

# **SPD Software & Computing**

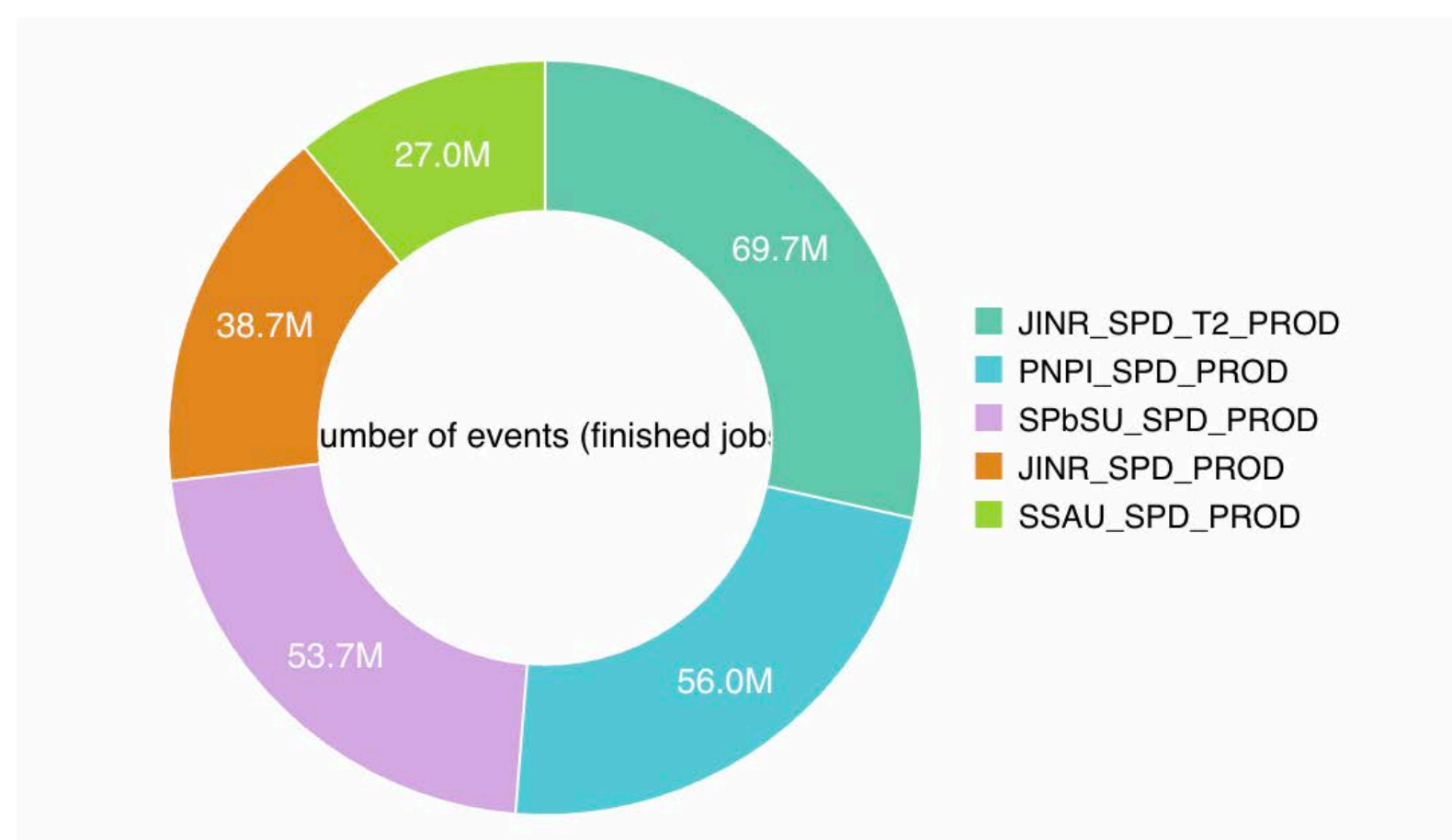
**Current status**

**Danila Oleynik 18.05.2026**

