Accelerating Data Warehousing Applications Using General Purpose GPUs

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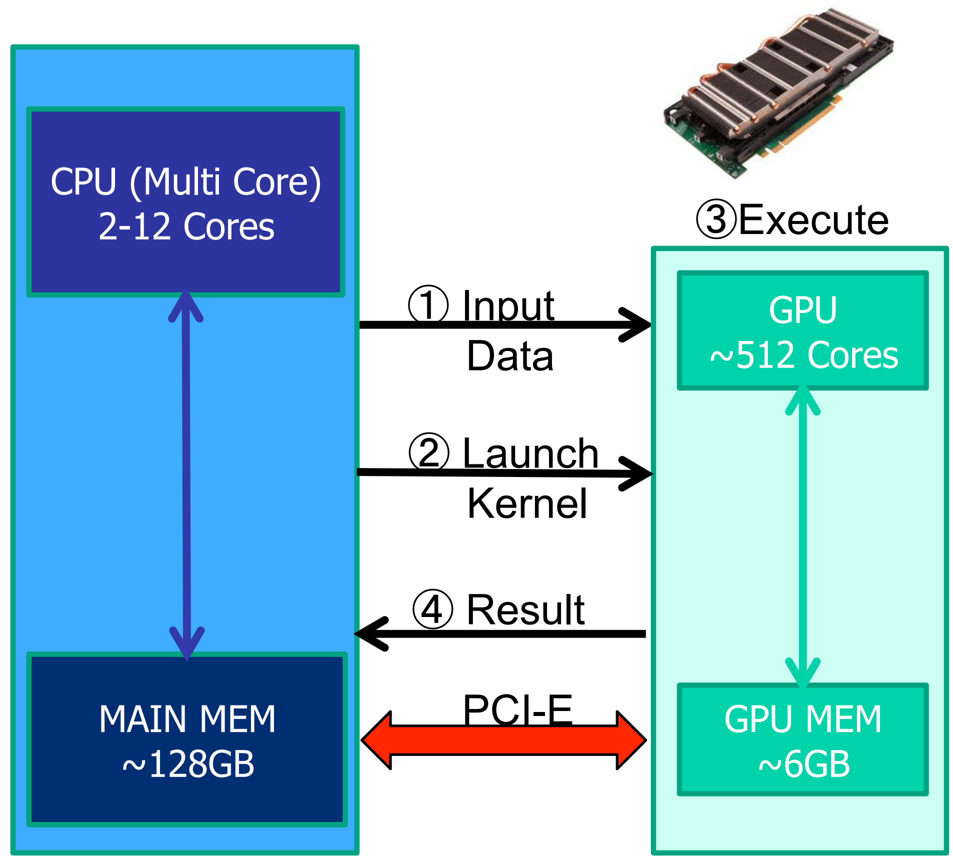
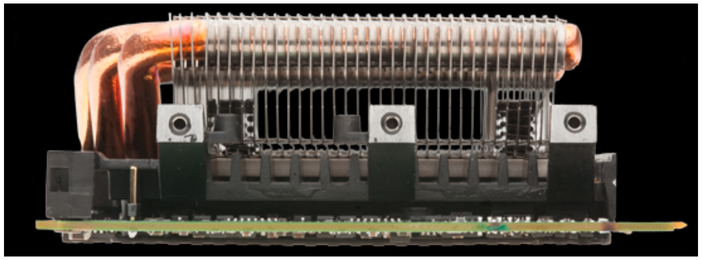
The General Purpose GPU

- GPU is a many core co-processor
  - 10s to 100s of cores
  - 1000s to 10,000s of concurrent threads
  - CUDA and OpenCL are the dominant programming models
- Well suited for data parallel apps
  - Molecular Dynamics, Options Pricing, Ray Tracing, etc.
- Commodity: led by NVIDIA, AMD, and Intel



Enterprise: Amazon EC2 GPU Instance



NVIDIA Tesla

Amazon EC2 GPU Instances

Elements	Characteristics
OS	CentOS 5.5
CPU	2 x Intel Xeon X5570 (quad-core "Nehalem" arch, 2.93GHz)
GPU	2 x NVIDIA Tesla "Fermi" M2050 GPU Nvidia GPU driver and CUDA toolkit 3.1
Memory	22 GB
Storage	1690 GB
I/O	10 GigE
Price	$2.10/hour

Data Warehousing Applications on GPUs

- The good
  - Lots of potential data parallelism
  - If data fits in GPU mem, 2x—27x speedup has been shown
- The bad
  - Very large data set (will not even fit in host memory)
  - I/O bound (GPU has no disk)
  - PCI data transfer takes 15–90% of the total time*

Order	Price	Discount
0	10	10%
1	20	20%
2	10	15%
3	51	14%
4	33	13%
5	22	10%
……	……	……

* B. He, M. Lu, K. Yang, R. Fang, N. K. Govindaraju, Q. Luo, and P. V. Sander. Relational query co-processing on graphics processors. In TODS, 2009.

