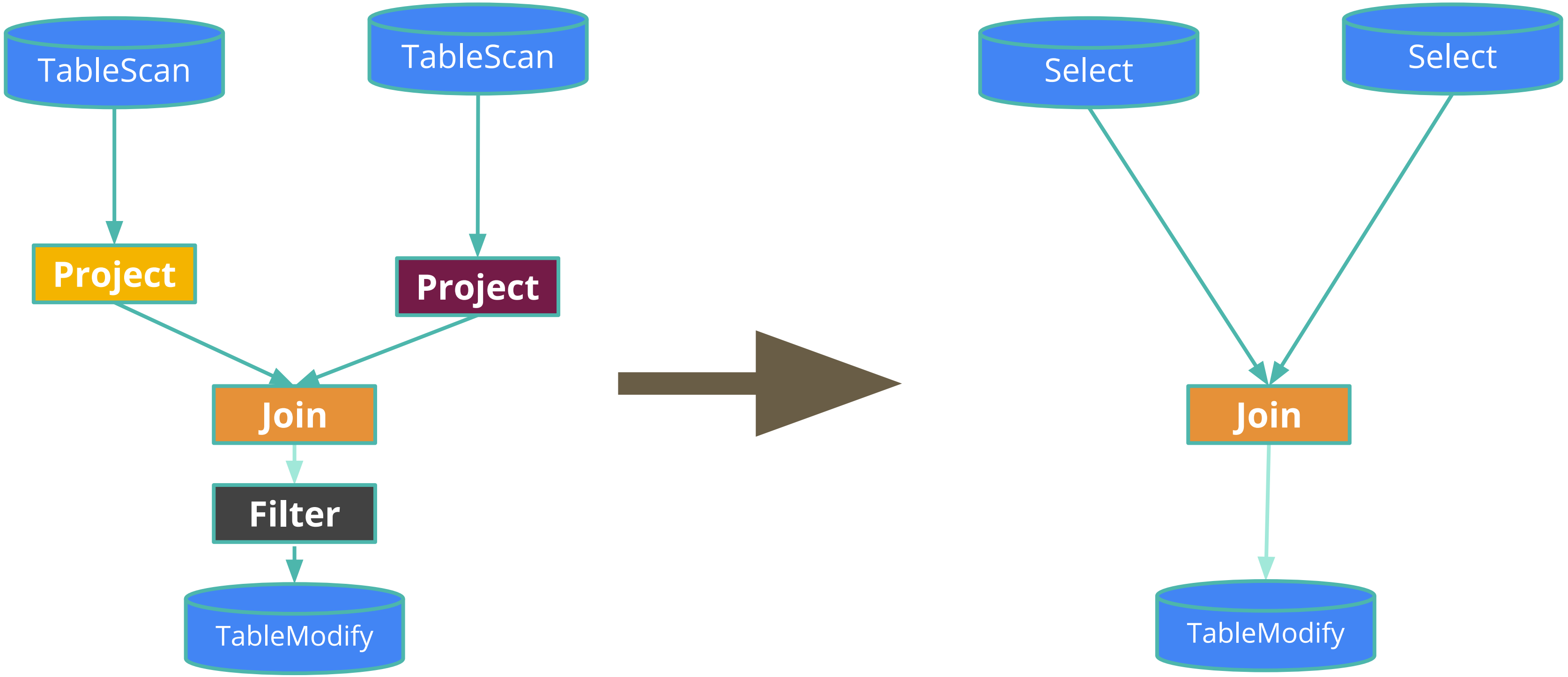
Filter Pushdown



Project Pushdown

- Stop passing unused data as soon as possible
  - Ideally at the source IO but also before shuffles
- Beam Java’s FieldAccessDescriptor may be extended
  - Need a “row expression” language
- Beam SQL has an implementation but no IO support

