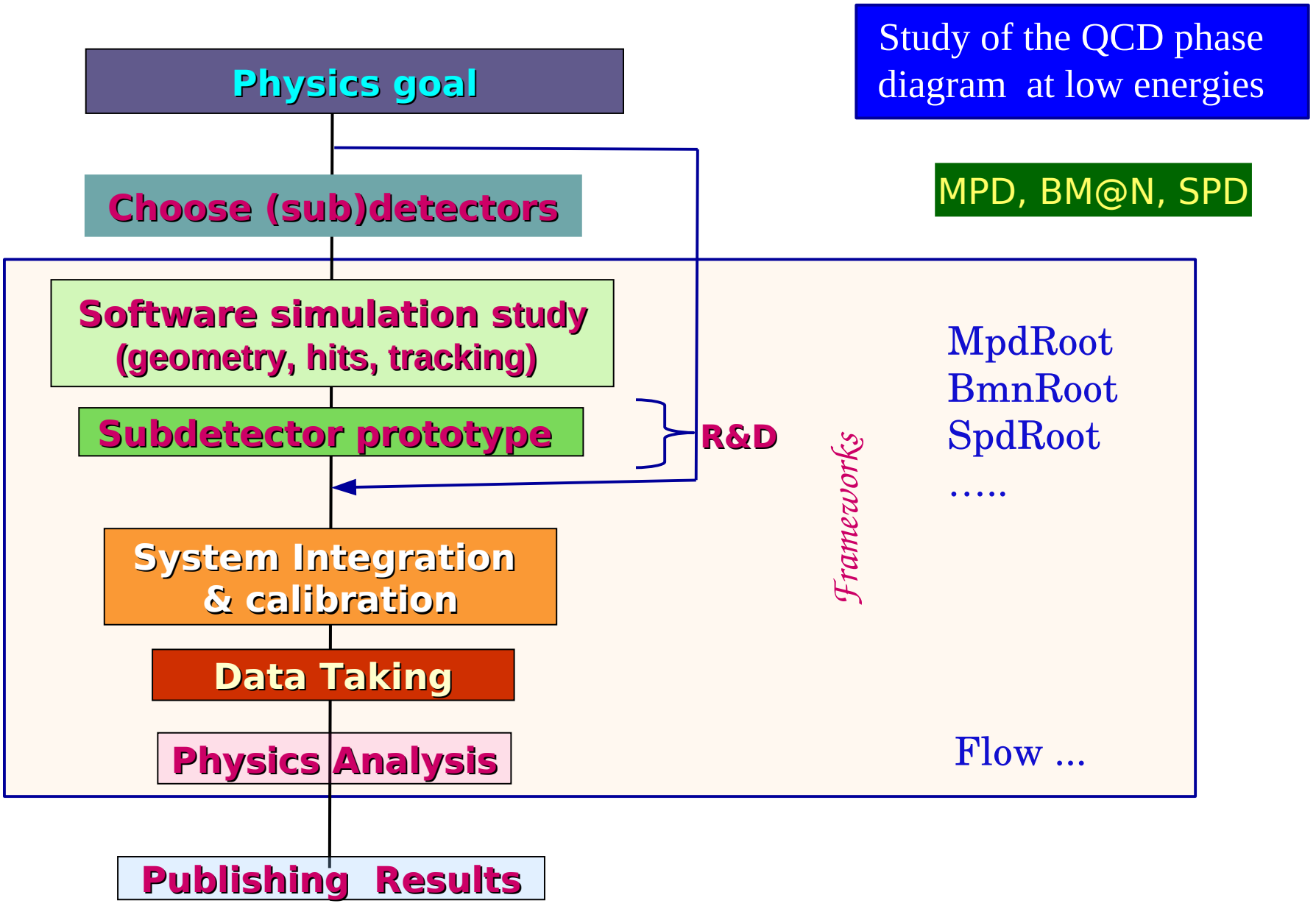
Software & Computing for NICA experiments

ROGACHEVSKY Oleg
MPD collaboration

NICA Days
October 2023
Belgrad

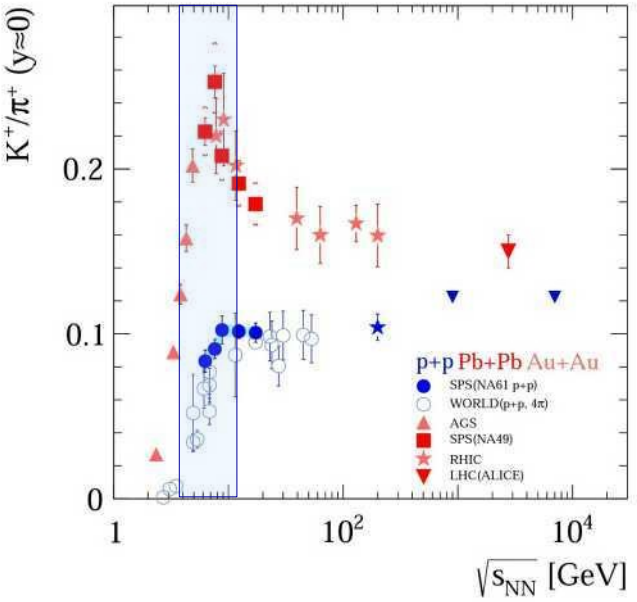
Workflow of the HEP experiments

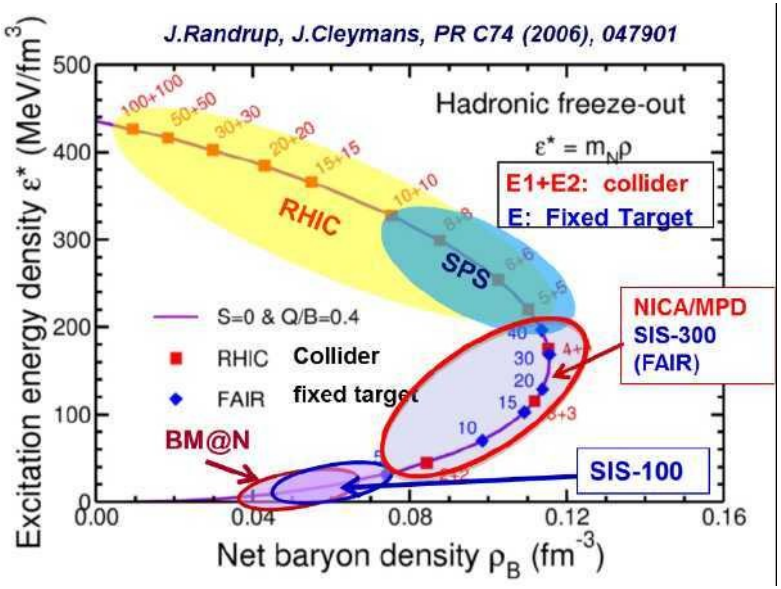


NICA advantagies

J. Cleymans
MPD collaboration Meeting April, 2018

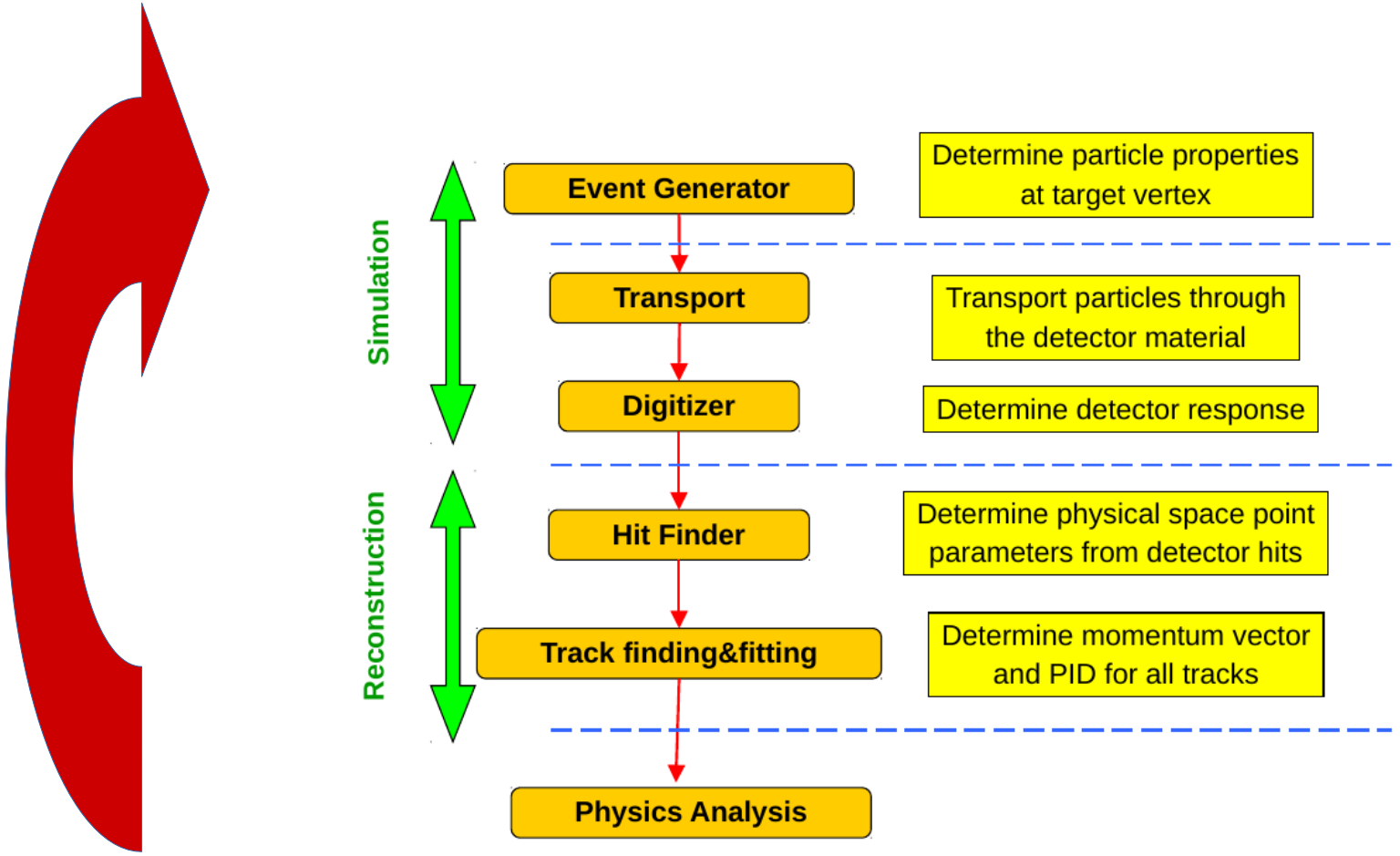
- ✔ Maximum in K^+/π^+ ratio is in the NICA energy region,
- ✔ Maximum in Λ/π ratio is in the NICA energy region,
- ✔ Maximum in the net baryon density is in the NICA energy region,
- ✔ Transition from a baryon dominated system to a meson dominated one happens in the NICA energy region.





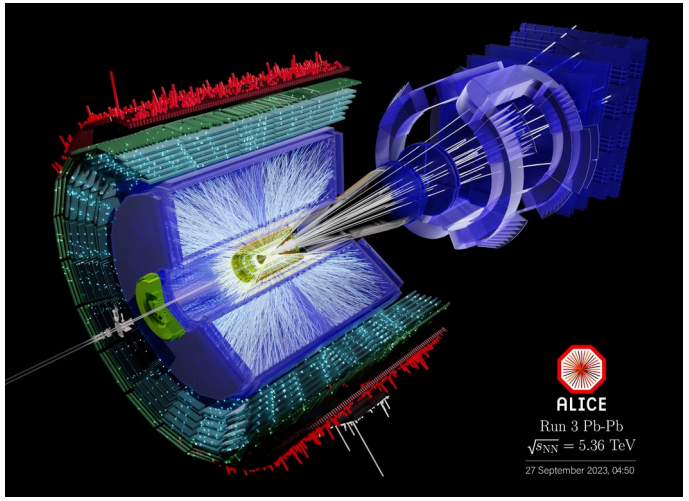
HEP experiments data flow

Experiment software development is a key task
for the whole experiment life.

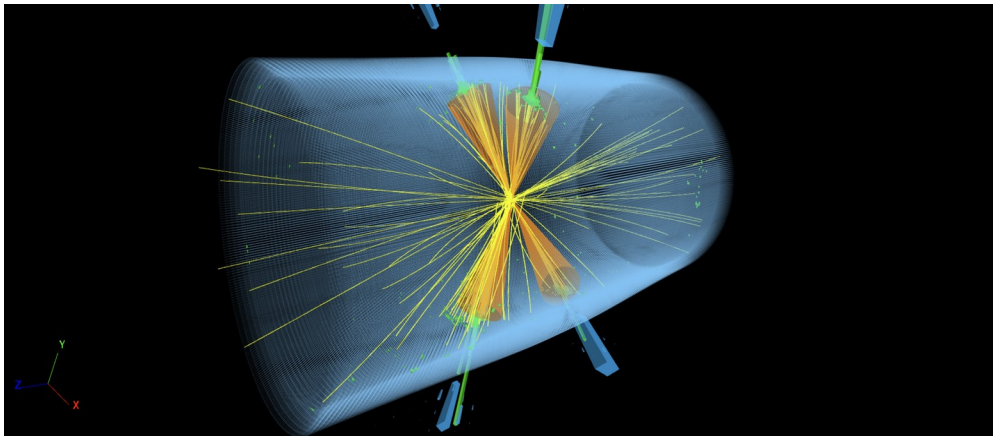


Experiment's frameworks

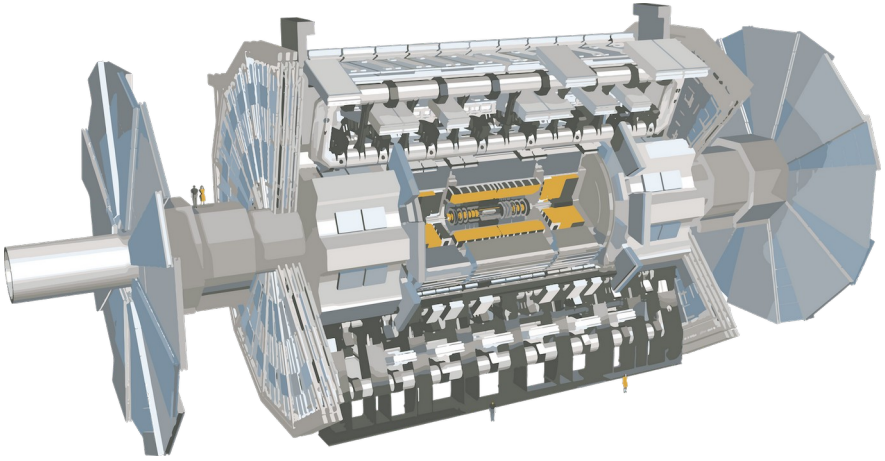
ALICE aliroot



CMS cmssw



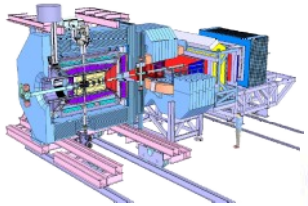
ATLAS Athena

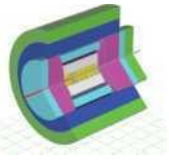


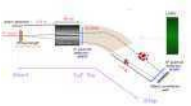
https://gaudi.web.cern.ch/gaudi/

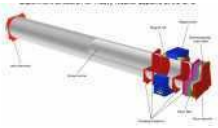
- LHCb Computing
- ATLAS Athena framework
- HARP Gaudino framework
- Fermi (previously GLAST)
- MINERvA
- BESIII BOSS framework
- LBNE (Long Baseline Neutrino Detector, WCD group), see also GARPI project
- Key4hep (common software for FCC, CLIC/ILC and CEPC)

FairRoot based frameworks









2004 — Start testing the VMC concept for CBM

2006 — Panda decided to join FairRoot: same base package for different experiments

2010 — R3B joined

2011 — EIC (Electron Ion Collider BNL) EICRoot

2012 — SOFIA (Studies On Fission with Aladin)

2013 — SHIP - Search for HIdden Particles

2014 — SPDRoot

2004 — First Release of CbmRoot

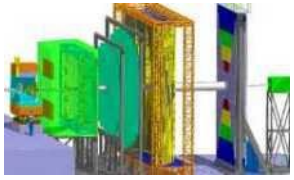
2006 — MPD (NICA) start using FairRoot

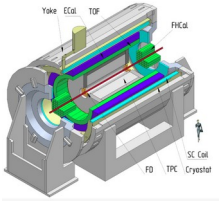
2010 — ASYEOS joined (ASYEOSRoot)

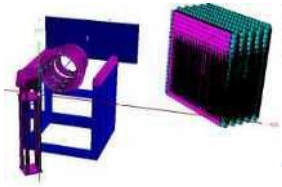
2011 — GEM-TPC seperated from PANDA branch (FOPIRoot)

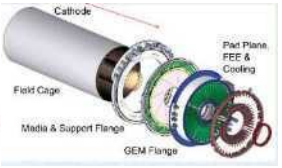
2012 — ENSAR-ROOT Collection of modules used by structural nuclear phsyics exp.

