SPD
DAQ & Computing & Software

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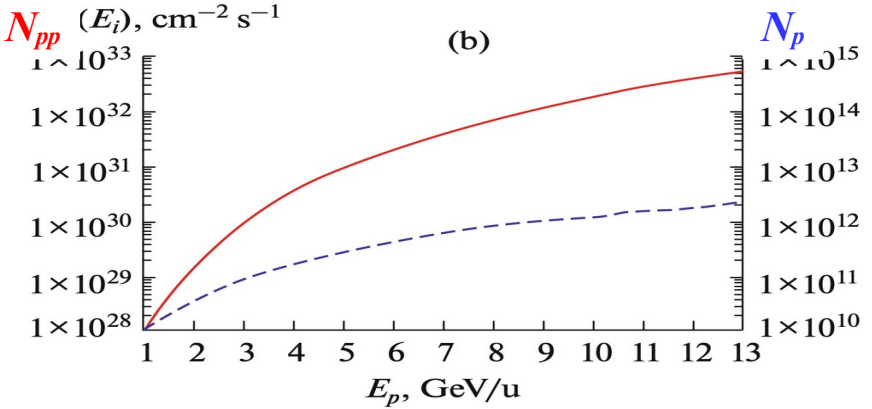
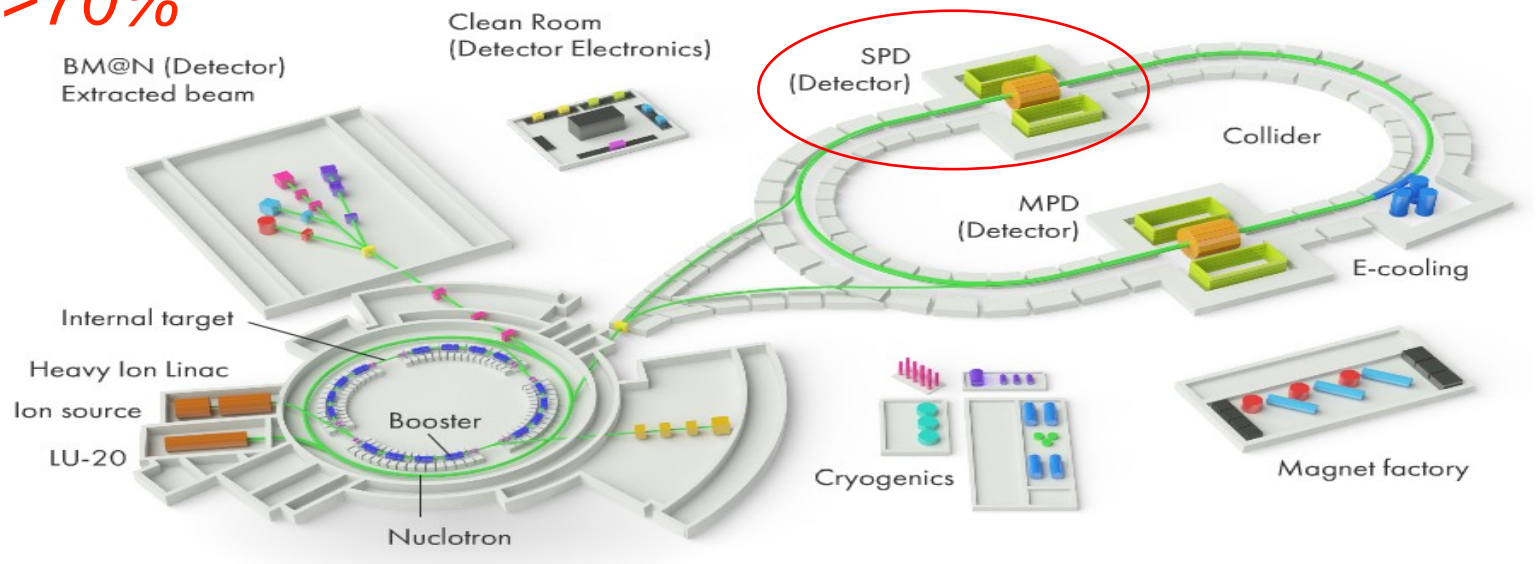
SPD at NICA

p ↑ p ↑ : $\sqrt{s} \leq 27$ GeV
d ↑d ↑ : $\sqrt{s} \leq 13.5$ GeV
d ↑p ↑ : $\sqrt{s} \leq 19$ GeV

