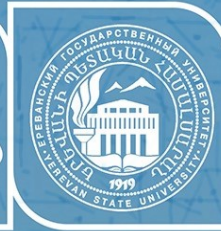


MATHEMATICAL MODELING AND COMPUTATIONAL PHYSICS 2024

21–25 Oct 2024

YEREVAN, ARMENIA



Computing Software Architecture for distributed processing of the BM@N experiment data

Konstantin Gertsenberger
Joint Institute for Nuclear Research, Dubna

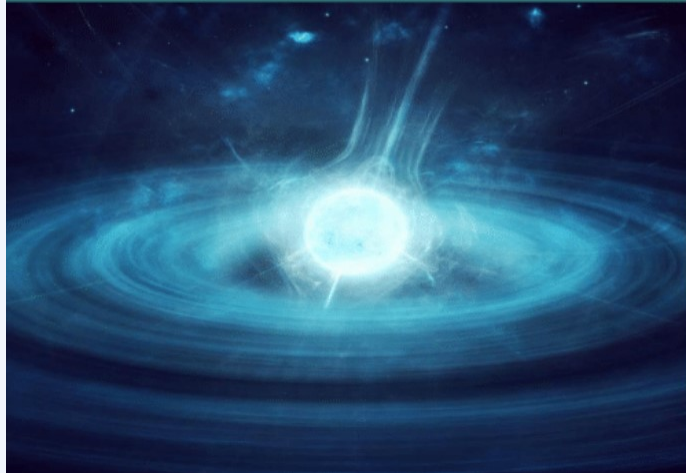
on behalf of the BM@N collaboration



October 25, 2024

BM@N Experiment at NICA

A shot glass filled with neutron star matter would weigh as much as Mount Everest.



Nuclotron-based Ion Collider facility



Nuclotron-based Ion Collider facility

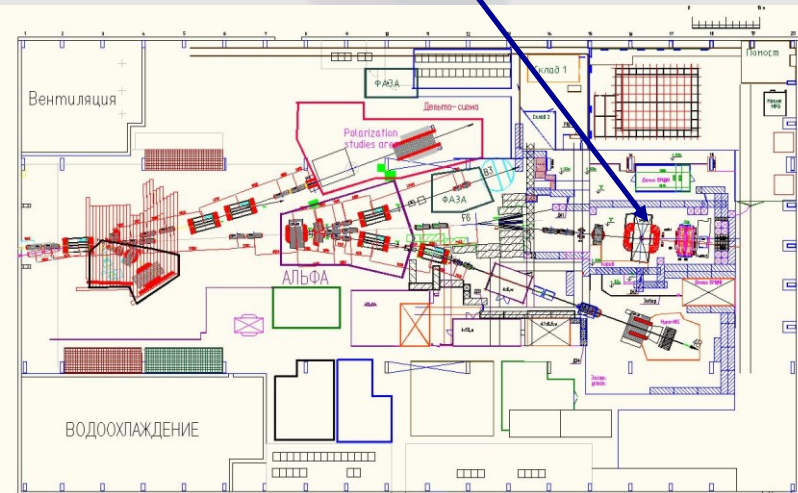
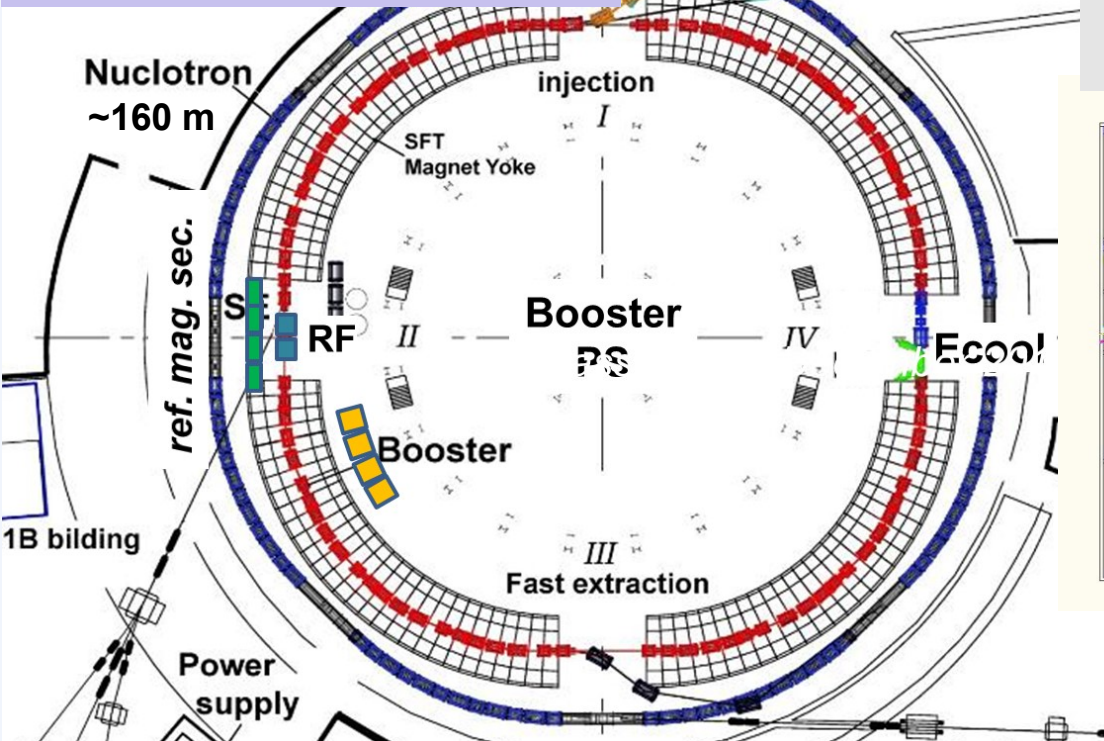
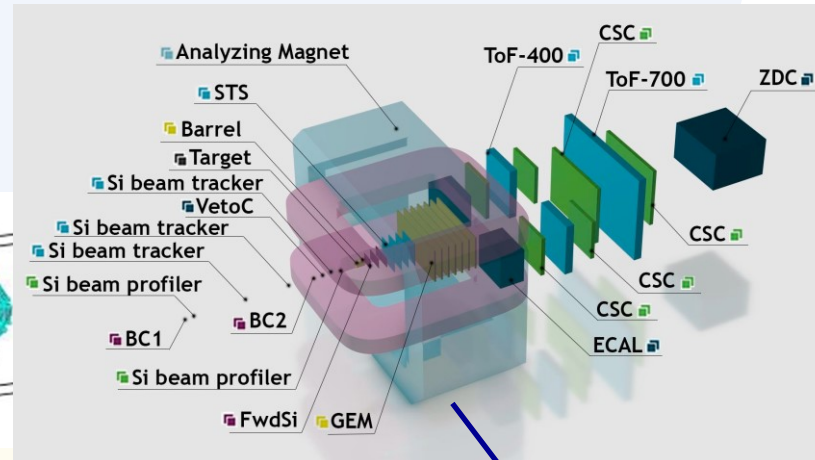
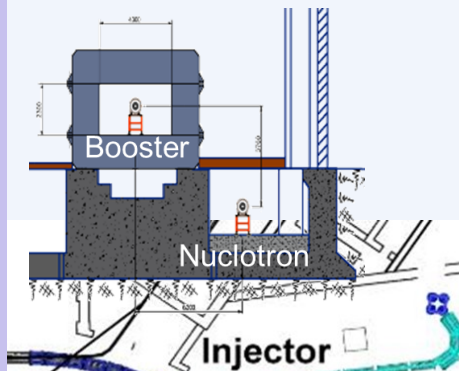
- Beams: from p, d^{\uparrow} to Bi
- Luminosity: 10^{27} (Bi), 10^{32} (p) $cm^{-2}s^{-1}$
- Collision energy: $\sqrt{S_{NNBI}} = 4 - 11$ GeV $E_{lab} = 1 - 5$ AGeV

- Fixed target experiment: BM@N (2018)
- 2 interaction points: MPD (2025) & SPD (2028)
- Official site: nica.jinr.ru, bmn.jinr.ru

Baryonic Matter @ Nuclotron

BM@N Physics Program:

- ✓ strange / multi-strange hyperon and hypernuclei production at the threshold
- ✓ in-medium modifications of strange & vector mesons in dense nuclear matter
- ✓ hadron femtoscopy
- ✓ short range correlations
- ✓ event-by-event fluctuations
- ✓ electromagnetic probes, states decaying into γ , e



BM@N in Nuclotron Runs (2015 – 2023)

❖ Nuclotron Run 51 (d,C)		<i>Feb. 22 – Mar. 15, 2015</i>
❖ Nuclotron Run 52 (d)	Technical	<i>June 29 – June 30, 2016</i>
❖ Nuclotron Run 53 (d, d [†])	<i>interaction rate: 5 kHz</i>	<i>Dec. 09 – Dec. 23, 2016</i>
❖ Nuclotron Run 54 (C)	Technical+SRC Physics	<i>Mar. 07 – Mar. 18, 2017</i>
❖ Nucl. Run 55 (C,Ar,Kr)	<i>interaction rate: 8 kHz</i>	<i>Mar. 03 – Apr. 05, 2018</i>
❖ Nucl. Run 56: SRC (C)	Physics	<i>Mar. 07 – Mar. 28, 2022</i>
❖ Nucl. Run 57: BM@N (Xe)	<i>interaction rate: 10 kHz</i>	<i>Dec. 12 – Feb. 02, 2023</i>



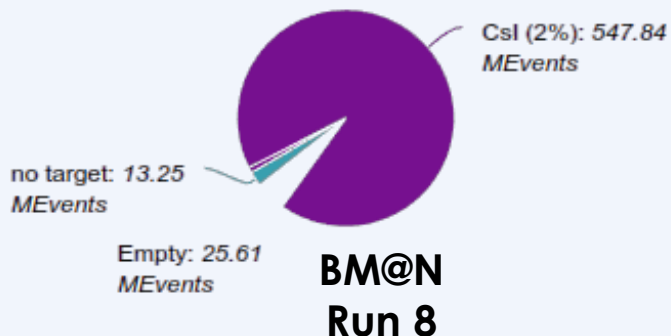
- Beam: **Xe** (3.8, 3.0 AGeV),
previous runs: Kr (2.3, 2.6, 3.0 AGeV), Ar (3.2 AGeV),
C¹² (3.5–4.5 AGeV), d (4, 4.6 AGeV)
- Target: **CsI** or **empty**
previous runs: Pb, Sn, Cu, Al, C₂H₄, C, H₂
- Integrated DAQ, T₀ and Trigger systems
- Detectors: FSD, GEM, CSC, ToF-400, ToF-700,
DCH 1&2, FHCAL, ECal, LAND, profilometers...
- Detect min bias beam-target interactions to
reconstruct hyperons, strange particles, identify
charged particles and nucleus fragments...

Data Production in BM@N Physics Run

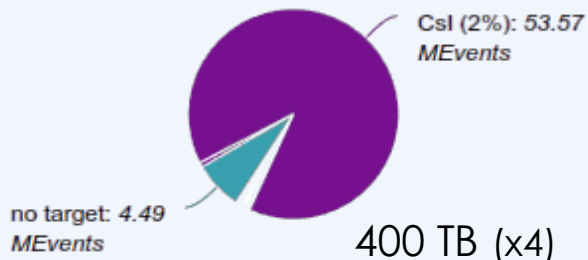
1st Physics BM@N Run

Two beam energy available for Xe-beam
CsI target is used as more similar to Xe
More than 600M events were collected

Beam Xe (E = 3.8 GeV/n)
Total: 592.66 MEvents



Beam Xe (E = 3 GeV/n)
Total: 59.86 MEvents



Parameter	Value (approx.)
Data acquisition time	720 hours
Average run duration	20 minutes
Average run time break	2.5 minutes
Beam intensity (3.8 AGeV)	up to 900k/2.2 Xe ⁺ /sec up to 900k/12 Xe ⁺ /sec
Trigger rate	8 000/2.2 event/sec
Average event size	0,57 MB
Data rate	up to 2 GB/sec
Raw file size	15 GB
Event count per file (total)	25 000
Total event count (+test, calibration, pedestal)	645 M
Total (complete) file count	25 800
Total run count	1 920
Total raw data size	400 TB
Total replicated raw data	1.6 PB
Avg digit file size	1.1 GB
Avg DST file size	2 GB

BmnRoot Framework

as a central BM@N software system

BmnRoot Framework

The **BmnRoot** framework is developed for realistic event simulation, reconstruction of experimental or simulated data and following physics analysis of ion collisions with a fixed target at the BM@N facility.

