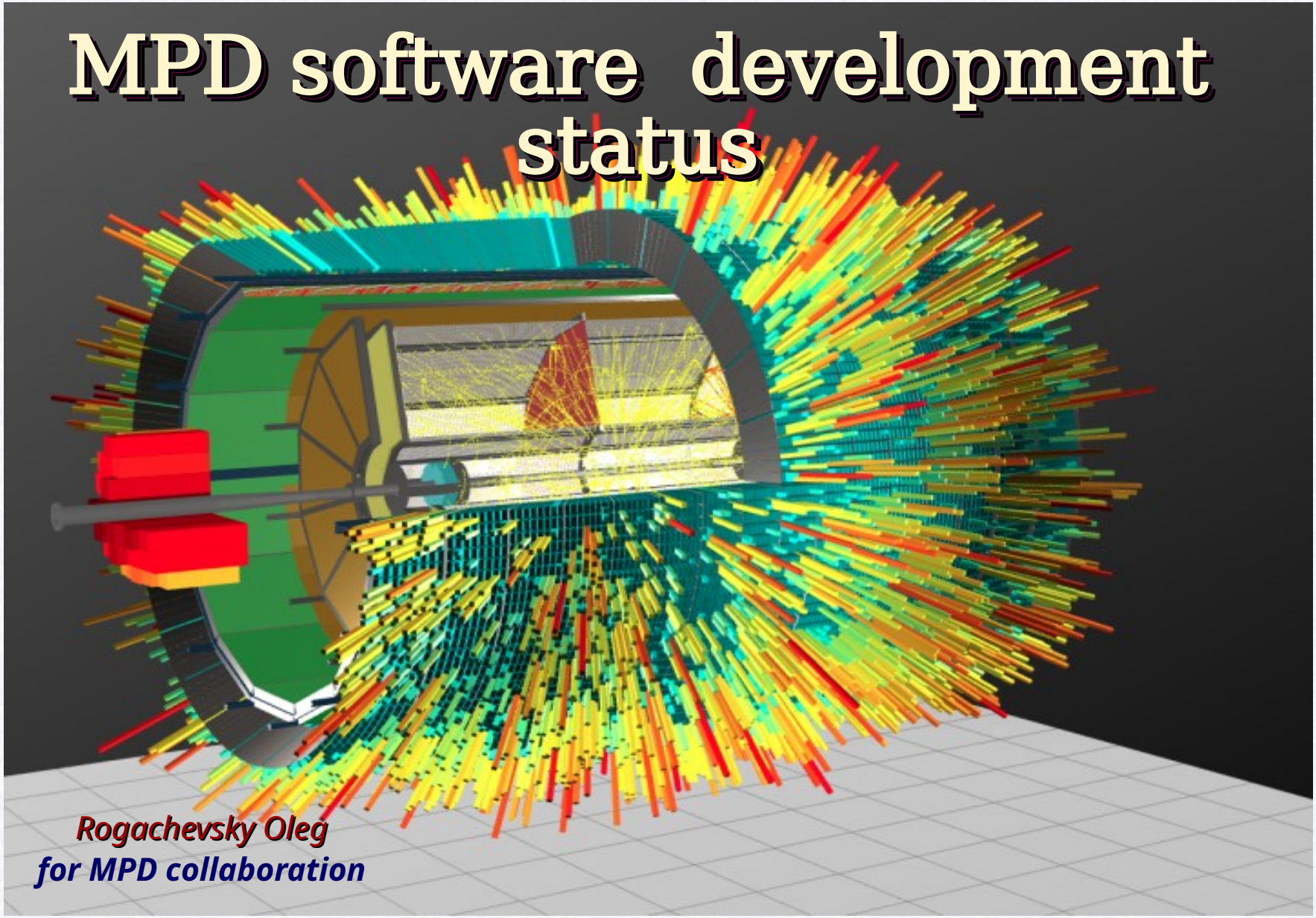
MPD software development status



Rogachevsky Oleg
for MPD collaboration

Git.jinr.ru updates in release v25.09.25

MOST IMPORTANT CHANGES

Milestone
v25.09.25
Issues 4
Open: 0 • Closed: 4

- Source code (zip)
- Source code (tar.gz)
- Source code (tar.bz2)
- Source code (tar)

Evidence collection

v25.09.25-evidences-130.json ade9ac28
Collected 1 month ago

Release notes

RELEASE NOTES v25.09.25

We encourage users to test new release and report any issues to us on https://mpdroot.jinr.ru/q-a/

Installation https://mpdroot.jinr.ru/running-mpdroot-on-local-machine-using-cvmfs/

Your feedback is valuable and makes our software better.

FOR USERS

- ACTS update v43.3.0 #358 nicadist@9c4c1188
- charge correlations update #349
- mpdHadronSpectra v2.0 !641
- mpdHadronSpectra v1.1 !640

FOR DEVELOPERS

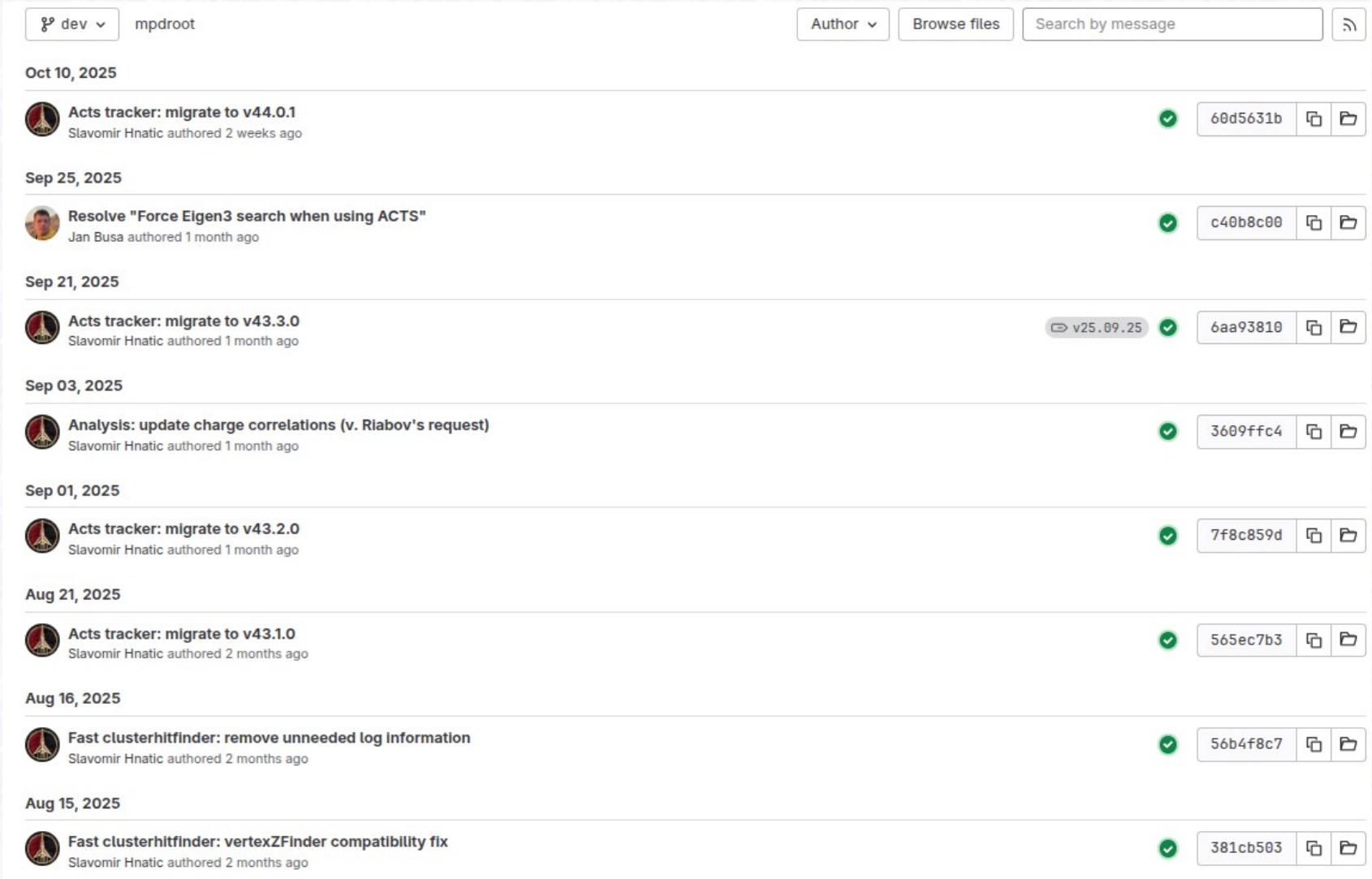
- Fast clustering v2.0.8b #307 !648
- Fast clustering bug fixed #193
- xboost v3.0.5 nicadist@09cb2e2e

Dependency list:v25-09-25_dependencies.txt

DETAILED INFO in RELEASE NOTES

git.jinr.ru/nica/mpdroot/-/releases

Commits in release v25.09.25



GIT: Value Stream Analytics

Lifecycle metrics

New issues	Commits	Deploys
7	1	-

Issues 7 items	Last event	Duration ↓
Replace CINT by CLING in LinkDefs #368 · Created 12 days ago by Jan Busa	12 days ago	0 s
Unnecessary linking of Zdc in Physics macros #364 · Created 25 days ago by Jan Busa	25 days ago	0 s
Using VMCWORKDIR in gconfig directory #366 · Created 25 days ago by Jan Busa	25 days ago	0 s
Using RooUnfold in Physics/GlobalObservables/PTNFluctCorr #365 · Created 25 days ago by Jan Busa	25 days ago	0 s
MpdPidML - add XGBoost to name and allow for multiple identification of particles in a single call #369 · Created about 8 hours ago by Jan Busa	about 8 hours ago	0 s
Align future_main with latest release (v25-09-25) #362 · Created 28 days ago by Jan Busa	28 days ago	0 s
Add compilation tests to all macros in Physics directory #363 · Created 26 days ago by Jan Busa	26 days ago	0 s

GIT status: branches

Active branches

`369-mpdpidml-add-xgboost-to-name-and-allow-for-multiple-identification-of-particles-in-a…` `4a5a3414` · Deprecated GetMaxProb - changed to MostProbablePGD as it better describes what… · 19 hours ago	25 | 32	✓	New
`future_main` `b46b52b9` · Resolve "Replace CINT by CLING in LinkDefs" · 1 week ago	25 | 30		New
`mp_fast_12` `7d3b6d44` · Set MP fast clustering parameters · 2 weeks ago	0 | 1		New
`mlem_vs_fast` `4a1b6991` · Mlem vs Fast clustering exact comparison · 2 weeks ago	0 | 1		New
`dev` default protected `60d5631b` · Acts tracker: migrate to v44.0.1 · 2 weeks ago		✓	

Show more active branches

Stale branches

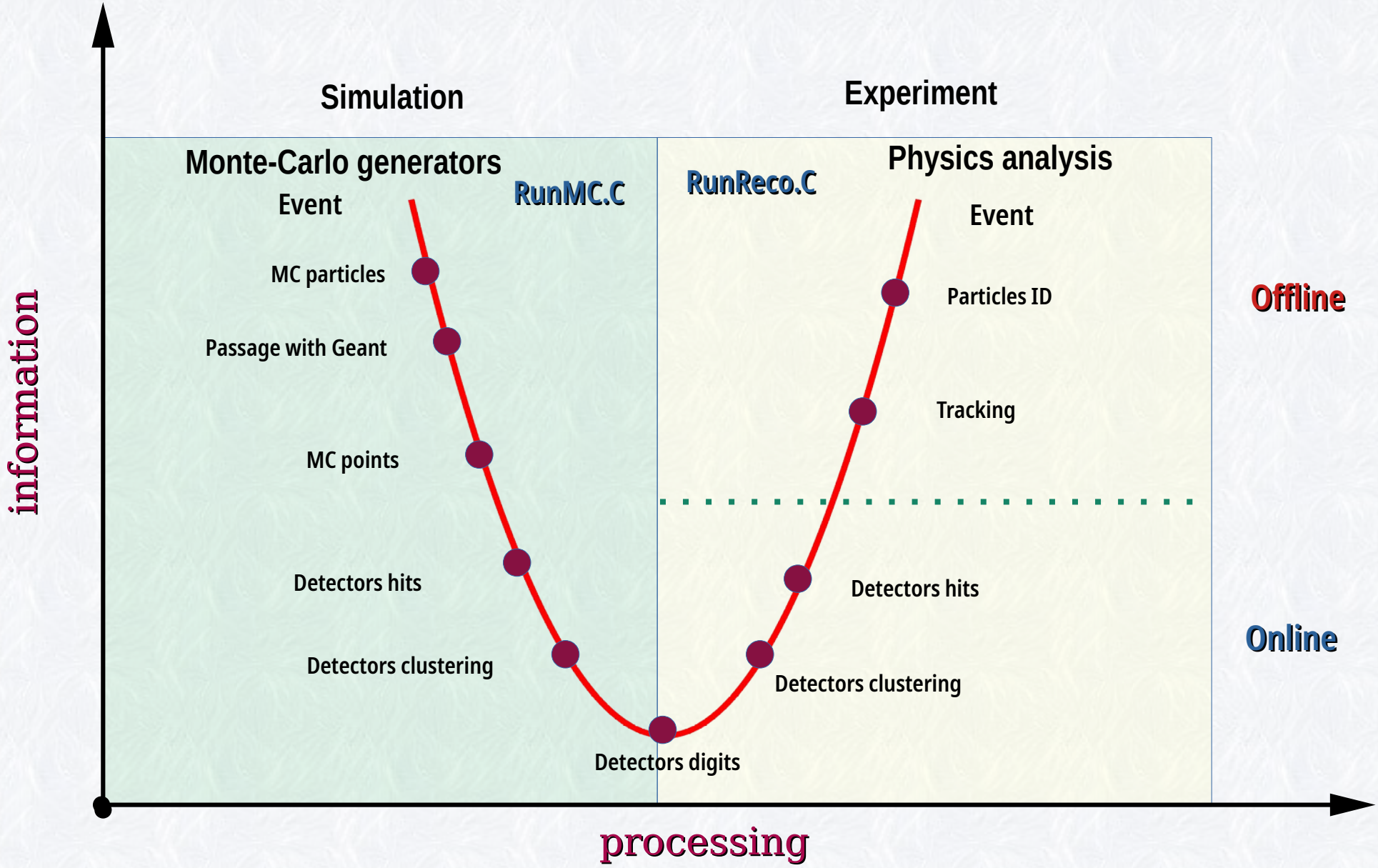
`master` protected `f49cc155` · Added execution parameter for CDash script · Apr 3, 2017	999+ | 0		New
`abychkov` `ccbcb37c` · updated pads count in rows and rows position on padplane for reconstruction · Apr 14, 2020	734 | 1		!130
`abychkov_test` `a128c1a9` · move macros to subfolder · May 14, 2020	728 | 2		New
`MP02_042020_BiBi_09_G4` `78c30450` · The second centralized production, BiBi@9 G4 · Jun 19, 2020	730 | 1		New
`pro` protected `9e471d0b` · Using local random number generator. · Jun 28, 2020	711 | 0	✓	New

Show more stale branches

MpdRoot: Used Packages

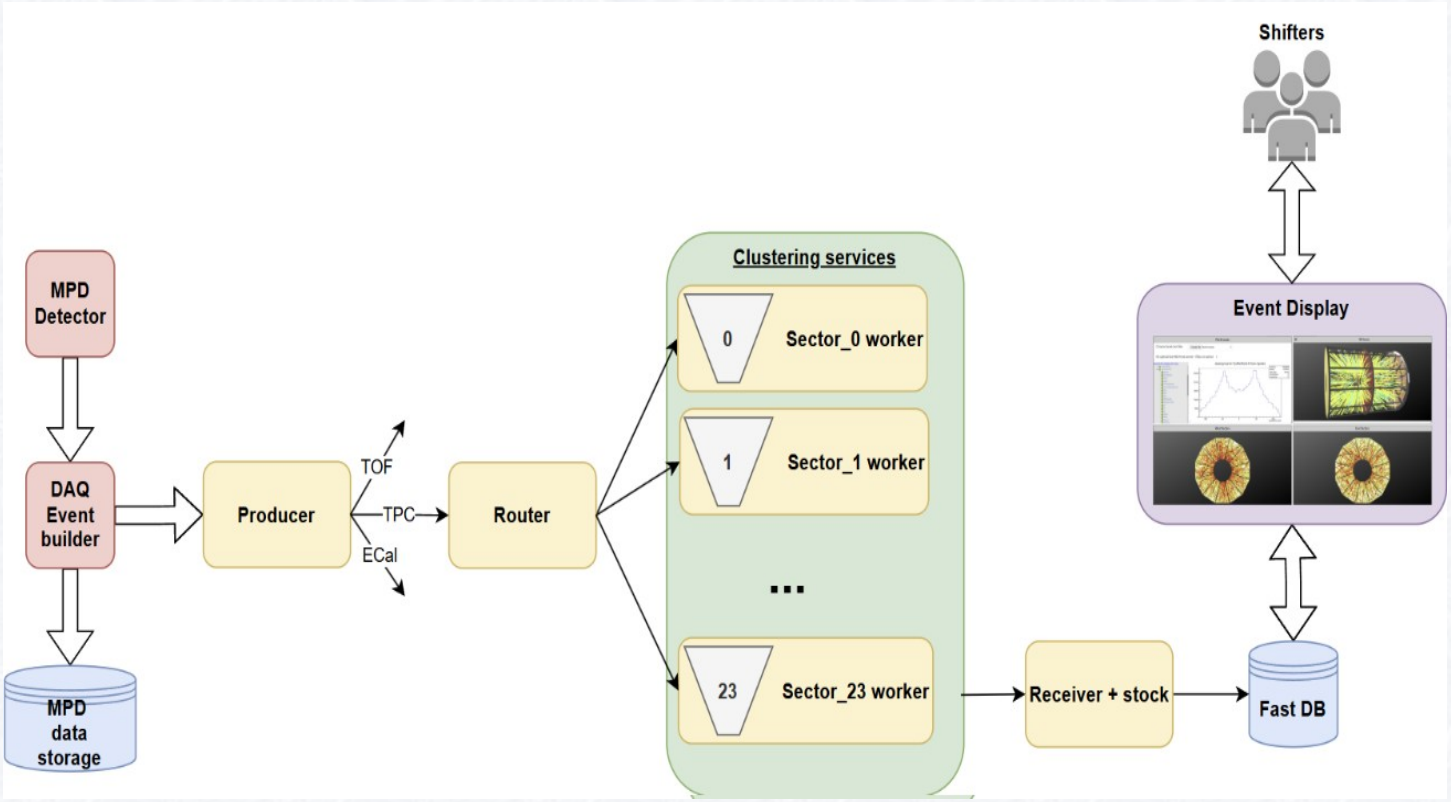
```
# List of packages with versions as are currently stored in the repository
abseil-cpp.sh             abseil-cpp             v20230802.1
acts.sh                   ACTS                   v33.0.0
alibuild-recipe-tools     alibuild-recipe-tools  v8.3.1 (wrapper for nicadist-recipe-tools)
alien-cas.sh              AliEn-CAs              f02625ede788d455b3b7878804bcfee6bd9a4f33
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          5fec8034933ef434a98dfbd2551b852c50343869 (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          5fec8034933ef434a98dfbd2551b852c50343869 (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
```

