Optimization of opportunistic utilization of the ATLAS High-Level Trigger farm for LHC Run 3

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on behalf of the ATLAS Computing Activity

HLT Farm & Sim@P1

Sim@P1

Opportunistic usage of the ATLAS Trigger and Data Acquisition High Level Trigger (HLT) computing farm for offline data processing workflows

Hypervisors

- Total: 119744 Cores
- 1216 x AS-2124BT-HNTR
  - 2 x AMD EPYC 7302 16-core
  - 64 HT cores
  - 125 GB RAM
- 440 x S2600TPR
  - Intel Xeon E5-2660 v4 @ 2.00GHz
  - 56 HT cores
  - 62 GB RAM
- 360 x S2600KPR
  - Intel Xeon E5-2650 v4 @ 2.20GHz
  - 48 HT cores
  - 62 GB RAM

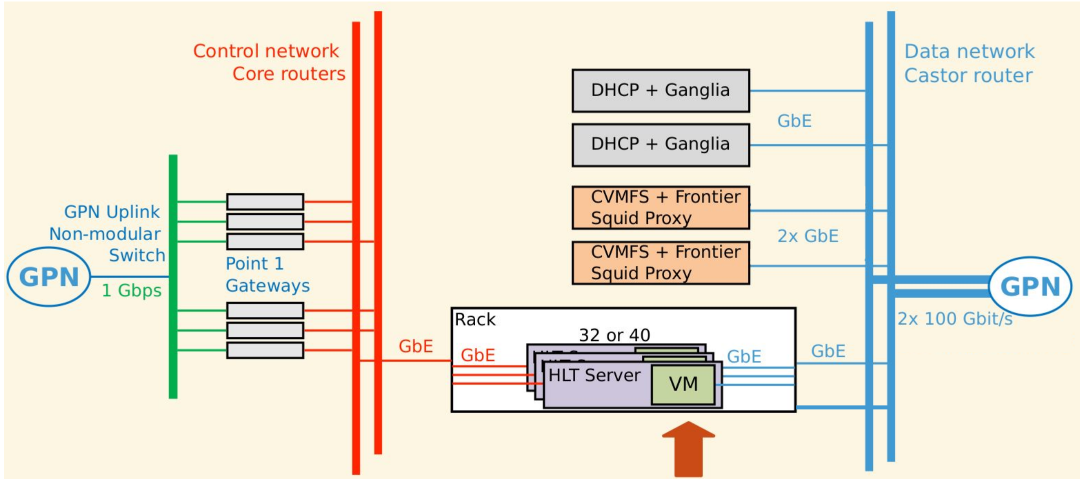
VMs

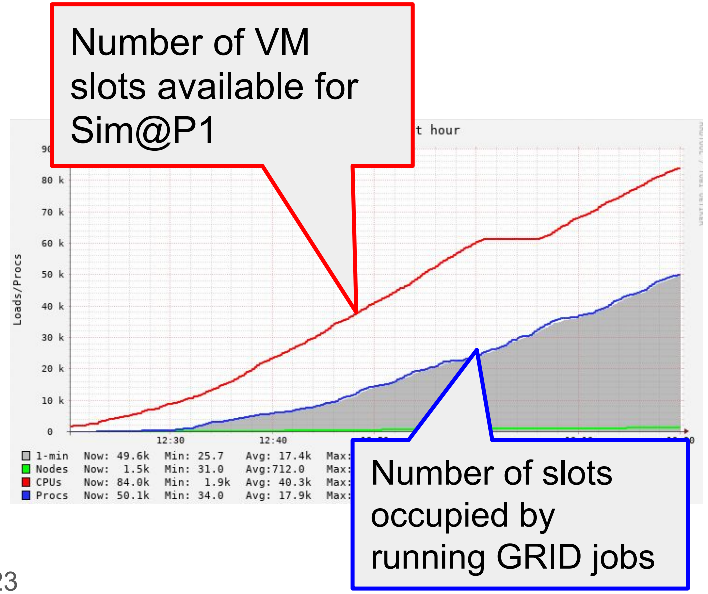
- Total: 111680 Slots
- x1216
  - 60 slots
  - 1.63 GB/slot
- x440
  - 52 slots
  - 0.94 GB/slot
- x360
  - 44 slots
  - 1.11 GB/slot

Less than the typically required 2 GB RAM/slot

HLT Farm to Sim@P1 Site

- Isolation of offline environment from detector control
  - Network: VLAN on data link layer from P1* to CERN
  - WN: VMs
- VMs
  - Switch / VM Creation is triggered by the TDAQ** shifter
  - Puppet triggers VM creation. It is configured to run at random times within an hour to avoid network overload
  - Libvirt VMs from CernVM image + config disk + ephemeral disk
  - Config disk - prepare CVMFS, ATLAS env, join batch





