Overview of the offline computing for the SPD experiment

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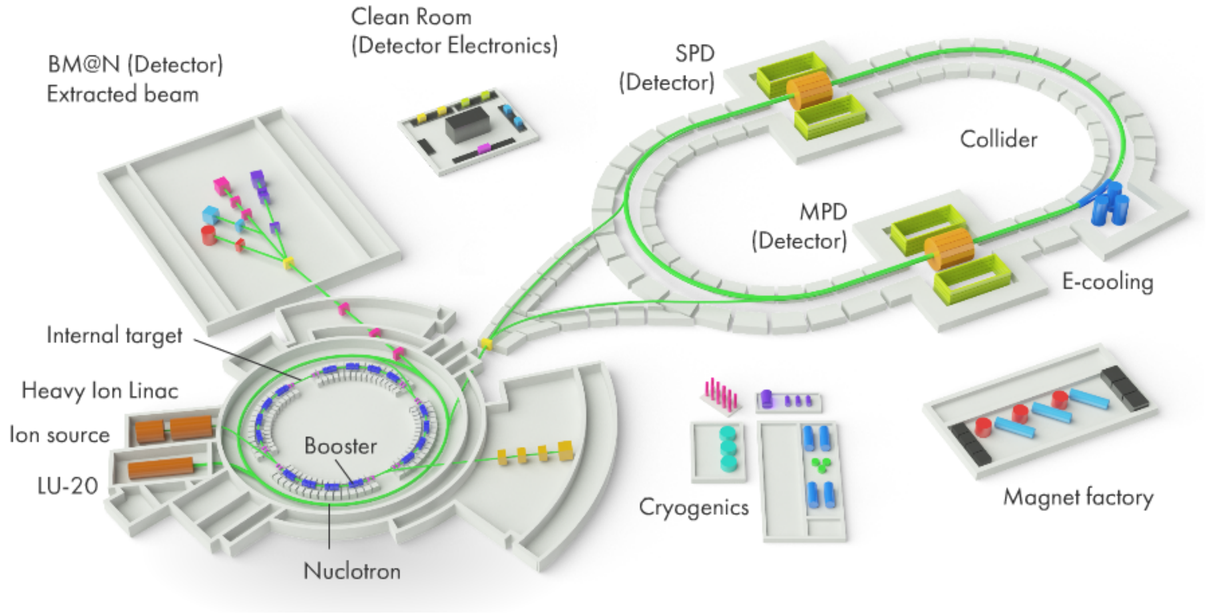
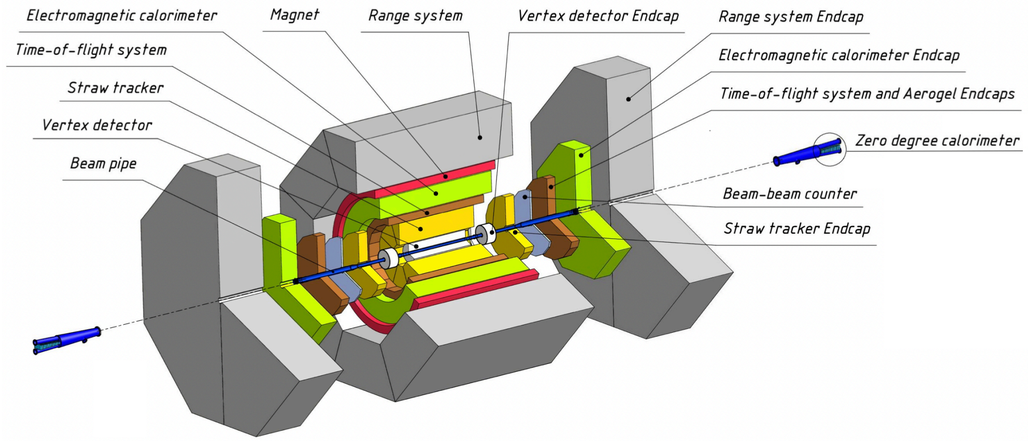
Spin Physics Detector at Nuclotron-based Ion Collider fAcility (NICA)

The spin structure of the **nucleon** is one of the fundamental properties of matter. The spin of a nucleon is distributed between its components — quarks and gluons, and their mutual movement.

The EMC, HERMES, and COMPASS experiments have made it possible to study in detail the contribution of quarks to spin. However, the role of gluons remains poorly understood and requires further research.

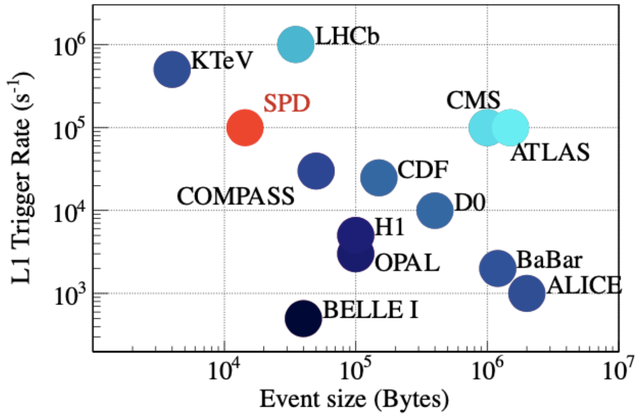




The SPD facility is being developed for a more accurate study of the contribution of gluons to the spin of the **nucleon**.

