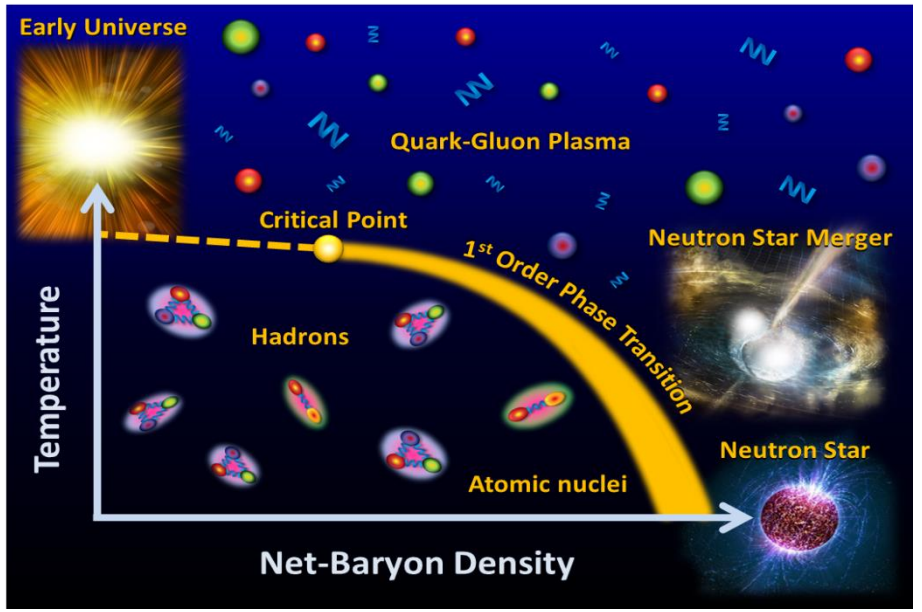
Full-scale simulation of the MPD-NICA experimental setup and data analysis techniques





Arkadiy Taranenko (JINR, MEPhI) on behalf of the MPD Collaboration

Mathematical Modeling and Computational Physics - MMCP'2026 ,
JINR Dubna, 25/06/2026

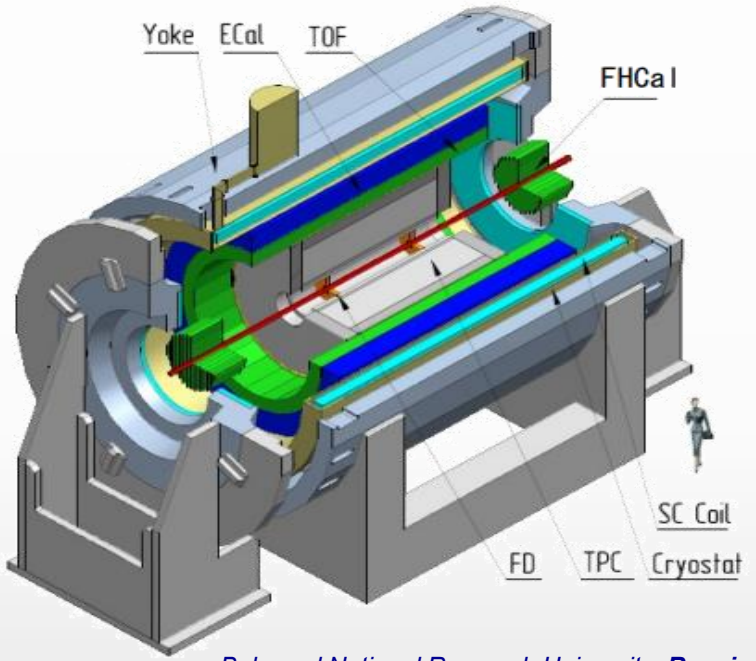
Multi-Purpose Detector (MPD) Collaboration

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

12** Countries, **>500** participants, **39** Institutions and **JINR

Organization

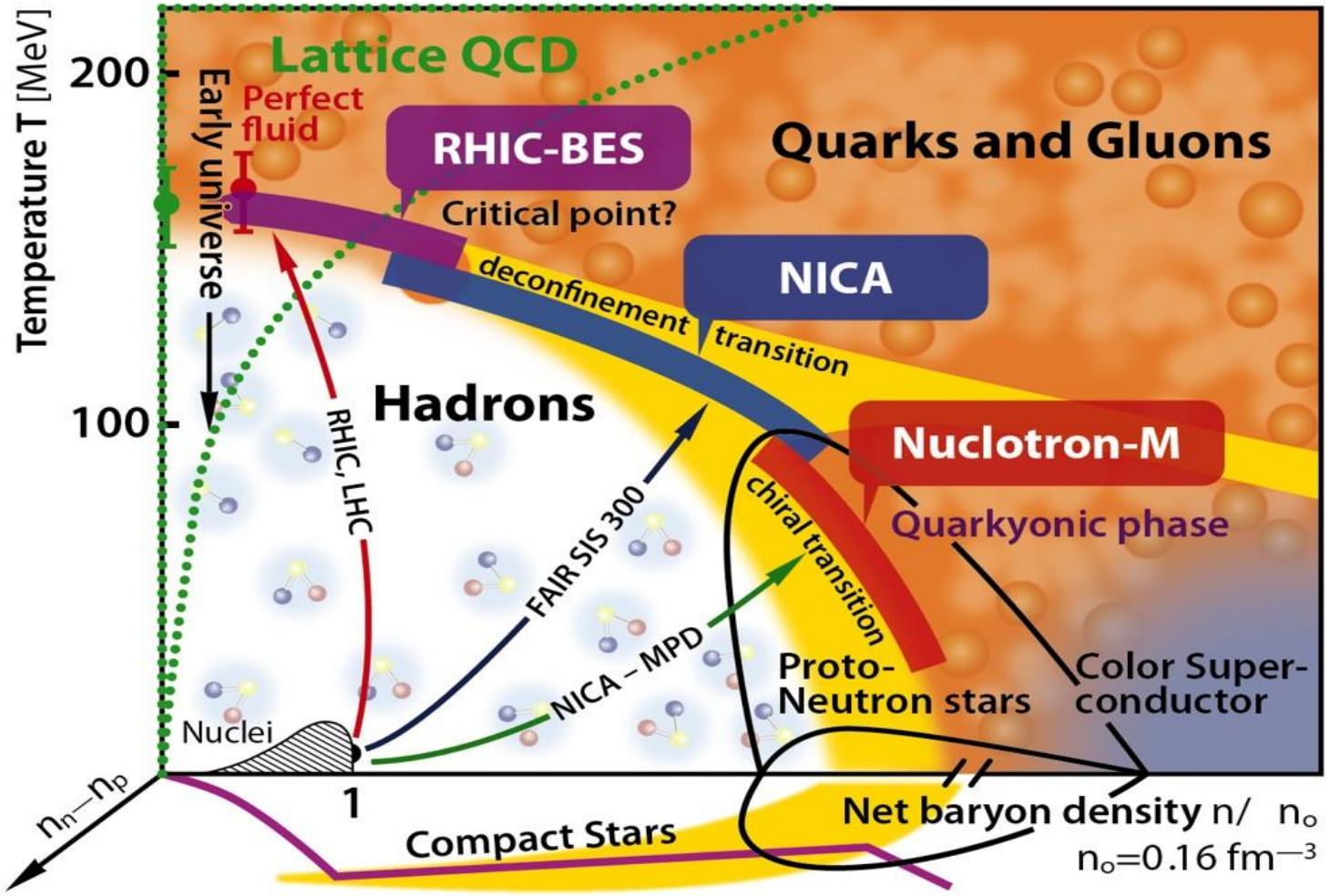
Acting Spokesperson:	***Victor Riabov***
Deputy Spokespersons:	***Arkadiy Taranenko, Chi Yang***
Institutional Board Chair:	***Alejandro Ayala***
Project Manager:	***Slava Golovatyuk***

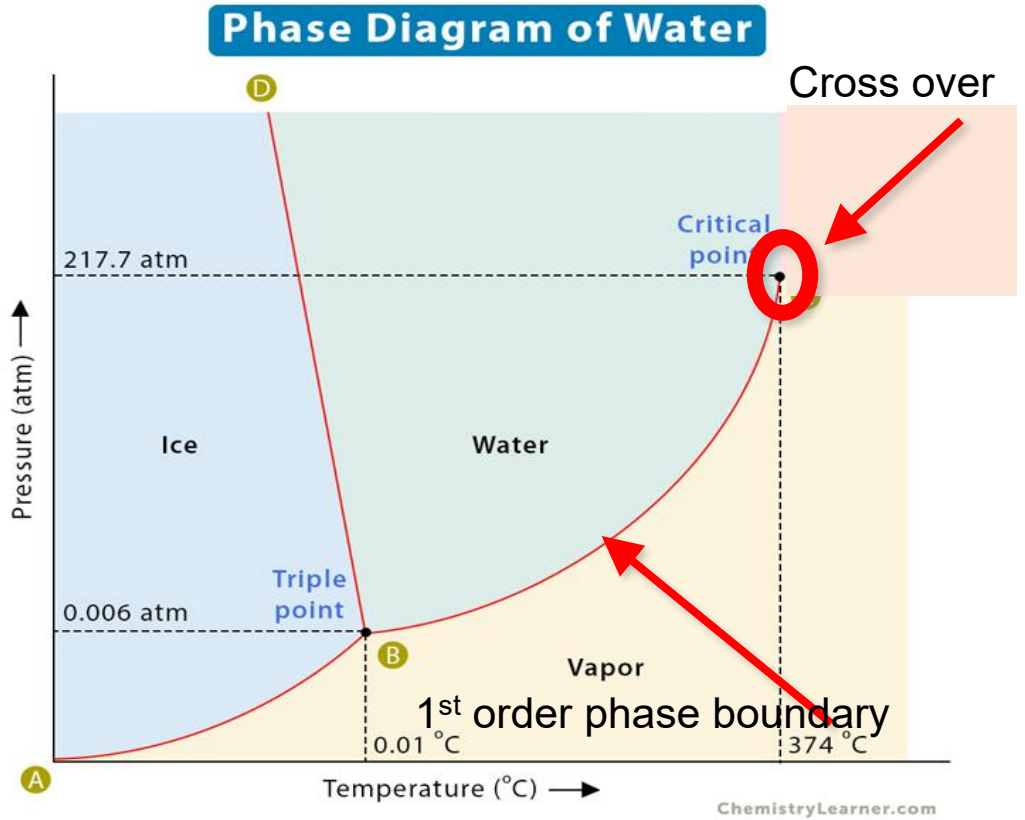


***Joint Institute for Nuclear Research**;*
*A.Alikhanyan National Lab of Armenia, Yerevan, **Armenia;***
*Institute for Nuclear Problems of Belarusian State University, **Belarus**;*
*Institute of Power Engineering of the National Academy of Sciences of Belarus, **Belarus**;*
*SSI "Joint Institute for 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, Huizhou, **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**;*
*Egyptian Center for Theoretical Physics, **Egypt**;*
*Tbilisi State University, Tbilisi, **Georgia**;*
*Institute of Physics and Technology, Almaty, **Kazakhstan**;*
*Instituto de Ciencias Nucleares, UNAM, **Mexico**;*
*Universidad Autónoma de Sinaloa, **Mexico**;*
*Universidad Autónoma Metropolitana, **Mexico**;*
*Universidad de Colima, **Mexico**;*
*Universidad Michoacana de San Nicolás de Hidalgo, **Mexico**;*
*Institute of Physics and Technology, **Mongolia**;*

*Belgorod National Research University, **Russia**;*
*High School of Economics University, Moscow, **Russia;***
*Institute for Nuclear Research of the RAS, Moscow, **Russia**;*
*National Research Nuclear University MEPhI , Moscow, **Russia**;*
*Moscow Institute of Science and Technology, **Russia**;*
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*National Research Center "Kurchatov Institute", **Russia**;*
*National Research Tomsk Polytechnic University, **Russia**;*
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*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***

Relativistic Heavy-Ion Collisions and QCD Phase Diagram





Method	μ_c (MeV)	T_c (MeV)
Holography + Bayesian	560 - 625	101 - 108
FRG/DSE	495 - 654	108 - 119
Lee-Yang edge singularities	500 - 600	100 - 105
Lattice QCD	$\mu_c/T_c > 3$	F. Karsch et al.
Summary	**495 - 654**	**100 - 119**

- ❖ What is the structure of the QCD phase diagram in the high baryon density region?
- ❖ How the dominant degrees of freedom in HIC change with the beam energy?
- ❖ Can the onset of the 1st order phase transition and QCD CEP be detected?

$(\mu_c, T_c) = (495 - 654, 100 - 119)$ MeV ➡ $3.5 < \sqrt{s_{NN}} < 4.9$ GeV

MPD and BM@N are both in the collision energy range of the predicted CEP location.

Neutron Stars and Big Questions



Nature of matter at extreme density?

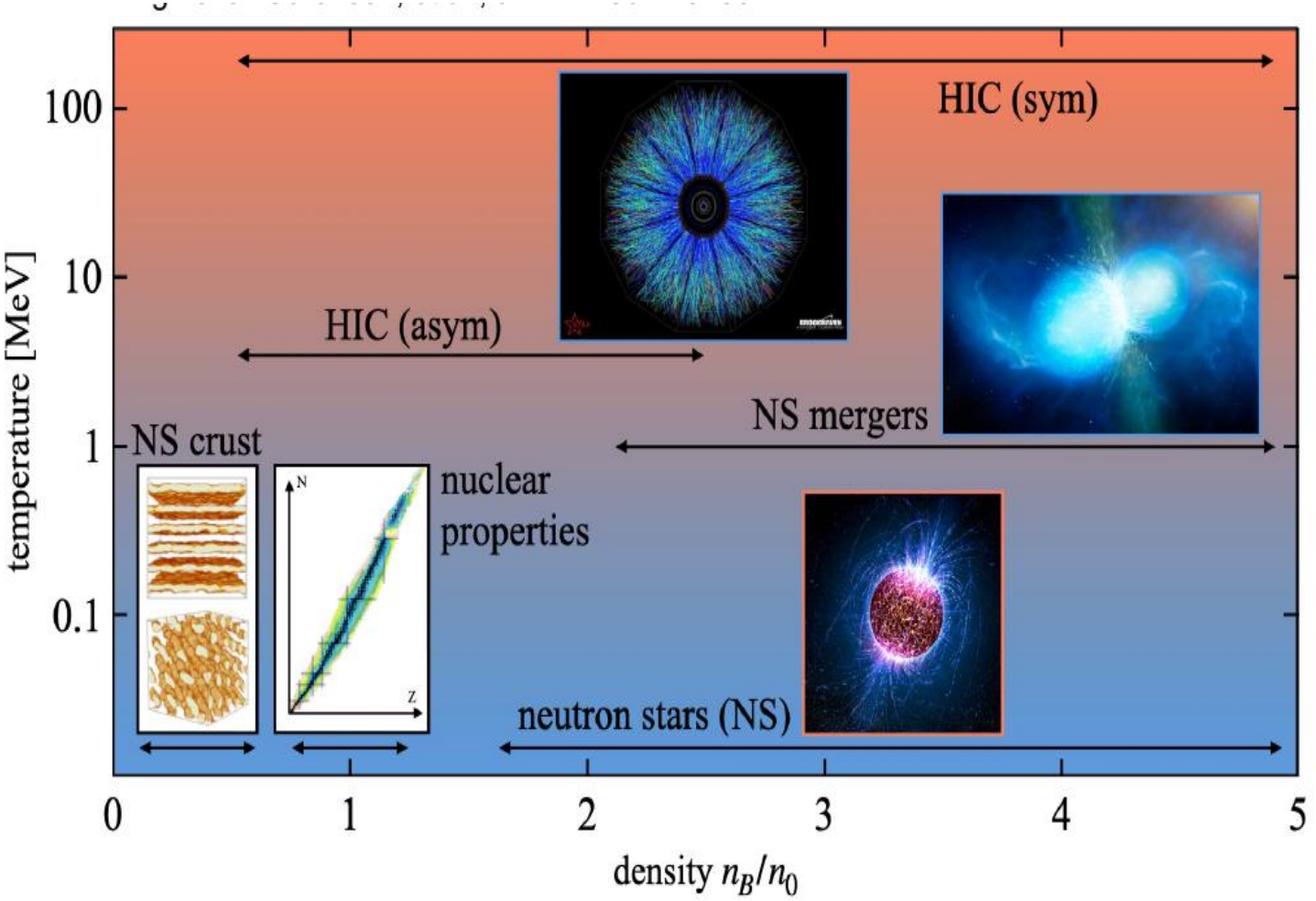


Origin of cosmic explosions?



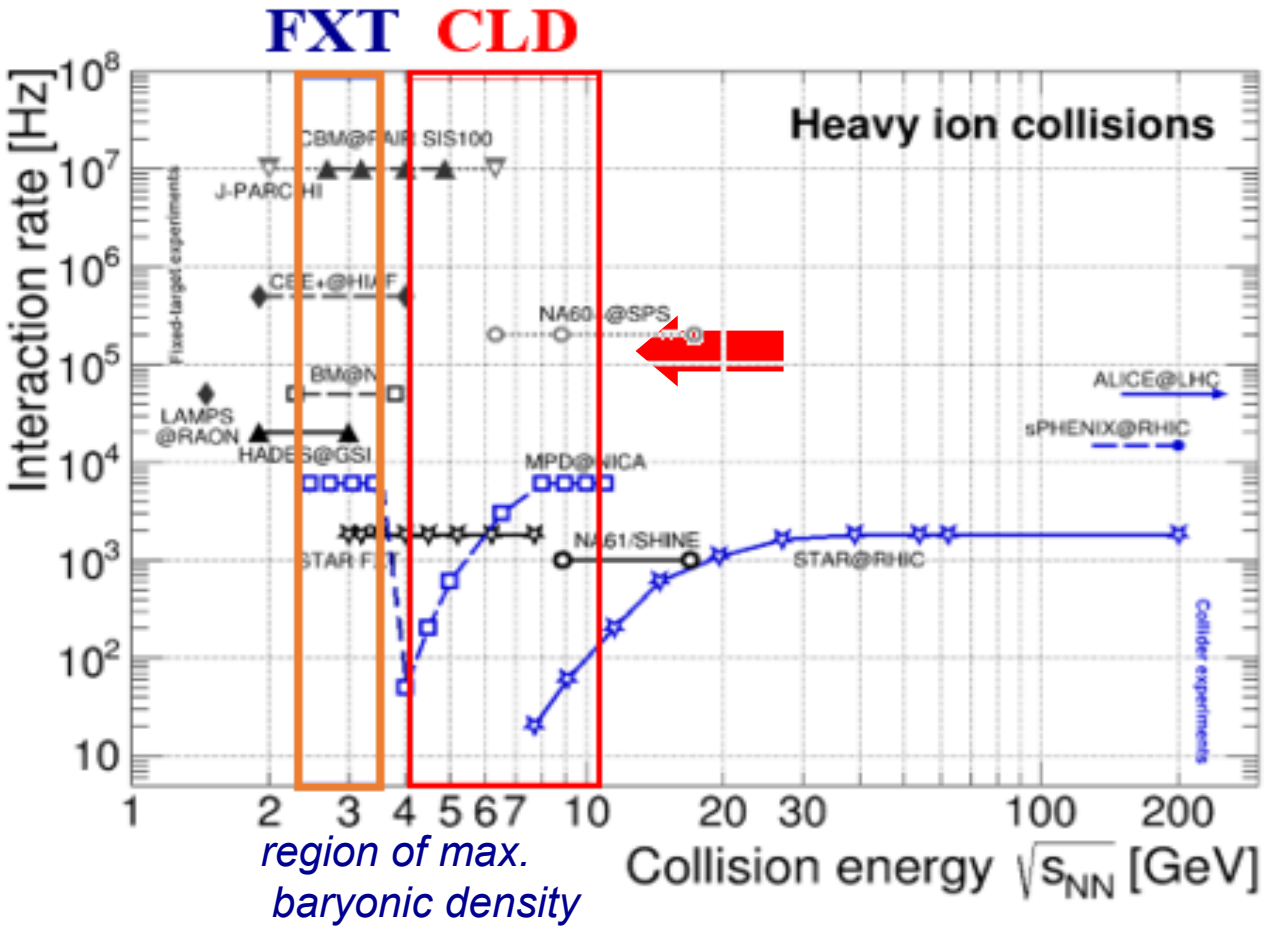
Synthesis of heavy elements?

