



# In-Memory Text Search Engines

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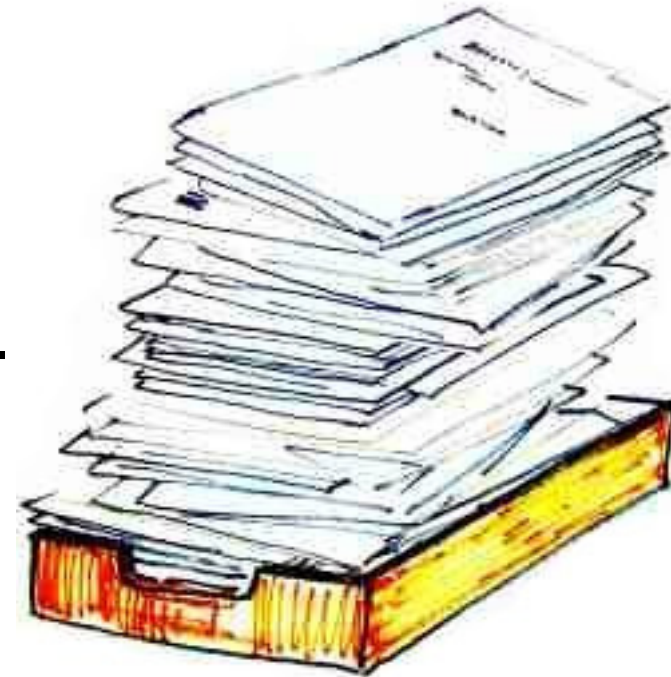


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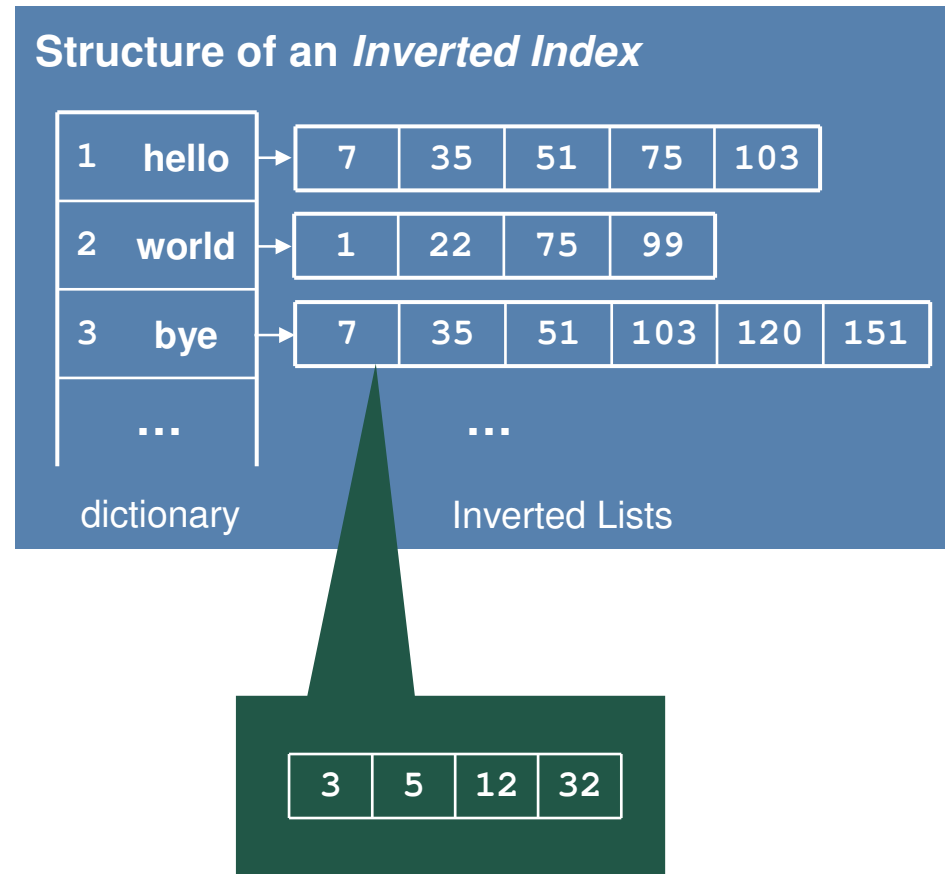
# Demands and Goals of Text Search Engines

- **Locating words in a huge number of documents.**
- **Important Operations: AND queries, phrase queries, document reporting.**
- **Using main-memory for maximum query performance.**



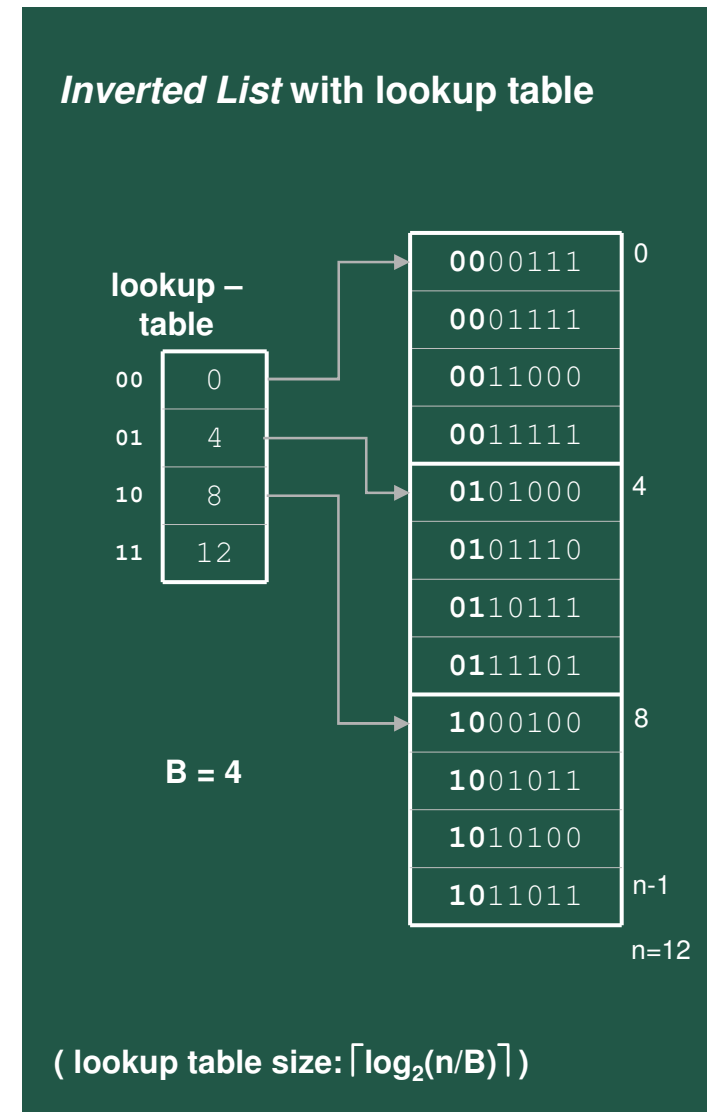
# Inverted Index

- **Unique IDs for:**
  - documents
  - terms
- **A document becomes a list of term IDs.**
- **Inverted Index:**  
For each term we store a list of document IDs.
- **Positional Inverted Index:**  
Positions list for each term / document pair.



# Intersection Algorithms: Randomized Inverted Indices

- **Randomized Inverted Index:** document IDs are assigned randomly. (e.g. using pseudo-random permutation)
- **Two-level data structure:**
  - Split the range of document IDs into buckets based on their most significant bits.
  - *Lookup-table:* direct access to the first value of a bucket



