Parallel Compression I/O with HDF5; Performance Tuning Techniques

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Outline

The HDF Group

- Overview of compression with HDF5
  - Chunking considerations
- Case studies of parallel compression in HDF5

Parallel HDF5 Compression

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- Relatively new functionality introduced in HDF5 version 1.10.2
  - Always seeking feedback on the performance you see in an application

- Limitations
  - ⛔ Doesn’t support independent operations. USE:

```
plist_id = H5Pcreate(H5P_DATASET_XFER);
H5set_dxpl_mpio(plist_id, H5FD_MPIO_COLLECTIVE);
```

  - Doesn't yet support linked chunk I/O for reading

Chunked Storage

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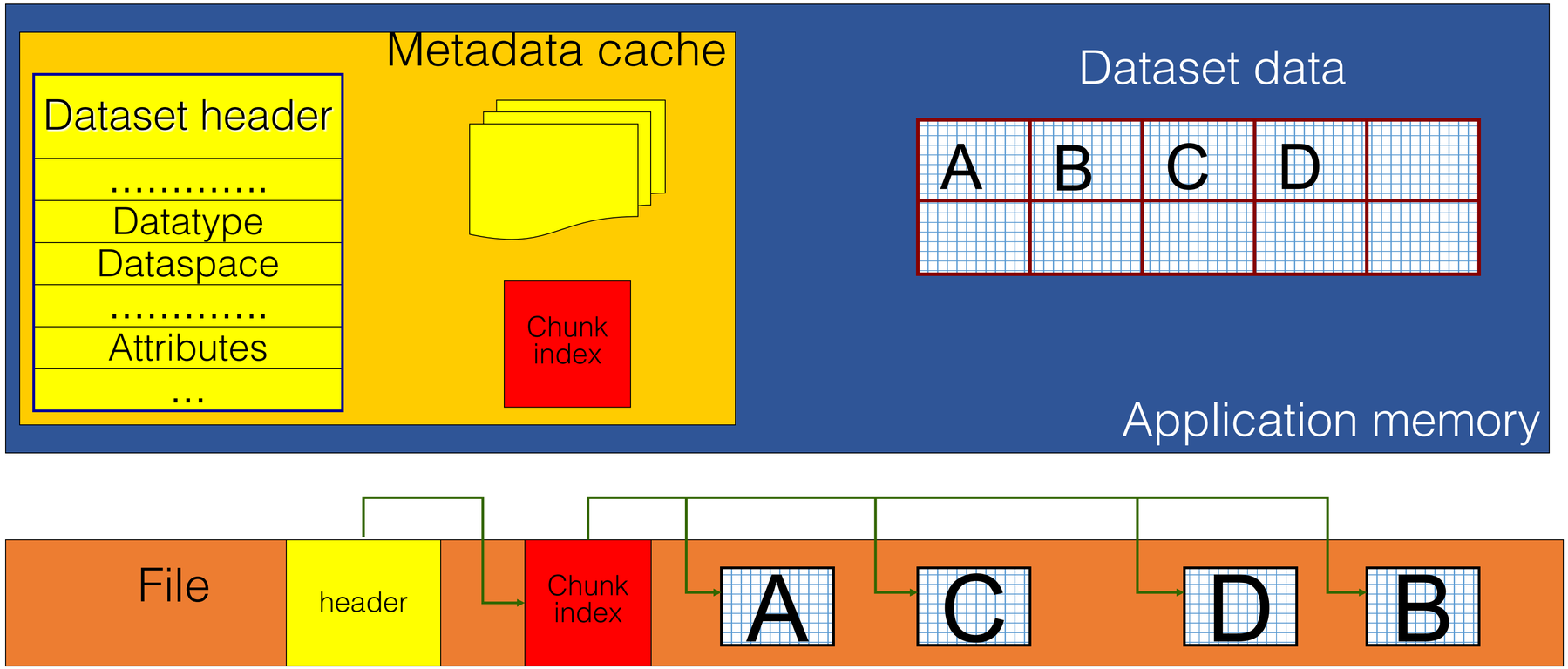
Good parallel HDF5 compression performance starts with good chunked dataset performance.

- Dataset data is divided into equally sized blocks (chunks).
- Each chunk is stored separately as a contiguous block in HDF5 file.