Dense Nuclear Matter



Relativistic heavy-ion collisions provide a unique and controlled experimental way to study the properties of nuclear matter at high baryon density.

Relativistic Heavy Ion Collision Experiments



MPD competitors:

Present:

RHIC/STAR (USA) 3-200 GeV
NA61/SHINE (CERN) 5.1-17.3 GeV
SIS18/HADES (Germany) 2.4-2.55 GeV

Future:

HIAF/CEE (China) 2.1-4.5 GeV (2026-?)
FAIR/CBM (Germany) 2.4-4.9 GeV (2029-?)
JPARC-HI (Japan) 2-5 GeV (2030-?)

BM@N: $\sqrt{s_{NN}}$ = 2.3 - 3.3 GeV
MPD (CLD): $\sqrt{s_{NN}}$ = 4 - 11 GeV
MPD(FXT): $\sqrt{s_{NN}}$ = 2.3 - 3.3 GeV

❖ **MPD-CLD and MPD-FXT from start-up (2026-):**

- ✓ Collider mode: Xe+Xe (Bi+Bi) at $\sqrt{s_{NN}} \sim 7$ GeV
- ✓ Fixed-target mode: Xe (Bi) beam + W/Au target (~ 50-100 μm wire) at $\sqrt{s_{NN}} \sim 3$ GeV :
  - extends energy range to those of (HADES, BM@N, CBM); high event rate even with low-intensity beam

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. Kireev, 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

MPD superconducting magnet

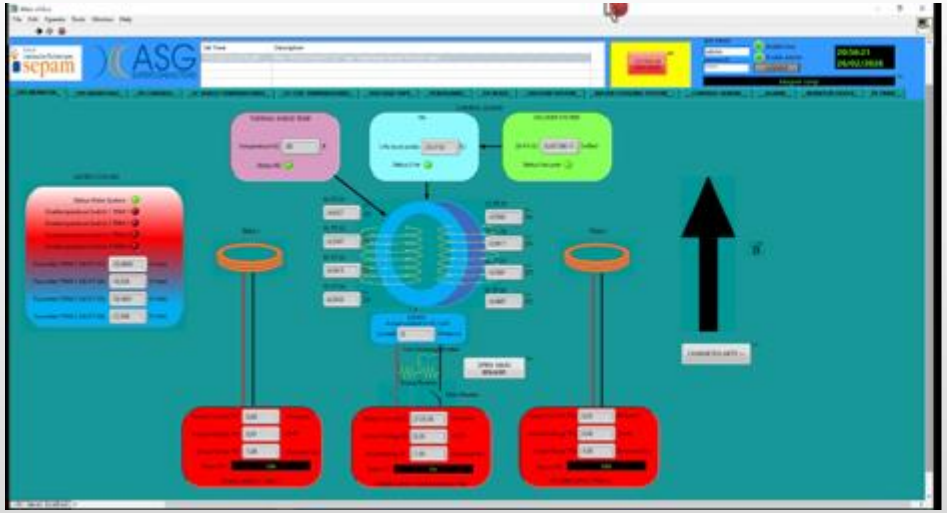
❖ Cooled the magnet to LN2 and LHe temperatures → nominal magnetic field of 0.57 T reached

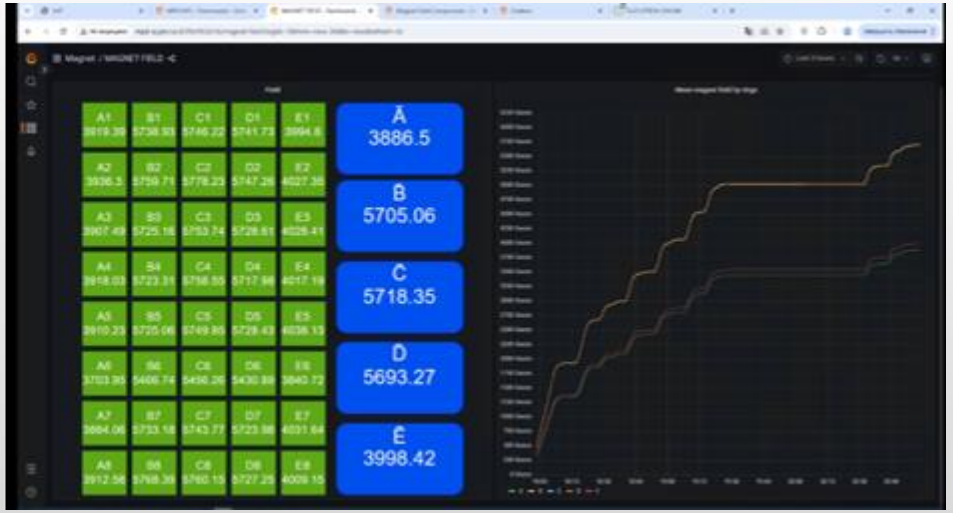
Magnet yoke and cryogenic platform



✓ Stable operation with trim coils at maximum field with no current/temperature fluctuations

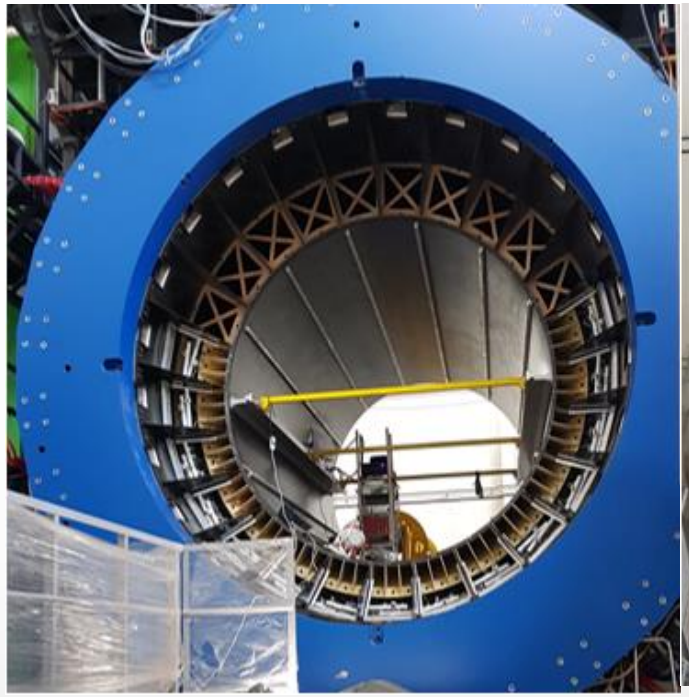
Magnet fully operational since mid-February





One of the major objectives has been successfully realized

Power frame / ECAL / TOF





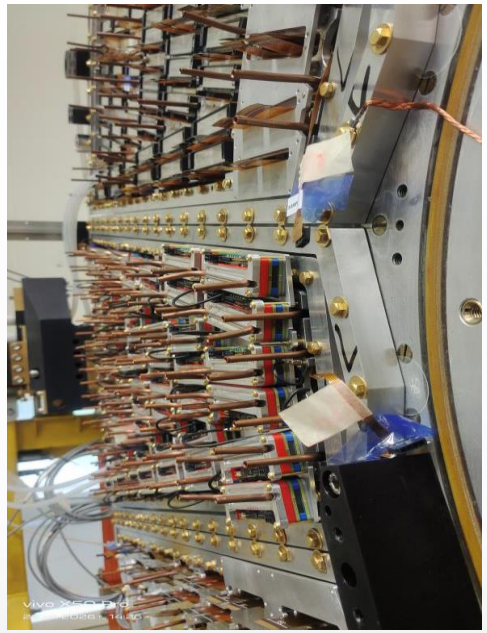


- Carbon fiber power frame has been installed in the magnet
  - ✓ sagita ~ 5 mm at full load
  - ✓ rails for TPC and TOF installed
- Installation of ECAL half-sectors is ongoing:
  - ✓ 38,400 towers (2400 modules) manufactured in Russia and China
  - ✓ 100% of half-sectors installed
- All 28 (100%) TOF modules are assembled and tested, ready for installations
- The TOF modules are tested after transportation to the MPD Hall
- 50% of TOF modules installed, to be finished by the end of June

TPC – central tracking detector

- Gas volume assembled, 24 Read-Out-Chambers (ROC) installed: leak and HV tests passed

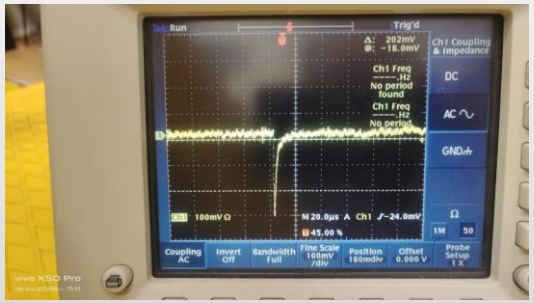




- Operational HV has been applied to membrane and ROC (Cathode), cosmics detected

Ar/CH_4 (90:10)
ROC chamber HV +1.6 kV
TPC HV -25 kV





- Electronics mounting is ongoing for mass read-out tests before transportation to the MPD Hall
- Installation to the MPD starts in August

MPD schedule

		2026
1	January 12th – January 23d	Fixation the Current leads cooling problem
2	January 26th February 15th	Cooling the Solenoid to working temperature
3	February 25 – March 25th	Magnetic field measurements at nominals 0.5T - 0.4T -0.3T
4	March 30th - April 17th	Support Frame installation into Magnet
5	April 30th – May 30th	Ecal installation from the East side
6	May 27th	West platform mounted
7	May 28th – June 15th	Installation of the TOF modules (access from both sides)
8	June 10th	Ecal module installation finishing
9	June 15 – June 20	Installation the Mapper into Magnet
10	June 22th - July 12th	Magnetic field measurements at 0.5T
11	July 15th – August 10th	Ecal&TOF cooling pipes and cabling laying
12	July 20th - August 10th	FHCal mounting
13	August 10th – September 30th	TPC installation and test
14	October 1st – October 15th	Beam pipe installation
15	October 20 - October 25th	Closing MPD (Installation of Poles)
16	October 30th	Moving MPD on the Collider beam line

MPD in the beam position by the end of October to comply with the NICA Run-2 schedule

Full-scale simulation of the MPD (NICA): collider mode

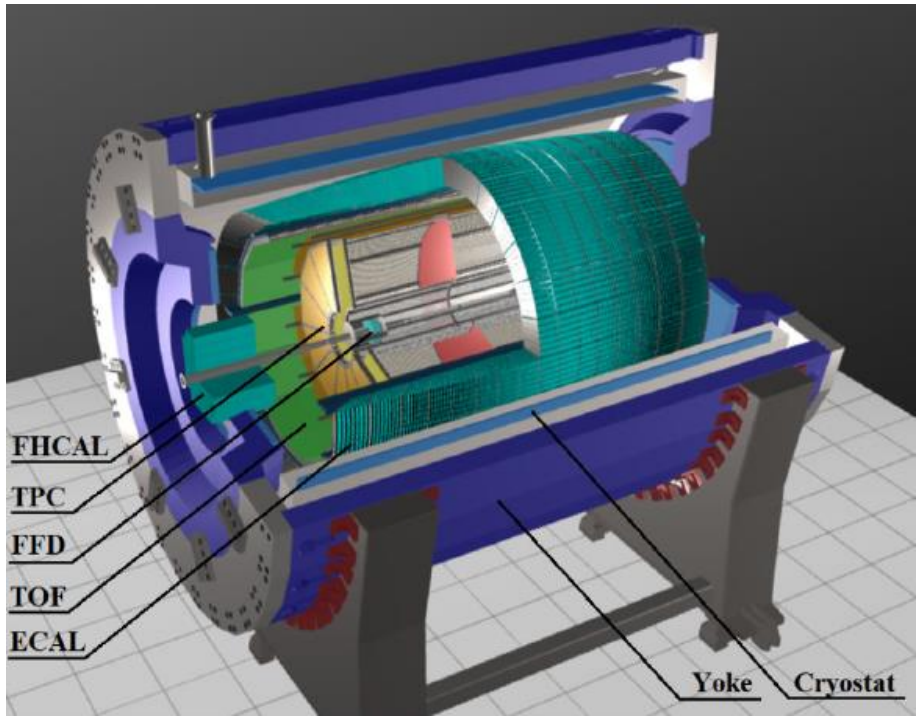
Nuclear Physics Revista Mexicana de Física **71** 041201 1–45 JULY-AUGUST 2025

MPD physics performance studies in Bi+Bi collisions at $\sqrt{s_{NN}} = 9.2$ GeV

R. Abdulin[20], V. Abgaryan[1], R. Adhikary[16], K.G. Afanaciev[16,13], S.V. Afanaciev[16], G. Agakishiev[16], E.I. Alexandrov[16], I.N. Alexandrov[16], M. Alvarado-Hernández[14], D.I. Andreev[16], S.V. Andreeva[16], T.V. Andreeva[16], E.V. Andronov[28], N.V. Anfimov[16], A. Anikeev[21], A.V. Anufriev[28], A.A. Aparin[16], R. Arteche-Diaz[16], V.I. Astakhov[16], T. Aushev[23], S.P. Avdeev[16], G.S. Averichev[16], A.V. Averyanov[16],A. Ayala[14], V.N. Azorskiy[16], L. Bavichev[32], V.A. Babkin[16], P. Bakhtin[19], A.I. Balandin[16], N.A. Balashov[16], A. Baranov[10], D.A. Baranov[16], N.V. Baranova[31], R.V. Baratov[16], N. Barbashina[21], V. Barbasová[23], V.M. Baryshnikov[16], K.D. Basharina[16], A.E. Baskakov[16], V.G. Bayev[13], A.G. Bazhazhin[16], S.N. Bazylev[16], P. Beletsky[25], S.V. Belokurova[28], A.V. Belyaev[16], E.V. Belyaeva[16], D.V. Belyakov[16], Y. Berdnikov[24], F. Berezov[22], M. Bhattacharjee[16], W. Bietenholz[14], D. Blau[19], G.A Bogdanova[31], D.N. Bogoslovsky[16], I.V. Boguslavski[16], E.A. Bondar[12], E.E. Boos[31], A. Botvina[10], A. Brandin[21], S.A. Bulychjov[19], V. Burdelnaya[25], N. Burmasov[20], M.G. Buryakov[16], J. Busa Jr.[16], A.V. Butenko[16], S.G. Buzin[16], A.V. Bychkov[16], Z. Cao[35], C. Ceballos-Sánchez[16], V.V. Chalyshev[16], V.F. Chepurnov[16], Vl.V. Chepurnov[16], G.A. Cheremukhina[16], A.S. Chernyshov[31],

https://doi.org/10.31349/RevMexFis.71.041201

(40+ pages, 445 auhors)



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**: $|\Delta\varphi| < 2\pi$, $2 < |\eta| < 5$

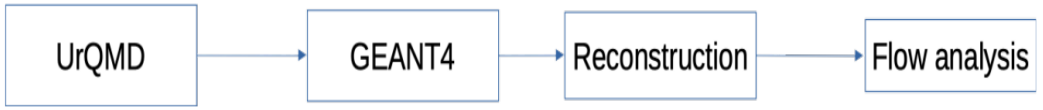


TABLE I. The list of centralized MC productions for physics feasibility studies.

No.	Generator	Events	Purpose
1	UrQMD	50 M	General purpose
2	DCM-QGSM-SMM	1 M	Trigger
3	PHQMD	20 M	(Hyper)nuclei
4	PHSD	15 M	Global polarization
5	vHLLE+UrQMD	15 M	Flow, correlations

Preparation of the 3d collaboration paper

Article

MPD physics performance studies in the fixed-target Xe+W collisions at $\sqrt{s_{NN}} = 2.87$ GeV

MPD Collaboration

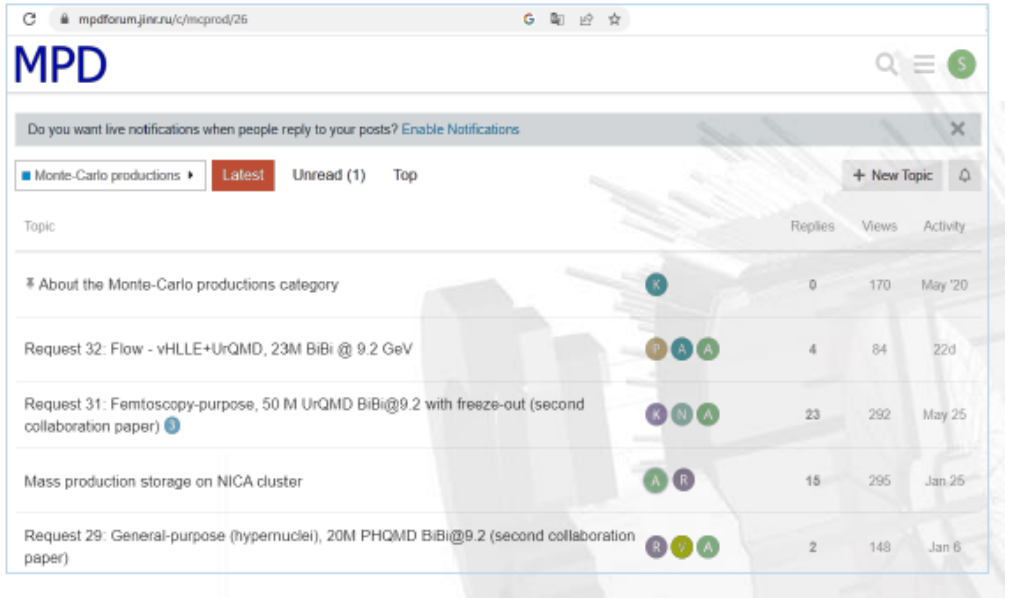
Abstract

This paper presents a comprehensive study of the physics performance of the Multi-Purpose Detector (MPD) at the NICA collider complex, specifically operating in the fixed-target regime. While MPD is primarily designed for collider experiments, the fixed-target mode significantly extends its research potential, allowing for the investigation of dense baryonic matter in ion collisions at lower center-of-mass energies. We evaluate the detector's efficiency in event triggering, its performance in particle reconstruction and identification, momentum resolution, and geometric acceptance. We present the MPD capabilities for reconstructing a wide range of physics observables, including reconstruction of charged light identified hadrons ($\pi^{\pm}$, $K^{\pm}$, p) and short-lived resonances ($\rho(770)^0$, $K^*(892)^{0,\pm}$, $\phi(1020)$, $\Sigma(1385)^{\pm}$), weakly decaying strange mesons (K^0_s) and hyperons (Λ, Ξ^-). Furthermore, we evaluate the efficiency in identifying light nuclei (d, ^3He) and reconstructing neutral mesons (π^0, η) via their decay into photons. Results for the measurement of the particle collective flow (v_1, v_2) and hyperon global polarization are also evaluated and discussed. The simulation framework utilizes the MpdRoot environment, which provides possibility to use different event generators, emulate realistic background conditions and calculate detector responses. The obtained results demonstrates that the MPD in the fixed-target configuration provides sufficient geometric acceptance and high-precision particle identification, making it a powerful tool for providing insights into the QCD phase diagram at high net-baryon density.