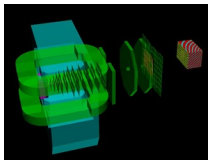
2013 — BMNRoot



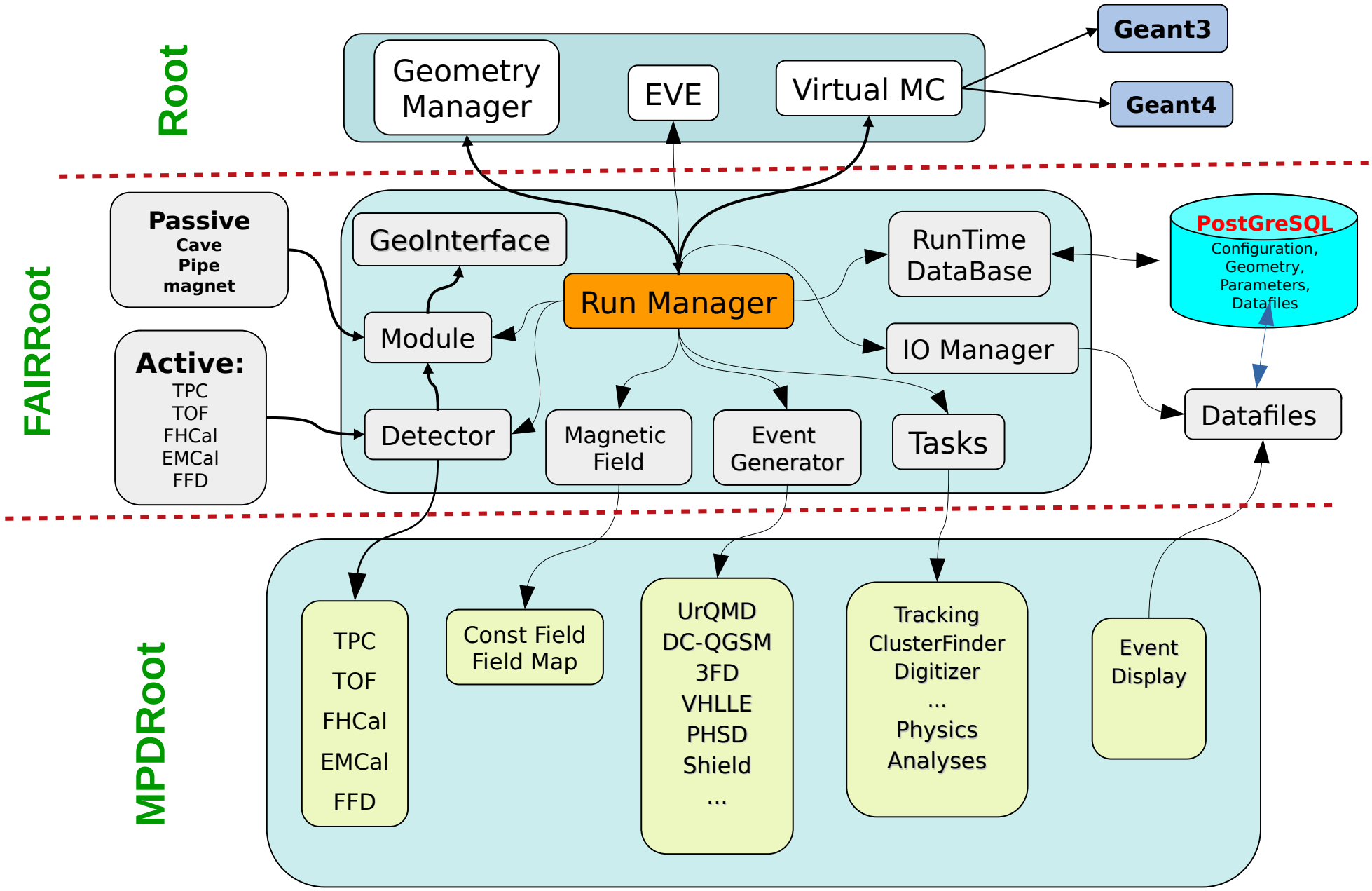








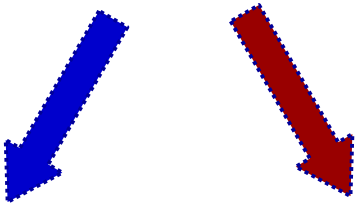
MpdRoot structure



Tools for programming

- C++
- Root
- GitLab git.jinr.ru
- CMake
- Jupyter
- Javascript
- PostgreSQL
- Geant4
- Boost
- GSL
- 0MQ
- ...

Physics analyses simulation



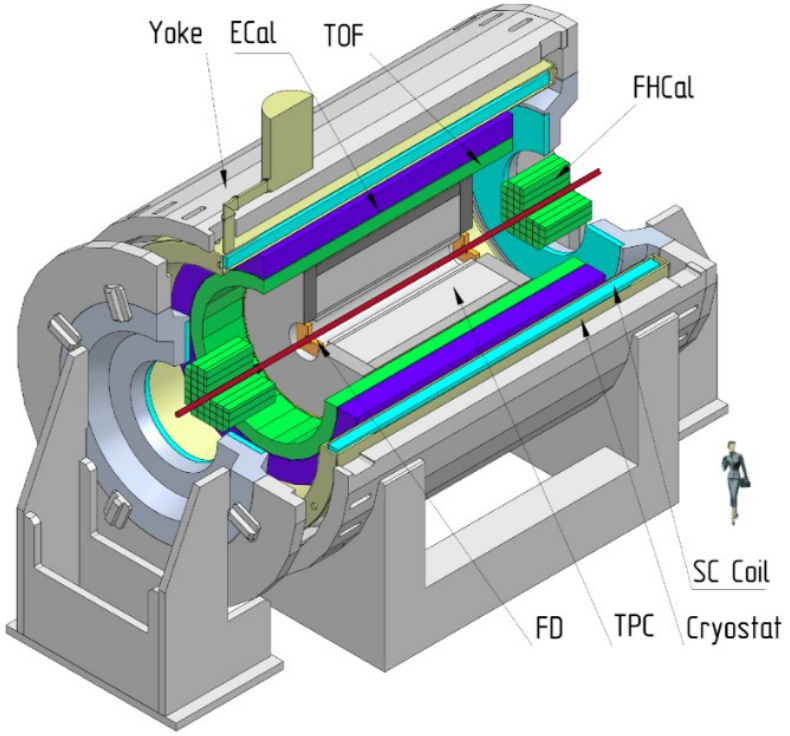
MC - generators

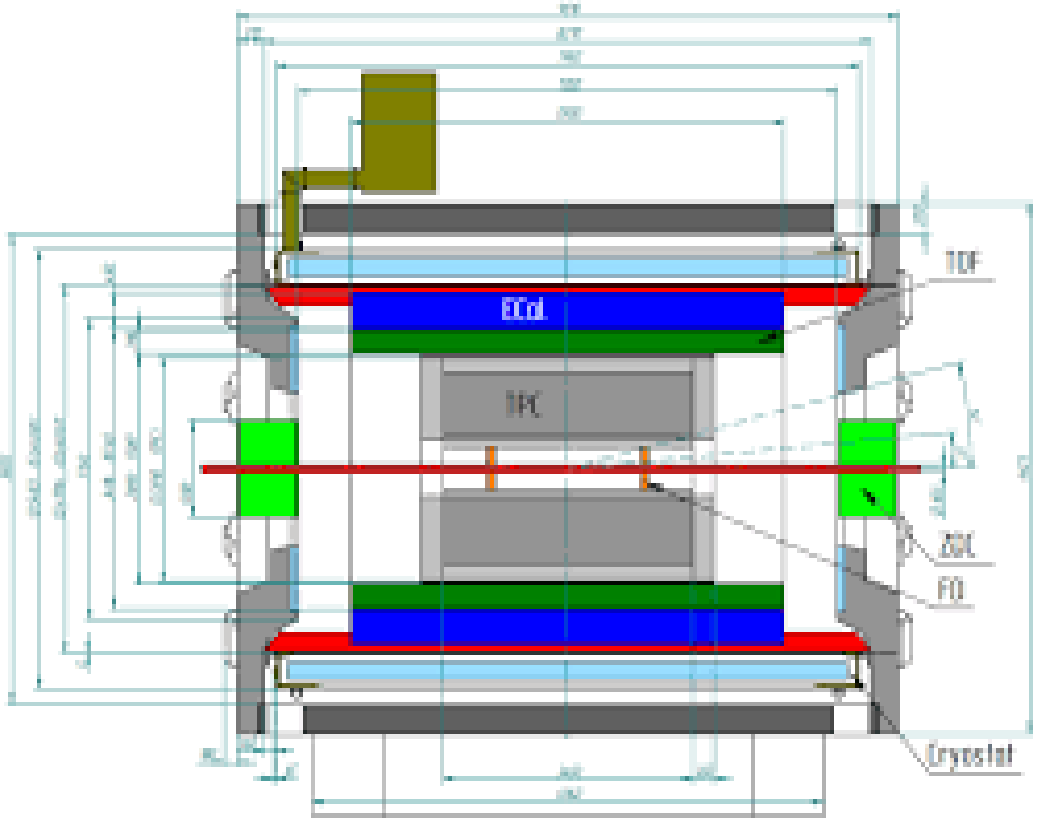
- UrQMD
- QGSM
- Hybrid UrQMD
- VHLLE
- PHSD
- THESEUS (3FD)
- …

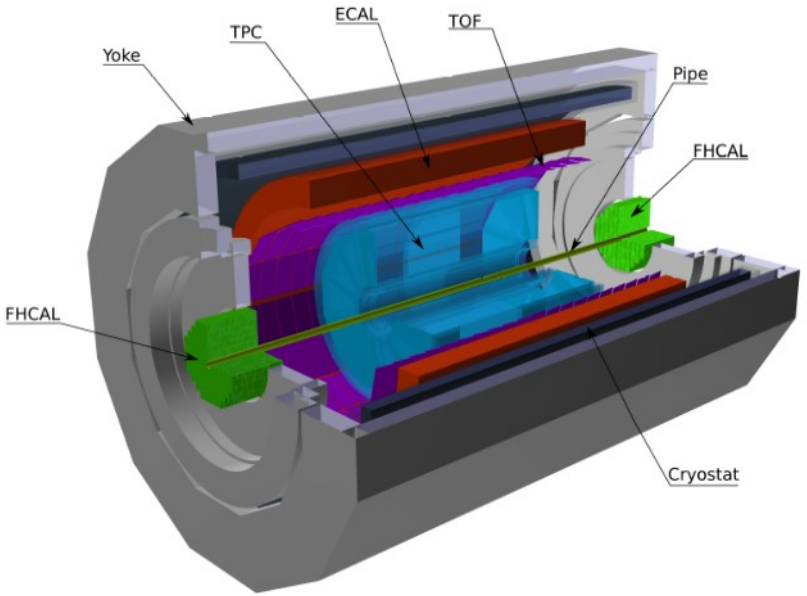
Physics analysis methods

- Flow
- Femtoscopy
- Dileptons
- Stopping power
- Particles decay
- Wiggle structure
- …

