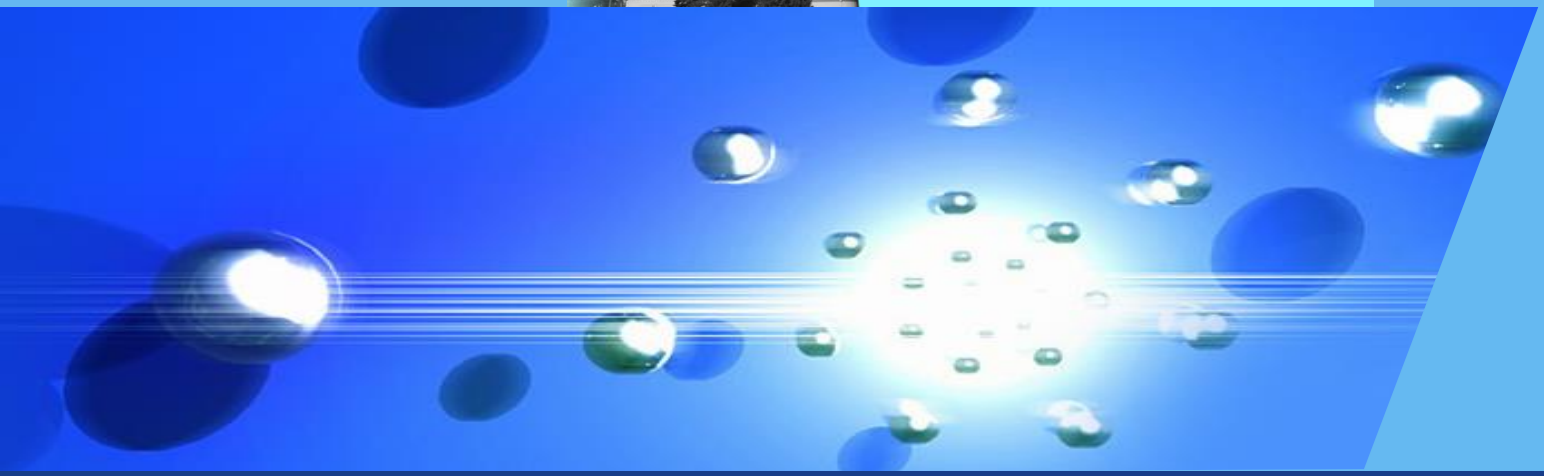
Школа по информационным технологиям ОИЯИ



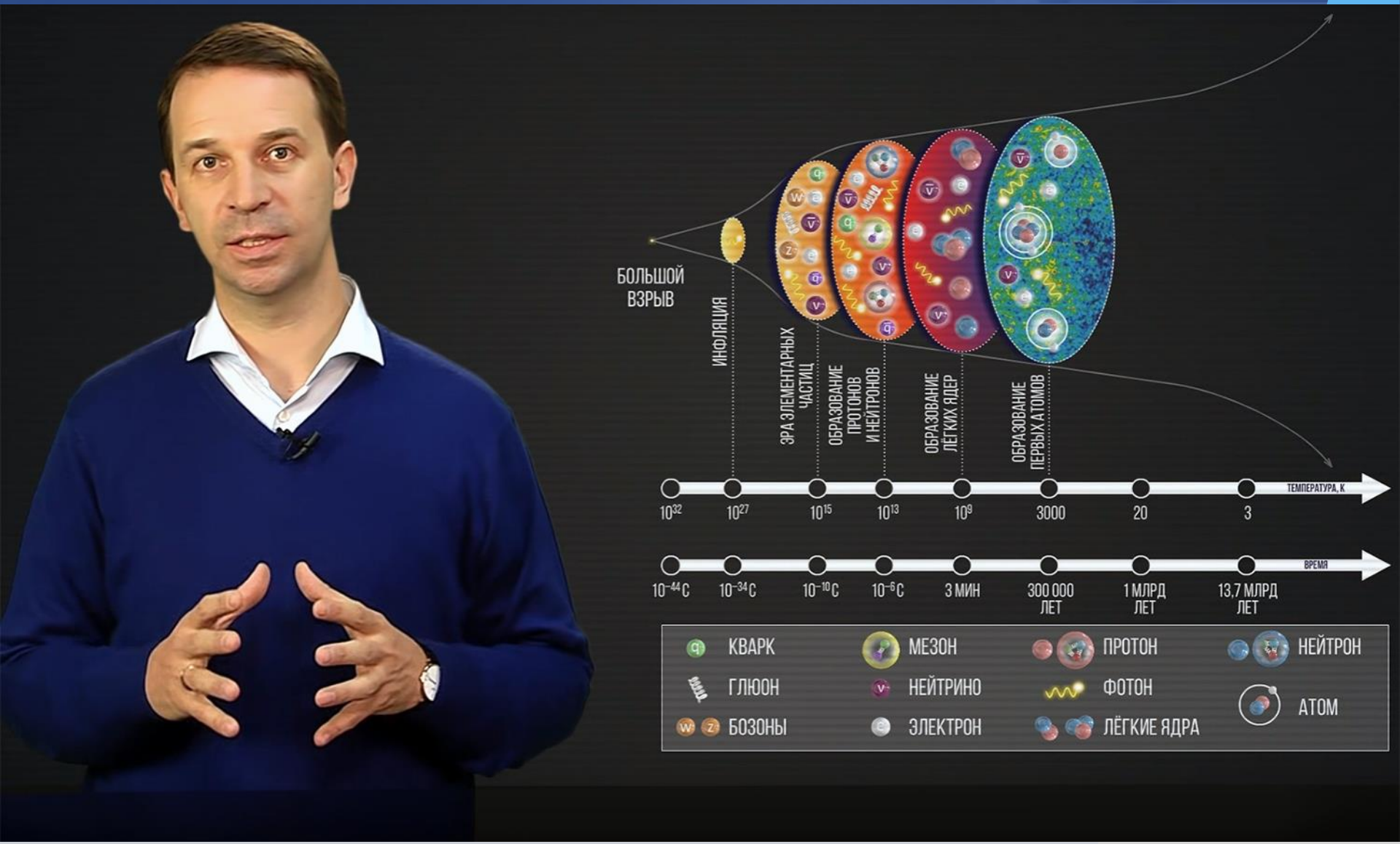
Информационные системы и сервисы сопровождения эксперимента BM@N

Константин Викторович Герценбергер
координатор программной части эксперимента BM@N
ЛФВЭ, Объединенный институт ядерных исследований

15 November 2022

BM@N Experiment at NICA

NICA – Вселенная в лаборатории



Nuclotron-based Ion Collider fAcility

- Beams: from $p, d^{\uparrow}$ to Au^{79+}
- Luminosity: 10^{27} (Au^{79+}), 10^{32} (p) $cm^{-2}s^{-1}$
- Collision energy: $\sqrt{S_{NN}}_{AU}$ = *4 – 11 Gev* E_{lab} = *1 – 6 AGev*
- Fixed target experiment: BM@N (2018)
- 2 interaction points: MPD (2023) & SPD (2027)
- Official site: *nica.jinr.ru*

Experimental Modes

fixed target

advantages

- *rate is limited just by detector capability*
- *easy upgradable*
- *….*

collider

advantages

- ***coverage of max. phase space***
- *minimum biased acceptance*
- *free of target parasitic effects*
- *….*

disadvantages:

- *a limited phase space*
- *momentum dependent corrections*
- *target influenced corrections*

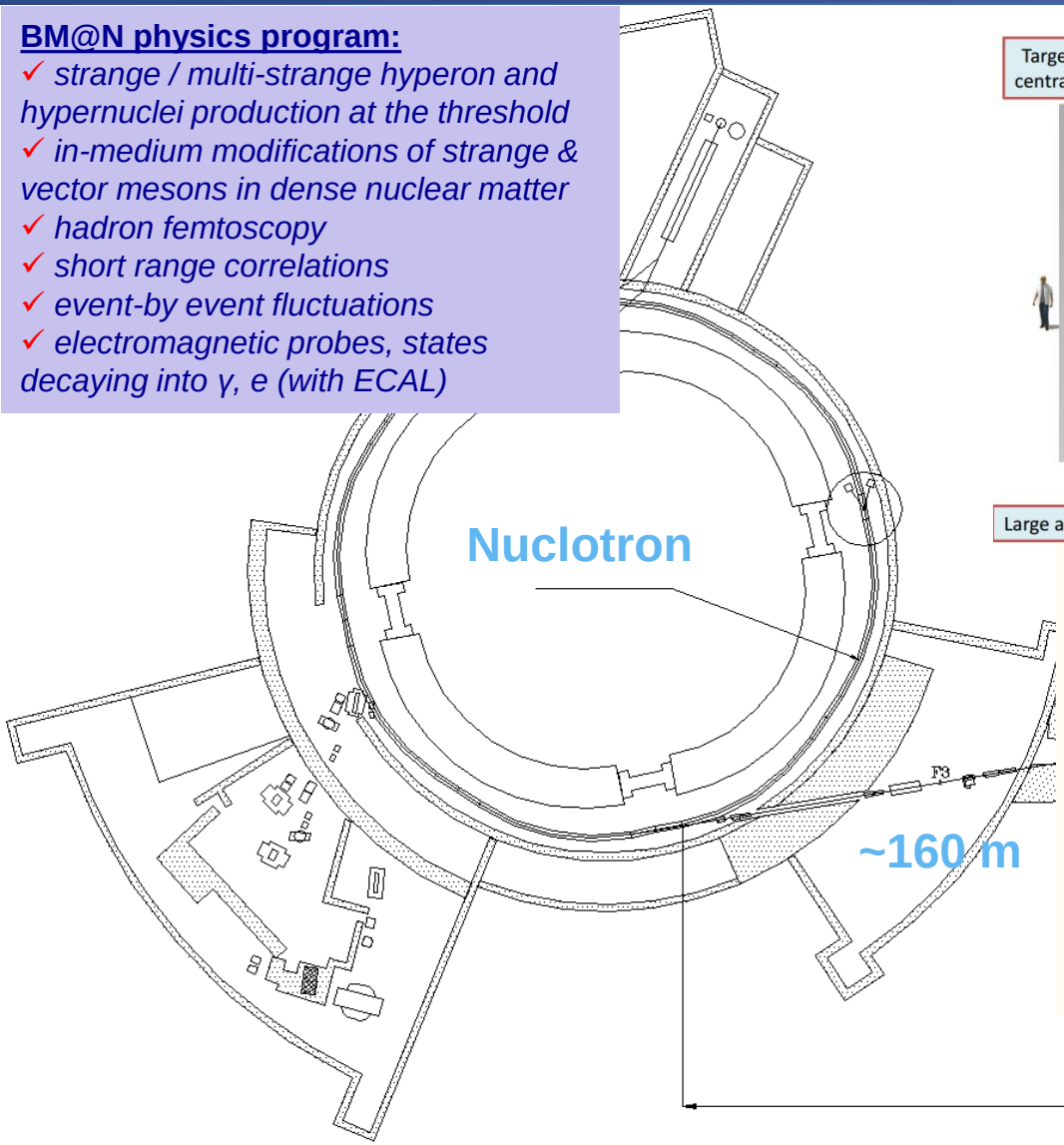
disadvantages:

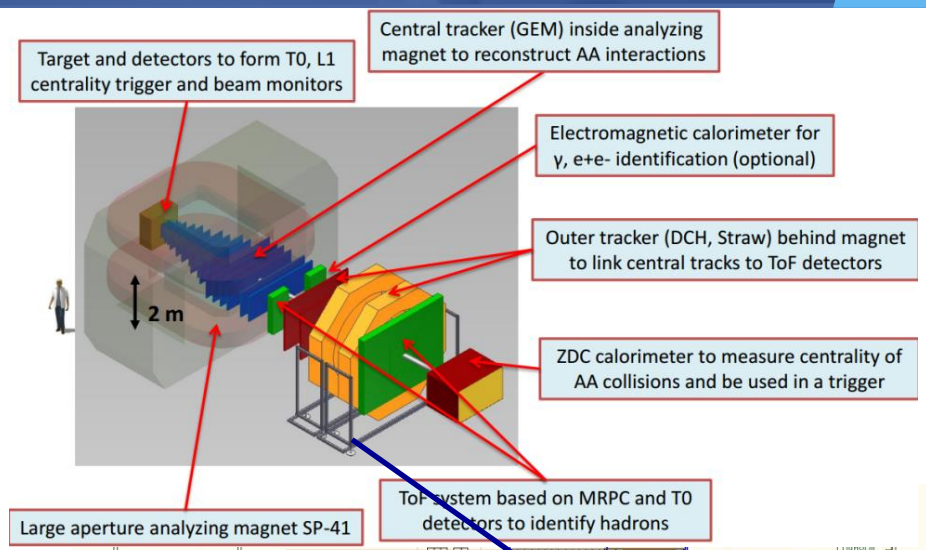
- *rate is limited by luminosity*
- *limited combinations “beam”/”target”*
- *…..*

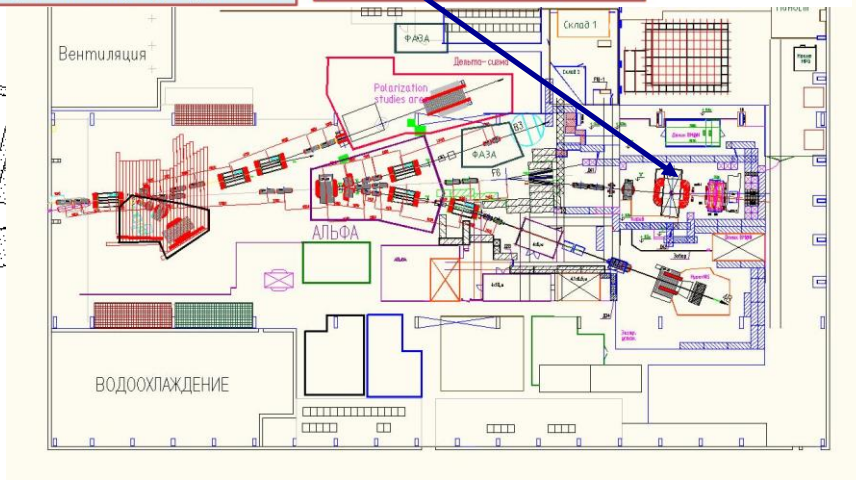
Baryonic Matter @ Nuclotron

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 (with ECAL)*







BM@N Collaboration

9 *Countries,* ***17*** *Institutions,* ***227*** *participants*

spokesperson – ***M. Kapishin****,* ***JINR***

technical coordinator – ***S. Piyadin****,* ***JINR***

BM@N in Nuclotron Runs (2015 – 2022)

❖ **Nuclotron Run 51** (d,C)		*Feb. 22 – Mar. 15,* ***2015***
❖ **Nuclotron Run 52** (d)	***Technical***	*June 29 – June 30,* ***2016***
❖ **Nuclotron Run 53** (d, d↑)	***interaction rate: 5 KHz***	*Dec. 09 – Dec. 23,* ***2016***
❖ **Nuclotron Run 54** (C)		*Mar. 07 – Mar. 18,* ***2017***
❖ **Nucl. Run 55** (C,Ar,Kr)	***Technical+SRC Physics*** ***interaction rate: 10 KHz***	*Mar. 03 – Apr. 05,* ***2018***
❖ **Nucl. Run 56: SRC** (C)	***Physics***	*Mar. 07 – Mar. 28,* ***2022***
❖ **Nucl. Run 57: BM@N** (Xe)	***interaction rate: 10 KHz***	*upcoming weeks*

- Beams: deutron (4 AGeV), C^{12} (3.5–4.5 AGeV), Ar (3.2 AGeV), Kr (2.4, 3.0 AGeV)
  Targets: C, Cu, Pb, Al, Sn, C_2H_4, H_2 or empty
- Trace beams, measure beam profile and time structure
- Test integrated DAQ, T_0 and Trigger system
- Detectors: MWPC, Si, GEM, ToF-400, DCH-1, DCH-2, ToF-700, ZDC, ECAL, LAND
- Detect min bias beam-target interactions to reconstruct hyperons, identify charged particles and nucleus fragments

Data Collected in Run 7 (Nucl. Run 55)

Main BM@N program:

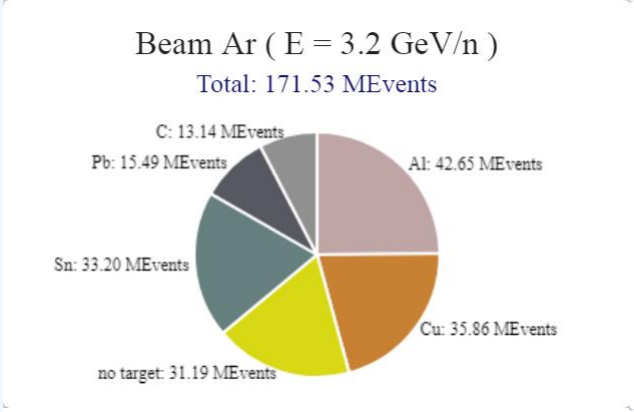
One beam energy available for Ar-beam and three for Kr-beam

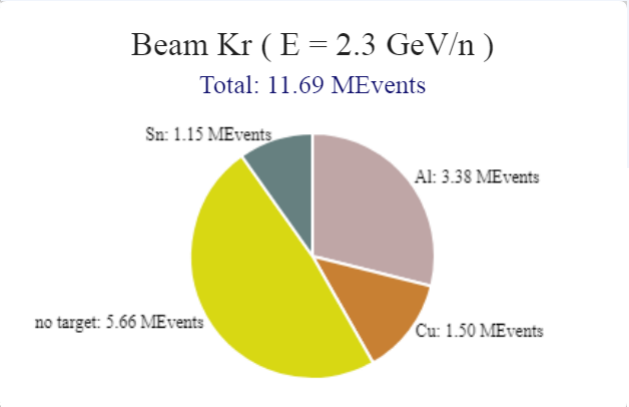
Wide set of targets used: (*C*; *Al*; *Cu*; *Sn*; *Pb*)

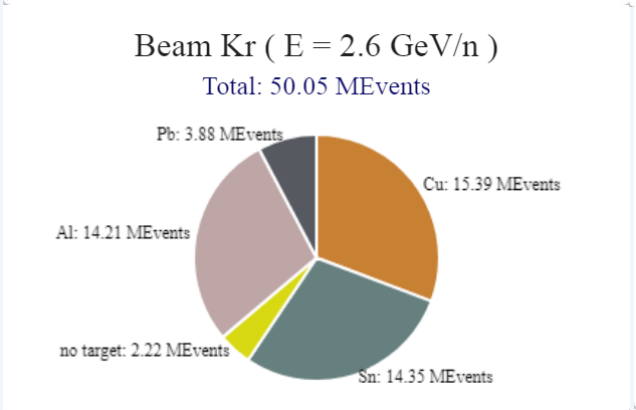
BM@N SRC program:

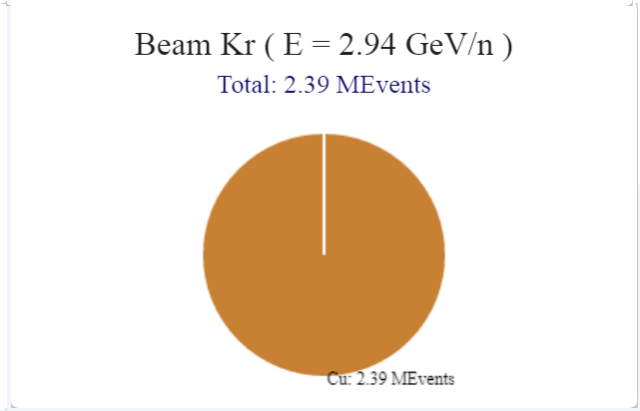
One beam energy available for C-beam

More than half of the collected statistics can be used for SRC analysis

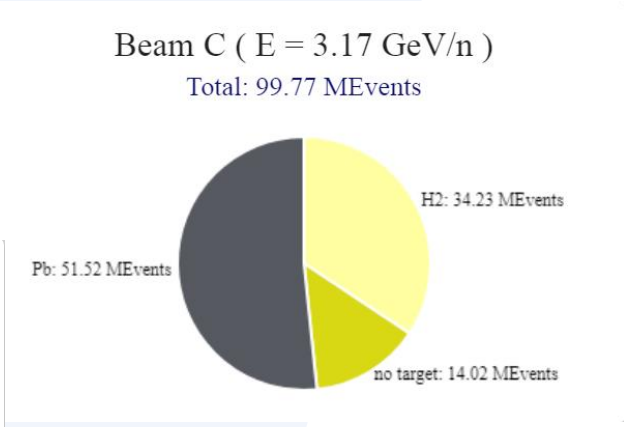








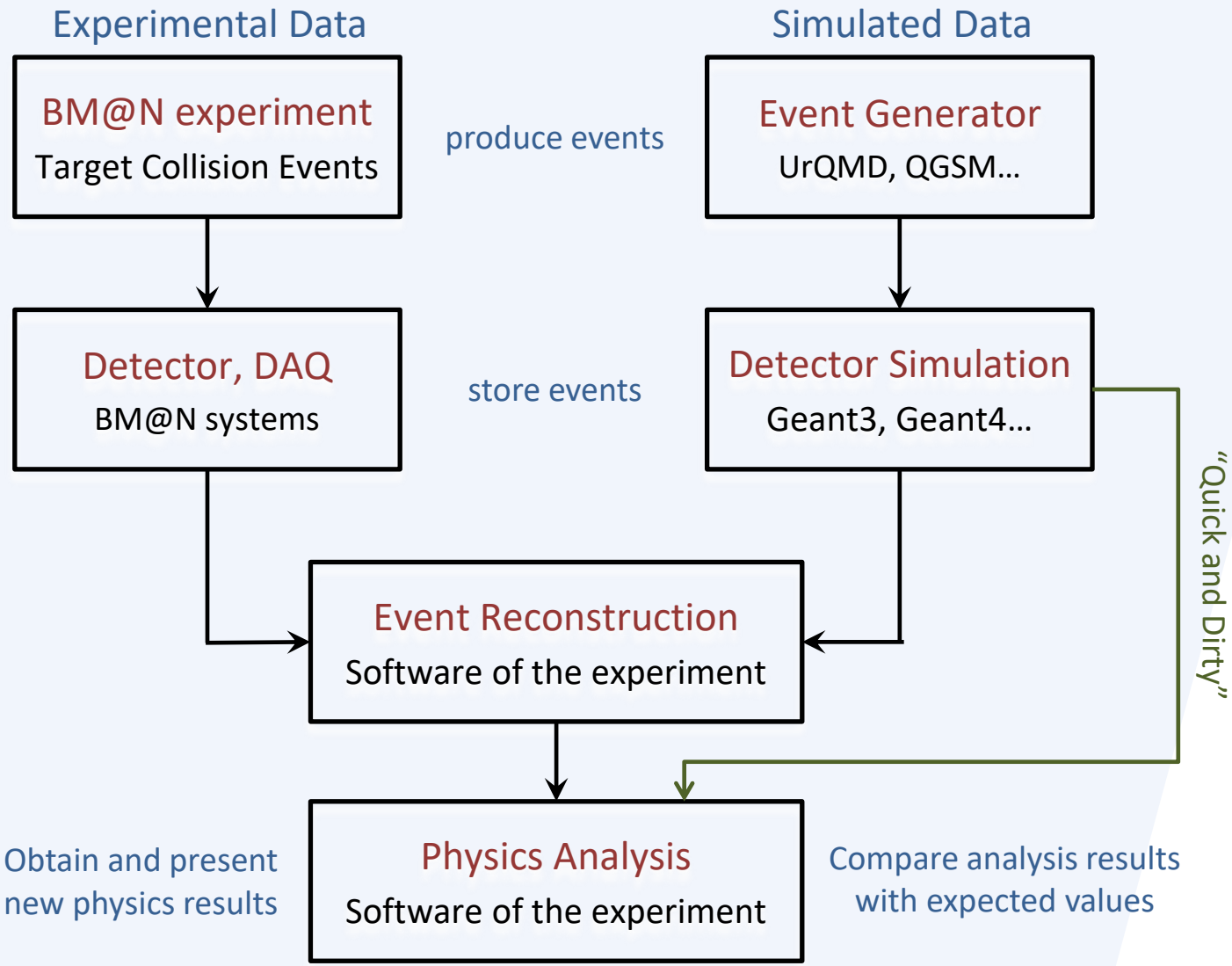
BM@N



SRC

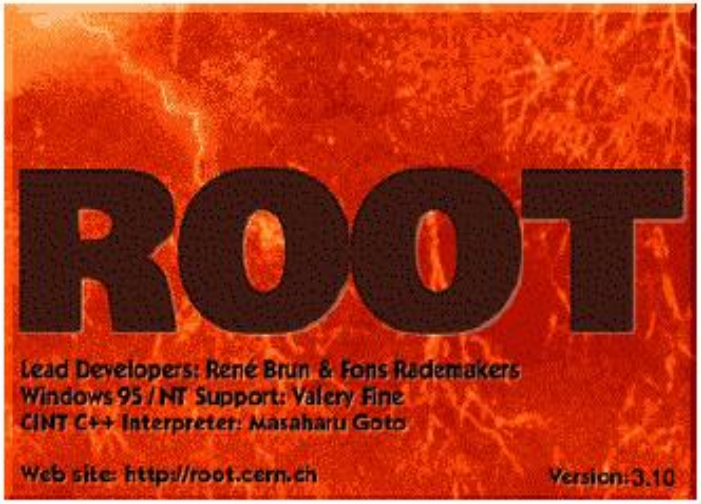
Physics Software

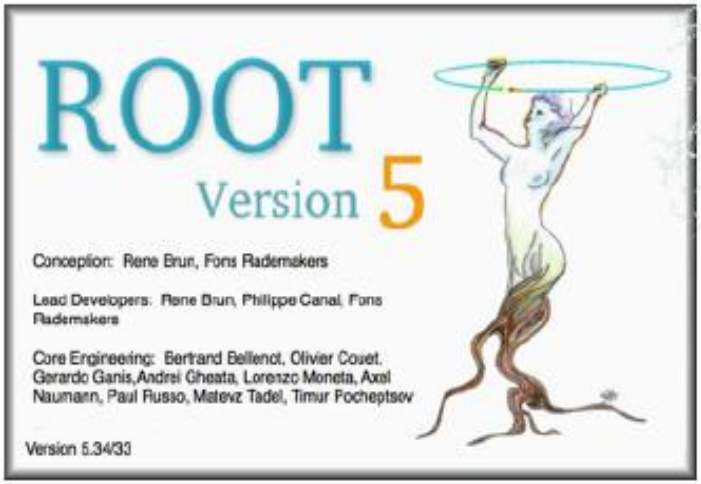
Common scheme of the BM@N experiment

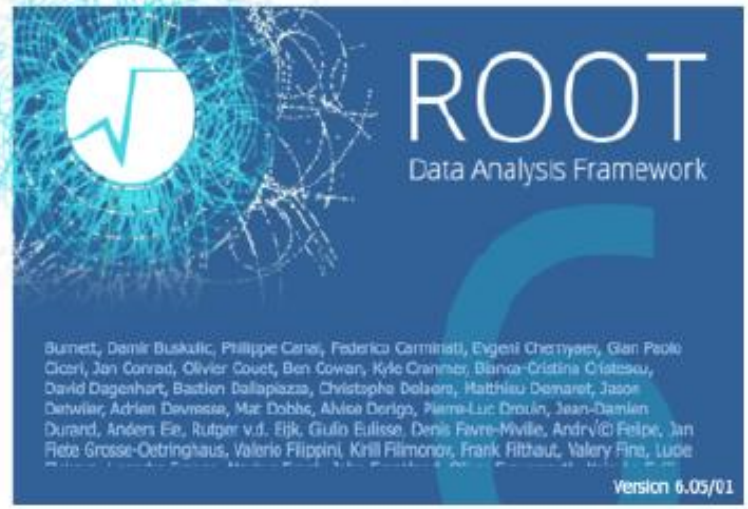


27 years of CERN ROOT evolution

https://root.cern.ch







FairRoot Framework

The FairRoot package is an object-oriented simulation, reconstruction and data analysis framework based on ROOT. It includes core services for detector simulation and data analysis for HEP experiments. The framework delivers base classes which enable the users to easily construct experimental setup in a fast and convenient way. By using the Virtual Monte Carlo concept it is possible to perform the simulations using either Geant3 or Geant4 without changing the user code or the geometry description.

The basic idea of FairRoot is to provide a unified package with generic mechanisms to deal with most commonly used tasks in HEP. FairRoot allow physicists to:

✗ Allows physicists to concentrate on detector performance details, avoiding purely software engineering issues like storage, retrieval, code organization etc.

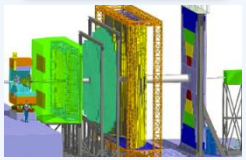
✗ Do not submerge into low-level details, use pre-built and well-tested code for common tasks.

✗ Focus on physics deliverables while reusing pre-built and well-tested software components for common tasks.

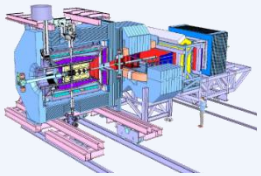
FairRoot Universe

Start testing the VMC concept for CBM

First Release of CbmRoot



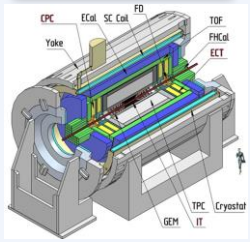
2004



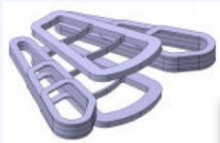
Panda decided to join → oct.

FairRoot: base package for experiments

MPD@NICA started with FairRoot

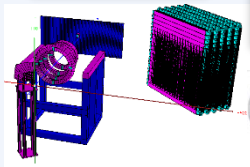


2006

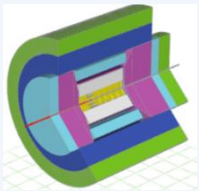


R3B joined

ASYEOS joined

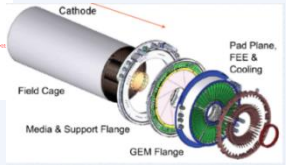


2010

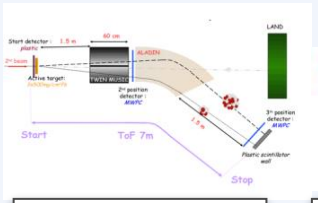


EIC (Electron Ion Collider BNL)

GEM-TPC seperated from PANDA branch



2011



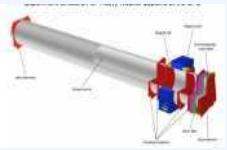
SOFIA (Studies On Fission with Aladin)

ENSAR-ROOT

Collection of modules used by structural nuclear phsyics exp.

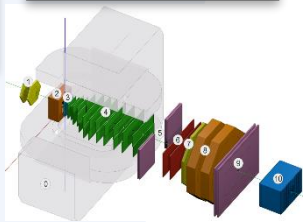
2012

2013

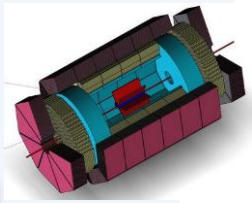


SHIP (Search for Hidden Particles)

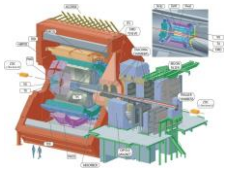
BM@N@NICA started with FairRoot



2014



SPD@NICA joined



2015

ALICE

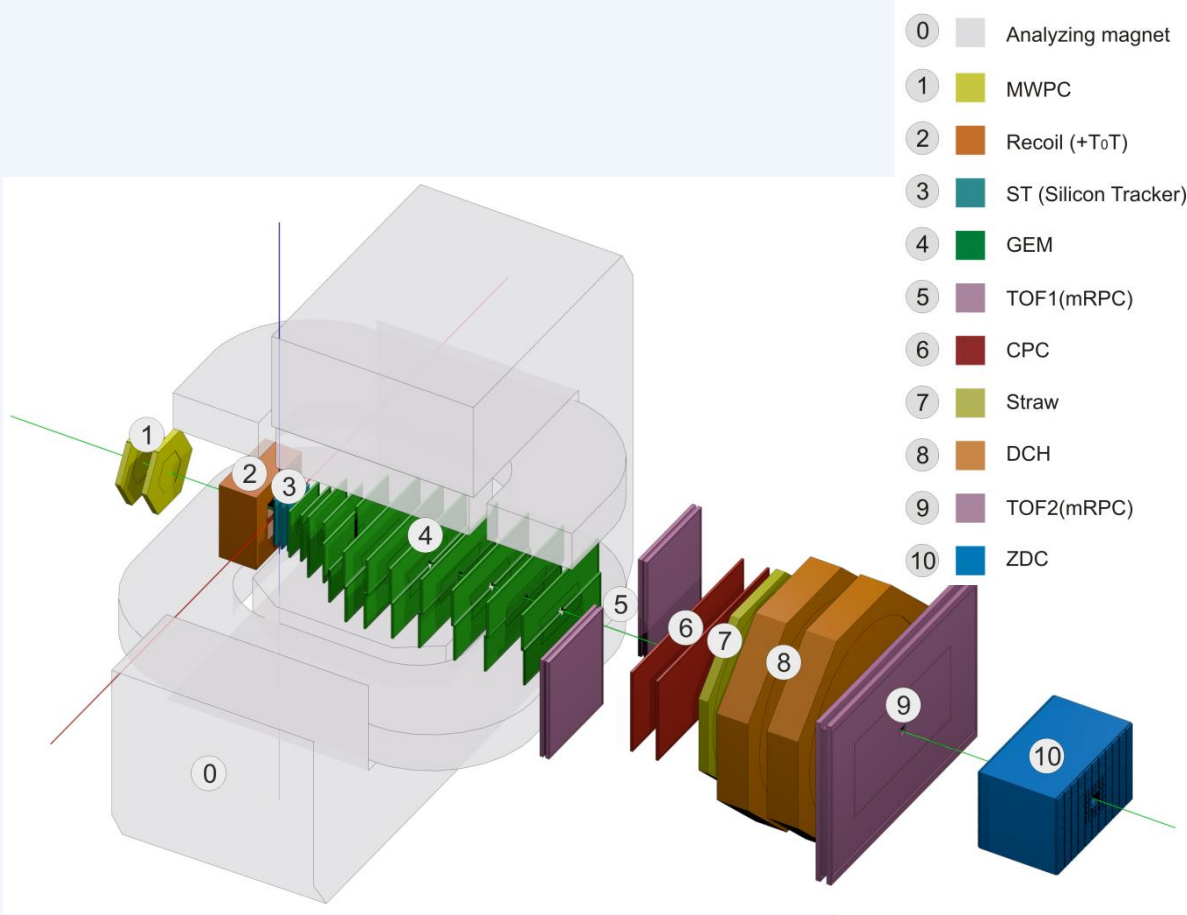
FAIR

BmnRoot Framework

BmnRoot Framework

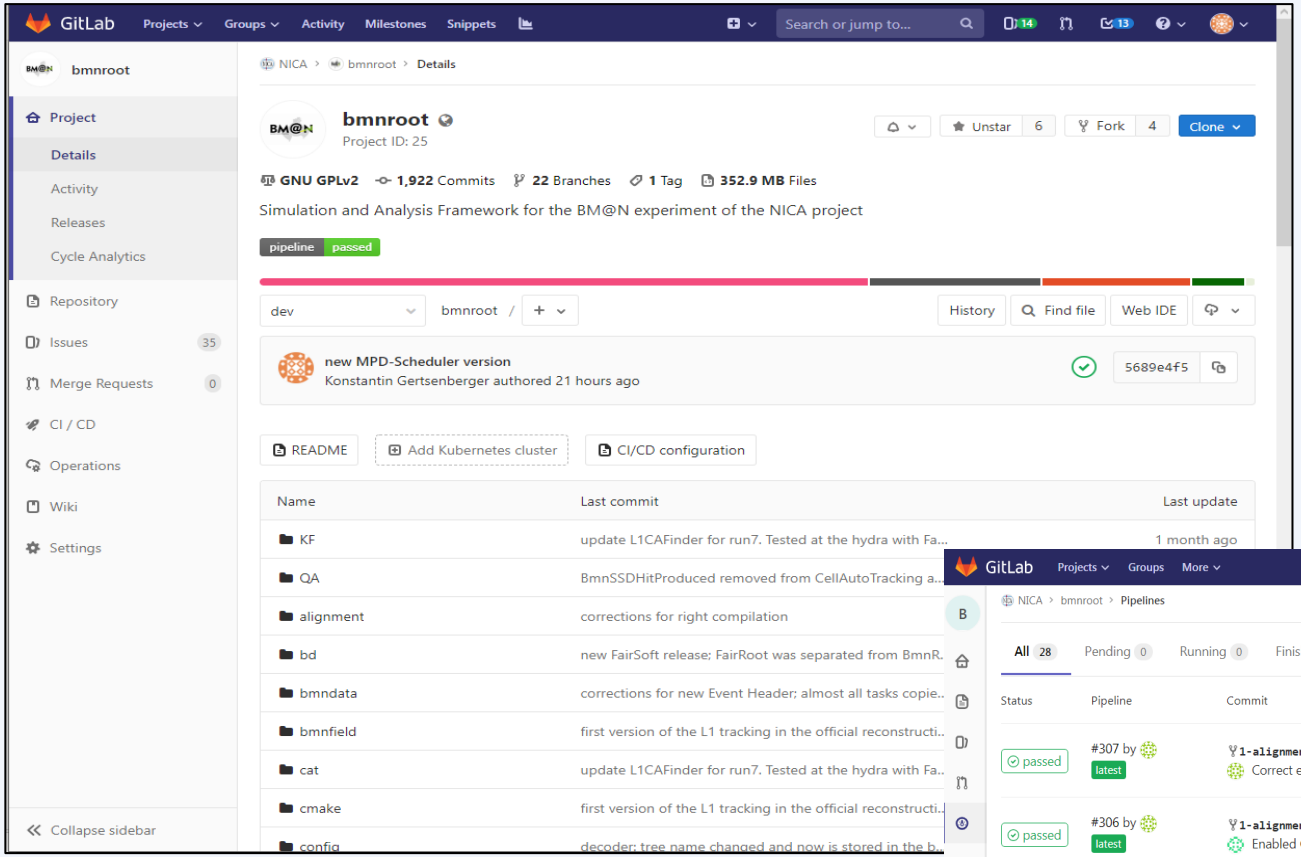
The software BmnRoot is developed for event simulation, reconstruction of experimental or simulated data and following physics analysis of collisions of elementary particles and ions with a fixed target at the BM@N facility.

