

ATLAS Distributed Computing Overview & Outlook

BNL Splinter Meeting
2025-01-23

Mario Lassnig (CERN), Andreu Pacheco Pages (IFAE)



- ATLAS Distributed Computing (ADC) comprises the hardware, software, and operations to
 - Support **distributed computing activities** of the experiments
 - Research and develop the **evolving computing needs** of the experiment

ATLAS DISTRIBUTED COMPUTING
October 2024

- Running 24 / 7 / 365

ADC COORDINATION

Mario Lassnig, Andreu Pacheco Pages

- **Computing never stops**
- 80+ people contributing centrally
- 50+ people across the world

PHYSICS
Production Coordination M. Borodin
Analysis Coordination A. Forti
Centralised Production Monte Carlo Production Group Production Data Reprocessing Physics Validation HLT Reprocessing
Physics Analysis User Analysis Tools Analysis Model Group DAST

FABRICS
Coordination I. Glushkov
Infrastructure Tier-0 Grid HPC Cloud BOINC Analysis Facilities
Operations Computing Run Coordination DA Operations DPA Operations Central Services CRIC HammerCloud Monitoring ADCoS

DATA MANAGEMENT
Coordination S. McKee, P. Vokac
System Rucio
Operations System Deployment DDM Central Operations Monitoring
Research Networks Caches Storage Cloud

WORKFLOW MANAGEMENT
Coordination R. Walker, F. Barreiro Megino
System Workflow Definition Workload Management Workload Execution
Operations System Deployment Monitoring
Research Data Analytics Analysis Facilities Cloud HPC

- Four major areas

- Physics computing activities
- Infrastructure, operations & support
- Data management
- Workload & workflow management

- Plus many task forces and working groups, including HPCs and monitoring

ADC communication flow

- Full information [here](#)
- The central point of communication dissemination is the [Operations Morning Meeting, 09:00 CERN time daily](#)
 - Content is brought by everyone via the [pre-filled minutes](#) and is typically about ongoing issues
 - The discussions and eventual decisions are then sent to [ELISA](#) shortly after the meeting
- The second important meeting is the [ADC Weekly](#)
 - This is to give quick reports by the various areas relevant to ADC
 - This meeting is the prime place to learn about upcoming campaigns/workloads
- ATLAS Virtual Control Room for real time chats
 - <https://mattermost.web.cern.ch/adcvcr/channels/adc-operations>
- Emails
 - ATLAS users who need general support
 - Already hosted by Discourse, new email address
 - Specific help with data management
 - Specific help with workflow management
 - If you don't know who to contact

hn-atlas-dist-analysis-help@cern.ch
atlas-comp-dist-analysis-help@cern.ch
atlas-adc-ddm-support@cern.ch
atlas-adc-dpa@cern.ch
atlas-adc-expert@cern.ch

- It is often times difficult to really understand site's needs
 - Even with years of experience we still have to resort to educated guesses
 - We'd like to streamline this a bit better
- We are currently fully rebuilding our documentation
 - Migration of content from TWiki from hosted CERN mkdocs-material based service
 - Website <https://atlas-computing.docs.cern.ch/>
 - Content <https://gitlab.cern.ch/atlas/computing-docs/atlas-computing-docs>
- If you have any suggestions to improve our documentation
 - Do not hesitate to open a ticket in gitlab
 - Do not hesitate to submit new documentation merge requests
 - Do not hesitate to update existing documentation merge requests

R2R4 - The Road to Run-4

- LHC performs a series of reviews of the Software and Computing plans of the LHC experiments towards HL-LHC
 - The [ATLAS HL-LHC Computing Conceptual Design Report](#) was published in May 2020
- A follow up [ATLAS Software and Computing HL-LHC Roadmap](#) was published in March 2022 with clearly defined *milestones* – nicknamed “The Road to Run-4” (R2R4)

