JINR

NICA

Why do we need another collider?

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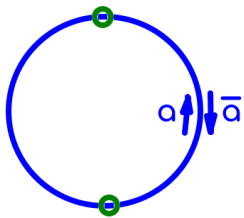
What is Collider?

A collider is a type of particle accelerator that brings two opposing particle beams together such that the particles collide.

The forms of Colliders

One storage ring

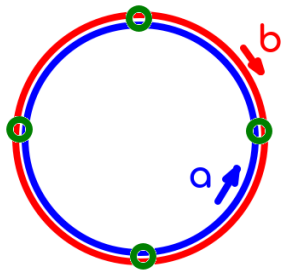
- Particles circulate and repeatedly collide
- Used for colliding particle and antiparticle beams of equal energy
- Only needed a single set of magnets and a single vacuum chamber
- Disadvantage: the number of bunches which can be circulated in each beam.



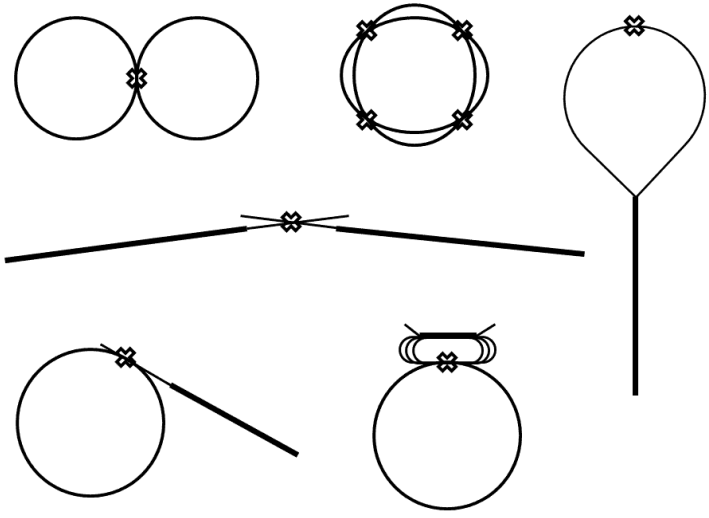
The forms of Colliders

Two storage rings

- Particles circulate and repeatedly collide
- Disadvantage: cost and technical complexity increased by a straight factor of up to 2
- Extremely high luminosity could be achieved by colliding a large number of bunches
- Variouse colliding particle combinations used



The forms of Colliders



Other configurations are possible and were considered

The main parameters of Colliders

The main parameters of Colliders

Collision energy

$E_{cm} = (2E_1E_2 + (m_1^2 + m_2^2) + 2\cos\theta_c\sqrt{E_1^2 - m_1^2}\sqrt{E_2^2 - m_2^2})^{1/2}$,

For the high energy accelerator ($E \gg m$) and zero angle ($\cos\theta_c = 0$):

$E_{cm} \approx \sqrt{2E_1m_2}$ – fixed target mode
$E_{cm} \approx 2\sqrt{E_1E_2}$ – collider mode

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Beam type

Generally hadrons or leptons
There were only one combined type (HERA)

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Luminosity

ratio of the number of events detected in a certain period of time to the cross-section

$$L = f_{coll}\frac{N_1N_2}{4\pi\sigma_x\sigma_y},$$

f_{coll} – collision frequency,
N_1, N_2 – number of particles in bunches,
$\sigma_x\sigma_y$ - transverse rms of beam

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Size

Just a linear measurement of the collider length

from 3 m (like AdA)
to 27 km (like LHC)

Not for home use!

Colliders are exclusively served the needs of frontier particle physics research!

