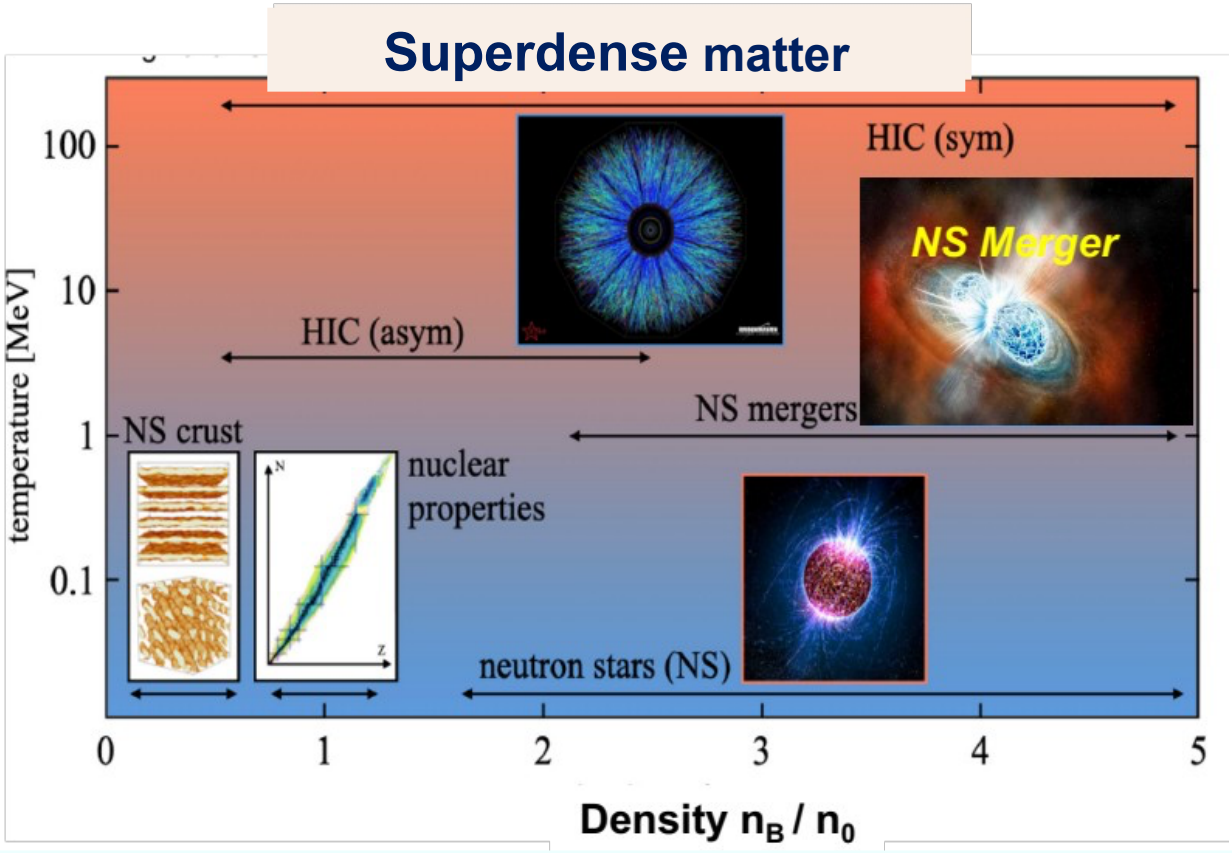
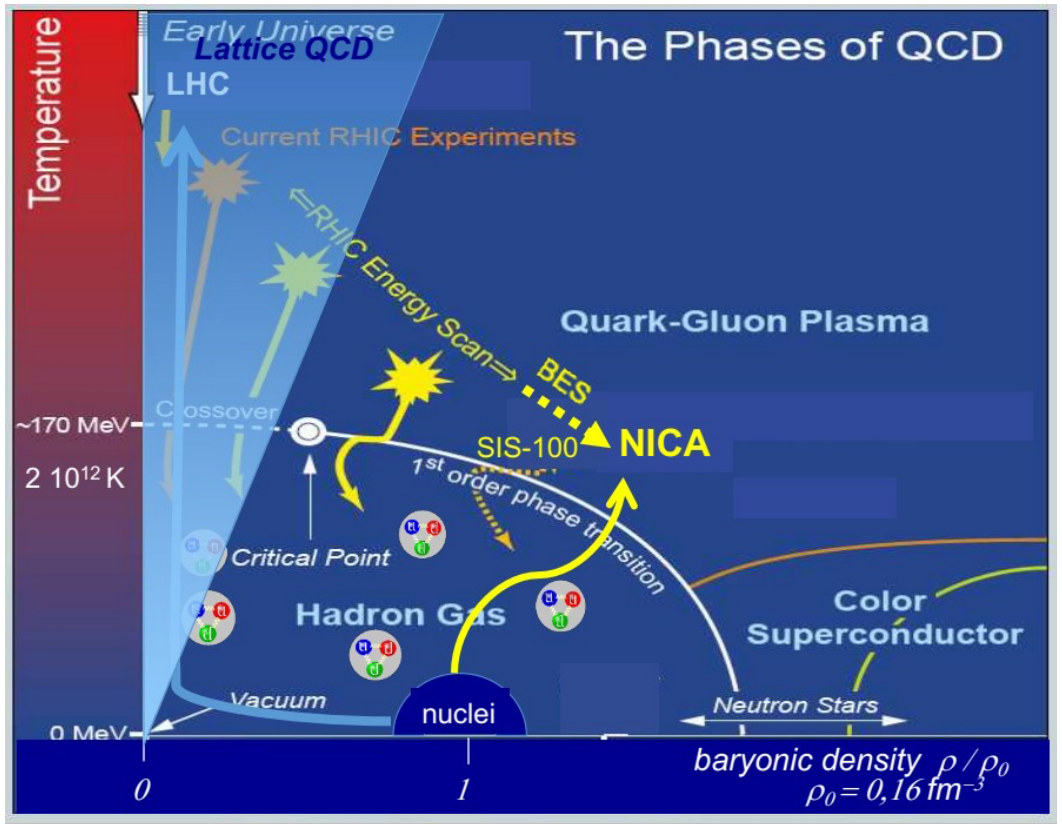
Similarities with Stellar Objects: Neutron Star & Relativistic Heavy Ions