# Outline

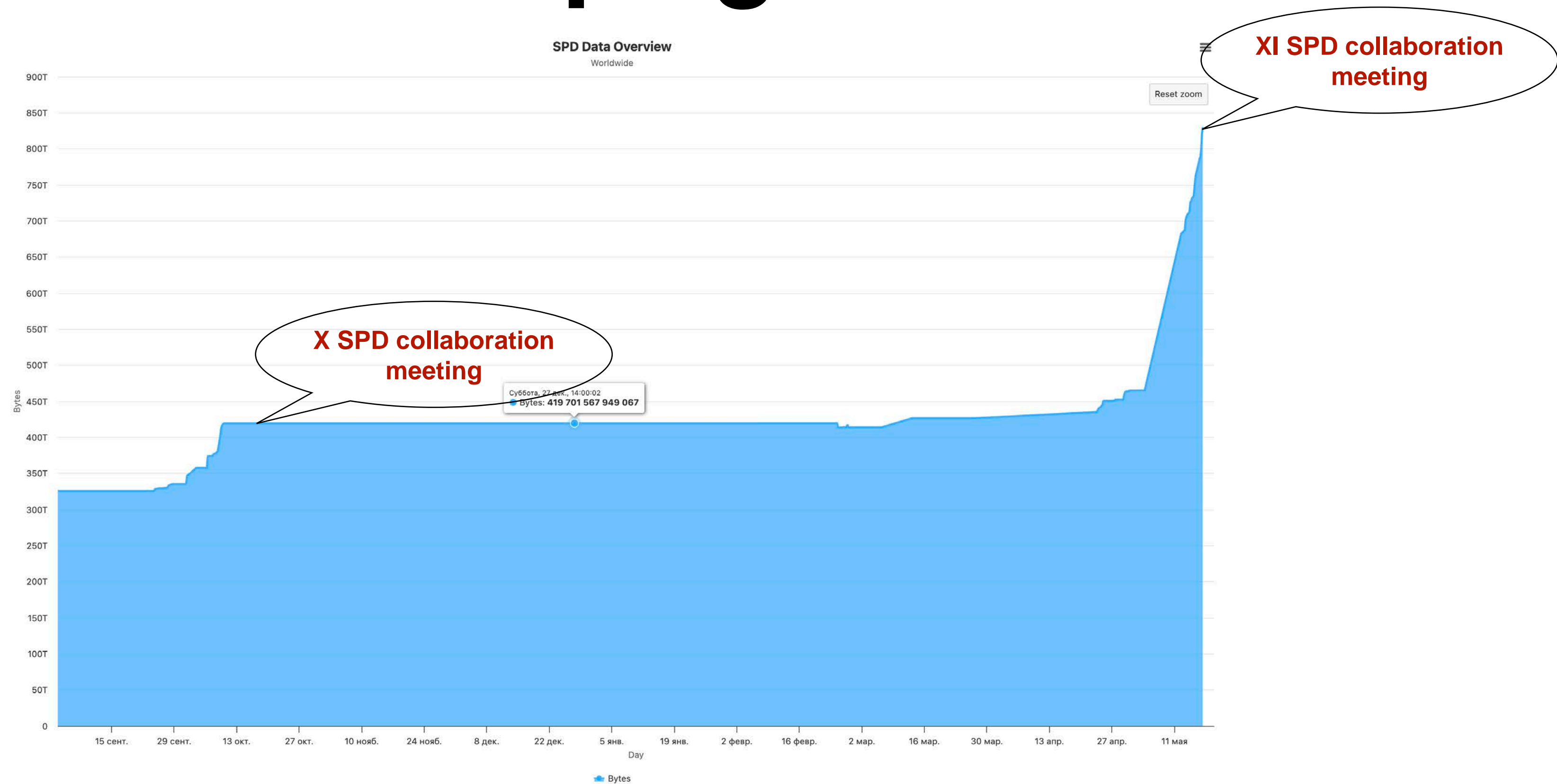
- Distributed data processing
- The SPD Online filter
- Software

