Empowered by Innovation NEC

PG-Strom

Query Acceleration Engine of PostgreSQL Powered by GPGPU

NEC OSS Promotion Center

The PG-Strom Project

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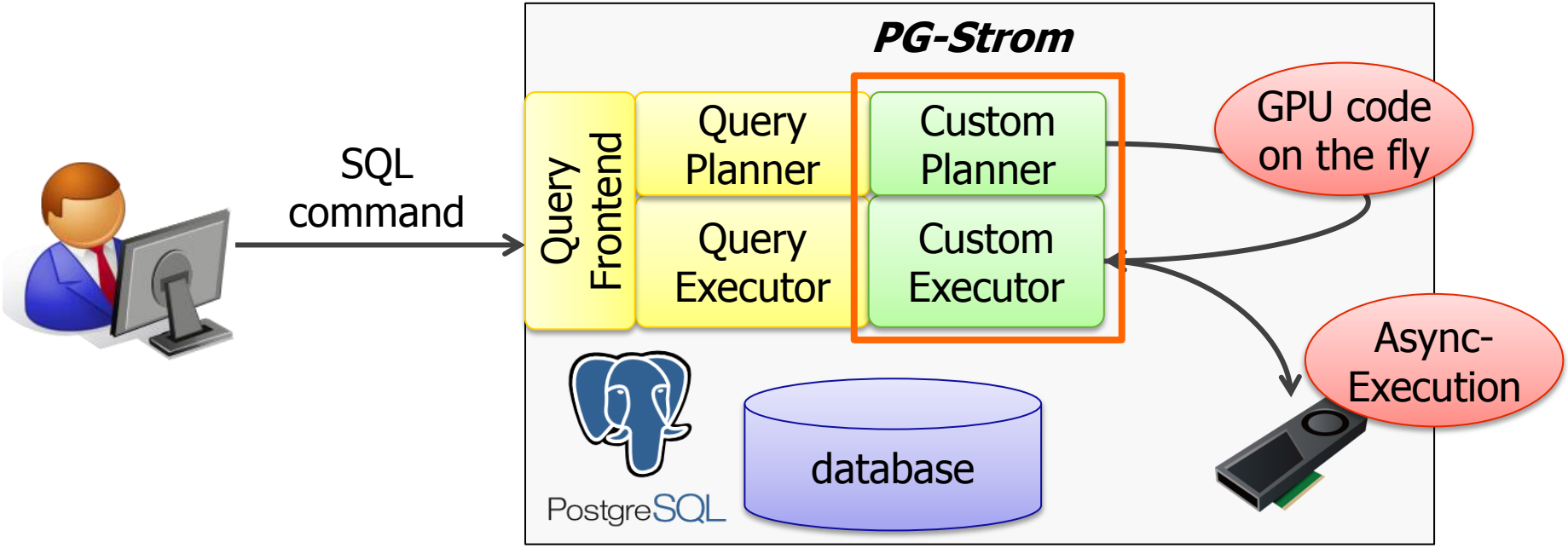
Self Introduction

- Name: KaiGai Kohei
- Company: NEC
- Mission: Software architect & Intrepreneur
- Background:
  - Linux kernel development (2003~?)
  - PostgreSQL development (2006~)
  - SAP alliance (2011~2013)
  - PG-Strom development & productization (2012~)
- PG-Strom Project:
  - In-company startup of NEC
  - Also, an open source software project

What is PG-Strom

- An Extension of PostgreSQL
- Off-loads CPU intensive SQL workloads to GPU processors
- Major Features
  - ① Automatic and just-in-time GPU code generation from SQL
  - ② Asynchronous and concurrent query executor



Concept

No Pain

- Looks like a traditional PostgreSQL database from standpoint of applications, thus, we can utilize existing tools, drivers, applications.

No Tuning

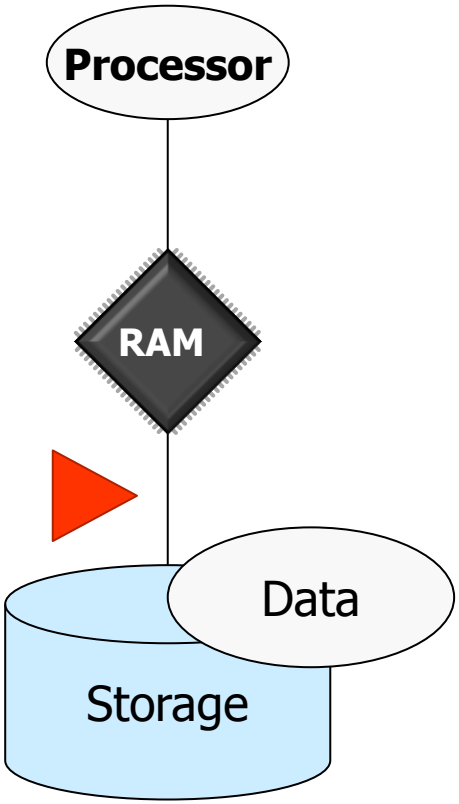
- Massive computing capability by GPGPU kills necessity of database tuning by human. It allows engineering folks to focus on the task only human can do.

No Complexity

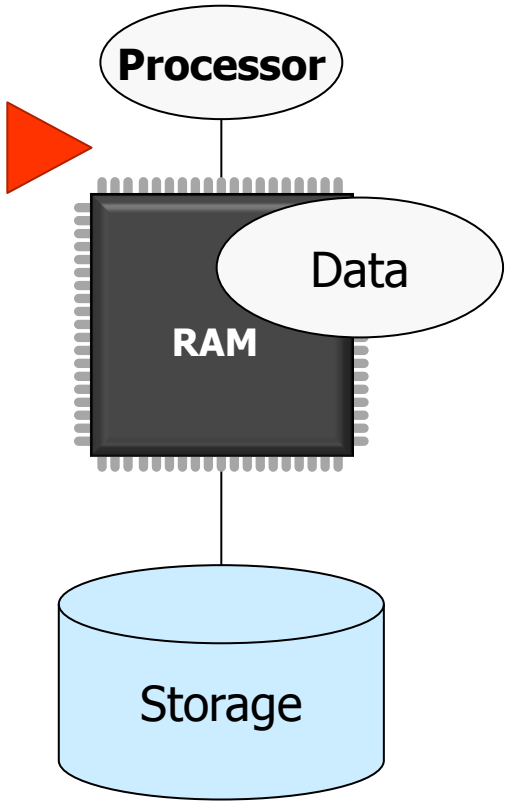
- No need to export large data to external tools from RDBMS, because its computing performance is sufficient to run the workloads nearby data.

RDBMS and bottleneck (1/2)

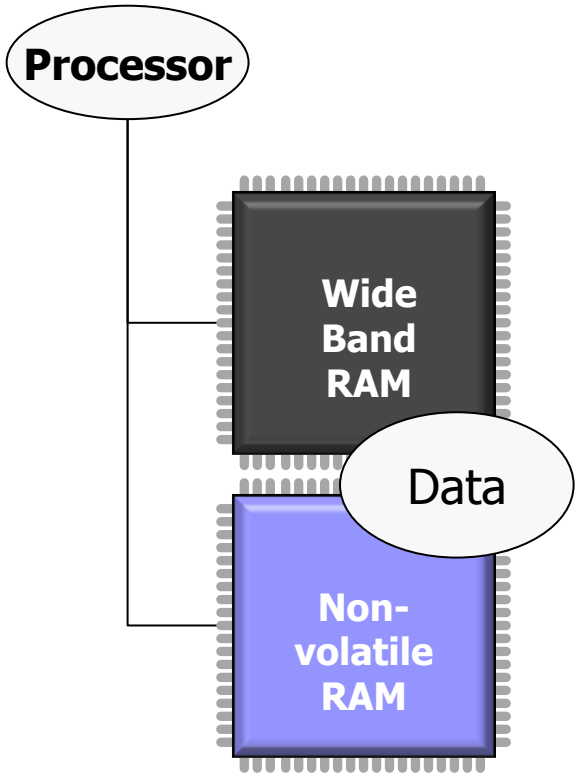
Data Size > RAM



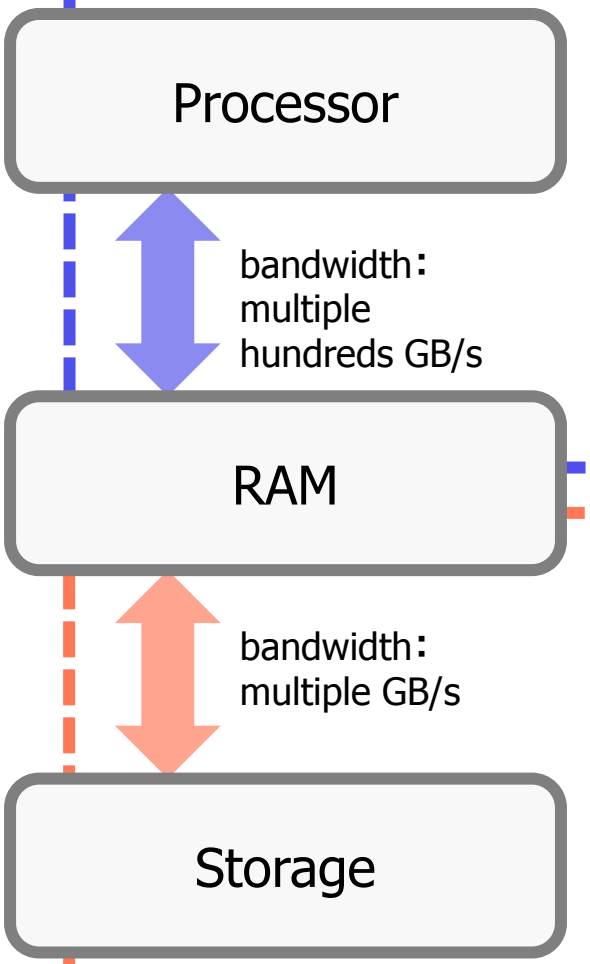
Data Size < RAM



In the future?