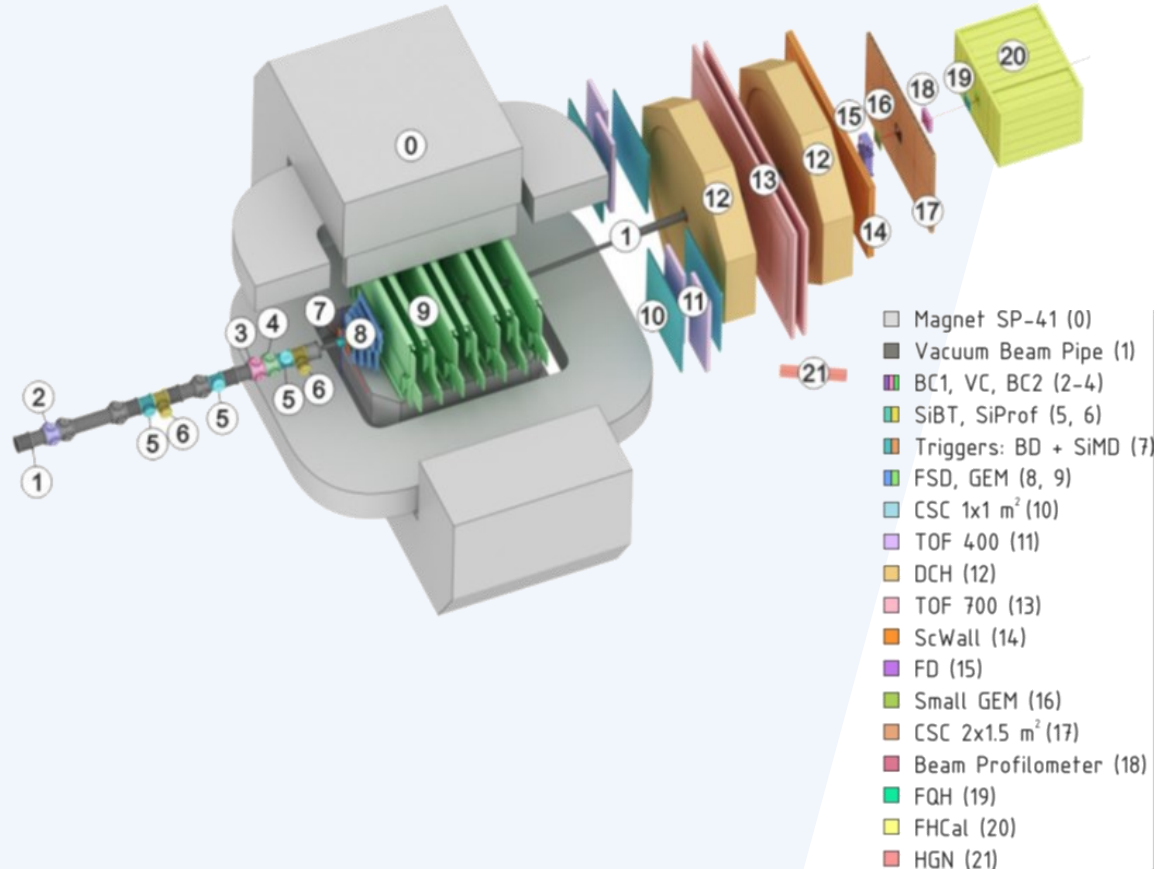
single stack for offline and online (FairMQ)

C++ classes, Linux/MacOS,

based on  ROOT and FairRoot

embedded services on Python

BM@N in the 1st physics Run



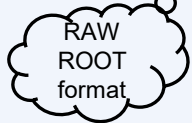
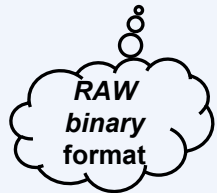
The BmnRoot software is available in GitLab@JINR: <https://git.jinr.ru/nica/bmnroot>

BmnRoot. Event Data Model

DAQ Storage

raw data in a binary format

raw_run.data
≈ 600 KB/event



raw processor

converter + decoder

digit_exp.root
≈ 35 KB/event



Geant4, Fluka

simulation

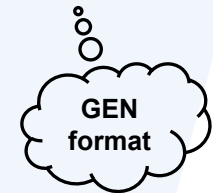
digit_sim.root



Event Generators

(DCM-)SMM, QGSM, UrQMD...

generator.dat
≈ 10 KB/event



reconstruction

dst_reco.root
≈ 90 KB/event



physics analysis



Storage Levels



RAW → **DIGIT** → **DSTexp** → PhA

RAW: raw (binary) event data collected by the DAQ system after the Event Builder

DIGIT: detector readings (event digits) after the raw data decoder (ROOT macro)

DSTexp: reconstructed data of experimental events



hists
plots
results

GEN → **SIM** → **DSTsim** → PhA

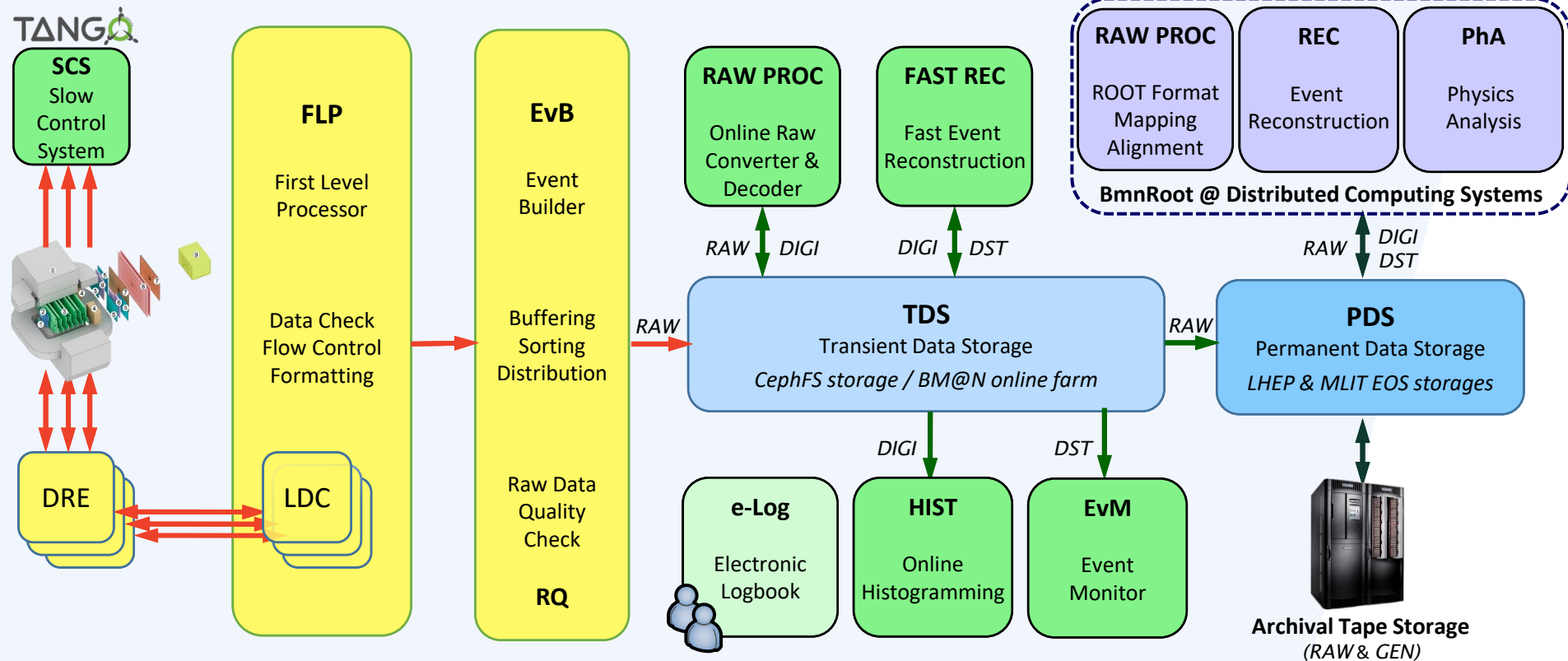
GEN: particle collisions description received by event generators

DSTsim: reconstructed data of simulated events

Information Systems

for online and offline data processing

BM@N Data Processing Flow



Information Systems = Databases + Interfaces (GUI + API) + Services + ...

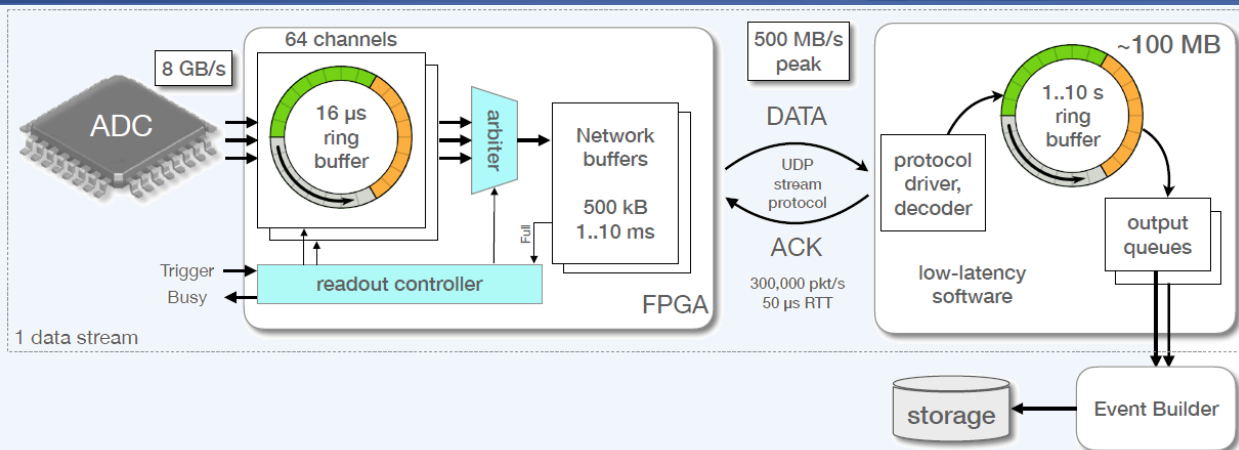
DAQ
(Data Acquisition System)

**Online
Processing**

**Offline
Processing**

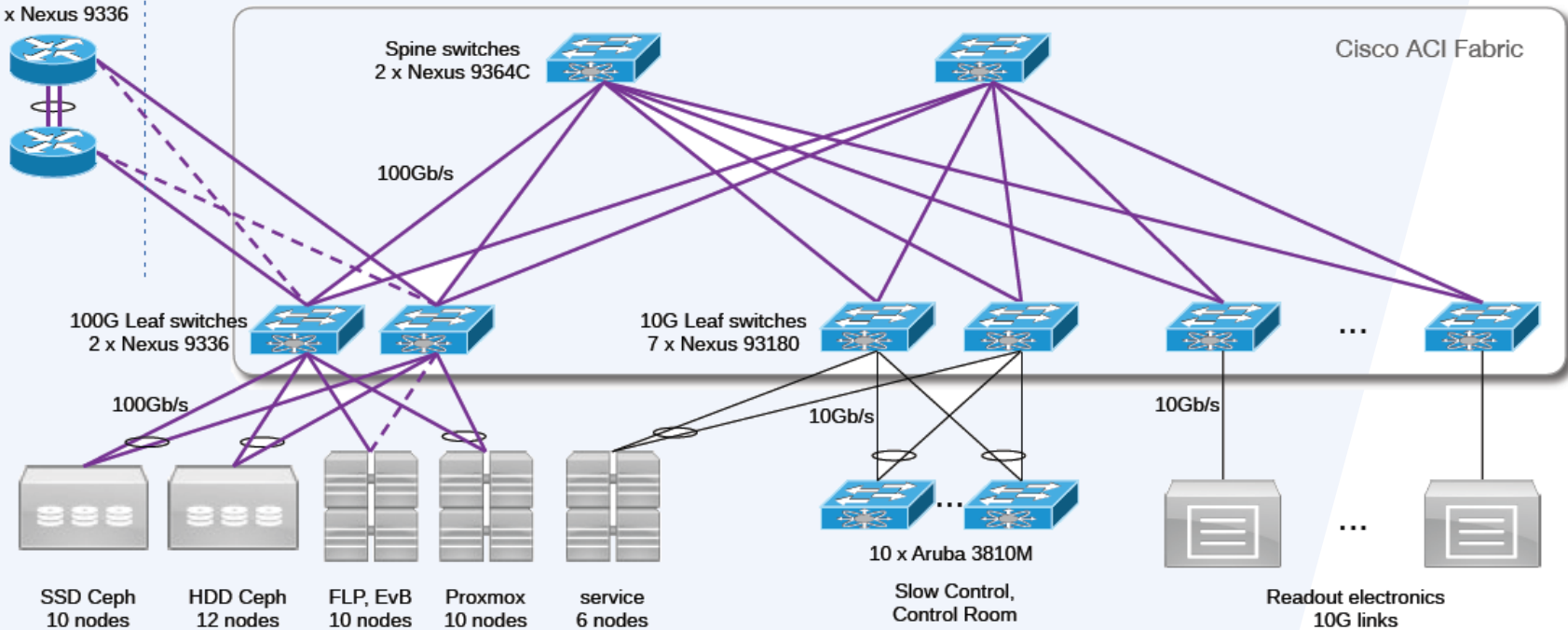
BM@N DAQ Infrastructure

BM@N DAQ
200 data streams
7 GB/s @ 15 kHz



CPU: 1500 cores
HDD: 2.8 PB (EC-replicated)
SSD: 100 TB (triple replicated)
Network external & fabric: 200 Gb/s

Technological Network
core routers
2 x Nexus 9336



Electronic Logbook Platform

Online Information System



Development Team
Alexander Chebotov,
Konstantin Gertsenberger,
Andrey Moshkin

Electronic Logbook (e-Log Platform)

create a new run

advanced search

current day records

user cabinet (event subs)

work with dictionaries

records per page

file attachments

username

page

fast search

BM@N Electronic Logbook

bmn-elog.jinr.ru

Logged in as shift

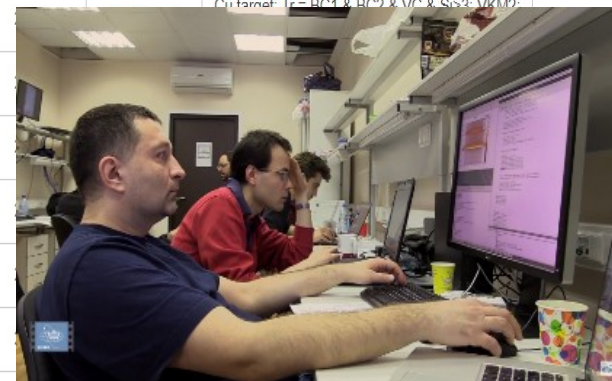
Home New Find Last day Account Reference Book

Page: 1 of 282



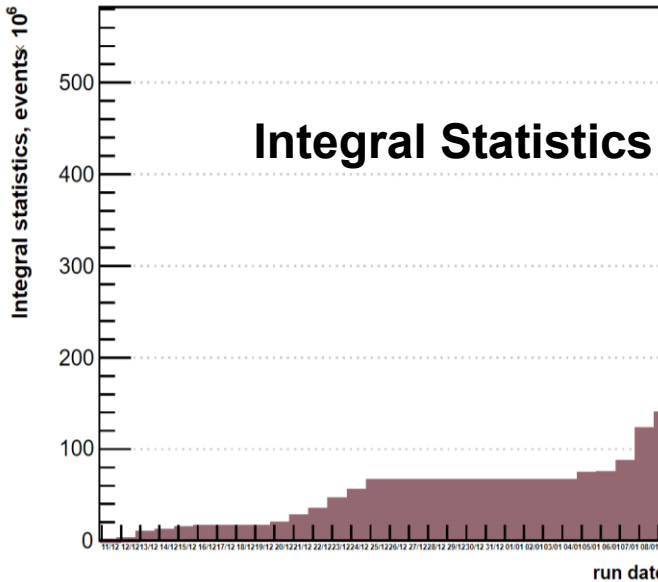
Number of items per page: 10 Logout

Date	Shift Leader	Type	No Run	Trigger	DAQ Status	SP-41, A	SP-57, A	VKM2, A	Beam	Energy, GeV	Target	Comment	Attachment
2018-04-05 11:47:06	Rumyantsev	Inform All	5185 per.7	Special Trigger	All	0	0	0	Kr	2.94	Cu (2 mm)	End of the RUN7	
2018-04-05 11:09:20	Rumyantsev	New Run	5184 per.7	Beam Trigger + Si >3	All	1250	50	125	Kr	2.94	Cu (2 mm)	Cu target; Tr.= BC1 & BC2 & VC & Si>3 VKM2: I=125A, SP-57=50A, SP41=1250A; 100 k	
2018-04-05 08:12:35	Rumyantsev	New Run	5183 per.7	Beam Trigger + Si >3	All	1250	50	125	Kr	2.94	Cu (2 mm)	Cu target; Tr.= BC1 & BC2 & VC & Si>2 VKM2: I=125A, SP-57=50A, SP41=1250A; 120 k	
2018-04-05 07:46:35	Babkin	New Run	5182 per.7	Beam Trigger + Si >3	All	1250	50	125	Kr	2.94	Cu (2 mm)	Cu target; Tr.= BC1 & BC2 & VC & Si>3 VKM2: I=125A, SP-57=50A, SP41=1250A; 208 kev	
2018-04-05 07:41:29	Babkin	New Run	5180 per.7	Beam Trigger + Si >3	All	1250	50	125	Kr			Cu target; Tr.= BC1 & BC2 & VC & Si>3 VKM2:	
2018-04-05 07:25:08	Babkin	New Run	5179 per.7	Beam Trigger + Si >3	All	1250	50	125	Kr				
2018-04-05 06:01:07	Babkin	New Run	5178 per.7	Beam Trigger + Si >3	All	1250	50	125	Kr				
2018-04-05 05:27:39	Babkin	New Run	5177 per.7	Beam Trigger + Si >3	All	1250	50	125	Kr				
2018-04-05 05:27:06	Babkin	New Run	5176 per.7	Beam Trigger + BD>3	All	1250	50	125	Kr				
2018-04-05 04:47:27	Babkin	New Run	5174 per.7	Beam Trigger + BD>3	All	1250	50	125	Kr				



