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**Referee Report to the 52nd N.P. PAC at JINR:**

**"Improvement of the JINR Phasotron and design of cyclotrons**

**for fundamental and applied research”**

In the submitted report the status of the project is presented by Karamysheva G.A and Yakovenko S.L. The presentation is divided according to the 4 activities: 1) Improvement of the JINR Phasotron and beam channels; 2) Design and modernization of the cyclotrons for medical purposes; 3) Research and development of the superconducting cyclotron for proton therapy for IPP CAS; 4) Development of the cyclotron for high-current beam acceleration.

Ad. 1). The power supply system and beam tracts were improved, automatic control system for the transport line has been implemented, modern switching devices in the power supply replaced the old ones, other crucial elements of the Phasotron were modernized. This resulted in the power saving of ca. 900 kW. In the years 2016-2018 Phasotron operated ca. 1000 h per year, mainly for the medical research. In 2020 it is planned 500 hours operation time, mostly for radiobiological research.

Ad. 2). In this task the work done over many years on designs related to few cyclotrons intended for medical purposes is presented. As a model case the group presents the work done for the improvements of the AIC-144 cyclotron at IFJ PAN in Krakow, which was used for the eye cancer therapy from 2011 till 2016. The group achieved here the increase of the proton beam extraction coefficient from 19% till 34% (at the nominal beam energy of 60 MeV). In addition, the improvement of the quality of the extracted beam (beam spot size, energy dispersion), which resulted in the narrower Bragg peak spectrum. In addition, the group started a development of the magnets for the beam transport line for the AIC-144, for the possible future use of the IAC for the isotope production. Similar work was carried out for the U-120 cyclotron at Rez (Czech Republic), but here very little relevant details were given.

Ad. 3). This task, presently ongoing, shows the work done for the developments of the superconducting cyclotron SC202, to be operated in Hefei (China), and the copy if it will replace the Phasotron in Medico-Technical Center of JINR and will be used for the cancer proton therapy. The design of the cyclotron and simulations of all systems are finished, the engineering design is completed and each subsystem is manufactured and positively tested. Assembling, tuning and testing of the whole system are not yet performed, the delay is partly due to the coronavirus pandemic in China. The modification if the system for the use the Heifey cyclotron in Dubna was developed, differing mainly with the extraction scheme. The simulations for the modified system are in progress.

Ad. 4) The current developments for the high-current beam acceleration are reported. Three different approaches are considered: ProNova K230, Ionetix Ion-12SC (both in collaboration with the Ionetic Corporation in US) and Linac-200 (homemade). The pros and cons of the different solutions are investigated in detail (as documented in the report, but there are no yet the final conclusions which approach will be the optimal one.

**Recommendations:**

The report presented by the authors, with many details of the developments, shows clearly very high technical standards and world-class expertise of the group. There is no doubt that the project is in very good hands.

However, the report itself is somewhat made less professionally. It presents for example many highly professional drawings also the historical already achievements (even back to 1970), which of course is also interesting, but slightly diverts from the recent progress.

What is also slightly lacking in the document, is the clear presentation of the main goals of project, which for sure must exist.

Nevertheless, **the PAC very positively evaluates the progress and looks forward with great interest for the future developments.**