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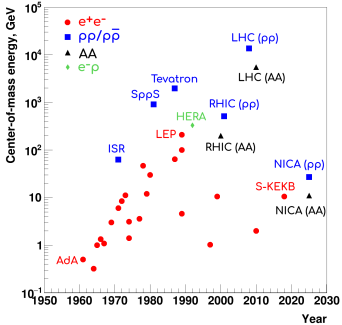
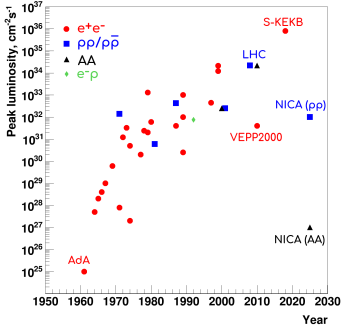
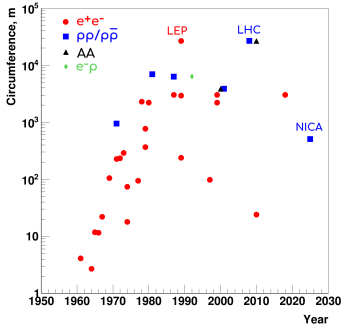
Highlights

- LHC – Higgs boson
- LEP – full validation of Standard Model
- Tevatron – discovery of top-quark
- $S\bar{p}pS$ – discovery of Z, W bosons
- RHIC – QGP observation
- HERA – detailed measurement of proton structure
- ...

Comparision of Colliders







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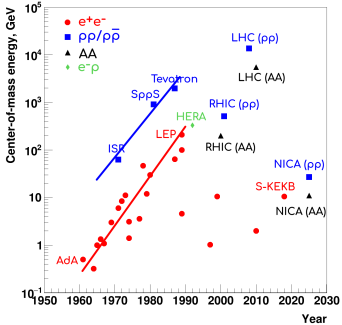

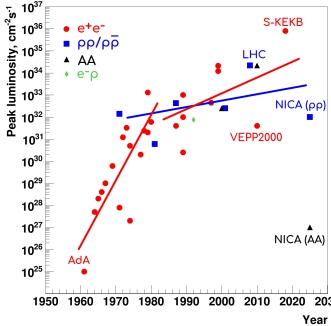

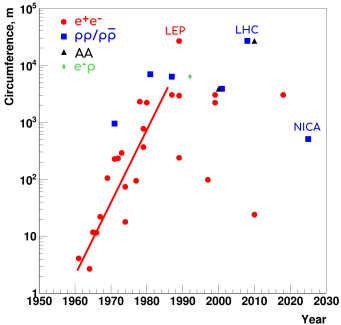

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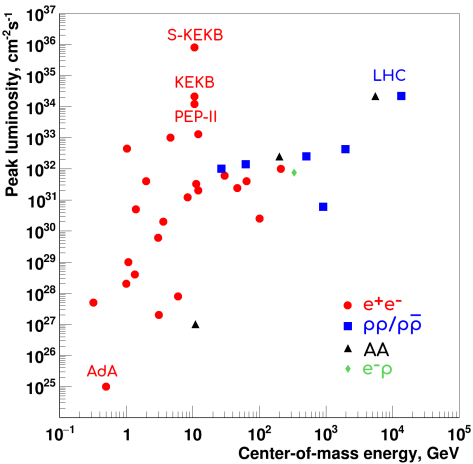

