How to bring HTC data to HPC resources - A caching solution for the ATLAS computing environment in Freiburg

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Albert-Ludwigs-Universität Freiburg

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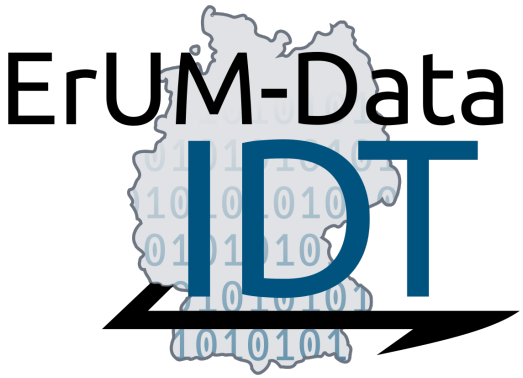

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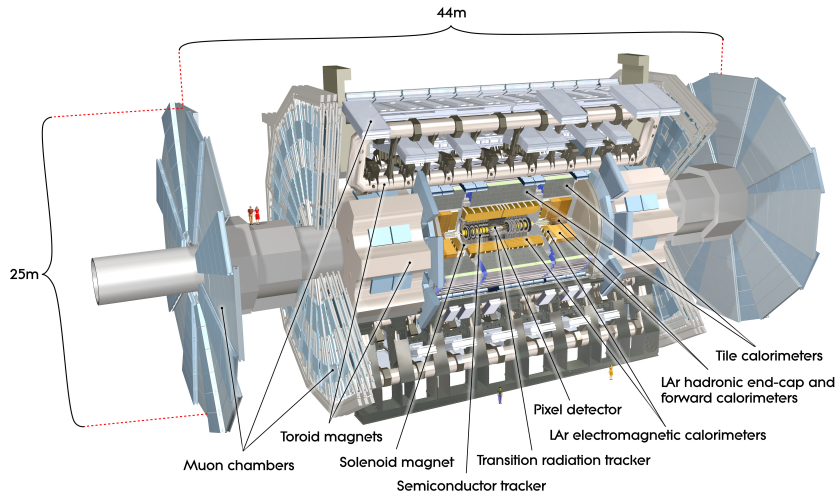
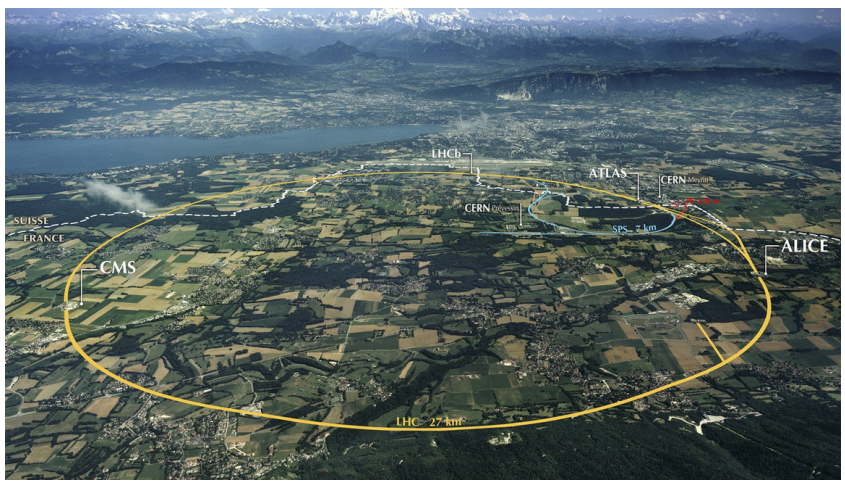
Introduction