HDF5 Dataset – Chunked Storage

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- Chunking is required when using extendibility and/or compression and other filters
- **I/O** is always performed **on a whole chunk**
- Understand how **chunking cache** works https://portal.hdfgroup.org/display/HDF5/Chunking+in+HDF5 and consider
  - Do you access the same chunk often?
  - What is the best chunk size (especially when using compression)? NOTE: maximum size for any chunk is 4GB.
  - Do you need to adjust chunk cache size? (1 MB default; can be set up per file or per dataset)
  - `H5Pset_chunk_cache` sets raw data chunk cache parameters for a dataset
    - `H5Pset_chunk_cache (dapl, …);`
  - `H5Pset_cache` sets raw data chunk cache parameters for all datasets in a file
    - `H5Pset_cache (fapl, …);`

HDF5 Dataset – Chunked Storage (cont'd)

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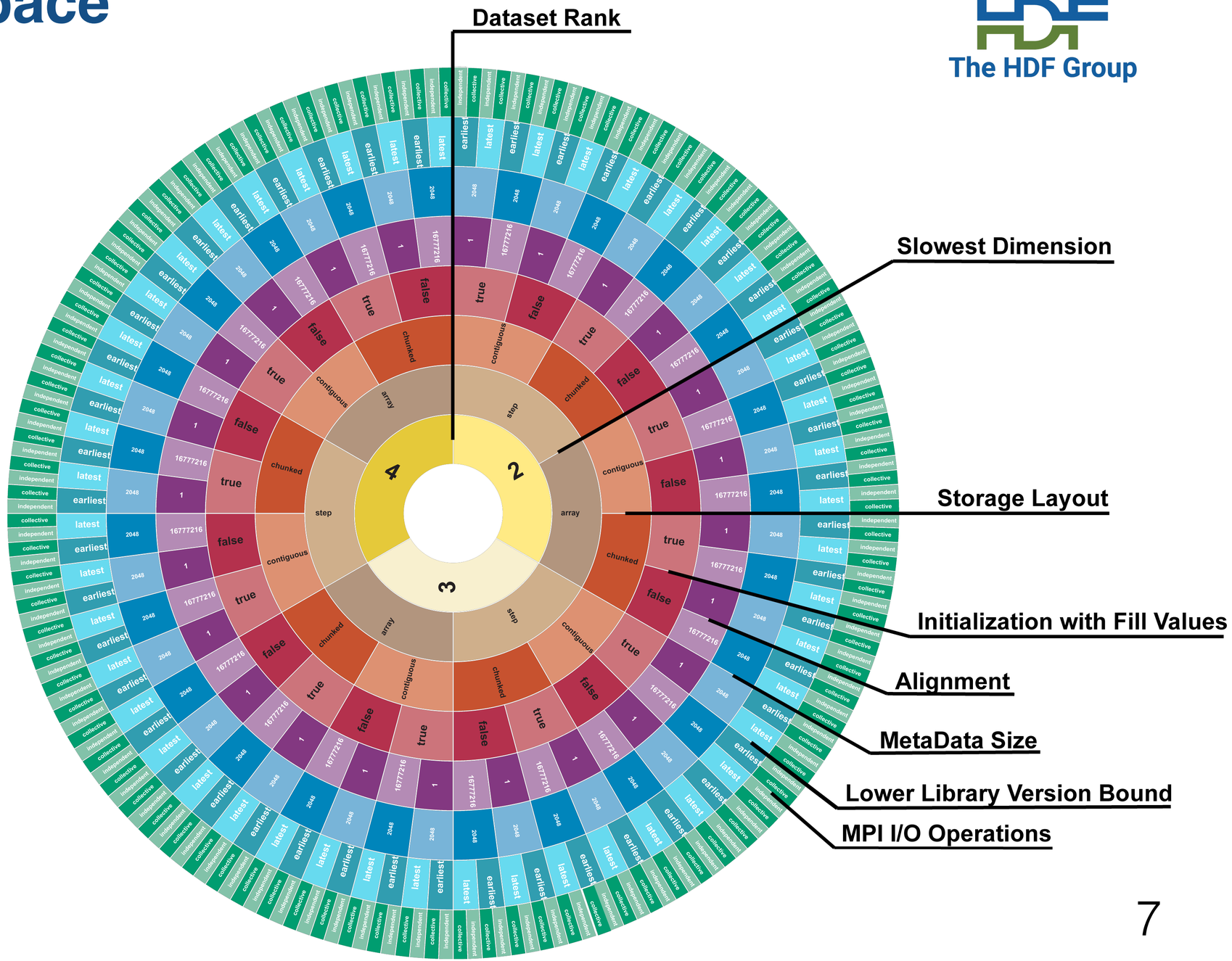
- Cache size is important when doing partial I/O to avoid many I/O operations
- With the 1 MB cache size, a chunk may not fit into cache
  - All writes to the dataset must be immediately written to disk

⚠ **With compression, the entire chunk must be read and rewritten every time a part of the chunk is written to**

  - Data must also be decompressed and recompressed each time
  - Non sequential writes could result in a larger file
- Without compression, the entire chunk must be written when it is first written to the file.
- To write multiple chunks at once increase the cache size to hold more chunks