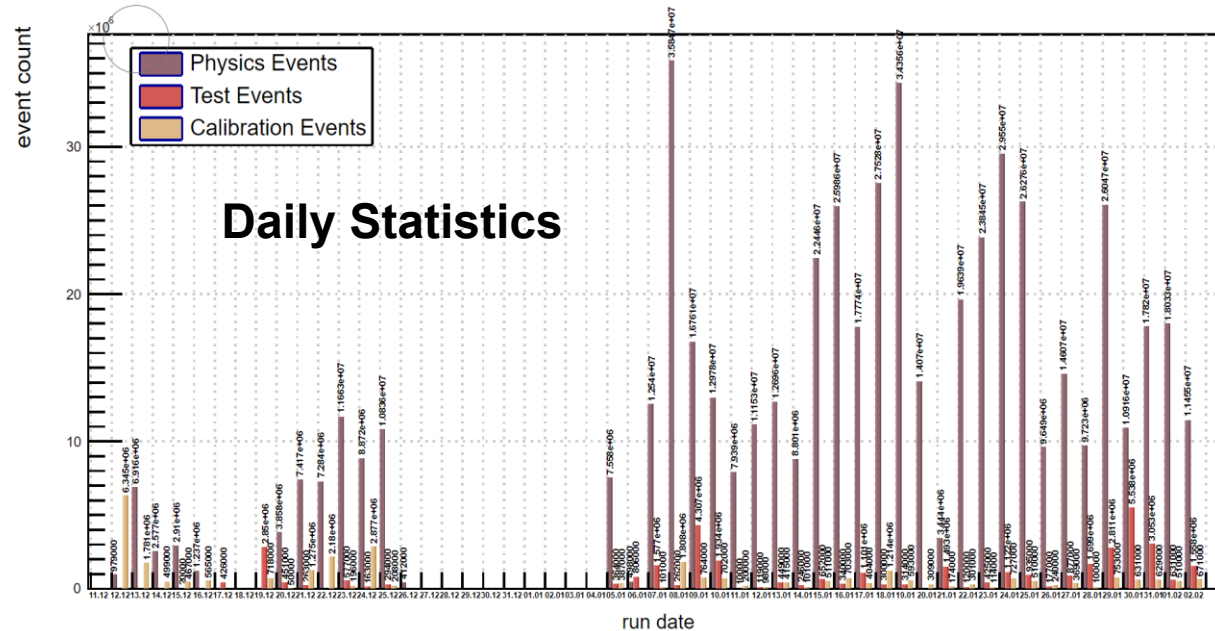
2020 - software team (contact e-mail: gertsen@jinr.ru)

Online Statistics of the e-Log Platform



e-Log event statistics (Run 8): statistics by event type / integral statistics of physics events

The information is current as of February 20 2023 23:59.



Online Monitoring System

Online Histogramming + Event Display



She says she's from Quality Control. We've failed the furniture inspection.

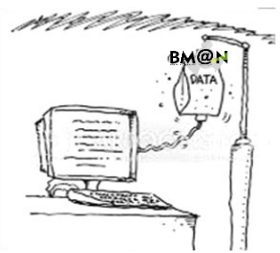
Online Histogramming System

jsROOT (Javascript ROOT) server provides control histograms via the Web

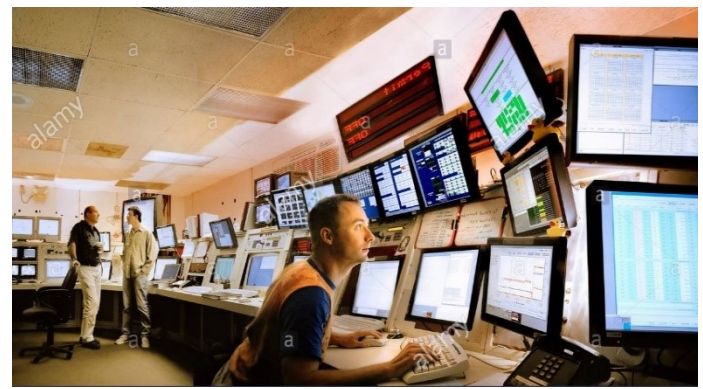
Welcome to the BM@N Experiment Triggers GEM Silicon ToF400 ToF700 DCH MWPC ZDC ECAL SRC Triggers LAND MSC



Run: 4147
Event: 20000
Run Type: beam

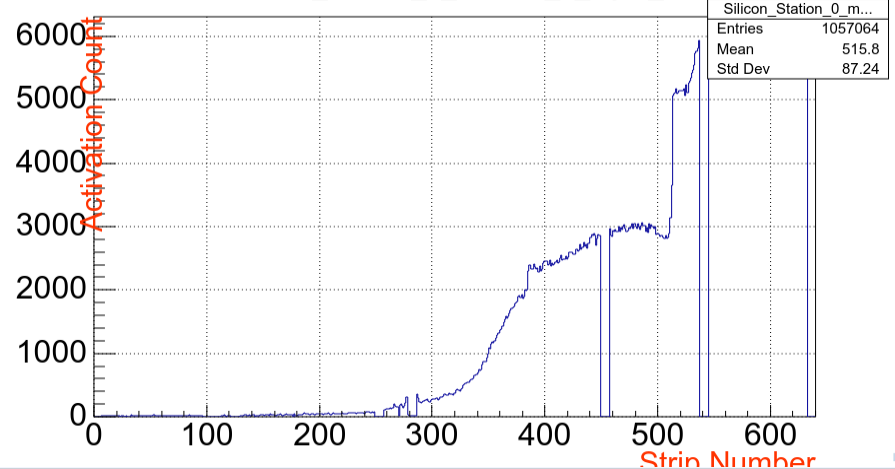


BM@N Silcons
Energy: 3.20
Beam: Ar
Target: C
Field Voltage: 77.60

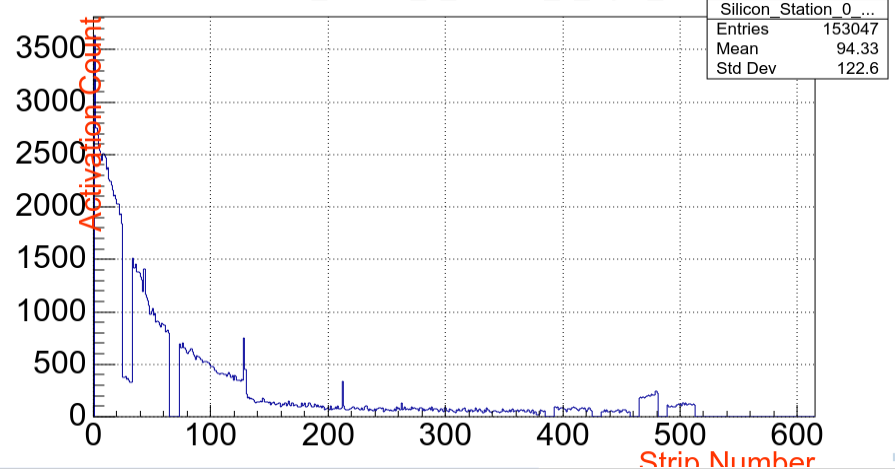


Reset Select Reference Run

Silicon_Station_0_module_0_layer_0

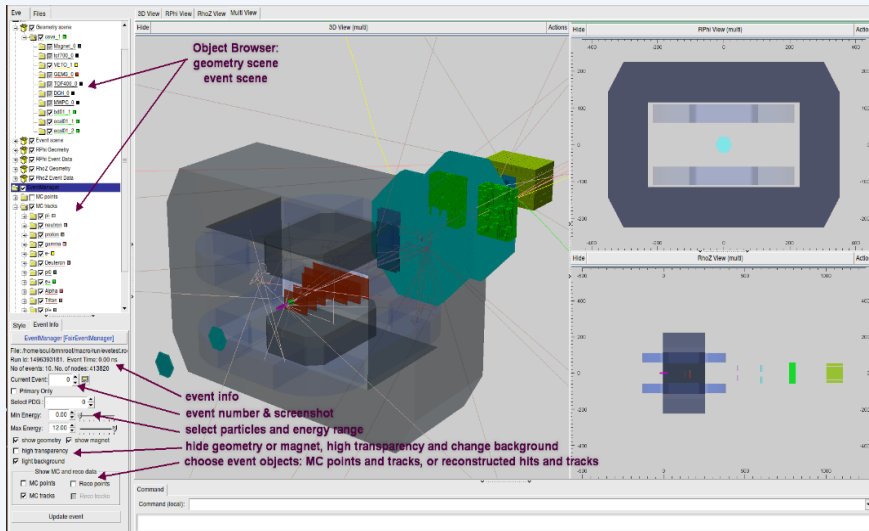


Silicon_Station_0_module_0_layer_1



Event Display for the BM@N experiment

Current Solution



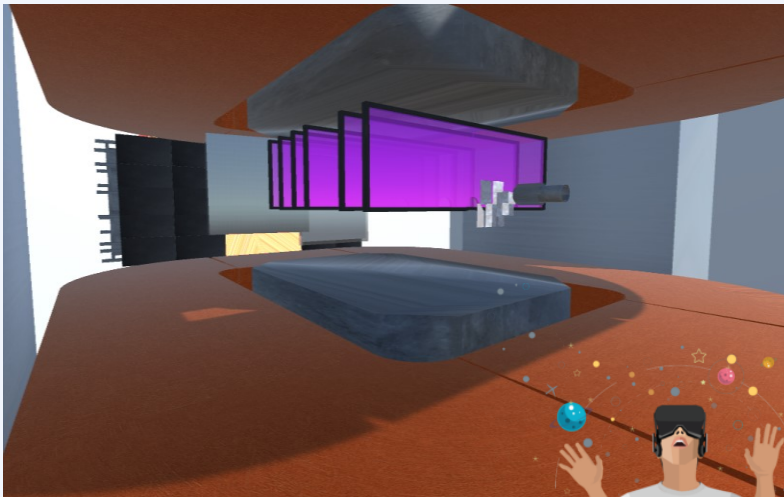
based on the **ROOT EVE** package
 can show/hide setup geometry, select an event to display, select particles with definite PDG codes, set energy range and many other visualization options

Event Display for **simulated** data
 MC points, tracks, calorimeter towers

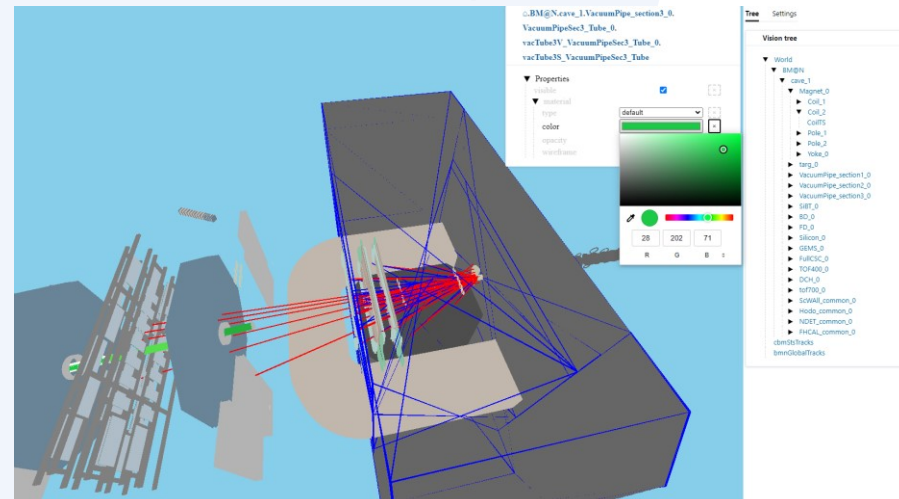
Event Display for **reconstructed** data
 hits, tracks, calorimeter towers