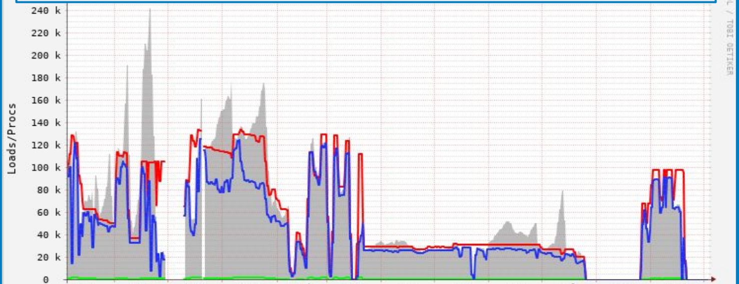
```
■ 1-min   Now: 49.6k   Min: 25.7    Avg: 17.4k   Max:
■ Nodes   Now:  1.5k   Min: 31.0    Avg:712.0    Max:
■ CPUs    Now: 84.0k   Min:  1.9k   Avg: 40.3k   Max:
■ Procs   Now: 50.1k   Min: 34.0    Avg: 17.9k   Max:
```

* P1 - Abbreviation of "Point 1" - the physical location of the ATLAS experiment on the LHC accelerator ring
** TDAQ - Trigger Data Acquisition System

Sim@P1: Contribution to ATLAS Distributed Computing

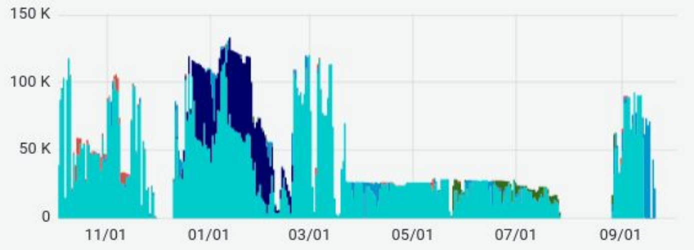
- Optimal for simulation workflow
  - Limited RAM
  - Limited Network
- Urgent Run2 Reprocessing was run in the beginning of 2022
  - Not optimal

Sim@P1 Resource Utilization



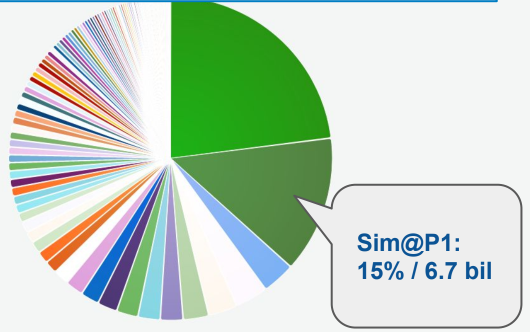
```
▨ 1-min   Now:440.3m   Min:328.1m   Avg: 57.4k   Max:241.6k
🟩 Nodes   Now:   4.0   Min:   4.0   Avg:  1.0k   Max:  2.5k
🟥 CPUs    Now:256.0    Min:256.0    Avg: 55.6k   Max:134.1k
🟦 Procs   Now:   1.1   Min:687.6m   Avg: 42.9k   Max:125.9k
```

Sim@P1 Running Slots



	min	max	avg
MC Simulation Full	0	120 K	35.0 K
MC Reconstruction	0	58.6 K	6.30 K
MC Simulation Fast	0	73.8 K	2.80 K

ATLAS Simulated Events



	Value	Percent
Vega	11.3 Bil	25%
CERN-P1	6.68 Bil	15%
praguelcg2	1.59 Bil	4%
MWT2	1.57 Bil	3%

Sim@P1 - Open questions

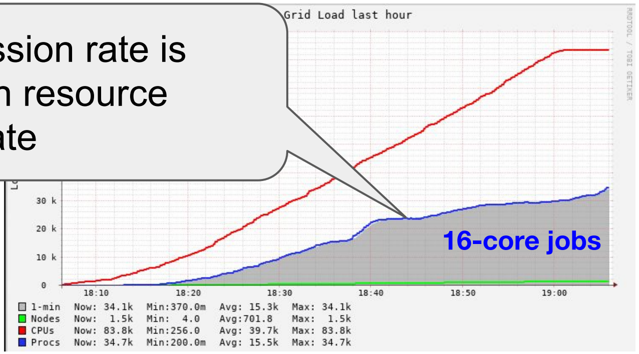
- When should we switch to Sim@P1?
  - What is the minimum LHC inter-fill time (IFT) from which ATLAS can benefit?
- What is the typical IFT to be expected?
- What should be optimized and where in order to best utilize the resources?
  - Workflow Management (Panda)
  - Pilot submission (Harvester)
  - Local Batch (HTCondor)
  - WN configuration
- What metrics shows that we are using Sim@P1 better?
  - Speed of releasing resources to Sim@P1
  - Speed of filling
  - Quality of filling
  - Job parameters
  - Number of events produced
- Let’s test!