RDBMS and bottleneck (2/2)



World of current cpu/memory bottleneck

Join, Aggregation, Sort, Projection, ...

[strategy]

- burstable access pattern
- parallel algorithm

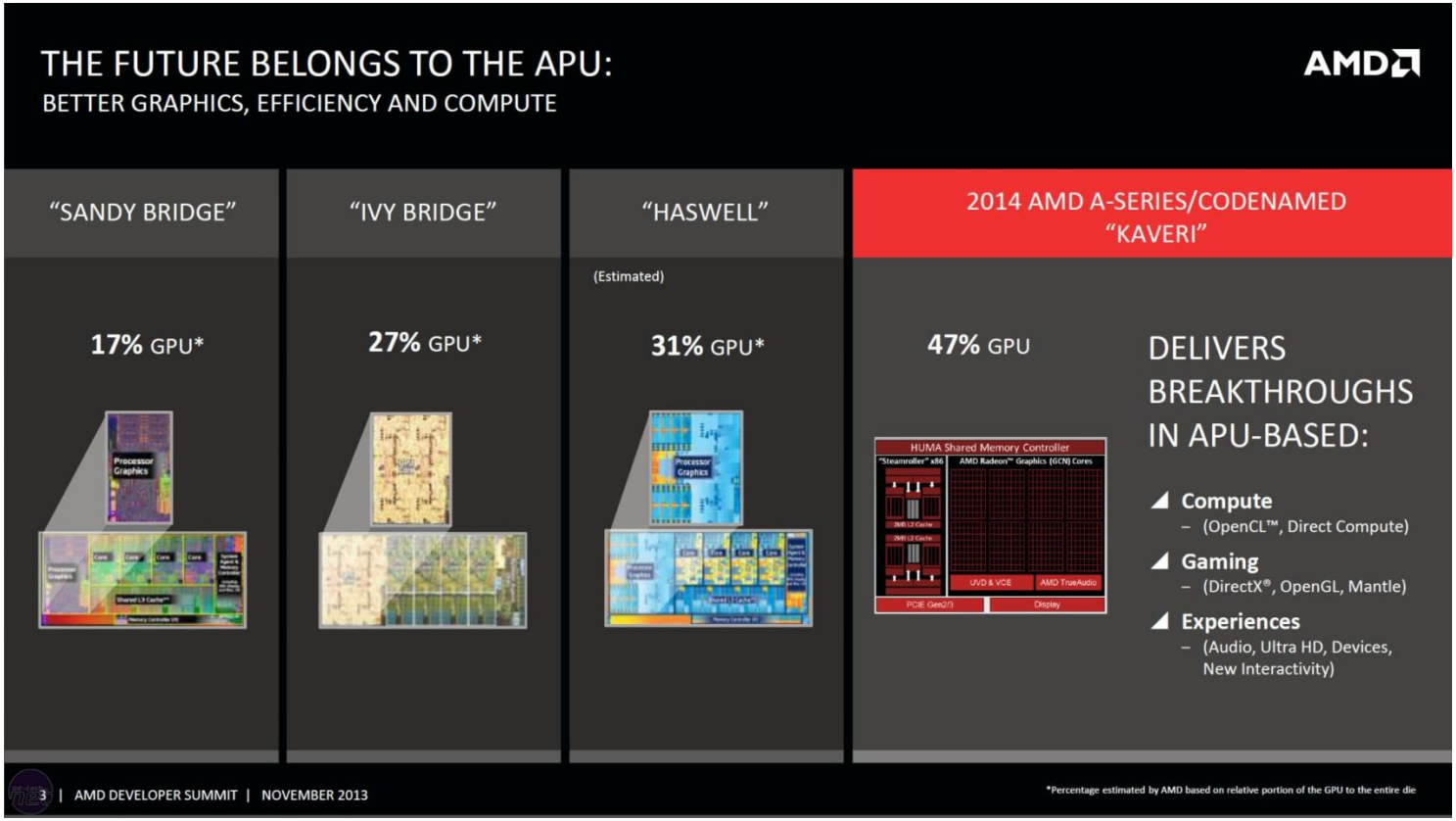
World of traditional disk-i/o bottleneck

SeqScan, IndexScan, ...

[strategy]

- reduction of i/o (size, count)
- distribution of disk (RAID)

Background (1/4) – Semiconductor Trend



SOURCE: [THE HEART OF AMD INNOVATION, Lisa Su, at AMD Developer Summit 2013]

- Movement to CPU/GPU integrated architecture rather than multicore CPU
- Free lunch for SW by HW evolution will finish soon

➔ Unless software is not designed to utilize GPU capability, unable to pull-out the full hardware capability.

Background (2/4) – Features of GPU

SOURCE: CUDA C Programming Guide (v6.5)

Characteristics

- Larger percentage of ALUs on chip
- Relatively smaller percentage of cache and control logic

➔ Advantages to simple calculation in parallel, but not complicated logic

- Much higher number of cores per price
  - GTX750Ti (640core) with $150

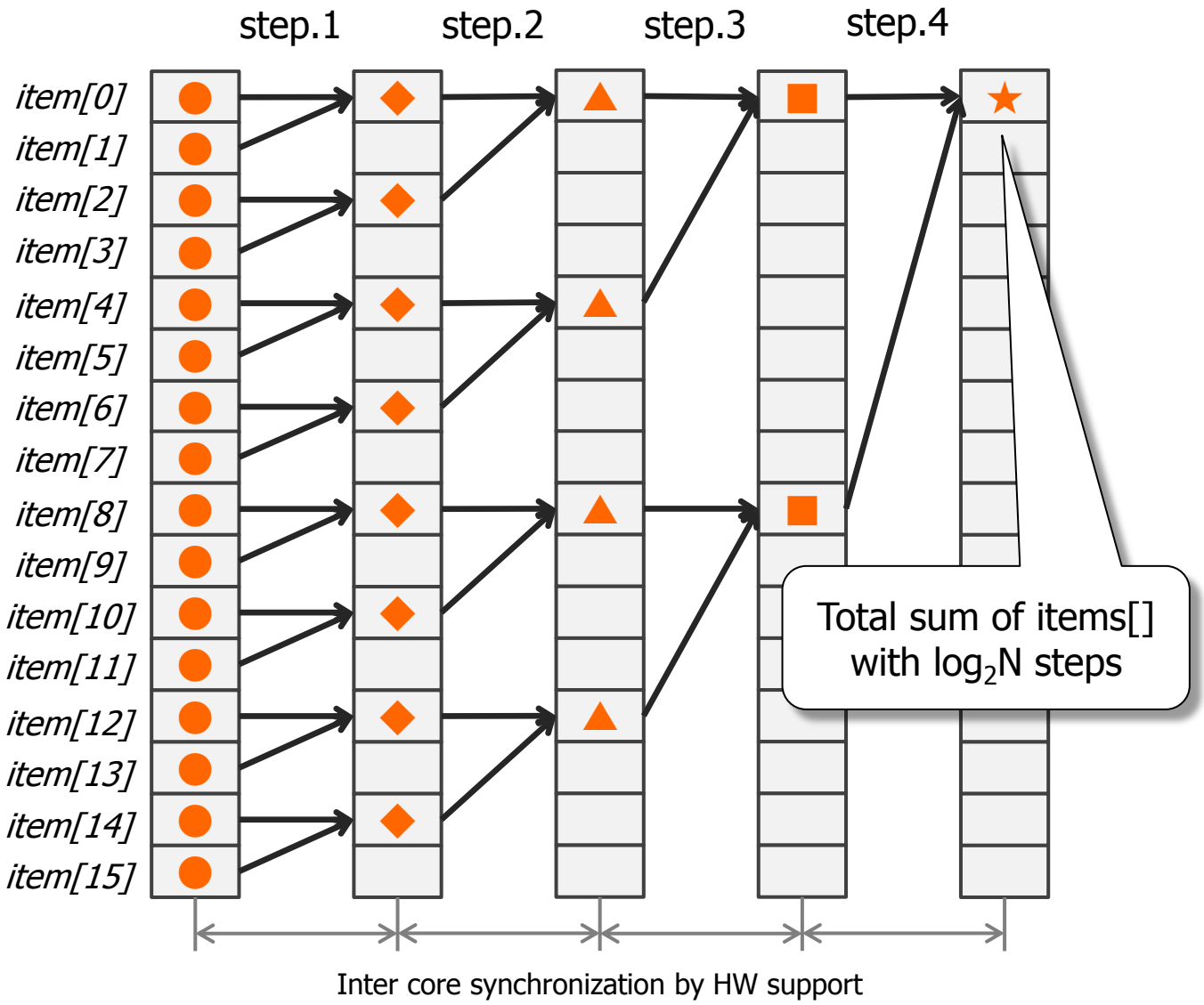
	GPU	CPU
Model	Nvidia Tesla K20X	Intel Xeon E5-2670 v3
Architecture	Kepler	Haswell
Launch	Nov-2012	Sep-2014
# of transistors	7.1billion	3.84billion
# of cores	2688 (simple)	12 (functional)
Core clock	732MHz	2.6GHz, up to 3.5GHz
Peak Flops (single precision)	3.95TFLOPS	998.4GFLOPS (with AVX2)
DRAM size	6GB, GDDR5	768GB/socket, DDR4
Memory band	250GB/s	68GB/s
Power consumption	235W	135W
Price	$3,000	$2,094

