CS564
BitWeaving: Fast Scans for Main Memory Data Processing

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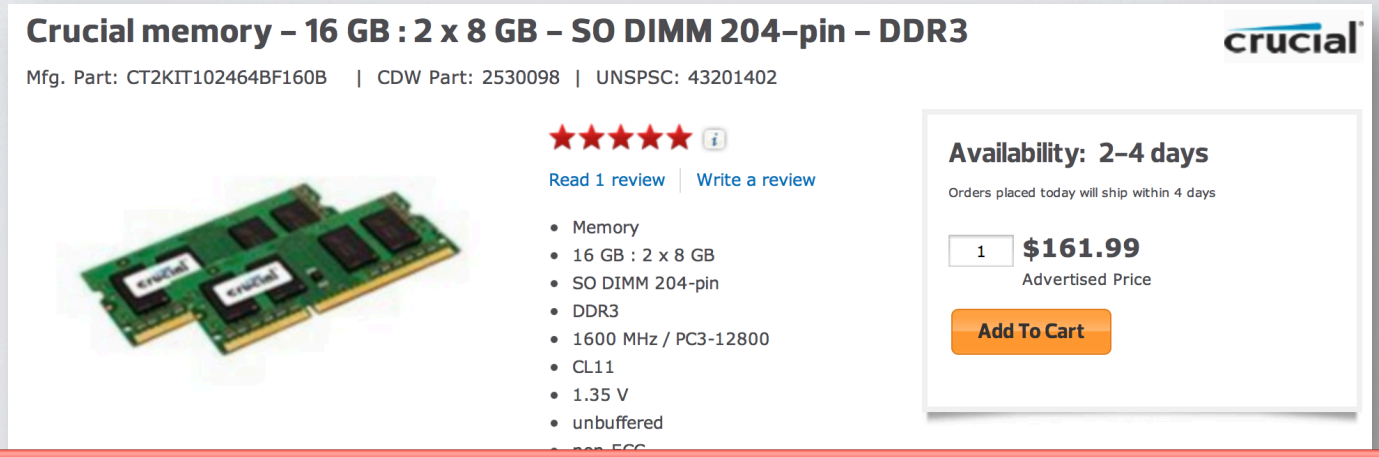
The Problem

- Need interactive analysis (complex SQL queries) run on large volumes of data
- New world in which business decisions are made by analytical engines
  - Speed is king

A common approach

- Disks are slow (yes – even flash is slow), but memory is fast
- Memory densities are increasing and price is dropping



Hence the rise of "in-memory" data processing for data analytics

Research Problem

- We know that for data analytics, using column stores is faster.
- But, can we go even faster than traditional column stores?
- Insights: Need to think about how the CPU sees the "data" and run data operations at the speed of the CPU
  - Recall CPU is the fastest component in the system

Column-store scans: Naïve method

- An example SQL scan query:

```
SELECT COUNT(*)
FROM Customer
WHERE age BETWEEN 20 AND 24
```

- An naïve implementation:

```
count = 0;
FOR EACH value v in column age
  IF (20 <= v and v <= 24)
    count++;
```

- Complexity: O(n). Need to run O(n) CPU instructions.

- **Better method?**

Encoded column values

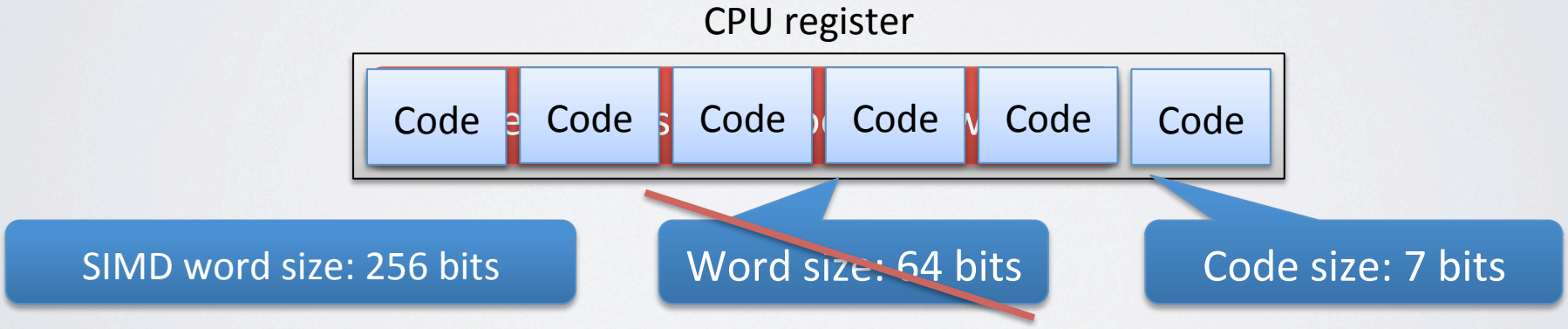
- Domain size of column is typically small
  - Gender: Male / Female — 1 bits
  - Age: 0-122 — 7 bits
  - States: 50 states — 6 bits
- DBMSs converts native column values to **codes**.
- Codes only use as many bits as are needed for fixed-length encoding.

Motivation

```
SELECT count(*)
FROM Customer
WHERE age BETWEEN 20 AND 24
```

7 bits

```
count = 0;
FOR EACH value v in column age
  IF (20 <= v and v <= 24)
    count++;
```



Intra-cycle parallelism!