HDF5 Parameter Space

HDF5 I/O[1] test explores the HDF5 parameter space



1 https://github.com/HDFGroup/hdf5-iotest

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IO Pattern Model

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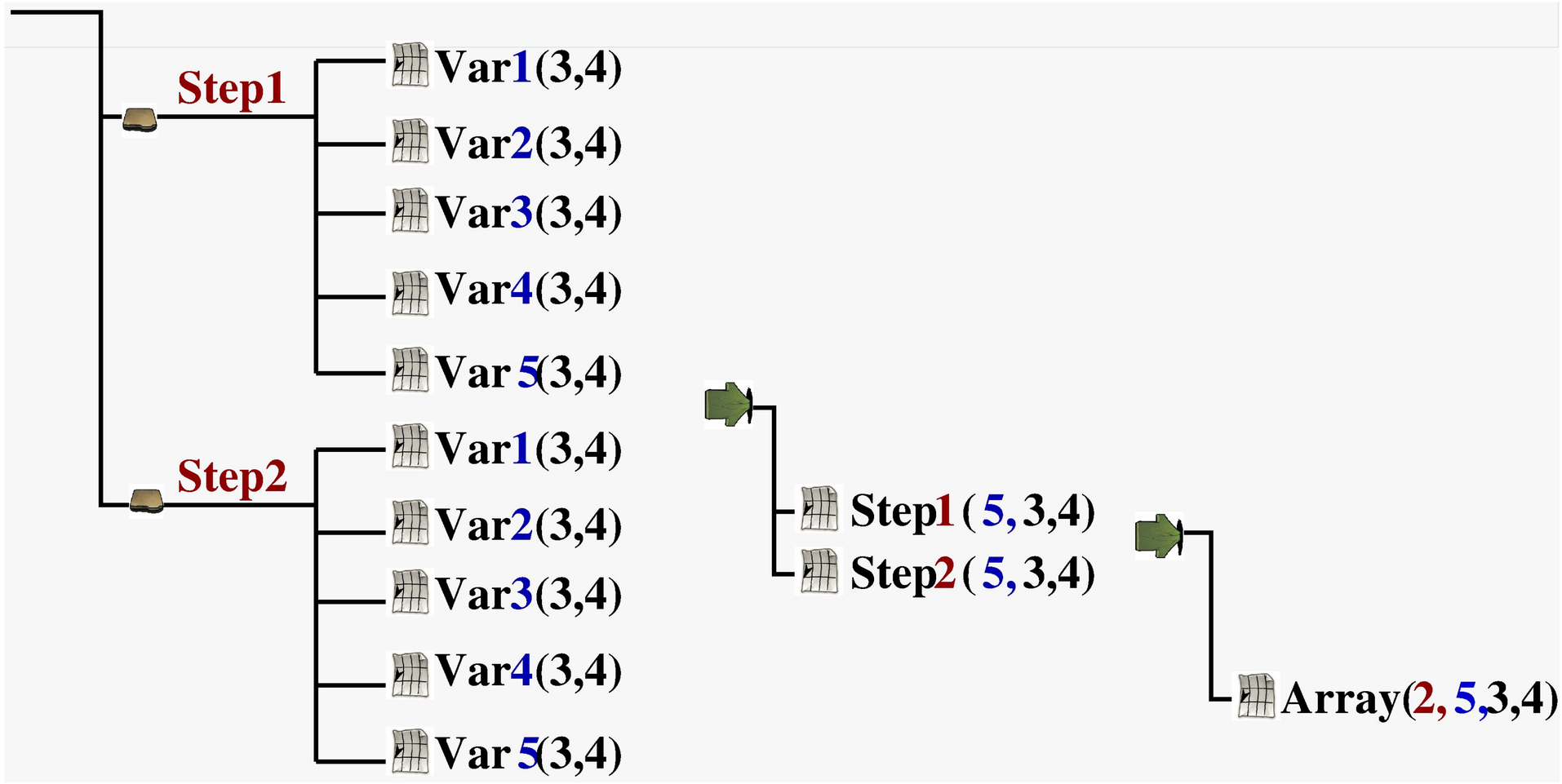
Step based IO Pattern