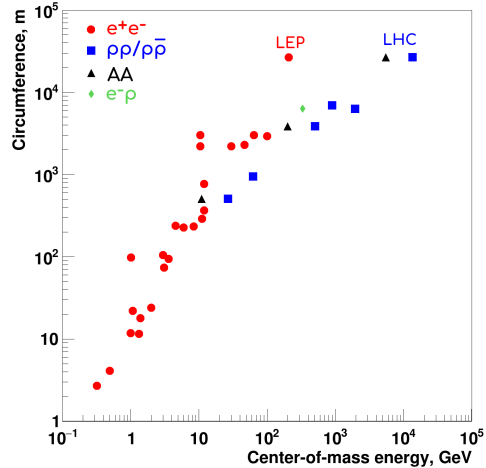

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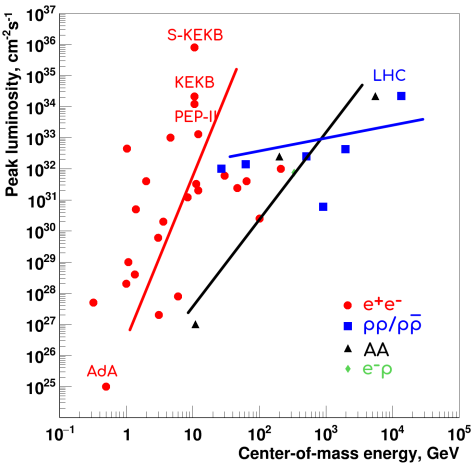
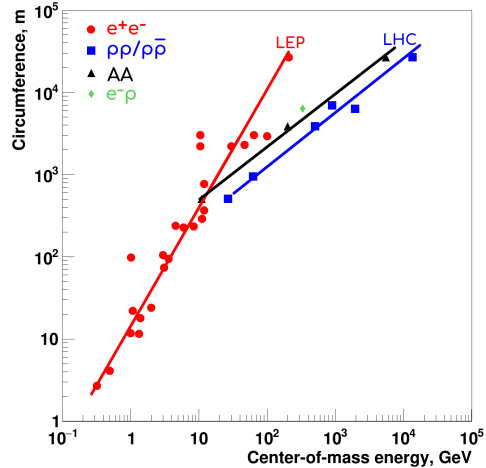
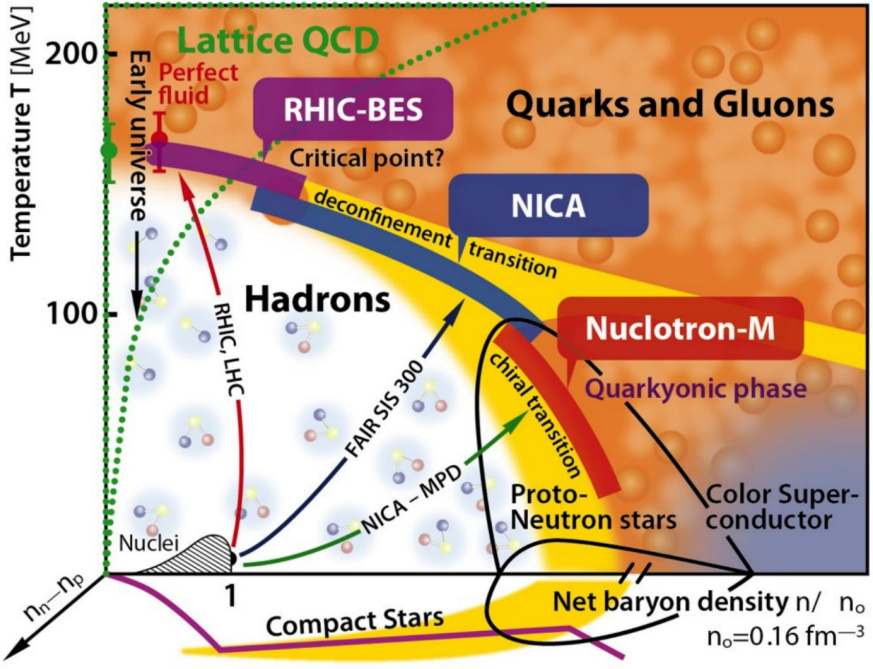




Why do we need another collider?


Temperature T [MeV]
200
100
Lattice QCD
Perfect fluid
Early universe
RHIC-BES
Critical point?
Quarks and Gluons
NICA
deconfinement transition
Hadrons
RHIC, LHC
FAIR SIS 300
NICA – MPD
chiral transition
Nuclotron-M
Quarkyonic phase
Proto-Neutron stars
Color Super-conductor
Nuclei
$n_n - n_p$
1
Compact Stars
Net baryon density n/ n_o
n_o=0.16 fm^{-3}

