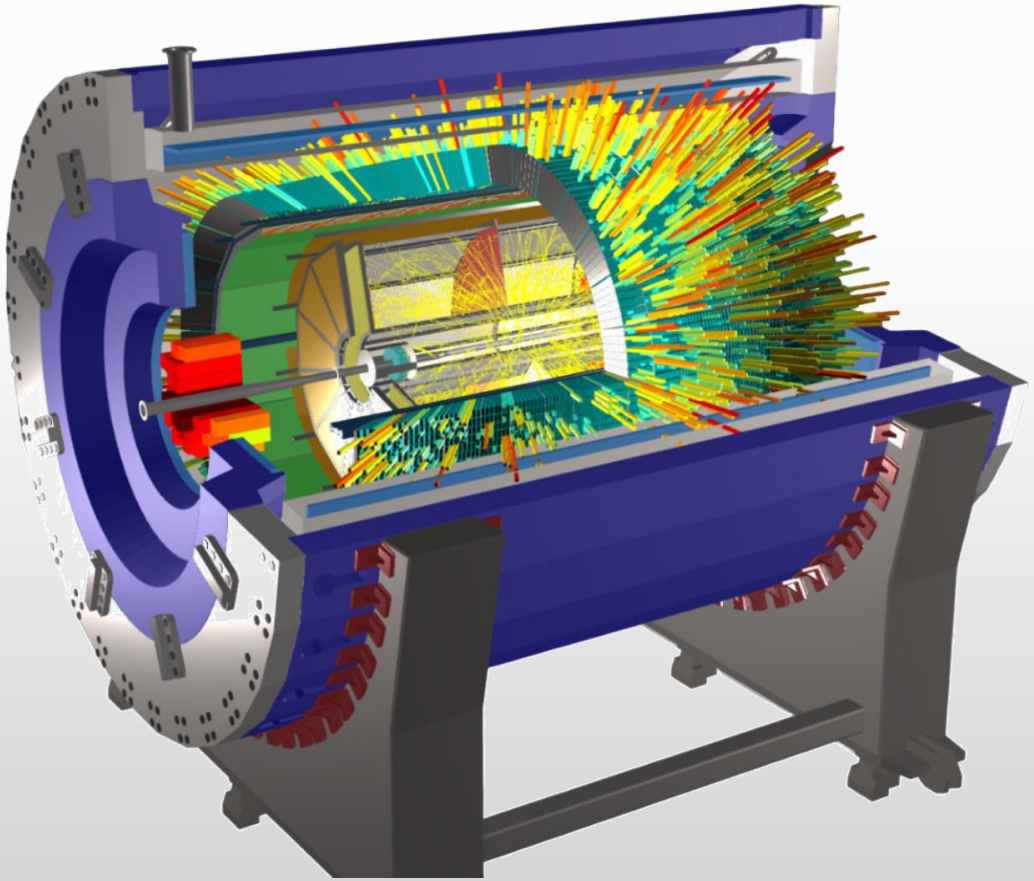
MPD Collaboration Status

V. Riabov for the MPD Collaboration



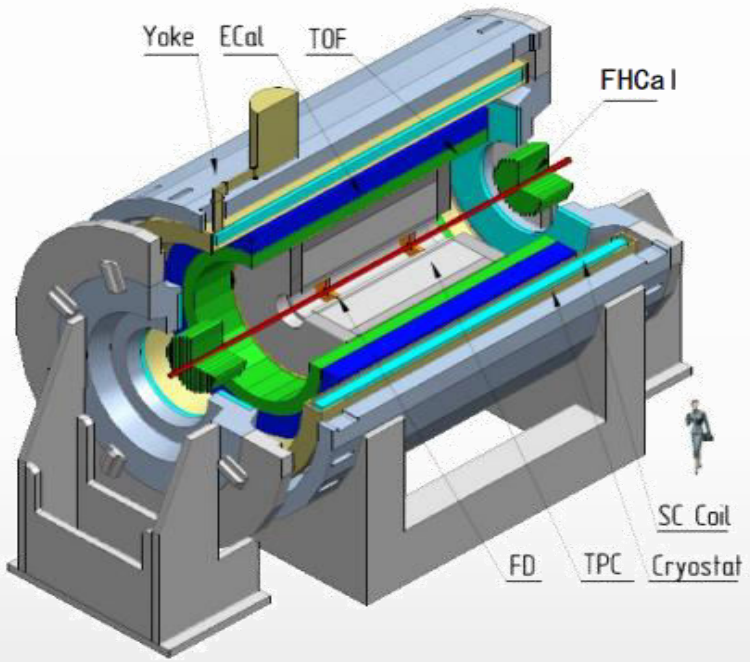
Multi-Purpose Detector (MPD) Collaboration

***MPD** International Collaboration was established in **2018** to construct, commission and operate the detector*

12** Countries, **>500** participants, **38** Institutes and **JINR

Organization

Acting Spokesperson:	***Victor Riabov***
Deputy Spokespersons:	***Zebo Tang, Arkadiy Taranenko***
Institutional Board Chair:	***Alejandro Ayala***
Project Manager:	***Slava Golovatyuk***

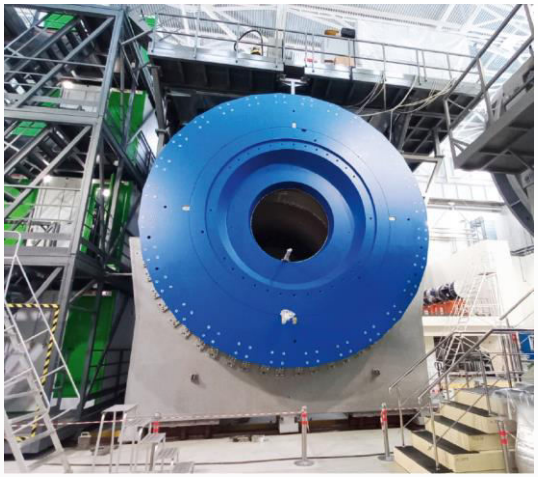


***Joint Institute for Nuclear Research, Dubna**;*
*A.Alikhanyan National Lab of Armenia, Yerevan, **Armenia;***
*SSI "Joint Institute for Energy and Nuclear Research – Sosny" of the National Academy of Sciences of Belarus, Minsk, **Belarus***
*University of Plovdiv, **Bulgaria;***
*Tsinghua University, Beijing, **China**;*
*University of Science and Technology of China, Hefei, **China**;*
*Huzhou University, Huzhou, **China**;*
*Institute of Nuclear and Applied Physics, CAS, Shanghai, **China**;*
*Central China Normal University, **China**;*
*Shandong University, Shandong, **China**;*
*University of Chinese Academy of Sciences, Beijing, **China**;*
*University of South China, **China**;*
*Three Gorges University, **China**;*
*Institute of Modern Physics of CAS, Lanzhou, **China**;*
*Tbilisi State University, Tbilisi, **Georgia**;*
*Institute of Physics and Technology, Almaty, **Kazakhstan**;*
*Benemérita Universidad Autónoma de Puebla, **Mexico**;*
*Centro de Investigación y de Estudios Avanzados, **Mexico**;*
*Instituto de Ciencias Nucleares, UNAM, **Mexico**;*
*Universidad Autónoma de Sinaloa, **Mexico**;*
*Universidad de Colima, **Mexico**;*
*Universidad de Sonora, **Mexico**;*
*Universidad Michoacana de San Nicolás de Hidalgo, **Mexico***
*Institute of Applied Physics, Chisinev, **Moldova**;*
*Institute of Physics and Technology, **Mongolia**;*

*Belgorod National Research University, **Russia**;*
*Institute for Nuclear Research of the RAS, Moscow, **Russia**;*
*High School of Economics University, Moscow, **Russia***
*National Research Nuclear University MEPhI , Moscow, **Russia**;*
*Moscow Institute of Science and Technology, **Russia**;*
*North Osetian State University, **Russia**;*
*National Research Center "Kurchatov Institute", **Russia**;*
*Peter the Great St. Petersburg Polytechnic University Saint Petersburg, **Russia**;*
*Plekhanov Russian University of Economics, Moscow, **Russia**;*
*St.Petersburg State University, **Russia**;*
*Skobeltsyn Institute of Nuclear Physics, Moscow, **Russia**;*
*Petersburg Nuclear Physics Institute, Gatchina, **Russia**;*
*Vinča Institute of Nuclear Sciences, **Serbia**;*
*Pavol Jozef Šafárik University, Košice, **Slovakia***

