T 75: Neutrino physics without accelerators VI

Time: Thursday 16:30–19:05 Location: H-HS XIII

Group Report T 75.1 Thu 16:30 H-HS XIII

The Electron Capture in ^{163}Ho Experiment — •Arnulf Barth for the ECHo-Collaboration — Kirchhoff Institute for Physics, Heidelberg University

The goal of the Electron Capture in ^{163}Ho (ECHo) experiment is the determination of the electron neutrino mass by analyzing the electron capture (EC) spectrum of ^{163}Ho. Metallic magnetic calorimeters operated at low temperatures, in which the ^{163}Ho has been implanted, present the best performance to conduct a high resolution and low background calorimetric measurement of the ^{163}Ho EC spectrum. During the first phase of the experiment, ECHo-1k, the detector production and the implantation process of a high purity ^{163}Ho source have been optimized. Additionally, large detector arrays have been developed, reaching an energy resolution below 5 eV and featuring an activity of about 1 Bq per pixel. High statistics and high resolution ^{163}Ho spectra have been acquired and analyzed in light of the newly developed theoretical description of the spectral shape, considering the independently determined value of the energy available to the EC process, Q_{EC}, and a dedicated background model. In this contribution, we present preliminary results obtained in the first phase of ECHo. At the same time, we discuss the necessary upgrades towards the second phase of the experiment, ECHo-100k.

T 75.2 Thu 16:50 H-HS XIII

Room Temperature and mK Characterisation of ECHo-100k MMC Array Chip — •Tom Wickenhäuser for the ECHo-Collaboration — Kirchhoff-Institute of Physics, Heidelberg University, Germany

The ECHo experiment is designed to determine the effective electron neutrino mass by the analysis of high resolution and high statistics ^{163}Ho electron capture spectra. The calorimetric measurement of the ^{163}Ho spectrum is performed using large arrays of low temperature metallic magnetic calorimeters (MMCs) hosting ^{163}Ho in the absorber and operated at mK temperature. For the ECHo-100k phase about 12000 detectors need to be operated. For a succesful integration of single array chips in the experiment we are developing a process to characterize the functionality of each detector without the need of measurements at mK temperatures. The idea is to find a correlation between resistance measurements of individual leads of a chip at room temperature and the performence at 4K and mK. The most important point is to ensure a reliable heat switching to insert a persistent current in the detector array. We discuss the result of the resistance measurements in correlation with the test performed at low temperatures and conclude with giving the reliability of the room temperature measurement for identifying working detectors.

T 75.3 Thu 17:05 H-HS XIII

Results of the First Neutrino Mass Measurement at the KATRIN Experiment — •Martin Slezák for the KATRIN-Collaboration — Max Planck Institute for Physics, Munich, Germany

The **Ka**rlsruhe **Tri**tium **N**eutrino (KATRIN) experiment aims to search for the effective electron antineutrino mass with a sensitivity of 0.2 eV/c^2 (90 % C.L.) from the shape of the tritium β-decay electron energy spectrum.

The first measurement campaign in KATRIN dedicated to the neutrino mass took place in Spring 2019 with about 22 % of the nominal tritium activity. The goal of this pilot measurement was to reach an improved sensitivity compared with the existing results while establishing a robust bias-free analysis and good initial understanding of systematic effects. Different analysis techniques were developed independently to further support the robustness of the result.

This talk presents the high-level analysis of the first neutrino mass data at KATRIN from which an upper limit of 1.1 eV/c^2 (90 % C.L.) was derived. The performance of the apparatus will also be discussed in detail. Besides, an overview of the analysis strategies and experimental systematic effects will be given.

T 75.4 Thu 17:20 H-HS XIII

Analysis of First KATRIN Neutrino Mass Data using Monte Carlo Propagation — •Christian Karl for the KATRIN-Collaboration — Max-Planck-Institut für Physik — Technische Universität München

The KATRIN experiment is designed to measure the effective electron anti-neutrino mass m_ν by investigating the energy spectrum of tritium beta-decay. The first neutrino mass measurement took place in spring 2019. For this first period, the source activity was set to about 22 % of the nominal value and around two million electrons were collected in the region of interest. This corresponds to an effective measurement time of five days at full source activity. Nevertheless, this data was used to improve existing laboratory limits and allowed to advance the analysis tools for forthcoming high-statistics data sets.

