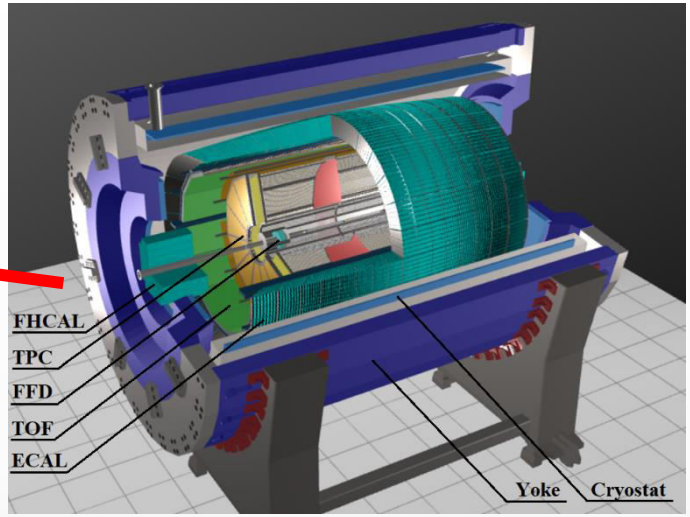
MPD Collaboration Status

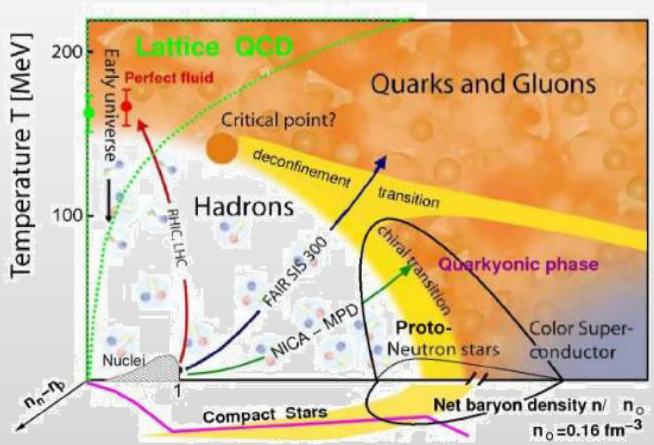
V. Riabov for the MPD Collaboration

MPD @ NICA

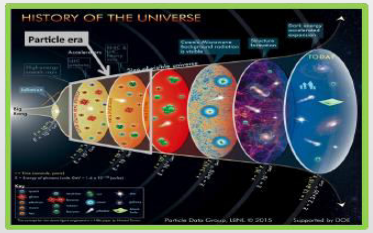
- One of two experiments at NICA collider to study heavy-ion collisions at $\sqrt{s_{NN}}$= 4(2.4)−11 GeV



TPC: |Δφ| < 2π, |η| ≤ 1.6; **TOF, EMC**: |Δφ| < 2π, |η| ≤ 1.4; **FFD**: |Δφ| < 2π, 2.9 < |η| < 3.3; **FHCAL**: |Δφ| < 2π, 2 < |η| < 5



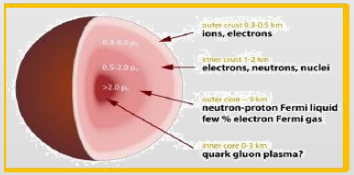
High beam energies ($\sqrt{s_{NN}}$ > 100 GeV)



High temperature:
Early Universe evolution

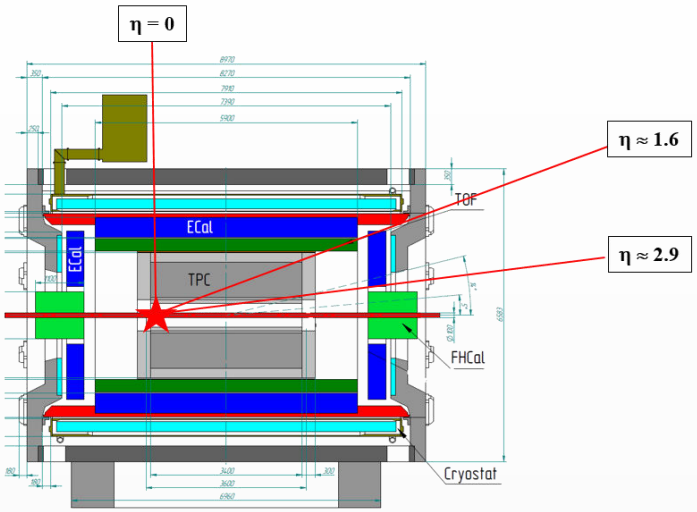
Low beam energies ($\sqrt{s_{NN}}$~ 10 GeV)

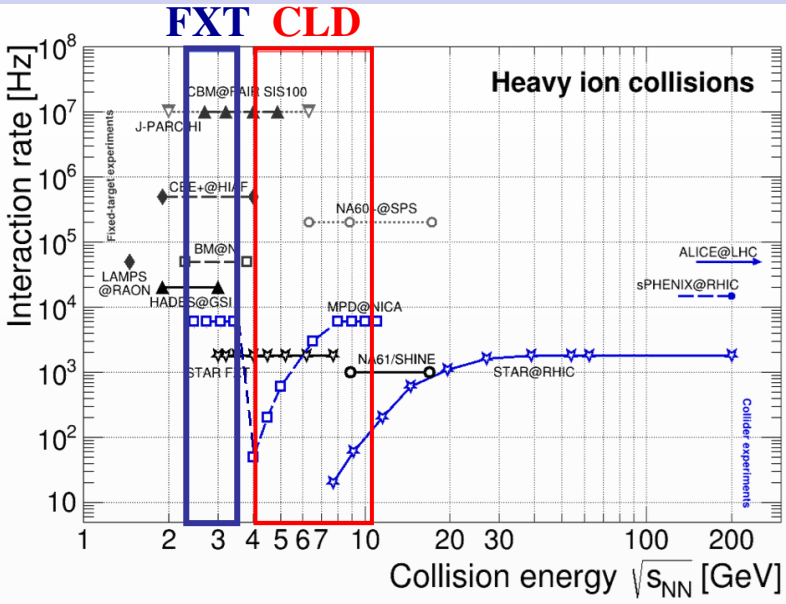
High baryon density:
Inner structure of
compact stars



BM@N and MPD @ NICA study QCD medium at extreme net baryon densities

Fixed-target operation





- MPD-CLD and MPD-FXT options approved by accelerator department
- Collider mode: two beams, $\sqrt{s_{NN}}$ = 4-11 GeV
- Fixed-target mode: one beam + thin wire (~ 100 μm) close to the edge of the MPD central barrel:
  - ✓ extends energy range of MPD to $\sqrt{s_{NN}}$ = 2.4-3.5 GeV (overlap with HADES, BM@N and CBM)
  - ✓ high event rate
- Expected beam condition for the first year(s):
  - ✓ MPD-CLD: Xe/Bi + Xe/Bi at $\sqrt{s_{NN}}$ ~ 7 GeV, reduced luminosity → collision rate ~ 50 Hz
  - ✓ MPD-FXT: Xe/Bi + W at $\sqrt{s_{NN}}$ ~ 3 GeV