Simulation @ Experiment chain

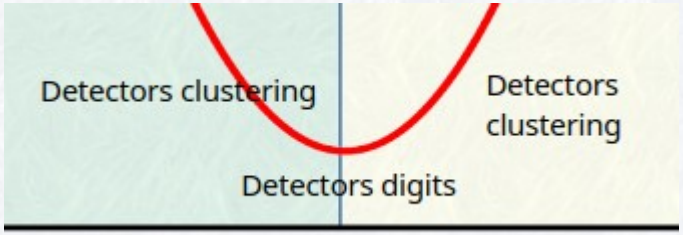


Experiment online soft tasks

Detectors digits
clustering
Hits
Tracking TPC
TOF
Emcal
Triggers FFD
FHcal



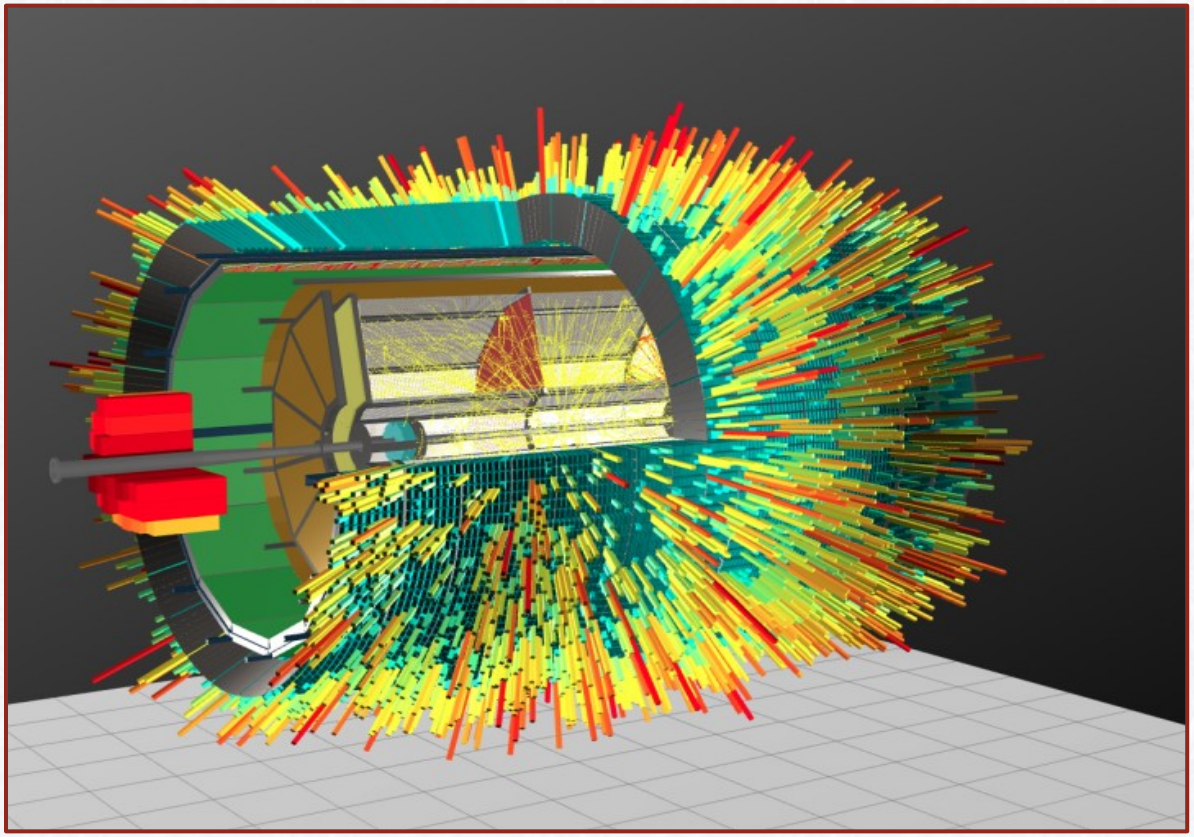
Online software with dockers



Experiment raw data

Krylov V.
Krylov A.