C++ classes, Linux OS support, based on ROOT and FairRoot

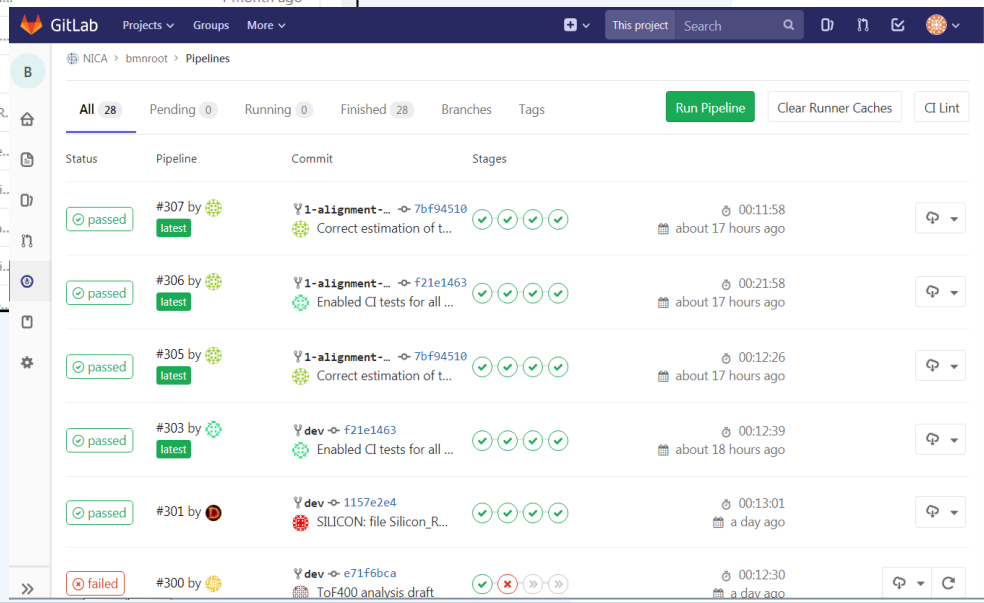


The BmnRoot software is available in GitLab@JINR: https://git.jinr.ru/nica/bmnroot

GitLab services for BM@N software

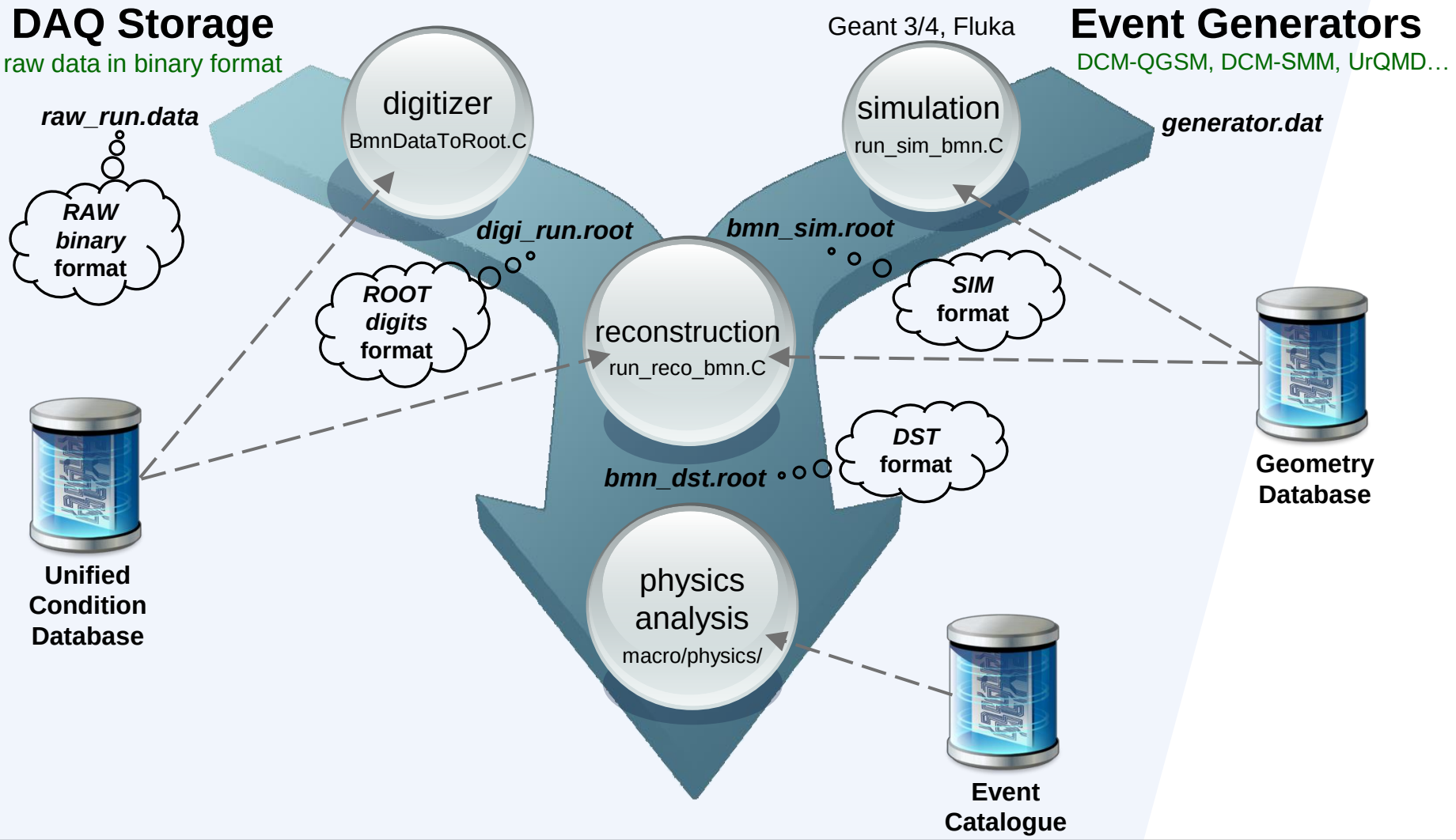


advanced opportunity for collective development



Version Control System – Git
Repository branch protection
Role-based access control to projects
Issue Tracker (as a Project Management System)
Automated Tests & Deployment – GitLab Runners

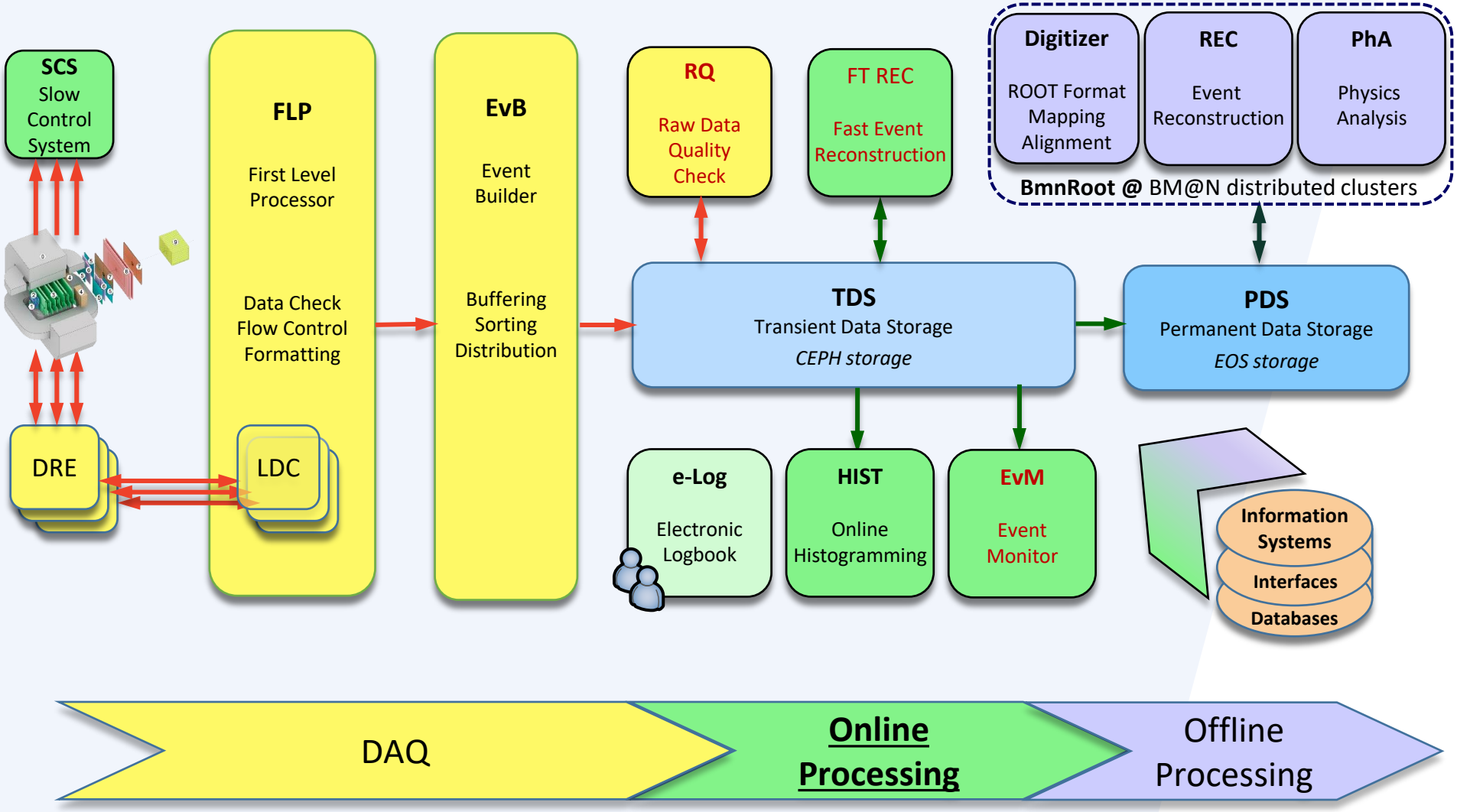
Event Data Processing in BmnRoot



Information Systems

Database + Interfaces + Services + …

BM@N Data Processing Flow



Online Information System

Electronic Logbook

Online Electronic Logbook (e-Log)

- The e-Log platform is a collaborative tool which provides shift crews with an interface to store and share information with offline users on various events or problems occurred in the experiment during its operation
- It uses the developed Logbook Database on PostgreSQL which ensures correct multi-user access, data consistency, integrity and automatic backup of the stored data
- Implemented interfaces provide a unified access to required logbook data for various online and offline systems, and convenient viewing, transparent managing and searching for required information by users
- A part of the logbook data is automatically transferred to the Condition Database of the experiment to use in offline analysis

User Web Interface of the e-Log Platform

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	№ 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	2.94	Cu (2 mm)	Cu target; Tr.= BC1 & BC2 & VC & Si>3; VKM2: I=125A, SP-57=50A, SP41=1250A; 201 kev	
2018-04-05 07:25:08	Babkin	New Run	5179 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; 201 kev	
2018-04-05 06:01:07	Babkin	New Run	5178 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; 201 kev	
2018-04-05 05:27:39	Babkin	New Run	5177 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; 204 kev	
2018-04-05 05:27:06	Babkin	New Run	5176 per.7	Beam Trigger + BD>3	All	1250	50	125	Kr	2.94	Cu (2 mm)	Cu target; Tr.= BC1 & BC2 & VC & BD>3; VKM2: I=125A, SP-57=50A, SP41=1250A; 150 kev	
2018-04-05 04:47:27	Babkin	New Run	5174 per.7	Beam Trigger + BD>3	All	1250	50	125	Kr	2.94	Cu (2 mm)	Cu target; Tr.= BC1 & BC2 & VC & BD>3; VKM2: I=125A, SP-57=50A, SP41=1250A; 213 kev	

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

Common FreeIPA Authentication: Administrator, Editor, Reader roles

File Attachments (text description, photo)

Email Subscription to selected event types

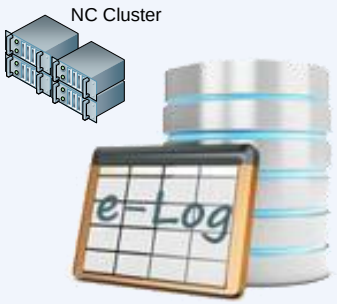
Multi-Column Sorting

Logbook Monitoring

User Cabinet

Easy Searching

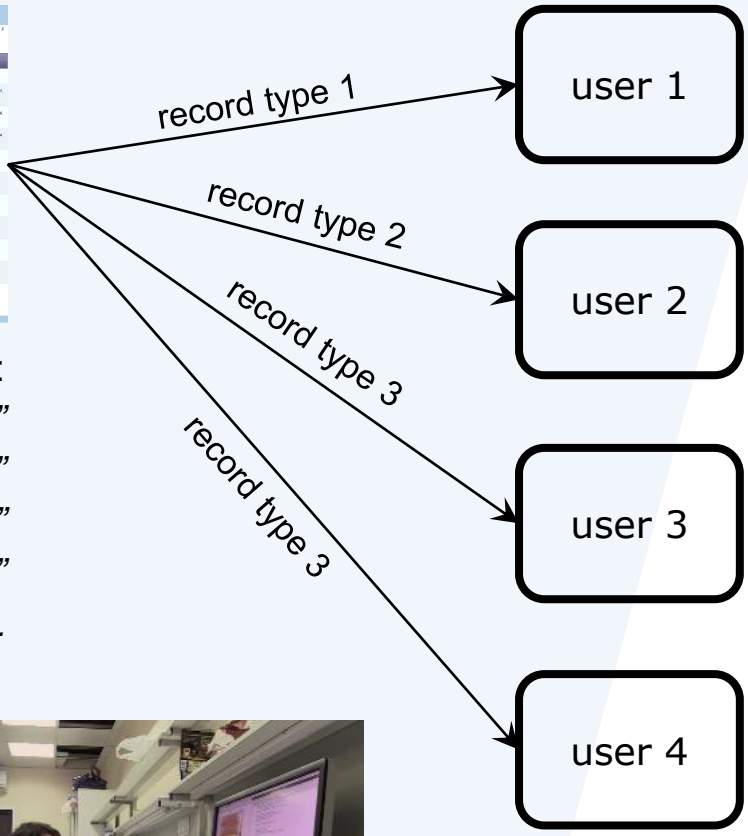
e-Log Platform. *Notification Service*



e-mail notifications

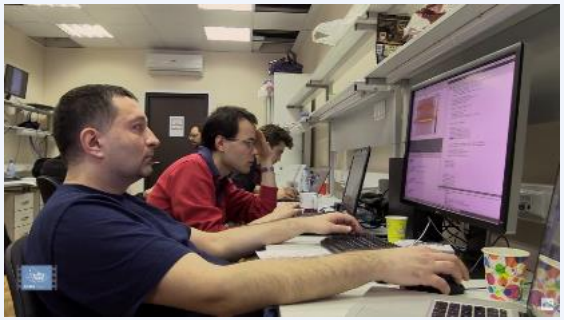
different types of events:

“shift started”
“problem report”
“configuration”
“new run”
…



User Cabinet

Event	Subscription
New record of the 'Configuration' type.	☐
New record of the 'Inform All' type.	☐
New record of the 'New Run' type.	☐
New record of the 'Other' type.	☐
New record of the 'Problem Fixed' type.	☐
New record of the 'Problem report' type.	☐
New record of the 'Routine' type.	☐
New record of the 'Shift started' type.	☐
New record of the 'Shift summary' type.	☐
New record of the 'Software Installation' type.	☐



C++ API → REST API (in progress)

Autogenerated class wrappers for the logbook objects allow to access and manage the data in the BmnRoot framework

ElogRecord – records written by a shift crew during the experiment runs which describe operating modes of various systems and detectors and different types of events

ElogType – record types: ‘Shift started’, ‘Problem report’, ‘Configuration’, ‘New Run’, etc.

ElogPerson – a list of the experiment staff

ElogTrigger – dictionary of all possible trigger types

ElogBeam – dictionary of all possible beam particles

ElogTarget – dictionary of all possible targets

ElogAttachment – files attached to a record for detailed description of the run

ElogConnection – serves to open and close connections to the databases including e-Log

ElogSearchCondition – forms criteria for selection of necessary records

The main functions of the e-Log interface:

for data objects (static): *Create*, *Delete, Get*, ***Search***, *PrintAll.*

for attributes (non-static)*: Getters* and *Setters* functions, *Print*.

Online metadata → BM@N Condition Database

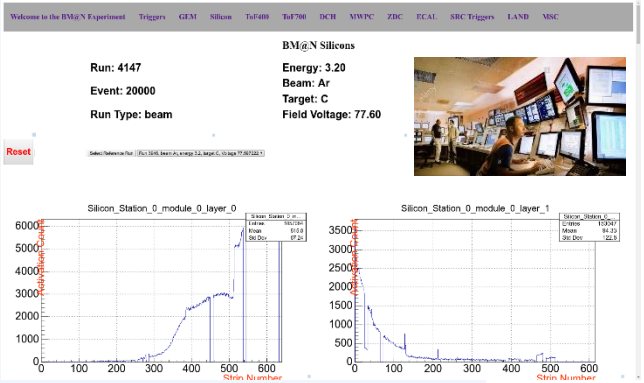
DAQ system

EvB

Raw Event Builder

HIST

Online Histogramming



new run

period, run
start & end time, event count, file path, file size

new run

period, run
beam, energy, target, magnetic field

Condition Database

offline data processing

Online/Offline System

Event Data Quality Assurance

Online Histogramming. *Web application*

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

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

BM@N Silicons

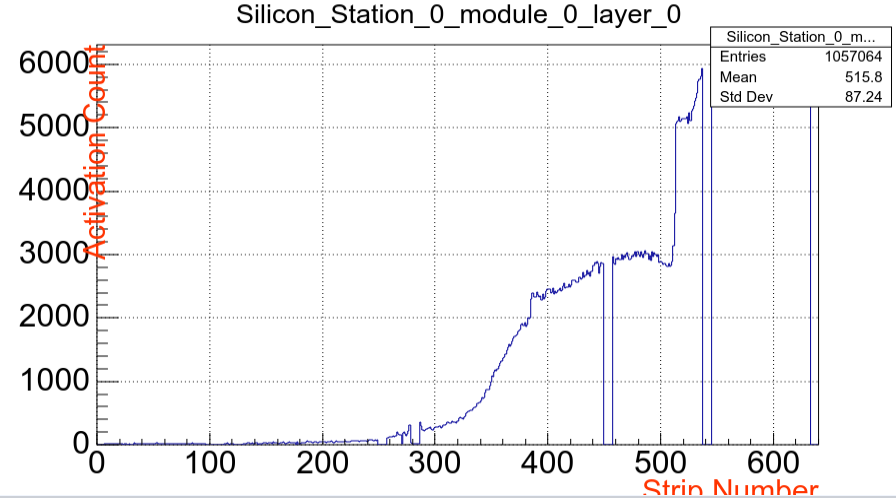
Run: 4147

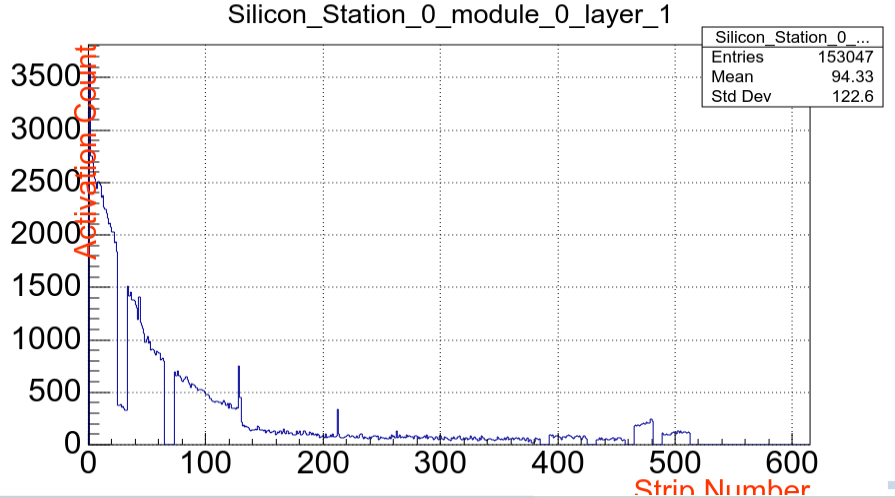
Event: 20000

Run Type: beam

Energy: 3.20
Beam: Ar
Target: C
Field Voltage: 77.60

Reset | Select Reference Run | Run 3946, beam Ar, energy 3.2, target C, Voltage 77.597222



