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Proposal from the NA61/SHINE Collaboration for the update of the European Strategy for Particle Physics

Building on the current program's success and driven by new physics challenges, the NA61/SHINE Collaboration proposes to continue measuring hadron production properties in reactions induced by hadron and ion beams after CERN Long Shutdown 3. These measurements are of significant interest to the heavy-ion, cosmic-ray, and neutrino physics communities and will focus on:

- (i) Investigating hadron production in the light-ion systems to explore the diagram of high-energy nuclear collisions, and to obtain new insight into the unexpected violation of isospin (flavour) symmetry recently observed by the experiment.
- (ii) Measuring charm–anti-charm correlations to gain unique insights into the production locality of charm and anti-charm quark pairs.
- (iii) Examining strangeness and multistrangeness production to improve our understanding of the early Universe's evolution and neutron star formation.
- (iv) Measuring cross-sections relevant for cosmic-ray measurements, significantly boosting searches for new physics in our Galaxy.
- (v) Conducting hadron production measurements with proton, pion, and kaon beams for neutrino physics, enhancing the precision of hadron production data needed for initial neutrino flux predictions in neutrino oscillation experiments.
- (vi) Measuring hadron production processes relevant for understanding the flux of atmospheric neutrinos as well as neutrinos and muons from spallation sources.

To achieve these objectives, a detector upgrade and a beam upgrade are required, with data-taking planned for the period 2029–2032 and beyond.

Authors: RYBICKI, Andrzej Krzysztof (Polish Academy of Sciences (PL)); ZIMMERMAN, Eric Daniel (University of Colorado Boulder (US)); STEPANIAK, Joanna Maria (National Centre for Nuclear Research (PL)); STEPANIAK, Joanna (NCBJ, Warsaw); GREBIESZKOW, Katarzyna (Warsaw University of Technology (PL)); GREBIESZKOW, Katarzyna (Warsaw University of Technology (PL)); TURKO, Ludwik (University Wroclaw); TURKO, Ludwik (University of Wroclaw (PL)); MACKOWIAK-PAWLOWSKA, Maja (Warsaw University of Technology (PL)); GAZDZICKI, Marek (Jan Kochanowski University (PL)); UNGER, Michael; UNGER, Michael (Karlsruhe Institute for Technology); VON DOETINCHEM, Philip (University of Hawaii at Manoa); ADRICH, Przemyslaw (National Centre for Nuclear Research (PL)); ADRICH, Przemyslaw (National Centre for Nuclear Research); KOWALSKI, Seweryn (University of Silesia (PL)); PULAWSKI, Szymon (University of Silesia (PL)); PULAWSKI, Szymon (University of Silesia); NAGAI, Yoshikazu (Eötvös Loránd University (HU))