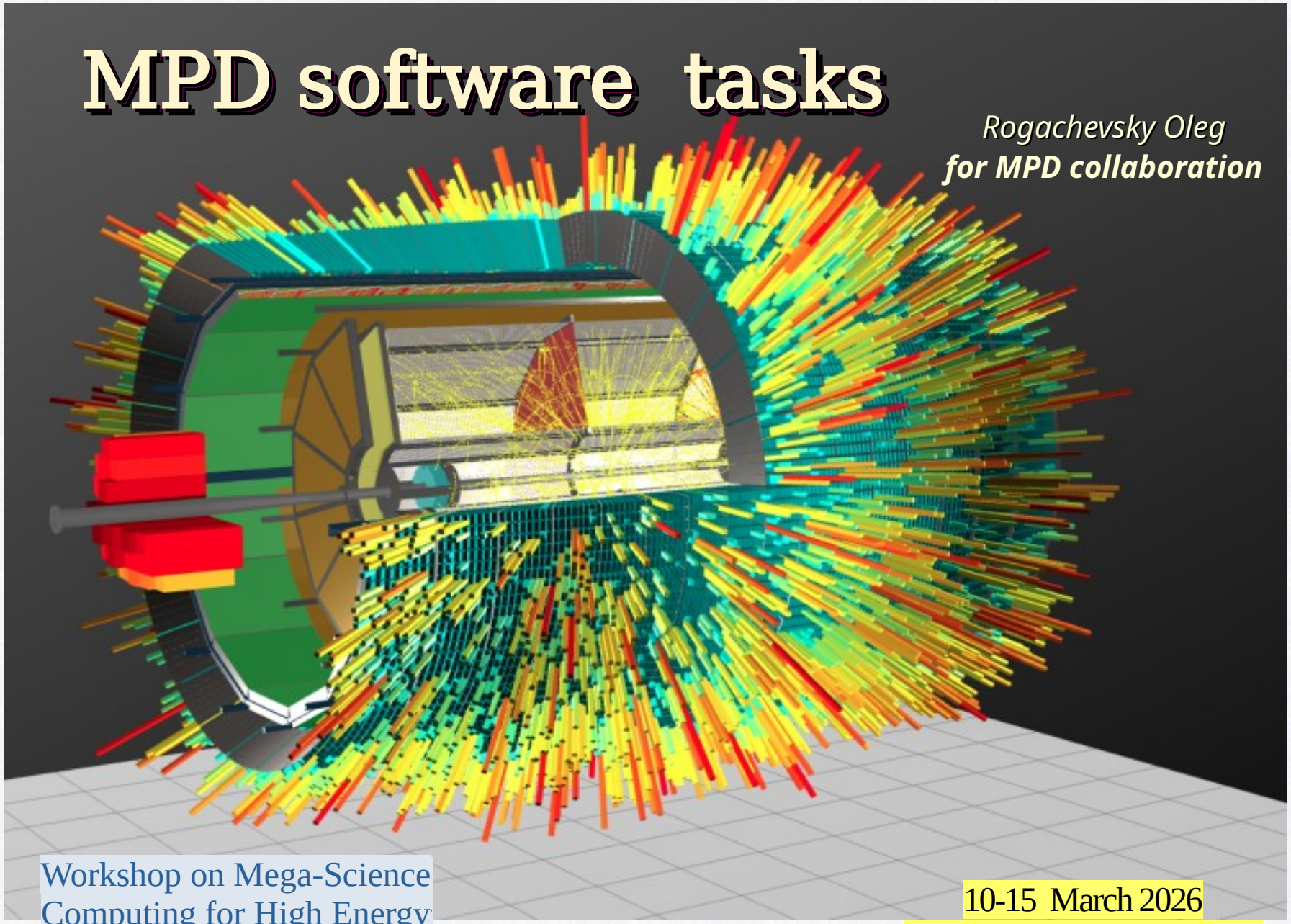
MPD software tasks

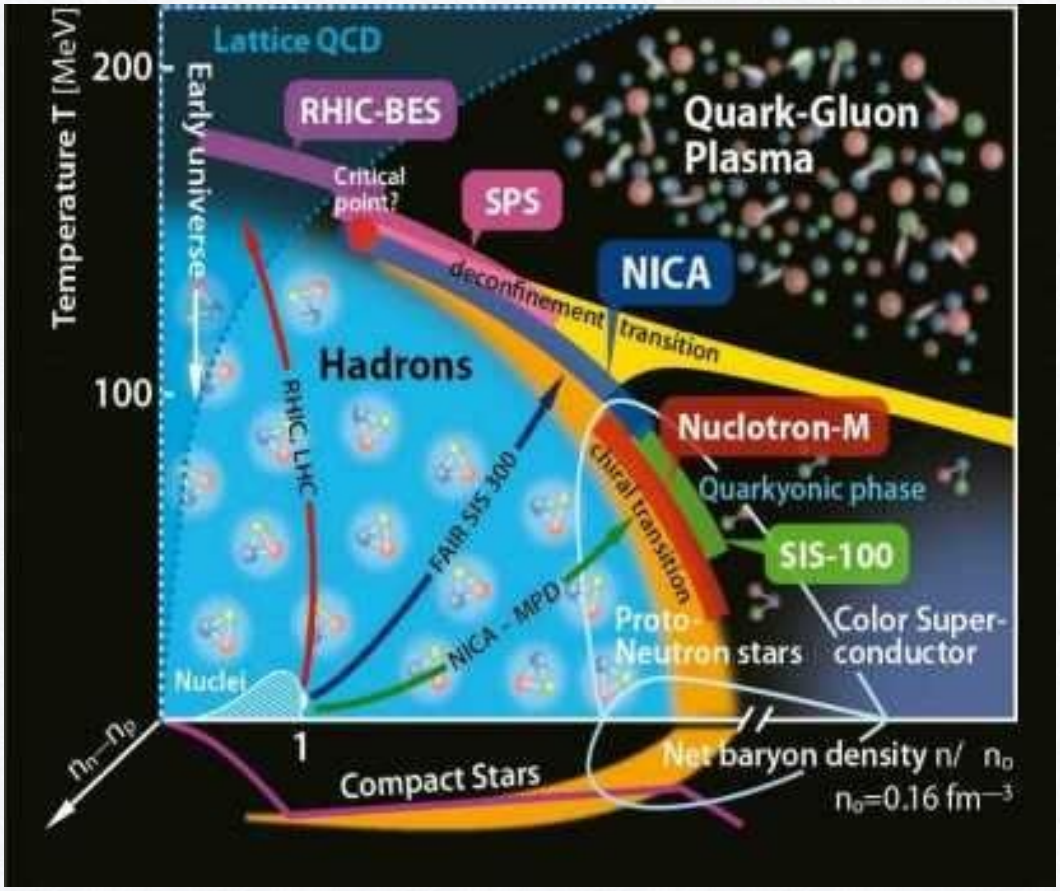
Rogachevsky Oleg
for MPD collaboration

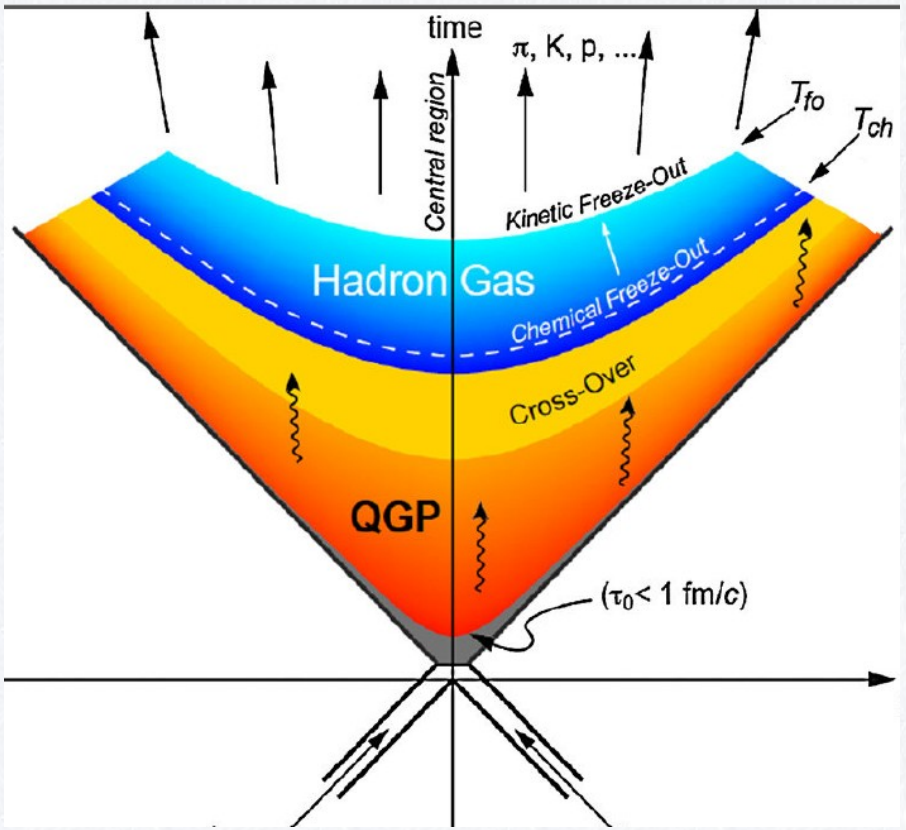


Workshop on Mega-Science Computing for High Energy Physics

10-15 March 2026
Listvyanka, Irkutsk, Russia

QCD phase diagram



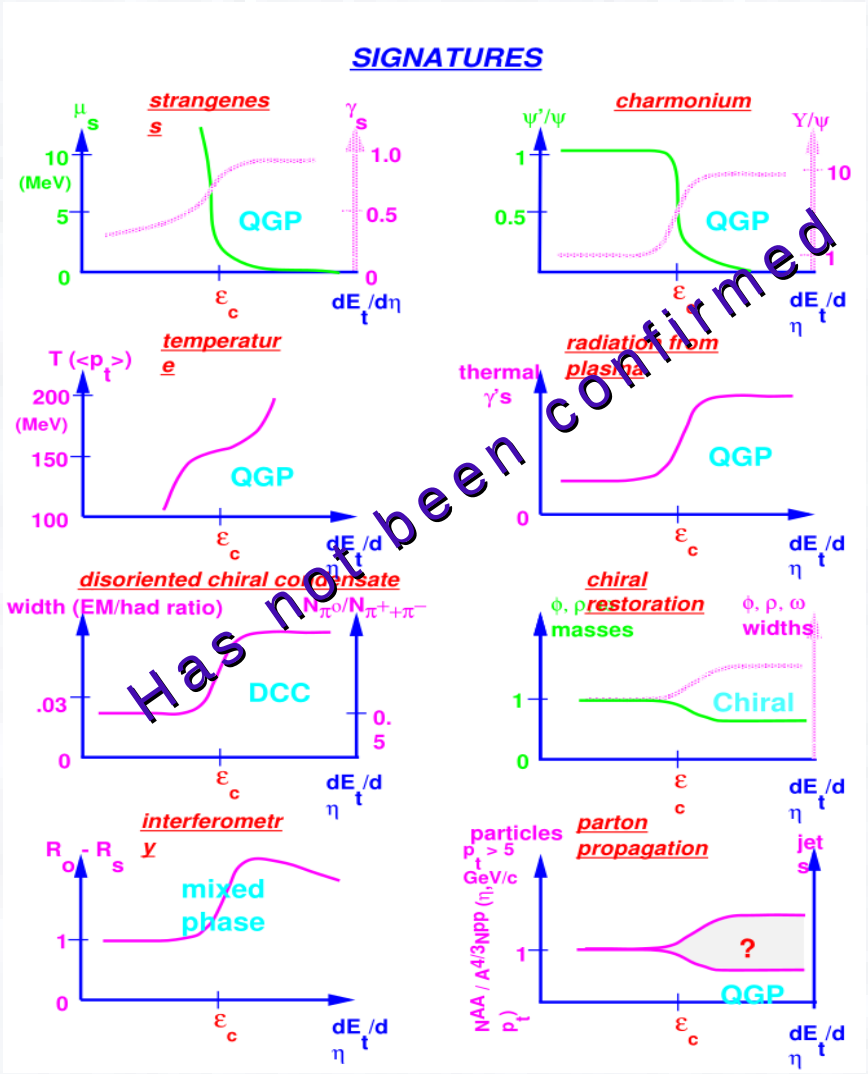


Quark–gluon plasma (QGP) is an interacting localized assembly of quarks and gluons at thermal (local kinetic) and (close to) chemical (abundance) equilibrium. In normal matter quarks are confined; in the QGP quarks are deconfined. Quark–gluon plasma occurs at energy densities high enough to melt the protons and neutrons that make up the nuclei of normal matter. It is a very low viscosity liquid composed of the elementary particles, quarks and gluons, a new state of matter.

