The ATLAS ROOT-based data formats: recent improvements and performance measurements

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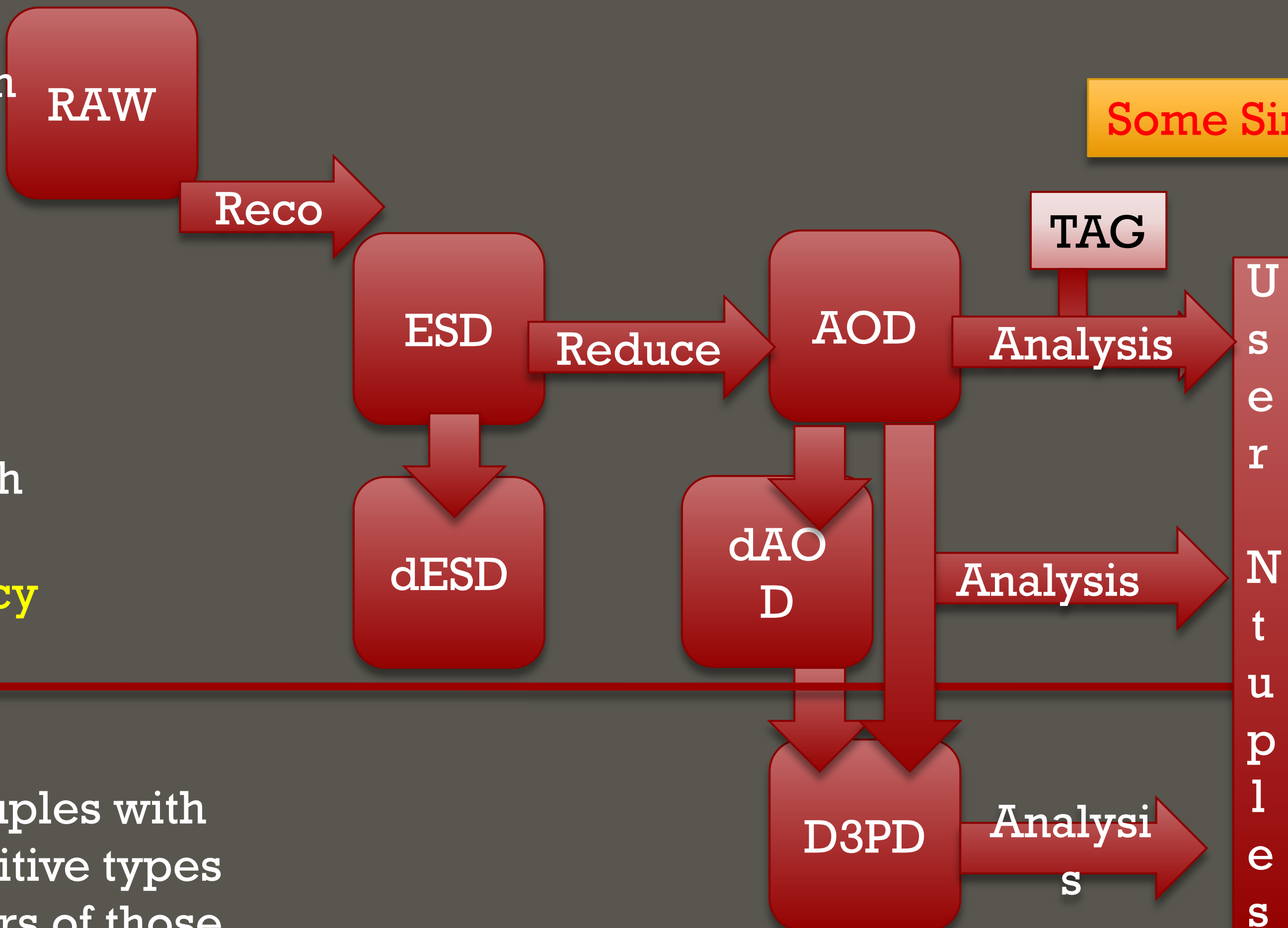
Overview

- ATLAS analysis workflows and ROOT usage
- Optimisations of ATLAS data formats
  - "AOD/ESD" and "D3PD"
- An ATLAS ROOT I/O testing framework

ATLAS ROOT I/O data flow

Bytestream
Not ROOT



Some Simplification!

AOD/ESD
ROOT with
POOL
Persistency

Athena
Software
Framework

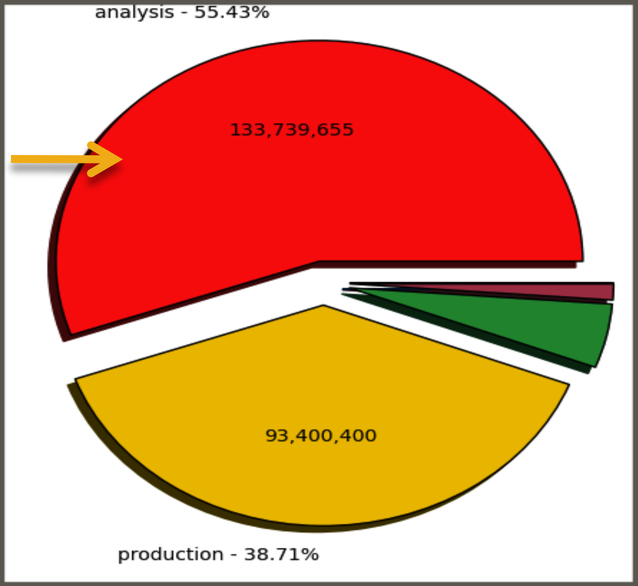
D3PD
ROOT ntuples with
only primitive types
and vectors of those

Non-Athena
User Code
(standard tools
and examples)