This Work

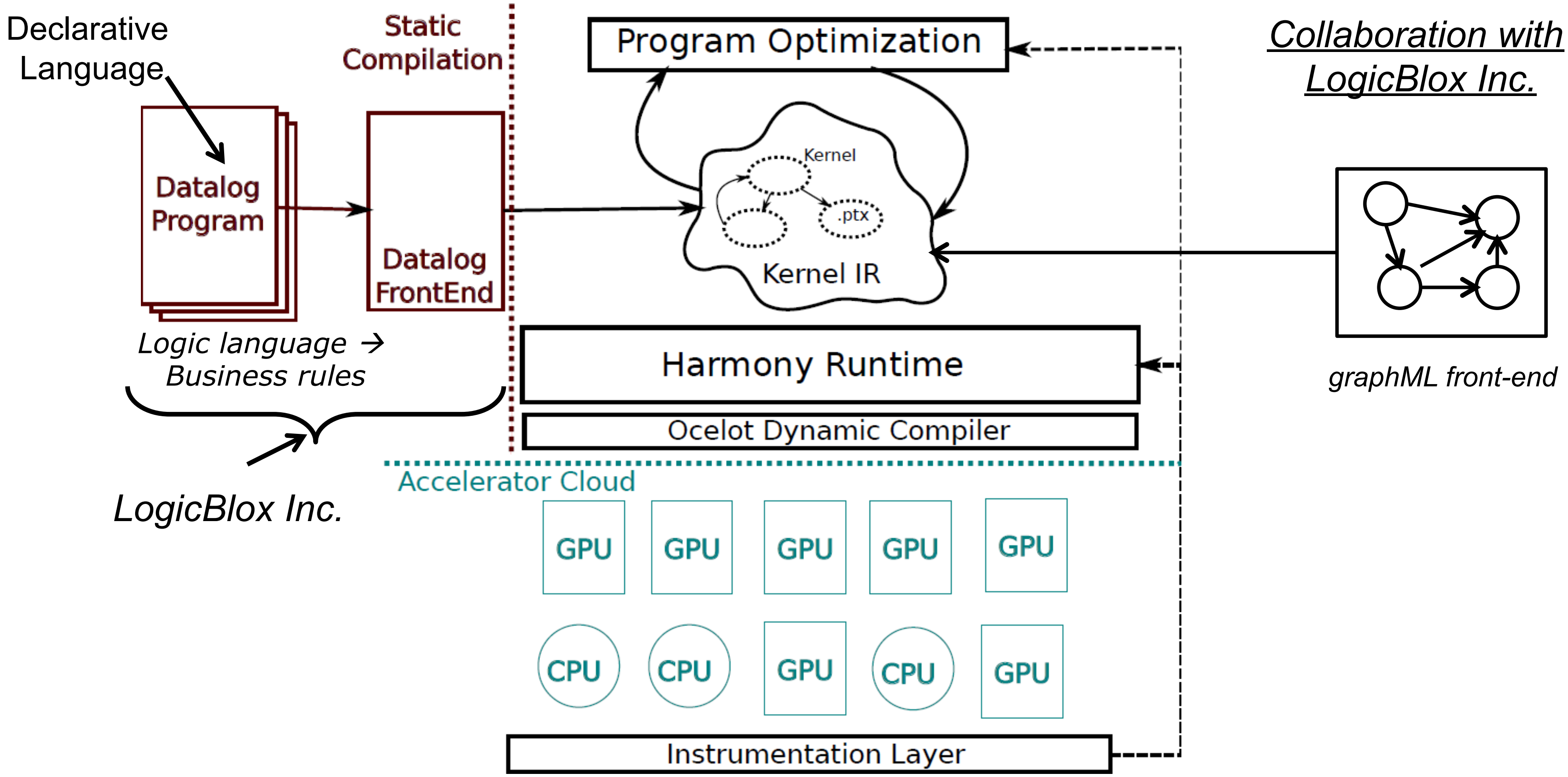
- Goal: Enable Large data warehousing applications on GPUs

- Assumptions
  - In-memory system
    - Host memory, not GPU memory
  - Not OLTP (*Online Transaction Processing*) type simple queries
    - Focus on data analysis instead of data entry/retrieval

Research Thrusts

- I: Optimized implementations of primitives
  - Relational algebra (RA)
  - Data management within the GPU memory hierarchy
- II: Data movement optimizations
  - Between host and accelerators
  - Within an accelerator
- III: In-core processing
  - Cluster wide memory aggregation techniques
  - Change the ratio of host memory size to accelerator memory size

Red Fox: Execution Environment for the Enterprise



- Bridge the x86-based Database Enterprise platform and Database backend with NVIDIA accelerators
- 10x-100x targeted improvement in application speedup

Thrust I: Optimized Primitives

- Optimized implementation of each relational algebra (RA) operator
  - Synthesized from micro-primitives
  - Implemented as a CUDA/PTX kernel template and available as a library
- The Redfox compiler synthesizes an application by instantiating templated skeletons of these primitives
  - Provides a framework for optimizations (e.g. kernel fusion)

Relational Algebra Operators in GPU

Operator	NVIDIA C2050	Phenom 9570	Speedup
Inner join	26.4-32.3 GB/s	0.11-0.63 GB/s	> 42x
Select	104.2 GB/s	2.55 GB/s	41x
Set operators	45.8 GB/s	0.72 GB/s	64x
Projection	54.3 GB/s	2.34 GB/s	23x
Cross product	98.8 GB/s	2.67 GB/s	37x