MPD magnet

Magnet yoke

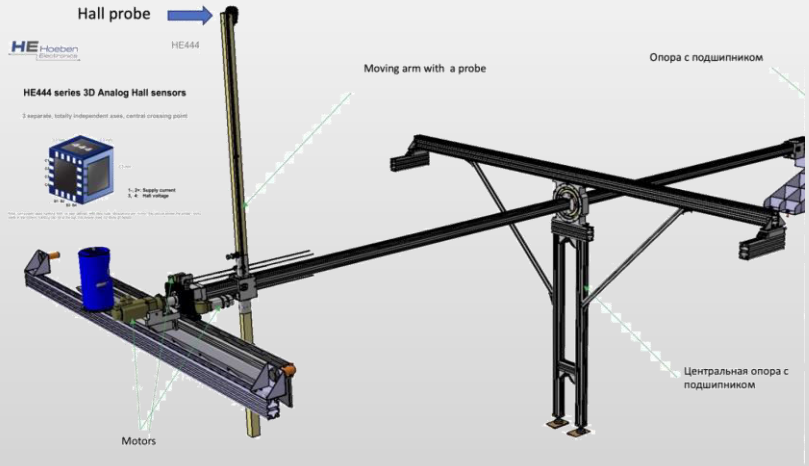


Cryogenic platform

Strings for cryogenic pipes and cables hold

- February: solenoid power cable thermal isolation inside of the Chimney
- Now: solenoid cooled down to the working temperature of 4.5 K, test current supply

Magnetic field mapper



Novosibirsk BINP magnetic field mapper

	Along radius (R)	Along azimuth angle (ϕ)	Along beam (z)
Step size, см	5	21	10
Total length, см	220	360° (1380 см at max. R)	700
Number of measurements	44	64	70

Single 3D Hall probe moves in 3 directions: z , R, ϕ
Accuracy: 0.1 – 0.3 Gs
Number of points: ~ $2 \cdot 10^5$ (90 hours)
Fields to measure: 0.3 – 0.57 T (5-6 points)
Number of tunes per field: 5
Total time of measurements: ~ 3-4 months

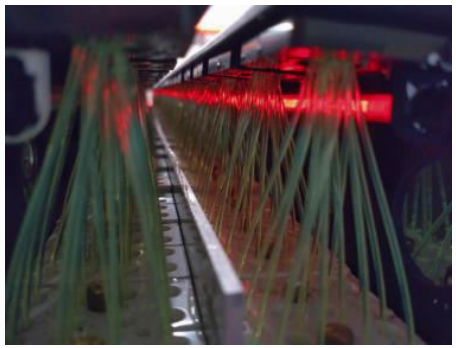
April: mapper delivery to JINR and installation of stationary Hall probes
Summer: MF measurements at 02-0.55 T

Central barrel subsystems

Frame - ready

Carbon fiber support frame delivered and unpacked, sagita ~ 5 mm at full load, rails for the TPC and TOF are installed

ECAL



ECAL ~ 38400 towers (2400 modules)
produced by Tsinghua University, Shandong University, Fudan University, South China University, Huzhou University and JINR – production in IHEP (Protvino) and Tenzor (Dubna)

45 half-sectors to be ready by August, the rest depends on WLS fiber supply from Tver

TOF - ready

All 28 (100%) TOF modules are assembled, tested, stored and ready for installation.
Spare modules in production

TPC – central tracking detector

24+ ROC ready; 100+ % FE cards manufactured
TPC gas volume assembly and HV/leakage tests – ongoing
TPC + ECAL cooling systems under commissioning

TPC mechanical body assembly with ROCs, leak test and HV test	**June 2025**
TPC installation to MPD and test	**Nov –Dec 2025**

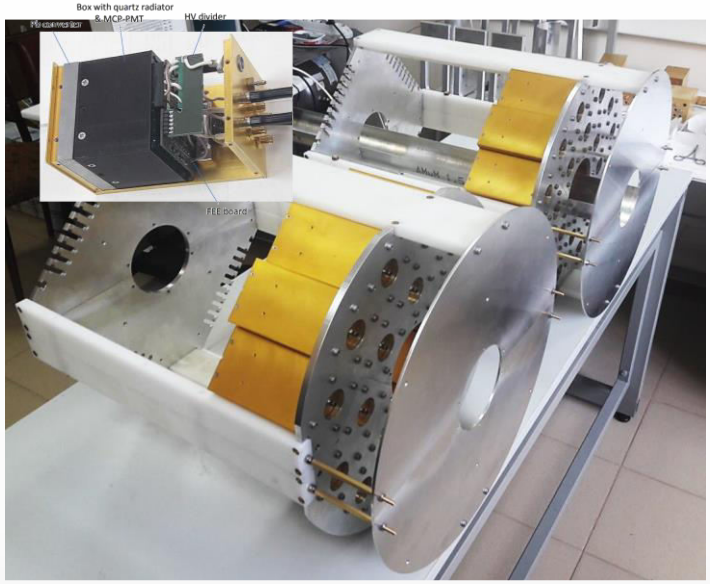
Forward subsystems

FHCAL - ready

FHCal assembled on the platform, (modules are equipped with FEE)

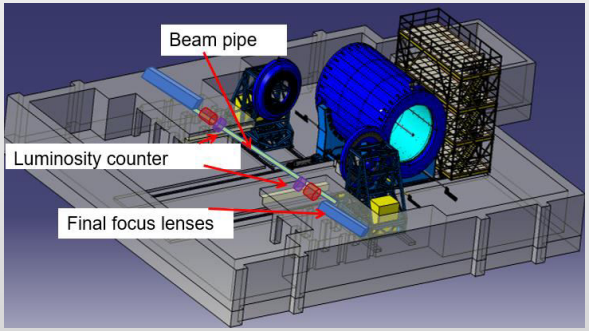
Test installation of FHCAL → autumn 2024
Final installation → August 2025

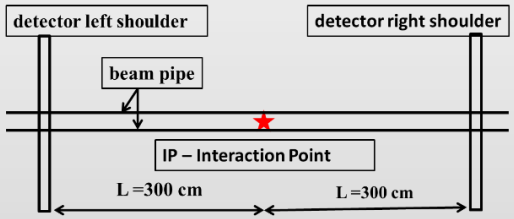
FFD - ready



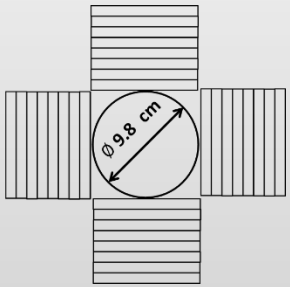
Cherenkov modules of FFDE and FFDW, mechanics for installation in container with beam pipe are available, Long term tests with cosmic rays & laser ongoing

Beam and luminosity monitoring





Measurement of transverse sizes of the bunches
Transvers and longitudinal convergence of bunches
Vertices distribution along the beam



Assembly of the main components of the detector for the Run on the collider beam - June 2025

MPD schedule – 2025

1	January 13th- 30th	Solenoid and Correction Coils Power Supplies control system tests
2	January 25th – February 21st	Solenoid Safety regimes of emergent energy evacuation working out Development of algorithms of cooling on base of experience with manual regime
3	February 1st – February 27th	Solenoid Power cable temperature isolation inside of the Chimney
4	March 3d – April 7th	Cooling down of the Solenoid to the working temperature 4K
5	April 7th -April 30th	Development procedure of current supplying to the Solenoid, training
6	April 20th – 30th	Installation stationary Hall probes (both INP Novosibirsk and Belorussia)
7	April 1st - April 20th	Final test of the Field Mapper at Novosibirsk
8	April 28	Delivery Mapper to the JINR
9	May 10th – May 18th	Installation Magnetic Field Mapper, Calibration, preparation for measurements of Field
10	May 20th - July 30th	Magnetic field measurements on nominals: 0.2T, 0.3T, 0.4T, 0.45T, 0.5T, 0.55T
11	June 15th	TPC mechanical body is assembled, leak test and HV test are finished
12	August 4th – August 22d	Installation FHCal into poles
13	August 6th – September 25th	Ecal installation
14	August 20th – September 30th	Installation TOF modules (access from both sides)
15	November 1st – December 20th	TPC installation and test
16	June 22d – November 30th	Cabling
17	December 4th – December 14th	Beam pipe installation
18	December 22d	Moving to the beam line
19	December 30th	Readiness for Data taking

Starting detector commissioning in late 2025 remains the main priority

Proposal for continuation of the MPD project

JOINT INSTITUTE FOR NUCLEAR RESEARCH

The Report on Project

“MPD. MultiPurpose Detector”

