T 18: Neutrino physics without accelerators I

Time: Monday 16:00–18:20 Location: Tr

Group Report T 18.1 Mon 16:00 Tr

The Project 8 neutrino mass experiment: First tritium results and future prospects — •Christine Claessens and Sebastian Böser for the Project 8-Collaboration — PRISMA+ Cluster of Excellence, JGU Mainz

The Project 8 collaboration aims for a direct measurement of the absolute neutrino mass scale from the distortion of the tritium decay spectrum near the endpoint. To this end, the collaboration has successfully established Cyclotron Radiation Emission Spectroscopy (CRES), a frequency-based approach for measuring differential beta decay spectra. By making use of the advantages of the CRES technique, Project 8 intends to overcome the statistical and systematic limitations of current-generation direct neutrino mass measurement methods and achieve a final sensitivity of 40 meV. To meet this goal, the collaboration has divided the development of the experiment into four phases with Phase II data collection completed in 2020. In this contribution I will report on the status and prospects of the Project 8 experiment, presenting the results of the first tritium spectrum recorded with the Phase II CRES prototype setup and providing an overview of systematic effects and plans to address them in the future Phases III and IV.

T 18.2 Mon 16:20 Tr

Real-time event reconstruction in the Project 8 Phase III Free Space CRES Demonstrator — •Florian Thomas and Sebastian Böser for the Project 8-Collaboration — PRISMA+ Cluster of Excellence, JGU Mainz

The Project 8 collaboration aims at measuring the absolute neutrino mass with a sensitivity of 40 meV in a tritium endpoint measurement using the recently demonstrated technique of Cyclotron Radiation Emission Spectroscopy (CRES).

In the upcoming Phase III of the experiment CRES will be demonstrated in free space instead of a closed waveguide for the first time. The free space cyclotron radiation emitted by tritium beta decay electrons in a background magnetic field is detected by an array of antennas. For the required sampling frequency a raw data rate of ∼60 GB/s is expected, which quickly exhausts today's permanent storage capacities. Therefore, most of the event reconstruction has to proceed in real-time. This talk presents beamforming as a proposed reconstruction technique as well as the implementation plans for real-time computing and triggering.

T 18.3 Mon 16:35 Tr

Absolute energy scale of the KATRIN experiment — •Manuel Klein and Rudolf Sack for the KATRIN-Collaboration — Karlsruhe Institute of Technology (KIT), IAP, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen

The KArlsruhe TRItium Neutrino (KATRIN) experiment performs a model-independent measurement of the electron neutrino mass. It is designed for a neutrino mass sensitivity of 0.2 eV (90% CL) after three full years of measurement time. KATRIN measures near the endpoint of the tritium beta-decay spectrum with a MAC-E filter, which relies on Magnetic Adiabatic Collimation of the beta electrons and an Electrostatic retarding potential: at the main spectrometer, the high voltage of about −18.6 kV is monitored with a precision of 2 ppm, and in the the tritium source, the electron start potential is provided by a weakly-ionised plasma created from the self-ionising source gas.

For the neutrino mass analysis, the endpoint is fitted from the high voltage of the main spectrometer as one of four free parameters. Nevertheless, the absolute energy scale is also relevant: a) in order to compare with the Q value of tritium, which serves as a precision benchmark for the retardation energy scale and b) because any time-dependence of the energy scale induces a broadening of the measured spectrum, which has to be considered in the analysis. A key aspect here is the effective electron start potential in the strongly-magnetised source plasma. This contribution shows that the systematic effect from drifts of the energy scale is not negligible but well within the uncertainty budget.

Supported by BMBF (Ø05A17VK2) and the Helmholtz Association.

T 18.4 Mon 16:50 Tr

Lorentz invariance violation (LV) at the KATRIN experiment — •Johannes Wickles for the KATRIN-Collaboration — Max-Planck-Institut für Physik, München

The **KA**rlsruhe **TRI**tium **N**eutrino (KATRIN) experiment uses the MAC-E filter principle to determine the mass of the neutrino in the beta-decay of Tritium. Besides measuring the neutrino mass, KATRIN offers insights into physics beyond the Standard Model. The violation of Lorentz invariance (LV) would manifest itself as a temporal oscillation of the spectral endpoint with siderial time. In this contribution first sensitivity studies based on MC data are presented. We will illustrate the analysis method and the impact of systematic uncertainties. The sensitivity of the first neutrino mass data set and the final KATRIN experiment will be presented.

T 18.5 Mon 17:05 Tr

Background reduction with the shifted analyzing plane configuration in KATRIN — •Alexey Lokhov for the KATRIN-Collaboration — University of Muenster, 48149 Muenster, Germany — Institute for Nuclear Research RAS, 117312, Moscow, Russia

To measure the effective electron antineutrino mass mv with a sensitivity of 0.2 eV/c2 the KATRIN experiment requires the level of background of about 10 mcps. One of the sources of the background electrons are the Rydberg atoms, created in the decay of Po-210, entering the spectrometer and ionized by thermal radiation. This yields low-energy electrons, almost uniformly distributed over the vessel volume.