# Distributed data processing



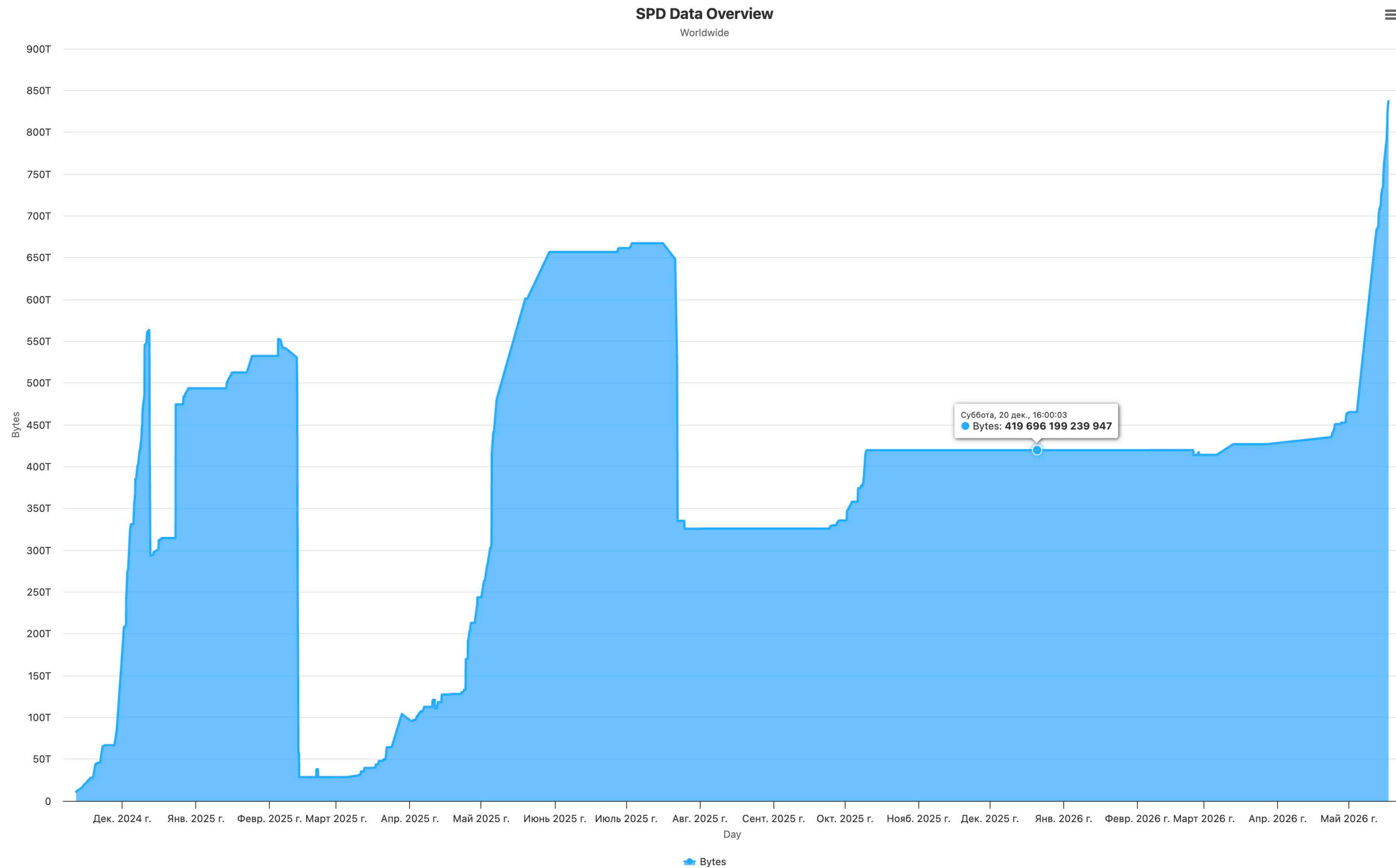
- Compute resources: Five sites are intergrated into production system:
  - JINR: around 1500 + 1500 CPUs on two different compute farms (total up to 3000)
  - PNPI: around 280 CPUs (most stable site)
  - SSAU (Samara): around 250 CPUs
  - SPbSU: around 250 CPUs
- Operational support increases step by step.
  - More monitoring and accounting tools would be desirable.
- Dedicated compute resources for SPD were acquired at JINR: approximately 3000 modern CPUs, each with up to 4 GB of RAM. These are expected to be available data production during the summer.

# Data production campaigns



- Resources are only available for production use on an occasional basis — a practice that is unacceptable.
  - The reliability of the system's components remains unknown. A test suite alone cannot guarantee smooth operation with real environment.
  - Competition for both computing and storage resources has already emerged.

# SPD MC Data



- More than 840TB of MC data already managed by SPD
- We may track way this data appears, and why this data is needed.

