T 60: Methods in Astroparticle Physics III

Time: Wednesday 16:15–18:30 Location: KS 00.004

T 60.1 Wed 16:15 KS 00.004

Test setup for a potential electron tagger at KATRIN — •Patrick Unkhoff, Volker Hannen, Christian Huhmann, and Christian Weinheimer for the KATRIN-Collaboration — Universität Münster

The neutrino mass experiment KATRIN has effectively collected 1000 days of tritium beta decay data, allowing to achive a sensitivity for an upper limit on the electron neutrino mass of m < 300 meV at 90% C.L.. After searching for sterile keV neutrinos with the TRISTAN detector at KATRIN a potential next generation experiment labeled KATRIN++ aims to go beyond this limit and probe the inverted mass ordering range down to neutrino masses m < 50 meV. Besides the necessary development of an atomic tritium source, achieving the required sensitivity requires a new differential method with a sub-eV energy resolution. This may be possible through direct time-of-flight spectroscopy of beta-decay electrons. This approach requires detecting the electron start time when entering the KATRIN spectrometer with minimal change of its energy. In this talk, the concept of electron tagging using the image current technique is discussed. Here, the electrons are detected by measuring tiny currents induced by the motion of passing electrons on a nearby electrode structure. A cryogenic test setup has recently been developed at the University Münster to investigate the feasibility of this method and will be presented in this talk. This work is supported by BMFTR under contract number 05A23PMA.

T 60.2 Wed 16:30 KS 00.004

Atomic tritium source development for future neutrino mass experiments — •Caroline Rodenbeck — Karlsruher Institut für Technologie, IAP-TLK

The Karlsruhe Tritium Neutrino experiment (KATRIN), which measures the tritium beta-decay spectrum, recently reached its goal of 1000 measurement days. It is now well on its way to achieving its targeted final neutrino mass sensitivity of $0.3\,\mathrm{eV/c^2}$. Already, efforts are ongoing for future experiments aiming at sensitivities below $0.05\,\mathrm{eV/c^2}$.

Beyond improved detector technologies, switching from a molecular to an atomic tritium source will likely be necessary: The molecular ro-vibrational excitations result in an effective broadening of the endpoint spectrum and thus in a reduced neutrino mass sensitivity, an issue avoided by the use of an atomic source.

Within the Karlsruhe Mainz Atomic Tritium Experiment (KAMATE), groups at the Johannes Gutenberg University (JGU) in Mainz and at the KIT's Tritium Laboratory Karlsruhe (TLK) benchmark different types of hydrogen dissociators (thermal dissociation versus RF-discharge plasma) as possible high-flux and high-efficiency sources. For the characterization of the dissociators, various analysis tools such as mass spectroscopy are under development.

After identifying suitable dissociators, key challenges such as multi-stage cooling and the magnetic trapping of atoms have to be addressed.

The talk gives an overview of the experimental achievements and an outlook for the cooling and trapping of atoms beyond the KAMATE efforts.

T 60.3 Wed 16:45 KS 00.004

Development of the LUIGI ASIC for LEGEND-1000 — •Juan Pablo Ulloa Beteta[1], Andreas Gieb[1], Susanne Mertens[1], Michael Willers[2], Edgar Sanchez Garcia[1], Hannes Bonet[1], and Florian Henkes[2] for the LEGEND-Collaboration — [1]Max-Planck-Institut für Kernphysik, Heidelberg DE — [2]Technische Universität München, München DE

The **L**arge **E**nriched **G**ermanium **E**xperiment for **N**eutrinoless $\beta\beta$ **D**ecay (LEGEND) is a ^{76}Ge-based experiment searching for the neutrinoless double-beta ($0\nu\beta\beta$) decay. The second stage of the experiment, LEGEND-1000, aims to reach discovery sensitivity at half-lives beyond 10^{28} years, covering the inverted-ordering neutrino mass region. Achieving this goal requires about 1000 kg of enriched germanium detectors, a substantial reduction of background in the region of interest, together with further improvements in noise performance and signal fidelity. An important contribution to the overall background budget arises from the readout electronics due to their proximity to the detectors. At the same time, the front-end electronics play a critical role for the energy resolution and pulse shape discrimination. In this context, we explore a novel approach to ASIC-based charge-sensitive front-end electronics designed for operation close to high-purity germanium detectors in liquid argon under low-background restrictions.