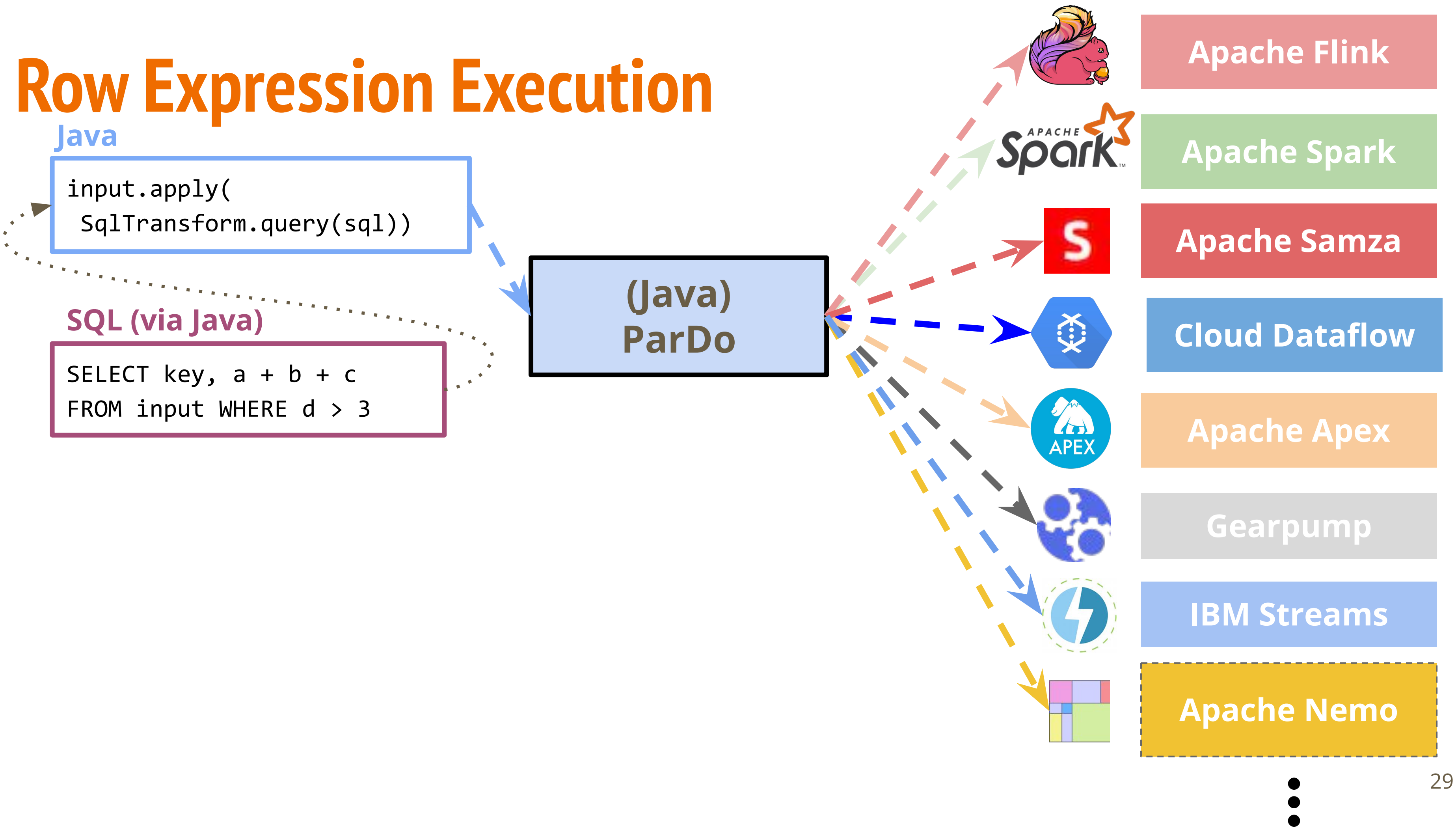
Filter and Project Pushdown



Row Expression Execution

- Allow the optimizer to decide how to execute
    - Eventually pushed down to Runner
- No core model for this yet!
    - Need a “row expression” language
- Beam SQL has multiple implementations

Row Expression Execution



Java

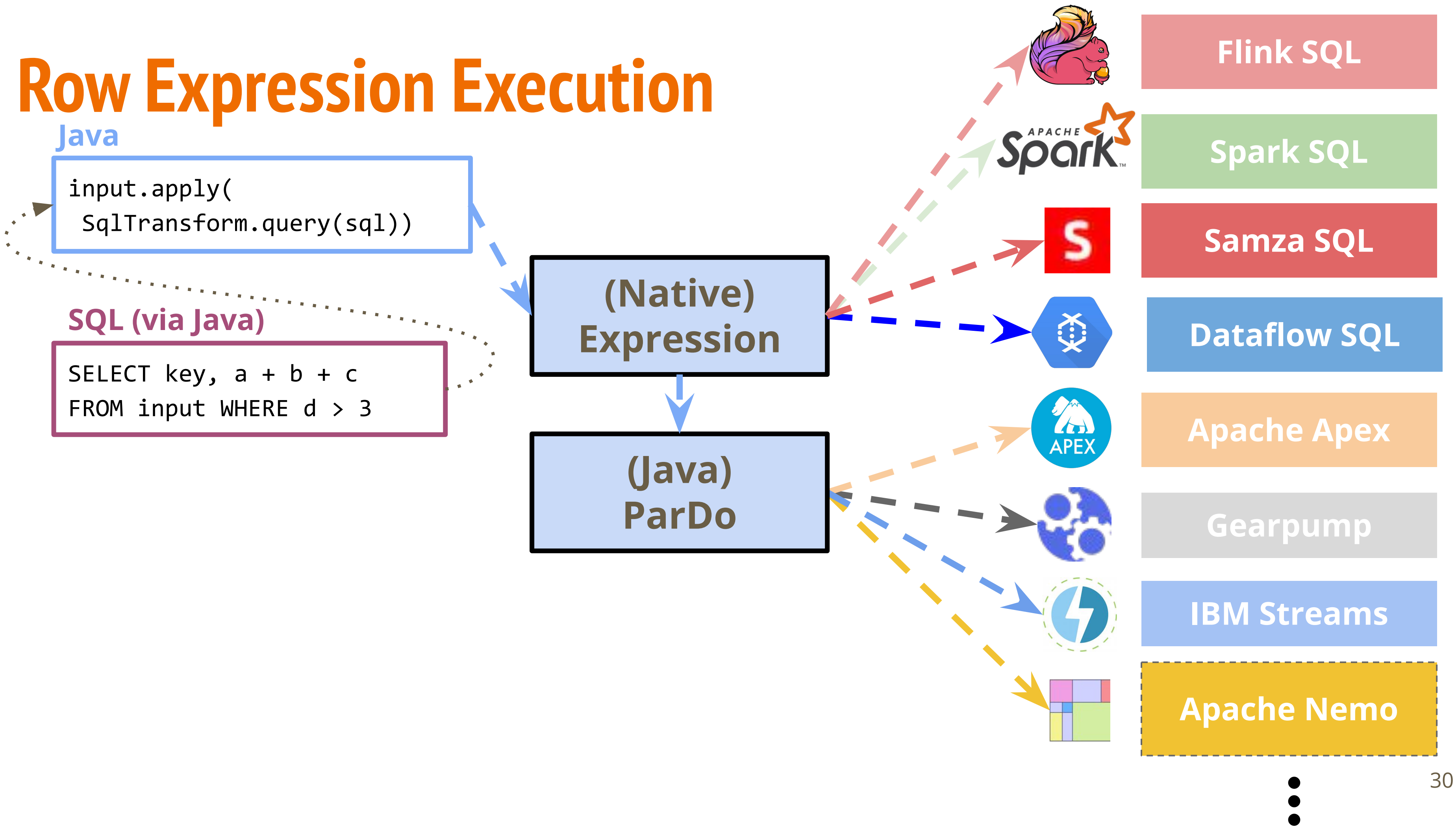
```
input.apply(
 SqlTransform.query(sql))
```