IO Pattern Model

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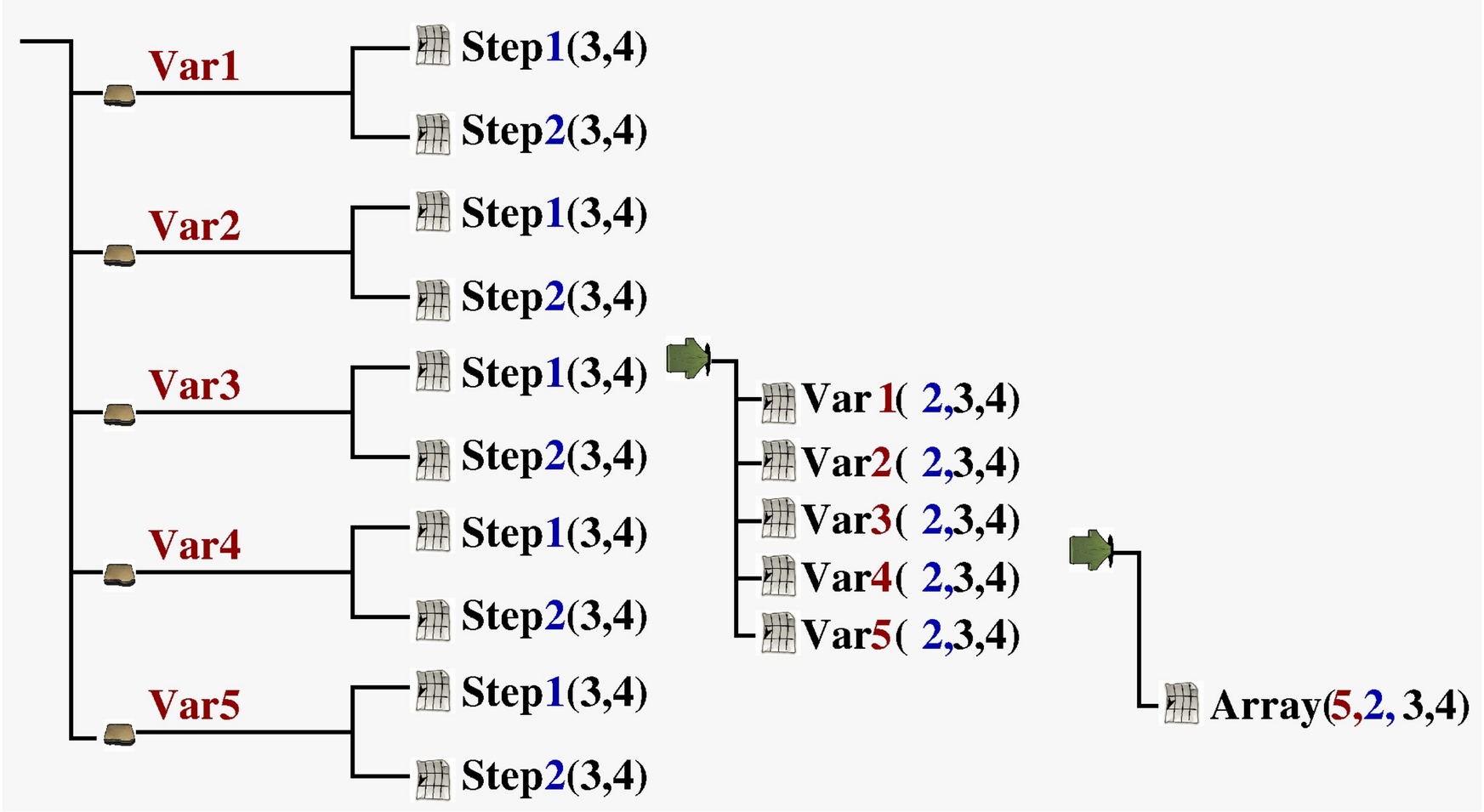
Array based IO Pattern