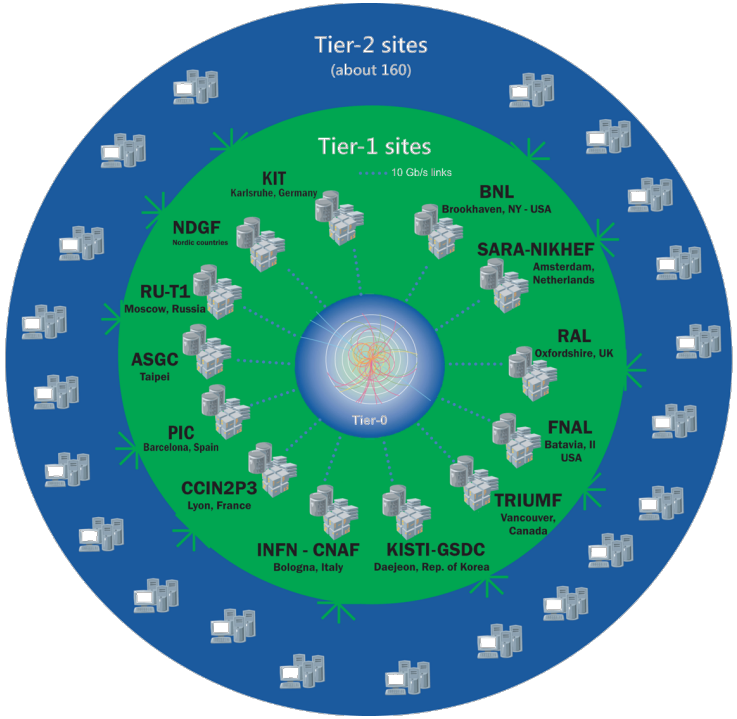
- ATLAS experiment at the LHC
- Initial data rate: $\sim 60\,\mathrm{TB/s}$!
  $\rightarrow$ trigger system
- Data written to disk: $\sim 300\,\mathrm{MB/s}$
- Data distributed & analyzed via Worldwide LHC Computing Grid (WLCG)