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Column-store scans: BitWeaving method

- An example SQL scan query:

```
SELECT COUNT(*)
FROM Customer
WHERE age BETWEEN 20 AND 24
```

- An BitWeaving implementation:

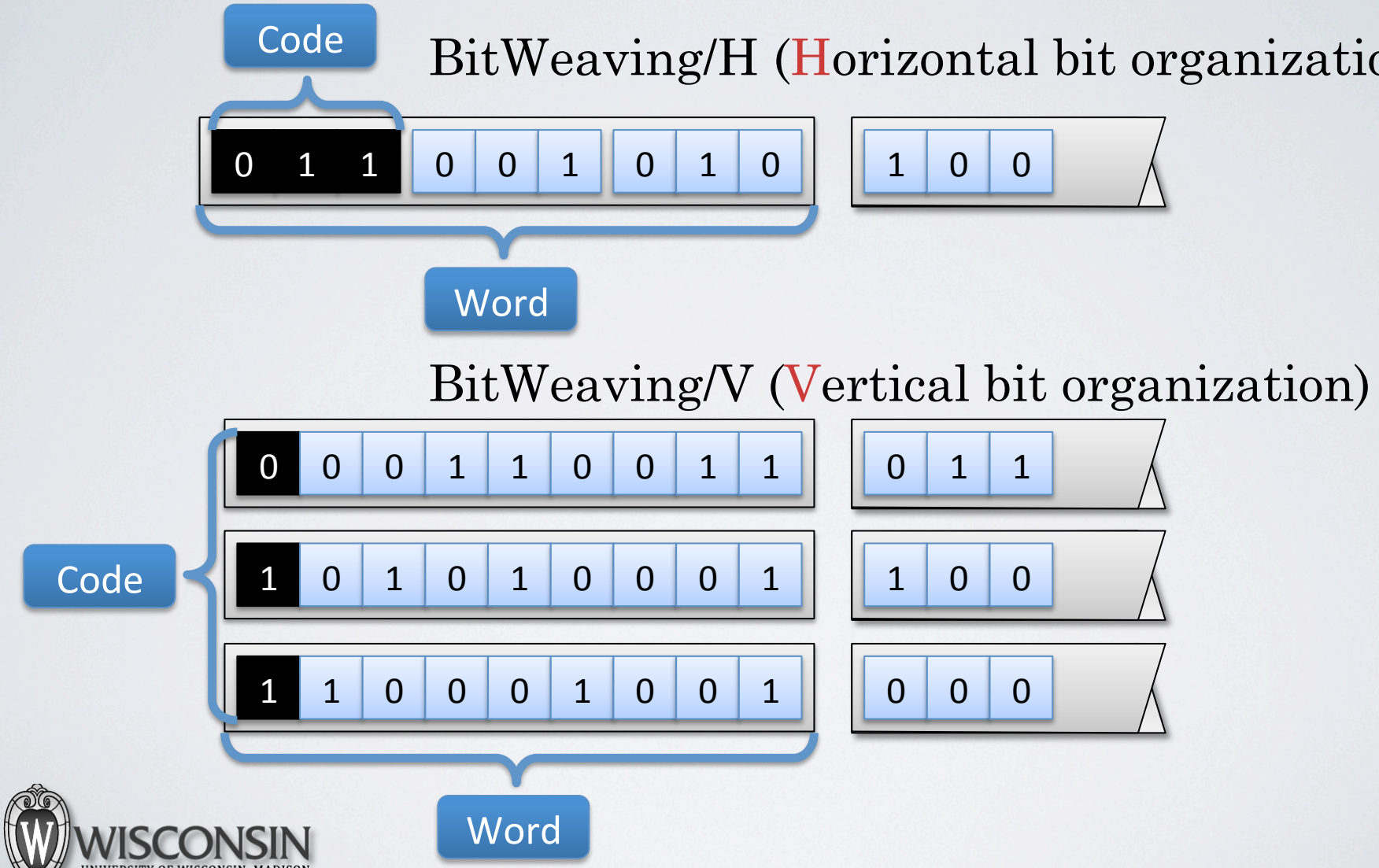
```
count = 0;
FOR EACH group of codes v in column age
  Evaluate 20 <= v <= 24 in parallel
  Update count;
```

- Complexity: O(n/w). w: gourp size.

BitWeaving

- In this lecture, we introduce BitWeaving
  - A fast **scan** method
  - for **column stores**
- Fully exploits intra-cycle parallelism
- How: By "gainfully" using every bit in every processor word.