Test Setup

- Data
  - Large FastSim LHC Run2 standard proton-proton collision dataset
- Schedule
  - 06.09.2022 - 20.09.2022
  - During LHC technical stop
  - Period with low simulation load on the system
- Hardware
  - “Only” 98.1k CPUs were available for the test (the rest were used by HLT)

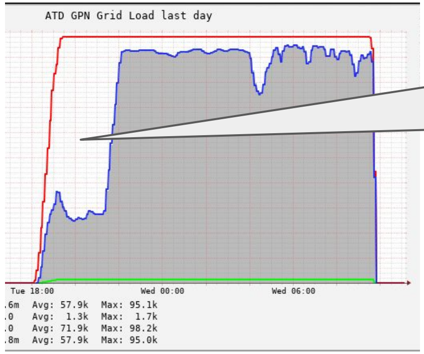
Speed of booting resources to Sim@P1

- No need to improve it if we cannot fill the resources fast enough with offline workflows, right?



```
▨ 1-min   Now: 34.1k   Min:370.0m   Avg: 15.3k   Max: 34.1k
🟩 Nodes   Now:  1.5k   Min:  4.0    Avg:701.8    Max:  1.5k
🟥 CPUs    Now: 83.8k   Min:256.0    Avg: 39.7k   Max: 83.8k
🟦 Procs   Now: 34.7k   Min:200.0m   Avg: 15.5k   Max: 34.7k
```

1. Submission rate is lower than resource release rate



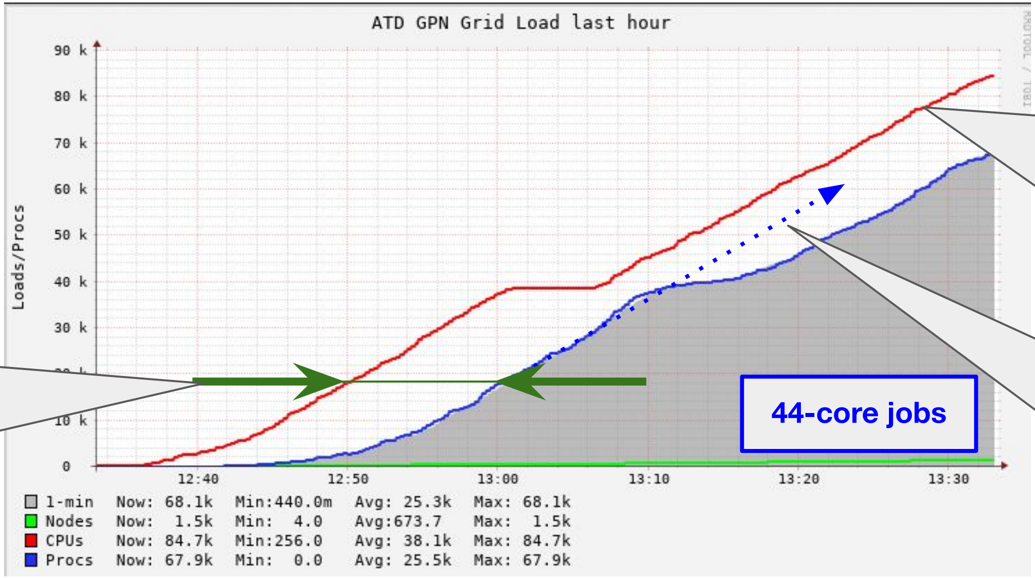
```
.6m   Avg: 57.9k   Max: 95.1k
.0    Avg:  1.3k   Max:  1.7k
.0    Avg: 71.9k   Max: 98.2k
.8m   Avg: 57.9k   Max: 95.0k
```

2. Long delay before filling with jobs

Solutions:

1.
   a. Increase the amount of queued workers in Harvester
   b. Increase the corecount on the jobs submitted
2.
   a. Use dedicated tasks
      i. Reduces the job brokerage time

