Referee report on the Project NOvA-DUNE (JINR participation)

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The report given to the Program Advisory Committee of JINR on 29 June 2020 outlines the activities of the JINR neutrino physics researchers on the NOvA and DUNE experiments in the USA, with the aim of a project extension for the years 2021-2023. This is the specific case for the running NOvA experiment, while DUNE is presented here for the first time.

Let's consider the case of NOvA first. Some of the most outstanding particle physics results obtained in the last two decades came from the study of neutrino oscillations, originally postulated by Bruno Pontecorvo. Experiments conducted with atmospheric and solar neutrinos, confirmed with man-made reactor and accelerator neutrinos, allowed us to build a coherent scenario pointing to neutrino mixing (PMNS matrix) and oscillations, the first indication of physics beyond the Standard Model of particles and interactions. NOvA is a running neutrino oscillation experiment in the USA along the NuMI neutrino beam from Fermilab. Two detectors (made of liquid scintillator calorimeters) are used, one at Ash River in Minnesota, 810 km from Fermilab, and another one only 1 km away from the neutrino production target.

So far, the science deliverables of the experiment have been excellent and concerned the understanding of the PMNS mixing matrix. The JINR group started their activities in 2014 (approved project in 2015). Presently, the NOvA experiment and the NuMI beam performed extremely well: the Fermilab accelerator complex is delivering (anti)neutrinos with the record power of 700 kW. This has allowed the experiment to collect 8.85×10^{20} p.o.t. and 12.33×10^{20} p.o.t., respectively, for the neutrino and antineutrino exposures. Much more is expected by 2025, also thanks to a beam power upgrade up to 900 kW. With the full statistics the experiment is eventually expected to contribute in narrowing down the allowed parameter space for both the neutrino mass hierarchy (with some chances, even a measurement) and the CP violating phase in the PMNS matrix. In addition, the proponents are planning a long series of detector technology studies and side physics subjects, such as e.g. monopole searches.

Among the contributions of the JINR group, we can highlight the realization in Dubna of the Remote Operation Center (ROC-Dubna), which allows the JINR researchers to participate in the data taking and quality monitoring of the detector located in USA. The local computer infrastructure of NOvA based on GRID and Cloud technologies is also being used by the international collaboration. Last but not least, both the JINR electronics and scintillator test benches provided inputs to simulations and calibration tasks. The JINR group will also be involved in several data analyses (in addition to the above-mentioned monopole searches) such

as PMNS matrix studies and near detector physics.

The other notable aspect of this proposal is the involvement of the group in the DUNE experiment also in the USA, currently in its preparation phase. This internationally born project can be considered the ultimate neutrino oscillation detector/observatory, with a scale comparable to that of the LHC experiments and a similar cost (~$2.5 billion), to be operated after the completion of the NOvA data taking (2026-2027). The setup includes four very large liquid argon TPCs placed underground at the SURF laboratory in South Dakota, hit by a neutrino beam produced thanks to the new PIP II accelerator at Fermilab. The large mass of the far detector (altogether nearly 70000 tons of liquid argon) will also provide sensitivity to a series of astrophysics subjects. The main goal of the project, however, is the discovery of the CP violating phase in the PMNS matrix and of the neutrino mass eigenstates hierarchy. The far experimental apparatus (~1300 km away from the neutrino source), as in the case of NOvA, is complemented by a near detector (ND) on the Fermilab site. This will be also centered around a liquid argon TPC detector of novel implementation (the ArgonCube concept), for which the JINR group is working from the early times with excellent results and strong commitment, despite the political issues affecting the participation in person to activities in USA. The group is actually responsible for the realization of the light detection system based on two similar approaches, one of the two proposed, devised and developed by JINR.

As a whole, the strategy of the group is sound: exploit the investments and the experience with NOvA in order to gather important scientific results by 2025, and adiabatically increase the effort on DUNE, a very large international collaboration expected to have a lifetime of 2 decades at least. The group includes now 37 heads for a total number of 21.2 FTEs. The average age of the team is adequate, being ~35 years. The total number of young people is good, with altogether 5 students and 14 young researchers. A crucial issue is to have already by now a sound planning for the activities of both projects and a clear subdivision of the efforts between the group members as a function of time, as far as the two experiments are concerned. The construction activities for DUNE, in fact, are already underway, e.g. concerning the large scale ArgonCube prototype (the 2x2 demonstrator) which is going to be assembled and operated at Fermilab starting from 2021, and the advanced design of the final ND device. The referee expresses two main worries: 1) FTE's at the level of 10% must be avoided for this kind of projects; 2) There is quite some overlap between the participation in the USA neutrino program and the one in JUNO. The complexity of both projects and the very different experimental techniques makes this choice unnatural and not optimal. Some corrective actions must be taken soon for both the above issues, also in the light of the consolidation of the responsibilities in the long-term DUNE/LBNF effort.

Very recently, after submission of this document, the JINR group has been formally accepted by the DUNE collaboration as a new member and has also joined the international consortium whose scope will be the realization of the liquid argon TPC for the ND complex. Last but not least, the

referee believes that, given the nature of the DUNE experiment, the JINR group should play the role of bridgehead in view of the future joining of more Russian groups. The project is so large that small-sized participations of individual groups do not produce the required visibility to the proponents. With this in mind, an increase of the number of heads and mostly of the number of large FTE fractions is required. Furthermore, the JINR directorate could identify if a contribution to the Fermilab neutrino beam facility (LBNF), as well as to the large infrastructure at SURF can be envisioned. This is rather natural for a large laboratory such as JINR, in the same line of what has been done (or pledged) by other major international players. One could think of bilateral agreement plans, as being currently done by different countries/labs/institutions.

As a conclusion, the referee welcomes the continuation of the NOvA project and of this new JINR initiative on DUNE, once again stressing that the effort must be commensurate to the size and the complexity of the scientific enterprise and not on the present consistency of the group. Lacking that, the participation of JINR risks not to be sufficiently relevant and rewarding.

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