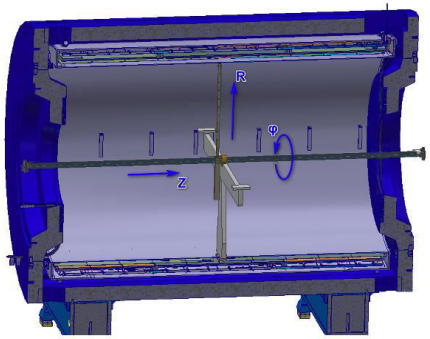
MPD schedule

- Latest estimates from Project Manager - V. Golovatyuk

	Year 2024	
1	October 15th. - November 22th	Cooling down of the Solenoid to the working temperature 4K
2	November 25th	Readiness to switching on Solenoid Power Supplies Cooling water supplying in the Central distributor system of bld. 17 (MPD) must be ready
3	November 25th - December 15th	Solenoid Safety regimes of emergent energy evacuation working out Development of algorithms of cooling on base of experience with manual regime
4	December 15th – December 30th	Installation Magnetic Field Mapper, Calibration, preparation for measurements of Field
5	November 20th – December 20th	Installation FHCal into poles
6	December 20th	TPC mechanical body is assembled, leak test and HV test are finished
7	December 30th	TPC/Ecal Cooling system is commissioned
8	December 30th	Production of Ecal half sectors (modules) are finished
	Year 2025	
9	January 15th - April 30th	Magnetic field measurements on nominals: 0.2T, 0.3T, 0.4T, 0,45T, 0.5T, 0,55T
10	May 5th - May 8th	Support Frame installation
11	May 12th – August 30th	Installation ECal sectors
12	June 16th – August 30th	Installation TOF modules (access from both sides)
13	September 1st – November 23d	TPC installation
14	June 2d – November 23d	Cabling
15	November 24th – December 14th	Beam pipe installation
16	December 22d	Moving on the beam line
17	December 30th	Commissioning

Detector construction

SC Solenoid + Iron Yoke + Mapper

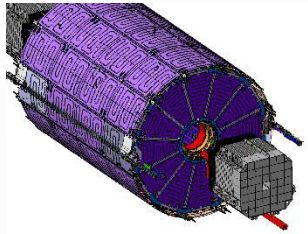


Novosibirsk BINP magnetic field mapper

	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

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: ~ 4 months

TPC – central tracking detector



24+ ROC ready; FE ~ 90% manufactured; TPC gas volume assembly and HV/leakage tests – ongoing; TPC + ECAL cooling systems commissioned in 2024; rails installation into support frame

Support structure

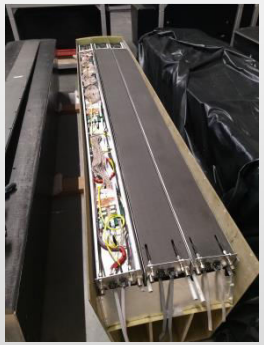
Carbon fiber support frame delivered and unpacked, sagita ~ 5 mm at full load, rails for the TPC and TOF are installed

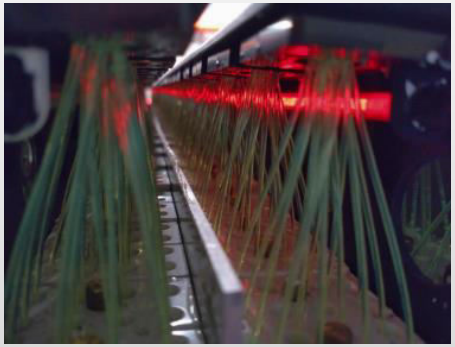
TOF - ready

28 modules are produced and ready for installation

ECAL

Assembly and tests of half-sectors





83% of calorimeter will be ready in 2024. The rest of the baskets will be ready for mounting into MPD at the April 2025

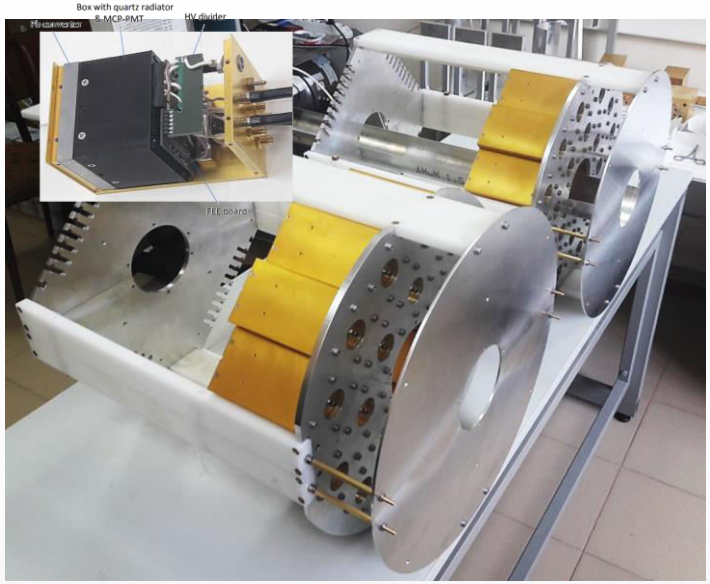
Forward subsystems in production

FHCAL

FHCal assembled on the platform, ready to be installed in the Poles (modules are equipped with FEE)

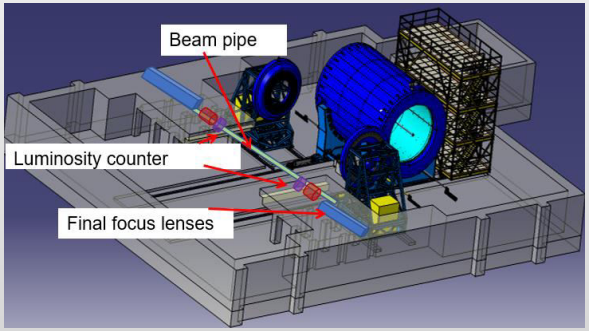
FHCAL modules have been produced and tested → installation in autumn 2024

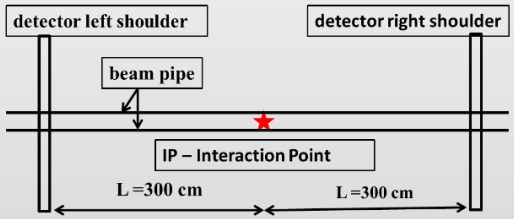
FFD



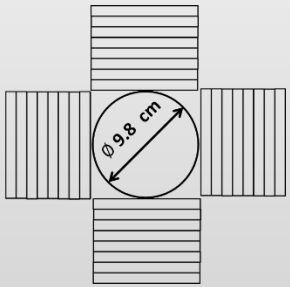
Cherenkov modules of FFDE and FFDW, mechanics for installation in container with beam pipe are available, Long term tests with cosmic rays & laser ongoing