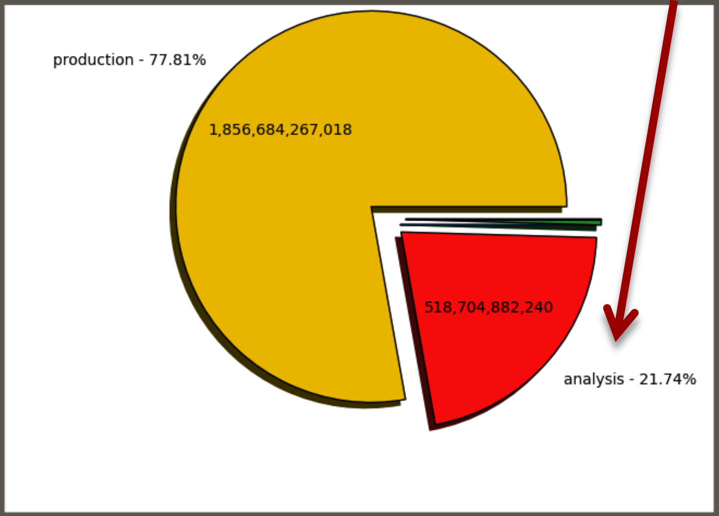
ATLAS analysis

- User analysis here called "analysis" as opposed to "production" is:
  - Not centrally organised
  - Heavy on I/O – all ATLAS analysis is ROOT I/O

By no. of jobs, Analysis =55%



By wallclock time, Analysis=22%



ATLAS ROOT I/O: POOL Formats

POOL:

- AOD/ESD use ROOT I/O via the POOL persistency framework.
- Could use other technologies for object streaming into files but in practice ROOT is the only supported.

ROOT versions in Athena s/w releases:

- 2011 data (Tier 0 processing) : ROOT 5.26
- 2011 data (Reprocessing): ROOT 5.28
- 2012 data : ROOT 5.30

ROOT I/O features we use

See e.g. P. Canal's talk at CHEP10

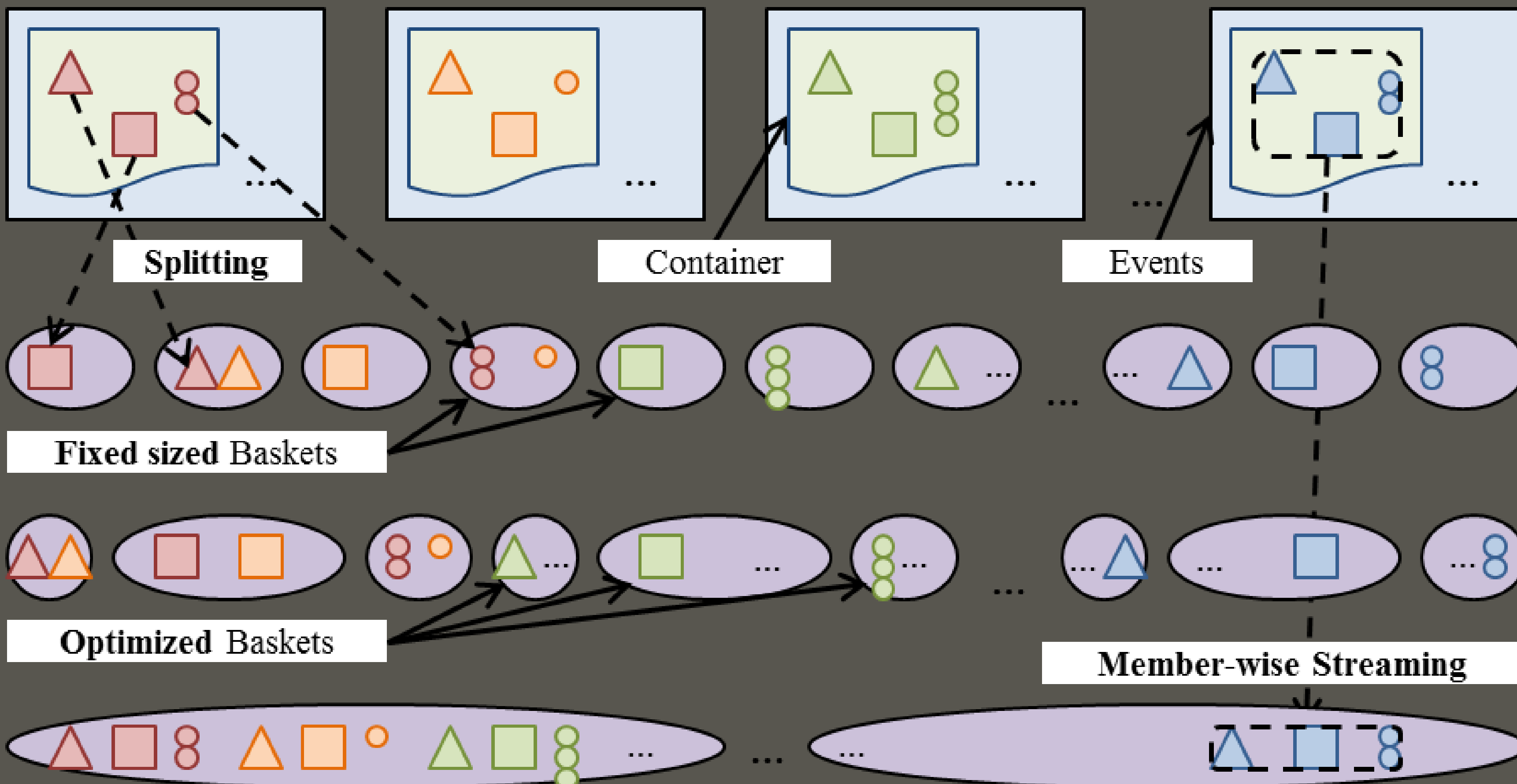
Writing files:

- Split level: object data members placed in separate branches
  - Initial 2011 running: AOD /ESD fully-split (99) into primitive data
- From 2011 use ROOT "autoflush" and "optimize baskets"
  - Baskets (buffers) resized so they have similar number of entries
  - Flushed to disk automatically once a certain amount of data is buffered to create a cluster that can be read back in a single read
  - Initial 2011 running we used the default 30 MB
- Also use member-wise streaming
  - Data members of object stored together on disk

Reading files:

- There is a memory buffer TTreeCache (TTC) which learns used branches and then pre-fetches them
- Used by default for AOD->D3PD in Athena
- For user code its up to them

ROOT streaming



ESD/AOD Optimisations

- ATLAS Athena processes event by event – no partial object retrieval
- Previous layout (fully-split, 30 MB AutoFlush): many branches and many events per basket
- Non–optimal particularly for event picking:
  - E.g. selecting with TAG:
    - Using event metadata: e.g. on trigger, event or object
    - No payload data is retrieved for unselected events
    - Can make overall analysis much faster (despite slower data rate)
  - Also multi-processor AthenaMP framework:
    - Multiple workers, each read a non-sequential part of input