Parallel Compression Case Studies

Parallel HDF5 Compression

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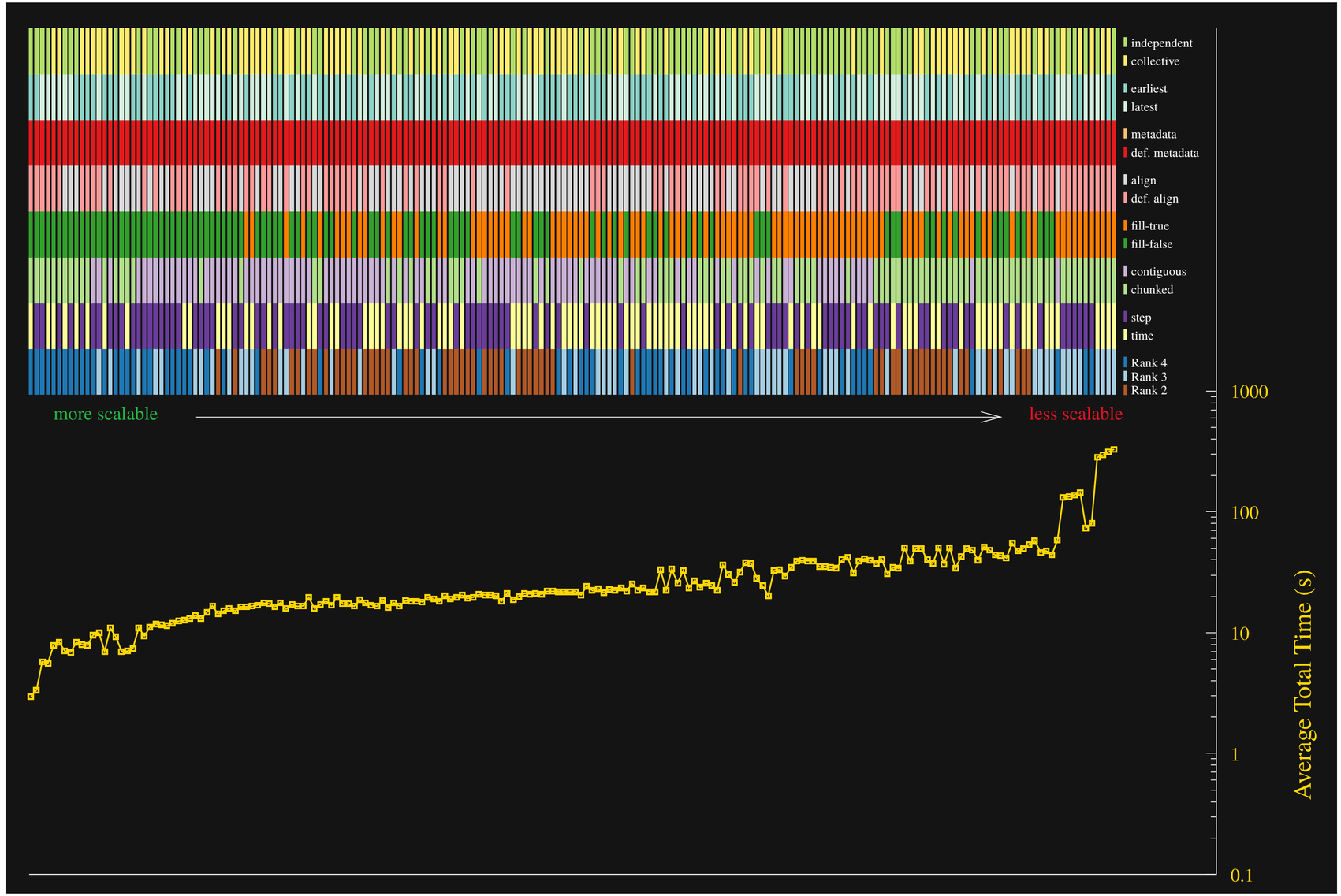
- Start from best weak scaling case scenario from ***hdf5-iotest*** on Summit :

1. Chunked dataset,
2. Collective with no-alignment,
3. Rank four array,
4. Step,
5. No fill values,
6. Earliest library version



Parallel HDF5 Compression

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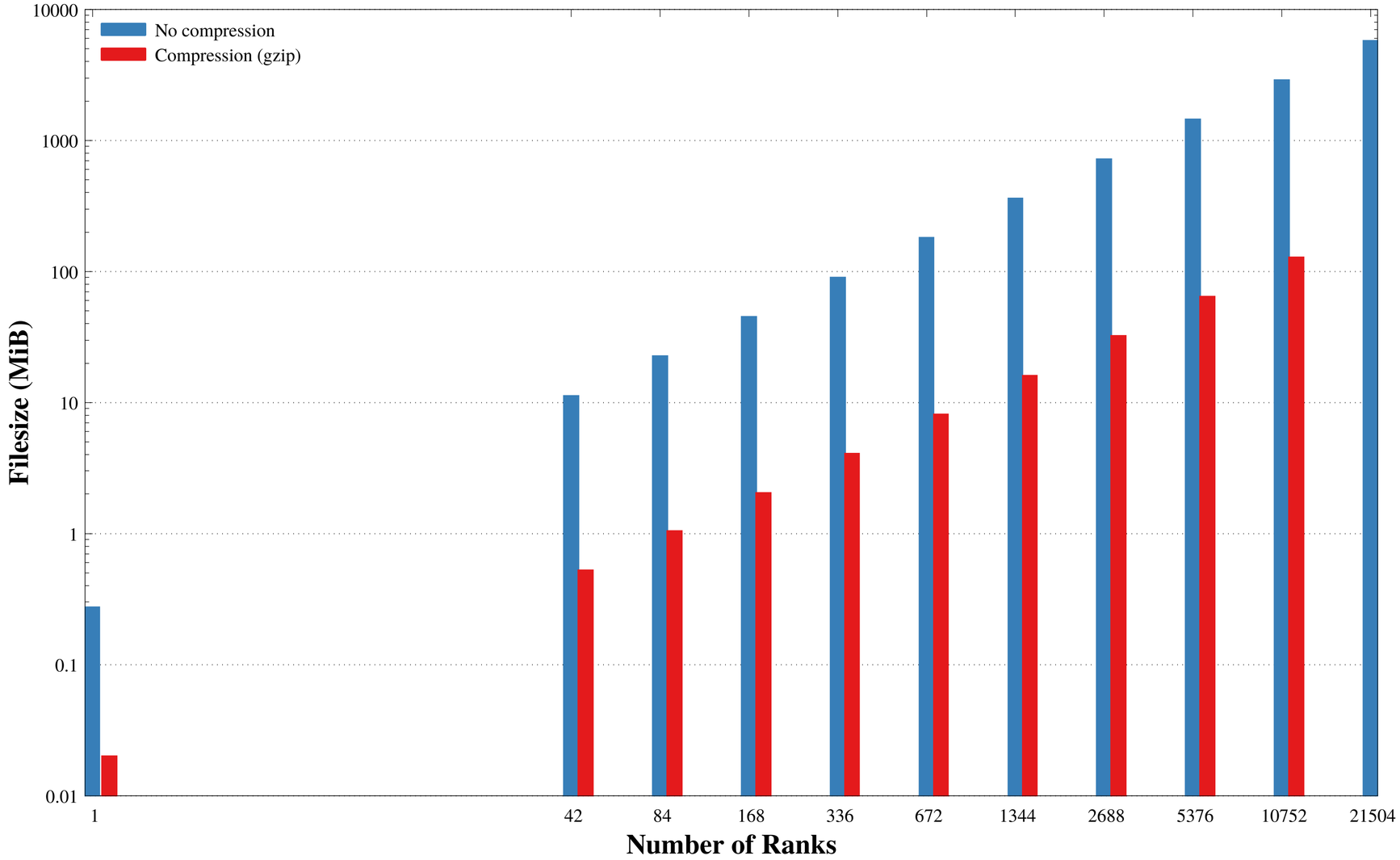
- Compressed and uncompressed file sizes as the number of processes are increased