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

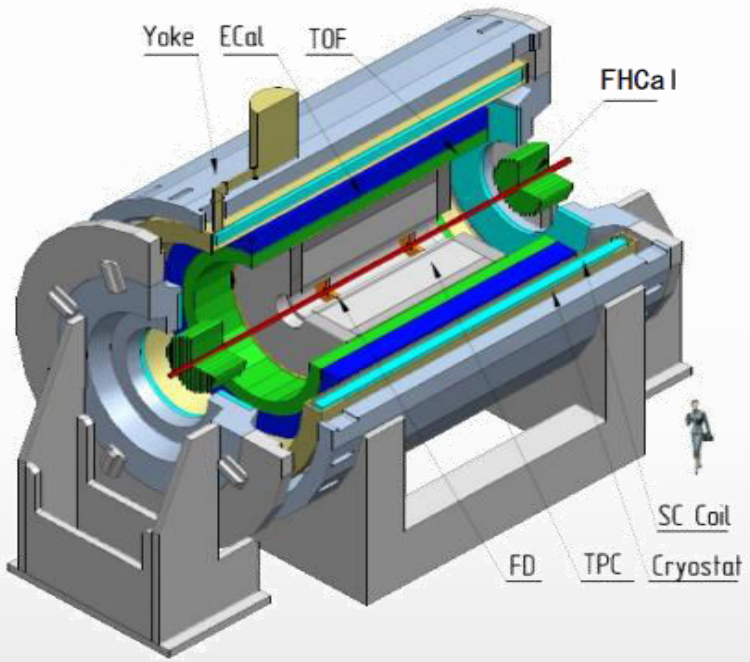
Multi-Purpose Detector (MPD) Collaboration

***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***



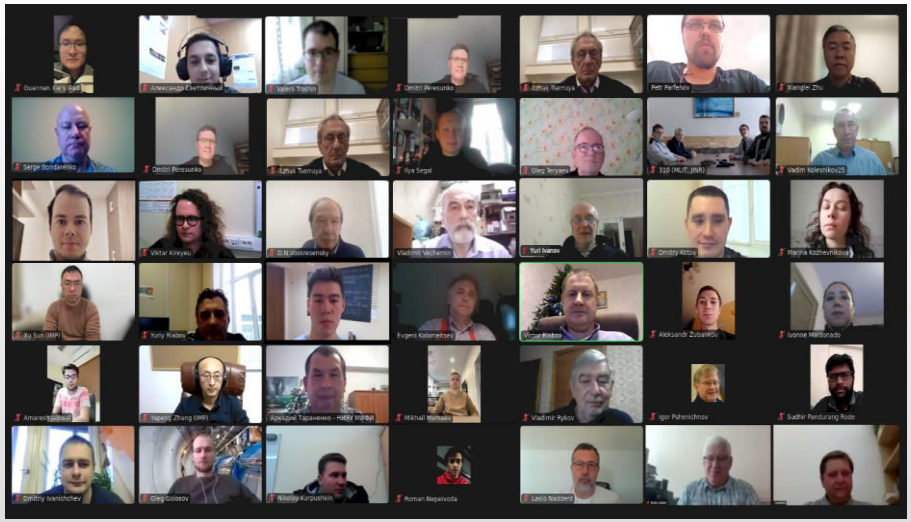
***Joint Institute for Nuclear Research, Dubna**;*
*A.Alikhanyan National Lab of Armenia, Yerevan, **Armenia;***
*SSI "Joint Institute for Energy and Nuclear Research – Sosny" of the National Academy of Sciences of Belarus, Minsk, **Belarus***
*University of Plovdiv, **Bulgaria;***
*Tsinghua University, 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***

Conferences and workshops

- MPD presentations at conferences since last meeting (> 20 talks):
  - ✓ ICPPA - 2024, Moscow, Russia, Oct 22-25
  - ✓ Hard Probes - 2024, Nagasaki, Japan, Sep 22-27
  - ✓ HEP&FT - 2024, Protvino, Russia, July 23025
  - ✓ Nucleus - 2024, Dubna, Russia, July 1-5
  - ✓ HSFI - 2024, Gatchina, Russia, July 8-12
  - ✓ XIV LASNPA - 2024, Mexico, June 17-21
  - ✓ CPOD - 2024, Berkeley, USA, May 20-24

- JINR-MEPhI organized International Workshop NICA-2024
  - ✓ joint platform for discussion of NICA physics at BM@N and MPD



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)

2nd China-Russia Joint Workshop on NICA Facility

The 2nd China-Russia Joint Workshop on NICA Facility will be held in China from September 10th-13th. The workshop consists of a three-day scientific program held at Qingdao (Sep.10th -12th) and a discussion session held at Beijing (Sep.13th). The first-day operation of NICA facility will start in year 2025. The joint workshop aims to bring together the experimental experts and theorists on NICA hardware/physics from both China and Russia, discussing the most recent progresses, plans and opportunities on NICA facility.

The proposed topics will include but are not limited to:

Local organization:

Sessions at Qingdao: Shandong University, Fudan University, Central China Normal University, University of Science and Technology of China.

Sessions at Beijing: Tsinghua University, Institute of Modern Physics of Chinese Academy of Sciences, University of Chinese Academy of Sciences.

Local organization committee:

Deqing Fang (Fudan University)

Shuang LI (Three Gorges University)

Zebo Tang (University of Science and Technology of China, *co-chair*)

Jiansong Wang (Huzhou University)

Xiaodong Wang (University of South China)

Yaping Wang (Central China Normal University)

YI Wang (Tsinghua University, *co-chair*)

Guannan Xie (University of Chinese Academy of Sciences)

Chi Yang (Shandong University, *co-chair*)

ChengXin Zhao (Institute of Modern Physics of the Chinese Academy of Science)

Indico.jinr.ru/event/4642

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

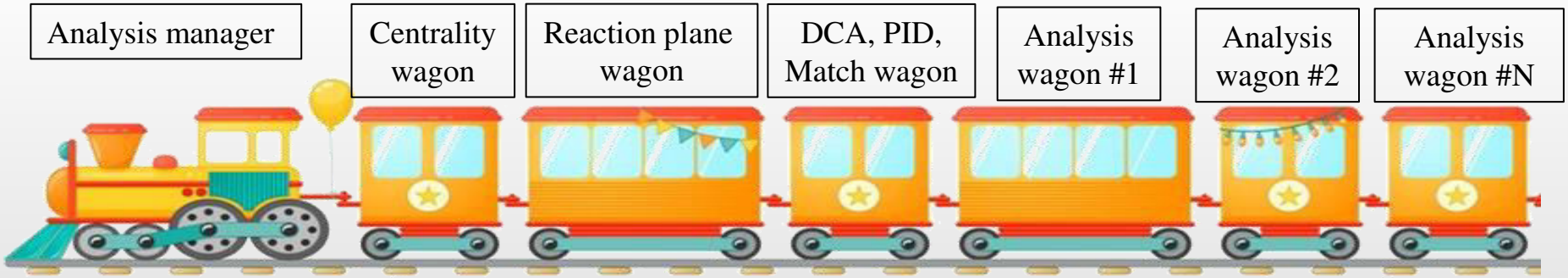
- Study of open charm production
- Charmonium with ECAL and central barrel
- Charmed meson through secondary vertices in ITS and HF electrons
- Explore production at charm threshold

Big data productions

- Physics feasibility studies using centralized large-scale MC productions → consistent picture of the MPD physics capabilities with the first data sets, preparation for real data analyses
- A new cycle of productions (https://mpdforum.jinr.ru/c/mcprod/26):
  - Request 34: General-purpose, 15M UrQMD BiBi@9.2 (dielectron enhanced)
  - Request 35: General-purpose, 15M UrQMD (mean-field) Xe-W (T = 2.5 GeV/n, FXT)
  - Request 36: Flow-purpose, 15M UrQMD (mean-field) Xe-Xe (T = 2.5 GeV/n, FXT)

Need event & track selections, measurement of centrality and event plane for MPD-FXT

- Centralized Analysis Framework for access and analysis of data → Analysis Train:



Regular runs on request since September, 2023 → ~ 12 hours to process 50M events for 10-15 wagons

Many new services and improvements (improved PID parameterizations, new wagons):

- ✓ https://indico.jinr.ru/event/4401/: constrained tracks, track ID refits
- ✓ https://indico.jinr.ru/event/4314/: track quality selections

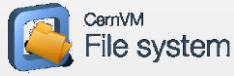
New standard for physics feasibility studies → ideally, all analysis codes should be committed to MpdRoot as Wagons

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.