Speed of filling



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▨ 1-min   Now: 68.1k   Min:440.0m   Avg: 25.3k   Max: 68.1k
🟩 Nodes   Now:  1.5k   Min:   4.0   Avg:673.7    Max:  1.5k
🟥 CPUs    Now: 84.7k   Min:256.0    Avg: 38.1k   Max: 84.7k
🟦 Procs   Now: 67.9k   Min:   0.0   Avg: 25.5k   Max: 67.9k
```

Irreducible delay due to job initialization:
~ 10 min

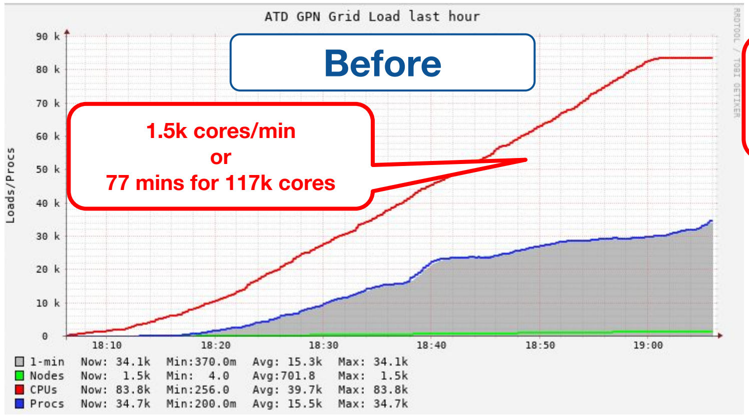
Average filling rate:
~1500 cores/min

Average time to fill all slots:
~80 min

Resource increase expected if it was limited only by submission infrastructure

Resource utilization rate is limited by resource availability rate

TDAQ: Forcing Puppet



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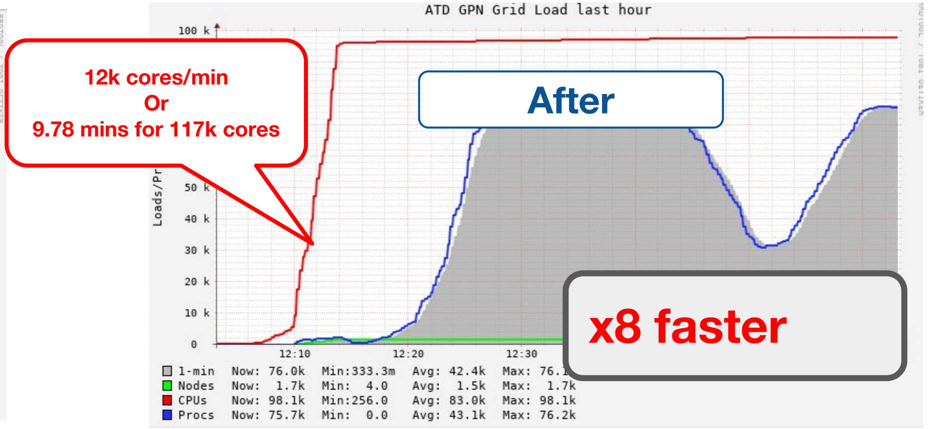
▨ 1-min  Now: 34.1k  Min:370.0m  Avg: 15.3k  Max: 34.1k
🟩 Nodes  Now:  1.5k  Min:  4.0   Avg:701.8   Max:  1.5k
🟥 CPUs   Now: 83.8k  Min:256.0   Avg: 39.7k  Max: 83.8k
🟦 Procs  Now: 34.7k  Min:200.0m  Avg: 15.5k  Max: 34.7k
```

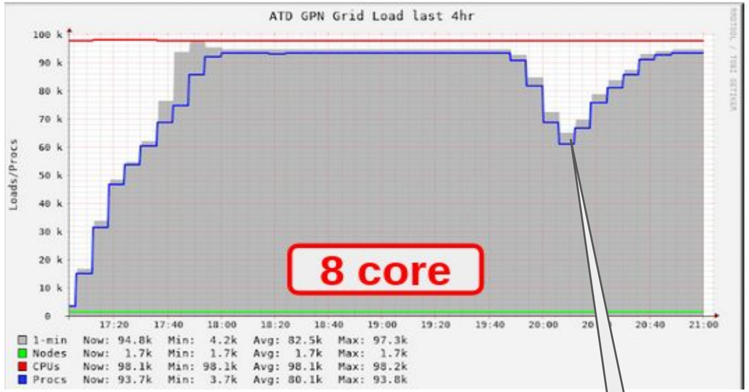


```
▨ 1-min  Now: 76.0k  Min:333.3m  Avg: 42.4k  Max: 76.1
🟩 Nodes  Now:  1.7k  Min:  4.0   Avg:  1.5k  Max:  1.7k
🟥 CPUs   Now: 98.1k  Min:256.0   Avg: 83.0k  Max: 98.1k
🟦 Procs  Now: 75.7k  Min:  0.0   Avg: 43.1k  Max: 76.2k
```

Tried to leave this setting “on” in production, BUT:

- This leaves the TDAQ monitor system in bad condition and it took a while to recover. We rely on monitoring to ensure system functionality.
- We cannot assure that a reboot of the other, critical netboot nodes (including ROS, Felix, SWROD) would work properly during the massive puppet run on the TPUs.