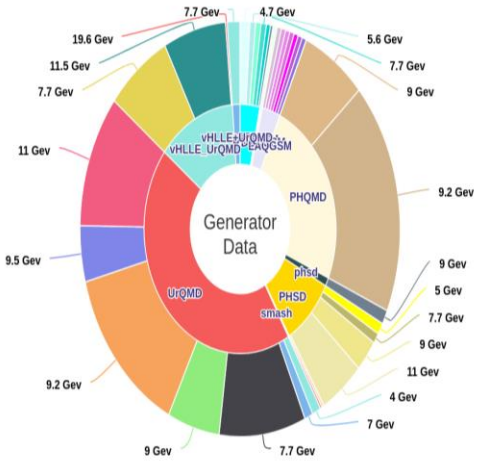
Content

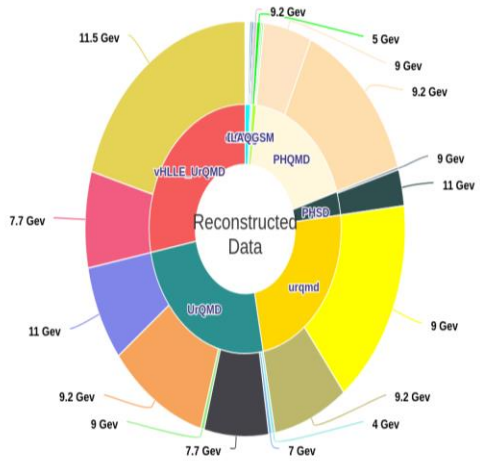
- ✓ Trigger system and efficiency
- ✓ Event centrality and event plane
- ✓ Light charged identified hadrons π/K/p
- ✓ Weakly decaying Ks, Λ, Ξ
- ✓ Collective flow (v_1, v_2)
- ✓ Resonances (ρ, K*, ϕ, Σ*)
- ✓ Photons and neutral mesons (π^0)
- ✓ Light nuclei

- ❖ Target journal – Particles (Q2) – ready to accept the paper for free
- ❖ First draft produced → currently in the collaboration review
- ❖ Submit/publish the paper by the end of the year, before start of data taking



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



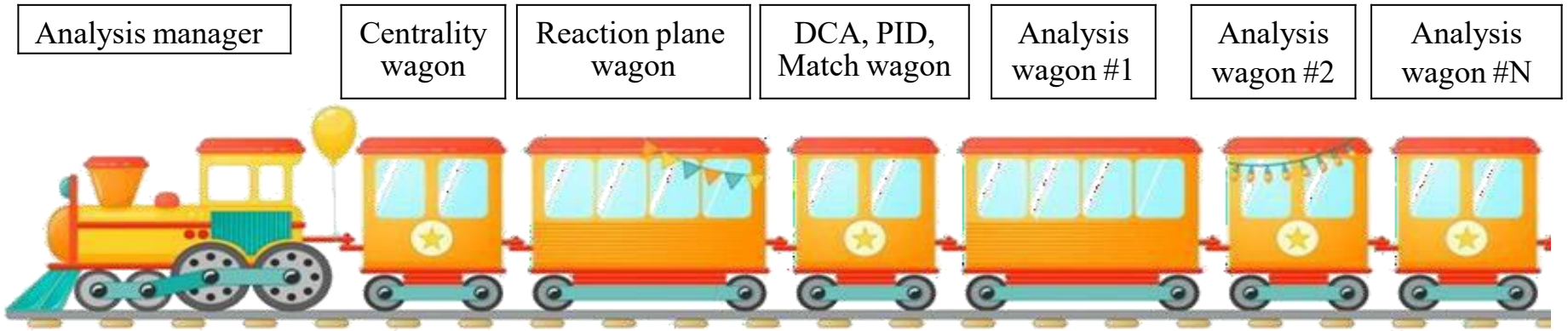


Generator	PWG	Coll.	$\sqrt{s}$	# of events(10^6)	Reco
UrQMD	PWG4	AuAu	11	15	+
		BiBi	9	10	+
			9.46	10	+
			9.2	135	+
	PWG2	AuAu	11	10	+
	PWG3	AuAu	7.7	10	+
		BiBi	7.7	10	+
			9	15	+
		pp	9	10	+
		BiBi fix target	2.5	12	+
		BiBi fix target	3.0	12	+
		BiBi fix target	3.5	12	+
		XeW fix target	2.5	15	+
		XeXe fix target	2.5	15	+
	PWG1	BiBi	9.2	76	+
DCM-SMM	PWG1	BiBi	9.2	2	+
PHQMD	PWG2	BiBi	8.8	15	+
			9.2	61	+
			2.4/3.0/4.5	10/10/2	-
vHLLE-UrQMD	PWG3	BiBi	11.5	15	+
		AuAu	11.5	15	+
		AuAu	7.7	20	+
		BiBi	9.2	48	+
Smash	PWG1	BiBi	9.46	10	+
		ArAr	4/7/9/11	20/20/20/20	-
		AuAu	4/7/9/11	20/20/20/22	-
		XeXe	4/7/9/11	20/20/20/20	-
		CC	4/7/9/11	20/20/20/20	-
		pp	4/7/9/11	50/50/50/50	-
JAM	PWG3	AuAu	3/3.3/3.5/3.8/4.0/4.2/4.5/5	40/40/40/40/40/40/40/40	
DCM-QGSM-SMM	PWG3	AuAu	4/9.2	5/5	+
		AgAg	4/9.2	5/5	+
		BiBi	4/9.2	5/6	+
PHSD		BiBi	9/9.2	25	+
Total				1453	609

Total amount of generated data is around 1.97 PB, 40 mass productions have been done.

Handling the big data sets

- Centralized Analysis Framework for access and analysis of data:
  - ✓ consistent approaches and results across collaboration, easier storage and sharing of codes and methods
  - ✓ reduced number of input/output operations for disks and databases, easier data storage on tapes
- Analysis manager reads event into memory and calls wagons one-by-one to modify and/or analyze data:

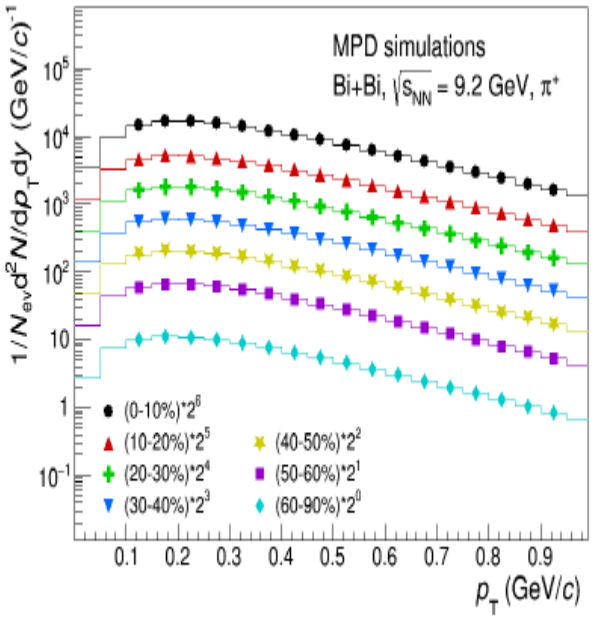


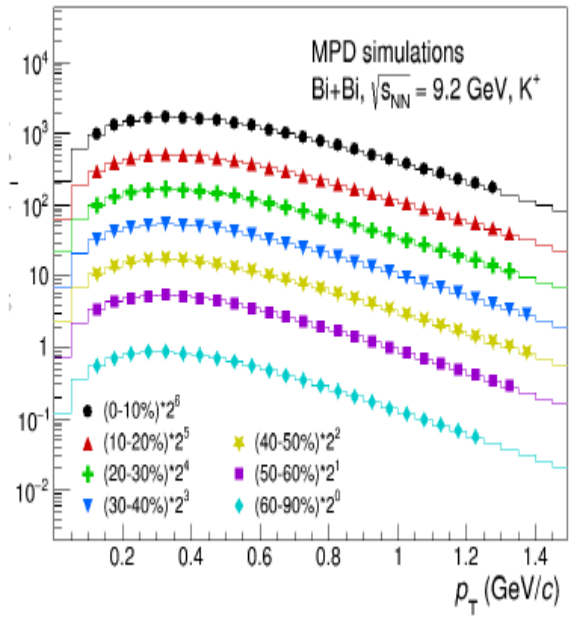
- 12 productions of physical analysis of simulated data already done.

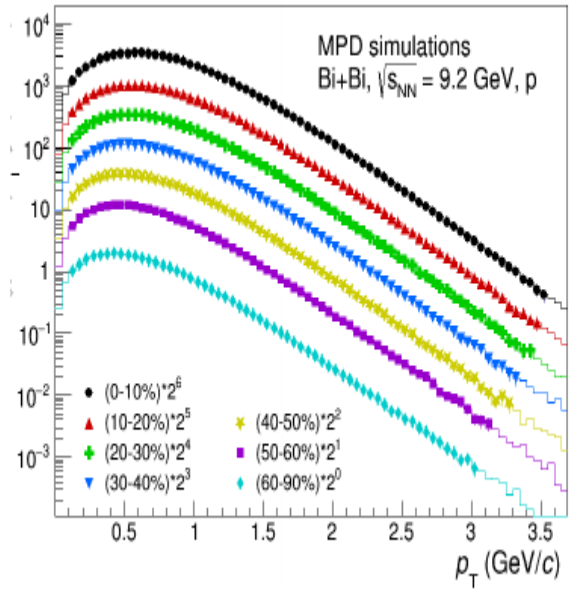
- Example:
- Wagon #1 – event selector – selects events to be analyzed
- Wagon #2 – centrality analyzer – returns values of centrality for all other wagons in the train
- Wagon #3 – recalibrator – redefines some DST variables that need recalibration after production
- ……
- Wagon #4, 5, … – physics analysis 1, 2, …

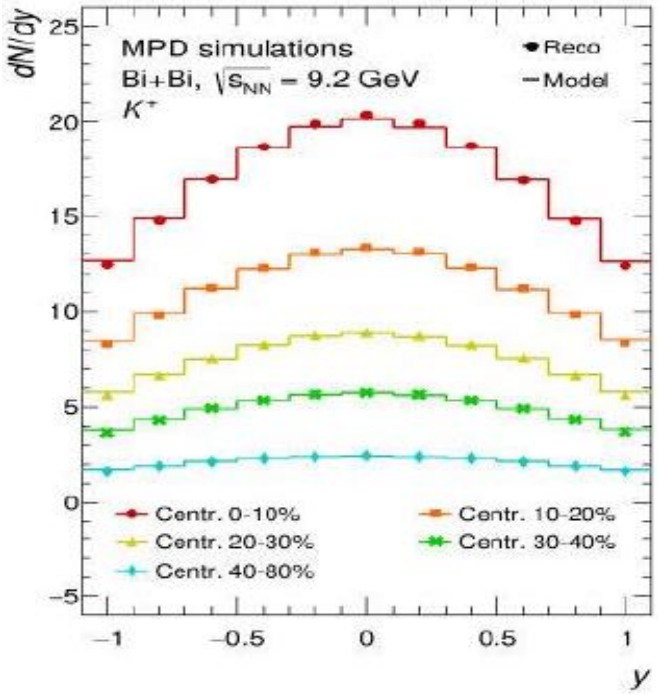
MPD feasibility study: light identified hadrons

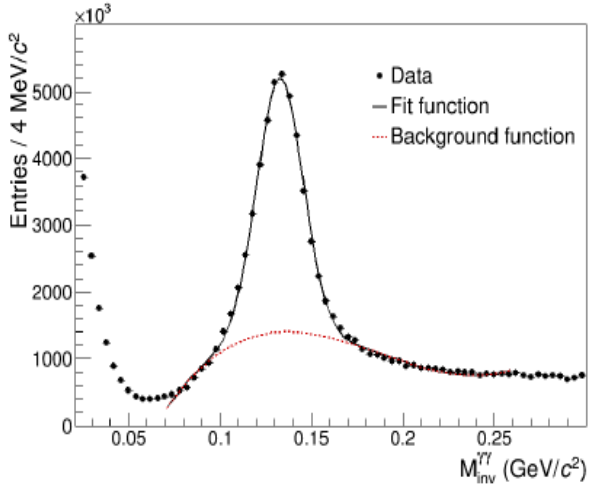
Rev. Mex. Fís., vol. 71, no. 4, pp.1–45,2025.

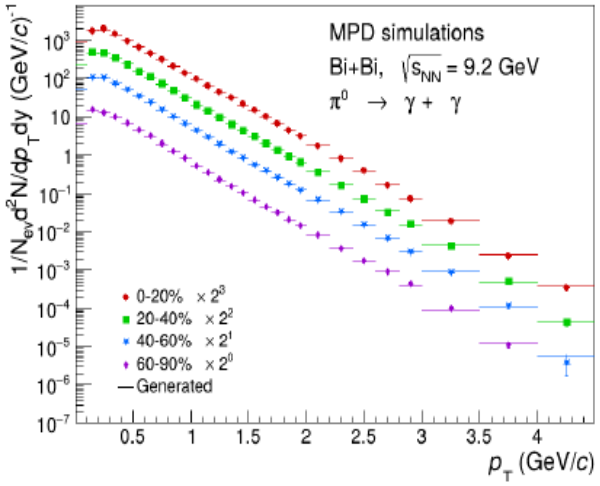








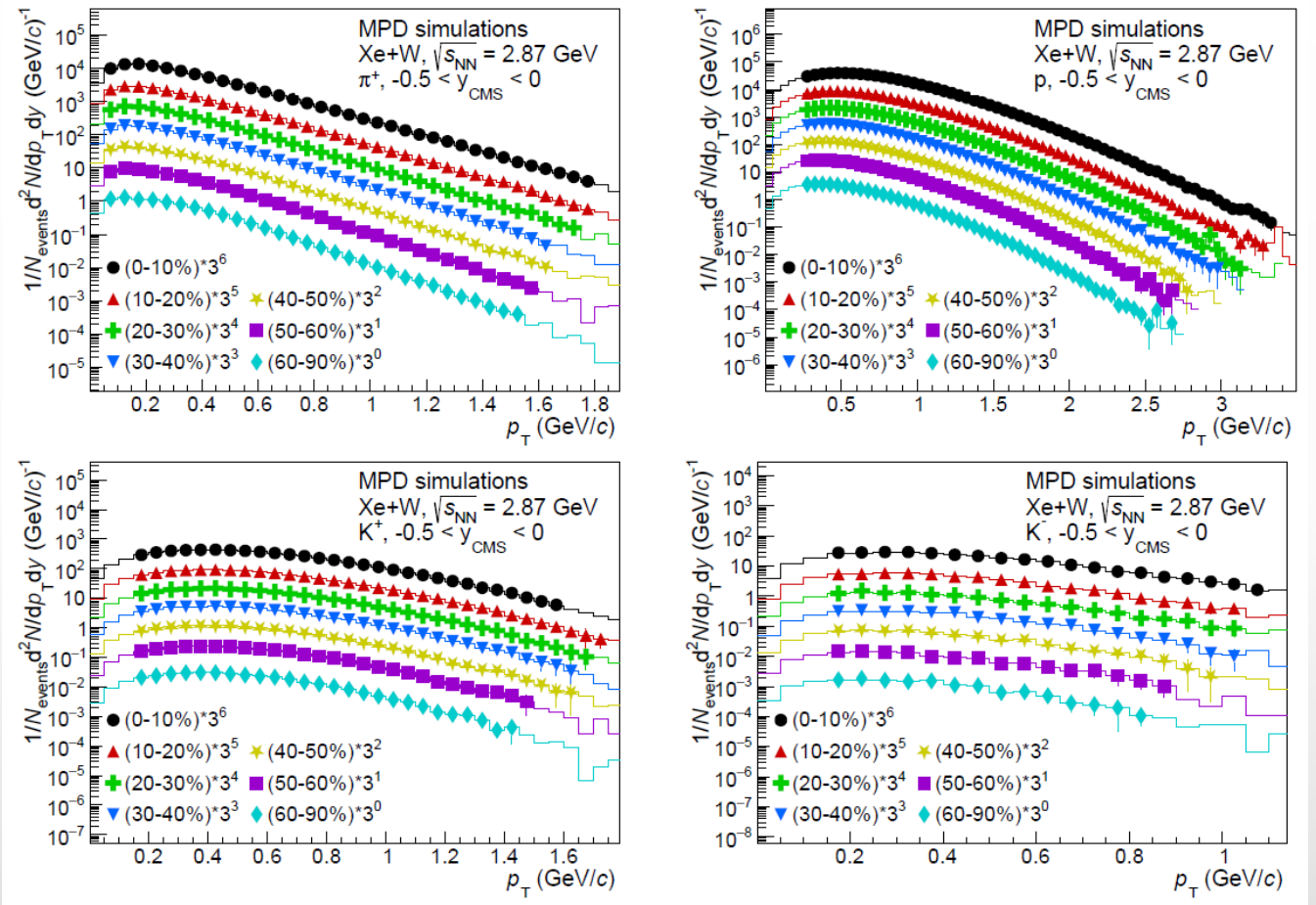




- Charged hadrons: excellent PID and good phase-space coverage (~ 70% of the π/K/p)
- Neutral mesons (π^0, η, K_s, ω, η'): ECAL reconstruction + photon conversion method (PCM) allow to extend p_T ranges of charged particle measurements and provide different systematics