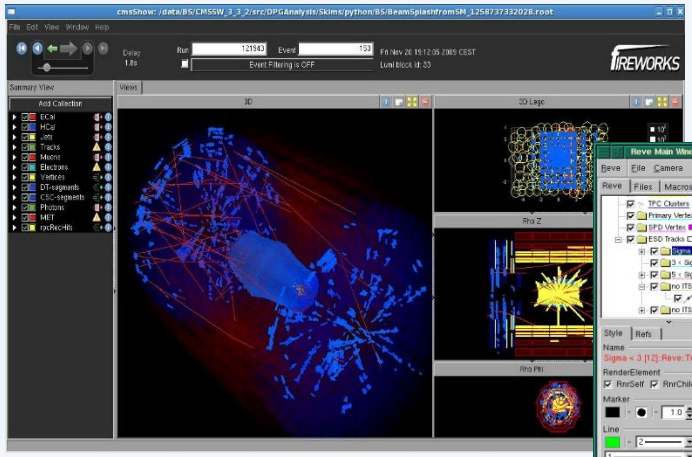


Online/Offline System

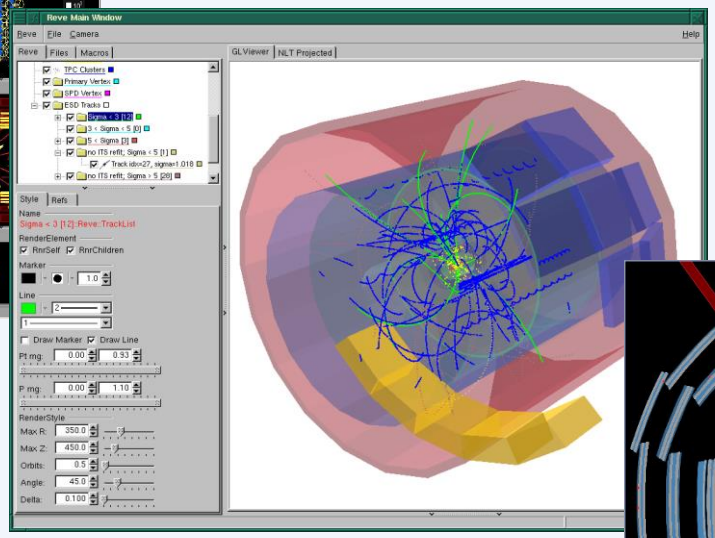
Event Monitor / Event Display

Event Display in modern experiments

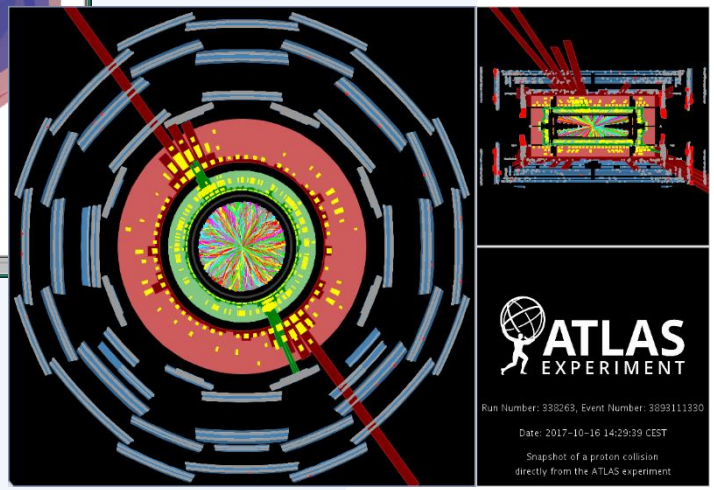
CMS (Fireworks)



ALICE (Ali**EVE**)



ATLAS (Atlantis)



Purposes of Event Display

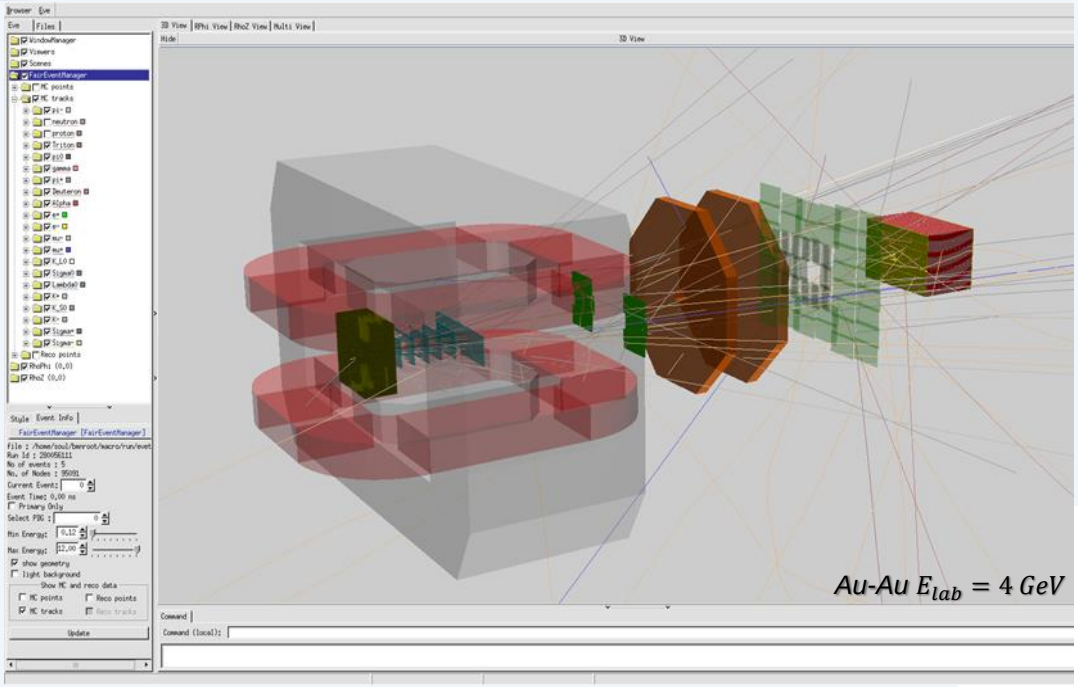
design / offline stage = **Offline Event Display**:

- model and algorithm checking and debugging for developers
- data reconstruction and analysis visualization for a better understanding of the detector and event structure
- demonstration and presentation of works

run / online stage = **Online Event Monitor**:

- visual online presentation of selective events during the experiment run as a monitoring system
- visual control and debugging of current events

Event Display for the BM@N experiment

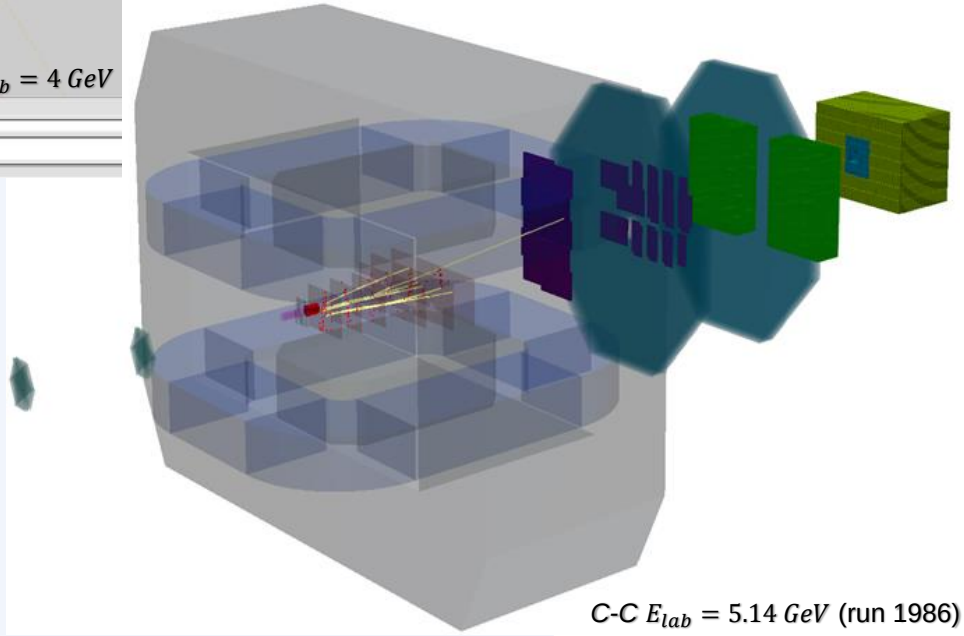


*based on the **ROOT EVE package***

graphically presents the events by means of ROOT GUI and OpenGL

Event Display for reconstructed data:

hits, tracks, calorimeter towers

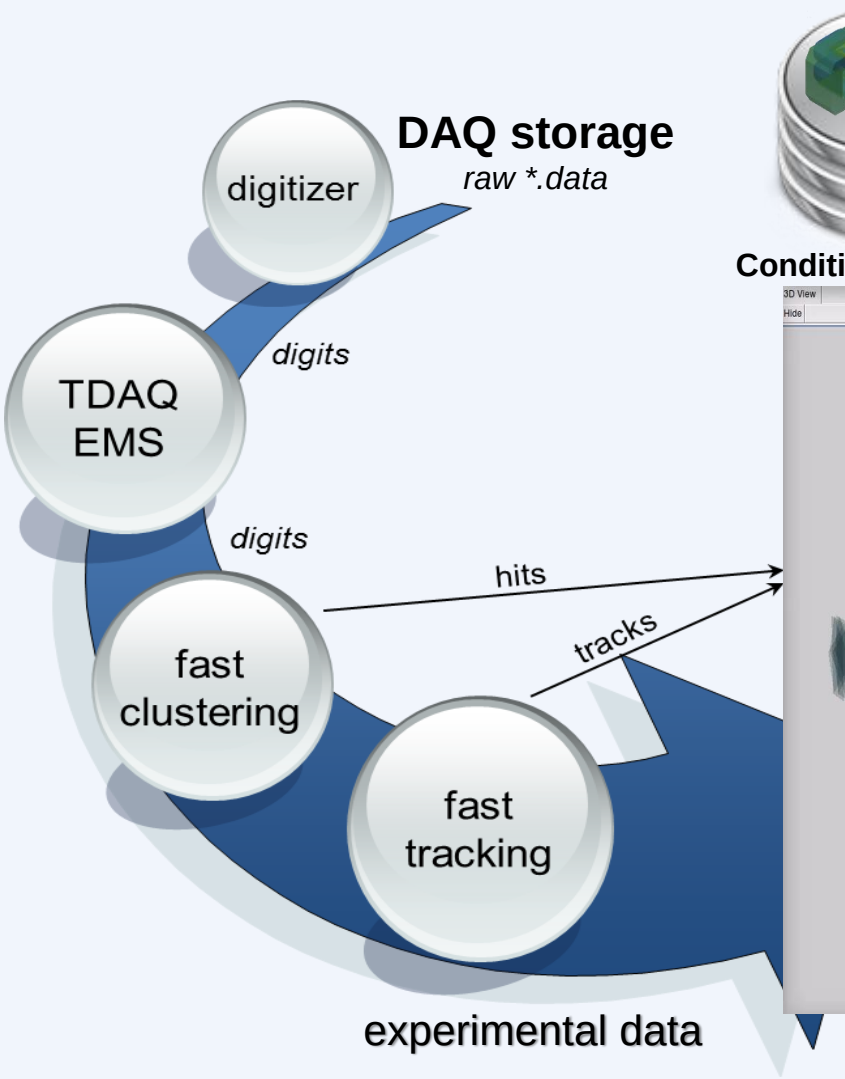


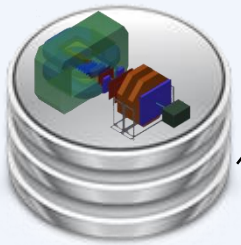
Event Display for simulated event data:

MC points, tracks, calorimeter towers

bmnroot/macro/eventdisplay/eventdisplay.C

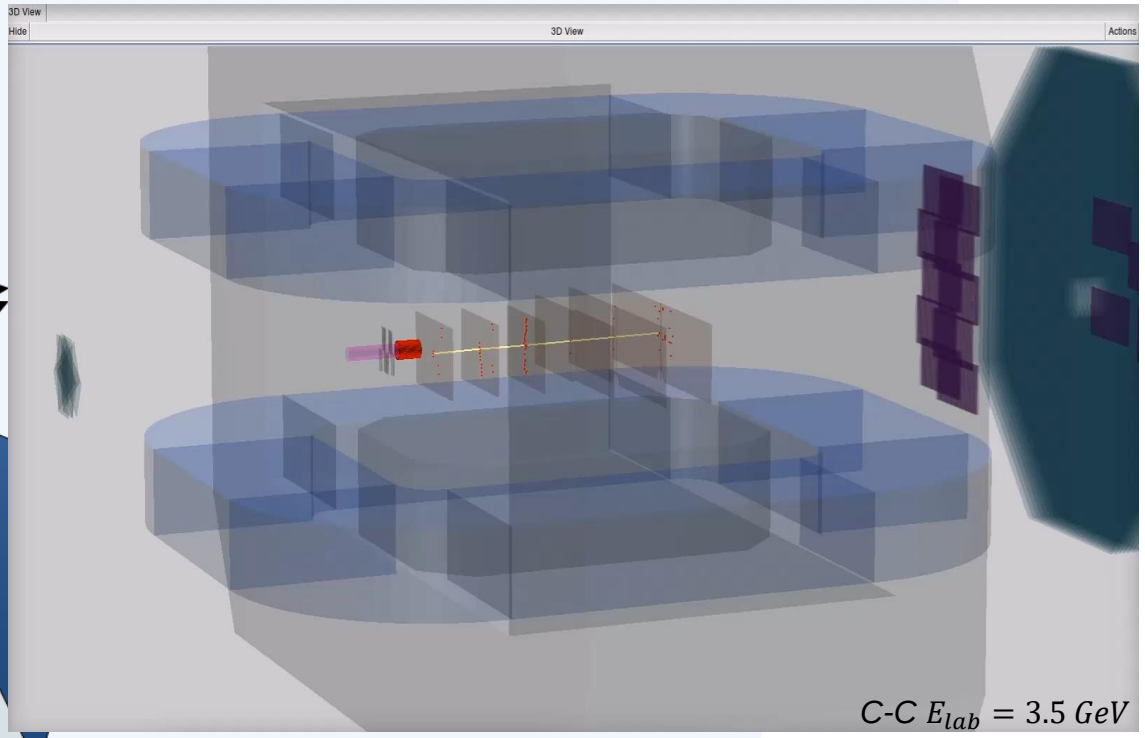
Event Monitor in BM@N Runs





Condition Database

BM@N geometry for a given run



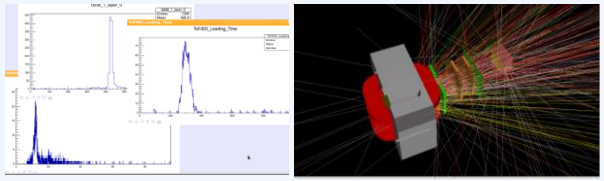
Online Event Display

GEM hits and tracks in run 1220 (C-C)

Online Information System

Online Configuration System

BM@N Online Configuration System



Process Tree

Configuration Monitor & Editor

HTTP web server

run configurations

process management (REST API)

PostgreSQL

Configuration Database

run configuration

HIST — Online Histogramming

digits

mappings

raw data from DAQ

Digitizer — Raw Data Converter

digits

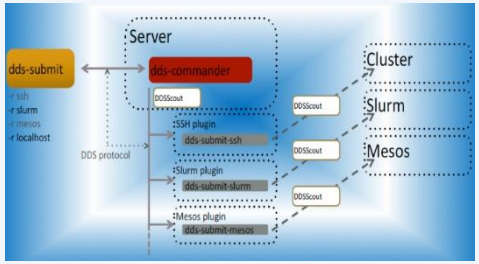
FT REC — Fast Event Reconstruction

DST

detector geometries

EvM — Event Monitor

FairMQ Devices



start control keep alive

process topology

DDS API

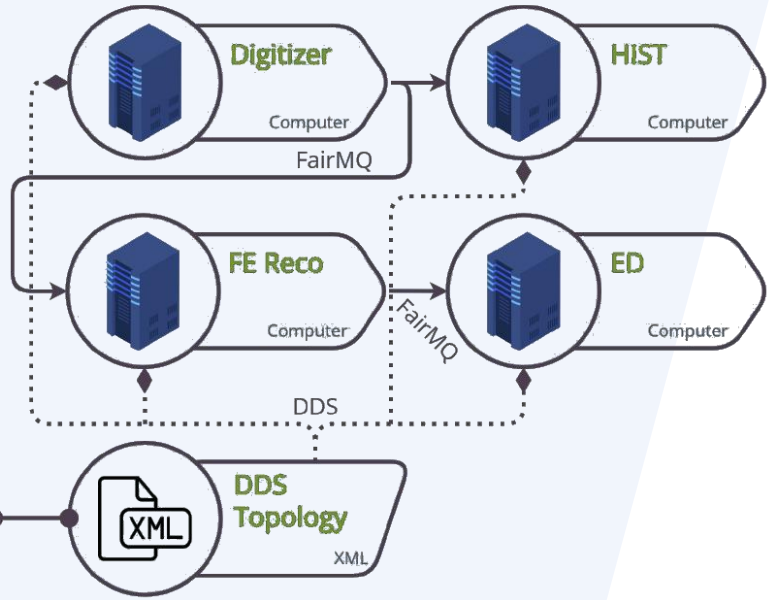
Dynamic Deployment System (DDS)

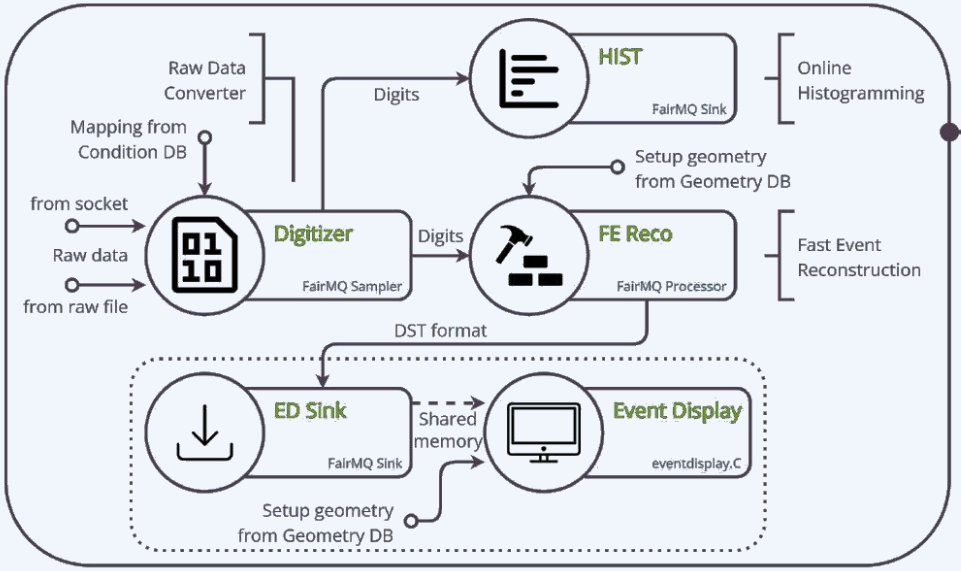
Configuration Manager

Online Processing System for BM@N

DDS (Dynamic Deployment System) is a set of tools that facilitates the process of system deployment. As a Remote Manipulator System (RMS), it initially provides SSH or SLURM, but also allows you to use other methods.

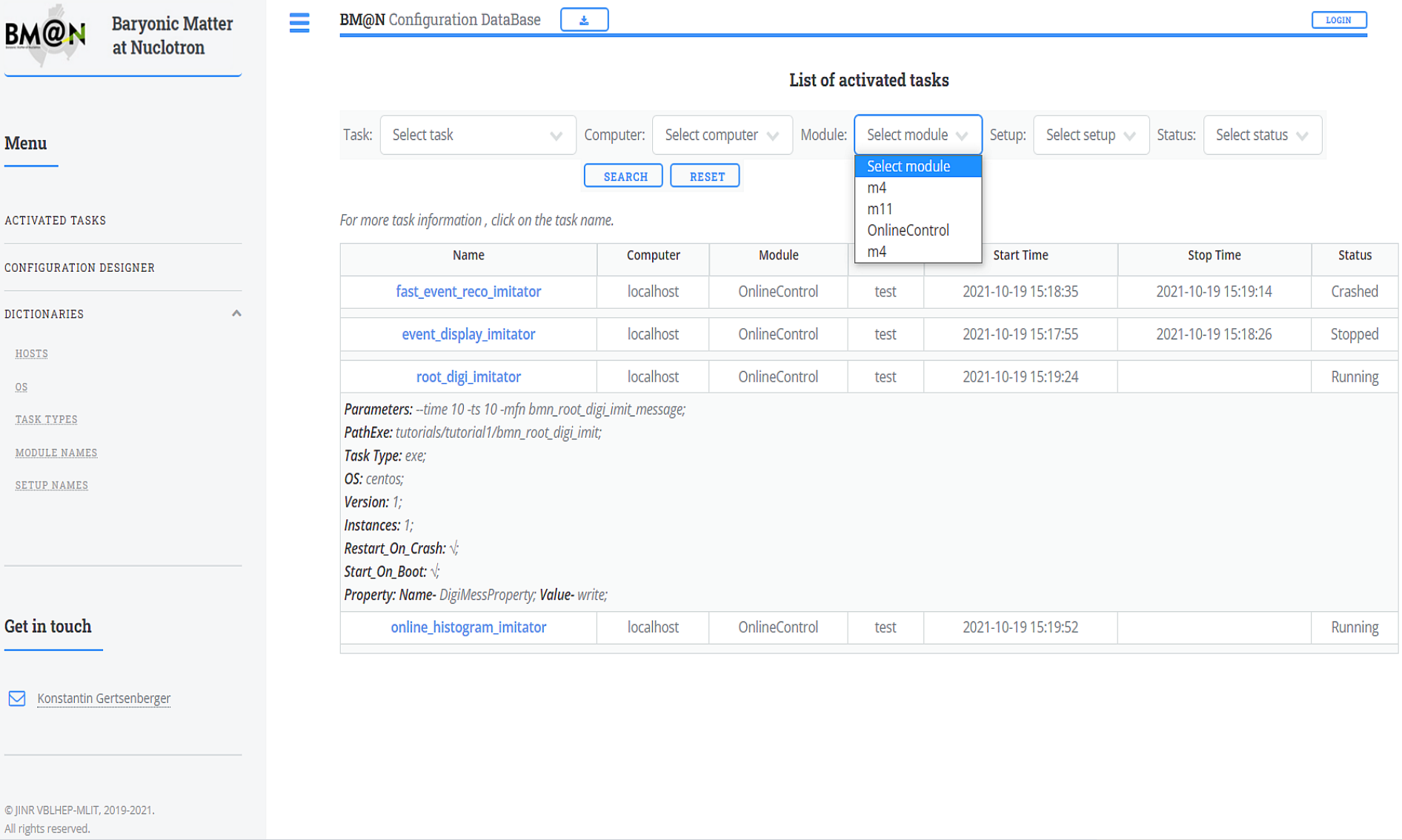
FairMQ is a messaging library focused on building modular systems for data processing in high energy physics experiments. It represents an abstraction over various messaging technologies such as ZeroMQ, Nanomsg, etc.



