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The first neutrino mass measurement of HOLMES experiment

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HOLMES collaboration

The determination of the absolute neutrino mass scale remains a fundamental open question in particle physics, with profound implications for both the Standard Model and cosmology. The only model-independent method for measuring the neutrino mass relies on the kinematic analysis of beta decay or electron capture (EC) decay, assuming only momentum and energy conservation. Embedding the radioactive source inside the detector ensures that all the energy is measured except the fraction carried away by the neutrino, minimizing the systematic uncertanties. Such calorimetric approach is chosen by the HOLMES experiment.

The HOLMES experiment investigates the EC decay of ^{163}Ho using an array of ion-implanted transition-edge sensor (TES) microcalorimeters. These superconducting devices operate in the transition region between resistive and superconducting states at temperatures around 100 mK. Each TES is coupled to an ^{163}Ho implanted gold absorber. The temperature rise following an interaction is proportional to the deposited energy. The readout system is based on microwave SQUID Multiplexing (μMUX), enabling the simultaneous monitoring of multiple detectors with minimal cabling.

During the first phase, Holmium was successfully implanted into an array of 48 detectors, with an activity ranging from tens of mBq to 0.6 Bq, with an average value of 0.27 Bq, constituting the first prototype of the final detector system. The total activity was approximately 15 Bq. Two physics runs, each lasting two months, produced a high-statistics calorimetric spectrum of ^{163}Ho. Data-taking periods ranged from two to five consecutive days, with a duty cycle of 82\% and a discarded event rate below 1\%. HOLMES achieved an average energy resolution of 6 eV FWHM.

We present the most stringent bound on electron neutrino mass obtained with a scalable low temperature microcalorimeter array by the HOLMES experiment. Over two months, with a total of 7×10^7 decay events, we set a Bayesian upper bound on the effective electron neutrino mass of $m_\beta < 27$ eV/c^2 at 90\% CI.

The results on the neutrino mass limit confirm the feasibility of ^{163}Ho calorimetry for next-generation neutrino mass experiments and highlight the potential of a TES-based approach to push the sensitivity of direct neutrino mass measurements beyond the current state of the art. The scalability of this technique enables larger arrays with enhanced statistics, paving the way for sub-eV sensitivity. During the next phase of the experiment we aim to scale up the detector arrays, optimize the readout, and enhance the implantation efficiency.

Neutrino Properties

direct neutrino mass

Neutrino Telescopes & Multi-messenger

Neutrino Theory & Cosmology

Data Science and Detector R&D

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