BitWeaving: Two Flavors

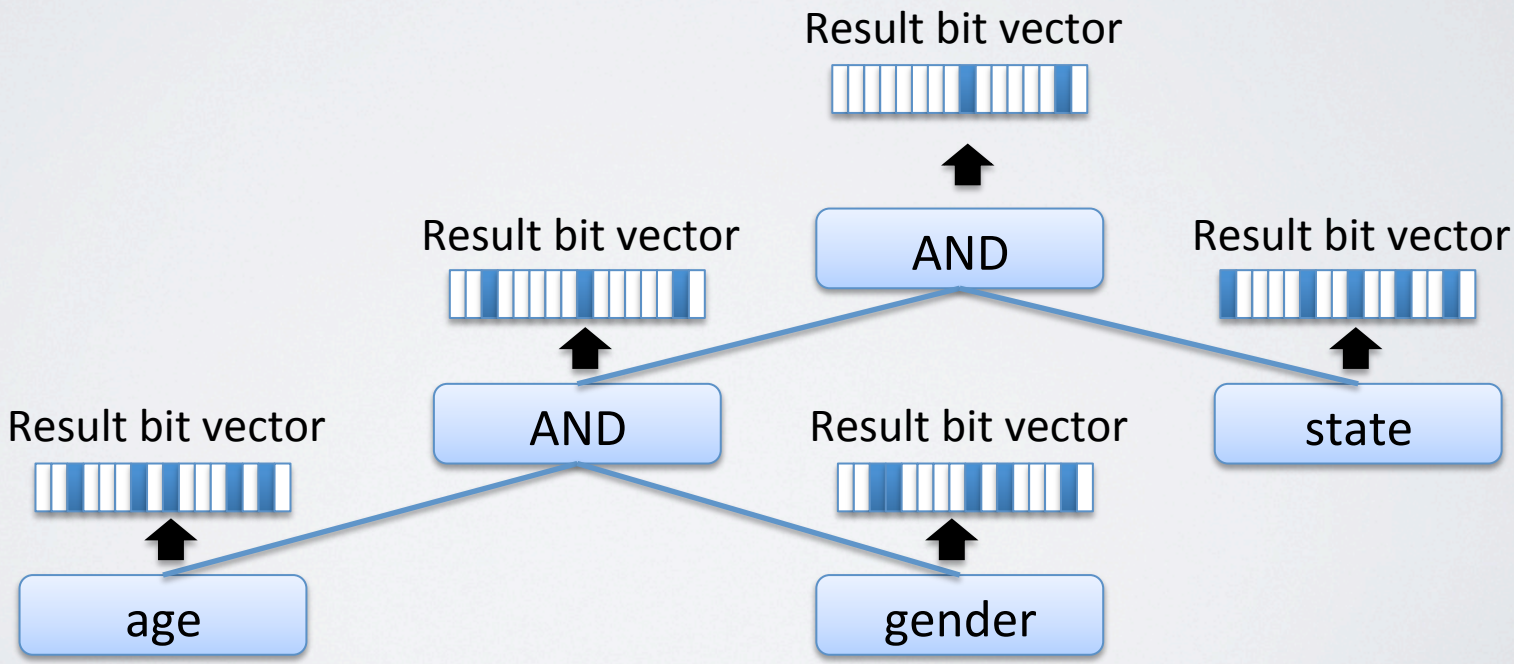


Framework

- Targets single-table scans
- Column-scalar scan: scan on a single column
  - produce a **result bit vector**, with **one** bit for each input tuple to indicate the matching tuples
- Complex predicates in the scan: logical AND and OR operations on these *result bit vectors*

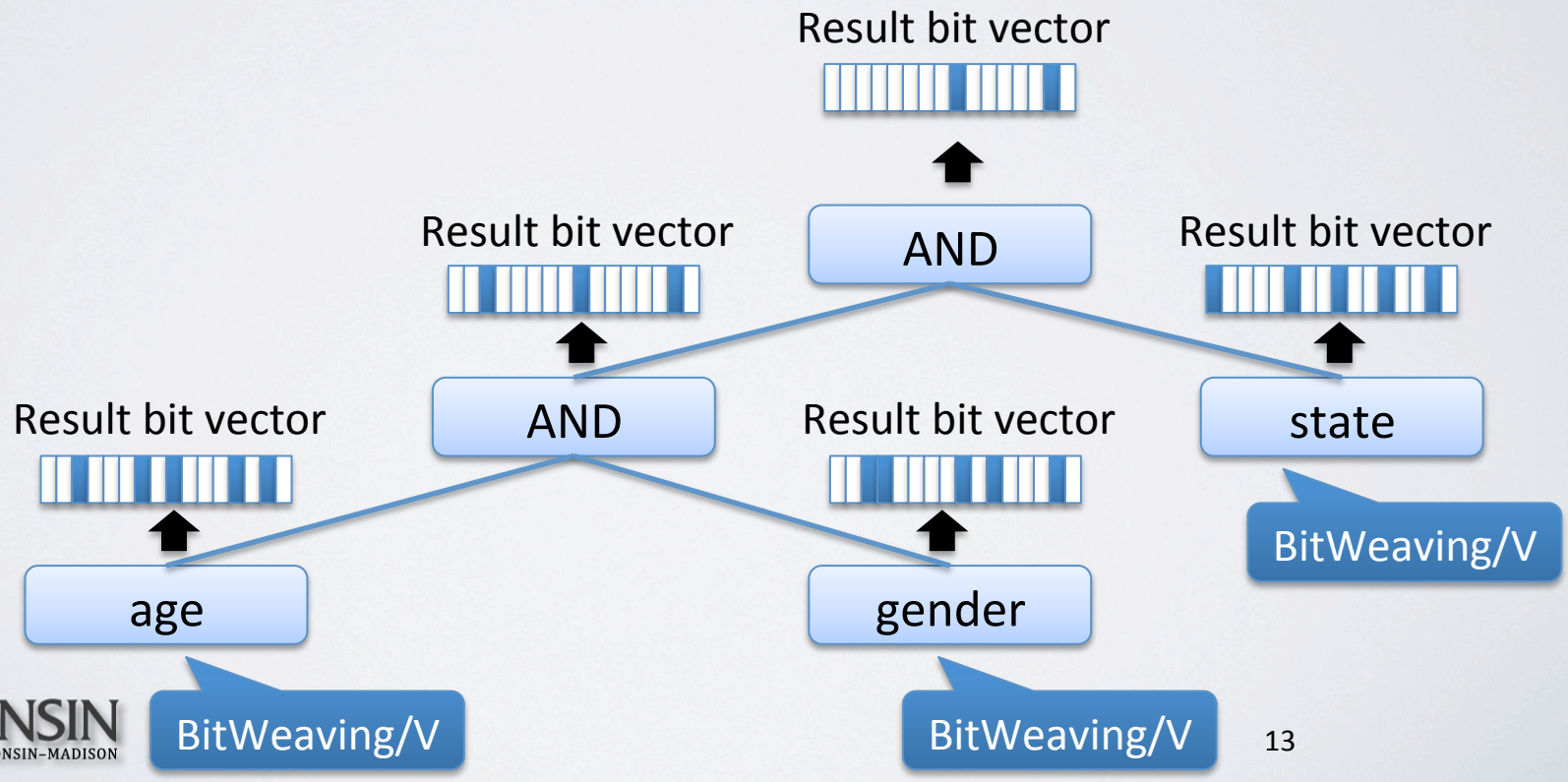
Framework – Example

```
SELECT COUNT(*) FROM Customer
WHERE age BETWEEN 20 AND 24
  AND gender = Male
  AND state = Wisconsin
```