02-1-1065-3-2011/2025

Feasibility study of the second stage of the MPD

Theme: 02-0-1065-2007/2026

LEADER *V.M.Golovatyuk, V.D.Kekelidze, V.G.Riabov*

Continuation of the MPD project

Cost estimation

Proposed schedule and resource request for the MPD Project

Expenditures, resources, funding sources			Cost (thousands of US dollars)/ Resource requirements	Cost/Resources, distribution by years				
				1st year	2nd year	3rd year	4th year	5th year
		International cooperation	1000	200	200	200	200	200
		Materials	23350	3700	5250	6500	5350	2550
		Equipment, Third-party company services	6450	1100	1150	1850	1550	800
		Commissioning	300	0	50	100	100	50
		R&D contracts with other research organizations	450	100	100	100	100	50
		Software purchasing						
		Design/construction						
		Service costs (*planned in case of direct project affiliation*)	1000	200	200	200	200	200
Resources required	Standard hours	Resources						
		- the amount of FTE,	625	125	125	125	125	125
		- accelerator/installation,	13720	2200	2880	2880	2880	2880
		- reactor,…						
Sources of funding	JINR Budget	JINR budget (*budget items*)	**33000**	**5400**	**7050**	**9050**	**7600**	**3900**
	Extra fudning (supplementary)	Contributions by partners Funds under contracts with customers	500	100	100	100	100	100

Project Leader _____ V.M.Golovatyuk

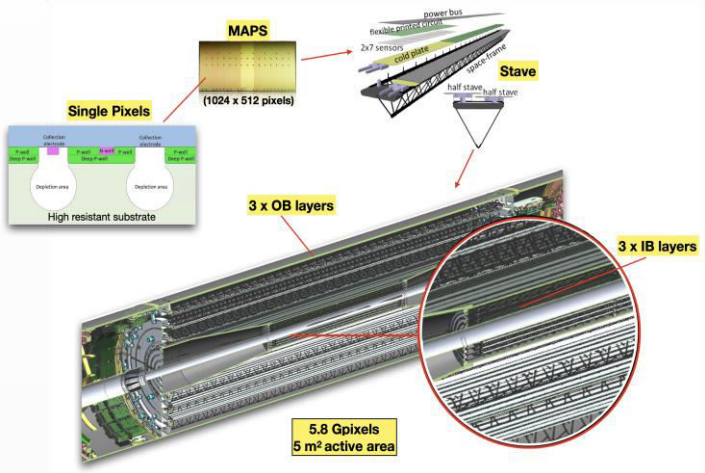
Laboratory Economist _____ V.V.Morozov

Resources distribution by years

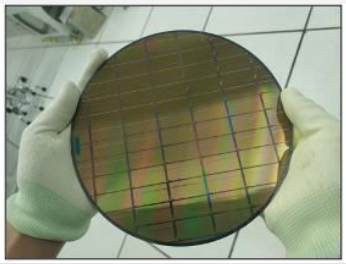
The main systems, resources, funding souces			Cost of the main subsystems (k$)	Cost/Resources distribution by years (k$)				
				1 y. (2026)	2 y. (2027)	3 y. (2028)	4 y. (2029)	(2030)
Resources required	The main systems	Time Projection Chamber upgrade (TPC)	5250	700	1200	1650	1000	700
		Upgrade of Ecal	700	200	200	100	100	100
		Upgrade of FHCal	350	100	100	50	50	50
		Upgrade of Forward FFD	250	50	50	50	50	50
		Cryogenic and Power Supply systems of Magnet	3500	1100	900	800	500	200
		Upgrade of DAQ	850	150	150	200	200	150
		Infrastructure of the MPD	900	250	250	200	100	100
		Second stage detectors						
		Forward TOF	3770	420	750	1100	1100	400
		Forward Ttracker	13140	1350	2850	3650	3450	1840
		Inner Tracker (ITS)	4290	1270	1050	1200	700	70
		Total:	**33000**	**5590**	**7500**	**9000**	**7250**	**3660**
		International Cooperation	825	165	165	165	165	165

Inner Tracking System – ITS

The ITS is the key to measuring the production of heavy-flavor hadrons



The complete structure of the 6-layer MPD-ITS detector, from a single pixel to the inner and outer cylindrical layers



- first prototype of ALPIDE-like MAPS (MICA) sensor developed at CCNU and produced in China

- FPGA-based Readout System and the Power Unit developed at USTC for reading out the "staves" comprising of MICA sensors of IB and OB → tests at LHEP in 2025

- first porotypes of the GBT ASICs for the fast aggregation of data and transfer via optical lines designed and manufactured → lab tests ongoing in CCNU.

1) The TDR was finalized to build an ITS consisting of six cylindrical layers of MAPS (Monolithic Active Pixel Sensors) around the interaction region: 3 layers of inner barrel (IB) surrounded by 3 layers of outer barrel (OB)

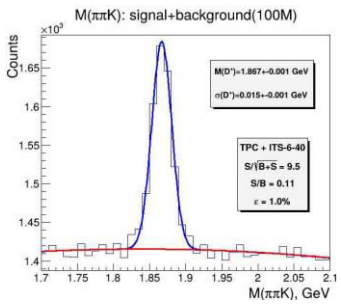
2) An agreement was reached with Chinese partners to jointly research, develop and manufacture in China the missing components needed to build the tracker and its readout system.

6 layers in 2 barrels final conceptional design and its optimization- by 2024

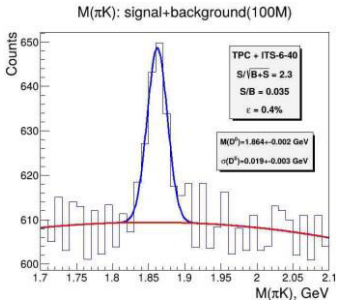
MPD - ITS

D⁺ and D⁰ reconstruction using KF with TPC-TOF PID

$D^+ \rightarrow K^- + \pi^+ + \pi^+$



$D^0 \rightarrow K^- + \pi^+$



N_D = 19 000 mesons/month for D^+
N_D = 3 200 mesons/month for D^0

Using the optimal BDT cut allows to reconstruct D^+ and D^0 with an efficiency of **1.0%** and **0.4%** respectively.

Particle	D^+	D^0
Efficiency, %	1.0	0.4
Significance	9.5	2.3
S/B(2σ) ratio	0.11	0.035

Courtesy of Prof. V.Kondratiev (SPbSU)

D^0 and D^+ reconstruction using information from ITS+TPC+TOF subsystems

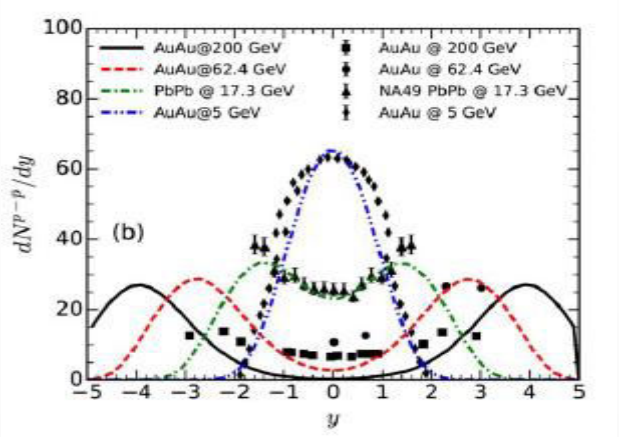
Rapidity scan with MPD at NICA

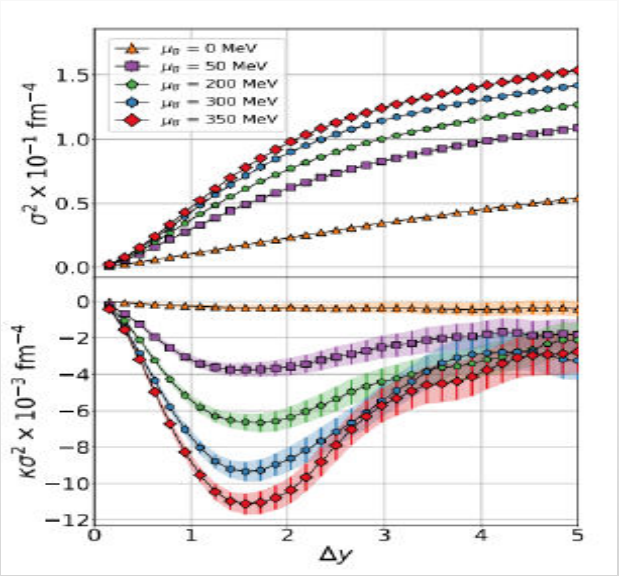
More detailed study of the QCD phase diagram by utilizing a three-dimensional scan in collision energy, interacting system size, and particle rapidity