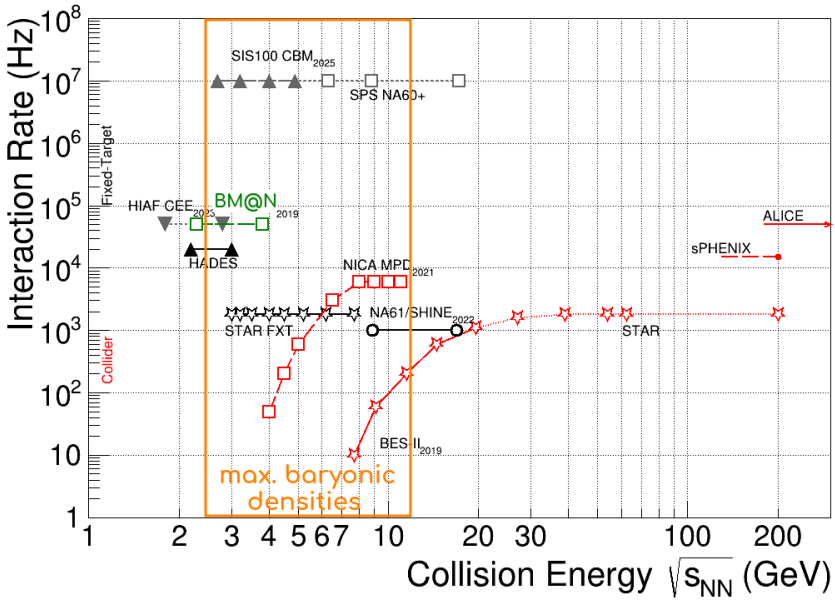
Heavy ion collisions

... are data driven physics, mostly progressed with observation of new phenomena

New data in less explored region of QCD phase diagram at high baryon density are very much required for both:

- observation/discovery of new phenomena;
- development of theoretical models

Optimal collision energy for realizing high baryon-density matter

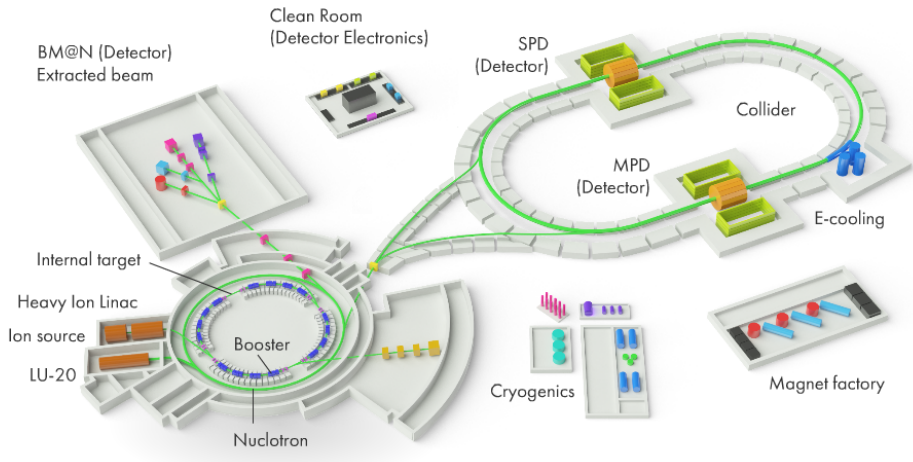


General goal of the NICA project

Study of hot baryonic matter at the region of max baryonic density through the tasks

- equation of state
- onset of deconfinement
- onset of chiral symmetry restoration
- first order phase transition observation
- search for critical end-point
- polarization phenomena

NICA complex



Superconducting magnet factory

- A unique production facility was created in VBLHEP
- Unique development of fast-cycling superconducting magnets (DUBNA-type)
- Assembly, testing, and certification of superconducting magnets
- Initial plan: 450 magnets for the NICA and FAIR projects

Booster

Main stages of Booster creation

- Installation in the Synchrophasotron yoke begins: September 2018
- Test run of the first Booster cascade: November 20, 2020
- Commissioning and beam extraction test to the Nuclotron: September 2021
- First physics experiment involving the Booster: March-April 2022

Why was the Synchrophasotron yoke saved?

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- A monument to great scientific history
- It is dangerous to remove 36,000 tons of metal at once
- The completed tunnel with protection

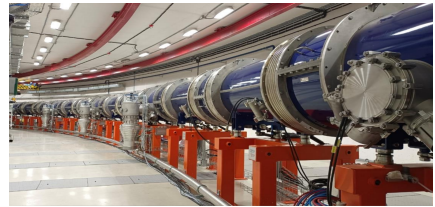
Nuclotron

- The first launch in March 1993 under the direction of A.M.Baldin
- Europe's first superconducting heavy-ion accelerator
- Unique development of fast-cycling superconducting magnets