Background (3/4) – How GPU works

Computing
the sum of array:

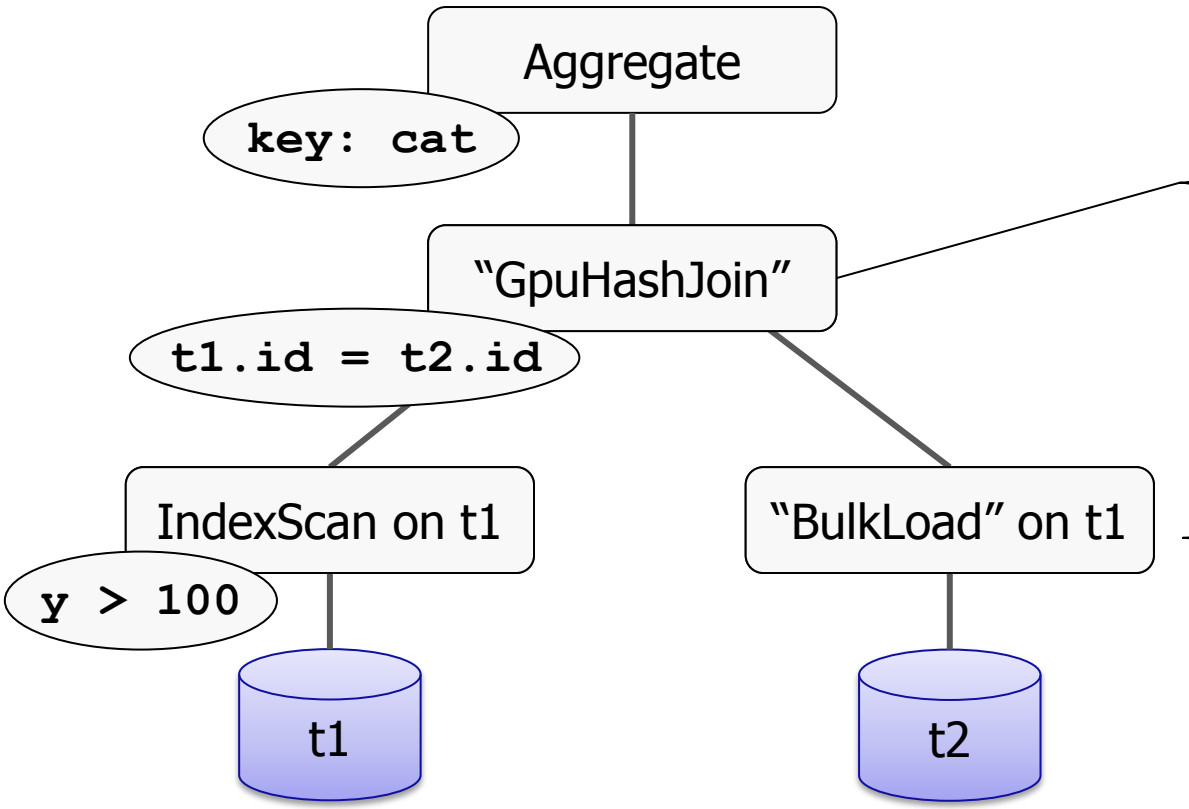
$$\sum_{i=0\ldots N-1} item[i]$$

with N-cores of GPU



Background (4/4) – Custom-Plan Interface

```
SELECT cat, avg(x) FROM t1, t2
WHERE t1.id = t2.id AND y > 100
      GROUP BY cat;
```



- Hash Join
- Merge Join
- Nested Loop
- **Custom Join**

- Seq Scan
- Index Scan
- Index-Only Scan
- Tid Scan
- **Custom Scan**

PG-Strom Features

Logics

- GpuScan ... Parallel evaluation of scan qualifiers
- GpuHashJoin ... Parallel multi-relational join
- GpuPreAgg ... Two phase aggregation
- GpuSort ... GPU + CPU Hybrid Sorting
- GpuNestedLoop (in develop)

Data Types

- Integer, Float, Date/Time, Numeric, Text

Function and Operators

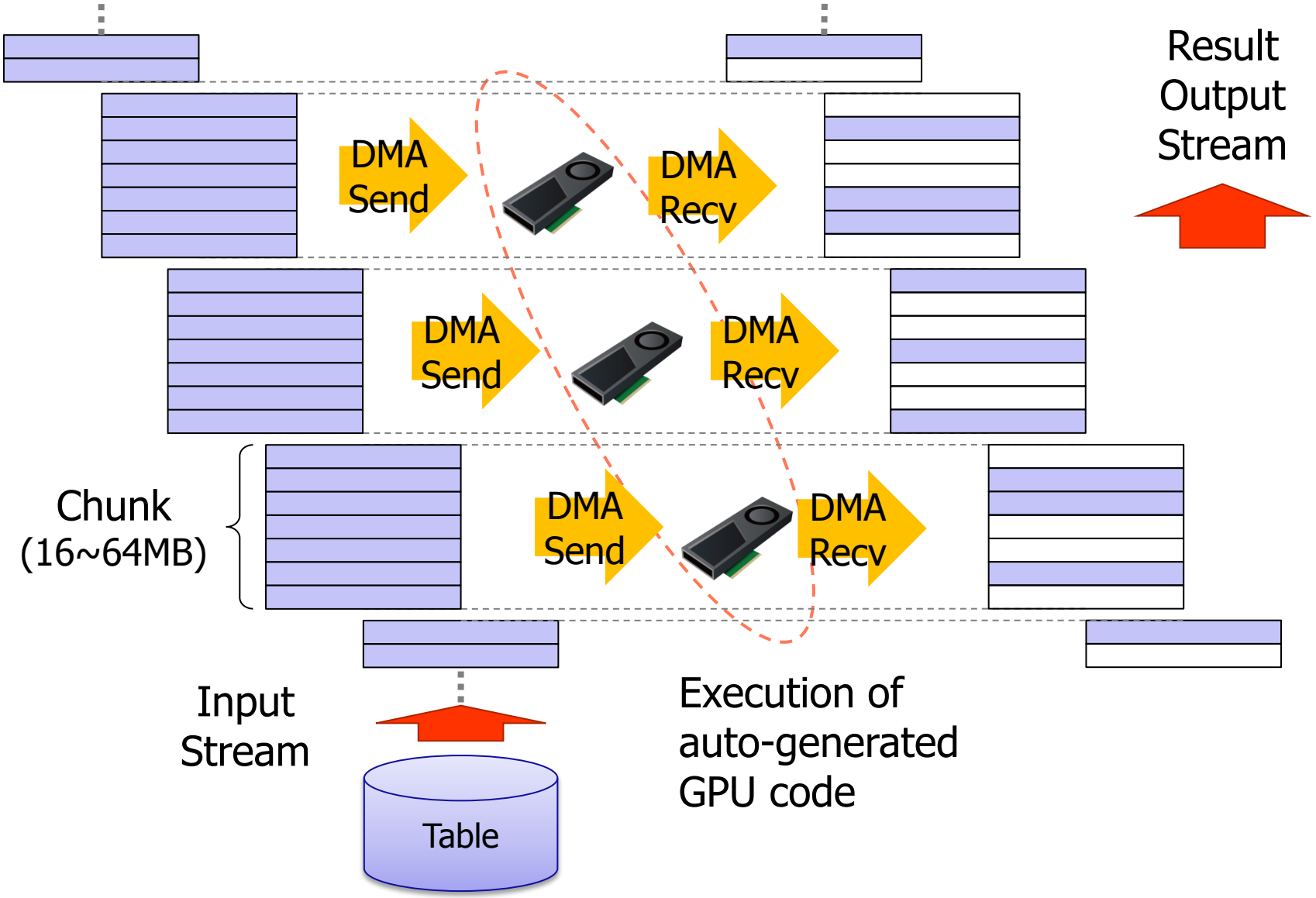
- Equality and comparison operators
- Arithmetic operators and mathematical functions
- Aggregates: count, min/max, sum, avg, std, var, corr, regr

