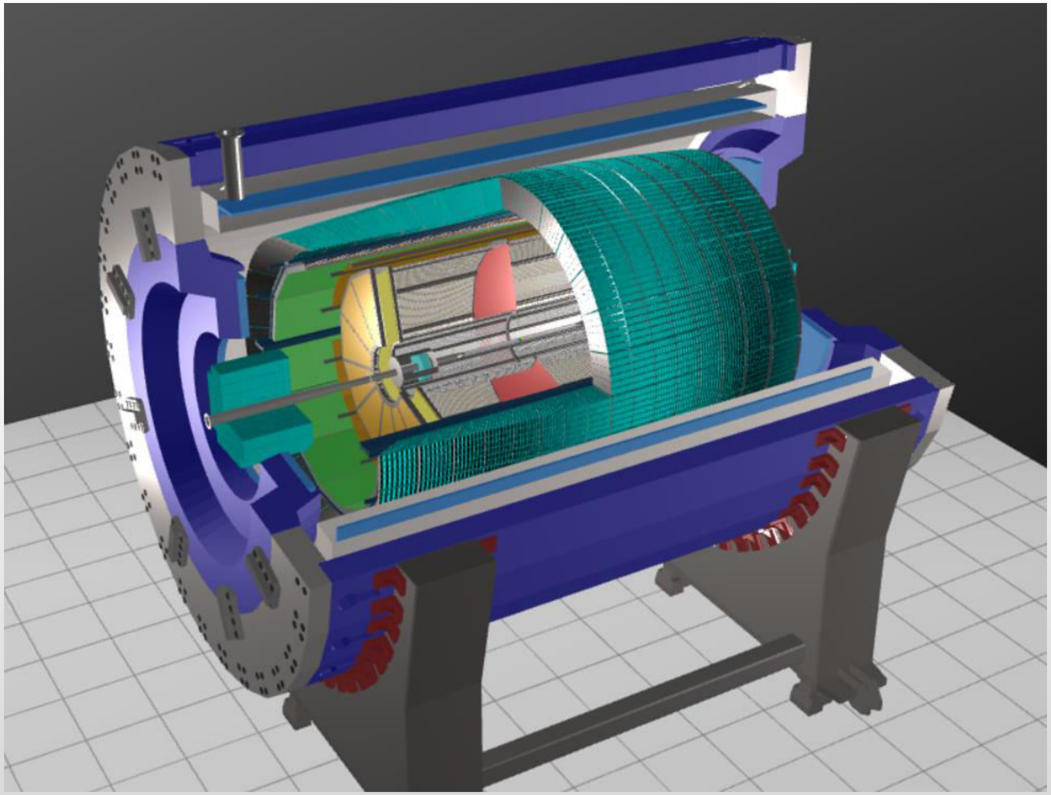
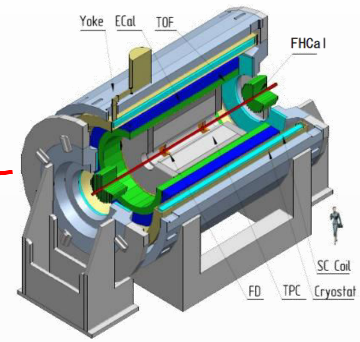
Implementation of the MPD project

V. Riabov for the MPD Collaboration



MPD at NICA

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

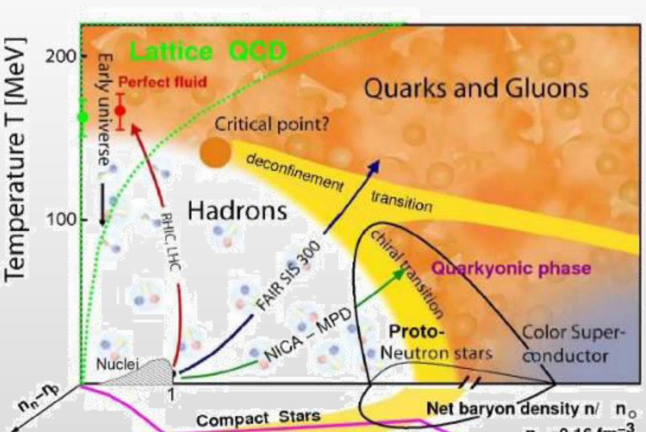


Stage- I

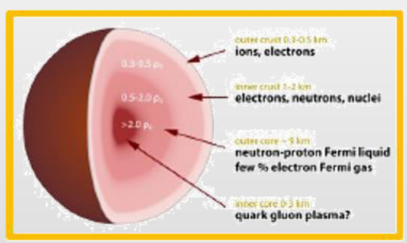
TPC: $|\Delta\varphi| < 2\pi$, $|\eta| \leq 1.6$
TOF, EMC: $|\Delta\varphi| < 2\pi$, $|\eta| \leq 1.4$
FFD: $|\Delta\varphi| < 2\pi$, $2.9 < |\eta| < 3.3$
FHCAL: $|\Delta\varphi| < 2\pi$, $2 < |\eta| < 5$

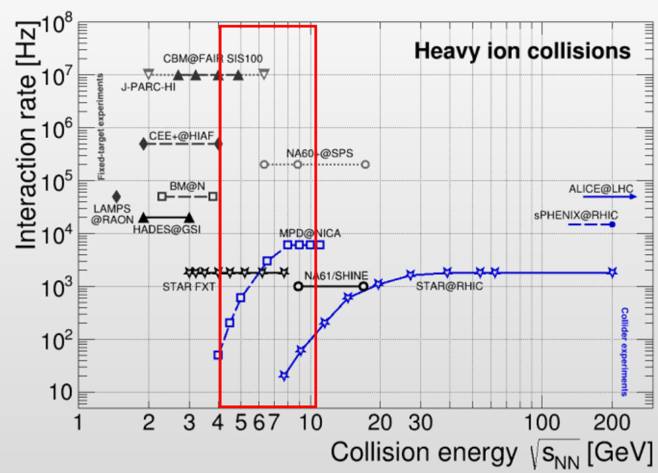
Expected configuration in first year(s) :

✓ not-optimal beam optics → wide z-vertex distribution, σ_z ~ 50 cm
✓ reduced luminosity (~10^{25}) → collision rate ~ 50 Hz
✓ first collision system → Xe+Xe / Bi+Bi @ 7 GeV max



high baryon densities
→ inner structure of
compact stars





❖ NICA will study QCD medium at extreme net baryon densities → 1st order phase transition + QCD CEP
❖ Many ongoing (NA61/Shine, STAR-BES) and future experiments (CBM) in ~ same energy range

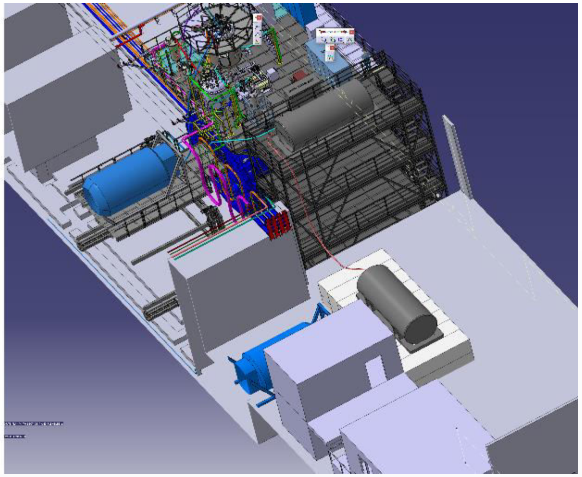
MPD assembling milestones and plans

- Latest estimates provided by Project manager (V. Golovatyuk)

Year 2023	
Jan 15 – April 15th	Preparation for Vacuum test of Solenoid with Cryostat
April 20 – May 20th	Vacuum tests
April 20 – June 15th	Electronic Platform construction
June 15 – September 15	Activities in the MPD Hall stopped
September – December	Test cooling down to the LN temperature
Year 2024	
January – March 30	**Cooling Solenoid to the working temperature: 4K (LHe)**
January 20th – April 15	Solenoid Safety regimes of emergent energy evacuation working out Development of algorithms of cooling on base of experience with manual regime
May 30th	Power Supplies are on working regimes
June 1st – August 31st	Magnetic Field measurements
September 1 – September 10	Support Frame installation
September 15 – October 30	Installation ECal sectors, FHCal into poles
November 1 – November 25	Installation TOF modules and rest of ECal sectors (access from both sides)
November 25 - December 15	TPC installation
December 16 – December 25	Installation of beam pipe
December - January	Move the MPD to the Collider beam line, Commissioning

Activities in the MPD Hall

Temporary scheme of Solenoid cooling

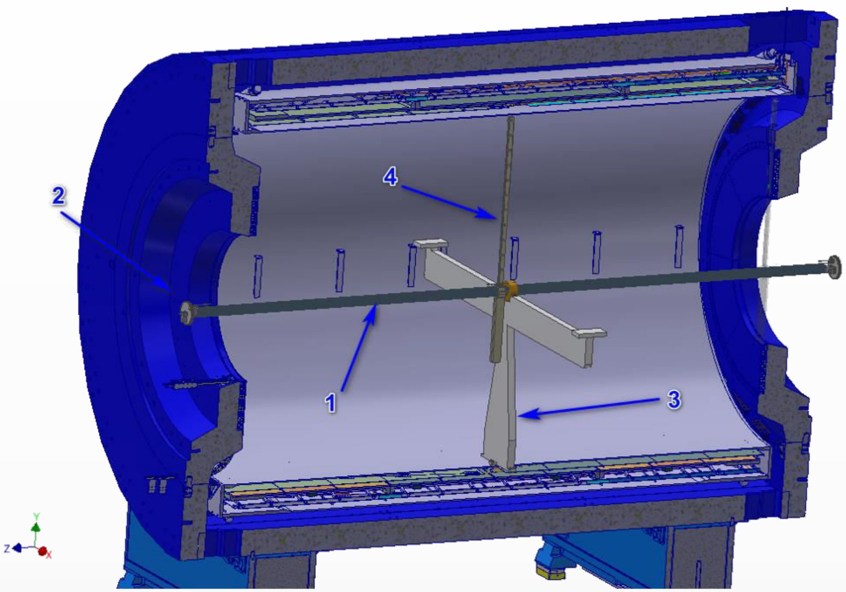


Cryogenic platform with Satellite Refrigerator and Control Dewar

Strings for cryogenic pipes and cables hold

- ❖ Continued preparation and assembly of the magnet cooling system
- ❖ Test system by cooling to -50^0 C in November-December, 2023
- ❖ Start of cooling to LN_2 and LHe temperatures in January

