DESC production

NPPS

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Overview

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Related talks

- [March 11 NPPS]

Introduction

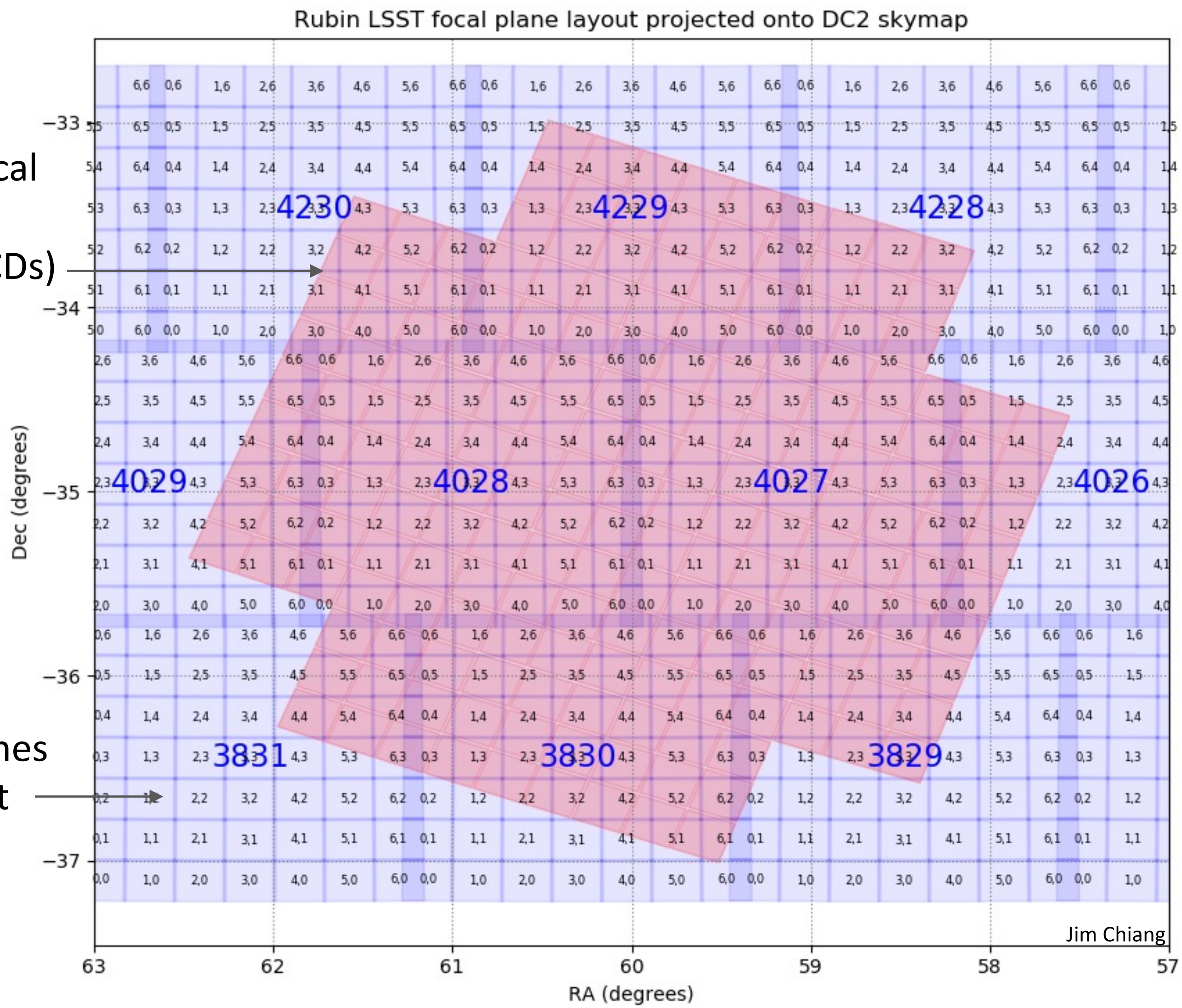
DESC production

DESC is running the LSST processing chain

- Start from raw CCD data all the way through to object catalog
  - Objects include stars, galaxies with 3D positions (angles, z)
  - Includes merging of many overlapping images
    - Wide variety of positions, orientations and offset to cover the (southern) sky and cancel systematics
    - Each visit (2 images) includes data from 189 sensors (CCDs)
  - Sky is divided up into tracts and patches for processing
    - Following page shows focal plane overlaid on tracts and patches
      - » Size of patch is about the same a CCD
    - I have been running jobs that process 10 patches
      - » Soon 1 tract = 49 patches
- When real data comes, DESC will reprocess some fraction (10%??)
  - Want to optimize use of compute resources at NERSC
  - Report code and workflow improvements to LSST

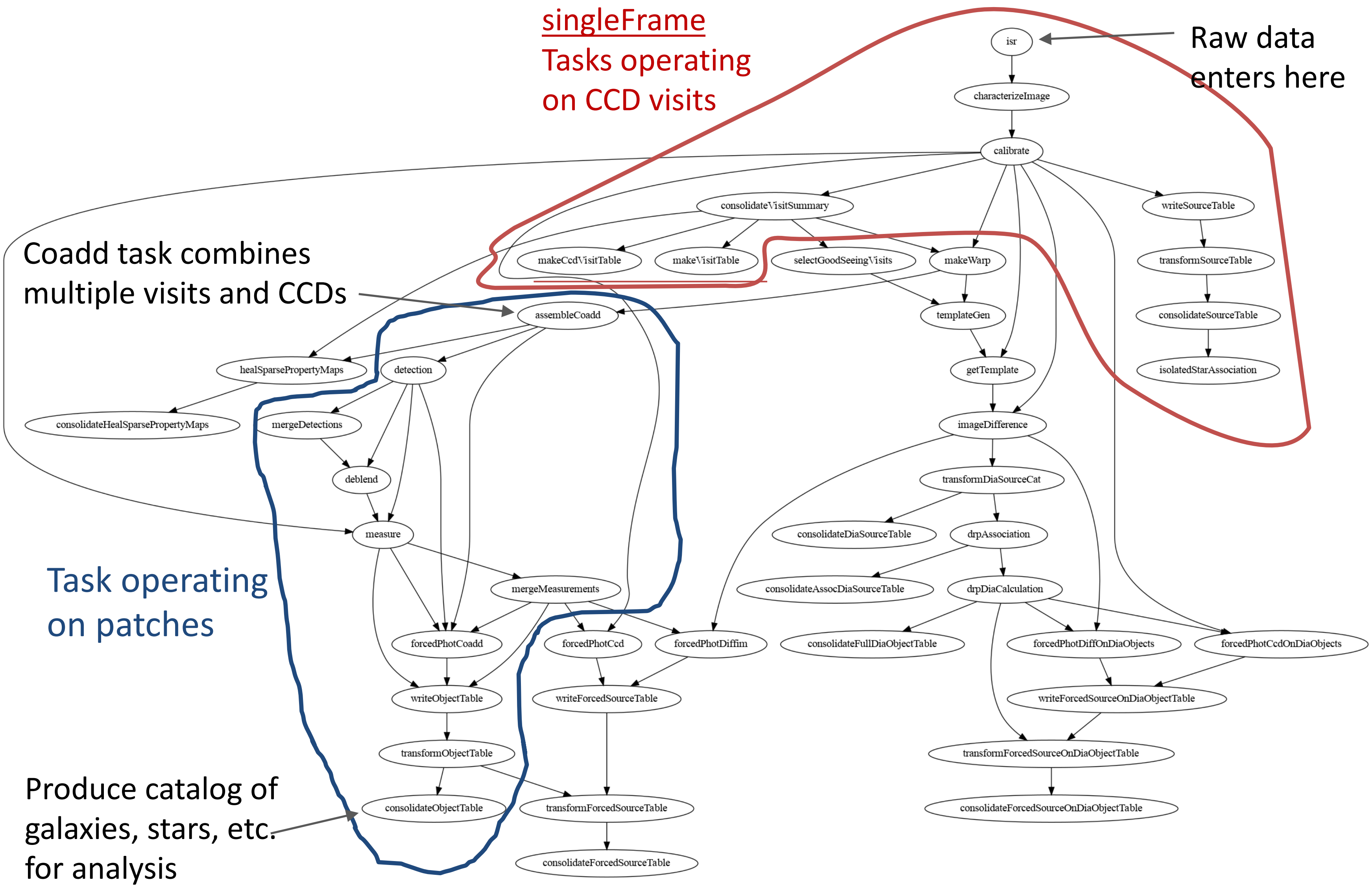
One example visit

LSST focal plane (189 CCDs)



49 patches Per tract

LSST/DESC workflow (from w_2022_10)



Scheduling

Result here are reported for NERSC Perlmutter

- Being commissioned but available for users to try out
- All runs here were done on a single node:
  - 128 CPUs (2 logical cores on each of 64 physical cores)
  - 256 GB total memory

Parsl does the scheduling

- User provides DAG specifying list of tasks and their dependencies
- Using the WorkQueue executor (scheduler)
- User limits the number of running tasks with
  - Specified number of CPUs per task
    - Here set to 1 except for a couple test runs
  - Specified memory to allocate for each task and total available
    - These are often depend on task type and were tuned in earlier studies

Example job configuration

```
includeConfigs:
  - ${GEN3_WORKFLOW_DIR}/python/desc/gen3_workflow/etc/bps_drp_baseline.yaml
  - ${GEN3_WORKFLOW_DIR}/examples/bps_DC2-3828-y1_resources.yaml

pipelineYaml: "${OBS_LSST_DIR}/pipelines/imsim/DRP.yaml#assembleCoadd"

payload:
  inCollection: u/dladams-pm/sfp_Y1_4430_20-29_ptest39
  payloadName: sfp_Y1_4430_20-29_ptest41
  butlerConfig: /global/cfs/cdirs/lsst/production/gen3/DC2/Run2.2i/repo
  dataQuery: "skymap='DC2' and tract=4430 and patch in (20..29) and visit < 262622"

parsl_config:
  retries: 1
  monitoring: parsl.monitoring.monitoring.MonitoringHub(
           hub_address=parsl.addresses.address_by_hostname(),
           hub_port=55055,
           monitoring_debug=False,
           resource_monitoring_interval=1,
       ),
  executor: WorkQueue
  provider: Local
  nodes_per_block: 1
  worker_options: "--memory=225000"

operator: dladams-pm
commandPrepend: "time perf stat -d"

# Default task properties.
requestCpus: 1
requestMemory: 1000
```

List of tasks to run

Full workflow definition

Input data location

Output data location

Memory available for scheduling tasks in 225 GB

Prepend each task execution command with time and perfstat to collect data for the logging monitor

By default, each task is assumed to use 1 CPU and 1 GB memory. The memory limit is overridden for some task types.

Monitoring

Performance data is taken from three sources

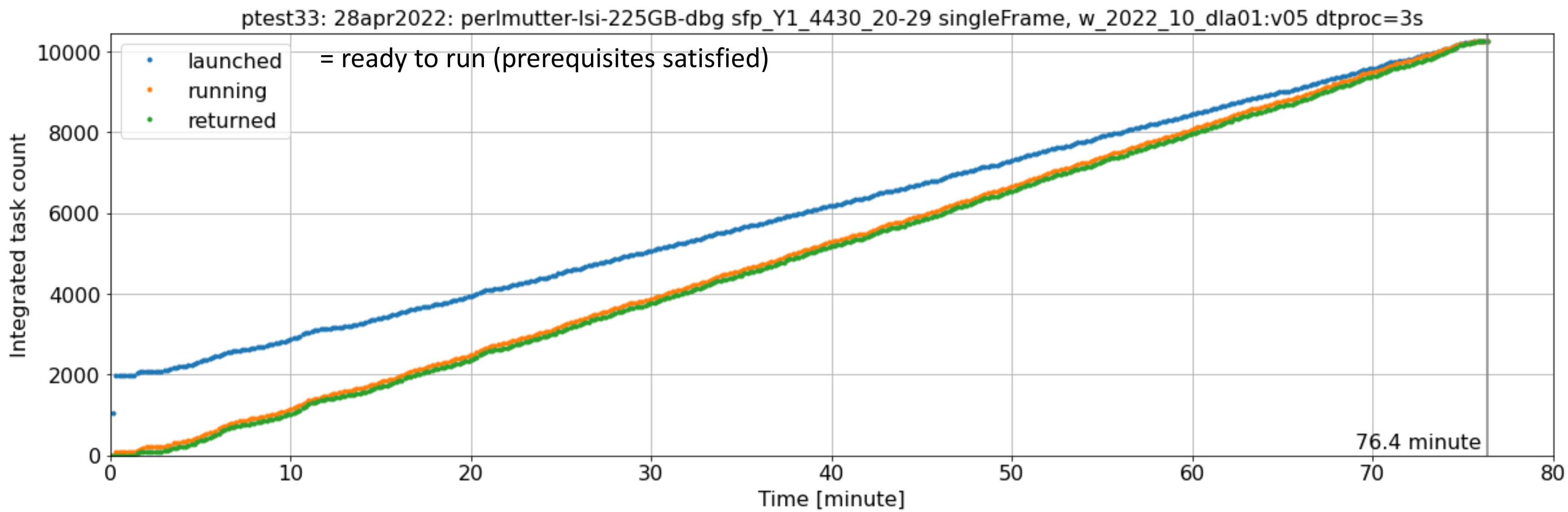
- Parsl monitoring (SQLite DB) includes
  - Information about each run (I do 1 run per job)
  - Information about each task and task try (only 1 if all goes well)
  - Process monitor does regular sampling of running tasks
    - Plus a sample at the end
- System monitor
  - Regular sampling of system info
- Log monitor
  - Parse the output log of each task

Notebooks used to make the plots shown here:

- monexp – Parsl and system monitors
- perfstat – Log monitor

SingleFrame perfomance

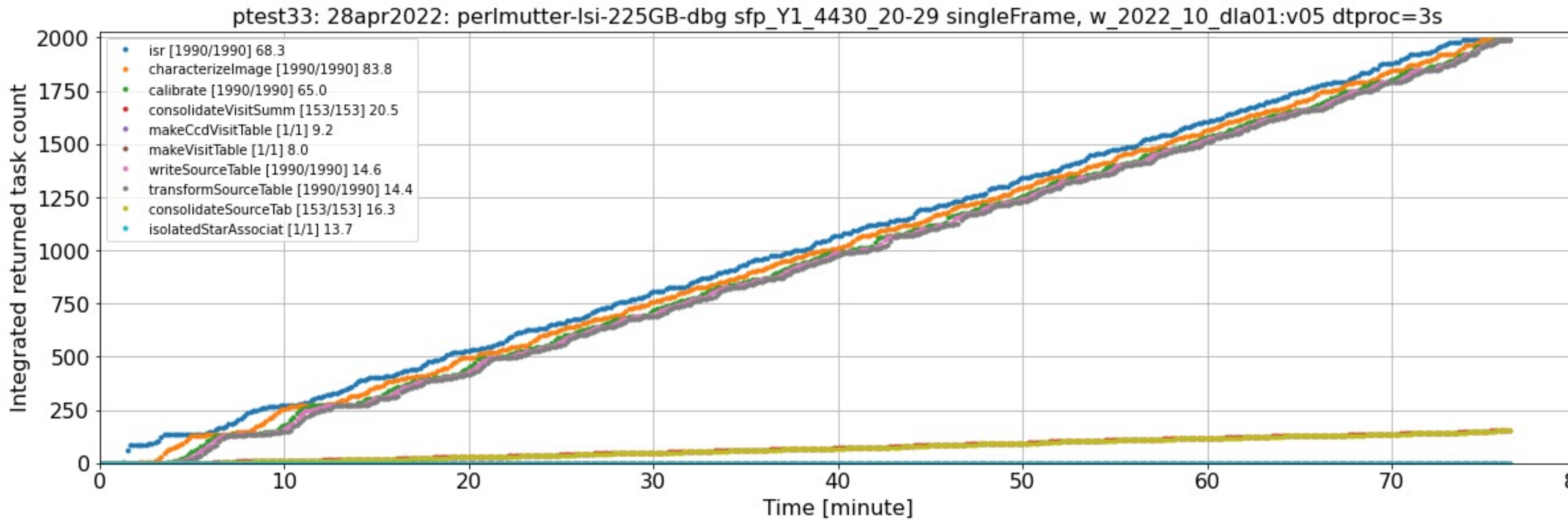
Throughput for singleFrame

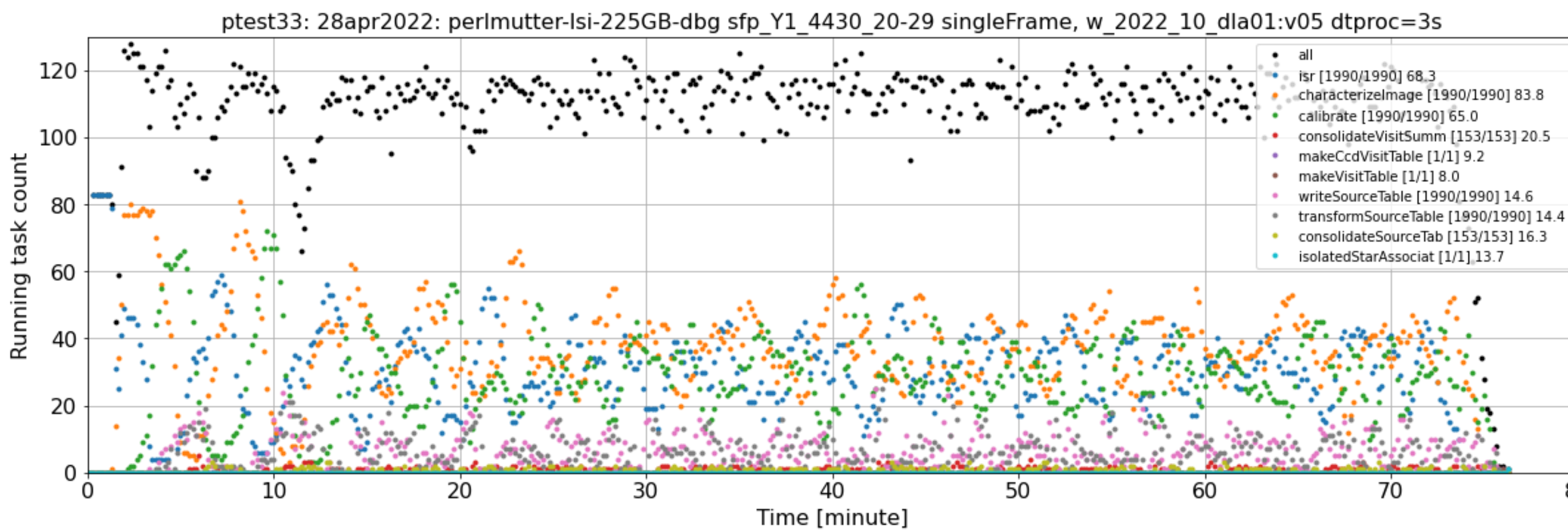


Above is an example throughput plot

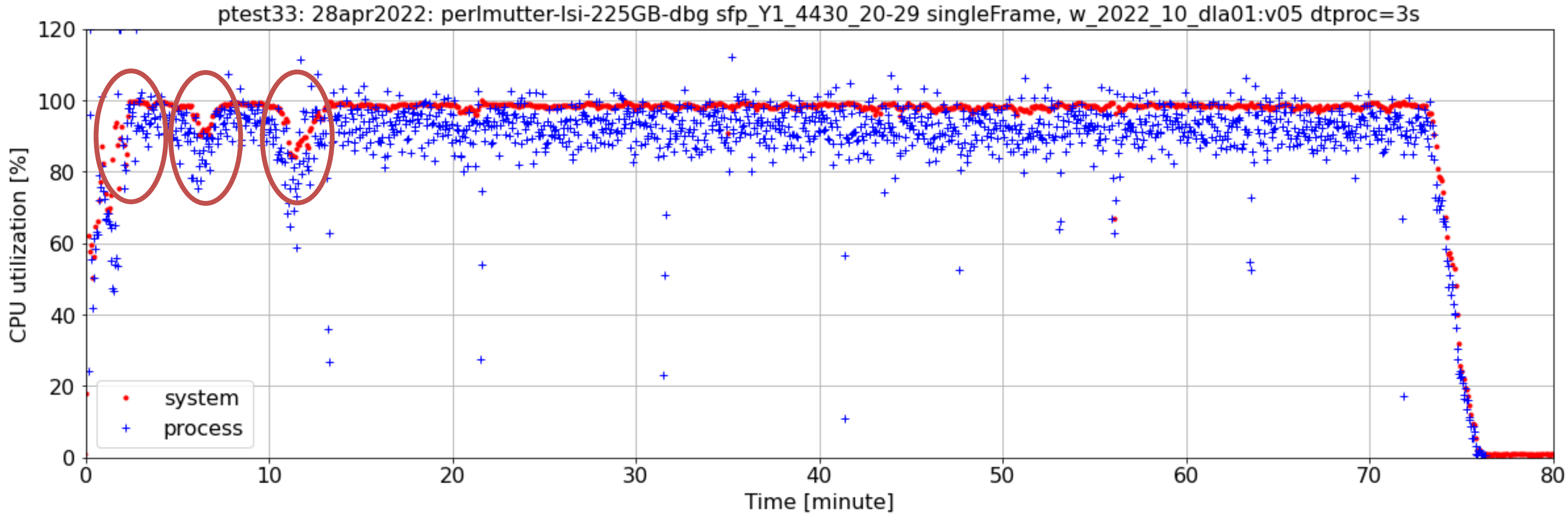
- Integrated numbers of launched, started and complete tasks vs time
  - From process monitor try table
- This is singleFrame processing for 10 patches with 1 year of data
- Processing took 76 minutes
  - Start up time (few min??) not included
  - Finalization (recording output in DB) not included (many min??)

Throughput and # running tasks by task type





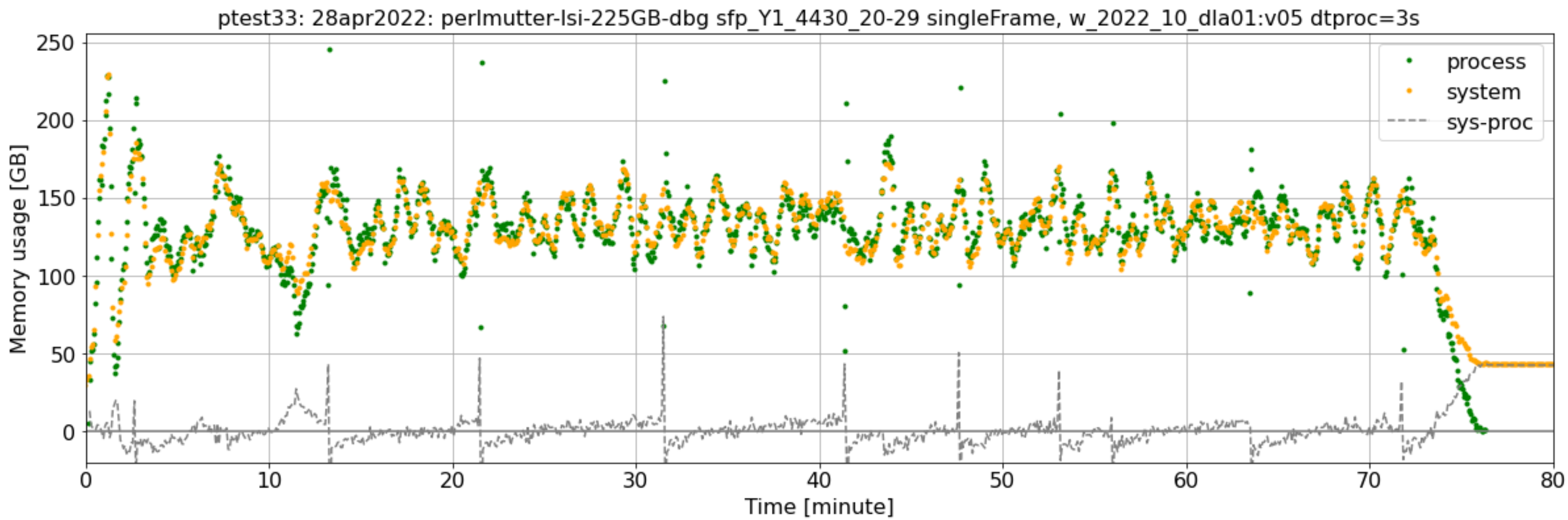
CPU utilization



Above plot shows CPU utilization vs. time

- Fraction of CPU cycles used on behalf of user
  - Red is the system monitor
  - Blue is the sum over running process from the parsl process monitor
- Some of the difference between these comes from cycles used by the scheduler and the monitor
- Generally close to 100% (good) except
  - Inevitable tail as jobs finish with none remaining to start
  - At start of processing, limited by high-memory isr jobs
  - Dips at 2, 7 and 11 minutes to be understood (more on this later)

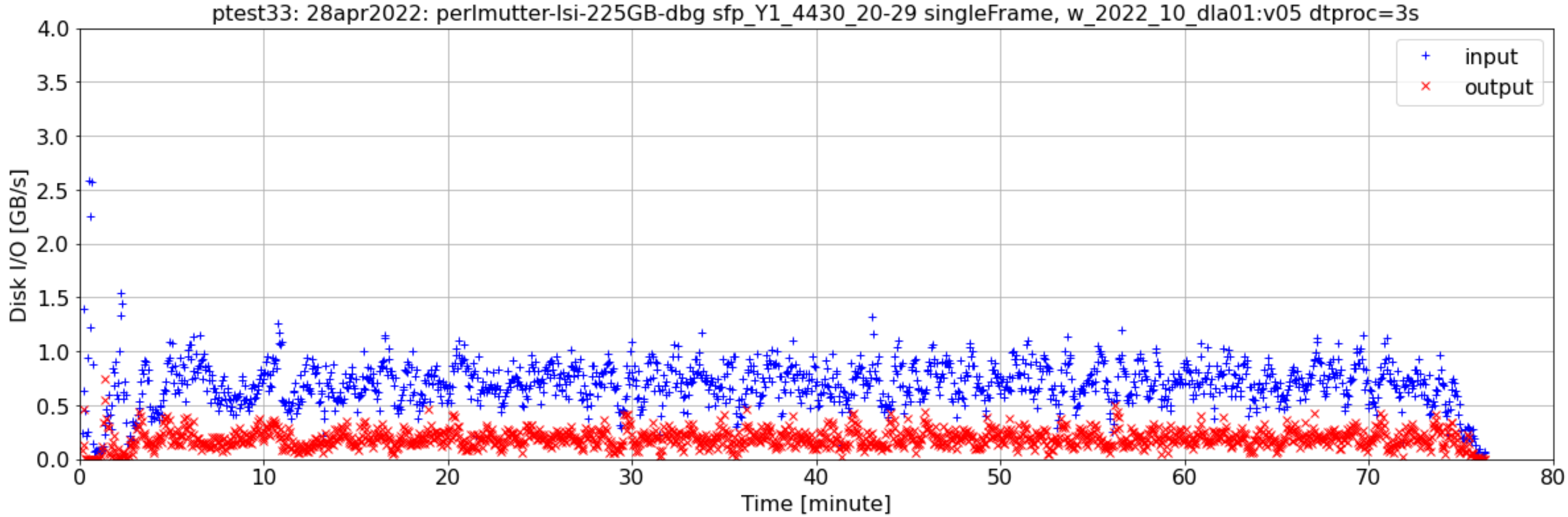
Memory usage



This plot show memory usage vs. time

- Again system report and sum of running tasks are shown
  - Gray is the difference of these
- Spikes likely due to catching extra samples in the rebinning needed for process sums. Maybe a better algorithm would help.
- We are comfortably in memory range (top of plot) except at beginning where synchronized jobs are growing together

Disk I/O

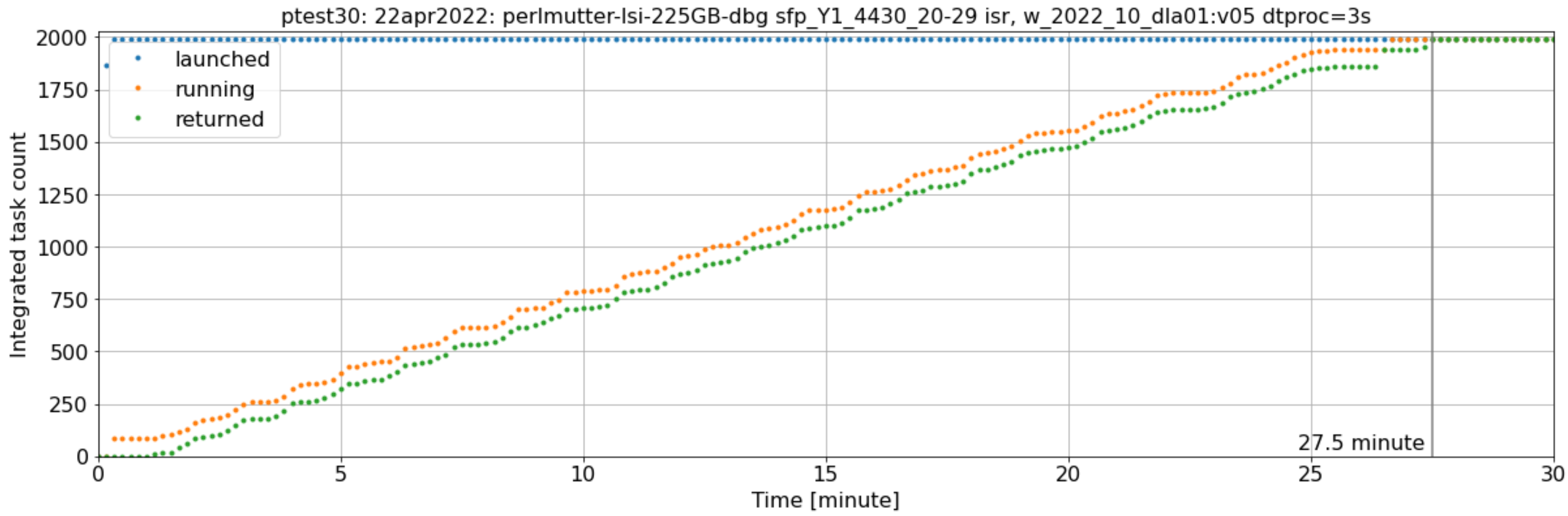


Above plot shows I/O vs time

- Process sums only
- System shows nothing
  - Because disks are network mounted?

