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The NNBAR Experiment: A Search for Free Neutron–Antineutron Oscillations

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The European Spallation Source (ESS), currently under construction in Lund, Sweden, will become the world's most powerful neutron research facility. The proposed NNBAR experiment aims to perform the first search in over three decades for free neutron–antineutron oscillations. Such a transformation would constitute direct evidence of baryon number violation, a phenomenon anticipated by several extensions of the Standard Model and a key component for explaining the observed matter–antimatter asymmetry of the Universe. NNBAR is designed to improve the sensitivity to free neutron-antineutron transitions by over three orders of magnitude. This leap is enabled by the high-intensity cold neutron beam from a liquid deuterium moderator, a 200-meter magnetically shielded beamline held below 10 nT, and a carbon annihilation target. The surrounding annihilation detector, combining a time projection chamber, calorimetry, and cosmic veto systems, is optimised for detecting the distinctive multi-pion annihilation signature with high efficiency and full background rejection. Supported by an INFRADEV design study from the European Commission, a conceptual design report for the experiment has been delivered [1], demonstrating its feasibility and possible integration into the ESS infrastructure. In this talk, I will describe the scientific motivation behind the search for neutron–antineutron oscillations, the experimental strategy and design choices of NNBAR, and the simulation-driven performance estimates that demonstrate its potential. I will also outline the next steps toward realisation of this flagship fundamental physics experiment at ESS. [1] V. Santoro et al. HighNESS conceptual design report: Volume II. The NNBAR experiment. Journal of Neutron Research. 2024;25(3-4):315-406. doi:10.3233/JNR-230951

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