Magnetic field measurements



1. Aluminum (carbon fiber plastic) guiding rod
2. End cap fixation
3. Intermediate support
4. Carbon fiber plastic carriage

Novosibirsk INP mapper: specifications

Parameter	Value
Length of movement for Z	2× 4,5 m
Length of movement for R	0.1 – 2.2 m
Rotation of measurement block	3600
Accuracy of movement for Z	50 microns
Accuracy of movement for R	50 microns
Accuracy of rotation	0.20
Hall 3D sensor	HE444, HE Hoeben Electronix,
Hall 3D sensor accuracy	0.1 Gs
Hall 3D sensor accuracy total (with accuracy of laser tracker and temperature correction)	0.3 Gs
Sag of guide line	5 mm
Weight of mapper	100 kg
Reading time per one measurement	1 sec

- One Hall 3D probe, moves in 3 directions: z , R and ϕ
- Range of fields: 0.2-0.57 T
- Range of measurements from R = 0 cm to 2 m
- 3 months to produce magnetic field map(s) at different currents in the Solenoid and Correction coils
- Able to do measurements in the TPC volume after installation of ECAL and TOF subsystems

- Magnetic field measurements: June-August, 2024

Time Projection Chamber (TPC)

- ❖ TPC cylinders, central membrane and service wheels are ready
- ❖ Assembly of the vessel with field cage is ongoing – full TPC assembly by November, 2024
- ❖ Read-out MWPC chambers (ROCs) – 28 out of 24 (12x2) needed are produced and tested

- ❖ LV/HV: CAEN based, purchased
- ❖ FEC (1488 pcs.): 65% manufactured, 100% components are available
- ❖ RCU (24 pcs.): 1st version tested, finalizing design of preproduction version
- ❖ DCU (6 pcs.), LDC (6 pcs.): based on commercial solutions - available
- ❖ Gas system: ready, testing
- ❖ DCS: in development
- ❖ TPC cooling: thermostabilization panels and FEE radiators in stock; TPC cooling system – (INP BSU, Belarus) assembled by September, 2024

TPC installation in the MPD: December, 2024

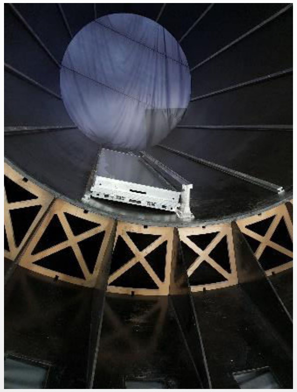
Time-of-Flight (TOF)

- ❖ Production of MRPC detectors was completed in September 2022, (107%) chambers
- ❖ All 28 TOF modules are assembled → long-term cosmic ray tests
- ❖ Electronics & cables, HV distribution modules → in stock
- ❖ Assembled the TOF gas system in the MPD hall

Storage of tested TOF modules

TOF installation bench in LHEP

TOF module in the carbon fiber mainframe



- ❖ Equipment for installing the modules in the MPD is ready for use and stored in the laboratory
- ❖ Rails for TOF modules have been installed in to the carbon fiber mainframe in May 2023

TOF installation in the MPD: November, 2024

Electromagnetic calorimeter (ECAL)

- Sampling calorimeter with projective geometry (70 tons): 38,400 towers packed in 50 half-sectors
- First 1600 modules (66%, 800 in Russia + 800 in China): tested/calibrated and mounted into half-sectors
- Installation of electronics and cooling system in assembled half-sectors → to be finished by March, 2024
- Long-term stability test of ECAL half-sectors using LED monitoring system
- Finalizing production of additional 400 modules (+12.5% → 83% in total)
- Production of components (including WLS) for the remaining 400 modules (+12.5% → 100% in total)
- Electronics: produced, in stock
- DCS: in development

ECAL installation in the MPD: September, 2024

Electronics platforms with clean rooms

Containers with rack clean rooms/containers on the platform

Inside view of the container

- ❖ The entire structure of the MPD platforms was assembled and installed
- ❖ 25 racks was installed in each container along with electrical and cooling water systems
- ❖ Power supply is distributed to all platform levels, each floor has its own distribution board → maintenance of the level without shutting down the entire MPD platform
- ❖ Video surveillance, ventilation and autonomous fire extinguishing systems were installed at each level
- ❖ Water cooling system for the platform was developed, necessary equipment was purchased and installed
- ❖ Real scale modeling and planning of the cable and pipe routs from detectors to the electronics platform

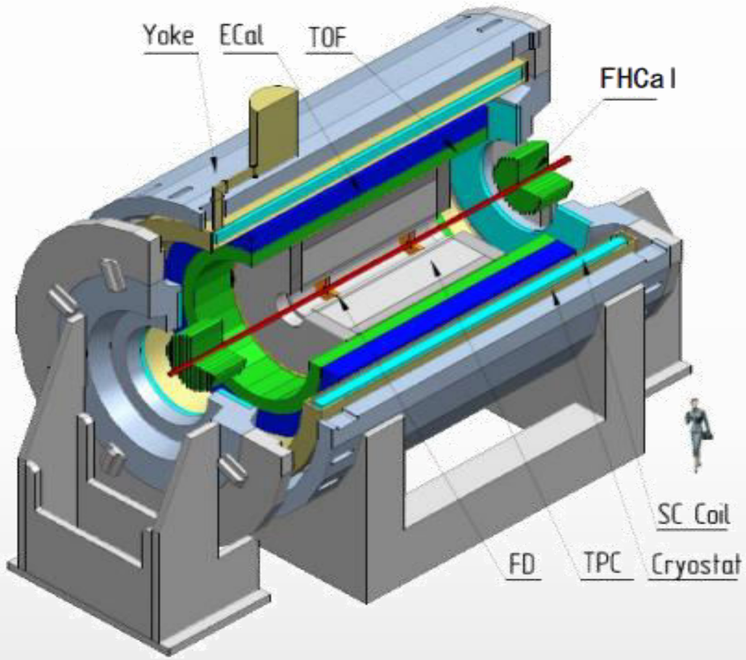
Multi-Purpose Detector (MPD) Collaboration

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***
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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***

XII-th MPD Collaboration Meeting, 2-6 October, 2023

- ❖ Held in mixed mode at Belgrade, Serbia with over 150 participants, over 50 present in-person
- ❖ 33 reports in three days for recent progress in MPD construction, development of computing and software infrastructure and preparations for physics analyses → preparation of the MPD detector and experimental program is continued
- ❖ Preceded by two days of ‘NICA Days’ with a series of lectures to review NICA physics for non-specialists and graduate students targeting scientists, engineers and students interested in heavy-ion physics and in the design and construction of equipment for the NICA experiments

Conferences and workshops

❖ MPD presentations at conferences, last 6 months:

- ✓ 10th International Conference "Distributed Computing and Grid Technologies in Science and Education", Dubna, 2-7 July
- ✓ 21st Lomonosov Conference on Elementery Particle Physics, Moscow, 24-30 August
- ✓ XXVth International Baldin Seminar on High Energy Physics Problems, Dubna, 18-23 September
- ✓ 2nd Workshop on Dynamics of QCD Matter, Bhubaneswar, 7-9 October
- ✓ 73-rd International conference on nuclear physics "Nucleus-2023", Sarov, 9-13 October
- ✓ India-JINR workshop on elementary particle and nuclear physics, and condensed matter research, Dubna, 16-19 October
- ✓ XX Mexican School on Particles and Fields 2023, Mexico, 30 October - 3 November

❖ JINR-MEPhI organized International Workshop NICA-2023 (http://indico.oris.mephi.ru/event/301/overview):

- ✓ 100+ participants from different countries:
  Belarus, Bulgaria, Israel, India, China, Kazakhstan, Mexica, Russia, Turkey, Serbia, USA and Uzbekistan
- ✓ active participation of the MPD Chinese group in the organizing committee and the work of the workshop
- ✓ 22 presentations in three days on experimental and theoretical topics
- ✓ 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)

Support of external groups

- Groups/tasks supported by internal JINR grants:
  - ✓ SPbSU, Methods for selecting centrality classes in the MPD experiment and their influence on fluctuation observables
  - ✓ NRC KI, Theoretical research and development of software for the experimental study of signals of direct photons and neutral mesons in heavy ion collisions in the NICA-MPD experimental complex
  - ✓ INR RAN, Modeling, testing and commissioning of the forward hadronic calorimeter
  - ✓ ITEP, Software support for the MPD electromagnetic calorimeter
  - ✓ PNPI, Modeling and optimization of the trigger system of the MPD experiment for operation in A-A, p-A and pp collisions at the energies of the NICA collider
  - ✓ MEPhI, Study of the efficiency of measuring anisotropic collective flows and collision geometry in the NICA-MPD experiment.
  - ✓ PNPI, Development of the design concept and physical research program for the MPD forward spectrometer

- Supported groups produced valuable results for hardware, software developments and physics studies

- Support of external groups enhanced their involvement, contribution and interest in the MPD

- Stable support of participation of external groups is a must for the development of Collaboration and success of the experiment

MPD physics program

NICA

G. Feofilov, A. Aparin

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

❖ Cross-PWG format of meetings for discussion of results and analysis techniques

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
- https://mpdforum.jinr.ru/c/mcprod/26:

  Request 25: General-purpose, 50M UrQMD BiBi@9.2 → **DONE**

  Request 26: General-purpose (trigger), 1M DCM-QGSM-SMM BiBi@9.2 → **DONE**

  Request 27: General-purpose (trigger), 1M PHQMD BiBi@9.2 → **DONE**

  Request 28: General-purpose with reduced magnetic field, 10M UrQMD BiBi@9.2 → **DONE**

  Request 29: General-purpose (hypernuclei), 20M PHQMD BiBi@9.2 → **DONE**

  Request 30: General-purpose (polarization), 15M PHSD BiBi@9.2 → **DONE**

  Request 31: General-purpose (femtoscopy), 50 M UrQMD BiBi@9.2 with freeze-out → **DONE**