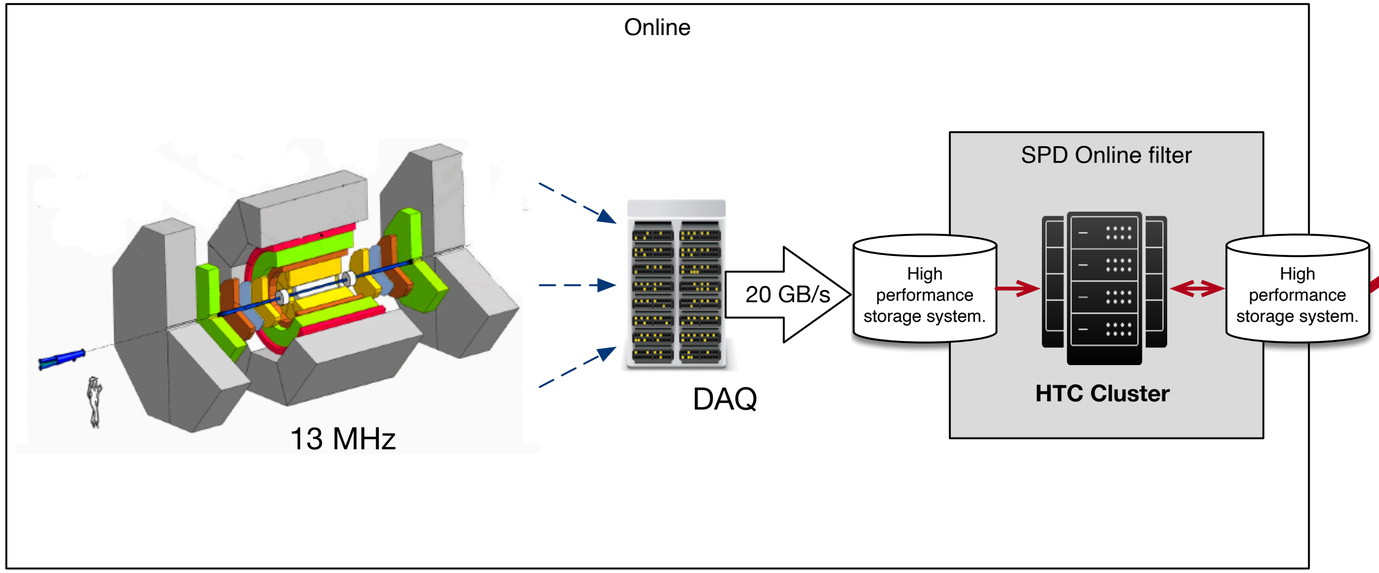
SPD as a data source

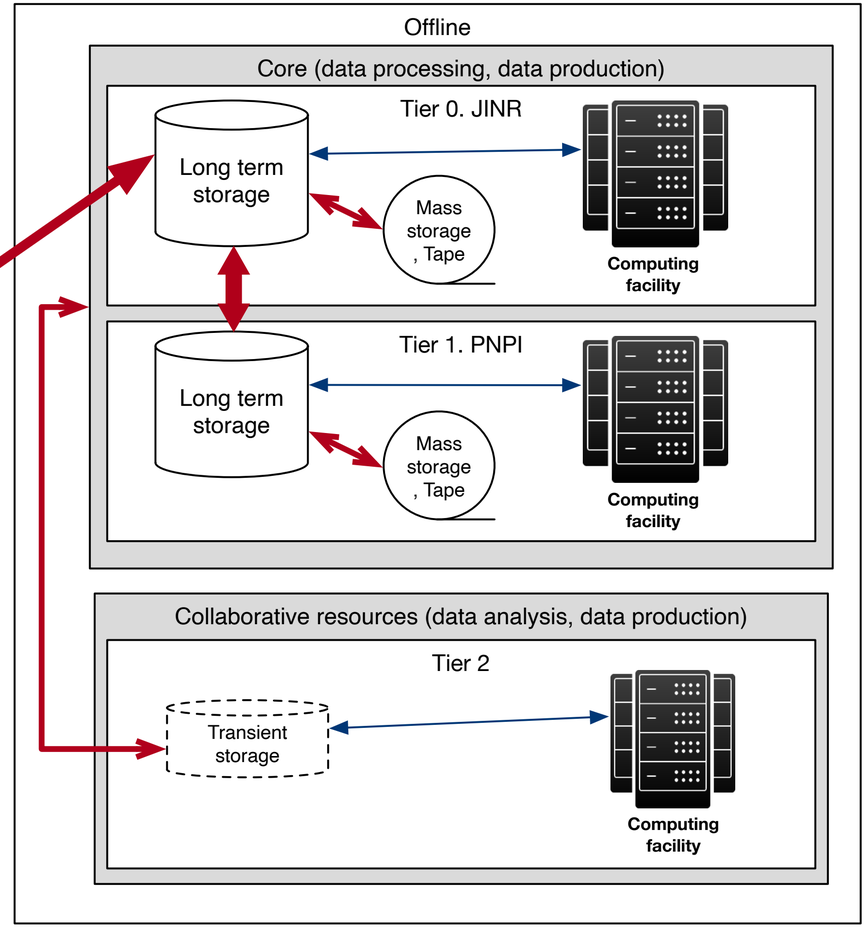
- The SPD detector is a medium scale setup in size, but a large scale one in data rate!
- Bunch crossing every 76,3 ns = crossing rate 13 MHz
- ~ 3 MHz event rate (at 10^{32} $cm^{-2}s^{-1}$ design luminosity)
- 20 GB/s (or 200 PB/year "raw" data, ~$3*10^{13}$ events/year)



- “Only" ~$1,5*10^{12}$ events/year are interesting for detailed study (~10PB/year) of data
- Selection of physics signal requires momentum and vertex reconstruction which means than no simple trigger is possible
- Comparable amount of simulated data