New Solutions from external teams

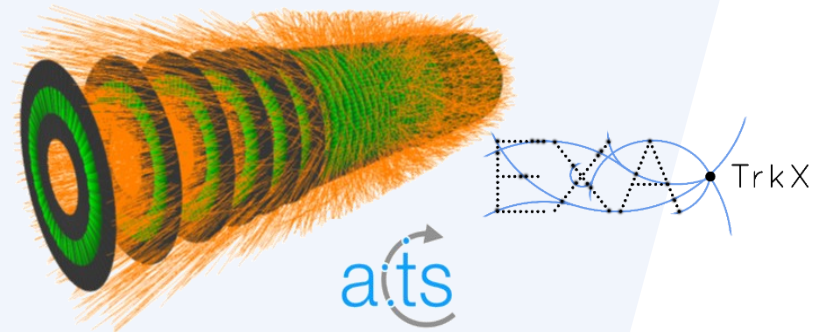
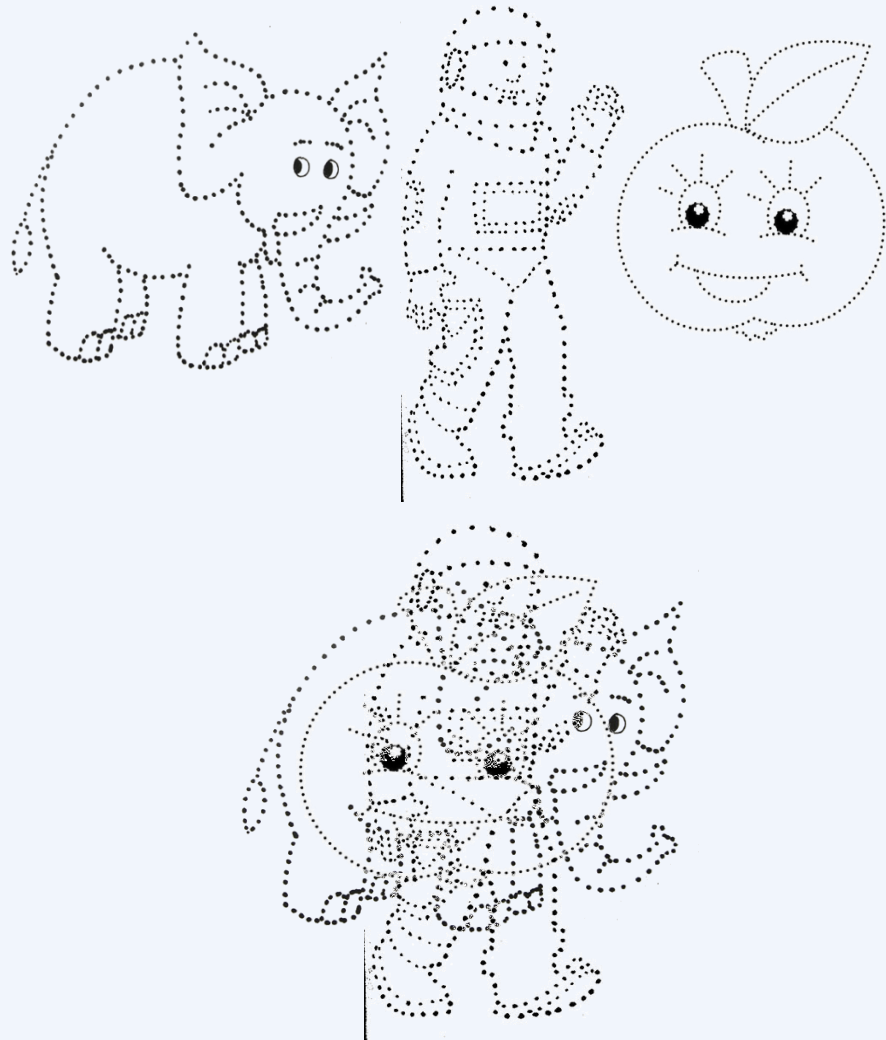
Event Display supporting VR and AR (SPbSU)



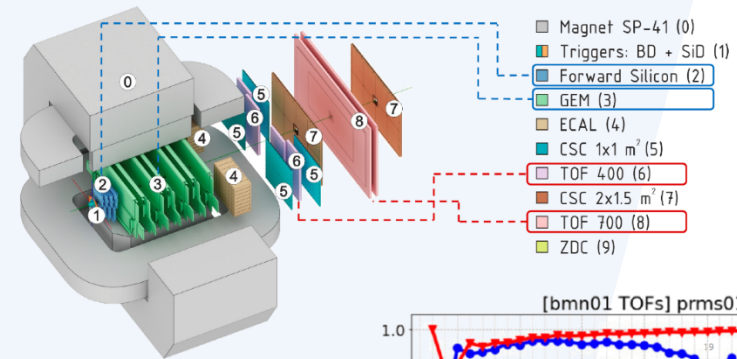
Next-Gen Event Display (MIPT)



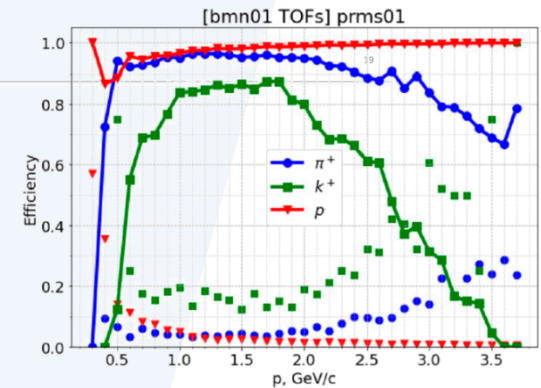
Machine Learning for Fast Event Reconstruction



Tracking machine learning challenge



Implementation of Particle IDentification based on ML
Alexander AYRIYAN,
Vladimir PAPOYAN



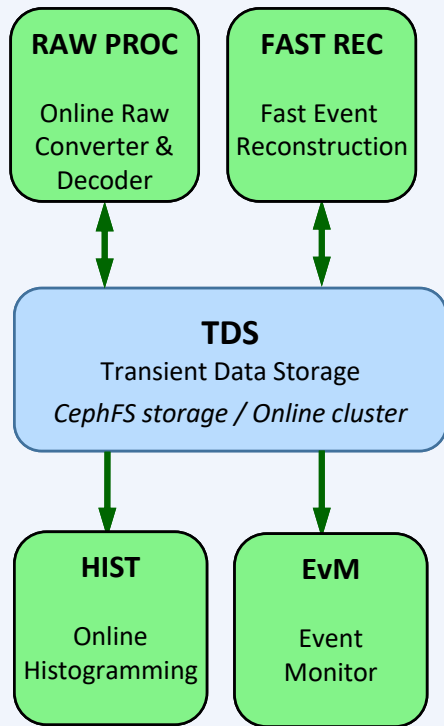
Online Configuration System

Online Data Processing

*Details in the report of Igor Alexandrov
(22 October 17:15)*

Production of the Configuration Information
system for the BM@N experiment

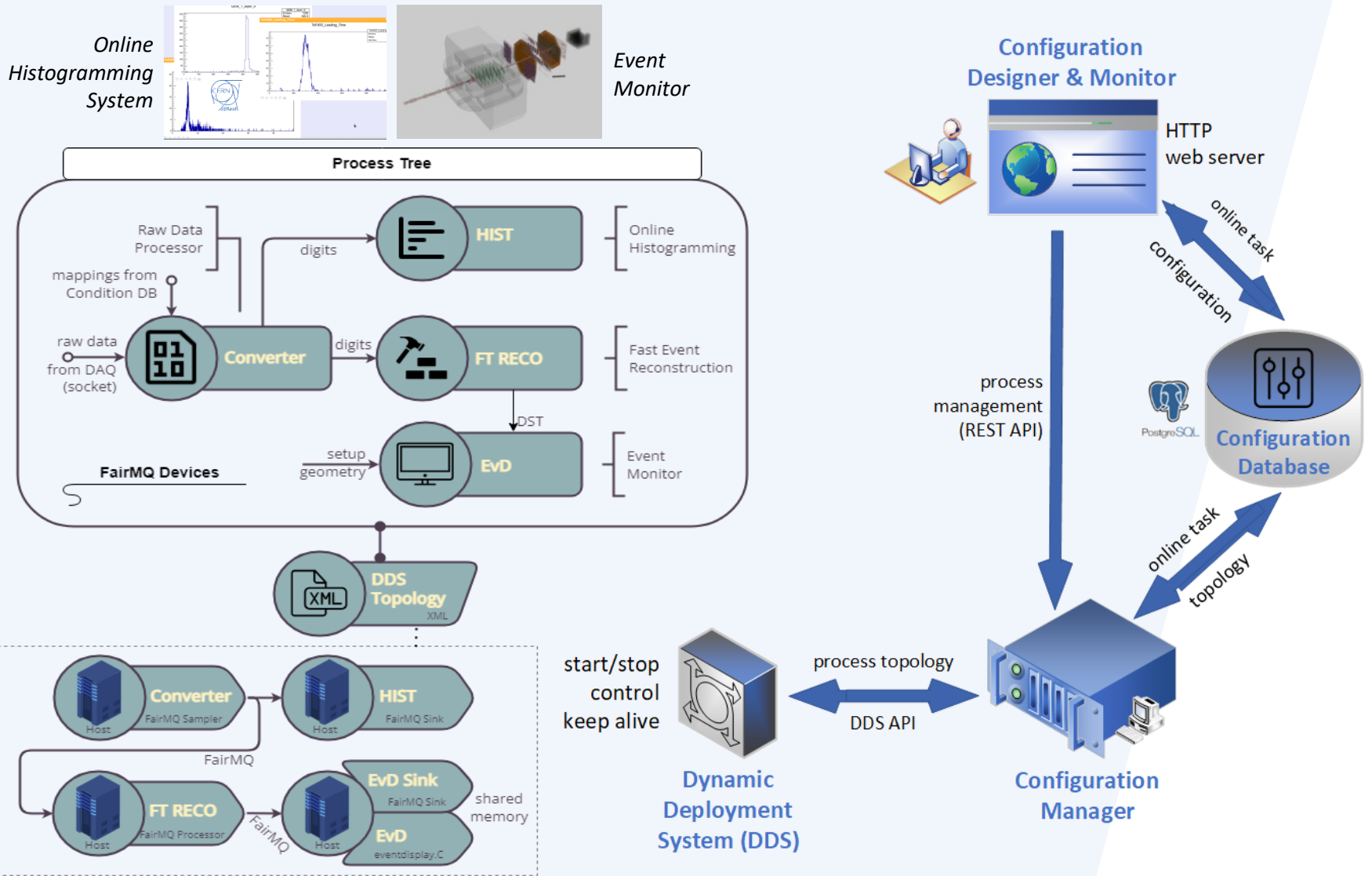
Online Process Control



Online
Processing

start → monitor → control → restart → stop

BM@N Online Quality Assurance



BM@N Online Configuration Platform

Menu

TASK MONITOR

CONFIGURATION MANAGER

DICTIONARY SET

Get in touch

✉ [Konstantin Gertsenberger](#)

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All rights reserved

Supported by

Configuration Manager

Select Setup Run:

BMN Run 7



Control panel

START

STOP

ADD SETUP MODULE

Module Name	Working Directory	Actions		
OnlineControl				

Module Tasks Module Properties

ADD MODULE TASK

Task Name	Host	Actions		
bmn_event_display_imit	[a-z]*[0-9]*[.]jinr[.]ru			
bmn_fast_event_reco_imit	[a-z]*[0-9]*[.]jinr[.]ru			
bmn_online_histo_imit	[a-z]*[0-9]*[.]jinr[.]ru			
bmn_root_digi_imit	[a-z]*[0-9]*[.]jinr[.]ru			

Task Monitor

Select task

Select setup

Select module

Started

Select host

FILTER

RESET

Task Name	Setup:Run	Module	Status	Log	Start Time	End Time	Host
bmn_event_display_imit	BMN:7	OnlineControl	Started		2023-05-05 18:39:16		vps104.jinr.ru
bmn_fast_event_reco_imit	BMN:7	OnlineControl	Started		2023-05-05 18:39:16		vm221-85.jinr.ru
bmn_online_histo_imit	BMN:7	OnlineControl	Started		2023-05-05 18:39:16		vps104.jinr.ru
bmn_root_digi_imit	BMN:7	OnlineControl	Started		2023-05-05 18:39:16		vps104.jinr.ru

Condition Database (UniConDa)

Offline Information System

Development Team
Alexander Chebotov,
Konstantin Gertsenberger

UniConDa in BM@N offline processing



ROOT-based framework

detector simulation
raw data processing
event reconstruction
physics analysis

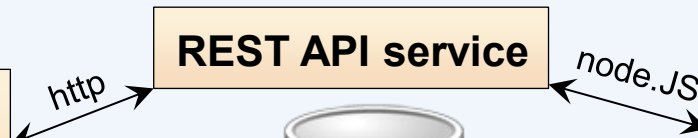
viewing and managing parameter data



users

Keycloak authentication authorization

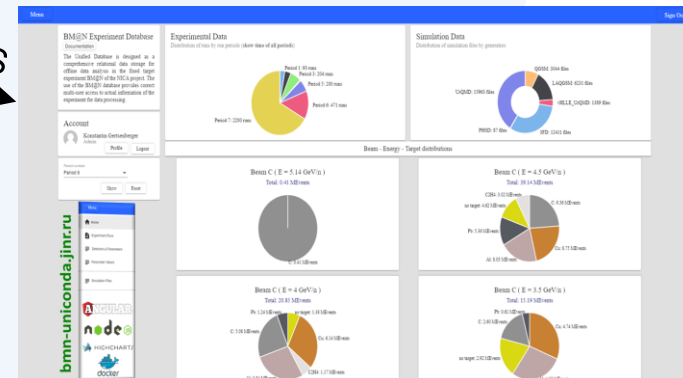
C++ interface
(connect, I/O, API)



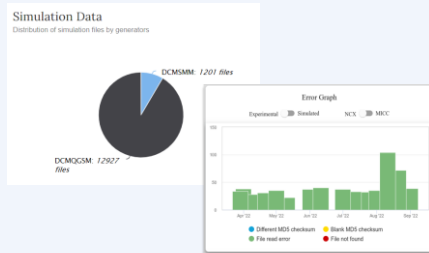
REST API service



Condition Database

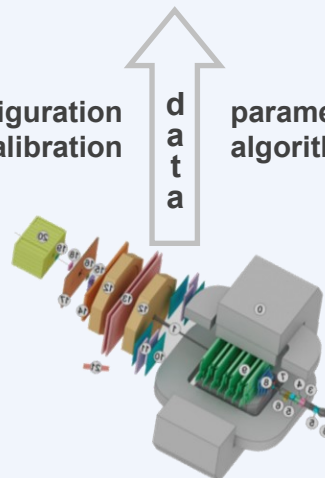


python service for auto updating of metadata on simulation files

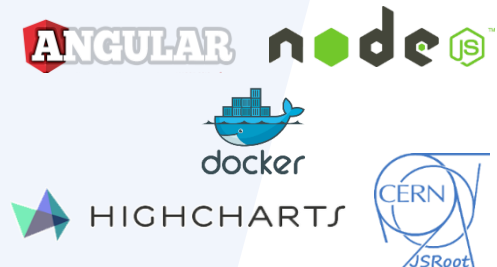


python service for automatic regular checking of file integrity

configuration calibration data parameter algorithm



Web Service



UniConDa. Web Application

The screenshot displays the UniConDa Web Application interface. At the top, there is a blue navigation bar with a 'Menu' button on the left and a 'Sign Out' button on the right. The main content area is divided into several sections:

- BM@N Experiment Database:** A section with a 'Documentation' link and a paragraph describing the database's purpose for the NICA project.
- Account:** A section showing the user's name 'Konstantin Gertsenberger Administrator' and a 'Logout' button.
- Experimental Data:** A section titled 'Distribution of events by run periods and time intervals of periods.' It features a pie chart with data for Period 2 (10 MEvents), Period 3 (22 MEvents), Period 5 (20 MEvents), Period 6 (76 MEvents), Period 7 (313 MEvents), and Period 8 (742 MEvents).
- Simulation Data:** A section titled 'Distribution of events by generators' with a 'DST' button. It features a pie chart with data for RQMD (10 MEvents), UrQMD (6 MEvents), DCMQSM (830 MEvents), and DCMSMM (153 MEvents).
- Beam - Energy - Target distributions:** Two sections showing distributions for 'Beam Xe (E = 3 GeV/n)' and 'Beam Xe (E = 3.8 GeV/n)'. Each section includes a pie chart with data for 'Csl (2%)', 'target', and 'Empty'.