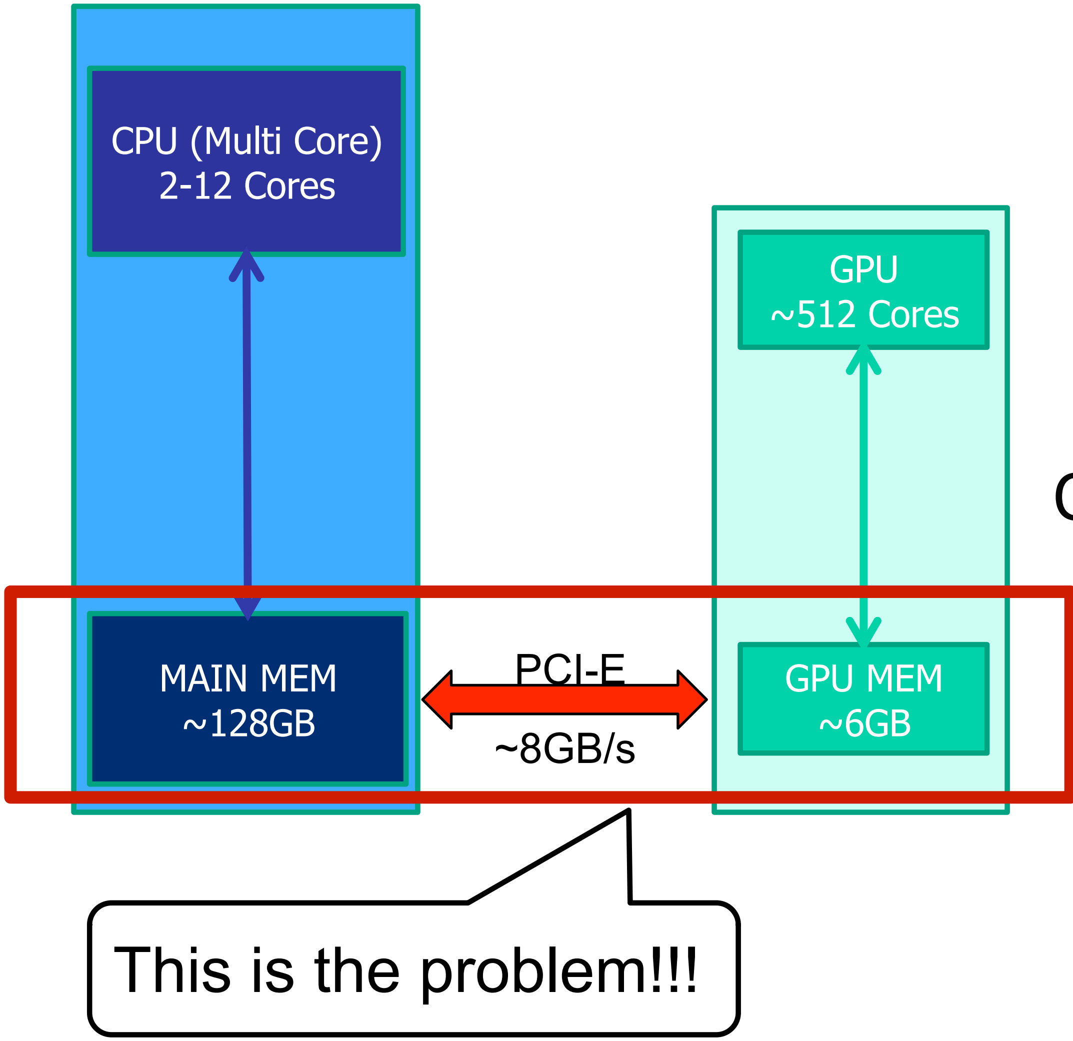
- 10 Datalog microbenchmarks running
- Metrics based on random data sets, compressed rows and 16M tuple relations
- Cost of initial sort not included

Status

- Moving Red Fox to the Amazon EC2
- Robustness extensions across
  - Scale and size of tables
  - Size and diversity of data types
- Performance extensions
  - Single node and multi-node implementations
    - Ocelot remote device interface
    - Using multiple GPU configurations