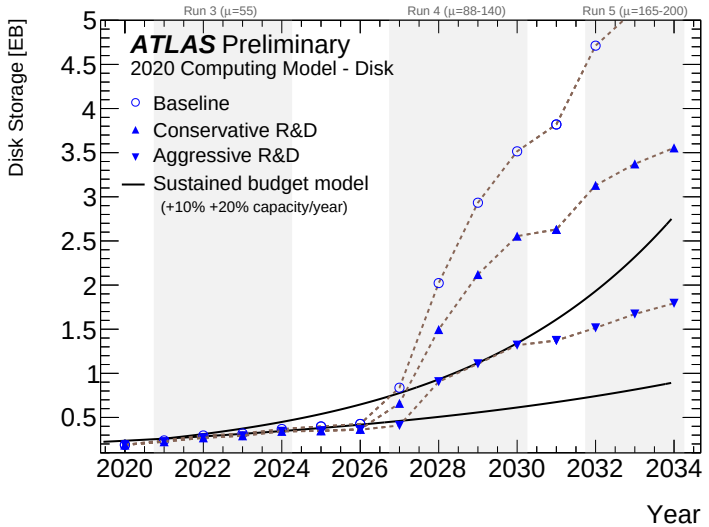




Introduction

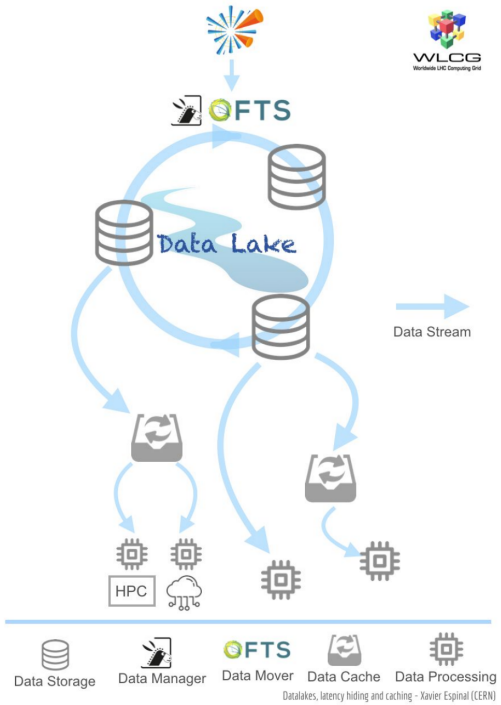
- WLCG: three different levels
  - Tier-0: CERN data centre
  - Tier-1: 13 computer centres with large storage
  - Tier-2: $\sim$ 160 smaller storage sites
- Tier-2 site in Freiburg: ATLAS-BFG
  - 2.5 PB of disk storage
  - Local users of 4 research groups
- Total ATLAS disk storage
  - $\sim$ 235 PB
  - After start of High-Luminosity LHC: $\geq$ 2.5 EB in 2030
  - Huge amounts of disk space required





Introduction

- ATLAS plans
  - Centralize data storage
  - Huge storage centers with long-term storage
  - Compute sites without local long-term storage
- How get compute sites the data?
  → implement a caching setup



- What is caching?
  → local, temporary storage of data
- Why caching?
  - Local: fast access for subsequent requests
  - Temporary: limited resources for long-term storage, automatic deletion if not accessed again

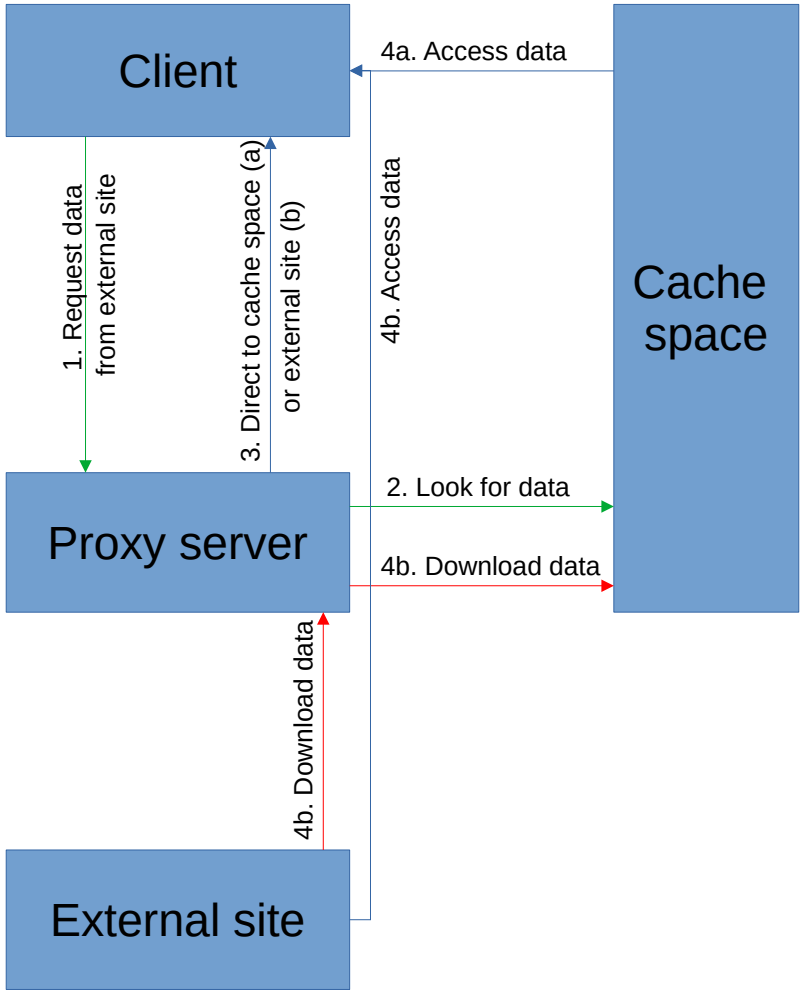
Caching in Freiburg

- Caching setup in Freiburg with XRootD
- Starting point: sandbox implementation by group of Dr. Kilian Schwarz at Uni. Frankfurt/GSI

