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The SuperNEMO Demonstrator: a unique technology for high-precision measurements of $\beta\beta$ -decay modes

There are still many open questions in understanding the nature of neutrinos, the most abundant matter particles in the Universe. Experimental neutrino physics is focused on measuring neutrino properties, such as absolute mass scale, the nature of neutrinos (Majorana or Dirac), and the possible violation of symmetries such as charge-parity and lepton-number conservation.

Neutrinoless double-beta decay ($0\nu\beta\beta$) is a hypothesized lepton-number-violating process whose discovery would have profound consequences for our understanding of neutrinos. Its half-life is directly dependent on the currently unknown neutrino coupling arising from beyond-the-Standard-Model physics involving Majorana neutrinos. The discovery of $0\nu\beta\beta$ is currently the only known way to prove the neutrino's Majorana nature.

The biggest challenge in searching for any rare process (such as $0\nu\beta\beta$) is separation of signal from potential backgrounds. SuperNEMO is searching for $0\nu\beta\beta$ using a unique tracker-calorimeter detector, which tracks individual particle trajectories and energies, enabling sophisticated particle identification and associated background rejection. This full topological reconstruction allows access to observables that are not accessible to other experiments in the field, such as the angle between the two electrons emitted in $\beta\beta$ decay and individual particle energies, opening the possibility to precisely study nuclear processes hidden to other technologies. SuperNEMO is able to search for $0\nu\beta\beta$ to excited nuclear states, as well as some of its more exotic modes, such as $0\nu\beta\beta$ with involvement of Majoron or right-handed weak current.

To further ensure ultra-low backgrounds, the SuperNEMO Demonstrator is placed at LSM (Underground Laboratory in Modane, France), and is protected with gamma and neutron shielding and an anti-radon tent flushed with radon-free air. The SuperNEMO Demonstrator has been collecting data since April 2025, using a 6.1 kg Se-82 $\beta\beta$ source. Its goal is to demonstrate the possibility of a future fully topological detector, with similar sensitivity to next-generation experiments, that is background-free in the $0\nu\beta\beta$ ROI and can be used to determine the $0\nu\beta\beta$ mechanism in the event of discovery. In addition, the Demonstrator has a rich physics program of its own, searching for exotic $0\nu\beta\beta$ decays and precisely studying $2\nu\beta\beta$ decay mechanisms.

The presentation is dedicated to the introduction of the SuperNEMO technology, its unique features and its physics goals.

Secondary track

T09 - Beyond the Standard Model

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