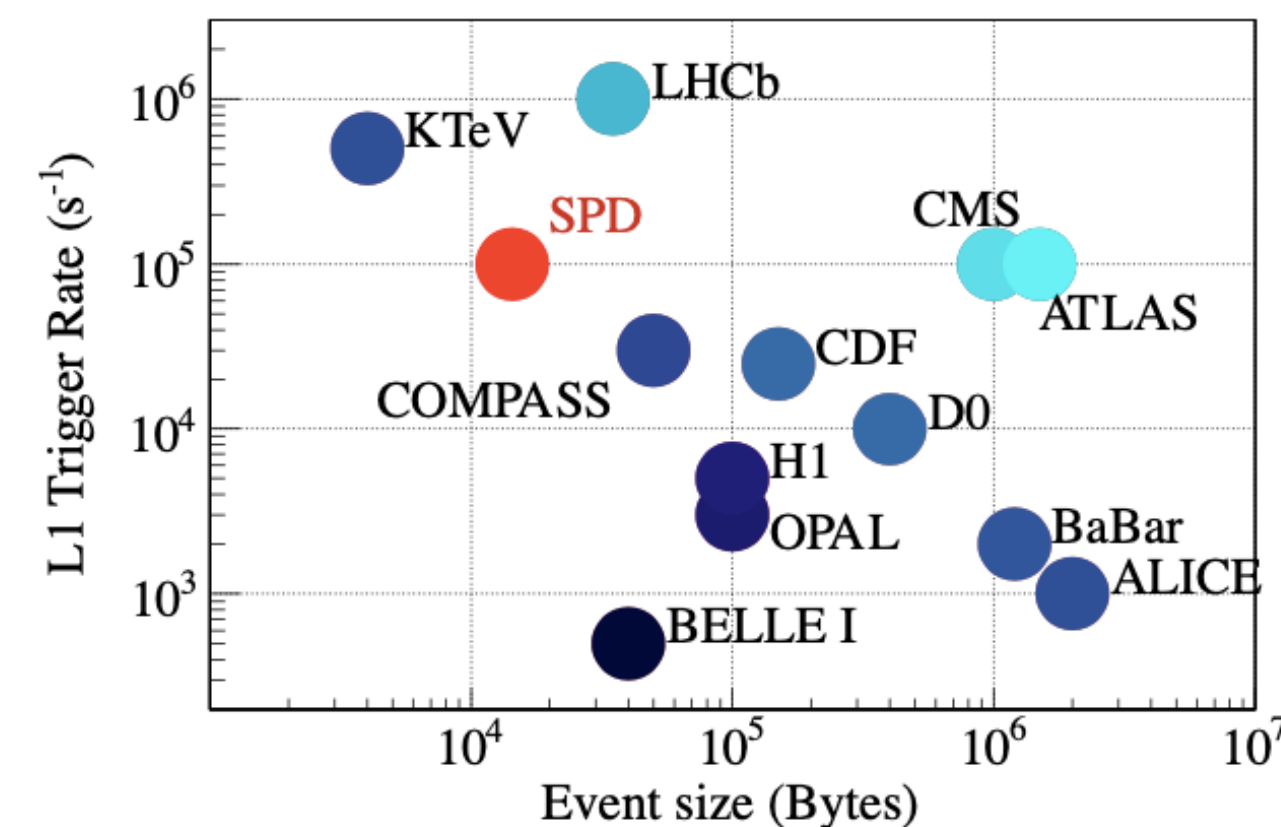


Overview of the offline computing system of the SPD experiment

Artem Petrosyan, Joint Institute for Nuclear Research, Dubna, Russia
Workshop on Mega-Science Computing for High Energy Physics
Listvyanka, Russia
March 13, 2026

SPD as a data source

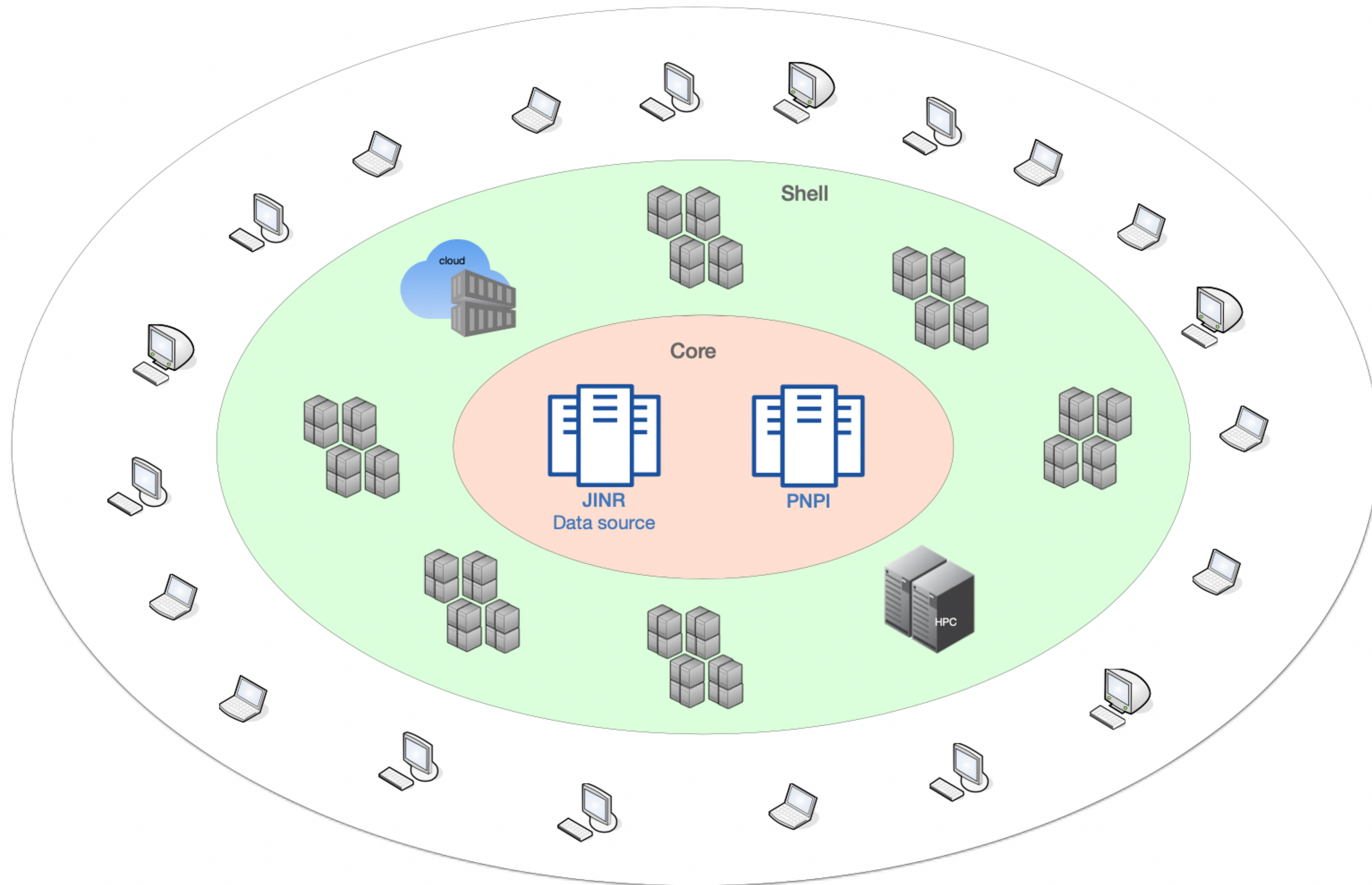
- The SPD detector is a medium scale setup in size, but a large scale one in data rate!
- Bunch crossing every 76,3 ns = crossing rate 13 MHz
- ~ 3 MHz event rate (at $10^{32} \text{ cm}^{-2}\text{s}^{-1}$ design luminosity)
- 20 GB/s (or 200 PB/year "raw" data, $\sim 3 \cdot 10^{13}$ events/year)
- "Only" $\sim 1,5 \cdot 10^{12}$ events/year are interesting for detailed study (~ 10 PB/year) of data
- Selection of physics signal requires momentum and vertex reconstruction which means that no simple trigger is possible
- Comparable amount of simulated data



General considerations on the organization of storage and processing

- Data cost in physics nowadays is very high and we would like to organize their storage as much reliable as it's possible in order not to lost them
- The best available way of storing data is to keep at least one copy of key data on the remote storage outside the home institute
- To do that we need to be ready to organize a distributed data management, which means that we need a distributed data management system to smoothly work with remote storages
- Requirements for the data processing are very high and at some point it becomes easier to organize a distributed data processing on smaller centers than to build a single large computing center
- It also helps to solve problem of reliability: to have several geographically distributed computing centers is much more reliable than to have only one
- Also, providing computing resources by collaborating institutes is considered as a contribution to the experiment

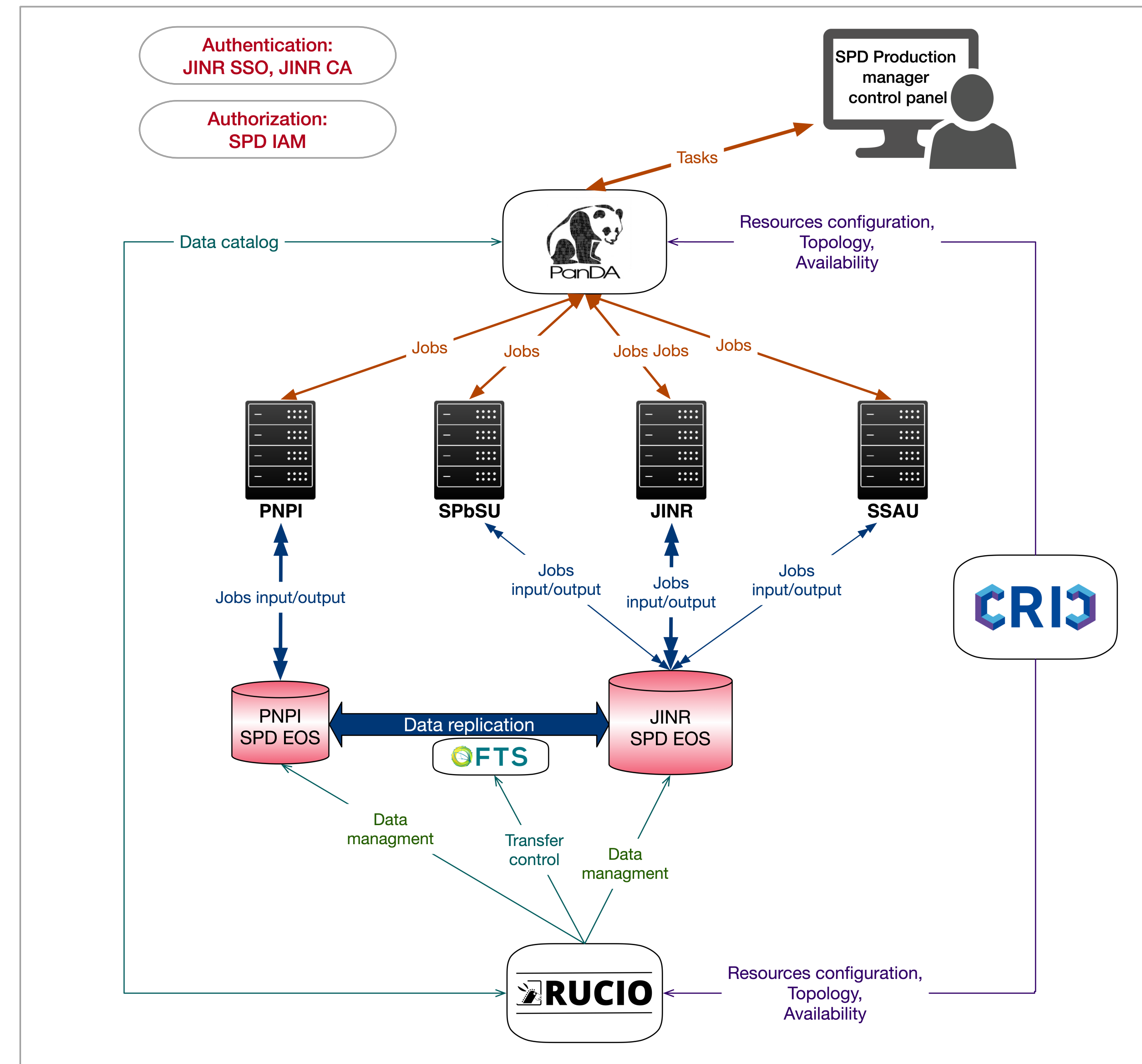
Sites hierarchy in SPD



- Core sites
 - require 100+ Gbit/s network connectivity
 - long term storage, mass data processing and producing
- Shell sites
 - should have at least 10 Gbit/s WAN connectivity
 - data analysis, data processing