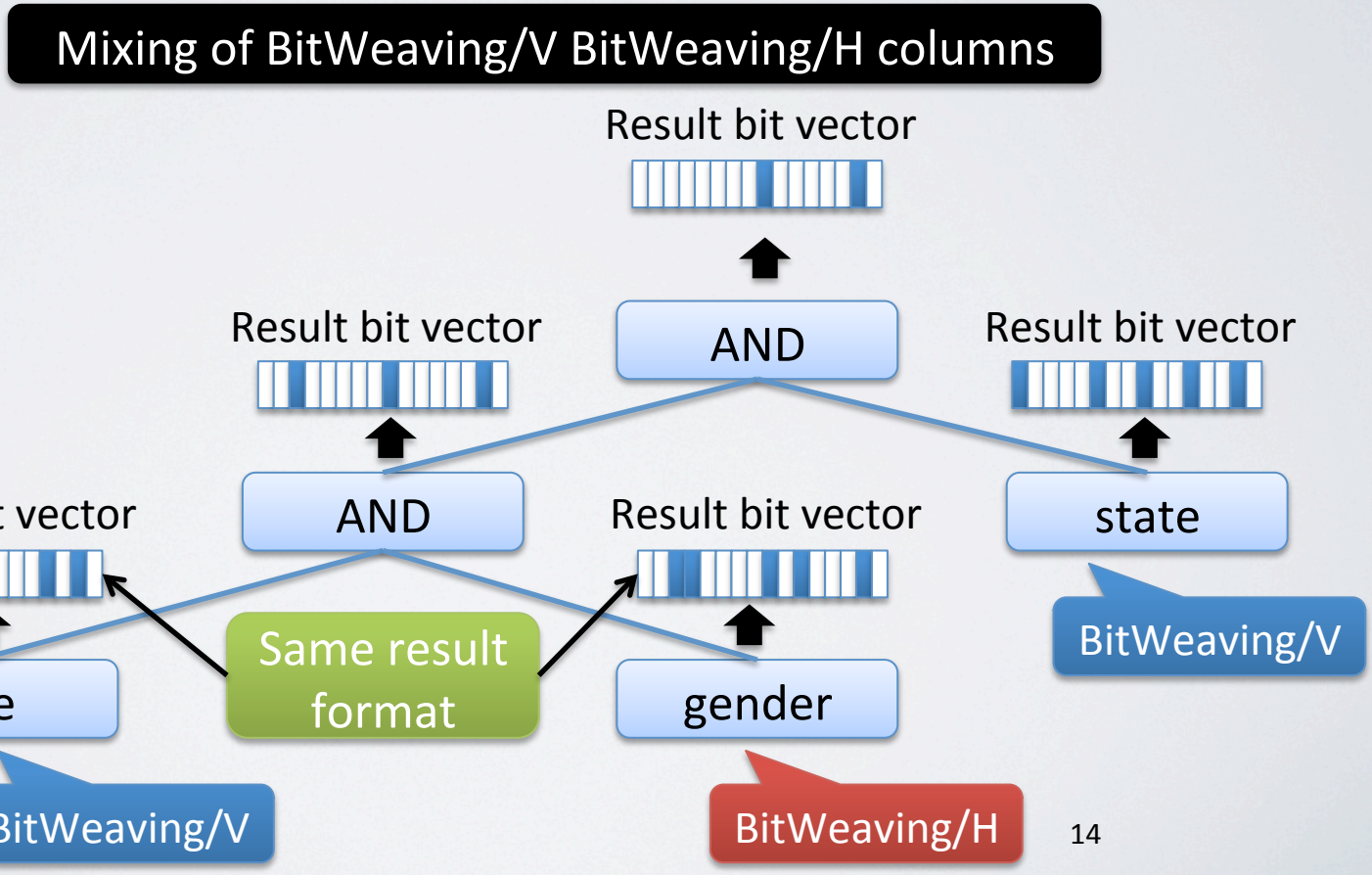
Framework – Example

```
SELECT COUNT(*) FROM Customer
WHERE age BETWEEN 20 AND 24
  AND gender = Male
  AND state = Wisconsin
```



Framework – Example

```
SELECT COUNT(*) FROM Customer
WHERE age BETWEEN 20 AND 24
  AND gender = Male
  AND state = Wisconsin
```