# Intersection Algorithms: Randomized Inverted Indices

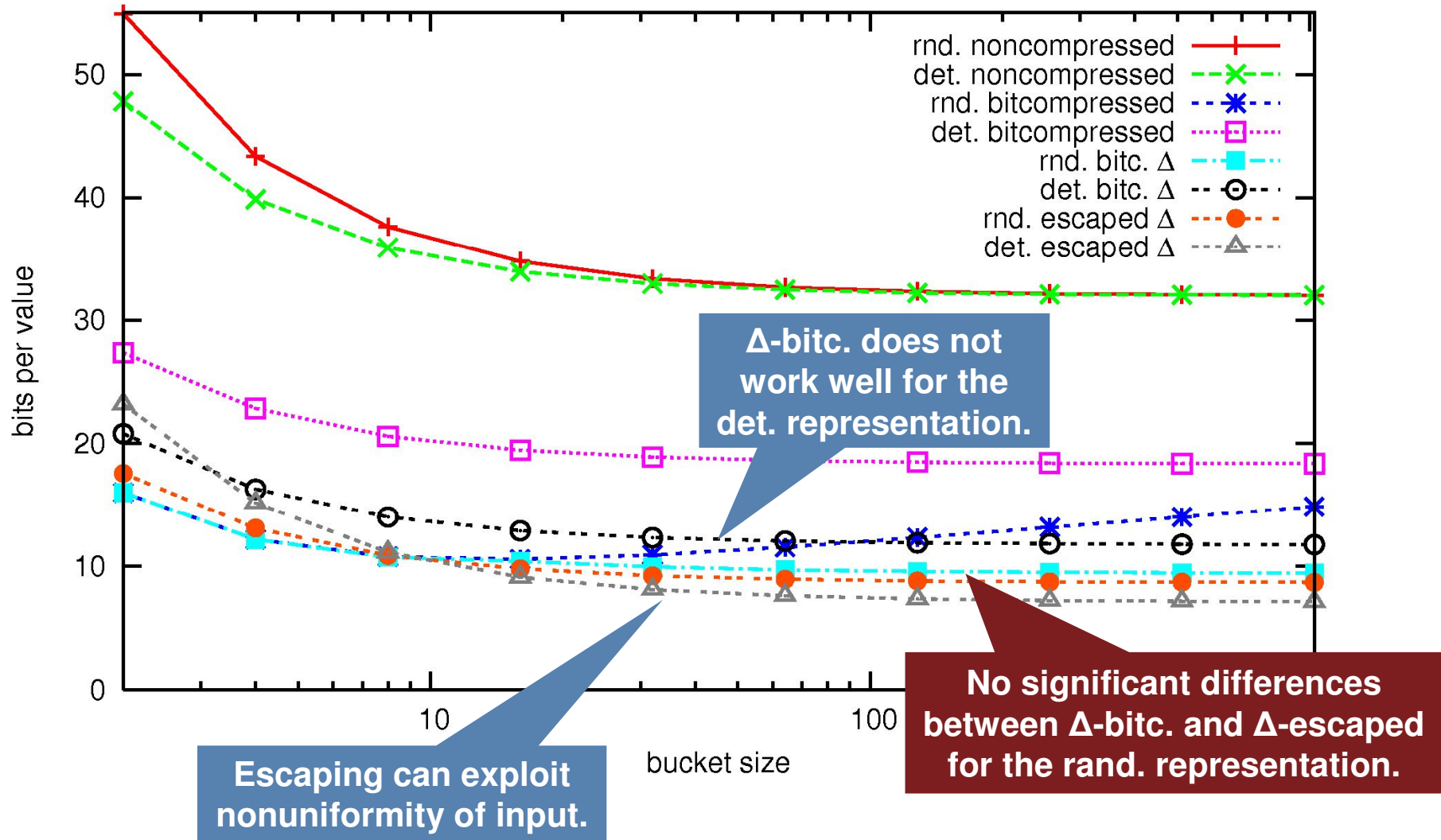
- *Lookup* is an intersection algorithm that runs on this data structure:

```
Function lookup(M, N)
    O := {} // output
    i := -1 // current bucket key (now a dummy)
    foreach d ∈ M do // unpack M
        h := d >> kN // bucket key
        l := d & (2kN-1) // least significant bits
        if h > i then // a new bucket
            i := h // set current bucket
            j := t[i] // get start position
            e := t[i+1] // get end position
            while j < e do // bucket not exhausted
                l' := N[j] // unpack if necessary
                if l ≤ l' then
                    if l = l' then O := O ∪ {d}
                    break while
            j++
    return O
```

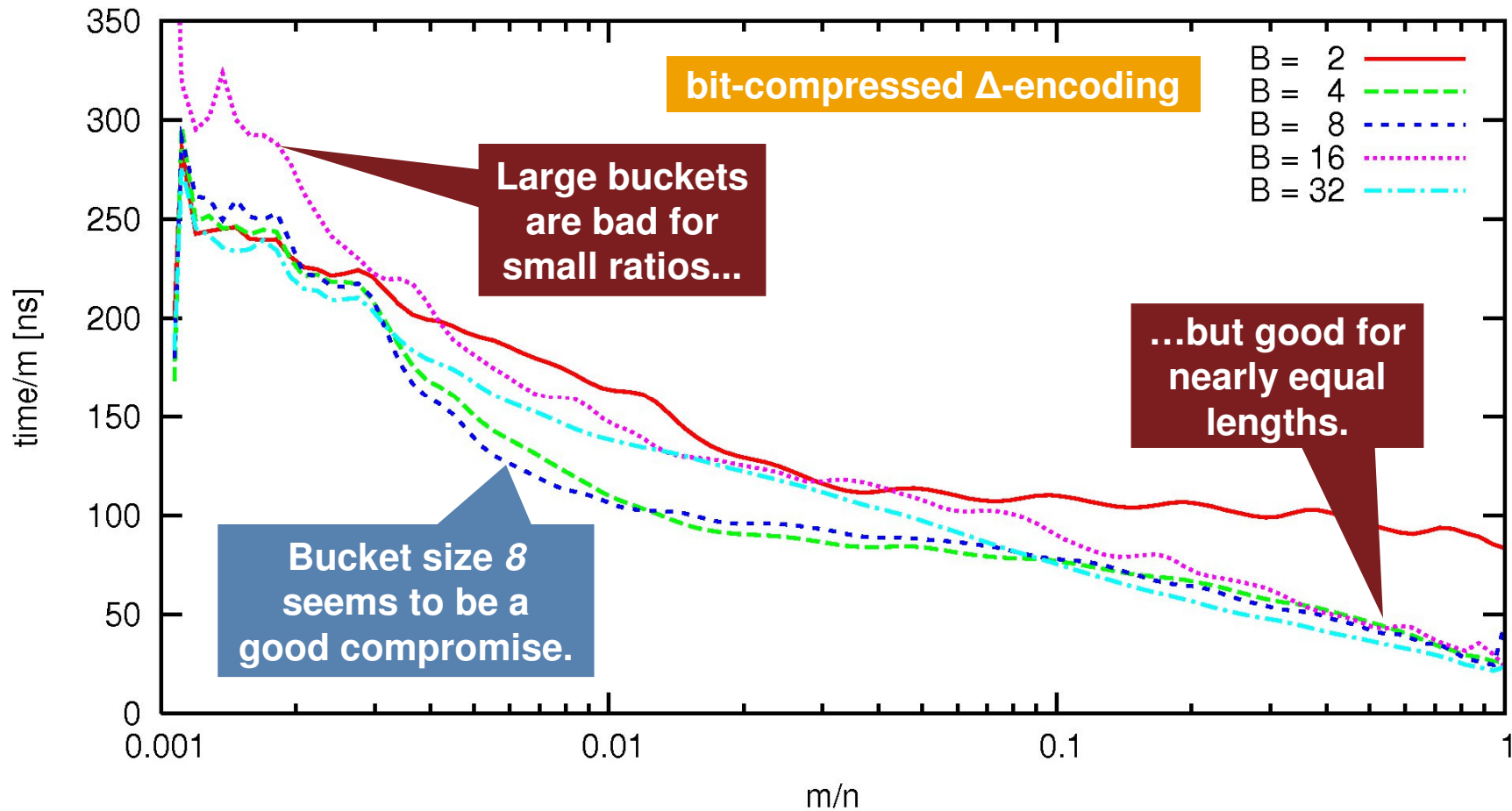
Lookup runs in  
expected time  
 $O(m + \min\{n, Bm\})$



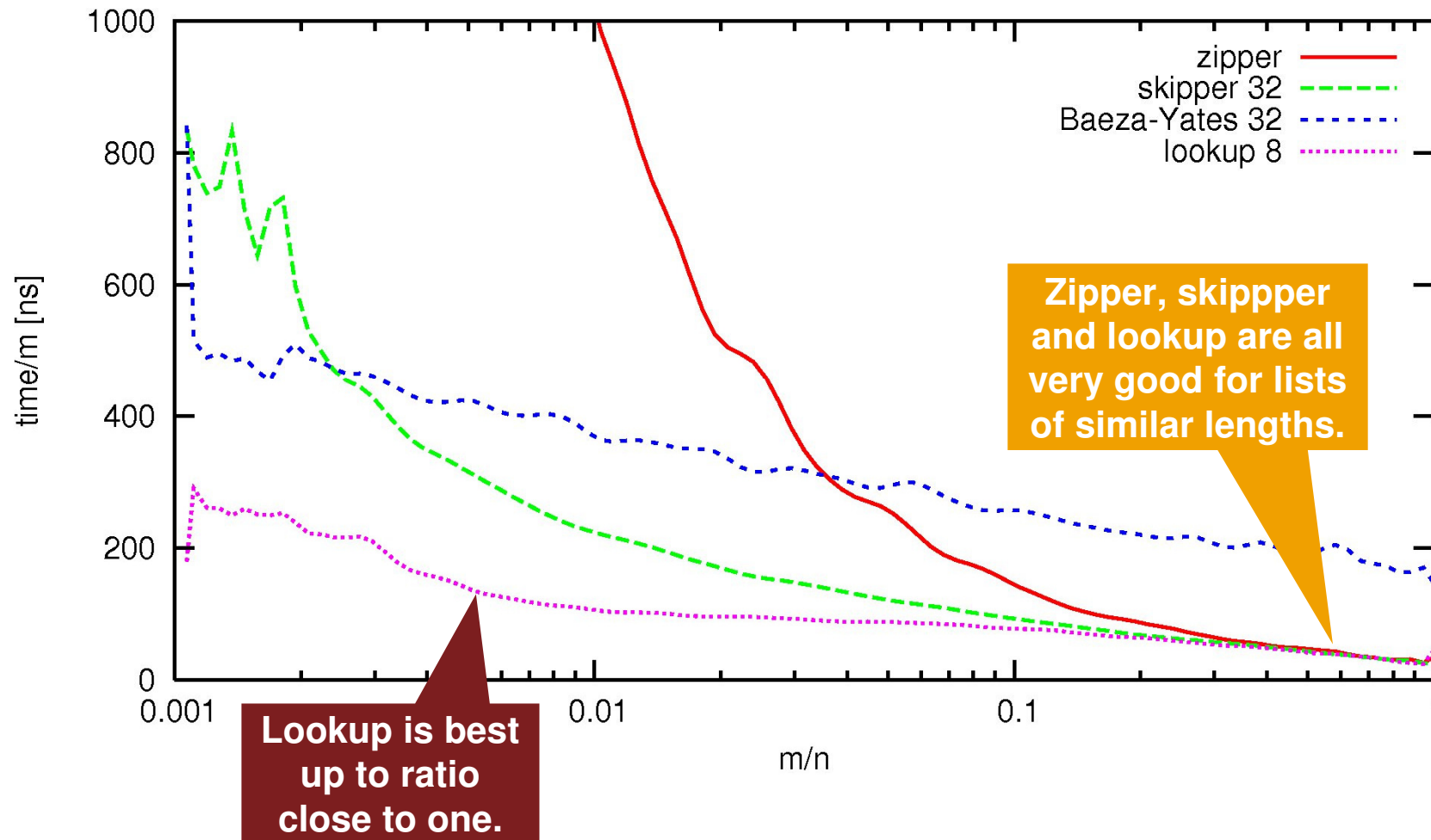
# Experiments: Space Consumption (WT2g)