# Production system updates

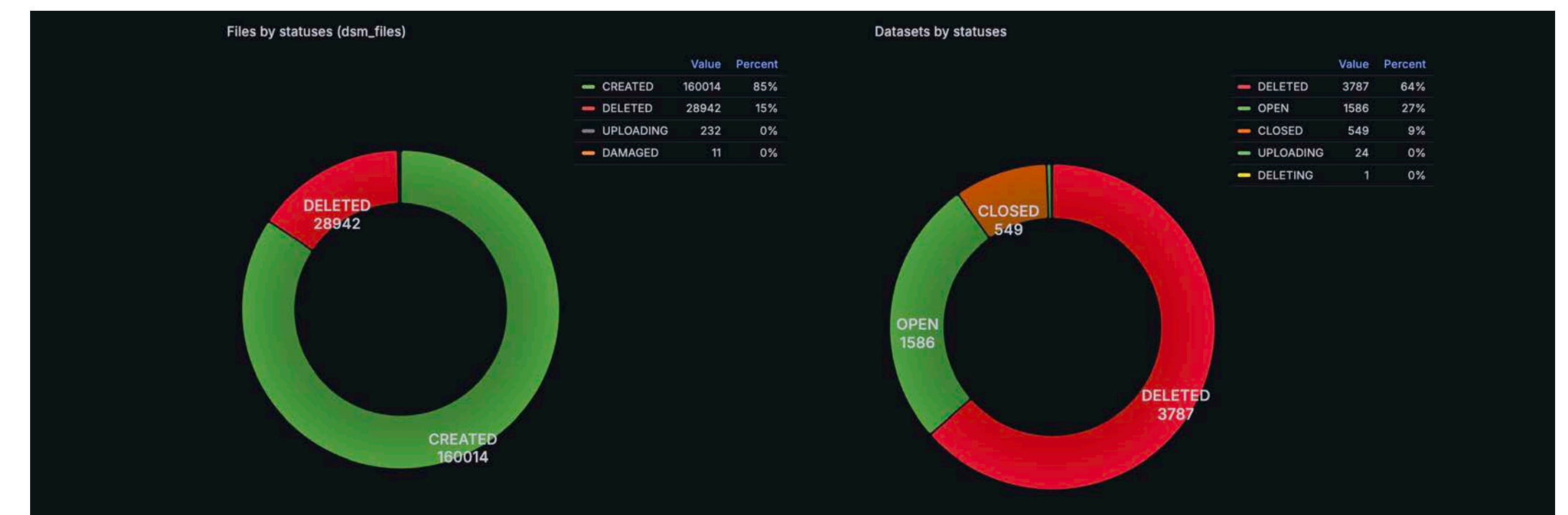
- Reorganization of JINR compute resources: two PanDA queues, each corresponding to a different CICC facility.
- Rucio upgrade and Rucio monitoring.
- Major upgrade of PanDA.
  - PanDA monitoring
- Integration between the production manager's control panel and the Requests DB is in progress.
- Development of the Distributed computing test suite has begun.

