The Gluten Open-Source Software Project: Modernizing Java-based Query Engines for the Lakehouse Era

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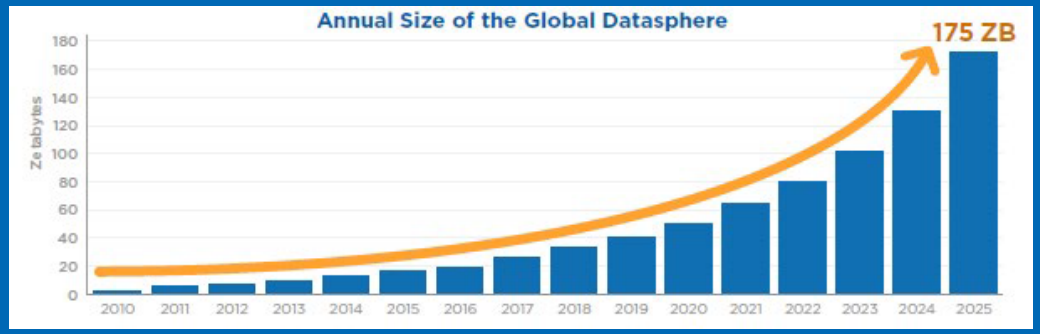
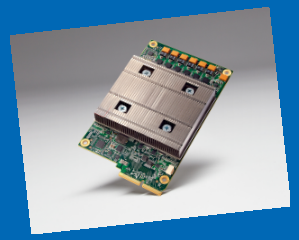
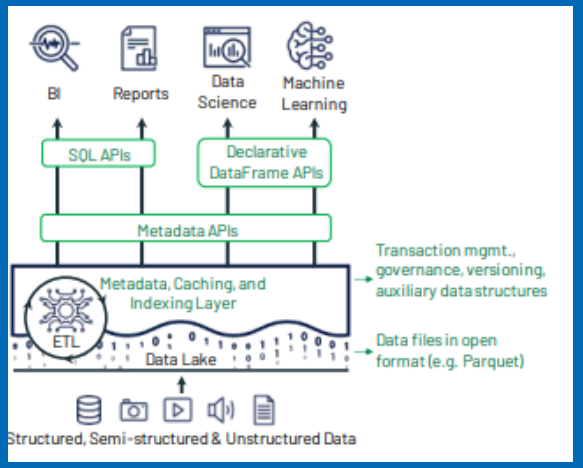
Background – Disruptive Trends

- Exponential growth in compute demand, largely driven by data supporting machine learning (ML), training models.
- Such data is increasingly processed over custom, heterogeneous hardware: CPUs, GPUs, TPUs, FPGAs, etc.
- Data lakehouses: Rise of open table formats, decouple query engine from storage, ability to perform mutable transactions on tables.



https://www.i-scoop.eu/big-data-action-value-context/data-age-2025-datasphere/





Motivation – SparkSQL as a Service

SparkSQL has been an **engine of innovation** in this market.