- Ingredients:
  - Client
    - Virtual machine on node of NEMO HPC cluster
    - Default client configuration
    - Non-evasive setup of caching via environment variables
    - Enable and configure XrdClProxyPlugin
  - Proxy server
    - Virtual machine independent from NEMO cluster
    - XRootD server daemon configured for disk caching and as "forward proxy"
  - Cache space
    - beeGFS file system in Freiburg

Workflow of caching setup

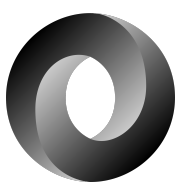
- Client:
  - Requests data from external site
  - XrdClProxyPlugin: redirects request to proxy server
- Proxy server:
  - Checks if data is already in cache
  - Yes:
    Forwards client to location in cache
  - No:
    Forwards client to external site and downloads data to cache



Benchmarking

- Python script with ROOT module
- 'Pseudo analysis', implements features of typical user analysis:
  - Open file
  - Retrieve data
  - Loop over events
  - Fill information in histograms
  - Write histograms to disk
- Output: information in JSON format
  $\rightarrow$ visualize with pandas & Matplotlib



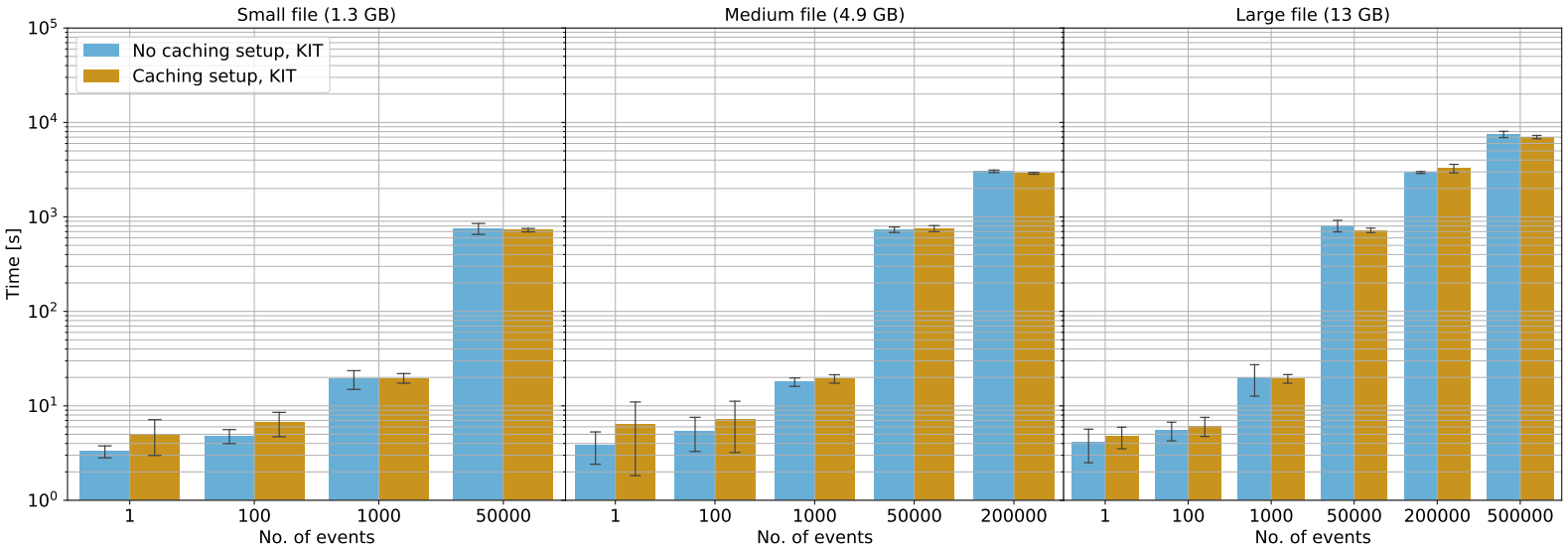



Benchmarking

- Access configurations:
  - Caching without file in cache space
    → caching setup, file read and downloaded from external site
  - Caching with file in cache space
    → caching setup, file read from local beeGFS
  - Local access
    → caching setup not active, file read from local beeGFS
  - External access
    → caching setup not active, file read from external site
- ATLAS sites
  - KIT (Karlsruhe)
  - LRZ (Munich)
  - TRIUMF (Vancouver, Canada)
  - BNL (Brookhaven, USA)
  - DESY (Hamburg)
  - UNI-FREIBURG (Freiburg)
- For each setup: vary file sizes and number of events
  - 1.3 GB, 4.9 GB, 13 GB (s, m, l)
  - 1, 100, 1000, 50k,
    200k (only m & l), 500k (only l)
- Repeat each test multiple times
  → mean value of elapsed time + standard deviation

Results - Overhead

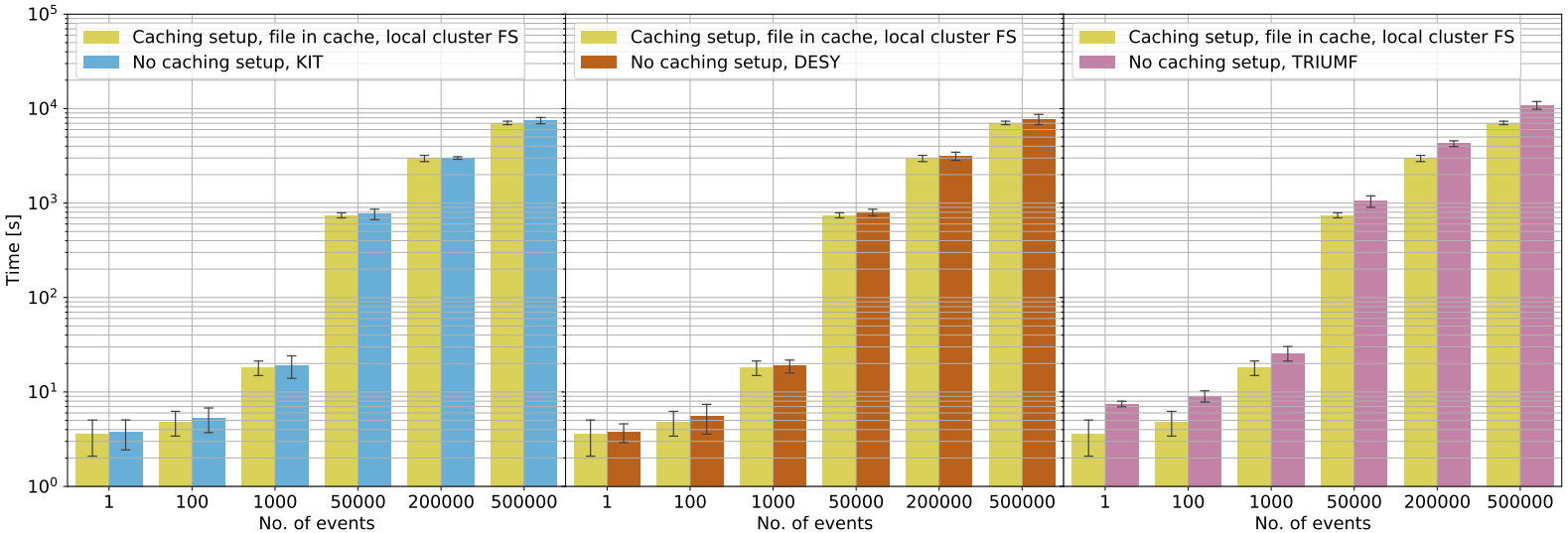
- Direct access to KIT vs. access with caching setup