MPD-FXT: π/K/p

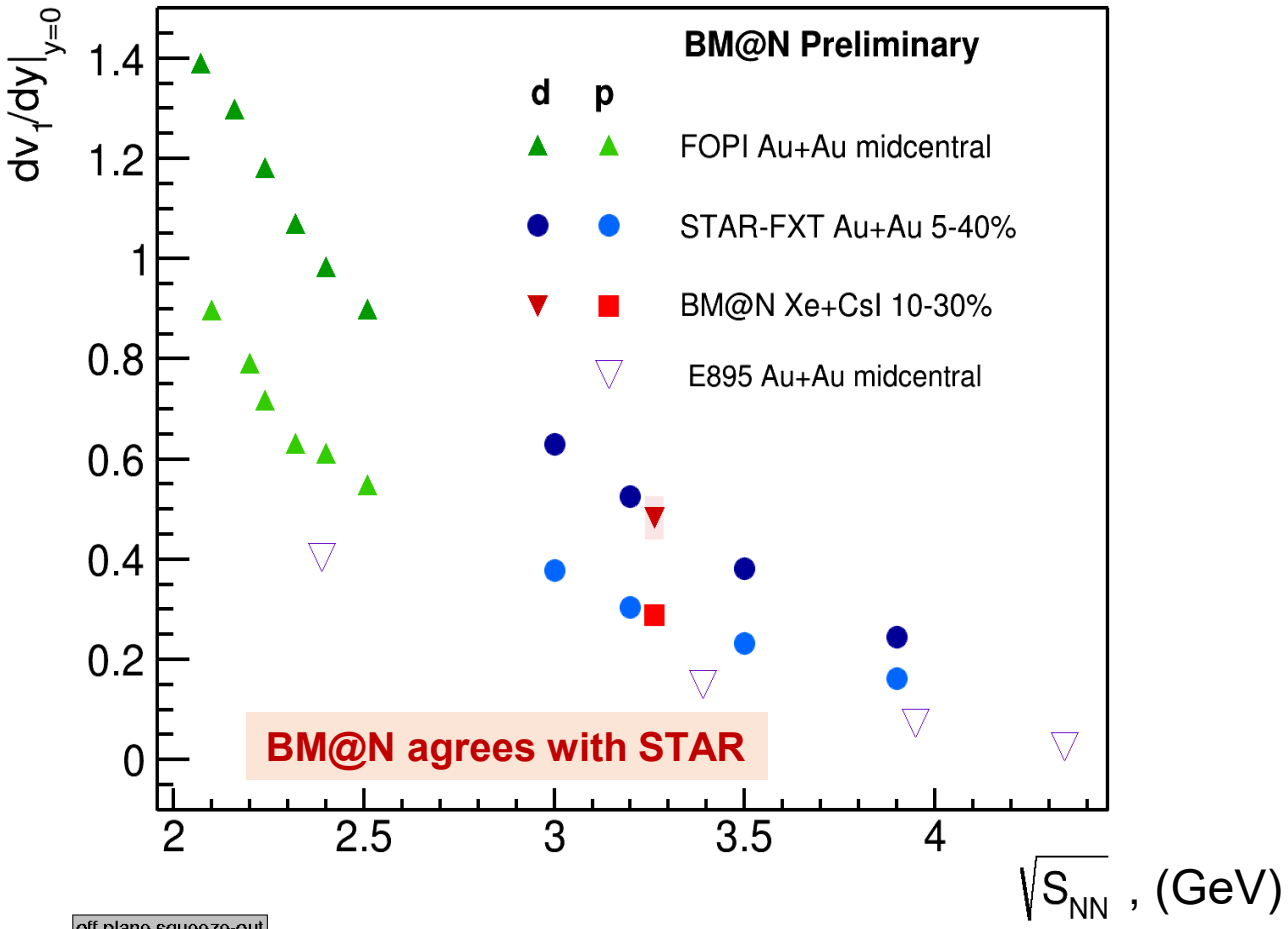
❖ MPD-FXT: XeW@ T=2.5 AGeV (UrQMD), 100M events → full event reconstruction

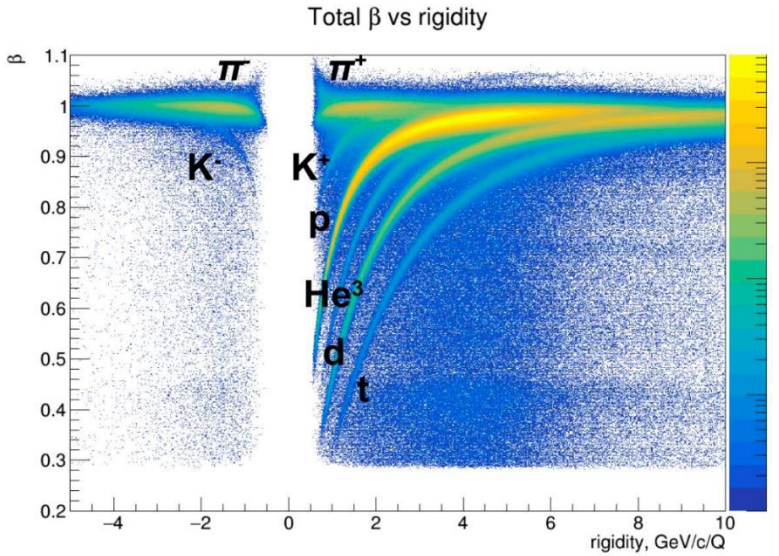


Rapidity coverage -1.3 < y_{CMS} < 0

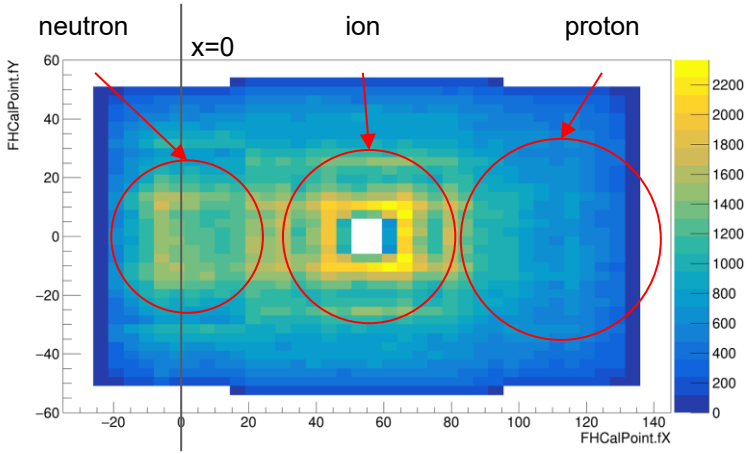
Spectra at mid-rapidity cover the p_T ranges that correspond to production of over 95% (85%) of the total $\pi^{\pm}$ (p) yields and 93% (85%) of K^+ (K^-) → robust basis for extracting the integrated yields

QnTools: Directed flow of protons and deuterons (BM@N run8 data)

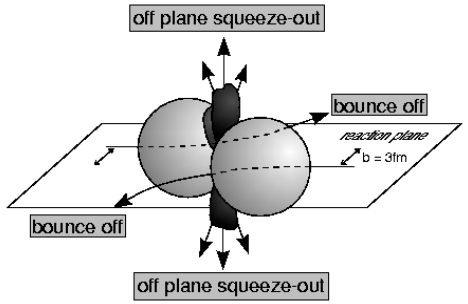




TOF



FHCaL



Talk by Peter Parfenov: "Framework for realistic flow measurements and centrality determination in MPD at NICA", 25/06/2026, 17:20.
https://indico.jinr.ru/event/5789/contributions/36387/

MLIT participation in MPD

Participants from MLIT:

Aleksandr Kokorev	Maria Lubimova
Anastasia Anikina	Maxim Zuev
Andrey Dolbilov	Natalia Gromova
Artem Petrosyan	Oksana Streltsova
Balashov Nikita	Olga Vlasova
Dmirty Belyakov	Sergei Shmatov
Dmitry Podgainy	Slavomir Hnatic
Evgeny Aleksandrov	Svetlana Lebedeva
Igor Aleksandrov	Tatyana Strizh
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.

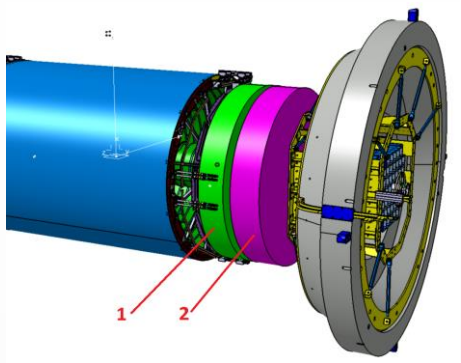


Summary

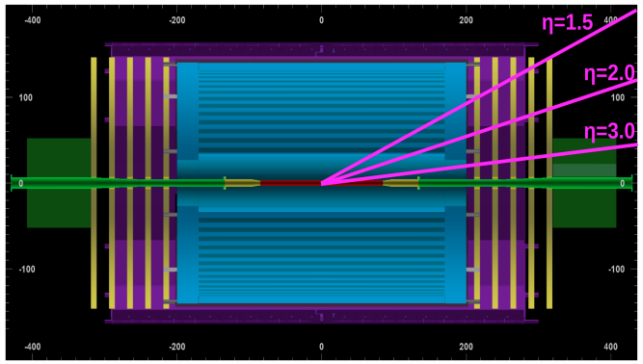


- MPD commissioning in the end of 2026 remains the main priority
- Extensive program of physics feasibility studies for MPD-CLD and MPD-FXT
- Prepare software and analysis infrastructure for real data analysis

Development of the Forward Spectrometers for MPD

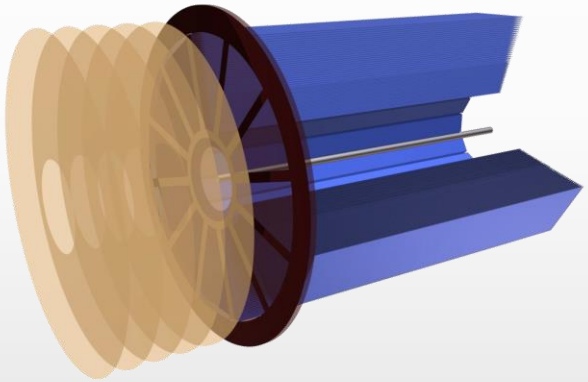


Two volumes available for the installation of forward tracker stations



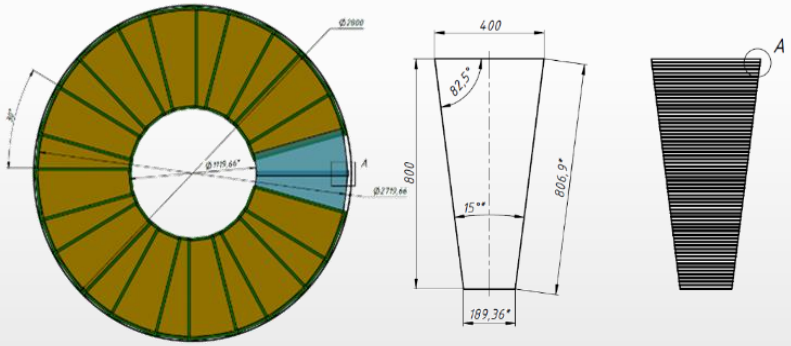
Pseudorapidity coverage of the forward spectrometer

Conception of the Forward Tracker (FTD)



- ✓ five tracking layers within z = 210–300 cm,
- ✓ 1% X_0, ~ 80 μm spatial resolution

Conception of the end-cup TOF detector



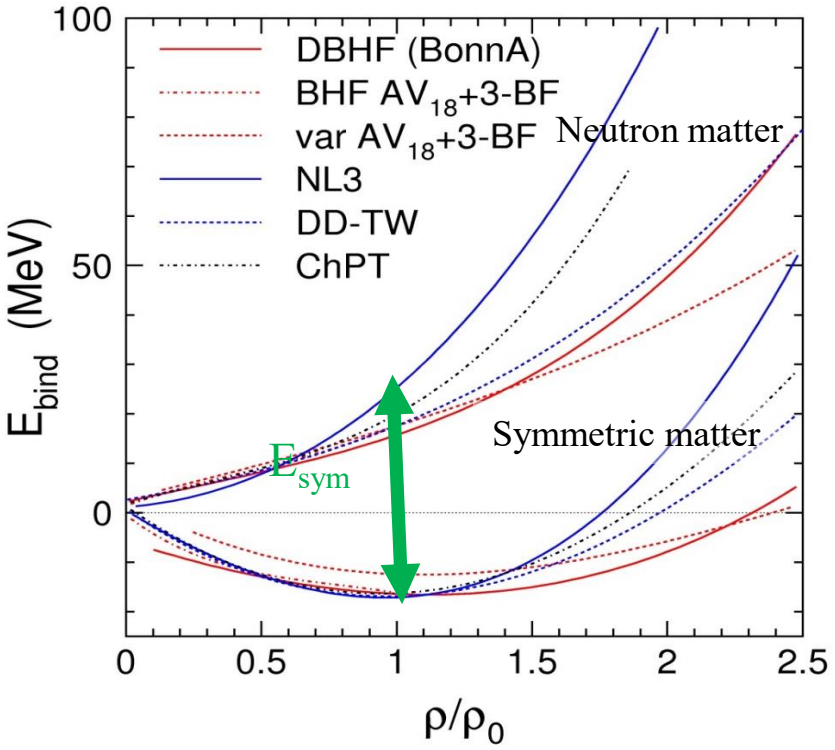
- ✓ a layer of MRPC-based TOF detectors, δτ ~ 50-70 ps

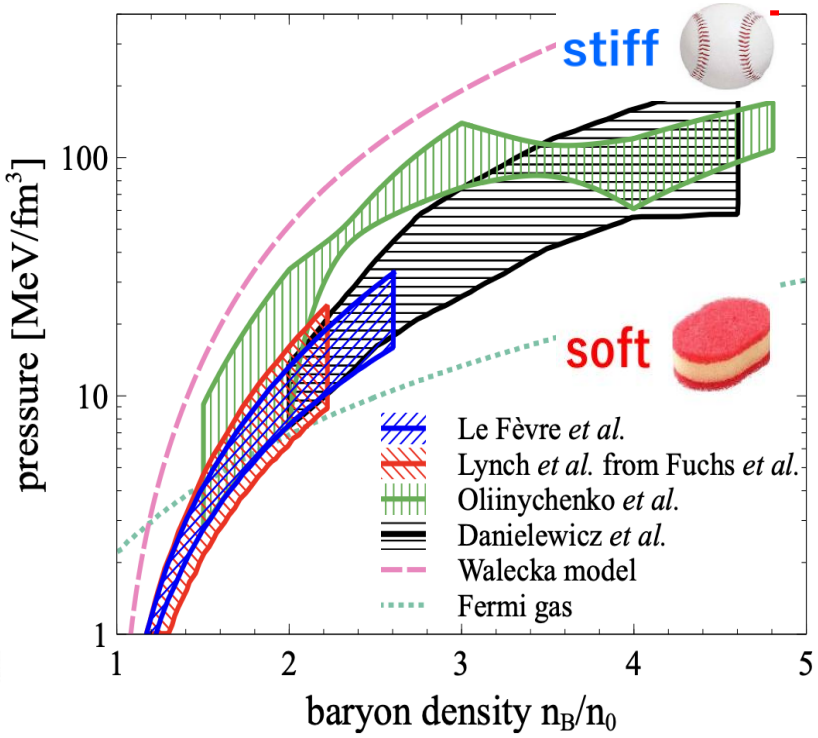
Equation of state (EoS) for high baryon density matter

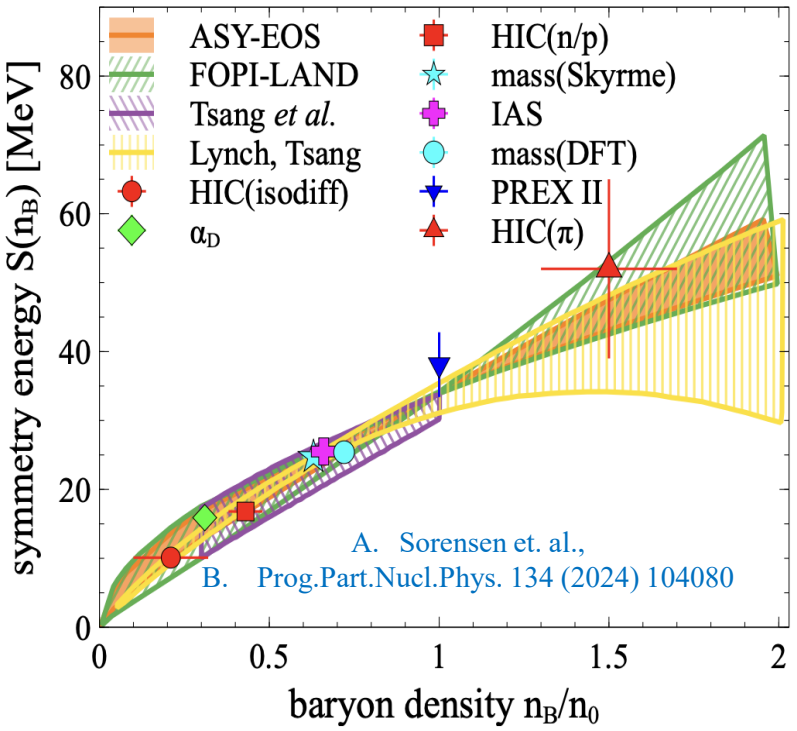
pressure $P = n^2 \frac{\mathrm{d}(E/A)}{\mathrm{d}n_b}$ *energy per nucleon* $\frac{E}{A} = m_N + E_A(n_\mathrm{B}) + E_\mathrm{sym}(n_\mathrm{B}) \frac{(n_p - n_n)^2}{n_\mathrm{B}^2}$ isospin asymmetry