Project Organization	MD	Del	Due
PH-1	PH-1	Finalisation of effort related to deliver on HL-LHC milestones	02/2022
PH-2	PH-2	HL-LHC Computing TDR	03/2024
PH-3	PH-3	Final project reports, Run 1-4 Run proposals, deliverables and final review of their implementation, and a program of work with effort and risk estimates in the end of Phase 7	04/2022
PH-4	PH-4	Define release, capabilities and perform to be used to evaluate Run-4 performance impact of components	04/2024
PH-5	PH-5	Run 4 projects release their performance	02/2024
PH-6	PH-6	Run 4 projects evaluate the performance impact of their R2R4 dependencies and estimate the effort needed to develop key functional products	02/2024
PH-7	PH-7	Run 4 Release	02/2027
PH-8	PH-8	Run 4 projects release fully functional products, release notes and effort needed to bring to production ready	02/2028
PH-9	PH-9	Run 4 Release Freeze	02/2027
PH-10	PH-10	Ready for Run 4 Data Taking	02/2028
PH-11	PH-11	Run 4 projects demonstrate required functionality in release	02/2028
PH-12	PH-12	Run 4 projects demonstrate required functionality in release	02/2028
PH-13	PH-13	Run 4 Release established	02/2028

Core Software, Heterogeneous Computing and Accelerators	MD	Del	Due
CS-1	CS-1	Final operations in Run-4/ATLAS production mode	04/2022
CS-2	CS-2	Finalise interoperability of AT production of assembled ML RDOs files	02/2022
CS-3	CS-3	Complete investigation of current component dependencies	04/2022
CS-4	CS-4	Final implementation of C++ based containerisation in the primary ATLAS	04/2021
CS-5	CS-5	Finalise containerisation of primary ATLAS	04/2022
CS-6	CS-6	Finalise containerisation of primary ATLAS	04/2022
CS-7	CS-7	Finalise containerisation of primary ATLAS	04/2022
CS-8	CS-8	Finalise containerisation of primary ATLAS	04/2022
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CS-100	CS-100	Finalise containerisation of primary ATLAS	04/2022

Reconstruction	MD	Del	Due
RE-1	RE-1	Finalise reconstruction for Run-4	02/2022
RE-2	RE-2	Finalise reconstruction for Run-4	02/2022
RE-3	RE-3	Finalise reconstruction for Run-4	02/2022
RE-4	RE-4	Finalise reconstruction for Run-4	02/2022
RE-5	RE-5	Finalise reconstruction for Run-4	02/2022
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Analysis	MD	Del	Due
AN-1	AN-1	Finalise analysis for Run-4	02/2022
AN-2	AN-2	Finalise analysis for Run-4	02/2022
AN-3	AN-3	Finalise analysis for Run-4	02/2022
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AN-50	AN-50	Finalise analysis for Run-4	02/2022

Operational Computing	MD	Del	Due
OC-1	OC-1	Finalise operational computing for Run-4	02/2022
OC-2	OC-2	Finalise operational computing for Run-4	02/2022
OC-3	OC-3	Finalise operational computing for Run-4	02/2022
OC-4	OC-4	Finalise operational computing for Run-4	02/2022
OC-5	OC-5	Finalise operational computing for Run-4	02/2022
OC-6	OC-6	Finalise operational computing for Run-4	02/2022
OC-7	OC-7	Finalise operational computing for Run-4	02/2022
OC-8			

ADC Milestones

- **DC-1** Transition to tokens
- **DC-2** Storage evolution
- **DC-3** Next operating system
- **DC-4** Network infrastructure
- **DC-5** Integration of HPCs
- **DC-6** Non-x86 hardware
- **DC-7** Replication management
- **DC-8** Data Carousel
- **DC-9** Storage usage
- **DC-10** Cloud computing
- **DC-11** Analysis experience
- **DC-12** Sustainability
- **DC-13** Workflow management

Demonstrators

- **DONE**
 - ATLAS-Google as a fully integrated site
 - ATLAS-Google as “bursty” resources
 - ARM based PanDA queues
 - Sustainability in ATLAS Computing
 - Recreate DAODs on demand with Data Carousel 
- **ONGOING**
 - Optimized writing to tape for efficient reading
 - Simulation of grid scheduling R&D 
 - Complex workflows R&D 
- **ON HOLD**
 - Using Xrootd to seamlessly integrate S3 storage
 - General ARM OSG queue at BNL
 - Measurement of ATLAS energy consumption
 - Storage for data intensive application