# Experiments: Performance of *Lookup* (WT2g)

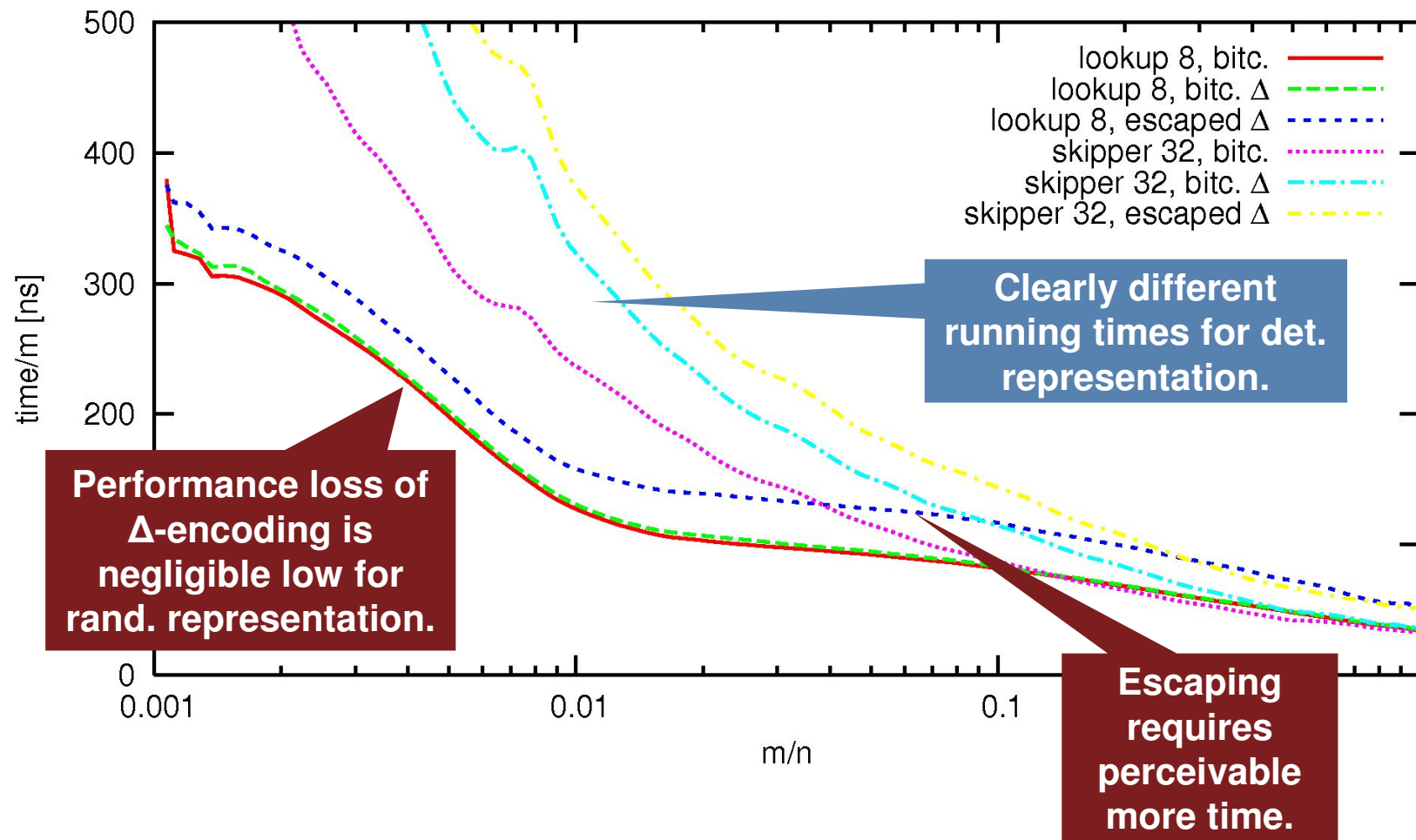


# Experiments: Performance Comparison (WT2g)

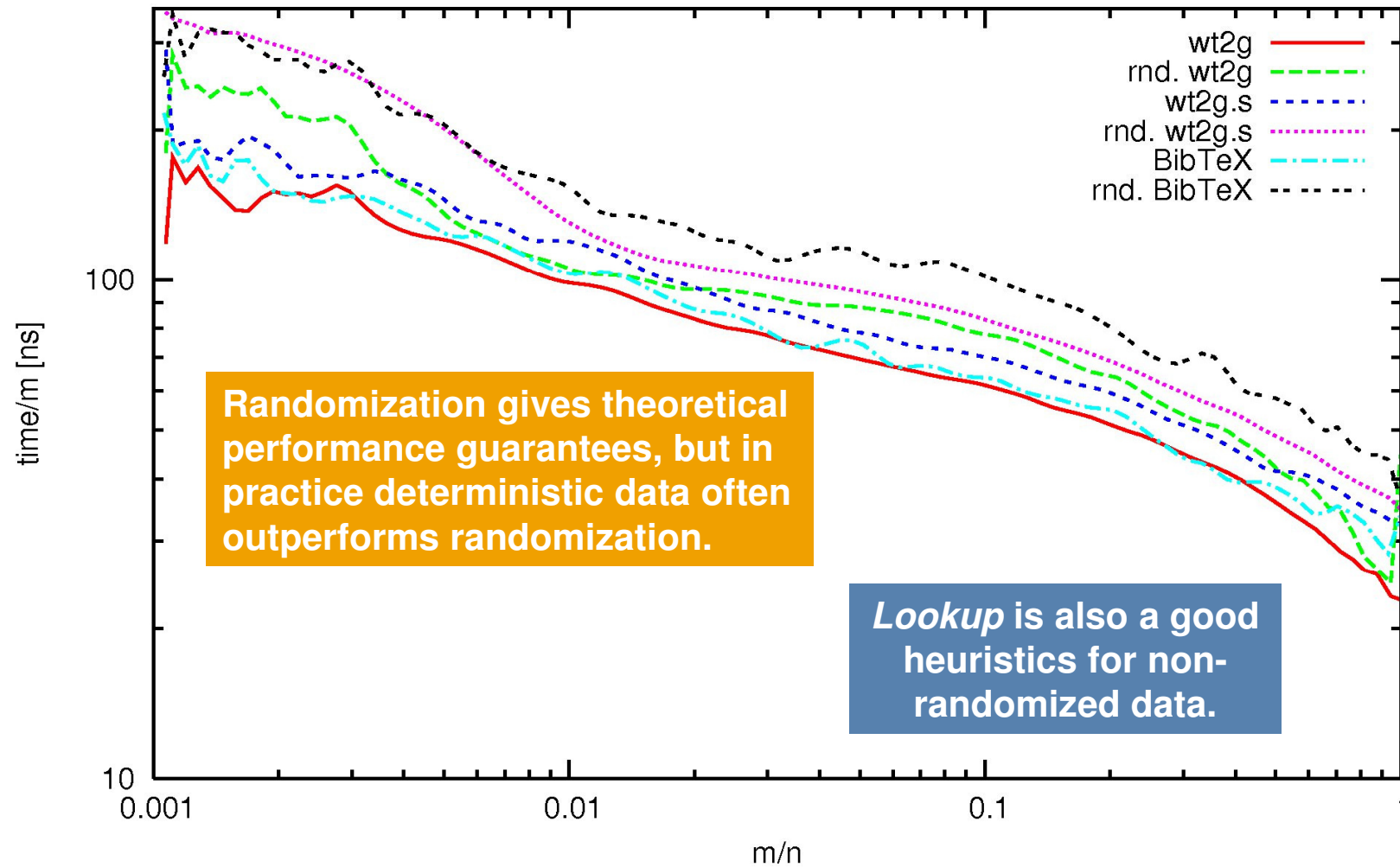




# Experiments: Space-time Tradeoff of Encodings (WT2g.s)



# Experiments: Impact of Randomization on *Lookup*



# Suffix Arrays

- Suffix Arrays as full-text index: concatenate all text documents.
- Phrase search: A home match for SAs.
- AND searches:
  - search for terms
  - Intersect the occurrence lists.
- Document reporting
- Compressed or distinct SAs are available from the Pizza&Chili website:

<http://pizzachili.di.unipi.it>

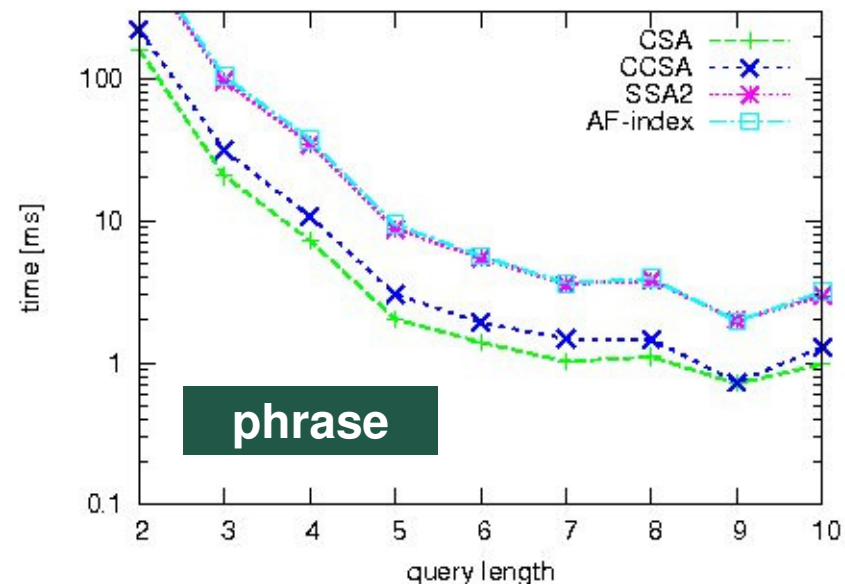
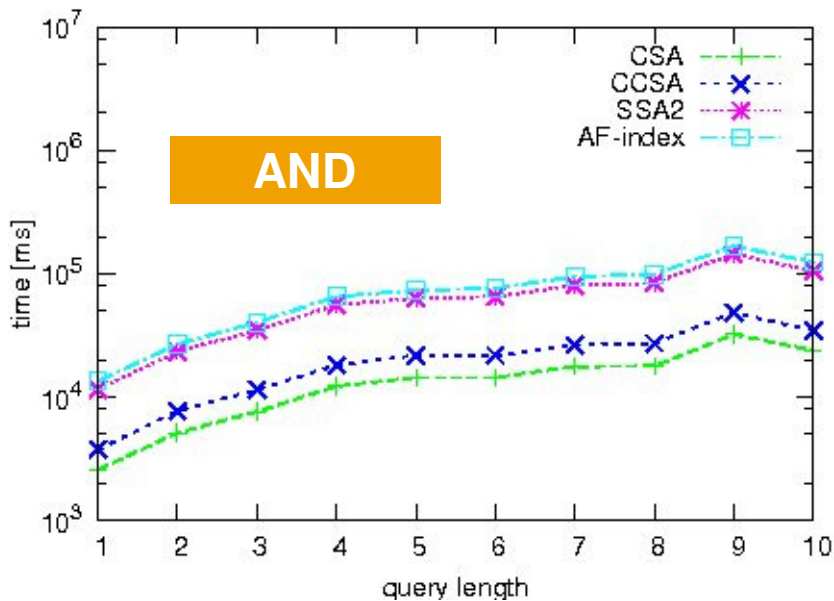
```
a  
abra  
abracadabra  
acadabra  
adabra  
bra  
bracadabra  
cadabra  
dabra  
ra  
racadabra
```

Suffix array of  
„abracadabra“

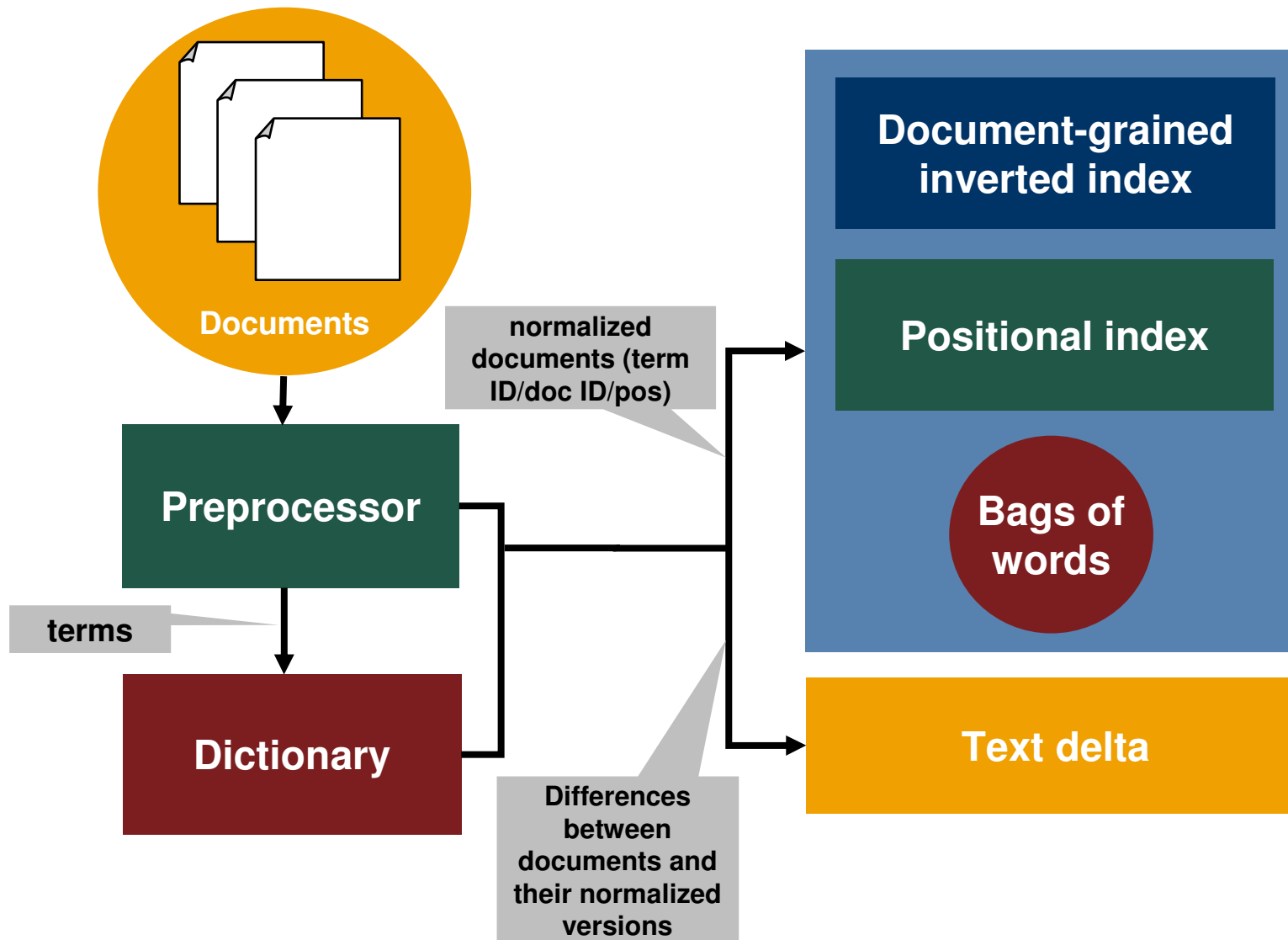


# Performance of different SAs on WT2g 1-50000

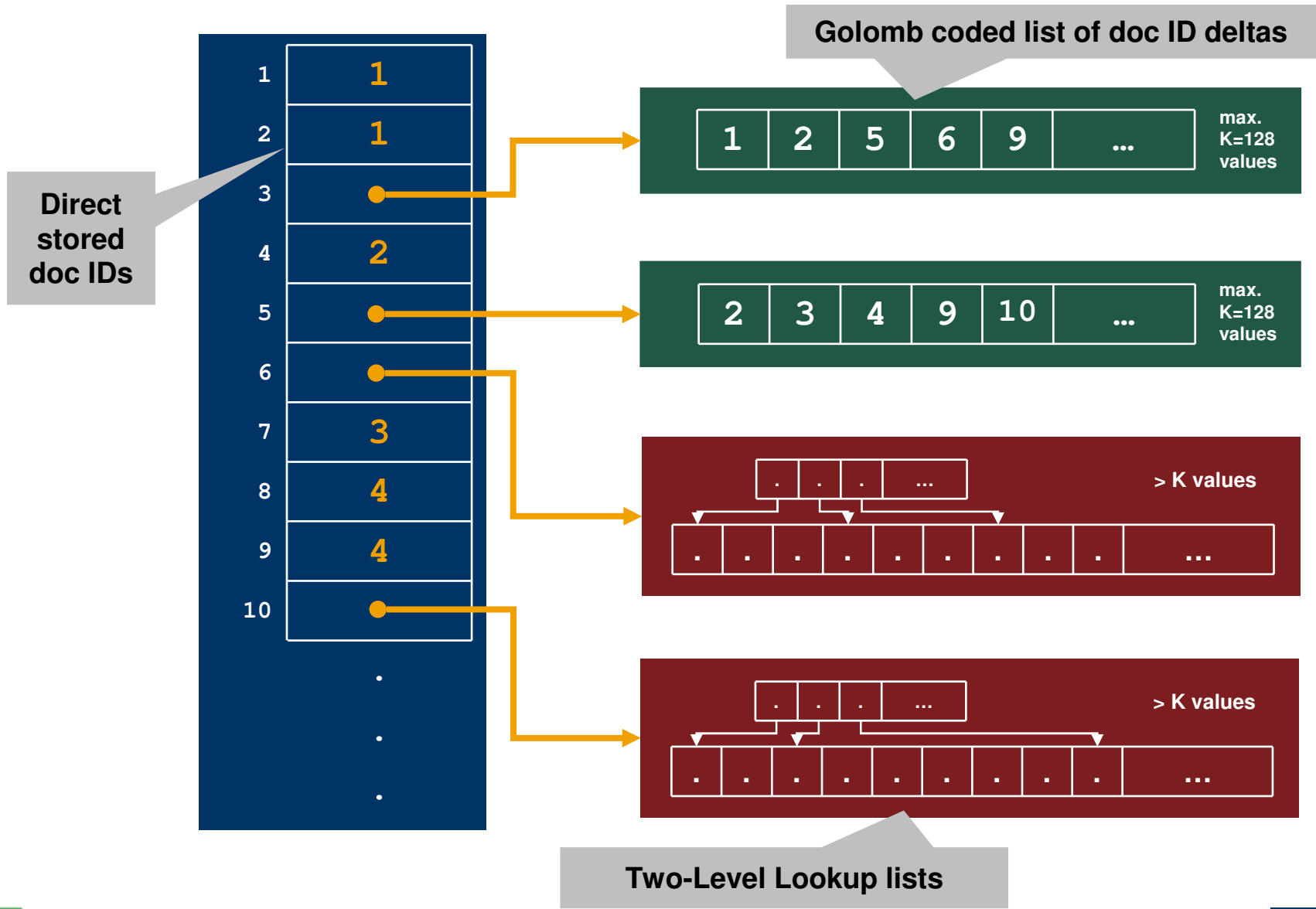
	CSA	CCSA	SSA2	AF-index
<b>size [MB]</b>	<b>230.9</b>	500.9	302.6	279.3
<b>compression</b>	<b>0.64</b>	1.39	0.84	0.77
<b>indexing time [min]</b>	<b>9.3</b>	11.5	8.7	23.0
<b>peak mem usage [GB]</b>	3.2	3.1	<b>2.1</b>	3.1



