Beyond the Wall:
Near-Data Processing for Databases

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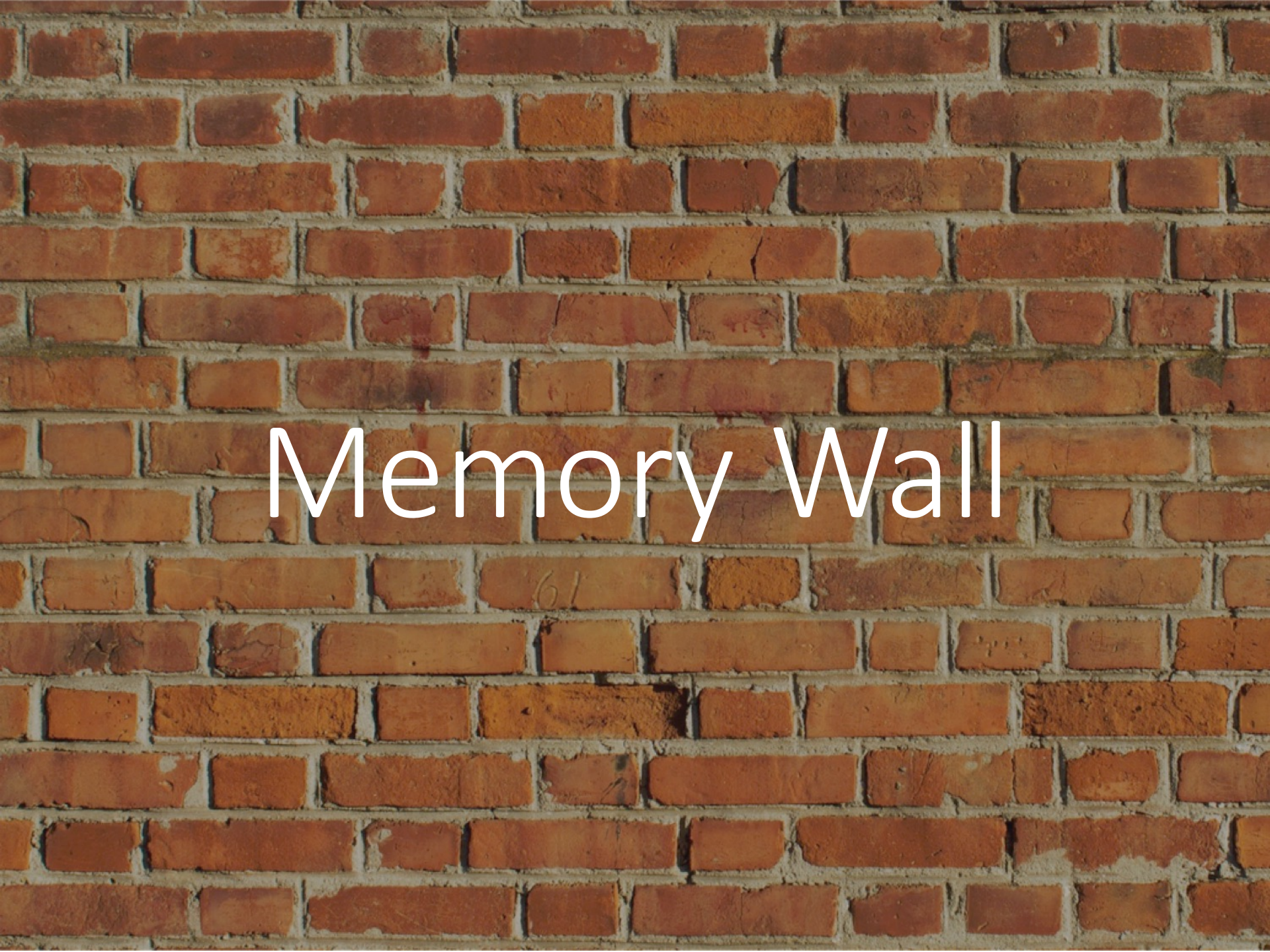
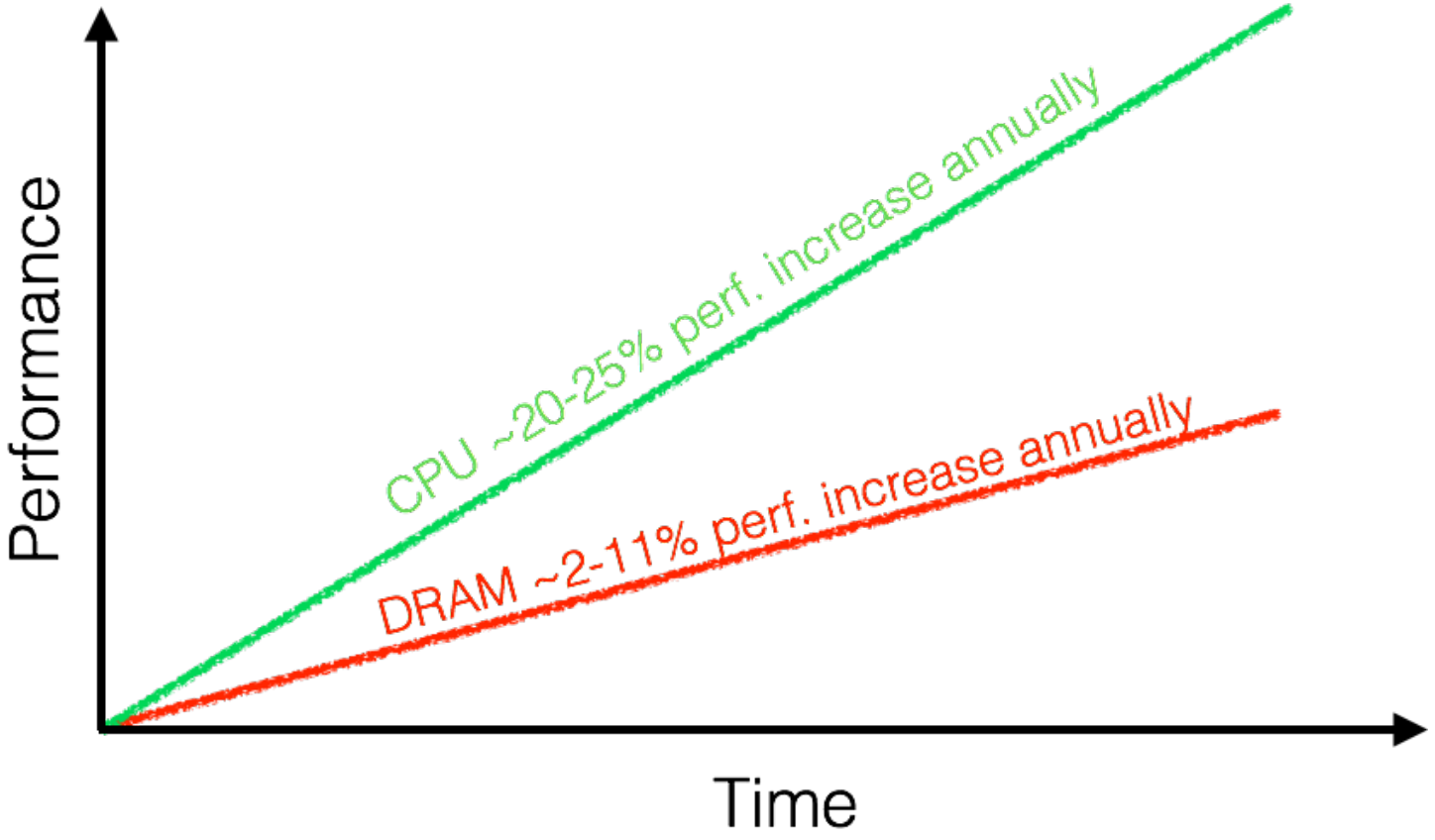
HARVARD
UNIVERSITY

