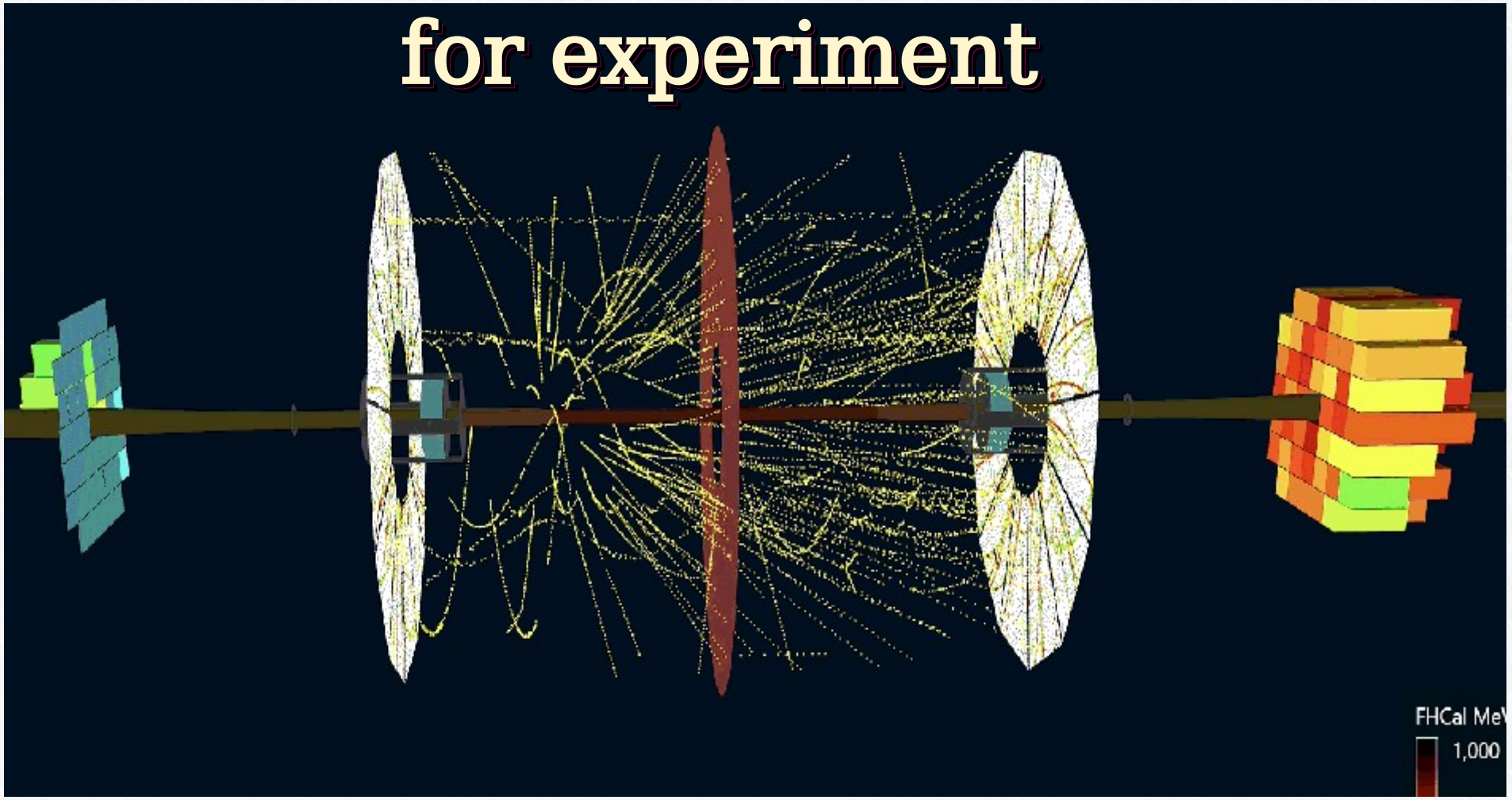
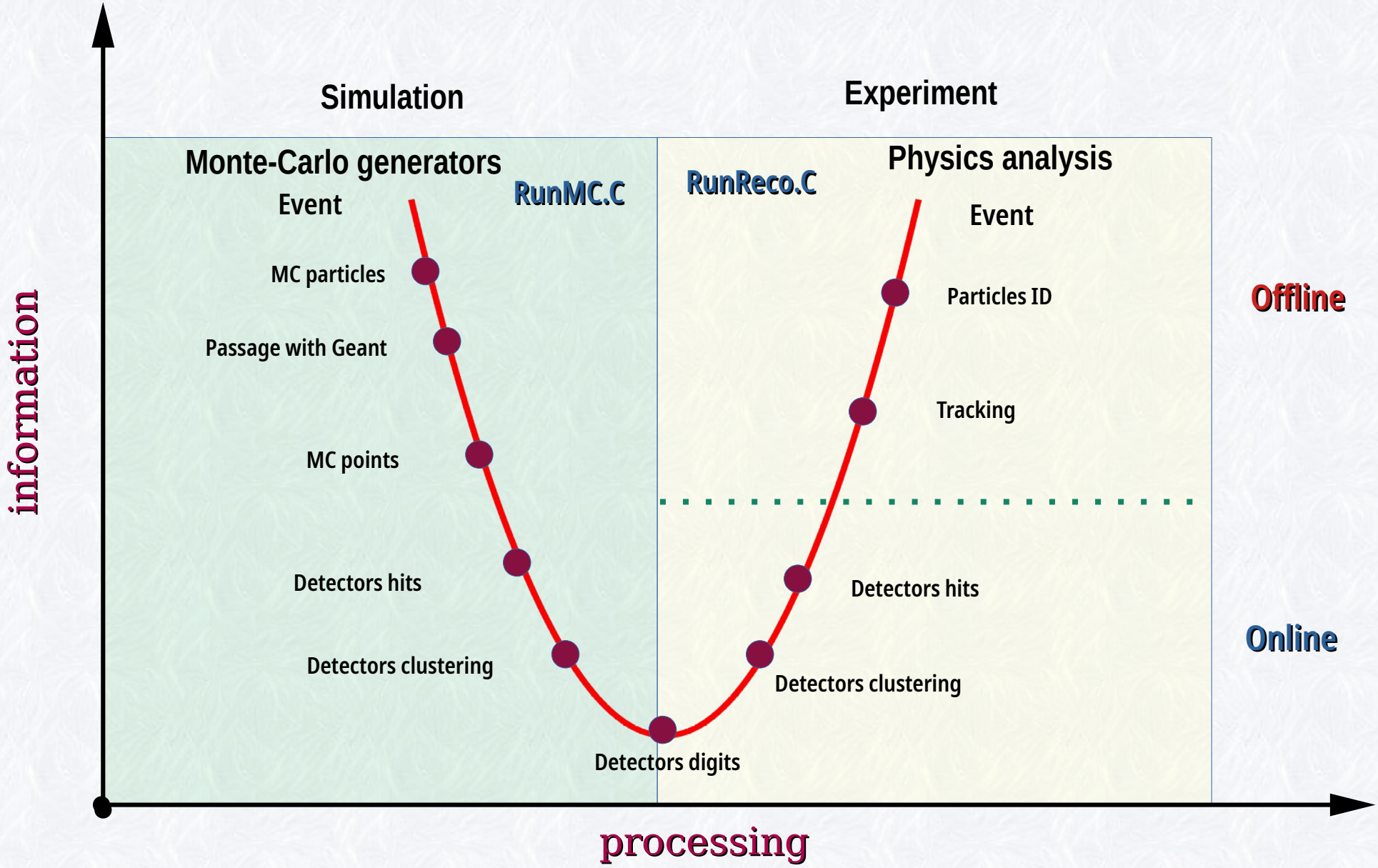
MPD software readiness for experiment