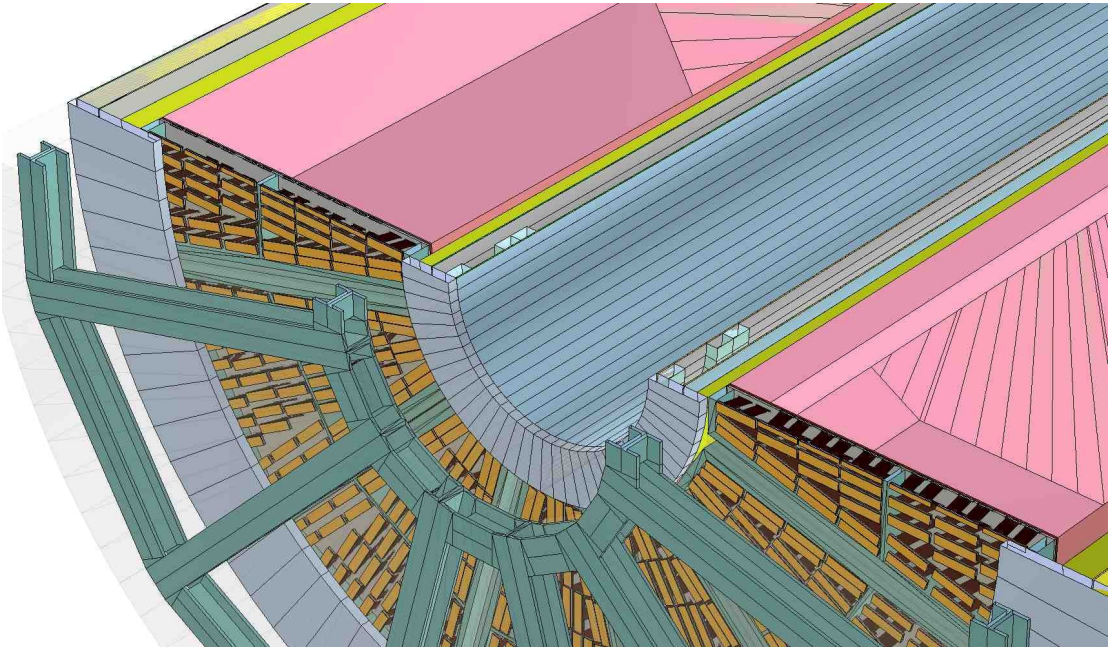
Detector geometry for simulation

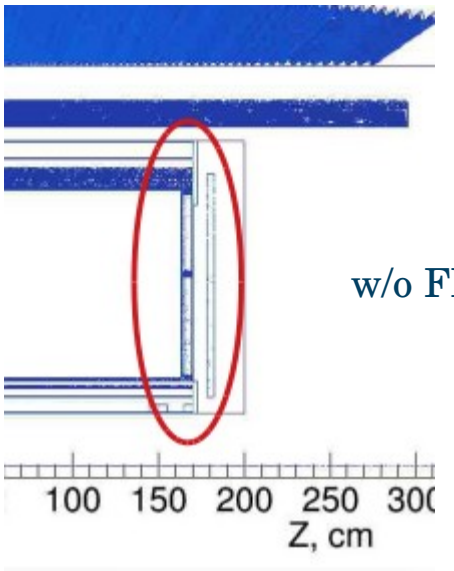




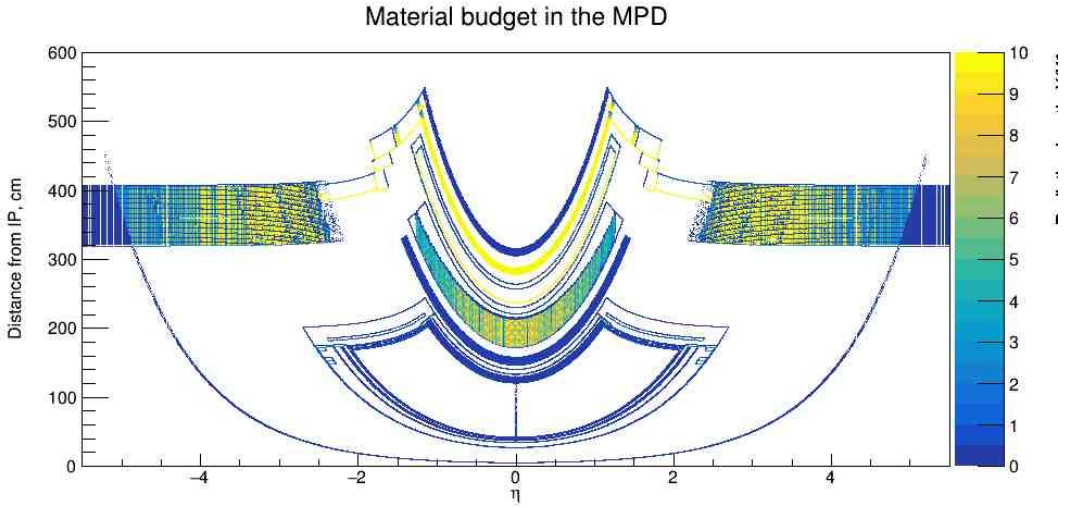


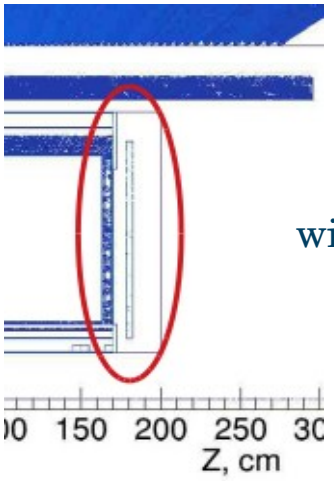
TPC endcap transparency





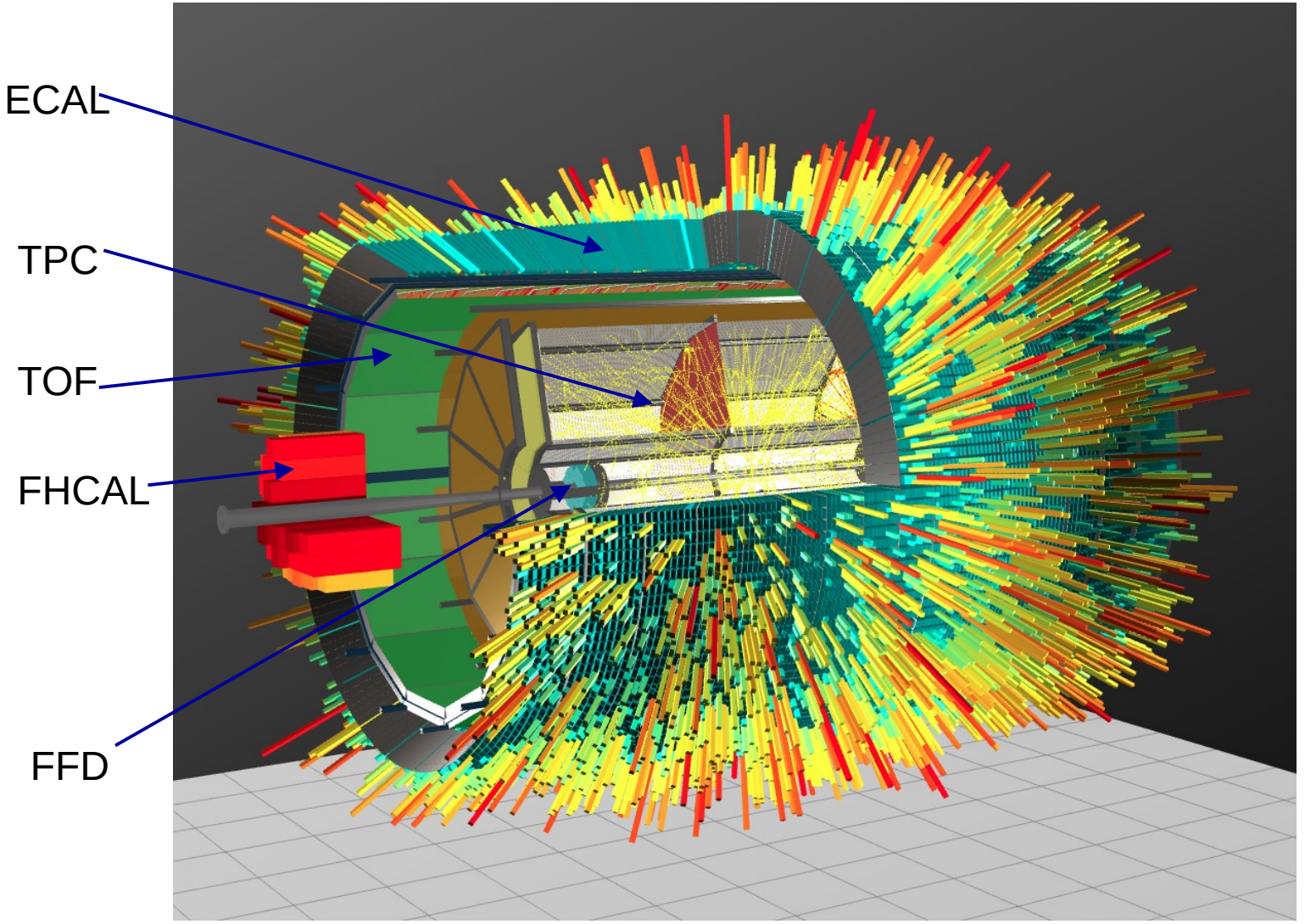
w/o FEE



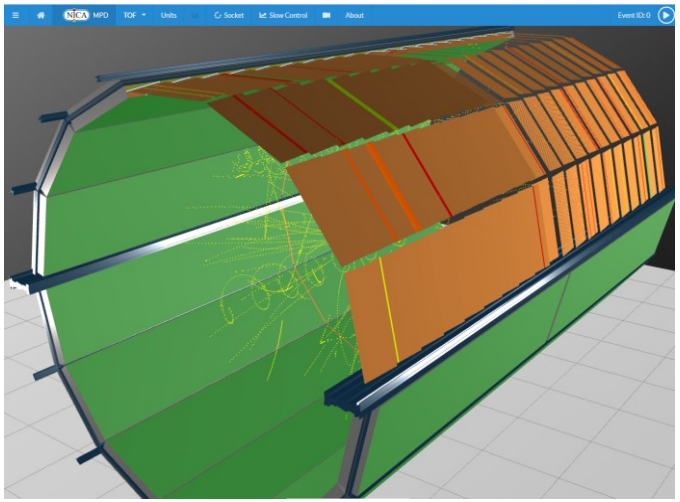


with FEE

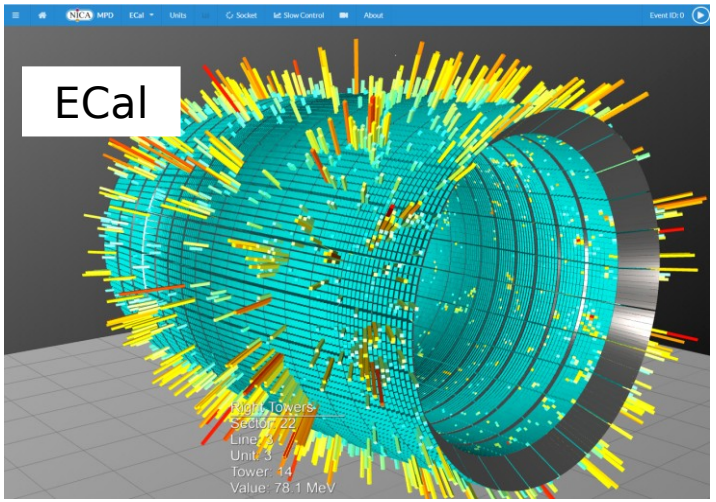
MPD eventdisplay

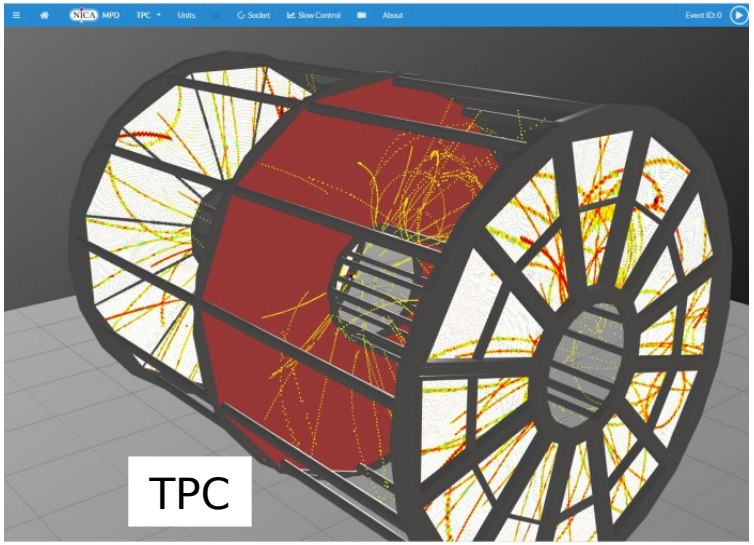


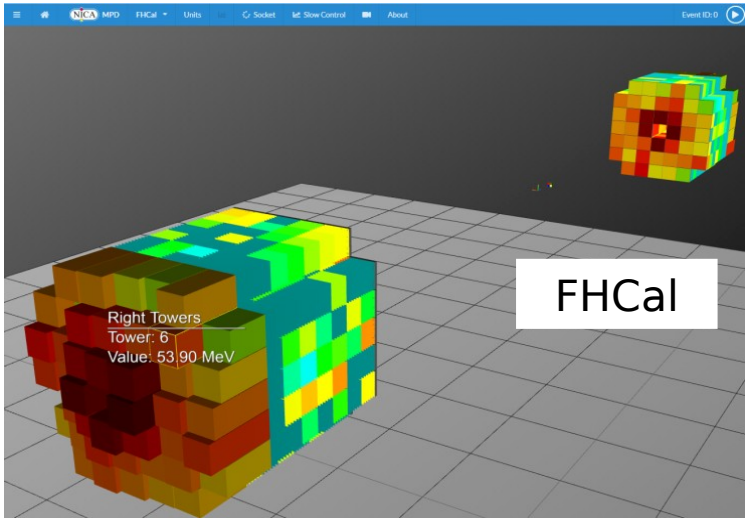
Detectors in event display



TOF

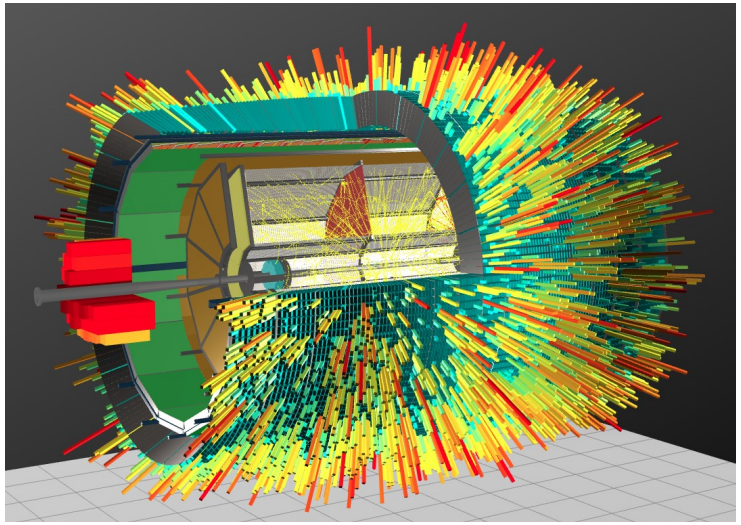






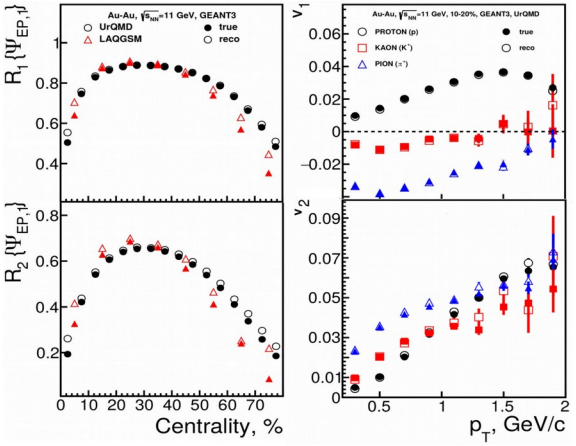
Event recontruction

Experiment

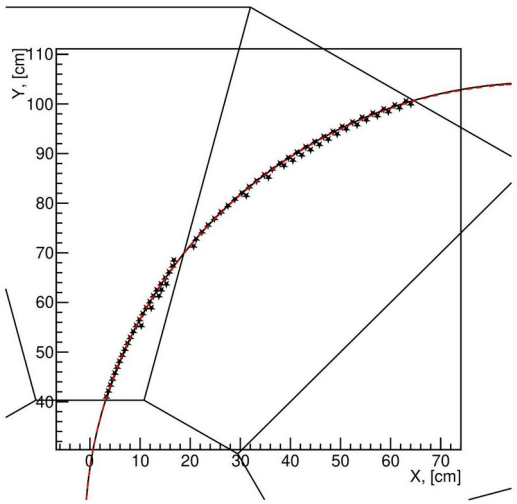


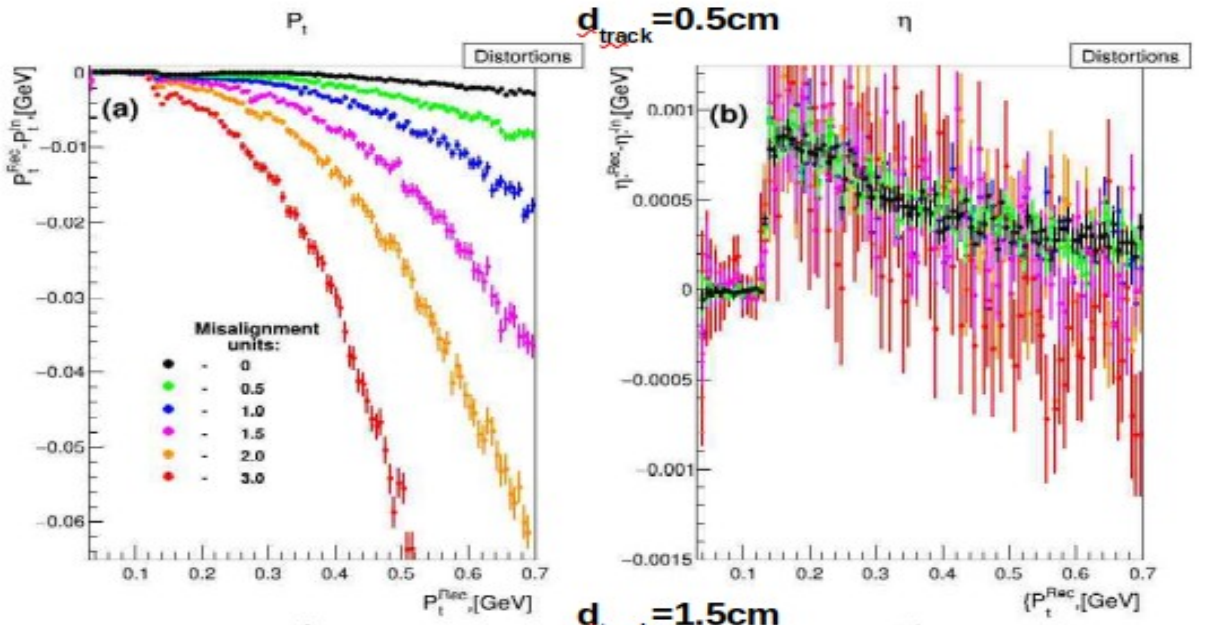
Reconstruction

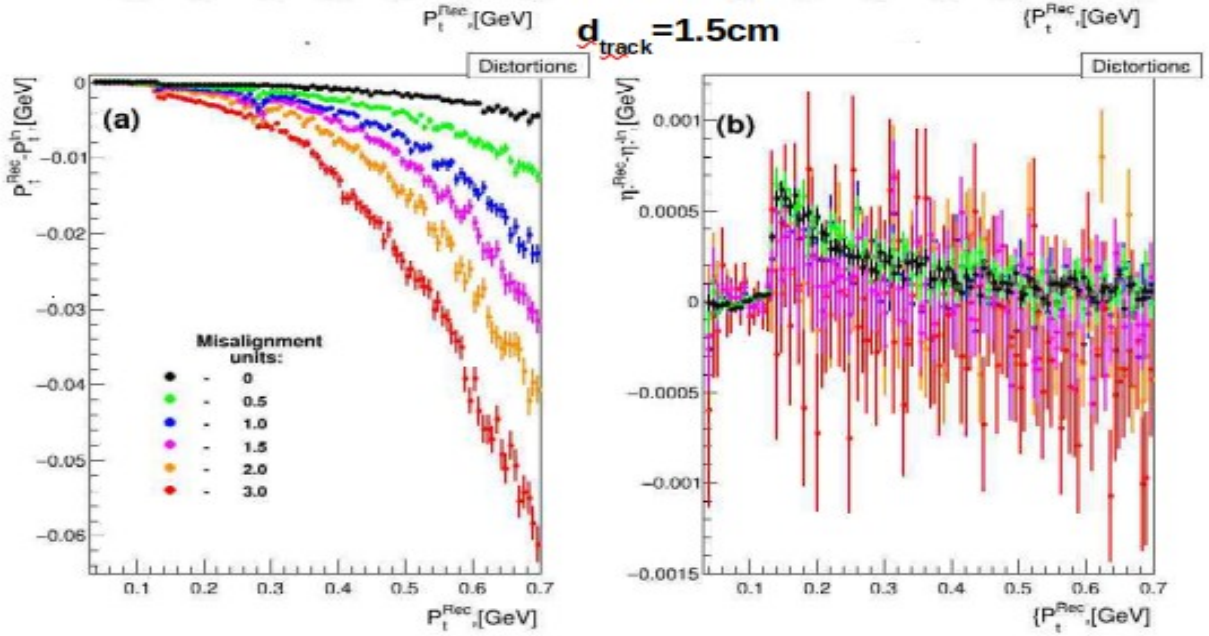
Physics analysis



Detectors alignment



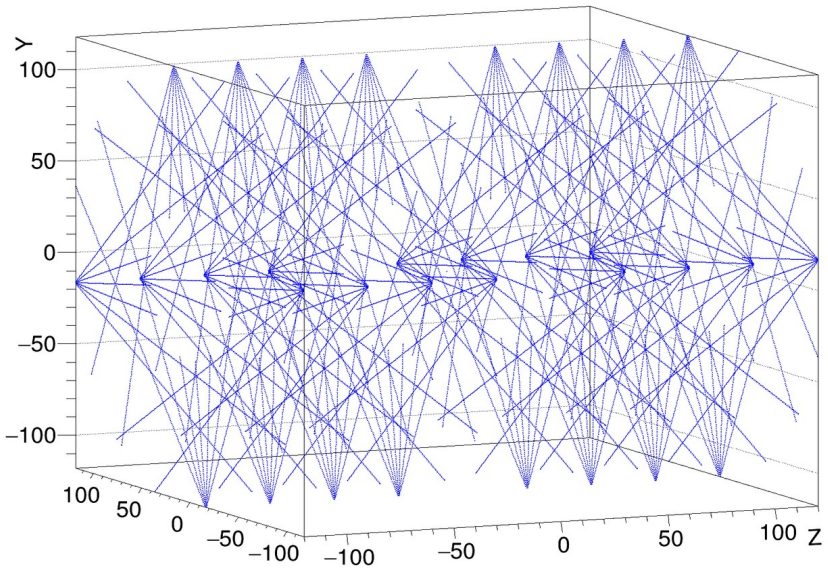


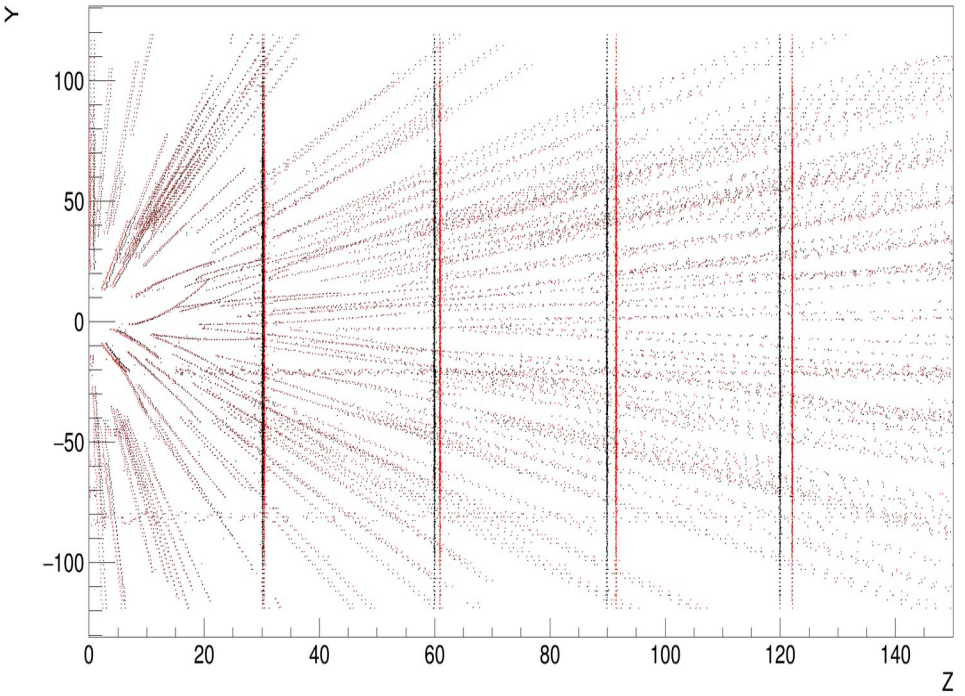