Outline

- Motivation & Overview
- BitWeaving/H
- BitWeaving/V
- Conclusion

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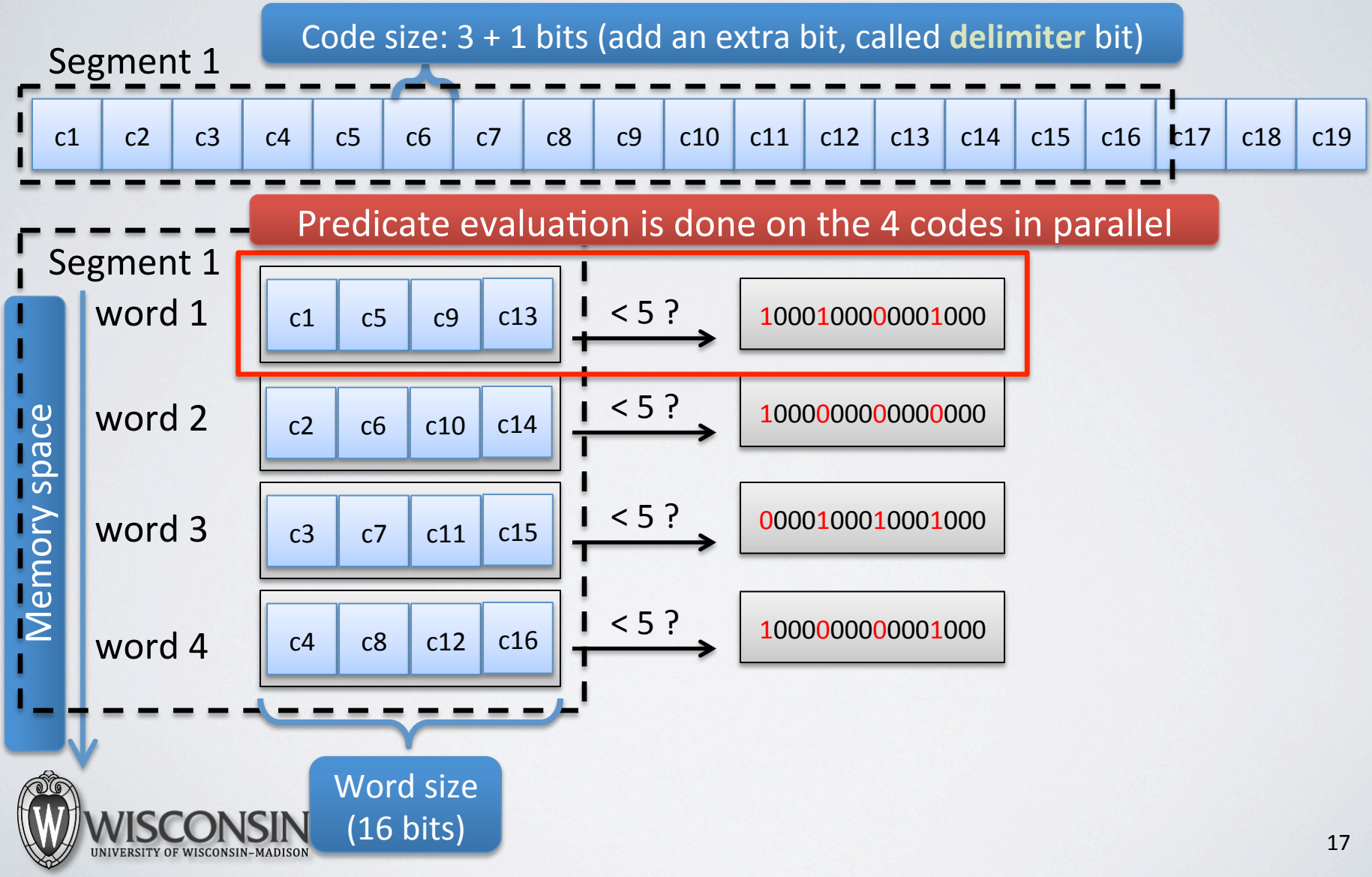
BitWeaving/H

- Storage layout
  - Packs codes "horizontally" into processor words
  - Uses an extra bit (**delimiter** bit) in each code
  - Staggers codes across words inside a segment

- Column-scalar scan
  - Parallel predicate evaluation on packed codes

BitWeaving/H - Example



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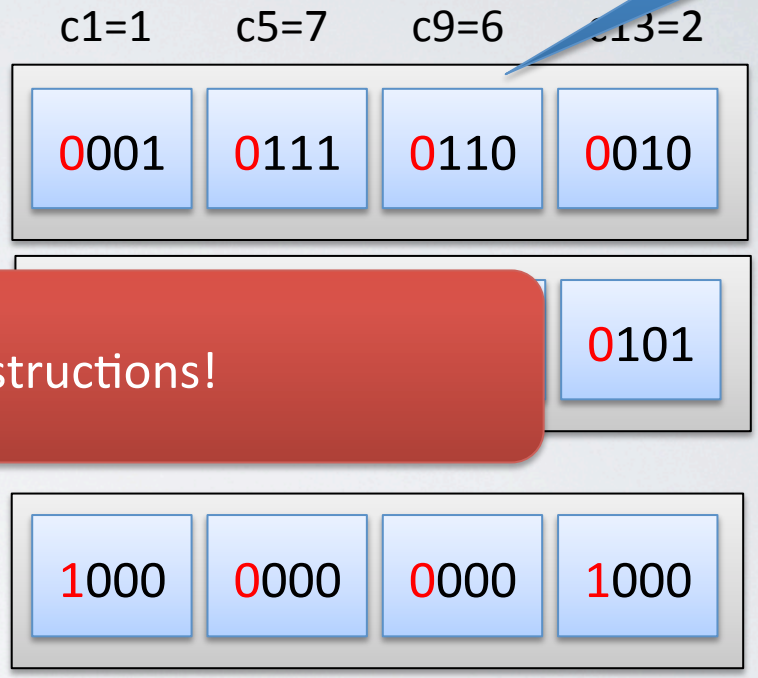
BitWeaving/H Example: Less Than Predicate (< 5)

Word size (16 bits)



$$X = \left(c_1 c_5 c_9 c_{13}\right)$$

Regular integer plus

Only use 3 instructions!

$$\left(Y + (X \oplus M1)\right) \wedge M2$$

$$M1 = 0111\ 0111\ 0111\ 0111$$

$$M2 = 1000\ 1000\ 1000\ 1000$$

Works for arbitrary code sizes & word sizes!