  Request 32: General purpose (flow), 15M vHLLE+UrQMD with XPT → **DONE**

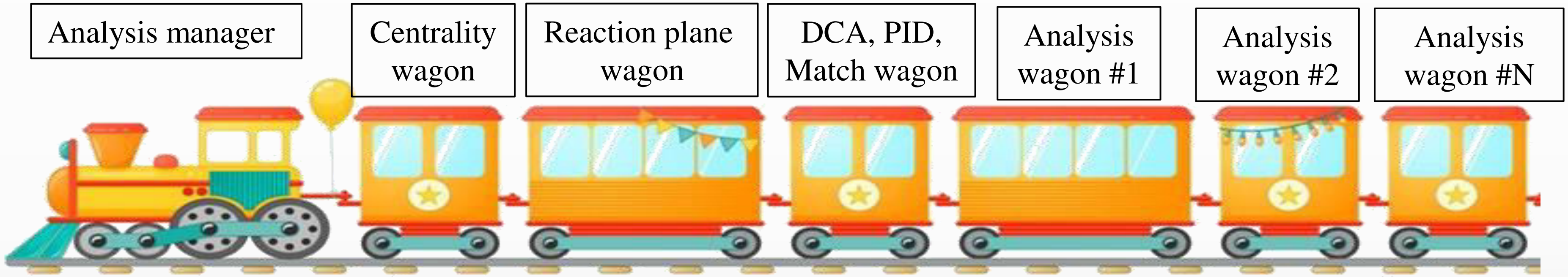
  Request 33: General purpose (FXT), (11M x 3 energies) UrQMD (mean field) → **DONE**

- Production comparable in size to the first expected real data samples test the existing computing and software infrastructure
- Develop realistic analysis methods and techniques, set priorities and find group leaders
- Thanks to A. Moshkin (production manager), LIT specialists, computing/software team !!!

Handling the big data sets

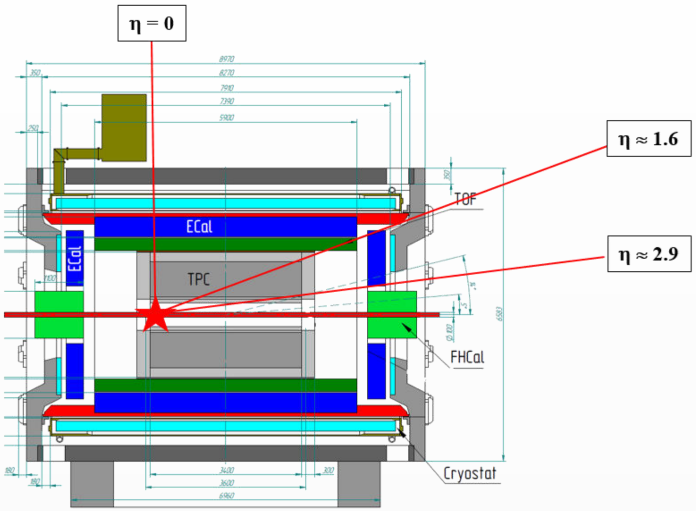
- Centralized Analysis Framework for access and analysis of data → Analysis Train:
  - ✓ consistent approaches and results across collaboration, easier storage and sharing of codes and methods
  - ✓ reduced number of input/output operations for disks and databases, easier data storage on tapes

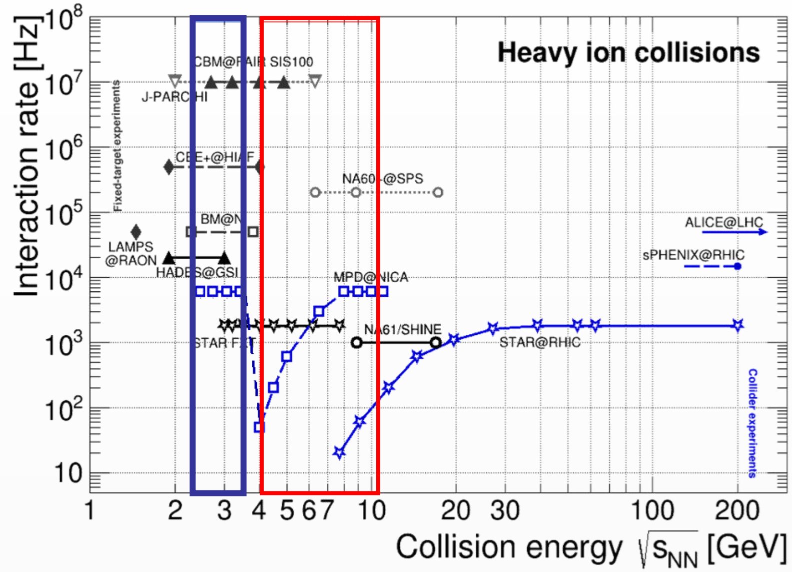
- Analysis manager reads event into memory and calls wagons one-by-one to modify and/or analyze data:



- The Analysis manager and the first Wagons have been created, in MpdRoot @ mpdroot/physics
- Eventually all analysis codes will be committed to MpdRoot as Wagons
- First Analysis Train runs started in September, regular runs on request to process centralized productions
- 50M events are processed in ~ 10 hours with ~ 15 wagons (1 year of CPU time)

Fixed-target operation





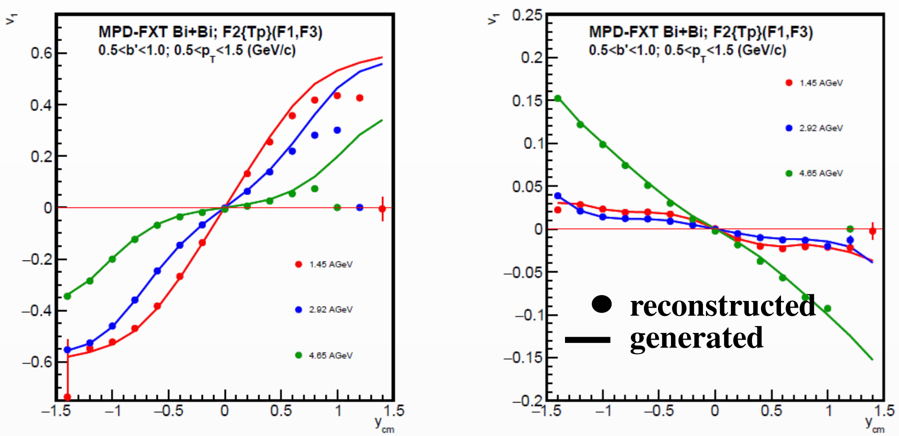
- ❖ Discussing the option of NICA operation in the collider and fixed-target modes in the same campaign
- ❖ Fixed-target mode: one beam + thin wire (~ 100 μm) close to the edge of the MPD central barrel:
  - ✓ extends energy range of MPD to $\sqrt{s_{NN}}$ = 2.4-3.5 GeV (overlap with HADES, BM@N and CBM)
  - ✓ solves problem of low event rate at lower collision energies (only ~ 50 Hz at $\sqrt{s_{NN}}$ = 4 GeV at design luminosity)
  - ✓ backup start-up solution (too low luminosity, only one beam, etc.)
- ❖ Collision systems: Xe (stable isotopes with A= 126, 128, 129, 130, 131, 132, 134) + W (A = 182, 183, 184, 186), La (A = 139), Cu (A=63, 65), Au (A = 197), … subject of further discussions
- ❖ MPD detector is able to run in the fixed-target mode in the default configuration:
  - ✓ existing trigger system remains to be efficient (FFD + FHCAL + TOF)
  - ✓ detector provides reasonable p_T coverage for light/heavy identified hadrons at midrapidity (y_{CMS} ~ 0)

Unique capability of target and collision energy overlap between MPD and BM@N experiments

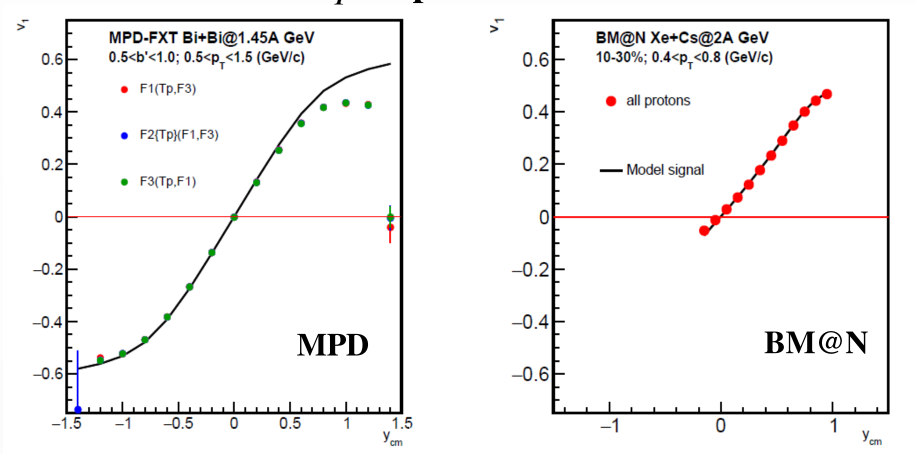
MPD-FXT, v_1 & v_2 for protons/pions

❖ Mass production 33 (UrQMD mean-field, fixed-target mode, 10M events): Bi+Bi @ 2.5, 3.0 and 3.5 GeV