SQL (via Java)

```
SELECT key, a + b + c
FROM input WHERE d > 3
```

(Java)
ParDo

Row Expression Execution



Java

```
input.apply(
 SqlTransform.query(sql))
```

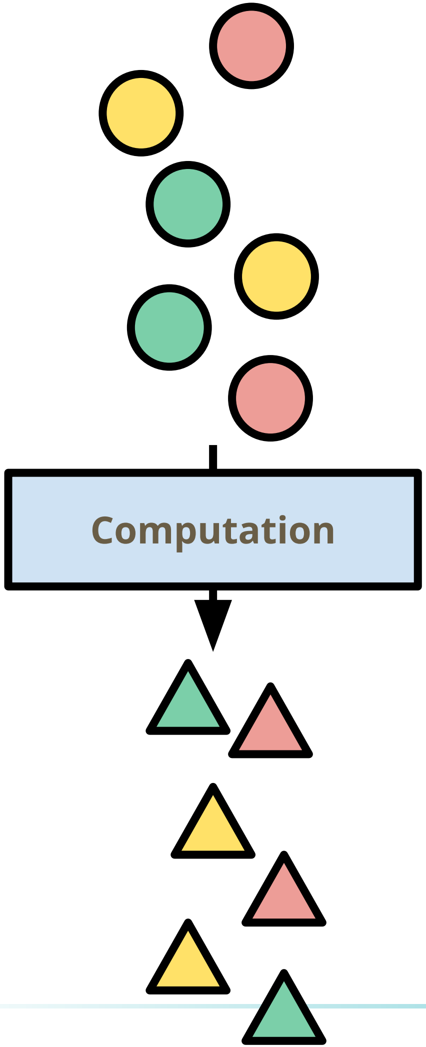
SQL (via Java)

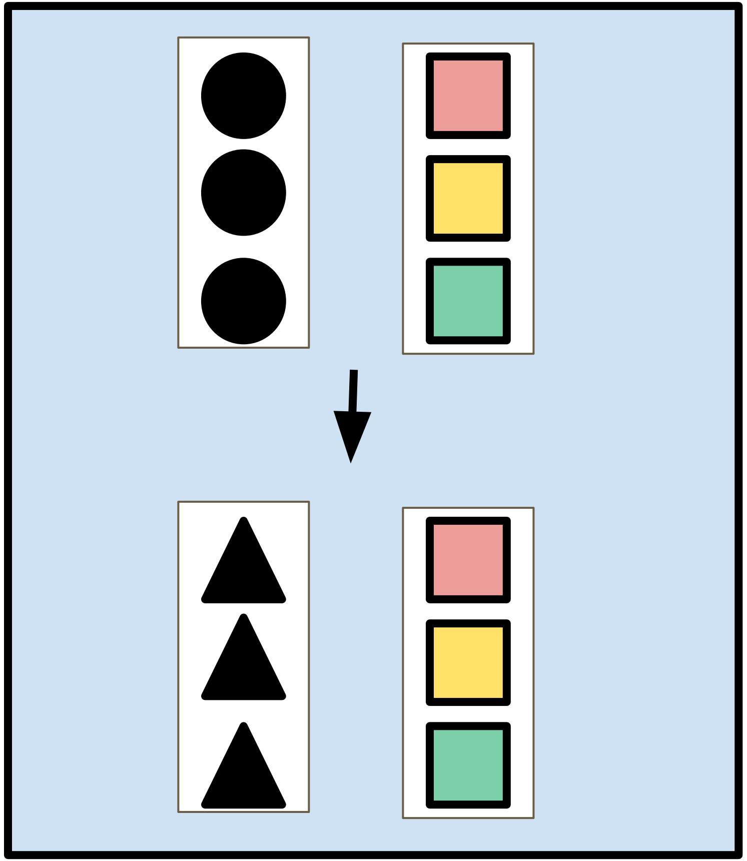
```
SELECT key, a + b + c
FROM input WHERE d > 3
```