QGP theoretical predictions

John W. Harris, Berndt Müller “THE SEARCH FOR THE QUARK-GLUON PLASMA”

arXiv:hep-ph/9602235v2 **1996**

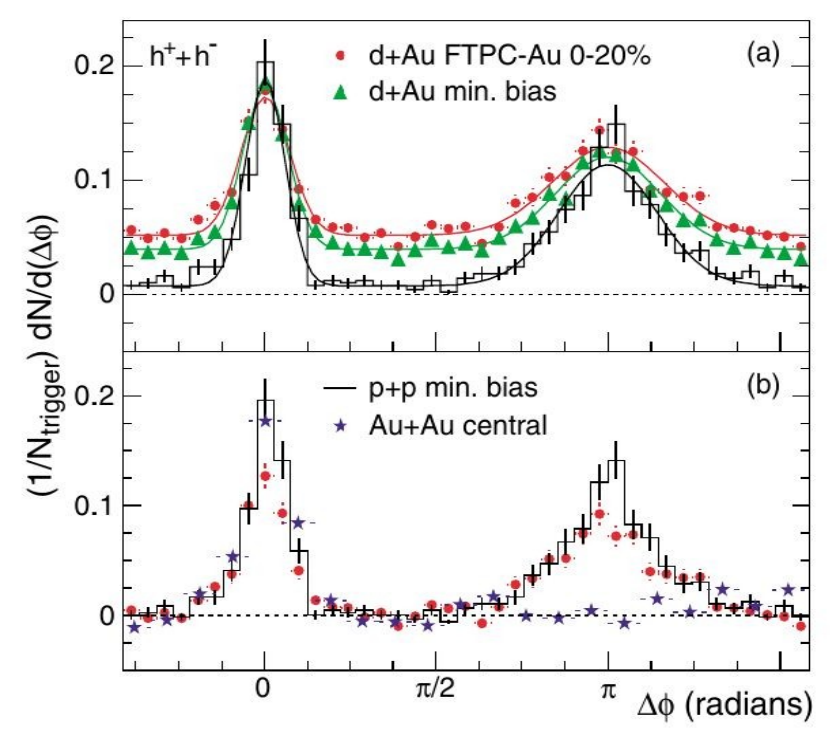


Signatures of quark-gluon plasma formation and the chiral phase transition. The expected behavior of the various signatures is plotted as a function of the measured transverse energy, which is a measure of the energy density, in the region around the critical energy density ϱc of the transit

QGP experimental results

Jet quenching

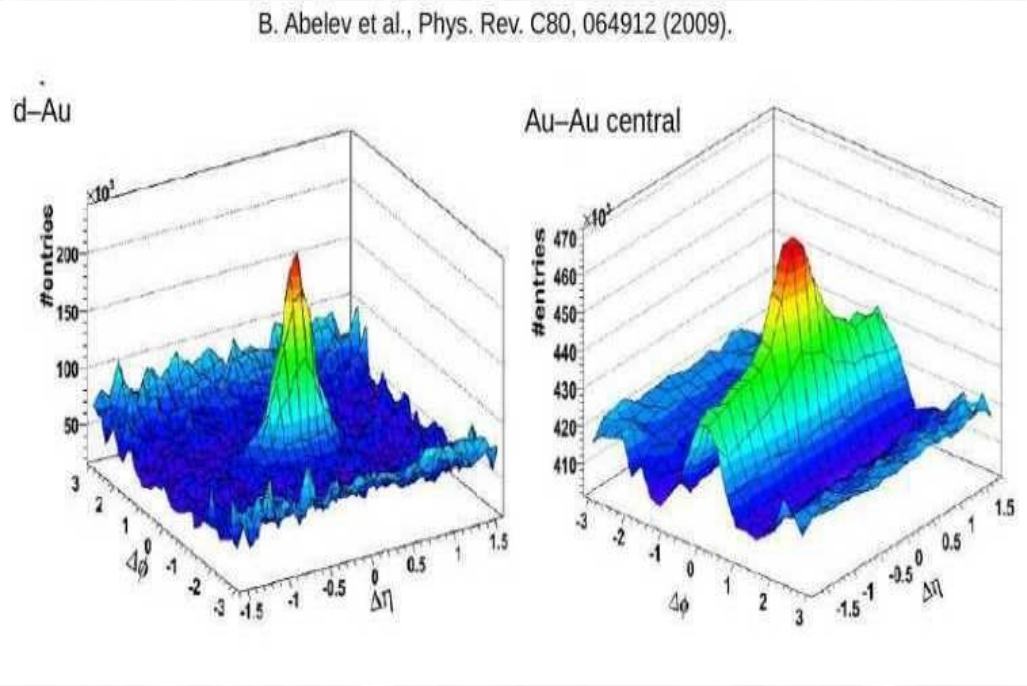
Evidence from d+Au measurements for final-state suppression of high pT hadrons in Au+Au collisions at RHIC



Jet-related dihadron azimuth correlations demonstrating disappearance of the away-side jet ($\Delta\varphi = \pi$) in central 200 GeV Au-Au collisions (blue points) compared its presence for p-p collisions (histogram). The away-side peak is also present in d-Au collisions (red and green points)

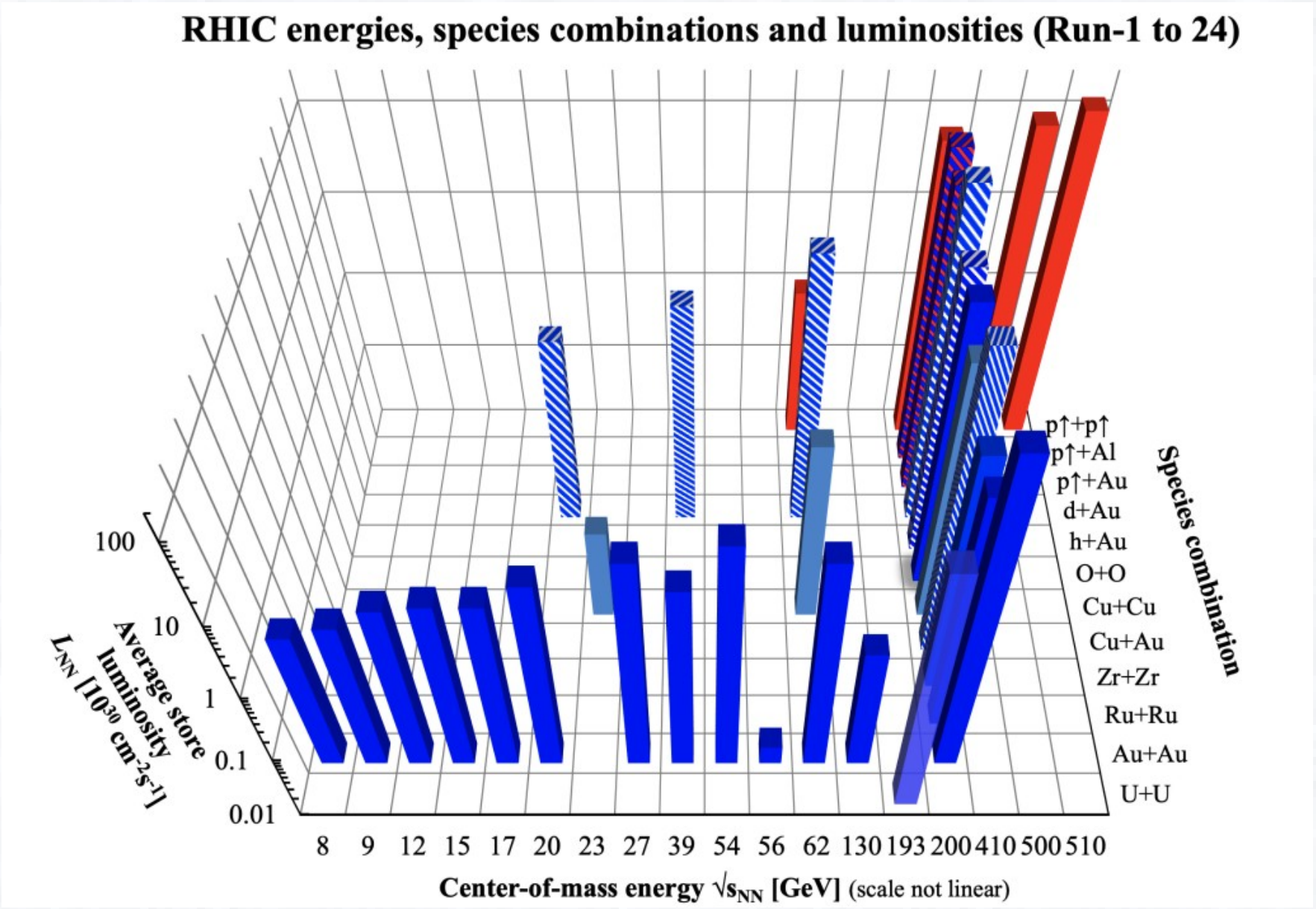
Ridge effect

Long range rapidity correlations and jet production in high energy nuclear collision

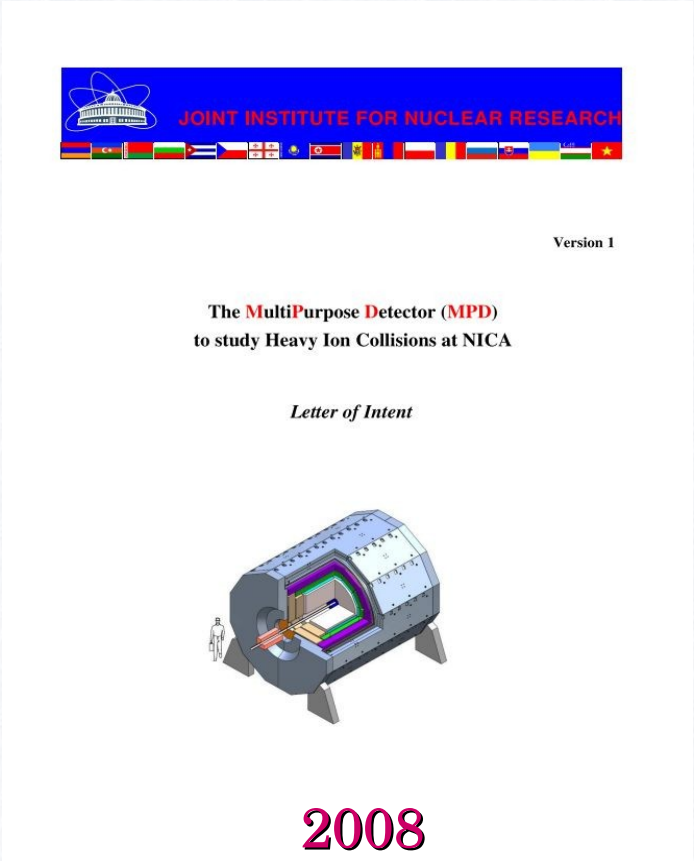


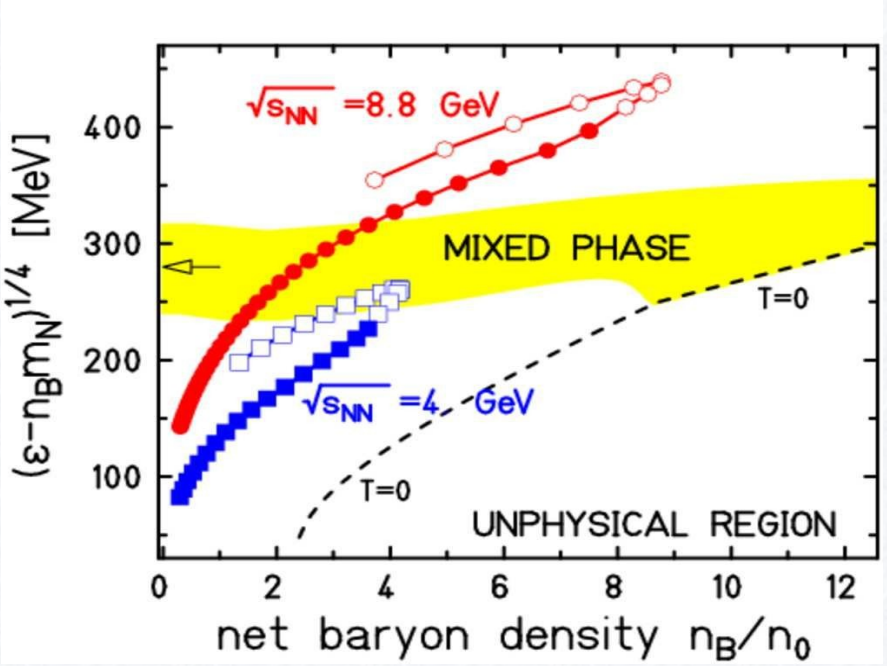
Analysis of di-hadron $\Delta\eta \times \Delta\varphi$ correlations in central Au+Au collisions reveals a more complex structure of the near-side correlation than expected from p+p and d+Au reference measurements, namely the observation of additional correlated yield at large $\Delta\eta$ (the ridge)