Performance for isr (first task) only

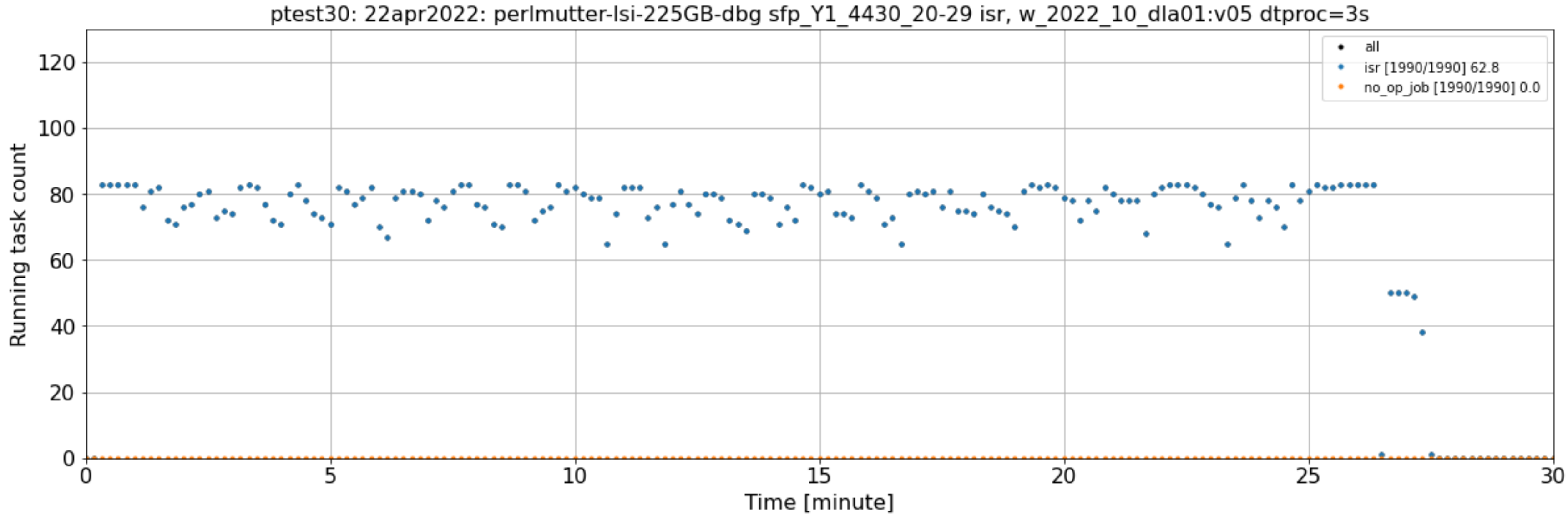
Throughput for isr only



Above plot is throughput

- Stairstep effect suggesting tasks may be stalling on a shared resource
  - Disk, input file location DB, processor speed, …

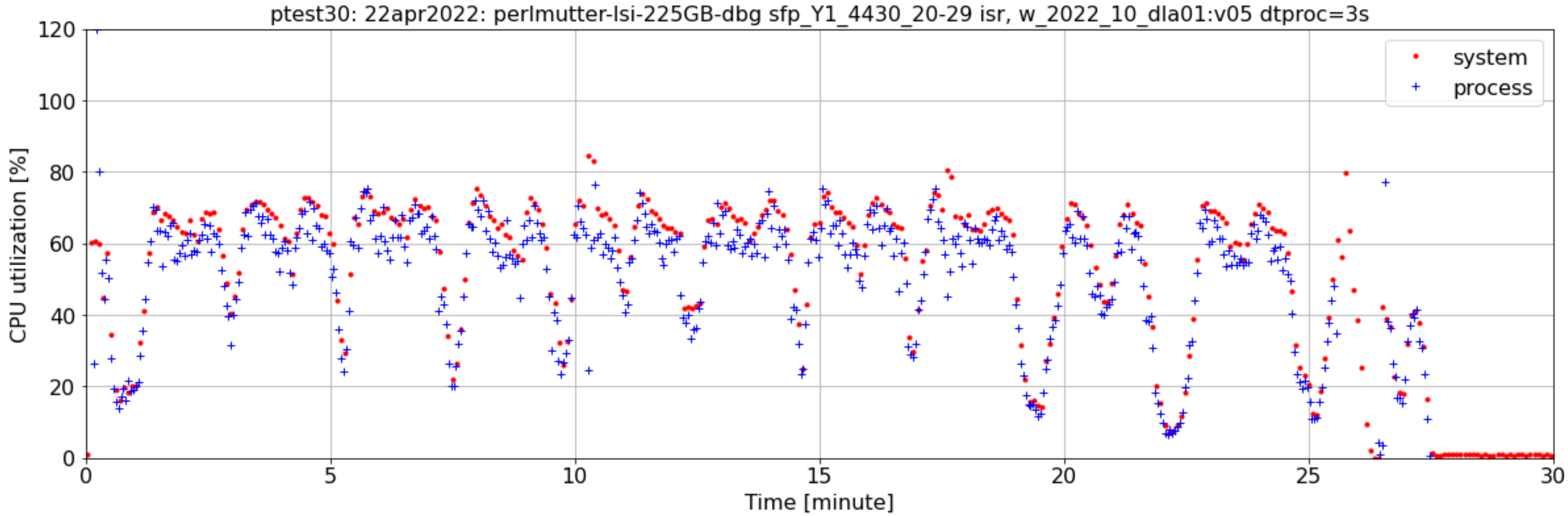
Number of running tasks



Plot show number of running tasks vs. time

- Ideal is memory limit (225 GB)/(2.7 GB/task) = 83 tasks
- Typically 10-15% below this value
    - Parsl is not keeping up?
    - Working now to understand/improve this
    - Latency of 6 sec in job submission, some tasks only run for 20 sec
    - Slow file system response importing code?

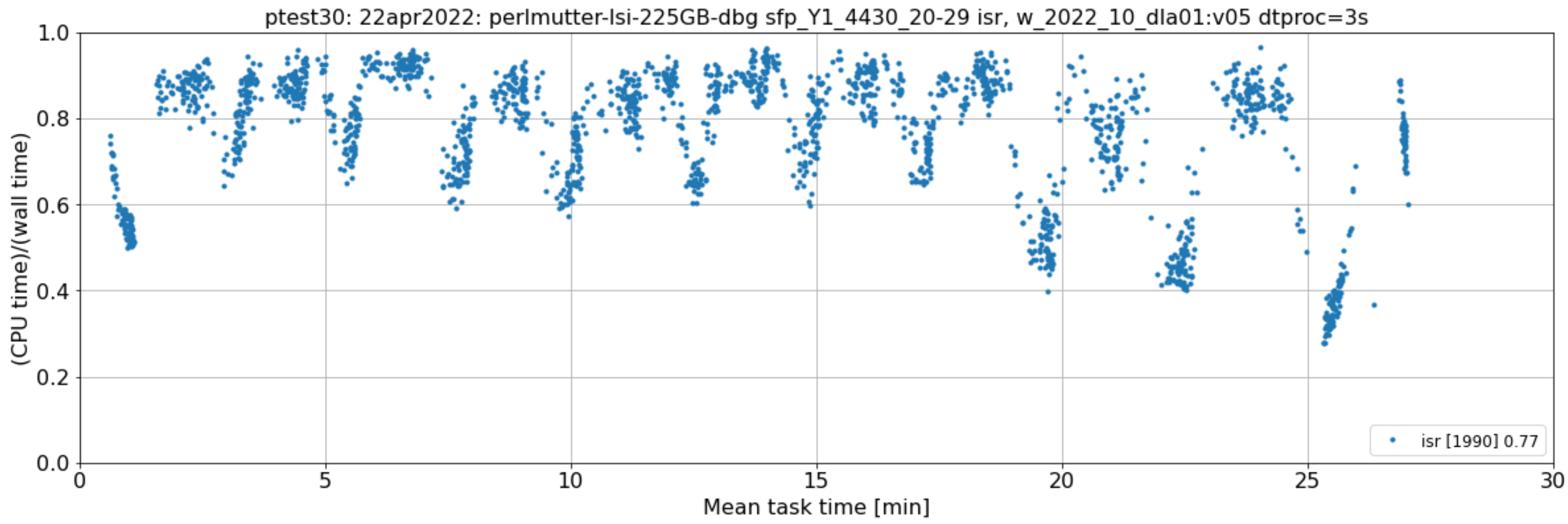
CPU utilization



Plot shows CPU utilization vs. time

- Many dips, some severe
- There are time periods when tasks are starved for a common resource
  - Again file system issues?

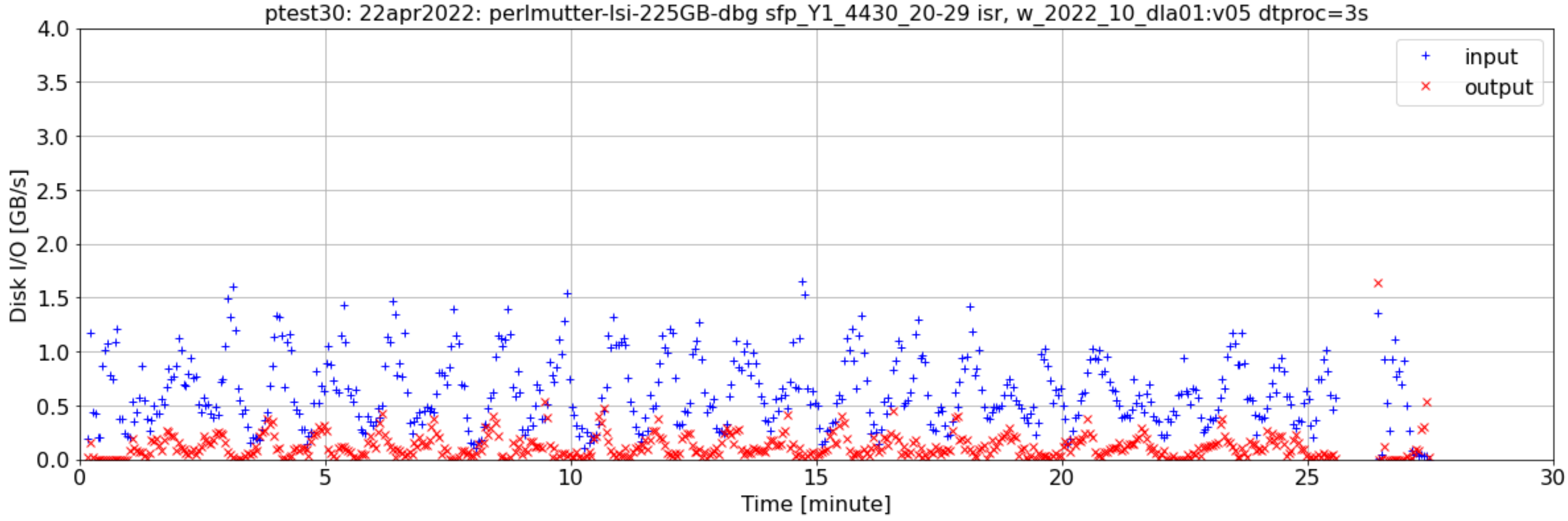
Task CPU utilization



Plot shows a different measure of CPU utilization

- Now one point for each task
  - X-axis is the mean of the process start and end times
- Data obtained from the logging monitor

Disk I/O



Plot show disk I/O

- Some correlation with preceding plots
- But hard to separate cause and effect

Varying the number of concurrent processes

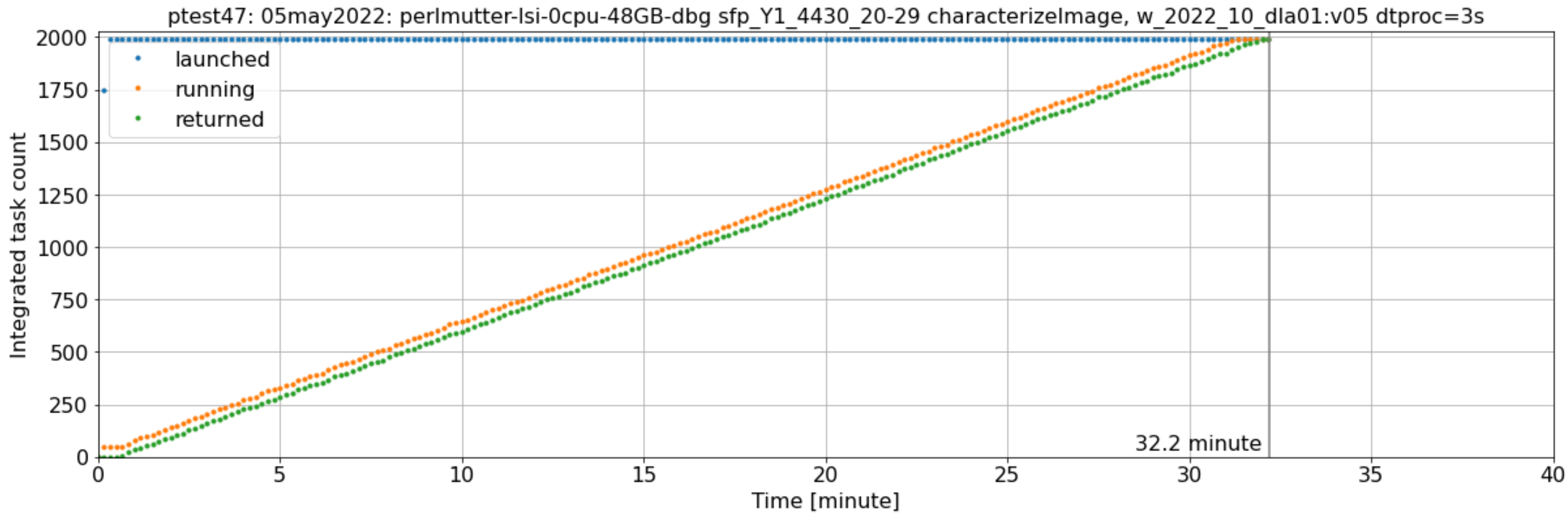
Varying the number of processes

What happens if we run more or fewer concurrent processes?