U, L, T
|P|>70%





SPD Collaboration

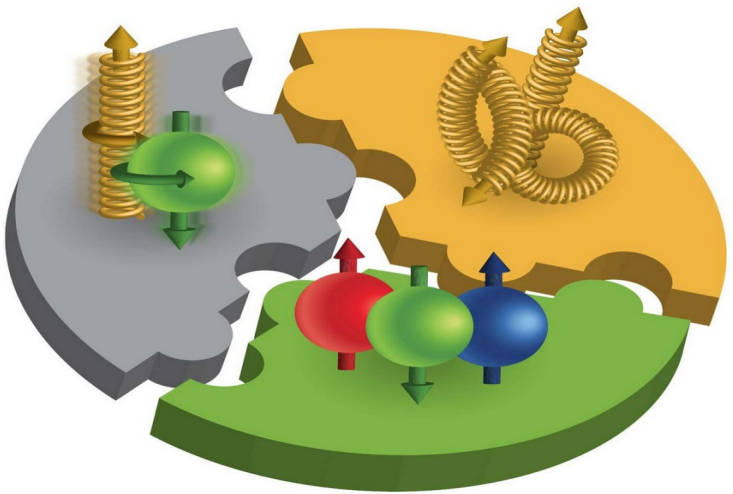
36 institutes from 15 countries, ~400 members

Alexey Zhemchugov on behalf of SPD Collaboration, 12.04.2024

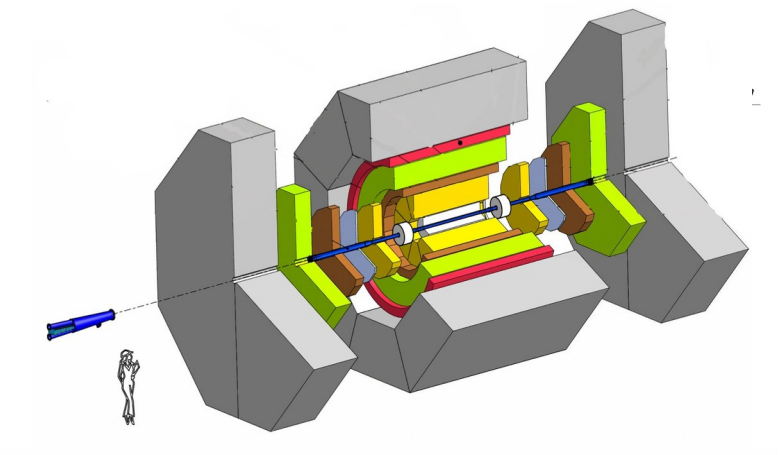
Physics program

- SPD - a universal facility for comprehensive study of gluon content in proton and deuteron at large x
  - Prompt photons
  - Charmonia
  - Open charm
- Other spin-related phenomena
- Other physics

More details:
Prog.Part.Nucl.Phys. 119 (2021) 103858
arXiv:2011.15005



SPD as a data source



- 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)
- Selection of physics signal requires momentum and vertex reconstruction → no simple trigger is possible