2011 ESD/AOD Optimisations

- Switched **splitting off but kept member-wise streaming**
  - Each collection stored in a single basket
  - Except for largest container (to avoid file size increase)
- Number of baskets reduced from ~10,000 to ~800,
  - Increases average size by more than x10
  - Lowers the number of reads
- Write **fewer events per basket in optimisation:**
  - ESD flush every **5 events**
  - AOD every **10 events**
- Less data needed if selecting events when reading

Performance Results

Repeated local disk read; Controlled environment; Cache cleaned

AOD Layout	Reading all events	Selective 1% read
OLD: Fully split, 30 MB Auto-flush	55 (±3) ms/ev.	270 ms /ev.
CURRENT: No split, 10 event Auto-flush	35 (±2) ms /ev.	60 ms/ev.

- Reading all events is ~30% faster
- Selective reading (1%) using TAGs: 4-5 times faster

Further Performance Results

- **File Size** is **very similar** in old and current format.
- **Virtual Memory** foot print **reduced by about 50-100 MB** for writing and reading:
  - Fewer baskets loaded into memory.
- **Write speed increased** by about **20%**.
  - The write speed was increased even further (to almost 50%), as the compression level was relaxed.

New scheme used for autumn 2011 reprocessing

Athena AOD read speed (including Transient/Persistent conversion and reconstruction of some objects)
~ 5 MB/s from ~3 MB/s in original processing
(including ROOT 5.26 to 5.28 as well as layout change)

Testing Framework

- ROOT I/O changes affect different storage systems on the Grid differently
  - E.g. TTC with Rfio/DPM needed some fixes
- Also seen cases where AutoFlush and TTC don't reduce HDD reads/time as expected

Need regular tests on all systems used (in addition to controlled local tests) to avoid I/O "traps"

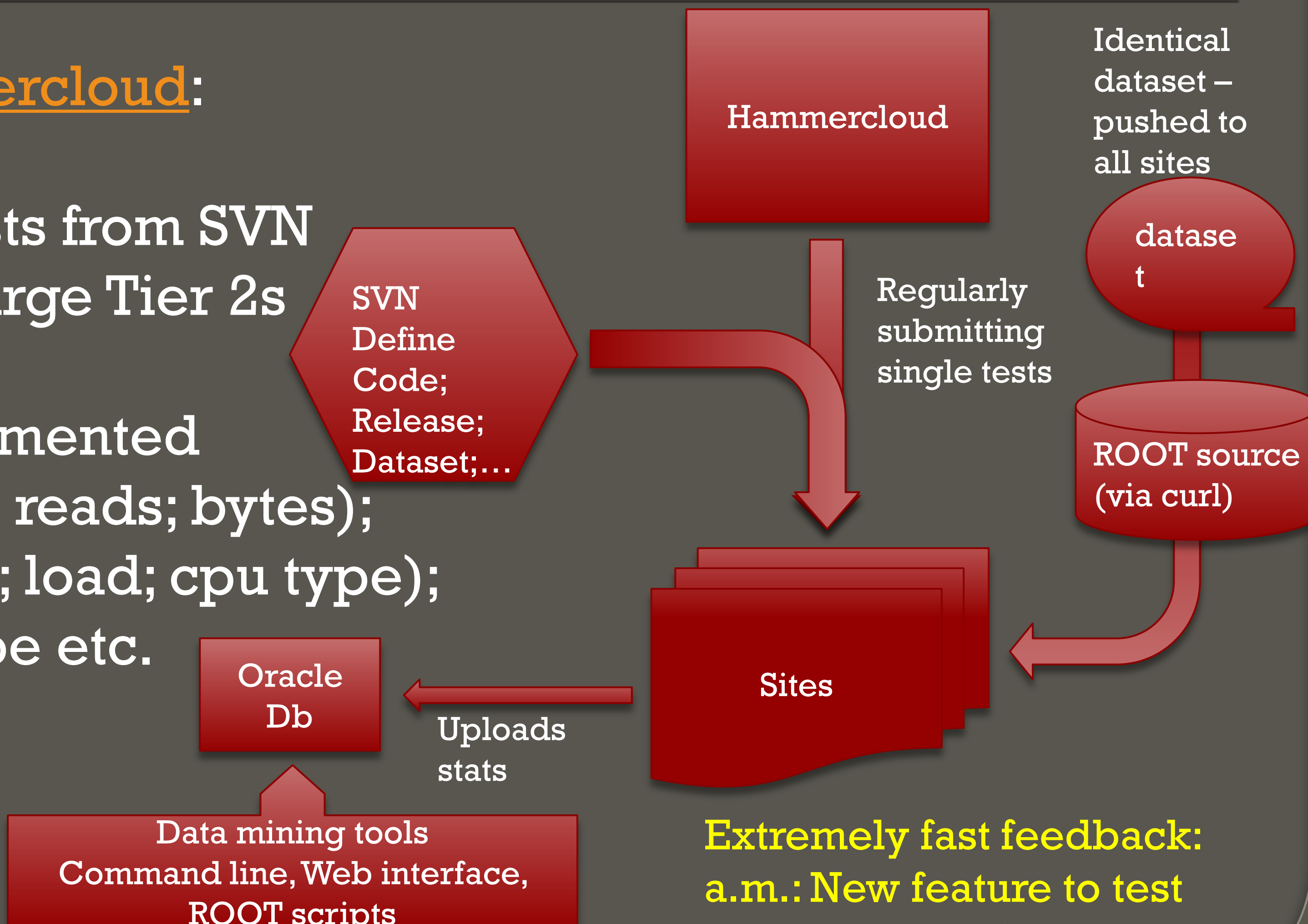
- Also now have a ROOT IO group well attended by ROOT developers ; ATLAS; CMS and LHCb
  - Coming up with a rewritten basket optimization
  - We promised to test any developments rapidly

Built a Testing Framework

Using hammercloud:

Takes our tests from SVN
Runs on all large Tier 2s

Highly instrumented
- ROOT (e.g. reads; bytes);
- WN (traffic; load; cpu type);
- storage type etc.