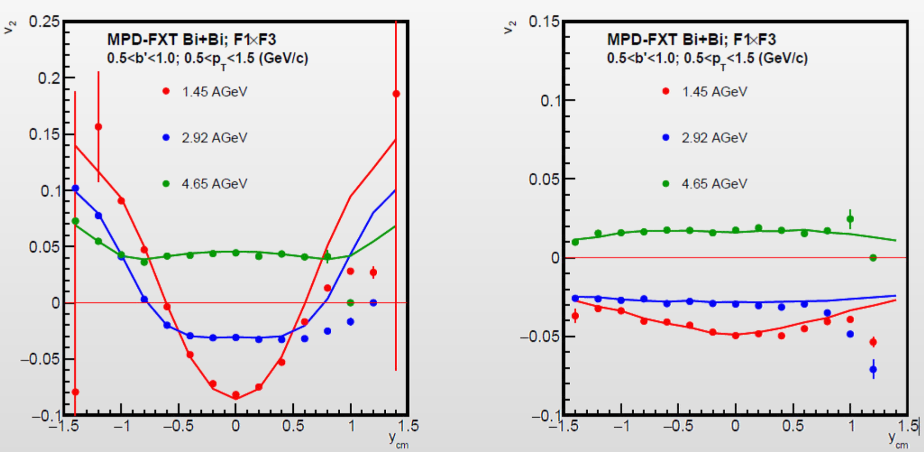
***v_1* for pions and protons**



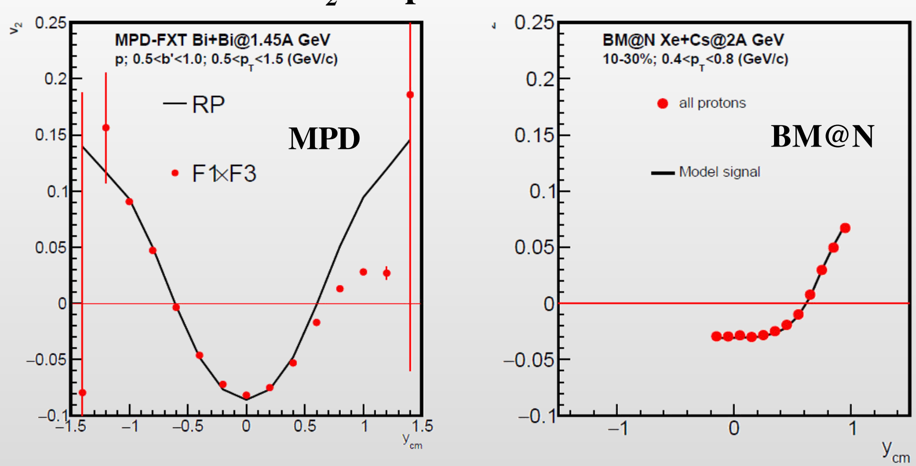
***v_1* for protons**



***v_2* for pions and protons**



***v_2* for protons**

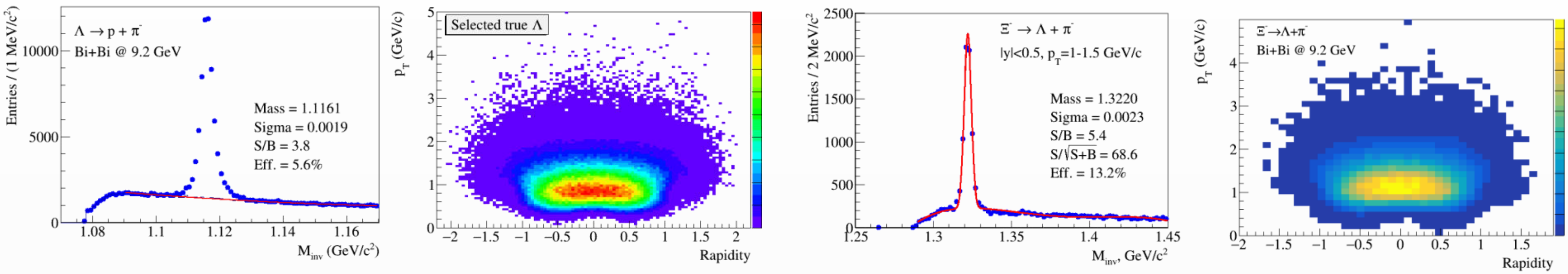


Reconstructed v_1 & v_2 are qualitatively consistent with truly generated signals at $y_{cms} < 0.5$

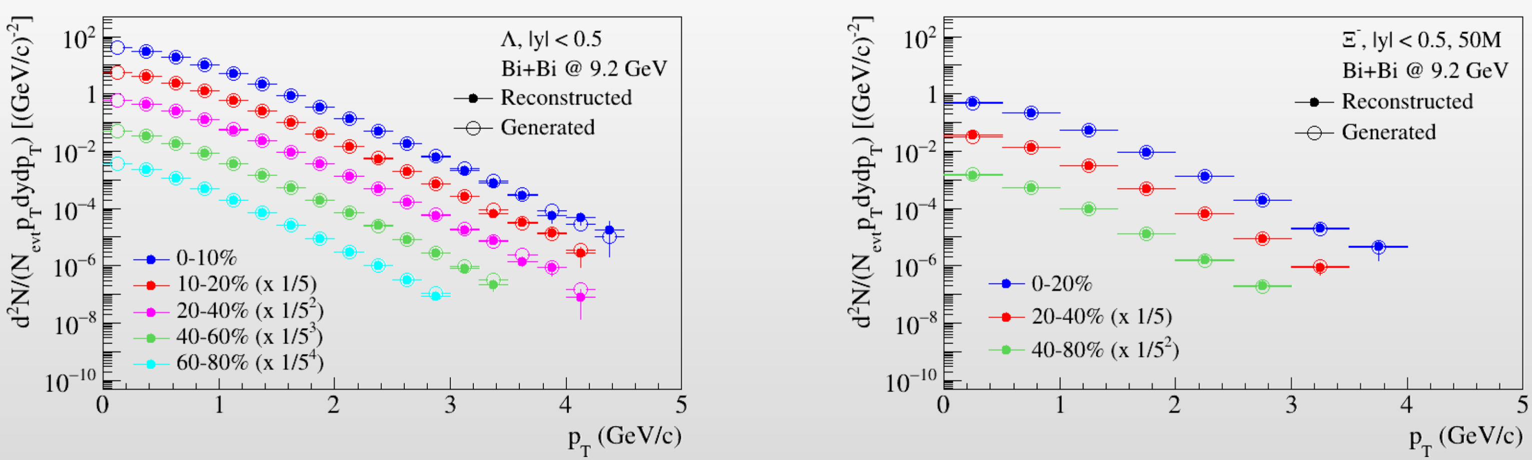
MPD has better coverage at backward and central rapidity, BM@N is superior at forward rapidity

Hyperon reconstruction

❖ Mass production 25 (UrQMD, BiBi@9.2 GeV, 50M events)



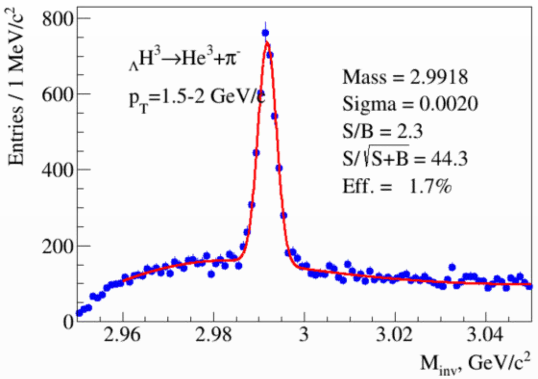
- different background estimates (fit function vs mixed-event)
- different PID selections for high-p_T daughter particles
- testing alternative Machine Learning techniques

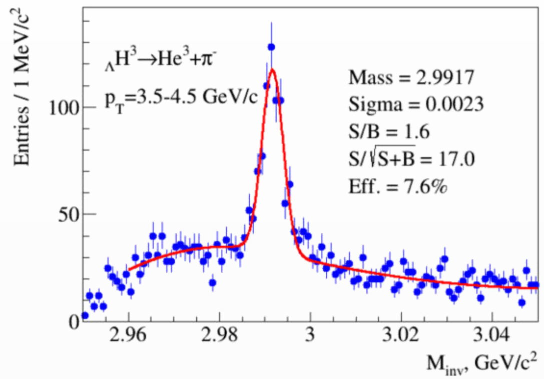


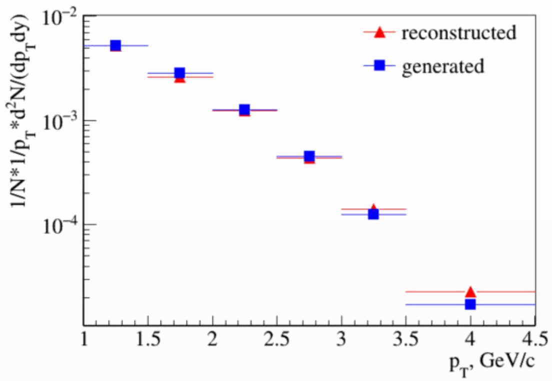
Differential production spectra are reconstructed in different centrality bins

Hypenuclei reconstruction

- Mass production 29 (PHQMD, BiBi@9.2 GeV, 40M events)



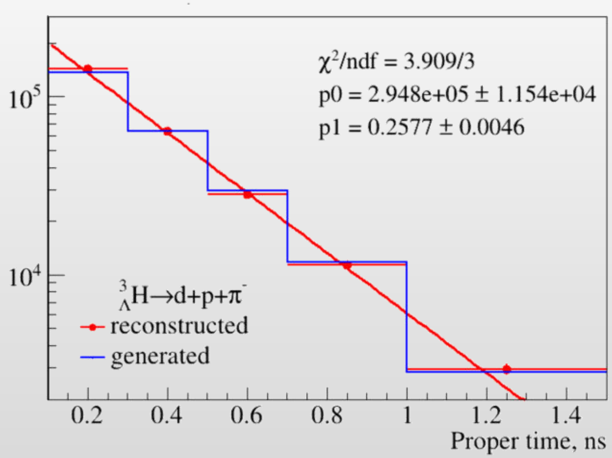


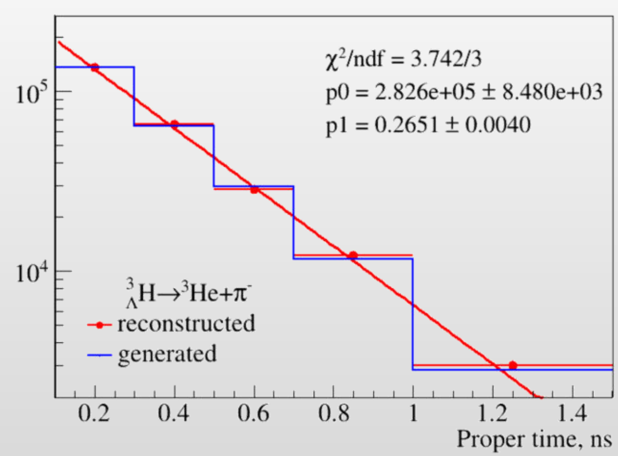


2- and 3-prong decay modes were studied separately to estimate systematics

$$N(\tau) = N(0)\exp\left(-\frac{\tau}{\tau_0}\right) = N(0)\exp\left(-\frac{ML}{cp\tau_0}\right),$$