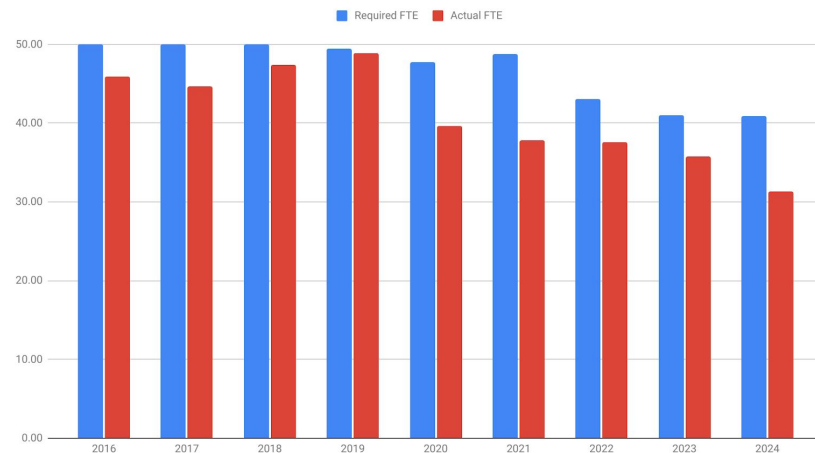
Distributed Computing Risk Register

Category	Risk	Likelihood	Impact	Severity	Owner	Effect
Consensus	Stagnant interactions between key community projects	3	4	12	WLCG, CERN-IT, ADC	Long-winded discussions with no clear decisions and outcomes; Non-working APIs; Incompatible implementations
Catastrophes	Significant downtimes related to environmental disasters	2	5	10	WLCG	Unavailability of large volumes of data for extended periods
Capacity	Not enough available storage, CPU, network and/or dedicated hardware (GPUs)	2	5	10	WLCG, ATLAS	Cannot execute jobs; Cannot distribute data; Cannot store data
Dependencies	Loss and/or frequent changes in software dependencies	3	4	12	CERN-IT, WLCG, ADC	Failures in software execution; Additional development effort; Being stuck with old unsupported software
Procurement	Mismatch of ATLAS requested resources vs. site-provided resources	2	4	8	WLCG, ATLAS	Starvation of tasks due to limited resources; Additional costs for sites due to unclear schedules; Loss of allocations
Central support	Lack of persons to support analysis users, production managers, and to follow-up daily operational tasks	4	4	16	ADC	Prolonged task execution; Task submission delays; Storage resource overloads; Angry users
Personpower	Difficulty in retaining key personnel, impact on progress of ongoing projects	5	5	25	ADC	Impact on progress of important projects; Long delays; Potential cancellation of projects
Organisation	Insufficient number of suitable persons in leading roles	4	3	12	ADC	Destabilise ADC organisation, effectiveness, and follow-up of tasks

● Continuous loss of FTEs since 2019

- With even bigger drops '19-'20, and '23-'24
 - Funding cycles ended, R&D projects ended
 - Lots of these people were involved in operations
- Now, operations at critical level
 - *Production* 2.4 FTE (4 persons)
 - *Data management* 0.7 FTE (3 persons)
 - *Analysis support* 1.7 FTE (4 persons)
- Central systems development
 - Rucio stable due to CERN & Community
 - PanDA/ProdSys stable due to USATLAS & Community
- Infrastructure
 - Hinges on 0.05 commitments across tens of people
 - Issues with non-ADC systems, e.g., CVMFS or IAM, still require valuable ADC expert time
 - Monitoring effort has almost vanished