Automatic GPU code generation

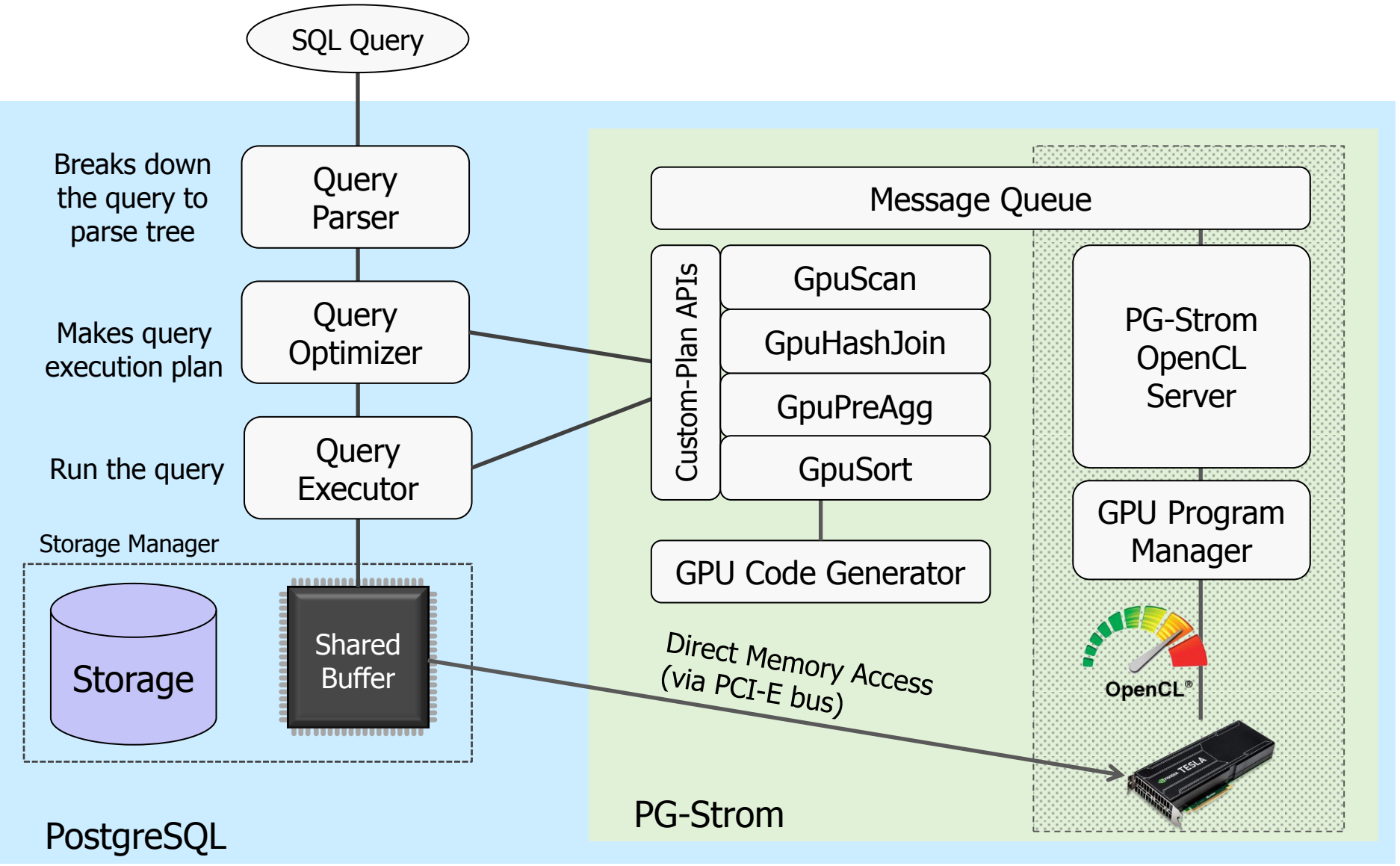
```
postgres=# SET pg_strom.show_device_kernel = on;
postgres=# EXPLAIN VERBOSE SELECT * FROM t0 WHERE sqrt(x+y) < 10;
                                                  QUERY PLAN
-------------------------------------------------------------------------------
Custom Scan (GpuScan) on public.t0  (cost=500.00..357569.35 rows=6666683 width=77)
   Output: id, cat, aid, bid, cid, did, eid, x, y, z
   Device Filter: (sqrt((t0.x + t0.y)) < 10::double precision)
   Features: likely-tuple-slot
   Kernel Source: #include "opencl_common.h"
            :
 static pg_bool_t
 gpuscan_qual_eval(__private cl_int *errcode,
                   __global kern_parambuf *kparams,
                   __global kern_data_store *kds,
                   __global kern_data_store *ktoast,
                   size_t kds_index)
 {
   pg_float8_t KPARAM_0 = pg_float8_param(kparams,errcode,0);
   pg_float8_t KVAR_8 = pg_float8_vref(kds,ktoast,errcode,7,kds_index);
   pg_float8_t KVAR_9 = pg_float8_vref(kds,ktoast,errcode,8,kds_index);

   return pgfn_float8lt(errcode,
          pgfn_dsqrt(errcode, pgfn_float8pl(errcode, KVAR_8, KVAR_9)), KPARAM_0);
 }
```