SPD offline computing landscape in one shot

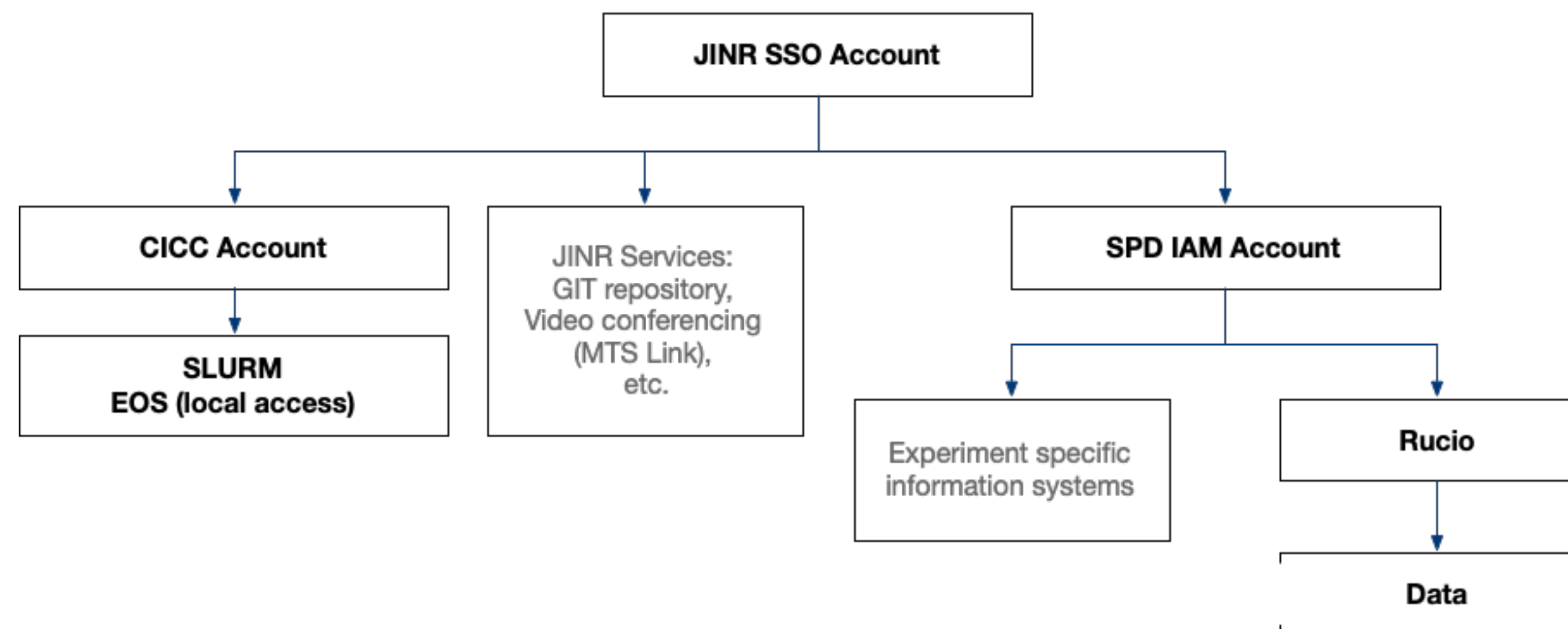
- Authentication system: **JINR SSO**.
- Authorization system: **SPD IAM**.
- Information system: **CRIC**.
- Software distribution service: **CVMFS**.
- Data management system: **Rucio**.
- Data transfer service: **FTS**.
- Workflow management system: **Requests/Control Panel/PanDA**.
- Workload management system: **PanDA/Harvester/Pilot**.



Middleware services integration

- Three main directions:
 - Integration modules development
 - IAM, CRIC, Rucio, PanDA, actually all services require some integration effort
 - Development of the plugins in the codebase of the core system
 - PanDA, PanDA Pilot
 - New systems development in order to help users and increase level of automation
 - Production requests management, control panel of the production manager, more to come

Identity and access management



- IAM is a single source of info about users and their rights in the distributed computing environment of the SPD experiment
- Unlike CERN experiments, we do not import all SPD users from the HR DB, users have to request registration
- We store quite all possible static user settings in the IAM
 - Recent development in this area is user quota, which is taken into account by Rucio and EOS
 - Two import modules were developed to deliver info from IAM to Rucio and EOS
- Other services of the distributed infrastructure also registered in the IAM

Artem Petrosyan



Artem Petrosyan

VO administrator

virthead

ff4f28c9-71e6-4660-999e-0514193c967c

Email	artem.petrosyan@jinr.ru
Status	Active
Created	a year ago
Updated	2 months ago
End time	N/A
Labels	eos.quota 5T

cosmo

Home

Core

Core API

NICA

NICA API

Admin

Logs

Help

artem.petrosyan@ji...

Key

Power

Export

Columns 14/20

Filter

Reload

NICA Site list

200

spd	filter by NICA Site	ACTIVE	filter	filter by Site	filter by Country	filter by Storage Units	filter by PanDA Sites	filter by	filter by	filter by	filter by c	filter by	filter by Data pc
VO	NICA Site	State	Tier	Site	Country	Storage Units	PanDA Sites	ADC notify	Auto proxy	core power	core energy	cloud	Data policy
spd	JINR-SPD	ACTIVE	T1	JINR	Russian Federation	SPD-JINR-DATA	JINR-SPD-PS	✓	✗	10	0	RU	
spd	PNPI-SPD	ACTIVE	T2	PNPI	Russian Federation	SPD-PNPI-DATA	PNPI-SPD-PS	✓	✗	6	0	RU	
spd	SPbSU-SPD	ACTIVE	T2	SPbSU	Russian Federation		SPbSU-SPD-PS	✗	✗	6	0	RU	
spd	SSAU-SPD	ACTIVE	T2	SSAU	Russian Federation		SSAU-SPD-PS	✗	✗	10	0	RU	
VO	NICA Site	State	Tier	Site	Country	Storage Units	PanDA Sites	ADC notify	Auto proxy	core power	core energy	cloud	Data policy

cosmo

Home

Core

Core API

NICA

NICA API

Admin

Logs

Help

artem.petrosyan@ji...

Key

Power

Export

+ new RSE

Columns 13/18

Filter

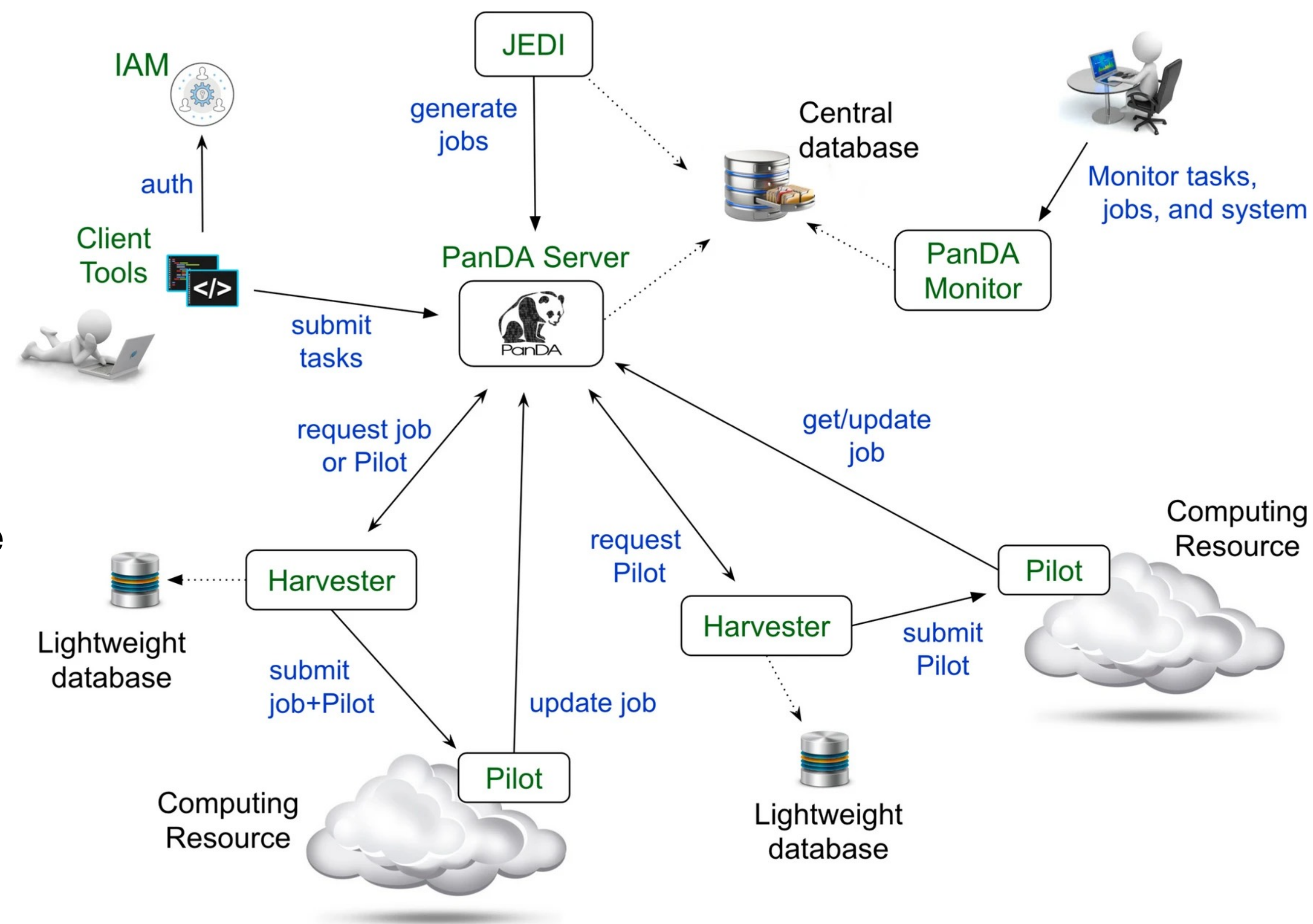
Reload

DDMEndpoint list

200

filter by DDMEndpoint	filter by Experimer	filter by Storage Unit	filter	filter by Ty	filter by Endpoint	ACTIVE	filter by Resource	filter by	filter by d	filter by	filter by	filter by Space m
DDMEndpoint	Experiment site	Storage Unit	Tier	Type	Endpoint	State	Resource	cache	determ	volat	mkdir	Space method
JINR_EOS2_DATADISK	JINR-SPD	SPD-JINR-DATA	T1	DATADISK	production/	ACTIVE	SPDDATA@JINR_SPD_EOS	✗	✓	✗	✗	rucio
PNPI_SPD_DATADISK	PNPI-SPD	SPD-PNPI-DATA	T2	DATADISK	datadisk/rucio/	ACTIVE	SPDDATA@PNPI_EOS	✗	✓	✗	✗	rucio
DDMEndpoint	Experiment site	Storage Unit	Tier	Type	Endpoint	State	Resource	cache	determ	volat	mkdir	Space method