protons / neutrons ~ x100 quark mass

It is largely unclear how the quarks and gluons within a particle determine its mass, spin, and other properties.

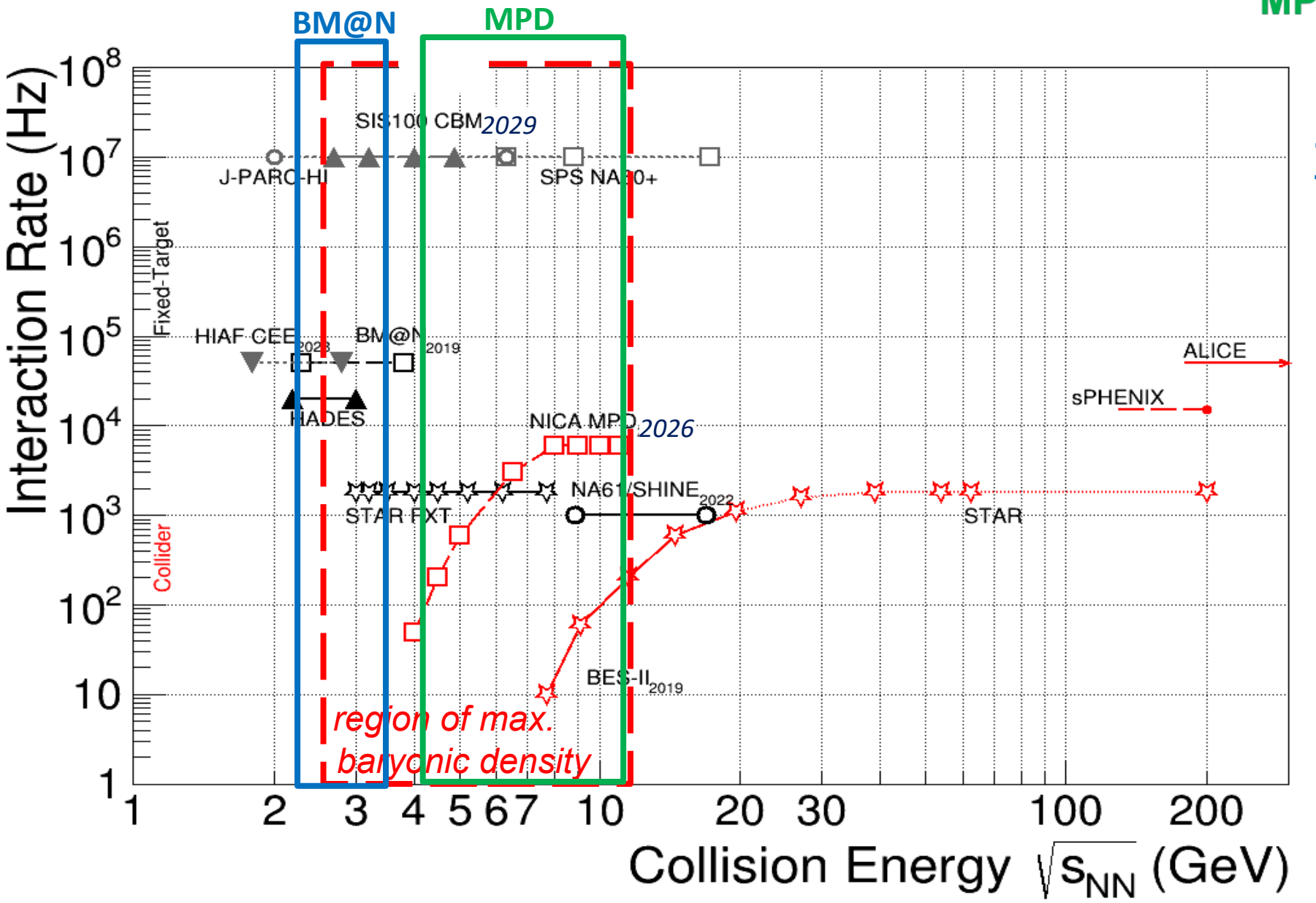
Under extreme conditions of ultra-high temperatures and densities, quarks and gluons cease to be confined within particles and form quark-gluon plasma.