Event display for the MPD experiment

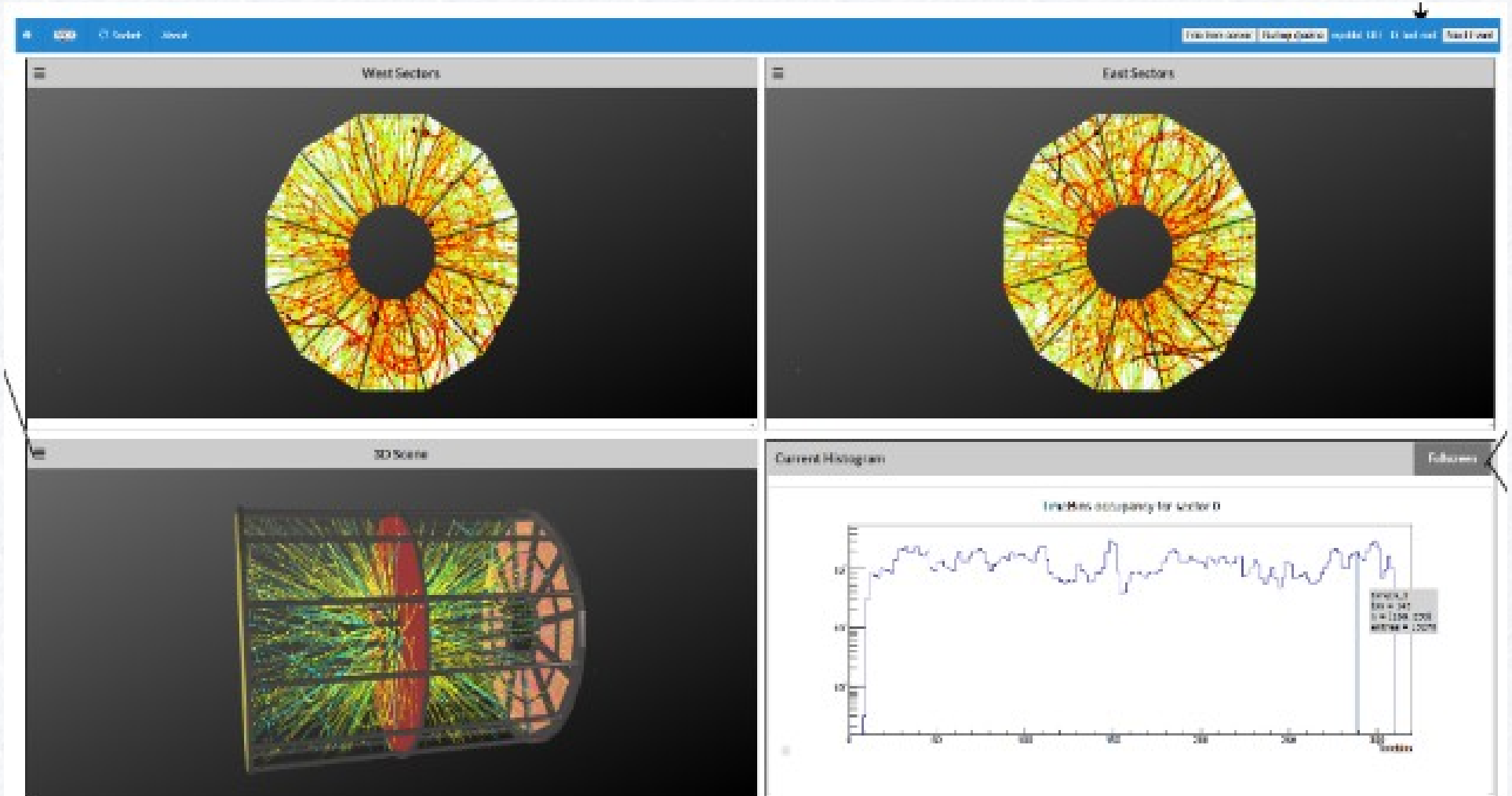


Event viewer for offline physics analyses

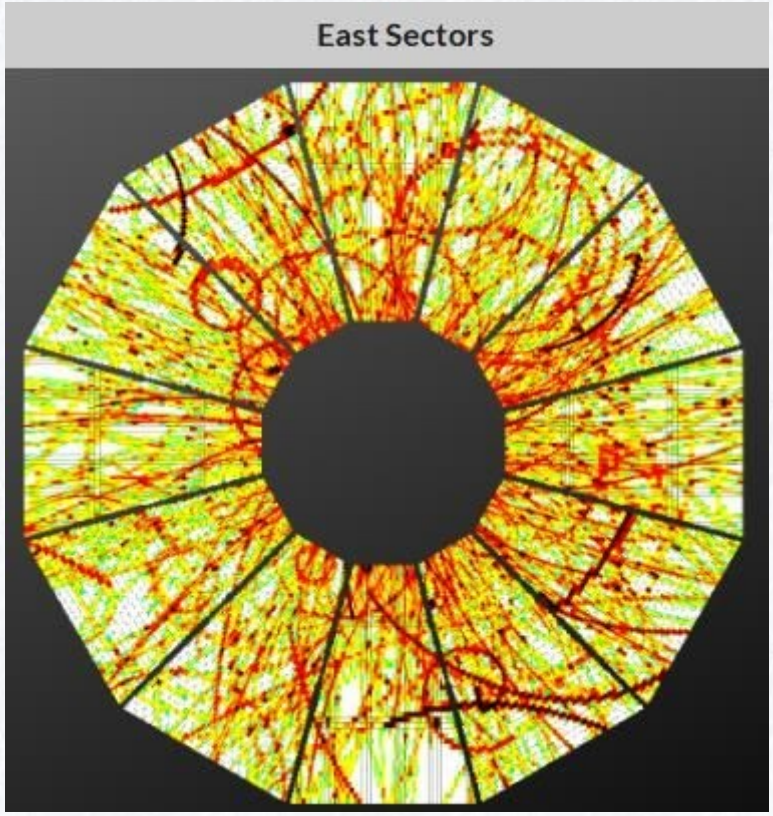
Physics analysis

Particles
PID

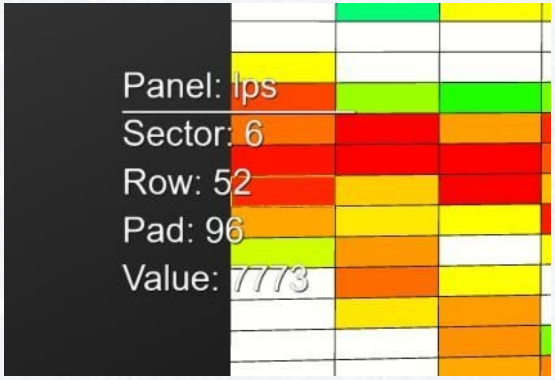
MonteCarlo (Experiment)
dst (aod) data



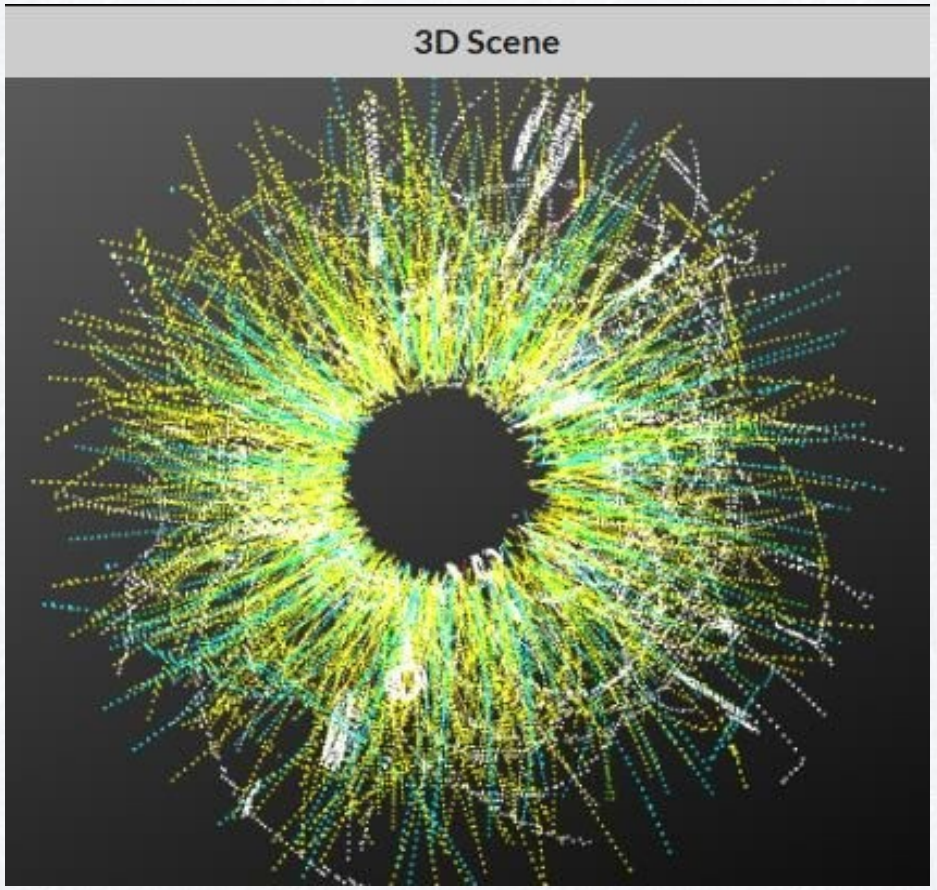
Event viewer TPC info



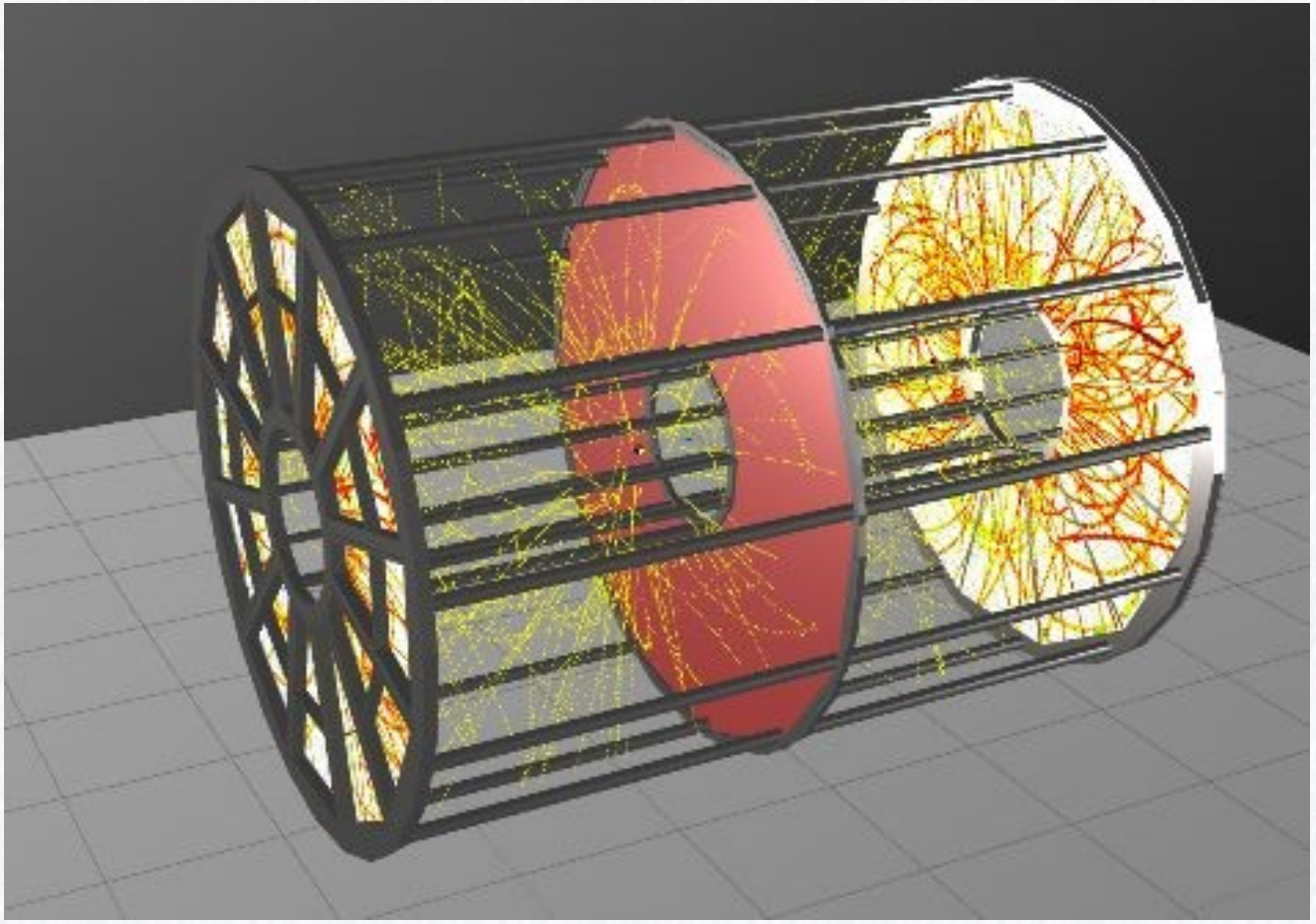
TPC hits + ADC



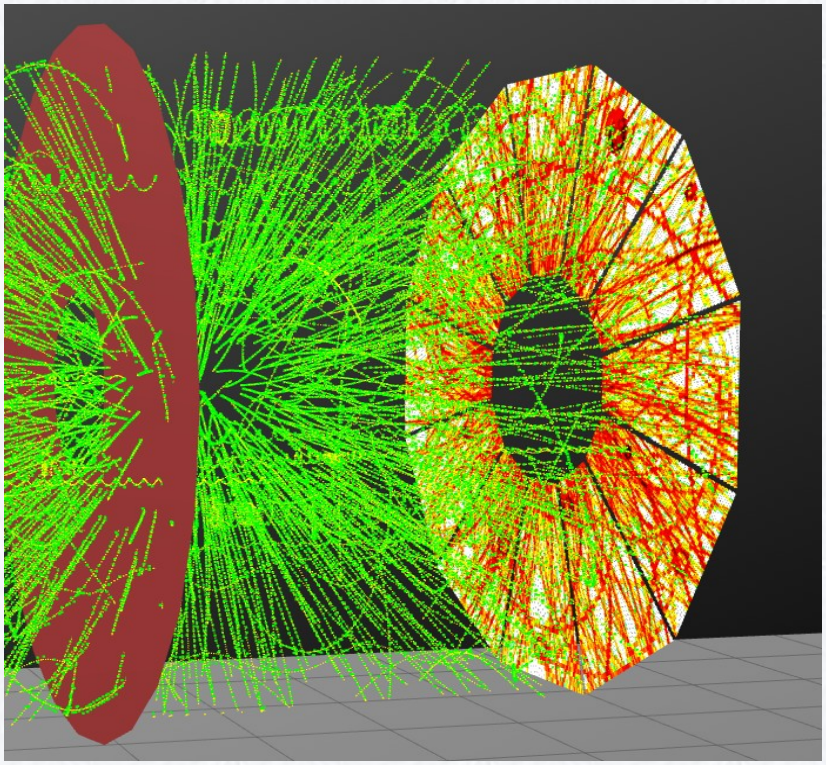
TPC hits + MC tracks PID



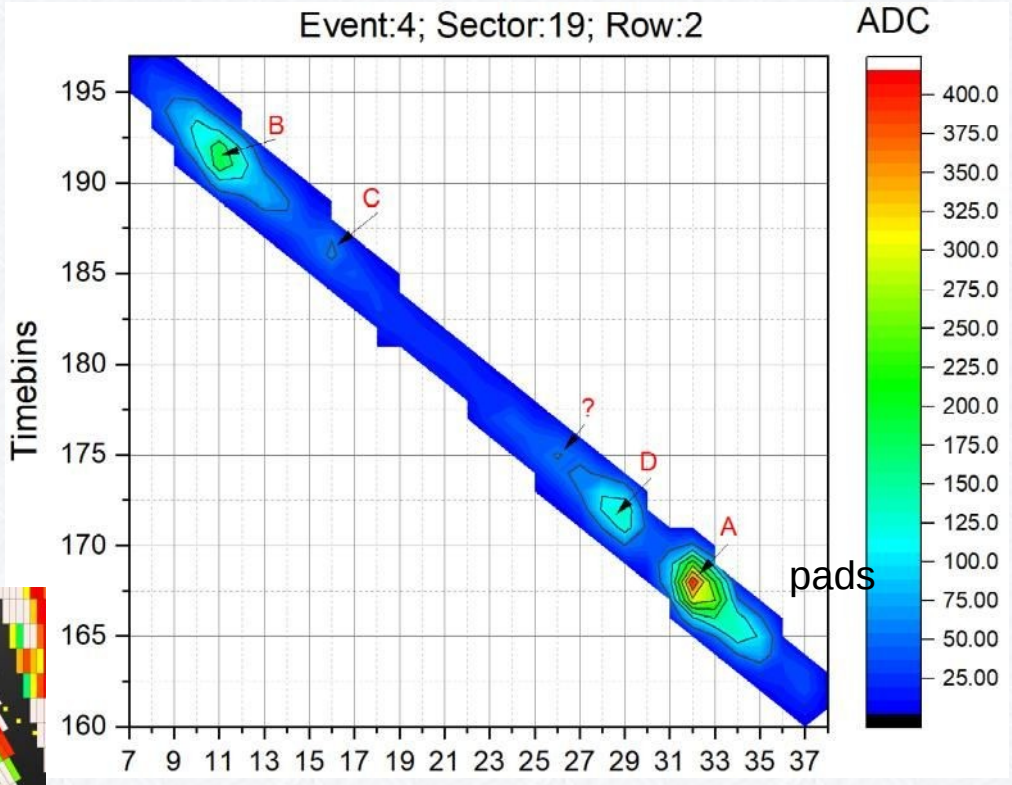
Detectors simulation (TPC)

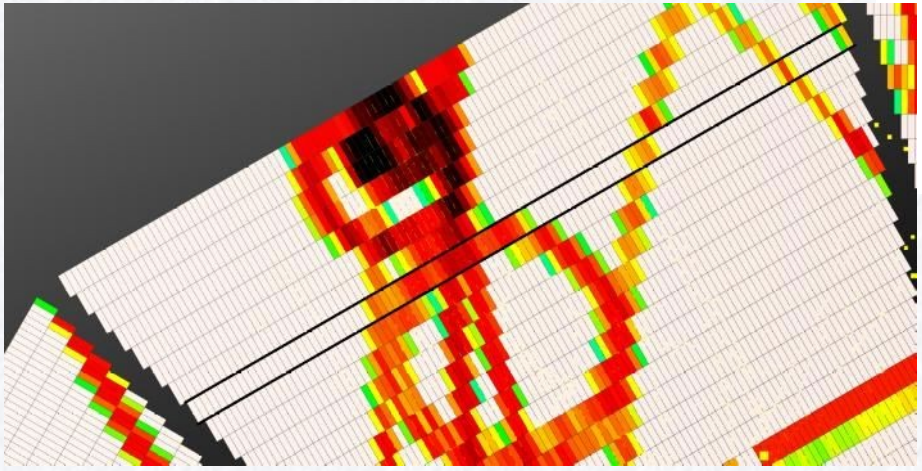


Online TPC clustering



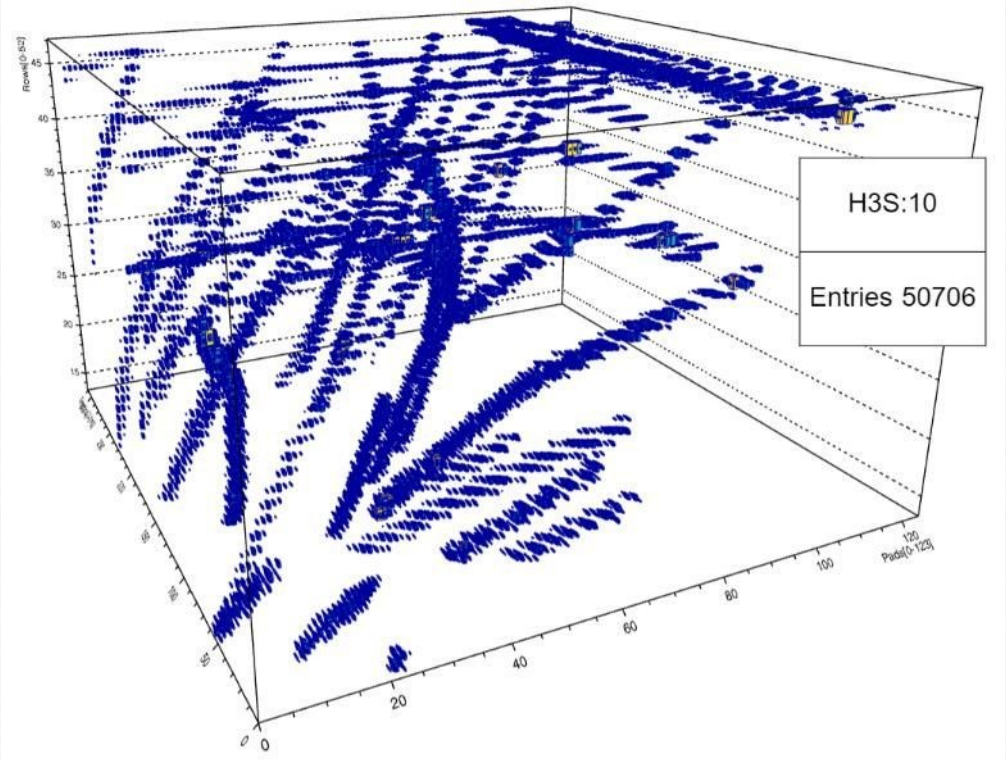
More details in the report of V.Krylov

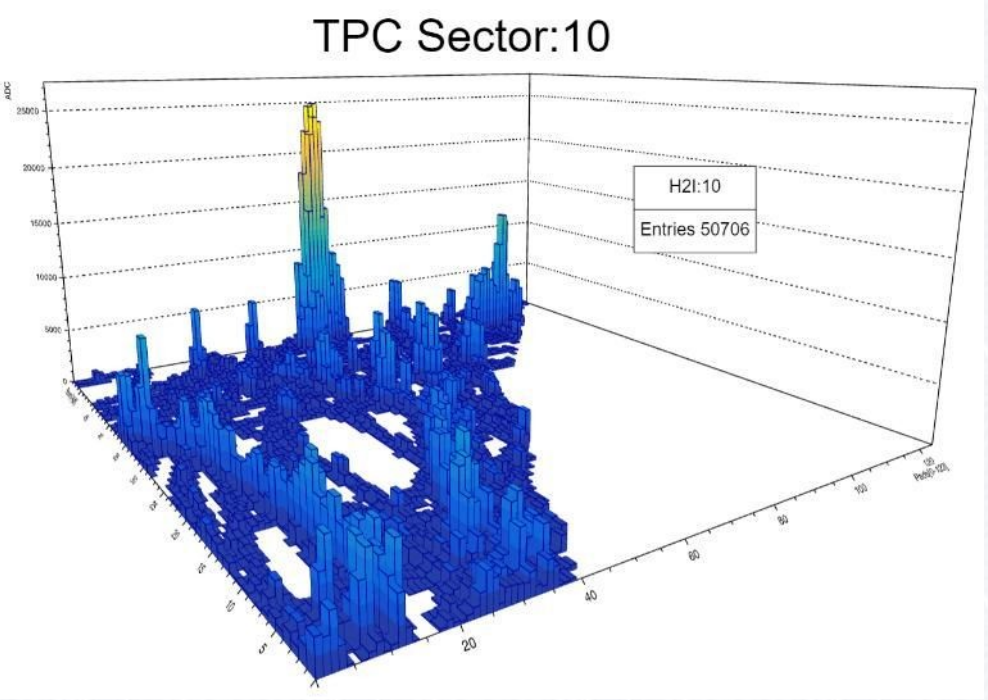




Data structure

Sector digits





Electronics response calibration

Read-out channel parameters

100 ns – time bucket, 310 time buckets

>95000 read-out channels in total

SAMPA impulse shape function

$$f(x)=\left(\frac{x-t}{\tau}\right)^{N} e^{-N\left(\frac{x-t}{\tau}\right)}+Bl$$

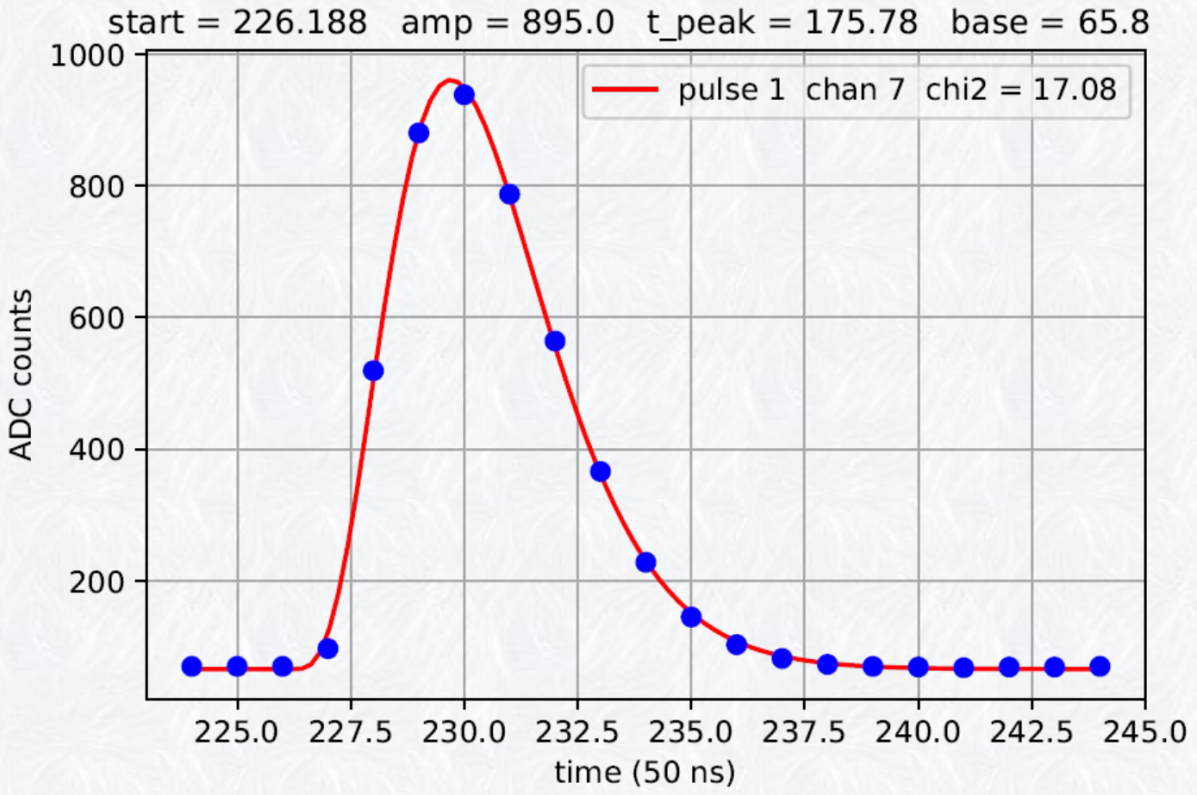
N = 4 — shaping order

τ = 160 — peaking time (ns)

Bl = 0 — baseline

t — start time

Ae^{-N} = 20 (30) — amplitude (fC per mV)



- realistic SAMPA digitizer was developed

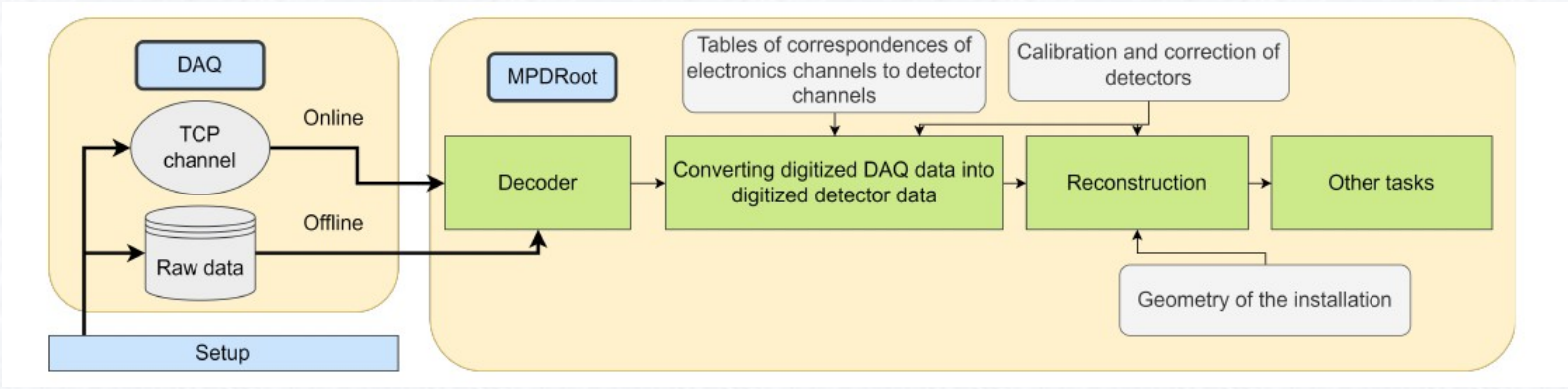
DAQ file structure for online clustering

Tasks:

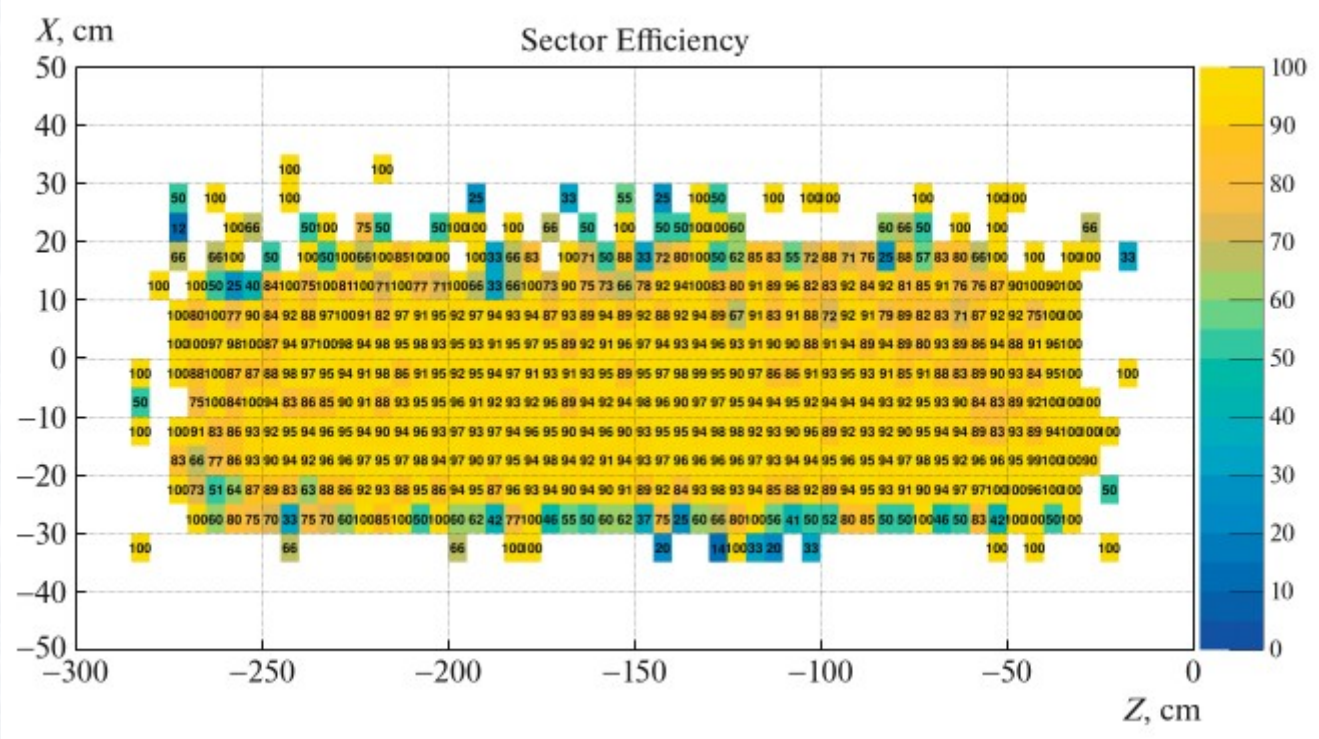
- Make the TPC clustering online and prepare it for 3D visualize by Event Display;
- Read input stream in the real experiment with data in SAMPA format;
- Parallelize TPC event processing;
- Decrease time for TPC clustering for event processing and rendering: <1 sec at the moment:
- Average time for TPC event processing: ~ 100 ms
- Maximum TPC event processing time: ~500 ms (depends on track multiplicity)