Data flow

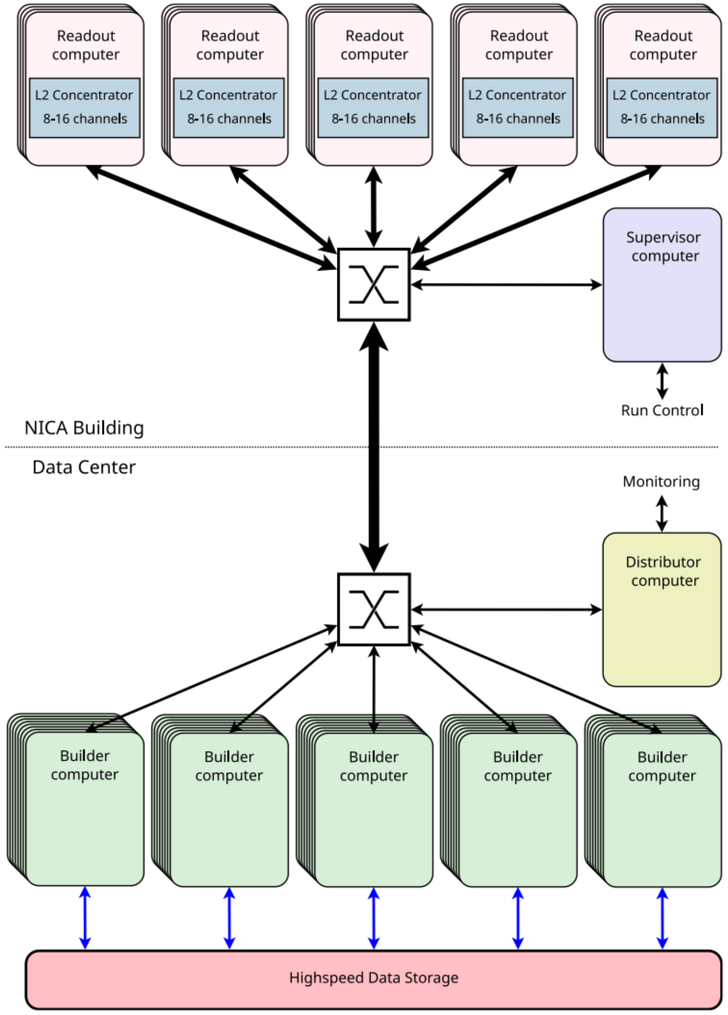


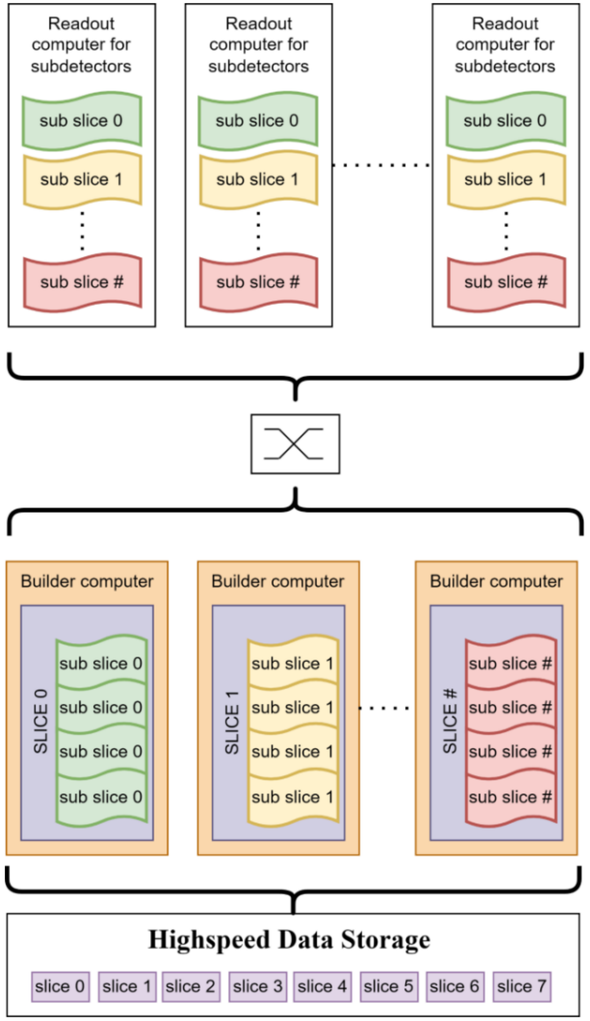


- DAQ
- Online filter: event building, partial reconstruction, software high-level trigger
- Offline computing: longterm storage, data production, data processing and analysis

DAQ

- Why triggerless DAQ:
  - No fast detectors to form a “classic” trigger signal
  - No 4π detector with 100% efficiency to detect the collisions
  - The wide SPD physical program eliminates a possibility of rejecting events at a hardware level
- Free run DAQ Speciality
  - DAQ provide data organized in time slices which placed in files with reasonable size (a few GB)
  - Each of these file may be processed independently as a part of top-level workflow chain