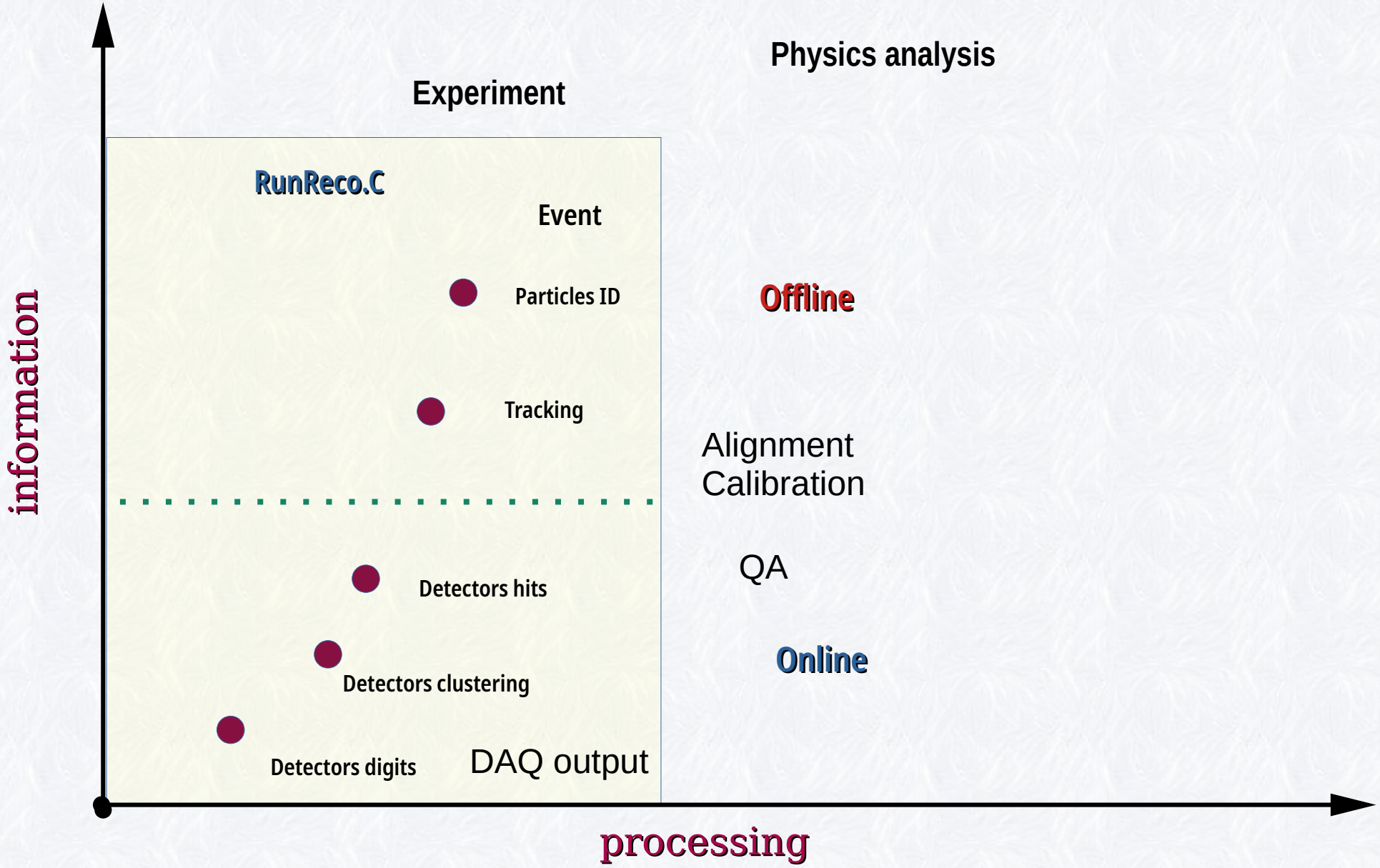
Rogachevsky Oleg
for MPD collaboration

XVIII MPD Collaboration meeting
20.10.26

Simulation @ Experiment chain



Simulation @ Experiment chain



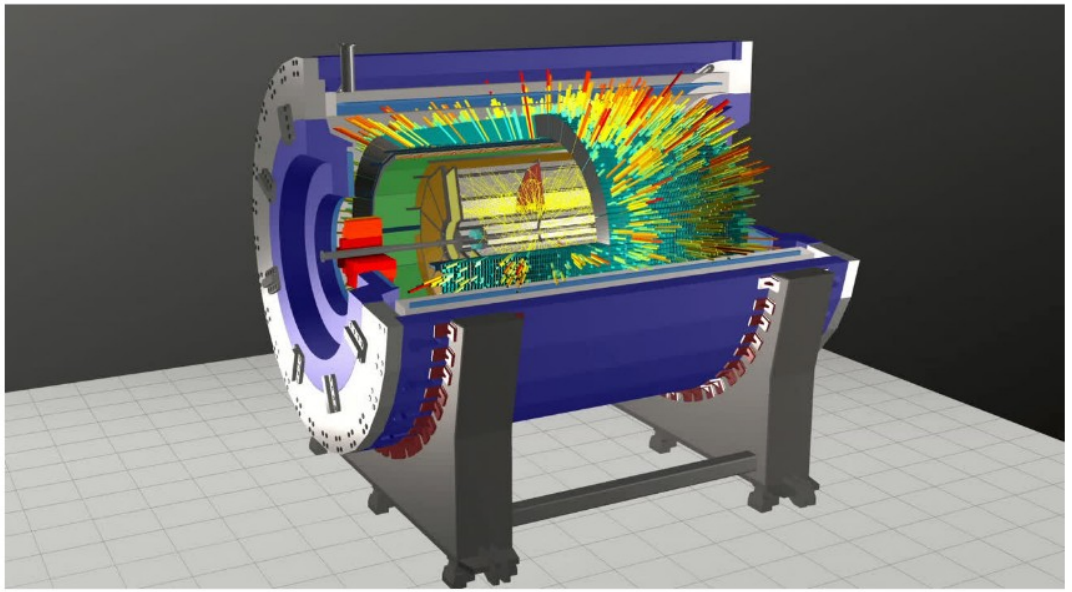
MPD Event display

Alexander Krylov

Data monitoring

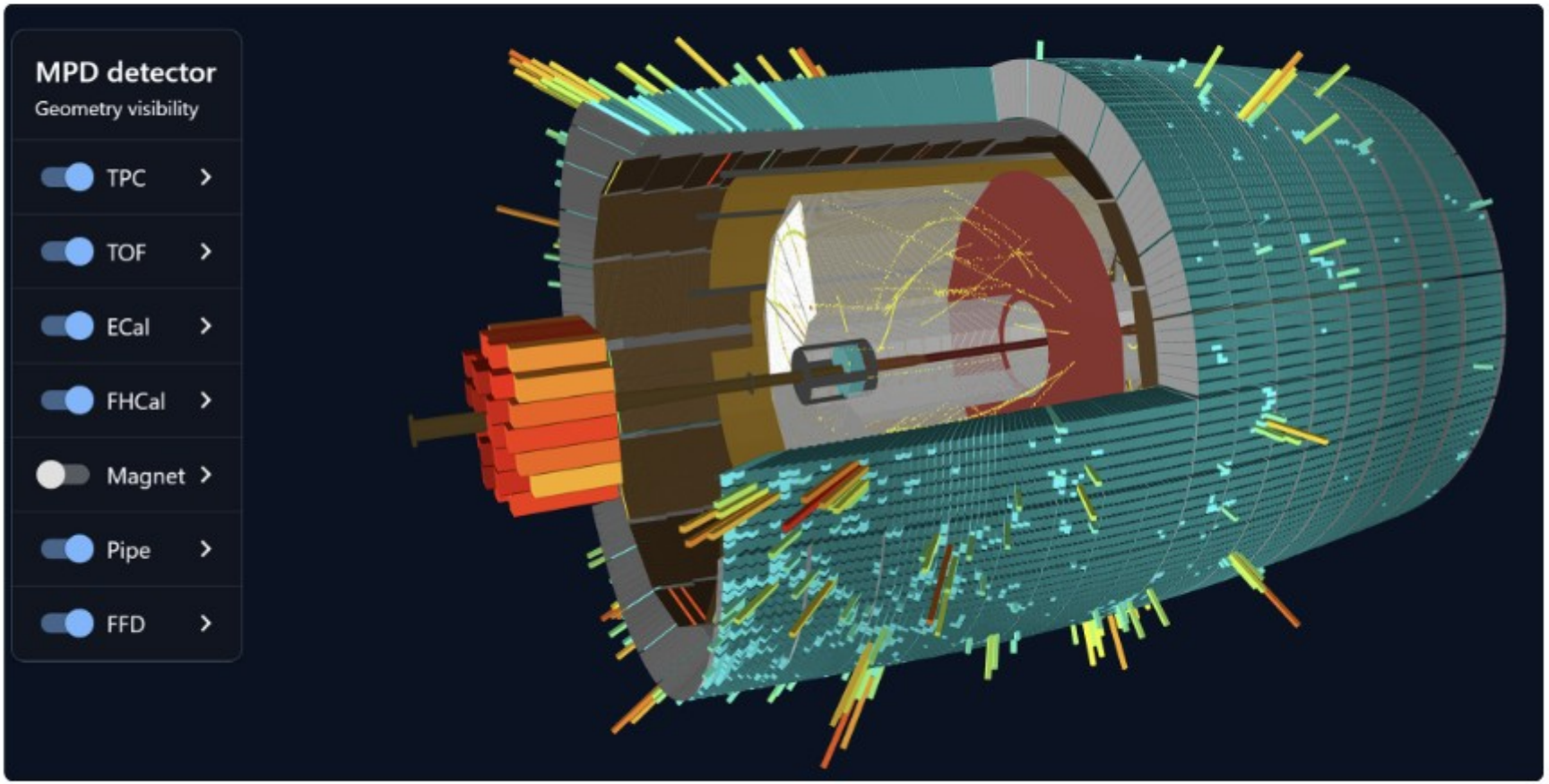
NICA MPD

MPD Online Data Monitoring



A. Krylov, JINR/LHEP
avkrylov@jinr.ru

Event display



MPD Run time data base

A. Moshkin, E. Alexandrov
I. Alexandrov, M. Kozhevnikova

MPD online webserver

https://mpd-online.jinr.ru/

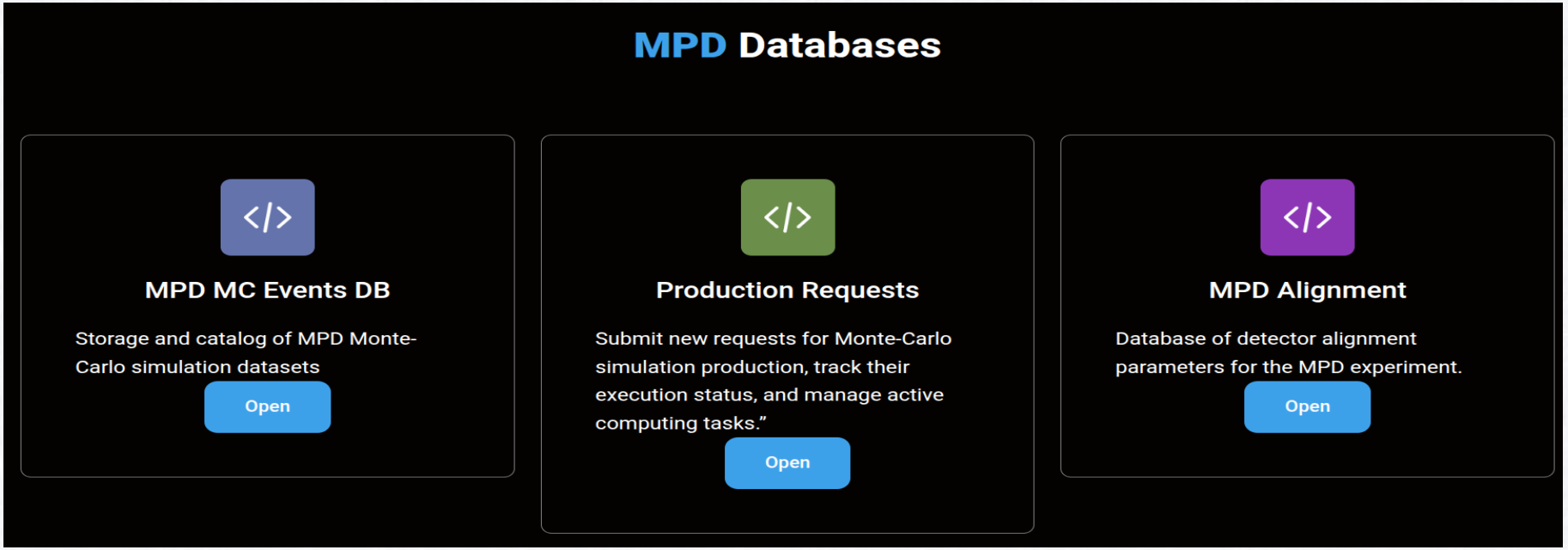


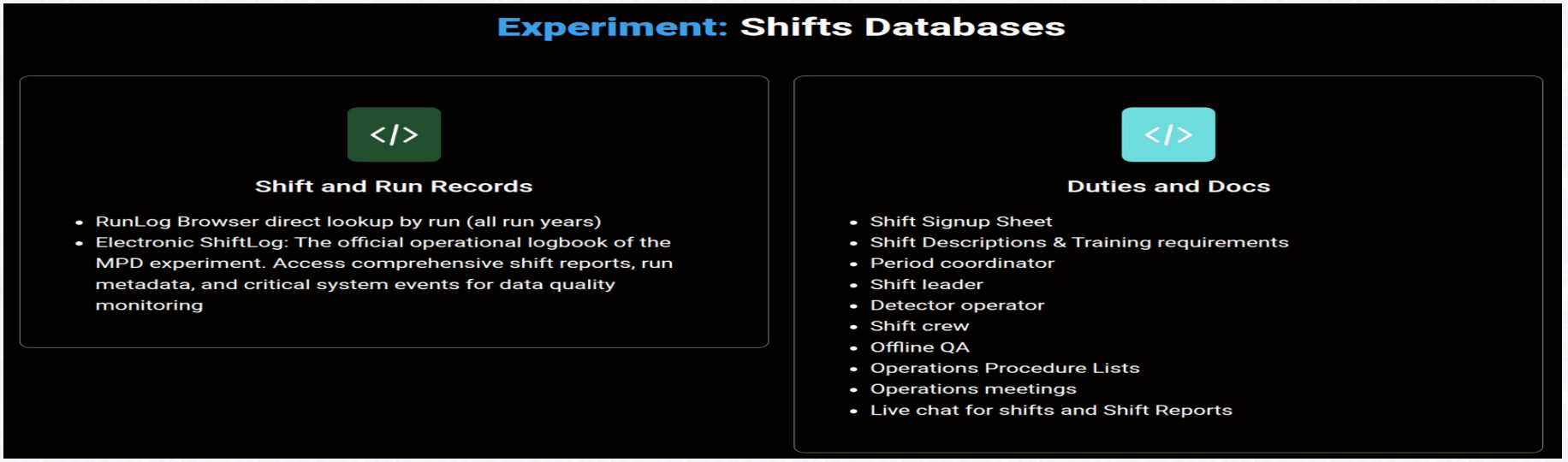
- Central entry point for monitoring and detector status.
- Access to online event display.
- Access to online QA histograms.
- Links to experiment databases.
- Production requests and production tracking.
- Shift records and logbook.

- Run status and detector-status information.
- Calibration/alignment/status information.
- Bridge between shifters, detector experts, software experts, production managers, and offline analysts.

MPD online webserver

https://mpd-online.jinr.ru/





MPD online webserver

https://mpd-online.jinr.ru/

Experiment Control System Databases

Monitoring & Status Links

- MPD Status page
- Run Control system monitoring
- DAQ monitoring
- DB monitoring
- Online-to-Offline database data flow
- Slow Controls monitoring
- Online Event Display
- Online QA Histograms