Studies of the QCD phase diagram in the least explored region — at the highest possible baryonic density, which exists only inside neutron stars; the existence of a critical end point (CEP) and a first-order phase transition — are the subjects of intensive research.

Heavy-Ion Experiments

BM@N: $\sqrt{s_{NN}}$ **= 2.3 - 3.3 GeV**
MPD: $\sqrt{s_{NN}}$ **= 4 - 11 GeV**



Rivals :

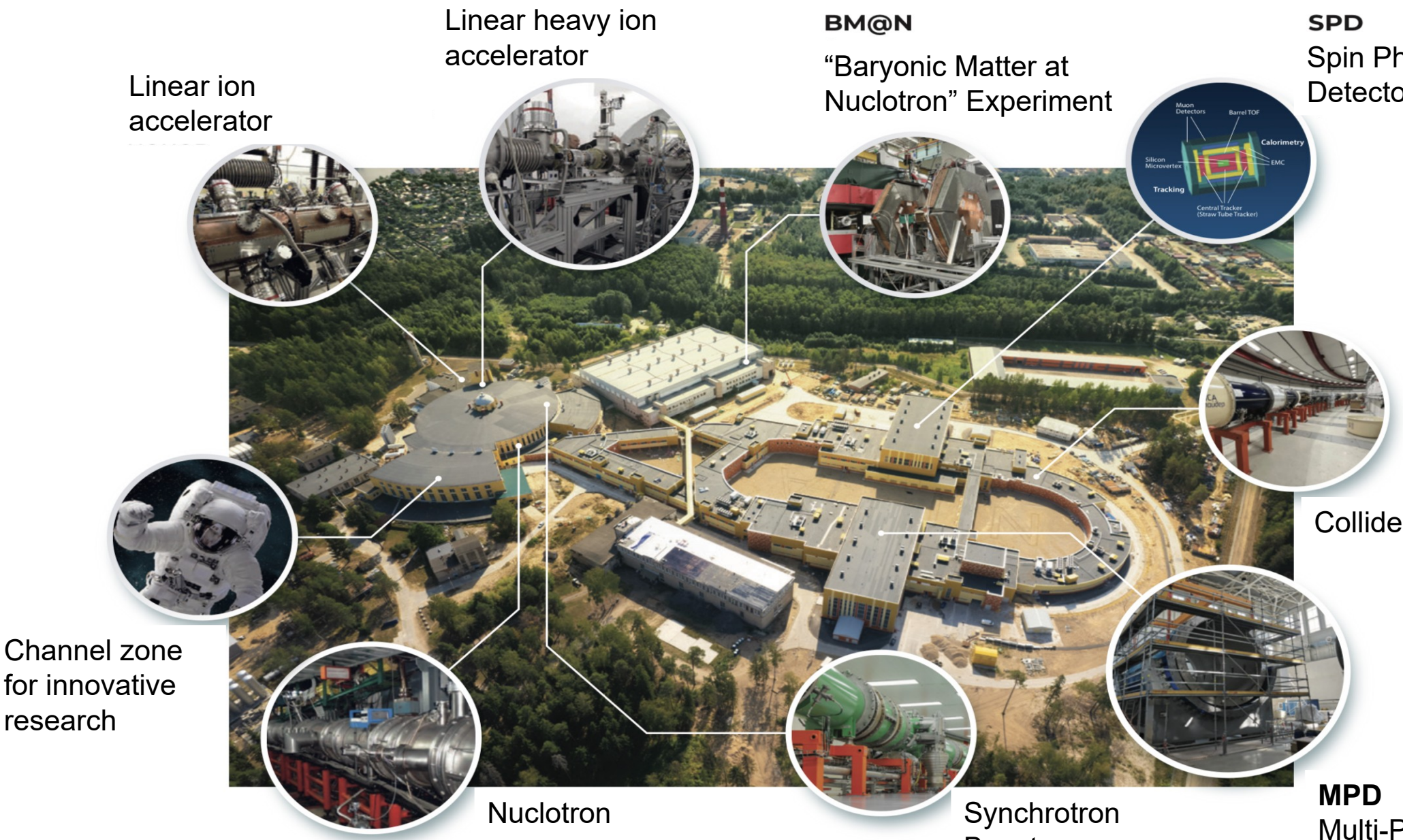
Today:

RHIC/STAR (USA)
3-200 GeV
SIS18/HADES (Germany)
2.4-2.55 GeV

In the future:

HIAF/CEE (China)
2.1-4.5 GeV (2027-?)
FAIR/CBM (Germany)
2.4-4.9 GeV (2029-?)
JPARC-HI (Japan)
2-5 GeV (2030-?)