Vectorized Execution

for (i) { z[i] = x[i] + y[i] }

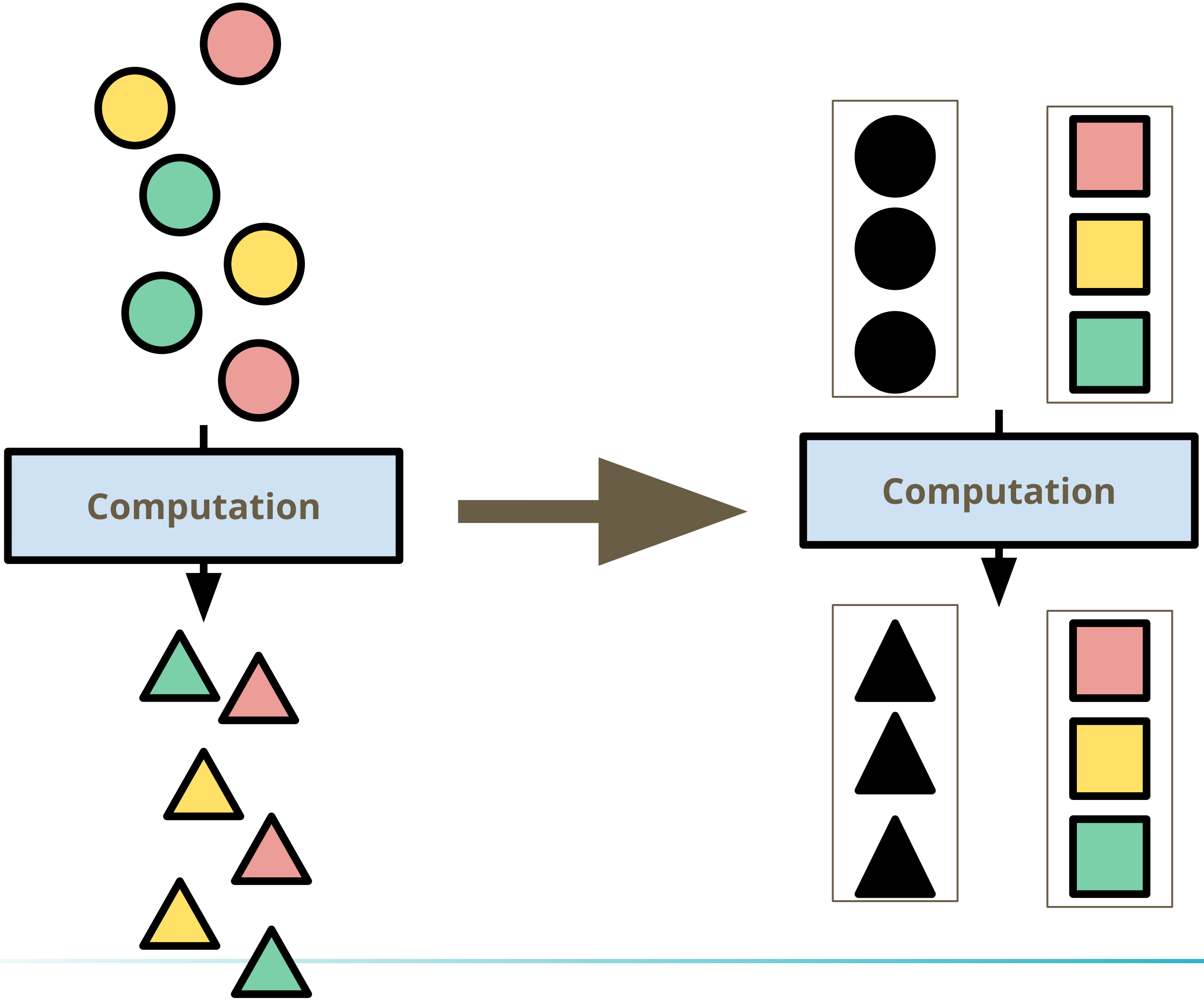
- Structure data in memory for efficient execution
  - Requires batches, Benefits unclear for Streaming
- No core model for this yet!
  - Java 16 may only require internal changes
- Beam Dataframes has an implementation