ADC FTE Evolution



● Observations

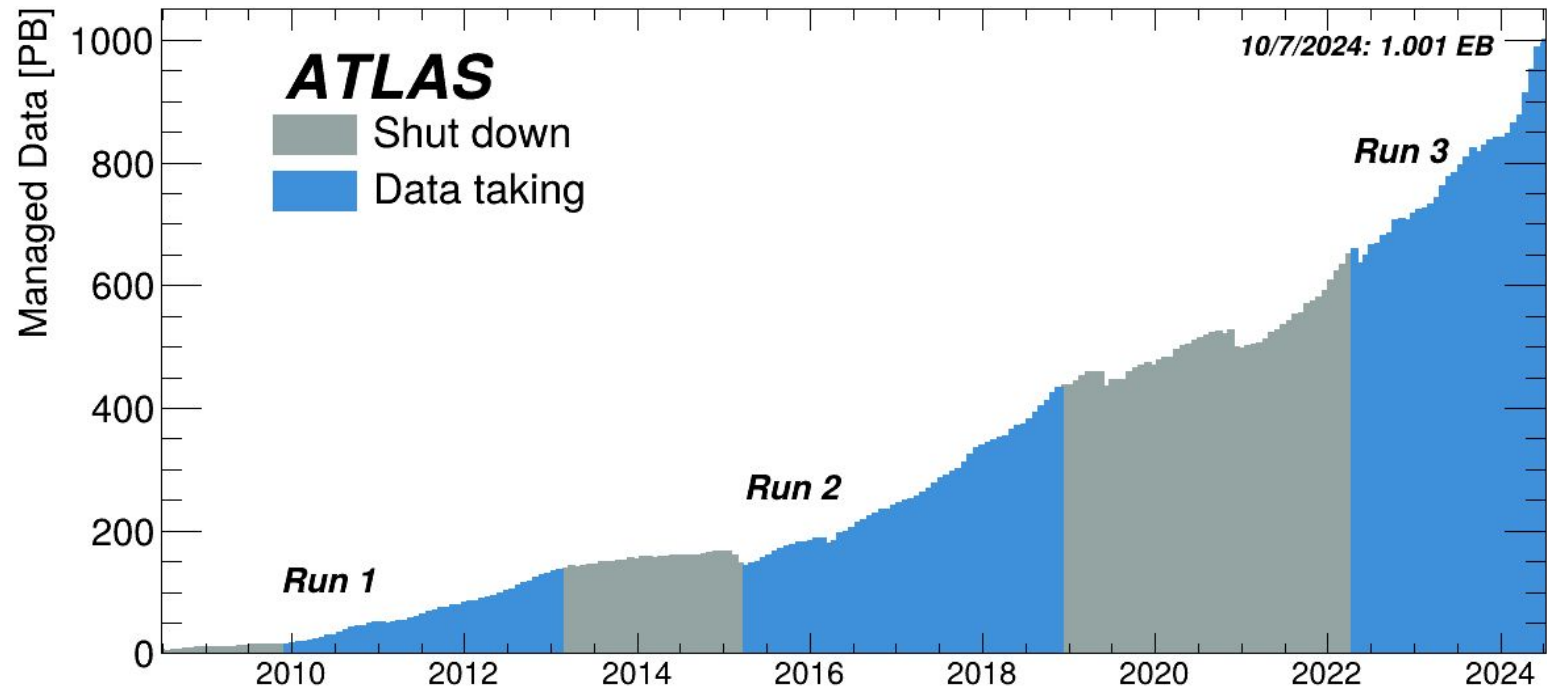
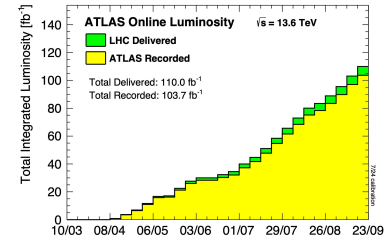
- The majority of the 77 persons in ADC have contributions of < 0.2 FTE
- Many critical services depend on single persons who are already overwhelmed with work
- Big '21-'22 drop in *Required FTE* due to acceptance that many R&D projects won't continue
- Barely any young/fresh persons join computing, and senior experts are getting dragged into coordination