Second collaboration paper

❖ Preliminary version of the paper draft as of 13.10.2024 - **https://mpdforum.jinr.ru/c/mpd-physics/21**

1. Introduction
2. MPD detector at NICA
3. Data analysis framework
   - 3.1 Event generators and centralized productions
   - 3.2 Analysis Train framework
4. Global event categorization
   - 4.1 Trigger system and efficiency
   - 4.2 Event centrality
   - 4.3 Event plane
5. Physics performance studies
   - 5.1 Light-flavor hadron production
     - 5.1.1 Charged hadrons (pi/K/p)
     - 5.1.2 Hyperons (Lambda, Ksi, Omega)
     - 5.1.3 Short-lived hadronic resonances
   - 5.2 Hyperon global polarization
   - 5.3 Light nuclei production
   - 5.4 Anisotropic flow
   - 5.5 Femtoscopy and correlations
     - 5.5.1 Femtoscopic correlations of charged pions
     - 5.5.2 Two-pion correlation function and the Lévy shape
     - 5.5.3 Charged balance function
     - 5.5.4 Factorial moments
   - 5.6 Electromagnetic signals
     - 5.6.1 Predictions for direct photon production
     - 5.6.2 Photons reconstruction
     - 5.6.3 Differential pT spectra for π0 and η mesons
     - 5.6.4 Collective flow of inclusive photons and neutral mesons
     - 5.6.5 Dielectrons
6. Conclusions

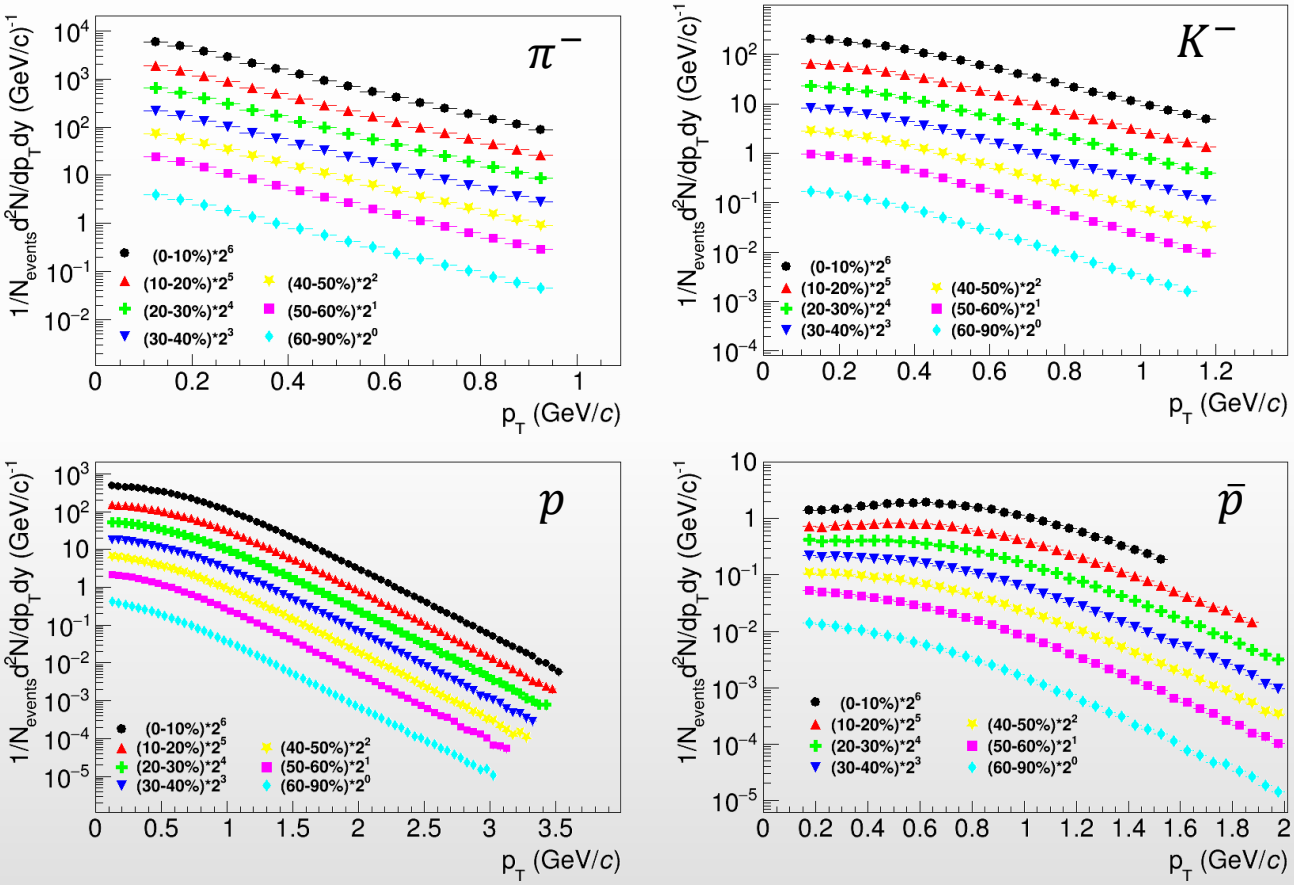
Material is mostly collected, missing parts will be droped

Lots of work to compile a draft → 1-2 months

Advancements in analyses

Identified charged hadrons (π/K/p) - I

- Request 25: BiBi@9.2 GeV (UrQMD), 50 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



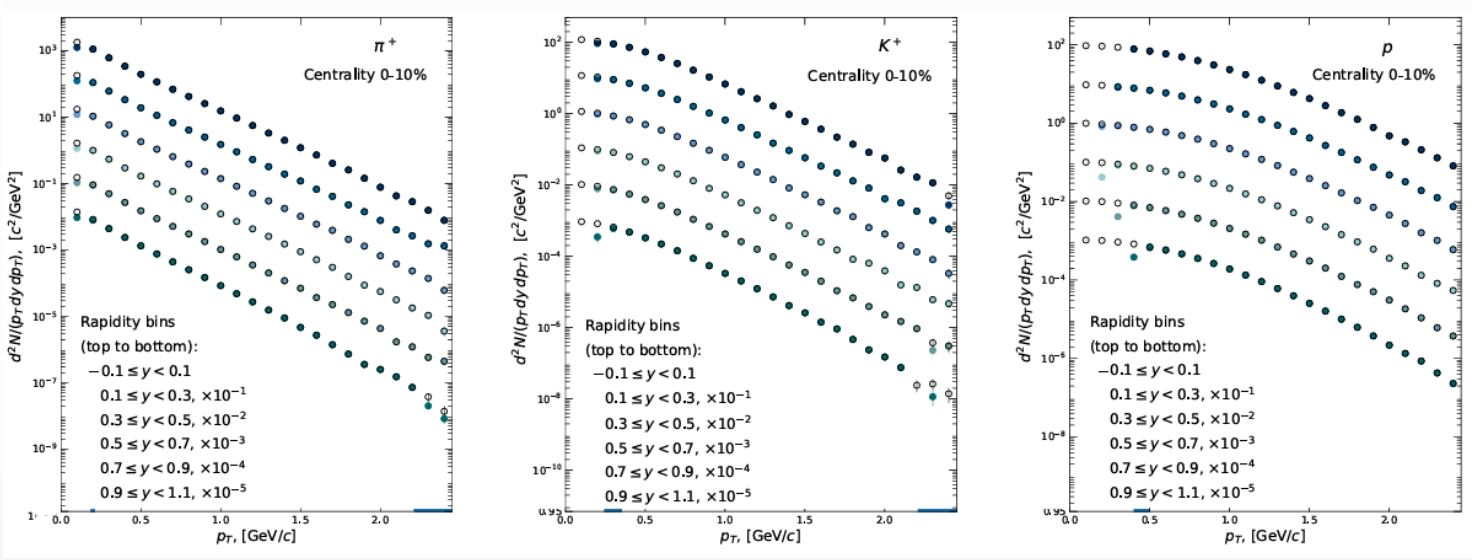
Good enough coverage for dN/dy, <p_T> and β/T (BW-fits) measurements