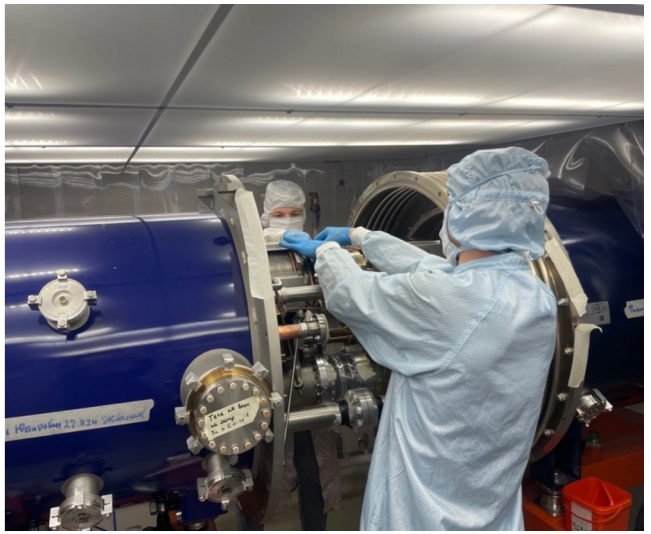
NICA Collider: Achieving the highest density of nuclear matter, unattainable by other laboratories in the world: the nature of neutron stars, the early Universe



NICA Collider in Dubna: Stages of the Grand Construction, 2016 - 2022

NICA Nuclotron-based Ion Collider fAcility

Commissioning of the NICA Collider



Assembly of the cryomagnetic system is underway.

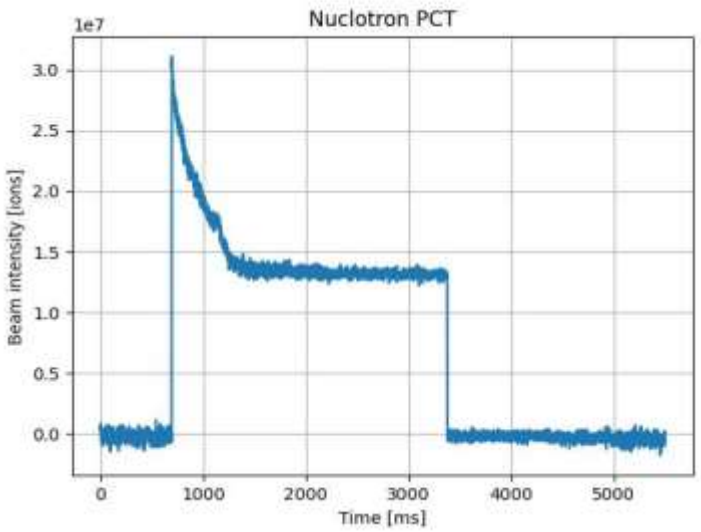
Transport lines from the Nuclotron are being assembled.

November 2024 – Applied research channels are ready for Nuclotron's extracted beams.

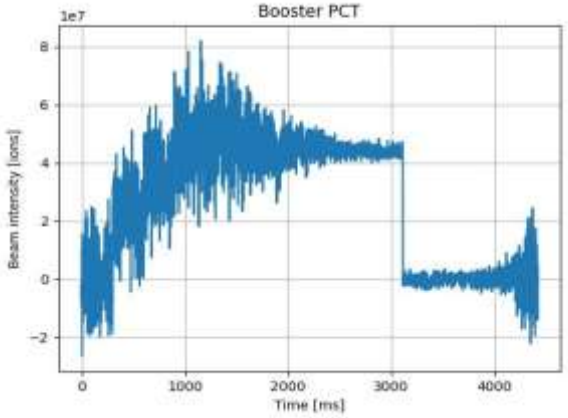
December 2024 – Final successful commissioning of GPP-1 from Rostekhnadzor.

NICA: Preparations and FIRST Collider Beam Run

Nuclotron Operation



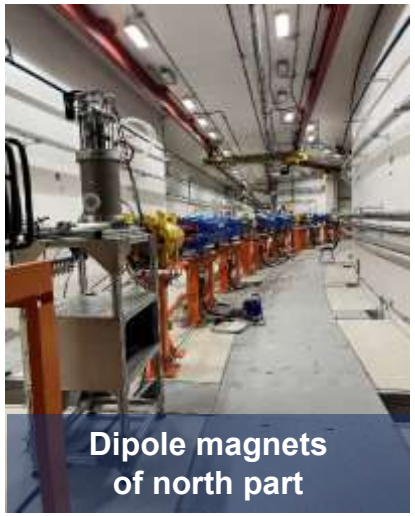
Xe beam @ Nuclotron: 1.3 E7 ions, 1.8 GeV/u