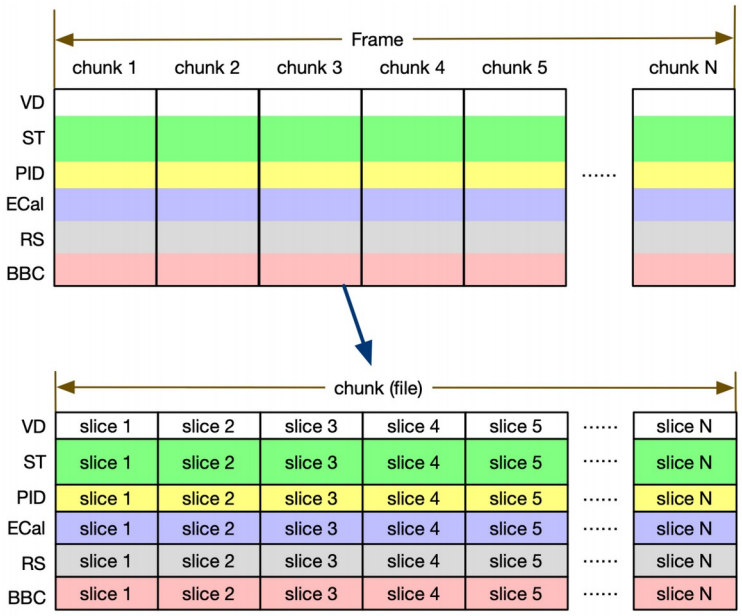
The SPD detector is a medium scale setup in size, but a large scale one in data rate!

Input data

- RAW event size 7 kB
- RECO event size 15 kB
- Time for Reconstruction (1 ev) 100 HepSPEC
- Time for Simulation (1 ev) 500 HepSPEC
- Event rate at maximum luminosity 3000 kHz
- Event rate after online data filter 150 kHz
- Operation time 50000 seconds/day
- Operation time 200 days/year

Free running DAQ

No trigger = No classical events anymore



- Primary data unit: **time slice** (1 us — 8.3 ms)
- Time slices combined in **time frames** (up to 549 s, 16 GB max, < 160 MB to fullfil 20 GB/s limit)
- Intermediate units — **time chunks** of 0.1-0.2 s (2-4 GB or ~10^5-10^6 events) are being discussed now
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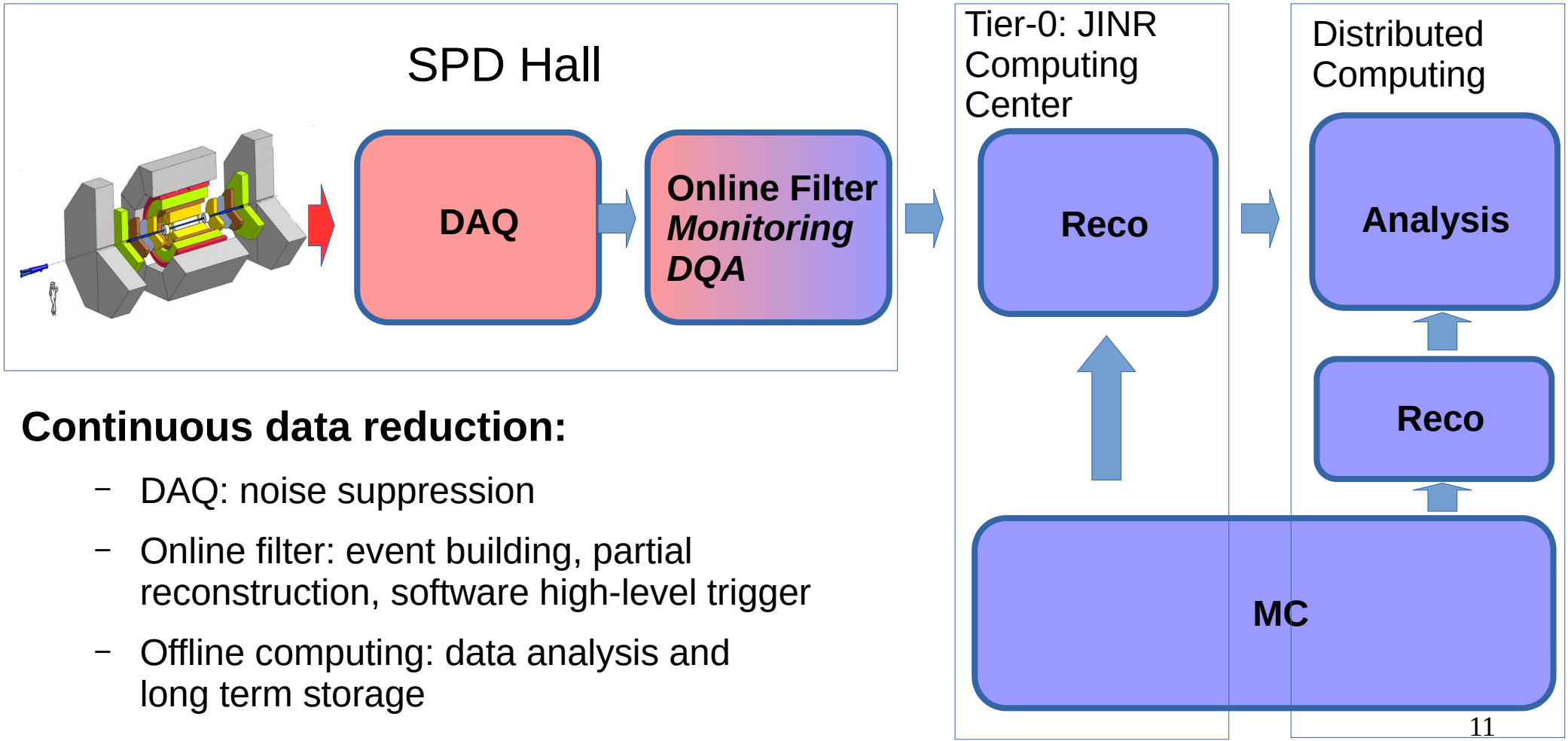
- Every time slices will contain signals from a few to many collisions (events)
- Event building have to unscramble events from a series of time slices.