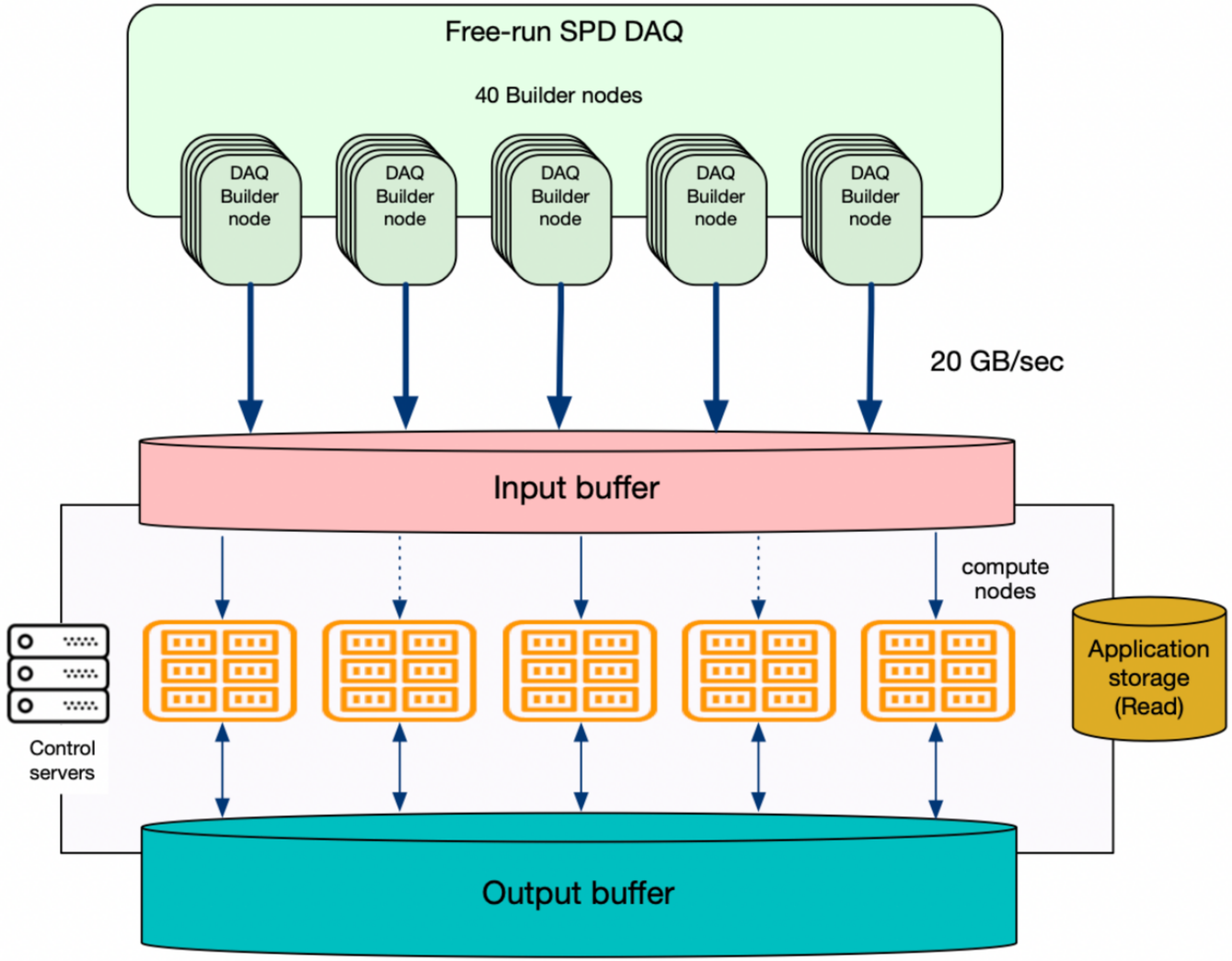




Online filter

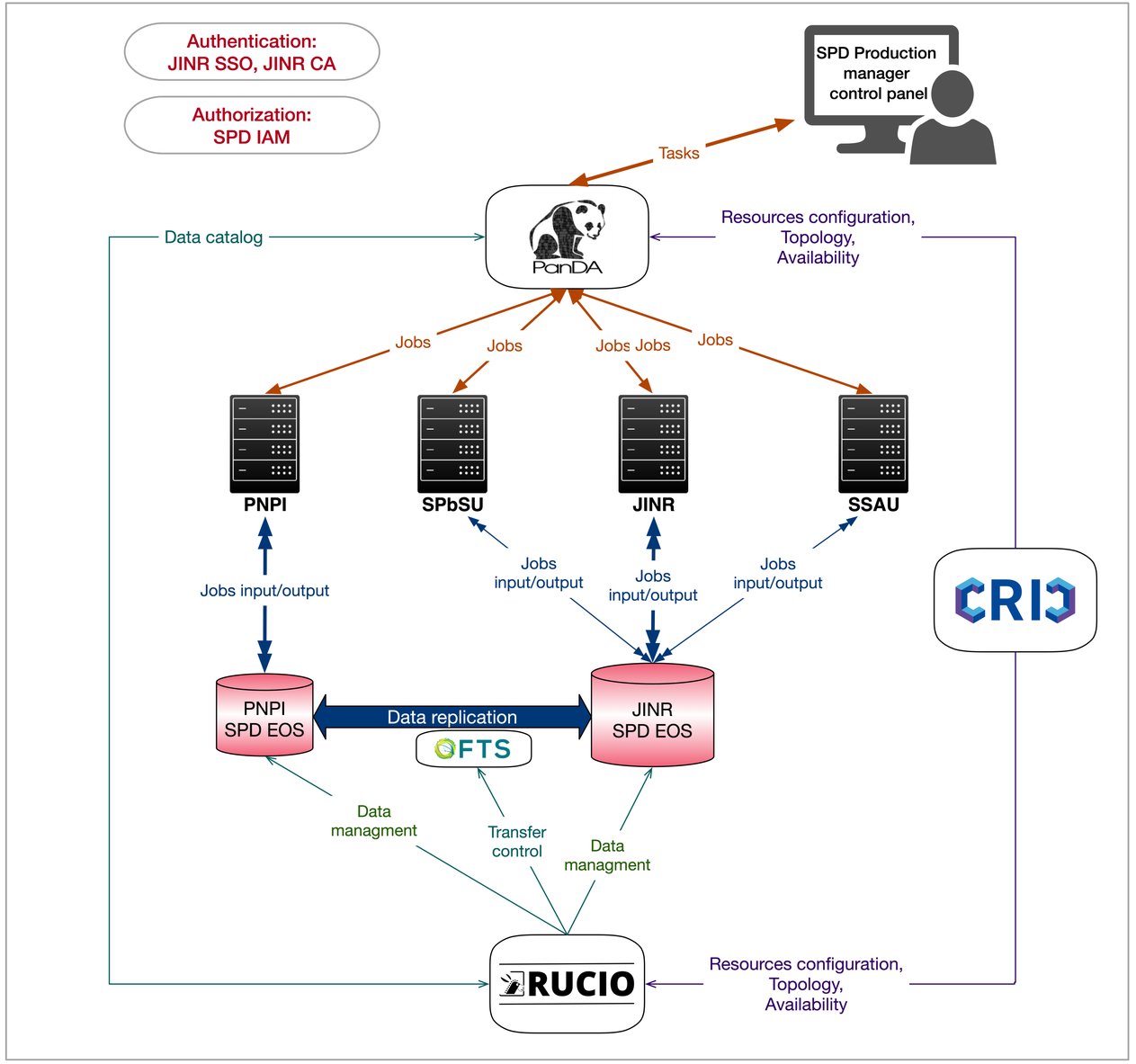
- Online filter is the first stage in data processing chain for SPD Experiment (right after DAQ)
- Main goals:
  - Events unscrambling through partial reconstruction
  - Software trigger, which essentially is event filter

- SPD Online Filter is a high performance computing system for high throughput processing
  - Hardware component: compute cluster with two storage systems and set of working nodes: multi-CPU and hybrid multi CPU + Neural network accelerators (GPU, FPGA etc.)
  - Applied software: performs informational processing of data. Had to use same framework as ‘offline’ applied software
  - Middleware component: software complex for management of multistep data processing and efficient loading (usage) of computing facility