Xe beam @ Booster: 4.5 E7 ions, 0.5 GeV/u

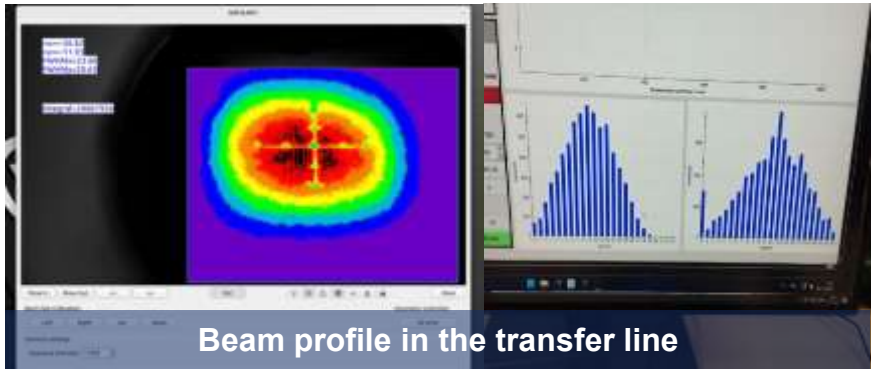
Nuclotron–Collider Beam Transfer Line

Nuclotron–Collider transfer line was assembled


Dipole magnets of north part


Quadrupole lenses

4th Nov – beam transportation line from Nuclotron to Collider was implemented

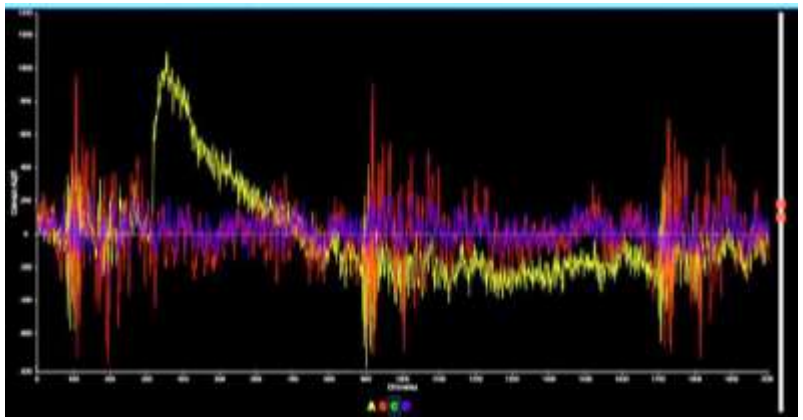

Beam profile in the transfer line

18th Dec – Xe beam profile signal from luminofor detector after Nuclotron -> Collider beam line

Collider Cryomagnetic System

24th Nov – NICA Collider SC rings were sealed

24th Dec – cooling of the collider ring was finished
30th Dec – 5 kA current powered the Collider magnetic system

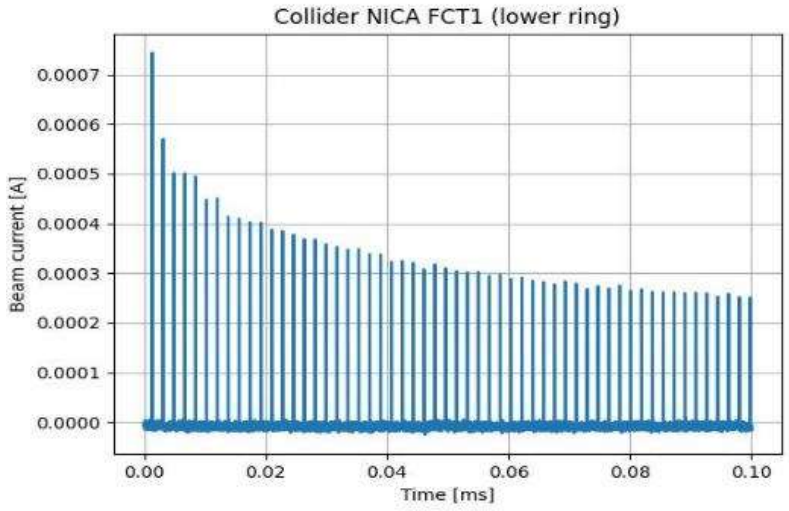


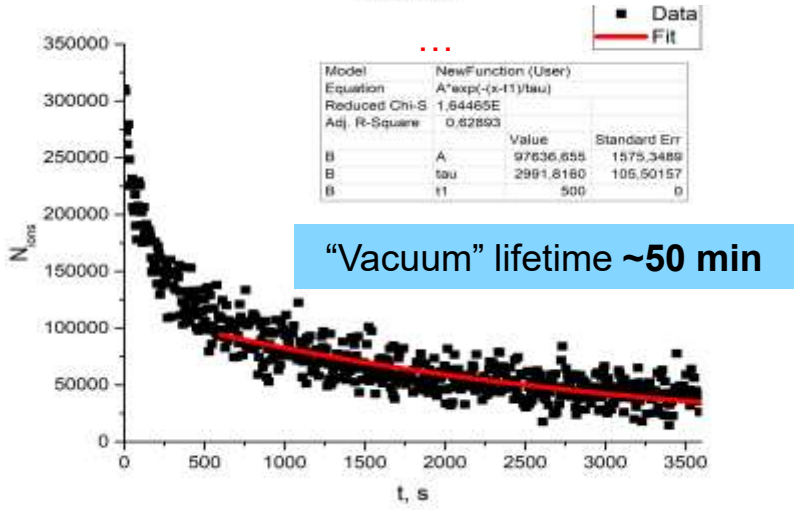
18th Dec – PicUp (BPM) station signal after Collider injection system (yellow curve)