Data workflow



Continuous data reduction:

- DAQ: noise suppression
- Online filter: event building, partial reconstruction, software high-level trigger
- Offline computing: data analysis and long term storage

Online Data Filter

High-performance heterogeneous computing cluster

- Partial reconstruction
  - Fast tracking and vertex reconstruction
  - Fast ECAL clustering
- Event unscrambling
- Software trigger
  - several data streams

Machine learning is a key technology

Control of systematics?

- Monitoring and Data quality assessment
- Local polarimetry

Reconstruction workflow

- **Tracking in the vertex detector (at the second stage)**
  - Vertices
  - Track seeds

- **Tracking in the straw tracker (+ MCT at the first stage)**
  - T0s (crude, ~10 ns) → bunch crossing time
  - Tracks
  - Unassociated straw hits

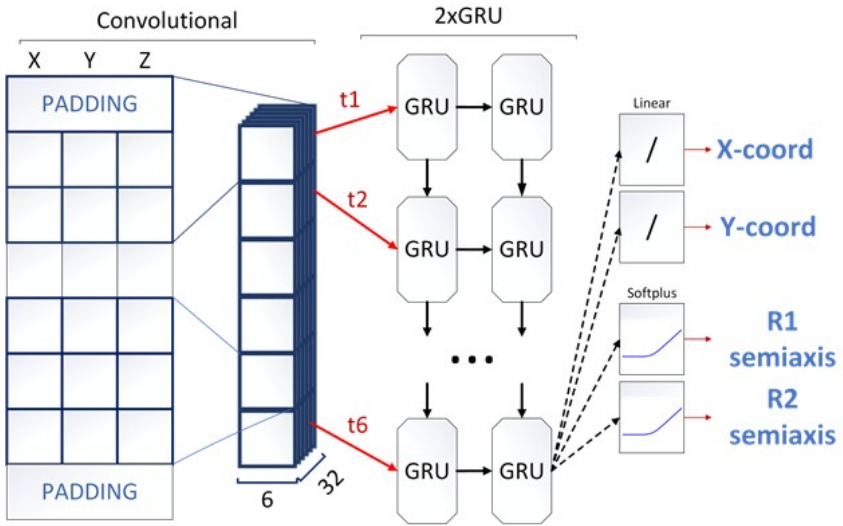
- **ECAL reconsruction**
  - Clusters
  - π^0 candidates

- **RS reconstruction**
  - Clusters
  - Muon candidates

- **Association of tracks, RS and ECAL clusters to vertices (event unscrambling)**
- **Copy raw data from PID, BBC, ZDC to events according to bunch crossing time**