The core of all project: NICA = Nuclotron-based Ion Collider fAcillity

Collider

- Area of the entire complex is more than 5 hectares
- Collider circumference ≈500 m
- Official start of construction is March 2016
- Technical launch: December 2024
- Registration of the first collisions in the collider: end of 2025



Full complex

Fundamental experiments at the NICA collider complex

- MultiPurpose Detector (MPD)
- Spin Physics Detector (SPD)
- Baryonic Matter at the Nuclotron (BM@N)

Multi-Purpose Detector (MPD)

>500 participants, 38 institutions, 12 countries

- Armenia (1),
- Belarus (2),
- Bulgaria (1),
- Georgia (1),
- Kazakhstan (1),
- China (10),
- Mexico (5),
- Egypt (1),
- Mongolia (1),
- Russia (13),
- Serbia (1),
- Slovakia (1)

The first collisions are expected to be registered in the end of 2025

Spin Physics Detector (SPD)

>400 participants, 30 institutions, 10 countries

- Armenia (1),
- Belarus (4),
- Egypt (1),
- China (2),
- Kazakhstan (1),
- Cuba (1),
- Russia (16),
- Serbia (1),
- Chile (2),
- South Africa (1)

We wait first beams of protons and deutrons in >2030

Baryonic Matter at Nuclotron (BM@N)

214 participants, 13 institutions, 5 countries

- Bulgaria (1),
- China (1),
- Kazakhstan (1),
- Russia (9),
- Uzbekistan (1)

- The first working experiment on the NICA complex
- Fixed target
- The first heavy ion run was performed in 2022-2023 (Xe + CsI @ 3.8A GeV)

We are waiting upcoming experimental run in Novemder of 2025!

The NICA complex will produce beams not only for fundamental research

Applied research at NICA:

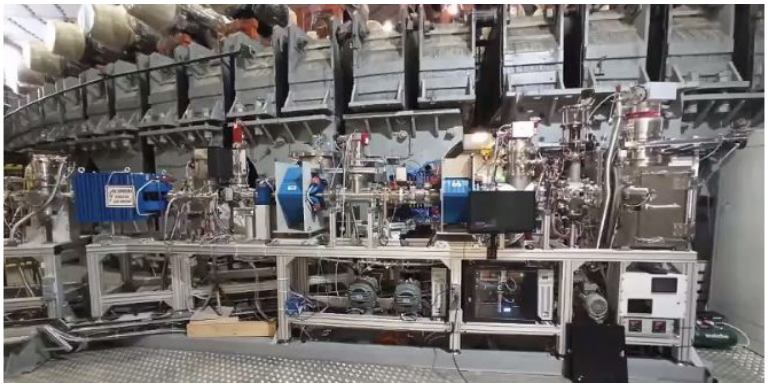
ARIADNA = Applied Research Infrastructure for Advanced Developments at NICA fAcility

Two main direction:

- Radiation resistance of materials
- Life science research

Radiation resistance of materials

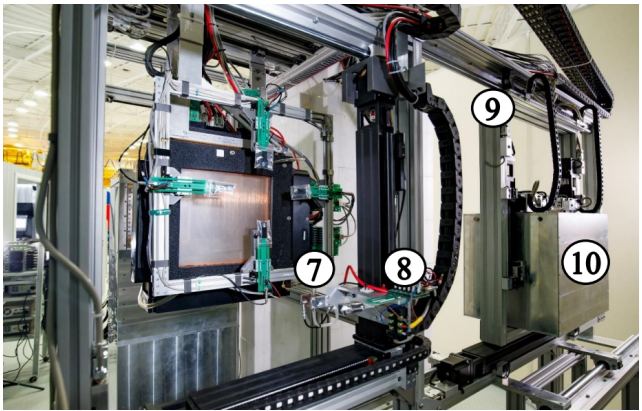
SOCHI (Station Of CHip Irradiation)



In December 2021 the first beam to the station was launched

Radiation resistance of materials

ISCRA



Radiation resistance of materials

In February 2023 two composite materials were irradiated over several days

Life science research

SIMBO

All these fundamental and applied research could be realized on the NICA complex so ...

All these fundamental and applied research could be realized on the NICA complex so ...

we definitely need another collider!