Computation



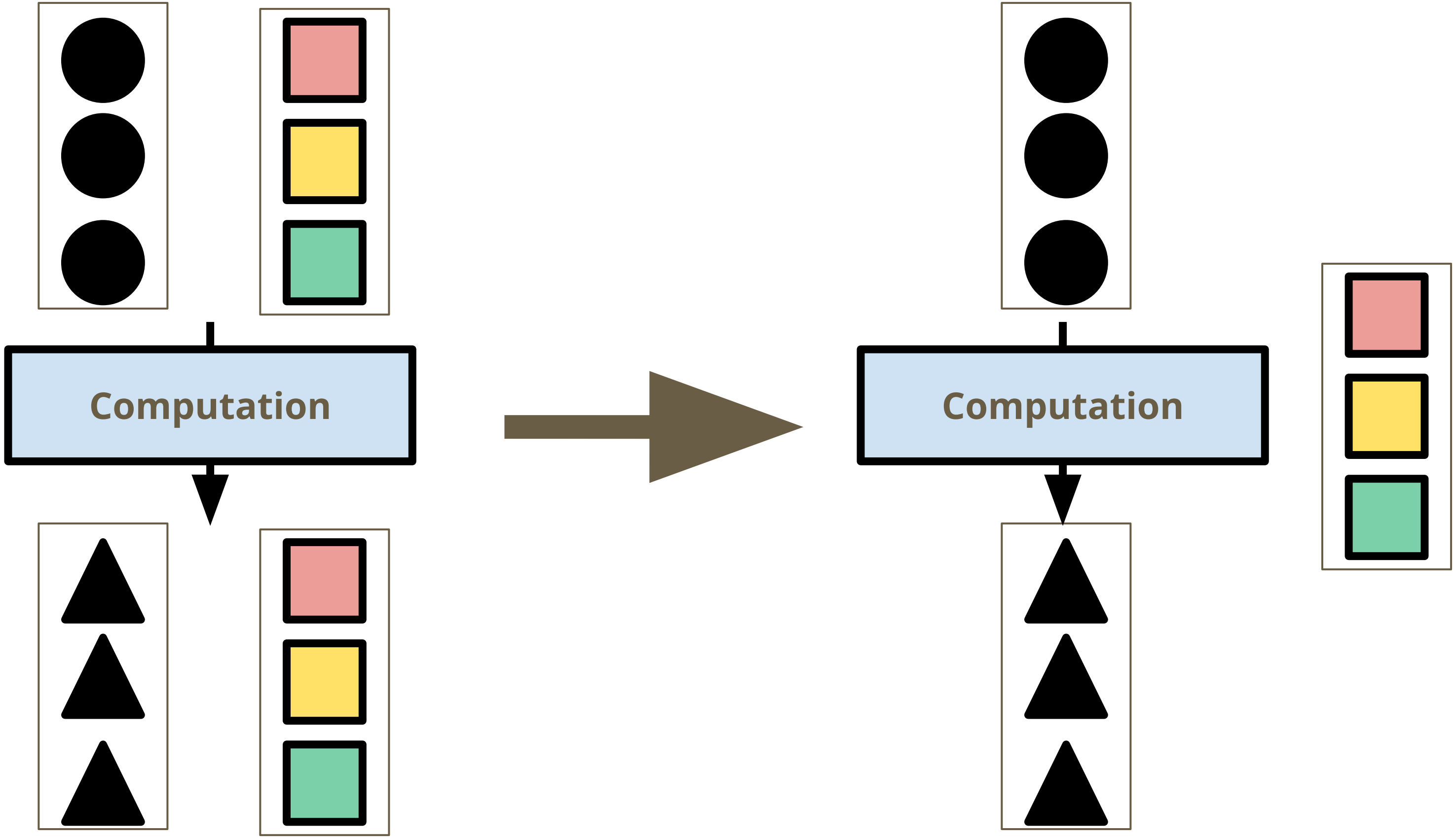
Columnar Coders

- Structure data in transit for efficient execution
  - Requires batches, Benefits unclear for Streaming
- No core model for this yet!
  - May only require internal changes
- Apache Arrow as a coder


Computation
Computation

Zero-Copy Project

- Fields can be projected without deserialization or copy
    - Benefit for columnar fields
    - Also for large or expensive streaming fields
- No core model for this yet!
    - May only require internal changes


Computation
Computation

Deferred Deserialization

- Don’t deserialize fields until first access
  - Benefit for large or expensive fields
- No core model for this yet!
  - May only require internal changes

Order Aware Pcollections

- Some attribute of the data is ordered
    - Could be time, could be another key
- No core model for this yet!