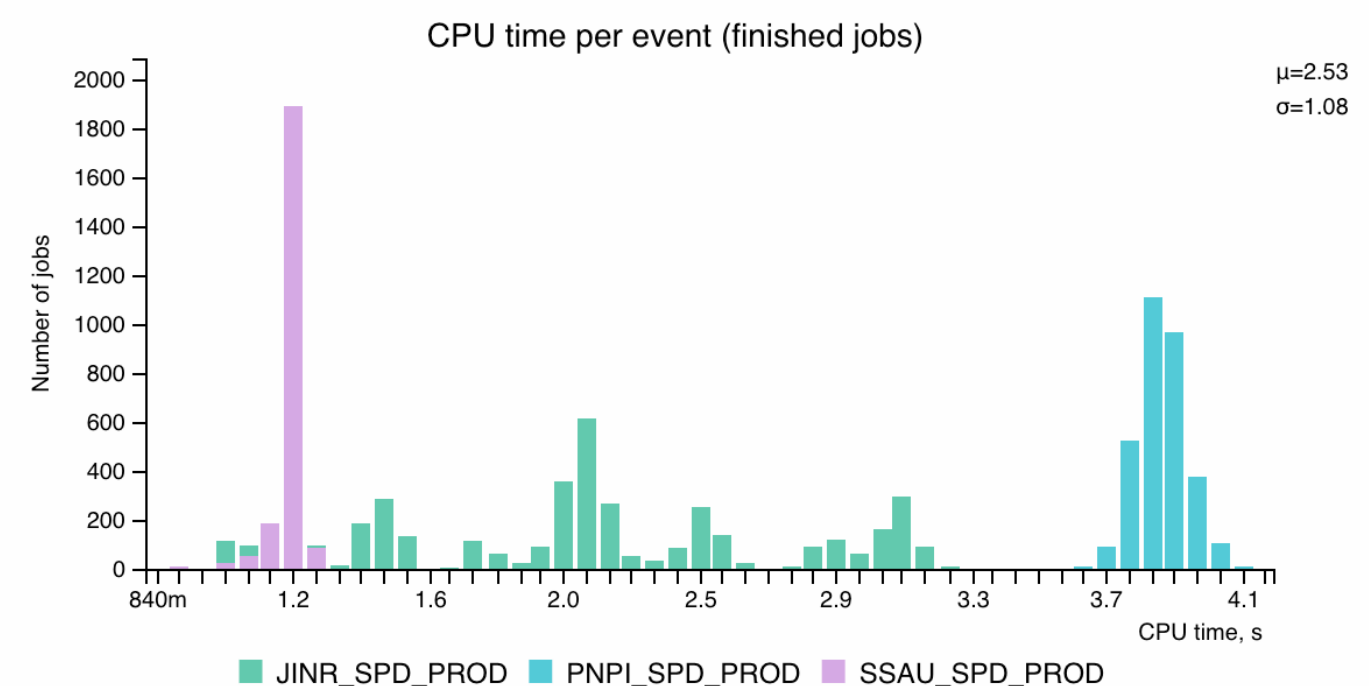
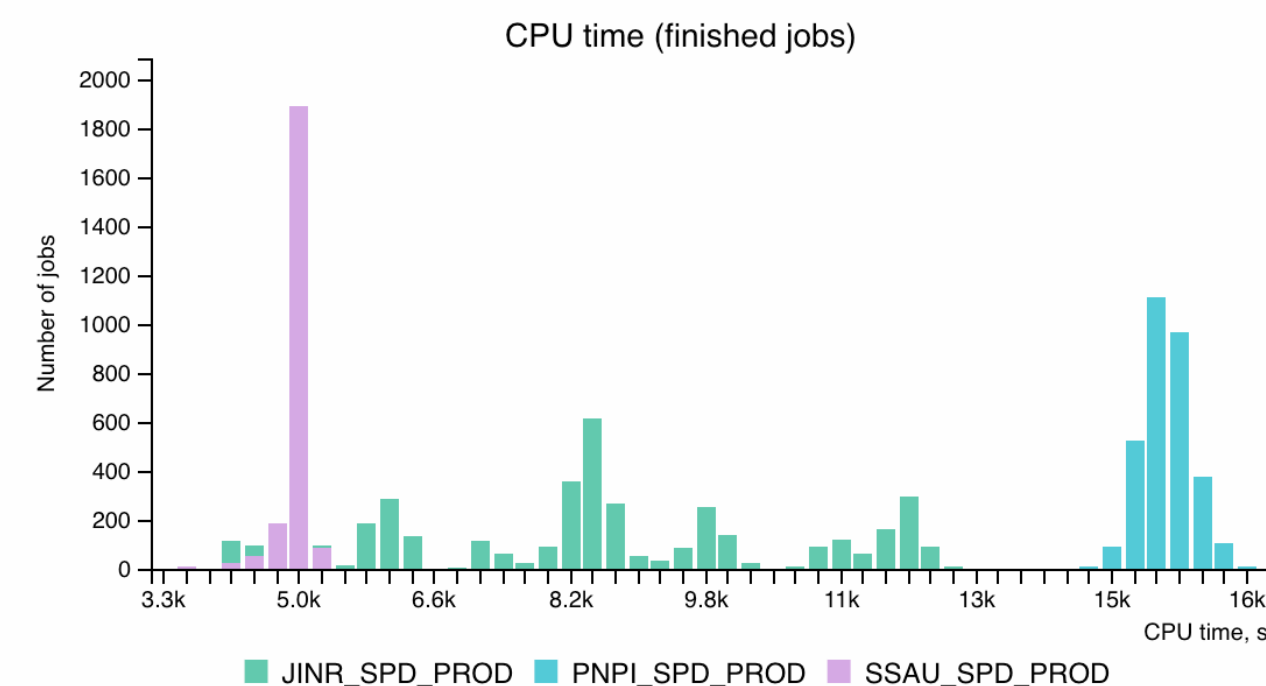
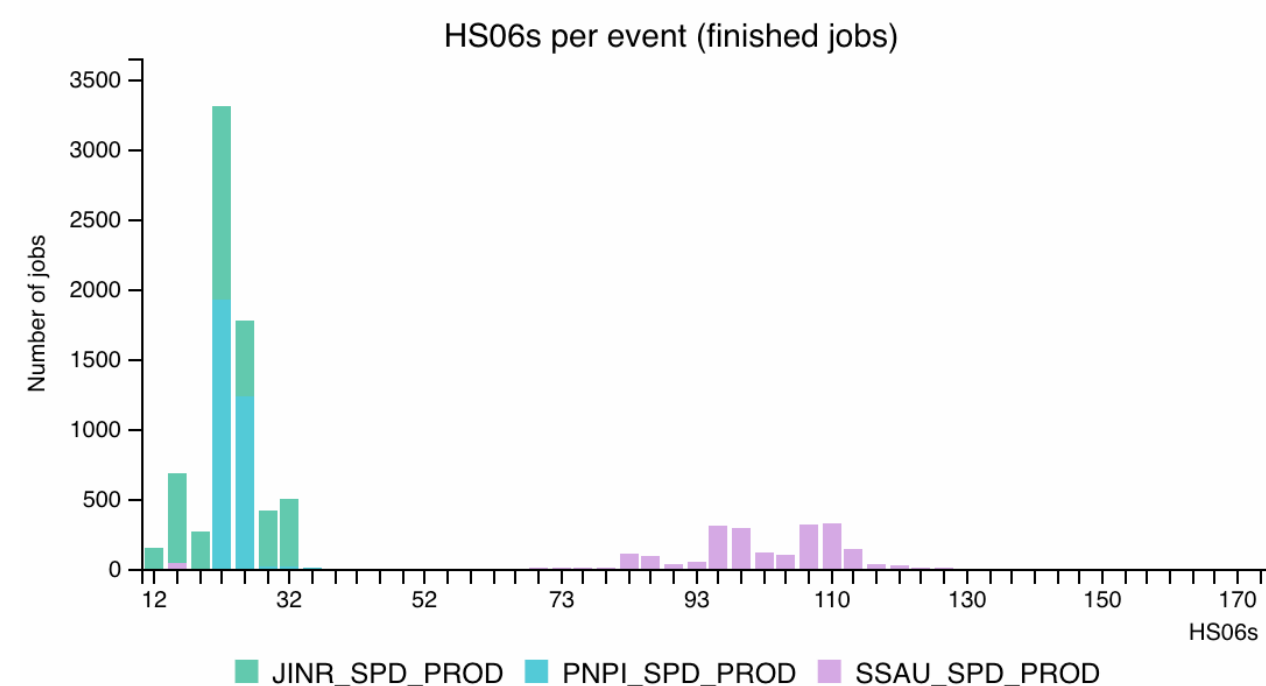
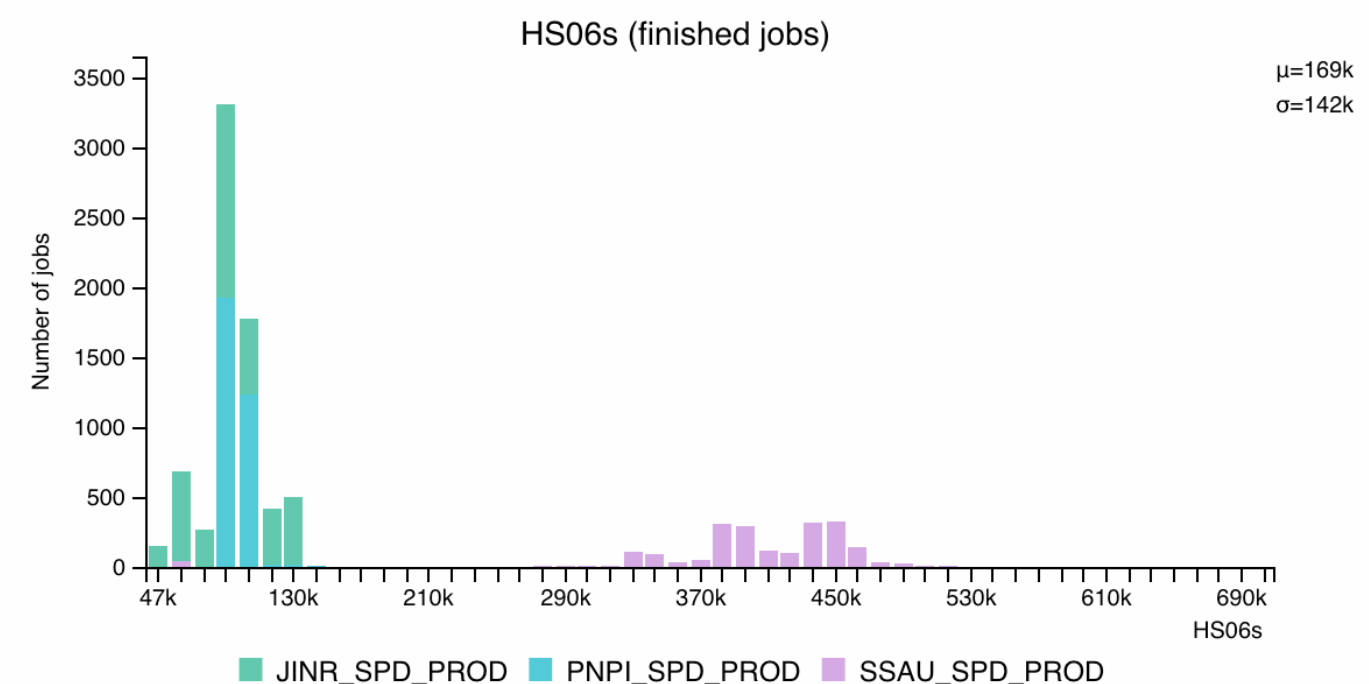
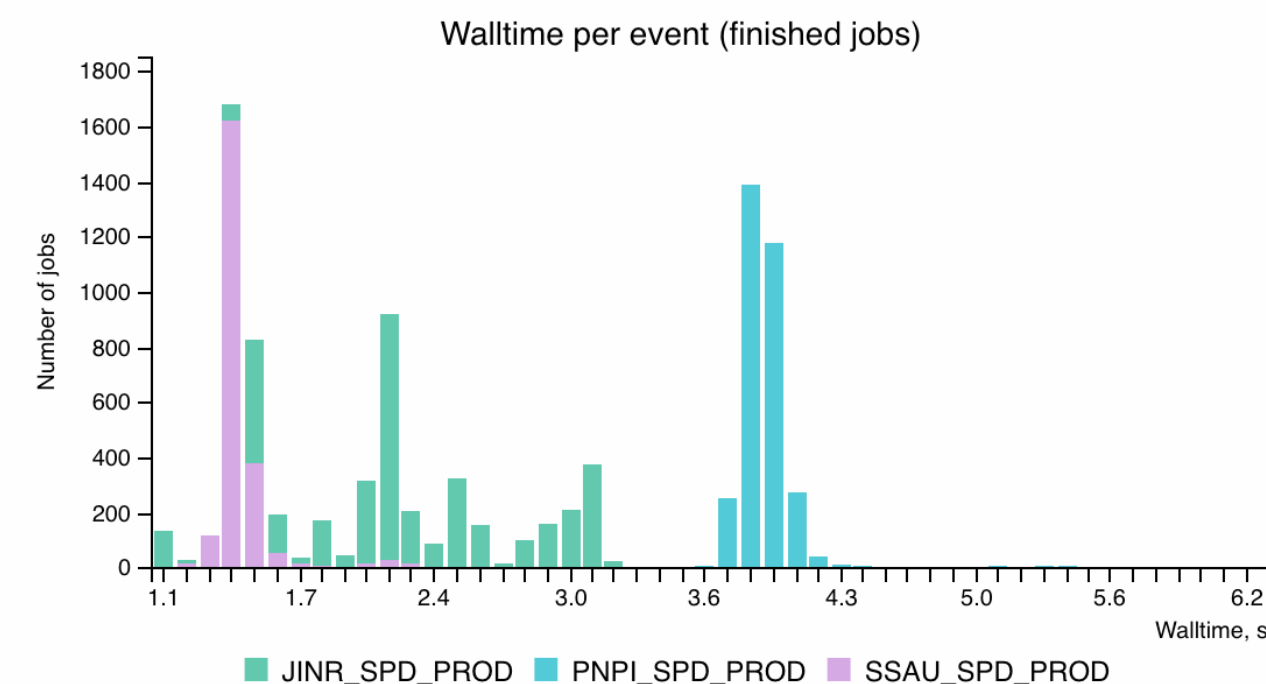
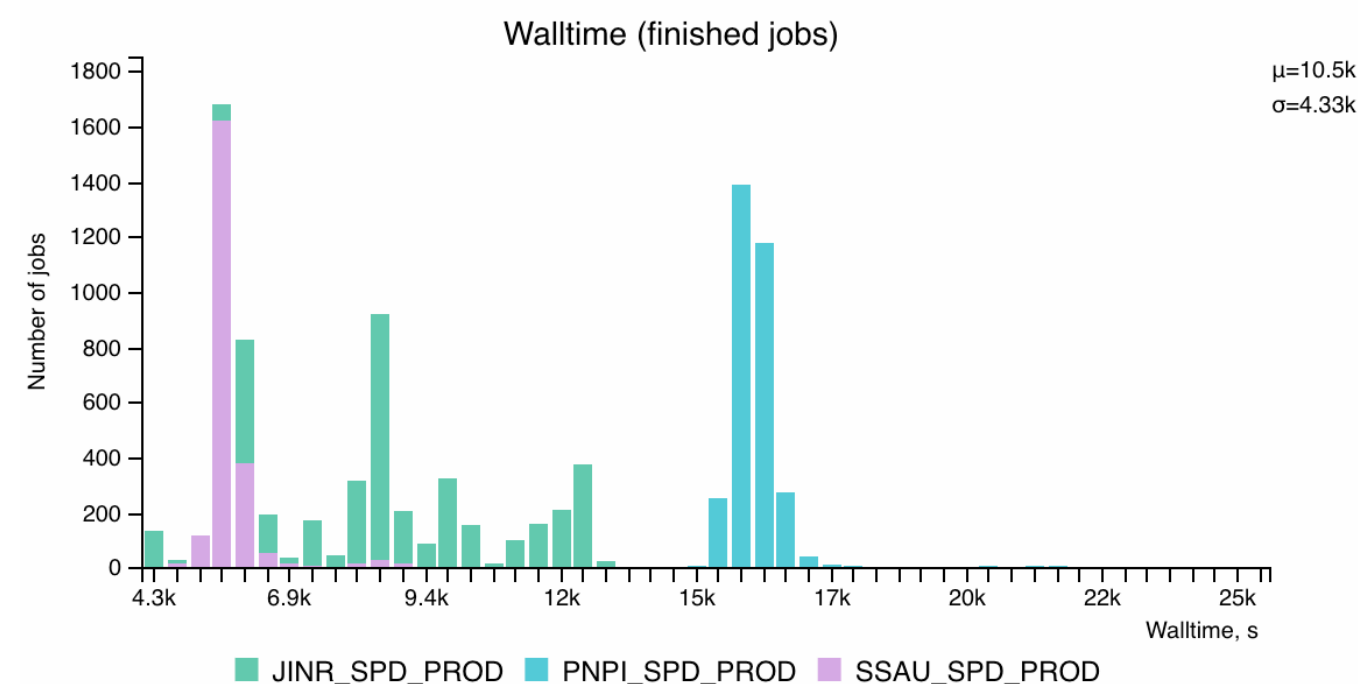
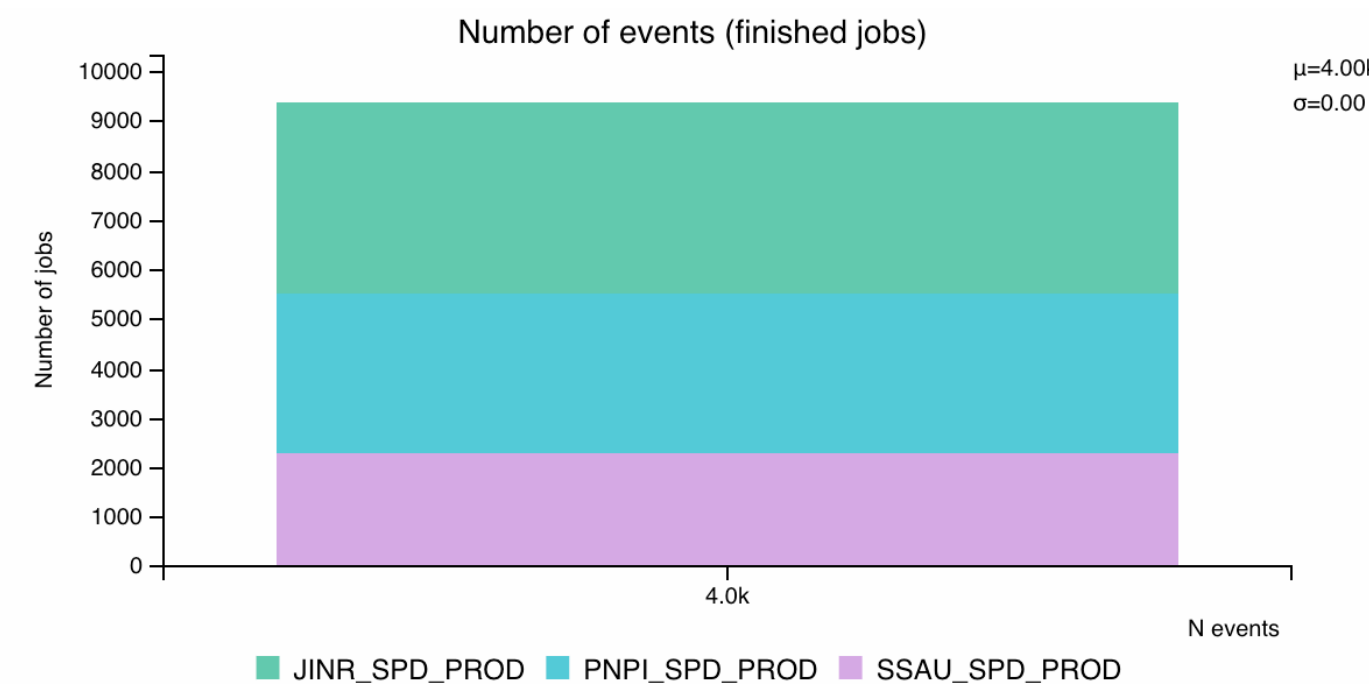
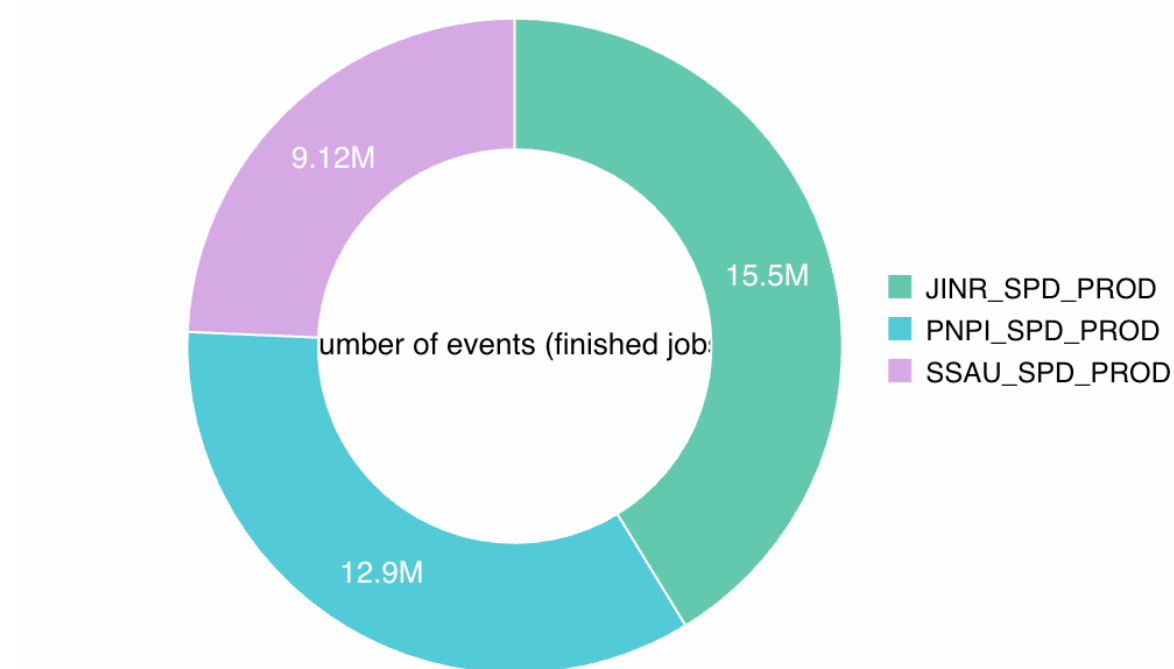
- The Production and Distributed Analysis (PanDA) is a data-driven workload management system capable of operating at massive data processing scale, designed to have the flexibility to adapt to emerging computing technologies in processing, storage, networking and distributed computing middleware
- The PanDA system has been developed to meet ATLAS production and analysis requirements for a data-driven workload management system capable of operating at the LHC data processing scale
- PanDA WMS is trusted by some of the world's most prominent scientific experiments and projects: ATLAS at CERN, COMPASS at CERN, sP HENIX at BNL and Vera C. Rubin Observatory in Chile