Misalignment "1" means that the average displacement of the sector from its theoretical position on each axis is 0.5 cm, and for the Euler angle this value is 0.5 degrees.

Calculations were carried out for two values of the width of the projection of the track on the surface of the sector: 5 and 15 mm.

Drift time in TPC





Laser system

Two pulsed 130 mJ 5-7 ns Nd:YAG lasers
~1mm diameter
224 laser beams in total

112 “tracks” in each half of the TPC

4 planes of laser beams, 300mm between planes
10 Hz impulses

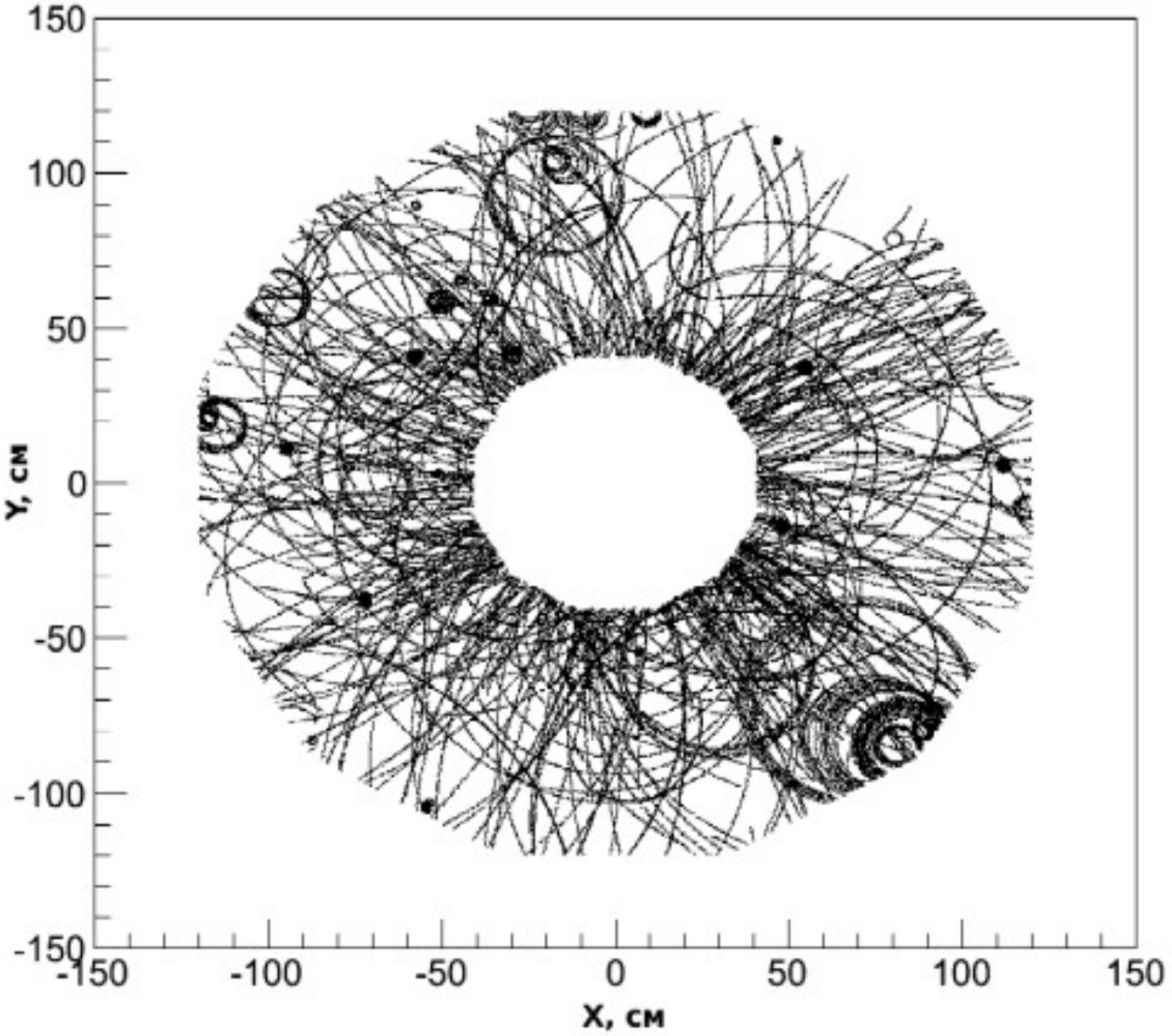
Example correction

V_{drift} = 5.4 cm/μs $t_{trigger}$ = 545 ns

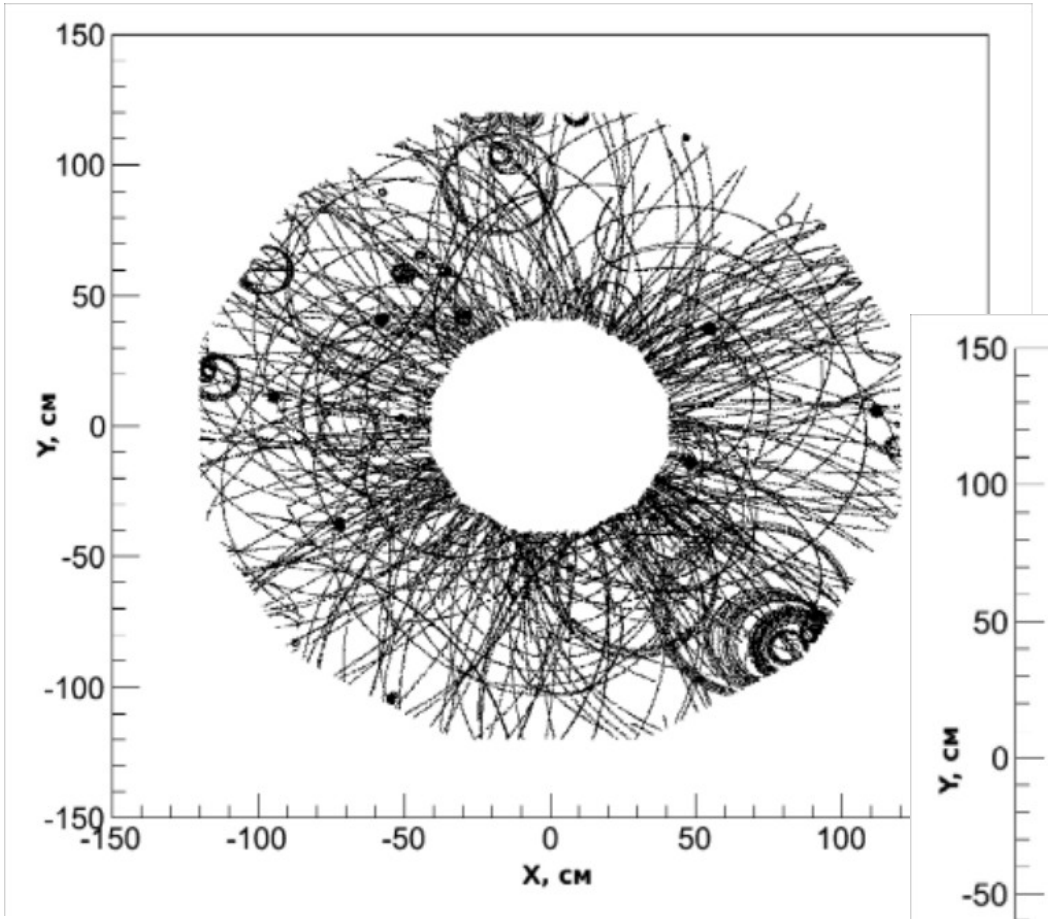
Realistic clustering in MPD TPC

The hit reconstruction algorithm contains the following main steps:

1) Searching for extended clusters in (Pad-Time) for each pad raw.
2) Searching for peaks in time-profile for each pad in the found extended cluster.
3) Combining the neighboring peaks into resulting hits.