25 years for RHIC

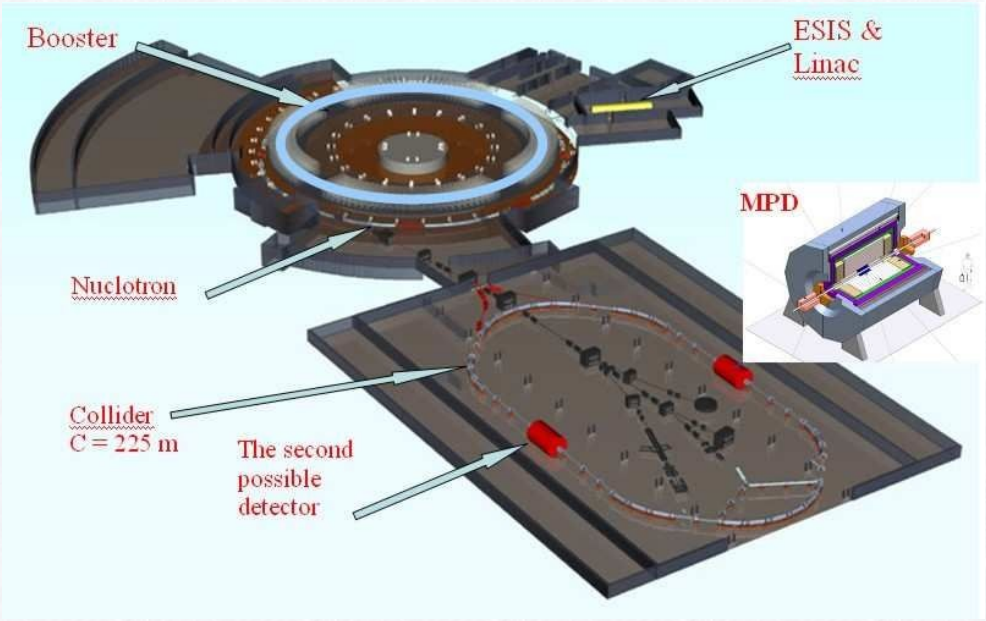


MPD project



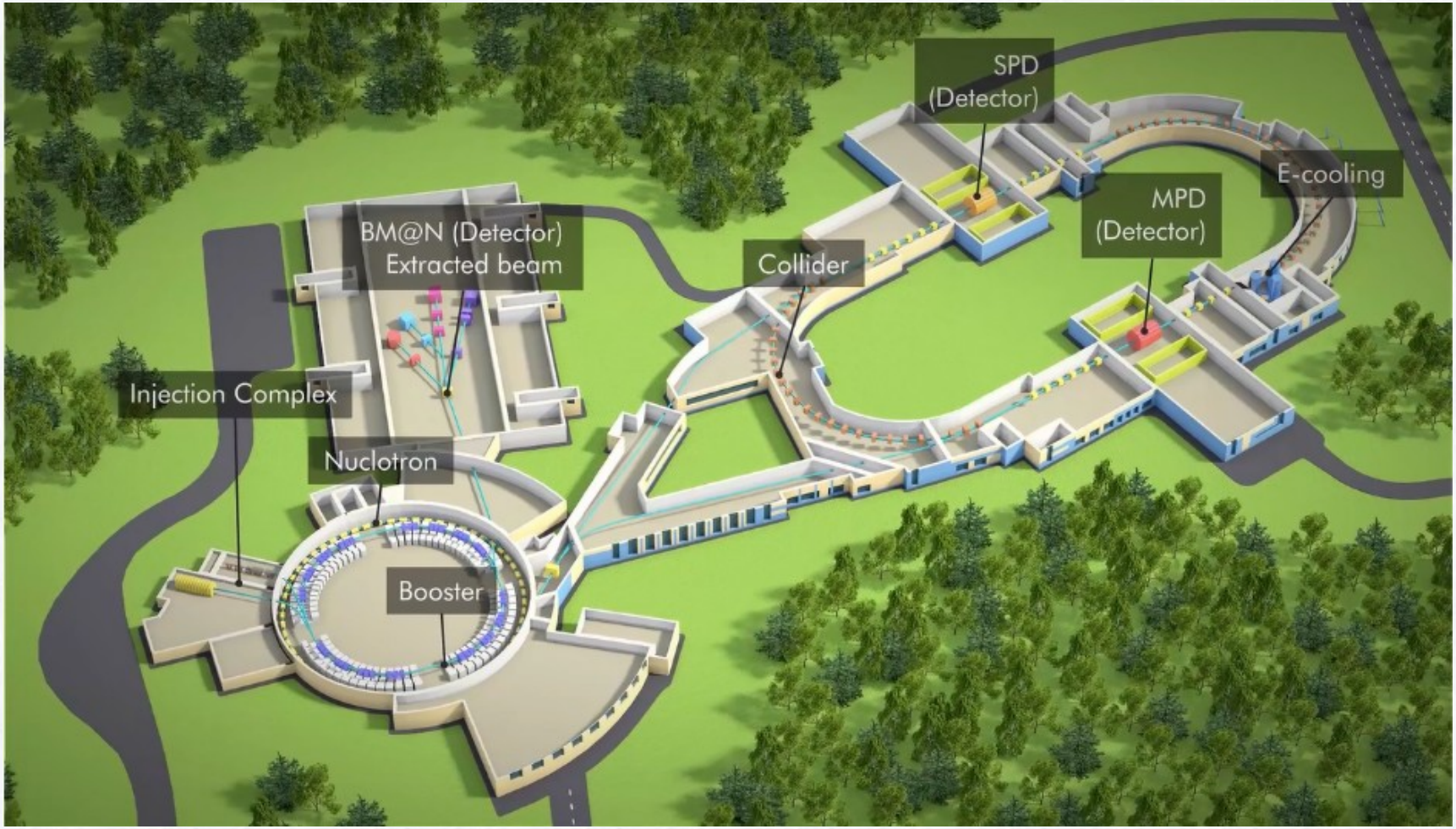


V. D. Toneev



The major goal of the MPD experiment is the study of the in-medium properties of hadrons and the nuclear matter equation of state, including a search for possible signals of deconfinement and/or chiral symmetry restoration, phase transitions and the QCD critical end point in the region of the collider energy $\sqrt{s_{NN}}$ = 4 – 9 GeV/u (for U^{92+})

Nuclotron based Ion Collider fAcility



Beams – p,d(h)..$^{197}Au^{79+}$

Collision energy √s= **4-11** GeV/u (Au), **12-27** (p)

Beam energy (fixed target) - **1-6** GeV/u

Luminosity: 10^{27} $cm^{-2}s^{-1}$(Au), 10^{32} (p)

Experiments:

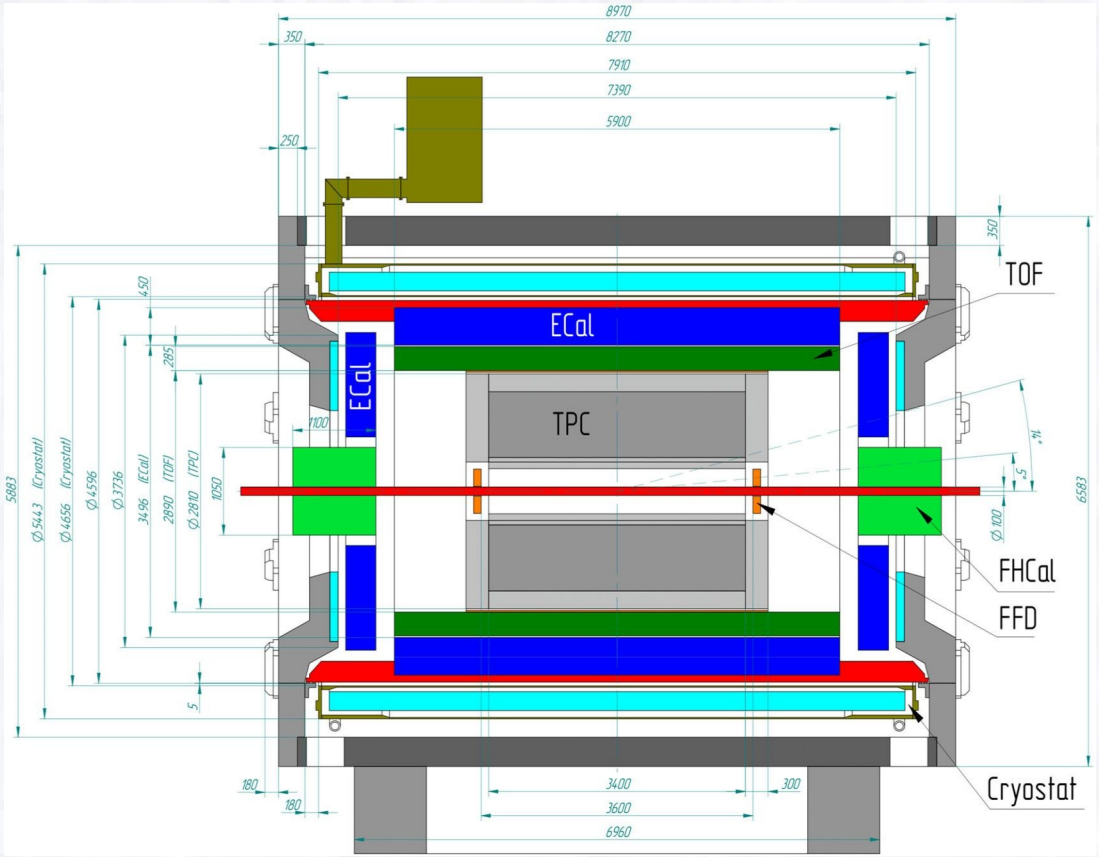
2 Interaction points – **MPD** and SPD

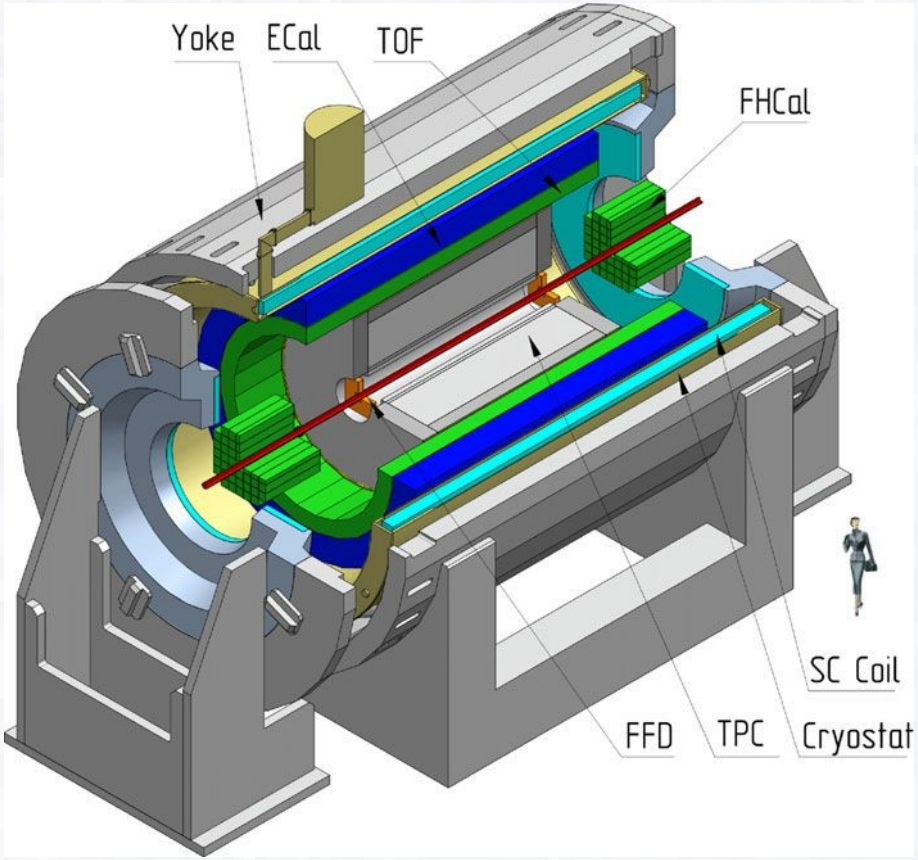
Fixed target experiment **BM@N**

MPD first stage

Status and initial physics performance studies of the MPD experiment at NICA
The MPD Collaboration

Eur. Phys. J. A (2022) 58:140

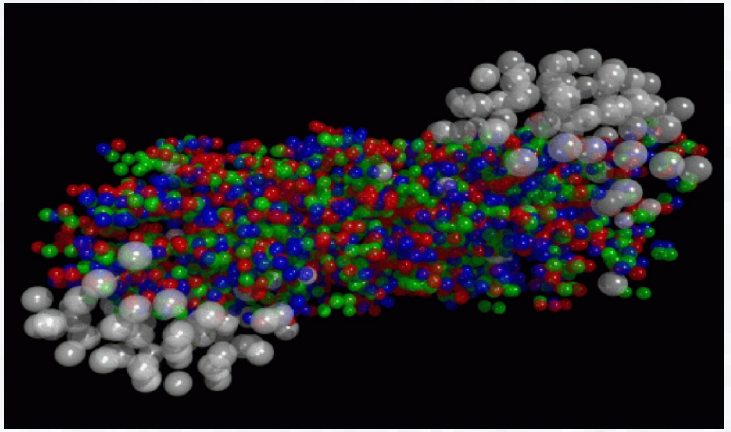




The overall schematic of the MPD subsystems in the first stage of operation (Stage 1)
left – cross-section by the vertical plane, right – three-dimensional view

Experiments software tasks

- Simulation physics of experiment
- Simulation detectors of experiment
- Clustering in detectors (hits)
- Tracking in tracking detectors
- PID of tracks (=> particles)
- Reconstruction of event (EbyE)
- Physics analyses



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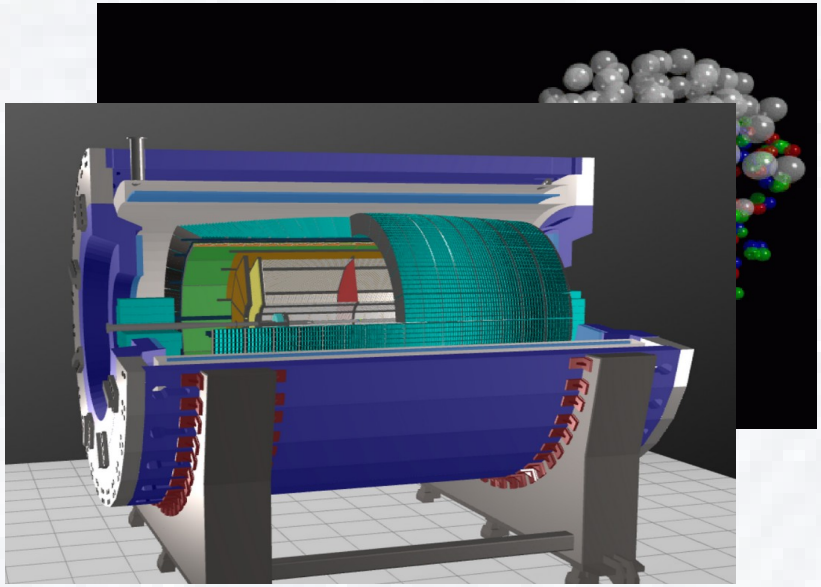

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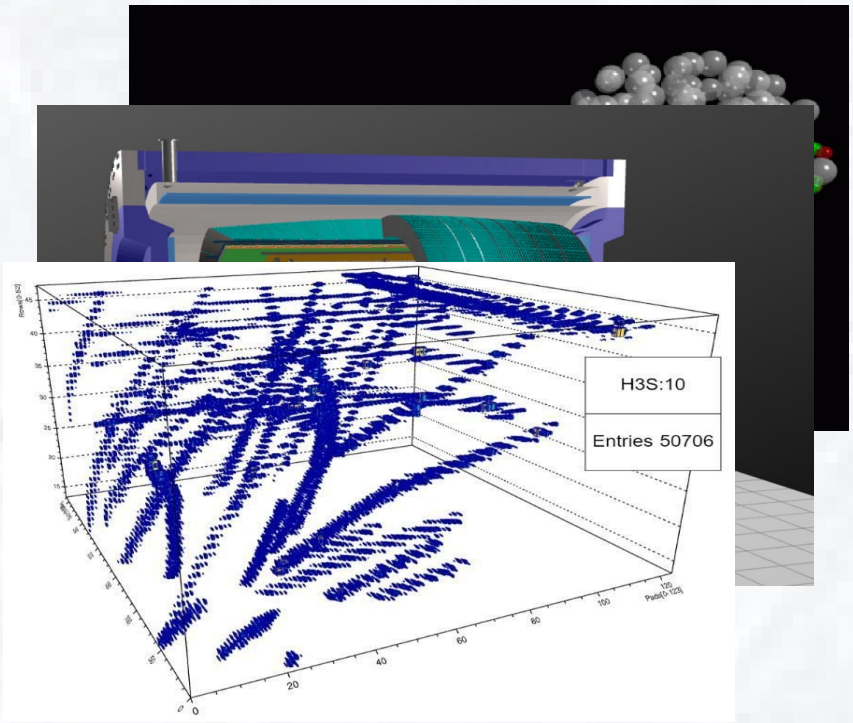