PanDA monitoring Oct'25

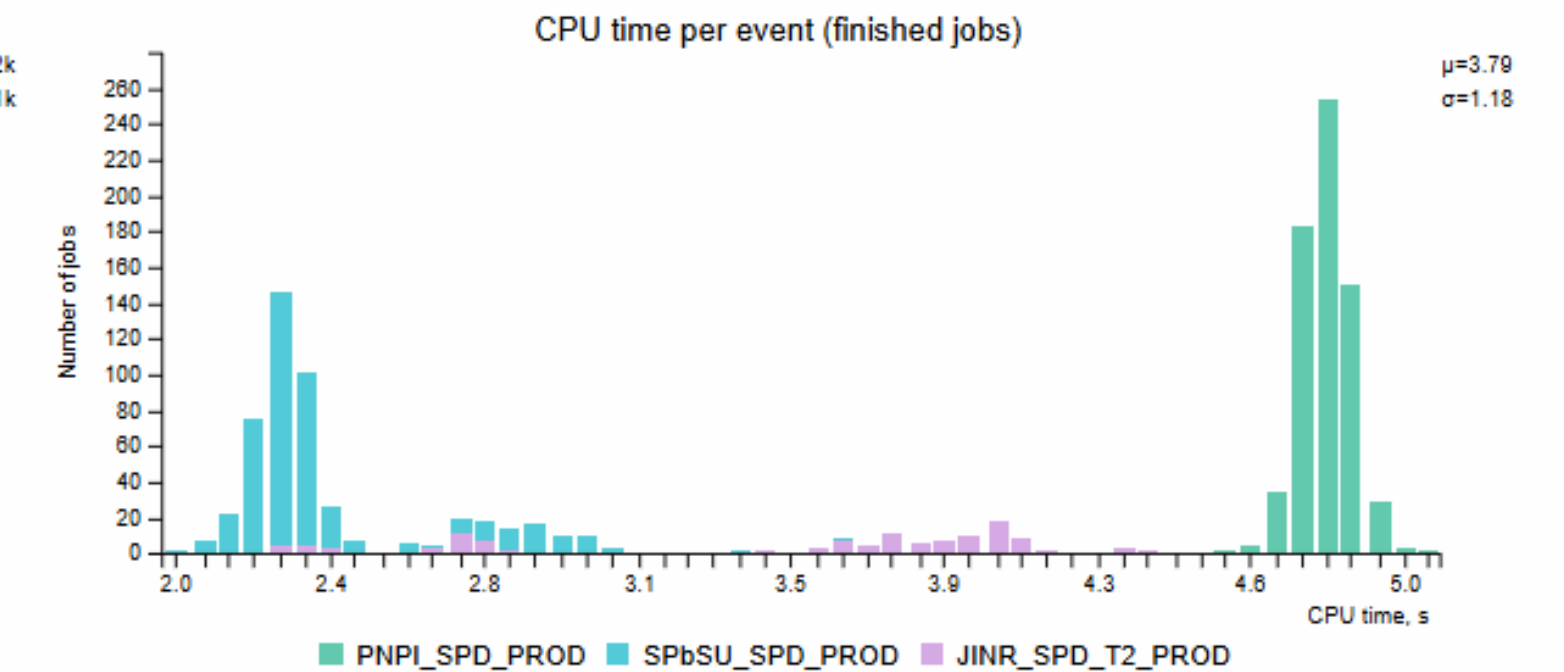
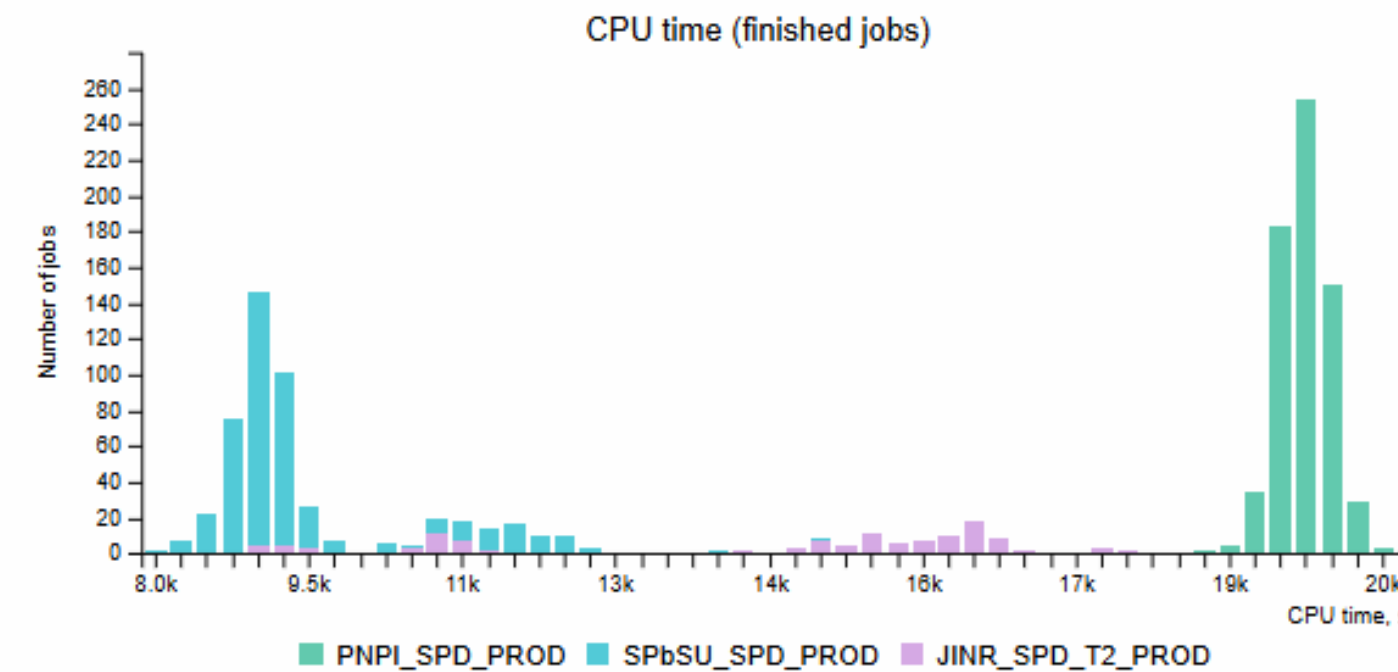
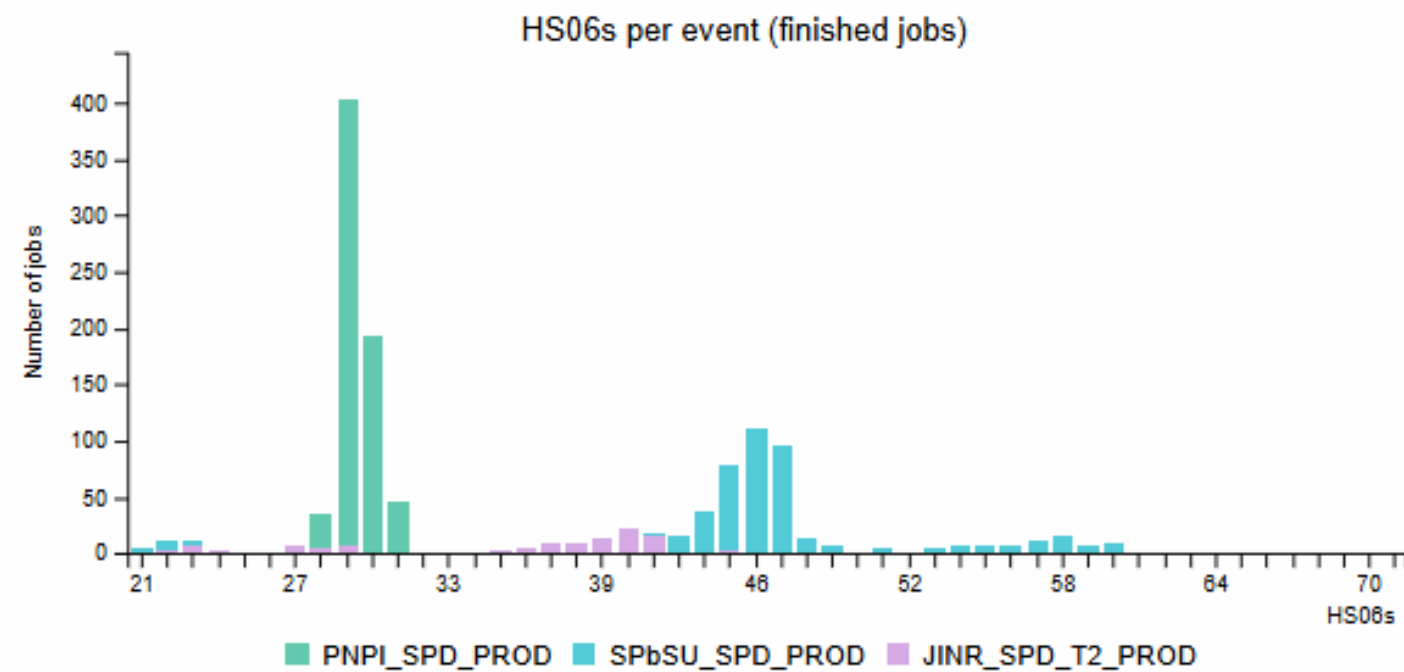
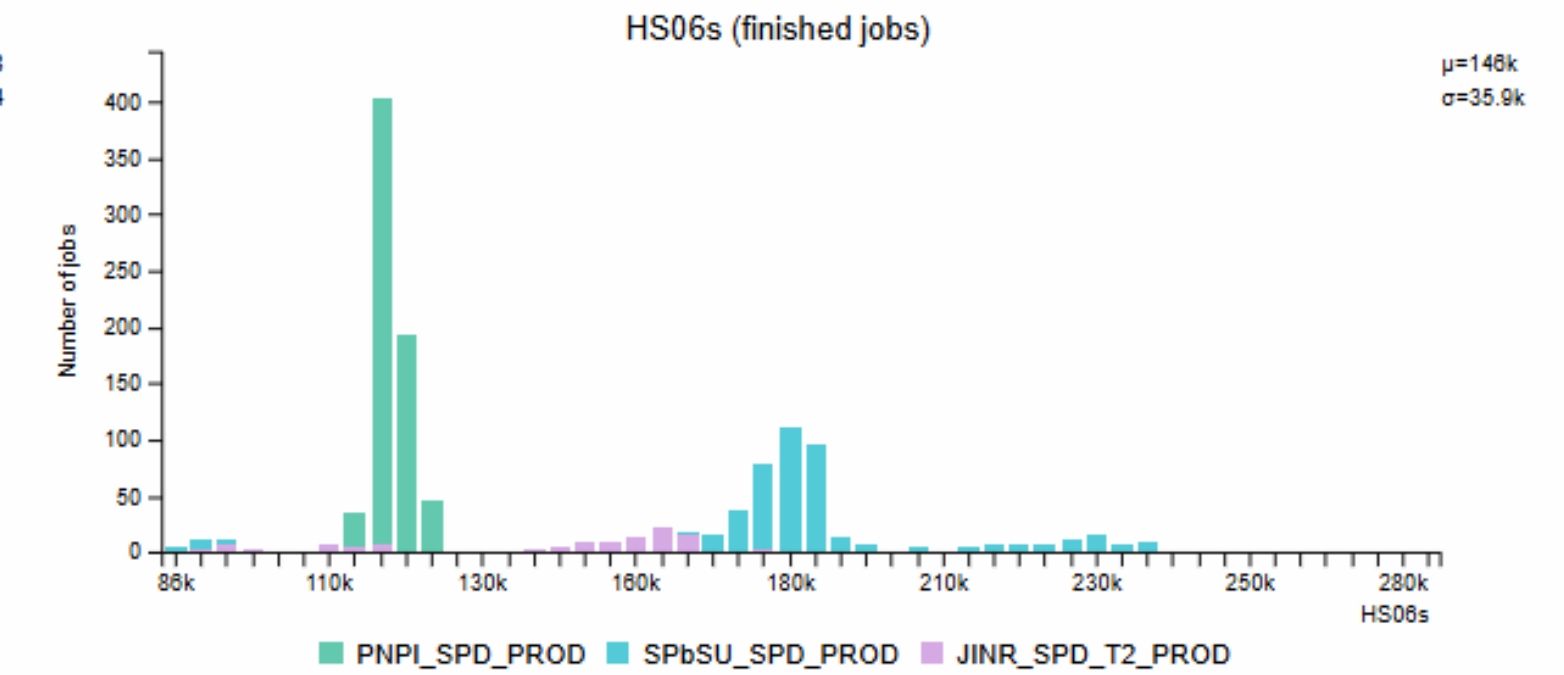