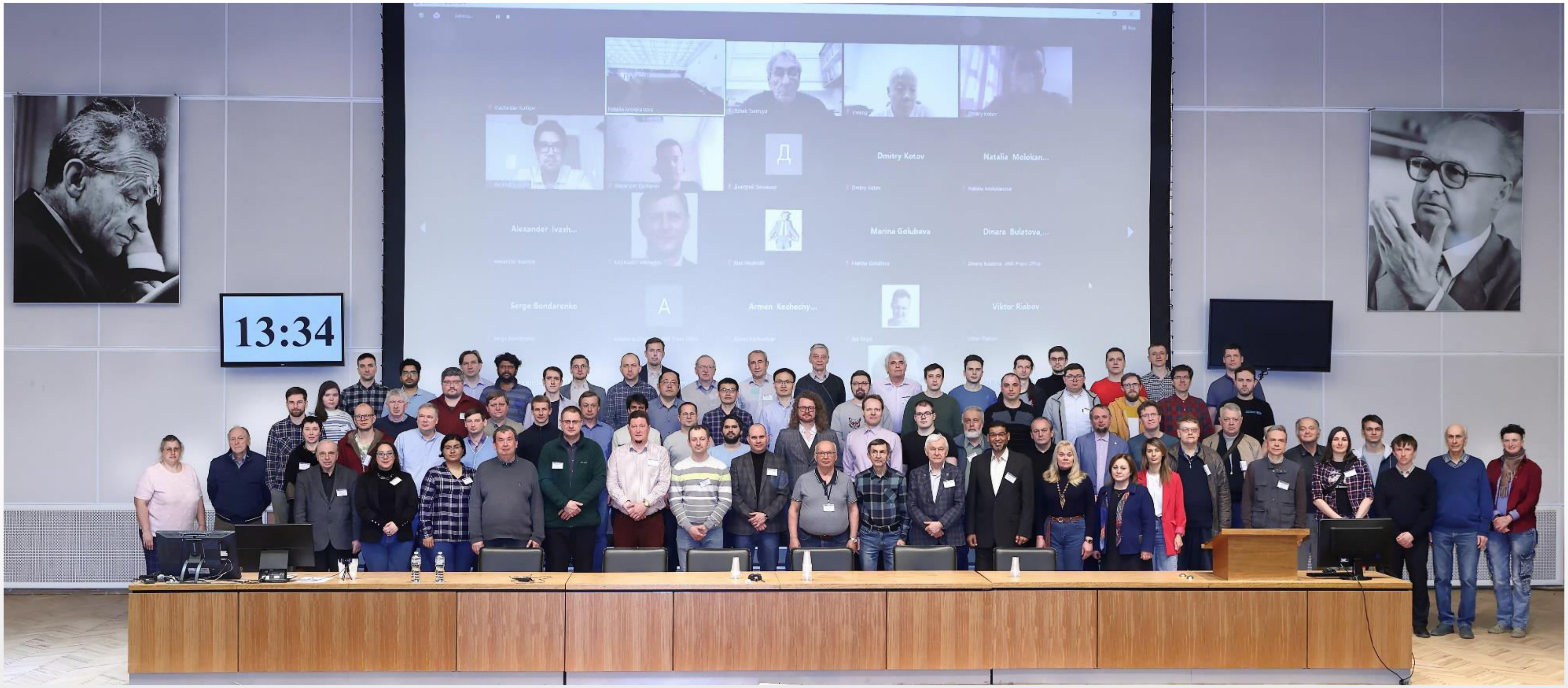
Decay channel	Branching ratio	Decay channel	Branching ratio
$\pi^- + {}^3He$	24.7%	$\pi^- + p + p + n$	1.5%
$\pi^0 + {}^3H$	12.4%	$\pi^0 + n + n + p$	0.8%
$\pi^- + p + d$	36.7%	$d + n$	0.2%
$\pi^0 + n + d$	18.4%	$p + n + n$	1.5%





Results for different decay modes are consistent

Summary

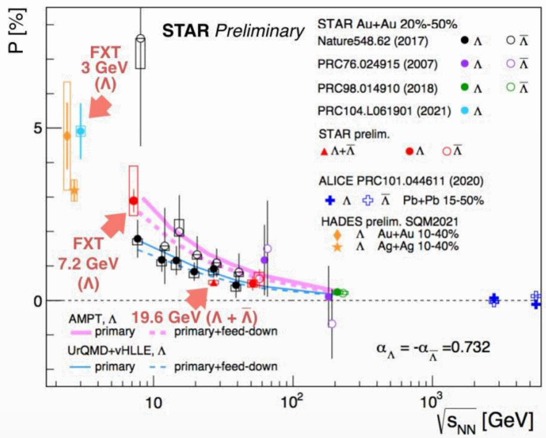


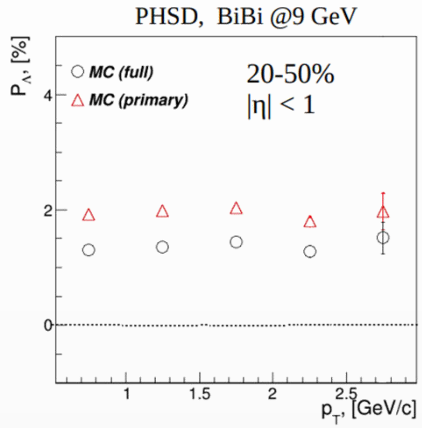
- ❖ Preparation of the MPD detector and experimental program is continued
- ❖ Consider different operation options (collider, fixed-target)
- ❖ Develop realistic analysis methods and techniques to be ready for analysis of the first data

BACKUP

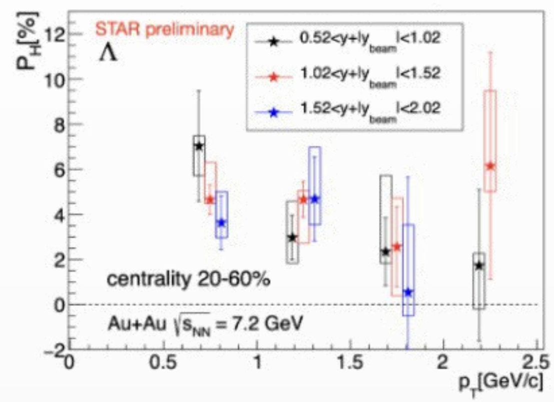
Hyperon global polarization

- Global polarization of hyperons was predicted and experimentally observed in non-central heavy-ion collisions
- Increasing effect at lower collision energies, ~ flat vs. p_T, increasing towards more peripheral collisions
- Measurements for $\Lambda/\bar{\Lambda}$ at NICA energies are reproduced by PHSD (thermodynamical Becattini approach [1])

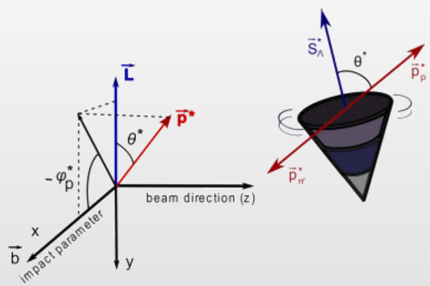




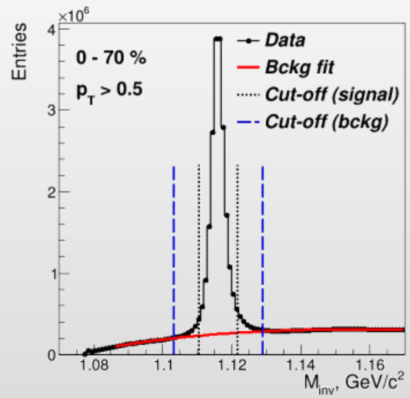
[1] F. Becattini et al., Ann. Phys. 338 (2013) 32

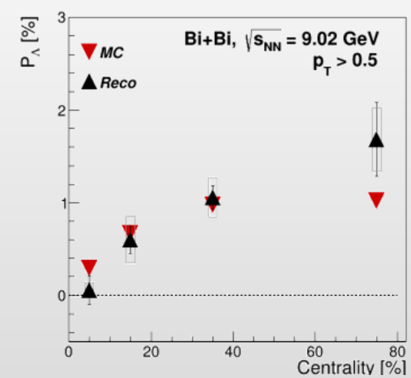


- MPD simulations - Λ global polarization, BiBi@9.2 GeV: first measurements would require ~ 10M sampled events



$$\overline{P}_{\Lambda/\bar{\Lambda}} = \frac{8}{\pi\alpha}\frac{1}{R^1_{\mathrm{EP}}}\left\langle \sin(\Psi^1_{\mathrm{EP}} - \phi^*_p) \right\rangle$$

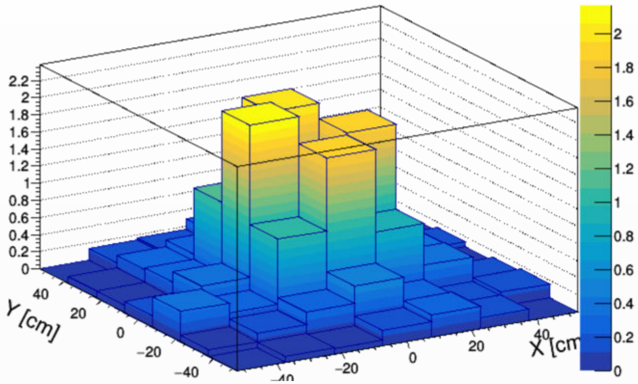


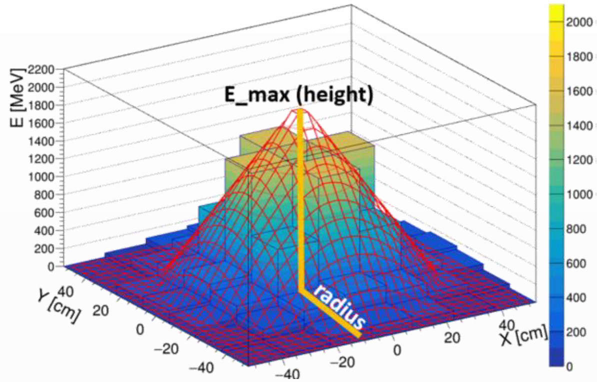


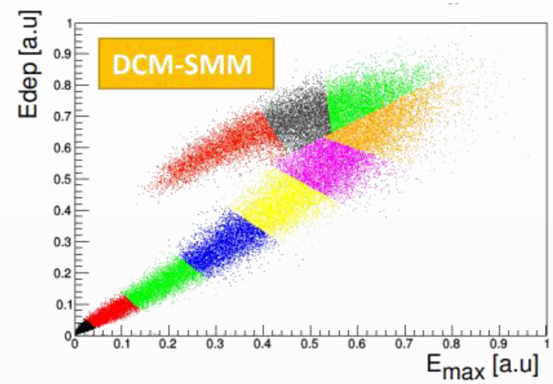
NICA: contribute extra points in the energy range 2-11 GeV with small uncertainties; centrality, p_T and rapidity dependence of polarization not only for Λ, but other (anti)hyperons (Λ, Σ, Ξ)