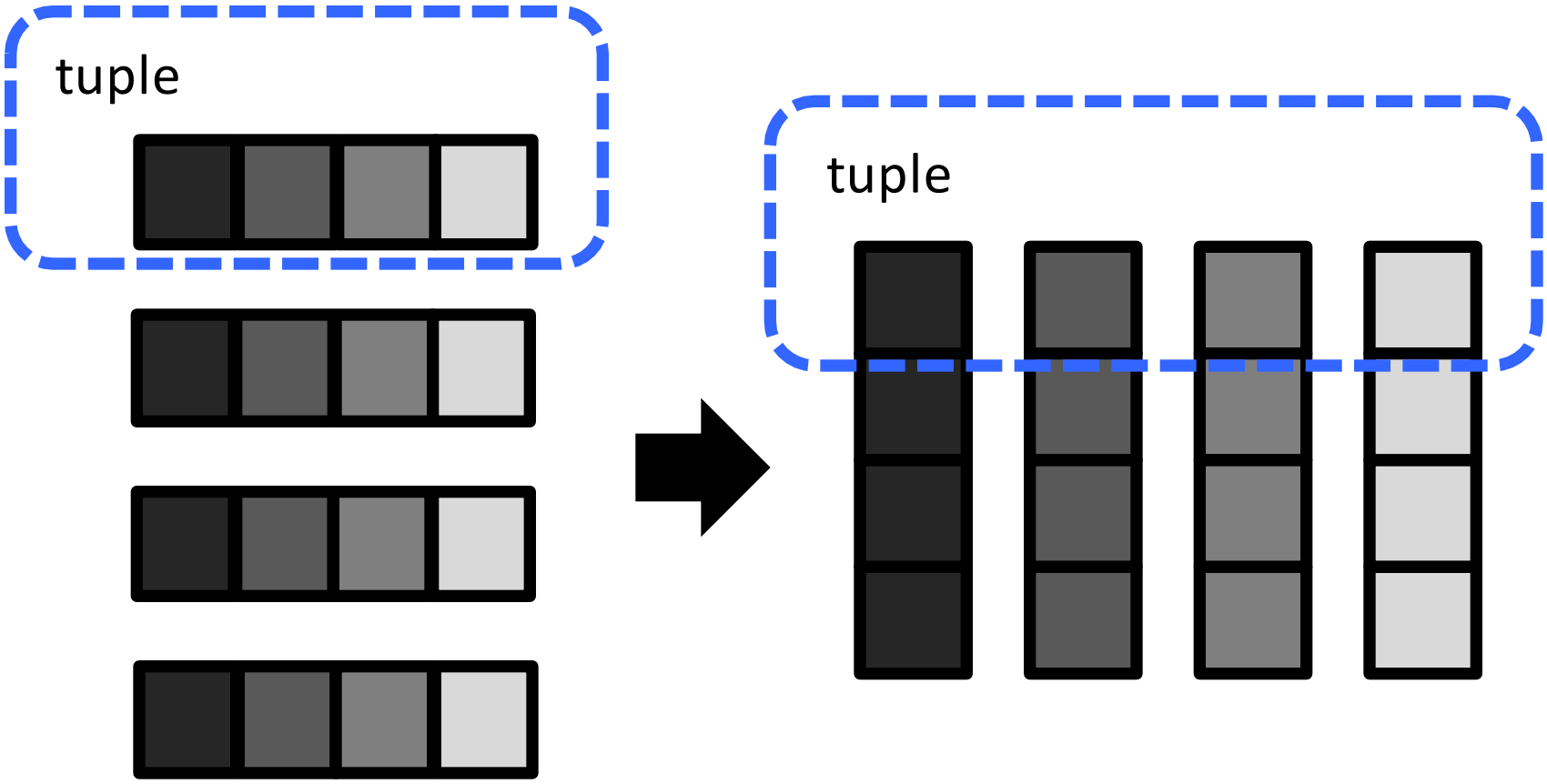

Memory Wall

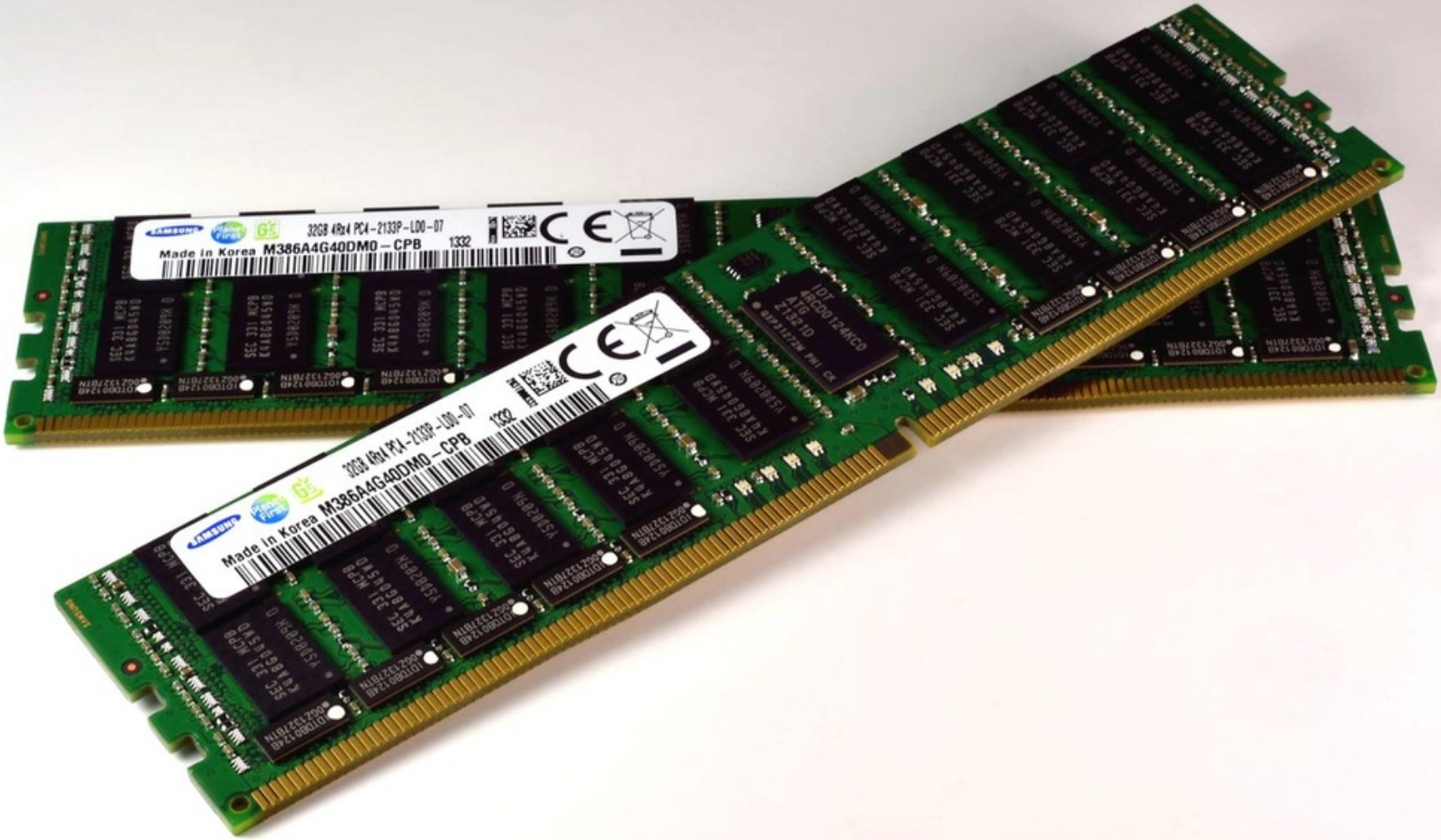
Memory Wall


Performance
CPU ~20-25% perf. increase annually
DRAM ~2-11% perf. increase annually
Time