# Modular Design of the Compressed Inverted Index (CII)

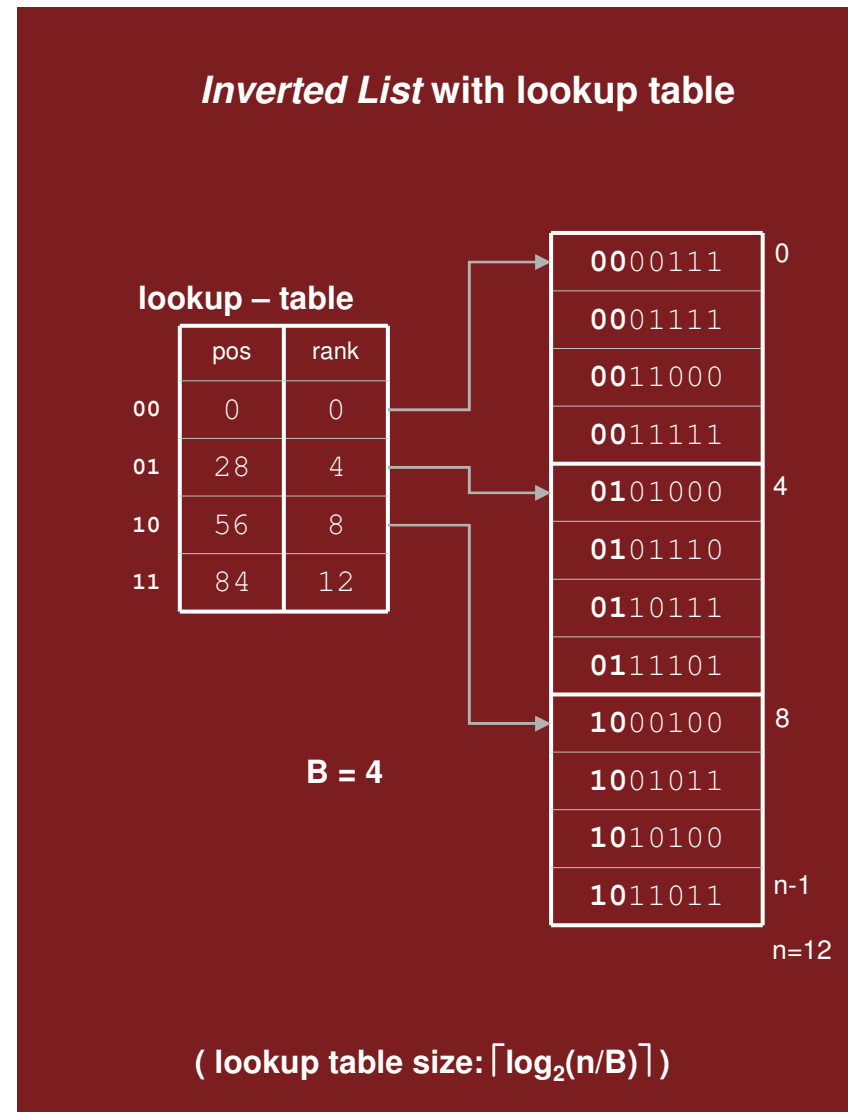


# CII: Document-grained Inverted Index

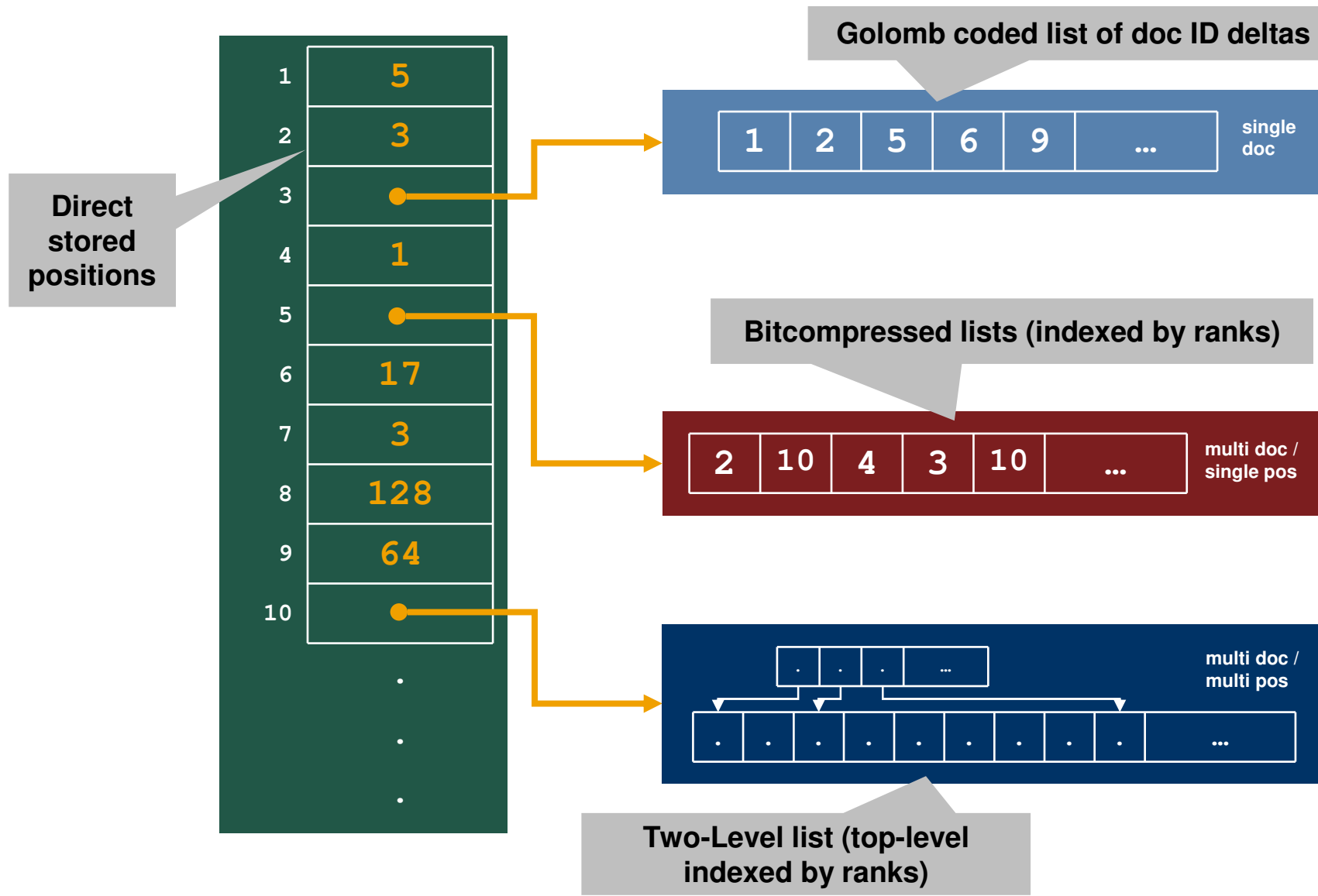


# Document-grained Index: Lookup List

- Two-level data structure, refinement of [Sanders and Transier, 2007]:
  - Split the range of document IDs into buckets based on their most significant bits.
  - **Lookup-table**: direct access to the first value of a bucket
  - **Rank information**: number of values smaller than the contents of a bucket.
  - **Variable Golomb coding**: estimating the average of each bucket.