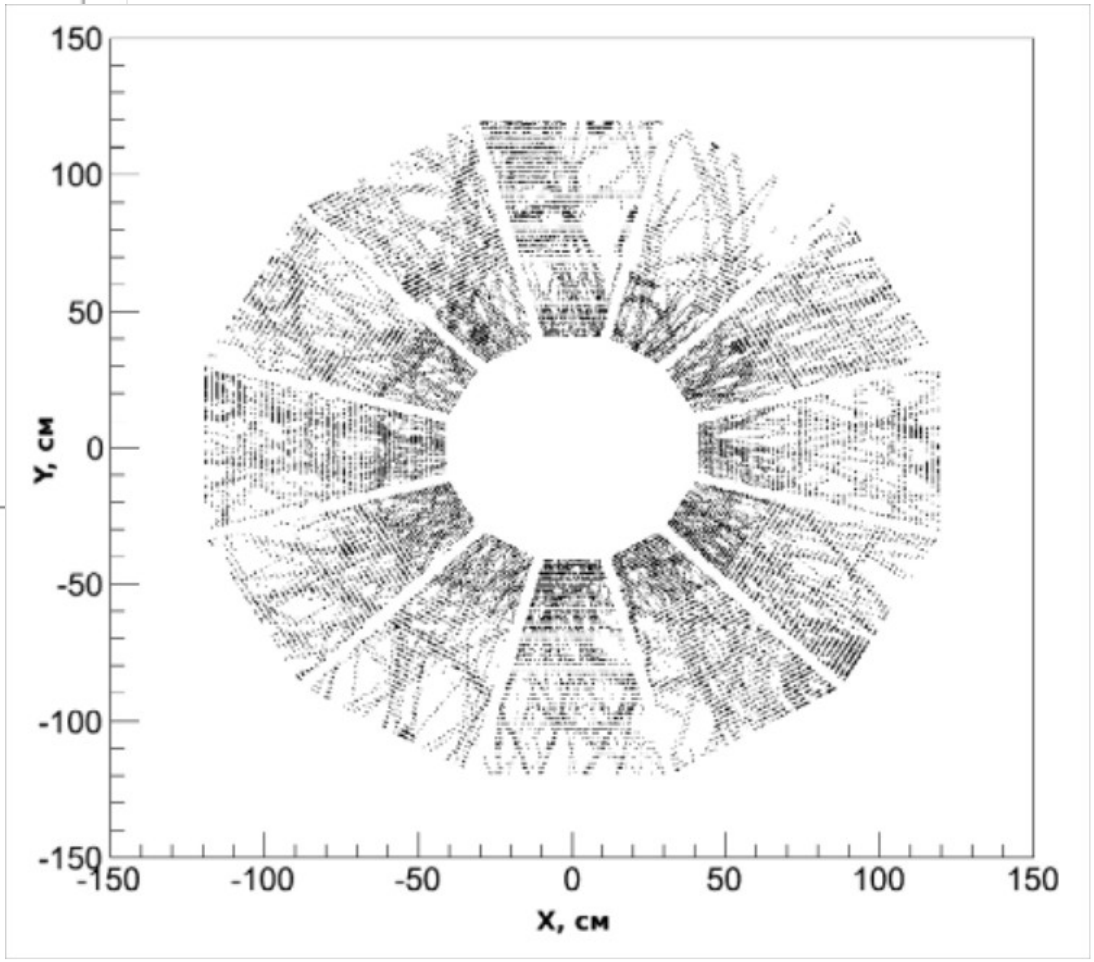


MPD TPC pad plane

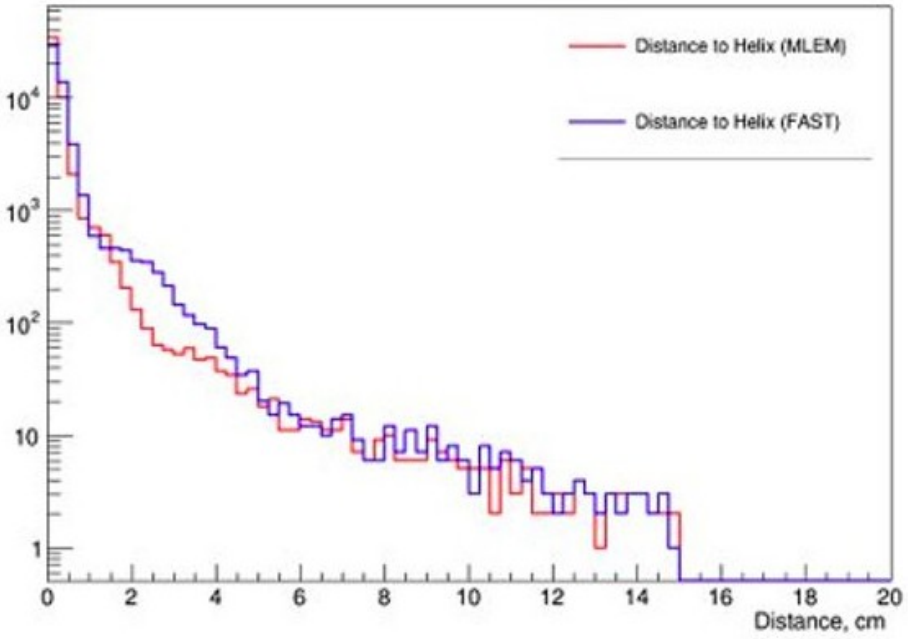


Monte-Carlo points

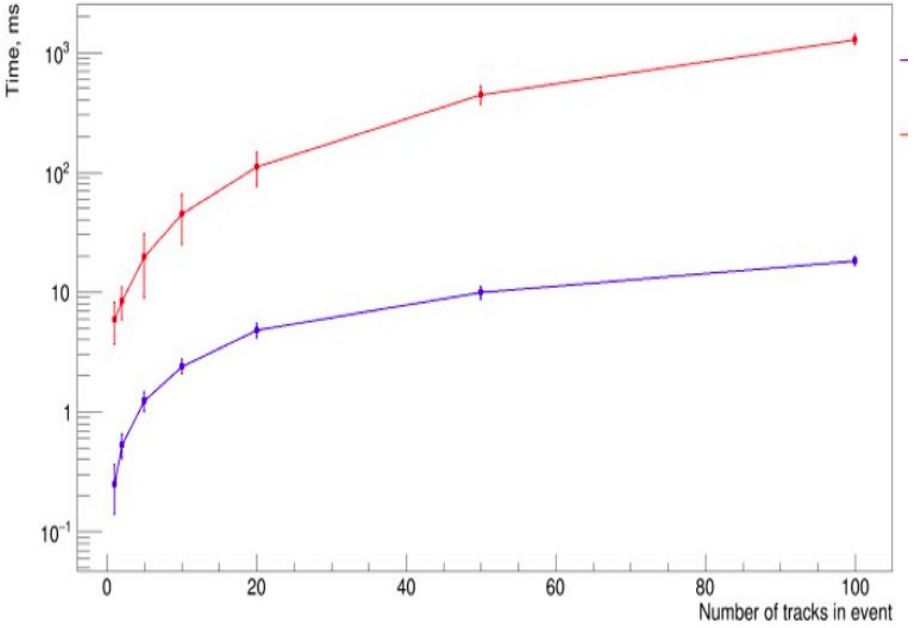
Hits



TPC clustering



standard

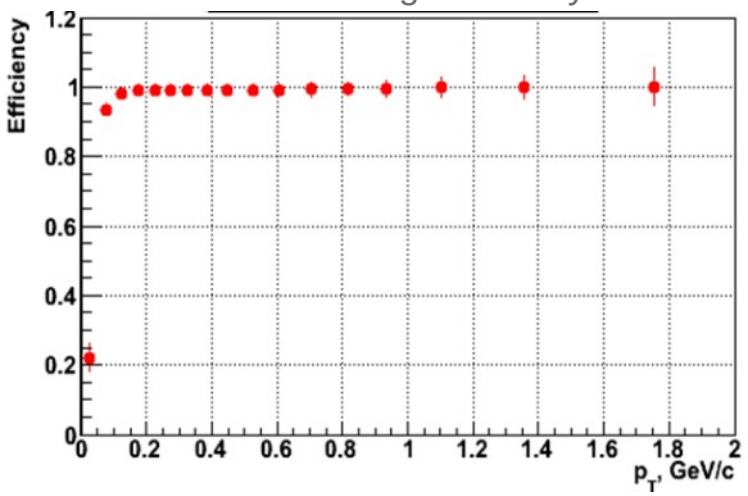


fast

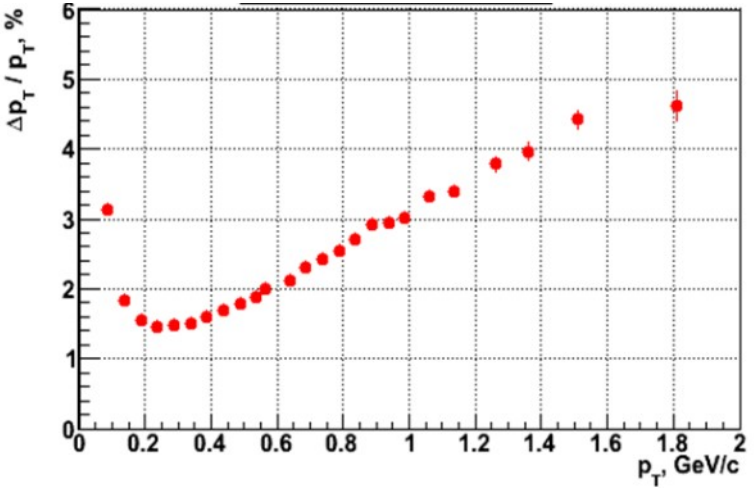
In the future ---> wavelets transform

Tracking in the MPD TPC

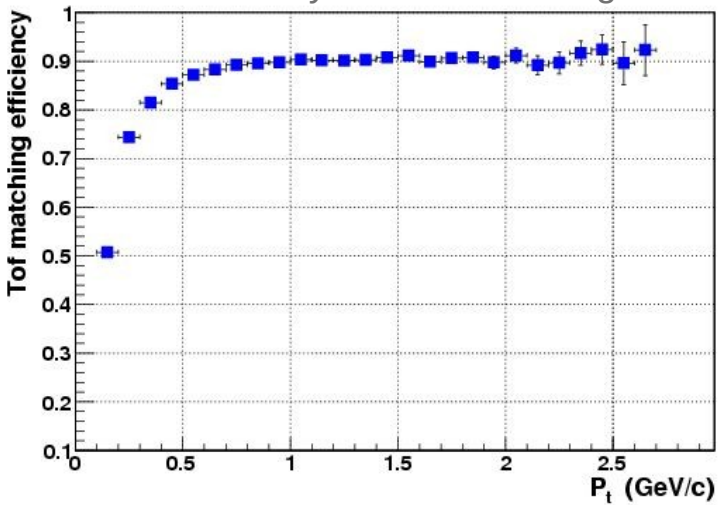
TPC tracking efficiency



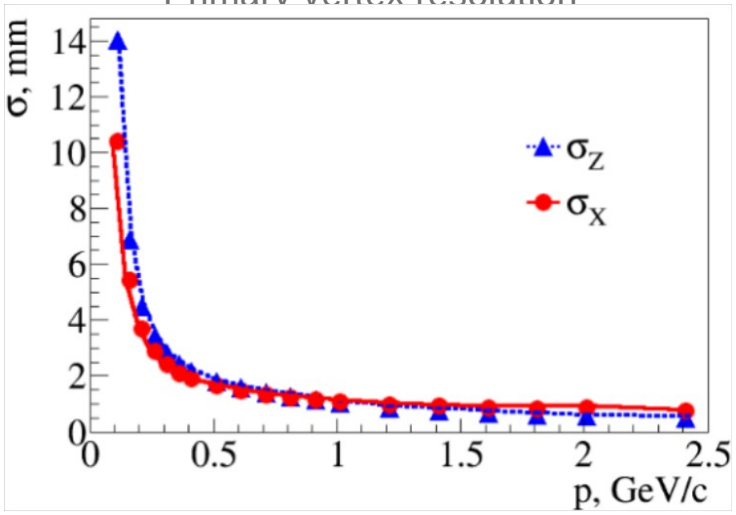
Momentum resolution



Efficiency of TOF matching



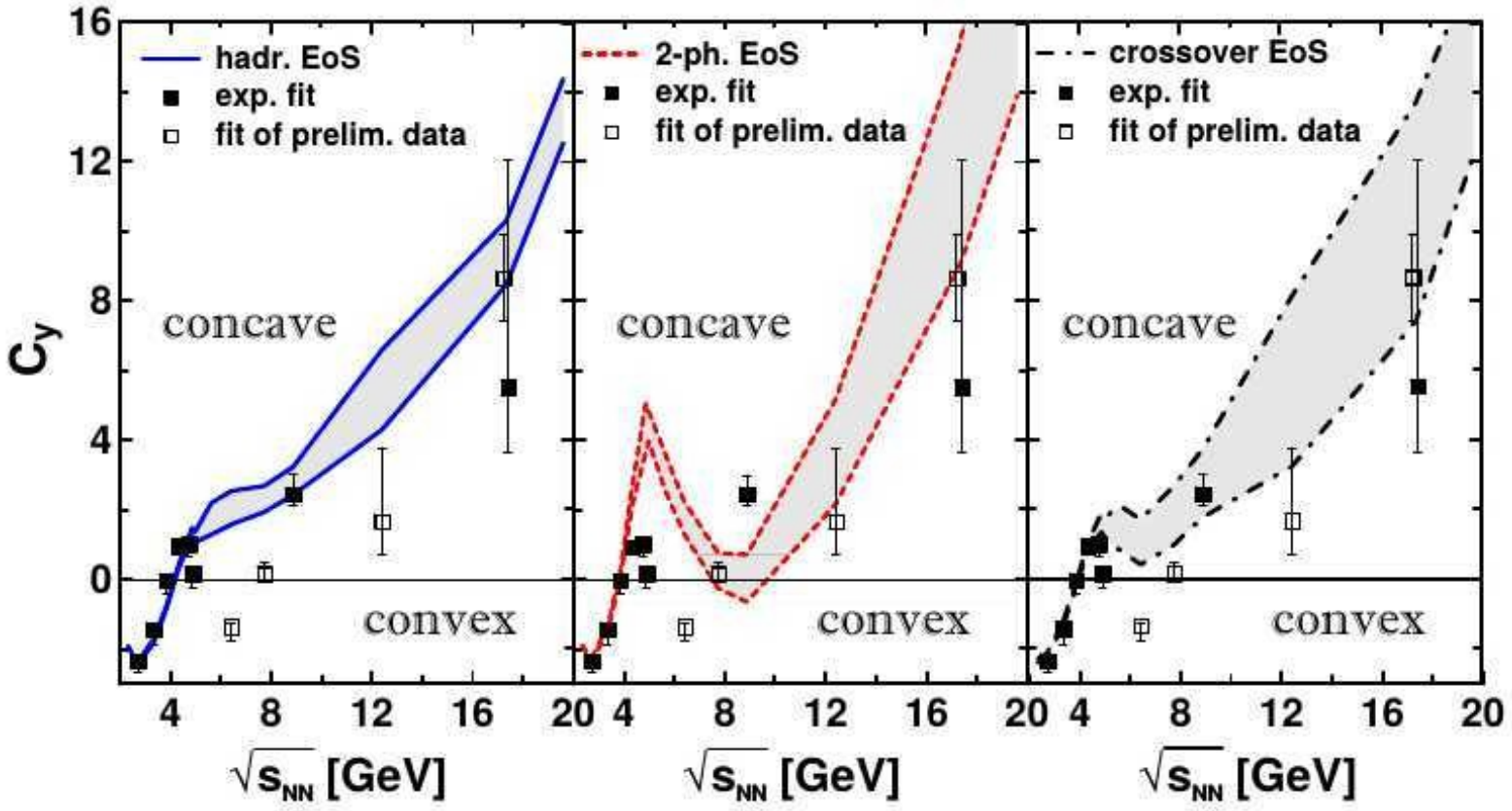
Primary vertex resolution



Net-proton mid rapidity curvature

Yu.B. Ivanov, Phys. Lett. B721 123 (2013)

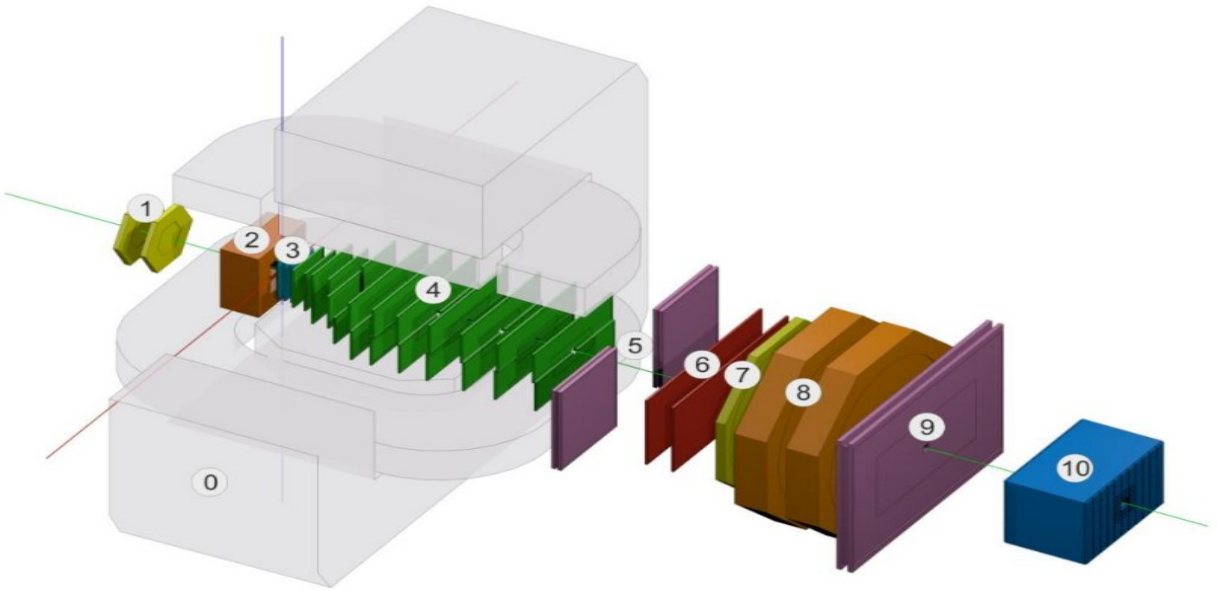
THESEUS



$$C_y = \left(y_{\text{beam}}^3 \frac{d^3N}{dy^3}\right)_{y=0} \Big/ \left(y_{\text{beam}} \frac{dN}{dy}\right)_{y=0} = (y_{\text{beam}}/w_s)^2 \left(\sinh^2 y_s - w_s \cosh y_s\right)$$

