Contribution ID: **82** Type: **invited presentation**

Particle physics possibilities at the ESS

Thursday 11 September 2025 09:30 (30 minutes)

The European Spallation Source (ESS), currently under construction in
Lund, Sweden, will soon become the world's most powerful pulsed neutron
source and simultaneously the brightest pulsed neutrino source. Its unique capabilities open unprecedented opportunities for a precision particle physics program, complementing other facilities worldwide. Neutron sources, when combined with precision measurements and theoretical insight, can probe energy scales far beyond those accessible at the LHC or even future high-energy colliders. In January 2025 [1], a dedicated workshop at Lund University surveyed the landscape of ongoing and planned experiments at neutron sources, providing strategic input for the European Strategy Update.
Among the most ambitious initiatives, the HIBEAM/NNBAR collaboration
proposes a two-stage experimental program to investigate baryon number violation and other manifestations of physics beyond the Standard Model [3]. The first phase, HIBEAM (High-Intensity Baryon Extraction and Measurement), will operate as the fundamental physics beamline during the early phase of ESS operation. It is designed to explore a broad range of phenomena, including neutron–antineutron ($n \longrightarrow \bar{n}$) oscillations, transitions to sterile neutrons potentially connected to a hidden dark sector, axion-like particle (ALP) searches, as well as searches for a non-zero neutron electric dipole moment (EDM) and non-zero neutron charge [2]. This will mark the first-ever $n \longrightarrow \bar{n}$ search at a spallation source, with world-leading sensitivity, and will serve as a pilot for the second phase, NNBAR. The second stage, NNBAR, will exploit a large dedicated beam port in the ESS target station monolith. Its goal is to improve the current $n \longrightarrow \bar{n}$ sensitivity by three orders of magnitude compared to the previous limit set at the Institut Laue-Langevin (ILL) [4]. The observation of neutron to antineutron oscillations, violating baryon number B by two units, would have profound implications for open questions in fundamental physics, including the origin of the matter-antimatter asymmetry, the unification of forces, and the nature of neutrino mass.
To achieve this sensitivity, NNBAR will employ a state-of-the-art annihilation detector, highly efficient magnetic shielding, advanced neutron reflectors,and a novel moderator system optimized to maximize the flux of cold neutrons.The Conceptual Design Report for the experiment was delivered through the HighNESS project [5], funded by the European Framework for Research and Innovation Horizon 2020.
In this talk, I will present an overview of the proposed experimental program at the ESS, focusing on fundamental neutron and neutrino physics, with particular emphasis on recent developments in the HIBEAM and NNBAR projects.
References
[1] H. Abele, J. Amaral, W. R. Anthony, L. AAstrand, M. Atzori Corona,
S. Baessler, M. Bartis, E. Baussan, D. H. Beck and J. Bijnens, et al.
[arXiv:2506.22682 [nucl-ex]].
[2] V. Santoro, D. Milstead, P. Fierlinger, W. M. Snow, J. Amaral, J. Barrow, M. Bartis, P. Bentley, L. Bj¨ork and G. Brooijmans, et al. J. Phys.
G 52 (2025) no.4, 040501 doi:10.1088/1361-6471/adc8c2 [arXiv:2311.08326
[physics.ins-det]].
[3] 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).
[4] M. Baldo-Ceolin et al., A New experimental limit on neutron - anti-neutron oscillations, DFPD-94-EP-13,

Z. Phys. C, 63, 409-416 (1994)
[5] V. Santoro, O. Abou El Kheir, D. Acharya, M. Akhyani, K. H. Andersen, J. Barrow, P. Bentley, M. Bernasconi, M. Bertelsen and Y. Beßler, et al. J.Neutron Res. 25 (2024) no.3-4, 315-406 doi:10.3233/jnr-230951

Authors: MILSTEAD, David (Stockholms Universitet); SANTORO, Valentina (ESS)

Presenter: MILSTEAD, David (Stockholms Universitet)

Session Classification: Session