Resume of the NICA Machine Advisory Committee at JINR (Dubna)

May 22-23, 2017

Considerable progress in the NICA project has been achieved since the previous MAC meeting in October 2015. The MAC highly appreciates the official start of the collider civil construction, the results of the operation of the source of polarized ions (SPI) and the new RFQ fore-injector in two Nuclotron runs. The MAC congratulates the NICA team for commissioning of the new heavy ion linear accelerator (HILac), and the facility for superconducting magnet assembly and cryogenic tests. The facility is in its full configuration required for the NICA and FAIR projects. It uses a new helium liquefier - largest in Russia. The MAC congratulates the NICA team on receiving a report verifying that the funds required for the NICA construction are secured by the Russian Federation and JINR for the stage 2A, at least; and that JINR secures the budget plan for the stages 2 - 3 as a 7 year plan.

Answers of MAC on the JINR directorate charge letter

1. **How MAC does estimate, in general, the state of the project execution and progress achieved since previous (October 2015) MAC meeting:**
   - Ion (particles) sources and Injectors' complex,
   -The Booster synchrotron,
   -The beam transfer lines and injection/extraction systems,
   -The Nuclotron upgrade and routine operation necessary for NICA,
   -The Collider development, and related systems: SC magnets, vacuum system, RF systems, cooling systems, diagnostics, control system, cryogenic system, design and construction workflow, CF&S, etc.)?
   The overall progress is good, however, it is different in various areas.
   The MAC observed a substantial progress with the source of polarized ions. Polarized beams were accelerated in the linac and injected into the Nuclotron with intensities which are approaching the project goal. The improvement of the acceleration efficiency of polarized proton beam is urgently required. The presented plan to install the debuncher cavity in the Medium Energy Beam Transport line should address the problem.
   A preparation for the Booster synchrotron construction is progressing reasonably well. However, the delay in the delivery of the beam pipes, the beam position monitors and the

coils of corrector magnets challenge the project schedule. The design of the beam transfer lines was completed, and the construction of the elements was started.

The status of the Nuclotron corresponds to the requirements of the routine operation necessary for NICA. Some optimization of the acceleration efficiency and the performance of slow extraction for the BM@N experiment have shown promising results, while an improvement of the spill structure of the extracted beam is still necessary.

The collider SC magnet development proceeds in accordance with the schedule, the design of the pumping system was complete, but the vacuum chamber design is not yet. The construction of the start-up RF system was started. A design of the stochastic cooling system should be examined including the complexity of bunched beam cooling. The electron cooling concept looks realistic. An addition of strip-line beam position monitors around the collision points has to be considered. The progress in the control system development is satisfactory; however, a more detailed development of the concept of the signal transfer is required for applications like beam transfer from Booster to Nuclotron and from Nuclotron to collider. The construction of the VBLHEP cryogenic complex is progressing well. MAC particularly appreciates the pace of the civil construction of the collider complex.

2. **How do MAC experts estimate schedule for the Booster and injection complex construction and commissioning?**

   The schedule for Booster and injection complex installation was presented in adequate detail. The proposed schedule looks very ambitious. The realization will strongly depend on available human resources. The presented estimate of the needed man-power for the assembly of Booster and injection complex looks quite low.

3. **How does MAC estimate present state of the Nuclotron as a matter of routine operation in NICA complex?**

   The development of the Nuclotron is a continuous effort in view of the parameters required for NICA. During the last runs substantial improvements in the Nuclotron performance were achieved. In particular, improvements in the reliability of operations were demonstrated. However, an operation with highly charged ions, which is of primary importance for NICA, can only be tested after the Booster commissioning.

4. **How does MAC estimate advance in simulation of the beam dynamics in the Collider, its lattice design and the beam instability problems? Are there problems not included in present simulation program?**

   Since the last meeting the progress is good, but the lattice design is not completed yet. The final choice of the operational modes has to be done as a compromise between flexibility and cost. Investigations of beam instabilities are to be intensified including the calculation of the impedance budget. Standard measures to decrease the impedance for all elements should already now be integrated into the design. The NICA collider has to be designed as a low impedance machine. Design of multiple fixed-aperture "catchers" embedded into the arcs needs to be revisited, taking the impedance issues, background and machine start-up procedures into account, with possible modifications of the design towards fewer adjustable-gap tapered collimators. Functional requirement specifications for all magnetic corrector elements and their connections and powering should be prepared. Field errors and fringe field effects of the final focus quadrupoles have to be included into the simulation of the dynamic aperture. The simulation work of the beam-beam effect has to be started.