Trigger, Scalers & Detectors Monitoring

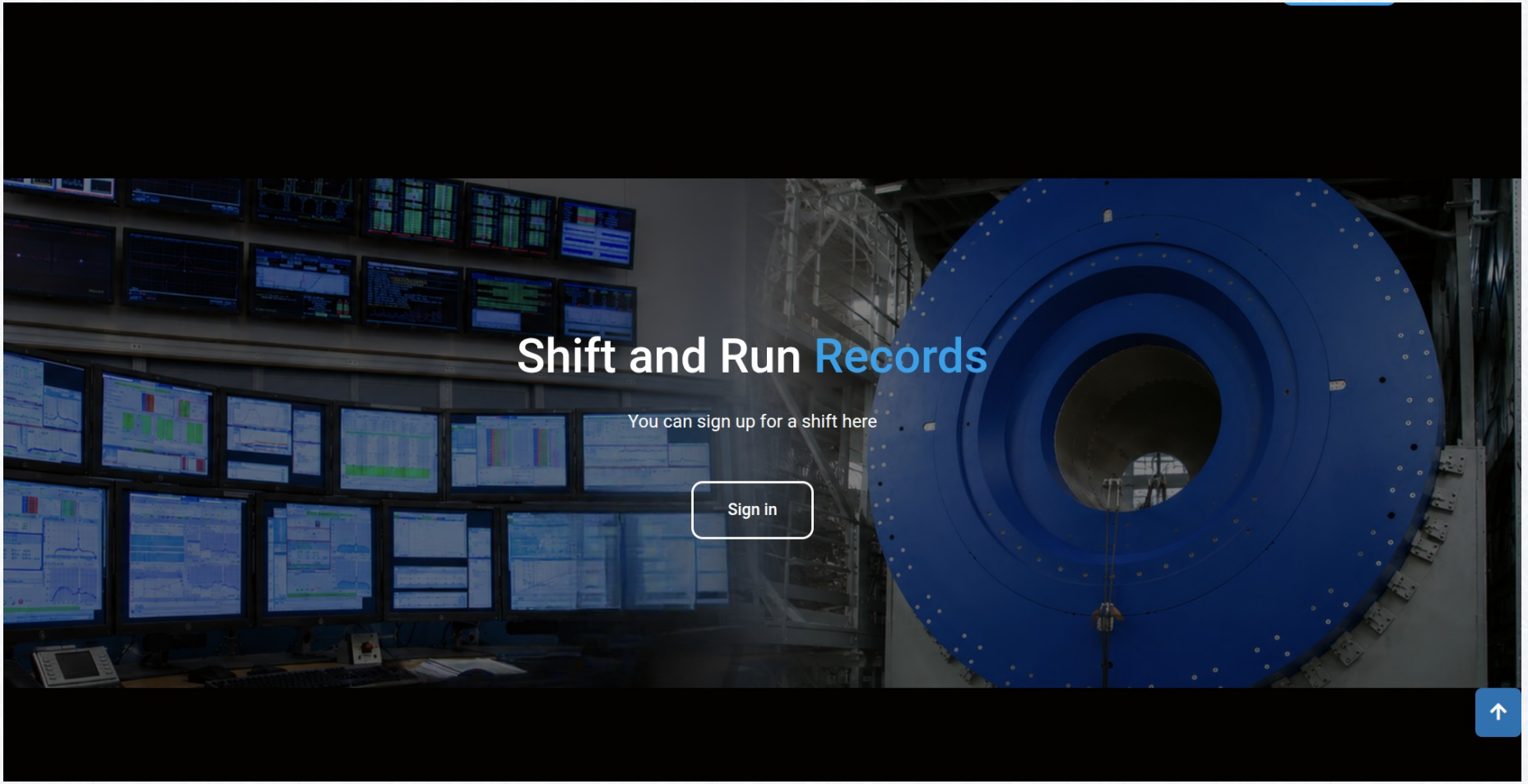
- Trigger
- HLT
- Scalers
- FFD
- TPC
- ECal: Database of calibration and monitoring parameters for the MPD Electromagnetic Calorimeter (ECAL).
- FHCal
- TOF
- LUSI

NICA Status & Scheduling

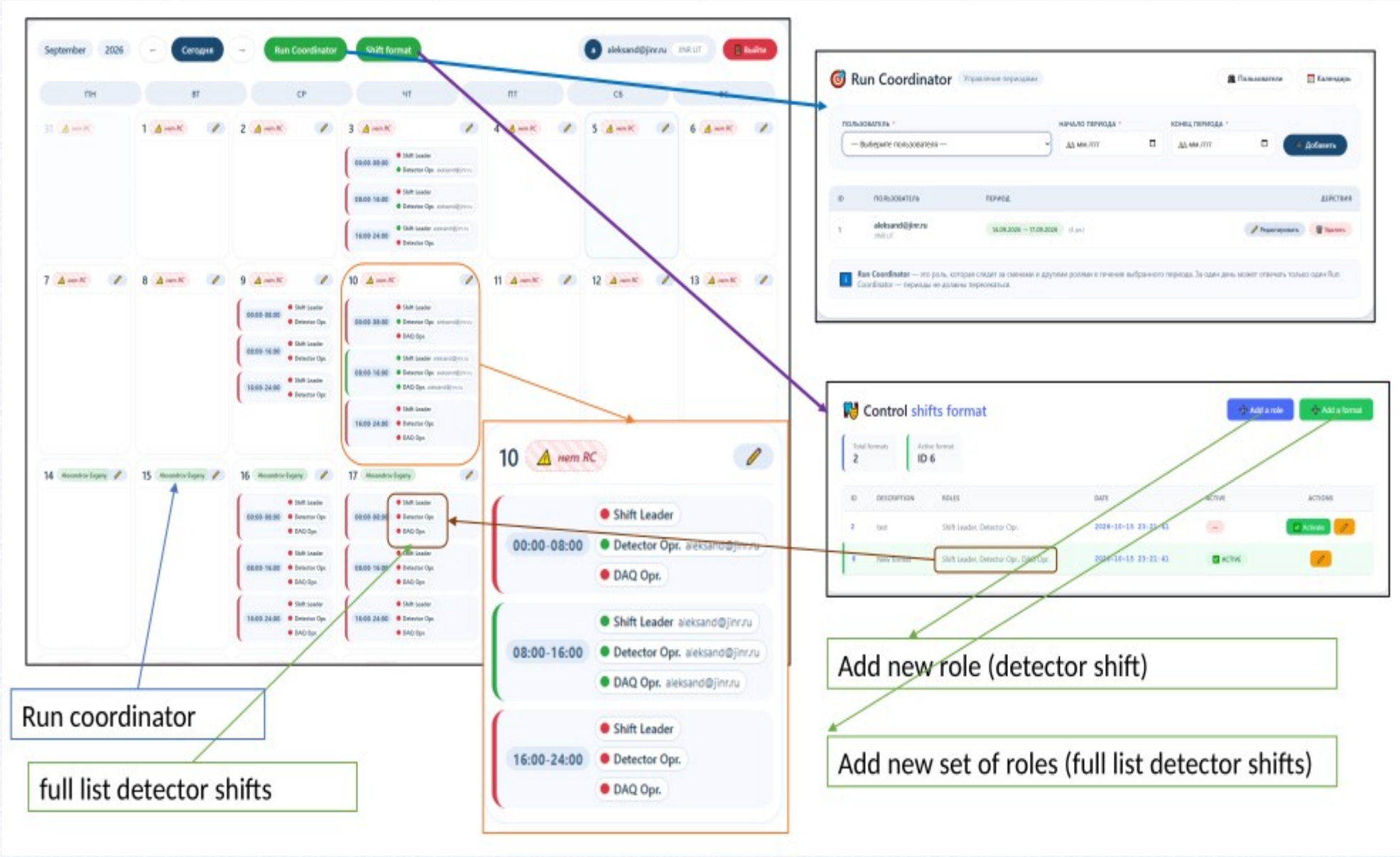
- NICA schedule
- NICA/MPD schedule
- NICA Machine Status Broadcast
- NICA Performance Plots

MPD online webserver

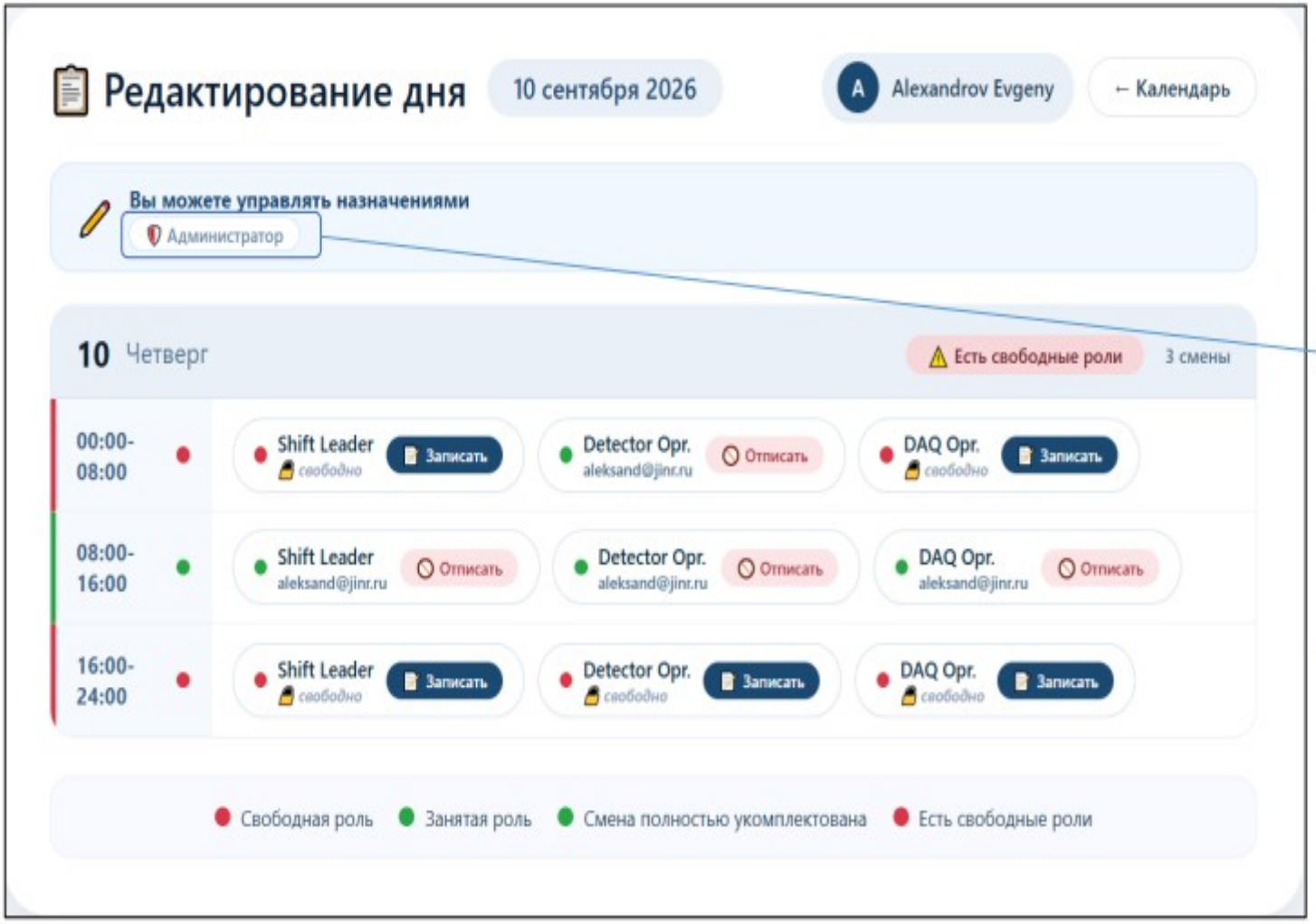
https://mpd-online.jinr.ru/



Shifts database



Booking



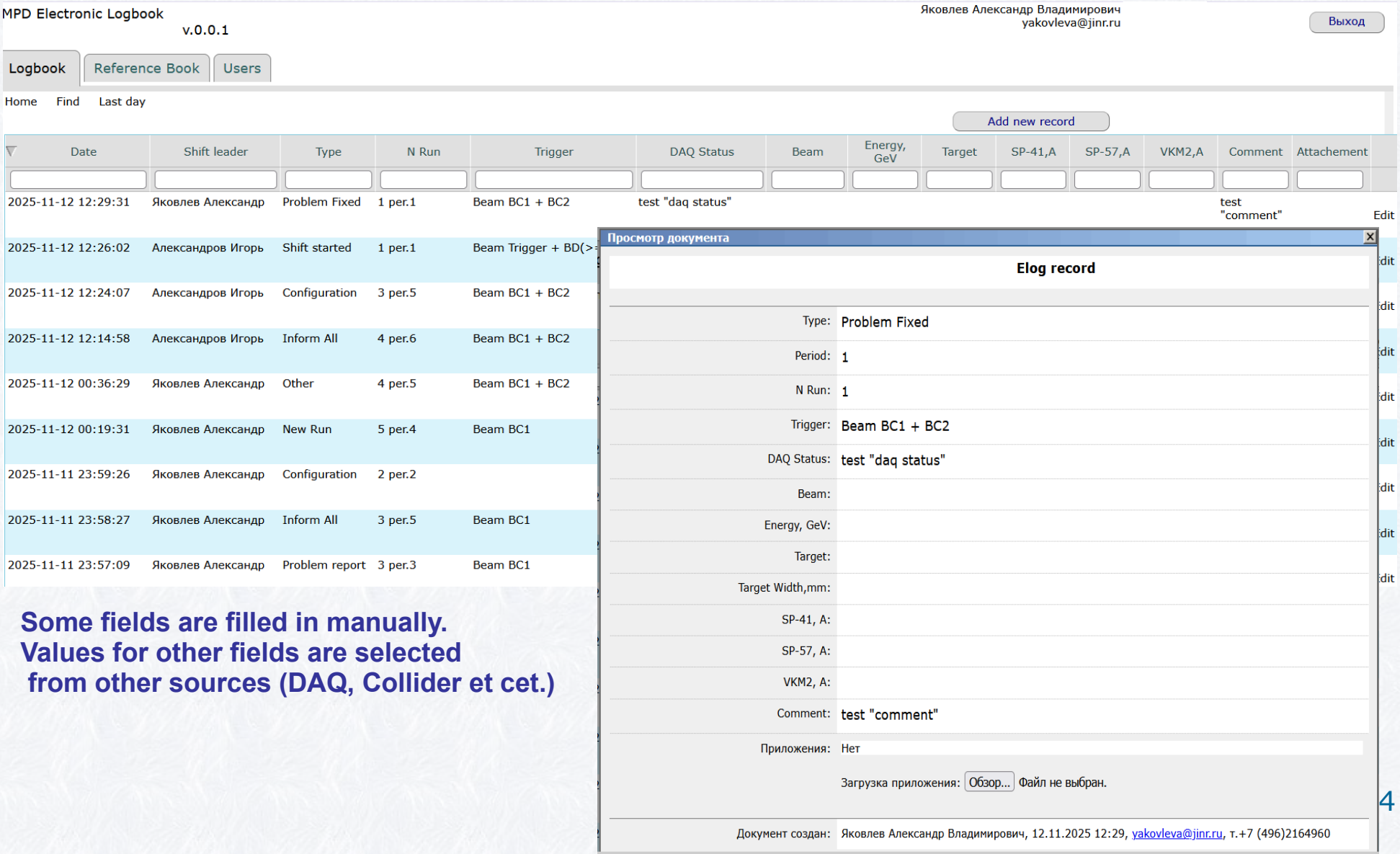
Administrator can subscribe/unsubscribe any roles

Run controller can subscribe/unsubscribe any roles for his days

Shift leader can subscribe/unsubscribe other roles but only for his shifts

MPD Logbook

The JINR single sign-on (SSO) is used to authenticate the user and his role.