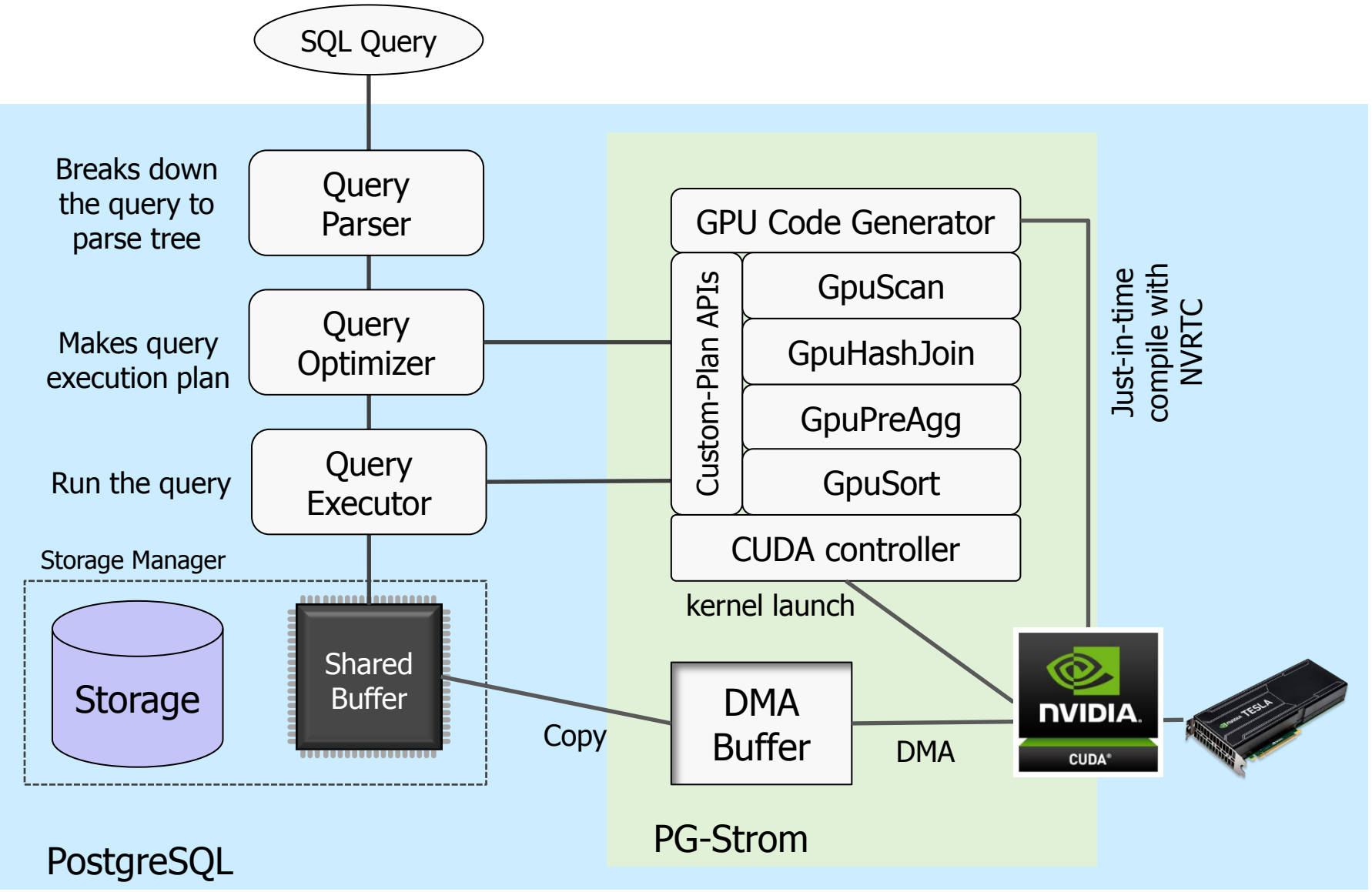
Implementation (1/3) – GpuScan



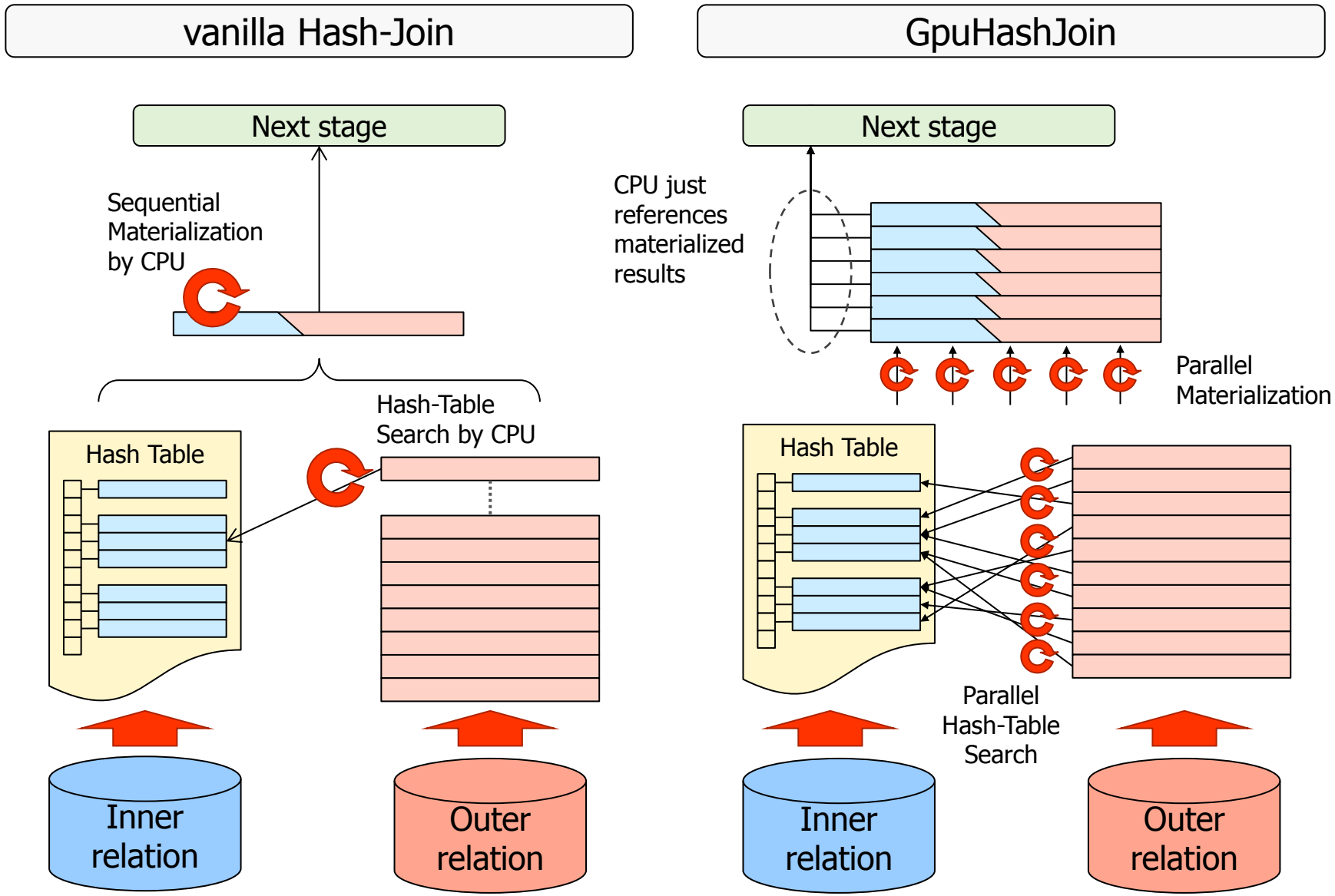
Software Architecture (1/2) – current version



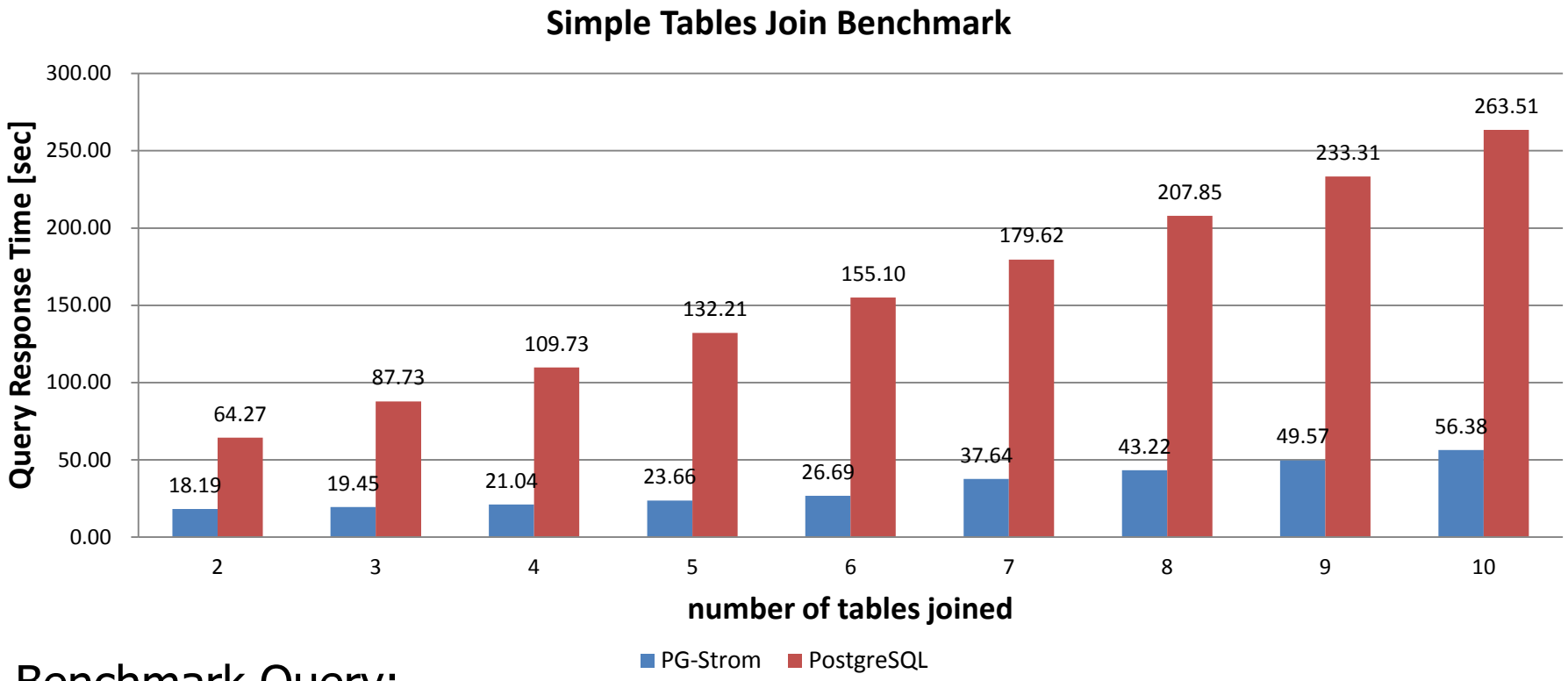
Software Architecture (2/2) – upcoming version