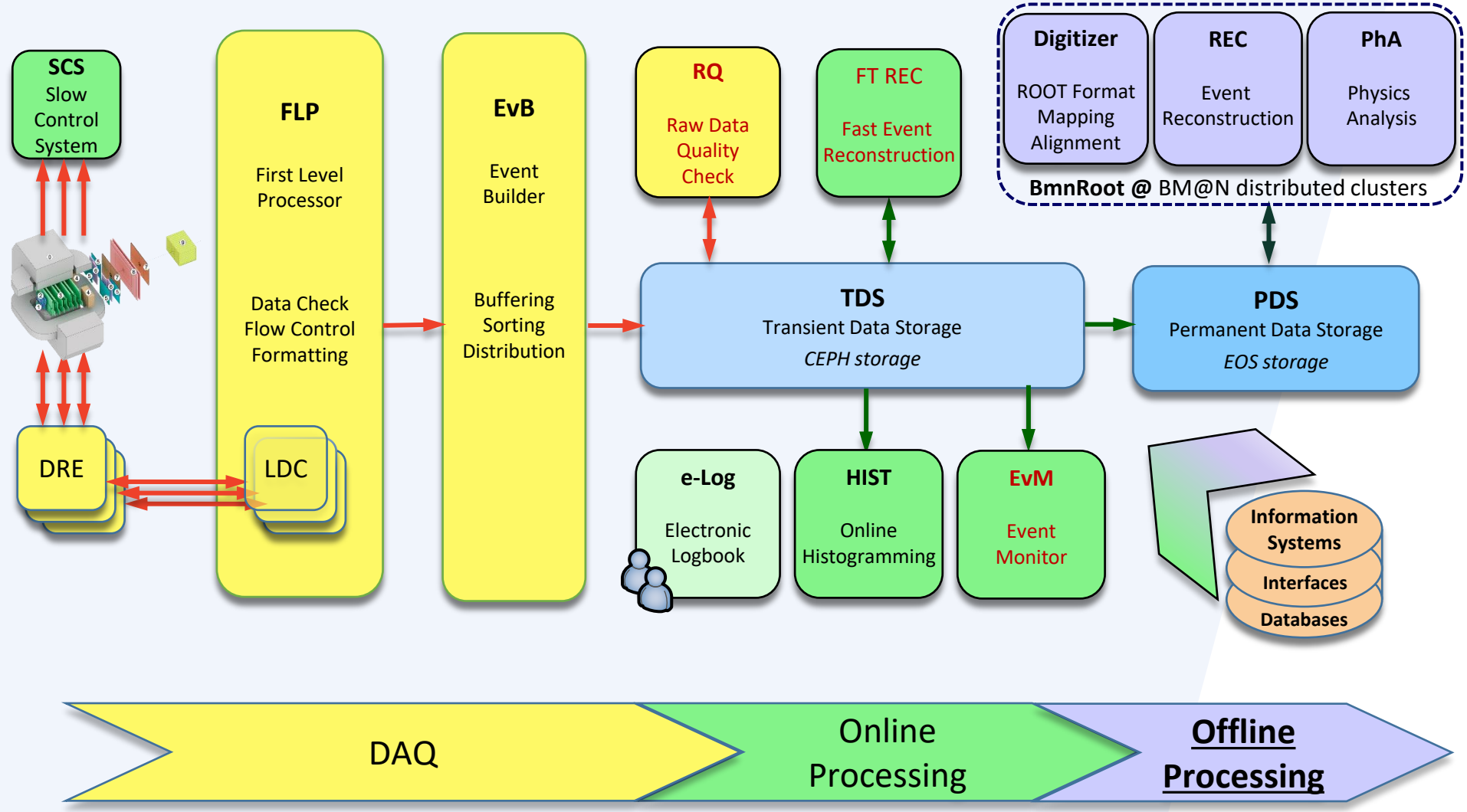


The purpose of the online data processing system is selective data processing (digitization of events and fast reconstruction) and monitoring of the data of the ongoing experiment.

OCS Web Interface. *Task monitor*



BM@N Data Processing Flow



matched from “Data Acquisition System TDR”, DAQ Collaboration

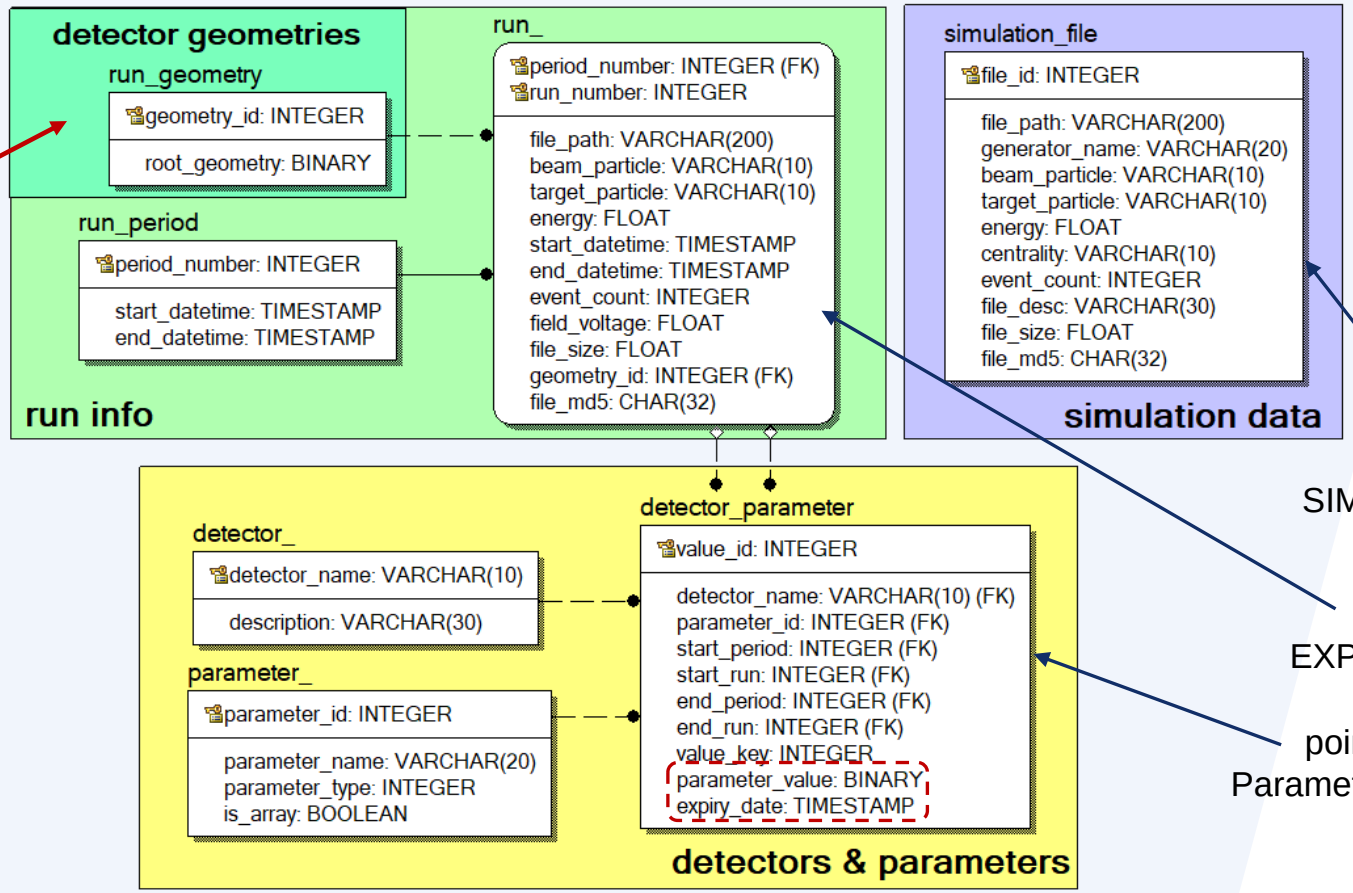
Offline Information System

Unified Condition Database (UniConDa)

Purposes of the Unified Database

- central data storage for offline data analysis (and may be online tasks) in the experiments of the NICA project
- unified access and data management for all collaboration members
- correct multi-user data processing
- ensuring the actuality of the information being accessed (sessions and run parameters, technical and calibration data, etc.), data consistency and integrity
- excluding the multiple duplication and use of outdated data
- automatic backup of the stored data

Unified Condition Database Structure



pointer to Geometry Storage *(will be removed after Geometry Database integration)*

pointer to SIM storage level

pointer to EXP storage level

pointer to Parameter Storage

storing information on experiment sessions and runs, setup geometries, detectors, parameters and parameter values, and generated simulation files

PostgreSQL 12

UniConDa in BM@N offline processing

detector simulation
raw data processing
event reconstruction
physics analysis

BmnRoot framework

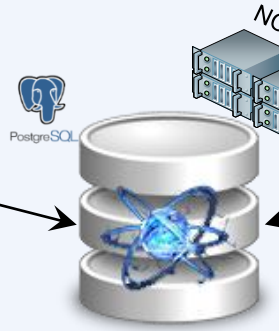
reading and changing data

users

FreeIPA authentication

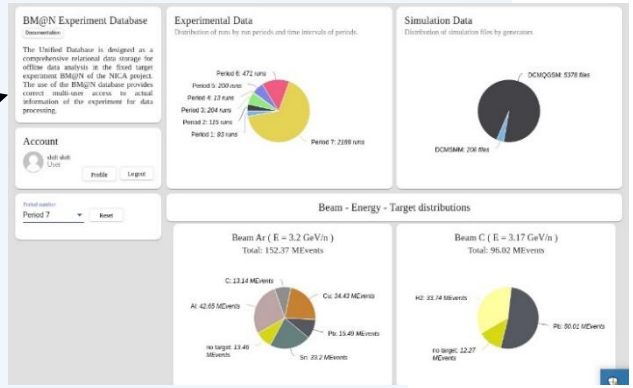
C++ interface → REST API (connect, I/O, API)

ROOT



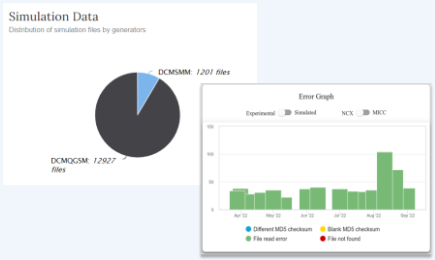
Node.JS

Condition Database



Web Service

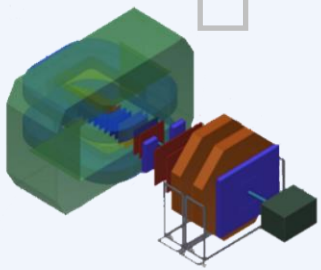
service python script for auto updating simulation file list



service python script for checking integrity of the raw data files

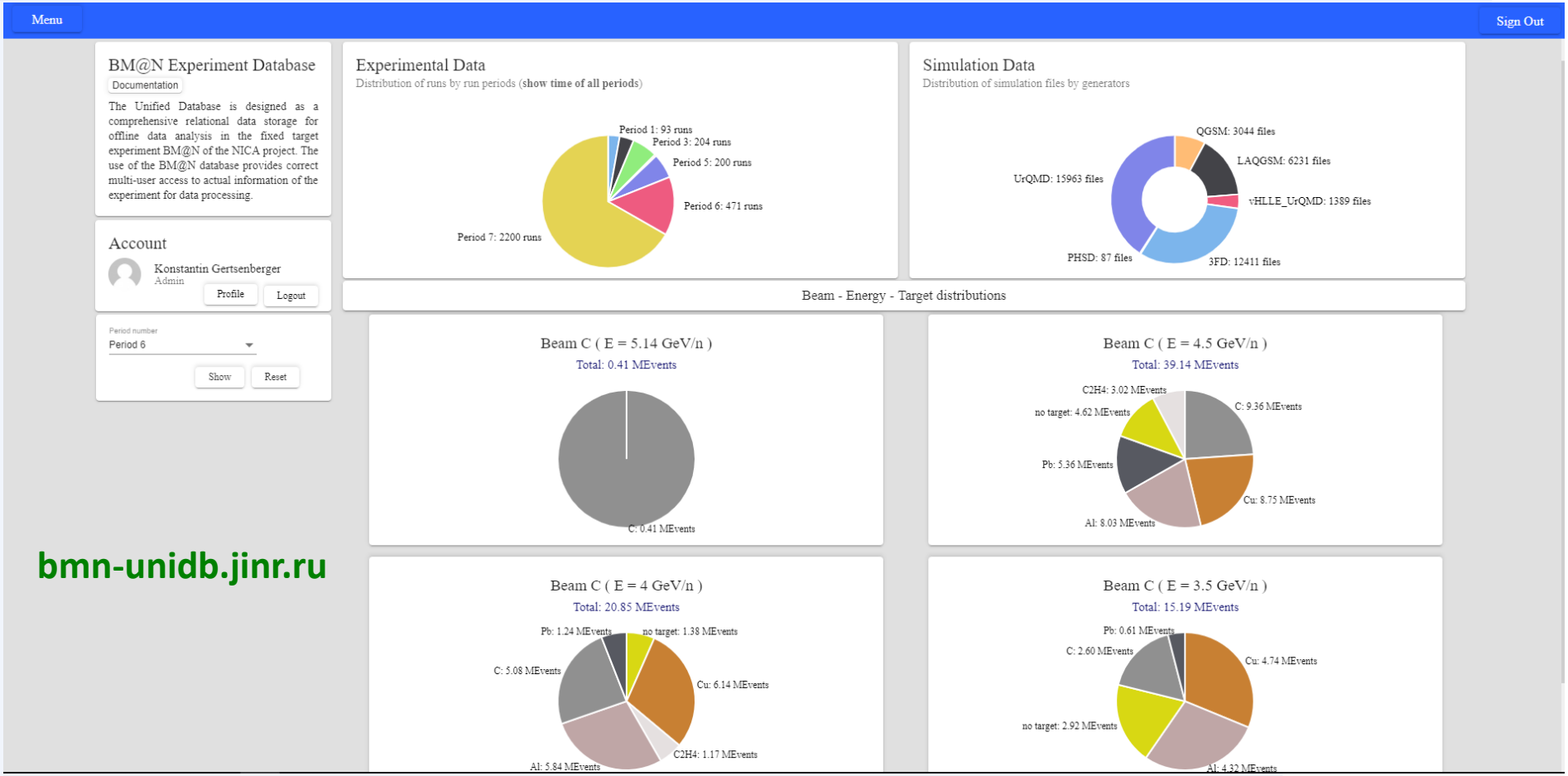
configuration calibration

parameter and algorithm data



ANGULAR docker HIGHCHARTS node.js CERN JSRoot

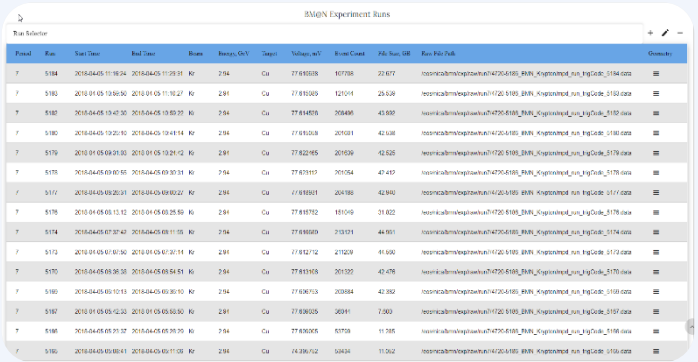
Web service for the Condition Database



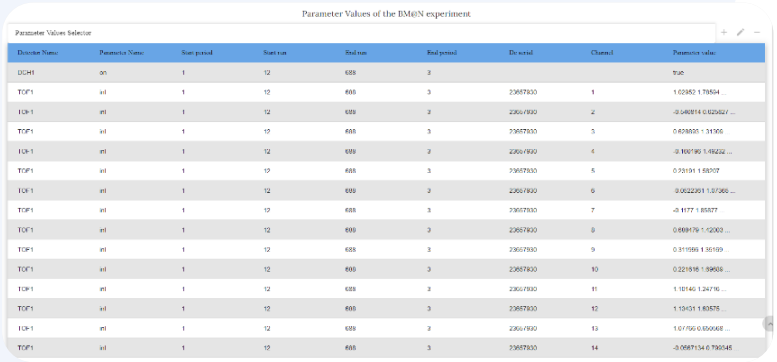
bmn-unidb.jinr.ru

- 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

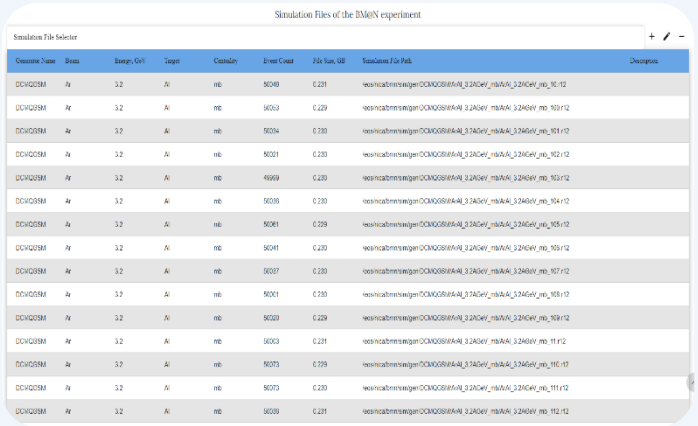
Tabular View of the Condition Database



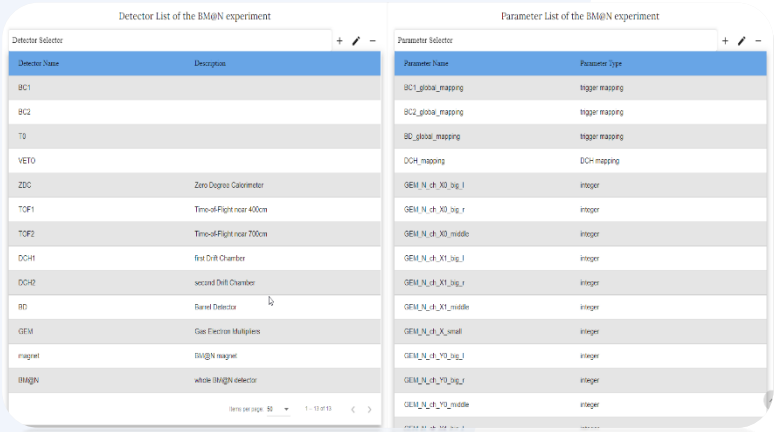
Experiment Runs



Parameter Values



Simulation Files



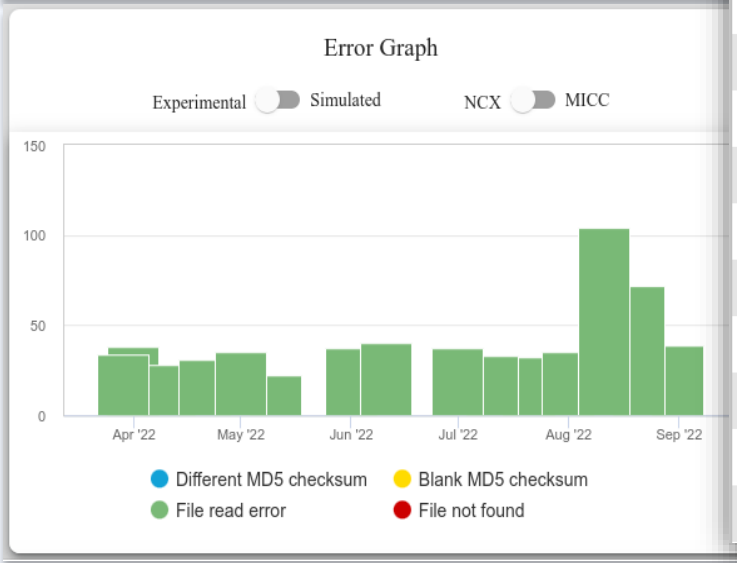
Detector & Parameters

Condition Database. *File Inspection Service*

Report Selector

Type name	Storage name	Check date	Complete date	File count	Errors
exp, data	NCX	2022-09-01 03:00	2022-09-05 04:00	3635	39
exp, data	NCX	2022-08-21 03:00	2022-08-25 05:11	3635	72
exp, data	NCX	2022-08-11 03:00	2022-08-14 22:05	3635	104
sim, data	NCX	2022-08-05 03:00	2022-08-05 08:08	23964	8
exp, data	NCX	2022-08-01 03:00	2022-08-05 12:15	3635	35