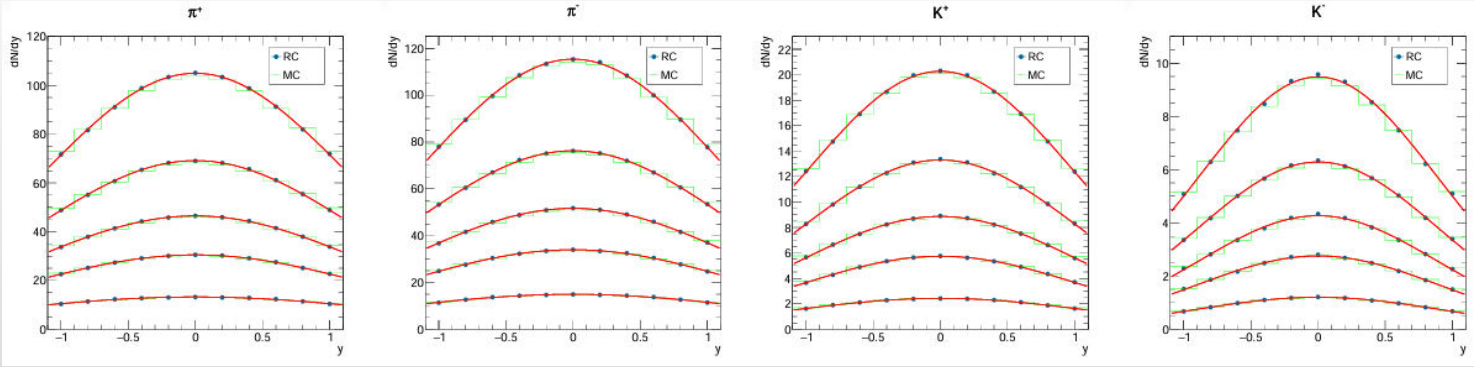
Unmeasured low-p_T range is as small as possible with the existing track reconstruction methods

Sampled yields > 92% for all species

Identified charged hadrons (π/K/p) - II

- Request 25: BiBi@9.2 GeV (UrQMD), 50 M events → full event/detector reconstruction
- Analysis Train wagon: MpdHadronSpectra, https://indico.jinr.ru/event/4928/





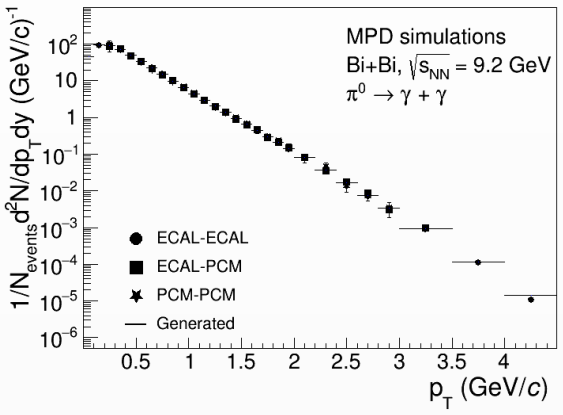
Better coverage at higher momenta, low-p_T coverage is limited due to TOF-matching requirement

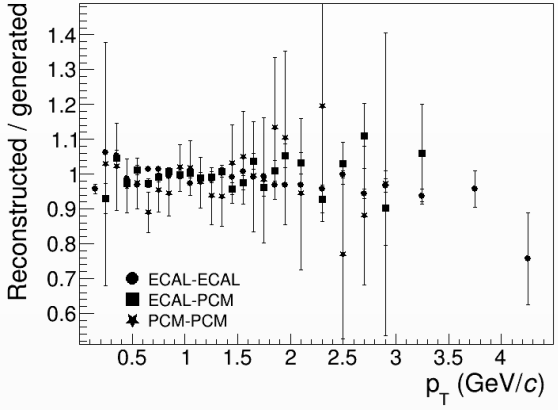
Advanced study of yields, T/β vs. rapidity and centrality

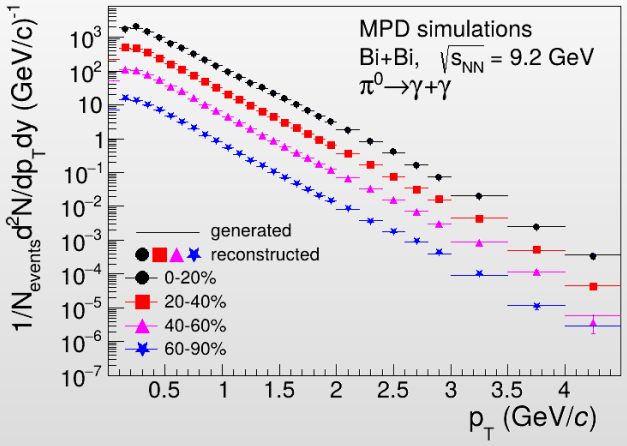
Contamination corrections require systematic study

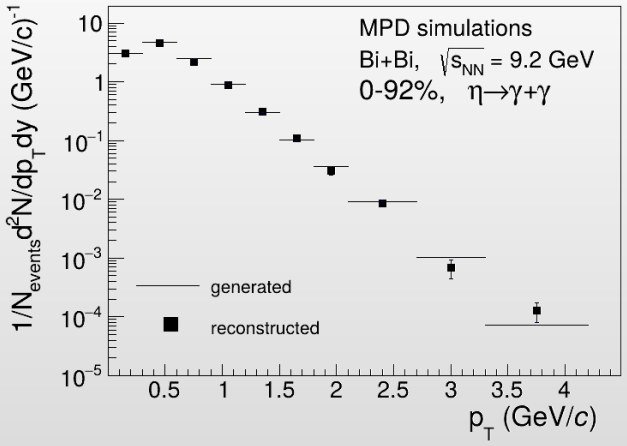
Neutral mesons (π^0/η)

- Request 25: BiBi@9.2 GeV (UrQMD), 50 M events → full event/detector reconstruction
- Analysis Train wagon: pairGG, https://indico.jinr.ru/event/4803/
- Photon reconstruction techniques:
  - ✓ ECAL
  - ✓ photon conversion (PCM)
- Meson reconstruction:
  - ✓ ECAL-ECAL
  - ✓ ECAL-PCM
  - ✓ PCM-PCM
- Transverse momentum spectra:









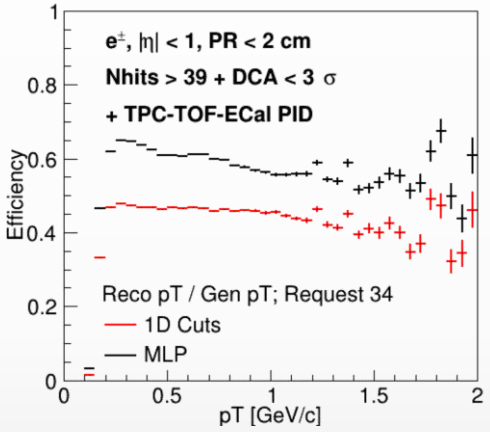
ECAL-ECAL: high efficiency but high combinatorial background and complex peak shape

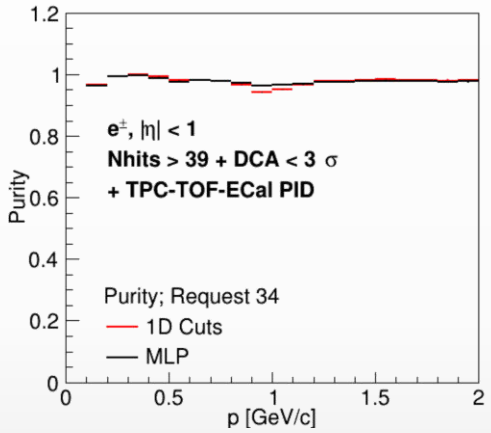
PCM-PCM: superb energy resolution, high signal purity, but low efficiency

Dielectrons

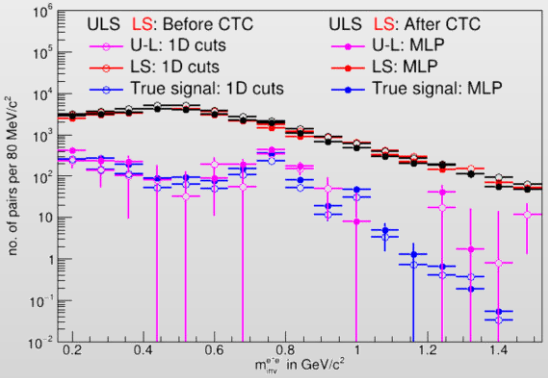
- Request 34: BiBi@9.2 GeV (UrQMD), 15 M events → full event/detector reconstruction
- Analysis Train wagon: dielectrons, https://indico.jinr.ru/event/4803/
- MPD has good capabilities for the reconstruction and identification of $e^{\pm}$

Now improved with MLP techniques





- Challenge for e^+e^- is a huge combinatorial background from Dalitz decays & conversion
- Possible solutions → higher tagging efficiency of Dalitz and conversion electrons:

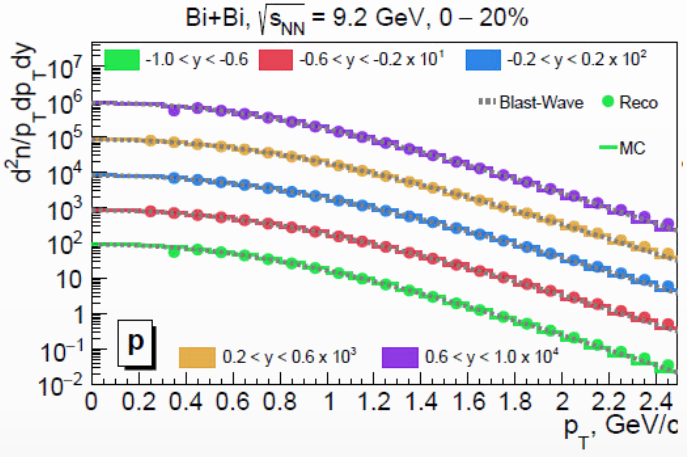


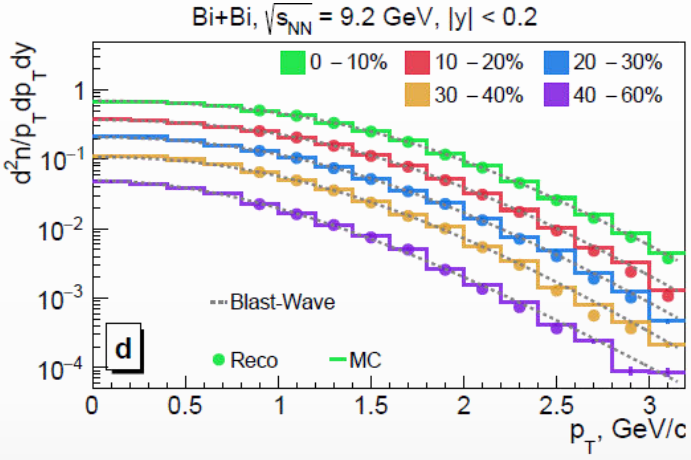
	Bef. CTC w/ 1D Cuts	Aft. CTC w/ MLP
$\frac{(U-B)}{B}$ (%)	3.53±0.03 (3.10)	5.69±0.05 (6.14)
BFE	19 (15)	40 (46)

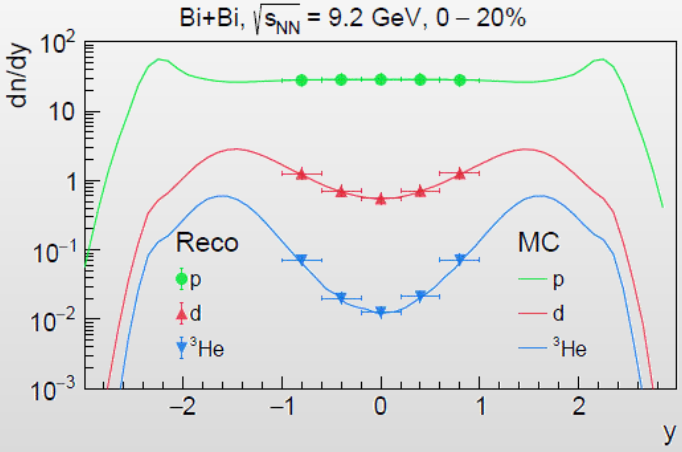
Significant improvement in p_T-integrated S/B ~ 0.06 in 0.2-1.5 GeV/c^2 → further improvements are expected

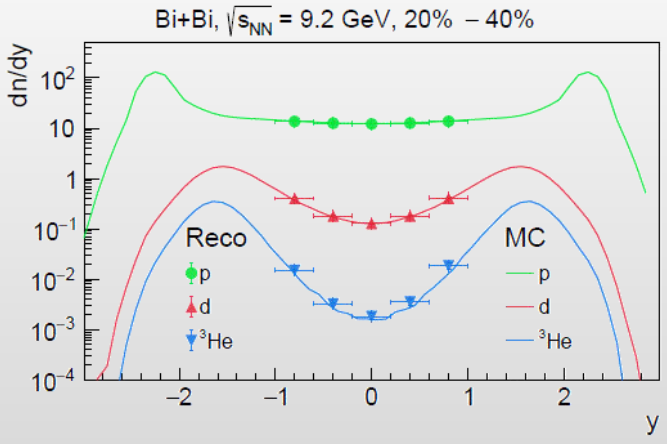
Light nuclei: p, d, ^{3}He in BiBi @ 9.2