Extremely fast feedback:
a.m.: New feature to test
p.m.: Answers for all storage systems in the world.

Examples of Tests

1. ROOT based reading of D3PD:
   - Provides metrics from ROOT (no. of reads/ read speed)
   - Like a user D3PD analysis
   - Reading all branches and 100% or 10% events (at random);
   - Reading limited 2% branches (those used in a real Higgs analysis)
2. Using different ROOT versions
   - Latest Athena Releases.
   - Using 5.32 (not yet in Athena)
   - Using trunk of ROOT
3. Athena D3PD making from AOD
4. Instrumented user code examples
5. Wide-Area-Network Tests

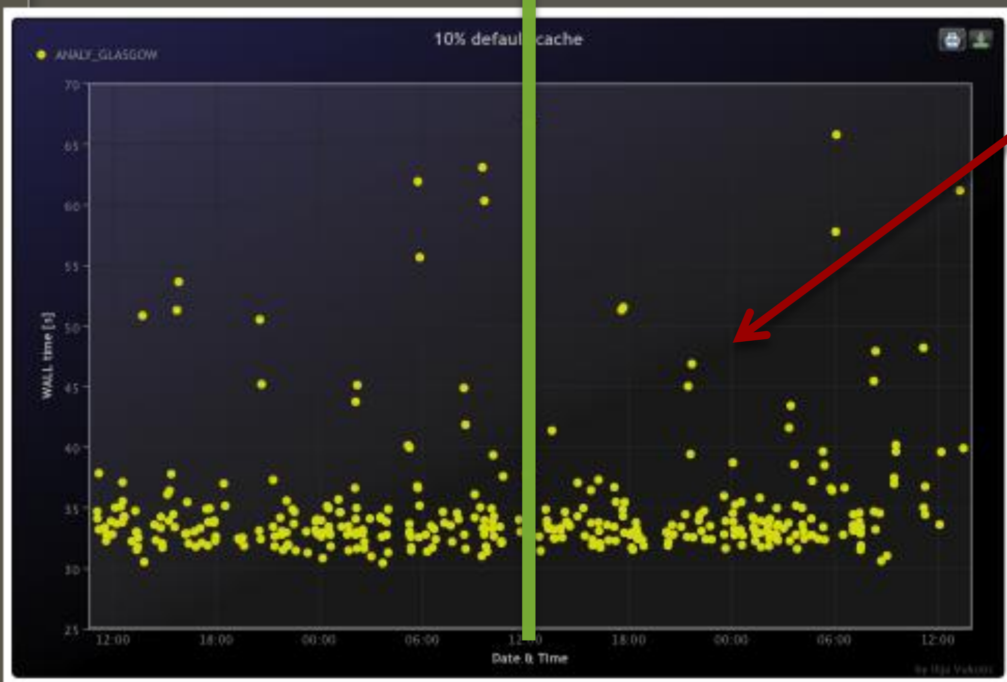
http://ivukotic.web.cern.ch/ivukotic/HC/index.asp


Login
From
2012-04-09
to
2012-04-17
100% default cache
x: root bytesread [bytes]
y: CPU time [s]
vs Time
line
avg.
proj. x
proj. y
Refresh
Annotations
Sites
CPUs
ROOT versions
tags/v5-32-01 v:43181
tags/v5-30-05 v:42230
d v:0
Storage
Input files
100% default cache
ANALY_CERN_XROOTD
ANALY_CSCS
ANALY_DESY-ZN
ANALY_GLASGOW
ANALY_QMUL
CPU time [s]
180
160
140
120
100
80
60
40
20
500M
525M
550M
575M
600M
625M
650M
675M
700M
725M
750M
775M
800M
root bytesread [bytes]
by Ilija Vukotic
CPU time [s] for 100% default cache
ANALY_CERN_XROOTD 62.26
ANALY_CSCS 72.16
ANALY_DESY-ZN 56.24
ANALY_GLASGOW 68.63
ANALY_QMUL 51.81
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

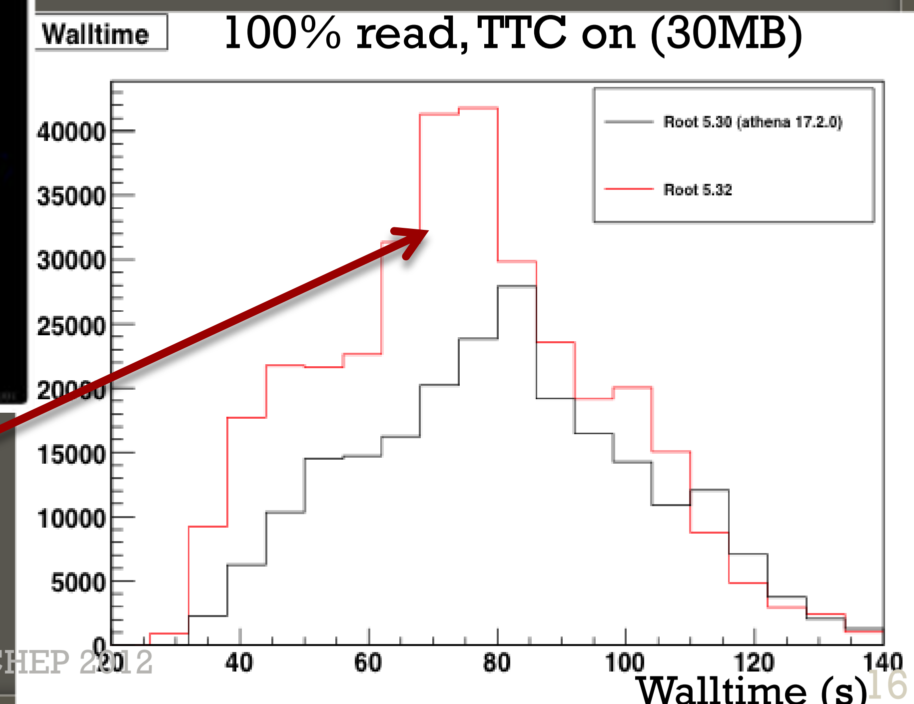
Testing ROOT Versions

ROOT 5.28 (Athena 17.0.4)