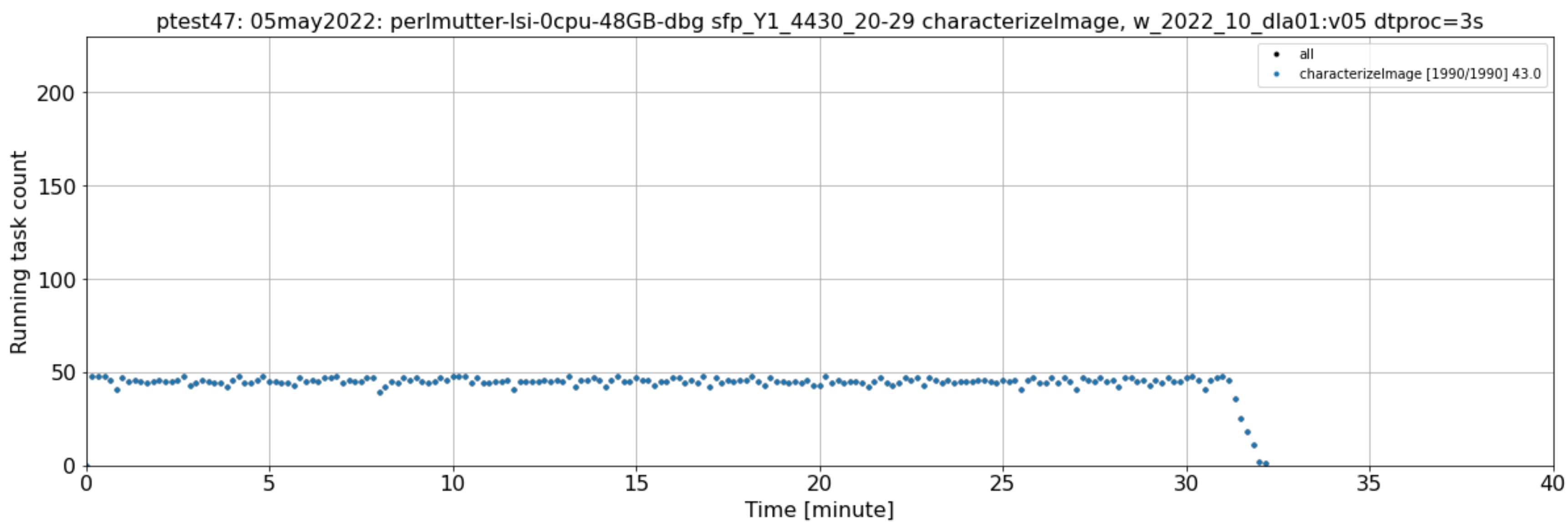
Consider an example:

- One task, characterizeImage, with 10 patches
- Fix the number nominal of concurrent processes to N with
  - E.g. with: 0 CPU/task, task memory=1 GB, total memory = N GB
  - Other configs used in some cases
- Following pages show throughput (top) and actual number of running tasks as this nominal task count is increased
  - Remember we have 128/64 logical/physical cores

48 tasks



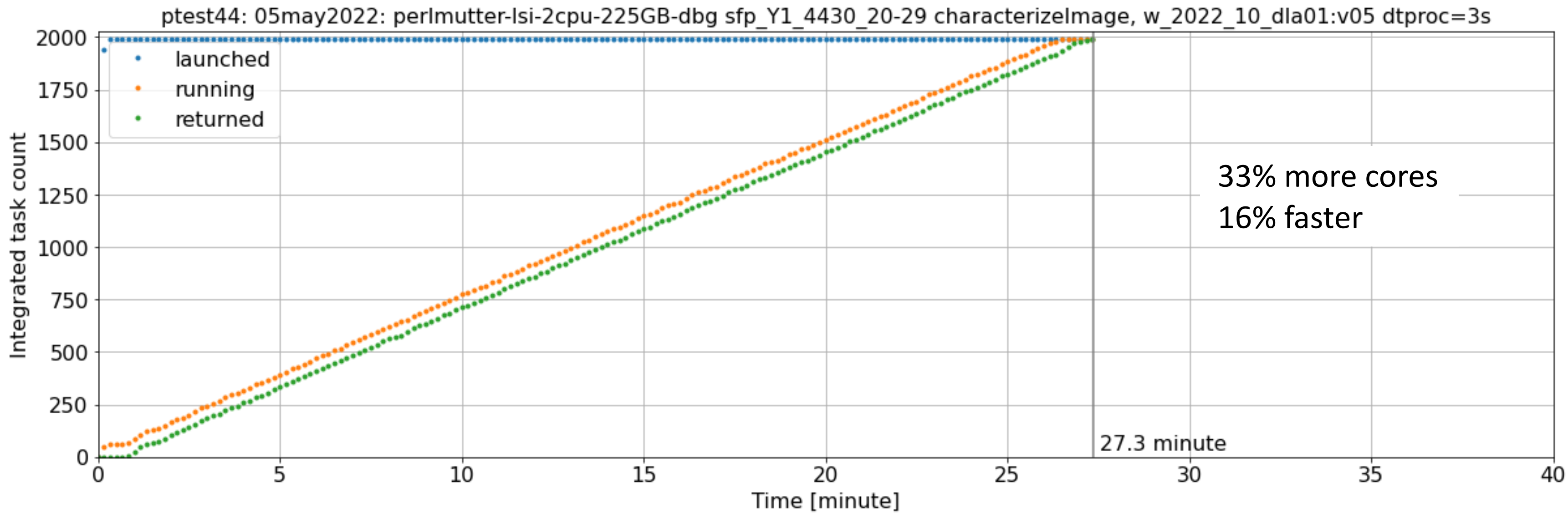
ptest47: 05may2022: perlmutter-lsi-0cpu-48GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
Integrated task count
launched
running
returned
32.2 minute
Time [minute]

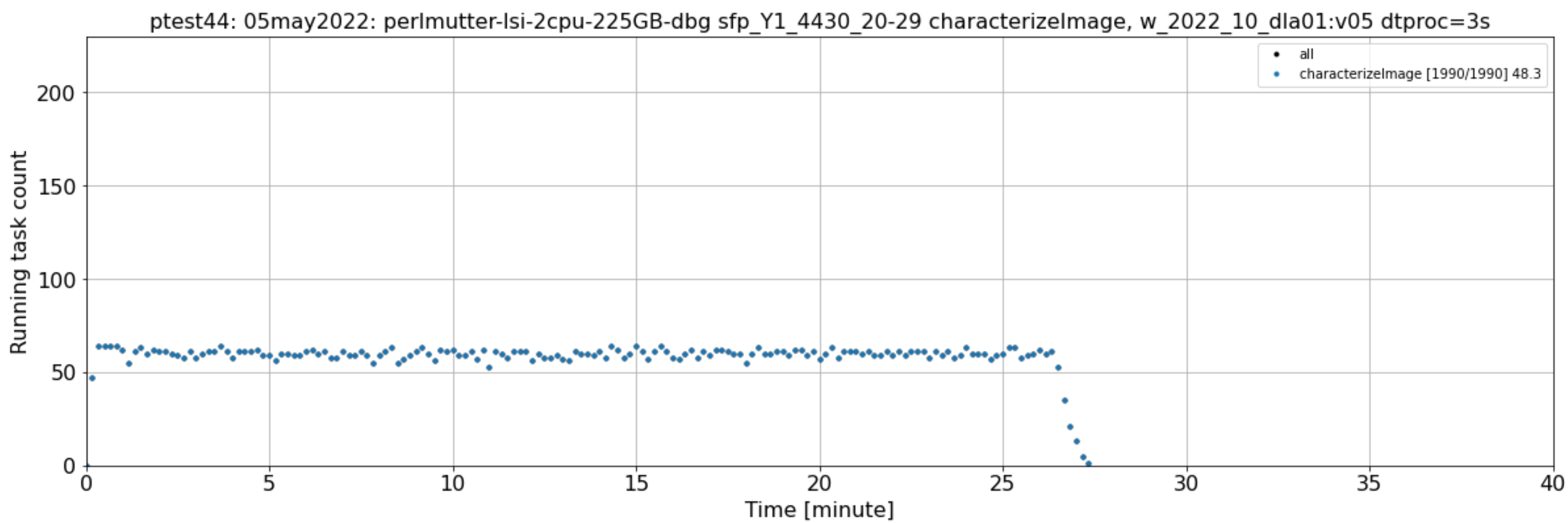


ptest47: 05may2022: perlmutter-lsi-0cpu-48GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
Running task count
all
characterizeImage [1990/1990] 43.0
Time [minute]

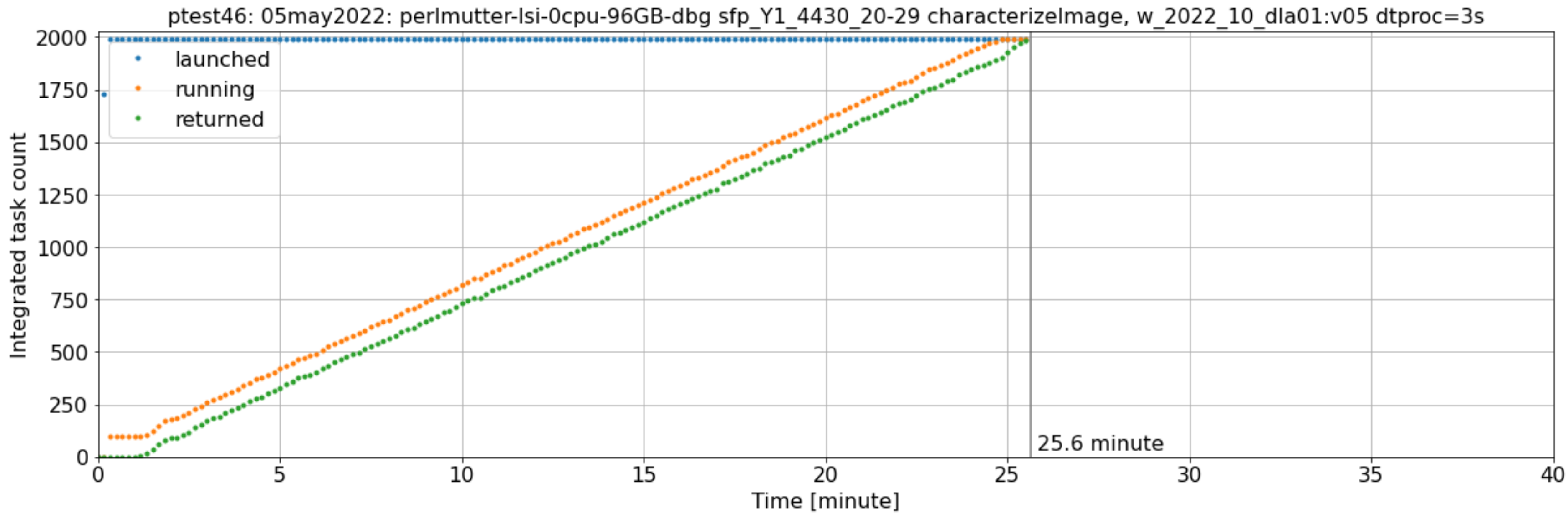
64 tasks

1 task/(physical core)

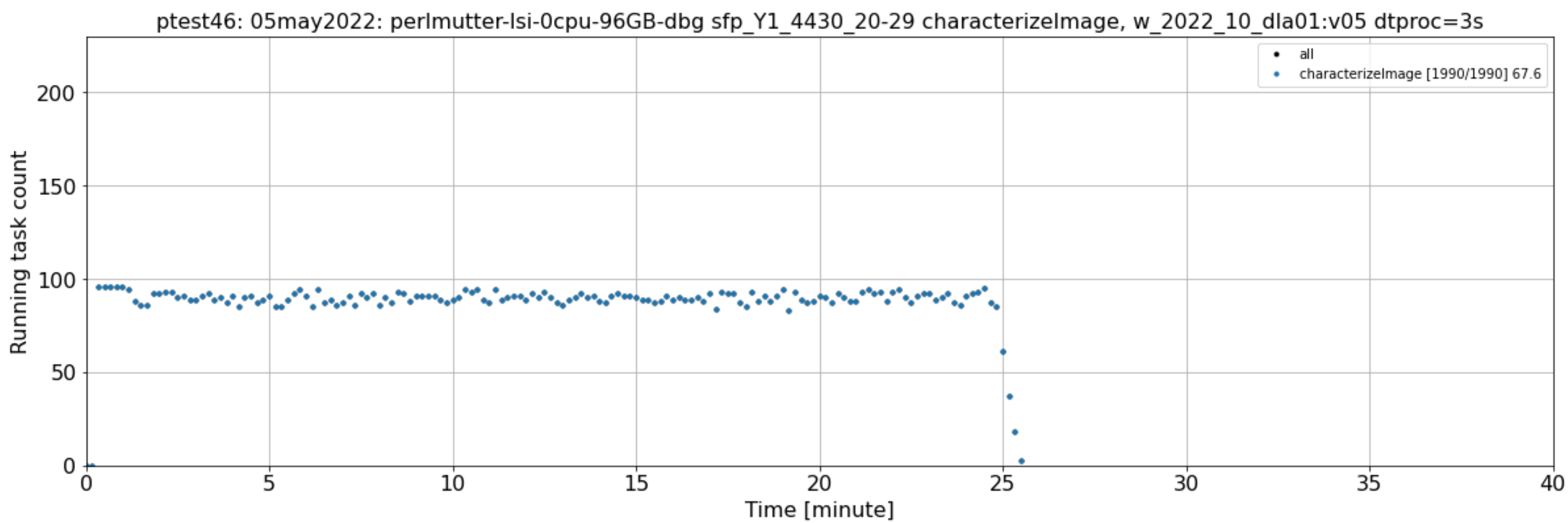




96 tasks



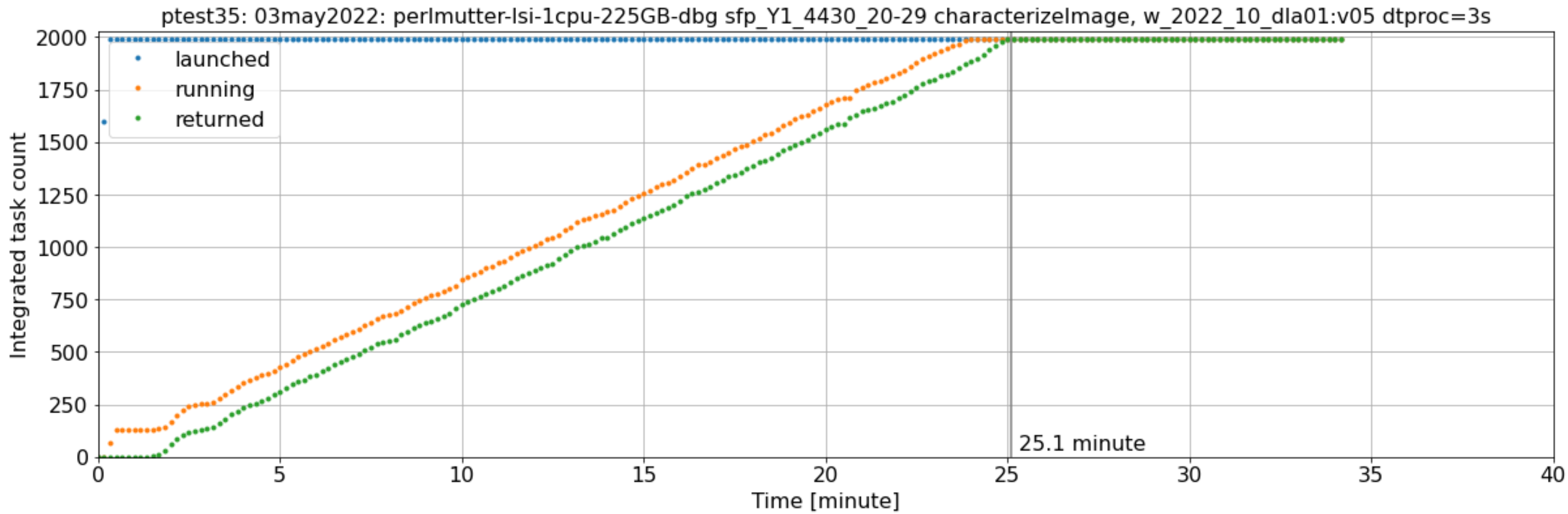
ptest46: 05may2022: perlmutter-lsi-0cpu-96GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
launched
running
returned
Integrated task count
25.6 minute
Time [minute]