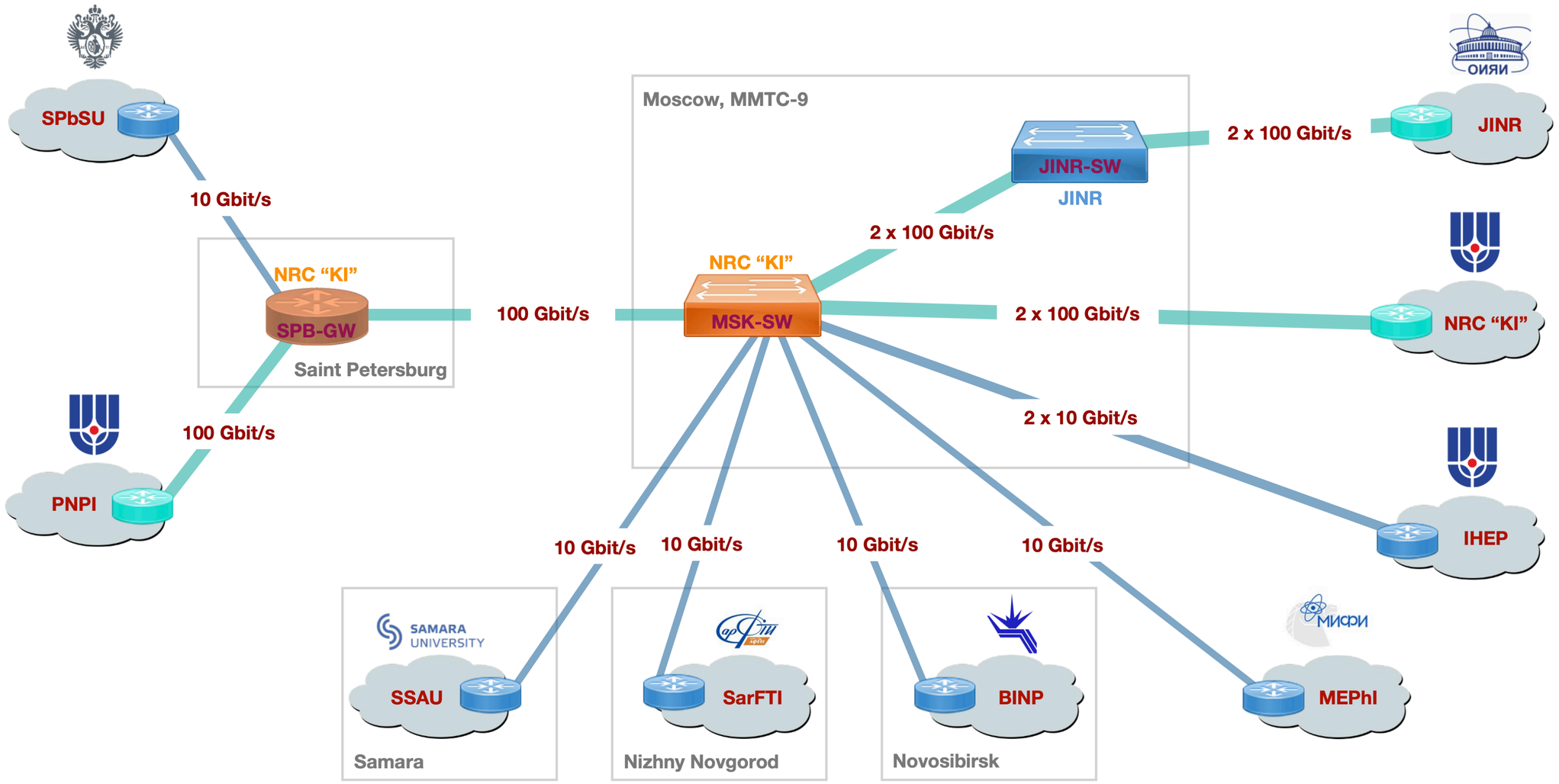


Offline computing

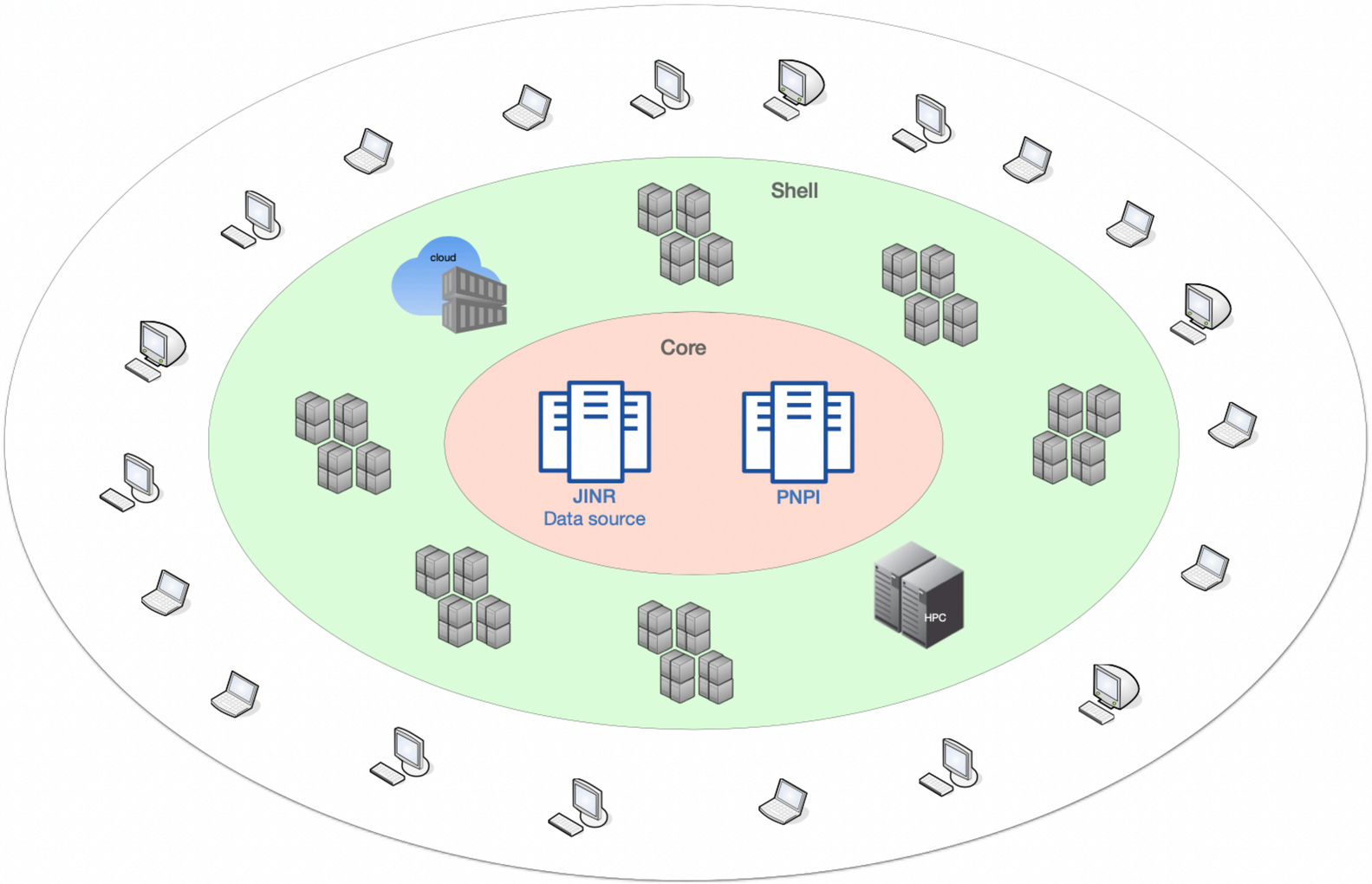
- Authentication system: **JINR SSO**.
- Authorization system: **SPD IAM**, an entry point to all members of the computing services of the collaboration: stores user profiles, their roles and rights to perform certain actions.
- Information system: **CRIC**, the main integration component of the computing system: contains info about all computing and storage resources, access protocols, entry points, and many other things in one place and distributes this info via API to all other components mentioned below.
- Software distribution service: **CVMFS**.
- Data management system: **Rucio**, responsible for data management, including data catalog, data integrity and data lifetime management.
- Data transfer service: **FTS**, enables massive data transfers.
- Workflow management system: Requests/Control Panel/ PanDA. **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.
- Workload management system: PanDA/Harvester/Pilot.



Russian scientific backbone



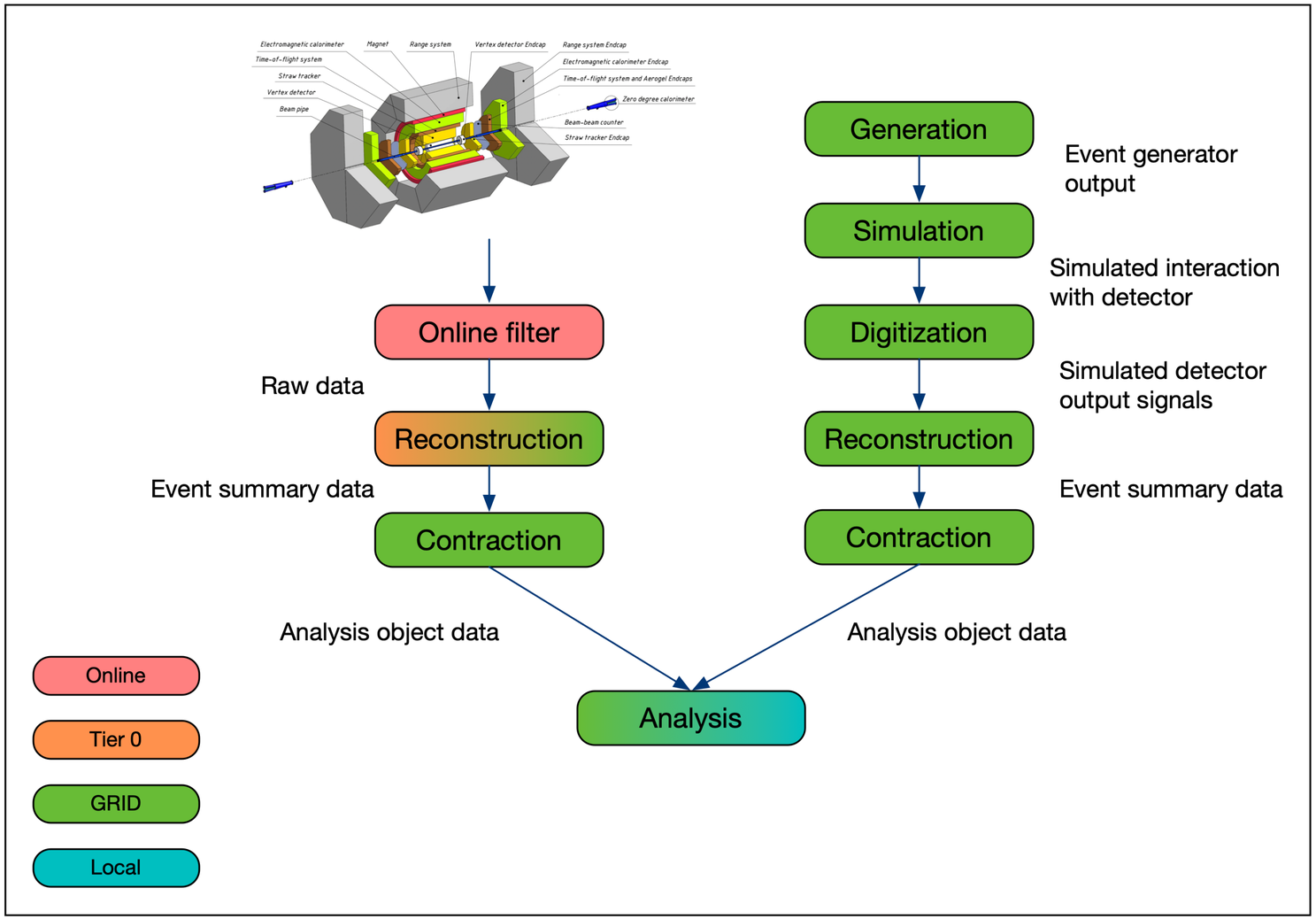
Sites hierarchy



- 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

Data processing steps in the distributed environment

- The tasks of event reconstruction and reprocessing are accompanied by intensive I/O operations and will be carried out mainly on dedicated core sites
- Less intensive I/O operations, especially Monte Carlo simulations, can be performed in remote computing centers, for example, at farms of members of the collaboration
- User analysis can be performed on any, most likely local, resource