- Request 29: BiBi@9.2 GeV (PHQMD), 20 M events → full event/detector reconstruction
- Analysis Train wagon: nuclei, https://indico.jinr.ru/event/4871/







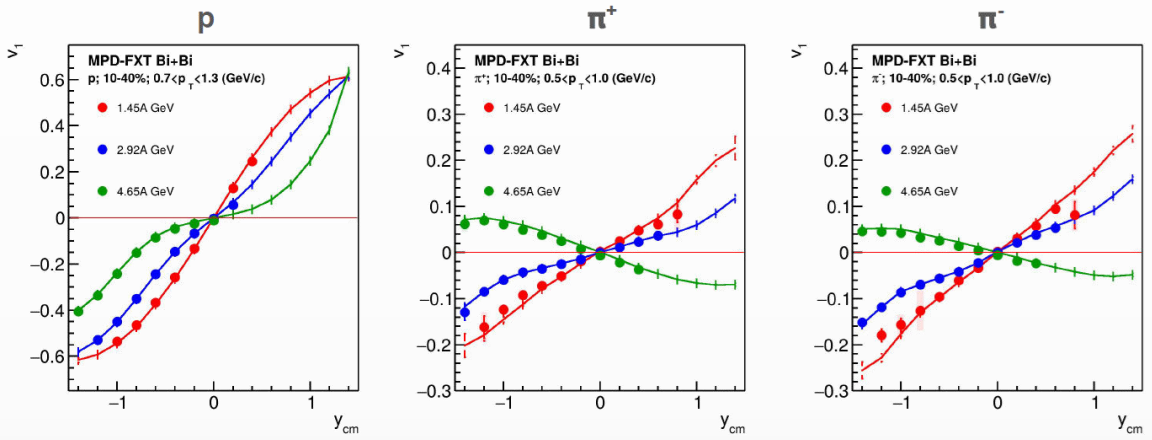


Centrality-dependent p_T- and rapidity spectra, coalescence parameters B2/B3

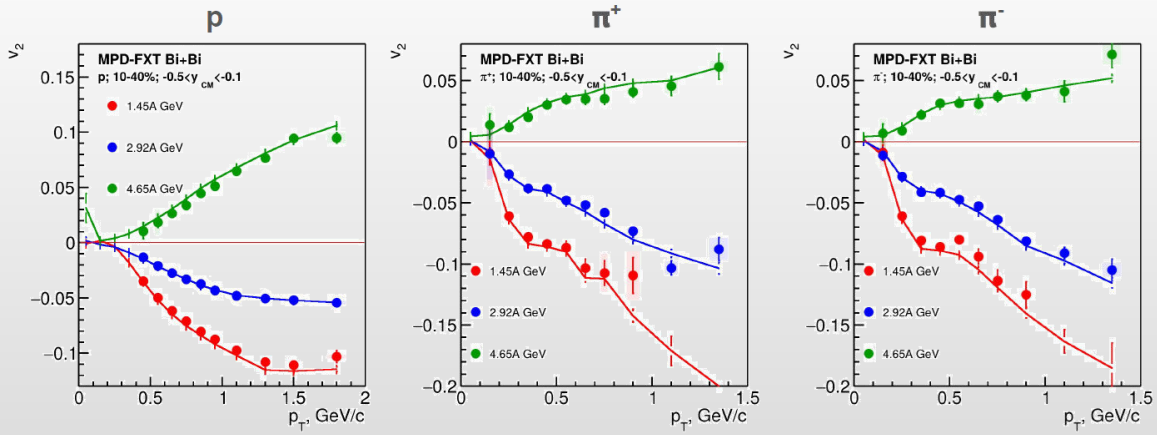
MPD-FXT, v_1 & v_2 for protons/pions

- Request 33 mass production (UrQMD mean-field, fixed-target mode), BiBi @ 2.5, 3.0 and 3.5 GeV
- New: realistic PID (TPC+TOF); efficiency corrections; centrality by TPC multiplicity

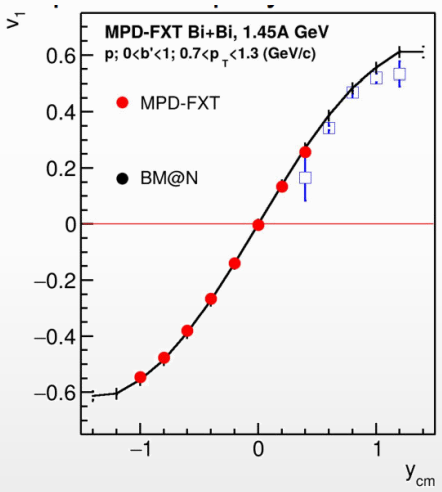
v_1 vs. rapidity



v_2 vs. p_T



MPD vs. BM@N

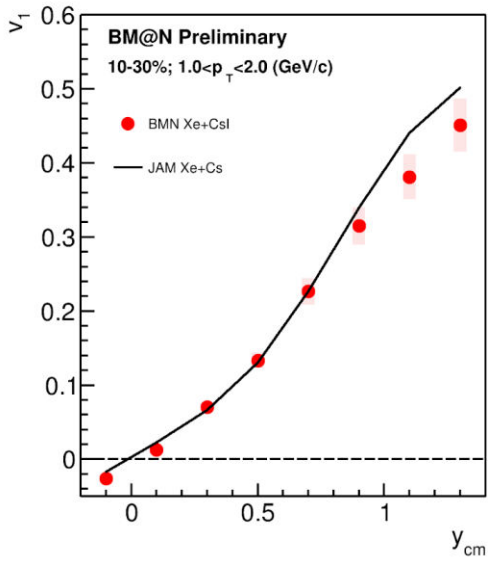


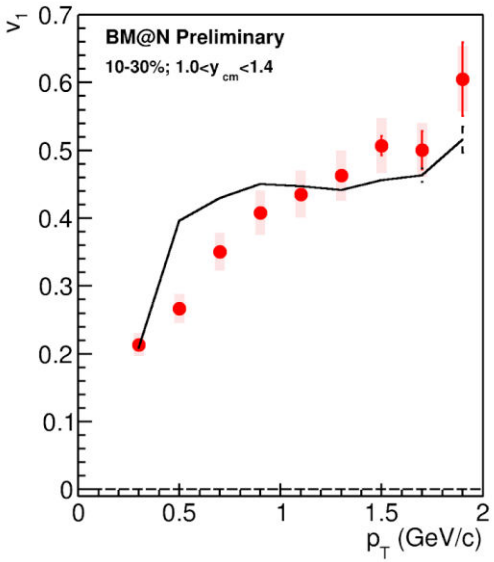
Reconstructed v_1 & v_2 are quantitatively consistent with truly generated signals