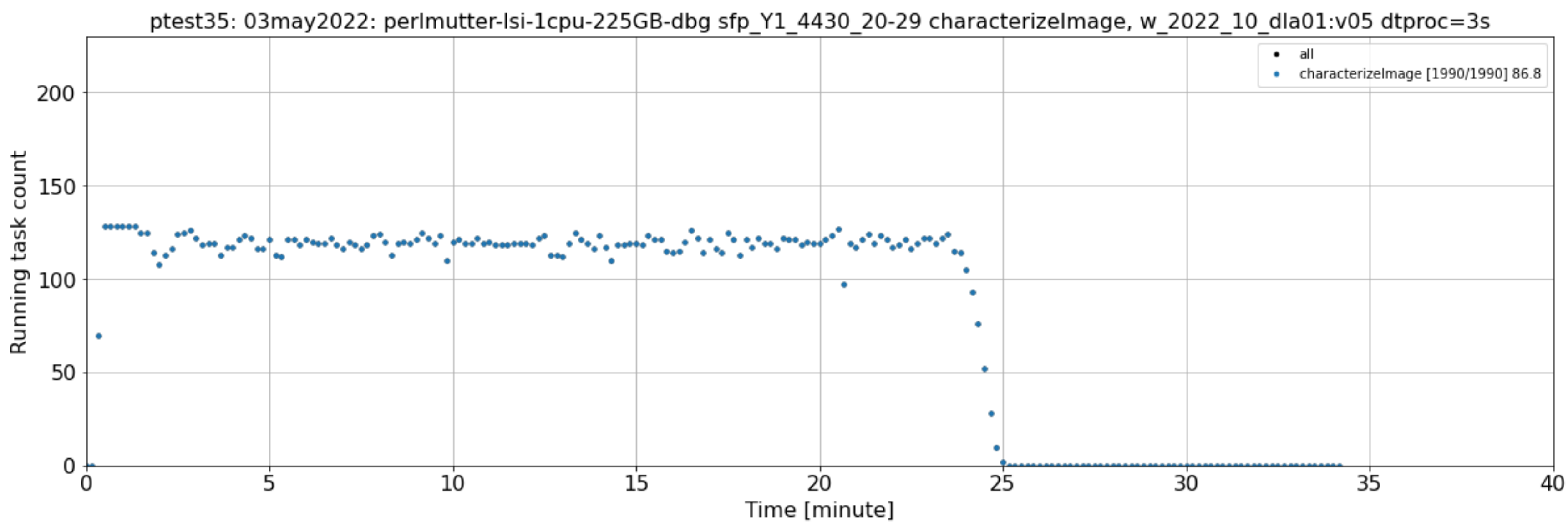


ptest46: 05may2022: perlmutter-lsi-0cpu-96GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
all
characterizeImage [1990/1990] 67.6
Running task count
Time [minute]

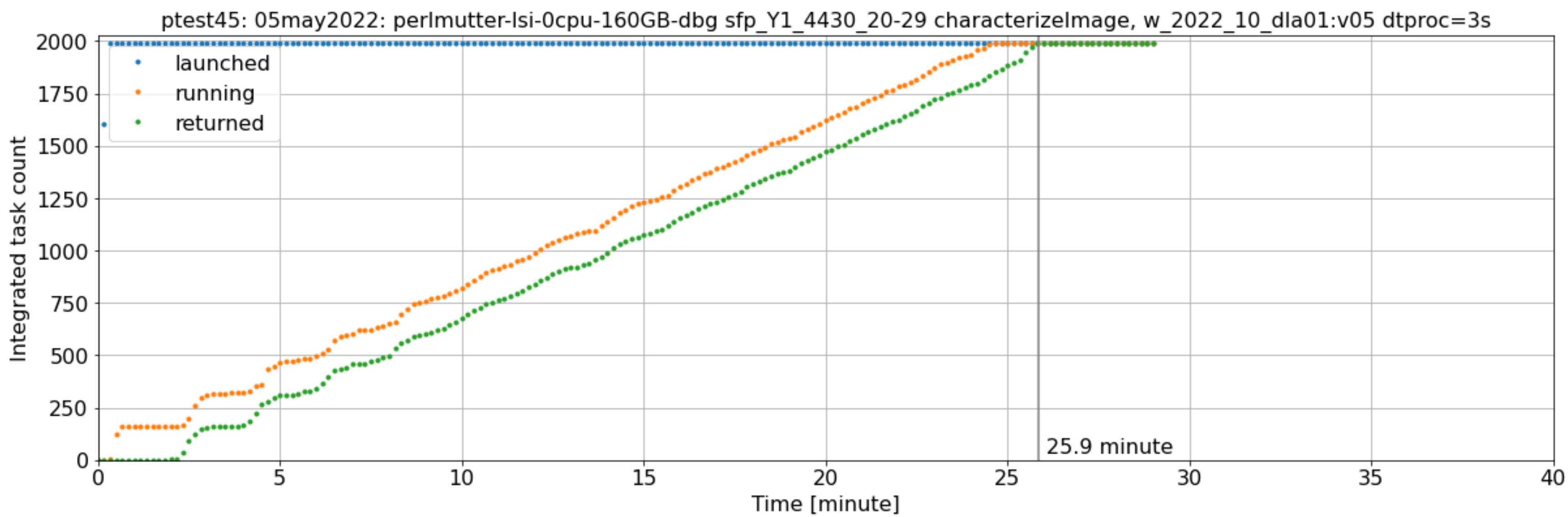
128 tasks

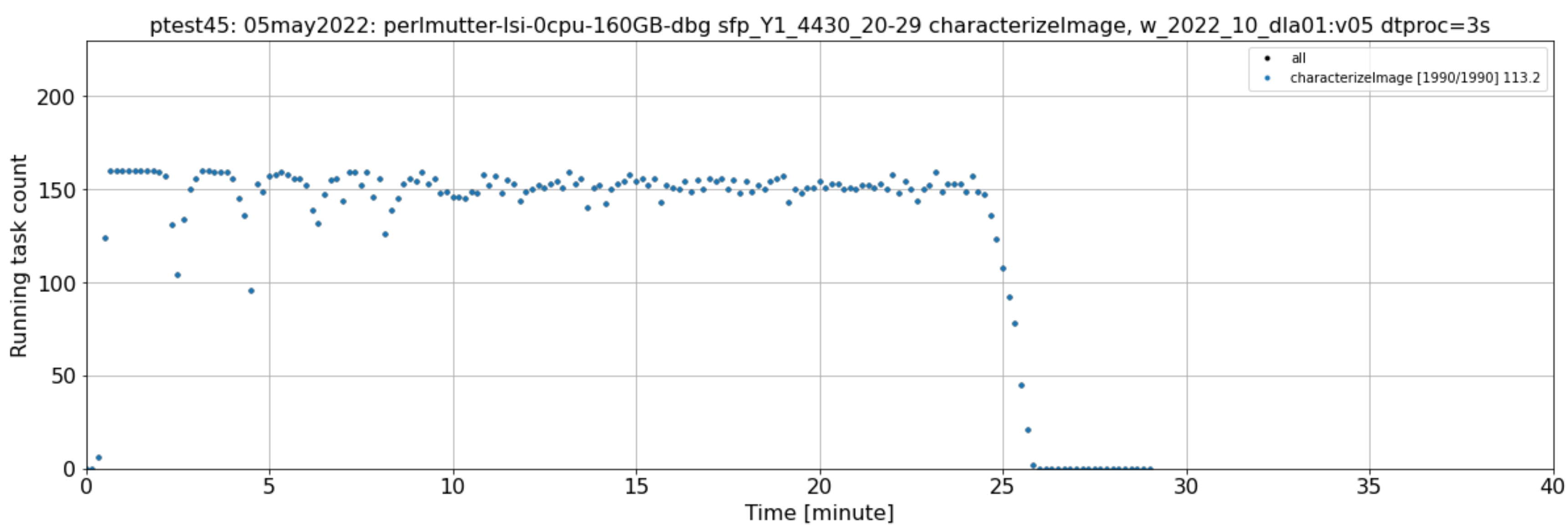
1 task/(logical core)



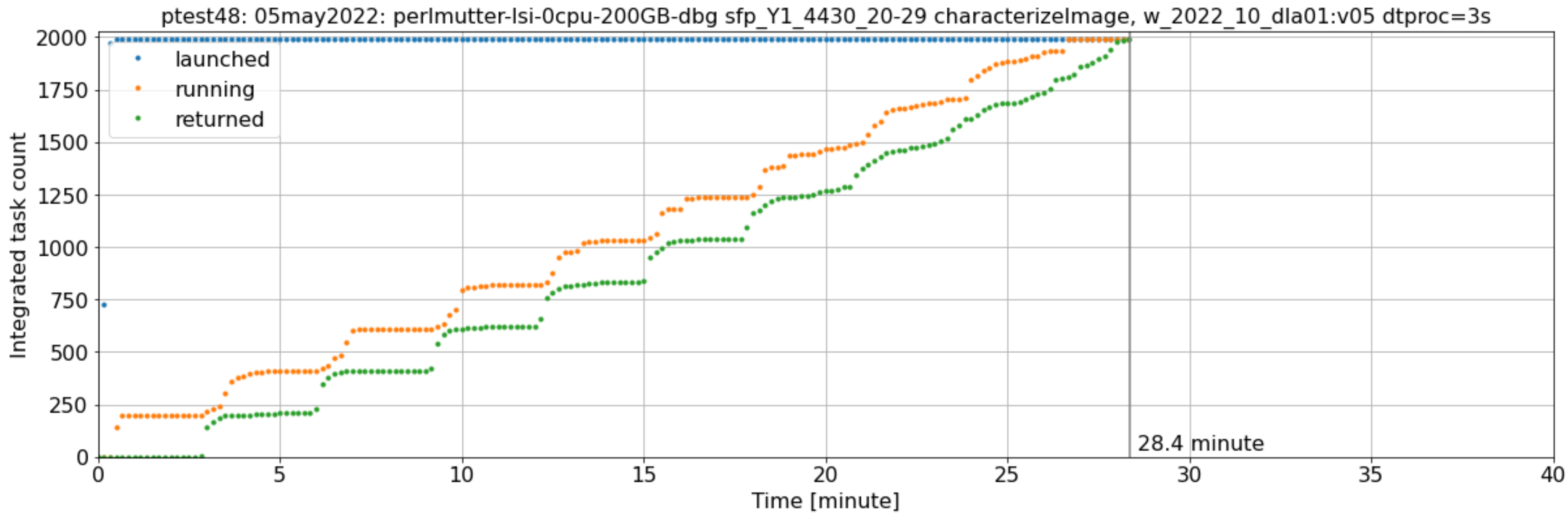


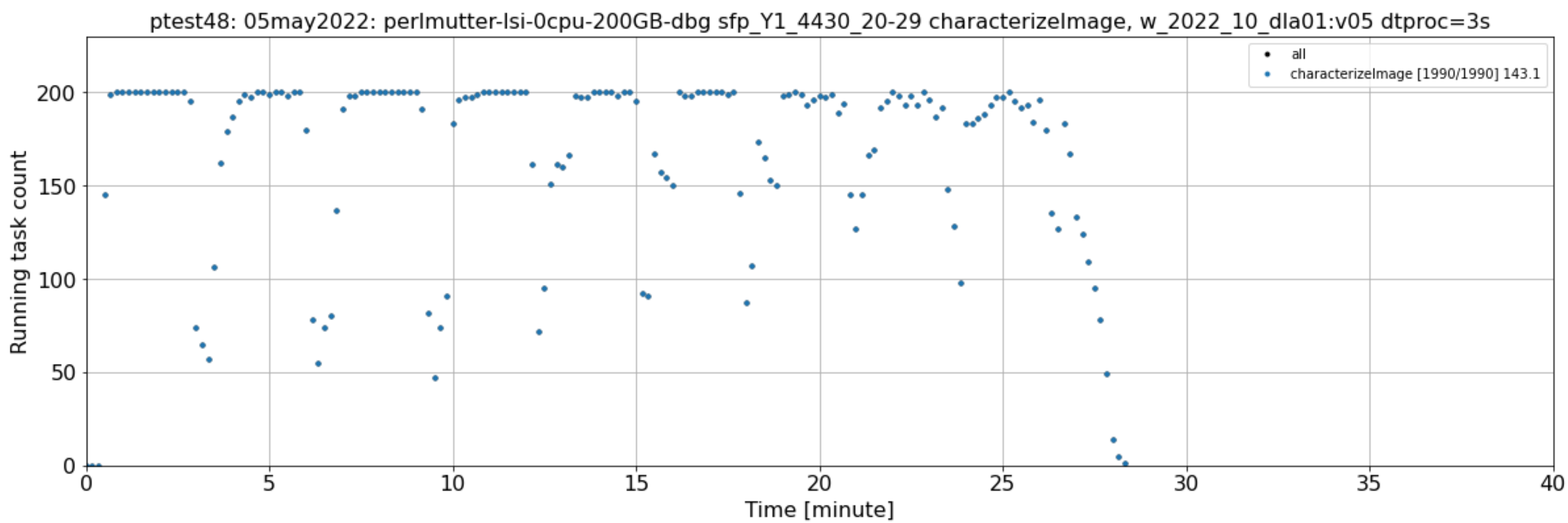
160 tasks


ptest45: 05may2022: perlmutter-lsi-0cpu-160GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
launched
running
returned
Integrated task count
25.9 minute
Time [minute]

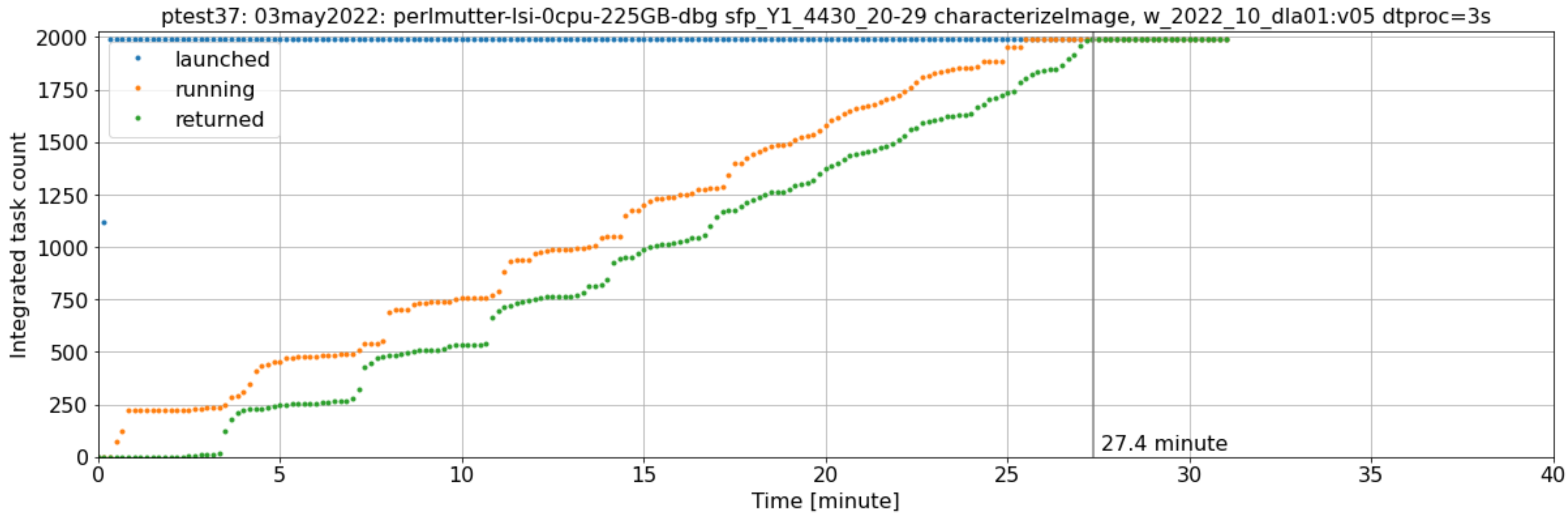

ptest45: 05may2022: perlmutter-lsi-0cpu-160GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
all
characterizeImage [1990/1990] 113.2
Running task count
Time [minute]