Row store

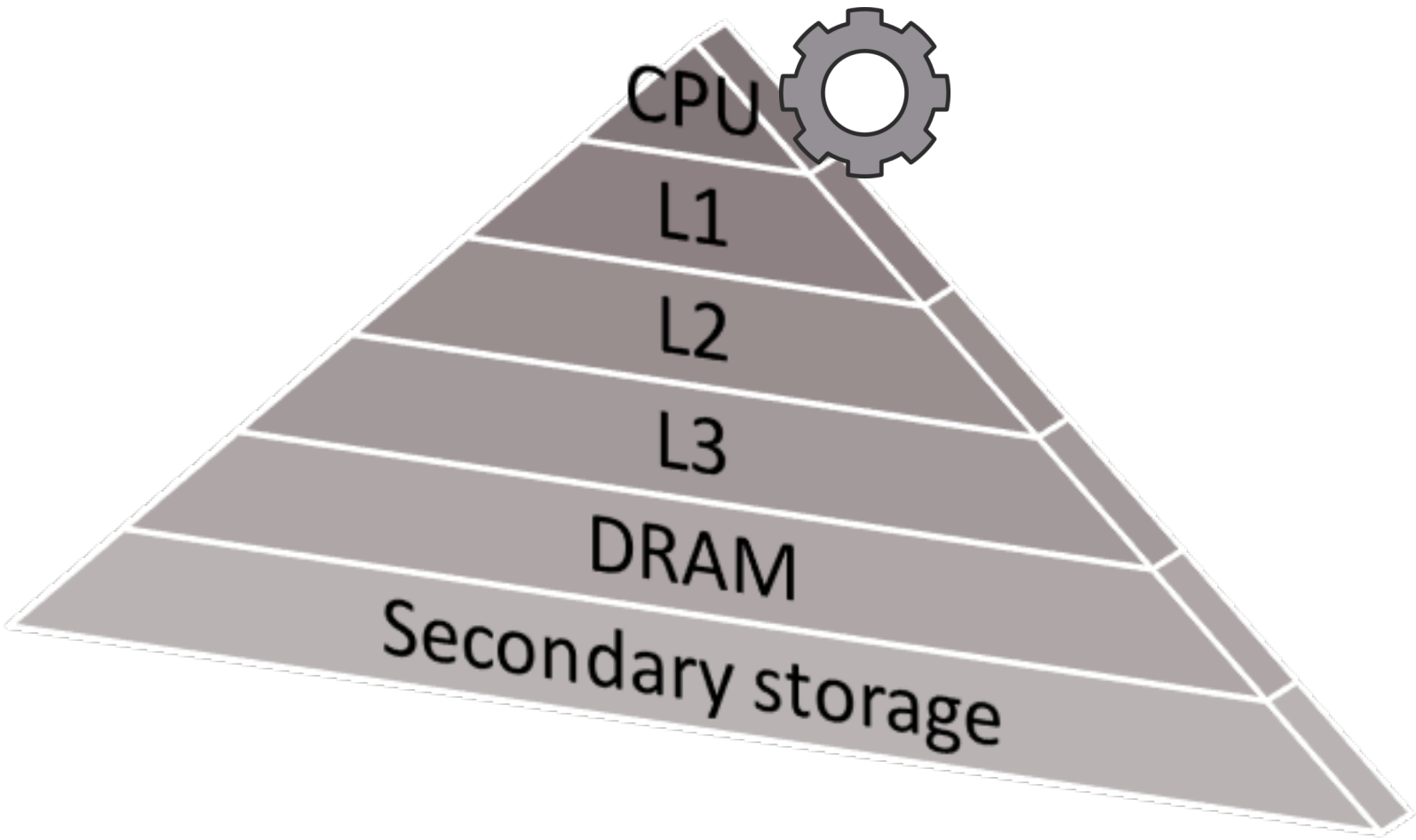
Column store

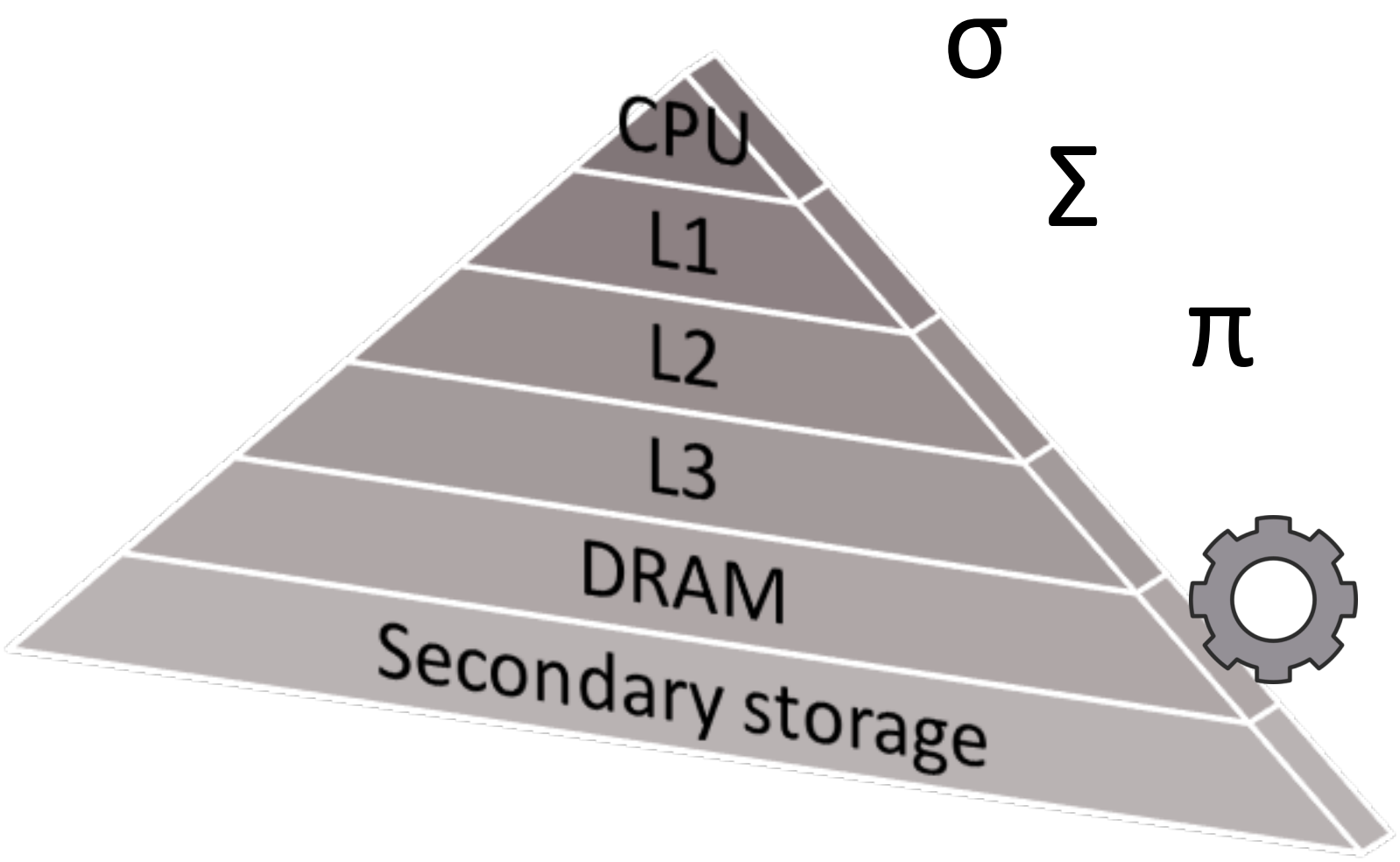




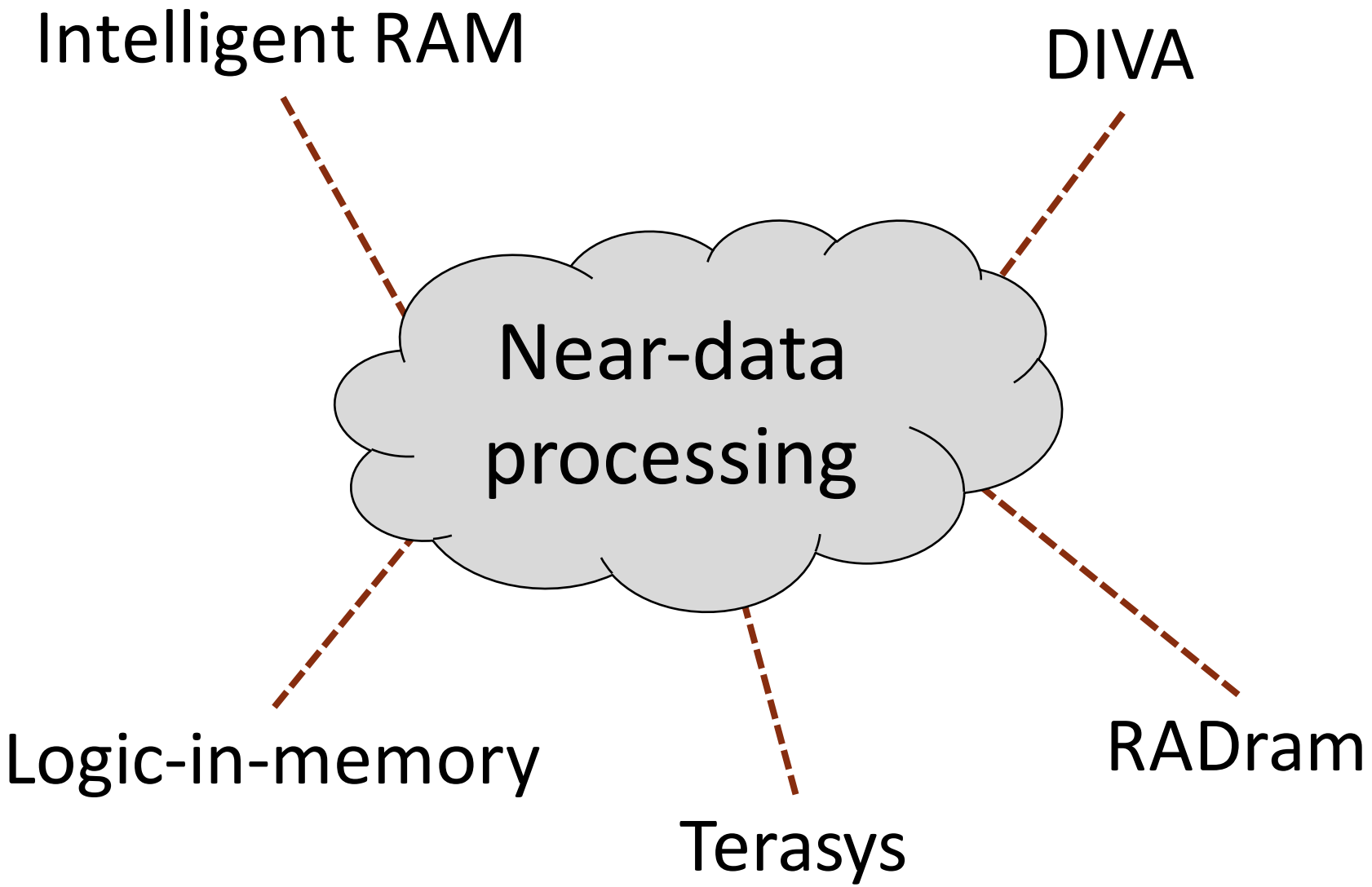
Memory-optimized data systems

Data access *remains* the bottleneck


CPU
L1
L2
L3
DRAM
Secondary storage


σ
Σ
π
CPU
L1
L2
L3
DRAM
Secondary storage


We are not the first to visit this pyramid!

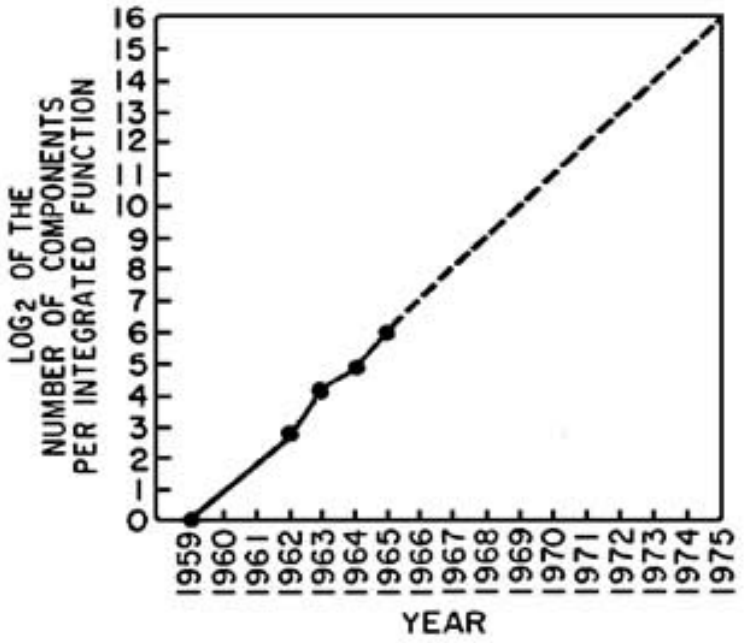

Intelligent RAM
DIVA
Near-data processing
Logic-in-memory
Terasys
RADram

Why did NDP not take off?

