

Searches for baryon number violation via neutron conversions at the European Spallation Source (ESS)

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Motivation of the HIBEAM/NNBAR experiment

- Conservation of Baryon Number is a result of an accidental global symmetry at perturbative level
- At non-perturbative level, baryon number, as well as the lepton number are not conserved, while the quantity $B - L$ is exactly conserved
- In cosmology, Baryon Number Violation (BNV) is needed by inflation model and baryogenesis
- BNV is also a key ingredient in many Beyond Standard Model theories (e.g. GUT, SUSY, extra dimensions)
- Observing BNV would be of fundamental significance

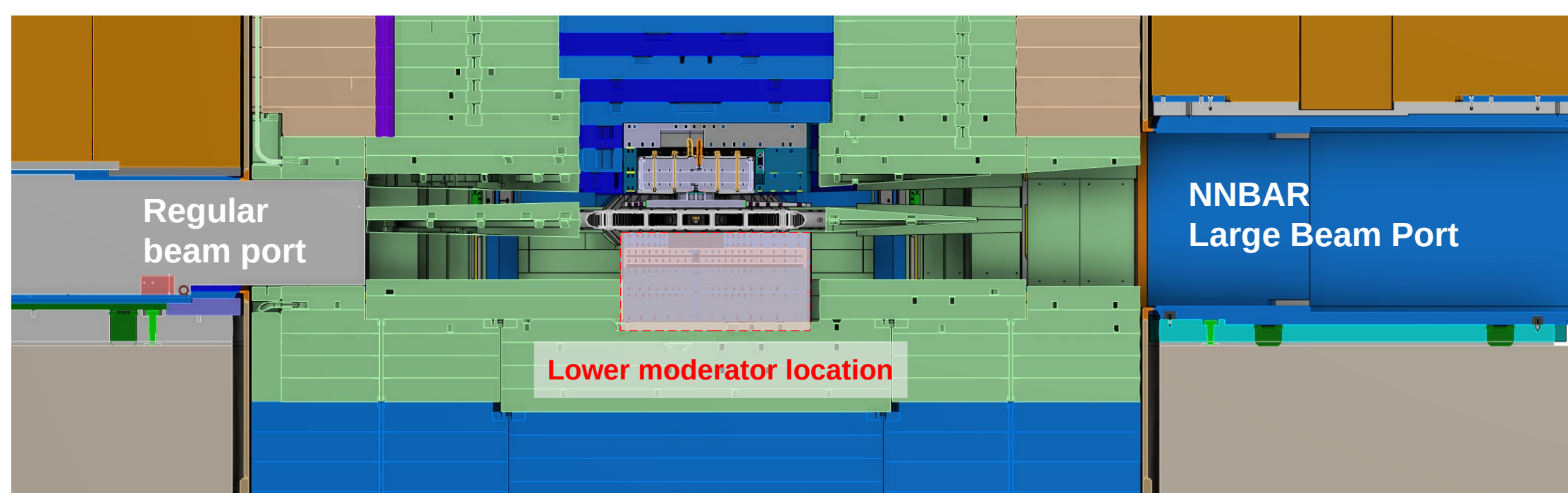
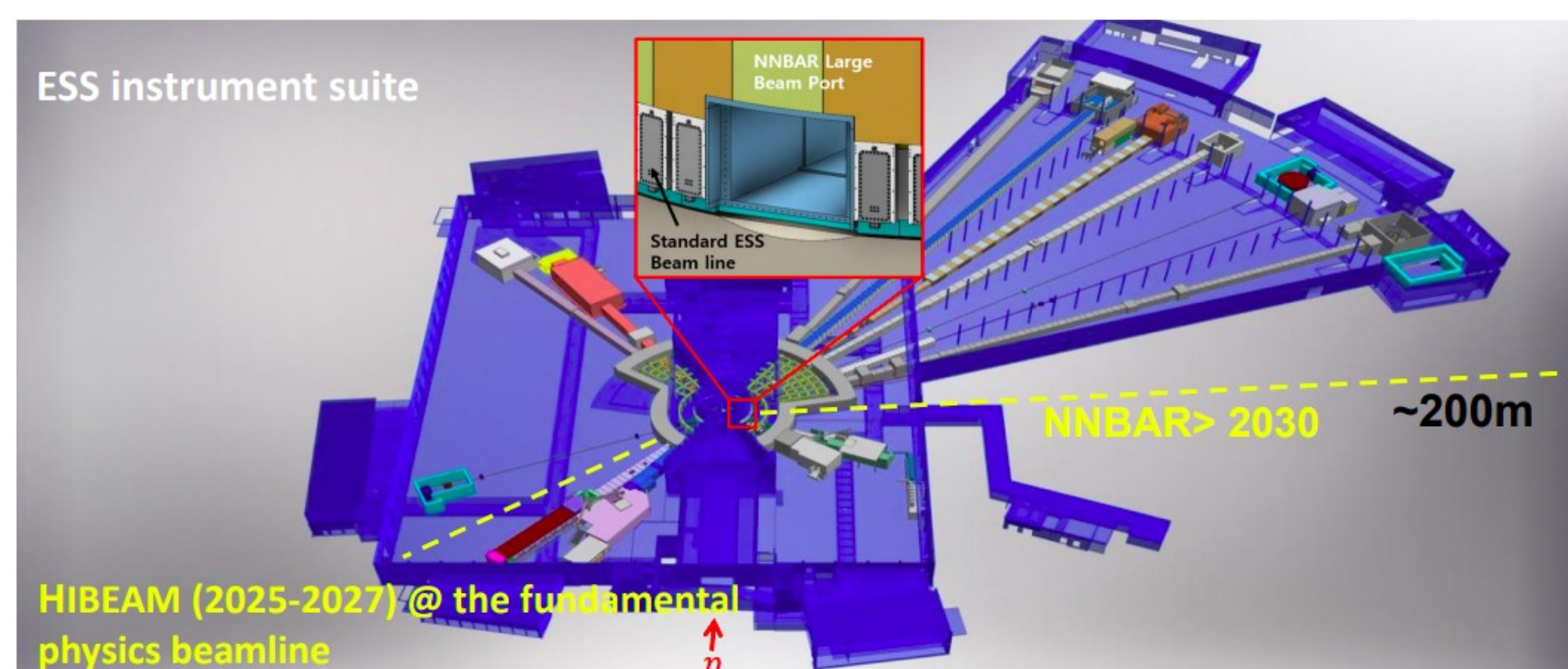
Free Neutron Oscillations Searches at the ESS