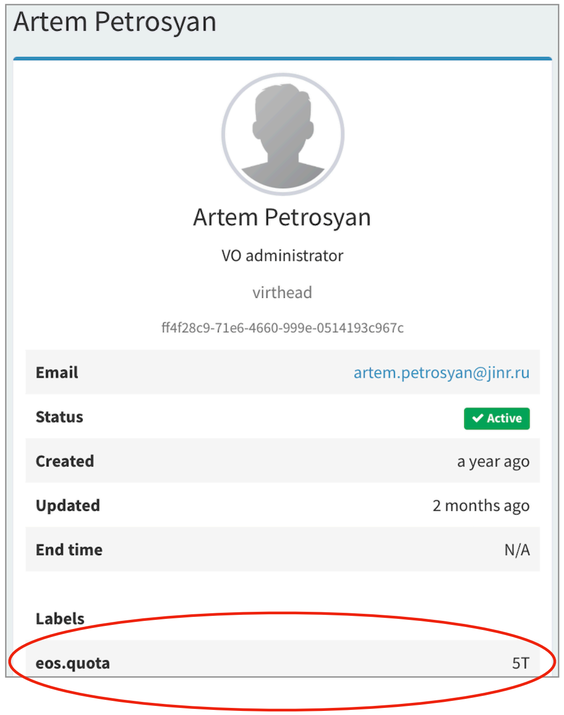


Middleware services integration

- 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



CRIC

cosmo | Core | Core API | NICA | NICA API | Admin | Logs | Help | artem.petrosyan@ji…

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 | Core | Core API | NICA | NICA API | Admin | Logs | Help | artem.petrosyan@ji…

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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**

Productions requests management system

SPD Data processing

Requests Config API artem.petrosyan@ji…

Export Columns 17/23 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: PROD2025-020.SIM.1

Output dataset name: MC2025_S2.minbias-P8-spdroot4174-dev.27GeV-UU.PROD2025-020.SIM.1

Naming convention here

Total events: 40000000

Events per job: 4000

Cloud: RU

Data disk: SPDDATA

Skip scout: ☑

Offset: 0

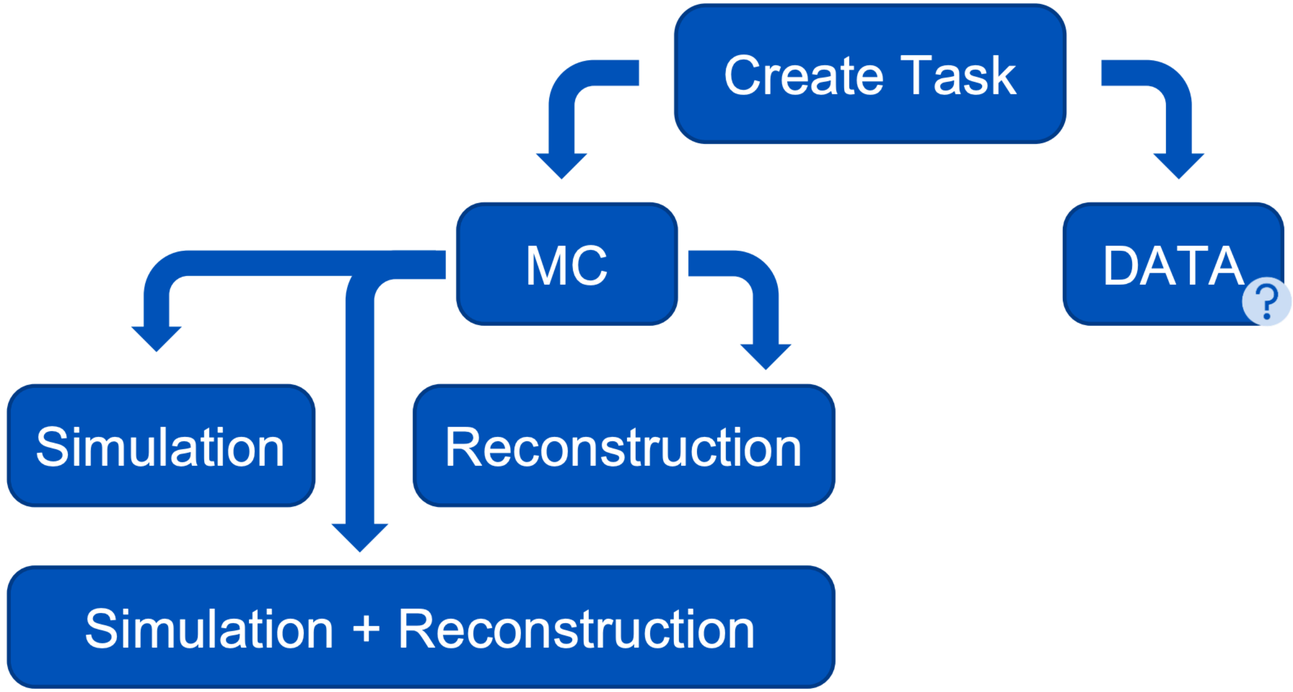
Path to execution files: /cvmfs/spd.jinr.ru/production/MC/minbias-P8-spdroot4174-dev.27GeV.V01

smth like -> /cvmfs/spd.jinr.ru/production/MC/minbias-P8-spdroot417-dev.10GeV.V01

Path to container: /cvmfs/spd.jinr.ru/images/spdroot-dev-4.1.7.4.sif

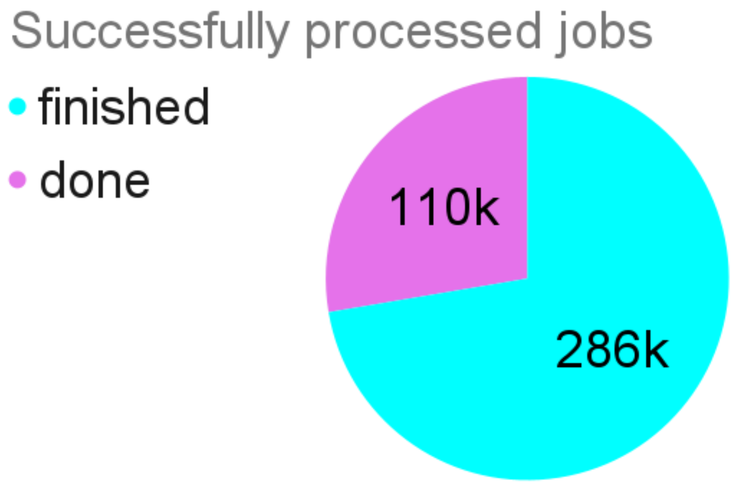
smth like -> /cvmfs/spd.jinr.ru/images/spdroot-dev-4.1.7.sif