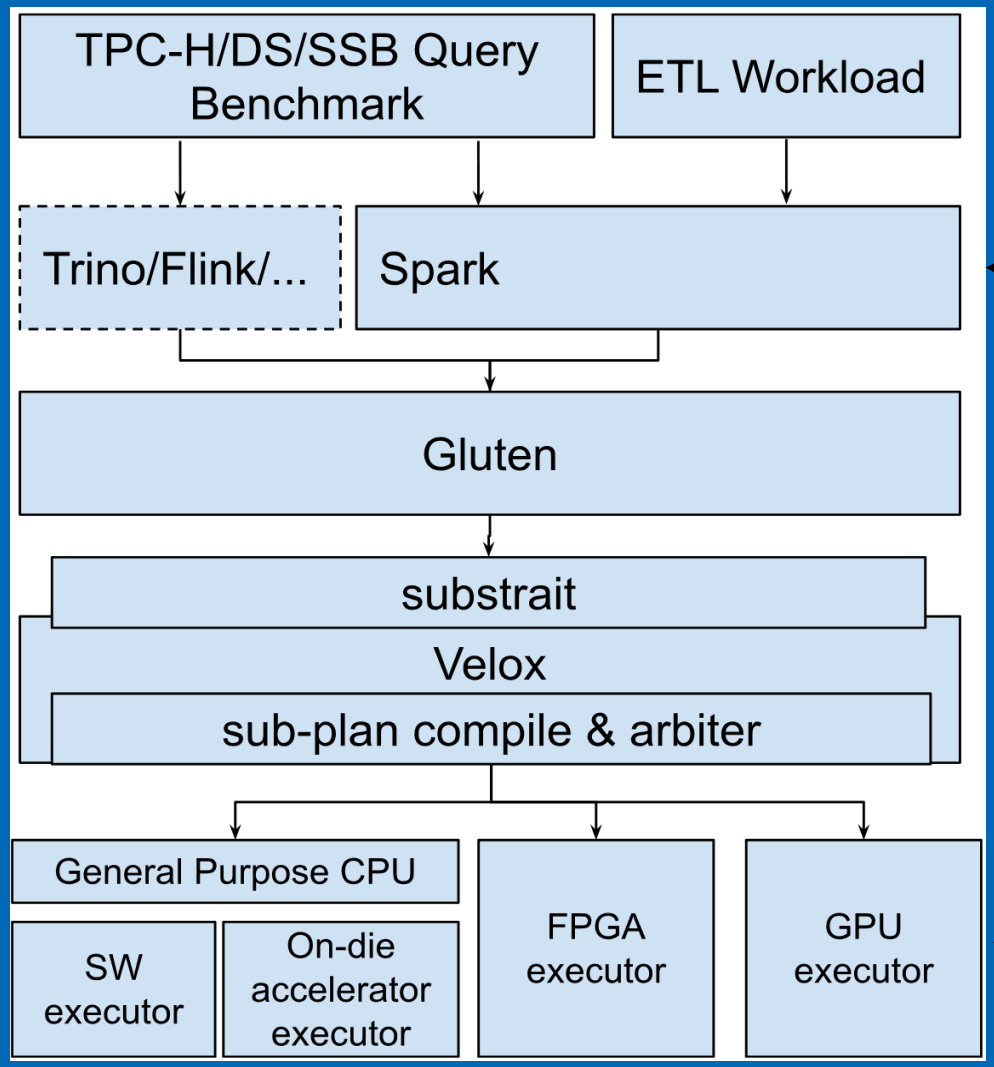
The shift towards lakehouses has created opportunities for SparkSQL-as-a-Service providers.

For external customers:	For internal constituents:
❖ Hyperscalers: Amazon EMR, Azure Synapse, Google Dataproc, Alibaba EMR, etc. ❖ Databricks (available on all public clouds)	❖ Pinterest, Meituan, Netflix, Stripe, etc. ❖ Operates at a scale that rivals the hyperscalers.

Motivation for an **open-source initiative** (Gluten):

- ❖ The Photon solution is not available to the Spark community.
- ❖ Due to scale/TCO for above customers, the Delta Lake approach is not feasible.

