T 49: Neutrino Physics without Accelerators 4

Time: Tuesday 16:15–18:40 Location: T-H34

Group Report T 49.1 Tue 16:15 T-H34

Direct neutrino mass measurement with the Project 8 experiment: status and outlook — •Larisa Thorne and Martin Fertl for the Project 8-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

There have been significant gains in characterizing neutrino properties in recent decades, however the absolute neutrino mass scale continues to be elusive. The Project 8 experiment seeks to probe this quantity directly via kinematic analysis of atomic tritium single beta decay, using the novel CRES (cyclotron radiation emission spectroscopy) technique. CRES employs a frequency-based approach to measure the differential tritium beta decay spectrum in the endpoint region, where the spectral shape is most sensitive to distortions from a non-zero neutrino mass. Here we present a roadmap of Project 8's milestones towards a neutrino mass measurement with a final design sensitivity of 40 meV. This includes recent results from a successful first-time demonstration of the CRES technique with molecular tritium, as well as status updates on the components comprising the experiment's future full-scale version.

T 49.2 Tue 16:35 T-H34

Atomic hydrogen beam monitor for Project 8 — •Christian Matthe and Sebastian Böser for the Project 8-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The Project 8 collaboration aims to determine the absolute neutrino mass with a sensitivity of 40 meV by measuring the tritium decay spectrum around the endpoint energy. For this level of precision it is necessary to use atomic tritium, since molecular tritium sensitivity is limited by the molecular final state distribution to about 100 meV. We anticipate using an atomic tritium flux of $\approx 10^{19}$atoms/s from a source to inject a beam with $\approx 10^{15}$atoms/s of the proper state and temperature into the detection volume.

For monitoring this beam, we are developing a detector that uses a wire with a micrometer-scale diameter intersecting the beam on which a small fraction of the beam's hydrogen atoms recombine into molecules. The energy released heats the wire and produces a measurable change in its resistance. Using either a grid of wires or a sweep with a single wire the beam profile will be determined. Such a detector is suitable for both development work and for minimally disruptive online monitoring in the final experiment. In this talk I will present first results using such a detector in the beam of the Mainz atomic hydrogen setup.

T 49.3 Tue 16:50 T-H34

Atom-source development for Project 8 — •Alec Lindman and Sebastian Böser for the Project 8-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The Project 8 experiment aims to make a direct measurement sensitive to much of the unexplored range of neutrino masses. Past experiments used molecular tritium, which has a large energy smearing from its final states. Project 8 will use atomic tritium to reach $m_\beta \leq 40$ meV. This requires $\mathcal{O}(10^{20})$ T atoms held at tens of mK in a several-cubic-meter magnetic trap. The efficiencies of cooling the atoms and their trapped lifetime require $> 10^{19}$ atoms/s at the source. Phase III of Project 8 will include an Atomic Tritium Demonstrator to confirm we can produce, cool, and trap sufficient atomic T for the final Phase IV experiment.

I will discuss work at the University of Mainz to develop a high-flux tritium-compatible atom source. Our tests extend to a hydrogen flow of 20 sccm, 20 times the previously-published values for this type of source. Recent progress includes a redesign that boosted the atomic signal 100-fold and separation of the atom signal from background via low-energy ionization. Upgrades are underway to definitively determine if the present atom source provides sufficient atomic flux for Project 8's neutrino mass sensitivity. Designs for a higher-output source, if needed, and subsequent cooling and trapping stages are in progress and will be tested in due course.

T 49.4 Tue 17:05 T-H34

Project 8 Free Space CRES Demonstrator: Signal characteristics and matched-filter detection — •René Reimann, Florian Thomas, and Martin Fertl for the Project 8-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The Project 8 collaboration aims to measure the neutrino mass with a sensitivity of 40 meV by measuring the endpoint region of the atomic tritium beta decay spectrum using the new technology of Cyclotron Radiation Emission Spectroscopy (CRES). While the measurement principle of CRES has been successfully demonstrated using the enclosed volume of a microwave guide filled with molecular tritium or krypton, one major challenge is to scale up the source volume in order to increase the overall statistics. One promising approach is to leave the confined space of the microwave guide and detect the cyclotron radiation emitted by the electron in free space using an array of antennas. To investigate the CRES technique in free space the so called Free Space CRES Demonstrator (FSCD) is under development. Because the signal is diluted into 4π an antenna array with a high number of readout channels is required, which drastically increases the data rate. Therefore real-time processing, triggering and reconstruction are required in the FSCD. The signal characteristics are mainly dominated by the magnetic field and the antenna response. In this talk we present the influence of the magnetic field on the signal spectrum and present how matched filtering can be used to detect and reconstruct CRES signals.

Group Report T 49.5 Tue 17:20 T-H34

The SNO+ experiment: current status and future prospects — •Johann Dittmer and Kai Zuber — IKTP, TU Dresden, Deutschland

SNO+ is a large liquid scintillator based experiment reusing the infrastructure of the successful Sudbury Neutrino Observatory (SNO). Located 2 km underground in a mine near Sudbury, Ontario, Canada, the detector consists of 12 m diameter acrylic vessel which is filled with 780 tonnes of a liquid scintillator. For the main goal, the search for the neutrinoless double beta decay ($0\nu\beta\beta$) of ^{130}Te, the scintillator will be doped by 0.5% natural Tellurium. Since SNO+ was designed as a general purpose neutrino detector, it is also possible to measure neutrinos from different sources (reactor, geo, solar, Supernova, etc.). After a commissioning water phase which was ended in 2018, the scintillator fill was completed in April 2021.

In this talk the recent results and broad physics program will be presented.