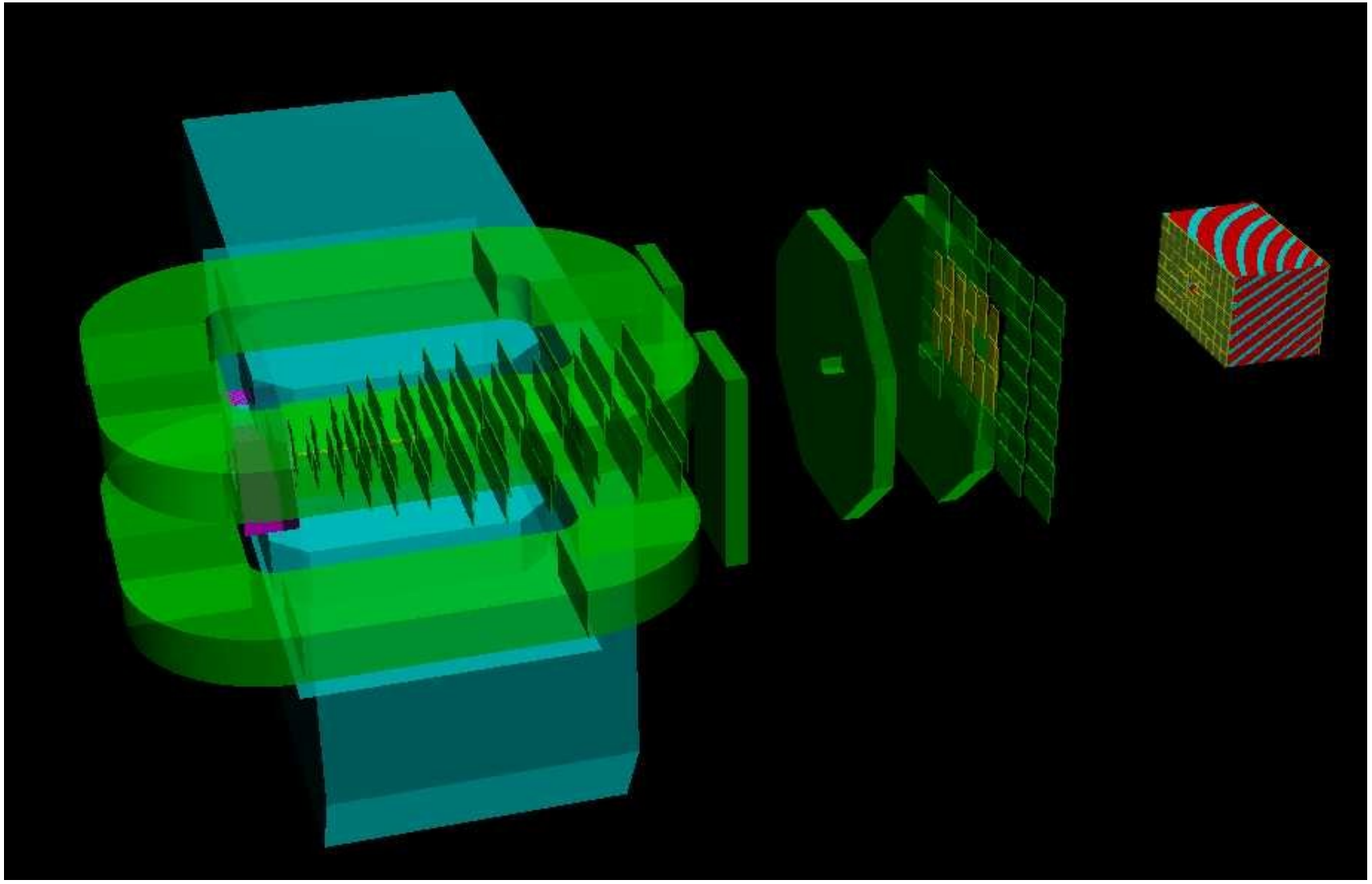
BM@N experiment at NICA

setup in experimental run with 3.2 AGeV Ar beam, 2018

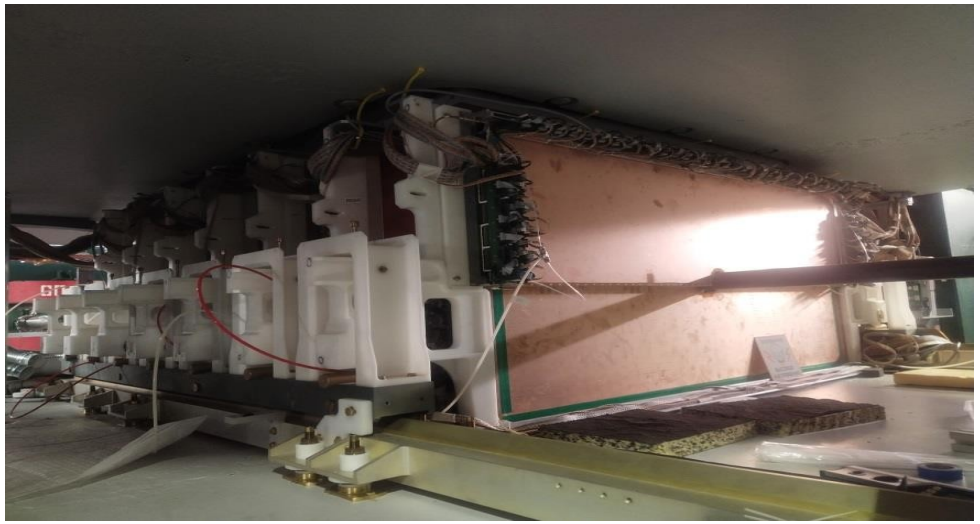


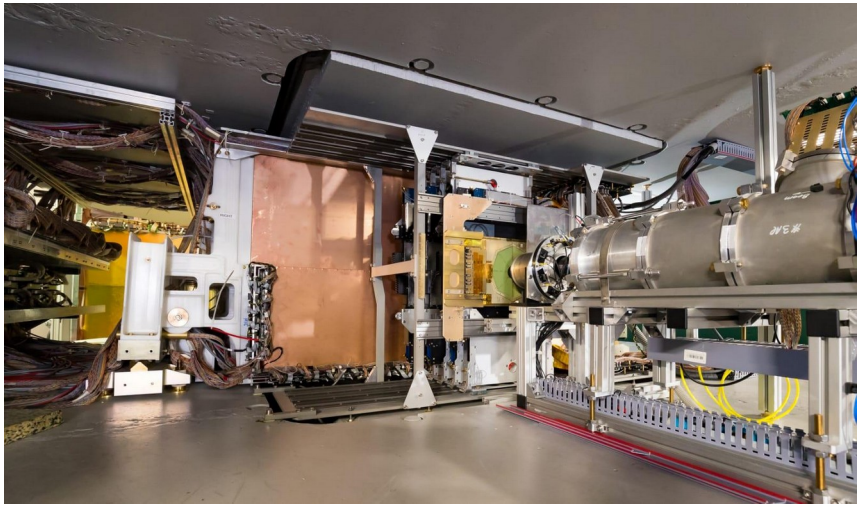
0 Analyzing magnet
1 MWPC
2 Recoil (+T0T)
3 ST (Silicon Tracker)
4 GEM
5 TOF1(mRPC)
6 CPC
7 Straw
8 DCH
9 TOF2(mRPC)
10 ZDC

BM@N Geant geometry



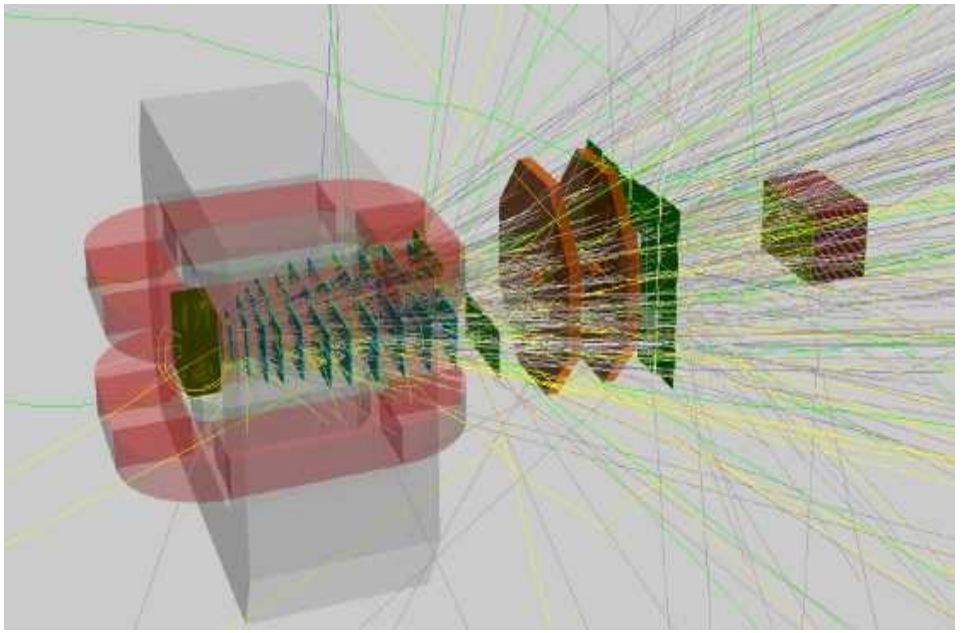
BM@N experiment at NICA



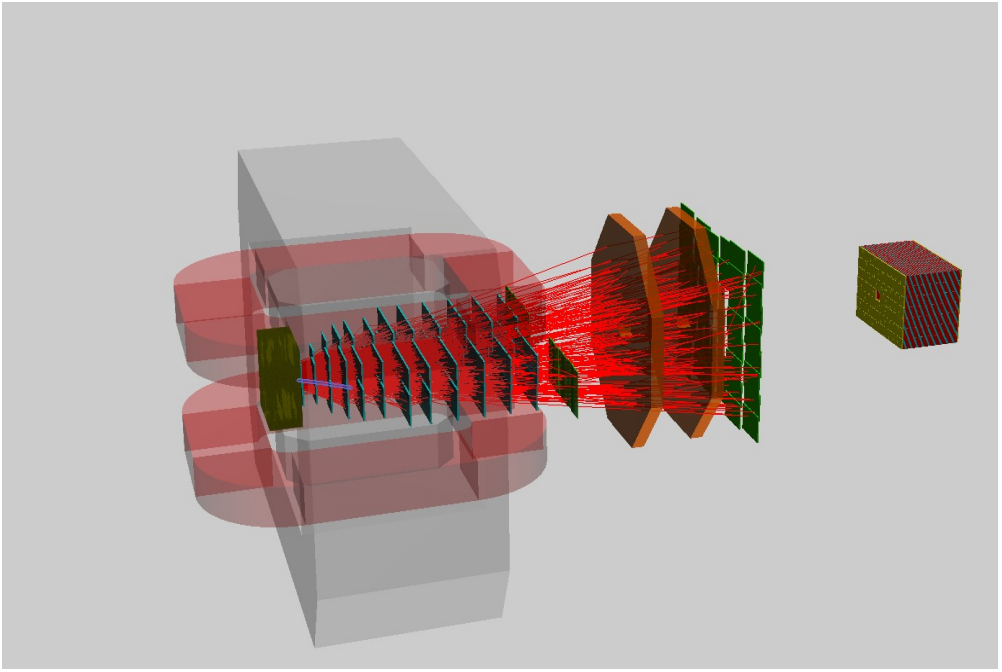


BM@N tracks

Monte-Carlo

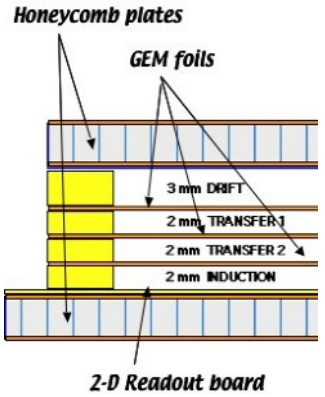


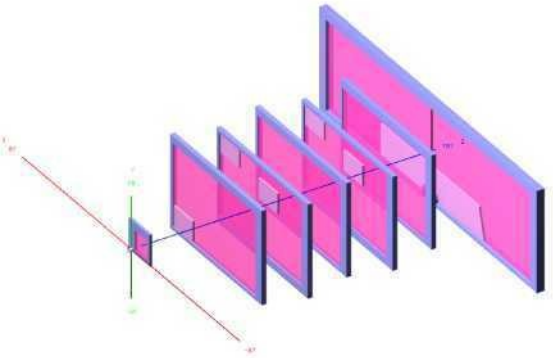
Reconstracted



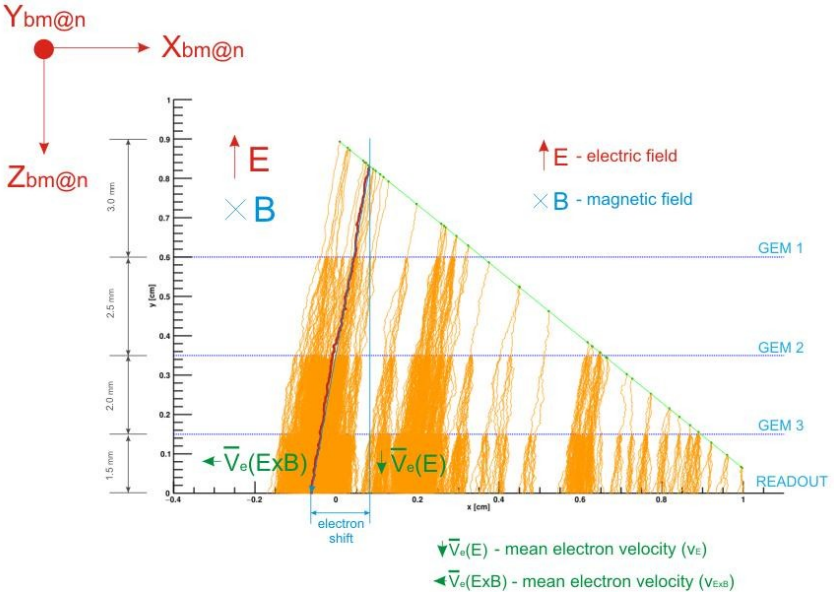
Clustering in GEM

- There are realistic hit finder in GEMs
- For the GEM stations procedure of the fake hits production is implemented

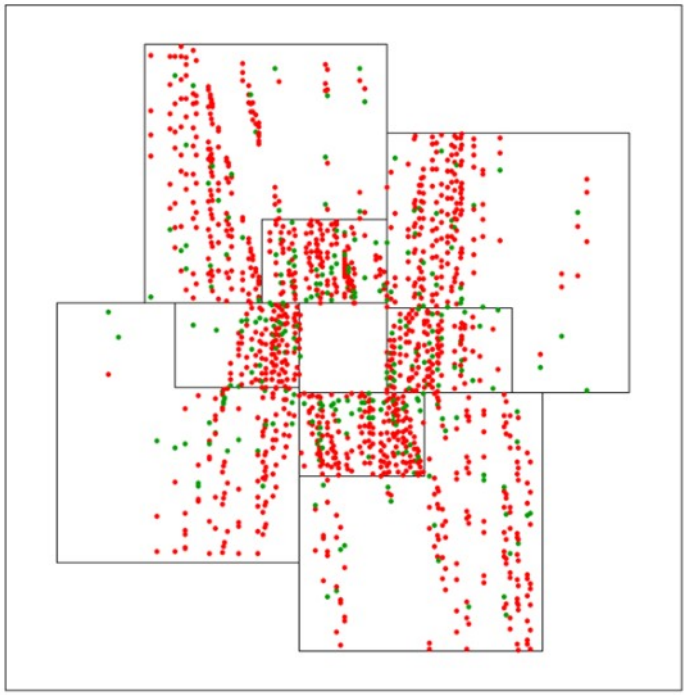




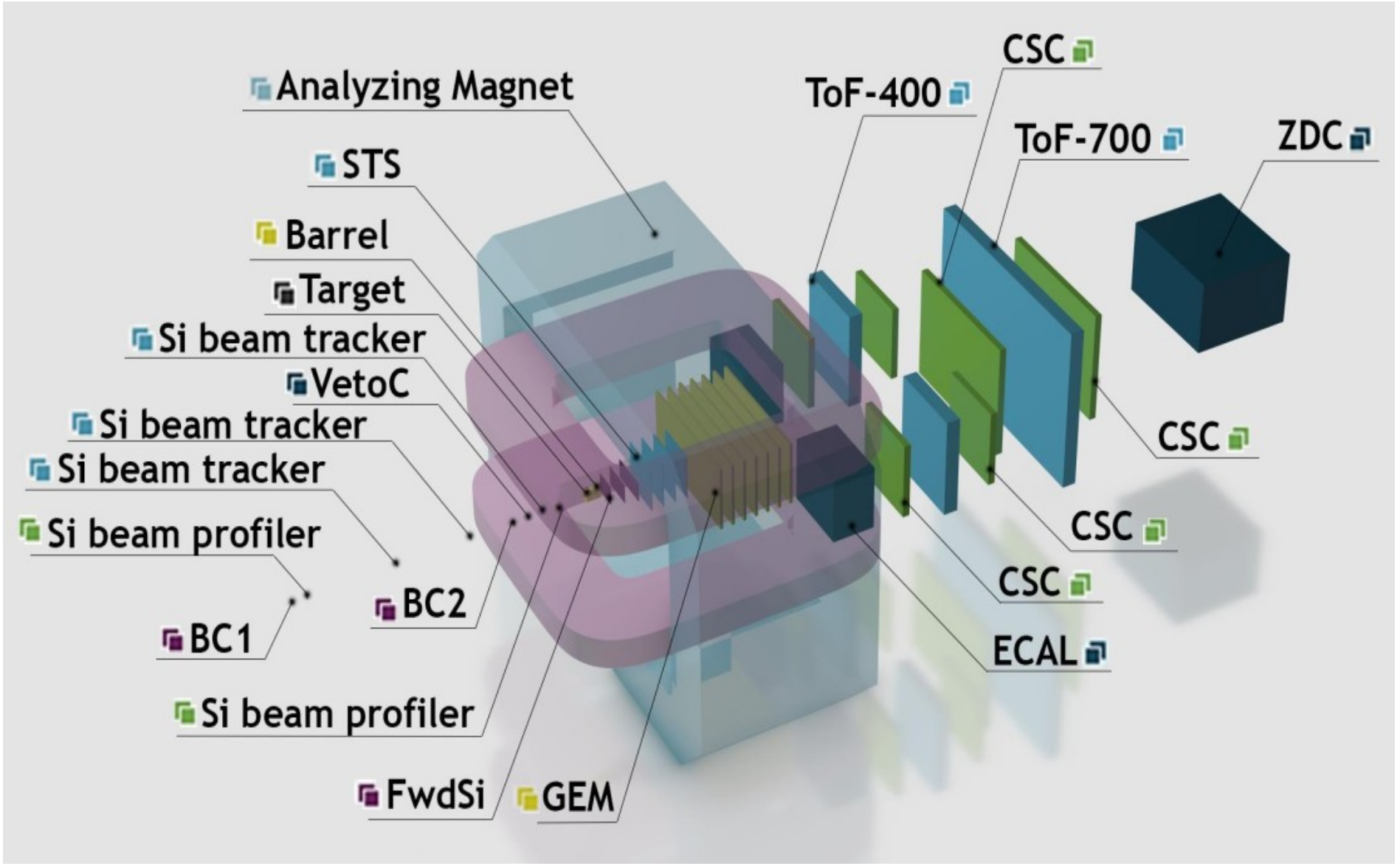
Station 0 (what is it)