- Both setups are comparable
  $\rightarrow$ no overhead by caching setup
- Results differ for number of events, but not for file sizes
  $\rightarrow$ merge file sizes in remaining figures

Results - File in cache space

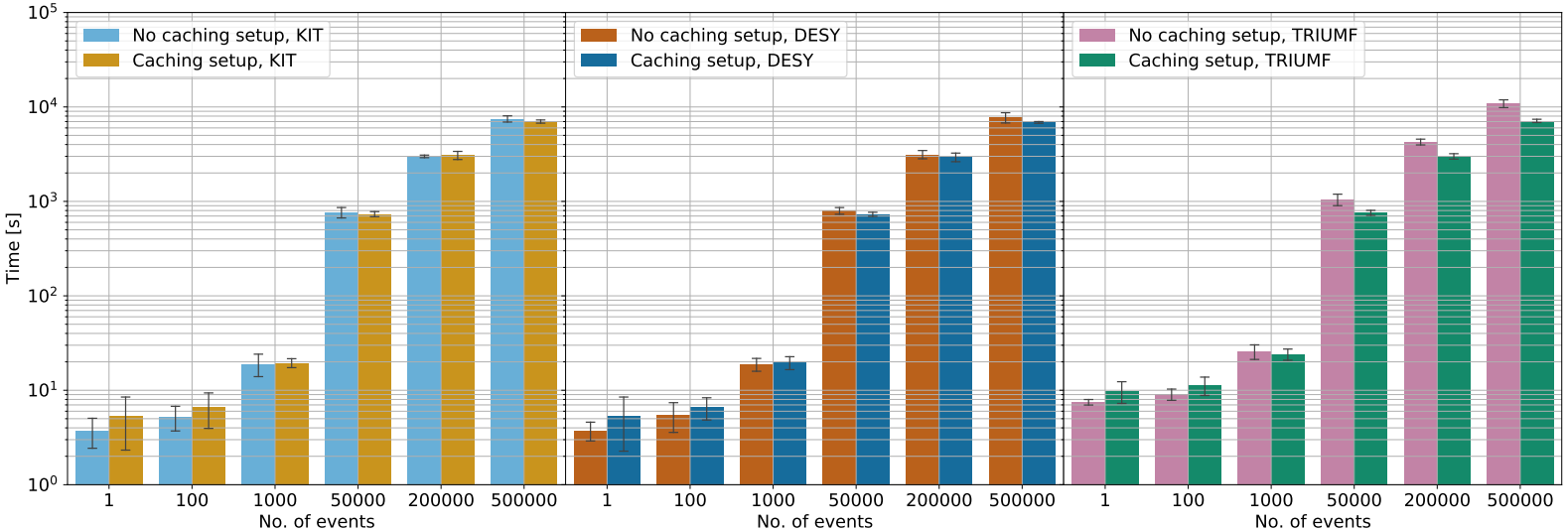
- Direct access to KIT/DESY/TRIUMF vs. file available in cache space



- Near sites (KIT/DESY): results are comparable
- Distant sites (TRIUMF): access to cached file faster
  $\rightarrow$ client profits from caching setup