	DRAM	Logic
Leakage	Low	High
Switching speed	Slow	Fast

Fabrication processes are incompatible

Moore's Law + Dennard scaling
provided consistent performance scaling for years

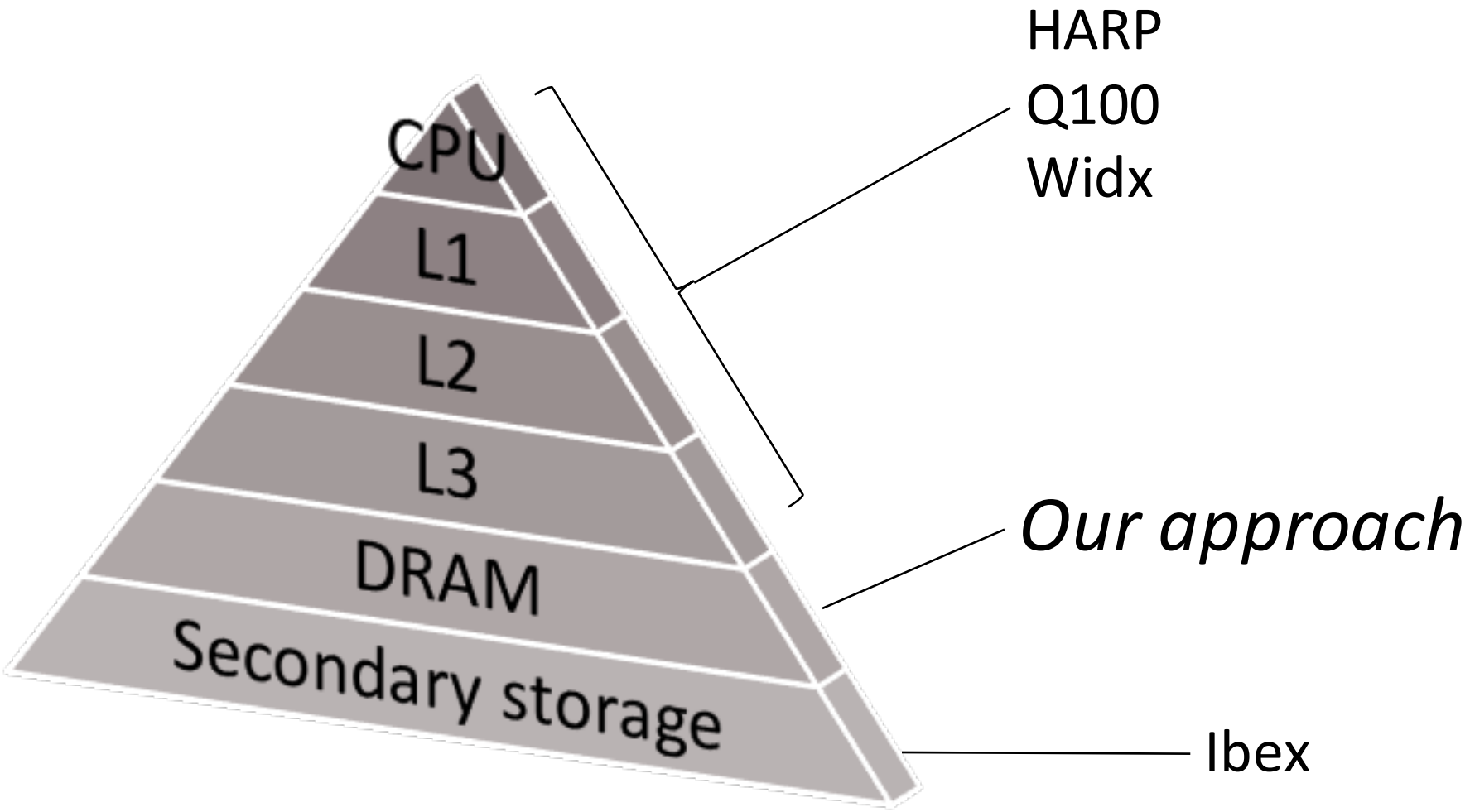


Moore's Law.

Metric	Scaling factor
Area	$1/\kappa^2$
Delay	$1/\kappa$
Power	1

Dennard scaling.

Not the case anymore!


HARP
Q100
Widx
CPU
L1
L2
L3
DRAM
Secondary storage
Our approach
Ibex

Outline

Intro

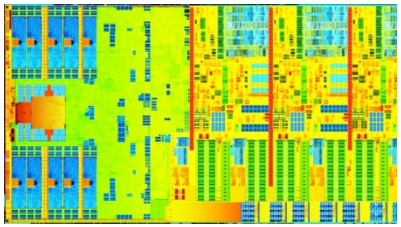
NDP for data systems: Past and present

The architecture of JAFAR

Experimental results

Conclusion

Opportunity for NDP



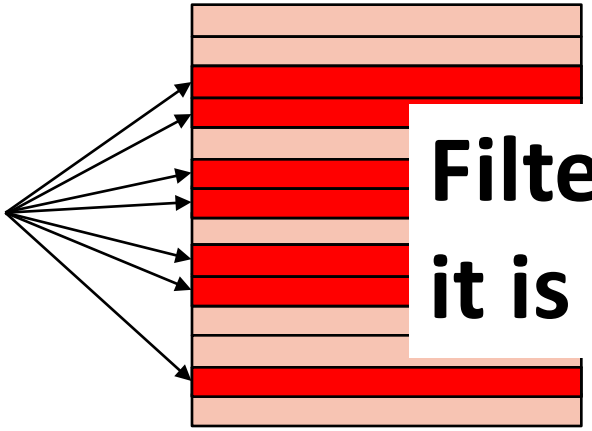
Host server

Query

Lots of data

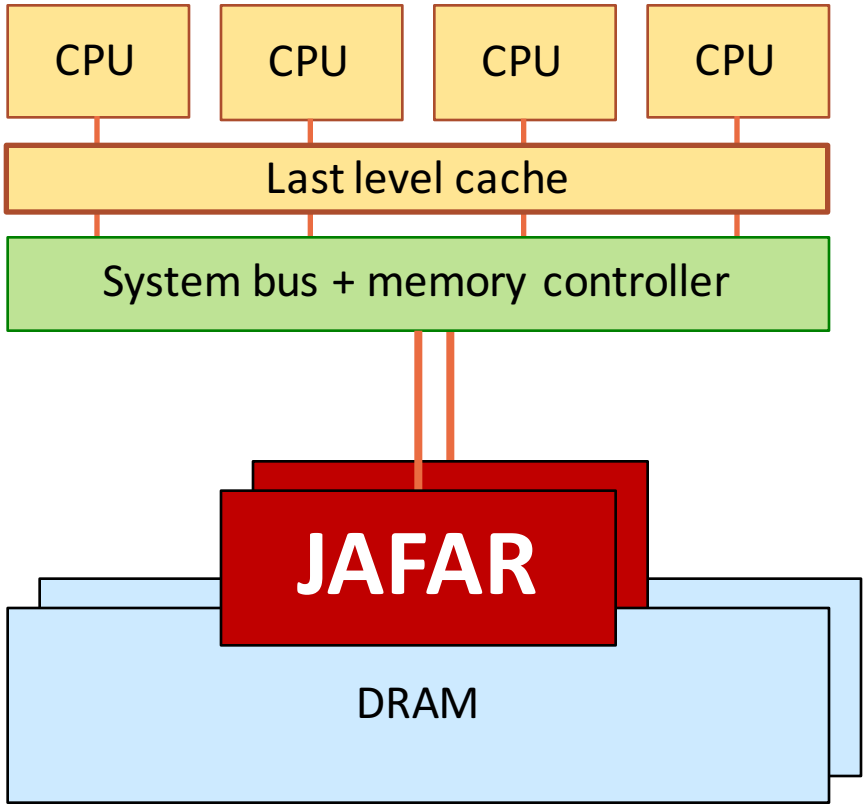
Database

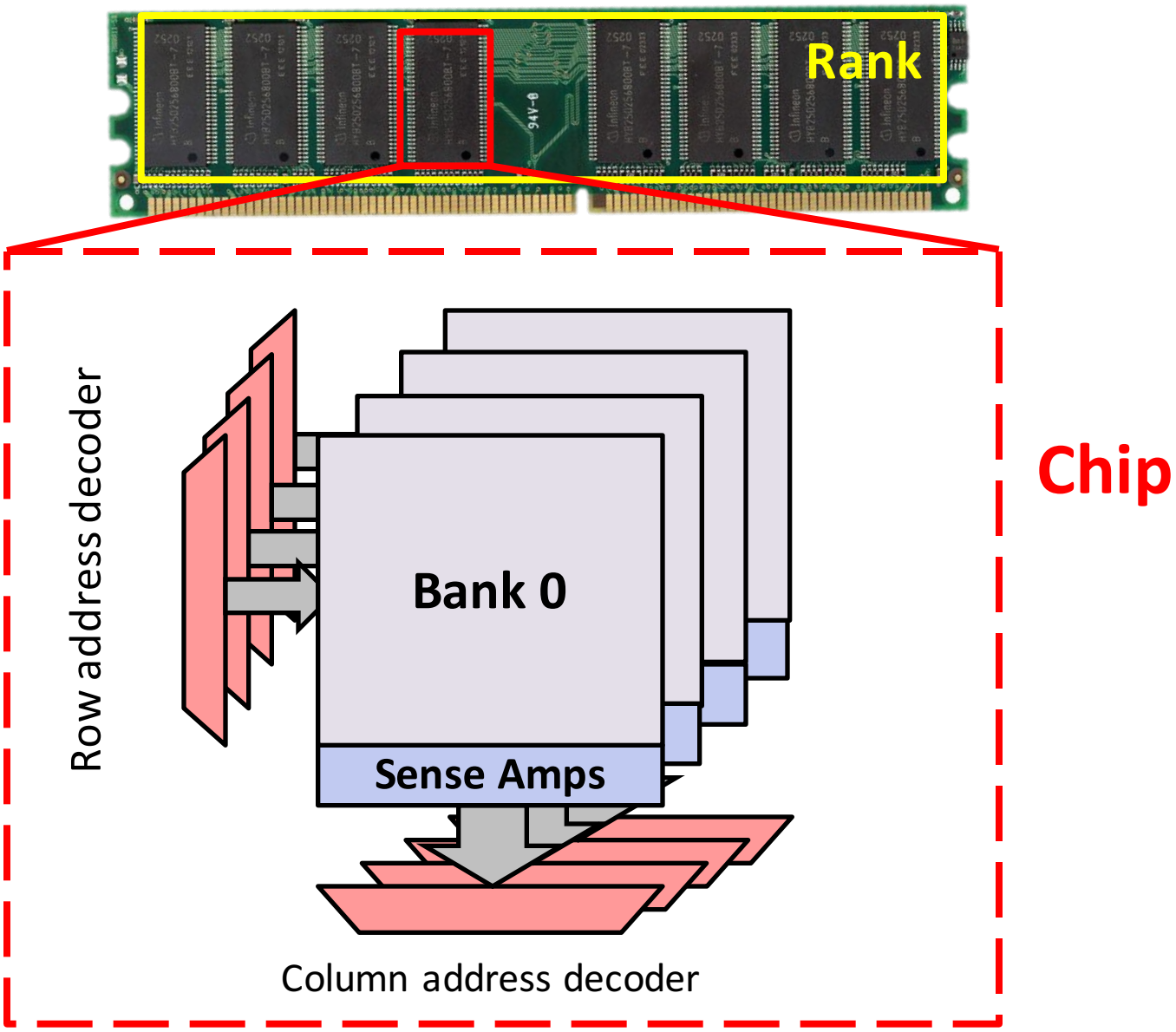
Many rows fail the query predicate and are discarded.