*More details in reports from Artem, Nikita, Alexey this Wednesday*

# The SPD Online filter

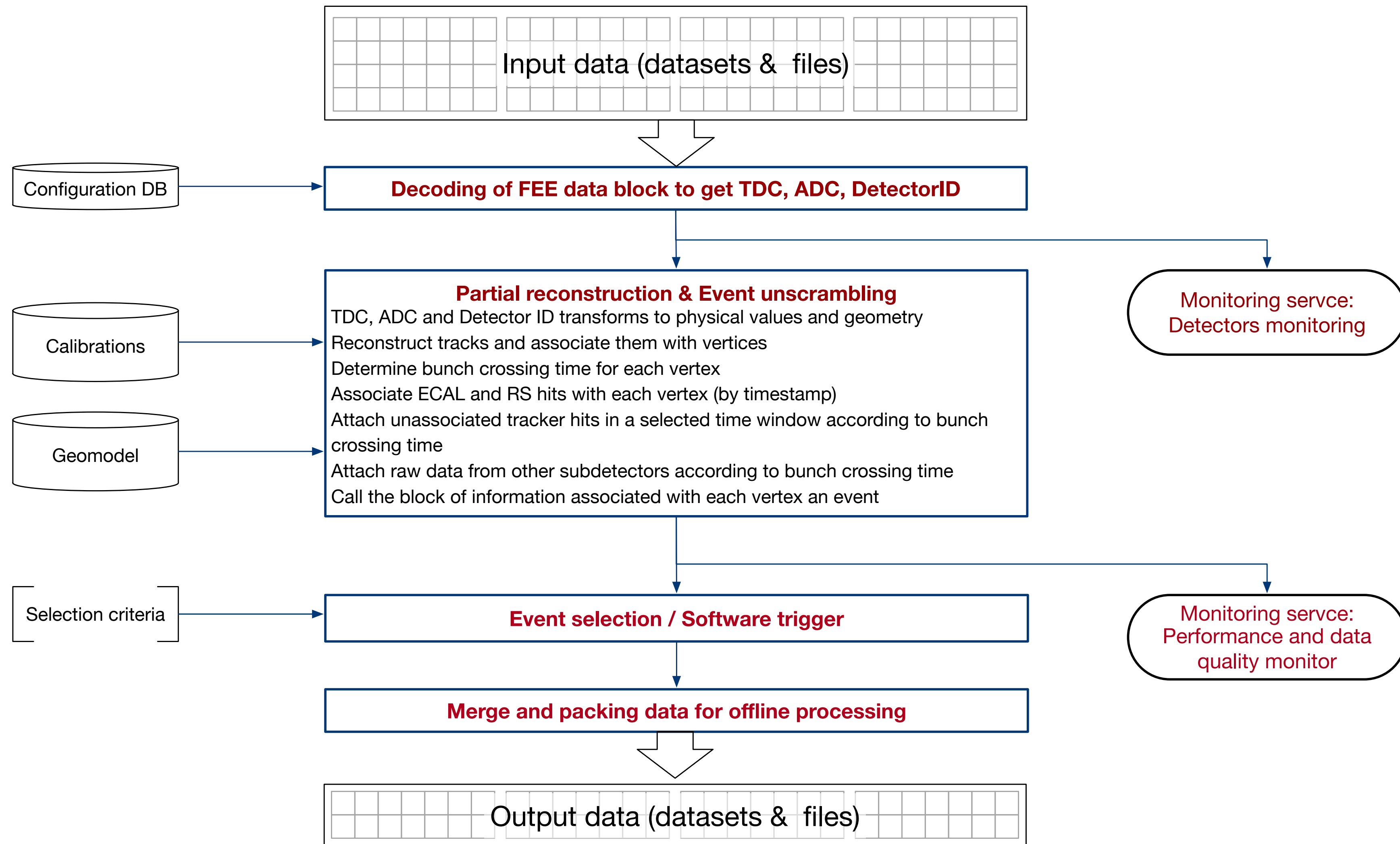
- Hardware for prototype have been have been up and running
  - 256 CPU Cores, 1TB RAM, 120TB HDD
- Private cloud managed through infrastructure as a code solution
- Scale up debugging of middleware components
- Development of monitoring system have been started