First NICA Collider Beams

Xe beam Circulation in Lower Ring of the Collider

11th Jan – beam of $2 \cdot 10^6$ Xe ions was injected into the Collider at 1.76 GeV/u and stable circulation was observed



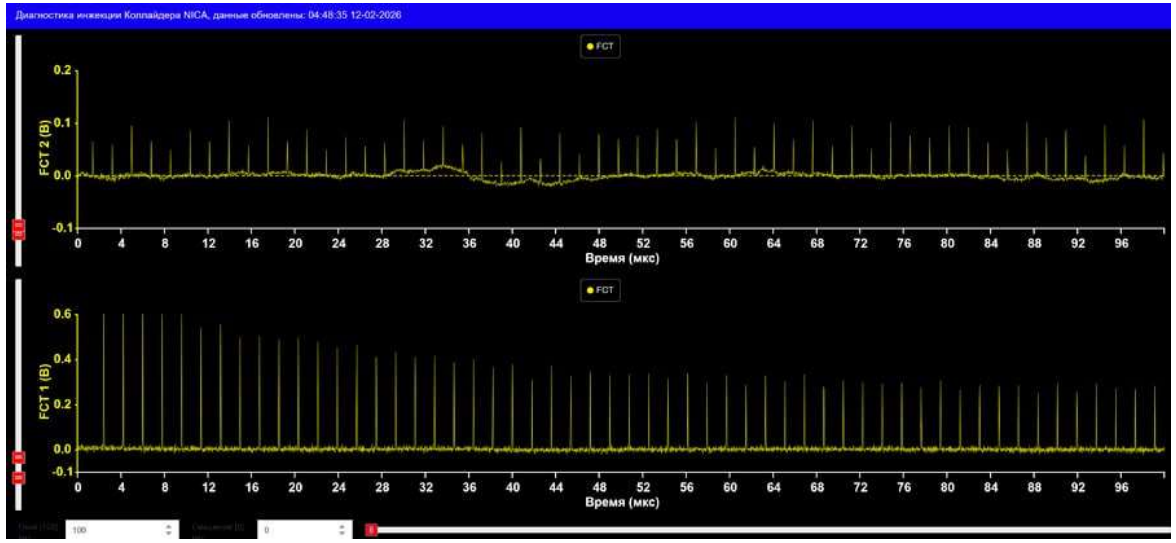


"Vacuum" lifetime **~50 min**

Intermediate Results

- Assembly of the Nuclotron–Collider beam line (BTL) is completed
- The Collider injection system is assembled, tested and tuned
- Commissioning of the Cryogenic facility
- Stable operation of Booster, Nuclotron, Collider cryo-magnetic systems
- Main power supply units of the Collider is put into operation
- The Collider RF1 & RF2 systems are tested

Two beams are converged in the collision region of the MPD zone, with a circulation frequency difference of $\Delta f = 3$ Hz, $\Delta f / f = 5 \cdot 10^{-6}$



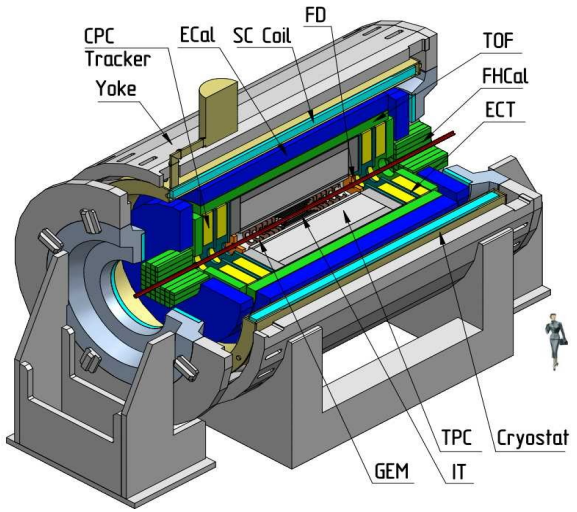
Jan 11th: Xe beam circulation was obtained in the lower Collider ring
Jan 23rd: Xe beam made its first turn in upper ring
Feb 12th: Xe beam – stable circulation in both Collider rings @ 1.76 A GeV

International colleborations at NICA

*The **NICA** scientific programme has been developed with the aim of researching: **QCD** diagrams in the little-studied region of **high baryonic density,** where lattice **QCD** is ineffective; the **spin structure** of nucleons; and a wide range of applied studies.*

2018: *International scientific collaborations began forming*

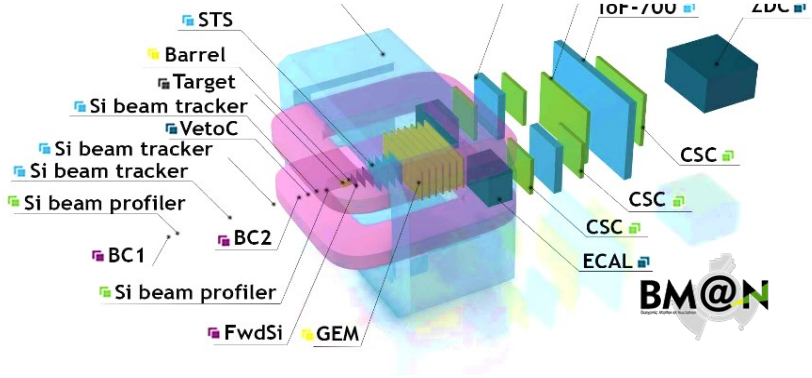
Multi Purpose Detector (MPD) Collaboration:



***12** countries + **JINR**, **39** centres;*
***> 500** participants;*
detector construction is soon to be finished, preparations for data collection are underway

Baryonic Matter at Nuclotron (BM@N) :

***5** countries + **JINR**, **13** centres, >**220** participants;*
experiments in process

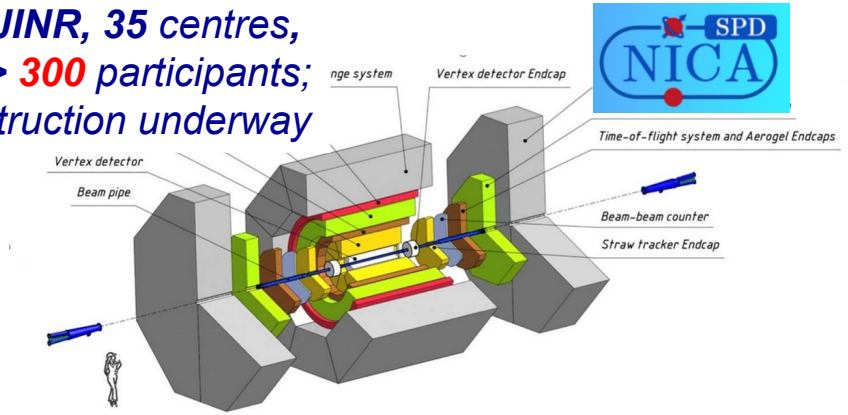


ARIADNA Collaboration

for applied and innovative research:
***6** countries, **27** centres, > **185** participants;*
research in process

Spin Physics Detector (SPD) Collaboration:

***12** countries + **JINR**, **35** centres,*
***> 300** participants;*
detector construction underway



BM@N physics run: beam energy scan in Xe(124) beam + Sn(124) target

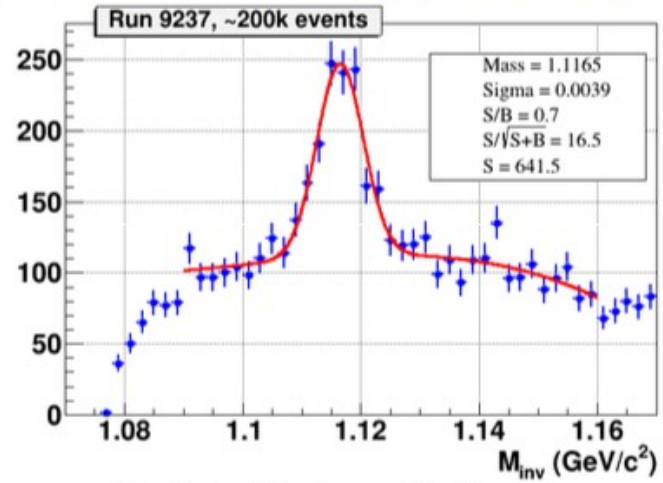
- For 1.5 months collected $2.8 \cdot 10^9$ events for physics analysis:

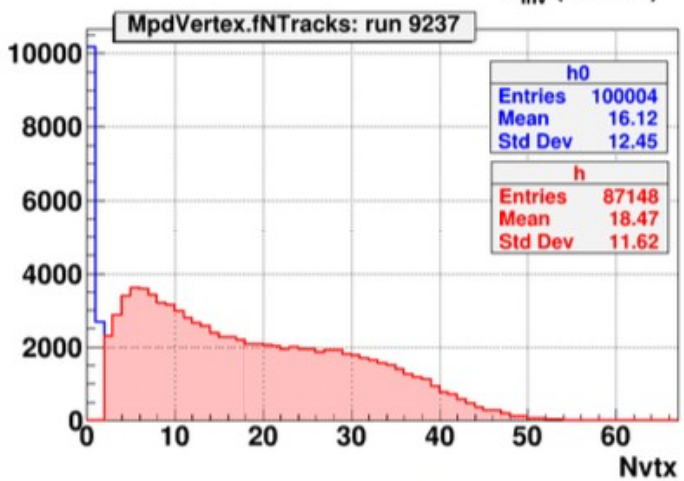
$0.86 \cdot 10^9$ events at beam energy 1.6A GeV