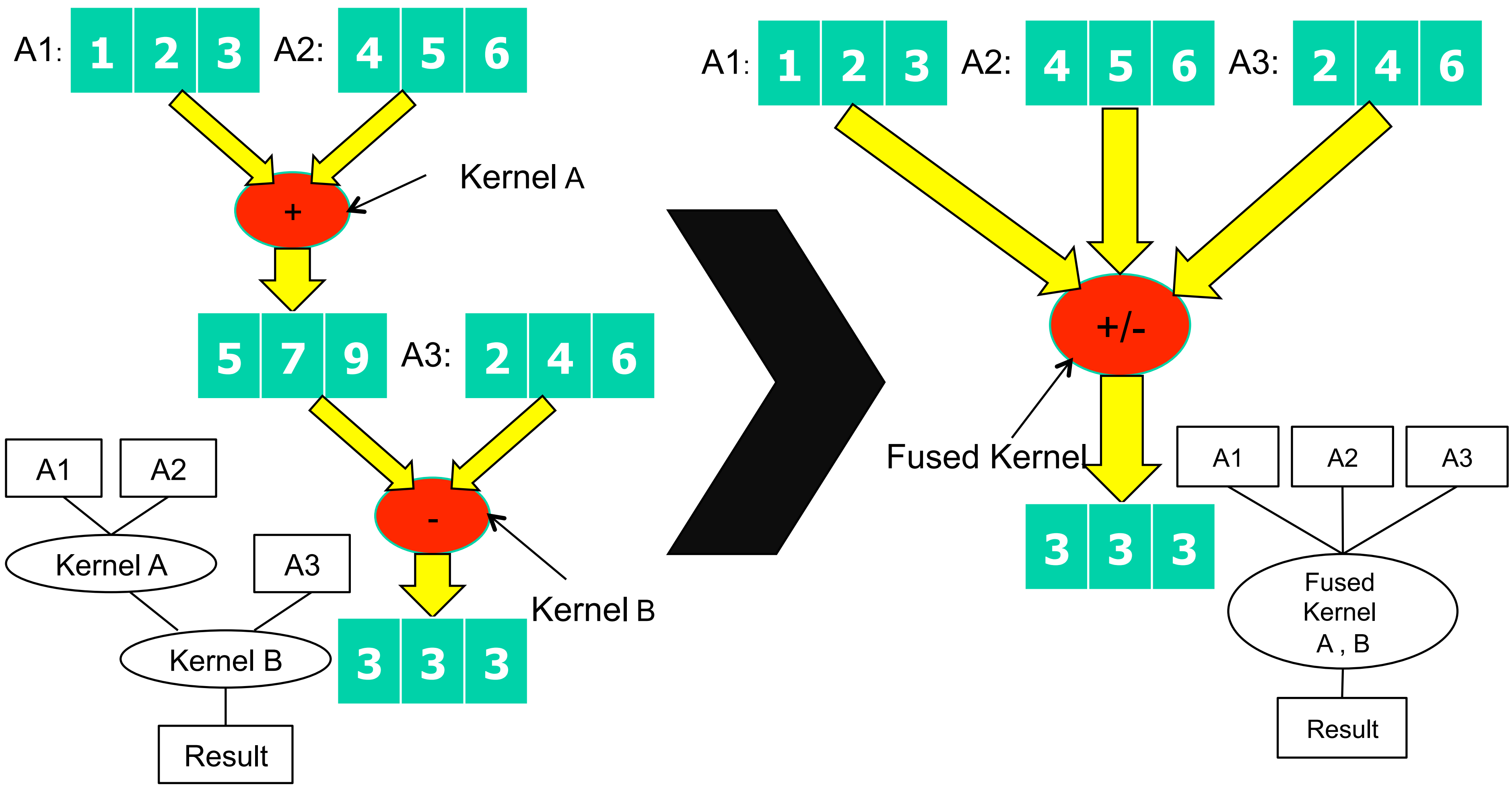
Thrust II: Optimization of Data Movement

Collaboration with NEC Inc.