Name	Comment	Host	IP Addresses	FQDN	Cluster	Data Center	Memory	CPU	Network	Graphics	Status	Uptime	Description	
AlmaLinux9.7-template-maker-v1		sof-srv1.jinr.ru	10.17.245.50 fe80::546fe0ff:fe38:0		SOF	JINR	--	--	--	None	Down		VM that will be used to	
AlmaLinux10.1-temp		sof-srv3.jinr.ru	10.17.245.55 fe80::546fe0ff:fe38:4e	daq	SOF	JINR	16%	0%	0%	0%	VNC	Up	85 days	first attempt
HostedEngine		sof-srv4.jinr.ru	10.17.245.31 fe80::2163eff:fe52:c95b	sof-virt.jinr.ru	SOF	JINR	44%	1%	0%	0%	VNC	Up	101 days	Hosted engine VM
pilot-agent-1		sof-srv2.jinr.ru	10.17.245.121 fe80::546fe0ff:fe38:53	pilot-agent-1	SOF	JINR	20%	5%	0%	0%	VNC	Up	17 days	
pilot-agent-2		sof-srv3.jinr.ru	10.17.245.218 fe80::546fe0ff:fe38:54	pilot-agent-2	SOF	JINR	21%	3%	0%	0%	VNC	Up	2 days	
pilot-agent-20		sof-srv2.jinr.ru	10.17.245.96 fe80::546fe0ff:fe38:66	pilot-agent-20	SOF	JINR	21%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-21		sof-srv4.jinr.ru	10.17.245.184 fe80::546fe0ff:fe38:67	pilot-agent-21	SOF	JINR	21%	4%	0%	0%	VNC	Up	10 days	
pilot-agent-22		sof-srv2.jinr.ru	10.17.245.135 fe80::546fe0ff:fe38:68	pilot-agent-22	SOF	JINR	21%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-23		sof-srv3.jinr.ru	10.17.245.188 fe80::546fe0ff:fe38:69	pilot-agent-23	SOF	JINR	20%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-24		sof-srv4.jinr.ru	10.17.245.131 fe80::546fe0ff:fe38:6a	pilot-agent-24	SOF	JINR	21%	5%	0%	0%	VNC	Up	10 days	
pilot-agent-25		sof-srv2.jinr.ru	10.17.245.207 fe80::546fe0ff:fe38:6b	pilot-agent-25	SOF	JINR	20%	4%	0%	0%	VNC	Up	10 days	
pilot-agent-26		sof-srv4.jinr.ru	10.17.245.146 fe80::546fe0ff:fe38:6c	pilot-agent-26	SOF	JINR	21%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-27		sof-srv3.jinr.ru	10.17.245.72 fe80::546fe0ff:fe38:6d	pilot-agent-27	SOF	JINR	21%	4%	0%	0%	VNC	Up	10 days	
pilot-agent-28		sof-srv2.jinr.ru	10.17.245.113 fe80::546fe0ff:fe38:6e	pilot-agent-28	SOF	JINR	21%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-29		sof-srv3.jinr.ru	10.17.245.171 fe80::546fe0ff:fe38:6f	pilot-agent-29	SOF	JINR	20%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-30		sof-srv4.jinr.ru	10.17.245.203 fe80::546fe0ff:fe38:70	pilot-agent-30	SOF	JINR	21%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-31		sof-srv2.jinr.ru	10.17.245.166 fe80::546fe0ff:fe38:71	pilot-agent-31	SOF	JINR	21%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-32		sof-srv4.jinr.ru	10.17.245.85 fe80::546fe0ff:fe38:72	pilot-agent-32	SOF	JINR	21%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-33		sof-srv3.jinr.ru	10.17.245.83 fe80::546fe0ff:fe38:73	pilot-agent-33	SOF	JINR	20%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-34		sof-srv2.jinr.ru	10.17.245.140 fe80::546fe0ff:fe38:74	pilot-agent-34	SOF	JINR	21%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-35		sof-srv3.jinr.ru	10.17.245.211 fe80::546fe0ff:fe38:75	pilot-agent-35	SOF	JINR	20%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-36		sof-srv4.jinr.ru	10.17.245.92 fe80::546fe0ff:fe38:76	pilot-agent-36	SOF	JINR	21%	3%	0%	0%	VNC	Up	10 days	
pilot-agent-37		sof-srv2.jinr.ru	10.17.245.57 fe80::546fe0ff:fe38:77	pilot-agent-37	SOF	JINR	21%	4%	0%	0%	VNC	Up	10 days	
pilot-agent-38		sof-srv4.jinr.ru	10.17.245.160 fe80::546fe0ff:fe38:78	pilot-agent-38	SOF	JINR	20%	4%	0%	0%	VNC	Up	10 days	
sof-export		sof-srv4.jinr.ru	10.17.245.41 fe80::546fe0ff:fe38:4d	dtm	SOF	JINR	11%	0%	0%	0%	VNC	Up	43 days	
template-maker		sof-srv2.jinr.ru	10.17.245.70 fe80::546fe0ff:fe38:40		SOF	JINR	10%	0%	0%	0%	VNC	Up	56 days	
test-dhcp		sof-srv2.jinr.ru	10.17.245.52 fe80::546fe0ff:fe38:4a	vasya	SOF	JINR	18%	0%	0%	0%	VNC	Up	45 days	
test-dhcp-2		sof-srv2.jinr.ru	10.17.245.53 fe80::546fe0ff:fe38:4b	petya	SOF	JINR	18%	0%	0%	0%	VNC	Up	45 days	
test-vm-01		sof-srv2.jinr.ru	10.17.245.61 fe80::546fe0ff:fe38:23		SOF	JINR	12%	0%	0%	0%	VNC	Up	72 days	
test-vm-02		sof-srv3.jinr.ru	10.17.245.62 fe80::546fe0ff:fe38:24		SOF	JINR	11%	0%	0%	0%	VNC	Up	72 days	
test-vm-03		sof-srv1.jinr.ru	10.17.245.63 fe80::546fe0ff:fe38:25		SOF	JINR	11%	0%	0%	0%	VNC	Up	70 days	
test-vm-04		sof-srv2.jinr.ru	10.17.245.64 fe80::546fe0ff:fe38:26		SOF	JINR	11%	0%	0%	0%	VNC	Up	70 days	
test-vm-05		sof-srv3.jinr.ru	10.17.245.65 fe80::546fe0ff:fe38:2d		SOF	JINR	12%	0%	0%	0%	VNC	Up	57 days	
VM-DSM		sof-srv1.jinr.ru	10.17.245.105 fe80::546fe0ff:fe38:47	dms	SOF	JINR	33%	16%	0%	0%	VNC	Up	52 days	
VM-WFMS		sof-srv4.jinr.ru	10.17.245.91 fe80::546fe0ff:fe38:48	wfms	SOF	JINR	14%	1%	0%	0%	VNC	Up	52 days	
VM-WMS		sof-srv3.jinr.ru	10.17.245.101 fe80::546fe0ff:fe38:43	wms	SOF	JINR	18%	0%	0%	0%	VNC	Up	52 days	