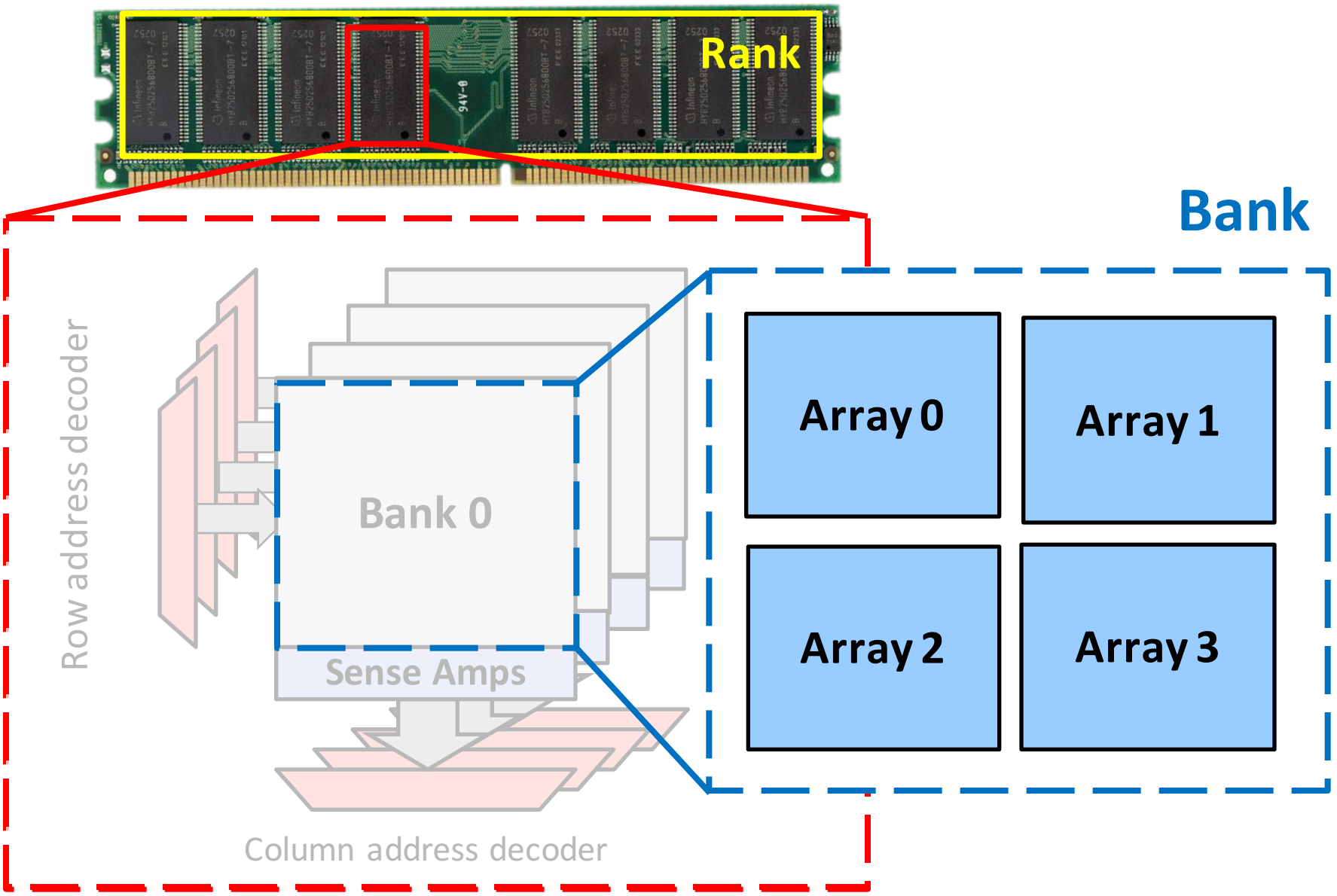


Filter data before it is sent to CPU.

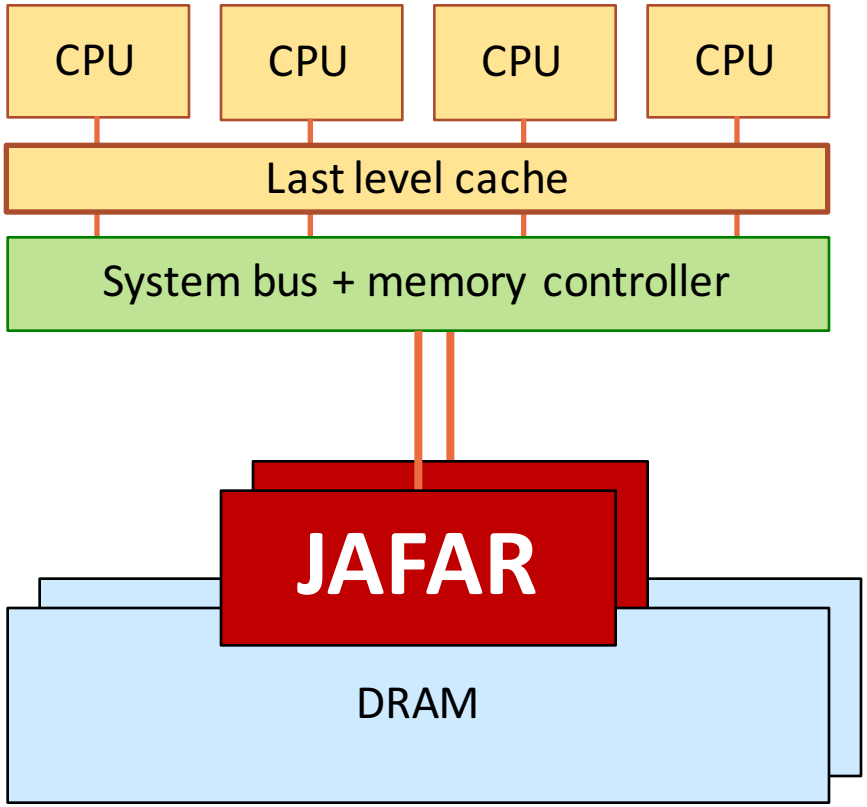
JAFAR: “Just” A Filtering Accelerator on Relations



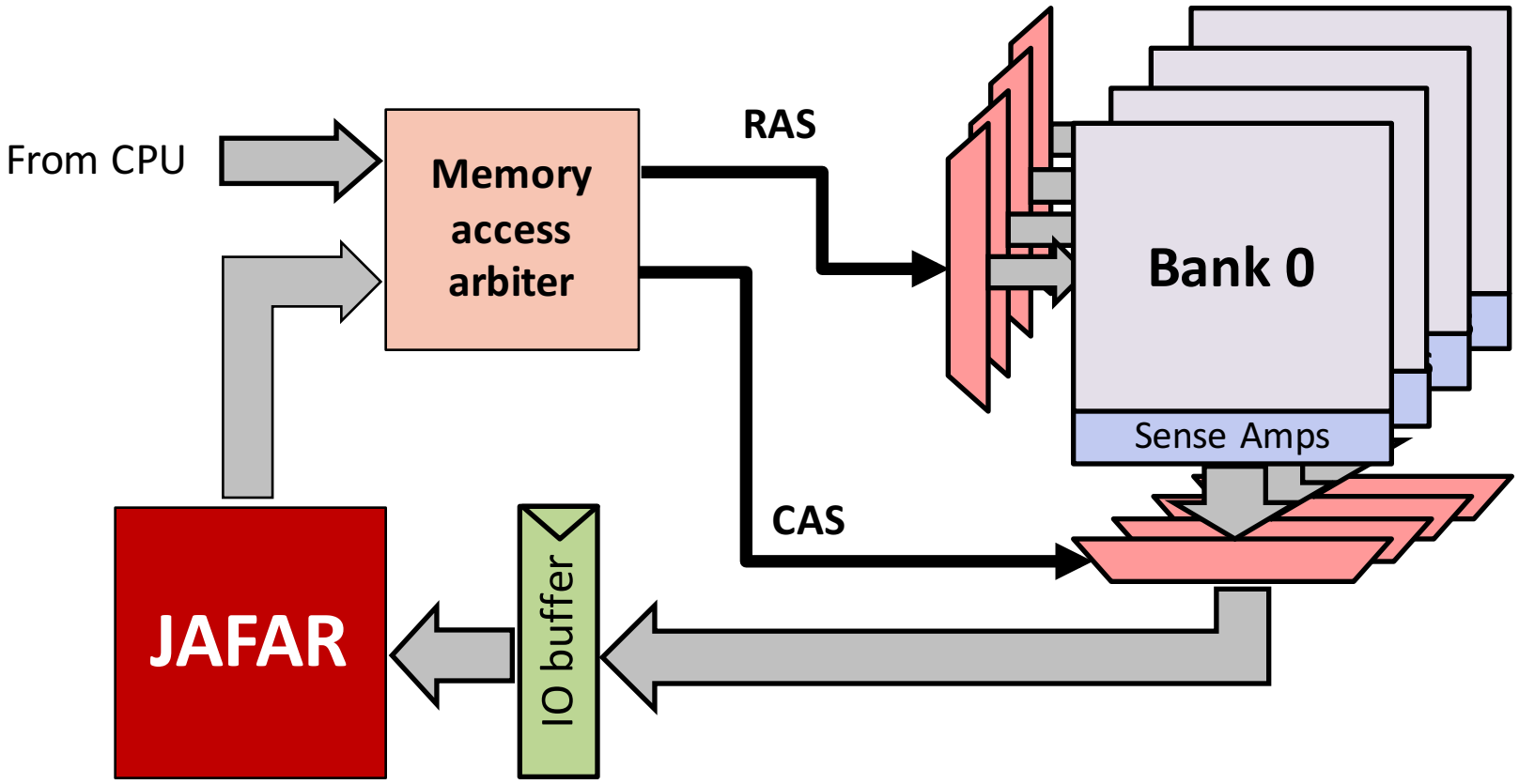

Rank
Row address decoder
Bank 0
Sense Amps
Column address decoder
Chip


Rank
Bank
Row address decoder
Bank 0
Sense Amps
Column address decoder
Array 0
Array 1
Array 2
Array 3