Centrality with FHCAL

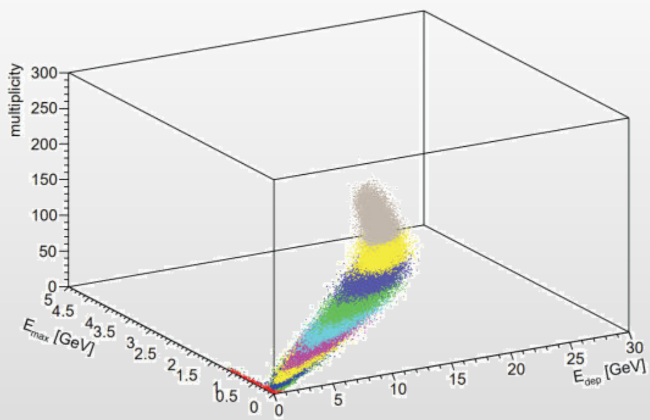
- Old approach – only FHCAL signals are analyzed:

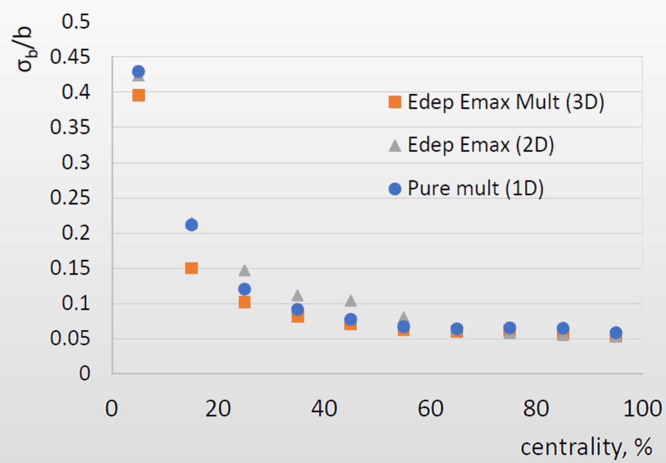






- New approach – adding TPC multiplicity for 3D analysis:

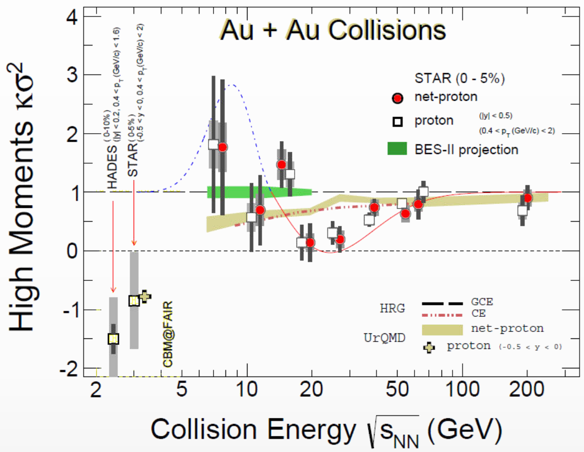


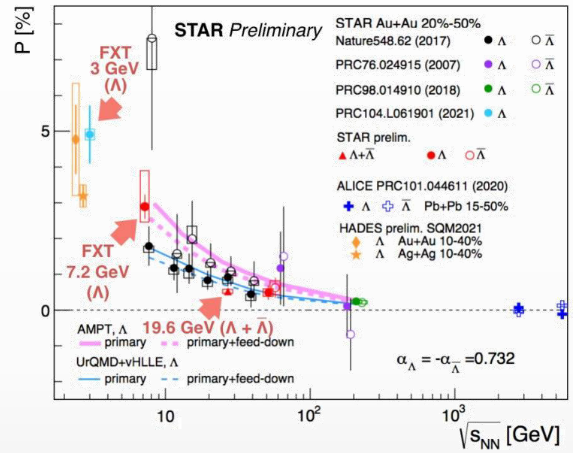


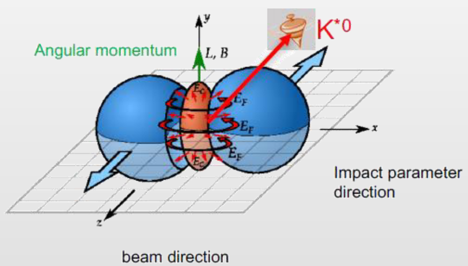
Improved resolution for most central and (semi)central collisions

Hot physics topics

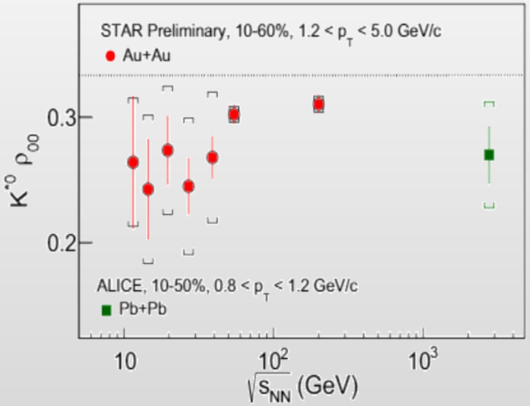
- Critical fluctuations for (net)proton/kaon multiplicity distributions
- Global hyperon polarization in mid-central A+A collisions (Λ, Ξ, Ω and antiparticles)
- Spin alignment of vector mesons ($K^*(892)$, $\phi(1020)$)

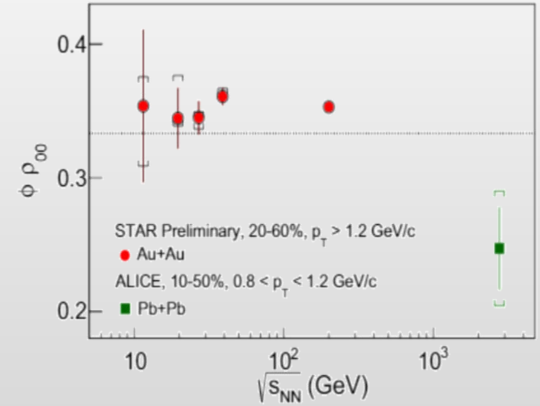






$$\frac{dN}{dcos\theta} = N_0\left[1 - \rho_{0,0} + cos^2\theta\left(3\rho_{0,0} - 1\right)\right]$$



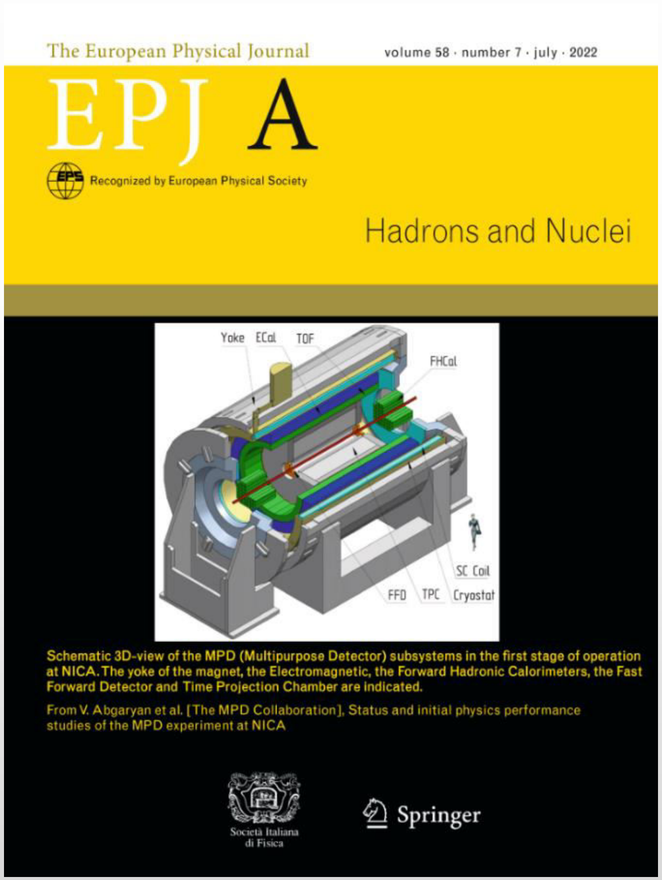


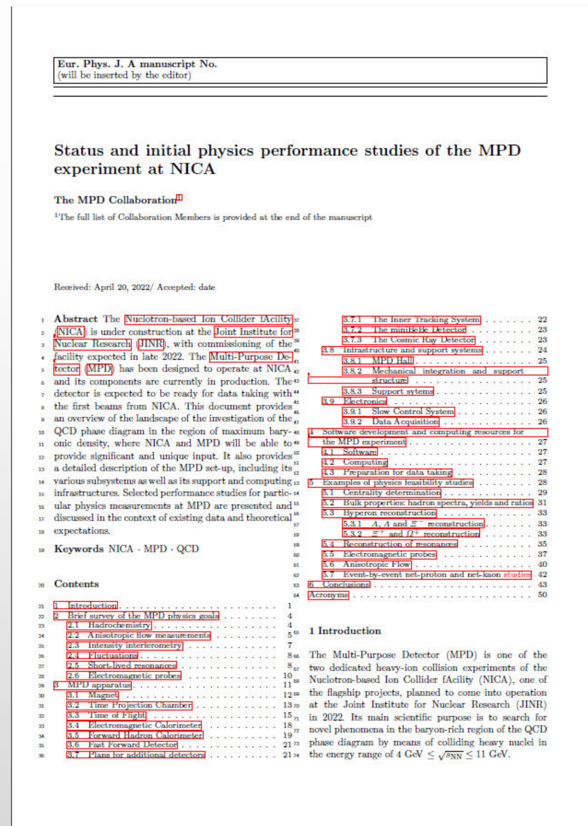
Task for NICA: extra points in the energy range 4-11 GeV with small uncertainties