electron avalanches in the BM@N GEM chamber

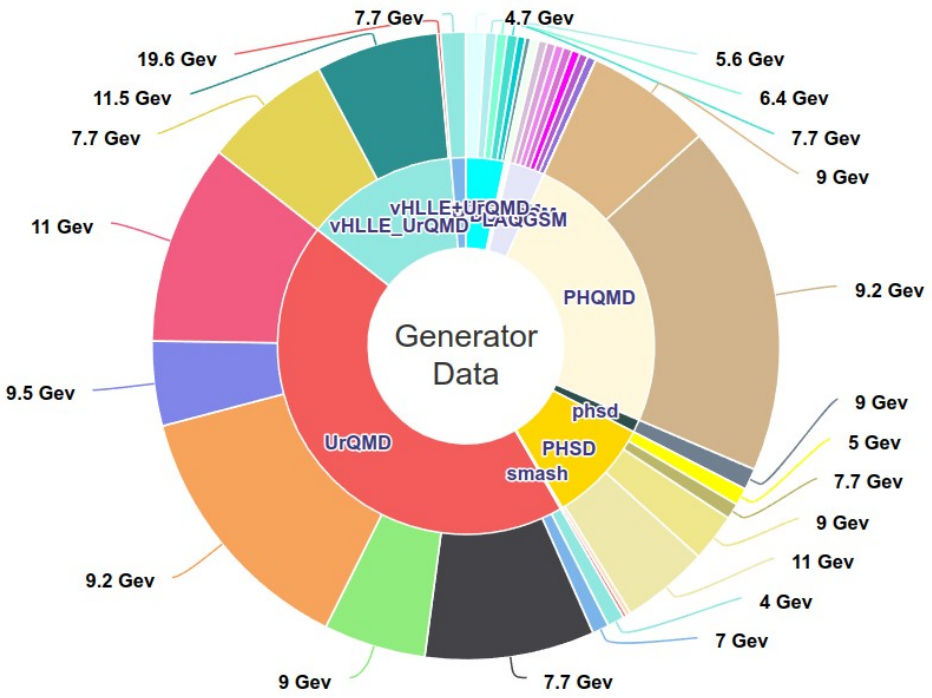


BM@N experiment after 2025

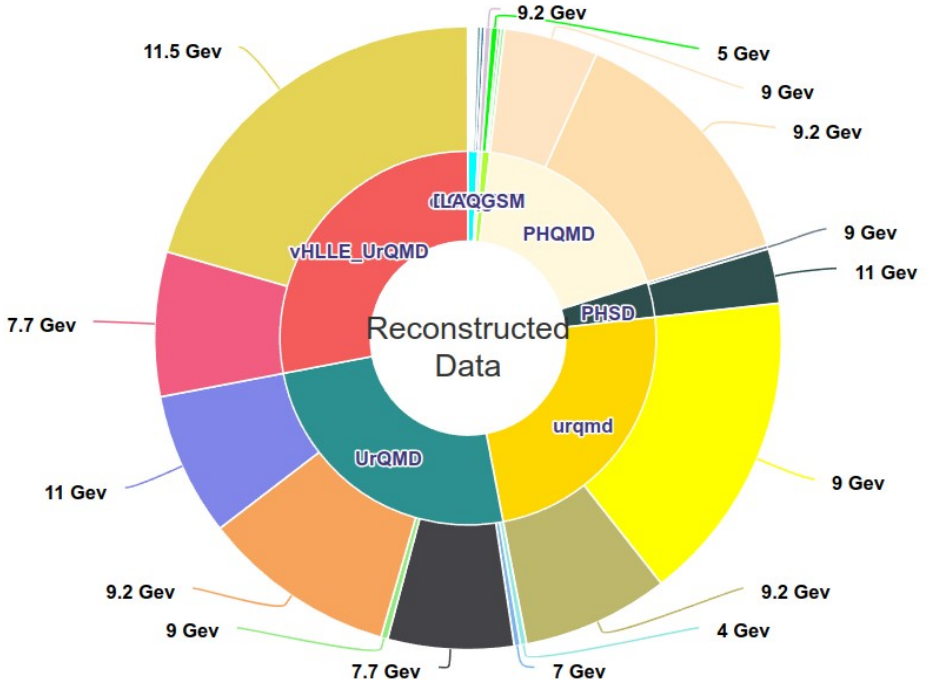


MPD MC data mass production

MC events
> 1300M



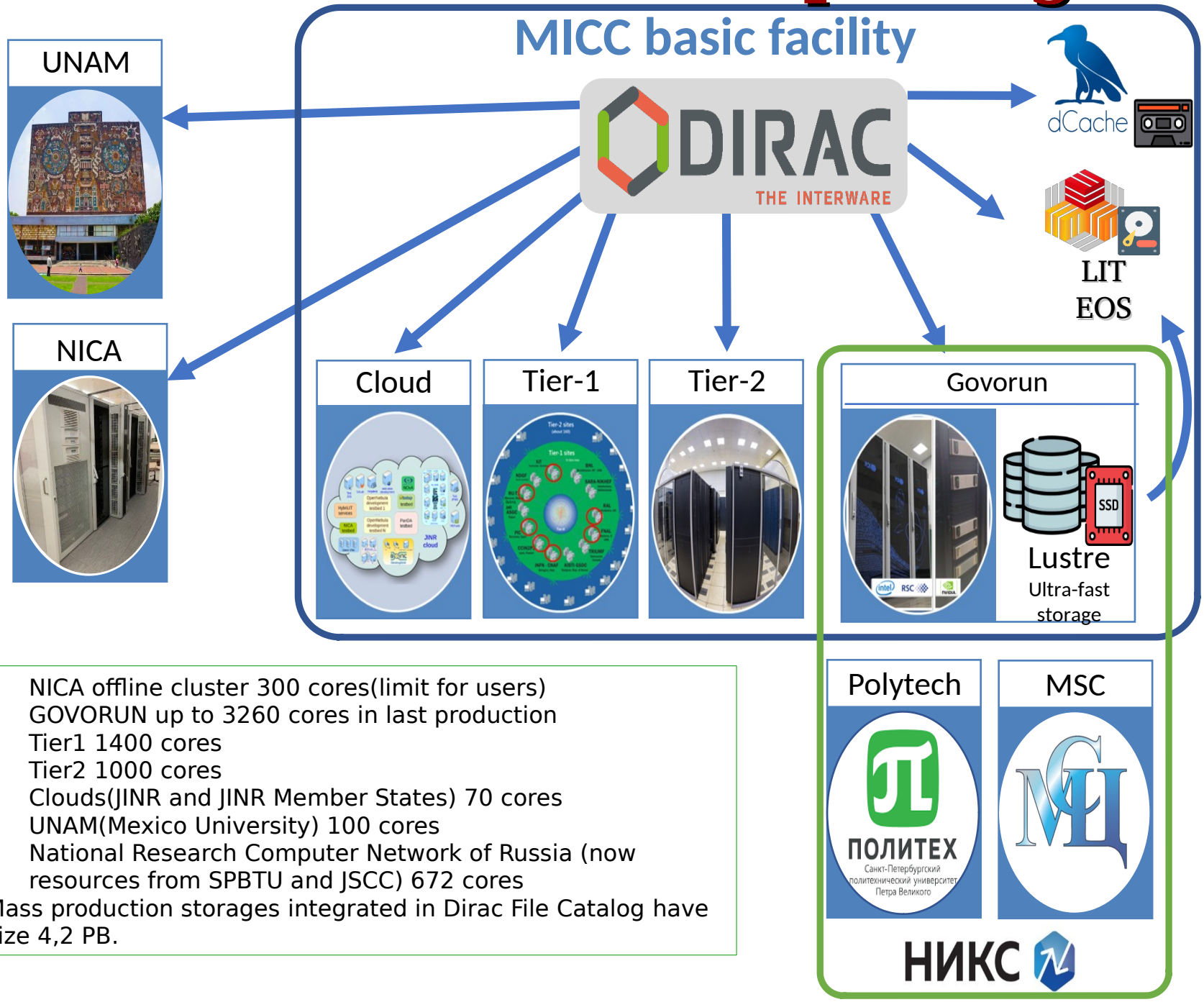
Reconstructed events
> 500M



MC Data set for MPD

Generator	PWG	Coll.		# of events()	Reco
UrQMD	PWG4	AuAu	11	15	+
		BiBi	9	10	+
			9.46	10	+
			9.2	95	+
	PWG2	AuAu	11	10	+
	PWG3	AuAu	7.7	10	+
		BiBi	7.7	10	+
			9	15	+
		pp	9	10	+
		BiBi fix target	2.5	12	+
		BiBi fix target	3.0	(12 underway)	+
		BiBi fix target	3.5	(12 underway)	+
	PWG1	BiBi	9.2	11(50 underway)	+
DCM-SMM	PWG1	BiBi	9.2	1	+
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				1293(74 underway)	449(74 underway)

NICA distributed computing



- NICA offline cluster 300 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 4,2 PB.

ЛАБОРАТОРИЯ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ имени М.Г. Мещерякова

hYBRI LIT/JINR

NICA

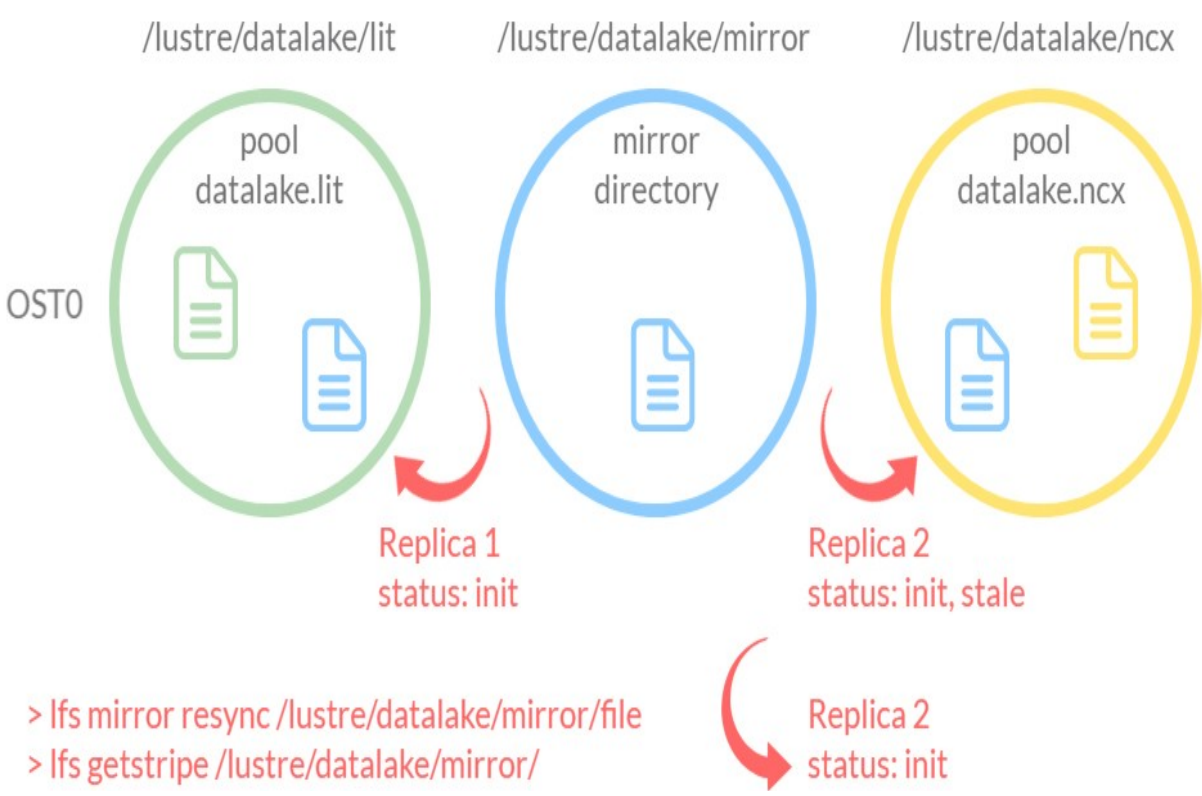
LHEP ЛФВЭ

lustre

Distributed system for processing and data storage for experiments at the Complex NICA

MLIT Team

Belyakov D.V., Dolbilov A.G., Kokorev A.A., Lyubimova M.A., Pelevanuk I.S., Podgainy D.V.



LHEP Team

Moshkin A., Rogachevsky O., Slepov I.

MLIT servers

2x Dell PowerEdge R730xd

2x 160 TB, SAS

Motherboard	PowerEdge R730/R730xd System Board
Processor	2x Intel Xeon E5-2660 v4 @ 2.00 GHz
Memory	8x Micron DDR4 2400 MHz, 16 GB (128 GB)
RAID	Dell PERC H730P
Disk	2x Dell MFC6G (Samsung) SSD SAS, 400 GB (2x 400 GB) 16x HGST UltraStar HE10 SAS, 10TB (160 TB)
Network	Dell 99GTM (Intel X540-T2 2x 10 Gb/s + Intel I350 Dual Port 2x 1 Gb/s)
Power	2x 750W Redundant Power Supply