Some fields are filled in manually.
Values for other fields are selected from other sources (DAQ, Collider et cet.)

TPC calibration & alignment

A. Bychkov, A.Fedotov, V. Kuzmin

TPC endcap planes alignment

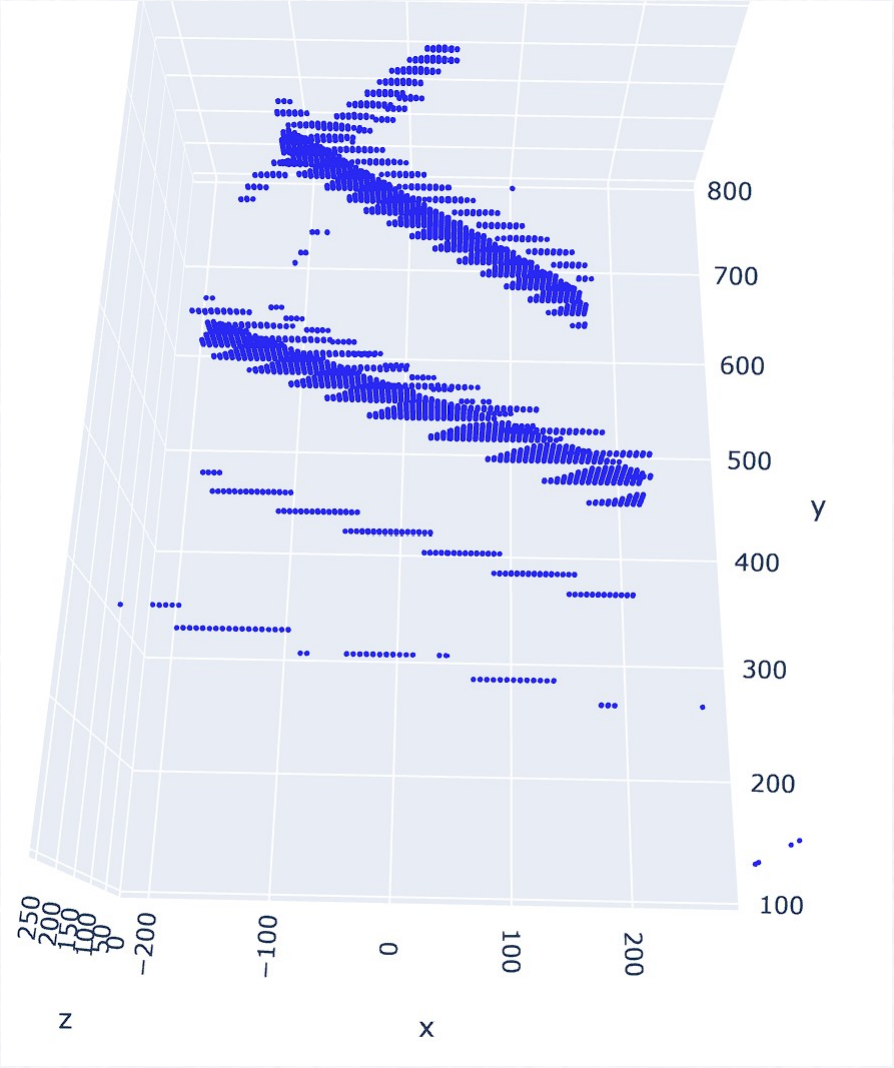
East



West



Laser calibration

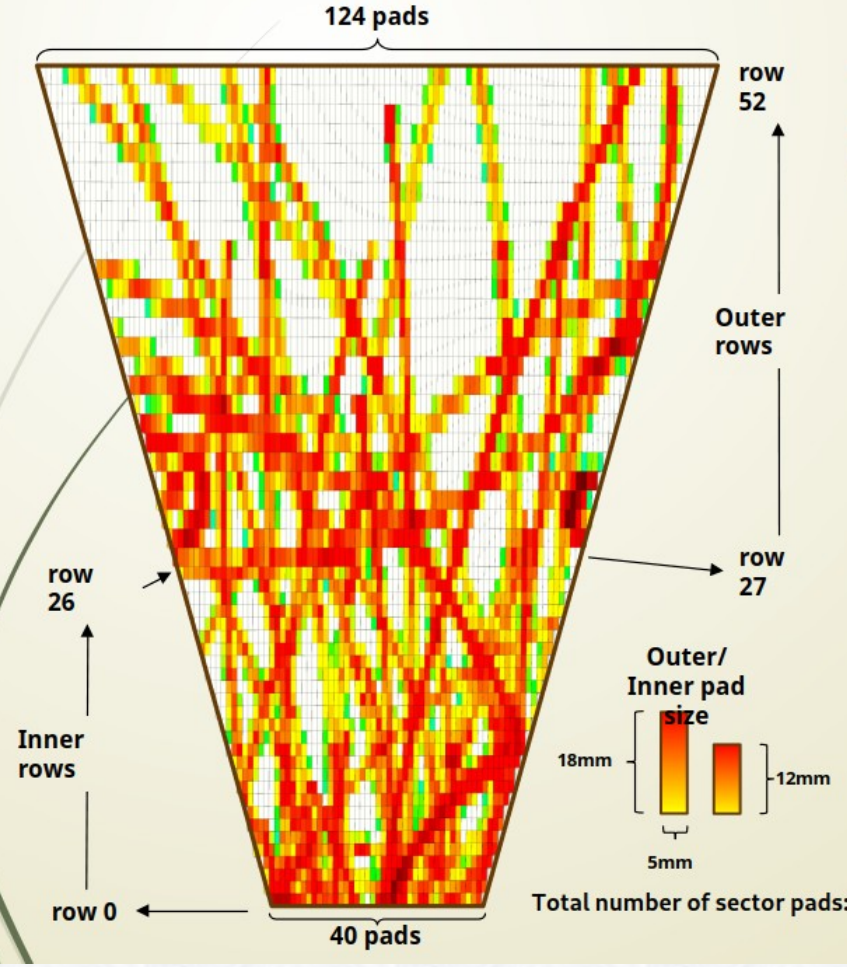


Laser beams in one chamber of TPC

MPD TPC clustering

Victor Krylov

TPC Sector Layout and the SAMPA chip

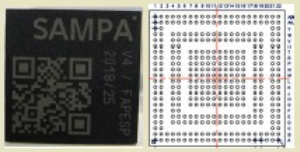


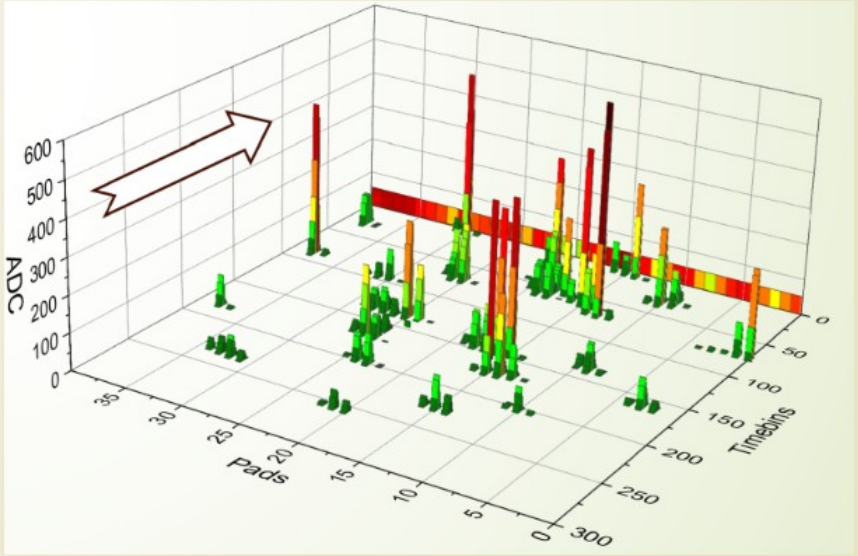
Total number of sector pads: 4112 pcs

- SAMPA chip is an ASIC developed for the readout of TPC detector *(15x15mm,130nm,32 channels,CSA+10-bit ADC+DSP)*
- Row data rate: 32channels x 10b x 10Mb/s = 3.2Gb/s
- Peaking time: 160ns

Where:

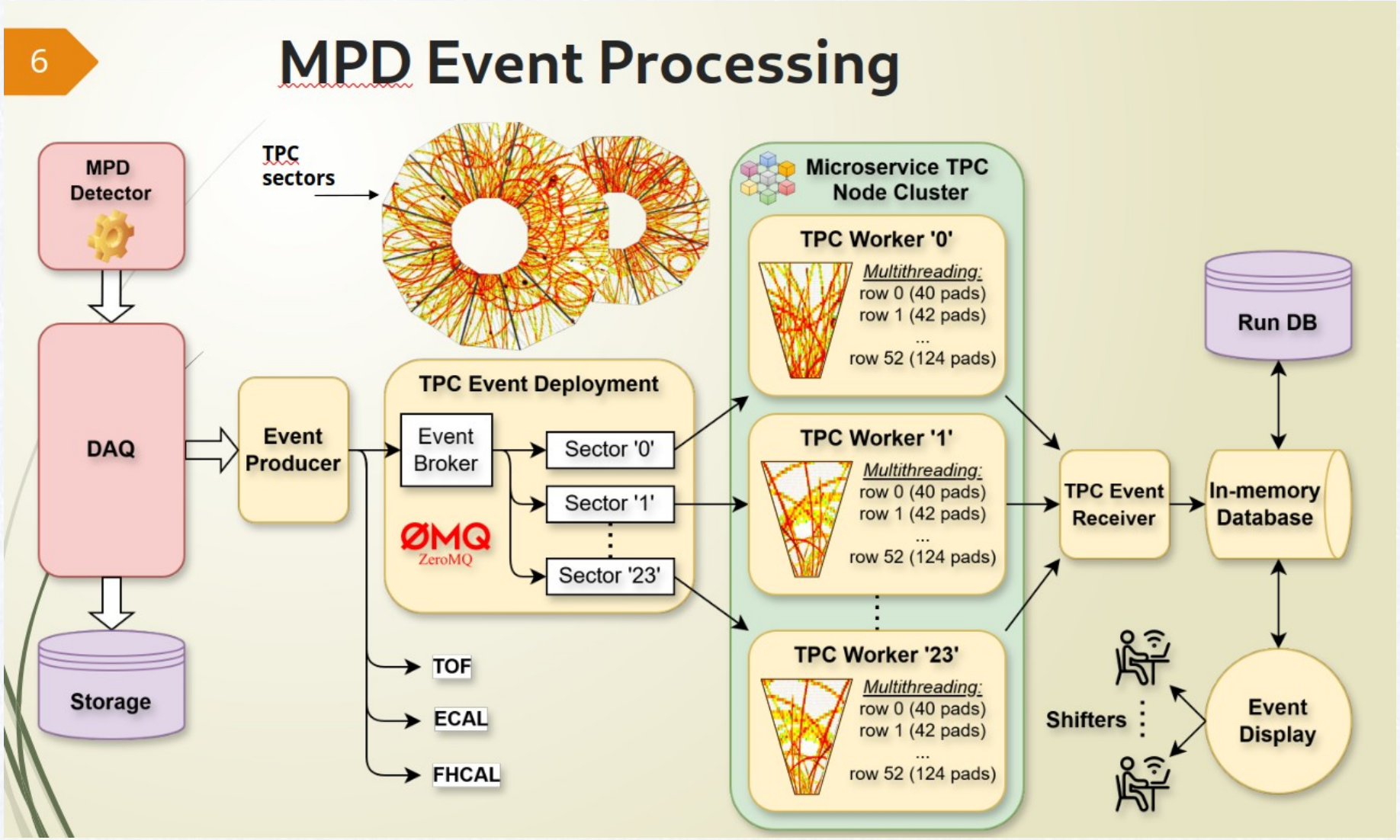
ASIC – Application-specific integrated circuit
CSA - Charge Sensitive Amplifier
DSP – Digital Signal Processor *(Baseline corrections, Zero suppression, Digital shaper, Huffman compression…)*