Implementation (2/3) – GpuHashJoin



Benchmark result (1/2) – simple tables join



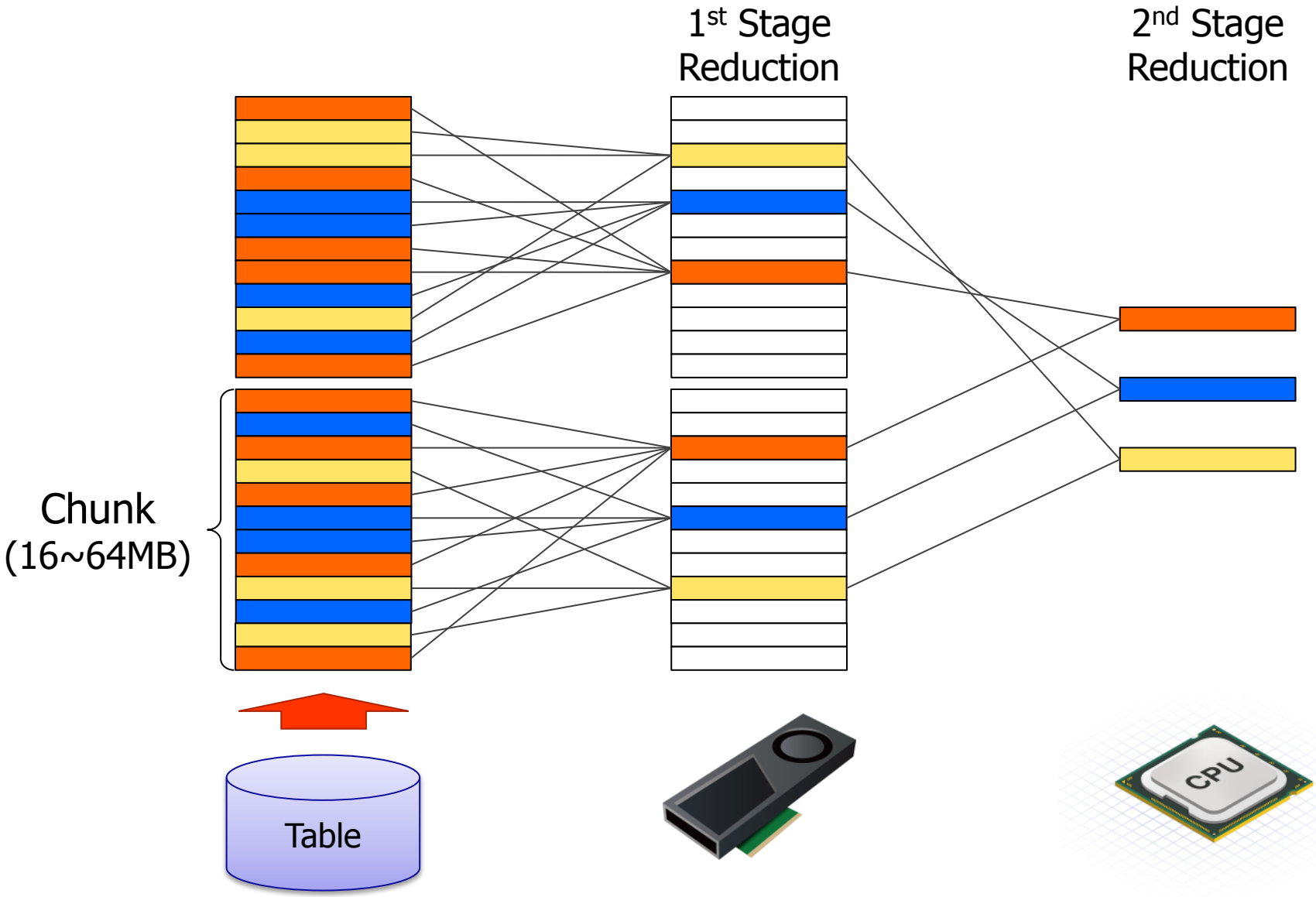
Benchmark Query:

```
SELECT * FROM t0 NATURAL JOIN t1 [NATURAL JOIN ....];
```

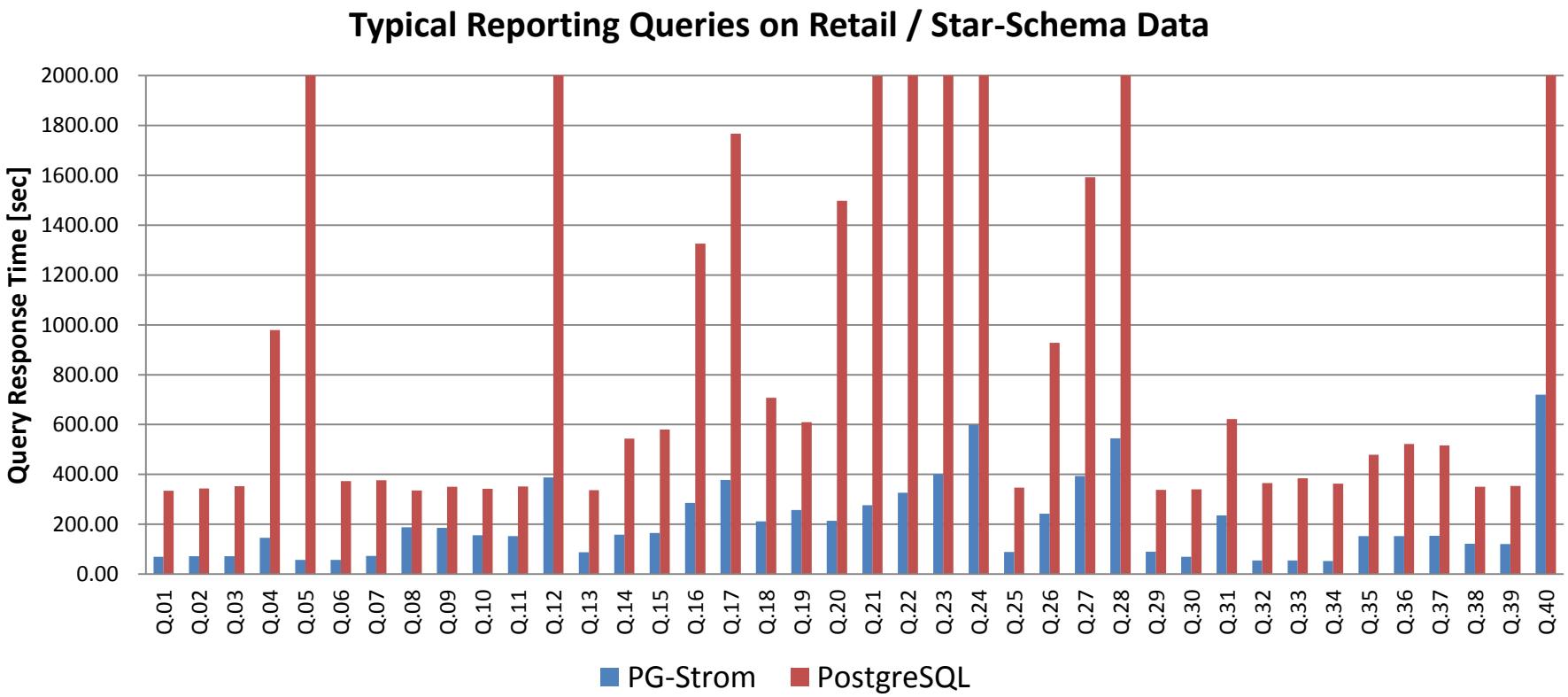
Environment:

- **t0** has 100million rows (13GB), **t1-t9** has 40,000 rows for each, all-data pre-loaded
- CPU: Xeon E5-2670v3 (12C, 2.3GHz) x2, RAM: 384GB, GPU: Tesla K20c x1