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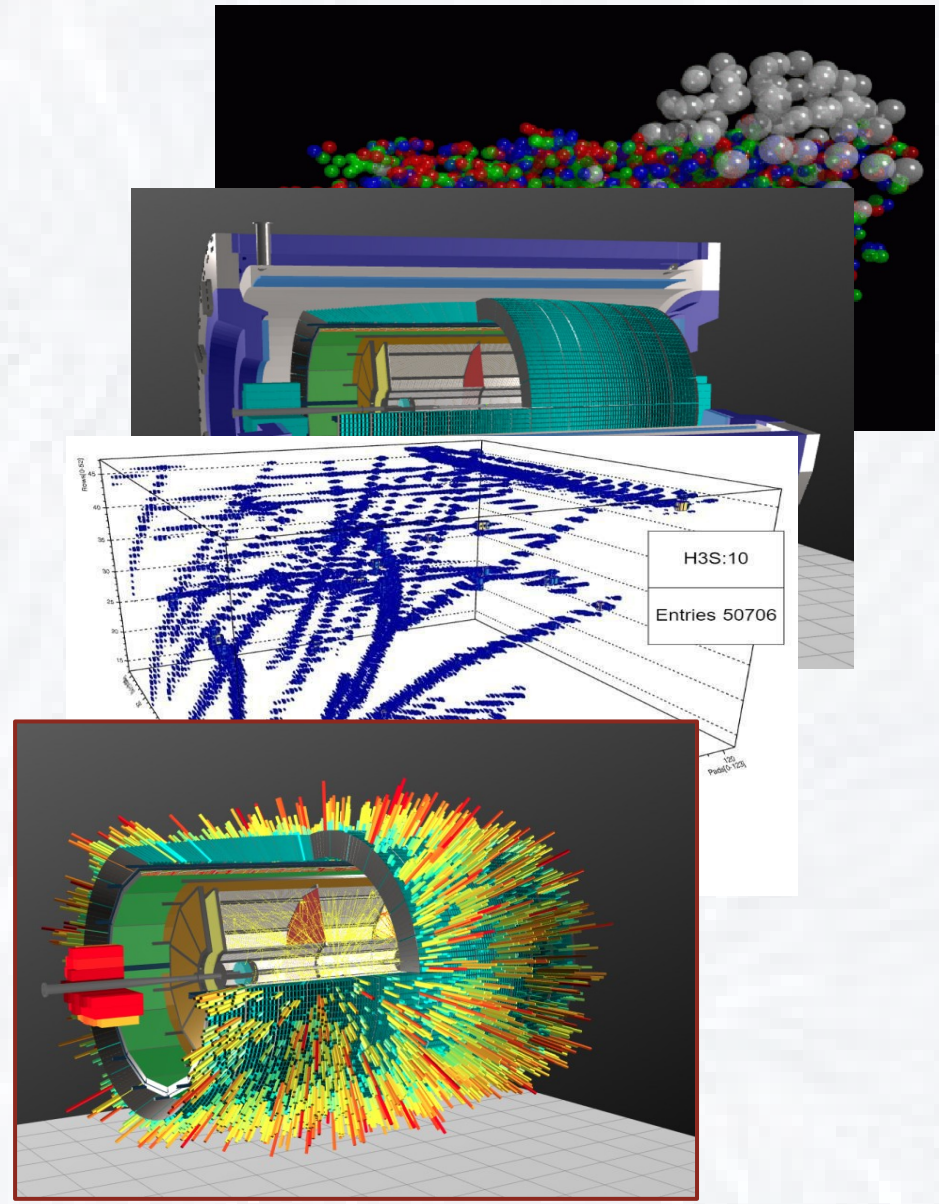
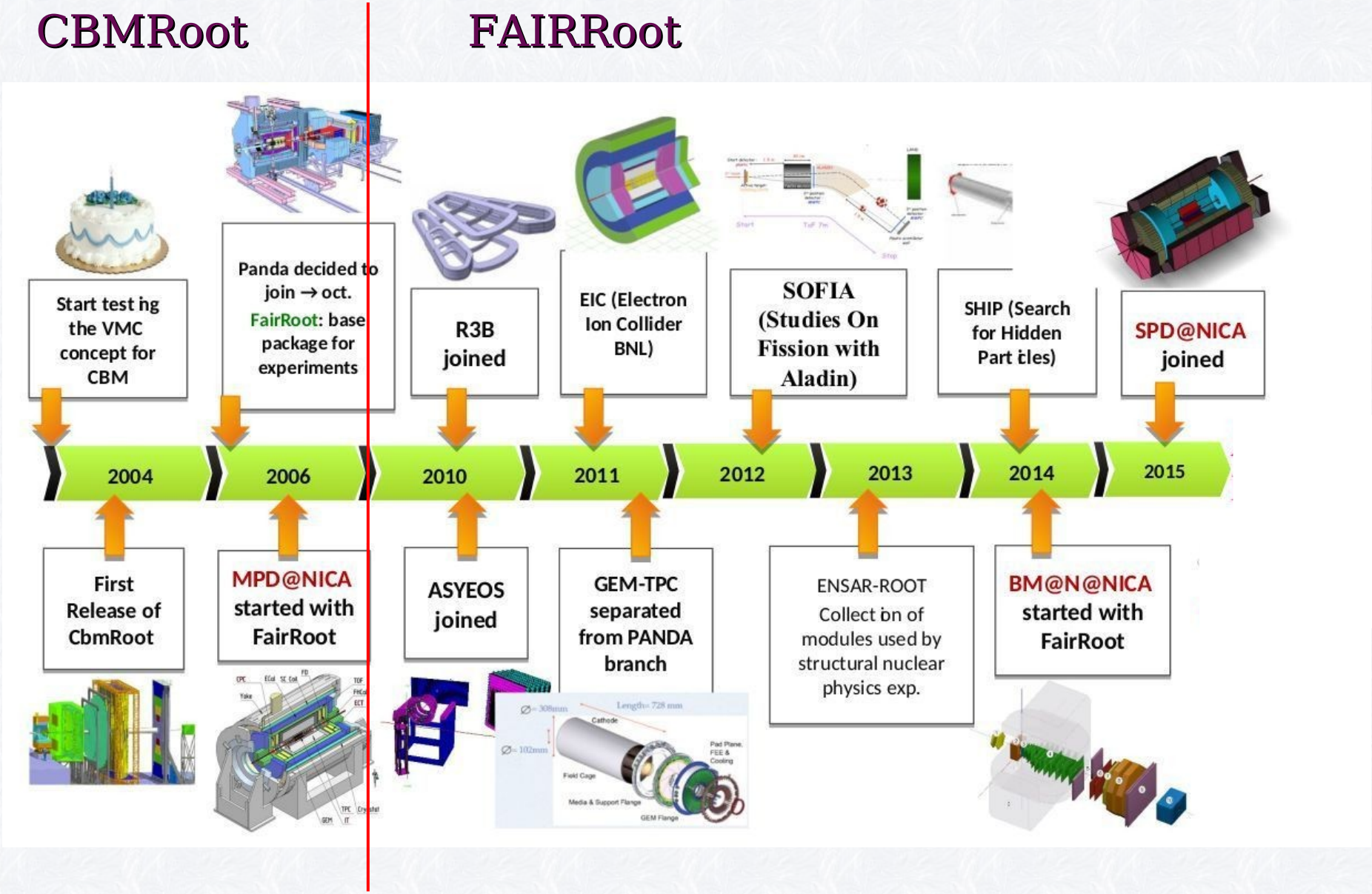


Software frameworks

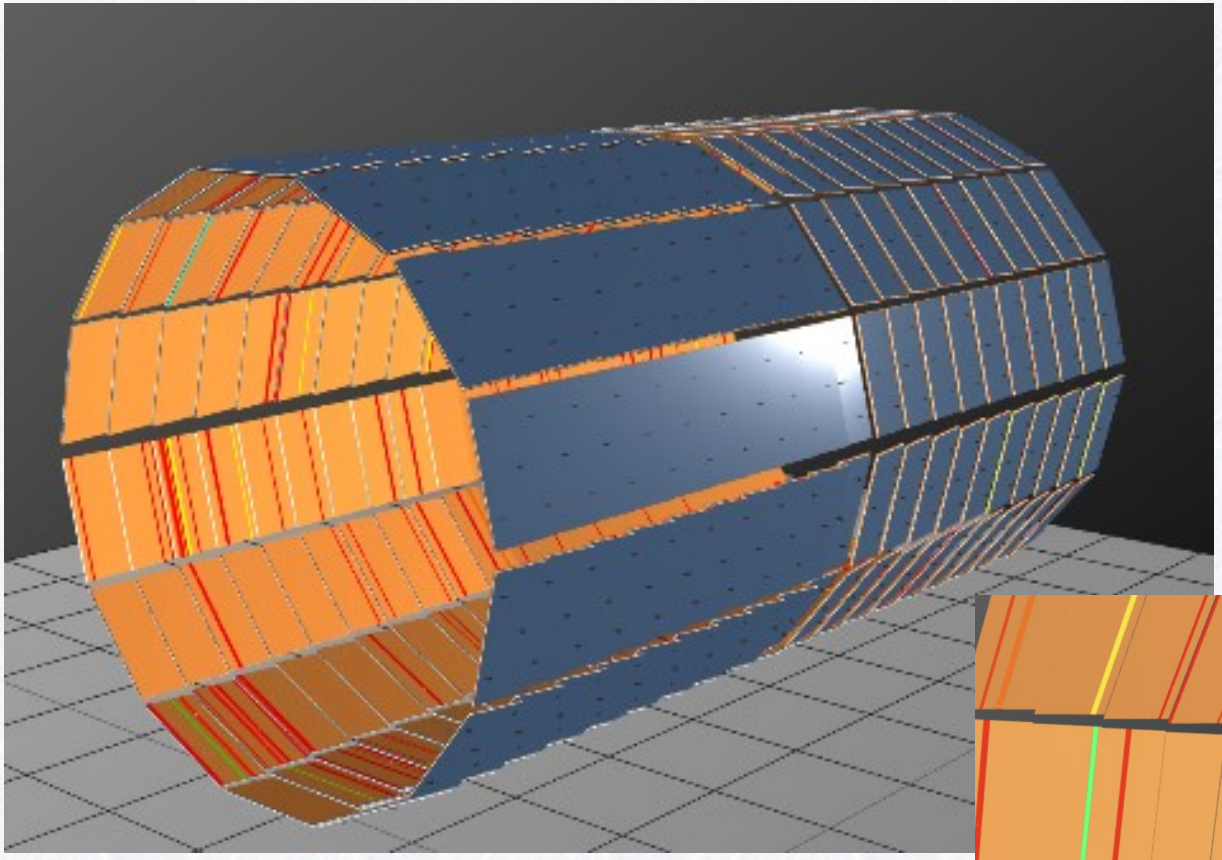
Denis Bertini
Mohammad Al Turani



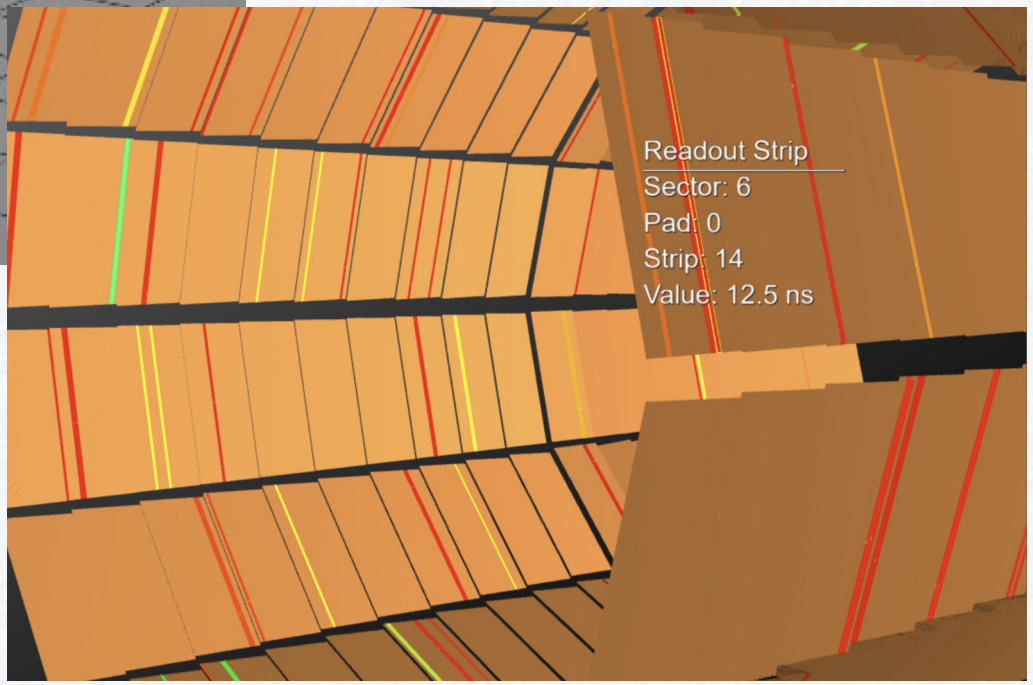
MPD MC physics generators

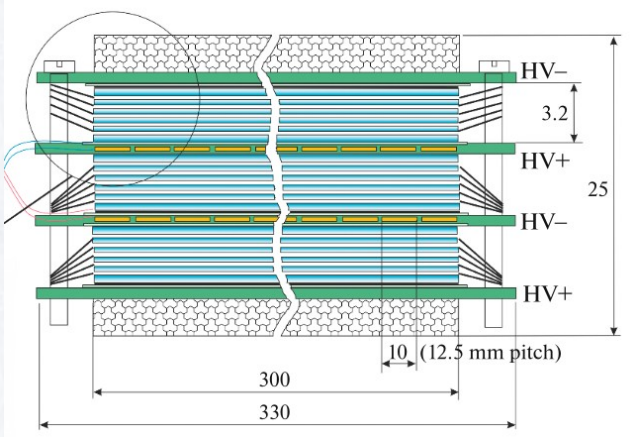
- UrQMD M. Bleicher et al., Relativistic hadron hadron collisions in the ultrarelativistic quantum molecular dynamics model, J.Phys. G 25 (1999) 1859
- VHLLE UrQMD I. Karpenko, P. Huovinen, and M. Bleicher A 3+1 dimensional viscous hydrodynamic code for relativistic heavy ion colLisions, Comput. Phys. Commun. 185 (2014) 3016
- DCM SMM M. Baznat et al., Monte-Carlo Generator of Heavy Ion Collisions DCM-SMM, Phys. Part. Nucl. Lett. 17 (2020) 303
- PHSD W. Cassing and E. L. Bratkovskaya, Parton-Hadron-String Dynamics: an off-shell transport approach for relativistic energies, Nucl. Phys. A 831 (2009) 215
- PHQMD J. Aichelin et al., Parton-hadron-quantum-molecular dynamics: A novel microscopic n -body transport approach for heavy ion collisions, dynamical cluster formation, and hypernuclei production, Phys. Rev. C 101 (2020) 044905

Detectors simulation (TOF)