Parallel HDF5 Compression

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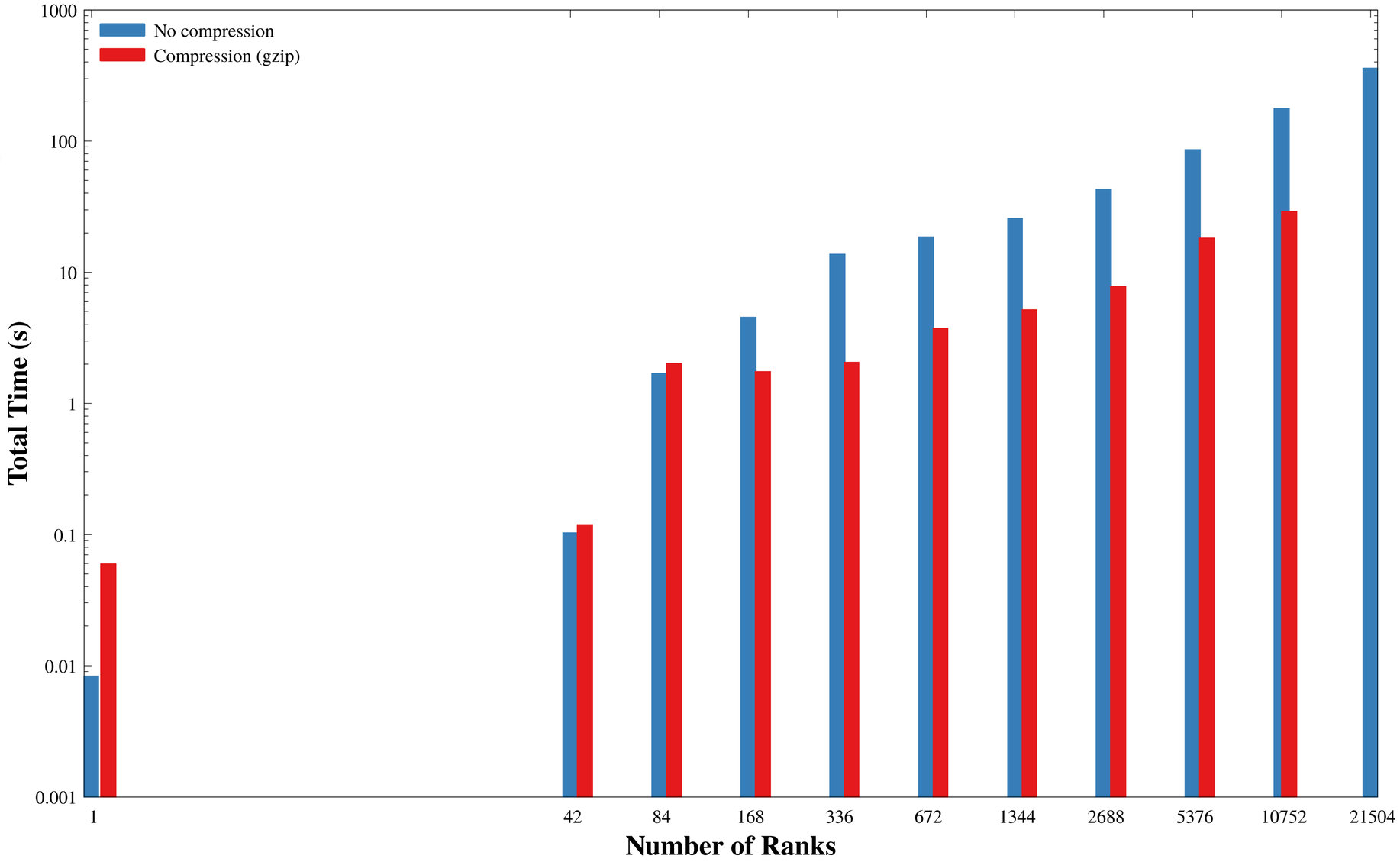
Total time with compression scales proportionally after 168 processes