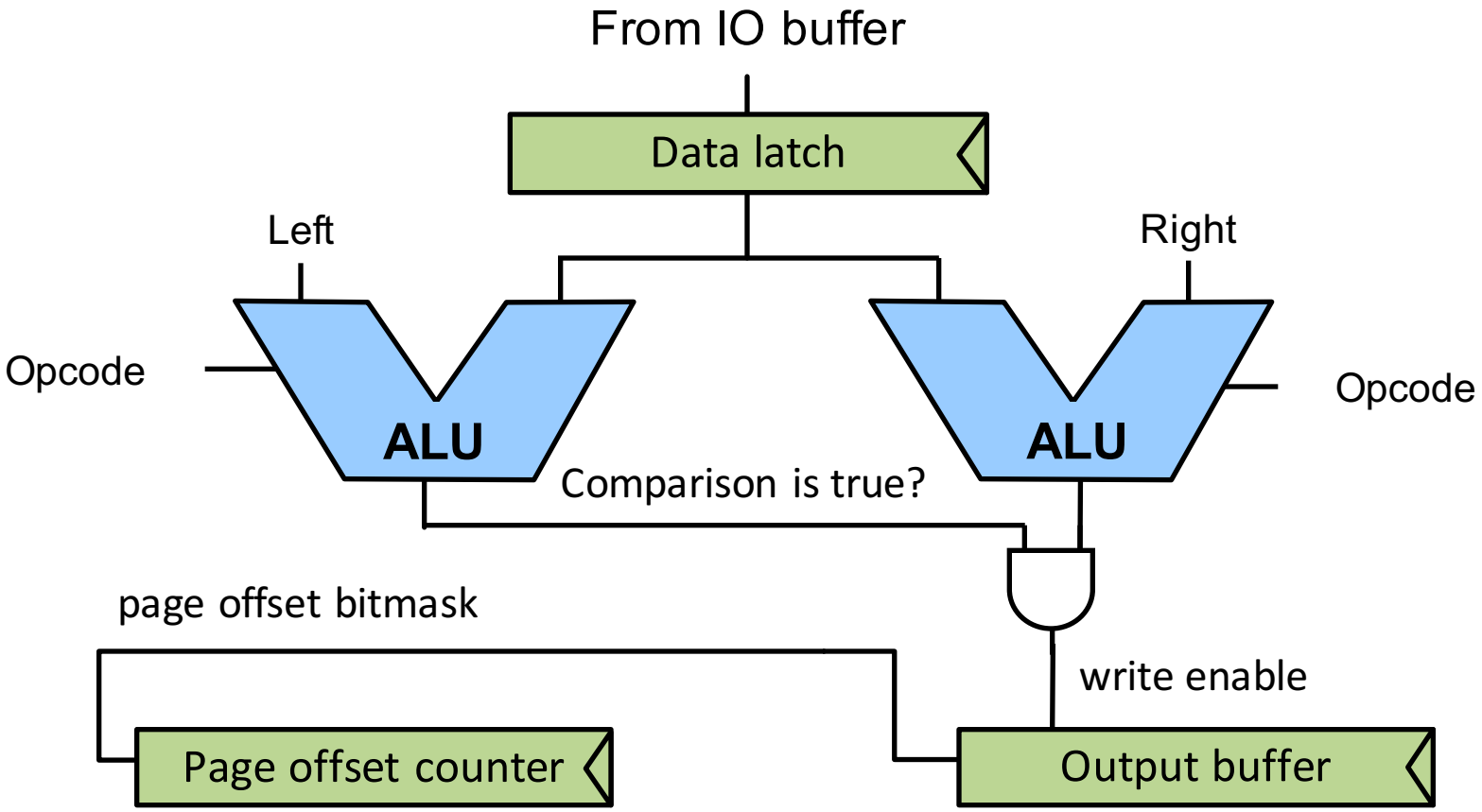
JAFAR: Overall design



JAFAR context



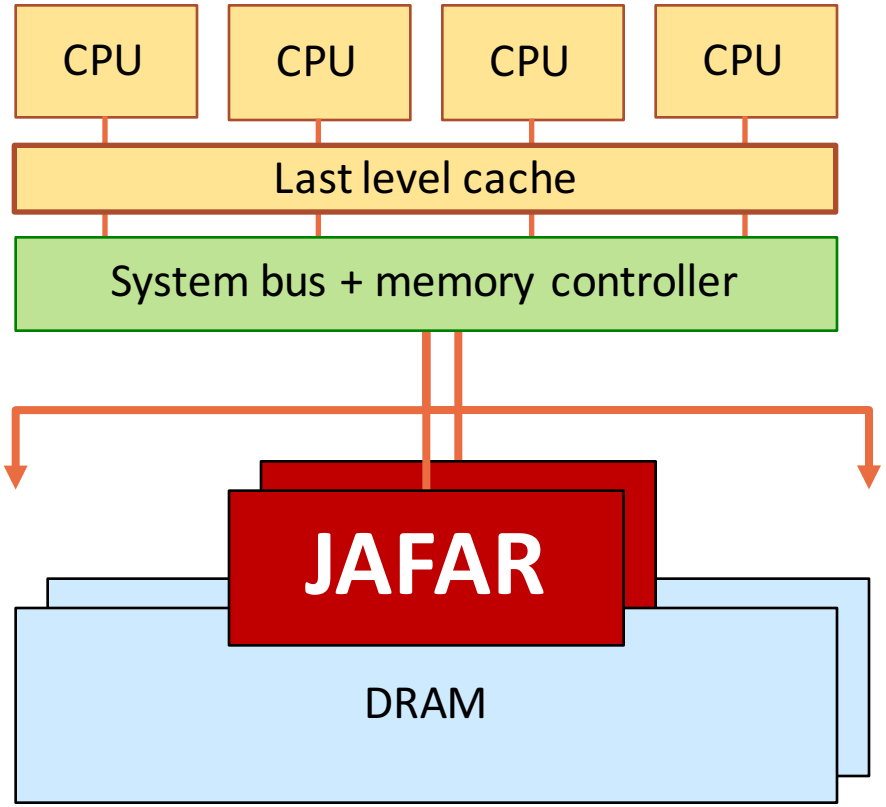
JAFAR architecture



Programming JAFAR

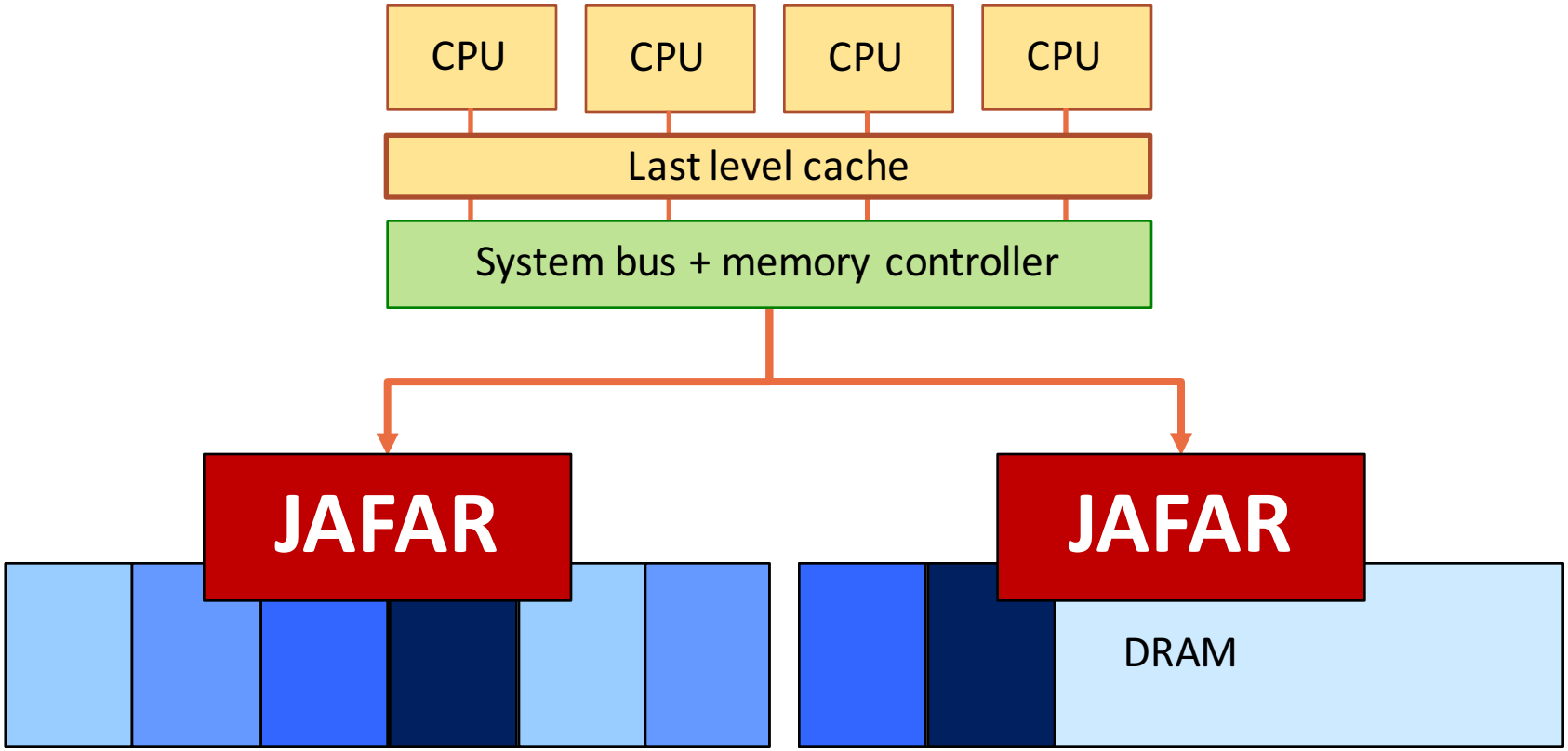
```
int errno =  select_jafar(
       void*          col_data,
       int            range_low,
       int            range_high,
       uint8_t*       out_buf,
       size_t         num_input_rows,
       size_t*        num_output_rows);
```