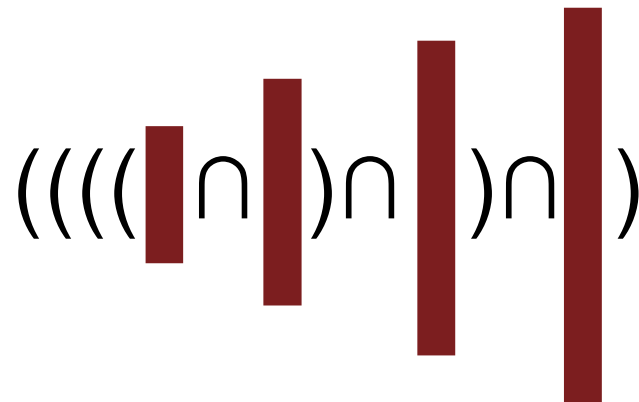


# CII: Positional Index



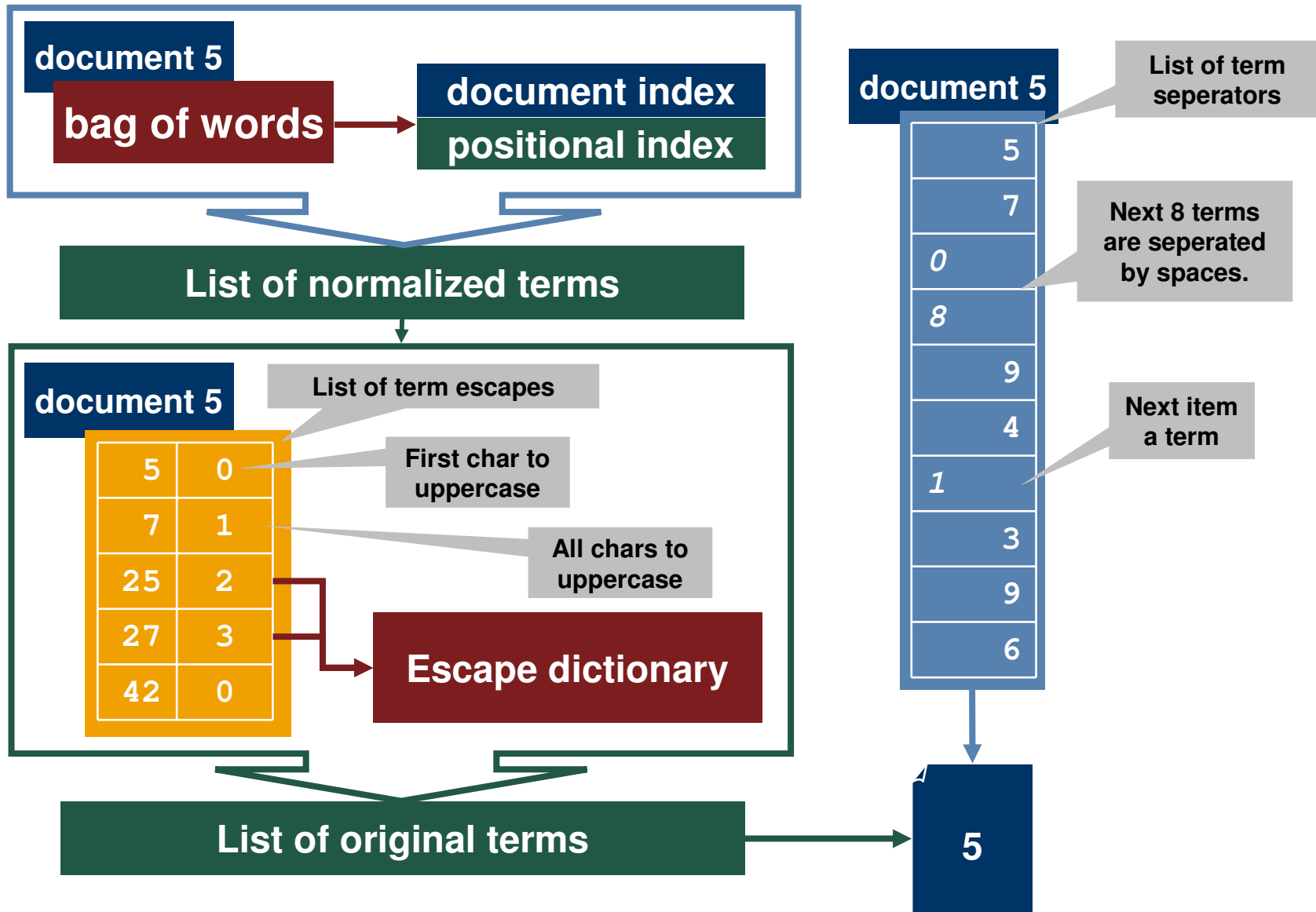


- **AND Query: Intersection of inverted lists in increasing order of list lengths.**



- **Phrase Query:**
  - As AND queries, but keeping track of the current ranks.
  - Retrieve corresponding position lists.
  - Check positions.

# CI: Document Reporting with Text Delta



- We have implemented all algorithms using C++.
- One core of an Intel Core 2 Duo E6600, clocked at 2.4 GHz with 2 x 2MB L2 cache and 4 GB main memory.
- openSuSE 10.2 (kernel 2.6.18), gcc 4.1.2 (-O3)
- Timing with PAPI 3.5.0



- **Real world instance: first 50.000 docs of WT2g.**
- **Pseudo real-world queries:**
  - **AND and phrase queries.**
  - **Selecting random hits.**
  - **Query lengths: 1-10 terms.**