Implementation (3/3) – GpuPreAgg

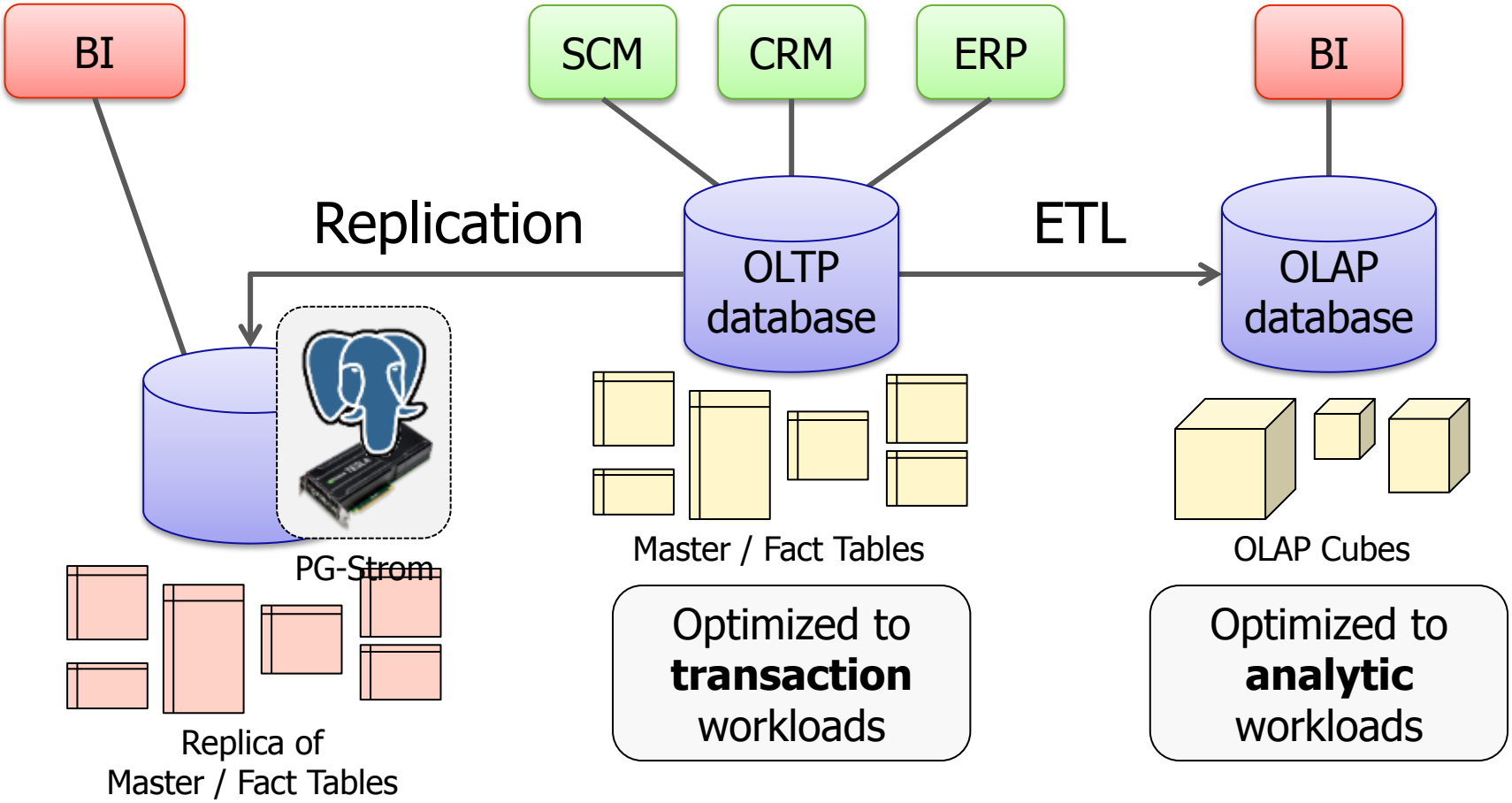


Benchmark result (2/2) – Star Schema Model



- 40 typical reporting queries
- 100GB of retail / start-schema data, all pre-loaded
- Environment
  - CPU: Xeon E5-2670v3(12C, 2.3GHz) x2, RAM: 384GB, GPU: Tesla K20c x1

Expected Scenario – Reduction of ETL



- ETL – Its design is human centric task
- Replication – much automatous task

Direction of PG-Strom

Development Plan

Current version: PG-Strom β + PostgreSQL v9.5devel

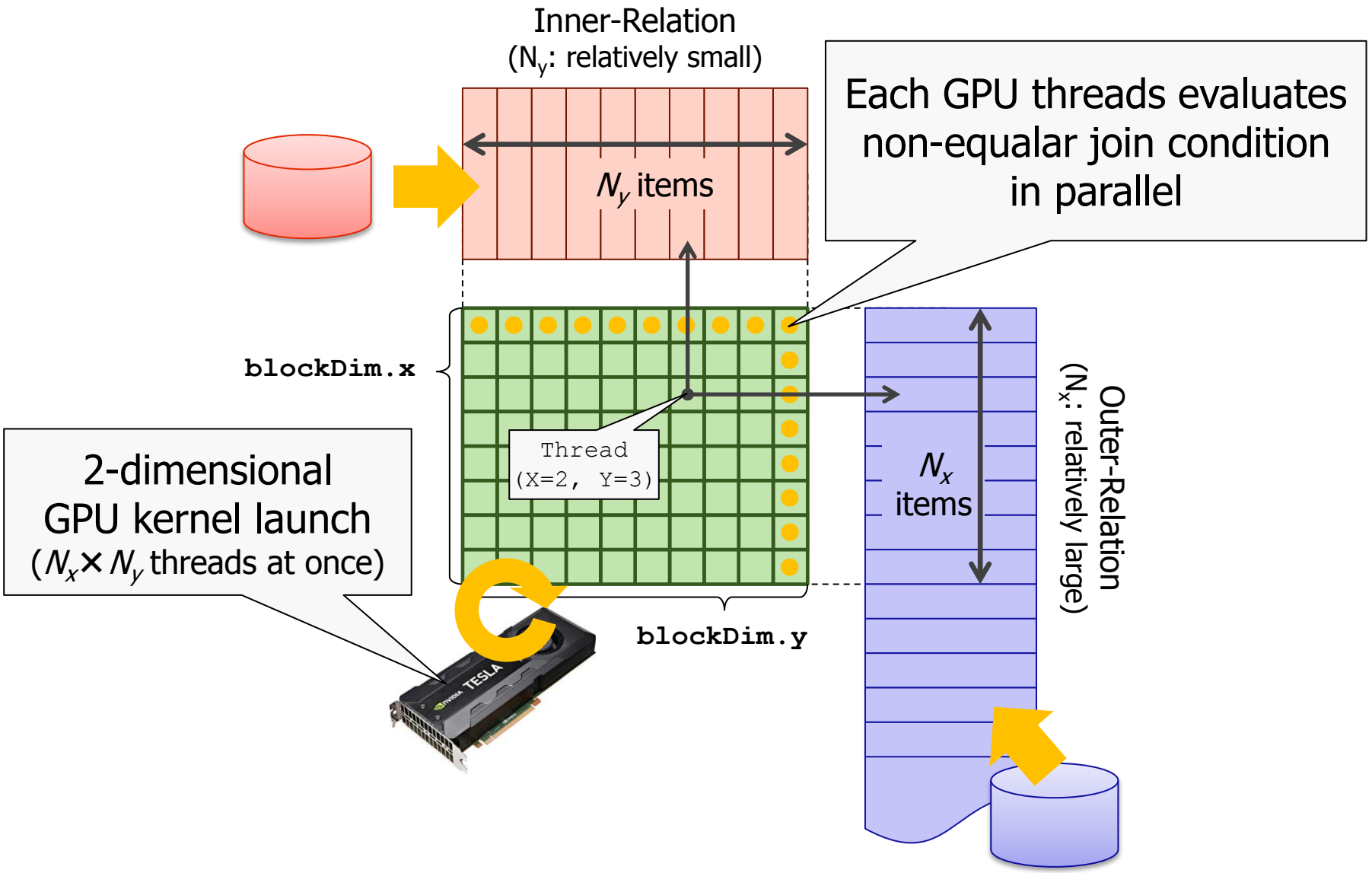
- Migration of OpenCL to CUDA
- Add support of GpuNestedLoop
- Add support multi-functional kernel
- Standardization of custom-join interface
- ...and more...?

Short term target: PostgreSQL v9.5 timeline (2015)

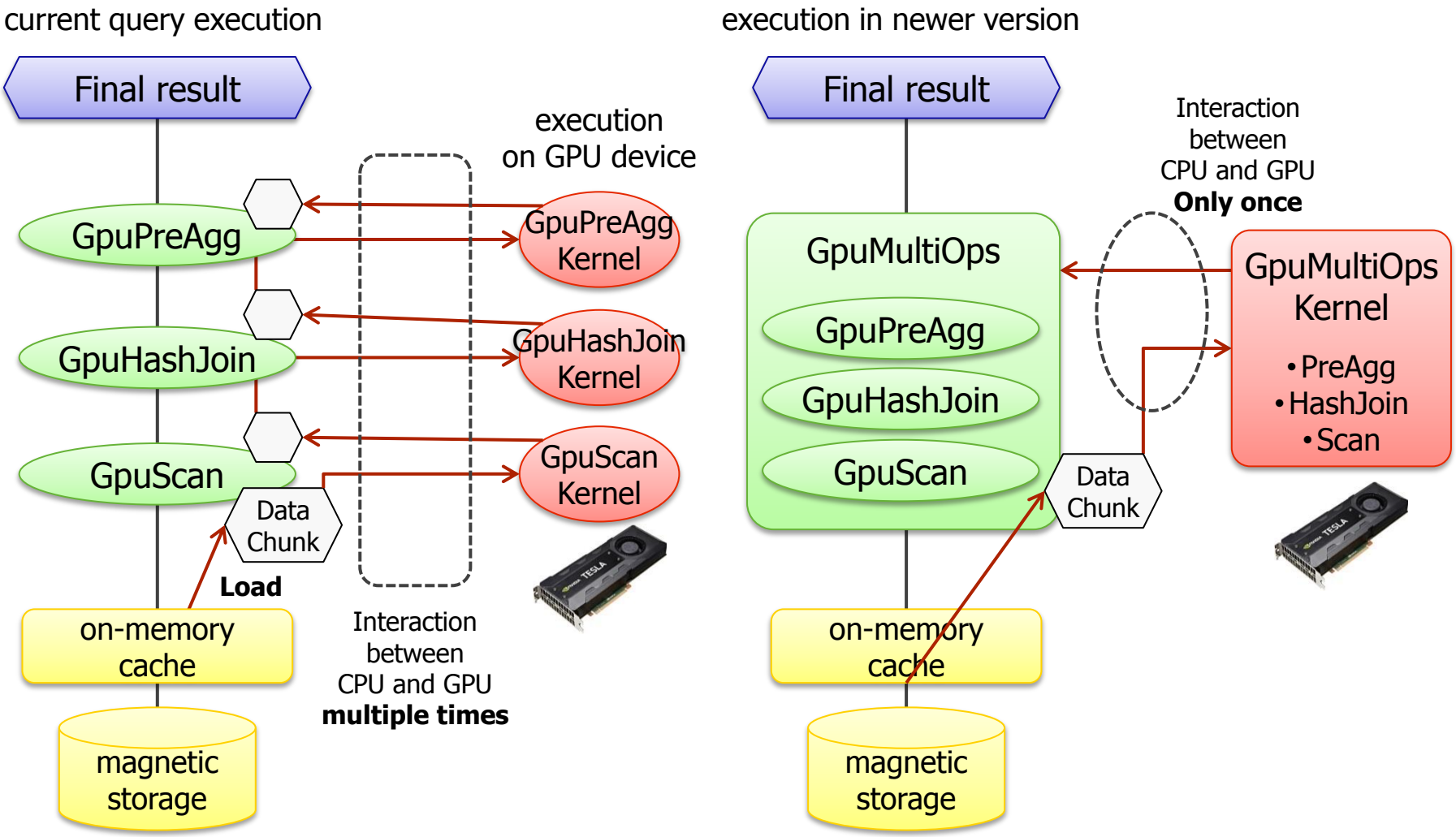
- Integration with funnel executor
- Investigation to SSD/NvRAM utilization
- Custom-sort/aggregate interface
- Add support for spatial data types (?)