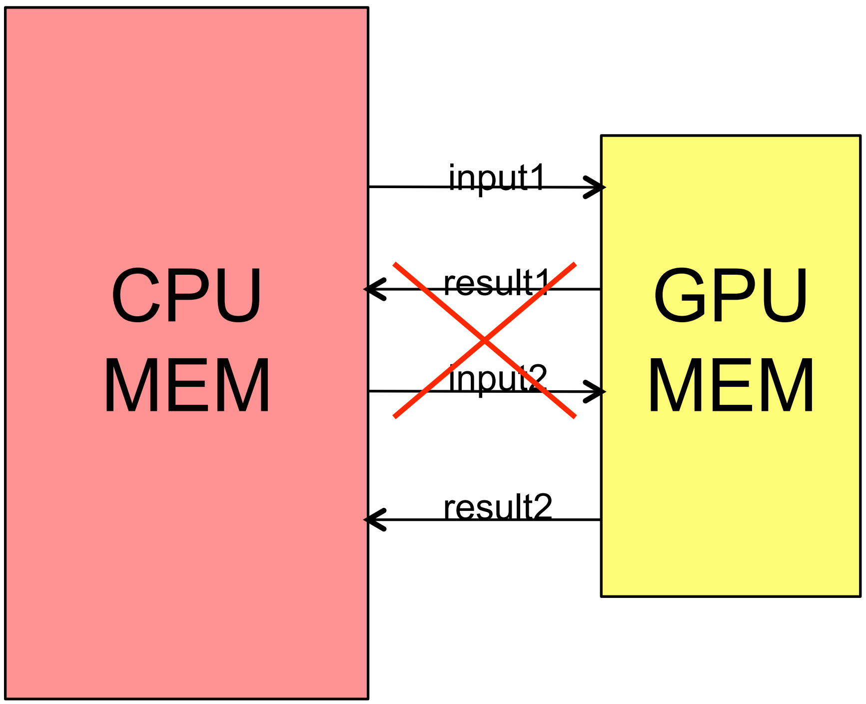
Our solution is Kernel Fusion

Kernel Fusion

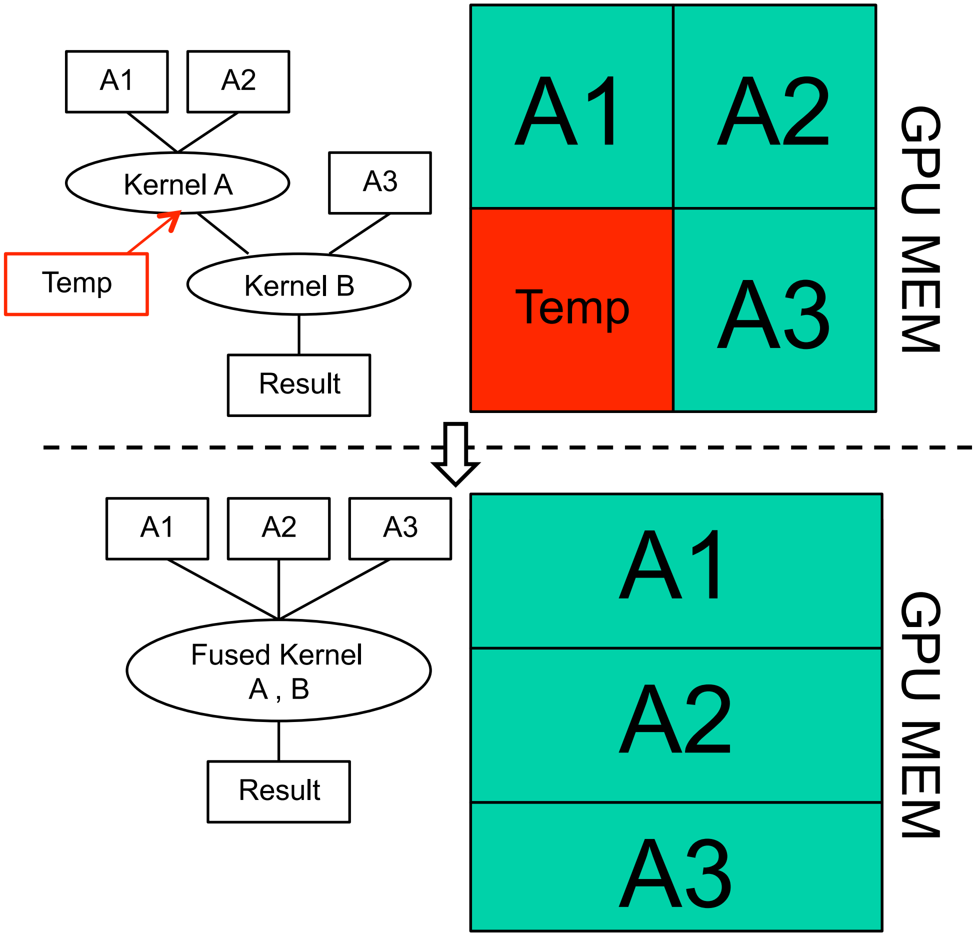


Benefits of Kernel Fusion-1

Reduce Data Transfer

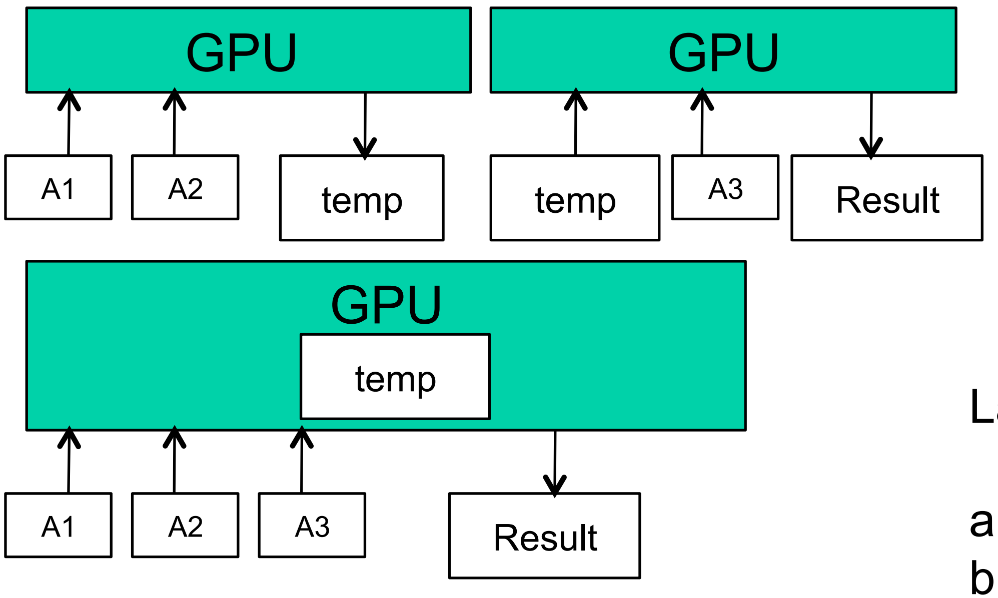


Reduce Temp Storage



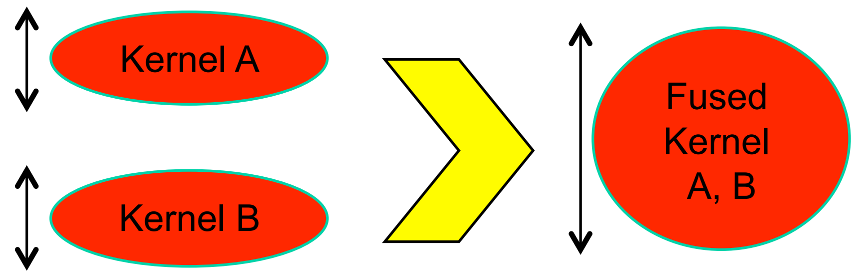
Benefits of Kernel Fusion-2

Faster Computation



Traverse the data only ONCE

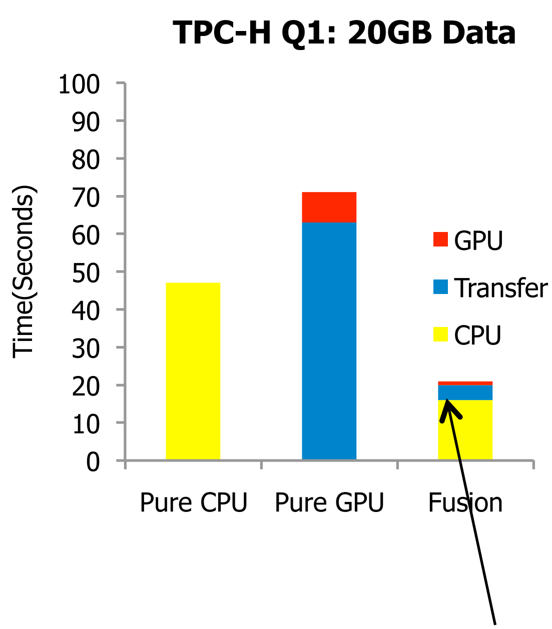
Enable More Optimization