Example: TrackNETv3 for track recognition

JINST 17 (2022) 12, P12023
D. Rusov et al, talk at PCT'2023



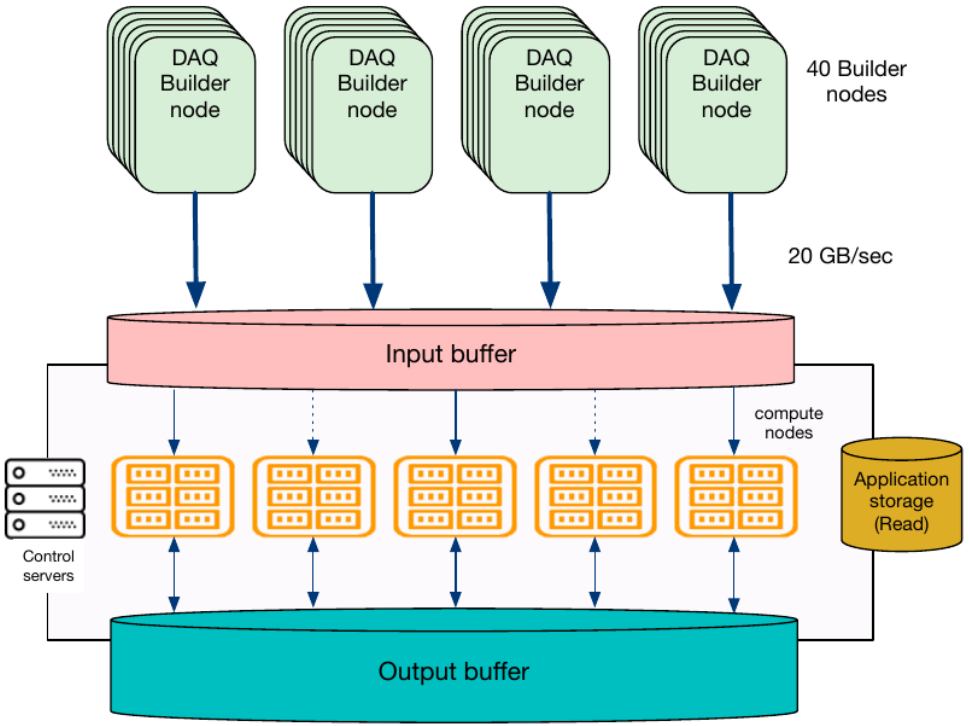
- Network predicts an area at the next detector layer where to search for the track continuation
- If continuation is found the hit is added to the track candidate and the procedure repeats again
- Essentially reproduces the idea of the Kalman filter: track parameters are predicted by synaptic weights determined by network training
- Generalization? Stability?

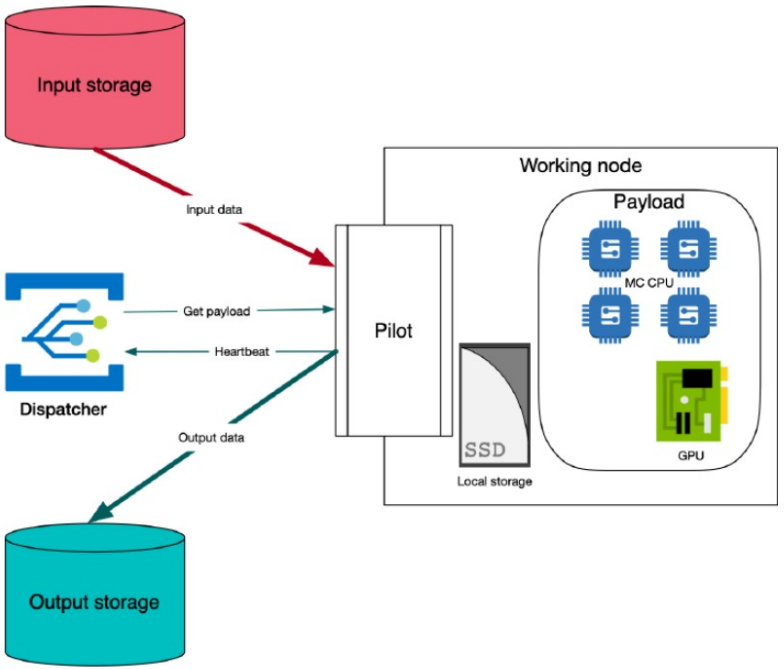
	Time slices of 40 events
Track efficiency (recall) (%)	96,54
Track purity (precision) (%)	94.75
Time slices / sec	63.74 (*40 = 2549.6)