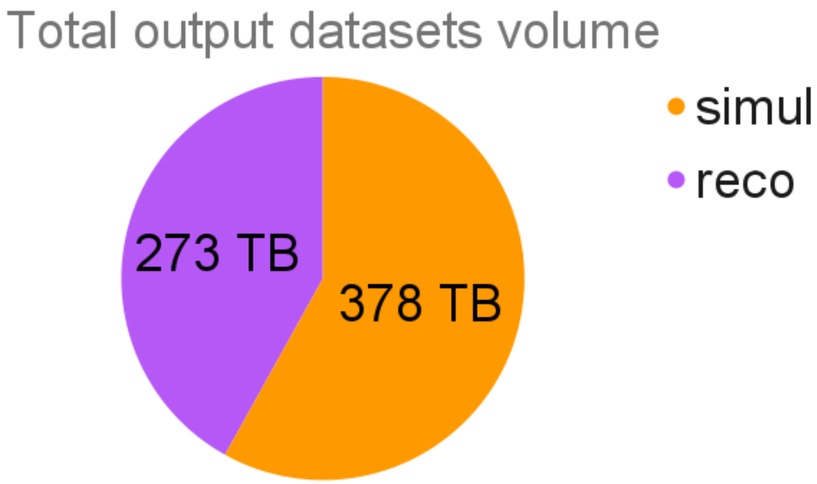
Create task



- 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

Central production stats in 2025





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

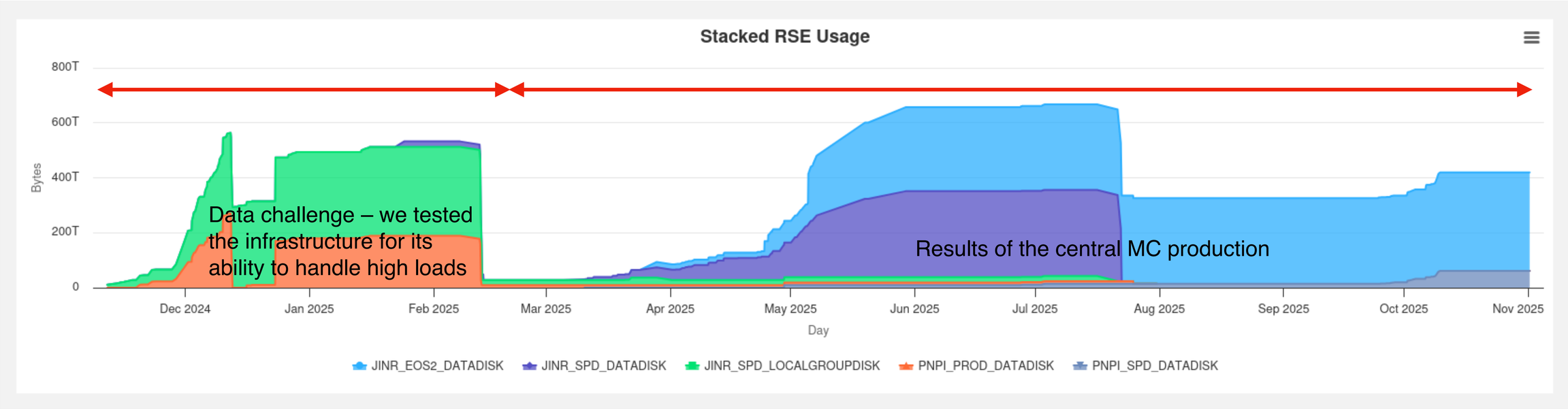
Content of the productions

- 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

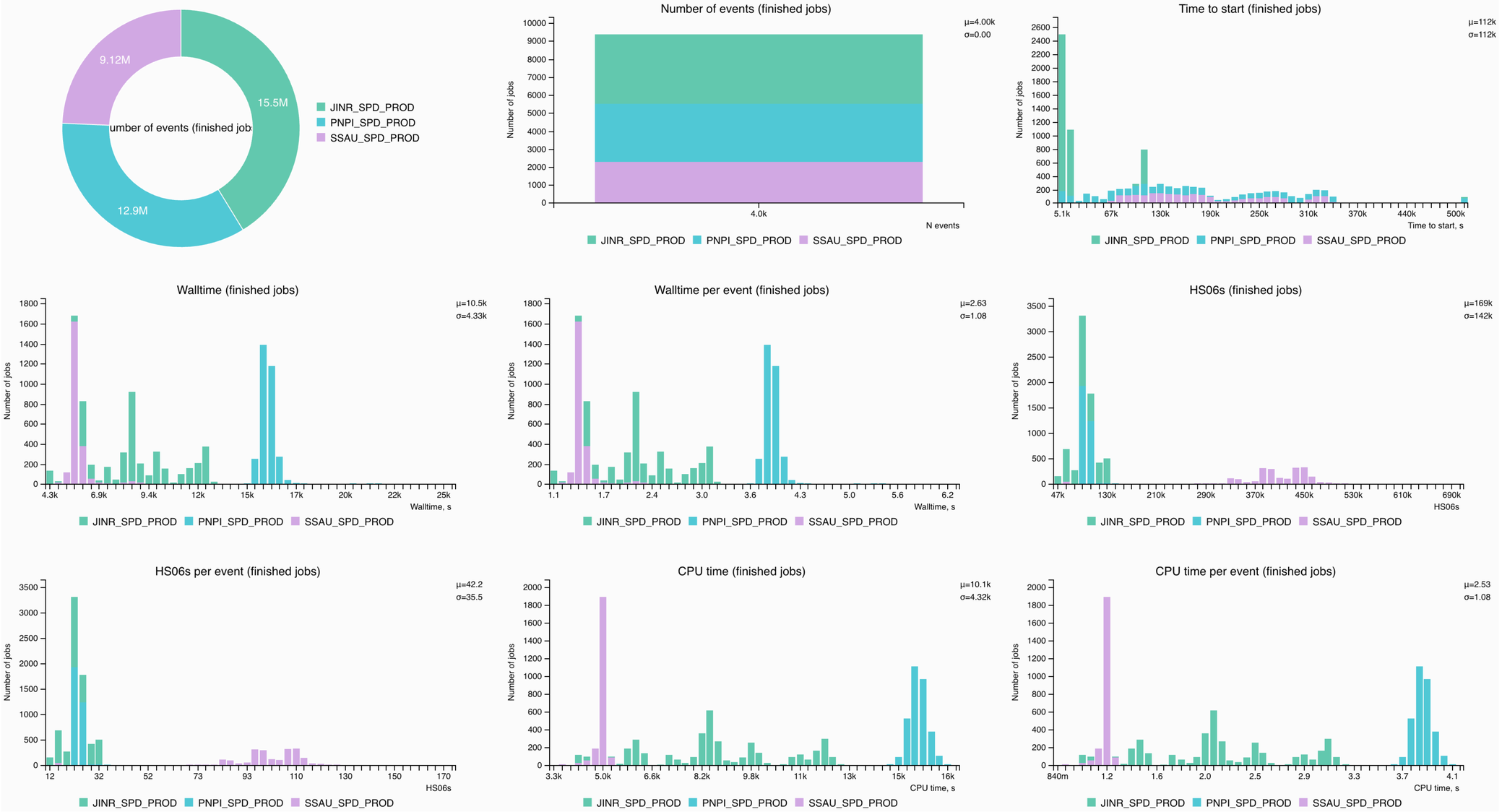
- Current simulation and performance studies are done by framework SpdRoot, based on FairRoot
  - Does not fit well for massive data processing
    - With current hardware it’s essential to provide multithreading mechanism
- A Gaudi-based software framework called Sampo is being developed:
  - Geometry 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