Motivation for Forward upgrade:

1. Full yields of (heavier) identified hadrons and light nuclei with non-trivial rapidity dependence due to baryon stopping, more detailed study of the "horn", the "step" effects for lighter hadrons
2. Two-particle correlation and multiparticle cumulant studies with wider coverage in $\Delta\eta$
3. Directed and elliptic flow → tighter constraints on η/s
4. Search for CEP with event-by-event fluctuations of conserved charges → higher sensitivity with wider rapidity coverage
5. Hyperon global polarization vs rapidity → insights on the origin of the global polarization signal, tighter constraints for models
6. Extended forward rapidity coverage may be beneficial for diffractive studies in proton-proton collisions, such as instanton searches
7. Improved trigger efficiency, centrality and event plane determination

… and more





Funding

- Support program from Russian Ministry of Education and Science for NICA:
  - ✓ russian groups from subordinated organizations participating in NICA with signed MOUs
  - ✓ 200 MRUB (~2.2 M$) in 2024 for all NICA activities: MPD, BM@N, SPD, ARIADNA collaborations, accelerator
  - ✓ program has been extended to 2025-2026
  - ✓ new participating institution are possible

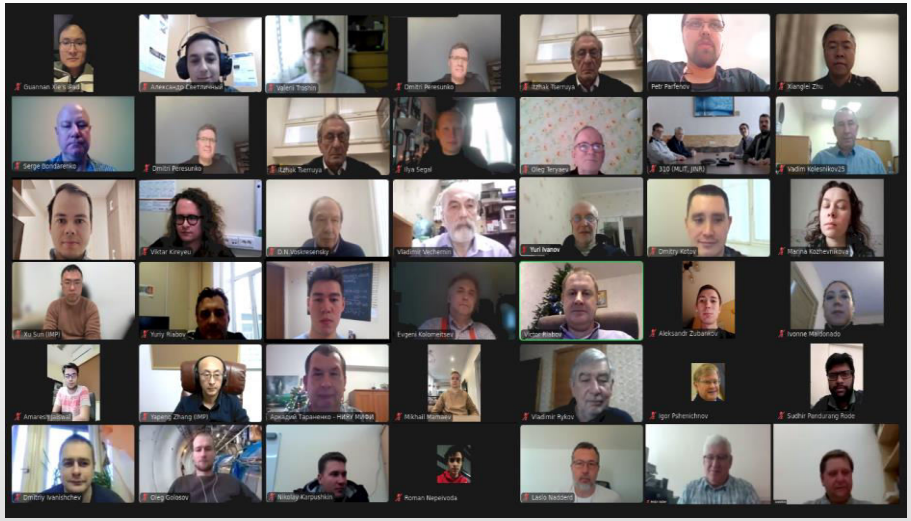
- ~ 40 MRUB for MPD per year:
  - ✓ supported organizations: MEPhI, St.Petersburg Polytechnic University, INR RAS, Belgorod National Research University, North Ossetia State University

- Problems:
  - ✓ KI, MSU, SPbSU, HSE University are excluded from the program (not subordinated organizations)
  - ✓ no funds for travel (shifts, etc.)

Conferences and workshops

- MPD presentations at conferences since last meeting (~ 15 talks):
  - ✓ ICPPA - 2024, Moscow, Russia, Oct 22-25
  - ✓ Session-Conference of the Section of Nuclear Physics Branch of the Russian Academy of Sciences - 2025, Russia, Feb. 17-21

- JINR-MEPhI organized International Workshop NICA-2024, Nov. 25-27
  - ✓ joint platform for discussion of NICA physics at BM@N and MPD
  - ✓ 175 participants from all over the world: Bangladesh, Brazil, Bulgaria, Check Republic, China, Cuba, Egypt, India, Kazakhstan, Mexico, Russia, Serbia, US, Uzbekistan, Vietnam
  - ✓ 22 talks in three days

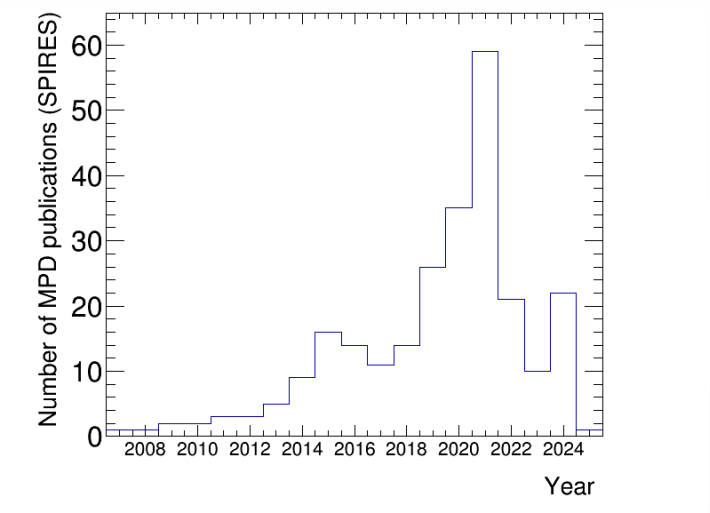


Co-chairs
Arkadiy Taranenko (MEPhI, JINR)
Evgeni Kolomeitsev (JINR, UMB, Banska Bystrica)
Victor Riabov (PNPI, MEPHI)

Organizing commitee
Zebo Tang (USTC, China)
Yi Wang (Tsinghua University, China)
Shusu Shi (CCNU, China)
Natalia Barbashina (MEPhI)
Ivan Astapov (MEPhI)
Dmitry Blau (NRC Kurchatov Institute)
Serge Bondarenko (BLTP JINR)
Fedor Guber (INR RAS)
Vadim Kolesnikov (JINR)

Publications

- Overall publication activity (SPIRES indexed)



- Collaboration papers:

I. **Status and initial physics performance studies of the MPD experiment at NICA**
Eur.Phys.J.A 58 (2022) 7, 140 (~ 50 pages)

II. **MPD physics performance studies in Bi+Bi collisions at $\sqrt{s_{NN}}$ = 9.2 GeV**
consolidation and publication of physics feasibility studies for BiBi@9.2 GeV, 40+ pages

arXiv:2503.21117 [nucl-ex]

paper has been submitted to the journal, Revista Mexicana de Física

MPD physics program

G. Feofilov, P. Parfenov

Global observables

- Total event multiplicity
- Total event energy
- Centrality determination
- Total cross-section measurement
- Event plane measurement at all rapidities
- Spectator measurement

V. Kolesnikov, Xianglei Zhu

Spectra of light flavor and hypernuclei

- Light flavor spectra
- Hyperons and hypernuclei
- Total particle yields and yield ratios
- Kinematic and chemical properties of the event
- Mapping QCD Phase Diag.

K. Mikhailov, A. Taranenko

Correlations and Fluctuations

- Collective flow for hadrons
- Vorticity, Λ polarization
- E-by-E fluctuation of multiplicity, momentum and conserved quantities
- Femtoscopy
- Forward-Backward corr.
- Jet-like correlations

D. Peresunko, Chi Yang

Electromagnetic probes

- Electromagnetic calorimeter meas.
- Photons in ECAL and central barrel
- Low mass dilepton spectra in-medium modification of resonances and intermediate mass region

Wangmei Zha, A. Zinchenko

Heavy flavor

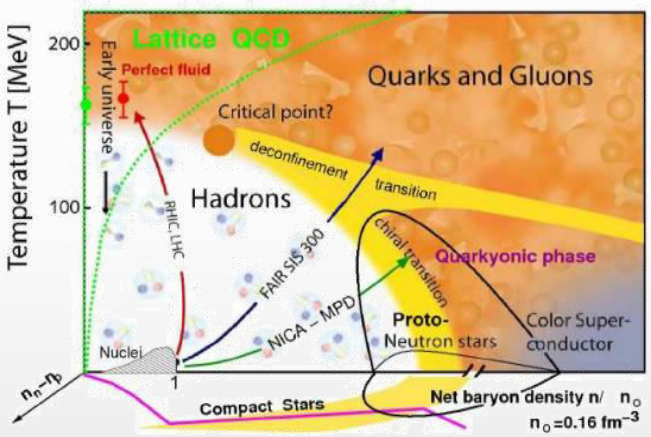
- Study of open charm production
- Charmonium with ECAL and central barrel
- Charmed meson through secondary vertices in ITS and HF electrons
- Explore production at charm threshold

❖ Changes:

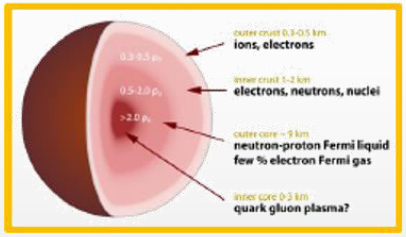
- ✓ PWG2: V. Kolesnikov steps down → thanks for the service !!!
- ✓ PWG2: V. Kireev steps in as a new convener

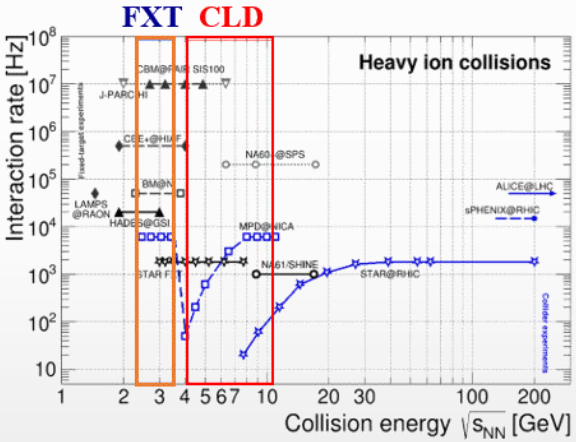
Physics feasibility studies

- Physics feasibility studies using centralized large-scale MC productions
- Centralized Analysis Framework for access and analysis of data → Analysis Train:
  - ✓ consistent approaches and results across collaboration, easy storage and sharing of codes
  - ✓ reduced number of input/output operations for disks and databases, easier data storage on tapes
- Develop physics program, software and analysis infrastructure for real data analysis



high baryon densities → inner structure of compact stars





QCD medium at extreme net baryon densities → 1st order phase transition + CEP

- MPD-CLD and MPD-FXT approved start-up:
  - ✓ Collider mode: two beams, $\sqrt{s_{NN}}$ = 4-11 GeV
  - ✓ Fixed-target mode: one beam + thin wire (~ 50-100 μm) :

    - extends energy range to $\sqrt{s_{NN}}$ = 2.4-3.5 GeV (HADES, BM@N, CBM)
    - no problem of low event rate at lower collision energies

MLIT participation in MPD

Participants from MLIT:

Aleksandr Kokorev	Maria Lubimova
Anastasia Anikina	Maxim Zuev
Andrey Dolbilov	Natalia Gromova
Balashov Nikita	Oksana Streltsova
Dmirty Belyakov	Sergei Shmatov
Dmitry Podgainy	Slavomir Hnatic
Evgeny Aleksandrov	Tatyana Strizh
Igor Aleksandrov	Valeriy Mitsin
Igor Pelevanyuk	Vladimir Korenkov
Irina Filozova	Vladimir Trofimov
Jan Busha Jr.	Vladimir Uzhinsky

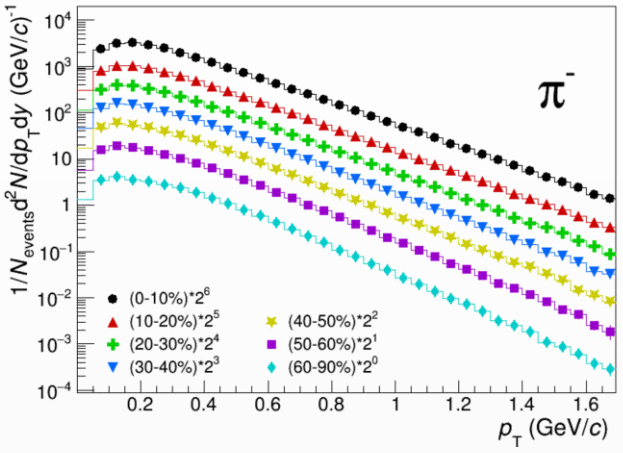
Mescheryakov Laboratory of Information Technologes take active participation in MPD collaboration works. We are grateful for provided computing resources, development and support of IT services.

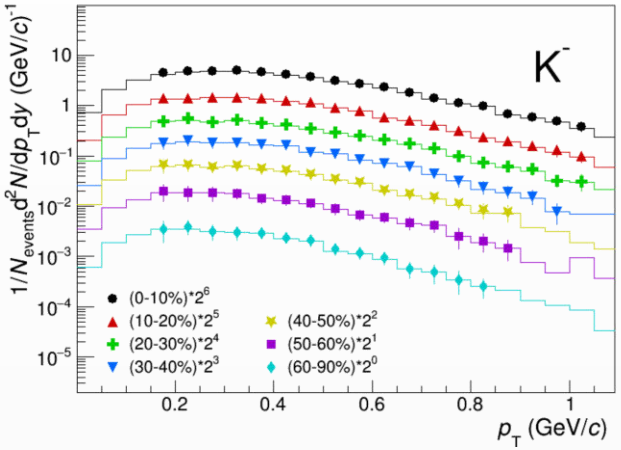
Advancements in analyses

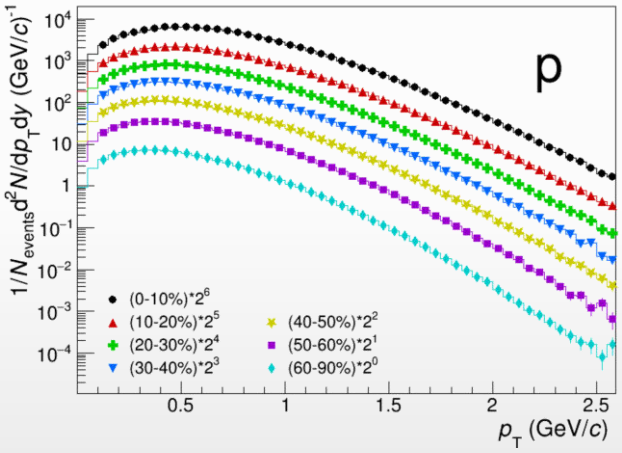
- MPD-CLD: continued analyses of BiBi@9.2 GeV (fluctuations, dielectrons, etc…)
- MPD-FXT: new productions and new analyses …
  - ✓ new centralized centrality wagon (evCentrality)
  - ✓ new centralized track parametrizations: n-sigma matchings to DCA and outer detectors, dEdx and β - PID, etc. (evPID)
  - ✓ new event-plane centralized wagon (evPlaneFXT)

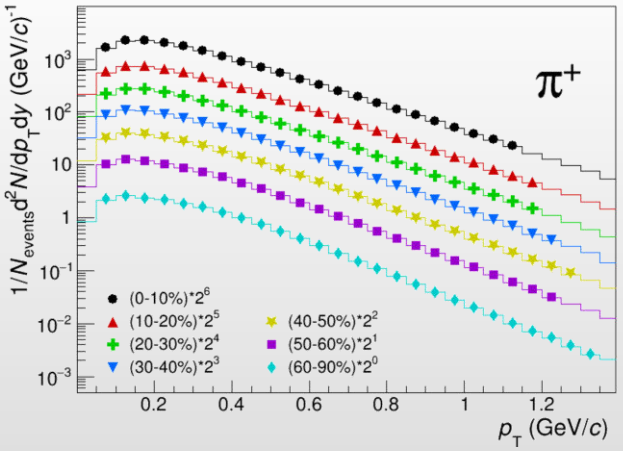
MPD-FXT: Identified charged π/K/p - I

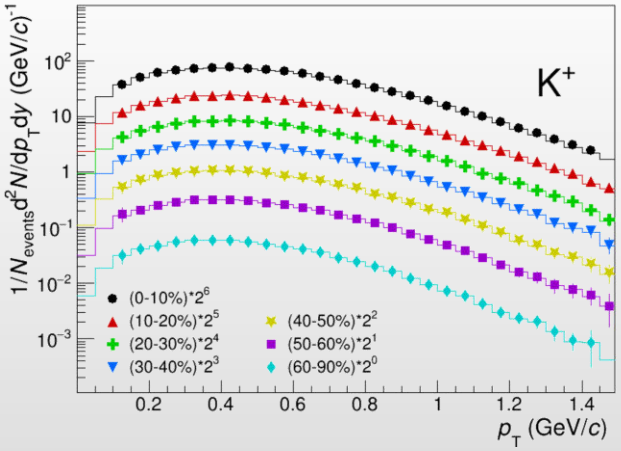
- Request 36 MPD-FXT: XeW@ T=2.5 AGeV (UrQMD), 15 M events → full event/detector reconstruction
- π/K/p identification based on n-sigma selections in the TPC/TOF → good for the first-day measurements