200 tasks

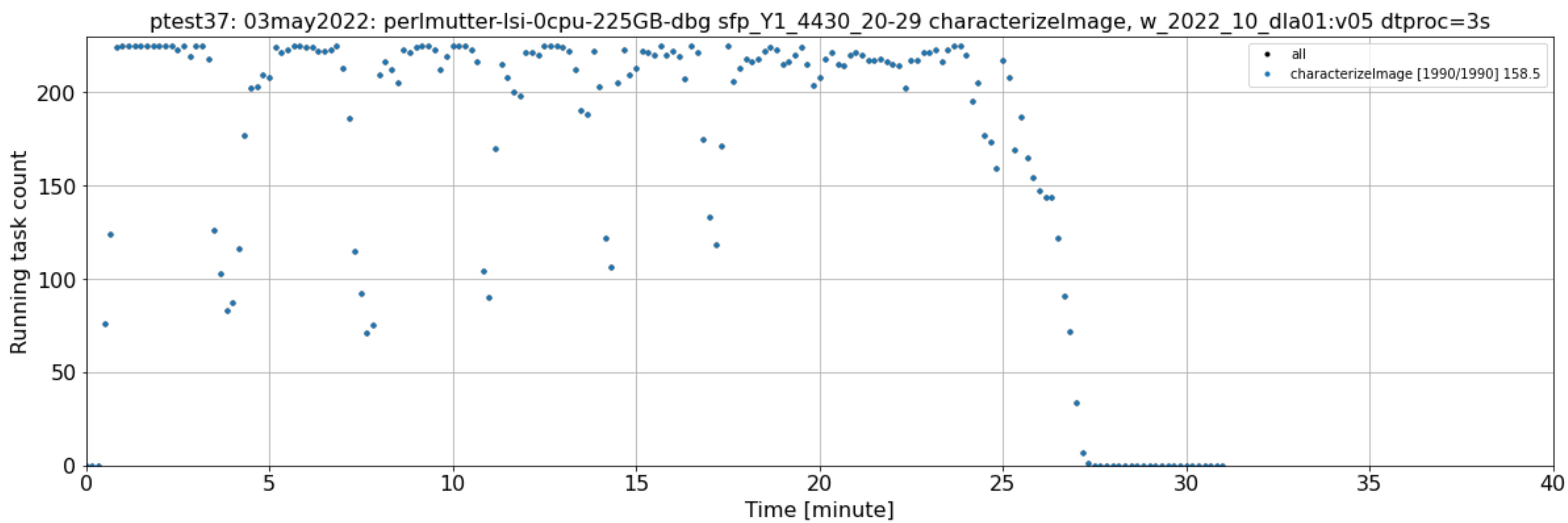

ptest48: 05may2022: perlmutter-lsi-0cpu-200GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
launched
running
returned
28.4 minute
Integrated task count
Time [minute]


ptest48: 05may2022: perlmutter-lsi-0cpu-200GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
all
characterizeImage [1990/1990] 143.1
Running task count
Time [minute]

225 tasks



ptest37: 03may2022: perlmutter-lsi-0cpu-225GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
launched
running
returned
Integrated task count
Time [minute]
27.4 minute



ptest37: 03may2022: perlmutter-lsi-0cpu-225GB-dbg sfp_Y1_4430_20-29 characterizeImage, w_2022_10_dla01:v05 dtproc=3s
all
characterizeImage [1990/1990] 158.5
Running task count
Time [minute]

Comments on varying number of processes

Results

- Best performance with ~1 task/(logical core)
- But only 8% better that 1/(physical core)

What is going on?

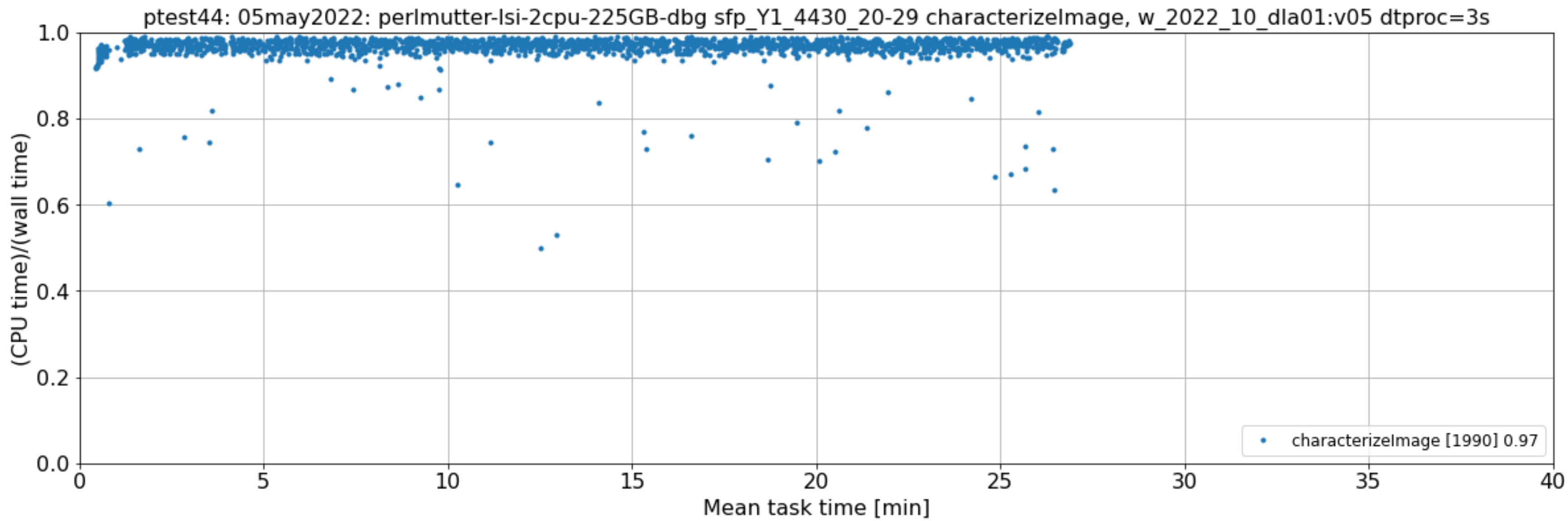
- Each physical core has
  - Two logical cores (hyperthreads)
    - Second process can execute instructions while the first is in a wait state
      - » E.g. fetching data from main memory
  - Four pipes/core
    - A (physical) core executes up to 4 instructions per cycle (IPC)
  - Varying clock speed
    - Core slows down to save power if not used or if warm from heavy use
    - Nominal 2.8 GHz
- When multiple processes run on a core, each process
  - Gets less CPU time because OS is servicing (e.g. memory fetch) the other
  - Gets fewer cycles/sec because busier (warmer) processor slows done
  - Gets fewer IPC because the four are shared between the two hyperthreds

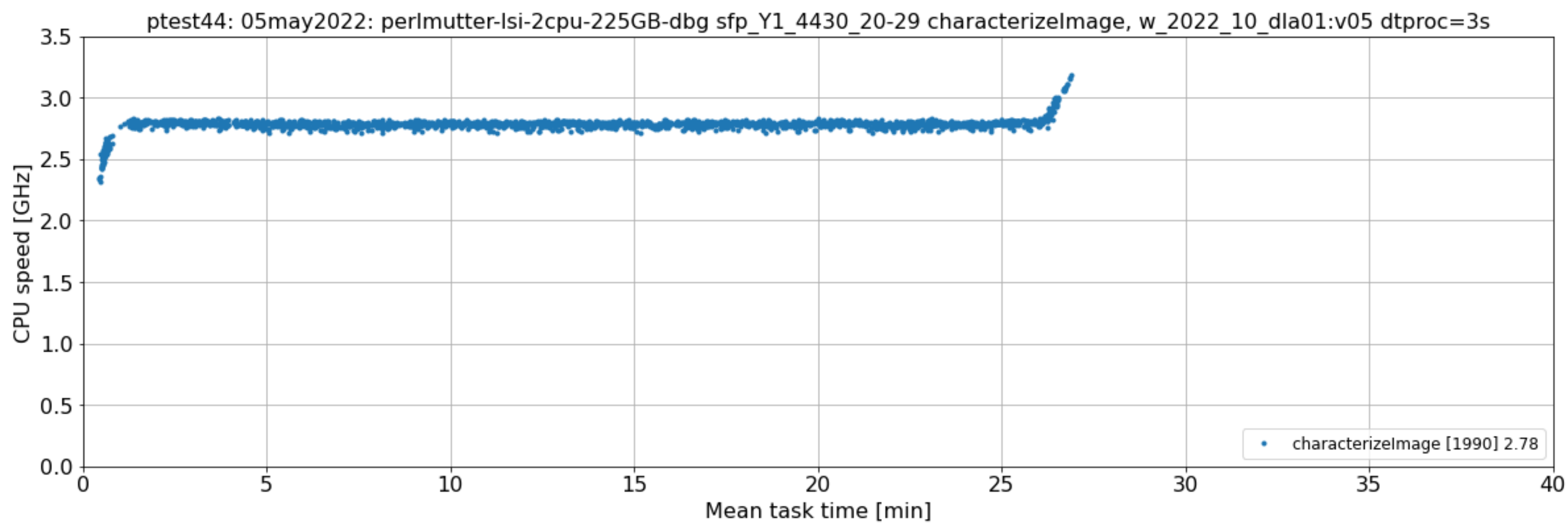
Performance plots

Following pages show plots of the preceding

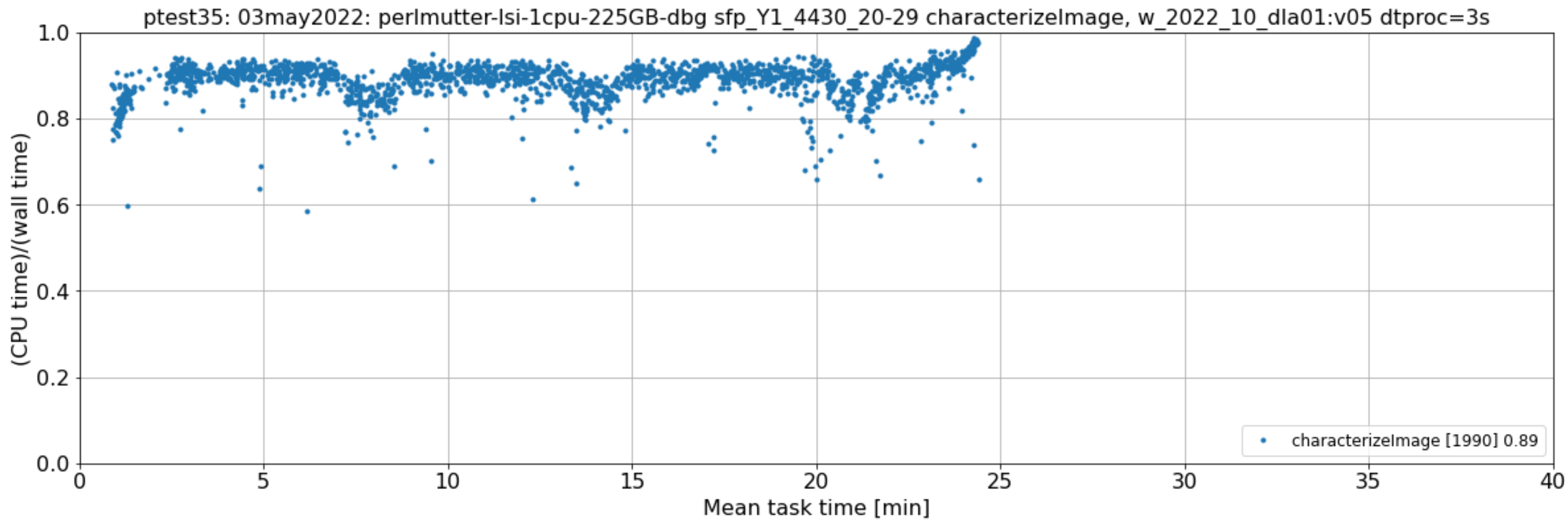
- All plots have one point per process
  - Mean value for the process is plotted
    - Not the mean/second
- For varying (nominal) number of tasks: 64, 128
  - I.e. 1 process/(physical core) and 1 process/(logical core)
  - Each on a separate page
- First pages
  - Top: CPU utilization = (active cycles)/(cycles)
    - fraction of cycles servicing the process
  - Bottom: CPU speed [cycles/(wall second)]
- Second pages
  - Top: IPC = instructions/(active cycle) used for the process
    - Two logical process share four physical pipes
  - Bottom: IPS = instructions/(wall second)
    - Product of the of the preceding three
    - Throughput is proportional to <number of processes> × IPS