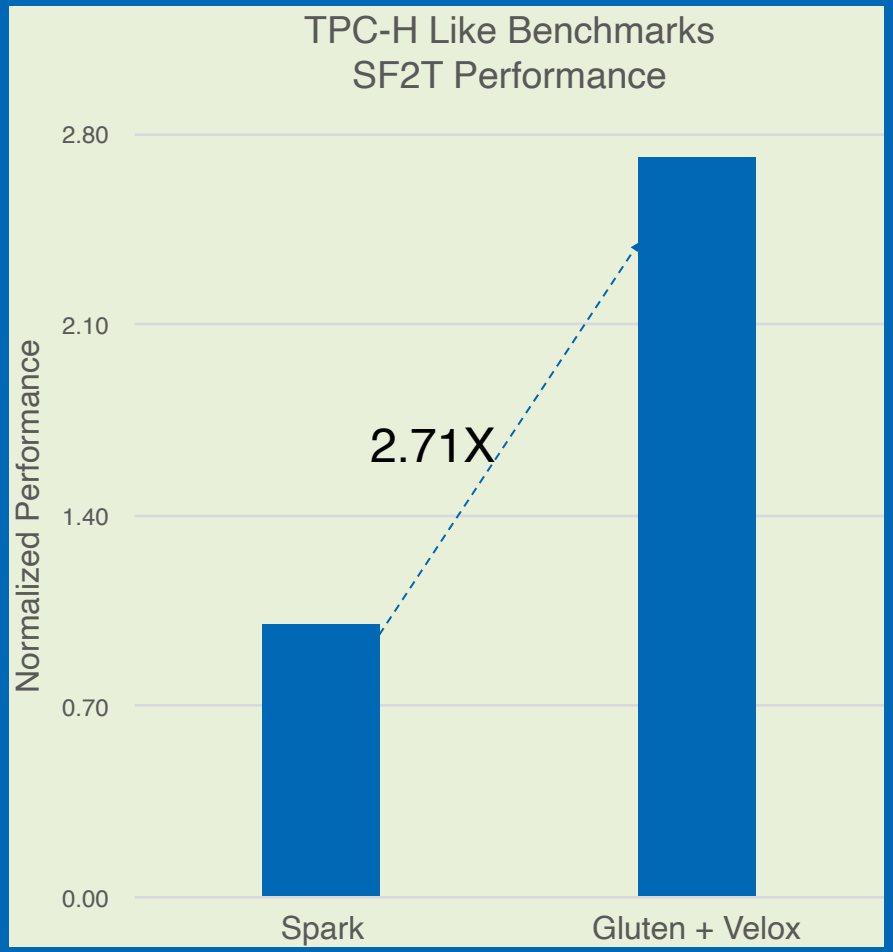
The Gluten Open-Source Software Project

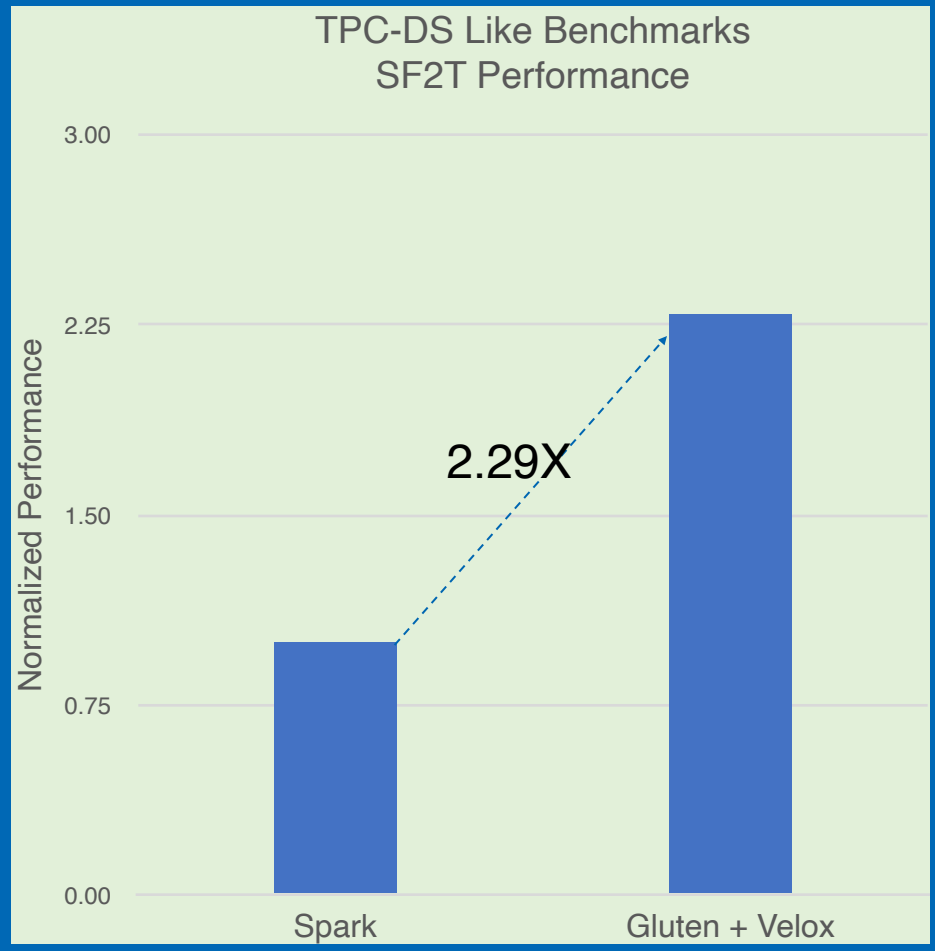


We envision Gluten to:

