PROCEEDINGS OF SCIENCE

NICA accelerator complex project at JINR

O.Kazinova[1]
Joint Institute for Nuclear Research
Dubna. Russia
E-mail: kazinova.olga@gmail.com

A.V.Butenko
Joint Institute for Nuclear Research
Dubna. Russia
E-mail: butenko@jinr.ru

S.A.Kostromin
Joint Institute for Nuclear Research
Dubna. Russia
E-mail: kostromin@jinr.ru

I.N.Meshkov
Joint Institute for Nuclear Research
Dubna. Russia
E-mail: meshkov@jinr.ru

E.M.Syresin
Joint Institute for Nuclear Research
Dubna. Russia
E-mail: esyresin@jinr.ru

The physics program and the present status of the NICA complex, which is under construction now at JINR (Dubna), are presented. The main goal of the project is to study hot and dense baryonic matter in heavy-ion collisions in the energy range up to 11 AGeV. The plan of the accelerator part development includes upgrade of the existing superconducting (SC) synchrotron Nuclotron and construction of the new injector complex, SC booster and SC collider with two interaction points (IPs). The physics program will be performed with the fixed target experiment Baryonic Matter at Nuclotron, the Multi-Purpose Detector at the first IP of the NICA Collider and the Spin Physics Detector at the second IP.

European Physical Society Conference on High Energy Physics - EPS-HEP2019 -
10-17 July, 2019
Ghent, Belgium

[1]Speaker

PoS(EPS-HEP2019)012

1. Introduction

The NICA (Nuclotron-based Ion Collider fAcility) is the accelerator facility which is now under construction at Joint Institute for Nuclear Research (JINR, Dubna) [1]. NICA complex is aimed to study in the laboratory the properties of nuclear matter in the region of the maximum baryonic density. Such matter existed only at the early stages of the evolution of our Universe and in the interiors of neutron stars. Lattice QCD calculations predict both the deconfinement phase transition and chiral symmetry restoration to be happened at high enough energy densities and there are strong experimental evidence that the deconfined phase of nuclear matter (Quark-Gluon Plasma – QGP) can be created in ultra-high-energy nuclear collisions (see Fig.1).

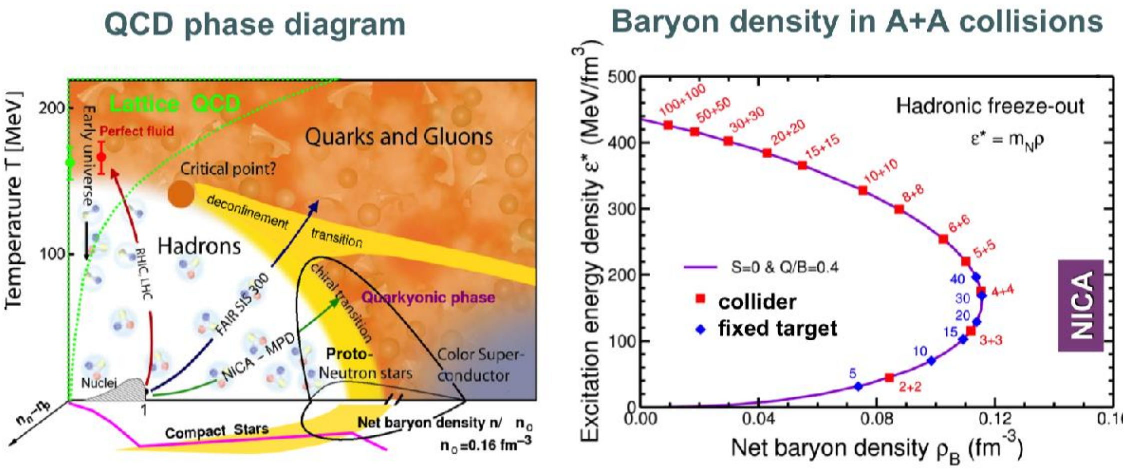

Figure 1: left: phase diagram for QCD matter (mixed phase is indicated by yellow); right: freezout diagrams for baryonic matter indicating baryon density reachable at different energies in collider and fixed target experiments (the region covered by the NICA experiments is indicated).