$n_\mathrm{B} = n_p + n_n$

Symmetric matter **Symmetry energy**

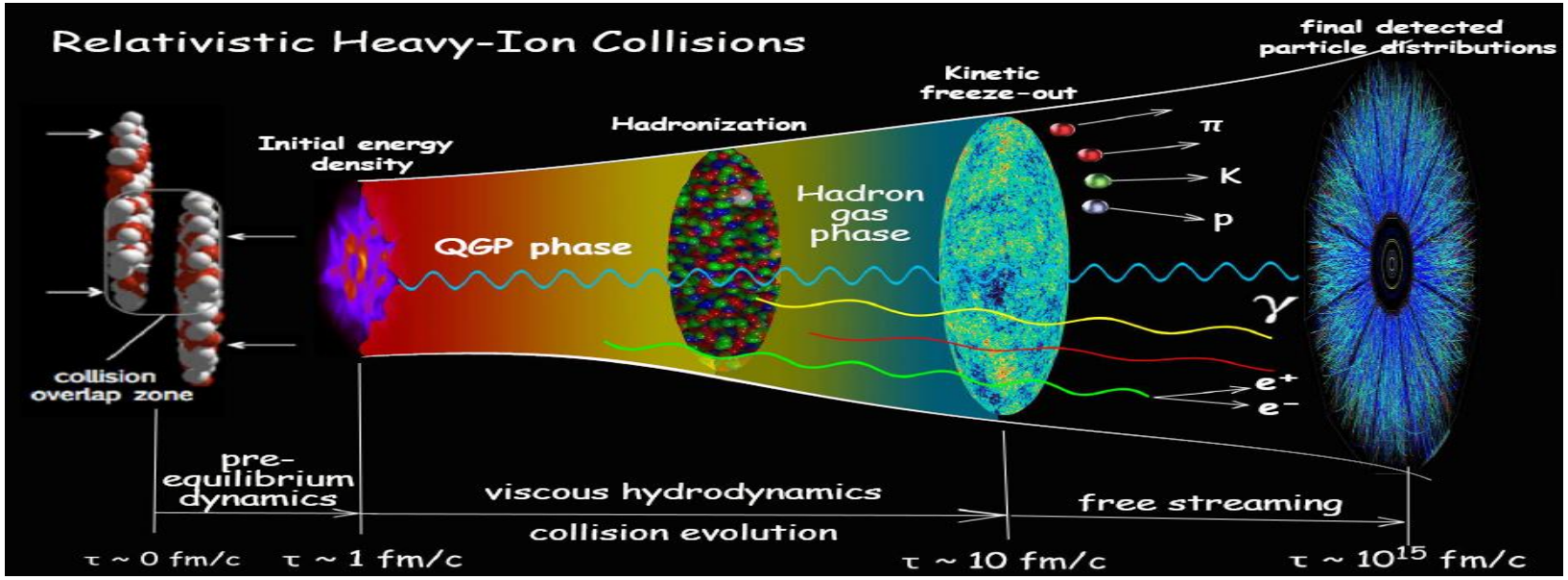


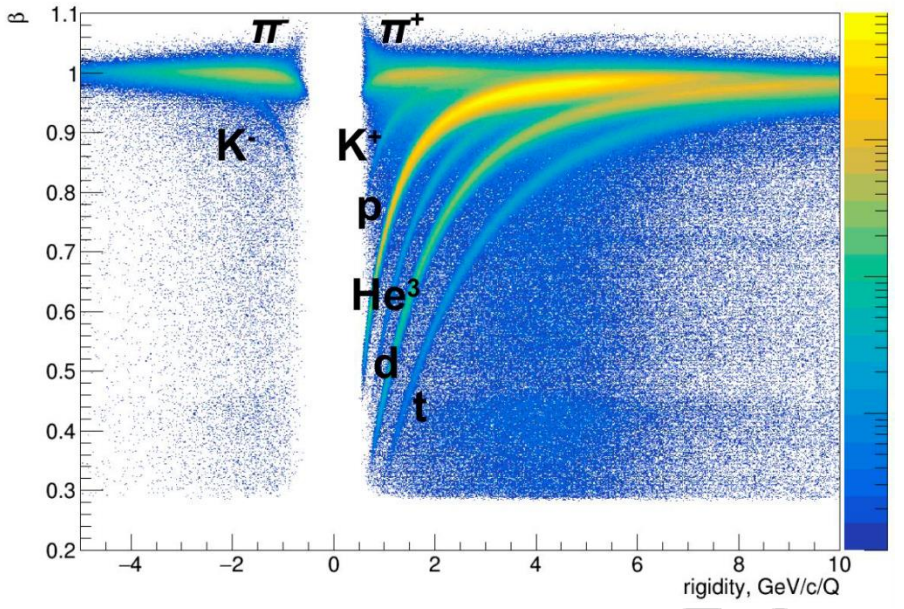




EOS describes the relation between density (n_B), pressure (P), temperature (T), energy (E), and isospin asymmetry (n_p-n_n)/n_B

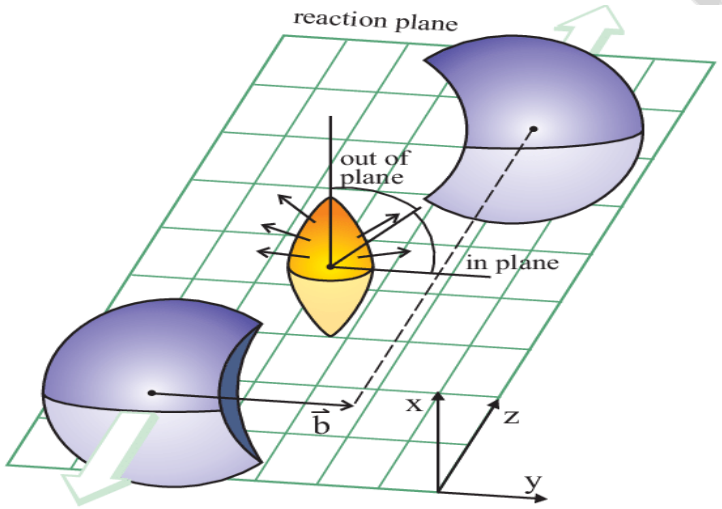






~200+200 nucleons in 10^{-22} seconds = 1000-30000 hadrons

Relativistic heavy-ion collisions provide a unique and controlled experimental way to study the properties of nuclear matter at high temperature and/or baryon density.

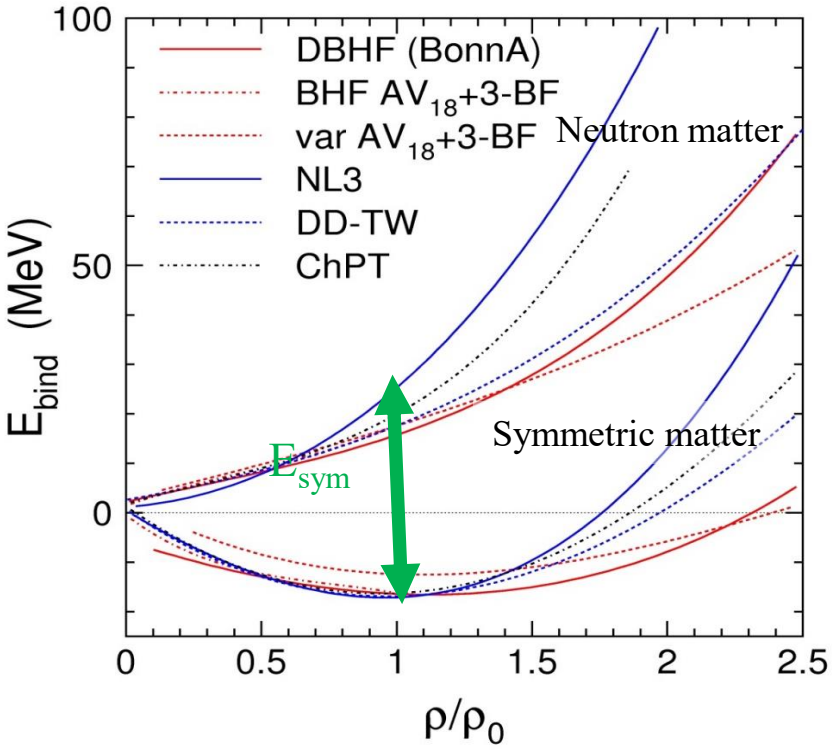


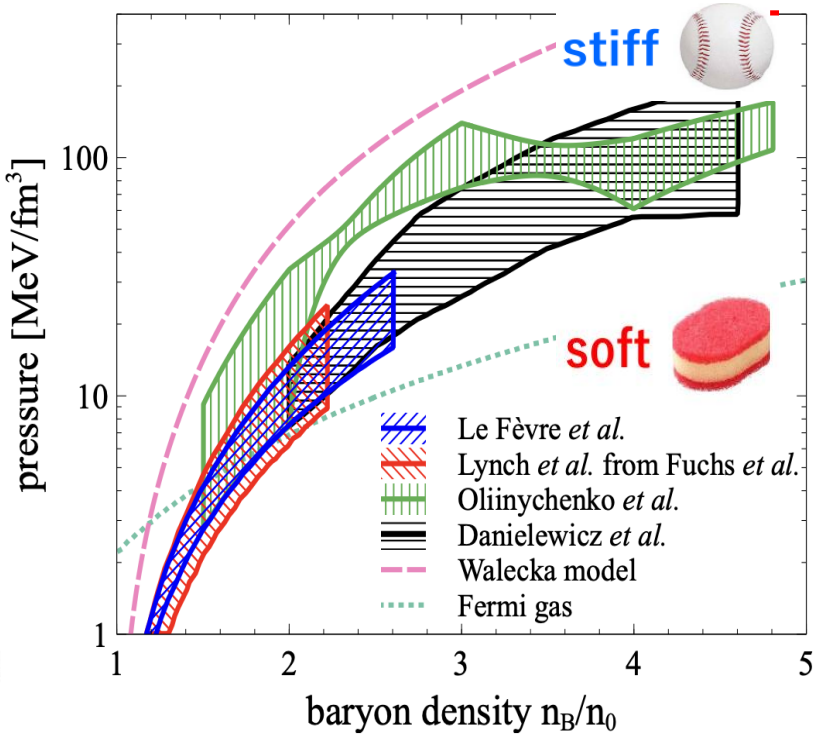
Equation of state (EoS) for high baryon density matter

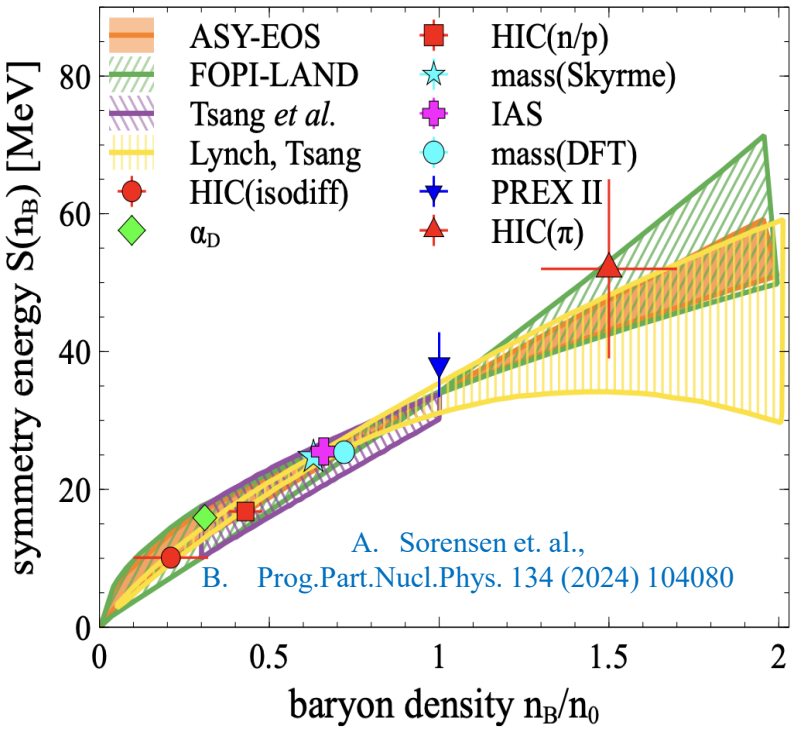
pressure ← $P = n^2 \frac{\mathrm{d}(E/A)}{\mathrm{d}n_b}$; *energy per nucleon* → $\frac{E}{A} = m_N + E_A(n_\mathrm{B}) + E_\mathrm{sym}(n_\mathrm{B}) \frac{(n_p - n_n)^2}{n_\mathrm{B}^2}$ ← isospin asymmetry

$n_\mathrm{B} = n_p + n_n$

Symmetric matter **Symmetry energy**

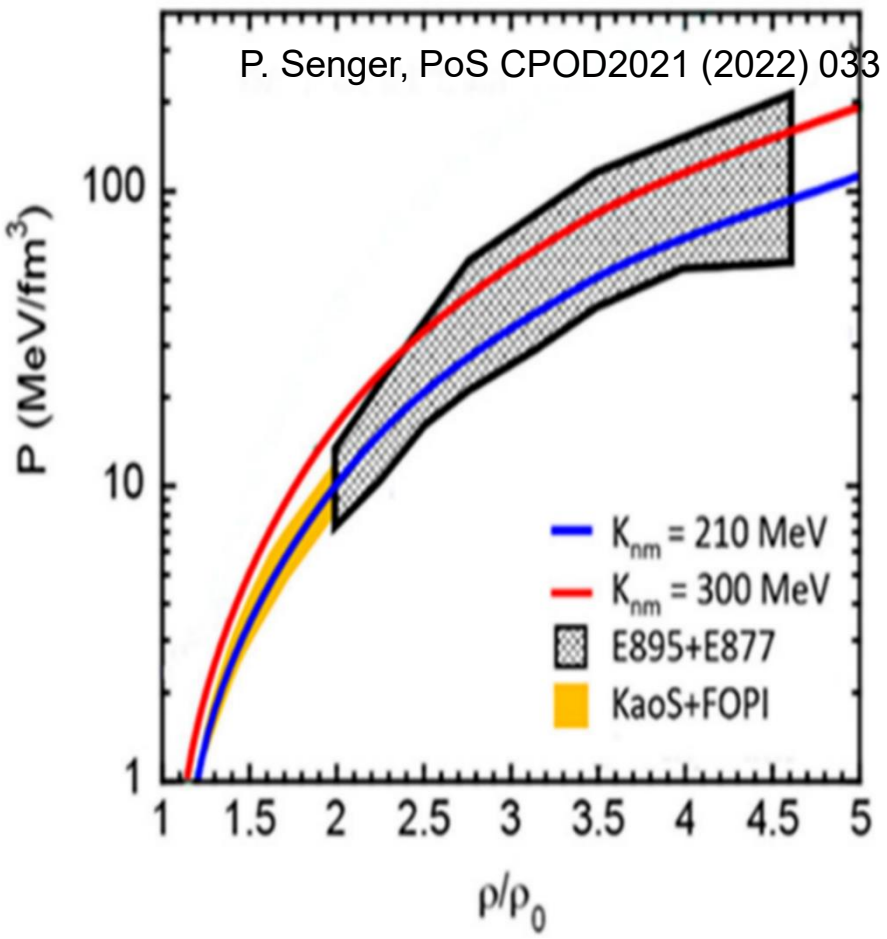


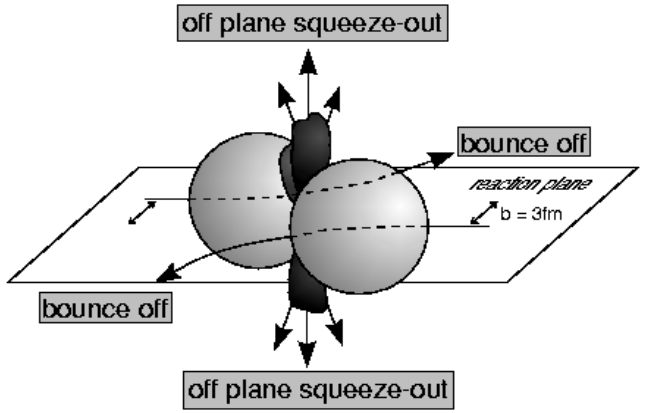


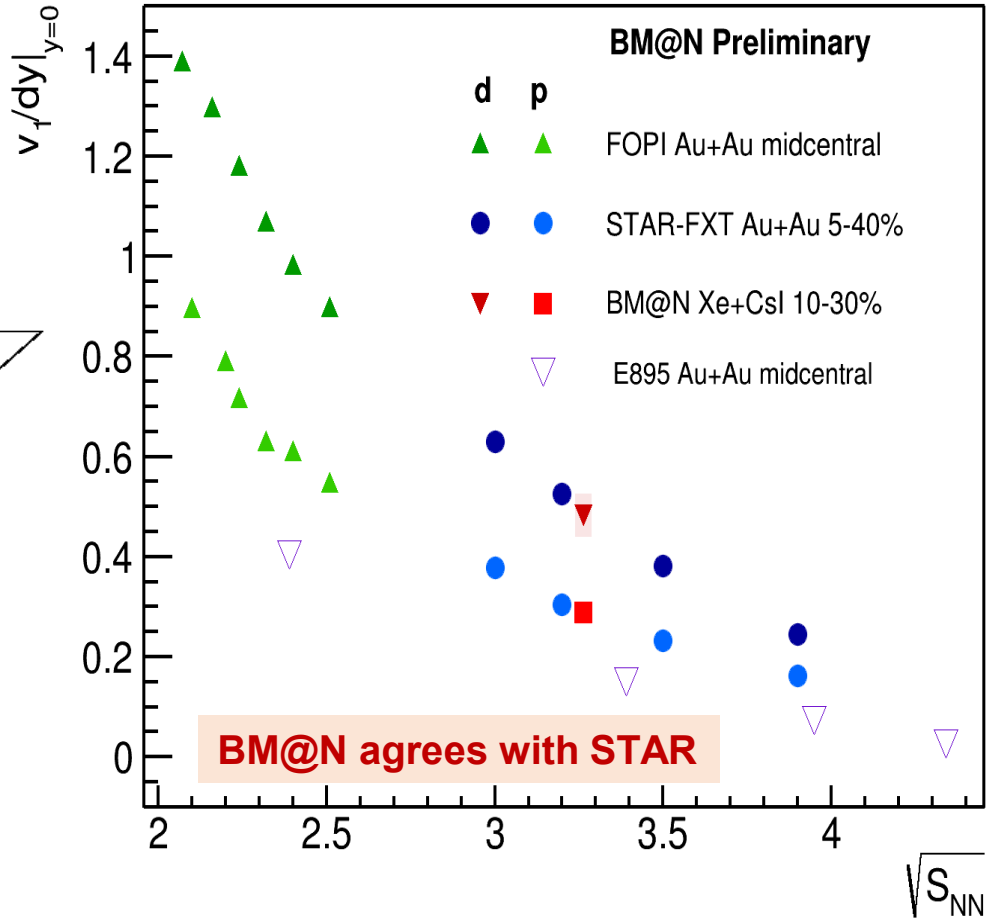


EOS describes the relation between density (n_B), pressure (P), temperature (T), energy (E), and isospin asymmetry (n_p-n_n)/n_B