5. **How do MAC experts estimate an importance and urgency of development of the Collider cooling systems – both stochastic and electron ones?**

   Both cooling systems – stochastic and electron – are mandatory for the collider operation in the entire collider energy range. R&D and construction work for both systems must be intensified and financially supported. The R&D for electron cooling is significantly more mature than for stochastic cooling. R&D for the stochastic cooling system design is at the very initial stage. The status of stochastic cooling design is behind other systems. Significant efforts are required to catch up and to move it to the level required by the project. The barrier bucket voltage is assumed as a rectangular one, the realistic voltage wave form still has to be demonstrated. It should include the droop and ringing of the RF voltage which can be harmful to the efficient beam accumulation.

6. **What is impression of the MAC members of a state of civil construction and infrastructure development?**

   MAC is very impressed with the rapid progress in civil construction. The status of the infrastructure development was presented and is at a very good level.

7. **What would be MAC recommendations related to development of the project of NICA operation in polarized beams' mode?**

   For the moment there are many open questions in the concept of the NICA operation with polarized beams. The proposed system based on spin-rotating solenoids looks adequate, but a realistic scenario of the accelerator complex operation was not presented and the possibility to achieve the proposed high luminosity is an open issue. MAC advises to establish a special scientific group to deeply investigate the spin dynamics (including the spin tracking) as well as the strategy to obtain the designed high luminosity. The work on a concept of the NICA complex operation with polarized beam collisions should be intensified.

8. **And the last (not the least) question: How does MAC estimate the fulfillment by the NICA accelerator team the recommendations of the previous (October 2015) MAC meeting?**

   The majority of the recommendations were fulfilled. However, a number of important tasks have not been completed yet and a few recommendations were missing.

   Consequently, MAC requests the following items being presented on the next MAC meeting:

   For the next meeting the MAC expects reports on the barrier bucket system for accumulation with realistic barrier pulses, a concept for impedance reduction and feedback systems and the TDR on the entire stochastic cooling system.

   Particular attention should be paid to the technical solution (either additional octupoles incorporated in the multipole correctors or separate magnets) of the problem of the reduction of dynamic aperture due to fringe fields. Besides MAC expects a realistic scenario for operation with polarized beams including the time structure and the requirements to optics to achieve the proposed luminosity.

At the meeting opening, V. Kekelidze thanked B. Sharkov for his excellent work chairing the NICA-MAC meeting from the beginning of the MAC. B. Sharkov has to step down from the chair as he is now affiliated with JINR. V. Kekelidze also announced that it will be proposed to the Scientific Council that M. Steck will take over the chair of MAC.

MAC suggests that the MAC meetings should be organized not less than once per year. In addition, it will be fruitful to organize workshops on the dedicated issues of the NICA project, *e.g.* on the beam dynamics concerning the NICA collider and RF systems.

The first considerations related to the machine-detector interface were presented. This is a good starting point, but further activities have to follow. Independent measurements of beam positions for each of the two counter-propagating beams near the interaction point must be anticipated. The necessity of collimators right in front of the interaction point must be checked and the purpose and layout of these collimators must be defined. In addition, the collimation system aimed at the background reduction in the particle detectors should be introduced and specified.

MAC appreciates the efforts of the JINR directorate for consolidation of human and financial resources on the NICA project and supports this strategy.

MAC strongly recommends to the JINR directorate to look for additional contributions from other Russian institutes. Particularly the expertise of the Budker INP with respect to collider design and operation will be invaluable for the success of the project. Establishing clear lines of communication and responsibility of BINP is essential. Successful collaboration could be the starting point for common activities with respect to future mega-science projects.

MAC congratulates the JINR directorate on including the NICA project into the ESFRI Road Map and the promotion of the NICA to a Russian Federation Mega-science project.