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

October 19-20, 2015

Considerable progress in the NICA project development has been achieved since the previous MAC meeting two years ago. The MAC highly appreciates the results of the test bench investigations of the new heavy ion and polarized particle sources and first experimental results obtained from the heavy ion source in the Nuclotron run. The MAC congratulates the NICA team for completion of the new heavy ion linear accelerator construction, attaining the important mile-stones - the beginning of the superconducting magnet serial production and the beginning of the civil construction at the NICA site.

Concerning the answers to requests of the previous MAC meeting:

- MAC is satisfied with the proposed correction scheme for the collider resulting in an increase in the momentum acceptance up to ±1% and providing a vertical dispersion correction,
- The presented information about the specification of RF system, the feedback for beam loading compensation and the functional specification of the feedback systems for suppression of beam instabilities is incomplete,
- MAC is satisfied with the JINR team's arguments against employing of the turbines in the nitrogen liquefier and in the nitrogen refrigerators (re-liquefiers),
- A proposal for radiation protection at NICA was not presented,
- MAC believes that the org-chart presenting responsibilities of management team and the project chef engineer satisfies the present status of the project,
- MAC is satisfied with presented project schedule.

A number of important tasks have not been completed yet. Consequently, MAC requests the following items being presented on the next MAC meeting:

- a report on instabilities and cures, which has to be based on the CDR for feedback systems,
- a study of the effect of fringe fields in quadrupoles on the particle dynamics and possible ways of mitigation, if required,
- a report on the beam dynamics simulations with high order non-linear terms, which are already known from magnetic measurements,
- a report on simulations for the collider dynamic aperture accounting effects of the electron cooler, including estimates of possible ion loss during cooling, and limitations on the electron beam current related to reduction of recuperation efficiency due to single intrabeam scattering

(scattering in the "pancake" electron distribution resulting in large energy transfer from transverse to longitudinal degree of freedom),

- results of a self-consistent simulation for stochastic cooling, intrabeam scattering and electron cooling (when needed) in the collider, especially for short bunches,
- simulations of the particle dynamics in the collider injection chain (HILac – Booster – Nuclotron) taking into account the space charge effects and accounting for possible sources of particle loss,
- the design of the stripping target in the Booster-Nuclotron transfer line with an estimate of the emittance growth after passing it,
- presentation on a strategy of the accelerator complex operation in the polarized beam mode, which should include machine optics used for polarized beam and transition energy crossing,
- a report on the radiation protection system, including detailed description of the collider collimation and beam dump systems as well as means for the protection of detectors.

Answers of MAC on the JINR directorate charge letter

1. **How MAC does estimate, in general, the extent of project development and progress achieved since previous MAC meeting (injection complex, SC magnets, beam cooling systems, RF systems, vacuum system, diagnostics, control system, cryogenic system, design and construction workflow, CF&S, etc.)?**

   In general the progress is good however it is different in various areas. The MAC emphasizes an impressive progress in the injection complex development and preparations for SC magnet fabrication. The presented materials for the beam cooling systems are incomplete and are insufficient to prepare the CDR and TDR. The MAC recommends to write a dedicated note for E-cooling scenario, which has to examine the cooling of large amplitude particle, and the interplay between electron and stochastic cooling, as well as to study another location for the Stochastic Cooling kicker in one of the rings to avoid possible interaction between stochastic cooling systems of different rings through the Electron cooler. Concerning the RF system the MAC notes that the beam cooling and, consequently, accumulation become sensitive to imperfections in the voltage pulse of the Barrier Bucket RF system. The project management has to discuss with the contractor a necessity of beam based feedback system to correct a potential well and particle distribution. During R&D for the BB RF system the problem of the amorphous metal activation in the resonator should be investigated. MAC requests to present a dedicated report on the progress of the beam diagnostic development, including results of the Nuclotron operation. Additional attention has to be paid to different regimes of operation requiring different resolution times for beam current measurements ranging from ms for slow current detectors to fraction of ns for beam diagnostics dedicated to bunch phase, length and

shape measurements. The progress in the control system development is satisfactory, however an integration of the entire systems has to be analyzed and the results have to be presented to the MAC. The VBLHEP cryogenic complex is developing well. MAC appreciates the beginning of the collider building construction.

2. **How does MAC estimate progress on collider beam dynamic simulations, lattice design and questions of beam instabilities?**
   The progress in the lattice design for heavy ion mode is obvious. The analysis of the beam instabilities is not completed. Most important issues for further work in beam dynamics simulations are listed in the MAC requests to the next meeting.

3. **How does MAC estimate strategy of the collider operation at start-up configuration of the equipment? Does the proposed strategy provides required technical reserve to reach the luminosity of $5 \cdot 10^{25}$ $cm^{-2}s^{-1}$?**
   The proposed strategy of the collider operation looks reasonable. MAC cannot judge a technical reserve to reach the target luminosity on the base of presented material. The most significant problem is related to the technical details in beam cooling. To estimate the technical reserve to reach the target luminosity the MAC requests to present for the next meeting a report about ion cooling and accumulation, the machine – detector interface (MDI) including background consideration, collimation requirements, limitations for parasitic bunch intensity, performance of HILac, Booster and Nuclotron, concentrating on output bunch intensity and emittance. In addition, we believe that the documents such as "NICA Accelerator Complex Passport" should also list the key MDI requirements – this document would need to be updated to include the appropriate tables of parameters.

4. **How do MAC experts estimate proposed TDR of the collider Stochastic Cooling System, simulation and experimental results, technical feasibility of the SCS?**
   The presented materials are far from a real TDR. MAC requests to prepare specifications of all general elements of the SCS and present them within 4-6 months. The TDR has to be presented at the next MAC meeting.

5. **How do MAC experts estimate schedule for the Booster and injection complex construction and commissioning?**
   The proposed schedule for the Booster construction is reasonable. MAC is waiting for detailed schedule for the whole complex.

Are these risks recognized and addressed effectively in the R&D plan?

– Does the execution strategy NICA project meet the requirements of NICA project?

– What recommendations and modifications to the R&D program, strategy of would be effective?

– Are there other approaches, beyond those being explored in the NICA sub-projects R&D program that should be investigated as the front end of the NICA facility?

MAC strongly supports the staging of the collider commissioning. The proposed execution strategy meets the requirements of the NICA experimental program.

Most critical issues in the R&D program are:

- complicated technology of manufacturing of curved elliptic dipole vacuum chambers for ultrahigh vacuum conditions,
- design of the Booster – Nuclotron beam transfer line including the Booster fast extraction and the Nuclotron injection systems. The proposed technical solutions are reasonable but there is an obvious delay in design and prototyping.
- delay in the design phase for the collider RF2 and RF3 systems, the work should be started as soon as possible.

MAC did not find mistakes in the proposed technical solutions for the collider systems working in the heavy ion collision mode. MAC advises that the work on a concept of the NICA complex operation for the polarized beam collisions is to be intensified. MAC underlines the necessity to use the matrix response technique at the collider, its development and test at the Nuclotron is of great importance. R&D for HV e-cooling system must be more active and financially supported.

MAC appreciates the efforts of the JINR directorate for consolidation of human and financial resources on the NICA project and this strategy has to be continued. MAC strongly supports establishment of a specialized research group working on beam dynamics at NICA accelerators.

MAC appreciates efforts of the JINR directorate for including the NICA project into ESFRI 2016 and BRICS RI Road Maps, extension of NICA to a Russian Federation Mega-science project and to provide other additional funding.