Report

on the project STAR (JINR participation), theme 1066.

The STAR detector is designed to work at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. The main goal of the physics program at RHIC is to produce a new state of the nuclear matter in collisions of heavy ions (Cu, Au, Pb) and to investigate its properties over a wide range of energy, centrality with various probes and to determine the features of the phase diagram of the nuclear matter. Experimental results from the RHIC support the hypothesis that a strongly coupled nuclear medium with partonic degrees of freedom, namely the Quark-Gluon Plasma (QGP), is created in heavy-ion collisions at high energy.

The new state at the top RHIC energy was found to be characterized by the suppression of the high transverse momentum hadron production in Au+Au collisions relative to p + p collisions, large elliptic flow for hadrons with light and heavier strange valence quarks, differences between baryon and meson v2 at intermediate p_T for Au+Au collisions, enhanced correlated yields at large $\Delta\eta$ and $\Delta\varphi$. These properties are associated with the existence of a quark-gluon phase of the nuclear matter.

This project of the JINR–STAR group for 2019-2021 yy. is focused on two compelling programs that are key to the completion of the RHIC mission. First, study of isobaric collisions (Ru+Ru,Zr+Zr) will provide enhanced clarity of the role of the magnetic field in the charge separation measurements. Second, STAR collaboration proposes Beam Energy Scan II (BES-II) program which will dramatically enhance our understanding of the QCD phase diagram in the range $\sqrt{s_{NN}}$ = 9-20 GeV. The fixed target mode in heavy-ion collisions at the STAR experiment also extends considerably the energy range $\sqrt{s_{NN}}$ = 3-7.7 GeV of search for the new physics.

Internal Time Projection Chamber (iTPC) and endcap Time of Flight detector (eTOF) upgrade will enable the particle identification at higher momenta in the extended rapidity coverage. The Event Plane Detector (EPD) will allow the centrality and the event plane to be measured in the forward region, thus reducing the systematic errors due to autocorrelations from mid-rapidity analyses.

The most interesting STAR results are bulk properties of the medium produced in relativistic heavy-ion collisions from the beam energy scan program, global hyperon polarization, the first high statistics measurement of $\Lambda\Lambda$ correlation, measurement of interaction between antiprotons, elliptic flow of light nuclei in Au+Au, strange particle production in Au+Au, spectra of heavy flavor probes (D,J/ψ) obtained with Heavy Flavor Tracker (HFT) and Muon Telescope Detector (MTD), nuclear modification factor R_{CP}.

The main contribution of the JINR group to the STAR project is the a significant contribution to the creation of the End-Cup of the Electromagnetic Calorimeter. All components of EEMC are designed, developed, integrated into the system of the STAR set-up and they work normally. JINR group support the systems of EEMC in the well working condition. This detector is an important component of the STAR to perform the forward physics with polarized protons: measurements of the forward rapidity Di-Jet double longitudinal asymmetry A_{LL} (polarized gluon distribution), the longitudinal single-spin asymmetry A_L of $W^{\pm}$ production (separation of polarized flavor parton distributions), the transverse single-spin pion asymmetry A_N at $\sqrt{s}$=500 GeV, the cross

section ratio W^+/W^- at $\sqrt{s}$= 510 GeV (new constraints on sea anti-d and anti-u distributions).

The physical results obtained by members of JINR group as principal authors were presented at international conferences and published in refereed journals.

Original method of data analysis based on z-scaling approach proposed by JINR group was extended for description of double longitudinal asymmetry A_{LL} for inclusive single jet and pion production, and the transverse spin transfer coefficient D_{TT} for Λ and anti-Λ production. Verification of self-similarity of spin-dependent scaling function and estimation of spin-dependent fractal dimensions of proton and Λ in these processes have been performed.

Members of the JINR team participate in data analysis on the study of the charged hadron spectra in Au+Au collisions at BES-I energies. A number of works on the data analysis and interpretation of results obtained by STAR are performed in the z-scaling approach. The method was used for analysis of particle spectra to search for new physical phenomena (signature of phase transitions, scaling,..). The distributions of charged hadrons on the transverse momentum over a wide range of energy $\sqrt{s_{NN}}$ = 7.7-200 GeV depending on the centrality of the collision obtained by JINR group have been used to verify the self-similarity of particle production, estimate parton energy loss and determine the energy dependence of fractal dimensions in the framework of z-scaling approach. This energy dependence gives additional motivation to perform the beam energy scan program at $\sqrt{s_{NN}}$ <20 GeV and search for CP in the cumulative range. The scaling function for the charged particle spectra for BES-I energies and different centralities is analyzed in low and high transverse momentum range. The results support self-similarity of particle production in Au-Au collisions. The data on strange meson and baryon production in proton-proton collisions over a range $\sqrt{s}$ = 7.7-200 GeV were analyzed to study of strangeness origin in searching for new physics with strange probes. The fractal dimension for particles (from K meson up to Ω hyperon) with different strangeness content was estimated. New indication on scaling properties of strangeness production in pp collisions at RHIC is obtained. Scaling features of cumulative particle production and production of particles with large transverse momentum in proton-nucleus (from D up to Pb) collisions at high energies were studied and the proposal to study self-similarity and search for signatures of phase transition in hard cumulative processes in fixed target experiment for BES-II at STAR is suggested.

JINR group plan to continue participate in data taking, data analysis in BES-II program. Methods of data analysis – pair correlation function, Λ pair spin correlations, fractal event analysis and z-scaling approach are developed. It is expected that higher statistics of particle spectra as a function of centrality and collision energy at BES-II allow us to obtain new constraints on the model parameters and new indication on location of CP. It is assumed that the kinematical region which is more preferable for search for signature of phase transition and critical point should to be for $\sqrt{s_{NN}} < 20$ GeV and high transverse momenta, where the parton energy loss is small.

STAR has received support over the years from a shifting array of cloud and grid production sites. Currently STAR is using the JINR (Joint Institute for Nuclear Research) tier-2 site with an agreement to opportunistically utilize 500 slots and later increase to 1,000 slots. STAR successfully reconstructed more 100 million events which are also discussed to produce a more compact (MuDST, PicoDst) format could past data.

Young scientists show interest in the research performed by the STAR

Collaboration. The experience of staff involved in the experiment, STAR, is extremely important for preparation of new heavy-ion physics projects JINR - MPD / NICA in the energy range $\sqrt{s}$ = 4-11 GeV, and the SPD / NICA for polarization physics in the energy range $\sqrt{s}$ = 12 - 25 GeV. It allows to consider both the technical advances in the creation of new facilities - MPD and SPD, and to prepare the physical program, taking into account the results obtained earlier at RHIC and SPS.

The resources required for the STAR project (JINR participation) in 2019-2021 are reasonable. I recommend to prolong this work with the first priority and present the Project at the JINR PAC.

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