Retractions

- Sometimes your data is actually a change log!
- Beam is “append only” today.
    - What about a delete?
    - What about a change?
- No core model for this yet!
    - How will it work with IOs

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Today:
Beam SQL

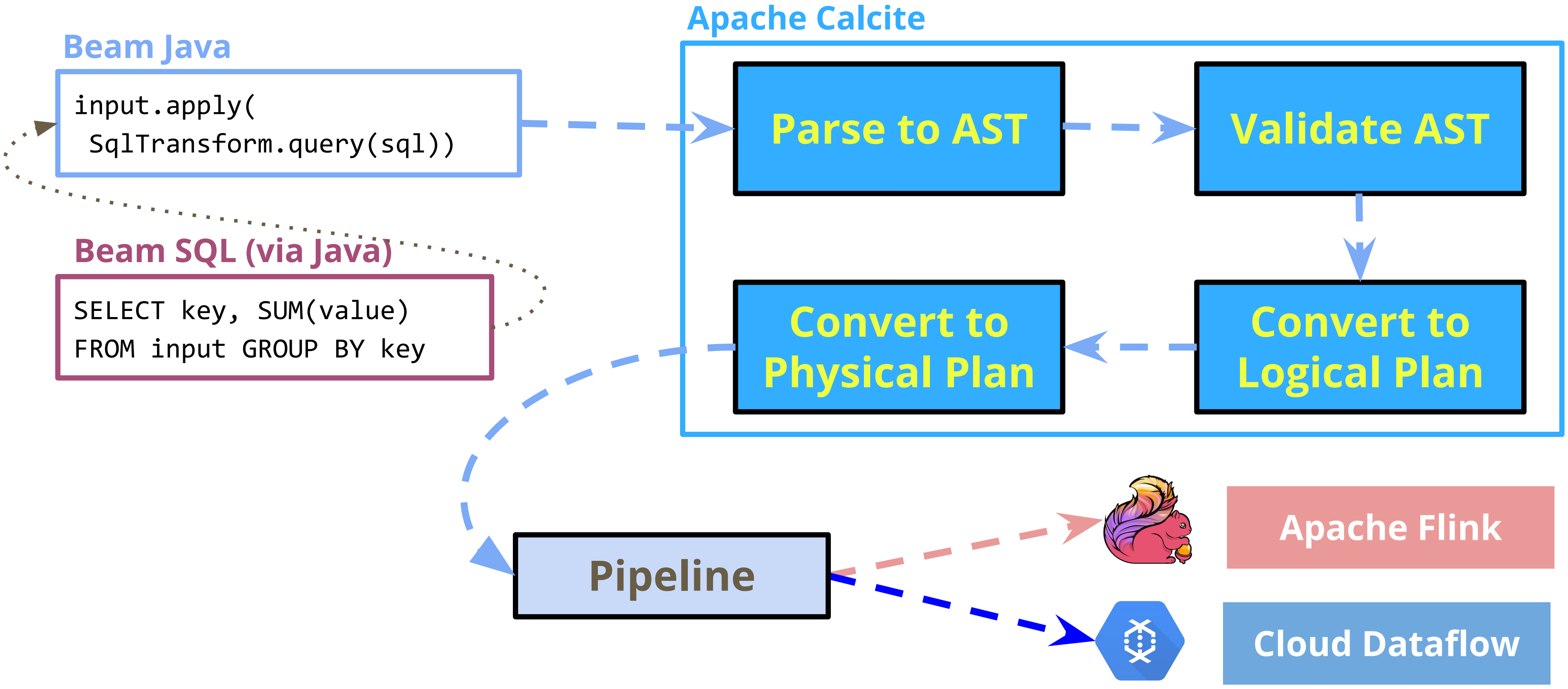
SqlTransform No Longer Experimental!

- As of Beam 2.33.0 (Coming late September)
    - https://github.com/apache/beam/pull/15244

Beam SQL: It’s Apache Calcite, essentially.

- SQL Parsing and Validation*
- Conversion to Relational Algebra*
- Conversion to Physical Execution Plan
- JDBC Driver
- Implementation of Built-in SQL operators
- Project and Filter Code Generation