ROOT 5.30 (Athena 17.1.4)



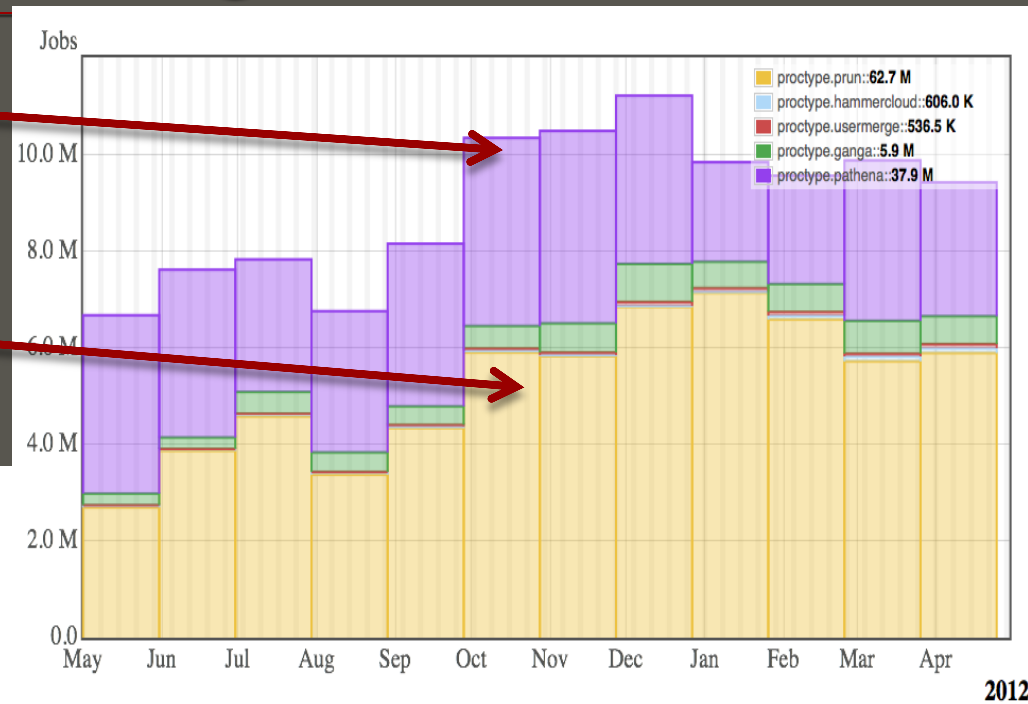
Tracking change to ROOT 5.30 in Athena – no significant changes in wall times for D3PD read on any storage system

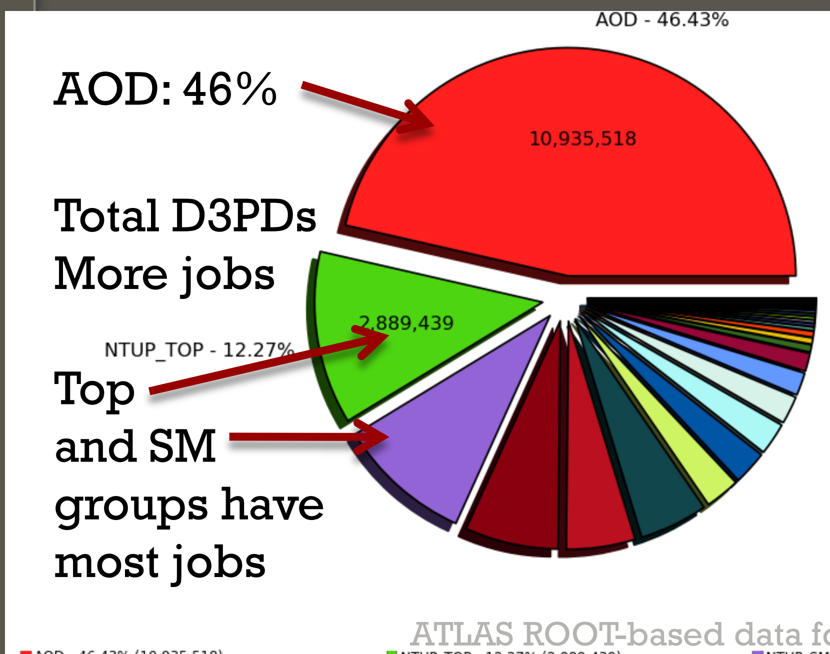


ROOT 5.32 (red) again no big change on average over all sites

Tuning D3PDs: growth of D3PD

- "pathena" jobs
  - running in framework
  - Eg. Private Simulation ; AOD Analysis
- "prun" jobs
  - Whatever user wants!
  - Mostly D3PD analysis

