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Accurate Raman Spectroscopy at the KATRIN Experiment

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Neutrinos are by far the lightest fermions in the Standard Model of particle physics and also the most numerous fermionic particles in the Universe. Originally, they were believed to be massless. However, later neutrino oscillation experiments indicated that neutrinos actually carry (some very small) mass, making them the lightest fermions in the Standard Model of particle physics. Their absolute mass scale is highly relevant both in particle physics and cosmology.

Several methods for measuring the neutrino mass scale exist of which high-precision electron spectroscopy of the tritium beta-decay is the most sensitive, model-independent method today. Within the context of said method, the Karlsruhe Tritium Neutrino experiment, KATRIN, is the next-generation direct neutrino mass experiment. It is targeted at improving the current experimental sensitivity realized in the Mainz and Troitsk experiments of the late 1990s, from 2 eV/c² down to 200 meV/c² (90\% C.L.).

This can only be achieved if systematic uncertainties are minimized; a key parameter is the isotopic composition of the tritium gas in the windowless source. This composition needs to be monitored inline and in near-time, and Raman spectroscopy was selected as the method of choice, being non-destructive and non-contact. For the KATRIN experiment to achieve the aforementioned sensitivity, the actual source gas composition needs to be determined on short sampling time scales of the order of one minute with a trueness of better than 10%, and a precision of 0.1%. This implies that the Raman source monitoring measurements need to mimic or better these boundary conditions; and it is essential that they are met for the full range of hydrogen isotopologues (H2, HD, D2, HT, DT, and T2) encountered in the source.

In the presentation, the KATRIN experiment and its requirements on the tritium source will introduced. The talk will focus on Raman spectroscopy as employed for the composition monitoring at the KATRIN source. It will be shown how the system exceeds the precision and trueness requirements for KATRIN and how it performs in long-term runs.

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