This talk presents one of the analysis strategies pursued which is based upon Monte Carlo propagation of uncertainties. A fit to the data including all dominant systematic effects leads to a best-fit value of $m_\nu^2 = -1.0^{+0.9}_{-1.1}\,\mathrm{eV}^2$. From this we derive an upper limit of $m_\nu < 1.1\,\mathrm{eV}$ at 90 % confidence level using the sensitivity limit method of Lokhov and Tkachov.

T 75.5 Thu 17:35 H-HS XIII

ECHo - A ^{163}Ho spectrum and a bit of theory — •Clemens Velte for the ECHo-Collaboration — Kirchhoff Institute for Physics, Heidelberg University

The ECHo experiment belongs to the group of direct neutrino mass experiments and is designed to reach a sub-eV sensitivity via the analysis of the electron capture energy spectrum of ^{163}Ho. This analysis is considered to be model-independent since it only relies on energy and momentum conservation. At the same time the precise description of the expected spectrum goes beyond simple atomic models. In particular many-body electron-electron interactions lead to additional structures besides the main resonances in calorimetrically measured electron capture spectra. A precise description of the ^{163}Ho spectrum is fundamental to gain information on a sub-eV neutrino mass due to a change in the spectral shape. Especially the end point region is here of interest, since there the impact of a finite neutrino mass is the largest. We present a low background and high-energy resolution measurement of the ^{163}Ho spectrum and study the line shape of the main resonances and multiplets with intensities spanning three orders of magnitude. Furthermore we discuss the need to introduce an asymmetric line shape contribution (usually Lorentzian form) to improve the theoretical description of the experimental spectrum. With this, we predict an enhancement of count rate at the endpoint region of about a factor of 2, compared to previous theoretical models. This relaxes the constraints to reach a sub-eV sensitivity on the effective electron neutrino mass.

T 75.6 Thu 17:50 H-HS XIII

Search for eV Sterile Neutrinos - The STEREO Experiment — •Stefan Schoppmann for the STEREO-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

In recent years, major milestones in neutrino physics were accomplished at nuclear reactors: the smallest neutrino mixing angle θ_{13} was determined and the emitted antineutrino spectrum was measured at unprecedented detail. However, two anomalies, the first one related to the absolute flux and the second to the spectral shape, have yet to be solved. The flux anomaly is known as the Reactor Antineutrino Anomaly (RAA) and could be caused by the existence of a light sterile neutrino eigenstate participating in the neutrino oscillation phenomenon. The RAA is best explained by an oscillation with a mass splitting at the eV^2-scale.

The STEREO experiment was built to probe this parameter region. At a short baseline of 10 metres, it measures the antineutrino flux and spectrum emitted by the compact research reactor at ILL Grenoble (France). The segmentation of the detector in six cells allows for independent measurements of the neutrino spectrum at multiple baselines. An active-sterile flavour oscillation could be unambiguously detected, as it distorts the spectral shape of each cell's measurement differently. In 2018, STEREO was able to exclude significant parts of the parameter space with its initial dataset.

In this contribution, updated results on the oscillation analysis as well as the absolute rate and shape of antineutrinos will be presented with the factor 3 increased dataset of 179 (235) days of reactor-on (off).

T 75.7 Thu 18:05 H-HS XIII

Measurement of the Low Energy Electron Capture Spectrum of ^{163}Ho — •Robert Hammann for the ECHo-Collaboration

— Kirchhoff-Institute for Physics, Heidelberg University, Germany

The aim of the electron capture in ^{163}Ho experiment (ECHo) is to directly measure the effective electron neutrino mass with sub-eV sensitivity by analysing the weak decay of ^{163}Ho. For this purpose, a high statistics and high energy resolution measurement of the electron capture spectrum is required. This can be achieved using arrays of metallic magnetic calorimeters with ^{163}Ho enclosed in the absorber operated at millikelvin temperatures.
In this contribution we present a calorimetric measurement of the spectrum with the 64 pixel ECHo-1k chip. Three detectors had an outstandingly low readout noise, which allowed for a very low threshold. With these detectors a total of $5.4 \cdot 10^6$ ^{163}Ho decay events were acquired in the energy range from 15 eV to 2800 eV with an energy resolution of 4.5 eV at the NI-line with 411 eV in the final spectrum.
Thanks to the low threshold as well as an improved algorithm used for data reduction, it was possible to resolve the low energy part of the spectrum with unprecedented detail. In particular, the OII-line was observed for the first time with a resonance energy of about 27 eV. Furthermore, features of the OI-line related to higher order atomic transitions similar to those found for the NI-line were observed.
These results are essential for the development of a precise description of the theoretical ^{163}Ho spectrum over the full energy range.