- ❖ support a variety of workloads & execution frameworks
- ❖ generalize across query engines (e.g., Velox, Clickhouse, Arrow)
- ❖ run on heterogeneous hardware (e.g., CPUs, GPUs, FPGAs)

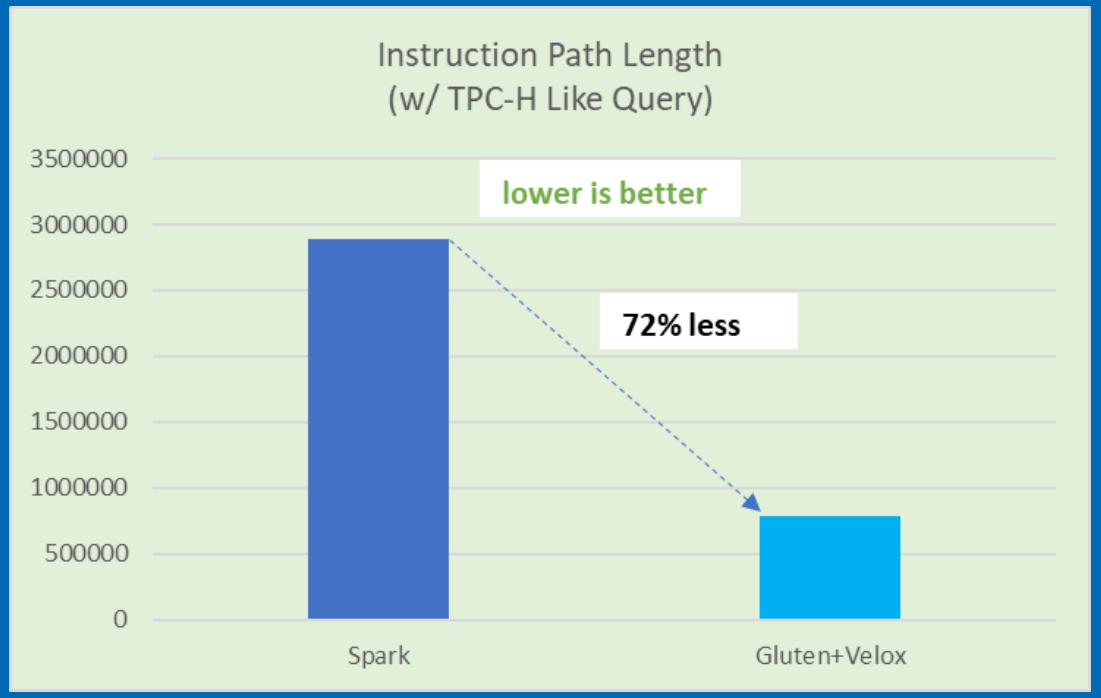
Performance Characterization
Spark vs. Spark+Gluten+Velox