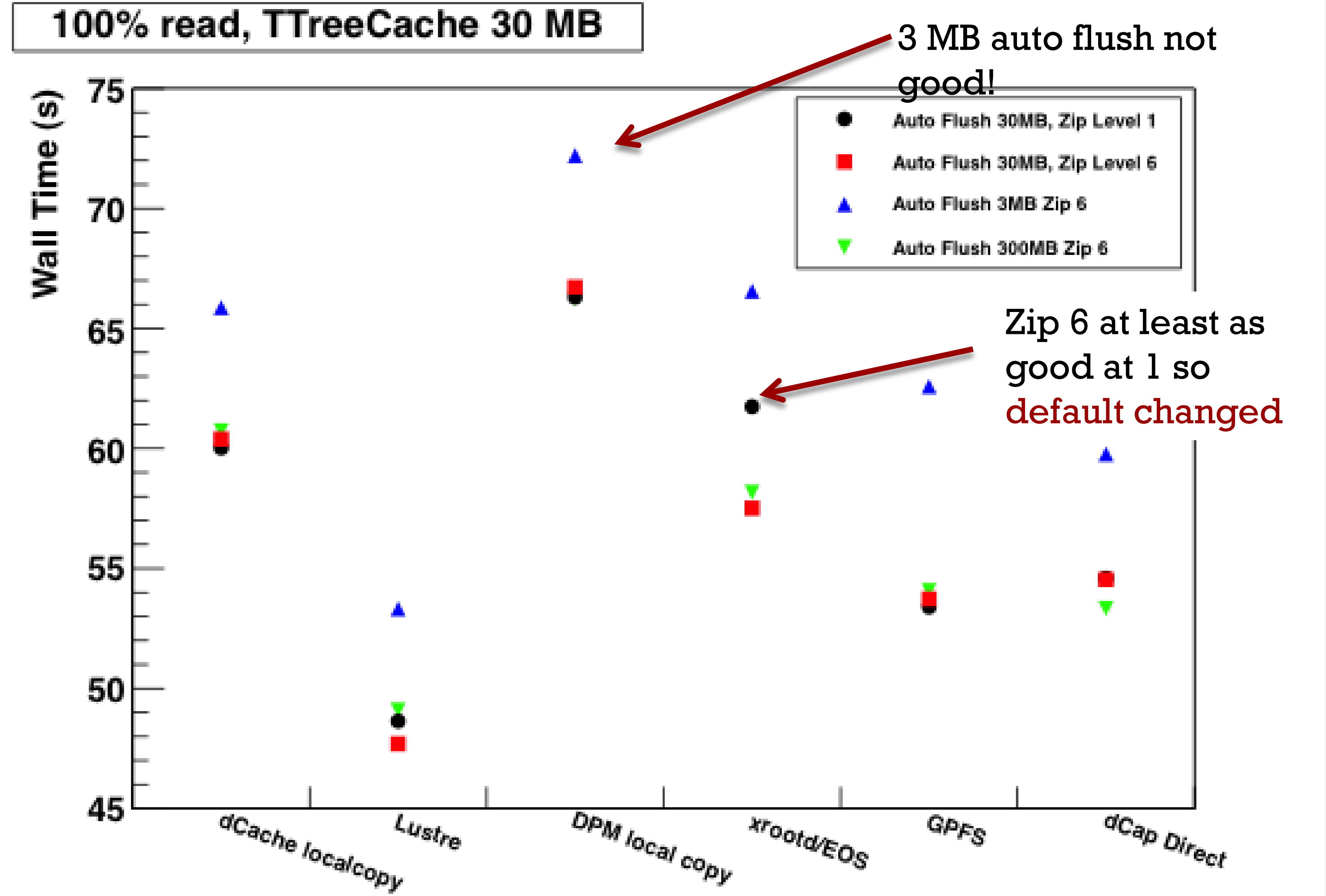




Optimisation of D3PD analysis becoming increasingly important

Tuning D3PDs: Compression and Auto-Flush

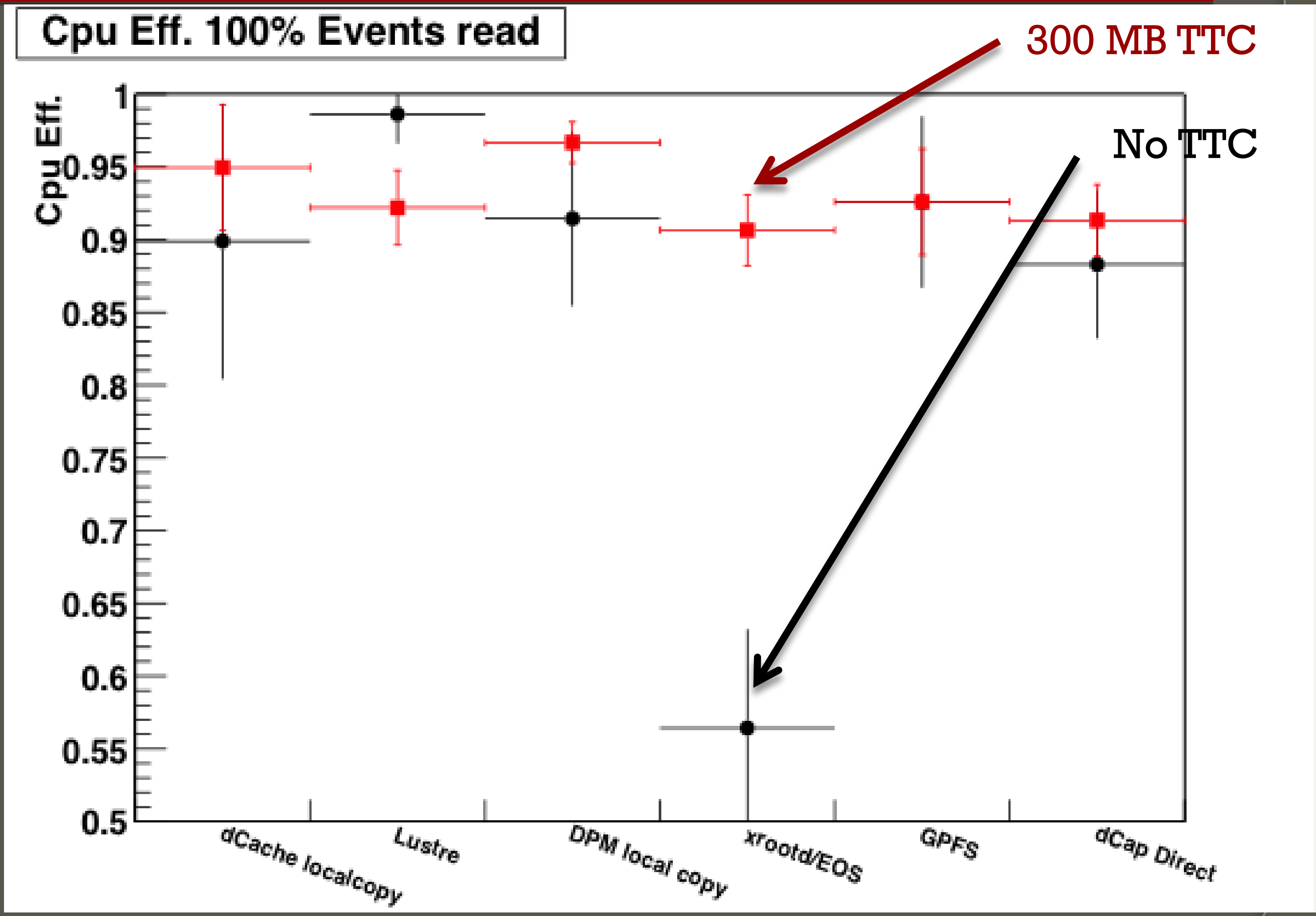
- Rewrite D3PD files:
  - Using ROOT 5.30 – current Athena release
- Try different zip levels, current default 1:
  - Local testing suggested "6" more optimal (in read speed) so copied this to all sites
  - Zip 6 files are ~5% smaller so also important gains in disk space and copy times
- Change autoflush setting, currently 30MB:
  - Try extreme values of 3 and 300 MB
- Showing results here for a few example sites
  - Labeled by the storage system they run
  - But use different hardware so this is not a measure of storage system or site performance