Beam SQL Java



Beam Java

```
input.apply(
 SqlTransform.query(sql))
```

Beam SQL (via Java)

```
SELECT key, SUM(value)
FROM input GROUP BY key
```

Apache Calcite

Parse to AST

Validate AST

Convert to Logical Plan

Convert to Physical Plan

Pipeline

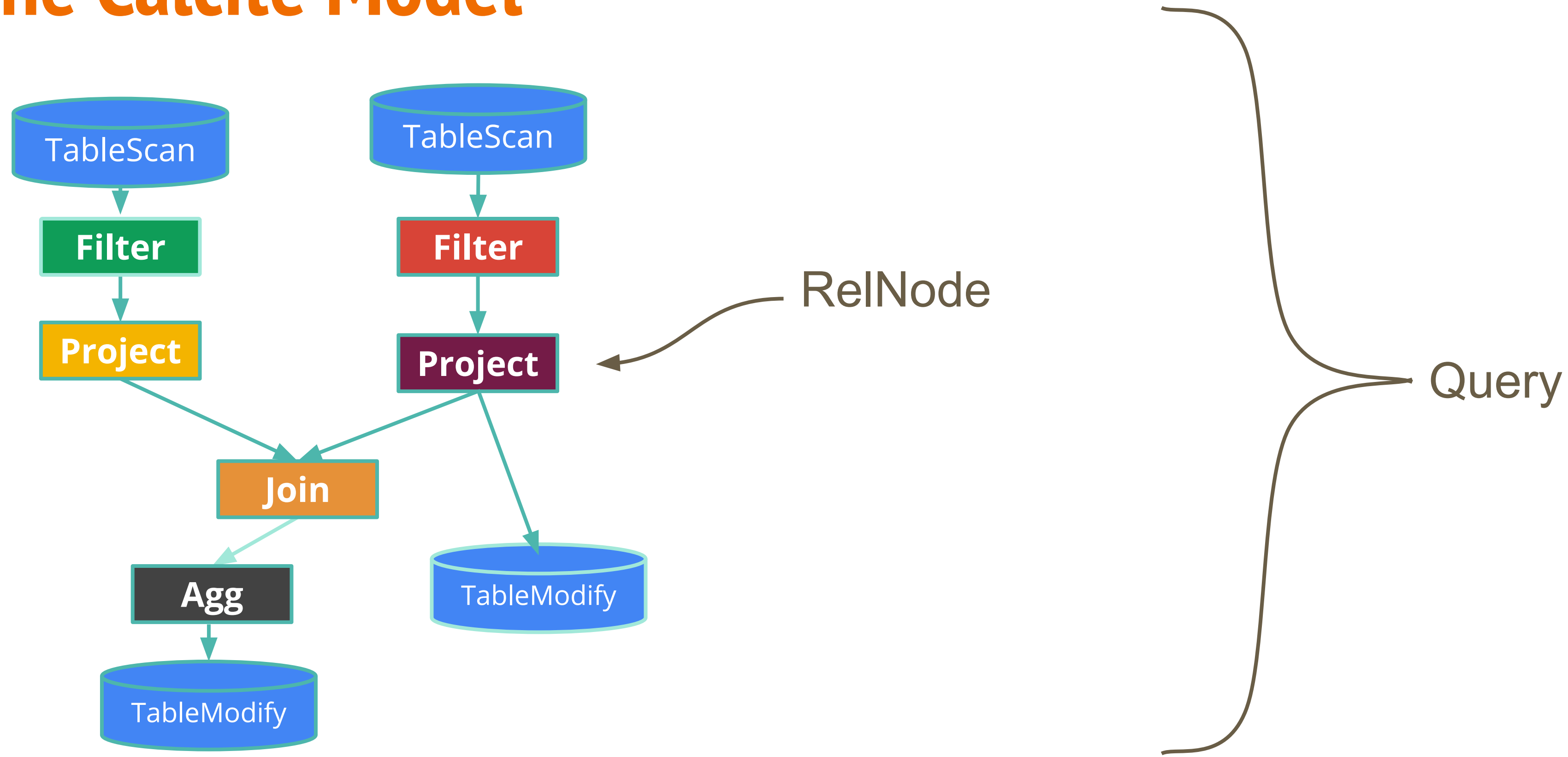
Apache Flink

Cloud Dataflow

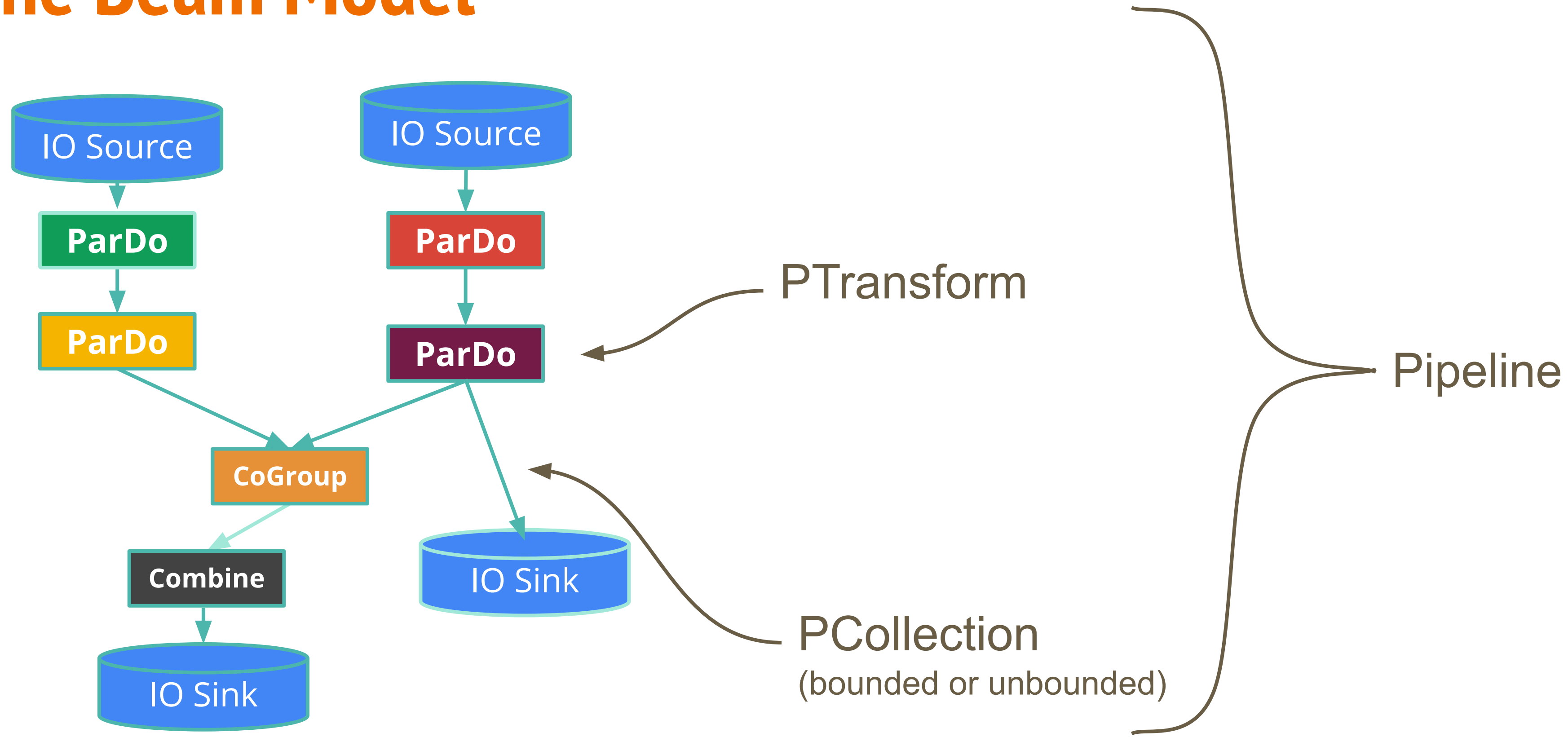
SQL Parsing, Validation, and Conversion

- Apache Calcite handles this
  - We’ve extended the parser to support our DDL syntax
  - We provide Calcite with schemas
- Outputs abstract Relational Algebra model of SQL (tree of RelNodes)
  - Filter
  - Project
  - Join
  - Aggregate
  - Values
  - TableScan* (BeamIOSource)
  - TableModify* (BeamIOSink)
  - …

The Calcite Model



The Beam Model



SQL Conversion to Physical plan

- We use Calcite's implementation of the Volcano Optimizer
  - Uses Rules to convert to a Physical plan and costs to optimize
- Calcite provides basic rules to simplify the RelNodes
  - Filter + Project = Calc
- Beam provides physical RelNodes and rules
  - Calc -> BeamCalc
  - Join -> BeamJoin
  - Aggregate -> BeamAggregation
  - Values -> BeamValues
  - BeamEnumerableConverter*
  - …
- Beam RelNodes are PTransforms

Beam Calc (Expression Evaluator)

- Beam Calc is a simple ParDo operation in Beam
- Wraps Calcite reference implementation of EnumerableCalc
    - Starting in Beam 2.10, prior versions used an interpreter
    - Generates Java code for operators at pipeline creation time
    - Complete support for Calcite built-in project functions
- Also have ZetaSQL Calc wrapping ZetaSQL's reference implementation
    - Relatively slow due to cost of calling from Java to C++

