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High-sensitivity searches for matter-antimatter conversions at the European Spallation Source

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The HIBEAM/NNBAR program is a proposed two-stage experiment at the European Spallation Source (ESS) to search for baryon number violation [1]. The goal of the program is to produce new insights into the origins of baryogenesis by performing searches for neutron–antineutron oscillations, increasing the sensitivity by three orders of magnitude compared with the previously established limit from the Institut Laue-Langevin (ILL) [2].

The first stage of the program, HIBEAM (High-Intensity Baryon Extraction and Measurement), will utilize the fundamental physics beamline during the early stages of ESS operation [3]. It represents the first search for neutron to antineutron oscillations at a spallation source. Already in this stage, searches with world-leading sensitivity can be conducted. The neutron extraction system for this project is currently under construction and expected to be installed at the ESS next year.

NNBAR will make use of the Large Beamport in the ESS target station monolith, specifically designed for this experiment. Apart from unprecedented intensities of slow neutrons, the experiment requires a magnetically shielded beamline, novel neutron reflectors and a state-of-the-art detector system to reach its sensitivity goal. The annihilation detector needs to be able to identify the multi-pion final state produced in the annihilation of an antineutron in a carbon target. The Conceptual Design Report of the experiment has recently been published [4].

A general overview over the HIBEAM/NNBAR program will be given and the current status of both experiments as well as their beamline and detector designs will be presented.

[1] A. Addazi et al., New high-sensitivity searches for neutrons converting into antineutrons and/or sterile neutrons at the HIBEAM/NNBAR experiment at the European Spallation Source, J. Phys. G: Nucl. Part. Phys., 48, 070501 (2021).
[2] M. Baldo-Ceolin et al., A New experimental limit on neutron - anti-neutron oscillations, Z. Phys. C, 63, 409-416 (1994)
[3] V. Santoro et al., The HIBEAM program: search for neutron oscillations at the ESS, arXiv:2311.08326
[4] V. Santoro et al., HighNESS Conceptual Design Report, arXiv:2309.17333 (Accepted by Journal of Neutron Physics)

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