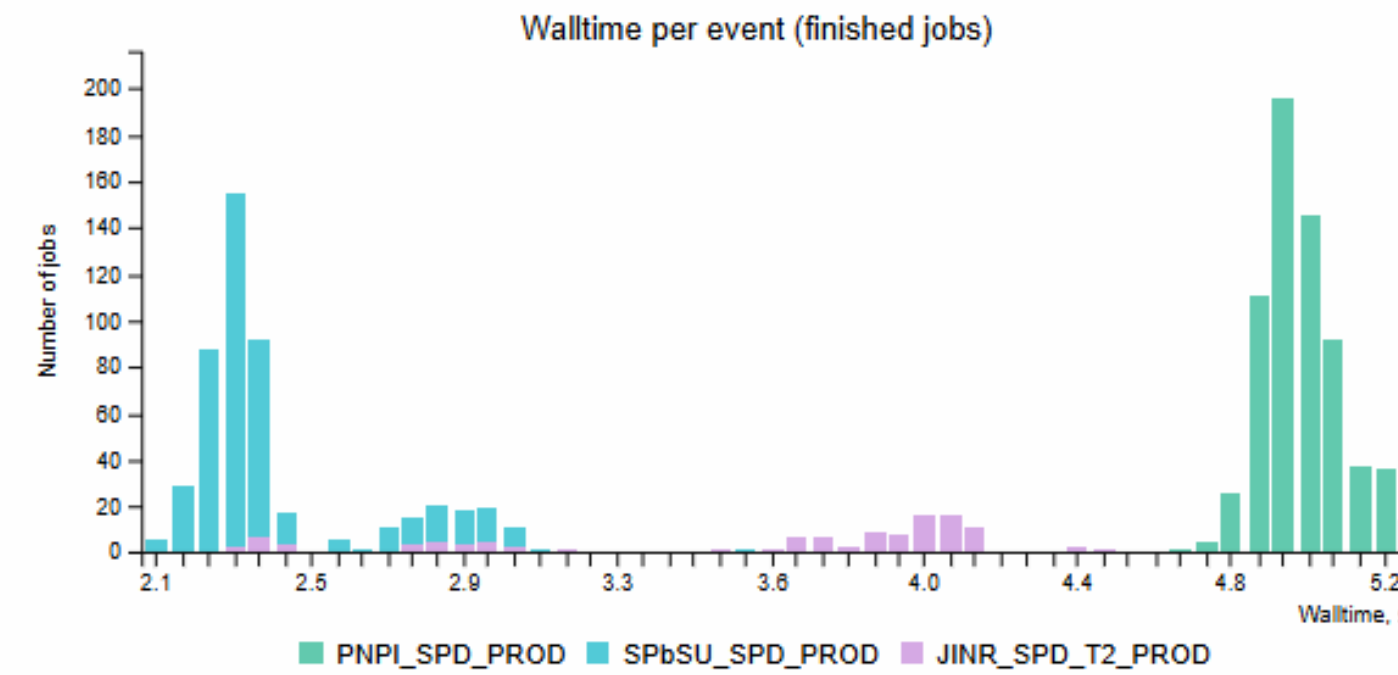
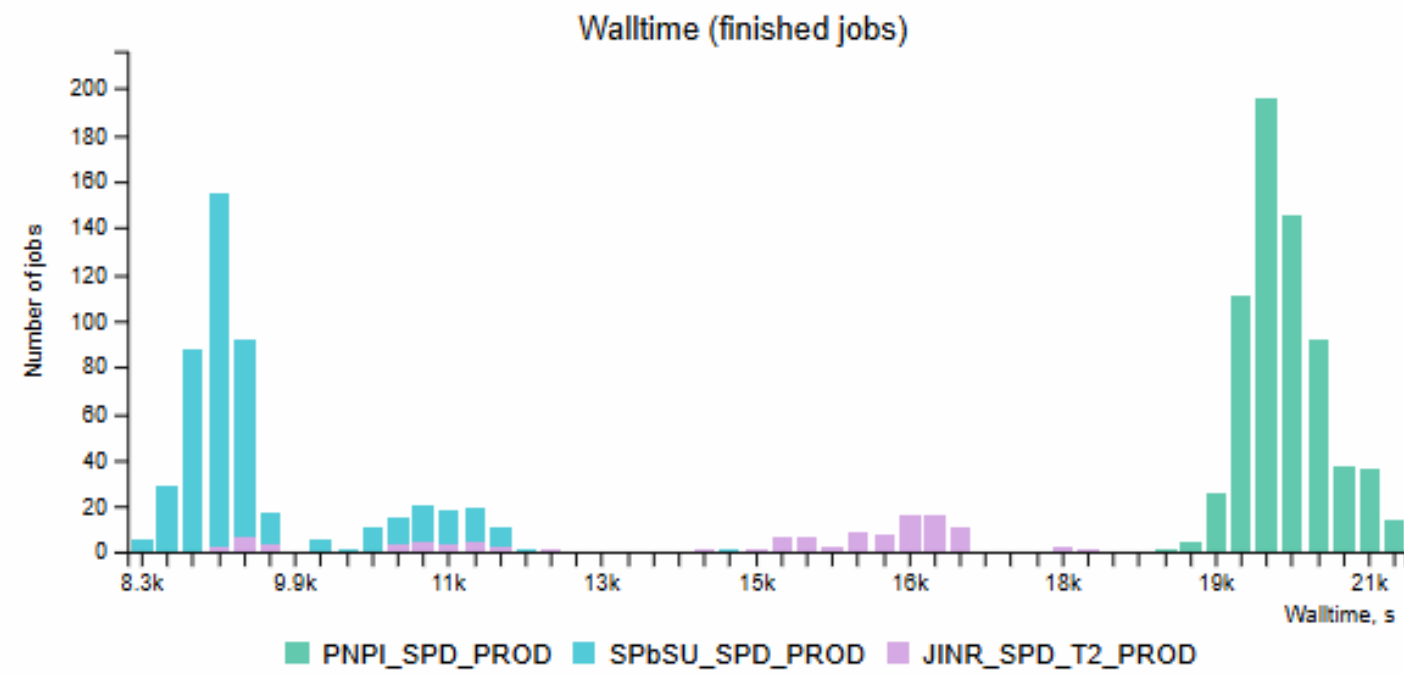
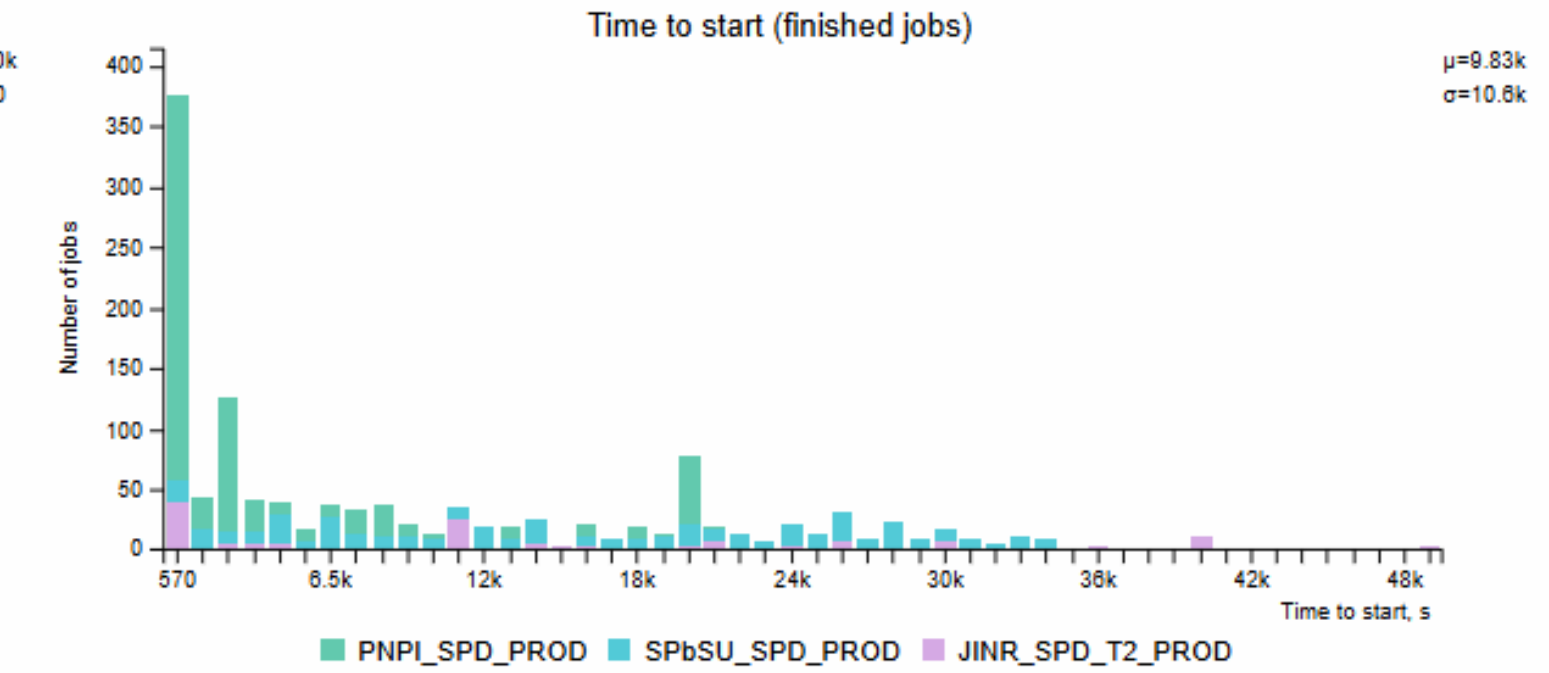
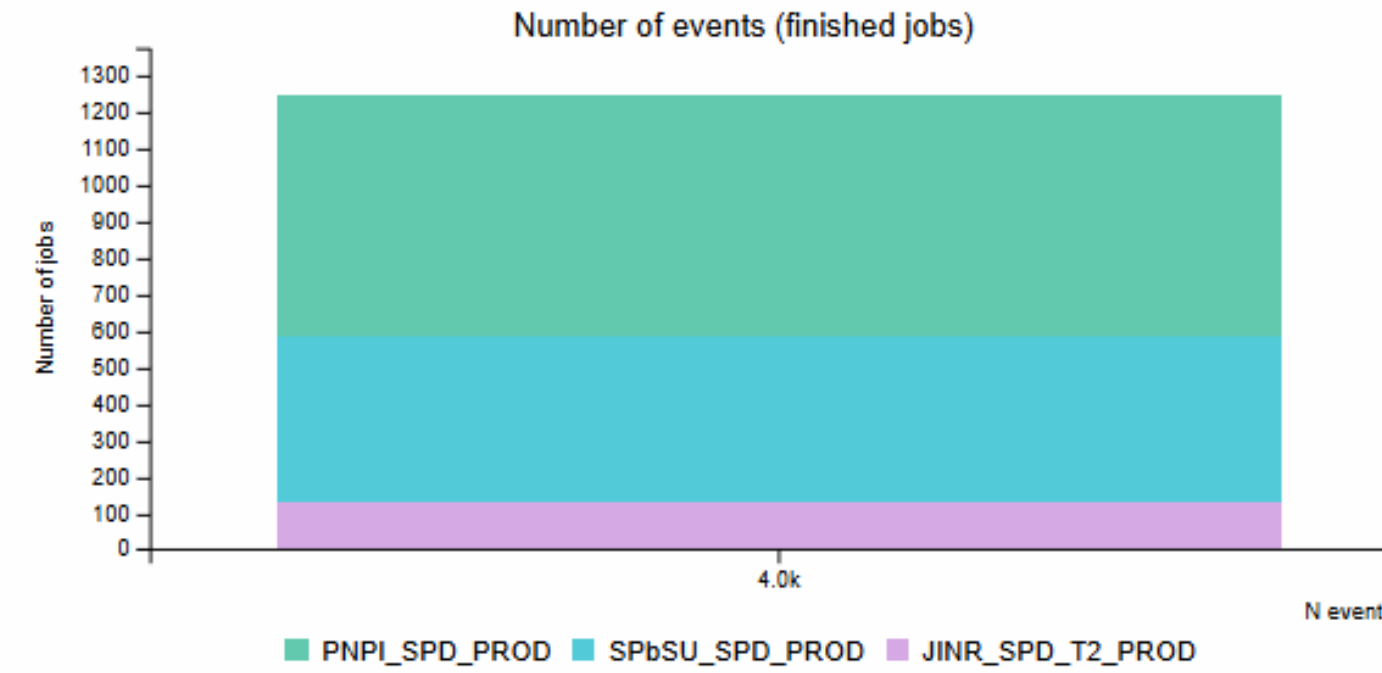
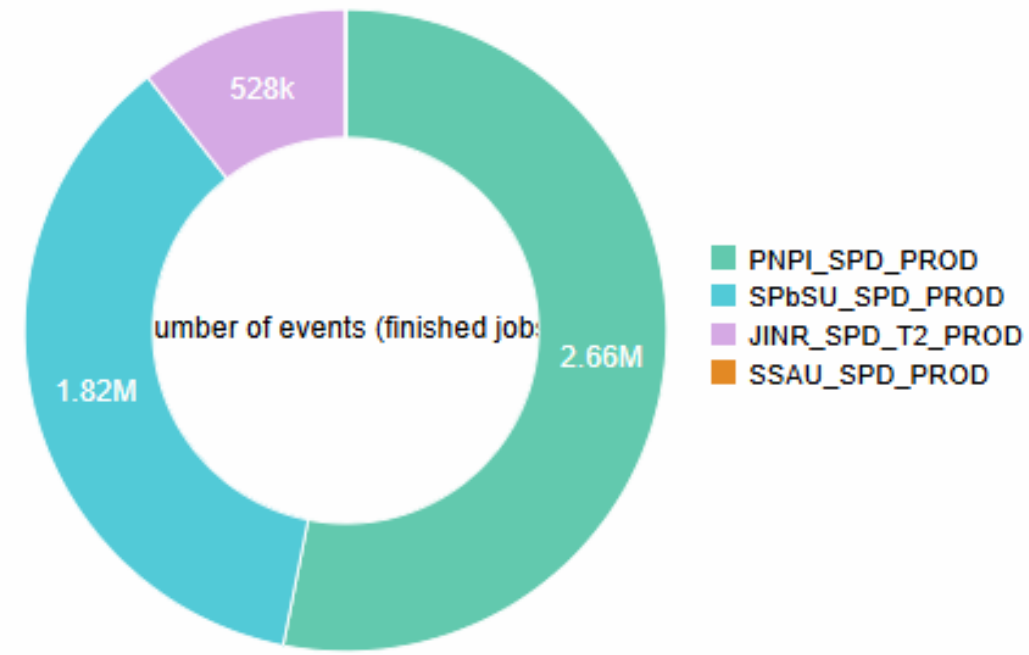