Resource Filling Efficiency



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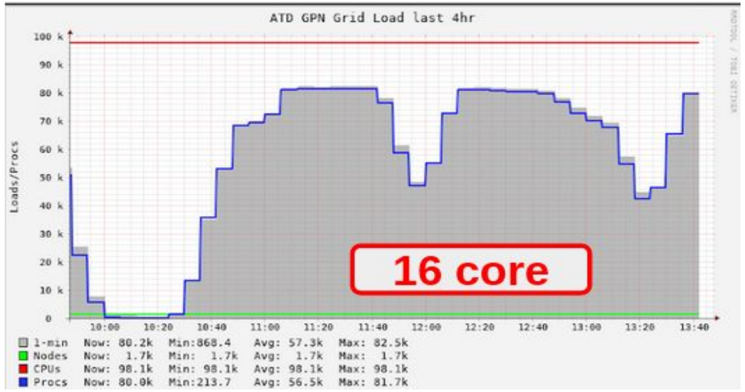
1-min  Now: 94.8k  Min:  4.2k  Avg: 82.5k  Max: 97.3k
Nodes  Now:  1.7k  Min:  1.7k  Avg:  1.7k  Max:  1.7k
CPUs   Now: 98.1k  Min: 98.1k  Avg: 98.1k  Max: 98.2k
Procs  Now: 93.7k  Min:  3.7k  Avg: 80.1k  Max: 93.8k
```

?



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Nodes  Now:  1.7k  Min:  1.7k  Avg:  1.7k  Max:  1.7k
CPUs   Now: 98.1k  Min: 98.1k  Avg: 98.1k  Max: 98.1k
Procs  Now: 80.0k  Min:213.7  Avg: 56.5k  Max: 81.7k
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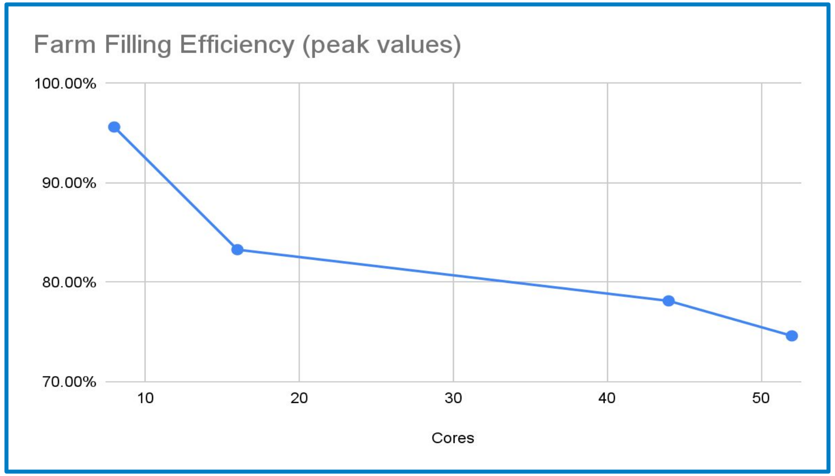


Less cores, better filling

FastSim Job Properties

Higher core count:

- Shorter jobs
- Lower CPU/WALL efficiency

⇨ **Better for shorter IFT**

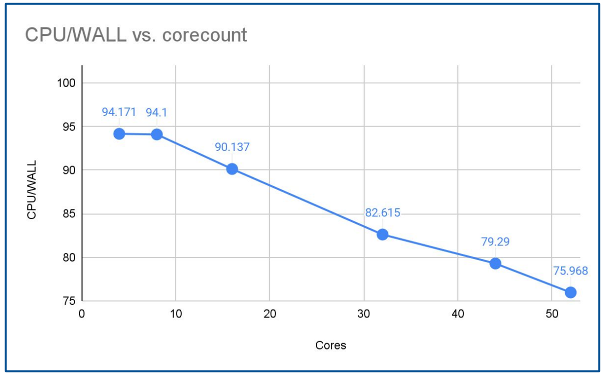
Lower core count:

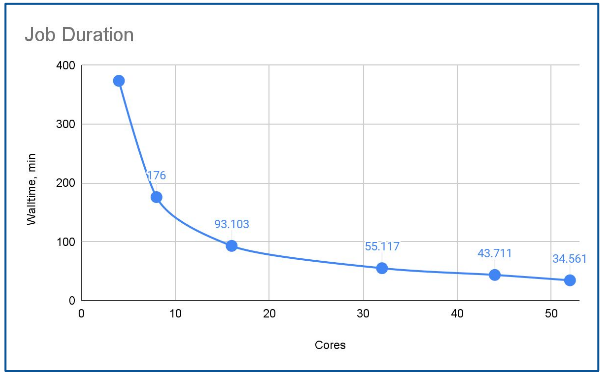
- Longer jobs
- Higher CPU/WALL efficiency

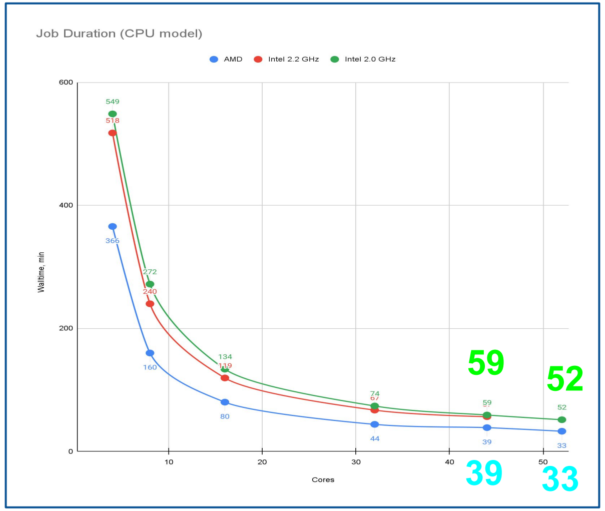
⇨ **Better for longer IFT**

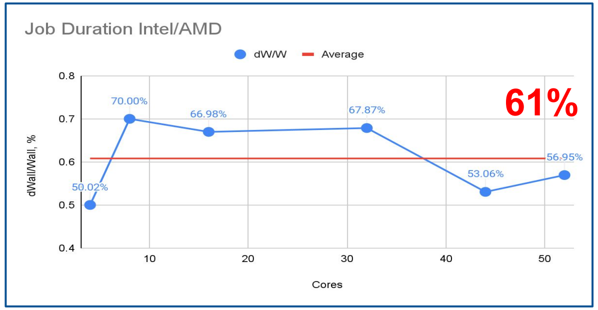
Older CPUs (i.e. Intel):

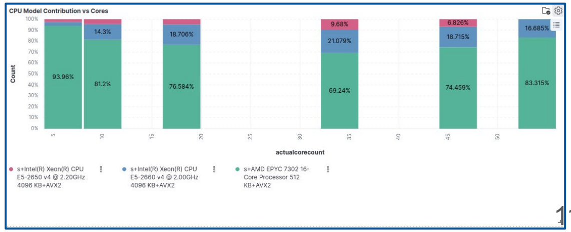
- *Up to 31% of jobs*
- *Up to 70% longer*





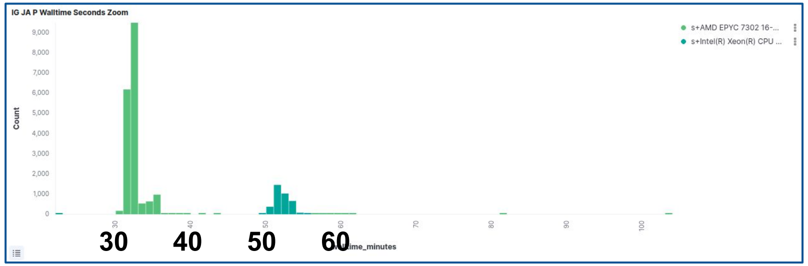


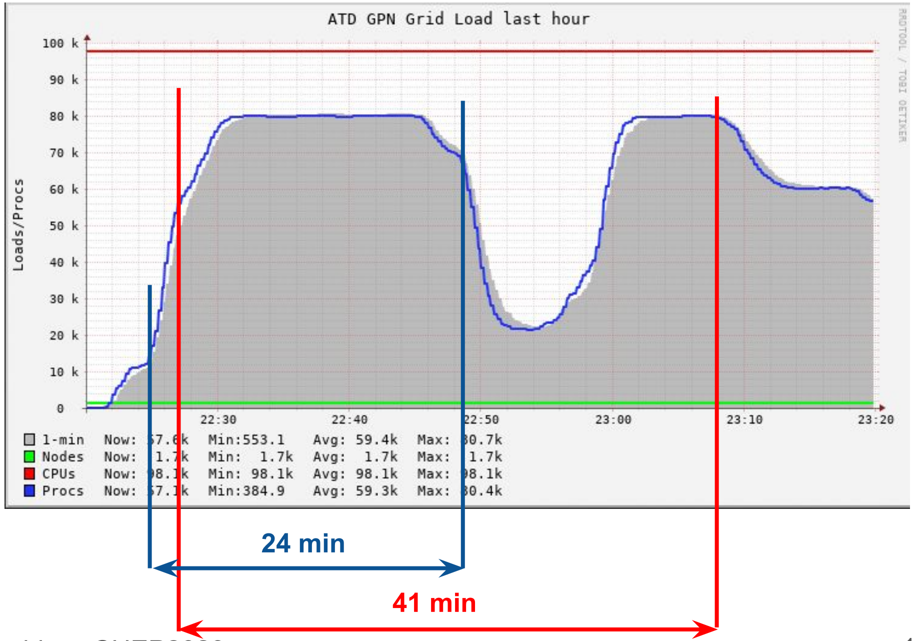