The accelerator part of the NICA project allows performing the wide experimental program using:

• colliding ion beams of high intensity (up to Au^{79+}) at an average luminosity of $L = 10^{27} cm^{-2}s^{-1}$ (Au^{+79}) in the energy range $\sqrt{S_{NN}} = 4\div11$ GeV;

• colliding beams of polarized protons and deuterons (with longitudinal and transversal polarization) with luminosity at least of $10^{32}cm^{-2}s^{-1}$;

• extracted beams of protons and ions at maximum energies of 12.6 GeV (for protons), 5.8 GeV (for deuterons) and 4.5 GeV per nucleon for heavy ions, as well as on polarized proton and deuteron beams with intensity of $>10^{10}$ particles per cycle;

• interdisciplinary programmes of applied research on big set of extracted beams with the wide range of energies.

More detailed information on the NICA experimental program is available at [2].

2. Structure of the facility

The NICA complex includes the linear accelerators, synchrotrons and collider (Fig.2). The first stage of the NICA experimental program will be started at existing accelerator facility which is based on injector comprising set of particle sources (PS) and linac LU-20, that will be equipped with a new RFQ foreinjector. Heaviest ions which were used at the LU-20 are $_{124}Xe^{42+}$. To increase the beam intensity at the exit of the main NICA synchrotron – the existing superconducting Nuclotron - a new injector will be constructed. It consists of ESIS-type ion source providing intensive beam of $_{197}Au^{31+}$ ions, heavy ion linac (HILAc) accelerating ions at A/Z < 6 up to the energy of 3.2 MeV/u, and Booster-synchrotron housed inside the JINR Synchrophasotron yoke. The Booster at circumference of 211 m and magnetic rigidity of 25 T·m will accelerate $_{197}Au^{31+}$ ions up to the energy of 600 MeV/u. To form required phase volume of the beam the Booster is equipped with an electron cooling system. After acceleration in the Booster the ions will be fully striped and injected into the Nuclotron providing acceleration of $_{197}Au^{79+}$ ions up to the energy of 4.5 GeV/u. The collider will be constructed in a tunnel with additional buildings for two detectors and HV electron cooler. It will be operated at a fixed energy, also possibility to have slow-rate acceleration of an injected beam is foreseen. To provide required linearity of the field the maximum bending field is chosen to be of 1.8 T. Two collider rings are constructed one above the other and the beam superposition/separation is provided in the vertical plane. The distance between the ring median planes is chosen to be 320 mm. That is achieved with dipole and quadrupole magnets having two apertures in one yoke and a common cryostat [3].

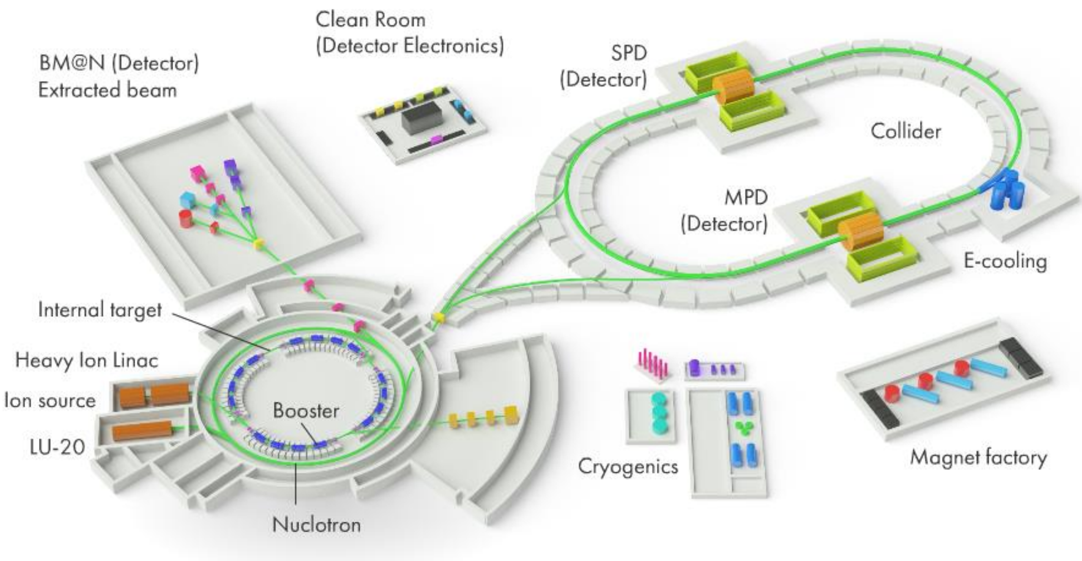

Figure 2: Scheme of the NICA facility.