PRELIMINARY

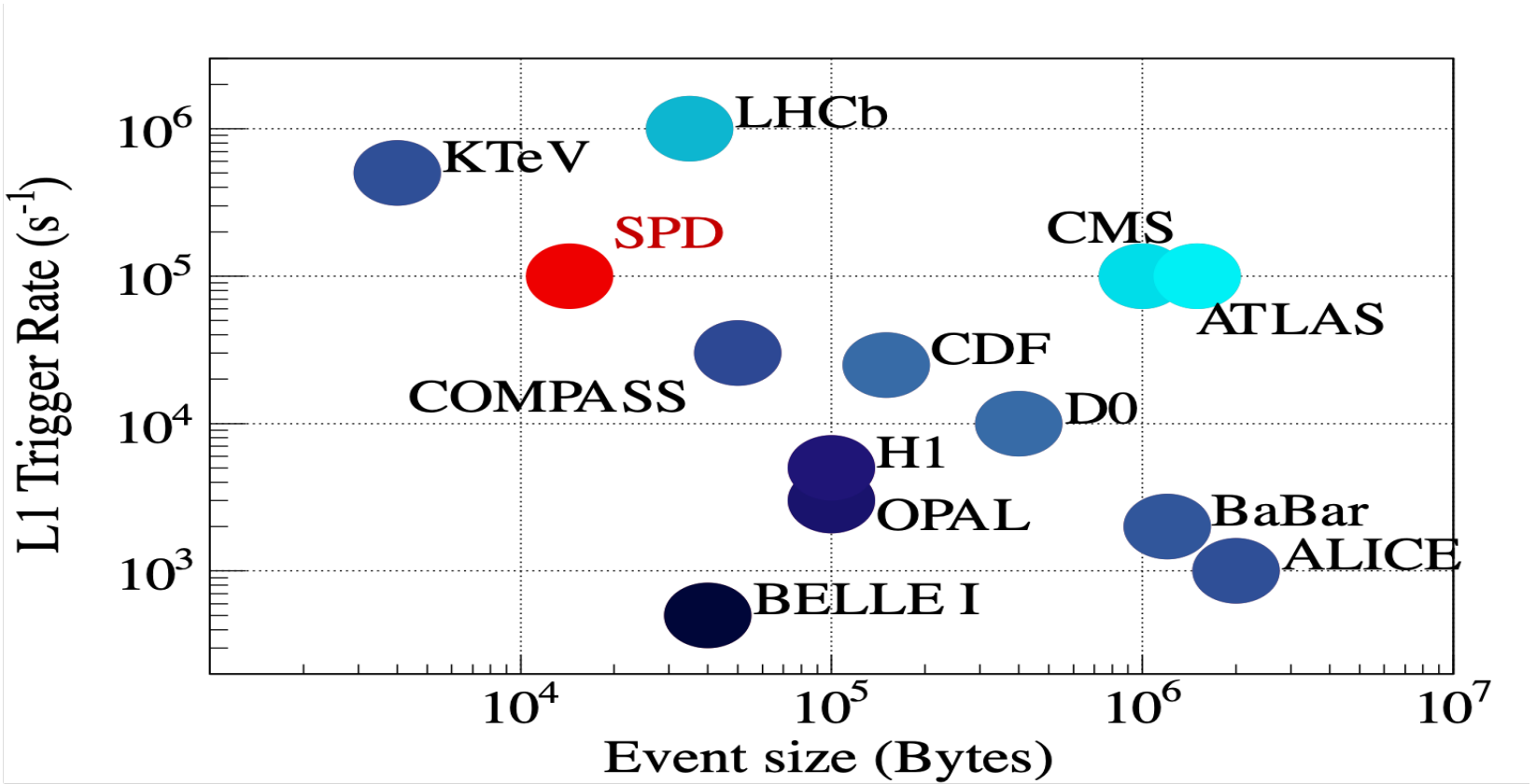
Intel(R) Xeon(R) Gold 6148 CPU @ 2.40GHz + GPU Nvidia V100 32Gb