Distributed data management



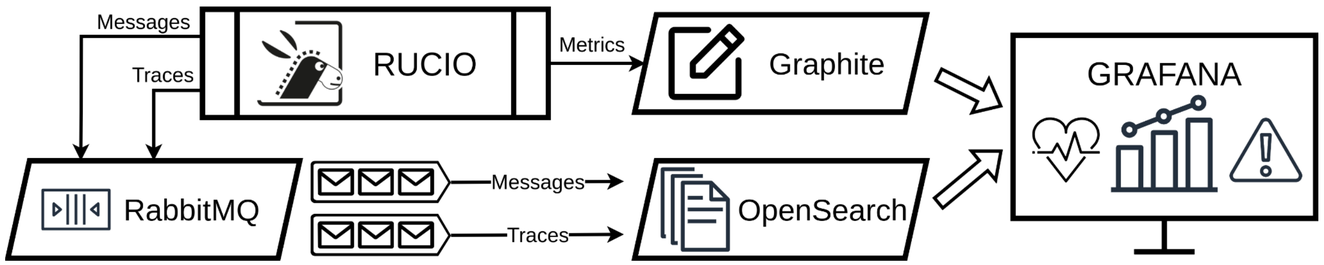
- At the moment there are two storages are available: at JINR and at PNPI, we expect more remote storages to connect
- This year we migrated from the shared JINR EOS to the dedicated EOS for the SPD
- Final results of the central productions replicated automatically to both JINR and PNPI
- There is ongoing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

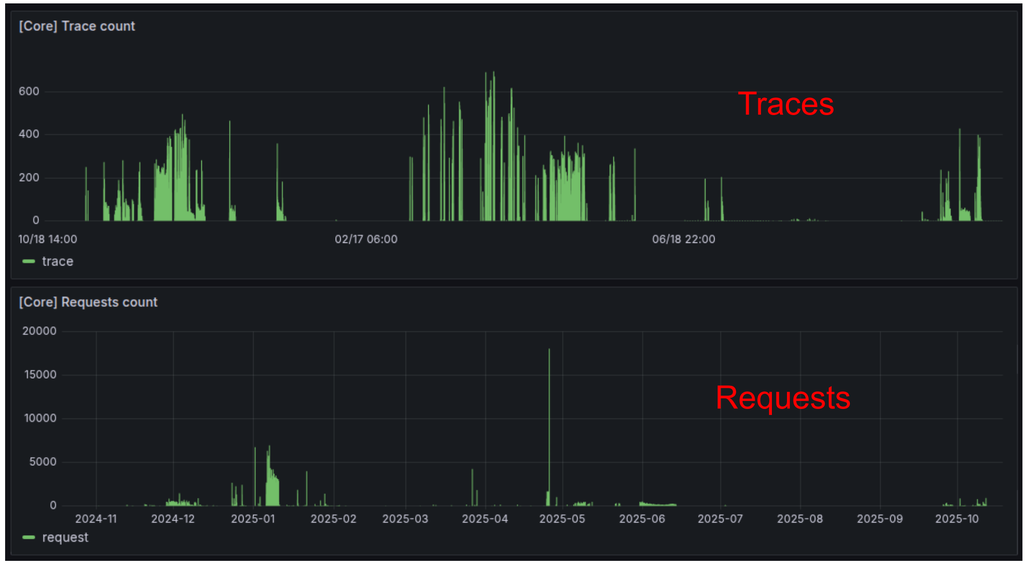
Processing monitoring



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

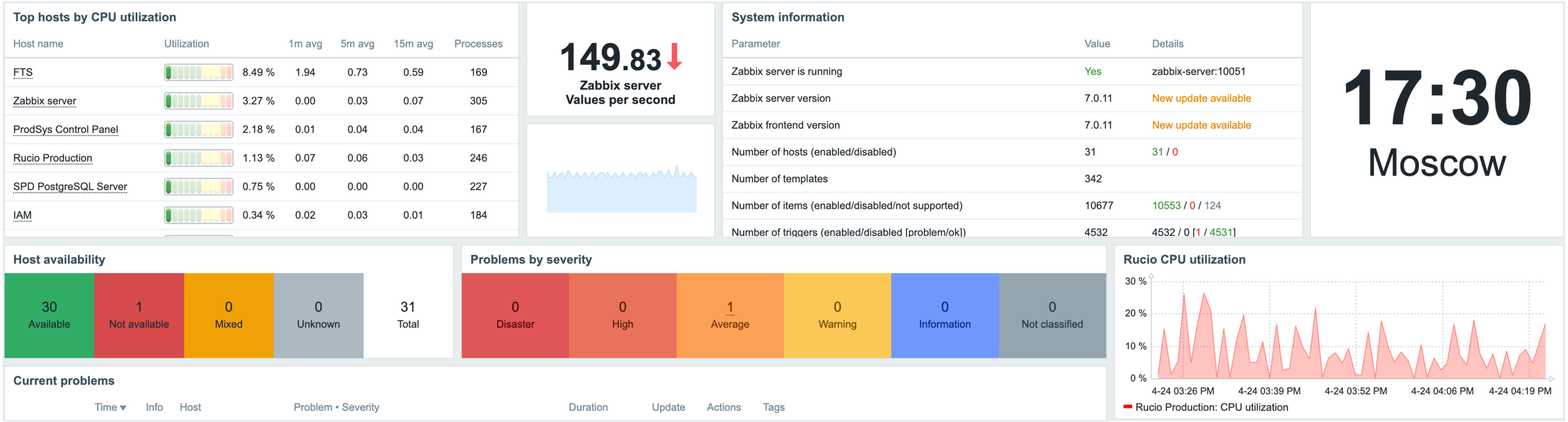
Data management monitoring





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

Infrastructure Monitoring



- An instance of Zabbix was deployed in order to enable monitoring of our growing infrastructure
- At the moment it is very basic setup but we expect to have an integrated monitoring with panels from service-specific metrics, not only OS metrics like CPU utilization, etc.
- There is ongoing development of regular middleware services tests (similar to Hammer Cloud in ATLAS)

Conclusions

- Offline computing environment of the SPD is now in the dev&ops stage: for some systems we have stable setups, 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
- Network is a crucial component of distributed computing systems
- Monitoring such multi component system is also rather large task, and it is under development
- Integration of Gaudi-based framework into the production system will be a challenging task for the next year
- We are grateful to our colleagues who are sharing their computing resources with us as their contribution to the experiment and looking forward for more participants

Thank you!

backup

Data processing steps

- Free run DAQ increased complexity of data production (Monte-Carlo)
- Raw data in timeslices should be simulated along with events simulation