3. Experimental program

3.1. Multi Purpose Detector (MPD)

The physic program in heavy ion collisions is aimed to explore the QCD phase diagram. The NICA energy covers the region of maximum baryonic density on the phase diagram. The strategy is to perform scan of energy and system size with an emphasis to the production of hadrons and dileptons, event-by-event fluctuations and correlations. The MPD apparatus has been designed as a 4π spectrometer capable of detecting of charged hadrons, electrons and photons in heavy-ion collisions at high luminosity [4]. To reach this goal, the detector will comprise a precise 3-D tracking system and a high-performance particle identification (PID) system based on the time-of-flight measurements and calorimetry (Fig.3).

PoS(EPS-HEP2019)012

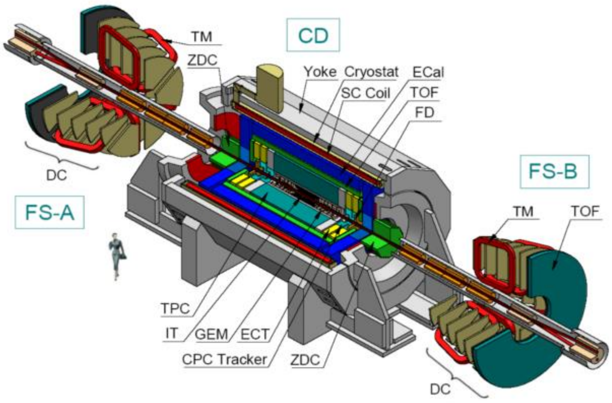

Figure 3: General view of the MPD detector with end doors retraced for access to the inner detector components. The detector consists of three major parts: CD-central detector and (FS-A, FS-B) – two forward spectrometers (optional). The following subsystems are drawn: superconductor solenoid (SC Coil) and magnetic yoke, inner detector (IT), straw-tube tracker (ECT), time-projection chamber (TPC), time-of-flight system (TOF), electromagnetic calorimeter (EMC), fast forward detectors (FFD) and zero degree calorimeter (ZDC).

The basic design parameters have been determined taking into account the physics measurements to be performed and several technical constrains guided by a trade-off of efficient tracking and PID against a reasonable material budget.

At the NICA design luminosity, the minimum bias event rate in the MPD interaction region is about 6 kHz in Au+Au collisions and the total charged particle multiplicity exceeds 1000 in the most central collisions at $\sqrt{s_{NN}}$ = 11 GeV. The average transverse momentum of the particles produced in a collision at NICA energies is below 500 MeV/c.

3.2. Spin Physics Detector (SPD)

The opportunity to have high luminosity collisions of polarized protons and deuterons in the NICA collider allows for studies of a great variety of spin and polarization dependent effects in hadron-hadron collisions:

- Drell-Yan pair, J/ψ and prompt-photon production with longitudinally and transversely polarized p and d beams aiming at extraction of unknown (poorly known) parton distribution functions;
- spin effects in baryon, meson and photon production in various exclusive reactions;
- diffractive processes;
- multiquark states and correlations;
- studies of cross sections, spin asymmetries (Krisch effect) and spin-dependent amplitudes in elastic scattering.

The SPD facility (Fig.4) is foreseen to be allocated in the south beam interaction point of the NICA collider. The aim is to have yet simple but universal detector that could be relatively easily reconfigured and/or upgraded. The current design foresees three modules: two end-caps and a barrel section. Each part has an individual magnet system: the endcaps – solenoidal coils, the barrel

– toroidal magnetic system. The main detector systems are as follows: Range System (RS) (for muon identification), Electromagnetic calorimeter (ECal), PID/Time-of-Flight system, Main Tracker (TR) and Vertex Detector (VD). The proposed three-module design gives a possibility for upgrade and modification of each of the main detector subsystems and for performing measurements with different detector configurations.