Online Filter operation





After the online filter



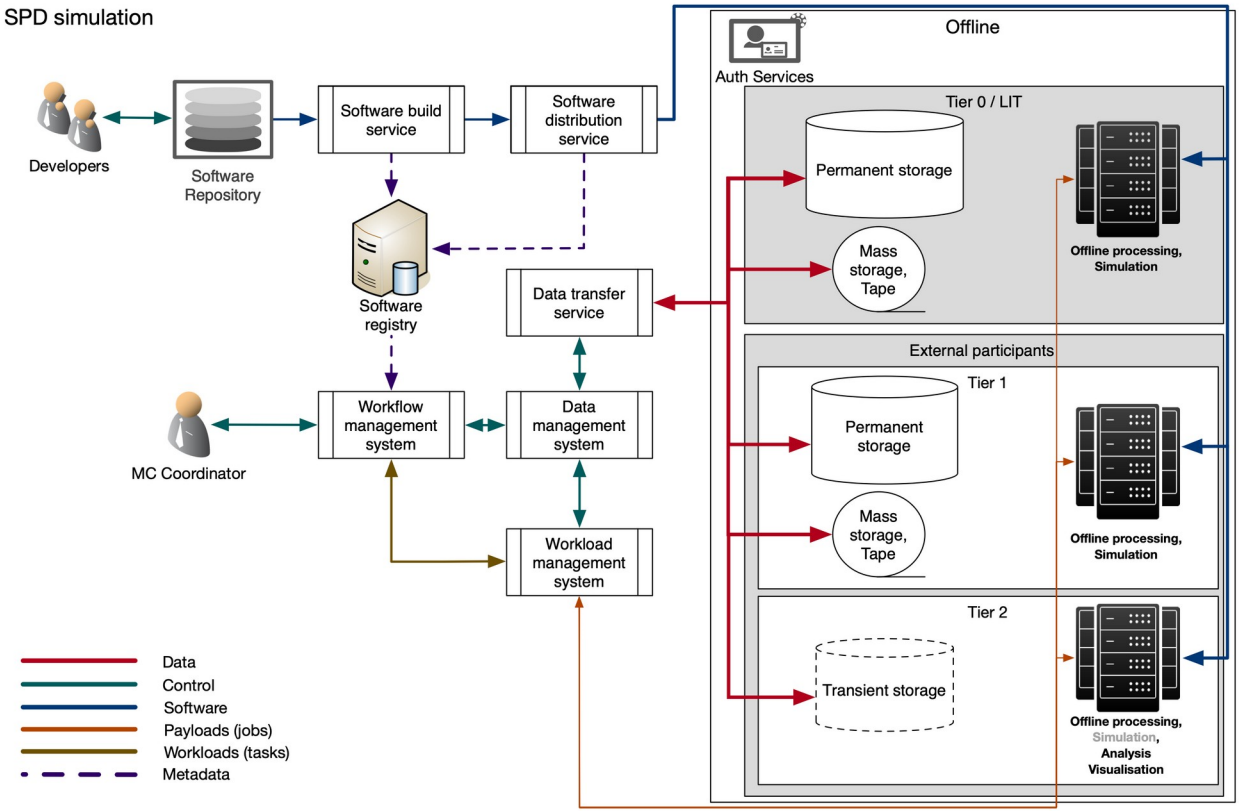
Expected data volumes

- **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: 18 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.