Curious about why? See our paper!

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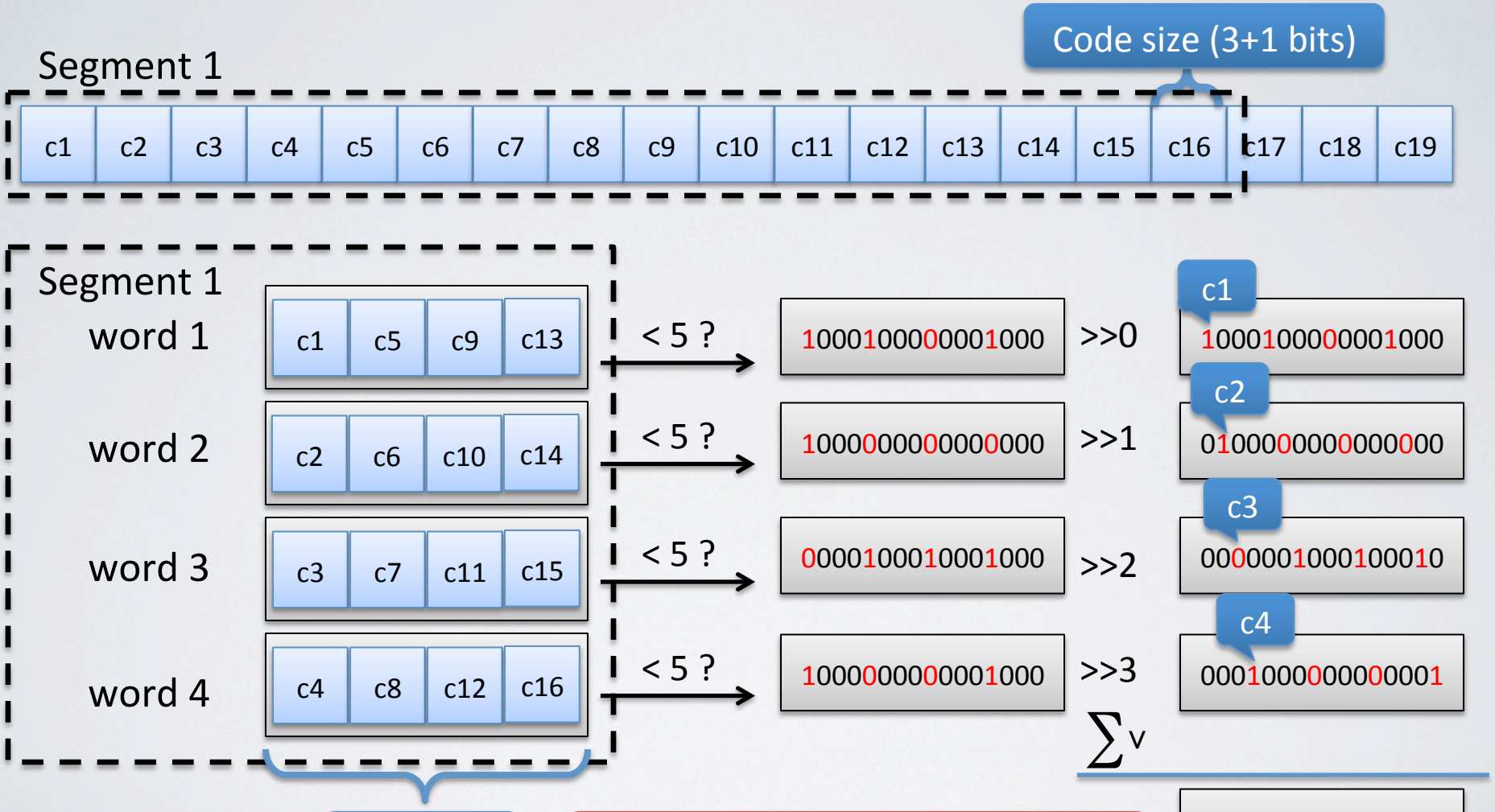
BitWeaving/H – Example…