Results - Initial access

- Direct access to KIT/DESY/TRIUMF vs. access with caching setup



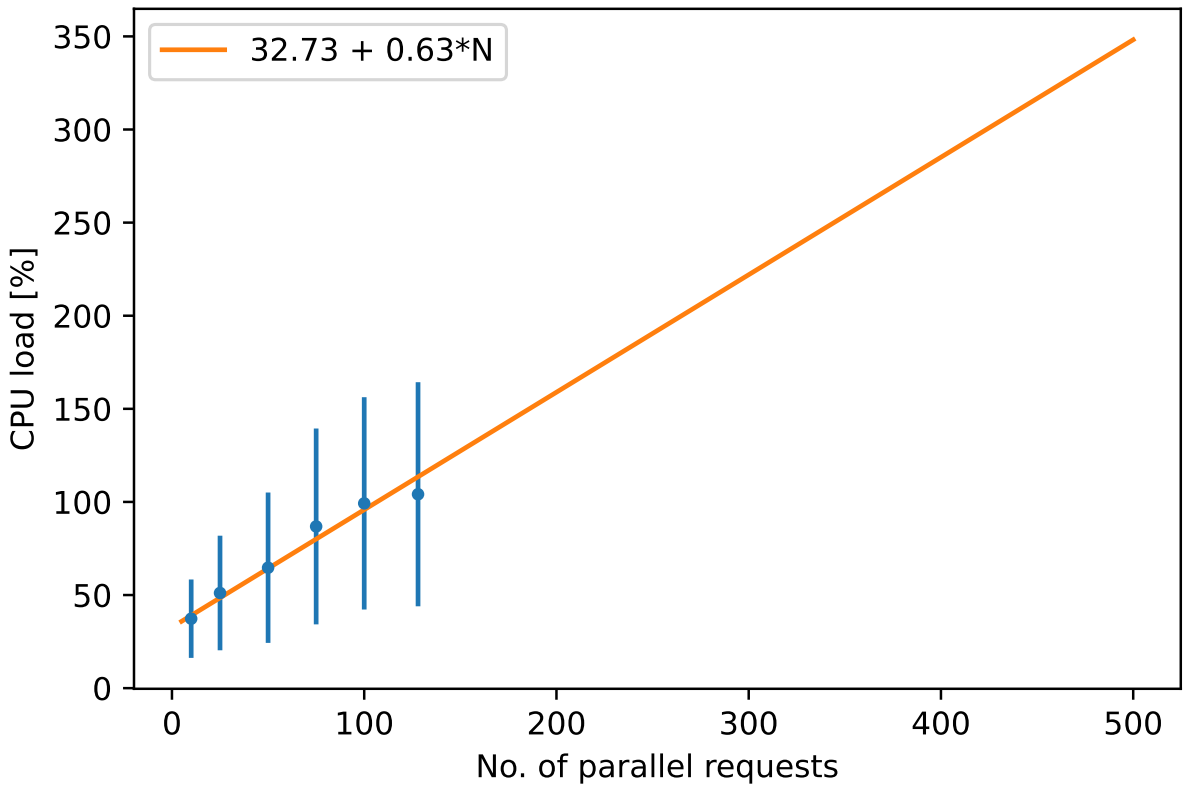
- Near sites (KIT/DESY): results are comparable
- Distant sites (TRIUMF):
  access with caching setup is faster for large numbers of events
  - Download of file via proxy server faster than benchmark runtime
  - After download: client reads file in cache $\rightarrow$ faster access
- Without caching setup: file access completely from external site

Parallel requests

- All results so far: only single file request on proxy server at once
  - Real world scenario: ∼500-1000 jobs at once
- How does the resource consumption scale for parallel file requests?
- Specs of proxy server:
  VM on machine with Intel(R) Xeon(R) CPU E5-2640 v3 @ 2.60 GHz
  - 4 vcores
  - 8 GB RAM
- Tested number of parallel requests:
  - 10, 25, 50, 75, 100, 128 ← client with 128 CPU threads
- 128 copies of large file at KIT
- Measure CPU load and memory consumption at proxy server during benchmark with 10k events