On the left side, there is a vertical navigation menu with a 'Menu' button at the top. The menu items are: Home, Experiment Runs, Detectors & Parameters, Parameter Values, Simulation Files, and a search icon. Below the menu, there are logos for ANGULAR, node.js, HIGHCHARTS, and docker. A red arrow points to the search icon in the bottom left corner, labeled 'File Inspector'. A vertical green text overlay 'bmn-uniconda.jinr.ru' is positioned to the right of the menu.

- visualization of **summary data** in the form of diagrams and charts
- convenient viewing, managing and searching for up-to-date information on the BM@N experiment in **tabular view** by collaboration members

Geometry Database Offline Information System

Development Team
E. Akishina, E. Alexandrov,
I. Alexandrov, I. Filozova,
K. Gertsenberger, V. Ivanov

Geometry Information System

Menu

HOME

VIEW GEOMETRY

VIEW SETUPS

VIEW SETUP MODULES

VIEW GEOMETRY FILES

VIEW MATERIALS

VIEW MAGNETIC FIELDS


EDIT GEOMETRY

Get in touch

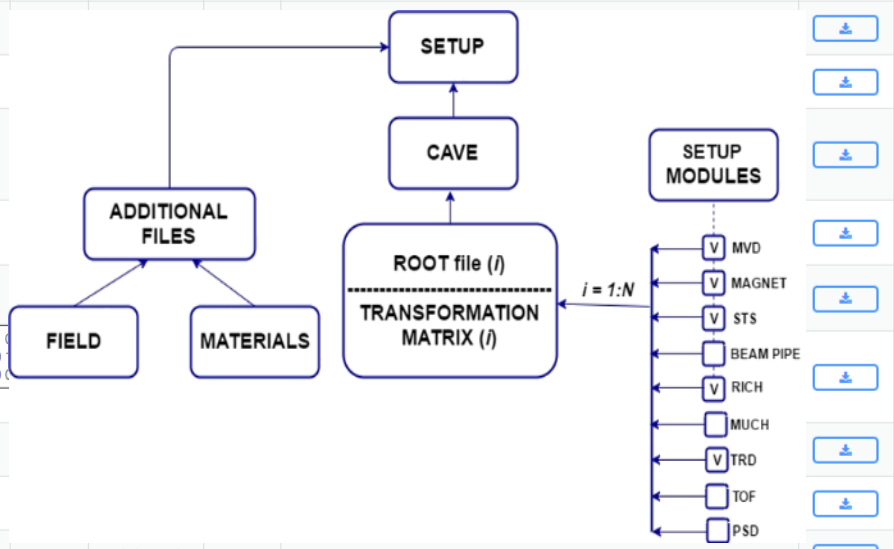
Konstantin Gertsenberger

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Setup Modules

KEYCLOAK  ➤ Keycloak auth
➤ or DB access

Module	Name (Tag)	Date	File	Transformation	Parent	Author	ParFile	Description	Download
BD	BD_run8_v1	2024-04-27	BD_run8_v1		CAVE	aleksand		BD_run8_v1	Download
CAVE	cave	2024-03-31	cave		none	administrator		Base cave	Download
CSC	FullCSC_Run8_detailed	2024-04-27	FullCSC_Run8_detailed		CAVE	aleksand	Download	FullCSC_Run8_detailed.root	Download
DCH	DCH_Run8	2024-05-02	DCH_Run8						Download
FD	FD_run8	2024-04-27	FD_run8						Download
FHCAL	FHCal_for_run8_cm_rotationY_1.6deg_v1	2024-05-02	FHCal_for_run8_cm_rotationY_1.6deg_v1						Download
HODO	Hodo_for_run8_v1	2024-05-02	Hodo_for_run8_v1						Download
MAGNET	magnet_modified	2024-04-27	magnet_modified						Download
NDET	nDet_VETO_slice_rotY_-27.30	2024-05-02	nDet_VETO_slice_rotY_-27.30						Download
Pipe	section3_Run8	2024-04-27	section3_Run8						Download
Pipe	section2_Run8	2024-04-27	section2_Run8						Download



BM@N Geometry Database has filled with the setup geometries for the last Run 8

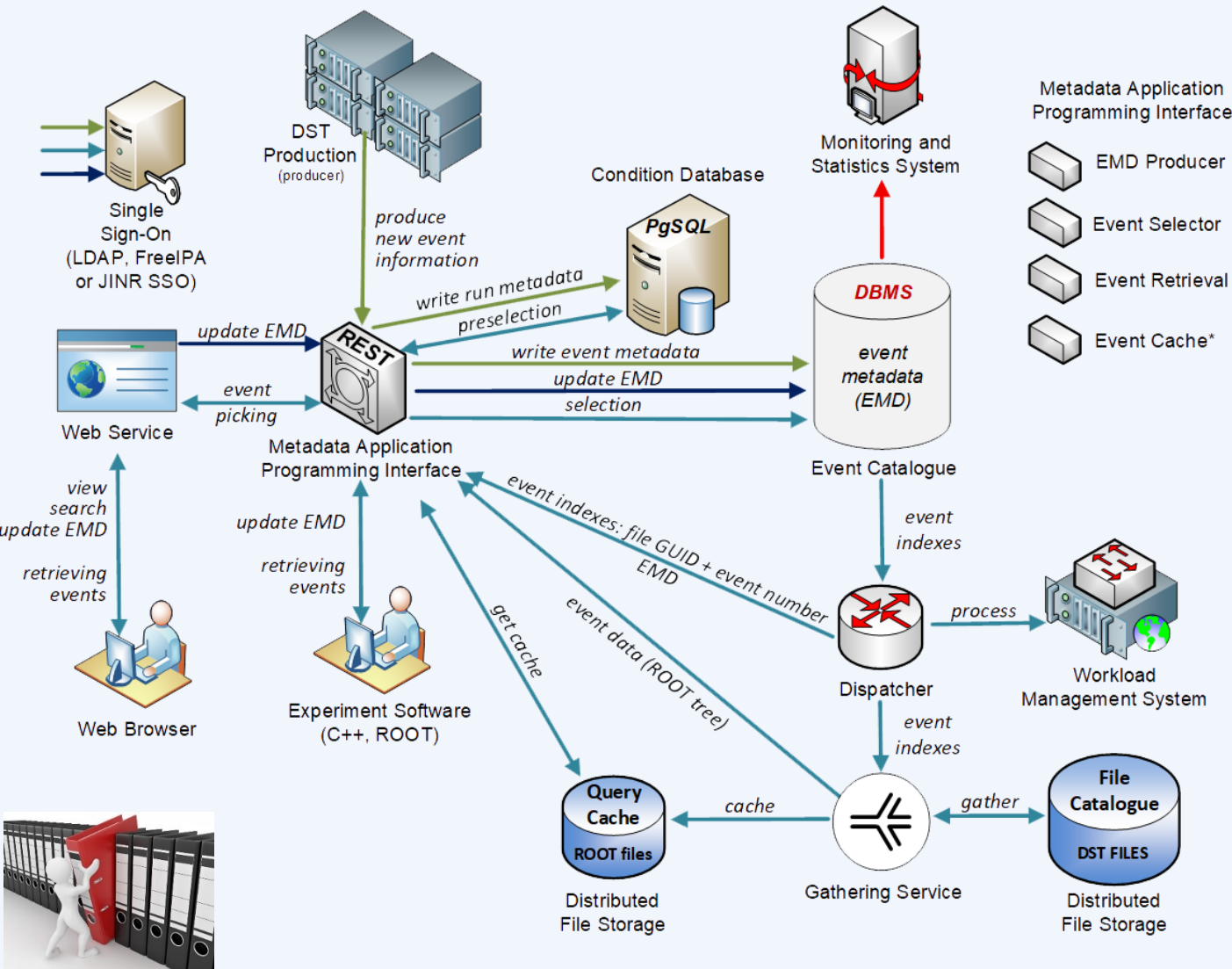
User Interface Functions:

View Add Edit Approve Download

Event Metadata System Offline Information System

Development Team
E. Alexandrov, I. Alexandrov,
A. Degtyarev, K. Gertsenberger,
I. Filozova, P. Klimai, A. Nozik, A. Yakovlev

BM@N Event Catalogue



- Metadata Application Programming Interface
- EMD Producer
 - Event Selector
 - Event Retrieval
 - Event Cache*

Event Catalogue based on PostgreSQL

Integrated with the Condition Database

REST API and Web UI developed on Kotlin multiplatform

Configurable to support arbitrary metadata

Service for automatic writing new event metadata to the Catalogue

Role-based access control

Monitoring System

Event Metadata System. *Web Interface*

BM@N Event Metadata System

BM@N Events
 Search Events
 SRC Events
 Search Events
 Test Events
 Search Events

Condition Database prefilter

base parameters

Test Events

Software Version

Period Number

Run Number

Beam Particle

Target Particle

Energy, GeV

Total track number

Triggers (string)

Primary vertex

Limit [dft=100]

Offset

Filter Reset

limits and offset

configured parameters

Storage	File path	# Event	Software	Period	# Run	Total track num...	Triggers (string)	Primary vertex
data1	/var/file1	150	19.1	7	5100	90	qwe	true
data1	/tmp/file4	1	19.1	7	5001	25	qwerty	true
data1	/tmp/file4	2	19.1	7	5001	77	qwerty1	false
data1	/tmp/file4	3	19.1	7	5001	25	qwerty	true
data1	/tmp/file4	4	19.1	7	5001	25	qwerty	true
data1	/tmp/file4	10	19.1	7	5001	25	qwerty	true
data1	/tmp/file4	11	19.1	7	5001	77	qwerty1	false
data1	/tmp/file4	12	19.1	7	5001	25	qwerty	true
data1	/tmp/file4	13	19.1	7	5001	77	qwerty1	false
data1	/tmp/file4	14	19.1	7	5001	25	qwerty	true