- We consider the following topics important for the TDR
- The new security model: Shift from X.509 to tokens
 - Has a profound impact on infrastructure, systems, and users
- Community computing as foundation of our shared infrastructures
 - Rucio already established and constantly pulling in new communities, recently SKA
 - PanDA is going the same way, which is very much appreciated
 - If we do not actively engage and cooperate with other big sciences we will be left out eventually
- Infrastructure stress-testing and system upgrades
 - ADC is driving the HL-LHC Data Challenges with our people in key positions
 - We need to continue to invest here
- Allowing more flexibility for our computing models
 - R&D projects to evaluate different approaches (Recreation, Data Carousel, Clouds, ...)
- Opportunistic resources (Clouds & HPCs)
 - Fundamental shift in infrastructure procurements from countries / funding agencies
 - We need to continue to invest here
- Sustainable computing (beyond ARM)
 - Unfortunately we do not have enough effort here, but we need to raise awareness

Backup

Major Rucio milestone - July 2024

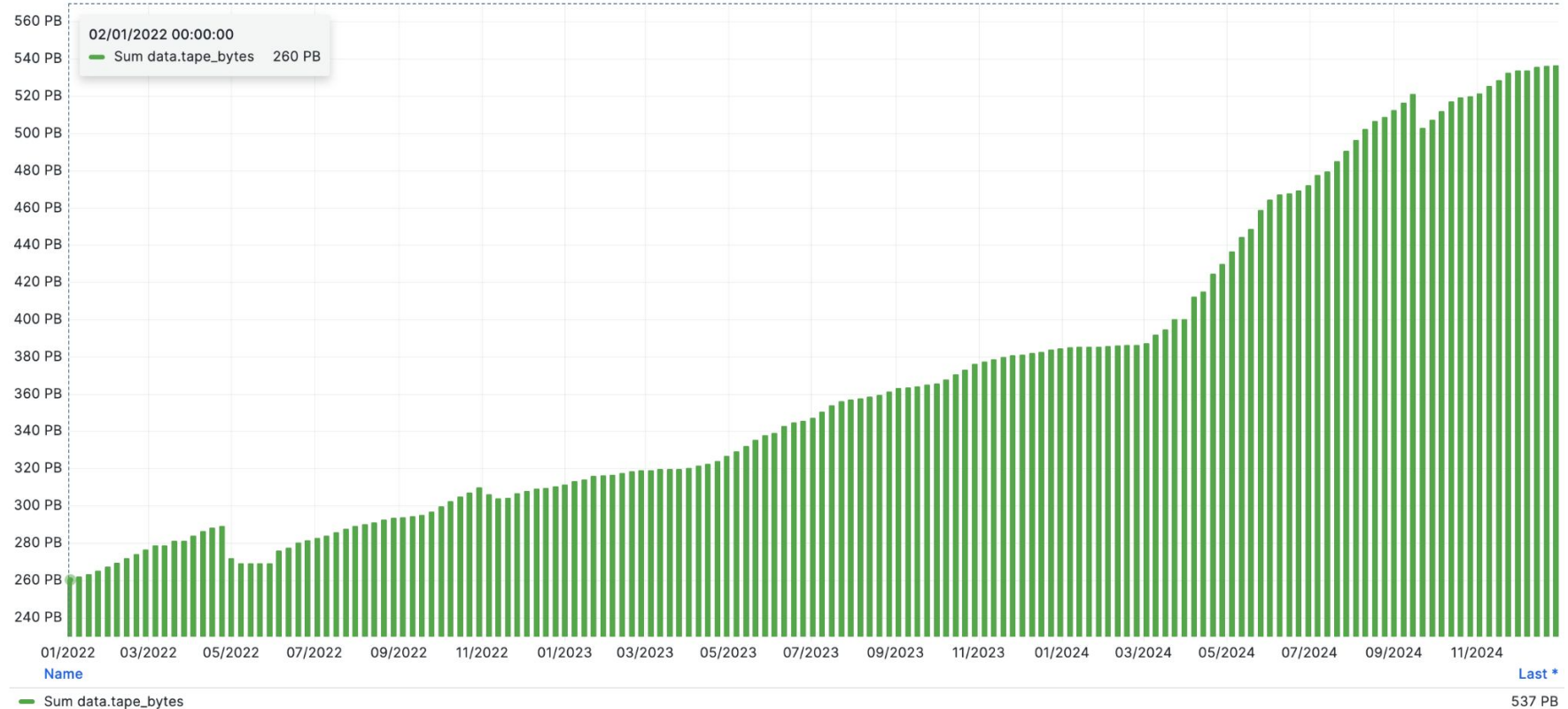
- ATLAS has reached 1 Exabyte of Rucio-managed data
 - LHC delivered more than full 2024 pp target of $110/\text{fb}^{-1}$ early
 - Data-taking efficiency at 94.3% !
 - Frequent applications of Lifetime model and Catmore-rule necessary