More details in reports from Nikita and Polina this Wednesday

# Data processing workflow on SPD online filter



# Sampo update

- **JobConfigurator** to simplify job configuring on python's side
- **GeometryManagers** to keep detector geometry information
- Interesting particles arising during simulation are now saved and can be used by downstream algorithms
- **MetaDataSvc** for metadata handling
- **HepMC2** compatibility
- **G4ParticleGunAlg** for debugging and testing purposes
- Functionality that allows to update materials exported from GeoModel
- Possibility to add arbitrary amount of Event- and Tracking- actions for Geant4 simulation
- pytests
- **Documentation** wiki (<https://git.jinr.ru/spd/spd-sw/sampo/-/wikis/home>)
- RSMCHits, ECalMCHits and ECalDigis

*Lev, Iliya, Alexandr will present details this Wednesday*

# Manpower

## Detectors geometry, MC Hit production + digitization

Detector	SPD Geomodel description	MC Hit production
Micromegas-based Central Tracker	✓	✓
Double-Sided Silicon Vertex Detector	Wanted	Wanted
MAPS-based vertex detector	Wanted	Wanted
Straw-based Tracking system	✓	✓
Outer Beam-Beam Counter	Wanted	Wanted
Inner Beam-Beam Counter	Wanted	Wanted
Range System	✓	✓
Zero Degree Calorimeters	✓	✓
Electromagnetic Calorimeter	✓	✓
Time-of-Flight system	Wanted	Wanted
Aerogel Cherenkov detector	✓	✓

# CHEP 2026 (Next week)

## Four SPD software&computing related presentations

- ▶ *The SPD Online filter.*
- ▶ *Distributed computing system for the SPD experiment.*
- ▶ *The SPD Software&Computing project. (Poster)*
- ▶ *Federation of compute and storage resources for SPD offline computing. (Poster)*

**The SPD Software & Computing project**  
Danila Oleynik, Artem Petrosyan, Andrey Kiryanov

The Spin Physics Detector (SPD) collaboration is building a versatile detector at the second interaction point of the NICA (Nucleon-based Ion Collider Facility) complex. As the detector's development progresses and the physics research program evolves, the demands for advanced data processing capabilities increase. A defining feature of the facility is its free-running Data Acquisition (DAQ) system. This system places substantial demands on the preprocessing of collected data, events must be unscrambled and filtered in real-time from a continuous data stream. The raw data stream is estimated at 20 GB/s, requires reduction to approximately 1 GB/s during initial processing at a dedicated computing facility. The annual volume of preprocessed data is projected to reach 10 petabytes (PB), supplemented by a comparable amount of simulated data. Offline processing and long-term storage for this data are managed through a distributed computing system. Consequently, the entire data processing chain, even for a mid-scale high-energy physics (HEP) experiment like the SPD, necessitates substantial software and computing support.

**No trigger = No "classical" events at the start**

- Free-running DAQ, means that the output of the system will not be a dataset of raw events, but a set of frontend electronics (FEE) data blocks from detectors organized in timeslices
- Primary data unit: timeslice** (1  $\mu$ s – 8.3 ms)
- Time slices combined in time frames (up to 549 s, 16 GB max, < 160 MB to full 20 GB/s limit)
- Each FEE data block has sub-detector specific format and may contain signals from a few colliders (events)

**The SPD Online Filter**  
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

The SPD Online Filter is a high performance computing system for high throughput processing:

- Hardware component:** compute cluster with two storage systems and set of compute nodes
- 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.

*Details: 28 May 2026, 17:27, Track 2 - Online and real-time computing*

**Expected data volumes**

- Preparation for the experiment**
  - Monte Carlo simulation from 2024 to 2028 will provide 2 PB per year.
  - Total per stage: 10 PB.
- Stage I: running at low luminosity of the NICA collider**
  - Monte Carlo simulation and real data taking from 2028 to 2030 will provide 4 PB per year. Reprocessing: 2 PB per year.
  - Total per stage: 16 PB.
- Upgrade of the setup for operation at high luminosity**
  - Monte Carlo simulation from 2031 to 2032 will provide 2 PB per year. Reprocessing: 2 PB per year.
  - Total per stage: 8 PB.
- Stage II: running at maximum design luminosity of the NICA collider**
  - Monte Carlo simulation and real data taking from 2033 to 2036 will provide 20 PB per year. Reprocessing: 10 PB per year.
  - Total per stage: 120 PB.
- Total for all stages: 156 PB.**

**SPD Distributed data processing**

**Core sites (JINR, PNPI)** – data longterm storage, main data processing and producing  
**Shell sites** – data analysis, data producing

- INDIGO IAM** – an entry point to all members of the computing services of the collaboration.
- CRIC information system** – the main integration component of the computing system.
- PanDA WMS** – is a data-driven workload management system capable of operating at massive data processing scale.
- Rucio DMS** – responsible for data management, including data catalog, data integrity and data lifetime management strategies.
- FTS DTS** – enables massive data transfers.