event pointer = file GUID + event number

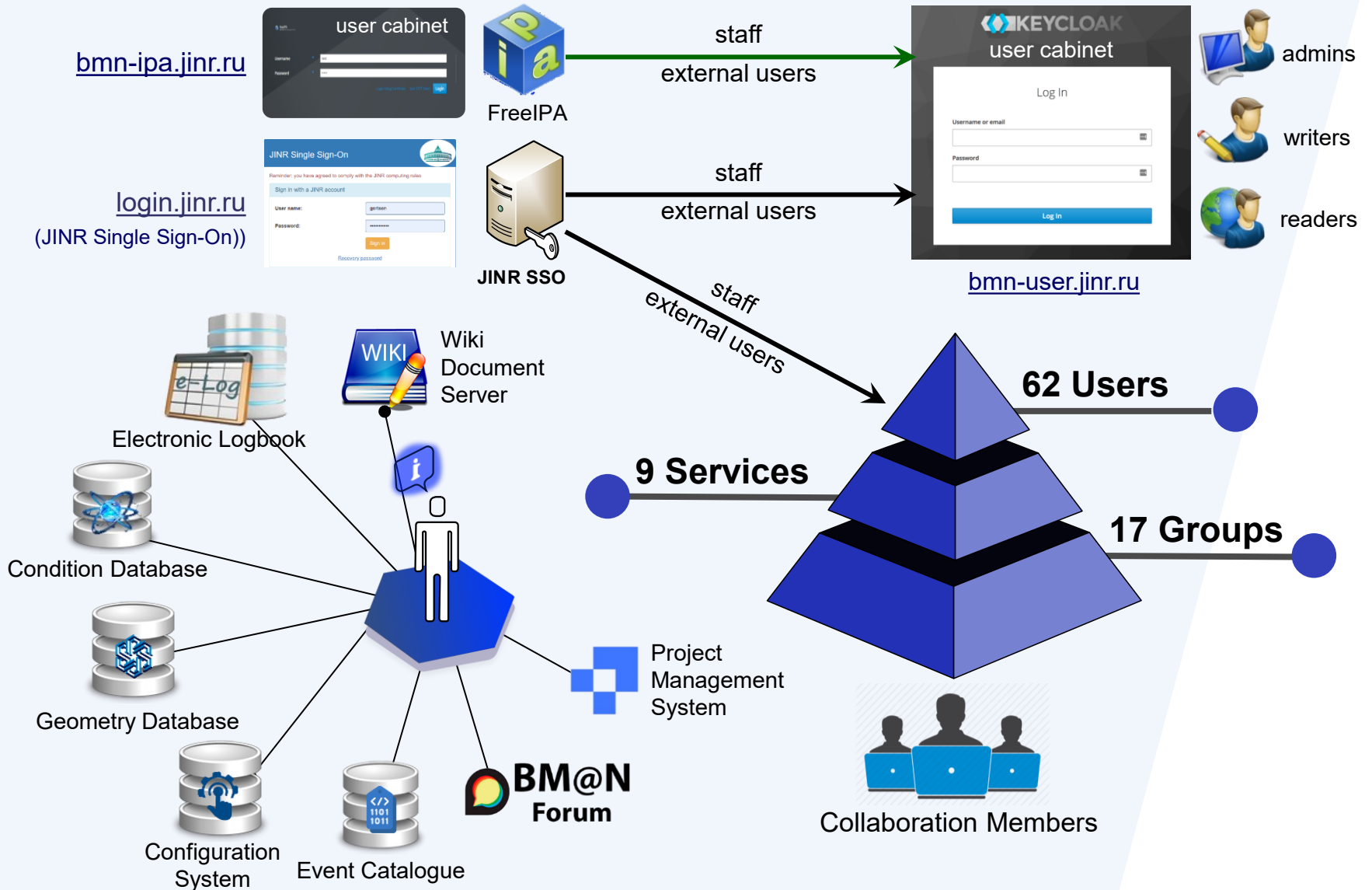
1-10 of 15

event metadata are written only if primary vertex has been found in the event

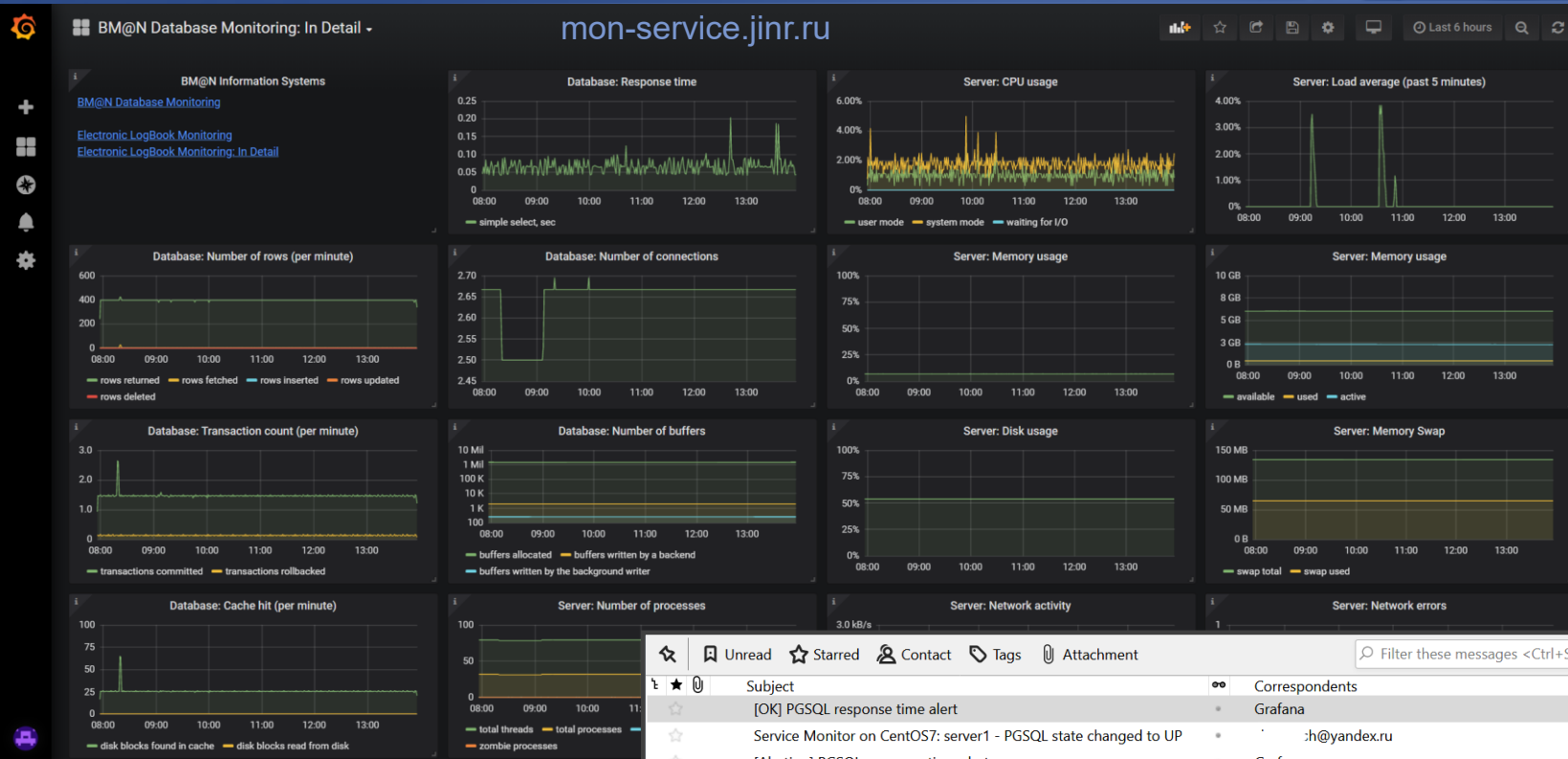
- enables users to browse and quickly search for event metadata stored in the Event Catalogue and retrieve events, which satisfy given parameters
- provides events according to the selected event metadata and run metadata of the Condition Database





BM@N Software Infrastructure

Single Sign-On (SSO) System for BM@N



Monitoring System for BM@N software complex



-  Telegraf
-  influxdb
-  Grafana
- 
- hosts
- databases
- web-sites

- Condition Database
- Electronic Logbook
- Configuration database
- Integrity Inspector

... *Email and Telegram Alerting*

Unread Starred Contact Tags Attachment Filter these messages <Ctrl+Shift+K>

Subject	Correspondents	Date
[OK] PGSQL response time alert	Grafana	2:41 PM
Service Monitor on CentOS7: server1 - PGSQL state changed to UP	h@yandex.ru	2:40 PM
[Alerting] PGSQL response time alert	Grafana	2:01 PM
Service Monitor on CentOS7: server1 - PGSQL state changed to *** ...	h@yandex.ru	1:54 PM

From Grafana <h@yandex.ru>

Subject [OK] PGSQL response time alert

To Me

[OK] PGSQL response time alert

Grafana: Database monitoring warning!

PGSQL response time

0.12

```

**Firing**
Value: 80=6.762580645161292
Labels:
- alertname = load5 alert [config]
- grafana_folder = BM@N
- rule_uid = csqj54z
Annotations:
- message = Load5 above threshold
Source: https://mon-service.jinr.ru/alerting/grafana/folder%2F3DBM%2F40N%2Fmatcher%2Frule%2Fcsqj54z%2Falert%2F8
Silence: https://mon-service.jinr.ru/alerting/silence/new?alertmanager=grafana&matcher.alertname%3Dload5%2Falert%2F8&conf%3Dmatcher-grafana_folder%2F3DBM%2F40N%2Fmatcher%2Frule%2Fcsqj54z%2Falert%2F8
Dashboard: https://mon-service.jinr.ru/d/ff7b37b1-2089-4fd1-9e79-3b8de735a4d4?orgid=8
Panel: https://mon-service.jinr.ru/d/ff7b37b1-2089-4fd1-9e79-3b8de735a4d4?orgid=8&viewPanel=5
    
```

Distributed Processing and Computing Clusters

Components of BM@N distributed complex

- ❖ **computing platforms** for the BM@N experiment
- ❖ **software distribution system** as a central repository of the experiment software
- ❖ **data storages** on distributed FS for experimental and simulated files
- ❖ **workload management system** for parallel task/job distribution
- ❖ **file and event catalogues** organizing smart namespaces with metadata
- ❖ **data transfer services** enabling the transfer of large amounts of data between users and storages within the federal administration
- ❖ **workflow management service** orchestrating task flows on data processing
- ❖ **information systems** based on databases providing necessary information for offline and online processing
- ❖ **user interfaces** (Web, API, CLI) to manage databases and distributed data processing
- ❖ **central authentication and authorization system** to regulate access rights
- ❖ **monitoring system** to control state of server nodes, databases and interfaces

BM@N Computing Platforms

BM@N Online Cluster
ddc.jinr.ru
(LHEP, b.205)



NICA Cluster
[ncx\[101-106\].jinr.ru](http://ncx[101-106].jinr.ru)
(LHEP, b.216)



GRID Tier1&2 Centres
lxui.jinr.ru (CICC)
(MLIT, b.134)



HybriLIT platform
(«Govorun» SC)
hydra.jinr.ru
(MLIT, b.134)



OS: AlmaLinux 9

OS: CentOS / Scientific Linux 7.9

Central Software Repository based on **CVMFS** for the experiment

CEPH: 2.8 PB (*replica*)
CEPH (hot): 100 TB_{ssd}
SLURM: ≈1000 cores

EOS: 1.2 PB (*replica*)
NFS: 300 TB (*for NICA*)
SLURM: ≈1800 cores
(*for all NICA users*)

EOS: 1.2 PB (*replica*)
EOS CTA: 500 TB_{tapes}
SLURM: 2500 cores
(*for all NICA users*)

ZFS: 200 TB
Lustre: 300 TB_{ssd} (*for NICA*)
SLURM: bmn – 192 cores

BM@N software has been installed & configured on JINR CVMFS ([/cvmfs/bmn.jinr.ru/](http://cvmfs/bmn.jinr.ru/))
Automatic software deployment of the BmnRoot package on CVMFS with GIT CI

Software Distribution System with CVMFS

NICA / bmnroot / Pipelines / #61482

clang-format files

Passed Konstantin Gertsenberger created pipeline for commit @ad9f7da 21 hours ago, finished 21 hours ago

Related merge request 11294 to merge tango_improving

latest merge request 17 jobs 19 minutes 14 seconds, queued for 1 seconds

Pipeline Needs Jobs 17 Tests 0

Group jobs by Stage Job dependencies

Code Format Checker

Simulation, Raw Data Decoder, Reconstruction Tests

Compilation

check_permissions
check_permissions

check_formatting
check_formatting_mr

build
build:alma9
build:centos
build:ubuntu

test_form_digi
run_raw_bmn:alma9
run_raw_bmn:centos
run_raw_bmn:ubuntu
run_sim_bmn:alma9
run_sim_bmn:centos
run_sim_bmn:ubuntu

test_run_reco
run_reco_exp:alma9
run_reco_exp:centos
run_reco_exp:ubuntu
run_reco_sim:alma9
run_reco_sim:centos
run_reco_sim:ubuntu

BM@N bmnroot

Project information
Simulation and Analysis Framework for the BM@N experiment of the NICA project

pipeline passed failed macros 356
unformatted files 1983

macros test format test

GIT Pipelines on Merge Requests

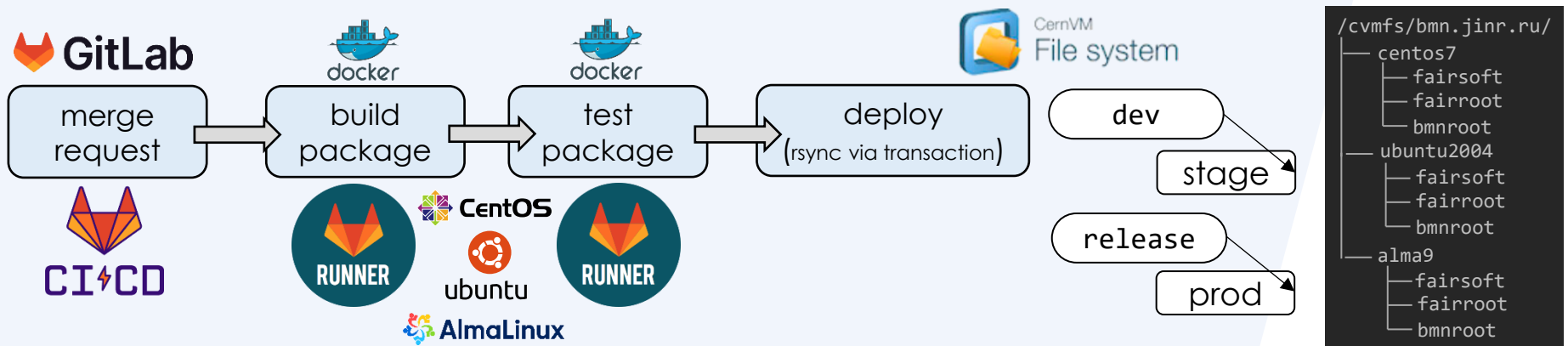
- checking compilation and main macros
→ stable dev & pro branches, all tags
- **deploy BmnRoot to the CVMFS storage**
- **deploy BmnRoot containers to the registry**
- checking Clang code formatting

GIT Night Tests

- test all BmnRoot macros
- test all C++ files for correct code format
- generate Doxygen documentation

Software Distribution via CernVM File System

Read-only network file system with aggressive caching, optimized for software distribution via HTTP in a fast, scalable and reliable way