Services for distributed data storage and data processing

- Authentification system
- Authorization system
- Information system
- Data management system
- Workload management system
- Workflow management system
- Data transfer service
- Software cache and distribution



Key management services

- JINR SSO - authentication service
- Indigo IAM - authorization service
- Information system - Computing Resource Information Catalog was deployed at JINR with certain modifications in 2020
- Production and Distributed Analysis System is deployed at JINR since 2015/ Firstly it was used for the COMPASS experiment. The instance for the SPD experiment was deployed in 2020, and updated in 2023. Now it is being gradually tuned along with the development of the SPD software and data structure.
- Data management system Rucio was deployed at JINR in 2022. Now it is being gradually tuned along with the development of the SPD data structure.
- Data transfer service is deployed at JINR in 2023

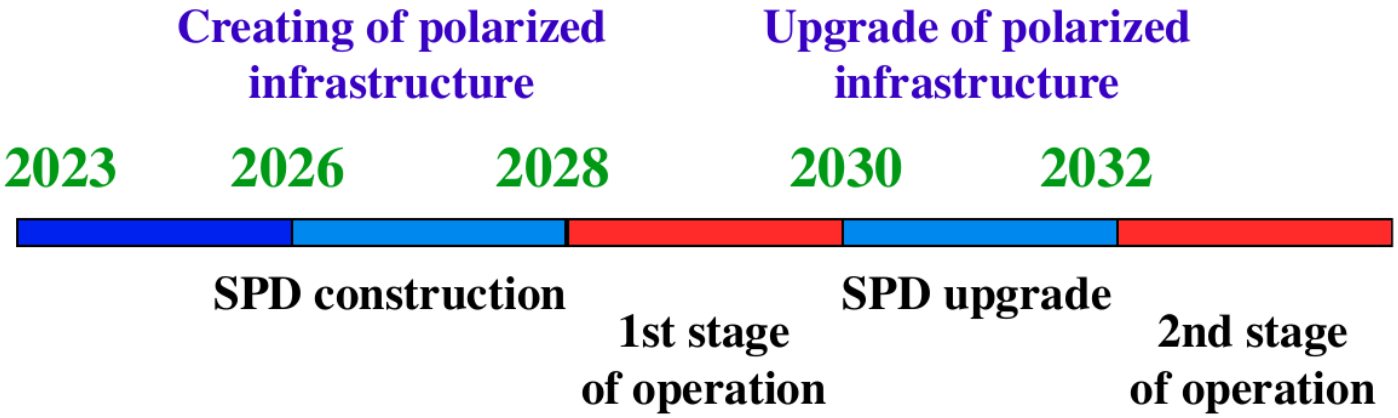
Databases

- Several databases are needed:
  - Data taking conditions and calibration data
  - Physics metadata (including MC input configurations)
  - EventIndex: catalog of physics events, both collected from the detector and simulated
  - Hardware database and mapping
  - Monitoring and logging
  - Collaboration management data.
- Designed as a complex information system that includes data collection and transfer tools, APIs for access from the production and analysis software, client software, supervisors, and monitoring.
- A PostgreSQL RDBMS is considered as a database platform

Offline Software

- A Gaudi-based software framework is being developed:
  - Geometry description: GeoModel
  - Generators: Pythia8, FTF, UrQMD + capability to add more generators
  - Simulation: Geant4
  - Reconstruction: ACTS or GenFit for tracking, Kfparticle for vertex reconstruction, own algorithms for other subsystems
- Current simulation and performance studies are done by another framework SpdRoot, based on FairRoot software

Timeline


Creating of polarized infrastructure
Upgrade of polarized infrastructure
2023
2026
2028
2030
2032
SPD construction
1st stage of operation
SPD upgrade
2nd stage of operation

Required SPD computing resources

	CPU [cores]	Disk [PB]	Tape [PB]
Online filter (Stage I)	3000	2	none
Offline computing (Stage I)	20000	5	6 per year
Cost estimate (Stage I) [k$]	5750	616	42 per year
Online filter (Stage II)	6000	4	none
Offline computing (Stage II)	60000	15	30 per year
Cost estimate (Stage II) [k$]	16500	1672	210 per year

Total for Stage I: 6.4 M$

Total for Stage II: 18.2 M$ + 0.2 M$ per year

Tier-0 at JINR will provide about 25-30% of all computing resources
Tier-1 at Gatchina is going to contribute about 25%
The rest should be distributed between the participating institutes