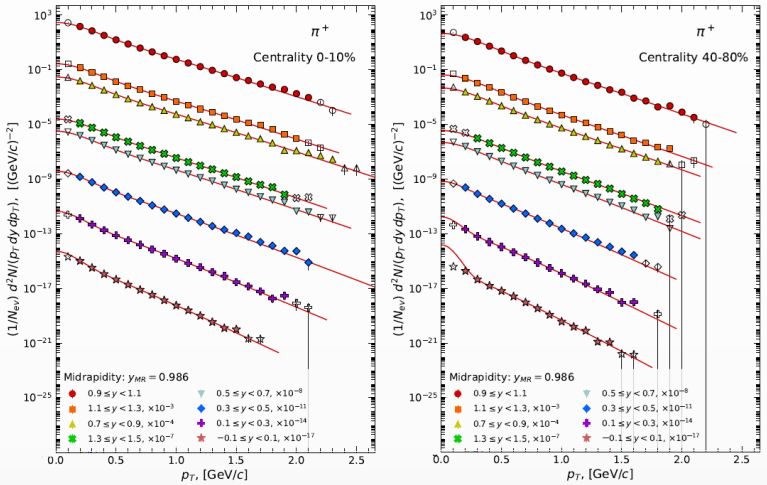


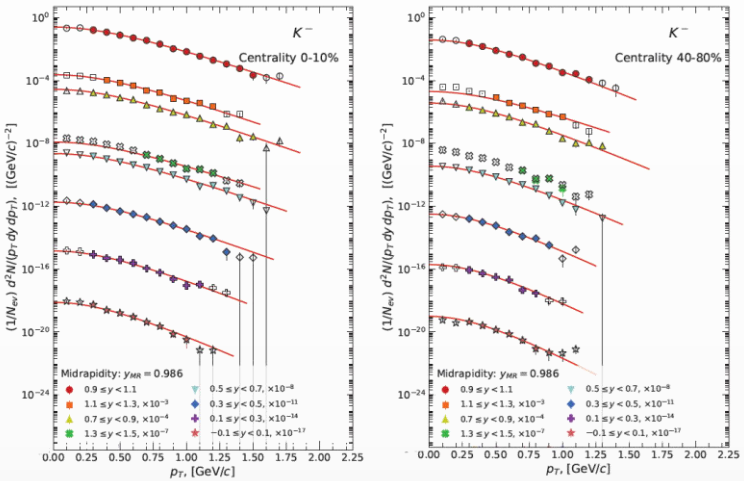
Best possible coverage at low-p_T → ideal for dN/dy and $\langle p_T \rangle$

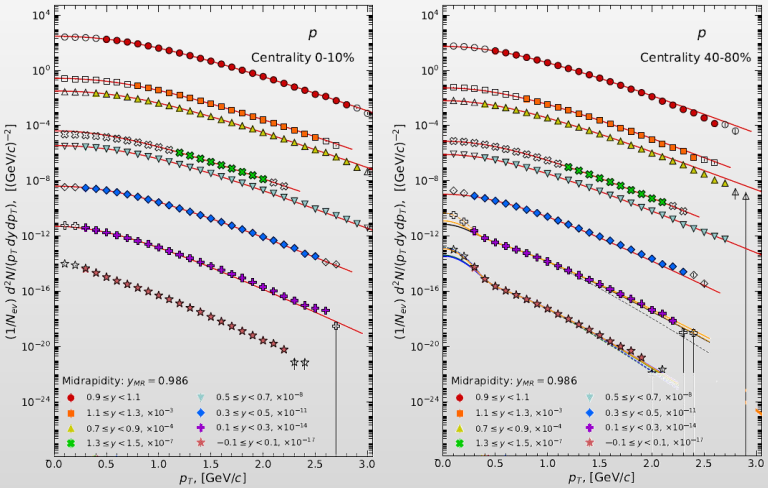
Sampled p_T range accounts for > 95% ($\pi^{\pm}$, K^+, p) and > 85% (K^-) of the total yield

MPD-FXT: Identified charged π/K/p - II

- Request 36 MPD-FXT: XeW@ T=2.5 AGeV (UrQMD), 15 M events → full event/detector reconstruction
- π/K/p identification based on Bayesian probability in the TPC&TOF combined



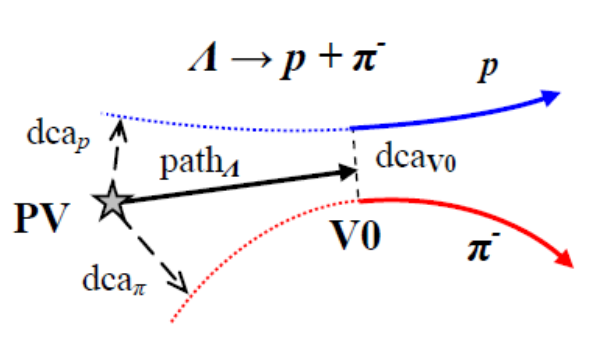




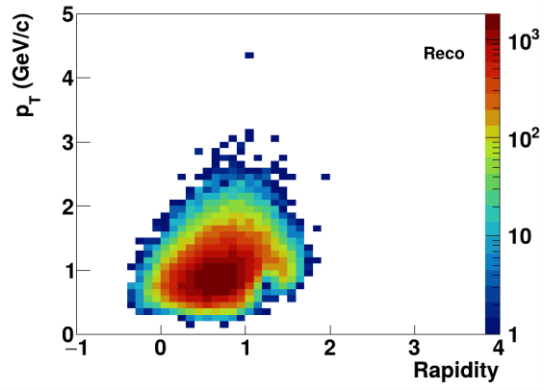
- **Better coverage at higher momenta, low-p_T coverage is limited due to TOF-matching requirement**
- **Good for advanced study of spectra shapes, radial flow, differential particle ratios (B/M, etc.)**
- **Contamination corrections may be quite significant → require systematic study**

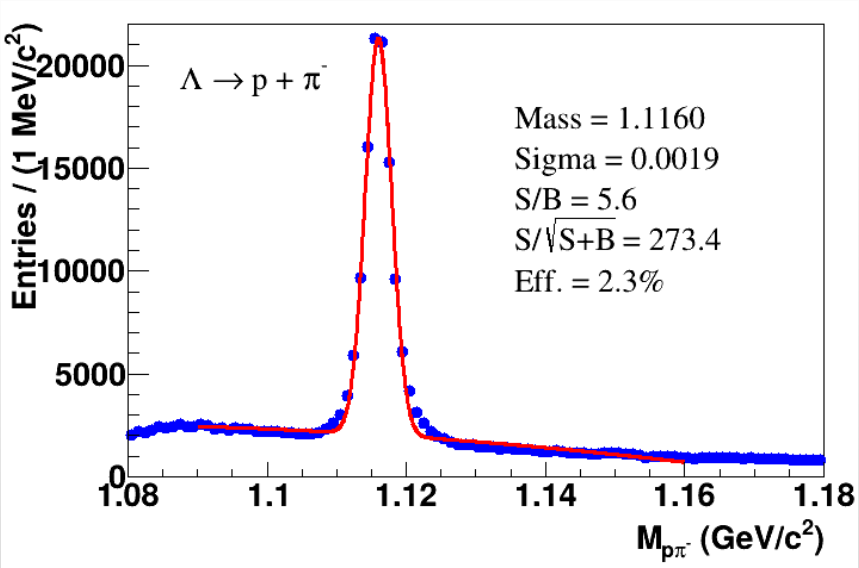
MPD-FXT: Λ hyperon

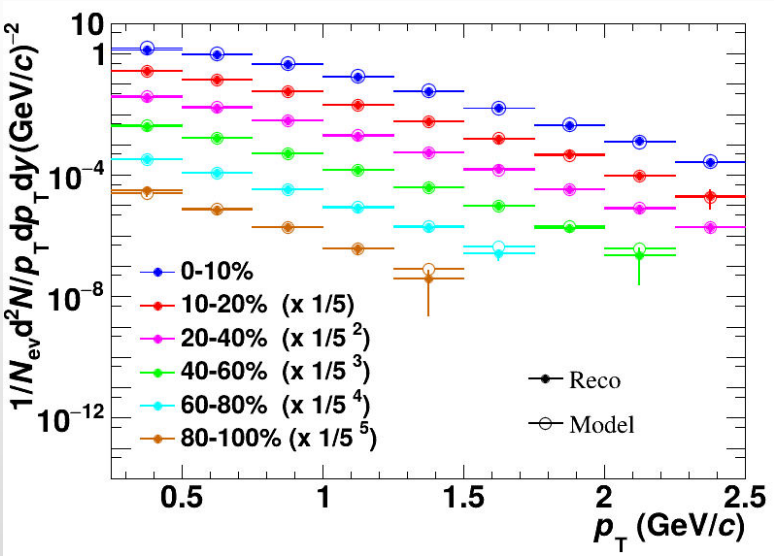
- Request 36 MPD-FXT: XeW@ T=2.5 AGeV (UrQMD), 15 M events → full event/detector reconstruction
- Λ identification based on topological selections