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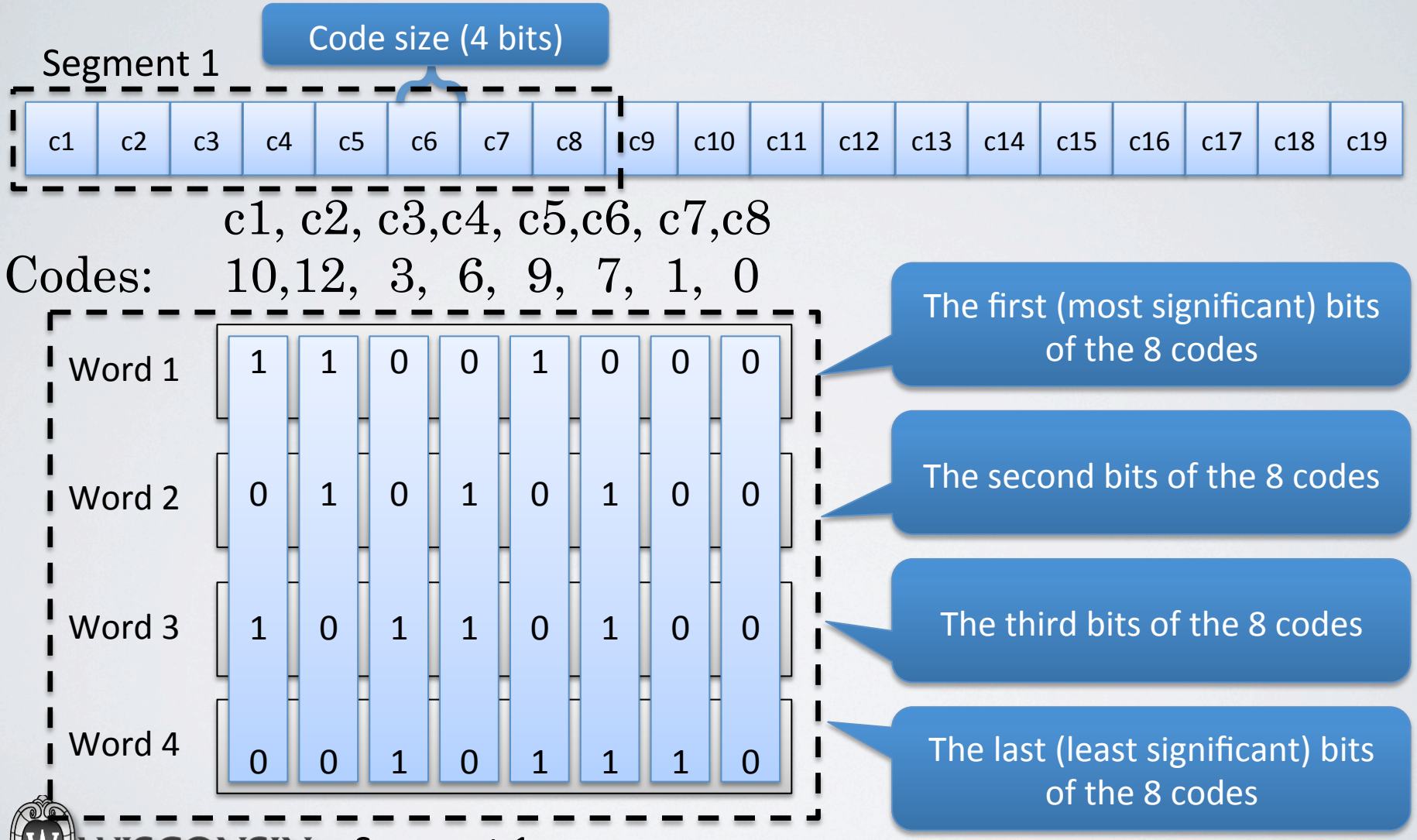
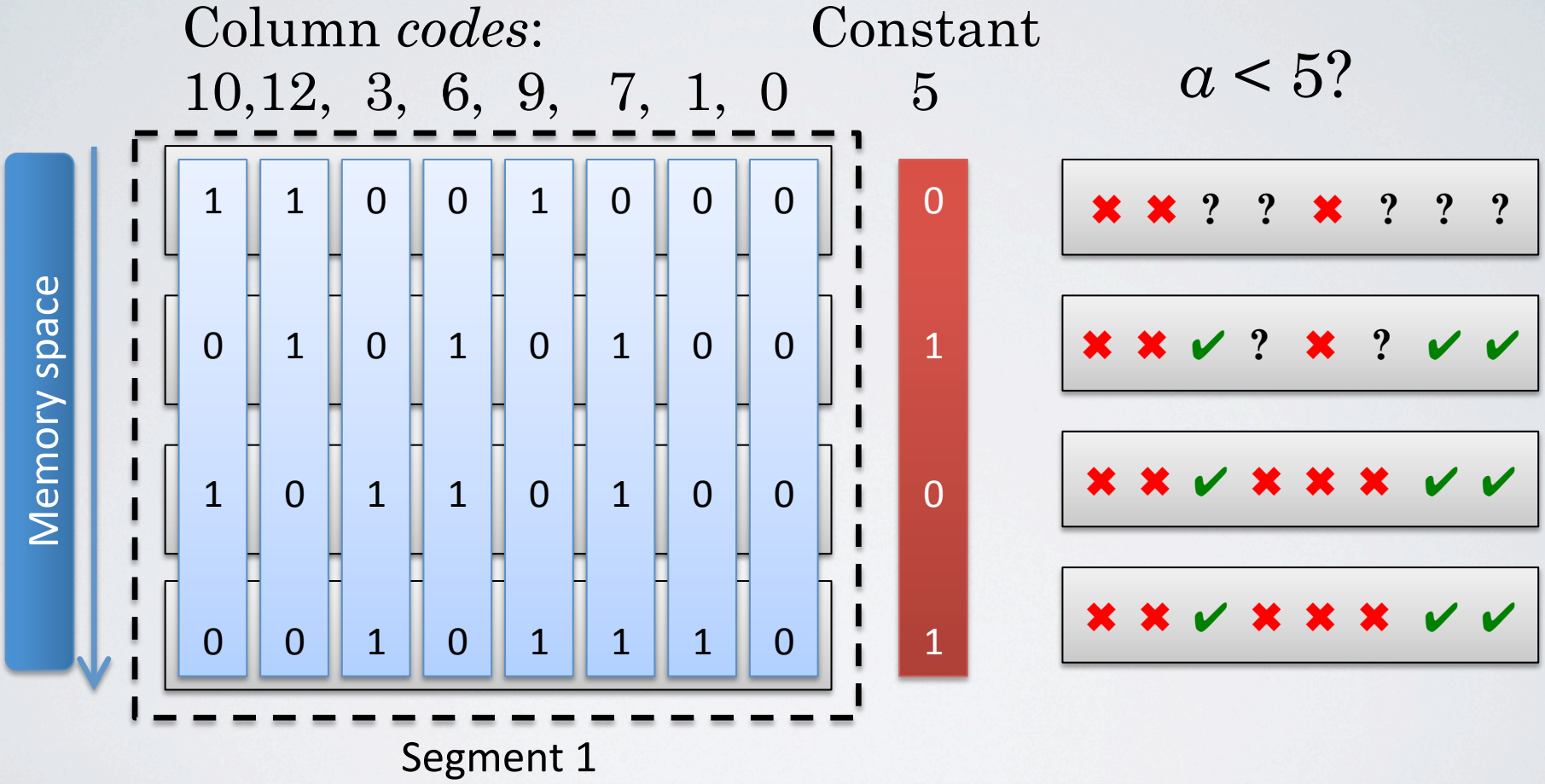
BitWeaving/V