Handling multiple modules



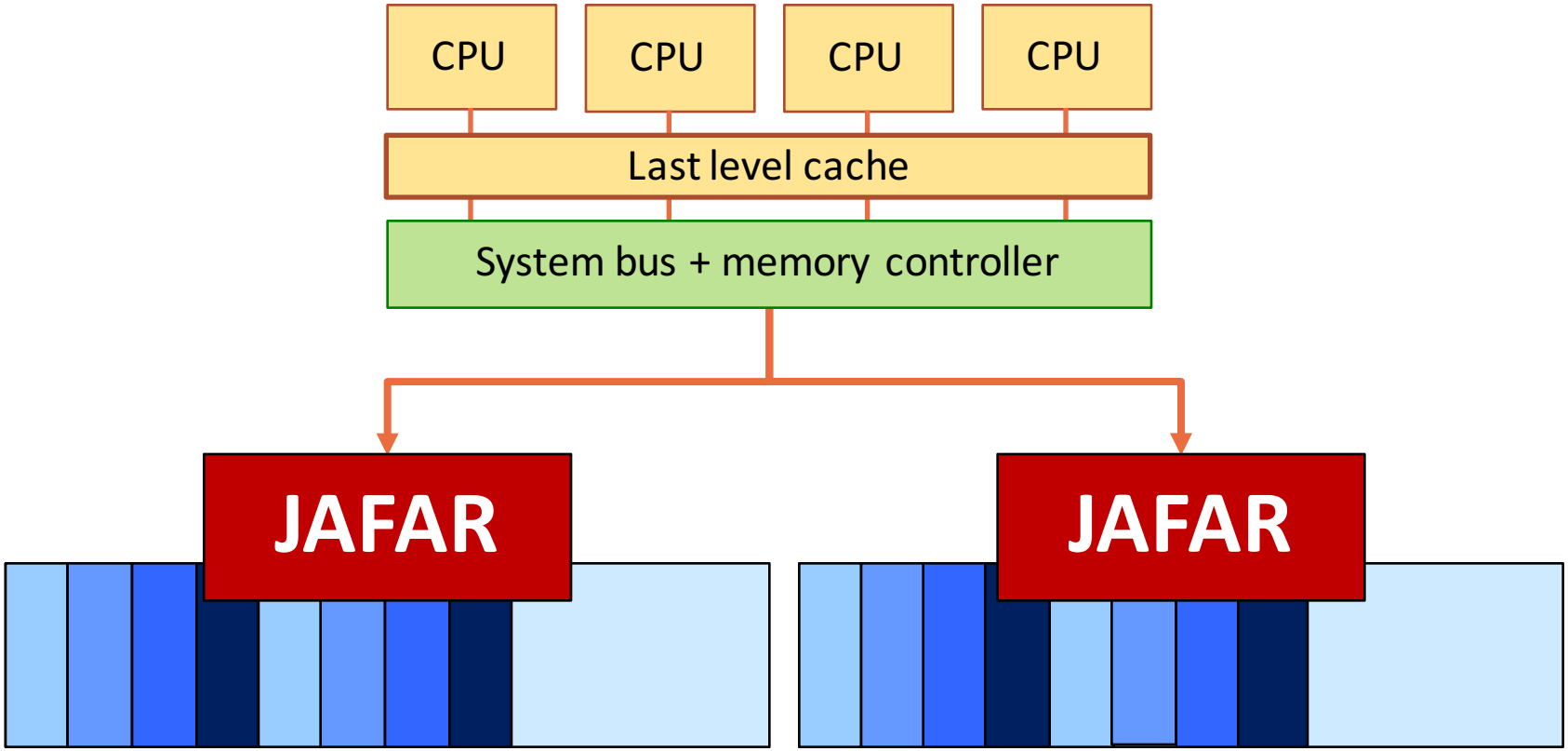
Handling multiple modules

Fill up each module first



Handling multiple modules

Interleave data across modules



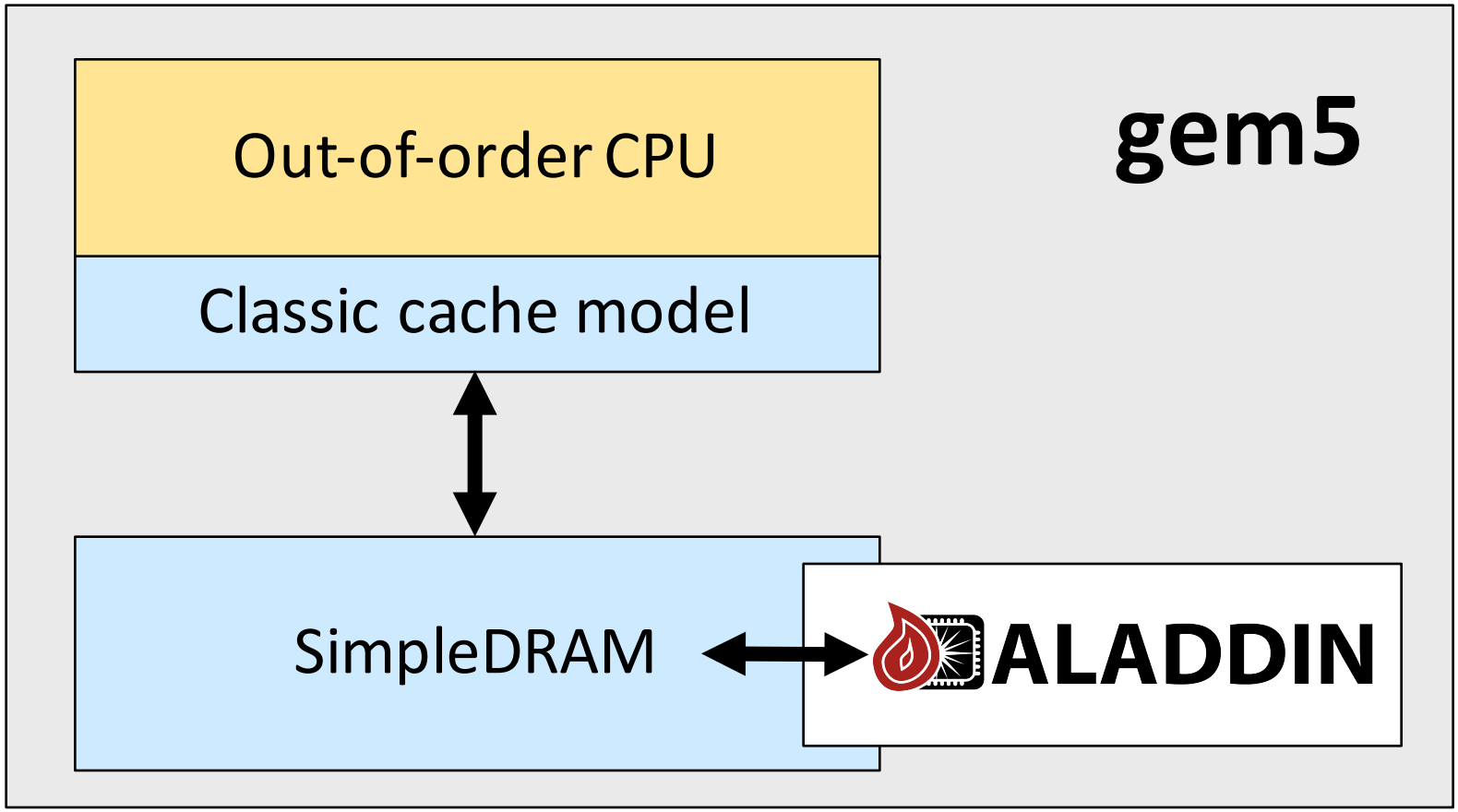
Coordinating memory access

The CPU and JAFAR cannot simultaneously attempt to access memory.

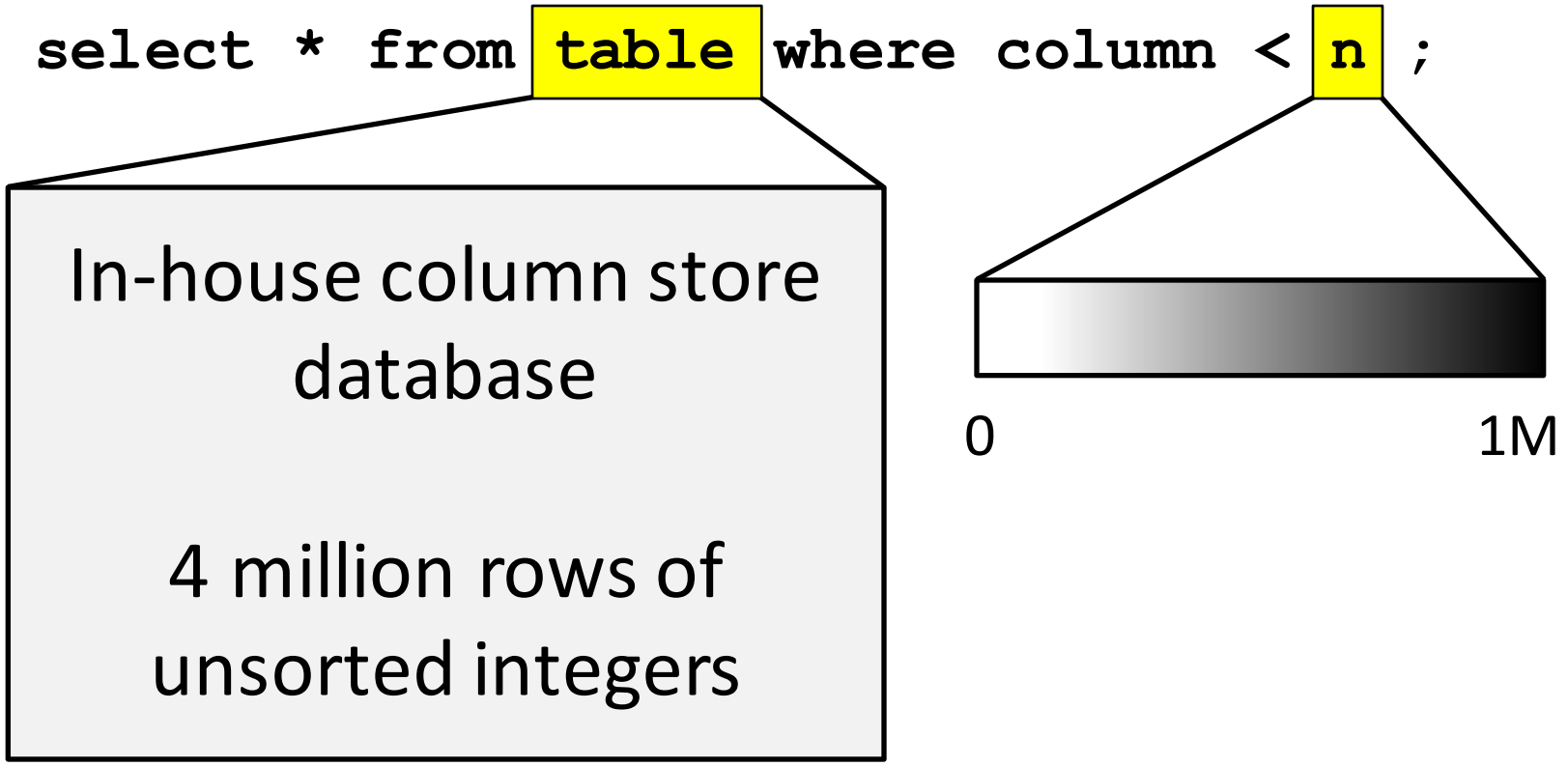
CPU grants JAFAR ownership to a DRAM rank for a period of time.