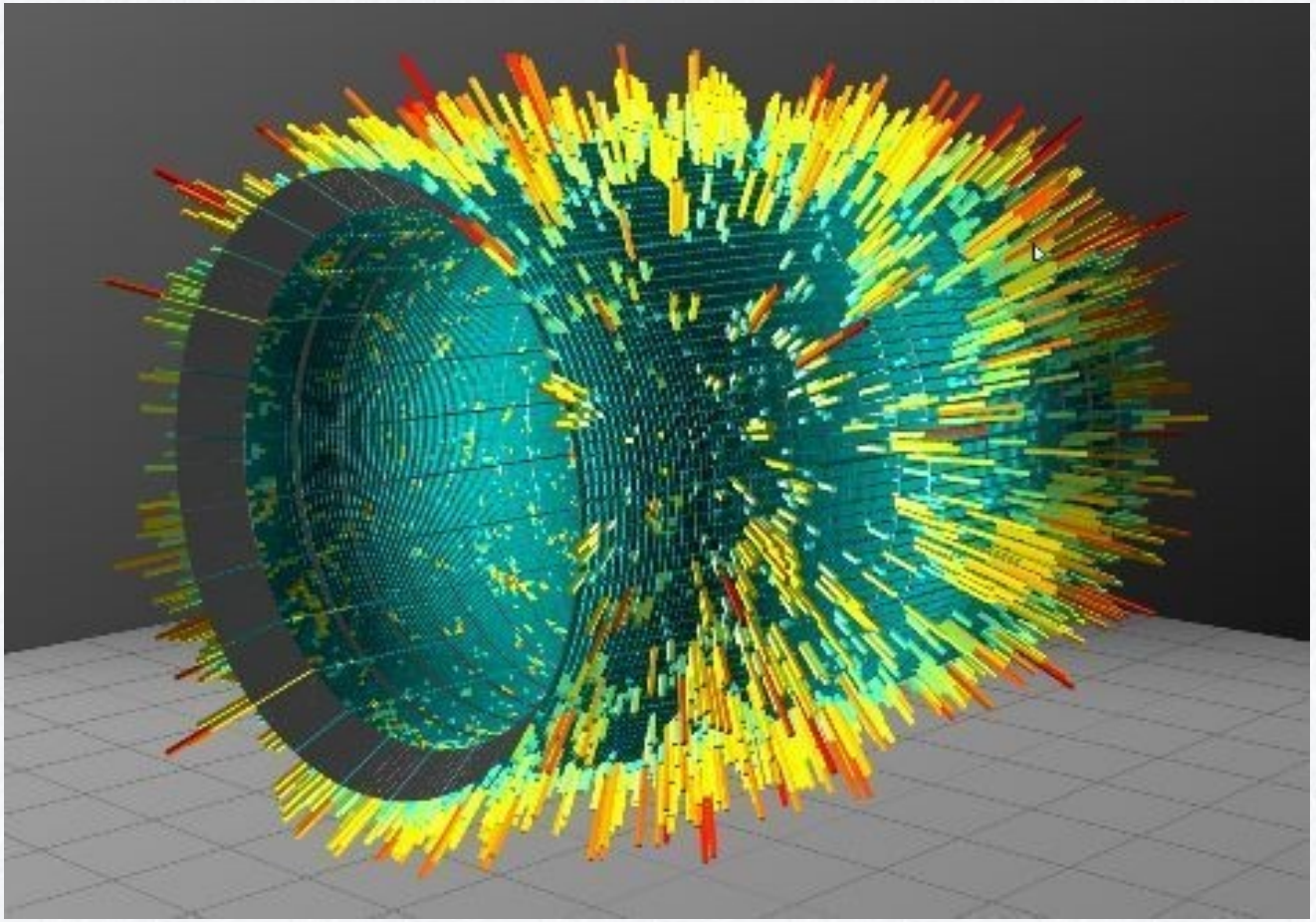


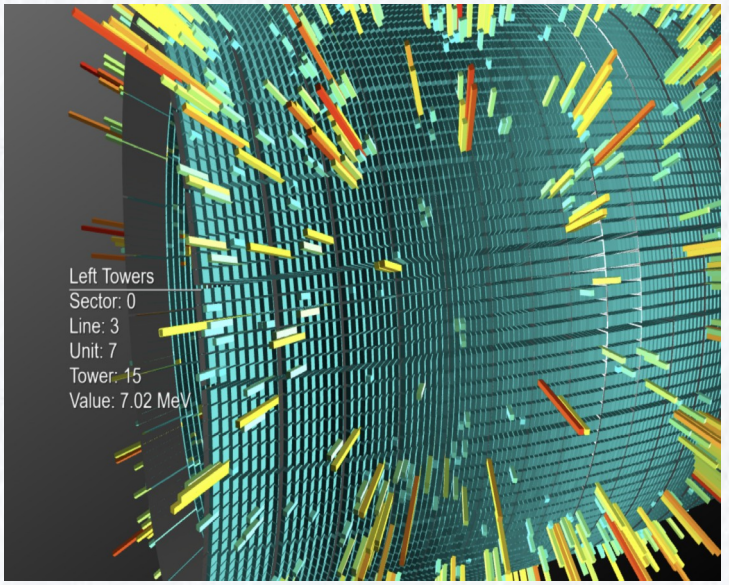
The Time of Flight together with the TPC must be able to identify charged hadrons and nuclear clusters in the broad rapidity range and up to total momentum of 3 GeV/c.

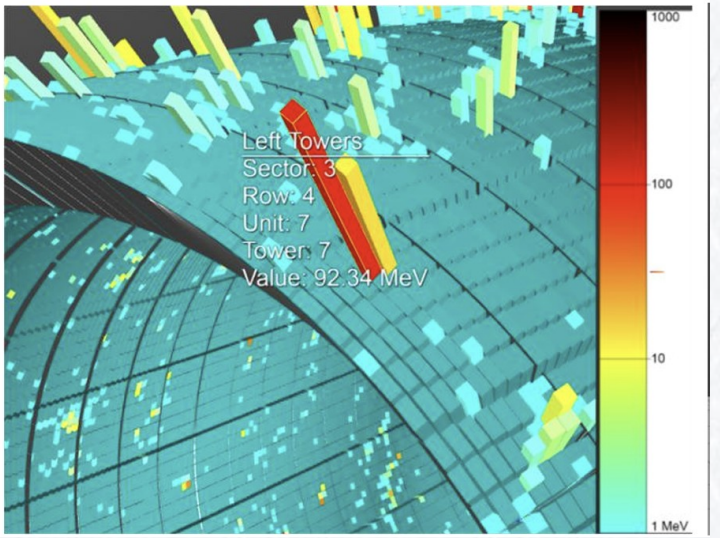


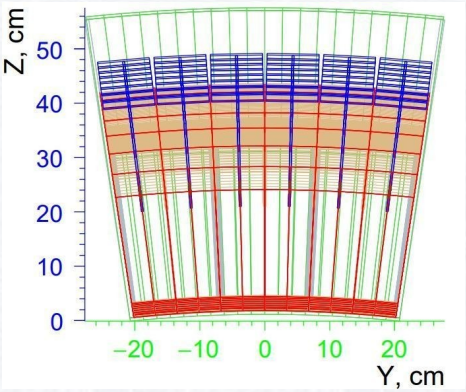


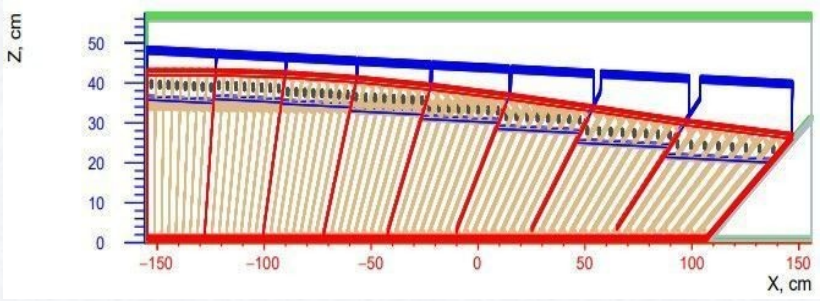
Detectors simulation (ECal)



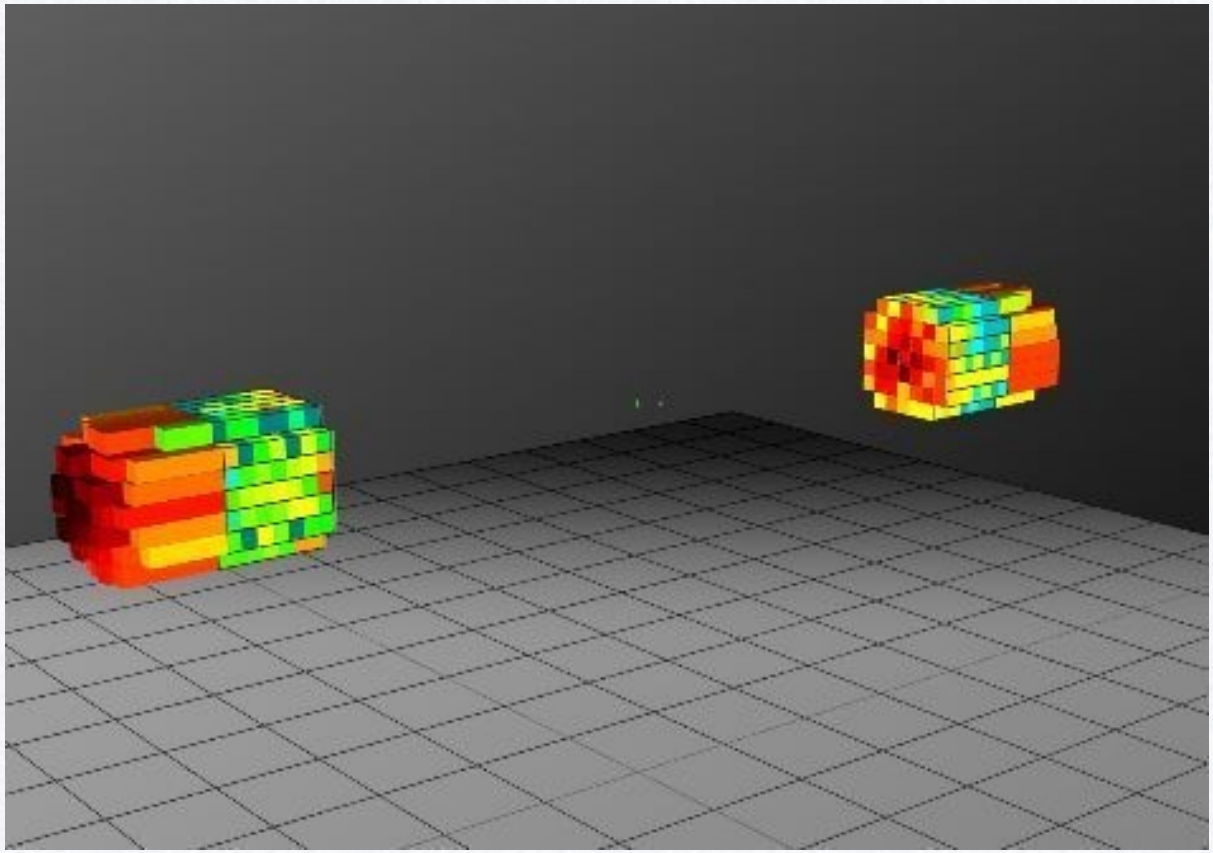




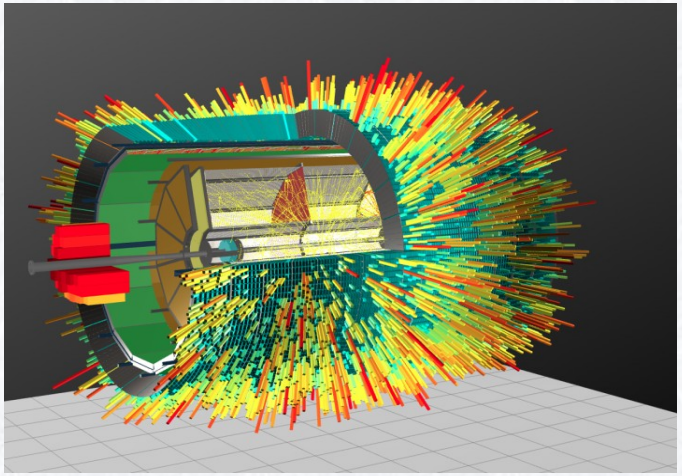


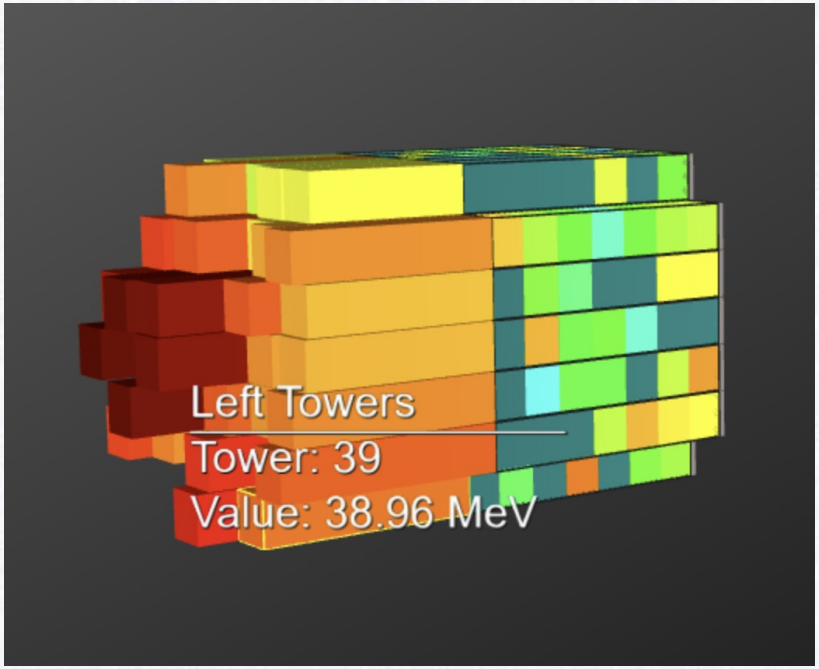


Detectors simulation (FHCal)