TOF software implementation

TOF and Ecal Data flow



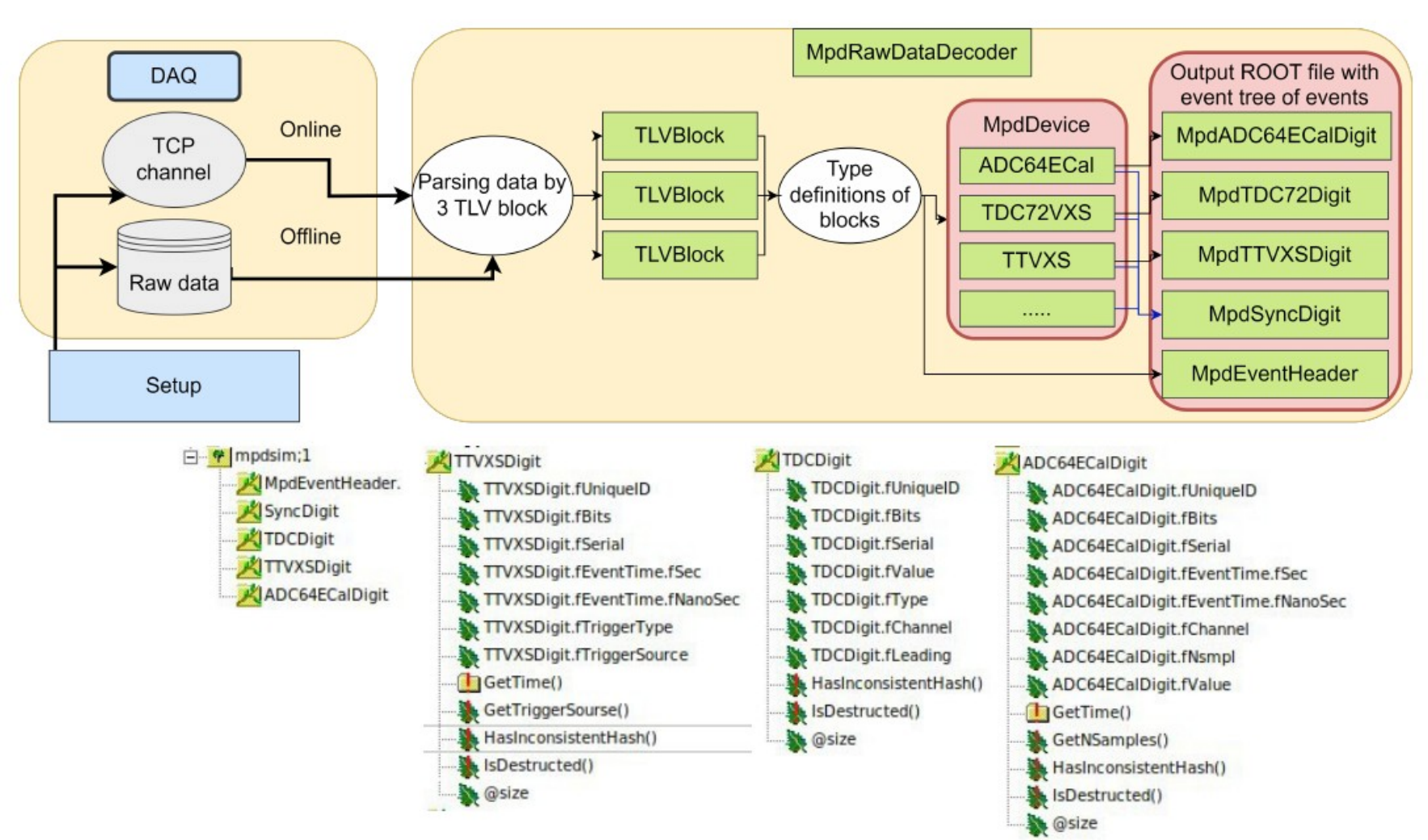
Baryshnikov V.M.
Lobastov S.P.
Babkin V.A
…



The average efficiency of one TOF module.

Physics of Atomic Nuclei, 2023, Vol. 86, No. 5, pp. 788–795

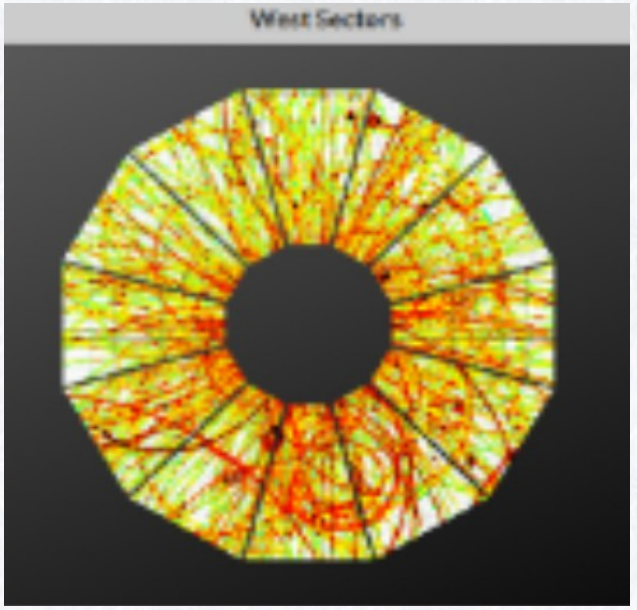
TOF(ECal) data chain



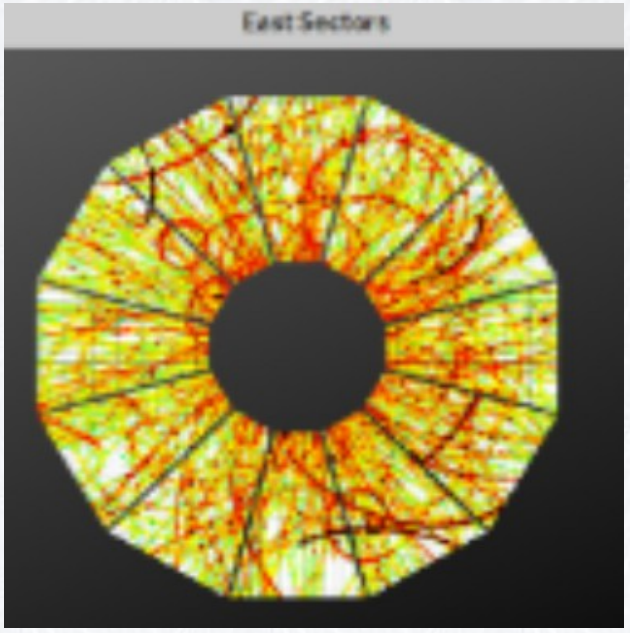
Decoder and electronics structure for TOF and ECal

Tracking, tracking, tracking ...

Kalman filter

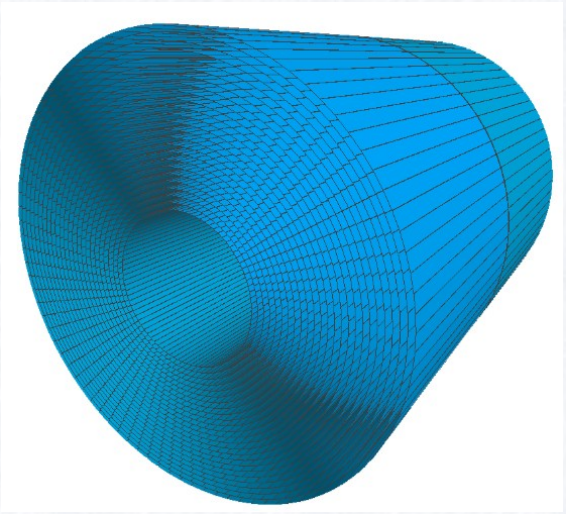


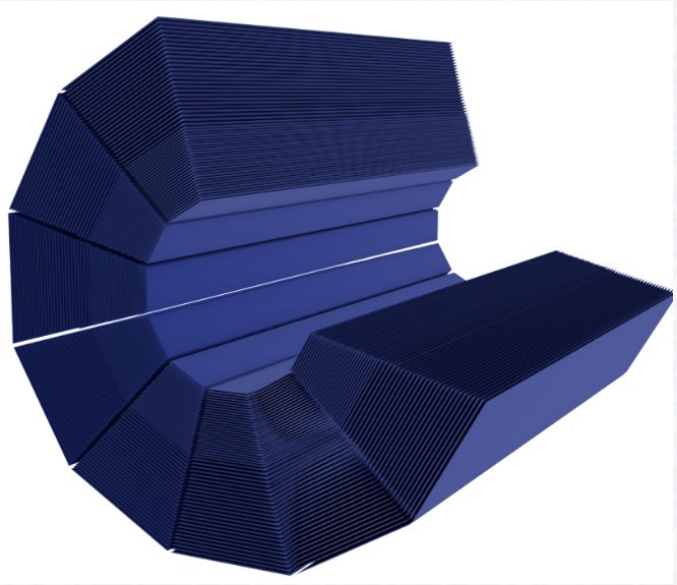
ACTS

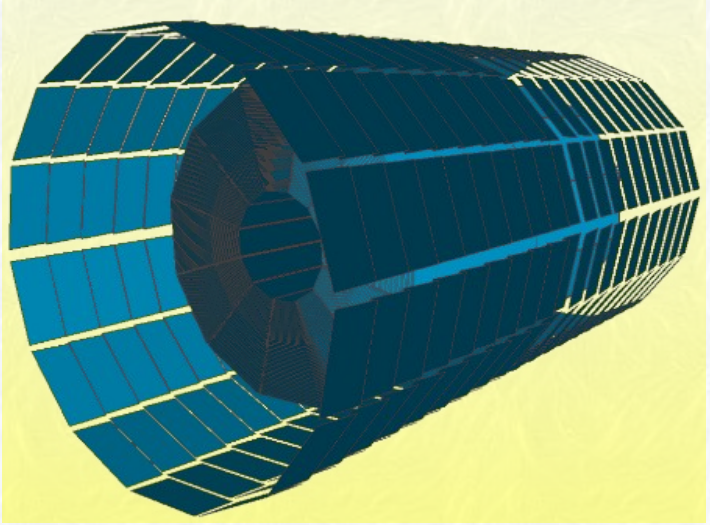


Graph Neural Networks

Adjust TPC geometry for ACTS

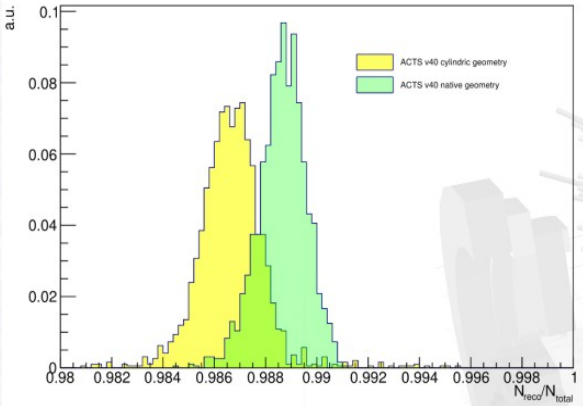


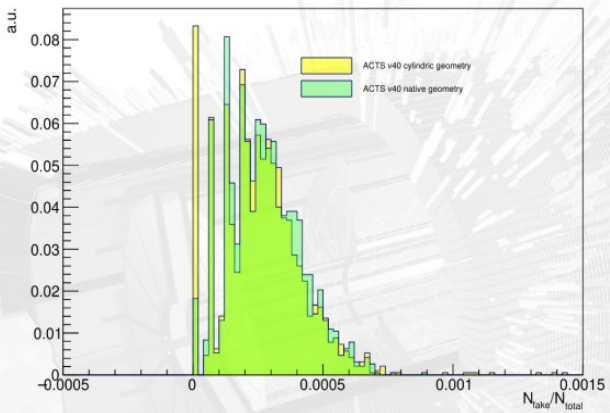


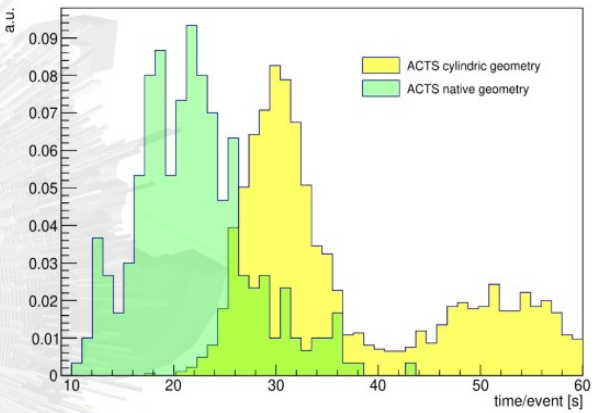


ACTS tracking implementation

Slavomir Hnatic report







	NATIVE	CYLINDRIC
Efficiency	μ = 98.8648 % σ = 0.09221 %	μ = 98.6674 % σ = 0.13296 %
Fakes	μ = 0.02748 % σ = 0.01397 %	μ = 0.02588 % σ = 0.01618 %
Speed	μ = 21.95 s / event σ = 5.6 s / event	μ = 36.73 s / event σ = 10.27 s / event

- UrQMD, 200000 events
- 9 minimum hits per track
- P_t > 0.1 GeV

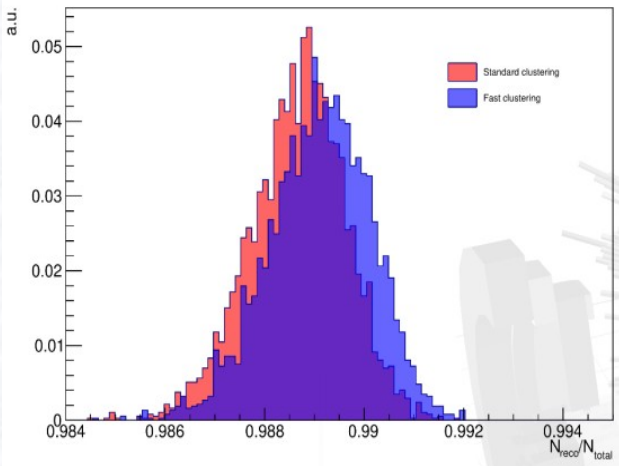
Maximizing efficiency – initial priority

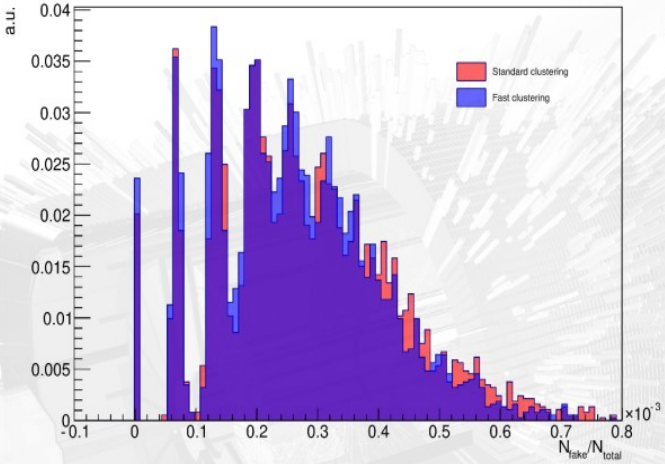
Duplicates to be handled by Ambiguity Solver (not yet implemented), *decreasing* efficiency

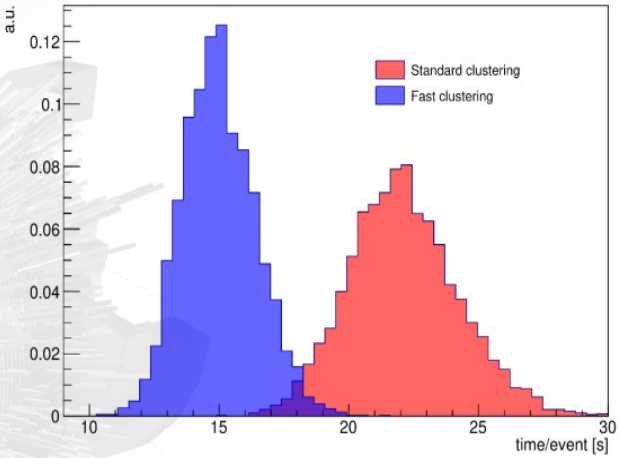
See: A Common Tracking Software Project *Computing and Software for Big Science*, *X.Ai et al, 2022*

Performance of Track Reconstruction at SCTF Using Acts, *EPJ Conferences*, *X.Ai et al, 2024*

ACTS with fast clustering







	FAST	STANDARD
Efficiency	μ = 98.9099 % σ = 0.1022 %	μ = 98.8663 % σ = 0.0968 %
Fakes	μ = 0.02645 % σ = 0.01329 %	μ = 0.02806 % σ = 0.01438 %
Speed	μ = 15 s / event σ = 1.42 s / event	μ = 22.12 s / event σ = 2.11 s / event