Disk Size	Primary Size	Disk Files	Primary Files
378 PB	254 PB	885014186	824445332
Tape Size	Secondary Size	Tape Files	Secondary Files
662 PB	124 PB	374358894	60568854
Total Size	Total Files		
1.04 EB	1259373080		

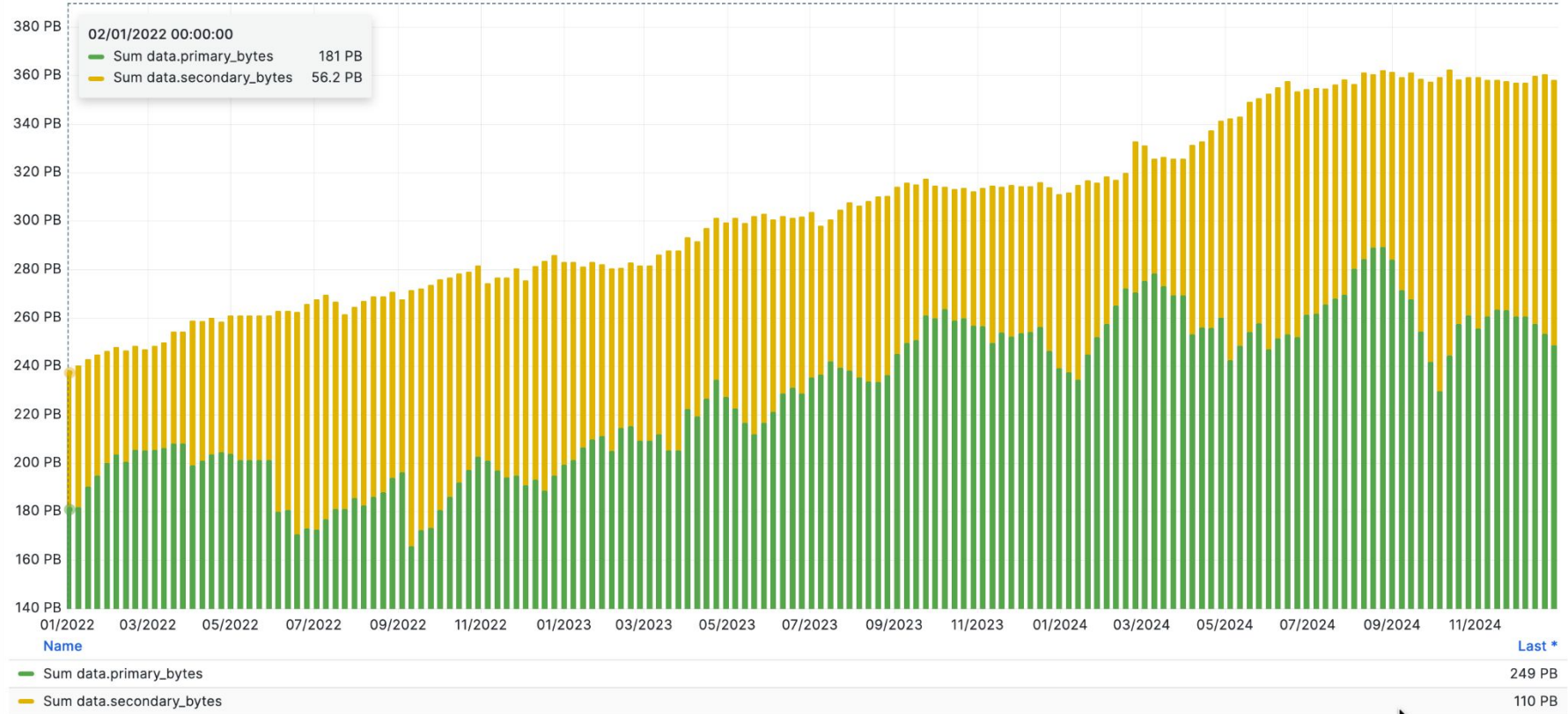
Where we are: 3-year pledged data volume on tape (source)