PanDA monitoring Nov'25



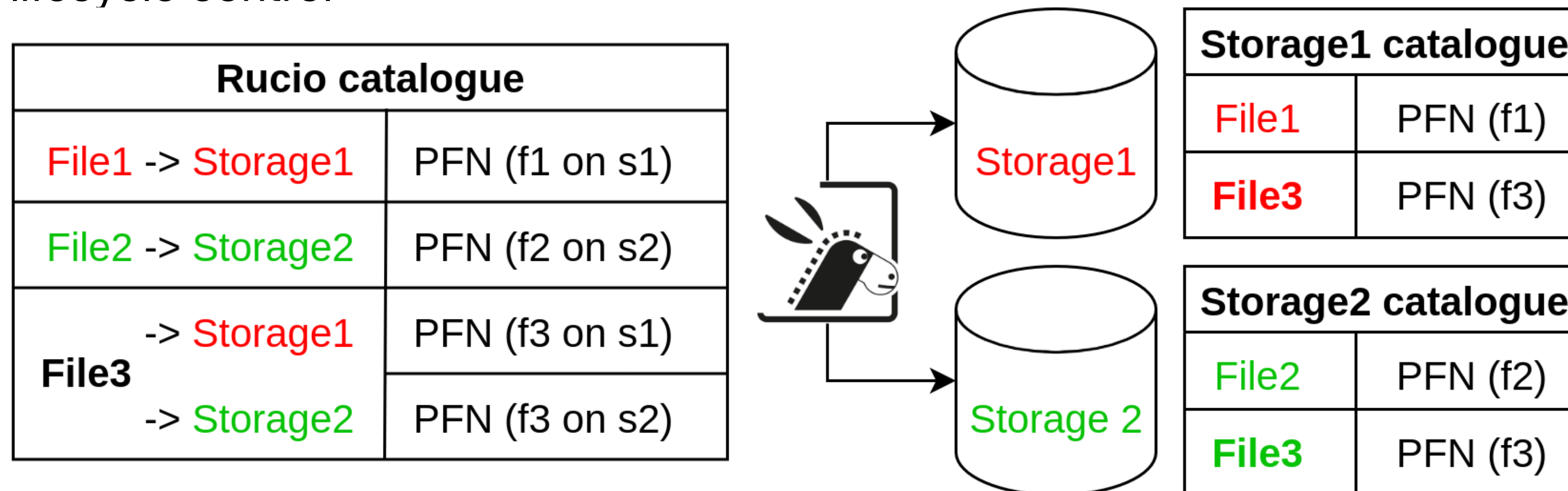
PanDA monitoring does not require development and comes in Docker container, requires only configuration to be deployed

PanDA monitoring Mar'26

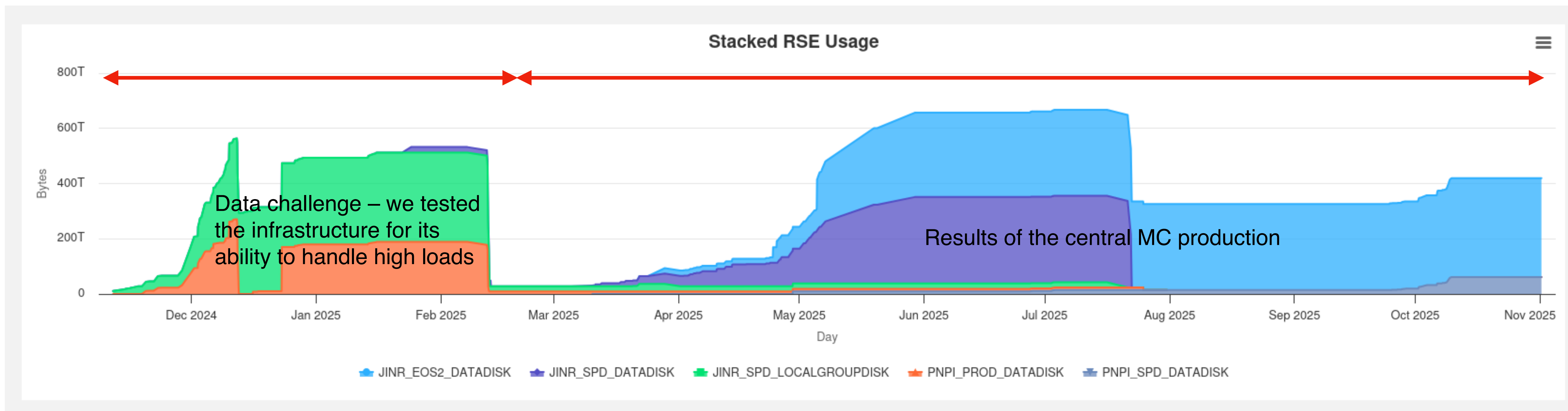


Distributed data management system

- Rucio is an open-source software framework that provides functionality for data management and access in a distributed storage environment
- Key Rucio features are:
 - Single catalog and management of any type of data and metadata
 - Automation: replication, recovery, and data migration between storages
 - Full data lifecycle control