MPD phase space for reconstructed Λ





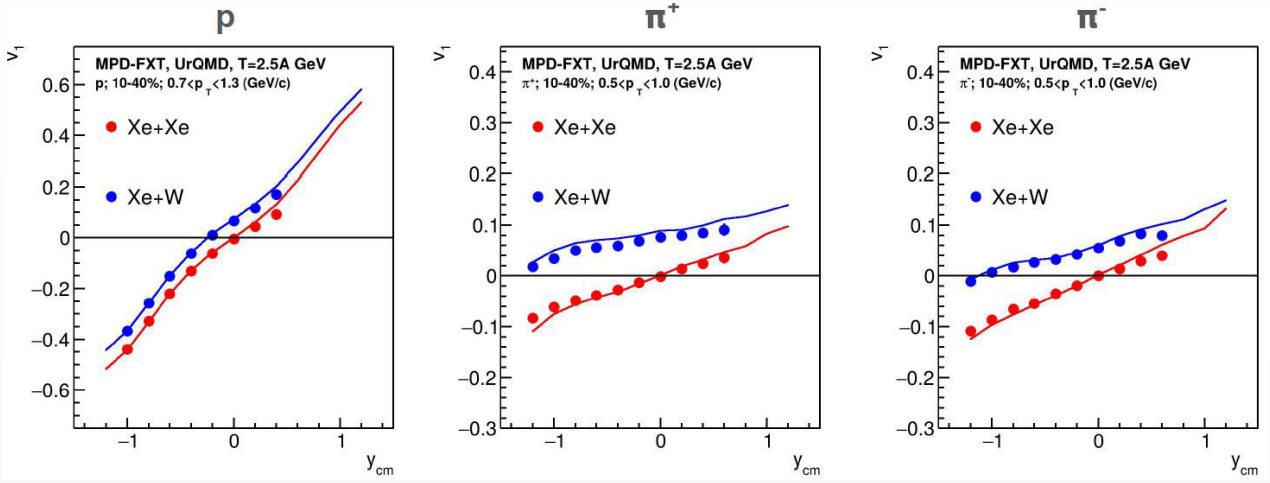


- **Good agreement between generated and reconstructed signals**

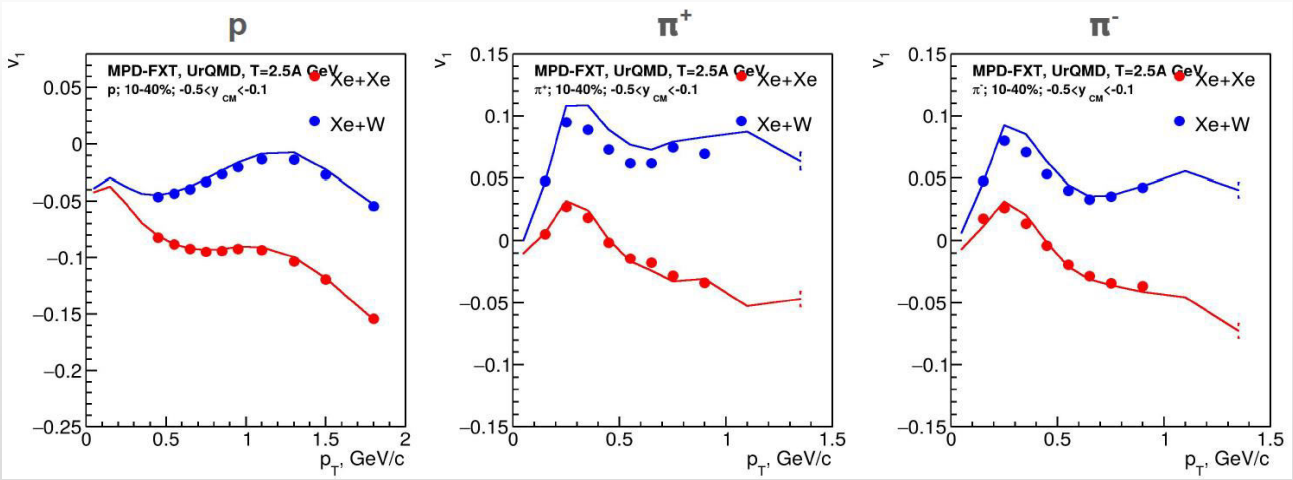
MPD-FXT: v_1 for charged π and protons

- Request 36 MPD-FXT: XeW@ T=2.5 AGeV (UrQMD), 15 M events → full event/detector reconstruction
- New: realistic PID (TPC+TOF); efficiency corrections; centrality by TPC multiplicity

v_1 vs. rapidity



v_1 vs. p_T



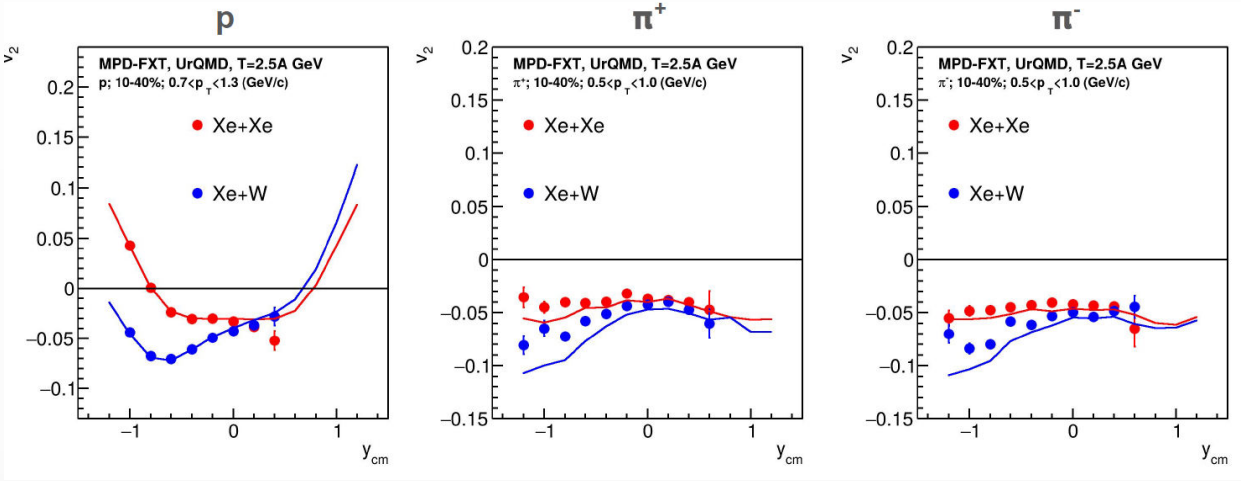
Reconstructed and generated signals mostly agree

Some remaining discrepancies to be resolved

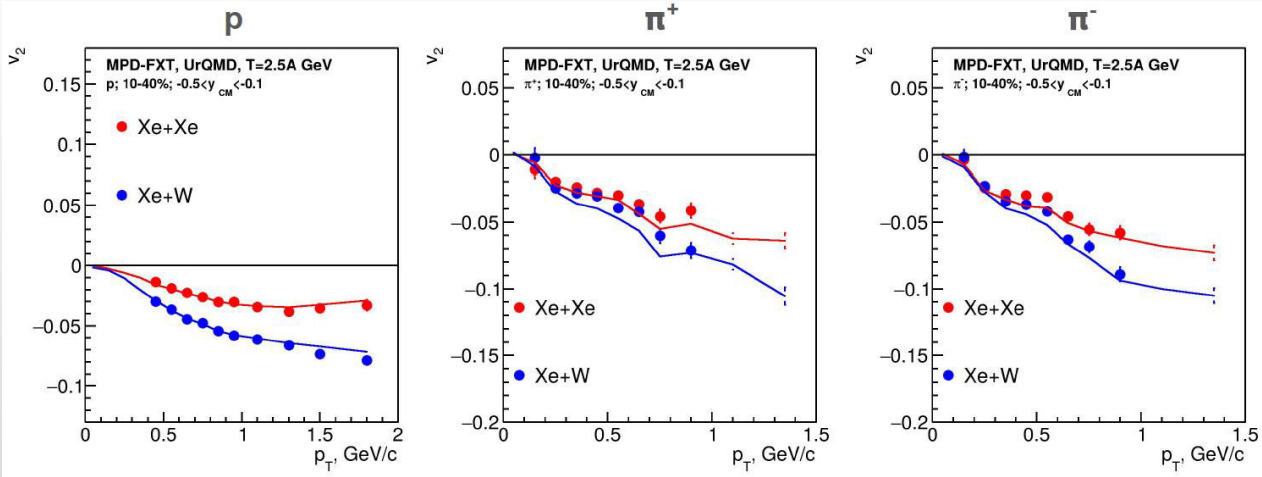
MPD-FXT: v_2 for charged π and protons

- Request 36 MPD-FXT: XeW@ T=2.5 AGeV (UrQMD), 15 M events → full event/detector reconstruction
- New: realistic PID (TPC+TOF); efficiency corrections; centrality by TPC multiplicity

