# Review of NA61/SHINE project: Proposal for Extension of JINR Participation

The JINR team of NA62/SHINE experiment seeks three years prolongation of the project in 2022-2024. The authors provided extensive description of the project and answered the detailed questionary proposed by the PAC. The experiment already provided and is expected to produce new important results not only in heavy ion physics, but also for neutrino and cosmic ray communities. The NA61 plans for the next three years are:

* to continue studying the properties of hadron and nuclear fragmentation in processes with hadron and nuclear beams.
* to search for a critical point in the phase diagram of nuclear matter by scanning the energy and using different beams and targets.
* to analyse
	+ the formation of light nuclei in nuclear interactions.
	+ the hyperon generation in Be+Be, Ar+Sc, Xe+La, Pb+Pb interactions.
	+ the antimatter production in the nucleus-nucleus interactions.
	+ the charm particle production in relativistic heavy ion collisions.

The NA61 detector was upgraded with new Vertex Detector, replaced TPC readout electronics, new trigger and data acquisition systems, modernised Projectile Spectator Detector, and additional ToF detectors for particle identification at mid-rapidity.

The experiment plans to collect Pb-Pb interactions with 40, and 150 A GeV/c beams for charm physics, with 13 A GeV/c beam for nuclear fragmentation cross-section measurements (important for cosmic-ray physics), and to provide series of measurements for further refined estimates of the LBNF neutrino flux at the DUNE detectors.

**The JINR group contributions and responsibilities are:**

* Construction of the TOF system based on MRPC.
* Software development and maintenance of the software library.
* Raw data reconstruction and DST production.
* Data analysis.

**The JINR group plans to work on the following subjects:**

Hardware & data taking:

* ToF-L maintenance and data taking
* ToF-R production and commissioning

Software:

* design of the ToF-L geometry
* implementation of the ToF-L reconstruction chain to the SHINE framework continued DST production

Data analysis:

* study of light nucleus formation (d, t, 3He, .. ) in nucleus-nucleus interactions
* the study of hyperon and hypernuclei production in Be + Be, Ar + Sc, Xe + La, Pb + Pb collisions
* analysis of anti-matter production in relativistic interactions
* participation in the study of open charm production in heavy ion collisions
* measurement of hadron production for neutrino and cosmic ray physics
* further development of theory models for better understanding the collected data

**The JINR group of NA61 is very balanced**. It consists of young and expirienced physicists. The synergy between the NICA and NA61 projects is well established in several fields: in theoretical research where common models and simulations are provided, in detector development with MRPCs and electronics.

**The reviews of the referees V.V.Burov and A.A.Baldin are positive and support the requested extension.** They underline the quality of the physics program, its complementarity to the studies being carried out at the Nuclotron (JINR), RHIC (BNL), the impact of the NA61 experimental results on the research planning of NICA (JINR) and FAIR (GSI). The referees point out the synergy between NA61 and NICA projects in the detector development, and in the training of young physicists in a running experiment. They also indicate that the required resources are modest and fully justified.

**I completely agree with the opinion of both referees and propose to extend the JINR participation in the NA61/SHINE experiment in 2022-2024.**

The project is well written and contains quite extensive information. I would point to some possible improvements:

* the SWOT analysis in the project is not complete. It is not enough to state the strengths and to declare “Weak points if found in the Project are justified to be negligible”. For example, the operation of TPC is a delicate process, its calibration is difficult, the rate is limited to 1kHz even with the new readout, etc.
* The charm studies were planned also in 2019-2021, but there are no cited results. Few words of explanation would be appreciated.
* One of the main physics goals is the search for the onset of the horn, kink, step, and dale structures in collisions of light nuclei. It would be interesting to summarise the current NA61 results on such structures.

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