Directed flow of protons and EOS of symmetric matter





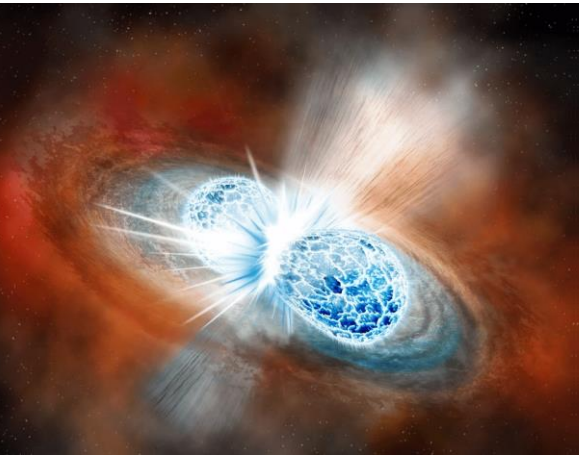


Nuclear incompressibility from collective proton flow

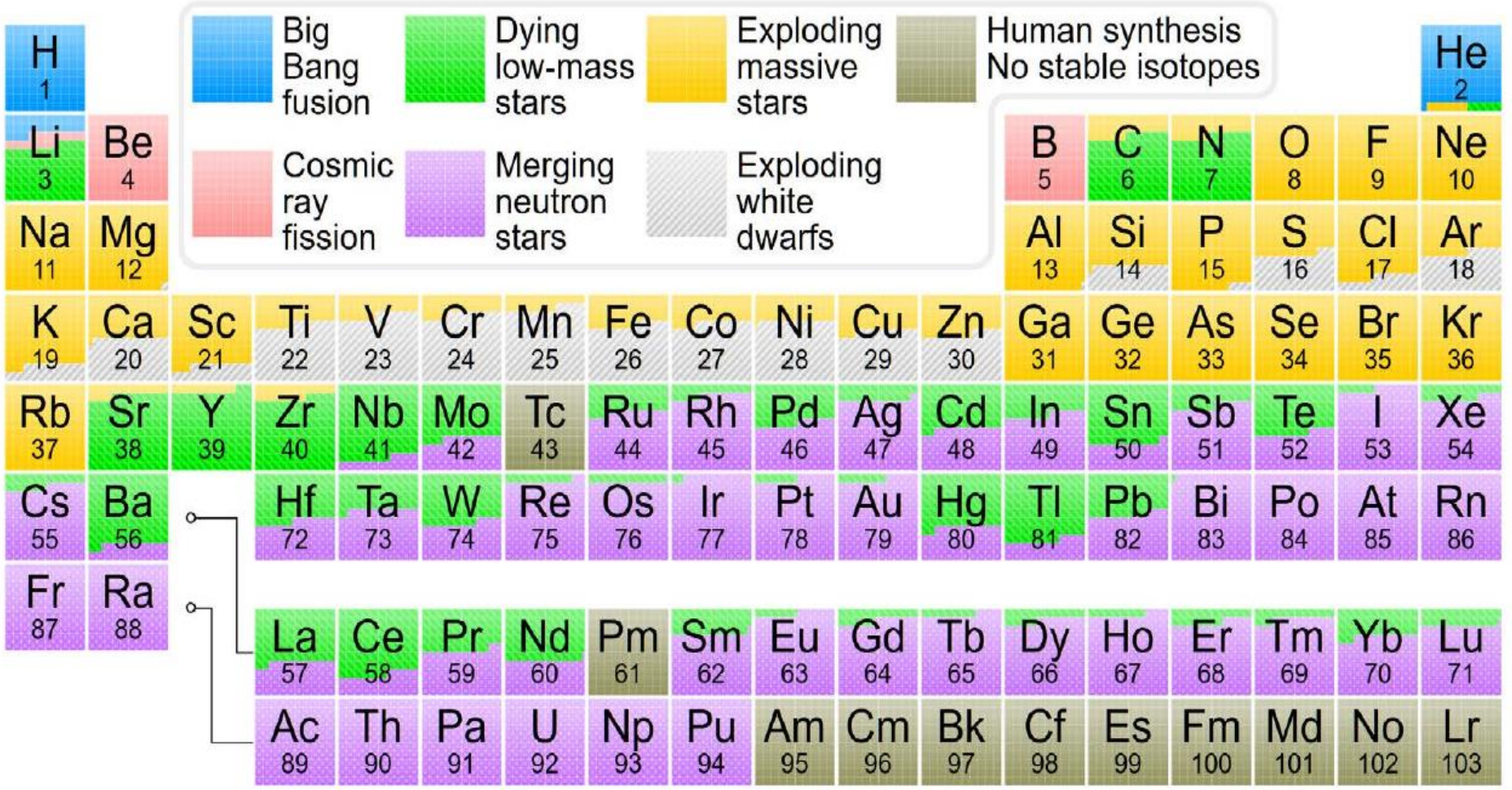
P. Danielewicz, R. Lacey, W.G. Lynch, Science 298 (2002) 1592

Both STAR and BM@N results for directed flow prefer stiff EOS

Nuclear EoS is important also for the r-process nuclear synthesis in neutron star merger



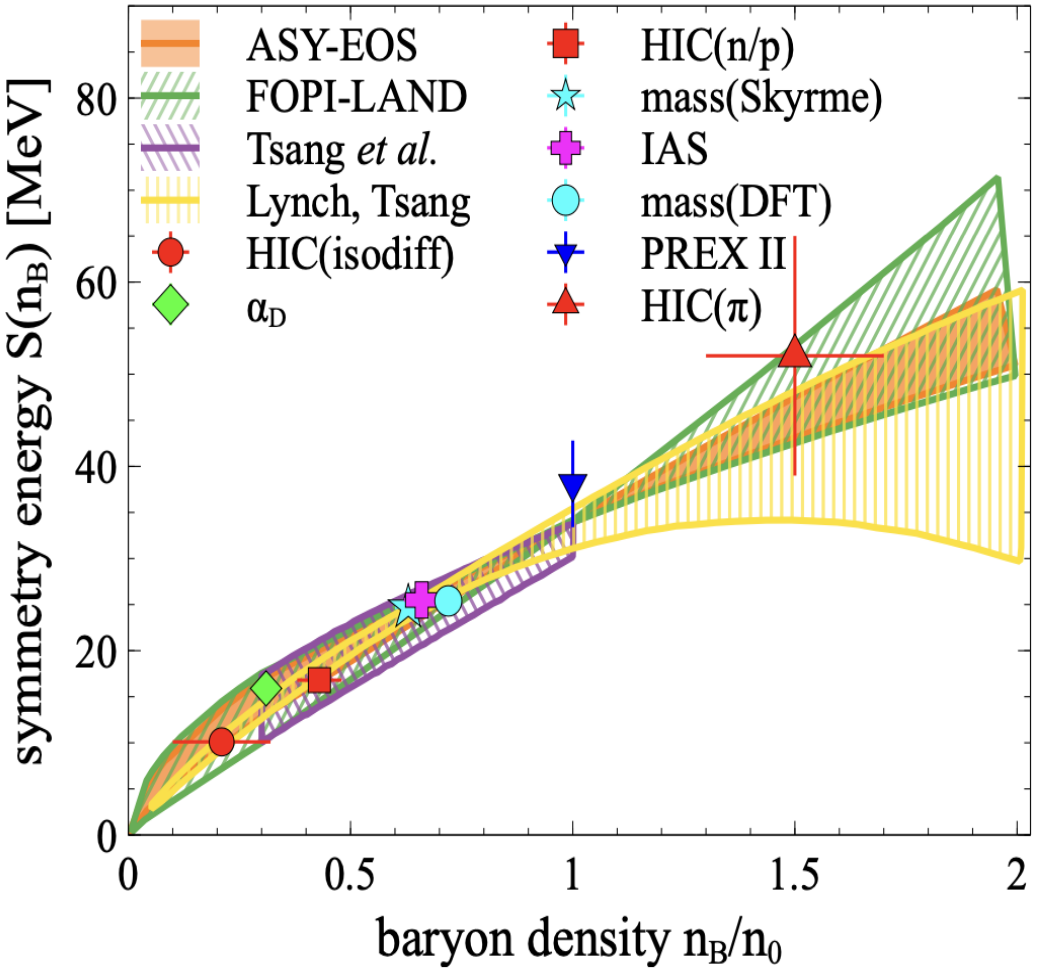




r-process - source of heavy elements including gold, platinum, and uranium.

Observables to study symmetry energy (EoS)

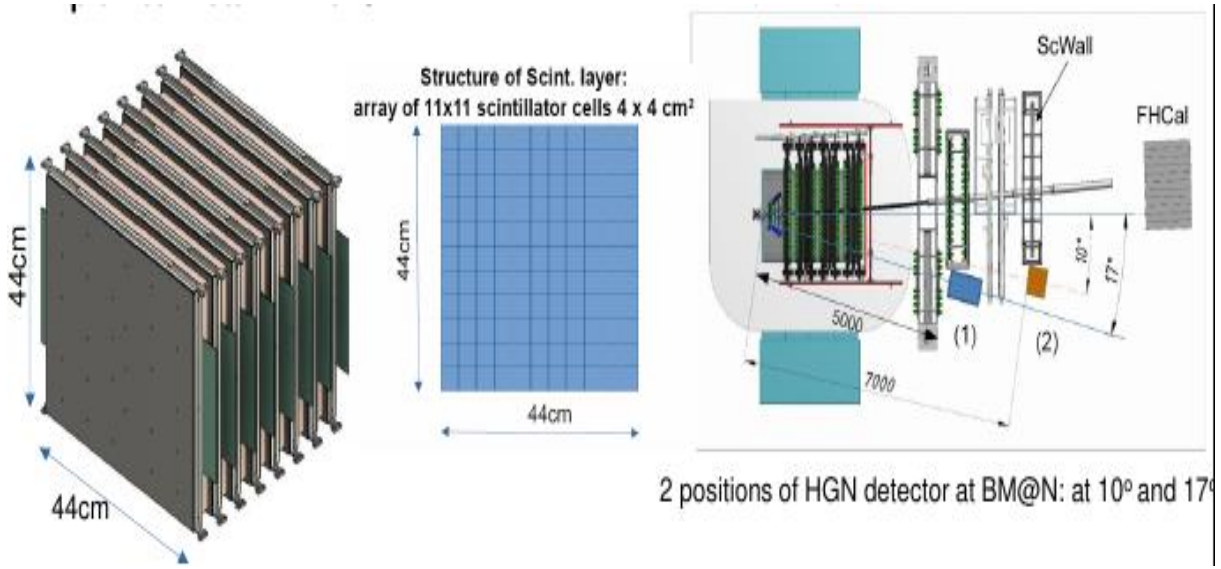
A. Sorensen et. al., Prog.Part.Nucl.Phys. 134 (2024) 104080



Nuclotron-NICA density region: $2 < n_B/n_0 < 8$

Symmetry energy E_{sym} has strong density dependence

BM@N Neutron Detector (2026-)

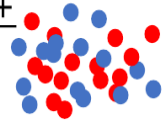


The Highly-Granular time-of-flight Neutron Detector for the BM@N experiment, Nucl. Instrum. Meth. A 1072 (2025) 170152

Stiff symmetry energy (large L)

→ lower ρ_n/ρ_p in higher dense region

→ lower n/p, lower π^-/π^+



Soft symmetry energy (small L)

→ larger ρ_n/ρ_p in higher dense region

→ larger n/p, higher π^-/π^+

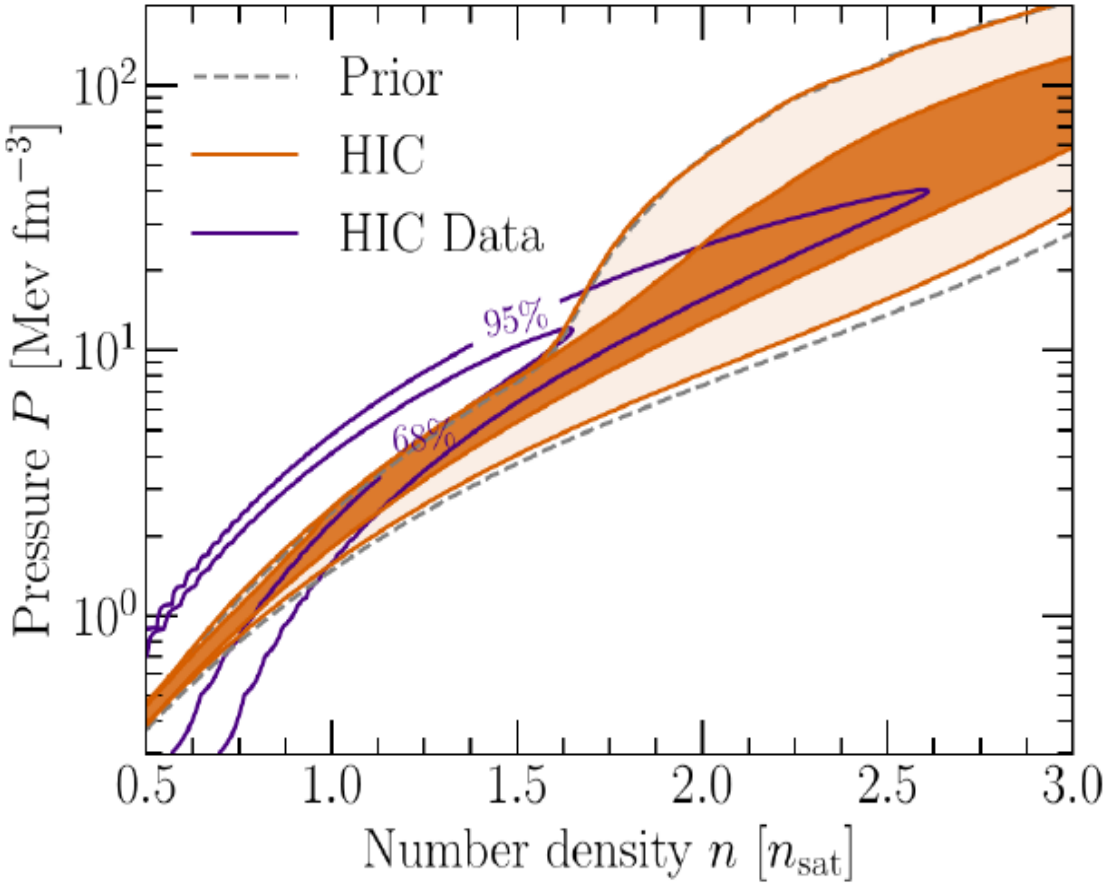


Constraining neutron-star matter with microscopic and macroscopic collisions

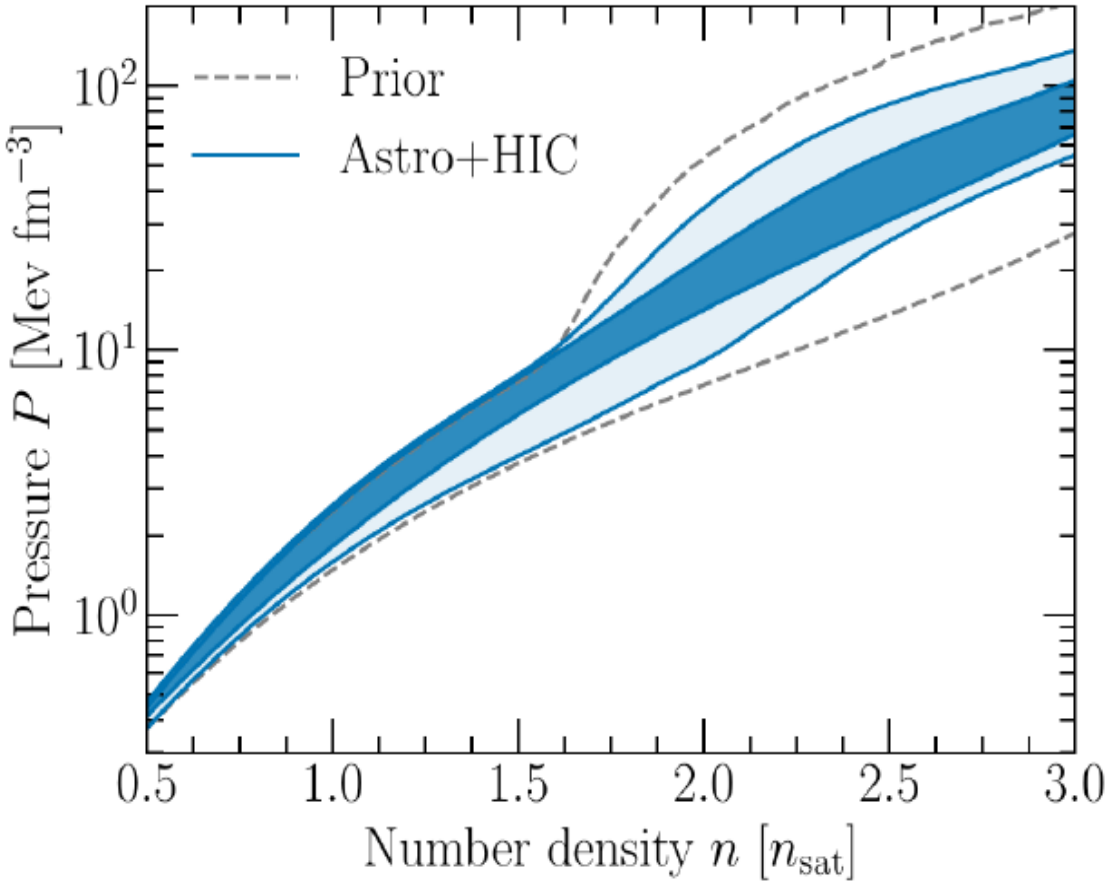
Huth, Pang et al. Nature 606(22)276

HIC experiments:

Bayesian combinations



HIC and Astro combined:



Astrophysical observations narrow constraints above 2 n_{sat}

Conclusion and outlook:

Relativistic Heavy-ion collisions at Nuclotron-NICA provide a unique and controlled experimental way to study the properties of nuclear matter at high baryon density.

Physics at High Baryon Density

- Critical point and phase boundary;
- Nuclear matter EOS at high baryon density;
- Y-N interactions, inner structure of compact stars.



Twelve young scientists and Ph.D. students from JINR member states are doing physics analyses at BM@N preparing their theses.