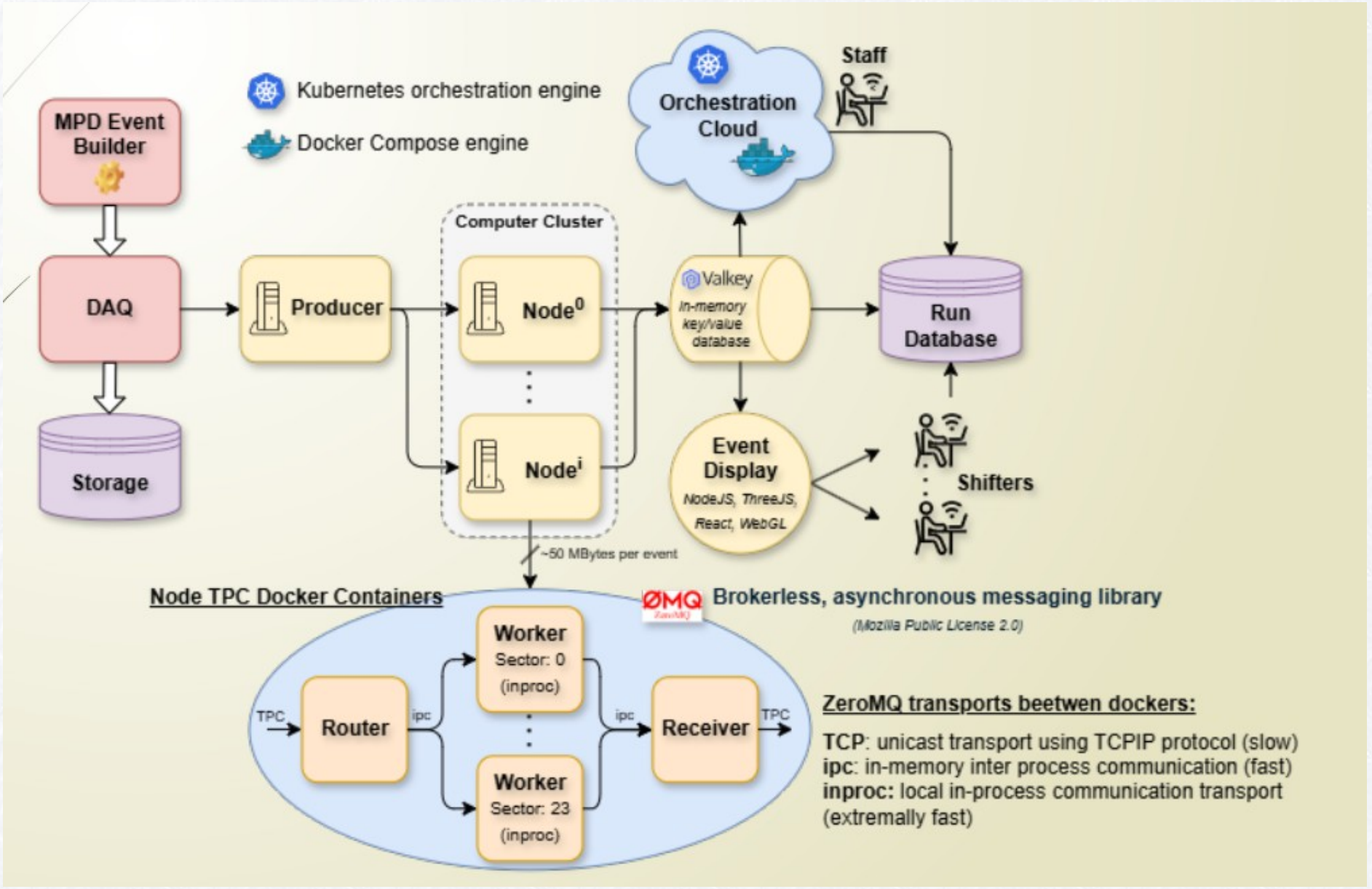


TPC sector row:0 SAMPA ADC contents, ~750 digits, mV
(after baseline correction and zero suppression)

Processing


6
MPD Event Processing
MPD Detector
DAQ
Storage
TPC sectors
Event Producer
TPC Event Deployment
Event Broker
ØMQ
ZeroMQ
Sector '0'
Sector '1'
Sector '23'
TOF
ECAL
FHCAL
Microservice TPC Node Cluster
TPC Worker '0'
TPC Worker '1'
TPC Worker '23'
Multithreading:
row 0 (40 pads)
row 1 (42 pads)
...
row 52 (124 pads)
TPC Event Receiver
Run DB
In-memory Database
Shifters
Event Display

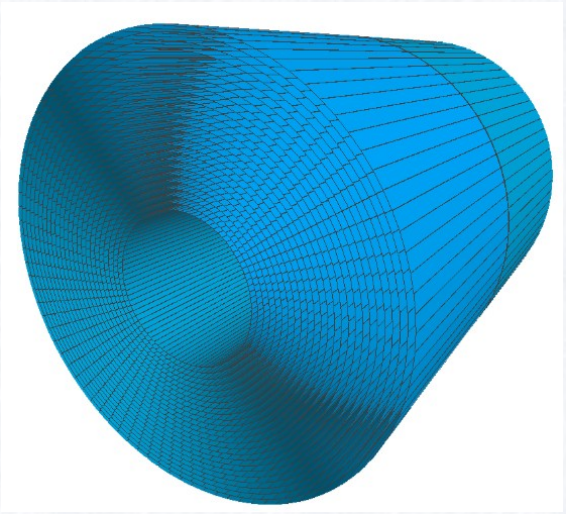
New architecture

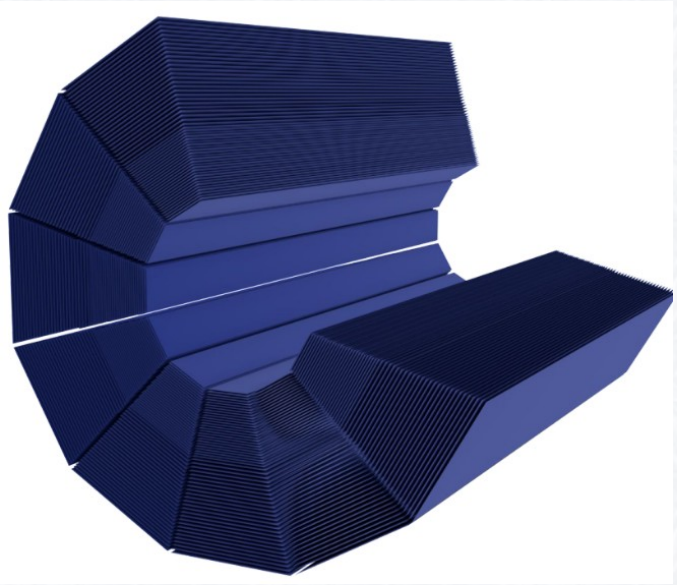


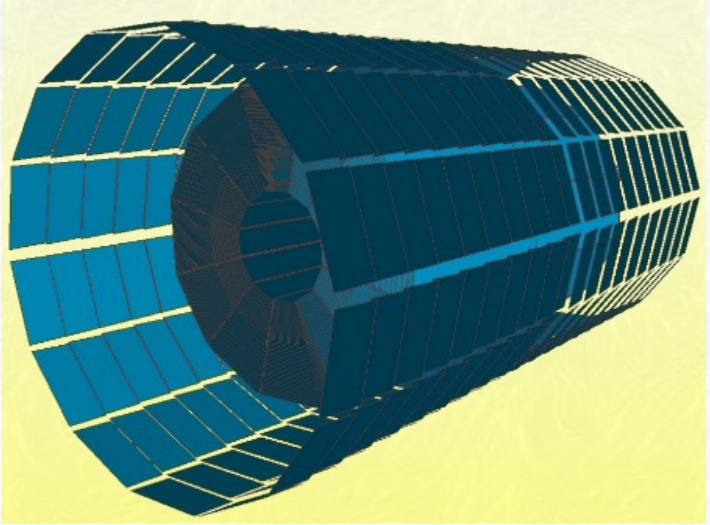
MPD tracking & ML PID

Slavomir Hnatic,
Vladimir Papoyan

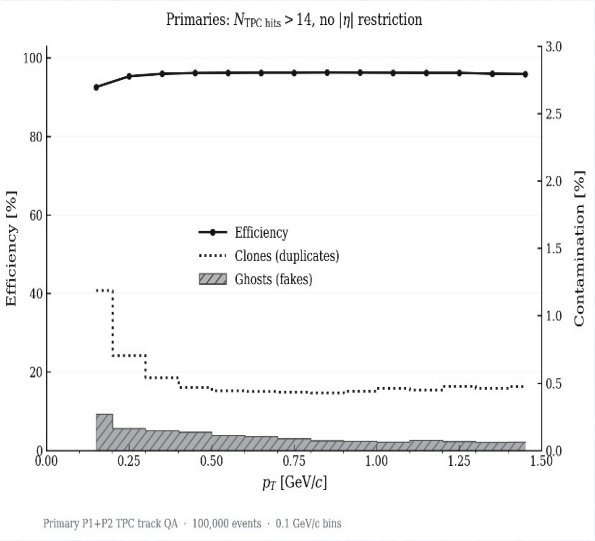
Adjust TPC geometry for ACTS

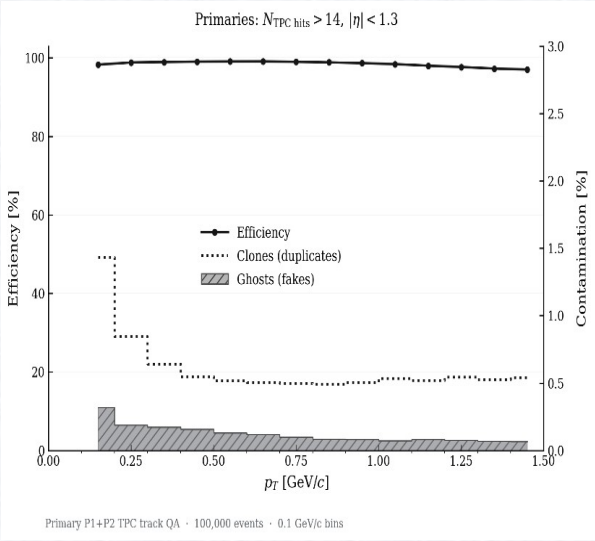


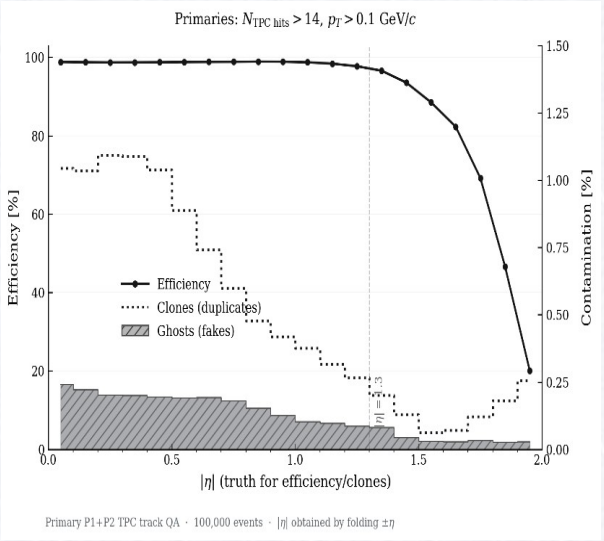




MPD TPC tracking performance







Primary-track reconstruction

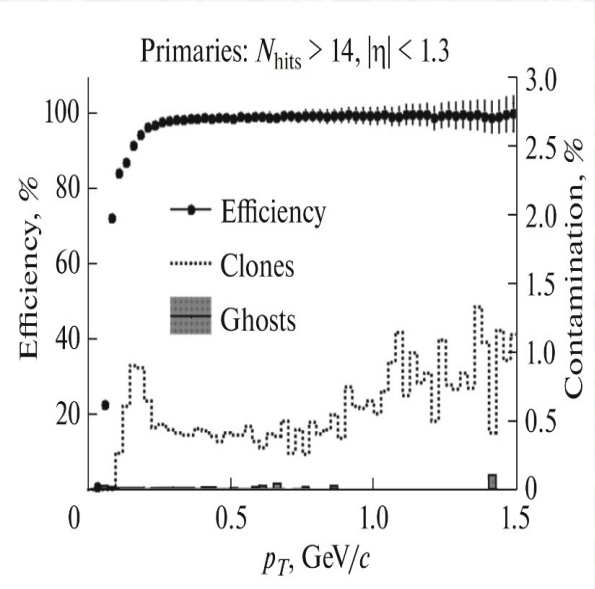
Efficiency / duplicates / fakes by transverse momentum