BiBi 9.2 GeV
UrQMD
3000 x 100 events
Min hits 9,12

How to run:

toolbox enter a9-nica-dev

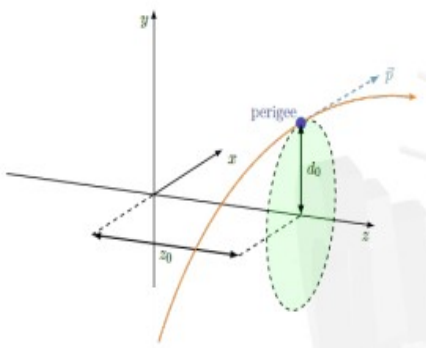
module add mpddev ACTS

build mpdroot's dev branch

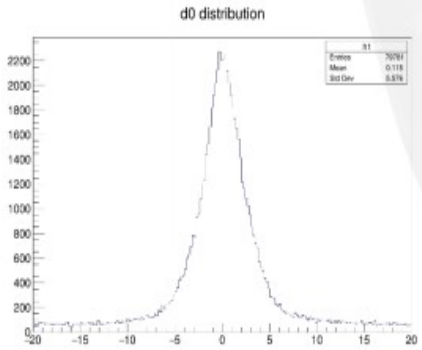
execute runReco.C with

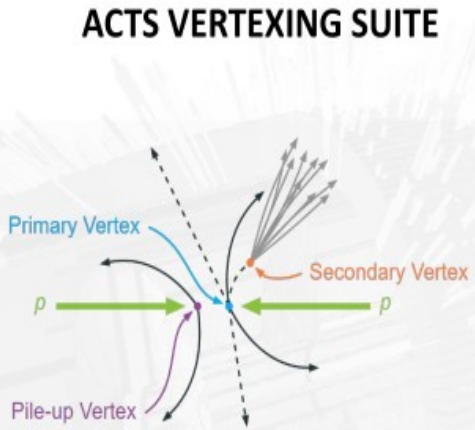
ETpcClustering::FAST, ETpcTracking::ACTS

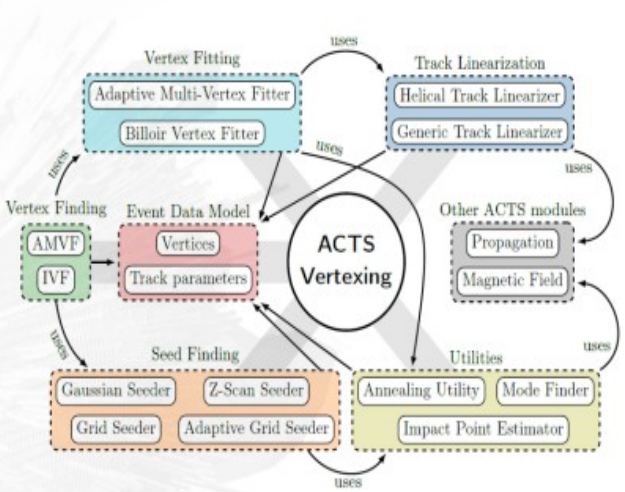
MPD Vertex with ACTS



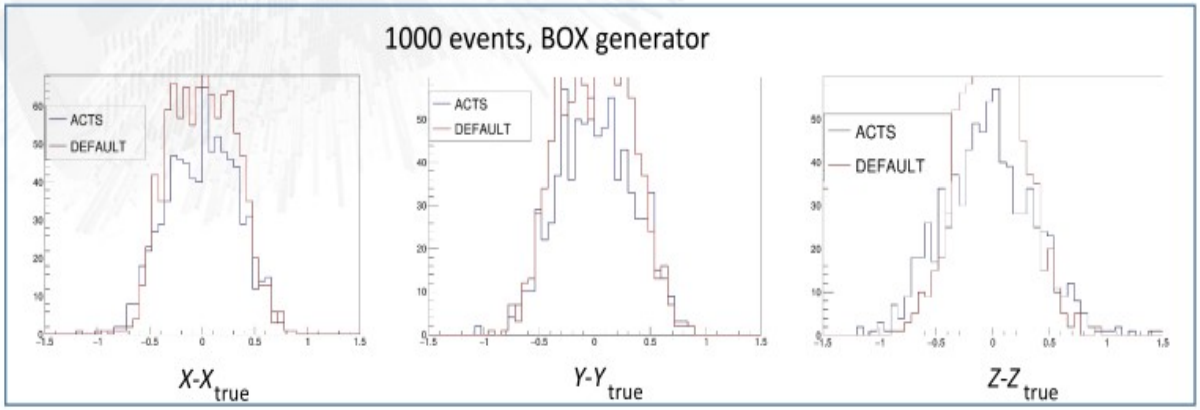
PERIGEE TRACK PARAMETRIZATION
Track selection: |d_0| < 2mm





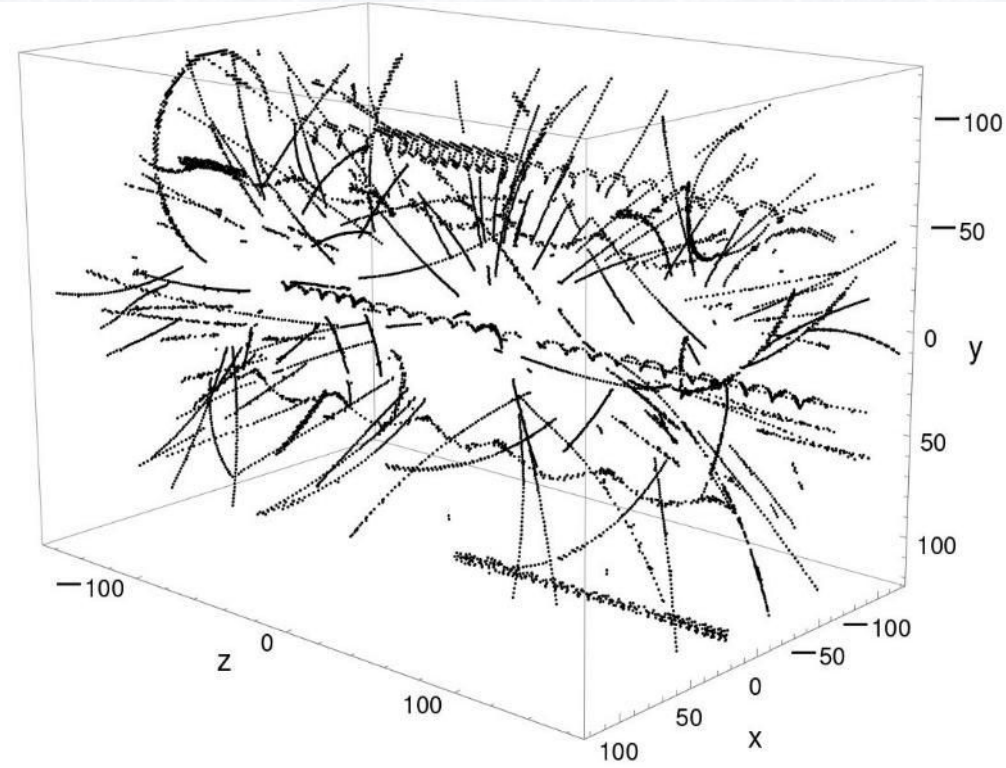


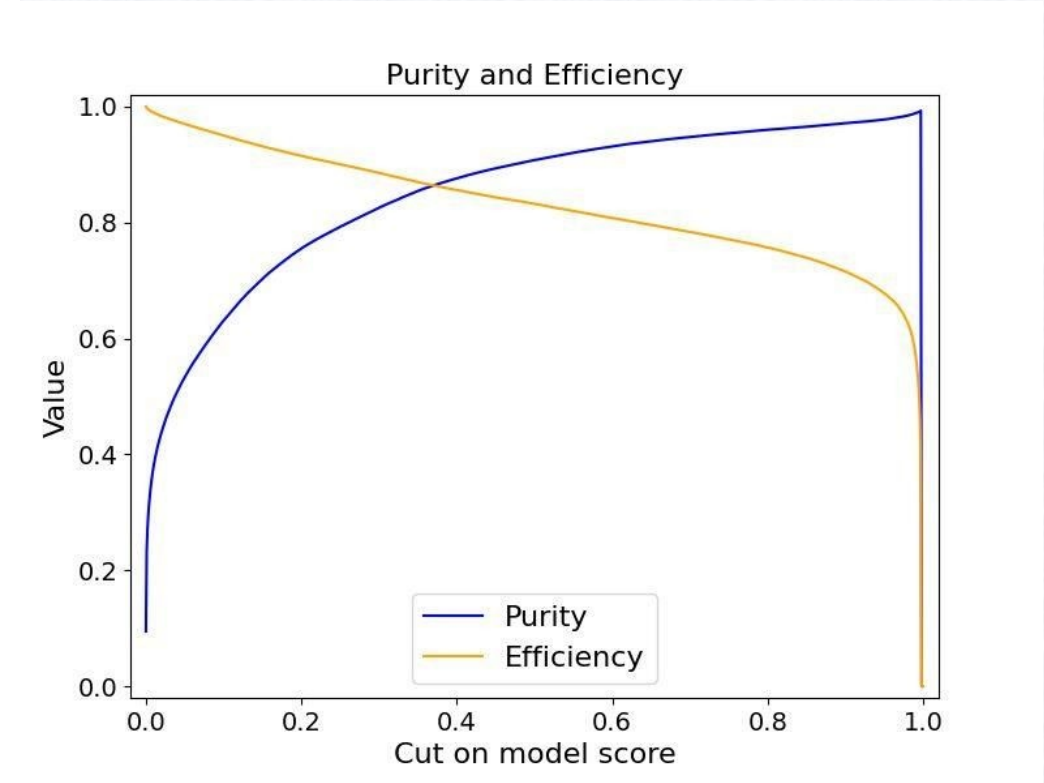
- many tunable parameters, to be fine tuned yet



Tracking with Graph Neural Networks

Talochka E.

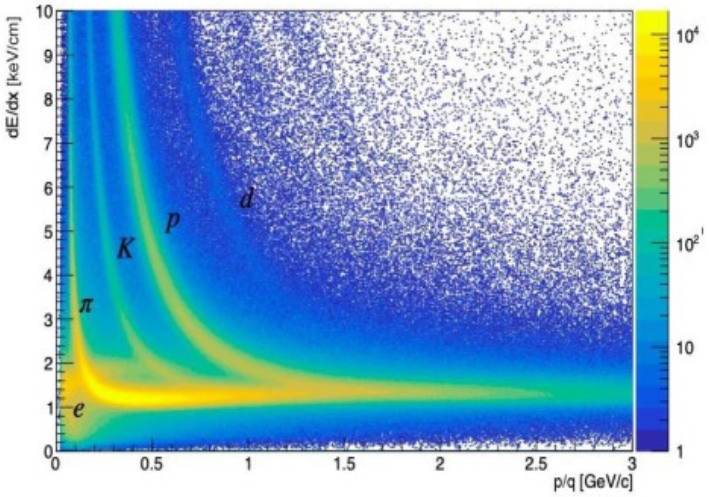




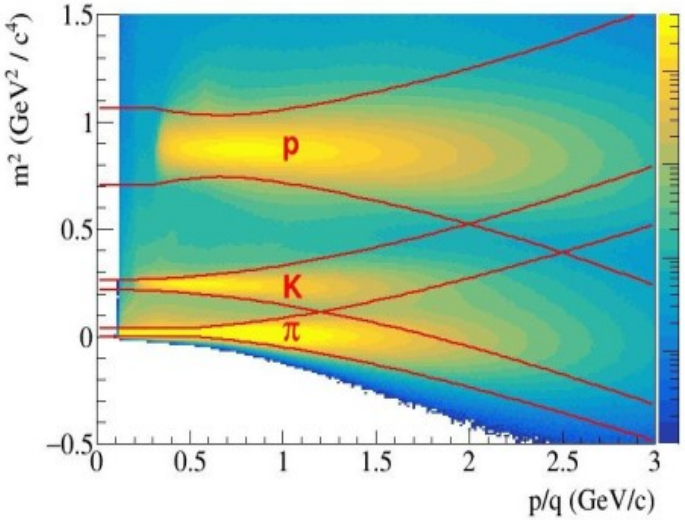
MPD AuAu √s = 11 GeV

PID in MPD

A TPC can identify charged particles by measuring their specific ionization **energy losses** (dE/dx);



A TOF measures the particle flight **time** over a given **distance** along the track trajectory;



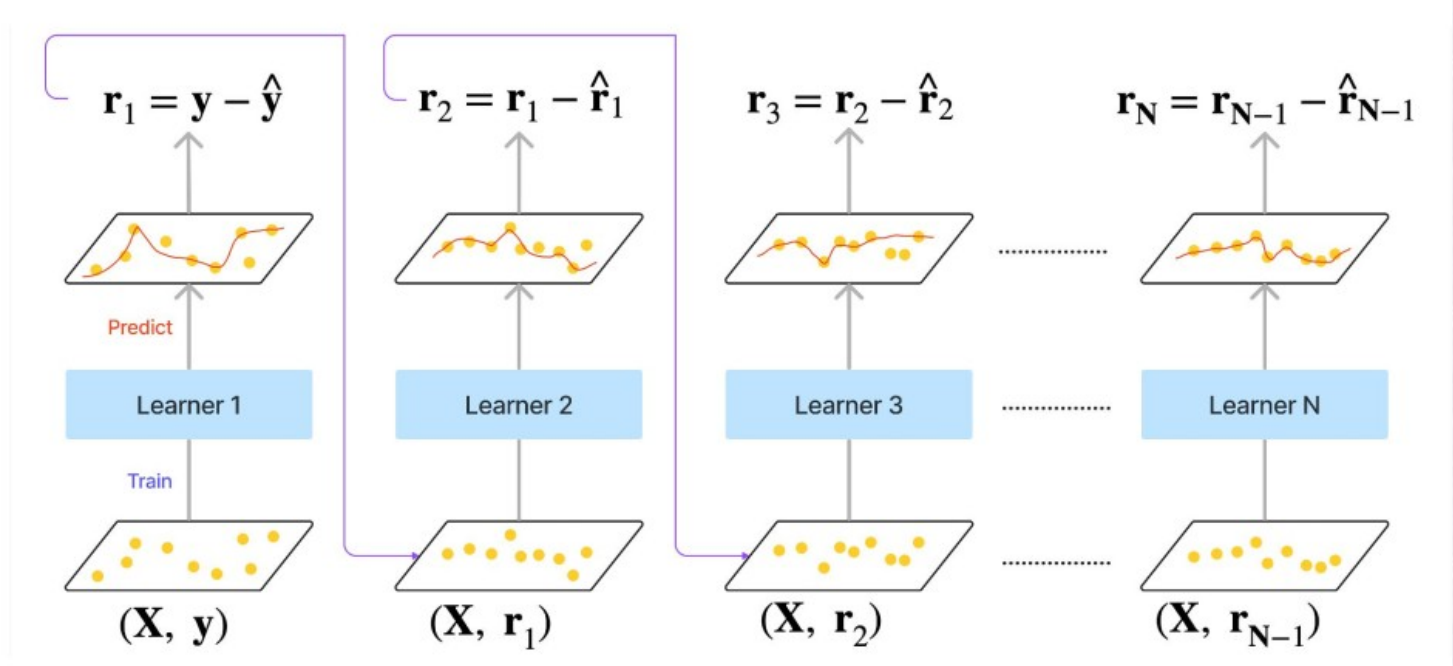
Knowing the particle **momentum** (from TPC) one obtains the **mass squared** and thus identity of the particle.

PID with Gradient Boosted Decision Tree

Gradient Boosted Decision Tree for Particle Identification at MPD

V. Papoyan

Gradient boosting is a machine learning technique which combines weak learners into a single strong learner in an iterative fashion