Status and performance

- MPD publications: over 200 in total for hardware, software and physics studies (SPIRES)
- First collaboration paper recently published EPJA (~ 50 pages): Eur.Phys.J.A 58 (2022) 7, 140

<u>Status and initial physics performance studies of the MPD experiment at NICA</u>





Eur. Phys. J. A manuscript No.
(will be inserted by the editor)

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

The MPD Collaboration[1]

[1]The full list of Collaboration Members is provided at the end of the manuscript

Received: April 20, 2022/ Accepted: date

Abstract The Nuclotron-based Ion Collider fAcility (NICA) is under construction at the Joint Institute for Nuclear Research (JINR), with commissioning of the facility expected in late 2022. The Multi-Purpose Detector (MPD) has been designed to operate at NICA and its components are currently in production. The detector is expected to be ready for data taking with the first beams from NICA. This document provides an overview of the landscape of the investigation of the QCD phase diagram in the region of maximum baryonic density, where NICA and MPD will be able to provide significant and unique input. It also provides a detailed description of the MPD set-up, including its various subsystems as well as its support and computing infrastructures. Selected performance studies for particular physics measurements at MPD are presented and discussed in the context of existing data and theoretical expectations.

Keywords NICA · MPD · QCD

Contents

1 Introduction

The Multi-Purpose Detector (MPD) is one of the two dedicated heavy-ion collision experiments of the Nuclotron-based Ion Collider fAcility (NICA), one of the flagship projects, planned to come into operation at the Joint Institute for Nuclear Research (JINR) in 2022. Its main scientific purpose is to search for novel phenomena in the baryon-rich region of the QCD phase diagram by means of colliding heavy nuclei in the energy range of 4 GeV $\le \sqrt{s_{NN}} \le$ 11 GeV.

RHIC BES program

❖ Data taking by STAR at RHIC: 3 < $\sqrt{s_{NN}}$ < 200 GeV (750 < μ_B < 25 MeV)

Au+Au Collisions at RHIC

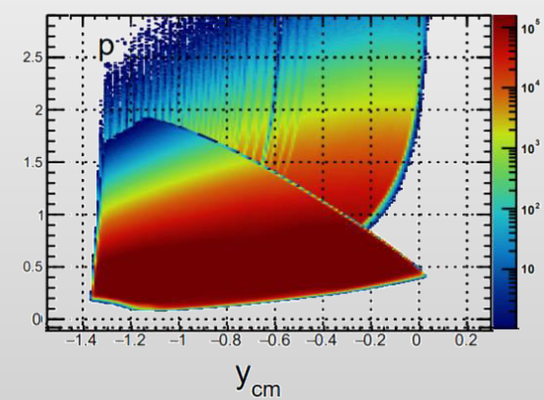
Collider Runs						Fixed-Target Runs					
	$\sqrt{s_{NN}}$ (GeV)	#Events	μ_B	y_{beam}	run		$\sqrt{s_{NN}}$ (GeV)	#Events	μ_B	y_{beam}	run
1	200	380 M	25 MeV	5.3	Run-10, 19	1	13.7 (100)	50 M	280 MeV	-2.69	Run-21
2	62.4	46 M	75 MeV		Run-10	2	11.5 (70)	50 M	320 MeV	-2.51	Run-21
3	54.4	1200 M	85 MeV		Run-17	3	9.2 (44.5)	50 M	370 MeV	-2.28	Run-21
4	39	86 M	112 MeV		Run-10	4	7.7 (31.2)	260 M	420 MeV	-2.1	Run-18, 19, 20
5	27	585 M	156 MeV	3.36	Run-11, 18	5	7.2 (26.5)	470 M	440 MeV	-2.02	Run-18, 20
6	19.6	595 M	206 MeV	3.1	Run-11, 19	6	6.2 (19.5)	120 M	490 MeV	1.87	Run-20
7	17.3	256 M	230 MeV		Run-21	7	5.2 (13.5)	100 M	540 MeV	-1.68	Run-20
8	14.6	340 M	262 MeV		Run-14, 19	8	4.5 (9.8)	110 M	590 MeV	-1.52	Run-20
9	11.5	157 M	316 MeV		Run-10, 20	9	3.9 (7.3)	120 M	633 MeV	-1.37	Run-20
10	9.2	160 M	372 MeV		Run-10, 20	10	3.5 (5.75)	120 M	670 MeV	-1.2	Run-20
11	7.7	104 M	420 MeV		Run-21	11	3.2 (4.59)	200 M	699 MeV	-1.13	Run-19
						12	3.0 (3.85)	2000 M	750 MeV	-1.05	Run-18, 21

❖ A very impressive and successful program with many collected datasets, already available and expected results

❖ Limitations:

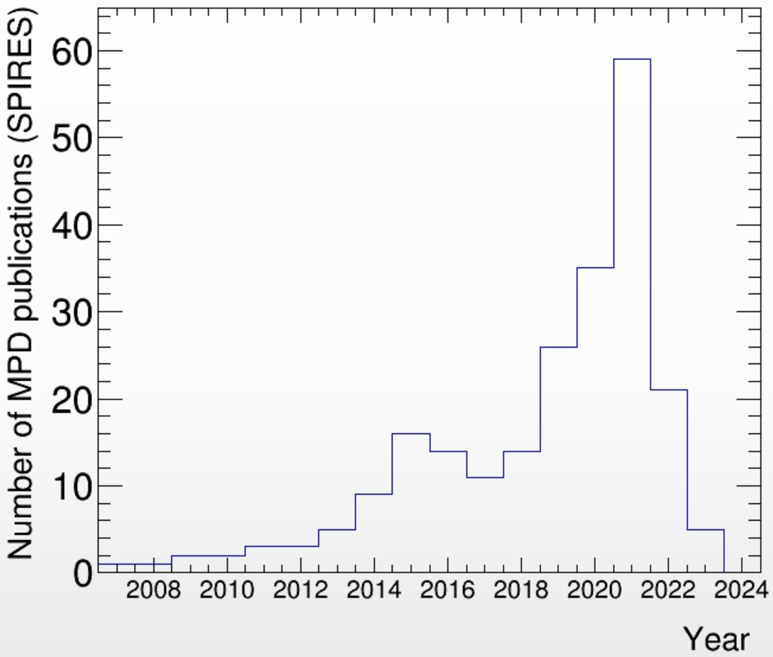
- ✓ Au+Au collisions only
- ✓ Among the fixed-target runs, only the 3 GeV data have full mid-rapidity coverage for protons (|y| < 0.5), which is crucial for physics observables

Au+Au @ 3.9 GeV



Collaboration activity

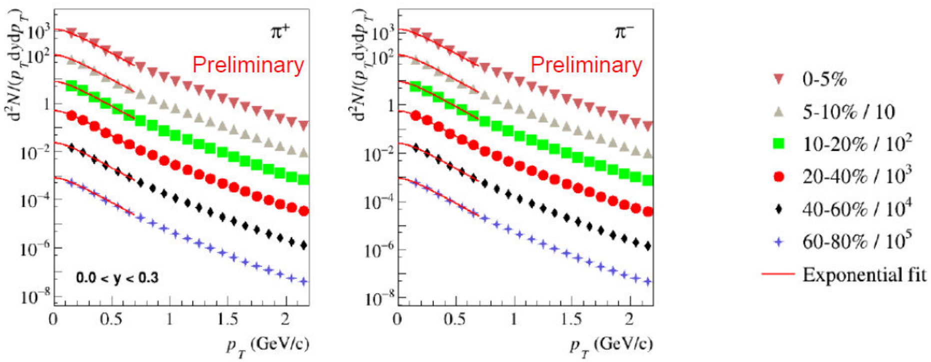
- ❖ Many ongoing hardware, software and physics feasibility studies
- ❖ MPD publications: over 200 in total for hardware, software and physics studies:

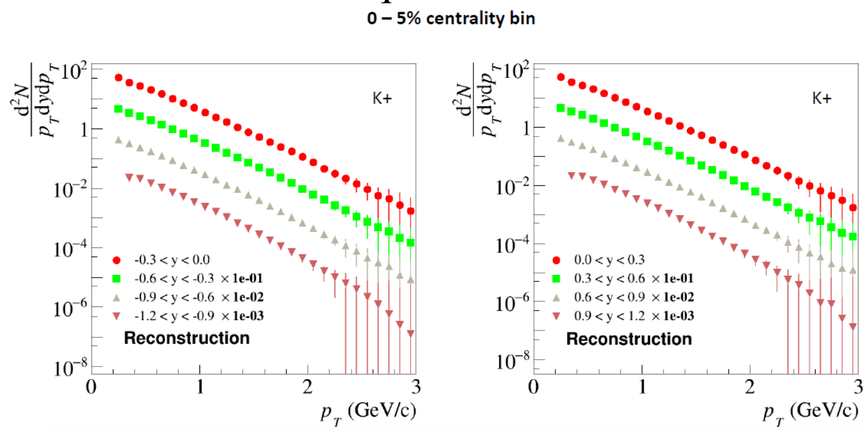


- ❖ Support of Russian institutions in the NICA project:
  - ✓ 2019-2021: RFBR grant program, 2019-2021
  - ✓ 2022: internal JINR grants for students/PhD, 2022
  - ✓ 2023: internal JINR grants for leaders/students/PhD, 2023
  - ✓ 2023 and beyond: expect support by Russian Ministry of Science