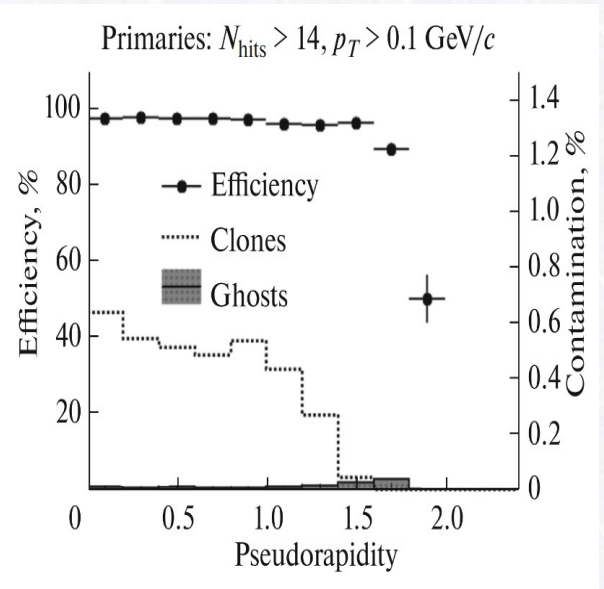
1,000 runs · 100,000 events

p_T [GeV/c]	$\|\eta\| < 1.3$ efficiency / duplicate / fake	Total (no η cut) efficiency / duplicate / fake
0.1–0.2	98.24% / 1.434% / 0.320%	92.54% / 1.185% / 0.271%
0.2–0.3	98.81% / 0.844% / 0.188%	95.28% / 0.705% / 0.163%
0.3–0.4	98.91% / 0.641% / 0.172%	95.92% / 0.541% / 0.150%
≥0.4	98.71% / 0.521% / 0.120%	96.16% / 0.451% / 0.105%

Combined P1+P2 primary tracks · ≥15 TPC hits · final row aggregates 0.4 ≤ p_T < 5.0 GeV/c

Towards a Realistic Monte Carlo Simulation of the MPD Detector at NICA
(Kolesnikov V., Mudrokh A., Vasendina V., Zinchenko A. - 2018)





3 passes for track finding

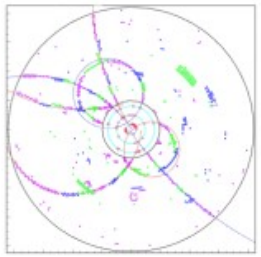
MPD EVENT RECONSTRUCTION IN ACTS

Tracking Philosophy & Flow

INPUT DATA	Monte-Carlo Simulation or Real Experimental Data
ACTS CKF STRATEGY	Maximize efficiency, minimize fakes, handles many duplicates
CLEANUP & OPTIMIZATION	Identify best tracks, filter fakes/duplicates, improve quality
OUTPUT DATA	Validated track pool ready for PID & Physical Analysis

KEY FACTOR: EVENT MULTIPLICITY

DILUTE (STCF)



DENSE (MPD TPC)



Dense Environment

In high-occupancy environments, combinatorial clutter is overwhelming. **Multi-pass reconstruction** reduces complexity by sequentially isolating and removing specific track populations.

Strategy for MPD Event Reconstruction:

Reconstruct Primary Tracks

PASS 1	Tracks reaching the TPC outer boundaries
PASS 2	Tracks confined to the inner TPC region
PASS 3	Residual tracks

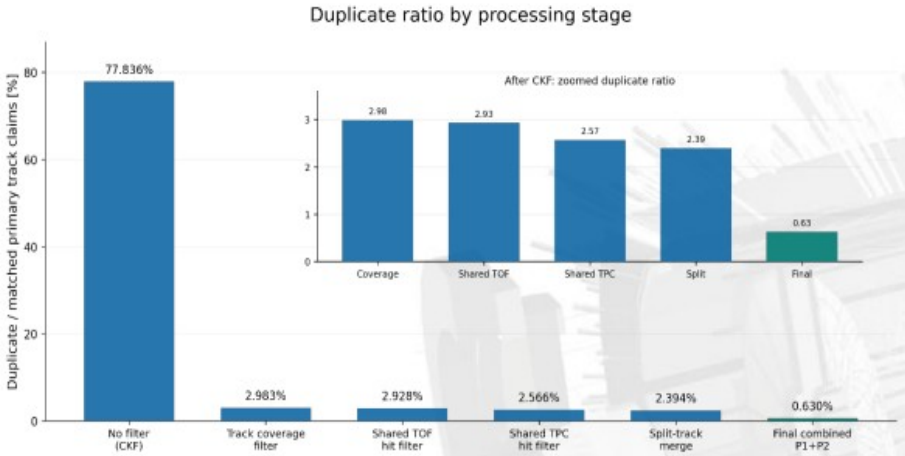
Secondaries

Decays, delta-electrons, material interactions, ...

Each successful pass removes associated hits from the global pool, simplifying the search space for the next pass.

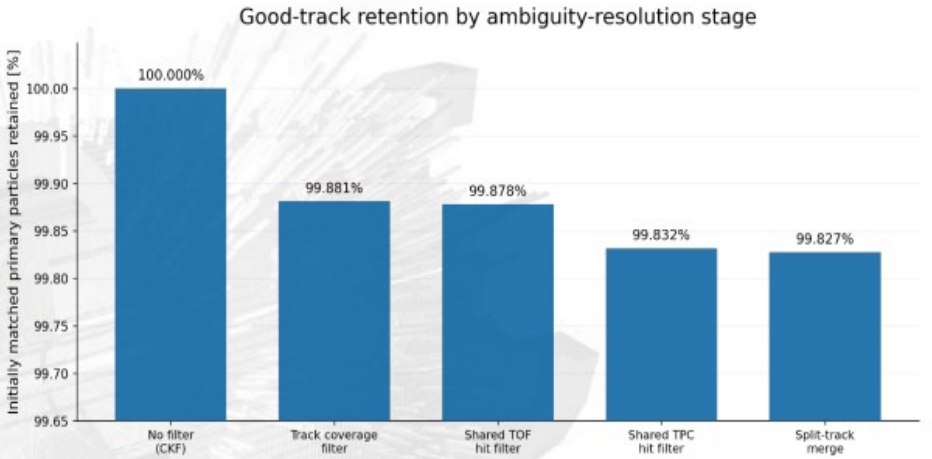
Ambiguity resolution

AMBIGUITY RESOLUTION



The first five snapshots are before final combined-track cleanup. The last bar is the final P1+P2 primary-track QA.

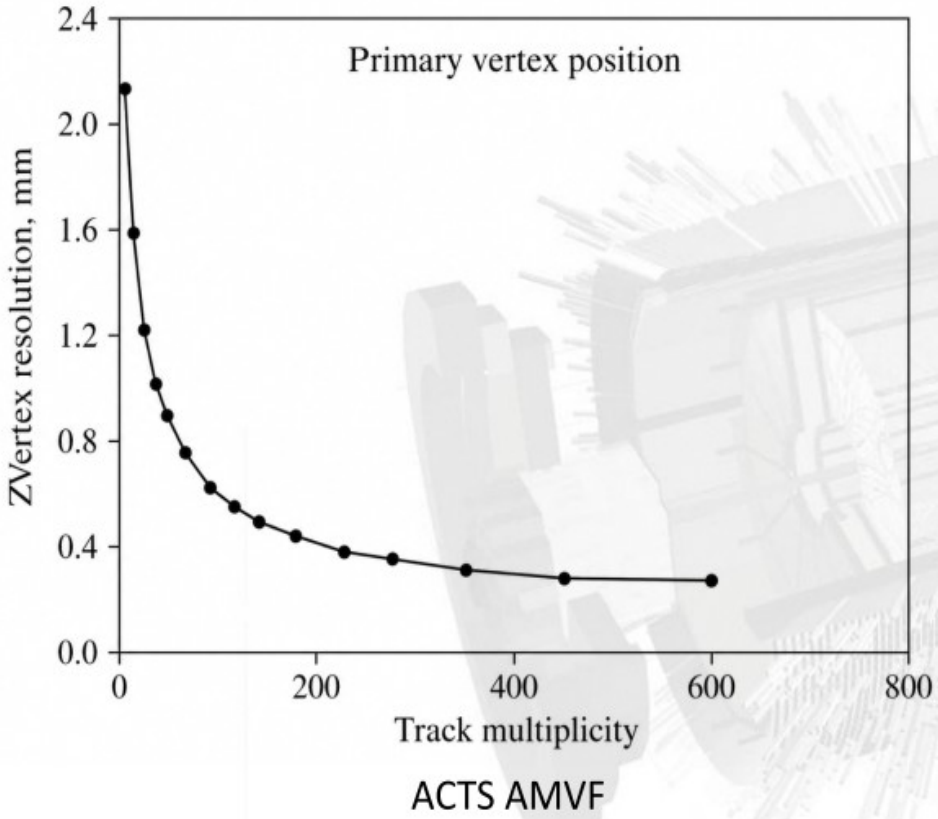
Final duplicate share including fakes in the denominator: 0.629%.



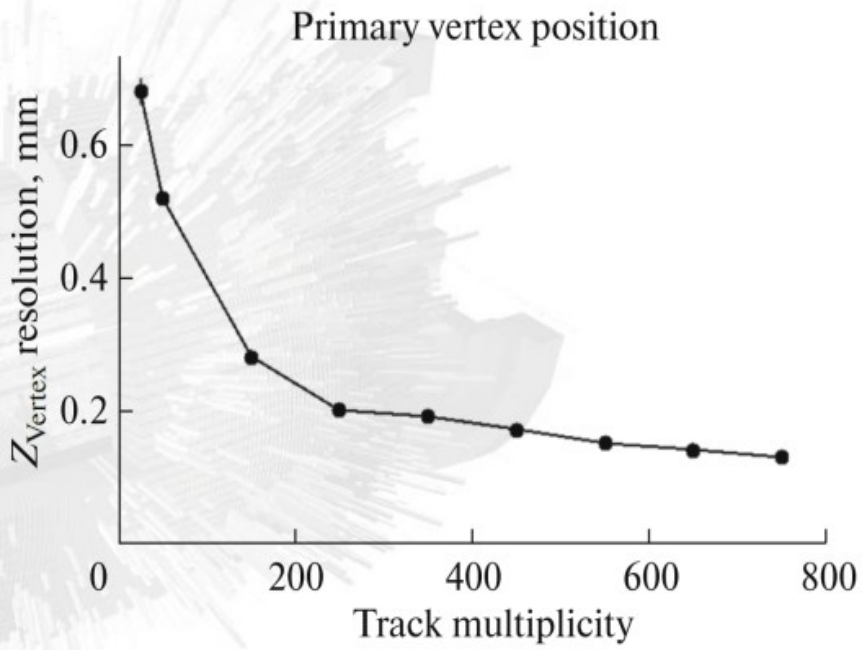
Final combined retention requires the additional cross-pass QA stages; the archived AWK files omitted these rows.

- For real experimental data, track-candidate ambiguities must be resolved at multiple stages of the reconstruction chain.
- Potentially one of the most computationally demanding and algorithmically challenging tasks in MPD track reconstruction.
- ACTS available AR algorithms do not provide satisfactory performance for MPD TPC reconstruction.
- Dedicated 4-stage AR algorithm: track-coverage filtering, shared TOF-hit filtering, shared TPC-hit filtering, split-track merging.