Possible mechanism: DRAM mode registers

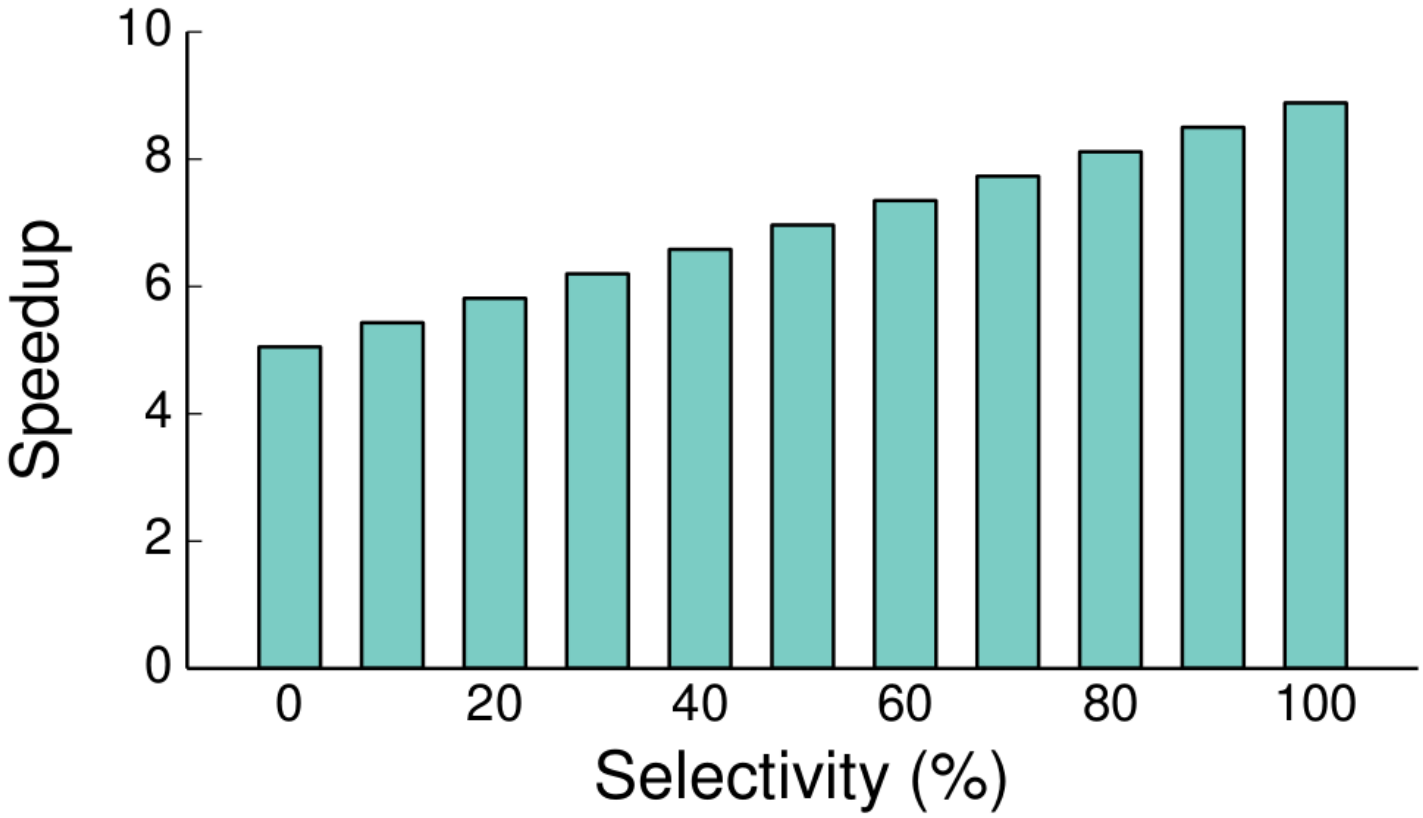
Experimental setup
Simulation framework



Experimental setup
Queries, input data, and database



Experimental results

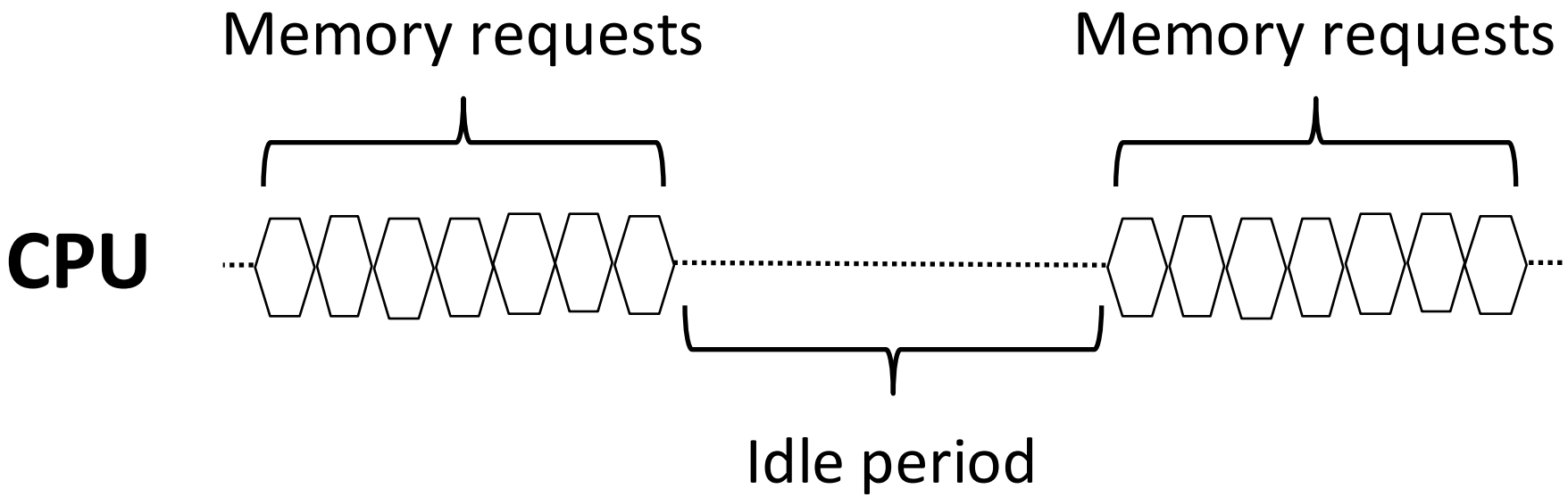


Memory contention

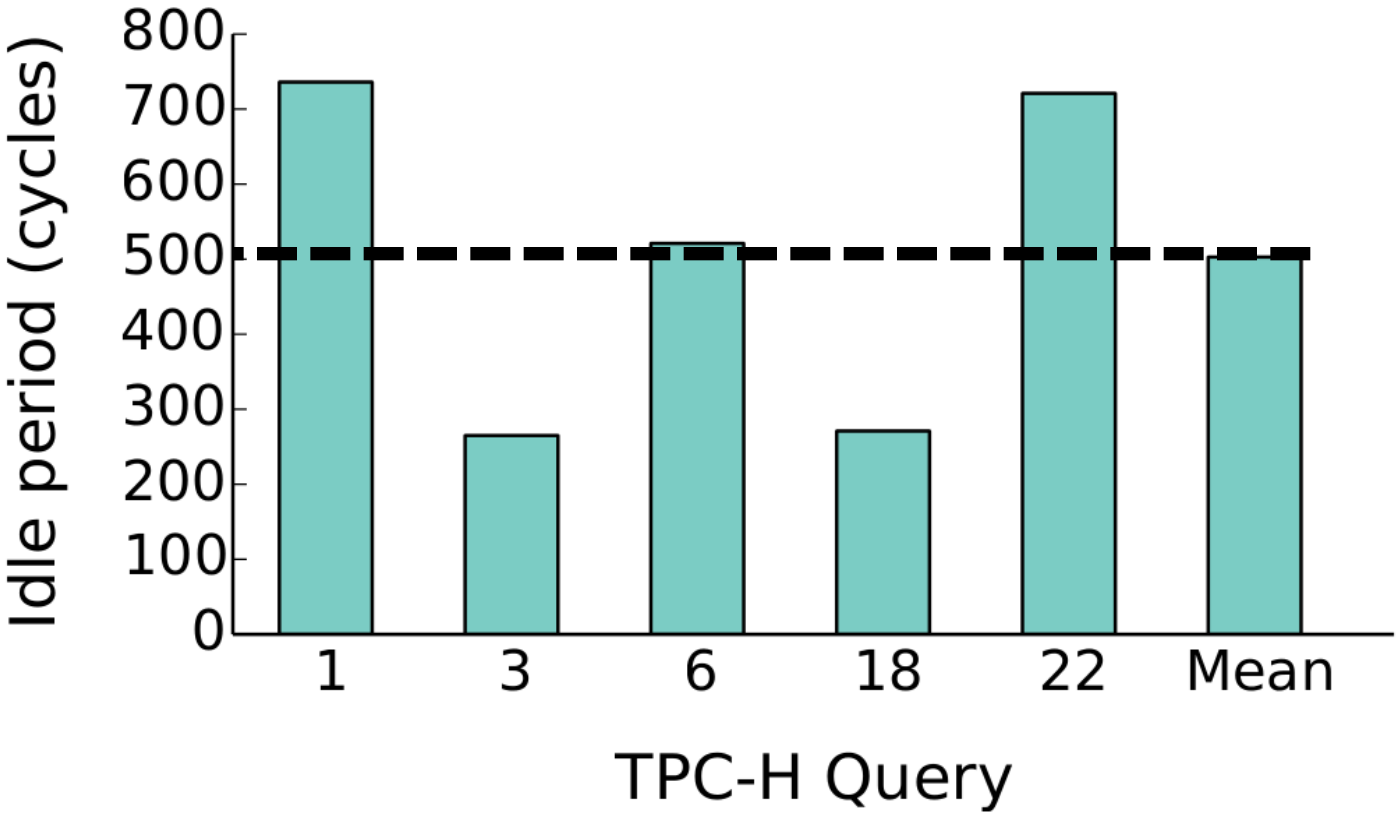
Scheduling of ownership transfers will be important

What would JAFAR's performance look like *without* a scheduler?

Memory contention



Idle periods on TPC-H



JAFAR as a framework
More operators

Aggregations ✓

Projections ✓

Sort ✓

Joins ?

JAFAR as a framework
Data types and layouts

Row-stores and hybrids

Multiple filters per row

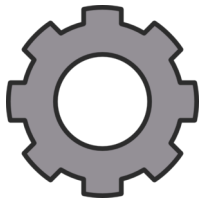
Efficient projections

Variable length datatypes

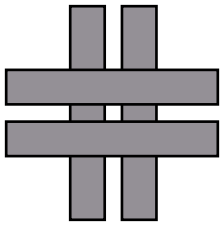
Process on CPU?

NDP is an exciting opportunity for innovation in data systems

NDP is a promising solution to the memory wall for data systems.



JAFAR provides up to 9x speedup on simple select queries.



JAFAR is built on an extensible framework for accelerating data systems.

Thank you