Feedback of referee H. Mkrtchyan on the NA64 project "The search for Light Dark Matter (LDM) and manifestations of physics beyond the SM at the extracted beams of the CERN SPS and PS accelerators" (extension of NA64)

The NA64 experiment at the CERN Super Proton Synchrotron (SPS) is a fixed-target, high-sensitivity experiment searching for light, sub-GeV Dark Matter (DM) and other dark sector particles that could act as mediators between visible and dark matter. NA64 are using electron, positron, muon and hadron beams to produce missing energy signatures, it aims to detect dark photons (A') or other dark bosons.

Among the most important achievements of the NA64 experiment are: **"Search for mediated A' Light Dark Matter (LDM) Photons", "Search for a new X(16.7 MeV) gauge Boson", "A model-independent search for axion-Like Particles",** and other Beyond Standard Model (BSM) physics.

The NA64 experiment has proven its ability to handle high-intensity electron and positron beams with robust background control, which was a key concern for the "missing energy" technique. In the e–/e+ program at H4, prototype tests and simulations demonstrated and motivated the development of a Veto Hadron Calorimeter. The positron data enabled exclusions of light dark matter in new mass ranges. In the muon program at M2, setup upgrades and higher intensities yielded an eightfold increase in efficiency and significantly reduced backgrounds.

The NA64 experiment at CERN is a highly effective, complementary, and innovative fixed-target experiment aimed at searching for physics in the dark sector. It is widely recognized for its ability to place world-leading constraints on light dark matter (LDM) and dark photons, particularly by providing a near-background-free environment.

The NA64 is praised for its ability to uniquely combine missing-energy and missing-momentum techniques with CERN SPS beamlines, delivering results that cannot be achieved elsewhere on the same timescale and are not easily reachable by high-energy collider experiments. It has obtained world-leading limits on light dark matter in the MeV–GeV range, significantly reducing the available parameter space for LDM models.

Results show that NA64 provides constraints on dark photons and light dark matter that are more stringent than those derived from traditional beam-dump experiments and neutrino-electron scattering in certain mass ranges.

The 2026 status report indicates that detector upgrades (such as improved hermeticity and new calorimeters) are successfully addressing potential limitations for the

post-LS3 (Long Shutdown 3) era, allowing for even higher sensitivity. The expansion of the experiment to use the M2 muon beam (NA64μ) to look for mediators has been welcomed as a critical step in addressing the anomaly.

Overall, the NA64 is performing remarkably well, delivering significant results, and is prepared to continue its "world-leading" search into the next phase. The successful results ensure that the NA64 experiment remains at the forefront of searching for dark photons and light dark matter in the sub-GeV mass range. As of late 2025, the NA64 experiment at CERN is delivering world-leading constraints on light dark matter (LDM) and dark sector particles, with over $2.5 \times 10^{12} e^-$, $\sim 2.4 \times 10^{10} e^+$, 3.5×10^{11} μ, and $\sim 1.4 \times 10^{10} \pi^-$ on target. Key results of NA64 include new limits from positron-beam resonant production (40/70/100 GeV), improved muon-beam (160 GeV) sensitivity, and ongoing 2023–2025 analysis.

Based on the search results of NA64 experiment from 2017 to 2025, its proposed extension, and the work planned for the future, my opinion is very positive. The achievements of these years confirmed that with additional beam-time and modest investment NA64 will continue to operate as a world-leading experiment after LS3, delivering results that cannot be achieved anywhere else in the world within this timescale. The project's continuation for 2027-2031 includes modernization of detectors and electronics, and the continuation of data accumulation after the third long-shutdown of the accelerator complex CERN. It is planned to accumulate statistics of 2 $\sim 10^{13}\, e^-$and $\sim 10^{11} e^+$on target (at energies 40 and 60 GeV), and $\sim 2 \times 10^{13}$ mesons on target, which will significantly expand the kinematic region of the studied parameters of the LDM and manifestations of new physics beyond the standard model (BSM). The requested financial and human resources for the project implementation are justified.

Considering the large volume of work involved in fulfilling JINR's obligations and the global significance of the expected results, I believe that the requested amount of funding is fully consistent with the goals and objectives of the project.

I fully support the extension of the NA project “The search for Light Dark Matter (LDM) and manifestations of physics beyond the SM at the extracted beams of the CERN SPS and PS accelerators”and propose to approve it and its funding for 2027-2031.

Hamlet Mkrtchyan,
Doctor of Phys.-Math. Sciences,
Leading scientist,
A.I. Alikhanyan National Science Laboratory
(Yerevan Physics Institute) Foundation.