Tape volume

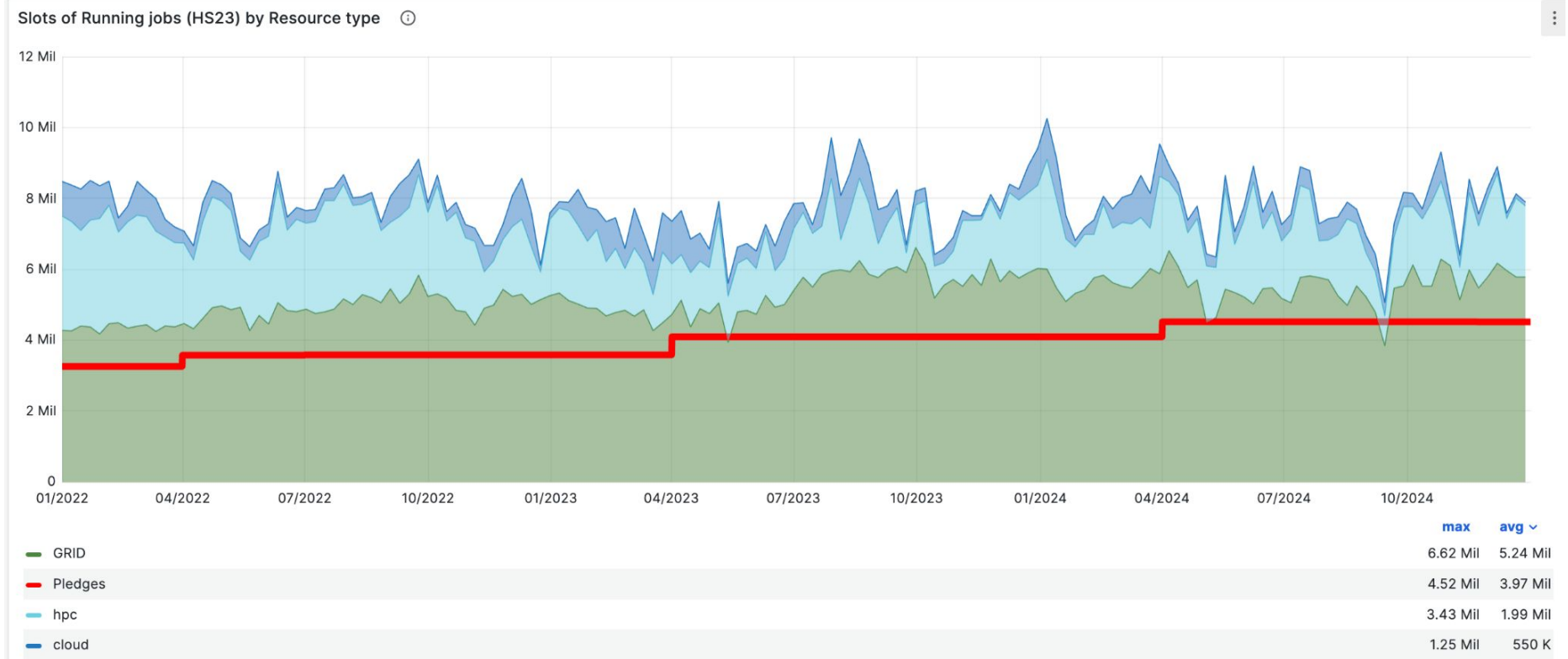


Where we are: 3-year pledged data volume on disk (source)

Disk volume



Where we are: 3-year normalized slots of running jobs (source)



- Centralised production and user analysis have been running at full steam
 - Multiple concurrent campaigns of various intensity and duration
 - Physics Validation, Production, Reprocessing, Derivation