v_2 vs. rapidity



v_2 vs. p_T



Reconstructed and generated signals mostly agree

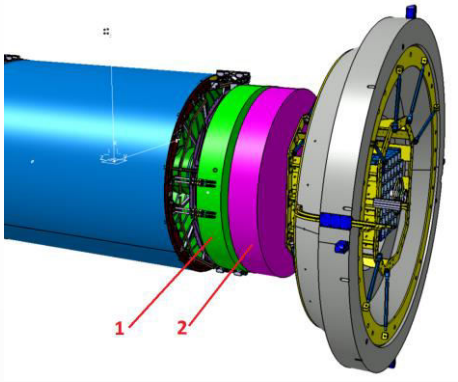
Some remaining discrepancies to be resolved

Summary

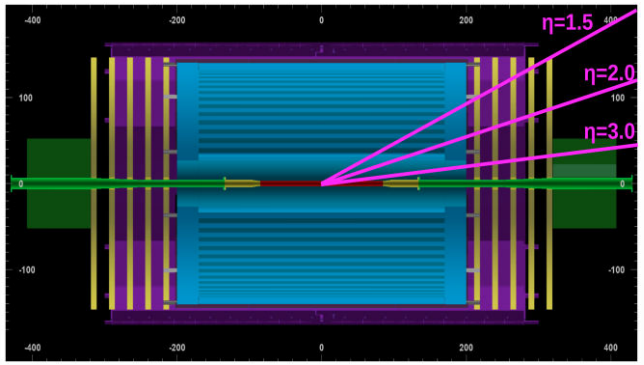
- Preparation of the MPD detector and experimental program is continued, start of MPD commissioning in late 2025 remains the main priority
- “Proposal for continuation of the MPD project” has been approved for the next five years
- Develop physics program, software and analysis infrastructure for real data analysis

BACKUP

Forward spectrometers – tracking



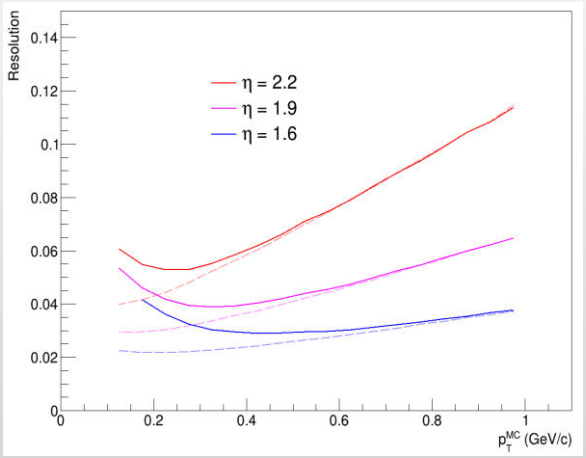
Two volumes (green and magenta) available for the installation of forward tracker stations

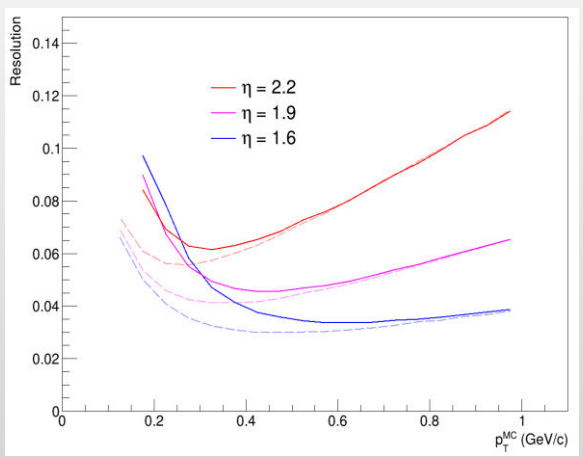


Pseudorapidity coverage of the forward spectrometer

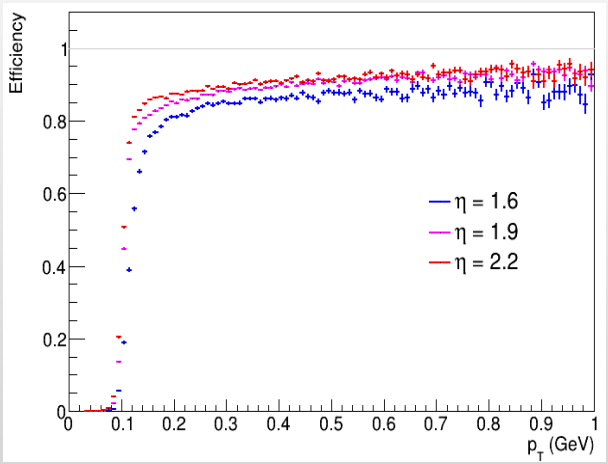
- Five tracking layers within z = 210–300 cm, 1% X_0, ~ 80 μm spatial resolution
- Tracking – ACTS package – experiment-independent high-level track reconstruction toolkit, including seeding tools and combinatorial Kalman Filter for track finding and vertex reconstruction

Momentum resolution for pions (left) and protons (right) at different η





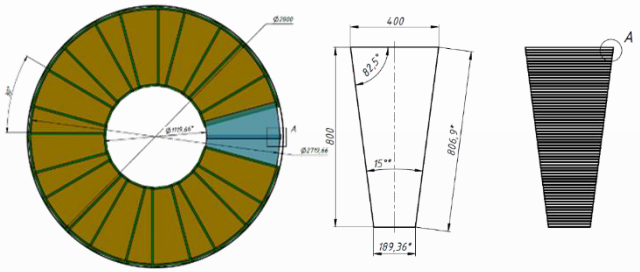
Tracking efficiency at different η



Forward spectrometers – PID

- Last layer is a TOF detector built of MRPC chambers

End-cap TOF detector(s)



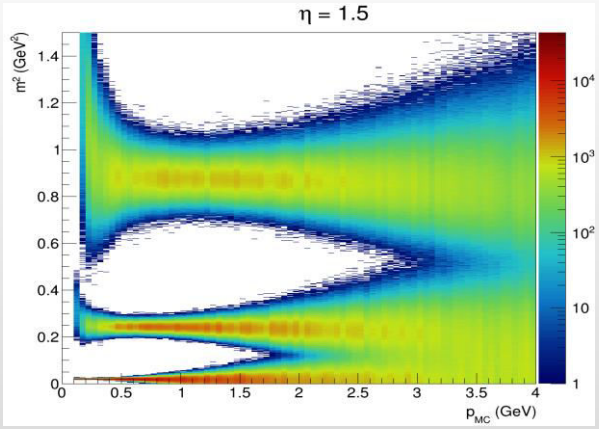
End-cap TOF ring design based on a trapezoidal MRPCs

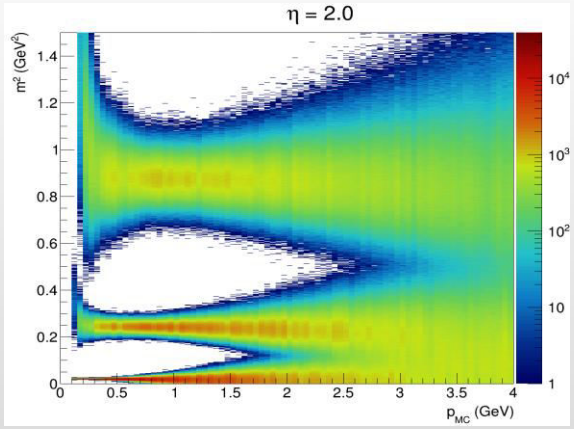
Each MRPC chamber contains 64 strips, which both-sides read-out

Each TOF ring contains 24 MRPCs → 6144 read-out channels in total

Same electronics based on NINO and HPTDC chips as in the basic TOF-MPD

- Reliable π/K/p separation vs. particle momentum for different rapidity ranges





Rather limited momentum resolution is compensated by a large path length (~3m) → reasonable PID for charged hadrons