Data Storages for BM@N

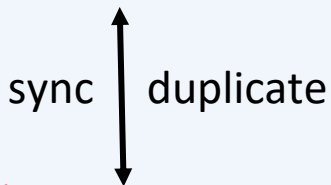


for BM@N online (2.8 PB)
build on HDD with SSD buffer

NICA cluster



for BM@N offline (1.2 PB)
build on HDD



MLIT CICC



for BM@N offline (1.2 PB)
build on HDD

NICA cluster



fast on NVMe SSD

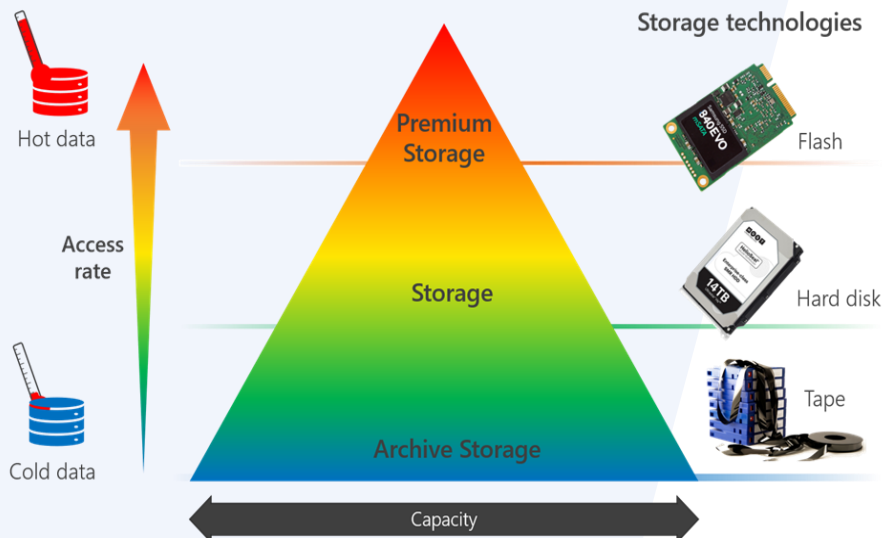
HybridLIT



fast on NVMe SSD

MLIT CICC

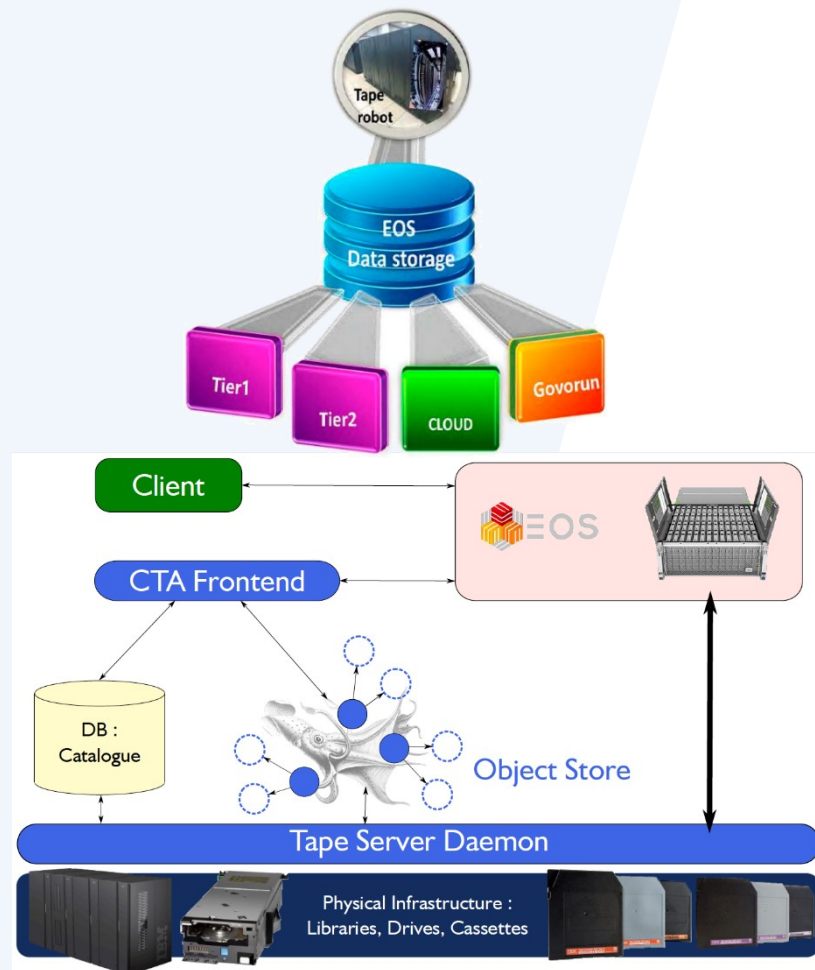
nope



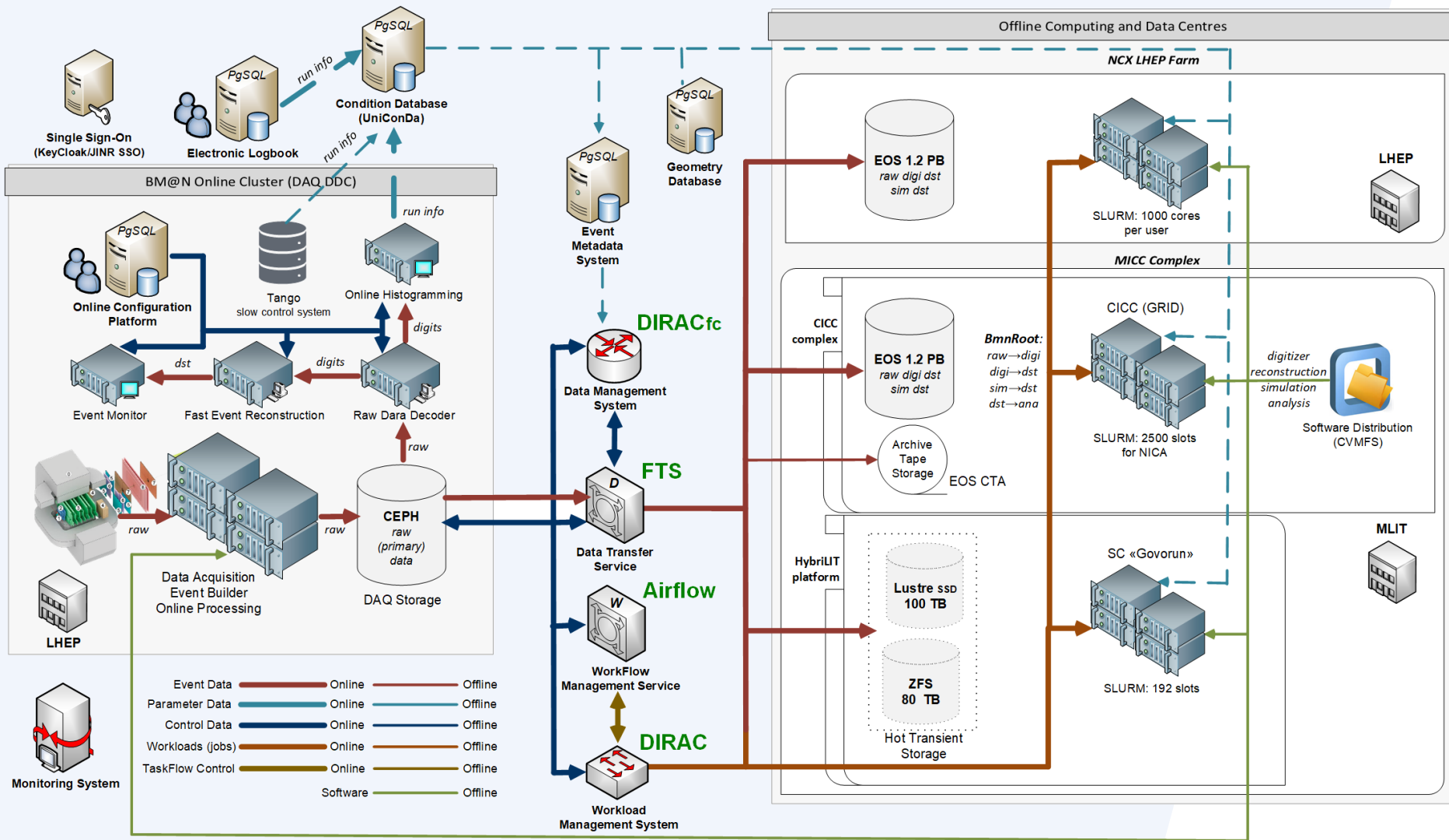
Archive Tape Storage for BM@N

EOS CTA Integration in MLIT

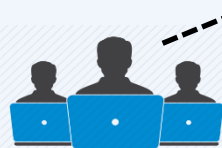
- ❖ CTA tape is a new archive solution developed at CERN to replace Castor
- ❖ Extends MLIT EOS with tape backend functionality
- ❖ Tape “bringonline” exposed via EOS and XRootD protocols
- ❖ Gfal2 XRootD plugin
- ❖ Can be handled transparently by FTS
- ❖ Advantages: long lifespan, cost of use, energy efficiency, security
- ❖ Tape robotic systems – a long-term storage for BM@N, stores *raw* and *gen* data, *online raw data backup to tapes*



Designed Computing Software Architecture



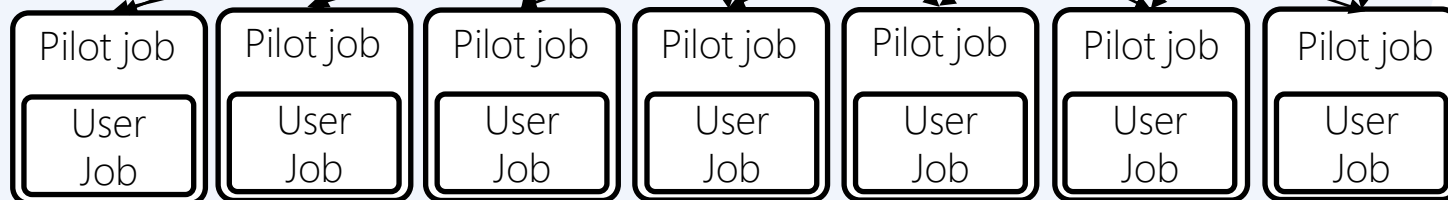
DIRAC Workload Manager for BM@N



Collaboration members

Production Manager: Igor Pelevanyuk

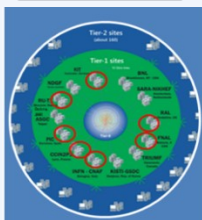
Submit thousand of jobs to DIRAC Job Queue



BM@N
Online Cluster



NICA Cluster



CICC
Tier-1



CICC
Tier-2



Clouds



Govorun



External
Collaborators

BM@N DST Production via DIRAC (Run 8)

Total duration of Raw2Digi campaign \approx 1.5 days (0.2 s/ev)

Quotas (cores):

Tier1: 1500 (for NICA)

Tier2: 1000 (for NICA)

Govorun: 192 (BM@N)

NICA cluster: 1000 (per user)

Duration of a job

Each point is a job with particular duration on a core with particular performance the benchmark

Tier1 old cores

Govorun

Tier1 new cores and NICA cluster

CPU core performance on benchmarks

DST production for Run 8 data (3.8 AGeV) took **1 week**

Total files: **30 741** Total raw size: **393 TB**

Average transfer speed (20 streams): **1.92 GB/s**

Total transfer duration: **2d 15h**

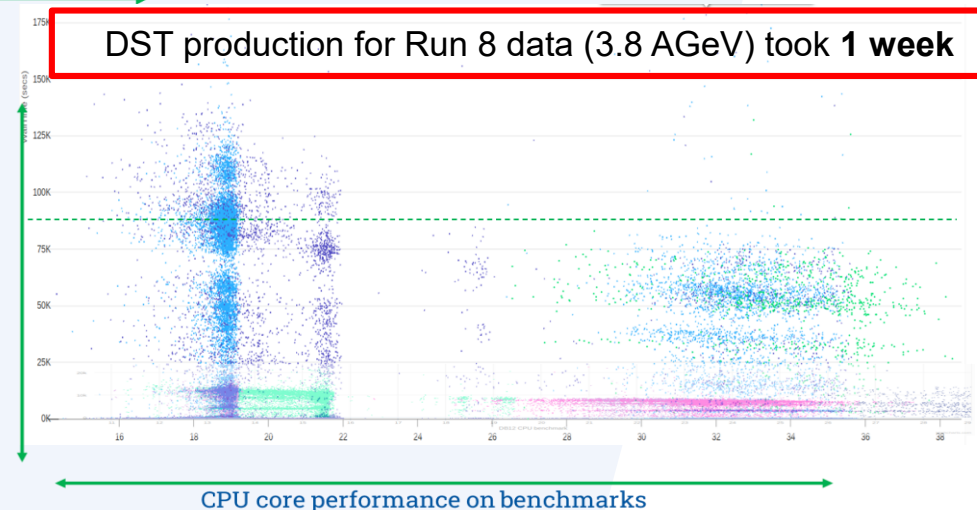
Max transfer speed (R+W) EOS@MLIT: **7.5 GB/s**

Achieved Drive \rightarrow Tape writing speed: **1.25 GB/s**

Total disk usage per job (15 GB): **25 GB**

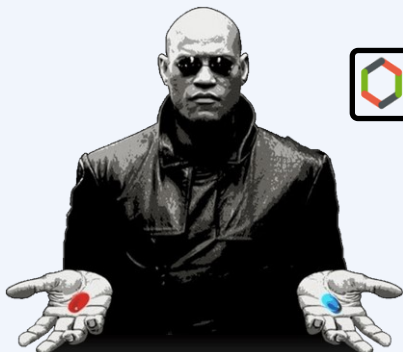
RAM usage: **2 GB**

Total wall time: **70 CPU years**



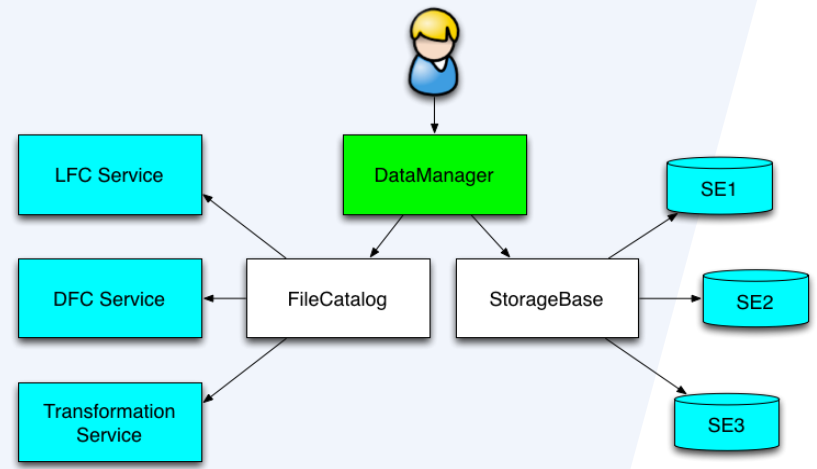
File Catalogue Choice for BM@N

- File Catalogues map a Logical File Name (LFN) to the Physical File Name (PFN) at distributed computing platforms
- The native **DIRAC** File Catalog (DFC) combines both replica and metadata functionality. In the DFC metadata can be associated with any directory, and subdirectories inherit the metadata of their parents
- RUCIO** is a Distributed Data Management System initially developed for the ATLAS experiment in 2014 providing file and dataset catalogue and transfers between sites and staging capabilities, policy engines, caching, bad file identification and recovery, and many other features.



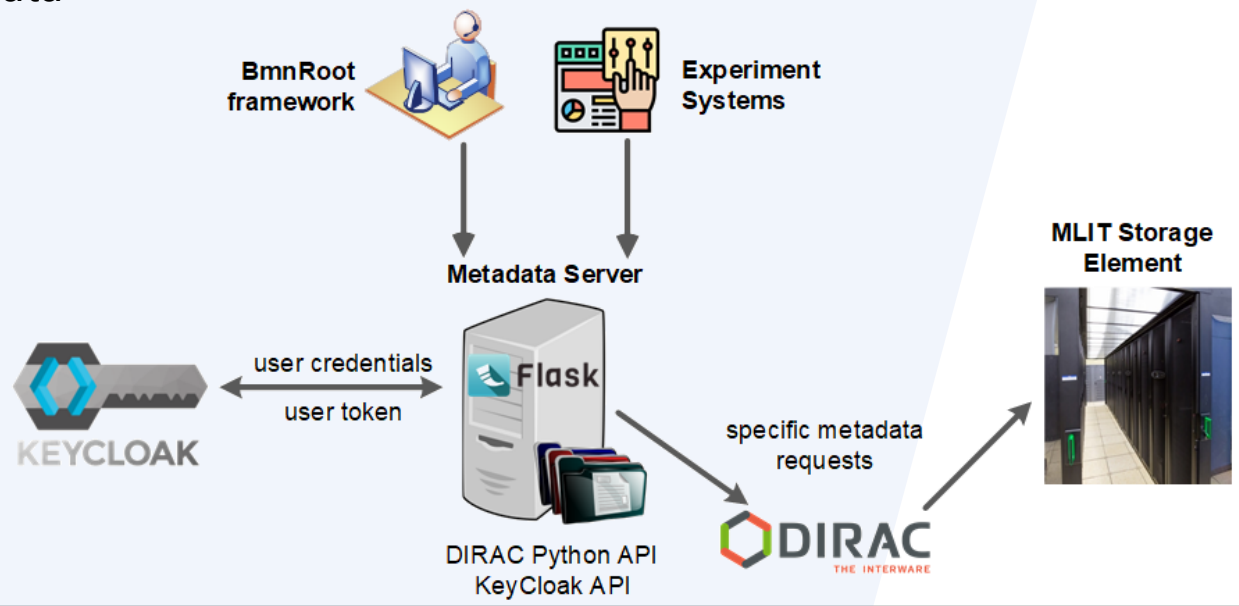
DFC Integration for the BM@N experiment

- DIRAC File Catalog (DFC) is maintaining a single global logical name space
- A user sees it as a single catalogue with additional features
- DataManager is a single client interface for logical data operations
- DFC also may host Metadata