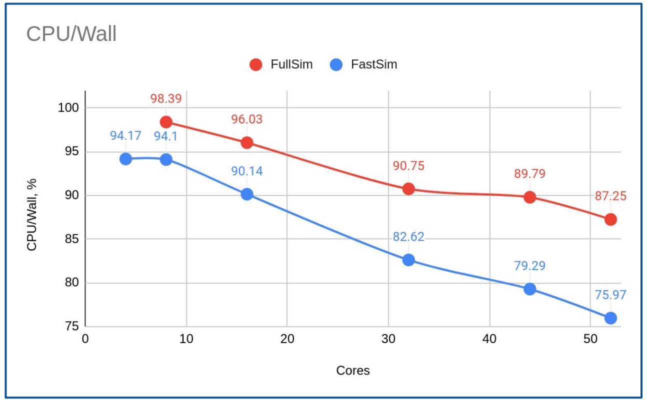
Resource Filling Shape

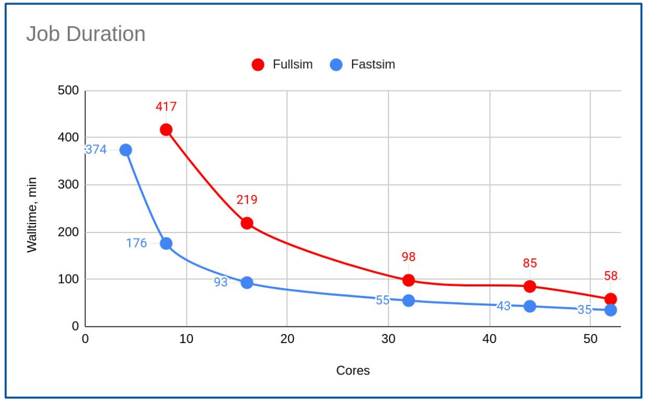
- Distribution Shape
  - Matches job walltime minus the initialization phase
- Due to
  - Too similar jobs (i.e. job lengths) all initializing at the same time
  - Non-zero job initialization time
  - Two different hardware types
- Solution
  - Mix of different jobs



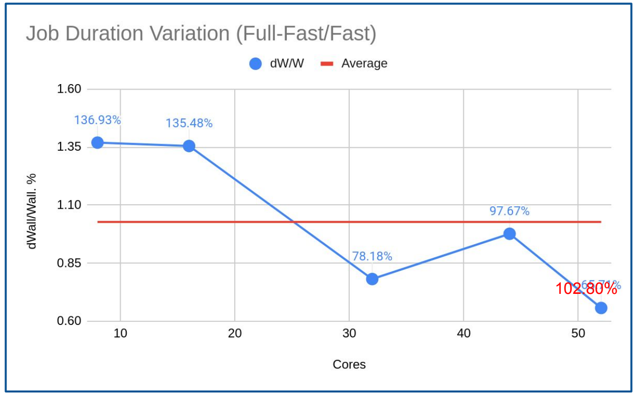


FullSim* vs FastSim* (indicative!)





- FullSim measurements are ONLY indicative due to:
  - Production job mix
  - Low statistics
- No dedicated tests with FullSim:
  - Looking for the shortest jobs
  - FastSim is expected to be the standard simulation production for Run3



FullSim vs FastSim jobs:
On average: x2 longer

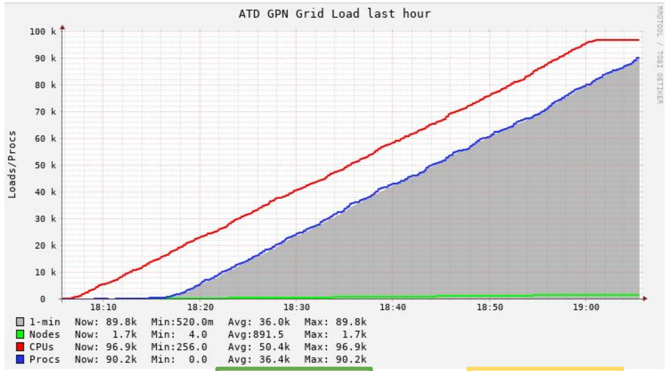
FullSim Sim@P1 Preferred corecount configuration:

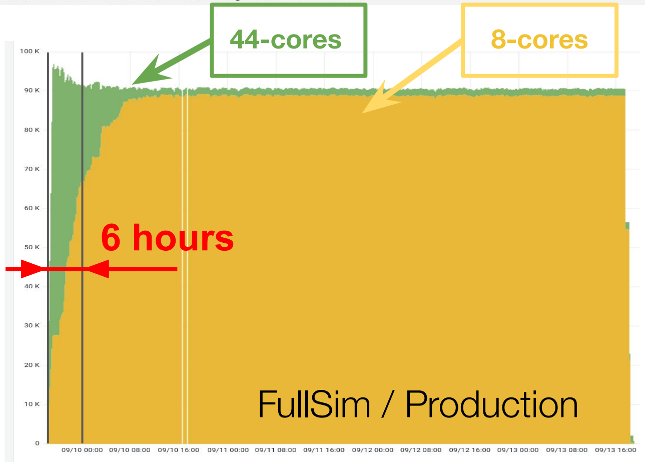
- Consistent with FastSim configuration
- Higher core count for short IFT
- Lower core count for long IFT

* FullSim - Full ATLAS detector simulation
** FastSim - Fast ATLAS detector simulation combining parametrization, machine learning, and modelling of physics object to minimize CPU utilization

Sim@P1: Proposed Configuration

- Proposed setup
  - MC: Dedicated low priority FastSim samples