SNO+ is supported by the German Research Foundation (DFG).

T 49.6 Tue 17:40 T-H34

Column Density Determination for the KATRIN Neutrino Mass Measurement — •Christoph Köhler[1], Fabian Block[2], and Alexander Marsteller[2] for the KATRIN-Collaboration — [1]Technical University of Munich/Max Planck Institute for Physics — [2]Karlsruhe Institute of Technology

The KATRIN experiment aims to model-independently probe the effective electron anti-neutrino mass with a sensitivity of 0.2 eV (90 % CL) by investigating the endpoint region of the tritium beta decay spectrum. To achieve this goal the gas quantity of the windowless gaseous tritium source, characterized by the column density, has to be known with great accuracy.

We present in this talk the principle of measuring the column density with an angular resolved photoelectron source and report on the monitoring accuracy of the column density achieved with dedicated activity monitoring devices in the first five measurement campaigns of KATRIN. The influence of the column density uncertainty on the neutrino mass determination is then discussed in light of KATRIN's world-leading direct upper limit on the neutrino mass and the ongoing further data-taking.

This work is supported by the Technical University of Munich, the Max Planck Society, the Helmholtz Association (HGF), the Ministry for Education and Research BMBF (05A17PM3, 05A17PX3, 05A17VK2, and 05A17WO3), the Helmholtz Alliance for Astroparticle Physics (HAP), the GRK 1694, and the Helmholtz Young Investigator Group (VH-NG-1055).

T 49.7 Tue 17:55 T-H34

^{83m}Kr N-line spectrum measurement at KATRIN — Matthias Böttcher[1], Moritz Machatschek[2], Magnus Schlösser[2], and •Jaroslav Storek[2] for the KATRIN-Collaboration — [1]Institute of Nuclear Physics, University of Münster — [2]Institute for Astroparticle Physics, Karlsruhe Institute of Technology

The KArlsruhe TRItium Neutrino experiment currently provides the best neutrino mass upper limit of 0.8 eV/c^2 (90% C. L.) in the field of direct neutrino-mass measurements. This result has been obtained with only 5% of the anticipated total measurement time. However, reaching the target sensitivity of 0.2 eV/c^2 at 90% C. L. not only requires the full measurement time, but also the detailed study of systematic measurement uncertainties. Several of them can be studied by measuring a shape distortion of the ^{83m}Kr intrinsic electron conversion N-lines which creates high demands on precise knowledge of the undistorted spectrum. Results of a dedicated measurement of the intrinsic ^{83m}Kr N-spectrum conducted at unprecedented precision at KATRIN will be presented in this talk.

This work is supported by the Ministry for Education and Research BMBF (05A17PM3, 05A17PX3, 05A17VK2, and 05A17WO3) and the Doctoral School "Karlsruhe School of Elementary and Astroparticle Physics: Science and Technology (KSETA)" through the GSSP program of the German Academic Exchange Service (DAAD).

T 49.8 Tue 18:10 T-H34

Unmodeled features in the KATRIN spectrum as a hint for unaccounted systematic effects * — •Karol Debowski for the KATRIN-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

The Karlsruhe Tritium Neutrino (KATRIN) Experiment is designed and operated to determine the mass of the electron-antineutrino with a final sensitivity of 200meV (90% C.L.) using the radioactive beta decay spectrum of tritium. In order to achieve the design sensitivity, a precise knowledge of all systematic effects is needed.

Simulations of the energy spectrum take all known systematic effects into account which are also used in the neutrino mass analysis. Using the measured slow control variables as inputs to the simulation, the measured and simulated spectra should agree with each other except for statistical fluctuations in the measured data. Any significant features exceeding those statistical fluctuations can be potential hints towards systematic effects which are not considered (correctly) in the simulation and hence also in the analysis. By intentionally introducing unprecisely modeled systematics into simulations, the nature and origin of potential unknown effects can be estimated for better understanding and modeling of the measured spectrum in the final analysis. This work aims on a simulation based proof of concept for upcoming analyses to find unaccounted systematic effects in the experiment.

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T 49.9 Tue 18:25 T-H34

Increasing KATRIN's luminosity by an enlarged acceptance angle — •Emanuel Weiss, Jan Behrens, Ferenc Glück, and Stephanie Hickford for the KATRIN-Collaboration — Institute for Astroparticle Physics and Institute of Experimental Particle Physics, Karlsruhe Institute of Technology

The KATRIN collaboration aims to determine the neutrino mass with a sensitivity of 0.2 eV/c^2 (90% CL). This will be achieved by measuring and fitting the endpoint region of the tritium β-electron spectrum. The integral spectrum is measured by a MAC-E filter, which features a high acceptance angle for electrons emitted by a high-luminosity, isotropically emitting tritium source, $\Delta\Omega/2\pi = 1 - \cos\theta_{\mathrm{max}}$.

One approach to improve the statistical uncertainty of the experiment is to further the acceptance angle θ_{max}, which depends on the ratio of source and maximum magnetic field. This can be achieved by keeping the source magnetic field at standard setting and scaling down the magnetic fields in the rest of the beam line. The changed electromagnetic conditions lead to increased β-electron statistics and influence several systematic effects. These effects, as well as the gain in statistics compared to the standard magnetic field settings, are evaluated by simulations and measurements that are presented in this talk.

This work is supported by the Helmholtz Association (HGF), the Ministry for Education and Research BMBF (05A17PM3, 05A17PX3, 05A17VK2, and 05A17WO3), the Helmholtz Alliance for Astroparticle Physics (HAP), and the Helmholtz Young Investigator Group (VH-NG-1055).