100% read, TTreeCache 30 MB
Wall Time (s)
75
70
65
60
55
50
45
Auto Flush 30MB, Zip Level 1
Auto Flush 30MB, Zip Level 6
Auto Flush 3MB Zip 6
Auto Flush 300MB Zip 6
dCache localcopy
Lustre
DPM local copy
xrootd/EOS
GPFS
dCap Direct
3 MB auto flush not good!
Zip 6 at least as good at 1 so default changed

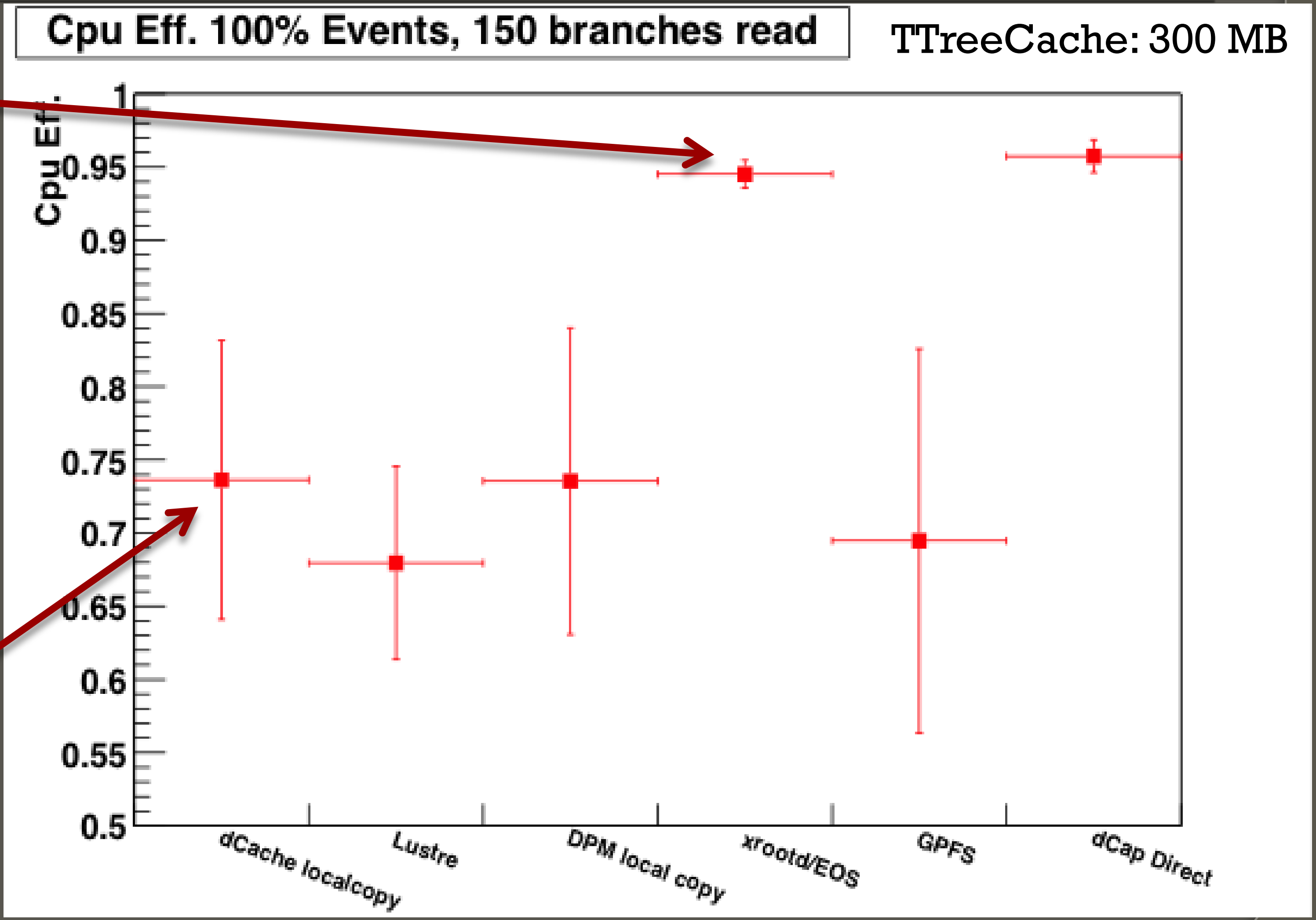
TTreeCache

- TTreeCache essential at some sites
- Users still don't set it
- Different optimal values per site
- Ability to set in job environment would be useful