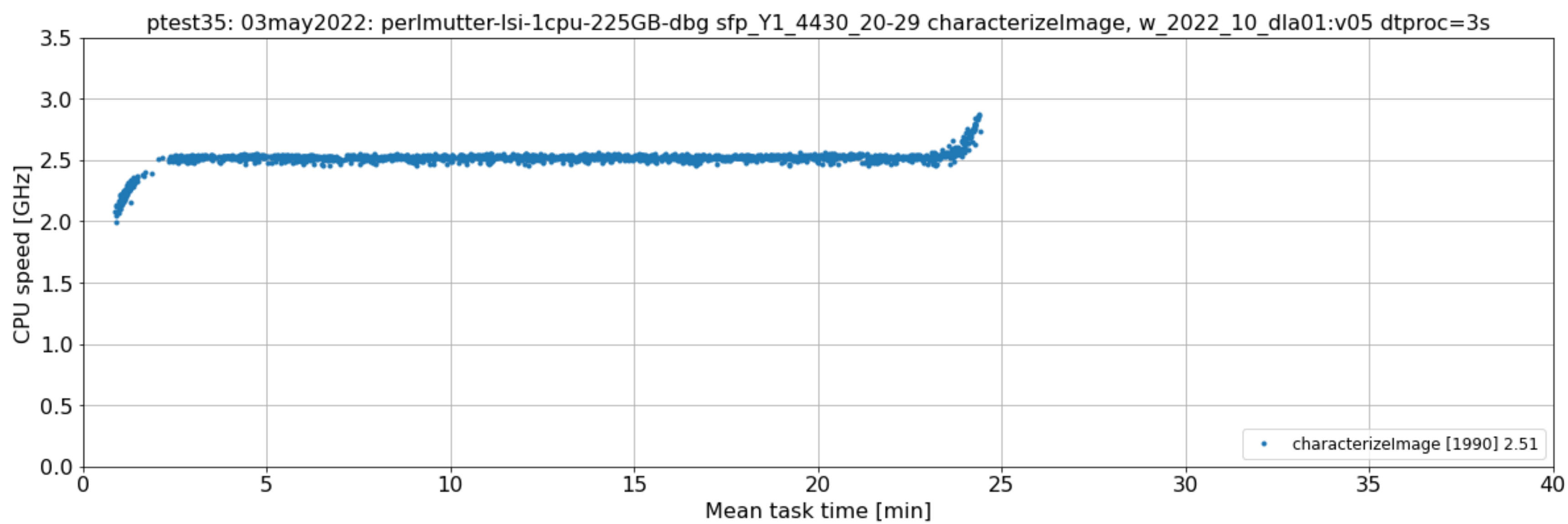
64 tasks: CPU utilization and speed



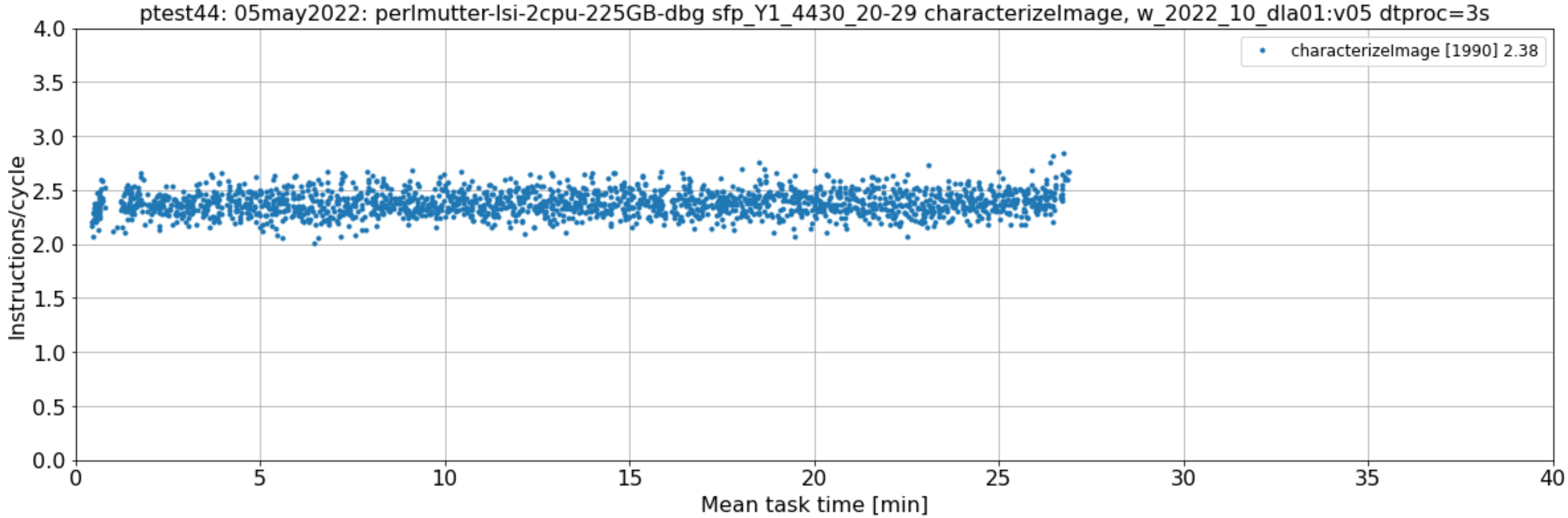


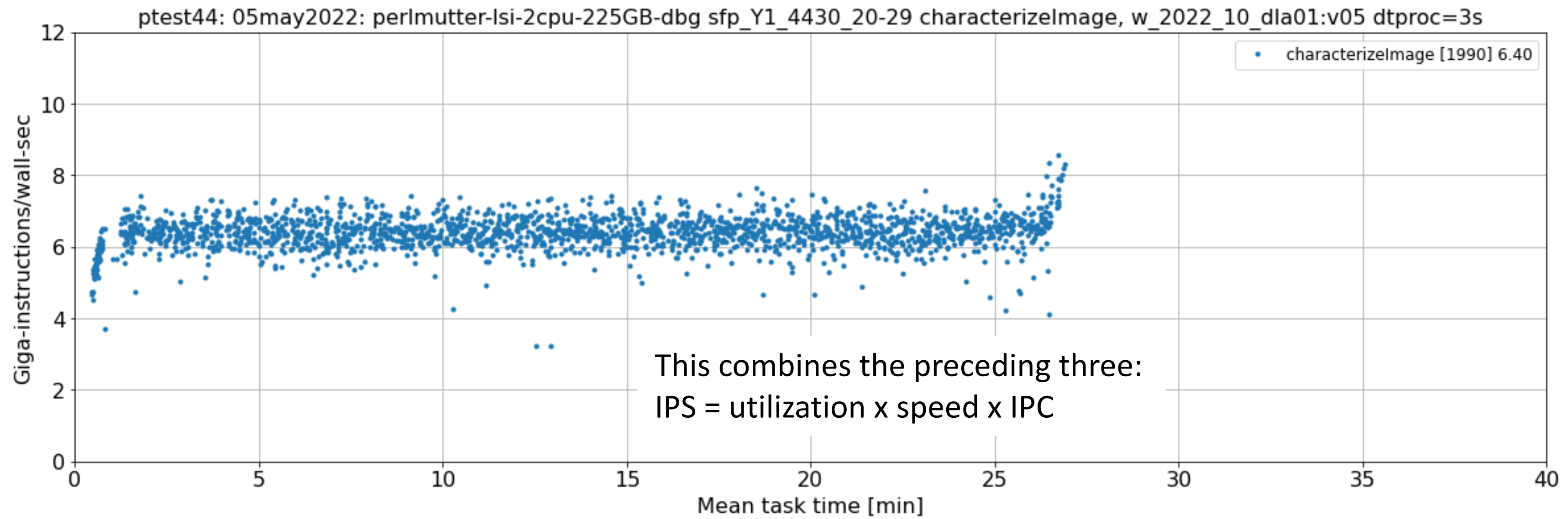
128 tasks: CPU utilization and speed





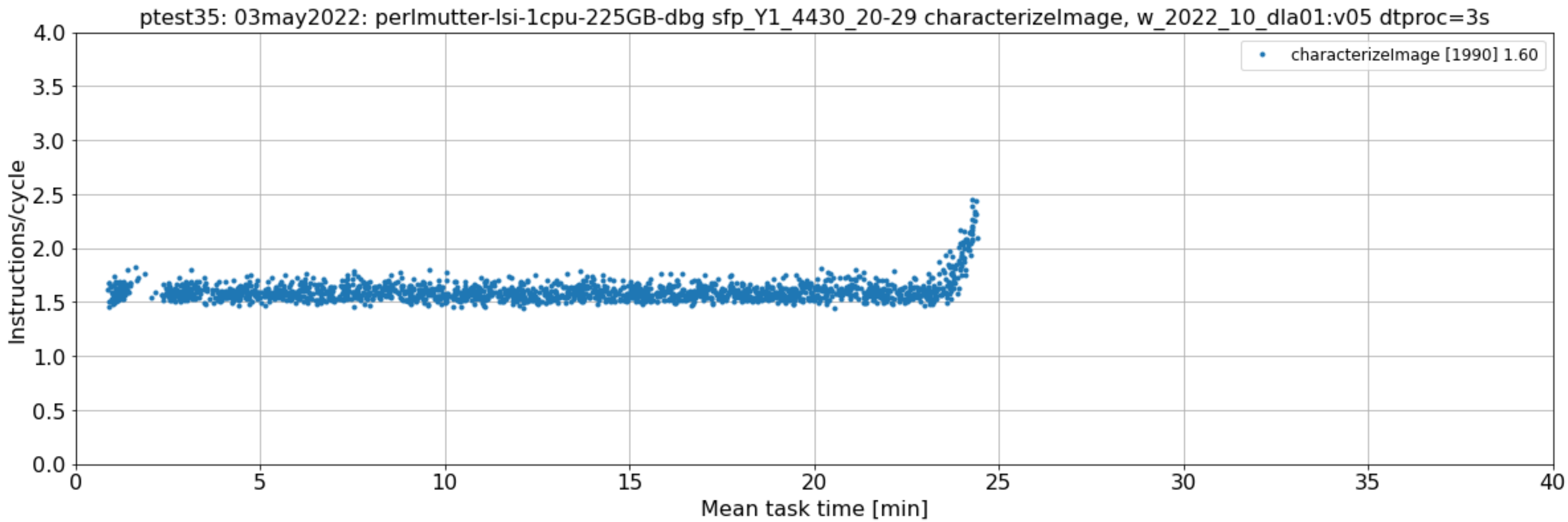
64 tasks: IPC and IPS

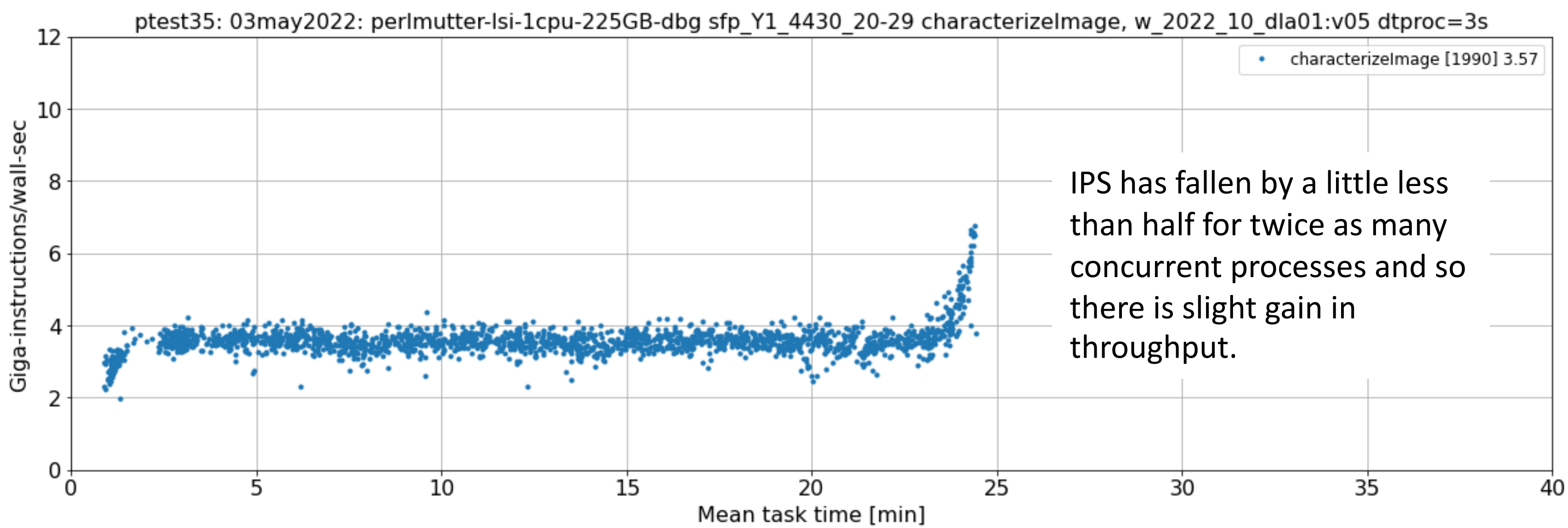




This combines the preceding three:
IPS = utilization x speed x IPC

128 tasks: IPC and IPS

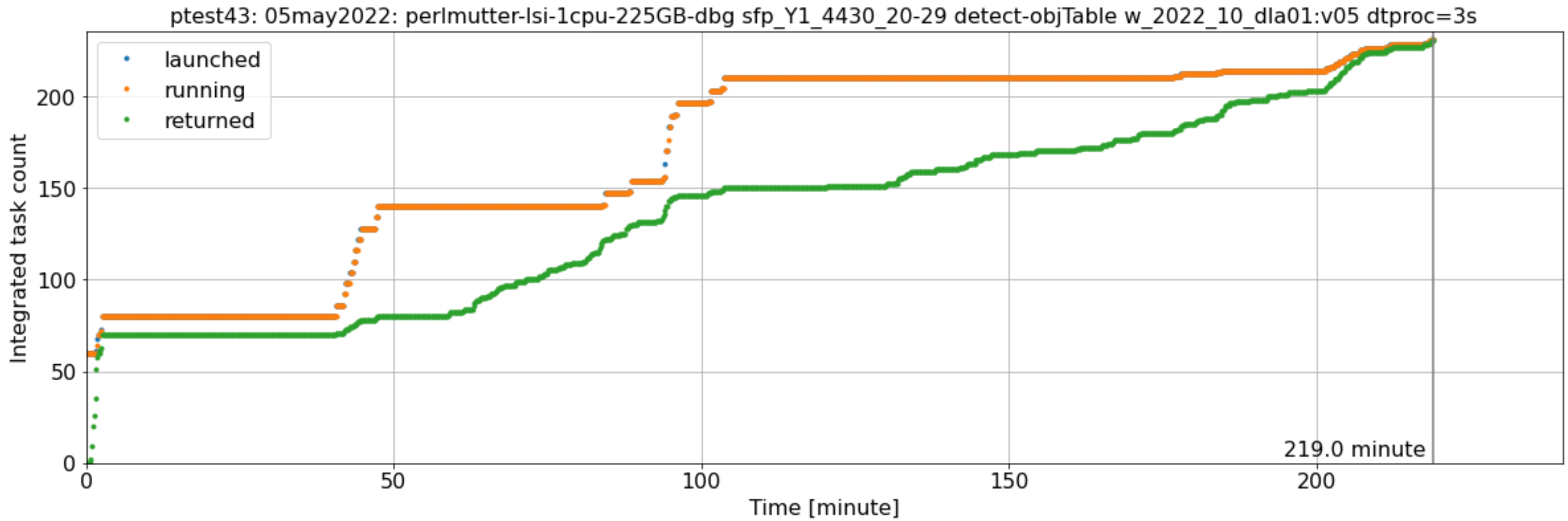




IPS has fallen by a little less than half for twice as many concurrent processes and so there is slight gain in throughput.