T 60.4 Wed 17:00 KS 00.004

Sputtered Transition Edge Sensors for the NUCLEUS Experiment — •Philipp Wasser for the NUCLEUS-Collaboration — Technical University of Munich

Coherent elastic neutrino-nucleus scattering (CEνNS) enables sensitive studies of neutrino properties and physics beyond the Standard Model at low momentum transfer. The NUCLEUS experiment aims to measure CEνNS using MeV reactor antineutrinos from the Chooz nuclear power plant with gram-scale cryogenic calorimeters at 7 mK. Detecting the resulting sub-keV nuclear recoils requires transition edge sensors (TES) with ultra-low energy thresholds, realized using thin superconducting tungsten films.

Good detector performance requires a sharp superconducting transition near the bulk tungsten value (15 mK), motivating magnetron sputtering as a scalable alternative to electron-beam evaporation. I present the successful development of a dedicated sputter facility allowing to produce detector-grade tungsten films for TES applications.

On differently coated silicon substrates, reproducible transition temperatures around 15 mK and narrow transition widths below 0.5 mK were achieved, allowing the fabrication of highly sensitive TES. A systematic variation of the sputter power revealed a linear dependence of the critical temperature on the applied power, with values varying from 15 mK to 36 mK, enabling controlled tuning of the TES properties via deposition parameters. These results establish sputtered tungsten films as a viable TES technology for NUCLEUS.

T 60.5 Wed 17:15 KS 00.004

Fabrication and characterization of MMC arrays for the ECHo-LE — •Krittika Sarkar for the ECHo-Collaboration — Kirchhoff Institute für Physik

The Electron Capture in Holmium-163 (ECHo) experiment is designed for the determination of the electron neutrino mass using the analysis of the 163-Holmium electron capture spectrum. It uses low temperature detectors called metallic magnetic calorimeters (MMCs) to measure the electron capture decay in samples of Holmium-163 that are implanted inside the MMCs. Each MMC pixel contains Ho-163 upto an activity of 10Bq. ECHo-LE aims to simultaneously operate ~20,000 such MMC detectors. Ten wafers hosting 40 arrays each will be fabricated. A quality check produce will be defined in order to confine the suitability of the arrays for the Holmium 163 implantation and therefore to be used in the experiment. Two such wafers have been fabricated and characterised. We present the quality control results obtained for the first two fabricated wafers and discuss the fabrication yield and its implications for the preparation of the ECHo-LE experiment.

T 60.6 Wed 17:30 KS 00.004

Development of an Integrated Photon Phonon Detector to be used for $0\nu\beta\beta$ Search — •Ashish Jadhav, Christian Enss, Andreas Fleischmann, Clara Günther, Daniel Hengstler, Sebastian Hilscher, Cagla Mahanoglu, Ioana-Alexandra Nitu, Andreas Reifenberger, Christian Ritter, Daniel Unger, and Loredana Gastaldo — Kirchhoff Institute for Physics, Heidelberg, Germany

The AMoRE project uses scintillating crystals, enriched with ^{100}Mo, which are operated at millikelvin temperatures to search for $0\nu\beta\beta$ decay in this isotope of molybdenum. An advantage of using scintillating crystals is that they allow for particle discrimination based on the ratio of light to heat energy released by an event. We present an integrated photon-phonon (P2) detector based on metallic magnetic calorimeters (MMC) operated at 20 mK. The P2 detector design utilizes a 3" Si wafer, with a central area that serves as a photon absorber with a stripline geometry MMC sensor. This central area is connected to the rest of the wafer via seven bridges, which are fabricated using silicon etching techniques. In the outer region of the wafer, three MMC sensors with a double meander geometry are fabricated, on top of which the crystal is resting, to act as phonon detectors. The three independent signals from these phonon detector units would allow a fiducial volume to be defined, while improving particle discrimination based on single- and multi-site events. We discuss the various fabrication challenges and the results of detector characterisation in a dilution refrigerator.