Identified light hadrons

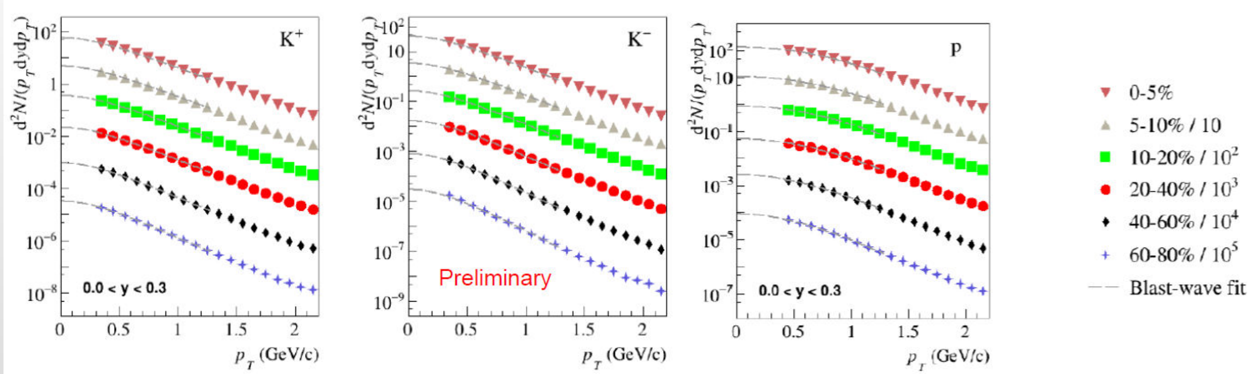
- Probe freeze-out conditions, collective expansion, hadronization mechanisms, strangeness production ("horn" for K/π), parton energy loss, etc. with particles of different masses, quark contents/counts





Functions used to fit spectra are m_T-exponential :

$$\frac{1}{p_T}\times\frac{d^2N}{dy\,dp_T}=\frac{dN/dy}{T(m+T)}\cdot\exp\left(-\frac{m_T-m}{T}\right)$$



Functions used to fit spectra are blast-wave:

$$\frac{d^2N}{p_t\,dp_t\,dy}=C\int_0^1 p_t f(\xi)K_1\left(\frac{m_t\cosh(\rho)}{T}\right)I_0\left(\frac{p_t\sinh(\rho)}{T}\right)\xi\,d\xi$$

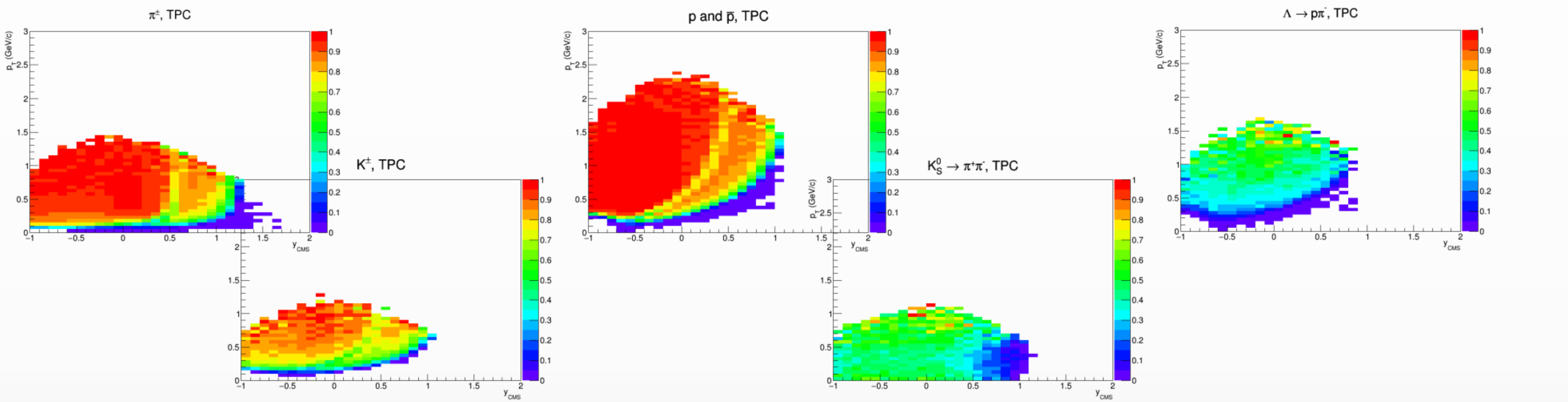
China MOST MPD-ECal project

- Hardware:
  - Construction of 8 sectors ECal prototype. 768 modules in total.
  - Production of FEE PCB (1800 FEEs)
  - R&D on fast readout electronics, time resolution is less than 150ps
- Software and simulation
- Schedule: 2020.6-2024.5
- Institutes:
  - Tsinghua University 100%
  - Shandong University 100%
  - University of South China 100%
  - Fudan University 90%
  - Huzhou University

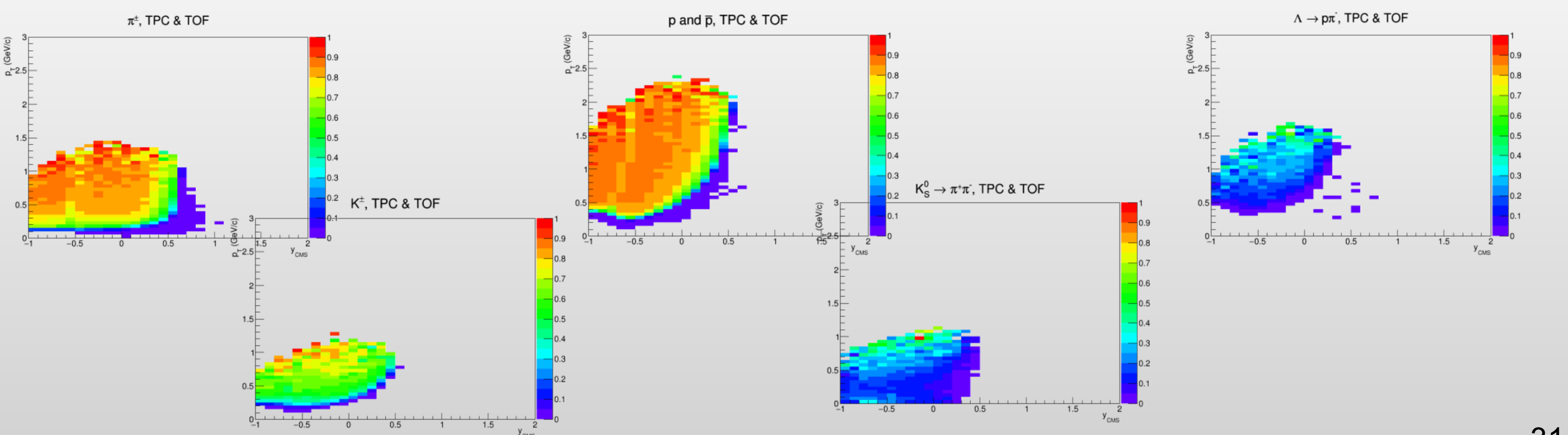
Efficiency for π/K/p/Ks/Λ, z_{vertex} = - 85 cm

Basic track selections: $N_{hits} > 10$; DCA < 2 cm; Primary particles ($R_{production} < 1$ cm)

❖ TPC-only tracks:



❖ TPC + TOF tracks:



Beam and luminosity monitoring

- To be used with MPD in service/working position:
  - ✓ assistance in controlling the transverse sizes of the bunches
  - ✓ assistance in setting up transvers and longitudinal convergence of bunches
  - ✓ control of the distribution of vertices in the longitudinal direction.

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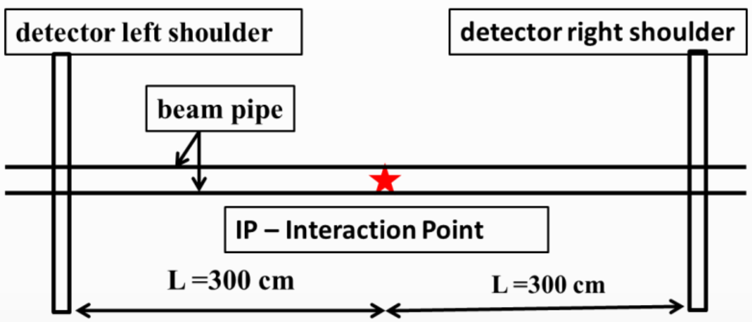

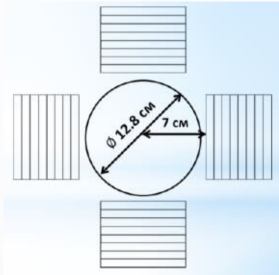

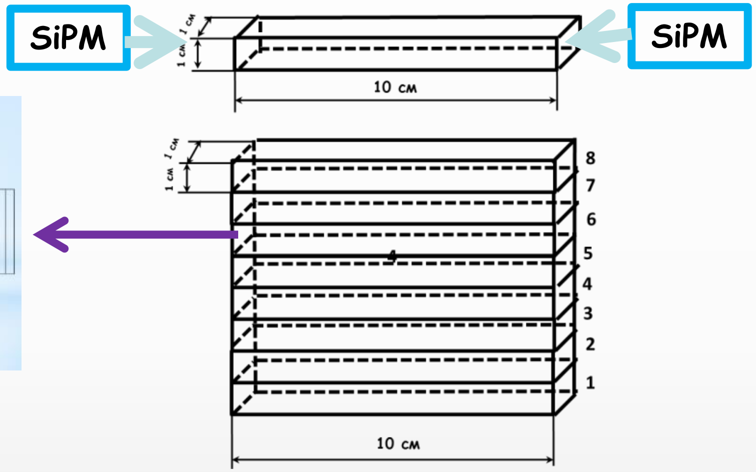

The detector consists of 100x10x10 mm^3 plastic scintillator strips (organic polystyrene scintillator with the addition of 1.5% p-terphenyl and 0.05% POPOP) viewed from both sides with SiPMs (HAMAMATSU S13360 6025 CS)

- Trigger: condition: $|T_L^{min} - T_R^{min}| < 10$ ns; efficiency – 77% in AuAu@11 GeV (DCM-SMM)
- Observables & methods:
  - ✓ counting rate and z-vertex distribution ($\sigma_{z\text{-vertex}}$ ~ 5 cm with $\delta\tau$ ~ 300 ps)
  - ✓ Van der Meer and ΔZ scans for optimization of beam optics
- Two planes have been assembled and tested with beams at CERN, analysis of results is in progress
- Mass production started