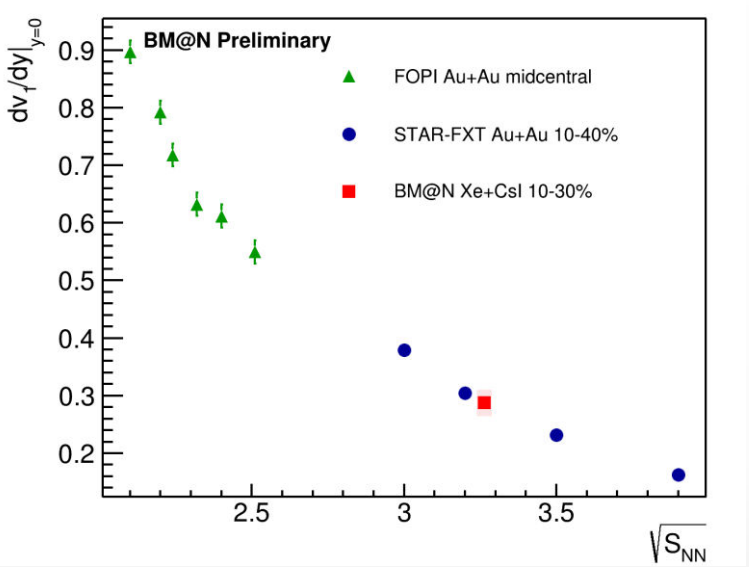
MPD and BM@N complete each other with modest overlap

v_1 for protons @ BM@N

- Reconstruction methods were tested with BM@N real data





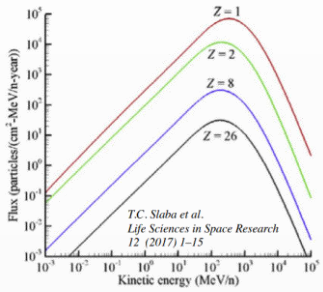


v_1 is measured as a function of p_T and y

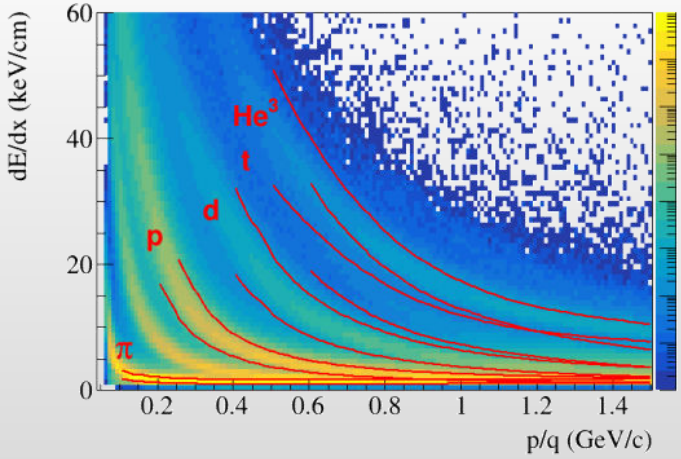
dv_1/dy is a good agreement with world data

High-energy heavy-ion reaction data

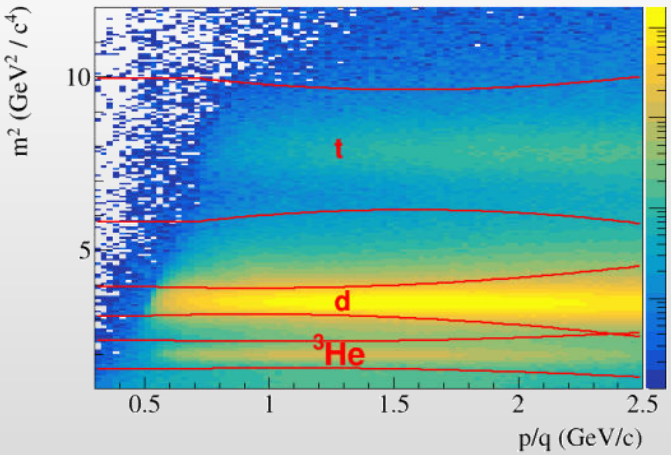
- Galactic Cosmic Rays composed of nuclei (protons, … up to Fe) and E/A up to 50 GeV
- Cosmic rays are a serious concern to astronauts, electronics, and spacecraft
- The damage is proportional to Z^2, therefore the damage from p, d, t, ^{3}He, and ^{4}He is important
- Need input information for transport codes for shielding applications (Geant-4, Fluka, PHITS, etc.):
  - ✓ total, elastic/reaction cross section
  - ✓ particle multiplicities and coalescence parameters
  - ✓ outgoing particle distributions: $d^2N/dEd\Omega$
- NICA can deliver different ion beam species and energies:
  - ✓ Targets of interest (C = astronaut, Si = electronics, Al = spacecraft) + He, C, O, Si, Fe, etc.
- No data exist for projectile energies > 3 GeV/n



dE/dx vs momentum in TPC



m^2 vs. momentum in TOF



Excellent light fragment identification capabilities in a wide rapidity range
→ important potential contribution to applied research

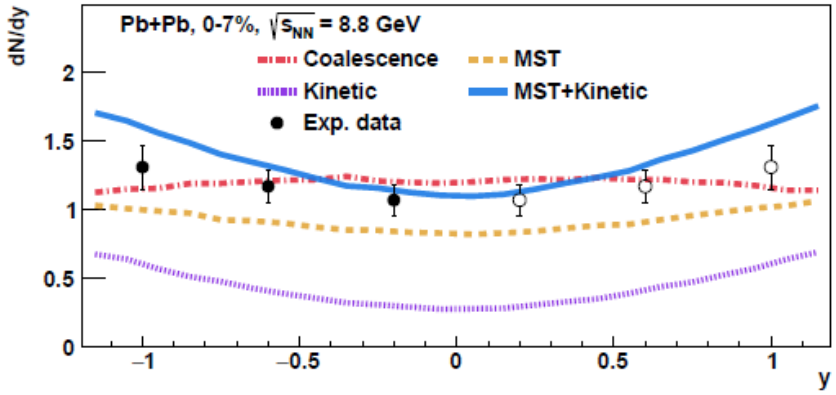
Summary

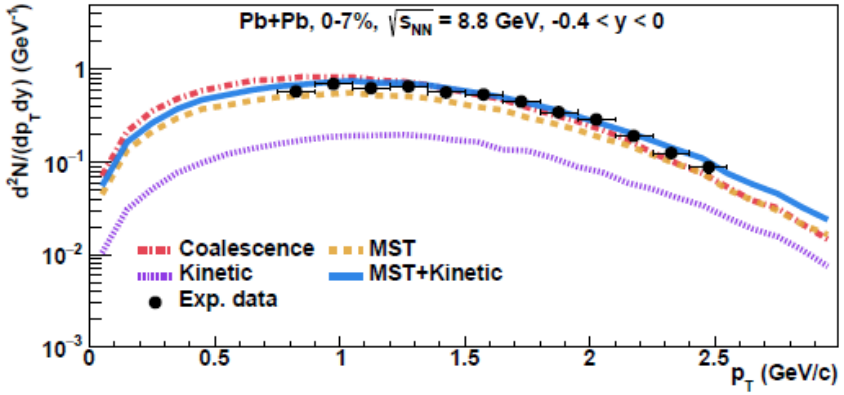
- Preparation of the MPD detector and experimental program is continued
- Start of the MPD commissioning in 2025 is the main goal
- Develop physics program of the experiment, prepare tools and methods for data analysis

BACKUP

PHQMD

Request 29: General-purpose, 20M PHQMD BiBi@9.2 was used for this analysis.





More on the PHQMD transport approach:

Aichelin, J. et al. (2020). "Parton-hadron-quantum-molecular dynamics: A novel microscopic *n* -body transport approach for heavy-ion collisions, dynamical cluster formation, and hypernuclei production". In: *Phys. Rev. C* 101.4, p. 044905.

Why it's important to look at high y and low p_T for light nuclei:

Kireyeu, V. et al. (2024). "Cluster formation near midrapidity: How the production mechanisms can be identified experimentally". In: *Phys. Rev. C* 109.4, p. 044906.