$1.2 \cdot 10^9$ events at 2.2A GeV

$0.75 \cdot 10^9$ events at 3A GeV

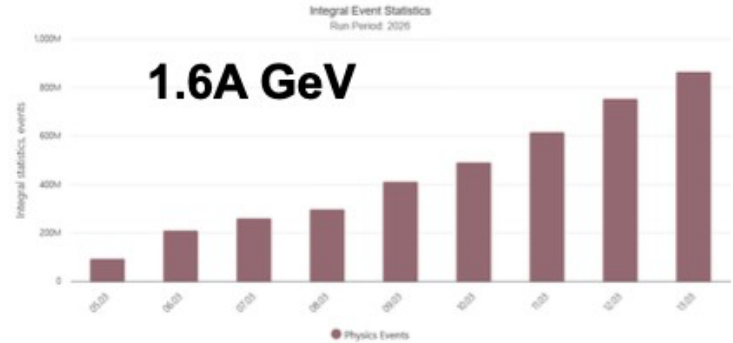
Online control plots: Λ hyperon signal

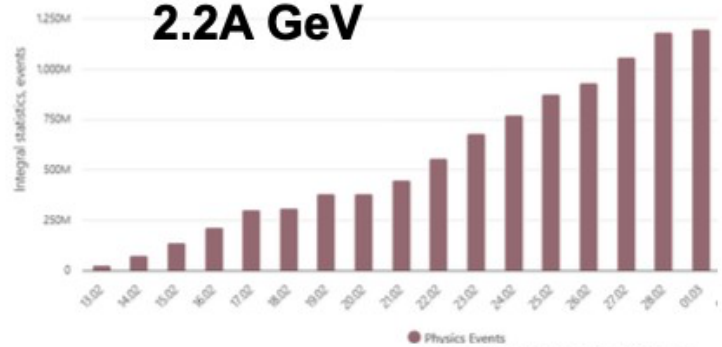




Number of tracks from the vertex

Collected statistics, M events






Low-energy testing facility
for electronic devices

ARIADNA

Infrastructure for Applied Research at NICA Facility


High-energy testing facility
for electronic devices


Target station for biological samples


Target station
for long-term exposure

Sample preparation room

Period of operation: 16 January – 13 March 2026

Facility: ARIADNA Target Station for **Long-Term Exposure**

Participants: 14 teams form **9** institutions and JINR Labs

Ion beams: 1.6 GeV/u, **1.76** GeV/u, **2.2** GeV/u $^{124}Xe^{54+}$

In this period, a full-scale applied research programme is implemented at the ARIADNA Target Station for Long-Term Exposure

Key topics:

- Radiation Materials Sciences
- Detector Technology
- Radiation Biophysics — **First Radiation Biophysics Experiments @ NICA (7.03–13.03.2026)!**
- Beam Calibration & Dosimetry


SCIENCE BRINGS NATIONS TOGETHER
70
JINR
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DOSCIENCE@DUBNA
Danke
Rahmat
Շնորհակալություն
Благодаря
감사합니다
جزيلاً
شكرًا
Mulțumesc
Спасибо
Gracias
Ďakujem
Thank you
Mulțumesc
Grazie
Рақмет
Çox sağ ol
Cảm ơn
Gracias
გმადლობთ
Köszönöm
Дзякуй
谢谢
Хвала
Баярлалаа
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Lv
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NICA Nuclotron-based Ion Collider fAcility

MPD Subsystems

Advancing with detector construction, many subsystems are ready for installation

Support Frame – ready

Successful test installation of the carbon fiber support frame in the magnet, sagita ~ 5 mm at full load, rails for the TPC and TOF are installed.

TPC – assembly of the gas volume (December 2025)

24+ ROC ready; 100+ % FE cards. Ongoing TPC gas volume assembly. Cooling system: commissioning

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

ECAL – 95% ready

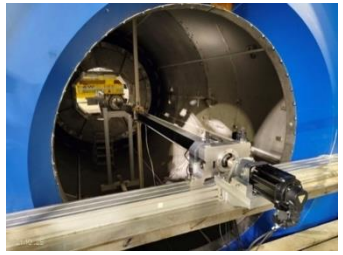
TOF – ready

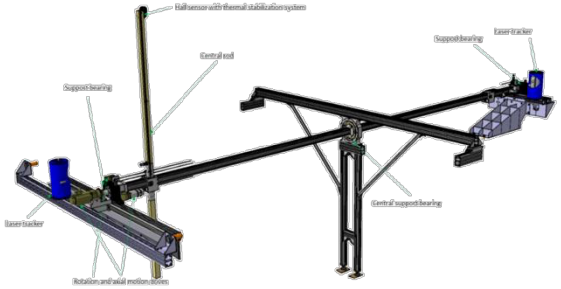
FHCAL, FFD – ready

ECAL ~ 38,400 towers (2,400 modules) produced by Tsinghua University, Shandong University, Fudan University, South China University, Huzhou University and JINR – production in IHEP (Protvino) and Tenzor (Dubna)
45 half-sectors ready, remaining half-sectors ready by April.

Cooling of the MPD Solenoid and MF Measurements

- A number of fixes in the chimney for better thermal isolation and optimized internal structure
- New cooling complain in autumn: solenoid cooled down to the working temperature of 4.5 K
- Magnetic field measurements: started in October 2025 at 0.2 and 0.3 T, full field at 0.5 T in February 2026





Novosibirsk BINP magnetic field mapper

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

Detailed measurements of the magnetic field started Autumn 2025. To be completed by mid-March 2026