Vertex resolution



ACTS AMVF



Towards a Realistic Monte Carlo Simulation of the MPD Detector at NICA
(Kolesnikov V., Mudrokh A., Vasendina V., Zinchenko A. - 2018)

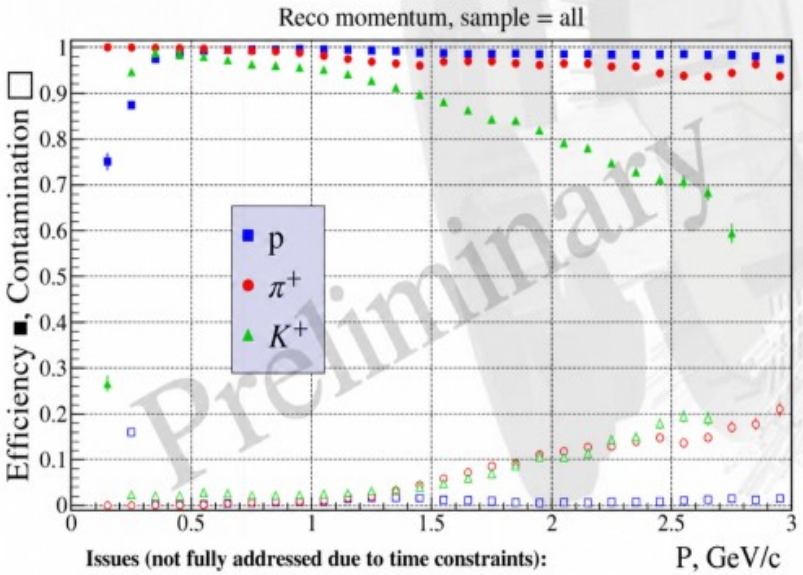
- Primary-vertex resolution was **not a primary optimization target** in the ACTS-based chain.
- Unlike the legacy tracker, the ACTS-based TPC reconstruction **does not use the PV during seeding**.
- Resolution is currently worse, AMVF tuning remains possible.

PID ML efficiency

PIdML Interface in MpdRoot

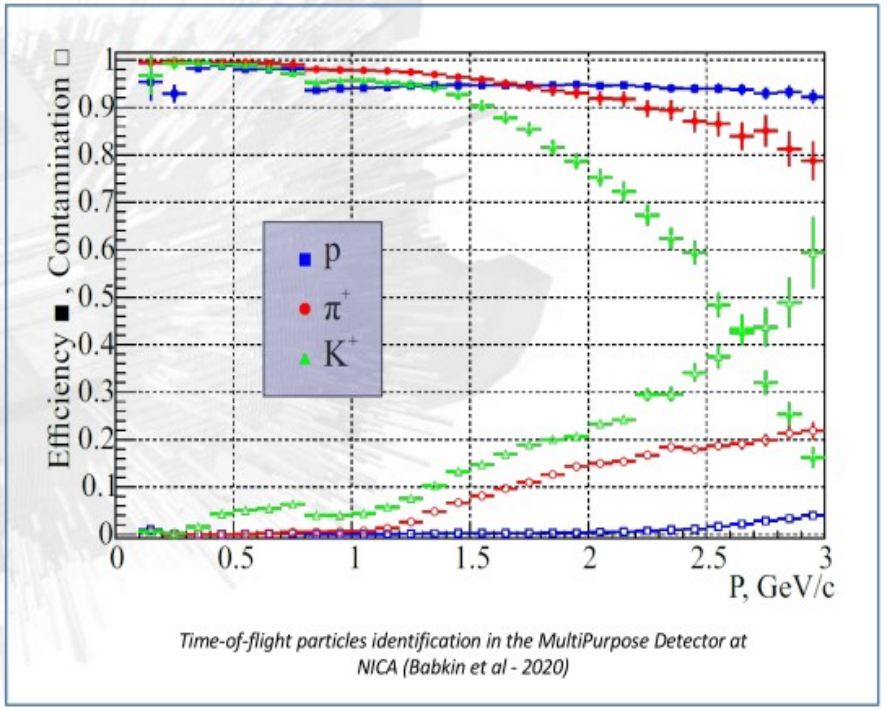
PIdML separates model training from inference in MpdRoot through a unified ONNX interface, supporting classifiers trained with different algorithms.

- Provides a unified API for ML-based particle identification.
- Returns both the most probable particle type and the full class-probability vector.
- Allows models to be replaced or updated without changing MpdRoot analysis code.



Issues (not fully addressed due to time constraints):

- The PIDML model was trained on a different dataset.
- The low-momentum region requires further investigation.
- Points with bin count < 500 were removed.



Time-of-flight particles identification in the MultiPurpose Detector at NICA (Babkin et al - 2020)

MPDRoot deployment & installation

Jan Busa

MPDroot deployment

Running MPDRoot locally using CVMFS

Questions? Click here

INSTALL CVMFS AND TOOLBOX
(Users and Developers)

Supported OS: Fedora, CentOS, AlmaLinux, Ubuntu 22.04, 20.04, Debian 11, 12, Manjaro 21

NOTE: If your OS is based on any of those, then pass it to nica-init script, for example

./nica-init.sh -d Ubuntu -v 20.04

```
[user@fedora ~]$ wget -N https://git.jinr.ru/nica/nicadist/-/raw/master/scripts/nica-init.sh --no-check-certificate
--2021-12-02 00:00:00--  https://git.jinr.ru/nica/nicadist/-/raw/master/scripts/nica-init.sh
.....
.....
2021-12-02 00:00:02 (87.9 MB/s) - 'nica-init.sh' saved [10794/10794]

[user@fedora ~]$ chmod +x nica-init.sh && ./nica-init.sh
Installing toolbox on Fedora 39
[sudo] password for user:
.....
.....
Creating container a9-nica-dev ...
.....
.....
Installing cvmfs service as container ...
.....
.....
==========================================

INSTALLATION SUCCESSFUL

How to use:

1. Enter toolbox container by:
   toolbox enter a9-nica-dev

2. Load MPDRoot environment as a user by:
   [user@toolbox ]$ module add mpdroot

   or MPDRoot environment as a developer by:
   [user@toolbox ]$ module add mpddev

==========================================
[user@fedora ~]$
```

USERS

NOTE: If you are using CentOS 7 instead of "toolbox enter a9-nica-dev" command, type:

"source /cvmfs/nica.jinr.ru/sw/os/login.sh"

MpdRoot: Used Packages

```
# List of packages with versions as are currently stored in the repository
abseil-cpp.sh             abseil-cpp             v20230802.1
acts.sh                   ACTS                   v33.0.0
alibuild-recipe-tools     alibuild-recipe-tools  v8.3.1 (wrapper for nicadist-recipe-tools)
alien-cas.sh              AliEn-CAs              f02625ede788d455b3b7878864bcfee6bd9a4f33
alien-runtime.sh          AliEn-Runtime          DEPENDENCY_CHECK
apmon-cpp.sh              ApMon-CPP              v2.2.8-alice5
autotools.sh              autotools              v1.7.0
boost.sh                  Boost                  v1.83.0
bzip2.sh                  bzip2                  v1.0.8
catch2.sh                 Catch2                 v3.5.1
cgal.sh                   CGAL                   v5.6
clang-format.sh           clang-format           v17.0.6
cmake.sh                  CMake                  v3.27.6
cuba.sh                   Cuba                   v4.2.2
cuda.sh                   CUDA                   v11.8
curl.sh                   curl                   v8.3.0
dd4hep.sh                 DD4hep                 v01-27-02
dds.sh                    DDS                    v3.7.23
defaults-nica.sh          defaults-nica          DEPENDENCY_CHECK (+ setting versions)
defaults-release.sh       defaults-release       DEPENDENCY_CHECK
edm4hep.sh                EDM4hep                v00-10-03
eigen3.sh                 Eigen3                 v3.4.0
einhard.sh                Einhard                v0.4
emacs.sh                  EMACS                  v29.1
emulzie.sh                emulzie                v1.0.0
environmentmodules.sh     EnvironmentModules     v5.3.1
faircmakemodules.sh       FairCMakeModules       v1.0.0
fairlogger.sh             FairLogger             v1.11.1
fairmq.sh                 FairMQ                 v1.8.0
fairroot.sh               FairRoot               v18.6.9-nica
fastjet.sh                FastJet                v3.4.2
fftw.sh                   FFTW                   v3.3.10
flatbuffers.sh            FlatBuffers            v23.5.26
fmt.sh                    fmt                    v10.1.1
freetype.sh               FreeType               VER-2-13-2
gcc-toolchain.sh          GCC-Toolchain          v13.2.0
geant3.sh                 GEANT3                 v4-2
geant4_vmc.sh             GEANT4_VMC             v6-3-p2
geant4.sh                 GEANT4                 v11.1.2
generators.sh             generators             DEPENDENCY_CHECK
git.sh                    git                    v2.43.0
gsl.sh                    GSL                    v2.7
hepmc.sh                  HepMC                  HEPMC_02_06_11
hepmc3.sh                 HepMC3                 3.2.7
heppdt.sh                 HepPDT                 v3.04.01
lcio.sh                   LCIO                   v02-20-02
lhapdf.sh                 LHAPDF                 v6.5.2
libff1.sh                 libff1                 v3.4.4
libicu.sh                 libICU                 release-73-2
libpng.sh                 libpng                 v1.6.40
libtirpc.sh               libtirpc               v1.3.3
libxml2.sh                libxml2                v2.11.5
lz4.sh                    lz4                    v1.9.4
lzma.sh                   lzma                   v5.4.4
make.sh                   make                   DEPENDENCY_CHECK
mfddev.sh                 mfddev                 dev
mpddev.sh                 mpddev                 dev
mpdroot.sh                mpdroot                dev (version see defaults-nica)
mxpfit.sh                 mxpfit                 vCPC
ndh.sh                    ndh                    v0.0.8
nica_packages.sh          nica_packages          DEPENDENCY_CHECK (v2023.9)
nica_scheduler.sh         NICA_scheduler         v22.08.0
nicadist-recipe-tools.sh  nicadist-recipe-tools  v8.3 (forces rebuild of all packages)
ninja.sh                  ninja                  v1.11.1.g95dee.kitware.jobserver-1
nlohmann_json.sh          nlohmann_json          5fec8034933ef434a98dfbd2551b852c56343869 (v3.11.3-pre)
opengl.sh                 opengl                 DEPENDENCY_CHECK
openssh.sh                OpenSSH                V_9_5_P1
openssl.sh                OpenSSL                openssl-3.1.3
libicu.sh                 libICU                 release-73-2
libpng.sh                 libpng                 v1.6.40
libtirpc.sh               libtirpc               v1.3.3
libxml2.sh                libxml2                v2.11.5
lz4.sh                    lz4                    v1.9.4
lzma.sh                   lzma                   v5.4.4
make.sh                   make                   DEPENDENCY_CHECK
mfddev.sh                 mfddev                 dev
mpddev.sh                 mpddev                 dev
mpdroot.sh                mpdroot                dev (version see defaults-nica)
mxpfit.sh                 mxpfit                 vCPC
ndh.sh                    ndh                    v0.0.8
nica_packages.sh          nica_packages          DEPENDENCY_CHECK (v2023.9)
nica_scheduler.sh         NICA_scheduler         v22.08.0
nicadist-recipe-tools.sh  nicadist-recipe-tools  v8.3 (forces rebuild of all packages)
ninja.sh                  ninja                  v1.11.1.g95dee.kitware.jobserver-1
nlohmann_json.sh          nlohmann_json          5fec8034933ef434a98dfbd2551b852c56343869 (v3.11.3-pre)
opengl.sh                 opengl                 DEPENDENCY_CHECK
openssh.sh                OpenSSH                V_9_5_P1
openssl.sh                OpenSSL                openssl-3.1.3
pigz.sh                   pigz                   v2.8
podio.sh                  podio                  v00-17-04
postgresql.sh             PostgreSQL             REL_16_0
protobuf.sh               protobuf               v24.3
pycudwt.sh                pycudwt                v1.0.2
pythia.sh                 pythia                 pythia8309
pythia6.sh                pythia6                428-alice2
python-modules-list.sh    Python-modules-list    v2023.12
python-modules.sh         Python-modules         v2023.09
python.sh                 Python                 v3.11.7
rivet.sh                  RIVET                  v3.1.8
root.sh                   ROOT                   v6-28-10 (version also set in defaults-nica)
rsync.sh                  rsync                  DEPENDENCY_CHECK
simulation.sh             simulation             DEPENDENCY_CHECK
smash-pack.sh             SMASH-pack             v2.2.1
sqlite.sh                 sqlite                 version-3.43.1
tbb.sh                    TBB                    v2021.10.0
termcap.sh                termcap                DEPENDENCY_CHECK
uuid.sh                   UUID                   v2.39.2
vgm.sh                    VGM                    v5-2
vhlle.sh                  vHLLE                  99ef7b44fb8a4b3423045b82cae3bf55a1f8b8fb (v2021.09.21)
virtest.sh                VirTest                95a85e23317e843843bdf324a93a37e13c34efe7 (v2020.09.17)
vmc.sh                    VMC                    v2-0
xdevel.sh                 Xdevel                 DEPENDENCY_CHECK
xerces-c.sh               xerces-c               v3.2.4
xrootd.sh                 XRootD                 v5.6.2
xxhash.sh                 xxHash                 v0.8.2
yacc-like.sh              yacc-like              DEPENDENCY_CHECK
yaml-cpp.sh               yaml-cpp               0.8.0
yoda.sh                   YODA                   yoda-1.9.8
zeromq.sh                 ZeroMQ                 v4.3.4
zlib.sh                   zlib                   v1.3
zstd.sh                   zstd                   v1.5.5
```

Refactoring

Refactoring is a disciplined technique for restructuring an existing body of code, altering its internal structure without changing its external behavior.