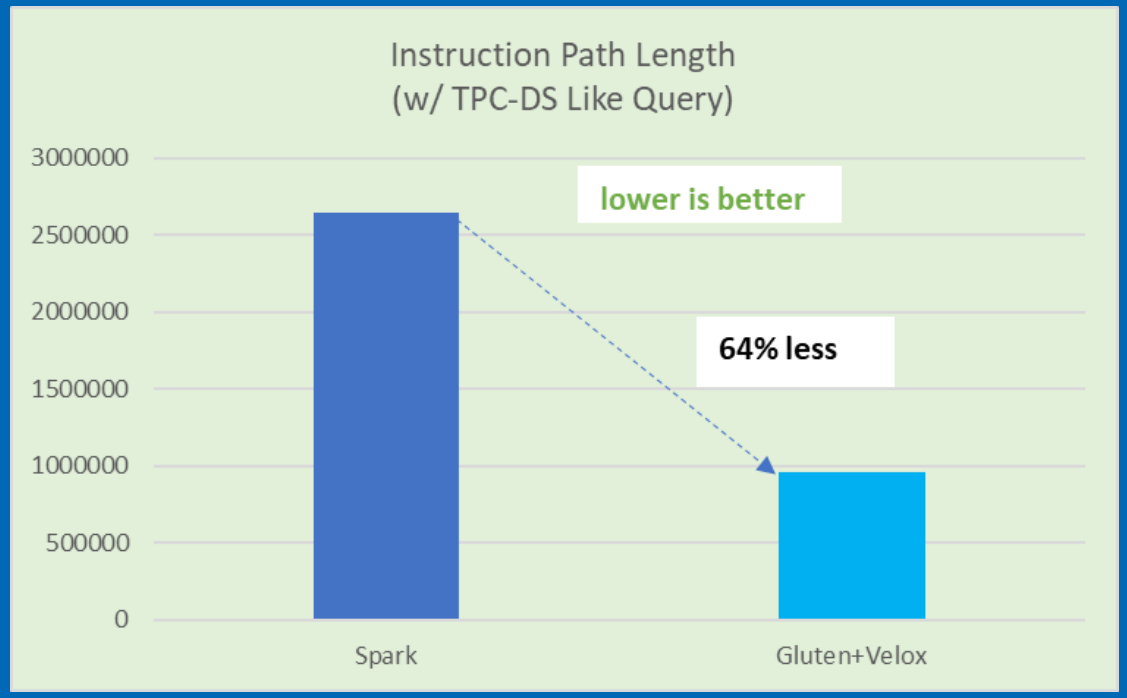




Performance Characterization
Microarchitectural Analysis

Instruction Path Length with and without Gluten+Velox



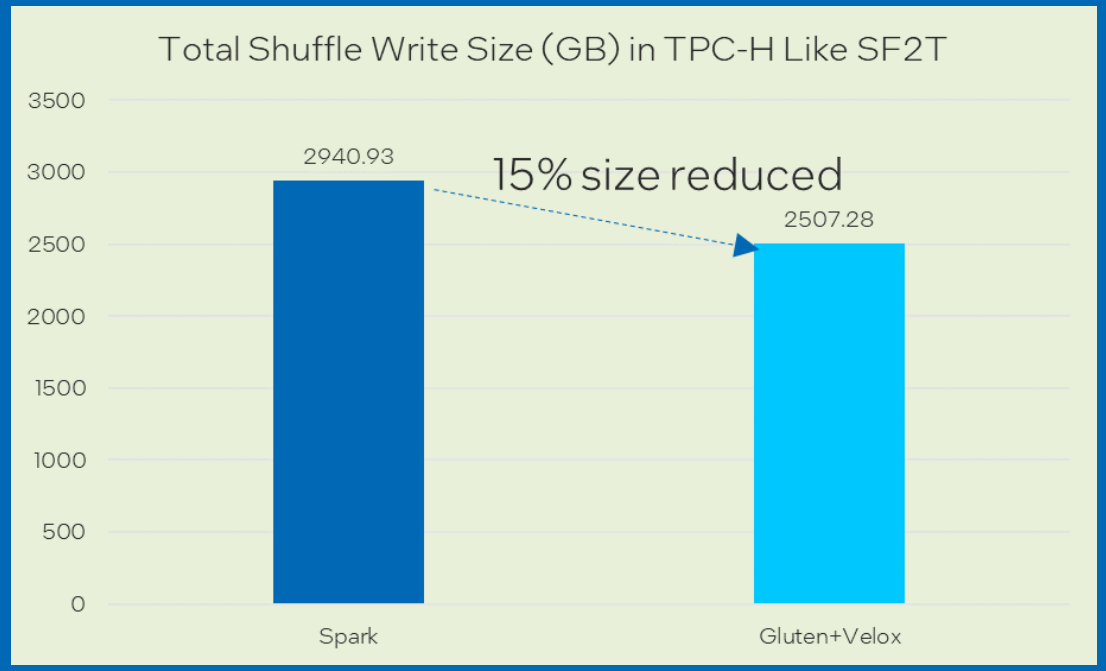


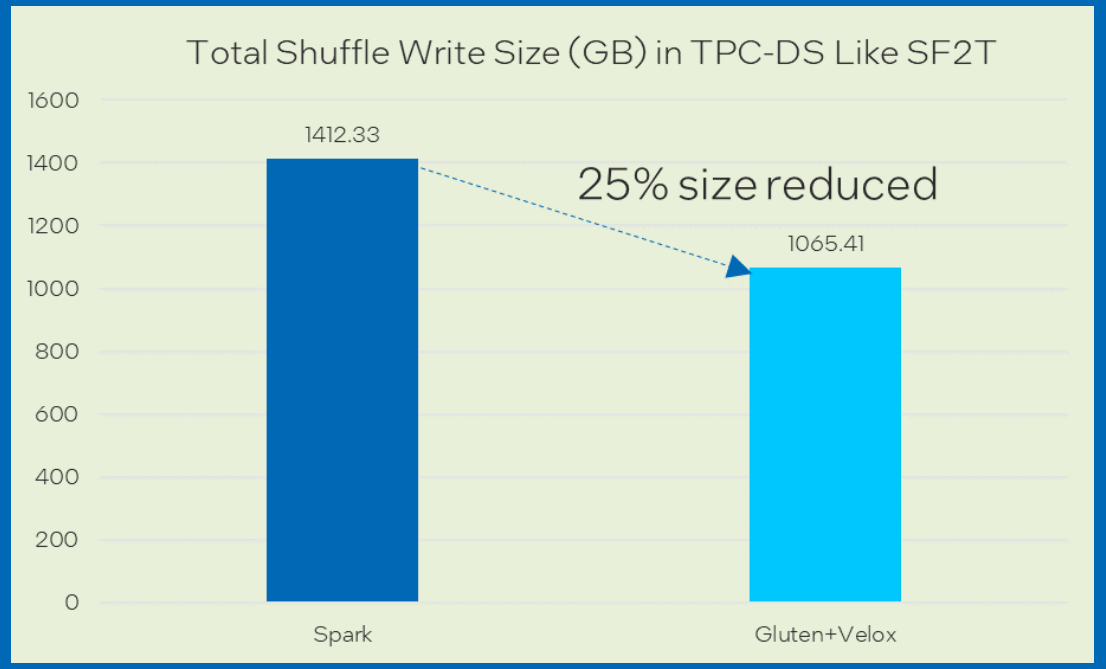
Reduction in Path Length leads to huge performance savings.

- fewer instructions required to produce the same output

Performance Characterization
Shuffle Write Reduction

Shuffle Write Sizes with and without Gluten+Velox (compression: lz4)





- Columnar-based shuffle can take advantage of compression codecs (e.g., lz4, zlib, zstd).
- Users can choose codec based on columnar data type to get higher compression ratio for better performance.

Gluten Community Participation and Adoption

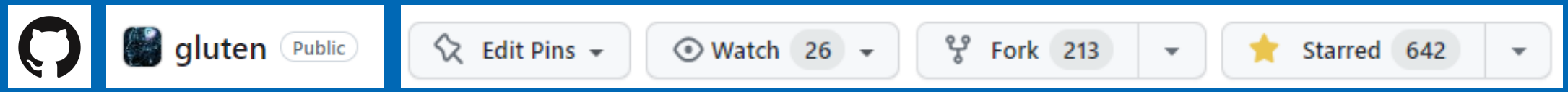
Active Community Participation:

- 10+ companies across the globe have made contributions to the Gluten Project.

Increasing Adoption:

- Strong interest from various hyperscalers and large Spark customers in trying Gluten for their offerings.

https://github.com/oap-project/gluten



Future Directions

- Develop an Application Binary Interface (ABI)
- Extend Gluten as a JNI bridge to other query engines
- Target heterogeneous hardware
- Offload Spark shuffle to hardware accelerators (e.g., Intel-QAT) for additional performance improvements

With Velox and Substrait, extend composability to the underlying heterogeneous hardware, supporting the vision of Composable Data Management Systems.