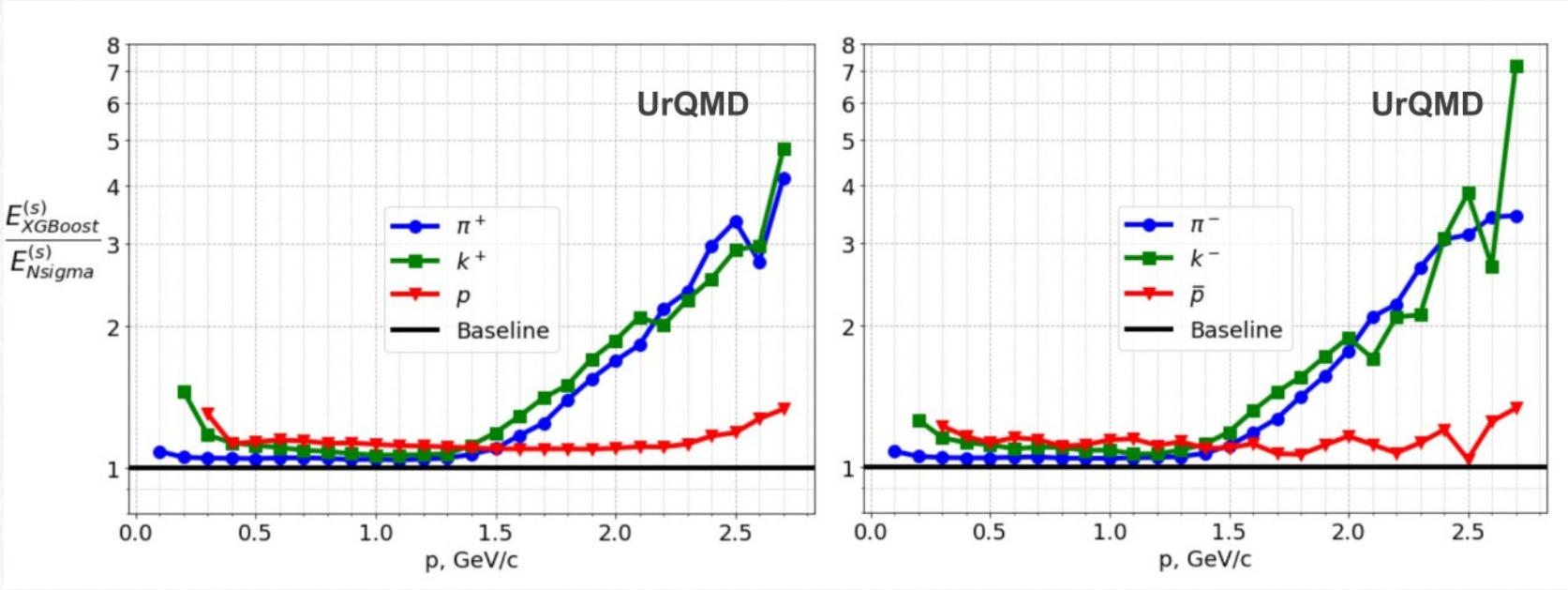


PID with Gradient Boosted Decision Tree

Gradient Boosted Decision Tree for Particle Identification at MPD

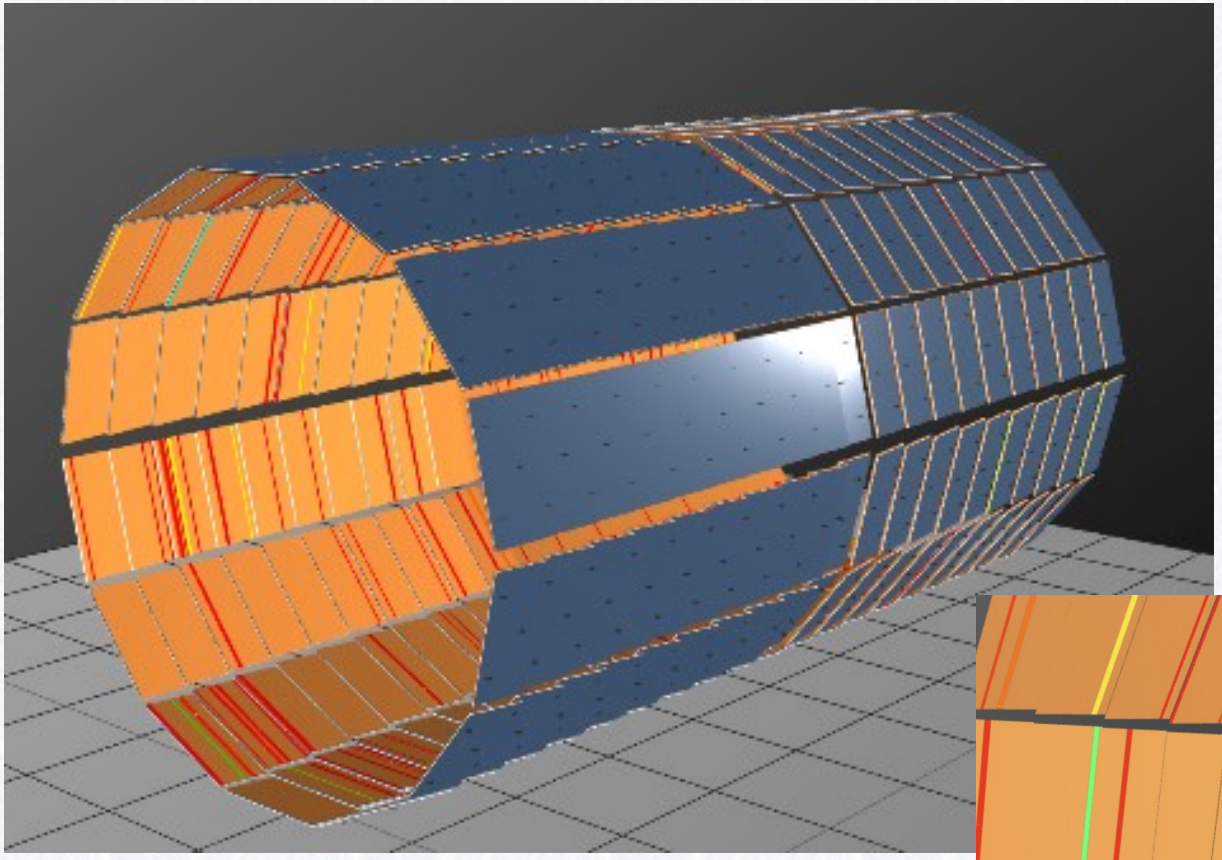
V. Papoyan

Comparison with N-sigma

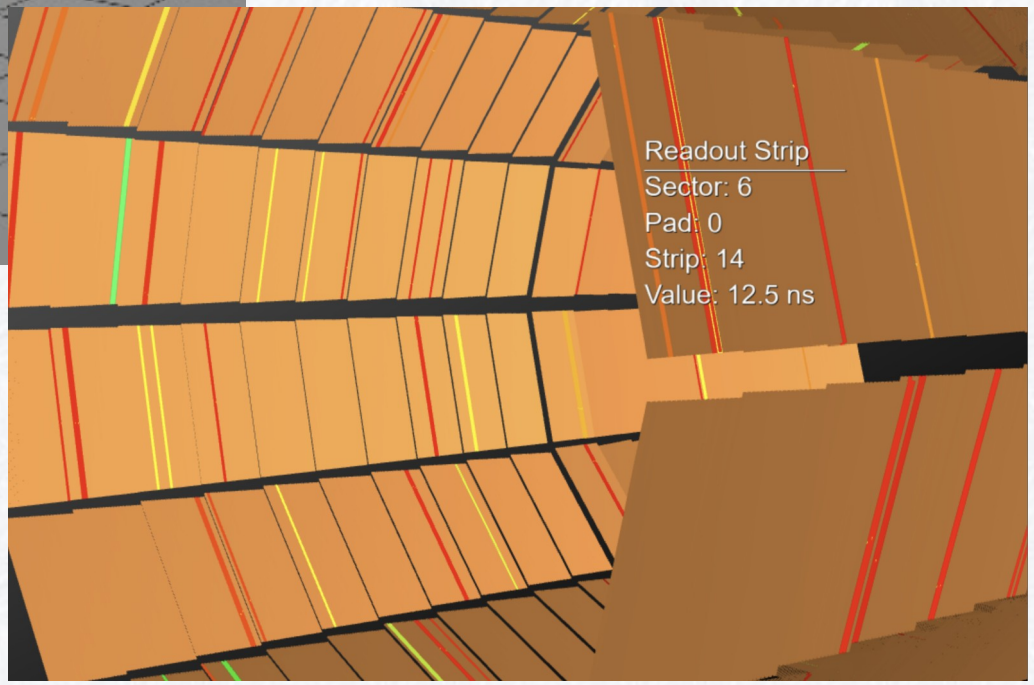


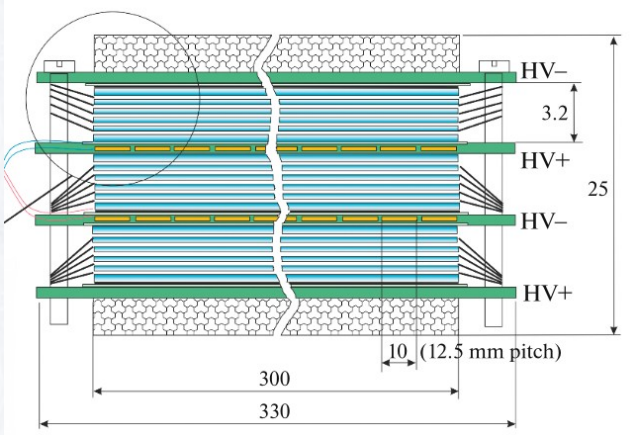
Efficiency ratio of XGBoost and n-sigma method

Detectors simulation (TOF)

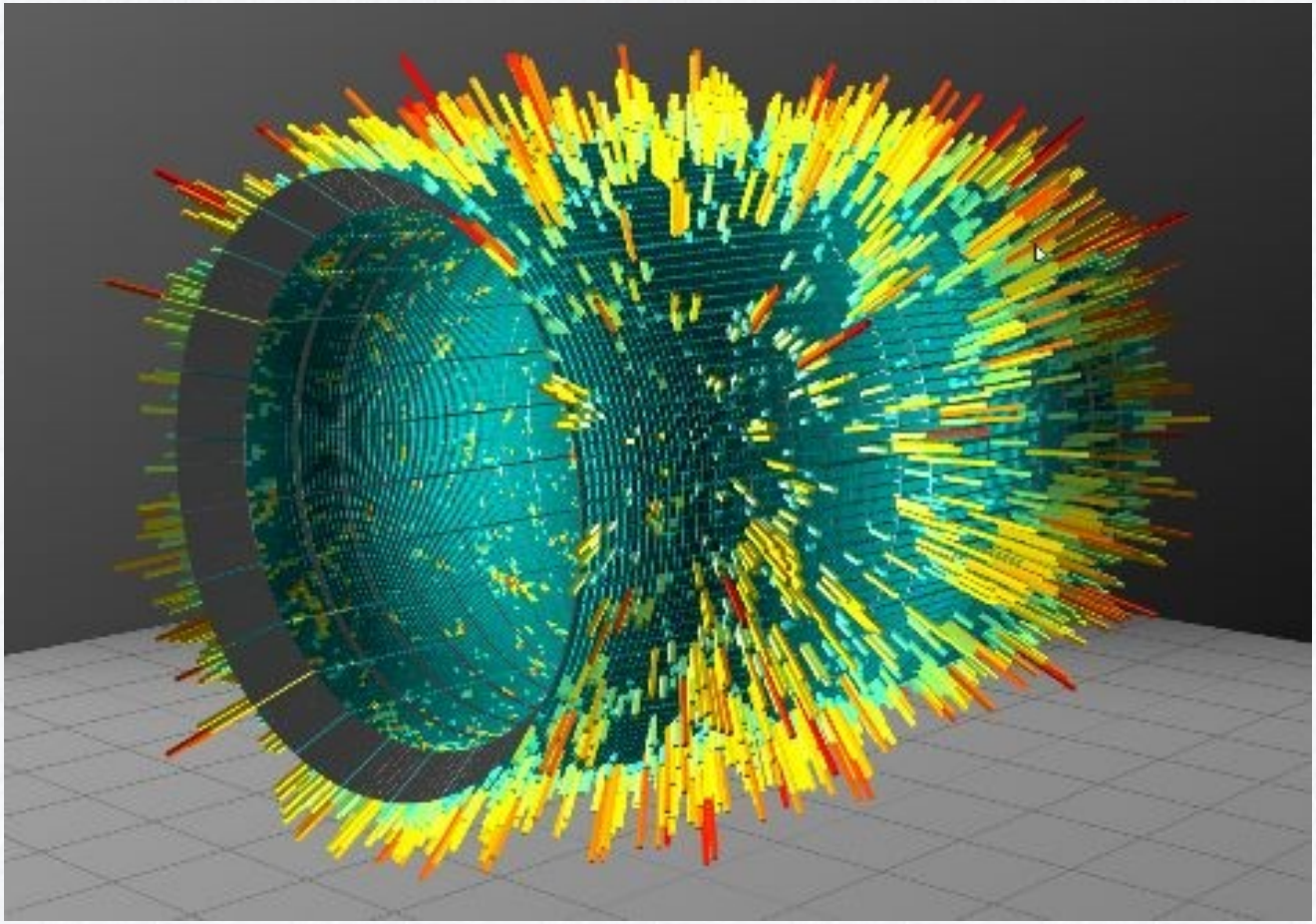


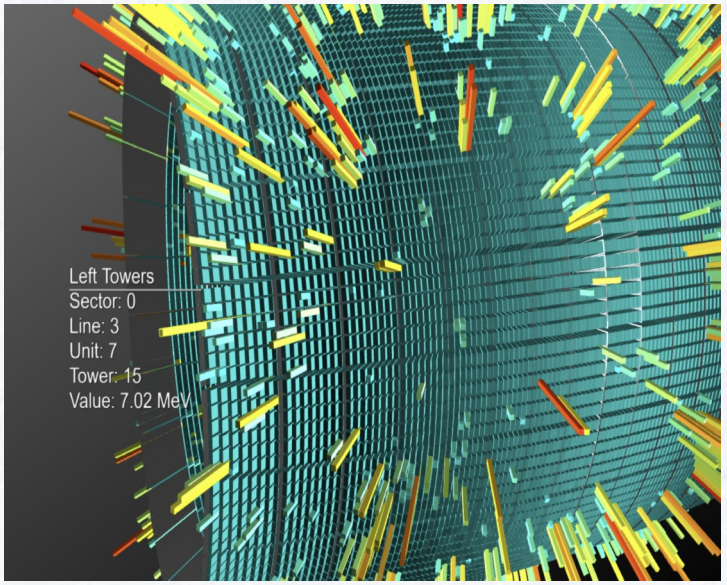
The Time of Flight together with the TPC must be able to identify charged hadrons and nuclear clusters in the broad rapidity range and up to total momentum of 3 GeV/c.

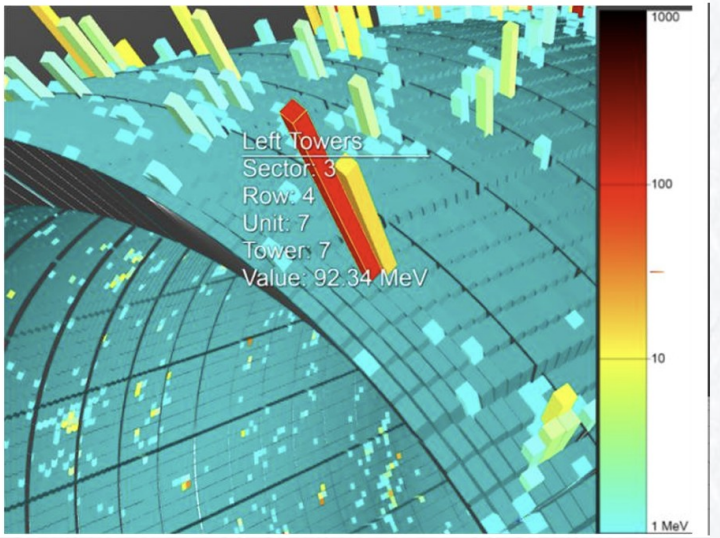


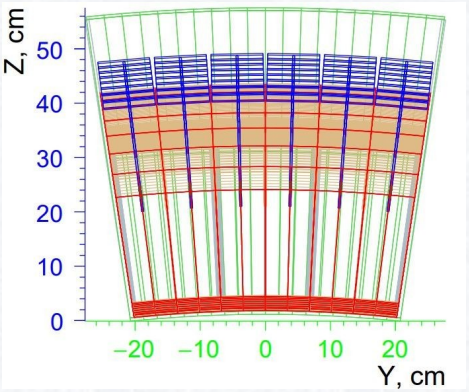


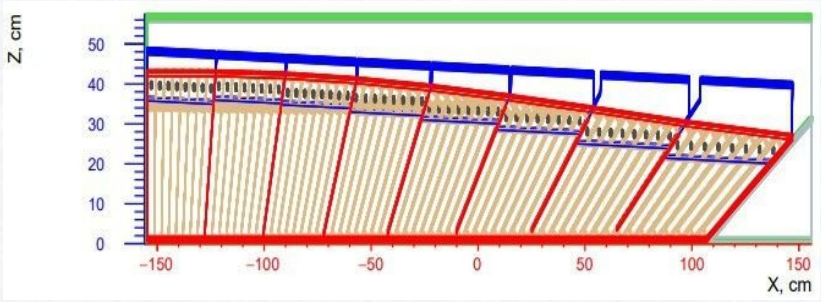
Detectors simulation (ECal)



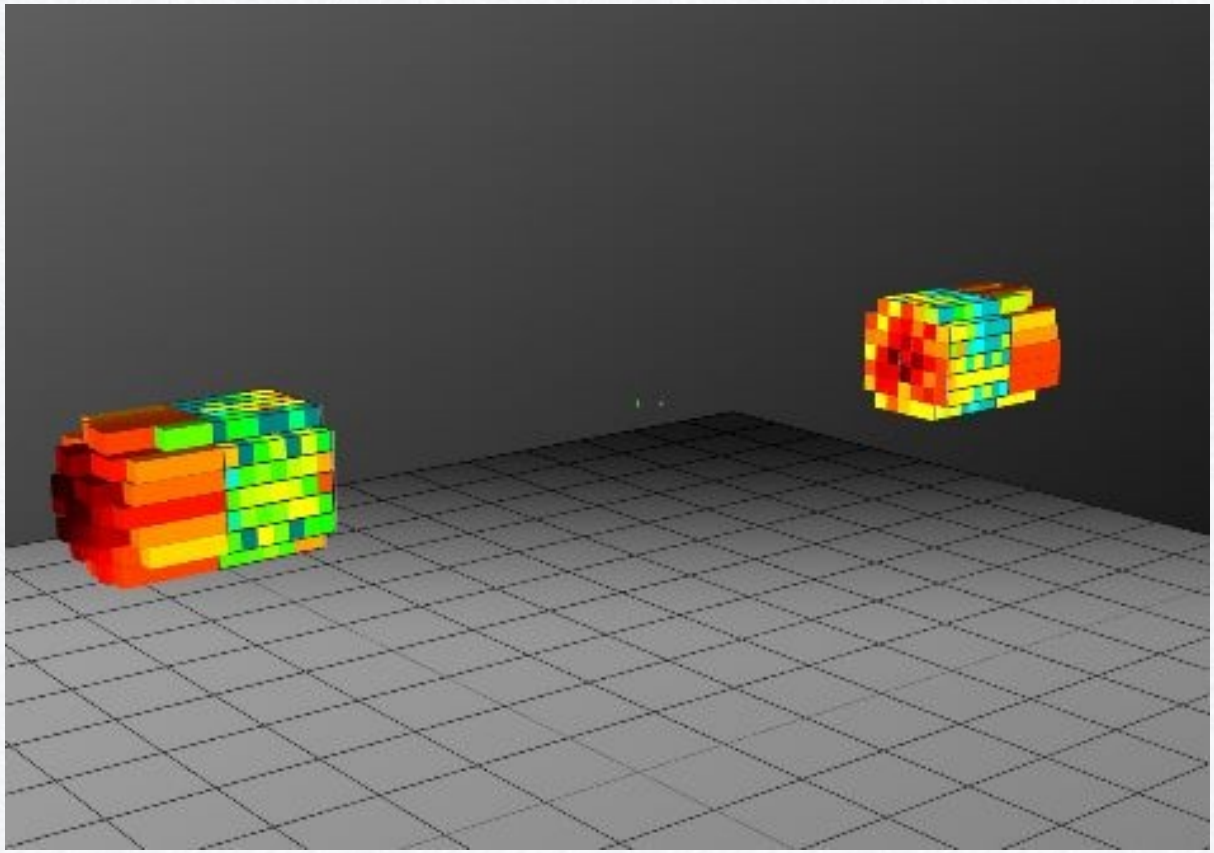




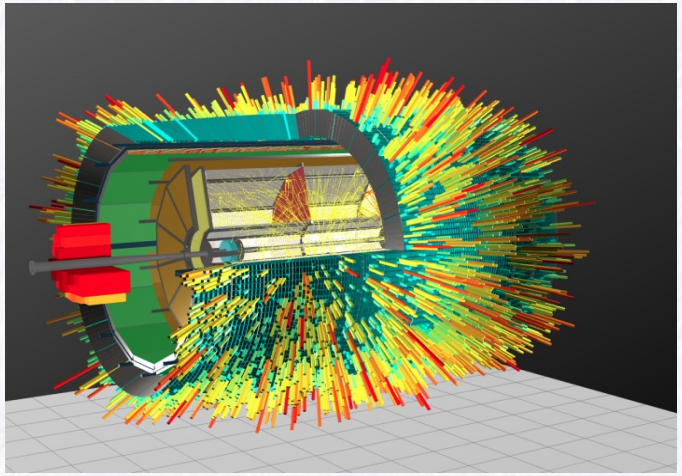


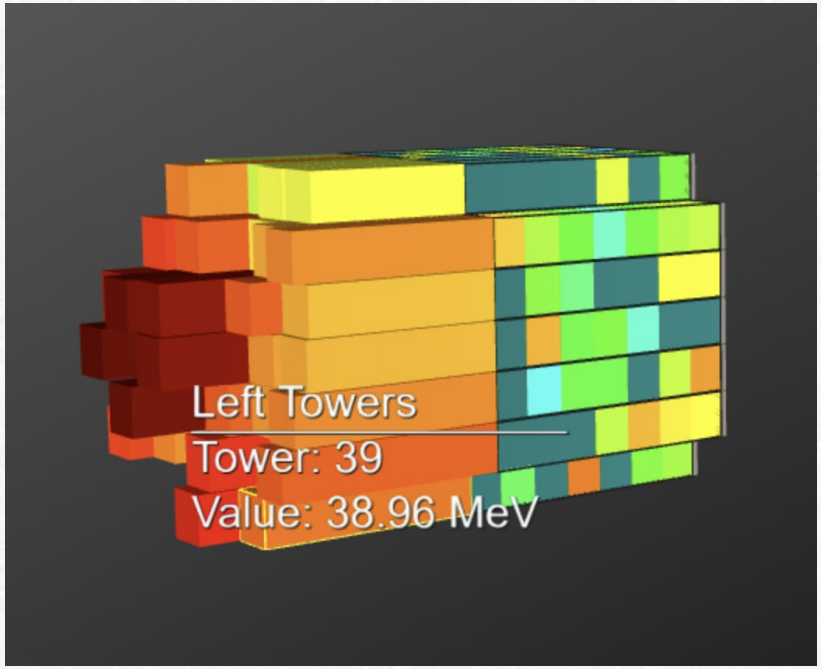


Detectors simulation (FHCal)