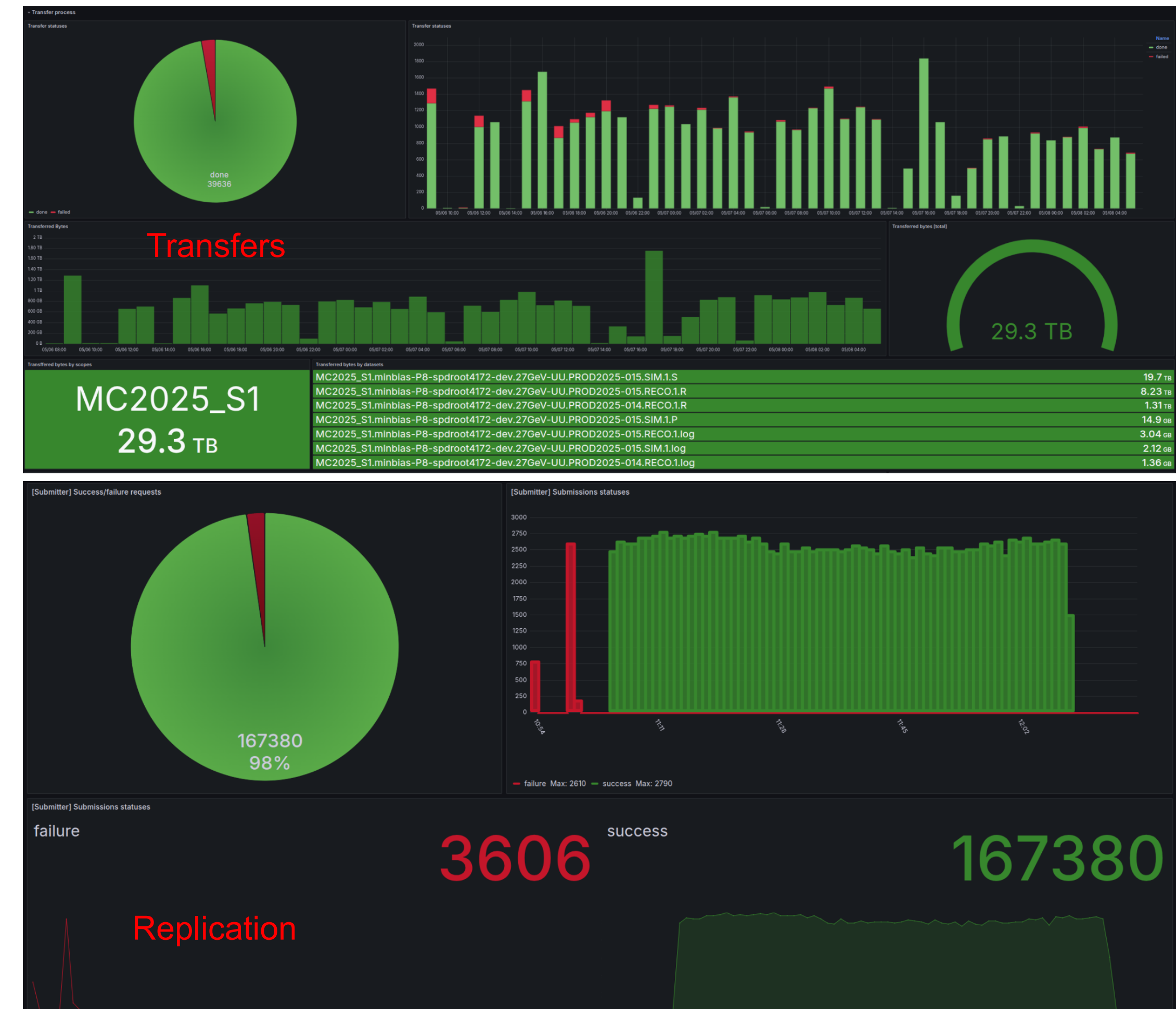
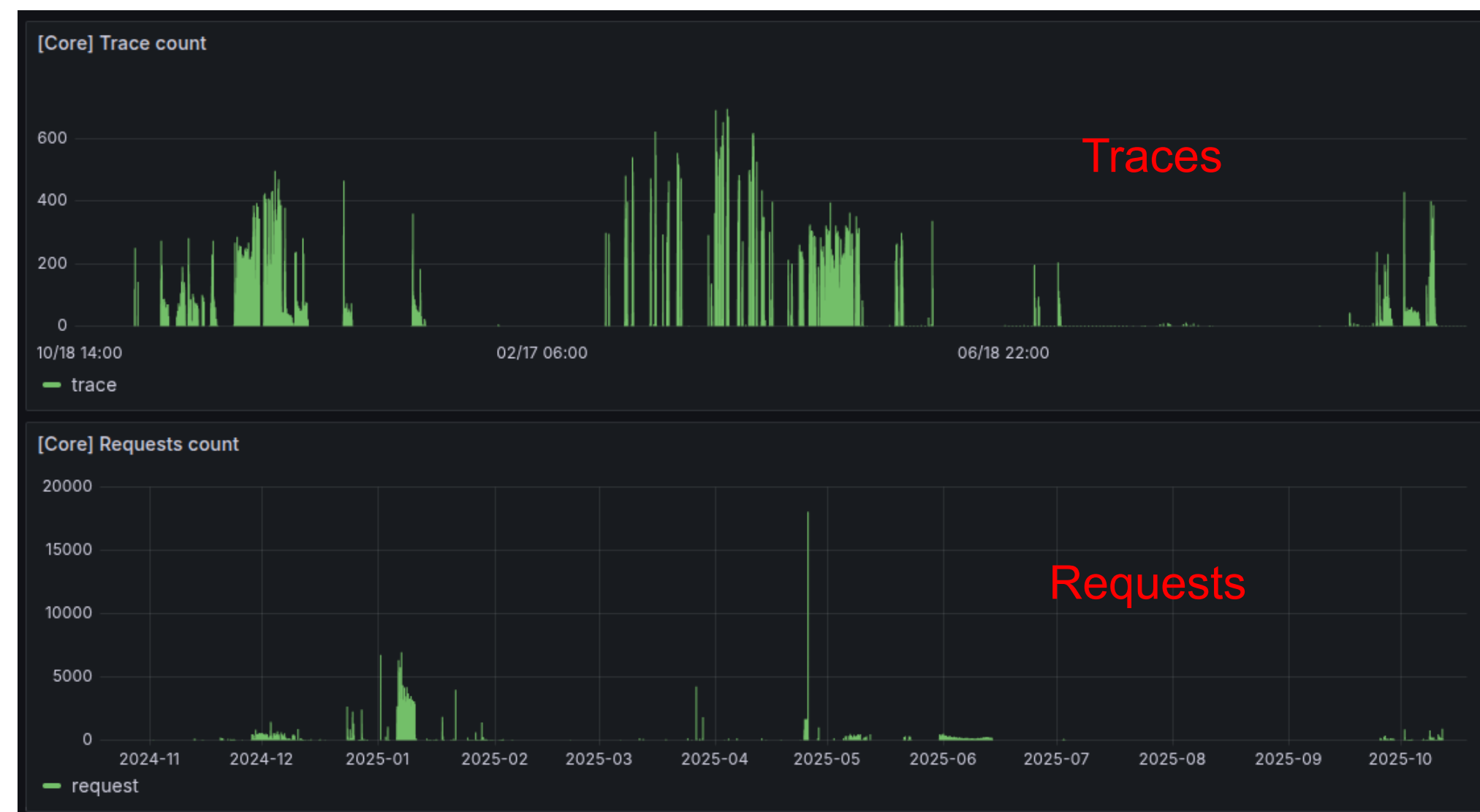
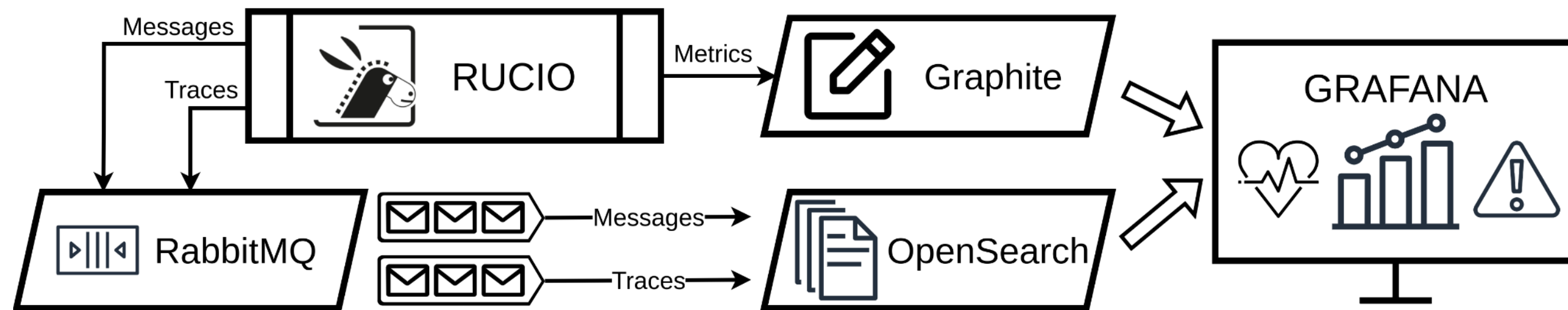


Distributed data management



- At the moment there are two storages are available: at JINR and at PNPI, we expect more remote storages to connect
- This year we migrated from the shared JINR EOS to the dedicated EOS for the SPD
- Final results of the central productions replicated automatically to both JINR and PNPI
- There is ongoing development of metadata import from the production requests system to Rucio

Data management monitoring



Rucio monitoring was recently deployed, it is not delivered out of the box, but deployment procedure is described in the documentation

Entities matching in PanDA & Rucio

PanDA	Rucio
Campaigns MC_2025_S1, MC_2025_S2	Scopes MC2025_S1, MC2025_S2
Requests PROD2025-020	Containers MC2025_S2:PROD2025-020
Tasks PROD2025-020.RECO.2	Datasets MC2025_S2:PROD2025-020:minbias-P8-spdroot4174-dev.27GeV- UU.PROD2025-020.RECO.2
Jobs PanDA ID	Files MC2025_S2:r.MC2025_S2.minbias-P8-spdroot4173-dev.27GeV- UU.PROD2025-018.RECO.1.001225.root.1

SPD Data processing

Requests

Config

API

artem.petrosyan@ji...

Export

Columns

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Filter

Reload

Processing Request list

?

100

Request	campaign	status	# procs	swproject	version	stage	C	E	P	Events	EF	Tag	S	S	Geometry	description
17 PROD2025-001	SPD MC 2025	DONE	0	spdroot-dev	4.1.7.0	S1	pp	10	UU	5000000	4000	minbias-P8-spdroot417-dev test	1	1250	Micromegas, TS, ECal, RS, BBC, ZDC (sketch)	PRE-PRODUCTION obsolete
16 PROD2025-002	SPD MC 2025	DONE	0	spdroot-dev	4.1.7.0	S1	pp	10	UU	20000000	4000	minbias-P8-spdroot417-dev	1	5000	Micromegas, TS, ECal, RS, BBC, ZDC (sketch)	/eos/nica/spd/users/elenazem/productions/PROD2025-002_recofiles.txt PROD2025-002_paramfiles.txt
15 PROD2025-003	SPD MC 2025	DONE	0	spdroot-dev	4.1.7.0	S1	pp	10	UU	20000000	4000	minbias-P8-spdroot417-dev	5001	10000	Micromegas, TS, ECal, RS, BBC, ZDC (sketch)	/eos/nica/spd/users/elenazem/productions/PROD2025-003_recofiles.txt PROD2025-003_paramfiles.txt
14 PROD2025-004	SPD MC 2025	DONE	0	spdroot-dev	4.1.7.0	S1	pp	10	UU	40000000	4000	minbias-P8-spdroot417-dev	1	10000	Micromegas, TS, ECal, RS, BBC, ZDC (sketch)	/eos/nica/spd/users/elenazem/productions/PROD2025-004_recofiles.txt PROD2025-004_paramfiles.txt
13 PROD2025-005	SPD MC 2025	DONE	0	spdroot-dev	4.1.7.1	S1	pp	5	UU	5000000	4000	minbias-FTF-spdroot4171-dev	1	1250	Micromegas, TS, ECal, RS, BBC, ZDC (sketch)	/eos/nica/spd/users/elenazem/productions/PROD2025-005_recofiles.txt PROD2025-005_paramfiles.txt
12 PROD2025-006	SPD MC 2025	DONE	0	spdroot-dev	4.1.7.1	S1	pp	10	UU	5000000	4000	minbias-FTF-spdroot4171-dev	1	1250	Micromegas, TS, ECal, RS, BBC, ZDC (sketch)	/eos/nica/spd/users/elenazem/productions/PROD2025-006_recofiles.txt PROD2025-006_paramfiles.txt

- Developed in May-June 2025, now developed in accordance with requests from physics groups
- Allows to organize requests, keeps the history, with built-in API has rich integration potential

Control panel of the production manager

Task Creation

Task name:

Output dataset name:
[Naming convention here](#)

Total events:

Events per job:

Cloud:

Data disk:

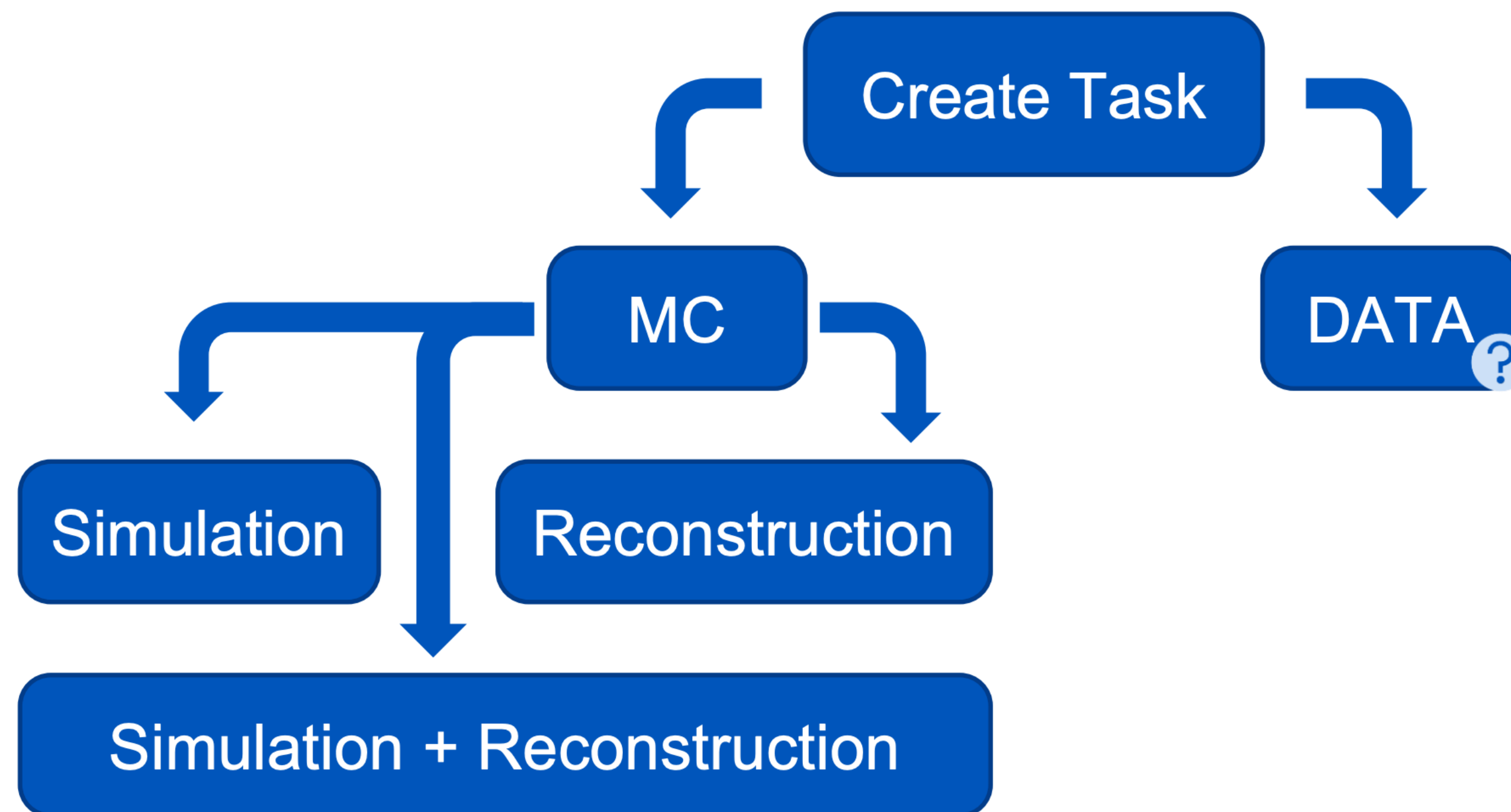
Skip scout: ☒

Offset:

Path to execution files:
smth like -> /cvmfs/spd.jinr.ru/production/MC/minbias-P8-spdroot417-dev.10GeV.V01

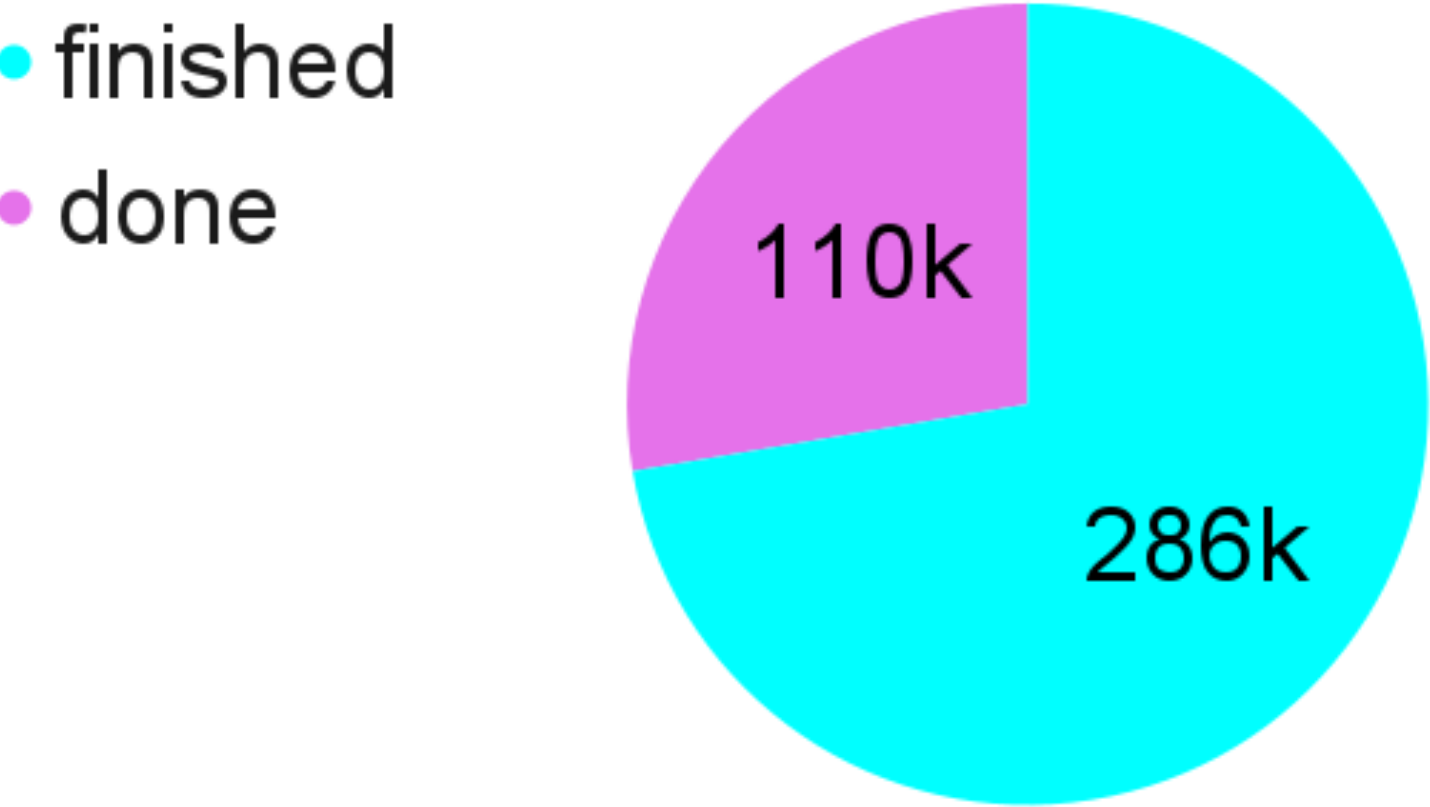
Path to container:
smth like -> /cvmfs/spd.jinr.ru/images/spdroot-dev-4.1.7.sif

Create task

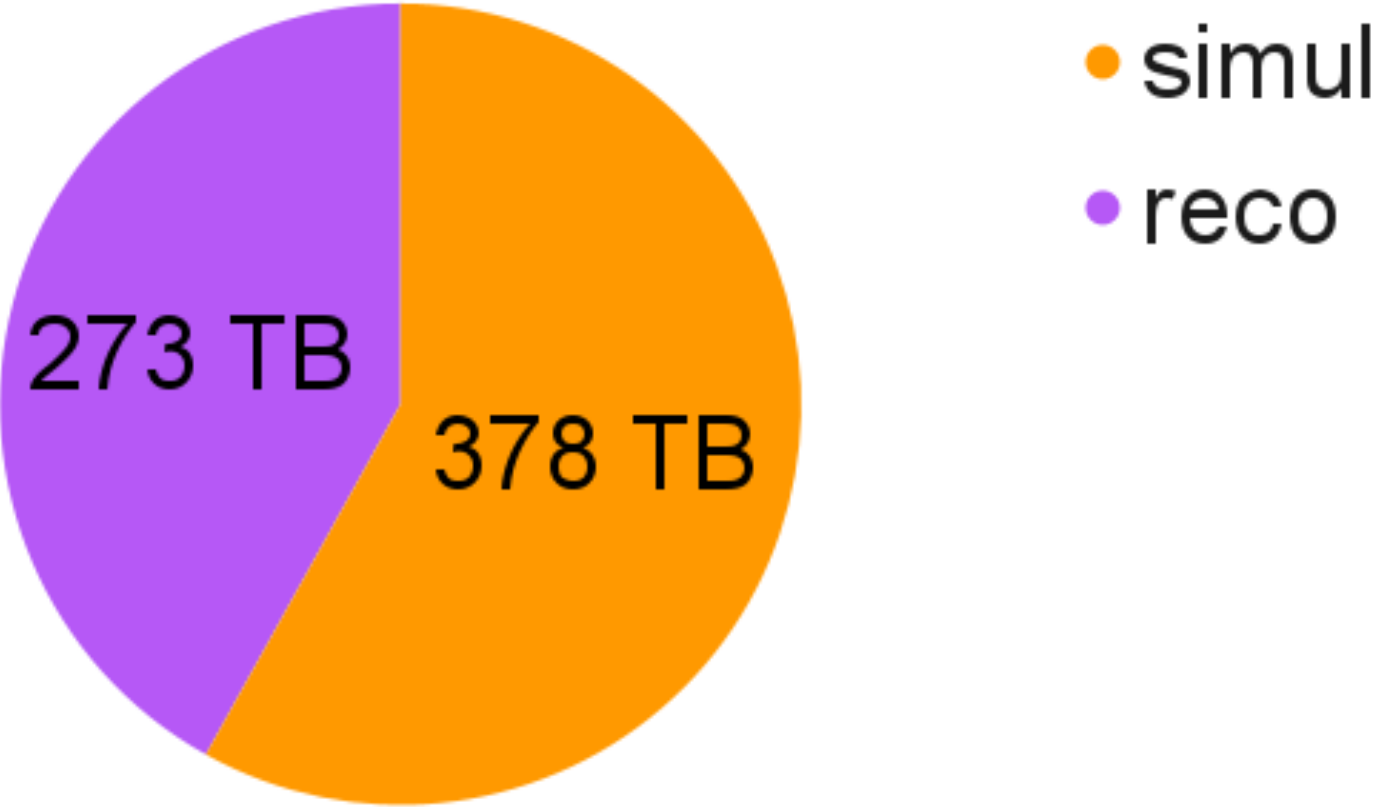


- Allows users to define a MC chain processing via Web UI, was put into pre-production in late 2024
- There is ongoing development to group output datasets into container for large productions
- Now we have only 2-steps processing chain, Simu and Reco, while others will be defined during the migration to the new applied software framework: Sampo

Successfully processed jobs



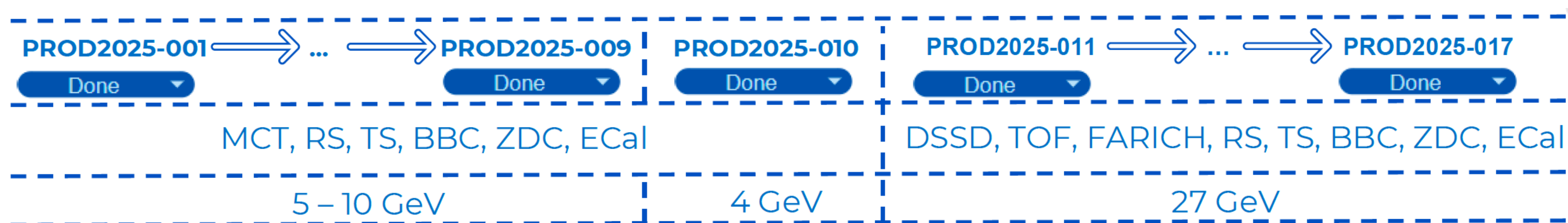
Total output datasets volume



Task ID	Task name ↑ ↓	Status	Start date	End date	Walltime	Total events	Events per job	Total jobs	Out DS size, GB	Out Log size, GB
364	PROD2025-014.SIM	done	03 May 2025	04 May 2025	24612	40000000	4000	10000	18358.86	1.96
363	PROD2025-013.RECO	finished	02 May 2025	04 May 2025	20	None	None	9992	18536.20	5.06
362	PROD2025-013.SIM.2	done	30 Apr 2025	02 May 2025	24899	40000000	4000	10000	18357.95	1.93
359	PROD2025-012.RECO	finished	28 Apr 2025	29 Apr 2025	24	None	None	9993	18546.74	5.08
358	PROD2025-012.SIM	done	25 Apr 2025	26 Apr 2025	23316	40000000	4000	10000	18360.80	1.89
357	PROD2025-011.RECO	done	23 Apr 2025	24 Apr 2025	10	None	None	1250	2319.57	0.63
356	PROD2025-011.SIM	done	22 Apr 2025	23 Apr 2025	22496	5000000	4000	1250	2295.55	0.24
355	PROD2025-010.RECO	finished	18 Apr 2025	18 Apr 2025	37	None	None	1244	287.74	0.49
354	PROD2025-010.SIM	done	17 Apr 2025	17 Apr 2025	0	5000000	4000	1250	259.39	0.13
353	MC2025_S1-003-SIM.4	done	17 Apr 2025	17 Apr 2025	0	1000	100	10	0.21	0.00

Contents of the productions

- Modeling and reconstruction are made for p-p collisions with SpdRoot framework, which includes
 - geometric description of the SPD detector
 - particle propagation with Geant4
 - simplified simulation of detector response
 - reconstruction algorithms
- At the current stage of development, redundant information about particle interactions within the detector is still being retained; this will be subject to future event-size optimization as well as optimization during the modeling and reconstruction phases
- We run jobs in containers, recent migration of our JINR farm from Cent OS 7 to Alma Linux 9 went smoothly

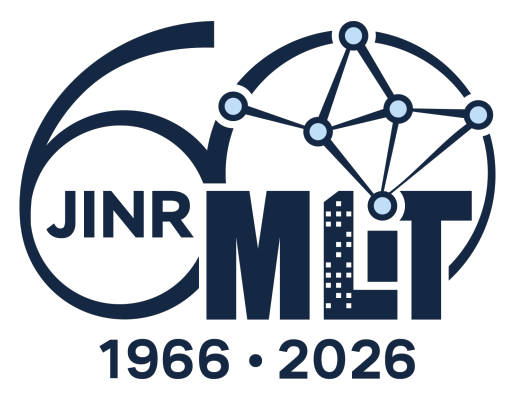


Applied software frameworks

- Current simulation and performance studies are done by framework SpdRoot, based on FairRoot
 - Does not fit well for massive data processing
 - With current hardware it's essential to provide multithreading mechanism
- A Gaudi-based software framework called Sampo is being developed:
 - Geometry description: GeoModel
 - Generators: Pythia8, FTF
 - In general any other generator can be used while it supports hepmc3 output format
 - Simulation: Geant4
 - Reconstruction: MdcHough track finding, ACTS (Kalman filter) for track fitting, Kfparticle for vertex reconstruction, own algorithms for other subsystems

Conclusions

- Offline computing environment of the SPD is now in the dev&ops stage: for some systems we have stable setups, while others are being intensively developed
- Middleware services came from the experience of the LHC experiments require quite an effort to be deployed and tuned, but allow to organize a distributed computing infrastructure which is able to cope with any pipelines and load
- We developed several systems and modules in order to make a simple, user friendly interface to tasks submission and to integrate middleware services
- Integration of Gaudi-based framework into the production system will be a challenging task for the current year
- We are grateful to our colleagues who are sharing their computing resources with us as their contribution to the experiment and looking forward to welcome more participants



Thank you!