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BACKUP

Configurations

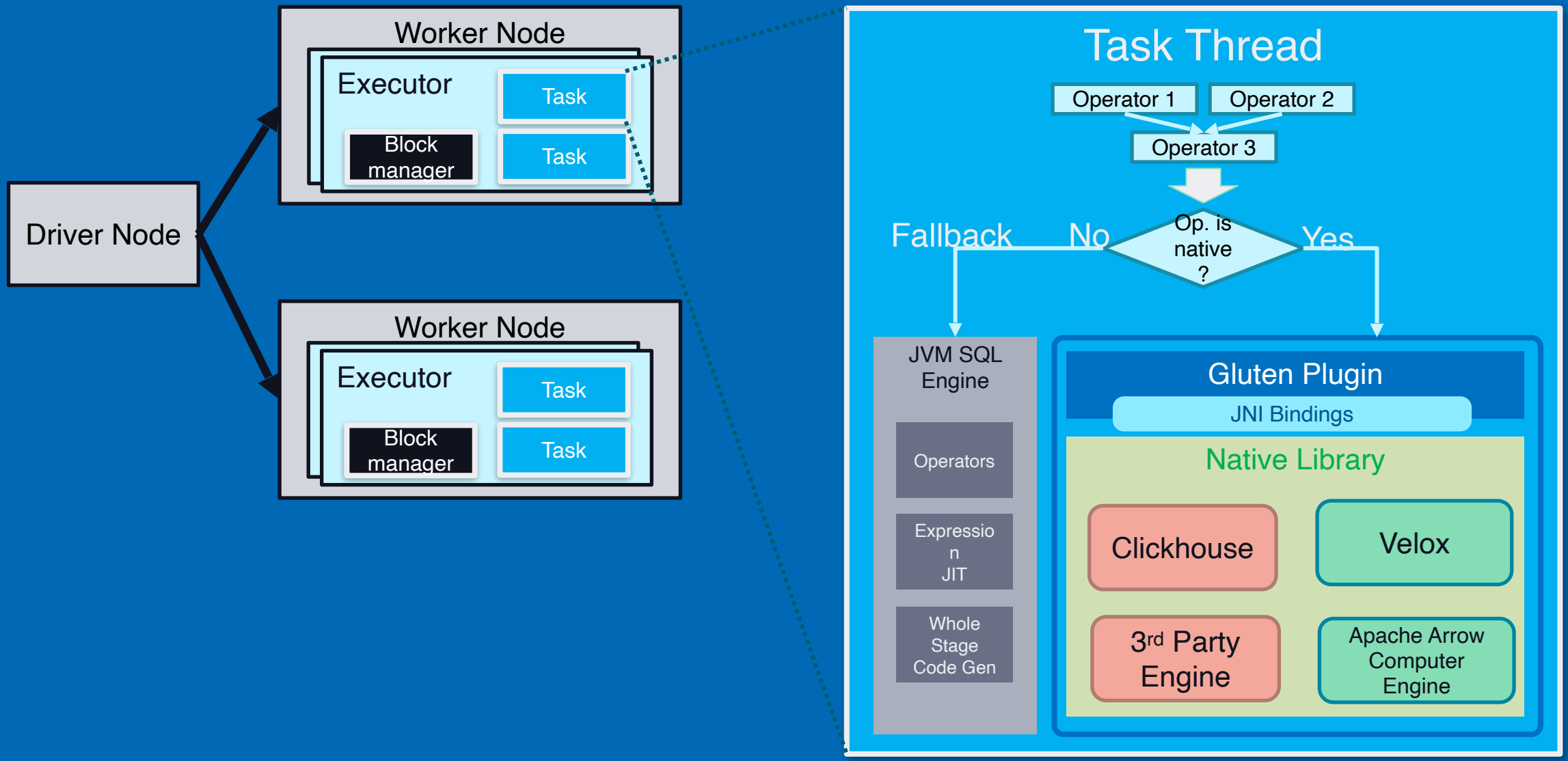
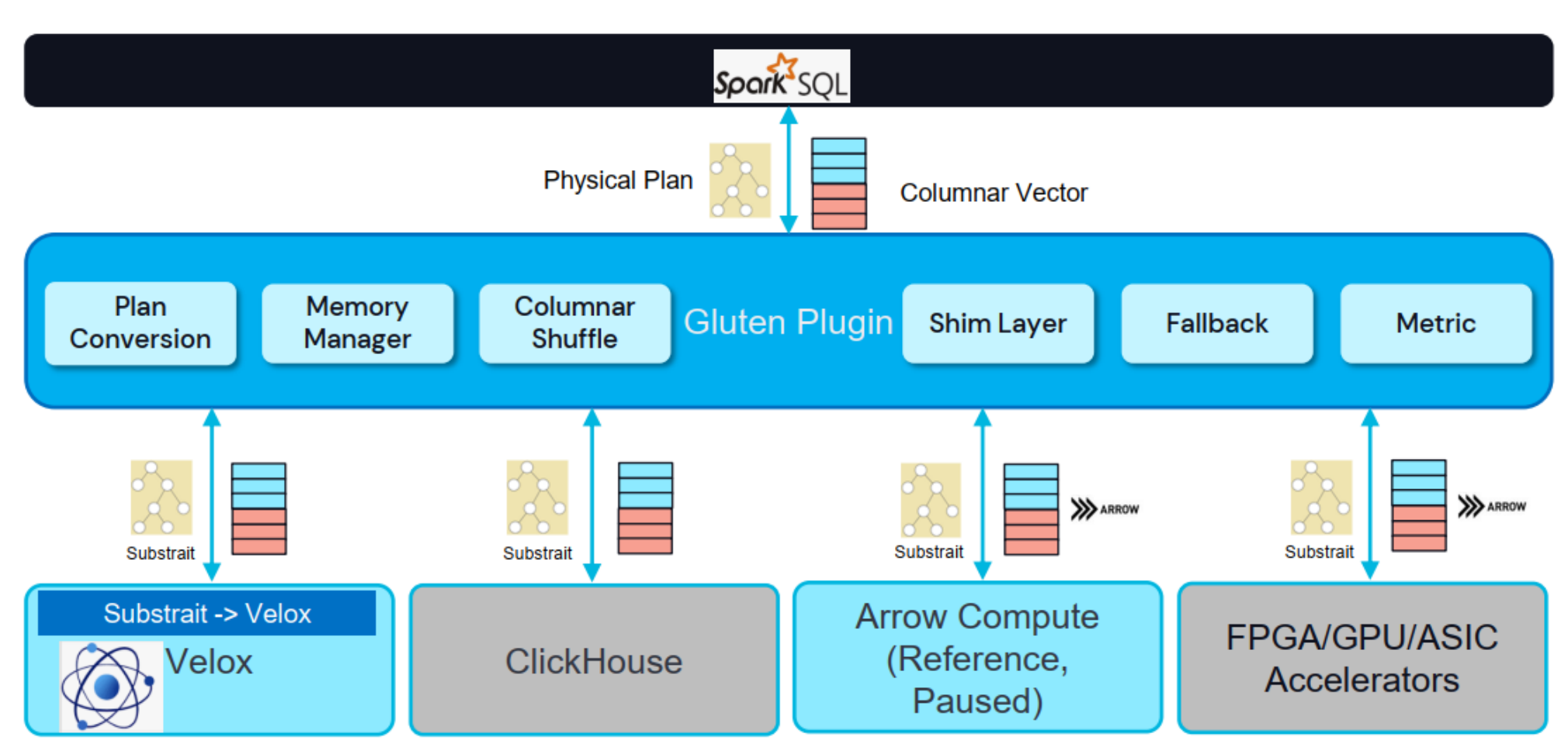
Name	Hardware Platform
CPU Model	Intel® Xeon® Platinum 8480+
Micro-architecture	Sapphire Rapids
CPUs	224
Memory	1024GB
NIC	1x Ethernet Controller I225-LM 1x Ethernet interface
Disks	2x 1.5T INTEL SSDPE2KE016T8 1x 447.1G INTEL SSDSC2BB48 1x 447.1G INTEL SSDSC2KB48 7x 3.5T INTEL SSDPF2KX038TZ

Table 1: Hardware Configuration.

Name	Software Platform
Operating System	Ubuntu 22.04.1 LTS
Linux Kernel	5.16.0-051600rc5-generic
JDK version	1.8
GCC version(Gluten only)	11
Spark version	3.3.1
Hadoop version	3.2

Table 2: Software Configuration.

Gluten working model



Gluten - architecture