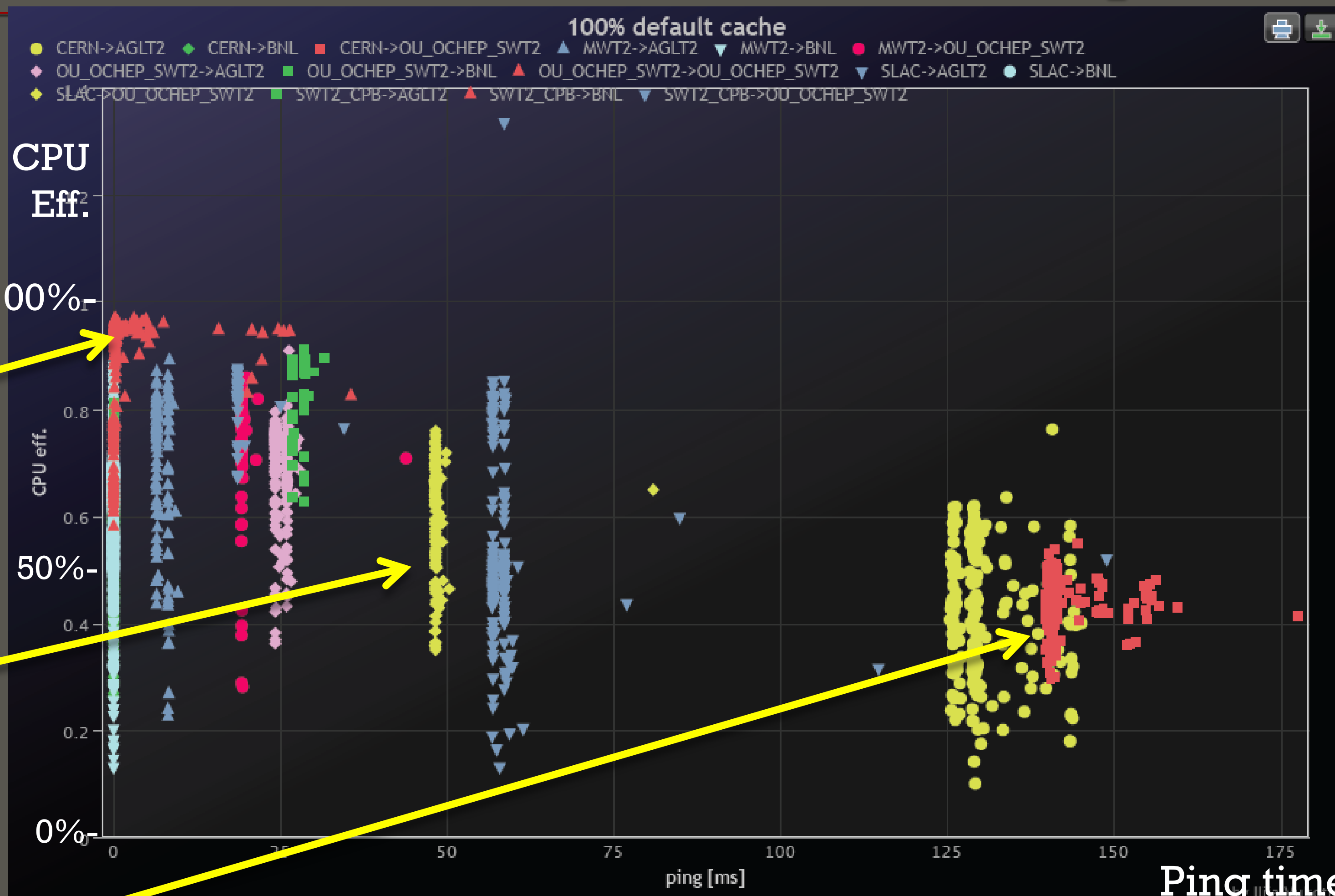
Reading limited branches

- Systems using vector reading protocol (dCap; xrootd) still have high eff.
- Drop in CPU efficiency on other storage systems



Wide-Area-Network Analysis

Running on various US sites

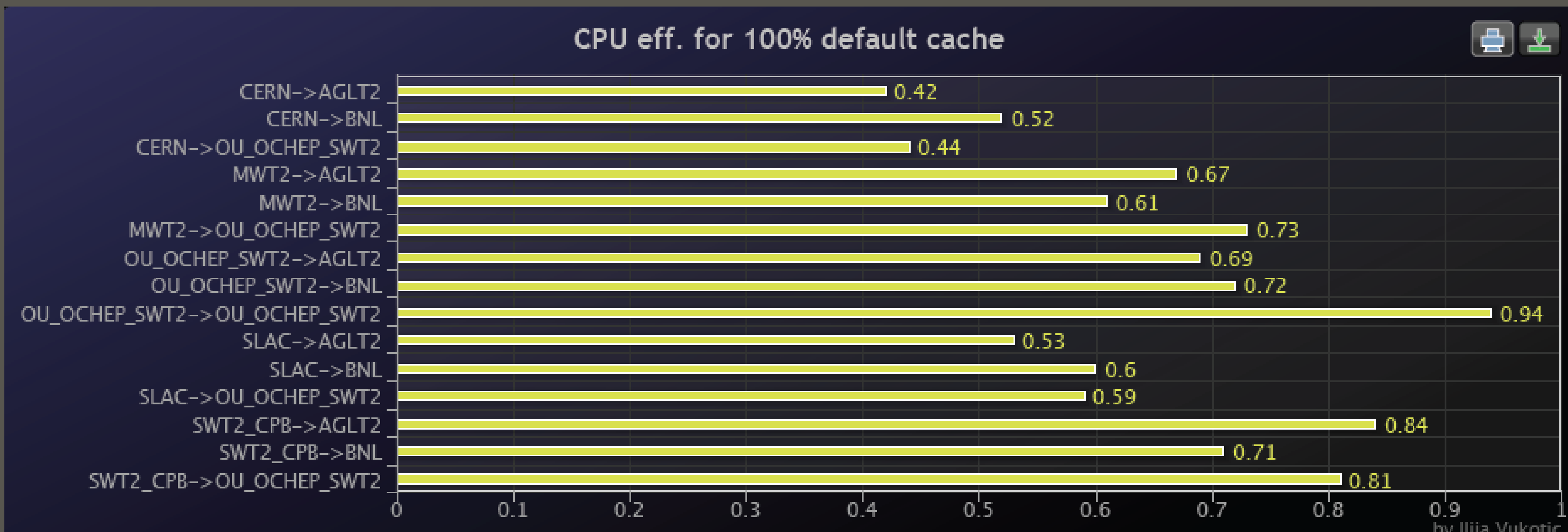


Local read

Reading from other US sites

Reading from CERN

CPU Efficiencies over WAN



- First measurements …. not bad rates
  - 94% local read eff. drops to 60%-80% for other US sites
  - and around 45% for reading from CERN
- Offers promise for this kind of running if needed
  - Plan to use such measurements for scheduling decisions

Conclusions

Made performance improvements in ATLAS ROOT I/O

Built I/O Testing framework: for monitoring and tuning

Plan to do:

- Lots more mining of our performance data ☺
- Test and develop core ROOT I/O with working group:
  - Basket Optimisation
  - Asynchronous Prefetching
- Provide sensible defaults for user analysis
- Further develop WAN reading
- Site tuning
- New I/O strategies for multicore (see next talk!)