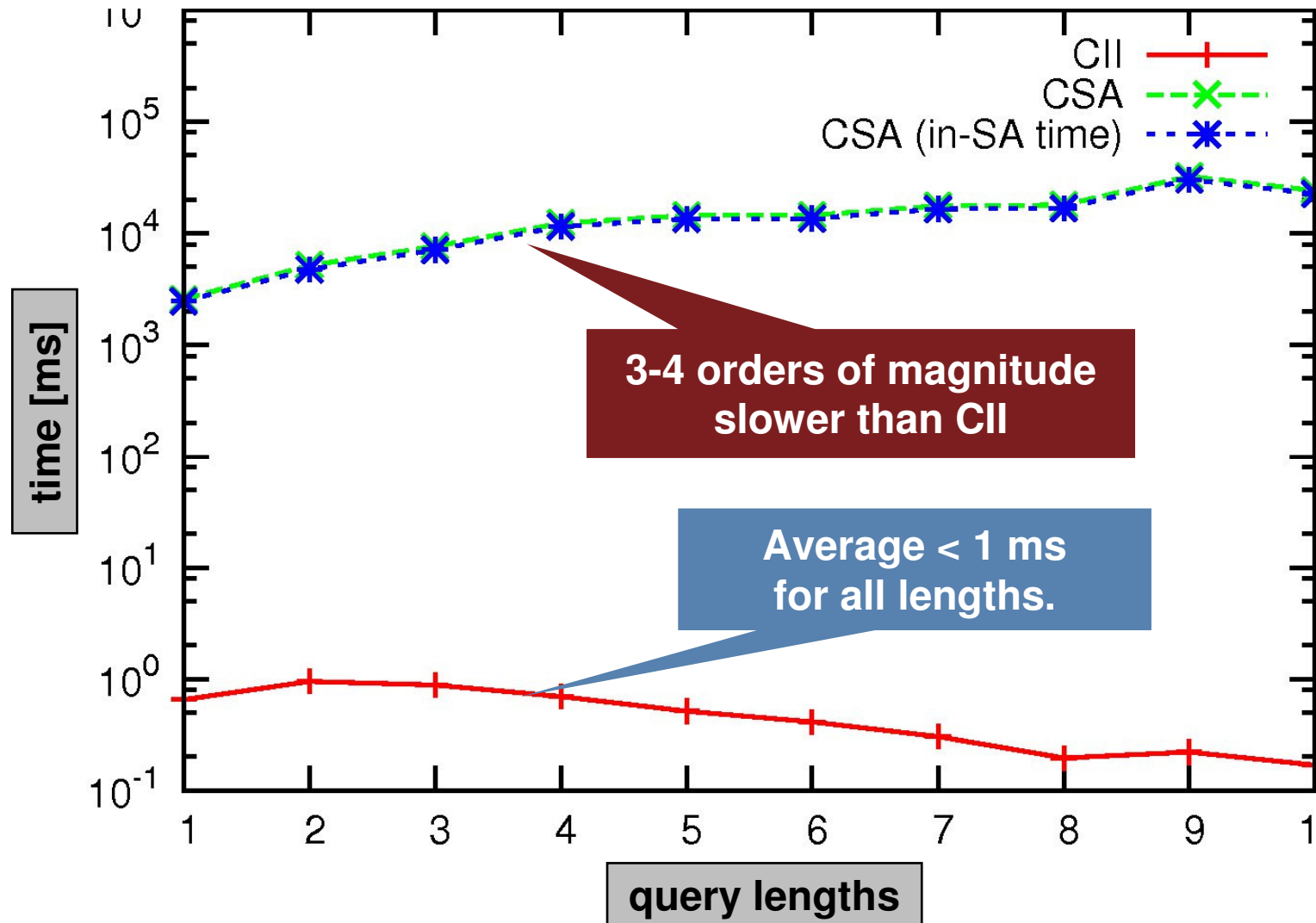


## Indexing: Space requirements

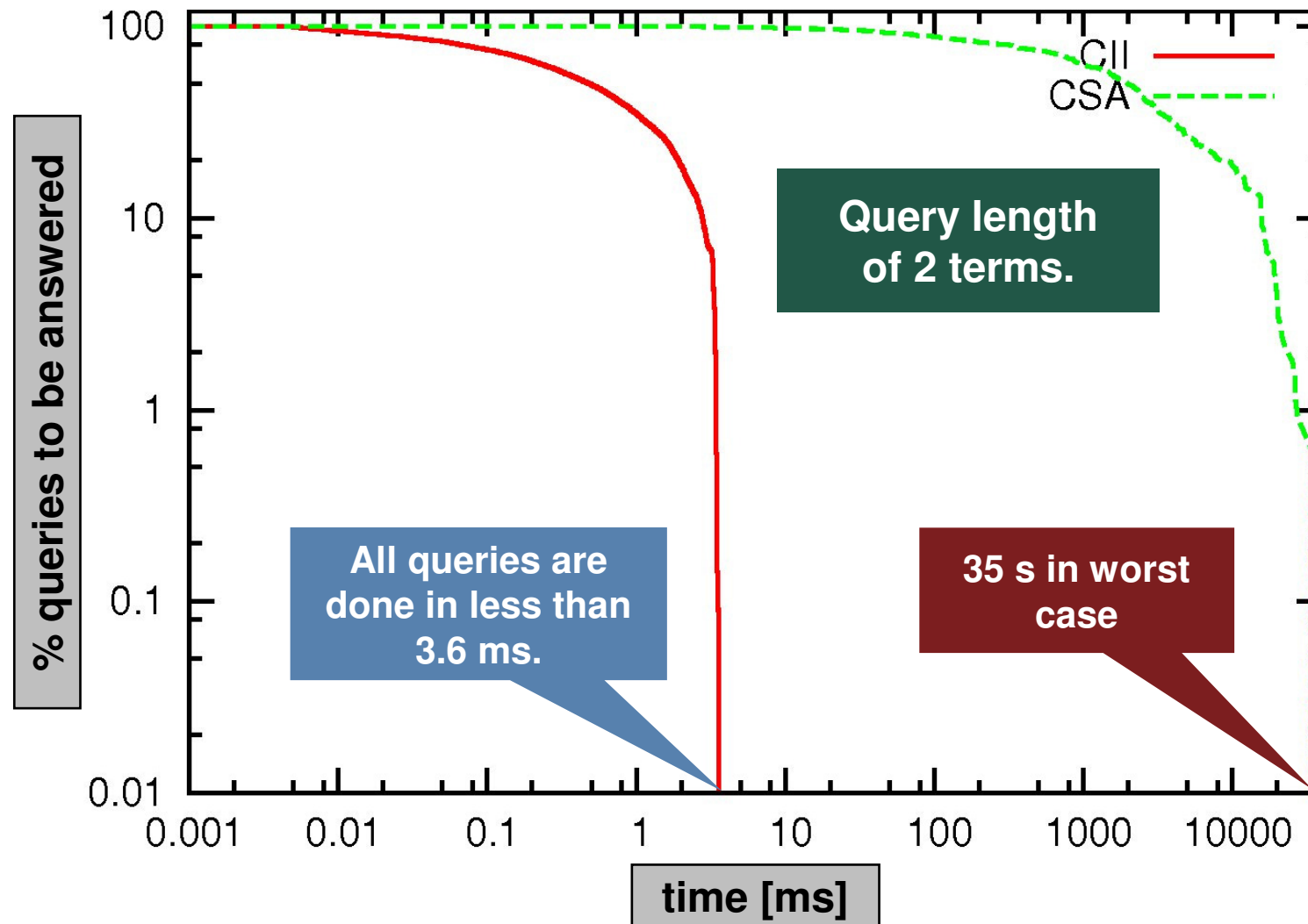
	CII	CSA
<b>dictionary</b>	23.9	
<b>document Index</b>	32.4	
<b>positional Index</b>	126.3	
<b>bag of words</b>	25.1	
<b>suffix array</b>		230.8
<b>doc bounds</b>		0.1
<b>sum [MB]</b>	<b>206.1</b>	<b>230.9</b>
<b>text delta [MB]</b>	108.7	
<b>sum + text delta [MB]</b>	<b>314.8</b>	
<b>input size (norm.)</b>	<b>412.8 (360.5)</b>	
<b>compression</b>	<b>0.76 (0.57)</b>	<b>- (0.64)</b>
<b>indexing time [min]</b>	<b>5.6 (5.1)</b>	<b>- (9.3)</b>
<b>peak mem usage [GB]</b>	<b>0.7</b>	<b>3.2</b>