  - WFMS: Constantly queued workers
  - Batch queue: 44 + 8 cores
  - TDAQ: Forced Puppet run at TDAQ > Sim@P1 change
- Advantages:
  - Perfect ramp-up
  - Faster ramp-up
  - Many 44-core jobs finishing in case of short IFT
  - Running 8-core jobs in case of longer IFT
- Results:
  - FastSim: 1h - 400k events simulated
- Work:
  - MC production
  - TDAQ
    - Not clear how much work would that imply
    - Priority is datataking!
    - Manpower

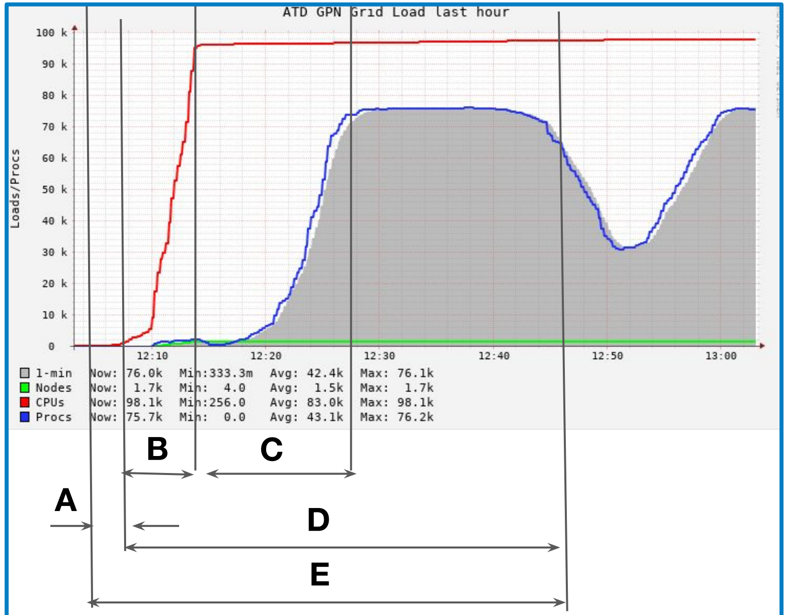




Sim@P1: Operation Scenarios

- Currently
  - LHC is not yet in stable operation mode - no interfills to talk about
- Parameters
  - A = 5 mins
  - B
    - 77 mins - currently
    - 9.8 mins - if Puppet is enforced
  - C
    - 10 mins - Job initialization, Input data download.
  - D - minimal values @44 cores
    - 43 mins (FastSim)
    - 85 mins (FullSim)

- Scenarios
  - Best:
    - Enforced puppet, dedicated FastFim
    - E = A+D = 5 + 43 **>= 48 mins**
  - "Worst":
    - No puppet changes, FullSim, random production
    - E = A+D = 5 + 85 + ? **>= 90 min**
  - Current:
    - == Worst
      - All WFMS related settings were optimized
      - Further improvement can be expected when we have low priority FastSim available at mass