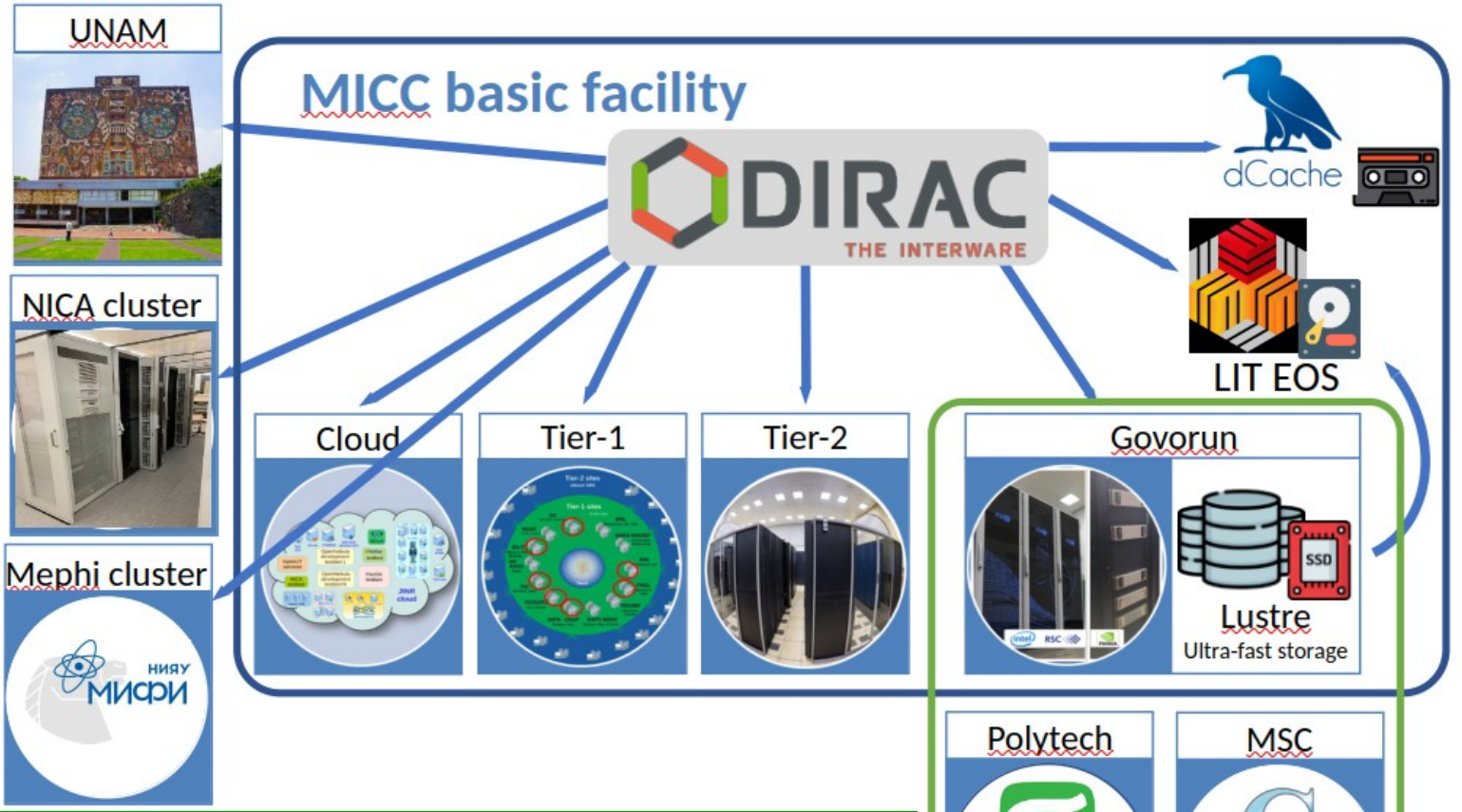
Tasks:

- Libraries Renaming
- Library Merging
- Directory Structure Change
- Examples and Macros
- Classes Renaming
- Virtual Classes
- Guard Rails
- Removing cout, cerr
- ClassImp
- mpdPassive
- CMake + New Library Versioning
- MpdGeneratorType
- Remove Dead Detectors
- Copyright Notice

MPD data mass production

A. Moshkin, I. Pelevanyuk

Computing resourses for MPD



- **NICA offline cluster 1000 cores(limit for users)**
- **GOVORUN up to 3260 cores in last production**
- **Tier1 1400 cores**
- **Tier2 1000 cores**
- **Clouds (JINR and JINR Member States) 70 cores**
- **UNAM (Mexico University) 100 cores**
- **National Research Computer Network of Russia (now resources from SPbTU and JSCC) 672 cores**

Mass production storages integrated in Dirac File Catalog have size 9,2 PB.

MPD MC data for physics analyses

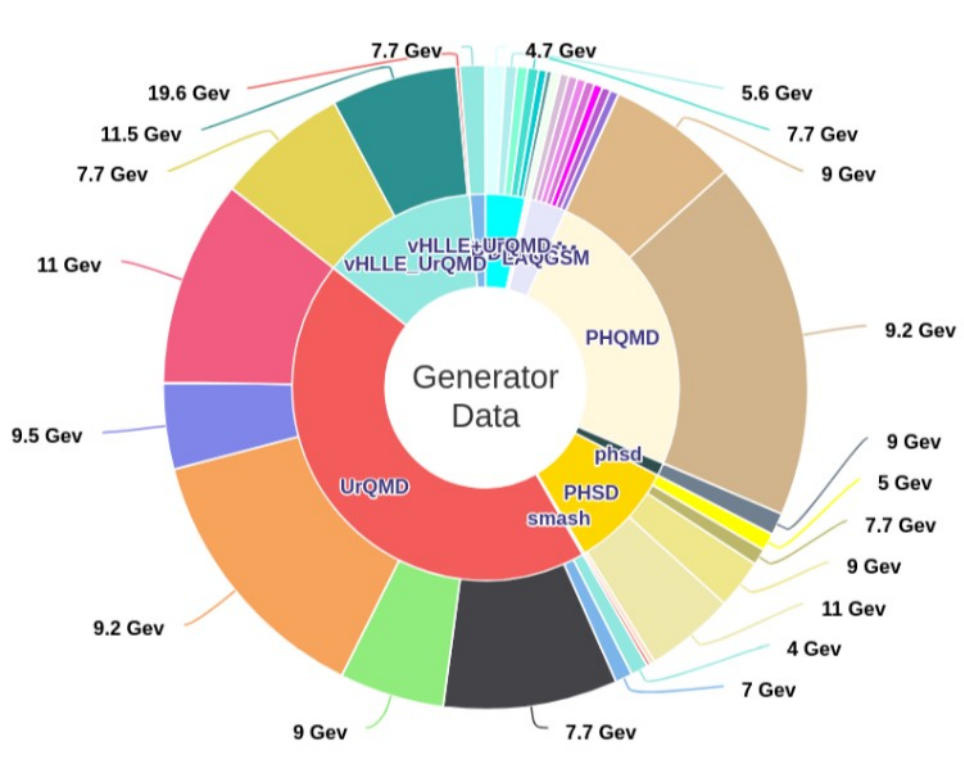
Generator	PWG	Coll.	√s(GeV)	# of events(10^6)	Reco
UrQMD	PWG4	AuAu	11	15	+
		BiBi	9	10	+
			9.46	10	+
			9.2	135	+
	PWG2	AuAu	11	10	+
	PWG3	AuAu	7.7	10	+
		BiBi	7.7	10	+
			9	15	+
		pp	9	10	+
		BiBi FT	2.5	12	+
		BiBi FT	3.0	12	+
		BiBi FT	3.5	12	+
		XeW FT	2.5	15	+
		XeXe FT	2.5	15	+
	PWG1	BiBi	9.2	76	+
DCM-SMM	PWG1	BiBi	9.2	2	+
PHQMD	PWG2	BiBi	8.8	15	+
			9.2	61	+
			2.4/3.0/4.5	10/10/2	-
vHLLE-UrQMD	PWG3	BiBi	11.5	15	+
		AuAu	11.5	15	+
		AuAu	7.7	20	+
		BiBi	9.2	48	+
Smash	PWG1	BiBi	9.46	10	+
		ArAr	4/7/9/11	20/20/20/20	-
		AuAu	4/7/9/11	20/20/20/22	-
		XeXe	4/7/9/11	20/20/20/20	-
		CC	4/7/9/11	20/20/20/20	-
		pp	4/7/9/11	50/50/50/50	-
JAM	PWG3	AuAu	3/3.3/3.5/3.8/4.0/4.2/4.5/5	40/40/40/40/40/40/40/40	
DCM-QGSM-SMM	PWG3	AuAu	4/9.2	5/5	+
		AgAg	4/9.2	5/5	+
		BiBi	4/9.2	5/6	+
PHSD		BiBi	9/9.2	25	+
Total				1453	609

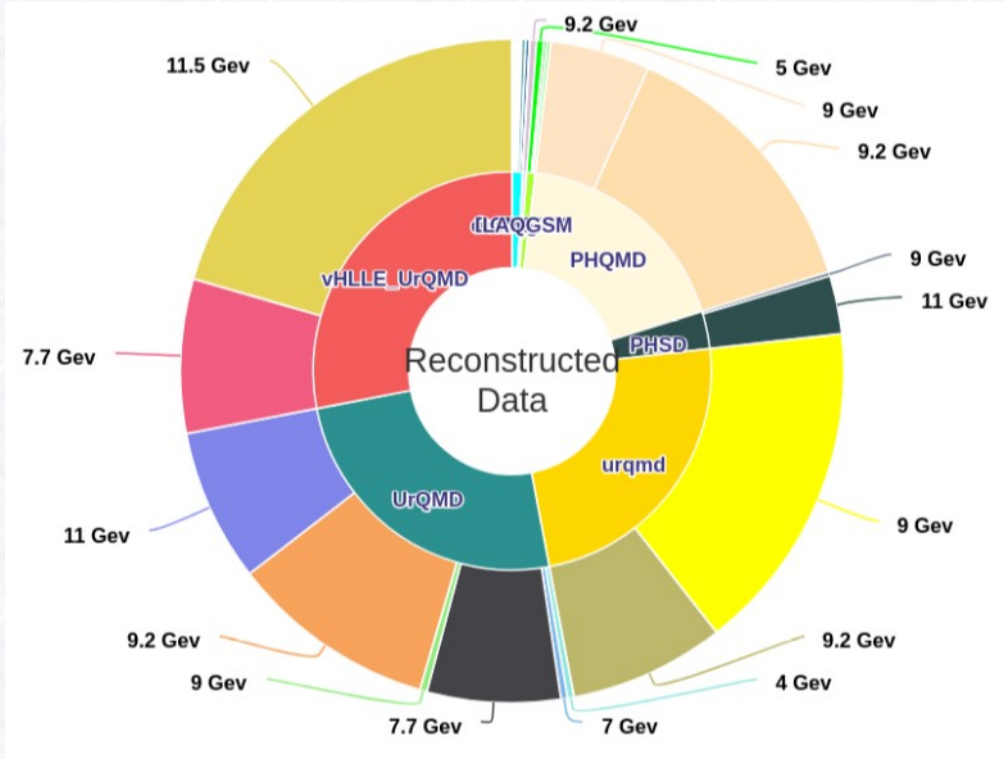
Total size > 2 PB

MPD mass production database

http://db-nica.jinr.ru/mpdmc/stat.php

Dirac File Catalog





+ experiment data

MPD Software development group

Rogachevsky O.	**Coordinator**
Krylov V.	Clustering, Microservices
Krylov A.	MPD Event Display
Bychkov A.	Detector Simulation
Kuzmin V.	Detector Alignment
Moshkin A., Pelevanyuk I.	Distributed Computing
Alexandrov E., Alexandrov I.	Databases
Kozhevnikova M.	Website design
Papoyan V.	PID with ML
Busa J.	Build System
Hnatic S.	Architecture, Tracking

Thanks for your attention

