Referee Report on the project STAR (JINR Participation) in 2022-2024

JINR Topic: 02-0-1066-2007/2023

The main scientific objective of the STAR experiment at the Relativistic Heavy Ion Collider (RHIC) is to study the formation and properties of the quark-gluon plasma. During the first 20 years of operation of RHIC, the STAR Collaboration has accomplished a vast scientific program, the results of which are published in more than 300 papers, which led to groundbreaking discoveries and shed light into the properties of the QGP. This year, the STAR Collaboration will complete a second phase of the "beam-energy scan program" (BES II), a series of measurements with heavy ions collisions at different center-of-mass energies, down to the lowest values attainable at RHIC. The BES-II data processing and analysis will continue for at least two more years.

After completing the BES-II program, the STAR collaboration will continue its scientific mission, in 2022-2025, to fully exploit a series of recent and planned detector upgrades, which will significantly enhance its rapidity coverage and rate capabilities. These upgrades, combined with the prospect for a substantial increase of the RHIC beam luminosity, puts STAR in the position to make significant progress in the study of the microstructure of the QGP (inner workings). To this purpose, a broad program of measurements with Au-Au collisions at RHIC top energy is planned for 2023 and 2025. This program will be complemented by measurements of pp and p-A collisions with polarized protons, in 2022 and 2024, which aim at studying fundamentals properties of the nucleon structure over the Bjorken x range from 0.5 down to $\sim 10^{-3}$. Besides providing discovery potentials on their own, these studies will prepare the ground for the Electron Ion Collider program.

JINR is participating in the STAR experiment since its inception, in the early nineties, and it is part of its backbone, both scientifically and technologically. It has contributed to numerous physics studies, for example with pioneering work on the study of femtoscopic correlations, to the construction and operation of the barrel and endcap calorimeters and more recently to the event plane detector (EPD). It also provided key contributions to the software and computing to process and analyze the physics data. At present, the JINR STAR team consists of 18 researchers (~13 FTEs), 4 programmers (~2 FTEs), 4 engineers (2.5 FTEs) and 7 students (3.5 FTEs), for a total of 33 members and ~20 FTEs.

In the past three years, members of the JINR STAR team have contributed to the experiment maintenance, operation and data processing, and participated in several data analyses, which led to the publications of six STAR papers. Moreover, scientists of the JINR team were very active developing new approaches and methods to study cumulative processes and event-by-event fractal analysis, which were applied to the STAR Au-Au collisions leading to a number of publications with a limited number of authors and several presentations at conferences.

I notice with surprise that in the past three years there were no Ph.D. theses completed by students working in the JINR team. The team reports that seven students have obtained their BSc or MSc degree in the past three years. However, no information is given regarding the prospects for the following years on new Ph.D. graduates. It is even more surprising and worrisome that in the past three years there was only one plenary talk given by a member of the JINR team on behalf of the STAR collaboration ("STAR Recent results on heavy-ion collisions", A. Aparin, Nucleus 2020, St. Petersburg). No other talks, plenary or parallel, were given by members of the JINR team on behalf of the STAR collaboration at main international conferences. This is quite surprising considering the large number of talks given by the STAR collaboration at the main conferences in the field.

While the relatively low contribution of the JINR team in the preparation of publications and dissemination of the STAR scientific results in the past three years might be determined by factors not directly related to its productivity, I advise the project leaders to analyze carefully the reasons and make all possible efforts to improve the situation in the following years.

The proposed participation of the JINR team in the future STAR scientific program leverages on the expertise developed in the past years and on possible synergies with the program planned for the experiments BM@N and NICA/MPD. It includes: the analysis of the BES-II data to study femtoscopic correlations, e.g. the measurement of the ΛΛ interaction, and features of particle production as self-similarity and cumulative processes; event-by-event "fractal" analysis of Au-Au collisions and comparison to AMPT simulations; the study of spin effects in collisions of polarized protons with protons and nuclei. Moreover, the JINR team plans to work on the optimization and further enhancement of the algorithms and software for the identification of electrons and hadrons using the TPC information, and also on the software for the calibration and reconstruction of the event plane detector (EPD) data. Finally, building on the expertise acquired in the past years with the development of the GRID framework for distributed multi-site computing, the JINR team will continue supporting the processing and analysis of the STAR data with a high-efficiency grid site plans to contribute to the development of new software to address future storage and computing challenges.

The resources requested to carry out the proposed program are commensurate with the objectives and scope of the research program, with about 60% of the total budget for travel expenses at the level of 55 kUSD/year.

In conclusion, STAR has a very reach and well-defined scientific plan for the period 2022-2025 and the contribution of the JINR team to this program is important for its success. The proposed project leverages on the scientific and technological knowledge developed by the JINR STAR group so far and aims at keeping its scientists and engineers at the forefront of the research in the field of relativistic nuclear collisions, as well as novel techniques for data processing and high-performance computing. More efforts should be done by the JINR STAR team in the following years to increase the impact and visibility of their contributions at the international level. The requested budget is well justified and commensurate with the objectives and scope of the program. I recommend the JINR STAR project be continued with high priority.

Sincerely,

Luciano Musa
CERN
ALICE Collaboration Spokesperson