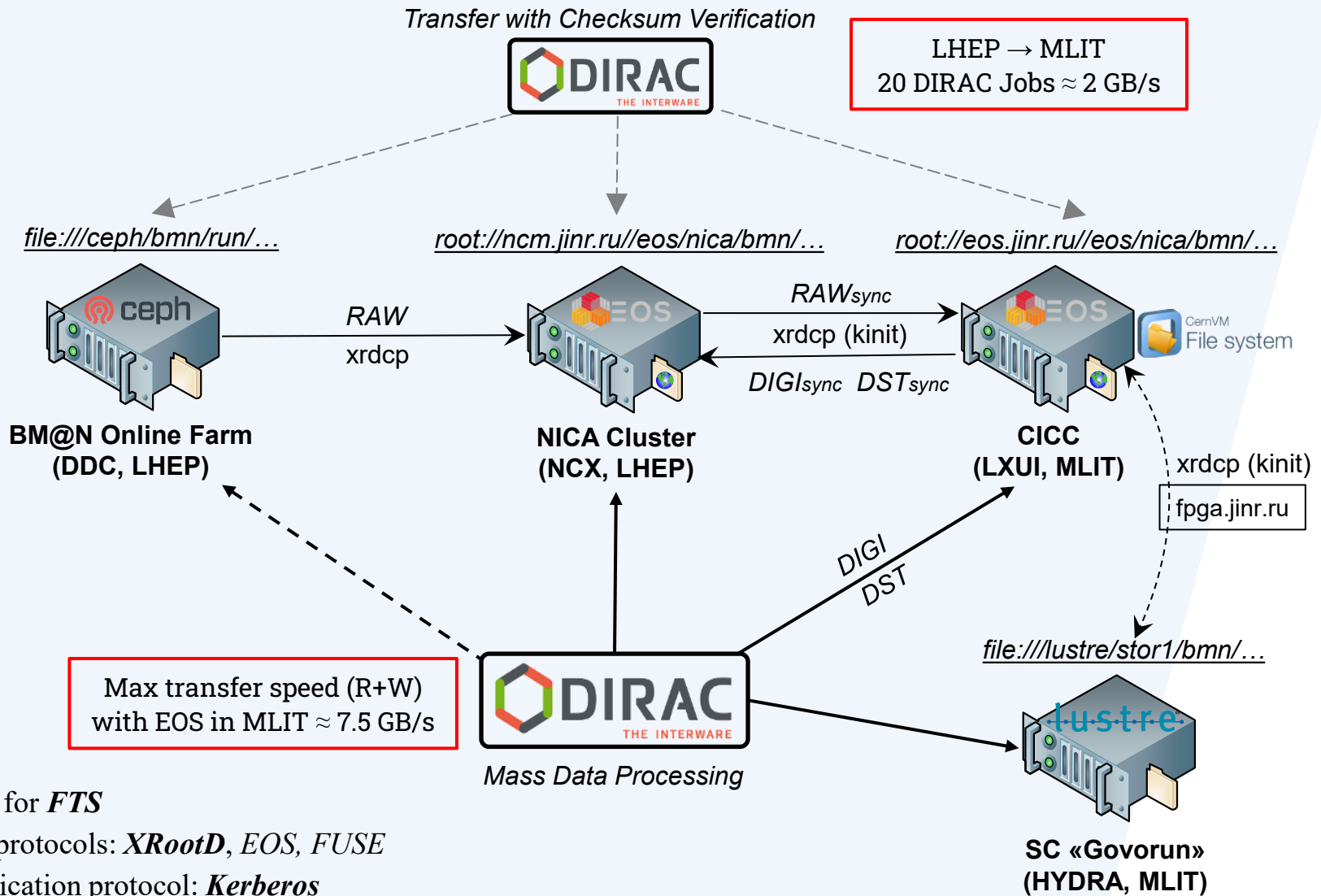


BM@N DFC Metadata (Run 8):

- period and run number
- start and end datetime
- beam and target particles
- run type
- energy
- magnetic field
- start and end event number
- event count
- file size



BM@N Data Transfer

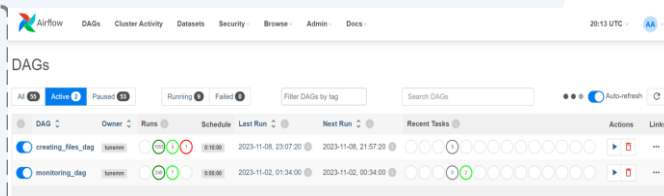
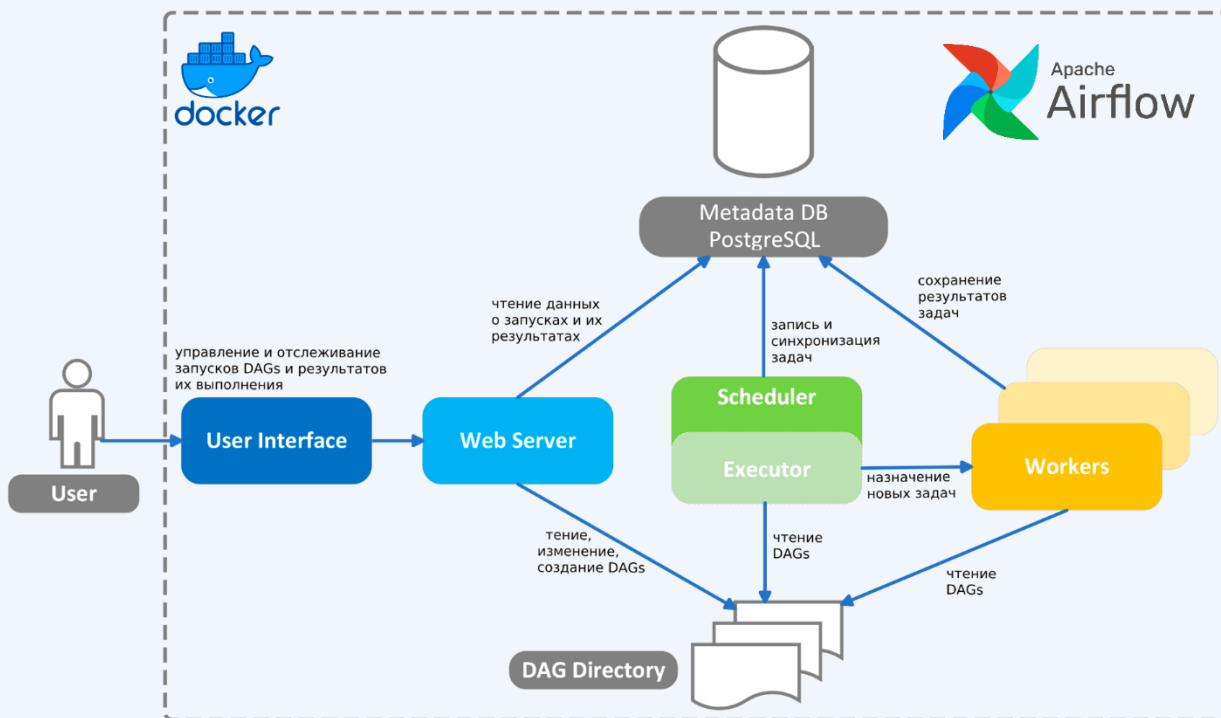


Waiting for *FTS*

Access protocols: *XRootD*, *EOS*, *FUSE*

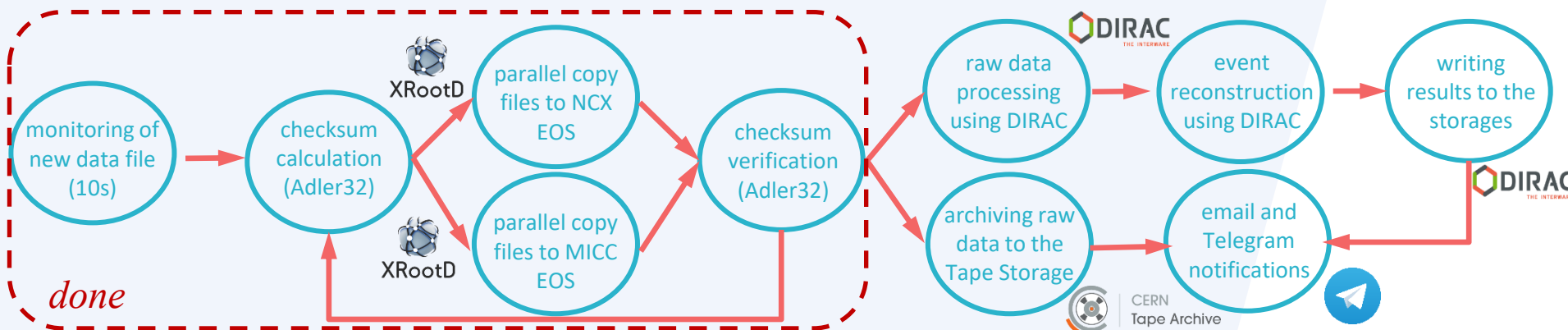
Authentication protocol: *Kerberos*

BM@N Orchestration with Workflow Manager



Airflow DAGs can be used for repeating data processing of simulation and experimental events

Airflow DAG for online transferring to the EOS storages, archiving to the Tape Storage and running online data processing using DIRAC



BM@N Collaboration

5 Countries, 13 Institutions, 214 participants

BM@N Spokesperson – R. Lednicky, JINR

Software Coordinator – K. Gertsenberger, JINR

BM@N official website: bmn.jinr.ru

my email contact: gertsen@jinr.ru



Հնորհակալութիւն ու Հաղորդքյան համար



Director: S. V. SHMATOV. Scientific Leader: V. V. KORENKOV

JINR MLIT
Contribution
to BM@N

***BM@N is open
for cooperation
and enthusiastic
people!***

Igor ALEXANDROV, Evgeniy ALEXANDROV, Irina FILOZOVA, et alia
Development of the Geometry Database and Online Configuration Systems

Nikita BALASHOV
CVMFS Deployment, GitLab Services, Docker Containers

Igor PELEVANYUK
DIRAC workload management system and BM@N mass production

Dmitriy PODGAYNY, Oksana STRELTSOVA, Maksim ZUEV
HybriLIT and SC Govorun support

Daria PRIAKHINA, Vladimir TROFIMOV
Modelling System for BM@N computing infrastructure

Zarif SHARIPOV, Zafar TUKHLIEV
Automation of BM@N Geometry Alignment



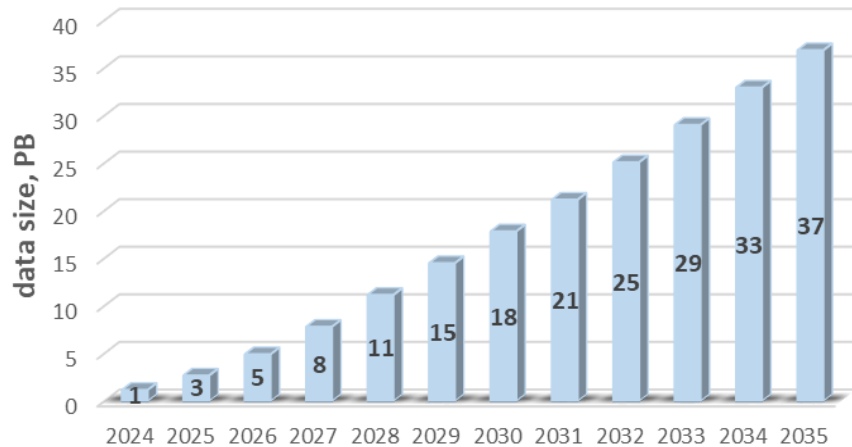
thanks to the DDC,
CICC, NCX &
HybriLIT teams for
computing support

contact email: gertsen@jinr.ru

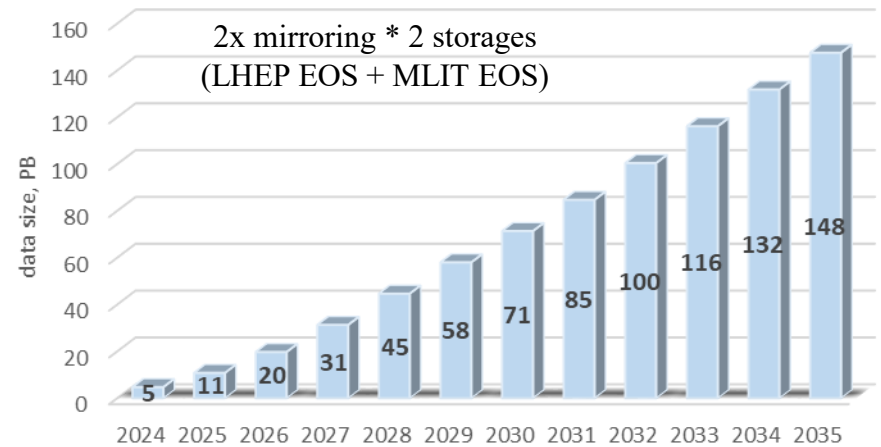
BACKUP

BM@N Resource Prospect for 2024-2035

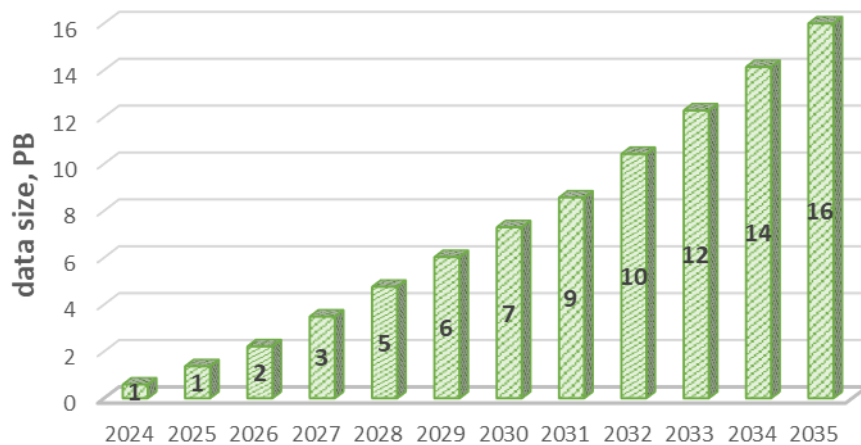
Disk Data Size



Disk Data Storage (4x replica)



Tape Data Size



Data Processing (CPU cores x days)