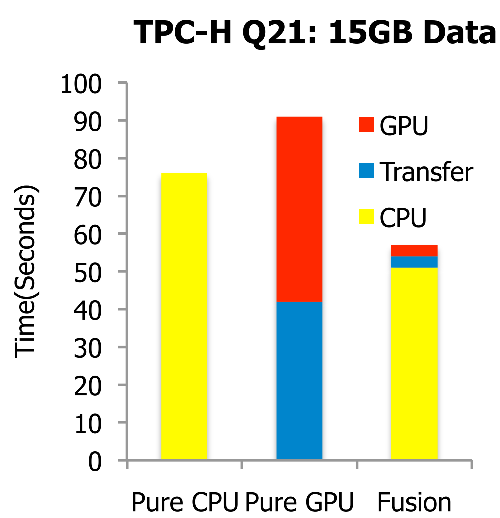


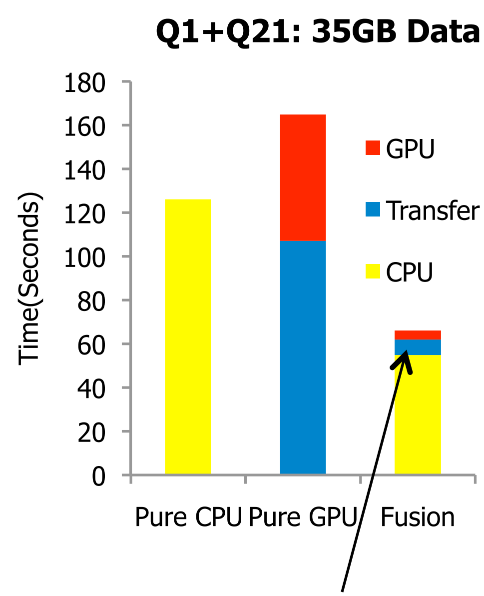
Larger code is good for other optimizations:

a) instruction scheduling,
b) register assignment,
c) constant propagation
……

Preliminary Result (2 Quad-Core CPU, C2070 GPU)



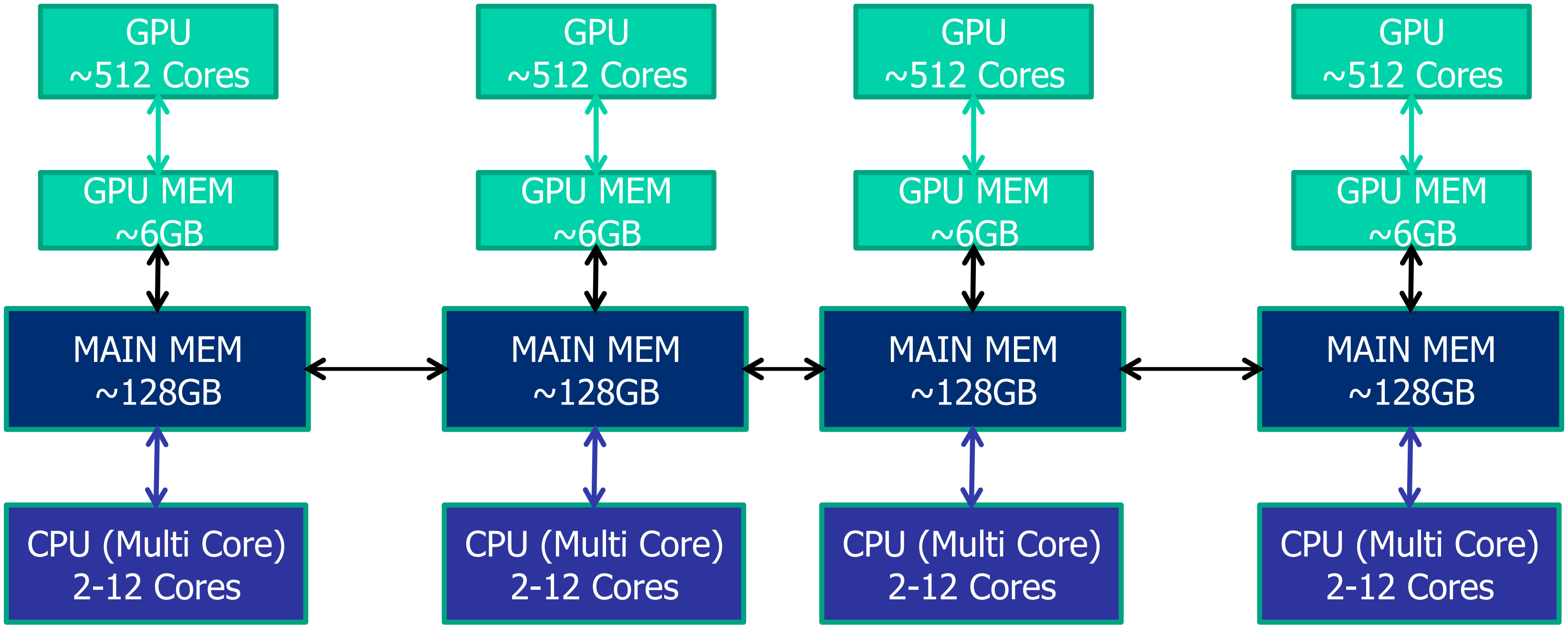




Fused across Queries

- Part of the query is run on CPU
- Transfer and GPU Computation time is much smaller