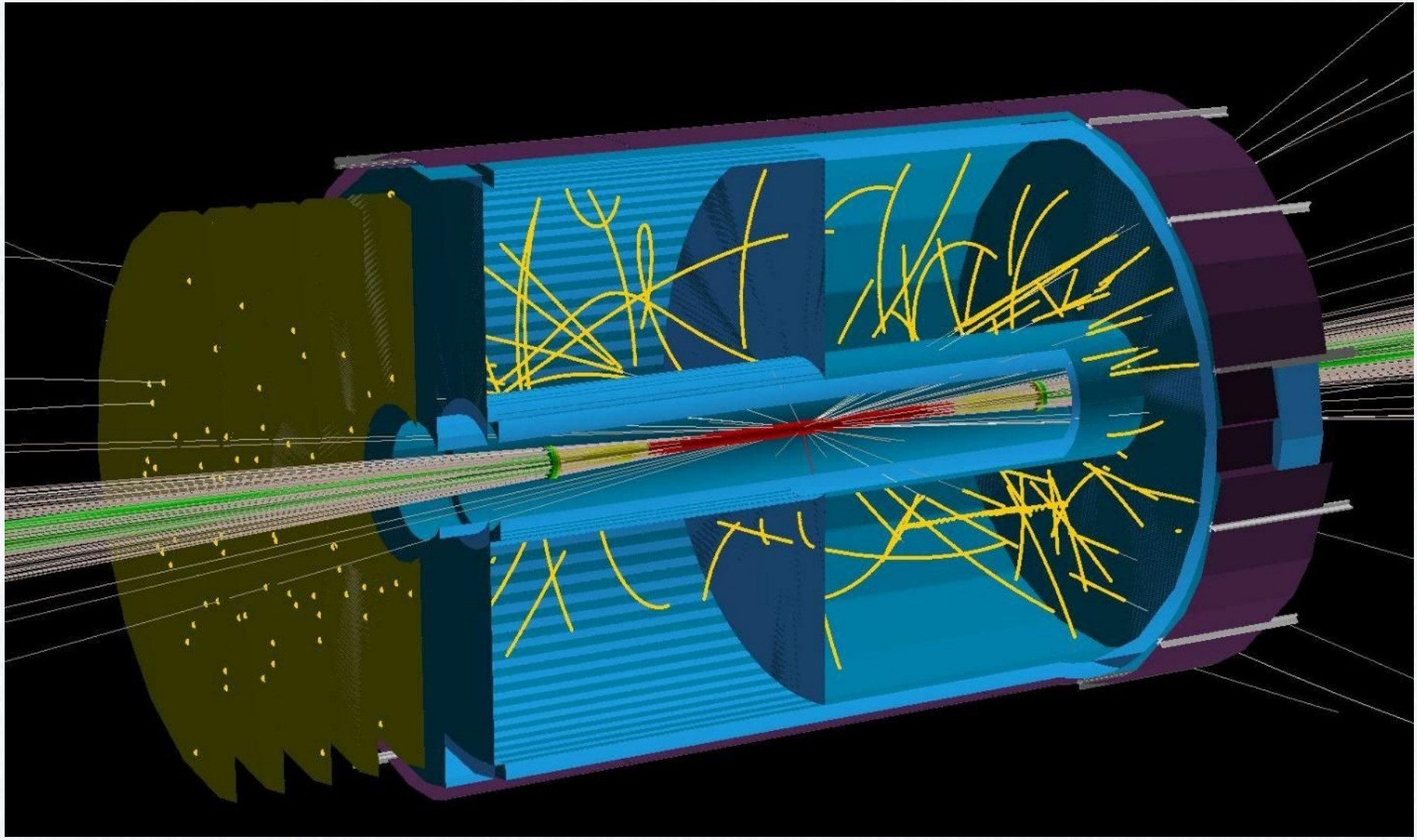
The efficient detection of nucleus+nucleus collisions at any centrality with time resolution of ~50 ps





Endcap tracking

Kryshen E. et al.



Refactoring

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

Refactoring

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

Thanks to Jan Busa Jr

(Jr – is not a qualification !!!)

MPDroot deployment

Running MPDRoot locally using CVMFS

Questions? Click here

INSTALL CVMFS AND TOOLBOX
(Users and Developers)