CPU load

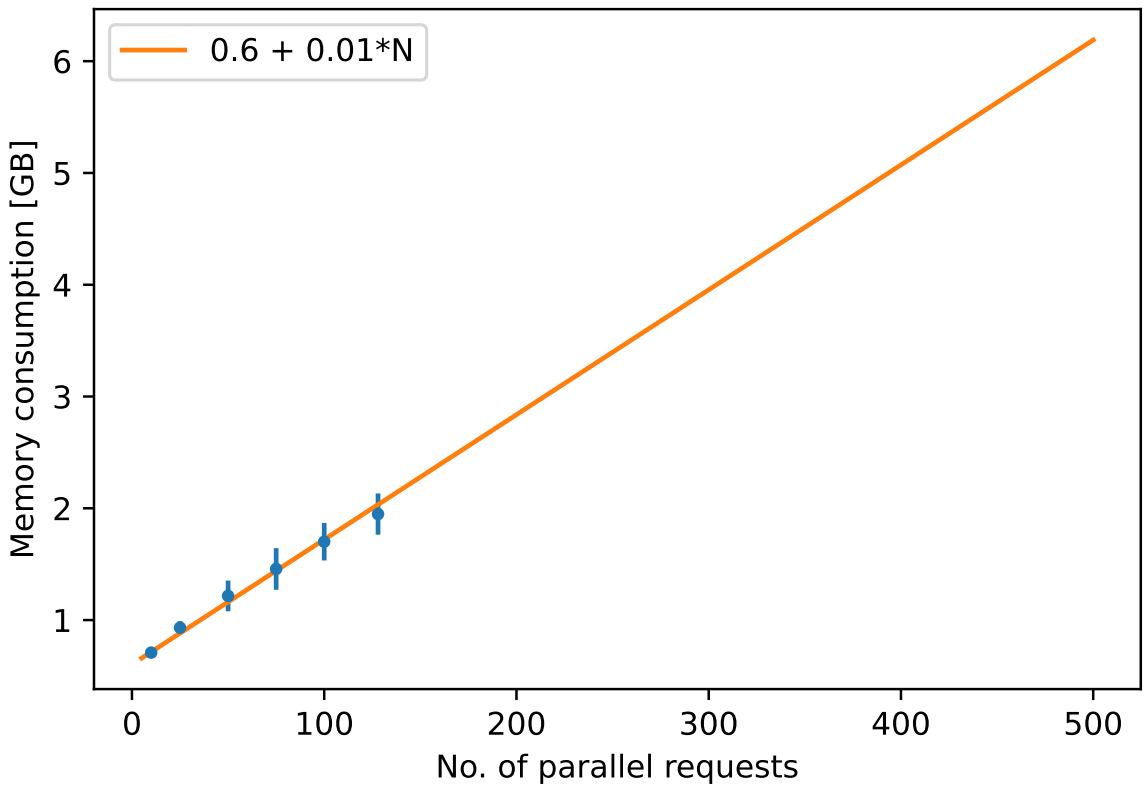
- Subtract CPU load from other processes
- Derive mean and standard deviation
- Simple approximation via linear fit



- 1 core $\equiv$ 100 % $\rightarrow$ in this setup max. 400 %
- Projection for 1k parallel requests: at least $\sim$7 cores required

Memory consumption

- Subtract memory consumption from other processes
- Derive mean and standard deviation
- Simple approximation via linear fit



- Projection for 1k parallel requests: at least ∼11 GB RAM required

Conclusion & Outlook

- Conclusion:
  - Successfull implementation of caching setup for NEMO HPC cluster
    - Clients: no additional installations, setup via environment variables
    - Proxy server: setup on VM, independent from NEMO cluster
  - Benchmark results
    - Caching setup causes no overhead
    - Access to already cached files is faster than access to distant external sites
    - Initial access to files on distant external sites is faster with caching setup
  - Caching is a good alternative to locally managed storage!
  - Estimated requirements for 1k parallel file requests at least
    - 7 cores
    - 11 GB RAM
    - Better: arrange several proxy servers as proxy cluster with one redirector

- Outlook:
  - Perform full user analysis with caching setup

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Thanks!