Parallel HDF5 Compression

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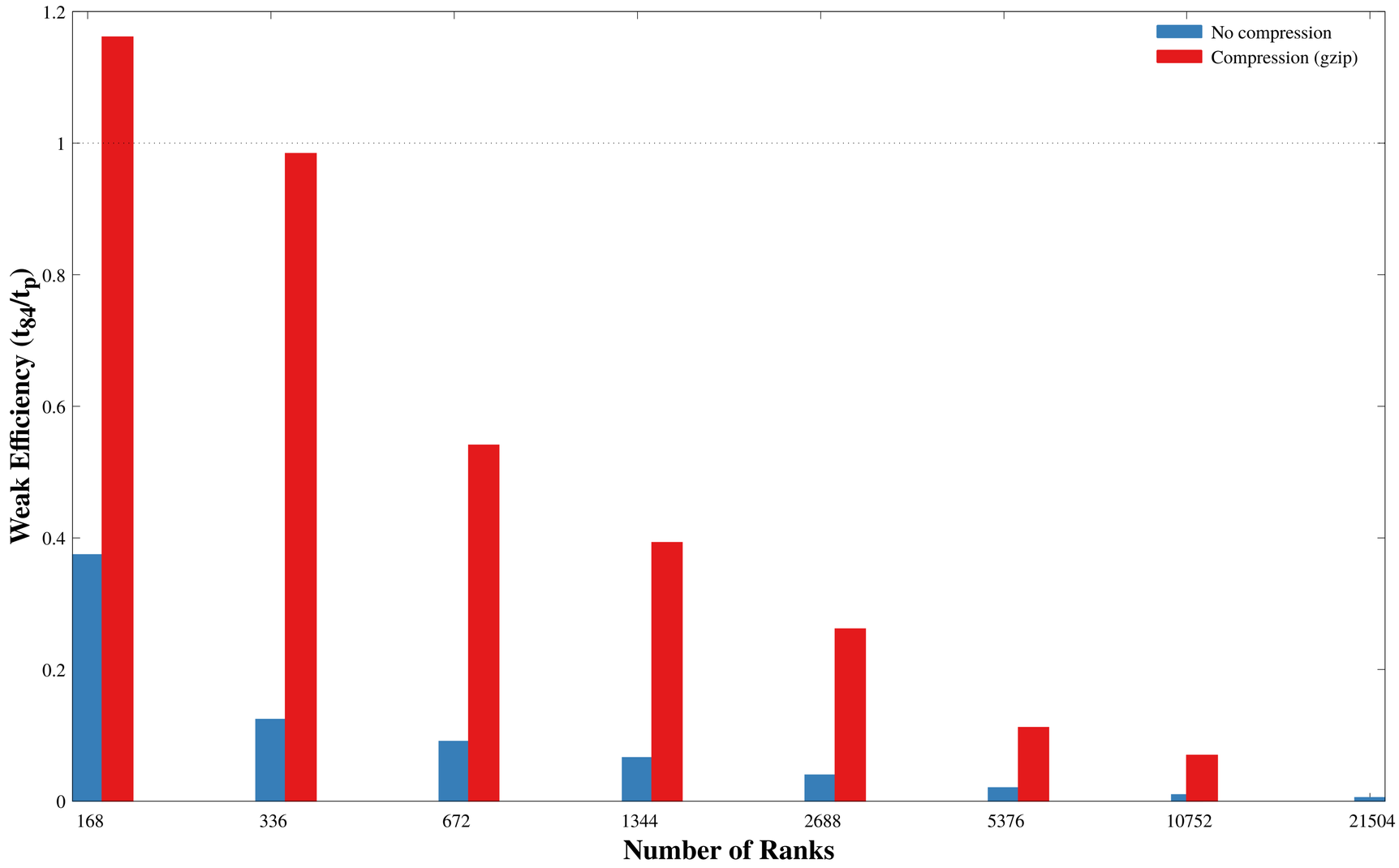
- Weak efficiency relative to 84 processes
- Using compression shows improvement over the non-compression case



CAUTION: Object Creation and Parallel Compression (Collective vs. Single Process)

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- In **sequential** mode, HDF5 allocates chunks incrementally, i.e., when data is written to a chunk for the first time.
  - Chunk is also initialized with the default or user-provided fill value.