We present here a technique to reduce this volume-dependent background of the KATRIN main spectrometer by using a specific configuration of the electromagnetic fields (so called shifted analyzing plane with a reduced fluxtube), that effectively decreases the volume of the fluxtube of electrons while preserving the energy resolution and allowing for the required neutrino mass sensitivity. The dedicated tests, which were performed recently, investigated the background reduction in this configuration and studied the EM fields at the shifted analyzing plane by calibration measurements using the Kr-83m conversion electrons and electron gun as reference sources.

T 18.6 Mon 17:20 Tr

Atomic hydrogen beam monitor for Project 8 — •Christian Matthe and Sebastian Böser for the Project 8-Collaboration — PRISMA+ Cluster of Excellence, JGU Mainz

The Project 8 collaboration aims to determine the absolute neutrino mass to a precision 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 final molecular state distribution to about 100 meV. We anticipate using an atomic tritium flux of $\approx 10^{19}$atoms/s from the 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 envision 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 could be determined. Thanks to the wires' minimal area, such a detector is suitable for both development work and for online monitoring in the final experiment. In this talk I will present first results from such a detector designed for the Mainz atomic hydrogen setup.

T 18.7 Mon 17:35 Tr

Atom-Source Development for Project 8 — •Alec Lindman, Sebastian Böser, and Christian Matthe for the Project 8-Collaboration — PRISMA+ Cluster of Excellence, JGU Mainz

The Project 8 experiment will make a direct measurement with sensitivity to much of the unexplored range of neutrino masses. Past experiments used molecular tritium, which has an unavoidable energy smearing from its final states. Project 8 will use atomic tritium to reach $m_\beta \leq 40$ meV. This requires $\mathcal{O}(10^{20})$ tritium atoms held at ~ 60 mK in a several-cubic-meter magnetic trap. The efficiencies of cooling the atoms and their trapped lifetime require, coincidentally, $>10^{20}$ atoms/s from the source. Phase III of Project 8 includes building a smaller Atomic Tritium Demonstrator to confirm solutions are ready to produce, cool, and trap atomic tritium at a scale suitable for the final Phase IV experiment.

This talk will discuss experiments at JGU Mainz to develop a cold, high-flux atom source. Our tests extend to a hydrogen flow of 20 sccm, some 40 times the previously-published values for this type of source. Highlights include improved understanding of atom transport in the test stand, automated analysis of large datasets, measurements of the atom-beam profile, and a redesign that boosted the atomic signal 100-fold. Upgrades to the test stand and its instrumentation are underway to definitively determine whether the present atom source provides sufficient atomic flux. Designs for a higher-output source, if needed, and the cooling and trapping stages are in progress and will be installed on the test stand in due course.

T 18.8 Mon 17:50 Tr

Magnetic Trap Design for the Project 8 Free Space CRES Demonstrator — •René Reimann and Martin Fertl for the Project 8-Collaboration — PRISMA+ Cluster of Excellence, JGU Mainz

The existence of non-zero neutrino masses is well established, however their absolute values are a major open question in particle physics. The most direct way to measure the neutrino mass is through a measurement of the spectral endpoint region for a low-energy beta decaying isotope, e.g. tritium. A new technique called Cyclotron Radiation Emission Spectroscopy (CRES) has been demonstrated by the Project 8 collaboration with krypton or molecular tritium confined in a section of a microwave guide. To collect sufficient statistics to reach a neutrino mass sensitivity of 40 meV requires to leave the confined space within a microwave guide and detect the feeble microwave signal in free-space by observing the volume with a set of antennas. All major challenges for a full-scale neutrino mass experiment will be investigated in the coming phase. A key component of the free-space CRES demonstrator is a magnetic trap to confine electrons in a region superimposed on to the homogeneous $\sim 1\,\mathrm{T}$ magnetic background field provided by an MRI magnetic. In this talk, we will present the design of the magnetic electron trap, characteristic parameters, and relationships to other key components of the free-space CRES demonstrator.

T 18.9 Mon 18:05 Tr

Characterization and First Integration of the TRISTAN Detector — •Korbinian Urban for the KATRIN-Collaboration — Max Planck Institut for Physics, Föhringer Ring 6, D-80805 München

The TRISTAN project aims at detecting a keV sterile neutrino signature by measuring the entire tritium beta-decay spectrum with an upgraded detector for the KATRIN experiment. To obtain a high sensitivity to the sterile neutrino mixing angle, a strong activity of the KATRIN source and as follows a high electron rate at the detector is necessary. At the same time excellent spectroscopic properties, like energy resolution and linearity, are important. To meet these challenging requirements a novel multi-pixel silicon drift detector and read-out are being developed to handle rates up to 100 kcps with an energy resolution of 300 eV (FWHM) at 20 keV.

In the last year, the first devices of the new TRISTAN detector became available. This talk addresses the characterization of seven-pixel TRISTAN detectors with X-ray sources and will show details of the first integration of a 47-pixel module in the Monitor Spectrometer at the KATRIN site.

This work is supported by the Max Planck society and the TU Munich (“Chair for Dark Matter, Susanne Mertens”)