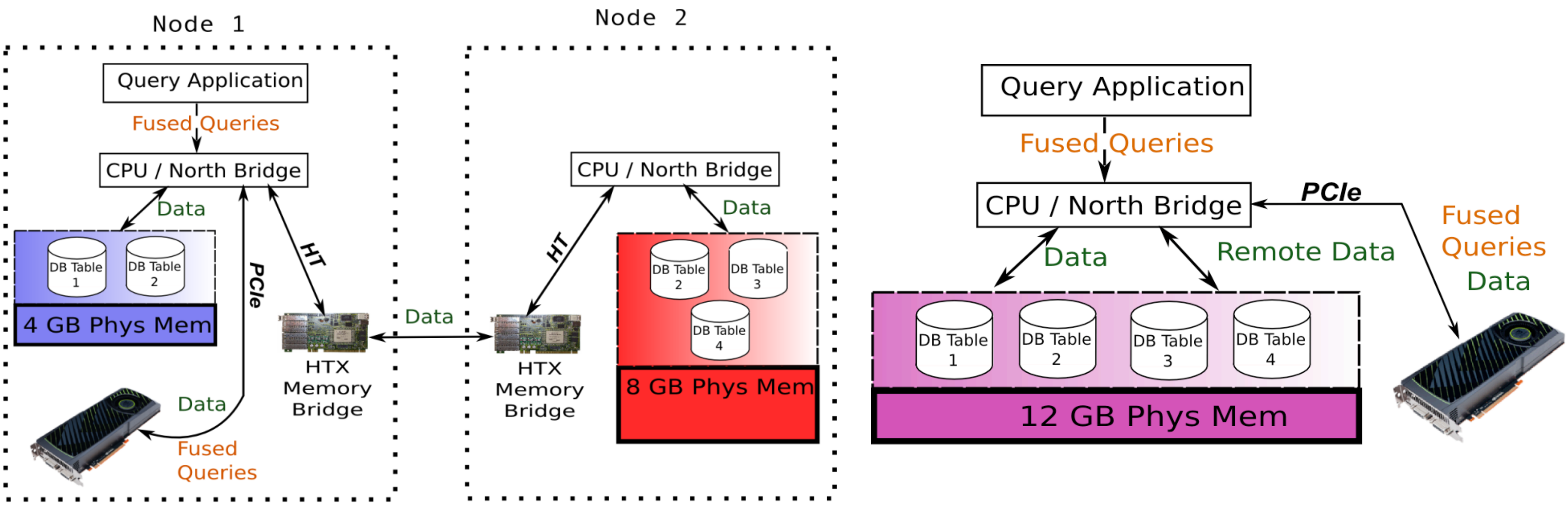
Thrust III: Cluster-based Memory Aggregation



- Hardware support for global non-coherent, physical address space system
- Change the ratio of *host-memory* : *GPU-memory*

Global Address Space Support for In-Core Databases

Collaboration with AIC Inc. & University of Heidelberg



- Use of low-latency, commodity network (HyperTransport) allows global, non-coherent access to remote memory
- Query app sees one large database / host memory from the application level
- Global address support can be extended in the future to support GPU memory
  - Applications could remotely read/write a remote GPU's memory without needing to involve its OS or CPU

Conclusions

- Fast GPU implementations of RA operators provide opportunity to run large data warehousing applications on GPU.

- Data movement optimization (Kernel Fusion) saves the memory transfer time and speeds up the computation time.