Backup slides

Relativistic Heavy-Ion Collisions and Quark Gluon Plasma (QGP)

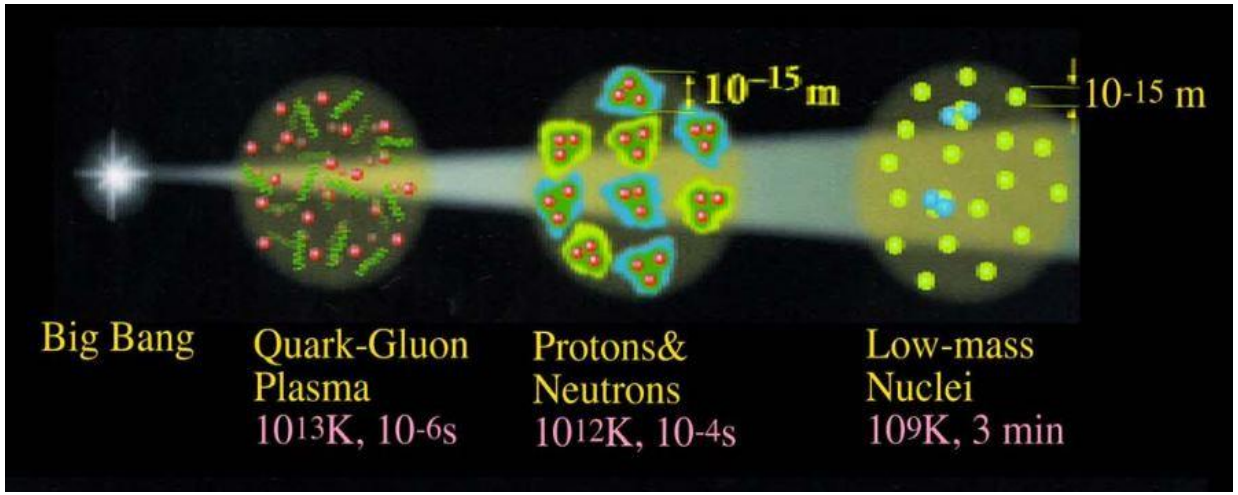


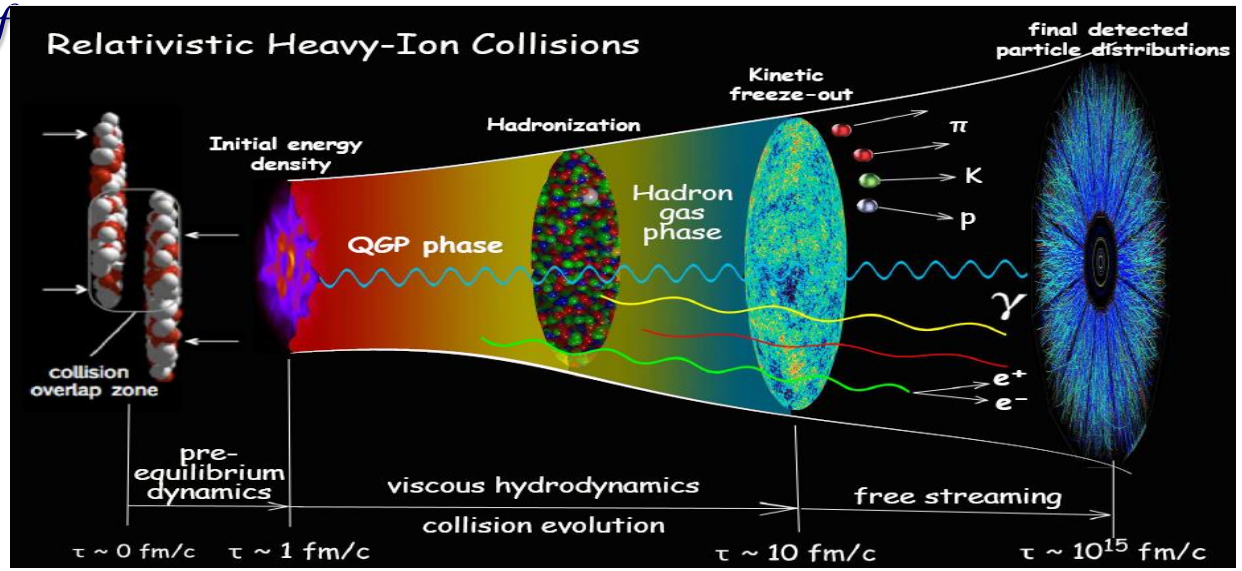
1

2. *It was present during the first few microseconds of the Big Bang.*

3. *It provides an example of phase transitions which may occur at a variety of higher temperature scales in the early universe.*

4. *It can provide important insights on the origin of mass for matter, and how quarks are confined into hadrons.*

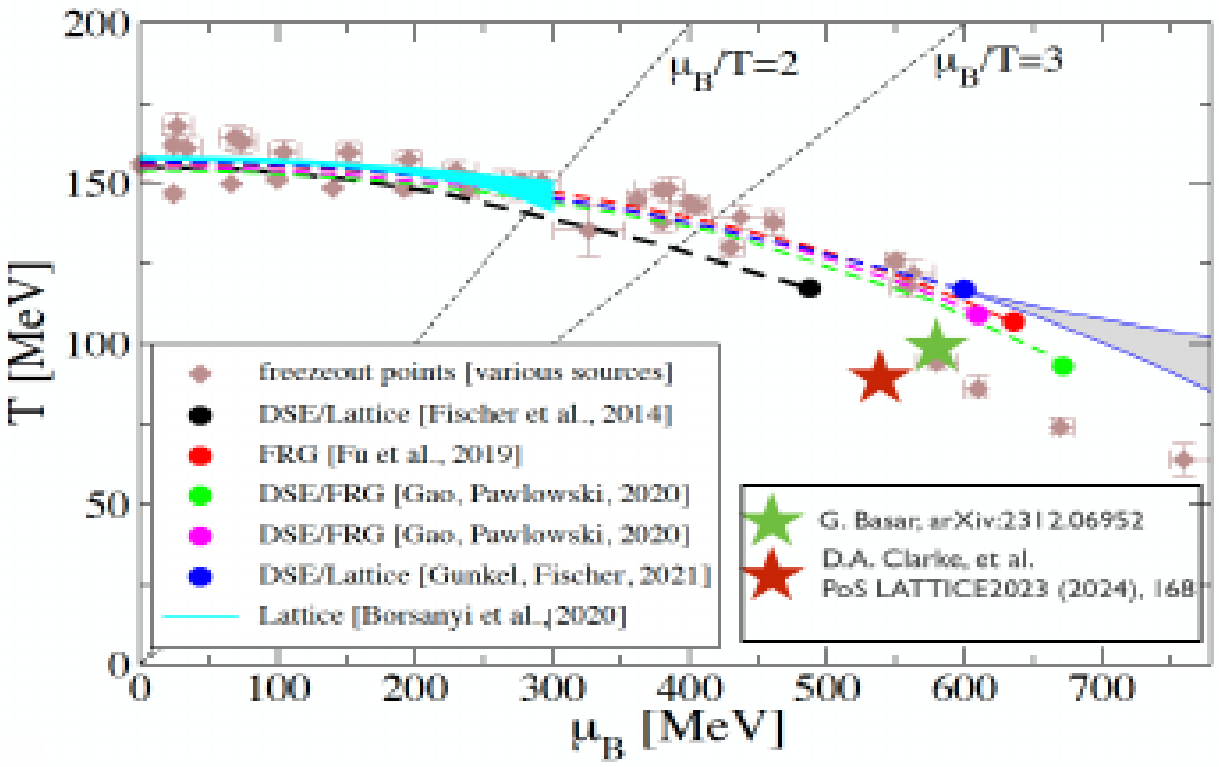




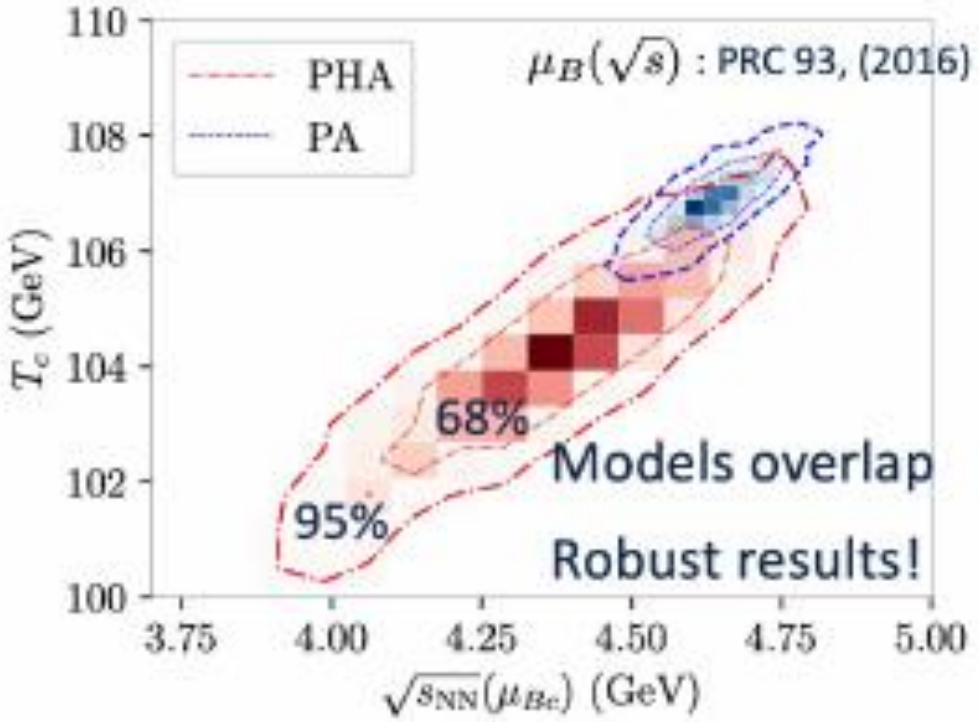
M. Gyulassy, Nucl. Phys. A750, 30-63, 2005

Temperature ~150-170 MeV ($2*10^{13}$ K)
and density ~1 GeV/fm^3 (10^{15} g/cm^3)

Location of the QCD Critical Point: Theoretical Estimation/Prediction



M. Hippert et al., Phys. Rev. D 110, 094006 (2024)



Method	μ_c (MeV)	T_c (MeV)
Holography + Bayesian	560 - 625	101 - 108
FRG/DSE	495 - 654	108 - 119
Lee-Yang edge singularities	500 - 600	100 - 105
Lattice QCD	$\mu_c/T_c > 3$	F. Karsch et al.
Summary	**495 - 654**	**100 - 119**

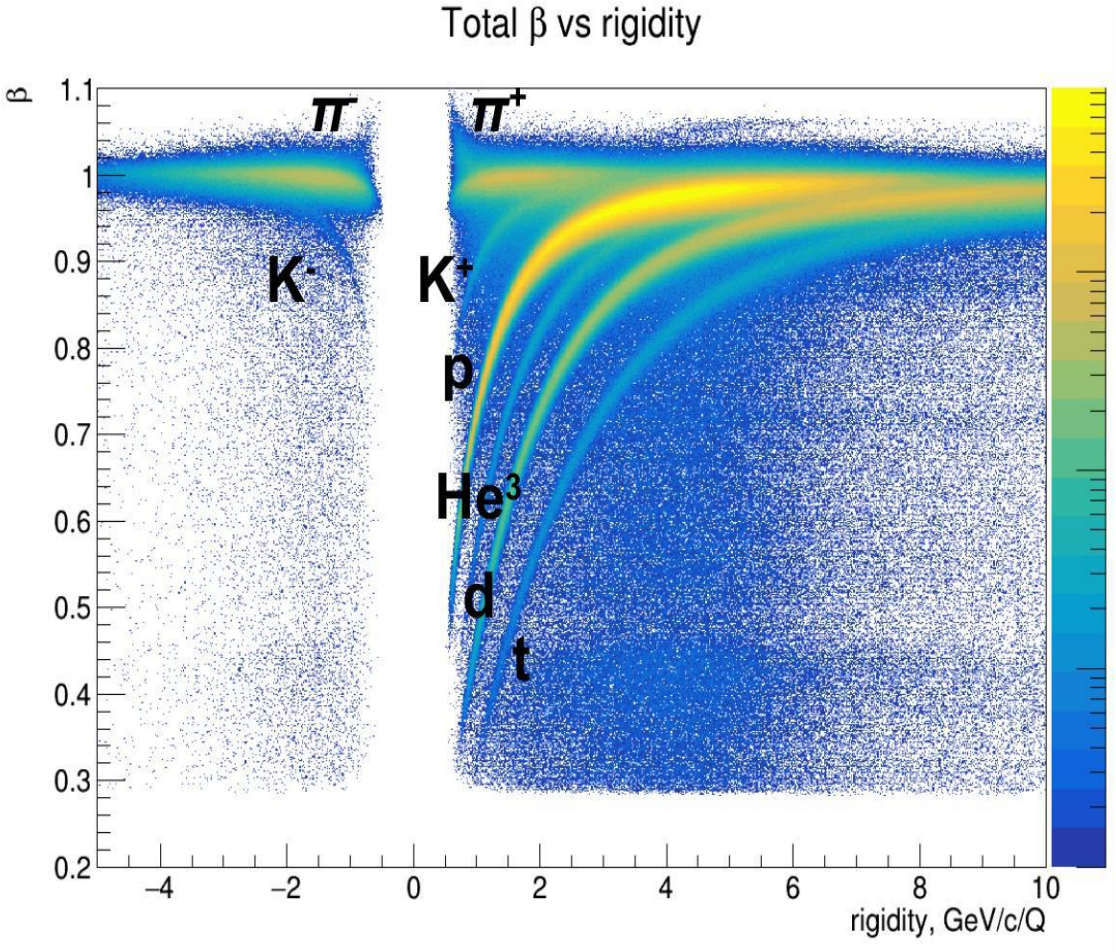
$(\mu_c, T_c) = (495 - 654, 100 - 119)$ MeV ➡ $3.5 < \sqrt{s_{NN}} < 4.9$ GeV

BM@N: $\sqrt{s_{NN}}$= 2.3 - 3.3 GeV

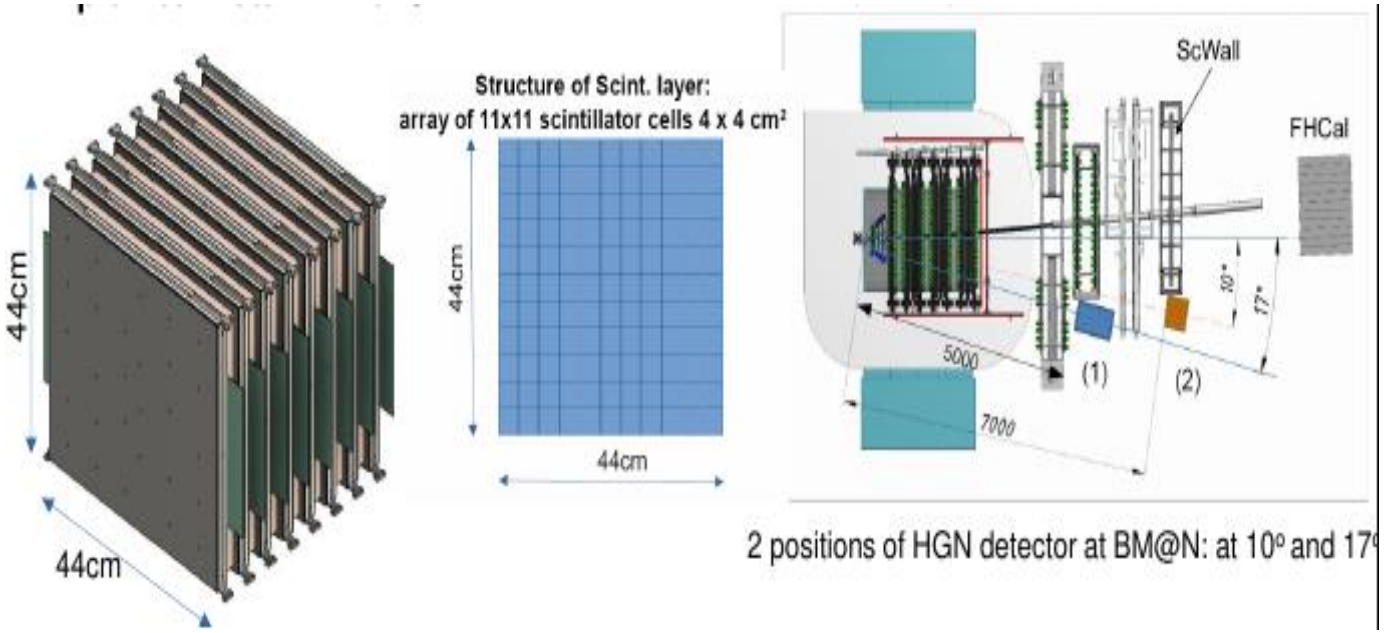
MPD: $\sqrt{s_{NN}}$= 4 - 11 GeV

BM@N and MPD are both in the collision energy range of the predicted CEP location.

BM@N: Observables to study symmetry energy



BM@N Neutron Detector



The Highly-Granular time-of-flight Neutron Detector for the BM@N experiment, Nucl. Instrum. Meth. A 1072 (2025) 170152

Nuclear Matter Equation of State

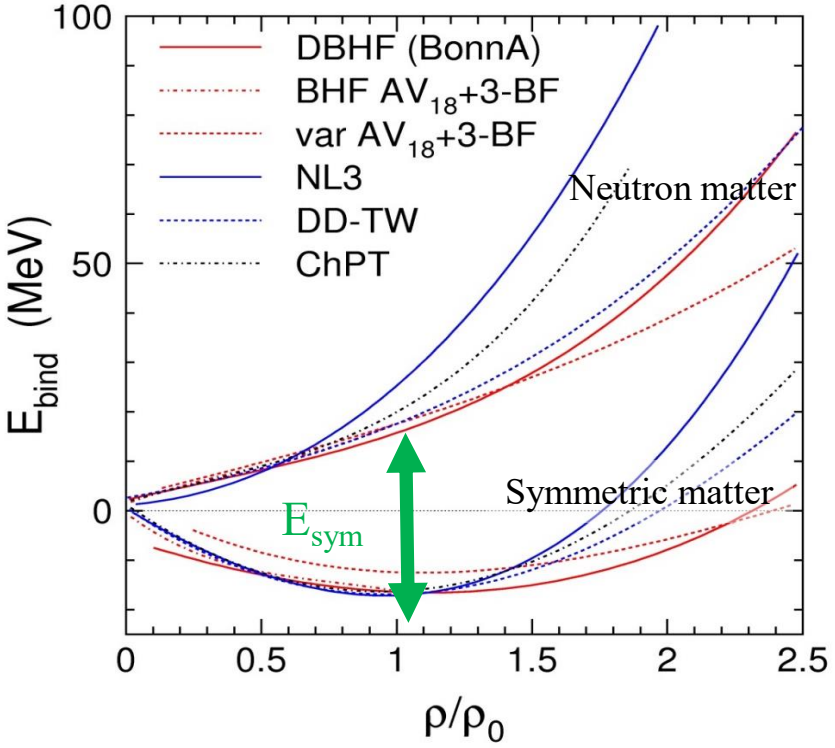
$E(N_p,N_n)$ Energy of the system of A nucleons (N_p, N_n=A-N_p) $\mathcal{E}$ - energy density

The binding energy per nucleon: $$E_{\rm bind}(n_p,n_n) = \frac{E}{A} - m_N = \frac{\mathcal{E}}{n} - m_N = E_A(n_b) + E_{\rm sym}(n_b)\frac{(n_p-n_n)^2}{n_b^2}$$

isospin asymmetry

symmetric matter

symmetry energy



Ch. Fuchs and H.H. Wolter, EPJA 30 (2006) 5

- Being extensively studied nowadays using observables (flow, meson yields, etc.) to explore compressibility
- $$K_0 = 9n_0^2\frac{{\rm d}^2E_A}{{\rm d}n^2}\Big|_{n_0}$$
- One of the main sources of uncertainty: discrepancy between experimental data

- One of the main parameters to study is the E_{sym} slope

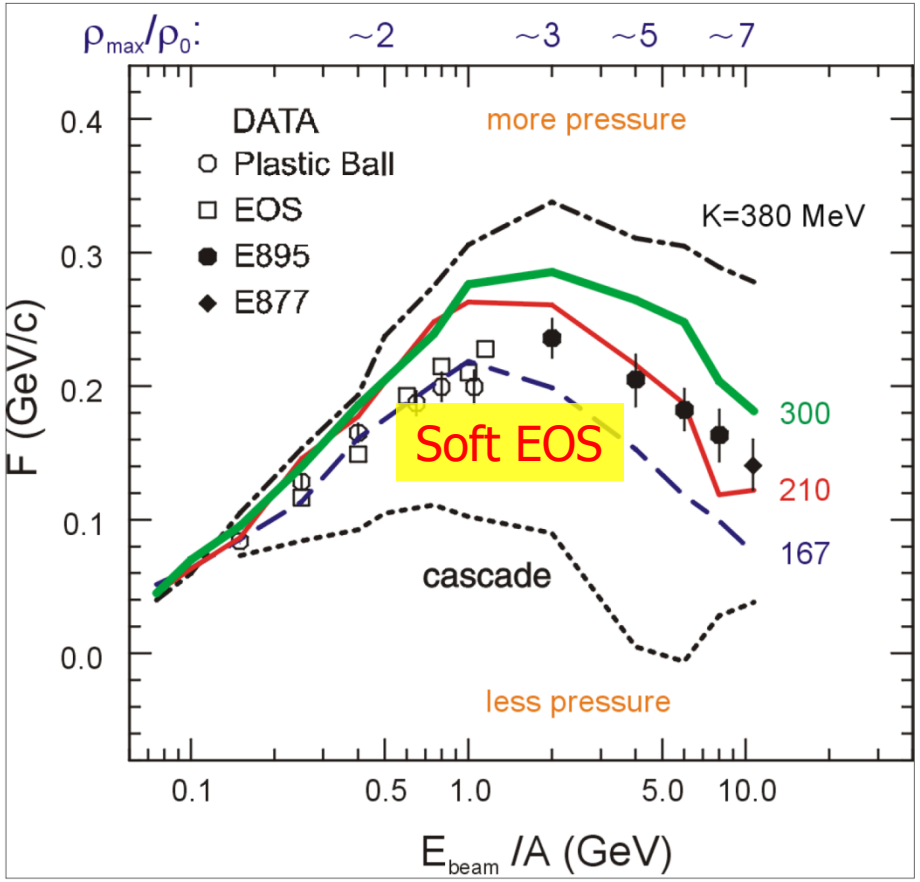
$$L = 3n_0\frac{{\rm d}E_{\rm sym}}{{\rm d}n}\Big|_{n_0}$$