T 75.8 Thu 18:20 H-HS XIII

Development and optimisation of metallic magnetic calorimeter arrays towards ECHo-100k — •Federica Mantegazzini, Arnulf Barth, Christian Enss, Andreas Fleischmann, Loredana Gastaldo, Sebastian Kempf, Clemens Velte, and Tom Wickenhäuser for the ECHo-Collaboration — Kirchhoff-Institute for Physics, Heidelberg University, Germany

The Electron Capture in ^{163}Ho (ECHo) experiment has been designed for the determination of the effective electron neutrino mass exploiting the electron capture spectrum of ^{163}Ho. The detector technology is based on metallic magnetic calorimeters (MMCs) loaded with ^{163}Ho and operated at millikelvin temperature. For the first phase of the experiment, ECHo-1k, MMC arrays consisting of 72 pixels have been microfabricated and implanted with high purity ^{163}Ho source reaching an activity of about 1 Bq per pixel. For the next phase of the experiment, ECHo-100k, the planned activity per pixel is 10 Bq and the required number of pixels simultaneously operated will be 12000. Therefore, a new dedicated chip design has been prepared and microfabricated in order to improve detector performances, ^{163}Ho implantation efficiency and to allow for parallel and multiplexed read-out. The detector geometry and the ^{163}Ho host material have been studied in order to optimise the detector response and the energy resolution. An energy resolution of 2.9 eV FWHM can be reached under optimal read-out noise conditions. In this contribution we present the new ECHo-100k design and the first results from pulse shape analysis and detector caratherisation obtained with an external ^{55}Fe source.

T 75.9 Thu 18:35 H-HS XIII

The TRISTAN project — •Tim Brunst for the KATRIN-Collaboration — Technische Universität München — Max-Planck-Institut für Physik

The KATRIN (Karlsruhe Tritium Neutrino) experiment investigates the energetic endpoint of the tritium beta-decay spectrum to determine the effective mass of the electron anti-neutrino. The TRISTAN project aims at detecting a keV-sterile neutrino signature by measuring the entire tritium beta-decay spectrum with an upgraded KATRIN system. One of the greatest challenges is to handle the high signal rates generated by the strong activity of the KATRIN tritium source while maintaining a good energy resolution. Therefore, a novel multi-pixel silicon drift detector and read-out system are being designed to handle rates up to 100 Mcps with an energy resolution of 300 eV (FWHM) at 20 keV. In this talk the current status of the project is presented as well as the next steps towards the final detector.

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Status of the ^{163}Ho Source Preparation for the ECHo Neutrino Mass Experiment — •Nina Kneip[1], Holger Dorrer[1], Christoph E. Düllmann[1,2,4], Tom Kieck[1,4], Ulli Köster[3], and Klaus Wendt[1] — [1]Johannes Gutenberg University Mainz, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH Darmstadt, Germany — [3]Institut Laue-Langevin, Grenoble — [4]HIM Johannes Gutenberg University Mainz, Germany

The ECHo collaboration addresses the determination of the electron neutrino mass by recording the deexcitation spectrum following the electron capture of ^{163}Ho. This nuclide is produced by neutron irradiation of enriched ^{162}Er in the ILL high flux reactor. The Ho fraction is then chemically separated. Isotope separation and implantation into the 0.18 mm x 0.18 mm Au-absorbers of the metallic magnetic calorimeters is performed at the RISIKO mass separator at JGU Mainz. This facility consists of a pulsed Ti:sapphire laser system for highly efficient laser resonance ionization, installed at the 30 kV sector field magnet mass separator. The combination of laser ionization and mass spectrometry allows for exceptional elemental and isotopic selectivity leading to a high purity ^{163}Ho beam for ion-implantation process. A submillimeter beam diameter ensures minimal losses of the precious ^{163}Ho source material. In parallel to ion implantation, in-situ deposition of Au onto the implantation area is performed by pulsed laser deposition, counteracting the losses of absorber material by sputtering process during implantation.