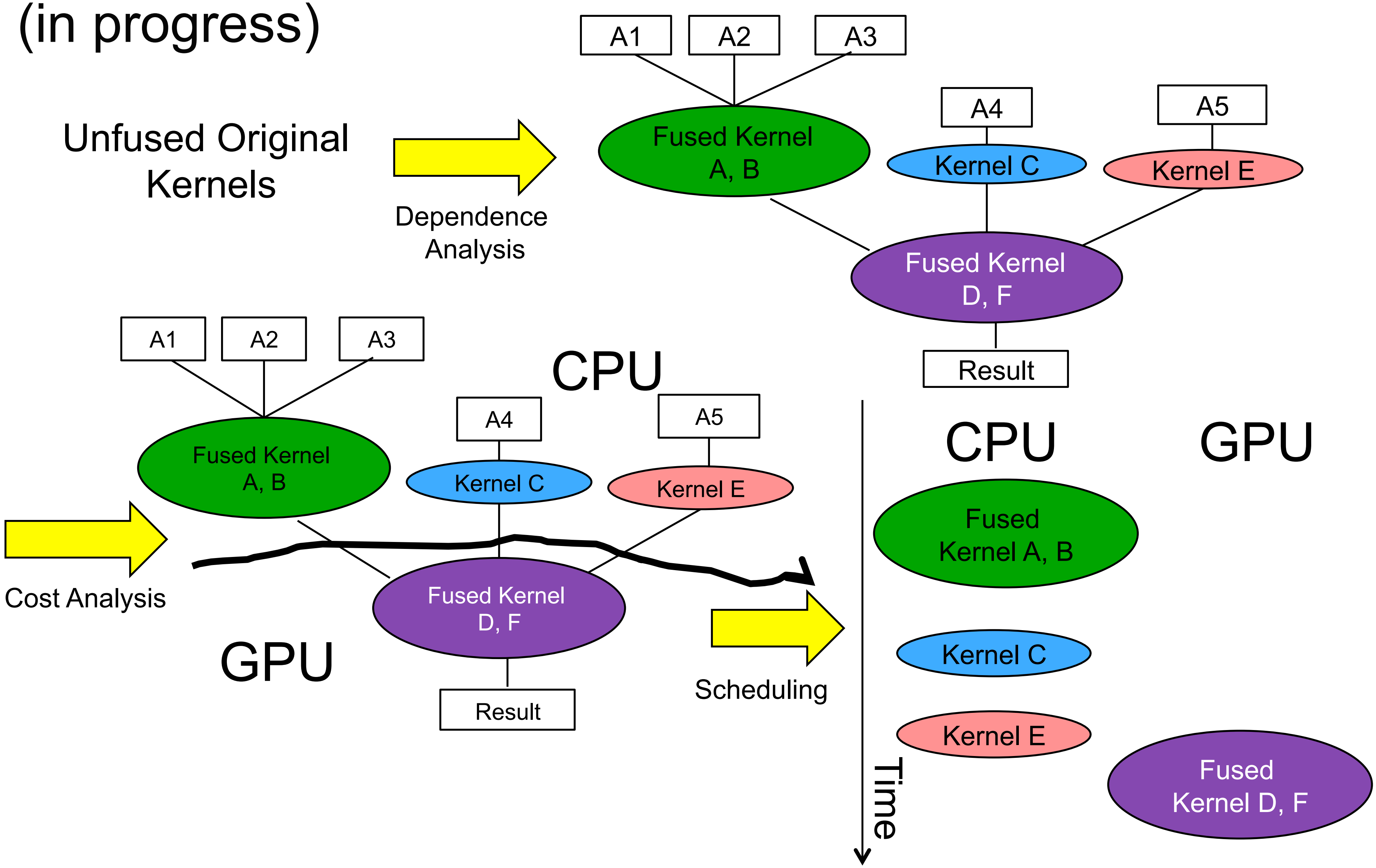
- New Memory Hierarchy (GAS) offers a larger logical memory for GPU database system.

Thank You

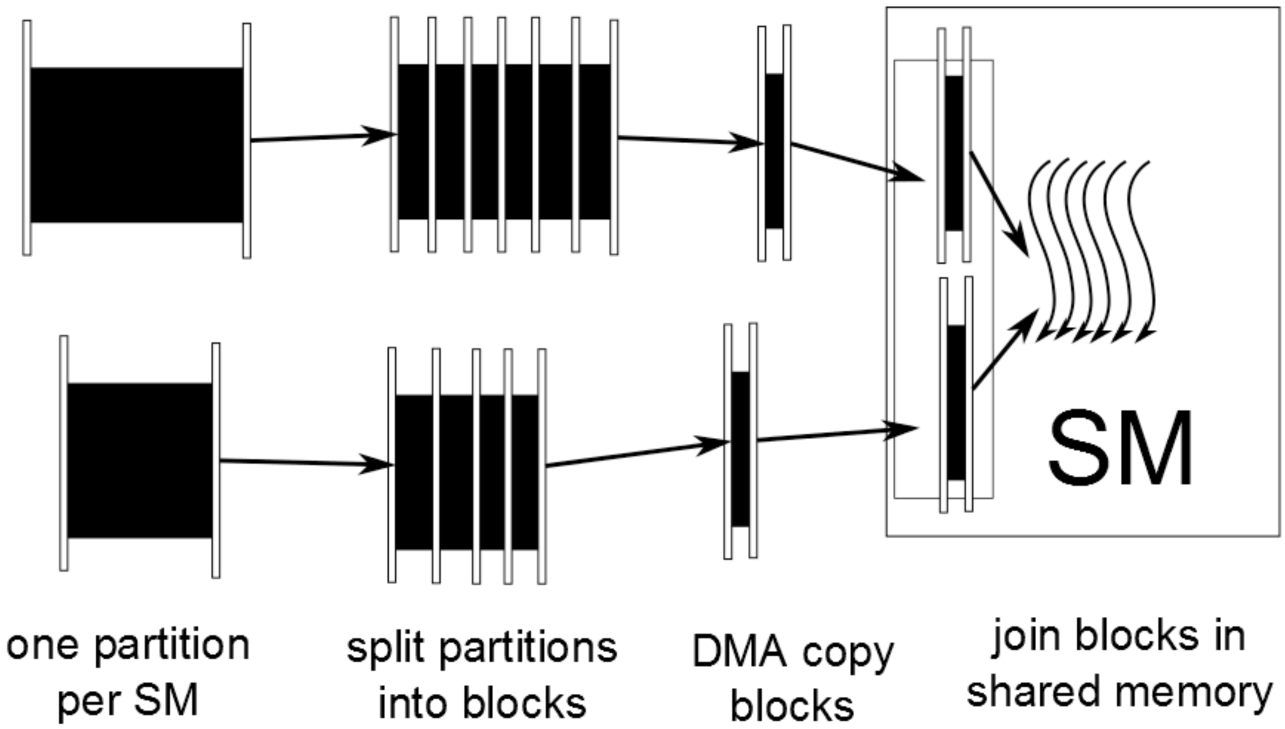
Questions?

Backup

Efficient Data Movement – Intelligent Scheduling (in progress)



Inner Join



Blocking into pages, shared memory buers, and transaction sized chunks makes memory accesses ecient.