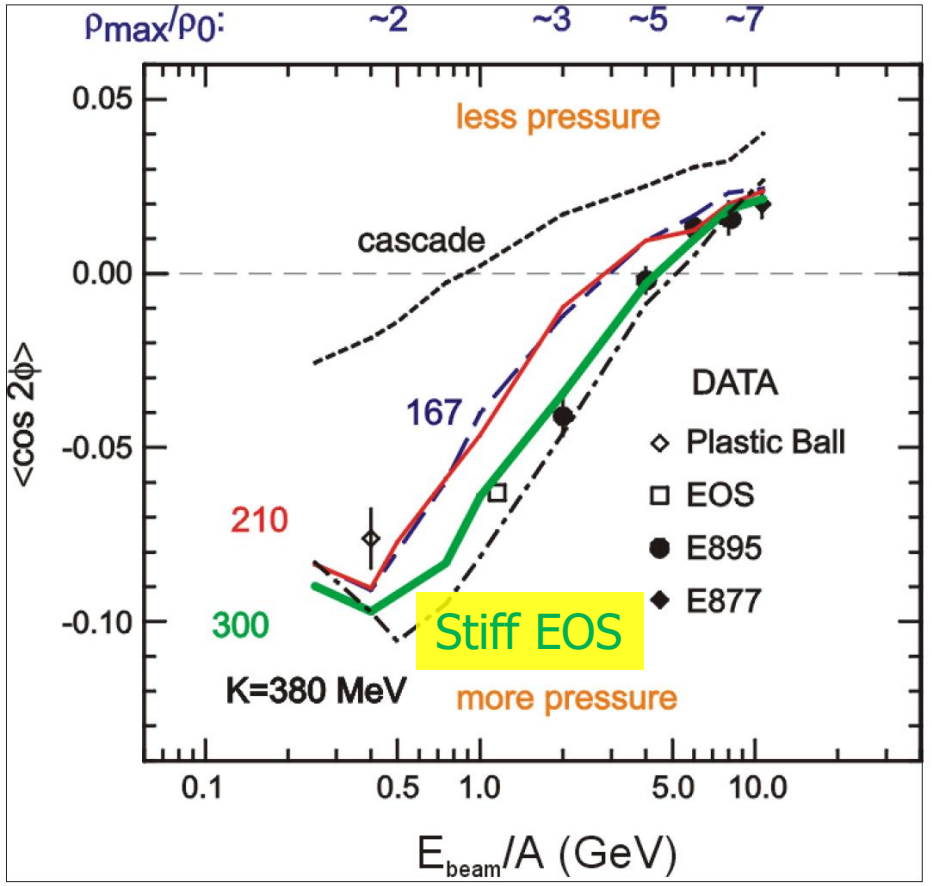
- No experimental data for beam energies $E_{kin} > 0.4$ GeV
- One needs to establish observables sensitive to ***L*** and obtain new experimental data

New data is needed to further constrain transport models with hadronic d.o.f.

Nuclear incompressibility from collective proton flow

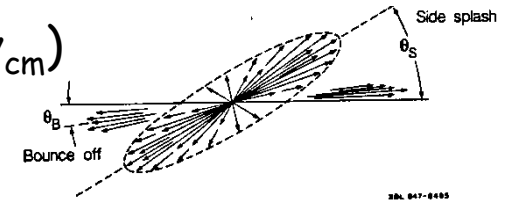
P. Danielewicz, R. Lacey, W.G. Lynch, Science 298 (2002) 1592



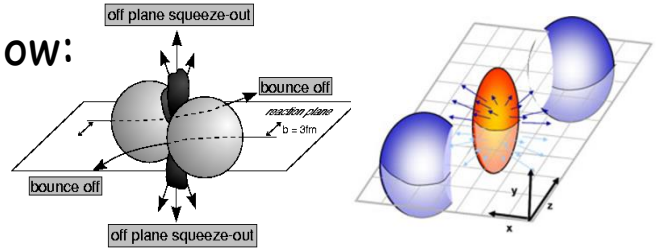


Transverse in-plane flow:

$F = d(p_x/A)/d(y/y_{cm})$



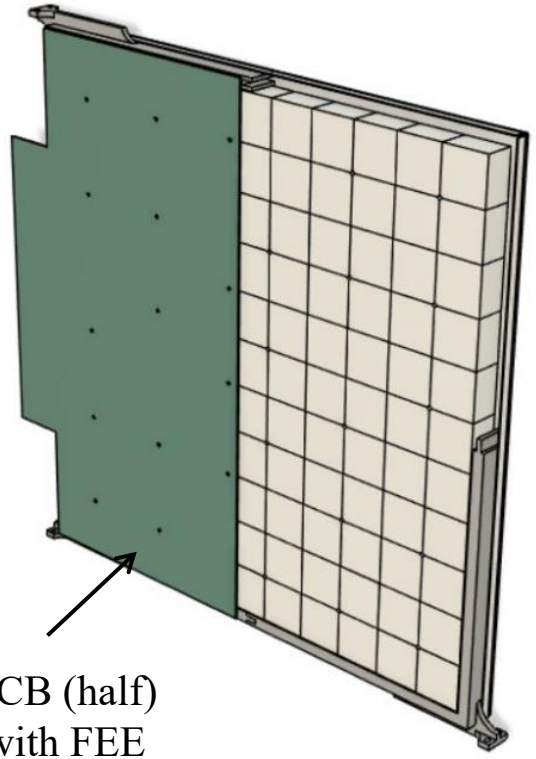
Elliptic flow:



$dN/d\Phi \propto (1 + 2v_1 \cos\Phi + 2v_2 \cos 2\Phi)$

Mechanical design

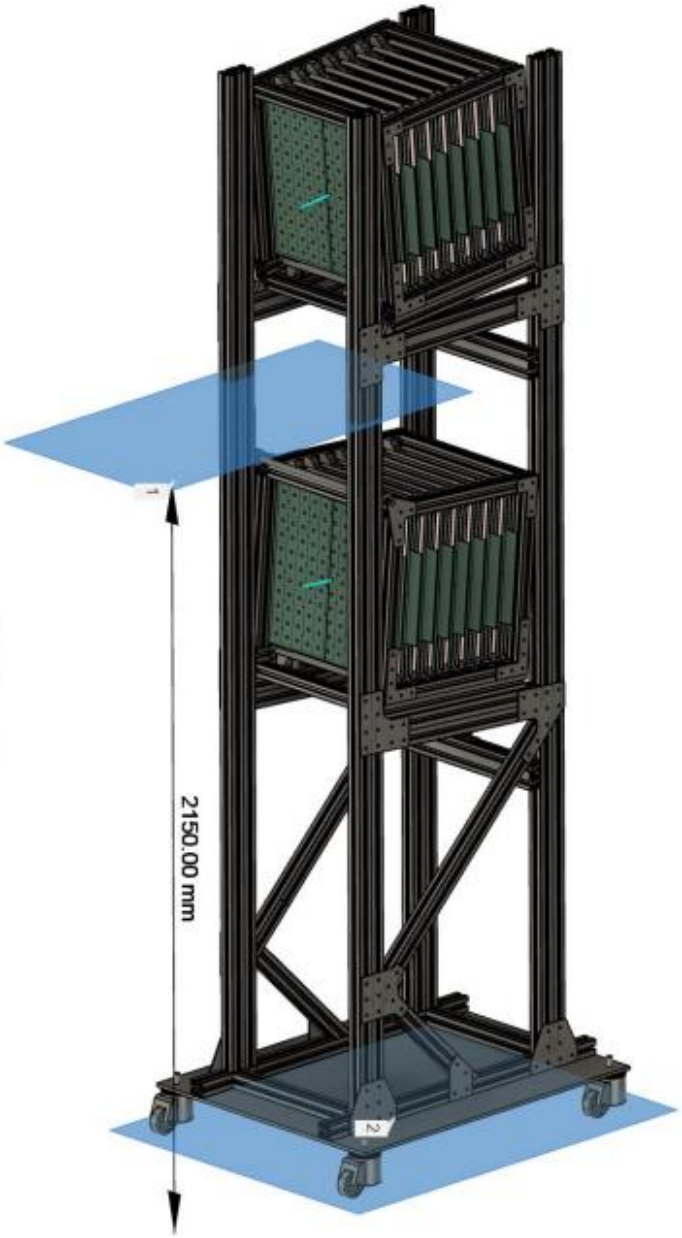
F. Guber, et al., Instrum. Exp. Tech. №3 (2024)



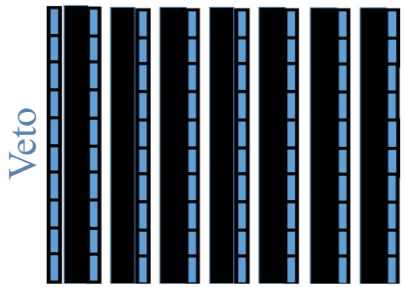
PCB (half)
with FEE

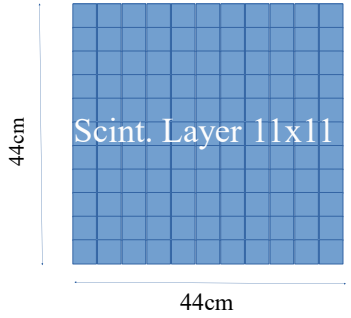
Light-tight and air-cooled assembly

- 1 veto-layer
- 7 Cu absorber layers (3 cm thick)
- 7 sensitive layers:
  - 11x11 matrix of scintillator detectors 4x4x2.5 cm^3
  - surrounded from both sides by PCBs
    - upstream board: LEDs for time calibration
    - downstream board: SiPMs and FEE

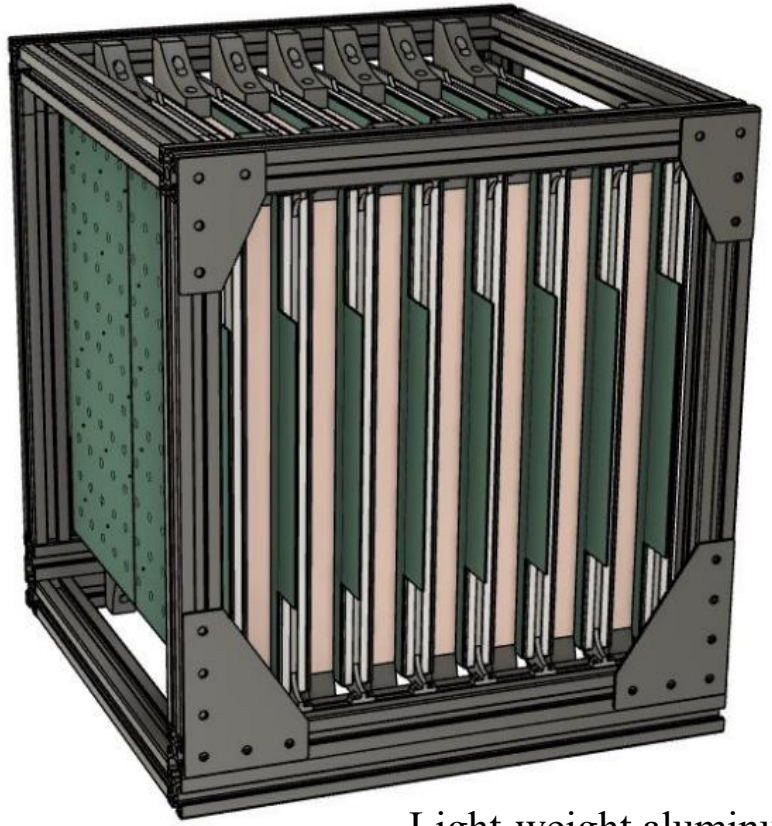


7 layers (Cu/Scint)





total length ~ 48cm (1.5 λ_{in})



Light-weight aluminum frame

EOS for high baryon density matter

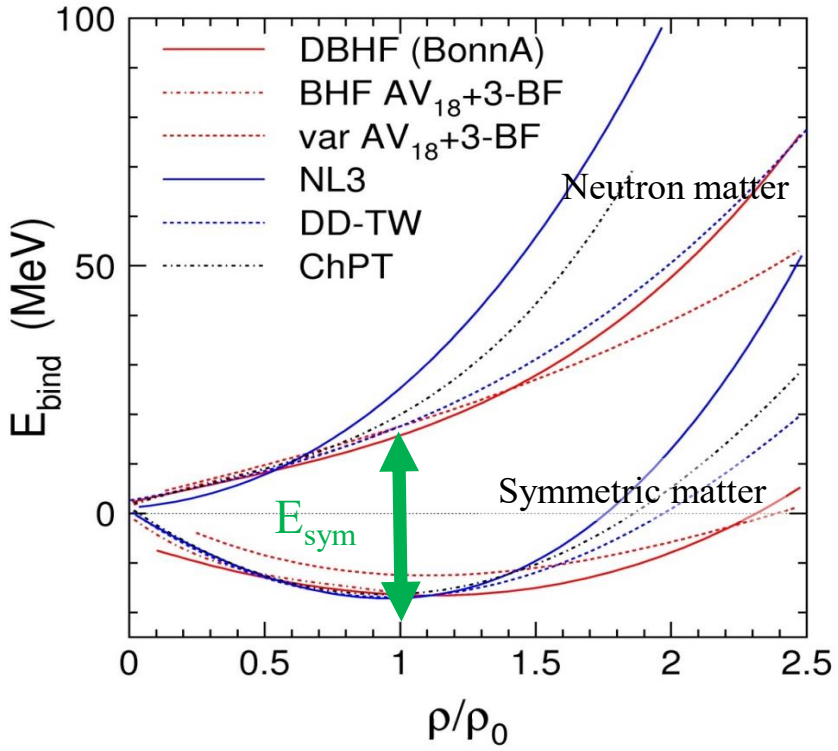
The binding energy per nucleon: $E_A(\rho,\delta) = E_A(\rho,0) + E_{sym}(\rho)\delta^2 + O(\delta^4)$

Isospin asymmetry:

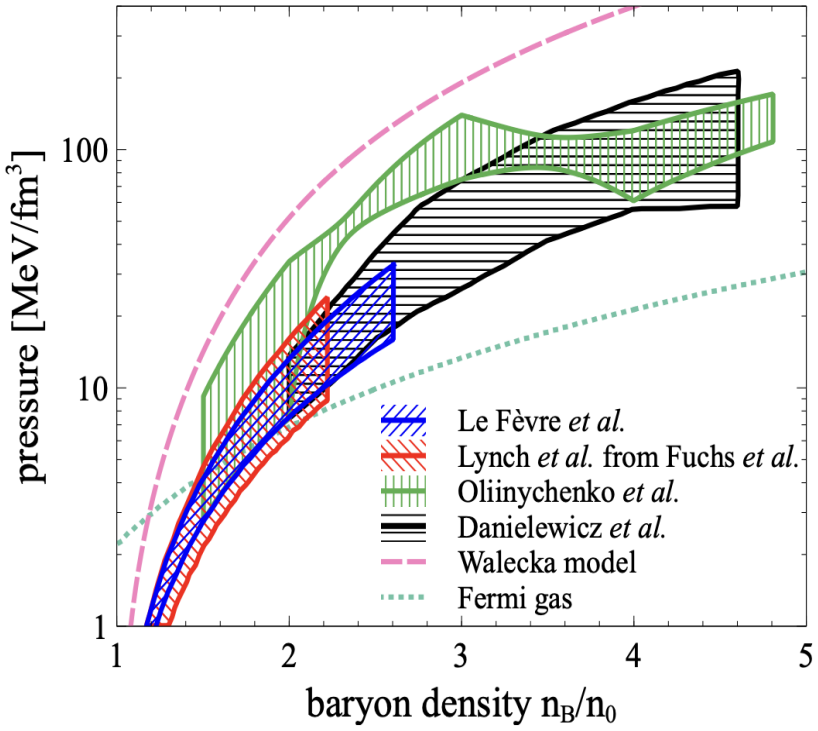
$\delta = (\rho_n - \rho_p)/\rho$

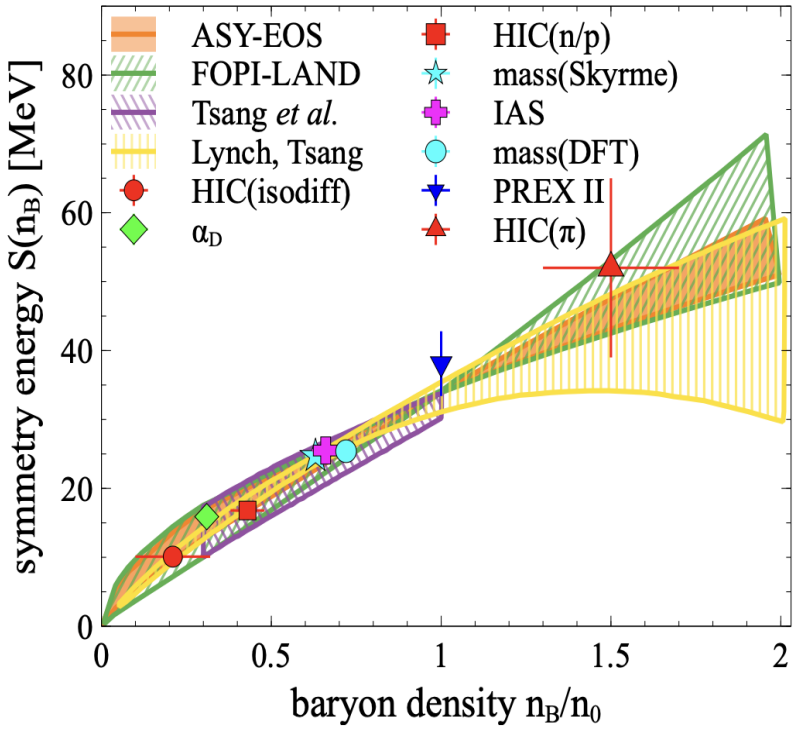
Symmetric matter

Symmetry energy



Ch. Fuchs and H.H. Wolter, EPJA 30 (2006) 5





A. Sorensen et. al., Prog.Part.Nucl.Phys. 134 (2024) 104080