- Storage layout
  - Bit-level columnar data organization, i.e. its like a **bit-level columnar store**.
- Column-scalar scan
  - Predicate evaluation is converted to logical computation on these "words of bits"

BitWeaving/V – Storage Layout

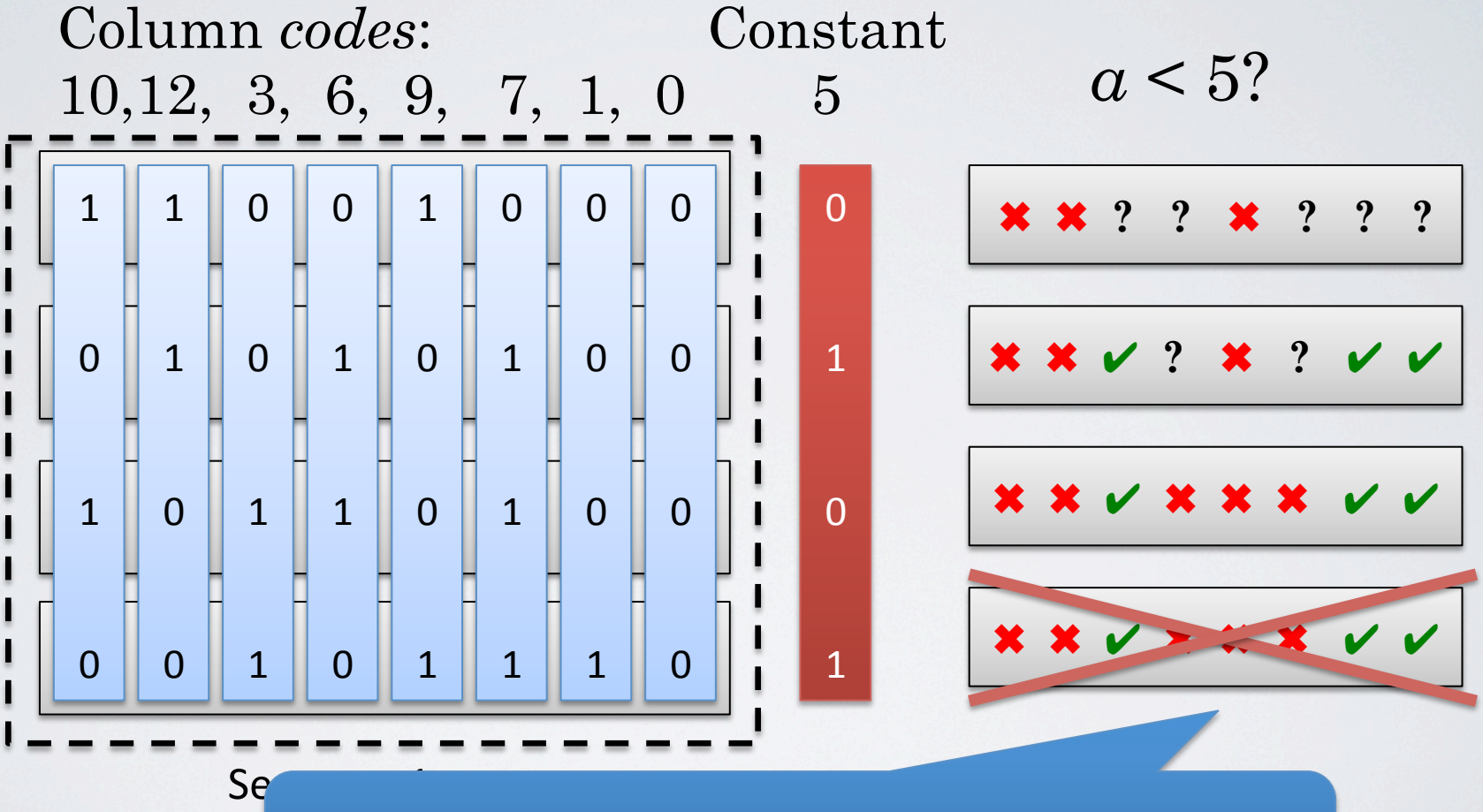


BitWeaving/V – Column-scalar Scan



The layout of the segment exactly matches the access pattern of column-scalar scans

BitWeaving/V – Early pruning



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Conclusions

BitWeaving: A new method to use all the bits in a processor word gainfully.

Two flavors: BitWeaving/H and BitWeaving/V.

BitWeaving are faster than state-of-the-art scan methods, in some cases by an order of magnitude.

Resource

- Blog article:
  - http://bigfastdata.blogspot.com/
- Paper:

  BitWeaving: Fast Scans for Main Memory Data Processing. In SIGMOD 2013.