T 60.7 Wed 17:45 KS 00.004

Development of an Experimental Platform for MMC Operation in the Next-Generation Neutrino Mass Experiment KATRIN++ — •Abdullah Özkara[1], Sebastian Kempf[2,3], and Michael Müller[2] for the KATRIN-Collaboration — [1]Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT) — [2]Institute of Micro- and Nanoelectronic Systems (IMS), Karlsruhe Institute of Technology (KIT) — [3]Institute for Data Processing and Electronics (IPE), Karlsruhe Institute of Technology (KIT)

The Karlsruhe Tritium Neutrino (KATRIN) experiment measures the electron antineutrino mass via high-precision electron spectroscopy of tritium β-decay. Currently, KATRIN has established an upper limit of 0.45 eV for the absolute neutrino mass and aims to reach a final sensitivity of 0.3 eV (90% C.L.). With the future upgrade to KATRIN++, the goal is to push the sensitivity down to 0.05 eV to probe the inverted mass ordering. To achieve this, a new experimental platform will be implemented, incorporating metallic magnetic calorimeters (MMCs). MMCs are low-temperature single-particle detectors based on quantum technology, offering excellent energy resolution. We present the scheme of a novel platform featuring a magnetic cold chicane, enabling a barrierless transition from the room-temperature vacuum of the KATRIN main spectrometer to the cryogenic environment of the MMC detector.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 60.8 Wed 18:00 KS 00.004

Microwave Multiplexing readout for the ECHo Experiment — •Dominik Zawierucha for the ECHo-Collaboration — KIP im Neuenheimerfeld 227 Heidelberg 69120

The Electron Capture in Holmium-163 (ECHo) experiment uses metallic magnetic calorimeters (MMCs) to measure the energy spectrum of the electron-capture decay of ^{163}Ho implanted inside the detector. The analysis of the end-point region of this spectrum can be used to determine the effective electron neutrino mass. To achieve sub-eV sensitivity to the neutrino mass, a high-statistics energy spectrum with more than 10^{13} events is required. This necessitates a multiplexed readout scheme that enables consistent, high-energy-resolution, simultaneous readout of approximately 20,000 ^{163}Ho-implanted MMC detectors over a long acquisition period.

In ECHo-LE (Large Experiment), this is achieved through the application of microfabricated microwave resonators coupled to radiofrequency superconducting quantum interference devices (rf-SQUIDs) used to acquire signals from the MMC detectors. In this scheme, each detector (400 in total) is coupled to an individual resonator with a resonance frequency in the 4–8 GHz range, allowing the simultaneous readout of multiple detectors by monitoring the transmission through a common feedline.

We discuss the preparation of the 25 high-frequency readout lines and present the status of the multiplexer development for ECHo-LE.

T 60.9 Wed 18:15 KS 00.004

KATRIN++ - New Detector Technologies for a Future Neutrino Mass Experiment with Tritium — •Neven Kovac for the KATRIN-Collaboration — Institute for Astroparticle Physics - Karlsruhe Institute of Technology

Currently, the tightest constraints on the absolute scale of neutrino mass from a direct, model-independent approach, are obtained by the KATRIN experiment, giving an upper limit on the mass of the electron anti-neutrino of 0.45 eV (DOI: 10.1126/science.adq959), with final projected sensitivity below 0.3 eV. Going beyond this limit, and probing the inverted mass ordering (and beyond), will be the task for future neutrino mass experiments. In this regard, development of new detector technologies is of utmost importance, with quantum sensor arrays currently being the front runners due to their exceptional performance and excellent energy resolution.

In this talk we present our recent results where we demonstrate the feasibility for measurements of external electrons using metallic microcalorimeters, and report on our plans for first ever measurements of tritium β-spectrum using quantum sensors.