Items per page: 5 1 – 5 of 51



Error name	File Path	Error Details
File read error	/eos/nica/bmn/exp/raw/run7/2213-3588_SRC_Carbon/mpd_run_trigCode_3567.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/3590-4707_BMN_Argon/mpd_run_trigCode_3799.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/3590-4707_BMN_Argon/mpd_run_trigCode_4260.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/3590-4707_BMN_Argon/mpd_run_trigCode_3735.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/3590-4707_BMN_Argon/mpd_run_trigCode_4500.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/3590-4707_BMN_Argon/mpd_run_trigCode_4633.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/3590-4707_BMN_Argon/mpd_run_trigCode_4662.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/3590-4707_BMN_Argon/mpd_run_trigCode_4689.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/4720-5186_BMN_Krypton/mpd_run_trigCode_5088.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/2213-3588_SRC_Carbon/mpd_run_trigCode_3455.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/4720-5186_BMN_Krypton/mpd_run_trigCode_5150.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/2213-3588_SRC_Carbon/mpd_run_trigCode_3303.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/2213-3588_SRC_Carbon/mpd_run_trigCode_2240.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/2213-3588_SRC_Carbon/mpd_run_trigCode_2687.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/3590-4707_BMN_Argon/mpd_run_trigCode_4327.data	[Errno 5] Input/output error
File read error	/eos/nica/bmn/exp/raw/run7/3590-4707_BMN_Argon/mpd_run_trigCode_4125.data	[Errno 5] Input/output error

File Inspection Service

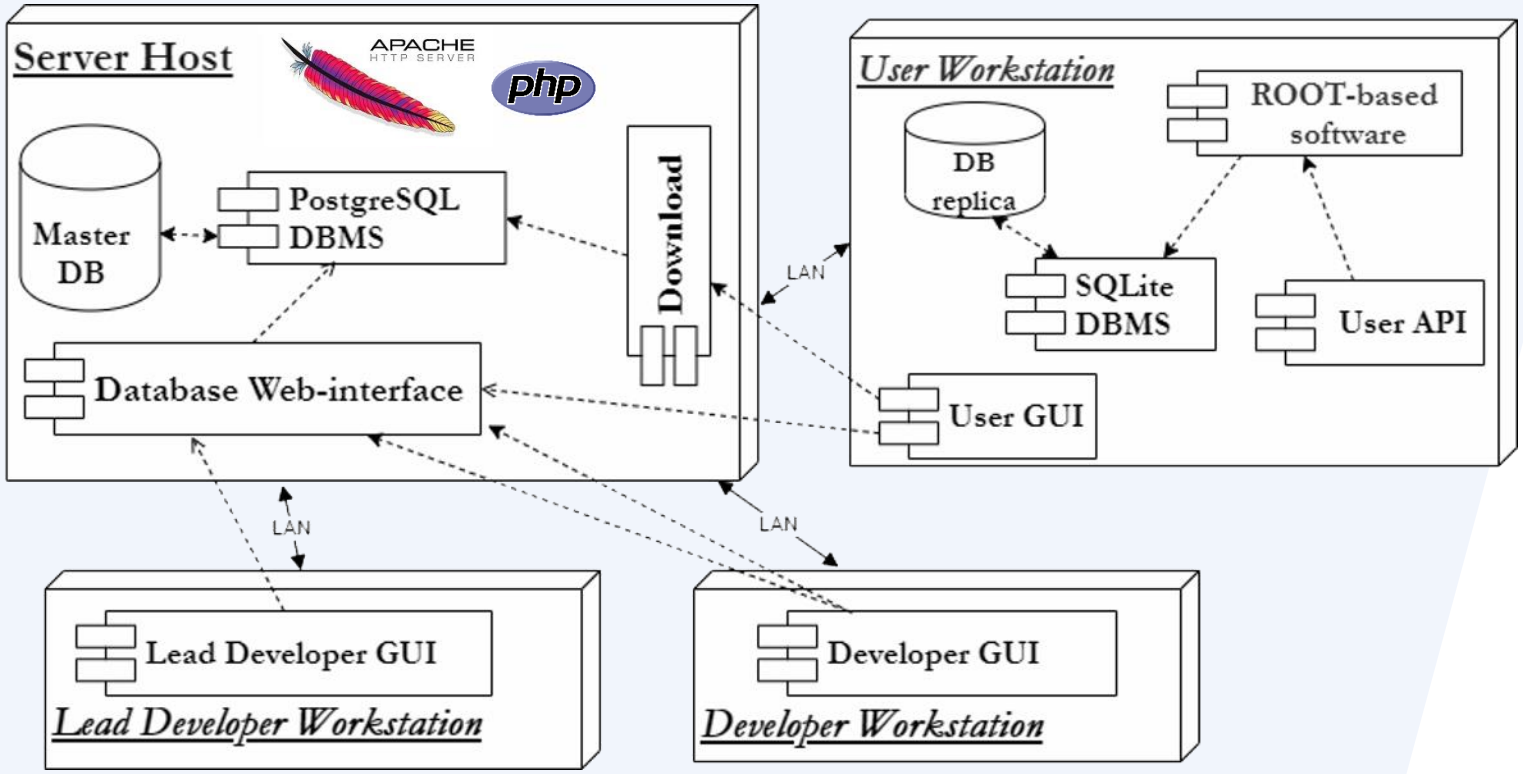
Offline Information System

Geometry Database

Geometry Information System

- is based on the Geometry Database to work with detector geometries of the NICA experiments and intended for storing and managing information on the geometry models of the detectors
- stores and manages geometry modules as ROOT binary objects
- each setup module stores a tag, version, transformation matrix, link to the parent module
- constructs and manages full setups as a combination of geometry setup modules, magnetic field and materials
- manages versions of the modules and setups
- provide users with viewing all components and setups
- provide detector geometries for online (e.g. monitoring the current events) and offline (e.g. event reconstruction and analysis) systems

Geometry Information System Architecture



Three user roles:
Lead Developer | Developer | User (Reader)

PostgreSQL

SQLite

Status of the Geometry Web Platform

BM@N Baryonic Matter at Nuclotron

Menu

HOME

VIEW GEOMETRY

- VIEW SETUPS
- VIEW SETUP MODULES
- VIEW FILES
- VIEW MATERIALS
- VIEW MAGNETIC FIELDS

EDIT GEOMETRY

Get in touch

Konstantin Gertsenberger

BM@N Geometry DataBase — bmn-geodb.jinr.ru — *User::* gertsen — CONFIGURE WEBACCESS — LOGOUT

- simple authorization
- or FreeIPA access

Setup Modules

Module	Name (Tag)	Date	File	Transformation	Description	Author	ParFile	Download
BD	bd_v1_0	2018-07-26	v1	1.000 0.000 0.000 0.000 0.000 1.000 0.000 0.000 0.000 0.000 1.000 0.000	bd_v1_0	aleksand		
BD	geom_BD_det_v2	2020-04-19	geom_BD_det_v2	1.000 0.000 0.000 0.000 0.000 1.000 0.000 0.000 0.000 0.000 1.000 0.000	geom_BD_det_v2	aleksand		
BD	bd_v1_run6	2019-12-24	bd_v1_run6	1.000 0.000 0.000 0.000 0.000 1.000 0.000 0.000 0.000 0.000 1.000 0.000	bd_v1_run6.geo	aleksand		
CSC	CSC_RunSpring2018	2020-04-19	CSC_RunSpring2018	1.000 0.000 0.000 0.000 0.000 1.000 0.000 0.000 0.000 0.000 1.000 0.000	CSC_RunSpring2018	aleksand		
DCH	DCH_RunWinter2016	2018-07-26	DCH_RunWinter2016	1.000 0.000 0.000 0.000 0.000 1.000 0.000 0.000 0.000 0.000 1.000 0.000	DCH_RunWinter2016	aleksand		
DCH	DCH_RunSpring2018	2019-12-24	DCH_RunSpring2018	1.000 0.000 0.000 0.000 0.000 1.000 0.000 0.000	DCH_RunSpring2018.ro	aleksand		

BM@N Geometry Database has filled with the setup geometries for Run 7 and 6 (all releases + dev)

Graphical User Interface Functions:

View Edit Download

Offline Information System

Event Metadata System

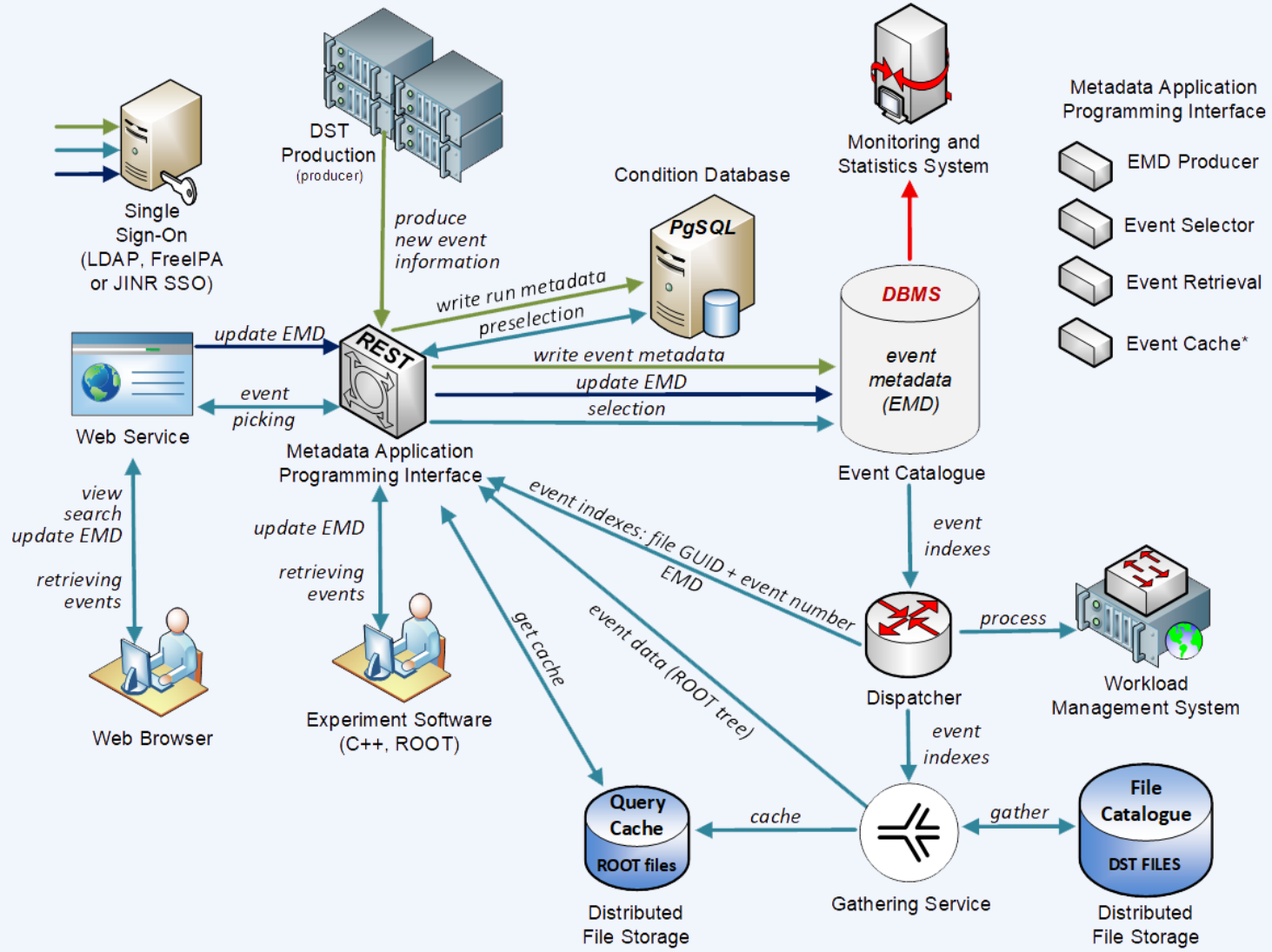
Event Metadata System (EMS)

- main functions are summary description of particle collision events and their identifiers to select events for a desired analysis goal; recording and storing necessary event metadata, their management and convenient access; organization of online and offline interfaces for selecting events of interest
- is based on the Event Database called Event Catalogue, which contains summary properties of particle collision events and references to their storage location
- allows user to quickly search for a set of events required for a particular physics analysis by various criteria and parameters
- is responsible for creating, maintaining and checking the quality of the catalogue of the physics events and for providing statistics

Event Metadata System Requirements

- Performance
  - There are not too many requests per seconds, but heavy ones
- Scalability
  - BM@N has recorded about 0.5B experimental events
  - Billions of events per year are expected for the NICA experiments
- Availability and fail safety
- Role-based access control (LDAP or database)
  - Event Consumer, EMD Writer, EMD Administrator
- Integration with other experiment systems
  - Run metadata are stored in the Condition Database
  - FairRoot-based frameworks (BmnRoot, MPDRoot, SPDroot).

Architecture of the Event Metadata System



Web interface

for viewing and searching for event metadata stored in the Event Catalogue and retrieving events which satisfy given user parameters

Metadata API

for writing new metadata to the Event Catalogue while data processing and requesting events selected by criteria for physics analysis in BmnRoot

Event Metadata Structure

- period and run number (4+4 bytes)

- **file pointer (GUID) (4 byte)**
- **event number (4 byte)**

- software version (2 bytes)
- event time (4 byte)
- flag to determine whether primary vertex was found (1 byte)
- number of primary tracks (4 byte)
- number of all reconstructed tracks (4 byte)
- track number of positively charged particles from primary vertex (4 byte)
- primary & secondary particles (4+4 bytes)
- number of hits by detectors (4 bytes)
- total input charge in the event (4 byte)
- total output charge in the event (4 byte)

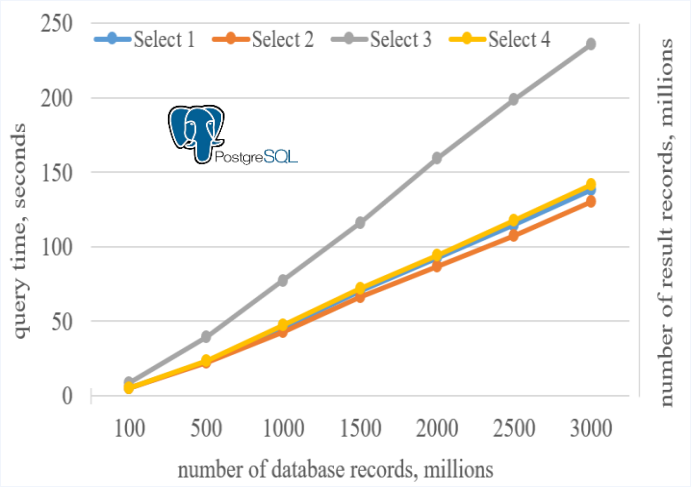
EMS provide the following functions: summary description of collision events and their identifiers, which can be used to select events for a desired analysis goal; recording and storing event metadata in the Event Catalogue; management and a convenient access to the metadata; organization of online and offline interfaces for selecting events of interest

Prototypes of the Event Catalogue

Configuration VM:

2 x Intel Xeon E5-2680
DDR4 240 GB 2133 MHz
SSD 400 GB Intel

Scientific Linux 7.9
PostgreSQL 12.5
HBase 2.2.3, Hadoop 3.2.1

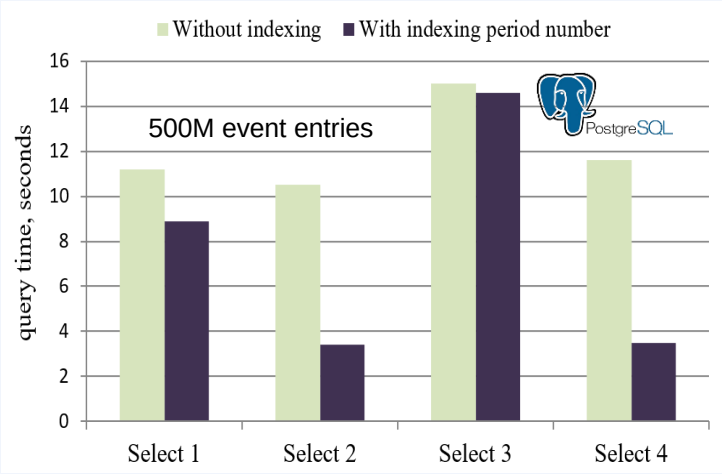


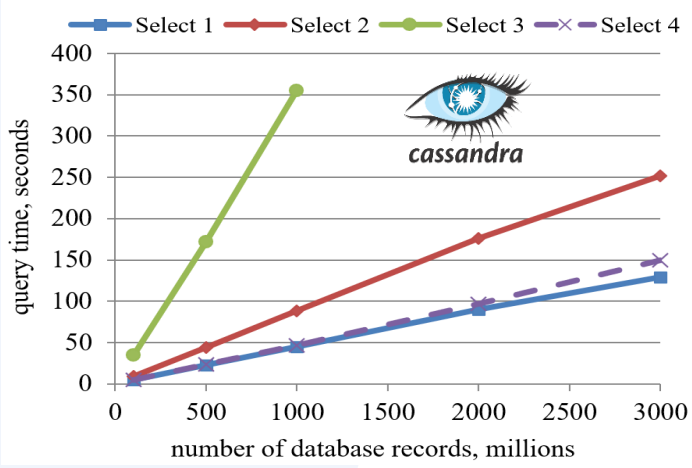
500M	HBase C1	HBase C2	HBase C3
Test 0	56 min	28 min	63 min
Test 1	29 min 55 sec	28 min 02 sec	5 min
Test 2	32 min 4 sec	28 min 47 sec	11 min
Test 3	30 min 20 sec	29 min 52 sec	8 min
Test 4	28 min	not supported by Apache Phoenix	1 min 52 sec
Test 5	29 min	not supported by Apache Phoenix	2 min 12 sec

Configuration:

Intel Core i9-10900F
DDR4 64 Gb 3200MHz
SSD 1TB NVMe Samsung

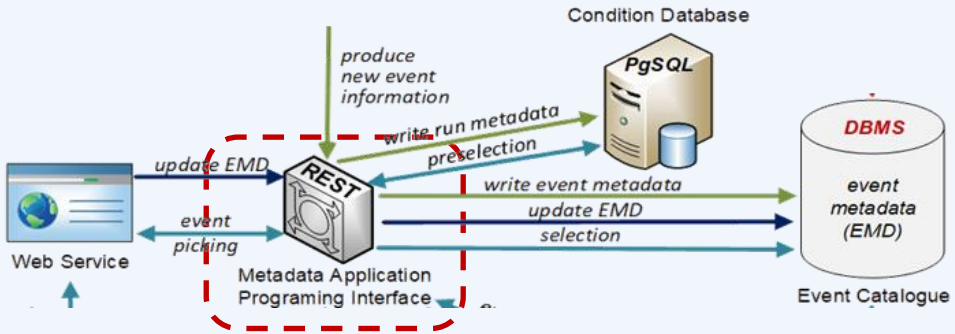
CentOS Linux 8.2
PostgreSQL 12.5
Apache Cassandra 3.11.8





primary key: ((*PERIOD_NUMBER*, *SOFTWARE_ID*), *PRIMARY_TRACKS*, *EVENT_NUMBER*)