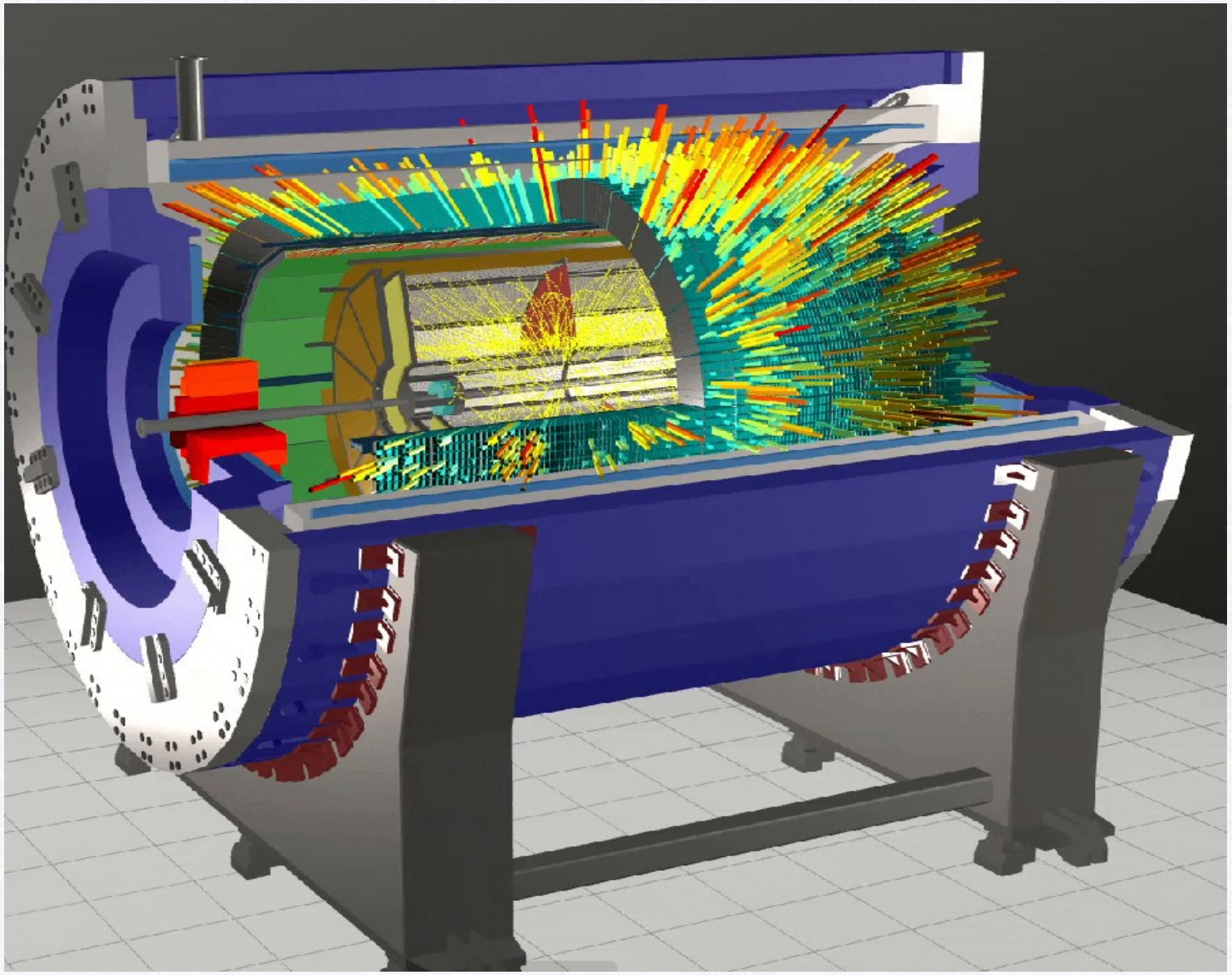


The efficient detection of nucleus+nucleus collisions at any centrality with time resolution of ~50 ps

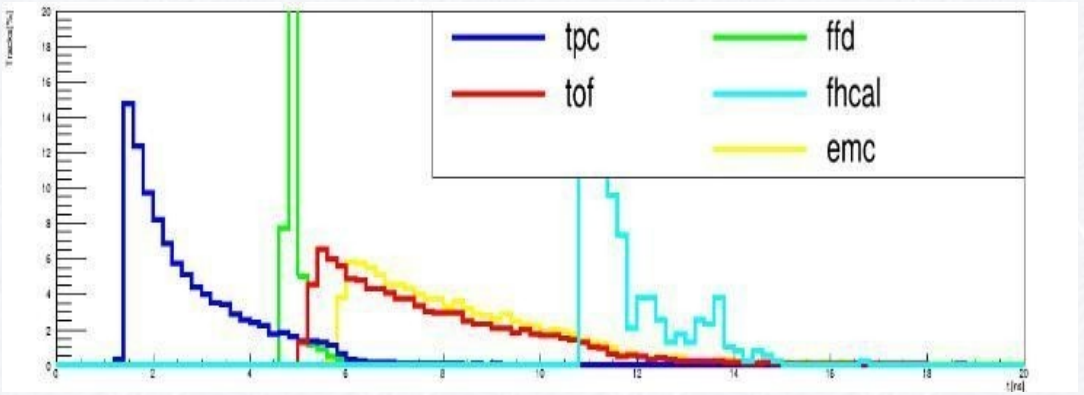




MPD eventdisplay

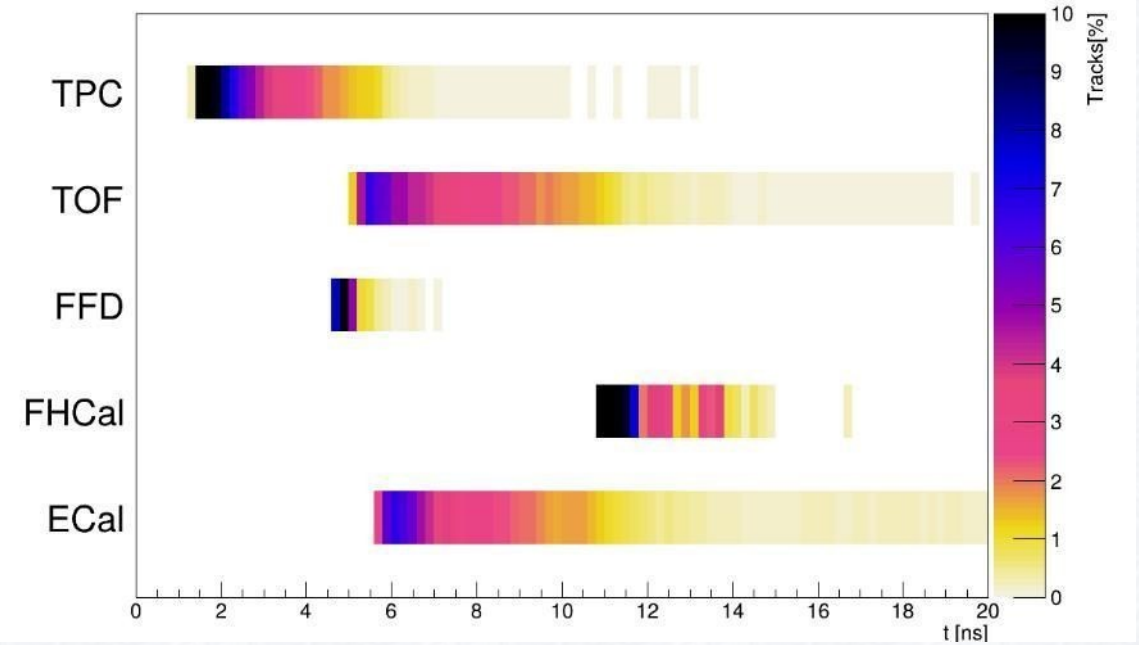


Trigger latency for data taking for MPD detectors



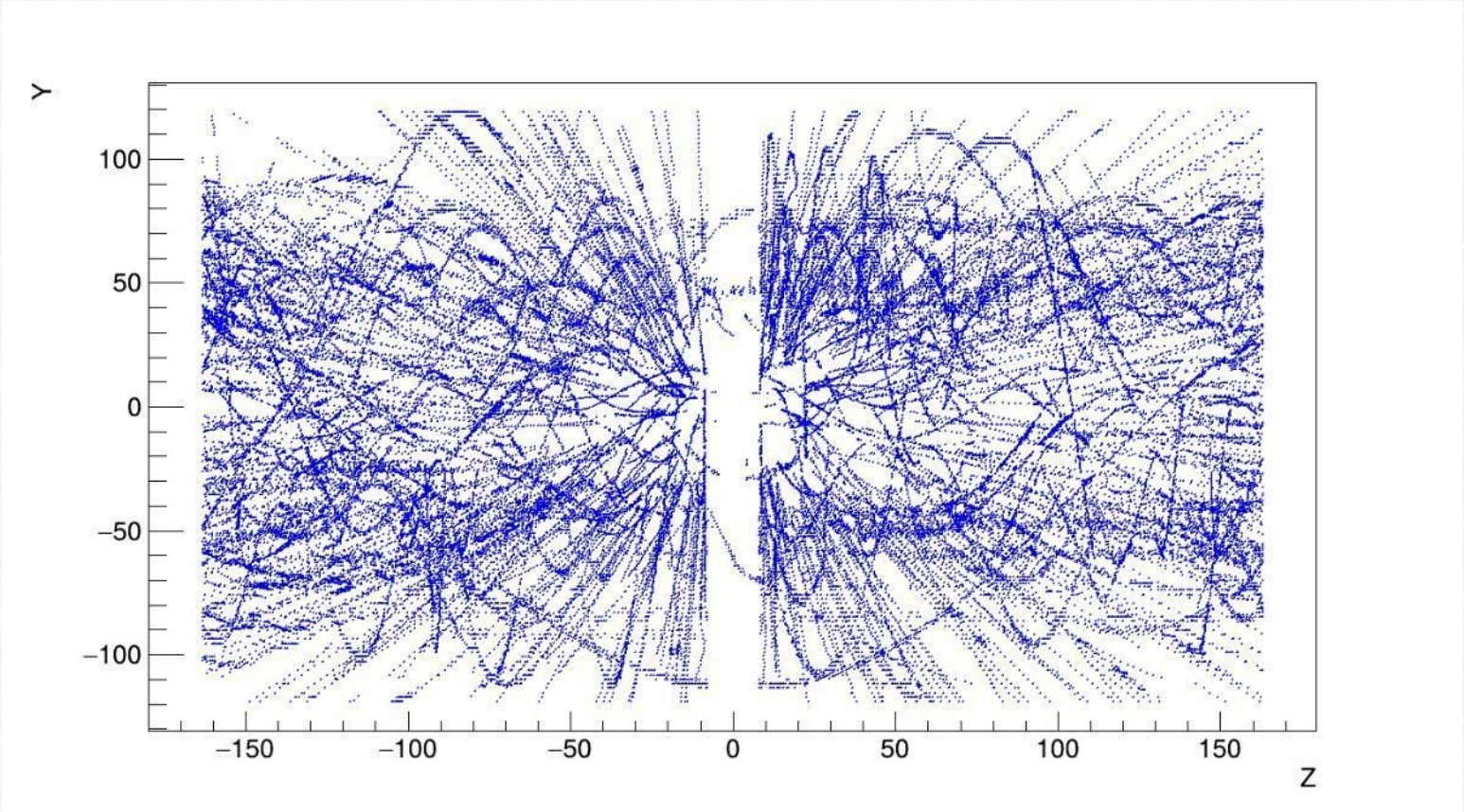
Collision point (0, 0, 0)

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



TPC data taking delay

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



Mass production & analyses 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.

Service wagons for Req.40 production (100M events in MPD-FXT)

Outline

- Request 40 mass production for MPD-FXT:
  /eos/nica/mpd/sim/data/exp/dst-XeW-02.5GeV-mp01-26-500ev-req40/XeW/02.5GeV-fl/urqmd/XeW-02.5GeV-mp01-26-500ev-req40/
  - ✓ Xe (T = 2.5 AGeV) + W
  - ✓ UrQMD (mean field)
    → stable resonances, decayed by Geant4
    → Λ global polarization & flow parameterized according to STAR, no embedding
  - ✓ Vertex: z = -85 cm, y = 1 cm, x = 0 cm, all smeared within wire diameter of 100 um
  - ✓ Target – 100M events, ready 171k files out of 200k in total (86%)
- Check status of Centrality and PID wagon

Centrality wagon

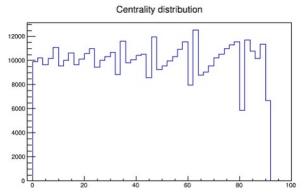
- pCentr.txt:

```
#-------Parameters used for analysis------
# Event selection: defined in the header, please do not change the cuts
#mZvtxCut 86 // cut on vertex z coordinate (fixed at -85 cm for FXT)

# Track selection: defined in the header, please do not change the cuts
mNofHitsCut 24
mEtaCut 1.0
mPtminCut 0.1
mDcaCut 2.0

# Production selection:
mProdGenerator Req35-UrQMD  // Production-Generator (use the same for Req36)
mInFileConvert nTr_Centr_Req35-UrQMD.root // input file with track-to-centrality converter (use the same for Req36)

# Track efficiecny corrections (use for all CLD and FXT productions):
mInFileTrEff TrackRecEff_FXT.root  // input file with track reconstruction efficiecnies
```

- Centrality definition file was updated: nTr_Centr_Req35-UrQMD.root

Centrality

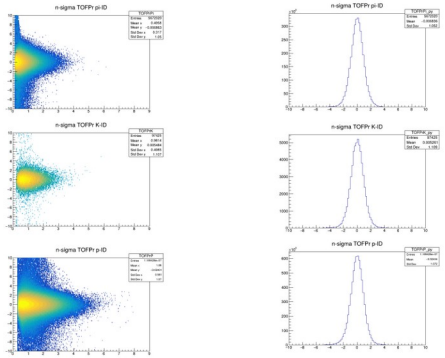
- QA sample for 500k events:



Flat in a range 0-91%

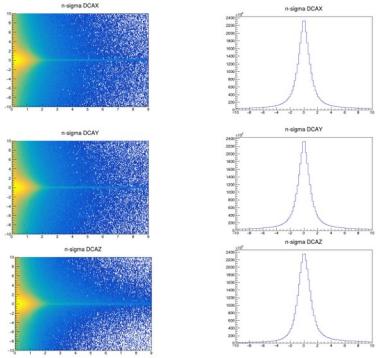
TOF Beta parameterization

- Sigmalized distributions:



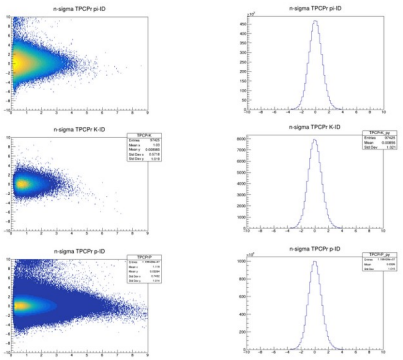
DCAx,y,z parameterization

- Sigmalized distributions:

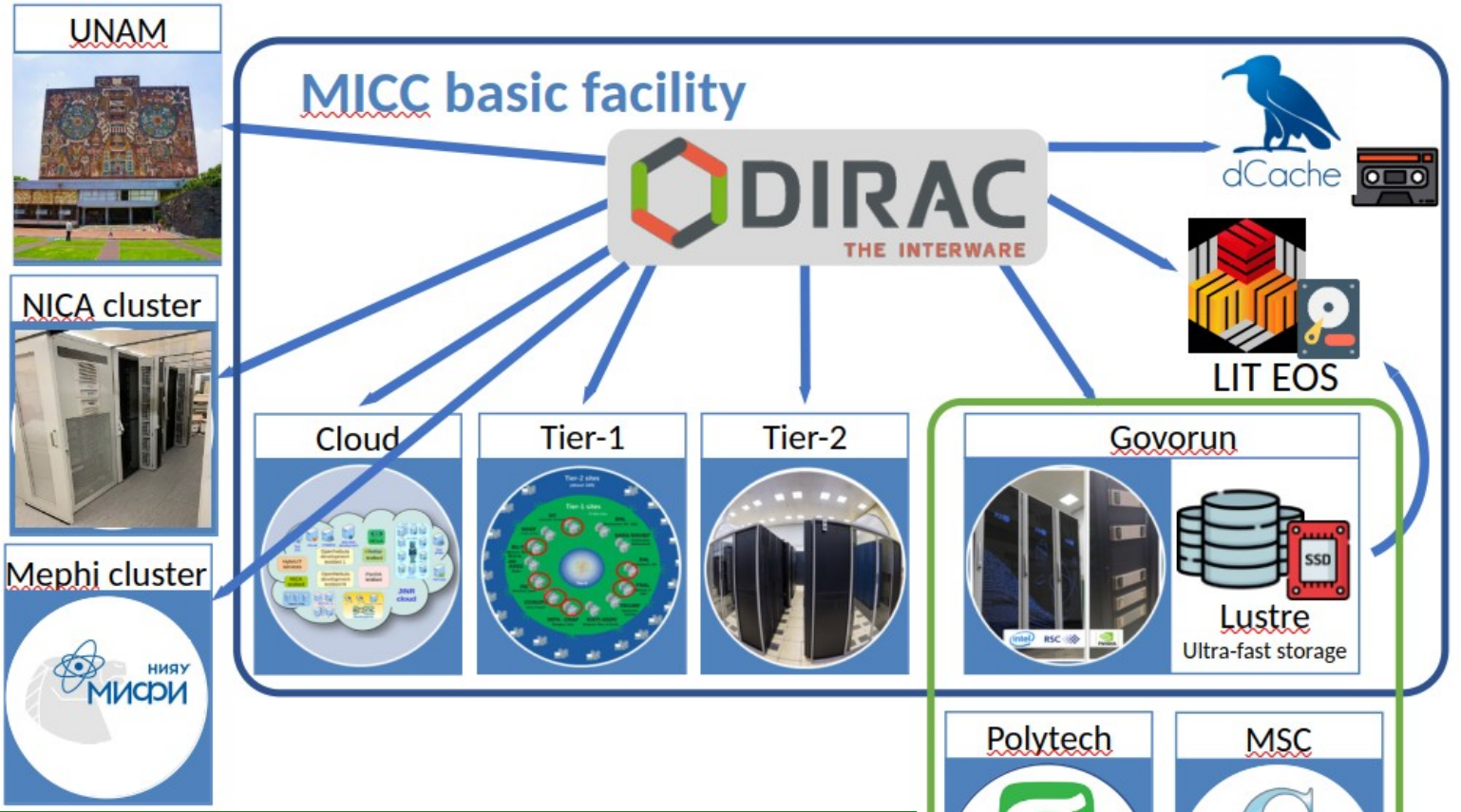


TPC dE/dx parameterization

- Sigmalized distributions:



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.

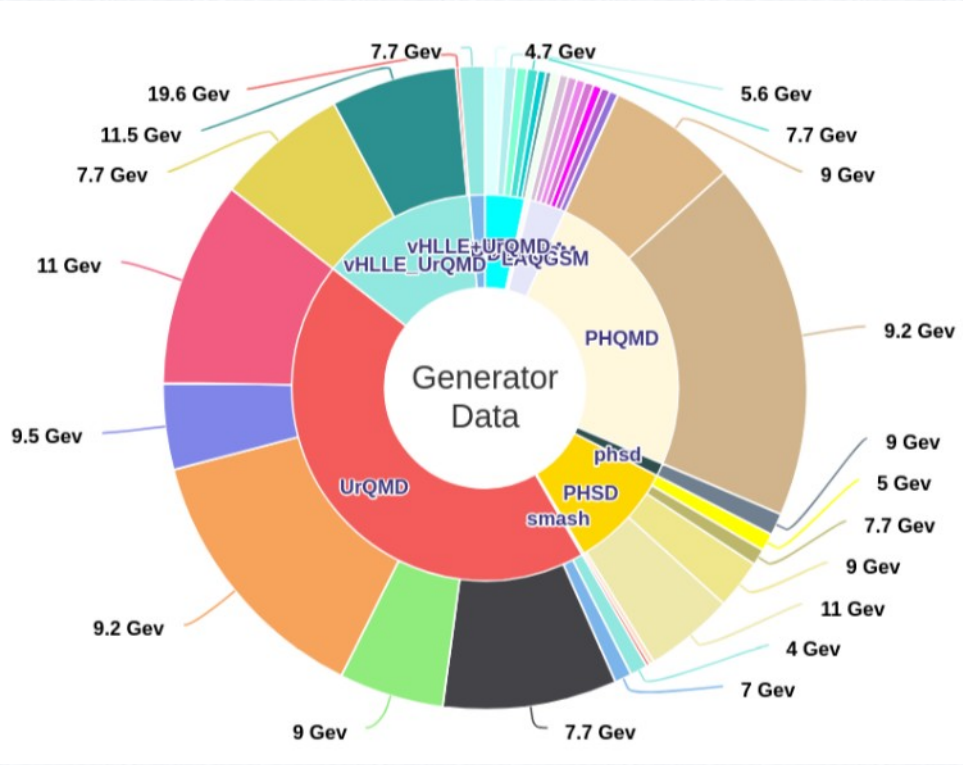
MC data for MPD physics group

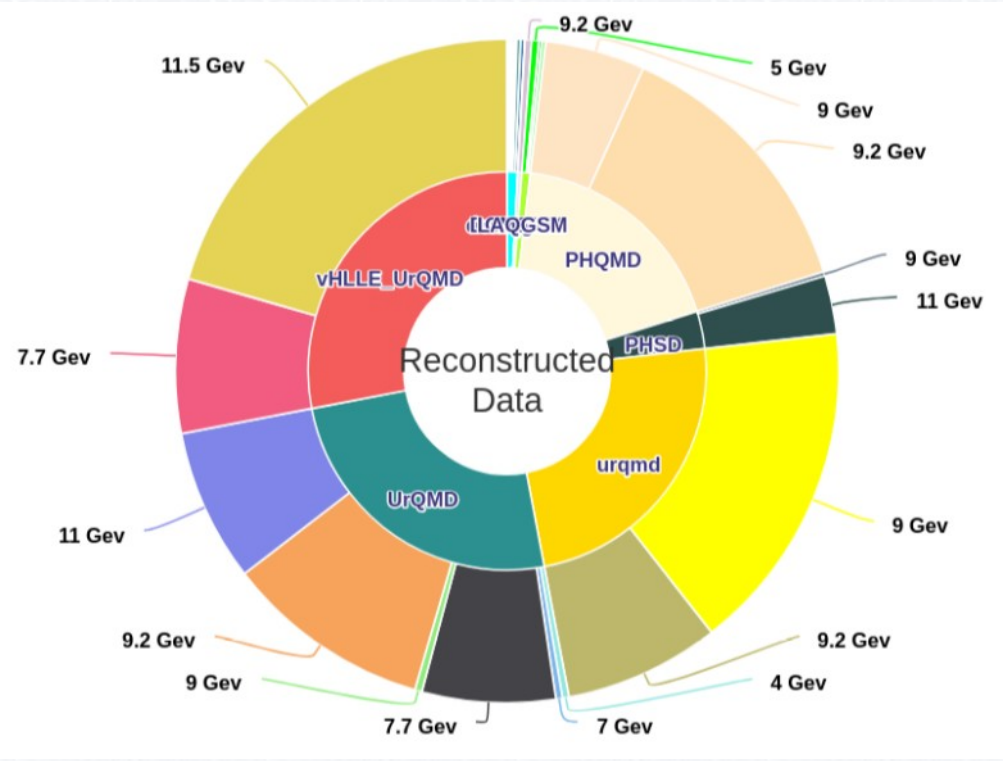
Generator	PWG	Coll.		# of events()	Reco
UrQMD	PWG4	AuAu	11	15	+
		BiBi	9	10	+
			9.46	10	+
			9.2	95	+
	PWG2	AuAu	11	10	+
	PWG3	AuAu	7.7	10	+
		BiBi	7.7	10	+
			9	15	+
		pp	9	10	+
		BiBi fix target	2.5	12	+
		BiBi fix target	3.0	12	+
		BiBi fix target	3.5	12	+
		XeW fix target	2.5	15	+
		XeXe fix target	2.5	15	+
	PWG1	BiBi	9.2	76	+
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				1412	568

~ 2 PB

MPD mass production database

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

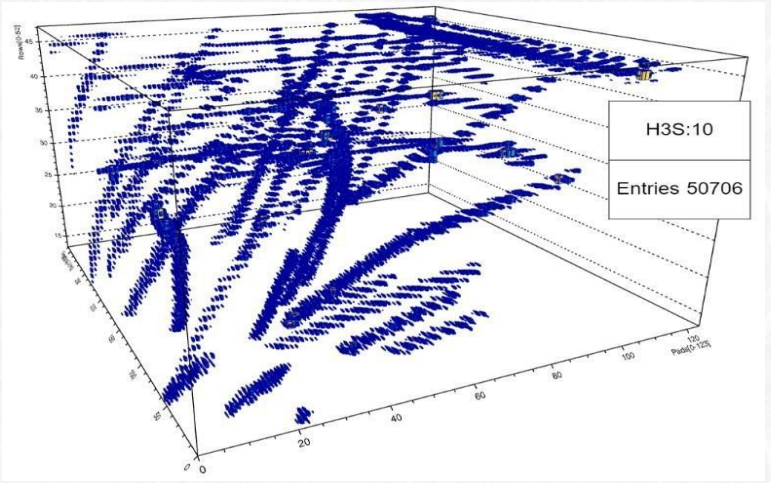


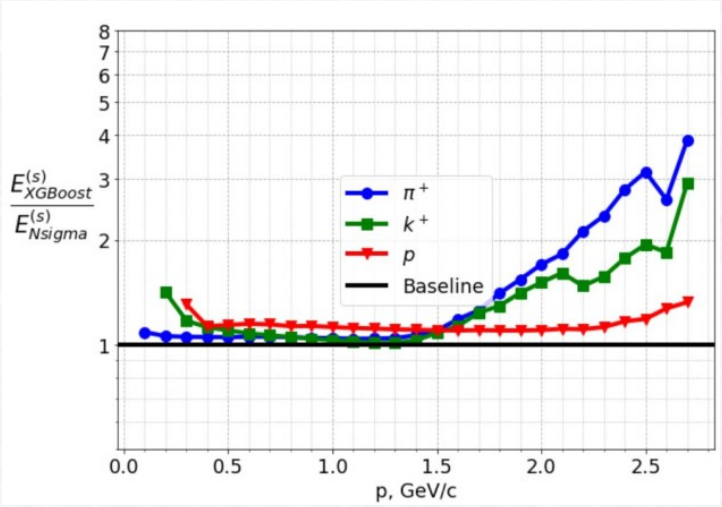


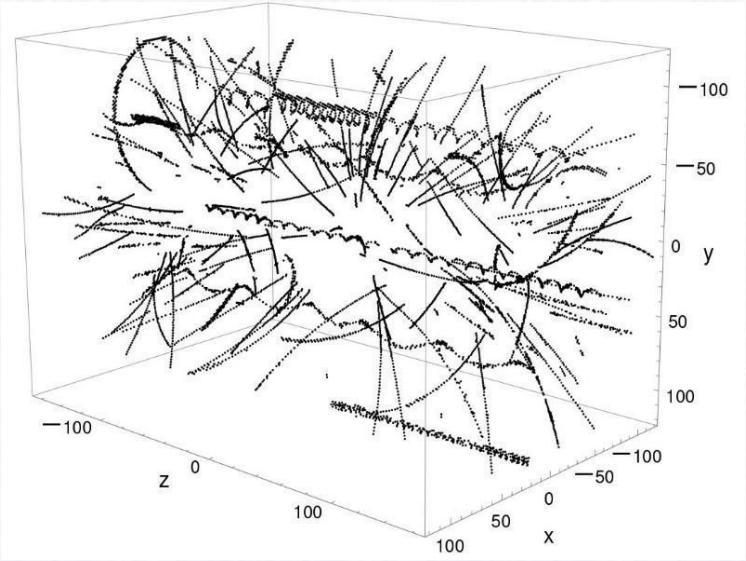
All production data stored in Dirac File Catalog

Upgrade MPD software

- *Fast clustering for online implementation*
- *Fast tracking for online*
- *New PID with ML*