Apache Calcite Code Generation

- Generates Java code for row expressions

```
SELECT id, convert(price), price * 10 WHERE item = “my item” ...
```

Becomes

```
doFn(Context c, Row r) {
    if ("my item".equals(r.get(2))) {
        int price = r.get(1);
        c.output(new Row(r.get(0),
          MyUdf.convert(price), price * 10));
    }
}
```

ZetaSQL

- ZetaSQL == BigQuery Standard SQL
- Written in C++, currently only works on (modern) Linux systems
- Currently Parses and Validates SQL
- Basic support in Beam with ZetaSQL SqlTransform
- Does not replace Calcite!
- Still @Experimental

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Tomorrow: Relational Beam

Relational Beam needs Schemas

- Beam Schemas expose the structure of your data
- Schema Row further abstracts the data
  - Enables some optimizations without user changes
  - Required for now
- Not using Schemas?
  - You Get Nothing! You lose! Good day, sir!

Relational Beam needs SchemaIO

- Schema IO is a standardized (internal) interface to IOs
  - Can be retrofitted into existing IOs
  - Not a replacement for builders
- We are still adding the Relational pieces
  - Project and Filter Push-down
  - Record Count and Rate Statistics

Relational Beam needs Field Access Descriptor

- Use Schema Transforms
- Use SqlTransform
- Annotate your Java ParDos with @FieldAccess
- Eventually Static analysis?

Relational Beam wants More!

- Use high level interfaces when possible
  - Schema Transforms
  - SqlTransform
  - Dataframes
  - More?

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Andrew Pilloud / apilloud@apache.org

These Slides - https://s.apache.org/beam-relational-2021