- A two stage experiment, HIBEAM/NNBAR, is proposed for the ESS
- J.Phys.G 48 (2021) 7, 070501 100 authors and supporters from 50 institutes in 8 countries).
- **Phase I - HIBEAM experiment** (≥ 2025)
Use cold neutrons from [ANNI fundamental physics beam line](#)
Smaller program of complementary experiments
Search for search for neutron to sterile state $n \rightarrow n'$ ($|\Delta B|=1$)
- **Phase II - NNBAR experiment** (> 2030)
Use cold neutrons from the [Large Beam Port](#)
Search for $n \rightarrow \bar{n}$ oscillations ($|\Delta B|=2$)
1000 times increase in sensitivity compared to the last free neutron search done at the Institut Laue Langevin

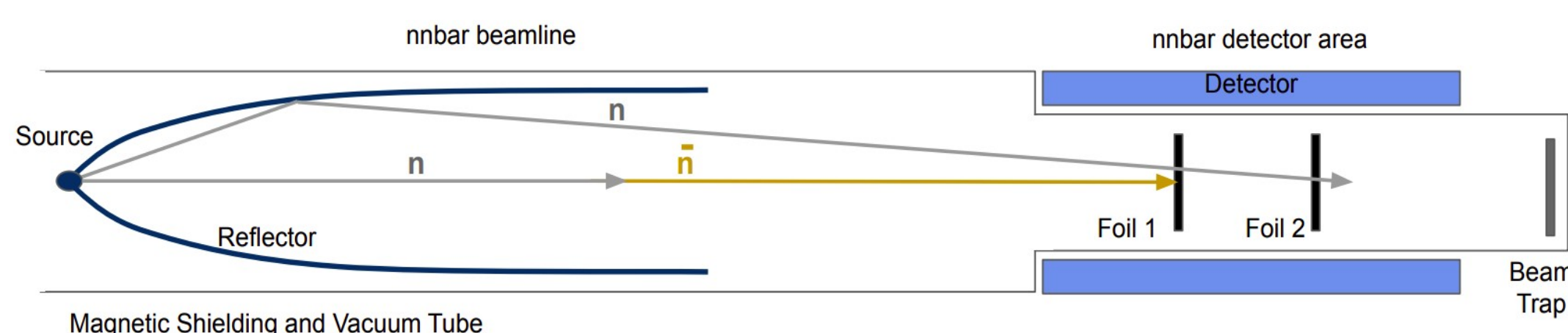
HighNESS project at the ESS

HighNESS

- The HighNESS project is funded by the European Union Framework Program for Research and Innovation Horizon 2020
- The project aims at developing a high intensity cold moderator for applications including the NNBAR experiment
- The Liquid deuterium lower moderator that will serve a UCN moderator and a VCN source using advanced reflectors
- Associated instruments will also be developed. The future instruments will complement the available instrument suite at the ESS
- Design driven by needs of condensed matter (neutron spin echo, SANS, and imaging) and fundamental physics (NNBAR + UCN/VCN applications)

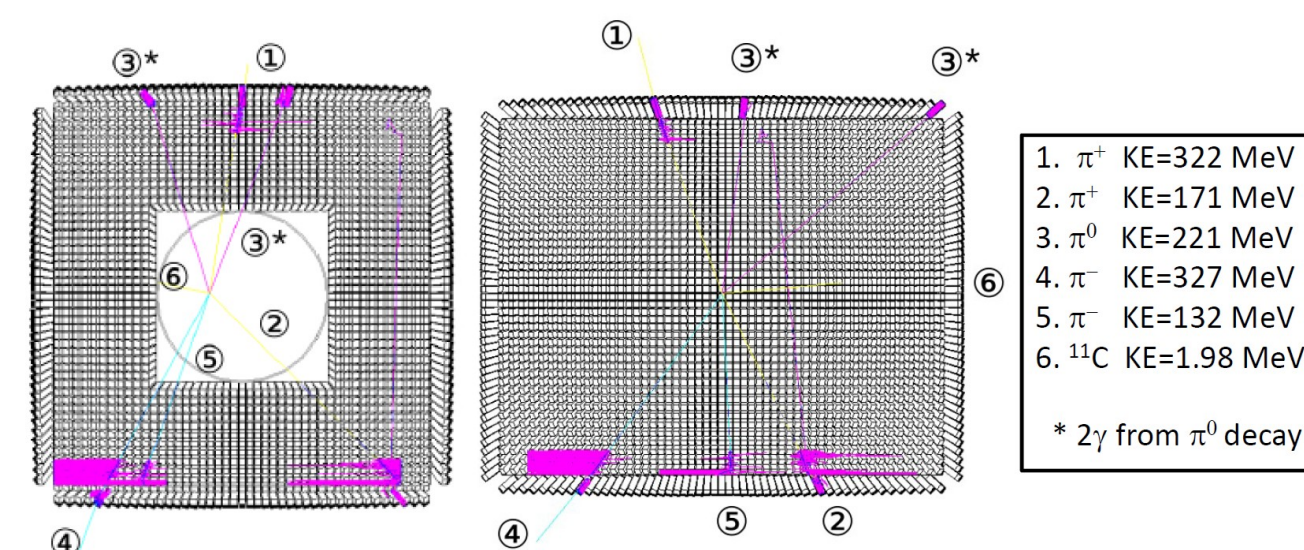


Setup and goal of the NNBAR experiment



- Claim a discovery of annihilation event between antineutron and neutron at the carbon foil target
- Annihilation event at the C foil target would generate:
On average 4~5 pions, including π^0 which decays immediately to 2 gammas
- Invariant mass of the final state ~ 1.88 GeV (2 neutron masses)
- Early detector design of lead-glass and scintillator calorimeter and time projection chamber for tracking is being studied

NNBAR full detector simulation studies



- Detector simulation done by GEANT4
- Different detector components have been studied systematically

NNBAR calorimeter prototype studies

- Calorimeter prototype will soon be built in Stockholm University
- Validate energy and angular resolution - benchmark against sampling calorimeter