Data flow rates 100 Gbps

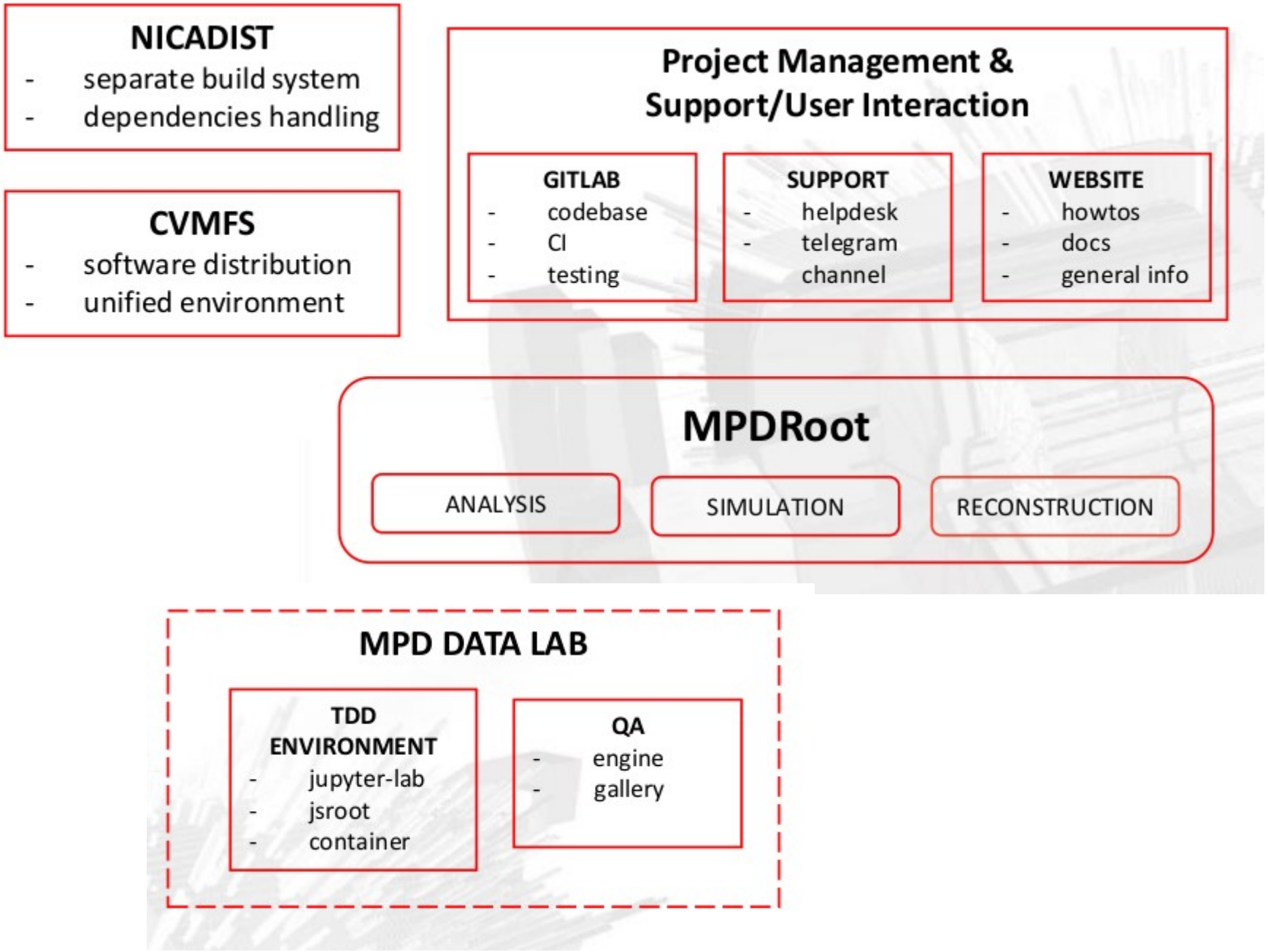
LHEP servers

2x Supermicro SSG 1029P-NEL32R

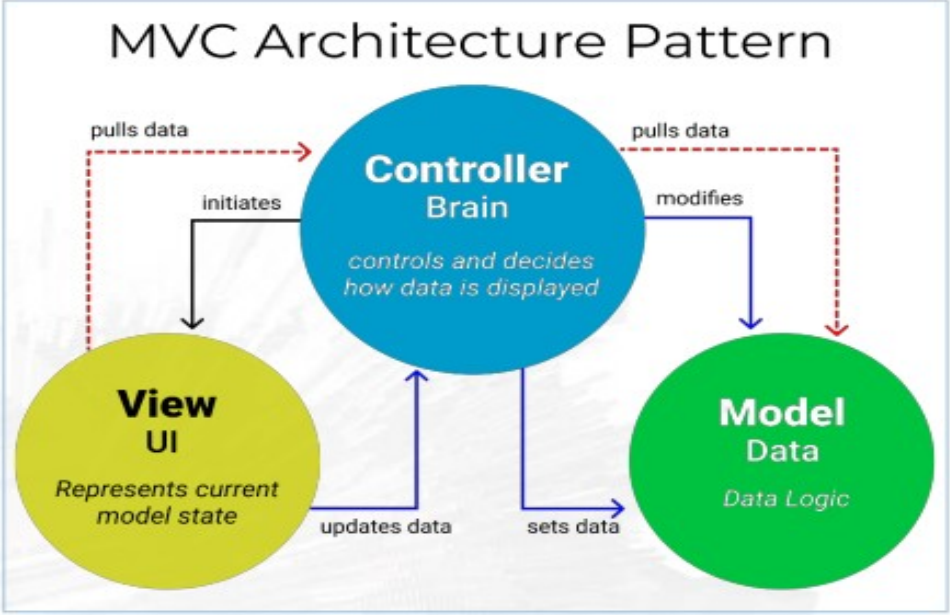
2x 244.8 TB, NVMe (Rulers)

Motherboard	Supermicro X11DPS-RE
Processor	2x Intel Xeon Gold 6230R @ 2.10 GHz
Memory	12x Samsung DDR4 2993 MHz, 64 GB (768 GB)
Disk	2x Apacer SSD NVME m.2 , 512 GB (2x 512 GB) 16x Intel DC P4510 SSD NVME (Ruler), 15.3TB (244.8 TB)
Network	Intel X550-T Dual Port 2x NVidia (Mellanox MT27800) ConnectX-5 Dual Port 2x 100 Gb/s Ethernet
Power	2x 1600W Redundant Power Supply

Software supports



QA tasks



QA ENGINE PROPERTIES

pluggable/switchable reconstruction modules
QA modes to choose Diagnostics depth
writing output in terms of MPD primitives into multiple structured root files
for modular diagnostics and postprocessing

RUNRECO.C
(upcoming v23.09.23 release)

Options:
tpcClustering = ETpcClustering::MLEM
= ETpcClustering::FAST
= ETpcClustering::WAVELET (soon)

qaSetting = EQAMode::OFF
= EQAMode::BASIC
= EQAMode::TPCCLUSTERHITFINDER
= EQAMode::TRACKER (soon)

Upcoming:
tracker = ETracking::DEFAULT
= ETracking::ACTS

Output example: BaseQA_Fast.root, QA_TpcClusterHitFinder_Fast.root
Settings: EQAMode::TPCCLUSTERHITFINDER, ETpcClustering::FAST

Test Driven Development

- Jupyter-Lab with JSRoot
- Custom code injection
- Cell structure with reprocess option
- Graphical output customized on demand
- Algo tuning to real experiment data

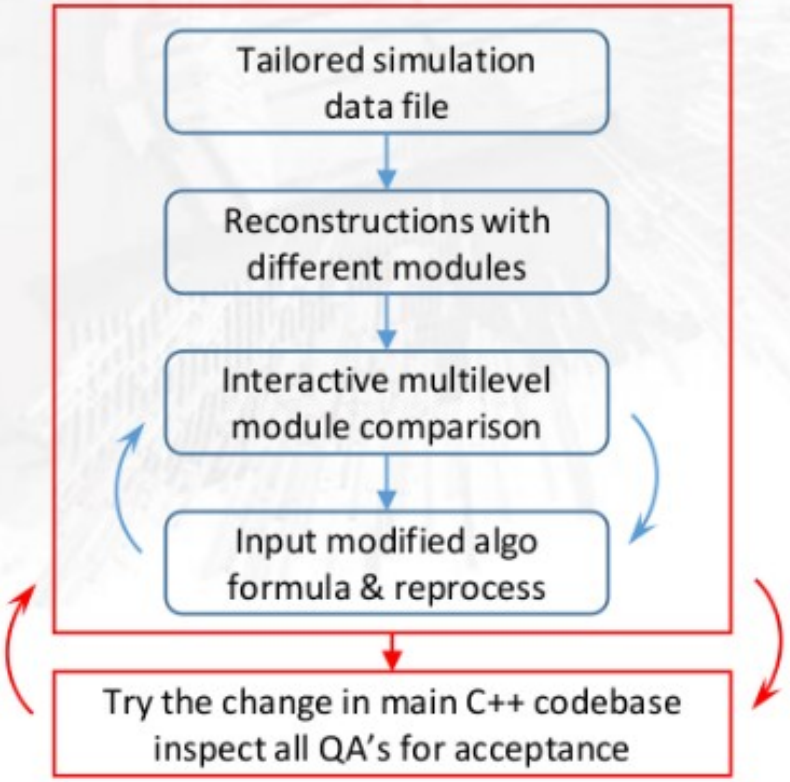
CLUSTERHITFINDER COMPARISON

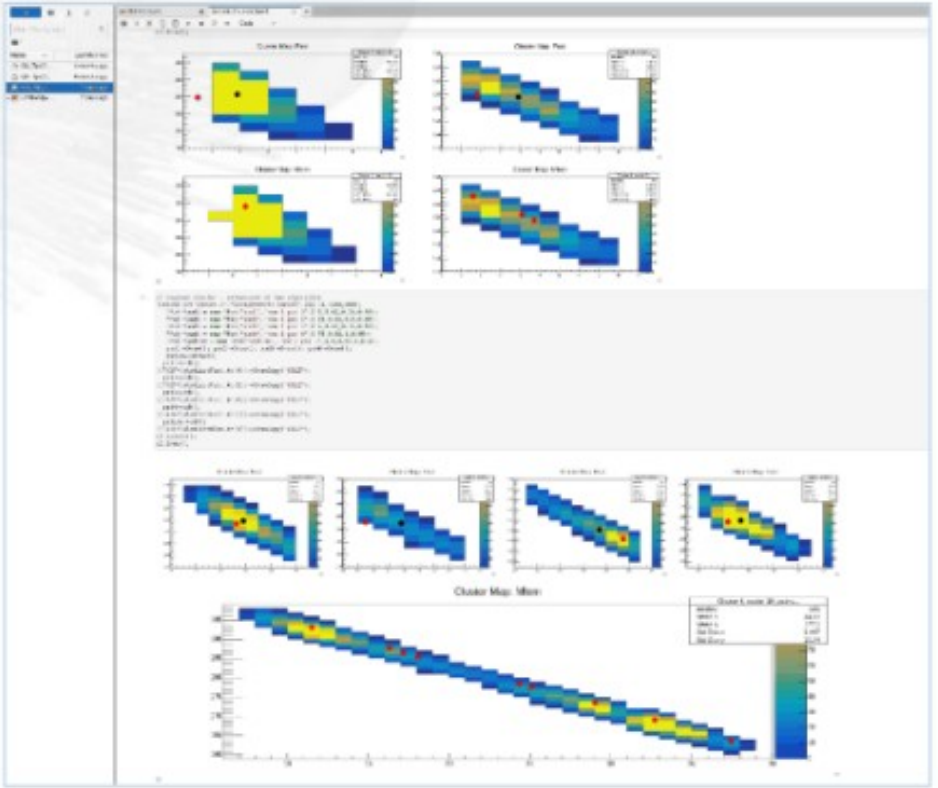
- Mlem
- Fast

ABSTRACTION LEVELS

- Top .....bench.....Reconstruction
- Middle.....component....ClusterHitFinder
- Bottom .....units.....Clustering, Topology, Hit extraction

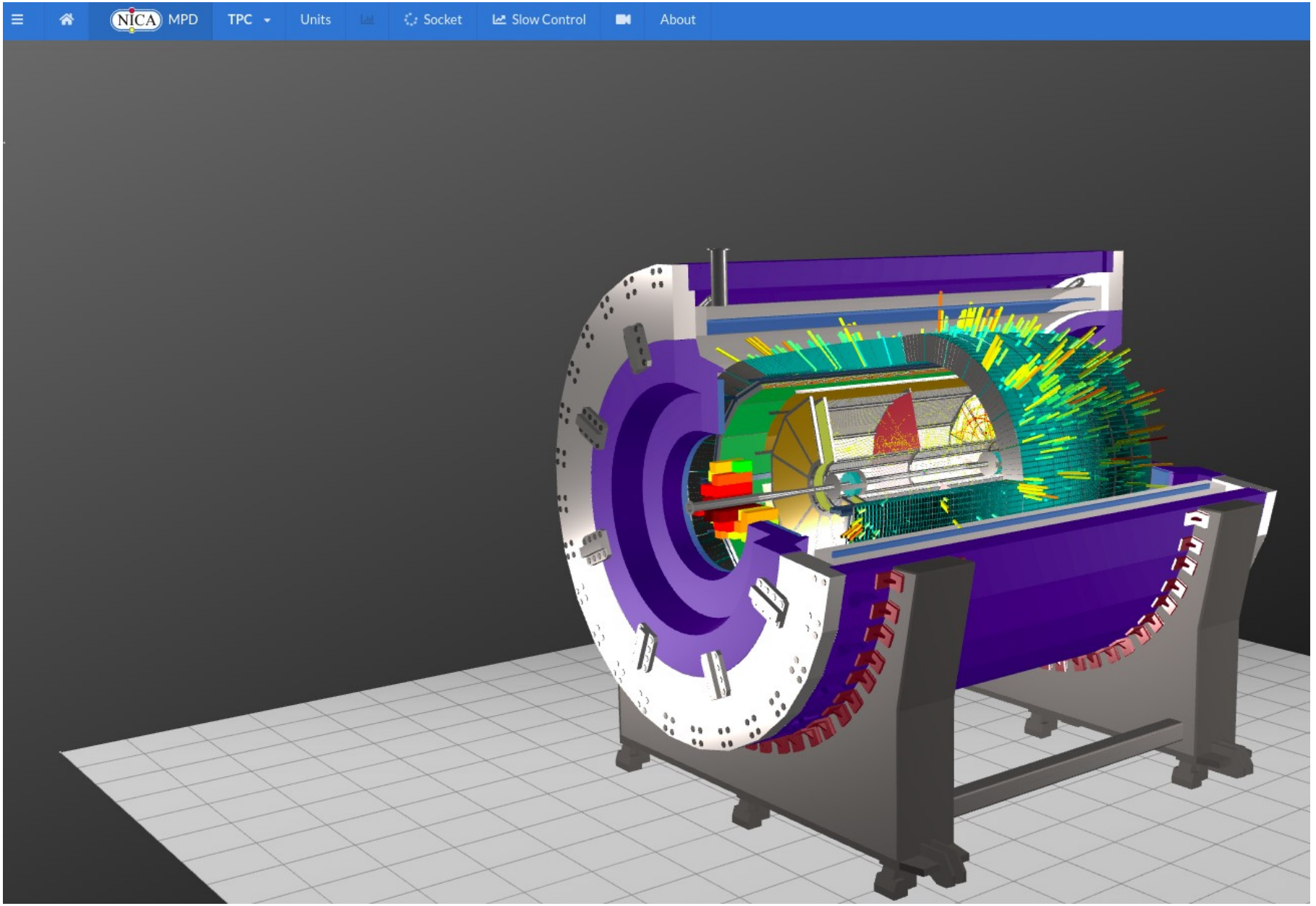
Interactive workflow example



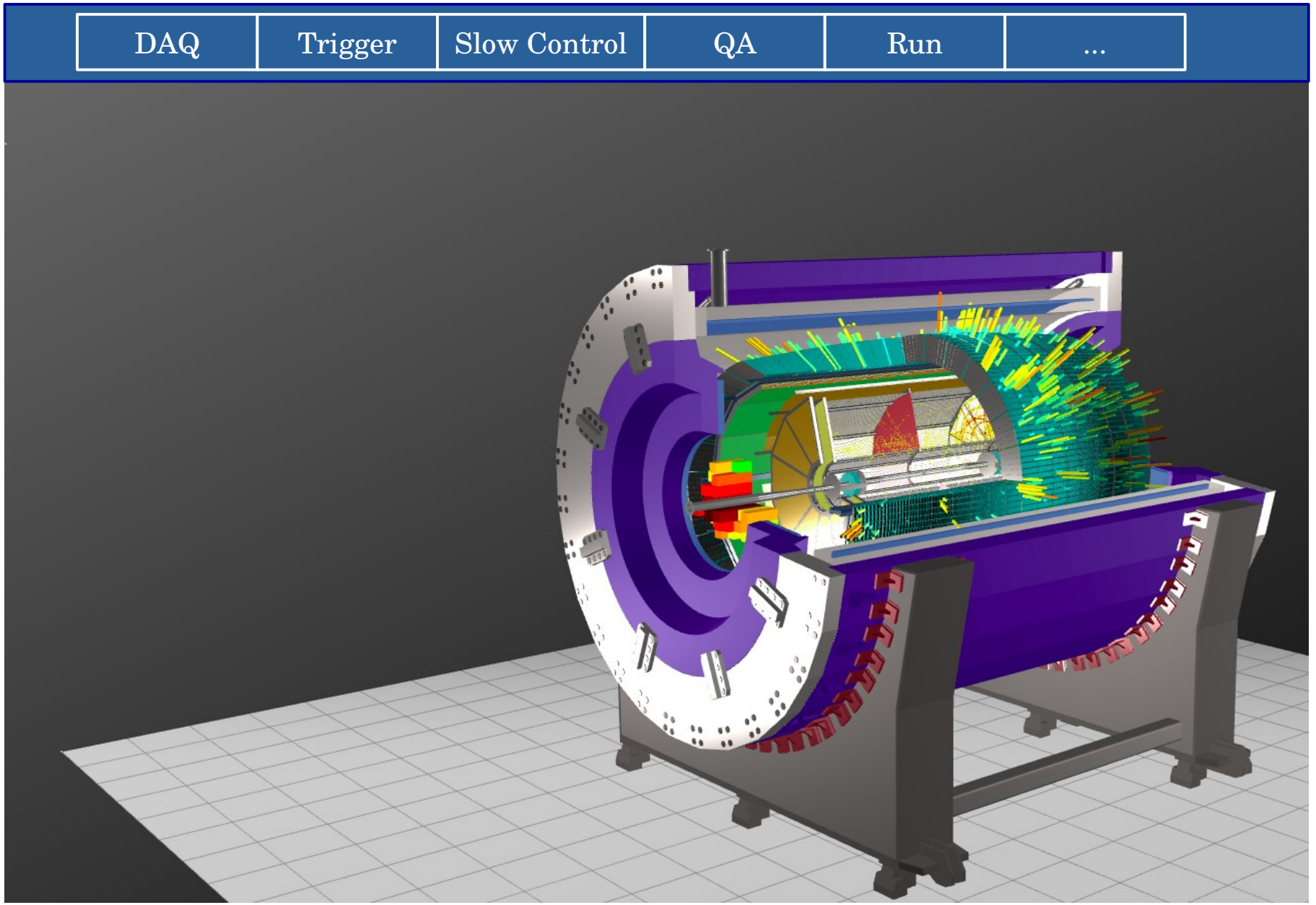


Eventdisplay

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



Eventdisplay to Run Control System



Thank you for attention

to NICA