- In the **parallel** case, chunks are always allocated when the dataset is created (not incrementally).
  - This can be an issue if dataset pre-created by rank 0
  - The more ranks there are, the more chunks need to be allocated and initialized/written, which manifests itself as a slowdown

CAUTION: Object Creation (SEISM-IO, Blue Waters—NCSA)

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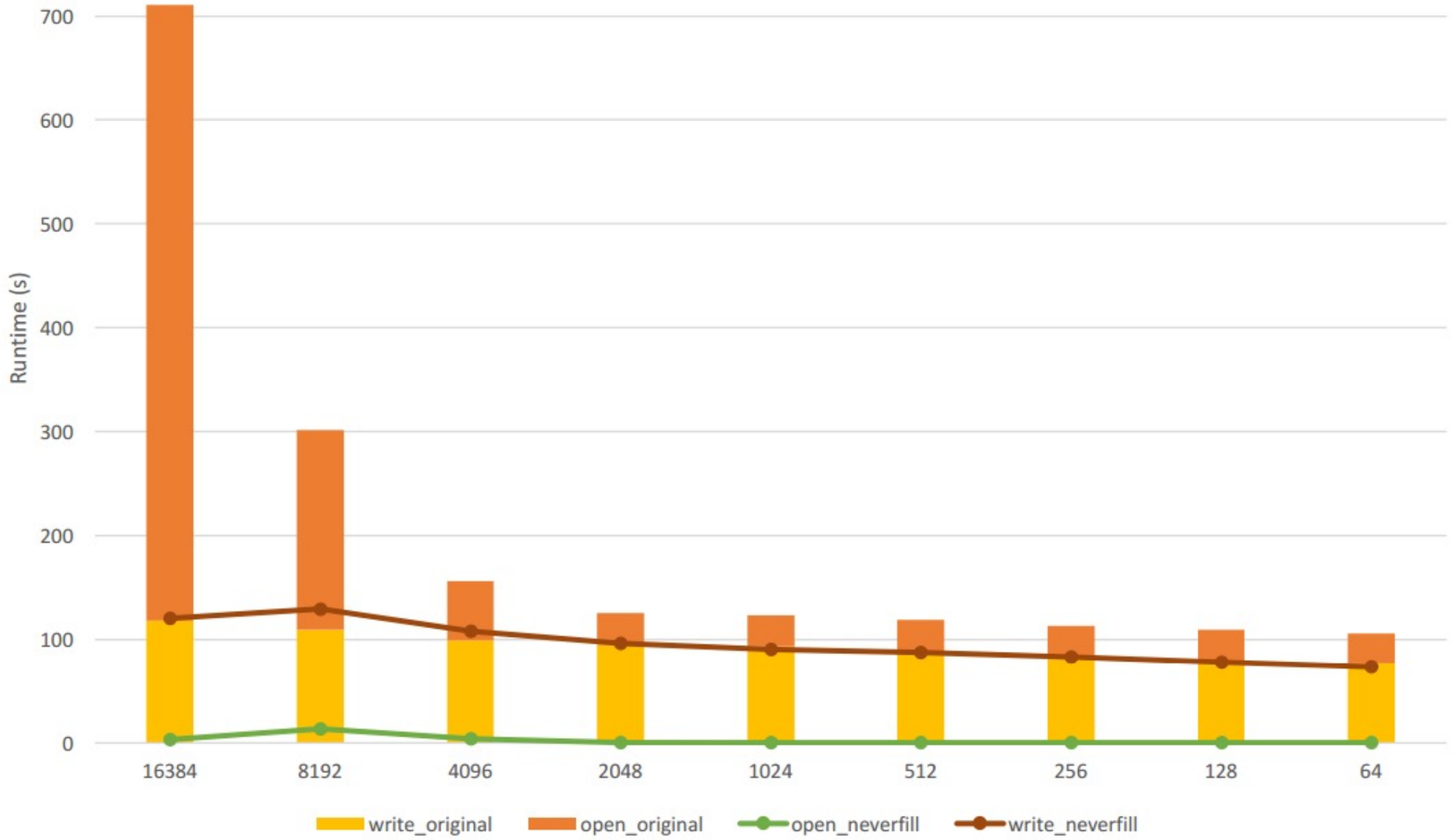
Set HDF5 to never fill chunks (H5Pset_fill_time with H5D_FILL_TIME_NEVER)



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THANK YOU!

Questions & Comments?