Patch processing performance

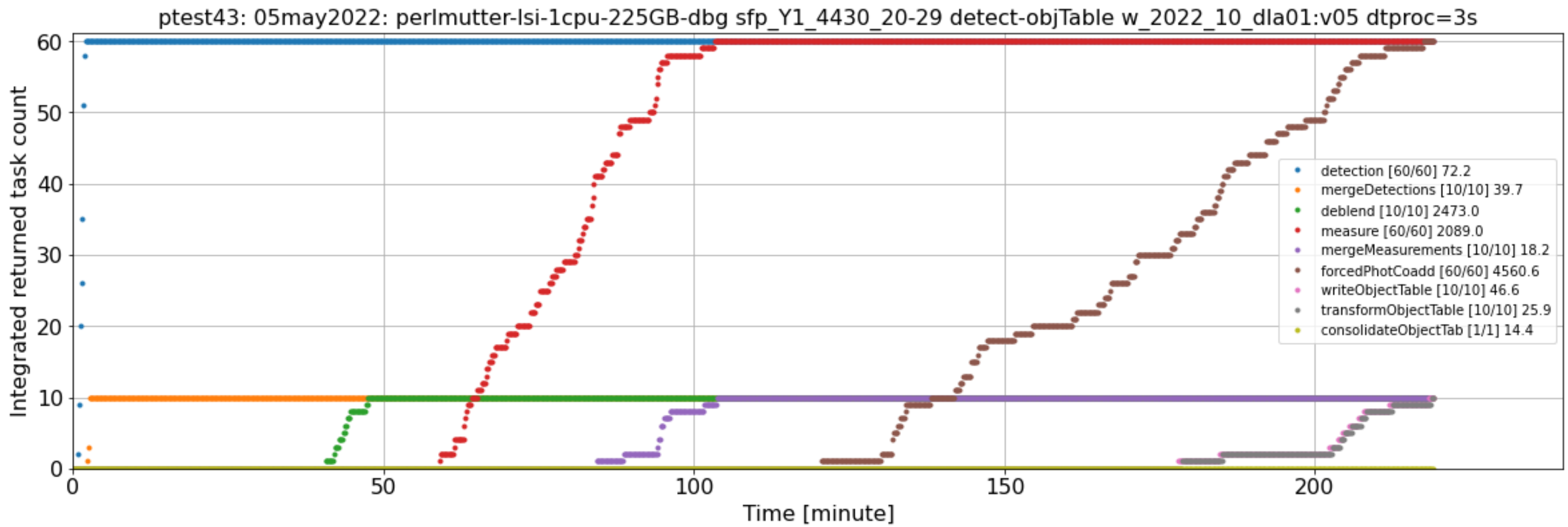
Throughput for patch processing

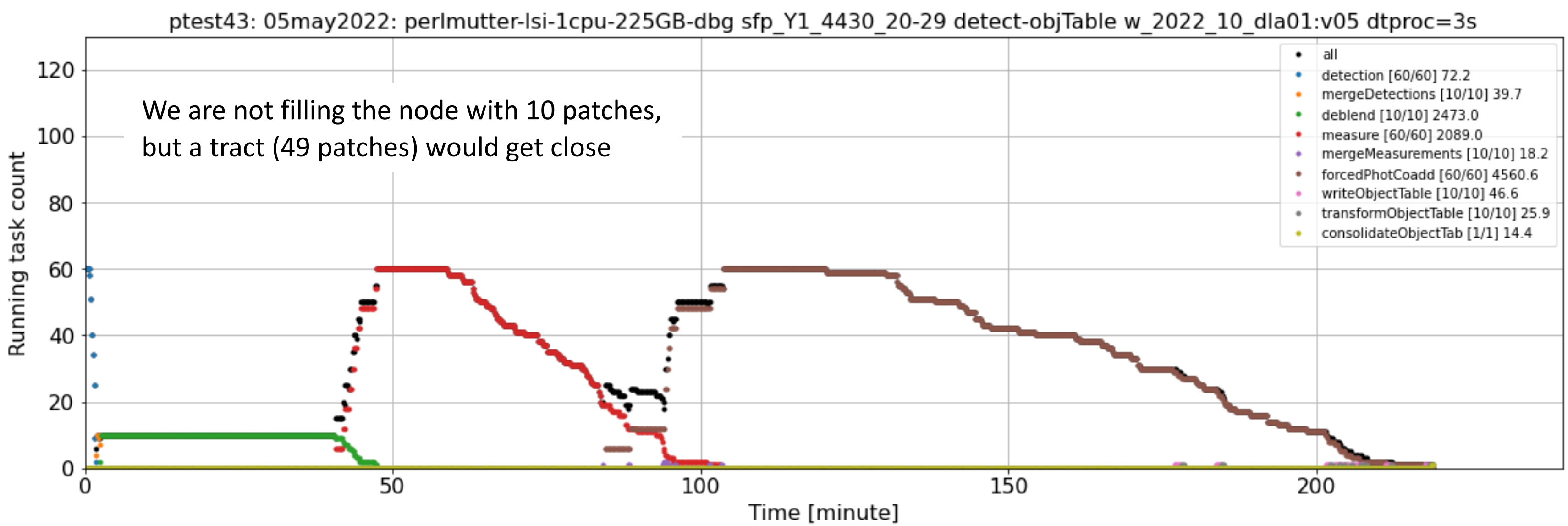


Plot show throughput for patch processing

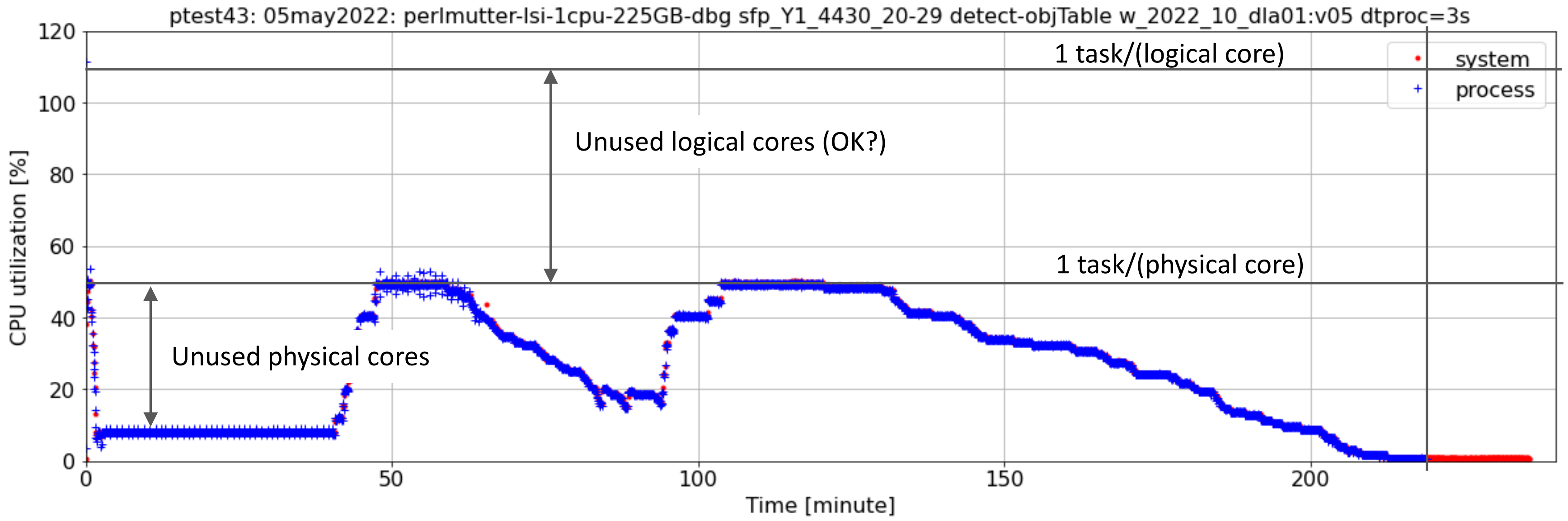
- assembleCoadd through makeObjectTable

Throughput and # running tasks by task type





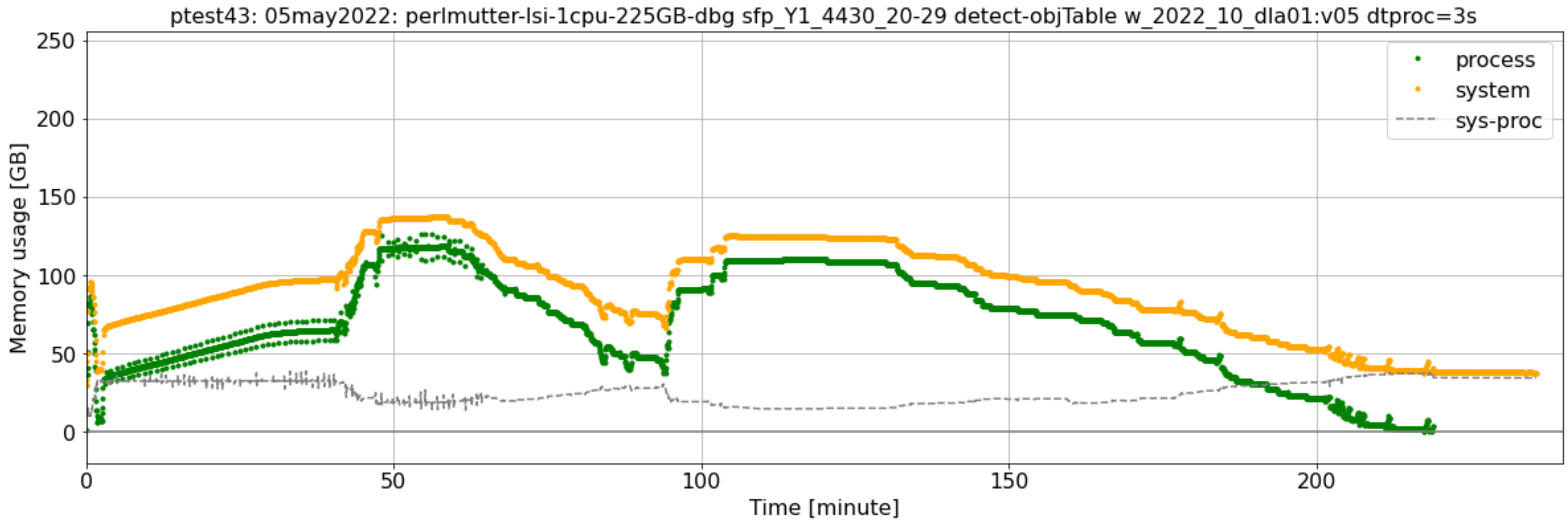
CPU utilization



Plot show CPU utilization

- Again, we need to run more than 10 patches to fill the node

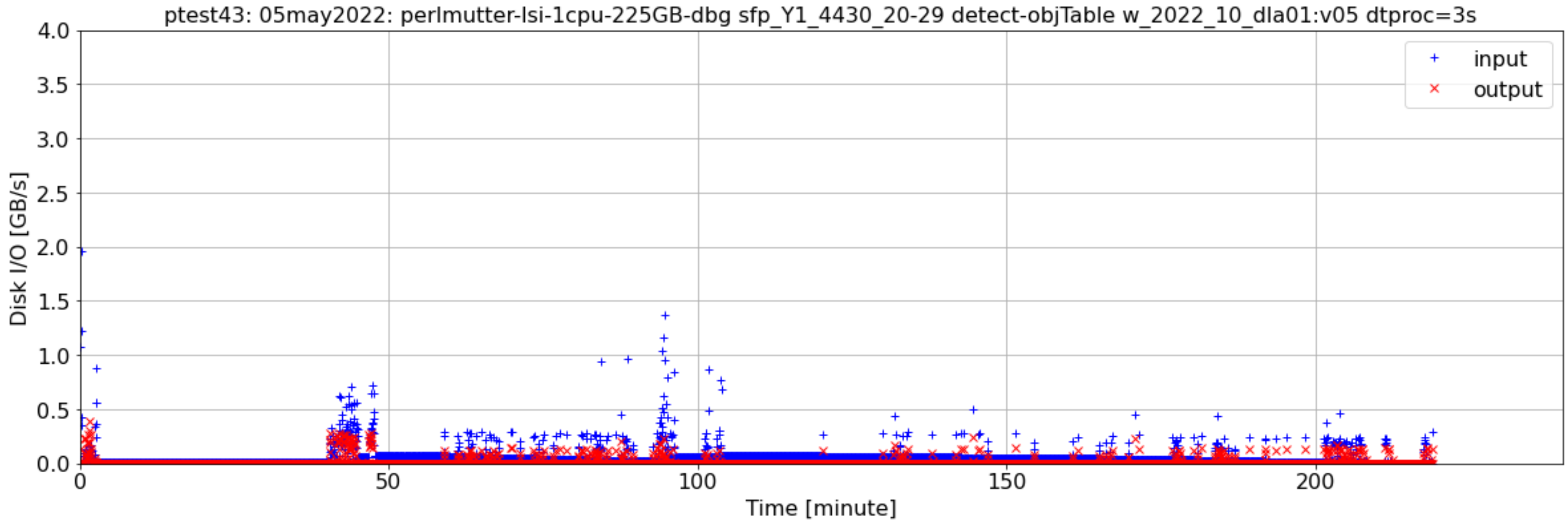
Memory usage



Plot shows memory usage

- Why the 20-40 GB difference between system and process sum?
- Even using the lower value, we will likely be memory limited and not able to use all the physical cores

I/O



Plot show I/O vs. time

- Just a few times when rates are higher
- We might want to stagger the patches to smooth some of this
  - Maybe fill with some of the other tasks

Issues

Issues

Issues to resolve:

- Parsl is not keeping up with our roughly 1 Hz integrated task submission rate on (a single node).
  - The number of concurrent jobs is 5-15% below the nominal value.
  - *Keep-up* problem
- There are occasional gaps of 10s of seconds in the a parsl monitoring
  - Maybe 1/10 runs show this.
- I sometimes see periods of few minutes when CPU utilization drop
  - This is dramatic in the isr test
  - Presumably an issue with some common resource (~~DB~~, filesystem, …).
  - *Stall* problem
- Improve efficiency of patch processing
  - More concurrent patches, split the workflow, …?
- Discrepancy between system and process memory in patch processing.

Thank you

Extras

Parsl monitoring raw data

Table workflow has 1 rows and 10 columns
Column names:

```
  object  run_id
  object  workflow_name
  object  workflow_version
  object  time_began
  object  time_completed
  object  host
  object  user
  object  rundir
   int64  tasks_failed_count
   int64  tasks_completed_count
```

I do 1 run

Table task has 2158 rows and 15 columns
Column names:

```
   int64  task_id
  object  run_id
  object  task_depends
  object  task_func_name
  object  task_memoize
  object  task_hashsum
  object  task_inputs
  object  task_outputs
  object  task_stdin
  object  task_stdout
  object  task_stderr
  object  task_time_invoked
  object  task_time_returned
   int64  task_fail_count
 float64  task_fail_cost
```

with 2158 tasks (jobs)

Table try has 2158 rows and 11 columns
Column names:

```
   int64  try_id
   int64  task_id
  object  run_id
  object  block_id
  object  hostname
  object  task_executor
  object  task_try_time_launched
  object  task_try_time_running
  object  task_try_time_returned
  object  task_fail_history
  object  task_joins
```

Three try states

Table node has 0 rows and 12 columns
Column names:

```
  object  id
  object  run_id
  object  hostname
  object  uid
  object  block_id
  object  cpu_count
  object  total_memory
  object  active
  object  worker_count
  object  python_v
  object  timestamp
  object  last_heartbeat
```

Table block has 559 rows and 6 columns
Column names:

```
  object  run_id
  object  executor_label
  object  block_id
  object  job_id
  object  timestamp
  object  status
```

Table status has 10220 rows and 5 columns
Column names:

```
   int64  task_id
  object  task_status_name
  object  timestamp
  object  run_id
   int64  try_id
```

Table resource has 3229 rows and 16 columns
Column names:

```
   int64  try_id
   int64  task_id
  object  run_id
  object  timestamp
 float64  resource_monitoring_interval
   int64  psutil_process_pid
 float64  psutil_process_cpu_percent
 float64  psutil_process_memory_percent
 float64  psutil_process_children_count
 float64  psutil_process_time_user
 float64  psutil_process_time_system
 float64  psutil_process_memory_virtual
 float64  psutil_process_memory_resident
 float64  psutil_process_disk_read
 float64  psutil_process_disk_write
  object  psutil_process_status
```

This table has data for each process (task try) sampled at regular intervals

Process level derived data

```
Table procsumDelta has 541 rows and 12 columns
Column names:
  float64   timestamp
    int64   nval
    int64   nproc
  float64   run_idx
  float64   procsum_memory_percent
  float64   procsum_memory_resident
  float64   procsum_memory_virtual
  float64   procsum_time_clock
  float64   procsum_time_user
  float64   procsum_time_system
  float64   procsum_disk_read
  float64   procsum_disk_write
```

This is derived from the resource table.
It sum contribution from all processes.

The times and disk I/O values are deltas—the contribution for each interval rather the the integral in the resource table.

Calculation is tricky and result is sometime misleading because samplings do not have the same phase for all processes and the sampling is occasionally irregular.

System level monitoring data

System monitor sample count: 619
System monitor columns:

- time
- cpu_count
- cpu_percent
- cpu_user
- cpu_system
- cpu_idle
- cpu_iowait
- cpu_time
- mem_total
- mem_available
- mem_swapfree
- dio_readsize
- dio_writesize
- nio_readsize
- nio_writesize

All sampled at regular intervals
Every 5 sec for jobs here

Assigned memory allocations

```
pipetask:
  isr:
    requestMemory: 2700
  characterizeImage:
    requestMemory: 1000
  calibrate:
    requestMemory: 1000
#  writeSourceTable:
#  transformSouceTable:
#  consolidateSourceTable:
  consolidateVisitSummary:
    requestMemory: 1000
#  selectGoodSeeingVisits:
  templateGen:
    requestMemory: 1500
  imageDifference:
    requestMemory: 3100
  forcedPhotDiffim:
    requestMemory: 2500
  skyCorrectionTask:
    requestMemory: 8000
  makeWarp:
    requestMemory: 3500
  assembleCoadd:
    requestMemory: 1600
  detection:
    requestMemory: 1300
  mergeDetections:
    requestMemory: 2000
  deblend:
    requestMemory: 7000
  measure:
    requestMemory: 1900
  mergeMeasurements:
    requestMemory: 2000
  forcedPhotCoadd:
    requestMemory: 1600
  forcedPhotCcd:
    requestMemory: 1000
#  writeObjectTable:
#  transformObjectTable:
#  consolidateVisitTable:
```

First 20 min of patch production: memory, # task