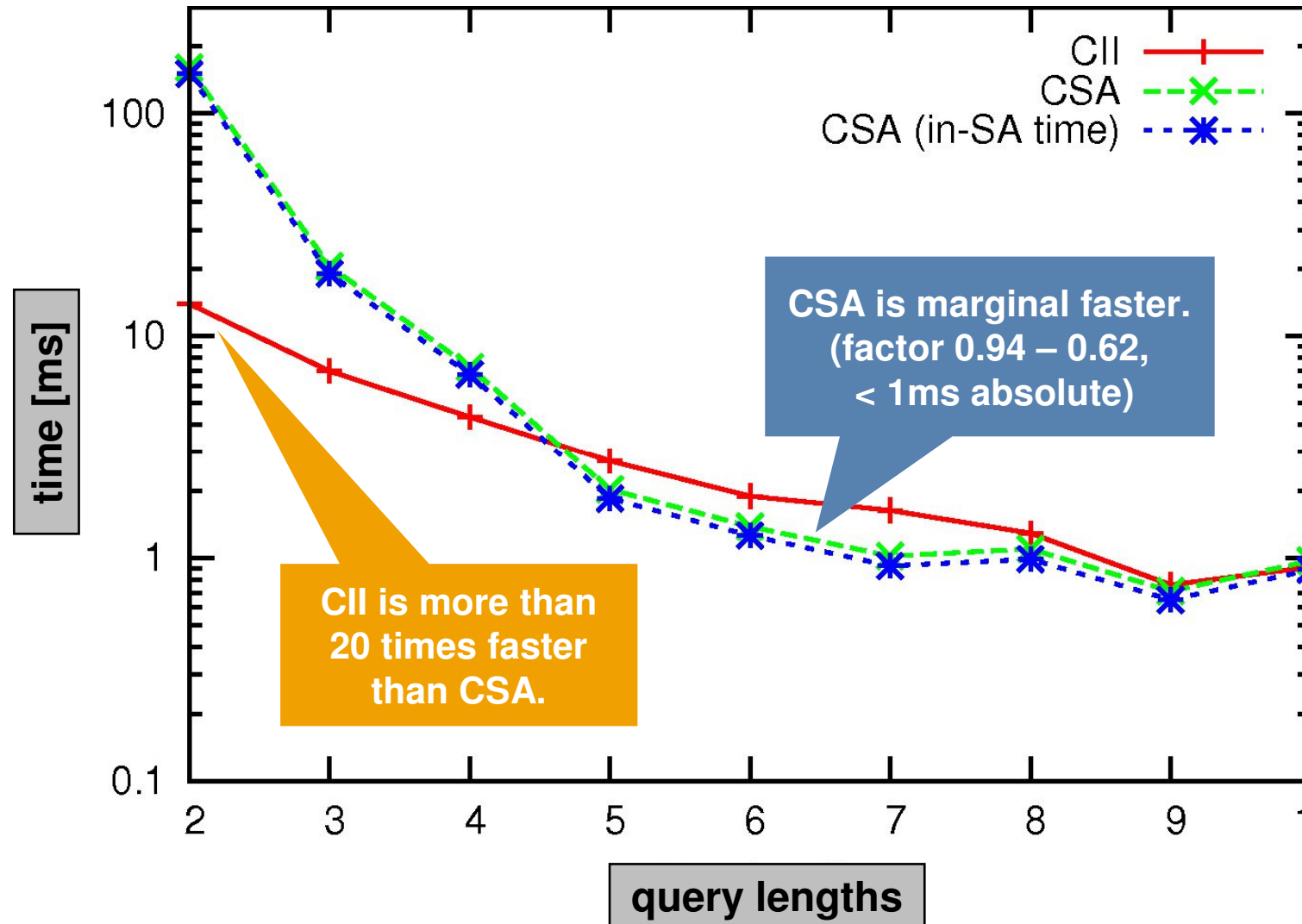
# Experiments: Average AND Query Time



# Experiments: How many % AND queries take longer than t?

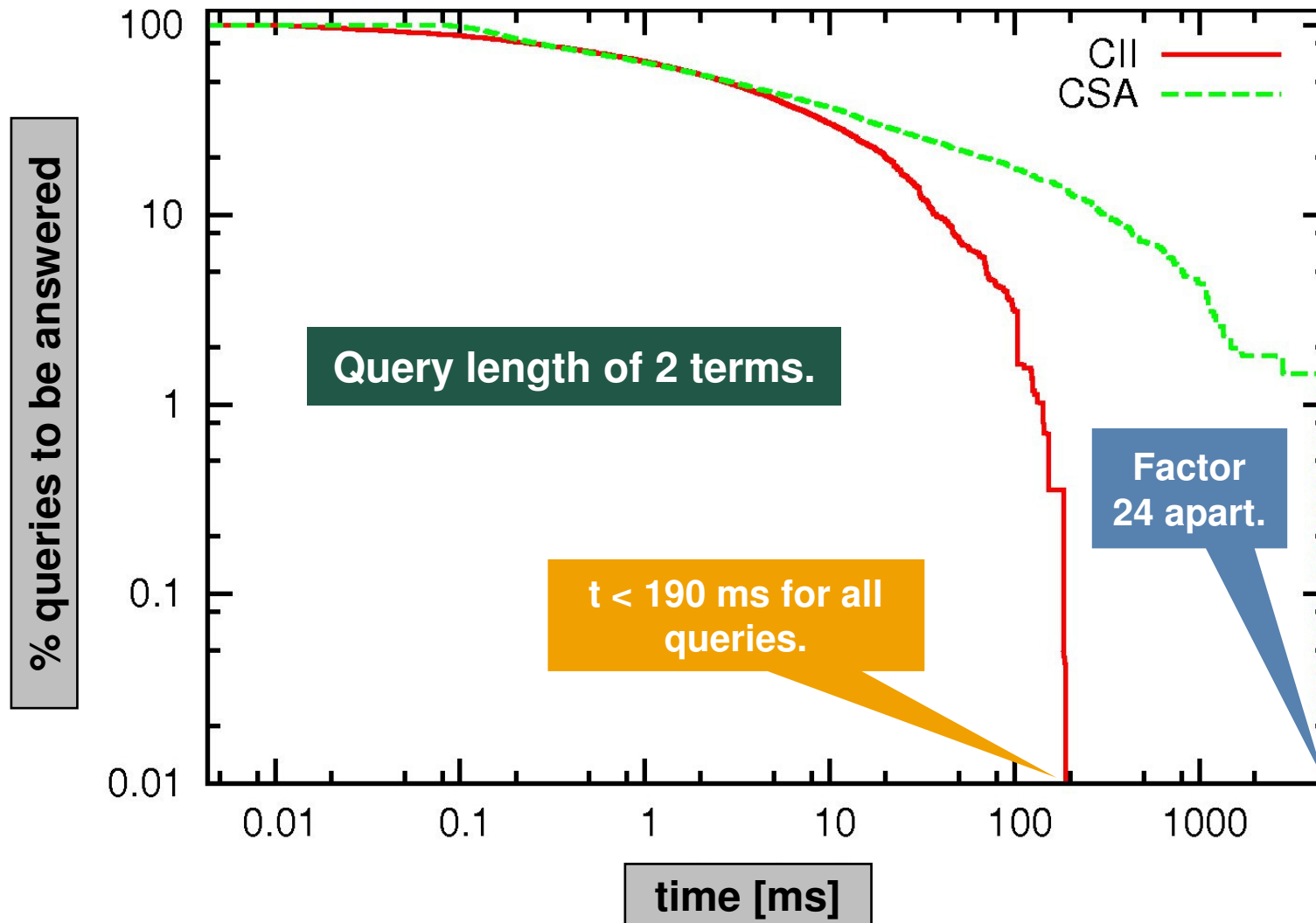


# Experiments: Average Phrase Query Time

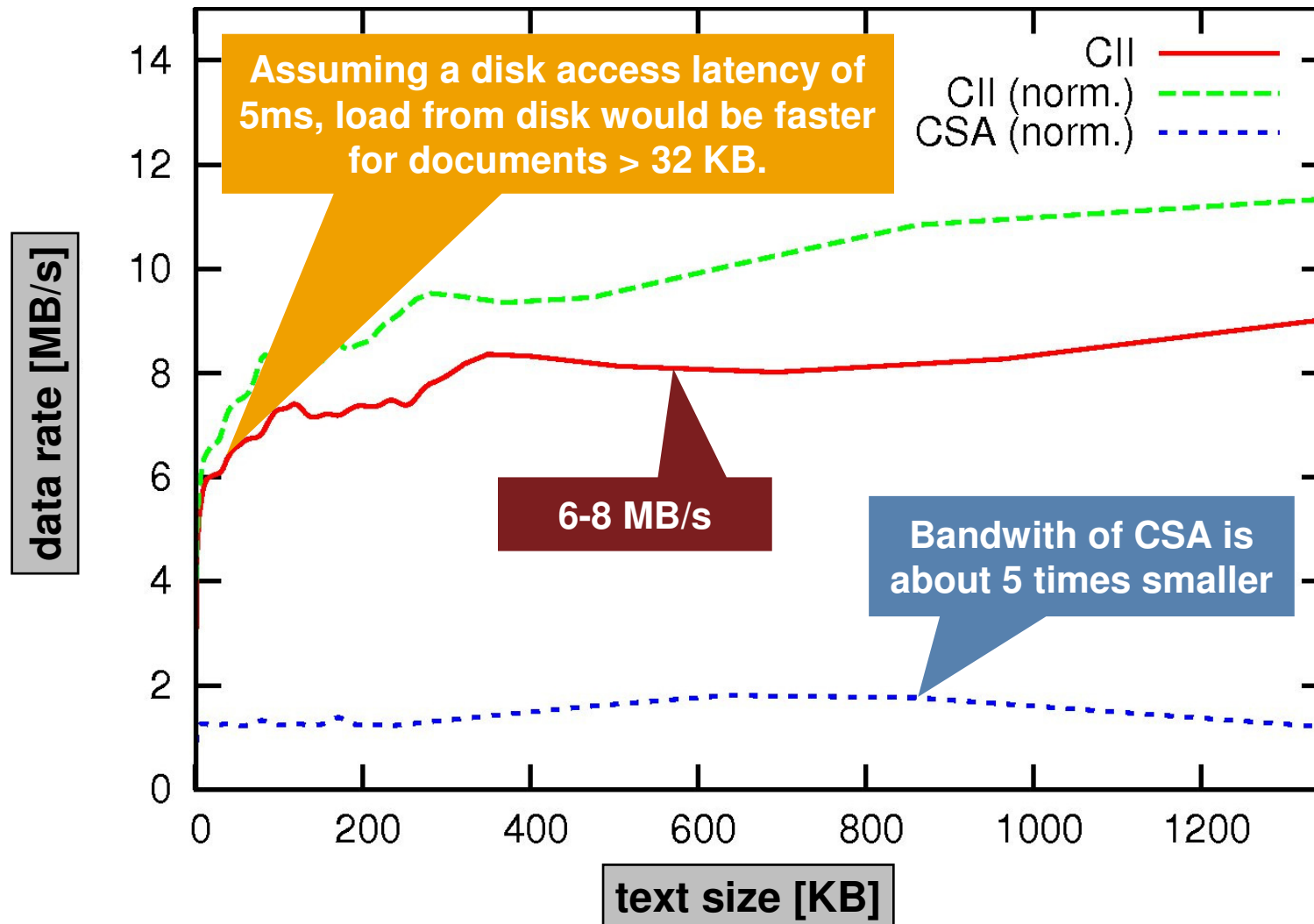




# Experiments: How many % phrase queries take longer than t?



# Experiments: Document Reporting



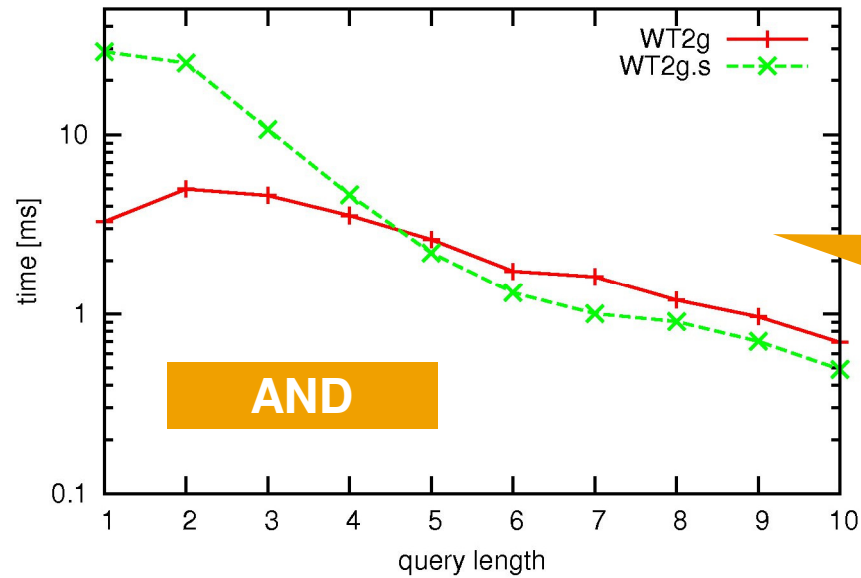
- Bag of words: adaptive coding scheme?
- Compression of the dictionary.
- Speeding up the most expensive phrase queries.
- Construction time?
- Fast updates?



**Thank You for  
Your attention!**



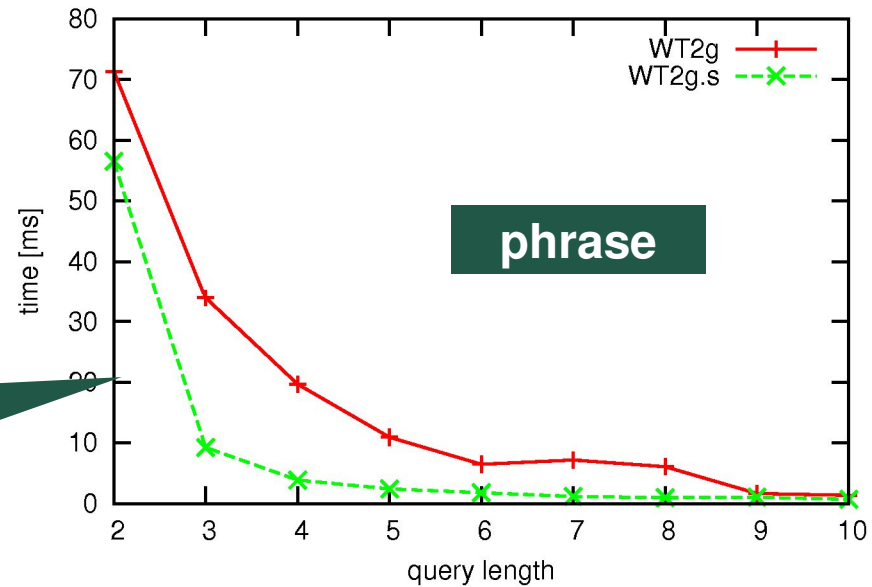
# CII on the complete WT2g / WT2g.s



**AND**

short queries are slower on WT2g.s, as there are more results.  
– Large queries are faster, as they benefit from more lookup lists.

Phrase queries are faster on WT2g.s, because the position lists are shorter.



**phrase**

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