REST API for the Event Metadata System



Event JSON scheme

```
{
  "reference": {
    "storage_name": "data1",
    "file_path": "/tmp/file1",
    "event_number": 1
  },
  "software_version": "19.1",
  "period_number": 7,
  "run_number": 5000,
  "parameters": {
    "track_number": 20
  }
}
```

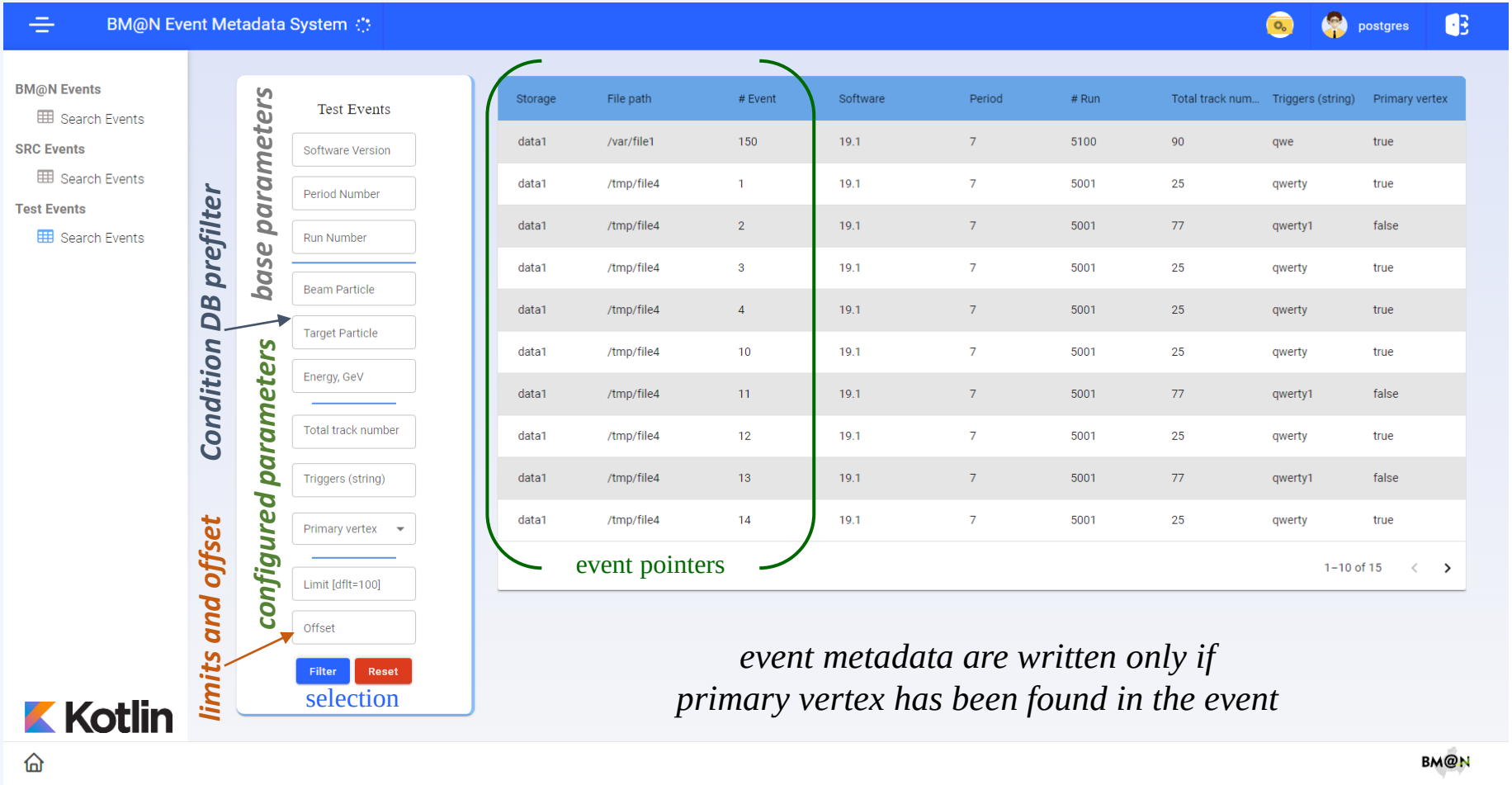
- Provides HTTP-based API using JSON formatting: *POST* command to create event metadata in the event catalogue, *GET* request to obtain event records by criteria, *DELETE* to delete event metadata
- Ensures writing new metadata to the Event Catalogue while data processing and requesting events by other experiment systems for chosen criteria, e.g. for physics analysis in the ROOT-based frameworks
- FreeIPA/LDAP protocol is supported for authentication (admin, writer and consumer roles)
- Uses the same selection criteria as the web service including range support

```
GET /emd?period_number=7&run_number=5000+&software_version=20.08.0&track_number=10-15
```

```
GET /eventFileRef[?parameters]          GET /eventFile[?parameters]
```

```
GET /count[?parameter1=value1[&parameter2=value2[...]]]
```

User Web Interface of the Event Metadata System



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

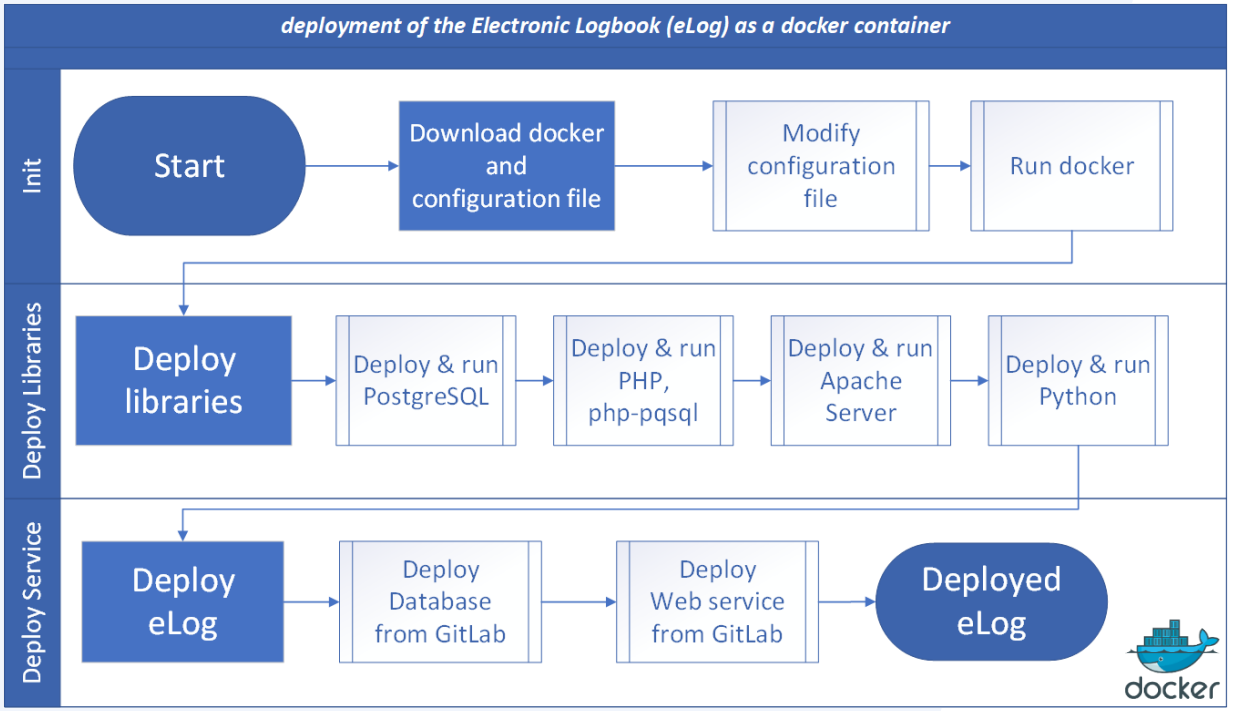
- enables users to browse and search for event metadata stored in the Event Catalogue and retrieve events, which satisfy given parameters
- provides events according to the selected event metadata and run metadata of the Condition Database

Information and Collaboration Services

Common Deployment System

Configuration File

```
{"remoteHost" : "db_host.jinr.ru",  // e-Log database host
"remoteUser" : "remote_user",      // remote host user
"dbname" : "elog_db",              // e-Log database name
"dbPort" : "5432",                 // e-Log database port
"dbAuth“ : true,                   // authorization type
// custom (additional, specific to experiment) column names
"colName": {  "sp_41" : "SP-41, A",
   "sp_57" : "SP-57, A",
   "vkm2"  : "VKM2, A"},
"colDef" : [
   "columns" : [ {"column" : "sp_41 int null"},
   {"column" : "sp_57 int null"},
   {"column" : "vkm2  int null"}],
"expName“ : “BM@N",            // experiment name
"expLogo" : "logo.png",        // experiment logo image
"expUrl“ : "https://bmn.jinr.ru",  // URL to official experiment site
"notifySend“ : true,           // activate notification system
….
```

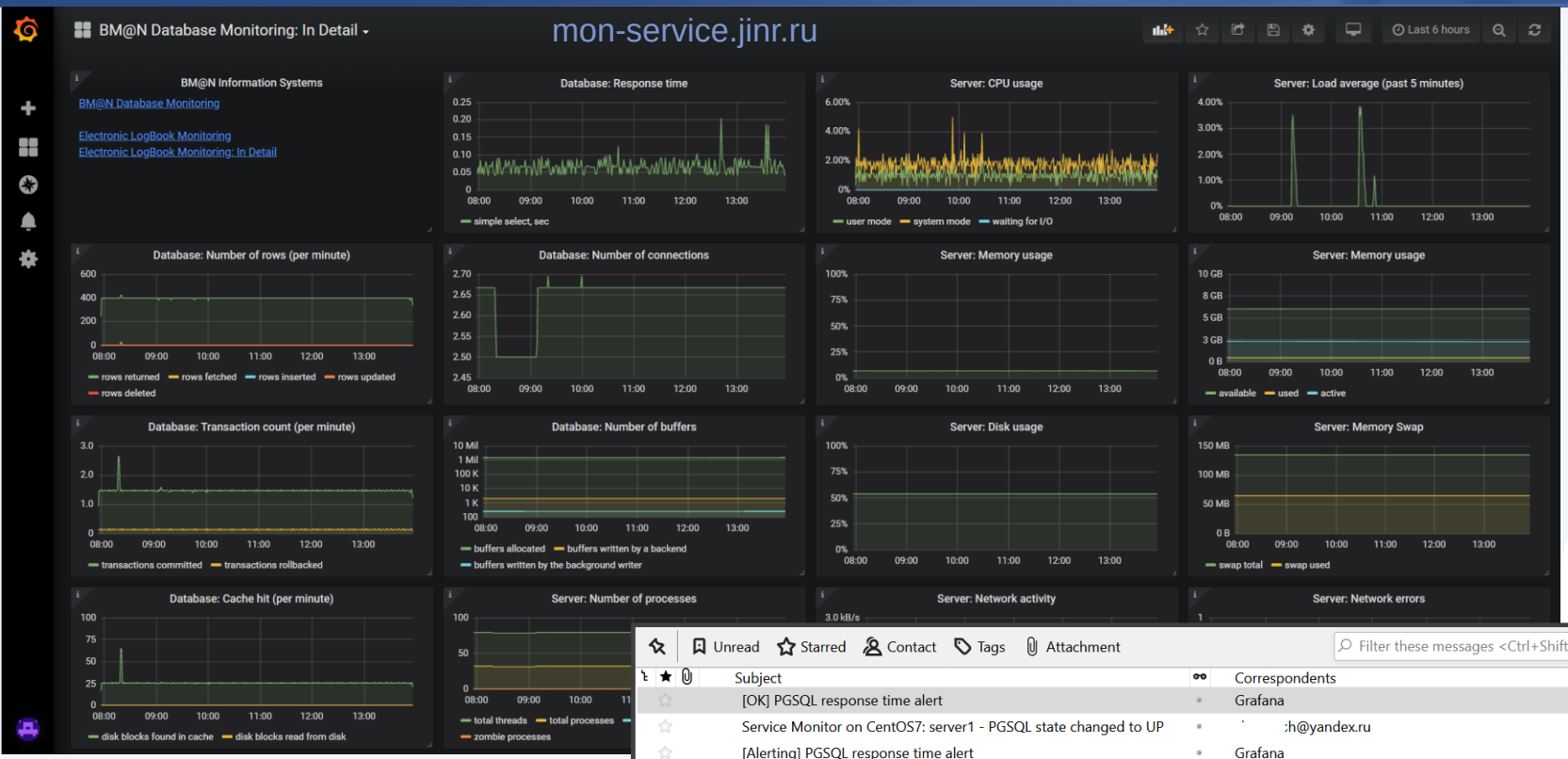


Deployment Scheme

The Common Deployment System is based on Docker containers and shell scripts

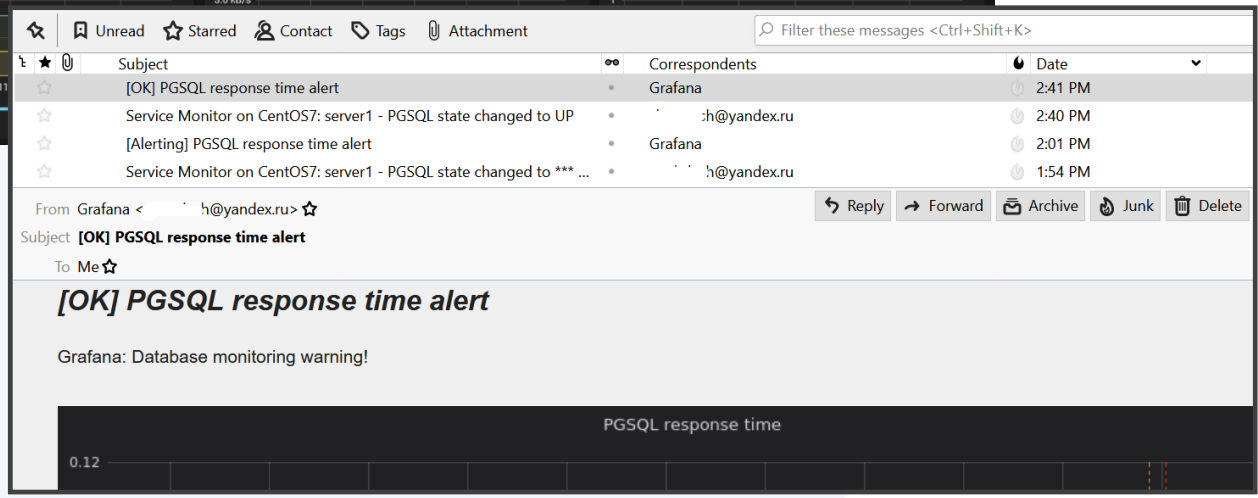
It allows to install the Electronic Logbook System for all the experiments of the NICA project taking into account some specifics of the experiments

Monitoring Information Systems



Grafana View

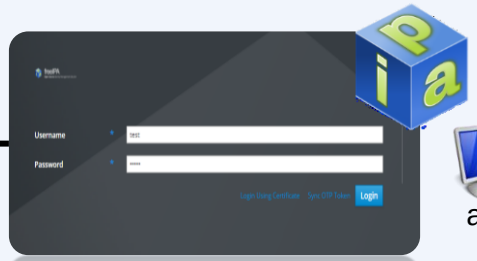
- Unified Database + detailed
- Electronic Logbook + detailed
- BM@N Web sites



Email Notifications

FreeIPA: Single Authentication & Authorization

BM@N Registration



bmn-ipa.jinr.ru

admins writers readers

Wiki Document Server

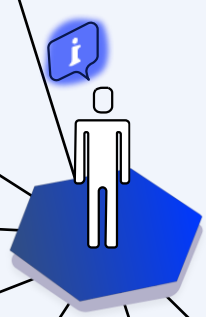
Electronic Logbook

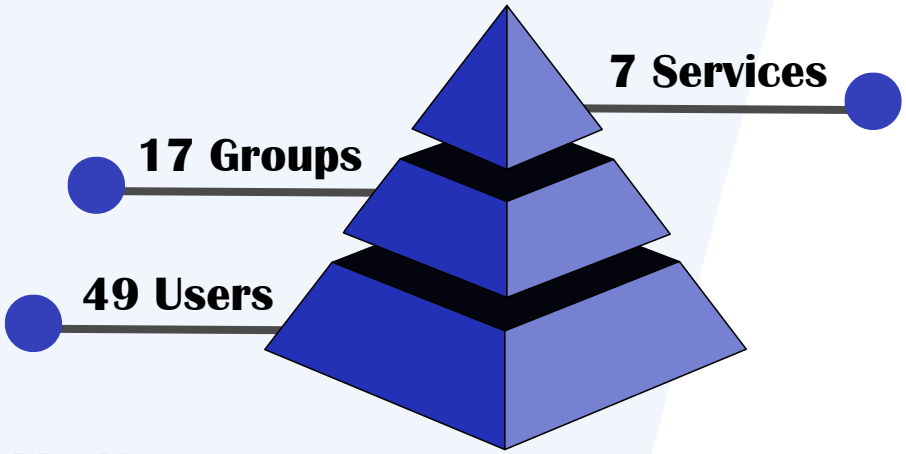
Condition Database

Geometry Database

Configuration System

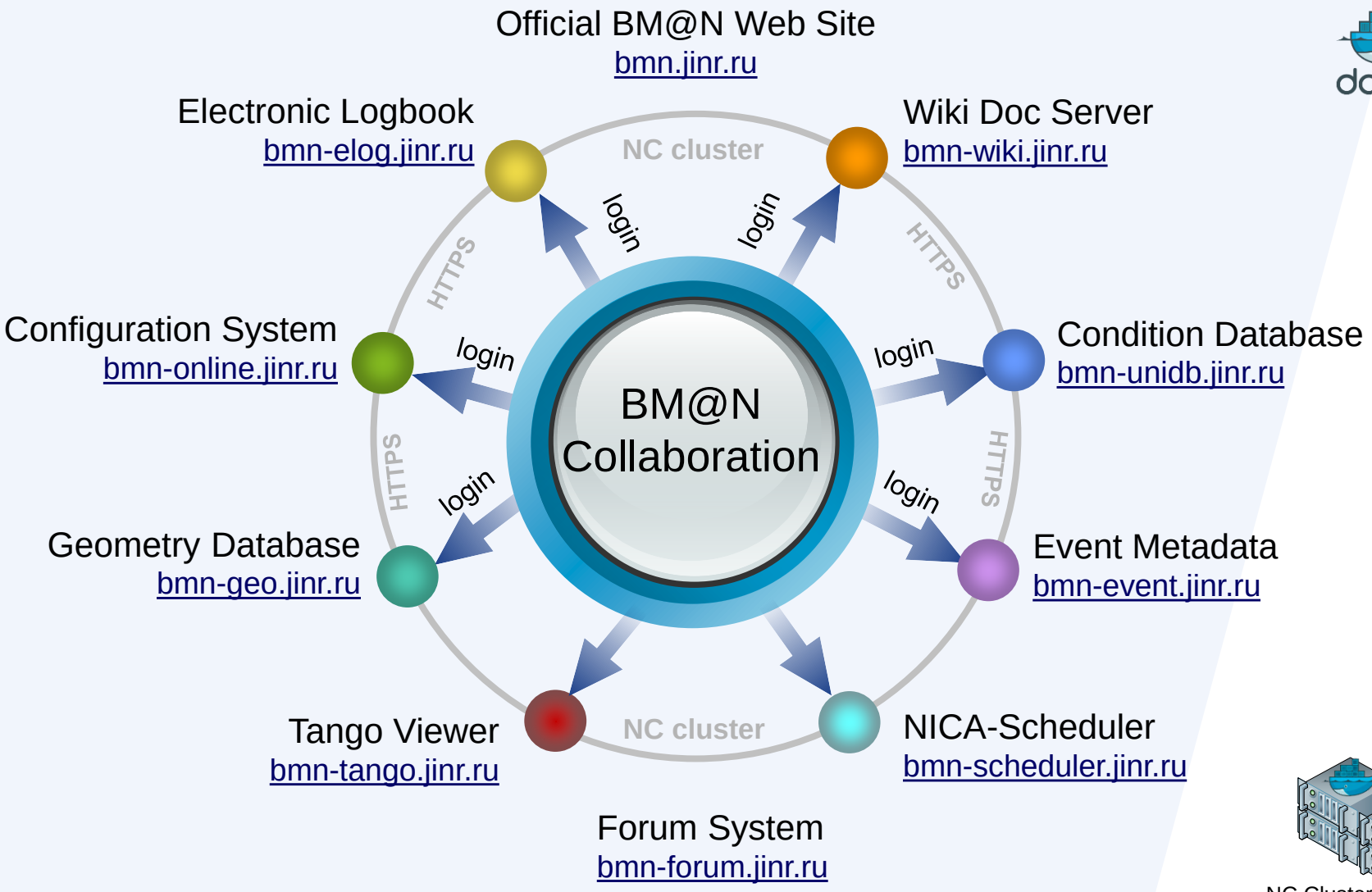
Event Metadata

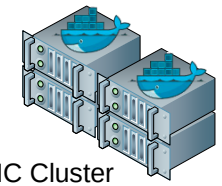




Collaboration members

Evolution of the BM@N Services





Distributed Processing and Computing Clusters

Status of Computing Clusters for BM@N

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

OS: CentOS 7.7
Exp. software: **CVMFS**

EOS: 1 PB (replicated)
GlusterFS: **116** (*replicated*)