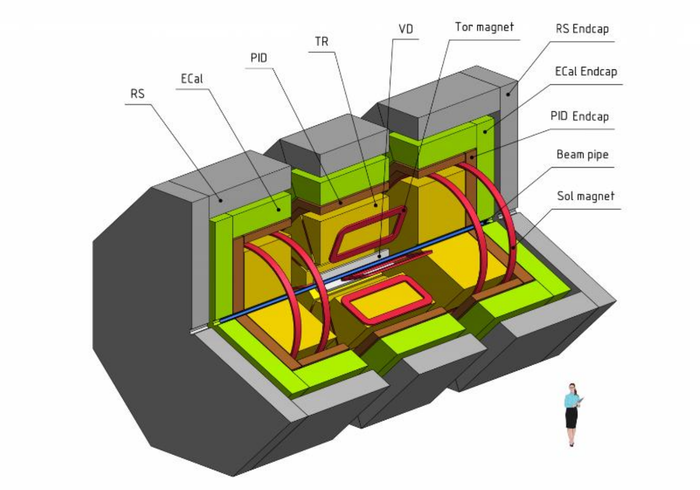

Figure 4: General view of the SPD detector.

3.3. Baryonic Matter at Nuclotron (BM@N)

The Nuclotron at JINR will provide beams of heavy ions with energies up to 6 AGeV for isospin symmetric nuclei and 4.65 AGeV for Au nuclei. In central heavy-ion collisions at these energies nuclear densities of about 4 times more nuclear matter density can be reached. These conditions are well suited to investigate the equation-of-state (EOS) of dense nuclear matter which plays a central role for the dynamics of core collapse supernovae and for the stability of neutron stars. At the same time, heavy-ion collisions are a rich source of strangeness, and the coalescence of kaons with lambdas or of lambdas with nucleons will produce a vast variety of multi-strange hyperons or of light hypernuclei, respectively. Even the production of light double-hypernuclei or of double-strange dibaryons is expected to be measurable in heavy-ion collisions at Nuclotron energies. The observation of those objects would represent a breakthrough in our understanding of strange matter, and would pave the road for the experimental exploration of the third (strangeness) dimension of the nuclear chart. The extension of the experimental program is related with the study of in-medium effects for vector mesons and strangeness decaying in hadronic modes. The studies of the p+p and p+A reactions for the reference is assumed.

For these purposes, it is proposed to install an experimental setup in the fixed-target hall of the Nuclotron with the final goal to perform a research program focused on the production of strange matter in heavy-ion collisions at beam energies between 2 and 6 AGeV [5]. The basic setup (Fig.5) will comprise a large-acceptance dipole magnet with inner tracking detector modules based on double-sided Silicon micro-strip sensors and gaseous detectors. The outer tracking will be based on the drift chambers and straw tube detector. Particle identification will be based on the time-of-flight measurements.

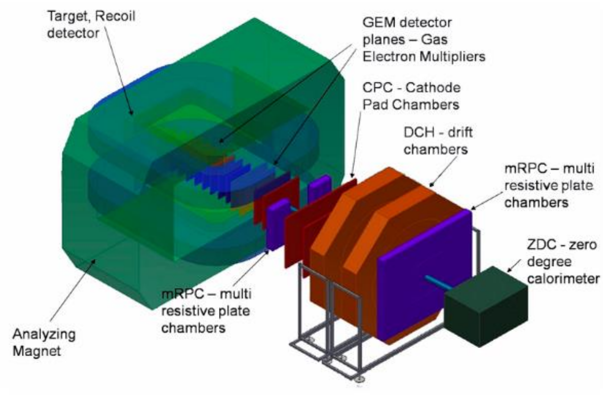

Figure 5: The BM@N experimental set-up.

4. Construction status

The NICA project as a whole has passed the phase of design and is presently in the stage of accelerator elements manufacturing and construction (Fig.6). The project realization plan foresees a staged construction and commissioning of all major parts and systems of the accelerator complex. The booster commissioning is planned for the end of 2019, beginning of 2020. The commissioning of the design configuration of the NICA accelerator complex is foreseen in 2023.

Figure 6: The construction site of the NICA collider.

References

[1] G. Trubnikov et.al., *STATUS OF THE NICA PROJECT AT JINR, Proc. of IPAC2014, Dresden, Germany*

[2] http://nica.jinr.ru/

[3] G. Trubnikov et.al., *THE NICA PROJECT AT JINR, Proceedings of IPAC2016, Busan, Korea.*

[4] Kh.U. Abraamyan et.al., *The MPD detector at the NICA heavy-ion collider at JINR, Nuclear Instruments and Methods in Physics Research, vol.628, 2011, p.99-102.*

[5] http://bmn.jinr.ru/