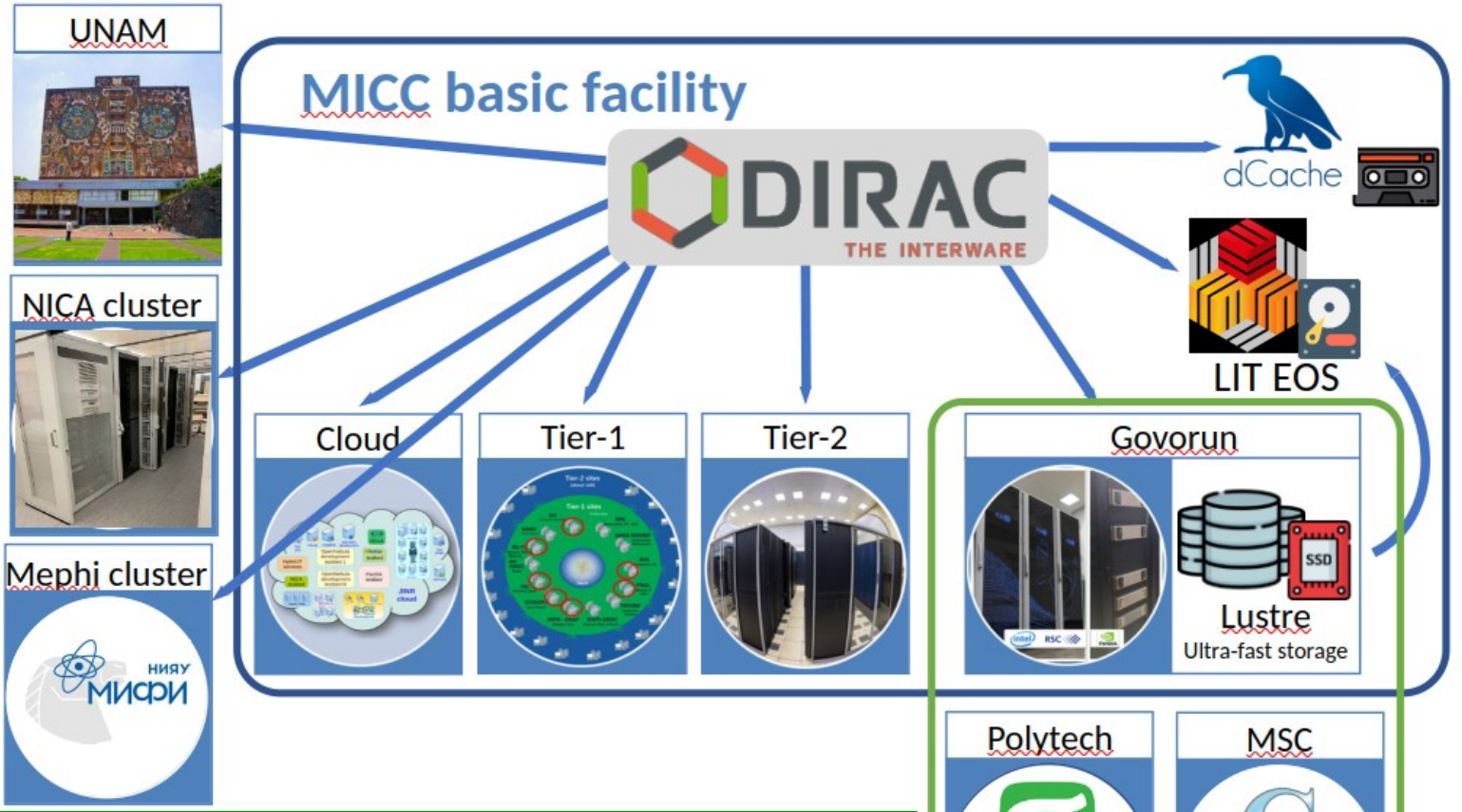
Supported OS: Fedora, CentOS, AlmaLinux, Ubuntu 22.04, 20.04, Debian 11, 12, Manjaro 21
NOTE: If your OS is based on any of those, then pass it to nica-init script, for example
./nica-init.sh -d Ubuntu -v 20.04

```
[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"

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.

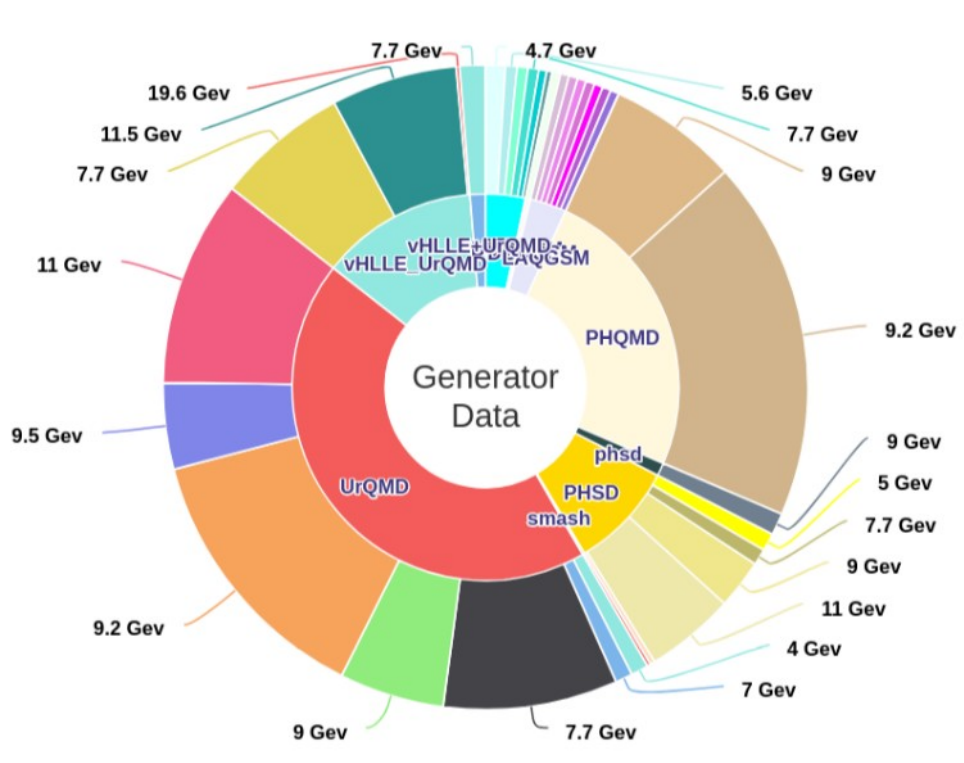
MPD MC data for physics analyses

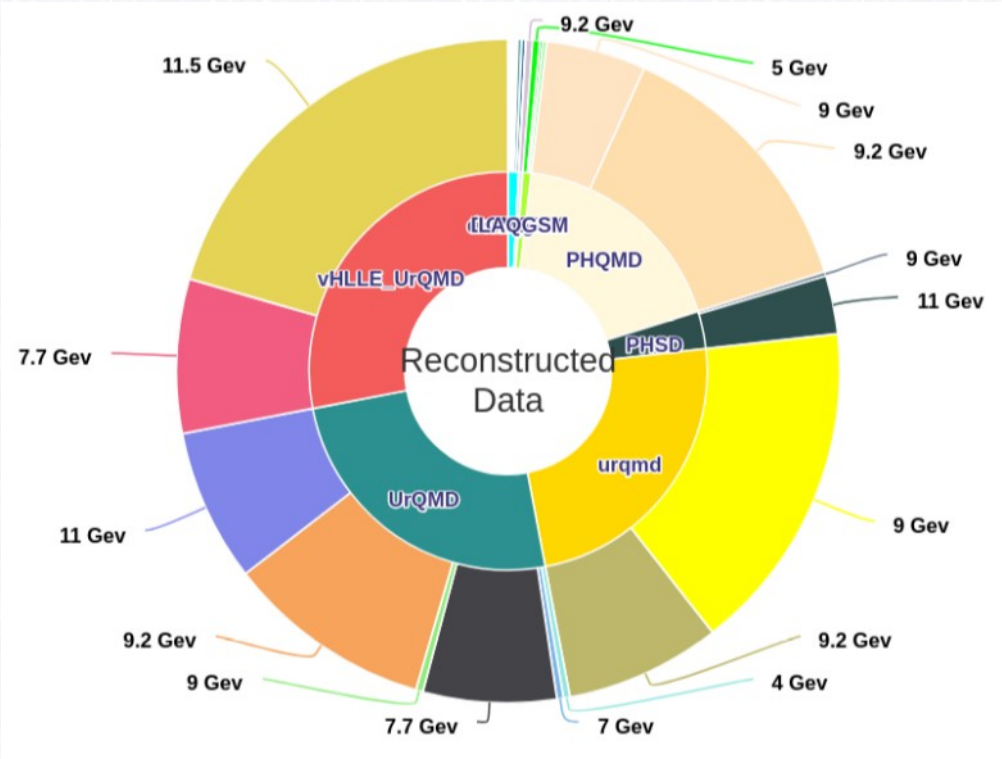
Generator	PWG	Coll.	√s(GeV)	# of events(10^6)	Reco
UrQMD	PWG4	AuAu	11	15	+
		BiBi	9	10	+
			9.46	10	+
			9.2	135	+
	PWG2	AuAu	11	10	+
	PWG3	AuAu	7.7	10	+
		BiBi	7.7	10	+
			9	15	+
		pp	9	10	+
		BiBi FT	2.5	12	+
		BiBi FT	3.0	12	+
		BiBi FT	3.5	12	+
		XeW FT	2.5	15	+
		XeXe FT	2.5	15	+
	PWG1	BiBi	9.2	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
1.8 PB

MPD mass production database

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





All production data stored in Dirac File Catalog

Mass production data

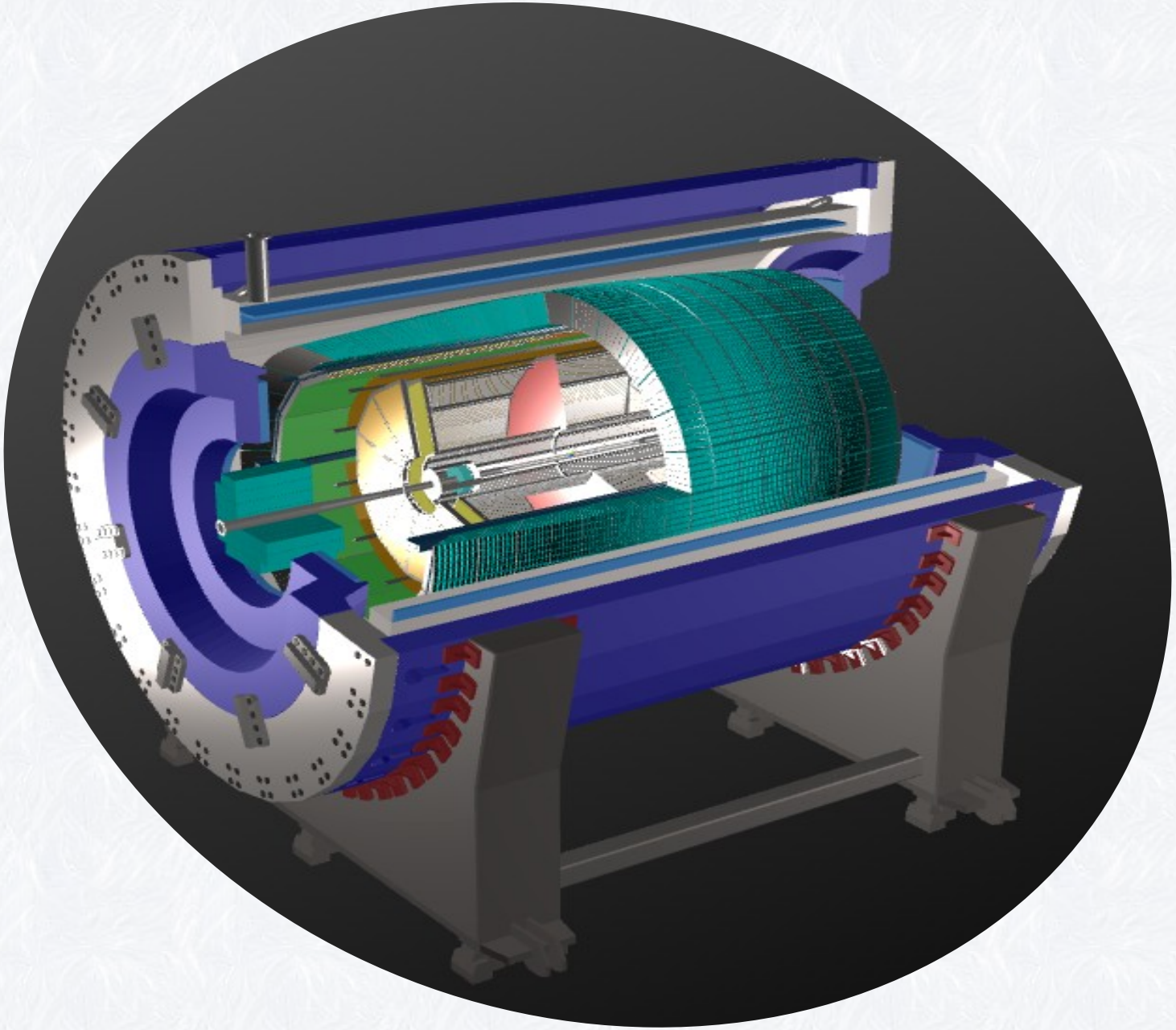
wagon for physics analyses

- Centralized Analysis Framework for access and analysis of data:
  - ✓ consistent approaches and results across collaboration, easier storage and sharing of codes and methods
  - ✓ reduced number of input/output operations for disks and databases, easier data storage on tapes
- Analysis manager reads event into memory and calls wagons one-by-one to modify and/or analyze data:

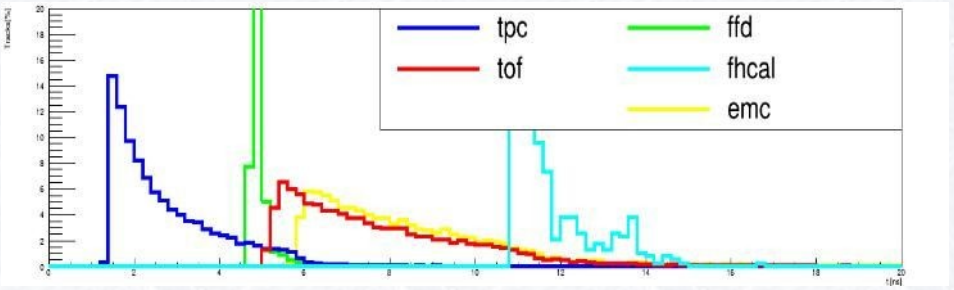
• Analysis manager	• Centrality • wagon	• Reaction plane • wagon	• DCA, PID, • Match wagon	• Analysis • wagon #1	• Analysis • wagon #2	• Analysis • wagon #N

- All productions for physical analyses of simulated data already have been done.

Thanks for your attention

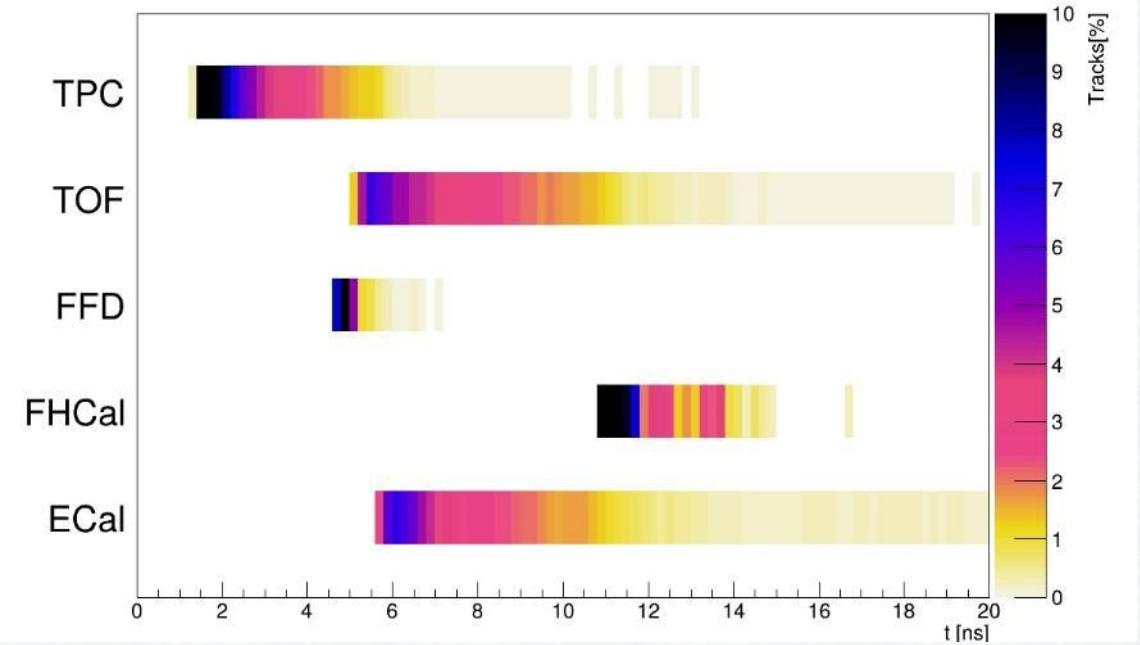


Trigger latency for data taking for MPD detectors

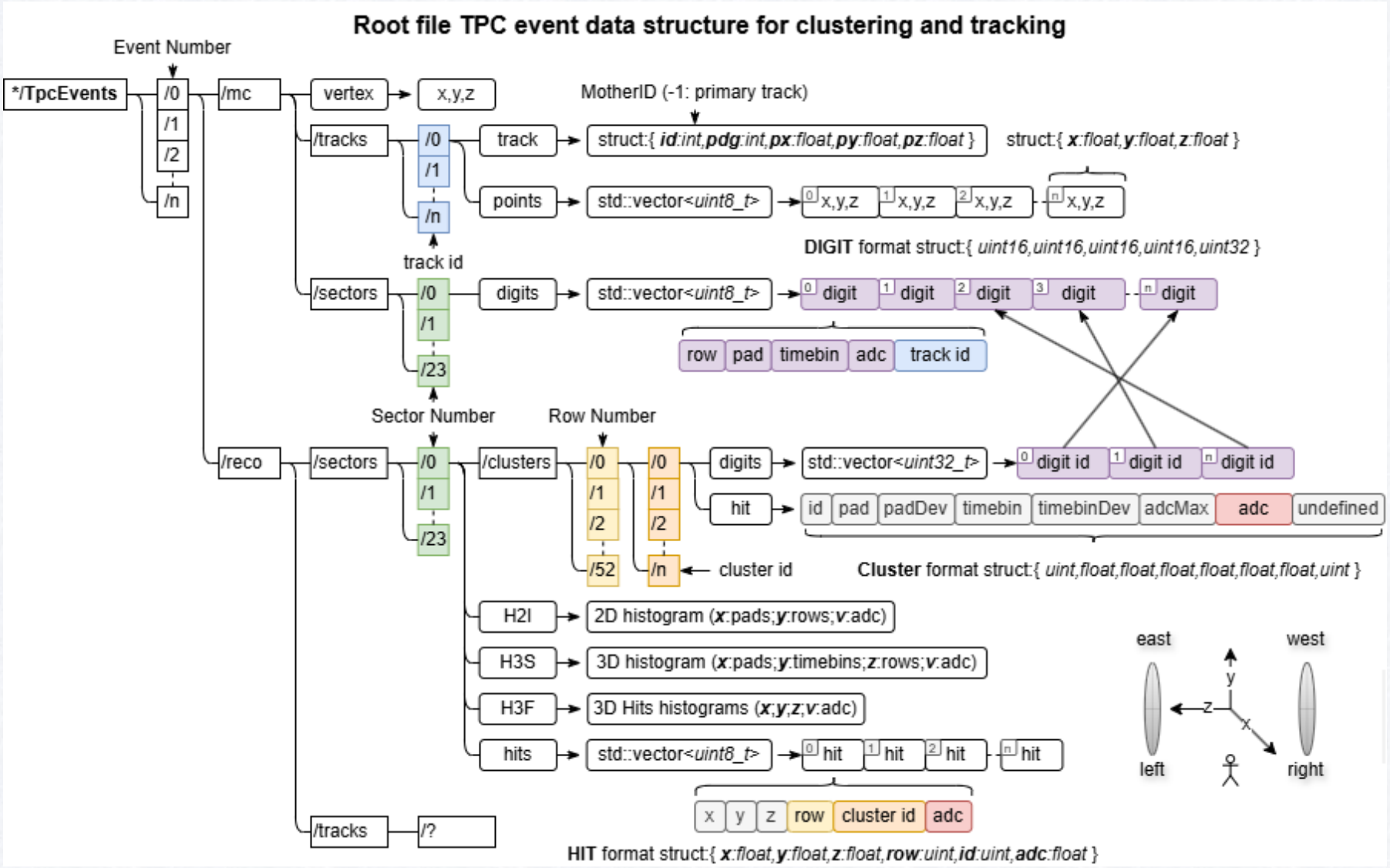


Collision point (0, 0, 0)

- 100 events from PHSD generator
- Reaching time for
  - Primary particles
  - π^0 gammas

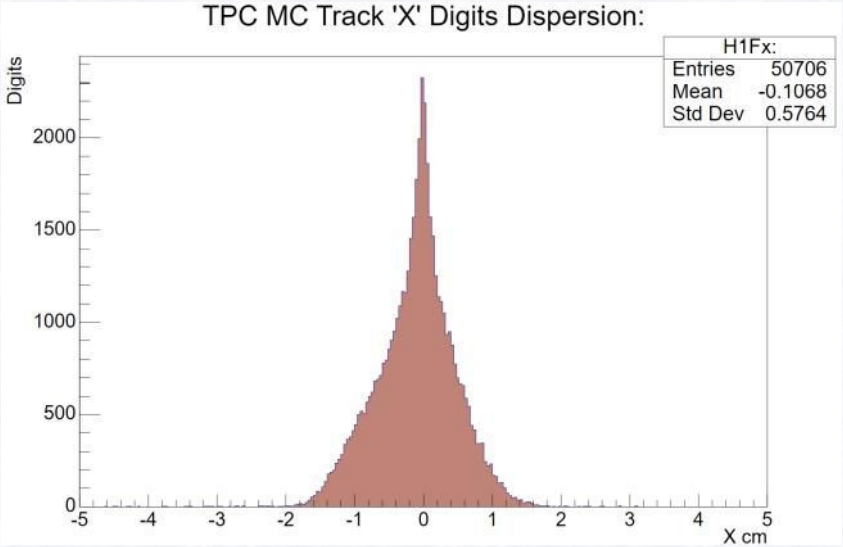


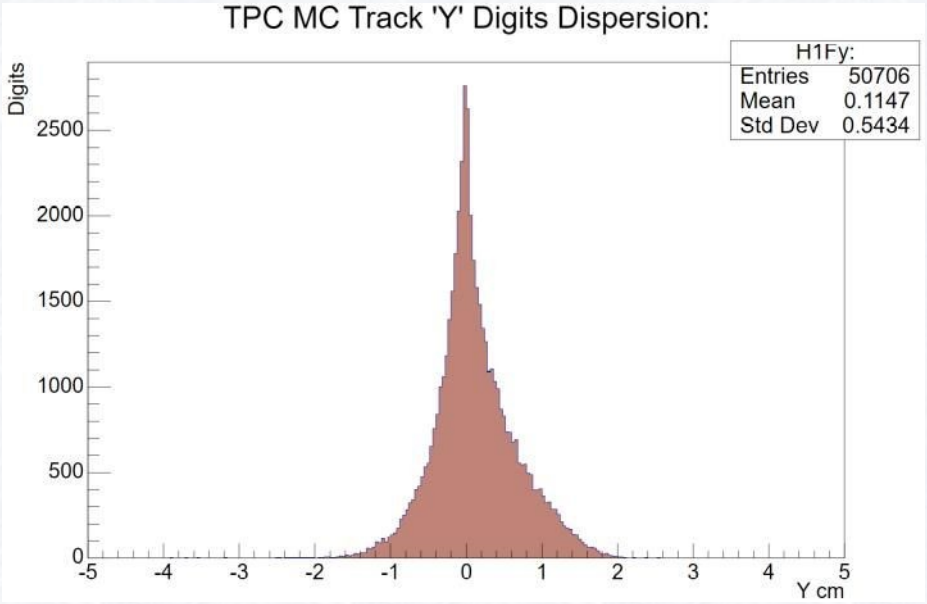
Data file structure

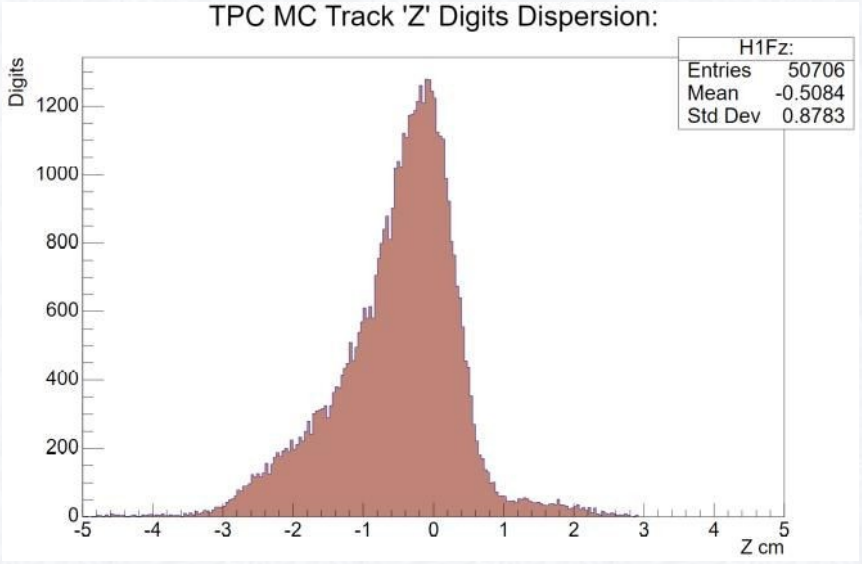


Data structure

Sector digits distribution

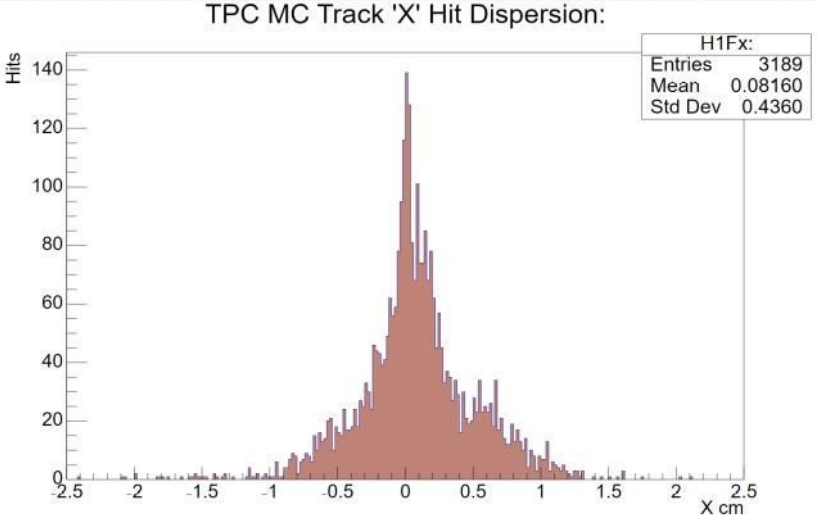


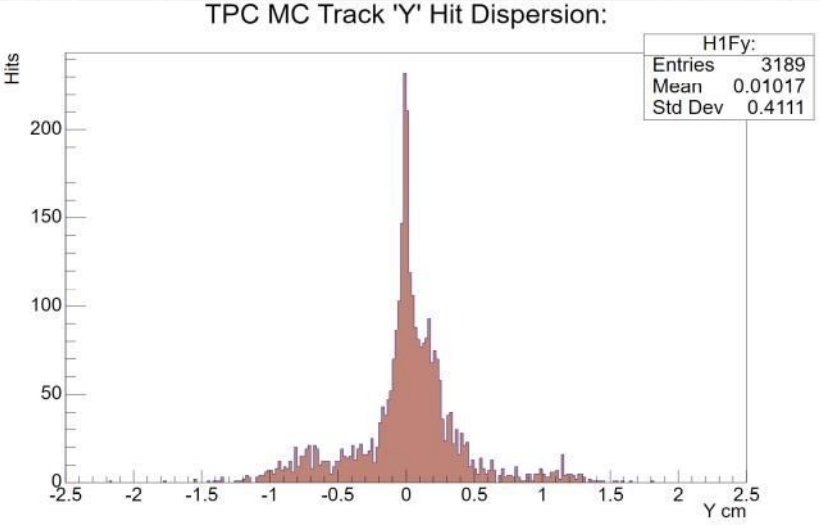


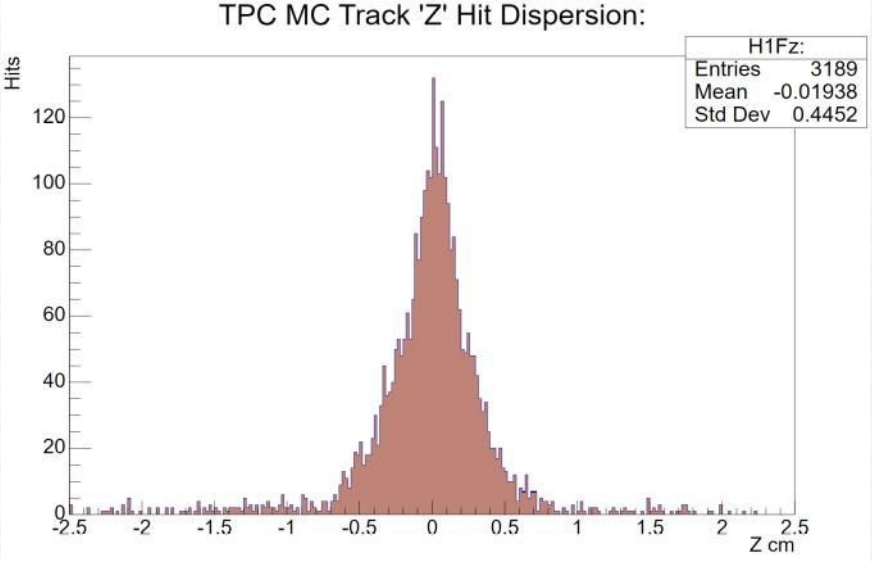


Data structure

Sector hits distribution







TPC data taking of events

- Collision point at (0, 0, 0)
- PHSD generator