*Details: 27 May 2026, 17:45, Track 4 - Distributed computing*

**SPD Data processing workflow**

**Sampo - SPD software framework**  
Information processing of physics data of SPD Experiment

Sampo - Gaudi-based software framework is being developed:

- Geometry description: GeoModel
- Generators: Pythia8, FTF, UKOMD + capability to add more generators
- Simulation: Geant4
- Reconstruction: MskHough track finding, ACTS (Kalman filter) for track fitting, Kiparticle for vertex reconstruction, own algorithms for other subsystems

**Information systems & databases**

Collaboration management data  
Hardware database and mapping  
Data production requests (including MC input configurations)  
Registries: Geometry, CalibAlign, Magnetic field  
Event Index  
Condition database  
Configuration database  
A PostgreSQL RDBMS is considered as a database platform

**SPD Software & Computing**

- SPD Software** - a set of activities related with development, support and evolution of applied software for information processing of physics data of SPD Experiment.
- SPD Computing** - a set of activities devoted to setup and operation of distributed computing environment for data processing of SPD Experiment.
- Infrastructure** - a set of computing and storage resources provided by collaboration members for shared usage in distributed data processing

**Federation of compute and storage resources for SPD offline computing**  
Andrey Kiryanov, Danila Oleynik, Artem Petrosyan

**SPD at scale**

The expected event rate of the SPD experiment is about 3 MHz (pp collisions at  $\sqrt{s} = 27$  GeV and  $10^{17}$  cm<sup>-2</sup> design luminosity). This is equivalent to a raw data rate of 20 GB/s or 200 PB/year, assuming a detector duty cycle is 0.3, while the signal-to-background ratio is expected to be on the order of  $10^1$ . Taking into account the bunch-crossing rate of 12.5 MHz, one may conclude that pile-up probability cannot be neglected. The goal of the SPD Online Filter is at least to decrease the data rate by a factor of 20, so that the annual growth of data, including the simulated samples, stays within 10 PB. From the Online Filter it is transferred to the Core facility, where a full reconstruction takes place and the data is stored permanently. The data analysis and Monte-Carlo simulation will likely run at the remote computing centers – Shell facilities. Given the large data volume, a thorough optimization of the event model and performance of the reconstruction and simulation algorithms are necessary.

**SPD production**

SPD production system is based on a number of well-known third-party components, such as PanDA, CRIC, IAM, and EOS, as well as several in-house tools, such as Production Control Panel and integration software, which ties everything together by interfacing software components with each other.

**Network Backbone**

With its resource requirements SPD relies heavily on a distributed offline computing, which is currently in active development. While JINR, as a hosting institute, provides central facilities for security, job and data management, software distribution, and monitoring, other collaboration participants can contribute to the experiment by providing Shell facilities that include computing and storage resources with standard interfaces. The Russian Scientific Backbone (here not an exhaustive list, just the part that pertains to the SPD), which began as part of the LHC-ONE network, provides broadband network infrastructure for the Russia's largest scientific organizations, three of which are interconnected via 100 Gbit/s links, while the rest are connected via 10 Gbit/s links. Network connectivity is steadily improving, and plans are in place to provide high-speed network connectivity to foreign participants of the SPD collaboration, such as China and South Africa.

**Storage Federation**

A Federated Storage is a collection of autonomous, geographically distributed storage resources controlled by a central management system, which defines the rules for data placement, redundancy and access control. Such storage system aims at providing a reliable and efficient access to data via a single entry point, while at the same time lowering the "entry threshold" for participating sites in terms of both storage capacity and the required level of expertise. In the SPD offline computing, Federated Storage is used to consolidate the storage resources of Shell facilities into a single distributed federation for storage of derived data. The current prototype is based on EOS with the head node (MGM) deployed at the Core facility and disk nodes (FST) deployed at the Shell facilities. Both Rucio and EOS built-in geo-scheduling capabilities are used to optimize data transfers between end users and storage servers.

**Computing Federation**

In the SPD offline computing, all of the computing resources of the Shell facilities will have a standard architecture consisting of ARC CE as the interface, Slurm as the batch system, and CVMF3 as the software distribution platform. Specific resource parameters are stored in CRIC, which is then used by the PanDA-based SPD production system for resource scheduling. From the user's perspective, all SPD computing resources constitute a Computing Federation that provides geographically distributed resources via a single entry point. In the event of a failure or malfunction of any resource, the load will be automatically redistributed to others.

# Invited talks

- Computing hardware trends (Valery Yegorshev, Cognitar LLC.)
- “Alfa” networks (Alexey Simonov, RFNC-VNIITF)