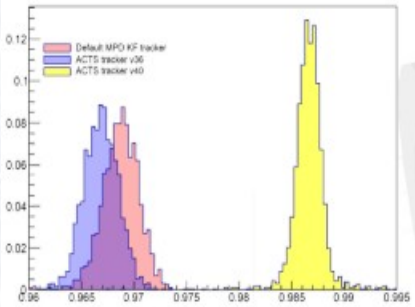




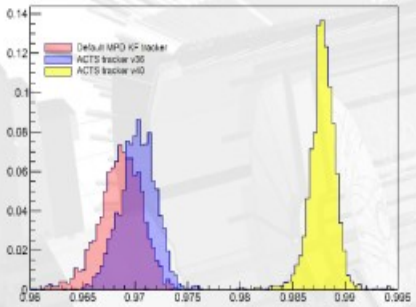
ACTS progress in MPD

CKF enhancements: better efficiency, far less fakes

Efficiency

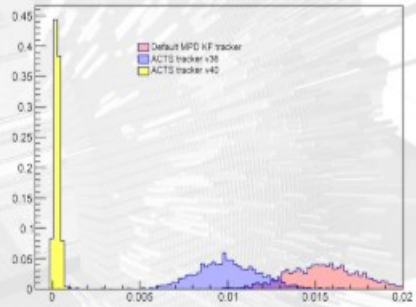


BiBi 9.2 GeV

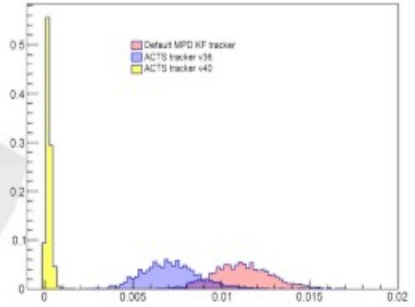


BiBi 7.7 GeV

Fake rate



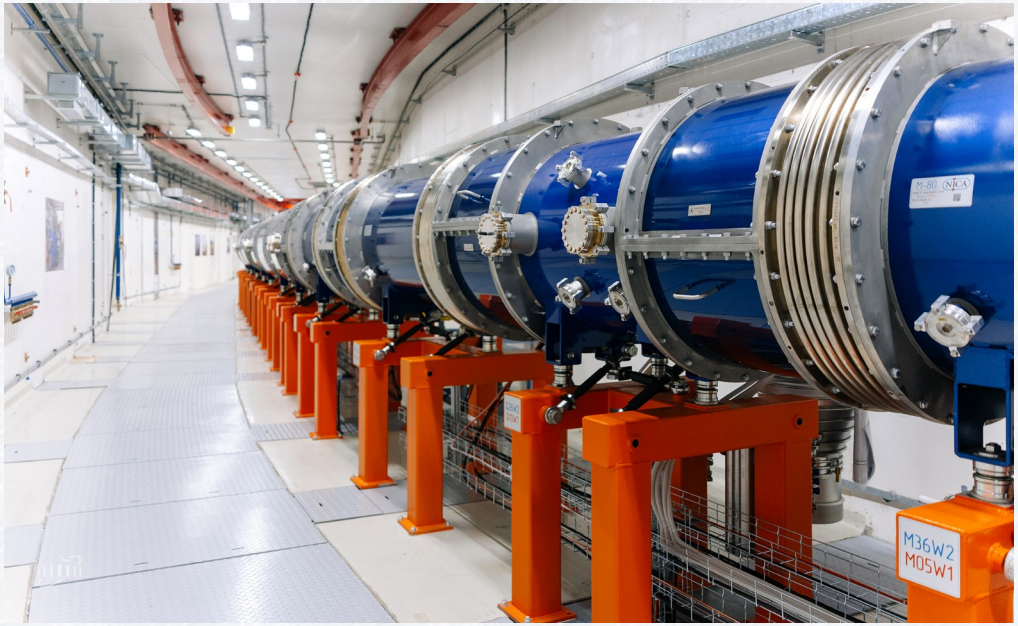
BiBi 9.2 GeV



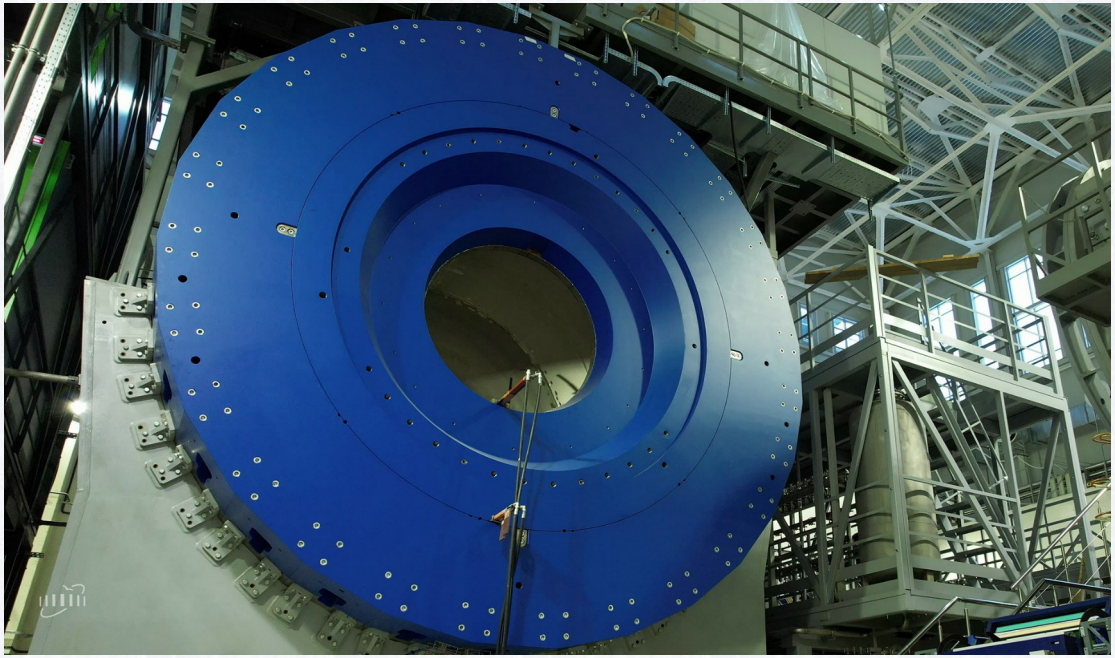
BiBi 7.7 GeV

	Default tracker		ACTS tracker v36.0.0		ACTS tracker v40.0.0	
	true rate	fake rate	true rate	fake rate	true rate	fake rate
BiBi 9.2 GeV	$\mu = 0.9686$ $\sigma = 0.00212$	$\mu = 0.01544$ $\sigma = 0.002012$	$\mu = 0.9668$ $\sigma = 0.001724$	$\mu = 0.00999$ $\sigma = 0.00189$	$\mu = 0.9866$ $\sigma = 0.001779$	$\mu = 0.00026$ $\sigma = 0.000172$
BiBi 7.7 GeV	$\mu = 0.9686$ $\sigma = 0.002107$	$\mu = 0.01122$ $\sigma = 0.001664$	$\mu = 0.9702$ $\sigma = 0.001772$	$\mu = 0.00713$ $\sigma = 0.001612$	$\mu = 0.9878$ $\sigma = 0.001427$	$\mu = 0.000225$ $\sigma = 0.000168$

NICA & MPD progress



The NICA Accelerator Complex reached an important milestone. On the night of 12 February 2026, during the commissioning, simultaneous circulation of counter-rotating beams of xenon nuclei in the collider rings was achieved for the first time.



On 26 February 2026 at 19:20 Moscow time the fixed 3D sensors of Hall, located on the inner surface of the solenoid cryostat, recorded a magnetic field with a design value of 0.57 Tesla. All systems were functioning as expected: temperature remained stable, no current fluctuations were observed. The stability of the operating parameters confirmed the reliability of the MPD magnetic system and the quality of the engineering solutions adopted.

TPC & ECal



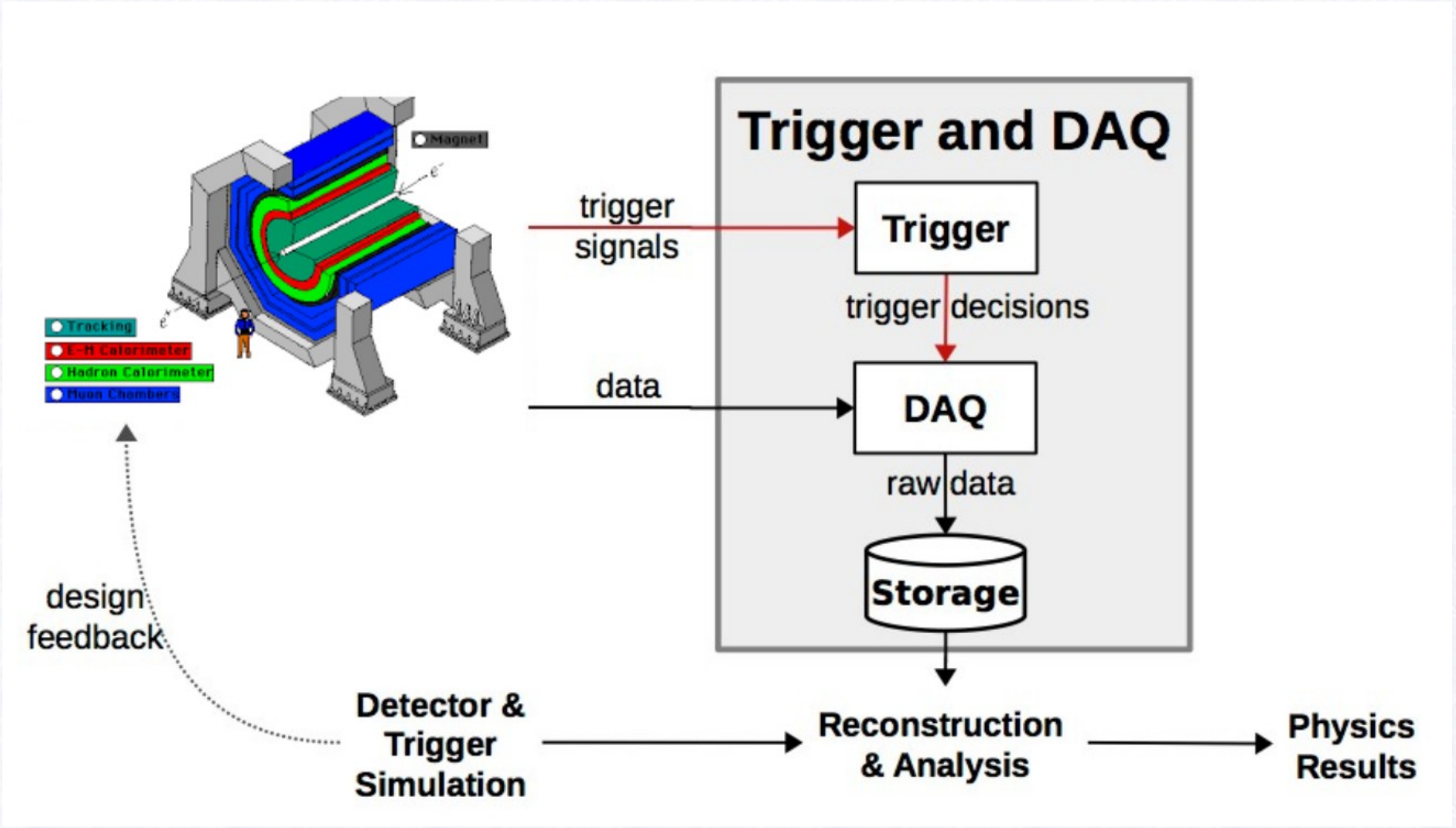




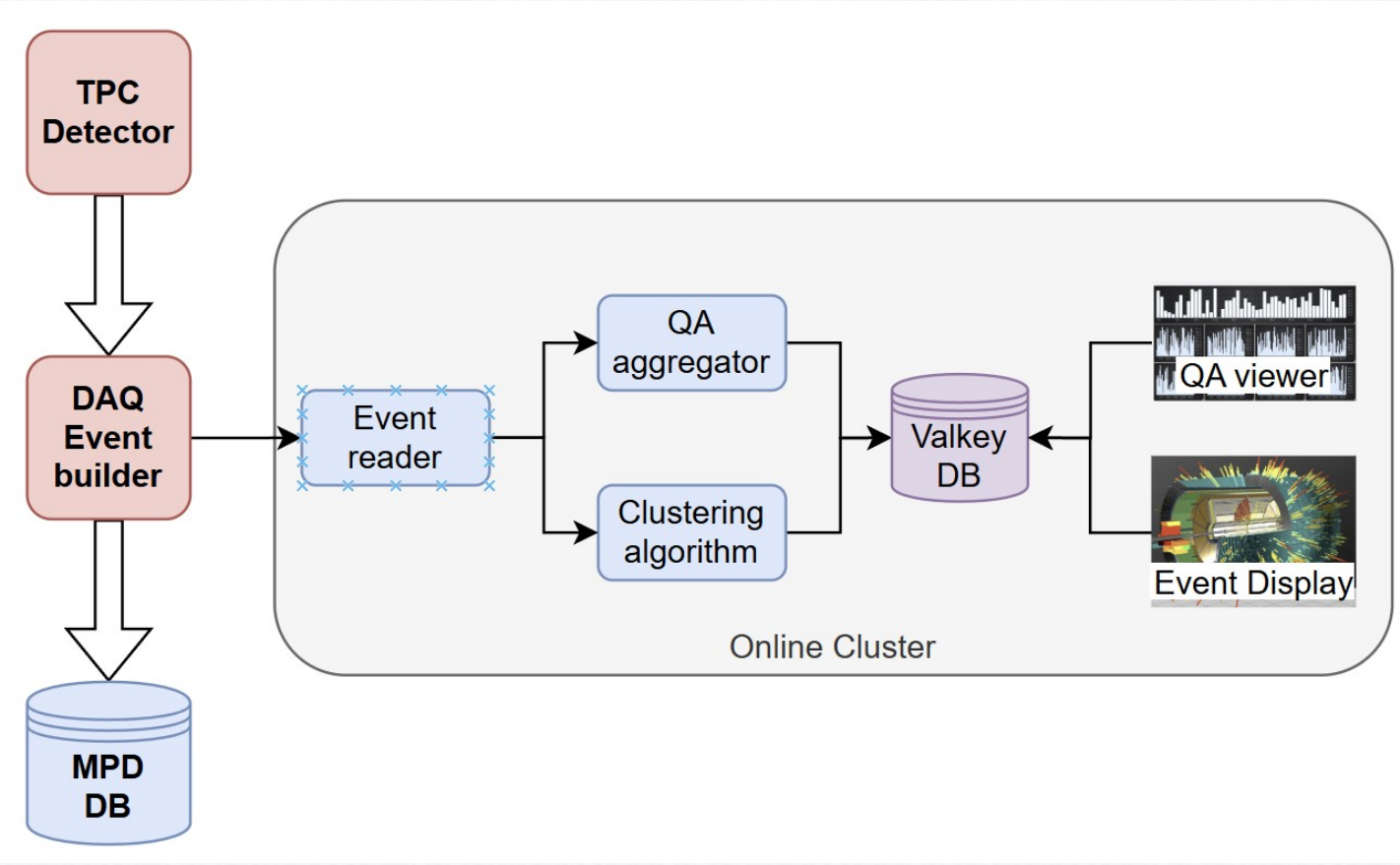
MPD assembling

		2026
9	January 12th – January 23d	Fixation of the Current leads cooling problem
10	January 26th February 12th	Cooling of the Solenoid to working temperature
11	February 13 – February 28th	Magnetic field measurements at nominals 0.4 -0.5T
12	March 2d - March 6th	Support Frame installation into Magnet
13	March 7th – March 22d	Ecal installation from the East side
14	March 7th – March 20th	West side Lifting Platform assembling
15	March 21d – Aprile 15th	Ecal installation from W side
16	March 21d – Aprile 15th	Installation of the TOF modules (access from both sides)
17	April 20th – May 30th	TPC installation and test
18	June 1st – June 10th	Beam pipe installation
19	June 12th	Moving MPD to the Collider beam line

To the real experiment



Online tasks



Thanks for your attention