Middle term target: PostgreSQL v9.6 timeline (2016)

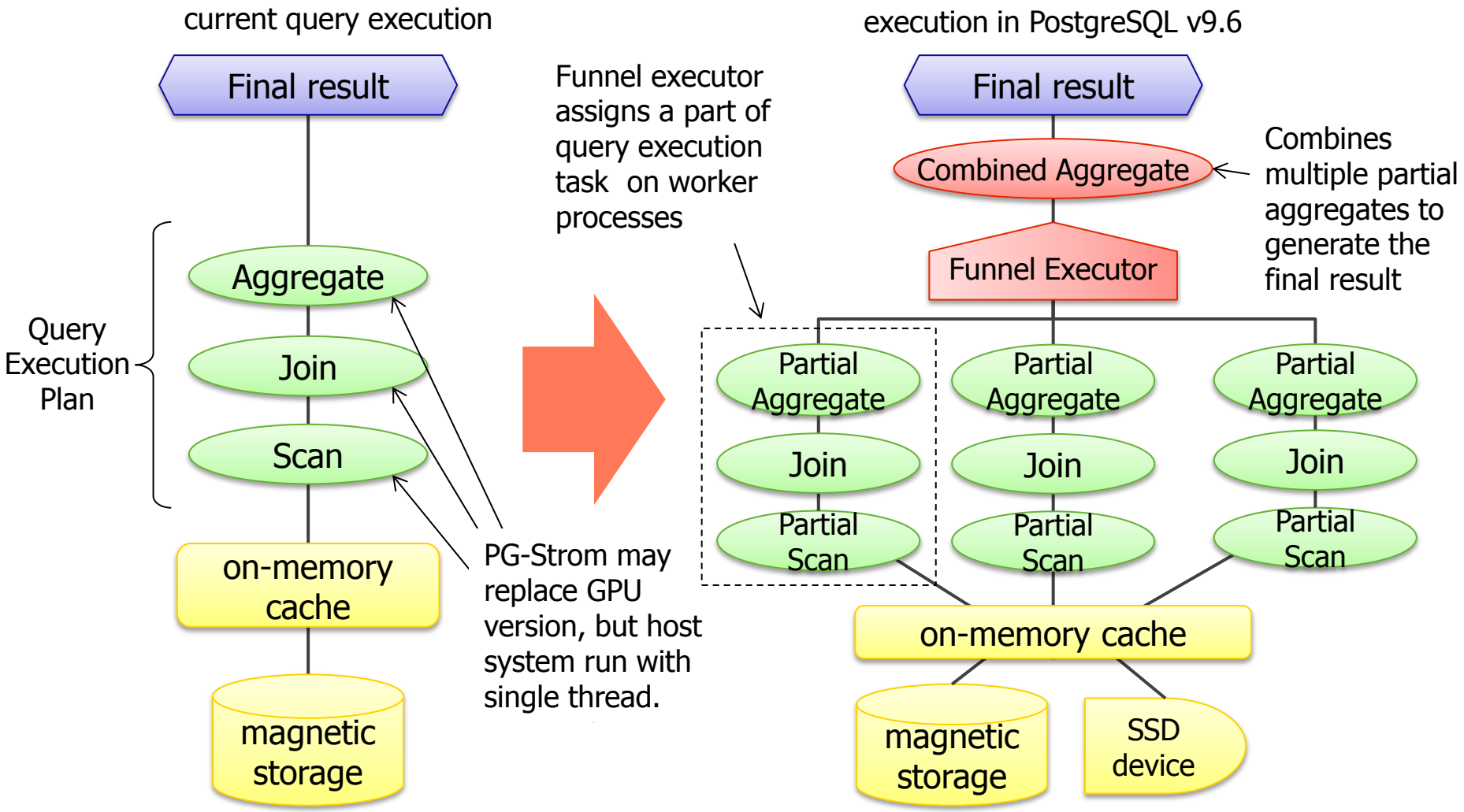
Enhancement Idea (1/3) – GpuNestedLoop



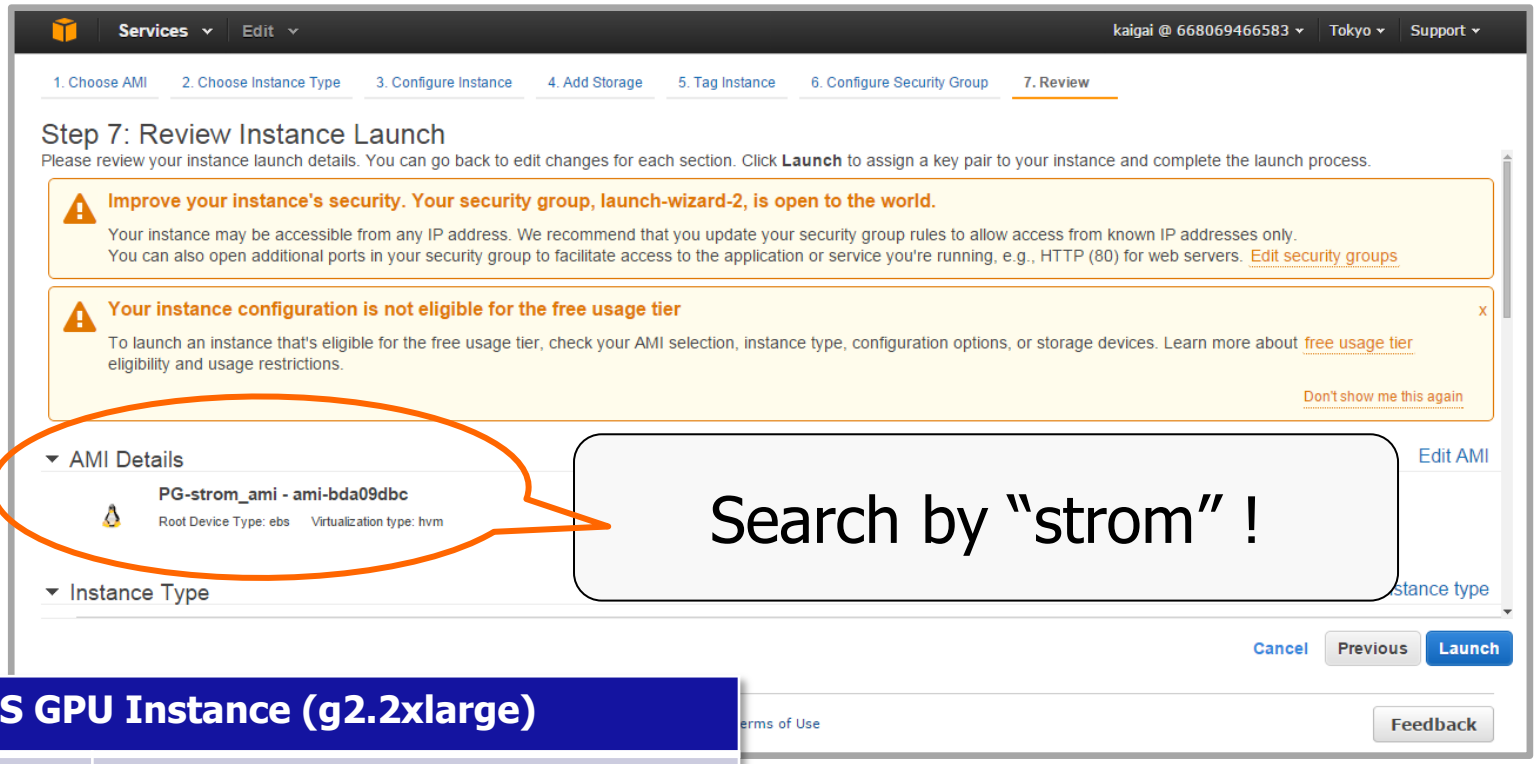
Enhancement Idea (2/3) – Multi-functional GPU kernel



Enhancement Idea (3/3) – Funnel executor integration



Let's try – Deployment on AWS



AWS GPU Instance (g2.2xlarge)	
CPU	Xeon E5-2670 (8 xCPU)
RAM	15GB
GPU	NVIDIA GRID K2 (1536core)
Storage	60GB of SSD
Price	$0.898/hour, $646.56/mon (*) Price for on-demand instance on Tokyo region at Nov-2014

Welcome to your involvement

How to be involved?

- as a user
- as a developer
- as a business partner

Source code

- https://github.com/pg-strom/devel

Contact US

- e-mail: kaigai@ak.jp.nec.com
- twitter: @kkaigai

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