```
□ 1-min  Now: 76.0k  Min:333.3m  Avg: 42.4k  Max: 76.1k
■ Nodes  Now:  1.7k  Min:  4.0   Avg:  1.5k  Max:  1.7k
■ CPUs   Now: 98.1k  Min:256.0   Avg: 83.0k  Max: 98.1k
■ Procs  Now: 75.7k  Min:  0.0   Avg: 43.1k  Max: 76.2k
```

A - Switching from TDAQ to Sim@P1. 5 mins.
B - Ramp-Up. Configuration of VMs
C - Job initialization time
D - Job length
E - Total minimal IFT needed to get any jobs finished

Summary

- We can do (almost) anything
  - Without significant changes we can get useful events from IFT as short as 2 hours
  - Potentially we can even go down to 1 hour
- The parameter phasespace is huge
  - How long is the IFT going to be?
    - During data taking
      - **1-2 hours - only FastSim can succeed.**
      - **3 hours and more - any simulation is fine**
    - Technical Stops / Machine Development
      - **Just another GRID site running simulation**
  - How much do we want to tailor the jobs?
    - Many convoluted parameters - no silver bullet to efficient resource utilization
    - Requires person-hours
- More tests can be done to optimize even better
  - …but we have a solid idea already
  - The first-approximation parameters were adjusted - good enough for the time being
- More experience during data taking would be welcome
  - Switch to Sim@P1 every time possible, please.
  - Data taking is paramount! Switching to Sim@P1 is up to Run Coordination and TDAQ Coordination