SGE: 500 slots/user

MICC Tier1/2 Centre
lxui,jinr.ru
(LIT, b.134)

OS: Scientific Linux 7.9
Exp. software: **CVMFS**

EOS: 1 PB (replicated)

SLURM: *cicc* – **400** slots/user

HybriLIT platform (HPC Govorun)
hydra.jinr.ru
(LIT, b.134)

OS: Scientific Linux 7.9
Exp. software: **CVMFS**, **Modules**

ZFS: 280 TB,
Fast Storage on Lustre 100 TB$_{ssd}$

SLURM: *bmn* – **192** slots

All external packages for BmnRoot have been installed & configured in JINR CVMFS

Automatic software deployment of the BmnRoot on CVMFS with GIT CI

Mass production for BM@N Runs

MICC Complex
1 PB available
BM@N experimental data

raw_run7.data / run_digi.root
xrdcp
run_digi.root / bmndst.root

Fast (Hot) Storage
100 TBssd available

Supercomputer GOVORUN

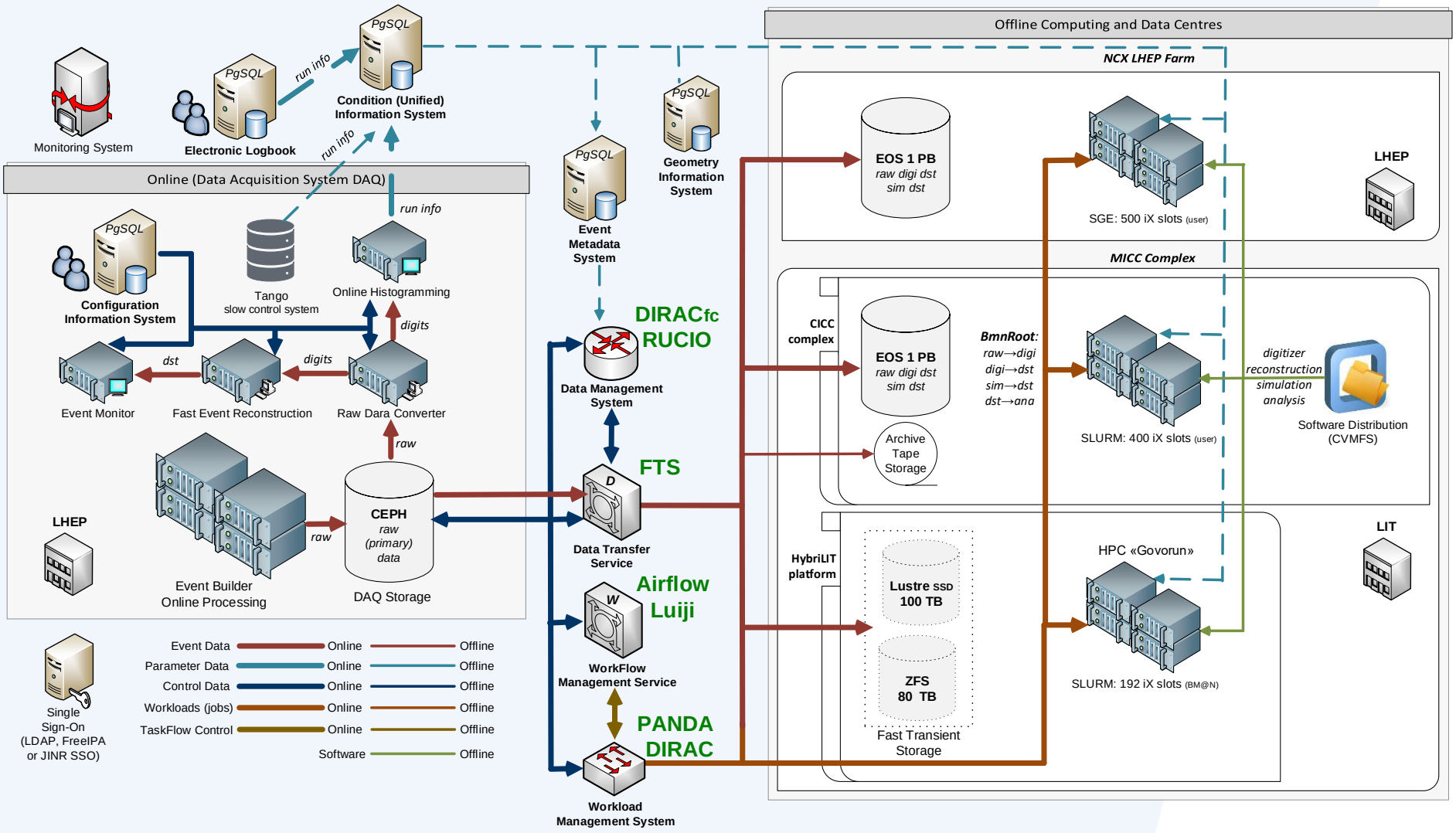
NICA-Scheduler
$ nica-scheduler
bmn_raw_run7_govorun.xml

BmnDataToRoot.C

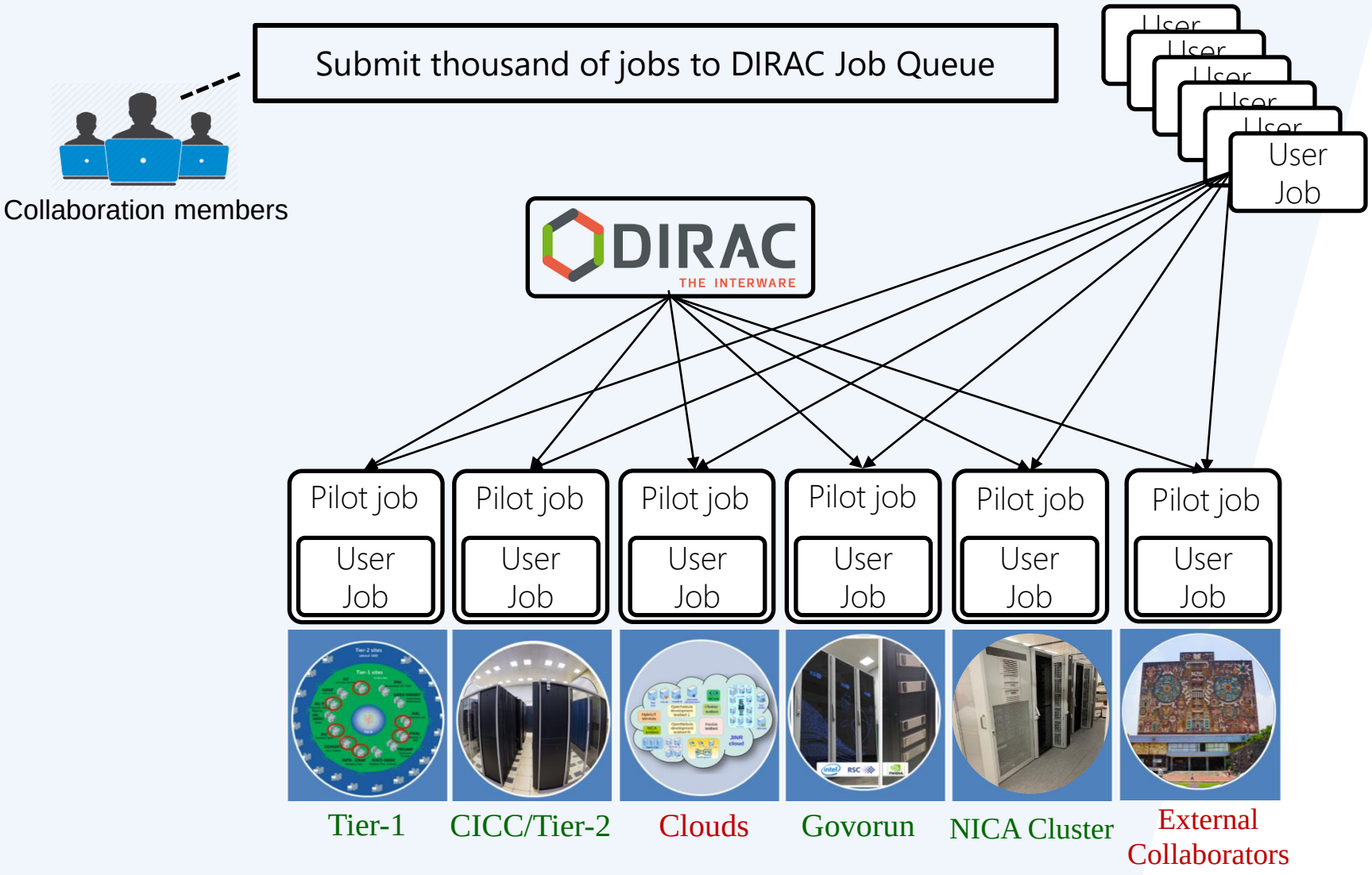
```
<job name="convert_bmn_raw">
 <macro path="~/bmnroot/macro/raw/BmnDataToRoot.C">
  <file input="/eos/nica/bmn/exp/raw/run7/*">
   <put command="xrdcp" path="/lustre/stor/${file_name_with_ext}"/>
   <get command="xrdcp" path="/lustre/stor/bmn_run${last_number}_digi.root"
output="/eos/nica/bmn/exp/digi/run7/bmn_run${last_number}_digi.root"/>
  </file>
 </macro>
 <run mode="global" count="200" config="~/bmnroot/build/config.sh"
work_dir="/lustre/stor"/>
</job>
```

Intel Xeon Platinum (queue ‘bmn’): 192 cores

BM@N Software – Computing Architecture



BM@N WorkFlow Services via DIRAC



BM@N event processing via DIRAC

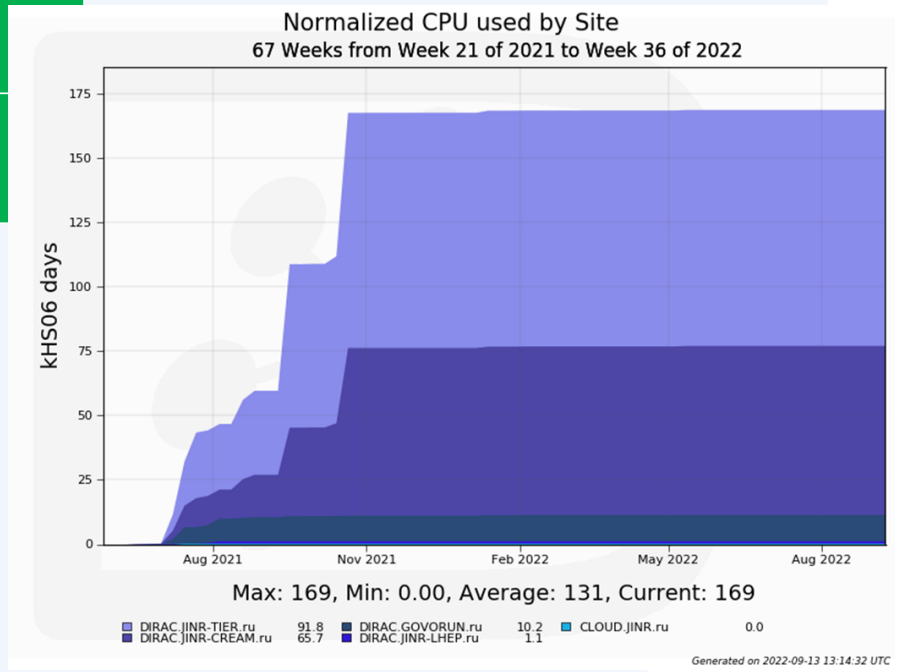
	Tier-1	CICC/Tier-2	Clouds	Govorun	NICA Cluster
RawToDigit			Only with CVMFS		
DigitToDst			Only with CVMFS		
GenToSim			Only with CVMFS		
SimToDst			Only with CVMFS		

Quotas (cores):
Tier1: 920 (for NICA)
Tier2: 1000 (for NICA)
Govorun: 192 (BM@N)
NICA cluster: 250 (for NICA)
JINR Cloud: 90 (for JINR)
Members-states clouds: ~500 (for JINR)

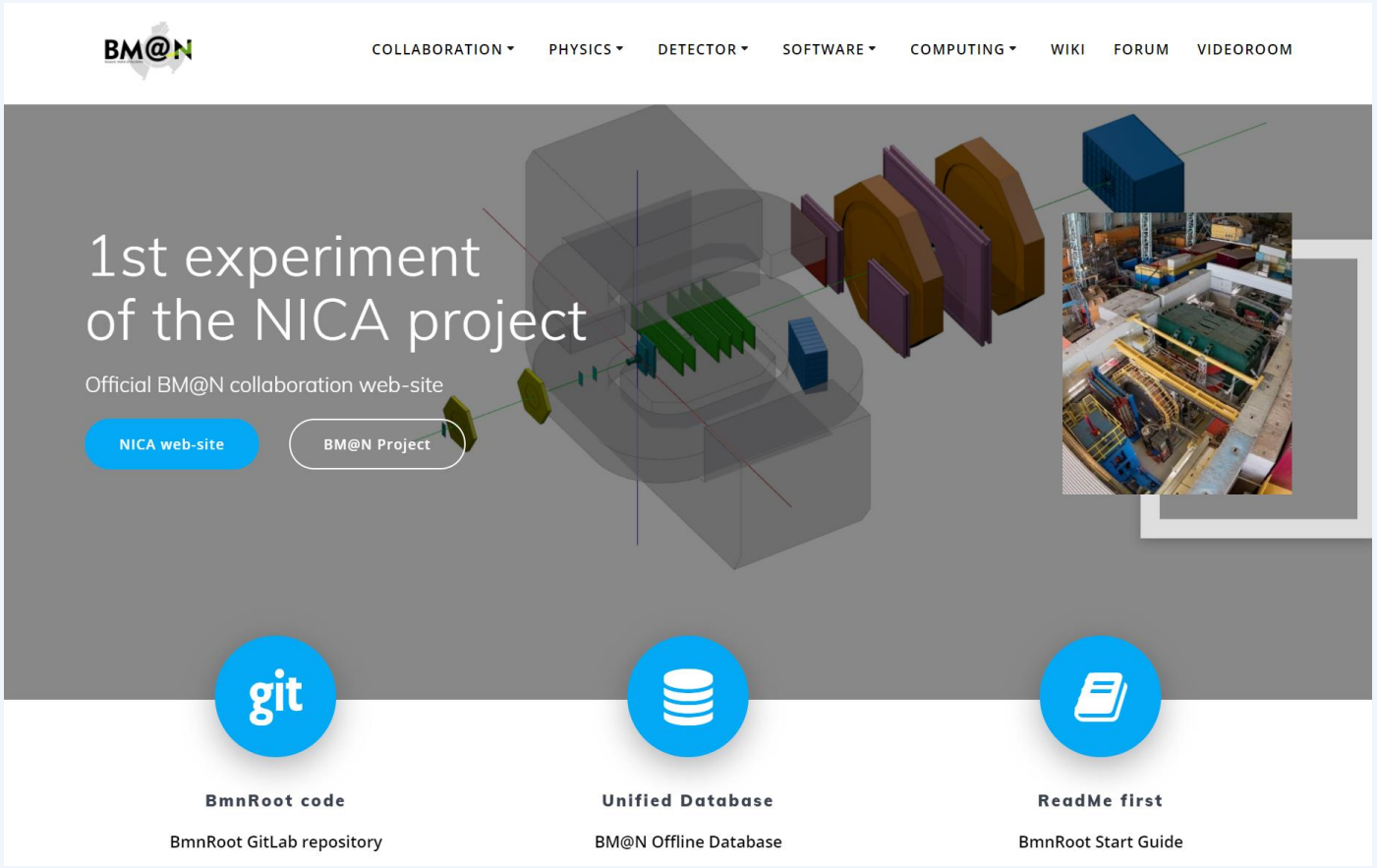
number of running jobs exceeded 1600

Total number of jobs: 18,900

Total wall time: 29 years Average duration: 13 hours



Official BM@N Web-site: *bmn.jinr.ru*



- ✓ ***Collaboration***
- ✓ ***Information***
- ✓ ***Documents***
- ✓ ***Software***
- ✓ ***Databases***
- ✓ ***Computing Section (NICA Cluster, MICC Complex, HybriLIT & Govorun)***
- ✓ ***Guides, Manuals***
- ✓ ***Wiki***
- ✓ ***Forum***
- ✓ ***Webex rooms***
- ✓ ***BM@N Mail-lists***
- ✓ ***etc.***

Global Development Issues

Distributed and High-Performance Computing	Workload Manager and File Catalogue for Big Data: DIRAC, PanDA, RUCIO… Using Docker technologies to organize and support data processing Implementing Distributed Data Flow | Computing Performance Evaluation Search-profiling-parallelizing: OpenMP, MPI, CUDA/OpenCL, RDataFrame… NICA-Scheduler evolution
Visualization	Event Display as a Web-service: Offline & Online systems Training course for the BM@N event display
Databases, User Interfaces and Services	Developing components of the Event Metadata System Implementing new database features on C++ and ROOT 6, REST API Database migration from SQL → NoSQL
Web-services & Online Systems	Implementation of Online and Offline Monitoring Systems Distributed Processing via the Web-service…
Simulation and Reconstruction	Development of a miniDST format and data generation Implementation of fast event reconstruction for online processing Optimization of the BmnRoot framework…

Задачи квалификационных работ *(часть)*

- Разработка системы распределенного запуска и управления задачами эксперимента по высокоинтенсивной обработке данных при помощи платформы DIRAC (python).
- Внедрение Каталога файлов со смоделированными и экспериментальными данными эксперимента для реализации высокоинтенсивной обработки (RUCIO/DIRAC Catalogue)
- Разработка сервиса автоматизации распределенной обработки данных эксперимента BM@N (Apache Airflow, python).
- Использование докер-контейнерных технологий для организации и поддержки обработки данных эксперимента BM@N (Dockers, python).
- Разработка веб-сервиса визуализации событий столкновения частиц эксперимента (React, TypeScript, CERN ROOT || Phoenix Event Display).
- Разработка специализированного формата miniDST в эксперименте (C++, ROOT)
- Разработка и внедрение информационных систем на базах данных, сопутствующих интерфейсов (React, REST API) и сервисов. Перевод на NoSQL параметрической части.
- Развитие основного фреймворка BmnRoot, устранение проблем (C++, ROOT).
- Создание и внедрение полной методики оценки производительности существующих вычислительных платформ для эксперимента BM@N.

Thank you for your attention!

You are welcome to take an active part in the building of the great project in Dubna!

More information: **bmn.jinr.ru**
nica.jinr.ru

Email: *gertsen@jinr.ru*

We are open for young people!